ERC Implementing Arrangements
Call for Expression of Interest
2019
The main question to be addressed by SPOCK’S MS is how protein complex conformation adapts to local changes, such as processing of polyproteins, protein phosphorylation or conversion of substrates. While labelling strategies combined with mass spectrometry (MS), such as hydrogen deuterium exchange and hydroxyl footprinting, are very versatile in studying protein structure, these techniques are employed on bulk samples averaging over all species present. SPOCK’S MS will remedy these by studying the footprinting and therefore exposed surface area on conformation and mass selected species. Labelling still happens in solution avoiding gas phase associated artefacts. The labelling positions are then read out using newly developed top-down MS technology. Ultra-violet and free-electron lasers will be employed to fragment the protein complexes in the gas phase. In order to achieve the highest possible sequence and thus structural coverage, lasers will be complemented by additional dissociation and separation stages to allow MS^N. SPOCK’S MS will allow sampling conformational space of proteins and protein complexes and especially report about the transient nature of protein interfaces. Constraints derived in MS will be fed into a dedicated software pipeline to derive atomistic models. SPOCK’S MS will be used to study intracellular viral protein complexes, especially coronaviral replication/transcription complexes, which are highly flexible and often resist crystallisation and are barely accessible by conventional structural biology techniques.

Objectives:
- Integrate labelling with complex species selective native MS for time-resolved structural studies
- Combine fragmentation techniques to maximise information content from MS
- Develop software suite to analyse data and model protein complex structures based on MS constraints
- Apply SPOCK’S MS to protein complexes of human pathogenic viruses

Link to the ERC project webpage:

Keywords of the ERC project: structural mass spectrometry, structural virology, coronavirus, soft X-rays

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Eukaryotic DNA replication: a single-molecule approach to the study of yeast replication on chromatin

DNA replication is essential to cellular function. During a lifetime, each of us synthesizes a light-year’s length of DNA, but this process is so robust that few of us will develop cancer. In eukaryotes, DNA is packed into chromatin, a hierarchical DNA-protein assembly of which the nucleosome forms the basic unit. Chromatin replication convolves DNA replication with the duplication and reassembly of all DNA-associated proteins. Understanding the coupling between these processes has fundamental implications for epigenetic inheritance and cancer.

The goal of this proposal is to gain spatiotemporal insight into chromatin replication by using our biophysical expertise in replication and chromosomal dynamics to build up a mechanistic timeline of the process. We will harness recent advances in the reconstitution of the yeast replisome alongside our novel, high-throughput single-molecule approach to visualize and quantify the collaboration between a single yeast replisome and the histone chaperones to achieve chromatin replication. We will:

• Monitor the assembly of the replisome on chromatin and visualize how nucleosomes impact its progression.
• Quantify how the replisome and histone chaperones disrupt nucleosomes and retain histones for further processing.
• Detect the deposition of newly synthesized histones behind the replisome and reveal the interactions between replisome components and histone chaperones that couple replication to nucleosome assembly.
• Report on the phenomenon of epigenetic inheritance by imaging histone recycling between parental and daughter DNA. We will examine its timing and efficiency, the conformations of reassembled nucleosomes, and any preferential recycling to either daughter DNA.

This proposal places us in a unique position to make major contributions to the field of chromatin replication, and to provide the field with a powerful tool to investigate topics from fundamental questions in molecular biology to the performance of new cancer drugs.

Link to the ERC project webpage: http://nynkedekkerlab.tudelft.nl

Keywords of the ERC project: DNA replication, eukaryotic replication, yeast replication, chromatin replication, histones, single-molecule fluorescence, single-molecule studies

Keywords that characterize the scientific profile of the potential visiting researcher/s: DNA replication, chromatin, biochemistry, biophysics
Protein synthesis in organelles

Protein synthesis in mitochondria is essential for the bioenergetics, whereas its counterpart in chloroplasts is responsible for the synthesis of the core proteins that ultimately converts sunlight into the chemical energy that produces oxygen and organic matter. Recent insights into the mito- and chlororibosomes have provided the first glimpses into the distinct and specialized machineries that involved in synthesizing almost exclusively hydrophobic membrane proteins. Our findings showed: 1) mitoribosomes have different exit tunnels, intrinsic GTPase in the head of the small subunit, tRNA-Val incorporated into the central protuberance; 2) chlororibosomes have divaricate tunnels; 3) ribosomes from both organelles exhibit parallel evolution. This allows contemplation of questions regarding the next level of complexity: How these ribosomes work and evolve? How the ribosomal components imported from cytosol are assembled with the organellar rRNA into a functional unit being maturated in different compartments in organelles? Which trans-factors are involved in this process? How the chlororibosomal activity is spatiotemporally coupled to the synthesis and incorporation of functionally essential pigments? What are the specific regulatory mechanisms?

To address these questions, there is a need to first to characterize the process of translation in organelles on the structural level. To reveal molecular mechanisms of action, we will use antibiotics and mutants for pausing in different stages. To reconstitute the assembly, we will systematically pull-down pre-ribosomes and combine single particle with tomography to put the dynamic process in the context of the whole organelle. To understand co-translational operations, we will stall ribosomes and characterize their partner factors. To elucidate the evolution, we will analyze samples from different species. Taken together, this will provide fundamental insights into the structural and functional dynamics of organelles.

Link to the ERC project webpage:

Keywords of the ERC project: cryo-EM, ribosome, ATP synthase, membrane proteins, mitochondria, chloroplast, photosystem

Keywords that characterize the scientific profile of the potential visiting researcher/s: cryo-EM
Mechanism of nucleosome assembly during DNA replication

Proper inheritance of the epigenetic information during cell division controls cell fate decisions, tissues homeostasis and development, ensuring disease avoidance. We have little understanding however of the mechanisms by which epigenetic information, specifically histone post-translational modifications in nucleosomes, are replicated in parallel to the DNA prior to cell division. This process strictly depends on proper nucleosome formation on the newly synthesized DNA strands. Here, I will study the molecular mechanism of nucleosome assembly during DNA replication. Nucleosome dynamics during DNA replication is controlled by an interconnected network of histone chaperones that converges on the key Chromatin Assembly Factor 1 (CAF-1). I recently elucidated the molecular mechanism of CAF-1-mediated nucleosome assembly, in absence of any other replication components. I developed a quantitative (NAQ) assay that allows, for the first time, the quantification of nucleosome assembly activity in vitro. In cells, CAF-1 is recruited to replication forks by the DNA polymerase processivity factor PCNA. Here, I will capitalize and expand on the assays above to integrate structural data, quantitative biochemical and biophysical measurements, and functional analyses, to elucidate how CAF-1 crosstalks to PCNA, DNA polymerases and other components of the DNA replication machinery in S phase. Specifically, the proposed research will 1) uncover how CAF-1 recruitment by PCNA affects its function in nucleosome assembly, and 2) examine how CAF-1 activity is regulated during ongoing DNA replication. This work will reveal the mechanism of nucleosome assembly during DNA replication and its interplay with S phase signaling. A mechanistic understanding of this pathway will uncover the fundamental principles that control genome and epigenome stability, thus cell fate decisions and disease avoidance.

Link to the ERC project webpage:

Keywords of the ERC project:

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Coat assembly and membrane remodelling: understanding regulation of protein secretion

Eukaryotic cells are organised in membrane-bound compartments, which have defined chemical identities and carry out specific essential functions. Exchange of material between these compartments is necessary to maintain cell functionality, and is achieved in a highly specific and regulated manner by vesicular transport. To mediate protein trafficking, coat complexes assemble on membranes and couple bilayer deformation with cargo capture into transport carriers. How coat assembly can deliver the flexibility necessary to accommodate a wide variety of cargo proteins, and how the process can be regulated, are outstanding questions in the field. This is exemplified by the COPII coat, which mediates export from the ER of about a third of newly synthesized proteins. COPII assembles into two concentric layers and can form transport carriers of a variety of shapes and sizes, including tubules and spherical vesicles. This is important for export of large cargoes and is a process targeted by cargo-specific regulatory factors. The aim of this project proposal is to shed light on the molecular interactions between coat components, and understand their role in determination of coat architecture and membrane shape. We will use a combination of structural and functional approaches to characterise COPII coat assembly, and its relationship with membranes in systems of increasing complexity, ranging from in vitro reconstitutions to cells. In particular, we will use cryo-electron tomography and subtomogram averaging to understand the architecture of the coat layers in these systems. These are fast-developing techniques that uniquely target complex structures while achieving high resolutions. With my lab at the forefront of current advances, we are perfectly placed to obtain a complete view of the COPII coat assembled on membranes. Our research will answer outstanding questions in the membrane trafficking field and open new perspectives to tackle ill-characterised regulation systems.

Link to the ERC project webpage: http://www.zanettlab.co.uk

Keywords of the ERC project: cryo-EM, cryo-tomography, subtomogram averaging, coat proteins, COPII, membrane trafficking

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Chromatin dynamics resolved by rapid protein labeling and bioorthogonal capture

Histone proteins provide a dynamic packaging system for the eukaryotic genome. Chromatin integrates a multitude of signals to control gene expression, only some of which have the propensity to be maintained through replication and cell division. For our understanding of cellular memory and epigenetic inheritance we need to know what features characterize a stable, heritable chromatin state throughout the cell cycle. State-of-the-art methods such as ChIP-Seq provide population-based snapshots of the epigenomic landscape but little information on the stability and relative importance of each studied feature or modification. This project pioneers a rapid, sensitive and selective protein labeling method (termed RAPID) for capturing genome-wide chromatin dynamics resolved over a period of time ranging from minutes to days. RAPID introduces a flexible time dimension in the form of pulse or pulse-chase experiments for studying genome-wide occupancy of a protein of interest by next-gen sequencing. It can also be coupled to other readouts such as mass spectrometry or microscopy. RAPID is uniquely suited for studying cell cycle-linked processes, by defining when and where stable ‘marks’ are set in chromatin. I will employ mouse embryonic stem cell (mESC) as a model system for pluripotency and lineage specification. RAPID will define fundamental rules for inheritance of histone and other chromatin-associated proteins and how they are modulated by the fast cell cycle of pluripotent cells. Using RAPID in combination with other state-of-the art genetics and epigenomics, I will collect multi-dimensional descriptions of the dynamic evolution and propagation of functionally relevant chromatin states, such as interstitial heterochromatin and developmentally regulated Polycomb domains.

Link to the ERC project webpage: http://www.elsaesserlab.org

Keywords of the ERC project: Chromatin, Epigenetics, Stem Cells

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Structural differences in mRNA translation machineries between eukaryotic pathogens and their mammalian hosts

mRNA translation consists on translating the genetic code to proteins by the ribosome that is universally conserved in all cells. However, its structure presents significant differences between bacteria and eukaryotes. Partly because of these differences, the bacterial ribosome can be targeted specifically by a number of antibiotics without affecting the eukaryotic host cells. However, the conservation of the ribosome among eukaryotes complicates the search for specific drugs against eukaryotic pathogens such as certain protozoa like plasmodium and kinetoplastids.

Our work along with other studies demonstrates the existence of significant structural differences between ribosomes of protozoa and mammals. Using Cryogenic electron microscopy, we endeavor to investigate such structural differences that are anticipated to affect some of the vital steps of mRNA translation, especially the initiation process, because of their position on the ribosome. 1. Thus we will focus on the structural differences in translation initiation between kinetoplastids and their mammalian hosts (i) by characterizing initiation complexes from several plasmodium and kinetoplastids species and compare them to their mammalian counterparts. (ii) We will also follow up on our previous works in solving the structures of various conventional, but also unconventional mammalian initiation complexes, in interaction with special mRNAs. 2. We will focus on the structure of protozoa-specific features characterized from elongating ribosomal complexes and (i) attempt to fish for regulators that they interact with from cell extracts. In addition, (ii) we will investigate the ribosomal structures from plasmodium at different stages of the parasite life cycle, as they vary according to the latter.

Our results will significantly advance our understanding of protein synthesis regulation in protozoa and will represent a promising step in the search for more efficient treatments against these eukaryotic pathogens.
For a long time the lysosome has been viewed as a “static” organelle that performs “routine” work for the cell, mostly pertaining to degradation and recycling of cellular waste. My group has challenged this view and used a systems biology approach to discover that the lysosome is subject to a global transcriptional regulation, is able to adapt to environmental clues, and acts as a signalling hub to regulate cell homeostasis. Furthermore, an emerging role of the lysosome has been identified in many types of diseases, including the common neurodegenerative disorders Parkinson’s and Alzheimer’s. These findings have opened entirely new fields of investigation on lysosomal biology, suggesting that there is a lot to be learned on the role of the lysosome in health and disease. The goal of LYSOSOMICS is to use “omics” approaches to study lysosomal function and its regulation in normal and pathological conditions. In this “organellar systems biology project” we plan to perform several types of genetic perturbations in three widely used cell lines and study their effects on lysosomal function using a set of newly developed cellular phenotypic assays. Moreover, we plan to identify lysosomal protein-protein interactions using a novel High Content FRET-based approach. Finally, we will use the CRISPR-Cas9 technology to generate a collection of cellular models for all lysosomal storage diseases, a group of severe inherited diseases often associated with early onset neurodegeneration. State-of-the-art computational approaches will be used to predict gene function and identify disease mechanisms potentially exploitable for therapeutic purposes. The physiological relevance of newly identified pathways will be validated by in vivo studies performed on selected genes by using medaka and mice as model systems. This study will allow us to gain a comprehensive understanding of lysosomal function and dysfunction and to use this knowledge to develop new therapeutic strategies.

Link to the ERC project webpage:

Keywords of the ERC project: lysosomes, autophagy

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Genomic DNA represents the blueprint of life: it instructs solutions to challenges during life cycles of organisms. Curiously DNA in higher organisms is mostly non-protein coding (e.g. 97% in human). The popular “junk-DNA” hypothesis postulates that this non-coding DNA is non-functional. However, high-throughput transcriptomics indicates that this may be an over-simplification as most non-coding DNA is transcribed. This pervasive transcription yields two molecular events that may be functional: 1.) resulting long non-coding RNA (lncRNA) molecules, and 2.) the act of pervasive transcription itself. Whereas lncRNA sequences and functions differ on a case-by-case basis, RNA polymerase II (Pol II) transcribes most lncRNA. Pol II activity leaves molecular marks that specify transcription stages. The profiles of stage-specific activities instruct separation and fidelity of transcription units (genomic punctuation). Pervasive transcription affects genomic punctuation: upstream lncRNA transcription over gene promoters can repress downstream gene expression, also referred to as tandem Transcriptional Interference (tTI). Even though tTI was first reported decades ago a systematic characterization of tTI is lacking. Guided by my expertise in lncRNA transcription I recently identified the genetic material to dissect tTI in plants as an independent group leader. My planned research promises to reveal the genetic architecture and the molecular hallmarks defining tTI in higher organisms. Environmental lncRNA transcription variability may trigger tTI to promote organismal responses to changing conditions. We will address the roles of tTI in plant cold response to test this hypothesis. I anticipate our findings to inform on the fraction of pervasive transcription engaging in tTI. My proposal promises to advance our understanding of genomes by reconciling how the transcription of variable non-coding DNA sequences can elicit equivalent functions.

Link to the ERC project webpage:

Keywords of the ERC project: long non-coding RNA (lncRNA), epigenetics, chromatin, RNA polymerase II transcription, genomics

Keywords that characterize the scientific profile of the potential visiting researcher/s: long non-coding RNA (lncRNA), epigenetics, chromatin, RNA polymerase II transcription, genomics
Targeting the Oncogenic Function of Myc in vivo

The transcription factor Myc plays a central role in tumourigenesis but was deemed undruggable due to it being an essential protein. However, recent proof-of-principle studies in mice using a dominant negative allele of Myc demonstrated the dependency of established tumours on Myc function and showed that mice tolerated Myc inhibition to a degree that allowed tumour regression. In line with these observations my group found Myc to regulate distinct sets of genes at low, physiological and high, oncogenic levels, because promoters differ in their affinity for Myc. This notion implies the compelling possibility to specifically target the oncogenic functions of Myc.

TarMyc aims to address four key questions required to bring this new concept from bench to bedside. Firstly, TarMyc will estimate the therapeutic window of Myc inhibition in vivo by expressing shRNAs against Myc in mice with established solid tumours. Secondly, TarMyc aims to identify in vivo Myc target genes crucial for tumourigenesis. Thirdly, this proposal aims to elucidate the role of Myc’s differential promoter affinity in untransformed cells. Analysis of published gene expression datasets revealed Myc binding to low-affinity promoters during the process of tissue regeneration. Thus, by characterizing the regeneration programme induced by Myc we hope to gain further insight on the therapeutic window of Myc inhibition and assess potential side-effects in a Myc-targeting anticancer therapy. Fourthly, we aim to develop strategies to interfere with the oncogenic functions of Myc by (i) developing a novel class of drugs that reduce Myc’s cellular concentrations, and (ii) by testing the therapeutic potential of Myc target genes by inhibiting their function in tumour models.

Taken together, TarMyc takes on the challenge of inhibiting the oncogenic functions of Myc in a highly multidisciplinary approach using state-of-the-art molecular biology, advanced tumour models and new concepts in drug development.

Link to the ERC project webpage: https://www.biozentrum.uni-wuerzburg.de/molbio/research-groups/ag-wolf/

Keywords of the ERC project: Myc, Cancer, transcription, medical chemistry

Keywords that characterize the scientific profile of the potential visiting researcher/s: medical chemistry, medicinal chemistry, biological chemistry, drug development
Metabolism of a cell pictured by single-cell approach

Every cell is unique. Metabolites define the composition of each cell and play key roles in essential intracellular processes of energy production and uptake, signaling, regulation, and cell death. Obtaining metabolite signatures of individual cells and linking them to cellular phenotypes is of paramount importance for a holistic understanding of these processes. This requires high-throughput single-cell metabolomics that is not generally attainable due to the limited sensitivity, low throughput, and disruptiveness of state-of-the-art metabolomics methods.

I propose to develop a spatial single-cell metabolomics approach for human cell culture systems. The approach will be based on using metabolite imaging mass spectrometry and will provide metabolite profiles of individual cells and metabolite signatures of single-cell phenotypes identified by light microscopy. With this approach developed, I will investigate the link between the intracellular metabolism and single-cell phenotype and focus on the following questions: How is the intracellular metabolism linked to cellular heterogeneity? How high is the variation of essential metabolites in a cell population? How do the energy metabolism and lipids biosynthesis change through the cell cycle and infection stages? What is the metabolic response to inflammatory signals?

I will scale up the analysis to discover novel cell phenotypes both in the cell culture systems and in big metabolite imaging mass spectrometry data from various biological systems provided to us by our collaborators and the community, and representing billions of cells.

My project will enable spatial single-cell metabolomics on a large scale and will provide yet lacking capacity for investigating and visualizing the intracellular metabolism on a single-cell level. It will advance our molecular understanding of key biological processes and pave the way to discoveries of molecular mechanisms of inflammation, cancer, and infection.

Link to the ERC project webpage: https://cordis.europa.eu/project/rcn/213785/factsheet/en

Keywords of the ERC project: single-cell, metabolomics, spatial, omics, mass spectrometry, imaging, machine learning

Keywords that characterize the scientific profile of the potential visiting researcher/s: single-cell, omics, microscopy, mass spectrometry, machine learning
Homologous recombination and its application in manipulating animal mitochondrial DNA

Mitochondrial DNA (mtDNA) is a multi-copy genome that works with the nuclear genome to control energy production and various cellular processes. To date, disorders associated with mutations in mtDNA are among the most common genetically inherited metabolic diseases. However, our knowledge regarding many aspects of mtDNA biology remains limited, and we know even less about how it influences development and organismal traits. This is largely due to our inability to manipulate mtDNA. Recently, a colleague and I developed novel genetic tools in Drosophila that allowed us to isolate animal mitochondrial mutants for the first time, and to create heteroplasmic organisms containing two mitochondrial genotypes. These advances make Drosophila a powerful system for mtDNA studies. Importantly, I showed that Drosophila mtDNA could undergo homologous recombination. Furthermore, I established a system to induce recombination at specific sites and select for progeny containing only the recombinant genome. Thus, my work has demonstrated the existence of recombination in animal mitochondria, and opens up the possibility of developing a recombination system for functional mapping and manipulating animal mtDNA. Here I propose to 1) identify components of the mitochondrial recombination machinery by a candidate RNAi screen; 2) develop a recombination toolkit to map trait-associated mtDNA sequences/SNPs; and 3) build a site-directed mutagenesis system by establishing robust ways to deliver DNA into fly mitochondria. Given the essential functions of mitochondria and their involvement in incurable diseases, the genetic tools developed in this proposal will transform the field by making it possible to link mtDNA variations to phenotypic differences and introduce specific mutations into mtDNA for functional studies at organismal level. These advances will open many possibilities to accelerate our understanding on how mtDNA impacts health, disease and evolution.

Link to the ERC project webpage:

Keywords of the ERC project:

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Early embryonic events, life-long consequences: DNA methylation dynamics in mammalian development

Immediately after fertilization, mammalian genomes undergo a dramatic reshaping of the epigenome as the embryo transitions from the zygote into the pluripotent cells primed for lineage commitment. This is best exemplified by DNA methylation reprogramming, as the gametic patterns are largely erased, and the embryonic genome undergoes a wave of de novo DNA methylation. Moreover, once DNA methylation patterns are established, mechanisms faithfully maintain the mark across cell division. Thus, there is latent potential for DNA methylation deposited in the early embryo to exhibit a lifelong effect.

DNA methylation is a modification that is typically associated with gene repression at repetitive elements and at a minority of protein coding genes. I previously described the regulation of the Zdbf2 gene in mice, which is programmed during the de novo DNA methylation program. Challenging the paradigm, in this case DNA methylation is required for activation of a gene via antagonism of the polycomb-group of silencing proteins. If the DNA methylation fails to occur, the gene stays silent throughout life, resulting in a reduced growth phenotype.

For my proposed research I will utilize both a cell-based system that recapitulates these early embryonic events as well as an in vivo mouse model to investigate the extent and mechanisms of non-canonical DNA methylation functions. I plan to use a combinatorial approach of genomics, genetics, and proteomics in order to ascertain novel insights into DNA methylation-based regulation. Furthermore, I plan to employ precision epigenome editing tools to address the locus-specific impact of DNA methylation. Ultimately, I strive to gain a clear understanding of the profound epigenetic consequences of DNA methylation on this window of development, which occurs in the first week of mouse embryogenesis, and the second of human, but the repercussions of which can ripple throughout life.
An experimental and bioinformatic toolbox for functional epigenomics and its application to epigenetically making and breaking a cancer cell

Epigenetic alterations can be detected in all cancers and in essentially every patient. Despite their prevalence, the concrete functional roles of these alterations are not well understood, for two reasons: First, cancer samples tend to carry many correlated epigenetic alterations, making it difficult to statistically distinguish relevant driver events from those that co-occur for other reasons. Second, we lack tools for targeted epigenome editing that could be used to validate biological function in perturbation and rescue experiments. The proposed project strives to overcome these limitations through experimental and bioinformatic methods development, with the ambition of making and breaking cancer cells in vitro by introducing defined sets of epigenetic alterations. We will focus on leukemia as our “model cancer” (given its low mutation rate, frequent defects in epigenetic regulators, and availability of excellent functional assays), but the concepts and methods are general. In Aim 1, we will generate epigenome profiles for a human knockout cell collection comprising 100 epigenetic regulators and use the data to functionally annotate thousands of epigenetic alterations observed in large cancer datasets. In Aim 2, we will develop an experimental toolbox for epigenome programming using epigenetic drugs, CRISPR-assisted recruitment of epigenetic modifiers for locus-specific editing, and cell-derived guide RNA libraries for epigenome copying. Finally, in Aim 3 we will explore epigenome programming (methods from Aim 2) of candidate driver events (predictions from Aim 1) with the ultimate goal of converting cancer cells into non-cancer cells and vice versa.

In summary, this project will establish a broadly applicable methodology and toolbox for dissecting the functional roles of epigenetic alterations in cancer. Moreover, successful creation of a cancer that is driven purely by epigenetic alterations could challenge our understanding of cancer as a genetic disease.

Link to the ERC project webpage:

Keywords of the ERC project:

Keywords that characterize the scientific profile of the potential visiting researcher/s: Medical Epigenomics, Bioinformatics, Machine Learning / Artificial Intelligence, Single-cell Sequencing, Cancer Immunology, CRISPR Technology
Dissecting the function and regulation of centriolar satellites: key regulators of the centrosome/cilium complex

Centrosomes are the main microtubule-organizing centers of animal cells. They influence the morphology of the microtubule cytoskeleton and function as the base of primary cilium, a nexus for important signaling pathways. Structural and functional defects in centrosome/cilium complex cause a variety of human diseases including cancer, ciliopathies and microcephaly. To understand the relationship between human diseases and centrosome/cilium abnormalities, it is essential to elucidate the biogenesis of centrosome/cilium complex and the control mechanisms that regulate their structure and function. To tackle these fundamental problems, we will dissect the function and regulation of centriolar satellites, the array of granules that localize around the centrosome/cilium complex in mammalian cells. Only recently interest in the satellites has grown because mutations affecting satellite components were shown to cause ciliopathies, microcephaly and schizophrenia. Remarkably, many centrosome/cilium proteins localize to these structures and we lack understanding of when, why and how these proteins localize to satellites. The central hypothesis of this grant is that satellites ensure proper centrosome/cilium complex structure and function by acting as transit paths for modification, assembly, storage, stability and trafficking of centrosome/cilium proteins. In Aim 1, we will identify the nature of regulatory and molecular relationship between satellites and the centrosome/cilium complex. In Aim 2, we will elucidate the role of satellites in proteostasis of centrosome/cilium proteins. In Aim 3, we will investigate the functional significance of satellite-localization of centrosome/cilium proteins during processes that go awry in human disease. Using a multidisciplinary approach, the proposed research will expand our knowledge of the spatiotemporal regulation of the centrosome/cilium complex and provide new insights into pathogenesis of ciliopathies and primary microcephaly.

Link to the ERC project webpage: http://mysite.ku.edu.tr/ekaralar/projects/

Keywords of the ERC project: centrosomes, cilia, ciliopathies, retinal degeneration, microtubules, proteomics

Keywords that characterize the scientific profile of the potential visiting researcher/s: centrosomes, cilia, ciliopathies, retinal degeneration, microtubules, proteomics
Cell division is fundamental for development. In the early mammalian embryo it drives the rapid proliferation of totipotent cells, the basis for forming the fetus. Given its crucial importance, it is surprising that cell division is particularly error-prone at the beginning of mammalian life, resulting in spontaneous abortion or severe developmental retardation, the incidence of which is increasing with age of the mother. Why aneuploidy is so prevalent and how early embryonic development nevertheless achieves robustness is largely unknown. The goal of this project is a comprehensive analysis of cell divisions in the mouse preimplantation embryo to determine the molecular mechanisms underlying aneuploidy and its effects on normal development. Recent technological breakthroughs, including light sheet microscopy and rapid loss-of-function approaches in the mouse embryo will allow us for the first time to tackle the molecular mechanisms of aneuploidy generation and establish the preimplantation mouse embryo as a standard cell biological model system. For that purpose we will develop next generation light sheet microscopy to enable automated chromosome tracking in the whole embryo. Mapping of cell division errors will reveal when, where, and how aneuploidy occurs, what the fate of aneuploid cells is in the embryo, and how this changes with maternal age. We will then perform high resolution functional imaging assays to identify the mitotic pathways responsible for aneuploidy and understand why they do not fully function in early development. Key proteins will be functionally characterised in detail integrating light sheet imaging with single molecule biophysics in embryos from young and aged females to achieve a mechanistic understanding of the unique aspects of cell division underlying embryonic aneuploidy. The achieved knowledge gain will have an important impact for our understanding of mammalian, including human infertility.
Unraveling complex organ regeneration through live imaging and molecular profiling approaches

Many animals have the ability to regenerate parts of their body following injury or amputation. While there is great biological and medical interest in this process, many fundamental questions remain unanswered, because complex organ regeneration is poorly represented in classic model organisms; flies, nematodes and mammals have limited regenerative abilities, in contrast to flatworms, crustaceans and fish.

reLIVE explores fundamental questions on regeneration in an emerging crustacean model, Parhyale hawaiensis, which combines extensive regenerative abilities, advanced genetic tools and live imaging.

The project will address the following fundamental, centuries-old questions on regeneration:

1) Which are the progenitors that underpin complex organ regeneration? Do epidermis, tendons, neurons, glia and muscle arise de novo from undifferentiated adult stem cells, or do they emerge from differentiated cell types? Are the progenitors unipotent/committed or multipotent? Which are their molecular responses and behaviors during the course of regeneration?

2) Do diverse animal groups regenerate in the same way? Do the regenerative progenitors of crustaceans have common molecular and functional properties with those of vertebrates and flatworms? Do they have a shared evolutionary history?

3) How does regeneration differ from development? Are these processes operating on comparable temporal and spatial scales? How similar are the transcriptional responses and cell behaviors that underpin embryonic and regenerative morphogenesis of the limb?

To answer these questions, reLIVE will take advantage of the unique opportunities offered by Parhyale limb regeneration and, for the first time, combine four cutting-edge approaches: a) CRISPR-mediated marking of specific cell types, b) continuous live imaging and cell tracking in regenerating limbs over week-long periods, c) a novel method of cell lineage reconstruction, and d) transcriptional profiling on individual cells.

Link to the ERC project webpage:

Keywords of the ERC project: regeneration, progenitors, comparative developmental biology, live imaging, transcriptional profiling

Keywords that characterize the scientific profile of the potential visiting researcher/s: genetic tools, live imaging, comparative transcriptomics, cis-regulatory sequences, live imaging, image analysis
Daylength measuring devices such as the photoperiodic timer enable animals to anticipate and thus survive adverse seasons. This ability has contributed to the great success of insects living in temperate regions. Yet the basis of photoperiodic sensing remains elusive, because of the lack of suitable genetic models expressing photoperiod-dependent seasonal phenotypes. We have developed the linden bug, Pyrrhocoris apterus, into a genetically tractable model with a robust, photoperiod-dependent reproductive arrest (diapause). With the available tools, this insect has become ideal for deciphering the regulation of seasonality. The project has 3 clear and ambitious objectives: 1). Our goal is to define the molecular and anatomical bases of the photoperiodic timer. To achieve this, we propose to identify photoperiodic timer genes, genes regulating input to the timer, and early output markers, through an RNA interference screen(s). To define the molecular mechanism of the timer, we will employ genome editing to precisely alter properties of the key players. 2). Next, we will combine techniques of neuronal backfilling, in-vivo fluorescent reporters, and microsurgery to define the photoperiodic timer anatomically and to examine its spatial relationship to the circadian clock in the insect brain. 3). We will exploit the great natural geographic variability of photoperiodic timing in P. apterus to explore its genetic basis. Genetic variants correlating with phenotypic differences will be causally tested by genome editing within the original genetic backgrounds. Both the established and the innovative strategies provide a complementary approach to the first molecular characterization of the seasonal photoperiodic timer in insects. The proposed research aspires to explain mechanisms underlying the critical physiological adaptation to changing seasons. Deciphering mechanisms underpinning widespread adaptation might bring general implications for environment-friendly pest control.
Chromatin-localized central metabolism regulating gene expression and cell identity

Epigenetics research has revealed that in the cell’s nucleus all kinds of biomolecules—DNA, RNAs, proteins, protein posttranslational modifications—are highly compartmentalized to occupy distinct chromatin territories and genomic loci, thereby contributing to gene regulation and cell identity. In contrast, small molecules and cellular metabolites are generally considered to passively enter the nucleus from the cytoplasm and to lack distinct subnuclear localization. The CHROMABOLISM proposal challenges this assumption based on preliminary data generated in my laboratory. I hypothesize that chromatin-bound enzymes of central metabolism and subnuclear metabolite gradients contribute to gene regulation and cellular identity.

To address this hypothesis, we will first systematically profile chromatin-bound metabolic enzymes, chart nuclear metabolomes across representative leukemia cell lines, and develop tools to measure local metabolite concentrations at distinct genomic loci. In a second step, we will then develop and apply technology to perturb these nuclear metabolite patterns by forcing the export of metabolic enzymes for the nucleus, aberrantly recruiting these enzymes to selected genomic loci, and perturbing metabolite patterns by addition and depletion of metabolites. In all these conditions we will measure the impact of nuclear metabolism on chromatin structure and gene expression. Based on the data obtained, we will model for the effects of cellular metabolites on cancer cell identity and proliferation. In line with the recent discovery of oncometabolites and the clinical use of antimetabolites, we expect to predict chromatin-bound metabolic enzymes that can be exploited as druggable targets in oncology. In a final aim we will validate these targets in leukemia and develop chemical probes against them.

Successful completion of this project has the potential to transform our understanding of nuclear metabolism in control of gene expression and cellular identity.
Evolution of cell fate specification modes in spiral cleavage

Spiral cleavage is a highly stereotypical early embryonic program, and the ancestral, defining feature to Spiralia, a major phylogenetic clade including almost half of the animal phyla. Remarkably, spiral-cleaving embryos specify homologous cell fates (e.g. the progenitor cell of posterodorsal structures) conditionally –via cell interactions– or autonomously –via segregation of maternal inputs. This variation occurs naturally, even between closely related species, and has been related to the precocious formation of adult characters (adultation) in larvae of autonomous spiral-cleaving species. How spiralian lineages repeatedly shifted between these two cell fate specification modes is largely unexplored, because the mechanisms controlling spiral cleavage are still poorly characterized.

This project tests the hypothesis that maternal chromatin and transcriptional regulators differentially incorporated in oocytes with autonomous spiral cleavage explain the evolution of this mode of cell fate specification. Through a comparative and phylogenetic-guided approach, we will combine bioinformatics, live imaging, and molecular and experimental techniques to: (i) Comprehensively identify differentially supplied maternal factors among spiral cleaving oocytes with distinct cell fate specification modes using comparative RNA-seq and proteomics; (ii) Uncover the developmental mechanisms driving conditional spiral cleavage, which is the ancestral embryonic mode; and (iii) Investigate how maternal chromatin and transcriptional regulators define early cell fates, and whether these factors account for the repeated evolution of autonomous specification modes.

Our results will fill a large gap of knowledge in our understanding of spiral cleavage and its evolution. In a broader context, this project will deliver fundamental insights into two core questions in evolutionary developmental biology: how early embryonic programs evolve, and how they contribute to phenotypic change.

Link to the ERC project webpage:

**Keywords of the ERC project:** evo-devo, annelids, spiral cleavage, epigenomics, comparative developmental biology, comparative genomics

**Keywords that characterize the scientific profile of the potential visiting researcher/s:** computational biology, developmental biologist, microscopy, epigenomics
The mammalian body plan blueprint, an in vitro approach

The development of an embryo requires the spatially structured emergence of tissues and organs. This process relies on the early establishment of a coordinate system in the form of three orthogonal axes that act as a reference for laying down the body plan, a template for the organism. Genetic analysis of this process has revealed an underlying transcriptional blueprint that links the coordinate system and the body plan. However, the way in which the gene products contribute to the emergence of the body plan remains an open question. A reason for this is that this process involves feedbacks and integration between the activity of Gene Regulatory Networks (GRNs) and the mechanics of multicellular ensembles, and that probing this relationship is experimentally challenging. In the case of mammalian embryos, which are particularly important as models for human development, our gaps in knowledge of these events are larger than in other organisms. This is partly due to the challenges associated with uterine development but also, and increasingly, because of the cost of mice and the difficulty of obtaining large numbers of embryos, as required for mechanistic experiments. In this project we shall use gastruloids, a novel and versatile Pluripotent Stem Cells based experimental system that we have developed for the study of mammalian development, to gain insights into the molecular and cellular basis underlying the emergence of the mammalian body plan. Gastruloids lack anterior neural structures and over a period of five days become organized in the fashion of a midgestation mouse embryo. We shall use the experimental versatility of the Gastruloid system to probe into the functional relationships between the mechanical activities of multicellular ensembles and the dynamics of GRNs that underlie the emergence of the mammalian body plan.

Link to the ERC project webpage:

Keywords of the ERC project: Gastruloid, organ engineering, developmental systems biology

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Deciphering and engineering the assembly of cellular organelles is a key pursuit in biology. The centriole is an evolutionarily conserved organelle well suited for this goal, and which is crucial for cell signaling, motility and division. The centriole exhibits a striking 9-fold radial symmetry of microtubules around a likewise symmetrical cartwheel containing stacked ring-bearing structures. Components essential for generating this remarkable architecture from alga to man have been identified. A next critical step is to engineer assays to probe the dynamics of centriole assembly with molecular precision to fully understand how these components together build a functional organelle. Our ambitious research proposal aims at taking groundbreaking steps in this direction through four specific aims:

1) Reconstituting cartwheel ring assembly dynamics. We will use high-speed AFM (HS-AFM) to dissect the biophysics of SAS-6 ring polymer dynamics at the root of cartwheel assembly. We will also use HS-AFM to analyze monobodies against SAS-6, as well as engineer surfaces and DNA origamis to further dissect ring assembly.

2) Deciphering ring stacking mechanisms. We will use cryo-ET to identify SAS-6 features that direct stacking of ring structures and set cartwheel height. Moreover, we will develop an HS-AFM stacking assay and a reconstituted stacking assay from human cells.

3) Understanding peripheral element contributions to centriole biogenesis. We will dissect the function of the peripheral centriole pinhead protein Cep135/Bld10p, as well as identify and likewise dissect peripheral A-C linker proteins. Furthermore, we will further engineer the HS-AFM assay to include such peripheral components.

4) Dissecting de novo centriole assembly mechanisms. We will dissect de novo centriole formation in human cells and water fern. We will also explore whether de novo formation involves a phase separation mechanism and repurpose the HS-AFM assay to probe de novo organelle biogenesis.

Link to the ERC project webpage:

Keywords of the ERC project:

Keywords that characterize the scientific profile of the potential visiting researcher/s:
How intraflagellar transport shapes the cilium: a single-molecule systems study

Sensory cilia are organelles extending like antennas from many eukaryotic cells, with crucial functions in sensing and signalling. Cilia consist of an axoneme built of microtubules, enveloped by a specialized membrane. Ciliary development and maintenance depend critically on a specific, microtubule-based intracellular transport mechanism, intraflagellar transport (IFT). In my laboratory, we study the chemosensory cilia of *C. elegans*, which sense water-soluble molecules in the animal’s environment for chemotaxis. Over the past years, we have developed a unique set of quantitative, single-molecule fluorescence microscopy tools that allow us to visualize and quantify IFT dynamics with unprecedented detail in living animals. So far, our focus has been on the cooperation of the motor proteins driving IFT. The overall objective of my current proposal is to zoom out and shed light on the connection between ciliary structure, chemosensory function and IFT, from a systems perspective. Recent work has indicated that axoneme length is controlled by IFT. Preliminary results from my laboratory show that axoneme length changes dynamically in response to perturbations of IFT or cilia. Furthermore, we have shown that IFT is substantially affected upon exposure of animals to known repellent solutions. The four major aims in my proposal are to:

• determine how directional changes in IFT are regulated and are affected by external disturbances,
• understand the dynamics of the axonemal microtubules and how IFT affects these dynamics and vice versa,
• study how sensory ciliary function affects IFT and ciliary structure,
• further develop our (single-molecule) fluorescence microscopy toolbox by improving instrumentation and using better fluorescent probes and sensors.

These experiments will place my lab in a unique position to push forward our understanding of the relationship between structure, function and dynamics of transport of this fascinating and fundamental organelle.

**Link to the ERC project webpage:** www.nat.vu.nl/~erwinp

**Keywords of the ERC project:** *C. elegans*, cilia, chemosensing, intraflagellar transport

**Keywords that characterize the scientific profile of the potential visiting researcher/s:** bit more senior visiting scientist, sabbatical, skills in *C. elegans* or advanced fluorescence microscopy.
**Project ID:** 678119  
**Project Acronym:** SiCMetabol  
**Evaluation Panel:** LS4  
Physiology, Pathophysiology and Endocrinology

**Principal Investigator:** Dr GRZEGORZ SUMARA  
**Host Institution:** JULIUS-MAXIMILIANS-UNIVERSITAT WURZBURG - DE

### Signaling Cascades in Metabolic Diseases

Over 380 million people suffer from diabetes worldwide, with majority of cases being attributed to type 2 diabetes (T2D). Obesity is a major risk factor predisposing to the development of this disease. T2D is characterized by peripheral insulin resistance in combination with relative insulin deficiency that results in hyperglycemia and hyperlipidemia. Liver and adipose tissue are central for regulation of glucose and lipids levels. However, during T2D the hepatic glucose uptake is reduced while rates of gluconeogenesis and lipogenesis are increased. In the adipose tissue, T2D leads to decreased glucose uptake, perturbations in secretion of adipokines and increased lipolysis. Importantly, dysfunction of the liver and the adipose tissue during T2D is caused by defective phosphorylation signaling cascades and normalization of these pathways was shown to attenuate the course of T2D. However, the specific roles of different classes of signaling molecules in these organs remain poorly characterized. We hypothesize that the cross-talk of different classes of signaling molecules determines regulation of metabolism.

Thus, we aim to identify the signaling networks regulating metabolism. The results generated in my own laboratory suggest that the Pkd family kinases are the crucial regulators of metabolic homeostasis. Specifically, Pkd1 and Pkd2 promote obesity and diabetes while Pkd3 controls liver function. Thus, we plan to characterize the molecular mechanisms controlling Pkds signaling. In parallel, we will utilize screening approaches to identify novel, non-canonical signaling modules (phosphatases and components of the ubiquitin system) regulating abundance, localization and phosphorylation of targets of Pkds and, in the long term, also other kinases implicated in T2D.

By identifying and characterizing the essential signaling networks in liver and adipose tissue the project will contribute to more targeted pharmacological strategies for the treatment of T2D.

**Link to the ERC project webpage:**

**Keywords of the ERC project:**

**Keywords** that characterize the scientific profile of the potential visiting researcher/s:
The role of chronic inflammation in obesity, metabolic and cardiovascular diseases is increasingly recognized. Bile acids (BA), synthesized in the liver and modified by the gut flora, facilitate lipid absorption in the intestine. BA modulate lipid and glucose homeostasis by activating the nuclear receptor FXR and the GPCR TGR5. Intriguingly, peripheral BA concentrations are elevated in type 2 diabetes (T2D) and FXR mediates the beneficial metabolic response to gastric bypass in mice. The immune system plays an important role in the cross-talk with metabolic tissues, such as liver, intestine and adipose tissues. However, whether BA modulate immune cell function is unknown. Our unpublished results identifying FXR and TGR5 expression in lymphoid cells, prompt us to study their role in the regulation of glucose and lipid metabolism through immune cell modulation. Using reporter mice and specific ligands, we will characterize the immune cells expressing active FXR and TGR5. We will determine their role in metabolism and inflammation by immune cell-specific gene inactivation in models of obesity, T2D and elevated peripheral blood BA concentrations. Mass cytometry, cell sorting and single cell transcriptomic analysis will allow the identification of gene networks regulated by BA and their receptors. As microbiota generate biologically active secondary BA, we will assess the impact of microbiota depletion and subsequent BA acid pool modifications on immune cell populations. Translational studies in humans with altered BA metabolism and pharmacological treatment with anti-diabetic BA sequestrants will allow assessment of alterations in immune functions. This project aims to identify an hitherto unexplored role of BA through modulation of the immune system on T2D, NAFLD and dyslipidemia. Success of the project critically depends on an integrative approach uniquely undertaken in my laboratory through its unique multidisciplinary expertise in basic and translational biology.

Link to the ERC project webpage:
Keywords of the ERC project:
Keywords that characterize the scientific profile of the potential visiting researcher/s: nuclear receptors; bile acids; epigenetics; immunology; animal models
Metastatic growth of cancer cells requires extracellular matrix (ECM) production. The current understanding is that transcription factors regulate ECM production and thus metastatic growth by increasing the expression of collagen prolyl 4-hydroxylase (CP4H). In contrast, we recently discovered that metabolism regulates CP4H activity independently of the known transcription factors. Specifically, we found that loss of pyruvate metabolism inhibits CP4H activity and consequently ECM-dependent breast cancer cell growth. Based on this discovery we propose the novel concept that metabolism regulates metastatic growth by increasing ECM production.

In this project we will investigate the following questions: 1) What is the mechanism by which pyruvate regulates CP4H activity in breast cancer cells? To address this question we will investigate pyruvate metabolism and ECM production in 3D cultures of various breast cancer cell lines using 13C tracer analysis, metabolomics, and two-photon microscopy based ECM visualization. 2) How can this novel metabolic regulation be exploited to inhibit breast cancer-derived lung metastases growth? To address this question we will inhibit pyruvate metabolism in metastatic breast cancer mouse models using genetically modified cells and small molecules in combination with immuno- and chemotherapy. 3) How can this novel regulation be translated to different metastatic sites and cancers of different origin? To address this question we will determine the in vivo metabolism of breast cancer-, lung cancer-, and melanoma-derived liver and lung metastases (using metabolomics and 13C tracer analysis), and link it to ECM production (using two-photon microscopy based ECM visualization).

With this project we will deliver a novel concept by which metabolism regulates metastatic growth. In a long-term perspective we expect that targeting this novel metabolic regulation will pave the way for an unexplored approach to treat cancer metastases.

Link to the ERC project webpage:

Keywords of the ERC project:

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Novel Metabolic Pathways in Cancer

Metabolic adaptations in central carbon metabolism play a key role in cancer. Yet, the success of therapeutic interventions in major pathways has been limited, although some of the changes have been known to exist for almost 100 years. Biochemical textbooks present intermediary metabolism as something canonical, and the molecular identity of most enzymes required for the production of known intermediary metabolites is indeed known. Yet, the function of many putative enzymes is still unknown, indicating that novel metabolic pathways containing so far unknown metabolites exist.

We have recently discovered a novel metabolic pathway containing two metabolites that have never been described before. Preliminary data indicate that this pathway might play an important role in a group of cancers sharing specific mutations. Furthermore, genetic inactivation of a component of this pathway in mice is compatible with normal development, indicating that pharmacological inhibition should be well tolerated.

In the present project, we will use a multi-dimensional approach combining biochemical, genetic and pharmacological techniques, to identify missing components of this metabolic pathway and assess its role in cellular metabolism and cancer development. In the process of this, we will develop tools that will allow us to test whether this pathway can be targeted in vivo. Thus, our work will lead to the description of a novel metabolic pathway, should reveal novel regulatory circuits and might open novel therapeutic avenues in cancer and beyond.

Link to the ERC project webpage:

Keywords of the ERC project: metabolism, cancer, mass spectrometry, novel biochemical pathways, mouse models

Keywords that characterize the scientific profile of the potential visiting researcher/s: Strong interest or experience in the following areas would be desirable:
- bioinformatics
- biochemistry
- mouse models of cancer; bone marrow transplantation in mice
- mass spectrometry of small molecules
Harnessing tumor metabolism to overcome immunosuppression

Anti-cancer immunotherapy has provided patients with a promising treatment. Yet, it has also unveiled that the immunosuppressive tumor microenvironment (TME) hampers the efficiency of this therapeutic option and limits its success. The concept that metabolism is able to shape the immune response has gained general acceptance. Nonetheless, little is known on how the metabolic crosstalk between different tumor compartments contributes to the harsh TME and ultimately impairs T cell fitness within the tumor. This proposal aims to decipher which metabolic changes in the TME impede proper anti-tumor immunity.

Starting from the meta-analysis of public human datasets, corroborated by metabolomics and transcriptomics data from several mouse tumors, we ranked clinically relevant and altered metabolic pathways that correlate with resistance to immunotherapy. Using a CRISPR/Cas9 platform for their functional in vivo selection, we want to identify cancer cell intrinsic metabolic mediators and, indirectly, distinguish those belonging specifically to the stroma. By means of genetic tools and small molecules, we will modify promising metabolic pathways in cancer cells and stromal cells (particularly in tumor-associated macrophages) to harness tumor immunosuppression. In a mirroring approach, we will apply a similar screening tool on cytotoxic T cells to identify metabolic targets that enhance their fitness under adverse growth conditions. This will allow us to manipulate T cells ex vivo and to therapeutically intervene via adoptive T cell transfer. By analyzing the metabolic network and crosstalk within the tumor, this project will shed light on how metabolism contributes to the immunosuppressive TME and T cell maladaptation. The overall goal is to identify druggable metabolic targets that i) reinforce the intrinsic anti-tumor immune response by breaking immunosuppression and ii) promote T cell function in immunotherapeutic settings by rewiring either the TME or the T cell itself.

Link to the ERC project webpage:

Keywords of the ERC project:

Keywords that characterize the scientific profile of the potential visiting researcher/s:
The PIDDosome in Centrosome and Ploidy-Surveillance

Tight control of the number of chromosome sets in a cell (ploidy) is fundamental for normal development and organismal health. Most cells in our body are diploid, yet, some cells, including cardiomyocytes or hepatocytes require a balanced increase in ploidy for proper function. Polyploidization is accompanied by an accumulation of centrosomes, structures needed for nucleating the mitotic spindle and ciliogenesis. Extra centrosomes, however, promote aneuploidy in proliferating cells by causing errors in chromosome segregation, underlying a series of human pathologies, most notably cancer and premature ageing. How polyploidization is controlled in organogenesis and how errors in ploidy control contribute to disease is poorly understood.

We recently demonstrated that the “PIDDosome” complex polices centrosome numbers in mammalian cells, alerting the tumor suppressor p53 in response to extra centrosomes. This is achieved by inactivating MDM2, the key-inhibitor of p53, by targeted proteolysis. MDM2-processing is mediated by caspase-2, a neglected member in a protease family that controls cell death and inflammation, activated in the PIDDosome. This exciting finding allows examining the consequences of deregulated ploidy and centrosome number in development and disease without interfering with p53, nor the cell fusion or cytokinesis machineries. This puts us in pole position to carry out an integrative study that aims to develop the PIDDosome as a new therapeutic target in cancer, related inflammation and in regenerative medicine. To meet this aim, we will define
(i) the relevance of the PIDDosome in aneuploidy tolerance of cancer
(ii) the role of the PIDDosome in controlling sterile inflammation and immunity
(iii) the PIDDosome as a key-regulator of organ development and regeneration

POLICE will open new lines of research at the interface of cell cycle, cell death & inflammation control and promote the PIDDosome as new target in our efforts to improve human health.

Link to the ERC project webpage:

Keywords that characterize the scientific profile of the potential visiting researcher/s:
B cell chronic lymphocytic leukemia (CLL) is the most frequent leukemia in adults. CLL cells are characterized by their universal dependency on pro-survival and pro-proliferative signals from immune niches. To achieve this they constantly re-circulate between blood and lymph nodes, which is inhibited by novel microenvironment-targeting therapies such as “BCR inhibitors”. We aim to reveal how the malignant B cells change the propensity of their signalling pathways in response to the different microenvironments such as peripheral blood vs lymph node to obtain the proliferative signals. This is of major relevance for CLL, but also transferable to the biology of some other B cell malignancies and/or normal B cells. We analyzed the “finger print” of microenvironmental interactions in many CLL samples at various times during the disease course or during therapy. The obtained data led us to hypothesize on the mechanisms of regulation of signalling propensity of two pathways that are responsible for proliferation and survival of CLL cells, namely B Cell Receptor (BCR) signalling and signals from T-cells mediated by CD40/IL4. In aim 1 we hypothesize that CD20 is one of the key proteins involved in CLL cell activation, and influences BCR and interleukin signalling (see figure). This has important therapeutic implication since CD20 is used as a therapeutic target for 20 years (rituximab), but its function in CLL/normal B cells is unknown. In aim 2 we hypothesize that miR-29 acts a key regulator of T-cell signalling from CD40 and down-stream NFkB activation (see figure). This represents the first example of miRNAs’ role in the propensity of T-cell interaction, and could be also utilized therapeutically. In aim 3 we will integrate our data on microenvironmental signaling (aim 1+2) and develop a first mouse model for PDX that would allow stable engraftment of primary CLL cells. Currently, CLL is non-transplantable to any animal model which complicates studies of its biology.

Link to the ERC project webpage: ceitec.cz/mrazlab

Keywords of the ERC project: BCR signalling; T cell interactions; development of targeted therapy for CLL; biomarkers of resistance to therapy; mouse model for PDX in chronic lymphocytic leukemia; ibrutinib; B cells; chronic lymphocytic leukemia; BCR inhibitors

Keywords that characterize the scientific profile of the potential visiting researcher/s: BCR signalling; B cells; CLL; chronic lymphocytic leukemia; lymphoma; BCR inhibitors
Enhancers Decoding the Mechanisms Underlying CAD Risk

In recent years, genome-wide association studies (GWAS) have discovered hundreds of single nucleotide polymorphisms (SNPs) which are significantly associated with coronary artery disease (CAD). However, the SNPs identified by GWAS explain typically only small portion of the trait heritability and vast majority of variants do not have known biological roles. This is explained by variants lying within noncoding regions such as in cell type specific enhancers and additionally ‘the lead SNP’ identified in GWAS may not be the ‘the causal SNP’ but only linked with a trait associated SNP. Therefore, a major priority for understanding disease mechanisms is to understand at the molecular level the function of each CAD loci. In this study we aim to bring the functional characterization of SNPs associated with CAD risk to date by focusing our search for causal SNPs to enhancers of disease relevant cell types, namely endothelial cells, macrophages and smooth muscle cells of the vessel wall, hepatocytes and adipocytes. By combination of massively parallel enhancer activity measurements, collection of novel eQTL data throughout cell types under disease relevant stimuli, identification of the target genes in physical interaction with the candidate enhancers and establishment of correlative relationships between enhancer activity and gene expression we hope to identify causal enhancer variants and link them with target genes to obtain a more complete picture of the gene regulatory events driving disease progression and the genetic basis of CAD. Linking these findings with our deep phenotypic data for cardiovascular risk factors, gene expression and metabolomics has the potential to improve risk prediction, biomarker identification and treatment selection in clinical practice. Ultimately, this research strives for fundamental discoveries and breakthrough that advance our knowledge of CAD and provides pioneering steps towards taking the growing array of GWAS for translatable results.

Link to the ERC project webpage:

Keywords of the ERC project:

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Regulation of bone metastases by age-associated angiocrine signals

Blood vessels form a versatile transport network and provide inductive signals called angiocrine factors to regulate tissue-specific functions. Blood vessels in bone are heterogeneous with distinct capillary subtypes that exhibit remarkable alterations with age. Bone is the most prevalent site of metastasis, and ageing is linked to the reactivation of dormant tumor cells (dorTCs) and metastatic relapse. Bone remodeling processes are also associated with metastatic relapse. Here, I will define the role of distinct vascular niches in regulating the fate of DTCs in bone. Finally, I will unravel the age-related angiocrine factors and identify key angiocrine signals that drive the reactivation of dorTCs. I will employ a powerful combination of advanced 3D, intravital, and whole body imaging, cell specific-inducible mouse genetics, transcriptional profiling and bioinformatics in an unprecedented manner to achieve my goals. New cutting-edge techniques such as advanced 3D and 4D bone imaging are important aspects of my proposal. I will also define the role of highly promising novel candidate age-related angiocrine signals with sophisticated inducible endothelial-specific humanised mouse models. My work will break new ground by unraveling a repertoire of age-related angiocrine factors and will contribute to a wider scientific community in bone, blood, and age-related diseases. This interdisciplinary work at the frontiers of bone, cancer and vascular biology will provide the first conceptual link between vascular ageing and bone metastasis and will contribute towards the development of therapeutic strategies for targeting DTCs in bone.

Link to the ERC project webpage:

Keywords of the ERC project: bone marrow microenvironment, ageing, angiogenesis, bone metastasis

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Form and Function of the Mitochondrial Retrograde Response

The molecular communication between mitochondria and nucleus is an integrated bi-directional crosstalk - anterograde (nucleus to mitochondria) and retrograde (mitochondria to nucleus) signalling pathways. The mitochondrial retrograde response (MRR) is driven by defective mitochondrial function, which increases cytosolic reactive oxygen species (ROS) and Ca2+. Metabolic reprogramming is a key feature in highly proliferative cells to meet the energy needs for rapid growth by generating substrates for cellular biogenesis. In these mitochondria retro-communicate with the nucleus to induce wide-ranging cytoprotective effects exploited to develop resistance against treatment and sustain uncontrolled growth. Recently, the mitochondrial management of cholesterol-derived intermediates for the synthesis of steroids has been demonstrated as a determinant in the oncogenic reprogramming of cellular environment.

We hypothesise that cholesterol-enriched domains facilitate the communication between remodelled mitochondria and nucleus to expedite MRR. This mechanism may be exploited during abnormal cell growth in which cholesterol metabolism and associated molecules are increased.

This application capitalizes on expertise in cell signalling and metabolism to interrogate core pathways and unveil molecular sensors and effectors that define form and function of the MRR by:

I. Elucidating the mechanism of metabolic regulation of MRR, describing the role exerted by cholesterol trafficking;
II. Unveiling microdomains for mito-nuclear communication established by remodelled, autophagy escaped, mitochondria;
III. Validating protocols to modulate and target MRR for diagnostic and therapeutic benefit;

The experimental plan will (i) define a molecular signalling axis that currently stands uncharacterized, (ii) provide mechanistic knowledge for preventive, and (iii) therapeutic applications to counteract deficiencies associated with stressed, dysregulated mitochondria.

Link to the ERC project webpage:
Keywords of the ERC project: Mitochondria, Quality Control, Contact Sites, Pharmacology, Signalling
Keywords that characterize the scientific profile of the potential visiting researcher/s: Mitochondria, Autophagy, Pharmacology, Inter-organelles, Communication, Signalling
Resilience and Trigger Factors in Cardiac Arrhythmia: Risk Stratification and Drug Design

Up to 30% of individuals with inherited cardiac arrhythmias such as Long QT syndrome are not protected from sudden cardiac death despite state-of-the-art treatment. A major hurdle for effective risk stratification and treatment of inherited cardiac arrhythmias is the poor correlation between genetic variant and clinical manifestations. Affected individuals, who harbour the same arrhythmia-causative mutation, paradoxically display a spectrum of clinical phenotypes ranging from a lifelong asymptomatic state to sudden death in infancy. Up to 40% of genotype-positive individuals, depending on type of arrhythmia, do not display clinical manifestation. Based on our unpublished observations, I propose that an important, yet unexplored, underlying cause of the diverse clinical manifestations are endogenous resilience and trigger factors, which interact with mutated cardiac ion channels to alter arrhythmia severity. MOLEC ANTI-ARRHYT utilizes front-line experimental and computational approaches and the cardiac IKs potassium channel, which is strongly linked to lethal arrhythmias and sudden cardiac death, as a prototype. We aim to: (i) identify major classes of endogenous ligands with therapeutic (resilience factors) or pathological (trigger factors) effects on the IKs channel, (ii) provide proof of mechanism for how the effect of resilience and trigger factors is determined by arrhythmia-causative mutations in the IKs channel, (iii) utilize resilience mechanisms to develop a fundamentally novel concept of anti-arrhythmic drug development: Resilience-Mimetic Drug Development. The successful completion of this project will open up new avenues for personalized risk stratification and clinical management, which ultimately will improve the clinical outcome for individuals with inherited arrhythmias.
Project ID: 852343  
Project Acronym: EPICAMENTE  
Evaluation Panel: LS4  
Physiology, Pathophysiology and Endocrinology

Principal Investigator: Dr SARA SDELCI  
Host Institution: FUNDACIO CENTRE DE REGULACIO GENOMICA - ES

At the epigenetics-cancer metabolism interface

Epigenetic regulation and metabolism are of great interest in cancer research. However, physical and functional connections between these two areas remain largely unexplored. While it is commonly believed that metabolites can randomly distribute inside the cell, recent evidence rather favors the hypothesis that production of certain metabolites in specific subcellular compartments orchestrates different cellular processes. EPICAMENTE aims at exploring whether the localization of enzymatic activities on chromatin can integrate cancer metabolism with chromatin remodeling to control epigenetic regulation and tumor progression. First, I aim at providing a dataset of chromatin-bound metabolic enzymes in a comprehensive panel of cancer cell lines. By combining a chromatin fluorescent reporter cell line strategy with epigenomic approaches, I will define the epigenetic and transcriptional scenarios orchestrated by chromatin-bound metabolic enzymes, and investigate their relevance in cancer cell proliferation. Performing genetic screenings with the chromatin fluorescent reporter cell lines will allow the identification of genetic interactors mediating the epigenetic role of chromatin-bound metabolic enzymes. In parallel, I aim to screen for small molecules able to counteract the epigenetic states mediated by those metabolic enzymes. Finally, I will validate my results in in vivo cancer models, thus adding an important translational aspect to the project, and opening up new opportunities for cancer therapy. The success of this project can impact our fundamental understanding of cellular and cancer biology. In most cases, the belief is that intracellular materials reside inside steady-state membrane-based compartments, which limit the interactions between different molecular pathways. By describing the role of chromatin-bound metabolic enzymes and discovering direct connections between cancer metabolism and epigenetic regulation, I will scrutinize this belief.

Link to the ERC project webpage:

Keywords of the ERC project: epigenetic, cancer, metabolism, screening, compounds, reporter, Warburg, transcription, chromatin

Keywords that characterize the scientific profile of the potential visiting researcher/s:
The role of tumour microenvironment in metastatic hormone-refractory prostate cancer

The goal of this proposal is to investigate the role of tumor microenvironment in metastatic hormone-refractory prostate cancer (mHRPC). Prostate Cancer (PC) is the most common malignancy in men in Europe while mHRPC is the most lethal form of the disease, causing over 95% of PC related deaths. Extensive clinical and preclinical research using state-of-the-art tumour models has led to the development of several new therapeutics that, unfortunately, provide only marginal patient benefit. One key element missing in standard preclinical models is the relevant metastasis microenvironment associated with mHRPC that may dramatically affect disease outcome. Here, I plan to significantly advance our understanding in mHRPC associated microenvironment with the first androgen dependent PC bone metastasis model I developed that mimics both the pathology and disease progression in patients. My preliminary data indicate that metastasis associated stromal cells may form a unique bone metastasis microenvironment that promotes mHRPC. I aim to identify the underlying molecular mechanisms using a multidisciplinary approach combining intra-vital microscopy, dynamic ADT resistance reporter system, innovative adoptive transfer approach and genetic tools of lineage specific knockout. This work is also designed to translate findings made in mouse models into human disease using innovative humanized in vivo models of mHRPC. The findings generated in this project will lead to innovative therapeutic approaches that can effectively treat mHRPC thus relieve this lethal threat on European societies. MetResistance will make a step change in the field of cancer medicine research by providing new standards to study therapy resistance of metastatic cancer an area representing the number one challenge in cancer research and patient care.

Link to the ERC project webpage:

Keywords of the ERC project:

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Deconstructing Ageing: from molecular mechanisms to intervention strategies

Over many years, our research group has explored the complex relationship between cancer and ageing. As part of this work, we have generated mouse models of protease deficiency which are protected from cancer but exhibit accelerated ageing. Further studies with these mice have allowed us to unveil novel mechanisms of both normal and pathological ageing, to discover two new human progeroid syndromes, and to develop therapies for the Hutchinson-Gilford progeria syndrome, now in clinical trials. We have also integrated data from many laboratories to first define The hallmarks of ageing and the current possibilities for Metabolic control of longevity. Now, we propose to leverage our extensive experience in this field to further explore the relative relevance of cell-intrinsic and -extrinsic mechanisms of ageing. Our central hypothesis is that ageing derives from the combination of both systemic and cell-autonomous deficiencies which lead to the characteristic loss of fitness associated with this process. Accordingly, it is necessary to integrate multiple approaches to understand the mechanisms underlying ageing. This integrative and multidisciplinary project is organized around three major aims: 1) to characterize critical cell-intrinsic alterations which drive ageing; 2) to investigate ageing as a systemic process; and 3) to design intervention strategies aimed at expanding longevity. To fully address these objectives, we will use both hypothesis-driven and unbiased approaches, including next-generation sequencing, genome editing, and cell reprogramming. We will also perform in vivo experiments with mouse models of premature ageing, genomic and metagenomic studies with short- and long-lived organisms, and functional analyses with human samples from both progeria patients and centenarians. The information derived from this project will provide new insights into the molecular mechanisms of ageing and may lead to discover new opportunities to extend human healthspan.

Link to the ERC project webpage:

Keywords of the ERC project:

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Inflammatory resolution and remodelling of the adipose extracellular matrix: key determinants of a metabolically healthy phenotype?

Obesity and its affiliated metabolic diseases pose serious public health challenges. However, certain patient subgroups appear protected. To halt the socio-economic burden of metabolic disease, we urgently need to understand what distinguishes the Metabolically-Healthy-Lean (MHL), Metabolically-Unhealthy-Lean (MUL), Metabolically-Healthy-Obese (MHO) and Metabolically-Unhealthy-Obese (MUO) phenotypes, and which factors promote metabolic health. Inflammation has been proposed as a target, as it is a key driver of metabolic disease. However, clinical trials show limited evidence that anti-inflammatory drugs reduce diabetes. Why is that?

Inflammation consists of a pro-inflammatory phase followed by a pro-resolving phase, which are regulated by different cells/pathways. This is critical to consider when attempting a therapeutic approach. Based on my preliminary data, I hypothesise that what separates MHL/MHO from MUL/MUO are not pro-inflammatory triggers, but rather the endogenous ability of individuals to resolve inflammation. Adipose extracellular-matrix remodelling appears critical, and pro-resolving lipids promote a MUO-to-MHO switch.

My overall goal is to determine molecular pathways that differentiate the MHL/MUL/MHO/MUO phenotypes (Aim 1-4), and to investigate the therapeutic potential of pro-resolving lipids (Aim 5). This multi-disciplinary project combines cutting-edge techniques with state-of-the-art translational approaches. Through my unique access to human biobanks, I will generate patient-specific cell-lines and test drug-targets ex vivo. Novel bioinformatics pipelines will produce protein/lipid/metabolite fingerprints associated with respective patient groups, ultimately providing a new approach to tackle obesity-related comorbidities. My experience in the specialised field of pro-resolving lipid biology, coupled with my lab’s unique placement at a translational site, makes me the right candidate to lead this research program.

Link to the ERC project webpage: https://www.borgesonlab.org/

Keywords of the ERC project:

Keywords that characterize the scientific profile of the potential visiting researcher/s: Inflammation, resolution, lipoxin, metabolic disease, obesity
Nutrient sensing enables metabolic homeostasis by matching energy use with fuel availability. The vast body of knowledge on pro-anabolic nutrient sensors, such as insulin and class 1 phosphoinositol-3 kinase (PI3K) signalling exposed the missing links in molecular coordination of catabolism. The cellular catabolism relies on mitochondrial activities and on lysosomal pathway of autophagy, both paced by the biological clock. However, how pro-catabolic nutrient sensors synchronize these catabolic activities is not well understood. We discovered that class 3 PI3K, the only PI3K present in all eukaryotes, is essential for catabolic homeostasis in vivo, but the mechanisms of its metabolic functions are still lacking. We found novel roles for class 3 PI3K in metabolic adaptation to fasting and mitochondrial activity, beyond its established functions in autophagy and endosomal trafficking. These findings form the basis of our innovative interdisciplinary research program that will investigate the molecular bases of Metabolic integration in vivo by a nutrient SENSing pathway of class 3 PI3K (MetaboSENS). In the MetaboSENS research program, we seek to identify transcription factor networks and regulatory complexes of class 3 PI3K that serve its catabolic integrator function. We aim to reveal the physiological oscillation of class 3 PI3K signalling and its reciprocal impact on metabolic timekeeping. Finally, the MetaboSENS project will combine patient analyses and the medical expertise of my team to reveal, for the first time, genetic alterations in class 3 PI3K signalling in inborn metabolic disease. The new mechanisms that we discover may provide therapeutic targets that we will test in the pre-clinical models. Altogether, the MetaboSENS project will redefine our view of systemic catabolism.

Link to the ERC project webpage: www.panasyuklab.fr

Keywords of the ERC project: metabolic homeostasis, nutrient sensing, catabolism, class 3 phosphoinositide 3-kinase, Vps15/Vps34, nuclear receptor transcription factors, autophagy, lysosome, endocytic trafficking, human rare liver disease

Keywords that characterize the scientific profile of the potential visiting researcher/s: motivated, pro-active, creative early career researcher (MD or PhD) with experience in cell biology, molecular biology, animal models and/or human genetics
Trained immunity: improving the next generation of vaccines for the older generation

The host defense, especially the adaptive immunity, is defective in the elderly, with a dramatic drop for the efficacy of vaccination with old age. Interestingly however, the innate immunity of older individuals is relatively intact, and we recently described that epigenetic and functional reprogramming of innate immune cells by certain vaccines and mild infections, termed ‘trained immunity’, induces potent heterologous protection against infections. I propose that induction of trained immunity is an important novel approach to improved vaccination in the elderly. Induction of trained immunity is regulated by the interaction between the host genome, microbiome, and the epigenetic and metabolic programs of specific populations of myeloid cells, and we need to understand how these factors are impacted by age and gender of the host. By understanding the factors that impact the response to BCG (Bacille Calmette-Guerin), the prototype vaccine that induces trained immunity, we will be able to design better vaccines for the elderly. The Key objectives of the project are: Key objective 1: To describe the innate immune cell (sub)populations, and their heterogeneity at single-cell level, responsible for mediating trained immunity in the young and elderly adults. Key objective 2: To identify the complex genetic, epigenetic, microbiome, and metabolic programs that represent the molecular and biochemical substrates of trained immunity in the myeloid cells of the elderly individuals. Key objective 3: To use systems biology to map the heterogeneity of trained immunity response determined by host (epi)genome, microbiome, and environmental factors in the elderly. Expected results: We will understand the main cellular and molecular mechanisms for the induction of trained immunity responses in vivo and the specificities of the response in the elderly. These findings will enable the design of innovative approaches to improve vaccination strategies.

Link to the ERC project webpage:

Keywords of the ERC project:

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Motor and cognitive functions of the monkey premotor cortex during free social interactions

A number of studies demonstrated that the primates' premotor cortex (PM) plays a crucial role not only in organizing movement, but also in perceptual and socio-cognitive functions. However, these studies have been carried out in laboratory settings, which deeply limit the possibility to understand the neural mechanisms underlying natural behaviours. To solve this problem, I propose a new approach consisting in a two-steps chronic recording of monkey PM neurons: first, single neurons response properties will be characterized in a traditional, head-restrained laboratory setting; then, in the same session, the same neurons activity will be recorded wirelessly during free interactions of the monkey with its physical and social environment. The project will initially focus on neurons belonging to the forelimb representation of the ventral (i.e. areas F4 and F5) and dorsal (area F2vr) PM, putatively well known for their role in sensorimotor transformations, goal coding, representation of space, and recognition of other’s observed actions. The same paradigm will then be applied to the study of the mesial pre-supplementary area F6, a crucial bridge between prefrontal and PM regions whose role in socio-cognitive functions remains still virtually unknown. Finally, by simultaneous, chronic recording of neuronal activity from lateral and mesial PM, we will first assess the functional interactions between these areas in both laboratory and natural settings, and then we will probe causality in these interactions by chemically manipulating neuronal activity of one region (i.e. F6) while recording from the other one (i.e. F5). The project will reveal the role of premotor cortex in motor and social functions during natural behaviours. In addition, it might open up new possibilities for future studies of neural plasticity and reorganization of ethologically-relevant motor, cognitive and social functions following chemical manipulation of neural activity and virtual brain lesions.

Link to the ERC project webpage: www.boninilab.unipr.it

Keywords of the ERC project: mirror neurons; peripersonal space; motor control; monkey; social interaction

Keywords that characterize the scientific profile of the potential visiting researcher/s: neurophysiology; data analysis; neuroethology; animal behaviour
Innovative problem solving is critical for all spheres of organised endeavour, including science and industry, and thus forms the cornerstone of a successful society. Such creative thinking often requires suppression of preconceptions and restructuring of existing knowledge. Pioneering work has shown that sleep facilitates problem solving, but exactly how, and which sleep characteristics are important, remain to be determined. We know that recent experiences are replayed in sleep, and that in Slow Wave Sleep (SWS) this replay integrates new knowledge with old. The role of such replay in Rapid Eye Movement (REM) sleep, a stage which is strongly linked to creativity, is unknown. Here, I propose a model which combines physiology, behavioural studies, and computational modelling to make testable predictions about the complimentary contributions of memory replay in REM and SWS to problem solving. I will test this model through explicit manipulation of memory replay in sleep. I will use a very recently developed technique to explicitly trigger memory replay, a pioneering method for quantifying this replay, and cutting-edge approaches for manipulation of neural oscillations during sleep. I expect two key results: first, I will uncover the principles of how memory replay in REM and SWS combines with specific neural oscillations to promote both long-term memory and creative problem solving. This will involve development of a computational model which will enable optimised experimental design, paving the way for efficient future investigation of how to enhance innovation through manipulation of sleep. Second, I will develop methods for boosting key sleep processes in a selective, targeted manner. Immediate consequences will include a translational project to facilitate everyday problem solving. My findings will revolutionist the understanding of sleep and how it impacts upon some of our most important cognitive abilities—memory and problem solving.

Link to the ERC project webpage: https://www.cardiff.ac.uk/research/explore/research-units/neuroscience-and-psychology-of-sleep-lab-naps

Keywords of the ERC project: sleep, memory, consolidation, creativity, abstraction, replay

Keywords that characterize the scientific profile of the potential visiting researcher/s: EEG, sleep, memory, creativity, MEG, fMRI
Wiring synaptic circuits with astroglial connexins: mechanisms, dynamics and impact for critical period plasticity

Brain information processing is commonly thought to be a neuronal performance. However recent data point to a key role of astrocytes in brain development, activity and pathology. Indeed astrocytes are now viewed as crucial elements of the brain circuitry that control synapse formation, maturation, activity and elimination. How do astrocytes exert such control is matter of intense research, as they are now known to participate in critical developmental periods as well as in psychiatric disorders involving synapse alterations. Thus unraveling how astrocytes control synaptic circuit formation and maturation is crucial, not only for our understanding of brain development, but also for identifying novel therapeutic targets.

We recently found that connexin 30 (Cx30), an astroglial gap junction subunit expressed postnatally, tunes synaptic activity via an unprecedented non-channel function setting the proximity of glial processes to synaptic clefts, essential for synaptic glutamate clearance efficacy. Our work not only reveals Cx30 as a key determinant of glial synapse coverage, but also extends the classical model of neuroglial interactions in which astrocytes are generally considered as extrasynaptic elements indirectly regulating neurotransmission. Yet the molecular mechanisms involved in such control, its dynamic regulation by activity and impact in a native developmental context are unknown. We will now address these important questions, focusing on the involvement of this novel astroglial function in wiring developing synaptic circuits.

Thus using a multidisciplinary approach we will investigate:
1) the molecular and cellular mechanisms underlying Cx30 regulation of synaptic function
2) the activity-dependent dynamics of Cx30 function at synapses
3) a role for Cx30 in wiring synaptic circuits during critical developmental periods

This ambitious project will provide essential knowledge on the molecular mechanisms underlying astroglial control of synaptic circuits.

Link to the ERC project webpage:
Keywords of the ERC project:
Keywords that characterize the scientific profile of the potential visiting researcher/s:
Enhancing brain function and cognition via artificial entrainment of neural oscillations

Neural oscillations are ubiquitous in the human brain and have been implicated in diverse cognitive functions to support both neural communication and plasticity. Their functional relevance is further supported by a large number of studies linking various cognitive deficits (e.g., attention deficit hyperactivity disorder, ADHD) with abnormal neural oscillations. However, this field of research faces two important problems: First, there is only correlative, but no causal evidence linking cognitive deficits to abnormal neural oscillations in humans. Second, there is virtually no theory-driven mechanistic approach that generates insights into how oscillations within and across neural networks are linked to human behavior. In this project, I propose to take decisive steps to provide a long-needed neurophysiological characterization—via (1) computational modelling, (2) electrophysiological measures, and (3) novel non-invasive manipulations of cortical rhythms—on how neural oscillations contribute to two types of cognitive processes that are fundamental for many aspects of human behavior: attention and short-term memory. I will go a step further by demonstrating that it is possible to augment performance in these cognitive functions with the design of non-invasive brain stimulation protocols individually tailored to the theory-driven neurocomputational characterizations and electrophysiological signatures of each individual. This will result in the applied goal of deriving new neuro-computational assays that can detect deviant network interactions causally related to cognitive functions, which is key for then renormalizing those functions in neuropsychological conditions such as ADHD. Thus, if successful, my proposed work will ultimately result in novel, low-cost, and painless non-invasive neural interventions for a wide range of neuropsychological disorders tied to abnormal neural oscillations.

**Link to the ERC project webpage:** [https://decision.ethz.ch/](https://decision.ethz.ch/)

**Keywords of the ERC project:** decision making, brain stimulation

**Keywords that characterize the scientific profile of the potential visiting researcher/s:** neuro-computational modeling, programming (R, C++, Matlab)
Our senses face a constant barrage of information. Hence, understanding how our brain enables us to attend to relevant stimuli, while ignoring distractions, is of increasing biomedical importance. Recently, I discovered that the claustrum, a multi-sensory hub and recipient of extensive neuromodulatory input, enables resilience to distraction.

In my ERC project, I will explore the mechanisms underlying claustral mediation of resilience to distraction and develop novel approaches for assessing and modulating attention in mice, with implications for humans. Transgenic mouse models that I identified as enabling selective access to claustral neurons overcome its limiting anatomy, making the claustrum accessible to functional investigation. Using this novel genetic access, I obtained preliminary results strongly suggesting that the claustrum functions to filter distractions by adjusting cortical sensory gain.

My specific aims are: 1) To delineate the mechanisms whereby the claustrum achieves sensory gain control, by applying in-vivo cell-attached, multi-unit and fiber photometry recordings from claustral and cortical neurons during attention-demanding tasks. 2) To discriminate between the functions of the claustrum in multi-sensory integration and implementation of attention strategies, by employing multi-sensory behavioral paradigms while modulating claustral function. 3) To develop validated complementary physiological and behavioral protocols for adjusting claustral mediation of attention via neuromodulation.

This study is unique in its focus and aims: it will provide a stringent neurophysiological framework for defining a key mechanism underlying cognitive concepts of attention, and establish a novel platform for studying the function of the claustrum and manipulating its activity. The project is designed to achieve breakthroughs of fundamental nature and potentially lead to diagnostic and therapeutic advances relevant to attention disorders.

Link to the ERC project webpage: www.citrilab.com

Keywords of the ERC project: claustrum physiology anatomy reward attention photometry neuropixels patch-clamp mice behavior

Keywords that characterize the scientific profile of the potential visiting researcher/s: physiologist behaviourist attention prefrontal
An open or closed process: Determining the global scheme of perception

Despite decades of intensive research, there is no agreement about the general scheme of perception: Is the external object a trigger for a brain-internal process (open-loop perception, OLP) or is the object included in brain dynamics during the entire perceptual process (closed-loop perception, CLP)? HOWPER is designed to provide a definite answer to this question in the cases of human touch and vision. What enables this critical test is our development of an explicit CLP hypothesis, which will be contrasted, via specific testable predictions, with the OLP scheme. In the event that CLP is validated, HOWPER will introduce a radical paradigm shift in the study of perception, since almost all current experiments are guided, implicitly or explicitly, by the OLP scheme. If OLP is confirmed, HOWPER will provide the first formal affirmation for its superiority over CLP.

Our approach in this novel paradigm is based on a triangle of interactive efforts comprising theory, analytical experiments, and synthetic experiments. The theoretical effort (WP1) will be based on the core theoretical framework already developed in our lab. The analytical experiments (WP2) will involve human perceivers. The synthetic experiments (WP3) will be performed on synthesized artificial perceivers. The fourth WP will exploit our novel rat-machine hybrid model for testing the neural applicability of the insights gained in the other WPs, whereas the fifth WP will translate our insights into novel visual-to-tactile sensory substitution algorithms. HOWPER is expected to either revolutionize or significantly advance the field of human perception, to greatly improve visual to tactile sensory substitution approaches and to contribute novel biomimetic algorithms for autonomous robotic agents.

Link to the ERC project webpage:

Keywords of the ERC project: perception, active-sensing, robotics, sensory-substitution, brain-machine-interface

Keywords that characterize the scientific profile of the potential visiting researcher/s: perception, active-sensing, robotics, sensory-substitution, brain-machine-interface
**Myelin at the crossroads of Development and Disease**

The oligodendrocyte, the largest cell in mammalian biology, greatly enables central nervous system (CNS) function through production of a single substance: myelin. Oligodendrocytes undergo a dramatic 1-2 day metamorphosis during myelination, increasing their cell surface area ~6500-fold with proteolipid extensions to nerve axons in the CNS white matter. How is this synthetic feat accomplished? We lack a comprehensive understanding of machinery that precisely coordinates transcription, translation, lipid synthesis and energy production. Moreover, how do these mechanisms become so intensively upregulated during myelination? Does this extraordinary transient state put the myelinating oligodendrocyte at risk of death in diseases of white matter? These questions underlie the Aims of the proposal “Myel-IN-crisis.”

I propose (Aim 1) testing whether an “Integrated Synthetic Programme (ISP)” controls oligodendrocyte differentiation, metabolic and synthetic requirements of developmental myelination. In Aim 2, I will investigate roles for “smart sensor” oxygen (HIF) and nutrient (mTOR) pathways in regulating initiation and termination of the ISP. During development, extrinsic white matter injury in preterm infants leads to cerebral palsy, while intrinsic defects in myelin protein PLP1 cause the fatal human leukodystrophy, Pelizaeus-Merzbacher disease (PMD). Preliminary studies indicate transcriptional and translational dysregulation in human PLP1-mutant oligodendrocytes, which become iron overloaded leading to apoptotic cell death. In Aim 3, I propose that either extrinsic (e.g., hypoxia) or intrinsic (e.g., PLP1 mutation) factors promote a “Universal Stress Response (USR)” in the pre-myelinating oligodendrocyte that leads to toxic dysregulation of the ISP. Finally, in Aim 4 we will identify the key pathways of the USR to generate strategies for rescue of myelination with potential translational impact in cerebral palsy and leukodystrophy, multiple sclerosis and stroke.

---

**Link to the ERC project webpage:**

**Keywords of the ERC project:**

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Tethers for sensory mechanotransduction: from molecules to perception

Touch sensation is built upon the ability of sensory neurons to detect and transduce nanometer scale mechanical displacements. The underlying process has been termed mechanotransduction: the high sensitivity and speed of which is enabled by direct gating (opening) of ion channels by mechanical force. Force detection is functionally compartmentalized and only takes place at the peripheral endings of sensory neurons in vivo. Two molecules are known to be genetically necessary for touch in many sensory neurons, the force gated ion channel PIEZO2 and its modulator STOML3. However, mechanotransduction complexes in all touch receptors absolutely require tethering to the extracellular matrix for function. Tethering is dependent on large extracellular proteins that are sensitive to site-specific proteases. Here we will not only identify the nature of these tethers, but will develop technology to acutely and reversibly abolish tethers and other mechanotransducer components. We will use genome engineering to tag tether and mechanotransduction components in order to visualize and manipulate these proteins at their in vivo sites of action. By engineering de novo cleavage sites for site-specific proteases we will render tethers and ion channels newly sensitive to normally ineffective proteases in the skin. We will engineer mutations into candidate ion channels that dramatically alter biophysical properties to physiologically “mark” function in vivo. Finally we will develop new behavioural paradigms in mice that allow us to measure touch perception from the forepaw. Psychometric curves for different vibrotactile tasks can then be precisely compared between humans and mice. Furthermore, the impact of acute and reversible manipulation of mechanotransduction on touch perception can be measured. Understanding how molecules assemble to function in a mechanotransduction complex in the skin will open up avenues to develop therapeutic strategies to modulate touch.

Link to the ERC project webpage:

Keywords of the ERC project: mechanotransduction, sensory, touch, pain

Keywords that characterize the scientific profile of the potential visiting researcher/s:
**Neural drivers of functional disconnectivity in brain disorders**

A rapidly expanding approach to understanding neural organization is to map patterns of spontaneous neural activity as an index of functional communication and connectivity across brain regions. Fostered by the advent of neuroimaging methods like resting-state fMRI (rsfMRI), this approach has revealed that functional connectivity is almost invariably disrupted in severe psychiatric disorders, such as autism or schizophrenia. However, the neural basis of such functional disconnectivity remains mysterious. What drives brain-wide functional synchronization? And are there shared pathophysiological mechanisms leading to impaired large-scale neural coupling?

This project aims to elucidate the neural drivers of macroscale functional connectivity, as well as its breakdown in brain connectopathies. To achieve this goal, I propose a multi-scale perturbational approach to establish causal relationships between specific neural events and brain-wide functional connectivity via a novel combination of rsfMRI and advanced neural manipulations and recordings in the awake mouse. By directionally silencing functional hubs as well as more peripheral cortical regions, I will provide a hierarchical description of spontaneous network organization that will uncover regional substrates vulnerable to network disruption. I will also manipulate physiologically-distinct excitatory or inhibitory populations to probe a unifying mechanistic link between excitatory/inhibitory imbalances and aberrant functional connectivity. Finally, to account for the hallmark co-occurrence of synaptic deficits and functional disconnectivity in developmental disorders, I will link cellular mechanisms of synaptic plasticity and learning to the generation of canonical and aberrant spontaneous activity patterns. These studies will pave the way to a back-translation of aberrant functional connectivity into interpretable neurophysiological events and models that can help understand, diagnose or treat brain disorders.

**Link to the ERC project webpage:**

Keywords of the ERC project: connectivity, fMRI, chemogenetics, optogenetics, mouse, autism, schizophrenia

Keywords that characterize the scientific profile of the potential visiting researcher/s: neural computation, image analysis, neuroscience, electrophysiology
Organization and learning-associated dynamics of prefrontal synaptic connectivity

How does experience alter the functional architecture of synaptic connections in neural circuits? This question is particularly pertinent for the complex circuits of the medial prefrontal cortex (mPFC), a high-order associative neocortical area that plays a crucial role in flexible, goal-directed behavior. The mPFC is densely interconnected with cortical and subcortical circuits, and its neurons were shown to undergo substantial experience-dependent structural remodeling that is thought to support learning and memory consolidation. However, little is known regarding the synaptic organization of this complex circuit, and of the functional implications of its experience-dependent structural remodeling. In this proposal, we aim to uncover the organization and learning-associated dynamics of functional connectivity in the mouse mPFC.

To obtain high-resolution maps of cell type-specific synaptic connectivity in the mPFC, we will combine single-cell optogenetic manipulation with calcium imaging and electrophysiology in vitro, and establish the circuit-wide organization of connectivity within and between defined projecting neuron populations. We will test the hypothesis that pyramidal neurons projecting to subcortical targets form tightly interconnected subnetworks, and that inhibitory inputs to these networks, through selective innervation, can modulate information output from the mPFC.

To understand how learning changes the functional synaptic organization of the mPFC, we will establish an all-optical system for interrogation of synaptic connectivity in vivo. We will utilize this powerful platform to test the hypothesis that prefrontal-dependent learning is associated with reorganization of local-circuit functional connectivity among identified subcortically-projecting cell assemblies.

Our innovative technology will be widely applicable for neural circuit analysis in a variety of systems, and allow us to gain new insights into the complex circuitry of the mPFC.

Link to the ERC project webpage:

Keywords of the ERC project: Synaptic connectivity, optogenetics, two-photon imaging, learning
Keywords that characterize the scientific profile of the potential visiting researcher/s: electrophysiology, imaging, patch-clamp
Human Subcortical-Cortical Circuit Dynamics for Remembering the Exceptional

Our memory system is optimised for remembering the exceptional over the mundane. We remember better those events that violate predictions generated by the prevailing context, particularly because of surprise or emotional impact. Understanding how we form and retrieve long-term memories for important or salient events is critical for combating the rapidly growing incidence of pathologies associated with memory dysfunction with huge socio-economic burden. Human lesion and non-invasive functional imaging data, motivated by findings from animal models, have identified subcortical structures that are critical for upregulating hippocampal function during salient event memory. However, mechanistic understanding of these processes in humans remains scarce, and requires better experimental approaches such as direct intracranial recordings from, and focal electrical stimulation of, these subcortical structures.

This project will characterise human subcortico-cortical neuronal circuit dynamics associated with enhanced episodic memory for salient stimuli by studying direct recordings from human hippocampus, amygdala, nucleus accumbens, ventral midbrain and cortex. Within this framework, I will elucidate the electrophysiological mechanisms underlying amygdala-hippocampal-cortical coupling that lead to better memory for emotional stimuli, extend the hippocampal role in detecting unpredicted stimuli to define its role in orchestrating cortical dynamics in unpredictable contexts, and discover the neuronal response profile of the human mesolimbic dopamine system during salient stimulus encoding. The predicted results, based on my own preliminary data, will offer several conceptual breakthroughs, particularly regarding hippocampal function and the role of dopaminergic ventral midbrain in memory. The knowledge gained from this project is a fundamental requirement for designing therapeutic interventions for patients with memory deficits and other neuropsychiatric disorders.

Link to the ERC project webpage: http://www.thestrangelab.org/erc-cog-rememberex/

Keywords of the ERC project: Memory, Emotion, Salience, Hippocampus; Amygdala; Nucleus accumbens; Ventral tegmental area; Human intracranial recordings; functional MRI (fMRI); magnetoencephalography (MEG)

Keywords that characterize the scientific profile of the potential visiting researcher/s:
**Whole-brain dynamics underlying self-generated behaviour**

The first behavioural theories conceived the organism as primarily driven by external sensory stimuli. However, the energy associated with momentary demands of the environment represent ~1% of the brain’s total energy budget, implying that the intrinsic activity represents a major aspect of the brain’s function. Indeed, more recent theories such as cognitivism and embodiment describe the organisms as capable of generating complex behaviours emerging from the brain’s intrinsic dynamics.

Past and current studies that investigated the neuronal basis self-generated behaviours mainly focus on the readiness potential (RP) signal, a build-up ramping activity in the premotor cortex, occurring ~ 2 sec before the movement’s onset. However, the neuronal mechanisms underlying the generation of self-generated behaviours (how RPs are generated), the involvement of other regions, and how the brain codes the impending movements (activity predictive of the onset and type of movement), still remain poorly understood.

The combination of light-sheet microscopy, optogenetics, and the zebrafish larva model enables monitoring whole-brain dynamics in an intact behaving vertebrate. Moreover, the diverse yet limited and well described repertoire of motor behaviours will enable to perform experiments in more natural unconstrained conditions, in comparison to previous studies, which were structured in trials and limited to one or two behavioural choices. These advantages will allow us to go beyond the current state-of-the-art in the field. More specifically, we propose to investigate the following specific aims:

1) Whole-brain dynamics basis and mechanisms underlying self-generated behaviours.
2) A comparison between the neuronal pathways underlying the initiation of self-generated and sensory induced behaviours.
3) The internal and external modulation of self-generated behaviours.

**Link to the ERC project webpage:** www.zebrain.biologie.ens.fr

**Keywords of the ERC project:** Neuronal circuit dynamics, motor behaviour, two-photon calcium imaging, light-sheet microscopy, computational neuroscience, zebrafish, criticality, neuroethology

**Keywords that characterize the scientific profile of the potential visiting researcher/s:** computational neuroscience, neuroscience, physics, big data analysis, mathematics, computer science, quantitative biology
Comprehensive anatomical, genetic and functional identification of cerebellar nuclei neurons and their roles in sensorimotor tasks

How does the brain integrate diverse sensory inputs and generate appropriate motor commands? Our cerebellum is a key region for such a sensorimotor processing, empowered by its sophisticated neural computation and constant communication with other brain regions. The well-timed cerebellar information is integrated and funneled to other brain regions through the cerebellar nuclei (CN). Yet, how CN circuitry contributes to the cerebellar control of sensorimotor processing is unclear. My recent work indicates that the CN activity serves various functions ranging from the online motor control, the amplitude amplification of cerebellar outputs to the control of motor planning. Given these advances, I am now in a unique position to decipher the properties of CN neurons and identify their specific roles in different forms of sensorimotor processing. It is my central hypothesis that depending on the specific demands of the task, CN neurons can either facilitate or suppress the activity of downstream regions with millisecond precision; and the anatomical, genetic and functional properties of CN neurons are tailored to the particular task involved. To test this hypothesis, I will 1) identify the activity patterns of different CN modules during the acquisition and execution of two sensorimotor tasks and characterize the relevant extra-cerebellar inputs to these modules; 2) identify the connectivity-transcription logic of different CN modules and link them to their task-specific outputs; and 3) examine the impacts of manipulating anatomically and/or genetically defined CN neurons on the downstream regions during different sensorimotor tasks. I will accomplish these key objectives by developing various novel electrophysiological, optogenetic, molecular and imaging techniques. My research is likely to break new ground, demonstrating that the identity of CN neurons is determined by their differential temporal demands of sensorimotor tasks controlled by different brain structures.

Link to the ERC project webpage: https://neuro.nl/research/gao

**Keywords of the ERC project:** brain circuits, cerebro-cerebellar communication, sensorimotor function, cerebellar nuclei

**Keywords that characterize the scientific profile of the potential visiting researcher/s:**
The Interleukin (IL)-1 family of pro-inflammatory cytokines are among the most potent pyrogens, and their excessive production can cause several auto-inflammatory syndromes. Additionally, overabundance of IL-1 cytokines can trigger, or contribute to a range of inflammatory and metabolic disorders. The expression of the key members of the IL-1 family, such as IL-1β and IL-18, is regulated at both the transcriptional and post-transcriptional levels. IL-1β and IL-18, are produced as inactive precursors, which require activation of caspase-1 by the inflammasomes for their maturation and release by from cells, occasionally at the cost of caspase-1 mediated-cell death. We have recently discovered that inflammasomes are released into the extracellular space where they remain active after the demise of activated cells, and that extracellular inflammasomes can amplify inflammation by sustaining extracellular production of IL-1β. However, the sources of extracellular pro-IL-1β are not known. Recent advances in platelet proteomics have revealed that these non-nucleated cells are able to produce their own cytokines, including soluble IL-1β and membrane-bound IL-1α, and are able to significantly magnify IL-1 production by immune cells. As platelets outnumber leukocytes by several folds, they could potentially be the major source of extracellular inflammasomes in the body, or be a major producer of IL-1 precursors that are cleaved by extracellular inflammasomes released from dying immune cells. In this proposal, we will investigate the mechanism(s) by which platelets produce IL-1, and the specific contribution of platelet-derived IL-1 to sterile inflammation, or host resistance to bacterial and viral infection. We believe that a deeper understanding of platelet-IL-1 and their interaction with immune cells during sterile inflammation, or infection might help to uncover new targets for immune-therapies.

Link to the ERC project webpage: http://www.iii.uni-bonn.de/franklin_lab/the_ag_franklin_lab.html

Keywords of the ERC project: Inflammation, Inflammasomes, Platelets

Keywords that characterize the scientific profile of the potential visiting researcher/s: Innate Immunity, Pattern Recognition, Receptors, NLRP3, Macrophages
Background
Humans and other animals harbour enormous microbial consortia, especially in the lower intestine. My group has now shown that effects of the microbiota on host are far earlier and more pervasive than previously appreciated, starting even before birth from exposure to defined maternal microbial metabolites.

Concept
There is a critical window for development of immunity and metabolism in early life. This shapes infectious resistance, lymphocyte repertoire development and the likelihood of later autoimmune or inflammatory disease. We will determine the molecular mechanisms of how the maternal microbiota prepares the newborn for the critical fetal/suckling/early-independent-nutrition transitions. The core hypothesis is that generally pervasive effects of maternal microbial influences, so-far investigated only for innate immunity and metabolism of germ-free offspring, can be defined in terms of a clear portfolio of maternal microbial molecular signatures and epigenetic marks as the newborn develops with its own microbiota.

Approach
Interdependence of microbial ↔ host interactions during gestation and lactation will be dissected using reversible colonisation systems under axenic and precisely controlled gnotobiotic conditions. The flow and identity of maternal microbial metabolites driving development and shaping incoming colonisation shall be determined from high-resolution metabolomics and host strain combinations that reveal in vivo signalling and epigenetic marks.

Significance
The project will reveal mechanisms of the earliest phases of mammalian adaptation to a microbiota, the epigenetic effects of maternal microbial metabolites and the resulting potential protection from metabolic disease or immunopathology. Conversely, there are profound effects of early life adaptation on the dynamics of microbial colonisation and the potential blooms and extinctions for the incoming microbiota: the project will define the different mechanisms involved.

Link to the ERC project webpage:

Keywords of the ERC project:

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Molecular mechanisms of interferon-induced antiviral restriction and signalling

Interferons (IFNs), which are signalling proteins produced by infected cells, are the first line of defence against viral infections. IFNs induce, in infected and neighbouring cells, the expression of hundreds of IFN-stimulated genes (ISGs). The ISGs in turn induce in cells a potent antiviral state, capable of preventing replication of most viruses, including Human Immunodeficiency Virus type 1 (HIV-1) and influenza A virus (FLUAV). Identifying the antiviral ISGs and understanding their mechanisms of action is therefore crucial to progress in the fight against viruses.

ISGs playing a role in the antiviral state have been identified, such as human MX1, a well-known antiviral factor able to restrict numerous viruses including FLUAV, and MX2, an HIV-1 inhibitor. Both proteins bind to viral components but their detailed mechanisms of action, as well as the consequences of restriction on the activation of the innate immune system, remain unclear. Moreover, our preliminary work shows that additional anti-HIV-1 and anti-FLUAV ISGs remain to identify.

In this context, this proposal seeks an ERC StG funding to explore 3 major aims: 1) unravelling the mechanisms of antiviral action of MX proteins, by taking advantage of their similar structure and engineered chimeric proteins, and by using functional genetic screens to identify their cofactors; 2) investigating the consequences of incoming virus recognition by MX proteins on innate immune signalling, by altering their expression in target cells and measuring the cell response in terms of gene induction and cytokine production; 3) identifying and characterizing new ISGs able to inhibit viral replication with a combination of powerful approaches, including a whole-genome CRISPR/Cas9 knock-out screen.

Overall, this proposal will provide a better understanding of the molecular mechanisms involved in the antiviral effect of IFN, and may guide future efforts to identify novel therapeutic targets against major pathogenic viruses.

Link to the ERC project webpage:

Keywords of the ERC project: antiviral restriction, interferon, HIV, influenza virus, crispr/cas9 screens

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Exploring the hidden life of African trypanosomes: parasite fat tropism and implications for disease

Background: The study of protozoan pathogens has been extensively explored often motivated to find suitable targets for new intervention strategies. However these studies have been mostly limited to those life-cycle stages that can be cultivated in vitro. Using a mouse model of African trypanosomiasis, we have recently discovered that the adipose tissue (fat) is a major reservoir for the extracellular protozoan Trypanosoma brucei and that, within this environment, parasites become phenotypically different from those in the blood. Our study exposed novel biology of the T. brucei life cycle, yet it remains unknown how parasites adapt to the fat and how parasite fat tropism affects disease.

Our first aim is to determine the molecular and cellular mechanisms underlying T. brucei fat tropism. We will perform a genetic screen in mice to identify key parasite genes required for establishing and maintaining chronic infection in the fat. Together with the information of the transcriptome and proteome, we will identify the mechanistic steps underlying parasite tissue-adaptation.

Our second aim is to identify the consequences of T. brucei fat tropism for the host and the importance for disease. We will first investigate if parasites can egress from the fat. We will also determine if parasites induce lipid breakdown in the host, leading to loss of fat mass. Finally, we will measure the impact of fat tropism in general traits of disease, including host survival and transmission potential.

Impact: This project represents a completely novel research avenue built on recent work from my laboratory. By uncovering fundamental aspects of the biology of T. brucei, we will also improve the understanding of clinically relevant features of African trypanosomiasis, including relapses and weight loss. In addition, since parasite fat tropism has also been observed in malaria and Chagas’ disease, our findings will help elucidate disease mechanisms relevant to other infectious diseases.

Link to the ERC project webpage: https://imm.medicina.ulisboa.pt/investigation/laboratories/luisa-figueiredo-lab/

Keywords of the ERC project: Adipose tissue, metabolism, infection, parasite, mice

Keywords that characterize the scientific profile of the potential visiting researcher/s: Vascular biology, single cell, metabolism, immunology,
Influenza Virus - Sugar Interactions, From Glycan Arrays To Better Vaccines

Our current assays to determine the receptor specificity and vaccine efficiency of influenza A virus fail as they do not represent receptors available in the human upper respiratory tract. The lack of these receptors in our laboratory hosts to create vaccines significantly dampen yields, the resulting mismatched vaccines do not afford proper protection and further drive antigenic drift.

The objective of this proposal is to elucidate the functional receptor of human influenza A viruses. By using antigenically drifted viruses, we expect to understand how glycan specificity changes due to immune pressure but it will also lead to the identification of a glycan that is utilized by all human IAV viruses. With this knowledge, better surveillance techniques, culture models and structure-based inhibitors can be developed.

Using a novel and sophisticated cell-engineering tool, based on lipidated sugars, we will show functional glycan receptor usage. In addition, I will create cell lines in which human influenza A vaccine viruses grow to high titers without adaptation, thus providing superior protection.

To achieve this goal, I propose to enzymatically synthesize complex glycans (AIM 1), including sialic acid modifications that are found on the respiratory tract epithelial cells of humans and other IAV hosts. Several enzymatic methods and glycan array tools are in place, and thus the chance of success is high. I already set-up preliminary methods for the use of lipidated N-glycan structures and extensive knowledge on SEEL is present in the department (AIM 2). For creating super vaccine producing cell lines I will use genetic approaches that previously have shown to be successful (AIM3).

The systems dealing with sugars enabling function, either for infection or vaccine research, I term sugar-enable, will provide new endeavors to create glycan-analog inhibitors and will bring us steps closer to better vaccines.

Link to the ERC project webpage:

Keywords of the ERC project: influenza A virus, hemagglutinin, glycan array, sialic acid

Keywords that characterize the scientific profile of the potential visiting researcher/s: virology, glycobiology, immunology
Viral infections are responsible for significant morbidity and mortality and frequency and impact of epidemics are expected to increase. Thorough understanding of basic virology is critical for informed development of prevention and control. Most systematic studies of virus-host interactions have focused on proteins, however, with recent methodological advances the intersecting fields of viral infection and RNA biology hold great promise for basic and therapeutic exploration. The goal of this application therefore is to discover and dissect RNA-based virus-host interactions and related regulatory mechanisms of gene expression. Micro-RNAs (miRNAs) fine-tune gene expression by repressing mRNA targets. However, cellular miRNAs increase translation and replication of certain viruses. Thus, hepatitis C virus (HCV) critically depends on the liver specific miR-122, which emerged as a therapeutic target. Further, HCV sequesters enough miR-122 to indirectly regulate cellular gene expression. I hypothesize that this RNA-based mechanism contributes to virus induced liver cancer, and aim to address this using our recently developed rodent model for HCV infection (Aim 1). Better understanding of viral RNA (vRNA) interactions could significantly contribute to basic infection biology and novel therapeutics. I therefore aim to systematically identify vRNA interactions with other cellular RNAs and proteins (Aim 2). I expect to identify interactions of value for functional regulation and therapeutic targeting. I finally hypothesize that translation of certain cellular mRNAs – similarly to viruses – increase upon miRNA binding, and aim to systematically screen for such virus-like alternative regulation, with potential to change understanding of post-transcriptional regulation (Aim 3).

In conclusion, this high-risk high-gain project has potential to shape novel dogmas for virus and RNA biology and to identify novel RNA-based therapeutic targets; a promising upcoming field of discovery.

Link to the ERC project webpage:

Keywords of the ERC project: Virus, Hepatitis, RNA, miRNA, Infection, Virus-host interaction,

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Assessing the role of ribosomes and mRNA translation in shaping the inflammatory response

Inflammation is a highly regulated process that acts as a first line of defense against pathogens infections. Triggered by cellular pattern recognition receptors (PRRs) that recognize specific microbial components and endogenous or exogenous non-microbial components, activation of inflammation induces a dynamic and coordinated gene expression program that leads to the production of cytokines and chemokines to attract effector cells to the site of infection. Although a robust inflammatory response is required for efficient clearance of pathogens, uncontrolled or prolonged inflammation can lead to inflammatory disorders such as septic shocks or to autoimmune diseases like lupus.

Most studies have focused so far on the transcriptional control of the inflammatory gene expression program. However, post-transcriptional regulatory mechanisms involving mRNA splicing, mRNA decay or translation have also been described to control the inflammatory response. Among these, regulation of mRNA translation allows for rapid and reversible modulation of gene expression but its precise role and control mechanisms in the inflammatory response remain poorly understood.

Using innovative technologies, our project aims at characterizing the role of ribosomes and mRNA translation in regulating the inflammatory response. In particular, we propose to identify the complete set of ribosome accessory proteins and to determine their role in the context of “specialized ribosomes” with specific regulatory activities. We will also study the cross-talks between ribosomes and other cellular processes such as mRNA decay and uncover the role of mRNA editing in regulating translation during the inflammatory response. From this work, we expect to identify new regulatory mechanisms that orchestrate inflammation as well as cellular factors that could represent new therapeutic targets for the design of drugs modulating inflammation.

Link to the ERC project webpage:

Keywords of the ERC project: ribosome, RNA, translation, inflammation, innate immunity, macrophage, dendritic cells

Keywords that characterize the scientific profile of the potential visiting researcher/s: RNA, cell biology, innate immunity, microscopy, metabolism, mitochondria
Spatiotemporal regulation of T-cell Priming

The initiation of adaptive cellular immunity requires antigen-specific interactions between Dendritic cells (DC) and naive CD8 T cells in secondary lymphoid organs. We aim to understand how the dynamic migratory behavior of myeloid and lymphoid cells is coordinated to ensure that “the right cells” communicate at “the right time” in “the right place” to enable robust immune responses. Using intravital microscopy, we have recently identified a critical phase (“Step 2”) of T cell priming that follows the initial encounter of DC and CD8 T cells and is essential to develop protective immunity.

The aim of this proposal is to identify the cellular and molecular mechanisms regulating T cell differentiation during Step 2. We will employ a newly developed imaging method (“Net-Vis”) to investigate how key elements of Step 2 (XCR1 DC) receive antigenic and inflammatory “information” within a network of myeloid cells. Next, we will test a novel model of T cell priming in which stepwise relocalization to multicellular clusters within the LN orchestrates T cell differentiation. Combining deep-tissue intravital microscopy, “Niche-seq” and novel genetic approaches, we will identify the cellular players and molecules guiding these processes and test their mechanistic implications. Finally, we will investigate the identity and mechanisms of Foxp3+ T cells that co-regulate CD8 T cell activation and differentiation during Step 2.

In summary, we will exploit an array of innovative imaging, spatiotemporal transcriptomics and genetic approaches to investigate novel fundamental aspects of CD8 T cell priming during a newly discovered distinct phase of T cell activation and differentiation. Investigating the mechanisms that guide these central steps in adaptive immunity is anticipated to reveal new avenues for the therapeutic manipulation of immune responses against infection and cancer.

Link to the ERC project webpage:

Keywords of the ERC project:
Keywords that characterize the scientific profile of the potential visiting researcher/s:
How Infection History Shapes the Immune System: Pathogen-induced Changes in Regulatory T Cells

Studying host-pathogen interactions by focusing on the interaction of a single pathogen with the host has defined our understanding of these events and the insights gained form the basis for the therapeutic and vaccination strategies we use today. However, people become infected with multiple pathogens throughout their lifetime, at times even simultaneously. Still, it is largely unknown how the immune response to one pathogen alters the body’s ability to respond to a second infectious agent or the susceptibility to autoimmunity or cancer. This project will address this question by focusing on infection-induced changes in regulatory T cells (Tregs) as they may lead to biased suppression and changes in the nature of subsequent immune responses.

Our efforts will focus on two areas: In a first part, we will use single cell RNA-Seq to address how infections shape the Treg compartment by defining the specialized Treg subsets generated during polarized infectious settings and analyzing how they interact with effector T cells. Based on the depth of information we expect to obtain from this approach, we envisage finding thus far unappreciated interactions and functions of Tregs in the course of an immune response. The second part will investigate how an altered Treg compartment, either through genetic modifications or infection-induced, affects disease susceptibility. In this context, we will also address stability and persistence of pathogen-induced changes in the Treg compartment. Collectively the proposed experiments will allow us to start addressing how preceding infections affect disease susceptibility. Deciphering how infection history shapes the Treg compartment and how this affects susceptibility to future challenges will lay the groundwork for addressing this question more broadly in the future and as such will likely have a transformative impact on the field.

Link to the ERC project webpage:

Keywords of the ERC project: immune regulation, infection history, regulatory T cells

Keywords that characterize the scientific profile of the potential visiting researcher/s: immunology, T cell biology, animal work, computational
An infection is defined by the deleterious consequences of the interactions between a pathogen and a host. Thus, studying the biology of infection reveals critical properties of hosts and pathogens, and is a way forward to address basic biological questions and improve health.

We study listeriosis, a systemic infection caused by Listeria monocytogenes (Lm). Lm is a human foodborne pathogen that crosses the intestinal barrier, disseminates systemically, replicates in liver and spleen and reaches the central nervous system (CNS) and fetoplacental unit. Given the remarkable journey Lm makes in its host, studying listeriosis offers unprecedented opportunities to understand host cell biology, physiology and immune responses, guided by Lm. The mucosal, CNS and fetoplacental tropisms of Lm are shared by other microbes which pathogenesis is far less understood. Lm therefore stands as a unique model microorganism of general biological and medical significance.

The major challenge of this project is to go beyond reductionist approaches and embrace the complexity of actual infections.

We will use stem cell-derived organoids, live imaging, genetically engineered mouse models, the clinical and biological data from a unique cohort of 900 patients and the corresponding causative Lm strains, to investigate the molecular mechanisms of Lm tissue invasion, dissemination and host responses.

Specifically, we will (i) decipher the cell biology of microbial translocation across the intestinal epithelium; (ii) study the impact of microbial portal of entry on microbial fate, dissemination and host responses; (iii) harness Lm biodiversity to identify novel virulence factors and (iv) discover new host factors predisposing to invasive infections.

Building on the unique combination of advanced experimental systems and exclusive clinical data, this integrative and innovative project will reveal novel, physiologically relevant mechanisms of infection, with scientific and biomedical implications.

Link to the ERC project webpage: https://research.pasteur.fr/en/team/biology-of-infection/

Keywords of the ERC project:

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Role of autonomous B cell receptor signalling and external antigen in the pathogenesis of chronic lymphocytic leukaemia (CLL)

The proposed project aims at investigating the molecular mechanisms that activate B cell antigen receptor (BCR) signalling in chronic lymphocytic leukaemia (CLL). While it is widely accepted that the unbroken BCR expression in CLL cells is indicative for a key role in disease development, the mechanisms that induce BCR activation and survival of malignant cells are still elusive. Using a unique reconstitution system, we have recently shown that CLL-derived BCRs possess the exceptional capacity for cell-autonomous signalling independent of external antigen. Crystallographic analyses confirmed our model that CLL-BCRs bind to intrinsic motifs in nearby BCRs on the very same cell. In addition to the BCR, several pathogenic factors influence the biological behaviour of CLL cells, but the functional hierarchy and the effect on BCR signalling are insufficiently understood. Here, we aim at investigating the structural cause of autonomous signalling as well as the characterization of important signalling pathways and their mechanistic action in CLL pathogenesis.

By combining crystallography with the measurement of autonomous signalling of wild type and mutated receptors in our unique reconstitution system, we will generate a structure-function relationship for CLL-BCRs. By generating new animal models and by employing classical as well as cutting-edge approaches of biochemistry and molecular/cellular immunology, we will comprehensively characterize the signalling pathways that are activated by autonomous signalling and might be important for CLL pathogenesis. These systematic efforts are necessary to understand how various biological mechanisms operate and ultimately activate downstream pathways that result in a lymphoproliferative disease. In addition, a cohesive model of CLL pathogenesis, which elucidates the hierarchical order of pathogenic factors and their interaction with BCR signalling, may well lead to novel disease-specific preventive or therapeutic intervention.

Link to the ERC project webpage:

Keywords of the ERC project:

Keywords that characterize the scientific profile of the potential visiting researcher/s:
From longitudinal proteomics to dynamic individualized diagnostics

Longitudinal omics data hold great promise to improve biomarker detection and enable dynamic individualized predictions. Recent technological advances have made proteomics an increasingly attractive option but clinical longitudinal proteomic datasets are still rare and computational tools for their analysis underdeveloped. The objective of this proposal is to create a roadmap to detect clinically feasible protein markers using longitudinal data and effective computational tools. A biomedical focus is on early detection of Type 1 diabetes (T1D).

Specific objectives are:
1) Novel biomarker detector using longitudinal data. DynaOmics introduces novel types of multi-level dynamic markers that are undetectable in conventional single-time cross-sectional studies (e.g. within-individual changes in abundance or associations), develops optimization methods for their robust and reproducible detection within and across individuals, and validates their utility in well-defined samples.
2) Individualized disease risk prediction dynamically. DynaOmics develops dynamic individualized predictive models using the multi-level longitudinal proteome features and novel statistical and machine learning methods that have previously not been used in this context, including joint models of longitudinal and time-to-event data, and one-class classification type techniques.
3) Dynamic prediction of T1D. DynaOmics builds a predictive model of dynamic T1D risk to assist early detection of the disease, which is crucial for developing future therapeutic and preventive strategies. T1D typically involves a relatively long symptom-free period before clinical diagnosis but current tools to predict early T1D risk have restricted power.

The objectives involve innovative and unconventional approaches and address major unmet challenges in the field, having high potential to open new avenues for diagnosis and treatment of complex diseases and fundamentally novel insights towards precision medicine.

Link to the ERC project webpage: https://elolab.utu.fi

Keywords of the ERC project: computational biomedicine, longitudinal data analysis, biomarker, machine learning, type 1 diabetes

Keywords that characterize the scientific profile of the potential visiting researcher/s: computational biomedicine, longitudinal data analysis, machine learning
Novel Approach to Systematically Characterize Exercise- and Nutrient- responsive genes in Type 2 diabetes and cardiovascular disease

Proposal summary
Type 2 diabetes and cardiovascular disease are devastating and costly morbidities whose prevalences are increasing rapidly around the world. As such, there is an urgent need to develop innovative and effective prevention and treatment strategies. As numerous clinical trials have shown, lifestyle modification is by far the best way to prevent these diseases, with lifestyle being twice as effective as the best drugs, less costly and free from side effects. Yet, human biology is complex, causing some people to respond well and others poorly to the same lifestyle interventions. Thus, a huge, as yet unrealised opportunity exists to optimize the prevention and treatment of cardiometabolic diseases by tailoring lifestyle interventions to the patient’s unique biology.

NASCENT is an integrated programme of research through which I will functionally annotate and later translate discoveries of gene-lifestyle interactions made through the interrogation of large epidemiological (N>100,000) datasets at my disposal. The functional annotation of these discoveries will be done using state-of-the-art epigenomic and targeted gene editing tools, whereas the translation of those findings will be achieved using an innovative and powerful clinical trial design that focuses on treatments that are tailored to the participant’s genotype (genotype-based recall).

NASCENT capitalizes on a solid foundation of cohorts, methods, and expertise that I have built-up over the past fifteen years, but also exploits state-of-the-art epigenomic and gene-editing technologies that have not previously been used in studies of gene-lifestyle interactions. I expect the integration of these established and new approaches in NASCENT to propel major advances in understanding gene-lifestyle interactions in cardiometabolic disease that help optimise disease prevention.

Link to the ERC project webpage:

Keywords of the ERC project: Genetics, Omics, Lifestyle, Diet, Exercise, Precision Medicine

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Translational and Transdisciplinary research in Modeling Infectious Diseases

TransMID focuses on the development of novel methods to estimate key epidemiological parameters from both serological and social contact data, with the aim to significantly expand the range of public health questions that can be adequately addressed using such data. Using new statistical and mathematical theory and newly collected as well as readily available serological and social contact data (mainly from Europe), fundamental mathematical and epidemiological challenges as outlined in the following work packages will be addressed: (a) frequency and density dependent mass action relating potential effective contacts to transmission dynamics in (sub)populations of different sizes with an empirical assessment using readily available contact data, (b) behavioural and temporal variations in contact patterns and their impact on the dynamics of infectious diseases, (c) close contact household networks and the assumption of homogeneous mixing within households, (d) estimating parameters from multivariate and serial cross-sectional serological data taking temporal effects and heterogeneity in acquisition into account in combination with the use of social contact data, and (e) finally the design of sero- and social contact surveys with specific focus on serial cross-sectional surveys. TransMID is transdisciplinary in nature with applications on diseases of major public health interest, such as pertussis, cytomegalovirus and measles. Translational methodology is placed at the heart of TransMID resulting in the development of a unifying methodology for other diseases and settings. The development of a toolbox and accompanying software allow easy and effective application of these fundamentally improved techniques on many infectious diseases and in different geographic contexts, which should maximize TransMID’s impact on public health in Europe and beyond.

Link to the ERC project webpage:

Keywords of the ERC project: Mathematical epidemiology

Keywords that characterize the scientific profile of the potential visiting researcher/s: Biostatistics, Epidemiologist
The overarching objective of STOP-HF is to generate human induced pluripotent stem cells (hiPSC) derived cardiomyocytes from two specific forms of heart failure (HF) with a clear trigger to unravel common pathophysiological mechanisms involved in the early development of HF. The project is focused on two specific forms of HF, both with a clear trigger: pregnancy and anthracyclines. Better understanding of early molecular pathways leading to HF and knowledge about inter-individual susceptibility is needed. For detection of early changes on a molecular level cardiac tissue is needed. Generation of patient specific cardiac cells from skin fibroblasts (hiPSC technology) is a novel and innovative approach.

SPECIFIC OBJECTIVES
1. Fabrication and maturation of 3D cardiac tissue from hiPS derived cardiomyocytes.
2. Generate and characterize hiPS derived cardiomyocytes and endothelial cells from females with pregnancy induced HF and unravel differences on transcriptome level.
3. Generate and characterize hiPSC derived cardiomyocytes from patients with high susceptibility and resilience to develop anthracycline-induced HF and compare them on transcriptome level.
4. Integrate the results for coding and non-coding RNAs from objective 1+2 and identify overlapping pathways.
5. Validate discoveries on transcriptome level in vitro, in vivo and apply for the development of HF in the general population.

WORKPACKAGES
WP1: Optimize fabrication and maturation of 3D cardiac tissue from hiPS derived cardiomyocytes
WP 2A: Validate the model and compare hiPS derived cardiomyocytes and endothelial cells from PPCM and healthy sisters on transcriptome level;
WP 2B: Validate the model and compare hiPS derived cardiomyocytes from both patients with high susceptibility and resilience to develop HF after anthracyclins on transcriptome level;
WP 3: Integration of transcriptome data from WP 2A+2B;
WP 4: Validation of novel pathways in vitro, in vivo and new onset HF in the general population.

Link to the ERC project webpage:

Keywords of the ERC project: human induced pluripotent stemcells; heart failure; cardiomyopathy; tissue engineering; cardiology

Keywords that characterize the scientific profile of the potential visiting researcher/s: tissue engineering; induced pluripotent stem cells; MD; cardiology; heart failure
Quantitative Surgical Guidance for Colorectal Surgery using Endogenous Molecular Contrast

Despite significant advances in medical imaging technologies, there currently exist no tools to effectively assist healthcare professionals during colorectal surgery. Surgeons mainly rely on their own senses, vision and touch to identify diseased tissue that should be removed or healthy tissue that should be avoided. In turn, surgery remains subjective and dependent on the experience of the surgeon, resulting in unacceptably high failure, recurrence and morbidity rates, as well as in significant quality of care disparities across hospitals.

The hypothesis underlying our study is that near-infrared light travels deeply into living tissues and interacts with endogenous molecular constituents, namely oxy- and deoxy-hemoglobin, water and lipids, providing key information regarding tissue perfusion, oxygenation, hydration and metabolism. In turn, such information can be used to differentiate diseased from healthy tissue. We recently introduced a novel concept that enables the quantitative imaging of endogenous molecular information over large fields-of-view. Because this concept can be implemented in real-time, it is amenable to provide video-rate endogenous information during colorectal surgery.

In this study, we propose to push the limits of this concept by developing ground-breaking theory & technology, and creating a novel surgical guidance device capable of real-time imaging of key endogenous information for colorectal surgery. Correlation between endogenous contrast measurements and histological tissue status will be investigated on bowel ischemia and colorectal cancer animal models. Finally, a clinically-compatible imaging device will be fabricated and translated into a first-in-human study in patients undergoing colorectal surgery. If successful, this study has the potential to solve a longstanding clinical problem by providing real-time objective feedback during colorectal surgery.

Link to the ERC project webpage: https://healthphotons.org/

Keywords of the ERC project: Image-Guided Surgery; Optical Imaging
Keywords that characterize the scientific profile of the potential visiting researcher/s:
Informatics approaches for the rational selection of personalized cancer drug combinations

Making cancer treatment more personalized and effective is one of the grand challenges in our health care system. However, many drugs have entered clinical trials but so far showed limited efficacy or induced rapid development of resistance. We critically need multi-targeted drug combinations, which shall selectively inhibit the cancer cells and block the emergence of drug resistance. This project will develop mathematical and computational tools to identify drug combinations that can be used to provide personalized and more effective therapeutic strategies that may prevent acquired resistance. Utilizing molecular profiling and pharmacological screening data from patient-derived leukaemia and ovarian cancer samples, I will develop model-based clustering methods for identification of patient subgroups that are differentially responsive to first-line chemotherapy. For patients resistant to chemotherapy, I will develop network modelling approaches to predict the most potential drug combinations by understanding the underlying drug target interactions. The drug combination prediction will be made for each patient and will be validated using a preclinical drug testing platform on patient samples. I will explore the drug combination screen data to identify significant synergy at the therapeutically relevant doses. The drug combination hits will be mapped into signalling networks to infer their mechanisms. Drug combinations with selective efficacy in individual patient samples or in sample subgroups will be further translated into in treatment options by clinical collaborators. This will lead to novel and personalized strategies to treat cancer patients.

Link to the ERC project webpage: https://cordis.europa.eu/project/rcn/210127/factsheet/en

Keywords of the ERC project: Bioinformatic approaches, personalized medicine, network pharmacology modelling

Keywords that characterize the scientific profile of the potential visiting researcher/s: drug target discovery, network models, text mining, artificial intelligence, statistical models
Vascular Tree Formation in Multi-Structural Tissue Engineering

Engineered tissues offer a great promise to the field of medicine as an alternative for donor tissues, for which the supply is not meeting the demands. However, the clinical application of engineered tissues is hampered. The integration of engineered tissues after implantation is limited due to the lack of a vascular network. Currently, strategies to include vascular networks rely on the spontaneous organization of vascular cells, or on the patterning of these cells. However, this results in either vascular networks that are not organized, or networks that lose their initial organization fast. This project will use a unique and novel approach to control vascular development and will therefore result in a vascular network with a controllable long-term organization. By allowing for anastomosis, and increasing nutrient delivery, this project will tackle an essential problem and will greatly enhance the clinical applicability of engineered tissues.

Within VascArbor, fluid flows through engineered tissues will be designed and controlled to guide vascular organization. Apart from that, growth factors will be patterned in space and time to further direct the formation of a vascular network with a controlled organization. In parallel, computational models will be developed that can predict vascular organization and development based on processing parameters. This will be a breakthrough in vascularized tissue engineering by enabling a direct link between a desired vascular organization, and the tissue construct geometry and processing conditions that are needed to acquire this organization.

To maximize the impact of VascArbor on the field of tissue engineering and medicine, the principles that will guide vascular organization are compatible with multiple current and future tissue fabrication technologies. Within VascArbor, tissue building blocks and bio-printing will be used to engineer vascularized cardiac muscle tissue based on the principles developed in this project.

Link to the ERC project webpage: https://cordis.europa.eu/project/rcn/207889/factsheet/en

Keywords of the ERC project:

- Keywords that characterize the scientific profile of the potential visiting researcher/s:
Nanomaterials in Oncology: Exploiting the Intrinsic Cancer-Specific Toxicity of Nanoparticles.

In our current society, therapeutic strategies against cancer suffer from dose-limiting toxicity, lack of specificity and high morbidity. To overcome this, the use of nanomaterials (NMs) is rising, where several NM formulations are undergoing clinical trials or are used in clinics where the NMs are used as drug delivery vehicles or as mediators in physical anticancer methods (e.g. hyperthermia), where to date, the success rate is limited due to low tumor targeting efficacy, lack of specificity and frequent re-use of classical toxicity mechanisms.

To overcome these issues, this research program aims to exploit the intrinsic toxicity of certain types of metal-based, degradation-prone NMs (Fe-doped ZnO, Fe-doped CuO and Ag of different sizes and coatings) towards only cancer cells as a novel and generic anti-cancer tool with 1) improved efficacy against difficult to treat cancers such as multidrug-resistant cancer cells, 2) enhanced specificity and selectivity of the treatment by the intrinsic cancer cell-specific toxicity of NMs towards cancer cells. To overcome the issues related to selective delivery of the NMs, tumor-homing cells will be used that have been shown to efficiently home to primary tumors and their metastases. In practice, the NMs used show distinct degradation kinetics that primarily induce cancer-selective toxicity. To obtain efficient tumor targeting, suicide gene-expressing tumor-homing cells will be loaded with the NMs in their cytoplasm, hereby impeding premature NM degradation. The tumor homing efficacy of these cells will be monitored via optical imaging and once at the target site these cells will be chemically destroyed using the suicide gene strategy. This will release the NMs into the tumor site, where they can selectively destroy the cancer cells. This research program will be the first to explore the full potential of cancer-specific toxicity of NMs and the use of cytoplasmic loading of cells as biological carriers for efficient delivery.

Link to the ERC project webpage: https://www.kulnanobmi.com/erc-nanonc

Keywords of the ERC project: nanomedicine

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Effects of Prenatal Exposure to Acrylamide on Health: Prospective Biomarker-Based Studies

Background: Acrylamide is a chemical formed in many commonly consumed foods and beverages. It is neurotoxic, crosses the placenta and has been associated with restriction of fetal growth in humans. In animals, acrylamide causes heritable mutations, tumors, developmental toxicity, reduced fertility and impaired growth. Therefore, the discovery of acrylamide in food in 2002 raised concern about human health effects worldwide. Still, epidemiological studies are limited and effects on health of prenatal exposure have never been evaluated. Research gaps: Epidemiological studies have mostly addressed exposure during adulthood, focused on cancer risk in adults, and relied on questionnaires entailing a high degree of exposure misclassification. Biomarker studies on prenatal exposure to acrylamide from diet are critically needed to improve exposure assessment and to determine whether acrylamide leads to major diseases later in life.

Own results: I have first authored a prospective European study showing that prenatal exposure to acrylamide, estimated by measuring hemoglobin adducts in cord blood, was associated with fetal growth restriction, for the first time.

Objectives: To determine the effects of prenatal exposure to acrylamide alone and in combination with other potentially toxic adduct-forming exposures on the health of children and young adults.

Methods: Both well-established and innovative biomarker methods will be used for characterization of prenatal exposure to acrylamide and related toxicants in blood from pregnant women and their offspring in prospective cohort studies with long-term follow-up. Risk of neurological disorders, impaired cognition, disturbed reproductive function and metabolic outcomes such as obesity and diabetes will be evaluated.

Perspectives: CHIPS project will provide a better understanding of the impact of prenatal exposure to acrylamide from diet on human health urgently needed for targeted strategies for the protection of the health.

Keywords of the ERC project: Acrylamide, Biomarker, Diet, Epidemiological, haemoglobin adducts, Prenatal

Keywords that characterize the scientific profile of the potential visiting researcher/s: Dietary/Nutrient epidemiology, Analytical chemistry
Imaging Perfusion Restrictions from Extracellular Solid Stress

Even the perfect cancer drug must reach its target to have an effect. The ImPRESS project main objective is to develop a novel imaging paradigm coined Restricted Perfusion Imaging (RPI) to reveal - for the first time in humans - vascular restrictions in solid cancers caused by mechanical solid stress, and use RPI to demonstrate that alleviating this force will repair the cancerous microenvironment and improve therapeutic response. Delivery of anti-cancer drugs to the tumor is critically dependent on a functional vascular bed. Developing biomarkers that can measure how mechanical forces in a solid tumor impair perfusion and promotes therapy resistance is essential for treatment of disease.

The ImPRESS project is based on the following observations; (I) pre-clinical work suggests that therapies targeting the tumor microenvironment and extracellular matrix may enhance drug delivery by decompressing tumor vessels; (II) results from animal models may not be transferable because compressive forces in human tumors in vivo can be many times higher; and (III) there are no available imaging technologies for medical diagnostics of solid stress in human cancers. Using RPI, ImPRESS will conduct a comprehensive series of innovative studies in brain cancer patients to answer three key questions: (Q1) Can we image vascular restrictions in human cancers and map how the vasculature changes with tumor growth or treatment? (Q2) Can we use medical engineering to image solid stress in vivo? (Q3) Can RPI show that matrix-depleting drugs improve patient response to conventional chemo- and radiation therapy as well as new targeted therapies?

The ImPRESS project holds a unique position to answer these questions by our unrivaled experience with advanced imaging of cancer patients. With successful delivery, ImPRESS will have a direct impact on patient treatment and establish an imaging paradigm that will pave the way for new scientific knowledge on how to revitalize cancer therapies.

Link to the ERC project webpage: https://www.ous-research.no/emblem/

Keywords of the ERC project: MRI, glioblastoma, perfusion, physical forces, extracellular matrix, cancer therapy, clinical trial, artificial intelligence, deep learning

Keywords that characterize the scientific profile of the potential visiting researcher/s: Senior researcher, imaging specialist, computer specialist, postdoctoral researcher
Despite decades of research, and the introduction of parenting interventions, children of mentally ill mothers remain substantially more likely to have mental health problems themselves. I propose to shed new light on why mental health problems in a mother are passed on to her child, and help break this reinforcing cycle of mental health risk across generations. In order to harness the potential of modifying parenting for the prevention of child mental health risk, I will study parenting using more detailed, ecologically valid and genetically sensitive designs than have been done before.

Objectives:
1: To investigate the respective role of genetic and environmental (chiefly parenting) mechanisms in explaining associations between mother and child mental health. HOW: using a consortium of international cohorts with intergenerational genetic and phenotypic data (n>10,000) and, for the first time, modeling genetic risk which is and is not transmitted from mother to child to test alternative hypotheses.
2: To identify behavioural manifestation of maternal mental health, in observed mother-infant interaction, in an ecologically valid way. HOW: recording 300 mother-child dyads at home, using novel wearable cameras, in the next generation of a key cohort (ALSPAC-G2).
3: To identify cognitive underpinnings of maternal behaviour. HOW: including cognitive tasks (with eye tracking) as new measures in ALSPAC-G2, applying computational models to cognitive and (uniquely) real life data (measured in 2).
4: To establish whether modification of maternal parenting (highlighted in 1-3), changes child mental health. HOW: systematic review of parenting intervention trials and new synthesis methods to extract which intervention components reduce child mental health problems.

My study will provide critical new evidence regarding the nature of parenting interventions that have potential to improve child mental health and break intergenerational transmission of mental health problems.

Link to the ERC project webpage:

Keywords of the ERC project: Depression, genetics, epidemiology, intergenerational, parents, behaviour

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Atherosclerosis and its complications such as acute coronary syndromes (myocardial infarction and unstable angina) are leading causes of death in the EU and worldwide. Mental stress is known to be a major trigger for the onset of acute coronary syndromes, even in patients with state-of-the-art medical treatment. How acute mental stress rapidly drives plaque destabilization causing acute coronary syndromes is poorly understood and consequently specific treatment, although urgently needed, is lacking. Mental stress is known to affect the immune system. Leukocytes, the effector cells of the immune system, are main instigators not only of plaque progression, but also of plaque destabilization. We hypothesize that acute mental stress rapidly aggravates plaque inflammation, which renders plaques more vulnerable and prone to rupture.

We aim to characterize the impact of stress on plaque inflammation in a mouse model of acute mental stress. We will explore the mechanisms by which acute mental stress drives plaque inflammation. Based on these findings, we aim to provide a novel treatment approach to mitigate stress exacerbated plaque inflammation. Further, we aim to translate our findings to stressed humans.

The STRATO study will be carried out in a multidisciplinary approach including basic and clinician scientists, immunologists, and psychosomatic specialists and will provide us with an unprecedented, comprehensive picture of how acute mental stress aggravates atherosclerosis. Our study will fill a gap in mechanistic knowledge and based on this will identify novel therapeutic measures with the aim to reduce acute mental stress related cardiovascular complications.
Towards the Understanding a Metal-Tumour-Metabolism

A tumour cell uses both genetic and protein weapons in its development. Gaining a greater understanding of these lethal mechanisms is a key step towards developing novel and more effective treatments. Because the metal ion metabolism of a tumour cell is not fully understood, we will address the challenge of explaining the mechanisms of how a tumour cell copes both with essential metal ions and platinum based drugs. The metal-based mechanisms help a tumour to grow on one side and to protect itself against commonly used metal-based drugs. On the other side, the exact description of these mechanisms, which are being associated with multi-drug resistance occurrence and failure of a treatment, still remains unclear. We will reveal the mechanism of the as yet not understood biochemical and molecularly-biological relationships and correlations between metal ions and proteins in a tumour development revealing the way how to suppress the growth and development of a tumour and to markedly enhance the effectiveness of a treatment.

To achieve this goal, we will focus on metallothionein and its interactions with essential metals and metal-containing anticancer drugs (cisplatin, carboplatin, and oxaliplatin). Their actions will be monitored both in vitro and in vivo. For this purpose, we will optimize electrochemical, mass spectrometric and immune-based methods. Based on processing of data obtained, new carcinogenic pathways will be sought on cell level and proved by genetic modifications of target genes. The discovered processes and the pathways found will then be tested on two animal experimental models mice bearing breast tumours (MCF-7 and 4T1) and MeLiM minipigs bearing melanomas.

The precise description of the tumour related pathways coping with metal ions based on metallothioneins will direct new highly effective treatment strategies. Moreover, the discovery of new carcinogenic pathways will open a window for understanding of cancer formation and development.

Link to the ERC project webpage: http://ucb.af.mendelu.cz/

Keywords of the ERC project: metallothionein, metallomics, tumour diseases, bioanalytical chemistry, cytostatics, metals, resistance

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Enabling Precision Immuno-oncology in Colorectal cancer

Immunotherapy with checkpoints blockers is transforming the treatment of advanced cancers. Colorectal cancer (CRC), a cancer with 1.4 million new cases diagnosed annually worldwide, is refractory to immunotherapy (with the exception of a minority of tumors with microsatellite instability). This is somehow paradoxical as CRC is a cancer for which we have shown that it is under immunological control and that tumor infiltrating lymphocytes represent a strong independent predictor of survival. Thus, there is an urgent need to broaden the clinical benefits of immune checkpoint blockers to CRC by combining agents with synergistic mechanisms of action. An attractive approach to sensitize tumors to immunotherapy is to harness immunogenic effects induced by approved conventional or targeted agents.

Here I propose a new paradigm to identify molecular determinants of resistance to immunotherapy and develop personalized in silico and in vitro models for predicting response to combination therapy in CRC. The EPIC concept is based on three pillars: 1) emphasis on antitumor T cell activity; 2) systematic interrogation of tumor-immune cell interactions using data-driven modeling and knowledge-based mechanistic modeling, and 3) generation of key quantitative data to train and validate algorithms using perturbation experiments with patient-derived tumor organoids and cutting-edge technologies for multidimensional profiling. We will investigate three immunomodulatory processes: 1) immunostimulatory effects of chemotherapeutics, 2) rewiring of signaling networks induced by targeted drugs and their interference with immunity, and 3) metabolic reprogramming of T cells to enhance antitumor immunity.

The anticipated outcome of EPIC is a precision immuno-oncology platform that integrates tumor organoids with high-throughput and high-content data for testing drug combinations, and machine learning for making therapeutic recommendations for individual patients.

Link to the ERC project webpage:

Keywords of the ERC project:

Keywords that characterize the scientific profile of the potential visiting researcher/s:
The goal of ENDOMICS is to drive forward a new paradigm of Raman endoscopic technology that enables proteomic and lipidomic analysis for diagnosis of bladder cancers in vivo. Raman endoscopy is a label-free optical technique that can provide a point-wise vibrational molecular fingerprint of tissue “optical biopsy” for cancer diagnosis in vivo. State-of-the-art Raman endoscopy, however, does not offer specific compositional analysis or insights into molecular biology of tissue. This is because the vibrational Raman bands are overlapping and cannot be deciphered into the myriad of biomolecules in complex tissue.

We will introduce a ground-breaking new methodology to enable Raman proteomic and lipidomic analysis in vivo. To this end, heterospectral co-registered Raman and mass spectrometry imaging will be used to develop a multivariate regression model “Rosetta Stone” for translating vibrational structural information (Raman spectroscopy) into compositional information. To meet the unmet clinical needs in urology we will tailor the first fibre-optic Raman endoscopic technology that can measure depth-dependent molecular profiles to simultaneously enable detection, grading and staging of bladder cancers. We will finally conduct a clinical trial by applying the technique to measure a comprehensive molecular database of bladder pathologies in vivo. The latter will allow for the identification of proteomic and lipidomic biomarkers to develop novel algorithms for real-time diagnosis of bladder cancers.

The synergy between scientific and technological advances in ENDOMICS will break ground for shedding new light on the molecular biology of bladder cancer in vivo including new insights into clinical diversity and identification of biomarkers for diagnostics, prognostics and novel therapeutic targets.

Link to the ERC project webpage:

Keywords of the ERC project:

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Paternal Epigenetic Inheritance: A man’s life experiences may impact health of his unborn children and grandchildren

Epigenetic inheritance may not only occur in plants and fungi but also in mammals. While the effect of maternal lifestyle and in utero exposures is well studied, paternal epigenetic inheritance is a novel research field, especially in regard to chemical exposures. Many environmental pollutants exhibit anti-androgenic function. Despite the vital role of androgens in spermatogenesis, the effects of adult anti-androgen exposure on the sperm epigenome and offspring phenotype have been scarcely studied.

The overall aim of this novel project is to increase the understanding of if, and how, male life experiences such as adult exposure to the anti-androgenic model substance and pollutant DBP (di-n-butyl phthalate) may affect offspring through paternal epigenetic inheritance. I accomplish this by integrating animal and human studies, using RNA-sequencing and mass spectrometry-based peptidomics to identify DBP-induced alterations in the sperm transcriptome and peptidome, examine noncoding RNAs and peptides role in embryogenesis, development and long-term health of the offspring in two generations. To validate the mechanistic importance of the sperm molecular alterations microinjections of selected biomolecules into zygotes will be conducted. This is the first project to investigate multigenerational effects of adult male exposure to anti-androgens in detail, and investigate the role of the sperm peptidome in paternal epigenetic inheritance. Directly linking animal experimental data about paternal transmission to human studies is unique and necessary to determine causal connection between environmentally-induced biomolecular alterations in sperm and offspring phenotype. The project can contribute to ground-breaking mechanistic understanding of how male life experiences may affect offspring through epigenetic inheritance. The findings may also have important public health implications via new regulations of anti-androgenic chemicals and male preconceptional interventions.

Link to the ERC project webpage:

Keywords of the ERC project:

Key words that characterize the scientific profile of the potential visiting researcher/s: Bioinformatics, RNA-seq, noncoding RNA, DNA methylation, epigenetics
Diabetes mellitus is characterised by hyperglycaemia caused by an absolute or relative insulin deficiency. The global prevalence of diabetes has reached more than 410 million individuals, underscoring the need for novel therapeutic strategies targeting the pathology as a multi-organ disease. Protein tyrosine phosphatases (PTPs) constitute a superfamily of enzymes that dephosphorylate tyrosine-phosphorylated proteins and oppose the actions of protein tyrosine kinases. My previous studies and preliminary data suggest that PTPs act as molecular switches for key signalling events in the development of diabetes, i.e. insulin/glucose/cytokine signalling. Dysregulation of these pathways results in metabolic consequences that are cell-specific. Oxidative stress abrogates the nucleophilic properties of the PTP active site and induces conformational changes that inhibit PTP activity and prevent substrate-binding. I have recently developed an innovative proteomic approach to quantify PTP oxidation in vivo and demonstrated that this occurs in liver/pancreas under pathological conditions, including obesity and inflammation. In this proposal, I aim to fully characterise the activity and oxidation status of PTPs in dysfunctional metabolic relevant cells in obesity and diabetes. Importantly, the crucial role of PTPs make them promising candidates for the treatment of metabolic disorders. I hypothesise that specific antioxidants, diets and/or adenovirus will restore PTP function and ameliorate the metabolic deleterious defects in pre-clinical studies. Over the next 5 years, I aim to:

- Identify the major oxidised PTPs in metabolic relevant tissues/cells in both obesity and diabetes.
- Determine the contribution of PTP inactivation in cellular responses to metabolic signalling in human samples.
- Assess the impact of tissue-specific PTP deficiency on the development of obesity and diabetes.
- Test novel therapeutic approaches targeting PTPs to prevent/reverse metabolic disorders.

Link to the ERC project webpage: https://erc.europa.eu/projects-figures/erc-funded-projects/results?search_api_views_fulltext=gurzov+

Keywords of the ERC project: Metabolism, diabetes, protein tyrosine phosphatase, liver, pancreas

Keywords that characterize the scientific profile of the potential visiting researcher/s: Molecular biology, metabolic signalling, hiPSC, mouse models
Targeting the epigenome: towards a better understanding of disease pathogenesis and novel therapeutic strategies in Multiple Sclerosis

Multiple Sclerosis (MS) is a leading cause of unpredictable and incurable progressive disability in young adults. Although the exact cause remains unknown, this immune-mediated disease is likely triggered by environmental factors in genetically predisposed individuals. I propose that epigenetic mechanisms, which regulate gene expression without affecting the genetic code, mediate the processes that cause MS and that aberrant epigenetic states can be corrected, spearheading the development of alternative therapies. We will exploit the stable and reversible nature of epigenetic marks, in particular DNA methylation, to gain insights into the novel modifiable disease mechanisms by studying the target organ in a way that has not been possible before. This highly ambitious project comprises three synergistic facets formulated in specific aims to: (i) identify epigenetic states that characterize the pathogenesis of MS, (ii) prioritize functional epigenetic states using high-throughput epigenome-screens, and (iii) develop novel approaches for precision medicine based on correcting causal epigenetic states. Our unique MS biobank combined with cutting-edge methodologies to capture pathogenic cells and measure their functional states provides a rational starting point to identify MS targets. I will complement this approach with studies of the functional impact of MS targets using innovative in vitro screens, with the added value of unbiased discovery of robust regulators of specific MS pathways. Finally, my laboratory has extensive experience with animal models of MS and I will utilize these powerful systems to dissect molecular mechanisms of MS targets and test the therapeutic potential of targeted epigenome editing in vivo. Our findings will set the stage for a paradigm-shift in studying and treating chronic inflammatory diseases based on preventing and modulating aggressive immune responses by inducing self-sustained reversal of aberrant epigenetic states.

Link to the ERC project webpage:

Keywords of the ERC project: epigenetics, multiple sclerosis, genetics, inflammation

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Facial reconstruction usually involves the use of autologous grafts or composite tissue allografts, which are highly complex tissues that pose significant challenges to tissue engineering experts. Tissue engineering of independent facial elements, e.g., bone, adipose, skin and muscle tissues, has been demonstrated. However, to date, no composite soft tissues composed of multiple facial layers have been created. Composite facial tissue engineering will require proper innervation and vascularization, essential to support generation of large thick implants. However, techniques for effective innervation of engineered tissues are currently insufficient and generation of well-vascularized large and thick engineered tissues is still one of the major obstacles limiting their translation to the clinic. Our goal is to engineer thick, composite, human-scale, facial tissues (muscle-adipose-dermis composite, and bone) of a personally adaptable shape, that will be vascularized in-vitro, and innervated upon transplantation. Our concept is to create in-vitro a functional vascular network (VesselNet), composed of both large and small vessels, within engineered constructs, which will allow for the generation of thick engineered tissues under continuous flow conditions. 3D bio-printing techniques will be applied to create the engineered tissues. These tissues will serve as a model to study mechanisms involved in vessel anastomosis, and tissue organization and stabilization. The applicability of the engineered composite soft and bone tissues will be evaluated in facial, breast and abdominal wall defect reconstruction models, and in an open fracture model. Such engineered large-scale composite tissues are expected to have a major impact on reconstructive surgery and will shed light on yet unknown tissue organization mechanisms.

Keywords of the ERC project: Engineered thick composite tissues, Vascularization, Muscle, Bone, Adipose, Innervation, 3D bioprinting, Reconstructive surgery

Keywords that characterize the scientific profile of the potential visiting researcher/s: Tissue engineering, 3D bio-printing
Deciphering and predicting the evolution of cancer cell populations

The fundamental evolutionary nature of cancer is well recognized but an understanding of the dynamic evolutionary changes occurring throughout a tumour’s lifetime and their clinical implications is in its infancy. Current approaches to reveal cancer evolution by sequencing of multiple biopsies remain of limited use in the clinic due to sample access problems in multi-metastatic disease. Circulating tumour DNA (ctDNA) is thought to comprehensively sample subclones across metastatic sites. However, available technologies either have high sensitivity but are restricted to the analysis of small gene panels or they allow sequencing of large target regions such as exomes but with too limited sensitivity to detect rare subclones. We developed a novel error corrected sequencing technology that will be applied to perform deep exome sequencing on longitudinal ctDNA samples from highly heterogeneous metastatic gastro-oesophageal carcinomas. This will track the evolution of the entire cancer population over the lifetime of these tumours, from metastatic disease over drug therapy to end-stage disease and enable ground breaking insights into cancer population evolution rules and mechanisms. Specifically, we will: 1. Define the genomic landscape and drivers of metastatic and end stage disease. 2. Understand the rules of cancer evolutionary dynamics of entire cancer cell populations. 3. Predict cancer evolution and define the limits of predictability. 4. Rapidly identify drug resistance mechanisms to chemo- and immunotherapy based on signals of Darwinian selection such as parallel and convergent evolution.

Our sequencing technology and analysis framework will also transform the way cancer evolution metrics can be accessed and interpreted in the clinic which will have major impacts, ranging from better biomarkers to predict cancer evolution to the identification of drug targets that drive disease progression and therapy resistance.

Link to the ERC project webpage:

Keywords of the ERC project: circulating tumor DNA, ultra-deep whole exome sequencing, sequencing error correction methods, bioinformatics

Keywords that characterize the scientific profile of the potential visiting researcher/s: bioinformatics, cancer genetics, coding, sequencing error correction
New molecular targets and proof-of-concept therapies for Autism Spectrum Disorders

Autism is the major neurodevelopmental health public issue, affecting 1/100 child births worldwide. These disorders are diagnosed before the age of 3, based on behavioural cues: deficits in social interaction and communication as well as stereotyped and restrained behaviours. There is no medication to improve this condition. Most recent molecular targets identified within narrow frameworks (unspecific molecule, single tissue targeted, single disease model used) have failed in clinical trials. My first objective aims at thwarting this autism research gap, unravelling the common molecular and cellular dysfunctions underlying autism-related behaviours across several preclinical models and neuronal circuits. In particular, setting up translatomic analyses in these paradigms will identify and validate new molecular therapeutic targets. I recently deciphered one such molecular substrate, involving the loss of oxytocin transcripts in oxytocinergic axon terminals thus demonstrating the feasibility of this global approach. The second major objective of my project is to hijack the properties of a newly identified protein function to restore this new target and rescue social deficits in different preclinical models of autism. This would yield a novel and safe gene therapy vector which has never been explored before. Altogether, my research project will deliver strategic resources to the scientific and medical communities that will spur the development of new treatment options for autistic patients.

Link to the ERC project webpage:

Keywords of the ERC project: autism, translatome, new targets, new therapies

Keywords that characterize the scientific profile of the potential visiting researcher/s: neuroscience, behavior or omic
More than 3.5 million people are newly diagnosed with heart failure every year in Europe with a long-term prognosis of 50% mortality within 4 years. There is a major need for more innovative, regenerative therapies that have the potential to change the course of disease. My hypothesis is that we can recondition heart failure by stimulating cardiac repair with extracellular vesicles that are derived from progenitor cells. In my laboratory, extracellular released vesicles containing a cocktail of stimulating factors, are amongst the most potent vectors for cardiac repair.

To achieve a sustainable and long-term therapeutic effect of these vesicles and enhance cardiac function by stimulating myocardial repair, we will 1) improve local cardiac delivery of progenitor cell-derived extracellular vesicles, 2) understand the mechanism of action of extracellular vesicles, and 3) stimulate extracellular vesicles release and/or production by progenitor cells.

These questions form the rationale for the current proposal in which we will co-inject extracellular vesicles and slow-release biomaterials into the damaged myocardium. By subsequent genetic tracing, we will determine fate mapping of injected vesicles in vivo, and perform further mechanistic understanding in in vitro culture models of targeted and identified myocardial cell types. Moreover, we will upscale the vesicles production by progenitor cells further via bioreactor culturing and medium-throughput screening on factors that stimulate vesicles release.

The use of stem cell-derived extracellular vesicles to stimulate cardiac repair will potentially allow for an off-the-shelf approach, including mechanistic understanding and future clinical use. Additionally, since these vesicles act as a natural carrier system outperforming current artificial drug delivery, we might understand and mimic their characteristics to enhance local (RNA-based) drug delivery systems for cardiovascular application.

**Link to the ERC project webpage:** https://www.umcutrecht.nl/en/Research/Researchers/Sluijter-Joost-P-G-JPG

**Keywords of the ERC project:** cardiac repair, extracellular vesicles, regeneration

**Keywords that characterize the scientific profile of the potential visiting researcher/s:** collaborative, passionate, technology driven, team-player
Oncolytic viruses for the treatment of pediatric brain tumors: An integrated clinical and lab approach

The overarching goal of my lab is to improve the prognosis of patients with high-risk pediatric brain tumors. To this end, I propose to integrate clinical and lab-based research to develop tumor-targeted oncolytic adenoviruses with the capacity to elicit a therapeutic immune response in those tumors. Our research will use novel and relevant models to accomplish the experimental aims. We have previously worked with Delta-24-RGD (DNX-2401) a replication-competent adenovirus that has been translated to the clinical scenario. In 2017, the first clinical trial phase I with DNX-2401 for newly diagnosed Diffuse Intrinsic Pontine Gliomas (DIPG; a lethal pediatric brain tumor) opened propelled by my team. Preliminary results from the first trials revealed that the intratumoral injection of the virus instigated an initial phase of oncolysis followed by a delayed inflammatory response that ultimately resulted in complete regression in a subset of the patients without associated toxicities. I hypothesized that enhancement of the immune component of the DNX-2401-based therapy will result in the complete regression of the vast majority of pediatric brain tumors. In our specific approach, we propose to understand the immune microenvironment of DIPGs and the response to viral therapy in the context of the trial. Moreover, that knowledge will leverage the design of Delta-24-based adenoviruses to recruit lymphocytes to the tumor with the competence of different type of ligands to activate the tumor infiltrating lymphocytes. I expect that this combinatorial innovative treatment will efficiently challenge the profound and inherent tumor immunosuppression and, in turn, will elicit a robust anti-tumor immune response resulting in the significant improvement of the prognosis and quality of life of patients with pediatric brain tumors. This project has the potential to produce a vertical advance in the field of pediatric oncology.

Link to the ERC project webpage:

Keywords of the ERC project: Pediatric Brain Tumors, Oncolytic Virus, Therapy, ImmunoVirotherapy, Clinical Trial,

Keywords that characterize the scientific profile of the potential visiting researcher/s: Translational Research, Bioinformatics, immunotherapy, flow cytometry, animal models, brain tumors,
Spatial fractionation of the dose in proton therapy: a novel therapeutic approach

Radiotherapy (RT) is one of the most frequently used methods for cancer treatment (above 50% of patients will receive RT). Despite remarkable advancements, the dose tolerances of normal tissues continue to be the main limitation in RT. Finding novel approaches that allow increasing normal tissue resistance is of utmost importance. This would make it possible to escalate tumour dose, resulting in an improvement in cure rate. With this aim, I propose a new approach, called proton minibeam radiation therapy (PROTONMBRT), which combines the prominent advantages of protons for RT and the remarkable tissue preservation provided by the use of submillimetric field sizes and a spatial fractionation of the dose, as in minibeam radiation therapy (MBRT). The main objectives of this project are to explore the gain of therapeutic index for radioresistant tumors, to disentangle the biological mechanisms involved and to evaluate the clinical potential of this novel approach. For this purpose, a method for minibeam generation adequate for patient treatments and a complete set of dosimetric tools will be developed. Then, tumour control effectiveness will be evaluated, and the possible biological mechanisms involved both in tumour and normal tissue responses will be disentangled. The gain in normal tissue recovery can foster one of the main applications of proton therapy, paediatric oncology, as well as open the door to an effective treatment of very radioresistant tumours, such as high-grade gliomas, which are currently mostly treated palliatively.

Link to the ERC project webpage:

Keywords of the ERC project:

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Therapeutic Allele Engineering: A novel technology for cell therapy

We are currently witnessing a revolution in cell therapies that are routed in decades of basic research in genetics, cell biology and immunology. A deep understanding of mammalian, and in particular immune, cells is currently being translated into highly efficient cell-based therapeutics. Technologic breakthroughs in genetic and genome engineering are further fueling the generation of customized, high precision therapies that are based on cells as “smart drugs”. For instance, reprogramming immune killer cells to recognize B cell leukemias resulted in unprecedented clinical responses in treatment-resistant and relapsed patients. However, currently only very few, highly selected patients benefit from these developments. A fundamental problem of today’s cell therapies is that transferred cells cannot be distinguished from host cells. We have developed “allele engineering”, a new technology that solves this challenge. Here, we outline how allele engineering will improve the safety and efficacy of cell therapies. We will 1) generate a non-viral, DNA-free safety/shielding switch 2) develop a radically new curative approach to acute myeloid leukemia 3) rationally design a safe allele engineering solution for human therapy and 4) use allele engineering as a curative therapy of scurfy syndrome, a lethal monogenic autoimmune disease. Allele engineering enables completely new treatment strategies and can be applied to any surface protein. Therefore, I anticipate that the results will have a major impact on the field.

Link to the ERC project webpage: https://erc.europa.eu/projects-figures/erc-funded-projects/results?search_api_views_fulltext=jeker

Keywords of the ERC project: Genome Engineering, cell therapy

Keywords that characterize the scientific profile of the potential visiting researcher/s: Expert in hHSC biology and/or genome editing of hHSCs. Alternatively: Human T cell engineering expert.
Deciphering the metabolic roles of the urea-cycle pathway in carcinogenesis for improving diagnosis and therapy

Almost 100 years ago, Warburg described a metabolic change in energy flux that occurs during carcinogenesis. Since then, multiple studies have demonstrated how anabolic synthesis of macromolecules can be altered to support cancer cell progression. Yet, the potential effect of altered catabolic degradation of macromolecules on tumour carcinogenesis has been much less studied.

The urea cycle (UC) is the main catabolic pathway by which mammals excrete waste nitrogen. Although the complete UC pathway is liver-specific, most tissues express different combinations of UC enzymes according to the cellular needs. Surprisingly, we find that changes in expression of UC components causing UC dysregulation, (UCD) is a global phenomenon in cancer, metabolically augmenting net nitrogen usage for the synthesis of macromolecules by reducing nitrogen waste. This metabolic alteration is associated with poor patient prognosis. Thus, we hypothesise that UCD provides a major metabolic advantage to multiple aspects of carcinogenesis and as such, leads to specific, identifiable genomic and biochemical signatures, with implications for cancer diagnosis and therapy.

To pursue our hypothesis, we will incorporate state-of-the-art comparative genomic, peptidomic, metabolomic, and molecular approaches to explore this scientific “blind spot” of nitrogen metabolism in carcinogenesis. We will investigate how UCD causally affects carcinogenesis, by characterising tumour-specific functions of UC enzymes (Aim I), correlating tumour phenotypes with systemic biomarkers (Aim II), and testing the treatment efficacy of drug combinations targeting UCD in cancers (Aim III).

Our proposal, strengthened by my training as a physician scientist, harbours considerable potential for translational diagnostic and therapeutic utility of our findings, enabling us to i) identify new diagnostic biomarkers for monitoring cancer initiation and progression and ii) predict and enhance the therapeutic response.

Link to the ERC project webpage:

Keywords of the ERC project:

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Bacterial isoprene metabolism: a missing link in a key global biogeochemical cycle

Isoprene is a very important climate-active biogenic volatile organic compound with both global warming and cooling effects. Globally, terrestrial plants emit huge amounts (~500-750 million tonnes) of isoprene per year. This is approximately the same quantity as methane released to the atmosphere. Isoprene emissions are predicted to rise due to global warming and increased use of isoprene-emitting trees (oil palm, poplar) for biofuel production but almost nothing is known about its biogeochemical cycle. Microbes are a sink for isoprene and through their activity in soils and on the leaves of isoprene-emitting plants, they will be important in removal of isoprene in the biosphere before it gets released to the atmosphere.

The aim of the project is to obtain a critical, fundamental understanding of the metabolism and ecological importance of biological isoprene degradation and to test the hypothesis that isoprene degrading bacteria play a crucial role in the biogeochemical isoprene cycle, thus helping to mitigate the effects of this important but neglected climate-active gas. Key objectives are to elucidate the biological mechanisms by which isoprene is metabolised, establish novel methods for the study of isoprene biodegradation and to understand at the mechanistic level how isoprene cycling by microbes is regulated in the environment. Bacteria that metabolise isoprene will be isolated from a range of terrestrial and marine environments and characterised using a multidisciplinary approach and a wide range of cutting edge techniques. We will elucidate the pathways of isoprene metabolism and their regulation by characterising genes/enzymes catalysing key steps in isoprene degradation, use innovative molecular ecology methods to determine distribution, diversity and activity of isoprene degraders and assess the contribution that microbes make in the removal of isoprene from the biosphere, thereby mitigating the effects of this climate-active compound.

Link to the ERC project webpage: www.jcmurrell.co.uk

Keywords of the ERC project: isoprene environmental microbiology microbial ecology monooxygenases

Keywords that characterize the scientific profile of the potential visiting researcher/s:
**Evolution of the honey bee gut microbiome through bacterial diversification**

Animals harbor specialized bacterial communities in their guts, typically referred to as gut microbiomes. Despite the importance of gut microbiomes for host health, surprisingly little is known about their evolution. There is evidence that the complexity of the mammalian gut microbiome has emerged through the diversification of a few founder lineages. However, how lineages have diversified into discrete species and which underlying mechanisms maintain the diversity in the gut remains elusive. The current project will address these questions by studying the gut microbiome of honey bees. We have recently found that the eight dominant bacterial lineages in the honey bee gut have substantially diversified, which is a striking parallelism to the evolution of the mammalian gut microbiome. Moreover, we have established experiments to colonize microbiota-free bees with cultured isolates of divergent bee gut bacteria. This provides us with unique opportunities to study bacterial evolution in the gut in a simple and experimentally amenable system. The project is divided into four work packages addressing interconnected research questions of current biology: We will (i) determine the population genomic landscape of divergent gut bacteria, (ii) investigate whether bacterial diversification has resulted in competition or cooperation, (iii) discover novel mechanisms of bacterial interactions, and (iv) reveal how bacterial diversification impacts the symbiosis with the host. To this end, we will use a multidisciplinary approach combining comparative metagenomics, transcriptomics, metabolomics, bee colonization experiments, microscopy, bacterial genetics, and automated bee tracking. This project situated at the forefront of microbial symbiosis will provide groundbreaking insights into microbial evolution and ecology, gut microbiology, and honey bee health and biology.

**Link to the ERC project webpage:**

**Keywords of the ERC project:**

Keywords that characterize the scientific profile of the potential visiting researcher/s:
What makes leaves fall in autumn? A new process description for the timing of leaf senescence in temperate and boreal trees

Leaf phenology is a key component in the functioning of temperate and boreal deciduous forests. The environmental cues for bud-burst in spring are well known, but little is known about the cues controlling the timing of leaf fall in autumn. Leaf fall is the last stage of leaf senescence, a process which allows trees to recover leaf nutrients. We urgently need to understand the controls timing leaf senescence to improve our projections of forest growth and climate change. I propose a new general paradigm of the onset of leaf senescence, hypothesizing that leaf senescence is triggered by the cessation of tree growth in autumn. I expect that: (i) in the absence of growth-limiting environmental conditions, tree growth cessation directly controls leaf-senescence onset; and (ii) in the presence of growth-limiting conditions, photoperiod controls leaf-senescence onset – this prevents trees from starting to senesce too early. I will test these hypotheses with a combination of: (i) manipulative experiments on young trees - these will disentangle the impact of photoperiod from that of other factors affecting tree growth cessation, namely: temperature, drought and soil nutrient availability; (ii) monitoring leaf senescence and growth in mature forest stands; (iii) comparing the leaf senescence dynamics of four major tree species (Fagus sylvatica, Quercus robur, Betula pendula and Populus tremula) in four European locations spanning from 40º to 70º N; and (iv) integrating the new paradigm into a model of forest ecosystem dynamics and testing it for the major forested areas of Europe. The aim is to solve the conundrum of the timing of leaf senescence in temperate and boreal deciduous trees, provide a new interpretation of the relationship between leaf senescence, tree growth and environment, and deliver a modelling tool able to predict leaf senescence and tree growth, for projections of forest biomass production and climate change.

Link to the ERC project webpage: https://www.uantwerpen.be/en/projects/leaf-fall/about-leaf-fall/
Keywords of the ERC project: deciduous trees, forest, phenology, ecophysiology
Keywords that characterize the scientific profile of the potential visiting researcher/s: PhD or Post-doc with expertise appearing from international publications
Reticulate evolution: patterns and impacts of non-vertical inheritance in eukaryotic genomes.

The traditional view is that species and their genomes evolve only by vertical descent, leading to evolutionary histories that can be represented by bifurcating lineages. However, modern evolutionary thinking recognizes processes of reticulate evolution, such as horizontal gene transfer or hybridization, which involve total or partial merging of genetic material from two diverged species. Today it is widely recognized that such events are rampant in prokaryotes, but a relevant role in eukaryotes has only recently been acknowledged. Unprecedented genomic and phylogenetic information, and recent work from others and us have shown that reticulate evolution in eukaryotes is more common and have more complex outcomes than previously thought. However, we still have a very limited understanding of what are the impacts at the genomic and evolutionary levels. To address this, I propose to combine innovative computational and experimental approaches. The first goal is to infer patterns of reticulate evolution across the eukaryotic tree, and relate this to current biological knowledge. The second goal is to trace the genomic aftermath of inter-species hybridization at the i) long-term, by analysing available genomes in selected eukaryotic taxa, ii) mid-term, by sequencing lineages of natural fungal hybrids, and iii) short-term, by using re-sequencing and experimental evolution in yeast. A particular focus is placed on elucidating the role of hybridization in the origin of whole genome duplications, and in facilitating the spread of horizontally transferred genes. Finally results from this and other projects will be integrated into emerging theoretical frameworks. Outcomes of this project will profoundly improve our understanding of reticulate processes as drivers of eukaryotic genome evolution, and will impact other key aspects of evolutionary theory, ranging from the concept of orthology to the eukaryotic tree of life.

Link to the ERC project webpage: www.cgenomics.org

Keywords of the ERC project: Evolution, Phylogenomics, Eukaryotes, Hybridization, Comparative Genomics

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Assisting Coral Reef Survival in the Face of Climate Change

CORALASSIST spans the disciplines of evolutionary biology, restoration ecology and proteomics and examines the role assisted gene flow (AGF) can play in sustaining biodiversity and ecosystem services in the face of climate change. AGF involves the deliberate movement of individuals or gametes within their natural range to facilitate adaptation to environmental change. Corals reefs provide an excellent model for testing AGF as a conservation tool because reef building corals are foundation species and are highly vulnerable to thermal stress. Selective breeding and translocation of thermotolerant individuals may lead to reductions in recipient population fitness due to resource trade-offs with other fitness traits, such as growth and fecundity. The overall aim of CORALASSIST is to establish the feasibility of implementing AGF in coral reef ecosystems using a combination of selective breeding, proteomics and innovative translocation techniques. CORALASSIST will address four primary questions: 1) Are there resource trade-offs between increased thermotolerance and other fitness traits in corals? 2) Which physiological and proteomic traits correlate with increased individual thermotolerance in corals? 3) Are phenotypic traits for thermotolerance heritable? 4) Can AGF and selective breeding lead to persistent shifts in thermotolerance in recipient populations? Phenotypic traits will be measured in permanently tagged individuals within selected coral populations to examine the relationships between thermotolerance and key fitness attributes. For the first time, state of the art proteomic approaches will be used to elucidate the physiological basis for increased levels of thermotolerance in corals. Innovative translocation methods will be used in tandem with selective breeding techniques to carry out the first long term assessment of heritability of thermotolerance and to test the feasibility of large scale AGF to assist conservation of coral reef ecosystems.

Link to the ERC project webpage: www.coralassistlab.org

Keywords of the ERC project: coral reefs, assisted gene flow, selective breeding, restoration ecology, proteomics, climate change

Keywords that characterize the scientific profile of the potential visiting researcher/s: coral reefs, assisted gene flow, selective breeding, restoration ecology, proteomics, climate change
Ecophysiology of membrane lipid remodelling in marine bacteria

Membrane lipids form the structural basis of all cells. In bacteria Escherichia coli uses predominantly phosphorus-containing lipids (phospholipids) in its cell envelope, including phosphatidylethanolamine and phosphatidylglycerol. However, beyond E. coli a range of lipids are found in bacterial membranes, including phospholipids as well as phosphorus (P)-free lipids such as betaine lipids, ornithine lipids, sulfolipids and glycolipids. In the marine environment, it is well established that P availability significantly affects lipid composition in the phytoplankton, whereby non-P sulfur-containing lipids are used to substitute phospholipids in response to P stress. This remodeling offers a significant competitive advantage for these organisms, allowing them to adapt to oligotrophic environments low in P. Until very recently, abundant marine heterotrophic bacteria were thought to lack the capacity for lipid remodelling in response to P deficiency. However, recent work by myself and others has now demonstrated that lipid remodelling occurs in many ecologically important marine heterotrophs, such as the SAR11 and Roseobacter clades, which are not only numerically abundant in marine waters but also crucial players in the biogeochemical cycling of key elements. However, the ecological and physiological consequences of lipid remodeling, in response to nutrient limitation, remain unknown. This is important because I hypothesize that lipid remodeling has important knock-on effects restricting the ability of marine bacteria to deal with both abiotic and biotic stresses, which has profound consequences for the functioning of major biogeochemical cycles. Here I aim to use a synthesis of molecular biology, microbial physiology, and "omics" approaches to reveal the fitness trade-offs of lipid remodelling in cosmopolitan marine heterotrophic bacteria, providing novel insights into the ecophysiology of lipid remodelling and its consequences for marine nutrient cycling.

Link to the ERC project webpage:

Keywords of the ERC project:

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Hunting for the elusive “sixth” sense: navigation and magnetic sensation in a nocturnal migratory moth

Many animals – including birds, sea turtles and insects – perform spectacular long-distance migrations across the surface of the Earth. Remarkably some, like birds, can accurately migrate between highly specific locations thousands of kilometres apart, a navigational feat that requires an external compass cue and a robust sensory system to detect it. The Earth’s magnetic field is one such compass cue. But exactly how the magnetic field is sensed, and which receptor cells are involved, remains a mystery and its discovery is one of the greatest “holy grails” in modern sensory physiology, and also the main aim of this proposal. Fortuitously, I have made a pioneering discovery that a migratory insect – the Australian Bogong moth – relies on the Earth’s magnetic field to navigate at night. Due to its tractable nervous system, this insect may thus hold the key to uncovering the identity of the enigmatic magnetosensor. By tethering flying migrating moths in a flight simulator, I will dissect for the first time how insects use magnetic cues to navigate, isolating which of the two current (contentious) hypotheses for magnetic sensation apply. The most likely of these involves the action of photoreceptor-based cryptochrome (Cry) molecules in the eyes. Having cloned genes for 4 visual opsins and 2 Cry in Bogong moths, I will use in situ hybridisation to localise putative magnetoreceptors in the eyes, targeting them with intracellular electrophysiology and magnetic stimulation in an attempt to describe the physiology of these elusive sensors for the first time. The project is ground breaking since it will elucidate how a migratory insect, despite its small eyes and brain, detects and uses the Earth’s magnetic field for navigation. The discovery of the enigmatic magnetoreceptor would be a sensation, opening the floodgates for international research on this little understood sense.

Link to the ERC project webpage:

Keywords of the ERC project: Magnetic sense, migration, navigation, insect, moth

Keywords that characterize the scientific profile of the potential visiting researcher/s: Sensory biology, entomology, sensory, ecology, navigation, migration
Age at maturity in Atlantic salmon: molecular and ecological dissection of an adaptive trait

Life history is the nexus of biology, because various biological questions ultimately revolve around the causes and consequences of variation in reproduction and survival, i.e. fitness. Traditionally, a major tool in life-history research has been quantitative genetics because it provides an important statistical link between phenotype and genotype. However, the mechanisms by which evolution occurs may remain unclear unless such traditional approaches are combined with molecular investigations. Another complicating factor is that the fitness of male vs female life histories do not always align, and hence life history traits may be shaped by sexual conflict. This is why life-history approaches focusing on both quantifying the conflict and understanding its resolution at the genetic level are needed.

As in many species, age at maturity in Atlantic salmon is tightly linked with size at maturity and thus represents a classic evolutionary trade-off: later maturing individuals spend more time at sea before returning to freshwater to spawn and have higher reproductive success due to their larger size but also have a higher risk of dying prior to first reproduction. Our recent cover paper in Nature reported a large-effect gene explaining 40% of the variation in this key life history trait. Remarkably, the locus exhibits sex-dependent dominance and this resolves a potential intra-locus sexual conflict in the species. The relatively simple genetic architecture of this trait combined with the features of Atlantic salmon as a model system offer an ideal opportunity to better understand the molecular mechanisms and ecological drivers underlying a locally adapted life history trait.

In MATURATION I will i) characterize age at maturity candidate gene functions and allelic effects on phenotypes ii) elucidate fitness effects of these phenotypes and GxE interactions iii) develop a mechanistic model for the sex-dependent dominance and validate intra-locus sexual conflict resolution.

Link to the ERC project webpage: https://www.helsinki.fi/en/researchgroups/evolution-conservation-and-genomics

Keywords of the ERC project: ecological genomics, evolutionary genomics, Atlantic salmon, sexual conflict

Keywords that characterize the scientific profile of the potential visiting researcher/s: functional genomics, ecological genomics, evolutionary genomics, sexual conflict, animal behavior, population genomics
The mechanical evolution from biting-chewing to piercing-sucking in insects

Insects are extremely efficient feeders that impact on the world's ecosystems and our agriculture with their feeding capabilities. Insects evolved diverse mouthpart types during ~400 million years of evolution which allowed them to conquer many food recourses. How this feeding system evolved, in particular the transition from one mouthpart type to the other, is unclear. My idea represents the first extensive assessment of insect head mechanics applying latest semi-automatic workflows and engineering approaches to unravel the factors driving insect mouthpart evolution and performance.

Specifically, I will study the mechanical evolution from early biting-chewing to piercing-sucking mouthparts and head types, considering recent as well as fossil species.

In contrast to earlier studies, I aim to quantify mechanical evolution for the whole head which has never been attempted before for insects. This will be done using engineering software to simulate insect feeding, followed by 3D shape analysis and finally evolutionary modelling using algorithms based on likelihood models of evolutionary processes. The project is therefore positioned at the interconnection between experimental biology, engineering and biological simulation.

The results will impact our understanding of insect evolution, with the project identifying which mechanical factors made insects such extraordinarily successful feeders, and why their mouthparts evolved into so many different types. To achieve an integrative understanding, my idea will furthermore take into account ecological, evolutionary and life history factors. Understanding the mechanical head evolution has never been tried before in a systematic way at this scale. However, my project idea also delivers results for industry: Since modern engineering methods are used, the results can be readily exported to the industry for the design of lighter robot arms with better lifting capabilities, thus advancing robotic techniques.

Link to the ERC project webpage:

Keywords of the ERC project: Biomechanics, geometric morphometrics, Morphology, evolution

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Modelling the genomic landscapes of selection and speciation

Understanding how natural selection, random genetic drift and demographic events interact to generate and maintain genetic and species diversity has been the central focus of population genetics for many decades. We now have the necessary genome sequence data to make detailed and powerful inferences about the evolutionary past of populations and species, yet our ability to meaningfully interpret such data has remained fundamentally limited.

This project will use a combination of theory, development of new inference tools and a large-scale comparative analyses of genome data and has two principal aims:

First to develop a general, statistical framework for making inferences about the joint action of past selection and demography from genome sequence data. This will be achieved using analytic calculations and approximations for the joint distribution of linked polymorphic sites. We will use these results to develop new methods to quantify the genome-wide rates of positive and background selection and to scan for genomic outliers of divergence between and positive selection within species. The new methods will be tested using simulations and data from model insects (Drosophila and Heliconius).

Second, we will apply the new inference approach to genome data for 20 species pairs of European butterflies and conduct a systematic comparison of the demographic and selective forces involved in speciation. This will reveal how repeatable speciation processes are both in terms of the demographic and selective events, and the genes and genomic architectures involved. Specifically, we will test whether selection during speciation is concentrated at chromosomal rearrangements and/or candidate gene families involved in mate recognition and host plant adaptation. This project will fundamentally improve both our understanding of speciation and selection and our ability to use sequence data to study population processes (be they selection, demography or both) in any system.

Link to the ERC project webpage:

Keywords of the ERC project: population genomics, speciation

Keywords that characterize the scientific profile of the potential visiting researcher/s:
The genetic basis of the convergent evolution of fungal multicellularity

The evolution of multicellularity (MC) has been one of the major transitions in the history of life. Despite immense interest in its evolutionary origins, the genomic changes leading to the emergence of MC, especially that of complex MC (differentiated 3-dimensional structures) are poorly known. Previous comparative genomics projects aiming to understand the genetic bases of MC in one way or another relied on gene content-based analyses. However, a pattern emerging from these studies is that gene content provides only an incomplete explanation for the evolution of MC even at ancient timescales. We hypothesize that besides gene duplications, changes to cis-regulatory elements and gene expression patterns (including protein isoforms) have significantly contributed to the evolution of MC. To test this hypothesis, we will deploy a combination of computational methods, phylogenomics, comparative transcriptomics and genome-wide assays of regulatory elements. Our research focuses on fungi as a model system, where complex MC evolved convergently and in subsequent two steps. Fungi are ideal models to tackle this question for several reasons: a) multicellularity in fungi evolved multiple times, b) there are rich genomic resources (>500 complete genomes), c) complex multicellular structures can be routinely grown in the lab and d) genetic manipulations are feasible for several cornerstone species. We set out to examine which genes participate in the building of simple and complex multicellular structures and whether the evolution of regulome complexity and gene expression patterns can explain the evolution of MC better than can traditionally assayed sources of genetic innovations (e.g. gene duplications). Ultimately, our goal is to reach a general synthesis on the genetic bases of the evolution of MC and that of organismal complexity.

Link to the ERC project webpage:

Keywords of the ERC project:
Keywords that characterize the scientific profile of the potential visiting researcher/s:
The application of antimicrobial compounds produced by hosts or defensive symbionts to counter the effects of diseases has been identified in a number of organisms, but despite extensive studies on their presence, we know essentially nothing about why antimicrobials do not trigger rampant resistance evolution in target parasites. In stark contrast to virtually any other organism, fungus-farming termites have evolved a sophisticated agricultural symbiosis that pre-dates human farming by 30 million years without suffering from specialised diseases. I will capitalise on recent pioneering work in my group on proximate evidence for antimicrobial defences in the termites, their fungal crops, and their complex gut bacterial communities, by proposing to develop the farming symbiosis as a major model to test three novel concepts that may account for the evasion of resistance evolution. First, the antimicrobial compounds may have properties and evolve in ways that preclude resistance evolution in pathogens. Second, resistance is only possible towards individual compounds and not natural antimicrobial cocktails. Third, pathogens can only successfully invade and proliferate if they bypass several consecutive lines of defence, analogous to the six hallmarks of metazoan defence against cancer development. Addressing these concepts will allow fundamental insights into the remarkable success of complementary symbiont contributions to defence, and they will clarify the forces of multilevel natural selection that have allowed long-lived insect societies to evolve sustainability. Documenting and understanding these disease management principles is fundamentally important for several branches of evolutionary biology, and strategically important for adjusting human practices for future antimicrobial stewardship.
Glaciers show a pattern of retreat at the global scale. Increasing areas are exposed and colonized by multiple organisms, but lack of global studies hampers a complete understanding of the future of recently deglaciated terrains. What will be the fate of these areas? How do animals, plants and microorganisms colonize them? How do they interact to perform successful colonization? Which are the climatic, geological and biogeographical processes determining colonization patterns? How does ecosystem functioning evolves through time? Until now, the complete reconstruction of soil communities was hampered by the complexity of identification of organisms, thus analyses at broad geographical and taxonomic scale have been so far impossible. IceCommunities will combine innovative methods and a global approach to boost our understanding of the evolution of ecosystems in recently deglaciated areas. I will investigate chronosequences ranging from recently deglaciated terrains to late successional stages of soil pedogenesis. Through environmental DNA metabarcoding I will identify species from multiple taxonomic groups (bacteria, fungi, protists, soil invertebrates, plants), to obtain a complete reconstruction of biotic communities along glacier forelands over multiple mountain areas across the globe. This will allow measuring the rate of colonization at an unprecedented detail. Information on assemblages will be combined with analyses of soil, landscape and climate to identify the drivers of community changes. I will also identify the impact of eco-geographical factors (climate, regional pool of potential colonizers) on colonization. Analysis of functional traits will allow reconstructing how functional diversity emerges during community formation, and how it scales to the functioning of food webs. IceCommunities will help to predict the future development of these increasingly important ecosystems, providing a supported rationale for the appropriate management of these areas.
Elucidating the causes and consequences of the global pattern of epigenetic variation in Arabidopsis thaliana

Epigenetics continues to fascinate, especially the notion that it blurs the line between “nature and nurture” and could make Lamarckian adaptation via the inheritance of acquired characteristics possible. That this is in principle possible is clear: in the model plant Arabidopsis thaliana (Thale cress), experimentally induced DNA methylation variation can be inherited and affect important traits. The question is whether this is important in nature. Recent studies of A. thaliana have revealed a pattern of correlation between levels of methylation and climate variables that strongly suggests that methylation is important in adaptation. However, somewhat paradoxically, the experiments also showed that much of the variation for this epigenetic trait appears to have a genetic rather than an epigenetic basis. This suggest that epigenetics may indeed be important for adaptation, but as part of a genetic mechanism that is currently not understood. The goal of this project is to determine whether the global pattern of methylation has a genetic or an epigenetic basis, and to use this information to elucidate the ultimate basis for the global pattern of variation: natural selection.
The macroevolutionary impact of epigenetics and lateral gene transfer on eukaryotic genomes

Multicellular organisms (e.g., animals, fungi and plants) are the best-studied eukaryotes but their ancestors and the vast majority of eukaryotic diversity correspond to microbial species (“protists”). The evolutionary history of protists is closely connected to the evolution of the eukaryotic cell itself. However, most protist diversity is still genomically unexplored, limiting our investigation of eukaryotic evolution. For example, while the importance of lateral gene transfer (LGT) in prokaryotic evolution is well recognized, its role in eukaryotic evolution is still debated. In addition, although epigenetic mechanisms represent a hallmark of eukaryotic genome regulation, we know surprisingly little about the evolution of these mechanisms across eukaryotic diversity.

The overarching goal of my project is to understand how epigenetic mechanisms and LGT have shaped the macroevolution of eukaryotic genomes. This project has several inter-related intermediate objectives, which each in themselves will bring crucial insights into eukaryotic evolution: 1) reconstructing a robust phylogeny of eukaryotes; 2) inferring the gene content of the Last Eukaryotic Common Ancestor; 3) tracing the evolution of genes involved in epigenetic mechanisms and obtaining epigenomic maps from under-studied protists; 4) investigating the intriguing hypothesis of a possible interplay between epigenetic regulation and horizontal gene transfer and its influence on eukaryotic genome evolution: Have genes involved in epigenomic mechanisms been transferred between eukaryotes? Do epigenomic modifications affect the frequency of LGT in different lineages?

To achieve this, I will characterize the transcriptomes, genomes, methylomes and small RNAs of understudied eukaryotic microbes selected for their key phylogenetic position, and to analyse them using state-of-the-art bioinformatic methods. I will target uncultivated protists, using single-cell techniques and novel genome-scaffolding approaches.

Link to the ERC project webpage:

Keywords of the ERC project: phylogenetics, protists, epigenetics, horizontal gene transfer, genomics, single-cell, transcriptomics

Keywords that characterize the scientific profile of the potential visiting researcher/s:
A major challenge in evolutionary biology is to quantify the processes and mechanisms by which populations adapt to new environments. In particular, the role of epistasis, which is the genetic-background dependent effect of mutations, and the constraints it imposes on adaptation, has been contentious for decades. This question can be approached using the concept of a fitness landscape: a map of genotypes or phenotypes to fitness, which dictates the dynamics and the possible paths towards increased reproductive success. This analogy has inspired a large body of theoretical work, in which various models of fitness landscapes have been proposed and analysed. Only recently, novel experimental approaches and advances in sequencing technologies have provided us with large empirical fitness landscapes at impressive resolution, which call for the evaluation of the related theory.

The aim of this proposal is to build on the theory of fitness landscapes to quantify epistasis across levels of biological organization and across environments, and to study its impact on the population genetics of adaptation and hybridization. Each work package involves classical theoretical modelling, statistical inference and method development, and data analysis and interpretation; a combination of approaches for which my research group has strong expertise. In addition, we will perform experimental evolution in Escherichia coli and influenza to test hypotheses related to the change of fitness effects across environments, and to adaptation by means of highly epistatic mutations. We will specifically apply our methods to evaluate the potential for predicting routes to drug resistance in pathogens. The long-term goal lies in the development of a modeling and inference framework that utilizes fitness landscape theory to infer the ecological history of a genome, which may ultimately allow for a prediction of its future adaptive potential.
Testing new hypotheses on the evolution of sex-related chromosomes

The sex chromosomes of plants and animals often contain large non-recombining regions due to a stepwise cessation of recombination generating “evolutionary strata” of genetic differentiation. The reasons for the extension of recombination suppression beyond sex-determining genes remain unclear. Sexual antagonism, involving the linkage to sex-determining genes of alleles beneficial in only one sex, is the prevailing hypothesis, as this explanation is both theoretically plausible and attractive. However, decades of research have unearthed little evidence to support this hypothesis. Furthermore, I have shown that chromosomes involved in sexual compatibility in systems lacking male and female functions can nevertheless display a stepwise suppression of recombination beyond mating-compatibility genes. Thus, evolutionary strata can evolve without sexual antagonism. Alternative hypotheses, such as neutral rearrangements, epigenetic changes associated with transposable elements and the sheltering of deleterious alleles accumulating near non-recombining regions, must thus be seriously considered. I propose to use a synergic combination of different approaches and biological systems to refine and test these hypotheses, to broaden the theory of sex-related chromosome evolution, and, more generally, of the evolution of supergenes (linked allelic combinations). I will use mathematical modeling to test hypothesis plausibility and generate predictions. I will use comparative and population genomic approaches to test predictions, and an innovative experimental evolution approach with functional manipulations to assess the ability of the proposed mechanisms to generate strata. The EvolSexChrom project will challenge the current theory, opening up new avenues of research and potentially creating a paradigm shift in the dynamic research field focusing on the evolution of sex-related chromosomes and other supergenes, relevant to diverse traits and organisms.

Link to the ERC project webpage:
Keywords of the ERC project: geonmics, evolution, sex chromosomes, fungi
Keywords that characterize the scientific profile of the potential visiting researcher/s: geonmics, evolution, sex chromosomes, fungi
The genetic and neural basis of reproductive isolation

Speciation is a fundamental evolutionary process, which relies on the accumulation of reproductive barriers. These barriers often act before mating, and many taxa remain separate not because they fail to produce viable offspring, but because they ‘choose’ not to mate in the first place. Although the significance of behavioural barriers has long been recognized, an integrated understanding remains elusive: How is behavioural isolation mediated through changes in the sensory systems? Are these changes driven by selection? And what is the genetic and developmental basis of behavioural divergence in natural populations?

My research will address these questions to understand how behavioural barriers are generated, both during development and across evolutionary time. This project will be novel in uniting genomic and neurosensory data, with ecological and behavioural studies across a single radiation. Heliconius butterflies offer an excellent opportunity to achieve this as they are a group of closely related species with well-characterised ecologies, high-quality genomic resources, and are emerging as a model of evolutionary neurobiology. These attributes will allow me to address the enduring problem of how natural selection and genetics interact to drive divergence in behavioural preferences. I will determine how components of behavioural isolation vary with ecology, both within and between species; and then explicitly test whether changes in sensory perception and processing in the brain are driven by selection imposed by the external environment. Genetic mapping will allow me to test for a link between changes in the sensory systems and mate choice. By combining these data with expression and functional analyses I will identify genes strongly implicated in the divergence of behavioural preferences. This will lead to novel insights into the developmental and neurological bases of behavioural isolation, a process fundamental to biodiversity.

Link to the ERC project webpage:

Keywords of the ERC project: speciation, behaviour, genetics, Heliconius, neuro

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Insect herbivores are a dominant element in terrestrial ecosystems, and pose a continuing threat to global food security. However, little is known about a key determinant of insect herbivore success: the mechanics of plant-feeding. MechAnt proposes to transform our understanding of insect-plant relations by providing a rigorous biomechanical investigation into how insects cut leaves, using the major ecosystem engineers and principal insect pest of the New World, the leaf-cutter ants, as a model system. Specifically, MechAnt will combine the traditionally separate fields of behavioural ecology, mechanical engineering, materials science, computer vision and machine learning to investigate: (1) the mechanical and energetic constraints determining the cutting ability, and ontogeny of task choice of differently-sized workers, and hence the adaptive value of physical castes in eusocial insects; (2) the relationship between plant material properties, ease of cutting, and mandibular wear, which will reveal the key mechanical determinants of plant-herbivore species interactions; (3) the division of labour, ontogeny and demography of leaf-cutter colonies foraging on leaves of different "toughness", testing the hypothesis that leaf-cutter colonies are organised according to ergonomic criteria. By integrating insights ranging from nano-scale mechanics up to whole-colony ecology, MechAnt will quantitatively link the mechanical properties of plants with the performance of individual foragers, the organisation of foraging parties, and the demography and social organisation of leaf-cutter ant colonies. The resulting understanding of the biomechanical innovations underpinning the success of the leaf-cutter ants will yield insights into the behavioural ecology of advanced plant-feeders, highlight the role of biomechanical constraints in the behaviour and evolution of herbivorous insects, and pave the way for the development of novel crop protection strategies.
Land plants abound on Earth’s surface. All of this diversity arose in a singular event. The algal progenitor of land plants was a streptophyte alga and only recent phylogenomic analyses have specified the particular algal lineage that is most closely related to land plants. But why did land plants evolve only once? And what properties did the ancestors of these terrestrial organisms possess that allowed them to conquer land? Life on land involves rapid and drastic shifts in temperature, light or water availability. Hence, a prime candidate property is the ability to deal with these terrestrial stressors by dynamically responding to shifting environmental cues. My recent data highlight that the streptophyte algae closest to land plants have the genetic makeup for land plant-like stress response signalling circuits—including genes for sensing the major stress phytohormone abscisic acid (ABA). This provides us with testable candidates. To shed light on the early evolution of one of land plants’ key properties, I, here, propose to combine in-depth molecular biological analyses of these candidate stress signalling and response pathways with large-scale systems biology approaches. For this, my team and I will develop streptophyte algal model systems. We will dissect the regulatory hierarchy employed during stress signalling and the response pathways it is regulating in real-time in vivo and across evolutionary time in silico. These approaches will go beyond a view of gene evolution that is based on presence/absence to address if land plant stress dynamics have evolved from algal stress regulatory networks that became hardwired into land plant biology. The aim of this work is to infer the biology of the earliest land plants by investigating their closest algal relatives and interrogating a candidate mechanism used to deal with the challenges of life on land. Understanding this mechanism means understanding a key player that paved the way for the success of plants on land.

**Terrestrialization: Stress Signalling Dynamics in the Algal Progenitors of Land Plants**

**Principal Investigator:** Dr JAN DE VRIES  
**Host Institution:** GEORG-AUGUST-UNIVERSITAT GOTTINGENSTIFTUNG OFFENTLICHEN RECHTS - DE

**Keywords of the ERC project:** streptophyte algae; plant evolution; comparative genomics; evolutionary bioinformatics; multi-omics

**Keywords that characterize the scientific profile of the potential visiting researcher/s:**
Bioenergetics in microalgae: regulation modes of mitochondrial respiration, photosynthesis, and fermentative pathways, and their interactions in secondary algae

During the course of eukaryote evolution, photosynthesis was propagated from primary eukaryotic algae to non-photosynthetic organisms through multiple secondary endosymbiotic events. Collectively referred to as “secondary algae”, these photosynthetic organisms account for only 1-2% of the total global biomass, but produce a far larger part of the global annual fixation of carbon on Earth.

ATP is the universal chemical energy carrier in living cells. In photosynthetic eukaryotes, it is produced by two major cellular processes: photosynthesis and respiration taking place in chloroplasts and mitochondria, respectively. Both processes support the production of biomass and govern gas (O2 and CO2) exchanges. On the other hand, anaerobic fermentative enzymes have also been identified in several primary and secondary algae. The regulation modes and interactions of respiration, photosynthesis and fermentation are fairly well understood in primary green algae. Conversely, the complex evolutionary history of secondary algae implies a great variety of original regulatory mechanisms that have been barely investigated to date.

Over the last years my laboratory has developed and optimized a range of multidisciplinary approaches that now allow us, within the frame of the BEAL (BioEnergetics in microALgae) project, to (i) characterize and compare the photosynthetic regulation modes by biophysical approaches, (ii) use genetic and biochemical approaches to gain fundamental knowledge on aerobic respiration and anaerobic fermentative pathways, and (iii) investigate and compare interconnections between respiration, photosynthesis, and fermentation in organisms resulting from distinct evolutionary scenarios. On a long term, these developments will be instrumental to unravel bioenergetics constraints on growth in microalgae, a required knowledge to exploit the microalgal diversity in a biotechnological perspective, and to understand the complexity of the marine phytoplankton.

Link to the ERC project webpage: http://labos.ulg.ac.be/genetique-physiologie-microalgues/research/erc-beal/

Keywords of the ERC project: photosynthesis, microalgae

Keywords that characterize the scientific profile of the potential visiting researcher/s: biochemist, spectroscopy
The evolution of barriers to gene exchange

Speciation is a central process in evolution that involves the origin of barriers to gene flow between populations. Species are typically isolated by several barriers and assembly of multiple barriers separating the same populations seems to be critical to the evolution of strong reproductive isolation. Barriers resulting from direct selection can become coincident through a process of coupling while reinforcement can add barrier traits that are not under direct selection. In the presence of gene flow, these processes are opposed by recombination. While recent research using the latest sequencing technologies has provided much increased knowledge of patterns of differentiation and the genetic basis of local adaptation, it has so far added little to understanding of the coupling and reinforcement processes.

In this project, I will focus on the accumulation of barriers to gene exchange and the processes underlying increasing reproductive isolation. I will use the power of natural contact zones, combined with novel manipulative experiments, to separate the processes that underlie patterns of differentiation and introgression. The Littorina saxatilis model system allows me to do this with both local replication and a contrast between distinct spatial contexts on a larger geographic scale. I will use modelling to determine how processes interact and to investigate the conditions most likely to promote coupling and reinforcement. Overall, the project will provide major new insights into the speciation process, particularly revealing the requirements for progress towards complete reproductive isolation.

Link to the ERC project webpage:

Keywords of the ERC project: speciation

Keywords that characterize the scientific profile of the potential visiting researcher/s: evolutionary biology
The Combined Effects of Climatic Warming and Habitat Fragmentation on Biodiversity, Community Dynamics and Ecosystem Functioning

Climatic warming and habitat fragmentation are the largest threats to biodiversity and ecosystems globally. To forecast and mitigate their effects is the environmental challenge of our age. Despite substantial progress on the ecological consequences of climatic warming and habitat fragmentation individually, there is a fundamental gap in our understanding and prediction of their combined effects.

The goal of FRAGCLIM is to determine the individual and combined effects of climatic warming and habitat fragmentation on biodiversity, community dynamics, and ecosystem functioning in complex multitrophic communities. To achieve this, it uses an integrative approach that combines the development of new theory on metacommunities and temperature-dependent food web dynamics in close dialogue with a unique long-term aquatic mesocosm experiment. It is articulated around five objectives. In the first three, FRAGCLIM will determine the effects of (i) warming, (ii) fragmentation, and (iii) warming and fragmentation combined, on numerous facets of biodiversity, community structure, food web dynamics, spatial and temporal stability, and key ecosystem functions. Then, it will (iv) investigate the extent of evolutionary thermal adaptation to warming and isolation due to fragmentation, and its consequences for biodiversity dynamics. Finally, (v) it will provide creative solutions to mitigate the combined effects of warming and fragmentation.

FRAGCLIM proposes an ambitious integrative and innovative research programme that will provide a much-needed new perspective on the ecological and evolutionary consequences of warming and fragmentation. It will greatly contribute to bridging the gaps between theoretical and empirical ecology, and between ecological and evolutionary responses to global change. FRAGCLIM will foster links with environmental policy by providing new mitigation measures to climate change in fragmented systems that derive from our theoretical and empirical findings.

Link to the ERC project webpage:

Keywords of the ERC project: Climate Change, habitat fragmentation, theoretical ecology, ecosystem functioning, food webs

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Genomic basis of convergent evolution in the Trinidadian Guppy

Many species have independently evolved similar phenotypes in response to similar environmental challenges. This phenomenon, termed convergent evolution, reflects both the power and the limits of adaptation. However, we often do not know at what scale evolution has repeated itself: did selection act on the same genes in different populations or species, or did convergence result from selection on different genes? This is because, until recently, it has not been possible to investigate the genomic basis of evolution in most systems, limiting our understanding of the factors that facilitate or inhibit convergence and adaptation. To fully understand convergent evolution we need to query the genomic response to selection and determine genotype-phenotype links in systems where convergent adaptation is well established. The Trinidadian guppy (Poecilia reticulata) is a system that offers the opportunity to test the roles of multiple factors in convergent evolution: this species includes multiple natural and experimentally established populations that have repeatedly evolved similar phenotypes under similar predation environments. I propose to fully characterize the genomic basis of repeated adaptive evolution in guppies. Aim 1 will identify regions that repeatedly show signatures of selection, and will contrast the nature of selection in natural and experimental populations that differ in age and levels of founding genetic diversity. Aim 2 will identify genomic regions associated with phenotypes that are known to play a significant role in local adaptation in the guppy using quantitative genetics approaches. I will then directly test the effects of candidate genes using novel functional genomic approaches, as detailed in Aim 3. Overall, this project will test whether repeated selection led to convergence at the genomic level, determine the genetic basis of convergent adaptations, and ultimately understand how convergent evolution has occurred in an important wild system.

Link to the ERC project webpage:
https://biosciences.exeter.ac.uk/staff/profile/index.php?web_id=Bonnie_Fraser

Keywords of the ERC project: Convergent evolution, fish, population genetics, quantitative genetics, Poecilia reticulata

Keywords that characterize the scientific profile of the potential visiting researcher/s: population genetics, quantitative genetics, evolution
Evolution of Physiology: The link between Earth and Life

The history of life is a subject that attracts the interest from both researchers and the society in general - it is in the human nature to wonder about our own history. Our only sources of information about microbial evolution reside in genomic data and geological records. Major advances in sequencing techniques are overwhelming databases with rich and novel insights into microbial taxonomic diversity, in particular about new uncultured lineages. Through metagenomics we now know that they are there but we still do not understand what they are doing. The key to that understanding is not genomics, it is physiology. Our main impediment to understand environmental microbial life is our lack of insights into the physiology of newly discovered lineages, how they harness and conserve energy. While phylogenetic trees based on universal genes can be generated for thousands of lineages at a time, they do not represent the genome as a whole and, most importantly, due to lateral gene transfer, branching patterns in the tree of life have never correlated well with key physiological traits. The goal of this proposal, whose focus is physiology, is to better understand how microbes harness energy from available environmental sources, how they learned to use new ones, and how this process unfolded during microbial evolution. This will involve i) large-scale comparative phylogenetic analysis of genes involved in and genomically associated with physiology combined with ii) experimental data, using as evolutionary constraints geochemical records of available environmental energy sources. With a top-down approach this work will successively eliminate among extant biological traits ones that cannot be ancient, constraining the physiological space of older microbial solutions. This proposal will lead to testable predictions regarding the order of events in evolutionary bioenergetic transitions, the focus on biological energy harnessing will narrow the gap between geochemistry and microbiology.

Keywords of the ERC project: evolution, bioenergetics, biochemistry, genomic analysis, geochemistry, early earth

Keywords that characterize the scientific profile of the potential visiting researcher/s: biochemist, geochemist, computational scientist
Ecological and Evolutionary Importance of Molecular Diversity in Dissolved Organic Matter

Dissolved organic matter (DOM) is central to the functioning of freshwater ecosystems that support life on Earth. For example, DOM has a major role in global carbon (C) cycling by helping to bury four times more C in the bottom of lakes and rivers than across all of the world’s oceans. DOM also majorly influences the growth of aquatic organisms and impedes drinking water treatment for millions of people, such as by increasing microbial growth. Yet, despite its importance, DOM remains poorly understood because it has been measured with little resolution for nearly 200 years. Recent technological advances have now shown that a handful of lake water can contain thousands of different molecules of varying origin and composition. But the role of all these different molecules in aquatic ecosystems largely remains a mystery.

This project will discover the importance of the tremendous diversity of molecules – termed chemodiversity – found in DOM for lake functioning and human wellbeing. It will do so by combining cutting-edge techniques in analytical chemistry, genomics, and statistical modelling with careful lab-based studies, proven field experiments, and large-scale observational surveys. By thinking about species of molecules as we would species of organisms, this project will draw upon rich theory and methods developed for the study of biodiversity. The work will allow us to learn how variation in chemodiversity across lakes is driven by associations with different microbes and how these microbes reciprocally adapt and evolve to different DOM. In the process, we will improve predictions of how important functions and services provided by lakes, such as C cycling and drinking water, vary with chemodiversity. An exciting application of this work is to improve emerging technologies for water purification by identifying microbial consortia that can consume chemodiversity and make water clearer.

Link to the ERC project webpage: https://www.ecosystemchange.com/ercfunded-seeingdom

Keywords of the ERC project: ecology, evolution, lakes, microbial, biogeochemistry, carbon cycling, diversity, genomics, mass spectrometry, water quality

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Ecosystem response to drought: unravelling the unexplored role of plant-soil feedback

Drought is severely threatening our ecosystems and their functioning: it causes strong shifts in plant community composition that are difficult to revert. Positive feedbacks often underlie these dramatic shifts, but in many ecosystems drought causes fast-growing species to increase. These species are not only vulnerable to drought, but they also suffer negative plant-soil feedback, i.e. they change the soil microbial community in a way that keeps their own abundance in check. Thus, drought-induced shifts in plant communities do not result from positive feedbacks, unless drought changes plant-soil feedback. We know that plant-soil feedback drives plant community succession, but its role in community response to drought has never been explored. Here, I will unravel whether and how changes in plant-soil feedback underlie strong shifts in plant community composition following drought. This knowledge is crucial for mitigating the effects of drought on terrestrial ecosystems.

My objectives are:
1. Examining how drought affects plant community and soil microbial community composition and the implications for plant-soil feedback
2. Quantifying the effects of plant-plant and plant-microbial interactions on plant growth and subsequent shifts in plant community composition in response to drought
3. Disentangling the mechanisms underlying drought-induced changes in plant-soil feedback

I will address these objectives in a novel set of approaches. I will identify general patterns in plant-soil feedback across European drought experiments, and assess the role of plant-plant and plant-microbial interactions across a Dutch secondary successional gradient. In a set of targeted mesocosm experiments, I will elucidate the mechanisms underlying changes in plant-soil feedback and the consequences for plant community composition. These approaches will result in a step-change in understanding the dynamics of plant-soil interactions under drought and the consequences for ecosystem change.

Link to the ERC project webpage:

Keywords of the ERC project: climate change, soil, plant communities, ecosystems, microbial communities, fungi, bacteria, roots, plant-soil interactions, plant-soil feedback, drought, grassland, shrubland

Keywords that characterize the scientific profile of the potential visiting researcher(s): climate change, soil, plant communities, ecosystems, microbial communities, fungi, bacteria, roots, plant-soil interactions, plant-soil feedback, drought, grassland, shrubland, plant physiology, root exudates, ecosystem restoration, nature conservation,
Cognitive Ageing in Dogs

The aim of this project is to understand the causal factors contributing to the cognitive decline during senescence and to develop sensitive and standardized behaviour tests for early detection in order to increase the welfare of affected species. With the rapidly ageing population of Europe, related research is a priority in the European Union.

We will focus both on characterising the ageing phenotype and the underlying biological processes in dogs as a well-established natural animal model. We develop a reliable and valid test battery applying innovative multidisciplinary methods (e.g. eye-tracking, motion path analysis, identification of behaviour using inertial sensors, EEG, fMRI, candidate gene, and epigenetics) in both longitudinal and cross-sectional studies. We expect to reveal specific environmental risk factors which hasten ageing and also protective factors which may postpone it. We aim to provide objective criteria (behavioural, physiological and genetic biomarkers) to assess and predict the ageing trajectory for specific individual dogs. This would help veterinarians to recognise the symptoms early, and initiate necessary counter actions.

This approach establishes the framework for answering the broad question that how we can extend the healthy life of ageing dogs which indirectly also contributes to the welfare of the owner and decreases veterinary expenses. The detailed description of the ageing phenotype may also facilitate the use of dogs as a natural model for human senescence, including the development and application of pharmaceutical interventions.

We expect that our approach offers the scientific foundation to delay the onset of cognitive ageing in dog populations by 1-2 years, and also increase the proportion of dogs that enjoy healthy ageing.

Link to the ERC project webpage:
Keywords of the ERC project:
Keywords that characterize the scientific profile of the potential visiting researcher/s:
noMAGIC has the visionary goal of engineering genetically encoded ion channels, which can be remotely controlled (gated) by stimuli that penetrate deep into human tissue without negative side effects. The control over ion channel activity by deep penetrating stimuli will revolutionize research in neurobiology and physiology as it paves the way for remote and genuine non-invasive control of cell activity in vivo. Synthetic channels, which can be gated by magnetic fields (MF), near infrared (NIR) radiation or ultrasound (US) will be engineered in the frame of noMAGIC by three complementary work packages (WP1-3). Design and engineering of the channels will be performed in WP1 by reiterated steps of rational and irrational design, high throughput screening and in vitro and in vivo functional testing. We have identified two sensor modules for MF and NIR radiation, respectively, which will be functionally connected to a channel pore for a remote control of gating. For the US-gated channel we will engineer a channel pore that is maximally responding to local changes in the lipid environment induced by US. Design and engineering of channels will be complemented by a computational approach (WP2), which analyses, from elastic network models, the mechanical connections in the channel pore and which extracts information on the forces, which are required to gate a channel by the three stimuli. The outcome of WP2 will provide general design rules for synthetic channels with implications much beyond the present project. WP3 also contributes to the engineering effort in WP1 by a spectrum of avant-garde spectroscopic methods, which resolve structural changes of the channel proteins under the influence of remote stimuli. These structural insights will greatly advance our understanding of structure/function correlates in composite ion channels and it will inspire the design and engineering of channels, which respond to remote stimuli.
Exploring the Chemical Biology of Sequence Space via Picoliter Droplets

Directed evolution of functional proteins has arguably emerged as an approach to protein engineering that can complement or better design-led approaches to protein function. However, as a random process, enormous numbers of variants have to be screened and selected to have a chance to identify successful catalysts. This process is costly and cumbersome: Industrial screening facilities require investment of tens to hundred millions of dollars. My group has implemented key steps towards conducting quantitative biological experiments in a much cheaper format. Screening of individual library members in monodisperse oil-in-water compartments ('microdroplets') that are generated at kHz frequencies in microfluidic devices has been shown to be possible. The droplet compartment constitutes a link between a given phenotype and its encoding genotype, by capturing reaction product, and thus providing a unique system to screen for catalysis. In this way quantitative fitness landscapes for interconversion of members of enzyme superfamilies along the lines of catalytic promiscuity, understanding the factors governing specificity and the mechanistic interpretation of the observed evolutionary pathways can be made. We now apply this screening system of unprecedented capacity for directed evolution and metagenomic screening of enzymes in vivo and in vitro formats. We plan to apply this system to do experiments that would not be possible with conventional, lower throughput approaches: (i) screening of metagenomic libraries for rare and promiscuous activities that characterise environmental gene collections for their reactivity and potential for applied biocatalysis; (ii) developing a fundamental understanding of and strategic guidelines for enzyme evolution based on fitness landscapes that record data on multiple, promiscuous activities in response to Indel mutations; and (iii) evolution of gene networks to build up signalling networks in vitro.

Link to the ERC project webpage:

Keywords of the ERC project: microfluidics, chemical biology, protein engineering, enzymology, antibody engineering, metagenomics, enzyme mechanism, physical-organic chemistry, reaction mechanism, bioacatalysis, high-throughput screening

Keywords that characterize the scientific profile of the potential visiting researcher/s: microfluidics, chemical biology, protein engineering, enzymology, antibody engineering, metagenomics, enzyme mechanism, physical-organic chemistry, reaction mechanism, bioacatalysis, high-throughput screening
Nanoscale Stress Imaging with Imperfect Diamonds

My goal is to optically detect the magnetic resonance of free radicals/ROS inside cells. Radicals are suspected to play a crucial role in numerous pathogenic conditions including diseases responsible for most deaths worldwide (as arteriosclerosis, cancer, immune responses to pathogens). They are also involved in many processes in healthy cells as mitochondrial metabolism or aging of cells and part of the working mechanism of many drugs. Despite their relevance relatively little is known about where and when radicals are built, how they work or which ones play a role. Their short lifetime and reactivity poses a problem for many state of the art methods. Thus they are often a bottleneck in understanding stress responses. My goal is to develop a method, which can detect their magnetic resonance in the nanoscale. The method is based on a fluorescent defect in diamond, which changes its optical properties based on its magnetic surrounding. While this technique has been able to detect even the faint signal of a single electron spin, this technique is entirely new to biological fields. We can localize where, when and how much of a certain radical is generated with nm resolution. This is impossible with the current state of the art. Furthermore, since we obtain spectra we can also differentiate radicals to some extent. I am proposing to investigate two systems: 1) the involvement of radicals in the aging of yeast cells 2) the response of macrophages to stress. In the first project I will test the so-called free radical theory, which states that organisms age because cells accumulate free radical damage over time. In the second project I will answer the question how a macrophage reacts to the impact of a pathogen or a drug. Outcomes of this project would enable us to increase our understanding on how stress responses work on a molecular level. This will open up new possibilities to assess if and how drugs are working or how and why certain pathogens are worse than others.

Link to the ERC project webpage:

Keywords of the ERC project: diamond magnetometry; biological applications

Keywords that characterize the scientific profile of the potential visiting researcher/s:
B cells are one of the main players of immunity, responsible for the production of immunoglobulins (Igs). In 2011, I was granted an ERC Starting grant to undertake the phenotypical and functional characterization of teleost B lymphocytes based on the hypothesis that they do not behave as mammalian B2 cells (conventional B cells) but closely resemble mammalian innate B1 lymphocytes involved in extrafollicular T-independent (TI) responses. Since then, my laboratory has gathered considerable evidences that strengthen this hypothesis. These studies were mostly carried out in central lymphoid compartments, but did not address how teleost B1-like cells regulate the delicate balance between immunity and tolerance at mucosal interfaces, in species lacking follicular structures. In this new project, I want to pursue my studies on B lymphocyte functionality, focusing on how teleost mucosal B cells are regulated, still under the assumption that fish B lymphocytes resemble better a B1 model. We will study how fish B cells differentiate to antibody secreting cells (ASCs) and establish extrafollicular long-term memory, taking into account novel results in mammals that have challenged traditional paradigms and revealed that long-term immunological memory can be established through TI IgM B1-like responses. Furthermore, we will also study the role of IgD in the gills, as previous studies from my group suggest that this Ig plays a key role in the regulation of immunity in this specific mucosa, as it seems to do in humans in areas such as the upper respiratory tract.

Addressing how fish B cells mount a protective mucosal immune response in the absence of T cell help from organized follicles could provide new mechanistic insights into IgM and IgD responses emerging in humans. From a practical view, our work will contribute to understand why satisfactory mucosal vaccination is still an unreached goal for most diseases in both mammals and fish, despite their strong demand.

Link to the ERC project webpage:

Keywords of the ERC project: fish, B cells, Immunoglobulins, 725061

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Single-cell temporal tracking of epigenetic DNA marks

Over the past decade, epigenetic phenomena have taken centre stage in our understanding of gene regulation, cellular differentiation and human disease. DNA methylation is a prevalent epigenetic modification in mammals, which is brought about by enzymatic transfer of methyl groups from the S-adenosylmethionine (SAM) cofactor by three known DNA methyltransferases (DNMTs). The most dramatic epigenomic reprogramming in mammalian development occurs after fertilization, whereby a global loss of DNA methylation is followed by massive reinstatement of new methylation patterns, different for each cell type. Although DNA methylation has been extensively investigated, key mechanistic aspects of these fascinating events remain obscure. The goal of this proposal is to bridge the gap in our understanding of how the genomic methylation patterns are established and how they govern cell plasticity and variability during differentiation and development. These questions could only be answered by precise determination of where and when methylation marks are deposited by the individual DNMTs, and how these methylation marks affect gene expression. To achieve this ambitious goal, we will metabolically engineer mouse cells to permit SAM analog-based chemical pulse-tagging of their methylation sites in vivo. We will then advance profiling of DNA modifications to the single cell level via innovative integration of microdroplet-based barcoding, precise genomic mapping and super-resolution imaging. Using this unique experimental system we will determine, with unprecedented detail and throughput, the dynamics and variability of DNA methylation and gene expression patterns during differentiation of mouse embryonic cells to neural and other lineages. This project will give a comprehensive, time-resolved view of the roles that the DNMTs play in mammalian development, which will open new horizons in epigenomic research and will advance our understanding of human development and disease.

Link to the ERC project webpage:

Keywords of the ERC project: Metabolic engineering, DNA methyltransferases, epigenetic regulation, S-adenosylmethionine analogs

Keywords that characterize the scientific profile of the potential visiting researcher/s: Enzyme engineering, directed evolution
Global food security will remain a worldwide concern for the next 50 years and beyond. Agricultural production undergoes an increasing pressure by global anthropogenic changes, including rising population, increased protein demands and climatic extremes. Because of the immediate and dynamic nature of these changes, productivity monitoring measures are urgently needed to ensure both the stability and continued increase of the global food supply. Europe has expressed ambitions to keep its fingers on the pulse of its agricultural lands. In response to that, this proposal - named SENTIFLEX - is dedicated to developing a European vegetation productivity monitoring facility based on the synergy of Sentinel-3 (S3) with FLEX satellite fluorescence data. ESA's 8th Earth Explorer FLEX is the first mission specifically designed to globally measure Sun-Induced chlorophyll Fluorescence (SIF) emission from terrestrial vegetation. These two European Earth observation missions offer immense possibilities to increase our knowledge of the basic functioning of the Earth’s vegetation, i.e., the photosynthetic activity of plants resulting in carbon fixation. Two complementary approaches are envisioned to realize quantification of photosynthesis through satellite SIF and S3. First, the work seeks to advance the science in establishing and consolidating relationships between canopy-leaving SIF and unbiased estimates of photosynthesis of the plants, thereby disentangling the role of dynamic vegetative and atmospheric variables. Second, consolidated relationships between SIF and photosynthesis will be used to build a FLEX-S3 data processing assimilation scheme through process-based vegetation models that will deliver spatiotemporally highly resolved information on Europe’s vegetation productivity. To streamline all these datasets into a prototype vegetation productivity monitoring facility, new data processing concepts will be introduced such as the emulation of radiative transfer models.

Link to the ERC project webpage: https://ipl.uv.es/sentiflex/

Keywords of the ERC project: vegetation properties mapping, FLEX, Sentinel, Earth Observation, fluorescence, photosynthesis, productivity

Keywords that characterize the scientific profile of the potential visiting researcher/s: Programmer, Matlab, Python, remote sensing, data analyst, machine learning
Recent global warming is acting across ecosystems and threatening biodiversity. Yet, due to slow responses, many biological communities are lagging behind warming of the macroclimate (the climate of a large geographic region). The buffering of microclimates near the ground measured in localized areas, arising from terrain features such as vegetation and topography, can explain why many species are lagging behind macroclimate warming. However, almost all studies ignore the effects of microclimatic buffering and key uncertainties still exist about this mechanism. Microclimates are particularly evident in forests, where understorey habitats are buffered by overstorey trees. In temperate forests, the understorey contains the vast majority of plant diversity and plays an essential role in driving ecosystem processes.

The overall goal of FORMICA (FORest MICroclimate Assessment) is to quantify and understand the role of microclimatic buffering in modulating forest understorey plant responses to macroclimate warming. We will perform the best assessment to date of the effects of microclimates on plants by applying microtemperature loggers, experimental heating, fluorescent tubes and a large-scale transplant experiment in temperate forests across Europe. For the first time, plant data from the individual to ecosystem level will be related to microclimate along wide temperature gradients and forest management regimes. The empirical results will then be integrated in cutting-edge demographic distribution models to forecast plant diversity in temperate forests as macroclimate warms.

FORMICA will provide the first integrative study on microclimatic buffering of macroclimate warming in forests. Interdisciplinary concepts and methods will be applied, including from climatology, forestry and ecology. FORMICA will reshape our current understanding of the impacts of climate change on forests and help land managers and policy makers to develop urgently needed adaptation strategies.

Link to the ERC project webpage: www.formica.ugent.be

Keywords of the ERC project: climate change, forests, microclimate

Keywords that characterize the scientific profile of the potential visiting researcher/s: climate change, forests
Building biological computers from bacterial populations

Biosensors detect compounds using a biological component combined with a physio-chemical detector. Using synthetic biology, we can now engineer bacteria into whole-cell biosensors where sensing, transduction and output occur within the living cell. Applications include the detection of harmful environmental agents, bioprocess monitoring, and detecting medically relevant biomarkers. As we move towards more sophisticated applications, single channel read-out will be replaced with sensors that have multiple inputs and more complex information processing capabilities. Whilst digital logic within a single strain of bacteria can be implemented, consortia offer a powerful alternative, where information is integrated and processed in a distributed fashion. This proposal sets out a research project that will construct biological computers formed from engineered bacterial populations that communicate using quorum sensing molecules. Information from multiple biosensor inputs will be integrated and processed by the biocomputer, the output of which will be spatial patterning. The architecture will be based on cellular automata, which can perform any computation, including logic and temporal logic operations, memory and counting, all of which can be used to distinguish states in complex biological and chemical environments. Our biocomputers will be housed in microfluidic devices using hydrogel structures to create two and three dimensional regular arrangements. As a proof-of-concept, we will develop a biocomputer for the analysis and monitoring of intestinal and microbiota health through stool samples. Sensors for inflammation, pH and short chain fatty acids will be combined into a device that can indicate whether an individual has inflammatory bowel disease or irritable bowel syndrome. A low-cost device for use at home, which distinguishes between these conditions, could potentially save the global health care industry billions of dollars in unnecessary diagnostic treatments.

Link to the ERC project webpage:

Keywords of the ERC project: synthetic biology; biosensors; systems biology; biological computation

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Large protein complexes carry out some of the most complex functions in biology. Such structures are often assembled spontaneously from individual components through the process of self-assembly. If self-assembled protein complexes could be engineered from first principle it would enable a wide range of applications in biomedicine, nanotechnology and materials science. Recently, approaches to rationally design proteins to self-assembly into predefined structures have emerged. The highlight of this work is the design of protein cages that may be engineered into protein containers. However, current approaches for self-assembly design does not result in the assemblies with the required structural complexity to encode many of the sophisticated functions found in nature. To move forward, we have to learn how to engineer protein subunits with more than one designed interface that can assemble into tightly interacting complexes. In this proposal we propose a new protein design paradigm, shape directed protein design, in order to address shortcomings of the current methodology. The proposed method combines geometric shape matching and computational protein design. Using this approach we will de novo design assemblies with a wide variety of structural states, including protein complexes with cyclic and dihedral symmetry as well as icosahedral protein capsids built from novel protein building blocks. To enable these two design challenges we also develop a high-throughput assay to measure assembly stability in vivo that builds on a three-color fluorescent assay. This method will not only facilitate the screening of orders of magnitude more design constructs, but also enable the application of directed evolution to experimentally improve stable and assembly properties of designed containers as well as other designed assemblies.

Link to the ERC project webpage:

Keywords of the ERC project: Computational protein design, protein self-assembly

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Molecular machines based on coiled-coil protein origami

Proteins are the most versatile and complex smart nanomaterials, forming molecular machines and performing numerous functions from structure building, recognition, catalysis to locomotion. Nature however explored only a tiny fraction of possible protein sequences and structures. Design of proteins with new, in nature unseen shapes and features, offers high rewards for medicine, technology and science. In 2013 my group pioneered the design of a new type of modular coiled-coil protein origami (CCPO) folds. This type of de novo designed proteins are defined by the sequence of coiled-coil (CC) dimer-forming modules that are concatenated by flexible linkers into a single polypeptide chain that self-assembles into a polyhedral cage based on pairwise CC interactions. This is in contrast to naturally evolved proteins where their fold is defined by a compact hydrophobic core. We recently demonstrated the robustness of this strategy by the largest de novo designed single chain protein, construction of tetrahedral, pyramid, trigonal prism and bipyramid cages that self-assemble in vivo.

This proposal builds on unique advantages of CCPOs and represents a new frontier of this branch of protein design science. I propose to introduce functional domains into selected positions of CCPO cages, implement new types of building modules that will enable regulated CCPO assembly and disassembly, test new strategies of caging and release of cargo molecules for targeted delivery, design knotted and crosslinked protein cages and introduce toehold displacement for the regulated structural rearrangement of CCPOs required for designed molecular machines, which will be demonstrated on protein nanotweezers. Technology for the positional combinatorial library-based single pot assembly of CCPO genes will provide high throughput of CCPO variants. Project will result in new methodology, understanding of potentials of CCPOs for designed molecular machines and in demonstration of different applications.

Link to the ERC project webpage:

Keywords of the ERC project: protein design, synthetic biology, coiled coil protein origami, designed molecular machines, designed vaccines, cryoelectron microscopy,

Keywords that characterize the scientific profile of the potential visiting researcher/s: structural biology, molecular modeling, synthetic biology, biophysics, molecular biology, protein chemistry, bionanotechnology
In search of uniqueness - harnessing anatomical hand variation

H-unique will be the first multimodal automated interrogation of visible hand anatomy, through analysis and interpretation of human variation. It will be an interdisciplinary project, supported by anatomists, anthropologists, geneticists, bioinformaticians, image analysts and computer scientists. We will investigate inherent and acquired variation in search of uniqueness, as the hand retains and displays a multiplicity of anatomical variants formed by different aetiologies (genetics, development, environment, accident etc).

Hard biometrics, such as fingerprints, are well understood and some soft biometrics are gaining traction within both biometric and forensic domains (e.g. superficial vein pattern, skin crease pattern, morphometry, scars, tattoos and pigmentation pattern). A combinatorial approach of soft and hard biometrics has not been previously attempted from images of the hand. We will pioneer the development of new methods that will release the full extent of variation locked within the visible anatomy of the human hand and reconstruct its discriminatory profile as a retro-engineered multimodal biometric. A significant step change is required in the science to both reliably and repeatably extract and compare anatomical information from large numbers of images especially when the hand is not in a standard position or when either the resolution or lighting in the image is not ideal.

Large datasets are vital for this work to be legally admissible. Through citizen engagement with science, this research will collect images from over 5,000 participants, creating an active, open source, ground-truth dataset. It will examine and address the effects of variable image conditions on data extraction and will design algorithms that permit auto-pattern searching across large numbers of stored images of variable quality. This will provide a major novel breakthrough in the study of anatomical variation, with wide-ranging, interdisciplinary and transdisciplinary impact.

Link to the ERC project webpage: https://www.lancaster.ac.uk/scc/research/h-unique/

Keywords of the ERC project: Forensic anthropology, image analysis, machine learning, biometrics, computer science, mathematics, anatomy

Keywords that characterize the scientific profile of the potential visiting researcher/s: Biometrics, machine learning, forensics
Wanted: Micronutrients! Phytosiderophore-mediated acquisition strategies in grass crops

Understanding how plants respond to micronutrient deficiency and which biogeochemical processes are induced at the root-soil interface, i.e. the rhizosphere, is crucial to improve crop yield and micronutrient grain content for high quality food and feed. Iron nutrition by grass species relies on the release and re-uptake of phytosiderophores, which are root exudates that form stable complexes with Fe but also other trace metals such as Zn and Cu. However, neither the importance of phytosiderophores under Zn and Cu deficient conditions nor the interplay of plant responses and rhizosphere processes are well understood as the majority of studies in the past was carried out under ‘soil-free’ hydroponic conditions. In this project, I aim to elucidate the mechanisms controlling phytosiderophore-mediated micronutrient acquisition of barley (Hordeum vulgare) under Zn, Cu, and as reference, Fe deficient conditions, with particular emphasis on soil environments. Barley is the fifth most produced crop worldwide and of great importance in regions that are characterized by harsh living conditions. In a holistic approach, my team and I will apply innovative soil-based and traditional hydroponic root exudation sampling approaches in combination with advanced plant molecular techniques to study the phytosiderophore release and uptake system under different experimental conditions. The chemical synthesis of otherwise commercially unavailable phytosiderophores in their natural and 13C-labelled form will allow us to trace their decomposition and metal solubilizing efficiency in the plant-microbe-soil system to uncover the interplay of plant genetic responses and rhizosphere processes affecting the time-window of PS-mediated MN acquisition. Moving beyond ‘soil-free’ experimental designs of the past, this project will generate key knowledge to improve selection of crops with highly efficient micronutrient acquisition traits to alleviate micronutrient malnutrition of people world-wide.

Link to the ERC project webpage: https://forschung.boku.ac.at/fis/suchen.projekt_uebersicht?sprache_in=en&ansicht_in=&menue_id_in=300&i d_in=12821

Keywords of the ERC project: Soil; Barley (Hordeum vulgare); Micronutrient (Fe, Zn, Cu) deficiency; Phytosiderophores; Root exudates;

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Modern cellular life strictly depends on DNA as genetic material. However, a large body of evidence infers the existence of a previous, more primitive biology in which RNA also stored information in cellular entities. Recreating a living cellular fossil representing this transition from an ancient RNA world to modern DNA-based life would fundamentally advance our understanding of our biology’s history, and enable us to explore its biological properties experimentally. However, the reengineering of existing molecular systems into a viable doppelganger of the Last Universal Common Ancestor (LUCA) or one of its precursors is extremely challenging.

I propose to use a novel, combined top-down and bottom-up approach to create a modern-day doppelganger of LUCA by engineering bacterial hybrids with core cellular functions encoded on RNA. Using Darwinian Evolution as driver, my team and I will prototype and refine synthetic RNA-replicons through alternating replication in both cell-free and intracellular environments. This “dual evolution” approach will shape increasingly complex RNA networks capable of encoding complex genetic information. Following this, we will use these networks to create information-rich RNA chromosomes, enabling the transfer of essential genomic information from DNA to RNA. Finally, we will address this intergenomic transplantation by combining a novel RNA-delivery strategy with iterative rounds of genome deletion and complementation using state-of-the-art CRISPR-Cas9 assisted genome editing.

The proposed research will fundamentally advance synthetic biology, and could positively answer the transformative questions: Can we create, program and evolve life-like systems that can survive in both cell-free and intracellular environments? Can we use these entities to construct an alternative biology in which central cellular activities are encoded on genomes not made of DNA?

Link to the ERC project webpage:

Keywords of the ERC project: RNA replication, directed evolution, genome engineering, RNA nanotechnology

Keywords that characterize the scientific profile of the potential visiting researcher/s: microbiology, imaging, genome engineering
Overcoming plant graft incompatibility by modifying signalling and perception

For millennia, people have cut and joined together different plants through a process known as grafting. Plants tissues from different genotypes fuse, vasculature connects and a chimeric organism forms that combines desirable characteristics from different plants such as high yields or disease resistance. However, plants can only be grafted to closely related species and in some instances, they cannot be grafted to themselves. This phenomenon is referred to as graft incompatibility and the mechanistic basis is completely unknown. Our previous work on graft formation in Arabidopsis thaliana has uncovered genes that rapidly activate in grafted tissues to signal the presence of adjoining tissue and initiate a vascular reconnection process. These genes activate around the cut only during graft formation and present a powerful tool to screen large numbers of chemicals and genes that could promote tissue perception and vascular formation. With these sensors and our previously established grafting tools in the model plant Arabidopsis, we can address fundamental questions about grafting biology that have direct relevance to improving graft formation through:

1. Identifying genes required for the recognition response using forward and reverse genetic screens.
2. Determining and characterising signals that activate vascular induction using a chemical genetics screen.
3. Characterising the transcriptional basis for compatibility and incompatibility by analysing tissues and species that graft and comparing these to tissues and species that do not graft.
4. Overcoming graft incompatibility and improving graft formation by applying the knowledge obtained from the three previous objectives.

We thus aim to broaden our fundamental understanding of the processes associated with grafting including wound healing, vascular formation and tissue regeneration, while at the same time, use this information to improve graft formation and expand the range of grafted species.
Automated computational design of site-targeted repertoires of camelid antibodies

We propose to develop the first high-throughput strategy to design, synthesize, and screen repertoires comprising millions of single-domain camelid antibodies (VHH) that target desired protein surfaces. Each VHH will be individually designed for high stability and target-site affinity. We will leverage recent methods developed by our lab for designing stable, specific, and accurate backbones at interfaces, the advent of massive and affordable custom-DNA oligo synthesis, and machine learning methods to accomplish the following aims:

Aim 1: Establish a completely automated computational pipeline that uses Rosetta to design millions of VHHs targeting desired protein surfaces. The variable regions in each design will be encoded in DNA oligo pools, which will be assembled to generate the entire site-targeted repertoire. We will then use high-throughput binding screens followed by deep sequencing to characterize the designs’ target-site affinity and isolate high-affinity binders.

Aim 2: Develop an epitope-focusing strategy that designs several variants of a target antigen, each of which encodes dozens of radical surface mutations outside the target site to disrupt potential off-target site binding. The designs will be used to isolate site-targeting binders from repertoires of Aim 1. Each high-throughput screen will provide unprecedented experimental data on target-site affinity in millions of individually designed VHHs.

Aim 3: Use machine learning methods to infer combinations of molecular features that distinguish high-affinity binders from non binders. These will be encoded in subsequent designed repertoires, leading to a continuous “learning loop” of methods for high-affinity, site-targeted binding. AutoCAb’s interdisciplinary strategy will thus lead to deeper understanding of and new general methods for designing stable, high-affinity, site-targeted antibodies, potentially revolutionizing binder and inhibitor discovery in basic and applied biomedical research.

Link to the ERC project webpage: https://erc.europa.eu/projects-figures/erc-funded-projects/results?f%5B0%5D=funding_scheme%3AConsolidator%20Grant%20%20CoG%29&page=10

Keywords of the ERC project: Antibody design; Rosetta; camelid antibodies; machine learning

Keywords that characterize the scientific profile of the potential visiting researcher/s: Experience in programming and practical methods in protein biochemistry
A unified drug discovery platform for protein misfolding diseases

It is now widely recognized that a variety of major diseases, such as Alzheimer’s disease, Huntington’s disease, systemic amyloidosis, cystic fibrosis, type 2 diabetes etc., are characterized by a common molecular origin: the misfolding of specific proteins. These disorders have been termed protein misfolding diseases (PMDs) and the vast majority of them remain incurable. Here, I propose the development of a unified approach for the discovery of potential therapeutics against PMDs. I will generate engineered bacterial cells that function as a broadly applicable discovery platform for compounds that rescue the misfolding of PMD-associated proteins (MisPs). These compounds will be selected from libraries of drug-like molecules biosynthesized in engineered bacteria using a technology that allows the facile production of billions of different test molecules. These libraries will then be screened in the same bacterial cells that produce them and the rare molecules that rescue MisP misfolding effectively will be selected using an ultrahigh-throughput genetic screen. The effect of the selected compounds on MisP folding will then be evaluated by biochemical and biophysical methods, while their ability to inhibit MisP-induced pathogenicity will be tested in appropriate mammalian cell assays and in established animal models of the associated PMD. The molecules that rescue the misfolding of the target MisPs and antagonize their associated pathogenicity both in vitro and in vivo, will become drug candidates against the corresponding diseases. This procedure will be applied for different MisPs to identify potential therapeutics for four major PMDs: Huntington’s disease, cardiotoxic light chain amyloidosis, dialysis-related amyloidosis and retinitis pigmentosa. Successful realization of ProMiDis will provide invaluable therapeutic leads against major diseases and a unified framework for anti-PMD drug discovery.

Link to the ERC project webpage:

Keywords of the ERC project: protein misfolding and aggregation, protein misfolding diseases, molecular evolution, combinatorial libraries, high-throughput screening, early-stage drug discovery, engineered microorganisms, synthetic biology

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Knowledge based design of complex synthetic microbial communities for plant protection

Complex microbial communities ("microbiota") that populate surfaces of higher organisms critically impact health of their hosts: They contribute to vital functions such as host fitness, nutrient acquisition, stress tolerance and pathogen resistance but are, at the same time, reservoirs for facultative pathogens or can promote pathogenesis. How and why communities shift from a beneficial to a detrimental state is largely unknown and we are far from utilizing identified mechanisms.

In order to cure detrimental microbiota, that were damaged or reverted through stress factors including previous diseases, decoding the complex processes governing microbiota dynamics is a key challenge. To develop durable probiotics, communal stability or the ability of a community to return to a steady state following perturbation is a key factor.

Our lab has broad expertise in studying microbial communities through lab experiments and analyzing factors that shape the microbiota of Arabidopsis thaliana plants under natural conditions and common garden experiments. We have discovered a hierarchical order in microbial community networks with hub microbes as key elements. A recent breakthrough was the discovery of microbial taxa that persist throughout the life of A. thaliana plants and their importance in network stability.

In this project we will use our expertise to identify key stability factors and drivers of communal dynamics to reconstitute synthetic communities. How to seed microbial communities that develop into functional probiotics is a key challenge. We will use knowledge based assembly of complex communities to seeds protective microbiota. We will challenge those through pathogens and abiotic factors to refine and test the predictive power of our analyses. Therefore, DeCoCt represents a highly innovative approach that holds the potential to gain novel insights beyond the current scope of microbiota and probiotics research.


Keywords of the ERC project: microbial communities, community structure, probiotics, plant, synthetic microbial communities

Keywords that characterize the scientific profile of the potential visiting researcher/s: microbiology, computational biolog
Snakebite envenoming is a Neglected Tropical Disease (NTD) that each year affects 2.5 million victims and kills >100,000, unless they are treated with antivenom. Conventional antivenoms, derived from immunized animals, inflict serum sickness and anaphylaxis in patients, and are costly to manufacture. Monoclonal human antibodies with special toxin-binding properties that are sensitive towards regulation by their microenvironment (e.g. pH), which may be discovered using phage display selection, may solve this issue, providing significant societal impact by enabling the development of cost-effective antivenoms to victims in low and middle-income countries. In this project, phage display selection, high-density peptide microarray technology, and antibody engineering techniques will in three scientific objectives be harnessed in the pursuit of developing novel methodologies for discovery of therapeutic human monoclonal antibodies that are recyclable (can neutralize more than one snake toxin per antibody), broadly cross-reactive (can neutralize different types of snake toxins), and that are both broadly cross-reactive and recyclable at the same time. This will open up for entirely new ways of designing biotherapeutics against complex indications, such snakebite envenoming, but also cancer, infectious, and parasitic diseases, where the targets can be elusive due to hyper-mutability. The ERC Starting Grant offers a unique opportunity to consolidate me as an international key scientific researcher in this field of antibody discovery and NTDs. I have already independently led a research group in this area for 2 years, I have in-depth experience with toxin-targeted antibody discovery (my dr.tech dissertation similar to the German “habilitation” will be submitted during fall 2018), and I am already involved in high level policy in the field of snakebite envenoming via my role as a scientific advisor for the World Health Organization.

Link to the ERC project webpage: http://tropicalpharmacology.com

Keywords of the ERC project: Antibody discovery; phage display; biotherapeutics; toxinology; antivenom; protein engineering; synthetic biology; antibody technologies; antibodies

Keywords that characterize the scientific profile of the potential visiting researcher/s: Antibody discovery; phage display; biotherapeutics; protein engineering; synthetic biology; antibody technologies; antibodies; molecular biology; genetic engineering; structural biology; bioinformatics; high-throughput technology; microbiology; drug disco
Currently a big concern of our aging society is to efficiently delay the onset of neurodegenerative diseases which are progressively rising in incidence. The paradigm that a diet rich in the phenolics, prevalent e.g. in fruits, is beneficial to brain health has reached the public. However their mechanistic actions in brain functions remain to be seen, particularly since the nature of those acting in the brain remains overlooked. I wish to address this gap by identifying candidate compounds that can support development of effective strategies to delay neurodegeneration.

Specifically, I will be analysing the potential of dietary phenolics in both prevention and treatment (i.e delay) of neuroinflammation – key process shared in neurodegenerative diseases. To break down the current indeterminate status of “cause vs effect”, my vision is to focus my research on metabolites derived from dietary phenolics that reach the brain. I will be investigating their effects in both established and unknown response pathways of microglia cells - the innate immune cells of the central nervous system, either alone or when communicating with other brain cells. Ultimately, to attain an integrated view of their effects I will establish nutrition trials in mice. LIMBo considers both pro- and anti-inflammatory processes to preliminary validate the action of any promising metabolite in prevention and/or therapeutics.

LIMBo provides valuable scientific insights for future implementation of healthy brain diets. My group is in a unique position to address LIMBo objectives due to multidisciplinary expertise in organic synthesis, metabolomics and molecular and cellular biology, together with our previous data on novel neuroactive metabolites.

LIMBo also creates far-reaching opportunities by generating knowledge that impacts our fundamental understanding on the diversity of phenolic metabolites and their specific influences in neuroinflammation and potential use as prodrugs.

**Key terms:**
- polyphenols metabolism
- neurodegeneration
- microglia
- brain

**Keywords that characterize the scientific profile of the potential visiting researcher(s):**
Integrating a novel layer of synthetic biology tools in Pseudomonas, inspired by bacterial viruses

As nature’s first bioengineers, bacteriophages have evolved to modify, adapt and control their bacterial hosts through billions of years of interactions. Indeed, like modern synthetic biologists aspire to do, bacteriophages already evade bacterial silencing of their xenogeneic DNA, subvert host gene expression, and co-opt both the central and peripheral metabolisms of their hosts. Studying these key insights from a molecular systems biology perspective, inspired us to develop these evolutionary fully-adapted phage mechanisms as a next-level layer of synthetic biology tools. Thus, BIONICbacteria will provide conceptual novel synthetic biology tools that allow direct manipulation of specific protein activity, post-translational modifications, RNA stability, and metabolite concentrations.

The goal of BIONICbacteria is to pioneer an unconventional way to perform synthetic biology, tapping an unlimited source of novel phage tools genetic circuits and phage modulators. To achieve these goals, we will apply and develop state-of-the-art technologies in molecular microbiology and focus on three principal aims:

(1) To exploit new phage-encoded genetic circuits as synthetic biology parts and as intricate biotechnological chassis.

(2) To build synthetic phage modulators (SPMs) as novel payloads to directly impact the bacterial metabolism in a targeted manner.

(3) To create designer bacteria by integrating SPMs-containing circuits into bacterial strains as proof-of-concepts for applications in industrial fermentations and vaccine design.

This proposed “plug-in” approach of evolutionary-adapted synthetic modules, will allow us to domesticate Pseudomonas strains in radically new ways. By building proofs-of-concept for applications in industrial fermentations and vaccine development, we address key problem in these areas with potentially high-gain solutions for society and industry.

Link to the ERC project webpage: https://www.biw.kuleuven.be/biosyst/a2h/LoGT/projects/

Keywords of the ERC project: microbial synthetic biology, bacteriophage, Pseudomonas

Keywords that characterize the scientific profile of the potential visiting researcher/s: systems biology, molecular microbiology, biotechnology
Artificial metabolic cells for biomanufacturing of bio-based chiral fine chemicals

One of the major challenges of sustainable chemistry is expanding the palette of bio-based chemicals that can replace, or at least ameliorate, the exploitation of fuel-based chemicals. Cell-free metabolic engineering using soluble enzymes is an emerging and versatile approach that seeks to increase the selectivity and productivity of chemical biomanufacturing processes. However, soluble and isolated enzymes present major issues in terms of efficiency, stability and re-usability that hamper industrial applications.

To solve these problems, enzymes can be rationally immobilized on smart materials resulting in robust, efficient and self-sufficient heterogeneous biocatalysts, but immobilization is still restricted to simple enzyme cascades. METACELL mission is developing self-sufficient artificial metabolic cells (AMCs) by immobilizing complex metabolic networks on hierarchical porous materials. To this aim, the solid surfaces must play an active role in the chemical process rather than just being a mere immobilization support.

This integrative proposal will exploit protein engineering, surface chemistry, bio-organic chemistry and protein immobilization tools for the successful development of 1) a cell-free artificial metabolism, 2) innovative engineering tools to modify both enzyme and material surfaces and 3) continuous synthesis of industrially relevant fine chemicals catalyzed by AMCs packed into flow reactors. The resulting technology of METACELL will serve as a prototyping platform to test artificial biosynthetic pathways with application in combinatorial chemistry (e.g. drugs discovery). METACELL may also offer long-term solutions for the on-demand production of drugs at the point-of-care.

In addition to the technological outputs, METACELL will also provide essential information to understand how spatial organization of multi-enzyme systems affect the performance of in vitro biosynthetic pathways confined into artificial chassis (solid materials).

Link to the ERC project webpage:

Keywords of the ERC project:

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Combinatorics with an analytic structure

Combinatorics, and its interplay with geometry, has fascinated our ancestors as shown by early stone carvings in the Neolithic period. Modern combinatorics is motivated by the ubiquity of its structures in both pure and applied mathematics.

The work of Hochster and Stanley, who realized the relation of enumerative questions to commutative algebra and toric geometry made a vital contribution to the development of this subject. Their work was a central contribution to the classification of face numbers of simple polytopes, and the initial success lead to a wealth of research in which combinatorial problems were translated to algebra and geometry and then solved using deep results such as Saito's hard Lefschetz theorem. As a caveat, this also made branches of combinatorics reliant on algebra and geometry to provide new ideas.

In this proposal, I want to reverse this approach and extend our understanding of geometry and algebra guided by combinatorial methods. In this spirit I propose new combinatorial approaches to the interplay of curvature and topology, to isoperimetry, geometric analysis, and intersection theory, to name a few. In addition, while these subjects are interesting by themselves, they are also designed to advance classical topics, for example, the diameter of polyhedra (as in the Hirsch conjecture), arrangement theory (and the study of arrangement complements), Hodge theory (as in Grothendieck's standard conjectures), and realization problems of discrete objects (as in Connes embedding problem for type II factors).

This proposal is supported by the review of some already developed tools, such as relative Stanley--Reisner theory (which is equipped to deal with combinatorial isoperimetries), combinatorial Hodge theory (which extends the "K"ahler package" to purely combinatorial settings), and discrete PDEs (which were used to construct counterexamples to old problems in discrete geometry).

Link to the ERC project webpage:

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Computation and analysis of statistical solutions of fluid flow

Entropy (admissible) weak solutions are widely considered to be the standard solution framework for hyperbolic systems of conservation laws and incompressible Euler equations. However, the lack of global existence results in several space dimensions, the recent demonstration of non-uniqueness of these solutions and computations showing the lack of convergence of state of the art numerical methods to them, have reinforced the need to seek alternative solution paradigms.

Although one can show that numerical approximations of these nonlinear PDEs converge to measure-valued solutions i.e Young measures, these solutions are not unique and we need to constrain them further. Statistical solutions i.e, time-parametrized probability measures on spaces of integrable functions, are a promising framework in this regard as they can be characterized as a measure-valued solution that also contains information about all possible multi-point spatial correlations. So far, well-posedness of statistical solutions has been shown only in the case of scalar conservation laws.

The main aim of the proposed project is to analyze statistical solutions of systems of conservation laws and incompressible Euler equations and to design efficient numerical approximations for them. We aim to prove global existence of statistical solutions in several space dimensions, by showing convergence of these numerical approximations, and to identify suitable additional admissibility criteria for statistical solutions that can ensure uniqueness. We will use these numerical methods to compute statistical quantities of interest and relate them to existing theories (and observations) for unstable and turbulent fluid flows. Successful completion of this project aims to establish statistical solutions as the appropriate solution paradigm for inviscid fluid flows, even for deterministic initial data, and will pave the way for applications to astrophysics, climate science and uncertainty quantification.

Link to the ERC project webpage:

**Keywords of the ERC project:** Fluid flows, Statistical solutions, computation, uncertainty quantification, turbulence, machine learning.

**Keywords that characterize the scientific profile of the potential visiting researcher/s:** Fluid dynamics, computation, UQ, Machine learning, Turbulence
Inverse boundary problems: toward a unified theory

This proposal is concerned with the mathematical theory of inverse problems. This is a vibrant research field at the intersection of pure and applied mathematics, drawing techniques from PDE, geometry, and harmonic analysis as well as generating new research questions inspired by applications. Prominent questions include the Calderón problem related to electrical imaging, the Gel’fand problem related to seismic imaging, and geometric inverse problems such as inversion of the geodesic X-ray transform.

Recently, exciting new connections between these different topics have begun to emerge in the work of the PI and others, such as
- the explicit appearance of the geodesic X-ray transform in the Calderón problem
- an unexpected connection between the Calderón and Gel’fand problems involving control theory
- pseudo-linearization as a potential unifying principle for reducing nonlinear problems to linear ones
- the introduction of microlocal normal forms in inverse problems for PDE

These examples strongly suggest that there is a larger picture behind various different inverse problems, which remains to be fully revealed.

This project will explore the possibility of a unified theory for several inverse boundary problems. Particular objectives include:
1. The use of normal forms and pseudo-linearization as a unified point of view, including reductions to questions in integral geometry and control theory
2. The solution of integral geometry problems, including the analysis of convex foliations, invertibility of ray transforms, and a systematic Carleman estimate approach to uniqueness results
3. A theory of inverse problems for nonlocal models based on control theory arguments

Such a unified theory could have remarkable consequences even in other fields of mathematics, including controllability methods in transport theory, a solution of the boundary rigidity problem in geometry, or a general pseudo-linearization approach for solving nonlinear operator equations.

Link to the ERC project webpage:

Keywords of the ERC project: Inverse problems, microlocal analysis, partial differential equations, integral geometry, X-ray transforms

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Loops and groups: Geodesics, moduli spaces, and infinite discrete groups via string topology and homological stability

This proposal lies at the intersection of algebra, topology, and geometry, with the scientific goal of answering central questions about homological stability, geodesics on manifolds, and the moduli space of Riemann surfaces. Homological stability is a subject that has seen spectacular progress in recent years, and recent work of the PI has opened up new perspectives on this field, through, among other things, associating a canonical family of spaces to any stability problem. The first two goals of the proposal are to give conditions under which this family of spaces is highly connected, and to use this to prove homological and representation stability theorems, with determination of the stable homology. Particular attention is given to Thompson-like groups, building on a recent breakthrough of the PI with Szymik. The last two goals concern geodesics and moduli spaces via string topology: The third goal seeks a geometric construction of compactified string topology, which we propose to use to address counting problems for geodesics on manifolds. Finally our fourth goal is to use compactified string topology to study the harmonic compactification itself, and give a new approach to finding families of unstable homology classes in the moduli space of Riemann surfaces. The feasibility of the last goals is demonstrated by the PIs earlier algebraic work in this direction; the proposal is to incorporate geometry in a much more fundamental way.

The project combines breakthrough methods from homotopy theory with methods from algebraic, differential and geometric topology. Some of the goals are high risk, but we note that in those cases even partial results will be of significant interest. The PI has a proven track record at the international forefront of research, and as a research leader, e.g., through a previous ERC Starting Grant. The research team will consist of the PI together with 3 PhD students and 3 postdocs in total during the 5 years.

Link to the ERC project webpage:

Keywords of the ERC project:

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Non-local dynamics in incompressible fluids

The goal of this project is to pursue new methods in the mathematical analysis of non-local and non-linear partial differential equations. For this purpose we present several physical scenarios of interest in the context of incompressible fluids, from a mathematical point of view as well as for its applications: both from the standpoint of global well-posedness, existence and uniqueness of weak solutions and as candidates for blowup. The equations we consider are the incompressible Euler equations, incompressible porous media equation and the generalized Quasi-geostrophic equation. This research will lead to a deeper understanding of the nature of the set of initial data that develops finite time singularities as well as those solutions that exist for all time for incompressible flows.

Link to the ERC project webpage:

Keywords of the ERC project:

Keywords that characterize the scientific profile of the potential visiting researcher/s:
We will establish stability conditions and wall-crossing in derived categories as a standard methodology for a wide range of fundamental problems in algebraic geometry. Previous work based on wall-crossing, in particular my joint work with Macri, has led to breakthroughs on the birational geometry of moduli spaces and related varieties. Recent advances have made clear that the power of stability conditions extends far beyond this setting, allowing us to study vanishing theorems or bounds on global sections, Brill-Noether problems, or moduli spaces of varieties.

The Brill-Noether problem is one of the oldest and most fundamental questions of algebraic geometry, aiming to classify possible degrees and embedding dimensions of embeddings of a given variety into projective spaces. Recent work by myself, a post-doc (Chunyi Li) and a PhD student (Feyzbakhsh) of mine has established wall-crossing as a powerful new method for such questions. We will push this method further, all the way towards a proof of Green's conjecture, and the Green-Lazarsfeld conjecture, for all smooth curves.

We will use similar methods to prove new Bogomolov-Gieseker type inequalities for Chern classes of stable sheaves and complexes on higher-dimensional varieties. In addition to constructing stability conditions on projective threefolds—the biggest open problem within the theory of stability conditions, we will apply them to study moduli spaces of sheaves on higher-dimensional varieties, and to characterise special abelian varieties.

We will use the construction of stability conditions for families of varieties in my current joint work to systematically study the geometry of Fano threefolds and fourfolds, in particular their moduli spaces, by establishing relations between different moduli spaces, and describing their Torelli maps. Finally, we will study rationality questions, with a particular view towards a wall-crossing proof of the irrationality of the very general cubic fourfold.

**Keywords of the ERC project:** Algebraic geometry, stability conditions, wall-crossing, Brill-Noether

**Keywords that characterize the scientific profile of the potential visiting researcher/s:**
Quadratic refinements in algebraic geometry

Enumerative geometry, the mathematics of counting numbers of solutions to geometric problems, and its modern descendents, Gromov-Witten theory, Donaldson-Thomas theory, quantum cohomology and many other related fields, analyze geometric problems by computing numerical invariants, such as intersection numbers or degrees of characteristic classes. This essentially algebraic approach has been successful mainly in the study of problems over the complex numbers and other algebraically closed fields. There has been progress in attacking enumerative problems over the real numbers; the methods are mainly non-algebraic. Arithmetic content underlying the numerical invariants is hidden when analyzed by these non-algebraic methods. Recent work by the PI and others has opened the door to a new, purely algebraic approach to enumerative geometry that recovers results in both the complex and real cases in one package and reveals this arithmetic content over arbitrary fields. Building on these new developments, the goals of this proposal are, firstly, to use motivic homotopy theory, algebraic geometry and symplectic geometry to develop new purely algebraic methods for handling enumerative problems over an arbitrary field, secondly, to apply these methods to central enumerative problems, recovering and unifying known results over both C and R and thirdly, to use this new approach to reveal the hidden arithmetic nature of enumerative problems. In 2009 R. Pandharipande and I applied algebraic cobordism to prove the degree zero MNOP conjecture in Donaldson-Thomas theory. More recently, I have developed several aspects of the theory of quadratic invariants using motivic homotopy theory.

Keywords of the ERC project:
motivic homotopy theory, Gromov-Witten theory, enumerative geometry, quadratic forms, real enumerative geometry, tropical enumerative geometry

Keywords that characterize the scientific profile of the potential visiting researcher/s:
expertise in: algebraic geometry, Gromov-Witten theory, motivic homotopy theory, enumerative geometry, real enumerative geometry,
Fibring of manifolds and groups

The study of manifolds that fibre over the circle has a long and exciting history at the core of modern manifold topology, starting with Farrell's work on the problem in high ('surgery') dimensions, and running through the celebrated work of Stallings and Thurston in dimension 3, to Agol's 2013 solution of Thurston's virtual fibring conjecture. Parallel developments in group theory have placed the study of Bieri-Neumann-Strebel (BNS) invariants, which emerged in the 1980s, at the heart of the subject; these invariants describe when a group fibres, i.e. admits a map onto Z with finitely generated kernel. In the research outlined here a powerful new set of algebraic invariants - agrarian polytopes - will be used to establish a new frontier in the theory of fibring. The main goal is to achieve a complete description of all possible fibrings over the circle for aspherical manifolds in surgery dimensions.

An agrarian polytope is a subset of the vector space $H_1(X;\mathbb{R})$, where $X$ is a group or a manifold. It is defined in the novel framework of agrarian invariants that I am developing, a theory that has already borne remarkable fruit. The theory provides algebraic counterparts to the (analytic) $L^2$-invariants that have proved so powerful in geometric topology, group theory and global analysis over the last four decades.

The primary focus of the research proposed here lies in establishing new deep connections between the algebra of group rings and their completions, and global properties of aspherical manifolds and groups. Three further goals of the proposal are: to develop the theory of agrarian invariants in positive characteristic; to show that agrarian invariants are profinitely rigid; to apply the new technology to the study of dynamical zeta functions. Each of these goals promises a breakthrough in its respective domain.

Link to the ERC project webpage:

Keywords of the ERC project: Fibring of manifolds over the circle, algebraic fibring of groups over the integers

Keywords that characterize the scientific profile of the potential visiting researcher/s:
From Open to Closed Loop Optimal Control of PDEs

The proposal addresses some of the most pressing topics in optimal control of partial differential equations (PDEs): Non-smooth, non-convex optimal control and computational techniques for feedback control. These two topics will be applied to the large scale optimal control problems for the bidomain equations, which are the established model to describe the electrical activity of the heart. Due to their rich dynamical systems behavior these systems are particularly challenging.

The use of non-smooth functionals is of great practical relevance in many diverse situations. They promote sparsity, and provide a perfect formulation for switching and multi-bang controls, and for the optimal actuator location problem. For inverse problems the case $L^p$ with $p \in (0,1)$ is of special statistical importance, and $L^0$ can be the basis of a new formulation for topology optimization problems. But lack of Lipschitz continuity and of convexity are significant obstacles which can only be overcome by the development of new analytical and numerical concepts. The new algorithmic concepts will also be applicable to important non-smooth problems in continuum mechanics, as for instance the quasi-static evolution of fractures.

Closed loop control is of paramount importance due to its robustness against system perturbations. Nevertheless, numerical realization of optimal feedback strategies for nonlinear PDEs has barely been touched since the curse of dimensionality makes direct numerical treatment of the Hamilton-Jacobi-Bellman equation unfeasible. We shall therefore develop and analyze suboptimal strategies based on model reduction and interpolation techniques, and on model-predictive control. The availability of boundary and near-to-the-boundary measurements together with dynamic observer techniques will allow to test the proposed methods to obtain suboptimal feedback controls for the bidomain equations.

Link to the ERC project webpage:

Keywords of the ERC project: optimal control, continuous optimization, partial differential equations,

Keywords that characterize the scientific profile of the potential visiting researcher/s:
The giant impact and the Earth and Moon formation

Very little is understood of the physics governing the Giant Impact and the subsequent formation of the Moon. According to this model an impactor hit the proto-Earth; the resulting energy was enough to melt and partially vaporize the two bodies generating a large protolunar disk, from which the Earth-Moon couple formed. Hydrodynamic simulations of the impact and the subsequent evolution of the protolunar disk are currently based on models of equations of state and phase diagrams that are unconstrained by experiments or calculations. Estimates of the positions of critical points, when available at all, vary by one order of magnitude in both temperature and density. Here we propose to compute the thermodynamics of the major rock-forming minerals and rock aggregates, and use it to study the formation and evolution of the protolunar disk. For this we employ a unique combination of atomistic state-of-the-art ab initio simulations. We use large-scale density-functional theory (DFT) molecular dynamics to study bulk fluids, coupled with Green functions (GW) and time-dependent DFT techniques to analyze atomic clusters and molecular species. We compute the vaporization curves, position the supercritical points, and characterize the sub-critical and supercritical regimes. We construct equations of state of the rocks at the conditions of the giant impact that are beyond current experimental capabilities. We employ a multiscale approach to bridge the gap between atomic, geological sample, and planetary scales via thermodynamics; we simulate the thermal profile through the disk, the ratio between liquid and vapor, and the speciation. From speciation we predict elemental and isotopic partitioning during condensation. Plausible impact scenarios, features of the impactor and of the proto-Earth will be constrained with a feedback loop, until convergence between predictions of final Earth-Moon compositions and observations is reached.

Link to the ERC project webpage: http://moonimpact.eu/

Keywords of the ERC project: liquids, molecular-dynamics, first-principles simulations

Keywords that characterize the scientific profile of the potential visiting researcher/s: statistical physics, liquids, shock experiments, planetology
Simulating Non-Equilibrium Dynamics of Atmospheric Multicomponent Clusters

Atmospheric aerosol particles play a key role in regulating the climate, and particulate matter is responsible for most of the 7 million deaths per year attributed to air pollution. Lack of understanding of aerosol processes, especially the formation of ice crystals and secondary particles from condensable trace gases, hampers the development of air quality modelling, and remains one of the major uncertainties in predicting climate.

The purpose of this project is to achieve a comprehensive understanding of atmospheric nanocluster and ice crystal formation based on fundamental physico-chemical principles. We will use a wide palette of theoretical methods including quantum chemistry, reaction kinetics, continuum solvent models, molecular dynamics, Monte Carlo simulations, Markov chain Monte Carlo methods, computational fluid dynamics, cluster kinetic and thermodynamic models. We will study non-equilibrium effects and kinetic barriers in atmospheric clustering, and use these to build cluster distribution models with genuine predictive capacity.

Chemical ionization mass spectrometers can, unlike any other instruments, detect the elemental composition of many of the smallest clusters at ambient low concentrations. However, the charging process and the environment inside the instrument change the composition of the clusters in hitherto unquantifiable ways. We will solve this problem by building an accurate model for the fate of clusters inside mass spectrometers, which will vastly improve the amount and quality of information that can be extracted from mass spectrometric measurements in atmospheric science and elsewhere.

DAMOCLES will produce reliable and consistent models for secondary aerosol and ice particle formation and growth. This will lead to improved predictions of aerosol concentrations and size distributions, leading to improved air quality forecasting, more accurate estimates of aerosol indirect climate forcing and other aerosol-cloud-climate interactions.

Link to the ERC project webpage: https://wiki.helsinki.fi/display/SimuWiki

Keywords of the ERC project:

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Subduction of one tectonic plate below another is the primary cause of catastrophic geological events such as earthquakes and explosive volcanism that directly impact thousands of kilometers of coastal and mountain areas located on convergent margins. Real-time geophysical or seismic data only provide static snapshots of these subduction zones today. Therefore, quantitative understanding of the rates and true depths of subduction can only be achieved by determining the pressure-temperature-time-depth histories of Ultra-High-Pressure Metamorphic (UHPM) rocks that have been subducted to pressures greater than 3 GPa and subsequently exhumed. Conventional mineral thermo-barometry is severely challenged in UHPM terrains and thus the mechanisms attending the downwards transport of crustal material, and its return back to the Earth’s surface (exhumation), are still a matter of vigorous debate.

The TRUE DEPTHS project will develop X-ray diffraction analysis of the anisotropic elastic interactions of inclusion minerals trapped inside host minerals. I will develop non-linear elasticity theory to provide a method that will be uniquely able to determine whether significant deviatoric stresses are recorded by UHPM rocks. By applying this method to samples from carefully selected field areas, I will be able to determine if metamorphic phase equilibria represent the true depths of UHPM, in which case subduction to depths in excess of 90 km must occur. Alternatively, quantitative measurements of large deviatoric stresses could indicate that tectonic over-pressure can account for the observed phase equilibria, thus not requiring deep subduction. If overpressurized domains are present in tectonically thickened lithosphere, they may represent a driving force for stress release leading to earthquakes. The results will provide new constraints on earthquake triggering mechanisms and how the styles of subduction and its detailed mechanisms have evolved over Earth’s history.
The amount of plastic in our ocean is exponentially growing, with recent estimates of more than 5 million metric tonnes of plastic reaching the ocean each year. This plastic infiltrates the ocean food chain and thus poses a major threat to marine life. However, understanding of plastic movement and its budget in the ocean is inadequate to fully establish its environmental impact, prompting the EU and G7 to recently make marine litter a top science priority.

It is now recognised that the amount of plastic entering our ocean is several orders of magnitude larger than the estimates of floating plastic on the surface of the ocean. More than 99% of plastic within our ocean is therefore ‘missing’.

This project will make breakthroughs towards closing the plastic budget by creating a novel comprehensive modelling framework that tracks plastic movement through the ocean. Building on well-established previous work to follow generic water parcels through hydrodynamic ocean models, this project will modify these ‘virtual’ parcels to represent pieces of plastic by, for the first time, simulating fragmentation, sinking, beaching, wave-mixing and ingestion by biota. The new parameterisations that underpin this modelling will be based on field data and new coastal flume wave tank lab experiments. The simulated plastic particles will be tracked within state-of-the-art hydrodynamic ocean models, in order to compute maps of pathways and transports around our oceans and on coastlines and in biota. This numerical modelling will be used to evaluate a broad suite of scenarios and test hypotheses, including where the risk to marine biota is greatest.

The results from this project will inform policymakers and the public on which countries, for example, are responsible for which part of the plastic problem, crucial for mitigation and legal frameworks. It will also inform engineers on where and how to best invest resources in mitigating the problem of plastic in our ocean.

**Link to the ERC project webpage:** http://topios.org/

**Keywords of the ERC project:** marine plastic litter, ocean circulation

**Keywords that characterize the scientific profile of the potential visiting researcher/s:** ocean modelling, physical oceanography
We are changing the composition of Earth’s atmosphere, with profound consequences for the environment and our wellbeing. Tiny aerosol particles are globally responsible for much of the health effects and mortality related to air pollution and play key roles in regulating Earth’s climate via their critical influence on both radiation balance and cloud formation. Every single cloud droplet has been nucleated on the surface of an aerosol particle. Aerosols and droplets provide the media for condensed-phase chemistry in the atmosphere, but large gaps remain in our understanding of their formation, transformations, and climate interactions. Surface properties may play crucial roles in these processes, but currently next to nothing is known about the surfaces of atmospheric aerosols and cloud droplets and their impacts are almost entirely unconstrained. My recent work strongly suggests that such surfaces are significantly different from their associated bulk material and that these unique properties can impact aerosol processes all the way to the global scale. Very few surface-specific properties are currently considered when evaluating aerosol effects on atmospheric chemistry and global climate. Novel developments of cutting-edge computational and experimental methods, in particular synchrotron-based photoelectron spectroscopy, now for the first time makes direct molecular-level characterizations of atmospheric surfaces feasible. This project will demonstrate and quantify potential surface impacts in the atmosphere, by first directly characterizing realistic atmospheric surfaces, and then trace fingerprints of specific surface properties in a hierarchy of experimental and modelled aerosol processes and atmospheric effects. Successful demonstrations of unique aerosol surface fingerprints will constitute truly novel insights into a currently uncharted area of the atmospheric system and identify an entirely new frontier in aerosol research and atmospheric science.

Link to the ERC project webpage: https://www.oulu.fi/nanomo/surface

Keywords of the ERC project: atmosphere, aerosols, climate, air pollution, surfaces, spectroscopy, thermodynamics, multi-phase processes

Keywords that characterize the scientific profile of the potential visiting researcher/s: surfaces, spectroscopy, thermodynamics, multi-phase processes, organic physical chemistry
Morphodynamic Stickiness: the influence of physical and biological cohesion in sedimentary systems

Our coasts, estuaries, & low-land river environments are some of the most sensitive systems to sea-level rise & environmental change. In order to manage these systems, & adapt to future changes, we desperately need to be able to predict how they will alter under various scenarios. However, our models for these environments are not yet robust enough to predict, with confidence, very far into the future. Moreover, we also need to improve how we use our understanding of modern environments in reconstructing paleo-environments, where significant assumptions have been made in the way in which relationships derived from the modern have been applied to ancient rocks.

One of the main reasons our models, & geological interpretations, of these environments, are not yet good enough is because these models have formulations that are based on assumptions that these systems are composed of only non-cohesive sands. However, mud is the most common sediment on Earth & many of these systems are actually dominated by biologically-active muds & complex sediment mixtures. We need to therefore find ways to incorporate the effect of sticky mud & sticky biological components into our predictions. Recent work my colleagues & I have published show just how important such abiotic-biotic interactions can be: inclusion of only relatively small (<0.1% by mass) quantities of biological material into sediment mixtures can reduce alluvial bedform size by an order of magnitude.

However, this is just a start & there is much to do in order to advance our fundamental understanding & develop robust models that predict the combined effects of abiotic & biotic processes on morphological evolution of these environments under changing drivers & conditions. GEOSTICK will deliver this advance allowing us to test how sensitive these environments are, assess if there are tipping points in their resilience & examine evidence for the evolution of life in the ancient sediments of early Earth and Mars.

Link to the ERC project webpage:

Keywords of the ERC project: Sediment, flow, flood

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Processes on the Antarctic continental shelf and slope are crucially important for determining the rate of future sea level rise, setting the properties and volume of dense bottom water exported globally, and regulating the carbon cycle. Yet our ability to model and predict these processes over future decades remains rudimentary. This deficiency in understanding originates in a lack of observations in this inaccessible region. The COMPASS project seeks to rectify that by exploiting new technology - autonomous marine vehicles called gliders - to observe, quantify and elucidate processes on the continental shelf and slope of Antarctica that are important for climate.

The COMPASS objective is to make a step-change in our quantitative understanding of:
(i) the ocean front that marks the boundary between the Antarctic continental shelf and the open ocean, and its associated current system;
(ii) the interaction between ocean, atmosphere and sea-ice on the Antarctic continental shelf; and
(iii) the exchange of heat, salt and freshwater with the cavities beneath ice shelves.

These goals will be met by a series of targeted ocean glider campaigns around Antarctica, spanning different flow regimes, including areas where warm water is able to access the continental shelf and influence ice shelves, areas where the continental shelf is cold and fresh, and areas where the continental shelf hosts cold, salty, dense water that eventually spills into the abyss. A unique circumpolar assessment of ocean properties and dynamics, including instabilities and mixing, will be undertaken. COMPASS will develop new technology to deploy a profiling glider into inaccessible environments such as Antarctic polynyas (regions of open water surrounded by sea-ice). As well as scientific breakthroughs that will feed into future climate assessments, improving projections of future sea level rise and global temperatures, COMPASS will deliver enhanced design for future ocean observing systems.

Link to the ERC project webpage: http://compass-erc.eu

Keywords of the ERC project: ocean science; glider; autonomous vehicles; Antarctic

Keywords that characterize the scientific profile of the potential visiting researcher/s: oceanographer
Towards Understanding the Impact of Climate Change on Eurasian Boreal Forests: a Novel Stable Isotope Approach

The vast boreal forests play a critical role in the carbon cycle. As a consequence of increasing temperature and atmospheric CO₂, forest growth and subsequently carbon sequestration may be strongly affected. It is thus crucial to understand and predict the consequences of climate change on these ecosystems. Stable isotope analysis of tree rings represents a versatile archive where the effects of environmental changes are recorded. The main goal of the project is to obtain a better understanding of δ₁³C and δ₁₈O in tree rings that can be used to infer the response of forests to climate change. The goal is achieved by a detailed analysis of the incorporation and fractionation of isotopes in trees using four novel methods: (1) We will measure compound-specific δ₁³C and δ₁₈O of leaf sugars and (2) combine these with intra-annual δ₁³C and δ₁₈O analysis of tree rings. The approaches are enabled by methodological developments made by me and ISOBOREAL collaborators (Rinne et al. 2012, Lehmann et al. 2016, Loader et al. in prep.). Our aim is to determine δ₁³C and δ₁₈O dynamics of individual sugars in response to climatic and physiological factors, and to define how these signals are altered before being stored in tree rings. The improved mechanistic understanding will be applied on tree ring isotope chronologies to infer the response of the studied forests to climate change. (3) The fact that δ₁₈O in tree rings is a mixture of source and leaf water signals is a major problem for its application on climate studies. To solve this we aim to separate the two signals using position-specific δ₁₈O analysis on tree ring cellulose for the first time, which we will achieve by developing novel methods. (4) We will for the first time link the climate signal both in leaf sugars and annual rings with measured ecosystem exchange of greenhouse gases CO₂ and H₂O using eddy-covariance techniques.

Link to the ERC project webpage: https://www.researchgate.net/profile/Katja_Rinne-Garmston/projects

Keywords of the ERC project: tree rings, stable isotopes, laser ablation, carbohydrates, climate change, CSIA, carbon, oxygen, nitrogen

Keywords that characterize the scientific profile of the potential visiting researcher/s: tree rings, stable isotopes, climate change, carbohydrates
Mixed-phase clouds and climate (MC2) – from process-level understanding to large-scale impacts

The importance of mixed-phase clouds (i.e. clouds in which liquid and ice may co-exist) for weather and climate has become increasingly evident in recent years. We now know that a majority of the precipitation reaching Earth’s surface originates from mixed-phase clouds, and the way cloud phase changes under global warming has emerged as a critically important climate feedback. Atmospheric aerosols may also have affected climate via mixed-phase clouds, but the magnitude and even sign of this effect is currently unknown. Satellite observations have recently revealed that cloud phase is misrepresented in global climate models (GCMs), suggesting systematic GCM biases in precipitation formation and cloud-climate feedbacks. Such biases give us reason to doubt GCM projections of the climate response to CO2 increases, or to changing atmospheric aerosol loadings. This proposal seeks to address the above issues, through a multi-angle and multi-tool approach: (i) By conducting field measurements of cloud phase at mid- and high latitudes, we seek to identify the small-scale structure of mixed-phase clouds. (ii) Large-eddy simulations will then be employed to identify the underlying physics responsible for the observed structures, and the field measurements will provide case studies for regional cloud-resolving modelling in order to test and revise state-of-the-art cloud microphysics parameterizations. (iii) GCMs, with revised microphysics parameterizations, will be confronted with cloud phase constraints available from space. (iv) Finally, the same GCMs will be used to re-evaluate the climate impact of mixed-phase clouds in terms of their contribution to climate forcings and feedbacks. Through this synergistic combination of tools for a multi-scale study of mixed-phase clouds, the proposed research has the potential to bring the field of climate science forward, from improved process-level understanding at small scales, to better climate change predictions on the global scale.

Link to the ERC project webpage:

Keywords of the ERC project:

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Comprehensive seismic programs undertaken in the past few years, combined with emerging new numerical technologies now provide the potential, for the first time, to explore in detail the Earth’s interior. However, such an integrated approach is currently not contemplated, which produces physical inconsistencies among the different studies that strongly bias our understanding of the Earth’s internal structure and dynamics. Of particular concern are nowadays apparent thermo-petrological anomalies in tomographic images that are generated by the unaccounted-for anisotropic structure of the mantle and that are commonly confused with real thermo-petrological features. Given the diffuse mantle seismic anisotropy, apparent thermo-petrological anomalies contaminate most tomographic models against which tectono-magmatic models are validated, representing a critical issue for the present-day window.

Here we aim to develop a new methodology that combines state-of-the-art geodynamic modelling and seismological methods. The new methodology will allow building robust anisotropic tomographic models that will exploit anisotropy predictions from petrological-thermomechanical modelling to decompose velocity anomalies into isotropic (true thermo-petrological) and anisotropic (mechanically-induced) components. As a major outcome, we expect to provide a new, geodynamically and seismologically constrained perspective of the current deep structure and tectono-magmatic evolution of different tectonic settings. This new methodology will be applied to the Mediterranean and the Cascadia subduction zone where, despite the abundant seismological observations, large uncertainties about the subsurface structure and tectono-magmatic evolution persist.

Furthermore, we plan to develop a new inversion technique for seismic anisotropy, and release an open source, sophisticated code for mantle fabric modelling, which will allow coupling geodynamic and seismological modelling in other tectonic settings.

Link to the ERC project webpage: http://147.162.183.167/xampp/newton/

Keywords of the ERC project: geodynamics; seismology; numerical modelling

Keywords that characterize the scientific profile of the potential visiting researcher/s: geodynamics; seismology; numerical modelling
Biogenic volatile organic compounds (BVOCs) influence atmospheric oxidation causing climate feedback thought to be especially significant in remote areas with low anthropogenic emissions, such as the Arctic. Still, we do not understand the dynamics and impact of climatic and biotic BVOC emission drivers in arctic and alpine tundra, which are highly temperature-sensitive BVOC sources.

TUVOLU will redefine tundra BVOC emission estimates to account for rapid and dramatic climate warming accompanied by effects of vegetation change, permafrost thaw, insect outbreaks and herbivory using multidisciplinary, established and novel methodology.

We will quantify the relationships between leaf and canopy temperatures and BVOC emissions to improve BVOC emission model predictions of emission rates in low-statured tundra vegetation, which efficiently heats up. We will experimentally determine the contribution of induced BVOC emissions from insect herbivory in the warming Arctic by field manipulation experiments addressing basal herbivory and insect outbreaks and by stable isotope labelling to identify sources of the induced emission. Complementary laboratory assessment will determine if permafrost thaw leads to significant BVOC emissions from thawing processes and newly available soil processes, or if released BVOCs are largely taken up by soil microbes. We will also use a global network of existing climate warming experiments in alpine tundra to assess how the BVOC emissions from tundra vegetation world-wide respond to climate change.

Measurement data will help develop and parameterize BVOC emission models to produce holistic enhanced predictions for global tundra emissions. Finally, modelling will be used to estimate emission impact on tropospheric ozone concentrations and secondary organic aerosol levels, producing the first assessment of arctic BVOC-mediated feedback on regional air quality and climate.

**Link to the ERC project webpage:** https://www1.bio.ku.dk/staff/rinnan/

**Keywords of the ERC project:** ecosystem-atmosphere interactions, tundra, climate change, permafrost, insect herbivory

**Keywords that characterize the scientific profile of the potential visiting researcher/s:** microbial ecology, ecosystem modelling, entomology, plant ecophysiology
Monitoring real faults towards their critical state

The last seismic sequence in Italy, responsible for 298 fatalities and important economic loss, remind us how urgent it is to improve our knowledge about earthquake physics to advance earthquake forecasting. While direct observations during laboratory earthquakes permit us to derive exhaustive physical models describing the behaviour of rocks and to forecast incoming lab-earthquakes, the complex physics governing the nucleation of earthquakes remain poorly understood in real Earth, and so does our ability to forecast earthquakes. I posit that this ‘ignorance’ emerges from our limited ability to unravel information about fault physics from geophysical data. The objective of this proposal is to introduce a new and integrated methodology to monitor the spatiotemporal evolution of elastic properties on real faults using seismological and geodetic data. We will apply machine learning and covariance matrix factorization for improved earthquake detection, and to discover ‘anomalous’ seismological signals, which will reveal unknown physical processes on faults. These novel observations will be integrated with time dependent measurements of rheology and deformation, obtained from cutting-edge techniques applied to continuous seismological and geodetic data. Our integrated monitoring approach will be applied to study how faults respond to known stress perturbations (as Earth tides). In parallel, we will analyse periods preceding significant earthquakes to assess how elastic properties and deformation evolve while a fault is approaching a critical (near rupture) state. Our natural laboratory will be Italy, given its excellent geodetic and seismological instrumentation, deep knowledge about faults geometry and the relevant risk posed by earthquakes. Our research will provide new insights about the complex physics of faults at critical state, necessary to understand how real earthquakes nucleate. This project will also have a major impact on observational earthquake forecast.

Link to the ERC project webpage:

Keywords of the ERC project: Seismology, seismological detection, earthquake physics, monitoring, earthquakes nucleation

Keywords that characterize the scientific profile of the potential visiting researcher/s: Seismology, seismological detection, earthquake physics, monitoring, earthquakes nucleation, laboratory experience, rocks physics, machine learning,
Robots Explore plankton-driven Fluxes in the marine twilight zoNE

The scientific objective of REFINE is to understand and quantify the physical, biological and biogeochemical processes controlling the biological carbon pump, a key component of the oceanic CO2 sequestration. The oceanic twilight zone (TZ), which is located between the depths of 100 and 1000 m and represents 20% of the ocean’s volume, is where these processes occur. Yet the TZ is not properly sampled during most ship-based oceanographic cruises and, because of its depths, it escapes satellite remote sensing. Hence the TZ is one of the least known environments on Earth. The functioning of the TZ is highly dependent on the flux of matter and energy coming from the overlying well-lit euphotic zone (EZ). I have developed the REFINE ground-breaking, robotic-based approach to address the physical, biological and biogeochemical linkages between the EZ and the TZ, with special emphasis on the roles of phyto and zooplankton communities. I will implement REFINE through the following four main coordinated actions:

• Development of a new generation of multidisciplinary vertically profiling floats, uniquely able to robotically address phyto and zooplankton community composition.

• Achievement of ~3 years robotic-based process studies in five oceanic zones, representative of the diversity of biogeochemical conditions and responses to climate change in the global ocean, over a continuum of temporal scales ranging from diel to interannual.

• In-depth analysis of the unique REFINE dataset to perform carbon flux budgets within the TZ, and understand the physical and plankton-driven mechanisms involved in the EZ-TZ linkage and their impacts on the resulting fate of organic carbon and fluxes to ocean depths.

• Upscaling of regional processes to the global ocean through the use of artificial intelligence methods, in particular by taking advantage of multisource observations from REFINE robots and earth observation satellites.

Link to the ERC project webpage:

Keywords of the ERC project:

Keywords that characterize the scientific profile of the potential visiting researcher/s:
The Earth System is impacted continually by dozens of volcanic eruptions per year. Predicting their collective effects is hampered by our incomplete mechanistic understanding of eruptive and post-eruptive processes. The activity of explosive volcanic systems especially, is a key to the evolution of our world, not only for the eruptive catastrophes themselves but also for the massive injection of volcanic materials into the critical zone of the Earth System. (e.g. Ayris and Delmelle, 2012; Baldini et al., 2015; Dingwell, 1996; Dingwell et al., 2012; Martin et al., 2009; Robock, 2000). For this reason - as well as the many pragmatic issues of living with active volcanism – a mechanistic understanding explosive volcanism and the interaction of its products in the Earth System is a grand challenge of modern Earth Sciences.

Fortunately, three recent experimental breakthroughs bring the challenge of mechanistic understanding within our grasp: these are the development of in situ high temperature 1) synchrotron-based real-time imaging techniques for deforming systems (Baker et al., 2012; Wadsworth et al., 2016). 2) acoustic monitoring of failure and fragmentation processes in exploding magma (Arciniega et al., 2015) and 3) dynamic ash-gas environmental reaction chambers (Ayris et al., 2015).

Accompanying these experimental advances, have been fundamental advances in our mechanistic view of magma ascent and eruption (Tuffen et al., 2003; Gonnermann and Manga, 2003; Lavallée et al., 2008; Castro and Dingwell, 2009), volcano seismicity (Arciniega et al., 2015; Vasseur et al., 2017) , and the fate of volcanic ash (Delmelle et al., 2018; Renggli et al., 2018). Vast experimental expertise, together with the global impact of our work to date, place me uniquely to exploit these recent advances and to bring the impact of an experimental approach to volcanology to its fullest potential, with Europe at its forefront.

Link to the ERC project webpage:

Keywords of the ERC project: geoscience, experimental, materials, rheology, volcanism

Keywords that characterize the scientific profile of the potential visiting researcher/s: geoscience, experimental, materials, rheology, volcanism
**New geochemical approach to reconstruct tropical palaeo-atmospheric dynamics**

Tropical climates are changing rapidly in the most populated regions of the planet. The changes largely arise from alterations in the Hadley circulation driven by natural and anthropogenic factors, whose relative roles and temporal variability are unclear. These knowledge gaps are in part due to the shortage of methods to study the atmospheric circulation before the advent of instrumental and satellites observations, and compounded by the contradictions between models and palaeo-data.

The aim of the project is to develop an innovative palaeo-proxy approach to investigate the natural range of variability of the Hadley circulation during past episodes of extreme warmth and cold. The approach relies on the exploitation as climate proxy of an untapped but widespread material in marine sediments: windborne pyrogenic carbon (PyC) derived from savannah and grassland fires in the tropics. Through the geochemical and isotopic spatial characterization of PyC, along with the analysis of mineral dust in the modern tropical deep ocean, and a PyC biogeochemical model, we will build an interpretative framework of PyC deposition in deep-sea sediments. Its application in Pliocene-Pleistocene sequences from the Atlantic and the Pacific will allow the reconstruction of past meridional and zonal shifts in the Intertropical Convergence Zone and the Southern hemisphere westerlies, and provide new constraints on the natural variability of the Hadley circulation and associated hydroclimates.

PALADYN is possible thanks to the combination of cutting-edge geochemical and satellite data, and GIS methodologies, with in-depth interdisciplinary expertise on the palaeoclimatic study of marine sediments. We will provide new important datasets of windborne deep-sea PyC for testing and refining prediction models of atmospheric circulation, carbon cycle, precipitation and wildfires, issues which are of paramount global importance from scientific as well as societal standpoints.

**Link to the ERC project webpage:**

**Keywords of the ERC project:** Paleoclimate, Hadley circulation, biomass burning aerosols, pyrogenic carbon, dust, marine carbon cycle

**Keywords that characterize the scientific profile of the potential visiting researcher/s:**
Quantifying the evolution of Earth’s atmosphere with novel isotope systems and modelling

Atmospheric oxygen is fundamental to life as we know it, but its concentration has changed dramatically over Earth’s 4.5 billion year history. An amazing qualitative story has emerged, in which Earth’s atmosphere was devoid of free oxygen for the first 2 billion years of planetary history, with two significant increases in concentration at ~2.4 and ~0.55 billion years ago. Both oxygenation events were accompanied by extreme climatic effects – the “snowball earth” episodes – and paved the way for massive reorganization of biogeochemical cycles such as the Cambrian radiation of macroscopic life. Despite these profound influences on the Earth system, we currently lack fundamental quantitative constraints on Earth’s atmospheric evolution. I am poised to add substantial quantitative rigor to Earth’s atmospheric history, by constraining the concentrations of important gases (e.g., O2, O3, CO2, CH4, organic haze) in ancient atmospheres to unprecedented accuracy. I will accomplish this via an innovative interdisciplinary program focused on the unusual mass-independent isotope fractionations observed in sedimentary rocks containing sulfur and oxygen. These signals are direct remnants of ancient atmospheric chemistry, and contain far more information than can currently be interpreted. This project combines novel experimental and methodological approaches with state-of-the-art numerical modelling to significantly advance our ability to decipher the isotope records. A unique “early Earth” UV lamp coupled to a custom-built photocell will enable direct production of isotope signals under Earth-like conditions, with time-dependent sampling. Groundbreaking analytical methodologies will vastly increase the global geochemical database. The experimental results and data will provide ground-truth for next-generation atmospheric models that will constrain atmospheric composition and its feedbacks with the Earth-biosphere-climate system during key points in our planetary history.

Link to the ERC project webpage:

Keywords of the ERC project: mass independent fractionation of sulfur and oxygen isotopes

Keywords that characterize the scientific profile of the potential visiting researcher/s: mass independent fractionation, photochemistry, modelling
Climate change driven by CO2 emissions from human activities is a significant challenge facing mankind. An important component of Earth’s carbon (C) cycle is the ocean’s biological C pump; without it atmospheric CO2 would be ~50% higher than it is now. The pump consists of sinking organic matter which is remineralised back into CO2 in the deep ocean. The depth at which remineralisation occurs is the main factor affecting the amount of organic C stored in the ocean. Currently we do not understand how or why remineralisation depth varies in time, which limits our ability to make robust predictions of how the future C cycle, and hence our climate, will change into the future. This is mainly due to the challenges of measuring remineralisation depth using conventional methods—a barrier which autonomous underwater vehicles are poised to overcome by providing high frequency data over long periods. This technological innovation will revolutionise our understanding of this important planetary C flux.

I propose an ambitious project to address current uncertainties in remineralisation depth. GOCART encompasses new observations, obtained using cutting-edge technology and novel methodology, through to global climate modelling. Underwater glider deployments will be used to establish the characteristics and significance of temporal variability in organic C flux and remineralisation depth during the most dynamic period of the year. This will enable new insights into the factors driving variability in remineralisation depth, ultimately leading to development of a new model parameterisation incorporating temporal variability. Using an innovative modelling framework, this parameterisation will be tested for its potential to improve predictions of ocean C storage. GOCART represents a significant advance in quantifying temporal variability in remineralisation depth, which is key to reducing uncertainty in model predictions of ocean C storage, and yet currently almost entirely unknown.

**Gauging Ocean organic Carbon fluxes using Autonomous Robotic Technologies**

*Link to the ERC project webpage:* http://projects.noc.ac.uk/gocart/

*Keywords of the ERC project:* ocean carbon flux, autonomous underwater vehicles

*Keywords that characterize the scientific profile of the potential visiting researcher/s:*
Signals from the Surface Snow: Post-Depositional Processes Controlling the Ice Core Isotopic Fingerprint

For the past 50 years, our use of ice core records as climate archives has relied on the fundamental assumption that the isotopic composition of precipitation deposited on the ice sheet surface determines the ice core water isotopic composition. Since the isotopic composition in precipitation is assumed to be governed by the state of the climate this has made ice core isotope records one of the most important proxies for reconstructing the past climate.

New simultaneous measurements of snow and water vapor isotopes have shown that the surface snow exchanges with the atmospheric water vapor isotope signal, altering the deposited precipitation isotope signal. This severely questions the standard paradigm for interpreting the ice core proxy record and gives rise to the hypothesis that the isotope record from an ice core is determined by a combination of the atmospheric water vapor isotope signal and the precipitation isotope signal.

The SNOWISO project will verify this new hypothesis by combining laboratory and field experiments with in-situ observations of snow and water vapor isotopes in Greenland and Antarctica. This will enable me to quantify and parameterize the snow-air isotope exchange and post-depositional processes. I will implement these results into an isotope-enabled Regional Climate Model with a snowpack module and benchmarked against in-situ observations. Using the coupled snow-atmosphere isotope model I will establish the isotopic shift due to post-depositional processes under different climate conditions. This will facilitate the use of the full suite of water isotopes to infer past changes in the climate system, specifically changes in ocean sea surface temperature and relative humidity.

By establishing how the water isotope signal is recorded in the snow, the SNOWISO project will build the foundation for future integration of isotope-enabled General Circulation Models with ice core records; this opens a new frontier in climate reconstruction.

Link to the ERC project webpage: https://steenlarsen.w.uib.no/erc-stg-snowiso/

Keywords of the ERC project: Water cycle, water vapor, snow, isotopes, ice core, Paleoclimate, Arctic, Greenland, isotope modelling, Polar climate

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Seismic observations imply that slab descent and plume ascent are impeded in the mid-mantle (MM) (depths of 660–1000 km, pressures of 23–40 GPa). A recent evaluation of viscosity variation suggested the presence of a viscosity increase or maximum in the MM that could drag the slab and plume motions. The viscosity variation may be caused by a change in the rheology of bridgmanite (Brg), the dominant mineral in the lower mantle (LM). The absence of seismic anisotropy suggests the dominance of diffusion creep in the majority of the LM. Element diffusivities and grain size are two essential factors of diffusion creep, and defect chemistry controls diffusivity. Hence, this project will determine defect chemistry, diffusivity and the grain growth rate of Brg. Since plume ascent originates in deep parts in the LM, these three properties need to be determined at pressures up to 80 GPa. Although use of a large-volume press (LVP) is vital for obtaining reliable high-pressure experimental data on mineral and rock properties, conventional LVP with carbide anvils can only generate 27 GPa. Recent LVP technology can generate over 100 GPa using sintered diamond (SD) anvils, but the process is currently very difficult for practical use. We developed a method to generate 50 GPa using hard carbide (HWC) anvils that allows practical investigation of Brg properties at mantle temperatures. We will investigate the three properties of Brg up to 50 GPa using LVP with HWC. We will develop LVP technology with SD to reliably generate pressures up to 80 GPa at mantle temperatures, and we will investigate the Brg properties under these conditions. These data will enable numerical modelling of slab and plume dynamics to explain the seismic observations. Through such modelling, we will investigate how materials are transported between the surface and deep mantle reservoirs, which can provide insight into Earth’s evolution and surface habitability.

Link to the ERC project webpage: https://www.ultralvp.eu/

Keywords of the ERC project: Earth’s interior, lower mantle, high-pressure, bridgmanite

Keywords that characterize the scientific profile of the potential visiting researcher/s:
A Genetic View into Past Sea Ice Variability in the Arctic

Arctic sea ice decline is the exponent of the rapidly transforming Arctic climate. The ensuing local and global implications can be understood by studying past climate transitions, yet few methods are available to examine past Arctic sea ice cover, severely restricting our understanding of sea ice in the climate system. The decline in Arctic sea ice cover is a ‘canary in the coalmine’ for the state of our climate, and if greenhouse gas emissions remain unchecked, summer sea ice loss may pass a critical threshold that could drastically transform the Arctic. Because historical observations are limited, it is crucial to have reliable proxies for assessing natural sea ice variability, its stability and sensitivity to climate forcing on different time scales. Current proxies address aspects of sea ice variability, but are limited due to a selective fossil record, preservation effects, regional applicability, or being semi-quantitative. With such restraints on our knowledge about natural variations and drivers, major uncertainties about the future remain.

I propose to develop and apply a novel sea ice proxy that exploits genetic information stored in marine sediments, sedimentary ancient DNA (sedaDNA). This innovation uses the genetic signature of phytoplankton communities from surface waters and sea ice as it gets stored in sediments. This wealth of information has not been explored before for reconstructing sea ice conditions. Preliminary results from my cross-disciplinary team indicate that our unconventional approach can provide a detailed, qualitative account of past sea ice ecosystems and quantitative estimates of sea ice parameters. I will address fundamental questions about past Arctic sea ice variability on different timescales, information essential to provide a framework upon which to assess the ecological and socio-economic consequences of a changing Arctic. This new proxy is not limited to sea ice research and can transform the field of paleoceanography.

Link to the ERC project webpage: www.agensi.eu

Keywords of the ERC project: Paleoceanography, Molecular ecology, Cryosphere, ancient DNA, organic geochemistry, palynology, sea ice

Keywords that characterize the scientific profile of the potential visiting researcher/s:
PROgrade metamorphism MOdeling: a new petrochronological and compuTING framework

Prograde metamorphism produces large amounts of fluids that have an important role for earthquake generation, arc magmatism, the growth of continental crust and for global geochemical cycles. Despite recent efforts, it remains challenging to recognize and quantify fluid fluxes in natural rocks and to model fluid pathways. The existing petrological modeling techniques are all based on the thermodynamic analysis of single rock types and neglect the chemical changes caused by fluid expulsion and the possible interactions with other rocks. The next frontier in metamorphic petrology is therefore to move our modeling capabilities from an isolated single rock system to an open and multi rock system, in which fluids can flow in, react and flow out. This concept introduces several challenges from the quantification of fluid-rock interactions in natural samples to the integration of aqueous thermodynamics and fluid dynamics in the petrological models. Based on the developments of high-resolution techniques such as quantitative compositional mapping, I have demonstrated that the petrological models can be inverted to quantify prograde metamorphism based on preserved mineral relics that partially re-equilibrated in the presence of fluids. The primary objective of PROMOTING is to develop a brand-new framework for petrological modeling of fluid-rock interactions in different, coupled rock types during prograde metamorphism. The models will be calibrated on two key tectonic settings that shaped Earth: subduction of oceanic crust and differentiation of the continental crust. A cutting-edge petrochronological strategy is required to identify at which conditions and when fluid-rock interactions occurred in natural rocks. The outcomes of this project will not only form the basis for a new generation of models integrating element mobility from rock scale to crustal sections, but they will also bring new constraints to test the validity of the most advanced subduction models.

Link to the ERC project webpage: http://pierre-lanari.com/research-group/

Keywords of the ERC project: Metamorphism; Petrology; Fluid-rock interactions; Thermodynamics; Fluid mobility; Modelling

Keywords that characterize the scientific profile of the potential visiting researcher/s: Petrology; Aqueous thermodynamics; Petrological modelling; Geochemical modelling; Oxygen isotopes
**Project ID:** 851460  
**Project Acronym:** MIMATOM  
**Evaluation Panel:** PE10  
**Earth System Science**

<table>
<thead>
<tr>
<th>Principal Investigator:</th>
<th>Dr LENNART DE GROOT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Host Institution:</td>
<td>UNIVERSITEIT UTRECHT - NL</td>
</tr>
</tbody>
</table>

**Paleomagnetism and rock-magnetism by Micro-Magnetic Tomography**

Our knowledge on the past behavior of the Earth’s magnetic field critically depends on our ability to obtain and interpret magnetic signals from geological materials such as lavas. These materials contain mixtures of different magnetic minerals, some of which are good recorders of the Earth’s magnetic field, others are not. Even the presence of a small amount of minerals with adverse magnetic properties obscures the signal of good recorders, resulting in >80% of measurements of the past Earth’s magnetic field strength being flawed. Understanding the Earth’s magnetic field is pivotal for predicting the future of its shielding capacity against the Sun’s electromagnetically charged particles, which globally weakened by >20% over the last millennium.

With MIMATOM, I aim to establish an entirely new way to obtain paleomagnetic and rock-magnetic information from geological materials. I will go beyond measuring magnetizations of bulk samples by determining the magnetic moments of individual minerals embedded in these samples in a non-destructive way. Starting from my recent proof-of-concept of Micro-Magnetic Tomography (MMT), I will develop a radically new technique to assess magnetizations of individual minerals inside geological materials. This will enable understanding which minerals are reliable recorders of the Earth’s magnetic field by characterizing their magnetic behavior as function of their grain size, shape, and chemistry. Then I will use MMT to obtain paleomagnetic information from selections of minerals that I identified as good recorders and unlock information on the past state of the Earth’s magnetic field from even the most challenging and magnetically complex geological materials, such as lavas.

My revolutionary new technique will open archives of the past behavior of the Earth’s magnetic field that currently are inaccessible. Moreover, it will pave the way for radically new venues in paleomagnetic and rock-magnetic research, at mineral level.

**Link to the ERC project webpage:**

**Keywords of the ERC project:**

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Fundamental understanding of reactive nitrogen in the global upper troposphere

The upper troposphere (UT), a severely under-researched part of the atmosphere, has profound impacts on global climate, air quality, major atmospheric oxidants, and the protective ozone layer. Key to its influence on the Earth system are reactive nitrogen compounds (collectively NOy). Models, since their inception, have grossly misrepresented observations of UT NOy, hindering application of these models to accurately estimate the impact of humans on climate, the ozone layer, and air quality. The reasons proposed for discrepancies between models and observations are unsatisfactory, as past studies have been hampered by observations that are limited in space and time. Only now are there unprecedented global, high-resolution measurements of the UT from instruments on aircraft and satellites that can be combined with detailed and advanced modelling tools to at last tackle this issue on a global scale. The ground-breaking UpTrop work programme will innovatively combine observations from the recently launched ESA Sentinel-5P mission and a long record of aircraft campaigns (most crucially the 2016-2018 NASA ATom campaign) to create the first truly global dataset of UT NOy abundance, interpreted with the state-of-the-art GEOS-Chem model. This pioneering multiplatform approach, the bedrock of my previous highly cited work, will deliver game-changing objectives: (i) novel insights into the processes controlling UT NOy, (ii) an unequivocal account of the role of the upper troposphere in altering climate and the chemical composition of the atmosphere, and (iii) interpretation of the disruptive impact of improved understanding of UT NOy on widespread application of satellite observations to constrain global air quality. UpTrop is ambitious, with bold objectives that will conceptually change fundamental understanding of UT NOy and address a challenge that has plagued atmospheric chemists for decades. A cascade of new avenues of cross-disciplinary research is inevitable.

Link to the ERC project webpage: http://maraisresearchgroup.co.uk/uptrop.html

Keywords of the ERC project: air quality, atmospheric composition, computer modelling, atmospheric chemistry, Earth observations

Keywords that characterize the scientific profile of the potential visiting researcher/s: atmospheric chemistry
Project ID: 682399  
Project Acronym: TEX-MEX  
Evaluation Panel: PE2  
Fundamental Constituents of Matter

Principal Investigator: Dr STUART MANGLES  
Host Institution: IMPERIAL COLLEGE OF SCIENCE TECHNOLOGY AND MEDICINE - UK

Time resolved X-ray probing of Matter under Extreme conditions

The unique properties of a new type of X-ray source produced by a compact laser-plasma accelerator will be used to probe the ultra-fast dynamics of the electronic structure of matter under extreme conditions. The TeX-MEx project will study: 1) hot dense matter, such as that found at the centre of the Sun; 2) warm dense matter such as that found at the centre of Jupiter and 3) photo-ionized plasmas far from equilibrium such as is found in the exotic environment of an accretion disk surrounding a black hole. These extreme conditions will be created in the laboratory using 1) direct laser heating, 2) proton heating and laser driven shock heating and 3) intense X-ray pumping using the betatron source itself and the extraordinary X-ray fluxes available with a free electron laser.

Using the unique combination of a few-femtosecond duration and broad spectral coverage that the X-rays produced by a laser wakefield accelerator possess, the TeX-MEx project will explore new physics in each of these regimes. For example we will be able to directly measure the rates of ionization of hot dense matter for the first time; we will observe the onset of ion motion in warm dense matter and how this affects the electron energy levels; we will make the first observations of non-collisional photo-ionized plasmas. These will allow us to accurately test and develop models used to describe matter under extreme conditions in the laboratory and in astrophysics.

This integrated program of innovative experiments and new approaches to modeling will open up a new field of femtosecond time-resolved absorption spectroscopy of matter under extreme conditions and will drastically improve our understanding of how matter behaves throughout our Universe. It will, for the first time, bring to our laboratories on Earth the ability to probe some of Nature’s most violent processes, to date only hinted at in data from a new generation of astronomical instruments.

Link to the ERC project webpage:

Keywords of the ERC project: High intensity laser plasma

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Search for electric dipole moments using storage rings

One of the great mysteries in the natural sciences is the dominance of matter over antimatter in the universe. According to our present understanding, the early universe contained the same amount of matter and antimatter. If the universe had behaved symmetrically as it developed, every particle would have been annihilated by one of its antiparticles. We therefore owe our very existence to mechanisms that have led to a world where something that we call matter remains. We propose to study such mechanisms by searching for electric dipole moments (EDMs) of charged hadrons in a new class of precision storage rings. Our project will lay the foundations for a new European flagship research infrastructure. The breaking of the combined charge conjugation and parity symmetries (CP-violation) in the Standard Model is not strong enough to explain the observed excess of matter and further sources of CP-violation must be sought. These sources could manifest themselves in Electric Dipole Moments of elementary particles, which occur when the centroids of positive and negative charges are mutually and permanently displaced. The observation of an electric dipole moment will elucidate the mechanisms which led to the matter that dominates the universe. Although the measurement principle, the time development of the polarization vector subject to a perpendicular electric field, is simple, the smallness of the effect makes this an enormously challenging project. This can only be mastered through the common effort of an international team of accelerator and particle physicists, working closely with engineers. The proponents of this design study and the research environment at the Forschungszentrum Jülich (Germany), including the conventional storage ring COSY, provide the optimal basis for one of the most spectacular possibilities in modern science: finding an EDM as a signal for new physics beyond the Standard Model and perhaps explaining the puzzle of our existence.

Link to the ERC project webpage:

Keywords of the ERC project: Fundamental Particle Physics, Electric Dipole Moments, Storage Rings, Matter-Antimatter Asymmetry, Dark Matter

Keywords that characterize the scientific profile of the potential visiting researcher/s: Experimental particle physics, accelerator physics, polarization physics
Low Temperature Glassy Systems

Jamming of hard spheres is a new critical phenomenon whose exponents are different from those of the other known transitions. These exponents have been recently computed in a mean field approximation whose limits of validity are not known. Even if their values are in very good agreement with the ones obtained by accurate numerical simulations, the deep reasons for this success are not understood.

Trampolining from these results I plan to develop a theory of the large scale properties of the free energy landscape of glasses at low temperature. I will use techniques of statistical field theory and of renormalization group to identify and compute universal features. This proposal has the following goals.

• We will develop a complete analytic theory of the infinite pressure limit (jamming) of hard spheres in dimensions greater than the upper critical dimensions. We will first compute analytically the upper critical dimension. Numerical simulations suggest that the upper critical dimensions is equal to or smaller than 2: this result is puzzling and it would be very interesting to find out if this indication is supported by the theory. We will also investigate in detail the scaling properties and the conformal invariance of the correlation functions.
• Starting from these results we will derive universal properties of glassy materials in the low temperature regions in the classical and in the quantum regime. The properties of multiple equilibrium configurations are crucial; we will study the structure of small (localized or extended) oscillations around them, the classical and quantum tunneling barriers.
• We will analyze both equilibrium features and off-equilibrium features (like plasticity and the time dependence of the specific heat). The subject has been widely discussed and phenomenological laws have been derived. I aim to obtain these laws from first principles using the properties of the free energy landscape in glasses that will be derived analytically.

Link to the ERC project webpage:

Keywords of the ERC project:

Keywords that characterize the scientific profile of the potential visiting researcher/s:
The most energetic electromagnetic phenomena in the Universe are believed to be powered by the collision of two neutron stars, the smallest and densest stars on which surface gravity is about 2 billion times stronger than gravity on Earth. However, a definitive identification of neutron star mergers as central engines for short-gamma-ray bursts and kilonovae transients is possible only by direct gravitational-wave observations. The latter provide us with unique information on neutron stars' masses, radii, and spins, including the possibility to set the strongest observational constraints on the unknown equation-of-state of matter at supranuclear densities.

Neutron stars binary mergers are among the main targets for ground-based gravitational-wave interferometers like Advanced LIGO and Virgo, which start operations this year. The astrophysical data analysis of the signals emitted by these sources requires the availability of accurate waveform models, which are missing to date. Hence, the theoretical understanding of the gravitational spectrum is a necessary and urgent step for the development of a gravitational-based astrophysics in the next years.

This project aims at developing, for the first time, a precise theoretical model for the complete gravitational spectrum of neutron star binaries, including the merger and postmerger stages of the coalescence process. Building on the PI's unique expertise and track record, the proposed research exploits synergy between analytical and numerical methods in General Relativity. Results from state of the art nonlinear 3D numerical relativity simulations will be combined with the most advanced analytical framework for the relativistic two-body problem. The model developed here will be used in the first gravitational-wave observations and will dramatically impact multimessenger astrophysics.
REsummation-Improved moNtecarlo eVEnt geNeraTor

With the start of the second run of the Large Hadron Collider and the discovery of a particle compatible with the Standard Model Higgs boson, the high-energy particle physics community faces the task to carry out precise measurements of the properties of this new particle, in order to establish its nature. At the same time, it will be equally important to keep looking for the yet elusive signs of New Physics. Both tasks rely on the ability to accurately predict the expected signals and to disentangle them from the known backgrounds. At hadronic colliders like the LHC, accurate modeling of the strong interactions is crucial to interpret the experimental outcomes.

The goal of this project is to push forward the frontier of precision QCD for event simulations. The key idea is to combine the three possible theoretical description (fixed-order perturbative expansion, resummed calculations and parton showers) into the same theoretical framework, in order to benefit from the advantages of each. The innovative approach proposed here improves over past efforts thanks to the inclusion of higher-logarithmic resummation, which bridges the gap between the perturbative description of hard radiation and the shower domain. This brings together three important advantages: the ability to use the best theoretical description in each region, the sizable reduction of the theoretical uncertainties gained by replacing the shower evolution with the higher-logarithmic resummation, and the ability to produce hadron-level events that can be directly interfaced to detector simulations.

By going beyond the state-of-the-art, REINVENT will obtain the most precise theoretical predictions for the LHC in an event generator form that allows for direct comparison to data, producing tools that will be used by both experimentalists and theorists. The technology developed for this project will also have important applications for precision studies at future lepton colliders.

Link to the ERC project webpage:

Keywords of the ERC project: QCD, Monte Carlo, Resummation, LHC

Keywords that characterize the scientific profile of the potential visiting researcher/s:
The Neutron Electric Dipole Moment: pushing the precision to understand the matter-antimatter asymmetry

The existence of a permanent electric dipole moment (EDM) of the neutron, or any subatomic particle, would have far reaching implications connecting particle physics with cosmology. Time reversal invariance and CP symmetry would be violated. A new fundamental interaction producing the EDM, that is, deforming the charge distribution inside the neutron, could also have generated the matter-antimatter asymmetry in the early Universe. After 60 years of evolution, techniques to measure the neutron EDM are now so evolved that experiments are sensitive to microphysics associated with an energy scale beyond that accessible at the LHC. This situation offers a high likelihood of discovery for the next generation of experiments. In the same time, any improvement in precision is technically challenging. The control of the magnetic field must surpass that of the state of the art of atomic magnetometers. The n2EDM project aims at improving the precision by an order of magnitude or more. Systematic effects need to be controlled at an unprecedented level. In particular, the use of a mercury co-magnetometer based on the precession of 199Hg spins induces a set of subtle false effects due to the relativistic motional field.

I propose to initiate a comprehensive program to master these systematic effects beyond the current research program. In particular, the proposed project includes a precise determination of the 199Hg magnetic moment with a precision of 0.1 ppm. To this end, I will attempt a novel approach: combining mercury and 4He magnetometry in the same cell. As a by-product, this will also produce an improved determination of the neutron magnetic moment, a quantity of interest for metrology. The cross-check I propose will prove that all disturbances on the neutron or mercury spins are mastered at the sub-ppm level, a decisive step in the quest for the neutron EDM.

Link to the ERC project webpage:
Keywords of the ERC project: precision measurement, metrology, atomic magnetometry
Keywords that characterize the scientific profile of the potential visiting researcher/s: low field NMR
The proton radius extracted from the measurements of the 2S-2P energy splitting in muonic hydrogen (μp) has attracted great attention because of a 7σ discrepancy with the values extracted from electron scattering and hydrogen (H) spectroscopy. Hundreds of publications have been devoted to the so-called “proton radius puzzle” ranging from studies of physics beyond the standard model, to reanalysis of electron scattering data, refinements of bound-state QED calculations, new theories describing the proton structure, and proposals for new scattering and H spectroscopy experiments.

As next step, I plan two new (i.e., never before attempted) measurements: the ground-state hyperfine splitting (1S-HFS) in both μp and μ3He+ with 1 ppm relative accuracy by means of pulsed laser spectroscopy. From these measurements the nuclear-structure contributions (two-photon-exchange) can be extracted with a relative accuracy of 100 ppm which in turn can be used to extract the corresponding Zemach radii (with a relative accuracy of 0.1%) and polarizability contributions. The Zemach radii can provide magnetic radii when form-factor data or models are assumed.

These radii are benchmarks for lattice QCD and few-nucleon theories. With the polarizability contribution they impact our models of the proton and of the 3He nucleus. Moreover, the μp measurement can be used to solve the discrepancy between the magnetic radii values as extracted from polarized and unpolarized electron scattering and to further test bound-state QED predictions of the 1S-HFS in H. These two experiments require a muon beam line, a target with an optical cavity, detector, and laser systems. As weak M1 transitions must be probed, large laser-pulse energies are needed, thus cutting-edge laser technologies (mainly thin-disk laser and parametric down-conversion) need to be developed.

Laser schemes of potentially high industrial impact that I have just patented will be implemented and refined.

Link to the ERC project webpage:

Keywords of the ERC project: Laser spectroscopy, muonic atoms,

Keywords that characterize the scientific profile of the potential visiting researcher/s: laser, optical parametric oscillators, laser spectroscopy, high-power laser
Quantifying Quantum Gravity Violations of Causality and the Equivalence Principle

Quantum gravity must violate at least one of three principles at the foundations of physics: unitarity, causality, or the equivalence principle. Recent theoretical work on black holes has shown that such violations are not limited to extremely short distances, where quantum gravity effects are expected, but also occur at distances much larger than the Planck scale. This work has revealed a huge gap in our understanding: we have no working criterion for when quantum gravity violations of the usual laws of physics are important. This theoretical crisis is also an opportunity, since quantum gravity effects may be observable if they occur at longer distance scales. I propose a series of concrete calculations in two theoretical situations: ordinary black holes, which evaporate due to Hawking radiation, and black holes in spacetimes with negative cosmological constant, which do not evaporate. These calculations will quantify, for the first time, the size of these violations. The calculations make use of existing techniques and results derived by myself and others, but a focused effort is needed in order to put together all of the necessary ingredients into a coherent quantitative result.

We will then generalize our results beyond black holes to obtain a generally applicable formula. The final result will be an answer to one of the most important questions in quantum gravity: how large are quantum gravity violations of the usual laws of physics? The impact of successfully completing this project extends far beyond black hole physics. As one application, our results will either justify existing calculations of cosmological observables, or make a prediction that quantum gravity effects can be observed.

Link to the ERC project webpage:

Keywords of the ERC project: black holes, quantum gravity, string theory

Keywords that characterize the scientific profile of the potential visiting researcher/s:
The objective of this project is to revolutionize the way the structure of the proton is accessed, determined, and used in the computation of physical processes at hadron colliders such as the Large Hadron Collider (LHC) of CERN. At a hadron accelerator, predictions require a precise, detailed, and accurate description and understanding of the structure of the colliding protons, as encoded in parton distributions (PDFs) - the distributions of quarks and gluons. At the LHC, PDFs are at present the major source of uncertainty, and in the near future they will be the main hurdle for discovery. The vision of this project is to remove this hurdle by attacking the problem using recent results from artificial intelligence (AI). I will lead a research team of two staff scientists, four postdocs and three PhD students, who will apply to PDF determination the recent methods of deep reinforcement learning and Q-learning, which will be coupled with deep residual networks to achieve a fully parameter- and bias-free understanding of proton structure. I will bring into high-energy physics a methodology so far used for object recognition in self-driving cars and automatic game playing, leading both to new physics, and new computational techniques. The application of these techniques to PDFs will enable me to reach two secondary goals. The first is theoretical: the full use for PDF determination of recent high perturbative order (next-to-next-to leading order or NNLO) computations, which will be integrated by means of a new approximation method which relies on combining known exact results with all-order information in various kinematic limits to extend the scope of the former to a more detailed ("more exclusive") description of the final state. The second is phenomenological: the integration in PDF determination of the Monte-Carlo event generators which are used to turn field theoretical prediction into a realistic description which may be directly compared to experimental data.

Link to the ERC project webpage: http://n3pdf.mi.infn.it/

Keywords of the ERC project: LHC, Standard Model, quantum chromodynamics, QCD, parton distributions, proton structure, machine learning, neural networks

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Dynamics of Probed, Pulsed, Quenched and Driven Integrable Quantum Systems

This proposal intends to develop and apply a new-generation theoretical toolbox for understanding the rich dynamics of strongly-interacting many-body quantum systems subjected to destabilizing manipulations bringing them very far from equilibrium.

In atomic systems, condensed matter and nanophysics settings, quantum matter is nowadays routinely pushed beyond the traditional low-energy/linear response/thermal equilibrium paradigms. Some experiments even clearly highlight the need to revise basic fundamental quantum statistical mechanics notions such as ergodicity, relaxation and thermalization in order to explain their behaviour. Theory must thus urgently revise its textbooks and develop new interpretations and capabilities for offering concrete, quantitative phenomenology. This proposal is focused on a set of systems at the very center of this strongly-correlated, experimentally realizable far-from-equilibrium spectacle: integrable models of quantum spin chains, interacting gases confined to one spatial dimension, and quantum dots. Building up on recent theoretical breakthroughs in dynamical correlations and post-quench steady states, this proposal aims to shed a new light on the fundamental principles at the heart of many-body quantum dynamics. It will implement a broad and ambitious research agenda consisting of synergetic projects from mathematically formal thought experiments all the way to phenomenologically applied practical calculations. The types of protocols to be studied include probes creating high-energy excitations, pulses inducing changes beyond linear response, quenches causing sudden global reorganizations, all the way to drivings completely metamorphozing the physical states.

The result will be to provide reliable, experimentally relevant and urgently-needed theoretical ‘anchoring points’ in our general understanding of the physics underlying far-from-equilibrium strongly-interacting quantum matter.

Link to the ERC project webpage:

Keywords of the ERC project: Integrable models, quantum spin chains, one-dimensional quantum gases, Heisenberg chain, Lieb-Liniger model, Bethe Ansatz, out-of-equilibrium dynamics, quench action, quantum quenches

Keywords that characterize the scientific profile of the potential visiting researcher/s: Integrable models, quantum spin chains, one-dimensional quantum gases, Heisenberg chain, Lieb-Liniger model, Bethe Ansatz, out-of-equilibrium dynamics, quench action, quantum quenches
Quantum nonlinear optics through Rydberg interaction

Optical photons, for all practical purposes, do not interact. This fundamental property of light forms the basis of modern optics and enables a multitude of technical applications in our every-day life, such as all-optical communication and microscopy. On the other hand, an engineered interaction between individual photons would allow the creation and control of light photon by photon, providing fundamental insights into the quantum nature of light and allowing us to harness non-classical states of light as resource for future technology. Mapping the strong interaction between Rydberg atoms onto individual photons has emerged as a highly promising approach towards this ambitious goal. In this project, we will advance and significantly broaden the research field of Rydberg quantum optics to develop new tools for realizing strongly correlated quantum many-body states of photons. Building on our successful work over recent years, we will greatly expand our control over Rydberg slow-light polaritons to implement mesoscopic systems of strongly interacting photons in an ultracold ytterbium gas. In parallel, we will explore a new approach to strong light-matter coupling, utilizing Rydberg superatoms made out of thousands of individual atoms, strongly coupled to a propagating light mode. This free-space QED system enables strong coupling between single photons and single artificial atoms in the optical domain without any confining structures for the light. Finally, we will experimentally realize a novel quantum hybrid system exploiting the strong electric coupling between single Rydberg atoms and piezo-electric micro-mechanical oscillators. Building on this unique coupling scheme, we will explore Rydberg-mediated cooling of a mechanical system and dissipative preparation of non-classical phonon states. The three complementary parts ultimately unite into a powerful Rydberg quantum optics toolbox which will provide unprecedented control over single photons and single phonons.

Link to the ERC project webpage: nqo.sdu.dk

Keywords of the ERC project:

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Towards the detection of the axion with the International Axion Observatory

The nature of the Dark Universe is an outstanding question in modern science, and is connected with our understanding of the reality at the most fundamental level. Despite the enormous success of the Standard Model (SM) of particle physics, a number of shortcomings of the theory and the fact that it does not account for the Dark Matter and Energy, prompt theorists to propose possible hypothetical extensions. Some of these extensions predict the existence of very-light and very-weakly-coupled axions (or axion-like particles, ALPs). Recent theoretical and phenomenological work is sharpening the physics case of these particles. They are now considered as very motivated portals for physics beyond the SM, and in particular as very plausible Dark Matter candidates. In addition, some intriguing astrophysical observations might be interpreted as hints for their existence.

The International Axion Observatory IAXO is one of the most ambitious proposals to find the axion. Its baseline configuration relies on the search for solar axions, but could also host relic axion detectors. IAXO will go well beyond current experiments’ sensitivity and will probe a large fraction of the -still unexplored- parameter space of the axion and ALPs. The scope of the present proposal encompasses the realization of a first complete intermediate experimental stage, BabyIAXO, including prototypes of the IAXO magnet and detection systems. It will already provide relevant physics outcome in the time-frame of the current grant, while preparing the ground for, and extending the physics reach of, the full IAXO. In particular, BabyIAXO will already be able to test a number of axion and ALP models that are invoked by the aforementioned astrophysical hints and therefore already at this stage there is potential for discovery. The detection of a new fundamental pseudoscalar - potentially solving the DM problem- would lead to a breakthrough in Particle Physics, Cosmology and Astrophysics.

Link to the ERC project webpage: gifna.unizar.es/iaxo

Keywords of the ERC project: axions; dark matter; low background detectors

Keywords that characterize the scientific profile of the potential visiting researcher/s: particle physics detectors; low background techniques; underground physics; time projection chambers; Micromegas;
Triggered by condensed matter, a new frontier recently emerged: Photonic Topological Insulators (PTIs). These are photonic structures where the transport of light is topologically protected: light propagates in a unidirectional manner without reflection, even in the presence of corners, defects, or disorder. The first step toward PTIs was the electromagnetic analogue of the quantum Hall effect, employing magnetic fields in gyrooptic media. Bringing the concepts of topological insulators into photonics required fundamentally different effects, eluding researchers until in 2013 we demonstrated the first PTI. That, along with experiments in silicon photonics and pioneering theory work, launched the field of Topological Photonics.

This proposal aims to explore the possibility of the “next big thing”, a fundamentally new concept, never suggested before in any context, with high potential impact on fundamentals and on lasers technology: we will explore the idea of the Topological Insulator Laser.

Topological Insulator Lasers are lasers where the lasing mode is topologically protected: light propagates around the cavity unaffected by disorder and defects. Based on our preliminary studies, we envision that by lasing in a topological mode, the interplay between the topology and gain will lead to a highly efficient laser, robust to defects and disorder, that lases in a single mode even at high gain values.

The road to achieve this goes against current knowledge: topological insulators are linear Hermitian closed systems, whereas the topological insulator laser is a non-Hermitian, highly nonlinear, open system.

Our study will be theoretical and experimental, starting at the fundamentals of topological transport in systems with gain, and we will take it all the way to experimentally demonstrate the concepts in several different platforms.

The idea of the Topological Insulator Laser is unique: success will mark a new milestone in optics and topological physics.

---

Link to the ERC project webpage:

Keywords of the ERC project: Photonic Topological Insulators, Photonics, localization, quantum optics

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Engineering and exploring anyonic quantum gases

This project enters the experimental investigation of anyonic quantum gases. We will study anyons – conjectured particles with a statistical exchange phase anywhere between 0 and π – in different many-body systems. This progress will be enabled by a unique approach of bringing together artificial gauge fields and quantum gas microscopes for ultracold atoms.

Specifically, we will implement the 1D anyon Hubbard model via a lattice shaking protocol that imprints density-dependent Peierls phases. By engineering the statistical exchange phase, we can continuously tune between bosons and fermions and explore a statistically-induced quantum phase transition. We will monitor the continuous fermionization via the build-up of Friedel oscillations. Using state-of-the-art cold atom technology, we will thus open the physics of anyons to experimental research and address open questions related to their fractional exclusion statistics.

Secondly, we will create fractional quantum Hall systems in rapidly rotating microtraps. Using the quantum gas microscope, we will i) control the optical potentials at a level which allows approaching the centrifugal limit and ii) use small atom numbers equal to the inserted angular momentum quantum number. The strongly-correlated ground states such as the Laughlin state can be identified via their characteristic density correlations. Of particular interest are the quasihole excitations, whose predicted anyonic exchange statistics have not been directly observed to date. We will probe and test their statistics via the characteristic counting sequence in the excitation spectrum. Furthermore, we will test ideas to transfer anyonic properties of the excitations to a second tracer species. This approach will enable us to both probe the fractional exclusion statistics of the excitations and to create a 2D anyonic quantum gas.

In the long run, these techniques open a path to also study non-Abelian anyons with ultracold atoms.

Link to the ERC project webpage: https://www1.physik.uni-hamburg.de/en/forschung/institute/ilp/forschung/sengstock/personen/weitenberg.html

Keywords of the ERC project: ultracold atoms, quantum simulation, topological matter, anyonic excitations

Keywords that characterize the scientific profile of the potential visiting researcher/s: ultracold atoms, topological matter, experiment, theory
Neutron-rich, EXotic, heavy nuclei produced in multi-nucleon Transfer reactions

The heaviest element which has been found in nature is uranium with 92 protons. So far, the elements up to atomic number 118 (oganesson) have been discovered in the laboratory. All transuranium elements are radioactive and their production rates decrease with increasing number of protons. An Island of Stability, where the nuclei have relatively long half-lives, is predicted at the neutron number 182 and, depending on the theoretical model, at the proton number 114, 120 or 126. Current experimental techniques do not allow to go so far to the neutron-rich side close to the Island of Stability.

The observation of gravitational waves as well as electromagnetic waves originating from a neutron star merger has been published on October 16, 2017 and is a first proof of the nucleosynthesis of heavy elements in the r-process. It still remains an open question if superheavy nuclei have been formed in our universe. To answer these questions, we need insight into the nuclear properties of the heaviest elements and how these properties evolve when one moves toward to the neutron-rich side on the nuclear chart.

In the NEXT project, I will set out to discover new, Neutron-rich, EXotic heavy nuclei using multi-nucleon Transfer reactions. I will measure their masses and, thus, pin down the ground state properties of these nuclei. These studies provide insight into the evolution of nuclear shells in the heavy element region. Furthermore, I will measure the fission half-lives of these isotopes. In order to realize the NEXT project, I will built a novel spectrometer, which is a combination of a solenoid separator and Multi-Reflection Time-of-Flight Mass Spectrometer.

The broad experience in heavy element research and mass measurements that I have acquired over the years, and the unique infrastructure at my home institute that houses the AGOR accelerator, makes it so that I am ideally placed to start and lead the NEXT project.

Link to the ERC project webpage:

Keywords of the ERC project: Multinucleon transfer reaction; neutron-rich nuclei, heavy elements, Multireflection Time-Of-Flight Mass Spectrometer MR-TOF MS, solenoid separator

Keywords that characterize the scientific profile of the potential visiting researcher/s: experimental nuclear physicist
**Strong Entanglement in Quantum many-body Theory**

This project addresses a frontier of modern quantum physics, entanglement in strongly correlated many-particle systems. At present, despite its importance for fundamental phenomena and potential applications, many-body entanglement is poorly understood theoretically and eludes experimental investigations. Three fundamental challenges are blocking further progress: there are infinitely many classes of many-body entangled states, the calculation of real-time quantum dynamics is inherently difficult, and the quantification of many-particle entanglement remains a hard experimental challenge.

StrEnQTh adopts a radically novel approach to force a breakthrough in each of these challenges, concentrating on specific targets motivated by next-generation AMO setups. 1. By designing a dedicated quantum resource theory, I will establish a novel framework for topological long-range entanglement. 2. By implementing crucial improvements on a tensor-network method, thermalization dynamics in gauge theories becomes tractable, especially hydrodynamization after heavy-ion collisions. 3. By exploiting the untapped potentials of time-reversing quantum dynamics and measuring high-order correlations, mixed-state entanglement becomes accessible. Further, by introducing a new paradigm of detection by dissipation, unequal-time correlators become available as a novel toolset for witnessing many-body entanglement.

To achieve these goals, StrEnQTh builds on (i) my expertise at the interface of quantum optics and information with quantum many-body theory; (ii) previous works and preliminary results that minimize risks; (iii) fruitful synergies between the goals; (iv) a high versatility of the developed methods.

The impact of this project will reach far beyond its immediate field. It will elucidate fundamental theoretical questions of relevance to strongly correlated matter at large, and it will deliver a new generation of detection tools that can find application in other platforms.

**Link to the ERC project webpage:**

**Keywords of the ERC project:** entanglement, topological order, cold atoms, gauge theories, quantum many-body physics, quantum dynamics

**Keywords that characterize the scientific profile of the potential visiting researcher/s:**
Precision Gravity: From the LHC to LISA

The nascent field of gravitational wave (GW) science will be an interdisciplinary subject, enriching different branches of physics, yet the associated computational challenges are enormous. Faithful theoretical templates are a compulsory ingredient for successful data analysis and reliable physical interpretation of the signals. This is critical, for instance, to study the equation of state of neutron stars, the nature of black holes, and binary formation channels. However, while current templates for compact binary sources may be sufficient for detection and crude parameter estimation, they are too coarse for precision physics with GW data. We then find ourselves in a situation in which, for key processes within empirical reach, theoretical uncertainties may dominate. To move forward, profiting the most from GW observations, more accurate waveforms will be needed.

I have played a pioneering role in the development and implementation of a new formalism, known as the ‘effective field theory approach’, which has been instrumental for the construction of the state-of-the-art GW template bank. The goal of my proposal is thus to redefine the frontiers of analytic understanding in gravity through the effective field theory framework. Even more ambitiously, to go beyond the current computational paradigm with powerful tools which have been crucial for ‘new-physics’ searches at the Large Hadron Collider. The impact of the high-accuracy calculations I propose to undertake will be immense: from probes of dynamical spacetime and strongly interacting matter, to the potential to discover exotic compact objects and ultra-light particles in nature. Furthermore, GW observations scan gravity in a regime which is otherwise unexplored. Consequently, the coming decade will tell whether Einstein's theory withstands precision scrutiny. In summary, my program will provide novel techniques and key results that will enable foundational investigations in physics through GW precision data.

Link to the ERC project webpage:

Keywords of the ERC project: Gravitational Waves, Effective Field Theory

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Yoctosecond imaging of QCD collectivity using jet observables

QCD is the only sector of the Standard Model where the exploration of the first levels of complexity, built from fundamental interactions at the quantum level, is experimentally feasible. An outstanding example is the thermalised state of QCD matter formed when heavy atomic nuclei are smashed in particle colliders. Systematic experimental studies, carried out in the last two decades, overwhelmingly support the picture of a deconfined state of matter, which behaves as a nearly perfect fluid, formed in a very short time, less than 5 yoctoseconds. The mechanism that so efficiently brings the initial out-of-equilibrium state into a thermalised system is, however, largely unknown. Most surprisingly, LHC experiments have found that collisions of small systems, i.e. proton-proton or proton-lead, seem to indicate the presence of a tiny drop of this fluid in events with a large number of produced particles. These systems have sizes of 1 fm or less, or time-scales of less than 3 ys. To add to the puzzle, jet quenching, the modifications of jet properties due to interactions with the medium, has not been observed in these small systems, while jet quenching and thermalisation are expected to be controlled by the same dynamics. Present experimental tools have limited sensitivity to the actual process of thermalisation. To solve these long-standing questions we propose, as a completely novel strategy, using jet observables to directly access the first yoctoseconds of the collision. This strategy needs developments well beyond the state-of-the-art in three subjects: i) novel theoretical descriptions of the initial stages of the collision — the first 5 ys; ii) jet quenching theory for yoctosecond precision, with new techniques to couple the jet to the surrounding matter and novel parton shower evolution; and iii) jet quenching tools for the 2020’s, where completely novel jet observables will be devised with a focus on determining the initial stages of the collision.

Link to the ERC project webpage:

Keywords of the ERC project:

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Discovery strategies for Dark Matter and new phenomena in hadronic signatures with the ATLAS detector at the Large Hadron Collider

The Standard Model of Particle Physics describes the fundamental components of ordinary matter and their interactions. Despite its success in predicting many experimental results, the Standard Model fails to account for a number of interesting phenomena. One phenomenon of particular interest is the large excess of unobservable (Dark) matter in the Universe. This excess cannot be explained by Standard Model particles. A compelling hypothesis is that Dark Matter is comprised of particles that can be produced in the proton-proton collisions from the Large Hadron Collider (LHC) at CERN.

Within this project, I will build a team of researchers at Lund University dedicated to searches for signals of the presence of Dark Matter particles. The discovery strategies employed seek the decays of particles that either mediate the interactions between Dark and Standard Model particles or are produced in association with Dark Matter. These new particles manifest in detectors as two, three, or four collimated jets of particles (hadronic jets).

The LHC will resume delivery of proton-proton collisions to the ATLAS detector in 2015. Searches for new, rare, low mass particles such as Dark Matter mediators have so far been hindered by constraints on the rates of data that can be stored. These constraints will be overcome through the implementation of a novel real-time data analysis technique and a new search signature, both introduced to ATLAS by this project. The coincidence of this project with the upcoming LHC runs and the software and hardware improvements within the ATLAS detector is a unique opportunity to increase the sensitivity to hadronically decaying new particles by a large margin with respect to any previous searches. The results of these searches will be interpreted within a comprehensive and coherent set of theoretical benchmarks, highlighting the strengths of collider experiments in the global quest for Dark Matter.

Link to the ERC project webpage: http://www.hep.lu.se/staff/doglioni/darkjets.html

Keywords of the ERC project: high energy physics, LHC, ATLAS, dark matter, dark sector, real time analysis, triggers

Keywords that characterize the scientific profile of the potential visiting researcher/s: high energy physics, LHC, ATLAS, dark matter, dark sector, real time analysis, triggers
Entanglement Generation in Universal Quantum Dynamics

A paradigm example of precise predictions in complex systems is the universal scaling of correlation functions close to phase transitions, with their associated critical exponents. The extension of this concept to time dependent problems has been studied in the classical regime as well as in the quantum regime. A clean experimental confirmation of this prediction in a quantum system as well as of its connection to non-local entanglement generation is the defined goal of this project.

The experimental system builds on atomic Bose-Einstein condensates with precisely controlled internal degrees of freedom. Their physics can be mapped onto extensively studied spin systems in the large-collective-spin limit. While the mean evolution of these large spins is well captured by classical descriptions, the detailed study of the fluctuations can reveal particle entanglement. The technology for such high-precision measurements has been pioneered by the PI, demonstrating entanglement in spin-squeezed as well as non-gaussian entangled states.

In this project one-dimensional gases will be realized allowing for the implementation of a spin system revealing a quantum phase transition. While the spatial spin-spin correlation functions can already be detected, the future experimental development concerns the implementation of non-demolition/weak measurements of the spin degree of freedom. This makes time-time and time-space correlation functions for the first time accessible, as a necessary prerequisite for the envisaged studies of universal dynamics out of equilibrium and the experimental confirmation of non-local entanglement. Observation of scale invariance in the then available full correlation landscape will allow the verification of the presence of a non-thermal fixed point.

The successful demonstration will lead to a paradigm shift in the description of quantum dynamics in complex systems and will also open up new routes for generating quantum resources for quantum metrology.

Link to the ERC project webpage:

Keywords of the ERC project:

Keywords that characterize the scientific profile of the potential visiting researcher/s:
How do extreme electromagnetic fields modify the dynamics of matter? Will quantum electrodynamics effects be important at the focus of an ultra intense laser? How are the magnetospheres of compact stellar remnants formed, and can we capture the physics of these environments in the laboratory? These are all longstanding questions with an overarching connection to extreme plasma physics.

Electron-positron pair plasmas are pervasive in all these scenarios. Highly nonlinear phenomena such as QED processes, magnetogenesis, radiation, field dynamics in complex geometries, and particle acceleration, are all linked with the collective dynamics of pair plasmas through mechanisms that remain poorly understood. Building on our state-of-the-art models, on the availability of enormous computational power, and on our recent transformative discoveries on ab initio modelling of plasmas under extreme conditions, the time is ripe to answer these questions in silico. InPairs aims to understand the multidimensional dynamics of electron-positron plasmas under extreme laboratory and astrophysical fields, to determine the signatures of the radiative processes on pair plasmas, and to identify the physics of the magnetospheres of compact stellar remnants, focusing on the electrodynamics of pulsars, that can be mimicked in laboratory experiments using ultra high intensity lasers and charged particle beams.

This proposal relies on massively parallel simulations to bridge the gap, for the first time, between the pair plasma creation mechanisms, the collective multidimensional microphysics, and their global dynamics in complex geometries associated with laboratory and astrophysical systems. Emphasis will be given to detectable signatures e.g. radiation and accelerated particles, with the ultimate goal of solving some of the central questions in extreme plasma physics, thus opening new connections between computational studies, laboratory experiments, and relativistic plasma astrophysics.

Link to the ERC project webpage: http://epp.ist.utl.pt

Keywords of the ERC project: Extreme plasma physics, plasma kinetic simulations, laser-plasma interactions, relativistic astrophysics, QED processes, ultra high intensity lasers

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Precision measurements to discover new scalar and vector particles

The Standard Model of particle physics successfully describes all known particles and their interactions. However, questions like the nature of dark matter or the hierarchy of masses and couplings of quarks and leptons remain to be understood. Hence, one searches for new phenomena that will lead to a superior theory that can explain these questions. All such theories introduce additional quantum corrections. Decay rates of processes which are strongly suppressed in the Standard Model are highly sensitive to these corrections. The LHCb experiment at CERN has recorded the world’s largest sample of beauty mesons. In the five years of this proposal, this sample will be enlarged by more than a factor of five. This sets an optimal environment for precision tests for new phenomena in strongly suppressed beauty decays.

This proposal aims to discover new scalar or vector particles in precision measurements of leptonic and semi-leptonic beauty decays. These new particles are not predicted by the Standard Model of particle physics, a potential discovery would mark the most important finding in High Energy Physics of the last decades. Some existing anomalies in flavour data can be interpreted as hints for the particles searched for in this proposal. Two classes of measurements are planned within this proposal: the complete scan of purely leptonic beauty decays which include flavour changing neutral current as well as lepton flavour violating modes. Lepton flavour universality is tested in loop decays through a novel inclusive strategy. All proposed measurements will advance the world’s knowledge significantly and have a large discovery potential.

Link to the ERC project webpage: https://www.e5.physik.tu-dortmund.de/albrecht/

Keywords of the ERC project: Particle Physics, LHC, Flavour, rare beauty decays

Keywords that characterize the scientific profile of the potential visiting researcher/s: Flavour
Neutrinoless double beta decay (0νββ) is considered the best potential resource to determine the absolute neutrino mass scale. Moreover, if observed, it will signal that the total lepton number is not conserved and neutrinos are Majorana particles. Presently, this physics case is one of the most important research “beyond the Standard Model” and might guide the way towards a Grand Unified Theory of fundamental interactions. Since the ββ decay process involves nuclei, its analysis necessarily implies nuclear structure issues. The 0νββ decay rate can be expressed as a product of independent factors: the phase-space factors, the nuclear matrix elements (NME) and a function of the masses of the neutrino species. Thus the knowledge of the NME can give information on the neutrino mass, if the 0νββ decay rate is measured. 

The novel idea of NURE is to use nuclear reactions of double charge-exchange (DCE) as a tool to determine the ββ NME. In DCE reactions and ββ decay, the initial and final nuclear states are the same and the transition operators have the same spin-isospin structure. Thus, even if the two processes are mediated by different interactions, the NME are connected and the determination of the DCE cross-sections can give crucial information on ββ matrix elements.

NURE plans to carry out a campaign of experiments using accelerated beams on different targets candidates for 0νββ decay. The DCE channel will be populated using (18O,18Ne) and (20Ne,20O) reactions by the innovative MAGNEX large acceptance spectrometer, which is unique in the world to measure very suppressed reaction channels at high resolution. The complete net involving the single charge-exchange and multi-step transfers characterized by the same initial and final nuclei will be also measured to study the reaction mechanism. The absolute cross-sections will be extracted. The comparison with microscopic state-of-the-art calculations will give access to the NMEs.
Novel structures in scattering amplitudes

This project focuses on developing quantum field theory methods and applying them to the phenomenology of elementary particles. At the Large Hadron Collider (LHC) our current best theoretical understanding of particle physics is being tested against experiment by measuring e.g. properties of the recently discovered Higgs boson. With run two of the LHC, currently underway, the experimental accuracy will further increase. Theoretical predictions matching the latter are urgently needed. Obtaining these requires extremely difficult calculations of scattering amplitudes and cross sections in quantum field theory, including calculations to correctly describe large contributions due to long-distance physics in the latter. Major obstacles in such computations are the large number of Feynman diagrams that are difficult to handle, even with the help of modern computers, and the computation of Feynman loop integrals. To address these issues, we will develop innovative methods that are inspired by new structures found in supersymmetric field theories. We will extend the scope of the differential equations method for computing Feynman integrals, and apply it to scattering processes that are needed for phenomenology, but too complicated to analyze using current methods. Our results will help measure fundamental parameters of Nature, such as, for example, couplings of the Higgs boson, with unprecedented precision. Moreover, by accurately predicting backgrounds from known physics, our results will also be invaluable for searches of new particles.

Link to the ERC project webpage:

Keywords of the ERC project: Scattering amplitudes, Collider Physics

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Many-body theory of antimatter interactions with atoms, molecules and condensed matter

The ability of positrons to annihilate with electrons, producing characteristic gamma rays, gives them important use in medicine via positron-emission tomography (PET), diagnostics of industrially-important materials, and in elucidating astrophysical phenomena. Moreover, the fundamental interactions of positrons and positronium (Ps) with atoms, molecules and condensed matter are currently under intensive study in numerous international laboratories, to illuminate collision phenomena and perform precision tests of fundamental laws. Proper interpretation and development of these costly and difficult experiments requires accurate calculations of low-energy positron and Ps interactions with normal matter. These systems, however, involve strong correlations, e.g., polarisation of the atom and virtual-Ps formation (where an atomic electron tunnels to the positron): they significantly effect positron- and Ps-atom/molecule interactions, e.g., enhancing annihilation rates by many orders of magnitude, and making the accurate description of these systems a challenging many-body problem. Current theoretical capability lags severely behind that of experiment. Major theoretical and computational developments are required to bridge the gap.

One powerful method, which accounts for the correlations in a natural, transparent and systematic way, is many-body theory (MBT). Building on my expertise in the field, I propose to develop new MBT to deliver unique and unrivalled capability in theory and computation of low-energy positron and Ps interactions with atoms, molecules, and condensed matter. The ambitious programme will provide the basic understanding required to interpret and develop the fundamental experiments, antimatter-based materials science techniques, and wider technologies, e.g., (PET), and more broadly, potentially revolutionary and generally applicable computational methodologies that promise to define a new level of high-precision in atomic-MBT calculations.

Link to the ERC project webpage:

Keywords of the ERC project: many-body theory for atoms, molecules and condensed matter, antimatter, positrons, positronium, scattering, annihilation, diagrammatic monte carlo,

Keywords that characterize the scientific profile of the potential visiting researcher/s: Theoretical atomic physics, many-body theory, condensed matter, quantum field theory
Anderson Localization of Light by Cold Atoms

I propose to use large clouds of cold Ytterbium atoms to observe Anderson localization of light in three dimensions, which has challenged theoreticians and experimentalists for many decades. After the prediction by Anderson of a disorder-induced conductor to insulator transition for electrons, light has been proposed as ideal non-interacting waves to explore coherent transport properties in the absence of interactions. The development in experiments and theory over the past several years have shown a route towards the experimental realization of this phase transition.

Previous studies on Anderson localization of light using semiconductor powders or dielectric particles have shown that intrinsic material properties, such as absorption or inelastic scattering of light, need to be taken into account in the interpretation of experimental signatures of Anderson localization. Laser-cooled clouds of atoms avoid the problems of samples used so far to study Anderson localization of light. Ab initio theoretical models, available for cold Ytterbium atoms, have shown that the mere high spatial density of the scattering sample is not sufficient to allow for Anderson localization of photons in three dimensions, but that an additional magnetic field or additional disorder on the level shifts can induce a phase transition in three dimensions.

The role of disorder in atom-light interactions has important consequences for the next generation of high precision atomic clocks and quantum memories. By connecting the mesoscopic physics approach to quantum optics and cooperative scattering, this project will allow better control of cold atoms as building blocks of future quantum technologies. Time-resolved transport experiments will connect super- and subradiant assisted transmission with the extended and localized eigenstates of the system. Having pioneered studies on weak localization and cooperative scattering enables me to diagnostic strong localization of light by cold atoms.

Link to the ERC project webpage:

Keywords of the ERC project: Cold Atoms, Anderson Localization

Keywords that characterize the scientific profile of the potential visiting researcher/s: experimental expertise in cold atoms, numerical expertise on Anderson localization
Coherent Back-Lasing from Atmospheric Insects

I received the prestigious Inaba award by the lidar community for advancing lidar entomology. Our Scheimpflug lidar can be implemented at 1% of the conventional cost and weight. It allows atmospheric observation with unprecedented sensitivity and spatiotemporal resolution. The kHz sampling rates can exceed the round-trip time of the light and reveal the modulation spectra for classifying free flying insect species over ground. The method has infinite focal depth and efficiently profiles sparse organisms in the airspace with 100000 observations per day. This tool is of key importance for tackling challenges related to pollinator diversity, agricultural pests and pesticides and malaria disease vectors. As in radar entomology, in situ lidar monitoring apparently has inevitable limitations: 1) Detection limit deteriorate with range, and far observations are biased towards larger organisms, 2) It takes several wing-beats, and therefore time, beam-width and energy to retrieve a modulation spectrum for classifying species. I propose to remove range biasing and classify insects by a microsecond flash of light. Back-lasing in air has been a dream of physicists for half a century. I now intend to capture specular reflexes from flat wing membranes. When the surface normal coincides with the lidar transect, collimated back-propagating laser light is accomplished. This flash of light is spectrally fringed and can report on the membrane thickness for target classification purpose. This project has three ambitious milestones of increasing challenge with in situ campaigns:

A) Polarimetric kHz lidar: Verification of specular flashes, investigation of range dependence, properties and likelihood.
C) Farfetched flatness: I will enhance apparent surface roughness and collimated back-scatter from diffuse specimen by infrared methods.

Link to the ERC project webpage:

Keywords of the ERC project: Lidar entomology biophotonics

Keywords that characterize the scientific profile of the potential visiting researcher/s: Atmospheric lidar thinfilm biophotonics entomology ecology
INhomogenieties and fluctuations in quantum CoHEnt matter Phases by ultrafast optical Tomography

Standard time domain experiments measure the time evolution of the reflected/transmitted mean number of photons in the probe pulses. The evolution of the response of a material is typically averaged over the illuminated area as well as over many pump and probe measurements repeated stroboscopically. The aim of this project is to extend time domain optical spectroscopy beyond mean photon number measurements by performing a full Time Resolved Quantum State Reconstruction (TRQSR) of the probe pulses as a function of the pump and probe delay. The nature of the light matter interaction and the transient light-induced states of matter will be imprinted into the probe quantum state after the interaction with the material and can be uncovered with unprecedented detail with this new approach to time domain studies. TRQSR will be implemented by combining pump and probe experiments resolving single light pulses with balanced homodyne detection quantum tomography in the pulsed regime. We will apply and exploit the unique capabilities of TRQSR to address two different unresolved problems in condensed matter. Firstly, we will investigate the coherent and squeezed nature of low energy photo-induced vibrational states. We will use TRQSR with probe pulses shorter than the phonon timescale to interrogate the time evolution of the vibrational state induced by the pump pulse. Secondly, we will address inhomogeneities in photo-induced phase transformations. With TRQSR we can perform time domain measurements with a very small photon number per pulse which will give information on the interaction between the material (as prepared by the pump pulse) and individual photons. In this limit, TRQSR will allow us to retrieve rich statistics. While the average will deliver the information of a standard pump and probe experiment, higher order moments will give information on the time evolution of spatial inhomogeneities in the transient state.

Link to the ERC project webpage: www.inceptproject.eu

Keywords of the ERC project: Ultrafast, quantum, complex materials

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Dissecting active matter: Microscopic origins of macroscopic actomyosin activity

Biological motion and forces originate from mechanically active proteins operating at the nanometer scale. These individual active elements interact through the surrounding cellular medium, collectively generating structures spanning tens of micrometers whose mechanical properties are perfectly tuned to their fundamentally out-of-equilibrium biological function. While both individual proteins and the resulting cellular behaviors are well characterized, understanding the relationship between these two scales remains a major challenge in both physics and cell biology.

We will bridge this gap through multiscale models of the emergence of active material properties in the experimentally well-characterized actin cytoskeleton. We will thus investigate unexplored, strongly interacting nonequilibrium regimes. We will develop a complete framework for cytoskeletal activity by separately studying all three fundamental processes driving it out of equilibrium: actin filament assembly and disassembly, force exertion by branched actin networks, and the action of molecular motors. We will then recombine these approaches into a unified understanding of complex cell motility processes.

To tackle the cytoskeleton’s disordered geometry and many-body interactions, we will design new nonequilibrium self consistent methods in statistical mechanics and elasticity theory. Our findings will be validated through simulations and close experimental collaborations.

Our work will break new ground in both biology and physics. In the context of biology, it will establish a new framework to understand how the cell controls its architecture and mechanics through biochemical regulation. On the physics side, it will set up new paradigms for the emergence of original out-of-equilibrium collective behaviors in an experimentally well-characterized system, addressing the foundations of existing macroscopic "active matter" approaches.

Link to the ERC project webpage: https://cordis.europa.eu/project/rcn/199508/factsheet/en
Keywords of the ERC project: http://lptms.u-psud.fr/membres/mlenz/
Keywords that characterize the scientific profile of the potential visiting researcher/s:
Electron-lattice-spin correlations and many-body phenomena in 2D semiconductors and related heterostructures

Two-dimensional crystalline materials exhibit exceptional physical properties and offer fascinating potential as fundamental building blocks for future two-dimensional electronic and optoelectronic devices. Transition metal dichalcogenides (TMDCs) are of particular interest as they show a variety of many-body phenomena and correlation effects. Key properties are: i) additional internal degrees of freedom of the electrons, described as valley pseudospin and layer pseudospin, ii) electronic many-body effects like strongly-bound excitons and trions, and iii) electron-lattice correlations like polarons. While these phenomena represent intriguing fundamental solid state physics problems, they are of great practical importance in view of the envisioned nanoscopic devices based on two-dimensional materials.

The experimental research project FLATLAND will address the exotic spin-valley-layer correlations in few-layer thick TMDC crystals and TMDC-based heterostructures. The latter comprise other 2D materials, organic crystals, metals and phase change materials as second constituent. Microscopic coupling and correlation effects, both within pure materials as well as across the interface of heterostructures, will be accessed by time- and angle-resolved extreme ultraviolet-photoelectron spectroscopy, femtosecond electron diffraction, and time-resolved optical spectroscopies. The project promises unprecedented insight into the microscopic coupling mechanisms governing the performance of van der Waals-bonded devices.

**Link to the ERC project webpage:** [https://pc.fhi-berlin.mpg.de/sesd/](https://pc.fhi-berlin.mpg.de/sesd/)

**Keywords of the ERC project:** 2D materials, ultrafast dynamics

**Keywords that characterize the scientific profile of the potential visiting researcher/s:**
Frontiers in Phononics: Parity-Time Symmetric Phononic Metamaterials

The boost experienced by acoustic and elastic (phononic) metamaterial research during the past years has been driven by the ability to sculpture the flow of sound waves at will. Thanks to recent developments at the frontiers of phononic metamaterials it can be identified that active phononic control is at the cutting edge of the current research on phononic metamaterials. Introducing piezoelectric semiconductors as a material platform to discover new avenues in wave physics will have the potential to open horizons of opportunities in science of acoustic wave control. Electrically biased piezoelectric semiconductors are non-reciprocal by nature, produce mechanical gain and are highly tunable.

The aim is to explore novel properties of sound and the ability to design Parity-Time (PT) symmetric systems that define a consistent unitary extension of quantum mechanics. Through cunningly contrived piezoelectric media sculpturing balanced loss and gain units, these structures have neither parity symmetry nor time-reversal symmetry, but are nevertheless symmetric in the product of both. PHONOMETA is inspired and driven by these common notions of quantum mechanics that I wish to translate into classical acoustics with unprecedented knowledge for the case of sound.

I expect that the successful realization of PHONOMETA has the potential to revolutionize acoustics in our daily life. Environmental and ambient noise stem from multiple scattering and reflections of sound in our surrounding. The extraordinary properties of PT acoustic metamaterials have the groundbreaking potential to push forward physical acoustics with new paradigms to design tunable diode-like behaviour with zero reflections, which is applicable for noise pollution mitigation. Also I anticipate to impact the progress on invisibility cloaks by introducing PT symmetry based acoustic stealth coatings for hiding submarines.

Link to the ERC project webpage: phonometa.eu

Keywords of the ERC project: Topological insulators, metamaterials

Keywords that characterize the scientific profile of the potential visiting researcher/s: Topological insulators, metamaterials
The explanation for the distinct low temperature behavior of amorphous solids (glasses) is a long-standing open question. Specific puzzles include the nature of the low energy excitations (LEEs) that are responsible for their low temperature thermal and mechanical behavior and the origin of the remarkable universality of their low temperature mechanical dissipation. The phenomenological tunneling model proposes that the LEEs are atomic-scale tunneling two level systems (TLSs) and successfully explains much of the low temperature behavior of glass, but not the universality. Recently, individual TLSs were probed in the amorphous tunnel junction of superconducting qubits, but such dielectric measurements might not access the LEEs responsible for universality. In contrast, I propose to search for individual TLSs using purely mechanical measurements. The glass samples containing the TLSs will be nanomechanical resonators, and the strain coupling between the mechanical mode and the TLS will be used to control the quantum state of the latter. This strain coupling allows coherent state transfer between the mechanical mode and the TLS. Identifying individual TLSs and controlling their quantum state in this manner will demonstrate that the LEEs responsible for the characteristic low temperature properties of glass are indeed TLSs. Furthermore, these measurements will reveal the characteristics of individual TLSs and their interactions with their environment, in contrast to bulk measurements in which, according to the model, the effects of many TLSs are averaged. The results of the proposed study may therefore strongly support the tunneling model. This would require reconsideration of potential explanations for universality which are thought to be inconsistent with the existence of TLSs. Alternatively, if the hypothesized TLSs are absent, then the tunneling model must be replaced by a new interpretation of the low temperature properties of glass.

Link to the ERC project webpage: http://uni-glass.eu/

Keywords of the ERC project: nanomechanics, optomechanics, quantum regime, microkelvin, amorphous solids

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Modification of Molecular structure Under Strong Coupling to confined Light modES

Understanding and controlling the properties of matter is one of the overarching goals of modern science. A powerful way to achieve this is by using light, usually in the form of intense laser beams. However, modern advances in nanophotonics allow us to confine light modes so strongly that their effect on matter is felt even when no external fields are present. In this regime of “strong coupling” or “vacuum Rabi splitting”, the fundamental excitations of the coupled system are hybrid light-matter states which combine the properties of both constituents, so-called polaritons. Little attention has been paid to the fact that strong coupling can also affect internal structure, such as nuclear motion in molecules. First experimental indications for this effect have been found, but current theory cannot explain or predict such changes. We will thus develop theoretical methods that can treat the modification of molecular structure under strong coupling to confined light modes. This will require advances in the microscopic description of the molecules under strong coupling by explicitly including their rovibrational degrees of freedom, as well as techniques to incorporate the influence of these modes in the macroscopic setting of collective strong coupling. In order to achieve this, we will adapt well-known techniques from quantum chemistry and combine them with the concepts of polariton physics. We will investigate what level of control can be gained through this approach, and whether confined light modes could act as a “photonic catalyst” to control molecular dynamics without requiring an active ingredient. This could present a novel tool to control photochemical reactions that are of paramount importance in the biological mechanisms of vision and photosynthesis, and hold great interest for use in memories, photoswitching devices, light-driven actuators, or solar energy storage. Consequently, this work could have wide-ranging impact on many different fields of science.

Link to the ERC project webpage: https://mmuscles.eu

Keywords of the ERC project: Polaritonic chemistry, molecular polaritonics, quantum nanophotonics

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Understanding the speed limits of magnetism

While the origin of magnetic order in condensed matter is in the exchange and spin-orbit interactions, with time scales in the subpicosecond ranges, it has been long believed that magnetism could only be manipulated at nanosecond rates, exploiting dipolar interactions with external magnetic fields. However, in the past decade researchers have been able to observe ultrafast magnetic dynamics at its intrinsic time scales without the need for magnetic fields, thus revolutionising the view on the speed limits of magnetism. Despite many achievements in ultrafast magnetism, the understanding of the fundamental physics that allows for the ultrafast dissipation of angular momentum is still only partial, hampered by the lack of experimental techniques suited to fully explore these phenomena. However, the recent appearance of two new types of coherent radiation, single-cycle THz pulses and x-rays generated at free electron lasers (FELs), has provided researchers access to a whole new set of capabilities to tackle this challenge. This proposal suggests using these techniques to achieve an encompassing view of ultrafast magnetic dynamics in metallic ferromagnets, via the following three research objectives: (a) to reveal ultrafast dynamics driven by strong THz radiation in several magnetic systems using table-top femtosecond lasers; (b) to unravel the contribution of lattice dynamics to ultrafast demagnetization in different magnetic materials using the x-rays produced at FELs and (c) to directly image ultrafast spin currents by creating femtosecond movies with nanometre resolution. The proposed experiments are challenging and explore unchartered territories, but if successful, they will advance the understanding of the speed limits of magnetism, at the time scales of the exchange and spin-orbit interactions. They will also open up for future investigations of ultrafast magnetic phenomena in materials with large electronic correlations or spin-orbit coupling.

Link to the ERC project webpage: www.magnetic-speed-limit.eu

Keywords of the ERC project: ultrafast magnetism, terahertz, x-ray free electron lasers

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Microstructured Topological Materials: A novel route towards topological electronics

Topological semi-metals such as Cd3As2 or TaAs are characterized by two bands crossing at isolated points in momentum space and a linear electronic dispersion around these crossing points. This linear dispersion can be mapped onto the Dirac- or Weyl-Hamiltonian, describing relativistic massless fermions, and thus relativistic phenomena from high-energy physics may appear in these materials. For example, the chirality, $\chi=\pm1$, is a conserved quantity for massless fermions, separating the electrons into two distinct chiral species. A new class of topological electronics has been proposed based on chirality imbalance and chiral currents taking the role of charge imbalance and charge currents in electronics. Such devices promise technological advances in speed, energy efficiency, and quantum coherent processes at elevated temperatures.

We will research the basic physical phenomena on which topological electronics is based: 1) The ability to interact electrically with the chiral states in a topological semi-metal is an essential prerequisite for their application. We will investigate whether currents in the Fermi arc surface states can be induced by charge currents and selectively detected by voltage measurements. 2) Weyl materials are more robust against defects and therefore of interest for industrial fabrication. We will experimentally test this topological protection in high-field transport experiments in a wide range of Weyl materials. 3) Recently, topological processes leading to fast, tuneable and efficient voltage inversion were predicted. We will investigate the phenomenon, fabricate and characterize such inverters, and assess their performance. MiTopMat thus aims to build the first prototype of a topological voltage inverter.

These goals are challenging but achievable: MiTopMat’s research plan is based on Focused Ion Beam microfabrication, which we have successfully shown to be a promising route to fabricate chiral devices.

Link to the ERC project webpage: https://www.epfl.ch/labs/qmat/

Keywords of the ERC project: topological semimetal; high magnetic fields; Focused Ion Beam; electrical transport

Keywords that characterize the scientific profile of the potential visiting researcher/s:
New mechanisms and materials for odd-frequency superconductivity

Odd-frequency superconductivity is a very unique superconducting state that is odd in time or, equivalently, frequency, which is opposite to the ordinary behavior of superconductivity. It has been realized to be the absolute key to understand the surprising physics of superconductor-ferromagnet (SF) structures and has also enabled the whole emerging field of superconducting spintronics. This project will discover and explore entirely new mechanisms and materials for odd-frequency superconductivity, to both generate a much deeper understanding of superconductivity and open for entirely new functionalities. Importantly, it will generalize and apply my initial discoveries of two new odd-frequency mechanisms, present in bulk multiband superconductors and in hybrid structures between topological insulators and conventional superconductors, respectively. In both cases odd-frequency superconductivity is generated without any need for ferromagnets or interfaces, completely different from the situation in SF structures. The result will be a significant expansion of the concept and importance of odd-frequency superconductivity to a very wide class of materials, ranging from multiband, bilayer, and nanoscale superconductors to topological superconductors. The project will also establish the connection between topology and odd-frequency pairing, which needs to be addressed in order to understand topological superconductors, as well as incorporate new materials and functionality into traditional SF structures. To achieve these goals the project will develop a novel methodological framework for large-scale and fully quantum mechanical studies with atomic level resolution, solving self-consistently for the superconducting state and incorporating quantum transport calculations.

Link to the ERC project webpage: http://materials-theory.physics.uu.se/blackschaffer/

Keywords of the ERC project:

Keywords that characterize the scientific profile of the potential visiting researcher/s:
The main goal of this theory project is to propose engineered topological phases emerging only in strongly interacting systems and to identify the most feasible systems for experimental implementation. First, we will focus on setups hosting topological states localized at domain walls in one-dimensional channels such as parafermions, which are a new class of non-Abelian anyons and most promising candidates for topological quantum computing schemes. Second, in the framework of weakly coupled wires and planes, we will develop schemes for novel fractional topological phases in two- and three-dimensional interacting systems. To achieve these two goals, my team will identify necessary ingredients such as strong electron-electron interactions, helical magnetic order, or crossed Andreev proximity-induced superconductivity and address each of them separately. Later, we combine them to lead us to the desired topological phases and states. On our way to the main goal, as test cases, we will also study non-interacting analogies of the proposed effects such as Majorana fermions and integer topological insulators and pay close attention to the rapid experimental progress to come up with the most feasible proposals. We will study transport properties, scanning tunneling and atomic force microscopy. Especially for systems driven out of equilibrium, we will develop a Floquet-Luttinger liquid technique. We will explore the stability of engineered topological phases, error rates of topological qubits based on them, and computation schemes allowing for a set of universal qubit gates. We will strive to find a reasonable balance between topological stability and experimental feasibility of setups. Our main theoretical tools are Luttinger liquid techniques (bosonization and renormalization group), Green functions, Floquet formalism, and numerical simulations in non-interacting test models.
Open dynamics of interacting and disordered quantum systems

This research proposal focuses on the open quantum system dynamics of disordered and interacting many-body systems coupled to external baths. The dynamics of systems which contain both disorder and interactions are currently under intense theoretical investigation in condensed matter physics due to the discovery of a new phase of matter known as many-body localization. With the experimental realization of such systems in mind, this proposal addresses an essential issue which is to understand how coupling to external degrees of freedom influences dynamics. These systems are intrinsically complex and lie beyond the unitary closed system paradigm, so the research proposed here contains interdisciplinary methodology beyond the mainstream in condensed matter physics ranging from quantum information to quantum optics. The project has three principal objectives each of which would represent a major contribution to the field:

O1. To describe the dynamics of interacting, disordered many-body systems when coupled to external baths.
O2. To perform a full characterization of spin and energy transport in their non-equilibrium steady state.
O3. To explore the system capabilities as steady state thermal machine from a systematic microscopic perspective.

This will be the first comprehensive study of the open system phenomenology of disordered interacting many-body systems. It will also allow for the systematic study of energy and spin transport and the exploration of the potential of these systems as steady state thermal machines. In order to successfully carry out the work proposed here, the applicant will build a world class team at Trinity College Dublin. Due to his track record and interdisciplinary background in many-body physics, quantum information and statistical mechanics combined with his personal drive and ambition the applicant is in a formidable position to successfully undertake this task with the platform provided by this ERC Starting Grant.

Link to the ERC project webpage: https://www.tcd.ie/Physics/research/groups/quSys/research/

Keywords of the ERC project: Disorder, quantum transport, quantum thermodynamics, open quantum systems

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Harvesting dark plasmons for surface-enhanced Raman scattering

Metal nanostructures show pronounced electromagnetic resonances that arise from localized surface plasmons. These collective oscillations of free electrons in the metal give rise to confined electromagnetic near fields. Surface-enhanced spectroscopy exploits the near-field intensity to enhance the optical response of nanomaterials by many orders of magnitude.

Plasmons are classified as bright and dark depending on their interaction with far-field radiation. Bright modes are dipole-allowed excitations that absorb and scatter light. Dark modes are resonances of the electromagnetic near field only that do not couple to propagating modes. The suppressed photon emission of dark plasmons makes their resonances spectrally narrow and intense, which is highly desirable for enhanced spectroscopy as well as storing and transporting electromagnetic energy in nanostructures. The suppressed absorption, however, prevents us from routinely exploiting dark modes in nanoplasmonic systems.

I propose using spatially patterned light beams to excite dark plasmons with far-field radiation. By this I mean a beam profile with varying polarization and intensity that will be matched to the dark electromagnetic eigenmode. My approach activates the excitation of dark modes, while their radiative decay remains suppressed. I will show how to harvest dark modes for surface-enhanced Raman scattering providing superior intensity and an enhancement that is tailored to a specific vibration. Another feature of dark modes is their strong coupling to the vibrations of nanostructures. I will use this to amplify vibrational modes and, ultimately, induce phonon lasing.

The proposed research aims at an enabling technology that unlocks a novel range of nanoplasmonic properties. It will put dark plasmons on par with the well-recognized bright modes to be used in fundamental science and for applications in analytics, optoelectronic, and nanoimaging.

Link to the ERC project webpage:

Keywords of the ERC project: nanoplasmonics, surface-enhanced spectroscopy, structured light

Keywords that characterize the scientific profile of the potential visiting researcher/s: quantum optics in materials, nanomaterials, optical spectroscopy, structured light
Multi-scale mechanics of dynamic leukocyte adhesion

Leukocytes, white blood cells, patrol the vascular wall of our vessels in search of sites of inflammation. In the so-called leukocyte adhesion cascade, leukocytes flowing at high velocities (up to mm/s) impact the vessel wall, roll at μm/s, and finally migrate at nm/s to the site of inflammation. They are thus subjected to mechanical forces from sub-msec to several minutes. Complete understanding of the physical processes behind leukocyte adhesion requires an approach over multiple length and time scales, from single protein molecules to the whole cell. This is far from being established due, in part, to the lack of techniques covering the wide range of length and time scales involved. We have recently implemented high-speed atomic force microscopy (HS-AFM) to perform force spectroscopy measurements on biological samples with microsec time resolution. The novel acoustic force spectroscopy (AFS) traps hundreds of particles in parallel allowing hours-long measurements on single molecules.

MechaDynA proposes to develop and apply these two novel nanotools to allow force measurements on living cells with the goal of obtaining a complete, multi-scale picture of the physics behind the leukocyte adhesion cascade over the widest dynamic range (μs-min). This will require development of HS-AFM technology and coupling with advanced optical microscopy. We will probe the binding strength of single adhesion complexes, and membrane and cytoskeleton mechanics at physiologically relevant time scales not explored so far. Technologically, it will establish HS-AFM and AFS as force measurement tools for living cells covering the widest temporal range. This will open the door to unexplored physical phenomena in cell biology, biological physics and soft condensed matter. Biomedically, the expected outcomes will provide a mechanistic description of the physical phenomena in leukocyte immune response that may lead to better diagnosis and therapeutics.

Link to the ERC project webpage:

Keywords of the ERC project: high-speed atomic force microscopy, single molecule, cell mechanics, protein mechanics, cell adhesion, force spectroscopy, biophysics, soft matter

Keywords that characterize the scientific profile of the potential visiting researcher/s: theoretical physics, molecular dynamics simulations, cell biologist, biophysics, soft matter
Thermal imaging of nano and atomic-scale dissipation in quantum states of matter

Energy dissipation is a fundamental process governing the dynamics of physical, chemical and biological systems and is of major importance in condensed matter physics where scattering, loss of quantum information, and even breakdown of topological protection are deeply linked to intricate details of how and where the dissipation occurs. But despite its vital importance, dissipation is currently not a readily measurable microscopic quantity. The aim of this proposal is to launch a new discipline of nanoscale dissipation imaging and spectroscopy and to apply it to study of quantum systems and novel states of matter. The proposed scanning thermal microscopy will be revolutionary in three aspects: the first-ever cryogenic thermal imaging; improvement of thermal sensitivity by five orders of magnitude over the state of the art; and imaging and spectroscopy of dissipation of single atomic defects. We will develop a superconducting quantum interference nano-thermometer on the apex of a sharp tip which will provide non-contact non-invasive low-temperature scanning thermal microscopy with unprecedented target sensitivity of 100 nK/Hz1/2 at 4 K. These advances will enable hitherto impossible direct thermal imaging of the most elemental processes such as phonon emission from a single atomic defect due to inelastic electron scattering, relaxation mechanisms in topological surface and edge states, and variation in dissipation in individual quantum dots due to single electron changes in their occupation. We will utilize this trailblazing tool to uncover nanoscale processes that lead to energy dissipation in novel systems including resonant quasi-bound edge states in graphene, helical surface states in topological insulators, and chiral anomaly in Weyl semimetals, and to provide groundbreaking insight into nonlocal dissipation and transport properties in mesoscopic systems and in 2D topological states of matter including quantum Hall, quantum anomalous Hall, and quantum spin Hall.
High resolution X-ray detectors based on nanowire arrays

In this project I will develop ultra-high resolution X-ray detectors based on semiconductor nanowires, whose spatial resolution will be radically better than the current state of the art. In X-ray detectors the primary X-ray absorption induces a cascade of secondary electrons and photons which are measured at the front or back of the detector, but during the long transport to the point of detection these can spread orthogonally to the optical axis. This limits the resolution in present bulk detectors.

My novel concept is to create a nanostructured detector based on an array of semiconductor nanowires, which will confine and physically prevent spreading of the secondary electrons and photons. In a nanowire array, the pixel size is the diameter of the nanowire, which can be as low as 10 nm, while the nanowires can be as long as the X-ray absorption length. The very high aspect ratio of nanowires allows detectors with simultaneously very high spatial resolution and sensitivity. I will investigate both direct detectors and scintillators, in which the secondary electrons and photons are detected, respectively.

The objective is to create detectors based on arrays of 10 nm-diameter nanowires. Time- and temperature resolved measurements will be used to improve understanding of the X-ray physics in these nanodevices, with strong quantum confinement of electrons and phonons and high surface to volume ratio. I will test the detectors within an imaging project targeting the neural connectome, and compare the nanowire detectors with commercial ones. This novel detector concept could revolutionize high-resolution imaging of samples on the nanoscale, maintaining the unique ability of X-rays to study samples in realistic conditions: DNA within live cells, the strained channel in single operational transistors or individual nanoparticles in a charging battery. High resolution detectors could also be employed in X-ray spectroscopy and diffraction.

Link to the ERC project webpage: http://www.sljus.lu.se/staff/jesper-wallentin/

Keywords of the ERC project: x-ray, nanowire, perovskite

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Exploiting Energy Flow in Plasmonic-Catalytic Colloids

The aim of CATALIGHT is to use sunlight as a source of energy in order to trigger chemical reactions by harvesting photons with plasmonic nanoparticles and channelling the energy into catalytic materials. Plasmonic-catalytic devices would allow efficient harvest, transport, and injection of solar energy into molecules. To achieve this, imaging the energy flow at the nanoscale will be crucial for establishing the true potential of plasmonics, both in the context of yielding fundamental knowledge about the light-into-chemical energy conversion processes, and for moving from active towards efficient reactive devices within nanoscale environments.

CATALIGHT has roots in three underlying components, making this project an interwoven effort to break new grounds in a crucial field for the further development of nanoscale energy manipulation: A) Super-resolution imaging of the energy-flow at the nanoscale – with a view to unravel the most efficient mechanisms to guide solar energy into catalytic materials using plasmonic structures as photon harvesters. B) Scaling-up this process through the fabrication of hierarchical photocatalytic colloids – using image-learning for the design of colloidal sources for energy manipulation. C) Light-into-chemical energy conversion – boosting efficiencies in environmental and industrial catalytic processes using tailored photocatalysts.

The outcomes of this project will not only yield a substantial amount of fundamental knowledge in these crucial areas for the further development of the field, but also provide directly exploitable results for the applied sciences, particularly photocatalysis and fuel cells.

Link to the ERC project webpage:

Keywords of the ERC project: Photocatalysis, Electrocatalysis, Plasmonics, Photonics, Super-resolution, Catalysis, Nanoparticles

Keywords that characterize the scientific profile of the potential visiting researcher/s: Catalysis, Optics, Nanomaterials, Electrochemistry, Photonics, Plasmonics, Nanoparticles
In this project I propose to take advantage of the enormous potential created by the recent material science revolution based on two-dimensional (2D) layered materials, by bringing it to the arena of nanoscale heat transport, where heat transport occurs on ultrafast timescales. This opens up a new research field of controllable ultrafast heat transport in layered materials. In particular, I will take advantage of the myriad of possibilities for miniature material and device design, with unprecedented controllability and versatility, offered by Van der Waals (VdW) heterostructures – stacks of different layered materials assembled on top of each other – and 1D systems of layered materials.

Specifically, I will introduce novel device geometries based on VdW heterostructures for passively and actively controlling phonon modes and thermal transport. This will be measured mainly using time-domain thermoreflectance measurements. I will also develop novel time-resolved measurement techniques to follow heat spreading and coupling between different heat carriers: light, phonons, and electrons. These techniques will be mainly based on time-resolved infrared/Raman spectroscopy and photocurrent scanning microscopy. Moreover, I will study one-dimensional layered materials and assess their thermoelectric properties using electrical measurements. And finally, I will combine these results into hybrid devices with a photoactive layer, in order to demonstrate how phonon control allows for tuning of electrical and optoelectronic properties.

The results of this project will have an impact on the major research fields of phononics, electronics and photonics, revealing novel physical phenomena. Additionally, the results are likely to be useful towards applications such as thermal management, thermoelectrics, photovoltaics and photodetection.

**Link to the ERC project webpage:**

**Keywords of the ERC project:** 2d materials, heat transport, ultrafast, optoelectronics

**Keywords that characterize the scientific profile of the potential visiting researcher/s:** nonlinear optics, thermal transport
3D Piezoresponse X-ray Microscopy

Polar materials, such as piezoelectrics and ferroelectrics are essential to our modern life, yet they are mostly developed by trial-and-error. Their properties overwhelmingly depend on the defects within them, the majority of which are hidden in the bulk. The road to better materials is via mapping these defects, but our best tool for it – piezoresponse force microscopy (PFM) – is limited to surfaces. 3D-PXM aims to revolutionize our understanding by measuring the local structure-property correlations around individual defects buried deep in the bulk.

This is a completely new kind of microscopy enabling 3D maps of local strain and polarization (i.e. piezoresponse) with 10 nm resolution in mm-sized samples. It is novel, multi-scale and fast enough to capture defect dynamics in real time. Uniquely, it is a full-field method that uses a synthetic-aperture approach to improve both resolution and recover the image phase. This phase is then quantitatively correlated to local polarization and strain via a forward model. 3D-PXM combines advances in X-Ray optics, phase recovery and data analysis to create something transformative. In principle, it can achieve spatial resolution comparable to the best coherent X-Ray microscopy methods while being faster, used on larger samples, and without risk of radiation damage.

For the first time, this opens the door to solving how defects influence bulk properties under real-life conditions. 3D-PXM focuses on three types of defects prevalent in polar materials: grain boundaries, dislocations and polar nanoregions. Individually they address major gaps in the state-of-the-art, while together making great strides towards fully understanding defects. This understanding is expected to inform a new generation of multi-scale models that can account for a material’s full heterogeneity. These models are the first step towards abandoning our tradition of trial-and-error, and with this comes the potential for a new era of polar materials.
Simulated Majorana states

Quantum computation using topologically protected Majorana bound states is a promising direction towards scalable quantum architectures due to their inherent noise immunity provided by the nonlocal storage of quantum information. Thus far, Majorana states have mostly been investigated in superconductor-semiconductor heterostructures which rely on induced superconductivity in a quasi-one-dimensional conductor. However, despite tremendous efforts in material development, these devices are still limited by uncontrolled local fluctuations due to disorder and it is unclear if future developments will solve these problems. Furthermore, disorder may even mimic the transport signatures of topological ordering, hindering an unambiguous identification of the Majorana states.

Here I propose a way to overcome these limitations: I will work towards the direct quantum simulation of the one-dimensional topological superconductor with Majorana bound states. I will use chains of semiconductor quantum dots, which is an emerging platform to simulate exotic many-body electron states. Building on this platform, I will be able to demonstrate for the first time the emergence of coherent, non-local superconducting states bound to the entire device similarly to the Kitaev chain model of topological superconductivity.

To demonstrate quantum coherence of the chain, we will build the first Andreev molecule quantum bit, which, while not topologically protected, will already combine advantages of superconducting and semiconductor qubits. Going one step further, we will investigate the simulated Kitaev chain. Upon establishing the presence of the simulated Majorana states, we will work towards a simple braiding protocol to demonstrate the non-Abelian nature of the edge modes.

This research direction, combining the scalability of semiconductor structures and the topological protection of Majorana states, will open new avenues towards universal quantum computation.

Link to the ERC project webpage:

Keywords of the ERC project: topological materials, quantum technologies, quantum transport, superconductivity, Andreev bound states

Keywords that characterize the scientific profile of the potential visiting researcher/s: topological materials, quantum technologies, quantum transport, superconductivity, Andreev bound states
ENFORCE

Condensed Matter Physics

Project ID: 811234
Project Acronym: ENFORCE
Evaluation Panel: PE3

Principal Investigator: Dr PIETRO TIERNO
Host Institution: UNIVERSITAT DE BARCELONA - ES

ENgineering FrustratiOn in aRtificial Colloidal icEs:
degeneracy, exotic lattices and 3D states

Geometric frustration, namely the impossibility of satisfying competing interactions on a lattice, has recently become a topic of considerable interest as it engenders emergent, fundamentally new phenomena and holds the exciting promise of delivering a new class of nanoscale devices based on the motion of magnetic charges. With ENFORCE, I propose to realize two and three dimensional artificial colloidal ices and investigate the fascinating manybody physics of geometric frustration in these mesoscopic structures. I will use these soft matter systems to engineer novel frustrated states through independent control of the single particle positions, lattice topology and collective magnetic coupling. The three project work packages (WPs) will present increasing levels of complexity, challenge and ambition:
(i) In WP1, I will demonstrate a way to restore the residual entropy in the square ice, a fundamental longstanding problem in the field. Furthermore, I will miniaturize the square and the honeycomb geometries and investigate the dynamics of thermally excited topological defects and the formation of grain boundaries.
(ii) In WP2, I will decimate both lattices and realize mixed coordination geometries, where the similarity between the colloidal and spin ice systems breaks down. I will then develop a novel annealing protocol based on the simultaneous system visualization and magnetic actuation control.
(iii) In WP3, I will realize a three dimensional artificial colloidal ice, in which interacting ferromagnetic inclusions will be located in the voids of an inverse opal, and arranged to form the FCC or the pyrochlore lattices. External fields will be used to align, bias and stir these magnetic inclusions while monitoring in situ their orientation and dynamics via laser scanning confocal microscopy.
ENFORCE will exploit the accessible time and length scales of the colloidal ice to shed new light on the exciting and interdisciplinary field of geometric frustration.

Link to the ERC project webpage:

Keywords of the ERC project: Geometric frustration, magnetism, colloids, spin ice
Keywords that characterize the scientific profile of the potential visiting researcher/s: Geometric frustration, magnetism, colloids, spin ice
Vibrating carbon nanotubes for probing quantum systems at the mesoscale

Many fascinating quantum behaviours occur on a scale that is intermediate between individual particles and large ensembles. It is on this mesoscopic scale that collective properties, including quantum decoherence, start to emerge.

This project will use vibrating carbon nanotubes – like guitar strings just a micrometre long – as mechanical probes in this intermediate regime. Nanotubes are ideal to explore this region experimentally, because they can be isolated from thermal noise; they are deflected by tiny forces; and they are small enough that quantum jitter significantly affects their behaviour. To take advantage of these properties, I will integrate nanotube resonators into electromechanical circuits that allow sensitive measurements at very low temperature.

First, I will study the motional decoherence of the nanotube itself, by using it as the test particle in a new kind of quantum interferometer. This experiment works by integrating the nanotube into a superconducting qubit, and will represent a test of quantum superposition on a larger mass scale than ever before. It will answer a longstanding question of physics: can a moving object, containing millions of particles, exist in a superposition of states?

Second, I will use the nanotube device as a tool to study superfluid helium 3 – the mysterious state of matter that may emulate the interacting quantum fields of the early universe. By measuring an immersed nanotube viscometer, I will be able to measure the behaviour of superfluid excitations on a scale where bulk superfluidity begins to break down.

Third, I will add to the device a nanomagnet on nanotube springs, creating an ultra-sensitive magnetic force sensor. This offers a way to perform nuclear magnetic resonance on a chip, ultimately creating a microscopy tool that could image for example single viruses.

Link to the ERC project webpage: http://wp.lancs.ac.uk/laird-group/

Keywords of the ERC project: Carbon nanotubes, nanomechanics, superfluids, force sensing, quantum electronics

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Revealing the adaptive internal organization and dynamics of bacteria and mitochondria

Bacteria cells appear to be less complex than our own cells -- yet they are better able to survive harsh conditions. Typically ~1 micron in size, they lack motor proteins; thus, they rely on fluctuations for intracellular transport. Bacteria in the environment often face starvation and exist in a non-proliferating quiescent state, which promotes antibiotic resistance and virulence. Entering quiescence, the bacterial cytoplasm displays signatures of the colloidal glass transition, with increasingly slow and heterogeneous diffusion. Also important for fitness during starvation is the formation of storage granules up to hundreds of nanometers in size. The complex state behavior of the bacterial cytoplasm is therefore important for their survival, but the physical nature of each of these processes is poorly understood. Our own cells are typically tens of microns in size and contain organelles including mitochondria, which originated from ancient bacterial endosymbionts. But little is known about the transport properties of the mitochondrial matrix, or how it responds to changes in mitochondrial membrane potential or energy production.

The goal of this project is to elucidate the organization and dynamics of the bacterial cytoplasm and the mitochondrial matrix. A major obstacle to studying the interior of bacteria and mitochondria is the relevant length scales, which lie below the diffraction limit. Furthermore, to observe and quantify their adaptive response, many cells must be measured. Our strategy to overcome both of these technical challenges is to use high-throughput super-resolution fluorescence microscopy. We have developed new microscopes, capable of capturing thousands of super-resolved cells in each experiment. We propose to translate these developments to dynamic structured illumination and long-term molecular tracking. Broadly applicable, this will also enable the quantitative study of the subcellular properties of single bacteria cells or mitochondria.
Quantum Plasmoremechanics with THz Phonons and Molecular Nano-junctions

QTONE aims at discovering new quantum phenomena involving THz vibrational modes, and at gaining control over them using novel concepts inspired from cavity quantum optomechanics and new techniques developed for nano-plasmonics and molecular break-junctions. The three main goals of the project are:

(i) Perform optomechanical quantum information processing with THz phonons in low-dimensional systems, using a combination of ultrafast spectroscopy and time-correlated photon counting to measure quantum correlations mediated by non-classical vibrational states.

(ii) Demonstrate the feasibility of dynamical backaction amplification of THz phonons by coupling molecules and nanomaterials to plasmonic cavities and by leveraging exciton-phonon coupling to realize exciton-assisted optomechanics.

(iii) Interrogate and drive a single-molecule inside a plasmonic nanocavity using simultaneous inelastic electron tunneling and Raman spectroscopies in a molecular break-junction with engineered plasmonic resonance.

I anticipate that this project will have widespread impacts on our understanding of quantum phenomena in molecular-scale oscillators, and will foster the excellence of Europe in fields ranging from fundamental science to quantum technologies and molecular electronics.

Link to the ERC project webpage: https://www.epfl.ch/labs/lqno/research/

Keywords of the ERC project: molecular vibration, surface-enhanced Raman scattering, quantum optomechanics, plasmonics

Keywords that characterize the scientific profile of the potential visiting researcher/s: molecular dynamics, ultrafast spectroscopy, physical chemistry, chemistry, dft, surface science
Statistics of Exotic Fractional Hall States

Since their discovery, Quantum Hall Effects have unfolded intriguing avenues of research, exhibiting a multitude of unexpected exotic states: accurate quantized conductance states; particle-like and hole-conjugate fractional states; counter-propagating charge and neutral edge modes; and fractionally charged quasiparticles - abelian and (predicted) non-abelian. Since the sought-after anyonic statistics of fractional states is yet to be verified, I propose to launch a thorough search for it employing new means. I believe that our studies will serve the expanding field of the emerging family of topological materials.

Our on-going attempts to observe quasiparticles (qp’s) interference, in order to uncover their exchange statistics (under ERC), taught us that spontaneous, non-topological, ‘neutral edge modes’ are the main culprit responsible for qp’s dephasing. In an effort to quench the neutral modes, we plan to develop a new class of micro-size interferometers, based on synthetically engineered fractional modes. Flowing away from the fixed physical edge, their local environment can be controlled, making it less hospitable for the neutral modes.

Having at hand our synthetized helical-type fractional modes, it is highly tempting to employ them to form localize para-fermions, which will extend the family of exotic states. This can be done by proximitizing them to a superconductor, or gapping them via inter-mode coupling.

The less familiar thermal conductance measurements, which we recently developed (under ERC), will be applied throughout our work to identify ‘topological orders’ of exotic states; namely, distinguishing between abelian and non-abelian fractional states.

The proposal is based on an intensive and continuous MBE effort, aimed at developing extremely high purity, GaAs based, structures. Among them, structures that support our new synthetic modes that are amenable to manipulation, and others that host rare exotic states, such as $v=5/2$, 12/5, 19/8, and 35/16.

Link to the ERC project webpage:
Keywords of the ERC project: FQHE, exotic states, shot noise, thermal noise, thermal transport, interference
Keywords that characterize the scientific profile of the potential visiting researcher/s: interest in the QHE and in abelian and non-abelian states (if theorist); as before plus interest in mesoscopic physics in 2DEG
Non-equilibrium states of matter occur in a wide range of systems. From microscopic scales of atoms and electrons to stars and galaxies in the universe. These phenomena have observable effects measurable by humans. In many of these systems the laws of thermodynamics do not apply. In spite of the ubiquity of non-equilibrium states, their universal understanding is still rudimentary. A general description of out of equilibrium states is of fundamental importance and can potentially spur technological innovation. Therefore, non-equilibrium systems host a family of questions which can be a source of knowledge and benefit to humankind. In this proposal I will tackle several open problems on correlated non-equilibrium quantum states in condensed matter physics. The remarkable twin discoveries of many-body localization (MBL) and time crystals have opened a new paradigm for non-equilibrium matter where an interacting quantum system violates the laws of equilibrium thermodynamics. By amalgamating tools and ideas from quantum information science, I will theoretically investigate these phenomena in regimes which are thus far unexplored. It will shed new light on MBL in higher dimensions and effect of long range interactions, a common feature in many physical systems. I will explicate the formation of discrete time crystals, a new phase of matter with broken time-translational symmetry, in dissipative systems. Until recently, MBL was considered to be an essential ingredient for time-crystallinity. The project will unravel the underlying principles of dissipative time crystals and the crossover from their semi-classical realization to the purely quantum effect protected by MBL. I will also predict smoking-gun signatures of these phenomena which are testable in semiconductor nanostructures. An answer to these vital questions will provide a deeper understanding of fundamental physics and may open new avenues for spatio-temporal control of entanglement in many-body quantum states.

Link to the ERC project webpage: https://arijeet1.wixsite.com/arijeetpal

Keywords of the ERC project: Quantum dynamics, many-body localization, time crystals, dissipation, semiconductors

Keywords that characterize the scientific profile of the potential visiting researcher/s: Quantum many-body physics
Photonically fused molecular materials

Molecular materials are ubiquitous, encompassing smart phone displays, plastic electronics and the molecular machinery of photosynthesis. Many of these remarkable uses depend on interactions between the molecules. Until now these interactions have been electric in character, and have been dictated by how electric charge is distributed over the molecules. PHOTMAT will transform the world of molecular materials by adding a new ingredient – photons. I will fuse photons and molecules together to create new hybrid states – part molecule and part photon – that are dramatically different from those of the constituent molecules and photons. The idea of coupling molecules with photons is a radical new approach with implications that reach across physics, quantum information, chemistry, materials science, nanotechnology and biology.

I propose a pioneering research programme that will catalyse the transition from embryonic early results to the creation of a new conceptual framework to unveil a new frontier in nanoscience and nanotechnology. We will perform new experiments that will provide clear proof-of-principle demonstrations of the incredible opportunities opened up by coupling molecules with photons. As examples, we will show how the range over which energy (excitons) can be transport may be extended by a factor of 1000, and we will show how the process of photosynthesis can be modified and controlled. This research has enormous potential, from transforming artificial photosynthesis for clean fuel production to inspiring a new generation of molecular metamaterials.

My goal is to explore the rich array of possibilities that arise when photons are made an integral part of molecular materials. At present much of the underlying physics is unclear and controversial. I will resolve the important open questions and show how photonic coupling of molecules leads to new molecular materials, new ways to control chemical and biological processes, and a new type of nanophotonics.

Link to the ERC project webpage: www.photmat.eu

Keywords of the ERC project: nanophotonics, molecular photonics

Keywords that characterize the scientific profile of the potential visiting researcher/s: physical chemist
Straining electromechanical coupling in layered crystals to new extremes

Inherent stability of layered 2D materials supports a remarkably large strain along the plane of these 1-atom-thick crystals. For example, graphene and MoS2 can stretch, in principle, by 20% - ten times more than the typical intrinsic breakdown strain of 3D crystals. Such extreme deformations of the interatomic distance can drive exciting structural phase transitions, support fascinating electronic orders, and profoundly impact the electronic or optical response.

Individually, however, pulling these ultimately thin materials to reliably approach their intrinsic limit poses great challenge. Cracks, defects, and out-of-plane motion all motivate early rupture, that prevented applicable demonstration of extreme strains so far.

STRAIN2EXTREME, instead, relies on recent advances in Van-der-Waals (VdW) structures; Sandwiched between thin impermeable layers the mechanical stability is reinforced, while suppressing unwanted chemistry and contamination at these "all-surface" materials. Notably, the minute amount of defects, dangling bonds, and disorder, do not pin-down the strain to relax locally to the rigid substrate as in common interfaces. It results in a nearly frictionless sliding between the weakly interacting layers.

Based on this finding, I set forward an entirely new approach to pull the structures while supporting them on a "super-lubricant" substrate. This support allows us to gradually narrow the shape into sub-micrometre constrictions, and "focus" a moderate pulling force to induce extreme local strains reliably. Moreover, we directly control the gradient of the strain in space by the precise shape. Remarkably, fixed strain gradients, can induce uniform "pseudo-vector-potentials" of extreme strength.

Using the unique mechanics and outstanding lubricity of VdW structure, I intend to realize highly ballistic time-reversal-protected transport, demonstrate a new "pseudo-Hall" effect, and explore crystal-induced electromagnetic fields in moiré super-lattices.

Link to the ERC project webpage:

Keywords of the ERC project:

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Biocompatible and Interactive Artificial Micro- and Nanoswimmers and Their Applications

Microswimmers, i.e., biological and artificial microscopic objects capable of self-propulsion, have been attracting a growing interest from the biological and physical communities. From the fundamental side, their study can shed light on the far-from-equilibrium physics underlying the adaptive and collective behavior of biological entities such as chemotactic bacteria and eukaryotic cells. From the more applied side, they provide tantalizing options to perform tasks not easily achievable with other available techniques, such as the targeted localization, pick-up and delivery of microscopic and nanoscopic cargoes, e.g., in drug delivery, bioremediation and chemical sensing.

However, there are still several open challenges that need to be tackled in order to achieve the full scientific and technological potential of microswimmers in real-life settings. The main challenges are: (1) to identify a biocompatible propulsion mechanism and energy supply capable of lasting for the whole particle life-cycle; (2) to understand their behavior in complex and crowded environments; (3) to learn how to engineer emergent behaviors; and (4) to scale down their dimensions towards the nanoscale.

This project aims at tackling these challenges by developing biocompatible microswimmers capable of elaborate behaviors, by engineering their performance when interacting with other particles and with a complex environment, and by developing working nanoswimmers.

To achieve these goals, we have laid out a roadmap that will lead us to push the frontiers of the current understanding of active matter both at the mesoscopic and at the nanoscopic scale, and will permit us to develop some technologically disruptive techniques, namely, targeted delivery of cargoes within complex environments, which is of interest for drug delivery and bioremediation, and efficient sorting of chiral nanoparticles, which is of interest for biomedical and pharmaceutical applications.

Link to the ERC project webpage: http://www.softmatterlab.org/

Keywords of the ERC project: Microswimmers, Active matter, Statistical Physics, Optical Tweezers, Artificial Intelligence, Machine Learning

Keywords that characterize the scientific profile of the potential visiting researcher/s: Microswimmers, Active matter, Statistical Physics, Optical Tweezers, Artificial Intelligence, Machine Learning
High throughput mass spectrometry of single proteins in liquid environment

Although mass spectrometry has brought about major advancements in proteomics in the last decade, protein mass spectrometers still have important limitations. One fundamental limitation is that they require sample ionization, desorption into the gas phase and fragmentation, clearly leading to protein denaturation. Since relevant protein complexes are unstable or transient, their characterization in its native state and physiological environment remains an unexplored route towards the full understanding of protein function and protein interactions. This problem has only been targeted to date through theoretical approaches or low throughput experimental techniques, such as atomic force spectroscopy, optical tweezers or FRET. A high throughput characterization technology capable of addressing single proteins in its native state would have a large impact in proteomics. The goal of LIQUIDMASS is to develop a high throughput spectrometric technique addressing single proteins from complex samples while in physiological conditions. LIQUIDMASS also proposes a new concept for protein spectrometry, by characterizing not only the mass, but also the hydrodynamic radius, geometry and stiffness of single proteins. This multiparameter approach will serve to open up new routes to understand protein structure-function relations by providing insight into the fast conformational changes that occur in liquids. In order to attain these goals, I propose to integrate nanomechanical resonators, nano-optics and nanofluidics. The disruptive approach proposed will bring about new knowledge about protein interactions and protein conformation that is elusive today. The enabling technologies aimed at the LIQUIDMASS will increase our understanding of protein misfolding related diseases, such as Alzheimer’s or diabetes, as well as bring closer a full understanding of the human interactome, contributing to the advancement of the proteomics field.

Link to the ERC project webpage: https://ercliquidmass.eu

Keywords of the ERC project: optomechanics, nanomechanics, mechanobiology

Keywords that characterize the scientific profile of the potential visiting researcher/s: physics, chemistry, nanotechnology, sensors
Coherent multidimensional spectroscopy of controlled isolated systems

Fundamental quantum mechanical processes determine the properties of matter and their functionality. In order to understand complex processes such as light harvesting in photosynthesis and photovoltaics, a detailed knowledge of coherent effects in excitation and charge transfer processes and related dynamics is required. To a large extent, the complexity of the systems induces too many interactions and perturbations of the processes to isolate and understand individual mechanisms. Advanced experimental methods, capable of detecting quantum coherences, so far are not applicable to quantum state controlled molecular complexes isolated from the perturbing environment, due to the low density of such targets. In this project we will for the first time employ coherent femtosecond multidimensional spectroscopy to dilute isolated molecular complexes. For a specific heterogeneous synthesis we will use aggregation in superfluid helium at millikelvin temperatures. In order to reach the needed sensitivity we will setup a novel phase modulation technique including lock-in demodulation in combination with mass-resolved ionization and photoelectron detection. Advanced mathematical methods will furthermore be developed and applied, boosting efficient collection of multidimensional datasets. We will be able to (a) identify processes and coherent dynamics of excitation and charge transfer in fundamental heterogeneous complexes, in particular van der Waals bound donor acceptor complexes (b) elucidate coherence and dissipation effects in contact with tailored external baths, (c) investigate microsolvation, i.e. measure the evolution of dynamic properties as a function of attached solvent molecules, (d) determine collective effects like autoionization in dilute atomic gases or exciton annihilation in semiconductor systems, (e) implement compressed sensing in multidimensional data acquisition, (f) implement largely parallelized phase-cycling into real-time data acquisition.

**Link to the ERC project webpage:** www.nanophysics.uni-freiburg.de

**Keywords of the ERC project:**

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Ultrasensitive Chirped-Pulse Fourier Transform mm-Wave Detection of Transient Species in Uniform Supersonic Flows for Reaction Kinetics Studies under Extreme Conditions

This proposal aims to develop a combination of a chirped-pulse (sub)mm-wave rotational spectrometer with uniform supersonic flows generated by expansion of gases through Laval nozzles and apply it to problems at the frontiers of reaction kinetics.

The CRESU (Reaction Kinetics in Uniform Supersonic Flow) technique, combined with laser photochemical methods, has been applied with great success to perform research in gas-phase chemical kinetics at low temperatures, of particular interest for astrochemistry and cold planetary atmospheres. Recently, the PI has been involved in the development of a new combination of the revolutionary chirped pulse broadband rotational spectroscopy technique invented by B. Pate and co-workers with a novel pulsed CRESU, which we have called Chirped Pulse in Uniform Flow (CPUF). Rotational cooling by frequent collisions with cold buffer gas in the CRESU flow at ca. 20 K drastically increases the sensitivity of the technique, making broadband rotational spectroscopy suitable for detecting a wide range of transient species, such as photodissociation or reaction products.

We propose to exploit the exceptional quality of the Rennes CRESU flows to build an improved CPUF instrument (only the second worldwide), and use it for the quantitative determination of product branching ratios in elementary chemical reactions over a wide temperature range (data which are sorely lacking as input to models of gas-phase chemical environments), as well as the detection of reactive intermediates and the testing of modern reaction kinetics theory. Low temperature reactions will be initially targeted; as it is here that there is the greatest need for data. A challenging development of the technique towards the study of high temperature reactions is also proposed, exploiting existing expertise in high enthalpy sources.

Link to the ERC project webpage: https://ipr.univ-rennes1.fr/cresuchirp-ERC

Keywords of the ERC project: laboratory astrophysics, astrochemistry, gas phase chemical kinetics, low temperature reactions, chemical physics, physical chemistry, chirped pulse mm-wave spectroscopy, rotational spectroscopy

Keywords that characterize the scientific profile of the potential visiting researcher/s: gas phase chemical kinetics, rotational spectroscopy, laboratory astrophysics
**Persistent and Transportable Hyperpolarization for Magnetic Resonance**

Magnetic resonance imaging (MRI) and nuclear magnetic resonance (NMR) are two well-established powerful and versatile tools that are extensively used in many fields of research, in clinics and in industry. Despite considerable efforts involving highly sophisticated instrumentation, these techniques suffer from low sensitivity, which keeps many of today’s most interesting problems in modern analytical sciences below the limits of MR detection.

Hyperpolarization (HP) in principle provides a solution to this limitation. We have recently pioneered breakthrough approaches using dissolution dynamic nuclear polarization (d-DNP) for preparing nuclear spins in highly aligned states, and therefore boosting sensitivity in several proof-of-concept reports on model systems. The proposed project aims to leverage these new advances through a series of new concepts i) to generate the highest possible hyperpolarization that can be transported in a persistent state, and ii) to demonstrate their use in magnetic resonance experiments with $>10'000$ fold sensitivity enhancements, with the potential of revolutionizing the fields of MRI and NMR.

By physically separating the source of polarization from the substrate at a microscopic level, we will achieve polarized samples with lifetimes of days that can be stored and transported over long distances to MRI centers, hospitals and NMR laboratories. Notable applications in the fields of drug discovery, metabolomics and real-time metabolic imaging in living animals will be demonstrated.

These goals require a leap forward with respect to today’s protocols, and we propose to achieve this through a combination of innovative sample formulations, new NMR methodology and advanced instrumentation. This project will yield to a broadly applicable method revolutionizing analytical chemistry, drug discovery and medical diagnostics, and thereby will provide a powerful tool to solve challenges at the forefront of molecular and chemical sciences today.

**Link to the ERC project webpage:** [http://hmrlab.eu](http://hmrlab.eu)

**Keywords of the ERC project:** NMR, DNP, hyperpolarization,

**Keywords that characterize the scientific profile of the potential visiting researcher/s:**

---

Project ID: 714519  
Project Acronym: HP4all  
Evaluation Panel: PE4  
Physical and Analytical Chemical Sciences

<table>
<thead>
<tr>
<th>Principal Investigator:</th>
<th>Dr SAMI JANNIN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Host Institution:</td>
<td>UNIVERSITE LYON 1 CLAUDE BERNARD - FR</td>
</tr>
</tbody>
</table>
Illuminating Atomic Scale Processes in Liquids and Gases

EvoluTEM: Illuminating Atomic Scale Processes in Liquids and Gases

Objective 1: To build new capability in atomic resolution environmental imaging and analysis.

Objective 2: To apply this platform to synthesise new photonic nanomaterials with enhanced performance.

The vision is to design, construct, and make available the next generation of multifunctional in situ specimen holders for the scanning/transmission electron microscope (S/TEM). This new experimental resource will enable ground-breaking characterisation of complex nanoscale reactions under realistic and relevant environmental conditions using a lab-on-a-chip configuration. By providing a platform with unparalleled atomic scale imaging and simultaneous elemental analysis capabilities, as well as flexible in situ (temperature, pressure, and illumination) environments, this effort will provide an experimental module for a wide range of breakthrough in situ nanomaterials experiments. Motivating this work is the goal of being able to fully characterize the synthesis of novel photonic 2D materials, optoelectronic nanoparticles, and photoactive organic-inorganic perovskites. This research could lead to a new level of mechanistic understanding, providing knowledge to realize routes for the production of new nanostructures, with properties that can be optimally tailored for photonic applications (photovoltaics, light emission or optoelectronics). This ambitious research program is only possible because of the principal investigators outstanding electron microscopy expertise, coupled with the world leading nanofabrication capabilities and in situ imaging facilities at the University of Manchester. The project has been structured into five work packages (WPs) with each having well-defined milestones and deliverables.

Link to the ERC project webpage:

Keywords of the ERC project: Transmission electron microscopy, 2d materials, nanoparticles

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Trans-Spin NanoArchitectures: from birth to functionalities in magnetic field

Control over electrons in molecules and periodic solids can be reached via manipulation of their internal quantum degrees of freedom. The most prominent and exploited case is the electronic spin accommodated in standalone spin units composed of 1 – 10^5 of spins. A challenging alternative to the spin is the binary quantum degree of freedom, termed pseudospin existing e.g. in two-dimensional semiconductors. The aim of the proposed research is to build prototypes of trans-spin nano-architectures composed of at least two divergent spin entities, the TSuNAMIes. The spin entities of interest correspond to single atomic spin embedded in spin crossover complexes (SCO), molecular spin of molecular magnets (SMM), superspins of single-domain magnetic nanoparticles (SuperS) and pseudospins in two-dimensional transition metal dichalcogenides (PseudoS). Ultimate goal of the project is to identify a profit from trans-spin cooperation between the different spin entities coexisting in a single TSuNAMI. Influence of external static and alternating magnetic fields on the elementary spin state, unit cell magnetic structure, long-range magnetic order, mesoscopic spin order, spin relaxations and pseudospin state mirrored in essential fingerprints of the spin units and their ensembles will be explored using macroscopic and microscopic in situ and ex situ probes, including Raman and Mössbauer spectroscopies in magnetic field. Within the proposed high-risk/high-gain trans-spin strategy, we thus expect: 1. Enhancement of magnetic anisotropy in SMM-SuperS with enormous impact on cancer therapy using magnetic fluid hyperthermia, 2. Control over SCO via coupling to giant classical spin giving rise to miniature ‘on-particle’ sensors, 3. Mutual visualization of electronic states in SCO-PseudoS pushing frontiers of nowadays pseudospintronics, and 4. Control over electronic states with nanometer resolution in SuperS-PseudoS giving rise to novel functionalization strategies of graphene successor.

Link to the ERC project webpage:

Keywords of the ERC project: magnetism, spin, two-dimensional materials, Raman spectroscopy, magnetic fluid hyperthermia

Keywords that characterize the scientific profile of the potential visiting researcher/s: condensed matter physicists with background in magnetism or graphene/two-dimensional materials
Photovoltaic conversion has the extraordinary property of transforming the solar energy directly into electric power. However, the available electrical power is known to be severely limited by the so-called Shockley-Queisser (SQ) photoconversion limit. The maximum efficiency for a single absorber is limited as photons with energy lower than the bandgap (BG) cannot be absorbed, and just an energy equivalent to the BG can be used for photons with higher energy than the BG, due to thermalization. Tandem cells have overcome this SQ limit upon exploiting complex and expensive configurations. Alternative approaches, even with higher potentiality, as Intermediate Bandgap Solar Cells (IBSCs) have not reached the expected performance mainly due to the limitations introduced by the monocrystalline matrix. The incorporation of quantum dots (QD) to create the IB produces layer strain and defects that limit the cell performance. No-LIMIT proposes to revamp IBSCs concept, using polycrystalline halide perovskites (HP) host matrix in order to take benefit from the strain relaxation at polycrystalline materials and from HP benign defect physics. HPs show an outstanding performance even when they are grown in a porous structure, indicating that their excellent transport and recombination properties are preserved with embedded materials. No-LIMIT will exploit this potentiality by using the states of embedded QD as IB in IBSC with HP matrix. The project will focus on the preparation of HPs-QD systems with enhanced light collection efficiency preserving charge transport, recombination and stability. No-LIMIT will study the properties and interactions of the HP and QD materials developed, as well as injection, recombination and transport properties in the coupled system. The combination of these strategies will build a ground-breaking synergistic system able to break the SQ limit. The achievements of IBSC, together with the intermediate steps, will have a colossal impact on photovoltaics.
Probing chemical dynamics at surfaces with ultrafast atom pulses

Ultra-short light pulses have become invaluable in time-resolved studies in chemistry and physics. But many important processes are initiated by collisions. While lasers have revolutionized experiments using light pulses, experimentally proven concepts for producing ultra-short pulses of neutral matter are still in their infancy. Hence, our ability to control when a collision occurs is still extremely limited. Recently, we have reported bunch-compression photolysis, the first demonstrated method for producing ultra-short pulses of neutral matter. Here, photolysis of jet-cooled hydrogen iodide is carried out with femto-second laser pulses whose frequency bandwidth has been spatially ordered. Thus, fast H-atom photoproducts overtake slow ones, producing an ultra-short pulse. The central objective of this project is to develop bunch-compression photolysis as a tool for ultrafast timing experiments involving collisions of ultrashort pulses of H-atoms at synchronously photo-excited solid surfaces. Bunch-compression photolysis allows collisions at a surface to be synchronized with photoexcitation on the ps time scale, opening up new ways to study the dynamics of collisions at selectively photo-excited surfaces that have not yet relaxed. Studies on collision dynamics involving excitons produced in 2D semiconductors is one exciting direction for this work. Experiments on synchronized H atom collisions with vibrationally excited surfaces prepared by infrared photoexcitation is another - this enables kinetics experiments with surface site-specificity as well as the direct observation of reaction intermediates. The work and ideas presented here show how to overcome the most challenging barrier to a new class of time-resolved dynamics experiments, opening new frontiers in the study of surface chemistry, where we will begin to understand how selected degrees of freedom of the solid influence collision dynamics and reaction rates.

Link to the ERC project webpage:

Keywords of the ERC project:

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Single-molecule spectroscopy of coordinated motions in allosteric proteins

Critical for the function of many proteins, allosteric communication involves transmission of the effect of binding at one site of a protein to another through conformational changes. Yet the structural and dynamic basis for allostery remains poorly understood. In particular, there is no method to follow coordinated large-scale motions of domains and subunits in proteins as they occur. Since the subunits of allosteric proteins often contain multiple domains, any such method entails probing the dynamics along several intra-protein distances simultaneously.

This proposal aims at ameliorating this deficiency by creating the experimental framework for exploring time-dependent coordination of allosteric transitions of multiple units within proteins. Our methodology will rely on single-molecule FRET spectroscopy with multiple labels on the same protein and advanced analysis. We will explore fundamental issues in protein dynamics: relative motions of domains within subunits, propagation of conformational change between subunits, and synchronization of these motions by effector molecules.

To investigate these issues, we have carefully selected three model systems, each representing an important scenario of allosteric regulation. While the homo-oligomeric protein-folder GroEL conserves symmetry in a concerted transition between major structural states, the symmetry of the homo-oligomeric disaggregating machine ClpB is broken via a sequential transition. Symmetry is attained only after binding to DNA and ligands in the third system, the family of RXR heterodimers.

This exciting project will provide the very first catalogue of coordinated and time-ordered motions within and between subunits of allosteric proteins and the first measurement of the time scale of the conformational spread through a large protein. It will enhance dramatically our understanding of how allostery contributes to protein function, influencing future efforts to design drugs for allosteric proteins.

Link to the ERC project webpage: www.weizmann.ac.il/chemphys/cfharan

Keywords of the ERC project: Protein dynamics; single-molecule FRET; protein conformational changes; protein machines.

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Accuracy and precision for molecular solids

The description of high pressure phases or polymorphism of molecular solids represents a significant scientific challenge both for experiment and theory. Theoretical methods that are currently used struggle to describe the tiny energy differences between different phases. It is the aim of this project to develop a scheme that would allow accurate and reliable predictions of the binding energies of molecular solids and of the energy differences between different phases.

To reach the required accuracy, we will combine the coupled cluster approach, widely used for reference quality calculations for molecules, with the random phase approximation (RPA) within periodic boundary conditions. As I have recently shown, RPA-based approaches are already some of the most accurate and practically usable methods for the description of extended systems. However, reliability is not only a question of accuracy. Reliable data need to be precise, that is, converged with the numerical parameters so that they are reproducible by other researchers.

Reproducibility is already a growing concern in the field. It is likely to become a considerable issue for highly accurate methods as the calculated energies have a stronger dependence on the simulation parameters such as the basis set size. Two main approaches will be explored to assure precision. First, we will develop the so-called asymptotic correction scheme to speed-up the convergence of the correlation energies with the basis set size. Second, we will directly compare the lattice energies from periodic and finite cluster based calculations. Both should yield identical answers, but if and how the agreement can be reached for general system is currently far from being understood for methods such as coupled cluster. Reliable data will allow us to answer some of the open questions regarding the stability of polymorphs and high pressure phases, such as the possibility of existence of high pressure ionic phases of water and ammonia.

Link to the ERC project webpage: http://quantum.karlov.mff.cuni.cz/~jklimes/apes.html

Keywords of the ERC project: quantum chemistry, molecular solids, reproducibility of results

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Electrically Tunable Functional Lanthanide Nanoarchitectures on Surfaces

Lanthanide metals are ubiquitous nowadays, finding use in luminescent materials, optical amplifiers and waveguides, lasers, photovoltaics, rechargeable batteries, catalysts, alloys, magnets, bio-probes, and therapeutic agents. In addition, they bear potential for high temperature superconductivity, magnetic refrigeration, molecular magnetic storage, spintronics and quantum information.

Surprisingly, the study of lanthanide physico-chemical properties on surfaces is at its infancy, particularly at the nanoscale. To address this extraordinary scientific opportunity, I will research the foundations and prospects of lanthanide elements to design functional nanoarchitectures on surfaces and I will study their inherent physico-chemical phenomena in distinct coordination environments, targeting novel approaches for sensing, nanomagnetism and electroluminescence. Importantly, our studies will encompass both metal substrates and decoupling surfaces including ultra-thin film insulators and graphene. Nurturing from these studies and in parallel, we will focus on graphene voltage back-gated supports, thus surpassing the seminal knowledge on electrically-inert substrates and enhancing the scope of our research to address the overarching objective of the proposal, i.e., the design of electrically tunable functional lanthanide nanomaterials.

The culmination of ELECNANO project will provide strategies for:
1.-Design of functional nanomaterials on high-technological supports.
2.-Development of advanced coordination chemistry on surfaces.
3.-Rationale of the physico-chemical properties of lanthanide-coordination environments.
4.-Engineering of lanthanide nanoarchitectures for ultimate sensing, nanomagnetism and electroluminescence.
5.-In-situ atomistic views of electrically tunable materials and unprecedented fundamental studies of charge-molecule/metal physics on devices.

Link to the ERC project webpage: www.ecijalab.com

Keywords of the ERC project: Surface Science; STM; nc-AFM

Keywords that characterize the scientific profile of the potential visiting researcher/s: Surface Science, STM, nc-AFM, UHV
Attosecond X-ray spectroscopy of liquids

Charge and energy transfer are the key steps underlying most chemical reactions and biological transformations. The purely electronic dynamics that control such processes take place on attosecond time scales. A complete understanding of these dynamics on the electronic level therefore calls for new experimental methods with attosecond resolution that are applicable to aqueous environments. We propose to combine the element sensitivity of X-ray spectroscopy with attosecond temporal resolution and ultrathin liquid microjets to study electronic dynamics of relevance to chemical, biological and photovoltaic processes. We will build on our recent achievements in demonstrating femtosecond time-resolved measurements in the water, attosecond photoelectron spectroscopy on a liquid microjet and measuring and controlling attosecond charge migration in isolated molecules. We will first concentrate on liquid water to study its electronic dynamics following outer-valence ionization, the formation pathway of the solvated electron and the time scales and intermolecular Coulombic decay following inner-valence or core-level ionization. Second, we will turn to solvated species and measure electronic dynamics and charge migration in solvated molecules, transition-metal complexes and photoexcited nanoparticles. These goals will be achieved by developing several innovative experimental techniques. We will develop a source of isolated attosecond pulses covering the water window (285-538 eV) and combine it with a flat liquid microjet to realize attosecond transient absorption in liquids. We will complement these measurements with attosecond X-ray emission spectroscopy, Auger spectroscopy and a novel heterodyne-detected variant of resonant inelastic Raman scattering, exploiting the large bandwidth that is naturally available from attosecond X-ray sources.

Link to the ERC project webpage: www.atto.ethz.ch

Keywords of the ERC project: attosecond, liquids, photoelectron spectroscopy, X-ray spectroscopy

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Liquid-liquid phase separation (LLPS) is a phenomenon inherent to the thermodynamics of liquids, is critical for the development of technologically useful fluids and underlies some of the biggest health changes in our society. LLPS is based on transitions between two different forms of liquid that have the same chemical composition, but distinct energy, entropy and density. Despite the importance of LLPS for technology and health, however, only a very low-resolution view primarily through light microscopy is currently available for LLPS states formed by peptides and proteins. Because of this bottleneck, the interactions, which stabilize liquid droplets, and regulate their biogenesis, as well as a rationale for the biochemical function of LLPS, have remained mysterious.

To tackle this massive unmet need, I propose to develop powerful methods of NMR spectroscopy that go far beyond the state-of-the-art and team them up with mechanobiology/force microscopy to break the resolution barrier of polypeptide LLPS and push the description of the internal organization of liquid droplets from micrometer to sub-nanometer. Although highly challenging, the novel methods when successful will (i) disentangle the structure and kinetics of intrinsically disordered proteins within LLPS reaction chambers in space and time, (ii) unravel the nature of chemical reactions in liquid droplets, and (iii) decipher LLPS regulation by posttranslational modifications, nucleic acids and critical changes in cellular environment at atomic resolution. The innovative nature of the proposal is designed to unravel the innermost forces in liquid droplets and to transform our knowledge about the chemistry of liquid phase-separated protein states. Findings from this proposal will provide critical guidance in the development of systems to encapsulate bioactive molecules and to develop better treatments for human diseases.

**Nuclear magnetic resonance spectroscopy of liquid-liquid phase separation**

Liquid-liquid phase separation (LLPS) is a phenomenon inherent to the thermodynamics of liquids, is critical for the development of technologically useful fluids and underlies some of the biggest health changes in our society. LLPS is based on transitions between two different forms of liquid that have the same chemical composition, but distinct energy, entropy and density. Despite the importance of LLPS for technology and health, however, only a very low-resolution view primarily through light microscopy is currently available for LLPS states formed by peptides and proteins. Because of this bottleneck, the interactions, which stabilize liquid droplets, and regulate their biogenesis, as well as a rationale for the biochemical function of LLPS, have remained mysterious.

To tackle this massive unmet need, I propose to develop powerful methods of NMR spectroscopy that go far beyond the state-of-the-art and team them up with mechanobiology/force microscopy to break the resolution barrier of polypeptide LLPS and push the description of the internal organization of liquid droplets from micrometer to sub-nanometer. Although highly challenging, the novel methods when successful will (i) disentangle the structure and kinetics of intrinsically disordered proteins within LLPS reaction chambers in space and time, (ii) unravel the nature of chemical reactions in liquid droplets, and (iii) decipher LLPS regulation by posttranslational modifications, nucleic acids and critical changes in cellular environment at atomic resolution. The innovative nature of the proposal is designed to unravel the innermost forces in liquid droplets and to transform our knowledge about the chemistry of liquid phase-separated protein states. Findings from this proposal will provide critical guidance in the development of systems to encapsulate bioactive molecules and to develop better treatments for human diseases.

**Link to the ERC project webpage:**

**Keywords of the ERC project:** Liquid-liquid phase separation, NMR spectroscopy, neurodegeneration

**Keywords that characterize the scientific profile of the potential visiting researcher/s:**
Structural mechanism coupling the reduction of oxygen to proton pumping in living cells

Every breath you take delivers oxygen to mitochondria within the cells of your body. Mitochondria are energy transducing organelles that accept electrons liberated from the food that you eat in order to generate a transmembrane proton concentration gradient. Cytochrome c oxidase is an integral membrane protein complex in the mitochondria that accepts four electrons and reduces molecular oxygen to two water molecules while simultaneously pumping protons against a transmembrane potential. Cytochrome c oxidase homologues are found in almost all living organisms. Because oxygen is the final destination of the transferred electrons, this enzyme family is referred to as the terminal oxidases. Crystal structures of terminal oxidases have been known for more than two decades and these enzymes have been studied with virtually all biophysical and biochemical methods. Despite this scrutiny, it is unknown how redox reactions at the enzyme’s active site are coupled to proton pumping. Here I aim to create a three dimensional movie that reveals how proton exchange between key amino acid residues is controlled by the movements of electrons within the enzyme. This work will utilize state-of-the-art methods of time-resolved serial crystallography, time-resolved wide angle X-ray scattering and time-resolved X-ray emission spectroscopy at European X-ray free electron lasers (XFELs) and synchrotron radiation facilities to observe structural changes in terminal oxidases with time. I will develop new approaches for rapidly delivering oxygen or electrons into the protein’s active site in order to initiate the catalytic cycle in microcrystals and in solution. This project will yield completely new insight into one of the most important chemical reactions in biology while opening up the field of time-resolved structural studies of proteins beyond a handful of naturally occurring light-driven systems.

Link to the ERC project webpage:

Keywords of the ERC project: membrane proteins, time-resolved structural biology

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Atomic resolution microscopy relies on beams of energetic electrons. These beams quickly destroy fragile materials, making imaging them a major challenge. I have recently developed a new approach that provides the greatest possible resolving power per electron. The method provides both double resolution and excellent noise rejection, via multidimensional data acquisition and analysis. Here I propose to couple the new method with breakthroughs in high speed cameras to achieve unprecedented clarity at low doses, almost guaranteeing major advances for imaging beam sensitive materials. Proof of principle will be achieved for biochemical imaging using the easy to handle, commercially available GroEL chaperone molecule. We will combine our enhanced imaging capabilities with the averaging methods recently recognized by the Nobel prize in chemistry for imaging biomolecules at ultra low doses. After proving our low dose capabilities we will apply them to imaging proteins of current interest at greater resolution. Similar techniques will be used for fragile materials science samples, for instance metal organic framework, Li ion battery, 2D, catalyst and perovskite solar cell materials. Furthermore the same reconstruction algorithms can be applied to simultaneously acquired spectroscopic images, allowing us to not only locate all the atoms, but identify them. The properties of all materials are determined by the arrangement and identity of their atoms, and therefore our work will impact all major areas of science, from biology to chemistry and physics.

Link to the ERC project webpage: https://www.uantwerpen.be/en/staff/timothy-pennycook/

Keywords of the ERC project: Advanced electron microscopy

Keywords that characterize the scientific profile of the potential visiting researcher/s:
This proposal implements slice imaging to measure catalytic rates for site-specific elementary reactions thus offering remarkable opportunities to advance our fundamental understanding of heterogeneous catalysis.

As evidence for global climate change continues to grow, catalysis has moved to the front line of the struggle to obtain new, sustainable technologies for the future. Catalysis and catalytic processes account, directly or indirectly, for 20-30 % of world Gross Domestic Product. Knowledge of elementary chemical reaction mechanisms in heterogeneous catalysis underlies our ability to construct comprehensive kinetic models for many such important chemical processes, in order to optimise them.

Our proposed strategy makes the formidable task of describing site-specific chemical reaction mechanisms and elementary rates in heterogeneous catalysis facile, while its necessity we justified (Nature 2018) on the prototypical CO oxidation reaction on Pt by demonstrating that 40 years of traditional experimentation led to false interpretation of the reaction mechanism.

The aim of this proposal is characterize the important factors that influence the kinetics of elementary reactions at surfaces, e.g. the chemical nature of the catalyst and the geometry of the active site (stereodynamics). We chose elementary reactions involving C, H, O, N, as these are important in many key industries, such as the methane reforming, syngas, fuel cells, Fischer-Tropsch synthesis and the Haber-Bosch process. Our strategy is that of a “bottoms up” approach to catalysis, i.e., building and understanding complex heterogeneous chemical catalysis, from the site-specific kinetics of the elementary building block reactions. Our measurements, will serve for benchmarking first principles calculations of reaction rates in surface chemistry. Our methodology measures the kinetics in the s regime with temperatures in the 200 to 1000 K range, i.e, more relevant to industrial conditions.

Link to the ERC project webpage:

Keywords of the ERC project:

Keywords that characterize the scientific profile of the potential visiting researcher/s: Ion Imaging the Kinetics and Dynamics on Surfaces
A New Strategy for Vibronic Spectroscopy of Radicals

This proposal aims to develop a novel strategy for high resolution vibronic spectroscopy of radicals, with unprecedented sensitivity, specificity, and applicability. The proposed scheme will provide answers to longstanding quantum mechanical questions about non-adiabatic dynamics, and, in combination with a unique, recently developed transparent microreactor source of reactive molecules, enable the pursuit of unknown reactive intermediates.

Radicals and transient reactive intermediates are centrally important to chemistry but notoriously difficult to study. The proposer has recently led several successful experimental and theoretical efforts directed at molecules and transition states thought to be extremely difficult if not impossible to characterize. Here we propose to launch a revolutionary approach to spectroscopy of these important species, exploiting a key insight into dissociation dynamics on top of elements of state of the art laser spectroscopy techniques in the infrared, ultraviolet, and vacuum ultraviolet to forge a new universal method. It possesses the high sensitivity and mass selectivity of ion detection, while simultaneously being multidimensional and fully rovibronic in scope to extract the maximum possible information about coupled nuclear and electronic dynamics.

We anticipate that this advance will also be of great interest and utility to a broad swath of researchers in related fields, such as combustion, atmospheric chemistry, and surface science, who require the ability to track rare but reactive species. The nitrate and cyclopentadienyl radicals will initially be targeted as particularly important examples, and we also plan to hunt for as yet unobserved reactive intermediates using our new spectroscopic scheme alongside the flexibility of our molecular source to rationally explore chemical phase space.

Link to the ERC project webpage:

Keywords of the ERC project: laser spectroscopy, radicals

Keywords that characterize the scientific profile of the potential visiting researcher/s: laser spectroscopy, radicals
A DNA NANOtechnology toolkit for artificial CELL design

Bottom-up synthetic biology aims to artificially replicate the emerging behaviours of cellular life but struggles to do so without relying on poorly controllable machinery borrowed from biological cells. DNA nanotechnology enables ab-initio design of nanoscale objects with fully programmable structure and dynamic response, making them ideal to mimic the complex functionalities of biological machinery in a truly bottom-up fashion.

NANOCELL will establish a fully modular and integrated platform that utilises DNA nanotechnology to prescribe structure and functionality of artificial cells. I will design a library of micron-scale DNA-based objects that mimic cell organelles in their ability to perform specific tasks in response to chemical and environmental stimuli including signal detection and amplification, the capture and release of cargoes, and the construction of structural elements.

These “membrane-less organelles” will self-assemble from a new class of amphiphilic DNA building blocks I recently introduced, which enable unprecedented control over the morphology and response of nanostructured frameworks.

Interaction between organelles will lead to the emergence of collective effects, and their encapsulation in lipid-bilayer compartments will enable the modular construction of artificial cells displaying a range of complex behaviours such as remote communication, dynamic adaptation, and spatiotemporal patterning in multicellular systems.

NANOCELL will consist of three Work Packages reflecting its hierarchical approach:

WP1: Mapping the self-assembly behaviour of amphiphilic DNA nanostructures.
WP2: Embedding different functionalities in amphiphilic DNA frameworks to produce artificial organelles.
WP3: Creating artificial cells by encapsulating DNA organelles in compartmentalised systems.

The full programmability afforded by NANOCELL will ultimately unlock long-awaited applications of artificial cells, spanning from biosensing to smart therapeutics.

Link to the ERC project webpage:

Keywords of the ERC project: DNA Nanotechnology, Synthetic Biology, Artificial Cells

Keywords that characterize the scientific profile of the potential visiting researcher/s: DNA Nanotechnology, Soft Matter Physics, Biophysics
Theoretical Chemistry of Unbound Electrons

T-CUBE aims at the theoretical modeling of chemistry involving the continuum. Traditionally, chemistry has been concerned with electrons that remain bound to the nuclei during a reaction. However, in many settings that deal with X rays or plasma, electrons can enter and leave the system; they are unbound. Most theoretical approaches for unbound electrons are not applicable to extended systems in complex environments. As a consequence, pathways and product distributions of processes such as dissociative electron attachment and Coulomb explosion are poorly understood. This hinders progress in laboratory and technology: The electron is a simple and versatile catalyst, but corresponding applications are still in an infant stadium.

T-CUBE seeks to overcome these limitations. Often, unbound electrons can be described by resonances, electronic states with complex-valued energy. In recent years, I contributed to advancing this approach significantly. Small molecules in gas phase can now be described with an accuracy that allows for quantitative comparison to experiment.

Here, I propose to investigate the chemistry of unbound electrons in larger molecules and condensed phase, for example, in solutions, polymeric networks, and biomolecules. Aspects that we will address include: energetics and character of resonances in different environments, resulting changes in chemical reactivity, and the interplay of nuclear motion and electron loss.

To achieve these goals, quantum chemistry for electronic resonances needs to be advanced substantially. We will develop electronic-structure methods suitable for over a hundred of atoms, a quantum embedding scheme for describing different environments, and molecular dynamics simulations that take into account electron loss. In addition, we will advance the theory of electronic resonances itself. In exemplary applications, we will investigate phenomena involving dissociative electron attachment, electron transfer, and Coulomb explosion.

Link to the ERC project webpage: http://jagau.cup.uni-muenchen.de/research/erc-stg-project-t-cube/

Keywords of the ERC project: quantum chemistry, electronic structure theory, electron-driven chemistry

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Towards Nanostructured Electrocatalysts with Superior Stability

In the last decades, significant progress has been made on understanding and controlling solid/liquid electrochemical interfaces at atomic levels. As the principles guiding the activity of electrochemical reactions are quite well established (structure-activity relationships), the fundamentals of stability are still poorly understood (structure-stability relationships). 123STABLE proposes to employ (1) identical location, (2) online monitoring and (3) modeling of noble metals based nanoparticles changes with the state-of-the-art electron microscopy equipment and online dissolution and evolution analytics using electrochemical flow cell coupled to online mass spectrometers. Projects unique methodology approach with picogram sensitivity levels, in combination with sub-atomic scale microscopy insights and simulations, promises novel atomistic insights into the corrosion and reconstruction of noble metals in electrochemical environments. This unique approach is based on observations of the same nanoparticles before and after electrochemical treatment where weak and stable atomic features and events can be recognized, followed, understood and finally utilized. Upon (1) doping, (2) decoration and/or (3) other synthetic modification of nanoparticles like a change in size and shape further stabilization is envisioned. For instance, blockage of nanoparticle vulnerable defected sites like steps or kinks by more noble metal could stop or significantly slow down their degradation.

The 123STABLE project will feature platinum- and iridium-based nanostructures as a model system to introduce a unique “123” approach, as they still possess the best electrocatalytic properties for the future electrification of society through the Hydrogen economy. However, their electrochemical stability is still not sufficient. Coupled with the fact that their supply is hindered by extremely scarce, rare and uneven geological distribution, the increase in their stability is of immense importance.

Link to the ERC project webpage:

**Keywords of the ERC project:** electrocatalysis, platinum, iridium, fuel cell, electrolyzer, nanoparticles, transmission electron microscopy, corrosion, oxygen evolution reaction, oxygen reduction reaction

**Keywords that characterize the scientific profile of the potential visiting researcher/s:** Kinetic Monte Carlo simulation, machine learning, image processing, electrochemistry method development, CO2 reduction reaction, photoelectrochemistry, colloidal synthesis, etc.
Tuneable Catalyst Surfaces for Heterogeneous Catalysis –
Electrochemical Switching of Selectivity and Activity

In heterogeneous catalysis surfaces decorated with uniformly dispersed, catalytically highly active particles are a key requirement for excellent performance. One of the main tasks in catalysis research is the continuous improvement or development of catalytically active materials.

An emerging concept in catalyst design, and the aim of this project, is to selectively and reversibly tune and modify the surface chemistry by electrochemical polarisation. Perovskite-type catalysts raise the opportunity to incorporate guest elements as dopants. Upon electrochemical polarisation these dopants emerge from the oxide lattice to form catalytically active clusters or nanoparticles on the surface (by exsolution). In consequence this leads to a strong modification or enhancement of catalytic selectivity and activity. Electrochemical polarisation offers the possibility to adjust the surface chemistry in response to an external signal (here the applied voltage).

Studies in a realistic catalytic reaction environment (in-situ) will enable a direct correlation of surface structure with catalytic activity, selectivity and the electrochemical stimulation. The unique combination of surface science, heterogeneous catalysis and electrochemistry will take this research to a new ground-breaking level.

No research group has yet tried to tackle this topic on a fundamental mechanistic level by this multidisciplinary approach.

The proposed project opens unprecedented possibilities for catalyst design and in-situ control due to the versatility of perovskite-type catalyst materials and dopant elements. Nanoparticle exsolution is a highly time- and cost-efficient way of catalyst preparation and it will offer solutions to major problems in heterogeneous catalysis, such as ageing (sintering) or catalyst deactivation (coking). Tuneable catalyst surfaces will facilitate tackling a major concern of the 21st century, the utilisation of CO2 and its conversion to renewable fuel.

Link to the ERC project webpage:

Keywords of the ERC project: catalysis, electrocatalysis, perovskite, model catalysis, surface science

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Industries creating inorganic, organic, and agricultural chemicals use a staggering 4.2% of the worldwide delivered energy, mainly from unsustainable fossil fuels. Meanwhile, the sun provides energy that could be utilized to power photochemical reactions sustainably and cleanly. Recent advances revealing how localized surface plasmon resonances (LSPRs), light-driven electron oscillations in metal nanoparticles, can concentrate light at the molecular scale made the dream of efficient photochemistry one step closer. However, plasmonic materials are almost exclusively constructed from the rare and unsustainable metals Ag and Au. In addition to being incompatible with current industrial practices relying on catalytic surfaces to lower energy barriers and guide reactions, Ag and Au cause prohibitive cost challenges for real-world applications. But there is hope: several of the few metals predicted to sustain LSPRs and become potential alternatives to Ag and Au are amongst the most abundant, i.e. sustainable, elements on Earth (Al, Mg, Na, K).

The way forward, and key objective of my proposal, is thus to design, synthesize, and understand multimetallic nanostructures where a cheap, Earth-abundant plasmonic material traps and concentrates (sun)light directly at a catalytic surface to efficiently and intelligently power and choreograph chemical reactions. To achieve this ambitious goal, I devised a project concurrently advancing important aspects of sustainable plasmon-enhanced catalysis, from the development of two synthetic approaches for Earth-abundant plasmonic catalysts, to the fundamental studies of light-trapping in these new materials with state-of-the-art numerical and experimental approaches and the unravelling of the relative contribution of plasmon-generated hot electrons, enhanced field, and heat using key model chemical reactions. These results will help develop a more sustainable future by lowering our reliance on both fossil fuels and rare metals.

Link to the ERC project webpage: https://www.on.msm.cam.ac.uk/

Keywords of the ERC project: magnesium nanoparticles, plasmonic nanoparticles, plasmon-enhanced catalysis, sustainable plasmonics

Keywords that characterize the scientific profile of the potential visiting researcher/s: photocatalysis, plasmon-enhanced catalysis, hot electrons, photothermal effects
Laser control over crystal nucleation

The CONTROL programme I propose here is a five-year programme of frontier research to develop a novel platform for the manipulation of phase transitions, crystal nucleation, and polymorph control based on a novel optical-tweezing technique and plasmonics. About 20 years ago, it was shown that lasers can nucleate crystals in super-saturated solution and might even be able to select the polymorph that crystallises. However, no theoretical model was found explaining the results and little progress was made.

In a recent publication (Nat. Chem. 10, 506 (2018)), we showed that laser-induced nucleation can be understood in terms of the harnessing of concentration fluctuations near a liquid–liquid critical point using optical tweezing. This breakthrough opens the way to a research programme with risky, ambitious, and ground-breaking long-term aims: full control over crystal nucleation including chirality and polymorphism.

New optical and microscopic techniques will be developed to allow laser manipulation on a massively parallel scale and chiral nucleation using twisted light. Systematically characterising and manipulating the phase behaviour of mixtures, will allow the use of the optical-tweezing effect to effectively control the crystallisation of small molecules, peptides, proteins, and polymers. Exploiting nanostructures will allow parallelisation on a vast scale and fine control over chirality and polymorph selection through plasmonic tweezing. Even partial success in the five years of the programme will lead to fundamental new insights and technological breakthroughs. These breakthroughs will be exploited for future commercial applications towards the end of the project.

Link to the ERC project webpage: https://cordis.europa.eu/project/rcn/222584/factsheet/en
Keywords of the ERC project: nucleation, crystallization, phase separation, optical tweezing, microscopy, phase transitions
Keywords that characterize the scientific profile of the potential visiting researcher/s:
Advanced EUV/soft X-ray microscopy in the ultrafast regime: imaging functionality of nanomaterials across length scales

Imaging charge, spin, and energy flow in functional materials when hit by a light pulse, is a current grand challenge in nanotechnology relevant to a host of systems including photovoltaics, optoelectronic and spin devices. The design of such materials relies critically on the availability of accurate characterisation tools of how light-induced function and performance are related to nano-to-mesoscale electronic and lattice structural properties.

To address this challenge, ULTRAIMAGE will introduce ground-breaking capabilities in microscopy of nanomaterials, providing access to their far-from-equilibrium states, with resolution on nanometer-to-Ångstrom length and femtosecond time scales. Key to this advance is the combination of extreme ultraviolet (EUV) to soft X-ray tabletop coherent light sources with a technique for coherent diffractive imaging called ptychography, in which multiple diffraction patterns from overlapping fields of view are processed by iterative algorithms to recover amplitude and phase images of sample and beam, separately.

Nanoscale movies of the sample’s impulsive response, irradiated by ultrafast laser pulses, will be obtained with extremely high fidelity and in a non-destructive approach, with sub-20nm transverse resolution, 0.5Å axial precision, and ≈10fs temporal resolution. Each movie frame will be characterized by amplitude and phase images of the sample, with exquisite quantitative contrast to material composition, and to its topography.

ULTRAIMAGE will introduce a world-class tabletop facility for ultrafast ptychography with coherent short-wavelength EUV light, which will enable the understanding with unprecedented detail of fundamental nanoscale behaviour, vital to a better design of energy-efficient next generation devices.

Link to the ERC project webpage:

Keywords of the ERC project:
Keywords that characterize the scientific profile of the potential visiting researcher/s: ultrafast imaging, diffraction, functional nanomaterials, high-harmonic generation
Unconventional Bifunctional Catalysts

The development of sustainable chemical processes is one of the most important features in modern chemistry. It has become a key research area worldwide providing solutions to important societal demands by optimizing the use of natural resources and minimizing waste and environmental impact. Among the relevant methods for achieving this goal, catalysis represents a key and central approach. Both Organocatalysis and Metal Catalysis have emerged as solutions to the problems in this context. In this field, the progress of a novel bifunctional organocatalyst that could increase the number of different activations, and therefore the synthesis of valuable enantio-enriched molecules, would be highly desirable. Especially important, but still unknown, are the bifunctional-catalysts based on a Neutral Coordinate Organocatalyst and Photo-Organocatalysts. This proposal aims to develop two new unconventional approaches for the synthesis of bifunctional organocatalysts.

The first one is based on the development of new Bifunctional Neutral Coordinate Organocatalyst and their application to the synthesis of biologically relevant compounds. I propose to use these bifunctional catalysts to promote the dual activation of silyl reagents and suitable electrophiles. This approach constitutes an unconventional way to synthesize asymmetric molecules and has no precedent in the literature.

The second section of this proposal explores the photo-activation-bifunctional organocatalyst. I propose the design and application of new metal-free Bifunctional Photo-Organocatalysts which are able to chemically and photo-activate the substrate simultaneously in an asymmetric manner.

This project has the potential to change the general view of asymmetric Neutral Coordinate Organocatalyst and Photo-catalysis as we know it today. These unconventional bifunctional would be incorporated into the privileged catalyst library for its applications in new asymmetric transformations.

Link to the ERC project webpage: www.uam.es/jose.aleman

Keywords of the ERC project: Catalysis, Photocatalysis, Organocatalysis, bifunctional

Keywords that characterize the scientific profile of the potential visiting researcher/s:
A central discipline of chemistry is the design and creation of molecules with defined structural and chemical properties. Stretching synthetic horizons is a never-ending endeavor to inspire the chemist’s creativity in preparing compounds and materials yet to be discovered. Relying on their high strain energy cyclopropanes, as carriers of the most fundamental ring geometry, offer a unique reactivity which allows for a multitude of transformations being grouped in ring-opening reactions, cycloadditions and rearrangements. Major advantage of all these processes is the cyclopropane-derived intrinsic atom-economy.

In this research project, we propose a number of uncommon and challenging reactions making use of donor-acceptor cyclopropanes. Introducing a distinctively controlled bond cleavage we seek to develop novel modes of 1,3-bifunctionalization by σ-bond metathesis, by using hypervalent iodine reagents and by merging organocatalysis with photoredox catalysis. Unprecedented ring-enlargements to four-membered rings by [3+1]-cycloadditions employing isonitriles, carbenes and nitrenes are envisioned, aryne insertions into the three-membered ring leading to indane systems are planned and a general concept for [3+3]-cycloadditions with 1,3-dipoles is presented paving the way to unusual syntheses of heterocycles.

A distinct class of compounds obtainable by our methodology will set the stage to access completely unexplored heterocyclic π-systems being of interest for material science and molecular electronics. Besides our central goals of advancing organic methodology and to demonstrating the synthetic utility of these novel reactions, we anticipate that mechanistic insights gained by experimental and computational means will be of high impact for the chemistry of this fundamental structural unit in general.

Link to the ERC project webpage: www.werzlab.de

Keywords of the ERC project: cyclopropane; organic methodology; strain; donor-acceptor

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Lanthanides as electron Dimmer switch in organometallic catalysis

Complexes containing redox non-innocent ligands have been well developed in the last decade with transition metal ions and have led to very important chemical transformations at lowest environmental and economic costs. Nonetheless examples with f-element are very rare and the field is almost empty with lanthanides. This is unfortunate since divalent lanthanides are excellent sources of single electron and would provide a good control of the ligand reduction because of strong electron correlation in these systems. Thus, this proposal aims at developing this field with organolanthanides. The synthesis of original complexes containing lanthanides, redox non-innocent ligands and transitions metals is herein proposed: the first providing reversible electron(s) source(s) (remote control), the second acting as electron(s) reservoir and controlling the electron correlation strength (“dimmer switch”), and the last being the site of the selective catalytic reaction. Because of this regulated electron transfer, the oxidation state of the transition metal will be modified only at specific steps, allowing the establishment of a new paradigm in organometallic catalysis with group 9 and 10 transition metals. These original complexes will be synthetized and deeply characterized by specific spectroscopic and theoretical analyses. The principal goal is to synthetize active catalysts toward C-H bonds activation, and methane activation is regarded as an ultimate achievement as is hydroalkylation of olefins. To increase the chances of success, the proposal is based on preliminary results obtained recently in the group. Several examples of original heterobimetallic and heterotrimetallic complexes containing lanthanides and transition metals of group 10 will be discussed as a good starting point for the feasibility of this challenging project that aims at answering a large societal concern: the reduction of atmospheric pollutants, such as methane, and transformation in valuable products.

Link to the ERC project webpage:

Keywords of the ERC project: Lanthanides, redox non-innocent ligand, catalyst

Keywords that characterize the scientific profile of the potential visiting researcher/s: Lanthanides
Vapor deposition of crystalline porous solids

Metal-organic frameworks (MOFs) are crystalline solids with highly regular pores in the nanometer range. The possibility to create a tailored nano-environment inside the MOF pores makes these materials high-potential candidates for integration with microelectronics, e.g. as sensor coatings, solid electrolytes, etc. However, current solvent-based methods for MOF film deposition, a key enabling step in device integration, are incompatible with microelectronics fabrication because of contamination and corrosion issues.

VAPORE will open up the path to integrate MOFs in microelectronics by developing a solvent-free chemical vapor deposition (CVD) route for MOF films. MOF-CVD will be the first example of vapor-phase deposition of any type of microporous crystalline network solid and marks an important milestone in processing such materials. Development of the MOF-CVD technology platform will start from a proof-of-concept case and will be supported by the following pillars: (1) Insight in the process, (2) expansion of the materials scope and (3) fine-tuning process control. The potential of MOF-CVD coatings will be illustrated in proof-of-concept sensors.

In summary, by growing porous crystalline films from the vapor phase for the first time, VAPORE implements molecular self-assembly as a scalable tool to fabricate highly controlled nanopores. In doing so, the project will enable cross-fertilization between the worlds of nanoscale chemistry and microelectronics, two previously incompatible fields.
Stable and High-Efficiency Perovskite Light-Emitting Diodes

Light-emitting diodes (LEDs), which emit light by a solid-state process called electroluminescence, are considered as the most promising energy-efficient technology for future lighting and display. It has been demonstrated that optimal use of LEDs could significantly reduce the world’s electricity use for lighting from 20% to 4%. However, current LED technologies typically rely on expensive high-vacuum manufacturing processes, hampering their widespread applications. Therefore, it is highly desirable to develop low-cost LEDs based on solution-processed semiconductors.

A superstar in the family of solution-processed semiconductors is metal halide perovskites, which have shown great success in photovoltaic applications during the past few years. The same perovskites can also be applied in LEDs. Despite being at an early stage of development with associated challenges, metal halide perovskites provide great promise as a new generation of materials for low-cost LEDs.

This project aims to develop high-efficiency and stable perovskite LEDs based on solution-processed perovskites. Two different classes of low-dimensional perovskites will be investigated independently. These new perovskite materials will then be coupled with novel interface engineering to fabricate perovskite LEDs with the performance beyond the state of the art. At the core of the research is the synthesis of new perovskite nanostructures, combined with advanced spectroscopic characterization and device development. This project combines recent advances in perovskite optoelectronics and low-dimensional materials to create a new paradigm for perovskite LEDs. This research will also lead to the development of new perovskites materials which will serve future advances in photovoltaics, transistors, lasers, etc.
Despite more than fifty years of scientific progress since Richard Feynman's 1959 vision for nanotechnology, there is only one way to manipulate individual atoms in materials: scanning tunneling microscopy. Since the late 1980s, its atomically sharp tip has been used to move atoms over clean metal surfaces held at cryogenic temperatures. Scanning transmission electron microscopy, on the other hand, has been able to resolve atoms only more recently by focusing the electron beam with sub-atomic precision. This is especially useful in the two-dimensional form of hexagonally bonded carbon called graphene, which has superb electronic and mechanical properties. Several ways to further engineer those have been proposed, including by doping the structure with substitutional heteroatoms such as boron, nitrogen, phosphorus and silicon. My recent discovery that the scattering of the energetic imaging electrons can cause a silicon impurity to move through the graphene lattice has revealed a potential for atomically precise manipulation using the Ångström-sized electron probe. To develop this into a practical technique, improvements in the description of beam-induced displacements, advances in heteroatom implantation, and a concerted effort towards the automation of manipulations are required. My project tackles these in a multidisciplinary effort combining innovative computational techniques with pioneering experiments in an instrument where a low-energy ion implantation chamber is directly connected to an advanced electron microscope. To demonstrate the power of the method, I will prototype an atomic memory with an unprecedented memory density, and create heteroatom quantum corrals optimized for their plasmonic properties. The capability for atom-scale engineering of covalent materials opens a new vista for nanotechnology, pushing back the boundaries of the possible and allowing a plethora of materials science questions to be studied at the ultimate level of control.

Link to the ERC project webpage: https://www.mostlyphysics.net/erc

Keywords of the ERC project: electron microscope, atom manipulation, nanotechnology, graphene

Keywords that characterize the scientific profile of the potential visiting researcher/s: transmission electron microscopy
Cooperative Catalysis: Using Interdisciplinary Chemical Systems to Develop New Cooperative Catalysts

Catalysis, a multidisciplinary science at the heart of many industrial processes, is crucial to deliver future growth and minimize anthropogenic environmental impact, thus being critical to our quality of life. Thus, the development and fundamental understanding of innovative new catalyst systems has clear, direct and long-term benefits to the chemical manufacturing sector and to the broader knowledge-based economy.

In this ERC project I will develop novel innovative cooperative catalysts using interdisciplinary chemical systems based on main group elements, transition metals and molecular clusters to achieve better efficiency and improve chemical scope and sustainability of key chemical transformations.

This will be achieved through 3 complementary and original strategies based on catalytic cooperation: (i) Transition-Metal Frustrated Lewis Pairs (TM-FLPs); (ii) hybrid systems combining low-valent heavier main group elements with transition metals (Hybrid TM/MGs); and (iii) intercluster compounds (ICCs) as versatile heterogeneized materials for Green Catalysis.

These systems, of high synthetic feasibility, combine fundamental concepts from independent areas, e.g. FLPs and low-valent heavier main group elements with transition metal chemistry, and homogeneous with heterogeneous catalysis. The overall approach will be pivotal in discovering novel reactions that rely on the activation of otherwise unreactive substrates. The experience and knowledge gained from (i)-(iii) will be used to inform the design of a second generation of ICC materials in which at least one of the nanoscale bricks is based on polymetallic TM-FLPs or Hybrid TM/MG systems.

Delivering ground-breaking new fundamental science, this pioneering project will lay the foundation for future broad ranging benefits to a number of EU priority areas dependant on innovations in catalysis: innovative and sustainable future energy systems, solar technologies, sustainable chemistry, manufacturing, and healthcare.

Link to the ERC project webpage: http://jcamposgroup.iiq.us-csic.es/

Keywords of the ERC project: organometallic chemistry, cooperative catalysis, frustrated Lewis pairs

Keywords that characterize the scientific profile of the potential visiting researcher/s: organometallic chemistry
This “Life-Cycle” ERC proposal aims to develop a new class of artificial supramolecular materials that are kept in sustained non-equilibrium states by continuous dissipation of chemical fuels. Supramolecular polymers in current artificial materials stick together through weak reversible bonds that can be exchange by thermal energy. In contrast, natural supramolecular polymers such as those in the cytoskeletal network use chemical fuels such as adenosine triphosphate (ATP) to achieve an incredible adaptivity, motility, growth, and response to external inputs. Development of chemically fueled artificial supramolecular polymers should therefore lead to more life-like materials that could perform functions so far reserved only for living beings.

The proposed materials are based on supramolecular reaction cycles that have both positive and negative feedback in order to achieve emergent properties, such as oscillations and waves. Two different approaches are used: i) supramolecular polymers that are fueled by redox reactions, and ii) enzyme-switchable supramolecular polymers that consume one of the natural fuels, namely ATP. The proposed polymers self-assemble cooperatively, which is used as a positive feedback mechanism. Using other co-assembling species we can engineer negative feedback in our reaction cycles to obtain unique supramolecular dynamics. Since the building blocks react, but also self-assemble they have built-in chemomechanical properties, much like in living materials such as the cytoskeleton.

First we study the temporal behavior (part A) of our reaction cycles in well-stirred environments. Next, we move to non-stirred conditions (part B), where spatiotemporal behavior can be studied. And lastly, we develop free-standing non-equilibrium interactive materials based on our reaction cycles (part C). Overall, our approach opens a new way to obtain more life-like artificial materials that can eventually perform complex (biological) functions.

Link to the ERC project webpage: WwW.hermanslab.com

Keywords of the ERC project: Non-equilibrium, supramolecular chemistry, self-assembly, dissipative systems

Keywords that characterize the scientific profile of the potential visiting researcher/s: Supramolecular, microfluidics, non-equilibrium thermodynamics
Stereoretentive-Enantioconvergent Catalysis: A New Concept in Asymmetric Synthesis

This project will experimentally establish a new concept in asymmetric synthesis: stereoretentive-enantioconvergent catalysis. This will represent a completely new method for accessing enantiopure materials starting from racemic substrates and will therefore impact all areas of synthetic chemistry. The ability to synthesise chiral molecules in enantiopure form is vitally important, most recognisably for the pharmaceutical industry. This is because the molecules of life are chiral (e.g., D-sugars and L-amino acids) and enantiomers often interact very differently with living organisms. Classically, asymmetric synthesis utilising racemic substrates is limited to achieving a maximum yield of 50% (e.g., kinetic resolutions). Enantioconvergent catalysis avoids this limitation with both enantiomers of the starting material being converted into a single enantioenriched product, thanks to complex stereoablative or stereomutative de-racemisation processes. This project will establish a conceptually new stereoretentive-dimerisation approach that results in both enantiomers of the starting material being incorporated into the product with no de-racemisation required. This new concept will prove highly valuable for the synthesis of small enantiopure building blocks, which will be of high value in many areas of synthesis, and also for more complex late-stage transformations in complex molecule synthesis. Several approaches will be pursued to demonstrate proof-of-principle, and applications in the synthesis of complex natural and unnatural products will then be used to demonstrate the potential of stereoretentive-enantioconvergent catalysis in target-orientated synthesis.

Link to the ERC project webpage: https://erc.europa.eu/projects-figures/erc-funded-projects/results?search_api_views_fulltext=SEC&f%5B0%5D=country%3AUnited%20Kingdom
Keywords of the ERC project: enantioconvergent catalysis, asymmetric synthesis
Keywords that characterize the scientific profile of the potential visiting researcher/s:
ENBION will engineer a platform to direct the differentiation of stem cells by developing principles for the rational design of the biointerface of nanowires.

It is increasingly evident that efficient tissue regeneration can only ensue from combining the regenerative potential of stem cells with regulatory stimuli from gene therapy and niche engineering. Yet, despite significant advances towards integrating these technologies, the necessary degree of control over cell fate remains elusive.

Vertical arrays of high aspect ratio nanostructures (nanowires) are rapidly emerging as promising tools to direct cell fate. Thanks to their unique biointerface, nanowires enable gene delivery, intracellular sensing, and direct stimulation of signalling pathways, achieving dynamic manipulation of cells and their environment.

This broad manipulation potential highlights the importance and timeliness of engineering nanowires for regenerative medicine. However, developing a nanowire platform to direct stem cell fate requires design principles based on the largely unknown biological processes governing their interaction with cells. Enabling localized, vector-free gene therapy through efficient transfection relies on understanding the still debated mechanisms by which nanowires induce membrane permeability. Directing cell reprogramming requires understanding the largely unexplored mechanosensory processes and the resulting epigenetic effects arising from the direct interaction of nanowires with multiple organelles within the cell. Engineering the cell microenvironment requires yet undeveloped strategies to localize signalling and transfection with a resolution comparable to the lengthscale of cells.

ENBION will develop this critical knowledge and integrate it into guidelines for dynamic manipulation of cells. Beyond the nanowire platform, the principles highlighted by this unique interface can guide the development of nanomaterials with improved control over cellular processes.

**Link to the ERC project webpage:** http://chiappinilab.com

**Keywords of the ERC project:** nanomedicine, biomaterials, drug delivery, tissue engineering, stem cell, niche, gene therapy

**Keywords that characterize the scientific profile of the potential visiting researcher/s:**
I propose here a research program aimed to the design a completely new platform for drug delivery. I will combine our existing repertoire of molecular engineering tools based around our established approach to design responsive nanoparticles known as Polymersomes to integrate new features using clinically safe and biodegradable components that will make them super-selective and chemotactic toward glucose gradients so to deliver large therapeutic payload into the central nervous systems and the brain in particular targeting cancer cells harbouring within the healthy. We will do so by engineering components using supramolecular interaction inspired by biological complexity equipping carriers with the ability to self-propelled as a function of glucose gradient. I will complement our proposed design with advanced biological characterisation associating functional information arising form the physiological barrier to structural parameters integrated into the final carrier design.

Keywords of the ERC project: Glioma, Brain, drug delivery, active matter, super-selective targeting

Keywords that characterize the scientific profile of the potential visiting researcher/s:
In DYNAFLUORS I will develop the first chemical toolbox for imaging in real time the activity of immune cells in tumours.

Although the management of cancer has improved over the years, the cure rates for patients with metastasis and advanced tumours remain low due to lack of appropriate therapies. Recent studies suggest that drugs empowering host immune cells (i.e. immunotherapies) are promising approaches for intractable tumours. However, there are no tools to visualise and understand how host immune cells stop cancer progression in vivo. This important unmet challenge drives the ambitious targets of this proposal.

Over the past 10 years, I have pioneered the development of chemical fluorophores that allow unparalleled analysis of biological systems. In this project, I will implement an innovative approach to unify cutting-edge methodologies in chemistry and biology and develop Dynamic Activatable Fluorophores (DYNAFLUORS) as a chemical toolbox with enhanced imaging capabilities over current technologies.

The cross-disciplinary and ambitious nature of this project will open multiple avenues for broad impact in many areas of chemistry as well as in basic biology, imaging and medicine. DYNAFLUORS will allow us to image, from the molecular level to human tissue, the activity of immune cells in tumours and the response to therapy in real time. This ground-breaking chemical platform will represent a step forward in the forefront of chemical imaging and will create new opportunities in the personalised management of cancer.

In the long term, DYNAFLUORS will become a transformative toolbox for monitoring disease in humans. The integration of functional fluorophores into imaging technologies to perform ‘optical biopsies’ in vivo and to create patient-specific drug-response assays has the potential to revolutionise the diagnosis, stratification and personalised treatment of disease.

Link to the ERC project webpage: www.dynafluors.co.uk

Keywords of the ERC project: Imaging, fluorescent probes, immunology, translational chemistry

Keywords that characterize the scientific profile of the potential visiting researcher/s: Organic chemistry, optical imaging, cell biology
A long standing dogma in the field of cell-based technologies is that bulk mechanical properties of solid substrates are essential to enable cell spreading, proliferation and fate decision. The use of solid materials to culture adherent cells constitutes an important hurdle for the scale up, automation and speed up of cell culture and recovery. Our recent results show that bulk solid substrates are not necessary to promote cell adhesion, growth and fate regulation as adherent stem cells spread and proliferate readily at the surface of ultra-soft materials, even liquids. In such cases, cell adhesion is enabled by the formation of a mechanically strong layer (nanosheet) of proteins at the interface between the oil (liquid substrate) and aqueous medium. This key discovery opens the door to the engineering of protein nanosheets enabling the use of liquid, free-flowing substrates sustaining cell adhesion, expansion, isolation and recovery.

ProLiCell will design the biochemical and mechanical properties of extracellular matrix (ECM) protein nanosheets that can sustain the formation of adhesion protein complexes and support cell proliferation and culture on materials with very weak bulk mechanical properties (liquids). The engineered ECM nanosheets will be applied to: 1. the design of 3D bioreactors based on emulsions, for the culture of stem cells; 2. the formation of stem cell sheets at oil-water interfaces for tissue engineering; 3. the isolation and purification of stem cells using emulsions presenting antibody-adsorbed interfaces. ProLiCell will provide fundamental insights into ECM nanosheet design and advance our understanding of the mechanisms via which cells adhering to such interfaces sense and respond to nanoscale cues. Such fundamental understanding will enable liquid-liquid platforms to transform stem cell technologies by borrowing a wider range of processing and manufacturing concepts to the field of Chemical Engineering.

Link to the ERC project webpage: http://biointerfaces.qmul.ac.uk/

Keywords of the ERC project: Soft Matter, Nanomaterials, Stem Cells, Mechanotransduction, Bioengineering

Keywords that characterize the scientific profile of the potential visiting researcher/s: Physico-chemistry, Soft Matter, Regenerative Medicine, Bioengineering
The avenue of magnetism in the field of 2D materials has marked the ultimate milestone in the discovery of one-atom-thick classes of materials. Bulk ferromagnets and antiferromagnets now have their 2D counterparts and are at one’s provision for the realization of imagination-limited artificial layered structures. At the same time, this awaited breakthrough has brought in new conundrums that demand investigation. This project is driven by the exploration of the limits of van der Waals 2D magnets from both a fundamental physics and a materials science and devices point of view. Firstly, it addresses fundamental key questions regarding spin order at the true 2D limit, which remain a mystery to the date. Here, the great variety of magnetic anisotropies exhibited by the transition metal halides will shed new light to the subtle equilibrium of interactions in few-layer magnets. Secondly, the project will invoke the control of the magnetic ground states and spin textures in true 2D magnets via electrical manipulation. Electric fields will assist in tuning the magnetic coupling and critical behaviour and the spatial manipulation of spin topologies. Anticipated breakthroughs will be the enhancement of the critical temperature in semiconducting single layer magnets towards room temperature 2D magnetism and the realization of single-layer multiferroic 2D materials. Thirdly, the field effect electrical control of magnetism in designer van der Waals and lateral heterostructures will allow for an enhanced magneto-electric coupling, yielding functional devices for effective charge-to-spin transduction that hold promise in spintronics. The proposal will achieve success by an integral approach to research, through the combination of the study of solid-state growth techniques together with the implementation of state-of-the-art deterministic manipulation of 2D materials in inert conditions and the use high resolution magnetism probes to test hybrid magnetic-optoelectronic devices.

Link to the ERC project webpage: www.crisol-lab.com

Keywords of the ERC project: Synthetic Chemistry and Materials
Current methods in organic synthesis only enable reactions at the most reactive bonds or at bonds predisposed by specific directing groups. Consequently, many less reactive bonds, including numerous C-H and C-C bonds, cannot be functionalized, enormously limiting the scope of possible transformations. To overcome these limitations, I propose Reverse&Cat, a revolutionary strategy using a novel method to change the reactivity pattern of molecules. This strategy combines the dynamic equilibrium mediated by the first catalyst and a functionalization reaction catalyzed by the second catalyst. The originality of the transformation stems from exploiting three simultaneous processes: (i) the dynamic exchange of one functional group (FG) for another FG that modulates the reactivity of the substrate; (ii) the functionalization of the temporarily activated bond; and (iii) the restoration of the initial FG. In essence, the processes (i) and (iii) – the components of the dynamic equilibrium – realize the novel concept of the temporary creation of non-inherent reactivity of a substrate.

The program is divided in three phases, which will establish the full potential of the strategy. In phase A, I will develop a set of new reactions enabled by the bi-catalytic systems. I will exploit two types of reversible reactions: (1) reversible oxidation of alcohols, which delivers temporarily activated aldehydes/ketones, with the distinct reactivity of their C-H bonds; and (2) reversible retro-hydrofunctionalization of nitriles or their analogues, which delivers temporarily activated alkenes, containing allylic C-H and C=C bonds. In phase B, I will conduct detailed mechanistic studies to gain the mechanistic understanding and enable further rational development. In phase C, I will establish the utility of this new strategy in practical organic synthesis. Overall, the strategy will open a new dimension of reactivity, with prospective applications in production of fine-chemcials and materials.
Living on the Edge: Tunable Electronics from Edge Structures in 1D Layered Materials

One of the driving forces of the ongoing nanotechnology revolution is the ever-improving ability to understand and control the properties of quantum matter even down to the atomic scale. Key drivers of this revolution are layered materials like transition metal dichalcogenides (TMD). The realisation of novel TMD-based electronic devices relies heavily on understanding the relation between structural and electrical properties at the nanoscale. Crucially, one-dimensional (1D) TMDs have been predicted to exhibit striking functionalities including metallic edge states, ferromagnetic behaviour, and mobilities that are not suppressed as compared to their 2D counterparts. Indeed, in the 1D nanoscale limit, the lateral edges of TMDs become dominant, opening novel opportunities to tune edge-induced electrical properties leading to i.e. enhanced charge carrier mobility. However, these predictions for novel phenomena in 1D TMDs lack experimental verification, due to the challenge in accessing the relevant information at the nanoscale. I propose to unravel the interplay between structural and electrical edge-induced properties by exploiting recent breakthroughs in electron microscopy (EM) allowing simultaneous unprecedented spatial and spectral resolution. I will focus on MoS2 nanoribbons, and use electron-energy loss spectroscopy to map the electronic properties at the nanometer-scale. Beyond the optimization of EM for 1D TMD characterization, I will investigate semiconducting-to-metal and ferromagnetic transitions by realising controllable edge structures. I have an extensive track record in pushing the frontier of EM characterization and growing nanostructures. I recently demonstrated the feasibility of pinning down the interplay between structure and electronic properties at the edges of 2D MoS2. This proposal will provide input towards novel quantum technologies for developing low-energy-consumption tunable electronics, efficient signal processing and quantum computation.

Link to the ERC project webpage: http://conesabojlab.tudelft.nl/

Keywords of the ERC project: Layered materials, low-dimensional nanostructures, electron energy-loss spectroscopy, transmission electron microscopy

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Advanced biohybrid lighting and photovoltaic devices

InOutBioLight aims to design multifunctional rubbers with enhanced mechanical, thermal, color-converting, and light-guiding features towards advanced biohybrid lighting and photovoltaic technologies. The latter are placed at the forefront of the EU efforts for low-cost production and efficient consumption of electricity, a critical issue for a sustainable development.

In this context, the use of biomolecules as functional components in lighting and photovoltaic devices is still a challenge, as they quickly denature under storage and device operation conditions. This paradigm has changed using an innovative rubber-like material, in which the biofunctionality is long preserved. As a proof-of-concept, color down-converting rubbers based on fluorescent proteins were used to design the first biohybrid white light-emitting diode (bio-HWLED). To develop a new generation of biohybrid devices, InOutBioLight will address the following critical issues, namely i) the nature of the protein-matrix stabilization, ii) how to enhance the thermal/mechanical features, iii) how to design multifunctional rubbers, iv) how to mimic natural patterns for light-guiding, and v) how to expand the technological use of the rubber approach.

To achieve these goals, InOutBioLight involves comprehensive spectroscopic, microscopic, and mechanical studies to investigate the protein-matrix interaction using new polymer matrices, additives, and protein-based nanoparticles. In addition, the mechanical, thermal, and light-coupling features will be enhanced using structural biocompounds and reproducing biomorphic patterns. As such, InOutBioLight offers three major advances: i) a thorough scientific basis for the rubber approach, ii) a significant thrust of the emerging bio-HWLEDs, and iii) innovative breakthroughs beyond state-of-the-art biohybrid solar cells.

Link to the ERC project webpage:

Keywords of the ERC project:

Keywords that characterize the scientific profile of the potential visiting researcher/s:
A 2018 joint report from pharma identified organic synthesis as one of the major bottlenecks in drug discovery today. In the highly competitive discovery environments, only fast-to-synthesise molecules are targeted, based mostly on five well-tested and proven synthetic methods. This approach has led to only a small portion of the chemical shape space being explored over the last decades and has been partly blamed for the recent low success rates in new drug development. The report emphasises the need for ideal tools such as late stage functionalisation, which would allow simply replacing any C–H bond in a bioactive molecule with any desired functionality, thus greatly accelerating the synthesis of new candidates from a lead compound. However, the field of C–H activation is significantly behind in achieving this aim: most biologically active molecules contain several polar and/or delicate functionalities (‘real world’ molecules), whereas most C–H activation methods use harsh conditions, incompatible with delicate groups, and catalysts that tend to poison in the presence of polar groups.

This ERC Advanced Grant addresses this major challenge by building a new tool-set of ruthenium catalysts that will finally be able to deliver late stage functionalisation on ‘real world’ molecules, thus allowing a new dawn for development not only of new drugs, but also of agrochemicals, aromatic based organic materials and associated areas. The project builds on a recent key mechanistic breakthrough by the PI’s group on the operation of Ru-catalysts (Nature Chemistry 2018) that reveals a completely different pathway to catalyst design from that followed in the field in the last two decades. This new class of catalysts presents unprecedented high reactivity and compatibility with sensitive ‘real world’ molecules. The PI is in a unique position to capitalize on this discovery and lead the way towards global late stage functionalisation of ‘real world’ molecules.
Topological Crystalline Insulator Nanowires

The key challenge in quantum computation is decoherence - the collapse of a quantum state due to local perturbations. In this proposal we address this challenge by developing a new nanomaterials system, which forms the core of a future topological quantum computer. In a topological quantum bit, information is encoded in Majorana modes, which are topologically protected by a local symmetry and therefore have long coherence times.

In this project we develop a new state of matter - topological crystalline insulator nanowires - in which the topology is defined by the band inversion and the crystal symmetry of the material. Therefore, these topological states should be exceptionally robust. Further, we integrate strong superconductors on these nanowires. These two features together should increase the energy scales of the system compared to current state-of-the-art devices, and therefore lead to stable and electrically-isolated Majorana states.

In this project we develop new crystal growth strategies, which enable to grow out-of-thermodynamic equilibrium structures. We will be the first to employ Molecular Beam Epitaxy (MBE) to precisely tune the SnTe nanowire growth conditions. We use the directionality offered by MBE to shadow-grow superconductors on one nanowire facet. The in-situ ultra-high-vacuum growth of hybrid semiconductor/superconductor devices will result in unprecedented device quality.

Due to the increased energy scales, experiments, which have been unattainable so far, come within reach. We use this new materials platform to demonstrate entanglement of two Majorana modes at the ends of a nanowire. This quantum teleportation is a groundbreaking experiment and is the key of a topological quantum computer.

Link to the ERC project webpage:

Keywords of the ERC project: Nanowire, Majorana, Topological Insulator

Keywords that characterize the scientific profile of the potential visiting researcher/s: nanowire growth, crystal growth, MBE, quantum transport
Light driven hybrid nanocrystal TMDC capacitors

Sunlight is an intermittent energy source coupled to the availability of the sun. Light-DYNAMO aims for an innovative solution to directly store the solar energy. The challenge is to implement solution-processable light-driven nanocrystal capacitors (NCCs), such as doped metal oxides. They show high charge-storage capacity accumulating multiple delocalized electrons after light absorption. This was to date shown in solution only with the additional drawback of reducing the hole with a sacrificial hole scavenger. The innovative aspect of Light-DYNAMO is to use 2D transition metal dichalcogenides (2D TMDCs), such as MoS2 or WS2, as efficient hole acceptors in a solid state structure. The sensitivity of the TMDCs’ spatial electronic landscape to the local environment (i.e. strain, defects or doping) serves as driving force for energetically driven hole relocation within the TMDC. The electrons instead remain in the NCCs. This results in long-lasting and efficient charge separation and opens novel design principles. In optimized device structures, such stored carriers are extracted. The working principle of the suggested NC/TMDC hybrid device is based on several challenges: first, the absorption and charge storage capacity of the NCCs will be enhanced by exploring novel materials. Second, the TMDC’s sensitivity to the surrounding will be extracted to a high level of control over the 2D energy level distribution. Third, the intentional design of the energy landscape (e.g. through strain manipulation) in the optimized hybrid geometry will be introduced to control carrier redistribution after charge transfer within the TMDC. Finally, appropriate devices for carrier extraction will be structured. The proposal embarks on a pioneering study by the PI on optical control over carrier density in NCC/TMDC hybrids, advancing such novel systems to a level in which the incoming sunlight is harnessed, converted, stored as charges and released on demand to power an electric circuit.

Link to the ERC project webpage:

Keywords of the ERC project:

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Lewis bases are a fundamental class of compounds that are of utmost importance in almost any chemical transformation. According to the HSAB concept, they determine important properties such as the stability or solubility of compounds or the selectivity of reactions. Yet, Lewis bases are used far beyond simple acid-base pairs. In coordination chemistry they act as efficient σ-donor ligands, which crucially affect the electronics of the metal and thus its reactivity. Additionally, bulky Lewis bases as part of Frustrated Lewis Pairs are applicable in bond activation reactions and also in catalysis. Typical Lewis bases are neutral compounds with a free pair of electrons, such as amines or phosphines. In contrast, carbon-centred Lewis bases such as carbenes have long been underestimated due to their usually high reactivity and sensitivity. Yet, the last decades have revealed a revolution in this context. Carbenes in particular have proven to be powerful reagents not only as ligands, but also in organocatalysis and bond activation chemistry. Bisylides and their dianionic congeners (methandiides) with formally two electron pairs at carbon are further classes of carbon bases that have started to find applications, but which are still profoundly underdeveloped.

This project takes aim at the development and application of novel ylidic, carbon-centred Lewis bases. By means of a smart molecular design, systems with unusual electronic properties and donor capacities will be prepared and their reactivity towards main group element compounds and transition metal complexes will be explored. Employing experimental and computational methods a fundamental understanding of the electronic structure and its influencing factors will be provided. This will allow a manipulation and tailoring of the properties and reactivities and thus open applications such as in bond activation reactions or their use as electronically flexible ligands in catalytically active metal complexes.

Link to the ERC project webpage: https://www.ruhr-uni-bochum.de/ac2/index.html.en
Keywords of the ERC project: homogenous catalysis - main group chemistry - organometallic chemistry
Keywords that characterize the scientific profile of the potential visiting researcher/s: Organometallic chemistry
Reactivity and Assembly of Multifunctional, Stimuli-responsive Encapsulation Structures

In biochemical systems, combinations of specialized molecular entities are precisely arranged to give highly complex architectures. Sophisticated functionality, such as the selective chemical transformation of substrates in enzymes, emerges from the interplay of the individual components that are often grouped around a nanoscopic cavity. Control mechanisms based on the cooperative binding of signal substances regulate the enzyme’s action, and complicated feedback loops may apply.

Since the advent of supramolecular chemistry, scientists construct artificial systems with ever increasing complexity and functionality that promise to serve as the basis for future developments in bottom-up nanotechnology with applications in medicine (drug delivery), diagnostics, catalysis, material science and molecular photonics/electronics.

Self-assembly of functional entities with pre-programmed connectivities has produced an impressive line-up of nanoscopic architectures such as coordination cages that recognize and transform molecular substrates. Most of these systems are based on one sort of ligand, joined by one kind of metal ion. My group has reported a number of cages, each equipped with a unique, single function such as chirality, redox-activity, light-switching, allosteric regulation or endohedral binding sites.

While all these mono-functionalized cages contribute to the progress of supramolecular architecture, nature demonstrates that the key to the most sophisticated systems lies in multi-functionalized structures. As breakthrough strategies for achieving this level of complexity with artificial systems we propose:
1) Heteroleptic coordination of ligands by a [Pd2Ligand4]-platform-specific way of steric fine-tuning
2) Biopolymer-inspired folding of a modular chain of covalently joined building blocks

Combined with our recent achievements in host-guest switching, we aim at adjustable receptors, controllable molecular reaction chambers and multifunctional photo/redox systems

Link to the ERC project webpage: http://www.clever-lab.de

Keywords of the ERC project: Supramolecular Chemistry, Self-Assembly, Synthetic Chemistry, Coordination Cages, Self-Sorting, Host-Guest Chemistry, Confinement-controlled chemistry, Catalysis, Photoswitches, Systems Chemistry, Chiroptical Properties, Ion Mobility Mass Spectrometry

Keywords that characterize the scientific profile of the potential visiting researcher/s: Homogeneous Catalysis, CD/CPL Spectroscopy, Ion Mobility Mass Spectrometry, Molecular Dynamics Simulation, Light-Induced Processes, Systems Chemistry
Efficient daytime cooling without the need for a heat engine is an essential technology to lower our overall energy consumption. Nature offers a chance to off-load heat directly into the cold outer space via the so-called “sky window”: a spectral range from 8 – 13 µm, where our atmosphere is transparent. Concomitantly, solar radiance influx needs to be minimized by scattering and reflection, which would counteract the radiatively removed energy. VISIRday aims to provide ground-breaking new materials and concepts to emit thermal energy directly into this transparent sky window. A radically holistic approach is necessary to understand and design the optical properties of nano- and mesostructured materials over the entire spectral range (300 nm – 20 µm), with the mid-IR sky window being fully emissive, and all other spectral wavelengths being fully reflective. I will therefore combine top-down direct write lithography with intricate bottom-up colloidal self-assembly to device hierarchically structured systems fully addressing these stringent optical properties. A new material class – surface phonon polariton supporting nano- and mesoparticles – with adjustable absorption properties in the mid-IR range, will take a leading role as novel colloidal building block. In combination with polymers and metallic nanostructures my team will demonstrate hybrid structures with finely adjusted and even externally tuneable optical properties. Simulations based on finite element modelling to conceive optimum design rules will complement the experimental work. Inspired by examples from nature, namely white beetles and the Saharan silver ant, I will push the fundamental insights towards novel technologies such as radiative daytime cooling paints and fibres. I am convinced that this project provides the urgently needed materials and concepts to add radiative daytime cooling to the existing mix of green energy technologies.
Exploring the Limits of High Potential Oxidizers
Prediction, Validation and Preparation of Unusual Molecules at the Edge of Stability

The very well-known concept of formal oxidation states, used e. g. for redox reactions is one of the most fundamental ones in general chemistry. However, in the area of very strong oxidizers even the familiar oxido(-II) ligand becomes redox-innocent and assigning oxidation states becomes ambiguous. Very strong (super-)oxidizers are compounds whose oxidizing strength exceeds that of elemental F2. Anyhow, not only molecular oxidizer but also their interaction with the environment in different media needs to be considered, as these dramatically affect their intrinsic oxidizing strength. Here we propose novel conjugate oxidizer/Lewis or Brønsted acid systems with extremely high ox. power. These new ox. media make use of the alliance of high ox. strength and Lewis /Brønsted super acidity. The investigation and development of oxidizers is of essential interest in all areas of chemistry and beyond. Unfortunately a detailed understanding of this fundamental chemistry is still lacking. Here we describe based on three work strands PV, MI, and BP, how we aim at a more fundamental understanding of such systems. The undertaken research, which includes qc investigations, molecular characterizations in matrices and synthetic fluorine chemistry as well as oxido complexes is summarized in five work packages describing different prototype areas (organigram). Based on the gained knowledge, the project will rank and specify such oxidizers and the mechanism leading to ox. media. By using the threefold work strand approach, our project will guide us in a systematic discovery of the systems with high application potential in terms of selectivity and disposability, and oxidizing systems with high to ultrahigh oxidation potentials, and into the chemical terra incognita of fragile molecules at the edge of stability. We envision to highlight that the outcome of the project will be extremely useful for scientists from almost all fields of chemistry and related disciplines.

Link to the ERC project webpage:

Keywords of the ERC project:
Supramolecular machineries with life-like mechanical functions

Artificial molecular motors and switches have the potential to become a core part of nanotechnology. However, a wide gap in length scales still remains unaccounted for, between the operation of these molecules in solution, where their individual mechanical action is randomly dispersed in the Brownian storm, and on the other hand their action at the macroscopic level, e.g. in polymer networks and crystals.

This proposal is about bridging this gap, by developing chemo-mechanical transduction strategies that will allow dynamic molecules to perform a range of unprecedented tasks, e.g. by generating strong directional forces at the nanoscale, and through shape-shifting microscopic formations.

This project aims to harness the mechanically-purposeful motion of dynamic molecules as to generate measurable forces from the nanoscale, and ultimately establish operational principles for chemo-mechanical transduction in supramolecular systems.

In my wholly synthetic approach, I draw inspiration from the operational principles of microtubules. I will incorporate molecular photo-switches into supramolecular tubes, and enable the controlled growth and disassembly of the tubes by using light as the energy input. Thus, I will: (i) Synthesize stiff supramolecular tubes that grow actively under continuous illumination, and disassemble with a power stroke as soon as illumination stops; (ii) Measure, and harvest the forces generated by the tubes to manipulate individual nanoparticles with a sense of directionality; and (iii) Encapsulate the tubes into water droplets and vesicles, to yield shape-shifting, and eventually rudimentary splitting models for cells.

This project reaches beyond the state of the art in adaptive molecular nano-systems, by pioneering strategies to engineer and harness strain in supramolecular assemblies. It thus lays the foundations for machineries that are capable of manipulating matter at length scales that are also those at which the cytoskeleton operates.

Link to the ERC project webpage:

Keywords of the ERC project: chemo-mechanical transduction, molecular self-assembly, molecular machines, mechano-adaptation, artificial cytoskeleton

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Automated Program Analysis for Advanced Web Applications

Web applications that execute in the user’s web browser constitute a substantial part of modern software. JavaScript is the main programming language of the web, although alternatives are emerging, in particular, TypeScript and Dart. Despite the advances in design of languages and libraries, it is difficult to prevent errors when programming such web applications. Although the basic principles of software verification have been known for decades and researchers have developed an abundance of techniques for formal reasoning about programs, modern software has lots of errors, as everyday users can testify.

The PAW project will create novel automated program analysis algorithms for preventing errors and improving performance of advanced web applications. The project hypothesis is that a scientific breakthrough is within reach, due to recent results in static and dynamic program analysis for JavaScript. The central idea is to combine static and dynamic analysis in new ways. In addition, the project will make program analysis algorithms and infrastructure available in a form that embraces reusability.

Link to the ERC project webpage: http://casa.au.dk/

Keywords of the ERC project: program analysis, automated testing, JavaScript

Keywords that characterize the scientific profile of the potential visiting researcher/s:
The AMPLify project will lay the foundations of a new field, computational behavioural game theory that brings a computational perspective, computational implementation, and behavioural insights to game theory. These foundations will be laid by tackling a pressing problem facing society today: the efficient and fair allocation of resources and costs. Research in allocation has previously considered simple, abstract models like cake cutting. We propose to develop richer models that capture important new features like asynchronicity which occur in many markets being developed in our highly connected and online world. The mechanisms currently used to allocate resources and costs are limited to these simple, abstract models and also do not take into account how people actually behave in practice. We will therefore design new mechanisms for these richer allocation problems that exploit insights gained from behavioural game theory like loss aversion. We will also tackle the complexity of these rich models and mechanisms with computational tools. Finally, we will use computation to increase both the efficiency and fairness of allocations. As a result, we will be able to do more with fewer resources and greater fairness. Our initial case studies in resource and cost allocation demonstrate that we can improve efficiency greatly, offering one company alone savings of up to 10% (which is worth tens of millions of dollars every year). We predict even greater impact with the more sophisticated mechanisms to be developed during the course of this project.

Link to the ERC project webpage:

Keywords of the ERC project: resource allocation, social choice, artificial intelligence

Keywords that characterize the scientific profile of the potential visiting researcher/s: resource allocation, social choice, artificial intelligence
Securing Software against Physical Attacks

More than 15 years ago, several seminal publications showed that cryptographic keys can be revealed by analysing the power consumption or by inducing faults to devices like smart cards. The publication of these so-called physical attacks sparked off research on all kinds of attack techniques and countermeasures to secure implementations of cryptographic schemes.

However, a system can still be attacked easily if only the execution of cryptographic schemes is secured. An attacker can for example induce a fault to bypass an authentication or to jump to a privileged function directly. The system might also leak the key before the execution of a cryptographic scheme starts.

Today, there is almost no research on securing systems and software execution against physical attacks. Products like smart cards rely on proprietary best-practice countermeasures. Also countless devices of the Internet of Things are exposed to physical attacks and lack protection.

Our goal is to close this fundamental gap in system security and to establish the scientific foundation for executing software securely and efficiently in the presence of physical attacks. We aim to address research questions that range from the modelling of the attacks at the hardware level up to system-level questions like how changing properties of programming languages can support achieving protection against physical attacks.

This project brings together research on physical attacks, cryptography, system architectures, fault tolerant design as well as formal methods. Combining the fields, we pursue novel approaches to securing the control flow, CPU computations and memories. We in particular aim to find efficient methods in hardware and software that allow building systems where critical parts of the overall software can be secured against physical attacks without affecting or trusting the rest of the system. Our research also includes automated generation and verification techniques for the secured software.

Link to the ERC project webpage:

Keywords of the ERC project: cybersecurity, processors, side channels, hardware

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Principles of Graph Data Integration

The present proposal tackles fundamental problems in data management, leveraging expressive, large-scale and heterogeneous graph structures in order to integrate both unstructured (e.g., text) and structured (e.g., relational) content. Integrating heterogeneous content has become a key hurdle in the deployment of Big Data applications, due to the meteoric rise of both machine and user-generated data storing information in a variety of formats. Traditional integration techniques cleaning up, fusing and then mapping heterogeneous data onto rigid abstractions fall short of accurately capturing the complexity and wild heterogeneity of today's information. Having closely followed the emergence of heterogeneous information sources online, I am convinced that only an interdisciplinary approach drawing both from classical data management and from large-scale Web information processing techniques can solve the formidable data integration challenges that they pose. The following project proposes an ambitious overhaul of information integration techniques embracing the scale and heterogeneity of today's data. I propose the use of expressive and heterogeneous graphs of entities to continuously and dynamically interrelate disparate pieces of content while capturing their idiosyncrasies. The following project focuses on three core issues related to large-scale and heterogeneous information graphs: i) the effective extraction of fine-grained information from unstructured sources and their proper integration into large-scale heterogeneous and probabilistic graphs, ii) the creation of novel physical storage structures and primitives to durably and efficiently manage the profusion of data considered by such graphs using clusters of commodity machines, and iii) the development of logical data abstraction mechanisms facilitating the effective and efficient resolution of complex analytic and data integration queries on top of the physical layer.

Link to the ERC project webpage: https://exascale.info/graphint-project/

Keywords of the ERC project: Graph Data; Graph Embeddings; Information Extraction; Knowledge Graphs; Queries on New Hardware

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Unified Principles of Interaction

Most of today’s computer interfaces are based on principles and conceptual models created in the late seventies. They are designed for a single user interacting with a closed application on a single device with a predefined set of tools to manipulate a single type of content. But one is not enough! We need flexible and extensible environments where multiple users can truly share content and manipulate it simultaneously, where applications can be distributed across multiple devices, where content and tools can migrate from one device to the next, and where users can freely choose, combine and even create tools to make their own digital workbench.

The goal of ONE is to fundamentally re-think the basic principles and conceptual model of interactive systems to empower users by letting them appropriate their digital environment. The project will address this challenge through three interleaved strands: empirical studies to better understand interaction in both the physical and digital worlds, theoretical work to create a conceptual model of interaction and interactive systems, and prototype development to test these principles and concepts in the lab and in the field. Drawing inspiration from physics, biology and psychology, the conceptual model will combine substrates to manage digital information at various levels of abstraction and representation, instruments to manipulate substrates, and environments to organize substrates and instruments into digital workspaces.

By identifying first principles of interaction, ONE will unify a wide variety of interaction styles and create more open and flexible interactive environments.

Link to the ERC project webpage: http://erc.one
Keywords of the ERC project: Human-Computer Interaction
Keywords that characterize the scientific profile of the potential visiting researcher/s: Human-Computer Interaction
One of the grand challenges of computer graphics has been to generate images indistinguishable from photographs for a naïve observer. As this challenge is mostly completed and computer generated imagery starts to replace photographs (product catalogues, special effects in cinema), the next grand challenge is to produce imagery that is indistinguishable from the real-world.

Tremendous progress in capture, manipulation and display technologies opens the potential to achieve this new challenge (at the research stage) in the next 5-10 years. Electronic displays offer sufficient resolution, frame rate, dynamic range, colour gamut and, in some configurations, can produce binocular and focal depth cues. However, most of the work done in this area ignores or does not sufficiently address one of the key aspects of this problem - the performance and limitations of the human visual system.

The objective of this project is to characterise and model the performance and limitations of the human visual system when observing complex dynamic 3D scenes. The scene will span a high dynamic range (HDR) of luminance and provide binocular and focal depth cues. In technical terms, the project aims to create a visual model and difference metric for high dynamic range light fields (HDR-LFs). The visual metric will replace tedious subjective testing and provide the first automated method that can optimize encoding and processing of HDR-LF data.

Perceptually realistic video will impose enormous storage and processing requirements compared to traditional video. The bandwidth of such rich visual content will be the main bottleneck for new imaging and display technologies. Therefore, the final objective of this project is to use the new visual metric to derive an efficient and approximately perceptually uniform encoding of HDR-LFs. Such encoding will radically reduce storage and bandwidth requirements and will pave the way for future highly realistic image and video content.

Link to the ERC project webpage: https://www.cl.cam.ac.uk/~rkm38/

Keywords of the ERC project: computational displays; computer graphics; perception-limited rendering

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Common Interactive Objects

In CIO, common interactive objects are developed and explored to extend human control over the technological environment by human beings, both individually and together. CIO leads to a coherent framework of user interfaces to be applied in interaction design. Common interactive objects will provide a useful frame for furthering human computer interaction (HCI) theory, development of interaction design methods and the underlying technical platforms. Common interactive objects will empower users to better understand and develop the technologies they use.

When carried through, the project offers new ways for people to construct and configure human physical and virtual environments, together, over time and within communities.

The main objectives of CIO are to

1. develop the conception of common interactive objects in order to offer a new understanding of human-computer interaction, focusing on human control.
2. develop support for building user interfaces in a coherent and unified framework.
3. make common interactive objects that will empower users to better understand and develop the technologies they use.
4. carry out ground-breaking research regarding the technological basis of common interactive objects with focus on malleability, control and shareability over time.

CIO is methodologically rooted in HCI. CIO’s research methods combine empirical, analytical, theoretical, and design approaches, all with focus on the relationship between common interactive objects and their human users.

CIO presents the idea that common interactive objects may radically innovate our understanding of use and building user interfaces. The gains of CIO will be a coherent, high-impact way of understanding and building HCI across physical and virtual structures, bringing control back to the users. The risks are in delivering this alternative in a manner that is able to confront the current strong commercial interests in the Internet-of-Things and the ‘new’ Artificial Intelligence

Link to the ERC project webpage:

Keywords of the ERC project:
Keywords that characterize the scientific profile of the potential visiting researcher/s:
Large-Scale Formal Proof for the Working Mathematician

Mathematical proofs have always been prone to error. Today, proofs can be hundreds of pages long and combine results from many specialisms, making them almost impossible to check. One solution is to deploy modern verification technology. Interactive theorem provers have demonstrated their potential as vehicles for formalising mathematics through achievements such as the verification of the Kepler Conjecture. Proofs done using such tools reach a high standard of correctness.

However, existing theorem provers are unsuitable for mathematics. Their formal proofs are unreadable. They struggle to do simple tasks, such as evaluating limits. They lack much basic mathematics, and the material they do have is difficult to locate and apply.

ALEXANDRIA will create a proof development environment attractive to working mathematicians, utilising the best technology available across computer science. Its focus will be the management and use of large-scale mathematical knowledge, both theorems and algorithms. The project will employ mathematicians to investigate the formalisation of mathematics in practice. Our already substantial formalised libraries will serve as the starting point. They will be extended and annotated to support sophisticated searches. Techniques will be borrowed from machine learning, information retrieval and natural language processing. Algorithms will be treated similarly: ALEXANDRIA will help users find and invoke the proof methods and algorithms appropriate for the task.

ALEXANDRIA will provide (1) comprehensive formal mathematical libraries; (2) search within libraries, and the mining of libraries for proof patterns; (3) automated support for the construction of large formal proofs; (4) sound and practical computer algebra tools.

ALEXANDRIA will be based on legible structured proofs. Formal proofs should be not mere code, but a machine-checkable form of communication between mathematicians.

Link to the ERC project webpage: https://www.cl.cam.ac.uk/~lp15/Grants/Alexandria/

Keywords of the ERC project: Interactive theorem proving, formalisation of mathematics

Keywords that characterize the scientific profile of the potential visiting researcher/s: Mathematician, physicist
Society generates increasing amounts of data, which is both a resource and a challenge. The data reveal new insights that may potentially improve our livelihood, but their quantity renders such insights difficult to find. Machine learning techniques sift through the data looking for statistical patterns of interest to a given task. Due to an exponential growth in available data, these techniques enable us to automate difficult decisions, such as those needed for personalized medicine and self-driving cars.

NoTape note that machine learning techniques depend on a distance measure to determine which data points are similar and which are not. As this measure is difficult to choose, NoTape develop methods for estimating an optimal distance measure directly from data. Empirical evidence suggest that the optimal distance measure in one region of data space need not coincide with the optimal measure in another region, i.e. that the distance measure should locally adapt to the data. Local adaptability imply that the distance measure itself will be sensitive to noise in the data, and therefore should be described as a random variable. NoTape estimate distance measures as random Riemannian metrics and perform statistical data analysis accordingly. The notion of statistical computations with respect to an uncertain locally adaptive distance measure is uncharted territory, which need new algorithms for numerical integration and for solving differential equations.

As a guiding example, we estimate statistical models that reflect human perception. As perception processes are not fully understood, an optimal distance measure cannot be precisely estimated and the uncertainty of NoTape is needed.

The geometric nature of the developed methods ensure that attained models are interpretable by humans, which contrast current locally adaptive techniques. As society automate more decisions, interpretability is increasing important to ensure that the machine learning system can be trusted.

Link to the ERC project webpage:

Keywords of the ERC project: Machine Learning; Differential Geometry; Stochastic Geometry

Keywords that characterize the scientific profile of the potential visiting researcher/s: Statistics; machine learning; mathematics; geometry; numerical analysis
**Accelerating Neuroscience Research by Unifying Knowledge Representation and Analysis Through a Domain Specific Language**

Neuroscience is at an inflection point. The 150-year old cortical specialization paradigm, in which cortical brain areas have a distinct set of functions, is experiencing an unprecedented momentum with over 1000 articles being published every year. However, this paradigm is reaching its limits. Recent studies show that current approaches to atlas brain areas, like relative location, cellular population type, or connectivity, are not enough on their own to characterize a cortical area and its function unequivocally. This hinders the reproducibility and advancement of neuroscience.

Neuroscience is thus in dire need of a universal standard to specify neuroanatomy and function: a novel formal language allowing neuroscientists to simultaneously specify tissue characteristics, relative location, known function and connectional topology for the unequivocal identification of a given brain region.

The vision of NeuroLang is that a unified formal language for neuroanatomy will boost our understanding of the brain. By defining brain regions, networks, and cognitive tasks through a set of formal criteria, researchers will be able to synthesize and integrate data within and across diverse studies. NeuroLang will accelerate the development of neuroscience by providing a way to evaluate anatomical specificity, test current theories, and develop new hypotheses.

NeuroLang will lead to a new generation of computational tools for neuroscience research. In doing so, we will be shedding a novel light onto neurological research and possibly disease treatment and palliative care. Our project complements current developments in large multimodal studies across different databases. This project will bring the power of Domain Specific Languages to neuroscience research, driving the field towards a new paradigm articulating classical neuroanatomy with current statistical and machine learning-based approaches.

**Link to the ERC project webpage:**

**Keywords of the ERC project:**

**Keywords that characterize the scientific profile of the potential visiting researcher/s:** Neuroscience, Logic programming, logical inference, neuroanatomy, machine learning
Decentralized Blockchain-based Organizations for Bootstrapping the Collaborative Economy

The Collaborative Economy (CE) is rapidly expanding through new forms of Internet labor and commerce, from Wikipedia to Kickstarter and Airbnb. However, it suffers from 3 main challenges: (1) Infrastructure: centralized surveillance that the central hubs of information exercise over their users, (2) Governance: disempowered communities which do not have any decision-making influence over the platform, and (3) Economy: concentration of profits in a few major players who do not proportionally redistribute them to the contributors. How can CE software platforms be implemented for solving these challenges? P2PMODELS explores a new way of building CE software platforms harnessing the blockchain, an emerging technology that enables autonomous agent-mediated organizations, in order to (1) provide a software framework to build decentralized infrastructure for Collaborative Economy organizations that do not depend on central authorities, (2) enable democratic-by-design models of governance for communities, by encoding rules directly into the software platform, and (3) enable fairer value distribution models, thus improving the economic sustainability of both CE contributors and organizations.

Together, these 3 objectives will bootstrap the emergence of a new generation of self-governed and more economically sustainable peer-to-peer CE communities. The interdisciplinary nature of P2PMODELS will open a new research field around agent-mediated organizations for collaborative communities and their self-enforcing rules for automatic governance and economic rewarding. Bringing this proposal to life requires a funding scheme compatible with a high-risk/high-gain vision to finance a fully dedicated and highly motivated research team with multidisciplinary skills.

Link to the ERC project webpage: https://p2pmodels.eu

Keywords of the ERC project: collaborative economy, blockchain, commons, decentralization, governance, democracy, economic sustainability, inclusive tech

Keywords that characterize the scientific profile of the potential visiting researcher/s: postdoc, interdisciplinary research, computer science, social sciences
Closing the 4D Real World Reconstruction Loop

4D reconstruction, the camera-based dense dynamic scene reconstruction, is a grand challenge in computer graphics and computer vision. Despite great progress, 4D capturing the complex, diverse real world outside a studio is still far from feasible. 4DRepLy builds a new generation of high-fidelity 4D reconstruction (4DRecon) methods. They will be the first to efficiently capture all types of deformable objects (humans and other types) in crowded real world scenes with a single color or depth camera. They capture space-time coherent deforming geometry, motion, high-frequency reflectance and illumination at unprecedented detail, and will be the first to handle difficult occlusions, topology changes and large groups of interacting objects. They automatically adapt to new scene types, yet deliver models with meaningful, interpretable parameters. This requires far reaching contributions: First, we develop groundbreaking new plasticity-enhanced model-based 4D reconstruction methods that automatically adapt to new scenes. Second, we develop radically new machine learning-based dense 4D reconstruction methods. Third, these model- and learning-based methods are combined in two revolutionary new classes of 4DRecon methods: 1) advanced fusion-based methods and 2) methods with deep architectural integration. Both, 1) and 2), are automatically designed in the 4D Real World Reconstruction Loop, a revolutionary new design paradigm in which 4DRecon methods refine and adapt themselves while continuously processing unlabeled real world input. This overcomes the previously unbreakable scalability barrier to real world scene diversity, complexity and generality. This paradigm shift opens up a new research direction in graphics and vision and has far reaching relevance across many scientific fields. It enables new applications of profound social pervasion and significant economic impact, e.g., for visual media and virtual/augmented reality, and for future autonomous and robotic systems.

Link to the ERC project webpage: 
Keywords of the ERC project: 
Keywords that characterize the scientific profile of the potential visiting researcher/s:
A Grand Unified Theory of Decidability in Logic-Based Knowledge Representation

Logic-based knowledge representation (KR) constitutes a vital area of IT. The field inspires and guides scientific and technological developments enabling intelligent management of large and complex knowledge resources. Elaborate languages for specifying knowledge (so-called ontology languages) and querying it have been defined and standardized. Algorithms for automated reasoning and intelligent querying over knowledge resources are being developed, implemented and practically deployed on a wide scale. Thereby, decidability investigations play a pivotal role to characterize what reasoning or querying tasks are at all computationally solvable.

Past decades have seen a proliferation of new decidable formalisms for KR, dominated by two major paradigms: description logics and rule-based approaches, most notably existential rules. Recently, these research lines have started to converge and first progress has been made toward identifying commonalities among the various formalisms. Still, the underlying principles for establishing their decidability remain disparate, ranging from proof-theoretic notions to model-theoretic ones.

DeciGUT will accomplish a major breakthrough in the field by establishing a "Grand Unified Theory" of decidability. We will provide a novel, powerful model-theoretic criterion inspired by advanced graph-theoretic notions. We will prove that the criterion indeed ensures decidability and that it subsumes most of (if not all) currently known decidable formalisms in the KR field.

We will exploit our results toward the definition of novel decidable KR languages of unprecedented expressivity. We will ultimately extend our framework to encompass more advanced KR features beyond standard first order logic such as counting and non-monotonic aspects.

Our research will draw from and significantly impact the scientific fields of AI, Database Theory and Logic, but also give rise to drastically improved practical information management technology.

Link to the ERC project webpage:

Keywords of the ERC project: knowledge representation, logic, decidability

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Towards Unification of Algorithmic Tools

Over last 50 years, extensive algorithmic research gave rise to a plethora of fundamental results. These results equipped us with increasingly better solutions to a number of core problems. However, many of these solutions are incomparable. The main reason for that is the fact that many cutting-edge algorithmic results are very specialized in their applicability. Often, they are limited to particular parameter range or require different assumptions.

A natural question arises: is it possible to get “one to rule them all” algorithm for some core problems such as matchings and maximum flow? In other words, can we unify our algorithms? That is, can we develop an algorithmic framework that enables us to combine a number of existing, only “conditionally” optimal, algorithms into a single all-around optimal solution? Such results would unify the landscape of algorithmic theory but would also greatly enhance the impact of these cutting-edge developments on the real world. After all, algorithms and data structures are the basic building blocks of every computer program. However, currently using cutting-edge algorithms in an optimal way requires extensive expertise and thorough understanding of both the underlying implementation and the characteristics of the input data.

Hence, the need for such unified solutions seems to be critical from both theoretical and practical perspective. However, obtaining such algorithmic unification poses serious theoretical challenges. We believe that some of the recent advances in algorithms provide us with an opportunity to make serious progress towards solving these challenges in the context of several fundamental algorithmic problems. This project should be seen as the start of such a systematic study of unification of algorithmic tools with the aim to remove the need to “under the hood” while still guaranteeing an optimal performance independently of the particular usage case.

Link to the ERC project webpage: http://tugboat.mimuw.edu.pl/

Keywords of the ERC project: algorithms, online algorithms, graph algorithms

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Manipulating Acoustic wavefronts using metamaterials for novel user interfaces

In this project we will leverage developments in acoustic meta-materials to build interactive systems that manipulate sound to create experiences with the same ease and fidelity as we are so accustomed to doing with light. This involves designing and evaluating new acoustic meta-materials AND building interactive systems that create novel interaction experiences that were hitherto impossible to achieve.

We will use acoustic metamaterials technology to build a Spatial Sound Modulator (SSM) that aims to be a software controlled device that transforms an input acoustic wave into a time-variable, user-defined acoustic field. SSM comprises of a surface made of electronically adjustable acoustic metamaterial bricks. Each brick in the surface can individually vary the phase of an incident acoustic field, to shape the complex output field.

Our objectives are:
1. Design, implement and evaluate dynamically reconfigurable metamaterial unit-cells and surfaces using transmissive modes of operation. We will explore narrow-band devices for air-borne operation at low ultrasonic frequencies (e.g. 40 kHz).
2. Design SSMs from a spatial distribution of metamaterial unit cells. Specifically, we will identify discretization strategies, digital control mechanisms and develop concepts that are efficient and reduce field reconstruction errors while at the same time constructing the SSM from a small set of reconfigurable metamaterial unit-cells.
3. Create multiple application-specific prototypes of the SUM and identify context specific design constraints and trade-offs.

Link to the ERC project webpage: http://interact-lab.com/

Keywords of the ERC project: Human-computer interaction; computational fabrication; metamaterials

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Online markets currently form an important share of the global economy. The Internet hosts classical markets (real-estate, stocks, e-commerce) as well allowing new markets with previously unknown features (web-based advertisement, viral marketing, digital goods, crowdsourcing, sharing economy). Algorithms play a central role in many decision processes involved in online markets. For example, algorithms run electronic auctions, trade stocks, adjusts prices dynamically, and harvest big data to provide economic information. Thus, it is of paramount importance to understand the algorithmic and mechanism design foundations of online markets. The algorithmic research issues that we consider involve algorithmic mechanism design, online and approximation algorithms, modelling uncertainty in online market design, and large-scale data analysis and approximation algorithms, large-scale optimization and data mining. The aim of this research project is to combine these fields to consider research questions that are central for today's Internet economy. We plan to apply these techniques so as to solve fundamental algorithmic problems motivated by web-based Internet advertisement, Internet market design, sharing economy, and crowdsourcing online labour marketplaces. While my planned research is focused on foundational work with rigorous design and analysis of algorithms and mechanism design and analysis, it will also include as an important component empirical validation on large-scale real-life datasets.

Link to the ERC project webpage: https://sites.google.com/a/uniroma1.it/stefanoleonardi/

Keywords of the ERC project: Algorithmic Mechanism Design, Online and Approximation Algorithms, Algorithmic Data Analysis, Online Markets, Economics and Computation

Keywords that characterize the scientific profile of the potential visiting researcher/s: Algorithmic Mechanism and Market Design, Learning in Online Markets and Sequential Decision Making, Algorithms for large-scale clustering and matching
Energy-optimized Symmetric Cryptography by Algebraic Duality Analysis

The main scientific contribution of this project will be a breakthrough in the understanding of cryptanalytic and side channel attacks of symmetric cryptosystems. We will do this by a unification of attacks that will a stepping stone to the holy grail of symmetric cryptography: provable security of concrete cryptosystems. The main real-world impact is that we will build cryptosystems that are much more efficient than those used today while having the same strength. Depending on the platform, higher efficiency translates to lower energy/power (in-body sensors, contactless payment cards etc.), but also lower latency (authentication for e.g car brakes or airbags) and/or lower heat dissipation (on-the-fly encryption of high bandwidth data streams). In a software implementation it simply means less CPU cycles per byte.

We build our cryptosystems as modes, on top of block ciphers or permutations. For these primitives we adopt the classical technique of iterating a simple round function (more rounds means more security but less efficiency). We focus on round functions of algebraic degree 2. Their relative simplicity will allow a unification of all cryptanalytic attacks that exploit propagation of affine varieties and polynomial ideals (their dual) through the rounds and to precisely estimate their success rates. Moreover, we will design modes that strongly restrict the exposure of the primitive(s) to attackers and that permit security reductions to specific properties of the underlying primitive(s) in a formally verifiable way. In comparison to the classical pseudorandom and ideal permutation models, this will allow reducing the number of rounds while preserving security with high assurance. We will also study side channel attacks of our round functions and ways to defend against them. We will make ASIC prototypes and implement novel efficient countermeasures against side channel attacks and use this to evaluate their effectiveness in practice.

Link to the ERC project webpage:

Keywords of the ERC project: symmetric cryptography

Keywords that characterize the scientific profile of the potential visiting researcher/s: real world relevance
Discrete harmonic analysis for computer science

Boolean function analysis is a topic of research at the heart of theoretical computer science. It studies functions on n input bits (for example, functions computed by Boolean circuits) from a spectral perspective, by treating them as real-valued functions on the group $\mathbb{Z}_2^n$, and using techniques from Fourier and functional analysis. Boolean function analysis has been applied to a wide variety of areas within theoretical computer science, including hardness of approximation, learning theory, coding theory, and quantum complexity theory.

Despite its immense usefulness, Boolean function analysis has limited scope, since it is only appropriate for studying functions on $\{0,1\}^n$ (a domain known as the Boolean hypercube). Discrete harmonic analysis is the study of functions on domains possessing richer algebraic structure such as the symmetric group (the group of all permutations), using techniques from representation theory and Sperner theory. The considerable success of Boolean function analysis suggests that discrete harmonic analysis could likewise play a central role in theoretical computer science.

The goal of this proposal is to systematically develop discrete harmonic analysis on a broad variety of domains, with an eye toward applications in several areas of theoretical computer science. We will generalize classical results of Boolean function analysis beyond the Boolean hypercube, to domains such as finite groups, association schemes (a generalization of finite groups), the quantum analog of the Boolean hypercube, and high-dimensional expanders (high-dimensional analogs of expander graphs). Potential applications include a quantum PCP theorem and two outstanding open questions in hardness of approximation: the Unique Games Conjecture and the Sliding Scale Conjecture. Beyond these concrete applications, we expect that the fundamental results we prove will have many other applications that are hard to predict in advance.

Link to the ERC project webpage:

Keywords of the ERC project: Computational complexity, Boolean function analysis

Keywords that characterize the scientific profile of the potential visiting researcher/s:
A Theory-Oriented Real-Time Operating System for Temporally Sound Cyber-Physical Systems

The TOROS project targets the challenge of implementing safety-critical cyber-physical systems (CPSs) on commodity multicore processors such that their temporal correctness can be certified in a formal, trustworthy manner.

While today it is in principle possible to construct a CPS in a temporally sound way, in practice this rarely happens because, with the current real-time foundations, the prerequisite investments in time, expertise, and resources are prohibitive.

This situation is caused in large parts by three fundamental shortcomings in the design of state-of-the-art real-time operating systems (RTOSs) and the applicable timing analyses: (i) current RTOSs expose primarily low-level mechanisms that suffer from accidental unpredictability, i.e., mechanisms that require too much expertise to be used and composed in a temporally sound way; (ii) most analyses rely on idealized worst-case execution-time assumptions that realistically cannot be satisfied on commodity multicore platforms; and (iii) the available real-time theory depends on often complex and tedious proofs, and cannot always be trusted to be sound.

As a result, formal timing analysis is rarely relied upon in the certification of CPSs in reality, and instead the use of ad-hoc, unsound "safety margins" prevails.

The TOROS project seeks to close this gap by moving the RTOS closer to analysis, the analysis closer to reality, and by ensuring that the analysis can be trusted.

Specifically, the TOROS project will
1. introduce a radically new, theory-oriented RTOS that by design ensures that the temporal behavior of any workload can be analyzed (even if the application developer is unaware of the relevant theory),
2. develop a matching novel timing analysis that allows for below-worst-case provisioning with analytically sound safety margins that yields meaningful probabilistic response-time guarantees, and
3. mechanize and verify all supporting timing analysis with the Coq proof assistant.

Link to the ERC project webpage:

Keywords of the ERC project: real-time operating system, real-time scheduling, temporal verification

Keywords that characterize the scientific profile of the potential visiting researcher/s: Coq, stochastic response-time analysis
Perceptually-Driven Optimizations of Graphics Content for Novel Displays

Displays play a vital role in many professional and personal activities. They are a crucial interface between a user and the digital world in tasks involving visualization and interaction with digital data. The abilities of new display technologies regarding reproduction of important visual cues, such as binocular disparity, accommodation, or motion parallax, outperform the capabilities of methods for optimizing graphics content to match the requirements of particular hardware designs. This leads to a poor visual quality and massive computational overhead, which hamper the adoption of novel displays. I argue that there are significant gaps between hardware, computational techniques, and understanding of human perception, which prevents taking full advantage of these technologies.

To overcome these limitations, I and my team will combine hardware, computation, and perception into a unique platform where the capabilities of displays and quality requirements are represented in a shared space. The basis for our project will be in-depth understanding of human perception. Our experiments will focus on three aspects: (1) investigation of perceptual limits across a wide field of view, (2) involving all visual cues, and (3) establishing optimal trade-offs between different quality aspects. We will build efficient computational models that will predict perceived quality and enable perceptual optimizations to drive new content adaptation techniques.

This project will contribute display-specific perceptual optimizations of graphics content to match the requirements of human perception. It will address the key aspects of portable devices such as energy efficiency and visual quality. Our experiments and modeling of human perception will provide crucial insights into new hardware developments. The contributions will be necessary for development and standardization of new, high-quality display devices which will not only improve existing applications but also enable new ones.

Link to the ERC project webpage:

Keywords of the ERC project:

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Digital communication permeates all areas of today's daily life. Cryptographic protocols are used to secure that communication. Quantum communication and the advent of quantum computers both threaten existing cryptographic solutions, and create new opportunities for secure protocols. The security of cryptographic systems is normally ensured by mathematical proofs. Due to human error, however, these proofs often contain errors, limiting the usefulness of said proofs. This is especially true in the case of quantum protocols since human intuition is well-adapted to the classical world, but not to quantum mechanics. To resolve this problem, methods for verifying cryptographic security proofs using computers (i.e., for "certifying" the security) have been developed. Yet, all existing verification approaches handle classical cryptography only - for quantum protocols, no approaches exist.

This project will lay the foundations for the verification of quantum cryptography. We will design logics and software tools for developing and verifying security proofs on the computer, both for classical protocols secure against quantum computer (post-quantum security) and for protocols that use quantum communication. Our main approach is the design of a logic (quantum relational Hoare logic, qRHL) for reasoning about the relationship between pairs of quantum programs, together with an ecosystem of manual and automated reasoning tools, culminating in fully certified security proofs for real-world quantum protocols.

As a final result, the project will improve the security of protocols in the quantum age, by removing one possible source of human error. In addition, the project directly impacts the research community, by providing new foundations in program verification, and by providing cryptographers with new tools for the verification of their protocols.

**Certified Quantum Security**

**Link to the ERC project webpage:** [https://cordis.europa.eu/project/rcn/220451/factsheet/en](https://cordis.europa.eu/project/rcn/220451/factsheet/en)

**Keywords of the ERC project:** quantum cryptography, formal verification, semantics, quantum programs, theorem proving

**Keywords that characterize the scientific profile of the potential visiting researcher/s:** quantum cryptography, formal verification, semantics, quantum programs, theorem proving
Lossy Preprocessing

A critical component of computational processing of data sets is the ‘preprocessing’ or ‘compression’ step which is the computation of a \emph{succinct, sufficiently accurate} representation of the given data. Preprocessing is ubiquitous and a rigorous mathematical understanding of preprocessing algorithms is crucial in order to reason about and understand the limits of preprocessing. Unfortunately, there is no mathematical framework to analyze and objectively compare two preprocessing routines while simultaneously taking into account ‘all three dimensions’ --

-- the efficiency of computing the succinct representation,
-- the space required to store this representation, and
-- the accuracy with which the original data is captured in the succinct representation.

``The overarching goal of this proposal is the development of a mathematical framework for the rigorous analysis of preprocessing algorithms. "

We will achieve the goal by designing new algorithmic techniques for preprocessing, developing a framework of analysis to make qualitative comparisons between various preprocessing routines based on the criteria above and by developing lower bound tools required to understand the limitations of preprocessing for concrete problems. This project will lift our understanding of algorithmic preprocessing to new heights and lead to a groundbreaking shift in the set of basic research questions attached to the study of preprocessing for specific problems. It will significantly advance the analysis of preprocessing and yield substantial technology transfer between adjacent subfields of computer science such as dynamic algorithms, streaming algorithms, property testing and graph theory.

Link to the ERC project webpage:

Keywords of the ERC project:

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Knowledge Graph based Representation, Augmentation and Exploration of Scholarly Communication

Despite an improved digital access to scientific publications in the last decades, the fundamental principles of scholarly communication remain unchanged and continue to be largely document-based. The document-oriented workflows in science have reached the limits of adequacy as highlighted by recent discussions on the increasing proliferation of scientific literature, the deficiency of peer-review and the reproducibility crisis.

In ScienceGRAPH we aim to develop a novel model for representing, analysing, augmenting and exploiting scholarly communication in a knowledge-based way by expressing and linking scientific contributions and related artefacts through semantically rich, interlinked knowledge graphs. The model is based on deep semantic representation of scientific contributions, their manual, crowd-sourced and automatic augmentation and finally the intuitive exploration and interaction employing question answering on the resulting ScienceGRAPH base.

Currently, knowledge graphs are still confined to representing encyclopaedic, factual information. ScienceGRAPH advances the state-of-the-art by enabling to represent complex interdisciplinary scientific information including fine-grained provenance preservation, discourse capture, evolution tracing and concept drift. Also, we will demonstrate that we can synergistically combine automated extraction and augmentation techniques, with large-scale collaboration to reach an unprecedented level of knowledge graph breadth and depth.

As a result, we expect a paradigm shift in the methods of academic discourse towards knowledge-based information flows, which facilitate completely new ways of search and exploration. The efficiency and effectiveness of scholarly communication will significant increase, since ambiguities are reduced, reproducibility is facilitated, redundancy is avoided, provenance and contributions can be better traced and the interconnections of research contributions are made more explicit and transparent.

Link to the ERC project webpage: https://projects.tib.eu/orkg/sciencegraph/

Keywords of the ERC project: knowledge graphs, scholarly communication, semantic technologies, NLP, artificial intelligence, digital libraries

Keywords that characterize the scientific profile of the potential visiting researcher/s: knowledge graphs, scholarly communication, semantic technologies, NLP, artificial intelligence, machine learning, digital libraries
White-Box Self-Programming Mechanisms

We are witnessing an increasing availability of mechanisms that operate in nondeterministic (uncertain) environments and offer some form of programmability. These include manufacturing devices, smart objects and spaces, intelligent robots, dynamic business process management systems, and many others. All these mechanisms are currently being revolutionized by advancements in sensing (vision, language understanding) and actuation components (autonomous mobile manipulators, automated storage and retrieval systems). However, such mechanisms are held back by the fact that their logic is still based on hard-wired rules encoded in hand-crafted programs. WhiteMech aims at developing the science and the tools for a new generation of mechanisms to emerge: mechanisms that are able to program themselves, automatically tailor their behavior so as to achieve desired goals, maintain themselves within safe boundaries in a changing environment, and follow regulations and conventions that evolve over time. Crucially, empowering mechanisms with self-programming carries significant risks and therefore we must be able to balance power with safety. For this reason WhiteMech intends to realize mechanisms that are white-box, that is, whose behavior is at any moment fully analyzable and comprehensible in human terms, and guarded by human oversight. Remarkable recent discoveries by the applicant in Reasoning about Action and Generalized Planning in Artificial Intelligence, and their connections to Verification and Synthesis in Formal Methods, and Data-Aware Processes in Databases, chart an unanticipated novel path to produce a breakthrough in realizing powerful self-programming mechanisms, while keeping them human-comprehensible and safe by design. WhiteMech will ground its scientific results upon three driving applications: smart manufacturing (Industry 4.0), smart spaces (IoT) and business process management systems (BPM).

Link to the ERC project webpage: https://www.diag.uniroma1.it/~degiacomo

Keywords of the ERC project: Planning in AI, Knowledge Representation, Reactive Synthesis from Temporal Logics Specs, Formal Methods, Autonomous Agents, Logics in AI, Reinforcement Learning, Automata, Logics and Games, Monitoring and Verification, Data-aware processes, Service Compos

Keywords that characterize the scientific profile of the potential visiting researcher/s: Planning in AI, Knowledge Representation, Reactive Synthesis from Temporal Logics Specs, Formal Methods, Autonomous Agents, Logics in AI, Reinforcement Learning, Automata, Logics and Games, Monitoring and Verification, Data-aware processes, Service Compos
A wealthy friend of mine asks for a vacation credit card to his bank, to discover that the credit he is offered is very low. The bank teller cannot explain why. My stubborn friend continues his quest for explanation up to the bank executives, to discover that an algorithm lowered his credit score. Why? After a long investigation, it turns out that the reason is: bad credit by the former owner of my friend's house.

Black box AI systems for automated decision making, often based on ML over (big) data, map a user's features into a class or a score without explaining why. This is problematic for lack of transparency, but also for possible biases inherited by the algorithms from human prejudices and collection artefacts hidden in the training data, which may lead to unfair or wrong decisions.

I strive for solutions of the urgent challenge of how to construct meaningful explanations of opaque AI/ML systems, introducing the local-to-global framework for black box explanation, articulated along 3 lines: a) the language for explanations in terms of expressive logic rules, with statistical and causal interpretation; b) the inference of local explanations for revealing the decision rationale for a specific case; c), the bottom-up generalization of many local explanations into simple global ones. An intertwined line of research will investigate both causal explanations, i.e., models that capture the causal relationships among the features and the decision, and mechanistic/physical models of complex system physics, that capture the data generation mechanism behind specific deep learning models.

I will also develop: an infrastructure for benchmarking, for the users' assessment of the explanations and the crowdsensing of observational decision data; an ethical-legal framework, for compliance and impact of our results on legal standards and on the “right of explanation” provisions of the GDPR; case studies in explanation-by-design, with a priority in health and fraud detection.

Link to the ERC project webpage: http://www.sobigdata.eu/exploratories/explainable-machine-learning

Keywords of the ERC project: Explainable Machine Learning, factual and counter factual, causal reasoning, explainable AI

Keywords that characterize the scientific profile of the potential visiting researcher/s: Deep learning expert or inductive logic programming expert, or causal reasoning expert, or cognitive science expert
With the ever-increasing use of internet-connected devices, such as computers, smart grids, IoT appliances and GPS-enabled equipments, personal data are collected in larger and larger amounts, and then stored and manipulated for the most diverse purposes. Undeniably, the big-data technology provides enormous benefits to industry, individuals and society, ranging from improving business strategies and boosting quality of service to enhancing scientific progress. On the other hand, however, the collection and manipulation of personal data raises alarming privacy issues. Both the experts and the population at large are becoming increasingly aware of the risks, due to the repeated cases of violations and leaks that keep hitting the headlines. The objective of this project is to develop the theoretical foundations, methods and tools to protect the privacy of the individuals while letting their data to be collected and used for statistical purposes. We aim in particular at developing mechanisms that: (1) can be applied and controlled directly by the user, thus avoiding the need of a trusted party, (2) are robust with respect to combination of information from different sources, and (3) provide an optimal trade-off between privacy and utility. We intend to pursue these goals by developing a new framework for privacy based on the addition of controlled noise to individual data, and associated methods to recover the useful statistical information, and to protect the quality of service.

**Link to the ERC project webpage:** https://project.inria.fr/hypatia/

**Keywords of the ERC project:** Privacy, Differential Privacy, Local Differential Privacy, Machine Learning and Privacy, Utility of Sanitized Data, Quantitative Information Flow.

**Keywords that characterize the scientific profile of the potential visiting researcher/s:** Privacy, Differential Privacy, Local Differential Privacy, Machine Learning and Privacy, Utility of Sanitized Data, Fairness in Machine Learning and relation with Privacy, Quantitative Information Flow, Robustness in Machine Learning.
Safe and Complete Algorithms for Bioinformatics

Many real-world problems are modeled as computational problems, but unfortunately with incomplete data or knowledge. As such, they may admit a large number of solutions, and we have no way of finding the correct one. This issue is sometimes addressed by outputting all solutions, which is infeasible for many practical problems. We aim to construct a general methodology for finding the set of all sub-solutions common to all solutions. We can ultimately trust these to be part of the correct solution. We call this set "safe". Ultimately, we aim at creating automated and efficient ways of reporting all safe sub-solutions of a problem. The main motivation of this project comes from Bioinformatics, in particular from the analysis of high-throughput sequencing (HTS) of DNA. One of the main applications of HTS data is to assemble it back into the original DNA sequence. This genome assembly problem admits many solutions, and current research has indeed considered outputting only partial solutions that are likely to be present in the correct original DNA sequence. However, this problem has been approached only from an experimental point of view, with no definite answer on what are all the safe sub-solutions to report. In fact, the issue of safe sub-solutions has been mostly overlooked in Bioinformatics and Computer Science in general. This project will derive the first safe algorithms for a number of fundamental problems about walks in graphs, network flows, dynamic programming. We will apply these inside practical tools for genome assembly, RNA assembly and pan-genome analysis. This is very relevant at the moment, because HTS goes from research labs to hospitals, and we need answers that are first of all accurate. Our approach changes the perspective from which we address all real-world problems, and could spur a new line of research in Computer Science/Bioinformatics. The grand aim is a mathematical leap into understanding what can be safely reported from the data.

Link to the ERC project webpage:

Keywords of the ERC project: bioinformatics, high-throughput sequencing, graph algorithms, string algorithms, data structures, genome assembly, RNA assembly, pan-genomes, variation calling

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Verification-Aware Programming Language Concurrency Semantics

With the proliferation of multi-core processors, concurrent programming regularly appears at the core of heavily relied-upon systems, where both performance and correctness are of paramount importance. The canonical concurrency model is sequential consistency-identifying concurrent programs with all possible interleavings of operations of their constitute threads. It is a simple model for programmers, but unsatisfactory as a programming language concurrency semantics. First, performance-wise, it is too costly to implement. In fact, no commodity hardware provides sequential consistency. Second, the number of interleavings is often so large, posing the infamous "state explosion problem" as the utmost obstacle to any verification attempt.

Our overarching goal is to develop a novel concurrency semantics for programming languages that will: allow efficient implementation; provide easily usable guarantees, sufficiently strong for concurrent algorithms; and be amenable to scalable verification. To achieve this, we will leverage our recent advances in addressing the flaws in the C/C++ and Java specifications and in model checking under certain weak concurrency semantics. Moreover, we will develop practical verification methods to facilitate the task of concurrent programming.

This proposal makes a conceptual leap beyond the state-of-the-art, by identifying the development of a weak concurrency semantics not only as an unfortunate necessity, but also as an opportunity to revolutionize software verification. It is high-risk: it tackles a longstanding open problem in programming languages. It is also high-gain: it will significantly increase the applicability of verification, bridge a major gap between verification research and practical concurrent programming, and shed light on the role of the underlying semantics. I aim for the proposed concurrency semantics to provide new foundations for the specifications of mainstream and emerging programming languages.

Link to the ERC project webpage:

Keywords of the ERC project: Weak-memory, concurrency, semantics, verification, programming languages, model checking, Coq

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Learning to Find Software Bugs

Software has become the cornerstone of modern society, economy, and life. Since software is created by humans, though, every non-trivial program contains various bugs, i.e., programming errors that may have disastrous consequences. Traditional approaches to find bugs include automated bug detection tools. Such tools search for instances of bug patterns that recur across projects and application domains. However, automated bug detection currently cannot unleash its full potential because each bug detector addresses one bug pattern and one programming language, while creating new bug detectors is feasible only for program analysis experts.

The objective of this proposal is to radically change the way automated bug detection tools are created. The core idea is to replace manually written program analyses with trained machine learning models. To this end, developers will train a bug detector for a particular bug pattern with examples of buggy and non-buggy code, which the model learns to distinguish. The project will realize this vision by developing a reusable framework that addresses several fundamental challenges at the intersection of software engineering, programming languages, and machine learning, e.g.: (i) How to support developers in creating large amounts of training data of buggy and non-buggy code examples? (ii) How to represent programs in a way suitable for advanced machine learning techniques?

The proposed project has the potential to revolutionize how software developers find bugs. To date, no other research has addressed the problem of automatically learning bug detection tools. If successful, the project will "democratize" bug detection by enabling all software developers, instead of a few program analysis experts, to create and share bug detection tools. Ultimately, the project will contribute to increasing the reliability, security, and efficiency of complex software systems used by millions of people.

Link to the ERC project webpage: http://software-lab.org/

Keywords of the ERC project: Deep learning, program analysis, bug detection

Keywords that characterize the scientific profile of the potential visiting researcher/s: Deep learning, program analysis, bug detection
Synthesising Inductive Data Models

Inpired by recent successes towards automating highly complex jobs like programming and scientific experimentation, the ultimate goal of this project is to automate the task of the data scientist when developing intelligent systems, which is to extract knowledge from data in the form of models. More specifically, this project wants to develop the foundations of a theory and methodology for automatically synthesising inductive data models. An inductive data model (IDM) consists of 1) a data model (DM) that specifies an adequate data structure for the dataset (just like a database), and 2) a set of inductive models (IMs), that is, a set of patterns and models that have been discovered in the data. While the DM can be used to retrieve information about the dataset and to answer questions about specific data points, the IMs can be used to make predictions, propose values for missing data, find inconsistencies and redundancies, etc. The task addressed in this project is to automatically synthesise such IMs from past data and to use these to support the user when making decisions. It will be assumed that the data set consists of a set of tables, that the end-user interacts with the IDM via a visual interface, and the data scientist via a unifying IDM language offering a number of core IMs and learning algorithms.

The key challenges to be tackled in SYNTH are: 1) the synthesis system must “learn the learning task”, that is, it should identify the right learning tasks and learn appropriate IMs for each of these; 2) the system may need to restructure the data set before IM synthesis can start; and 3) a unifying IDM language for a set of core patterns and models must be developed.

The approach will be implemented in open source software and evaluated on two challenging application areas: rostering and sports analytics.

Link to the ERC project webpage: https://synth.cs.kuleuven.be/

Keywords of the ERC project: artificial intelligence, probabilistic programming, automating data science

Keywords that characterize the scientific profile of the potential visiting researcher/s: computer science, artificial intelligence, data science
Probabilistic programs describe recipes on how to infer statistical conclusions about data from a complex mixture of uncertain data and real-world observations. They can represent probabilistic graphical models far beyond the capabilities of Bayesian networks and are expected to have a major impact on machine intelligence.

Probabilistic programs are ubiquitous. They steer autonomous robots and self-driving cars, are key to describe security mechanisms, naturally code up randomised algorithms for solving NP-hard problems, and are rapidly encroaching AI. Probabilistic programming aims to make probabilistic modeling and machine learning accessible to the programmer.

Probabilistic programs, though typically relatively small in size, are hard to grasp, let alone automatically checkable. Are they doing the right thing? What’s their precision? These questions are notoriously hard — even the most elementary question “does a program halt with probability one?” is “more undecidable” than the halting problem — and can (if at all) be answered with statistical evidence only. Bugs thus easily occur. Hard guarantees are called for. The objective of this project is to enable predictable probabilistic programming. We do so by developing formal verification techniques.

Whereas program correctness is pivotal in computer science, the formal verification of probabilistic programs is in its infancy. The project aims to fill this barren landscape by developing program analysis techniques, leveraging model checking, deductive verification, and static analysis. Challenging problems such as checking program equivalence, loop-invariant and parameter synthesis, program repair, program robustness and exact inference using weakest precondition reasoning will be tackled. The techniques will be evaluated in the context of probabilistic graphical models, randomised algorithms, and autonomous robots.

FRAPPANT will spearhead formally verifiable probabilistic programming.

Formal Reasoning About Probabilistic Programs: Breaking New Ground for Automation

Keywords of the ERC project: probabilistic programming, formal semantics, formal verification, probabilistic model checking, synthesis

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Staggering amounts of information are stored in natural language documents, rendering them unavailable to data-science techniques. Information Extraction (IE), a subfield of Natural Language Processing (NLP), aims to automate the extraction of structured information from text, yielding datasets that can be queried, analyzed and combined to provide new insights and drive research forward.

Despite tremendous progress in NLP, IE systems remain mostly inaccessible to non-NLP-experts who can greatly benefit from them. This stems from the current methods for creating IE systems: the dominant machine-learning (ML) approach requires technical expertise and large amounts of annotated data, and does not provide the user control over the extraction process. The previously dominant rule-based approach unrealistically requires the user to anticipate and deal with the nuances of natural language.

I aim to remedy this situation by revisiting rule-based IE in light of advances in NLP and ML. The key idea is to cast IE as a collaborative human-computer effort, in which the user provides domain-specific knowledge, and the system is in charge of solving various domain-independent linguistic complexities, ultimately allowing the user to query unstructured texts via easily structured forms.

More specifically, I aim to develop:
(a) a novel structured representation that abstracts much of the complexity of natural language;
(b) algorithms that derive these representations from texts;
(c) an accessible rule language to query this representation;
(d) AI components that infer the user extraction intents, and based on them promote relevant examples and highlight extraction cases that require special attention.

The ultimate goal of this project is to democratize NLP and bring advanced IE capabilities directly to the hands of domain-experts: doctors, lawyers, researchers and scientists, empowering them to process large volumes of data and advance their profession.

Link to the ERC project webpage:

Keywords of the ERC project: natural language processing; information extraction; relation extraction; human-computer interaction; pattern based extraction

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Learning Generative 3D Scene Models for Training and Validating Intelligent Systems

Recently, the field of computer vision has witnessed a major transformation away from expert designed shallow models towards more generic deep representation learning. However, collecting labeled data for training deep models is costly and existing simulators with artist-designed scenes do not provide the required variety and fidelity. Project LEGO-3D will tackle this problem by developing probabilistic models capable of synthesizing 3D scenes jointly with photo-realistic 2D projections from arbitrary viewpoints and with full control over the scene elements. Our key insight is that data augmentation, while hard in 2D, becomes considerably easier in 3D as physical properties such as viewpoint invariances and occlusion relationships are captured by construction. Thus, our goal is to learn the entire 3D-to-2D simulation pipeline. In particular, we will focus on the following problems:

(A) We will devise algorithms for automatic decomposition of real and synthetic scenes into latent 3D primitive representations capturing geometry, material, light and motion.

(B) We will develop novel probabilistic generative models which are able to synthesize large-scale 3D environments based on the primitives extracted in project (A). In particular, we will develop unconditional, conditioned and spatio-temporal scene generation networks.

(C) We will combine differentiable and neural rendering techniques with deep learning based image synthesis, yielding high-fidelity 2D renderings of the 3D representations generated in project (B) while capturing ambiguities and uncertainties.

Project LEGO-3D will significantly impact a large number of application areas. Examples include vision systems which require access to large amounts of annotated data, safety-critical applications such as autonomous cars that rely on efficient ways for training and validation, as well as the entertainment industry which seeks to automate the creation and manipulation of 3D content.

Link to the ERC project webpage: https://avg.is.tuebingen.mpg.de/

Keywords of the ERC project: computer vision, 3d deep learning, generative models, differentiable rendering

Keywords that characterize the scientific profile of the potential visiting researcher/s: computer vision, 3d deep learning, generative models, differentiable rendering
Advanced Reasoning in Arithmetic Theories

Arithmetic theories are logical theories for reasoning about number systems, such as the integers and reals. Such theories find a plethora of applications across computer science, including in algorithmic verification, artificial intelligence, and compiler optimisation. The appeal of arithmetic theories is their generality: once a problem has been formalised in a decidable such theory, a dedicated solver can in principle be used in a push-button fashion to obtain a solution. Arithmetic theories are also of great importance for showing decidability and complexity results in a variety of domains. Decision procedures for quantifier-free and linear fragments of arithmetic theories have been among the most intensively studied and impactful topics in theoretical computer science. However, emerging applications require more expressive theories, including support for quantifiers, counting, and non-linear functions. Unfortunately, the lack of understanding of the computational properties of such extensions means that existing decision procedures are not applicable or do not scale. The overall goal of this proposal is to advance the state-of-the-art in decision procedures for expressive arithmetic theories. To this end, starting with a recent breakthrough made by the PI, we will develop novel and optimal quantifier-elimination procedures for linear arithmetic theories, which we plan to eventually integrate into mainstream SMT solvers. Furthermore, we aim to improve complexity bounds and push the decidability frontier of extensions of arithmetic theories with counting and non-linear operations. The proposed research requires to tackle long-standing open problems---some of them being decades old. In short, the project will lay algorithmic foundations on which next-generation decision procedures and reasoners for arithmetic theories will be built.

Link to the ERC project webpage: www.cs.ucl.ac.uk/staff/C.Haase/project/ariat/

Keywords of the ERC project: logic in computer science, arithmetic theories, decision procedures, automata theory, algorithmic verification

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Hybrid Digital-Analog Networking under Extreme Energy and Latency Constraints

The objective of the BEACON project is to (re-)introduce analog communications into the design of modern wireless networks. We argue that the extreme energy and latency constraints imposed by the emerging Internet of Everything (IoE) paradigm can only be met within a hybrid digital-analog communications framework. Current network architectures separate source and channel coding, orthogonalize users, and employ long block-length digital source and channel codes, which are either suboptimal or not applicable under the aforementioned constraints. BEACON questions these well-established design principles, and proposes to replace them with a hybrid digital-analog communications framework, which will meet the required energy and latency constraints while simplifying the encoding and decoding processes. BEACON pushes the performance of the IoE to its theoretical limits by i) exploiting signal correlations that are abundant in IoE applications, given the foreseen density of deployed sensing devices, ii) taking into account the limited and stochastic nature of energy availability due to, for example, energy harvesting capabilities, iii) using feedback resources to improve the end-to-end signal distortion, and iv) deriving novel converse results to identify fundamental performance benchmarks.

The results of BEACON will not only shed light on the fundamental limits on the performance any coding scheme can achieve, but will also lead to the development of unconventional codes and communication protocols that can approach these limits, combining digital and analog communication techniques. The ultimate challenge for this project is to exploit the developed hybrid digital-analog networking theory for a complete overhaul of the physical layer design for emerging IoE applications, such as smart grids, tele-robotics and smart homes. For this purpose, a proof-of-concept implementation test-bed will also be built using software defined radios and sensor nodes.

Link to the ERC project webpage: http://www.imperial.ac.uk/information-processing-and-communications-lab
Keywords of the ERC project: wireless communications, machine learning, energy efficiency, resource allocation, multimedia compression, multimedia transmission

Keywords that characterize the scientific profile of the potential visiting researcher/s: wireless communications, machine learning, information theory, optimization theory, statistics
The proposed research will make a contribution towards the analysis and synthesis of large scale complex networks: fundamental theory will be developed and important applications will be addressed, by extending tools from control theory. Networks are present throughout the physical and biological world, but nowadays they also pervade our societies and everyday lives. Major challenges that will be addressed are:

I. The engineering of large scale heterogeneous networks that are guaranteed to be robust and scalable.

II. The reverse engineering of biological networks.

A distinctive feature of the networks we would like to engineer, which falls outside more traditional domains in systems and control, is that of scalability, i.e. the ability to guarantee robust stability for an arbitrary interconnection by conditions on only local interactions. The methodologies that will be developed will have a significant impact in various applications where scalability is important, such as data network protocols, group coordination problems and power distribution networks, as they can lead to network designs with guaranteed robustness, thus avoiding conservative schemes with poor performance. The proposed project will also make a contribution towards the reverse engineering of biological networks at the molecular level. Life in the cell is dictated by chance; noise is ubiquitous with its sources ranging from fluctuating environments to intrinsic fluctuations due to the random births and deaths of molecules. The fact that a substantial part of the noise is intrinsic provides a major challenge in control theoretic methodologies. How can feedback be used to suppress these fluctuations, what are the associated tradeoffs and limitations, and how does nature manage to handle these so efficiently? These are questions that will be addressed by developing tools for analyzing known configurations, but more importantly, by deriving fundamental limitations that hold for arbitrary feedback.

Link to the ERC project webpage:

Keywords of the ERC project: control, networks, power systems/smart grids, systems biology

Keywords that characterize the scientific profile of the potential visiting researcher/s:
MYKI aims at developing and clinically evaluating a dexterous hand prosthesis with tactile sensing which is naturally controlled and perceived by the amputee. This will be possible by overcoming the conventional approaches based on recording electrical signals from the peripheral nervous system (nerves or skeletal muscles) through the development of a radically new Human-Machine Interface (HMI) based on magnetic field principles, both able to decode voluntary motor commands and to convey sensory feedback to the individual. Core of this system is a multitude of magnets implanted in independent muscles and external magnetic readers/drivers (MRDs) able to (i) continuously localize the movements of the magnets and, at specific times, (ii) induce subtle movements in specific magnets. In fact, as a magnet is implanted it will travel with the muscle it is located in, and its localization will provide a direct measure of the contraction/elongation of that muscle, which is voluntarily controlled by the central nervous system. In this way it will be possible to decode the efferent signals sent by the brain by observing a by-product of the muscle fibres recruitment. On the other hand, a movement induced in the implanted magnet by the external MRD, could provide a perceivable stimulus, conveyed to the brain by means of the peripheral sensory receptors present in the muscle (e.g. muscle spindles or Golgi tendon organ) or in the neighbouring skin (tactile mechanoreceptors). In this way we aim to provide tactile and/or proprioceptive sensory information to the brain, thus restoring the physiological sensorimotor control loop. Remarkably, with passive magnetic tags (that do not require to be powered-on) and wearable readers/drivers, it will be possible to implement a wireless, bidirectional HMI with dramatically enhanced capabilities with respect to the state of the art interfaces, as illustrated in this proposal.
Microtechnology and integrated microsystems to investigate neuronal networks across scales

To advance knowledge in electrophysiology and information processing of neuronal networks, we propose employing microtechnology and microelectronics to rigorously study neural networks in vitro across scales. Across scales pertains to the spatial domain - from details of subcellular components through single neurons to entire networks - and the temporal domain - from single action potentials to long-term developmental processes. Besides our CMOS-microelectronics-based high-density microelectrode arrays for recording and stimulation, the methodology will encompass patch-clamping directly on the microelectrode chips, high-resolution microscopy, genetic methods, large-scale data handling strategies, and dedicated data analysis and modeling algorithms. We will use mammalian cortical neuron cultures and brain slices.

We will potentially have access to every neuron and every action potential. We aim at studying - at the same time in the same preparation - details of specific neurons and subcellular components (somas, axons, synapses, dendrites) in their functional context and the characteristics of the corresponding networks (functional connectivity, emergent properties, plasticity). We will study alterations of components and networks over time and upon defined perturbations and mutual interdependence of network and component characteristics.

The high-spatio-temporal-resolution methodology will enable new fundamental neuroscientific insights through, e.g., facilitating investigation of axonal and axonal initial segment signaling characteristics, with the “axonal” side of neuronal activity being largely inaccessible to established methods. It will also enable the mapping of the overall synaptic input to a specific neuron, or the high-throughput monitoring of all action potentials in a network over extended time to see developmental effects or effects of disturbances. Potential applications include research in neural diseases and pharmacology.

Link to the ERC project webpage: https://cordis.europa.eu/project/rcn/203423/factsheet/en

Keywords of the ERC project: CMOS microelectrode arrays, subcellular-resolution electrophysiology, neuronal networks, network analysis

Keywords that characterize the scientific profile of the potential visiting researcher/s: neuronal network analysis, computational neuroscience, modeling of neurons and networks
Project ID: 694974  
Project Acronym: POSTCELL  
Evaluation Panel: PE7 Systems and Communication Engineering

Principal Investigator: Dr ANGEL LOZANO  
Host Institution: UNIVERSIDAD POMPEU FABRA - ES

**Post-Cellular Wireless Networks**

POSTCELL aims at laying the foundation for future generations of wireless networks as they move past the reigning cell-centric paradigm and into the post-cellular era. This entails the definition of a new architecture for such networks and the characterization of the ensuing performance. For the future of wireless communications, the implications would be far-reaching.

The growth of wireless traffic is relentless, and it is actually gaining new momentum on account of fresh mechanisms: smartphones, cloud computing, and machine-to-machine communication. As a result, the volume of wireless traffic is poised to increase to truly staggering levels and, to face this challenge, wireless networks need to enter a new stage.

There is a fledging awareness that this challenge can only be fended off by a process of network massification, with two views about it. In the first view, densification is the only strategy through which dramatic improvements can be attained hereafter; this leads to a vision where base stations become tiny and exceedingly abundant. The second view, in turn, is built on the idea of dramatically scaling the number of colocated antennas per base station from the current handful to possibly hundreds. One of the seeds of POSTCELL is that, since neither form of massification can by itself resolve the challenge facing wireless systems, the two forms will have to end up coexisting.

Reconciling these two forms of massification and enabling a truly phenomenal scaling calls for an entirely new architecture where cells and physical base stations become things of the past, replaced by dynamically defined virtual base stations, powerful caches, and the possibility of device clustering, among other leaps forward. The signal processing needs to shift away from base stations, which become deconstructed, so as to gather at new places. POSTCELL seeks to drive this transformation and to gauge the performance of post-cellular wireless networks.

**Link to the ERC project webpage:**

**Keywords of the ERC project:** Wireless communications, wireless networks, communication theory

**Keywords that characterize the scientific profile of the potential visiting researcher/s:**
A new concept for ultra-high capacity wireless networks

The project will address the following key question:

How can we provide fibre-like connectivity to moving objects (robots, humans) with the following characteristics: very high dedicated bitrate of 100 Gb/s per object, very low latency of <10 μs, very high reliability of 99.999%, very high density of more than one object per m2 and this at low power consumption?

Achieving this would be groundbreaking and it requires a completely new and high-risk approach: applying close proximity wireless communications using low interference ultra-small cells (called “ATTO-cells”) integrated in floors and connected to antennas on the (parallel) floor-facing surface of ground moving objects. This makes it possible to obtain very high densities with very good channel conditions. The technological challenges involved are groundbreaking in mobile networking (overall architecture, handover with extremely low latencies), wireless subsystems (60 GHz substrate integrated waveguide-based distributed antenna systems connected to RF transceivers integrated in floors, low crosstalk between ATTO-cells) and optical interconnect subsystems (simple non-blocking optical coherent remote selection of ATTO-cells, transparent low power 100 Gb/s coherent optical / RF transceiver interconnection using analogue equalization and symbol interleaving to support 4x4 MIMO). By providing this unique communication infrastructure in high density settings, the ATTO concept will not only support the highly demanding future 5G services (UHD streaming, cloud computing and storage, augmented and virtual reality, a range of IoT services, etc.), but also even more demanding services, that are challenging our imagination such as mobile robot swarms or brain computer interfaces with PFlops computing capabilities.

This new concept for ultra-high capacity wireless networks will open up many more opportunities in reconfigurable robot factories, intelligent hospitals, flexible offices, dense public spaces, etc.

Link to the ERC project webpage: http://atto.ugent.be

Keywords of the ERC project: wireless communications, radio over fiber, optical, high speed transceivers

Keywords that characterize the scientific profile of the potential visiting researcher/s: strong experience in the field (level of ERC starter grant)
Structured nonlinear Metamaterials for efficient generation and Active functional control of Radiation of THz light

The terahertz optical regime, covering the long wavelength end of the optical spectrum, has been for many years the least explored spectral regime. Recent interest in this regime has led to important emerging applications spanning many disciplines including medical, biological, materials sciences, communications, security, and basic sciences. However, advances in these emerging applications are held back by the lack of good and controllable terahertz light sources.

I propose to lead a potential breakthrough in this field by developing a new family of THz sources with unmatched functionality. The developed sources will be based on nano-engineered nonlinear heterostructured metamaterials, man-made materials with artificial optical properties. The proposal is based on very recent studies that show that metamaterials can be used to emit THz light with excellent efficiency, comparable to the best available nonlinear materials in nature. In addition it relies on our recent experimental demonstrations of functional nonlinear metamaterials that allow unprecedented control of nonlinear optical interactions. We will apply this recent knowledge to design novel active metamaterials that efficiently emit THz light at any desired frequency, shape and polarization, focus it directly from the emitter to a desired sample location and even actively steer and modify its radiation properties all-optically. In addition, we will enhance the THz generation efficiency from metamaterials by more than three orders of magnitude compared to the state of the art. We will also use our expertise to fabricate large scale and multi-layered THz light emitting metamaterials by leveraging novel nanolithography methods. Overall I expect that the outcome of this research will be in development of one of a kind family of THz light emitters that will lead to the, long sought for, leap in THz technology and will open the door to new applications and to new tools for advancing fundamental science.

Link to the ERC project webpage:

Keywords of the ERC project: metasurfaces, nonlinear optics, THz, nonlinear nanophotonics, plasmonics

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Towards programmable cyber-physical systems: a symbolic control approach

Cyber-physical systems (CPS) consist of computational elements monitoring and controlling physical entities. The main objective of the PROCSYS project is to propose a general framework for the design of programmable CPS that will allow engineers to develop advanced functionalities using a high-level programming language for specifying the behaviours of a CPS while abstracting the details of the physical dynamics. Controllers enforcing the specified behaviours will be generated from a high-level program using an automated model-based synthesis tool. Correctness of the controllers will be guaranteed by following the correct by construction synthesis paradigm through the use of symbolic control techniques: the continuous physical dynamics is abstracted by a symbolic model, which is a purely discrete dynamical system; an interface consisting of low-level controllers is designed such that the physical system and the symbolic model behaves identically; a high-level symbolic controller is then synthesized automatically from the high-level program and the symbolic model. We will develop a high-level programming language, based on the intuitive formalism of hybrid automata, which will enable to specify a rich set of behaviours while enabling the development of efficient controller synthesis algorithms. The project will also tackle the two main bottlenecks in the area of symbolic control, which will enable its use in challenging real-life applications. Firstly, scalability of symbolic control will be achieved by the computation of more compact symbolic models and by controller synthesis algorithms that require only partial exploration of the symbolic models. Secondly, robustness will be ensured at all levels of control by developing novel algorithms for the synthesis of robust interfaces and of symbolic controllers. The algorithms developed in the project will be implemented in a symbolic control toolbox, which will enable the use of our approach by systems engineers.

Link to the ERC project webpage: https://sites.google.com/site/antoinesgirard/

Keywords of the ERC project: Control, cyber-physical systems, formal methods

Keywords that characterize the scientific profile of the potential visiting researcher/s:
FOG-aided wireless networks for communication, caching and computing: theoretical and algorithmic foundations

The FOGHORN project aims at developing the theoretical and algorithmic foundations of fog-aided wireless networks. This is an emerging class of wireless systems that leverages the synergy and complementarity of cloudification and edge processing, two key technologies in the evolution towards 5G systems and beyond. Fog-aided wireless networks can reap the benefits of centralization via cloud processing, in terms of capital and operating cost reductions, greening, and enhanced spectral efficiency, while, at the same time, being able to cater to low-latency applications, such as the "tactile" internet, by means of localized intelligence at the network edge. The operation of fog-aided wireless networks poses novel fundamental research problems pertaining to the optimal management of the communication, caching and computing resources at the cloud and at the edge, as well as to the transmission on the fronthaul network connecting cloud and edge. The solution of these problems challenges the theoretical principles and engineering insights which have underpinned the design of existing networks. The initial research activity on the topic, of which the EU is at the forefront, focuses, by and large, on ad hoc solutions and technologies. In contrast, the goal of this project is to develop fundamental theoretical insights and algorithmic principles with the main aim of guiding engineering choices, unlocking new academic opportunities and disclosing new technologies. The theoretical framework is grounded in network information theory, which enables the distillation of design principles, along with signal processing, (non-convex) optimization, queuing and distributed computing to develop and analyse algorithmic solutions.

Link to the ERC project webpage: https://nms.kcl.ac.uk/osvaldo.simeone/index.htm

Keywords of the ERC project: information theory, wireless communications

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Spatiotemporal multimode complex optical systems

The STEMS project is about exploiting the new concept that has been recently introduced by the PI and his co-workers, namely the self-control of the spatial coherence of optical beams in multimode nonlinear optical fibers. This concept will enable a breakthrough technology, capable of delivering high-energy optical pulses with high-average powers and much higher beam quality from fiber lasers than what is possible today. High-power fiber lasers are largely limited by transverse mode instabilities, and the loss of spatial coherence in delivery fibers. Optical fibers provide the backbone of today’s internet communication networks, and enable compact, low cost light sources for a variety of industrial and biomedical applications. In most of these applications, single-mode fibers are used. Replacing single-mode fibers with multimode fibers leads to a dramatic growth of transmission capacity, and a substantial increase of average power and pulse energy from fiber lasers. However, because of spatial dispersion and resulting mode interference, multimode fibers suffer from an inherent randomization of the spatial transverse beam profile, leading to a loss of spatial coherence. My approach is to exploit the intensity dependent refractive index, or Kerr nonlinearity, of glass fibers to recover the spatial coherence of a multimode wave, and compensate for temporal modal dispersion. First, I propose to develop methods to control fiber nonlinearity, to compensate for temporal and spatial dispersion, thus preventing information spreading in the temporal domain, and coherence loss in the spatial domain. Second, by adding rare-earth dopants to multimode fibers, I will demonstrate self-control of modal dispersion and beam quality in active multimode fibers. Third, via the spatio-temporal control of beam propagation, I will introduce a new fast saturable absorber mechanism for the mode-locking of high-power fiber lasers, analogous to Kerr-lens mode-locking with bulk crystals.

Link to the ERC project webpage: https://sites.google.com/view/erc-stems/home
Keywords of the ERC project: nonlinear optics; optical fibers; optical communications
Keywords that characterize the scientific profile of the potential visiting researcher/s:
Universal microwave photonics programmable processor for seamlessly interfacing wireless and optical ICT systems

Information and communication technology (ICT) systems are expanding at an awesome pace in terms of capacity demand, number of connected end-users and required infrastructure. To cope with these rapidly increasing growth rates there is a need for a flexible, scalable and future-proof solution for seamlessly interfacing the wireless and photonic segments of communication networks.

RF or Microwave photonics (MWP), is the best positioned technology to provide the required flexible, adaptive and future-proof physical layer with unrivalled characteristics. Its widespread use is however limited by the high-cost, non-compact and heavy nature of its systems. Integrated Microwave Photonics (IMWP) targets the incorporation of MWP functionalities in photonic chips to obtain cost-effective and reduced space, weight and power consumption systems. IMWP has demonstrated some functionalities in through application specific photonic circuits (ASPICs), yielding almost as many technologies as applications and preventing cost-effective industrial manufacturing processes. A radically different approach is based on a universal or general-purpose programmable photonic integrated circuit (PIC) capable of performing with the same hardware architecture the main required functionalities. The aim of this project is the design, implementation and validation of such processor based on the novel concept of photonic waveguide mesh optical core and its integration in a Silicon Photonics chip. Its three specific objectives are: (1) The architecture design and optimization of a technology-agnostic universal MWP programmable signal processor, (2) The chip mask design, fabrication and testing of the processor and (3) The experimental demonstration and validation of the processor. Targeting record values in bandwidth and footprint its potential impact will be very large by unlocking bandwidth bottlenecks and providing seamless interfacing of the fiber and wireless segments in future ICT systems.

Link to the ERC project webpage:

Keywords of the ERC project: integrated optics, microwave photonics, programmable photonics

Keywords that characterize the scientific profile of the potential visiting researcher/s: integrated photonics, silicon photonics
Tunable optoelectronic devices by strain engineering of 2D semiconductors

The goal of 2D-TOPSENSE is to exploit the remarkable stretchability of two-dimensional semiconductors to fabricate optoelectronic devices where strain is used as an external knob to tune their properties. While bulk semiconductors tend to break under strains larger than 1.5%, 2D semiconductors (such as MoS2) can withstand deformations of up to 10-20% before rupture. This large breaking strength promises a great potential of 2D semiconductors as ‘straintronic’ materials, whose properties can be adjusted by applying a deformation to their lattice. In fact, recent theoretical works predicted an interesting physical phenomenon: a tensile strain-induced semiconductor-to-metal transition in 2D semiconductors. By tensioning single-layer MoS2 from 0% up to 10%, its electronic band structure is expected to undergo a continuous transition from a wide direct band-gap of 1.8 eV to a metallic behavior. This unprecedented large strain-tunability will undoubtedly have a strong impact in a wide range of optoelectronic applications such as photodetectors whose cut-off wavelength is tuned by varying the applied strain or atomically thin light modulators.

To date, experimental works on strain engineering have been mostly focused on fundamental studies, demonstrating part of the potential of 2D semiconductors in straintronics, but they have failed to exploit strain engineering to add extra functionalities to optoelectronic devices. In 2D-TOPSENSE I will go beyond the state of the art in straintronics by designing and fabricating optoelectronic devices whose properties and performance can be tuned by means of applying strain. 2D-TOPSENSE will focus on photodetectors with a tunable bandwidth and detectivity, light emitting devices whose emission wavelength can be adjusted, light modulators based on 2D semiconductors such as transition metal dichalcogenides or black phosphorus and solar funnels capable of directing the photogenerated charge carriers towards a specific position.

Link to the ERC project webpage: https://sites.google.com/view/2d-topsense

Keywords of the ERC project: 2D materials, strain engineering, optoelectronics, straintronics

Keywords that characterize the scientific profile of the potential visiting researcher/s: nanofabrication, devices, photodetectors, exfoliation, heterostructures
Memristive In-Memory Processing System

Our project aims to develop a new computer architecture that enables true in-memory processing based on a unit that can both store and process data using the same cells. This unit, called a memristive memory processing unit (mMPU), will substantially reduce the necessity to move data in computing systems, solving the two main bottlenecks exist in current computing systems, i.e., speed ('memory wall') and energy efficiency ('power wall'). Emerging memory technologies, namely memristive devices, are the enablers of the mMPU. While memristors are naturally used as memory, these novel devices can also perform logical operations using a technique we have invented called Memristor Aided Logic (MAGIC). This combination is the basis of mMPU.

The goal of this research is to design a fully functional mMPU, and by that, to demonstrate a real computing system with significantly improved performance and energy efficiency. We have identified four main research tasks which must be completed to demonstrate a full system utilizing mMPU: mMPU design, system architecture and software, modeling and evaluation, and fabrication. Both memristive memory array and mMPU control will be designed and optimized for different technologies in the first objective. The second objective will deal with the different aspects of the system, including programming model, different mMPU modes of operation and their corresponding system implications, compiler and operating systems. For system evaluation, we will develop models and tools in the third objective in order to measure the performance, area and energy and to compare them to other state-of-the-art computing systems. Lastly, we will fabricate the different parts of the system to demonstrate the full system.

Encouraged from our preliminary experimental results, we expect to achieve 10X improvement in performance, and 100X improvement in energy efficiency as compared to state-of-the-art von Neumann systems when working with appropriate workloads.

Link to the ERC project webpage:

Keywords of the ERC project: memristor, processing-in-memory, computer architecture, VLSI

Keywords that characterize the scientific profile of the potential visiting researcher/s: computer engineering
Analysis and synthesis of wideband scattered signals from finite-size targets – aspect-independent RF analog footprint

The need for information identification and capture is a matter of prime importance in modern societies. Every sectors of society rely on the identification of data exchanged, the updating of the data recorded on a tag and the measurement of physical parameters. The ability to make objects interact with one another or with humans is an important factor in many applications, all the more so if this interaction can occur without human presence. The way to reduce power consumption, improve the communication quality-of-service and enhance connectivity has become key issues for lots of industries. Researchers need to consider the multiple factors simultaneously to design state-of-the-art RF devices for the next generation of identification services. One important direction is to develop low-power, low cost tags for wireless identification and sensing. Lots of improvements have been done today on communication systems based on electronic devices where an integrated circuit is at the heart of the whole system. The democratization of these chipped based systems like the RFID one will give rise to environmental issues in the future. However, these improvements pave the way for the development of new concepts based on approaches where the presence of the chip is not mandatory. These approaches are based on radar or reflectometry principles; these are non-invasive techniques but they require specific theoretical and practical developments. The difficulty is to be able to retrieve a small signal coming from a totally passive label placed in an unknown and movable environment. The objective of this project is to introduce the paradigm of RF communication system based on chipless labels, i.e. tags without any chip, bringing an ID, able to communicate with radio waves and having extremely low costs. This project aims at showing that it is possible to associate the paper based chipless label ID with other features like the ability to write and rewrite the ID, or a sensor function.

Link to the ERC project webpage: https://www.scattererid.eu/

Keywords of the ERC project: RF, RCS, backscattering, scatterer, antenna, machine learning

Keywords that characterize the scientific profile of the potential visiting researcher/s: RF and machine learning
Contextualizing biomolecular circuit models for synthetic biology

Synthetic biology is the bottom-up engineering of new molecular functionality inside a biological cell. Although it aims at a quantitative and compositional approach, most of today’s implementations of synthetic circuits are based on inefficient trial-and-error runs. This approach to circuit design does not scale well with circuit complexity and is against the basic paradigm of synthetic biology. This unsatisfactory state of affairs is partly due to the lack of the right computational methodology that can support the quantitative characterization of circuits and their significant context dependency, i.e., their change in behavior upon interactions with the host machinery and with other circuit elements.

CONSYN will contribute computational methodology to overcome the trial-and-error approach and to ultimately turn synthetic circuit design into a rational bottom-up process that heavily relies on computational analysis before any actual biomolecular implementation is considered. In order to achieve this goal, we will work on the following agenda: (i) develop biophysical and statistical models of biomolecular contexts into which the synthetic circuit or synthetic part can be embedded in silico; (ii) devise new statistical inference methods that can deliver accurate characterization of circuits and their context dependency by making use of cutting-edge single-cell experimental data; (iii) derive new context-insensitive circuit designs through in silico sensitivity analysis and application of filtering theory; (iv) optimize protocols and measurement infrastructure using model-based experimental design yielding a better circuit and context characterization; (v) experimentally build synthetic circuits in vivo and in cell-free systems in order to validate and bring to life the above theoretical investigations. We are in the unique position to also address (v) in-house due to the experimental wetlab facilities in our group.

**Link to the ERC project webpage:**

**Keywords of the ERC project:** synthetic biology, synthetic circuit design, modeling, cell-free system, microfluidic

**Keywords that characterize the scientific profile of the potential visiting researcher/s:** biology, biophysics, physics, biotechnology, modelers, interdisciplinary
Network Motion

NEMO, NEtwork MOtion, is an inter-disciplinary proposal centered on network dynamics. The inter-disciplinarity spans from communication engineering to mathematics, with an innovative interplay between the two.

NEMO’s focus is on stochastic geometry. This emerges as one of the most important new conceptual and operational tools of the last 10 years in wireless networking, with a major academic and industrial impact on architecture, protocol design, planning and economic analysis.

Nevertheless, the state of the art is unable to cope with the dynamics introduced in recent and future network functionalities. NEMO’s aim is to introduce dynamics in wireless stochastic geometry. The dynamic versions of stochastic geometry to be developed will capture these new functionalities and specifically tackle two core promises and challenges of the future of wireless networking: that of ultra-low latency networking, required for enabling the unfolding of future real time interactions, and that of draining to the Internet the unprecedented amount and structure of data stemming from the Internet of Things.

Several fundamental types of random network dynamics underpinning these functionalities are identified. General mathematical tools combining stochastic geometry, random graph theory, and the theory of dynamical systems will be developed to analyze them. This will provide parametric models mastering the complexity of such networks, which will be instrumental in addressing the above challenges. The aim is to have, through these dynamical versions, the same academic and industrial impact on wireless networks as static stochastic geometry has today.

NEMO will leverage structural interactions of INRIA with Ecole Normale Supérieure on the mathematical side, and with Nokia Bell Labs and Orange on the engineering side. This will create in Europe a group focused on this mathematics-communication engineering interface, and to become the top innovation group of the field worldwide.

Link to the ERC project webpage: https://project.inria.fr/ercnemo/

Keywords of the ERC project: Stochastic geometry, point processes, random graphs, dynamical systems, modelling of communication networks.

Keywords that characterize the scientific profile of the potential visiting researcher/s: Stochastic geometry, point processes, random graphs, dynamical systems, modelling of communication networks.
New Frontiers in Nanophotonics: Integrating Complex Beams and Active Metasurface Devices

Complex, structured optical beams have unique properties offering new degrees of freedom for achieving unusual wavefront, polarisation and optical angular momentum demanded in microscopy, optical trapping and manipulation of nano-objects, information encoding in optical communications, holography, quantum technologies and laser micromachining. Metasurfaces, a subwavelength-thin nanostructured films, which were initially developed for controlling the phase of light and its reflection and transmission beyond the Snell’s law, provide a rich playground for generation and manipulation of structured beams. iCOMM will establish a metasurface platform for generating and controlling complex vector beams in space and time and develop its applications in sensing and identification of chiral molecules and nonlinear optical trapping. Using unique optical properties of designer-metasurfaces capable of controlling both phase and amplitude of light, nonlinear interactions of pulsed vector beams will be optimised and explored. We will aim to develop a series of active metamaterial chips for nonlinear control of CVBs, linear and nonlinear sensing of chiral molecules and optical trapping applications, opening new application areas in information processing and biochemical technologies. This will be a transformative development for the applications of complex vector beams and metasurfaces in optical communications, displays, security and bio- and chemical sensing and optical trapping. The success of the project will unlock the potential of metasurfaces in providing tuneability for the improvement of the real-world photonic devices and provide insight into physical phenomena which are vital for various areas of photonics and sensing, demonstrating commercially-viable application of metasurfaces and complex beams. It will transform the areas of both complex beams and metasurfaces by introducing real-time active control and consolidate and enhance the European leadership in this field.

Link to the ERC project webpage: www.nano-optics.org.uk

Keywords of the ERC project: metasurfaces, vector beams, polarisation, nonlinear-optics, chirality

Keywords that characterize the scientific profile of the potential visiting researcher/s: metasurfaces, vector beams, polarisation, nonlinear-optics, chirality
Multimode light shaping: from optical fibers to nanodevices

The project MODES arises in the framework of the emerging interest for nonlinear multimode processes in optical fibers, and wants to extend it to on-chip waveguides and nanoparticles, where the study of the nonlinear multimode dynamics is still on its infancy. This project is based on a central key-idea: by properly engineering a multimode system, we can shape and master the nonlinear interaction between the modes into play, and finally exploit it for novel applications in several strategic areas. This project has therefore a dual nature: one key-idea but multidisciplinary, heterogeneous applications. It focuses on 4 main strategic areas (SA) and identifies an objective (OBJ) for each one, which is related to the exploitation of a specific nonlinear multimode process:

SA1: Support technology for Spatial Division Multiplexing (SDM) >>> OBJ1: the project investigates the development of wideband multimode wavelength converters and amplifiers
SA2: High-capacity SDM data-transmission >>>OBJ2: the project investigates the existence of multimode solitons leading to an undistorted, high-quality propagation in multicore and multimode optical fibers
SA3: On-chip infrared optical sources >>>OBJ3: the project targets the development of on-chip, widely tunable optical sources that may be used to selectively detect important environmental gases in the whole infrared spectrum
SA4: Shaping the nonlinear radiation at nanoscale >>>OBJ4: the project aim at developing a new theoretical insight into the way higher-harmonic radiation is emitted in complex nanostructures. Finally, it wants to and to exploit this new knowledge in view of an ultrafast conversion from invisible to visible light.

To conclude, by addressing new theoretical problems and unveiling a new multimode technology, MODES aim at opening new frontiers in nonlinear optics and being pioneer in the field of nonlinear multimode nanophotonics.

Link to the ERC project webpage:

Keywords of the ERC project:

Keywords that characterize the scientific profile of the potential visiting researcher/s: Theoretical and computational nonlinear optics; Experiments in nonlinear optical fibers and silicon waveguides
Modelling the neuromusculoskeletal system across spatiotemporal scales for a new paradigm of human-machine motor interaction

Neurological injuries such as stroke leave millions of people disabled worldwide every year. For these individuals motor recovery is often suboptimal. The impact of current neurorehabilitation machines is hampered by limited knowledge of their physical interaction with the human. As we move, our body adapts positively to optimal stimuli; motor improvement after stroke is promoted via physical training with an appropriate afferent input to the nervous system and mechanical loads to muscles. Loss of appropriate stimuli leads to motor dysfunction.

Motor recovery requires positive neuromuscular adaptations to be steered over time. If neuro-modulative and orthotic machines could be controlled to generate optimal stimuli to the neuromuscular system, a new era in neurorehabilitation would begin.

This project creates multi-scale models of human-machine interaction for radically new closed-loop control paradigms. We will combine biosignal recording and numerical modeling to decode the cellular activity of motor neurons in the spinal cord with resulting musculoskeletal forces at a resolution not considered before. This will enable breakthroughs for tracking the spinal-musculoskeletal system across spatiotemporal scales: short-to-long term adaptation from cellular to organ scales. We will use these concepts to design new machine control schemes. With a focus on spinal cord electrical stimulation and mechatronic exosuits, we will demonstrate how motor dysfunction is repaired by inducing optimal changes in neuromuscular targets. The innovative aspect is that of gaining control of the stimuli that govern neuromuscular function over time. This will enable machines to co-adapt with the body; an achievement that will disrupt the development of man-machine interfaces from neuroprostheses, to robotic limbs, to exosuits.

INTERACT will answer fundamental questions in movement neuromechanics via novel principles of human-machine interaction with broad impact on bioengineering and robotics.

Keywords of the ERC project: neuro-mechanics; neuromusculoskeletal modelling; spinal cord stimulation; exoskeleton

Keywords that characterize the scientific profile of the potential visiting researcher/s: spinal cord stimulation; spinal neuron modelling; spinal cord finite element modelling; muscle remodeling; exosuit design
Integrated Implant Technology for Multi-modal Brain Interfaces

Bioelectronic medicine may soon replace systemic drugs for treating some chronic conditions. The clinician will implant a miniature laboratory to deliver and coordinate a multi-modal treatment program directly at the affected tissue. The technology to bring this vision to the clinic is not yet available.

The IntegraBrain project will contribute by building an implantable network of sensors and actuators. Actuators will deploy electricity, light, drugs and thermal energy as modalities of the therapeutic program, while sensors will monitor its progress. A key technological advance will be a method for direct writing of the sensor-actuator network. To achieve this, we will develop a palette of functional inks where each ink supports one of the therapeutic modalities.

The technology has the potential to be tailored for applications in soft tissue organs, especially in the nervous system, where injury or degeneration can result in chronic disability. We will apply IntegraBrain technology in two niches of the nervous system in rodents. In the central nervous system, we will demonstrate seizure control by multi-modal neuromodulation. In the peripheral nervous system, we will demonstrate reversible block and excitation. For the first time, we will observe if multi-modal neuromodulation leads to synergistic effects on the nervous system.

With the IntegraBrain project, we hope to catalyse pre-clinical development of implantable human-machine interfaces for therapeutic applications.

Link to the ERC project webpage: https://www.europeandissemination.eu/integrabrain-project-dr-ivan-minev/4756

Keywords of the ERC project: bioelectronics, implants, 3D printing

Keywords that characterize the scientific profile of the potential visiting researcher/s:
High-speed optical fiber networks form the backbone of the information and communication technologies, including the Internet. More than 99% of the Internet data traffic is carried by a network of global optical fibers. Despite their great importance, today's optical fiber networks face a looming capacity crunch: The achievable rates of all current technologies characteristically vanish at high input powers due to distortions that arise from fiber nonlinearity. The solution of this long-standing complex problem has become the holy grail of the field of the optical communication.

The aim of this project is to develop a novel foundation for optical fiber communication based on the nonlinear Fourier transform (NFT). The NFT decorrelates signal degrees-of-freedom in optical fiber, in much the same way that the conventional Fourier transform does for linear systems. My collaborators and I have recently proposed nonlinear frequency-division multiplexing (NFDM) based on the NFT, in which the information is encoded in the generalized frequencies and their spectral amplitudes (similar to orthogonal frequency-division multiplexing). Since distortions such as inter-symbol and inter-channel interference are absent in NFDM, it achieves data rates higher than conventional methods. The objective of this proposal is to advance NFDM to the extent that it can be built in practical large-scale systems, thereby overcoming the limitation that fiber nonlinearity sets on the transmission rate of the communication networks. The proposed research relies on novel methodology and spans all aspects of the NFDM system design, including determining the fundamental information-theoretic limits, design of the NFDM transmitter and receiver, algorithms and implementations. The feasibility of the project is manifest in preliminary proof-of-concepts in small examples and toy models, PI's leadership and track-record in the field, as well as the ideal research environment.

Link to the ERC project webpage:

Keywords of the ERC project:

Keywords that characterize the scientific profile of the potential visiting researcher/s: Information theory, communication theory, nonlinear Fourier transform
Ultrasound nanometer-scale microscopy

Ultrasound-speed microscopy at Tera-scale frames per second frame-rate is essential for various applications in science and technology. In particular, it is critical for observing ultrafast non-repetitive events, for which the pump-probe technique is inapplicable. The spatial resolutions of such microscopes is to date limited to the micrometer scale.

I propose to develop such microscopes with nanometric resolution.

The Tera-scale frames per second frame rate microscopes with nanometric resolution will be based on a new approach for ultrahigh-speed imaging that we recently proposed: time-resolved imaging by multiplexed ptychography (TIMP). In TIMP, multiple frames of the object are recovered algorithmically from data measured in a single CCD exposure of a single-shot ptychographic microscope. The frame rate is determined by the light source (burst of pulses) and it is largely uncoupled from the microscope spatial resolution, which can be sub-wavelength. Also important, TIMP yields movies of both the amplitude and phase dynamics of the imaged object. It is simple and versatile, thus it can be implemented across the electromagnetic spectrum, as well as with other waves.

I aim to develop TIMP-based microscopes, in the visible, extreme UV and x-ray spectral regions with Tera-scale frames per second frame rate and nanometric resolution. We will utilize the unprecedented imaging capabilities in applications, including exploring ultrafast phase transitions, ultrafast dynamics in nanostructures, and tracking the spatiotemporal dynamics during passive mode-locking build-up in lasers and Kerr micro-resonators.

This program, if successful, will bring the field of imaging into a new era, where ultrafast dynamics of non-repetitive transient complex-valued objects can be viewed at nanometric resolution.

Link to the ERC project webpage: https://oren.net.technion.ac.il/

Keywords of the ERC project: ultrahigh-speed microscopy, high harmonic generation, coherent imaging

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Wireless power transfer (WPT), pioneered by Tesla, is an idea at least as old as radio communications. However, on the one hand, due to health concerns and the large antenna dimensions required for transmission of high energy levels, until recently WPT has been limited mostly to very short distance applications. On the other hand, recent advances in silicon technology have significantly reduced the energy needs of electronic systems, making WPT over radio waves a potential source of energy for low power devices. Although WPT through radio waves has already found various short-range applications (such as the radio-frequency identification technology, healthcare monitoring etc.), its integration as a building block in the operation of wireless communications systems is still unexploited. On the other hand, conventional radio wave based information and energy transmissions have largely been designed separately. However, many applications can benefit from simultaneous wireless information and power transfer (SWIPT).

The overall objective of the APOLLO project is to study the integration of WPT/SWIPT technology into future wireless communication systems. Compared to past and current research efforts in this area, our technical approach is deeply interdisciplinary and more comprehensive, combining the expertise of wireless communications, control theory, information theory, optimization, and electronics/microwave engineering.

The key outcomes of the project include: 1) a rigorous and complete mathematical theory for WPT/SWIPT via information/communication/control theoretic studies; 2) new physical and cross-layer mechanisms that will enable the integration of WPT/SWIPT into future communication systems; 3) new network architectures that will fully exploit potential benefits of WPT/SWIPT; and 4) development of a proof-of-concept by implementing highly-efficient and multi-band metamaterial energy harvesting sensors for SWIPT.
Chip-Scale Self-Referenced Optical Frequency Comb Sources

As a Nobel-honored technology, optical frequency combs, which consist of equidistant spectral lines, have revolutionized applications in time-keeping, and metrology as they offer unprecedented precision in frequency via self-referencing. However, conventional frequency comb systems have been confined to laboratories due to the cost, size, and power requirements of their components. This project aims to develop a chip-scale optical frequency comb source that can be self-referenced.

Key components to realize self-referencing are comb generators and frequency doublers. However, it is challenging to integrate both functionalities on the same chip as they typically rely on different nonlinear processes and thus different material platforms. Another major challenge in the system miniaturization is how to achieve ultra-efficient comb generation and frequency doubling to enable on-chip comb pumping and self-referencing beat note detection, respectively.

In this project, we will circumvent the multi-material issue by developing both comb generator and frequency doubler based on the same nonlinear material: aluminum gallium arsenide (AlGaAs). This material exhibits both strong cubic and quadratic nonlinearities which can be utilized for comb generation and frequency doubling, respectively. Ultra-efficient comb generation will be realized by developing ultra-high-quality-factor microresonators and employing new comb generation methods combining cubic and quadratic nonlinearities while highly-efficient frequency doubling will be achieved by adaptively-controlling the phase-matching condition. We will also develop heterogeneous integration technologies to bridge the nonlinear devices with on-chip laser sources and detectors by using intermediate silicon nitride circuits. Successful miniaturization of a self-referenced frequency comb source will enable applications like LIDAR, coherent communications, chemical sensing, medical imaging, and precision metrology.

Link to the ERC project webpage:

Keywords of the ERC project: integrated nonlinear optics; frequency comb; Kerr comb; second harmonic generation;

Keywords that characterize the scientific profile of the potential visiting researcher/s: soliton comb generation; self-referencing; metrology; spectroscopy;
Advanced Analytics to Empower the Small Flexible Consumers of Electricity

David against Goliath: Could small consumers of electricity compete in the wholesale markets on equal footing with the other market agents? Yes, they can and FlexAnalytics will show how.

Activating the demand response, although a major challenge, may also bring tremendous benefits to society, with potential cost savings in the billions of euros. This project will exploit methods of inverse problems, multi-level programming and machine learning to develop a pioneering system that enables the active participation of a group of price-responsive consumers of electricity in the wholesale electricity markets. Through this, they will be able to make the most out of their flexible consumption. FlexAnalytics proposes a generalized scheme for so-called inverse optimization that materializes into a novel data-driven approach to the market bidding problem that, unlike existing approaches, combines the tasks of forecasting, model formulation and estimation, and decision-making in an original unified theoretical framework. The project will also address big-data challenges, as the proposed system will leverage weather, market, and demand information to capture the many factors that may affect the price-response of a pool of flexible consumers. On a fundamental level, FlexAnalytics will produce a novel mathematical framework for data-driven decision making. On a practical level, FlexAnalytics will show that this framework can facilitate the best use of a large amount and a wide variety of data to efficiently operate the sustainable energy systems of the future.

Link to the ERC project webpage: https://groupoasysflexanalytics.readthedocs.io/en/latest/index.html
Keywords of the ERC project: Smart grid, data-driven optimization, big data, statistical learning, mathematical programming, power systems, renewable energy sources, decision-making under uncertainty, demand-side management
Keywords that characterize the scientific profile of the potential visiting researcher/s: Mathematical programming, optimization, operations research and statistics, energy systems, energy markets
The advances in electronic communication and computation have enabled the ubiquity of Cyber-Physical Systems (CPS): digital systems that regulate and control all sorts of physical processes, such as chemical reactors, water distribution and power networks. These systems require the timely communication of sensor measurements and control actions to provide their prescribed functionalities. Event-triggered control (ETC) techniques, which communicate only when needed to enforce performance, have attracted attention as a mean to reduce the communication traffic and save energy on (wireless) networked control systems (NCS). However, despite ETC’s great communication reductions, the scheduling of the aperiodic and largely unpredictable traffic that ETC generates remains widely unaddressed – hindering its true potential for energy and bandwidth savings.

To address this problem, I will take up the following scientific challenges: (1) the construction of models for ETC’s communication traffic; (2) the design of schedulers based on such models guaranteeing prescribed performance levels. To reach these goals, I will employ scientific methods at the cross-roads between theoretical computer science, control systems and communications engineering. I propose to follow a two step approach that I have recently demonstrated:

(i) modeling as timed-priced-game-automata (TPGA) the timing of communications of event-triggered control systems; and (ii) solving games over TPGAs to prevent data communication collisions and ensure prescribed performances for the control tasks.

I will produce algorithms facilitating the efficient implementation of control loops over shared communication resources and increasing the energy efficiency of wireless NCS by orders of magnitude. The advances will be demonstrated on automotive and wireless water-distribution control applications, showcasing the potential economic impact from the reduction of implementation and maintenance costs on CPSs.

Link to the ERC project webpage: https://mmazojr.3me.tudelft.nl/sentient/

Keywords of the ERC project: Control systems, Wireless Networks, Scheduling, formal methods

Keywords that characterize the scientific profile of the potential visiting researcher/s: control, formal methods, networking
Fibre optics are critical infrastructure for society because they carry nearly all the global Internet traffic. For a long time, optical fibre systems were thought to have infinite information-carrying capabilities. With current traffic demands growing by a factor between 10 and 100 every decade, however, this is no longer the case. In fact, it is currently unknown if the installed optical infrastructure will manage to cope with these demands in the future, or if we will face the so-called "capacity crunch".

To satisfy traffic demands, transceivers are being operated near the nonlinear regime of the fibres. In this regime, a power-dependent nonlinear phenomenon known as the Kerr effect becomes the key impairment that limits the information-carrying capability of optical fibres. The intrinsic nonlinear nature of these fibres makes the analysis very difficult and has led to a series of unanswered fundamental questions about data transmission in nonlinear optical fibres, and nonlinear media in general. For example, the maximum amount of information that optical fibres can carry in the highly nonlinear regime is still unknown, and the design of transceivers well-suited for this regime is also completely unexplored.

In this project, the PI will answer these fundamental questions by studying the simplest nontrivial building blocks underlying optical fibres, and will give a definitive answer to the capacity crunch question. The PI will use a systematic methodology that aims at embracing nonlinear effects, consider the continuous-time channel as the correct starting point for analysis, and redesign optical transceivers from scratch, lifting all linear assumptions. The proposed methodology is in sharp contrast with current research trends, which aim at mitigating nonlinearities, and consider discrete-time models in the linear regime. Due to the central role of information transmission in modern society, the results in this project will have broad societal impact.

Link to the ERC project webpage: https://www.sps.tue.nl/ictlab/project/funnotch/

Keywords of the ERC project: fiber optical communications, information theory, communication theory, forward error correction

Keywords that characterize the scientific profile of the potential visiting researcher/s: fiber optical communications, information theory, communication theory, forward error correction
An iono-electronic neuromorphic interface for communication with living systems

While our understanding of the brain have made huge progresses, we are still inefficient in interfacing biological systems with electronics, both in terms of energy and integration potential. Pushed by the need to use conventional computers for building complex systems dedicated to brain interface applications, we have mostly capitalized on technologies and architectures inherits from microelectronic that are intrinsically not adapted to interface living systems. The IONOS project will shift the brain interface paradigm by developing new technologies designed to interact intimately with biological cells and capitalizing heavily on bio-inspiration.

To reach this goal, the IONOS project will explore how to sense, stimulate and compute biological signals from in-vitro neural cells' assembly based on iono-electronic materials and devices. These emerging devices offer basics functionalities such as memory, ion-electron signal's transduction, and amplification paving the way to a new field of device and circuit engineering that could efficiently reproduce key biological functions such as learning and spatio-temporal processing of information. This project will demonstrate how these concepts associated to the bio-inspired computing paradigm can unlock our fundamental limitations for communicating with living neural cells. Proof of concept will show how an artificial system can efficiently send, receive and compute information from a biological one, which constitutes the basic of communication.

Link to the ERC project webpage:

Keywords of the ERC project: neuromorphic engineering, memristors, bio-interfaces, neural networks

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Modern society is based on large-scale, interconnected, complex infrastructures, e.g. power, transportation and communication systems, with network structure and interacting subsystems controlled by autonomous components and human users, generically called “agents”. These systems possess the features of “complex” systems of systems (C-SoS), such as rationality and autonomy of the agents, and require effective multi-agent coordination and control actions for their safe and efficient operation. Multi-agent optimization has attracted an extraordinary amount of research attention as a methodology to let agents cooperatively coordinate their actions, but it is inappropriate and ineffective for systems with noncooperative (selfish) agents, virtually all modern C-SoS.

A paradigm shift is necessary to ensure safe and efficient operation of complex systems with possibly noncooperative agents. With this aim, COSMOS shall embrace dynamic game theory and pursue a twofold scientific and technical objective: 1) to conceive a unifying framework for the analysis and control of complex, multi-agent, mixed cooperative and noncooperative, systems; 2) to provide automated computational methods for solving coordination, decision and control problems in C-SoS. To achieve these goals, COSMOS will adopt a novel operator-theoretic approach, and integrate methods within and across dynamic game theory, networked multi-agent systems and control, statistical learning, stochastic and mixed-integer optimization.

**Link to the ERC project webpage:** https://sites.google.com/site/grammaticosergio/

**Keywords of the ERC project:** Game theory, Distributed optimization, Distributed control

**Keywords that characterize the scientific profile of the potential visiting researcher/s:**
More than a century ago, the invention of alternating current (AC) transformer has made AC the preferred choice over the direct current (DC) technologies. Line AC transformers are bulky but simple and reliable devices, made out of copper and iron, providing voltage adaptation and galvanic isolation in AC power systems. Currently, DC technology is increasing its presence in AC power systems, enabled by progress in semiconductor devices and power electronics based energy conversion. DC power distribution networks can effectively support energy transformation and high penetration of distributed energy resources and energy storage integration (both increasingly being DC by nature) in future energy systems. Despite this shift towards the DC power distribution networks, DC Transformer, offering AC transformer like features (and beyond) does not exist, either conceptually or practically.

To enable the next (r)evolution in power systems, the EMPOWER project will develop the DC Transformer, a novel, flexible, highly efficient, compact, and reliable conversion principle for seamless energy routing in high-power DC distribution networks. Through a holistic approach, novel concepts, integration and optimization, we will demonstrate new design paradigms for galvanically-isolated power conversion. Our approach relies on resonant conversion utilizing high-voltage semiconductor devices in combination with high-frequency magnetic materials. We propose a new approach for the DC Transformer, avoiding active power flow control and instead utilizing control effort for the safety and protection. The DC Transformer will unify functions of a power converter and a protection device into a single power electronics system, improving drastically the conversion efficiency, reliability and power density in future DC power distribution networks. The success of this project will place Europe at the edge of reliable, efficient and safe energy distribution and transmission technologies.

**Keywords of the ERC project:** power electronics, magnetics, semiconductors, DC networks

**Keywords that characterize the scientific profile of the potential visiting researcher/s:** power electronics
Project ID: 835284  
Project Acronym: M-Runners  
Evaluation Panel: PE7 Systems and Communication Engineering

Principal Investigator: Dr ALIN ALBU-SCHAEFFER  
Host Institution: DEUTSCHES ZENTRUM FUER LUFT - UND RAUMFAHRT EV - DE

Modal Nonlinear Resonance for Efficient and Versatile Legged Locomotion

The aim of M-Runners is to thoroughly advance the understanding of fundamental dynamic principles of legged locomotion to the point that those principles can be used to design robots which display similar motion characteristics, versatility, and efficiency as their biological paragons. The central hypothesis of the project is that biological locomotion is fundamentally determined by the mechanical resonance properties of the body and that a breakthrough in robot locomotion is essentially linked to understanding and exploiting these phenomena. If body design is such that walking and running correspond to intrinsic periodic motions of the body, then the control is simple and efficiency and robustness are natural consequences. However, large-amplitude nonlinear oscillations of such complex systems are today still not well understood. Mathematical methods to describe, analyze, design and control elastic resonant robots are lacking to a large extent. The project is thus dedicated to develop a new theory of nonlinear oscillations, applicable to elastic multibody systems, be they biologic or robotic.

M-Runners will perform interdisciplinary research at the border between robotics, nonlinear dynamical systems and vibration theory, biomechanics, and machine learning. We will take inspiration from biology regarding the basic motion sequences and the muscle arrangements (couplings, redundancies, compliance distributions). Conversely, we expect our theory to generate new hypotheses for a deeper understanding of locomotion biomechanics and its control by the nervous system.

We will design and demonstrate robots which can move at similar speed and mechanical energetic efficiency as animals and humans and which have comparable uneven terrain versatility and robustness. The primary application scenario is space exploration on Mars in canyons, caves or steep ridge slopes. Applications of the technology reach, however, from health-care over personal-assistance to disaster management.

Link to the ERC project webpage: https://m-runners.dlr.de/

Keywords of the ERC project: robotics, locomotion, nonlinear dynamics, space exploration, mechatronics, biomechanics

Keywords that characterize the scientific profile of the potential visiting researcher/s: see above
Fluorescence microscopy is an invaluable tool for exploring the structure and function of biological processes. It provides high specificity and contrast for the observation of cellular components tagged with fluorescent molecules in a minimally invasive fashion, allowing the study of live specimens. Furthermore, the development of super resolution (SR) fluorescence microscopy has unlocked the access to spatial resolutions beyond the diffraction limit of visible light (~250nm), fuelling the discovery of new biological structures and dynamics. Nevertheless, achieving resolutions below ~10nm is challenged by multiple trade-offs between spatial and temporal resolutions, depth of observation and photo toxicity, making it difficult or impossible to obtain a molecular resolution. Additionally, axial resolutions are inevitably poorer than lateral ones, unless utilizing a complex multi-objective lens approach.

I recently developed MINFLUX, a localization technique that merges concepts of SR with information theory. It achieves isotropic nanometer resolution in three dimensions with a single objective lens and has unrivaled spatio temporal resolution. However, a platform that enables these capabilities in a high-throughput manner for entire cells and tissue has not yet been developed. I aim to fill this technological gap; with my background and experience, I am in a unique position to assure the success of this project and establish these technologies in the scientific community. The performance of fluorescence imaging and tracking will progress orders of magnitude in the years to come, signaling yet another revolution for optical nanoscopy.

Link to the ERC project webpage: https://balzarottilab.org/

Keywords of the ERC project: fluorescence, super resolution microscopy, MINFLUX

Keywords that characterize the scientific profile of the potential visiting researcher/s: molecular biology, optics, microscopy
Control for Orbit Manoeuvring through Perturbations for Application to Space Systems

Space benefits mankind through the services it provides to Earth. Future space activities progress thanks to space transfer and are safeguarded by space situation awareness. Natural orbit perturbations are responsible for the trajectory divergence from the nominal two-body problem, increasing the requirements for orbit control; whereas, in space situation awareness, they influence the orbit evolution of space debris that could cause hazard to operational spacecraft and near Earth objects that may intersect the Earth. However, this project proposes to leverage the dynamics of natural orbit perturbations to significantly reduce current extreme high mission cost and create new opportunities for space exploration and exploitation.

The COMPASS project will bridge over the disciplines of orbital dynamics, dynamical systems theory, optimisation and space mission design by developing novel techniques for orbit manoeuvring by “surfing” through orbit perturbations. The use of semi-analytical techniques and tools of dynamical systems theory will lay the foundation for a new understanding of the dynamics of orbit perturbations. We will develop an optimiser that progressively explores the phase space and, though spacecraft parameters and propulsion manoeuvres, governs the effect of perturbations to reach the desired orbit. It is the ambition of COMPASS to radically change the current space mission design philosophy: from counteracting disturbances, to exploiting natural and artificial perturbations.

COMPASS will benefit from the extensive international network of the PI, including the ESA, NASA, JAXA, CNES, and the UK space agency. Indeed, the proposed idea of optimal navigation through orbit perturbations will address various major engineering challenges in space situation awareness, for application to space debris evolution and mitigation, missions to asteroids for their detection, exploration and deflection, and in space transfers, for perturbation-enhanced trajectory design.

Link to the ERC project webpage: www.polimi.it

Keywords of the ERC project: space debris, near Earth asteroids, astrodynamics, space engineering, space, orbits, mission analysis, trajectory optimisation, space sustainability, small spacecraft, formation flying, large constellations

Keywords that characterize the scientific profile of the potential visiting researcher/s: numerical modelling, dynamical system theory, optimisation, mathematical modelling, simulation
Monitoring bone healing around endosseous implants: from multiscale modeling to the patient’s bed

Implants are often employed in orthopaedic and dental surgeries. However, risks of failure, which are difficult to anticipate, are still experienced and may have dramatic consequences. Failures are due to degraded bone remodeling at the bone-implant interface, a multiscale phenomenon of an interdisciplinary nature which remains poorly understood. The objective of BoneImplant is to provide a better understanding of the multiscale and multitime mechanisms at work at the bone-implant interface. To do so, BoneImplant aims at studying the evolution of the biomechanical properties of bone tissue around an implant during the remodeling process. A methodology involving combined in vivo, in vitro and in silico approaches is proposed. New modeling approaches will be developed in close synergy with the experiments. Molecular dynamic computations will be used to understand fluid flow in nanoscopic cavities, a phenomenon determining bone healing process. Generalized continuum theories will be necessary to model bone tissue due to the important strain field around implants. Isogeometric mortar formulation will allow to simulate the bone-implant interface in a stable and efficient manner.

In vivo experiments realized under standardized conditions will be realized on the basis of feasibility studies. A multimodality and multi-physical experimental approach will be carried out to assess the biomechanical properties of newly formed bone tissue as a function of the implant environment. The experimental approach aims at estimating the effective adhesion energy and the potentiality of quantitative ultrasound imaging to assess different biomechanical properties of the interface. Results will be used to design effective loading clinical procedures of implants and to optimize implant conception, leading to the development of therapeutic and diagnostic techniques. The development of quantitative ultrasonic techniques to monitor implant stability has a potential for industrial transfer.

Link to the ERC project webpage:

Keywords of the ERC project: Biomechanics, acoustics, mechanical engineering, ultrasound, bone, implant, modeling and simulation, multimodality experimental approach

Keywords that characterize the scientific profile of the potential visiting researcher/s: Biomechanics, acoustics, mechanical engineering, ultrasound, bone, implant, modeling and simulation, multimodality experimental approach
**Electro-motion for the sustainable recovery of high-value nutrients from waste water**

Current water treatment technologies are mainly aimed to improve the quality of water. High-value nutrients, like nitrate and phosphate ions, often remain present in waste streams. Electro-driven separation processes offer a sustainable way to recover these nutrients. Ion-selective polymer membranes are a strong candidate to achieve selectivity in such processes.

The aim of E-motion is to chemically modify porous electrodes with membranes to introduce selectivity in electro-driven separation processes. New, ultrathin ion-selective films will be designed, synthesized and characterized. The films will be made by successively adsorbing polycations and polyanions onto the electrodes. Selectivity will be introduced by the incorporation of ion-selective receptors. The adsorbed multilayer films will be studied in detail regarding their stability, selectivity and transport properties under varying experimental conditions of salinity, pH and applied electrical field, both under adsorption and desorption conditions.

The first main challenge is to optimize and to understand the film architecture in terms of 1) stability towards an electrical field, 2) ability to facilitate ion transport. Also the influence of ion charge and ion size on the transport dynamics will be addressed. The focus of E-motion is set on phosphate ions, which is rather complex due to their large size, pH-dependent speciation and the development of phosphate-selective materials. Theoretical modelling of the solubility equilibria and electrical double layers will be pursued to frame the details of the electrosorption of phosphate.

E-motion represents a major step forward in the selective recovery of nutrients from water in a cost-effective, chemical-free way at high removal efficiency. The proposed surface modification strategies and the increased understanding of ion transport and ionic interactions in membrane media offer also applications in the areas of batteries, fuel cells and solar fuel devices.

**Link to the ERC project webpage:** www.louisdesmet.nl

**Keywords of the ERC project:** ion selectivity, polymers, capacitive deionization, membranes, electrodes

**Keywords that characterize the scientific profile of the potential visiting researcher/s:** chemical selectivity, polyelectrolytes, desalination, coating, surface chemistry
Correlative tomography

Proposal summary (half page)
The vision is firstly, to develop correlative tomography to radically increase the nature and level of information (morphological, structural and chemical) that can be obtained for a 3D volume of interest (VoI) deep within a material or component by coupling non-destructive (3D+time) X-ray tomography with destructive (3D) electron tomography and, secondly to exploit this new approach to shed light on damage accumulation processes arising under demanding conditions. Successful completion of this project will provide new 3D & 4D insights across many areas and yield key experimental data for multiscale models.

Objective 1: To build the capability of correlative tomography
- To connect platforms across scales and modalities in order to track a VoI that may be located deep below the surface and to combine multiple techniques within a single platform.
- To add new facets to correlative tomography including
  + 3D chemical imaging
  + 3D crystal grain mapping
  + the local stress distribution
  + mechanical performance mapping at the VoI scale

Objective 2: To apply it to gain new insights into damage accumulation
Correlative tomography will provide a much richer multi-faceted hierarchical picture of materials behaviour from life science to food science from geology to cultural heritage. This project will focus specifically on identifying the nucleation, propagation and aggregation of damage processes in engineering materials.
- We will identify and track the mechanisms that control the progressive degradation of conventional bulk engineering materials operating under demanding conditions.
- We will examine the hierarchical strategies nature uses to control failure in natural materials through heterogeneous chemistry, morphology and properties. Alongside this we will examine the behaviour of man-made nano-structured analogues and whether we can exploit some of these strategies.

Link to the ERC project webpage:
Keywords of the ERC project:
Keywords that characterize the scientific profile of the potential visiting researcher/s:
Three-dimensional nanoelectrochemical systems based on low-cost reduced graphene oxide: the next generation of water treatment systems

The ever-increasing environmental input of toxic chemicals is rapidly deteriorating the health of our ecosystems and, above all, jeopardizing human health. Overcoming the challenge of water pollution requires novel water treatment technologies that are sustainable, robust and energy efficient. ELECTRON4WATER proposes a pioneering, chemical-free water purification technology: a three-dimensional (3D) nanoelectrochemical system equipped with low-cost reduced graphene oxide (RGO)-based electrodes. Existing research on graphene-based electrodes has been focused on supercapacitor applications and synthesis of defect-free, superconductive graphene. I will, on the contrary, use the defective structure of RGO to induce the production of reactive oxygen species and enhance electrocatalytic degradation of pollutants. I will investigate for the first time the electrolysis reactions at 3D electrochemically polarized RGO-coated material, which offers high catalytic activity and high surface area available for electrolysis. This breakthrough approach in electrochemical reactor design is expected to greatly enhance the current efficiency and achieve complete removal of persistent contaminants and pathogens from water without using any chemicals, just by applying the current. Also, high capacitance of RGO-based material can enable further energy savings and allow using intermittent energy sources such as photovoltaic panels. These features make 3D nanoelectrochemical systems particularly interesting for distributed, small-scale applications. This project will aim at: i) designing the optimum RGO-based material for specific treatment goals, ii) mechanistic understanding of (electro)catalysis and (electro)sorption of persistent pollutants at RGO and electrochemically polarized RGO, iii) understanding the role of inorganic and organic matrix and recognizing potential process limitations, and iv) developing tailored, adaptable solutions for the treatment of contaminated water.

Link to the ERC project webpage: electron4water.com

Keywords of the ERC project: development of nanostructures electrodes, electrochemical water treatment, graphene foams, TiO2 nanotubes, MnO nanostructures

Keywords that characterize the scientific profile of the potential visiting researcher/s: material science, environmental electrochemistry
Combustion science will play a major role in the future quest for sustainable, secure and environmentally friendly energy sources. Two thirds of the world energy supply rely on combustion of fossil and alternative fuels, and all scenarios forecast an increasing absolute energy supply through combustion, with an increasing share of renewables. Thus, combustion will remain the major actor in transportation and power generation as well as in manufacturing processes, like steel and glass.

Nevertheless, combustion science will need profound innovation to meet future energy challenges, such as energy efficiency and fuel flexibility, and ensure future generations with affordable and sustainable energy and healthy environment. In this context, MILD combustion represents a very attractive solution for its fuel flexibility and capability to deliver very high combustion efficiency with virtually zero pollutant emissions. Such a combustion regime is the result of a very strong interaction between turbulent mixing and chemical kinetics. The fundamental mechanism of this interaction is not fully understood, thus justifying the need for experimental and numerical investigations.

The overall objective of the present research proposal is to drive the development of modern and efficient combustion technologies, by means of experimental, theoretical, and numerical simulation approaches. New-generation simulation tools for MILD combustion will be developed, to reduce the dependence on sub-grid models and increase the fidelity of numerical simulations. High-fidelity experimental data will be collected on quasi-industrial systems, to disclose the nature of the interactions between fluid dynamics, chemistry and pollutant formation processes in MILD combustion. Experiment and numerical simulations will be tied together by Validation and Uncertainty Quantification techniques, to allow the ground-breaking application of the developed approaches and promote innovation in the energy sector.

Link to the ERC project webpage: www.vademecom.eu

Keywords of the ERC project: Combustion modelling, optimisation, reduced-order models

Keywords that characterize the scientific profile of the potential visiting researcher/s: Machine learning and reduced-order modelling
Precise and smart nanoengineered surfaces: Impact resistance, icephobicity and dropwise condensation

Water freezing (icing) and condensation are ubiquitous in our life. Preventing undesirable icing on surfaces with minimal energy and chemical use, and improving the efficiency of condensation heat exchangers has broad societal value. Thus, I aim to use fundamental insights to offer energy-efficient solutions for undesirable ice formation and promoting dropwise condensation using novel and robust nanoengineered surfaces. My objectives are:

i) to realise thermodynamically guided metallic surfaces with precise (<10 nm) morphology and controlled superficial stiffness for energy-efficient icing prevention and sustaining dropwise flow condensation

ii) to rationally intercalate polymers and/or suspensions into surface nanotextures and exploit nanomechanics in order to enable robust and smart nanoengineered surfaces for high speed impact, abrasion and chemical resistance; stable icephobicity (delaying freezing); and sustained dropwise condensation.

iii) to develop new fundamental insights to: a) prevent icing due to high speed (~100 m/s) supercooled droplet/ice crystal impact; b) realise icephobicity down to -30 degrees Celsius; c) minimise ice-surface adhesion; and d) sustain dropwise condensation at high (50-100 m/s) vapour speeds.

The proposal emphasis on energy efficiency is aligned with the EU’s 20/20/20 Strategic Energy Technology (SET) Plan. To exemplify their salient impact, the proposed smart nanoengineered surfaces offer a passive solution for airplane icing (and related accidents) and will delay evaporator icing on air source heat pumps and refrigerators, thereby helping to lower the energy use in buildings and cold storages. The latter are tied to the global food storage and distribution challenges. Similarly, sustained dropwise condensation will make condensers in process industry and steam power plants compact and efficient. Optimally, only ~1 micron of the surface depth will require treatment – this will minimize chemical use and promote sustainability.

Link to the ERC project webpage: https://cordis.europa.eu/project/rcn/207380/factsheet/en

Keywords of the ERC project: smart surfaces, superhydrophobic and superoleophobic materials, anti-icing, steam condensation, nanoengineering surfaces, nanomanufacturing, droplet impact, ice crystal impact, icephobicity tests, thermofluid sciences, interfacial phenomena

Keywords that characterize the scientific profile of the potential visiting researcher/s: Exceptional chemists, material scientists, applied mathematicians, and of course engineers with interest in nanoengineered and smart surfaces in general. We are interested in working on and collaborating on cutting edge research topics in this domain.
Unraveling Interdiffusion Effects at Material Interfaces -- Learning from Tensors of Microstructure Evolution Simulations

Multi-materials, combining various materials with different functionalities, are increasingly desired in engineering applications. Reliable material assembly is a great challenge in the development of innovative technologies. The interdiffusion microstructures formed at material interfaces are critical for the performance of the product. However, as more and more elements are involved, their complexity increases and their variety becomes immense. Furthermore, interdiffusion microstructures evolve during processing and in use of the device. Experimental testing of the long-term evolution in assembled devices is extremely time-consuming. The current level of materials models and simulation techniques does not allow in silico (or computer aided) design of multi-component material assemblies, since the parameter space is much too large.

With this project, I aim a break-through in computational materials science, using tensor decomposition techniques emerging in data-analysis to guide efficiently high-throughput interdiffusion microstructure simulation studies. The measurable outcomes aimed at, are

1) a high-performance computing software that allows to compute the effect of a huge number of material and process parameters, sufficiently large for reliable in-silico design of multi-materials, on the interdiffusion microstructure evolution, based on a tractable number of simulations, and
2) decomposed tensor descriptions for important multi-material systems enabling reliable computation of interdiffusion microstructure characteristics using a single computer.

If successful, the outcomes of this project will allow to significantly accelerate the design of innovative multi-materials. My expertise in microstructure simulations and multi-component materials, and access to collaborations with the top experts in tensor decomposition techniques and materials characterization are crucial to reach this ambitious aim.

Link to the ERC project webpage: https://www.mtm.kuleuven.be/Onderzoek/Semper/SolMicS/ERC-Grant_at_Department_of_MaterialsEngineering

Keywords of the ERC project: microstructure simulations; tensor calculations; high performance computing; diffusion; high entropy alloys;

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Applying silicon solar cell technology to revolutionize the design of thin-film solar cells and enhance their efficiency, cost and stability

Thin film (TF) photovoltaics (PV) hold high potential for Building Integrated PV, an important market as European buildings require to be nearly zero-energy by 2020. Currently, Cu(In,Ga)(S,Se)2 (= CIGS(e)) TF solar cells have high efficiency, but also a simple one-dimensional cell design with stability and reliability concerns. Furthermore, its present research has been mainly focused on improving the absorber and buffer layers.

Scientifically, Uniting PV aims to study the practical boundaries of CIGS(e) TF solar cell efficiency. For that reason, its goal is to revolutionize the design of CIGS(e) solar cells through implementation of advanced three-dimensional silicon (Si) solar cell concepts. This novel design consists of (i) surface passivation layers and (ii) light management methods integrated into ultra-thin (UT) CIGS(e) solar cells: (i) Passivation layers will be studied to reduce charge carrier recombination at CIGS(e) surfaces. The aim is to create new understanding and thus scientific models. (ii) Light management methods will be studied to optimize optical confinement in UT CIGS(e) layers. The aim is to examine the interaction between light management and charge carrier recombination in UT CIGS(e), and to create scientific models. The main reasons to introduce these developments is to reduce charge carrier recombination at the CIGS(e) surfaces and in the CIGS(e) bulk, while maintaining optical confinement.

Technologically, the project targets to establish a solar cell with: (1) Increased cell efficiency, at least 23.0 % and up to 26.0 %; (2) improved stability and reliability, due to reduced CIGS(e) thickness and passivation layers hindering alkali metal movement; and (3) reduced cost, due to the use of less Ga and In, and industrially viable materials, methods and equipment. Hence, its outcome will be upscalable, valuable for other TF PV materials, and start a new wave of innovation in and collaboration between TF and Si PV research fields.
Nanophosphor-based photonic materials for next generation light-emitting devices

Energy-efficient and environmentally friendly light sources are an essential part of the global strategy to reduce the worldwide electricity consumption. Light-emitting diodes (LEDs) emerge as a key alternative to conventional lighting, due to their high power-conversion efficiency, long lifetime, fast switching, robustness, and compact size. Nonetheless, their implementation in the consumer electronic industry is hampered by the limited control over brightness, colour quality and directionality of LED emission that conventional optical elements relying on geometrical optics provide.

This project exploits new ways of controlling the emission characteristics of nanophosphors, surpassing the limits imposed by conventional optics, through the use of exciting nanophotonic concepts - an approach that has not been explored so far due to the strong multiple light-scattering that standard micrometre-sized phosphors present. The development of reliable and scalable nanophosphor-based photonic materials will allow ultimate spectral and angular control over the light emission properties, addressing the critical shortcomings of current LEDs. The new optical design of these devices will be based on multilayers, surface textures and nano-scatterers of controlled composition, size and shape, to attain large-area materials possessing photonic properties that will enable a precise management of the visible radiation. To prove and on-demand control over the colour appearance and the angular emission pattern of emitting devices, the project will culminate in an experimental demonstration of two paradigmatic cases: i) directional white-light emission within a narrow angular cone; ii) omnidirectional emission of monochromatic light.

Nanophom will significantly advance our comprehension of fundamental phenomena like the formation of photonic modes in complex optical media to which light can couple, as well as advancing the state of the art of high-efficiency solid-state lighting devices.

Link to the ERC project webpage: http://nanophom.eu/

Keywords that characterize the scientific profile of the potential visiting researcher/s:
When solids become liquids: natural deep eutectic solvents for chemical process engineering

Sugars, aminoacids or organic acids are typically solid at room temperature. Nonetheless when combined at a particular molar fraction they present a high melting point depression, becoming liquids at room temperature. These are called Natural Deep Eutectic Solvents – NADES. NADES are envisaged to play a major role on different chemical engineering processes in the future. Nonetheless, there is a significant lack of knowledge on fundamental and basic research on NADES, which is hindering their industrial applications. For this reason it is important to extend the knowledge on these systems, boosting their application development. NADES applications go beyond chemical or materials engineering and cover a wide range of fields from biocatalysis, extraction, electrochemistry, carbon dioxide capture or biomedical applications. Des.solve encompasses four major themes of research: 1 – Development of NADES and therapeutic deep eutectic solvents – THEDES; 2 – Characterization of the obtained mixtures and computer simulation of NADES/THEDES properties; 3 – Phase behaviour of binary/ternary systems NADES/THEDES + carbon dioxide and thermodynamic modelling 4 – Application development. Starting from the development of novel NADES/THEDES which, by different characterization techniques, will be deeply studied and characterized, the essential raw-materials will be produced for the subsequent research activities. The envisaged research involves modelling and molecular simulations. Des.solve will be deeply engaged in application development, particularly in extraction, biocatalysis and pharmaceutical/biomedical applications. The knowledge that will be created in this proposal is expected not only to have a major impact in the scientific community, but also in society, economy and industry.

Link to the ERC project webpage:

Keywords that characterize the scientific profile of the potential visiting researcher/s:
I aim to progress substantially the understanding and applications of extremely non-wetting surfaces, tying together basic research and attractive technological advancements. The first part focuses on robust synthesis methods for superslippery liquid-repellent (SS-LR) surfaces. Furthermore, using new types of ultrasensitive force measurement for droplets, I will investigate in depth the dissipation dynamics of mobile water droplets and adhesion of droplets to surfaces, to promote understanding on low-friction surfaces. The second part aims at applying these SS-LR surfaces in droplet actuation with potential to outperform existing technologies. Additionally, the potential of SS-LR surfaces for anti-icing and for preventing bio-fouling will be investigated. The research results will have a major impact on liquid-repellent technology and will explore the fundamental physical limits of non-wetting.

Link to the ERC project webpage: http://physics.aalto.fi/smw/

Keywords of the ERC project: superhydrophobic, liquid-repellent surfaces

Keywords that characterize the scientific profile of the potential visiting researcher/s: 
Design of NanoMOFs Capsules for Drug Delivery and Bioimaging.

Cancer is a major health problem worldwide, being the most common cause of death after cardiovascular diseases. The major goal of new anticancer therapies is to specifically kill tumour cells while leaving healthy cells unharmed. A main challenge to achieve this aim is the development of better drugs, including novel treatments based on the use of siRNAs. These macromolecules are potentially the most powerful anti-cancer drugs that exist, but still there is no efficient way of getting them delivered specifically to the tumour. Indeed, lifetime of such molecules is generally too short and therefore need to be protected in a carrier until they are delivered into tumour target cells.

This project focuses in the development of nanocarriers based on metal-organic frameworks (MOFs), one of the most exciting developments in recent porous materials science. The study of the mechanisms that control drug delivery is of critical importance to nanomedicine applications, where nanotechnology has the potential to revolutionise cancer therapy. Given the challenging nature of the drug delivery problem for cancer therapy, this project builds on 4 interrelated main concepts: i) the design of bio-compatible MOFs for drug delivery applications; ii) the post-synthesis engineering of MOFs to enhance stability, controlled drug release, and targeting; iii) the identification of optimal textural properties (i.e. pore size distribution, surface area, pore volume) and surface chemistry of MOFs for siRNA delivery using experiments and molecular simulation techniques; iv) the assessment of their performance in vitro and in vivo, giving a translational dimension to the proposed research. The novelty of this work lies therefore in the synergistic combination of tools from different areas and disciplines (chemistry, biochemical engineering and medicine) to produce advances that are of both fundamental scientific interest and of bioengineering relevance in nanomedicine applications.

Link to the ERC project webpage: http://aam.ceb.cam.ac.uk/

Keywords of the ERC project: Metal-organic frameworks; MOF; Drug delivery; RNA; Cancer

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Diffusive Droplet Dynamics in multicomponent fluid systems

Liquid-liquid extraction - the transfer of a solute from one solvent to another - is a core process in chemical technology and analysis. The current challenge is to miniaturise the analyte extraction process and to optimize the extraction recovery and preconcentration factor. Lacking a priori calculations, this is now often done by trial-and-error. However, to control and optimize the extraction processes, it is crucial to quantitatively understand the diffusive droplet dynamics in multicomponent fluid systems. This is essential and urgently needed not only for modern liquid-liquid extraction processes for diagnostics & microanalysis, for droplet microfluidics, or in the paint & coating industry, but on larger scales also in remediation industry, in chemical technology, or in food processing. These applications of droplets governed by diffusion include cases of immersed droplets in the bulk & on a surface, single & multicomponent droplets & solvents, and cases with high droplet number density. In spite of their relevance, multiphase & multicomponent fluid systems with relevant diffusive droplet dynamics are poorly understood.

The objective of DDD is a breakthrough: to fill this gap and to come to a quantitative understanding of diffusive droplet dynamics, thus illuminating the fundamental fluid dynamics of diffusive processes of immersed (multicomponent) (surface) droplets on multiple scales. To achieve this objective, we will perform a number of key controlled experiments and numerical simulations for idealized setups on 9 orders of magnitude in length scale, allowing for one-to-one comparison between experiments and numerics/theory. It is now time to bridge the gap from modern fluid dynamics to process-technology, colloidal & interface science, from nano/microscopic and purely diffusively governed droplets to macroscopic ones and from single droplets to multiple & multi-component droplets, to arrive at multiscale high-precision chemical engineering for droplets.

Link to the ERC project webpage:

Keywords of the ERC project:

Keywords that characterize the scientific profile of the potential visiting researcher/s:
The decrease of weight and the increase of efficiency of magnetic components are essential for the reduction of CO2-emission and an improvement of their performance. Nanostructuring can dramatically improve the magnetic properties of soft and hard magnetic materials, hence opening up entirely new possibilities for the development of novel magnets. Nanocomposite magnets, for example, have been the focus of research since two decades. One of the remaining key challenges is to synthesize bulk nanostructured magnets of a reasonable size. In this project, this challenge is explicitly addressed and the potential to fabricate bulk nanostructured magnets by severe plastic deformation (SPD) as an innovative processing route is evaluated. The aim of the project is not only to synthesize different nanostructured magnets by SPD, but also to tailor their microstructure to attain the desired magnetic properties. It has been shown by the applicant that the magnetic properties of SPD processed nanocrystalline materials can be modified in wide range by decomposition of metastable solid solutions. By using different immiscible systems, decomposition mechanisms and annealing treatments, unique nanostructures can be obtained and the magnetic properties can be optimized. Through the choice of different magnetic starting materials, such as soft, hard and antiferromagnetic-ferromagnetic powders, different types of hard magnetic nanocomposites will also be obtained. Fine tuning of the microstructure and resulting magnetic properties through adjustments in the composition, SPD processing parameters and annealing treatments is planned. The project systematically addresses the entire process from the synthesis to the in-depth microstructural characterization by electron microscopy and atom probe tomography. In combination with simultaneous measurements of magnetic properties, the newly developed knowledge will be used to improve the performance of SPD processed nanostructured magnets.

Link to the ERC project webpage: https://www.oeaw.ac.at/esi/research/nanomaterials-by-severe-plastic-deformation/spdtum-spd-nanostructured-magnets-with-tuneable-properties/

Keywords of the ERC project:

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Controlling earthQuakes

According to the Centre for Research on the Epidemiology of Disasters (CRED), earthquakes are responsible for more than half of the total human losses due to natural disasters from 1994 to 2003. There is no doubt that earthquakes are lethal and costly. CoQuake proposes an alternative, ground-breaking approach for avoiding catastrophic earthquakes by inducing them at a lower energetic level. Earthquakes are a natural phenomenon that we cannot avoid, but—for the first time—in CoQuake I will show that it is possible to control them, hence reducing the seismic risk, fatalities and economic cost. CoQuake goes beyond the state-of-the-art by proposing an innovative methodology for investigating the effect and the controllability of various stimulating techniques that can reactivate seismic faults. It involves large-scale, accurate simulations of fault systems based on constitutive laws derived from micromechanical, grain-by-grain simulations under Thermo-Hydro-Chemo-Mechanical couplings (THMC), which are not calibrated on the basis of ad-hoc empirical and inaccurate constitutive laws. A pioneer experimental research programme and the design and construction of a new apparatus of metric scale, will demonstrate CoQuake’s proof-of-principle and it will help to explore the transition from aseismic to seismic slip. CoQuake is an interdisciplinary project as it takes knowledge from various fields of engineering, computational mechanics, geomechanics, mathematics and geophysics. CoQuake opens a new field and new line of research in earthquake mechanics and engineering, with a direct impact on humanity and science.

Link to the ERC project webpage: coquake.eu

Keywords of the ERC project:
Keywords that characterize the scientific profile of the potential visiting researcher/s:
Computational modelling for personalised treatment of congenital craniofacial abnormalities

Craniosynostosis is a group of congenital craniofacial abnormalities consisting in premature fusion (ossification) of one or more cranial sutures during infancy. This results in growth restriction perpendicular to the axis of the suture and promotes growth parallel to it, causing physical deformation of the cranial and facial skeleton, as well as distortion of the underlying brain, with potential detrimental effects on its function: visual loss, sleep apnoea, feeding and breathing difficulties, and neurodevelopment delay. Conventional management of craniosynostosis involves craniofacial surgery delivered by excision of the prematurely fused sutures, multiple bone cuts and remodelling of the skull deformities, with the primary goal of improving patient function, while normalising their appearance. Cranial vault remodelling surgical procedures, aided by internal and external devices, have proven functionally and aesthetically effective in correcting skull deformities, but final results remain unpredictable and often suboptimal because of an incomplete understanding of the biomechanical interaction between the device and the skull.

The overall aim of this grant is to create a validated and robust computational framework that integrates patient information and device design to deliver personalised care in paediatric craniofacial surgery in order to improve clinical outcomes. A virtual model of the infant skull with craniosynostosis, including viscoelastic properties and mechano-biology regulation, will be developed to simulate device implantation and performance over time, and will be validated using clinical data from patient populations treated with current devices. Bespoke new devices will be designed allowing for pre-programmed 3D shapes to be delivered with continuous force during the implantation period. Patient specific skull models will be used to virtually test and optimise the personalised devices, and to tailor the surgical approach for each individual case.

Link to the ERC project webpage:

Keywords of the ERC project: patient specific computational models, craniofacial abnormalities, devices

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Opening a new route in solid mechanics: Printed protective structures

Dynamic fragmentation of metals is typically addressed within a statistical framework in which material and geometric flaws limit the energy absorption capacity of protective structures. This project is devised to challenge this idea and establish a new framework which incorporates a deterministic component within the fragmentation mechanisms.

In order to check the correctness of this new theory, I will develop a comprehensive experimental, analytical and numerical methodology to address 4 canonical fragmentation problems which respond to distinct geometric and loading conditions which make easily identifiable from a mechanical standpoint. For each canonical problem, I will investigate traditionally-machined and 3D-printed specimens manufactured with 4 different engineering metals widely used in aerospace and civilian-security applications. The goal is to elucidate whether at sufficiently high strain rates there may be a transition in the fragmentation mechanisms from defects–controlled to inertia–controlled. If the new statistical-deterministic framework is proven to be valid, defects may not play the major role in the fragmentation at high strain rates. This would bring down the entry barriers that the 3D-printing technology has found in energy absorption applications, thus reducing production transportation and repairing, energetic and economic costs of protective structures without impairing their energy absorption capacity.

It is anticipated that leading this cutting-edge research project will enable me to establish my own research team and help me to achieve career independence in the field of dynamic behaviour of ductile solids.

Link to the ERC project webpage: https://www.nonsolmecgroup.com/

Keywords of the ERC project: Solid Mechanics, Printed Materials, Fragmentation, Inertia

Keywords that characterize the scientific profile of the potential visiting researcher/s: Analytical Mechanics, Computational Mechanics, Dynamic Behaviour of Material, Constitutive Modelling
REACT aims to dramatically impact the targeted release of diagnostic agents and drugs with nanomedicines that respond to biological cues or changing pathophysiological conditions, thus enabling ultrasensitive diagnosis and exquisite therapy selectivity. Nanomedicine research against cancer focuses on the local targeted delivery of chemotherapeutics to enhance drug efficacy and reduce side effects. Despite all the efforts in the design of chemotherapeutic agents as nanomedicines, hardly any improvement has been translated into benefits for patients’ survival. There is an urgent need for improved carrier systems able to deliver high doses of diagnostic agents and anti-cancer drugs to the tumor. Stimuli responsive carriers are promising candidates since the release of the cargo can be triggered locally in the tumor environment. Currently, there exists an unparalleled effort to identify genes, proteins and metabolites implicated in human disease and utilize systems biology and mathematical approaches in order to develop new prognostic tools for the treatment of cancer and develop more targeted therapies for patients. As an expert in drug delivery systems, the PI intends to bring all these efforts and advances into the design of stimuli responsive organic-inorganic hybrid nanoparticles that can adapt their response to the biological milieu. The novel engineered delivery systems will consist of an inorganic porous matrix surface-modified with tumor-specific molecules with the ability to sense changes in the environmental conditions and react by providing a proportional release. These nanosystems can potentially be employed for early in vitro diagnosis through effective screening of deadly tumors, such as neuroblastoma and glioblastoma. Moreover, through the sustained delivery of the nanosystems from injectable gels that can be locally implanted in patients at risk of developing a tumor, a clinically relevant tool for in vivo diagnosis and targeted therapy can be achieved.

Link to the ERC project webpage: https://www.tcd.ie/research/profiles/?profile=ruizhere

Keywords of the ERC project: drug delivery systems; triggered release; nanotheranostics; injectable hydrogels; MRI

Keywords that characterize the scientific profile of the potential visiting researcher/s:
A Multiscale Dislocation Language for Data-Driven Materials Science

Crystalline defects in metals and semiconductors are responsible for a wide range of mechanical, optical and electronic properties. Controlling the evolution of dislocations, i.e. line-like defects and the carrier of plastic deformation, interacting both among themselves and with other microstructure elements allows tailoring material behaviors on the micro and nanoscale. This is essential for rational design approaches towards next generation materials with superior mechanical properties.

For nearly a century, materials scientists have been seeking to understand how dislocation systems evolve. In-situ microscopy now reveals complex dislocation networks in great detail. However, without a sufficiently versatile and general methodology for extracting, assembling and compressing dislocation-related information the analysis of such data often stays at the level of “looking at images” to identify mechanisms or structures. Simulations are increasingly capable of predicting the evolution of dislocations in full detail. Yet, direct comparison, automated analysis or even data transfer between small scale plasticity experiments and simulations is impossible, and a large amount of data cannot be reused.

The vision of MuDiLingo is to develop and establish for the first time a Unifying Multiscale Language of Dislocation Microstructures. Bearing analogy to audio data conversion into MP3, this description of dislocations uses statistical methods to determine data compression while preserving the relevant physics. It allows for a completely new type of high-throughput data mining and analysis, tailored to the specifics of dislocation systems. This revolutionary data-driven approach links models and experiments on different length scales thereby guaranteeing true interoperability of simulation and experiment. The application to technologically relevant materials will answer fundamental scientific questions and guide towards design of superior structural and functional materials.

Link to the ERC project webpage:

Keywords of the ERC project: machine learning, materials science, materials informatics, data science, data mining

Keywords that characterize the scientific profile of the potential visiting researcher/s:
'If immortality unveil…’ – development of the novel types of energy storage systems with excellent long-term performance

The major goal of the project is to develop a novel type of an electrochemical capacitor with high specific power (up to 5 kW/kg) and energy (up to 20 Wh/kg) preserved along at least 50 000 cycles. Thus, completion of the project will result in remarkable enhancement of specific energy, power and life time of modern electrochemical capacitors. Advanced electrochemical testing (galvanostatic cycling with constant power loads, electrochemical impedance spectroscopy, accelerated aging and kinetic tests) will be accompanied by materials design and detailed characterization. Moreover, the project aims at the implementation of novel concepts of the electrolytes and designing of new operando technique for capacitor characterization. All these efforts aim at the development of sustainable and efficient energy conversion and storage system.

Link to the ERC project webpage:

Keywords of the ERC project: energy storage, supercapacitors, electrochemical energy conversion, sustainable development

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Deformation Mechanisms are the Key to Understanding and Tailoring Tribological Behaviour

Tribology, the science of interacting surfaces in relative motion, is crucial for many aspects of modern life. Friction and wear decisively impact the lifetime and durability of many products - from nanoelectromechanical systems to gears and engines. In the USA alone, an estimated 1E18 joules of energy could be saved each year through improved tribological practices.

During sliding of a metallic contact, a mutated surface layer forms, carries most further plastic deformation and largely determines friction and wear. The origin and evolution of this distinct subsurface layer remains elusive, since our knowledge of the elementary mechanisms promoting these changes is limited. Only this knowledge however will allow for a strategic tailoring of tribologically loaded metals.

In this project, we will elucidate these elementary mechanisms for a wide range of alloys and strain rates. We will develop groundbreaking new strategies for probing the subsurface microstructure during the tribological test itself with non-destructive testing sensors like ultrasound and eddy current, resulting in subsurface in situ tribology. The data from these sensors will be analysed online, during the tribological experiment, relying on cutting edge data science methods as they have already been applied for fatigue testing. Based on these analyses, implemented on a Field Programmable Gate Array, we will interrupt the test exactly when the dominating elementary mechanisms manifest themselves. These mechanisms will then be revealed by sophisticated electron microscopy and be visualized in deformation mechanism maps for unidirectional and reciprocating sliding. Such maps have proven very successful in other fields of materials science, e.g. creep at elevated temperatures. They are used to guide material selection and alloy development processes, yielding materials tailored for each specific tribological scenario, promising enormous savings in energy and resources, an important challenge of our time.

Link to the ERC project webpage:

Keywords of the ERC project: Materials, Tribology, Friction, Data Science,

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Multifunctional Digital Materials Platform for Smart Integrated Applications

DIGISMART creates new avenues into two main areas: 1) processing nanomaterials/nanostructures applied to electronic devices by exploring a new digital multifunctional direct laser writing (LDW) method for in situ synthesis of small-sized nanomaterials/nanofilms micro-patterned growth by selective photothermal decomposition of semiconductors, dielectrics and conductors precursors and 2) provide simultaneously multifunction to single based metal oxide devices (like thin film transistors, the workhorses for large area electronics having electron, charge and color modulation), as the basic unit to promote systems’ integration by exploring the use of new advanced materials with unique multi-functionalities using low cost process solutions. This new fabrication process will be very useful for low-cost, eco-friendly, and efficient fabrication of nanostructures and thin films-integrated microelectronic devices due to its low-power, simple setup as well as excellent reliability. This new and disruptive concept will be achieved with low cost and non-toxic materials (new metal oxides, MO semiconductors, conductors, dielectrics and electrochromics free of In and Ga) associated to a low cost process multifunctional platform technology (ALL-IN-ONE TOOL) well supported by high-resolution nano-characterization techniques. With DIGISMART new and unexplored materials will be produced as well as to boost the original properties of conventional materials in order to contribute to the needs for low cost and flexible electronics. If we succeed to embed some level of intelligence in every object, this would change electronics and it would change society, ranging from embedded window displays to a wide range of biomedical electronics, just to mention a few and this is what the Internet of Things is looking for.

Link to the ERC project webpage: not yet available, see the PI group page: https://docentes.fct.unl.pt/emf

Keywords of the ERC project: advanced materials for device application, thin film transistors, electrochromic devices

Keywords that characterize the scientific profile of the potential visiting researcher/s: materials science with experience on thin films, devices, microelectronics, nanoparticles
Fluid injection related to underground resources has become widespread, causing numerous cases of induced seismicity. If felt, induced seismicity has a negative effect on public perception and may jeopardise wellbore stability, which has led to the cancellation of several projects. Forecasting injection-induced earthquakes is a big challenge that must be overcome to deploy geo-energies to significantly reduce CO2 emissions and thus mitigate climate change and reduce related health issues. The basic conjecture is that, while initial (micro)seisms are caused by well-known mechanisms that could be predicted, subsequent activity is caused by harder to understand and, at present, unpredictable coupled thermo-hydro-mechanical-seismic (THMS) processes, which is the reason why available models fail to forecast induced seismicity. The objective of this project is to develop a novel methodology to predict and mitigate induced seismicity. We propose an interdisciplinary approach that integrates the THMS processes that occur in the subsurface as a result of fluid injection. The methodology, based on new analytical and numerical solutions, will concentrate on (1) understanding the processes that lead to induced seismicity by model testing of specific conjectures, (2) improving and extending subsurface characterization by using industrial fluid injection operations as a long-term continuous characterization methodology, so as to reduce prediction uncertainty, and (3) using the resulting understanding and site specific knowledge to predict and mitigate induced seismicity. Project developments will be tested and verified against fluid-induced seismicity at field sites that present diverse characteristics. Arguably, the successful development of this project will provide operators with concepts and tools to perform pressure management to reduce the risk of inducing seismicity to acceptable levels and thus, improve safety and reverse public perception on fluid injection activities.

**PredictinG EaRthquakES induced by fluid injecTion**

**Link to the ERC project webpage:** www.georest.eu

**Keywords of the ERC project:** induced seismicity, fault reactivation, geomechanics, hydrogeology, geothermal energy, CO2 storage

**Keywords that characterize the scientific profile of the potential visiting researcher/s:** civil engineering, mathematics, physics, hydrogeology
Bacterial biofilms in porous structures: from biomechanics to control

The key ideas motivating this project are that: 1) precise control of the properties of porous systems can be obtained by exploiting bacteria and their fantastic abilities; 2) conversely, porous media (large surface to volume ratios, complex structures) could be a major part of bacterial synthetic biology, as a scaffold for growing large quantities of microorganisms in controlled bioreactors.

The main scientific obstacle to precise control of such processes is the lack of understanding of biophysical mechanisms in complex porous structures, even in the case of single-strain biofilms. The central hypothesis of this project is that a better fundamental understanding of biofilm biomechanics and physical ecology will yield a novel theoretical basis for engineering and control.

The first scientific objective is thus to gain insight into how fluid flow, transport phenomena and biofilms interact within connected multiscale heterogeneous structures - a major scientific challenge with wide-ranging implications. To this end, we will combine microfluidic and 3D printed micro-bioreactor experiments; fluorescence and X-ray imaging; high performance computing blending CFD, individual-based models and pore network approaches.

The second scientific objective is to create the primary building blocks toward a control theory of bacteria in porous media and innovative designs of microbial bioreactors. Building upon the previous objective, we first aim to extract from the complexity of biological responses the most universal engineering principles applying to such systems. We will then design a novel porous micro-bioreactor to demonstrate how the permeability and solute residence times can be controlled in a dynamic, reversible and stable way - an initial step toward controlling reaction rates.

We envision that this will unlock a new generation of biotechnologies and novel bioreactor designs enabling translation from proof-of-concept synthetic microbiology to industrial processes.

Link to the ERC project webpage: http://yohan-davit.com/

Keywords of the ERC project: bioengineering, biophysics, fluid mechanics, biofilm, bacteria, porous media, flow, transport phenomena, microfluidics, bioreactor, tomography, microscopy, smart materials

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Universal Equilibrium and Beyond - Challenging the Richardson-Kolmogorov Paradigm

Turbulence is at a crossroads: The old, established ideas of Richardson and Kolmogorov have with accumulating evidence come under renewed scrutiny, especially in non-stationary and non-equilibrium flows. Many in the community seek new and more accurate ways to describe turbulence. This is a time of re-evaluation and opportunity!

The assumed statistical equilibrium of the smallest and intermediate scales is identified as the main cause of the potentially erroneous deductions. This problem was not previously noticed because experiments that confirmed the previous theories were all in statistical equilibrium. And those experiments and theories which disagreed were labelled ‘anomalous’, no matter how carefully performed or argued.

The proposed theory-intensive approach will therefore specifically use non-equilibrium and statistically non-stationary flows to:
1. Investigate the underlying mechanisms determining the level of dissipation
2. Quantify the resulting effects on the balance equations of central importance
3. Test the results against the established, as well as competing, theories

I will use stationary and accelerating jets well-suited for studying the non-linear interactions and quantifying departures to the assumed equilibrium and the non-stationary dissipation. The feasibility is demonstrated with preliminary results. The databases which will be established should contribute substantially to settling the long-lived ultimate question of turbulence: what are the true underlying mechanisms that set the level of dissipation.

The results will be ground breaking scientifically and economically. The impact for engineering applications is extensive, since Kolmogorov-based turbulence models are routinely used, and since developing flows constitute the rule rather than the exception in the majority of engineering applications. The potential economic consequences for e.g. transportation, climate predictions and power extraction are impossible to underestimate.

Link to the ERC project webpage: [http://www.trl.mek.dtu.dk/erc-unieqturb](http://www.trl.mek.dtu.dk/erc-unieqturb)

Keywords of the ERC project: Turbulence, mathematical analysis of sophisticated optical particle based flow measurements

Keywords that characterize the scientific profile of the potential visiting researcher/s: Strong mathematical or experimental background (specifically optics related)
Superelastic Porous Structures for Efficient Elastocaloric Cooling

Cooling, refrigeration and air-conditioning are crucial for our modern society. In the last decade, the global demands for cooling are growing exponentially. The standard refrigeration technology, based on vapour compression, is old, inefficient and environmentally harmful. In the SUPERCOOL project we will exploit the potential of elastocaloric cooling, probably the most promising solid-state refrigeration technology, which utilizes the latent heat associated with the martensitic transformation in superelastic shape-memory alloys. We have already demonstrated a novel concept of utilizing the elastocaloric effect (eCE) by introducing a superelastic porous structure in an elastocaloric regenerative thermodynamic cycle. Our preliminary results, recently published in Nature Energy, show the tremendous potential of such a system. However, two fundamental challenges remain. First, we need to create a geometry of the superelastic porous structure (elastocaloric regenerator) to ensure sufficient fatigue life, a large eCE and rapid heat transfer. Second, we must have a driver mechanism that can effectively utilize the work released during the unloading of the elastocaloric regenerator. To succeed I am proposing a unique approach to design advanced elastocaloric regenerators with complex structures together with a driver mechanism with the force-recovery principle. We will employ a systematic characterization and bottom-up linking of all three crucial aspects of the elastocaloric regenerator, i.e., the thermo-hydraulic properties, the stability and the structural fatigue, together with a new solution for force recovery in effective drivers. Based on these theoretical, numerical and experimental results we will combine both key elements of our novel elastocaloric concept into a prototype device, which could be the first major breakthrough in cooling technologies for 100 years, providing greater efficiency and reduced levels of pollution, by applying a solid-state refrigerant.

Link to the ERC project webpage: https://cordis.europa.eu/project/rcn/218620/factsheet/en

Keywords of the ERC project: elastocaloric effect; cooling; shape-memory alloy

Keywords that characterize the scientific profile of the potential visiting researcher/s: elastocaloric effect; cooling; shape-memory alloy
PrOcess intensification and innovation in olefin Production by Multiscale Analysis and design

New manufacturing techniques such as 3D printing have the potential to drastically transform the chemical industry. Novel, complex, integrated reactor designs can now be created, that will allow to unlock alternative chemical routes, such as for methane activation. Driven by process intensification and the power of high performance computing, this project will enhance heat and mass transfer in advanced chemical reactors by multiscale modelling and experimentation. OPTIMA aims to:

1. develop in silico novel 3D reactor technologies and concepts with significantly improved selectivity and heat transfer by the use of additive manufacturing;
2. generate new fundamental understanding of kinetics, heat transfer and mass transfer by using advanced measuring techniques for processes of both current and future importance;
3. demonstrate the practical applicability of an open-source multiscale large eddy simulation (LES) platform in combination with finite rate chemistry for turbulent reacting flows;
4. transform the chemical industry by valorising methane and converting it to a platform molecule through oxidative coupling of methane.

OPTIMA will focus on two olefin production processes of industrial and social importance in Europe, the exothermal oxidative coupling of methane and the endothermic steam cracking, demonstrating the universality of the proposed new paradigm. Starting from fundamental experiments and kinetic modelling (WP1), detailed chemistry will be implemented in an open-source LES multiscale modelling framework (WP2) generating in silico novel 3D reactor technologies with significantly improved selectivity (WP3). The power of the approach will be ultimately demonstrated in a novel, 3D integrated reactor, in which the studied exothermic and endothermic processes are cleverly combined (WP4).

OPTIMA will pave the way for designing the 3D reactors of tomorrow and promote the new techniques and tools that will be driving innovation in the next decades.

Link to the ERC project webpage:

Keywords of the ERC project: process intensification, CFD, open source, olefin production, catalysis, reactor design

Keywords that characterize the scientific profile of the potential visiting researcher/s: process intensification, CFD, open source, olefin production, catalysis, reactor design
Hetero-structures for Efficient Luminescent Devices

We propose to engineer stable-highly luminescent heterostructures based on defect tolerant benign perovskites and their integration into efficient planar/thin film optoelectronic devices. Primary targeted devices are: blue and white planar electroluminescent devices, high efficiency solar cells and electrically pumped lasers. We will use processing methods that are compatible with large area industrial processes, in particular focusing on vapour deposition using thermal sublimation of the perovskite precursors. The boundaries of this simple, scalable and economic coating method will be determined using an advanced real time in-situ optical monitoring system based on hyperspectral imaging. This tool will unveil the limits and processing conditions for the preparation of uniform and very thin (< 10 nm) crystalline thin-film semiconductors.

We will also attempt to replace the toxic lead in today’s most studied perovskite materials, by less toxic materials such as tin and silver/bismuth mixtures. Here vacuum based processing is beneficial in view of the limited air-stability and solubility of their pre-cursor salts.

Accurate vapour deposition methods will allow the fabrication of perovskites in multiple layered heterostructures (MLH) that passivate the perovskite crystal boundaries. This will increase their thermal and structural stability and above all their photoluminescence efficiency. With the sophisticated processing control, multiple quantum wells (MQWs) will be engineered. MQWs are promising for light-emitting devices, in particular for lasers.

The impact of the project is large on various fields ranging from processes, materials and device engineering, physics, and energy. High efficiency, planar LEDs and solar cells, can shift the energy landscape and strongly help to meet the worlds CO2 reduction targets. The demonstration of electrically pumped lasing in easily processed thin film semiconductors will generate so far un-available fields of science.

Link to the ERC project webpage:

Keywords of the ERC project: Perovskite semiconductor, luminescence, LED, photovoltaic

Keywords that characterize the scientific profile of the potential visiting researcher/s: Vacuum deposition, atomic layer deposition, semiconductor physics
Particles-on-Demand for Multiscale Fluid Dynamics

Computational fluid dynamics achieved undeniable success in many sectors of flowing matter. However, with the variety of different physical phenomena involved, also the computational methods have specialized and a uniform platform for high-quality simulations has long been in pursuit. With its roots in kinetic theory and statistical mechanics, the lattice Boltzmann method was conceived as an alternative paradigm for fluid dynamics but only partially succeeded in a subclass of incompressible flows. The reasons for that are structural: fixed particles’ velocities in traditional approaches imply rigid constraints on Mach number and temperature in the simulations, and which can only be mitigated at a price of ever increased number of particles’ speeds. A novel formulation of fluid dynamics as a kinetic theory with a small number of tailored, on-demand constructed particles removes any restrictions on flow speed and temperature as compared the lattice Boltzmann methods and their modifications. Particles-on-Demand method is a disruptive change of perspective on computational fluid dynamics through kinetic theory that opens up an unprecedented wide domain of applications, and for the first time delivers a seamless and universal computing of any type of flow, from high Knudsen number rarefied gas to supersonic flow and turbulence. Our approach is inherently physical and rigorous, with kinetic theory translated onto a fully discrete framework in position, momentum, time and space system. Particle-on-Demand shall deliver new solutions to hypersonic flows involving fluid-structure interaction and makes it easy to incorporate mixing and chemical reactions. The strength and universality of PonD method shall be demonstrated with simulations of a wide spectrum of multiscale problems such as atmospheric reentry, geostrophic turbulence, micro-flows and multiphase flow.

Link to the ERC project webpage:

Keywords of the ERC project: fluid dynamics; turbulence; lattice Boltzmann method; kinetic theory; compressible flow; multiphase flow; reactive flow; statistical mechanics

Keywords that characterize the scientific profile of the potential visiting researcher/s: fluid dynamics; kinetic theory; statistical mechanics
**Multiscale Magnetic Models for Emerging Energy Conversion Applications**

About 30% of all the electrical power generated passes through a power electronic converter, and the proportion is expected to rise to 80% in 10-15 years. The amount of electricity annually wasted due to the losses in such systems in the EU corresponds to at least billions of euros. A major part of these losses arises in passive magnetic components, such as inductors and transformers, which are also the largest and heaviest components of a power electronic device. The physical phenomena related to the power losses in the magnetic cores of these components are not properly understood at the moment. In addition, the engineering community is currently lacking efficient modeling tools for analyzing the losses in the windings of such components at high frequencies.

Improvement of high-frequency magnetic components would require accurate understanding of the power loss mechanisms. However, the device-level losses are affected by physical effects taking place in the microscopic grain and domain structures and very thin conductors, which are often subject to geometrical uncertainties. Accurate geometrical models cannot be used for analyzing the devices due to the impossibly large computational burden.

In MULTIMAG, we will address these challenges by establishing a set of new multiscale numerical modeling tools, which will provide insight into the origin of the power losses and make it possible to perform statistical analysis of the electromagnetic behaviour of such components. The application potential of these new numerical tools will be demonstrated by designing working prototypes of emerging power electronic devices, such as a solid-state transformer and a wireless power transfer system. We will also develop inverse problem approaches for identifying the models from available catalog data, lowering the threshold for adopting the models into use.

As the outcome, new means for improving the energy efficiency and power density of power electronic devices will arise.

**Link to the ERC project webpage:** https://www.tuni.fi/en/news/models-decreasing-energy-loss-being-developed-tampere

**Keywords of the ERC project:** computational electromagnetics, eddy currents, finite element analysis, inductors, magnetic materials, micromagnetic simulation, multiscale modeling, power electronics, power losses, transformers, wireless power transfer

**Keywords that characterize the scientific profile of the potential visiting researcher/s:** computational electromagnetics, eddy currents, finite element analysis, inductors, magnetic materials, micromagnetic simulation, multiscale modeling, power electronics, power losses, transformers, wireless power transfer
Resource efficient bio-chemical production and waste treatment

The REBOOT project will create a disruptive wet waste valorisation technology where valuable resources are re-used rather than disposed of while tackling two urgent environmental challenges: nutrient circularity and climate change. Wastewater treatment sludge and manure treatment technologies are currently not satisfactory and there is no solution to efficiently re-use the resources it contains: phosphorous and carbon.

The aim of REBOOT is to completely recover phosphorous from wastes while generating carbon neutral transportation fuels and a carbon sink in the form of carbon materials. The project will employ a frontier technology called hydrothermal liquefaction (HTL) which uses high temperature and pressure to produce a liquid product similar to petroleum termed bio-crude. This will be used for a range of innovative applications such as renewable aviation fuel, functionalized carbon materials and bio-bitumen.

The possibility of complete phosphorous recovery in HTL is a completely new concept, previously thought impossible as only continuous HTL reactors can theoretically achieve this. The complex hydrothermal chemistry of salts can only be exploited on such advanced reactors that are currently beyond state-of-the-art. The specific objectives of REBOOT are: (1) mechanistic understanding of salt behaviour in multi-phase hydrothermal systems with the aim of full recovery. (2) Develop tailored strategies for in-situ jet fuel synthesis. (3) Establish microbial electrolysis cells for in-situ hydrogen production and nutrient recovery.

REBOOT will be carried out on pilot continuous reactors, where the challenging physical conditions can be explored, exploited and new engineering solutions developed. If REBOOT is successful it will enable society to tackle existing waste problems while recovering nutrients and producing renewable materials, replacing fossil derived ones; representing a revolutionary solution to wet waste management in the emerging circular bio-economy.

Link to the ERC project webpage:

Keywords of the ERC project:

Keywords that characterize the scientific profile of the potential visiting researcher/s:
A new paradigm to re-engineering printed composites

Additive manufacturing and Automated Fibre Placement (AFP) processes brought to the emergence of a new class of fibre-reinforced materials; namely, the Variable Angle Tow (VAT) composites. AFP machines allow the fibres to be relaxed along curvilinear paths within the lamina, thus implying a point-wise variation of the material properties. In theory, the designer can conceive VAT structures with unexplored capabilities and tailor materials with optimized stiffness-to-weight ratios. In practise, steering brittle fibres, generally made of glass or carbon, is not trivial. Printing must be performed at the right combination of temperature, velocity, curvature radii and pressure to preserve the integrity of fibres. The lack of information on how the effect of these parameters propagates through the scales, from fibres to the final structure, represents the missing piece in the puzzle of VAT composites, which today are either costly or difficult to design because affected by unpredictable failure mechanisms and unwanted defects (gaps, overlaps, and fibre kinking).

This proposal is for an exploratory study into a radical new approach to the problem of design, manufacturing and analysis of tow-steered printed composite materials. The program will act as a pre-echo, a precursor, to: 1) implement global/local models for the simulation and analysis of VATs with unprecedented accuracy from fibre-matrix to component scales; 2) develop a (hybrid) metamodeling platform based on machine learning for defect sensitivity and optimization; and 3) set new rules and best-practices to design for manufacturing. A 5-year, highly inter-disciplinary programme is planned, encompassing structural mechanics, numerical calculus, 3D printing and AFP, measurements and testing of advanced composites, data science and artificial intelligence, and constrained optimization problems to finally fill the gap between the design and the digital manufacturing chain of advanced printed materials.

Link to the ERC project webpage: http://www.pre-eco.eu/

Keywords of the ERC project:
Keywords that characterize the scientific profile of the potential visiting researcher/s:
Penetrating microjets in soft substrates: towards controlled needle-free injections

The needle-free delivery of liquid jets into soft and heterogeneous substrates, e.g. human tissue, has been hindered by (1) the need to reach specific penetration depths with energy efficient means, (2) the break-up of jets that impedes control over the dose delivery, and (3) liquid splash-back after impacting the substrate that cause cross-contamination between injections. BuBble Gun is aimed at overcoming these challenges. My team and I have recently uncovered new operational regimes of cavitation with continuous-wave lasers. My next goal is to study the energy partition between the creation of bubbles, the formation of liquid jets, and the penetration of these jets into soft substrates. Fundamental insights on energy partitioning will then be applied to achieve major breakthroughs in jet injection, by (1) controlling cavitation within microfluidic confinement, (2) tuning the rheology of jets emerging from confined cavitation, and (3) deriving the relationships between fluid dynamics and material properties governing jet injection into soft substrates. I expect to advance the knowledge at the intersection of microfluidics, physics, and bioengineering, to enable unprecedented control over cavitation, jetting, and injection phenomena. We will develop a portable energy-efficient injection platform by using ultra-high-speed imaging, and quantifying injections with experimental resolutions below the microsecond and micrometer scales. The rheological properties of the jets will be tuned with biocompatible additives to ensure cohesion, before injecting them into in-vitro targets and ex-vivo skin. Numerical models will assist untangling the influence of microfluidic configuration and material properties on the injection outcomes. The ultimate result will be the predictable, reproducible, and efficient injection of liquids that will enable a wide-range of technologies, such as additive manufacturing, coating modifications, the delivery of drugs and vaccinations.

Link to the ERC project webpage: http://www.bubble-gun.eu

Keywords of the ERC project: cavitation, needle-free injection, jet, microfluidics

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Deconstructing and rebuilding the evolution of cell and tissue mechanoadaptation

Cells in our body are exceptionally robust: they constantly adapt their properties and behavior to their physical environment. Less appreciated but equally important, the extracellular matrix (ECM) around the cells also adapts to accommodate cell activity. This highly dynamic feedback between the cell and the ECM has been increasingly recognized to play a key role in not only tissue morphogenesis and functions, but also a variety of diseases, from cardiomyopathies to cancer. Moreover, it presents an unprecedented challenge in healthcare and therapeutics, especially regenerative medicine, as progress in this field requires a paradigm shift from conventional, static cell descriptions to a co-evolving cell and tissue physiology. This proposal aims to instigate this transformation by unravelling the fundamental biophysical principles behind cell–matrix dynamic reciprocity and generating a multiscale roadmap of mechanoadaptation critical in functional tissue regeneration.

To achieve this goal, we will develop cutting-edge in vitro manipulation tools to deconstruct and rebuild the dynamics of cells and the ECM independently and interactively, thereby granting us full spatiotemporal control of each component in the system. Using this unique tissue-environment-inspired bottom-up approach, we will dissect how 1) physical changes in the environment are sensed and elicit response by the cell, 2) cell-induced ECM remodeling contributes to mechanical signal transmission, and 3) these local changes are orchestrated into global coordinated mechanoadaptation at the tissue level. The findings will have a broad impact on our fundamental understanding of cell and tissue physiology by identifying novel concepts in mechanoadaptation and will offer specific biomaterial design principles for tissue regeneration. The developed methodology will also advance the field in new directions by enabling further studies on downstream cell and tissue (mal)functions under dynamic conditions.

Link to the ERC project webpage:

Keywords of the ERC project: cell-material interactions

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Crafting Complex Hybrid Materials for Sustainable Energy Conversion

With an unprecedented rise in solar cell efficiencies and ease of fabrication, hybrid lead halide perovskites (PbHP) have gained worldwide popularity. However, these materials still rely on the use of toxic Pb and lack of long-term stability. Moreover, distracted by a race for higher conversion efficiencies, the development of in-vacuum deposition techniques to reproducibly and controllably grow these hybrid films has been highly overlooked. This is now the main hurdle for the full exploration of Pb-free and stable hybrid halides, which might not be as defect tolerant or easily produced by solution process as PbHP. Therefore, a revolutionary method allowing the discovery of new sustainable complex hybrid materials is now, more than ever, of paramount importance. Here I describe a completely new approach that allows stoichiometric and layer-by-layer in-vacuum deposition of wide families of organic-inorganic materials, and their mixture in any predetermined ratio. To overcome the specific challenges of hybrid film growth (incompatible volatility and solubility) I propose Pulsed Dual-Laser Deposition (PDLD) to decouple the deposition of the inorganic and organic sources with two distinct laser sources, a high energy (UV) and a low energy (IR), all in one vacuum system. Only this decoupling will allow the control and versatility to bridge the hybrid materials discovery gap and to tackle open scientific questions regarding the interplay between the organic and inorganic components, defect nature and their influence on optical properties, carrier scattering and recombination phenomena. Combining these fundamental insights with controlled growth, will enable the design of a new generation of stable and non-toxic hybrid films. My extensive experience in in-vacuum materials synthesis for solar cells, supported by the unique PLD expertise at the host institution will enable a leap in the discovery and understanding of hybrid materials for solar energy conversion and beyond.

Link to the ERC project webpage:

Keywords of the ERC project:
Keywords that characterize the scientific profile of the potential visiting researcher/s:
Microscale Processes Governing Global Sustainability

Reactive transport modelling is a key tool in understanding the extremely complex interplay of flow, transport and reactions occurring over various temporal and spatial scales in the subsurface. The most difficult challenge in reactive transport is the capture of scale dependence, and upscaling reactive transport will ultimately only be successful if there is a detailed understanding of fundamental mechanisms at the pore level and the supporting data are available. State-of-the-art tools (e.g. X-ray microtomography and on-chip porous media) are not sufficient to understand reactive flow, as they do not provide real-time mapping of propagation of fronts (e.g. temperature, pressure, concentration) that are critical to refine and validate simulations.

The ambition is to progress beyond the state of the art via additive manufacturing tools to print 3D replicas of porous cores that enable monitoring the properties within the pores. Our unique approach is to develop for the first time three-dimensional instrumented replicas of porous structures, so we can gain much needed dynamic data at the pore scale that can be incorporated into validated simulations coupling flow and reactive transport processes.

We combine expertise and integrating ground-breaking work in: (i) additive manufacturing to produce three dimensional replicas of porous structures; (ii) tools to embed sensors to determine in-vivo propagation of fronts (pressure, temperature, pH) within complex structures; and (iii) novel high-fidelity in-silico pore models coupling relative permeability functions and critical saturations with compositional changes and validated using virtual reality tools. The ERC MILEPOST project will transform our ability to analyse and predict the behaviour of a wide range of pore-scale processes governing the macroscopic behaviour of complex subsurface systems and open up new horizons for science in other areas, e.g. porosity controlled in polymers and bioprinting.

Link to the ERC project webpage:

Keywords of the ERC project: reactive transport, flow in porous media, CO2 storage

Keywords that characterize the scientific profile of the potential visiting researcher/s:
In Vivo Single-Cell Mechanomics of Bone Adaptation and Regeneration in the Aging Mouse

Osteoporosis, one of the most prevalent degenerative diseases, is characterized by a reduction in bone mass and increased fracture risk and has been partly attributed to the decrease in mechanical usage of the skeleton. A detailed understanding of the molecular mechanisms governing load-regulated bone remodeling could therefore lead to the identification of molecular targets for the development of novel therapies. Bone remodeling is a multiscale process mediated through complex interactions between multiple cell types and their local 3D environments. However, the underlying mechanisms of how cells respond to mechanical signals are still unclear. By combining single-cell “omics” technologies with well-established tissue-scale models of bone mechanobiology, MechAGE proposes to develop the technology required to allow spatially resolved in vivo single-cell mechanomics of bone adaptation and regeneration. CRISPR/Cas technology will be exploited to generate fluorescent reporter mice to identify the different cell types involved in the bone remodeling process. By combining RNA-sequencing of single cells isolated by laser-capture microdissection with micro-finite element analysis and time-lapsed in vivo micro-CT, MechAGE will link the transcriptome of hundreds of single cells to their local mechanical in vivo environment (LivE). This will allow investigation of molecular responses of the cells to LivE changes with aging in established mouse models of bone adaptation and regeneration. In addition to in vivo mechanomics, MechAGE proposes to use cellular and multiscale computational modeling to run in silico simulations of real-world events for better understanding of diseases of aging in mice and to maximize the use of the high quality in vivo mechanomic data. Findings from MechAGE will lead to a systems level understanding of the spatio-temporal regulation of gene expression during the process of load-induced bone adaptation and regeneration in the aging mouse.

Keywords of the ERC project: Bone, Osteoporosis, Fracture, Mechanobiology, Omics, Micro-Computed Tomography, Imaging, Computational Modeling, Single Cell, Adaptation, Regeneration

Keywords that characterize the scientific profile of the potential visiting researcher/s: omics, bioinformatics, next generation sequencing, molecular biology, single cell analysis
Multiscale Imaging-through-analysis Methods for Autonomous Patient-specific Simulation Workflows

Due to the intricate process of transferring diagnostic imaging data into patient-specific models, simulation workflows involving complex physiological geometries largely rely on the manual intervention of specially trained analysts. This constitutes a significant roadblock for a wider adoption of predictive simulation in clinical practice, as the associated cost and response times are incompatible with tight budgets and urgent decision-making. Therefore, a new generation of imaging-through-analysis tools is needed that can be run autonomously in hospitals and medical clinics. The overarching goal of ImageToSim is to make substantial progress towards automation by casting image processing, geometry segmentation and physiology-based simulation into a unifying finite element framework that will overcome the dependence of state-of-the-art procedures on manual intervention. In this context, ImageToSim will fill fundamental technology gaps by developing a series of novel comprehensive variational multiscale methodologies that address robust active contour segmentation, upscaling of voxel-scale parameters, transition of micro- to macro-scale failure and flow through vascular networks of largely varying length scales. Focusing on osteoporotic bone fracture and liver perfusion, ImageToSim will integrate the newly developed techniques into an imaging-through-analysis prototype that will come significantly closer to automated operation than any existing framework. Tested and validated in collaboration with clinicians, it will showcase pathways to new simulation-based clinical protocols in osteoporosis prevention and liver surgery planning. Beyond its technical scope, ImageToSim will help establish a new paradigm for patient-specific simulation research that emphasizes full automation as a key objective, accelerating the much-needed transformation of healthcare from reactive and hospital-centered to preventive, proactive, evidence-based, and person-centered.

Link to the ERC project webpage:

Keywords of the ERC project: Computational biomechanics, patient-specific modeling, variational image processing, liver tumor growth, liver regeneration

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Tough Interface Tailored Nanostructured Metals

The ideal structural material should excel in strength and toughness. Strength describes the capability of a defect free component to carry load during operation, while toughness defines the load-bearing capability and ductility in the presence of a crack. For an energy-efficient and safe design, both quantities should be simultaneously high. Unfortunately, they are mutually exclusive, rendering their combination a Holy Grail in materials science.

The reason for this incompatibility is rooted in the inverse strength-ductility paradigm. Focussing on metals, the strength is enhanced via microstructure refinement to the nanometer scale, but ductility and damage tolerance simultaneously drop dramatically. Safety-related or highly stressed components are thus made from rather soft metals, indicating tremendous economic impact conceivable.

The objective of this project is to design new bulk materials that uniquely combine high strength and toughness.

Severe plastic deformation will be employed to create novel nanostructured bulk metals and nanocomposites, utilizing atomistically informed alloy and interface design to promote plastic deformation. The largely unknown nanoscale processes that limit fracture toughness of nanostructured materials will for the first time be directly identified by quantitative nanomechanical fracture experiments performed in-situ in high resolution electron microscopes. Correlation of these unique insights with ab-initio calculations and energy-based elastic-plastic fracture mechanics computations will guide paths for further improvement of the fracture resistance.

By combining a versatile synthesis technique with highly advanced in-situ nanomechanical testing permitting unique atomistic-level insights into nanoscale fracture processes and a scale-bridging modelling approach, new mechanism-based strategies to tailor innovative nanostructured metals and composites with unprecedented strength and toughness will be established.

Link to the ERC project webpage:

Keywords of the ERC project:

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Real-time Data-Informed Multi-scale Computational Methods for Material Design and Processing

The fundamental importance of materials to modern society is evidenced by the way new materials have revolutionized almost every aspect of our lives. Despite the many advances, dwindling resources and more stringent demands on product cost and performance demand increasingly better material designs and production processes, resulting in a heightened reliance on computational methods.

In the field of computational materials engineering, the recent emergence of data science into the mainstream is causing a paradigm shift in the way models and data are used. There is a shift from traditional simulation methods which use data mainly to calibrate parameters in models, to data-driven simulation methods which seek to bypass the use of models by extracting knowledge from large data sets. This project synergistically combines aspects of both – by developing advanced computational methods that permit multi-scale material models to be informed by available measurement data.

This project addresses this challenging problem through two main tasks. In the first part, we develop dimension reduction techniques for rapid multi-scale materials simulations. These methods must be capable of dealing with deterministic and stochastic microstructure parameters reflecting variations in loading, material, and morphological properties. In the second part, the reduced order models serve as an enabler for the development of computational methods for the selection of the most informative data and its assimilation into multi-scale material models. By enabling parameter estimation and model correction, this leads to increased accuracy and precision in the prediction of engineering quantities of interest.

The success of the project will give rise to a novel computational framework that enables real-time multi-scale materials simulations informed by optimally chosen data, thus permitting effective risk management and cost reduction in the design of materials and control of manufacturing processes.

Link to the ERC project webpage:

Keywords of the ERC project: data assimilation, model order reduction, multiscale simulations, microscale to macroscale

Keywords that characterize the scientific profile of the potential visiting researcher/s: Experience in open source software development (e.g., MOOSE); finite element methods, particularly for nonlinear problems in mechanics (e.g., plasticity); crystal plasticity; multi scale modelling

-382-
Breaking of highly energetic waves

HIGHWAVE is an interdisciplinary project at the frontiers of coastal/ocean engineering, earth system science, statistics and fluid mechanics that will explore fundamental open questions in wave breaking. Why do waves break, how do they dissipate energy and why is this important? A central element of the work builds on recent international developments in the field of wave breaking and wave run-up led by the PI that have provided the first universal criterion for predicting the onset of breaking of water waves in uniform water depths from deep to intermediate. This work has also shown that the run-up of nonlinear waves impinging on a vertical wall can exceed up to 12 times the far-field amplitude of the incoming waves. These results have now opened up the possibility for more accurate operational wave models. They have practical and economic benefits in determining structural loads on ships and coastal/offshore infrastructure, evaluating seabed response to extreme waves, and optimizing operational strategies for maritime and marine renewable energy enterprises.

This is a tremendous advance comparable to the introduction of wave prediction during World War II, and the PI aims to be at the forefront of this research effort to take research in wave breaking into fundamentally new directions. The objectives of the project are: (i) to develop an innovative approach to include accurate wave breaking physics into coupled sea state and ocean weather forecasting models; (ii) to obtain improved criteria for the design of ships and coastal/offshore infrastructure; (iii) to quantify erosion by powerful breaking waves, and (iv) to develop new concepts in wave measurement with improved characterization of wave breaking using real-time instrumentation. This highly interdisciplinary project will involve an ambitious and unconventional combination of computational simulation/theory, laboratory experiments, and field measurements of sea waves, closely informed by application needs.

Link to the ERC project webpage: https://www.highwave-project.eu/

Keywords of the ERC project: Wave breaking, wave measurement, erosion, extreme waves

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Towards mastering the long-standing challenge of ageing infrastructures in corrosive environments

TAMING CORROSION proposes a radically new approach to the long-standing challenge of mitigating corrosion of infrastructures – such as bridges, pipelines, etc. The socio-economic burden of replacing and repairing infrastructures due to corrosion is staggering. In the EU alone, estimates are in the range of 250 billion € annually, with an expected steep increase over the coming decades. This urgently calls for new, cost-effective corrosion mitigation strategies to prolong the useful life of ageing civil infrastructures. Electrochemical corrosion protection (ECP) methods have a large potential to play a key role in addressing this challenge. However, to match these expectations, game-changing advances are needed in both science and engineering. Limited routine use and poor engineering practice of ECP can be traced to insufficient theoretical grounds and a lack of fundamental quantification of key processes. The aim of this proposal is to develop the scientific basis to deliver the first scientifically anchored engineering model and to unlock the potential of ECP as an innovative solution to the grand challenge of rapidly deteriorating infrastructures. The focus areas include: 1) for the first time integrating all relevant physical, chemical, and electrochemical processes into a quantitative model framework for the systematic study of fundamental processes and evaluation of solution strategies. An important novelty lies in combining reactive transport modeling in porous media with rigorous corrosion science. 2) Elucidating the poorly understood role of microbiology in corrosion; and 3) Devising new experiments that link corrosion science and electrochemistry with environmental science methods. Only by delivering ground-breaking scientific contributions will it be possible to abandon empiricism in the field and pave the way towards a new, scientifically sound generation of ECP technology to ensure safety, cost-efficiency, and sustainability of our infrastructures.

Link to the ERC project webpage:
Keywords of the ERC project:
Keywords that characterize the scientific profile of the potential visiting researcher/s:
Thermophone - a novel heat transfer based approach to global TOnal Noise cancellation in aviation

Limiting the number of people affected by significant aircraft noise is one of the most important tasks of modern civil aviation. Among different contributors, tonal noise is the most important due to regulatory definitions and its attenuation characteristics, with the largest contributor being the fan aero-acoustics. Current passive noise reduction methods alone are insufficient to conform with the increasingly stringent noise emission regulations. This motivates our research in active noise cancellation, based on creation of equal amplitude and frequency pressure waves, in opposite phase to the disturbance. Having identified that the actuator technology is the main hindrance against hardware implementation in flying platforms, we have been investigating a revolutionary technology based on a truly static and surface-deposited sound emitter (thermophone), which creates pressure fields by thermo-acoustic effects rather than the vibro-acoustics utilized by common speakers. Comprising of a periodically Joule heated electrically conductive thin layer, a highly efficient thermophone requires modeling of non-Fourier heat conduction in deposits.

The project is divided into 4 multi-disciplinary objectives:
1. Derivation of accurate macro-scale heat conduction model, including non-Fourier effects
2. Developing thermophone performance model by analyzing thermo-acoustic effect
3. Optimization of performance by material and geometric selection, and by manufacturing processes
4. Demonstrating aero-acoustic fan noise cancelation via the thermo-acoustic effect created by static heat flux transducer

In addition to the significance that this project will have to the field of aviation, I strongly believe that successful completion of each work package will provide dramatic improvements over the state of the arts in conduction heat transfer modelling, consumer electronics such as speakers, manufacturing methods for thermo-acoustic devices, and active aero-acoustic noise cancellation.

Link to the ERC project webpage:
Keywords of the ERC project:
Keywords that characterize the scientific profile of the potential visiting researcher/s:
Design and engineering of porous nitride-based materials as a platform for CO2 photoreduction

CONTEXT: Reshaping our energy portfolio considering the sustainability of global energy resources is central to the European Energy Roadmap 2050. Hence, researchers need to identify efficient routes towards solar fuels production. Unlike H2 evolution, CO2 photoreduction has been poorly studied. Given the scope for CO2 utilisation in a carbon-constrained future, there is an exciting opportunity to devote targeted research towards CO2 photoreduction. Photocatalysis is one route towards CO2 reduction. Yet, the design of a cost-effective, sustainable, efficient and robust photocatalyst remains a highly challenging task.

PROPOSAL: I propose to merge catalysis, materials science and engineering to develop a radically new class of photocatalysts, i.e. porous boron nitride (BN)-based materials for CO2 reduction. My approach is opposite to current research trends which explore non-crystalline and non-porous materials, and aims to compete with the 40-year old benchmark in the field, TiO2. Porous BN combines key attributes for CO2 photoreduction: (i) chemical, structural and optoelectronic tunability, (ii) high porosity, (iii) semi-crystalline to amorphous nature. These features provide unique pathways towards effective sorption of reactants/products, facile band gap engineering, and enhanced surface charge transfer. Their semi-crystalline to amorphous nature may facilitate scale-up.

IMPACT: I will address three major challenges:
1. Creating a porous BN-based material platform with adsorptive and photocatalytic functionalities
2. Adding a new dimension to photocatalyst design via porosity control
3. Creating approaches to molecular- and micro-structure engineering in porous BN

Realization of these advances would lead towards a ‘dream photocatalyst’ with integrated adsorptive, optoelectronic and catalytic functionalities. The impact will benefit fields for which interfacial phenomena are key: molecular separation, catalysis and drug delivery.

Link to the ERC project webpage:

Keywords of the ERC project:

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Evolution of white dwarfs with 3D model atmospheres

The vast majority of stars will become white dwarfs at the end of the stellar life cycle. These remnants are precise cosmic clocks owing to their well-constrained cooling rates. They provide one of the most sensitive tests of when baryonic structure formation began in the Universe. These compact matter laboratories also unravel the mass-loss in the post-main-sequence evolution and establish critical constraints for galactic evolution models. I will design a robust theoretical framework to shed new light on the interior structure of white dwarfs, associate them with their progenitor stars, and enhance their potential as probes of fundamental astrophysical relations. I have recently computed the first 3D simulations of pure-hydrogen white dwarf atmospheres including full radiation-hydrodynamics. These improved calculations demonstrate that the widely used 1D model atmospheres are unable to correctly solve the thermodynamic stratification of convective layers, and therefore lead to incorrect masses and cooling ages. My ambitious goal is to expand the 3D simulations to stellar remnants of all atmospheric compositions and connect these surface calculations to interior structure models. The project is timely since my improved theoretical tools will be essential to analyse the forthcoming Gaia sample, where the number of known white dwarfs is expected to increase by a factor of ten. I will use my theoretical framework with Gaia data, supplemented by other surveys and dedicated follow-up observations, to extract an unprecedented wealth of information from white dwarfs. I will set the standards for the star formation history and initial mass function in the Milky Way, as well as constrain the fundamental mass-radius relation for white dwarfs. I will also study evolved planetary systems that are currently being accreted in the convection zone of their white dwarf hosts, providing direct and unique insight into the bulk composition of exo-terrestrial material.

Link to the ERC project webpage: https://warwick.ac.uk/fac/sci/physics/research/astro/people/tremblay/

Keywords of the ERC project: stellar astrophysics, white dwarfs

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Accretion, Winds, and Evolution of Spins and Magnetism of Stars

This project focuses on Sun-like stars, which possess convective envelopes and universally exhibit magnetic activity (in the mass range 0.1 to 1.3 MSun). The rotation of these stars influences their internal structure, energy and chemical transport, and magnetic field generation, as well as their external magnetic activity and environmental interactions. Due to the huge range of timescales, spatial scales, and physics involved, understanding how each of these processes relate to each other and to the long-term evolution remains an enormous challenge in astrophysics. To face this challenge, the AWESoMeStars project will develop a comprehensive, physical picture of the evolution of stellar rotation, magnetic activity, mass loss, and accretion.

In doing so, we will
(1) Discover how stars lose the vast majority of their angular momentum, which happens in the accretion phase
(2) Explain the observed rotation-activity relationship and saturation in terms of the evolution of magnetic properties & coronal physics
(3) Characterize coronal heating and mass loss across the full range of mass & age
(4) Explain the Skumanich (1972) relationship and distributions of spin rates observed in young clusters & old field stars
(5) Develop physics-based gyrochronology as a tool for using rotation rates to constrain stellar ages.

We will accomplish these goals using a fundamentally new and multi-faceted approach, which combines the power of multi-dimensional MHD simulations with long-timescale rotational-evolution models. Specifically, we will develop a next generation of MHD simulations of both star-disk interactions and stellar winds, to model stars over the full range of mass & age, and to characterize how magnetically active stars impact their environments. Simultaneously, we will create a new class of rotational-evolution models that include external torques derived from our simulations, compute the evolution of spin rates of entire star clusters, & compare with observations.

Link to the ERC project webpage: http://empslocal.ex.ac.uk/AWESoMeStars/

Keywords of the ERC project: Sun-like stars, angular momentum, rotation, magnetism, winds, star-disk interaction, pre-main-sequence rotational evolution, rotational evolution

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Structured ACCREtion Disks: initial conditions for planet formation in the time domain

In this ERC Starting Grant, I propose an ambitious research program to target important challenges in predicting realistic initial conditions for the planet formation process. I will perform a large systematic study of the accretion-driven eruptions of newborn stars, and evaluate their influence on the structure, composition, and chemistry of the terrestrial planet forming zone in the circumstellar disk. The research will focus on three main questions:
- How does the mass accretion proceed in realistic, structured, non-axisymmetric disks?
- What physical mechanisms explain the accretion-driven eruptions?
- What is the effect of the eruptions on the disk?

My new research group will study young eruptive stars, pre-main sequence objects prone to episodes of extremely powerful accretion-driven outbursts, and combine new observations, state-of-the-art numerical modelling, and information from the literature. With a novel concept, we will first model the time-dependence of mass accretion in circumstellar disks, taking into account the latest observational results on inhomogeneous disk structure, and determine what fraction of young stellar objects is susceptible to high mass accretion peaks. Next, we will revise the paradigm of the eruptive phenomenon, compelled by recently discovered young eruptive stars whose outbursts are inconsistent with current outburst theories. Finally, we will determine the impact of accretion-driven eruptions on the disk, by considering the increased external irradiation, internal accretion heating, and stellar winds. With my experience and track record, I am in a position to comprehensively synthesize existing and newly acquired information to reach the proposed goals. The expected outcome of the ERC project is a conclusive demonstration of the ubiquity and profound impact of episodic accretion on disk structure, providing the initial physical conditions for disk evolution and planet formation models.

Link to the ERC project webpage: https://konkoly.hu/SACCRED/

Keywords of the ERC project: astrophysics, star formation, circumstellar matter, mass accretion, protoplanetary disks

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Back-reaction Of Solar plasma to WAVES

The solar coronal heating problem is a long-standing astrophysical problem. The slow DC (reconnection) heating models are well developed in detailed 3D numerical simulations. The fast AC (wave) heating mechanisms have traditionally been neglected since there were no wave observations. Since 2007, we know that the solar atmosphere is filled with transverse waves, but still we have no adequate models (except for my own 1D analytical models) for their dissipation and plasma heating by these waves. We urgently need to know the contribution of these waves to the coronal heating problem.

In BOSS-WAVES, I will innovate the AC wave heating models by utilising novel 3D numerical simulations of propagating transverse waves. From previous results in my team, I know that the inclusion of the back-reaction of the solar plasma is crucial in understanding the energy dissipation: the wave heating leads to chromospheric evaporation and plasma mixing (by the Kelvin-Helmholtz instability).

BOSS-WAVES will bring the AC heating models to the same level of state-of-the-art DC heating models. The high-risk, high-gain goals are (1) to create a coronal loop heated by waves, starting from an "empty" corona, by evaporating chromospheric material, and (2) to pioneer models for whole active regions heated by transverse waves.

Link to the ERC project webpage:

Keywords of the ERC project: solar physics, solar corona, MHD waves, coronal heating

Keywords that characterize the scientific profile of the potential visiting researcher/s: MHD, plasmas, waves, numerical modelling
The Interstellar Medium of High Redshift Galaxies

When and how did the first galaxies form across cosmic history? Were they different from present-day ones? This is only a small subset of key cosmological questions that the combination of deep galaxy observations, theoretical modeling, and powerful simulations envisaged here will allow us to answer for the first time.

Deep galaxy surveys have provided a first valuable characterization of early galaxies in the Epoch of Reionization (redshift $z > 6$), mostly in terms of their stellar content. However, almost nothing is known about their internal structure and Interstellar Medium (ISM). This is in striking contrast with galaxies at $z < 2$, for which ISM observations have enabled a much more complete physical description. Hence, a substantial progress in the study of early galaxies must be based on techniques able to probe their ISM. Conversely, ISM studies will help completing the “stellar” picture.

Interstellar will bridge this gap. Its main aim is to understand the internal structure and interstellar medium of galaxies in the Epoch of Reionization by performing theoretical modeling and high fidelity simulations. By post-processing the simulations and calibrating them with local analogs, we will produce mock images/spectra used to (i) interpret available high-redshift observations, and (ii) plan breakthrough experiments with ALMA, JWST and E-ELT.

The advent of ALMA, JWST, E-ELT and advances in computational cosmology make the study of high-$z$ ISM one of the most promising areas of development in cosmology.

The aim will be achieved through 5 objectives distributed among 3 Work Packages (WPs). WP1 is concerned with theoretical work, a preparatory phase for the cosmological simulations performed in WP2. WP2 represents the production phase of the project and will deliver cutting-edge zoom simulations of a sample of high-$z$ galaxies and their ISM. Finally, WP3 is concerned with the exploitation of the numerical results and their integration with observations.

Link to the ERC project webpage:

Keywords of the ERC project: galaxy formation - cosmology - interstellar medium - cosmic reionization

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Cosmic reionization corresponds to the period in the history of the Universe during which the predominantly neutral intergalactic medium was ionised by the emergence of the first luminous sources. Young stars in primeval galaxies may be the sources of reionization, if the ionising radiation, called Lyman continuum (LyC), that they produce can escape their interstellar medium: the escape fraction of LyC photons from galaxies is one of the main unknowns of reionization studies. This ERC project will contribute to answer this question, by computing from simulated galaxies three indirect diagnostics of LyC leakage that were recently reported in the literature, and comparing the virtual observables with the direct escape of LyC photons from simulated galaxies, and with observations. The first diagnostic for LyC leakage relates the escape of the strongly resonant Lyman-alpha radiation from galaxies to the LyC escape. It was proposed by the PI (Verhamme et al. 2015), and recently validated by observations (Verhamme et al. 2016). The second diagnostic proposes that the strength of Oxygen lines ratios can trace density-bounded interstellar regions. It was the selection criterion for the successful detection of 5 strong Lyman Continuum Emitters from our team (Izotov 2016a,b). The third diagnostic relates the metallic absorption line strengths to the porosity of the absorbing interstellar gas in front of the stars. The increasing opacity of the intergalactic medium with redshift renders direct LyC detections impossible during reionisation. Indirect methods are the only probes of LyC leakage in the distant Universe, and the proposed diagnostics will soon become observables at the redshifts of interest with JWST. They have passed the validation tests, it is now urgent to calibrate these indicators on state-of-the art simulations of galaxy formation. This is the main objective of the proposed project.
Type Ia supernovae: from explosions to cosmology

Type Ia supernovae (SNe Ia) are the incredibly luminous deaths of white dwarfs in binaries. They play a vital role in chemical enrichment, galaxy feedback, stellar evolution, and were instrumental in the discovery of dark energy. However, what are the progenitor systems of SNe Ia, and how they explode remains a mystery. My recent work has concluded the controversial result that there may be more than one way to produce SNe Ia. As SN Ia cosmology samples reach higher precision, understanding subtle differences in their properties becomes increasingly important. A surprising diversity in white-dwarf explosions has also been uncovered, with a much wider-than-expected range in luminosities, light-curve timescales and spectral properties. A key open question is 'What explosion mechanisms result in normal SNe Ia compared to more exotic transients?'

My team will use novel early-time observations (within hours of explosion) of 100 SNe Ia in a volume-limited search (<75 Mpc). The targets will come from the ATLAS and Pan-STARRS surveys that will provide unprecedented sky coverage and cadence (>20000 square degrees, up to four times a night). These data will be combined with key progenitor diagnostics of each SN (companion interaction, circumstellar material, central density studies). The observed zoo of transients predicted to result from white-dwarf explosions (He-shell explosions, tidal-disruption events, violent mergers) will also be investigated, with the goal of constraining the mechanisms by which white dwarfs can explode. My access to ATLAS/Pan-STARRS and my previous experience puts me in a unique position to obtain ‘day-zero’ light curves, rapid spectroscopic follow-up, and late-time observations. The data will be analysed with detailed spectral modelling to unveil the progenitors and diversity of SNe Ia. This project is timely with the potential for significant breakthroughs to be made before the start of the next-generation ‘transient machine’, LSST in ~2021.

Link to the ERC project webpage:

Keywords of the ERC project: supernovae, extragalactic transients, gravitational wave counterparts

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Massive stars dominate their surroundings during their short lifetimes, while their explosive deaths impact the chemical evolution and spatial cohesion of their hosts. After birth, their evolution is largely dictated by their ability to remove layers of hydrogen from their envelopes. Multiple lines of evidence are pointing to violent, episodic mass-loss events being responsible for removing a large part of the massive stellar envelope, especially in low-metallicity galaxies. Episodic mass loss, however, is not understood theoretically, neither accounted for in state-of-the-art models of stellar evolution, which has far-reaching consequences for many areas of astronomy. We aim to determine whether episodic mass loss is a dominant process in the evolution of the most massive stars by conducting the first extensive, multi-wavelength survey of evolved massive stars in the nearby Universe. The project hinges on the fact that mass-losing stars form dust and are bright in the mid-infrared. We plan to (i) derive physical parameters of a large sample of dusty, evolved targets and estimate the amount of ejected mass, (ii) constrain evolutionary models, (iii) quantify the duration and frequency of episodic mass loss as a function of metallicity. The approach involves applying machine-learning algorithms to existing multi-band and time-series photometry of luminous sources in ~25 nearby galaxies. Dusty, luminous evolved massive stars will thus be automatically classified and follow-up spectroscopy will be obtained for selected targets. Atmospheric and SED modeling will yield parameters and estimates of time-dependent mass loss for ~1000 luminous stars. The emerging trend for the ubiquity of episodic mass loss, if confirmed, will be key to understanding the explosive early Universe and will have profound consequences for low-metallicity stars, reionization, and the chemical evolution of galaxies.

Link to the ERC project webpage:

Keywords of the ERC project:

Keywords that characterize the scientific profile of the potential visiting researcher/s:
The MAgnetic field in the GALaxy, using Optical Polarization of Stars

What makes our Galaxy’s ecosystem so fascinating is the complex interactions between its components: stars, gas, dust, magnetic fields, and cosmic rays. Of these components, the Galactic magnetic field (GMF) may well be the most enigmatic. Only partially observable through indirect means, its study relies heavily on modeling, almost exclusively using line-of-sight integrated radio-polarimetric data. Although much has been learned, many questions are still unanswered especially about the turbulent, small-scale field component and out-of-plane field.

The crucial innovations proposed here are large independent data sets with 3D (distance) information – which can only be provided by stars polarized due to differential absorption by interstellar dust, with known distances – and more advanced Bayesian statistics which allows including prior knowledge and enables quantitative model comparison.

I propose to use 2 new polarization surveys in the V (visual) band, resulting in polarimetry of millions of stars across the southern sky. With distance information provided by the GAIA satellite, this improves the current data situation by 3 orders of magnitude. We will test GMF models against all available data, employing a Bayesian inference software package which we are developing. In the process, we will produce the first 3D all-sky (out to absorption limits) dust distribution consistent with both UV/optical/near IR absorption and optical polarization.

This research will result in a next-generation GMF model that includes all observational GMF tracers and can use informative priors. It will allow mapping out interstellar magnetized turbulence in the Galaxy, instead of providing averaged parameters only, and understanding the interplay between the local GMF, gas and dust. Its legacy is a 1000x increased stellar polarization catalog, an all-sky 3D dust model, a bayesian sampler for GMF models, and a superior GMF model for use in cosmic ray modeling or foreground subtraction.

Link to the ERC project webpage: https://astro.ru.nl/~haverkorn/magalops/index.html

Keywords of the ERC project: galactic magnetic fields; interstellar medium; interstellar dust; optical polarimetry

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Catastrophic Interactions of Binary Stars and the Associated Transients

One of the crucial formation channels of compact object binaries, including sources of gravitational waves, critically depends on catastrophic binary interactions accompanied by the loss of mass, angular momentum, and energy ("common envelope" evolution - CEE). Despite its importance, CEE is perhaps the least understood major phase of binary star evolution and progress in this area is urgently needed to interpret observations from the new facilities (gravitational wave detectors, time-domain surveys).

Recently, the dynamical phase of the CEE has been associated with a class of transient brightenings exhibiting slow expansion velocities and copious formation of dust and molecules (red transients - RT). A number of RT features, especially the long timescale of mass loss, challenge the existing CEE paradigm.

Motivated by RT, I will use a new variant of magnetohydrodynamics to comprehensively examine the 3D evolution of CEE from the moment when the mass loss commences to the remnant phase. I expect to resolve the long timescales observed in RT, characterize binary stability in 3D with detailed microphysics, illuminate the fundamental problem of how is orbital energy used to unbind the common envelope in a regime that was inaccessible before, and break new ground on the amplification of magnetic fields during CEE.

I will establish RT as an entirely new probe of the CEE physics by comparing my detailed theoretical predictions of light curves from different viewing angles, spectra, line profiles, and polarimetric signatures with observations of RT. I will accomplish this by coupling multi-dimensional moving mesh hydrodynamics with radiation, dust formation, and chemical reactions. Finally, I will examine the physical processes in RT remnants on timescales of years to centuries after the outburst to connect RT with the proposed merger products and to identify them in time-domain surveys.

Link to the ERC project webpage: http://utf.mff.cuni.cz/~pejcha

Keywords of the ERC project: Astrophysics, hydrodynamics

Keywords that characterize the scientific profile of the potential visiting researcher/s:
<table>
<thead>
<tr>
<th>Principal Investigator:</th>
<th>Dr ENRICO BARAUSSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Host Institution:</td>
<td>SCUOLA INTERNAZIONALE SUPERIORE DI STUDI AVANZATI DI TRIESTE - IT</td>
</tr>
</tbody>
</table>

**GRavity from Astrophysical to Microscopic Scales**

General Relativity (GR) describes gravity on a huge range of scales, field strengths and velocities. However, despite its successes, GR has been showing its age. Cosmological data support the existence of a Dark Sector, but may also be interpreted as a breakdown of our understanding of gravity. Also, GR is intrinsically incompatible with quantum field theory, and should be replaced, at high energies, by a (still unknown) quantum theory of gravity.

This deadlock may prelude to a paradigm change in our understanding of gravity, possibly triggered by the direct observations of neutron stars and black holes by gravitational-wave interferometers. The recent LIGO/Virgo observations, and in particular the coincident detection of electromagnetic and gravitational signals from neutron-star binaries, have already made a huge impact on our theoretical understanding of gravity, by severely constraining several extensions of GR.

GRAMS is a high-risk/high-gain project seeking to push the implications of these observations even further, by exploring whether the existing LIGO/Virgo data, and in particular their absence of non-perturbative deviations from GR, are consistent with gravitational theories built to reproduce the large-scale behaviour of the Universe (i.e. the existence of Dark Energy and/or Dark Matter), while at the same time passing local tests of gravity thanks to non-perturbative screening mechanisms. I will prove that the very fact of screening local scales makes gravitational emission in these theories much more involved than in GR, and also intrinsically unlikely to yield results in agreement with existing (and future) gravitational-wave observations. This would be a huge step forward for our understanding of cosmology, as it would rule out a modified gravity origin for the Dark Sector. Even if this conjecture is incorrect, GRAMS will provide the first numerical-relativity simulations of compact binaries ever in gravitational theories of interest for cosmology.

**Link to the ERC project webpage:**

**Keywords of the ERC project:**

**Keywords that characterize the scientific profile of the potential visiting researcher/s:**
Magnetic fields are ubiquitous in the universe. The special property of cosmic magnetism is that, in the majority of objects hosting magnetic fields, those fields are organized, such that some meaningful averaging can reveal global structure and systematic behavior. In the Sun, averaging over longitude reveals the equatorward migration of the emergence region of the sunspots, forming the famous butterfly diagram. Further, vigorous turbulence is present in a wide variety of astrophysical systems, and yet they still exhibit organized magnetic fields. These observations prompt the search for a theory to explain how order can arise and sustain itself in such chaos. We claim that the available theories are incomplete, especially in the case of solar-like stars which becomes apparent if we view the Sun as one star among many. We propose a coherent plan of advancement in which each theory shall be tested by requiring it also to explain the cyclic dynamo action seen in more active rapid rotators.

UNISDYN project attacks these very problems with novel simulations and data analysis tools. Our path to resolve them is to enhance the state-of-the-art stellar dynamo models with the relevant descriptions of the turbulent processes. This goal is reached in three steps. (i) We will produce improved convection dynamo simulations to serve as laboratories from which (ii) the turbulent transport coefficients are directly measured with a novel test methods suite. (iii) Finally, global dynamo models incorporating the turbulent effects in full are constructed based on (i) and (ii) results. These results will allow us to unify stellar dynamo theory for solar-like inactive and rapidly rotating active stars. The developed toolbox has direct applications in other fields of astrophysics, such as accretion and galactic disk dynamos, and industry, such as combustion engines and fusion reactors.

Link to the ERC project webpage: https://www.mps.mpg.de/solar-stellar-magnetic-activity/erc-unisdyn

Keywords of the ERC project: Stellar dynamos, solar dynamo, convection, turbulence, magnetohydrodynamics, numerical modelling

Keywords that characterize the scientific profile of the potential visiting researcher/s: magnetohydrodynamics, numerical modelling, turbulence, convection
Searching for life signatures on another planet is one of the key endeavours of astrophysics and today, we are in a unique position to make this possible. The TESS satellite, which just started observing, will find the first Earth-twins orbiting bright stars, which will allow follow-up studies with JWST and ELTs to characterize the atmosphere of those exoplanets. However, TESS will only measure the radius of the detected Earth-twins, which is not enough to interpret the spectroscopic features in their atmospheres. The mass is also required, and it can be obtained using the radial-velocity (RV) technique, which measures the gravitational influence of an exoplanet on its host star. To measure the mass of the Earth-twins that TESS will detect, the community have built incredible RV instruments that can reach a RV precision of 0.25 m/s (ESPPRESSO commissioning). Such an extreme precision is required to measure the tiny signature of an Earth-twin, however, this is without considering the perturbing signals induced by its host star, by Earth’s atmosphere and by instrumental noise. Indeed, we know that these perturbing signals mask completely the signal induced by an Earth-twin, and now that the RV instruments have the sensitivity to detect such planets, it is urgent to develop novel methods for mitigating the different perturbing signals. Understanding the different perturbing signals is extremely challenging and require incredible data. The PI have built two telescopes that feed Sun-light into the best RV instruments. The obtained data are of exceptional quality, and the goal of SCORE is to analyse them, explore novel promising methods for mitigating the different perturbing signals and find the tiny signatures of Earth and Venus. This will open the way towards the mass-measurement of Earth-twins, which is essential in the quest for finding life elsewhere, but also to understand planetary formation and dynamics. SCORE will therefore benefit the entire planet community.

Link to the ERC project webpage:

Keywords of the ERC project: exoplanets, extreme precision in radial velocity, stellar signals, instrumental noise,

Keywords that characterize the scientific profile of the potential visiting researcher/s: statistics, machine learning, time-series analysis
The last 30 years have been a golden era of cosmological discoveries, which revolutionized our understanding of the physical concepts, which govern our Universe. New discoveries indicate that the beginning of our Universe might have been dominated by the inflaton field, which decayed during the first second of the Universe’s existence, introducing tiny ripples in the matter distribution, which ultimately sourced later galaxy formation. The future of our Universe is dominated by dark energy, which causes the current Universe to accelerate in its expansion. Both inflation and dark energy are theoretical constructs, which help to explain current observational results, but their fundamental role in physics is not yet understood.

The distribution of galaxies in the Universe encodes an enormous amount of information, which holds the key to unravel new fundamental concepts of nature. The main goal of this proposal is to use galaxy surveys to uncover convincing evidence for the inflationary scenario and to reveal clues that will help to determine the nature of dark energy.

My team will make use of data from the DESI and Euclid experiments, a new generation of galaxy surveys, which will provide datasets more than an order of magnitude larger than what is available today, thus allowing a decisive step forward with an exciting discovery potential. Such measurements will face significant challenges in systematics control, non-linear modeling, and computational limitations. In this proposal, I will outline my plan to develop new statistical estimators, apply cutting-edge modeling techniques, and access new observables to constrain cosmological models. This project will produce results going beyond cosmology, impacting particle- as well as high energy physics. With DESI starting in late 2019 and Euclid in 2021 this work is timely and my experience in the clustering analysis with such datasets puts me in a unique position to lead the cosmological exploitation of these experiments.
DELPHI: a framework to study Dark Matter and the emergence of galaxies in the epoch of reionization

Our Universe started as a dark featureless sea of hydrogen, helium, and dark matter of unknown composition about 13 and a half billion years ago. The earliest galaxies lit up the Universe with pinpricks of light, ushering in the era of ‘cosmic dawn’. These galaxies represent the primary building blocks of all subsequent galaxies and the sources of the first (hydrogen ionizing) photons that could break apart the hydrogen atoms suffusing all of space starting the process of ‘cosmic reionization’. By virtue of being the smallest bound structures in the early Universe, these galaxies also provide an excellent testbed for models wherein Dark Matter is composed of warm, fast moving particles as opposed to the sluggish heavy particles used in the standard Cold Dark Matter paradigm.

Exploiting the power of the latest cosmological simulations as well as semi-analytic modelling rooted in first principles, DELPHI will build a coherent and predictive model to answer three of the key outstanding questions in physical cosmology:
- how did the interlinked processes of galaxy formation and reionization drive each other?
- what were the physical properties of early galaxies and how have they evolved through time to give rise to the galaxy properties we see today?
- what is the nature (mass) of the mysterious Dark Matter that makes up 80% of the matter content in the Universe?

The timescale of the ERC represents an excellent opportunity for progress on these fundamental questions: observations with cutting-edge instruments (e.g. the Hubble and Subaru telescopes) are providing the first tantalising glimpses of early galaxies assembling in an infant Universe, required to pin down theoretical models. The realistic results obtained by DELPHI will also be vital in determining survey strategies and exploiting synergies between forthcoming key state-of-the-art instruments such as the European-Extremely Large Telescope, the James Webb Space Telescope and the Square Kilometre Array.

Link to the ERC project webpage: https://pratika24.wixsite.com/delphi

Keywords of the ERC project: Reionization, galaxy formation, dark matter

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Collisional excitation of interstellar molecules: towards reactive systems

Accurate determination of physical conditions of interstellar molecular clouds is a crucial step to better understand the life cycle of the interstellar matter and particularly the formation of stars and planets as well as the synthesis of organic molecules that may lead to emergence of life in the universe. A key parameter for the determination of these conditions from interstellar spectra is the calculation of accurate collisional rate coefficients of interstellar molecules with the most abundant species (H, He, H2 and e-). Whereas the knowledge of collisional processes has reached a certain level of maturity for collisions involving non-reactive molecules, very few reliable data exist for collisions involving reactive radicals and ions. The computation of such data is a real challenge since inelastic and reactive processes compete during collisions. In this project, we plan to overcome this complex problem and to provide collisional data for these radicals and ions in order to derive as much information as possible from the molecular spectra collected by current telescopes. As it is hardly possible to consider both collisional and reactive processes simultaneously, we will set up a new methodology based on quantum approach that allows obtaining accurate data. We will focus on molecular hydrides that are good candidates because of both their astrophysical importance and their quantum accessibility. We will carry out the determination of interaction potentials using quantum chemistry ab initio methods while the treatment of the dynamics of the nuclei will primarily be done using quantum time-independent reactive and non-reactive approaches. When exact quantum calculations will not be usable, innovative statistical quantum mechanical methods will also be explored. The new data will then be used in radiative transfer models and the predictions will be finally compared to observations in order to derive the abundances of reactive radicals with unprecedented accuracy.

Link to the ERC project webpage:

Keywords of the ERC project: Astrochemistry - Molecular scattering -

Keywords that characterize the scientific profile of the potential visiting researcher/s: quantum chemistry, astrophysical modelling, inelastic scattering
The influence of stellar outflows on exoplanetary mass loss

ASTROFLOW aims to make ground-breaking progress in our physical understanding of exoplanetary mass loss, by quantifying the influence of stellar outflows on atmospheric escape of close-in exoplanets. Escape plays a key role in planetary evolution, population, and potential to develop life. Stellar irradiation and outflows affect planetary mass loss: irradiation heats planetary atmospheres, which inflate and more likely escape; outflows cause pressure confinement around otherwise freely escaping atmospheres. This external pressure can increase, reduce or even suppress escape rates; its effects on exoplanetary mass loss remain largely unexplored due to the complexity of such interactions. I will fill this knowledge gap by developing a novel modelling framework of atmospheric escape that will, for the first time, consider the effects of realistic stellar outflows on exoplanetary mass loss. My expertise in stellar wind theory and 3D magnetohydrodynamic simulations is crucial for producing the next-generation models of planetary escape. My framework will consist of state-of-the-art, time-dependent, 3D simulations of stellar outflows (Method 1), which will be coupled to novel 3D simulations of atmospheric escape (Method 2). My models will account for the major underlying physical processes of mass loss. With this, I will determine the response of planetary mass loss to realistic stellar particle, magnetic and radiation environments and will characterise the physical conditions of the escaping material. I will compute how its extinction varies during transit and compare synthetic line profiles to atmospheric escape observations from, eg, Hubble and our NASA cubesat CUTE. Strong synergy with upcoming observations (JWST, TESS, SPIRou, CARMENES) also exists. Determining the lifetime of planetary atmospheres is essential to understanding populations of exoplanets. ASTROFLOW’s work will be the foundation for future research of how exoplanets evolve under mass-loss processes.

Link to the ERC project webpage: https://www.tcd.ie/Physics/research/groups/vidotto/

Keywords of the ERC project: stellar winds; exoplanetary winds; atmospheric escape; MHD simulations

Keywords that characterize the scientific profile of the potential visiting researcher/s: star; exoplanet; MHD simulation
The impact of highly magnetic neutron stars in the explosive and transient Universe

The gravitational wave window is now open. It is then imperative to build quantitative models of neutron stars that use all the available tracers to constrain fundamental physics at the highest densities and magnetic fields. The most magnetic neutron stars, the magnetars, have been recently suggested to be powering a large variety of explosive and transient events. The enormous rotational power at birth, and the magnetic energy they can release via large flares, put the magnetars in the (yet) hand-wavy interpretations of gamma-ray bursts, the early phases of double neutron star mergers, super-luminous supernovae, hypernovae, fast radio bursts, and ultra-luminous X-ray sources. However, despite knowing about 30 magnetars, we are lacking a census of how many we expect within the pulsar population, nor we have robust constraints on their flaring rates. The recent discovery of transient magnetars, of magnetar-like flares from sources with measured low dipolar magnetic fields and from typical radio pulsars, clearly showed that the magnetar census in our Galaxy is largely underestimated. This hampers our understanding not only of the pulsar and magnetar populations, but also of them as possibly related to many of Universe’s explosive events. MAGNESIA will infer a sound Magnetar Census via an innovative approach that will build the first Pulsar Population Synthesis model able to cope with constraints/limits from multi-band observations, and taking into account 3D magnetic field evolution models and flaring rates for neutron stars. Combining expertise in multi-band observations, numerical modeling, nuclear physics, and computation, MAGNESIA will solve the physics, the observational systematic errors, and the computational challenges that inhibited previous works, to finally constrain the spin period and magnetic field distribution at birth of the neutron star population.

Link to the ERC project webpage:

Keywords of the ERC project: neutron stars, high energy astrophysics, magnetic field evolution, population synthesis, period and transient searches

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Project ID: 818930  Project Acronym: KETJU  Evaluation Panel: PE9

Universe Sciences

Principal Investigator: Dr PETER JOHANSSON
Host Institution: HELSINGIN YLIOPISTO - FI

Post-Newtonian modelling of the dynamics of supermassive black holes in galactic-scale hydrodynamical simulations (KETJU)

Supermassive black holes (SMBHs) with masses in the range \( \sim 10^6-10^{10} \, M_\odot \) are found at the centres of all massive galaxies in the Local Universe. In the ΛCDM picture of structure formation galaxies grow bottom-up through mergers and gas accretion, leading to multiple SMBHs in the same stellar system. Current simulation codes are unable to resolve in a single simulation the full SMBH merging process, which involves dynamical friction, three-body interactions and finally gravitational wave (GW) emission. KETJU will provide a significant breakthrough in SMBH research by following for the first time accurately global galactic-scale dynamical and gaseous astrophysical processes, while simultaneously solving the dynamics of SMBHs, SMBH binaries and surrounding stellar systems at sub-parsec scales. Our code KETJU (the word for ‘chain’ in Finnish) is built on the GADGET-3 code and it includes regions around every SMBH in which the dynamics of SMBHs and stellar particles is modelled using a non-softened Post-Newtonian algorithmic chain regularisation technique. The remaining simulation particles far from the SMBHs are evolved using softened GADGET-3. Using KETJU we can study at unprecedented accuracy the dynamics of SMBHs to separations of \( \sim 10 \) Schwarzschild radii, the formation of cores in massive galaxies, the formation of nuclear stellar clusters and finally provide a realistic prediction for the amplitude and frequency distribution of the cosmological gravitational wave background. The UH theoretical extragalactic team is ideally suited for this project, as it has an unusually versatile background in modelling the dynamics, feedback and merging of SMBHs. KETJU is also particularly timely, as the spectacular direct detection of GWs in 2016 is paving the way for a new era in gravitational wave astronomy. Future space-borne GW observatories, such as the European Space Agency’s LISA, require accurate global GW predictions in order to fully realise their science goals.

Link to the ERC project webpage: https://www.mv.helsinki.fi/home/phjohans/Site/Research.html

Keywords of the ERC project: Supermassive black holes, galaxy formation, gravitational waves

Keywords that characterize the scientific profile of the potential visiting researcher/s: Modelling of feedback from supermassive black holes, calculation of gravitational waves from merging black holes.
The build up of galaxies is mainly driven by the availability of gas that can cool and form new stars. Any physical process that is able to alter the gas content of a galaxy has therefore important consequences for its evolution. The study of processes that can remove gas from galaxies is the subject of GASP (GAs Stripping Phenomena in galaxies), an ESO Large Program I am leading. GASP has obtained integral field spectroscopy (IFS) with MUSE of 114 low-z galaxies with masses in the range $10^9$-$10^{11.5}$ Msun, hosted in X-ray selected clusters, in groups and filaments. The GASP sample includes the largest existing IFS sample of so-called “jellyfish galaxies” that have long tails of ionised gas, as well as other galaxies in different stages of ram pressure stripping in clusters and galaxies undergoing gas disturbance due to various phenomena in groups and filaments. GASP has the unique capability to combine the power of spatially resolved observations covering galaxy disks, outskirts and surroundings with the virtues of a statistical study of a significant number of galaxies. The MUSE GASP dataset, combined with ALMA, APEX, JVLA, UVIT and HST follow-up programs, form the basis for this ERC program. The goal is to accomplish an unprecedented break-through in our understanding of jellyfish galaxies, ram pressure stripping, gas removal processes in different environments and their consequences for the stellar history of galaxies. This multi faced, coherent program will investigate the physics of the baryonic cycle between the various gas phases (ionised, molecular and neutral) and the star formation under extreme conditions, the connection between ram pressure and AGN activity, the quenching of galaxies undergoing gas removal phenomena, and the physics of such phenomena in clusters, groups and filaments. The GASP ERC program will be a game changer in this field of research: there is no previous similar study, nor there can be a comparable one for quite a long time.

Link to the ERC project webpage:

Keywords of the ERC project:

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Direct Detection of TeV–PeV Cosmic Rays in Space

The DArk Matter Particle Explorer (DAMPE) mission has recently marked a new epoch in astroparticle physics, extending the direct measurements of cosmic ray spectra beyond a TeV with unprecedented energy resolution. With this project, based on my leadership position in DAMPE and its unique data, I propose to fundamentally improve the precision of direct cosmic ray measurements at the highest energies – in the TeV–PeV range, using for the first time a state-of-the-art artificial intelligence approach. The project will help to solve the century-long problem of cosmic-ray origin at such high energies and its effects on the Universe composition. It will study the cosmic-ray spectrum close to the region of a mysterious decline, so-called “knee”, and shed light on the nature of Dark Matter through the discovery of characteristic fine structures in cosmic-ray and gamma-ray spectra. To achieve this, based on my expertise I propose: i) to develop the TeV–PeV cosmic-ray track reconstruction and identification techniques, using a deep learning or similar artificial intelligence approach; ii) to set up a unique research programme to iteratively improve the precision of hadronic Monte-Carlo models in this rarely explored energy domain, based on the available DAMPE data and data from future experiments. The developed results will be applied to the processing of DAMPE data at the first stage, and will be then extended to the next generation High Energy Cosmic Radiation Detection (HERD) experiment. The research strategy is designed to reduce drastically the dominant uncertainties of the cosmic-ray measurements in space, related to the particle type/direction identification and modeling of hadronic interactions in the detector. As a result of the project, cosmic ray spectra will be directly measured in space in TeV–PeV energy range with qualitatively higher precision, opening up an unprecedented opportunities for new discoveries.

Link to the ERC project webpage:

Keywords of the ERC project: space astroparticle missions, cosmic rays, artificial intelligence, dark matter

Keywords that characterize the scientific profile of the potential visiting researcher/s: high energy physics, astroparticle physics, machine learning
Banking crises are thought to be recurrent phenomena that generally come on the heels of strong credit growth. Their damaging real effects have generated a broad agreement among academics and policymakers that financial regulation needs to tighten and to obtain a macroprudential dimension that aims to lessen the negative externalities from the financial to the macro real sector.

Among the main ingredients that are often mentioned to have played a role in the explosive growth of credit in the run-up to the latest financial crisis are the financial innovations by financial institutions, in particular loan securitization, the boom in mortgage lending and prices of real estate, the lack of information about prospective borrowers, and the high leverage (and corresponding low capital ratios) of financial institutions. Yet, despite the singling out of these ingredients by policymakers, decisive empirical evidence about their role and relevancy is lacking. However, given the magnitude and complexity of the global banking system and the lack of encompassing micro-level data, it is currently impossible to confidently study the impact of all ingredients jointly. This project therefore analyses pertinent settings where we can empirically identify the correspondence between the aforementioned individual ingredients and the credit granting by financial institutions.

The objective of the project is to advance identification and estimation of the impact of each respective factor on loan growth by combining the appropriate methodology with an exceptional set of micro-level datasets. When missing in the literature a theoretical framework will be provided. The project further aims to assess how potential combinations of these ingredients may have interacted in spurring credit growth. While the identification of the impact of each ingredient on credit growth is paramount, the individual setting of the studied datasets and employed methodologies will ensure maximum external validity.

Link to the ERC project webpage:
Keywords of the ERC project: bank credit; corporate finance; monetary transmission

Keywords that characterize the scientific profile of the potential visiting researcher/s: bank credit; corporate finance by banks; monetary transmission
BEHAVFRICTIONS will use novel models focussing on information-processing frictions to explain choice patterns described in behavioral economics and psychology. The proposed research will provide microfoundations that are essential for (i) identification of stable preferences, (ii) counterfactual predictions, and (iii) normative conclusions.

(i) Agents who face information-processing costs must trade the precision of choice against information costs. Their behavior thus reflects both their stable preferences and the context-dependent procedures that manage their errors stemming from imperfect information processing. In the absence of micro-founded models, the two drivers of the behavior are difficult to disentangle for outside observers. In some pillars of the proposal, the agents follow choice rules that closely resemble logit rules used in structural estimation. This will allow me to reinterpret the structural estimation fits to choice data and to make a distinction between the stable preferences and frictions.

(ii) Such a distinction is important in counterfactual policy analysis because the second-best decision procedures that manage the errors in choice are affected by the analysed policy. Incorporation of the information-processing frictions into existing empirical methods will improve our ability to predict effects of the policies.

(iii) My preliminary results suggest that when an agent is prone to committing errors, biases--such as overconfidence, confirmatory bias, or perception biases known from prospect theory--arise under second-best strategies. By providing the link between the agent's environment and the second-best distribution of the perception errors, my models will delineate environments in which these biases shield the agents from the most costly mistakes from environments in which the biases turn into maladaptations. The distinction will inform the normative debate on debiasing.

Link to the ERC project webpage: https://home.cerge-ei.cz/steiner/

Keywords of the ERC project: micro-economic theory, information economics, bounded rationality, behavioral economics

Keywords that characterize the scientific profile of the potential visiting researcher/s: micro-economic theory, information economics, bounded rationality, behavioral economics
The Causal Effect of Public Policy and Income on Child Health and Human Capital

A recent literature in economics on the “fetal origins hypothesis” has documented that a range of early (prenatal and postnatal) shocks and interventions can have substantial effects on long-term human capital formation (e.g. adult health, wages). However, we still know little about the years in between early infancy and adulthood, referred to as the “missing middle”. How do early shocks affect health and human capital formation during childhood? How do the effects of different types of interventions, or shocks at different ages, compare? What are the most cost-effective ways of improving young children’s future outcomes?

I aim to fill this gap in the literature by taking advantage of a range of natural experiments in a country, Spain, for which high quality administrative data are available for the past 35 years. State of the art econometric techniques, combined with large sample sizes, will allow me to evaluate credibly and precisely the causal effects of a number of different public policies and shocks on child development.

I will consider five different “shocks” in early childhood (at different ages), affecting: i) Household material resources (an unconditional mother’s allowance); ii) Parental time (subsidized paternity leave); iii) Medical treatments around birth (elective delivery); iv) The availability of family planning services (access to abortion); and v) Aggregate demand shocks to different sectors of the economy.

I will evaluate their impact on health and cognitive development at ages 0-15, as measured in hospital and primary health care records, school grades, and standardized test scores, among other data sources. I will also study the potential channels linking treatments to child outcomes, including family size (fertility), parental time use and labor market outcomes, expenditure patterns, etc.

My results will help us understand how shocks in early life can have long-term effects on human capital, with direct policy implications.

Link to the ERC project webpage: https://www.europeandissemination.eu/missingmiddle-project/1448

Keywords of the ERC project:
Keywords that characterize the scientific profile of the potential visiting researcher/s:
Value Judgments and Redistribution Policies

Heterogeneity and diversity are a pervasive aspect of modern societies. Differences in individuals’ preferences, needs, skills, and information are key to explain variation in individuals’ behavior and to anticipate individuals’ responses to policy changes. There is no consensus, however, about how to take these differences into account when evaluating policies.

Project VALURED will reexamine this ethical challenge by characterizing the mapping between value judgments—i.e. principles of distributive justice—and redistribution policies. This mapping is tremendously important for welfare analysis and policy design. First, it associates the most desirable policy to each set of value judgments, providing an “ethical menu” to policy design. Second, it gives an ethical identity of each policy proposal, that is, it identifies the value judgments a policymaker endorses when proposing a specific policy.

The main objectives of VALURED are to:
1) identify transparent and compelling value judgments that accommodate heterogeneity and diversity;
2) show the implications of these value judgments for the evaluation and design of redistribution policies;
3) characterize welfare criteria that respect individuals’ preferences and account for individuals’ differences in needs, skills, and information;
4) provide new insights for the design of income, capital, and inheritance taxation;
5) develop simple formulas that express optimal policies as a function of observable heterogeneity and ethical parameters.

Project VALURED combines welfare economics with public economics. The first part deals with income taxation and addresses the ethical challenges related to individuals’ heterogeneity in preferences, needs, and skills. The second part focuses on capital taxation and addresses individuals’ differences in risk preferences and information. The third part analyses the design of inheritance taxation and addresses the social concerns for intergenerational and intragenerational equity.

Link to the ERC project webpage: https://www.sv.uio.no/esop/english/research/projects/valured/index.html

Keywords of the ERC project: Welfare criteria; taxation; fairness; inequality.

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Monetary Economics and Communication: New Data, New Tools, New and Old Questions

In the last 25 years, communication has become a core lever of monetary policy. This has important implications for academic research in monetary economics -- an area intrinsically linked to the policy environment. The framework change raises new questions, and we must rethink how we empirically study existing questions. We need new approaches and new data.

My ground-breaking research agenda, rooted in important academic questions, comprises of 6 pioneering projects across 3 related themes that emphasise the increasingly-important role of central bank communication in policy.

Theme I concerns the fundamental empirical question in monetary economics: what is the effect of monetary policy? Though an old question, two projects innovate by using tools from data science to develop new measures of monetary and information shocks from central bank communication.

Three projects in Theme II examine the issue of monetary communication and expectations management. The projects will (i) test, for the first time, the Morris-Shin prediction that communication might overly-coordinate expectations formation; (ii) develop a rich, new high-frequency dataset of expectations for EU countries to enable us to better address the questions in this theme; and (iii) develop new surveys and pioneering research on the role of the communication in affecting expectations of the general public.

Theme III examines the complex interaction between monetary policy and uncertainty; monetary policy both reacts to shocks to the economy, but it is also a source of policy uncertainty. We shall develop new indices of each type of uncertainty. This unique combination is central to our being able to understand the complex, but vital, relationship.

The novelty of the data and the complexity of analysing communication make this research program highly ambitious. Nonetheless, the importance of developing our academic understanding make this agenda incredibly high-return.

Link to the ERC project webpage:

Keywords of the ERC project: Monetary Policy; Communication

Keywords that characterize the scientific profile of the potential visiting researcher/s: Economist or Data Scientist; interests in information and communication
Sharing Gains from Trade: Global Markets and Farmers Welfare in Developing Countries

The majority of the global poor live in rural areas and earn their livelihoods in agriculture. Linking farmers in developing countries (LDCs) to global markets, therefore, could potentially spur growth and reduce poverty. Market imperfections in agricultural chains in producing countries, however, limit these gains. Which policy tools, if any, help farmers in LDCs realize and share the gains from trade? I propose three broad projects that develop the tools to answer this question.

The first project designs and implements the first randomized control trial (RCT) to test for the causes and consequences of market failures interacting along multiple layers of agricultural value chains. This is a necessary step to design targeted policy responses.

The second project develops and estimates the first structural model of an agricultural value chain to evaluate different regulatory interventions. Historically, as well as today, governments have intervened in agricultural chains through a diverse array of policies and regulations. RCTs are not sufficient to evaluate these policies. The project develops flexible tools to perform counterfactual analysis and evaluate the merits of alternative policies and regulations in a variety of contexts.

The third project studies voluntary sustainability standards (VSSs) (e.g., Fair Trade, Rainforest Alliance). VSSs are increasingly popular responses to market failures in agricultural chains in LDCs. Unlike regulatory interventions, VSSs directly affect only market participants that take them up. The project combines quasi-experimental and structural techniques to evaluate the direct impact, the indirect spillover effects, and the broader distributional consequences of VSSs.

The three projects form a coherent research agenda that develops a comprehensive set of tools to evaluate existing agricultural policies and design better ones so that small producers in developing countries can realize and share the gains from globalization.

Link to the ERC project webpage:

Keywords of the ERC project:

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Labour Politics and the EU’s New Economic Governance Regime

Trade unions play a major role in democratic interest intermediation. This role is currently threatened by the increasingly authoritarian strain in EU’s new economic governance (NEG). This project aims to explore the challenges and possibilities that the NEG poses to labour politics. Until recently, European labour politics has mainly been shaped by horizontal market integration through the free movement of goods, capital, services and people. After the financial crisis, the latter has been complemented by vertical integration effected through the direct surveillance of member states. The resulting NEG opens contradictory possibilities for labour movements in Europe.

On the one hand, the reliance of the NEG on vertical surveillance makes decisions taken in its name more tangible, offering concrete targets for contentious transnational collective action. On the other hand however, the NEG mimics the governance structures of multinational firms, by using key performance indicators that put countries in competition with one another. This constitutes a deterrent to transnational collective action. The NEG’s interventionist and competitive strains also pose the threat of nationalist counter-movements, thus making European collective action ever more vital for the future of EU integration and democracy.

This project has the following objectives:
1. To understand the interrelation between NEG and existing ‘horizontal’ EU economic governance; and the shifts in labour politics triggered by NEG;
2. To open up novel analytical approaches that are able to capture both national and transnational social processes at work;
3. To analyse the responses of established trade unions and new social movements to NEG in selected subject areas and economic sectors at national and EU levels, and their feedback effects on NEG;
4. To develop a new scientific paradigm capable of accounting for the interplay between EU economic governance, labour politics and EU democracy.

Link to the ERC project webpage: https://www.erc-europeanunions.eu/

Keywords of the ERC project: labor relations, industrial relations, political science, sociology, European Union, governance, political economy, social policy, social movements, trade unions

Keywords that characterize the scientific profile of the potential visiting researcher/s: labor relations, industrial relations, political science, sociology, European Union, governance, political economy, social policy, social movements, trade unions
The Rules of Interpretation of Customary International Law

This ERC proposal revolves around the rules of interpretation of customary international law (CIL). CIL along with treaties are the rules most often used in international law. However, whereas rules of interpretation of treaties have been enshrined in Articles 31-33 of the Vienna Convention on the Law of Treaties (VCLT), the rules of interpretation of CIL have not been the subject of critical study. This gap becomes even more pronounced if we consider that interpretation plays a key role in every judicial case, and that one of the basic markers of effectiveness of any legal system is its predictability. By not knowing the rules that govern the interpretation of CIL, we end up playing a ‘game’ the rules of which are unknown, and by consequence predictability is far from guaranteed.

Therefore the aim of this project is to determine the existence and to examine the content of the rules of interpretation of customary international law. It will: 1) prove the theoretical validity of CIL being open to interpretation; 2) induce the rules of interpretation of CIL and their content; 3) track the points of convergence/divergence and reasons thereof amongst rules of interpretation of CIL, treaties and unilateral acts as they evolve through time; and 4) create a set of articles/guidelines on the interpretation of CIL.

The results will influence the study and theory of CIL; will lead to a re-conceptualization of the theory of sources of international law; will spark a long overdue debate on the interaction between sources of international law; will further our understanding of the process of interpretation and of the basic precepts of the international legal system; and its findings will become the staple point of reference by any ‘user’ of international law.

Its ultimate outcomes will clarify the foundations of the international legal system, reduce normative conflict, and provide greater legal certainty and foreseeability in all international law-related interactions.
Law, Governance and Space: Questioning the Foundations of the Republican Tradition

Administrative professionalization is the hallmark of a modern state, but its origins contain a dilemma. Why were there no offices in ancient Rome? How is it possible that it nevertheless formed the model for the Western administrative state? The purpose of this project is to challenge earlier research and to propose a new model of the Roman Republican governance that integrates domestic and private space and to reinterpret its links with the Republican tradition.

The significance of these issues extends much beyond this: the development of administrative space in the European context amounts to nothing less than the emergence of the concept of public. Ever since Weber, the conceptual separation of the office and its holder has defined the European way of governance. The origin of this separation of public and private has often been seen in the Roman Republican state with its strict responsibilities, term limits and defined powers of its magistracies, who operated in open public spaces.

Using unconventional methodological tools to challenge the conventional view, the project explores the social and cultural dimensions of legal and administrative space, transcending modern assumptions of public and private. Two main research questions explore the confrontation of ideas and their contexts from the Roman Republic to modern Republicanism:

1) How the conflict between Republican ideals, political power and administrative practices transformed the spaces of administration?
2) How did this conflict change the social topography of Rome, the public and private spheres of governance?

While much of the earlier research on Republican administration has been constitutional, focused on sovereignty or the individual magistrates, this project advances a radical new interpretation through spatial and topographical analysis. It is a comprehensive re-evaluation of the Roman administrative tradition and its links with the European heritage through the lens of administrative space.

Link to the ERC project webpage: spacelaw.fi

Keywords of the ERC project: republicanism, legal history, history, spatial theory, ancient history, Rome

Keywords that characterize the scientific profile of the potential visiting researcher/s:
A NUDGE IN THE RIGHTS DIRECTION? REDESIGNING THE ARCHITECTURE OF HUMAN RIGHTS REMEDIES

Recent years have seen a renewed interest in the effectiveness of human rights law and judgments, yet almost no attention has been given to the impact of remedies on states’ compliance practices or the internalisation of human rights into their domestic legal systems. Through a combination of quantitative and qualitative research in six countries, the project aims to expose the dynamics of the (non)compliant state and the efficacy of different types of remedies in changing the behaviour of human rights violators. These goals will be achieved through three sub-studies: (1) an empirical study of the case law of the European Court of Human Rights (ECtHR) to determine the compliance and internalisation practices and their link to different remedies; (2) the exploration and analysis of states’ internalisation practices and policies (including the identification of players that shape this practice) to determine whether remedies play a crucial role in shifting states’ actions; (3) a computer simulation to discover how we can change the architecture of human rights remedies to increase compliance and internalisation, and to deter future violations.

The central aim of the project is to identify new remedy options – incentives or nudges – which human rights institutions can use to deter future violations. Using the example of the ECtHR and its caselaw, the research will build on insights from behavioural economics to interrogate widespread assumptions about monetisation of human rights, public shaming, and deference shown to states in the specification of remedies. Through computer simulation, the project will aim to predict how monetary and non-monetary remedies could be used separately or together to alter the behaviour of states and their key players. The research will be ground-breaking in many ways, reshaping the field of human rights remedies and contributing crucially to the emerging field of behavioural international law.

Link to the ERC project webpage: www.humanrightsnudge.com
Keywords of the ERC project: human rights, nudge, behavioral economics, remedies, law
Keywords that characterize the scientific profile of the potential visiting researcher/s:
Concepts, theories and models for planning, operating and evaluating the dynamics of Mobility as a Service

Online marketplaces enable in the travel context the dynamic matching of supply and demand. The shared economy can revolutionize urban mobility by blurring the traditional division between private and public transport, shifting from an ownership model to Mobility as a Service (MaaS).

Existing transport models are designed with the premise that transport consists of either fully scheduled and controlled fleets or individual privately owned vehicles. Since MaaS breaks the conventional division between individual (ownership) and collective (usage) travel alternatives, existing theories and models of travel behaviour, transport network and operations cannot explain the behavioural dynamics, interactions and evolution of both supply-side and demand-side of the marketplace.

This research program develops and tests theories and models of transport network in the domain of two-sided mobility market.

CriticalMaaS will produce a set of new behavioural models of traveller and supplier choices in transport marketplace settings. The supply- and demand-side dynamics and their interactions will be mathematically formalized and developed in both network flow distribution and agent-based modelling frameworks designed for the analysis of their co-evolution. Models will be used to study emerging patterns, transition phases and critical mass concepts by testing the conditions required for generating economies of scale in market adoption and evolution of MaaS.

Models will be estimated and validated using a series of surveys, choice experiments, laboratory experiments, observed behavioural data from on-demand services, focus groups and interviews. The proposed research efforts will result with several theoretical and methodological breakthroughs in the field of transport modelling. In addition, the research program will make methodological and empirical contributions to the field of travel behaviour as well as insights into the dynamics of a two-sided (mobility) marketplace.
The Politics of Marine Biodiversity Data: Global and National Policies and Practices of Monitoring the Oceans

In order to protect marine biodiversity and ensure that benefits are equally shared, the UN General Assembly has decided to develop a new legally binding treaty under the United Nations Convention on the Law of the Sea. Marine biodiversity data will play a central role: Firstly, in supporting intergovernmental efforts to identify, protect and monitor marine biodiversity. Secondly, in informing governments interested in particular aspects of marine biodiversity, including its economic use and its contribution to biosecurity. In examining how this data are represented and used, this project will create a novel understanding of the materiality of science-policy interrelations and identify new forms of power in global environmental politics as well as develop the methodologies to do so. This is crucial, because the capacities to develop and use data infrastructures are unequally distributed among countries and global initiatives for data sharing are significantly challenged by conflicting perceptions of who benefits from marine biodiversity research. Despite broad recognition of these challenges within natural science communities the political aspects of marine biodiversity data remain understudied. Academic debates tend to neglect the role of international politics in legitimising and authorising scientific concepts, data sources and criteria and how this influences national monitoring priorities. The central objective of MARIPOLDATA is to overcome these shortcomings by developing and applying a new multiscale methodology for grounding the analysis of science-policy interrelations in empirical research. An interdisciplinary team, led by the PI, will collect and analyse data across different policy-levels and spatial scales by combining 1) ethnographic studies at intergovernmental negotiation sites with 2) a comparative analysis of national biodiversity monitoring policies and practices and 3) bibliometric and social network analyses and oral history interviews for mapping marine biodiversity science.

Link to the ERC project webpage: https://www.maripoldata.eu/

Keywords of the ERC project: Marine Biodiversity Politics; ocean governance; global environmental politics; Practices, discourses and institutions in international biodiversity politics; Institutions interfacing science and policy & global environmental assessments; Knowledge and power

Keywords that characterize the scientific profile of the potential visiting researcher/s:
### Digital Campaigning and Electoral Democracy

Overview: This project will set a new agenda and direction for the study of political campaigns. It will examine whether and how new digital technologies are transforming election campaigns and citizen behaviour in new and established democracies. More specifically, it will assess claims that democracies are now entering a new data-driven era of political campaigning that is profoundly reconfiguring how campaigns’ are run, who runs them and their implications for the quality of voter decision-making, the vibrancy of political parties and ultimately, the future of representative democracy. It will do so in three main stages: (1) First, it will define what data-driven campaigning is and critically assess whether it forms new and distinct era of electioneering in conceptual and historical terms? In particular, it will argue that the two key traits of this new mode of camping are the increased individualization or micro-targeting of party messages and the automated use of misinformation to mobilize and persuade voters. (2) Based on this definition it will map the ‘supply’ of the new mode of campaigning across new and older democracies by designing an innovative new index to compare use of data-driven techniques by parties. Where is it most commonly seen and why are some parties and countries more likely to promote its growth? (3) Finally, it will assess the impact of these new methods on key political actors and assess the consequences for the longer term future of liberal democracy. Does use of these techniques help counter recent declines in voter turnout by identifying under-mobilized groups? Or, do they ensure parties focus on the already engaged, bypassing those that are harder to reach? Can data-driven campaigning improve citizen choices by giving them the information on the issues they primarily care about or does it help to increase disinformation and even manipulation of voter choices?

**Link to the ERC project webpage:**

**Keywords of the ERC project:** Digital, Campaigns, Elections, New Methods, Data-Driven Democracy, Political Parties

**Keywords that characterize the scientific profile of the potential visiting researcher/s:** Methodologist, Social Media Analysis, Survey Experiments, Political Behaviour, Campaigning, Political Parties
Monitoring Biodiversity from Space

Life, with all its diversity, is in crisis. As humans increasingly encroach on biologically complex semi-natural landscapes, no organism, place or ecological function remains unaffected. While all 196 parties (195 countries plus the European Union) to the UN Convention on Biodiversity (CBD) have agreed to monitor the state of biodiversity, the currently available methods to do so leave much to be desired. Traditional monitoring involves the field observation of species by trained specialists, aided by skilled volunteers, whose expertise is restricted to specific biotic groupings. In a process that is both time consuming and inconsistent across time and space, botanists identify and record the presence of plant species and ornithologists the bird biota, resulting in 'unpopular' biotic groups such as fungi, bacteria and insects being under-observed or escaping identification altogether. In this project, a fundamentally different approach to terrestrial biodiversity monitoring couples next generation satellite remote sensing with environmental DNA (eDNA) profiling, complemented where available by legacy human-observed datasets. Satellite remote sensing is able to survey the environment as a single, continuous, fine-resolution map, while eDNA profiling can rapidly quantify much greater taxonomical and functional breadth and depth than human field observation. This project combines, for the first time, these two powerful, cutting-edge techniques for monitoring biodiversity at the global level in a consistent manner. Following from this, another key innovation will be the deepening of our scientific understanding of how biodiversity is impacted by anthropogenic pressure as well as by natural environmental gradients. In concert, these scientific developments will enable the accurate and fine grain monitoring of biodiversity from space—a ground-breaking contribution to the quest to meet the UN Sustainable Development Goals and CBD Aichi targets.

-421-
<table>
<thead>
<tr>
<th>Principal Investigator:</th>
<th>Dr NICOLE STREMLAU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Host Institution:</td>
<td>THE CHANCELLOR, MASTERS AND SCHOLARS OF THE UNIVERSITY OF OXFORD - UK</td>
</tr>
</tbody>
</table>

The Politics and Practice of Social Media in Conflict

Over the next five years an unprecedented number of initiatives will coalesce, contributing to an extension of the reach of the Internet to the world’s most remote regions. While previous efforts to expand Internet access have focused on urban areas, current initiatives are leveraging new technologies from drones to satellites to provide affordable access to the world’s poorest, many of whom are in Africa and live in regions where the state is weak and there is protracted violent conflict. Current debates have largely focused on technical issues of improving access, or assumed ways that technology will help ‘liberate’ populations or improve governance. This project focuses on a key puzzle that is often overlooked: How does increased access to social media affect the balance between peace-building efforts and attempts perpetuate violence in conflict-affected communities?

With a focus on Africa (and particularly on religious and political violence in Eastern Africa), this project will investigate the relationship between social media and conflict through three research questions at the macro, meso and micro level: how are social media altering the transnational dimensions of conflict and peacebuilding? How are public authorities reacting to, and appropriating, social media to either encourage violence or promote peace? And in what ways are social media changing the way people experience, participate in, or respond to violent conflict? It will examine these questions in the context of dangerous speech online; the exit and entry of individuals away from, and into, conflict; the tactics and strategies actors adopt to shape the Internet; and how governance actors are leveraging social media in conflict-affected communities.

Link to the ERC project webpage:

Keywords of the ERC project:

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Hidden Emissions of Forest Transitions: GHG effects of socio-metabolic processes reducing pressures on forests

A forest transition, i.e. forest expansion after a long period of deforestation, has occurred in many, mostly industrialized countries. Forest transitions have recently resulted in declining rates of global net deforestation and contributed to carbon (C) sinks in terrestrial ecosystems. Studies have shown the concurrence of forest transitions and industrialization processes, but the systemic links between forest transitions, their underlying socio-metabolic processes and associated greenhouse gas (GHG) emissions have been neither systematically explored nor quantified.

HEFT introduces the idea of “hidden emissions of forest transitions”, i.e. the GHG emissions from socio-metabolic processes reducing pressures on forests. Hidden emissions may stem from processes such as substitution of fuelwood by modern energy sources, intensification of agriculture, and externalization of biomass production to remote regions. Building on the concept of socio-ecological metabolism, HEFT develops a consistent methodological framework to quantify the full GHG emissions and sinks from socio-metabolic and ecological processes in the course of forest transitions, within which their hidden emissions are identified.

Forest transitions in multiple contexts are analyzed at local, national and supranational scales: in Europe since c. 1850, North America since c. 1880, and South East Asia since 1980. A coarse global-scale assessment complements the regional case studies.

We will integrate sources and analytical methods from environmental and social sciences as well as the humanities to analyze context-specific trajectories and general features of socio-ecological GHG budgets and their respective socio-political contexts since the onset of forest transitions. The sound understanding of hidden emissions will be used to identify the least GHG-intensive trajectories and to draw lessons for future climate-friendly forest transitions.

Link to the ERC project webpage: heft.boku.ac.at

Keywords of the ERC project:

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Inclusive Public Space: Law, Universality and Difference in the Accessibility of Streets

This project considers the accessibility of public space – focusing on pedestrian access to streets. It explores law’s engagement with the exclusion which occurs when streets are designed, operated or managed so as to deny access to pedestrians whose bodies, minds or life circumstances do not ‘fit’. Such exclusion is damaging both to individuals and communities.

With a view to understanding how states and the EU can more effectively ensure that public space is inclusive, the project aims to deepen understanding of what physical features of streets are experienced as exclusionary in 5 countries and by whom; how effectively law is used to challenge such exclusion in these countries; and how the problem is perceived and politically challenged. It also aims to foster shared concern about this form of exclusion, in the 5 countries and beyond, and to raise awareness of how law can be used to challenge it.

The methodology will be comparative, transdisciplinary and participatory in nature. It will develop innovative videovoice techniques for data gathering. It will also develop groundbreaking awareness-raising tools – such as software to simulate experiences of pedestrian exclusion – as well as digital story telling and legal orientation guides. Theoretical context and framing will be provided by an innovative blending of Martha Fineman’s universal vulnerability thesis with the social model of disability.

The project will be the first to bring a multinational sociolegal perspective to bear on this significant social justice problem. It is timely - given concerns about the move in EU countries (often supported by EU funding) toward streets in which space is shared by vehicles and pedestrians; and the ratification (including by the EU) of the UN Convention on the Rights of Persons with Disabilities, which is the first such treaty to include provisions on the accessibility of public space.

Link to the ERC project webpage:

Keywords of the ERC project: Accessibility; Equality; Streets; Pedestrians; Law; Social policy; Disability; Older people; Technology; Solidarity.

Keywords that characterize the scientific profile of the potential visiting researcher/s: Social policy; Inclusive design; Legal theory; Human-computer interaction; Cities
The Foundations of Institutional Authority: a multi-dimensional model of the separation of powers

‘Almost three centuries later, it is past time to rethink Montesquieu’s holy trinity’ (Ackerman, 2010).
As Ackerman (and many others) have observed, political reality has long left the traditional model of the separation of powers behind. The problems posed by this gap between constitutional theory and political practice have recently acquired fresh urgency as developments in Hungary, Poland, Turkey, Russia, the UK, US, Bolivia and elsewhere place the separation of powers under strain. These include the emergence of authoritarian leaders; personalisation of political authority; recourse to non-legal plebiscites; and the capture or de-legitimisation of other constitutional bodies.
This project argues that these difficulties are rooted in a deeper problem with constitutional thinking about institutional power: a constitution-as-law approach that equates the conferral of legal power with the authority to exercise it. This makes it possible for a gap to emerge between legal accounts of authority and its diverse – and potentially conflicting (Cotterrell) – sociological foundations. Where that gap exists, the practical authority of an institution (or constitution) may be vulnerable to challenge from rival and more socially-resonant claims (Scheppele (2017)).
It is this gap between legal norms and social facts that the project aims to investigate – and ultimately bridge.
How is authority established? How is it maintained? How might it fail? And how does the constitution (as rule? representation (Saward)? mission statement (King)?) shape, re-shape and come to be shaped by those processes? By investigating these questions across six case studies, the project will produce a multi-dimensional account of institutional authority that takes seriously the sociological influence of both law and culture.
The results from these cases provide the evidential foundation for the project’s final outputs: a new model and new evaluative measures of the separation of powers.

Link to the ERC project webpage:

Keywords of the ERC project: Constitutionalism, government, populism, separation of powers, democracy, social movements

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Sustainability, efficiency, equity and resilience of land and water use for global food and energy security: synergies and fundamental trade-offs

Humanity faces major challenges: stay below local and global ecological thresholds; increase natural resources use efficiency; share resources fairly; and increase societal resilience. Most research focusses on one or two of these challenges at a time; there is a major scientific gap in understanding synergies and inevitable trade-offs between the development principles of environmental sustainability, equitability, efficiency and resilience. This project aims to analyse synergies and trade-offs between environmental sustainability, resource efficiency, social equity and social-ecological resilience in the context of land and water use for food and energy supply. We consider production, consumption and trade patterns globally, at high spatial resolution, analyse past developments, and develop alternative future pathways, based on coherent sets of assumptions regarding demographic and economic developments, technological innovation, changes in local diets and energy mixes, and climate change. The project team will pioneer in integrating methods and computational tools from the fields of Environmental Footprint Assessment, Life Cycle Assessment and Input-Output Analysis, applied at unrivalled high level of granularity. Coherent perspectives on handling uncertainty and risk from cultural theory will be used in a unique approach to develop alternative futures. Finally, an original framework will be developed to analyse synergies and traded-offs between competing development principles. The project will revolutionize our understanding of different pathways to food and energy security given limited land and water resources, and particularly how each pathway will make trade-offs between environmental sustainability, fair sharing, efficient resources use and resiliency. This knowledge is key in understanding how to achieve UN’s Sustainable Development Goals with limited land and water resources and reveal synergies and trade-offs embedded in specific strategies.

Link to the ERC project webpage: www.earthalternatives.net

Keywords of the ERC project: land water food energy sustainability resource-efficiency equity resilience

Keywords that characterize the scientific profile of the potential visiting researcher/s: integrated modelling and assessment
Global Governance through Goals? Assessing and Explaining the Steering Effects of the United Nations Sustainable Development Goals

Achieving sustainable development worldwide remains probably the biggest political challenge of our time. In 2015, the international community adopted 17 'Sustainable Development Goals' with no less than 169 'targets' as part of a global '2030 Agenda for Sustainable Development'. The ambition expressed in these goals is unprecedented. But can such goal-setting, as a new central approach in global governance, help resolve the pressing challenges of economic development, poverty eradication, social justice and global environmental protection? Nobody knows at this stage. While the United Nations and its member states place high hopes on this novel strategy, there is little scientific knowledge on whether such global goals can live up to exceedingly high expectations. Sustainability research has tended to focus on concrete institutions, actors and practices – not on aspirational goals that bring little in terms of normative specificity, stable regime formation or compliance mechanisms. How can 'global governance through goals' nonetheless be effective – and under which conditions? GLOBALGOALS will address this puzzle and break new ground in sustainability and global governance theories. It offers the first and most comprehensive data compilation, network mapping and comparative institutional analysis of the evolution, effectiveness and future prospects of 'global governance through goals' as a central novel steering mechanism in world politics. This 5–year study programme deploys a unique set of cutting-edge methodologies, including social network analysis and online surveys, to assess and explain the steering effects of nine Sustainable Development Goals through a detailed investigation of their institutional arrangements and actor networks, at international and national levels. GLOBALGOALS makes a crucial knowledge contribution to both the theory of global sustainability governance and the successful implementation of the 2030 Agenda for Sustainable Development.

Link to the ERC project webpage: www.globalgoalsproject.eu

Keywords of the ERC project:

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Management of marine fisheries is still far from incorporating adaptation to climate change, even though global stocks are heavily overexploited and climate change is adding additional pressure to the resource. In fact, there is growing evidence that current fisheries management systems may no longer be effective under climate change, and this will translate into both ecological and socioeconomic impacts. This research project argues that the combination of fisheries management science and socio-ecological systems thinking is necessary in order to advance in fisheries adaptation to climate change. To this end, the main objectives are set to: 1) Identify and understand the new challenges raised by climate change for current sustainable fisheries management; 2) Develop a novel approach to fisheries adaptation within a socio-ecological framework; 3) Provide empirical evidence on potential solutions for the adaptation of fisheries management systems; and 4) Help introduce fisheries adaptation at the top of the regional and international adaptation policy agendas. To do this, I will combine model and simulation approaches to fisheries with specific case studies where both biophysical and economic variables will be studied and modelled, but also individuals will be given the opportunity to participate in an active way, learning from participatory methods their preferences towards adaptation and the consequences of the new scenarios climate change poses. Three potential case studies are identified for property rights over stocks, property rights over space, and Marine Reserves in two European and one international case study areas. As a result, I expect to develop a new Adaptation Framework for fisheries management that can be scalable, transferable and easily operationalized, and a set of case study examples on how to integrate theory and participatory processes with the aim of increasing social, ecological and institutional resilience to climate change.

Link to the ERC project webpage: https://futureoceanslab.org/clock/

Keywords of the ERC project: adaptation, social-ecological systems, shifting stocks, fisheries livelihoods

Keywords that characterize the scientific profile of the potential visiting researcher/s: social scientist, fisheries scientist, resource economics, marine ecology
Discontinuities in Household and Family Formation

Household, family and fertility changes are key drivers of population dynamics. Discovering and explaining the velocity of these changes is essential to understand the current situation and to provide scientific evidence on our demographic future. DisCont will provide seminal contributions by studying the impact of macro-level discontinuities on household and family formation (including fertility) in post-industrial contemporary societies. In the past decade, two macro-level discontinuities have radically transformed lives: the Great Recession and the digitalization of life and of the life course. Although their short-term and long-term impacts are likely to be fundamental, they have not yet been systematically analysed. Through a coordinated series of theoretically-founded empirical studies based on linked macro- and micro-level data, and using a comparative perspective, DisCont will argue that macro-level discontinuities are crucial in explaining broad changes in household and family formation, and that their effects can be persistent either for the population as a whole, or for specific cohorts. DisCont will contribute to five areas: 1) it will make theoretical advances by showing the importance of macro-level discontinuities in the explanation of changes in household and family formation in particular, and in population dynamics in general; 2) it will substantially advance our knowledge of household and family formation in post-industrial contemporary societies; 3) it will contribute in a systematic and path-breaking way to research on the broader societal impact of digitalization and of the Great Recession; 4) it will bring a paradigm shift in Age-Period-Cohort modelling; 5) it will make ground-breaking contributions on the demographic use of “big data” and on the use of agent-based models for the population-level implications of household and family change.

Link to the ERC project webpage: http://www.dondena.unibocconi.it/wps/wcm/connect/Cdr/Centro_Dondena/Home/Research/DisCont/

Keywords of the ERC project:

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Discretion and the child’s best interests in child protection

DISCRETION aims to unlock the black box of discretionary decision-making in child protection cases by a comparative-empirical study of how discretionary decisions are made and justified in the best interests of the child. There are huge research gaps in this important area of the welfare state, with a great deal of uncertainty concerning how, when and why discretionary decisions about the child’s best interests are different between decision-makers within and between child protection systems.

The main objectives for this project are to reveal the mechanisms for exercising discretion, and improve the understanding of the principle of the child’s best interests. These objectives will be reached by systematically examining the role of institutional, organisational and individual factors including regulations of best interest principles; professions involved; type of courts; type of child protection system; demographic factors and individual values; and the populations’ view on children and paternalism. DISCRETION employs an innovative methodological approach, with multilevel and cross-country studies.

DISCRETION will, by conducting the largest cross-national study on decision-making in child protection to date, lift our understanding of international differences in child protection to a new level. By conducting randomized survey experiments with both decision-makers in the system and the general population, DISCRETION generates unique data on the causal mechanisms explaining differences in discretionary decisions.

The outcomes of DISCRETION are important because societies are at a crossroad when it comes to how children are treated and how their rights are respected, which creates tensions in the traditional relationship between the family and the state. DISCRETION will move beyond the field of child protection and provide important insights into the exercise of discretion in all areas where the public interest as well as national interest must be interpreted.

Link to the ERC project webpage: https://www.discretion.uib.no/projects/discretion-and-the-childs-best-interest-in-child-protection/

Keywords of the ERC project: Child Protection, Child Welfare, Discretion, Decision-making, Paternalism

Keywords that characterize the scientific profile of the potential visiting researcher/s: Social science, Law, Psychology, Philosophy
Context, Identity and Choice: Understanding the constraints on women's career decisions

There has been vast improvement in workplace gender equality, but there remain marked differences in the roles in which women and men work. Explanations for this inequality have focused on the barriers women face. However, as women begin to enter male-dominated roles, a new explanation has arisen: that remaining gender inequality must reflect fundamental differences between women and men, including differences in (a) ambition and desire for power, (b) needs for work-life balance, and (c) willingness to take career risks. Central to this analysis is the assumption that the glass ceiling is broken and thus inequality must be due to women’s active choices. This explanation downplays the fact that social context continues to be a barrier to women’s success and places responsibility for gender inequality on women themselves. Indeed, there has arisen the suggestion that gender equality necessitates women overcoming ‘internal obstacles’, ‘leaning-in’ and altering their choices (Sandberg, 2013), rather than challenging the status quo. I argue that diametrically contrasting structural barriers with women’s choices is unhelpful. Instead, I suggest that women’s choices are shaped and constrained by the gendered nature of organisational and social contexts and how women see themselves within these contexts. I propose a programme of research, across 3 integrated streams, that investigates how social and organisational structures define identities and constrain women’s choices in relation to ambition, work-life balance, and career risk-taking. I have four key objectives: (1) to clarify how organisational and social contexts define identity and constrain women’s choices, (2) to use an interdisciplinary, multi-methodological approach, to produce innovative theory and data, (3) to work collaboratively with stakeholders, and (4) to inform practical interventions designed to facilitate the increase of women’s participation in hitherto male-dominated roles.

Link to the ERC project webpage: http://psychology.exeter.ac.uk/cic/

Keywords of the ERC project: gender equality

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Intergroup toleration: It’s Nature, Processes, and Consequences for Culturally Diverse Societies

Increasingly our societies are becoming more diverse and how to live with this diversity is one of the most pressing questions of our time. In Europe, intergroup tolerance has been proposed as a key aspect of living harmoniously and productively with diversity; it is critical because objection and disagreement about what is good and right are inevitable. A diverse, egalitarian, and peaceful society does not require that we all like each other, but it does require that people at least tolerate one another. Yet, there has been very little by way of social psychological theorizing and systematic empirical research on intergroup toleration.

This research will advance the state of the art in the social sciences by moving beyond intergroup stereotypes, prejudices and discrimination, and focusing on the social psychology of intergroup toleration in which differences are endured. This new line of research will unravel the interrelated aspects of toleration. We will elucidate: (1) the underlying psychological aspects of tolerance (the objection component), 2) the psychological processes underlying tolerance (the acceptance component), 3) the limits of tolerance (the rejection component), and 4) the social psychological consequences of being tolerated. This program has a coherent theoretical framework and empirically toleration will be examined by using a combination of survey data, framing experiments, and lab experiments involving EEG. The research will provide key insights into the social psychological dynamics of intergroup toleration. This can form the basis for developing and implementing initiatives and approaches that contribute to a more tolerant society. Given the contested nature of cultural diversity and the absence of systematic social psychological investigations, the proposed research is both ground-breaking and timely.

Link to the ERC project webpage: https://intergrouptolerance.eu

Keywords of the ERC project: diversity, intergroup relations, prejudice reduction, tolerance, toleration

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Ghosts from the past: Consequences of Adolescent Peer Experiences across social contexts and generations

Positive peer experiences are crucial for young people’s health and wellbeing. Accordingly, multiple studies (including my own) have described long-term negative psychological and behavioral consequences when adolescents’ peer relationships are dysfunctional. Paradoxically, knowledge on adult social consequences of adolescent peer experiences –relationships with others a decade later- is much less extensive. Informed by social learning and attachment theory, I tackle this gap and investigate whether and how peer experiences are transmitted to other social contexts, and intergenerationally, i.e., passed on to the next generation. My aim is to shed light on how the “ghosts from peer past” affect young adults’ relationships and their children. To this end, I examine longitudinal links between adolescent peer and young adult close relationships and test whether parents’ peer experiences affect offspring’s peer experiences. Psychological functioning, parenting, temperament, genetic, and epigenetic transmission mechanisms are examined separately and in interplay, which 1) goes far beyond the current state-of-the-art in social development research, and 2) significantly broadens my biosocially oriented work on genetic effects in the peer context. My plans utilize data from the TRAILS (Tracking Adolescents’ Individual Lives’ Survey) cohort that has been followed from age 11 to 26. To study intergenerational transmission, the TRAILS NEXT sample of participants with children is substantially extended. This project uniquely studies adult social consequences of peer experiences and, at the same time, follows children’s first steps into the peer world. The intergenerational approach and provision for environmental, genetic, and epigenetic mediation put this project at the forefront of developmental research and equip it with the potential to generate the knowledge needed to chase away the ghosts from the peer past.
The Disrupted Society: mapping the societal effects of blockchain technology diffusion

Recent advances in cryptography yielded the blockchain technology, which enables a radically new and decentralized method to maintain authoritative records, without the need of trusted intermediaries. Bitcoin, a cryptocurrency blockchain application has already demonstrated that it is possible to operate a purely cryptography-based, global, distributed, decentralized, anonymous financial network, independent from central and commercial banks, regulators and the state. The same technology is now being applied to other social domains (e.g. public registries of ownership and deeds, voting systems, the internet domain name registry). But research on the societal impact of blockchain innovation is scant, and we cannot properly assess its risks and promises. In addition, crucial knowledge is missing on how blockchain technologies can and should be regulated by law.

The BlockchainSociety project focuses on three research questions. (1) What internal factors contribute to the success of a blockchain application? (2) How does society adopt blockchain? (3) How to regulate blockchain? It breaks new ground as it (1) maps the most important blockchain projects, their governance, and assesses their disruptive potential; (2) documents and analyses the social diffusion of the technology, and builds scenarios about the potential impact of blockchain diffusion; and (3) it creates an inventory of emerging policy responses, compares and assesses policy tools in terms of efficiency and impact. The project will (1) build the conceptual and methodological bridges between information law, the study of the self-governance of technological systems via Science and Technology Studies, and the study of collective control efforts of complex socio-technological assemblages via Internet Governance studies; (2) address the most pressing blockchain-specific regulatory challenges via the analysis of emerging policies, and the development of new proposals.

**Link to the ERC project webpage:** https://blockchain-society.science/

**Keywords of the ERC project:** decentralization, trust, regulation, identity, copyright, data protection

**Keywords that characterize the scientific profile of the potential visiting researcher/s:** social sciences, law, economics, computer science, humanities, art
MISFIRES opens up new theoretical and empirical horizons for analysing and innovating ‘concerned markets’, where multiple actors’ interests, values and concerns clash. It asks how actors can engage with a market’s failures to challenge its organisation and make it more collaborative, more open to civic values and to social or political concerns. Concerned markets are contested by diverse actors with equally diverse perspectives and value measures. Evaluating such a market’s efficiency is as much of an illusion as redesigning its inner workings on a blackboard. We need new conceptual frameworks to understand how to innovate concerned markets from the inside to make them ‘better’ (as defined by concerned actors), and we urgently need empirical insights into how collaborative action in markets with such social and political stakes may translate into market change. MISFIRES relies on science and technology studies, pragmatic sociology and critical market studies to shift thinking around market organisation from failure and design to collaboration and experimentation. I devise an ethnographic and participatory inquiry to explore how a market’s failures can lead us to markets that are more attentive to and accommodating of the concerns they create. I choose three exemplary contested markets in healthcare (licensing of antiretroviral drugs, Hepatitis C pricing, and the sale of DNA information) and two emergent controversies to investigate the activities concerned actors undertake, and the instruments and devices they experiment with, to re-organise that market. MISFIRES will comprehensively map, engage in, and conceptualise this collaborative turn in organising markets. With this, MISFIRES will guide new academic and policy thinking by establishing how:
1) concerned actors voice and mobilise around the notion that a market has ‘failed’ them;
2) concerned actors seek to negotiate and address market failures;
3) this process may lead to ‘better’ markets.

Link to the ERC project webpage: https://misfires.ucd.ie/

Keywords of the ERC project: markets, economic sociology, healthcare, STS, patents

Keywords that characterize the scientific profile of the potential visiting researcher/s: STS, healthcare, sociology of markets, economic sociology, patents
SOCSEMICS aims at developing a set of integrated, groundbreaking methods to address the possible existence of so-called “filter bubbles” in the digital public space. In all generality, this phenomenon may be construed as communities whose actors are more or less prone to interaction and open to informations coming from “outside” of these communities. SOCSEMICS will contribute to the formalization and operationalization of this question by addressing three current challenges: (i) developing a comprehensive theory of reinforcing and self-sustaining socio-semantic communities by appraising the social, semantic and socio-semantic realms simultaneously, (ii) drastically improving content analysis by replacing classical distributional approaches with clause analysis, and thereby enabling quantitative analyses which render the linguistic complexity of utterances in web corpuses, (iii) fostering the interface between these methods and qualitative approaches, especially through a couple of broad case studies, together with the development of interactive platforms implementing the above innovations and facilitating digital social research.

Link to the ERC project webpage: http://socsemics.huma-num.fr

Keywords of the ERC project: socio-semantic networks, internet communities, bubbles, online public space, fragmentation, claim analysis, qual-quant approaches

Keywords that characterize the scientific profile of the potential visiting researcher/s: social network analysis, natural language processing, information visualization, online sociology
Dynamic Attitude Fixing: A novel theory of opinion dynamics in social networks and its implications for computational propaganda in hybrid social networks (containing humans and bots)

Understanding the coordination of attitudes in societies is vitally important for many disciplines and global social challenges. Network opinion dynamics are poorly understood, especially in hybrid networks where automated (bot) agents seek to influence economic or political processes (e.g. USA: Trump vs Clinton; UK: Brexit). A dynamic fixing theory of attitudes is proposed, premised on three features of attitudes demonstrated in ethnomethodology and social psychology; that people: 1) simultaneously hold a repertoire of multiple (sometimes ambivalent) attitudes, 2) express attitudes to enact social identity; and 3) are accountable for attitude expression in interaction. It is proposed that interactions between agents generate symbolic links between attitudes with the emergent social-symbolic structure generating perceived ingroup similarity and outgroup difference in a multilayer network. Thus attitudes can become dynamically fixed when constellations of attitudes are locked-in to identities via multilayer networks of attitude agreement and disagreement; a process intensified by conflict, threat or zero-sum partisan processes (e.g. elections/referenda). Agent-based simulations will validate the theory and explore the hypothesized channels of bot influence. Network experiments with human and hybrid networks will test theoretically derived hypotheses. Observational network studies will assess model fit using historical Twitter data. Results will provide a social-psychological-network theory for attitude dynamics and vulnerability to computational propaganda in hybrid networks.

The theory will explain:
(a) when and how consensus can propagate rapidly through networks (since identity processes fix attitudes already contained within repertoires);
(b) limits of identity-related attitude propagation (since attitudes outside of repertoires will not be easily adopted); and
(c) how attitudes can often ‘roll back’ after events (since contextual changes ‘unfix’ attitudes).

Link to the ERC project webpage: https://www.ul.ie/dafinet/

Keywords of the ERC project: networks; attitudes; opinion dynamics; agent based modelling; computational social science; social psychology

Keywords that characterize the scientific profile of the potential visiting researcher/s: mathematical modelling; network modelling; computational social science; social psychology; social identity; network models of attitudes
**The effects of unemployment on health of family members**

Previous research has investigated the relationship between unemployment and health from a perspective of an isolated individual. HEALFAM takes a novel approach and examines how transition to unemployment triggers diffusion of ill mental and physical health within families. It investigates how becoming unemployed affects health outcomes of partners, children and elderly parents of the unemployed and whether the magnitudes of these influences differ across families and societies. Thus, instead of viewing the unemployed as functioning in isolation, HEALFAM assesses the consequences of unemployment for family members taking a multi-actor perspective and international comparative approach.

Guided by the life course theoretical framework, which views health and well-being as a process rather than a state and calls for considering interrelatedness of individuals, HEALFAM employs longitudinal data that provide information about multiple members of families. In order to analyse these datasets, HEALFAM uses longitudinal dyadic data analysis techniques as well as multilevel models for longitudinal data.

HEALFAM aims to open a new frontline of research on health and wellbeing from a life course perspective. It benefits from my knowledge on three interrelated social phenomena: (1) the role of labour market career and experiences of unemployment (2) family structure and intra-family resources (3) social antecedents of health and wellbeing among family members. It draws on high quality register and panel survey data as well as the expertise at the interdisciplinary research centres that I am connected to at Umeå University. Through international collaborations, it brings together experts in multiple disciplines carrying out research taking a life course perspective.

---

**Link to the ERC project webpage:**

**Keywords of the ERC project:**

**Keywords that characterize the scientific profile of the potential visiting researcher/s:**
Whales of Power: Aquatic Mammals, Devotional Practices, and Environmental Change in Maritime East Asia

In various parts of East Asia, aquatic mammals are associated with divine power, and serve as objects of devotion. In south and central Vietnam, cetaceans are worshipped as life-saving deities. In some Japanese coastal areas, the spirits of whales are venerated during ritual ceremonies. In China, Cambodia and the Ryukyu Islands, aquatic mammals have all been associated with water deities. These animals continue to carry significant symbolic capital today – if no longer as gods, at least as local “heritage” and symbols of nature conservation, acquiring new meanings in the context of secularisation, (forced) displacement, and environmental degradation.

Whales of Power is concerned with the comparative study of human-cetacean relations in maritime East Asia, as expressed in popular worship practices and beliefs. We will examine several of these traditions in different parts of the region, through a combination of historical and ethnographic research. Our main hypothesis is that changes in local worship traditions reflect changes in human-nature relations, which are caused by wider social, economic and environmental developments. Thus, marine mammals and associated worship practices serve as a prism, through which we approach human responses to socio-economic and environmental change in Asian coastal communities.

The innovative character of Whales of Power lies in the ways in which it combines state-of-the-art theoretical approaches from different disciplinary backgrounds in order to reach new understandings of the ways in which human-nature-god relations reflect social and environmental changes. It has three important theoretical objectives: 1) apply recent theoretical developments associated with “environmental humanities” to the comparative study of popular religion; 2) reconsider the role of local worship traditions in the Asian Secular Age, examining the new meanings attributed to ritual practices; and 3) establish a new comparative paradigm in Asian studies.

Link to the ERC project webpage: https://www.hf.uio.no/ikos/english/research/projects/whales-of-power/

Keywords of the ERC project: Japan, Vietnam, East Asia, popular religion, maritime culture, human-animal relations, marine mammals, environmental humanities, intangible heritage

Keywords that characterize the scientific profile of the potential visiting researcher/s: History of religions, Japan, Vietnam, East Asia, classical Chinese, maritime gods
Cognitive Aging: From Educational Opportunities to Individual Risk Profiles

Cognitive impairment and dementia have dramatic individual and social consequences, and create high economic costs for societies. In order to delay cognitive aging of future generations as long as possible, we need evidence about which contextual factors are most supportive for individuals to reach highest cognitive levels relative to their potential. At the same time, for current older generations, we need scalable methods to exactly identify individuals at risk of cognitive impairment. The project intends to apply recent methodological and statistical advancements to reach two objectives. Firstly, contextual influences on cognitive aging will be comparatively assessed, with a focus on inequalities related to educational opportunities and gender inequalities. This will be done using longitudinal, population-representative, harmonized cross-national aging surveys, merged with contextual information. Secondly, the project will quantify the ability of singular and clustered individual characteristics, such as indicators of cognitive reserve and behaviour change, to predict cognitive aging and diagnosis of dementia. Project methodology will rely partly on parametric ‘traditional’ multilevel- or fixed-effects modelling, partly on non-parametric statistical learning approaches, to address objectives both hypothesis- and data-driven. Applying statistical learning techniques in the field of cognitive reserve will open new research avenues for efficient handling of large amounts of data, among which most prominently the accurate prediction of health and disease outcomes. Quantifying the role of contextual inequalities related to education and gender will guide policymaking in and beyond the project. Assessing risk profiles of individuals in relation to cognitive aging will support efficient and scalable risk screening of individuals. Identifying the value of behaviour change to delay cognitive impairment will guide treatment plans for individuals affected by dementia.

Link to the ERC project webpage: https://anjaleist.wordpress.com/2018/07/27/new-erc-project-on-cognitive-aging/

Keywords of the ERC project: dementia; inequalities; life course; risk reduction; prevention; cross-national; gender

Keywords that characterize the scientific profile of the potential visiting researcher/s: inequalities in education; stratification / machine learning; causal inference; target trial
The Cultural Logic of Honor and Social Interaction: A Cross-Cultural Comparison

Understanding (un)willingness to coordinate with others, to compromise when faced with different choices, or to apologize for transgressions is crucial as these behaviors can act as strong facilitators or inhibitors of important interpersonal processes such as negotiations and coalition building. These behaviors play a major role when individuals from different cultural backgrounds work together to solve disputes or address joint challenges. Yet, we know little about what these behaviors mean in different cultural groups or how they are approached. With HONORLOGIC, I aim to initiate a step-change in our understanding of cultural variation in these important domains of social behavior by providing unique, multimethod, comparative and converging evidence from a wide range of cultural groups. I will answer the question “How do cultural groups that promote honor as a core cultural value approach coordinating with others, reaching compromise, and offering apologies?” by integrating insights from social/cultural psychology, behavioral economics, and anthropology. I will do this by collecting quantitative data using economic games, experiments, and surveys from Spain, Italy, Greece, Turkey, Cyprus, Lebanon, Egypt and Tunisia, as cultural groups where honor has been shown to play a defining role in individuals’ social worlds. I will also run the proposed studies in the US, the UK, Japan and Korea to provide a broader comparative perspective.

HONORLOGIC will produce transformative evidence for theories of social interaction and decision making in psychology, economics, and evolutionary science by (a) producing innovative theory and data with an interdisciplinary and multi-method approach, (b) increasing the diversity of the existing evidence pool, (c) testing established theoretical assumptions in new cultural groups, and (d) contributing to capacity building in under-researched cultural groups in psychological research.

Link to the ERC project webpage:

Keywords of the ERC project: honor, apologies, coordination, compromise, culture

Keywords that characterize the scientific profile of the potential visiting researcher/s:
CApturing Paradata for documenTing data creation and Use for the REsearch of the future

Considerable investments have been made in Europe and worldwide in research data infrastructures. Instead of a general lack of data about data, it has become apparent that the pivotal factor that drastically constrains the use of data is the absence of contextual knowledge about how data was created and how it has been used. This applies especially to many branches of SSH research where data is highly heterogeneous, both by its kind (e.g. being qualitative, quantitative, naturalistic, purposefully created) and origins (e.g. being historical/contemporary, from different contexts and geographical places). The problem is that there may be enough metadata (data about data) but there is too little paradata (data on the processes of its creation and use).

In contrast to the rather straightforward problem of describing the data, the high-risk/high-gain problem no-one has managed to solve, is the lack of comprehensive understanding of what information about the creation and use of research data is needed and how to capture enough of that information to make the data reusable and to avoid the risk that currently collected vast amounts of research data become useless in the future. The wickedness of the problem lies in the practical impossibility to document and keep everything and the difficulty to determine optimal procedures for capturing just enough.

With an empirical focus on archaeological and cultural heritage data, which stands out by its extreme heterogeneity and rapid accumulation due to the scale of ongoing development-led archaeological fieldwork, CAPTURE develops an in-depth understanding of how paradata is #1 created and #2 used at the moment, #3 elicits methods for capturing paradata on the basis of the findings of #1-2, #4 tests the new methods in field trials, and #5 synthesises the findings in a reference model to inform the capturing of paradata and enabling data-intensive research using heterogeneous research data stemming from diverse origins.

Link to the ERC project webpage: http://www.uu.se/en/research/capture

Keywords of the ERC project: paradata, archaeology, research data, research process, data creation, data use, re-use

Keywords that characterize the scientific profile of the potential visiting researcher/s:
### Politics of Patents: Re-imagining citizenship via clothing inventions 1820 - 2020

From Victorian women cyclists, who suffered social stigma for daring to replace their skirts with bloomers a century ago, to the recent French burkini ban, where women were forcibly removed from beaches, specifically clothed bodies have long been sites of debate about gender, race, class and religion in public space. Clothing is directly connected to social life and the political world and as such is central to ideas around the politics of identity, participation and belonging. Yet, it is under explored in relation to citizenship studies. This five-year project undertakes for the first time a transnational sociological investigation of 200 years of clothing inventions. It focuses on clothing patents in Espacenet, the European Patent Office’s free online database. Inventors are the focus as they operate on the cutting edge of social and political change; building on the past to make claims on the present and imagine different futures. Central to this research is the idea that clothing inventors can be explored as citizen-makers and that clothing patents are rich untapped sources of data that render visible alternative citizenship possibilities, which may provoke new questions about things we take for granted. The research will be located in a Patent Lab using an inventive mixed-methods approach including quantitative and in-depth visual and document analysis, interviews with inventors and garment reconstruction.

**Link to the ERC project webpage:** [http://www.politicsofpatents.org](http://www.politicsofpatents.org)

**Keywords of the ERC project:** patents, invention, clothing, inventive methods, reconstruction, citizenship, bodies, gender/queer studies, sociology, science & technology studies (STS), archives

**Keywords that characterize the scientific profile of the potential visiting researcher/s:** practice research, social science, STS, inventive methods, wearable technology, archives, mobilities, gender /queer studies, history, performance
Extreme Citizen Science: Analysis and Visualisation

The challenge of Extreme Citizen Science is to enable any community, regardless of literacy or education, to initiate, run, and use the result of a local citizen science activity, so they can be empowered to address and solve issues that concern them. Citizen Science is understood here as the participation of members of the public in a scientific project, from shaping the question, to collecting the data, analysing it and using the knowledge that emerges from it. Over the past 3 years, under the leadership of Prof. Muki Haklay, the Extreme Citizen Science programme at UCL has demonstrated that non-literate people and those with limited technical literacy can participate in formulating research questions and collecting the data that is important to them. Extreme Citizen Science: Analysis and Visualisation (ECSAnVis) takes the next ambitious step – developing geographical analysis and visualisation tools that can be used, successfully, by people with limited literacy, in a culturally appropriate way. At the core of the proposal is the imperative to see technology as part of socially embedded practices and culture and avoid ‘technical fixes’.

The development of novel, socially and culturally accessible Geographic Information System (GIS) interface and underlying algorithms, will provide communities with tools to support them to combine their local environmental knowledge with scientific analysis to improve environmental management. In an exciting collaboration with local indigenous partners on case studies in critically important, yet fragile and menaced ecosystems in the Amazon and the Congo-basin, our network of anthropologists, ecologists, computer scientists, designers and electronic engineers will develop innovative hardware, software and participatory methodologies that will enable any community to use this innovative GIS. The research will contribute to the fields of geography, geographic information science, anthropology, development, agronomy and conservation.

Link to the ERC project webpage: https://www.geog.ucl.ac.uk/research/research-centres/excites/projects/extreme-citizen-science-analysis-and-visualisation-ecsanvis

Keywords of the ERC project: Citizen Science, Indigenous knowledge, geographical information science, Participatory technologies, Traditional Ecological Knowledge

Keywords that characterize the scientific profile of the potential visiting researcher/s: Anthropology, Geography, Computer Science, Human-Computer Interaction, Science and Technology Studies, Ecology

This research project aims to identify a new welfare regime in emerging market economies and explain why it has emerged. The project will compare Brazil, China, India, Indonesia, Mexico, South Africa and Turkey to test two hypotheses: (i) emerging market economies are forming a new welfare regime that differs from liberal, corporatist and social democratic welfare regimes of the global north on the basis of extensive and decommodifying social assistance programmes, (ii) the new welfare regime emerges principally as a response to the growing political power of the poor as a dual source of threat and support for governments. Based on a comparative and interdisciplinary perspective, the project follows a multi-method strategy that combines state-of-the-art computer-based protest event data collection techniques, macro-historical methods, quantitative data analyses and qualitative content analysis. The project will radically expand the literatures on welfare regimes, welfare state development and contentious politics, by challenging the existing paradigms dominated by structuralist perspectives, a myopic focus on Western countries, and limited data collection and analysis techniques. This project is genuinely innovative, unprecedented, ground-breaking, ambitious and high-risk/high-gain in three ways: (i) it re-shapes the welfare regimes literatures as the first study to classify and explain welfare systems of emerging markets as a new welfare regime and (ii) the project demonstrates a causal link between changes in grassroots politics and welfare policies and challenge the structuralist preponderance in the existing welfare state development literature (iii) it makes a prodigious contribution to our empirical knowledge on contentious politics in emerging markets by creating the first cross-national databases on protest event, employing state-of-the art computer methods, such as natural language processing and machine learning, on newspaper archives.

Link to the ERC project webpage: https://emw.ku.edu.tr/

Keywords of the ERC project: welfare, social movements, protest, party politics, emerging markets, natural language processing, machine learning, computational social sciences

Keywords that characterize the scientific profile of the potential visiting researcher/s: welfare, social movements, protest, party politics, emerging markets, natural language processing, machine learning, computational social sciences
The ‘Declining Significance of Gender’ Reexamined: Cross-Country Comparison of Individual and Structural Aspects of Gender Inequality

The comparative research of long-term trends largely neglects structural mechanisms of gender inequality, i.e. the gender bias in which jobs and activities are evaluated and rewarded. I argue that as more women become integrated in positions of power, the stronger the role of structural elements is likely to become. However, because these are less visible and amenable to empirical assessment, they are under-researched compared to individual aspects, and are commonly assumed to be gender-neutral. The implication is that the importance of gender as a determinant of economic inequality in the labour market becomes insufficiently acknowledged, and thus difficult to track and eradicate.

My empirical objective is to track structural vs. individual processes of gender inequality over a period of 40 years, using the case of occupations. My aim is to uncover the countervailing processes of women’s (individual) upward occupational mobility versus women’s (collective) effect on occupational pay. I argue that the effects of structural aspects of gender inequality increase over time, but are concealed by women’s (individual) upward mobility.

I expect the dynamic of the two processes to vary between countries and also by class. I thus seek to examine the processes in four representative countries – Sweden, Germany, Spain and the United States – that differ in many of the institutional aspects that affect gender inequality, including the provision of welfare, gender ideology, wage structure, and political economy factors. Therefore, gender in/equality processes in these countries are expected to take different forms in both structural and individual appearances. That said, in all countries I expect gender equality processes to be more pronounced and rapid for advantaged women. At the structural level, however, the rapid upward occupational mobility of skilled and educated women may expose highly rewarded occupations to devaluation and pay reduction more than others.

Link to the ERC project webpage: https://people.socsci.tau.ac.il/mu/hadasm/

Keywords of the ERC project:

Keywords that characterize the scientific profile of the potential visiting researcher/s: quantitative research methods, gender inequality, occupational segregation, devaluation, wage inequality, gender division of labour, cross-country comparative research
Enhancing Capabilities? Rethinking Work-life Policies and their Impact from a New Perspective

We have witnessed significant work-life policy advancements designed to help men and women more equally combine employment with other spheres of life in recent decades, yet gender inequality persists. Improving gender equality in work-life balance is therefore high on policy agendas throughout Europe. Decades of research in this area have produced key insights but work-family theories fail to sufficiently explain the tenacity of this inequality. Earlier applications of a capabilities approach to work-life balance offer promising inroads, yet the importance of community remains absent. The CAPABLE project will generate fundamentally new knowledge on how work-life balance policies impact an individual’s capability to achieve this balance in Europe by incorporating the understudied dimension of community.

Capabilities reflect what individuals are effectively able to achieve. CAPABLE asks: To what extent do work-life balance policies enhance men and women’s capabilities to achieve work-life balance? To answer this question, we will develop and apply complex models derived from Sen’s capability approach to analyse: 1. the availability, accessibility and design of work-family policies; 2. what these policies mean for men and women’s capabilities to achieve work-life balance based on their embeddedness in individual, community and social contexts; 3. whether work-life policies enhance individual wellbeing; and 4. what policy tools are needed for developing sustainable work-life balance policies that enhance gender equal work-life capabilities. CAPABLE will progress scientific and policy frontiers using innovative, mixed-methods approaches at multiple policy levels. The conceptual clarity and empirical advancements provided will significantly expand our understanding of work-life policies in relation to individual capabilities. Furthermore, it will produce key insights into how sustainable work-life policies addressing gender inequality in work-life can be developed.

Link to the ERC project webpage: www.worklifecapabilities.com

Keywords of the ERC project: gender equality, capabilities, work-life balance, comparative social policy

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Sacralizing Security: Religion, Violence and Authority in Mega-Cities of the Global South

In mega-cities of the Global South, state agencies often lack the capacity to provide infrastructure and security to all citizens. In such contexts, religious organizations and non-state security actors (vigilantes) have merged into alternative governance organizations.

The emergence of religious vigilantes suggests a different connection between religion and violence than emphasized in current research on religious fundamentalism and terrorism. While religious vigilantes use violence systematically, they generally do not aim to overthrow the state, nor do they seek a global audience to witness their violence. They operate side-by-side with state actors to maintain order.

Major questions are: why do mega-city residents grant these religious vigilantes authority? And what is the role of religion in the legitimation of vigilante practices?

SACRASEC will analyze the production of authority of religious vigilantes in mega-cities of the Global South through an ethnographic comparison of three mega-cities. The case studies focus on Christian and Afro-Brazilian religion in Rio de Janeiro; Christian, Islamic and Indigenous religion in Lagos; and Islamic and Indigenous religion in Jakarta. This comparative focus makes it possible to draw general conclusions about the role of religion in alternative governance, while also enabling an analysis of the particularities of each religious tradition in the context of vigilantism.

This research extends the boundaries of the anthropology of religion and political anthropology. It will provide critically needed knowledge on the power structures in mega-cities of the Global South, and in so doing will contribute important insights to policies aimed at improving human security.

Link to the ERC project webpage:

Keywords of the ERC project: urban studies, religion, security, vigilantism,

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Polarization and its discontents: does rising economic inequality undermine the foundations of liberal societies?

The project will examine the relationship between economic inequality and societal openness, one of the foundational elements of liberal society. Specifically, the project will provide new empirical evidence on the purportedly negative relationship between inequality and social mobility, support for democracy, and social cohesion in the West. The challenge addressed by the project is foremost empirical: for each dimension of openness, there are straightforward theoretical arguments to link rising inequality with declining openness. In each case, there is widely-known evidence to support a negative relationship in bivariate cross-sectional cross-country data. In each case, however, the best available research has regularly failed to confirm the negative relationships in longitudinal designs that sought to identify the causal impact from within-country changes in inequality. To possibly reconcile the discrepancies, the project will create four new multilevel databases that combine survey microdata across more than 30 countries and over observation windows possibly extending back to the 1970s to gain leverage for an encompassing and stringently longitudinal empirical analysis. The newly constructed databases will be used for a detailed decomposition of inequality trends, a disaggregated description of trends in social mobility, social cohesion and support for democratic governance, and for a differentiated causal analysis of the role of economic inequality for societal openness in the West. The latter rests on suitable multilevel regression specifications that distinguish between mechanical, power- and composition-dependent mechanisms and that involve temporal lags, effect thresholds, systematic treatment effect heterogeneity, and appropriate controls for concomitant trends in order to provide valid effect estimates, but also to contextualize effect occurrence and to possibly identify societal and institutional sources of resilience.

Link to the ERC project webpage:

Keywords of the ERC project: Economic inequality, social mobility, fairness, social cohesion, political participation, trust in institutions, cross-national comparison, survey data, multilevel modelling

Keywords that characterize the scientific profile of the potential visiting researcher/s: expertise in quantitative social research, econometrics, statistics; relevant fields: sociology - social stratification, political sociology, sociology/economics - income distribution and inequality
The Human Behavioral Immune System: Consequences for Health and Innovation

Modern innovations such as soap, condoms, and indoor plumbing have allowed billions of people to reduce their contact with viruses and bacteria and, as a result, dramatically increase length and quality of life. But how did members of the genus homo avoid pathogens for the two million years that preceded these technological innovations and, more broadly, discoveries that infectious disease is caused by microbes? And, importantly, how do any natural behavioral defenses against pathogens impact our behavior in the modern world? Recent research and theory in the field of evolutionary psychology suggests that natural selection has shaped a human behavioral immune system (HBIS)—a suite of psychological mechanisms, ranging from aspects of our olfactory systems (e.g., that detect specific chemical compounds) to our emotion systems (e.g., the emotion disgust) and our learning systems (e.g., conditioned aversions to foods) that are coordinated for a common function: to detect and motivate the avoidance of pathogens. Given that myriad universal human behaviors connote some pathogen risk—including interpersonal contact, mating, and eating—gaining a holistic understanding of the HBIS has the potential to offer critical new insights into multiple fundamental aspects of human nature. Here, I utilize an interdisciplinary approach to answer three foundational, yet currently opaque questions concerning the nature of the HBIS, including: (1) Where does trait variation in HBIS activation come from? (2) What effect does the HBIS have on behavior when cues to pathogens are detected? and (3) How does the HBIS facilitate learning of avoidance and rejection? To answer these questions, I propose an array of methodologically diverse studies to investigate how trait HBIS activation shapes rejection versus acceptance of innovations, how state HBIS activation can be harnessed to promote the use of health-promoting technologies, and how the HBIS can be leveraged for shaping dietary behavior.

Link to the ERC project webpage:

Keywords of the ERC project:

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Microcontact. Language variation and change from the Italian heritage perspective.

This project aims to add an important block to syntactic theory, by developing new theoretical tools to account for microvariation and change. The central idea is that change and microvariation are necessary parts of grammar, and that they are in fact constrained by Universal Grammar (Chomsky 1957 ff.); in order to understand them we need not focus on the starting point and endpoint of change only, but also on the process itself. Observing change in progress can offer insights into its causes and the mechanisms underlying it. We aim at getting snapshots of change in progress by examining endogenous, diachronic change and change in contact for a number of genetically and typologically related varieties.

Between the end of the 19th c. and the 1920s, many Italians migrated to the Americas. After World War II, a third wave of migration took place: around 400,000 people left Italy between 1950-1960. Interestingly, most of these Italians did not speak Italian as their native language: they all spoke some “dialect”. With this term we traditionally refer to those Romance languages spoken in Italy that evolved from Latin, and are sister languages to standard Italian. When these immigrants moved across the Atlantic, their languages entered in contact with other Romance varieties, like Argentinian Spanish, Brazilian Portuguese, or Québécois French, as well as with English.

The languages spoken by these 1st generation immigrants, who are now very old, are extremely important, as they potentially give a unique window into the mechanisms of language change in general, and of syntactic change in particular.

**Link to the ERC project webpage:** https://microcontact.sites.uu.nl/

**Keywords of the ERC project:** syntax, language change, contact linguistics, heritage languages, Romance languages

**Keywords that characterize the scientific profile of the potential visiting researcher/s:** syntax, language change, heritage language linguistics
Acute stress has a profound impact on cognitive functioning: it raises alertness for threat, yet it impairs our ability to think clearly. Repeated exposure to stressors is furthermore a critical transdiagnostic factor in etiology, relapse, and chronification in almost all psychiatric disorders. We know from animal work at the cellular level how stressors trigger a neurochemical cascade that alters properties of widespread neuronal populations. A critical gap in our knowledge, however, is how such cellular effects translate to the level of large-scale neural systems which implement higher-order cognition. Here, I propose a novel framework for understanding such alterations as shifts in network balance: I hypothesize that acute stress causes dynamic shifts in resource allocation at the level of large-scale networks. First, I will leverage recent advances in network connectivity modeling to characterize the spatiotemporal dynamics of such shifts during acute stress and recovery. Using wearable biosensors and mobile applications, I aim to identify which neural markers predict resilience to stress in real life. Second, I will cross-validate these markers in a patient group characterized by high stress sensitivity. Third, to investigate how rapid network shifts are generated, I will examine the distinct roles of noradrenergic and dopaminergic neuromodulatory systems. Fourth, I will test the hypothesis that cognitive functions supported by one network can be disrupted by shifting balance towards another. Finally, I will develop a network-based implementation of functional MRI neurofeedback to train stress-sensitive participants to adaptively reallocate neural resources during acute stress. When successful, this project will yield 1) unprecedented insight into how our brain adapts to acute stress; 2) novel ecologically validated transdiagnostic biomarkers of stress resilience versus sensitivity; and 3) a potentially groundbreaking method for training stress resilience.

Link to the ERC project webpage: www.ernohermans.com

Keywords of the ERC project: neuroimaging, stress, cortisol, norepinephrine, dopamine, neurofeedback

Keywords that characterize the scientific profile of the potential visiting researcher/s: cognitive neuroimaging, clinical neuroscience, stress
**Goal-directed eye-head coordination in dynamic multisensory environments**

Rapid object identification is crucial for survival of all organisms, but poses daunting challenges if many stimuli compete for attention, and multiple sensory and motor systems are involved in the processing, programming and generating of an eye-head gaze-orienting response to a selected goal. How do normal and sensory-impaired brains decide which signals to integrate (“goal”), or suppress (“distracter”)?

Audiovisual (AV) integration only helps for spatially and temporally aligned stimuli. However, sensory inputs differ markedly in their reliability, reference frames, and processing delays, yielding considerable spatial-temporal uncertainty to the brain. Vision and audition utilize coordinates that misalign whenever eyes and head move. Meanwhile, their sensory acuities vary across space and time in essentially different ways. As a result, assessing AV alignment poses major computational problems, which so far have only been studied for the simplest stimulus-response conditions.

My groundbreaking approaches will tackle these problems on different levels, by applying dynamic eye-head coordination paradigms in complex environments, while systematically manipulating visual-vestibular-auditory context and uncertainty. I parametrically vary AV goal/distracter statistics, stimulus motion, and active vs. passive-evoked body movements. We perform advanced psychophysics to healthy subjects, and to patients with well-defined sensory disorders. We probe sensorimotor strategies of normal and impaired systems, by quantifying their acquisition of priors about the (changing) environment, and use of feedback about active or passive-induced self-motion of eyes and head.

I challenge current eye-head control models by incorporating top-down adaptive processes and eye-head motor feedback in realistic cortical-midbrain networks. Our modeling will be critically tested on an autonomously learning humanoid robot, equipped with binocular foveal vision and human-like audition.

*Link to the ERC project webpage:* [https://www.mbfys.ru.nl/~johnvo/OrientWeb/orient.html](https://www.mbfys.ru.nl/~johnvo/OrientWeb/orient.html)

**Keywords of the ERC project:** Multisensory integration / computational modelling / psychophysics / hearing impaired

**Keywords that characterize the scientific profile of the potential visiting researcher/s:** psychophysics / computational modelling / auditory system
An Empirical Foundation for Understanding Positive Emotions

Positive emotions are of great importance for our physical and mental health and for our social relationships. However, scientific knowledge of positive emotions is lacking, with research to date being both fractionated and scarce. The Positive Emotions Project (PEP) takes on the challenge of formulating a foundational, empirically-based framework of positive emotions. This is accomplished by a set of studies combining methodologies that examine both subjective and objective elements of 17 positive emotions, including gratitude, awe, amusement, compassion, and relief. Central to the investigation is the integration of cross-cultural and developmental approaches, in order to differentiate between consistent patterns and idiosyncratic features. Project 1 will use experience sampling to map out the experience of positive emotions across ten dramatically different cultures, examining subjective elements of emotions, such as antecedent events and psychological states. Project 2 will comprehensively establish which nonverbal facial and vocal signals are associated with different positive emotions across cultures and ages. Project 3 will provide an integrated multi-level account of positive emotions, considering similarities and differences across emotions, taking into account cross-cultural and developmental patterning of subjective and objective features. The empirical and theoretical results of PEP will result in new, innovative paradigms, and substantial, freely available datasets that will help to redress the current dearth of data and approaches for understanding positive emotions. It will also provide the basis for a much-needed scientific, multifaceted account of positive emotion. Such a model will benefit scientists across many disciplines, including affective computing, behavioural economics, and psychiatry, whose work builds on psychological models of emotions.

Link to the ERC project webpage:

Keywords of the ERC project:

Keywords that characterize the scientific profile of the potential visiting researcher/s:
In daily social interactions, we constantly attribute mental states, such as beliefs or intentions, to other humans – to understand and predict their behaviour. Today we also routinely interact with artificial agents: from Apple’s Siri to GPS navigation systems. In the near future, we will casually interact with robots. However, since we consider artificial agents to have no mental states, we tend to not attune socially with them in the sense of activating our mechanisms of social cognition. This is because it seems pointless to socially attune to something that does not carry social meaning (mental content) under the surface of an observed behaviour. INSTANCE will break new ground in social cognition research by identifying factors that influence attribution of mental states to others and social attunement with humans or artificial agents. The objectives of INSTANCE are to (1) determine parameters of others’ behaviour that make us attribute mental states to them, (2) explore parameters relevant for social attunement, (3) elucidate further factors – culture and experience – that influence attribution of mental states to agents and, thereby social attunement. INSTANCE’s objectives are highly relevant not only for fundamental research in social cognition, but also for the applied field of social robotics, where robots are expected to become humans’ social companions. Indeed, if we do not attune socially to artificial agents viewed as mindless machines, then robots may end up not working well enough in contexts where interaction is paramount. INSTANCE’s unique approach combining cognitive neuroscience methods with real-time human-robot interaction will address the challenge of social attunement between humans and artificial agents. Subtle features of robot behaviour (e.g., timing or pattern of eye movements) will be manipulated. The impact of such features on social attunement (e.g., joint attention) will be examined with behavioural, neural and physiological measures.

Link to the ERC project webpage: https://instanceproject.eu

Keywords of the ERC project: Intentional stance, artificial agents, social cognition

Keywords that characterize the scientific profile of the potential visiting researcher/s:
A distributional MOdel of Reference to Entities

When I asked my seven-year-old daughter "Who is the boy in your class who was also new in school last year, like you?", she instantly replied "Daniel", using the descriptive content in my utterance to identify an entity in the real world and refer to it. The ability to use language to refer to reality is crucial for humans, and yet it is very difficult to model. AMORE breaks new ground in Computational Linguistics, Linguistics, and Artificial Intelligence by developing a model of linguistic reference to entities implemented as a computational system that can learn its own representations from data.

This interdisciplinary project builds on two complementary semantic traditions: 1) Formal semantics, a symbolic approach that can delimit and track linguistic referents, but does not adequately match them with the descriptive content of linguistic expressions; 2) Distributional semantics, which can handle descriptive content but does not associate it to individuated referents. AMORE synthesizes the two approaches into a unified, scalable model of reference that operates with individuated referents and links them to referential expressions characterized by rich descriptive content. The model is a distributed (neural network) version of a formal semantic framework that is furthermore able to integrate perceptual (visual) and linguistic information about entities. We test it extensively in referential tasks that require matching noun phrases ("the Medicine student", "the white cat") with entity representations extracted from text and images.

AMORE advances our scientific understanding of language and its computational modeling, and contributes to the far-reaching debate between symbolic and distributed approaches to cognition with an integrative proposal. I am in a privileged position to carry out this integration, since I have contributed top research in both distributional and formal semantics.

Link to the ERC project webpage: https://www.upf.edu/web/amore

Keywords of the ERC project:
Keywords that characterize the scientific profile of the potential visiting researcher/s: computational cognitive science, linguistics, computational linguistics
Cognitive Semantics and Quantities

At the heart of the multi-faceted enterprise of formal semantics lies a simple yet powerful conception of meaning based on truth-conditions: one understands a sentence if one knows under which circumstances the sentence is true. This notion has been extremely fruitful resulting in a wealth of practical applications. But to what extent can it also account for the human linguistic behavior? The past decade has seen the increasing interaction between cognitive science and formal semantics, and the emergence of the new field of experimental semantics. One of its main challenges is the traditional normative take on meaning, which makes semantic theories hard to compare with experimental data. The aim of this project is to advance experimental semantics by building cognitive semantics, that is semantics founded on cognitive representations instead of normative logical abstractions.

Numerical information plays a central role in communication. We talk about the number of students in a class, or the proportion of votes for a particular political party. In this project, I will focus on the linguistic expressions of quantities, known as quantifiers. Recent progress in the study of computational constraints on quantifier processing in natural language laid the groundwork for extending semantic theory with cognitive aspects. In parallel, cognitive science has furthered the study of non-linguistic quantity representations. This project will integrate formal models of quantifier semantics with cognitive quantity representations in order to obtain cognitive semantics of quantifiers, which is both logically precise and psychologically plausible. The theory will have significant repercussions, not only in the immediately related disciplines as semantics and psycholinguistics, but also beyond, e.g., in philosophy and in language technology.

Link to the ERC project webpage: https://www.jakubszymanik.com/CoSaQ/

Keywords of the ERC project: semantics, cognition, psycholinguistics, computational modeling

Keywords that characterize the scientific profile of the potential visiting researcher/s: cognitive modeling, experimental semantics
Characterizing neural mechanisms underlying the efficiency of naturalistic human vision

Our daily-life visual environments, such as city streets and living rooms, contain a multitude of objects. Out of this overwhelming amount of sensory information, our brains must efficiently select those objects that are relevant for current goals, such as cars when crossing a street. The visual system has developed and evolved to optimally perform tasks like these, as reflected in the remarkable efficiency of naturalistic object detection. Little is known about the neural mechanisms underlying this efficiency. NATVIS aims to fill this gap, presenting a comprehensive multi-method and hypothesis-driven approach to improve our understanding of the neural mechanisms underlying the efficient detection of objects in natural scenes. fMRI, MEG, and TMS will be used to study the neural basis of rapid attentional guidance based on scene context and episodic memory, resulting in a full characterization of when, where, and how context- and memory-based expectations interact with attentional templates in visual cortex and beyond. The powerful effects of scene context on object recognition will be studied by testing how context-disambiguated objects are represented in visual cortex, characterizing when context-based predictions bias object processing, and testing for causal interactions between scene- and object-selective pathways in visual cortex. NATVIS will study how the brain uses real-world regularities to support object grouping and reduce clutter in scenes, modelling the cortical representation and neural dynamics of multiple simultaneously presented objects as a function of positional regularity. Finally, advanced multivariate modelling of fMRI data will test the functional relevance and representational content of internally generated templates that are hypothesized to facilitate object detection in scenes. This program of research tackles the next frontier in the neuroscience of high-level vision and attention, embracing the complexity of naturalistic vision.

Link to the ERC project webpage:

Keywords of the ERC project: Object perception, Natural scenes, Vision, Neuroimaging, Attention

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Human interaction and the evolution of spoken accent

If a group of people were stranded on a desert island with limited contact to outside communities for a period of time, then the group would develop its own characteristic way of speaking or spoken accent. A lack of suitable data as input to an evolutionary computational model has meant that we have but a poor understanding of how spoken accent emerges out of human interaction. Yet a breakthrough in this area is critical for explaining the various forces - including contact between individuals through increased migration - that shape spoken accent development ultimately leading to language diversification and change. The project remedies this deficiency by developing a model of how random, local interactions between individuals leading to group-specific spoken accents can push the sound patterns of languages between stable and changing states. The methodological innovation is that the model’s predictions of how spoken accent evolves will be constrained by longitudinal observations about how it actually develops within a group of speakers over time. We seek to generalise from diverse types of data: from children growing up in remote rural communities as opposed to high-contact urban settings; from languages that differ markedly in their sound structure; and from groups of adults isolated together for several months during an Antarctic winter. The project’s scientific impact is on developing a computational framework for unifying historical sound change with the cognitive mechanisms by which speech is communicated and adapted to different social settings. The further impact is on understanding how migration and exposure to other accents change the sounds of language. The long-term significance of the project is to build a computationally predictive model of the way that microscopic idiosyncrasies in how humans process speech in everyday conversations accumulate into group-level macroscopic spoken accent change leading to language diversification.

Link to the ERC project webpage:

Keywords of the ERC project: agent-based modelling; spoken accent; sound change; laboratory phonology

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Discourse reporting in African storytelling

The project explores the role of discourse reporting in West African storytelling and the grammatical strategies used by storytellers to achieve their goals. It focuses on three phenomena characteristic of the narrative grammar of a number of West African languages:

- logophoricity, or the use of special markers to signal self-reference by characters other than the current narrator,
- the use of quotative markers (commonly described as "epistemic validators"),
- and the use of foreign language or modified versions of the native language to represent the speech of certain characters.

The different phenomena are argued to serve the same purpose: they help speakers manage the distance between the role of the current narrator and the roles of story characters that the same speaker performs. The use of specific discourse reporting strategies is therefore closely related to the modes of textual production and performance in the culture-specific narrative genres, and to the construction of deixis in relation to the event of narration.

The comparative part of the project analyses similarities and differences in the ways discourse reporting functions in several West African cultures with similar data from an unrelated cultural area: the Turkic-speaking areas of Central Russia. The comparison of the organization of the same functional domain in two typologically and culturally distinct areas will assist in advancing our knowledge of universal structural and cognitive motivations underlying typologically diverse and culture-specific systems of discourse reporting.

Link to the ERC project webpage:

Keywords of the ERC project:

Keywords that characterize the scientific profile of the potential visiting researcher/s:
The emergence and evolution of linguistic tone

This project will investigate the origins, acquisition, and evolution of linguistic tone: the use of pitch to distinguish between the meaning of words. Despite the typological ubiquity of tone, there is still no phonetic, structural, or psychological model that explains how and why tones emerge (or fail to emerge) in language after language, nor how they evolve once they are formed. This is because there has never been a systematic analysis of the principles that govern the evolution of tone systems. EVOTONE will provide the first comprehensive study of tonal emergence and evolution, combining detailed phonetic and perceptual studies of Himalayan and Southeast Asian minority languages with innovative experimental methodologies and large-scale computational analysis of the structural principles correlated with the emergence of tone.

EVOTONE is guided by a novel hypothesis that, if correct, will have important repercussions for the study of sound change. The core idea is deceptively simple: rather than being the result of small, incremental changes in pronunciation, features like tone come about due to a sudden failure to articulate a particular aspect of a sound. If the risk of focusing on tone is to overemphasize a single feature, the potential reward is enormous: an opportunity to transform our understanding of how physical and cognitive pressures interact to shape human behavior and language change. The outcomes of this project will provide a new empirical foundation for the typology and evolution of tone systems; break new ground in the study of how structural and phonetic factors interact in sound change; and establish, for the first time, an empirically grounded set of principles of tonal evolution. In addition to resolving a number of outstanding questions about tonogenesis, the results will substantially advance our more general understanding of how language changes over time.

Link to the ERC project webpage: https://erc.europa.eu/projects-figures/erc-funded-projects/results?search_api_views_fulltext=EVOTONE

Keywords of the ERC project: Phonetics, phonology, tone languages, sound change, historical linguistics

Keywords that characterize the scientific profile of the potential visiting researcher/s:
In light of major demographic trends, building and maintaining health and well-being amongst citizens is one of the most important societal challenges European countries face. People who feel well, function better, are less susceptible to mental illness, and thus are better able to retain competitive advantage and expand human capital. People who feel well also facilitate social capital by enjoying stronger and more-lasting relationships. Consequently, maintaining, facilitating, and building well-being (WB) would not only improve individual (health) outcomes, but also reduce economic and health care burdens. To sustainably facilitate and build WB, thorough understanding of its underlying dynamics, especially the interplay between an individual’s genetic makeup, epigenetic make-up, and (social) environmental exposure, is crucial.

In this project, I will cross disciplinary boundaries to initiate the urgently needed integration of multiple layers of influence in the study of WB. The key objectives are to (1) identify, quantify, and integrate static and dynamic environmental and social exposures to build the well-being exposome, (2) understand the multi-layer interplay of the genome, the epigenome, and the exposome, and (3) integrate the empirical findings into a novel comprehensive framework of WB. I will employ an interdisciplinary approach, using association, real-life, and network methodology to assess the dynamics underlying WB. To apply these state-of-the-art techniques, I will bring together longitudinal twin-family data, molecular genetic data, and big data from satellite positioning (GPS), bluetooth beacons, geographical information systems (GIS), ambulatory assessment, and social network linkage. This project will mark a shift in scientific approach and enables the development of interdisciplinary academic theories and health, social, and economic policies to maintain, facilitate, and build WB to withstand our demanding and rapidly changing world.

Link to the ERC project webpage:

Keywords of the ERC project: Wellbeing Genetics Environment Twins

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Cognitive function in old age can be predicted from how you functioned when you were young. This is remarkable, as there are substantial cognitive age changes. Are we neurodevelopmentally set to change through life in certain ways? The objective of Set-to-change is to test whether and how early life environmental factors and genetic makeup interact to regulate neurocognitive plasticity through the lifespan. Neurocognitive plasticity; i.e. changes in brain and cognition in response to environmental demands over time, shows huge individual variability, for unknown reasons. Neurodevelopmental origins of functional variation through the lifespan are acknowledged, but the pathways need to be identified. As individual constitution and environment are intrinsically correlated, to make progress beyond state of the art, this can only be tested in an experimental setting.

The novelty and ground-breaking nature of the project lies in the synthesis of a targeted experimental approach testing differences in neurocognitive plasticity by training of younger and older adult mono- (MZ) and dizygotic twins (total n = 400 individuals), with varying degrees of prenatal environmental variance, as indexed by their extent of discordance in birth weight (BW). BW discordance in MZ twins enables me to disentangle early environmental and genetic influences on neurocognitive plasticity. I will employ a novel ecologically valid memory intervention utilizing navigation with true locomotion and prospective memory in virtual reality. Twins will be assessed with brain MRI, cognitive, health and epigenetic measures at multiple time points spread across 2.5 years pre- and post- 3 months intervention in a AB/BA crossover design, to investigate neurocognitive plasticity and age change longitudinally, as well as possible lifestyle and epigenetic mediators. I hypothesize that early life environmental influences will interact with genetic makeup in determining neurocognitive plasticity in adulthood.

Link to the ERC project webpage: https://www.oslobraains.no/presentation/set-to-change/

Keywords of the ERC project: early life factors, brain, cognition, lifespan development, plasticity

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Taking turns: The ‘missing’ link in language evolution?

Language — the most distinctive human trait — remains a ‘mystery’ or even a ‘problem’ for evolutionary theory. It is underpinned by cooperative turn-taking, which has been implicated with highly sophisticated cognitive skills such as mindreading. Some have claimed that this turn-taking system is uniquely human, but others argue that it provides the evolutionary ‘missing link’ between animal and human communication.

This debate has been constrained by a lack of comparative data, methodological confounds that often prevent meaningful comparisons, and a lack of information on key components of social relationships that might strongly impact upon turn-taking propensities.

Objectives. TURNTAKING will quantify turn-taking production and comprehension in human children, chimpanzees, and two distantly related species — geladas and common marmosets. It will apply a powerful combination of systematic behavioral observations, eye-tracking paradigms, and established measures from Conversational Analysis and Primatology that allow the same type of data to be collected and analyzed in directly comparable ways across species. This will provide the first rigorous test of whether cooperative turn-taking is uniquely human, ancestral in the primate lineage, or evolved independently in different species.

TURNTAKING will identify which hallmarks of human turn-taking are shared across different primate species, and which key components of relationship quality act upon turn-taking skills.

Outcomes. This project will found the field of comparative turn-taking, and provide pioneering insights into the behavioral flexibility underlying different turn-taking systems. It will go beyond the state of the art by exposing whether cooperative turn-taking is the evolutionary ‘missing link’ between our species and our inarticulate primate cousins, and whether pro-social behaviors drove its emergence.

Link to the ERC project webpage: https://www.comparative-biocognition.de/research-topics

Keywords of the ERC project: Evolution of language, comparative approach, communication, turn-taking, primates

Keywords that characterize the scientific profile of the potential visiting researcher/s: Evolution of communication, Primatology, gestures, vocalizations, turn-taking, eye-tracking
Curiosity and the Development of the Hidden Foundations of Cognition

How do human infants develop complex cognition? We propose that artificial intelligence (AI) provides crucial insight into human curiosity-driven learning and the development of infant cognition. Deep learning—a technology that has revolutionised AI—involves the acquisition of informative internal representations through pre-training, as a critical precursory step to learning any specific task. We propose that, similarly, curiosity guides human infants to develop ‘hidden’ mature mental representations through pre-training well before the manifestation of behaviour. To test this proposal, for the first time we will use neuroimaging to measure the hidden changes in representations during infancy and compare these to predictions from deep learning in machines. Research Question 1 will ask how infants guide pre-training through directed curiosity, by testing quantitative models of curiosity adapted from developmental robotics. We will also test the hypothesis from pilot data that the fronto-parietal brain network guides curiosity from the start. Research Question 2 will further test the parallel with deep learning by characterising the developing infant’s mental representations within the visual system using the powerful neuroimaging technique of representational similarity analysis. Research Question 3 will investigate how individual differences in curiosity affect later cognitive performance, and test the prediction from deep learning that the effects of early experience during pre-training grow rather than shrink with subsequent experience. Finally, Research Question 4 will test the novel prediction from deep learning that, following perinatal brain injury, pre-training creates resilience provided that curiosity is intact. The investigations will answer the overarching question of how pre-training learning lays the foundations for cognition and pioneer the new field of Computational Developmental Cognitive Neuroscience.

Link to the ERC project webpage: www.cusacklab.org

Keywords of the ERC project: deep learning, neuroimaging, infant cognition

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Every day, everywhere, people make unethical choices ranging from minor selfish lies to massive frauds, with dramatic individual and societal costs. Embodied cognition theories posit that even seemingly abstract processes (like grammar) may be biased by the body-related signals used for building and maintaining self-consciousness, the fundamental experience of owning a body (ownership) and being the author of an action (agency), that is at the basis of self-other distinction. Applying this framework to morality, we hypothesize that strengthening or weakening participants’ bodily self-consciousness towards virtual avatars or real others will influence dishonesty in real, virtual, and web-based interactions. To test this hypothesis, we will measure:
i) individual dishonesty after modifying body ownership (e.g., by changing the appearance of the virtual body) and agency (e.g., by changing the temporal synchrony between participant’s and avatar’s actions) over an avatar through which decisions are made;
ii) intergroup dishonesty after inducing inter-individual sharing of body self-consciousness (e.g., blur self-other distinction via facial visuo-tactile stimulation);
iii) individual and intergroup dishonesty by manipulating exteroceptive (e.g., the external features of a virtual body) or interoceptive (e.g., changing the degree of synchronicity between participant’s and avatar/real person’s breathing rhythm) bodily inputs.
Dishonesty will be assessed through novel ecological tasks based on virtual reality and web-based interactions. Behavioural (e.g., subjective reports, kinematics), autonomic (e.g., heartbeat, thermal imaging) and brain (e.g., EEG, TMS, lesion analyses) measures of dishonesty will be recorded in healthy and clinical populations. Our person-based, embodied approach to dishonesty complements cross-cultural, large-scale, societal investigations and may inspire new strategies for contrasting dishonesty and other unethical behaviours.
Understanding the origins of language speaks to the fundamental question of what it means to be human. Other species’ communication contains rich information exchange; but humans do more than broadcast information. Language is used to communicate goals to partners, it goes beyond information: it has meaning. Only great ape gestures show similarly systematic meaningful communication; they are essential to understanding how human language evolved.

Beyond meaning, two core features of human language are social learning and syntactic structure. These are universals, present across cultures. We all learn words and how to use them from others, leading to languages and dialects. We all use syntax; expressing different meanings by recombining words. In fact, these two features are common in animal communication: sperm whales learn songs from others; finches re-order notes into different songs. But, in a significant evolutionary puzzle, both appear absent in the communication of our closest relatives.

The discovery of meanings in ape gesture resulted from studying ape communication under the challenging natural conditions that allow its full expression. A single study of a single group: it was the tip of the iceberg. Employing pan-African data across 17 ape and 9 human groups. I will tackle three major objectives. (1) Is there cultural variation in ape gesture? We will look at how species, physical environment, and social interaction affect how apes acquire and use gestures. (2) When apes combine signals, does it change their meaning? Moving beyond sequential structure we will look at how apes combine signals to construct meaning, and how the speed, size, and timing of gestures impacts meaning. (3) Human-ape gesture. We will investigate adults’ and children’s use and comprehension of gestures to compare them directly to other apes. Using new and established techniques across a dramatically wider sample I will address the fundamental question of how human language evolved.

Link to the ERC project webpage: www.greatapedictionary.com

Keywords of the ERC project: gesture, communication, ape, language, cognition

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Information Sampling in Multiattribute Choice

Do we prefer a small flat with a short commute or a large house with a long commute? Many real-life decisions require combining information across different attributes. It has been shown that during such multiattribute decisions people serially attend to (or sample) a subset of the available information. The way this process takes place largely influences the final choice: for example, if the “commute” attribute is considered for longer, then the small flat will tend to appear better.

Up to date, information sampling has been studied within the social sciences using eye-tracking techniques. However, in the context of choice tasks, the way eye fixations influence the upcoming choice is not precisely known and, thus, this line of research has not yielded any definitive mechanistic conclusions. Recently, theorists have proposed different mechanisms of information sampling but these proposals were not constrained by relevant data.

I propose to fill this gap in a data-driven fashion by harnessing tools from sensory neuroscience. Using magnetoencephalography (MEG) we will simultaneously track the locus of attention and the tendency to choose one alternative over the other, during the entire time-course of a single multiattribute decision. This approach will enable us to unravel the computational and neural mechanisms that guide attention towards different aspects of a multiattribute choice problem.

This project will yield a neurophysiologically detailed theory of multiattribute choice—from the level of neurotransmitters, to large-scale brain networks, to behaviour— that will ultimately shed light on century-long questions, such as why humans reverse their preferences irrationally, when irrelevant alternatives are added to the choice-set. The emerging framework will be useful to policy makers and practitioners, interested in a descriptively enriched model of choice; and to clinicians aiming to understand how information sampling goes awry in neuropsychiatric disorders.

Link to the ERC project webpage:

Keywords of the ERC project:

Keywords that characterize the scientific profile of the potential visiting researcher/s: Decision-making, cognitive neuroscience
Humans can monitor their own mental lives and build representations that contain knowledge about themselves. This capacity to introspect and report one’s own mental states, or in other words “knowing how much one knows”, is termed metacognition. Although metacognition is crucial to behave adequately in a complex environment, metacognitive judgments are often suboptimal. Specifically for neurological and psychiatric diseases, metacognitive failures are highly prevalent, with severe consequences in terms of quality of life. This project proposes a new hypothesis to explain the determining factors of metacognitive failures: namely, that metacognition does not operate in a vacuum but relies on the monitoring of signals from the body, and more specifically, on motor signals involved during action execution. We suggest several experiments to test the motor hypothesis for self-monitoring, and propose a new remediation procedure to resolve metacognitive failures resulting from deficient action monitoring. We will start by assessing the contribution of motor signals to metacognition by identifying the behavioral and neural correlates for detecting self-committed vs. observed errors (WP1), and by using virtual reality and robotics to probe metacognition in a vacuum, operating in the complete absence of voluntary actions (WP2). Finally, we will use these results to develop and evaluate a method to train metacognition in healthy volunteers and individuals with schizophrenia in a bottom-up manner, using online feedback based on motor signals (WP3). This new metacognitive remediation procedure will be performed both in a clinical context and on mobile devices. The goal of this ambitious project is therefore twofold, theoretical in shedding new light on a cognitive process central to our most profound mental states, and clinical in establishing a new remediation method to tackle a major health and societal issue.
"Anne believes that Bob assumes that Anne believes that Bob's assumption is false. Does Anne believe that Bob's assumption is false?" Don't try too hard answering the question - any straightforward attempt will lead to paradox.

But what are we to make of sentences such as "Anne believes that Bob's assumption is false." Is the sentence true or false? On the face of it, it would seem that answering this question is a pressing problem for natural language semantics that assigns truth conditions to sentences of natural language. However, semanticists have largely ignored problems of this kind, leaving the field to philosophical logicians working on paradoxes, in particular, the paradoxes of truth such as the Liar paradox. But research on the paradoxes of truth has often focused on exploring the space of possible coherent "solutions" to the paradoxes thereby ignoring desiderata of natural language semantics. The project provides a unified perspective on natural language semantics, conceived of as truth-conditional semantics, and the research on the so-called semantic paradoxes in form of theories of self-applicable truth. A unified approach to truth and semantics will need to answer two principal challenges, which divides the research project into two interrelated parts. The first part, Truth in Semantics, aims at developing semantic accounts for rich fragments of natural language, that is, fragments in which, besides the notion of truth, we allow for, e.g., modal expressions, propositional attitudes but also natural language conditionals. The second part, Truth and the Foundations of Semantics, assumes a metasemantic perspective and explores the role of the notion of truth in the foundations of natural language semantics, conceived of as truth-conditional semantics. The project constitutes the first systematic study of truth and natural language semantics from such a combined perspective.
Perception is a complex process, where prior knowledge is incorporated into the current percept to help the brain cope with sensory uncertainty. A crucial question is how this mechanism changes during interaction, when the brain is faced with two conflicting goals: either optimizing individual perception by using internal priors, or maximizing perceptual alignment with the partner, by limiting the reliance on individual priors. wHiSPER proposes to study for the first time how visual perception of space and time is modified during interaction, by moving the investigation to an interactive shared context, where two agents dynamically influence each other. To allow for scrupulous and systematic control during interaction, wHiSPER will use a humanoid robot as a controllable interactive agent. The research will be articulated along five main objectives: i) determine how being involved in an interactive context influences perceptual inference; ii) assess how perceptual priors generalize to the observation of other’s actions; iii) understand whether and how individual perception aligns to others’ priors; iv) assess how is it possible to enable shared perception with a robot and v) determine whether perceptual inference during interaction is modified with aging, when lowered sensory acuity could increase priors relevance. To these aims wHiSPER will exploit rigorous psychophysical methods, Bayesian modeling and human-robot interaction, by adapting well-established paradigms in the study of visual perception to a novel interactive context. In several experiments the humanoid robot and the participants will be shown simple temporal or spatial perceptual stimuli that they will have to perceive either to reproduce them or to perform a coordinated joint action (as passing an object). The measures of the reproduced intervals and of the kinematics of the actions will allow to quantify through Bayesian modeling how social interaction influences visual perception.

Link to the ERC project webpage: https://whisperproject.eu/

Keywords of the ERC project: Robot; perception; interaction; space; time; HRI

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Action selection under threat: the complex control of human defense

Run away, sidestep, duck-and-cover, watch: when under threat, humans immediately choreograph a large repertoire of defensive actions. Understanding action-selection under threat is important for anybody wanting to explain why anxiety disorders imply some of these behaviours in harmless situations. Current concepts of human defensive behaviour are largely derived from rodent research and focus on a small number of broad, cross-species, action tendencies. This is likely to underestimate the complexity of the underlying action-selection mechanisms. This research programme will take decisive steps to understand these psychological mechanisms and elucidate their neural implementation.

To elicit threat-related action in the laboratory, I will use virtual reality computer games with full body motion, and track actions with motion-capture technology. Based on a cognitive computational framework, I will systematically characterise the space of actions under threat, investigate the psychological mechanisms by which actions are selected in different scenarios, and describe them with computational algorithms that allow quantitative predictions. To independently verify their neural implementation, I will use wearable magnetoencephalography (MEG) in freely moving subjects.

This proposal fills a lacuna between defence system concepts based on rodent research, emotion psychology, and clinical accounts of anxiety disorders. By combining a stringent experimental approach with the formalism of cognitive-computational psychology, it furnishes a unique opportunity to understand the mechanisms of action-selection under threat, and how these are distinct from more general-purpose action-selection systems. Beyond its immediate scope, the proposal has a potential to lead to a better understanding of anxiety disorders, and to pave the way towards improved diagnostics and therapies.

Link to the ERC project webpage: www.bachlab.org
Keywords of the ERC project: threat avoidance; virtual reality; motion capture; machine learning; computational neuroscience
Keywords that characterize the scientific profile of the potential visiting researcher/s:
This project builds new foundations for collective attitudes and representational states: group belief and group desire. The platform is the PI’s recent advances in the metaphysics of representation for individual representational states, where he develops and defends a substantive, realist interpretationism: (i) what it is to believe/desire that p is for the selected interpretation to attribute that belief/desire to them; (ii) the selected interpretation is that which makes the subject most reason-responsive, given the way they act and the evidence available to them. This project leverages this work to construct a common structure for the metaphysics of group representation and individual representation, isolating parameters that differentiate the cases and theorizing the distinctive ingredients of the group case.

The first phase of the work places group representation in context, studying the theoretical deployments of group attitudes, and dependencies between accounts of individual representation, group representation and linguistic representation. The second phase lays the basis on which interpretations of individuals and groups are selected---individual and joint action, and individual and joint evidence. An account of such facts must be given prior to and independent of belief and desire, on pain of circularity in the overall account. The third phase examines the relation between foundations of representation and metaphysics of persistence---required if the basis for interpretation is to be modally and temporally extended. The fourth shows how key issues in the theory of normative reasons will impact the metaphysics of content, given appeal to reasons responsiveness at the heart of the account. The fifth phase identifies the boundaries between realist and anti-realist accounts of group thought.

Link to the ERC project webpage: https://natureofrepresentation.wordpress.com/

Keywords of the ERC project: Collective intentionality, metasemantics, joint action, group thinking, social ontology

Keywords that characterize the scientific profile of the potential visiting researcher/s:
**Speech Prosody in Interaction: The form and function of intonation in human communication**

Intonation, the modulation of voice pitch, is essential for communication as it conveys information that helps listeners make inferences about the pragmatic intent of the speaker. Despite increased understanding of intonation’s importance, there is little agreement even about essential aspects of its structure and meaning. This is in large part because research has focused either on the form of intonation, often taking a reductive approach to meaning, or has concentrated on meaning but without full scrutiny of form. Crucially, most research has eschewed the study of intonational variability, seeing it as a problem, rather than a natural facet of speech production that needs to be understood and accounted for. Examining all three aspects in tandem is critical for understanding how intonation is structured and functions in communication: considering meaning in the study of intonational form (i.e. phonetics and phonology) can help delimit intonational categories and uncover the limits of within-category variability; in turn, a robust understanding of form will lead to insights into intonational pragmatics. The present proposal will take exactly this integrative approach, based on the PI’s recent research, to examine intonational phenomena attested in English and Greek that have vexed researchers for some time (uptalk, high accents, question tunes). Two varieties per language will be studied, Standard Southern British, Bristol English, Standard Athenian, and Corfiot Greek. Their systematic differences with respect to the phenomena under investigation will allow me to examine cross-linguistic differences, and dialectal variation and its role in communication. The investigation will involve phonetic and pragmatic analysis and modelling, followed by series of behavioural and neurophysiological experiments. Together, these methods will shed light onto the realization, structure and function of intonation, and lead to a robust model of intonational phonology and pragmatics.

**Link to the ERC project webpage:** https://www.amaliaarvaniti.info/sprint  
**Keywords of the ERC project:** linguistics, phonetics, prosody, intonation, pragmatics, English, Greek, individual differences  
**Keywords that characterize the scientific profile of the potential visiting researcher/s:** phonetics, pragmatics, prosody, computational modelling
This project aims to synthesize expertise and insights from the fields of ancient Indian and modern Western linguistics, to enable deeper understanding and innovation in linguistic theory.

An extensive and highly sophisticated linguistic tradition flourished in ancient India between c. 500 BC and 1700 AD. Panini’s grammar the Astadhyayi is often recognized by generative linguists as the earliest generative grammar ever developed, more than 2000 years before Chomsky. Yet beyond this recognition, modern Western linguistics has very little knowledge of the millennia of linguistic insights and analyses developed in India. In the context of the academic enterprise - building on the achievements of our predecessors to advance human knowledge and understanding - this ignorance is a hindrance to the progress of linguistic science. The aims of this project are:

1. To systematically explore and analyse the neglected riches of ancient Indian linguistic thought;
2. To uncover lost linguistic insights and analyses;
3. To build on these insights to create innovative approaches to contemporary issues in modern Western linguistics.

The project will focus on ancient Indian contributions to linguistic thought in three broad areas: morphosyntax and formal language systems, semantics/pragmatics and the philosophy of language, and phonetics/phonology. In all three fields ancient Indian analyses provide new perspectives which challenge standard assumptions of modern Western linguistics.

This project will bring together expertise in modern linguistics and the ancient Indian linguistic tradition, enabling innovative interactions between traditions. This project is challenging, but the potential rewards for modern linguistics are significant. This project aims to be paradigm changing, redefining modern linguistics as a field which can and does draw and build on three thousand years of academic insights, rather than drawing merely on two hundred years of linguistic work in the West.

Link to the ERC project webpage:

Keywords of the ERC project: Sanskrit, Linguistics, Ancient Indian Grammar, Vyakarana

Keywords that characterize the scientific profile of the potential visiting researcher/s: Sanskrit, Ancient Indian Grammar, Vyakarana, Linguistics
Scientific inference is principally a matter of using observable data to estimate the parameters of models of interest, e.g., models of the climate system. In traditional Bayesian statistics, uncertainty about model parameters is quantified using a single, precise probability distribution. This approach has proved extremely successful in applications where data is plentiful and model parameters are few. But many models are high dimensional (thousands of parameters), and relevant data is comparatively sparse. In such contexts, imprecise probabilities are required to adequately capture uncertainty. The mathematical foundations of imprecise probability theory (IP) have been in place for 25 years, and IP has proved successful in practice. But IP methods lack rigorous accuracy-centered, philosophical justifications. Traditional Bayesian methods can be justified using epistemic scoring rules, which measure the accuracy of the estimates that they produce. But there has been little work extending these justifications to the IP framework. Thus, the key aim of the proposed research is to develop scoring rules for IP distributions (IP scoring rules), and use them to justify and extend IP methods. There are four main objectives: (1) characterise reasonable IP scoring rules; (2) derive scoring-rule based justifications for existing IP methods; (3) use IP scoring rules to discover novel methods for selecting and updating IP distributions; (4) use IP scoring rules to engineer new deference and aggregation principles for IP distributions. Objectives 1 and 2 will deliver firm foundations for existing IP methods. Objectives 3 and 4 will extend the range of IP methods available for both individual and group inquiry. The results of this project will not only make IP a central focus in contemporary epistemology, and shape ongoing philosophical debates about IP’s role in inference and decision-making, but also furnish new tools aimed at influencing how IP methods are used in practice.
Identifying Predictors of Risk and Resilience for poor neuropsychological Outcome following childhood Brain Insults (PROBIt)

The impact of insults to the developing brain upon cognition and behaviour has far-reaching consequences for the child, their family, education and health care systems, and government expenditure. Many variables (illness, environmental) contribute to different outcomes following similar insults, and they exert their influence via the child’s developing brain. Predicting which child will recover from early brain insult and identifying those at risk of poor outcome represents a major challenge, with significant health economic implications. An unexplored question is whether direct measurement of the structure and function of the developing brain can improve our ability to predict outcomes in the long-term. Thus, PROBIt aims to assess the utility of brain imaging biomarkers to predict individual neuropsychological and neurobehavioural outcomes following paediatric brain injury, and to identify those factors that combine optimally to classify outcomes. The proposal adopts an unorthodox approach of combining heterogeneous injury groups to explore the structural and functional consequences of perturbing developing brain networks. PROBIt integrates data from clinically relevant paediatric cognitive and behavioural assessment, neuroimaging and computational modelling in large cohorts of children with brain insults. Multivariate pattern analysis will be used to train a statistical classifier to reliably predict individual child outcomes across three core domains: achievement, behaviour and cognitive ability. PROBIt significantly advances our understanding of features that confer risk and resilience to different neurodevelopmental outcomes and has important implications for clinical diagnosis and rehabilitation of children with early brain insults.

Link to the ERC project webpage: https://cordis.europa.eu/project/rcn/205320/en

Keywords of the ERC project: child brain development; machine learning; neuropsychology; brain injury; neuroscience; MRI; neuroimaging; quantitative analysis

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Seeing things you don’t see: Unifying the philosophy, psychology and neuroscience of multimodal mental imagery

When I am looking at my coffee machine that makes funny noises, this is an instance of multisensory perception – I perceive this event by means of both vision and audition. But very often we only receive sensory stimulation from a multisensory event by means of one sense modality. If I hear the noisy coffee machine in the next room (without seeing it), then how do I represent the visual aspects of this multisensory event?

The aim of this research project is to bring together empirical findings about multimodal perception and empirical findings about (visual, auditory, tactile) mental imagery and argue that on occasions like the one described in the last paragraph, we have multimodal mental imagery: perceptual processing in one sense modality (here: vision) that is triggered by sensory stimulation in another sense modality (here: audition).

Multimodal mental imagery is rife. The vast majority of what we perceive are multisensory events: events that can be perceived in more than one sense modality – like the noisy coffee machine. And most of the time we are only acquainted with these multisensory events via a subset of the sense modalities involved – all the other aspects of these events are represented by means of multisensory mental imagery. This means that multisensory mental imagery is a crucial element of almost all instances of everyday perception, which has wider implications to philosophy of perception and beyond, to epistemological questions about whether we can trust our senses.

Focusing on multimodal mental imagery can help us to understand a number of puzzling perceptual phenomena, like sensory substitution and synaesthesia. Further, manipulating mental imagery has recently become an important clinical procedure in various branches of psychiatry as well as in counteracting implicit bias – using multimodal mental imagery rather than voluntarily and consciously conjured up mental imagery can lead to real progress in these experimental paradigms.

Link to the ERC project webpage:

Keywords of the ERC project: Perception, Mental imagery, Attention

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Disagreement is a pervasive feature of human life, which finds linguistic expression in the speech-act of rejection. If you assert that Amsterdam is in Belgium, I can express my dissent by responding 'No', thereby rejecting your assertion.

In the study of human language, assertion has taken centre stage and the investigation of rejection traditionally regarded as a chapter in the study of assertion. Thus, the orthodox treatment of rejection equates it with negative assertion, so that rejecting that Amsterdam is in Belgium is tantamount to asserting that Amsterdam is not in Belgium. However, recent theories of truth have employed a notion of rejection not reducible to negative assertion. Moreover, linguistic evidence shows that rejections and negative assertions have different functions in discourse. So what is rejection? And how does it behave?

The EXPRESS project will articulate a full-fledged theory of rejection as a speech-act not reducible to negative assertion. This theory will be incorporated into extant models of conversation and used to develop a novel logic of rejection faithful to the linguistic phenomena. The basic logical framework is that of a calculus containing formulae accompanied by signs for assertion and rejection. This bilateral framework will be modified to accommodate both weak and strong forms of rejection and extended into a unified multilateral framework capable of also handling weak forms of assertion.

The theory and logical framework developed will be used to establish a novel approach to expressivist semantics which will be applied to the case of negation and epistemic modals. This approach will lead to distinctive hypotheses about language evolution which will be tested using computational methods.

Based at the ILLC and advised by a board of researchers from Europe and the US, EXPRESS will deliver momentous advances in speech-act theory, its logic and semantics.

Link to the ERC project webpage: https://inferentialexpressivism.com/

Keywords of the ERC project:

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Today, five out of ten diseases worldwide resulting in long-term disability are related to the central nervous system. Due to the immense complexity and inter-individual variability of the human mind and brain there are still no effective and side effect free treatment options for many serious neuropsychiatric disorders, such as major depression, dementia or schizophrenia. Recent advancements in sensor technology and computational capacities resulted in the development of brain/neural-machine interfaces (B/NMIs) that translate electric, magnetic or metabolic brain activity into control signals of external devices, robots or machines. Moreover, novel transcranial magnetic and electric brain stimulation (TMS/TES) systems were developed allowing for direct modulation of brain activity. However, current B/NMIs are limited by the low information extraction rate constraining fluent direct brain-machine interaction. Furthermore, as simultaneous assessment of brain oscillations during TES was regarded unfeasible due to stimulation artefacts, current TES systems can only deliver “open-loop” stimulation unrelated to the underlying dynamic brain states resulting in highly variable TES effects. Building on the applicant’s previous work that includes pioneering work on in vivo assessment of brain oscillations during TES (Soekadar et al. 2013, Nature Communications) and full restoration of daily living activities after quadriplegia using a novel B/NMI hand exoskeleton (Soekadar et al. 2016, Science Robotics), the NGBMI project will overcome these limitations by merging both techniques. After developing the first real-time B/NMI-TES system allowing for effective modulation of brain functions and fluent direct brain-machine interaction, the system will be tested in persons with impaired brain function (e.g. depression, dementia or stroke). Finally, the B/NMI-TES paradigm will be implemented in a wireless and wearable EEG-based system that can be used in everyday life environments.

Keywords of the ERC project: Brain-Computer Interface, Brain Stimulation, Quantumsensors

Keywords that characterize the scientific profile of the potential visiting researcher/s: real time signal processing, machine learning, neurophysiology, neural engineering, computational live sciences
Incentive salience in human cognition during health and disorder

Incentive salience is a form of motivation for reward that is triggered by environmental cues. These come to be ‘wanted’: they create an urge or craving for approach and consumption that influences choice and guides action. Stimuli imbued with incentive salience are thought to become salient, attention-drawing, and impossible to ignore, and a leading theory of addiction proposes that drug stimulation of the brain’s reward system may create intense and abnormal incentive salience for drug-related stimuli. Consistent with this, work with animals has linked incentive salience to signaling in mesocorticolumbic brain systems, and the release of nigrostriatal dopamine in particular. But direct investigation of incentive salience in human cognition is sparse, and the application of ideas from animal research to our understanding of human incentive salience has led to pervasive ambiguity and misunderstanding. The objective of INSENSE is therefore to use cutting-edge tools from cognitive neuroscience to a.) characterize the computational and neural substrates of human incentive salience, and b.) determine how failures in these systems underlie addictive human behaviour. This is accomplished through the combined use of techniques like transcranial electrical stimulation, psychopharmacology, electroencephalogram, multivariate pattern analysis of functional magnetic resonance data, and computational modelling in order to index, characterize, and manipulate the neural representation of naturalistic reward-associated stimuli.

Link to the ERC project webpage: www.cognitionlab.org

**Keywords of the ERC project:** EEG, fMRI, incentive salience, reinforcement learning, vision, addiction, attention, memory

**Keywords that characterize the scientific profile of the potential visiting researcher/s:** EEG, fMRI, transcranial stimulation, vision, reinforcement learning, addiction, attention, memory
Worlds of Imagination. A Comparative Study of Film Tourism in India, Brazil, Jamaica, South Korea and the United Kingdom.

This research project focuses on film tourism: the phenomenon of people visiting locations from popular films or TV series. Recent years have seen a dramatic, worldwide increase of this type of tourism, with far-reaching implications for the experience and organization of landscapes. While the number of empirical studies on film tourism is growing, most have been limited to isolated, Western examples. This Western focus tends to overlook the fact that the face of the media industry as well as the tourism industry has been changing rapidly on a global scale.

In order to take the next step and move this field of research to a higher level, a more comparative and cross-case approach is essential. This project aims to do so, by exploring more generic processes and relationships of power involved in the development and experience of film tourism worldwide. The principal question underlying this project is: why, under what conditions and in which ways do films and TV series give rise to new and diverse tourism flows across the globe?

This question is addressed by analysing and comparing film tourism in five geographically and culturally different contexts: South Korea, Brazil, United Kingdom, Jamaica and India. These cases will be subjected to the same lines of inquiry, focusing on 1) the visual traditions in the local media cultures; 2) the effect of local policies aimed at developing film tourism; 3) the commonalities and differences in motives and experiences of film tourists with diverse backgrounds.

This project is groundbreaking in at least three ways: 1) its international and comparative approach delivers a fundamental contribution to a growing but fragmented field of investigation; 2) it will deliver a theorization of the role and importance of imagination in everyday life, based on an elaboration of the concept lieux d’imagination; 3) methodologically, the project is located on the cutting edges of the humanities and social sciences and applies new methods.

Link to the ERC project webpage: www.worldsofimagination.eu

Keywords of the ERC project: media film tourism imagination heritage popular culture

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Respect for diversity has been at the forefront of political accession to the European Union since 1993 and socio-legal scholarship has developed articulated reflections on the accommodation of ethnic and religious minorities in Europe. Country-experts have been instructed with increasing frequency in judicial and pre-judicial proceedings involving members of diasporic communities. In some common law countries the role of the expert witness has expanded to systematically assist the judge when litigants or defendants belong to minorities; in most civil law countries, similar roles are played by translators and cultural mediators, including notaries and lawyers. Cultural expertise is sometimes used in order to avoid excessive judicialisation. Notwithstanding, disbelief is developing around cultural expertise; and, escalations of violence and counter-violence signal that European majority and the so-called minorities are drifting apart. Hence our question: Cultural Expertise in Europe: What is it useful for? A comprehensive assessment of cultural expertise was entrenched by its narrow technical definition. This project develops around a new integrated concept of cultural expertise to empirically investigate its use and impact in fourteen European countries. In-context data will be collected through ethnographic fieldwork conducted by a modular team allowing real time analysis and immediate use of results by the stakeholders. The objectives will be to: 1) map the terms, condition, and costs of cultural expertise in private and public law; 2) create a toolkit for measuring the impact of cultural expertise; 3) establish an open access searchable data base for the consultation of cases and solution including cultural expertise; 4) design a teaching and learning module using the cultural expertise impact toolkit; and 5) formulate policy-making guidelines which include tested solutions for a sustainable inclusiveness in Europe.
Not very long ago, it was still common to hold that little of interest took place in Islamic philosophy, theology and science after the death of the Peripatetic commentator Averroes in 1198. Recent research has produced increasing evidence against this view, and experts now commonly agree that texts from the so-called post-classical period merit serious analysis. That evidence, however, is still fragmentary, and we lack a clear understanding of the large scale and long run development in the various fields of Islamic intellectual culture after the twelfth century.

This project will investigate debates concerning the nature and methods of knowledge in four of the most ambitious strands of Islamic theoretical thought, that is, philosophy, theology, natural science, and philosophically inclined Sufism. Its temporal scope extends from the end of the twelfth century to the beginning of the colonial era, and it focuses on foundational epistemological questions (how knowledge is defined, what criteria are used to distinguish it from less secure epistemic attitudes, what methods are identified as valid in the acquisition of knowledge) as well as questions concerning knowledge as the goal of our existence (in particular, whether perceptual experience is inherently valuable).

Our study of the four strands is based on the hypothesis that the post-classical period is witness to a sophisticated discussion of knowledge, in which epistemic realism, intuitionism, phenomenalism, and subjectivism are pitted against each other in a nuanced manner. Hence, the project will result in a well-founded reassessment of the common view according to which post-classical Islamic intellectual culture is authoritarian and stuck to an epistemic paradigm that stifles insight and creativity. Thereby it will provide new ingredients for projects of endogenous reform and reorientation in Islam, and corroborate the view that our future histories of philosophy should incorporate the Islamic tradition.

Link to the ERC project webpage: www.islamepistemology.com

Keywords of the ERC project: History of philosophy, Islamic philosophy, Islamic science, mediaeval philosophy

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Ethnobotany of divided generations in the context of centralization

Understanding the logics of obtaining, managing and perceiving of local natural resources, particularly plants, is crucial for ensuring sustainability of human life, as the use of plants is a key for survival of humans. The proposed research will create an advanced understanding of the mechanisms of changes in ethnobotanical knowledge experienced by traditional societies/minor ethnic groups when dominating group try to unify and/or erode this practical knowledge. It will also evaluate the effects of the sudden cease to existence of such centralization and following impact of the trial of revival of discontinued traditional ethnobotanical knowledge. Research will evaluate the effect of several social and cultural factors on the evolution of ethnobotanical knowledge of four compact, but divided ethnic minorities that had experienced for shorter (25 years) or longer (70 years) period different influences affecting their plant use and very different social conditions (including welfare and economy). As a long-term outcome, based on the result of present and consequent studies scientists will be able to predict the extent and depth of the changes occurring in the ethnobotanical knowledge and as a applied outcome learn to direct and educate people in the way that the knowledge necessary for sustainable maintenance and utilization of local plant resources will be constantly evolving in the way supporting health and well-being of different populations.

Link to the ERC project webpage: https://www.unive.it/pag/33443

Keywords of the ERC project: ethnobotany, ethnobiology, etnomedicine, ecosemiotics, borders

Keywords that characterize the scientific profile of the potential visiting researcher/s:
The Arctic has risen to global attention in recent years, as it has been reconfigured through debates about global environmental change, resource extraction and disputes over sovereign rights. Within these discourses, little attention has been paid to the cultures of the Arctic. Indeed, it often seems as if the Circumpolar Arctic in global public understanding remains framed as a 'natural region' - that is, a place where the environment dominates the creation of culture. This framing has consequences for the region, because through this the Arctic becomes constructed as a space where people are absent. This proposal aims to discover how and why this might be so.

The proposal argues that this construction of the Arctic emerged from the exploration of the region by Europeans and North Americans and their contacts with indigenous people from the middle of the eighteenth century. Particular texts, cartographic representations and objects were collected and returned to sites like London, Copenhagen, Berlin and Philadelphia. The construction of the Arctic thereby became entwined within the growth of colonial museum cultures and, indeed, western modernity. This project aims to delineate the networks and collecting cultures involved in this creation of Arctic Cultures. It will bring repositories in colonial metropoles into dialogue with sites of collection in the Arctic by tracing the contexts of discovery and memorialisation. In doing so, it aspires to a new understanding of the consequences of certain forms of colonial representation for debates about the Circumpolar Arctic today.

The project involves research by the Principal Investigator and four Post Doctoral Researchers at museums, archives, libraries and repositories across Europe and North America, as well as in Greenland and the Canadian Arctic. A Project Assistant based in Oxford will help facilitate the completion of the research.

Link to the ERC project webpage: https://www.arcticcultures.org/

Keywords of the ERC project: Arctic; cultures; cultural production; archives; histories; museums; indigenous knowledges; decolonial methods

Keywords that characterize the scientific profile of the potential visiting researcher/s: Arctic; cultures; cultural production; archives; histories; museums; indigenous knowledges; decolonial methods
Alchemy in the Making: From ancient Babylonia via Graeco-Roman Egypt into the Byzantine, Syriac and Arabic traditions (1500 BCE - 1000 AD)

The AlchemEast project is devoted to the study of alchemical theory and practice as it appeared and developed in distinct, albeit contiguous (both chronologically and geographically) areas: Graeco-Roman Egypt, Byzantium, and the Near East, from Ancient Babylonian times to the early Islamic Period. This project combines innovative textual investigations with experimental replications of ancient alchemical procedures. It uses sets of historically and philologically informed laboratory replications in order to reconstruct the actual practice of ancient alchemists, and it studies the texts and literary forms in which this practice was conceptualized and transmitted. It proposes new models for textual criticism in order to capture the fluidity of the transmission of ancient alchemical writings. AlchemEast is designed to carry out a comparative investigation of cuneiform tablets as well as a vast corpus of Greek, Syriac and Arabic writings. It will overcome the old, pejorative paradigm that dismissed ancient alchemy as a "pseudo-science", by proposing a new theoretical framework for comprehending the entirety of ancient alchemical practices and theories. Alongside established forms of scholarly output, such as critical editions of key texts, AlchemEast will provide an integrative, longue durée perspective on the many different phases of ancient alchemy. It will thus offer a radically new vision of this discipline as a dynamic and diversified art that developed across different technical and scholastic traditions. This new representation will allow us to connect ancient alchemy with medieval and early modern alchemy and thus fully reintegrate ancient alchemy in the history of pre-modern alchemy as well as in the history of ancient science more broadly.

Link to the ERC project webpage: www.alchemeast.eu

Keywords of the ERC project: history of chemistry, Babylonian proton-chemistry, Graeco-Arabic alchemy, modern replications

Keywords that characterize the scientific profile of the potential visiting researcher/s:
In the medieval Eurasian geopolitical space, Byzantium and China stand out as two centralised imperial orders that drew on seemingly unbroken, in fact purposely constructed, traditions of classicising learning. PAIXUE examines in tandem, with equal focus on structural parallels and divergences, the conscious revival and subsequent dialectics of classicising learning in middle and later Byzantium (c.800–1350) and Tang/Song China (618–1279). Initially tied into aristocratic culture, it became a tool by which the imperial state sought to monopolise prestige and access to power so as to effectively channel the activities of newly emerging burgeoning ‘middling’ strata into the service of empire. As time progressed, it was also the basis upon which these new elites constructed novel forms of subjectivity that claimed authority and agency increasingly independent of the imperial state.

PAIXUE traces this evolution of classicising learning in Byzantine and Tang/Song literati culture from two angles. The rst examines the galvanising function of social performances that involved classicising learning in the imperial systems. The second places the individual literatus centre-stage and explores the transformations of self-awareness, ethos, and self-cultivation. Given PAIXUE’s concern with examining phenomena cross-culturally in the longue-durée, rather than merely juxtaposing ‘spotlight’ impressions, a comparison of these two imperial systems does not only allow for deeper insights into the historical development of both China and Byzantium: it opens the possibility of studying cultural mechanisms behind the formation of institutions, practices and values. The project explores novel forms of collaboration in the humanities, including the co-authoring of research output between Byzantinists and Sinologists. Byzantium, frequently perceived as the ‘Other’ within western culture to the present day, serves here to build meaningful bridges to (pre-modern) China.

Link to the ERC project webpage: http://paixue.shca.ed.ac.uk/

Keywords of the ERC project: Byzantium, China, Learning, Imperial Systems, Cross-cultural, Cross-disciplinary

Keywords that characterize the scientific profile of the potential visiting researcher/s: Innovative and interested in cross-cultural approaches
Honour in classical Greece: esteem, status, identity, and society in ancient Greek literature, life, and thought

If ‘honour’ is an outmoded term, its modern analogues – esteem, respect, recognition, dignity, status, prestige, deference, face, image, etc. – still shape the dynamics of human social interaction. But modern understandings of honour in the societies and literatures of the past – especially the literature of ancient Greece – tend to present it as a single, specific, and more or less monolithic notion especially associated with zero-sum competition between alpha-males, a notion that is typically superseded by more co-operative, inclusive, and egalitarian values, whether in fifth-century BC Athenian democracy or in the eighteenth-century AD enlightenment. Where honour survives in popular perception as a characteristic of modern communities it is typically ghettoized in the world of inner-city gangs, in the Muslim East, or in the traditional machismo of the Mediterranean.

These and similar perceptions are erroneous, and their application to ancient Greek literature, society, and thought is deeply misleading. Using the findings of contemporary sociology and philosophy, with contributions from other disciplines from economics to literary studies, cognitive linguistics, and psychology, this project will lead to a root and branch transformation of the idées fixes that still mould the understanding of honour (Greek timê) in our ancient Greek sources. Far from being one value among many, timê is a pluralist, inclusive, and flexible notion, as important to ancient values of justice, friendship, and social solidarity as it is to the violence of heroic self-assertion and the pursuit of vengeance. It underpins not only the wrath of Achilles in the Iliad but also the community standards that seek to restrain and assuage that wrath. In Athenian law and politics it is as much about the rights that the law protects as it is about the pursuit of rivalry and competition through litigation. It pervades ancient Greek literature, thought, and society. This project will write its history.

Link to the ERC project webpage:

Keywords of the ERC project: ancient Greek society and history

Keywords that characterize the scientific profile of the potential visiting researcher/s: Classics, Greek, social history, emotion, history
Children in Comics: An Intercultural History from 1865 to Today

Owing to their visual essence and status as a popular, modern medium, comics – newspaper strips, comics magazines and graphic novels – provide valuable insight into the transformation of collective consciousness. This project advances the hypothesis that children in comics are distinctive embodiments of the complex experience of modernity, channeling and tempering modern anxieties and incarnating the freedom denied to adults. In testing this hypothesis, the project constructs the first intercultural history of children in European comics, tracing the changing conceptualizations of child protagonists in popular comics for both children and adults from the mid-19th century to the present. In doing so, it takes key points in European history as well as the history of comics into account.

Assembling a team of six multilingual researchers, the project uses an interdisciplinary methodology combining comics studies and childhood studies while also incorporating specific insights from cultural studies (history of family life, history of public life, history of the body, affect theory and scholarship on the carnivalesque). This enables the project to analyze the transposition of modern anxieties, conceptualizations of childishness, child-adult power relations, notions of liberty, visualizations of the body, family life, school and public life as well as the presence of affects such as nostalgia and happiness in comics starring children.

The project thus opens up a new field of research lying at the intersection of comics studies and childhood studies and illustrates its potential. In studying popular but often overlooked comics, the project provides crucial historical and analytical material that will shape future comics criticism and the fields associated with childhood studies. Furthermore, the project’s outreach activities will increase collective knowledge about comic strips, which form an important, increasingly visible part of cultural heritage.

Link to the ERC project webpage: https://www.comics.ugent.be/

Keywords of the ERC project: comics, childhood, cultural history, comics magazines

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Manuscripts which contain commentary alongside the biblical text are some of the most significant and complicated witnesses to the Greek New Testament. First compiled around the fifth century, the commentaries consist of chains of extracts from earlier writers (catenae). These manuscripts became the main way in which users encountered both the text and the interpretation of the New Testament; revised editions produced in the eleventh and twelfth centuries continued to hold the field until the invention of printing. Recent advances have shown that commentary manuscripts play a much more important role than previously thought in the history of the New Testament. The number of known copies has increased by 20% following a preliminary survey last year which identified 100 additional manuscripts. A recent comprehensive textual analysis of the Catholic Epistles indicated that all witnesses from the third generation onwards (some 72% of the total) could stem from the biblical text of three commentary manuscripts occupying a key place in the textual tradition. Investigation of the catena on Mark has shown that the selection of extracts could offer a new approach to understanding the theology of the compilers and the transmission of the commentaries.

The CATENA Project will use digital tools to undertake a fuller examination of Greek New Testament commentary manuscripts than has ever before been possible. This will include an exhaustive survey to establish a complete list of witnesses; a database of extracts to examine their principles of organisation and relationships; and electronic transcriptions to determine their role in the transmission of the biblical text. The results will have a direct impact on editions of the Greek New Testament, providing a new understanding of its text and reception and leading to broader insights into history and culture.
Project ID: 771292  
Project Acronym: LUDEME  
Evaluation Panel: SH5  
Cultures and Cultural Production

Principal Investigator: Dr CAMERON BROWNE  
Host Institution: UNIVERSITEIT MAASTRICHT - NL

The Digital Ludeme Project: Modelling the Evolution of Traditional Games

The development of games goes hand in hand with the development of human culture. Games offer a rich window of insight into our cultural past, but early examples were rarely documented and our understanding of them is incomplete. While there has been considerable historical research into games and their use as tools of cultural analysis, much is based on the interpretation of partial evidence with little mathematical analysis. This project will use modern computational techniques to help fill these gaps in our knowledge empirically.

I will represent games as structured sets of ludemes (units of game-related information), which will allow the full range of traditional strategy games to be modelled in a single software system for the first time. This system will not only model and play games, but will evaluate reconstructions for quality and authenticity, and automatically improve them where possible. This will lay the foundations for a new field of study called digital archaeoludology, which will involve addressing technical challenges that could yield significant benefits in their own right, particularly in artificial intelligence.

The ludemic model reveals innate mathematical relationships between games, allowing phylogenetic analysis. This provides a mechanism for creating a family tree/network of traditional games, which could reveal missing links and allow ancestral state reconstruction to shed light on the gaps in our partial knowledge. Locating ludemes culturally provides a mechanism for creating interactive maps that chart the transmission of mathematical ideas across cultures through play. This project seeks to bridge the gap between historical and computational studies of games, to provide greater insight into our understanding of them as cultural artefacts, and to pioneer new tools and techniques for their continued analysis. The aim is to restore and preserve our intangible cultural heritage (of game playing) through the tangible evidence available.

Link to the ERC project webpage: http://ludeme.eu/index.html

Keywords of the ERC project: artificial intelligence; traditional games; cultural heritage; computational phylogenetics; digital archaeoludology

Keywords that characterize the scientific profile of the potential visiting researcher/s: games; puzzles; machine learning; deep learning; history of mathematics
Global Horizons in Pre-Modern Art

The horizon is the line that seems to separate earth from sky, the line that divides all visible categories into two categories: those that intersect the earth’s surface and those that do not. The horizon is key to the experience of space; it defines our perspective on the visible world. The GLOBAL HORIZONS project will investigate the historical meanings and functions of the horizon in visual and intellectual cultures of the pre-Modern world on a global scale. Examining how pre-Modern cultures conceived of the horizon opens a crucial line of inquiry into understanding the many different ways in which humans have conceived of the relationship between an invisible cosmos and the visible world.

Non-western art history is rarely taught at European institutions although countless important works of Non-Western art are kept in museum collections all across Europe. Including non-western concepts of pictorial space is key to the project, however, for Eurocentric models of art history have generally privileged the rise of the linear perspective. This framing has limited our understanding of the horizon’s complex rhetorical, visual and epistemological roles.

The project’s specific question connects a variety of objects and epistemological categories, such as panel painting, manuscript illumination, profane und religious objects, cartography, travel accounts, and cosmological treaties. The applied methodological approaches will range from art history, visual studies and cultural anthropology. They will also draw upon interdisciplinary expertise, such as technologies of art production, history of science and philosophy. The project thus makes an important contribution to global art history, a highly innovative area in which only very few pre-modern topics have been addressed. It is the ultimate goal of GLOBAL HORIZONS is to suggest a new history of representation in Western medieval art.

Link to the ERC project webpage: www.global-horizons.ch

Keywords of the ERC project: art history, medieval art, horizons, history of representation, historiography, global/world art history

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Machine Vision in Everyday Life: Playful Interactions with Visual Technologies in Digital Art, Games, Narratives and Social Media

In the last decade, machine vision has become part of the everyday life of ordinary people. Smartphones have advanced image manipulation capabilities, social media use image recognition algorithms to sort and filter visual content, and games, narratives and art increasingly represent and use machine vision techniques such as facial recognition algorithms, eye-tracking and virtual reality.

The ubiquity of machine vision in ordinary peoples’ lives marks a qualitative shift where once theoretical questions are now immediately relevant to the lived experience of ordinary people.

MACHINE VISION will develop a theory of how everyday machine vision affects the way ordinary people understand themselves and their world through 1) analyses of digital art, games and narratives that use machine vision as theme or interface, and 2) ethnographic studies of users of consumer-grade machine vision apps in social media and personal communication. Three main research questions address 1) new kinds of agency and subjectivity; 2) visual data as malleable; 3) values and biases.

MACHINE VISION fills a research gap on the cultural, aesthetic and ethical effects of machine vision. Current research on machine vision is skewed, with extensive computer science research and rapid development and adaptation of new technologies. Cultural research primarily focuses on systemic issues (e.g. surveillance) and professional use (e.g. scientific imaging). Aesthetic theories (e.g. in cinema theory) are valuable but mostly address 20th century technologies. Analyses of current technologies are fragmented and lack a cohesive theory or model.

MACHINE VISION challenges existing research and develops new empirical analyses and a cohesive theory of everyday machine vision. This project is a needed leap in visual aesthetic research. MACHINE VISION will also impact technical R&D on machine vision, enabling the design of technologies that are ethical, just and democratic.

Link to the ERC project webpage: https://www.uib.no/en/machinevision

Keywords of the ERC project: humanities, aesthetics, algorithms, digital humanities, machine vision, social media, art, narratives, games, internet studies, datafication, digital culture

Keywords that characterize the scientific profile of the potential visiting researcher/s: digital humanities, anthropology, sociology, art history, literary studies, distant reading, internet studies, visual studies, cultural studies, electronic literature,
The belief that ‘the end of music is to move human affections’ (Descartes, Compendium musicae) has been a central issue in European musical thought since Plato. Opera was invented to recover the power of Ancient music to move the human heart, and its history is a permanent exploration of the capacity of action, words and music to convey emotions.

In the eighteenth century a new type of opera consolidated with the chief concern of expressing the character’s emotions as they changed throughout the drama, inspired by Descartes’ theory of human passions. The key expressive medium was the aria col da capo, where a single, distinct passion was represented, like a concentrated pill of emotional meaning. The ideal corpus to study this issue are the 900 operas set to music by 300 composers on the 27 dramas by Pietro Metastasio (1698-1782). It contains a comprehensive catalogue of emotions in music, a unique window of opportunity to scrutinize conventions that defined music expression and meaning for over a century, paving the way for the emergence of ‘absolute’ instrumental music, autonomous from any other art form.

DIDONE presents an innovative approach to unveil these conventions: the creation of a corpus of 4,000 digitized arias from 200 opera scores based on Metastasio’s eight most popular dramas, to be analysed using traditional methods and big data computer technology. The comparative scrutiny of dozens of different musical settings of the same librettos will reveal how composers correlate specific dramatic circumstances and emotions with distinct poetic and musical features. The results will be applicable to three main fields: (i) opera performance; (ii) analysis and interpretation of other types of music; and (iii) composition in several scenarios, from film soundtracks to creation by Artificial Intelligence. An opera festival will be designed to recover and disseminate this hitherto ignored repertoire, which was essential to define the European musical identity.

Link to the ERC project webpage: http://www.didone.eu/

Keywords of the ERC project: emotions, opera, digitizing, music information retrieval, music analysis

Keywords that characterize the scientific profile of the potential visiting researcher/s: music information retrieval, music analysis, 18th-century opera, music philology, corpus analysis
The normalisation of natural philosophy: how teaching practices shaped the evolution of early modern science

Early modern natural philosophy underwent dramatic transformations that completely reshaped its conceptual framework and set of practices. The main contention of my ERC project is that teaching practices had a decisive and ‘normalising’ impact on the progressive dissemination, adaptation and selection of rival conceptions of natural philosophy. Normalisation occurs when historical actors collectively present certain tenets as crucial for the study of a discipline, and thus prescribe them as a necessary subject for teaching and learning.

The overall aim of this ERC project is to determine and explain how the process of normalisation embedded in teaching practices shaped the evolution of early modern natural philosophy. To study normalisation, it is necessary to operate a systematic comparative investigation of hundreds of works through which natural philosophy was taught, learned and reshaped, both within and outside universities. The size of this corpus defies the traditional method of close reading used by historians of philosophy and science. I will meet this challenge by organically integrating close reading with digital ‘distant reading’. I will digitally transcribe a corpus of approximately 500 early modern works on natural philosophy, published in Britain, France and the Dutch Republic. Using digital tools to investigate how the networks of authors and concepts of natural philosophy co-evolved over time will allow me to identify textual excerpts that are representative of historical trends. By analysing these excerpts with close reading and assessing them against the digital results, I will determine and explain how normalisation shaped the evolution of natural philosophy.

This project will boost the integration of digital approaches in the history of philosophy and science by producing a newly digitised corpus, tools customized for analysing early modern texts, and methodological reflections on their implementation.

Link to the ERC project webpage: https://www.rug.nl/filosofie/organization/departments/history/gcmemt/research-projects/andrea-sangiacomo

Keywords of the ERC project: natural philosophy, digital humanities, history of philosophy, history of science, history of ideas

Keywords that characterize the scientific profile of the potential visiting researcher/s: natural philosophy, digital humanities, history of philosophy, history of science, history of ideas
Jewish Translation and Cultural Transfer in Early Modern Europe

Contemporary scholarship has often envisioned modernity as a kind of immense cultural earthquake, originating somewhere in western or central Europe, and then gradually propagating throughout the continent. This massive upheaval is said to have shaken the very foundations of every culture it frequented, subsequently eliminating the world which once was, to make way for a new age. This project offers a new understanding of modernization, not as a radical break with tradition, but as the careful importation of new ideas by often timid, almost inadvertent innovators. The project focuses on the rich corpus of translations of non-Jewish texts into Jewish languages, which developed during the early modern period. Largely neglected by modern scholars, these translations played a pivotal role in fashioning Jewish culture from the sixteenth century into modern times.

Jewish translators were never merely passive recipients of their non-Jewish sources; they mistranslated both deliberately and accidentally, added and omitted, and harnessed their sources to meet their own unique agendas. Throughout the process of translation then, a new corpus was created, one that was distinctly Jewish in character, but closely corresponded with the surrounding majority culture.

JEWTACT offers the first comprehensive study of the entire gamut of these early modern Jewish translations, exposing a hitherto unexplored terrain of surprising intercultural encounters which took place upon the advent of modernity—between East and West, tradition and innovation, Christians and Jews. The project posits translation as the primary and most ubiquitous mechanism of Christian-Jewish cultural transfer in early modern Europe. In so doing, I wish to revolutionize our understanding of the so-called early modern “Jewish book,” revealing its intensely porous, collaborative and innovative nature, and to offer a new paradigm of Jewish modernization and cultural exchange.

Link to the ERC project webpage: www.jewtact.com

Keywords of the ERC project:

Keywords that characterize the scientific profile of the potential visiting researcher/s:
In folk psychology and in bioethical discussions, the central dogma of genetics is often taken for granted: humans are seen as defined in a genetic blueprint. The conceptualization of psychiatric conditions as innate or acquired, biological or psychosocial, genetic or environmental, influences the ascription of both capacity responsibility (the capacity to adapt or adjust one’s own behavior) and normative responsibility of individuals or the society towards those diagnosed. But findings in the field of epigenetics indicate that the social and physical environment influence how genes are expressed. Indeed, epigenetics may shed a new light on distinctions such as innate/acquired, genetic/environmental, biological/psychosocial: a far more complex view on neurodevelopmental disorders may emerge, with ethical implications. However, the implications of epigenetics for discussions on the scope and extent of normative responsibility have not been adequately addressed.

NEUROEPIGENETHICS aims to investigate the ethical implications of epigenetics for neurodevelopmental disorders. We will use theoretical and empirical methods to investigate how certain concepts (innate/biological/genetic) affect the ways in which professionals and stakeholders (persons with a neurodevelopmental disorder and their families) conceive of responsibility. We will evaluate how the emerging field of epigenetics alters the ascription of capacity responsibility and normative responsibility. We will research how individuals with Autism Spectrum Disorder (ASD), Tourette Syndrome (TS) and Attention Deficit Hyperactivity Disorder (ADHD) and their families experience the interaction between their condition and their biological and social environment. Finally, we will define moral responsibility in light of the emerging field of epigenetics in the area of neurodevelopmental disorders and child psychiatric practice.

Link to the ERC project webpage: http://www.neuroepigenethics.com/

Keywords of the ERC project: ethics, epigenetics, development, autism, ADHD, Tourette, philosophy of biology, disability studies

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Deep uncertainties in bioethics: genetic research, preventive medicine, reproductive decisions

Uncertainty is everywhere, as the saying goes, but rarely considered in ethical reflections. This project aims to reinterpret ethical discussions on current advances in biomedicine: instead of understanding bioethical positions as extensions of classical normative views in ethics (consequentialism, deontologism, contractualism etc.), my project interprets them more accurately as involving various normative approaches to decision making under uncertainty. The following hard cases in bioethics provide the motivation for research:

1) Regulating scientific research under uncertainty about the ontological/moral status (e.g. parthenogenetic stem cells derived from human parthenotes) in the context of meta-reasoning under normative uncertainty.
2) The value of preventive medicine in healthcare (e.g. vaccinations) in the context of decision-making under metaphysical indeterminacy.
3) Population or reproductive decisions (e.g. preimplantation genetic diagnosis) in the context of valuing mere existence.

The main drive behind this project is the rapid progress in biomedical research combined with new kinds of uncertainties. These new and “deep” uncertainties trigger specific forms of emotions and cognitions that influence normative judgments and decisions. The main research questions that will be addressed by conceptual analysis, new psychological experiments, and case studies are the following: how do the heuristics and biases (H&B) documented by behavioral scientists influence the formation of normative judgments in bioethical contexts; how to demarcate between distorted and undistorted value judgments; to what extent is it permissible for individuals or policy makers to yield to H&B. The hypothesis is that many existing bioethical rules, regulations, practices seem to have emerged from unreliable reactions, rather than by means of deliberation on the possible justifications for alternative ways to decide about them under several layers and types of uncertainty.

Link to the ERC project webpage: https://incet.uj.edu.pl/

Keywords of the ERC project: ethics, bioethics, uncertainty, risk, philosophy of science, moral psychology

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Classical Influences and Irish Culture

The hypothesis of this project is that Ireland has a unique and hitherto underexplored history of cultural engagement with models from ancient Greece and Rome. Unlike Britain and mainland Europe, Ireland was never part of the Roman Empire. Yet the island has an extraordinarily vibrant tradition of classical learning that dates back to its earliest recorded literature, and is unparalleled in other northern European countries. Research for this project will address why this is the case, by examining sources through nine significant diachronic themes identified by the PI: language; land; travel and exile; Troy; satire; Neoplatonism; female voices; material culture; and global influence. This multi-thematic approach will enable analysis of what is remarkable about classical reception in Ireland. It will also provide a heuristic framework that generates dialogue between normally disparate fields, such as classical reception studies, Irish and British history, English-language literature, Irish-language literature, medieval studies, postcolonial studies, philosophy, material culture, women’s studies, and global studies. The project will engage with contemporary preoccupations surrounding the politics and history of the divided island of Ireland, such as the current decade of centenary commemorations for the foundation of an independent Irish state (1912-1922, 2012-2022), and the on-going violence and political divisions in Northern Ireland. These issues will serve as a springboard for opening new avenues of investigation that look far beyond the past 100 years, but are linked to them. The project will thus shed new light on the role of classical culture in shaping literary, social, and political discourse across the island of Ireland, and throughout its history.

Link to the ERC project webpage: http://clic.au.dk/

Keywords of the ERC project: classical reception; Irish studies

Keywords that characterize the scientific profile of the potential visiting researcher/s:
REAL opens up new perspectives in moral and political philosophy by closing the rift between analytical theories of rights and egalitarian theories of distributive justice. There is a perception in both the academic and public discourse that pursuing egalitarian economic policies is incompatible with a commitment to rights. Socialist thinkers have traditionally been sceptical of rights, and contemporary egalitarian theories are often silent about them. At the same time, theories that take rights seriously either neglect the distributive dimension or suggest that egalitarian redistribution may infringe on individual rights. Egalitarianism and rights thus appear to be inhospitable to each other. This project seeks first, to understand what explains this divide and second, to demonstrate that it can be bridged.

REAL is motivated by the thought that a theory of justice, including economic justice, would be more action-guiding if it could translate its recommendations into moral and subsequently legal rights. It thus aims to show that egalitarianism is not only compatible with a commitment to rights but that they are mutually supportive. The project has three main objectives:

- to refute the idea that the concept of rights rules out egalitarian commitments
- to uncover the reasons why egalitarianism is inhospitable to rights and show that they are inconclusive
- to propose a rights-friendly egalitarian theory of justice

The project will critically examine theories of rights and egalitarian theories of justice and adopts an analytical approach that blends arguments from political and legal philosophy, normative ethics and axiology in order to provide a novel and solid framework that integrates the two and advances current debates in these areas.

**Rights and Egalitarianism**

**Link to the ERC project webpage:**

**Keywords of the ERC project:** egalitarianism, human rights, cosmopolitanism

**Keywords that characterize the scientific profile of the potential visiting researcher/s:** political philosophy, legal theory, rights, distributive justice, global justice
Face Aesthetics in Contemporary E-Technological Societies

FACETS studies the meaning of the face in contemporary visual cultures. There are two complementary research foci: widespread practices of face exhibition in social networks like Facebook, Instagram, Snapchat, and Tinder; and minority practices of occultation, including the mask in anti-establishment political activism (e.g., Anonymous) and in anti-surveillance artistic provocation (e.g., Leonardo Selvaggio). Arguably, the meaning of the human face is currently changing on a global scale: through the invention and diffusion of new visual technologies (e.g., digital photography, visual filters, as well as software for automatic face recognition); through the creation and establishment of novel genres of face representation (e.g., the selfie); and through new approaches to face perception, reading, and memorization (e.g., the ‘scrolling’ of faces on Tinder). Cognitions, emotions, and actions that people attach to the interaction with one’s and others’ faces might soon be undergoing dramatic shifts. In FACETS, an interdisciplinary but focused approach combines visual history, semiotics, phenomenology, visual anthropology, but also face perception studies and collection, analysis, and social contextualization of big data, so as to study the cultural and technological causes of these changes and their effects in terms of alterations in self-perception and communicative interaction. In the tension between, on the one hand, political and economic agencies pressing for increasing disclosure, detection, and marketing of the human face (for reasons of security and control, for commercial or bureaucratic purposes) and, on the other hand, the counter-trends of face occultation (writers and artists like Banksy, Ferrante, Sia, or Christopher Sievey / Frank Sidebottom choosing not to reveal their faces), the visual syntax, the semantics, and the pragmatics of the human face are rapidly evolving. FACETS carries on an innovative, cross-disciplinary survey of this phenomenon.

Link to the ERC project webpage:

Keywords of the ERC project: Face; Representations; Digital Cultures; Facial Recognition; Artificial Intelligence; Semiotics

Keywords that characterize the scientific profile of the potential visiting researcher/s: Face studies; Visual Semiotics; Visual Studies; Digital Philosophy
Rewriting Global Orthodoxy Oriental Christianity in Europe between 1970 and 2020

Over the last fifty years, Oriental Orthodox Christians (Armenians, Copts, Syriacs/Arameans, Ethiopians and Eritreans) from the Middle East and Africa have settled in Europe, fleeing war-related violence and societal pressures. One of the prominent aspects of religious practice of these transnational Oriental communities is their strong emphasis on the writing and publishing of texts. These include traditional religious texts (from liturgy to history), re-translated and re-contextualized texts, and completely new texts. From simple leaflets and books to sophisticated internet productions where text is persuasively embedded in sound and image, these textual practices aim to transmit the religious heritage to a new generation in an increasingly globalized context.

Scholarship has largely ignored these texts, being too popular or too modern for scholars of the written religious traditions and too textual for social scientists working on these transnational communities, even though they make up a crucial source for the study of these communities’ European integration, especially as to the hybrid character of many of these traditions, among Oriental and Eastern Orthodox Christianities, and among European and global Christianity. Unfortunately, the popular nature of these texts, whether published on paper or digitally, threatens their long-term survival.

The project takes these textual practices as its main source to understand how these Oriental Christians inscribe themselves in European societies and so contribute not only to the transformation of their own transnational churches but also to that of Orthodoxy worldwide. It hypothesizes that diachronic and synchronic comparison among Oriental and Eastern Orthodox churches will show that this rewriting includes the actualization of their religious heritage vis-à-vis ethnic and national self-definitions, vis-à-vis European society, and vis-à-vis other churches, particularly Orthodox ones.

Link to the ERC project webpage:

Keywords of the ERC project: global orthodoxy; oriental churches; migration; Europe; language; literature; texts; textual practices

Keywords that characterize the scientific profile of the potential visiting researcher/s: migration studies; religious studies/theology; Syriac/Coptic/Armenian/Ethiopian Studies
The problem this project addresses is that operative modes for interpreting the Greek New Testament (NT) rely upon critical editions, not manuscripts. NT editions are scholarly abstractions that focus on reconstructing an “original” text, and that fail to account for a rich manuscript tradition that preserves evidence for key disciplinary questions. Instead of asking how manuscripts help reconstruct a text, this project examines what manuscripts say about the ways the NT was interpreted by the communities that produced them. This is accomplished by comprehensively analysing the forms and wordings of the title preserved in all non-lectionary NT manuscripts (c. 3500). Titles are malleable paratexts that provide a substantive vector to rethink approaches to the NT by seriously considering contexts of production and interpretation ranging from 2nd century Egypt to modern Mt. Athos, moving beyond the 1st century Roman world. Titles demonstrate that material and paratextual variance in form and design are constitutive aspects of the NT. Adopting New Philology as a methodology, the project critiques dominant approaches by taking each manuscript seriously as evidence for specific reading events, using titles as primary evidence. Titular analysis informs a range of topics, including authorship, locales of production, contexts of use, bibliography, and literary interpretation. The NT is best understood as an omnibus of manuscripts that constitute specific reading events, reflecting the interpretations of the communities that used them. The NT has never been a single reconstructed text, but a collection of texts in specific material and paratextual contexts. Despite the value inherent in the manuscripts, scholarship has focused almost exclusively on the NT’s original context of composition. Resisting this trend, the project argues that titles are a rich resource for mapping the interpretation of the NT in contexts overlooked by critical scholarship: its own manuscript matrix.
This project investigates future fictions from five distinct traditions: Afrofuturism, Sinofuturism, Arab/Gulf-futurism, Latin@futurism, and Indofuturism. All these fictions respond to the burning issues of the present, the transnational discourses of demographic change, climate change, and technological change, but they imagine different, localized ways of engaging with these transnational discourses.

Research Questions
What contributions can contemporary future fictions make to our understanding of global issues?

The project is split into three sub-questions to structure the enquiry:
1. What are the cultural and scientific bases for the development of different geography based future fictions?
2. What are the future changes – societal and technological – imagined in these future fictions?
3. How can we understand the response to global challenges – demographic change, climate change and technological change – in the local changes imagined in these futures?

Based on this, the project will develop a theory of "COFUTURES" (Co: Complex –Coexisting –Comparative).

Context
The project studies the recent proliferation of fiction based on ethnic, cultural, or national identity as take-off points for imagining possible futures even if their locations of production are globally spread. While many of these have older histories, these fictions have come together in this decade as alternative visions of the future that are resistant to perceived colonial or neo-colonial hegemony and are read as new forms of self-assertion.

No methodologies have been developed to study all these together as shared phenomena, and no theories exist that can even make sense of them as similar yet distinct phenomena. There have also been no attempts to understand the specific sources for these futures in terms of the kinds of scientific and technological developments they project and the societal developments they imagine as localized responses to global challenges. This is the COFUTURES aim.

Link to the ERC project webpage: https://cordis.europa.eu/project/rcn/225510/factsheet/en?WT.mc_id=RSS-Feed&WT.rss_f=project&WT.rss_a=225510&WT.rss_ev=a

Keywords of the ERC project: Science Fiction, Global Science Fiction, Cultural Studies, Science and Technology Studies, Innovation Studies, Futures Studies, Games Studies, Video Games

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Papyri and Latin Texts: INSights and Updated Methodologies.
Towards a philological, literary, and historical approach to Latin papyri

The aim of PLATINUM is to scrutinize Latin texts on papyrus from several points of view in order to highlight their substantial contribution to our knowledge of innovations in ancient Roman literature, language, history, and society, especially in the multilingual and multicultural contexts of the Eastern part of the Empire between the 1st century B.C. and 8th century A.D. The first phase of the project will consist in assembling, updating and publishing critical editions, in order to present a new and more accurate corpus of Latin papyri on an easily accessible online platform. The second phase will be focused on providing the texts with a specific, pluridisciplinary commentary that gives new insights on Roman culture.

Coming mainly from Egypt and other Roman provinces (as well as Herculaneum and Ravenna), Latin papyri deserve more scholarly attention not only from papyrologists and paleographers, but also from scholars of Latin language, as well as intellectual and cultural historians of Rome. Latin papyri, tablets, and ostraka (potsherds) are constantly increasing in number through archaeological discoveries. Because they are so rare, they are even more valuable than the Greek papyri, which have garnered much attention. The Latin papyri have hitherto represented a border-line field of study that has not been fully exploited either by papyrologists or by scholars of Latin literature. Moreover, the obsolete bibliography and the considerable number of unpublished texts make the study of Latin papyri (and bilingual Latin-Greek, Latin-Coptic, Latin-Punic texts) - whether literary (e.g. Cicero, Vergil, law), paraliterary (grammar, medicine, magic), or documentary (letters, official registers, receipts) – a pioneering and challenging task. A more through study will reveal the untapped potential of Latin texts on papyrus for renewing our knowledge of the circulation and reception of Latin language and education, as a cultural engine in Mediterranean societies.

Link to the ERC project webpage: https://platinum-erc.it

Keywords of the ERC project: Classics, Latin, Papyri, Ancient Multilingualism, Ancient Multiculturalism, Ancient Literature

Keywords that characterize the scientific profile of the potential visiting researcher/s:

Developing Theatre: Building Expert Networks for Theatre in Emerging Countries after 1945

This research project proposes a fundamental re-examination of the historiography of theatre in emerging countries after 1945. It investigates the institutional factors that led to the emergence of professional theatre in the post-war period throughout the decolonizing world. The particular focus will be on the massive involvement of internationally coordinated ‘development’ and ‘modernization’ programs both East and West. The project will introduce the concepts of epistemic community, expert networks and techno-politics to theatre historical research as a means to historicize theatre within transnational and transcultural paradigms and examine its imbrication in globalization processes. This institutional and transnational approach will enable theatre studies to overcome its still strong national and local focus on plays and productions and connect it to current discourses on transnational history.

The main objectives of this project are to:

- examine how a global ‘epistemic community’ centred around theatre emerged in the post-war period;
- investigate how ‘expert networks’ composed of government bodies, private foundations, transnational corporate philanthropy, local elites and individual artists sought to institutionalize particular forms and practices of professional theatre as an interconnected, transnational phenomenon;
- develop a new interdisciplinary approach to theatre historiography by focusing on institutional structures, path dependencies and transnational imbrications rather than on works and authors.

The principal investigator will bring to this project two decades of internationally recognized research into intercultural and global theatre. With its combination of institutional historiography and innovative research methods the project will provide a new foundation for current discussions of cultural policy and sustainability in emerging societies.

Link to the ERC project webpage: http://developing-theatre.de

Keywords of the ERC project: postcolonial theatre history, development, philanthropy,

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Narrating the Mesh: Ecology and the Non-Human in Contemporary Fiction and Oral Storytelling

Today’s ecological crisis prompts us to rethink our attitude towards physical and natural realities that have traditionally been seen as opposed to human subjectivity and agency. What emerges from this “non-human turn” is a sense of our interdependence on things like the bacteria in our intestines or the carbon atoms supporting life on Earth. Ecological theorist Timothy Morton uses the metaphor of the “mesh” to express this idea of human/non-human interconnectedness. This project will map the formal and thematic strategies through which contemporary narrative practices engage with the non-human and envisage this interconnectedness.

Storytelling is an indispensable tool for making sense of experience by establishing temporal and causal relations. But it is also biased towards the human-scale realities of action and social interaction. How can narrative overcome this bias? How does it convey phenomena that challenge our belief in the ontological and material self-sufficiency of the human?

Comparing fictional narratives in print (novels and short stories) and conversational storytelling, we will systematically explore the ways in which narrative can forge connections across levels of reality, weaving together the human and the non-human into a single plot. The assumption is that narrative is a field where fictional practices are in constant dialogue with the stories told in everyday conversation—and with the culture-wide beliefs and concerns those stories reflect.

Through its three sub-projects, the proposed research charts this complex dialogue while greatly advancing our understanding of how stories can be used to heighten people’s awareness of the mesh and its significance. The project builds on a combination of methods (close readings of novels, qualitative analysis of interviews), aiming to open up a new field of study at the intersection of literary scholarship and the social sciences—with narrative theory serving as a catalyst for the interdisciplinary exchange.

Link to the ERC project webpage: http://www.narmesh.ugent.be/

Keywords of the ERC project: ecological crisis, contemporary fiction, science and literature, narrative theory

Keywords that characterize the scientific profile of the potential visiting researcher/s:
The Metaphysical Unity of Science

The Metaphysical Unity of Science project will pursue the question of what, if anything, unifies the natural sciences. The project studies the question from the perspective of metaphysics and philosophy of science by way of employing case studies from biology, chemistry, and physics.

What does it mean for one scientific phenomenon to be explained in terms of another? Under what conditions does scientific unification take place? In philosophy these questions are often discussed under the rubric of reduction. Typically, in asking whether one phenomenon reduces to another, we aim to understand what the ultimate or fundamental basis of the first phenomenon is. In the mid to late 20th century, there was a hope to reduce all higher level phenomena to fundamental physics. Yet, it was soon discovered that there are phenomena that cannot be easily reduced, so unification may not be available via this route.

The project’s ambitious goal is to produce a novel account of unification. This is made possible by recent breakthroughs in the methodology of metaphysics, an area sometimes called “metametaphysics”. The project’s objectives are (1) to establish the criteria for scientific unification; (2) to conduct case studies of actual scientific reductions at the biology-chemistry and the chemistry-physics interfaces; (3) to study the role of dependence relations weaker than reduction.

A cross-disciplinarily applicable toolbox for unification would be enormously useful for identifying the kind of expertise needed for studying a given phenomenon. This is not merely a philosophical problem. If there are reasons to think that a given biological phenomenon reduces to chemical phenomena, then biologists studying that phenomenon had better be prepared to consult and collaborate with the chemists. If a unification can be achieved, we can determine when scientists ought to consult their colleagues in other sciences and also when this is likely to be a hindrance instead of an advantage.

Link to the ERC project webpage: https://metascience.xyz/

Keywords of the ERC project: Philosophy, Metaphysics, Philosophy of Science, Philosophy of Physics, Philosophy of Biology, Philosophy of Chemistry

Keywords that characterize the scientific profile of the potential visiting researcher/s: Philosophy, Metaphysics, Philosophy of Science, Philosophy of Physics, Philosophy of Biology, Philosophy of Chemistry
Constructing Age for Young Readers (CAFYR)

CAFYR starts from the observations that Europe has recently witnessed a few pertinent crises in intergenerational tension, that age norms and ageism frequently go unchecked and that they are part of children’s socialization. It aims at developing pioneering research for understanding how age is constructed in cultural products. CAFYR focuses on fiction for young readers as a discourse that often naturalizes age norms as part of an engaging story and that is endorsed in educational contexts for contributing to children’s literacy, social and cultural development. The effect of three factors on the construction of age in children’s books is studied: the age of the author, the age of the intended reader, and the age of the real reader. CAFYR aims to lay bare whether and how the age and aging process of children’s authors affect their construction of the life stages in their works. It will show how various crosswriters shape the stages in life differently for young and adult readers. It considers the age of young readers as varied in its own right, and investigates how age is constructed differently for children of different ages, from preschoolers to adolescents. Finally, it brings together readers of various stages in the life course in a reception study that will help understand how real readers construct age, during the reading process and in dialogue with each other. CAFYR also aims to break new theoretical and methodological ground. It offers an interdisciplinary approach that enriches children’s literature research with concepts and theories from age studies. It combines close reading strategies with distant reading and tools developed for digital text analysis. It provides a platform to people of different stages in life, contributing to their awareness about age, and facilitating and investigating dialogues about age, with the aim of ultimately fostering them more.

Link to the ERC project webpage:

Keywords of the ERC project: children’s literature, digital humanities, English literature, Dutch literature

Keywords that characterize the scientific profile of the potential visiting researcher/s: children's literature studies, digital humanities
The healthy self as body capital: Individuals, market-based societies and body politics in visual twentieth century Europe.

From testicular grafting (1920s) to step counting watches (2014), the perceptions and practices of health seeking individuals have been marked by continuities and profound changes during a twentieth century largely shaped by the advent of a communication society. Visuals can be a source to understand transformations by postulating an interactive, performative power of mass media in societies. Which roles did visuals play in changes from public health and human capital collective understandings of the healthy self to new (sometimes debated) perceptions and practices of our bodies as forms of individual capital in an increasing market-economized world?

Pursuing these questions, the project focuses on four fields of investigation - food/nutrition; movement/exercise/sports; sexuality/reproduction/infants and dependency/addiction/overconsumption - in Germany, France and Great Britain studied with an entangled history framework. Within this scope the project aims at understanding (1) how visuals shape our health related self-understandings and practices in a continuity/discontinuity from the bio-political to the bio-economic logic. (2) The project will explore and explain how and why understandings of body capital differ or overlap in European countries. (3) The project will analyse if and how visual media serve as a promotion-communication hyphen for twentieth century preventive-self understanding.

With a visual perspective on a long twentieth century, the project seeks to better understand changes and continuities in the history of health intertwined with the history of media. This will provide new insights into how the internalization of bodycapital has evolved throughout the past century, how transformations in the media world (from film to TV to internet) play out at the individual level and how health challenges and cultural differences in body perceptions and practices persist in producing social distinction in an age of global information and advanced health systems.

Link to the ERC project webpage: bodycapital.unistra.fr

Keywords of the ERC project: history, 20th century, audiovisuals, health, medicine, body, film, television, internet

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Of all the technical and scientific developments that made possible the early modern maritime expansion, the nautical chart is perhaps the least studied and understood. This fact is very surprising as it was through those charts that the newly discovered world was first shown to the amazed eyes of the European nations. Although the History of Cartography is a well-established academic discipline and old charts have been examined for many years, their detailed technical study is still in its infancy. What is the origin of the pre-Mercator nautical chart, how charts evolved technically over time and how they were used at sea are all critical questions that remain to be answered. I intend to approach these challenges in a truly interdisciplinary way, by using innovative and powerful tools as a complement to the traditional methods of historical research: analytical cartometric methods, numerical modelling and the examination of the manuscripts through special lighting. By applying these tools to a large sample of charts of various periods and origins, I aim to unveil hidden graphic content related to their construction and use, to characterize their main geometric features, to establish meaningful connections with contemporary navigational methods and exploration missions, and to numerically simulate their construction by taking into account the explanations given in the textual sources. The effectiveness of those techniques has already been demonstrated in my previous studies, such as in the solution of an historical enigma which had been alive for more than a century: the construction of the Mercator projection, in 1569. Now, I propose to handle a broader and more complex set of questions, which has eluded the historians of cartography for even a longer period. The clarification of these issues will have a ground-breaking impact, not only in the strict field of the History of Cartography, but also in the context of the intellectual history at large.

Link to the ERC project webpage: https://www.medea-chart.org/
Keywords of the ERC project: History of Cartography, History of Science, Portolan Charts, Maps
Keywords that characterize the scientific profile of the potential visiting researcher/s: history, philosophy, science, mathematics, medieval
Non-Territorial Autonomy as Minority Protection in Europe: An Intellectual and Political History of a Travelling Idea, 1850-2000

Over the past 150 years, non-territorial autonomy has been one of three models for dealing with linguistic or ethnic minorities within several European states. Compared with the other two, i.e. the recognition of minority rights as individual rights and territorial self-rule, non-territorial autonomy has received little attention. This project proposes to write the first history of non-territorial autonomy as an applied policy tool in minority protection and as an intellectual concept with a chequered history across Europe. Intellectuals, politicians, and legal scholars across the political spectrum from the far left to the far right supported this idea, although they were aware of the risks of strengthening national differences by promoting such a collective approach to minority protection. The project explores how this idea of granting cultural rights to a national group as a corporate body within a state, as a means of integrating diverse nationalities, travelled and transformed throughout the Habsburg Empire from 1850 to the present. We propose to 1) trace the development/circulation of theoretical conceptions and political applications of non-territorial autonomy within the Habsburg Empire, by mapping the networks of scholars as well as politicians who advocated for it; 2) explain the continuities in the development of the idea, and its manifestations in policies adopted by interwar Central and Eastern European nation states, where communists, socialists, liberals and fascists alike were able to translate elements of non-territorial autonomy into their ideologies and programs; 3) analyse the treatment of non-territorial autonomy, which was advocated by minority lobby groups, in international minority protection in the 20th century despite strong opposition to practices based on it by international organisations. We rely on a mixture of historiographical methods developed in nationalism studies to analyse the idea’s translation in entangled transnational spaces.

Link to the ERC project webpage: https://ntautonomy.univie.ac.at/en/

Keywords of the ERC project: non-territorial autonomy, nationalism studies, history of ideas, political history, Central and Eastern Europe, group rights, minority protection, cultural translation, 19th and 20th century

Keywords that characterize the scientific profile of the potential visiting researcher/s: non-territorial autonomy, nationalism studies, intellectual ideas, political history, group rights, minority protection, cultural translation, comparative methods
Disasters, Communication and Politics in South-Western Europe: the Making of Emergency Response Policies in the Early Modern Age

The connections between the circulation of news of extreme events, the making of influential narratives of collective traumas and the development of emergency response policies lie at the heart of this research proposal, which focuses on four Southern European areas: Catalonia, Naples, Sicily and Valencia, from the 16th to the 18th century. How did accounts and individual memories of extreme events amount to authoritative interpretations? In which ways, and to what extent, did the latter orient collective behaviours and the recovery process, in both the short and the long term?

Starting from the assumption that human relations are enhanced by the increased levels of socialisation that commonly occur in the aftermath of shocking events, which trigger the sharing of information, opinions and memories; and that the emotional impact of such events is likely to create a public opinion that draws attention to government’s action; the research proposal aims to contribute new insights into these issues by adopting an original methodology, developed across a variety of disciplines, including Cultural and Social History, Textual Criticism, Philology and Anthropology. Moreover, it will adopt a transnational perspective: since the selected regions belonged to the Spanish Monarchy, the development of practices and policies aimed to respond to disruption depended not only on the specific social and cultural features of local societies, but also on the circulation of political and technical staff, as well as on the sharing of knowledge, experiences and policy models, among the various areas of the Empire and its colonies. Studying the information exchange in the aftermath of disasters and the formation of an imagery of extraordinary events, will allow a comprehensive perspective on the policies and practices adopted by early modern societies to manage uncertainty, and on the potential impact that such narratives could have on the renegotiation of political and social relations.

Link to the ERC project webpage: http://discompose.unina.it

Keywords of the ERC project: Early Modern History, History of Natural Disasters, History of Communication, Spanish Empire

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Living with Radiation: The Role of the International Atomic Energy Agency in the History of Radiation Protection

This project addresses the central question of how the International Atomic Energy Agency, a diplomatic and political international organization, came to dominate scientific institutions with a long tradition in radiation protection. Despite the importance of international organizations for the development of postwar science there is no work on the history of radiation protection in relation to the development of the IAEA. The project addresses this lacuna in a groundbreaking way: it analyses what is usually treated as a strictly techno-scientific issue—how best to protect us from ionized radiation—using methods from history, philosophy, and sociology of science, and in the context of international history. The main hypothesis is that scientific knowledge about radiation protection has been shaped by diplomatic, social, economic, and political concerns. This approach casts new light on important aspects of postwar history of science, combining attention to state actors, science diplomacy, and the roles played by international organizations. Given the enormous interest in radiation protection the time is ripe for providing a comprehensive social, historical, and political study of the role of the IAEA in the field.

The main objectives of the project are:
• to retrace the international history of radiation protection after World War II, focusing especially on the Technical Assistance Programs of the IAEA;
• to investigate the role of the IAEA in sponsoring knowledge production in the field of radiation protection in competition with other regulatory agencies; and
• to analyze the standardization of instruments, objects, procedures, and technical vocabulary as the main strategy used by the IAEA for guiding radiation protection worldwide.

The project advocates a "diplomatic turn": diplomacy becomes analytical category in history of science. Highly interdisciplinary it brings together expertise from several disciplines, promising a significant advancement across them.

Link to the ERC project webpage: https://iaeahistory.weebly.com/

Keywords of the ERC project: history of radiation protection; nuclear diplomacy; IAEA; transnational history; standardization

Keywords that characterize the scientific profile of the potential visiting researcher/s: historian of science; diplomatic historian; international studies scholar
NUCLEARWATERS develops a groundbreaking new approach to studying the history of nuclear energy. Rather than interpreting nuclear energy history as a history of nuclear physics and radiochemistry, it analyses it as a history of water. The project develops the argument that nuclear energy is in essence a hydraulic form of technology, and that it as such builds on centuries and even millennia of earlier hydraulic engineering efforts worldwide – and, culturally speaking, on earlier “hydraulic civilizations”, from ancient Egypt to the modern Netherlands. I investigate how historical water-manipulating technologies and wet and dry risk conceptions from a deeper past were carried on into the nuclear age. These risk conceptions brought with them a complex set of social and professional practices that displayed considerable inertia and were difficult to change – sometimes paving the way for disaster. Against this background I hypothesize that a water-centred nuclear energy history enables us to resolve a number of the key riddles in nuclear energy history and to grasp the deeper historical logic behind various nuclear disasters and accidents worldwide. The project is structured along six work packages that problematize the centrality – and dilemma – of water in nuclear energy history from different thematic and geographical angles. These include in-depth studies of the transnational nuclear-hydraulic engineering community, of the Soviet Union’s nuclear waters, of the Rhine Valley as a transnational and heavily nuclearized river basin, of Japan’s atomic coastscapes and of the ecologically and politically fragile Baltic Sea region. The ultimate ambition is to significantly revise nuclear energy history as we know it – with implications not only for the history of technology as an academic field (and its relationship with environmental history), but also for the public debate about nuclear energy’s future in Europe and beyond.

Link to the ERC project webpage: www.nuclearwaters.eu

Keywords of the ERC project: nuclear energy, history of technology, environmental history

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Cirulating Gender in the Global Enlightenment: Ideas, Networks, Agencies

Research on the role played by women as actors and by gender as a cultural category has crucially contributed to historiographical revision of the Enlightenment and its legacy to the modern world. However, the perspective adopted has been national or, if comparative, mostly radial. A leap forward is urgent because current circulationist approaches to the Enlightenment tend to forget its key gender dimension and to underplay contributions from Southern Europe. This project offers, for the first time in the field, a systematic, truly transnational and transatlantic approach, which knits together cultural, intellectual, gender and postcolonial history, literary, philosophical and visual studies. It looks at the cultural transfer of gender notions in global perspective around five axes: translation, learned sociability, travel, reading and sensibility, to be explored through textual and iconographic analysis and archival research. Adopting the vantage point of Spain and its empire will allow us to question approaches based either on the “national context” or the centre-periphery dichotomy, to reassess the role of the Catholic Enlightenment in the making of modernity and to highlight the mediating roles played by local actors, male and female, in processes of sociocultural change.

CIRGEN's specific objectives are: to challenge dichotomous visions of Enlightenment discourses of gender by stressing their plural (and often conflictive) contribution to modernity; to decenter customary radial perspectives by stressing multilateral dialogues both within Europe and beyond; to better understand the role played by gender in the cultural geography of Enlightenment, particularly in the construction of the South/North symbolic divide; to produce empirically grounded evidence of the practical and iconic role of women in the making of modern reading publics; to foster innovative scholarship on the gendering of emotions in defining national identities and moral standards of civilization.

Link to the ERC project webpage: https://cirgen.eu

Keywords of the ERC project: Enlightenment; modernity; gender; women; circulation; global history; transnational history; Hispanic empire; Catholicism; travel; sensibility; translation; sociability; networks; readers

Keywords that characterize the scientific profile of the potential visiting researcher/s: Cultural history; intellectual history; literary criticism; philosophy; global history; comparative history; gender; Enlightenment
Patristic sermons in the Middle Ages. The dissemination, manipulation and interpretation of late-antique sermons in the medieval Latin West

PASSIM will study the medieval reception of the Latin sermons preached by the Early Church Fathers, using a digital network of manuscripts. The sermons of Augustine, Gregory the Great and other patristic preachers were transmitted throughout medieval Europe in the form of sermon collections, preserved in thousands of manuscripts. Nearly every manuscript contains a new combination of sermons, attesting to a continuous, widespread engagement with the authorities of the Early Church. The dynamic tradition of reorganising and rewriting the patristic heritage is largely overlooked by scholars of medieval religious practices, who concentrate on medieval preachers, and by scholars of Early Christianity, whose focus is the patristic context.

Medieval collections of patristic sermons were part of the liturgical life of the monastery, but also of an intellectual tradition. They offer unique insights into medieval attitudes toward authority, techniques of appropriation, church organisation, monastic networks and knowledge exchange. PASSIM will execute the first large-scale analysis of the formation and spread of patristic sermon collections in medieval Europe. The project will develop a digital network of manuscripts, using well-tried principles from the field of textual criticism. Building on this network, PASSIM will pursue three lines of inquiry: the customizing of standard liturgical collections as indicative of individual purposes and contexts, the impact of transmission on the popularity of patristic sermons, and pseudo-epigraphic sermons as revelatory of medieval perceptions of the Church Fathers. PASSIM will bridge two disciplinary divides, between patristic and medieval sermon studies and between textual criticism and reception studies. Developing an interdisciplinary methodology with a wide applicability in the study of intellectual history, this project will introduce patristic preaching as a vibrant strand in the tapestry of the medieval religious tradition.

Link to the ERC project webpage: https://applejack.science.ru.nl/passimproject/

Keywords of the ERC project:

Keywords that characterize the scientific profile of the potential visiting researcher/s:
CREATIVE IPR aims to study the rise of intellectual property rights in the creative industries, from the international treaties of the late nineteenth century to the present day, with a focus on Europe in the global world.

CREATIVE IPR examines the consequences of this development for the creators. What did intellectual property rights mean to a musician, or to a fashion designer in twentieth century Europe? Who captured economic value or failed to do so? In order to answer these questions, CREATIVE IPR proposes an original bottom-up approach, examining from the ground the macro and the micro aspects of the rise of intellectual property rights in the creative industries.

CREATIVE IPR pursues the questions in three arenas. The first arena is the formation and impact of national and international institutions and organizations for intellectual property. The second and third arenas are the role of authors’ rights societies in the music industries, and the management of creativity in the fashion industries. For each arena, cross-cutting themes are pursued: authorship and creativity, firms, technological change, legal frameworks, and the role of the commons – the public domain.

In recent years, intellectual property rights have, due to technological and economic change, attracted significant scholarly interest. Yet attention has not been paid to their impact on creators in a historical perspective. By analyzing the micro histories of the creators who negotiated the growing legal regime in the light of a transnational context CREATIVE IPR will fill a significant knowledge gap, help refine our ideas about the impact of intellectual property rights on creators, and open paths for future research. Ultimately it will help us understand how societies can foster rich and diverse creative industries.

Link to the ERC project webpage: https://www.hf.uio.no/iakh/english/research/projects/creative-intellectual-property-rights/index.html

Keywords of the ERC project: intellectual property rights, creative industries, history, copyright, economic history

Keywords that characterize the scientific profile of the potential visiting researcher/s: legal historian, economic historian, cultural historian, business historian
The Structure and Impact of Trans-Pacific Trade, 16th to 18th Centuries: The Manila Galleon Trade Beyond Silver and Silks

This project will provide a radically new history of early modern trans-Pacific trade, by critically re-evaluating conventionally-used sources, examining hitherto neglected historical archives and records in a range of Asian and European languages, and analysing recent archaeological evidence using new methodologies and perspectives. An interdisciplinary team, comprising specialists in Chinese, Japanese, Latin American, Southeast Asian, economic, environmental, and medical history, maritime archaeology, and geographical sciences, will, for the first time, systematically investigate the roles of actors, objects, side-effects, and exchanges that were ‘invisible’ or marginal to conventional histories of the Manila Galleon trade (1565 to 1815). They will also examine informal trade routes and networks in this trans-Pacific trade connection, concentrating on the 16th to 18th centuries. To achieve this goal, this project will expand upon the structure and impacts of contraband, informal, accidental, and undesired exchanges of cargoes, people, knowledge, technologies, and diseases across the Pacific, to evaluate, first, the complexity, nature, and degree of the global interconnectivity of Asian and European sub-regional networks, and, second, to reassess both their positive and negative impacts on trans-Pacific trade generally, and on indigenous actors and societies in China, Japan, and the Viceroyalty of Peru specifically. Our aim is to replace the outdated image of the galleon trade as being a pure exchange of silks, ceramics, and spices for silver between Acapulco and Manila, and to create a novel and more comprehensive bottom-up narrative that places human-environment interaction at the core of analysis. TRANSPACIFIC will substantially transform the understanding of the trans-Pacific Manila Galleon trade and its impacts, and, in so doing, will open the way for the re-evaluation of other major trans-maritime networks.
Making the Earth Global: Early Modern Nautical Rutters and the Construction of a Global Concept of the Earth

Early modern nautical rutters (sailing directions) are the earliest Western documents that testify to the stable and regular lived experience of traversing the earth’s oceans on a global, planetary scale. Nautical rutters (and ship’s logbooks) are technical documents that collect and analyse critical information for the successful accomplishment of oceanic navigation. This includes elements of strict nautical nature (courses, distances, and latitudes), as well as information on oceanography (currents and tides), meteorology (winds and storms), geography, geophysics (magnetic declination) and the natural world. Their unique value lies not only in the fact that they are exceptional historical repositories of information about the world on a planetary scale but, more importantly, that they document the emergence of global concepts about the earth. In fact, no earlier documents contain information about the earth on a comparable worldwide scale. Thus, their historical value is peerless. Using these exceptional, yet poorly known sources, the main objective of this project is to write a narrative of the scaling up of a scientific description of the earth in the sixteenth and seventeenth centuries, from the lived experience of travelling and observing the earth in long-distance sea voyages. As a preliminary task, a systematic search, identification and classification of the information contained in early modern Iberian rutters and ship’s logbooks will be performed. This will be followed by an extensive multidisciplinary study of their content aiming at radically improving our present knowledge of the historical process that led to the formation of global concepts about the earth.

Link to the ERC project webpage: rutter-project.org

Keywords of the ERC project: History of Science, Early Modern History, Maritime History

Keywords that characterize the scientific profile of the potential visiting researcher/s: History of Science, Early Modern History, Maritime History
Communities and Connectivities: Iron Age Britons and their Continental Neighbours

Recent breakthroughs in ancient DNA and isotope analysis are transforming our understanding of diversity, mobility and social dynamics in the human past. COMMIOS integrates these cutting-edge methods on a scale not previously attempted, within a ground-breaking interdisciplinary framework, to provide a radically new vision of Iron Age communities in Britain (800 BC – AD 100) within their wider European context.

At the broad scale, we will conduct the first concerted programme of genome-wide ancient DNA analysis on Iron Age populations anywhere in the world (c. 1000 individuals in the UK, 250 in Europe), mapping genetic clusters to shed light on ancient populations themselves and on their relationships to modern genetic patterning. Together with isotope analysis, and underpinned by both osteoarchaeological and cultural archaeological approaches, this will also enable us to directly address critical issues of population movement and inter-regional connectivity in Iron Age Europe. We will utilise the power of these new scientific methods to examine the structure and social dynamics of Iron Age societies in Britain, including household and kin-group composition, the identification of familial relationships, gender-specific mobility, and the development of social inequalities. Previously the preserve of cultural anthropologists studying recent societies, we will draw these questions into the archaeological domain, opening up new areas of enquiry for prehistoric societies.

The scope and scale of the project represents a new departure for European archaeology, made possible by the coming-of-age of new analytical methods. Many of these have been pioneered by the project team, which comprises world-leaders in the fields of ancient DNA, isotope analysis, osteoarchaeology, chronological modelling and cultural archaeology. Although focussed on Iron Age Britain, the project will establish a new benchmark for future analyses of other regions and periods in Europe and beyond.

Link to the ERC project webpage:

Keywords of the ERC project: Iron Age; European archaeology; Bioarchaeology; ancient DNA; isotopes; funerary archaeology

Keywords that characterize the scientific profile of the potential visiting researcher/s: Iron Age; European archaeology; Bioarchaeology; ancient DNA; isotopes; funerary archaeology
Tropical forests are globally recognised as biodiversity hotspots and environments that are crucial for climate regulation, landscape stability, and the carbon cycle. Local deforestation can have regional and global feedbacks and 20th-21st century human actions in tropical forests are seen as a key part of the ‘Anthropocene’ – or the anthropogenic domination of earth systems. It remains an open question, however, as to whether pre-industrial human impacts on these environments had similar earth systems effects. 15th to 18th century European colonial empires drew together long-separated Old and New World ecologies, with implications for species distributions, demography, and land management in the tropics. This followed millennia of indigenous activities with possible regional and global cumulative results. Yet, we have no concrete understanding of how pre-industrial impacts varied spatially and temporally, what they meant for local sustainability, and how they compare to modern human impacts. The PANTROPOCENE Project addresses these questions by taking the Spanish Empire as a frame of reference for using archaeological, historical, and palaeoenvironmental data to build ‘pan-tropical’ spatial characterisations of pre-colonial, colonial, and industrial land-use. Undertaking novel palaeoecological and landscape survey fieldwork in the Philippine Archipelago, the often-neglected centre of the Spanish East Indies, the project will bring new data together with existing records, notably from the Neotropics, to ensure full tropical coverage of the Spanish Empire. The results will be factored into climate, geomorphological, and atmospheric models to determine how changing pre-industrial technology, subsistence, and administration had regional and global feedbacks on occupied human environments, informing understandings of the pace and threat of contemporary land-use changes in the context of endemic Island Southeast Asian biodiversity and the tropics more broadly.

Link to the ERC project webpage: https://www.patrickjroberts.com/
Keywords of the ERC project:
Keywords that characterize the scientific profile of the potential visiting researcher/s:
Back to the Future: Future expectations and actions in late medieval and early modern Europe, c.1400-c.1830

From the eighteenth century onwards, the future was considered as open, uncertain and constructible – the way we tend to perceive the future today. In contrast, early modern Europeans believed that the future was beyond the control of man. The aim of this project is to challenge such grand narratives on past futures, which are generally highly linear and focused on modernity, have a fuzzy chronology and thin empirical base, biased by learned text. Moreover, these hypotheses fail to do justice to the presence and interplay of various (multi)temporalities and do not link future expectations to the concrete actions of men and women in the past. Most historians simply ignore the topic, since past futures are extremely hard to find in the written record. Hence, they focus on the actions of men and women in the past rather than their motivations.

To gain more insight in how people in the past thought about the future and how this affected their actions, this project draws on a highly innovative combination of close and distant reading methods of more than 15,000 letters written in (varieties of) Italian, German, French, Dutch and English by and to European merchants in the period 1400-1830. These practical documents enable us to reconstruct different types of future thinking of these merchants and to assess how these thoughts powered their actual behaviour. Better still, they also shed light on the future expectations of their non-merchant correspondents: their wives, children and other family members, clerks, clergy, nobles, craftsmen, etc. A comparative analysis of the letters from these different social groups, written in several languages, in a variety of European regions and during distinct moments, allows us to identify the impact/speed of potential agents of change that loom large in the literature (capitalism, the Reformation, probability calculus, and the Enlightenment) more carefully. With this methodology, we will be able to provide fine-grained explanations.

Link to the ERC project webpage: https://cordis.europa.eu/project/rcn/225075/factsheet/en

Keywords of the ERC project: medieval history; early modern history; future expectations

Keywords that characterize the scientific profile of the potential visiting researcher/s: 
Zooming into the Population History of Iron Age Europe with Rare Genetic Variants.

In recent years, archaeogenetic studies have yielded striking insights into European prehistory from ancient DNA. However, these studies focus on times prior and up to the Bronze Age, whereas more recent periods are still poorly covered. A key challenge with studying more recent time periods is the homogenisation of European populations since the late Neolithic, which exposes the limits of many existing analytical methods that try to detect population movements. To overcome these limits, in this proposal I will develop a genetic 'microscope', a new set of fine-scaled analytical methods based on rare genetic variation, which will allow us to analyse ancient genomic data to infer population structure with unprecedented detail. With this new toolbox, I will undertake the largest archaeogenetic investigation of the pre-Roman European Iron Age to date. A specific focus will be the ‘Celtic’ world, encompassing a core region spanning from parts of France into Slovakia, and which reached its maximum extent in the third century BC, spanning from the Iberian Peninsula to Anatolia. I will collaborate with a large number of partners from archaeology and anthropology, as well as genetic laboratories, to sample and analyse 600 skeletal remains from this region and time period. Using the new methods, I aim to investigate i) population structure during the early Iron Age in the ‘Celtic’ core region of Western and Central Europe; ii) the genetic evidence for the so-called ‘Celtic migrations’ from the third century BC, specifically by analysing samples from the Iberian Peninsula, Northern Italy, Hungary/Romania and the British isles; iii) how migration and population admixture are reflected at the community- and family level by ‘zooming in’ into selected archaeological sites to reconstruct family pedigrees. With new methodology, new reference data, and hundreds of ancient genomes from the pre-Roman Iron Age, this project will set new standards for archaeogenetic studies in Europe.
Localizing 4000 Years of Cultural History. Texts and Scripts from Elephantine Island in Egypt

The aim of this project is to write a cultural history of 4000 years, localized on Elephantine Island in Egypt. Elephantine was a militarily and strategically very important island in the river Nile on the southern border of Egypt. No other settlement in Egypt is so well attested over such a long period of time. Its inhabitants form a multi-ethnic, multicultural and multi-religious community that left us vast amounts of written sources detailing their everyday lives from the Old Kingdom to beyond the Arab Conquest. Today, several thousand papyri and other manuscripts from Elephantine are scattered in more than 60 institutions across Europe and beyond. Their texts are written in different languages and scripts, including Hieroglyphs, Hieratic, Demotic, Aramaic, Greek, Coptic and Arabic. 80% of these manuscripts are still unpublished and unstudied. The great challenge of this project is to use this material to answer three key questions covering:

1) Multiculturalism and identity between assimilation and segregation,
2) Organization of family and society,
3) Development of religions (Polytheism, Judaism, Christianity and Islam).

Thus, access needs to be gained to these texts, making them publicly available in an open access online database. Links are to be identified between papyrus fragments from different collections and an international ‘papyrus puzzle’ will be undertaken, incorporating cutting-edge methods from digital humanities, physics and mathematics (e.g. for the virtual unfolding of papyri). Using this database with medical, religious, legal, administrative, even literary texts, the micro-history of the everyday life of the local and global (i.e. ‘glocal’) community of Elephantine will be studied within its socio-cultural setting in Egypt and beyond. It will be linked back to macro-historical questions and benefit from newly-introduced methodologies of global history: Elephantine can thus be used as a case study and a model for the past, present and future.

Link to the ERC project webpage:

Keywords of the ERC project:

Keywords that characterize the scientific profile of the potential visiting researcher/s:
MMS-II pursues the hypothesis that the Mamluk sultanate was a cultural product constructed in the interaction between state formation and historiography. MMS-II follows up from the ERC-project MMS’ focus on the social production of power networks in the Syro-Egyptian sultanate between the 1410s and 1460s, but it does so by directing the themes of political history and Arabic historiography towards entirely new, unexplored horizons. Current understanding of the late medieval Middle East continues to rely heavily on the rich Arabic historiographical production of the period. However, the particular nature, impact and value of this highly politicized historiography remains hugely underexplored and underestimated. MMS-II aims to remedy this, by arguing with and beyond instead of against or outside of this historiography’s subjectivities. It wants to understand its texts as products of particular socio-cultural practices and, at the same time, as a particular type of actors in such practices. Analytically, state formation will be prioritised as one extremely relevant patterned set of effects of such practices. Heuristically, the project will focus on practices related to claims of historical truth and order, asking how Arabic historiographical texts written between the 1410s and the 1460s related to the regularly changing social orders that were produced around the different sultans of these decades. My main hypothesis is that of these texts’ active participation in the construction of a particular social memory of one longstanding sultanate of military slaves (‘Mamlukisation’). MMS-II has three specific objectives: the creation of a reference tool for Arabic historiographical texts from the period 1410-1470; the in-depth study of particular sets of these texts; the analysis of political vocabularies in these texts. By thus exploring the inter-subjective re/production of Arabic historiography MMS-II will generate a welcome cultural turn in late medieval Islamic history.

Link to the ERC project webpage: www.mms.ugent.be

Keywords of the ERC project: Arabic historiography- state formation -late medieval Egypt and Syria

Keywords that characterize the scientific profile of the potential visiting researcher/s: Islamic history -Arabic literature - historiography- late medieval/ early modern history
Cultures of Occupation in Twentieth-century Asia

How has foreign occupation shaped culture? What has been the lasting cultural legacy of foreign occupation in those societies where it represented the usual state of affairs for much of the modern era? These are key questions which, in light of ongoing cases of occupation around the world, remain crucial in the 21st century. Cultures of Occupation in Twentieth-century Asia (COTCA) will answer these questions by analysing how occupation—be it under colonial, wartime or Cold War powers—gave rise to unique visual, auditory and spatial regimes in East and Southeast Asia. The core objective of this important project is to produce a paradigm shift in the study of occupation, and to challenge the 'collaboration'/resistance' dichotomy which has defined the field thus far. It will adopt a transnational, intertextual and comparative approach to the study of cultural expression produced under occupation from the 1930s to the 1970s. It will also break new methodological ground by drawing on and contributing to recent developments in visual, auditory and spatial history as a means of highlighting intersections and cultural convergences across different types of occupation. By doing so, COTCA will, for the first time, determine what occupation looked, sounded and felt like in twentieth-century Asia. The COTCA team will consist of the PI, 2 postdoctoral researchers and 3 PhD students, and will run along 3 streams: (i) Representations of occupation; (ii) sounds of occupation; and (iii) spaces of occupation. Case studies based on hitherto rarely examined examples will be undertaken in each stream. These include: A visual history of Japanese-occupied China; soundscapes of the US naval bases in the Philippines; and, spaces of occupation in late-colonial Malaya. COTCA will also build a Digital Archive which will enable researchers to trace the development of narratives, tropes and motifs common to 'occupation' cultural expression in Asia across national and temporal borders.

Link to the ERC project webpage: https://www.nottingham.ac.uk/research/groups/cotca/index.aspx

Keywords of the ERC project: history; foreign occupation; culture; Asia

Keywords that characterize the scientific profile of the potential visiting researcher/s:
The First Bantu Speakers South of the Rainforest: A Cross-Disciplinary Approach to Human Migration, Language Spread, Climate Change and Early Farming in Late Holocene Central Africa

The Bantu Expansion is not only the main linguistic, cultural and demographic process in Late Holocene Africa. It is also one of the most controversial issues in African History that still has political repercussions today. It has sparked debate across the disciplines and far beyond Africanist circles in an attempt to understand how the young Bantu language family (ca. 5000 years) could spread over large parts of Central, Eastern and Southern Africa. This massive dispersal is commonly seen as the result of a single migratory macro-event driven by agriculture, but many questions about the movement and subsistence of ancestral Bantu speakers are still open. They can only be answered through real interdisciplinary collaboration. This project will unite researchers with outstanding expertise in African archaeology, archaeobotany and historical linguistics to form a unique cross-disciplinary team that will shed new light on the first Bantu-speaking village communities south of the rainforest. Fieldwork is planned in parts of the Democratic Republic of Congo, the Republic of Congo and Angola that are terra incognita for archaeologists to determine the timing, location and archaeological signature of the earliest villagers and to establish how they interacted with autochthonous hunter-gatherers. Special attention will be paid to archaeobotanical and palaeoenvironmental data to get an idea of their subsistence, diet and habitat. Historical linguistics will be pushed beyond the boundaries of vocabulary-based phylogenetics and open new pathways in lexical reconstruction, especially regarding subsistence and land use of early Bantu speakers. Through interuniversity collaboration archaeozoological, palaeoenvironmental and genetic data and phylogenetic modelling will be brought into the cross-disciplinary approach to acquire a new holistic view on the interconnections between human migration, language spread, climate change and early farming in Late Holocene Central Africa.

Link to the ERC project webpage: https://www.bantufirst.ugent.be/

Keywords of the ERC project:
Dunes are now protected environments, being top priority for coastal managers, because of their important role as coastal defences. But, it was not like that in the past. For centuries dunes were considered unproductive and dangerous. The sand blown by the wind was taken inland, invading fields, silting rivers and destroying villages. In the eighteenth century, a strategy was developed to fight against the dunes: trapping them with trees, with the double purpose of preventing the destruction of arable land and increasing their economic value converting them into forest areas. Different governments, in different countries supported the immobilization of the shifting sands. The strategy, developed in Europe, was taken to other places in the world. These works caused profound changes in vast coastal areas transforming arid landscapes of sandy dunes into green tree forests.

This project aims to explore human-environment relations in coastal areas worldwide, since the eighteenth century until today, through the study of dunes as hybrid landscapes. Based on selected case-studies and comparative approaches, the project will focus on the origins, reasons and means of dunes afforestation; the impacts of the creation of new landscapes to local communities and ecosystems; and the present situation of dunes as coastal defences and rehabilitated environments. The final purpose is to produce an innovative global history of coastal dunes, combining knowledges from both Humanities and Social Sciences and Physical and Life Sciences, which has never been done.

Supported by an interdisciplinary team, this research will result in new developments in the field of the Environmental History studies; provide relevant knowledge considering the need of efficient management solutions to adapt to the expected mean sea level rise; and stimulate environmental citizenship by disseminating the idea that the future of the world coasts depends on today’s actions.

Link to the ERC project webpage: http://dunes.letras.ulisboa.pt/projeto/

Keywords of the ERC project: Environmental History, dune, coastal, sustainability

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Late Pleistocene/early Holocene Europe is said to be the ideal laboratory for the investigation of human responses to rapidly changing climates and environments, migration and adaptation. Yet, pinpointing precisely how and why contemporaneous Final Palaeolithic/earliest Mesolithic (15,000-11,000 years BP) foragers migrated, and which environmental or other factors they adapted to – or failed to – has remained remarkably elusive. At the core of ClioArch is the radical but, in light of research-historical insights, necessary hypothesis that the current archaeological cultural taxonomy for this iconic period of European prehistory is epistemologically flawed and that operationalisations and interpretations based on this traditional taxonomy – especially those that seek to relate observed changes in material culture and land-use to contemporaneous climatic and environmental changes – are therefore problematic. Hence, novel approaches to crafting the taxonomic building blocks are required, as are novel analyses of human-environment relations in this period. ClioArch’s premier ambition is to provide operational cultural taxonomies for the Final Palaeolithic/earliest Mesolithic of Europe and to couple these with interdisciplinary cultural evolutionary, quantitative ecological methods and field archaeological investigations beyond the state-of-the-art, so as to better capture such adaptations – almost certainly with major implications for the standard culture-historical narrative relating to this period. In so doing, the project will pioneer a fully transparent and replicable – and eminently transferable – methodology for the study of the impacts of climate change and extreme environmental events in deep history. In turn, such a quantitative understanding of past adaptive dynamics will position archaeology more centrally in contemporary debates about climate change, environmental catastrophe and their cultural dimensions.

Link to the ERC project webpage: http://cas.au.dk/en/ERC-clioarch/

Keywords of the ERC project: archaeology, distribution modelling, Palaeolithic, climate change

Keywords that characterize the scientific profile of the potential visiting researcher/s: computational archaeology, Stone Age, palaeodemography, epistemology
Migration and Holocaust: Transnational Trajectories of Lubartow Jews Across the World (1920s-1950s)

Migrations are a central issue of the modern period, particularly since World War One. At the same time, the implementation of a systematic policy of categorization, discrimination, persecution, and extermination of European Jews is one of the major events of the first half of the 20th century. How should the relations between these two histories be understood? The goal of this project is to explore the links between migration and the Holocaust from a transnational microhistorical perspective.

To this end, it will implement an original method: producing the collective biography of the Jewish inhabitants from the Polish shtetl of Lubartow from the 1920s to the 1950s, whether they emigrated or stayed behind, whether they were exterminated or survived the Holocaust. This research will, for the first time, reconstruct the trajectories of a group of persecution victims across the different places they travelled through, which is possible today thanks to new access to an impressive body of archives and the affordances of the digital humanities. The methodological and archival challenge is immense. This transnational collective biography explores the directions of individual journeys, the diversity of fates, as well as the connections between those who remained and those who left.

By doing so, the LUBARTWORLD project addresses some prominent theoretical issues: the dynamics of a social structure drawn into a major disruption, the variability of social categorizations in diverse national and political contexts, and the complex making of identities. From an epistemological point of view, it will develop innovative ways of reconstructing and analyzing life-course information. Although the project begins with Lubartow, it leads to the world in its globality. Lubartow residents crisscrossed the globe, and their trajectories outline and embody in their own way the upheavals of Europe’s relations with the world before, during, and after the Holocaust.

Link to the ERC project webpage:

Keywords of the ERC project: History-Migration-Holocaust-Modelization

Keywords that characterize the scientific profile of the potential visiting researcher/s: Historian-Social scientist
Biogeographic and cultural adaptations of early humans during the first intercontinental dispersals

Our understanding of the emergence and dispersal of the earliest tool-making hominins has been revolutionised in the last decade, with sites in eastern Africa and China pushing both events more than half a million years earlier than previously thought. Traditional models linking biological speciation, cultural innovation and migration events with climatic pulses have remained theoretical, and recent discoveries suggest that the picture of the earliest human colonization across the Old World is far more complex, demanding heuristic approaches to understand the biogeography and adaptive behaviours of early humans.

This project will be the first substantive attempt to produce a global synthesis of earliest human occupation dynamics by comparing the world’s longest sequences of early archaeological sites, namely eastern Africa and China. Our objective is to understand the alternative evolutionary trajectories adopted by hominins that shared an overarching biological and cultural background, but who faced different climatic and biogeographic challenges and opportunities.

The ambition of our global-scale objectives is accompanied by the unmatched quality of our datasets and the ground-breaking perspective we will adopt in their study. Fieldwork in the two most renowned sequences in each region alongside a primary study of additional top-quality assemblages in both subcontinents, will be combined with extensive metadata sets to produce comprehensive views of temporal trends and paleoecological patterns. Our state-of-the-art methodological sets (which combine an exceptionally diverse range of disciplines from geochemistry to niche modelling) and ground-breaking analytical perspective (which considers data from micro-stratigraphy to satellite imaging) will enable us to develop new approaches to challenge established paradigms and produce a new picture of the biogeographic adaptations of early stone-tool makers.

Link to the ERC project webpage:

Keywords of the ERC project:

Keywords that characterize the scientific profile of the potential visiting researcher/s:
Widespread Bacterial CORE Complex Executes Intra- and Inter-Kingdom Cytoplasmic Molecular Trade

The enormous versatility of bacteria enables the formation of multi-species communities that colonize nearly every niche on earth, making them the dominant life form and a major component of the biomass. Exchange of molecular information among neighboring bacteria in such communities, as well as between bacteria and proximal eukaryotic cells, is key for bacterial success. Yet, the principles controlling these multicellular interactions are poorly defined. Here we describe the identification of a bacterial protein complex, herein termed CORE, whose function is to traffic cytoplasmic molecules among different bacterial species, and between pathogenic bacteria and their human host cells. The CORE is composed of five membrane proteins, highly conserved across the entire bacterial kingdom, providing a ubiquitous platform that facilitates both intra- and inter-kingdom crosstalk. Our preliminary data support the idea that the CORE acts as a shared module for the assembly of larger apparatuses, executing this universal molecular flow among organisms. We propose to elucidate components, structure and biogenesis of the CORE machinery, operating during bacteria-bacteria and pathogen-host interactions. We further aim to provide an unbiased-global view of the extent and identity of cytoplasmic molecules traded via CORE including metabolites, proteins and RNA, and to reveal the criteria determining the specificity of the transported cargo. Furthermore, we intend to decipher the impact of CORE-mediated molecular exchange on bacterial physiology and virulence, and devise anti-CORE compounds to combat pathogenic bacteria. This study is expected to transform the way we currently view bacterial communities and host-pathogen interactions. We anticipate these findings to lead to the development of creative strategies to modulate, predict and even design bacterial communities, and lay the foundation for new and innovative approaches to fight bacterial diseases.

Link to the ERC project webpage:

Keywords of the ERC project:

Keywords that characterize the scientific profile of the potential visiting researcher/s: Bacteria, nanotubes, Bacillus, host-pathogen interactions, intercellular communication
Clouds play a lead climatic role, controlling energy fluxes and regulating fresh water distribution. There is an acute need for cloud-resolving and global-climate models that accurately describe and parametrize the physics of warm convective and stratiform clouds, and the clouds’ sensitivity to environmental changes. Currently this requirement is not being met due to a gap in observational capabilities. Namely, there is a lack of sufficient sensing tailored to capture the 3D macro and microphysical properties of warm clouds, which are often spatially unresolved. Moreover, current retrievals use a plane-parallel radiative model, which is incompatible with the 3D heterogeneous nature of clouds. These gaps lead to uncertainties in climate models and prediction.

We propose an innovative sensing approach: cloud scattering-tomography, relying on an unprecedented large formation of ten cooperating, high performance pico-satellites. They will simultaneously image cloud fields from multiple directions, at 50m resolution. Based on this data, the novel tomography approach will seek the 3D volumetric structure of cloud fields, base-to-top profiles of droplets' size and their variance, volumetric distribution of optical extinction and rain indicators. The required pointing accuracy, data size and coordinated control of a complex 10 pico-satellite formation demands advanced space engineering, beyond existing technologies of traditional single satellites and constellations of satellites. Realizing a large formation requires innovative, distributed, networked, cooperative control, including advanced sensors and actuators for pico-satellites, as well as in-orbit autonomy. On-board hardware and flexible software will be adapted to meet computational needs within the physical limitations of pico-satellites (energy, mass, volume).

Using the acquired spaceborne images for tomography-based 3D atmospheric retrievals requires advancements in computer vision and efficient analysis based on three-dimensional radiative transfer. New information gained will improve and validate our cloud resolving models, leading to more realistic simulations of cloud fields. This will enable better understanding of how environmental changes affect warm clouds and help improve their representation in climate models.

This multidisciplinary, synergic approach will establish and test critical and currently unconventional aspects of remote sensing and mathematical retrieval based on a pico-satellite formation. It will yield a database of 3D macro and microstructure of warm cloud fields, while setting the stage for next-generation distributed spaceborne global observations.

Link to the ERC project webpage: https://www.youtube.com/watch?v=_DF-SCbpQi8

Keywords of the ERC project: Computational imaging, Optics, Inverse problems, Atmospheric radiative transfer, Space engineering, Autonomous systems, satellite formations, cloud physics, climate prediction

Keywords that characterize the scientific profile of the potential visiting researcher/s:
ConnectToBrain will introduce whole-brain multi-locus transcranial magnetic stimulation (mTMS), in which the brain-stimulating electric-field location, direction, magnitude and timing are controlled electronically based on real-time high-density electroencephalography (hdEEG) information of activity and connectivity in brain networks. The final mTMS apparatus will consist of 50 coils. Superpositions of electric fields produced by the different overlapping coils allow spatiotemporally millimeter- and millisecond-precise stimulus sequences to arbitrary cortical sites without physical movements of the coil set. Spatial targeting of mTMS will be further improved by measuring individual brain conductivity distributions with ultra-low-field MRI. The proposed hdEEG methodology uses a brain–computer interface (BCI) and a computer–brain interface (CBI) in a closed, algorithmically-controlled loop. BCI receives real-time information about brain activity and connectivity from hdEEG, while CBI adapts mTMS to drive brain activity and connectivity into desired directions. ConnectToBrain will allow unprecedented tracking of dynamic changes and reorganization of brain networks in real-time, and network-targeted closed-loop stimulation. This radically novel technology will cause a paradigm shift from current open-loop practice that is only moderately effective in therapy. We will apply ConnectToBrain to reach new levels of efficacy of therapeutic applications. Patients after stroke and with Alzheimer’s disease will be tested and treated as models of network disorders.

Our high-risk, high-gain endeavor will reach the ambitious goals only through the Synergy of the 3 PIs, world leaders in their complementary areas of expertise (instrumentation, algorithms, translation). If the project succeeds, we expect the value of societal, health and industrial benefits in Europe to exceed €1 billion annually, not to mention the immense value of alleviating human suffering from brain disorders.

Link to the ERC project webpage: connecttobrain.eu

Keywords of the ERC project: TMS, EEG, TMS-EEG, TMS therapy, coil design, power electronics, electromagnetism, brain networks

Keywords that characterize the scientific profile of the potential visiting researcher/s: hardware, software architecture, software design, user interface, electronics, control systems, neurotechnology, brain tissue modeling, machine learning, applied mathematics, physics, signal processing, brain networks
Connecting to the Networks of the Human Brain

ConnectToBrain will introduce whole-brain multi-locus transcranial magnetic stimulation (mTMS), in which the brain-stimulating electric-field location, direction, magnitude and timing are controlled electronically based on real-time high-density electroencephalography (hdEEG) information of activity and connectivity in brain networks. The final mTMS apparatus will consist of 50 coils. Superpositions of electric fields produced by the different overlapping coils allow spatiotemporally millimeter- and millisecond-precise stimulus sequences to arbitrary cortical sites without physical movements of the coil set. Spatial targeting of mTMS will be further improved by measuring individual brain conductivity distributions with ultra-low-field MRI. The proposed hdEEG methodology uses a brain–computer interface (BCI) and a computer–brain interface (CBI) in a closed, algorithmically-controlled loop. BCI receives real-time information about brain activity and connectivity from hdEEG, while CBI adapts mTMS to drive brain activity and connectivity into desired directions. ConnectToBrain will allow unprecedented tracking of dynamic changes and reorganization of brain networks in real-time, and network-targeted closed-loop stimulation. This radically novel technology will cause a paradigm shift from current open-loop practice that is only moderately effective in therapy. We will apply ConnectToBrain to reach new levels of efficacy of therapeutic applications. Patients after stroke and with Alzheimer’s disease will be tested and treated as models of network disorders.

Our high-risk, high-gain endeavor will reach the ambitious goals only through the Synergy of the 3 PIs, world leaders in their complementary areas of expertise (instrumentation, algorithms, translation). If the project succeeds, we expect the value of societal, health and industrial benefits in Europe to exceed €1 billion annually, not to mention the immense value of alleviating human suffering from brain disorders.

Link to the ERC project webpage: connecttobrain.eu

Keywords of the ERC project: TMS, EEG, TMS-EEG, MEG, electromagnetism, brain networks, real-time connectivity.

Keywords that characterize the scientific profile of the potential visiting researcher/s: software architecture, software design, user interface, machine learning, applied mathematics, physics, signal processing, brain networks, connectivity.
We propose to thoroughly investigate and characterise the sources of variation that results in varying phenotypes in a complex vertebrate. As well as characterising the genetic and environmental sources of variation, we will also investigate individual stochastic variation present even in fixed settings (both genetically and environmentally). To achieve this we will exploit the unique properties of Medaka fish, which can be fully inbred from the wild. We have already inbred and performed whole genome sequencing of a panel of 111 diverse Medaka fish from a single location; we propose to phenotype these fish in depth with high replication structure, ranging from organismal to molecular phenotypes. We will also phenotype entirely wild fish from the same source population as the panel with a subset of the phenotypes. We will analyse the data using state of the art methods to partition variation between genetic, environmental and stochastic components, and their interactions. We will integrate across both the different levels of phenotypic information across the cardiovascular system, and also across vertebrate phenotypes, in particular the extensive human phenotypes. By using genetic crosses and CRISPR-Cas9 techniques we will definitively prove specific interactions. We will host a “Research Hotel” for other phenotyping schemes to be applied to this panel, in particular from the Zebrafish community. This comprehensive and carefully replicated study will allow us to understand the opportunities and limitations of genetic stratification and personalised medicine in humans.

Link to the ERC project webpage:
Keywords of the ERC project: Medaka and human genetics
Keywords that characterize the scientific profile of the potential visiting researcher/s: Quantitative Genetics
The survival of an organism depends on energy homeostasis, involving the control of neuroendocrine functions that integrate metabolic feedback and adapt the response of the organism to physiological demands. Tanycytes, specialized glial cells lining the floor of the third ventricle in the median eminence of the hypothalamus, act as linchpins of these processes, dynamically controlling the secretion of neuropeptides by hypothalamic neurons into the pituitary portal circulation and regulating blood-brain and blood-cerebrospinal fluid exchanges, both processes that depend on their morphological plasticity in response to the physiological state. In addition to their barrier properties, they actively shuttle circulating metabolic signals to hypothalamic neurons that control food intake. The overarching goal of WATCH is to synergistically employ state-of-the-art technologies in systems neuroscience, mouse genetics and bench-to-bedside research, to explore the role of these unique and versatile cells, providing new directions in biomarker research and new therapeutic approaches for a variety of disorders that impair well-aging. Our specific aims are:

1. Genetic dissection of the in vivo regulation, pathophysiological function and molecular markers of tanycytes classified according to their anatomical location.
2. Identification of novel heterogeneous, molecularly distinct tanycytes and associated endothelial cells and determining how these characteristics evolve under distinct physiological and pathological conditions.
3. Functional validation of newly classified subgroups of tanycytes and the specific modulation of the activity of these subgroups at the experimental level.
4. Exploration of the functional consequences of pharmacologically activating pathways required for the tanycytic shuttling of metabolic signals on their CSF levels of these factors, hypothalamic activity and cognition in animal models and patients with morbid obesity or age-related cognitive deficits.

**Well-Aging and the Tanycytic Control of Health**

The survival of an organism depends on energy homeostasis, involving the control of neuroendocrine functions that integrate metabolic feedback and adapt the response of the organism to physiological demands. Tanycytes, specialized glial cells lining the floor of the third ventricle in the median eminence of the hypothalamus, act as linchpins of these processes, dynamically controlling the secretion of neuropeptides by hypothalamic neurons into the pituitary portal circulation and regulating blood-brain and blood-cerebrospinal fluid exchanges, both processes that depend on their morphological plasticity in response to the physiological state. In addition to their barrier properties, they actively shuttle circulating metabolic signals to hypothalamic neurons that control food intake. The overarching goal of WATCH is to synergistically employ state-of-the-art technologies in systems neuroscience, mouse genetics and bench-to-bedside research, to explore the role of these unique and versatile cells, providing new directions in biomarker research and new therapeutic approaches for a variety of disorders that impair well-aging. Our specific aims are:

1. Genetic dissection of the in vivo regulation, pathophysiological function and molecular markers of tanycytes classified according to their anatomical location.
2. Identification of novel heterogeneous, molecularly distinct tanycytes and associated endothelial cells and determining how these characteristics evolve under distinct physiological and pathological conditions.
3. Functional validation of newly classified subgroups of tanycytes and the specific modulation of the activity of these subgroups at the experimental level.
4. Exploration of the functional consequences of pharmacologically activating pathways required for the tanycytic shuttling of metabolic signals on their CSF levels of these factors, hypothalamic activity and cognition in animal models and patients with morbid obesity or age-related cognitive deficits.

**Link to the ERC project webpage:**

**Keywords of the ERC project:** tanycytes, hypothalamus, brain-body communication

**Keywords that characterize the scientific profile of the potential visiting researcher/s:** neuroscience, Energy homeostasis, aging, hypothalamus