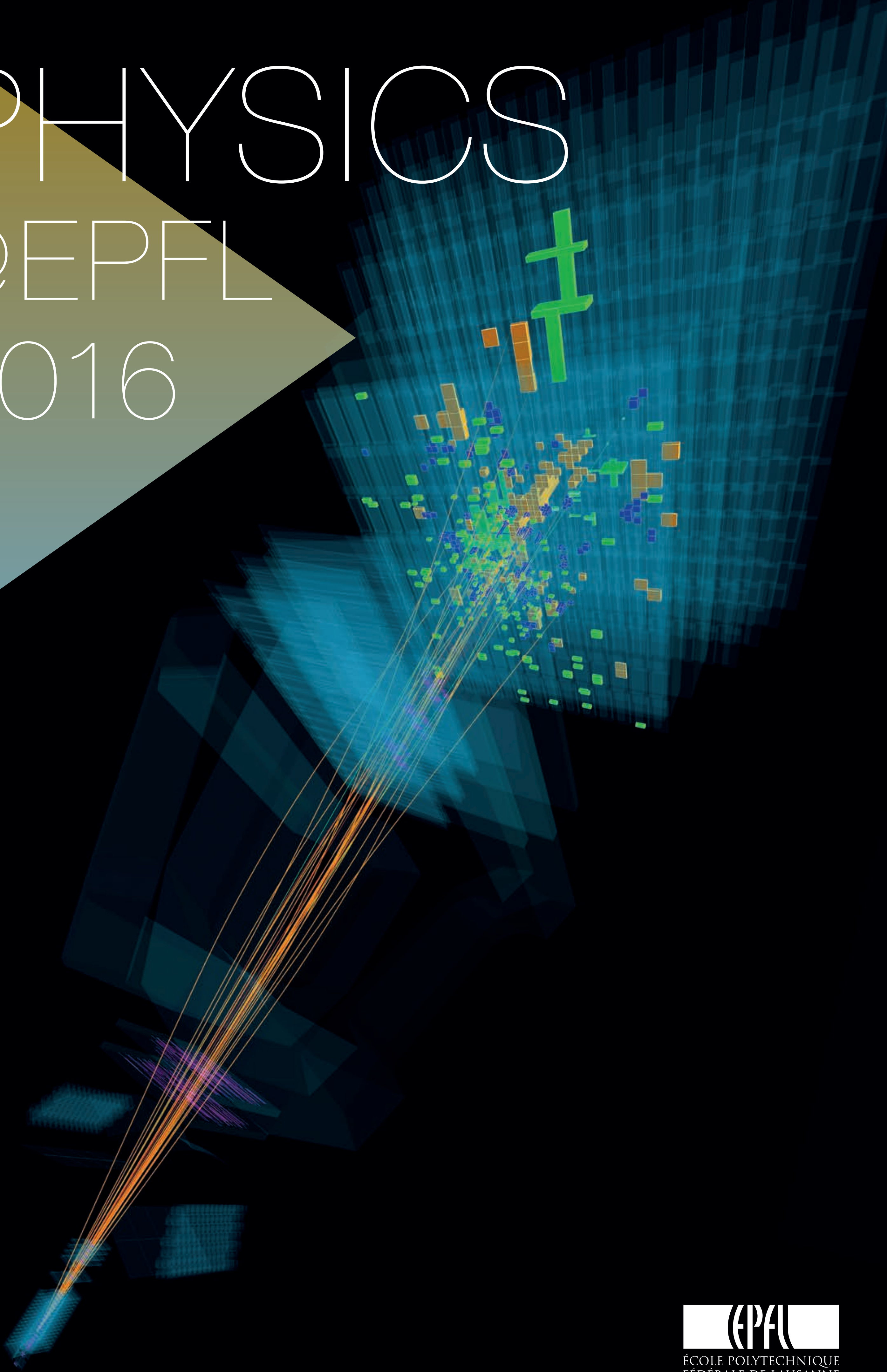
PHYSICS @EPFL 2016



ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

CONTENTS 2016

FRONT COVER
Event display of a proton-proton collision at 13TeV recorded by the LHCb detector (CERN)

LETTER OF THE DIRECTOR

I am quite proud to present here the first newsletter of the newly organized Institute of Physics of the EPFL. This brochure, which we intend to prepare each year now, will allow you to get an overview of the activities in Physics at EPFL. This year is very special indeed because this is the first year when the four former Physics Institutes, plus the Swiss Plasma Center, joined forces into a single Institute of Physics, which will allow us to improve on our synergies.

We had the pleasure to welcome 5 new colleagues over the period: Jean-Paul Kneib as a Full Professor in Astrophysics, and Jean-Philippe Brantut, João Penedones and Christian Theiler as Tenure Track Assistant professors, respectively in Atomic, Molecular and Optical Physics, Mathematical Physics and Plasma Physics. We also welcomed Alessandro Vichi, a SNSF Professeur Boursier in Theoretical Physics. This has allowed us to open the panorama of the fields that we are able to study.

As you will discover reading this issue, many important results deserve your attention. Let me first insist on teaching issues. IPhys delivers a major contribution to teaching in particular by the number of students that follow the courses given by physics teachers. Over the last years, we have considerably enhanced our course offering particularly through our contributions to the MOOCs of EPFL.

In terms of research, as the different rankings or all other indicators show, Physics at EPFL is very strong. You will see this in numbers, but also through a few stories that we have selected for you to highlight the quality and diversity of what we are doing. Not only do we publish top quality research, but also some of our results make it towards real applications and a few of these stories will be detailed.

I hope that you will enjoy learning about some of the highlights from this fantastic year. Please also visit our website **iphys.epfl.ch** for fresh news and for information concerning forthcoming events that might be of interest to you. Your comments are always welcome and we will be available at **iphys@epfl.ch**.

I should not terminate without thanking Blandine Jérôme for the organization and the production of this newsletter. This was a really demanding task.

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JOÃO PENEDONES USES HOLOGRAPHY TO VIEW OUR SPACE-TIME

João Penedones has been appointed as Tenure Track Assistant Professor for Theoretical Physics.

There exists a quadrant of theoretical physics that toys with the very notions of quantum mechanics and space-time, in the quest for a deeper understanding of the laws of physics. One aspect of that endeavour is the search for a theory of quantum gravity, which in recent decades has lead to the development of string theory. Perhaps the most astonishing result in this context has been the realization that space-time can be an emergent concept, as concretely embodied by the Anti-de-Sitter/quantum field theory (AdS/CFT) correspondence. According to AdS/CFT, quantum gravity over a 5-dimensional space-time with constant negative curvature, Anti-de-Sitter (AdS) space-time, ontologically coincides with conformal (i.e. scale invariant) quantum field theory (CFT) without gravity on a 4-dimensional space-time: quantum gravity and the 5^{th} dimension emerge as nothing more than convenient, but unnecessary, notions to describe phenomena. From the perspective of the 4-dimensional description, the 5^{th} dimension can be viewed as a holographic image of the quantum data stored in the system.

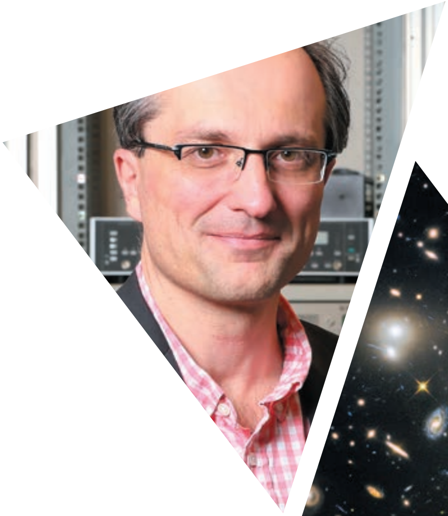
Space-time can be an emergent concept

With the hiring of João Penedones as Tenure Track Assistant Professor, EPFL has finally endowed itself with one of the young leaders of this fascinating research field. After his studies at Porto and Cambridge, and before arriving at EPFL last February, Penedones has been research associate at the Kavli Institute for Theoretical Physics (Santa Barbara), at the Perimeter Institute for Theoretical Physics (Waterloo, Canada) and at CERN.

João Penedones' main field of activity concerns gravity and the AdS/CFT correspondence, where he has already derived some groundbreaking results. Among these one should mention a technique based on Mellin transforms that both simplifies the computation of CFT correlators and elucidates their deeper physical meaning as particle scattering amplitudes for quanta propagating in the holographic 5-dimensional space-time. In another famous paper he wrote a few years ago, Penedones made very important progress towards the solution of a long standing problem concerning the very origin of AdS space-time locality in the AdS/CFT correspondence. He was basically able to prove that the freedom in the choice of the dynamics on the AdS side was in a one-to-one correspondence with the freedom on the CFT side as codified by the basic principles of quantum mechanics. In practice, Penedones' results indicate that geometry arises from quantum mechanics.

Recently João Penedones embarked on a new adventure aimed at exploring the "space" of all possible quantum field theories as characterized by their scattering matrix, the S-matrix. The new program builds from all his previous results, in particular on the use of holography to view our 4-dimensional space-time as the boundary of 5-dimensional hyperbolic space-time. This program is inserted in a multi-front effort carried out by João together with a bunch of the most active theorists of his generation and for which they have recently been awarded a very prestigious 10 M$ grant from the Simons Foundation (SEE P. 15).

Whoever feels the need to deepen this exciting research field is invited to attend the specific course on AdS/CFT and gravity João Penedones will teach every year starting in the fall of 2017.



JEAN-PAUL KNEIB EXPLORES THE DARK SIDE OF THE UNIVERSE

Professor Jean-Paul Kneib was named as Full Professor of Astrophysics in the School of Basic Sciences (SB).

Jean-Paul Kneib received his PhD in Astrophysics in 1993 at Toulouse University. He held postdoc positions at the European Southern Observatory in Chile, and then at Cambridge University. In 1996, he obtained a research position at CNRS in Toulouse. From 2002 to 2004 he was visiting professor at Caltech. He then moved back to France where he led the Cosmology group at the Laboratory of Astrophysics of Marseille. Kneib was awarded a European ERC advanced scholarship in 2012 at EPFL. In April 2016, he was nominated Director of the EPFL Laboratory of Astrophysics.

Kneib's scientific activities focus on observational astrophysics and cosmology to challenge the dark side of the Universe with new observations and reveal some of its key mysteries.

In the last 15 years, cosmological observations have shown that more than 95% of the mass and energy content of the Universe is unknown to us. Dark Matter (DM), the existence of which has been first postulated in 1933 and has now been confirmed by gravitational lensing observations, represents 80% of the mass in the Universe. However, particles of DM remain undetectable, as they do not interact (or only extremely weakly) with ordinary luminous matter (stars and gas). More recently, the measured accelerated expansion of the Universe has lead to include a new component called "Dark Energy" (DE) that represents 75% of the mass-energy budget of the Universe. Elucidating the mysteries of DM and DE is one of the biggest challenges of cosmology and fundamental physics.

Kneib has worked for more than 25 years on these issues. In particular, he has participated in the development of several techniques to probe these "dark" components.

Early works of Kneib focused on the gravitational lensing technique applied to clusters of galaxies. By modelling the latest observations coming from the *Hubble Space Telescope*, one can measure the mass of these clusters with a very high level of precision (better than 1%), revealing that 80% of their mass is indeed Dark Matter. With further analysis and the new *James Web Space Telescope* and *Euclid observations* (to be launched in 2018 and 2020, respectively), it shall be possible to put constraints on the level of interaction between DM and luminous matter.

Kneib also studied the spatial distribution of galaxies at large scales to measure accurately the accelerated expansion of the Universe. Since 2012, he coordinates the international project eBOSS (extended Baryonic Oscillation Spectroscopic Survey), conducted on the Sloan telescope (located in New Mexico). eBOSS aims for the first time at the precise measurement of the expansion of the Universe between 6 and 11 billion light years in the past using the distribution of galaxies and quasars. Kneib is also very active in the DESI, 4MOST and *Euclid projects*, which will continue in the next decade to map the 3D distribution of the galaxies in the Universe.

In 2013, he created the interdisciplinary Astrobots research group, with the goal of developing fiber-positioned robotic systems for massive spectroscopic surveys. This research group is strongly involved in the DESI and MOONS research projects, but also develops new solutions for next generation projects.

Since 2015, Kneib is leading the Swiss initiative to participate in the data intensive Square Kilometre Area project: the largest radio interferometer observatory to be built in South Africa and Australia.

JEAN-PHILIPPE BRANTUT SETS UP A QUANTUM SIMULATOR WITH COLD ATOMS

Jean-Philippe Brantut has been named Sandoz Tenure Track Assistant Professor of Atomic, Molecular and Optical Physics in the School of Basic Sciences (SB). This position has been opened thanks to the generous support of the *Fondation de Famille Sandoz.*

Before his nomination at the EPFL, Jean-Philippe Brantut obtained his PhD at the Institut d'Optique under the supervision of Alain Aspect, and has then been a post-doctoral researcher at ETH-Zurich in the group of Tilman Esslinger. He joined that lab with the aim of using atoms to simulate the motion of electrons in solids. "Following this motivation", says Brantut, "I realized that it was not only possible to simulate bulk materials, but also the entire operation of electronic devices. I started this as a side project, but after talking with a few colleagues, Tilman and I got quickly convinced that an entire new field was opening to us." Building on this original intuition, they reproduced several key experiments of electronic transport, establishing their simulation of devices as a subfield of atomic physics. Jean-Philippe Brantut pursued this line of research with an Ambizione fellowship from the SNSF and was able to observe the quantization of atomic conductance, a universal hallmark of quantum mechanics in electronic devices.

"My research is based on the laser cooling and trapping of atoms", explains Jean-Philippe Brantut. "Once atoms are cold enough, they form a *quantum gas*, which has a lot in common with electrons in a solid. Their properties are universal, so what we learn by looking at atoms in the lab applies equally well to other systems that are far harder to observe. Over the years, we have developed a wide range of techniques to engineer particular conditions and put the atoms in specific states. Quantum gases are now almost as controlled as a computer simulation: we tune the parameters, let the system evolve, and read out the corresponding behavior". Such systems are now referred to as *quantum simulators*, to highlight their ability to simulate the behaviour of quantum systems with widely controllable conditions.

Atoms in a quantum gas tell us how electrons behave in electronic devices.

"My first goal is to build a new quantum simulation machine. Even twenty years after the first observation of a quantum gas, building such a setup remains quite a complicated task, likely to take a couple of years". The main conceptual change that Jean-Philippe Brantut will introduce is the ability to look at gases without disturbing them. This will open a new window for the study of the time evolution of complex quantum systems, a problem that cannot be solved using classical computer simulations.

"It is a privilege to work in the environment of EPFL, which offers the very best infrastructure for research" comments Jean-Philippe. "At the same time, I look forward to the contact with students: I had a very good time here as a student and it is a special feeling to come back as a teacher. I also would like my lab to be a place where the best hands-on education is provided. With the fast expansion of online courses, the opportunity of face-to-face teaching has more value than ever".

INNOVATION

Nano-watermark sorts fake from genuine

Nanoga, an EPFL-based startup, developed a nanoscopic watermark that can be added on glass or ceramic. It can only be seen under ultraviolet light, and is impossible to counterfeit.

The technique was developed at EPFL after Nanoga's CEO, Nasser Hefyene, contacted Professor Nicolas Grandjean, head of EPFL's Laboratory of Advanced Semiconductors for Photonics and Electronics. Using lithographic printing, expensive machinery, and a patent-protected recipe of chemicals, the developers can etch a nano-sized image that is invisible to the naked eye and can only be seen under UV light.

The watermark itself is a series of layers of atoms more than 10,000 times thinner than a hair, and does not affect the material's properties in any way. In a machine normally used to make LEDs, the substances are deposited onto the surface as a vapor. Using lithographic printing, certain areas are then activated in order to form the watermark. The activated atoms that have been activated react when exposed to UV light, instantly revealing themselves to the human eye.

The nano-scale lithographic printing means that discrete details can be added, invisible even under UV light, no bigger than a grain of sand, which can only be seen with a very strong magnifying glass. Forging the watermark would be as complicated as trying to forge a Swiss 50-franc note.

AWARDS

APS FELLOW

Tobias Kippenberg elected APS Fellow

Professor Tobias J. Kippenberg has been elected a Fellow of the American Physical Society (APS).

The American Physical Society (APS) is the world's largest organization of physicists. It was founded in 1899 with the aim "to advance and diffuse the knowledge of physics". This year, it has elected into its Fellows Professor Tobias J. Kippenberg, Director of EPFL's Laboratory of Photonics and Quantum Measurements (SB/STI): *"For his pioneering contributions to the science and applications of high Q optical micro-resonators in cavity quantum optomechanics and optical frequency metrology"*.

Tobias J. Kippenberg's research concerns the science and applications of high-Q optical microresonators. These are devices that store light for extended amounts of time in micron- and nano- scale volumes, and that Kippenberg's lab fabricates at EPFL's Center for Micro-Nanotechnology. Using microresonators, he studies the fundamental interaction of mechanical vibrations and light via the radiation pressure force, as well as applications in frequency metrology.

In addition, his work also focuses on a new class of microresonator-based optical frequency combs ("micro-combs" or "Kerr combs"), that can be used in metrology, spectroscopy and telecommunications, and which offer compact form factor in computer design, chipscale integration, and operation over broad bandwidth from the visible to the mid-infrared spectral range.

PROMOTIONS

Suliana Manley: Visualizing the inner workings of the cell.

Suliana Manley has been promoted Associate Professor in April 2016.

Suliana joined Physics at EPFL in 2009, after a PhD at Harvard, followed by postdoctoral tenures at MIT and at the National Institutes of Health. There, working with Jennifer Lippincott-Schwartz and Eric Betzig, she took part in the first explorations of the incredible possibilities opened by the then newly developed super-resolution microscopy techniques, for which Betzig himself, together with Stephan Hell and William Moerner, have won the Nobel Prize in Chemistry in 2014. Super-resolution microscopy allows the visualization and tracking in the cell of individual molecules, such as proteins and DNA, as well as resolving cellular features below the wavelength of light, which was not accessible to traditional microcopy.

In her laboratory Suliana uses super-resolution microscopy to obtain a precise and quantitative understanding of the inner workings of the cell, thus overcoming crucial barriers in building comprehensive physical models of living organisms. Her work brings together physics techniques with the chemical biology tools necessary to investigate fundamental biophysical questions.

The complexity of the biophysical problems that she addresses also represents a technological challenge. She has made several breakthroughs, extending super-resolution techniques in the area of high-throughput, automated microscopy, which is enabling exciting biological findings in diverse areas such as chromatin organization and cell division.

CHRISTIAN THEILER TACKLES THE BOUNDARY PLASMA CHALLENGE

Christian Theiler has been appointed Tenure-Track Assistant Professor of Plasma Physics.

The boundary region of magnetically confined fusion plasmas is of critical importance for the development of fusion as a clean, save, and virtually inexhaustible energy source. Its dynamics determines to a large extent the quality of the confinement of the superhot, 100 million °C plasma and also defines the extent of plasma interaction with the surrounding vessel, which needs to be controlled to avoid erosion or even melting.

The heat which constantly leaks out of the confined plasma usually gets deposited on a relatively narrow layer of the vessel in a competition of transport along and across magnetic field lines. During his PhD on the basic plasma device TORPEX at EPFL, Christian Theiler has studied the turbulent edge plasma and the resulting transport based on optimized probe techniques. He has in particular focused on coherent structures emerging from the turbulence, called blobs; their generation and propagation mechanism and ways to control them. A highlight of this research is an experimentally validated analytical expression for their cross-field velocity.

During a subsequent postdoctoral stay at the Alcator C-Mod tokamak at MIT, Christian Theiler has developed and performed spectroscopic measurements to probe edge transport barriers, regions of reduced turbulence-driven energy losses that can form spontaneously in the outermost region of the core plasma. This gave new insight on the structure of transport barriers and in particular revealed unexpected variations of plasma parameters along the field.

Christian Theiler's current research interest focuses primarily on ways to improve the boundary plasma by modifying the magnetic geometry. In the simplest configuration, the plasma directly touches the wall. A more sophisticated solution is to divert the plasma-wall interaction to locations more remote from the core plasma. A big advantage of such diverted geometries is that, as plasma flows along the magnetic field towards the wall, it can cool down and strongly interact with neutral gas and impurity ions. This results in volumetric power dissipation, which allows to distribute the exhaust heat over a much larger area. If cold enough, the plasma can even be almost entirely extinguished in the divertor and thus detach from the wall.

We know today that such a detached plasma will be necessary in a reactor. However, there is a fine balance between sufficient levels of detachment to protect the wall and the start of a degradation of the edge transport barrier and the entire core plasma. Whether this challenge can be mastered in standard divertors or if alternative solutions with more complex geometries are needed is a number one question today.

"And this is exactly the question we are addressing in my group at the Swiss Plasma Center at EPFL" says Christian Theiler. "The main experimental facility is the TCV tokamak, which excels by an unmatched flexibility of the plasma shape". In collaboration with the entire team at the center and extensive international collaborations, they attack the boundary plasma challenge by designing and conducting new experiments, building new diagnostics, and benchmarking their results with analytical and complex numerical simulations.

"Being able to pursue exciting and fascinating research on a major experimental facility and at the same time contribute to the development of an alternative energy source is just a perfect combination" comments Christian Theiler. "I'm extremely grateful for this opportunity and look very much forward to the next years!"

INNOVATION

Using nanostructured filters to reduce shipping pollution

Cargo ships are among the leading sources of pollution on Earth. But stricter sulfur emission standards will take effect from 2020. Developing a nanostructured filter for use in ships' exhaust stacks, an EPFL start-up may offer a low-cost solution for meeting the new targets.

Around 55,000 cargo ships ply the oceans every day, powered by a fuel that is dirtier than diesel. And owing to lax standards, maritime transport has emerged as one of the leading emitters – alongside air transport – of nitrogen oxide and sulfur. But the International Maritime Organization has enacted tighter emission limits, with new standards set to take effect in 2020. In response, an EPFL start-up is developing a low-cost and eco-friendly solution: a filter that can be installed in the ships' exhaust stacks. The start-up, Daphne Technology, could do well on this massive market.

The main challenges now are to figure out a way to make these filters on large surfaces, and to bring down the cost. It was at EPFL's Swiss Plasma Center that researcher Mario Michan found a nanostructured filter that uses plasma to deposit thin layers of substances to cut sulfur emissions below 1% and nitrogen oxide emissions to 15% of current standards. This is a major improvement, as the new standards will require an approximately 14% reduction in sulfur emissions.

The next step is to produce a prototype that can be tested under real-world conditions. Meanwhile an EPFL patent on the technology was filed in 2016.

AWARDS

Fabrizio Carbone wins the University Latsis Award

The award distinguishes his thesis entitled "Ultrafast phenomena in solids and nanostructures" and was given *"for his major contributions in the field of femtosecond time resolved electron microscopy, and in particular in the dynamical study of the electronic and plasmonic excitations of solids."*

Microscopy is among the most dated techniques for observing nature at scales below the human eye's abilities. Pictures of cells, viruses, microelectronic circuits or nano-objects can be routinely obtained. In recent years, movies of molecular motions all the way down to the atomic spatial and temporal scale have been obtained with ultrafast X-ray photons or electron sources. Carbone's laboratory uses electron-based techniques to film the transformation of materials and nanostructures upon light excitation. In particular, they can record movies of a form of light termed surface plasmon polariton (SPP), which holds promise for future applications in optoelectronic circuits.

Thanks to their novel methodology that allows to take snapshots of plasmonic fields projected onto space and energy coordinates, simultaneous spatial and spectroscopic information can be gained, providing a unique insight into the properties of electromagnetic fields confined in spaces smaller then their wavelength. This technique also provided a snapshot of the electromagnetic field in which both its interference and quantization properties are visible. Light was used in addition for the spatial manipulation of such plasmonic fields in single nano-wires and nano-cavities.

PROMOTIONS

Paolo Ricci unravels the complexity of plasma turbulence

Paolo Ricci was named Associate Professor in Plasma Physics in August 2016.

After obtaining his Master's degree in Nuclear Engineering at the Politecnico di Torino in 2000, Paolo conducted his PhD at the Los Alamos National Laboratory. After a postdoc at Dartmouth College, he joined the EPFL's Swiss Plasma Center (SPC) as a Marie Curie fellow in 2006. He is now at the head of the SPC theory group where he focuses on turbulence in fusion plasmas.

A deep understanding of the plasma dynamics in fusion experiments is essential to provide an interpretation of their results and offer suggestions for their improvement. A plasma is an extremely complex medium, characterized by nonlinearly coupled phenomena occurring on a wide range of temporal and spatial scales. Consequently, plasmas are typically turbulent, and much more complex than standard neutral fluids because of the interaction with electric and magnetic fields. Paolo's activity focuses on plasma turbulence at the edge of fusion devices, where plasma temperature, around ten times higher than the one in the center of the Sun, drops to room temperature in a few centimeters. To get insight into the nonlinear phenomena associated with this extremely steep temperature gradient, probably the steepest in the whole Universe, Paolo develops analytic theories, together with simulation codes running on some of the most powerful existing computers.

Graduation Day

Graduation Day is always one of the highlights of the year. Students get finally in their hands the degree for which they have worked so hard over the past couple of years, parents get a boost of pride in seeing the success of their offspring, and teachers get a sense of fulfilled duty as a whole class of students is ready for their next challenge.

The EPFL Graduation Day 2016 was no different. It was definitely a great moment for the Physics Section that could look back at a very successful year. This year the section delivered 71 bachelors degrees and 78 masters degrees. These numbers are expected to grow in the future as Physics studies are increasingly appreciated in the EPFL community. In the new Academic year 2016-17, the Physics Section had a record increase in the number of freshmen of 42%.

We warmly congratulate all our students for getting their degrees. We are especially proud of our students who earned a special distinction. Fiona Seibold was awarded a prize for her top 3rd grade point average (5.91) of all EPFL masters and Victor Gitton got the best grade of all EPFL at the propedeutic exam. Martin Millon was awarded the Hausmann prize for his master thesis (SEE ARTICLE P. 21).

We are already looking forward to Graduation Day 2017. In the meantime, students and teachers alike are busier than ever. Physics teaching is not limited to the Physics curriculum, as over 4500 students of various sections and even UNIL attend introductory physics courses every year. Around 3500 physics experiments per year are shown in physics auditoriums. For many students, this might be the last time they attend a physics course. All the teachers and all the staff of the Physics section are committed to make it a valuable experience.

Paolo Ricci awarded the Teacher Prize of the Physics Section

The Physics Section honours every year one teacher who has particularly excelled in this important mission.

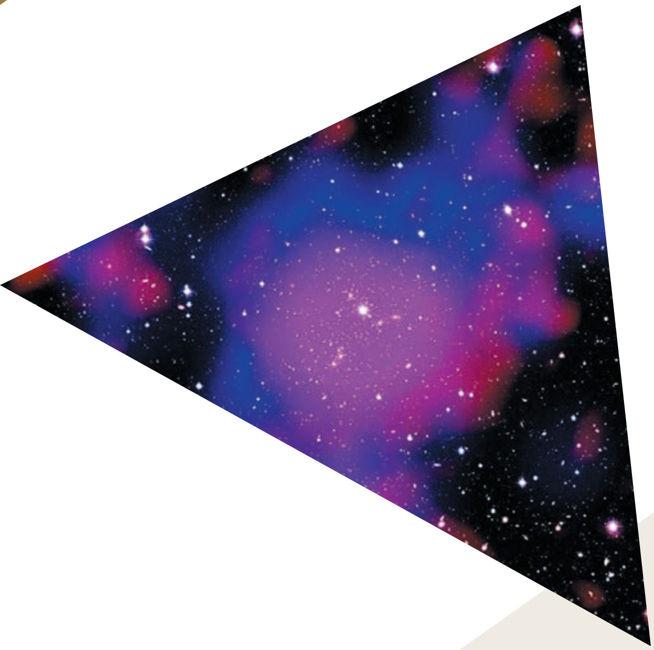
Last year, physics teachers decided that this recognition deserves a trophy that can be physically handed to Physics Teachers of the Year. Therefore Pierre Wets, head technician of the Physics Auditoriums, designed a very elegant trophy that awardees will be proud to have on their shelves.

Physics Teacher of 2016 prof. Paolo Ricci received the trophy in a ceremony preceding Graduation Day. In front of his class of 300 students, Physics Teacher of 2015 prof. Nicolas Grandjean received his trophy, retrospectively.

This award recognizes Paolo Ricci's full engagement in teaching service courses as well as in developing a MOOC on Plasma Physics.

Not surprisingly, Paolo Ricci says: "I love interacting with students, deriving great satisfaction from motivating them. I learn a lot from the students' questions, comments, and their refreshing views. As a matter of fact, I deeply enjoy being able to explain things and, if it works out, watch students understand."

Paolo Ricci teaches, among others, Introductory Physics for the students of the Mechanical Engineering Section. About this course, Paolo Ricci says: "My goal is to show that physics is much more than an abstract set of definitions and equations. Ultimately, physics laws allow us to effectively solve problems and the ability to use them critically will be one of the students' most important assets in their professional life."



FINDING MISSING MATTER IN THE COSMIC WEB

Astronomers from EPFL and the University of Geneva show that the universe's missing "ordinary matter" is found in the form of a very hot gas in intergalactic filaments.

Most physical objects are made up of a type of matter known as "ordinary". Nonetheless, ordinary matter corresponds to only 5% of the universe, but about half of this lies beyond our means of detection. Computer simulations predict that the unseen part of ordinary matter should be located in the "cosmic web": galaxies and galaxy clusters linked in a gigantic filamentary network, with temperatures between 100,000 and 10 million degrees Celsius. A team of researchers including the Laboratory of Astrophysics of EPFL have shown that most of the missing ordinary matter is found as a very hot gas associated with intergalactic filaments. The discovery is published in Nature.

Galaxies tend to group together and then congregate into galaxy clusters held together by gravity. But galaxy clusters also contain large amounts of hot gas and even larger amounts of invisible dark matter. The distribution of ordinary matter in the Universe is not homogeneous. Instead, under the action of gravity, matter is concentrated into filamentary structures, forming a network of knots and links called the "cosmic web".

Galaxies and galaxy clusters are located within a giant filamentary network, where the biggest clusters are located in the densest hubs. The cosmic web is mostly made up of dark matter and some ordinary matter; computer simulations indicate that it acts as the "scaffolding of the cosmos" – a framework where stars, galaxies and clusters can form and evolve.

Astrophysicists from UNIGE and EPFL (Laboratory of Astrophysics) have now discovered that the cosmic web contains the missing ordinary matter of the universe.

The researchers observed a massive galaxy cluster called Abell 2744 using the European Space Agency's (ESA) XMM-Newton X-ray space telescope, which can detect the signature of very hot gases by their X-ray signature.

Drawn by gravitational forces, matter is concentrated into the filamentary structures that make up the cosmic web. The areas that experience the highest gravitational force collapse to form the "knots" of the network. Abell 2744 is one such knot. Like in a neural network, these knots connect to one another through filaments.

Observing the filaments with the XMM-Newton telescope, the researchers detected the presence of gas. With that, they also found the missing part of ordinary matter, which the field refers to as "missing baryons".

The astrophysicists pointed XMM in the direction of the areas where they suspected to find the presence of filaments, and therefore, the presence of hot gas structures at temperatures of 10 million degrees Celsius. For the first time ever, they were able to measure the temperature and density of these structures, and found that they corresponded to the predictions of previous computer simulations.

This work involved collaboration between EPFL's Laboratory of Astrophysics (Observatoire de Sauverny), UNIGE's Department of Astronomy, INAF - IASF Milano, the University of KwaZulu-Natal (Durban SA), Aix Marseille Université (CNRS-LAM), Argelander-Institut für Astronomie (Bonn), and the Lyon Observatory (Université Lyon).

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A TINY RING THAT PRODUCES LIGHT PULSES

Researchers led by EPFL have made a tiny, ring-shaped device that can generate a pulsed laser signal. Their work could be used in telecommunications applications and in chemical analysis.

Solitons are a type of wave that, unlike other waves, retains its shape even as it moves further away from its source. Soliton waves of light are of great interest because they can produce evenly spaced frequencies of light, like the teeth of comb. These "frequency combs" can be used in technologies that require widely spaced frequencies, such as telecommunications and chemical analysis. Researchers led by EPFL have successfully produced light solitons with a small chip-based device, setting a new record in the field. This unprecedented work was published in *Science* [1].

The project was led by Victor Brasch and Michael Geiselmann at Tobias J. Kippenberg's lab, working with colleagues at the Russian Quantum Center. To generate the solitons, the scientists used microscopic ring-shaped structures made from very fine silicon nitride. These are called "microresonators", and have been Kippenberg's expertise for years.

Microresonators are coupled to a laser, and can store light coming from it for a few nanoseconds. "This period of time is enough for the light to circumnavigate the ring thousands of times and to accumulate there, which greatly increases the intensity of the light," explains Kippenberg. The interaction between the microresonator and the light becomes non-linear. The laser, which is normally continuous by nature, is converted into ultra-short pulses: solitons.

The light is made up of a range of frequencies, which can be thought of as different colors. In the microresonator, the frequencies are separated very precisely by the same distance, producing something that looks like the regular spacing between the teeth of a comb, hence the name of "frequency comb".

By adjusting the microresonator manufacturing parameters, the researchers were also able to broaden the generated frequency spectrum over two thirds of an octave compared with the frequency of the incoming laser (an octave refers to either double or half the frequency); in other words, it allows the comb to have more teeth. The achievement sets a new record for these microresonators.

A field that stands to gain from this work is optical communications. Using this approach, a single laser would be enough to create a range of individual frequencies that could carry information separately, even through the same optical fiber. Chemical spectroscopy and atomic timekeeping are other potential applications.

This work is part of a very fruitful collaboration between Kippenberg's laboratory and the group of Michael Gorodetsky at Lomonosov Moscow State University. In a publication in *Nature Physics*, they also reported a way to precisely control the dynamics and number of solitons in nonlinear optical microresonators [2].

All the microresonator samples used in this work were manufactured at EPFL's Centre for MicroNanotechnology (CMi). The work included contributions from the Lomonosov Moscow State University. The project was funded by the European Space Agency, the Swiss National Science Foundation, DARPA and USAF.

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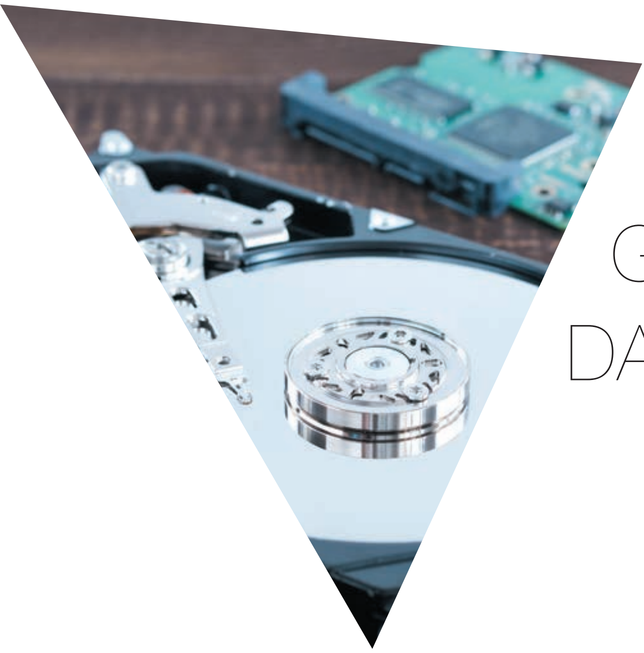

A SINGLE-ATOM MAGNET BREAKS NEW GROUND FOR FUTURE DATA STORAGE

Scientists at EPFL and ETH Zurich have built a single-atom magnet that is the most stable to-date. The breakthrough paves the way for the scalable production of miniature magnetic storage devices.

Magnetic storage devices such as computer hard drives or memory cards are widespread today. But as computer technology grows smaller, there is a need to also miniaturize data storage. This is epitomized by an effort to build magnets the size of a single atom. However, a magnet that small is very hard to keep "magnetized", which means that it would be unable to retain information for a meaningful amount time. In a breakthrough study published in *Science*, researchers led by EPFL and ETH Zurich have now built a single-atom magnet that, although working at around 40 Kelvin (-233.15 °C), is the smallest and most stable to date.

Magnets work because of electron spin, which is a complicated motion best imagined as a spinning top. Electrons can spin up or down (something like clockwise or anti-clockwise), which creates a tiny magnetic field. In an atom, electrons usually come in pairs with opposite spins, thus cancelling out each other's magnetic field. But in a magnet, atoms have unpaired electrons, and their spins create an overall magnetic field.

A challenge today is to build smaller and smaller magnets that can be implemented in data storage devices. The problem is something called "magnetic remanence", which describes the ability of a magnet to remain magnetized. Remanence is very difficult to observe from a single atom, because environmental fluctuations can flip its magnetic fields. In terms of technology, a limited remanence would mean limited information storage for atom-sized magnets.

A team of scientists led by Harald Brune at EPFL and Pietro Gambardella at ETH Zurich, have built a prototypical single-atom magnet based on atoms of the rare-earth element holmium. The researchers placed single holmium atoms on ultrathin films of magnesium oxide, which were previously grown on a surface of silver. This method allows the formation of single-atom magnets with robust remanence. The reason is that the electron structure of holmium atoms protects the magnetic field from being flipped.

It is very hard to observe magnetic remanence from a single atom

The magnetic remanence of the holmium atoms is stable at temperatures around 40 Kelvin (-233.15 °C), which, though far from room temperature, are the highest achieved ever. The scientists' calculations demonstrate that the remanence of single holmium atoms at these temperatures is much higher than the remanence seen in previous magnets, which were also made up of 3-12 atoms. This makes the new single-atom magnet a worldwide record in terms of both size and stability.

This project involved a collaboration of EPFL's Institute of Condensed Matter Physics with ETH Zurich, Swiss Light Source (PSI), Vinča Institute of Nuclear Sciences (Belgrade), the Texas A&M University at Qatar and the European Synchrotron Radiation Facility (Grenoble). It was funded by the Swiss National Science Foundation, the Swiss Competence Centre for Materials Science and Technology (CCMX), the ETH Zurich, EPFL and the Marie Curie Institute, and the Serbian Ministry of Education and Science.

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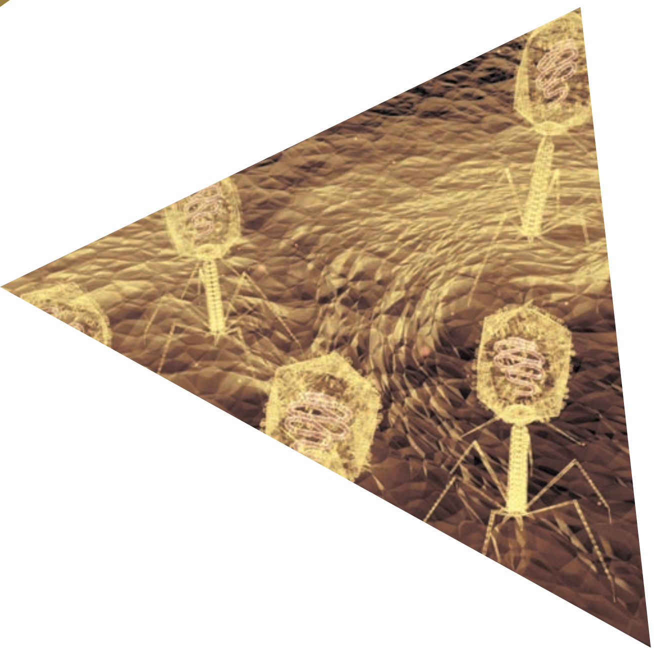

HOW VIRUSES INFECT BACTERIA: A TALE OF A TAIL

Bacteriophages are viruses that infect bacteria. Using state-of-the-art tools, EPFL scientists have described a million-atom "tail" that bacteriophages use to breach bacterial surfaces. The breakthrough has major implications for science and medicine, as bacteriophages are widely used in research.

To infect bacteria, most bacteriophages employ a 'tail' that stabs and pierces the bacterium's membrane to allow the virus' genetic material to pass through. The most sophisticated tails consist of a contractile sheath surrounding a tube akin to a stretched coil spring at the nanoscale. When the virus attaches to the bacterial surface, the sheath contracts and drives the tube through it. All this is controlled by a million-atom baseplate structure at the end of the tail. EPFL scientists have now shown, in atomic detail, how the baseplate coordinates the virus' attachment to a bacterium with the contraction of the tail's sheath. The breakthrough has made the cover of *Nature*, and has important implications for science and medicine.

145 chains of 15 proteins modeled at the atomic level

Phages are widely distributed on the planet. They accompany bacteria everywhere – in the soil, water, hot springs, algal bloom, animal intestines etc – and have a dramatic impact on the diversity of bacterial populations, including for example, the microbiome of the human gut. Phages are also indispensible tools in genetics and molecular biology, and are even being developed as an alternative to antibiotics. However, the mechanisms by which these viruses attach to their host cells and deliver their genetic material remain poorly understood.

The laboratory of Petr Leiman at EPFL has now created a detailed, atom-level model of the transformation of a phage's baseplate, an important structure that controls the phage's ability to find its target bacterium and attach to it, contract its tail, and inject its DNA. The entire baseplate-tail-tube complex consists of one million atoms, making up 145 chains of 15 different proteins, most of which had to be modeled from scratch. To do this, Nicholas Taylor and Ricardo Guerrero-Ferreira, two postdoctoral fellows in Leiman's lab, first acquired high-resolution data using state-of-the-art equipment of the Center for Cellular Imaging and NanoAnalytics (C-CINA) at the University of Basel. Then, Nicholas Taylor, the first author of the Nature paper, analyzed the data with the help of EPFL's High Performance Computing facilities. The scientists were also able to identify a minimal set of molecular components in the baseplate that work together like miniature gears to control the activity of the virus' tail.

"These findings set a benchmark for the complexity of biological systems that can be described at the atomic level," says Leiman. The human body contains almost as many bacteria as human cells (30-40 trillion), and the human gut microbiota will likely represent an important target for personalized medicine in the future. "It is clear that we need to understand the detailed mechanisms by which these bacteria interact with each other and how phages are involved in these interactions."

This study is a collaboration of EPFL's Laboratory of Structural Biology and Biophysics with the Center for Cellular Imaging and NanoAnalytics (C-CINA) at the University of Basel. It was funded by EPFL, University of Basel, NCCR TransCure, and the Swiss National Science Foundation.

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Mikhail Shaposhnikov awarded an ERC Advanced Grant

Professor Mikhail Shaposhnikov was awarded an Advanced ERC grant for his project "From Fermi to Planck: a bottom up approach".

These Advanced ERC grants are designed to allow outstanding research leaders of any nationality and any age to pursue groundbreaking, high-risk projects in Europe. The scheme targets researchers who have already established themselves as top independent research leaders. The grant was shared between EPFL, which leads the project, Leiden University (Prof. A. Boyarsky) and Niels Bohr Institute (Prof. O. Ruchayskiy).

The Standard Model of particle physics is a hugely successful theory that has been tested in experiments at ever increasing energies, culminating in the recent discovery of the Higgs boson. Nevertheless, some major riddles cannot be addressed by the Standard Model, such as neutrino oscillations, the existence of Dark Matter, and the absence of antimatter in the Universe.

New fundamental principles, interactions and as-yet-unknown particles are required to address these questions. Much of the research during the last three decades on physics "beyond the Standard Model" (BSM) has been driven by attempts to find a "natural" solution of the hierarchy problem: why the Planck and the electroweak scales are so different. The most popular approaches to this problem predict new particles with the masses right above the electroweak scale.

This project explores an alternative idea that the absence of new particles with masses between the electroweak and Planck scales, supplemented by extra symmetries (such as scale invariance) may itself explain why the mass of the Higgs boson is much smaller than the Planck mass. This calls for a solution of the BSM problems by extremely feebly interacting particles with masses below the electroweak scale. Along the same lines, the researchers will also explore the possibility that cosmological inflation does not require a new field, but is driven by the Higgs field of the Standard Model.

The proposed model offers solutions for BSM puzzles and is among a few ones that can be tested with existing experimental technologies and are valid even if no evidence for new physics is found at the Large Hadron Collider.

Constructing such a theory requires consolidated efforts in domains of high-energy theory, particle physics phenomenology, physics of the early Universe, cosmology and astrophysics as well as analyses of the available data from previous experiments and from cosmology. The researchers aim to make predictions and establish the sensitivity goals for future high intensity experiments.

AWARDS

Two New Simons collaborations funded

Professors Matthieu Wyart and João Penedones are each part of a collaboration established to shed new light on long-standing theoretical problems.

Matthieu Wyart is part of the Simons Collaboration on Cracking the Glass Problem, directed by Sidney Nagel of the University of Chicago (USA). Glass — the prototypical and ubiquitous amorphous solid — inhabits an incredibly complex energy landscape in which systems are often stranded far from equilibrium. Dealing with so many relevant energy minima has emerged as one of the central problems of statistical physics and requires the invention of a new set of tools and concepts. Matthieu Wyart's focus is the classification of the elementary excitations controlling the linear and the plastic response in amorphous materials.

João Penedones is part of the Simons Collaboration on the Non-Perturbative Bootstrap, directed by Leonardo Rastelli of the Yang Institute for Theoretical Physics, Stony Brook (USA). Quantum field theory (QFT) is a universal language for theoretical physics, describing phenomena ranging from the early universe inflation to superconductivity in terrestrial materials. The main goal of the Simons collaboration is to map and understand the whole space of QFTs, including strongly coupled models, which requires new physical insight, mathematics, and computational tools. The main research activity of João Penedones lies in the context of the gauge/gravity duality and the conformal bootstrap approach to conformal field theory.

NEW MATERIALS TO HOST ELUSIVE WEYL FERMIONS

Weyl semimetals are a new class of materials that have been attracting the attention of the condensed matter physics community since its discovery last year in transition metal monopnictide compounds. These materials exhibit a novel topological phase of matter whose unique properties are of great interest for potential applications as well as for fundamental physics. In particular, they can host a particle that has remained elusive for more than 85 years: the Weyl fermion. The group of Prof. Oleg Yazyev is predicting novel materials realizing the Weyl semimetal phase, while the group of Prof. Joël Mesot performs photoemission spectroscopy studies of the novel materials.

Weyl fermions were predicted in 1929 by Hermann Weyl as an alternative solution to the Dirac equation. These massless particles travel at the speed of light and possess a given handedness ("left" or "right"). However, they remained unobserved until their discovery as quasiparticles in so-called Weyl semimetals.

In a semimetal, only a small number of electrons contribute to electrical conductivity. In a Weyl semimetal, these electrons are located at only a few points in momentum space called the Weyl nodes. The low-energy excitations of the electrons around these points are solution of the Weyl equation and, as such, are a realization of the Weyl fermions. The presence of Weyl fermions in a material has important implications for its potential use in new technological applications, such as fast and efficient electronics, spintronics and quantum computing.

The existence of Weyl semimetals was first predicted by theorists, shortly after the discovery of topological insulators. Two independent groups in Beijing and Princeton later proved in 2015 that compound TaAs hosts Weyl nodes, triggering a vast research activity. At IPhys, experiments performed by the group of Joël Mesot, in collaboration with the computational condensed matter group of Oleg Yazyev, confirmed the presence of a Weyl semimetal phase in two other compounds, TaP and NbP [1].

To observe Weyl fermions, experimentalists use angle-resolved photoemission spectroscopy (ARPES), which is able to probe the electronic structure of materials. In the case of Weyl semimetals, the electrons on the surface of the crystal should be present only along an arc in momentum space, connecting two Weyl nodes. The observation of these so-called Fermi arcs is a signature of the presence of Weyl fermions.

Weyl semimetals are good candidates for fast and efficient quantum computing

To interpret the results of ARPES experiments, electronic structure calculations, as the ones performed in the group of Oleg Yazyev, are often required. More importantly, such calculations can also be used to discover new, previously unknown Weyl semimetals and thus provide an efficient alternative to experimental search. Using the high-throughput computational screening of a large database of existing materials, scientists from the group of Oleg Yazyev were able to identify new potential Weyl semimetals. In particular, they revealed that two materials, molybdenum diphosphide MoP_2 and tungsten diphosphide WP_2, host very robust Weyl fermions [2]. This research has been performed in close collaboration with physicists at ETHZ within the NCCR Marvel project focusing on computational materials discovery.

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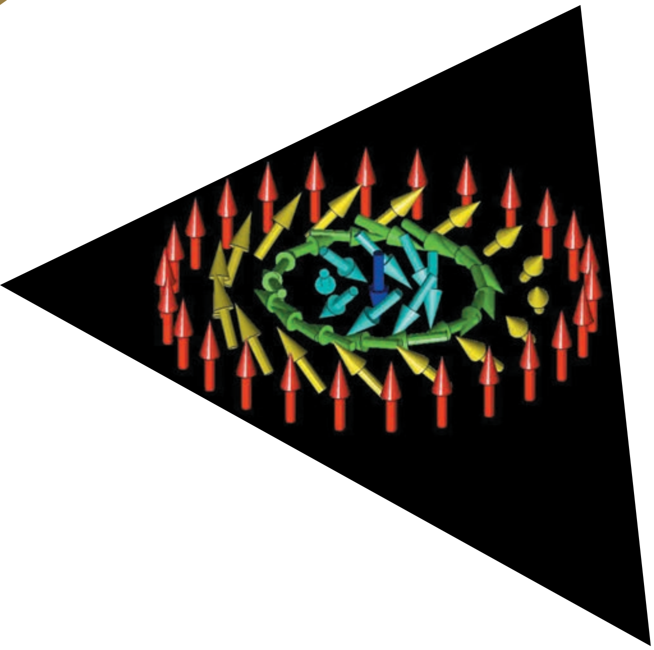

MAGNETISM WITH A TWIST

Skyrmions are electromagnetic vortices that can be used for spintronics. EPFL scientists have now discovered a material that can produce stable skyrmions in a wide range of temperatures, making it ideal for building devices.

The discovery that certain materials which tends to twist their magnetization like a spiral stair-case can host nano-sized "vortices" named Skyrmions, has sparked excitement among scientists. As we learn more about their electromagnetic properties, skyrmions are showing promise as information carriers in low-power, dense-memory devices that depend on electron spin rather than charge – a next-generation field of "spintronics".

Several laboratories at EPFL are engaged in skyrmion research. The Laboratory for Quantum Magnetism of Henrik Rønnow explores since several years the structure and dynamics of skyrmions and means to control them. For this purpose, they employ, together with the Laboratory for Ultrafast Microscopy and Electron Scattering of Fabrizio Carbone, a new technique allowing the direct imaging of their lattice dynamics. At the Department of Materials, the Laboratory of Nanoscale Magnetic Materials and Magnonics of Dirk Grundler has reported the all-electrical spectroscopy of skyrmion dynamics. These pioneering activities recently led to the creation of a Swiss Sinergia network on Skyrmionics [skyrmions.epfl.ch].

One prerequisite for using this type of materials in practical applications is their stability across a wide range of temperatures around room temperature. The Laboratory for Quantum Magnetism of Henrik Rønnow, working with colleagues at RIKEN (Japan) and Jonathan White at the Paul Scherrer Institut (Aargau), had recently discovered a material in which skyrmions are stable up to and above room temperature [1].

The material is a mix of cheap, abundant and non-toxic elements: cobalt, zinc, and manganese, and skyrmions appear at temperatures up to 130°C degrees, well above room temperature.

In their most recent article published in Nature Materials [2] they demonstrate remarkable stability of skyrmions in this material – another important property for future applications. The researchers found that cooling the material at moderate rates actually allows the skyrmions to stay stable at lower temperatures. "In practice, this means we can start with a compound where skyrmions stabilize, say, below 400 K (130°C), and then, as long as we cool it moderately quickly, they will be metastable at any temperature below that, which is perfect for applications," says Henrik Rønnow.

The material also exhibits a more fundamental peculiarity. When skyrmions appear, they normally form a kind of triangular lattice. In this material, however, the skyrmion lattice transforms into a square-like lattice. Going against all previous predictions, this is a first for the field. "It opens a new field of research into the lattice types possible for skyrmions," says Rønnow.

This work represents a collaboration between EPFL, the Paul Scherrer Institut, RIKEN, and the University of Kyoto.

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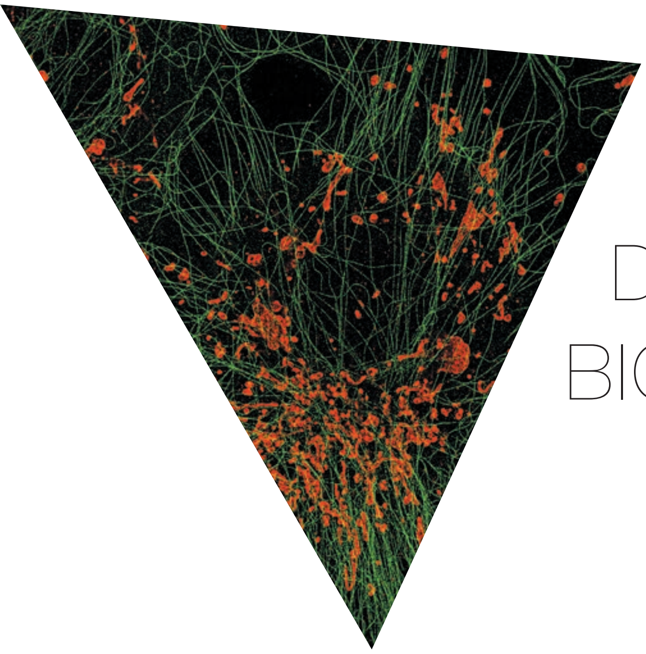

NEW MICROSCOPE OFFERS UNPRECEDENTED VIEW OF BIOMOLECULES

EPFL scientists have developed a new low-cost microscope with nano-scale resolution and an unprecedented large field-of-view. Overcoming the limitations of similar systems, the new microscope can take gigapixel-sized images of multiple cells and bacteria with nanometer-scale resolution, offering a powerful tool to observe biological processes.

One of the biggest challenges in microscopy is the natural limit of resolution imposed by light diffraction as it goes through the microscope's lenses and circular apertures. This means that anything smaller than 200 nanometers will appear blurry. When it comes to biological molecules, which can be hundreds of times smaller, this can be a real problem. EPFL scientists have now developed a new low-cost microscopy technique that can image multiple cells at the same time efficiently on a nanoscale resolution. The work is published in Nature Photonics.

Most biological processes take place on the nanoscale, but their effects travel up to the cell's level, at the microscale — and even beyond. In order to address this difference, microscopy engineers have developed "single-molecule localization microscopy" techniques, which can allow scientists to study cellular features with resolutions around 10 nm. But these techniques tend to have a very constrained field of view and non-uniform image resolution.

The lab of Suliana Manley at EPFL has now developed a new microscopy technique called "flat illumination for field-independent imaging" or FIFI. The system is based on a pair of microlens arrays and uses epi-illumination — that is, the illumination and detection occurs on only one side of the sample. The optical principle behind FIFI is an extension of the Köhler integrator. A free simulation package, published with the paper, further elucidated and modeled it.

Biological processes are inherently multi-scale

The scientists used FIFI successfully to image multiple cells and bacteria in culture. Specifically, they imaged multiple Cos7 and bacteria cells in 100×100 μm^2 single-molecule localization microscopy images, showing how the system more than quadruples the size of the field-of-view in conventional systems while producing near-gigapixel-sized, nano-scale images of uniformly high quality.

This work was funded by the National Centre of Competence in Research Chemical Biology, the European Research Council (PALMassembly), and SystemsX.ch.

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Jean-Philippe Brantut awarded an ERC Starting Grant

European Research Council
Established by the European Commission

Professor Jean-Philippe Brantut, Tenure Track Assistant Professor in Atomic, Molecular and Optical Physics, was awarded an ERC Starting Grant in the area of Physical Sciences and Engineering for his project "Devices, engines and circuits: quantum engineering with cold atoms" (DECCA).

ERC Starting Grants are designed to encourage young talented research leaders to gain independence in Europe and to build their own careers. The scheme targets promising researchers who have the proven potential of becoming independent research leaders.

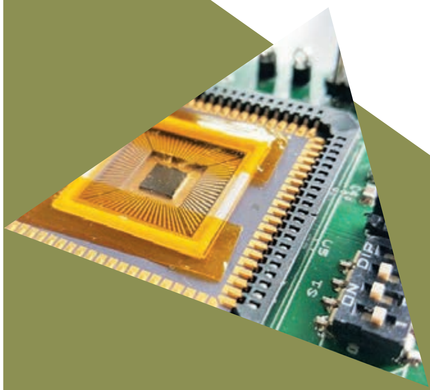
Over the last decade, cold atomic gases have become one of the best-controlled quantum systems. This novel, synthetic material is hundred billion times thinner than a solid and about a billion times colder than room temperature. By combining magnets and laser beams, it is possible to shape it at the scale of individual atoms in order to mimic a wide range of systems: atoms can be made to behave like electrons in a solid crystal, or like the coherent waves emitted by lasers.

Importantly, the system can be used to simulate some of the physics of systems with strong interactions between particles or far from thermal equilibrium, which is very hard to calculate with classical computers. This approach is known as Quantum Simulation.

The DECCA project pioneers a new approach to quantum simulations, jumping from cold atoms as a material into the realm of devices: systems carved out of cold gases, separated by interfaces, connected to each other by engineered contacts and allowing for a controlled driving. This new type of quantum simulator will be used to investigate the full operation of complex devices with quantum properties, from the precise measurements of the transport properties of matter, to the exploration of novel types of states that appear at interfaces between different quantum systems.

The ERC Starting Grant will allow for the development of a new quantum simulation machine at EPFL, with novel manipulation and detection techniques required to operate cold atoms devices.

AWARDS



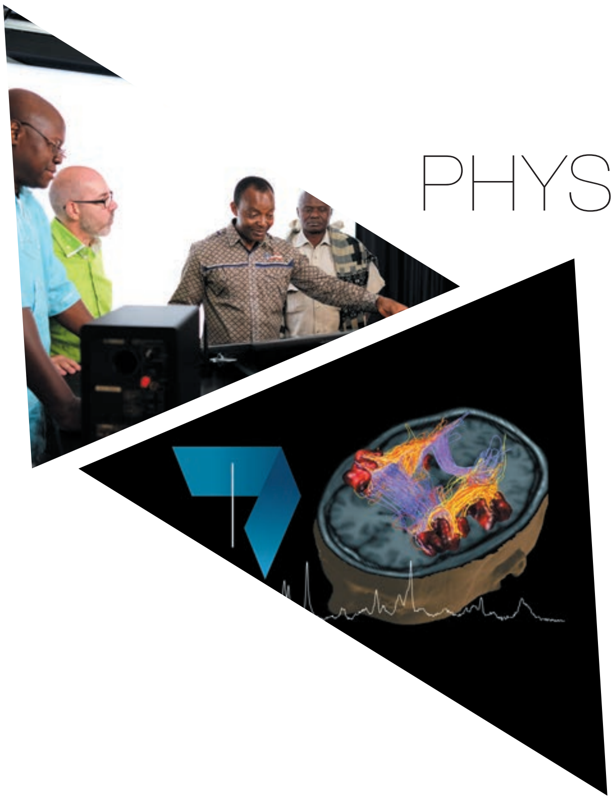
Institute of Physics is part of next-gen, quantum optics microscope

EPFL's Institute of Physics is among the members of the EU's "All Solid-State Super-Twinning Photon Microscope" (SUPERTWIN) project.

The "All Solid-State Super-Twinning Photon Microscope", or SUPERTWIN, project is a collaborative research effort funded by the European Union. Part of Horizon 2020 Framework Programme, SUPERTWIN launched on March 1st 2016 with a 3-year grant of 3.9 million Euros, and is coordinated by Fondazione Bruno Kessler (Italy) in a consortium of nine leading European experts, including EPFL's Institute of Physics (LASPE).

SUPERTWIN aims to develop a highly innovative microscopy technique that will exploit the principles of quantum photonics to overcome the limitations of existing optical microscopes. The resolution of current optical microscopes is limited at about half the wavelength of a photon, which is called the "Rayleigh limit". Overcoming the Rayleigh limit has been difficult, and it means that most objects under study first need to be prepared by treating them with fluorescent dyes.

SUPERTWIN will address the problem by developing a prototype microscope that exploits entangled photons to overcome the limits of classical optics. If successful, the SUPERTWIN microscope will introduce a radically new line of technology for super-resolution imaging devices that exploit the principles of quantum optics. The new paradigm of optical imaging is expected to trigger *"the development of novel microscopy systems that will surpass existing super-resolution microscopy techniques."*



PHYSICS IN MOOCS

The teaching of Physics at EPFL has taken a worldwide dimension several years ago with the offering of Massive Open Online Courses or MOOCs.

These are complete courses with lectures that students follow in the form of videos, assignments that students need to submit and that are evaluated and graded, and a forum on which students can interact with each other and with the teachers. One of the main differences with a usual course on campus is that all of this does not happen in a classroom but online with participants scattered all over the world.

There are a variety of Physics courses that can be taken online (see moocs.epfl.ch for details):

- Fundamentals of biomedical imaging (since 2016, in English)
- Thermodynamique (since 2016, in French)
- Plasma Physics (since 2015, in English)
- Introduction à l'astrophysique (since 2014, in French)
- Mécanique (since 2013, in French)

With their huge audience, our MOOCs contribute to the reputation of EPFL for its teaching commitment.

These MOOCs have been very successful in attracting the attention of the student community and beyond. And it is not incidental that the "M" of MOOC stands for "MASSIVE". For instance, the YouTube version of the MOOC on Mechanics has generated over 900 views per day during the semester when the course was taught at EPFL. It is interesting to note that the great majority of the participants to this MOOC already have a university degree.

Several of these MOOCs (Thermodynamics, Introduction to Astrophysics, Mechanics) are offered in the framework of MOOCS Afrique, a collaboration program aiming at strengthening higher education and continuing education in Africa. The MOOC on thermodynamics involves 11 teachers from 5 campuses located on 4 continents:

- Université Catholique de Louvain,
- Université Saint Joseph, Beirut,
- Ecole Nationale Polytechnique, Yaoundé,
- Polytechnique Montréal,
- EPFL

The success of MOOCS does not only depend on producing great videos of inspiring lectures and posting well-thought assignments for the students. The long-term challenge of running a MOOC is in the animation of the forum. The art is in balancing between bringing the expert information and letting the community interact using their own means and words. The Physics Section has hired several students to scan the forums and bring the attention of the MOOC teachers to the most challenging questions raised in the discussions.

For all the involved staff and teachers, it is very rewarding to see their courses attended by so many students all over the world. There is also a direct benefit of the huge endeavor that producing and running a MOOC represents, namely the re-engineering of courses. Physics MOOCs have been developed for courses that were already taught for many years. The MOOC, by the necessity to bring the lectures to a video format, has driven the teachers to open new perspectives in the approach of many concepts. Not to mention that, if our own EPFL students missed a lecture of did not understand some concepts, these MOOCs are also a great resource to help them catch up. This all contributes to the constant effort of our teachers to adapt their teaching to the evolution of the needs of their students, on campus or online.

Gilbert Hausmann Award attributed to Martin Millon

This award has been founded in 2015 and rewards two graduates having completed an EPFL master project and one PhD student having completed an EPFL PhD thesis in the field of mechanical engineering, electricity or physics. The three prize-winning projects should stand out through their excellence, particularly in terms of originality and the prospects that they open.

Martin Millon got the award for his master thesis entitled “Source/lens separation: application to the Hubble Frontier Fields”. He had performed his master project in the Laboratory of Astrophysics under the supervision of Frédéric Courbin and Rémy Joseph.

The project used some of the best images of distant galaxy clusters taken with the Hubble Space Telescope, known as the Hubble Frontier Fields. Using a new image processing technique based on wavelets and developed at the Laboratory of Astrophysics the goal was to separate the blue and red components of objects in the field of view. The method was used to separate the young (blue) stellar populations from the old (red) stellar populations in the galaxies of the clusters, and to separate the galaxies of the cluster from the much more distant gravitationally lensed arcs seen in their background. It is the first time such a technique is used without any assumption made on the light profile of the galaxies.

The prize consists in 5’000.- CHF, and is supported by a donation of Mr Gilbert Hausmann. It was presented during Graduation Day 2016.

AWARDS

Jiandong Feng gets the Physics Doctoral Thesis Award

Founded in 2014, the Physics Doctoral Thesis Award is given to one doctoral thesis within the EPFL Doctoral Program in Physics, which has produced a highly significant advance in physical sciences. This year, several outstanding theses in physics have been examined by a committee of experts. The Award has been attributed to Jiandong Feng, who carried out his PhD under the supervision of Prof. Aleksandra Radenovic, Head of the Laboratory of Nanoscale Biology. The title of the thesis was “Probing chemical structures and physical processes with nanopores” and Jiandong Feng has completed it at the age of 24. The Award was attributed with the following motivation: *For exceptional contributions to the applications and fundamental understanding in the field of nanofluidics and biophysics. In particular applications include: engineering innovations in nanopore based DNA sequencing and osmotic power generation, while in basic science the introduction of ionic Coulomb blockade model may contribute to our understanding of voltage-gated ion channels.*

The prize consists in 3’000.- CHF, and is supported jointly by the Physics Doctoral Program and by the School of Basic Sciences. It will be bestowed during the general assembly of the School of Basic Sciences on December 16th 2016.

AWARDS

Lina Carlini won the 2016 Chorafas Foundation Award

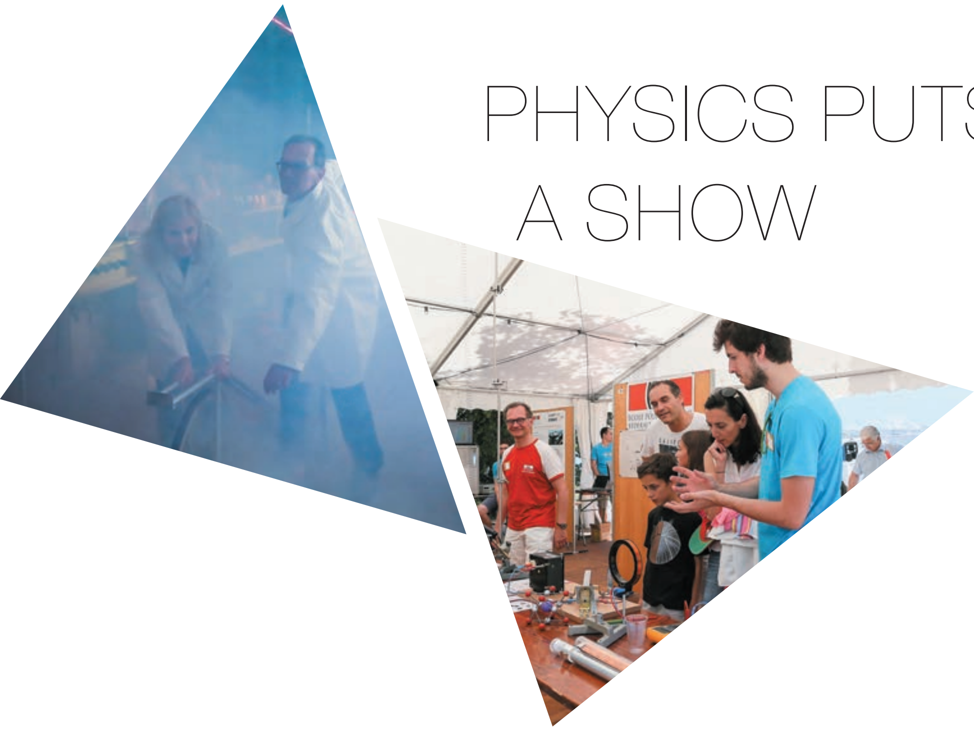
Lina Carlini got the award for her PhD thesis entitled ‘Exploring dynamic organellar shape using live-cell fluorescence super-resolution microscopy’, supervised by Prof. Suliana Manley.

The purpose of the award is to distinguish innovative and high level research in a variety of scientific fields, with a particular emphasis on applied research. It was given to Lina Carlini for *“her outstanding contributions to the field of super-resolution fluorescence microscopy, with novel discoveries revealing the fundamental physical processes of organelle dynamics in living cells.”*

In the past decade, several live-cell, fluorescence-based super-resolution imaging techniques have emerged. Among these is single-molecule localization microscopy (SMLM), which achieves unsurpassed spatial resolution compared to other fluorescence-based methods. This technique exploits the bright and dark state switching behavior of fluorophores, termed photoswitching. Despite its advantages, SMLM is limited by factors that prevent non-perturbative, fast, live-cell imaging.

Carlini developed several strategies to overcome challenges associated with live-cell SMLM. With these novel methods, Carlini could acquire live SMLM snapshots in just 2 seconds. Many of these tools could be applied to study the biophysics of mitochondrial division.

PHYSICS PUTS ON A SHOW



In the weekend of 5 and 6 November, the EPFL was unusually busy as it opened its doors to thousands of visitors eager to discover the wide variety of activities taking place on campus. During these “Portes Ouvertes”, our Physics laboratories presented all kinds of activities with great success.

Visitors could hear about the fascinating world of lasers and discover how semi-conductors revolutionize these light sources, hear astronaut Claude Nicolier talk about the discoveries made by the Hubble telescope, follow in real time the detection of cosmic particles, wonder through space with stunning movies, or get at the heart of the research facilities of the Swiss Plasma Center or the Crocus reactor. Youngsters did real experiments with the optics activities organized by the Photonics Chapter.

Some activities were presented in the framework of the yearly science festival “Festival Scientastic”, whose theme was this year “A time for everything…”. The staff of the Physics Auditoriums provided support for the demonstrators at the “Espace comment ça marche?” where visitors of all ages could discover scientific principles or phenomena interactively. As usual, the Physics Show was a great success. Following the theme of the festival, it explored time with “A la recherche du temps perdu”, taking the public all the way back to the time of Galileo through an amazing series of experiments.

If the Portes Ouvertes were a climax in terms of outreach activities, there were many other occasions during the year when physicists brought their enthusiasm for science to a wide audience.

The Physics Show is a regular highlight of EPFL science events. On the Friday preceding the Portes Ouvertes, it was performed four times for the delight of 800 young students who were on campus for the “Journées des classes”. During this yearly event, middle school students come to EPFL to discover the fascinating world of science. A Physics Show also entertained the children participating to the initiative “A la découverte des Sciences” when they came on campus with their families in June.

Come and discover the fascinating world of science

The staff of the Physics Auditoriums is prepared to take their experiments outside of campus and to bring them directly to the public. They are always present on the EPFL stand at “La Nuit de la Science”. This great outreach event is organized every other year by the “Musée d’histoire des sciences de la Ville de Genève” in the park “La Perle du Lac” on the banks of the lake of Geneva where it attracts some 30’000 visitors. This year the theme chosen by EPFL was “tout se transforme” and this was illustrated with stunning demonstrations.

Another important component of outreach activities is the continuing education program organized by the UNIL and EPFL to help high school teachers stay aware of the latest developments in science so that they can bring those over to their students. 29 physics teachers from the high schools of the canton come over to our Practical Work classrooms in February to participate in a two-day practical training in Electronics managed by the Practical Work staff and the Engineering Discovery Learning Laboratories.



Three professors retire

Professors Giorgio Margaritondo, Jean-Jacques Meister and Georges Meylan retired after a rich and successful carrier. We warmly thank them for their commitment in teaching generations of students and serving the community of EPFL and beyond.

After graduating in Rome, Giorgio Margaritondo joined the Italian National Research Council, and became a pioneer in the use of synchrotron radiation at the National Laboratory of Frascati, marking the beginning of a lifelong interest.
He next moved to Bell Laboratories, where his research married the two emerging fields of semiconductor interfaces and photoelectron spectroscopy, a research he later pursued as professor at the University of Wisconsin and Director of the Synchrotron Radiation Center. He joined the EPFL faculty in 1990, later to become Director of the Department of Physics (2000-2001). Giorgio Margaritondo has been a leading figure in the Direction team of EPFL. He was the first Dean of the Faculty of Basic Sciences (2001-2004), the first Provost (2004-2010) and then the Dean for Continuing Education. His 700 scientific publications contributed to shape fields as diverse as semiconductor physics, high-temperature superconductivity and phase-contrast microscopy. Among his 10 books, "Introduction to Synchrotron Radiation" is a classic reference. At EPFL his handout "Ma physique" brought a fresh, original view of physics to generations of students.

Jean-Jacques Meister obtained a PhD in medical physics. After a period of R&D consulting in Biomedical Engineering, he was nominated full professor of experimental physics at EPFL in 1990. His laboratory has made significant contributions in cellular biophysics and more specifically in the bio-mechanics of the vascular system. He taught very appreciated physics courses to various sections of EPFL as well as advanced biophysics lectures. He was instrumental in establishing biophysics as one of the research and teaching directions in the physics department. He served the EPFL as director of the Physics Section, director of the Institute of Applied Physics and director of the College of Sciences of the University of Lausanne.

Georges Meylan obtained a PhD in Astrophysics on the study of Globular Clusters. He then went as a postdoc to Berkeley, and followed his international career at the European Southern Observatory near Munich and at the Space Telescope Science Institute in Baltimore. In 2004, he was nominated full Professor at EPFL. He is a highly recognized specialist of the dynamics of star clusters and gravitational lensing by quasars. He re-oriented the research activities of the Laboratory of Astrophysics towards observational cosmology. In particular, he created and developed research programmes with his collaborators, aiming at the characterization of the content and expansion rate of the Universe through the measurements of important cosmological parameters. Meylan is also an outstanding lecturer, both for students and the general public, and he has taught both science and humanities students.

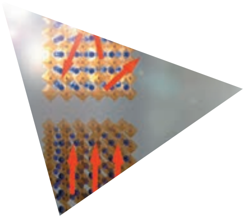
Professor Emeritus Francis Troyon passed away

Professor Emeritus Francis Troyon (1933-2016) passed away on January 10th, 2016 at the age of 83.

The Swiss Plasma Center, with the whole of EPFL, pay tribute to the outstanding scientist, the pioneer and the visionary who combined science and political skills for the development of fusion energy, the man of conviction and the extraordinary teacher.

After his physicist-engineer diploma of the Ecole Polytechnique de l'Université de Lausanne (EPUL) in 1957, Francis Troyon went on to pursue his doctoral thesis at the University of Rochester. Upon his return to Switzerland in 1962, he devoted himself to the physics of fusion plasmas. He was appointed Adjunct Professor in 1974, became Director of EPFL's then Centre de Recherches en Physique des Plasmas (CRPP) in 1981, finally becoming Full Professor in 1983.

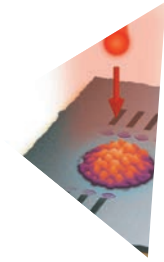
As researcher and director of the CRPP, Professor Troyon led Swiss research in fusion and in plasmas physics to the highest international level.
The scientific themes and objectives that he proposed for the CRPP in the 1980s contributed to the success of the laboratory so far and still impact its work today. Professor Troyon also played an extremely important role in the EURATOM-fusion program from the point of view of both its strategy and management.
His enthusiasm for training has deeply marked generations of students and PhD students.



A new perovskite could lead the next generation of data storage

As we generate more and more data, we need storage systems, e.g. hard drives, with higher density and efficiency. But this also requires materials whose magnetic properties can be quickly and easily manipulated in order to write and access data on them. Scientists at the Laboratory of Physics of Complex Matter have now developed a perovskite material whose magnetic order can be rapidly changed without disrupting it due to heating. This work describes the first ever magnetic photoconductor.

B. Náfrádi *et al*, **Optically switched magnetism in photovoltaic perovskite $CH_3NH_3(Mn{:}Pb)I_3$.** *Nat Comm* **7**, 13406 (2016). DOI: 10.1038/ncomms13406



Filming coupled light and electrons as they travel undercover

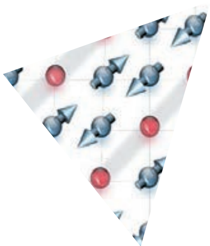
When light couples to electrons on a surface, their concerted motion can travel as a wave guided by the surface geometry itself. These waves might be useful in telecommunications and future computing, where data will be shuttled across processors using light instead of electricity. These processors could be miniaturized down to the nanoscale but they would be built from stacking layers of materials and, so far, we didn't have a reliable way of tracking the guided light as it moves across their interfaces. EPFL scientists have now done exactly that using a new, ultrafast method.

T.T.A. Lummen *et al*, **Shaping, imaging and controlling plasmonic interference fields at buried interfaces.** *Nat Comm* **7**, 13156 (2016). DOI: 10.1038/ ncomms13156

A new class of materials could realize quantum computers

Electron spin generally refers to the rotation of electrons around their axis. In a material, electrons also orbit the atom's nucleus. When these two electron motions, spin and orbit interact, they locally produce a very strong magnetic field. As such, spin is used in MRI, NMR spectroscopy, and hard drives. Spintronics, an emerging field of technology, explores spin-orbit interactions to develop a new generation of power-saving electronics and high-capacity memory cells. Scientists at EPFL and the Swiss Light Source (PSI) have now identified a new class of materials whose electronic properties can prove ideal for spintronics.

J. Krempaský *et al*, **Entanglement and manipulation of the magnetic and spin-orbit order in multiferroic Rashba semiconductors.** *Nat Comm* **7**, 13071 (2016). DOI: 10.1038/ ncomms13071

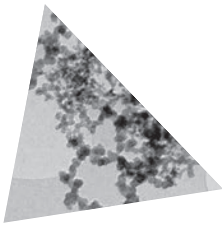


Neutron scattering brings insight on magnetic materials

The Laboratory for Quantum Magnetism, teaming up with colleagues around the world, has used neutron scattering to reveal the relation between the electronic structure of materials and their original magnetic properties in the case of an hourglass compound and magnetic quadrupolar order.

P. Babkevich *et al*, **Direct evidence for charge stripes in a layered cobalt oxide.** *Nat Comm* **7**, 11632 (2016). DOI: 10.1038/ ncomms11632

K. Kimura *et al*, **Magnetodielectric detection of magnetic quadrupole order in $Ba(TiO)Cu_4(PO_4)_4$ with Cu_4O_{12} square cupolas.** *Nat Comm* **7**, 13039 (2016). DOI: 10.1038/ncomms13039



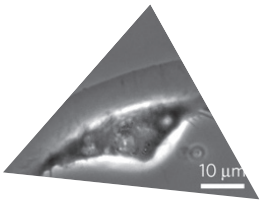
Carbon nanospheres overcome quantum computer, spintronics hurdles

Electron spin is a term that can be thought of as the rotation of an electron around itself, which creates a magnetic moment. As such, spin has direction, and can point upward and downward. Preserving this direction long enough is key to building quantum computers. The problem so far has been to develop material platforms where electron spins last long enough and can be controlled. EPFL scientists have now found a solution by using a special kind of carbon nanospheres.

B. Náfrádi, M. Choucair, K.P. Dinse, L. Forró, **Room temperature manipulation of long lifetime spins in metallic-like carbon nanospheres.** *Nat Comm* **7**, 12232 (2016). DOI: 10.1038/ncomms12232

Holger Reimerdes receives the 2016 Landau-Spitzer Award

The 2016 Landau-Spitzer Award has been attributed to a group of four plasma physicists, H. Reimerdes (EPFL), J. W. Berkery, S. A. Sabbagh (both of Columbia University, USA) and Y. Liu (Culham Centre for Fusion Energy, UK) for their work on Magneto-Hydrodynamic stability of fusion plasmas.



Minimal model for spontaneous cell polarization

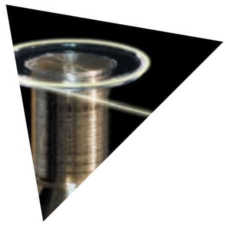
How cells break symmetry and organize activity at their edges to move directionally is a fundamental question in cell biology. Physical models of cell motility commonly incorporate gradients of regulatory proteins and/or feedback from the motion itself to describe the polarization of this edge activity. These approaches, however, fail to explain cell behaviour before the onset of polarization. Researchers at the Laboratory for Cell Biophysics have bridged the gap between cell behaviours before and after polarization. Their analysis suggests a novel and simple principle of self-organizing cell activity, in which local cell-edge dynamics depends on the distance from the cell centre.

F. Raynaud *et al*, **Minimal model for spontaneous cell polarization and edge activity in oscillating, rotating and migrating cells.** *Nat Phys* **12**, 367 (2016). DOI: 10.1038/nphys3615

Computational challenges in magnetic-confinement fusion physics

Scientists from the Swiss Plasma Center have published an extensive review on magnetic-fusion plasmas, focusing on computational approaches to modeling and exploiting magnetic-fusion plasmas and reviewing the computational challenges to simulate the burning-plasma regime. Given the complex nature of plasmas, and their extremely wide range of spatial and time scales, the scientists highlight the need for sophisticated numerical techniques and algorithms and state-of-the-art, high-performance computers when trying to model them with realistic configurations.

A. Fasoli *et al*, **Computational challenges in magnetic-confinement fusion physics.** *Nat Phys* **12**, 411 (2016). DOI: 10.1038/nphys3744



Capturing an elusive spectrum of light

The mid-infrared spectral window is a virtual goldmine for spectroscopy, chemical and biological sensing, materials science, and industry, as it is the range where many organic molecules can be detected. A way to harness the potential of this window is to use optical cavities, which are micro-devices that confine light for extended amounts of time. However, such devices are currently unexplored due to technological challenges at theses wavelengths. Researchers led by Kippenberg's Laboratory have successfully built ultra-high quality optical cavities for the mid-infrared region using crystalline materials, setting a new quality factor record in the field.

C. Lecaplain, C. Javerzac-Galy, M.L. Gorodetsky, T.J. Kippenberg, **Mid-infrared ultra-high-Q resonators based on fluoride crystalline materials.** *Nat Comm* **7**, 13383 (2016). DOI: 10.1038/ ncomms13383

Andreas Pautz appointed Head of Nuclear Energy and Safety at PSI

Professor Andreas Pautz has been appointed Head of the Nuclear Energy and Safety (NES) research division at the Paul Scherrer Institut (PSI) in Villigen.

Alessandro Vichi awarded an SNSF Professorship

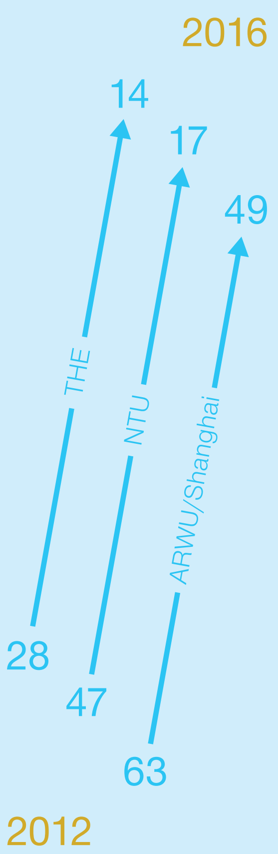
Alessandro Vichi was awarded a professorship in Theoretical Physics for his project entitled "Numerical and theoretical investigation of scale invariant systems".

SNSF awards five Ambizione grants

The Swiss National Science Foundation (SNSF) has awarded Ambizione grants to five young researchers to perform their own projects within the Institute of Physics: Jonathan Blazek and Carmela Lardo (LASTRO), Rajeswari Jayaraman (LUMES), Fabian Natterer (LNS), Daniel Johnson (LPHE, but he has accepted a staff position at CERN).

PHYSICS IN FIGURES

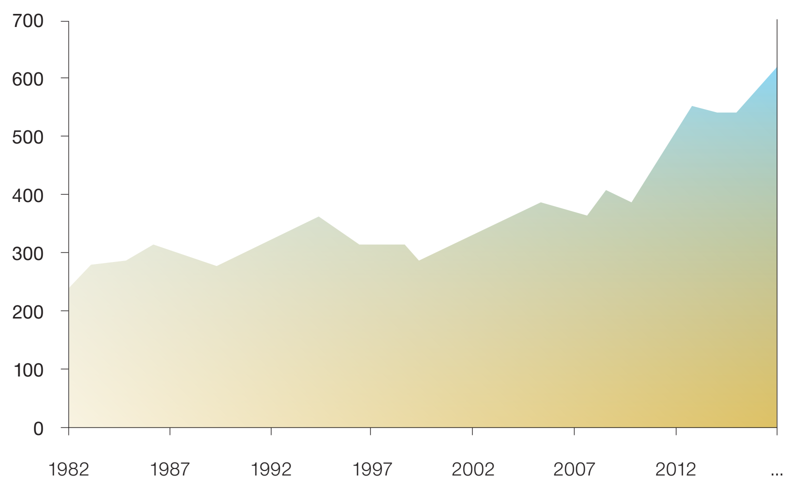
WORLD RANKINGS



EDUCATION IN 2016

4744	students receiving physics courses (EPFL + UNIL)
28	teachers for service courses (“physique générale”)
40	high-school teachers in continuing education course
71	bachelor degrees delivered
78	master degrees delivered
35	PhD degrees delivered

NUMBER OF REGISTERED STUDENTS IN PHYSICS



EXTERNAL FUNDING

33 %	external funding in total budget
802k	CHF/ FTE professor of external funding
7	ERC grants running
11	Ambizione grants running

2015 PUBLICATIONS
(Web of Science 06/01/2017)

560	peer-reviewed articles
20 %	published in a journal with high impact factor (≥7)
22	highly cited articles (top 1 % in their fields in citations)
3	hot articles (top 0.1 % in their fields in citations)
77 %	publications involving international collaboration

TECH TRANSFER 2011-2016

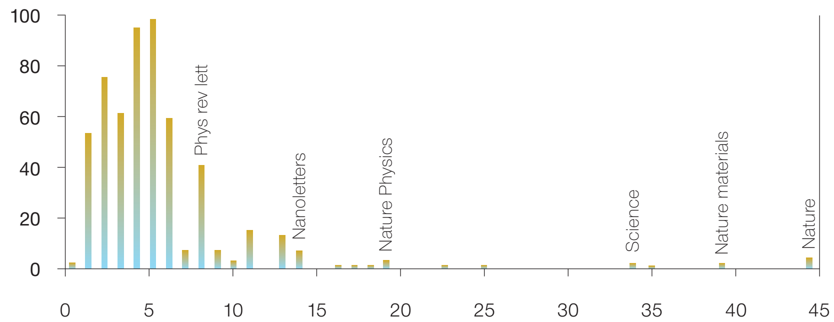
28
patent applications

14
patents pending

5
patents granted

5
start-up companies created

DISTRIBUTION OF JOURNAL IMPACT FACTORS FOR 2015 PUBLICATIONS



PROPORTION OF WOMEN

15 %	of bachelor graduates
17 %	of master graduates
23 %	of PhD graduates
15 %	of scientific staff
31 %	of administrative & technical staff
5 %	of professors

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Physics@EPFL 2016

TEXT
Mediacom, Institute of Physics, Swiss Plasma Center, Physics Section and Doctoral Program in Physics, EPFL

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l'atelier de aude

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p. 7: Tobias Kippenberg
p. 8: Christian Theiler
p. 8 & 25: Inside of TCV Tokamak, SPC
p. 9: Daphne Technology
p. 9 & 10: Paolo Ricci
p. 21: Jiandong Feng
p. 22: Physics puts on a show
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Event display of a proton-proton collision at 13TeV recorded by the LHCb detector (CERN)
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