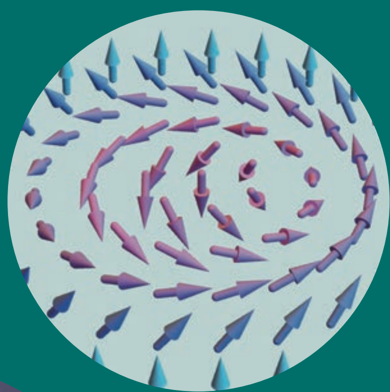
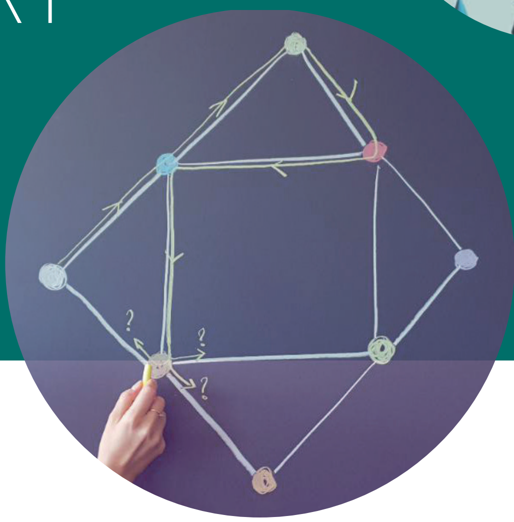
School of Basic Sciences FSB

ANNUAL REPORT 2020





IPHYS ISIC MATH

School of Basic Sciences FSB

EPFL

DEAN'S FOREWORD

Looking back at 2020 leaves me with mixed feelings. On one hand, we have all been impacted by a global pandemic which has turned our lives upside down and made the daily life difficult for many of our colleagues. Dealing with this situation has required all of us to make sacrifices in our lives, be it professionally or personally. Many of our colleagues in the School of Basic Sciences, be it students, staff or faculty, have found themselves required to very significantly adjust how they work, where they work, and how this impact their work-life balance. The situation has been difficult for many, most severely those of our colleagues who have lost loved ones to the disease.

On the other hand, this terrible situation has also shown me just how unique a community the School of Basic Sciences is – one where people care about each other, where staff and faculty went well beyond their call of duty to adapt to a new and fully online mode of teaching overnight, one where group leaders worked hard to develop online communities to maintain a healthy group dynamics, and one where the strong ones reached out and offered to help those struggling in their private or professional life. During the last year I have been told numerous stories, reflecting care, concern, and empathy for your colleagues and students, and I want to thank you for this. Without this, we would have been in a very different place.

Despite these unusual circumstances, the School of Basic Sciences continues to thrive. Looking through the annual report, the quality and quantity of research and education across the School is simply striking, even more so when remembering that we have been working virtually and with limited access to laboratories for substantial parts of 2020. Our faculty members continue to receive numerous national and international honors and awards, the size of the incoming classes is increasing every year, and we maintain an excellent success rate for highly competitive grants. Furthermore, during 2020 we have added seven new professors to the School, who will further strengthen the impact and quality of the School.

This special year of 2020 also marks the end of my tenure as Dean of the School of Basic Sciences. Let me therefore conclude by expressing my most sincere gratitude for having been granted the privilege of serving as Dean – not the privilege offered by the EPFL President, but the privilege afforded by you by allowing me get to know you and experience your passion for the success of EPFL. It has truly been an honor and privilege.

With the best wishes for a successful and rewarding 2021,

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

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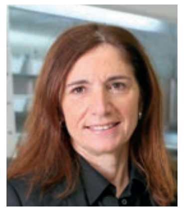
PRIZES AND AWARDS

IPHYS ISIC MATH

ACS awards and honors for EPFL scientists





Five scientists from EPFL's Institute of Chemical Sciences and Engineering won awards and honors from the American Chemical Society.

The American Chemical Society (ACS) is one of the largest scientific societies in the world, numbering nearly 157,000 members. Each year, the ACS gives various awards and honors to researchers to recognize their contributions across various fields of chemistry. The ACS has now announced the 2021 winners of 60 different awards. Among them are five scientists working with EPFL's Institute of Chemical Sciences and Engineering (ISIC):

Professor **Marinella Mazzanti** receives the F. Albert Cotton Award in Synthetic Inorganic Chemistry, which recognizes "distinguished work in synthetic inorganic chemistry". Professor Mazzanti is also the first recipient of the award working outside the USA.

Professor **Majed Chergui** receives the Ahmed Zewail Award in Ultrafast Science & Technology, which recognizes "outstanding and creative contributions to fundamental discoveries in ultrafast science & technology".

Professor **Yimon Aye** receives an Arthur C. Cope Scholars Award, which recognizes and encourages "excellence in organic chemistry".

Professor **Wendy Queen** has been included among the 2020 Talented 12 of the ACS magazine "Chemical & Engineering News", which every year highlights "a dozen young rising stars who are using chemical know-how to change the world".

Professor **Jeremy Luterbacher** has been awarded one of the 2021 Sustainable Chemistry & Engineering Lectureship Awards, which "recognize the research contributions of scientists working in green chemistry, green engineering, and sustainability in the chemical enterprise".

Michael Grätzel wins two prestigious Awards

Professor Michael Grätzel from the Ecole Polytechnique Fédérale de Lausanne (EPFL), Switzerland, receives this year's Diels Planck Lecture Award of KiNSIS (Kiel Nano, Surface and Interface Science), a priority research area of Kiel University. The interdisciplinary research association thus honors his outstanding research in the field of photochemistry.

Michael Grätzel was also the winner of the **2020 Materials Today Innovation Award** "for his ground-breaking work on solar energy conversion". The Materials Today Innovation Award recognizes "monumental" work, which has opened a new, significant field of research and resulted in impactful, practical applications. Previous winners include Nobel Laureate Prof. M. Stanley Whittingham (Binghamton University) and Prof. Russell Dupuis (Georgia Tech) for their work on Li-ion batteries and MO-CVD, respectively.

Prof. Grätzel is regarded as the inventor of a new type of efficient solar cell that can be manufactured particularly cost-effectively. "Grätzel's solar cell represents one of the most promising approaches to the use of solar energy – it is not without reason that he has long been considered a candidate for a Nobel Prize in Chemistry. With over 1,600 scientific papers, which have been cited over 313,000 times to date, and a h-index of 250 he is one of the most influential chemists in the world," emphasized Rainer Herges, Professor of Organic Chemistry at Kiel University, and organizer of the conference, in his laudation.

Both awards ceremonies and plenary lectures took place virtually online due to the pandemic.

Paul Dyson receives two important recognitions

Professor Paul Dyson at EPFL's School of Basic Sciences received the 2020 Green Chemistry Award "for major advances in the catalytic transformations of renewable substrates leading to industrial processes and products".

The goal of Professor Dyson's team is to replace chemicals derived from fossil resources with chemicals derived from renewable materials and other waste streams to facilitate the transition towards a sustainable circular economy. To achieve this goal they need to understand how these renewable materials are transformed at a molecular level, and armed with this knowledge, they are able identify bottlenecks and then design new catalysts that overcome these bottlenecks. In his own words, "Basically, we have a lot of fun, learn a lot, create new knowledge and occasionally discover something useful".

Later in 2020, Professor Dyson has been elected Fellow of the American Association for the Advancement of Science, "the world's largest multidisciplinary scientific society".

This year, the AAAS has honoured some of its members with the lifetime title of elected Fellow to recognize their "important contributions to STEM disciplines, including pioneering research, leadership within a given field, teaching and mentoring, fostering collaborations, and advancing public understanding of science".

The newly elected AAAS Fellows were honoured at a virtual induction ceremony on February 13th, 2021, just after the AAAS Annual Meeting.

Maryna Viazovska wins the European Mathematical Society Prize and the National Latsis Prize

EPFL Professor Maryna Viazovska, head of the Chair of Number Theory at EPFL, has been awarded one of the 10 European Mathematical Society (EMS) Prizes for 2020 in recognition of her contributions to number theory and optimal configuration on manifolds. She is also the recipient of the 2020 National Latsis Prize, awarded to young researchers under the age of 40 by the Latsis Foundation in collaboration with the Swiss National Science Foundation.

Every four years, the EMS awards ten EMS Prizes during the European Congress of Mathematics to young researchers up to 35 years and who work in Europe or are of European nationality. The prizes are awarded to researchers for their excellent contributions in mathematics. They are selected by a committee of members appointed by the EMS and presided over by Professor Martin Bridson.

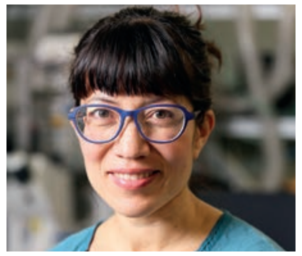
The Swiss science prizes, Marcel Benoist Prize and Latsis Prize, were presented by Federal Councillor Guy Parmelin at an award ceremony in Bern on 4 November. The scientific selection process was conducted by the Swiss National Science Foundation on behalf of both foundations. The president of the Marcel Benoist Foundation, Federal Councillor Guy Parmelin, said: "We are delighted by the cooperation with the Fondation Latsis and the first joint awarding of the two prizes. In doing so, we are enhancing Switzerland's standing as a location for scientific research".

Viazovska came to international fame when, in 2016, she achieved a scientific breakthrough in solving the sphere-packing problem in the 8th dimension. Later, in collaboration with other mathematicians, she also solved it in dimension 24. She is also known for her work on spherical designs, which is part of combinatory design theory.

Viazovska has received multiple awards, including the Salem Prize (2016), the Clay Research Award, and the Ramanujan SASTRA Prize (2017). She also won a 2018 New Horizons Prize in Mathematics, and in 2019, the Ruth-Lyttle-Satter and Fermat Prizes.

"I am delighted that the Latsis Prize will boost the outstanding reputation of my Institute and all its staff. Naturally, I also hope that the prize will help to inspire young girls to go into mathematics", said Viazovska.

Suliana Manley elected APS Fellow



EPFL Professors Suliana Manley (School of Basic Sciences) and Sylvie Roke (School of Engineering) have been elected Fellows of the American Physical Society.

The American Physical Society (APS) is the world's largest organization of physicists. It was founded in 1899 with the aim to "to advance and diffuse the knowledge of physics". Today, the APS numbers some 50,000 members worldwide, and publishes over a dozen scientific journals, including the prestigious *Physical Review* and *Physical Review Letters*. It also runs more than twenty science conferences each year, and is a member society of the American Institute of Physics. APS Fellows make up a mere 0.5% of the Society's membership, making the Fellowship a distinct honor.

Professor Manley's research focuses on the dynamic assembly of proteins and developing a physical paradigm for how proteins form mesoscale assemblies. Her lab develops and uses automated super-resolution fluorescence imaging techniques combined with live cell imaging and single molecule tracking to determine how the dynamics of protein assembly are coordinated.

Professor Roke's research focuses on understanding the molecular-level details of water-related biological processes. Her lab investigates such processes on various length scales and with varying degrees of complexity using a number of cutting-edge techniques including second harmonic scattering, sum frequency scattering, wide-field multiphoton microscopy, and modeling.

Teaching Awards

BEST TEACHER AWARD OF THE SCHOOL OF ENGINEERING

Anna Fontcuberta i Morral (IPHYS-IMX)

BEST TEACHER AWARD OF THE SCHOOL OF BASIC SCIENCES (POLYSPHÈRE D'OR)

David Strütt (MATH)

BEST TEACHER AWARD OF THE MATHEMATICS SECTION

Donna Testerman
Juhan Aru

BEST TEACHER AWARD OF THE PHYSICS SECTION

Frédéric Blanc

BEST TEACHER AWARD "CRAIE D'OR" BY THE PHYSICS BACHELOR STUDENTS

Paolo De Los Rios

EXCELLENCE IN TEACHING AWARD OF THE CHEMISTRY AND CHEMICAL ENGINEERING SECTION

Anne-Sophie Chauvin
Christophe Roussel
Samuel Terrettaz

Doctoral Schools Thesis Awards

MATHEMATICS DOCTORAL THESIS AWARD

Fabian Mönkeberg
"High-order essentially nonoscillatory methods based on radial basis functions"
THESIS DIRECTOR
Prof. Jan S. Hesthaven

PHYSICS DOCTORAL THESIS AWARD

Edoardo Martino
"Electrons Leave the Flatland: Out-of-Plane Charge Dynamics in Layered Materials"
THESIS DIRECTOR
Prof. László Forró et Prof. Ana Akrap

CHEMISTRY AND CHEMICAL ENGINEERING DOCTORAL THESIS AWARD

Seyedmohamad Moosavi
"Advancing computational and data-driven methods for the design and discovery of nanoporous materials"
THESIS DIRECTOR
Prof. Berend Smit

EPFL Thesis Awards

EPFL DOCTORATE AWARD 2020

Marta Falcone (EDCH)
"Small Molecule Activation by Multimetallic Uranium Complexes (Thesis year: 2019)"
THESIS DIRECTOR
Prof. M. Mazzanti

PROFESSOR RENÉ WASSERMAN AWARD 2020

Filip Podjaski (EDPY)
"Investigations into Nanostructured Materials for Water Splitting and Direct Solar Energy Harvesting"
THESIS DIRECTORS
Prof. B. V. Lotsch and
Prof. A. Fontcuberta i Morral

HANS EGGENBERGER PRIZE 2020

Maxim Karpov (EDPY)
"Dynamics and Applications of Dissipative Kerr Solitons"
THESIS DIRECTOR
Prof. T. Kippenberg

Bachelor and Master Students Prizes and Awards

MATHEMATICS

Sofia Giampietro (Master)
EPFL Prize for the second best average in an EPFL Master cursus (ex aequo, 5.90/6) and Prix Douchet for the best grade average in a Mathematics Master cursus

Arnaud Pannatier (Master in Computational Science and Engineering)
Kudelski Prize for the best Master Project in the field of cryptography and security of information systems

PHYSICS

Kelian Häring
EPFL Prize for the best average in an EPFL Master cursus (5.91/6)

Margot Coste-Sarguet
Youth Prize (youngest Master graduate at EPFL at 21.5 years)

Virginie Solans
Prix Gilbert Hausmann

CHEMISTRY AND CHEMICAL ENGINEERING

Ane Laura Fineid Pedersen
Prix Pelet Prize for the best average in an EPFL Bachelor cursus

Constantin Krüger and Claire Bourmaud
shared the Prix Syngenta Monthey for the best average in Chemistry and Chemical Engineering Master cursus

Constantin Krüger et Diane Bernard-Bruls
shared the Prix BASF Monthey (best Master Project in Chemistry and Chemical Engineering)

Samuel Van Gele
Prix de la Commune de Chavannes-près-Renens

EPFL

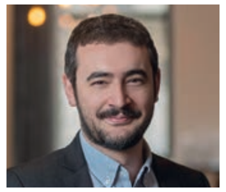
FACULTY NEWS

IPHYS ISIC MATH

Nominations and Promotions 2020

Christian Rüegg was named as Full Professor of Physics from April 2020.

Christian Rüegg is Adjunct Professor at the University of Geneva and Member of the Board of Directors of the Paul Scherrer Institute (PSI), Villigen. Rüegg is an internationally acclaimed solid-state physicist. In 2019, the Federal Council appointed him as the new director of the PSI. The two Federal Institutes of Technology have each appointed him to a full professorship in recognition of his scientific achievements. Christian Rüegg's work has a particular focus on strongly correlated quantum phenomena in low-dimensional magnetic materials. He has been awarded prestigious prizes including the Lewy-Bertaut Prize and the Nicolas Kurze European Science Prize, as well as an ERC Grant.



Giuseppe Carleo was named as Tenure-Track Assistant Professors of Physics from September 2020.

Giuseppe Carleo is a young researcher who has already gained international recognition in the field of many-body quantum systems. Among other achievements, he has developed a machine learning software programme which not only helps computers "learn" the quantum state of a complex physical system based on experimental observations but also enables them to predict the results of hypothetical measurements. His pioneering achievements in this promising field have already had a significant scientific impact.

Marius Lemm was named as Tenure-Track Assistant Professors of Mathematics from September 2020.

Marius Lemm's work focuses on problems of mathematical physics originating in quantum physics and quantum information. At just 31 years of age, Marius Lemm has already proved himself to be an outstanding mathematician whose work to date combines several mathematical areas, including operator theory, random matrices and partial differential equations. At EPFL he will set up a research group in the area of mathematical analysis and mathematical physics, further strengthening the links between mathematics and physics.

Mats Stensrud was named as Tenure-Track Assistant Professors of Mathematics from September 2020.

Mats Stensrud's unusual career path (Master in applied statistics, Doctorate in Neuroscience, Doctor of Medicine and post-doctorate in Biostatistics) enables him to combine all these fields very creatively. He is currently conducting research in the area of biostatistics and causal inference with the aim of discovering whether a specific treatment can have a causal effect on the risk of a disease in the presence of competing risks. Mats Stensrud will further strengthen statistics at EPFL while building links with the School of Life Sciences and with Biomedical establishments in the greater area.

Oleg Yazyev was named as Associate Professor of Theoretical Physics from October 2020.

Oleg Yazyev is one of the world's leading researchers in condensed matter physics. He is particularly recognized for his studies on defects in graphene, as well as for computational discovery of novel materials. His numerous articles in well-regarded publications have become standard works of references and his research has been awarded an ERC Starting Grant and the EPFL's Latsis Prize. Oleg Yazyev is a highly creative researcher and a dedicated teacher and mentor.

Florent Krzakala was named as Full Professor of Physics and Electrical Engineering/Electronics in the School of Basic Sciences (SB) and Engineering (STI) from September 2020.

Professor Florent Krzakala, Professor at Sorbonne University and Researcher at the Ecole normale supérieure, Paris, France, was named Full Professor of Electrical Engineering/Electronics and of Physics at EPFL, in the School of Basic Sciences (SB) and Engineering (STI) from September 2020.

Florent Krzakala has employed his interdisciplinary approach to establish new areas of research at the intersection of mathematics, physics and computer science. He is a pioneer in the field of statistical physics applied to machine learning and to signal processing. In addition to establishing a research programme in these areas, this internationally acclaimed researcher brings an extensive network of contacts that will benefit EPFL.

Pasquale Scarlino was named as Tenure Track Assistant Professor of Physics from October 2020.

Pasquale Scarlino is a talented young experimental physicist with great potential. His main focus is on quantum dots for spin qubits, a promising technology for quantum computers. The results he has already achieved have provided a real stimulus in the area of circuit quantum electrodynamics based on semiconductor quantum dots, and have attracted international attention. At EPFL, Pasquale Scarlino will build on this foundation and press ahead in the field of hybrid quantum circuits.

Lenka Zdeborová was named as Associate Professor of Physics and of Computer Science and Communication Systems in the Schools of Basic Sciences (SB) and Computer and Communications Sciences (IC) from September 2020.

Lenka Zdeborová is an internationally renowned researcher in the field of statistical physics who has won multiple awards, including an ERC Starting Grant in 2016. Her unparalleled expertise will make a significant contribution to the creation of new synergies with other research areas at EPFL, such as mathematics, materials science and information science, as well as with industry – and notably among leading IT companies.

Five Professors named Emeritus in 2020

- Professor **Tatsuya Nakada**, who directed the High Energy Physics Laboratory 3 at the Institute of Physics from 2003 to 2020.
- Professor **Aurelio Bay**, who directed the High Energy Physics Laboratory 1 at the Institute of Physics from 2003 to 2020.
- Professor **Giovanni Dietler**, who directed the Laboratory of the Physics of Living Matter at the Institute of Physics from 2003 to 2020.
- Professor **Stephan Morgenthaler**, who directed the Chair of Applied Statistics at the Institute of Mathematics from 1988 to 2020.
- Professor **Lazlo Forro**, who directed the Laboratory of Nanostructures and Novel Electronic Materials at the Institute of Physics from 2002 to 2020.

Three Professors left the School of Basic Sciences in 2020

- Professor **Elena Goun**, who directed the Laboratory of Bioorganic Chemistry and Molecular Imaging from 2011 to 2020.
- Professor **Amin Shokrollahi**, who directed the Laboratory of Algorithmic Mathematics from 2003 to 2020.
- Professor **Anders Hagfeldt**, who directed the Laboratory of Photomolecular Science from 2013 to 2020.

RESEARCH GRANTS

IPHYS ISIC MATH

IPHYS

SNSF Eccellenza Grants and Professorial Fellowships 2020

The Swiss National Foundation's Eccellenza Grants aim at "researchers in all disciplines who have recently been appointed as tenure-track assistant professors at a Swiss higher education institution". The Grants offer project funds up to 1,500,000 Swiss francs over five years.

In 2020, 244 researchers applied to the Eccellenza scheme. Following a two-stage evaluation process, the SNSF selected 45 projects. Two FSB professors have been awarded Eccellenza Grants, while another has received a Professorial Fellowship.

Prof. Juhan Aru, who holds the Chair of Random Geometry in MATH has received an Eccellenza Grant. His research lies mainly in probability theory, in the domain of random planar geometry. His group studies random curves, surfaces, and other random geometric structures that help to geometrically encode and describe the large-scale behaviour of complex systems like 2D statistical physics models
Title of awarded project: ***"The geometry of the Gaussian free field and applications".***

Prof. Mitali Banerjee, who leads the Laboratory of Quantum Physics, Topology, and Correlations in IPHYS has received an Eccellenza Grant. Her research focuses on the understanding of fundamentals of emergent quantum many-body physics. Strong correlations in solid-state systems often make the regular electrons behave differently, and sometimes the resultant quantum states host quasi-particles that are rather immune to local environmental disturbance. These quasi-particles are fundamentally different from electrons or any other fundamental particles. Being fragile, they are elusive and experiments to detect them are much more challenging; yet their understanding may change the way we presently look at advanced technology.
Title of awarded project: ***"Unambiguous identification of the topological order of the quantum Hall states".***

Dr. Richard I. Anderson, who will join IPHYS in February 2021, has received an Eccellenza Professorial Fellowship as well as an ERC Starting Grant. His research lies at the interface between stellar astrophysics and observational cosmology and seeks to measure the local expansion rate of the Universe, Hubble's constant, to within 1%. Specifically, Anderson and his team will focus on the ability of pulsating stars, such as Cepheids, to accurately trace cosmic distances while simultaneously pursuing a better astrophysical understanding of so-called "standard candles". Thus, the team will probe the origins and implications of the looming cosmological crisis suggested by the current discord among observed and predicted values of Hubble's constant.
Title of awarded project: "***Measuring Hubble's constant to 1% with pulsating stars".***

ISIC

Sandrine Gerber awarded a SNSF Grant for COVID-related research

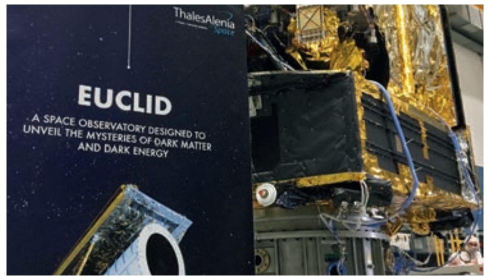
Professors Sebastian Maerkl, from the School of Engineering, and Sandrine Gerber, from the School of Basic Sciences, each received a grant for their coronavirus-related research projects.

Two EPFL projects received grants from the Swiss National Science Foundation, which has made CHF 28.6 million available to support 28 studies on the coronavirus.

The project led by Professor Sandrine Gerber is interdisciplinary. Its aim is to develop a small portable device to identify coronavirus in airports, railway stations and other places where rapid screening can help detect the disease at an early stage. "There is an urgent need for a set of measures to control the spread of the virus, reduce the severity of the disease in infected patients and ultimately prevent infection with effective vaccines. With a low-cost and highly sensitive biosensor, we are proposing an approach to overcome the limitations of current testing procedures, which should eliminate the need for biomedical staff and specialized laboratory infrastructure", explains the scientist.

IPHYS

Euclid space cosmology mission receives a 3rd SNSF Sinergia grant



Prof. Frédéric Courbin (LASTRO) associated with CIS was allocated, for the 3rd time in a row, a SNSF sinergia grant related to the ESA-NASA Euclid space mission. The grant, to be shared between EPFL (PI), UniGE, UniZH and FHNW will allow to finalize the preparation of the satellite, to be launched by the end of 2022, and will enable the exploitation of the very first data to come.

Euclid will image with unprecedented quality the whole extragalactic sky in the optical and near-IR domain and mesure the small apparent distortions of 2.5 billion galaxies due to gravitational lensing by large-scale structures. This statistical measurement of so-called weak gravitational lensing, will allow cosmologists to study the nature of dark matter and dark energy. The latter, so far completely unknown in its nature and distribution, is thought to be responsible for the observed accelerated expansion of the Universe, a discovery that lead to the 2011 Nobel Prize in Physics.

MATH

Emmanuel Abbé part of team that wins deep-learning research award

Two international teams of scientists have been awarded a total of $10 million grant from the US National Science Foundation and the Simons Foundation to research the mathematics of deep learning. Among them is Professor Emmanuel Abbé of the School of Basic Sciences' MATH Institute.

The grant is one of two research awards sponsored by the National Science Foundation (NSF) Directorates for Mathematical and Physical Sciences, Computer and Information Science and Engineering, and Engineering, and the Simons Foundation Division of Mathematics and Physical Sciences.

The aim of the grants was to establish two new research collaborations between mathematicians, statisticians, electrical engineers, and theoretical computer scientists who will work on some of the most challenging questions in the general area of Mathematical and Scientific Foundations of Deep Learning (MoDL).

The NSF-Simons grant, a total of 10 million USD, has now been awarded to two large international teams of scientists who will be splitting the amount. One of the teams includes Professor Emmanuel Abbé at EPFL's School of Basic Sciences. Professor Abbé holds EPFL's Chair of Mathematical Data Science and his research focuses on fundamental questions in machine learning and information theory.

The team that includes Abbé also includes scientists from UC Berkeley (P. Bartlett, B. Yu), Stanford (A. Montanari), MIT (E. Mossel, S. Rakhlin, N. Sun), UCSD (M. Belkin), TTIC (N. Srebro), UCI (R. Vershynin), and the Hebrew University of Jerusalem (A. Daniely).

At EPFL, the collaboration will also run a "training center" that will run various activities for visitors, talks, workshops, summer schools, postdoc programs.

"It's a great honor to get the award and an exciting time to start such a collaboration", says Emmanuel Abbé. "The team has a unique synergy and I'm very glad to be part of it. We are all eager to now dive into the research program and to get the activities started across the schools".

IPHYS

Akselos and EPFL awarded major innovation grant by Swiss government

Deep Tech engineering firm Akselos and École Polytechnique Fédérale de Lausanne (EPFL) have won a major grant from the Swiss Innovation Agency (Innosuisse), worth 1.2 million Swiss francs to deliver a next-generation structural design and assessment tool for wind turbines.

Switzerland has been ranked most innovative country in the world for ten straight years, and the grant from Innosuisse (the Swiss Government Agency responsible for promoting the highest standards in science-based innovation) was awarded as part of the Europe-wide drive to create a carbon neutral and sustainable economy by 2050. The project aims to increase the computational capabilities of wind turbine applications, lowering the Levelised Cost of Electricity (LCOE) of wind power overall, making it more competitive with coal and other fossil fuels.

"Globally, there is an urgent need for higher power renewable production capacities and improved efficiency", said Prof. Jan Hesthaven from EPFL. "Yet the ever-growing size of turbines has left manufacturers and operators with increasingly higher design and operational challenges. We need newer, better technologies to mitigate the associated risks and thus reduce cost".

Currently the high computational demands of simulating large assets – such as wind turbines operating in harsh conditions – limits the number of designs that realistically can be explored, leading to non-optimal designs and thus higher energy cost. The research carried out by Prof. Jan Hesthaven and Prof. Annalisa Buffa, alongside engineers from Akselos, will expand the engineering limits of new turbine designs.

"This grant allows us to keep working at the cutting edge of computational design and engineering", said Prof. Buffa, who is also a member of the Presiding Board of the National Research Council for the Swiss National Science Foundation. "It's hugely exciting to be able to work on problems of such economic and societal importance as managing the energy transition. By developing superior designs we can help governments and operators generate clean, sustainable power for future generations".

"Being headquartered at EPFL's Innovation Park, one of the most effective innovation hubs in the world, allows us to have constant contact with the latest developments in the scientific community", commented Akselos' CEO Thomas Leurent. "By staying connected to internationally renowned research teams we've been able to continually improve our digital twin technology and stay 10 years ahead of the competition. This grant is recognition of the value of that relationship".

Through its patented component-based reduced basis finite element analysis (RB-FEA) technology Akselos already provides the most advanced structural Digital Twins in many industry sectors. In collaboration with EPFL Akselos will implement key features into their Akselos Wind product and provide a complete solution for the offshore wind industry.

IPHYS

Two IPHYS Scientists win Quantum-Research Grants

EPFL Professors Nicolas Grandjean and Tobias J. Kippenberg are among eighteen international research teams sharing a grant for quantum research and innovation, awarded by the US Air Force Office of Scientific Research.

This year, the US Air Force Research Laboratory Information Directorate, the Griffiss Institute, Oneida County, and State University of New York formed a partnership with the purpose of being "a global catalyst to converge world-class talent with cutting-edge facilities and focused technology challenges to accelerate the development of game-changing capabilities". The partnership was named Innovare Advancement Center.

As part of its launch, Innovare hosted a global quantum-focused pitch competition under the title "$1,000,000 International Quantum U Tech Accelerator" between 1-2 September 2020. The competition was supported by the US Air Force Office of Scientific Research (AFOSR), the US Office of Naval Research, and the Air Force Research Laboratory Information Directorate.

Nearly 250 research teams from 22 countries submitted proposals for the competition, and 36 of these were finally selected to pitch their "potentially game-changing concepts related to quantum timing, sensing, information processing/computing, and communications/networking".

Eighteen teams have now qualified for a part of basic research funding, which totals to more than $1 million. Among the 18 winning teams are the groups of Professors Nicolas Grandjean and Tobias J. Kippenberg at EPFL.

Professor Grandjean directs the Laboratory of Advanced Semiconductors for Photonics and Electronics within EPFL's School of Basic Sciences. His research explores quantized structures based on emerging semiconductors in both photonics and electronics, from fundamental studies around light-matter interaction in microcavities and nanostructures, to photonic devices such as blue lasers and light-emitting diodes (LEDs). He also studies III-V nitride semiconductors, which are promising materials for novel electronic and optoelectronic technologies, e.g. quantum microcavities, quantum dots and nanostructures, photonic crystals, and short-wavelength optoelectronics.

Professor Kippenberg directs the Laboratory of Photonics and Quantum Measurements, affiliated with EPFL's School of Basic Sciences and School of Engineering. His research interest lies in experimental and theoretical research in photonics, notably high quality factor (Q) optical microcavities and their use in cavity quantum optomechanics and frequency metrology. His group famously discovered chip-scale Kerr frequency comb generation and observed radiation pressure backaction effects in microresonators that have now developed into the field of cavity optomechanics.

IPHYS

EPFL joins the giant radio telescope SKA for the Swiss community

The Square Kilometre Array, or SKA, will be the biggest radio telescope ever built. EPFL became a member of the SKA Organisation (SKAO) beginning of April 2020 and will co-ordinate the contributions to this project on behalf of the Swiss academic community.

This is one of the biggest and most ambitious scientific tools of the XXI century. The Square Kilometre Array, or SKA, is an impressive radio telescope project, which will build an array of 130 15m-diameter dish antennas in South Africa and an array of 130'000 TV-like antennas in Western Australia in the coming years. Thanks to it, some of the Universe's greatest mysteries will be studied with a whole new level of precision. Along with thirteen countries officially involved, Switzerland is considering participating in this huge adventure. As an initial step, EPFL was just granted special member status of the SKA Organisation (SKAO) and will be the lead institution coordinating the contributions to the SKA on behalf of the Swiss academic community*.

EPFL joins the giant radio telescope SKA for the Swiss community ©Joseph Diamond (SKA)

Most telescopes we readily think of use optical light similar to what we see with our eyes. The SKA will capture light of celestial objects at radio waves, similar to the light used by our smartphones to communicate together. At radio waves, the sky is much different than the one we see in optical light.

"This new high-performance radio telescope will open a new view of the whole Universe", commented Prof. Jean-Paul Kneib of EPFL leading the consortium of Swiss Scientists interested in the SKA project, "SKA will detect the formation of planetary system around distant stars, the cold Hydrogen gas around galaxies, the nuclei of distant galaxies harbouring an active super-massive black holes"

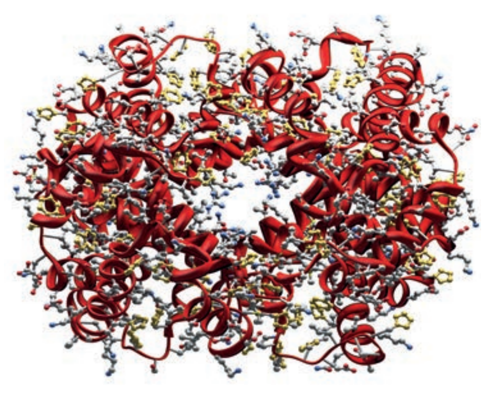
"SKA will also measure the magnetic field in galaxies and at larger scales and map the fluctuation of the Hydrogen distribution in the first billion year of the beginning of the Universe", added Prof. Daniel Schaerer from University of Geneva, "SKA will allow us to address some key questions on our Universe, such as the nature of the dark energy and dark matter, or explore the Cosmic Dawn, the period of time when the first stars and first galaxies formed".

Switzerland has held observer status within the Organisation since 2016, with many Swiss research institutions* and industry partners contributing to various aspects of the SKA. The country has a history of world-class research and development in science and astronomy, including leading the recent CHEOPS mission to study exoplanets and developing instrumentation for the future European-Extremely Large Telescope (ELT) in Chile, among other things. And for five years now, the Swiss SKA Days bring together national and international representatives of academia, industry and government, showcasing the breadth of opportunities for Swiss institutions and companies to be involved in the SKA.

* The Swiss Academic Community includes the Universities of Geneva, Zurich and Bern, ETHZ, CSCS, FHNW, HES-SO, Verkehrshaus Lucerne and EPFL.

ISIC

Unravelling the initial molecular events of respiration



Hemoglobin. © iStock photos/theasis

Physicists from Switzerland, Japan and Germany have unveiled the mechanism by which the first event of respiration takes place in heme proteins.

Respiration is a fundamental process of all living things, allowing them to produce energy, stay healthy, and survive. In cells, respiration involves what are known as "respiratory proteins", e.g. hemoglobin in the blood and myoglobin in muscles.

Respiratory proteins work by binding and releasing small molecules like oxygen, carbon monoxide etc., called ligands. They do this through their "active center", which in many respiratory proteins is a chemical structure called heme porphyrin.

Binding and releasing small molecules causes changes in the heme's molecular and electronic structure. Such a change is the transition from a planar low spin ligated porphyrin form to a domed high spin un-ligated form and vice-versa. This shift is a key step for respiration, ultimately switching hemoglobin between a "relaxed" and "tense" conformation.

Electrons spin around atoms, and also have a spin quantum number, and can cross over from one spin state to another. The debate about the transition from low-spin planar to a high-spin domed heme has been dominated by two schools of thought: the process is either by thermal relaxation or by a cascade among electron spin states.

Now, a team of scientists led by Majed Chergui at EPFL's School of Basic Sciences have solved the debate. The researchers detached the small molecule from the heme using short, energizing laser pulses. They then used another short, hard X-ray pulse from an X-ray free-electron laser to induce X-ray emission (XES), a very sensitive fingerprint of the spin state of molecules, which monitored the heme's changes as a function of time. They could thus determine that the passage from planar to domed and back is caused by a cascade among spin states.

The study was carried out on nitrosyl-myoglobin, which is myoglobin that has bound a nitric oxide molecule. Nitrosyl-myoglobin plays a crucial role in neurotransmission, regulation of vasodilatation, platelet aggregation, and immune responses.

"The conclusions of our work apply to all heme proteins", says Chergui. "In particular to hemoglobin in its uptake and release of oxygen when we breathe. Although this takes place at the thermal temperatures of the body, breathing is governed by electronic changes in the heme".

OTHER CONTRIBUTORS

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- University of Agriculture and Technology (TUAT), Japan
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- Sofia University, Japan
- Newcastle University
- European XFEL, Germany
- Adam Mickiewicz University, Poland
- Paul-Scherrer-Institut (PSI), Switzerland

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ISIC

Lego-like assembly of zeolitic membranes improves carbon capture

© IStock photo

EPFL chemical engineers have developed a new way to manufacture zeolitic membranes, state-of-the-art materials used for gas separation in harsh conditions.

Zeolites are porous minerals that occur both naturally but also are being synthesized artificially. Because they are stable and durable, zeolites are used for chemical catalysis, purification of gases and liquids, and even in medical applications such as drug delivery and blood-clotting powders, e.g. the QuickClot trauma bandages used in the US military.

Zeolites used in gas separation are usually produced as membranes. The state-of-the-art zeolitic membranes are manufactured by a lengthy and complex crystallization process. Unfortunately, this method has proved difficult to reproduce. Also, it lacks in producing efficient gas-separation membranes, especially when it comes to the separation of hydrogen and carbon dioxide, which is necessary for pre-combustion carbon capture from power plants.

A team of chemical engineers led by Kumar Agrawal at EPFL Valais Wallis have now successfully simplified the chemistry behind zeolite membrane synthesis, making it simple, reproducible, and scalable. The achievement of the longstanding goal is published in Nature Materials.

The scientists developed a new material chemistry that eliminates the lengthy crystallization process altogether. "We build Lego-like crystals – nanosheets – and bonded them on top of each other using silanol condensation chemistry", says Agrawal. The resulting membrane shows ideal hydrogen-carbon dioxide separation performance, with selectivity up to 100 at 250-300 degrees Celsius.

The authors conclude: "The scalable synthesis of high-temperature hydrogen-sieving zeolitic membranes is expected to improve the energy-efficiency of pre-combustion carbon capture".

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- King Abdullah University of Science and Technology (KAUST)
- ETH Zurich

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REFERENCE

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MATH

Ethics and AI: an unethical optimization principle

EPFL professor Anthony Davison and co-authors provide a mathematical basis for concerns about ethical implications of AI.

Artificial intelligence (AI) is increasingly deployed around us and may have large potential benefits. But there are growing concerns about the unethical use of AI. Professor Anthony Davison, who holds the Chair of Statistics at EPFL, and colleagues in the UK, have tackled these questions from a mathematical point of view, focusing on commercial AI that seek to maximize profits.

One example is an insurance company using AI to find a strategy for deciding premiums for potential customers. The AI will choose from many potential strategies, some of which may be discriminatory or may otherwise misuse customer data in ways that later lead to severe penalties for the company. Ideally, unethical strategies such as these would be removed from the space of potential strategies beforehand, but the AI does not have a moral sense, so it cannot distinguish between ethical and unethical strategies.

In work published in Royal Society Open Science on 1 July 2020, Davison and his co-authors Heather Battey (Imperial College London), Nicholas Beale (Sciteb Limited) and Robert MacKay (University of Warwick), show that an AI is likely to pick an unethical strategy in many situations. They formulate their results as an "Unethical Optimization Principle":

If an AI aims to maximize risk-adjusted return, then under mild conditions it is disproportionately likely to pick an unethical strategy unless the objective function allows sufficiently for this risk.

This principle can help risk managers, regulators or others to detect the unethical strategies that might be hidden in a large strategy space. In an ideal world one would configure the AI to avoid unethical strategies, but this may be impossible because they cannot be specified in advance. In order to guide the use of the AI, the article suggests how to estimate the proportion of unethical strategies and the distribution of the most profitable strategies.

"Our work can be used to help regulators, compliance staff and others to find problematic strategies that might be hidden in a large strategy space. Such a space can be expected to contain disproportionately many unethical strategies, inspection of which should show where problems are likely to arise and thus suggest how the AI search algorithm should be modified to avoid them", says Professor Davison. "It also suggests that it may be necessary to re-think the way AI operates in very large strategy spaces, so that unethical outcomes are explicitly rejected during the learning process".

Professor Wendy Hall of the University of Southampton, known worldwide for her work on the potential practical benefits and problems brought by AI, said: "This is a really important paper. It shows that we can't just rely on AI systems to act ethically because their objectives seem ethically neutral. On the contrary, under mild conditions, an AI system will disproportionately find unethical solutions unless it is carefully designed to avoid them. The tremendous potential benefits of AI will only be realized properly if ethical behavior is designed in from the ground up, taking account of this Unethical Optimisation Principle from a diverse set of perspectives. Encouragingly, this Principle can also be used to help find ethical problems with existing systems which can then be addressed by better design".

FUNDING

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http://dx.doi.org/10.1098/rsos.200462

IPHYS

Cosmic magnifying glasses show faster expanding universe

© Hubble, ESA & NASA

New measurements using gravitational lensing, an innovative method that EPFL researchers have been working on for many years, suggest the universe is expanding faster than previously thought.

A team of astronomers using NASA's Hubble Space Telescope have announced that the universe is expanding faster than expected. They measured the expansion rate – called the Hubble constant, or H_0, – using gravitational lensing, a brand-new technique, completely independent of any previous method, that EPFL's Laboratory of Astrophysics (LASTRO) has been working on for many years.

The study was led by a group called H0 Lenses in COSMOGRAIL's Wellspring, or H0LiCOW. COSMOGRAIL, which stands for COsmological MOnitoring of GRAvItational Lenses, is a large international project initiated by EPFL astrophysicists to monitor gravitational lenses. It represents the most precise measurement yet using the gravitational lensing method, where the gravity of a foreground galaxy acts like a giant magnifying lens, amplifying and distorting light from background objects.

The results suggest a faster expansion rate in the local universe than expected. The researchers calculated a Hubble constant value of 73 kilometers per second per megaparsec (with 2.4% uncertainty). This means that for every additional 3.3 million light-years away a galaxy is from Earth, it appears to be moving 73 kilometers per second faster, because of the universe's expansion. This value differs significantly from the previous number of 67, which was based on observations by the European Space Agency's Planck satellite on how the cosmos behaved more than 13 billion years ago.

This troubling discrepancy between the two values – the expansion rate calculated from gravitational lensing measurements of the local universe, and the rate as conventionally predicted from background radiation in the early universe – has caused turmoil in the astrophysics community. This is because knowing the precise value for how fast the universe expands is important for determining the age, size and fate of the cosmos. Unraveling this mystery has been one of the greatest challenges in astrophysics in recent years.

"If these results do not agree, it may be a hint that we do not yet fully understand how matter and energy evolved over time, particularly at early times", said H0LiCOW team leader Sherry Suyu of the Max Planck Institute for Astrophysics in Germany.

SIX FARAWAY QUASARS

The H0LiCOW team used Hubble to observe the light from six faraway quasars, the brilliant searchlights from gas orbiting supermassive black holes at the centers of galaxies. Quasars are ideal background objects for many reasons; for example, they are bright, extremely distant, and scattered all over the sky. The telescope observed how the light from each quasar was multiplied into four images by the gravity of a massive foreground galaxy.

The light rays from each lensed quasar image take a slightly different path through space to reach Earth. The pathway's length depends on the amount of matter that is distorting space along the line of sight to the quasar. To trace each pathway, the astronomers monitor the flickering of the quasar's light as its black hole gobbles up material. When the light flickers, each lensed image brightens at a different time.

This flickering sequence allows researchers to measure the time delays between each image as the lensed light travels along its path to Earth. To fully understand these delays, the team first used Hubble to make accurate maps of the distribution of matter in each lensing galaxy. Astronomers could then reliably deduce the distances from the galaxy to the quasar, and from Earth to the galaxy and to the background quasar. By comparing these distance values, the researchers measured the universe's expansion rate.

"The length of each time delay indicates how fast the universe is expanding", said team member Kenneth Wong of the University of Tokyo's Kavli Institute for the Physics and Mathematics of the Universe. "If the time delays are shorter, then the universe is expanding at a faster rate. If they are longer, then the expansion rate is slower".

OBSERVING 40 LENSED SYSTEMS

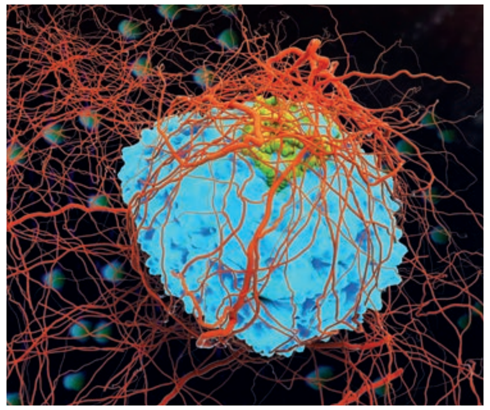
"One of the challenges we overcame was having dedicated monitoring programs through COSMOGRAIL to get time delays for several of these quasar lensing systems", said **Frédéric Courbin**, a researcher in EPFL's LASTRO lab, and the founder and leader of COSMOGRAIL.

"New mass modeling techniques were developed to measure a galaxy's matter distribution, including models we designed to make use of the high-resolution Hubble imaging", added Suyu. "The images enabled us to reconstruct, for example, the quasars' host galaxies and to characterize the environment of the lens system, which affects the bending of light rays. The new mass modeling techniques, in combination with the time delays, help us to measure precise distances to the galaxies".

Begun in 2012, the H0LiCOW project now has Hubble images and time-delay information for ten lensed quasars and intervening lensing galaxies. The team's goal is to observe 30 more lensed quasar systems to reduce their 2.4% uncertainty to 1%.

ISIC

A new model of metabolism draws from thermodynamics and "omics"



3D rendering of a tumor. © iStock photos

Scientists at EPFL have developed an algorithm that can model biochemical reactions from metabolism down to RNA synthesis with unprecedented accuracy.

All living things are made of carbon, and sugars, e.g. glucose, are a very common source of it. Consequently, most cells are good at eating sugars, using enzymes to digest them through a series of chemical reactions that transform the initial sugar into a variety of cell components, including amino acids, DNA building blocks, and fats. Because they help these sugar-metabolism reactions run efficiently, these enzymes are called biocatalysts.

Given how critical all enzymes are to life itself, scientists have built several mathematical models that describe how the cells use enzymes to transform a sugar. Such models have been successfully used, for instance, to improve 2nd generation biofuel production or identify drug targets for malaria, but they don't take into account the metabolic "cost" of producing the enzymes that catalyze all these chemical reactions.

Accounting for this phenomenon, called "expression", is key to describing many other phenomena, including beer fermentation and the growth of cancer cells. But all this first depends on accurately modeling the mechanisms of expression.

Now, Professor Vassily Hatzimanikatis at EPFL and Pierre Salvy, a PhD student in his lab, have developed a mathematical model that can efficiently model the expression of enzymes in living cells, as well as its associated metabolic cost. It is called ETFL for "Expression and Thermodynamics Flux models" and draws its accuracy from its accuracy from taking into account both biochemistry and thermodynamics – a set of physico-chemical laws that describe how energy flows in systems. Combining this with mathematical tools from the field of optimization, the researchers were able to drastically improve the accuracy of the model's predictions.

"This integration of metabolism, expression, and thermodynamics is the first of its kind, and is 10 to 100 times faster than the previous state-of-the-art models, which do not feature thermodynamics", says Salvy.

To further increase its predictive power, the ETFL model was designed to take into account a wide variety of measurements made through the massive field of "omics", which measures characteristics of cells such as gene expression, protein profiles etc. "Our algorithm can be used to improve the production of biochemical products, or to accurately predict how cancer cells metabolize", says Salvy. "It can also open the door to applications in personalized medicine".

FUNDING
- Horizon 2020
- Swiss National Science Foundation

REFERENCE
Nat. Commun. **11**, 30 (2020).
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IPHYS

A titanate nanowire mask that can eliminate pathogens

© Swoxid SA

Filter "paper" made from titanium oxide nanowires is capable of trapping pathogens and destroying them with light. This discovery by an EPFL laboratory could be put to use in personal protective equipment, as well as in ventilation and air conditioning systems.

As part of attempts to curtail the Covid-19 pandemic, paper masks are increasingly being made mandatory. Their relative effectiveness is no longer in question, but their widespread use has a number of drawbacks. These include the environmental impact of disposable masks made from layers of non-woven polypropylene plastic microfibres. Moreover, they merely trap pathogens instead of destroying them. "In a hospital setting, these masks are placed in special bins and handled appropriately", says László Forró, head of EPFL's Laboratory of Physics of Complex Matter. "However, their use in the wider world – where they are tossed into open waste bins and even left on the street – can turn them into new sources of contamination". Researchers in his lab are working on a promising solution to this problem: a membrane made of titanium oxide nanowires, similar in appearance to filter paper but with antibacterial and antiviral properties. Their material works by using the photocatalytic properties of titanium dioxide. When exposed to ultraviolet radiation, the fibers convert resident moisture into oxidizing agents such as hydrogen peroxide, which have the ability to destroy pathogens. "Since our filter is exceptionally good at absorbing moisture, it can trap droplets that carry viruses and bacteria", says Forró. "This creates a favorable environment for the oxidation process, which is triggered by light".

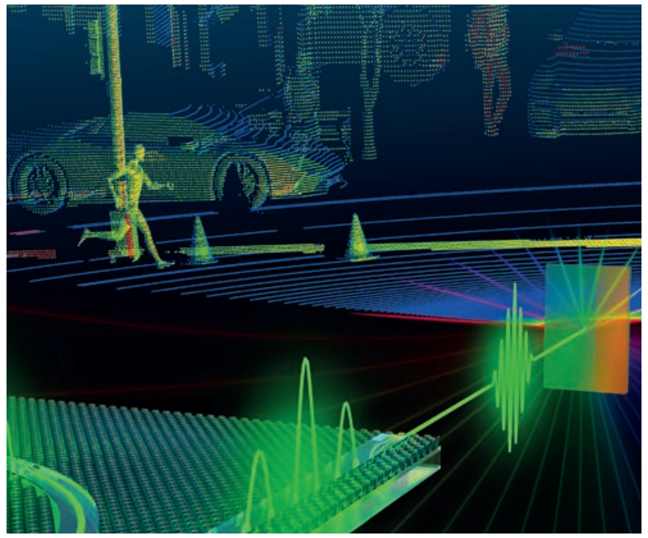
The researcher's work appeared in Advanced Functional Materials, and included experiments that demonstrate the membrane's ability to destroy E. coli, the reference bacterium in biomedical research, and DNA strands in a matter of seconds. Based on these results, the researchers assert – although this remains to be demonstrated experimentally – that the process would be equally successful on a wide range of viruses, including SARS-CoV-2.

Their article also states that manufacturing such membranes would be feasible on a large scale: the laboratory's equipment alone is capable of producing up to 200 m2 of filter paper per week, or enough for up to 80,000 masks per month. Moreover, the masks could be sterilized and reused up a thousand times. This would alleviate shortages and substantially reduce the amount of waste created by disposable surgical masks. Finally, the manufacturing process, which involves calcining the titanite nanowires, makes them stable and prevents the risk of nanoparticles being inhaled by the user.

A start-up named Swoxid is already preparing to move the technology out of the lab. "The membranes could also be used in air treatment applications such as ventilation and air conditioning systems as well as in personal protective equipment", says Endre Horváth, the article's lead author and co-founder of Swoxid.

IPHYS

Speeding up long-range coherent LiDAR



An illustration of LiDAR waves.

LiDAR is a technique used for measuring distances with laser light. In a study published in Nature, researchers at EPFL show a new way to speed up a type of LiDAR engine by using photonic circuits.

Light detection and ranging (LiDAR) comprised an array of techniques using laser light to measure distances by multiplying the time delay between transmitted and received optical signals with the speed of light. Modern 3D LiDAR sensors combine high lateral/vertical and radial resolution, and are key components in the ongoing revolution of level 4 and 5 self-driving cars.

The prominence of 3D LiDAR sensing has its roots in 2007 DARPA autonomous driving challenge with the introduction of the first Velodyne spinning laser array sensors measuring up to 128 laser lines in parallel. Most modern LiDAR sensors rely on the time-of-flight operation principle where short pulses or pulse patterns are emitted from the sensor aperture and the power of back-reflected light is detected using a square-law photodetector.

A different principle is that of coherent laser ranging, most importantly frequency-modulated continuous wave (FMCW) LiDAR, where the laser is set up to emit linear optical frequency chirps. Heterodyne mixing with a replica of the emitted laser light maps the target distance to a radiofrequency.

Coherent detection has many inherent advantages such as enhanced distance resolution, direct velocity detection via the Doppler effect, and imperviousness to sunlight glare and interference. But the technical complexity of precisely controlling narrow-linewidth frequency-agile lasers has so far prevented the successful parallelization of FMCW LiDAR.

Now, researchers at the lab of **Tobias Kippenberg** at EPFL have found a new way to implement a parallel FMCW LiDAR engine by using integrated nonlinear photonic circuitry. They coupled a single FMCW laser into a silicon-nitride planar microresonator, where the continuous wave laser light is converted into a stable optical pulse train due to the double balance of dispersion, nonlinearity, cavity pumping and loss. The study is published in Nature.

"Surprisingly, the formation of the dissipative Kerr soliton, does not only persist when the pump laser is chirped, but transfers the chirp faithfully to all the generated comb teeth", says Johann Riemensberger, postdoc at Kippenberg's lab and first author of the study.

The small size of the microresonator means that the comb teeth are spaced 100 GHz apart, which is enough to separate them using standard diffraction optics. Because each comb tooth inherits the linear chirping of the pump laser, it was possible to create up to 30 independent FMCW LiDAR channels in the microresonator.

Each channel is capable to measure distance and velocity of a target simultaneously, while the spectral separation of the different channels makes the device immune to channel crosstalk, as well as a natural fit for co-integration with recently deployed optical phased arrays based on photonic integrated optical grating emitters.

The spatial separation of emitted beams and operation in the 1550 nm-wavelength band relaxes otherwise stringent eye and camera safety limitations. "The technology developed here at EPFL could improve acquisition rates of coherent FMCW LiDAR tenfold in the near future", says Anton Lukashchuk, PhD student in Kippenberg's lab.

The concept relies on high-quality silicon-nitride microresonsators with record-low losses amongst planar nonlinear waveguide platforms, which were produced at EPFL's Center of MicroNanoTechnology (CMi). The silicon-nitride microresonators are already commercially available by EPFL spinoff LiGenTec SA that has specialized on fabrication of silicon nitride-based photonic integrated circuits (PIC).

This work paves a way for the widespread application of coherent LiDAR in autonomous vehicle applications in the future. The researchers are now focused on heterogeneous co-integration of laser, low-loss nonlinear microresonators, and photodetectors in a single and compact photonic package.

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ISIC

Could mining gold from waste reduce its great cost?

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A research group lead by prof. Wendy Queen designed new sponge materials with microscopic holes that can selectively extract and concentrate gold from a variety of the world's most complex liquid mixtures. A record breaking gold-extraction rate of one gram of high purity gold per gram of sponge is attained.

The myth of King Midas tells one of the world's first stories about alchemy. The greedy Midas was granted one wish by the Greek god Dionysus, and he chose the ability to transmute anything he touched into gold. Unfortunately, the king quickly realised that this gift was more of a curse as he could no longer enjoy many of life's real pleasures, such as the taste of good food and wine, or the embrace of a loved one.

While the Midas myth is meant to warn against becoming a slave to one's desires, it also reflects our human infatuation with gold. This alluring metal has captivated humans for millennia, certainly since the days of the ancient Egyptians, and has been the basis of currency for many civilisations for hundreds of years. Its high value, stemming from its rarity, chemical stability and beauty, makes it a seductive tempter whether used in coins, in a church, or on the human body.

However, despite intensive efforts throughout history to extract gold from the Earth, best estimates suggest that to date only 190,000 metric tonnes of this precious metal have been mined, an amount that will surprisingly fit into a cube of approximately 20 metres on each side (which might be the reason why gold is less and less the basis of our currency).

But gold remains the foundation of the luxury jewellery industry and, in recent years, has become one of the most prominent materials in the production of our latest obsession – modern electronics. Gold is used to make many of the devices we love, such as cellphones, tablets and laptops. This is due to its highly efficient electrical properties and corrosion resistance, which are unmatched by any other metal. But the fabrication of just 40 mobile phones requires approximately one gram of gold, which corresponds to nearly a ton of mined ore. Given the persistent rise in electronics production, and the limited and diminishing supply of gold, how will we maintain the supply of this precious material for many years to come?

One solution might be found in the recycling of electronic waste, a process often referred to as urban mining. Given that a metric tonne of recycled laptop circuit boards can have between 40 and 800 times more gold than found in a metric tonne of ore, it seems irrational to redeposit the precious metal into the earth via landfills. Despite this, and the fact that urban mining is growing more cost-effective by the day, only 20 per cent of all electronic waste is currently recycled. In 2017, the Global E-Waste Monitor projected that the amount of electronic waste generated by the end of 2021 would reach 52.2 million metric tonnes. Given these numbers, it is estimated that the value of the gold in our garbage exceeds €10 billion ($11.2 billion). On top of that, the many other precious metals in the garbage, such as silver, copper and platinum, add even more value to our waste. Therefore, given its economic and technological importance, it is time to consider whether other sources of gold, which are not yet decidedly viable, can also be exploited in the future.

What might futuristic gold mining actually look like? For instance, the valuable metal is appearing in sewage systems throughout the world, the result of its increasing use in various industries. As well as in sewage, trace quantities of gold are also found in both freshwater, such as rivers, and seawater. In fact, since the British chemist Edward Sonstadt first uncovered the existence of gold in the sea in 1872, many have dreamt of its eventual extraction, yet to date all efforts have failed. The lack of success stems from the absence of an adequate and eco-friendly chemical process that is able to efficiently concentrate the precious metal from such dilute solutions. Also, while more than 20 million metric tonnes of gold are in our oceans for the taking, the amount of gold in seawater is minuscule when compared with the large quantities of other metals. In fact, it takes 100 million metric tonnes of seawater to extract a single gram of gold.

The fact that our seas are laden with this valuable metal continues to fuel the efforts of many scientists around the world, even if no technologies have yet demonstrated performance in such complex environments. These shortfalls have sparked the interest of many chemists: with my colleagues at the Swiss Federal Institute of Technology in Lausanne, we designed new sponge materials with microscopic holes that can selectively extract and concentrate gold from a variety of the world's most complex liquid mixtures. One such sponge can rapidly extract gold from Swiss industrial wastewater, river water and many other solutions in as little as two minutes. The sponges exhibit record-breaking gold-extraction rates because they can concentrate as much as one gram of gold inside a gram of sponge. Further, due to the sponge's remarkable selectivity for gold over other metals, the gold extract purity is an impressively high 23.9 karats. This is the highest purity reported to date for such an extraction process.

So while King Midas might have looked to the gods for an easy solution to acquire gold, modern alchemists use ingenuity to achieve ancient dreams. It is these qualities that might eventually lead to environmentally mindful and energy-efficient technologies for extracting gold from inconceivable places. However, let's just be careful to not become slaves to our own desires, too. After all, all that glitters ain't gold.

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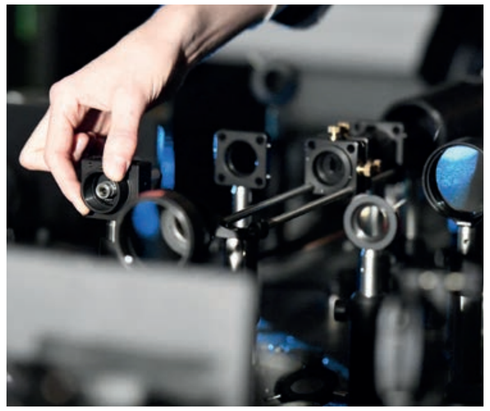
IPHYS

Super-resolution microscopy reveals a twist inside cells



EPFL biophysicists have developed a high-throughput super-resolution microscope to probe nanoscale structures and dynamics of mammalian cells, showing in unprecedented detail the twists and turns of an organelle important for cell division.

If you want to understand the underlying mechanisms of cellular motility and division, then the centriole is the organelle of interest. Each cell has a pair of centrioles which help to segregate chromosomes during cell division. These special organelles are multi-molecular machines composed of hundreds of proteins and have a hidden code of post-translational modifications (PTMs), that contribute to their rigidity or flexibility, which in turn may help explain how centrioles function.

Based on previous studies mostly using electron microscopy, the basic structure of centrioles is known. But PTMs are invisible to the electron microscope, so what do they look like?

Thanks to improved super resolution fluorescence microscope technology developed by EPFL biophysicists, we now have a detailed picture of these nanoscale structures, both isolated and in situ. As expected, the centrioles are shaped like ridged bullets, i.e. they are cylindrical with nine lengthwise ridges and their diameter tapers off at one end. Given this high degree of organization, the scientists were surprised to find that one PTM actually twists around these ridges. The results are published today in Nature Methods.

"The symmetries of multi-molecular machines often explain how they can perform diverse functions. PTMs can form a special code that tells proteins where to dock, but can also stabilize the centriole while forces are pulling during division. We still don't know why the twist is there, but it offers a clue to how centrioles work. Our study underlines that super-resolution microscopy is an important partner to electron microscopy for structural biology", says biophysicist **Suliana Manley** who leads the Laboratory of Experimental Biophysics (LEB).

IMPROVED SUPER RESOLUTION IMAGING TECHNIQUES

Centrioles are about 100 times smaller than a mammalian cell, and a thousand times smaller than a human hair. So observing them inside of living cells required improving super-resolution microscope technology that uses light to probe specimens, since the methods tend to be too slow for structural studies. Dora Mahecic, a PhD student in the LEB, improved the illumination design to increase the size of images their microscope could capture by delivering light more uniformly across the field of view.

The microscope, a super-resolution fluorescence microscope, is not at all the typical optical microscope that one would see in an introductory biology class. It is actually a complex setup of carefully aligned mirrors and lenses that shape and deliver laser light into the specimen. The biophysicists combined this setup with advanced sample preparation that uses physical magnification of the sample and fluorophores to make proteins, the building blocks of life, re-emit light.

This new super resolution technology could be used to study numerous other structures within the cell, like mitochondria, or to look at other multi-molecular machines such as viruses.

REFERENCE
Nat Methods **17**, 726-733 (2020).
https://doi.org/10.1038/s41592-020-0859-z

ISIC

Photoelectrochemical water-splitting efficiency hits 4.55%

Solar-to-fuel conversion offers a promising technology to solve energy problems, yet device performance could be limited by undesired sunlight absorption. Researchers show copper thiocyanate can assist hole transport in oxide photoelectrodes and enable a 4.55% solar-to-hydrogen efficiency in tandem devices.

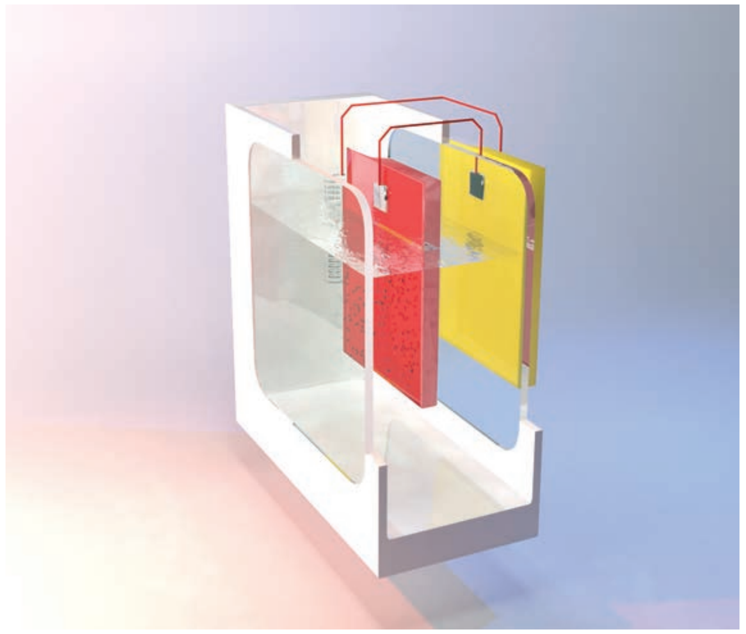
Photoelectrochemical (PEC) water splitting for hydrogen fuel generation has been considered the Holy Grail of electrochemistry. But to achieve it, many scientists believe the materials have to be abundant and low cost.

The most promising oxide photocathodes are cuprous oxide (Cu_2O) photoelectrodes. In 2018 and 2019, researchers at EPFL achieved champion performance with cuprous oxide, rivaling photovoltaic (PV) semiconductor-based photocathodes.

But there was still a piece missing from the puzzle. Even state-of-the-art Cu_2O photocathodes still use metallic back contacts (copper or gold), allowing for considerable electron-hole recombination. Other disadvantages include high cost and that the metal contact won't allow unabsorbed sunlight to pass through.

Now, scientists at EPFL show for the first time, that copper thiocyanate (CuSCN) can be used as a transparent and effective hole transport layer (HTL) for Cu_2O photocathodes with overall enhanced performance. The research was led by Professors **Anders Hagfeldt**, **Michael Grätzel**, and **Kevin Sivula** at EPFL's Institute of Chemical Sciences and Engineering.

Detailed analysis on two types of CuSCN showed that a defective structure could be beneficial for hole conduction. Moreover, due to the coincidental alignment between valence bands of CuSCN and Cu_2O, the band-tail states assisted hole transport in CuSCN was discovered to allow smooth hole conduction while efficiently block electron transport.



Cu2O photocathode-based PEC-PV tandem delivering 4.55% solar-to-hydrogen efficiency.

The optical advantages of CuSCN were further exhibited through a standalone PEC-PV tandem delivering a solar-to-hydrogen efficiency of 4.55%. This efficiency (4.55% for 12 h) is currently the highest among all Cu_2O-based dual-absorber tandems.

The study presents a clear and impressive advancement beyond the state-of-the-art Cu_2O photocathodes, which can contribute and inspire future development in the field.

"Though top numbers are achieved with the oxide material in this work, we believe higher values are not far", says Pan Lingfeng, the paper's first author. "At least three aspects are found to be not optimal, but improving them is very feasible. The efficiency value is getting closer and closer to the one that was previously thought to be the threshold for commercialization".

FUNDING
- Swiss National Science Foundation
- Sino-Swiss Science and Technology Cooperation
- Strategic Japanese-Swiss Science and Technology Programme

REFERENCE
Nat. Commun. **11**, 318 (2020).
https://dx.doi.org/10.1038/s41467-019-13987-5

ISIC

Microbes working together multiply biomass conversion possibilities

© iStock Photos

Non-edible plants are a promising alternative to crude oil, but their heterogenous composition can be a challenge to producing high yields of useful products. Scientists from EPFL, the University of Cambridge, and the Bern University of Applied Sciences have developed a platform that combines different microorganisms that can make a dramatic difference.

With the race for renewable energy sources in full swing, plants offer one of the most promising candidates for replacing crude oil. Lignocellulose in particular – biomass from non-edible plants like grass, leaves, and wood that don't compete with food crops – is abundant and renewable and offers a great alternative source to petroleum for a whole range of chemicals.

In order to extract useful chemicals from it, lignocellulose is first pretreated to "break it up" and make it easier to further process. Then it's exposed to enzymes that solubilize cellulose, which is a chain of linked up sugars (glucose). This step can be done by adding to the pre-treated lignocellulose a microorganism that naturally produces the necessary, cellulose-cleaving enzymes, e.g. a fungus.

The enzymes "crack" the cellulose and turn it into its individual sugars, which can be further processed to produce a key chemical: lactic acid. This second step is also accomplished with a microorganism, a bacterium that "eats" the sugars and produces lactic acid when there's no oxygen around.

In the final step of this microbial assembly line, the lactic acid can then be processed to make a whole host of useful chemicals.

A team of scientists from the Bern University of Applied Sciences (BFH), the University of Cambridge, and EPFL have made this assembly chain possible in a single setup and demonstrated this conversion can be made more versatile and modular. By easily swapping out the microorganisms in the final, lactic-acid processing, step, they can produce a whole range of useful chemicals.

The breakthrough study is published in Science, and was carried out by Robert Shahab, an EPFL PhD student in Professor **Jeremy Luterbacher**'s lab, while working at the lab of Professor Michael Studer at the BFH, who led the study.

The researchers present what they refer to as a "lactate platform", which is essentially a spatially segregated bioreactor that allows multiple different microorganisms to co-exist, each performing one of the three steps of lignocellulose processing.

The platform consists of a tubular membrane that lets a defined amount of oxygen to go through it. On the tube's surface can be grown the fungus that consumes all oxygen that passes through the membrane, and provides the enzymes that will break up cellulose into sugars. Further away from the membrane, and therefore in an atmosphere without oxygen, grow the bacteria that will "eat" the sugars and turn them into lactic acid.

But the innovation that Shahab made was in the last step. By using different lactic acid-fermenting microorganisms, he was able to produce different useful chemicals. One of these is butyric acid was butyric acid, which can be used in bioplastics, while Luterbacher's lab recently showed that it can even be turned into a jet fuel.

Fungal biofilm growing on an oxygen permeable, helically coiled tubular membrane in an otherwise anaerobic bioreactor. The biofilm is removed from the reactor at the end of a fermentation run. © M. Studer (BFH) © 2020 EPFL

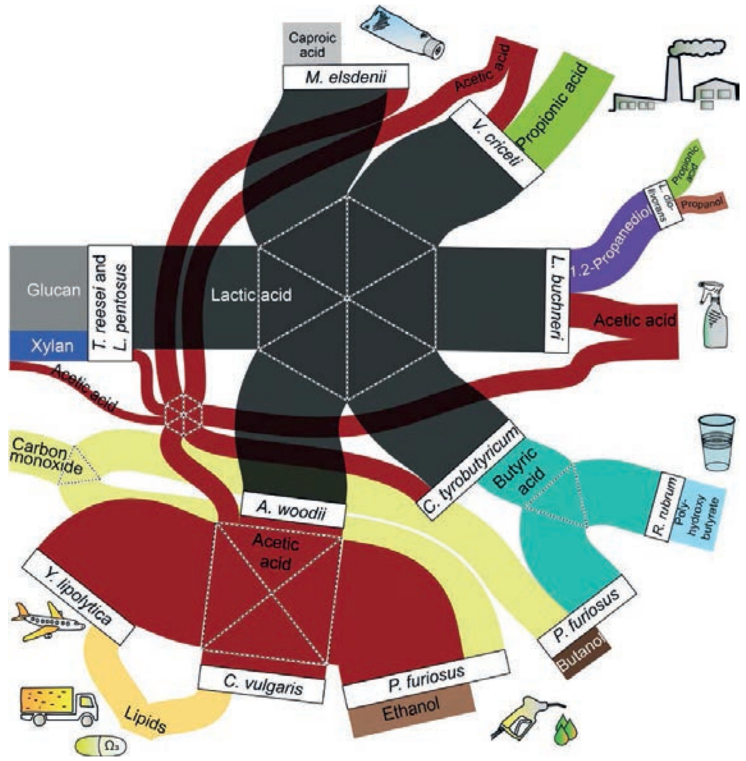
The work demonstrates the benefits of mixed microbial cultures in lignocellulose biomass processing: modularity and the ability to convert complex substrates to valuable platform chemicals.

"The results achieved with the lactate platform nicely show the advantages of artificial microbial consortia to form new products from lignocellulose", says Michael Studer. "The creation of niches in otherwise homogeneous bioreactors is a valuable tool to co-cultivate different microorganisms".

"Fermenting lignocellulose to a lot of different products was a significant amount of work but it was important to show how versatile the lactate platform is", says Robert Shahab. "To see the formation of lactate and the conversion into target products was a great experience as it showed that the concept of the lactate platform worked in practice".

Jeremy Luterbacher adds: "The ultimate goal is to rebuild a green manufacturing sector to replace one that produces many products from crude oil. A method that introduces flexibility and modularity is an important step in that direction".

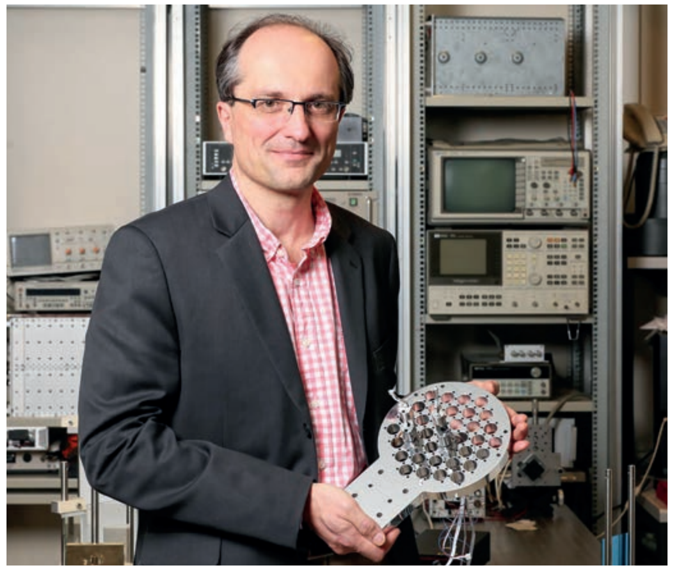
REFERENCE
Science **369**, eabb1214 (2020).
https://doi.org/10.1126/science.abb1214



An illustration of the different chemicals that can be produced from beechwood using the lactate platform. © RL Shahab/Science

IPHYS

Astrophysicists fill gaps in the history of the Universe



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An international consortium of scientists has analyzed, as part of a vast program of cosmological surveys, several million galaxies and quasars, thus retracing a more continuous history of the Universe and offering a better understanding of the mechanisms of its expansion. The latest six-year-long survey called eBOSS was initiated, and led in part, by EPFL astrophysicist Jean-Paul Kneib.

It is the largest 3D map of the Universe produced to date. It is the fruit of a twenty-year collaboration of several hundred scientists from around thirty different institutions around the world, all united within the “Sloan Digital Sky Survey” (SDSS), with data collected from an optical telescope dedicated to the project located in New Mexico, United States.

Released today in the form of more than twenty scientific publications, this latest mapping of the night sky is an unprecedented and ambitious astronomical survey from 2014 until 2020. Resulting from the analysis of several millions of galaxies and quasars, this latest survey builds upon existing data as early as 1998 to fill certain gaps in cosmological history and to improve our understanding of the mechanisms underlying the expansion of the Universe.

EPFL is directly involved in this important project. This latest cosmological survey of the SDSS, called “The extended Baryon Oscillation Spectroscopic Survey” (eBOSS), includes more than 100 astrophysicists, of which several are researchers from EPFL. Jean-Paul Kneib, who heads EPFL’s Astrophysics Laboratory (LASTRO), initiated the eBOSS survey and was its principal investigator (PI) for several years.

“In 2012, I launched the eBOSS project with the idea of producing the most complete 3D map of the Universe throughout the lifetime of the Universe, implementing for the first time celestial objects that indicate the distribution of matter in the distant Universe, galaxies that actively form stars and quasars”, reports Jean-Paul Kneib. “It is a great pleasure to see the culmination of this work today. "

Thanks to the extensive theoretical models describing the Universe after the Big Bang, as well as observation of the Cosmic Microwave Backgound Radiation (CMBR), the infant Universe is relatively well known. Scientists have also explored its expansion history over the most recent few billion years from Supernovae distance measurements and galaxy maps, including those from previous phases of the SDSS. “We know both the ancient history of the Universe and its recent expansion history fairly well, but there’s a troublesome gap in the middle 11 billion years”, says cosmologist Kyle Dawson of the University of Utah, who leads the team announcing today’s results. “Thanks to five years of continuous observations, we have worked to fill in that gap, and we are using that information to provide some of the most substantial advances in cosmology in the last decade”.

“Taken together, detailed analyses of the eBOSS map and the earlier SDSS experiments, we have now provided the most accurate expansion history measurements over the widest-ever range of cosmic time”, says Will Percival of the University of Waterloo, eBOSS’s Survey Scientist. “These studies allow us to connect all these measurements into a complete story of the expansion of the Universe”.

The finalized map shows filaments of matter and voids that more precisely define the structure of the Universe since its beginnings, when it was only 380,000 years old. From there, the researchers measured the recurring patterns in the distribution of galaxies, thus identifying several key cosmological parameters, including the density of hypothetical dark matter and energy in the Universe, with a high degree of precision.

To carry out this survey, the teams involved in the eBOSS project looked at different galactic tracers that reveal the mass distribution in the Universe. For the part of the map relating to the Universe six billion years ago, researchers observed the oldest and reddest galaxies. For more distant eras, they concentrated on the youngest galaxies, the blue ones. To go back further, that is to say up to eleven billion years, they used quasars, galaxies whose super-massive black hole is extremely luminous.

SLOWER EXPANSION?

This map reveals the history of the Universe, and in particular, that the expansion of the Universe began to accelerate at some point and has since continued to do so. This seems to be due to the presence of dark energy, an invisible element that fits naturally into Einstein’s general theory of relativity but whose origin is not yet understood.

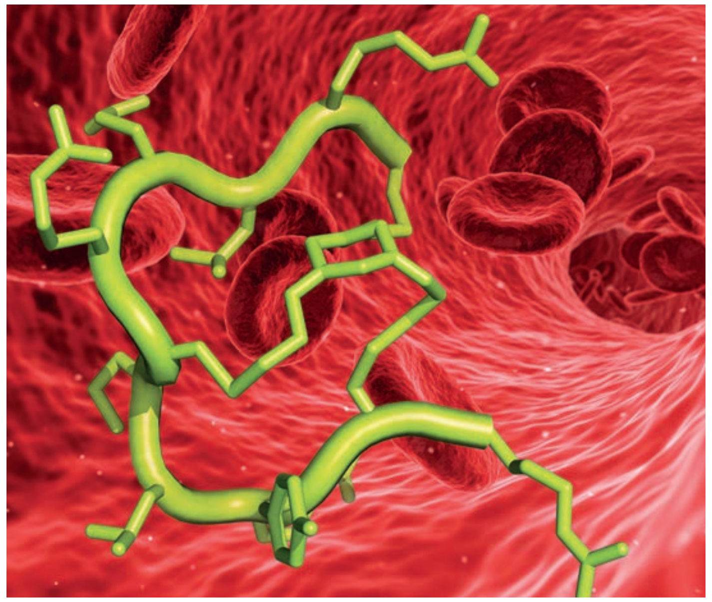
When eBOSS observations are compared with studies of the Universe’s early days, discrepancies appear in estimates of the Universe’s expansion rate. The value of the expansion rate, called the "Hubble constant", calculated by eBOSS is 10% slower than the currently accepted value, it is unlikely that this 10% difference can be accommodated due to the high precision and wide variety of data in the eBOSS database.

To date, there is no commonly accepted explanation for these disagreements between the different estimations of the speed of expansion, but the fact that a still unknown form of matter or energy from the early Universe could have left traces in our history is an interesting possibility.

REFERENCE
SDSS website: https://www.sdss.org/
Video: https://youtu.be/Ld5kE1k8-Ls

ISIC

Blood-thinner with no bleeding side-effects is here



A FXII inhibitor cyclic peptide blood-thinner.

In a study led by EPFL, scientists have developed a synthetic blood-thinner that, unlike all others, doesn't cause bleeding side-effects. The highly potent, highly selective, and highly stable molecule can suppress thrombosis while letting blood clot normally following injury.

Patients who suffer from thrombosis, pulmonary embolism or stroke are usually put on drugs that help their blood flow more smoothly through their body. Occupying a large section of the drug market, anticoagulants, or "blood thinners" as they are popularly known, can keep blood clots from forming or getting bigger, and can therefore help with recover from heart defects or prevent further complications.

But there is a catch: blood thinners work by blocking enzymes that help to stop bleeding after an injury. Because of this, virtually every blood thinner available today can lead to serious, and even life-threatening bleeding following an injury.

The problem remained unsolved until a few years ago, when a study was carried out on mice that had been genetically modified to be deficient in an enzyme that normally helps blood clot. The enzyme is called "coagulation factor XII" (FXII), and the mice without the enzyme had a very reduced risk of thrombosis without having bleeding side-effects. The discovery triggered a race for FXII inhibitors.

FINALLY, A SYNTHETIC INHIBITOR

Participating in the race, the Laboratory of Therapeutic Proteins and Peptides of Professor Christian Heinis at EPFL has developed the first synthetic inhibitor of FXII. The inhibitor has high potency, high selectivity, and is highly stable, with a plasma half-life of over 120 hours. Published in Nature Communications, the study is the result of an extensive collaboration with three other labs in Switzerland and the US.

"The FXII inhibitor is a variation of a cyclic peptide that we identified in a pool of more than a billion different peptides, using a technique named phage display", says Heinis. The researchers then improved the inhibitor by painstakingly replacing several of its natural amino acids with synthetic ones. "This wasn't a quick task; it took over six year and two generations of PhD students and post-docs to complete".

With a potent FXII inhibitor in hand, Heinis's group wanted to evaluate it in actual disease models. To do this, they teamed up with experts in blood and disease-modeling at the University Hospital of Bern (Inselspital) and the University of Bern.

Working with the group of Professor Anne Angelillo-Scherrer (Inselspital), they showed that the inhibitor efficiently blocks coagulation in a thrombosis model without increasing the bleeding risk. Then they assessed the inhibitor's pharmacokinetic properties with the group of Professor Robert Rieben (University of Bern). "Our collaboration found that it is possible to achieve bleeding-free anti-coagulation with a synthetic inhibitor", says Heinis.

ARTIFICIAL LUNGS

"The new FXII inhibitor is a promising candidate for safe thromboprotection in artificial lungs, which are used to bridge the time between lung failure and lung transplantation", says Heinis. "In these devices, contact of blood proteins with artificial surfaces such as the membrane of the oxygenator or tubing can cause blood clotting". Known as 'contact activation', this can lead to severe complications or even death and limits the use of artificial lungs for longer than a few days or weeks.

To test the effectiveness of the FXII inhibitor in artificial lungs, Heinis's group turned to Professor Keith Cook at Carnegie Mellon University (US), an expert for artificial lung system engineering. Cook's group tested the inhibitor in an artificial lung model, and found that it efficiently reduced blood clotting, all without any bleeding side-effects.

The only problem is that the inhibitor has a relatively short retention time in the body: it's too small and the kidneys would filter it out. In the context of artificial lungs, this would mean constant infusion, since suppressing blood clotting for several days, weeks or months requires a long circulation time. But Heinis is optimistic: "We're fixing this; we're currently engineering variants of the FXII inhibitor with a longer retention time".

FUNDING

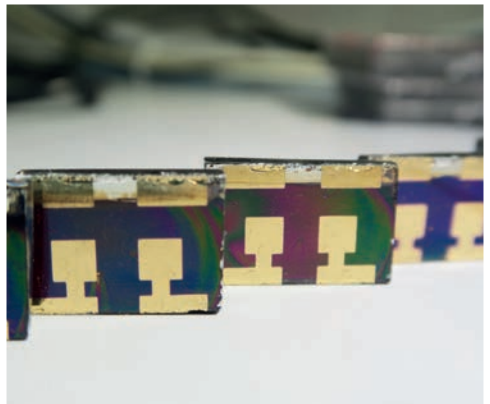
- Swiss National Science Foundation
- NCCR Chemical Biology
- Marie Skłodowska-Curie individual fellowship

REFERENCE

Nat. Commun. **11**, 3890 (2020).
https://doi.org/10.1038/s41467-020-17648-w

ISIC

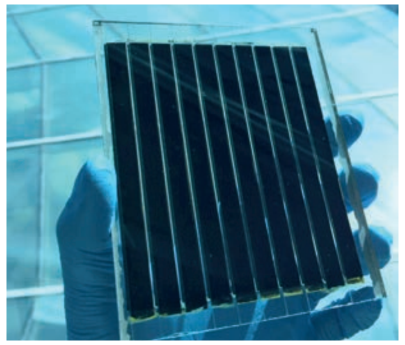
Chemical innovation stabilizes best-performing perovskite formulation



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

Publishing in Science, researchers at EPFL have successfully overcome a limiting problem with stabilizing the best-performing formulation of metal-halide perovskite films, a key player in a range of applications, including solar cells.

Perovskites are a class of materials with a peculiar crystal structure. Their fascinating structure and properties have propelled perovskites into the forefront of materials' research, where they are studied for use in a wide range of applications. Metal-halide perovskites are especially popular, and are being considered for use in solar cells, LED lights, lasers, and photodetectors.



A pervoskite solar cell.
© Nripan Mathews NTU, Singapore

For example, the power-conversion efficiency of perovskite solar cells (PSCs) have increased from 3.8% to 25.5% in only ten years, surpassing other thin-film solar cells – including the market-leading, polycrystalline silicon.

Perovskites solar cells are usually made by mixing and layering various materials together on a transparent conducting substrate, which produces thin, lightweight films. The process, known as "chemical deposition", is sustainable and relatively cost-effective.

But there is a problem. Since 2014, metal halide perovskites have been made by mixing cations or halides with formamidinium ($FAPbI_3$). The reason is that this recipe results in high power-conversion efficiency in perovskite solar cells. But at the same time, the most stable phase of $FAPbI_3$ is photoinactive, meaning that it does not react to light – the opposite of what a solar power harvester ought to do. In addition, solar cells made with $FAPbI_3$ show long-term stability issues.

Now, researchers led by **Michael Grätzel** and **Anders Hafgeldt** at EPFL, have developed a deposition method that overcomes the formamidinium issues while maintaining the high conversion of perovskite solar cells. The work has been published in Science.

In the new method, the materials are first treated with a vapor of methylammonium thiocyanate (MASCN) or formamidinium thiocyanate FASCN. This innovative tweak turns the photoinactive $FAPbI_3$ perovskite films to the desired photosensitive ones.

The scientists used the new FAPbI3 films to make perovskite solar cells. The cells showed more than 23% power-conversion efficiency and long-term operational and thermal stability. They also featured low (330 mV) open-circuit voltage loss and a low (750 mV) turn-on voltage of electroluminescence.

OTHER CONTRIBUTORS
- EPFL Laboratory of Computational Chemistry and Biochemistry,
- EPFL Laboratory of Magnetic Resonance
- Shanghai Synchrotron Radiation Facility (SSRF)
- Swiss Federal Laboratories for Materials Science and Technology
- Fudan University

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- China Postdoctoral Science Foundation
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REFERENCE
Science **370**, eabb8985 (2020).
https://doi.org/10.1126/science.abb8985

IPHYS

Physics Olympiad: high school students are training at EPFL

© Lê Thanh Phong

Between the 14th and 16th of February 2020, the traditional training camp of the Physics Olympiad took place at EPFL. While the latter was getting prepared for a festive weekend, twenty-two participants from every corner of Switzerland gathered on the campus to improve their knowledge of physics.

The scientific program was particularly busy, with lectures about electrodynamics, statistics and special relativity. Experimental physics was covered as well, with an afternoon spent at the electronics lab to study a high-pass filter as well as black boxes. During another afternoon, the students had the opportunity to work on a dozen of former experimental tasks of the Olympiads. Using playful experimental setups, they studied various phenomena encountered in everyday life, such as the cooling of a cup, the radiation of an incandescent lamp, the friction of a rope, or even Foucault currents.

The camp was not only the opportunity to study and discover the campus, but also to get informed about EPFL's numerous study programs, thanks to a presentation of the Education Outreach Department.

After three intense days of physics, the students went back to their respective cantons with their heads full of new formulas. We hope that they will keep good memories of their stay on the campus, and that this might provide the motivation to come back in the future.

Seven volunteers were involved in the teaching and supervision of the students and contributed to the success of this camp. Above all, it is thanks to the generous support of the Physics Section and the Education Outreach Department of the EPFL that this event could take place. Indeed, since over a decade, they support the transportation, board and lodging of these high-school students, therefore deserving once again all the warm thanks from the organizers and the students.

MATH

Matheminecraft: when Mathematics merge with Minecraft

© 2020 EPFL

Using the famous computer game Minecraft, Mathematicians at EPFL have developed a video game around Eulerian Cycles. It is now freely available online to everyone.

Mathematician David Strütt, a scientific collaborator at EPFL, worked for four months to develop Matheminecraft, a math video game in Minecraft, where the gamer has to find a Eulerian cycle in a graph. Minecraft is a sandbox video game released in 2011, where the gamer can build almost anything, from simple houses to complex calculators, using only cubes and fluids. These countless possibilities are what lured David Strütt into Minecraft's universe: "the game might be first intended for kids but I was studying for my Bachelor's degree in mathematics when I discovered it. I fell in love with the game when I realized there is all the necessary blocks to build a Turing machine inside the game. It was a long time ago, so I have since forgotten what a Turing machine is. But the gist of it is: anything is possible inside the game".

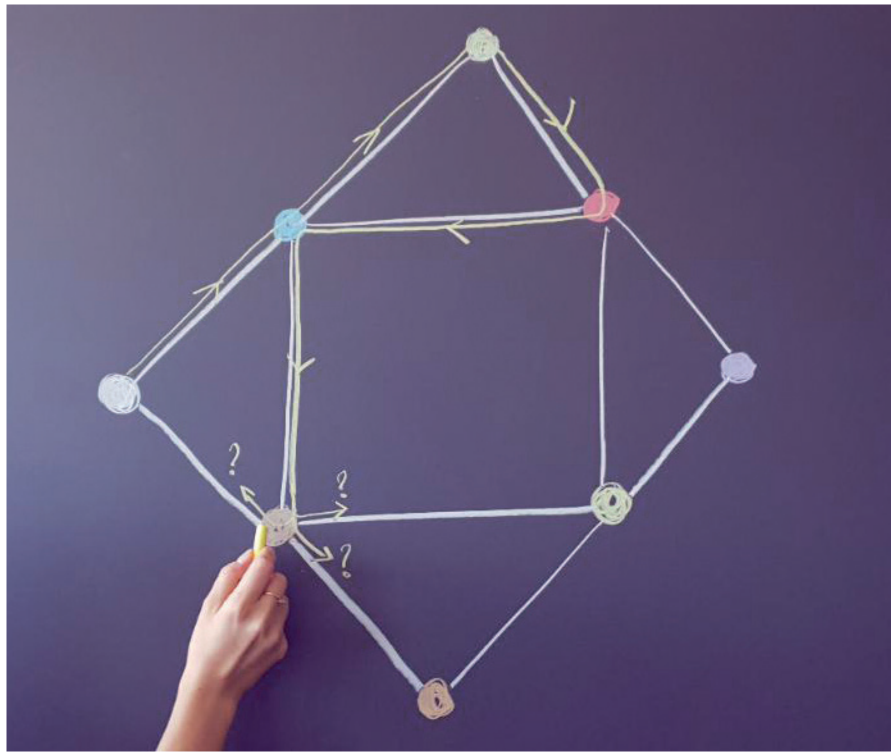
Matheminecraft, now freely available to everyone, is a video game around Eulerian graphs with a tutorial and four levels. The project was made for the Maths Outreach team with the idea that it should be ready for the EPFL Open days in September 2019. After the success encountered at the Open Days, it was decided that the game will be proposed to classes of the region as a series of ateliers organized by the Maths Outreach Team and the Science Outreach Departement (SPS). During 4 weeks, 36 classes of children – 8 to 10 years old– registered to visit EPFL and took part in a two hours matinée where they played Matheminecraft and did various chemistry experiments. Minecraft is a very popular game and has been described as one of the greatest games of all time. Children immediately recognize the game and a growing roar of "are we going to play Minecraft" fills the air as they enter the room. "I think Minecraft digitally plays the same role LEGOs did in my childhood. It appeals to anyone who takes a bit of their time to dive into it" speculates David.

The idea behind the project is the following. Consider a graph: that is a drawing on a board made of dots called vertices which are linked by lines called edges. The question that is asked about graphs is: "is it possible to cross each edge exactly once, pass by each vertex at least once, and end up at the starting vertex?". The first mathematician to ask that question is the Swiss Leonhard Euler in 1736. Not only did he wonder about that, but he provided the answer, giving an exhaustive description of which graphs admit such a path and which don't.

In the Matheminecraft atelier, we try to answer Leonhard Euler's question. An easy way to introduce Eulerian cycles to schoolchildren is to ask them about figures or drawings that can be done without lifting the pen and going twice on the same line. Triangle, square, star, a plethora of examples comes to their minds. In Matheminecraft each level consists of a graph that admits an Eulerian cycle. The game uses graphs that are easy enough, in the following sense: an Eulerian cycle will be found if the gamers make sure they don't get stuck. Such graphs are quite easy to work with, making the game suited to grade-schoolers.

In the game, each vertex is represented as a large color dot and each edge as a bridge. To keep the video game spirit, and to ensure that one bridge is only crossed once, David Strütt added a "lava condition", meaning that bridges, once crossed, will turn into lava. That makes them unable to be crossed again. A map of the graph is there to help the children. Famous Minecraft animals were added to decorate the levels, such as skeleton horses and mooshrooms.

The story of Matheminecraft will not end there, as additional levels are in preparation and new series of ateliers – organized with the SPS – will take place in 2020 and 2021 Furthermore, a Matheminecraft 2.0 will see the day. It will include Eulerian trails, where the gamer will have to choose the starting point of his cycle. This would make the game harder and suitable for older grade-schoolers.



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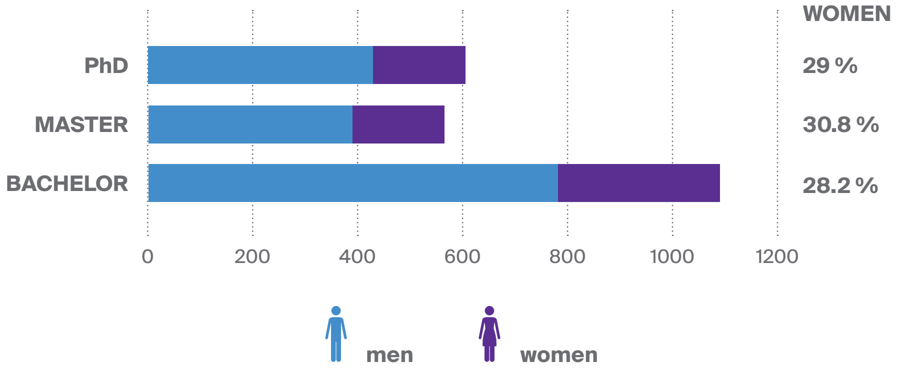
2020 IN FIGURES

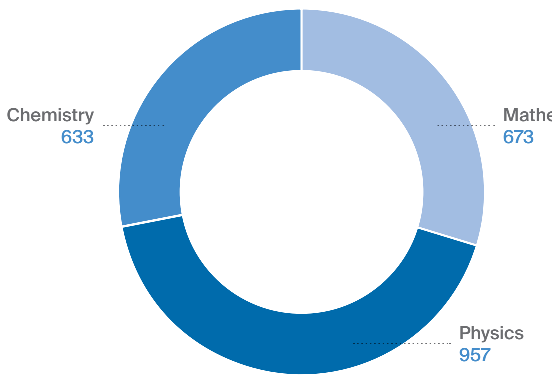
IPHYS ISIC MATH

PEOPLE

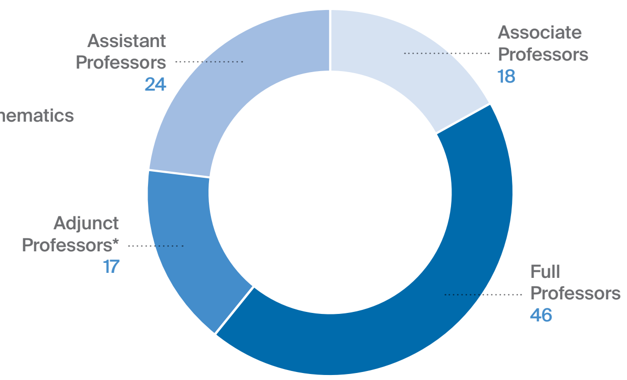
FSB Students



FSB Students (incl. PhD)

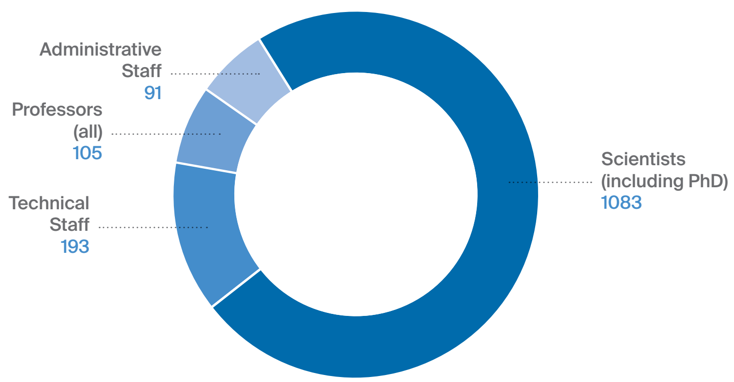


FSB Professors



* Including 1 SNSF-funded Professor

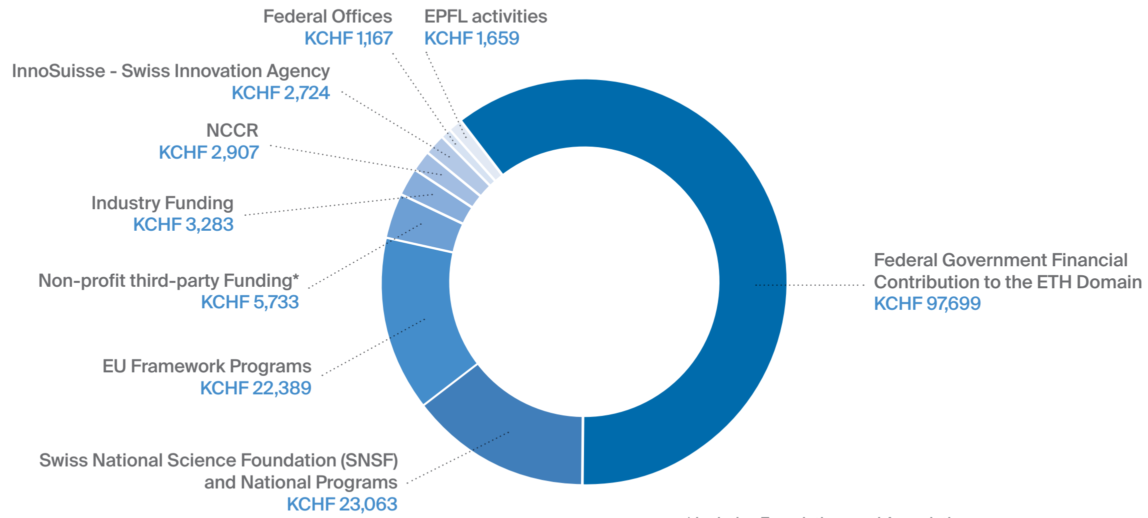
FSB Staff



FSB Staff

STAFF	TOTAL	WOMEN %
PhD students	616	29
Scientific staff / postdocs	467	25
Technical /IT staff	193	14
Administrative staff	91	70
Emeriti Professors	71	4
Full professors	46	8
Apprentices	39	5
Senior Scientists / MER	33	9
Tenure-Track Assistant Professors	24	25
Associate Professors	18	17
Adjunct Professors / Titulaires	16	25
SNSF-Funded Professors	1	0

FUNDING



* includes Foundations and Associations

KEY FIGURES

128	Research Groups
3	Research Institutes
2	Campuses
3	Doctoral Programs
2263	Students
105	Professors
784	Staff

RESEARCH

1003	Journal articles
16	Conferences papers
46	Reviews
4	Book Chapters
86	Thesis
22	Patents

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