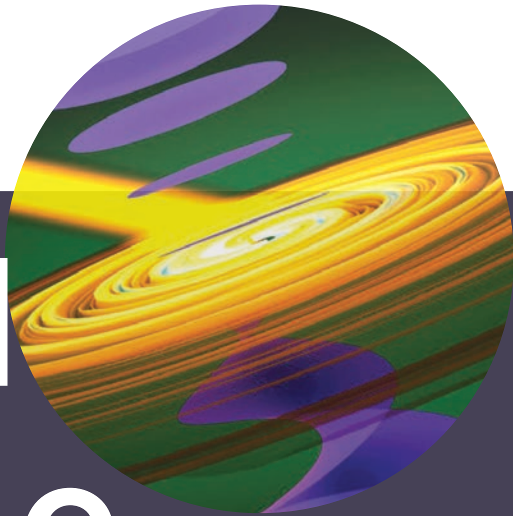
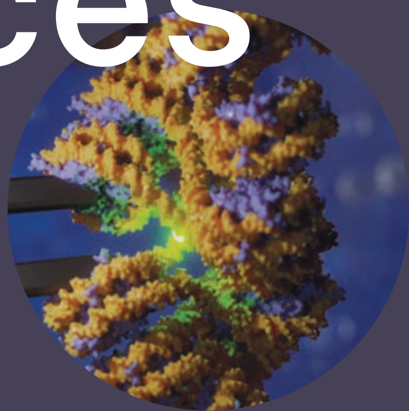
EPFL



School of Basic Sciences FSB



ANNUAL REPORT 2019

IPHYS ISIC MATH

School of Basic Sciences FSB

DEAN'S FOREWORD

During 2019, the School of Basic Sciences (FSB) went through the federally mandated external review process. It required everyone in SB to coordinate their effort and develop a vision for the future direction of basic sciences at EPFL. While we, at the point of completing the annual report for 2019, are still waiting for the final assessment report, the initial feedback received suggests a very positive outcome, and highlights the many advances since the previous 2012 evaluation, as well as the extremely high quality of research, education, and innovation throughout FSB.

Looking through the 2019 annual report, it is indeed difficult to see how the evaluation committee could reach any other conclusion. We have been very successful in our efforts to hire and promote the very best researchers and professors with a continued emphasis on gender balance. Our faculty members continue to receive numerous national and international honors and awards; the size of the incoming classes is increasing every year; we maintain an excellent success rate for highly competitive grants such as European Research Council and, very recently, the successful allocation of the NCCR in Sustainability through Catalysis, led by a team of researchers in the Institute of Chemical Sciences and Engineering.

During 2020, we will use the evaluation report to develop a strategy for the next four-year period. There is an expected growth, with an emphasis on strengthening the basic sciences at EPFL: this presents a unique opportunity to think long-term and develop new areas of expertise and leadership across FSB and in collaboration with other domains at EPFL.

I hope you will enjoy browsing through this annual report and experience the broad diversity of activities, the outstanding quality of the research, and the commitment of all FSB members to the success of the School and EPFL.

With the best wishes for a successful and rewarding 2020,

Jan S. Hesthaven

JAN S. HESTHAVEN
Dean of the School of Basic Sciences, EPFL

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ISIC

Ardemis Boghossian wins Nano Research Award

Professor Ardemis Boghossian has been awarded a Young Innovators Award in Nano-Energy from the journal Nano Research.

Nano Research is a journal that *"focuses on all aspects of nanoscience and nanotechnology."* It covers all topics across nanoscience and nanotechnology *"ranging from basic aspects of the science of nanoscale materials to practical applications of such materials."*

Each year, *Nano Research* awards Young Innovator Awards in various areas related to nanoscience and nanotechnology to researchers under 45 years of age. This year, it has awarded 44 Awards in Nano Energy *"in recognition of their distinguished accomplishments and/or potential to make substantial contributions to their field"*.

One the awardees is Professor Ardemis Boghossian at EPFL's Institute of Chemical Sciences and Engineering. Boghossian's research takes a highly interdisciplinary approach to address fundamental challenges and develop novel technologies that exploit the synergy between nanotechnology and synthetic biology. Focusing on optoelectronics and protein engineering, Boghossian's work contributes new biological and biochemical methods for the production of durable hybrid nanomaterials for energy and biosensing applications.

"Nature has given us materials that are dynamic - materials that can automatically modulate their activities, repair themselves, and even self-replicate," says Boghossian. "These materials are known as cells and are, in many ways, ideal for sustainable energy technologies. We aim to make living devices, such as photovoltaics and fuel cells that run off the metabolism of live cells."

MATH

Maryna Viazovska awarded two prestigious prizes

Professor Maryna Viazovska, who holds EPFL's Chair of Number Theory at EPFL, was awarded the 2019 Ruth Lyttle Satter Prize in Mathematics and the 2019 Fermat prize in mathematics for her solution to the famous sphere-packing problem.

The Ruth Lyttle Satter Prize in Mathematics was established in 1990 with a donation by mathematics Professor Joan S. Birman in memory of her sister, the botanist Ruth Lyttle Satter, to honor her commitment to research and to encourage women in science. Administered by the American Mathematical Society (AMS), the Satter Prize recognizes outstanding contributions to mathematics research made by a woman in the previous six years.

The Fermat prize in mathematics is a bi-annual prize named after the famous French mathematician Pierre de Fermat and awarded by the Institut de Mathématiques de Toulouse. The prize rewards mathematicians under 45 years old whose research words are in Number Theory, analytic geometry, probability and research related to the variational principles. The Fermat prize was created in 1989. The official ceremony will take place in spring 2020 in Toulouse.

Viazovska's elegant 2017 paper "The sphere packing problem in dimension 8" brought her worldwide fame, and the solution was soon adapted to solve the problem for dimension 24. Her mathematical breakthroughs have been recognized with a number of awards, including the Salem Prize, the Clay Research Award, the SASTRA Ramanujan Prize, and the New Horizons in Mathematics Prize.

ISIC

Xile Hu wins International Catalysis Award

The International Association of Catalysis Societies (IACS) is an association of catalysis societies across thirty countries that exists *"to promote scientific and technological progress in the fields of catalytic chemistry."* The organization also works to structure, support, and defend catalysis as science and technology throughout the world.

Every four years, IACS award the International Catalysis Award, *"to recognize and encourage individual contributions by a young person in the field of catalysis."* Examples of such contributions include significantly improving a catalytic process or making an important contribution to the understanding of catalytic phenomena.

This year, IACS has given its prestigious award to Professor Xile Hu at EPFL's Institute of Chemical Sciences and Engineering. Hu is the founder and director of the Laboratory of Inorganic Synthesis and Catalysis, where his research focuses on developing catalysts made of earth-abundant elements for chemical transformations related to synthesis, energy, and sustainability.

Professor Hu is specifically awarded "for the creative and high-impact work in combining material development, electrochemistry and concepts of homogeneous catalysis for the production of solar fuels".

The Award consists of a plaque and a check for $5,000. It will be presented to Professor Hu during the award ceremony of the ICC2020 conference in San Diego (June 14-19, 2020). As winner of the Award, Professor Hu will also present a plenary lecture on his research.

IPHYS

Benoit Deveaud wins Charpak Ritz Prize from SPS-SFP

Physicist Benoît Deveaud, Professor Emeritus with EPFL's Institute of Physics, has been awarded 2019 Charpak-Ritz Prize from the Swiss and French Physical Societies.

The Swiss Physical Society (SPS) exists to *"provide all those interested in physics with access to the current state of science and to exchange information with experts."* Since 1991, the SPS has been awarding prizes in various categories, donated by various renowned institutions and companies, to ensure that Switzerland continues to maintain its high level of research quality.

One the SPS awards is the Charpak-Ritz Prize, created and given since 2016 with the Société Française de Physique (SFP) to "*highlight the tight relationship between the two societies and to keep the memory alive of Georges Charpak and Walther Ritz who both have profoundly contributed to physics in their respective times*". The prize distinguishes exceptional contributions in physics or in its development, to honor physicists who have made significant contributions in France and Switzerland.

This year the SPS and SFP have awarded the Charpak-Ritz Prize to Benoît Deveaud, now Professor Emeritus with EPFL's Institute of Physics and Vice-Provost for Research at the École Polytechnique (France). The SPS announcement states that Professor Deveaud is honored for his "*pioneering optical spectroscopy studies dedicated to the ultrafast and quantum optical properties of semiconductor nanostructures*".

MATH

Dalang and Panaretos become IMS Fellows

Robert Dalang, Head of the Chair of Probability and Victor Panaretos, Head of the Chair of Mathematical Statistics and Director of the MATH Institute, have been named Fellows of the Institute of Mathematical Statistics (IMS).

Their Fellowships was officially conferred during the IMS Presidential Address and Awards Session on the 29th of July.

Robert Dalang is nominated for his "pioneering contributions to the study of SPDEs driven by a Gaussian noise".

His research concerns the study of quantities that vary randomly over space and time, according to fundamental partial differential equations that appear in physics, biology, and the engineering sciences.

Victor Panaretos is nominated for his "contributions to functional data analysis and stochastic geometry".

His research focuses on the analysis of random functions and their interactions with stochastic geometry and statistical inverse problems, as well as their applications in the natural sciences.

ABOUT THE IMS

The Institute of Mathematical Statistics (IMS), created in 1935, is an international professional and scholarly society dedicated to the development and application of statistics and probability. The IMS has about 3,500 members all around the world, amongst which approximately only 10 percent have earned the status of Fellow. Fellowships are awarded based on a competitive process, including a nomination step and a selection process. In 2019, 25 new Fellows were nominated.

ISIC

Jeremy Luterbacher wins the 2019 Werner Prize

SCS Swiss Chemical Society

Professor Jeremy Luterbacher has been awarded the Swiss Chemical Society's Werner Prize for 2019.

The Werner Prize is awarded annually to promising young Swiss scientists or scientists working in Switzerland under 40 to recognize *"their outstanding research in the field of chemistry."*

Jeremy Luterbacher, head of EPFL's Laboratory of Sustainable and Catalytic Processing, has been awarded for his *"his original and groundbreaking research on chemical conversion of plant material using protection group chemistry during biomass depolymerization and upgrading."*

"It's wonderful to get this kind of support from the Swiss research community, and especially exciting to join so many friends and mentors on the past winners' list!" says Luterbacher.

The Prize was awarded on 5 April 2019 during the SCS Spring Meeting in Dübendorf, where Luterbacher presented his research in the Werner Prize Award Lecture.

IPHYS

Tatsuya Nakada awarded the Enrico Fermi Prize

Tatsuya Nakada was awarded the Enrico Fermi Prize from the Italian Physical Society.

Given by the Italian Physical Society (IPS) since 2001, the prestigious Enrico Fermi Prize is awarded to commemorate the great physicist and Nobel laureate, Enrico Fermi. The Prize is awarded yearly to one or more Members of the Society.

In 2019, an Enrico Fermi Prize has been awarded to Professor Tatsuya Nakada at EPFL, co-director of the High Energy Physics Laboratory. The IPS states that Professor Nakada is being awarded *"for the conception and crucial leading role in the realization of the LHCb experiment that led this year to the discovery of the CP violation in D mesons with charm quarks."*

The Prize was presented to Professor Nakada on 23 September 2019 during the opening ceremony of the 105th National Congress of the Italian Physical Society in L'Aquila, Italy. Another Enrico Fermi Prize was given to Professor Marcello Giorgi at the University of Pisa.

ISIC

Yimon Aye wins 2020 Eli Lilly Award

ACS Chemistry for Life® American Chemical Society

Lilly

Professor Yimon Aye, at EPFL's Institute of Chemical Sciences and Engineering, won the 2020 Eli Lilly Award in Biological Chemistry.

Established in 1934, the Eli Lilly Award in Biological Chemistry is given annually by the American Chemical Society's Division of Biological Chemistry to *"stimulate fundamental research in biological chemistry by scientists not over thirty-eight years of age"*. The Award itself consists of a bronze medal and an honorarium.

The 2020 Award has been given to Professor Yimon Aye, who directs EPFL's Laboratory of electrophiles and genome operation, and is a member of the Swiss National Science Foundation's NCCR Steering Committee.

In an announcement, NCCR Chemical Biology referred to the ACS award letter which stated that Aye's "*selection by a committee of peers speaks highly of her tremendous accomplishments as a scientist as well as her independence of thought and originality."* The Award will be presented to Aye at the 2020 Eli Lilly Award Symposium, during the ACS 2020 Fall meeting in San Francisco.

IPHYS

Lesya Shchutska wins EPS Young Experimental Physicist Prize

Professor Lesya Shchutska has been awarded a Young Experimental Physicist Prize from the European Physical Society.

The European Physical Society (EPS) is a not-for-profit association whose members include 42 National Physical Societies in Europe, individuals from all fields of physics, and European research institutions. Each year, the EPS High Energy Particle Physics Board awards a Young Experimental Physicist Prize *"for outstanding work by one or more young physicists (less than 35) in the field of Particle Physics and/or Particle Astrophysics."*

This year, one of the awardees is Professor Lesya Shchutska who directs EPFL's High Energy Physics Laboratory. Shchutska is an internationally acclaimed and highly innovative young scientist whose research focuses on the search for physical phenomena beyond the standard model of particle physics.

To this end, she had been exploring energy frontier with the collaborative CMS experiment at CERN's Large Hadron Collider (LHC) in Geneva. With no evidence for new heavy particles produced at the LHC, Shchutska initiated searches for light feebly interacting particles (like heavy neutrinos) within the large volumes of data delivered by the LHC, and she came to EPFL and the LHCb experiment to challenge standard model predictions with the precision measurements in bottom quarks, and is searching heavy neutrinos in B meson decays.

The EPS has awarded Shchutska *"for outstanding contributions to experimental activities in particle physics, from the design and simulation of novel experiments, test-beam operations and analyses, to data analyses and their final theoretical interpretations."*

Lesya Shchutska is one of two winners of the Prize, the other being Josh Bendavid (CIT/CERN).

ISIC

Three FSB Professors awarded prestigious prizes from the RCS

The Royal Society of Chemistry's Awards and Prizes are awarded in recognition of originality and impact of research, or for each winner's contribution to the chemical sciences industry or education. They also acknowledge the importance of teamwork across the chemical sciences, as well as the abilities of individuals to develop successful collaborations.

Of those to have won a Royal Society of Chemistry Award, an illustrious list of 50 have gone on to win Nobel Prizes for their pioneering work, including 2016 Nobel laureates Jean-Pierre Sauvage, Fraser Stoddart, and Ben Feringa.

Nicolai Cramer wins RCS Merck, Sharp & Dohme Award

Professor Nicolai Cramer has won the award for the development of chiral cyclopentadienyl ligands and Pd(0)-catalysed asymmetric C(sp3)–H activations.

Receiving the award, Professor Cramer said: "I am really excited and feel deeply honoured by the Merck, Sharp and Dohme award. For me, this is a very rewarding event as it acknowledges ideas and concepts on the development of particular chiral ligands that my group is pursuing for years. I was – and am still – blessed with an amazing group of talented students and coworkers that bring their dedication and contributions to bring the ideas to life."

The work has developed catalysts, molecules that are little, powerful helpers to convert carbon-hydrogen bonds into things with lots of useful properties. The technology is used to upgrade cheap, abundant and widely accessible precursors that are rich in hydrogen bonds into sought-after and value-added intermediates that can be used for instance for the production of pharmaceuticals.

Xile Hu wins RCS Homogeneous Catalysis Award

Professor Xile Hu has won the award for original contributions to base metal catalysis, particularly in C–C and C–N coupling of alkyl electrophiles and in functionalization of alkenes and alkynes.

Receiving the award, Professor Hu said: "I am thrilled to receive the RSC Homogeneous Catalysis award this year. This award is a recognition of the teamwork of many talented co-workers with whom I am privileged to work."

Currently the most efficient catalysts are made of precious and scarce metals. Professor Hu is working to develop catalysts made of non-precious, Earth-abundant metals, paving the way for sustainable chemical production.

Majed Chergui wins RCS Liversidge Award

Professor Majed Chergui won the award for pioneering picosecond and femtosecond X-ray spectroscopy of molecular species in solutions.

Receiving the award, Professor Chergui said: "I am very honoured to receive the Royal Society of Chemistry Liversidge Award. This award acknowledges the insights delivered by ultrafast X-ray spectroscopic methods into the dynamics of chemical bonds in a large variety of systems: proteins, molecules and materials. This area of research, on which my group worked for the past 20 years, has reached a turning point with new instrumentation being developed world-wide. I look forward to sharing some highlights from my group's research during the lecture tour."

In winning the RCS award, each professor also received £2,000 and a medal.

IPHYS - ISIC - MATH

Excellence in Teaching Awards 2019

Clémence Corminboeuf
Chemistry and Chemical Engineering Section (SCGC)

Cécile Hebert
Physics Section (SPH)

Victor Panaretos
Mathemathics Section (SMA)

IPHYS - ISIC - MATH

Craie d'or 2019

The 3rd year Bachelor students in Physics have awarded the "Craie d'or" of the best Bachelor Teacher to Professor Donna Testerman for her course on advanced linear algebra.

IPHYS - ISIC - MATH

Polysphère d'or

During the Graduation Ceremony, the AGEPoly has presented the Polysphère d'or to Arnaud Magrez, lecturer in the Physics Section.

Every year, during the Graduation Ceremony, the students honor the best teacher of each school with a Polysphere. The teacher who obtains the highest mark in the vote receives the Polysphère d'or.

This year, the Polysphère d'Or has been awarded to Arnaud Magrez who is responsible for the physics lab work for 3rd year bachelor students in physics, together with Daniel Oberli and Iva Tkalvec Vâju. In this course, students conduct experiments in the form of projects every Friday for four weeks.

"I love my lab work course, because I spend one day a week with the students," says Arnaud Magrez, "They are in groups of two or three, which allows me to easily interact with them, help them develop experimental skills, and test their fundamental knowledge. Over time, it creates a kind of co-operation. Many are sincerely grateful, and I have the impression of having accomplished my mission. In fact, the Section did not ask me to give this course; *I* asked the Section to take it, which takes a lot of time during and outside the semester but gives me a lot of fun."

Obviously, his students share in this fun, while describing him as 'demanding', 'strict', but pedagogical. For Magrez, "it is an exceptional honor to receive an award from the students. They are the raison d'être of a school. I am very proud."

IPHYS - ISIC - MATH

Best PhD Thesis Awards 2019

MATHEMATICS (EDMA)

Hélène Ruffieux
FOR HER THESIS ENTITLED
"Large-scale variational inference for Bayesian joint regression modelling of high-dimensional genetic data"
UNDER THE SUPERVISION OF
Prof. Anthony Davison and Dr. Jörg Hager (Nestlé Research)

CHEMISTRY AND CHEMICAL ENGINEERING (EDCH)

Marta Falcone
FOR HER THESIS ENTITLED
"Small Molecule Activation by Multimetallic Uranium Complexes"
UNDER THE SUPERVISION OF
Prof. Marinella Mazzanti.

PHYSICS (EDPY)

Rogério Manuel Cabete DeJesus Jorge
FOR HIS THESIS
"A moment-based model for plasma dynamics at arbitrary collisionality"
UNDER THE SUPERVISION OF
Prof. Paolo Ricci and Prof. Nuno Filipe Gomes Loureiro.

FACULTY NEWS

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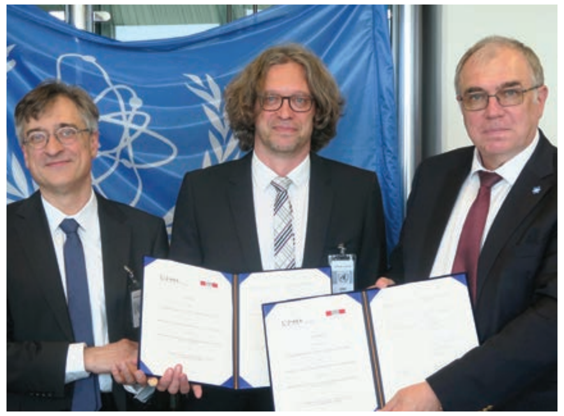
IPHYS

EPFL becomes a Collaborating Centre of the IAEA



Andreas Mortensen and Andreas Pautz from EPFL, with Mikahil Chudakov, IAEA Deputy Director General (right) after signing the cooperation agreement, Vienna, 12 June 2019.

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The International Atomic Energy Agency has designated EPFL as one of its worldwide Collaborating Centers.

On 12 June 2019, EPFL was officially designated as a Collaborating Centre of the International Atomic Energy Agency (IAEA) in the fields of open-source data and code development for nuclear applications. The IAEA is the world's central inter-governmental forum for scientific and technical co-operation in the nuclear field. It works for the safe, secure, and peaceful uses of nuclear science and technology, contributing to international peace and security and the United Nations' Sustainable Development Goals. For its work, the IAEA won the Nobel Peace Prize in 2005.

The IAEA endorses the EPFL for spearheading the creation of an international network of industries and research institutions that will develop an advanced, open-source simulation platform for the analysis of nuclear reactors. "This will be a unique opportunity to work on a major paradigm shift in the nuclear sector towards open, collaborative, and efficient R&D," says Carlo Fiorina, the main initiator of this activity and a researcher at EPFL's Laboratory for Reactor Physics and System Behavior, headed by Professor Andreas Pautz.

The need for a new development strategy in the nuclear sector comes from its ever more stringent safety requirements, but also from the vibrant worldwide research activities dedicated to the development of new nuclear technologies for CO_2-free energy generation, production of medical radioisotopes, incineration of existing nuclear waste, water desalination, and hydrogen production.

The EPFL Collaborating Centre's objective will be to step beyond traditional development strategies, which are based on relatively old and often proprietary software and data. At the core of the Centre's activities will be the promotion of R&D work fostering the concepts of open-source and shared development. This will boost R&D activities and contribute to a safe operation of nuclear plants by increasing synergies, limiting inefficiencies, promoting networking, and contributing to standardization.

In addition to leading this international effort, EPFL will produce new, open, and high-quality validation data at its CROCUS reactor. "This is an exciting chance to use our unique facility to bring about a real impact in the nuclear sector," says Pavel Frajtag, who heads the reactor.

The open software and experimental data produced during the project will be distributed to the IAEA member states. This will empower innovation and spread IAEA's safety culture, notably in developing countries that aim to include nuclear technologies as part of their strategic development targets for public welfare and reduced CO_2 emissions.

"The designation as an IAEA Collaborating Center is a big honor and a strong recognition of EPFL's reputation, the high nuclear safety standards in our country, and the excellence of nuclear research in Switzerland," says Andreas Pautz. "It will put the CROCUS reactor on the map of outstanding nuclear facilities, and open pathways to global collaboration."

During the inauguration ceremony on 12 June, the IAEA Deputy Director General and Head of the Department of Nuclear Energy Mikhail Chudakov presented Professor Andreas Mortensen, vice president of research at EPFL, with the official nomination document (photo). The ceremony was also attended by representatives of the Federal Department of Foreign Affairs (FDFA) and the Swiss Federal Office of Energy (OFEN), which have provided strong diplomatic support to EPFL's designation as Collaborating Center.

ISIC

LACUS becomes full member of Laserlab Europe

The Lausanne Centre for Ultrafast Science (LACUS) has become the first Swiss laser center to be admitted as a full member of Laserlab Europe, a European consortium of leading organizations in laser-based inter-disciplinary research.

The Integrated Initiative of European Laser Research Infrastructures Laserlab Europe is a consortium of 33 leading organizations in laser-based inter-disciplinary research from 16 European countries. With its associate partners, Laserlab also covers the majority of European member states. Its twenty-two facilities offer access to their labs to research teams from Europe and beyond.

Laserlab Europe promotes the use of advanced lasers and laser-based technologies for research and innovation, in a highly coordinated way and on a European scale. It serves a cross-disciplinary user community, from both academia and industry, by providing trans-national access to a comprehensive set of advanced laser-research sites, which include two free-electron laser facilities.

Laserlab Europe has just been renewed by the EU for another four years. Having been admitted as an associate member in 2017, the Lausanne Centre for Ultrafast Science (LACUS) has now become a full member of Laserlab. "Thanks to the uniqueness of its own laser facilities, LACUS now takes on the competitive status of access provider," says Professor Majed Chergui, Director of LACUS. "So it is now the first Swiss laser center to become part of Laserlab since its birth 15 years ago."

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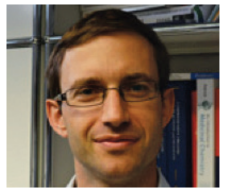
Nominations and Promotions 2019

Professor Kathryn Hess Bellwald was named as Full Professor of Life Sciences and Mathematics in the School of Life Sciences (SV) and in the School of Basic Sciences (SB) from August 2019.

Kathryn Hess Bellwald is internationally recognised for her research on the theory of homotopy, category theory and algebraic topology. Her work has attracted particular interest for the way she uses methods of algebraic topology to achieve a better understanding of neurological processes. Through the appointment of Kathryn Hess Bellwald, EPFL is obtaining the expertise of an outstanding scientist who will in particular drive the development of new applications in structured data analysis as part of the Blue Brain Project over the next few years.



Professor Jérôme Waser was named as Full Professor of Organic Chemistry from August 2019.

Jérôme Waser's research focuses on unconventional organic synthons (structural entities inside a molecule to which a possible synthesis stage can be attributed). He has achieved significant advances in this field, such as the development of new catalytic processes for the introduction of alkynyl groups. His scientific contributions have been awarded an ERC Starting Grant, among others. Jérôme Waser shows great potential in a multidisciplinary context and will continue to make an important contribution to EPFL's standing in the area of organic synthesis.

Dr Dimitri Wyss was named as Tenure Track Assistant Professor of Mathematics from September 2019.

Dimitri Wyss is an innovative and creative young mathematician. He works principally in the area of mathematical physics and algebraic geometry. In addition, he uses methods derived from arithmetic geometry, topology and mathematical logic. His elegant, alternative proof of the fundamental lemma of the Langlands program surprised the mathematical community and attracted worldwide attention. With the appointment of Dimitri Wyss, EPFL is boosting research in the field of mathematical physics and strengthening this subject area's important links with various other disciplines.

Professor Anna Fontcuberta i Morral was named as Full Professor of Materials Science and Engineering in the School of Engineering (STI) and in the School of Basic Sciences (SB) from October 2019.

An internationally renowned scientist, Anna Fontcuberta i Morral specializes in the synthesis of nanostructures within semiconductors and, in particular, in nanowire crystal growth techniques. The results of her research aid in the development of materials with innovative physical and chemical properties and are used, for example, to increase the efficiency of photovoltaic cells and in quantum computing. The promotion of Anna Fontcuberta i Morral underlines EPFL's strong position in materials science and engineering.

Professor Anne-Clémence Corminboeuf was named as Full Professor of Theoretical and Computational Chemistry from October 2019.

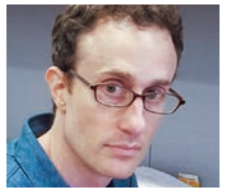
Anne-Clémence Corminboeuf has attracted international recognition for her ground-breaking contributions to theoretical and computational chemistry, particularly for her novel approaches of electronic structures driven by non-covalent phenomena, opening promising perspectives in the domains of catalysis and organic electronic materials. Her work based on non-covalent interactions was already supported by two ERC Grants and has major impact on the design of homogeneous catalysts and organic semi-conductors. By promoting Anne-Clémence Corminboeuf, EPFL is strengthening its position in a future-oriented field of study.

Professor Beat Fierz was named as Associate Professor of Biophysical Chemistry from October 2019

Beat Fierz has gained worldwide recognition as one of the top specialists in the structure, regulation and dynamics of chromatin – the main component of chromosomes. His research approach combines biophysics and chemical biology in a unique way; he has already been awarded an ERC Consolidator Grant and has been published in leading academic journals. Beat Fierz has the increasingly important ability to work successfully in a multidisciplinary context. His dynamism and high potential will further strengthen the international reputation of EPFL.

Dr Mitali Banerjee was named as Tenure Track Assistant Professor of Physics from January 2020.

Mitali Banerjee is a scientist with exceptional potential. She attracted particular international attention for designing and setting up an experimental installation for measuring thermal conductivity in two-dimensional materials. In doing so, she rose to an exceptionally difficult challenge which many experts had regarded as impossible. With her appointment, EPFL is recruiting a scientist who will make key contributions to both research and teaching.



Professor Adam Marcus was named as Tenure Track Assistant Professor of Mathematics from January 2020.

Adam Marcus is regarded as one of the most talented mathematicians of his generation. He attracted worldwide attention in 2013, when he and other scientists solved the Kadison-Singer problem – a problem posed in 1959 in the theory of operator algebras and functional analysis. At EPFL, Adam Marcus will build up a strong research group in combinatorial analysis, continuing the Federal Institute's long tradition in this field. He will also help strengthen the link between mathematics and theoretical computer science.

IPHYS - ISIC - MATH
Nominations and Promotions 2019

Professor Jacques Duparc was named Adjunct Professor at EPFL from October 2019.

Full professor of mathematical logic at the University of Lausanne (Faculty of Advanced Commercial Studies HEC), Jacques Duparc is a world expert in descriptive set theory, game theory and its applications to theoretical computer science. He has been a successful teacher at EPFL for over ten years.

Dr Mike Seidel was named Full Professor of Physics in the School of Basic Sciences (SB) from January 2020.

Mike Seidel is a recognised expert in the physics of particle accelerators and related technologies. He has gained international attention for various scientific projects and results, including some of the most recent ones at the Paul Scherrer Institute (PSI), the modernisation of the proton accelerator and the conceptual development of new applications at the Center for Proton Therapy. With the appointment of Mike Seidel, also Head of the Division Large Research Facilities at PSI, EPFL will strengthen its global position in the physics of particle accelerators and enhance its fruitful collaboration with PSI in this area.

Professor Henning Stahlberg was named Full Professor of Physics in the School of Basic Sciences (SB) from January 2020.

Henning Stahlberg is an internationally recognized leader in the field of cryogenic electron microscopy. He contributed significantly to the development of this technology thanks to his expertise in all types of imaging, and he has also worked successfully on detectors and software for data processing and analysis. Henning Stahlberg is an outstanding scientist who knows how to run a scientific institution and forge links with practitioners in different fields of application. At EPFL, he will continue to develop cryo-electron microscopy and will manage the center dedicated to this discipline, which will be set up in collaboration with the University of Lausanne

Professor Nicolas Boumal was named Tenure-Track Assistant Professor of Mathematics in the School of Basic Sciences (SB) from July 2020.

Nicolas Boumal is a talented and highly regarded young scientist. His research focuses on non-convex optimisation, which has particular applications in statistical estimates, inverse problems and automatic learning. Nicolas Boumal's work is both theoretical and application-based. His goal is to understand the mathematical structures behind the performance of non-convex optimisation algorithms. At EPFL, Nicolas Boumal will set up his own research group and collaborate with other researchers in a multidisciplinary manner.

SIX PROFESSORS WERE NAMED EMERITUS:

- Professor **Janos Pach**, who directed the Chair of Combinatorial Geometry at the Institute of Mathematics from 2008 to 2019.
- Professor **Bernard Dacorogna**, who directed the Chair of Mathematical Analysis and Applications at the Institute of Mathematics from 2003 to 2019.
- Professor **Leonid Rivkin**, who directed the Particle Accelerator Physics Laboratory at the Institute of Physics from 2006 to 2019.
- Professor **Elyahou Kapon**, who directed the Laboratory of the Physics of Nanostructures at the Institute of Physics from 1993 to 2019.
- Professor **César Pulgarin**, who directed the Group of Advanced Oxidation Processes at the Institute of Chemical Sciences and Engineering from 1989 to 2019.
- Professor **Gabor Laurenczy**, who directed the Group of Catalysis for Energy and Environment at the Institute of Chemical Sciences and Engineering from 1998 to 2019.

RESEARCH GRANTS

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Swiss National Science Foundation Grants

AMBIZIONE GRANTS



The Swiss National Science Foundation (SNSF) aims its Ambizione grants to *"young researchers who wish to conduct, manage and lead an independent project at a Swiss higher education institution."* The grants cover salaries and funding necessary for the awarded research project for a maximum of four years.

This year, the SNSF has awarded 78 Ambizione grants. Eight of these have gone to researchers hosted by EPFL, including three physicists who will perform their project at its Institute of Physics:

- **Mayeul Chipaux** (Advanced Semiconductors for Photonics and Electronics Lab): *Electron-Beam Based Selective Quantum Manipulations of Nitrogen-Vacancy Centers in Diamond*
- **Tom de Geus** (Physics of Complex Systems Laboratory): *The Five 'D's in Friction*
- **Nils Johan Engelsen** (Laboratory of Photonics and Quantum Measurements): *Quantum Optomechanics with Ultralow Mechanical Dissipation*

PRIMA GRANT

Jennifer Schober, a researcher with EPFL's Laboratory of Astrophysics, has been awarded a PRIMA grant from the Swiss National Science Foundation.

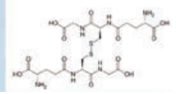
PRIMA grants are awarded by the Swiss National Science Foundation (SNSF) and are "aimed at excellent women researchers who show a high potential for obtaining a professorship". The grant covers the grantee's salary and project costs for five year. Those awarded carry out an independent research project with their own team at a Swiss research institution.

In 2019, the SNSF has awarded PRIMA grants to 19 researchers, each receiving CHF 1.3 million. Among the successful grantees is Jennifer Schober, a researcher with EPFL's Laboratory of Astrophysics.

"Being awarded a major research grant like PRIMA is an amazing honor and a recognition of my previous work," says Schober. "It gives me the exciting opportunity to establish my own group with which I will explore in depth a mysterious and fascinating realm of the Universe."

Schober's winning project is titled "Magnetohydrodynamical dynamos: Astrophysical and cosmological applications and observational signatures".

ECCELLENZA GRANT

Pablo Rivera Fuentes, assistant professor tenure track at the EPFL Institute of Chemcal Sciences and Engineering, received a Eccellenza Grant form the SNSF for his project "Chemical probes to control redox biology with subcellular precision".

SNSF Eccellenza Grants are aimed at researchers in all disciplines who have recently been appointed as tenure-track assistant professors at a Swiss higher education institution. They can apply for project funds for five years.

In 2019 the Swiss National Science Foundation awarded 34 SNS Eccellenza Professorial Fellowships and 11 SNSF Eccellenza Grants to promising young researchers who have proved to be of exceptional scientific ability. The share of women who received an Eccellenza award is 40%.

IPHYS - ISIC - MATH

European Research Council Grants

ERC ADVANCED GRANT

The ERC Advanced Grants are given each year to established, leading principal investigators to fund long-term funding for *"ground-breaking, high-risk"* research projects in any field.

Professor Tobias J. Kippenberg, who directs EPFL's Laboratory of Photonics and Quantum Measurements, has been awarded an ERC Advanced Grant for the study of "Extremely Coherent Mechanical Oscillators and circuit Cavity Electro-Optics".

The quest for mechanical oscillators with ultra-low dissipation is motivated by classical and quantum sensing and technology, as well as precision measurements. The project proposes a new generation of strain-engineered crystalline and superconducting micro- and nano-mechanical oscillators, whose Q-factors are predicted to exceed tens of billions. The project aims to exploit these systems to observe quantum optomechanical phenomena at room temperature. Secondly, the project will explore a fundamentally new method for measurement and manipulation of microwave fields with optical fields via measurement backaction – the nascent field of circuit Cavity-Electro-Optics. Taken together, we propose to open the new field of cavity circuit electro-optics, and usher in a new era of mechanical coherence within both classical and quantum domains.

ERC CONSOLIDATOR GRANT

The ERC Consolidator Grants are given annually to researchers of any nationality with 7-12 years of research experience after completion of their PhD, as well as *"a scientific track record showing scientific talent and an excellent research proposal"*. The Consolidator Grants, which generally provide funding for five years, are part of the ERC's commitment to support *"the highest quality research in Europe with competition-based financing"*, with the ultimate aim *"to establish and solidify European research as cutting-edge research."*

Professor Elena Goun, who directs the Laboratory of Bioorganic Chemistry and Molecular Imaging at ISIC, was awarded an ERC Consolidator Grant for her project: "METABOLIGHT: Optical imaging platform to unravel metabolic reprogramming of cancer: a path for improved treatments".

ERC STARTING GRANTS

The ERC Starting Grants are given each year to researchers of any nationality and in any field of research with 2-7 years of research experience after the completion of their PhD and who show a promising scientific track record, and offer an excellent research proposal. Application must come from an EU or associated country, and each Starting Grant can be up to €1.5 million given over a period of five years, with an additional €1 million to cover specific "start-up" costs.

Ardemis Boghossian receives ERC Starting Grant

Ardemis Boghossian (Institute of Chemical Sciences and Engineering) has received a Starting Grant for her project: "A Synthetic Biology Approach to Developing Optical NanoAnalytics". Boghossian's research takes a highly interdisciplinary approach to address fundamental challenges and develop novel technologies that exploit the synergy between nanotechnology and synthetic biology. Focusing on optoelectronics and protein engineering, Boghossian's work contributes new biological and biochemical methods for the production of durable hybrid nanomaterials for energy and biosensing applications.

"This project is really about blurring the lines between the living and non-living worlds to create new possibilities," says Boghossian. "We use bioengineering to discover new synthetic materials and devices, and this opens up a whole new domain that was previously inaccessible. The possibilities are, even in the statistical sense, unquantifiably limitless!"

Zsolt Patakfalvi receives ERC Starting Grant
Professor Zsolt Patakfalvi, who holds the Chair of Algebraic Geometry at EPFL's Institute of Mathematics, has received a Starting grant from the ERC to work on the classification of varieties.

The awarded project is titled: *Moduli spaces of stable varieties and applications*. Over the course of five years, Patakfalvi will work on an important part of the classification theory of algebraic geometry. This theory classifies "varieties", which are the main objects of algebraic geometry, and which can be defined as common zero sets of polynomials. The moduli space of stable varieties is then the list of the most numerous class of elementary varieties to which all other varieties can be decomposed.

The fundamental objective of Patakfalvi's project is to "construct the coarse moduli space of stable surfaces with fixed volume over the integers (possibly excluding finitely many primes, not depending on the volume)". The main goal of the project is to find applications for the general algebraic geometry and arithmetic of higher dimensional varieties.

ERC PROOF OF CONCEPT GRANT

The Proof of Concept (PoC) grants are given annually by the European Research Council (ERC) to researchers who already hold other ERC grants, in a range of research fields "from new health therapies to regenerate nerves, to prototyping soft robotic system for industrial handling, to building a charity that will promote welfare and job quality of digital workers of so-called 'gig economy'." Set up in 2011, the PoC grants are worth up to €150,000 and can be used for different purposes, including establishing intellectual property rights, investigating business opportunities, or conducting technical validation.

This year, the ERC has given 54 PoC grants. One of the winners is Tobias J. Kippenberg, Professor at EPFL's Laboratory of Photonics and Quantum Measurements. His project is entitled: *Photonic Integrated Microcombs as Multi-wavelength Sources for Edge Data Centers (PhoMEC).*

Over the past ten years the Laboratory of Photonics and Quantum Measurements (LPQM) has developed and pioneered microcombs – photonic integrated optical frequency combs (OFC) – providing access to equidistant optical carriers. Due to their broad bandwidth, high repetition rates, compactness and wafer-scale fabrication, such microcombs represent a novel disruptive technology with a proven track record. While their advantages were shown in ultrafast ranging (LIDAR), high speed coherent telecommunications, as well as chip-scale atomic clocks and frequency synthesizers, the technology is not yet commercially available and only present in a few research laboratories worldwide.

Recent LPQM advances have led to the development of unique proprietary Si_3N_4 microfabrication processes for ultra-low power microcombs, and allowed in-house photonic packaging. Taken together, the laboratory is now able to implement the full cycle production of a packaged microcomb ready for integration into a commercial product.

RESEARCH HIGHLIGHTS

IPHYS ISIC MATH

IPHYS - ISIC - MATH

EPFL Basic Sciences in 2019 Highly Cited Researchers list

Sixteen researchers from EPFL's School of Basic Sciences have been included in the Web of Science's 2019 Highly Cited Researchers list.

Since 2014, Clarivate Analytics has produced an annual Highly Cited Researchers list of scientists whose publications during the previous decade contain a notable number of papers that are in the top 1% most cited paper for their publication year.

The papers are categorized in one or more of 21 main subject fields the Essential Science Indicators (ESI), which forms a database of emerging science trends in various fields of research used by policymakers, government agencies, universities, corporations, recruiters, the press and others.

© EPFL / Alain Herzog

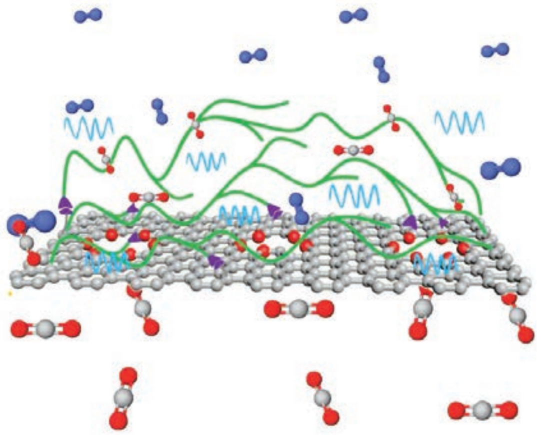
This year, the Highly Cited Researchers list includes 24 EPFL scientists, sixteen of which are or were researchers with the School of Basic Sciences:

- Professor **Paul J. Dyson** (ISIC)
- Professor **Michael Grätzel** (ISIC)
- Professor **Anders Hagfeldt** (ISIC)
- Professor **Xile Hu** (ISIC)
- Professor **Mohammad Khaja Nazeeruddin** (ISIC)
- Professor **Kevin Sivula** (ISIC)
- Professor **Tobias J. Kippenberg** (IPHYS)
- Professor **Annalisa Buffa** (MATH)
- Professor **Fabio Nobile** (MATH)
- Dr **Wolfgang Tress** (ISIC)
- Dr **Antonio Abate** (ISIC; now at Helmholtz-Zentrum Berlin)
- Dr **Juan-Pablo Correa-Baena** (ISIC; now at Georgia Tech)
- Dr **Peng Gao** (ISIC; now at the Shanghai Advanced Research Institute)
- Dr **Jun-Ho Yum** (ISIC)
- Dr **Stefaan De Wolf** (ISIC; now at KAUST)
- Dr **Shaik M. Zakeeruddin** (ISIC)

Professor Michael Grätzel is named in three different ESI fields (Chemistry, Materials Science, and Engineering), while Professor Mohammad K. Nazeeruddin and Dr Shaik M. Zakeeruddin in two (Chemistry and Materials Science).

ISIC

Next-gen membranes for carbon capture



CO_2-selective polymeric chains anchored on graphene effectively pull CO_2 from a flue gas mixture.

© KV Agrawal (EPFL)

EPFL chemical engineers have developed a new class of high-performance membranes for carbon capture that greatly exceed current targets.

A major greenhouse gas, CO_2 produced from burning fossil fuels is still mostly released into the atmosphere, adding to the burden of global warming. One way to cut down on it is through a carbon capture: a chemical technique that removes CO_2 out of emissions ("postcombustion"), preventing it from entering the atmosphere. The captured CO_2 can then be either recycled or stored away in in gas or liquid form, a process known as sequestration.

Carbon capture can be done using so-called "high-performance membranes", which are polymer filters that can specifically pick out CO_2 from a mix of gases, such as those coming out of a factory's flue. These membranes are environmentally-friendly, they don't generate waste, they can intensify chemical processes, and can be used in a decentralized fashion. In fact, they are now considered as one of the most energy-efficient routes for reducing CO_2 emissions.

Scientists led by **Kumar Varoon Agrawal** at EPFL Valais Wallis have now developed a new class of high-performance membranes that exceeds post-combustion capture targets by a significant margin. The membranes are based on single-layer-graphene with a selective layer thinner than 20 nm and are highly tunable in terms of chemistry, meaning that that can pave the way for next-generation high-performance membranes for several critical separations.

Current membranes are required to exceed 1000 gas permeation units (GPUs), and have a "CO_2/N_2 separation factor" above 20 – a measure of their carbon-capturing specificity. The membranes that the EPFL scientists developed show six-fold higher CO_2 permeance at 6,180 GPUs with a separation factor of 22.5. The GPUs shot up to 11,790 when the scientists combined optimized graphene porosity, pore size, and functional groups (the chemical groups that actually react with CO_2), while other membranes they made showed separation factors up to 57.2.

"Functionalizing CO_2-selective polymeric chains on nanoporous graphene allows us to fabricate nanometer-thick yet CO_2-selective membranes," says Agrawal. "This two-dimensional nature of the membrane drastically increases the CO_2 permeance, making membranes even more attractive for carbon capture. The concept is highly generic, and a number of high-performance gas separations are possible in this way."

OTHER CONTRIBUTORS

EPFL Interdisciplinary Centre for Electron Microscopy (CIME)

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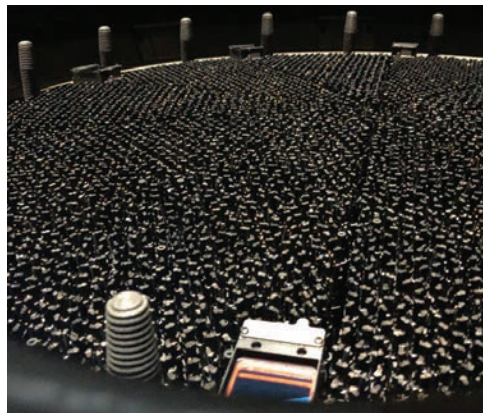
IPHYS

5,000 “eyes” will track the expansion of the Universe



DESI's focal plate with its 5,000 robot “eyes”
© National Optical Astronomy Observatory

The Dark Energy Spectroscopic Instrument (DESI), is a US-led project that will measure the accelerated expansion of the Universe in order to reveal the nature of dark energy. The DESI project, which has received significant contributions from EPFL's astrophysicists, is entering its final testing phase, gearing up to charter the skies.

The Dark Energy Spectroscopic Instrument (DESI) was developed to probe the nature of dark energy through the detailed measurement of the accelerated expansion of the universe. Dark Energy is a mysterious component that makes up about 68% of the mass-energy budget of today's Universe. DESI has now announced its “First Light”, entering its final testing and commissioning phase on the telescope, meaning that the instrument will be ready to begin science observations in early 2020. The first major release of data is expected in 2021.

Installed on the Mayall telescope at Kitt Peak National Observatory, DESI will spend the next four years obtaining optical spectra from tens of millions of galaxies and quasars, constructing a 3D map spanning the nearby universe up to 11 billion light-years.

To do this, DESI will use 5,000 fiber-optic “eyes” to capture light from 5,000 different objects – mostly galaxies, but also quasars and some stars, although the latter will be mostly for calibration purposes. DESI is designed to automatically point at preselected sets of galaxies, gather their light, and then using ten spectrographs split that light into narrow bands of color to precisely map the distance of those galaxies from Earth.

Through the detailed analysis of the 3D distribution of galaxies and quasars, the scientists will be able to derive how much the universe has expanded as the function of the galaxies' light traveled to Earth. Ideally, DESI can cycle through a set of about 5,000 galaxies every 20 minutes, thus measuring the distance of nearly one million of galaxies every 30 nights of observation.

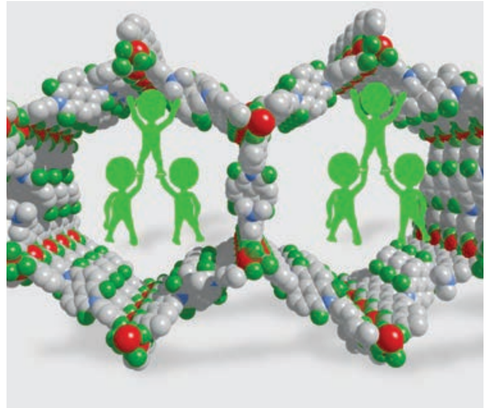
EPFL scientists have contributed to the development of the survey's targeting strategy (deciding which of the galaxies will be observed), as well as through the development of the robotic fiber-positioner system. The latter has been conducted as part of the interdisciplinary “Astrobots” group, which includes EPFL's Laboratory of Astrophysics (LASTRO), as well as Mohamed Bouri and Denis Gillett's teams from the School of Engineering, all of whom will be involved in processing the enormous amount of data that will be coming in from DESI.

The Astrobots group also procured most of the parts used for the construction of the fiber-positioner robots, which were manufactured the companies Maxon Motor in Switzerland and Namiki in Japan. In addition, the group contributed to the development of the firmware of the DESI positioner, and also carried out some tilt-verification tests on a few DESI positioners to validate their performance. An EPFL engineer also spent several months in the US to assist and help with the production of the positioners.

EPFL and the Swiss National Science Foundation have contributed almost 1 million CHF to the DESI project.

ISIC

Adding a polymer stabilizes collapsing metal-organic frameworks



Polymer braces, placed inside large-pore MOFs, help to inhibit the collapse of the framework. © Li Peng (EPFL)

Porous metal-organic frameworks (MOFs) have many applications like carbon capture and water-cleaning. However, MOFs with large pores tend to collapse. Chemists and chemical engineers at EPFL have now solved the problem by adding small amounts of a polymer into the MOF pores, an act that impedes pore collapse. Metal-organic frameworks (MOFs) are a special class of sponge-like materials with nano-sized pores. The nanopores lead to record-breaking internal surface areas, up to 7800 m^2 in a single gram. This feature makes MOFs extremely versatile materials with multiple uses, such as separating petrochemicals and gases, mimicking DNA, hydrogen production and removing heavy metals, fluoride anions, and even gold from water – to name a few.

One of the key features is pore size. MOFs – and other porous materials – are classified based on the diameter of their pores: MOFs with pores up to 2 nm in diameter are called “microporous”, and anything above that is called “mesoporous”. Most MOFs today are microporous, so they are not useful in applications that require them to capture large molecules or catalyze reactions between them – basically, the molecules don't fit the pores.

So more recently mesoporous MOFs have come into play, because they show a lot of promise in large-molecule applications. Still, they aren't problem-free: when the pore sizes get into the mesoporous regime – they tend to collapse.

Understandably, this reduces the internal surface area of mesoporous MOFs and, with that, their overall usefulness. Since a major focus in the field is finding innovative ways to maximize MOF surface areas and pore sizes, addressing the collapsing problem is a top priority.

Now, Dr Li Peng a postdoc at EPFL Valais Wallis has solved the problem by adding small amounts of a polymer into the mesoporous MOFs. Because the polymer pins the MOF pores open, adding it dramatically increased accessible surface areas from 5 to 50 times. The study was led by the research group of Wendy Lee Queen, in collaboration with the labs of Berend Smit and Mohammad Khaja Nazeeruddin at EPFL's Institute of Chemical Sciences and Engineering (ISIC).

After adding the polymer to the MOFs, their high surface areas and crystallinity were maintained even after heating the MOFs at 150°C – temperatures that would previously be unreachable due to pore collapse. This new stability provides access to many more open metal coordination sites, which also increases the reactivity of the MOFs.

In the study, published in the Journal of the American Chemical Society, two PhD students, Sudi Jawahery and Mohamad Moosavi, use molecular simulations to investigate why pores collapse in mesoporous MOFs in the first place, and also propose a mechanism to explain how polymers stabilize their structure on a molecular level. “We envision that this method for polymer-induced stabilization will allow us to make a number of new mesoporous MOFs that were not before accessible due to collapse,” says Queen. “Hence, this work can open up new, exciting applications involving the separation, conversion, or delivery of large molecules.”

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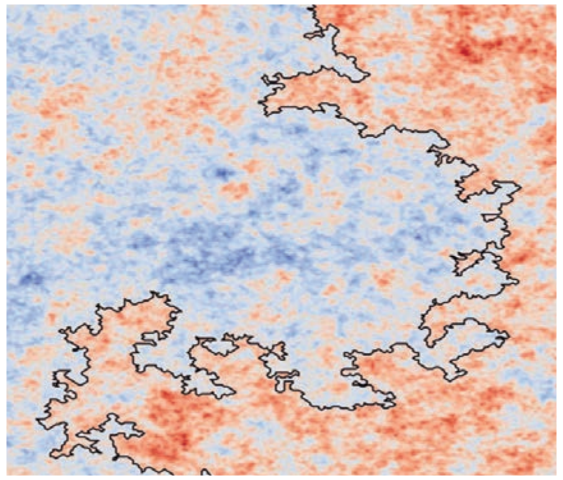
MATH

The random importance of clouds



A heat map of the heights of an approximation of the 2D GFF (red is high, blue is low) together with a zero contour line, drawn in black.
© Juhan Aru, EPFL

Juhan Aru holds the Chair of Random Geometry at EPFL Institute of Mathematics. His work aims at understanding geometric properties of models where randomness and geometry meet.

Randomness and geometrical structures interact with one another in a plethora of real-life examples, such as bubbles in boiling water or snowflakes. But Professor Juhan Aru, EPFL's Chair of Random Geometry, found a way to link his hobbies with work in another everyday phenomenon: clouds.

"In the north, from where I come from, the summer skies are often filled with small puffy clouds – cumulus clouds," he says. "You often see them in Switzerland too. One of my favourite pastimes has always been to lie down on a field, a beach – why not a mountaintop? – and to watch these clouds." Aru considers himself lucky, as his current field of mathematics is actually linked to clouds.

The field Aru is working on is sometimes called "random geometry", where geometric structures and randomness interact. If one looks at cumulus clouds, then a certain structure – or geometry – is clear and apparent to the eye. But even so, randomness is present, hidden in the formation of clouds through the aggregation of water molecules, each flying around the sky independently, randomly, before ultimately "deciding" to contribute to the cloud itself.

Mathematicians don't have a good, satisfactory mathematical description of cumulus clouds – or at least a model that can describe and understand their detailed and beautiful shapes. For now, we have to work on simpler things, e.g. restricting ourselves to two dimensions – or as mathematicians would say, to "planar structures" – some of them still resemble clouds, but two-dimensional clouds.

Aru and his group are trying to understand the mathematical properties of these cloud-like planar structures. Their work is similar to that of a biologist, who taxonomizes different species – classifying them, and describing their distinctive and common properties.

One of the models Aru works with is called the "2D Gaussian free field" (2D GFF; see an example in the figure) We can think of it as the height function of a mountainous landscape, like the Alps.

"I try to understand the peaks, valleys, and the level lines of this landscape," says Aru. "It turns out that the 2D GFF has many connections to models of statistical physics, to quantum field theories, to simplified theories of quantum gravity, and also to what is called 'Brownian motion'." Brownian motion is a probabilistic model used in mathematics to describe the random motion of particles. "Errantly moving particles are like water molecules in the summer sky," explains Aru. "So, at least for me, the GFF is also linked to clouds".

The past few years have seen remarkable progress in the field, and now Aru and his colleagues have been able to understand further aspects of the 2D GFF. "Yet, the work is by no means done," says Aru. "Indeed, many connections of the GFF are still being uncovered. For example, at the moment we have no mathematical means to study geometric questions in three dimensions; and yet, clouds are three-dimensional. So the questions are challenging, and inspiration is important - so I often go for a walk, lie down, and take a look at the sky!"

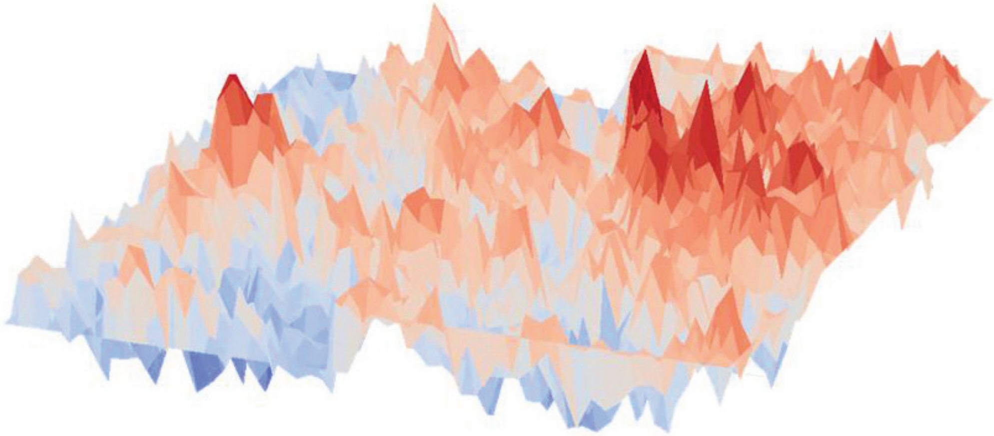
TRACKING THE MATHS

The Gaussian free field (GFF) is a random height function. It is different every time you look at it, but even so there are some geometric properties that are (almost) always true. Therefore, when we study a 2D GFF, we are interested in describing its statistical properties. Together with co-authors, the Chair of Random Geometry has been studying such properties.

The difficulty is that the 2D GFF fluctuates so much that you cannot assign a value to it at any point – mathematically speaking, at any point the random height has infinite variance. One can only ask about averages of the height around any point. Mathematically, this means that the 2D GFF can be only be described as a random generalized function, as a random Schwartz distribution, which makes the study of geometric properties more difficult – how do you even give a sense to for example contour lines, when the height-function has no pointwise values?

Nevertheless, around 15 years ago Oded Schramm and Scott Sheffield found a way to describe the level lines of the 2D GFF and since then there has been tremendous progress in the subject. Part of the progress has been in giving sense to a wider variety of geometric notions, e.g. excursions off the level lines.

Another part of the progress has been related to the many applications of the GFF: it helps construct 2D toy models of quantum gravity, called Liouville quantum gravity, and to better understand Schramm–Loewner evolution processes – a family of random curves that describes the geometry of many statistical physics models, e.g. those of long random polymers.



A surface plot of an approximation of the 2D Gaussian free field.
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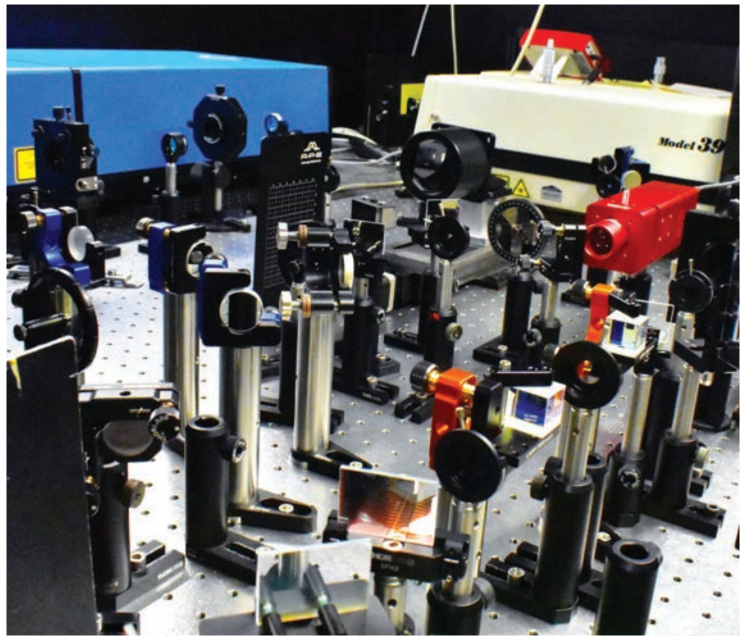
IPHYS

Creating a single phonon in ambient conditions



The experimental setup for the laser part of the study.

EPFL physicists have for the first time successfully observed a single quantum of vibrational energy at ambient conditions, involving the oscillation of more than 100 billion atoms. The work opens up new possibilities for the study of quantum phenomena and ultrafast quantum technologies at room temperature.

The atoms in a crystalline solid material are arranged in what we call a crystal lattice. The structure of this lattice determines most mechanical and thermal properties of the bulk solid. However, the atoms within the lattice are not still but instead vibrate around their central position. This movement is generally random, and its energy then corresponds to the temperature of the material. But if carefully triggered, it may happen in unison, leading to billions of atoms moving together as a whole.

The vibrational energy of such a collective oscillation manifests in discrete, "quantized" units called phonons. Phonons are not "real" particles that can exist in vacuum, like e.g. electrons, but they behave as if they were particles, and are called "quasiparticles". For example, any vibrating object can only gain or lose energy by exchanging individual phonons, which is something that actually conflicts with our common experience of vibrating objects continuously losing energy.

Meanwhile, it's been hard to study phonons one at a time against the random thermal movement of the atoms; so far, individual phonons have only been observed at extremely low temperatures and under high vacuum.

In a new experiment, physicists led by Christophe Galland at EPFL's Institute of Physics have shown that a single phonon can be excited and detected at room temperature and in the air, making the quantum behaviour of vibrating matter more tangible. The work, in collaboration with MIT, is published in *Physical Review X*.

To generate the phonon, the scientists shot ultrafast laser pulses onto a diamond crystal to excite its atomic lattice into vibrating. By careful design of the experiment, they triggered a collective vibration involving more than 100 billion atoms that exchanged energy with single photons from the laser light. By measuring the energy exchanged by this vibration with single photons, the scientists were able to prove that a single phonon was excited, confirm that the collective oscillation behaves as a single particle.

"Our work opens exciting perspectives in the study of quantum phenomena in other naturally occurring materials and molecular systems," says Galland, adding that it "could have applications in room-temperature ultrafast quantum technologies."

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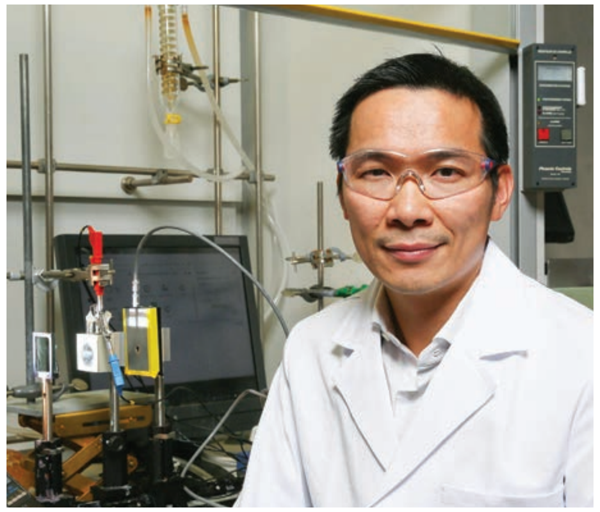
ISIC

Carbon-neutral fuels move a step closer



Chemists at EPFL have developed an efficient process for converting carbon dioxide into carbon monoxide, a key ingredient of synthetic fuels and materials.

The carbon dioxide (CO_2) produced when fossil fuels are burned is normally released into the atmosphere. Researchers working on synthetic fuels – also known as carbon-neutral fuels – are exploring ways to capture and recycle that CO_2. At EPFL, this research is spearheaded by a team led by Professor Xile Hu at the Laboratory of Inorganic Synthesis and Catalysis (LSCI). The chemists have recently made a landmark discovery, successfully developing a high-efficiency catalyst that converts dissolved CO_2 into carbon monoxide (CO) – an essential ingredient of all synthetic fuels, as well as plastics and other materials. The researchers published their findings in Science on 14 June.

REPLACING GOLD WITH IRON

The new process is just as efficient as previous technologies, but with one major benefit. "To date, most catalysts have used atoms of precious metals such as gold," explains Professor Hu. "But we've used iron atoms instead. At extremely low currents, our process achieves conversion rates of around 90%, meaning it performs on a par with precious-metal catalysts."

"Our catalyst converts such a high percentage of CO_2 into CO because we successfully stabilized iron atoms to achieve efficient CO_2 activation," adds Jun Gu, a PhD student and lead author of the paper. To help them understand why their catalyst was so highly active, the researchers called on a team led by Professor Hao Ming Chen at National Taiwan University, who conducted a key measurement of the catalyst under operating conditions using synchrotron X-rays.

CLOSING THE CARBON CYCLE

Although the team's work is still very much experimental, the research paves the way for new applications. At present, most of the carbon monoxide needed to make synthetic materials is obtained from petroleum. Recycling the carbon dioxide produced by burning fossil fuels would help preserve precious resources, as well as limit the amount of CO_2 – a major greenhouse gas – released into the atmosphere.

The process could also be combined with storage batteries and hydrogen-production technologies to convert surplus renewable power into products that could fill the gap when demand outstrips supply.

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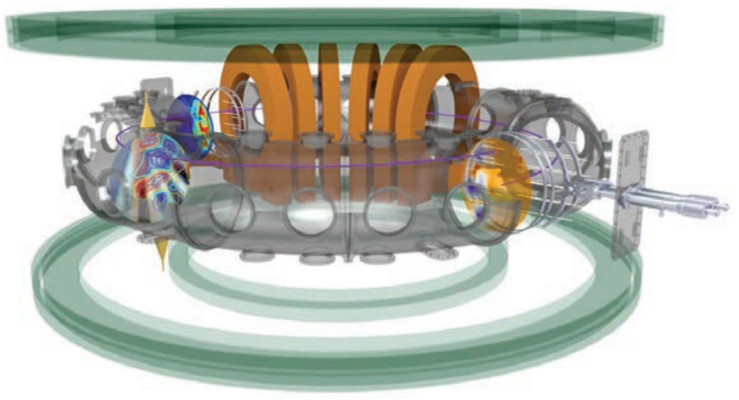
IPHYS

Links between basic plasma physics and fusion in *Nature Physics*



TORPEX
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An article recently published by the Swiss Plasma Center in Nature Physics illustrates the value of basic plasma physics research and numerical simulations in the quest for fusion.

Starting from the premise that basic plasma physics and theoretical models are necessary to define the characteristics of future fusion reactors and that certain technological obstacles can also be overcome by improving our basic knowledge, Professors Ambrogio Fasoli, Ivo Furno and Paolo Ricci describe in *Nature Physics* the role of this type of basic research in the realization of fusion, through several results obtained in recent years.

They discuss in particular the experiments made on the TORPEX installation of the SPC, which made it possible to isolate a number of phenomena occurring in the plasmas in order to study them in detail. Examples include the characterization of the dynamics of 'blobs', macroscopic structures resulting from the turbulent evolution of plasma instabilities, and the possibility of controlling them as well as their influence on the propagation of microwaves in their vicinity.

The advantage of numerical simulations based on first principles is also highlighted, together with the need to validate these theoretical results with basic experiments, since the measurements of the modeled quantities are easier to carry out in small, dedicated devices rather than in more complex fusion facilities. The authors describe in particular the successful validation and verification of the model describing the propagation of microwaves in the vicinity of these blobs.

Finally, the authors explain how these various basic experimental facilities, dedicated to the study of particular phenomena, make it possible to select the models best describing each of these phenomena.

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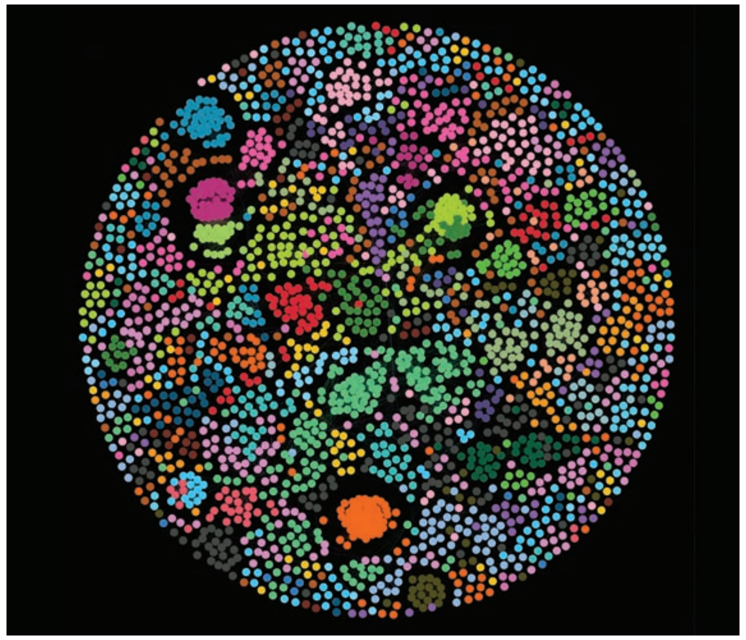
MATH

Big data toolkit to mine the dark genome for precision medicine

EPFL researchers have developed Big Data tools for identifying new gene functions. The work identifies millions of connections between genes and their functions, and can facilitate the development of precision medicine.



Gene networks. © J. Auwerx, EPFL

Genes are the functional units of heredity, and the understanding of gene function is the major focus of biomedical research, serving as the basis of precision medicine. However, most research efforts have been devoted to only a small part of the genes, neglecting the larger "dark genome". This impedes our understanding of the underlying mechanisms of complex traits and diseases, which is necessary for the advancement of precision medicine.

"Most of the research are gene-oriented and largely influenced by our prior knowledge, therefore many potentially important genes are ignored," says Johan Auwerx, whose lab at EPFL led the study, along with colleagues from the University of Lausanne and the University of Tennessee, and EPFL professors Kristina Schoonjans (School of Life Sciences) and Stephan Morgenthaler.

In an article published in Genome Research, the scientists address the issue of the "dark genome" by developing novel approaches based on systems genetics. "Genes with similar functions tend to have similar expression patterns," explains first author Hao Li. "We used this feature to predict the function of unknown genes by learning from those of the known ones."

The researchers collected large-scale gene-expression datasets containing more than 300,000 samples from six different species. They then used these to develop a toolkit termed "GeneBridge" that can identify potential gene functions. The toolkit was then used by the team to identify hundreds of thousands of novel functions of genes, many of which have been verified by Auwerx's group as well as by other research groups.

"We have deposited GeneBridge and its seven billion data points on systems-genetics.org along with the already existing 300 million data points," says Auwerx. "This resource will undoubtedly improve our knowledge of the 'dark genome', and promote the development of precision medicine."

OTHER CONTRIBUTORS
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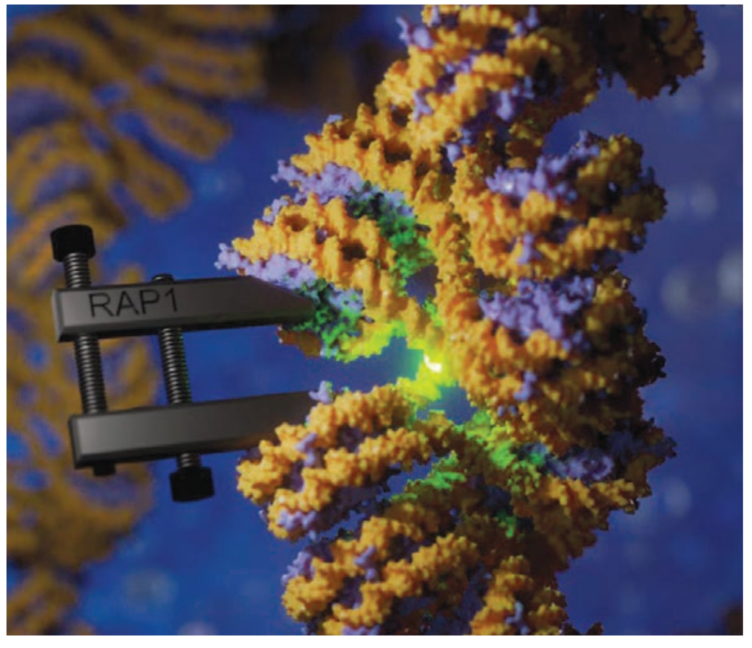
ISIC

Unraveling gene expression



The pioneer transcription factor Rap1 pries open compact chromatin structure to activate genes. © B. Fierz, EPFL

The DNA of a single cell is 2-3 meters long end-to-end. To fit and function, DNA is packaged around specialized proteins. These DNA-protein complexes are called nucleosomes, and they are a small part of a larger structure called chromatin. Nucleosomes can be thought of as the cell's DNA storage and protection unit.

When a particular gene needs to be expressed, the cell requires access to the protected DNA within chromatin. This means that the chromatin structure must be opened and the nucleosomes must be removed to expose the underlying target gene.

This takes place in the orchestrated process of "chromatin remodeling", which regulates gene expression and involves a multitude of actors. Unravelling this pivotal step not only furthers our fundamental understanding, but may also help in the development of genetic engineering tools.

Now the lab of Beat Fierz at EPFL's Institute of Chemical Sciences and Engineering, has been able to uncover the first steps in the chromatin-opening process at the level of a single molecule, using a combination of chemical biology and biophysical methods. Published in *Molecular Cell*, the work looks at the role of a group of proteins called "pioneer transcription factors". These proteins bind to specific DNA regions within chromatin that are themselves shielded from other proteins. Little is known about how these factors overcome the barriers of the chromatin maze.

Fierz's lab looked at yeast, which is a model organism for human genetics. The method involved replicating the architecture of yeast genes, combined with single-molecule fluorescence. The researchers studied a yeast pioneer transcription factor called Rap1, and found that it choreographs chromatin remodeling, allowing access to other proteins required for gene expression that were previously obstructed.

To do this, Rap1 first binds chromatin and then influences the action of a large molecular machine called "Remodeling the Structure of Chromatin" (RSC), displacing nucleosomes and paving the way to the now-exposed DNA for other proteins involved in controlling gene expression.

By revealing the physico-chemical mechanism of how Rap1 gains access to chromatin and opens it up, the EPFL study proposes a biological model for other pioneer transcription factors, but also provides the tools for investigating them at the level of a single molecule.

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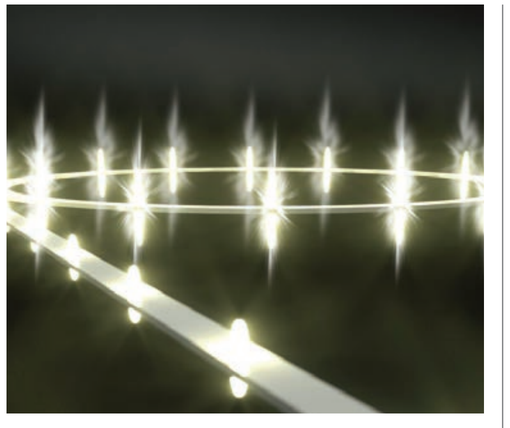
IPHYS

Making and controlling crystals of light



Light pulses in an optical microresonator forming a perfect soliton crystal. © Second Bay Studios

EPFL scientists have shown how light inside optical on-chip microresonators can be crystallized in a form of periodic pulse trains that can boost the performance of optical communication links or endow ultrafast LiDAR with sub-micron precision.

Optical microresonators convert laser light into ultrashort pulses travelling around the resonator's circumference. These pulses, called "dissipative Kerr solitons", can propagate in the microresonator maintaining their shape.

When solitons exit the microresonator, the output light takes the form of a pulse train – a series of repeating pulses with fixed intervals. In this case, the repetition rate of the pulses is determined by the microresonator size. Smaller sizes enable pulse trains with high repetition rates, reaching hundreds of gigahertz in frequency. These can be used to boost the performance of optical communication links or become a core technology for ultrafast LiDAR with sub-micron precision.

Exciting though it is, this technology suffers from what scientists call "light-bending losses" – loss of light caused by structural bends in its path. A well-known problem in fiber optics, light-bending loss also means that the size of microresonators cannot drop below a few tens of microns. This therefore limits the maximum repetition rates we can achieve for pulses.

Publishing in Nature Physics, researchers from the lab of Tobias J. Kippenberg at EPFL have now found a way to bypass this limitation and uncouple the pulse repetition rate from the microresonator size by generating multiple solitons in a single microresonator.

The scientists discovered a way of seeding the microresonator with the maximum possible number of dissipative Kerr solitons with precisely equal spacing between them. This new formation of light can be thought of as an optical analogue to atomic chains in crystalline solids, and so the researchers called them "perfect soliton crystals" (PSCs).

Due to interferometric enhancement and the high number of optical pulses, PSCs coherently multiply the performance of the resulting pulse train – not just its repetition rate, but also its power.

The researchers also investigated the dynamics of PSC formations. Despite their highly organized structure, they seem to be closely linked to optical chaos, a phenomenon caused by light instabilities in optical microresonators, which is also common for semiconductor-based and fiber laser systems.

"Our findings allow the generation of optical pulse trains with ultra-high repetition rates with several terahertz, using regular microresonators," says researcher Maxim Karpov. "These can be used for multiple applications in spectroscopy, distance measurements, and as a source of low-noise terahertz radiation with a chip-size footprint." Meanwhile, the new understanding of soliton dynamics in optical microresonators and the behavior of PSCs opens up new avenues into the fundamental physics of soliton ensembles in nonlinear systems.

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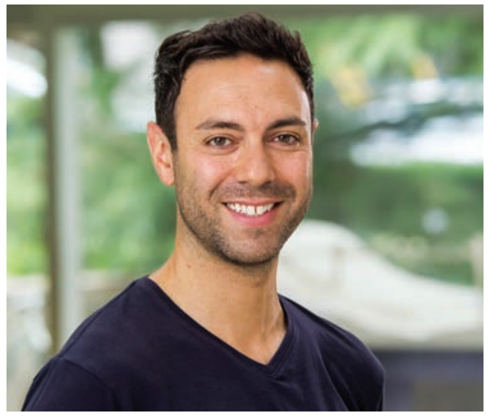
MATH

The math of detecting communities



Emmanuel Abbé is the new Chair of Mathematical Data Science at EPFL. His work answers fundamental questions in machine learning and information theory, and in particular on community detection.

The graph above represents the data set of the political blogs from Adamic et al. 2005. Each vertex represents a blog during the political election period in the US in 2008, and each edge represents the fact that one of the blogs refers to the other. The goal is to reconstruct the political inclinations of the blogs (collected by Adamic et al.) by observing only the connections. The blue/red coloring represents the output of the algorithm in Abbe-Sandon NIPS16, which gives 95% accuracy on the reconstruction of the political inclinations (blue and red correspond to left and right leaning blogs).

Sociologists study the patterns of everyday social interactions and relationships by structuring society in a network. Likewise biologists use networks to record similarities of species or co-expressions of genes. In these networks, every item is represented by a dot – or "node" – and each interaction by lines between dots. Networks of interacting items are what we know as graphs.

One of the main points of interest in such networks is to figure out which nodes are "alike"; for example, co-workers or family members. When similar nodes group together they begin to form what are called "communities", but detecting a "community" is a complex and key problem. It is crucial, for example, when studying protein-protein interactions or gene expression in cells, or for performing medical diagnosis and finding patterns in social behavior.

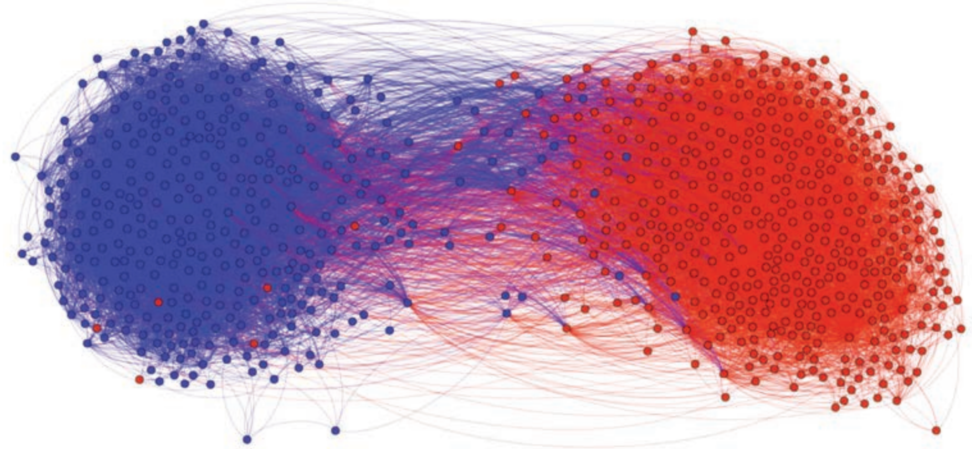
The most basic task of community detection consists in partitioning the nodes of a graph into clusters that are more densely connected, e.g. members of a sport club. Having grown tremendously since the 1980's, the field of community detection today employs a remarkable diversity of models and algorithms developed in different scientific communities such as machine-learning and computer science.

COMMUNITY QUESTIONS

"Despite this growth, there are still several fundamental questions," says Professor Emmanuel Abbé, EPFL's Chair of Mathematical Data Science, (Schools of Basic Sciences and Computer and Communication Sciences). His work focuses on addressing persistent problems in community detection.

The first problem has to do with the validity of detected communities in graphs. "Algorithms may output communities, but are these meaningful or artefacts?" asks Abbé. Another question involves the reliability of the field's current methods: "Can we always extract the communities when they are present? Can we extract them fully or partially?" And finally, there's quality control: "What are good benchmarks for measuring the performance of algorithms – and which are the best algorithms?"

In recent years, Abbé's group has been able to answer these questions for a class of random graphs used widely in machine learning and statistics. These random graphs are called "stochastic block models" and are useful benchmarks for scientists as they are very insightful and admit a vast collection of practical extensions. Abbé's work in stochastic block model analysis puts forward a research direction bridging information theory and machine learning that has seen various follow-up works in both communities.



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Abbé and his co-authors have characterized when the extraction of communities is possible or not for general stochastic block models. Their research improves on decades-long work, obtaining the tight bounds (a.k.a. "fundamental limits") for various community-detection requirements, and developing various algorithms for achieving these bounds.

"Communities are one of the first features of interest in networks, and block models are one of the first network models," says Abbé. "There are many more problems concerned with extracting patterns in graphical data; hopefully the recent developments will give us guidance on these too."

TRACKING THE MATH

In a paper published in 2016 [1], Abbé's group first derived the fundamental limit for exact recovery in the two-community case, giving a closed form expression for the limit. The paper further showed that the limit is efficiently achievable, and connected the exact recovery problem to coding theory, thus establishing a new perspective on community detection and graph clustering.

This work was extended in another paper [2] – that was actually published in 2015 – by solving exact recovery in the general SBM, with an arbitrary number of clusters of arbitrary sizes and arbitrary connectivity rates between communities. In particular, it quantified the fundamental limit in terms of the Chernoff-Hellinger divergence, giving a new operational meaning to this mathematical divergence in terms of community detection.

Weaker recovery requirements where the communities are only partially recovered were investigated in another paper [3] in 2017 for the general SBM. The paper proves the optimality of an algorithm that consists in a linearization of the belief-propagation (BP) algorithm from statistical physics, settling a conjecture made by physicists. While it is an open problem to establish rigorous performance guarantees for BP in loopy graphs, the paper obtained a rigorous proof of the optimality of the linearized BP algorithm by connecting it to a spectral algorithm on certain nonbacktracking operators.

These works and the relevant literature are overviewed in References [4], and [5] below.

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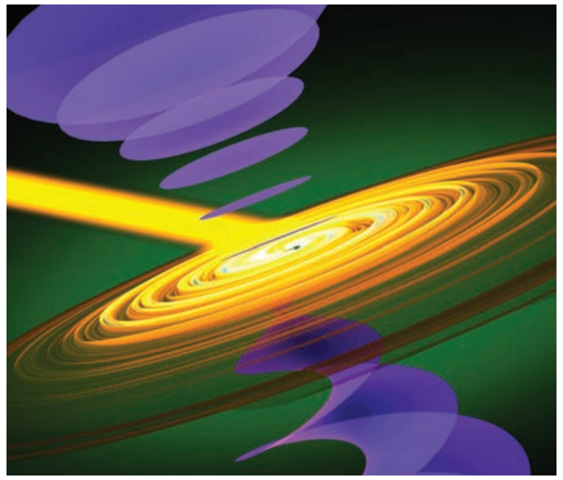
IPHYS

Twisting whirlpools of electrons



© Ella Marushchenko (Ella Maru Studio)

Using a novel approach, EPFL physicists have been able to create ultrafast electron vortex beams, with significant implications for fundamental physics, quantum computing, future data-storage, and even certain medical treatments.

In Jules Verne's famous classic *Twenty Thousand Leagues Under the Sea*, the iconic submarine *Nautilus* disappears into the Moskenstraumen, a massive whirlpool off the coast of Norway. In space, stars spiral around black holes; on Earth, swirling cyclones, tornadoes, and dust-devils rip across the land.

All these phenomena have a particular shape in common: the vortex. From galaxies to stirring milk into coffee, vortices appear everywhere in nature – even in the subatomic world, when a stream of elementary particles or energy can spiral around a fixed axis like the tip of a corkscrew.

When particles move like this, they form what we call "vortex beams". These beams are very interesting because they imply that the particle has a well-defined orbital angular momentum, which describes the rotation of a particle around a fixed point.

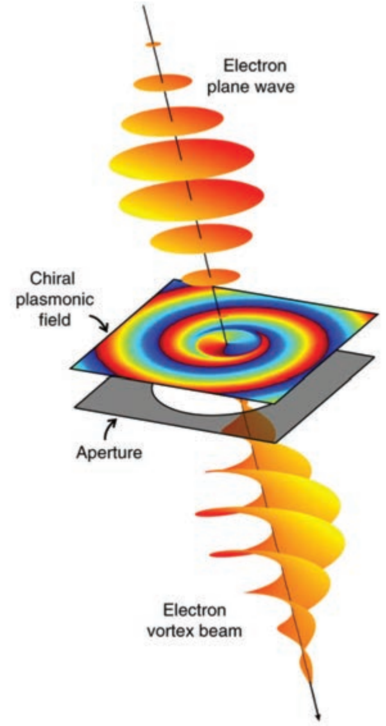
What this means is that vortex beams can give us new ways of interacting with matter, e.g. enhanced sensitivity to magnetic fields in sensors, or generate new absorption channels for the interaction between radiation and tissue in medical treatments (e.g. radiotherapy). But vortex beams also enable new channels in basic interactions among elementary particles, promising new insights into the inner structure of particles such as neutrons, protons or ions.

The strange thing about matter is that, along with its particle nature, it also has a wave-nature. This means that we can make massive particles form vortex beams by simply modulating their wave function. This can be done with a device called a "passive phase mask", which can be thought of as a standing obstacle in the sea. When waves at sea crash into it, their "wave-ness" shifts and they form whirlpools. So far, physicists have been using the passive phase mask method to make vortex beams of electrons and neutrons.

But now, scientists from the lab of Fabrizio Carbone at EPFL are challenging this idea. Demonstrating for the first time that it is possible to use light to dynamically twist an individual electron's wave function, the researchers were able to generate an ultrashort vortex electron beam and actively switching its vorticity on the attosecond (10^{-18} seconds) timescale.

To do this, the team exploited one of the fundamental rules governing the interaction of particles on the nanoscale level: energy and momentum conservation. What this means is that the sum of the energies, masses and velocities of two particles before and after their collision must be the same. Such a constraint is responsible for an electron to gain orbital angular momentum during its interaction with an ad hoc prepared light field, i.e. a chiral plasmon. In experimental terms, the scientists fired circularly polarized, ultrashort laser pulses through a nano-hole fabricated onto a metallic film. This induced a strong, localized electromagnetic field (the chiral plasmon), and individual electrons were made to interact with it.

The scientists used an ultrafast transmission electron microscope to monitor the resulting phase profiles of the electrons. What they discovered was that, during the interaction of the electrons with the field, the wave function of the electrons took on a "chiral modulation"; a right- or left-handed movement whose "handiness" can be actively controlled by adjusting the polarization of the laser pulses.



A schematic representation of the OAM transfer to electrons: the interaction between a pulsed electron plane wave synchronized with a chiral plasmonic field creates an OAM-carrying vortex electron wavepacket.
© F. Carbone, EPFL

"There are many practical applications from these experiments," says Fabrizio Carbone. "Ultrafast vortex electron beams can be used to encode and manipulate quantum information; the electrons' orbital angular momentum can be transferred to the spins of magnetic materials to control the topological charge in new devices for data storage. But even more intriguingly, using light to dynamically 'twist' matter waves offers a new perspective in shaping protons or ion beams such as those used in medical therapy, possibly enabling new radiation-matter interaction mechanisms that can be very useful for selective tissue ablation techniques."

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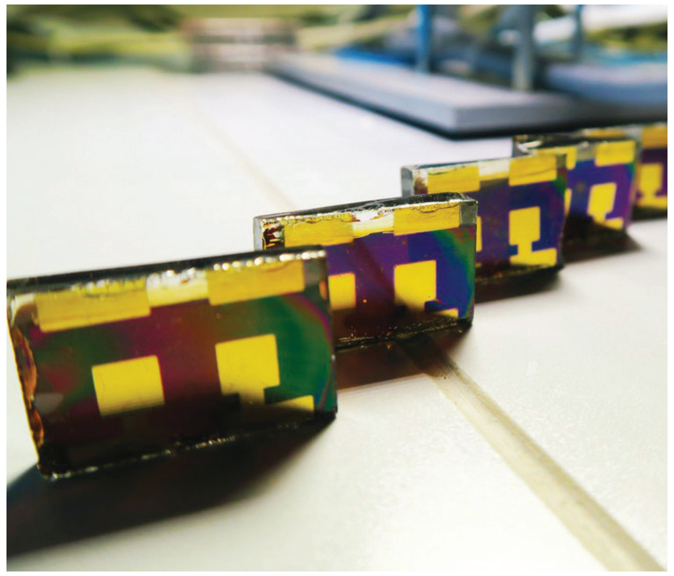
ISIC

Perovskite solar cells tested for real-world performance – in the lab



Perovskite solar cells in the lab. © W. Tress (EPFL)

Researchers at EPFL bring diurnal and seasonal variations into the lab to test the performance of perovskite solar cells under realistic conditions. The findings are published in *Nature Energy*.

It was only ten years ago that metal-halide perovskites were discovered to be photovoltaic materials. Today, perovskite solar cells made are almost as efficient as the best conventional silicon ones, and there is much hope that they will become a highly efficient and low-cost alternative, as they can be manufactured by rather simple and fast methods like printing.

The major obstacle for commercialization is the stability of perovskite devices. Operational stability is commonly assessed either by continuous illumination in the lab or by outdoor testing. The first approach has the disadvantage of not accounting for real-world operation variations in irradiance and temperature because of day-night and season changes. These are especially important for perovskite solar cells because of their slow response times.

On the other hand, outdoor tests require that the devices are encapsulated to protect them against exposure to harsh weather conditions. But encapsulation mainly addresses parasitic failure mechanisms that are not necessarily related to the perovskite material itself.

To escape from this dilemma, Wolfgang Tress, a scientist with the lab of Anders Hagfeldt at EPFL, working with colleagues at the lab of Michael Grätzel, brought the real-world conditions into the controlled environment of the lab. Using data from a weather station near Lausanne (Switzerland) they reproduced the real-world temperature and irradiance profiles from specific days during the course of the year. With this approach, the scientists were able to quantify the energy yield of the devices under realistic conditions. "This is what ultimately counts for the real-world application of solar cells," says Tress.

The study found that temperature and irradiance variations does not affect the performance of perovskite solar cells in any dramatic way, and although the efficiency of the cells decreases slightly during the course of a day, it recovers during the night.

"The study provides a further step towards the assessment of the performance and reliability of perovskite solar cells under realistic operation conditions," says Tress.

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IPHYS

EPFL hosted the International Physicists' Tournament 2019

© Clara Beaubis

Between 21 and 26 April, EPFL hosted and competed in the International Physicists' Tournament (IPT) 2019. The event brought together over 200 physics students from around the world – all representing their university and country. The EPFL team defended the gold medal it won in 2018 - this time on home turf.

"This is a record-breaking year, with 19 teams from 16 different countries," says Evgenii Glushkov, a PhD student in the laboratory of nanoscale biology (LBEN). Glushkov also lead the 10-member student organizing committee, chaired by Jean-Philippe Ansermet, a physics professor at EPFL's School of Basic Sciences.

The IPT isn't just about the competition itself. Members of the public are able to watch the presentations at every stage of the event, and there are plenty of surprises in store – including live experiments and demonstrations, as well as easily digestible explanations.

Planning, pragmatism, and creativity

Is it possible to estimate how far away a train is, and how fast it's traveling, merely from the sound it makes as it approaches? Why does a thin metal wire acquire a rotational motion when placed on top of a Tesla coil? How can the structure of a *samara* – the helicopter-like fruit that grows on certain trees – inspire more efficient parachute design? The six-strong Swiss team, all students from EPFL, has been gearing up for the tournament for a few months, working on questions like these – all physics problems inspired by everyday observable phenomena.

In that intense week-long competition, the teams presented their solutions, compared their ideas against their opponents, and demonstrated the validity of their methods and models. The students used all their pragmatism and creativity in order to impress the international jury of professional physicists – and wow the public. The best teams made it through the qualifying stages and into the final on April 26th. The EPFL team, composed entirely of Physics Bachelor Students, qualified for the semi-finals and obtained a nice 5th place among 19 teams coming from all over the world. The battle has been very exciting to the very end.

Participating is what counts

Competition aside, the IPT is a chance for students and professors to rub shoulders with fellow participants from around the world. "Once the qualifying stages are over, you often see teams discussing how physics is taught in their country," says Glushkov. "Competing for the medals is only part of what the IPT is about. We all head home having learned something – and met lots of new people along the way."

ISIC

EPFL startup develops innovative method for recycling PET

© iStock photo

DePoly, a startup based at EPFL's Valais-Wallis campus, has developed a chemical-based method for recycling PET containers. Its process, which offers several advantages over existing technology, has just won the company first place at the 2019 "venture" competition.

While the technology for recycling PET already exists, the systems currently out there have a number of limitations. For example, there is no way to create plastic bottles made entirely of recycled PET – at least some of the raw materials must be new. "That means purchasing them from refineries, which convert oil into ethylene glycol and terephthalic acid, the two compounds needed to make PET," says Samantha Anderson, founder & CEO of DePoly and a PhD student at the Laboratory of Molecular Simulation (LSMO) at EPFL's Valais-Wallis campus. In addition, many PET containers can't be recycled because they contain chemical and food contaminants, additives or dyes – most of these containers end up being incinerated.

Recycling through depolymerization

DePoly has developed an innovative method that can recycle just about any PET container using a chemical process that breaks down the plastic into its base compounds. "It doesn't matter if the container held water, peanut butter or soap, or if it's crystal clear or pitch black," says Anderson. With the new method, PET containers don't have to be sorted by color, meaning they can all be processed in one batch. The method also works with fabrics like polyester, breaking down old t-shirts, for example, into cotton and PET fibers.

The chemical process involves depolymerizing the PET – hence the name DePoly. "We combine the plastic with various compounds in a reactor and then apply light to the mixture to trigger a series of chemical reactions. These reactions break the bonds between the ethylene glycol and terephthalic acid, freeing up the compounds for further use," says Anderson. The process results in ethylene glycol in clear liquid form and terephthalic acid as a white powder, which are then easily separable. The process also generates a small amount of dyes, additives and other waste. Anderson will not reveal any more details, since a patent for the technology is pending.

An award-winning innovation

This year DePoly competed in the 2019 "venture" competition, in the Hardware category, and took home the grand prize. "venture" is a Swiss entrepreneurship competition held every year by EPFL, ETH Zurich, McKinsey & Company, Knecht Holding and Innosuisse. Winners receive 150,000 francs and a package of business consulting services. They also join the "venture" network to make contacts and boost their visibility.

To develop the method, Anderson teamed up with two LSMO colleagues: postdoc Christopher Ireland and PhD student Bardiya Valizadeh. "DePoly had already received funding from the Swiss National Science Foundation and an Innogrant before winning "venture"," says Professor Berend Smit, head of LSMO, the lab that supported the research. "I'm very proud of the team's success."

Members of the start-up DePoly: Bardiya Valizadeh, Samantha Anderson and Christopher Ireland © Patrick Favre

Tests on an industrial scale

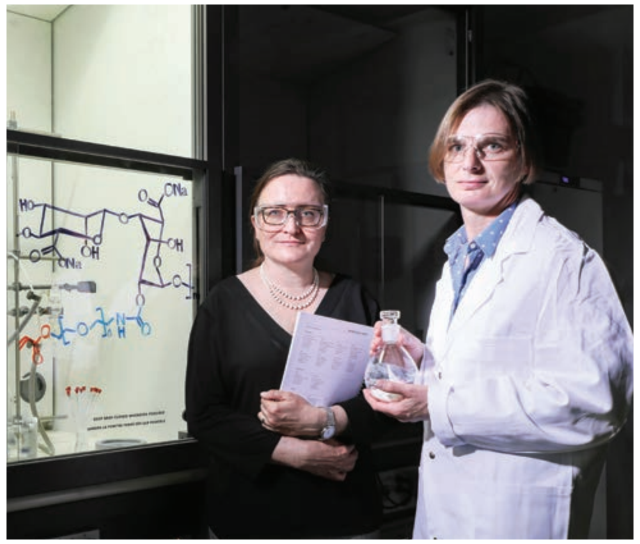
The next step for DePoly will be to scale up its technology from the lab to industry. "In November, we will begin building a pilot unit with more capacity than the lab," says Anderson. The unit, located at the Central Valais Waste Treatment Plant in Uvrier, will allow the startup to test and refine its method so that it performs well under industrial conditions. "The testing phase will probably last a year," says Anderson. "I'm sure chemical recycling methods for PET will eventually hit the market – if not our method, then someone else's. We aren't the only ones working on this approach."

For now Anderson is dividing her time between managing DePoly and writing her thesis. But after she graduates in November, she will devote herself fully to her project, which promises to help clean up the plastic polluting our environment.

DePoly has also received support from local business incubator The Ark.

ISIC

Hydrogel developed at EPFL offers real promise in treating diabetes



With the help of the TTO (Natalia Giovannini on the left), a hydrogel developed by the Functionalized Biomaterials Group (piloted by Sandrine Gerber) has been licensed.

Researchers at EPFL have developed a hydrogel that offers unrivaled protection against transplanted cell rejection. The School's Technology Transfer Office has licensed the new product to Cell-Caps, a Geneva-based startup specialized in cell encapsulation for treating diabetes.

Transplanted tissue often comes under attack from the body's immune system and struggles to survive in the hostile host environment. This has resulted in a shortage of suitable transplants for patients with dysfunctional cells and organs, prompting researchers to devise alternative strategies. One idea that several teams have been working on in recent years is to coat cells from human donors – and even animals – with a semi-permeable gel that protects them from attack and means patients can receive the tissue without having to take immunosuppressive drugs. The technology, which has been studied extensively in pancreatic islet cell transplantation, appears to have promising applications for the treatment of type 1 diabetes. A gel developed by an EPFL team, led by Sandrine Gerber, has been exclusively licensed to Geneva-based startup Cell-Caps SA. The company, founded by researchers at Geneva University Hospitals (HUG) who specialize in pancreatic islet cell transplantation, works closely with InsuLéman, a diabetes research foundation. Thanks to an enable grant from EPFL's Technology Transfer Office (TTO), the researchers were able to license their technology exclusively to Cell-Caps.

Limiting the need for immunosuppressive therapy

The semi-permeable gel is made from sodium alginate, a gum extracted from the cell walls of brown algae, and water-soluble polymers. It acts as a selective filter, blocking immune-system cells and antibodies while allowing oxygen and other molecules to pass through, in both directions, so that the coated cells can metabolize – and, ultimately, survive. It also enables the cells to secrete metabolic byproducts such as insulin.

The gel forms a soft cocoon that mechanically protects the cells and limits inflammation in the host body – a process that causes scarring and adversely affects transplant function. Gerber's team, from EPFL's Group for Functionalized Biomaterials (GBF), added active ingredients to the gel, binding them to the gelatinous structure. One of the compounds they included was ketoprofen, a nonsteroidal anti-inflammatory that stops inflammation at its early stages. The researchers developed a special process that releases the drug steadily and in a targeted, controlled fashion, meaning they could add more of it to the gel. They published details of the process in the journal *Bioconjugate Chemistry*.

More recently, the EPFL team successfully tested new polymer formulas that alter the viscosity and other physical properties of the coating, meaning it can be used in different physiological environments. This latest research, published in *ACS Applied Polymer Materials*, paves the way for developing more mechanically robust coatings, or even memory gels that quickly regain their original shape. What makes the new formula so effective is that it can withstand the physical, mechanical and biological conditions that transplant coatings have to endure.

A one-step production process

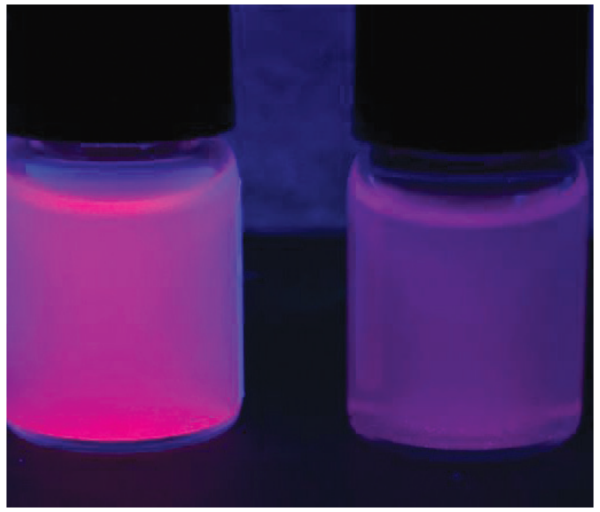
Part of the hydrogel's appeal to the private sector stems from the fact that it is relatively straightforward to make. Indeed, the production process is included in the licensing agreement. "We'll have to carry out further tests to measure the gel's long-term performance," says Gerber, who sits on Cell-Caps' board of directors. "We'll also need a more reliable source of transplantable cells that we can reproduce. It could be another five or even eight years before the gel is used in clinical settings." HUG, which also has several representatives on the firm's board, has one of only ten laboratories worldwide capable of transplanting animal cells in humans.

Other applications in the pipeline

Aside from pancreatic islet cell transplants, the technology has potential applications for other tissues and in other clinical fields, such as the treatment of acute liver failure. "We think this new gel holds real promise," says Natalia Giovannini, technology transfer manager at TTO. "We've had a lot of interest from elsewhere in the private sector, and we're currently holding talks about a new licensing agreement."

ISIC

New device simplifies measurement of fluoride contamination in water



A photograph of SION-105 suspended in solvents with (L) and without (R) fluoride ion contamination. © Mish Ebrahim

Seeking to address fluoride contamination in drinking water, chemical engineers at EPFL have developed a portable and user-friendly device that can measure fluoride concentration accurately and reliably.

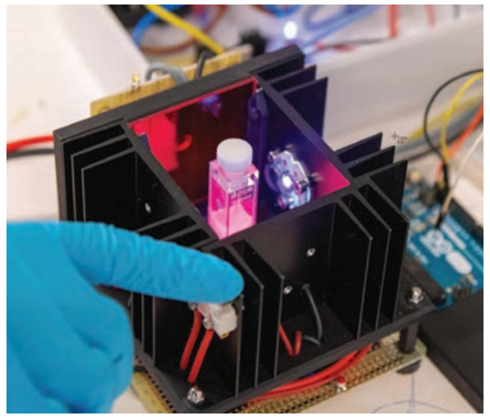
Adding fluoride to water has been common practice in a number of countries, including the US, Australia, Brazil, Malaysia, India and Vietnam. In low concentrations (below 1.5 mg/L) can help prevent tooth decay and even strengthen bones, but going above that can have the opposite effect, causing serious dental and bone disease, especially in children and developing fetuses.

To keep things in check, the WHO has set 1.5 mg/L as the maximum limit for fluoride in drinking water. "To determine whether drinking water is safe we need to detect fluoride in water at the level of parts-per-million (ppm)," says Kyriakos Stylianou at the Laboratory of Molecular Simulation at EPFL Valais Wallis. "Around 1-1.5 ppm is good for teeth, but in many countries the water sources have concentrations above 2 ppm can cause serious health issues."

But measuring fluoride at such low concentrations with sufficient accuracy is expensive and requires a well-equipped chemical lab. Because of this, fluoride contamination in water affects a number of developing countries today, and even parts of developed countries.

Led by Stylianou, a team of scientists have now built a device that can accurately measure fluoride concentrations using only a few drops of water – even with low-level contamination – resulting in a simple change in color brightness. Published in the *Journal of the American Chemical Society* (JACS), the device is named SION-105, is portable, considerably cheaper than current methods, and can be used on-site by virtually anyone.

The key to the device is the design of a novel material that the scientists synthesized (and after which the device is named). The material belongs to the family of "metal-organic frameworks" (MOFs), compounds made up of a metal ion (or a cluster of metal ions) connected to organic ligands, thus forming one-, two-, or three-dimensional structures. Because of their structural versatility, MOFs can be used in an ever-growing list of applications, e.g. separating petrochemicals, detoxing water, and getting hydrogen or even gold out of it.



The prototype device used with SION-105 to detect fluoride anions in drinking water. © Marie-Thé and Etienne Roux

SION-105 is luminescent by default, but darkens when it encounters fluoride ions. "Add a few droplets of water and by monitoring the color change of the MOF one can say whether it is safe to drink the water or not," explains Mish Ebrahim, the paper's first author. "This can now be done on-site, without any chemical expertise."

The researchers used the device to determine the fluoride content in different groundwater samples from Vietnam, the United Arab Emirates, and Saudi Arabia. The data corresponded very well when compared to measurements made using ion chromatography, a standard method for measuring fluoride concentration in water.

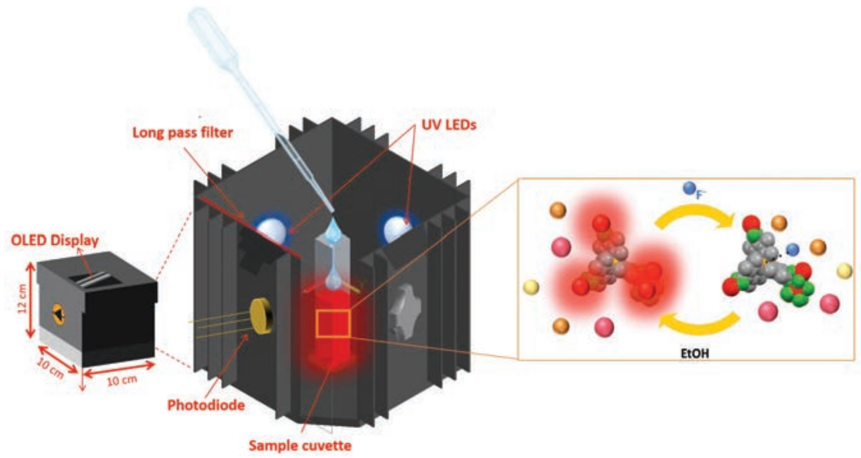
"This comparison showcases the performance and reliability of SION-105, which, coupled with the portability and ease-of-use of the device, make it a very user-friendly solution for water sampling in remote areas where frequent fluoride concentration monitoring is paramount," says Stylianou.

Having confirmed the successful function of SION-105 and the device, EPFL has now filed a patent application for it. The device was developed by scientist at the Laboratory of molecular simulation, the Laboratory of Organometallic and Medicinal Chemistry, and the Electronic Workshop at EPFL Valais Wallis.

OTHER CONTRIBUTORS
University of Cyprus

REFERENCES

Fatmah Mish Ebrahim, Tu N. Nguyen, Serhii Shyshkanov, Andrzej Gładysiak, Patrick Favre, Anna Zacharia, Grigorios Itskos, Paul J. Dyson, Kyriakos C. Stylianou. **a selective, fast-response and regenerable metal–organic frame-work for sampling excess fluoride levels in drinking water.** *Journal of the American Chemical Society* 11 February 2019. DOI: 10.1021/jacs.8b11907



A diagram of the SION-105 prototype device: A vial containing a red luminescent suspension of SION-105 crystals is placed inside the device. When two drops of water sample are added to the vial, resulting changes in the brightness of SION-105 are measured by the photodiode, and instantly converted into an accurate quantitative reading of the fluoride concentration in the sample. The inset is a schematic of how the luminescence is quenched at the molecular level. © Mish Ebrahim

IPHYS

A chip to measure vacuums

Ian Rousseau, CEO of Hexisense, brings to the market a gallium nitride-based chip that can measure vacuums

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Vacuums are a vital part of the processes – such as freeze-drying – used to make and preserve countless everyday items and must be measured with precision. An EPFL spin-off, Hexisense, is bringing to market a gallium nitride-based chip that can measure the quantity of certain gas molecules cheaply and with unrivalled precision.

What do a mirror, a cup of yogurt, an electric car battery and an LED lightbulb have in common? Their production processes all require a vacuum, i.e. an environment in which gas molecules are removed. Usually, when the last drop has been poured from a bottle, the bottle is considered empty. Physically, however, it remains full of gas. When a vacuum is required, suction pumps leave a varying amount of gas depending on the process used. A vacuum is therefore assessed on the basis of pressure exerted by the number of molecules that remain in the container. This measurement is crucial for manufacturers – and an EPFL spin-off is preparing to bring to market a small chip that could make their lives easier.

An ideal tool for freeze-drying

Let's take freeze-drying as an example. This is a technique for preserving food that maintains its color and texture and most of its nutritional qualities and flavor. It is often used when researching and producing food and medicines, and is very energy-intensive and time-consuming. Items are dried in a vacuum, and the main stumbling block is that there is no low-cost way of determining the exact moment at which the process can be stopped. This means that the machinery does more work than is necessary. The sensor developed by EPFL's Laboratory of Advanced Semiconductors for Photonics and Electronics could overcome this drawback by indicating the remaining amount of water vapor in real time.

Vacuum systems contain various residual gases: nitrogen, oxygen, argon, hydrogen, water vapor etc. To measure them, manufacturers currently have two options. The cheap one involves various methods to measure the total pressure of all those gases on the basis of parameters such as deformation, displacement and heat. The other, mass spectrometry, distinguishes between the gases, but cannot be used in all systems because the equipment is expensive. The small 0.4 cm^2 chip developed and soon to be marketed by the EPFL spin-off aims to offer an affordable way of measuring individual gases in all vacuum systems.

Using light to unstick gas molecules

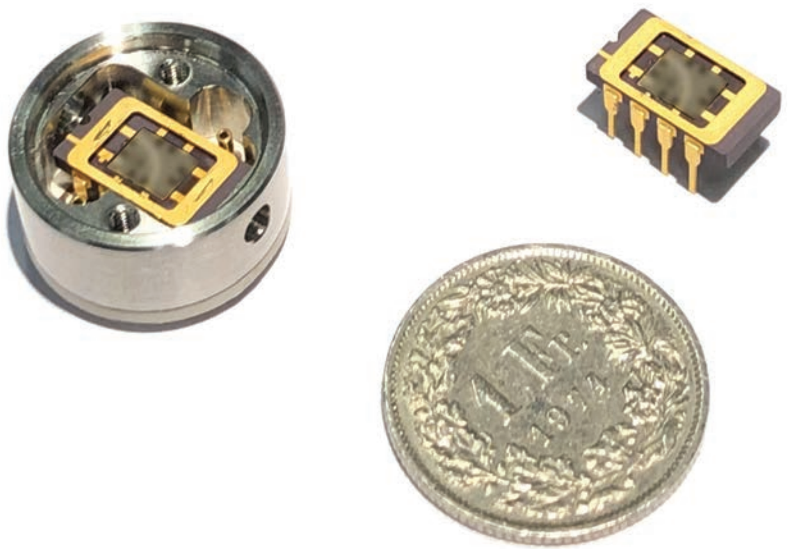
The mini-sensor harnesses two physical characteristics of its main component, gallium nitride: its reactivity to light and its status as a semiconductor. In a vacuum vessel, when gas molecules become less numerous, they move towards the walls and stick there. Gallium nitride, when exposed to a light source, repels certain gas molecules, like oxygen. So an LED is placed on the chip, which unsticks molecules from the walls. Once the light goes off, gallium nitride's semiconductor properties allow the chip to measure how quickly gas molecules return to the walls. Specific algorithms then analyze the number of molecules on the surface along with the partial pressure of each gas. These tiny chips boast excellent efficiency: for example, they can detect oxygen within nitrogen at a concentration of less than 0.5%.

An all-purpose chip that is heat- and shock-resistant

These all-purpose chips are heat-resistant up to 250°C and do not contain any microelectromechanical systems, which means they can withstand mechanical vibrations and shocks. In addition, unlike low-pressure ionization-based vacuum gauges, these sensors do not produce ionized particles or magnetic fields that could affect certain technical equipment. These advantages mean that the new-generation chips are highly versatile, making life easier for their users because all they need to do is place the chips within their pressure systems in order to get the data they need.

Production underway

The two inventors, Ian Rousseau and Pirouz Sohi, supported by various startup programs such as Bridge – the joint accelerator set up by the Swiss National Science Foundation and Innosuisse – EPFL Innogrant, Enable and Venture Kick, are now starting to produce these chips. Hexisense, the resultant spin-off company, aims to commercially develop and produce the sensors, from design to characterization, production, and packaging.



The chip is 0.4 cm^2

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EPFL

IPHYS

Spin-off SWISSto12 raises 18.1 million

Swissto12 antennas are used for satellite communication
© 2015 Alain Herzog

EPFL spin-off SWISSto12, which manufactures antennas for satellite communications, has raised CHF 18.1 million from investors. The firm will use the fresh injection of capital to ramp up marketing of its 3D-printed waveguides and expand its offices in the US and Israel.

SWISSto12, an EPFL spin-off that supplies telecommunications components to the satellite and aerospace industries, announced the completion of a CHF 18.1 million fundraising round. The company plans to use the money, secured from Swisscanto Invest, Swisscom Ventures and Constantia New Business (CNB), to scale up the production and marketing of its components, some of which went into orbit several months ago.

Metal-coated 3D-printed components

Data-transfer needs, driven by TVs, telephones, surveillance, GPS and the internet, are growing non-stop. This requires ever more satellite bandwidth, and thus increasingly high wave frequencies – the microwave threshold was crossed several years ago. Yet the higher the frequency, the more difficult it is to control, and this is where the quality and shape of antennas play a crucial role. SWISSto12 uses a patented process to manufacture metal-plated 3D-printed components. Behind their brightly colored veneer lies a complex maze of tiny conduits, each custom-built for a specific application. The firm's antennas are ten times lighter than their all-metal equivalents – a significant difference in an industry where every gram saved translates into lower cost.

"We may be a new player on the scene, but we've already attracted the attention of major names in the satellite and aerospace industries," says CEO Emile de Rijk, whose PhD thesis led to the spin-off. "Our partners include Airbus Defense and Space, Thales Alenia Space, Cobham Advanced Electronic Solutions, and the European Space Agency." SWISSto12's technology could also change the way miniature satellites and constellations, two fast-growing market segments, and the antennas fitted to airplane fuselages are designed and manufactured.

Expanding operations in the US and Israel

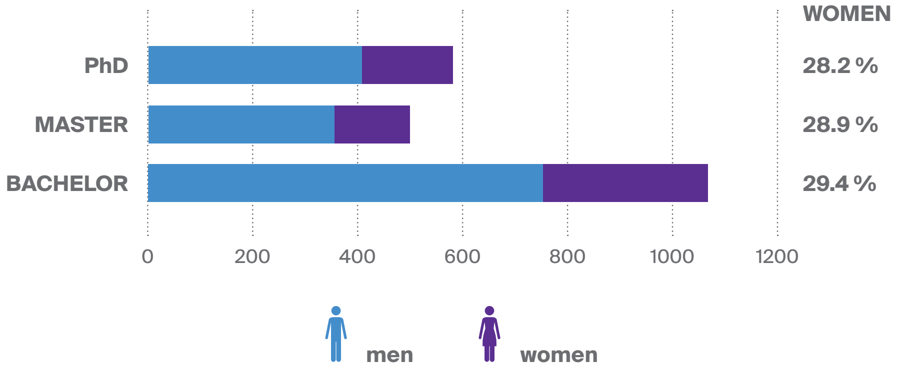
"This investment will allow us to take our business to the next level," adds de Rijk. As SWISSto12 expands its new premises in the US and Israel, it intends to begin production of complete antennas – waveguide and transmitter combined. It is also exploring some initial opportunities in terrestrial communication systems such as 5G. The firm presented its work at the World Satellite Business Week conference in Paris from 9 to 13 September 2019.

2019 IN FIGURES

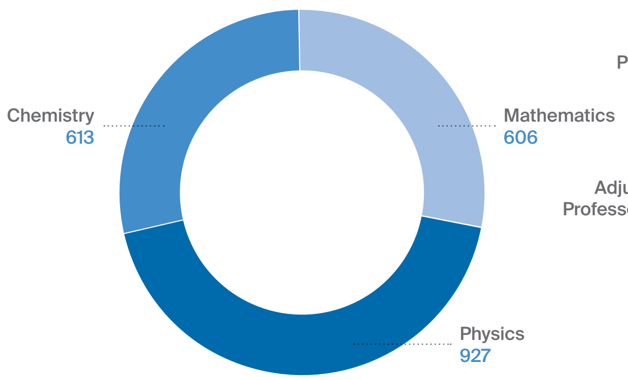
IPHYS ISIC MATH

PEOPLE

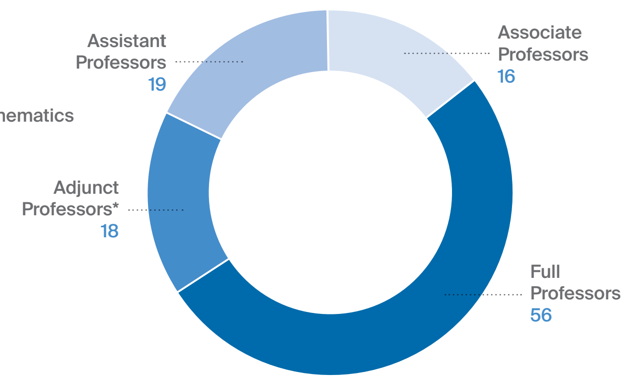
FSB Students



FSB Students (incl. PhD)

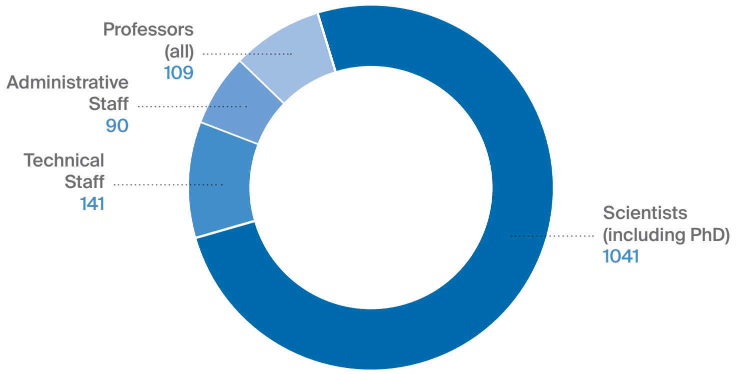


FSB Professors



* Including 2 SNSF-funded Professors

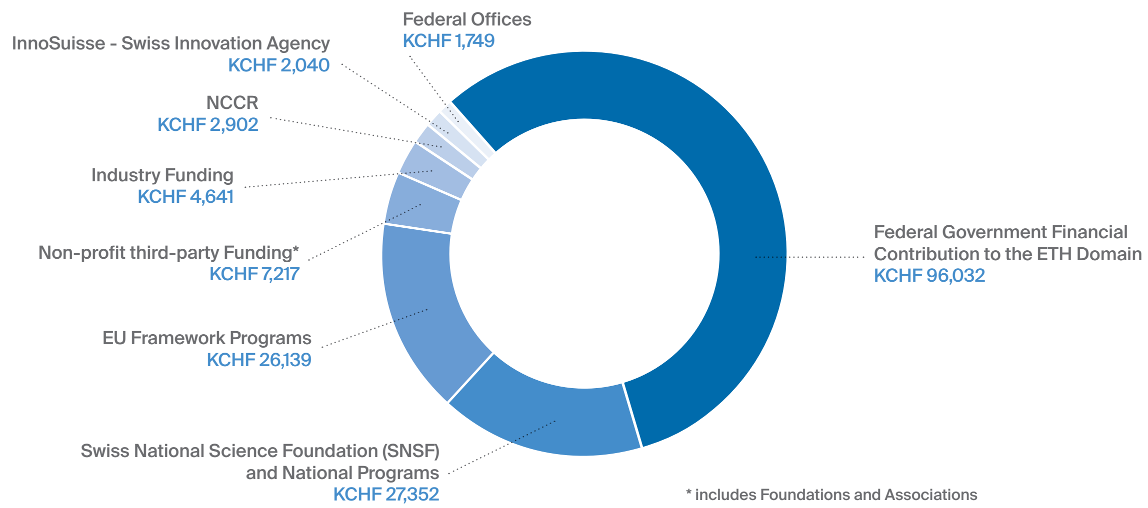
FSB Staff



FSB Staff

STAFF	TOTAL	WOMEN %
PhD students	580	30.0
Scientific staff / postdocs	431	22.7
Technical /IT staff	141	8.5
Administrative staff	90	96.7
Emeriti Professors	67	4.5
Full professors	56	9.1
Apprentices	37	29.7
Senior Scientists / MER	30	6.7
Tenure-Track Assistant Professors	19	31.6
Associate Professors	16	18.8
Adjunct Professors / Titulaires	16	25.0
SNSF-Funded Professors	2	0

FUNDING



* includes Foundations and Associations

KEY FIGURES

120	Research Groups
3	Research Institutes
1	Research Center
2	Campuses
3	Doctoral Programs
2146	Students
109	Professors
692	Staff

RESEARCH

1001	Journal articles
68	Conferences papers
45	Reviews
4	Book Chapters
99	Thesis
17	Patents

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