Periodic report 2017-2020

Strategic projects and activities in the focus areas of ‘Changing climate and northern environment’ and ‘Sustainable materials and systems’ of the University of Oulu

Pirjo Taskinen, Riitta Kamula, Jouko Inkeröinen (eds.)
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The Kvantum Institute, Periodic report 2017–2020
Pirjo Taskinen, Riitta Kamula, Jouko Inkeröinen (eds.)
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The Kvantum Institute was established in 2017 to promote, coordinate and strengthen research in the University of Oulu’s (UOULU) strategic focus areas of ‘Sustainable materials and systems’ and ‘Changing climate and northern environment’. The Kvantum Institute coordinates and develops doctoral training in the fields of Science and Technology with the University of Oulu Graduate School (UniOGS). Kvantum’s work is conducted in collaboration with UOULU’s vice rector of research, the Tellus arena and the other three focus institutes at the UOULU. The overall aim is to promote and coordinate research on strategic focus areas of the UOULU. Kvantum also participates in research training, funding and strategy work at the UOULU.

The name “Kvantum” is derived from the Latin quantum, meaning “how much” or “how significant” and is a word that captures the nature of research in the fields of natural sciences and technology.

The backbone of Kvantum is its funded projects and its principal investigators (PIs) and research staff that are expected to take part in its activities. Kvantum allocates strategic university funding to 10–15 projects over four years involving around 15 post-doctoral researchers and 20 PhD students. In addition to these positions, research groups use their own funding and staff. Kvantum aims to promote research collaboration across projects and faculty boundaries to strengthen multidisciplinary research. The activities organised by Kvantum are open to all researchers at the university.

Kvantum’s research includes a wide diversity of research excellence at the UOULU. In the focus area of ‘Sustainable materials and systems’ the research contributes to the sustainable and responsible use of natural resources by creating smart solutions that are based on and combine our expertise in different fields. These range from fundamental materials science to the production and use of superior materials and (bio)catalytic systems, bioeconomics and circular economics, cleantech, ICT, and open data solutions. In the focus area of ‘Changing climate and northern environment’, researchers are seeking to understand near-Earth space, the Earth’s atmosphere and the Earth’s changing environment. Research is primarily conducted in the Faculty of Science, Faculty of Technology and Faculty of Information Technology and Electrical Engineering.

I wish to warmly thank all researchers on the strategic projects for their excellent work in the period 2017–2020.
1. Promoting multidisciplinary research and communality

A key task for the Kvantum Institute is to promote and coordinate multidisciplinary research across faculties and research units. Promoting multidisciplinary research is realised through high-level seminars and other events that bring researchers together and activate networking and cooperation between research groups, faculties and focus institutes. From 2017–2020, we organised, or co-organised over 30 events. The topics were truly multidisciplinary, ranging from the microbiomes we breathe to the space climate. The events were open to everyone in the university community and were organised as part of R3 (Rapid Research Radicals) activities in the UOULU’s Tellus Linnanmaa environments.

Promoting research excellence in the UOULU’s focus areas is a way to strengthen the research groups and the university’s profile. Recruiting talented post-docs and PhD students via Kvantum projects provides the basis to grow and develop. Working on the strategic projects provides peer support and ways to access scientific networks both at the UOULU and internationally. The strategic projects also have broad international collaboration with universities and other research institutions, for example, in the use of research infrastructures.

The Kvantum Institute also actively participated in preparing multidisciplinary funding applications, coordinating project cooperation and supporting university management with knowledge on ongoing research and scientific experts from our current and past project base. During the project period, we applied funding for Arctic Interactions programme that was highly ranked by the Academy of Finland (AoF) and received funding of around EUR 3 million.

New infrastructure supporting polar middle atmosphere research and research collaboration. Comments from spearhead project Mesospheric Monitoring of Ozone (MeMO) PI THOMAS ULICH, Head of Observations, Sodankylä Geophysical Observatory (see page 21)

In support of the Kvantum spearhead project Mesospheric Monitoring of Ozone (MeMO), the British Antarctic Survey (BAS) deployed its microwave radiometer at the Sodankylä Space Campus. The instrument had previously operated at BAS’ Halley VI research base in Antarctica. The radiometer enables us to gain a better understanding of the chemistry and physics of the polar middle atmosphere, from 35–90 km above the ground, and how it affects climate. It is a highly valuable and welcome contribution to the MeMO project, which will make the Sodankylä Space Campus a reference location for middle-atmospheric observations of ozone, nitric oxide and other trace gases. This allows us to validate the results from the MeMO-developed, simple ozone radiometer with those of a highly sophisticated instrument. While the MeMO observations will lack temporal resolution, their cost is low enough to deploy them at many locations covering large geographic areas.

"The radiometer is built around an incredibly sensitive superconducting detector that works at a temperature of 4K (~-269°C), which requires liquid Helium cooling."
2. Supporting multidisciplinary research projects

The Kvantum Institute improves the quality of multidisciplinary research by funding four-year research projects that have been selected based on international assessments. Kvantum projects from the period 2017–2020 are presented in this report. 12 projects were selected to Kvantum through international assessment conducted in 2017. Kvantum provided funding for 12 post-doctoral researchers and 17 doctoral students. A total of around 75 researchers worked in research groups related to Kvantum projects from 2017–2020.

The Kvantum also funds “Emerging projects”, aimed at promising and talented young researchers. The Emerging projects programme was launched in 2018 by the UOULU and is targeted at projects led by starting group leaders who develop an association between their own emerging research and a top research project in a related focus area. Four-year doctoral student positions (with partial funding) are allocated to each project. Five projects received funding and the funding period for doctoral students is 2018–2022. The projects’ interim reports are presented below. 12 researchers worked on emerging projects.

From 2017–2020, the researchers published a total of 230 articles in scientific peer-reviewed journals. The projects actively applied for competitive funding. 12 new Academy of Finland projects and three EU projects were funded. In addition, a few new projects started that were funded from national sources.

Table 1. Key figures of Kvantum projects from 2017-2020 (note: the figures indicate activities on the Kvantum projects, not only researchers funded by Kvantum)

<table>
<thead>
<tr>
<th>Key figures of the Kvantum research projects</th>
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<tr>
<td>Spearhead projects</td>
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<td>Emerging projects</td>
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<tr>
<td>Number of researchers involved in projects research activities</td>
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<td>Number of publications (directly related to research on Kvantum projects)</td>
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<tr>
<td>Number of doctoral defences</td>
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<td>New competitive funding projects related to Kvantum projects (AoF and EU)</td>
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As part of the UOULU’s strategy for building a responsible and sustainable society, it was assessed how the Kvantum’s projects research relates to the United Nations Sustainable Development Goals (SDGs). The SDGs that most relate to the Kvantum projects reflect the UOULU’s focus areas of ‘Changing climate and northern environment’ and ‘Sustainable materials and systems’, represented by the Kvantum. The most common SDG-related themes were Climate Action (SDG 13) and Life on Land (SDG 15). In addition, Good Health and Wellbeing (SDG 3) and Industry, Innovation and Infrastructure (SDG 9) were linked several projects.

United Nations Sustainable Development Goals and Kvantum projects connected to a goal
The focus to sustainability - principal investigator’s view to sustainable development. Professor MEHDI BENNIS, Resource optimization for context-aware smart cities (SAFARI) project (see page 23).

Future smart cities – are they automatically also the cities of sustainable development?

“Smart cities and sustainability are two faces of the same coin, now more than ever after the COVID19 pandemic. I like to call them cognitive cities inspired from human cognition to better reflect the smartness in Smart cities. The goal is to leverage the vast amount of data coming from a plethora of multimodal sensors to optimize a multitude of operations ranging from city planning, transport/mobility, modular infrastructure (for shared services), logistics, and livelihoods and much more. And all this should be carried out while being cognizant of citizens’ privacy and the limited nature of our resources.

What do you think are the key factors in sustainable city development in your research field?

“Leveraging advances in AI, robotics, AR/VR, metamaterials and beyond 5G/6G connectivity (+others) will be instrumental in enabling the vision of a cognitive/sustainable city. A cognitive city will be more resilient, efficient, and sustainable based on sensing, understanding, and swiftly addressing environmental and societal challenges.”
Project description

CAESAR aims to improve our understanding of space-related factors that are ultimately, but not necessarily directly, controlled by solar activity. In addition to direct factors like solar electromagnetic radiation (total and spectral irradiance), these factors include particle radiation, in particular solar wind particles that are known to affect the polar and high-latitude atmosphere and surface climate at interannual to decadal timescales. This topic is highly relevant because the climate at high latitudes, especially in the Arctic, is quite variable and extremely vulnerable to external and internal forcings. Moreover, the dramatic changes in solar magnetic activity during the recent decades enhances the acuteness and importance of these this research. In addition to the long-term change, the Arctic climate shows large year-to-year variability, which is demonstrated during the winter season as the leading northern-hemisphere pattern called the Northern Annular Mode (NAM) and its Atlantic part, the North Atlantic Oscillation (NAO). These are hemispheric-scale patterns of air circulation, which arise from internal atmospheric dynamics and dominate the winter-time climate in the Northern hemisphere. Caesar aims to study whether and how the solar wind related particle precipitation can affect the winter climate in the Arctic.

Key words: Space climate, solar activity, long-term change, solar effects to atmosphere and climate

Results and impact

We have studied the effect of energetic particle precipitation (EPP) to Northern hemisphere winter climate variability. EPP is known to enhance the formation of NOx molecules in the upper mesosphere, which are transported downward into the stratosphere during winter. There they catalytically destroy ozone and thereby affect atmospheric temperature and dynamics. However, the detailed mechanisms and conditions when and how this happens have been unclear. Using various long-term climate datasets, we studied the connection between EPP and atmospheric dynamics and found that enhanced EPP causes a strong,
significant response in the polar stratosphere during winter, which is seen as a strong polar vortex, a westerly wind that circulates the pole during winter. Changes in polar vortex are also reflected to ground weather, e.g., the North Atlantic Oscillation, which influences the winter weather in large parts of Eurasian and North American continents. We found that this EPP effect is dramatically modulated by the level of planetary wave activity propagating from the troposphere to the stratosphere. Our results help to better understand the EPP effect and its joint effects with planetary waves.

We also discovered that EPP greatly influences the occurrence of wintertime breakings of the polar vortex, so-called sudden stratospheric warmings (SSW), which have long-lasting (i.e., several weeks) effects on the winter weather in large parts of the Northern Hemisphere. We found that, during the easterly phase of equatorial stratospheric winds, low EPP level is strongly associated with the occurrence of SSWs. This is a very important result for practical purposes, because SSWs are extremely influential for ground winter weather, and predicting their occurrence has a huge stake. EPP level and QBO phase behave in predictable ways over the solar cycle time scale, which potentially allows improved prediction of SSW-type winters years beforehand.

We have made advances for improved modeling of EPP effects on climate. We produced a novel homogenized composite data series using historical POES satellite data from 1979 to present. This was coupled to numerical models of atmospheric ionization and used as input in a large-scale climate model intercomparison experiment, which aimed at clarifying the level of NOx molecules produced by the ionization, and how it compares with measurements of NOx amounts. This work forms the first step towards incorporating our unique EPP dataset into climate models thereby allowing improved modeling capability to study the EPP influences.

Results of CAESAR clarify the role of solar-wind driven EPP as a natural driver of wintertime climate variability in the Northern hemisphere. The results have shown that EPP can have a significant influence on interannual variation of winter weather, and that these influences offer a potential for a long-term prediction of winter climate/weather variability. This will have obvious practical relevance for any field of society that is dependent on weather, e.g. energy consumption, transport, and agriculture. Since CAESAR results clarify natural climate variability, they may also influence and be included in the contents of future IPCC reports, which would have a significant impact on policy measures.

Top five publications


The research of this project supports the following United Nations Sustainable Development Goal:

**Solar Wind Driven Influence Begins at the Boundary of Space and Atmosphere**

Near-Earth space is filled with energetic particles, electrons and protons, trapped in Earth’s magnetic field. During fast solar wind streams these particle populations intensify.

Disturbances in space cause particles to precipitate along spiral trajectories into the upper atmosphere, the mesosphere around Earth’s polar regions. The particles ionize and excite atmospheric atoms, which leads to formation of HOx and NOx molecules which can destroy ozone ($O_3$).

Ozone loss changes air temperatures and thereby also influences the atmospheric circulations.

As a result the polar stratosphere cools and the westerly wind circulating the polar regions, so called polar vortex, intensifies.

The variations beginning up in the mesosphere and stratosphere cumulate over the winter season and propagate downwards in the atmosphere. The clearest signal on ground level is often seen in mid- to late winter in January-March.

During these times the westerly winds related to the large scale level air circulation modes Arctic Oscillation and North Atlantic Oscillation intensify and provide warmer and moister winter weather, e.g. for us in Finland.
2.1.2. Diversity of species interactions: a missing key for understanding biodiversity in a changing world

Project description
Coevolution among species via species interactions is the major driving force of biodiversity. Yet, the concept of and metrics to estimate species interactions is largely missing from biodiversity studies. The project had two major aims. First, our goal was to create a novel community diversity index and second, we aimed to estimate a species-specific characteristic, which describes species competitive – facilitative interaction abilities. The association of this new metric with species capability to adapt to global changes was then examined. We used long-term and geographically comprehensive passerine breeding bird and moth data. We used a state-of-the-art statistical modelling technique, Joint Dynamic Species Distribution Modelling, in extracting species associations from the survey data.

Key words: species interactions, biodiversity, climate change, global change, species distribution modeling, macroecology, community ecology, human disturbance, anthropogenic disturbance, boreal ecosystem

Results and impact
According to the results from the project, birds belonging to the family Paridae (tits), all of which are forest-dwelling, can be used as an indicator of total abundance of forest birds. A positive association between abundance of tits and abundance of other forest birds was found both in Finland and France, but the relationship was stronger in Finland, suggesting that tits are a better indicator of forest bird abundance in Northern than in western Europe. The possibility to use tits as indicators of forest bird abundance suggests that many forest birds use tit abundance as a cue in breeding habitat selection. Such an informed breeding habitat selection has consequences for the distribution of animals in space, and on the associations and interactions among individuals. In a theoretical analysis, we predicted that the spatial distribution of individuals deviates from the so-called ideal free distribution – theory of the ideal free distribution being one of the bedrock theories in ecology – if acquisition of information is costly. Information acquisition can be assumed to be costly in general, which is why the ideal free distribution should not be a baseline expectation in ecological studies.

The project also studied how particular species are associated with other species among communities. This research suggests that the whooper swan (Cygnus cygnus) is neg-
atively associated with other water birds in the duckling stage, while other water birds are generally positively associated with each other in the duckling stage. The negative association of the whooper swan ducklings with ducklings of other water bird species is consistent with the hypothesis that the whooper swan is aggressive towards other water bird species during the breeding time and may so exclude other species from sites that it occupies. This result highlights the importance of species interactions for the assembly of water bird communities, which has also applied significance because many water birds are important game species.

The project still continues, and we can expect results that have importance and relevance for nature conservation and game species management.

**Top five publications**


The research of this project supports the following United Nations Sustainable Development Goal:
2.1.3. Ecology and evolution in trophic interactions in changing boreal forest habitats

University’s focus area, where the project is related to:
Changing climate and northern environment

Responsible Principal Investigators

MARKKU ORELL, Professor, Ecology and Genetics, Faculty of Science, UOULU, 2017-2019

SEPPO RYTKÖNEN, University Lecturer, Ecology and Genetics, Faculty of Science, UOULU, 2019-2020

Other project researchers

Panu Välimäki, Postdoctoral Researcher
Coen Westerdun, Doctoral Student
Emma Vatka, Coordinator
Marko Mutanen, Senior Curator
Sami Kivelä, Academy Research Fellow
Veli-Matti Pakanen, University Teacher
Netta Keret, MSc, Doctoral Student

SEPPPO RYTKÖNEN, University Lecturer, Ecology and Genetics, Faculty of Science, UOULU, 2019-2020

MARKKU ORELL, Professor, Ecology and Genetics, Faculty of Science, UOULU, 2017-2019

Project description

The project focused on temporal variation in seasonality and consequent changes in the selection regime within a boreal forest food chain. We studied the following tri-trophic system: (1) the birch and (2) associated folivorous insects, (3) insectivorous birds. We aimed at revealing the roles of phenotypic plasticity within and between generations as well as indirect genetic effects on the adaptation of wild animal populations to changing environment. We utilized the unique long-term data of individually marked birds and extensive life-history data on moths. In addition, we have access to the nationwide data on weather parameters that define the seasonality, phenology and abundance of nocturnal moths and leaf succession of deciduous trees. In research, we applied experimentation, state-of-the-art quantitative genetics and metabarcoding. We quantified both selection agents that act on phenotypes and evolutionary potential in life history traits. These were used to produce predictions of evolutionary trajectories for traits affecting adaptation within a trophic level, and its implications for trophic interactions that define ecosystem function.

Key words: climate change, boreal food chain, adaptation, additive genetic variance, indirect genetic effects, phenotypic plasticity, long-term data, experimentation, thermal sensitivity, quantitative genetics, metabarcoding, birch, folivorous moths, birds

Results and impact

We showed that an important life-history trait, timing of breeding, of two northern passerines showed low level of evolutionary potential. This means that their responses to warming climate do not promote microevolution but show phenotypic plasticity without genetic changes. This finding is important when we consider the possibilities how wild animals adapt to the changing environment and warming climate. If they don’t have enough evolutionary potential, local extinctions are inevitable. This kind of case studies form the very important network of studies that can find generality for this crucial question.

We developed a new DNA-metabarcoding method in analyzing both the consumed and the available prey species of insectivorous passerines, which has good potential for further use and applicability in many corresponding studies. The diet analyses of insectivorous passerines by using DNA-metabarcoding methodology revealed an unexpectedly diverse prey species lists, consisting mostly of Lepidoptera moths. The more detailed ecological analysis is ongoing and will give new insight to the roles of interspecific competition and/
or resource partitioning among the ecologically similar species – a key question for understanding the mechanisms behind the changes in community structures due to northward shift of flora and fauna caused by the warming climate.

The results of our project are based on an internationally important long-term data of individually marked birds collected for decades. This is the only way to get insight to the effects of climate warming and environmental change on the ecology and evolution of wild animals.

Societal importance and applicability of the results have a lot of potential for wide use in solving various kinds of practical environmental issues, e.g., in sustainable land use planning, practical nature conservation and monitoring of changing landscape structure and species distributions. Predicting how ecosystems respond to environmental change enables global and local economics and politics to make informed decisions regarding the management of natural resources that provide the very basis of human well-being.

Top five publications


The research of this project supports the following United Nations Sustainable Development Goals:

- [3 Good Health and Well-being](#)
- [4 Quality Education](#)
- [5 Gender Equality](#)
- [13 Climate Action](#)
- [15 Life on Land](#)
- [16 Peace, Justice and Strong Institutions](#)
- [17 Partnerships for the Goals](#)
2.1.4. Frontiers of materials NMR

**University’s focus area, where the project is related to:**
Sustainable materials and systems

**Responsible Principal Investigator**
JUHA VAARA, Professor, NMR Research Unit, Faculty of Science, UOULU

**Other project researchers**
- Sanna Komulainen, Postdoctoral Fellow
- Vladimir Zhivonitko, Associate Professor (Tenure Track)
- Pär Häkansson, Postdoctoral Fellow
- Anne Selent, Postdoctoral Fellow
- Maryam Arianpouya, Doctoral Student
- Yashu Kharbanda, Doctoral Student
- Ben Tickner, Postdoctoral Fellow
- Nazmul Hossain, Doctoral Student
- Jyrki Rantaharju, Doctoral Student
- Shubham Agarwal, Doctoral Student
- Sharif Ullah, Doctoral Student
- Akseli Mansikka, Postdoctoral Fellow
- Anand Chekkottu Parambil, Doctoral Student

**Project description**

In the project we developed experimental, theoretical and computational research methods based on magnetic resonance phenomena and applied the methods to topical problems in molecular and materials sciences. The project topics were:

a) ultrafast multidimensional Laplace NMR, in which spatial encoding is used to correlate dynamic properties such as T1/2 relaxation times and molecular diffusion to achieve unforeseen speed and applications potential in the chemical resolution and dynamics in macromolecular systems;

b) nuclear magneto-optic spectroscopy to combine nuclear site-specific information similar to but also adding to that of NMR;

c) theory of paramagnetic NMR, in which we developed quantum-chemical methodology for the NMR parameters (nuclear shielding, spin-spin coupling and relaxation times) of electronically open-shell molecules and materials; and

d) computational NMR of materials systems, where we developed and applied molecular modelling (quantum chemistry and molecular simulation) to assign, analyse, and predict the NMR spectral parameters of complex materials.

**Keywords:** Natural Sciences, environment, physical sciences

**Results and impact**

We improved the efficiency and sensitivity of multidimensional relaxation and diffusion experiments by developing ultrafast Laplace NMR experiments and combining them with modern nuclear spin hyperpolarization techniques and exploited the methodology in multidisciplinary applications ranging from materials science to biochemistry and climate research. We developed and applied methods for the calculation of nuclear magnetic resonance spectra of molecules and solids that contain unpaired electrons. In particular, relativistic effects, environmental and thermal effects, the couplings between nuclei, and the so-called point dipole approximation were focused on. The latter renders it possible to calculate very large systems. In addition, we developed method for calculating the frequency shifts as well as spin polarization transfer taking place in spin-exchange optical hyperpolarization processes. We have shown a proof-of-concept for increasing the signal strength in a new emerging NMOS methods. The work is of basic research type with plenty of applications in applied materials studies as well as the high-precision measurements of fundamental physics.
Methods developed in this project open new avenues in research by enabling further physical processes to be studied by this technique, as well as detailed analysis and prediction of the results. In the long run these methods contribute to the development of sustainable materials, improved health care methods, investigation of items belonging to cultural heritage, and improved understanding of fundamental physics phenomena.

**Top five publications**


2.1.5. Impact of extreme weather events in the Arctic on technological system, critical facilities and urban environment (ARCEMIS)

University's focus area, where the project is related to:
Changing climate and northern environment

**Responsible Principal Investigator**

ELENA KOZLOVSKAYA, Professor,
Oulu Mining School (OMS),
Faculty of Technology, UOULU

**Other project researchers**

Jarkko Okkonen, Postdoctoral Researcher,
OMS, Faculty of Technology,
At present, Senior Researcher at the Geological Survey of Finland

Nikita Afonin, Doctoral Student,
OMS, Faculty of Technology

Taewook Kim, Doctoral Student,
Environmental and Chemical Engineering,
Faculty of Technology

Kari Moisio, Senior Researcher,
OMS, Faculty of Technology

**Project description**

Despite measures taken to reduce emission of greenhouse gases to the atmosphere, the processes initiated by climate change and their negative consequences cannot be stopped immediately. Among such consequences is rapid warming of the Arctic that results in occurrence of extreme weather or climate events. They can be very unexpected and hazardous for buildings and roads in the urban environment and for such critical facilities as mining waste storage facilities, dams, underground communication lines and pipes, windmills etc. On the other hand, rapid warming of the Arctic attracts more businesses and activities to the area. Particularly mining activities are expanding in Finland as well as in other Arctic countries due to increased need of minerals. Development of these activities can have a positive effect on local communities (for example, job creation, common infrastructure development). However, mining in the Arctic climate conditions is a risky and challenging task and without proper planning and control can result in negative impacts on both the environment and local communities. The main target of our project was to increase amount of knowledge about impact of climate variability and change, in particular, of extreme weather events on the environment and infrastructures and about their possible consequences for society, communities and individuals in the Arctic.

**Results and impact**

The ARCEMIS project aimed to investigate the phenomenon of frost quakes that are caused by extreme weather conditions in the Arctic and sub-Arctic areas. These unexpected weather conditions can initiate massive fracturing of water-saturated soil and rock as water has suddenly frozen and expanded. Fractures in frozen soils (frost quakes) can cause damage to buildings and other infrastructure, but their formation mechanisms remain poorly understood. A proposed mechanism for frost quakes is when liquid water trapped within pores of saturated soil freezes and expands due to a rapid decrease in atmospheric temperature followed by a sudden decrease in soil temperature. This expansion of the freezing water increases the stress within the soil, which can be released quickly in an explosive
way. Based on this conceptual idea, we developed a method that can be used to predict the timing of frost quake. This method is based on calculating thermal stress due to intrusion of cool air in soil and comparing the results of calculated thermal stress to strength of the soil. The results of the project can be used to predict occurrence of such events and minimize their destructive effect on urban infrastructures and industrial facilities.

Top five publications


The research of this project supports the following United Nations Sustainable Development Goal:
2.1.6. Impact of mining on the rate of molecular aging in Arctic wildlife

**University’s focus area, where the project is related to:**
Changing climate and northern environment

**Responsible Principal Investigator**
PHILLIP WATTS, Professor, Ecology and Genetics, Faculty of Science, UOULU, since 2020 Department of Biological and Environmental Science, University of Jyväskylä

**Other project researchers** at Ecology and Genetics research unit, Faculty of Science, UOULU
Eugene Tukalenko, Postdoctoral Researcher
Anton Lavrinienko, Doctoral Student
Ilze Brila, Doctoral Student

**Project description**
This project quantified some key molecular signatures (e.g., telomere and mitochondrial homeostasis) associated with inhabiting areas containing elevated levels of metals, released through mining activities, in Arctic field sites. The project also examined the potential for variation in metal pollution to affect gut microbiota (host-associated bacteria inhabiting the gastrointestinal tract) composition and infection status. The principle model species is a small rodent, the bank vole *Myodes glareolus*.

**Keywords:** telomere, cellular stress, ecotoxicology, immunity, microbiota, amplicon sequencing

**Results and impact**
We studied the bank vole *Myodes glareolus*, a small rodent that is common in mixed forest and woodland areas of much of northern Europe. This small mammal lives in burrows in the ground where it may be exposed to metal pollution derived from mining activities. We measured the lengths of telomeres, the protective ends of chromosomes, and damage to mitochondrial DNA in our study animals, as these are widely-used biomarkers of the rate of ‘molecular ageing’. We found few consistent impacts on telomere length and damage to mitochondrial DNA in bank voles inhabiting areas with elevated levels of metals (and metalloids), reflecting the relatively low level of metal uptake in bank vole tissues. Nonetheless, exposure to chronic, low level metal pollution (total metal load, and specifically the elements Cd, Hg, Pb and Se) was found to impact the gut microbiota (the community of microbes residing within the gut, principally bacteria) and these changes are associated with the probability of infection/co-infection by certain pathogens. These data indicate how exposure to low levels of pollution derived from mining activities can elicit a change in the mammalian gut microbiota, and potentially affect wildlife health.

Our data imply that low level metal pollution derived from mining activities does not have a major impact on telomere length and integrity of mitochondrial DNA in terrestrial wildlife. By contrast, exposure to low levels of specific metals can associated with a change in the animal gut microbiota. We also identified moderate effects of infection on bank vole gut microbiota, with a difference between animals that had one infection and those with multiple infections. The mechanisms behind these impacts on gut microbiota should be explored further in wildlife to improve biodiversity conservation, and possibly also to act as a model to understand how exposure could affect human gut health.

**Top publication**

https://doi.org/10.1016/j.scitotenv.2021.148224
2.1.7. Loss of ice in the Arctic system: geological perspective of global environmental change

Project description

The research group’s task was to study the role of the glaciated high latitude areas as a part of the Earth system in order to setting boundary conditions for future climate and environmental change. The research group owns expertise of the Eurasian Arctic ice-sheet distribution and ice streaming during melting episodes in the Arctic land environment as well as successfully use mineralogical, including clay and heavy minerals, radiogenic isotope proxies and other source area fingerprints in sediments for study sediment distribution and meltwater releases in the Arctic marine environment.

Keywords: Arctic, sea ice, glacier ice, sediment, mineralogy, geochemistry, isotopes, paleoclimate, environment

Results and impact

This project was a part of a wider scientific venture through the International Arctic Science Committee (IASC) endorsed international network programme PAST Gateways (Palaeo-Arctic Spatial and Temporal Gateways) and its follow-up research network programme PalaeoArc. New sediment geochemistry and varietal mineral geochemical data has been generated in this project to evaluate past glacial dynamics and events such as loss of ice and related meltwater releases and to understand processes behind those changes. Research on past Arctic ice-sheet collapses, transitions are extremely important today when human effected climate change is warming the Earth, still constantly.

Arctic ice is an important component of the Earth climate system affecting global sea level, ocean circulation and heat transport. The Arctic glaciers and the Arctic Ocean sea ice are very dynamic in response to global warming as well as affecting environmental change for the rest of the world. The achieved research results can be used for better planning e.g., future Arctic operations.

University’s focus area, where the project is related to:
Changing climate and northern environment

Responsible Principal Investigator

KARI STRAND, Professor, Oulu Mining School, Faculty of Technology, UOULU

Other project researchers
Ninna Immonen, Post-Doctoral Researcher
Olli-Matti Kärnä, Post-Doctoral Researcher
Ekaterina Kaparulina, Doctoral Student
Tiina Nikarmä, Doctoral Student
Tiina Eskola, Doctoral Student
Raisa Alatarvas, Doctoral Student
Matleena Hyvärinen MSc Student
Hanna Koskinen MSc Student
Linnea Kaislo, MSc Student

Other project PI
Juha Pekka Lunkka, Professor, Oulu Mining School, Faculty of Technology, UOULU

University’s focus area, where the project is related to:
Changing climate and northern environment
Top five publications

Nikarmaa, T., Lunkka, J. P. and Putkinen, N. 2017. Factors affecting the dynamics of the North Karelian/Oulu Ice Lobe, Central Finland, during the last deglaciation – a LiDAR and DEM interpretation of subglacial lineation patterns. Bulletin of the Geological Society of Finland 89, 100-120. https://doi.org/10.17741/bgsf/89.2.003


Ice melting from a glacier in the ice fjord in Greenland. Photo by Kari Strand.
2.1.8. Mesospheric monitoring of ozone above the polar vortex (MeMO)

University’s focus area, where the project is related to:  
Changing climate and northern environment

Responsible Principal Investigator

THOMAS ULICH, Head of Observations, Sodankylä Geophysical Observatory (SGO), OULU

Other project researchers

Jia Jia, Postdoctoral Researcher, SGO
Emranul Sarkar, Doctoral Student, SGO
Kenneth Nilsen, Doctoral Student, SGO
Alexander Kozlovsky, Adjunct Professor, SGO
Pekka Verronen, Professor, SGO & Finnish Meteorological Institute (FMI)
Antti Kero, Assistant Professor, SGO
Rigel Kivi, Dr, Senior Researcher, FMI

Project description

Both solar radiation and energetic particle precipitation from space affect the physics and chemistry of the middle atmosphere. We do know that energetic electron precipitation destroys ozone in the mesosphere and indirectly in the stratosphere. While solar radiation effects on atmospheric chemistry are quite well studied, particle effects are much less understood. Mesospheric ozone chemistry plays a crucial role in the dynamic of the middle atmosphere. The project “Mesospheric Monitoring of Ozone” (MeMO) utilises a novel method to measure ozone using standard, low-cost satellite-TV receivers. The MOSAIC receiver is based on the 11.07-GHz radio emission of ozone, which happens to lie in the same radio band as TV signals.

Keywords: ozone, mesosphere, ionosphere, near-Earth space, space weather, radiometer

Results and impact

SGO operates more than 75 scientific instruments at 29 locations including 2 in Sweden and 1 in Antarctica. The project makes of use of, among others, the new MOSAIC receiver, the Sodankylä-Leicester Ionospheric Coupling Experiment (SLICE, meteor radar), magnetometers, riometers, and the KILPI Atmospheric Imaging Receiver Array (KAIRA).

MOSAIC receiver: while stratospheric ozone shields the biosphere from harmful UV radiation, mesospheric ozone is important for atmospheric dynamics. The MOSAIC receiver concept provides a low-cost means to measure mesospheric ozone alas with lower accuracy, making large-area coverage feasible. The relative simplicity of the instrument allows any interested party to build a receiver, even as a school project, and join the international MOSAIC network. Due to the measurement geometry, it is possible to study ozone above otherwise inaccessible areas such as the Barents Sea.

Solar Protons in the Stratosphere: During relatively infrequent Solar Proton Events (SPE), very high-energy protons from the Sun penetrate the Earth’s middle atmosphere. Earlier studies of balloon soundings of stratospheric ozone have shown effects of ozone depletion after SPEs. Using Microwave Limb Sounder (MLS) satellite measurements and Whole Atmosphere Community Climate Model (WACCM-D) simulations, we did not see a statistically significant effect of SPEs in the lower stratosphere. Overall, we find a very good consistency between WACCM-D simulations and MLS observations.
Mesopause Temperature from Meteor Radars: For 2 decades, meteor radars have been routinely used to monitor atmospheric temperature around 90 km altitude, i.e. at or below the mesopause. Traditionally this is done by fitting a linear regression model to meteor decay time and decay height and requires calibration with temperature observation from another instrument. Compared to lidar data, meteor radar temperatures have a systematic offset, which is due to the inability of classic linear regression to take into account measurement errors in both decay time and decay height. Using the errors-in-variables (EIV) model, we obtain meteor radar temperatures independently without external calibration with greatly reduced systematic offset of 5 % or better on average.

Observations and studies of the polar middle atmosphere are crucial for understanding how climate change will affect the polar regions and to mitigate climate change effects. The mesosphere is notoriously hard to observe: it lacks ionisation and it is out of reach of atmospheric balloons. The new 8-channel MOSAIC receiver is a low-cost instrument measuring continuously mesospheric and lower thermospheric ozone. The instrument can be assembled in a high-school classroom. Collaboration with schools and higher education institutes in circumpolar regions ensures large geographical coverage and will have a significant impact on inspiring interest in STEM subjects in young people.

Top publications


2.1.9. Resource optimization for context-aware smart cities (SAFARI)

University’s focus area, where the project is related to:
Sustainable materials and systems

Responsible Principal Investigator

Other project researchers
Sumudu Samarakoon, Postdoctoral Researcher
Mohamed Abdelaziz, Doctoral Student
Hamza Khan, PhD (Doctoral Student during the project)

MEHDI BENNIS, Professor,
CWC-Radio Technologies, Faculty of Information Technology and Electrical Engineering, UOUL

Project description

Our cities are becoming increasingly complex to optimize and manage. Optimizing these multi-dimensional networks over time and space warrants a fundamental paradigm shift from traditional centralized optimization toward self-organizing and context-aware networked cities. Exploiting Intelligent Transportation systems (ITS) via vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications, holds the promise of making our future transportation system safer, efficient, and environmentally sustainable. This project investigated how to exploit urban analytics, computing, storage, in conjunction with recent advances in 5G wireless technologies to address the myriad of challenges in traffic safety, mobility, sustainability, and energy-efficiency. This project was multidisciplinary in nature and aimed at weaving in notions from optimization theory, game theory, control theory, statistical physics and others whose applications will go beyond SAFARI.

Keywords: Smart mobility, smart cities, 5G-vehicle-to-everything (V2X), ultra-reliability and low-latency communication (URLLC)

Results and impact

The research in SAFARI project has led to several publications in IEEE conference and journal publications. In fact, the very first application of federated learning in V2X has been done under this project. This has opened the new area of federated learning over wireless networks. I was also invited by Google to present out works in their HQ in Seattle. Moreover several tutorials, panels and keynotes were given. Central to the project was the graduation of two PhD students who were been directly and indirectly funded by SAFARI project. New collaborations were also enabled by this project which have led to new proposal submissions. In terms of impact, our scientific outputs have not only helped address many challenges related to vehicular communication but also enabled new research areas, for e.g. in sustainability, resiliency and cognitive cities.

V2X as a topic is related to mobility, transport, climate change via electrification and how to plan smart cities of the future. The vertical of vehicular communication will continue to evolve as we transition to 6G and parts of the economy will be automated. We will be witnessing autonomous vehicles, fleets of trucks and lorries and so forth.
Top five publications

http://urn.fi/urn:nbn:fi-fe202002195825


The research of this project supports the following United Nations Sustainable Development Goals:
2.1.10. Surface-groundwater interaction in boreal peatland-esker systems: conceptualization of hydrogeological process, integrated numerical modelling and assessment of climate change

**University’s focus area, where the project is related to:**
Changing climate and northern environment

**Responsible Principal Investigator**
BJÖRN KLÖVE, Professor,
Water, Energy and Environmental Engineering, Faculty of Technology, UOUL

**Other project researchers**
Filip Muhic, Doctoral Student
Kashif Noor, Doctoral Student
Anna Autio, Doctoral Student
Leo-Juhani Meriö, Doctoral Student
Ali Torabi Haghighi, Associate Professor (Tenure Track)
Pertti Ala-aho, Docent
Hannu Marttila, Assistant Professor (Tenure Track)

**Project description**
Hydrological conditions are expected to change rapidly in snow-influenced northern environments due to global warming. Snowmelt recharges groundwater storages, which provide a stable water source for both ecosystems and human needs, especially during dry spells. However, hydrological flow paths from snowmelt to streamflow via groundwater storage are changing which effect groundwater discharge into streams and peatlands. The projects combines the use of environmental traces and numerical modeling to understand how groundwater and surface water interact in northern ecosystems. Special focus is put in conceptualizing snowmelt processes with stable water isotopes, which will produce new information on the role of snow in the boreal hydrological regime. The work is done in collaboration with biogeochemical and biological research to significantly advance the holistic understanding of environmental change in the north.

**Keywords:** hydrological modeling; groundwater – surface water interaction; peatland hydrology; cold climate hydrology; environmental tracers

**Results and impact**
Our studies have developed new hydrological methods and analysis on global change in northern ecosystems. The project has improved the understanding of hydrological processes and groundwater-surface water interaction. We have successfully applied advanced numerical modelling to study flows in complex ecosystems such a northern peatlands. We have carried out a series of detailed studies at Pallas research site to understand critical landscape level processes related to water availability and vegetation water use. Our work has advanced the understanding on northern rivers and climate change by improved analysis and understanding of ice jam and flow regulation. The studies provide input and support to ongoing long-term assessment of climate change, biodiversity and carbon balances in the North.
Top five publications


The research of this project supports the following United Nations Sustainable Development Goals:
2.1.11. Towards the genomic era in species identification and delimitation

University’s focus area, where the project is related to:
Changing climate and northern environment

Responsible Principal Investigator
MARKO MUTANEN, Senior Curator, Ecology and Genetics, Faculty of Science, UOULU

Other project researchers
Kyungmin Lee, Postdoctoral Researcher
Vladislav Ivanov, Doctoral Student

Project description
Species underpin all biological research and are important in many other ways for humanity; yet until now we have been unable to efficiently document the vast biodiversity of Earth with available methods. The research particularly focus, at genomic level, on molecular delimitation of species and clarifying issues caused by DNA barcode sharing between species, deep intraspecific splits in DNA barcodes, introgression and endosymbionts on DNA-based taxonomy. Butterflies and moths, sawflies, spiders and other invertebrates were used as model groups. As methods, ddRAD sequencing and other NGS techniques were applied. The project aimed at pointing the way ahead towards the genomic era for the scientific field of taxonomy.

Keywords: Species delimitation, species identification, DNA barcoding, ddRAD sequencing, molecular taxonomy, molecular phylogenetics, DNA taxonomy

Results and impact
This project focused on elucidating and understanding patterns observed in mitochondrial DNA, particularly in so called DNA barcodes, using genomics tools. DNA barcodes are of great importance in modern biodiversity research, because enable identification of individuals to the species level without taxonomic expertise in a straightforward and accurate manner. DNA barcodes are also efficient in revealing cryptic diversity, i.e. species that have remained unnoticed because of high morphological similarity. We have demonstrated that wide intraspecific variability in DNA barcodes sometimes indeed flag true cases of cryptic diversity, but in many cases other evolutionary phenomena, for example introgression through hybridization, may explain the observed patterns. We also studied species that do not have species-specific DNA barcodes and clarified the evolutionary causes behind this pattern, termed mitonuclear discordance. Furthermore, we investigated the extent of DNA barcode variability in space, that is, across geographical areas. Our results suggest that in many cases populations tough to belong to a single species and separated geographically actually represent genetically widely distinct populations that could even be considered distinct at species level. This observation may have remarkable effect on our understanding of biodiversity at a global scale.

Species is a central unit of biological diversity. Being able to assign organisms into species is important not only for biologists, but also for all people interested in nature and working on fields that are connected to biodiversity. Being able to identify individuals into species is also critical in many areas of the society, for example in food and construction industries in which products must be labelled by species. DNA barcoding is a rapid,
straightforward, and accurate tool to identify organisms by short standard tags of DNA. In this project, we focused on understanding phenomena that are of great relevance for DNA barcoding and that potentially may compromise its use. Taking a benefit of efficient genomics tools, we studied insects and spiders to understand causes of DNA barcode sharing across species. We also focused on cryptic diversity and whether DNA barcodes are efficient in revealing such species. Thirdly, we focused studying genetic variation in a special scale to better understand how the observed variability could be delineated into species.

**Top five publications**


https://doi.org/10.1093/sysbio/syy029

The research of this project supports the following United Nations Sustainable Development Goals:

![UN SDGs icons]
2.1.12. Understanding and predicting environmental change in northern rivers: biodiversity and ecosystem functioning in a changing climate

**University’s focus area, where the project is related to:**
Changing climate and northern environment

**Responsible Principal Investigator**
TIMO MUOTKA, Professor. Ecology and Genetics, Faculty of Science, OULU.

**Other project researchers**
Kaisa-Leena Huttunen, Postdoctoral Researcher
Jacqueline Malazarte, Doctoral Student

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**Project description**

The project had three focus areas: 1) What are the likely effects of climate change on stream invertebrate diversity across multiple spatial scales (α, β and γ diversity)? 2) Do land-use disturbances modify the responses of stream biodiversity and ecosystem functioning to climate change? 3) Does diversity beget stability to stream communities? Each subproject included both large-scale correlative surveys and mesocosm experiments. The research group focused on different aspects of community ecology of stream and groundwater-dependent ecosystems.

**Keywords:** biodiversity change, boreal streams, climate change, community variability, land-use impacts

**Results and impact**

Much of our field work is based at Oulanka Research Station. We have collected a unique data set of benthic invertebrates in 24 streams draining rivers Oulanka-, Kitka and Kusinskijoki across 21 consecutive years (2000-2020). Our experimental studies on multiple environmental stressors related to land use and climate change are mostly based at Paltamo Research Station hosted by National Resources Institute Finland (Luke).

We selected 23 sites to represent reference (mature second growth) and clear-cut, buffered sites (buffers of 1-40 m wide) for an intensive study on biodiversity and functional responses of headwater streams to forest management. We found that the reduction of riparian buffers resulted in higher water temperatures, intensified primary production, streambed sedimentation and reduced invertebrate diversity. Current forest certificates only require very narrow riparian buffers, which clearly is insufficient for protecting headwater stream ecosystems.

Growing bioeconomy increases the pressure to clear-cut drained peatland forests. We studied the effects of peatland drainage and clear-cutting on stream benthic biodiversity. We used extensive field material to show that the impact of clear-cutting of drained peatland forests exceeded the sum of the effects of drainage or clear-cutting alone. We also found that small headwater streams were more sensitive to forestry impacts than the larger downstream sites. This study was based on collaboration with Finnish Environment Institute (SYKE).
Air temperature at the northernmost latitudes is predicted to increase and precipitation to become more variable by the end of the 21st century, resulting in altered thermal and hydrological regimes. We applied five climate-change scenarios in a species distribution model to predict future (2070–2100) benthic macroinvertebrate assemblages at 239 near-pristine sites across Finland. As expected, projected air temperature increased most in northernmost Finland. Predicted taxonomic richness also increased most in northern Finland. Northern streams were predicted to lose much of the seasonality of their flow regimes, causing potentially marked changes in stream benthic assemblages. One of the most important practical implications of our research is related to effectiveness (or rather, lack of it) of forest certificates in providing protection for small streams from forest harvesting.

Our results were used by environmental authorities to justify their withdrawal from the national working group for reformation of PEFC, the most widely used certificate in Finland. Another finding that should have direct relevance for environmental decision making is a study where we quantified the effects of clear-cutting of drained peatlands on stream biodiversity. Our results showed that the combined effect of peatland drainage and forest harvest on stream biodiversity is much more dramatic than could be expected based on the individual effects of each pressure alone.

**Top five publications**


2.2. Emerging research projects 2018 – 2022, interim report

2.2.1. Bayesian techniques for radar observations of the near-Earth space

University’s focus area, where the project is related to:
Changing climate and northern environment

**Responsible Principal Investigator**

ILKKA VIRTANEN, University Lecturer, Space Physics and Astronomy, Faculty of Science, UOULU

**Other project researcher**

Habtamu Tesfaw, Doctoral Student, Space Physics and Astronomy, Faculty of Science, UOULU

**Project description**

At the high latitudes, almost vertical geomagnetic field couples the top of the Earth’s atmosphere with the magnetosphere and the solar wind. The magnetic field maps electric fields and guides energetic particles from the magnetosphere down to the ionosphere, a partially ionized region of the atmosphere between 60 and 1000 km in altitude. In the ionosphere, electric fields and particle precipitation drive electric currents and plasma drifts, ionize and heat the atmosphere, and cause changes in both ion and neutral chemical composition. The visible auroras are formed when precipitating electrons excite atoms and molecules, which emit light when returning to their ground states. The ionosphere is observed with various instruments including radars, optical instruments, rockets and satellites. The EISCAT scientific association operates incoherent scatter radars in the northern Fenno-Scandinavia. These radars have the benefit that they can observe the whole altitude range of the ionosphere from ground, and they are not affected by weather. EISCAT is building the next-generation EISCAT_3D radar system, which will provide an order-of-magnitude improvement in resolution and volumetric observations. However, resolutions of the radar observations will still need to be improved to catch the rapid, small-scale processes of the high-latitude ionosphere, and information of the ion chemical composition is currently not extracted from EISCAT radar data. In this project we develop cutting-edge data analysis tools for the EISCAT and EISCAT_3D radars and use them for high-resolution observations of the aurora and the related ionospheric phenomena.

**Keywords:** EISCAT, EISCAT_3D, Bayesian techniques

**Recent progress**

We have developed an incoherent scatter radar data analysis tool that can be used for fitting ion composition in the 150-400 km altitude range, and for simultaneously reaching high time resolutions and altitude resolutions in radar observations of the ionization related to the northern lights. Neither of these have been possible with the existing radar data analysis tools. We have shown that the new analysis tool can remove a significant bias from radar observations of the auroral electron precipitation. We have also applied sophisticated hier-
archival prior models to radar signal deconvolution and found that such models work better than previously used techniques in presence of narrow ionospheric layers. The hierarchical priors are expected to be beneficial for our new radar data analysis tool.

The project produces improved techniques for observing the near-Earth space and upper atmospheric effects of space weather phenomena that ultimately originate from the Sun. The improved observations will lead to better understanding of processes that are important for satellite orbit predictions, including space debris collision avoidance, in future. The improved radar observations may help to fill in a gap in observations of the mesosphere, where chemical processes that affect thermal balance of the atmosphere take place. The computational tools developed in the project could potentially be used in some of the many practical applications that use Bayesian filtering and prior models.

**Top publications**


2.2.2. Charge carrier recombination dynamics in semiconductor materials

**University’s focus area, where the project is related to:**
Sustainable materials and systems

**Responsible Principal Investigator**

SATU OJALA, University Researcher, Environmental and Chemical Engineering, Faculty of Technology, UOULU

**Project researcher**

He Zhao, Doctoral Student, Environmental and Chemical Engineering, Faculty of Technology, UOULU

**Other project PI**

Krisztian Kordas, Professor, Microelectronics, Faculty of Information Technology and Electrical Engineering, UOULU

**Project description**

Semiconducting materials are used in both photocatalytic and optoelectronic applications basically due to the same reason: they absorb photons while electrons are excited from the valence band to the conduction band thus creating electron-hole pairs that can participate in number of events. In photocatalysis, these photogenerated charge carriers reduce as well as oxidize surface adsorbed moieties. However, a pitfall is the partial recombination of the carriers before their participation in the surface reactions. There are several approaches that can minimize this adverse effect, such as using co-catalysts and other semiconductors to form hybrid structures, which can enable efficient charge separation and limit recombination. We approach the research problem by developing novel perovskite-based materials and their hybrid structures to variety of applications and by studying the charge-carrier recombination dynamics in real conditions with advanced research methods.

**Keywords:** photocatalysis, perovskites, Time-gated Raman, environmental catalysis, environmental technologies

**Recent progress**

The project focuses on the development of sustainable hybrid perovskites for the production of hydrogen from water. As the developed materials have band gap of ~2.1 eV, photocatalytic activation of reactions using visible light is anticipated. Hybrid perovskites have earlier been used in the presence of concentrated hydrohalic acids due to their instability in water. In the project, a way to avoid degradation of the perovskite in water was discovered. It was also demonstrated that the new bismuth-containing perovskite is able to produce hydrogen from water under visible light irradiation. Currently, the work is focused on the modification of the material to improve hydrogen production rates.

We expect that the project will bring out new understanding on fundamental mechanisms behind the photocatalytic hydrogen production based on hybrid halide perovskites. This knowledge can be utilized in the development of greener and more sustainable materials for clean fuel production. Using of cleaner fuel will eventually have strong impact on the environment by reducing the atmospheric pollution and emissions. Development of less toxic, more efficient, and sustainable materials will also decrease contamination of the
environment and reduce the need of the virgin raw materials. Improved environment has direct impact on human wellbeing as well.

**Top publication**


The research of this project supports the following United Nations Sustainable Development Goals:
2.2.3. Localization and dissipation in superconducting quantum simulations

Responsible Principal Investigator
MATTI SILVERI, Academy Research Fellow,
Nano and Molecular System Research Unit, Faculty of Science, UOUL

Other project researcher
Olli Mansikkamäki, Doctoral Student

University’s focus area, where the project is related to:
Sustainable materials and systems

Project description
Many important quantum mechanical problems, for example in material science or quantum chemistry, are out of reach of even the most modern computational methods. Quantum simulation is an alternative approach to solve these kinds of problems. In a quantum simulation, one studies a controllable and measurable quantum system whose physics simulates accurately an otherwise computationally intractable system. Thus, the quantum simulations are expected to yield valuable information on hard problems. In this project, we concentrate on the theory of quantum simulations based on superconducting circuits. Our focus is in strongly interacting and disordered superconducting transmon circuits. The motivation is the recently discovered phenomenon of non-equilibrium quantum phases, such as, many-body localization and dynamical quantum phase transition. The goal is to show compelling theoretical evidence that an array of superconducting transmon circuits constitutes a versatile experimental platform for non-equilibrium quantum phases, such as, localization phases and other dynamical phases and phase transitions. Project develops novel numerical methods for studying dissipation, localization, and bosonic many-body dynamics. The results will contribute in near-future quantum simulations and novel quantum memories.

Keywords: superconducting circuits, open quantum systems, localization, dynamical phase transitions, dissipation, dephasing, quantum simulation, quantum devices, quantum trajectories

Recent progress
During the first half of the four-year period the project has resolved the ground state quantum phases and the phase diagram of the disordered Bose-Hubbard model with attractive interactions. The model supports three phases: (I) Localized phase, (II) A multi-site and multi-particle entangled W-phase, (III) Superfluid. Current superconducting-circuit based small-scale quantum processors realize the disordered-attractive Bose-Hubbard model in a natural manner. Thus, our results are important in understanding on implications of the disorder and bosonic multi-occupancy on quantum computation and development of quantum devices.

In the field of quantum technologies, boosted by over 20 years of academic successes, industrial and governmental investments have increased to noteworthy levels during the last couple of years. Startup companies (like the Finnish IQM Oy) beside mega tech cor-
Portions race towards building working quantum computing architecture. This Emerging project focusing on localization and dissipation phenomena with superconducting transmon arrays is an advancement step on building robust quantum technologies and quantum computations and educating future critical workforce in the field.

In long-term, quantum computation can unleash huge computation powers to currently overwhelmingly difficult problems, for example, in medicine development, quantum chemistry and material development.

Top publications

The research of this project supports the following United Nations Sustainable Development Goals:
2.2.4. Wildlife-originated zoonoses in the changing northern environment

University’s focus area, where the project is related to:
Changing climate and northern environment

Responsible Principal Investigator
Since 2019 Department of Biological and Environmental Sciences, University of Jyväskylä.

Project researcher
Mahdi Aminikhah, Doctoral Student,
Ecology and Genetics, Faculty of Science, UOULU

Since 2019 Department of Biological and Environmental Sciences, University of Jyväskylä.

Project description
Wildlife-originated zoonotic diseases pose a substantial risk to humans. Quantifying this risk is complex as it arises from the interplay of multiple hosts, vector and parasite species, and the environment. This project will quantify the role of host community composition and environmental drivers in wildlife-originated zoonotic disease epidemiology in Finland. This will be achieved by integrating long-term human disease incidence data with unique data on host communities and environmental factors, using state-of-the-art community ecological analytical and modeling tools.

Keywords: Wildlife-originated zoonoses, infection ecology, host community composition, environmental change

Recent progress
The project utilizes many national datasets from Finnish institute for health and welfare (THL), Natural Resources Finland (Luke) and Finnish Meteorological Institute (FMI). Research collaboration has started during this project with Dr Sami Kivelä (UOULU), co-supervisor for Mahdi Aminikhah and Dr Jukka Forsman (Luke), co-supervisor for Aminikhah.

This still ongoing project will help us to quantify factors that drive the epidemiology of zoonotic diseases in changing northern environment.

Top publication
2.2.5. Zero-\(\text{CO}_2\) cement concept via phase-separated nano-glass

**Project description**

Cement is the third largest anthropogenic \(\text{CO}_2\) emitter. Alternative binders are actively developed in order to reduce global cement \(\text{CO}_2\) emissions to zero or below by 2050 as necessitated by climate predictions. In this research we combine high-level NMR research competence to the characterization of cementitious materials to study low-\(\text{CO}_2\) cement binders.

**Keywords**: NMR, Cement, geopolymer, porosity, pore structure

**Recent progress**

Geopolymers are environmentally materials with applications as low-\(\text{CO}_2\) cements as well as catalysts and in water purification applications. We have applied novel NMR methods to study these materials and have shown that \(^{129}\text{Xe}\) NMR is effective for detecting the pore sites, diameters and connectivity of amorphous geopolymers and that NMR relaxometry and cryoporometry are effective tools to monitor the curing and characterize the pore structure of geopolymers, providing important tools to develop further these sustainable materials. Research is done in collaboration between Fibre and Particle Engineering Research Unit (FPERU) in the Faculty of Technology and NMR Research Unit in the Faculty of Science, enabling unique cross-disciplinary approach. Equipment of Centre for Material analysis, including NMR facilities, and FPERU research facilities are used in the research project.

Cement is responsible for 8% of anthropogenic \(\text{CO}_2\) emissions, and alternative materials are actively sought after. One class of them are aluminosilicate binders, called geopolymers, which can also be used for water purification and in catalysis. The porosity and the pore geometry of these materials are extremely important in all of these applications, however there are only few tools to study them. Furthermore, pore connectivity is very difficult to study. Here, we have applied novel methods to study the porosity and pore connectivity among other variables and assessed how they change as a function of dilution.

**Top five publications**


3. Creating new research openings and strengthening international networking

The Kvantum Institute supports the strategic profiling of the UOULU's research by coordinating a profiling project called Arctic interactions (ArcI) and by impacting future profiling themes. Kvantum represents the UOULU in its focus areas by participating in preparation of the Academy of Finland's and the EU's research programmes.

Kvantum and profiling research projects

The Academy of Finland grants competitive funding to Finnish universities to strengthen their research profiles. These research profiles are part of the research strategy of the UOULU. Funding of the Academy of Finland and the equal co-funding of the university significantly boost the development of a specific research field through high-level recruitment, targeted seed money projects, international research mobility, visiting professors, communication activities and other activities. The funding opportunity is referred to as a Profi.

Coordination work for one of the UOULU’s multidisciplinary Profis is conducted at the Kvantum Institute. This comprises Arctic interactions (ArcI) 2018–2023, which combines the Arctic research expertise of three faculties – Technology, Science and Humanities. The directors of the ArcI are Professor Björn Klove at the Faculty of Technology and Kvantum Institute and Professor Jeffrey Welker at the Faculty of Science, and the coordinator is Jouko Inkeröinen at Kvantum. ArcI promotes cooperation between the UOULU’s Arctic research institutes and coordination units, namely, the Thule Institute, the Giellagas Institute and the faculties. The multidisciplinary themes of the ArcI are global change and northern environments; human-environmental relationship; and sustainable systems, resource use and development. The joint work strongly promotes multidisciplinary planning and the realisation of Arctic research projects.

The profiling measures to advance Arctic research at the UOULU include 1) recruitment of a cohort of new Arctic scientists through tenure track and post-doc programmes, 2) further development of the Sámi Culture Archive, 3) development of the research infrastructures in northern research stations, 4) visiting scientist programme (internationalisation), 5) new initiatives research project programmes, and 6) communication and visibility actions, all supported by Profi funding.

During the first years of operation, ArcI has recruited four tenure track professors and a senior researcher, as well as eleven postdoctoral researchers and five PhD students to the UOULU’s research units. Two top level part-time visitor professorships have been agreed with the Universities of Aarhus and Tromsø. 22 international research visits have been granted, six of which have been outgoing visits from the UOULU and 16 incoming visits to the UOULU. Three internal seed money or twinning project calls have been organised to support both established and new research groups in their Arctic research. Research infrastructures have also been modernised.

The ArcI coordinator also participates in the management of the UOULU’s network of Arctic researchers, in which all Arctic researchers at the UOULU are brought together to promote cooperation and communication. This network is hosted by the Thule Institute. The network supports international activities and networking through small grants to its members.
Similar kinds of profiling in Kvantum’s focus areas are Space research and the Genome of Steel, Inorganic side streams and partly Arctic Anthropocene Natures and Transdisciplinary Science. These profiling actions, hubs and programmes are led and coordinated by the respective faculties and their research units.

Arctic collaborator’s comment
JEFFREY WELKER, Arcl Vice-Chair, UArctic Research Chair

Oulu is Arctic

The Arctic programme at the UOULU is now an internationally recognised major participant and leader in Arctic research across the North, a major aim of the AoF Profile 4 programme; Arctic Interactions-Arcl. This framework and the emphasis on studies that focus on appreciating and exploring Arctic System interactions are unique in Finland and the Nordic region. Arcl has an emphasis on how combinations of earth, biological and cultural processes and their independent and combined effects influence climate feedback and community responses to a New Arctic. A landmark study, funded by the AoF regarding the role of sea ice loss in driving extreme snow events and the cascading processes to atmosphere, ecosystems and societies, is a prime example of Oulu’s dramatic elevation and recognition in its scope and scale with Arcl as a new platform for the UOULU. Other major programmes that address permafrost and its degradation and consequences for infrastructure, as well as the extent to which ancient C is leaking into the atmosphere and amplifying warming, are further evidence that the UOULU’s Arctic programme has reached new heights and is on a trajectory of supreme research excellence and contributions to globally relevant issues in the Arctic and beyond.

An established programme in Arcl at the UOULU is now fully solidified with a fresh set of Arctic-centric new hires at faculty level and with an excellent set of postdoctoral scientists and PhD students led by senior faculty staff. This Arctic System thematic approach positions the UOULU to contribute to major global sustainability efforts in the north through programmes such as: One Health, Sustaining Arctic Observing Systems, UArctic Thematic Networks, Synoptic Arctic Survey and Pan Arctic, synthesis and integration associated with the International Tundra Experiment and MOSAiC.

Arctic Research Chair, UOULU Professor Welker, aboard the US Coast Guard icebreaker Healy, on the 2021 NW Passage-Baffin Bay: Arctic Freshening and Fertilization study. He had just completed a 45-day, 12,000 km, 30,000,000 data point study of the water and C isotopes in marine air and seawater.
4. Supporting and developing doctoral training

An important role of the focus institutes is to develop field-specific doctoral training and coordinate official doctoral programmes related to their fields of research in cooperation with the University of Oulu Graduate School (UniOGS). The UniOGS provides the framework for doctoral training by promoting equal processes and requirements for every doctoral student, regardless of their doctoral degree programme. The UniOGS provides support for doctoral students and their supervisors regarding timely degree completion of their doctoral studies. The focus institutes support doctoral training in their four-year research projects via four-year funded doctoral student positions. The focus institutes also coordinate calls for four-year funded doctoral student positions open to all applicants.

The Kvantum Institute is responsible for the activities of the Technology and Natural Sciences Doctoral Programme, TNS-DP, which is one of the four official doctoral programmes of the UniOGS. TNS-DP supports field-specific doctoral training activities and courses organised by the research units in technology and natural sciences, as well as across fields. TNS-DP organises research plan seminar courses twice a year.

During the project period for 2017–2020, the Kvantum participated in doctoral training, in addition to its projects, via:

› TNS-DP: the DP supported and participated organising a total of 80 courses. These courses were mainly field-specific courses organised by the research units in technology and natural sciences. The courses included seven UniOGS Winter School courses, several I4FUTURE-related courses, eight TNS research plan seminars (1–3 days, longer seminars in connection with the Kvantum Science Days).

› I4Future Doctoral Programme – Imaging for the Future: Novel Imaging and Characterization Methods in Bio, Medical and Environmental Research and Technology Innovations, which was a Marie Sklodowska-Curie action co-funded international, interdisciplinary and inter-sectoral doctoral programme, hosted by the UOULU. The programme period was 2016–2021 and included a total of 20 funded four-year doctoral student positions starting at the beginning of 2017. Over one half of the selected doctoral students have defended their theses during the programme period and all the selected students are expected to graduate.

Comments from the UniOGS Dean, Professor HARRI OINAS-KUKKONEN

Focus institutes collaborate with the UniOGS in organizing field-specific doctoral training at the University of Oulu. A recent successful joint addition to the doctoral training offering has been the introduction of the UniOGS Arctic Attitude Winter School, a collection of one weeklong intensive doctoral courses on selected topics given by enthusiastic faculty members and staff organized in the spring winter. In addition to doctoral training through such field-specific courses, the institutes have also had the privilege to organize open calls for the university’s funded doctoral student positions. Focus institutes are an important alliance with the UniOGS.
5. Promoting co-operation and societal impact

The Kvantum promotes innovation activities and cooperation among national and international networks. The Kvantum has been working with Finnish research institutes and cooperation with business sector has strengthened.

Science Garden and project videos

Kvantum participated in the development of the new Science Garden Visitor Centre at the University of Oulu Botanical Gardens in the EKI project (European Regional Development Fund 2017–2020). Part of the Kvantum projects from 2017-2020 were video recorded in order to present the UOULU’s research to the public. In order to promote wider visibility of Kvantum’s research, the videos were submitted to the Year of Research-Based Knowledge 2021 campaign, which was a joint initiative organised by the Ministry of Education and Culture, the Academy of Finland and the Federation of Finnish Learned Societies. The campaign aims to make research-based knowledge more visible and accessible.

Video page:

Societal impact, strengthening collaboration with stakeholders and industry

The Kvantum was one of the co-organisers of the University Business Forum 2019. The overall theme of this academy and business forum was resilience. The main sessions were about resilient and smart solutions, responsibility and sustainability and skills and competencies for the future. The Kvantum organised the resilient and smart solutions session by way of science and business expert talks. Speakers and actors working at the interface between science and business were introduced.

Public outreach and the popularisation of science

The Kvantum was one of the co-producers of the university’s pop-up studio campaign in the city centre of Oulu during spring 2021. Kvantum coordination planned the topics for the popup studios in the theme of Nature, Environment and Climate and designed and hosted three studios:

- Lumi – riemu vai riesa? 2.2.2021 (“Snow – joy or nuisance?”)
- Tavoitteena hiilineutraali teollisuus – utopiaako? 9.2.2021
  (“Aiming for a carbon-neutral industry – utopia?”)
- Kestävyystudio: Ruokahävikki kurin – mutta miten? 29.3.2021
  (“Sustainability studio: Food waste under control – but how?”)

As part of early research career training, Kvantum participated in the UOULU’s Class of 18, 20 and 21 – a training event for young researchers.
6. Main events

One way to promote multidisciplinary scientific collaboration is through joint events. Arranging these kinds of events was one of the main activities during Kvantum’s period from 2017–2020. The multidisciplinary collaboration created in the focus institutes in the focus areas is supported by the Rapid Research Radicals (R3) operating model, facilitated by the Strategy and Science Policy Unit and implemented in the Tellus environments.

The Kvantum has participated in developing the R3 activities, for example, by creating the Kvantum Science Coffee concept and developing the Science Days concept in which the events have been organised in the Tellus.

Comments from Tellus partners about R3 cooperation.
Director JOHANNA BLUEMINK and specialist NINA JACKSON

"R3 activities boost multi and transdisciplinary collaboration on various levels from informal get-togethers, multidisciplinary seminars and events to facilitated workshops and workshop series aimed at new research openings. During the previous term, nine informal Science Coffee events were organised and researchers from the institute have been actively involved in the monthly Brown Bag lunch seminars in which two researchers from different fields present their latest research and discuss possible contact points between the research topics. All this happens during lunch, which saves time from the audience’s busy schedules. Also, Meet the top scientist -seminars and Twitter conferences have been piloted with Kvantum during the previous period. The idea of Meet the top scientist seminars is that top scientists from one focus institute present their research. The presenters and audience are encouraged to multidisciplinary discussions. However, the Twitter conference is a novel way of organising a research seminar via social media. The seminar is excellent at reaching a wide audience as the previous conference reached thousands of people in one day.

The R3 activities have successfully triggered some new research ideas. In future, more activities and workshops will take place in order to trigger multi and transdisciplinary encounters on different levels. Also, further activities between the four different focus institutes are being planned.

Main events that Kvantum has organised and participated in

Science Days
Kvantum Science Days were held three times, during the autumn from 2017–2019. Science Days are a two-day seminar in which strategic research projects present their progress and project news. According to the Science Day concept, the first day introduces the highlights of the strategic research projects in the focus areas of ‘Changing climate and northern environment’ and ‘Sustainable materials and systems’. The programme comprises keynote talks and the projects’ progress narratives. The second day features presentations from doctoral students and researchers. The seminar serves as a research plan seminar for doctoral students. The Science Days are organised jointly with Kvantum and the related Technology and
Natural Sciences Doctoral Programme. In addition, doctoral training seminars were held on three occasions, from 2018–2020.

The first Kvantum Science Days were held on 20–21 November on the theme of Sustainable Resource Use and Earth's Changing Environment. Keynote talks were given by Associate Professor Nonne Prisle, Nano and Molecular Systems Research Unit, UOULU (New understanding of atmospheric aerosols and climate from a synchrotron super-microscope) and Professor Jouni Pulliainen, Head of the Arctic Research Centre, Finnish Meteorological Institute (Earth Observation satellite-based Arctic services and research: Perspective of the Finnish Meteorological Institute).

In 2018, Science Days were held on 21–23 November on the theme of Environmental Change and Sustainable Resource Use. Keynote speakers were Professor Bjørn Kløve, Water Resources and Environmental Engineering, Faculty of Technology, UOULU and the Kvantum Institute (Hydrology of groundwater dependent ecosystems of the boreal landscape) and Academy Research Fellow Minna Patanen, Nano and Molecular Systems Research Unit, Faculty of Science, UOULU (Soft X-ray studies of soft matter).

Science Days 2019 were held on 15–16 October. A keynote talk was given by Professor Jukka Kömi, Materials and Mechanical Engineering, Faculty of Technology, UOULU (Steel know-how solves climate change) and Academy Research Fellow Satu Ojala, Environmental and Chemical Engineering, Faculty of Technology, UOULU (JUFO – Publication forum; What? Why? and How?)

In 2020, the Science Days were held online in December as a doctoral training seminar.

**Science Coffees**

The Science coffee concept was developed during 2018. The events were a casual discussion forum for researchers to present their research, receive feedback and collaboration within or outside of their own discipline, discuss methods or just topical themes. Science Coffees were held approximately once a month during the semesters at Tellus Linnanmaa and the events were open for all. Nine events were held, attracting approx. 20 participants each.

**Kvantum Institute's Science Coffee event programmes**

8 JUNE, 2018. The Biodiversity that we breathe: Microbiomes in the air and their implications for the health of individuals and ecosystems. Nonne Prisle, Phillip Watts, Eva Kallio and Jukka Forsman

21 SEPTEMBER, 2018. Academy of Finland's Strategic Research themes and research priority for 2019. Director Teija Kekonen, Research support services, Professor Rauli Svento, the BCDC energy research project.


18 DECEMBER, 2018. Wireless AI (artificial intelligence). Associate Professor Mehdi Bennis, Centre for Wireless Communications.

21 MARCH, 2019. Space research. Professor Anita Aikio, Ionosphere Research Unit, Head of observations, Thomas Ulich, Sodankylä Geophysical Observatory.

7 JUNE, 2019. Climate and resource smart peatland use – do we improve biodiversity by compromising? Professor Anne Tolvanen, Natural Resources Institute Finland (LUKE).

27 SEPTEMBER, 2019. Space Climate and Solar effects on climate system. Professor Ilya Usoskin and Docent Timo Asikainen, Space Physics and Astronomy.


Meet the top scientists

The Meet the top scientist seminar is a concept that gathers top scientists to discuss selected research themes and welcomes people to hear the most recent news. Kvantum held the first seminar in autumn 2018. The topic of the event was Arctic issues with top scientists Jeffrey Welker, Anna-Kaisa Salmi and Arja Rautio.

Twitter conferences

Kvantum’s Research coordinator Jouko Inkeröinen and Tellus Innovation Development Manager Simo Kekäläinen developed and introduced a new concept to Tellus Rapid Research Radicals in spring 2019. The concept was a Twitter Conference – a combination of research presentations, scientific communication, and the popularisation of research. In practice, Twitter conferences involve chaining a researcher’s presentation into a series of Tweets on the Twitter microblogging platform. The presentation is based on a summary of the researcher’s message (results or goals) and a strong visual look. There are several presentations during the conference and the Tweets from each presentation are sent from the researcher’s own account but moderated from the conference’s account. Social media applications make it easy to reach a large number of people with relatively little organising. Thus, the audience of one Twitter conference could comprise thousands of people. Tellus created a Twitter account for the Twitter conferences of the UO: @OuluTC. Similarly, a unified visual look was created for the Tweets from the moderator.
The first conference SCENE2050 was held online on 17 May 2019 and was organised together with UOULU researchers on the Horizon 2020 project SIMRA. There were presentations from Finland, Scotland and The Netherlands.

The second Tellus & Kvantum Twitter conference was STARCTIC2019, focusing on Arctic Sustainability. It featured presentations on the subject of Arctic Sustainability from the perspective of a multitude of different fields of research. The conference was organised as a part of the UOULU’s and the Student Union of the UOULU’s Sustainable Development Week.

After these two conferences, the concept was also adopted by other research actors co-operating with Tellus. Kvantum and Tellus held their next Twitter conference on 29 October 2020. The theme for the SUSTMAT2020 conference was “Sustainable steelmaking and low CO₂ materials” and the co-organiser was the Genome of Steel research profile area.
Key events of the Kvantum Institute on a timeline

Kvantum timeline 2018

- Emerging projects call open
- Workshop for research group P14: 12.3.
- Doctoral Training Seminar 14.5.
- Science Coffee 21.9.
- iArctic Congress 3.7.9.
- Science Coffee 30.11.
- Research seminar and workshop 20.21.11.

Jan
- Workshop for research group P16: 19.2.
- Class of 19 call and selection
- Science Coffee 6.9.
- Arctic interaction project check off 31.5.

Aprl
- Meet the Top Scientist 16.10.
- Science Coffee 19.10.

May
- Science Coffee 13.12.

Kvantum activities 2019

- Brown Bag Seminar 18.1.
- Science Coffee 21.3.
- Science Day 5.4.
- Co-evolution lectures 3rd & 4th 4.4.
- Brown Bag Seminar 12.2.
- ISCORD 2019 Symposium Oulu 17-19.11.
- Science Coffee 7.6.
- Science Days 15-16.10.
- Science Coffee 13.12.
Research coordinator Jouko Inkeröinen hosting an event in the UOULU Science Forum 2019.

Kvantum Science coffee event on November 2018. Photo by Riitta Kamula.
7. Staff

7.1. Administrative staff

Professor **Bjørn Kløve**. Director of Kvantum Institute 2017-2020. Water, Energy and Environmental Technology, Faculty of Technology, OUULU

Research Coordinator **Jouko Inkeröinen**. Kvantum Institute, OUULU

Coordinator **Riitta Kamula**. Kvantum Institute, OUULU

Coordinator **Pirjo Taskinen**. Kvantum Institute, OUULU

7.2. Spearhead project principal investigators

Associate Professor **Timo Asikainen**. Space Physics and Astronomy, Faculty of Science, OUULU

Professor **Mehdi Bennis**. CWC-Radio Technologies, Faculty of Information Technology and Electrical Engineering, OUULU

Researcher Professor **Jukka Forsman**. Ecology and Genetics, Faculty of Science, OUULU. Since 2018 Natural Resources Institute Finland (Luke)

Academy Research Fellow **Sami Kivelä**. Ecology and Genetics, Faculty of Science, OUULU

Professor **Bjørn Kløve**. Water, Energy and Environmental Engineering, Faculty of Technology, OUULU

Professor **Elena Kozlovskaya**. Oulu Mining School, Faculty of Technology, OUULU

Professor **Timo Muotka**. Ecology and Genetics, Faculty of Science, OUULU

Professor Emer. **Kalevi Mursula**. Space Physics and Astronomy, Faculty of Science, OUULU

Senior Curator **Marko Mutanen**. Ecology and Genetics, Faculty of Science, OUULU

Professor Emer. **Markku Orell**. Ecology and Genetics, Faculty of Science, OUULU

University Lecturer **Seppo Rytkönen**. Ecology and Genetics, Faculty of Science, OUULU

Professor **Kari Strand**. Oulu Mining School, Faculty of Technology, OUULU

Head of Observations **Thomas Ulich**, Sodankylä Geophysical Observatory, OUULU

Professor **Juha Vaara**. NMR Research Unit, Faculty of Science, OUULU

Professor **Phillip Watts**. Ecology and Genetics, Faculty of Science, OUULU. Since 2019 Department of Biological and Environmental Sciences, University of Jyväskylä
7.3. Emerging project principal investigators

Academy Research Fellow **Eva R. Kallio**. Ecology and Genetics, Faculty of Science, UOULU. Since 2019 Department of Biological and Environmental Sciences, University of Jyväskylä

Associate Professor **Päivi Kinnunen**. Fibre and Particle Engineering, Faculty of Technology, UOULU

Senior Research Fellow **Satu Ojala**. Environmental and Chemical Engineering, Faculty of Technology, UOULU

Academy Research Fellow **Matti Silveri**. Nano and Molecular Systems Research Unit, Faculty of Science, UOULU

University Lecturer **Ilkka Virtanen**. Space Physics and Astronomy, Faculty of Science, UOULU