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The long-sought-after Higgs boson
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Transforming physics pedagogy in the UK
The Exoplanet revolution

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Cover picture: Three years after its final landing in Abu Dhabi (UAE), Solar Impulse, the solar-powered airplane in which Bertrand Piccard and André Borschberg flew around the world without a drop of fuel, may once again reach the skies.
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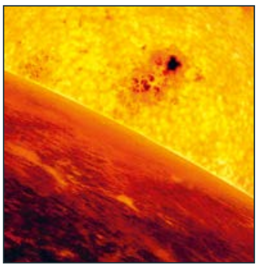
Carbon Neutral Aviation



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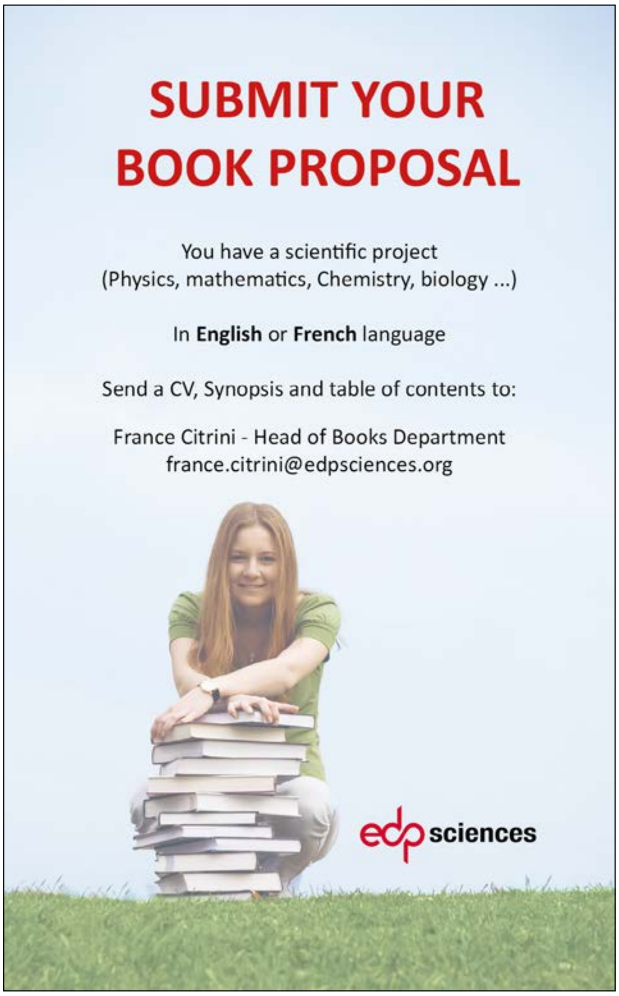
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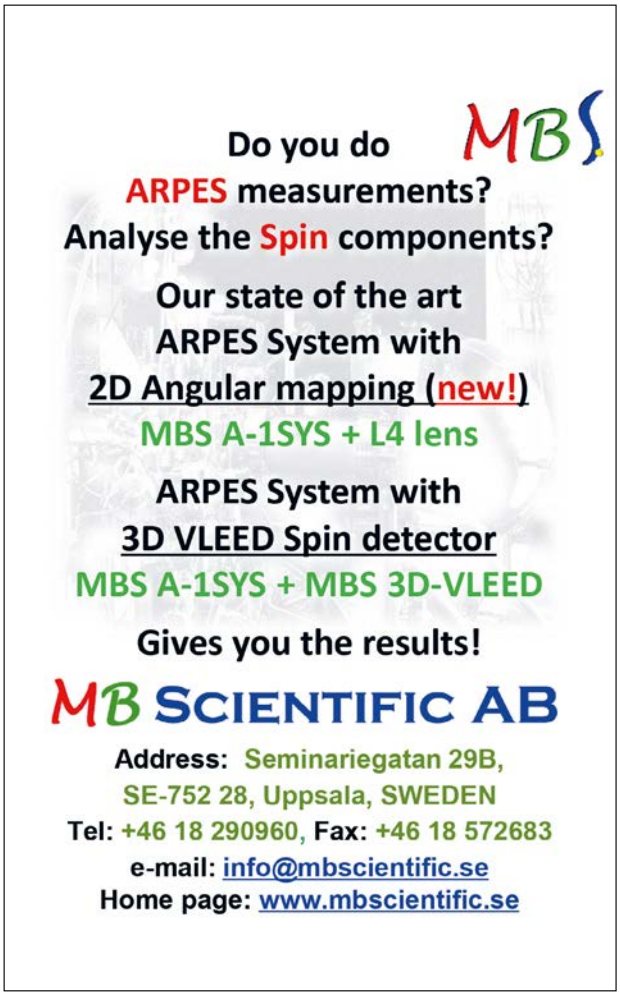
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[EDITORIAL]

Physics and Innovation

In October, the EPS presented to the press "The Importance of Physics to the Economies of Europe", an analysis of the contribution of our scientific discipline to the economies of Europe over the six-year period 2011-2016.

This study, prepared by the Centre for Economics and Business Research (Cebr) using statistics available in the public domain through Eurostat, shows that the physics-based sector accounts for 16% of the total turnover of the EU28 business economy, which is more than the gross turnover contribution of the entire retail sector. Physics-based industries within Europe employed 17.8 million people in 2016, more than a million more than in 2011.

The production of physics-based goods and services also has a significant knock-on 'downstreamstream' effect throughout the supply chain. This multiplier effect entails that for every €1 of physics-based output, a total of €2.49 output is generated throughout the EU28 economy as a whole. The employment multiplier is even higher, with every job in physics-based industries supporting a total of 3.34 jobs in the economy as a whole by these industries.

To keep its competitiveness, the European physics-based sector is highly R&D intensive and its expenditure on R&D within the EU28 exceeded €22 billion in every year of the period 2011-2016. However, what seems to be difficult to comprehend for policy makers and for the general public that elects them is that keeping the physics-based sector in the economy strong and addressing global societal challenges is a process of a very long-term nature. Solutions to these challenges will require investments in innovation and development but also in all stages of research, from basic (frontier and open-ended) to applied. Indeed, it will not suffice to develop technologies on the basis of the current knowledge: new paths and new knowledge will be needed, which can only be generated by open-ended research.

In this context it is worrying that in the new European Commission the areas of education and research are not explicitly represented anymore but hidden under the "Innovation and Youth" title. Accentuating economic exploitability (*i.e.* "innovation") at the expense of research and education, and reducing "education" to "youth" while it is essential to all ages, neglects that research and education are the foundation of the wealth and comfort we enjoy in Europe. Many of you, together with members of other disciplines forming the scientific community of Europe, have signed the open letter demanding that the EU commission revise the title for commissioner Gabriel to "Education, Research, Innovation and Youth" reflecting Europe's dedication to all of these crucial areas. At the time of writing this editorial, the letter has been signed by more than 10.000 scientists and institutions, among them 19 Nobel Prize winners but its effect is not known yet. Even if I have had very positive feedback from some Europarliamentarians who have emphasized that they support this request and that they will fight for more EU funding for research and education, the walk is still very much uphill.

This is why I would like to invite each and everyone of you to reach out to the general public, as well as to relevant politicians on the local, regional, national and European Union level: it is important that we show them our work and explain that while industrial R&D is important for product improvement and for creating the next generation of goods and services, basic and foundational research often lead to discoveries and applications with long term economic impact. As Serge Haroche said at the Festakt for the 50 years of EPS: Einstein certainly did not think of improving eye-operations with lasers when working on stimulated emission. We as a community are very much aware of the link between research and innovation but people outside science very often are not.

Another issue that needs to be clarified to the general public and to policy makers is the importance to fund academic research in order to guarantee the quality of education required for generating a sufficient number of highly skilled graduates for the physics-based industry. In many European countries investments in research have been stagnating and the urgently needed growing numbers of graduate and post-graduate students are difficult to sustain at the present investment level. More and more often I also hear of talented young researchers, who decide to leave university because they are frustrated by the low success rates of their grant proposals. When student numbers increase not only more staff has to be hired but research budgets need to increase if we want our universities to retain their academic standards.

If you are willing to advocate but feel unsure how to approach this, your Member Society may help: EPS will support this by offering a "train the trainers" workshop in 2020, where a delegate of each member society will be trained in how to organize (and give) workshops for teaching physicists how to talk to policy makers.

According to the Lisbon treaty of 2000, European governments and firms should together spend 3% of GDP annually on R&D, but in many countries this objective is not yet reached. Let's all engage in convincing our policy makers that more dedicated funding for education and research is urgently needed to maintain a sound basis for innovation in Europe and to guarantee a high standard of living for European citizens in the future, as well as to warrant a high research content of the Physics educational programmes of our students who will be the ones to produce the science for this. ■

■ **Petra Rudolf,**
EPS President

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EPS HISTORIC SITES

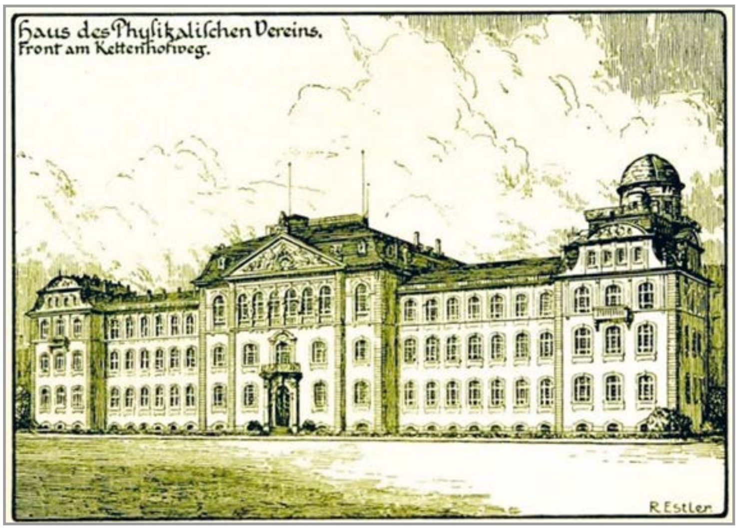
The former Department of Theoretical Physics of the Goethe University

Frankfurt, Germany

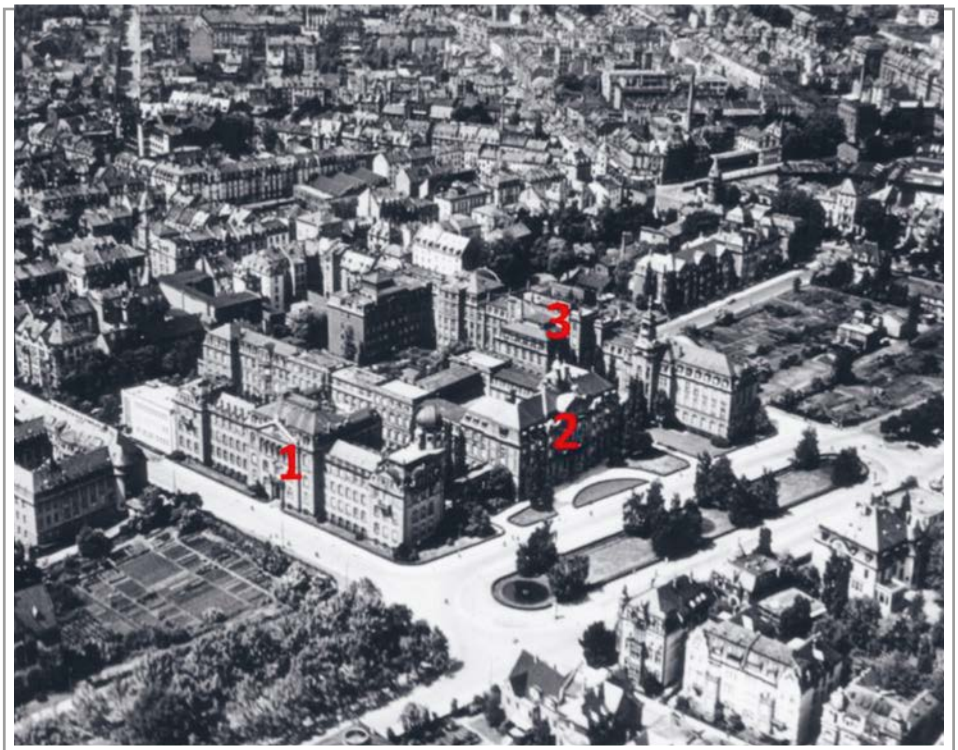
An EPS Historic Site was inaugurated at the University of Frankfurt in recognition of key contributions to quantum mechanics made by its Physics Department in 1919-1922.

The former Department of Theoretical Physics of the Goethe University of Frankfurt has been recently recognised by the European Physical Society (EPS) as an "EPS Historic Site," the fifth in Germany. On 3 September 2019, a plaque marking the site was unveiled by the Presidents of the European and German Physical Societies, the Goethe University, the Physics Association of Frankfurt as well as by the speakers and audience of an international symposium "Otto Stern's Molecular Beam Research and its Impact on Science." The Historic Site honors the work of Max Born, Otto Stern, Walther Gerlach, Elisabeth Bormann, and Alfred Lande done at Frankfurt during 1919-1922.

At the Institute of Theoretical Physics, then headed by Born, key discoveries were made that contributed decisively to the development of quantum mechanics. In 1919, Otto Stern launched there the revolutionary molecular beam technique that made it possible to send atoms and molecules with well-defined momentum through vacuum



▲ Past Physics Institute built in 1906.



▲ Frankfurt-Bockenheim with University around 1920 (1 Physics building, 2 Senckenberg Museum and 3 Main University building with Auditorium)

and to measure with high accuracy the deflections they underwent when acted upon by transversal forces. Thereby, heretofore unforeseen quantum properties of nuclei, atoms, and molecules could be revealed that became the basis for our current understanding of quantum matter. Stern would receive the 1943 Nobel Prize in Physics for developing the molecular beam technique and for his later measurements of the magnetic moment of the proton. Experiments done in 1920 by Born and Bormann sent a beam of silver atoms through molecular gases and measured their mean free path in order to estimate sizes of molecules. An iconic experiment in 1922 by Stern and Gerlach demonstrated space quantization of atomic magnetic moments and thereby also, for the first time, of the quantization of atomic angular momenta. In 1921, Landé postulated the coupling of angular momenta as the basis of the electron dynamics within atoms. The Historic Site includes the seat of the Physical Society of Frankfurt, the oldest in Germany, founded in 1824.

A host of prominent descendants of the Stern-Gerlach experiment make use of the key concept of space quantization of angular momentum. Foremost are nuclear magnetic resonance, optical pumping, the laser, and atomic clock, as well as incisive discoveries such as the Lamb shift and the anomalous increment in the magnetic moment of the electron, which launched quantum electrodynamics. In the 1960s, the molecular beam technique made inroads into chemistry as well, by enabling to study binary collisions of chemically well-defined reagents. In the 1990s, the diffraction of atoms, pioneered by Stern's group, became one of the leading methods for the non-destructive investigation of surface structures as well as surface phonons and adsorbate vibrations. At about the same time, a renaissance had begun in atomic physics, nurtured by the development of techniques to cool and trap atoms. Based on a combination of molecular beams with laser cooling, these techniques enabled the realization of quantum degeneracy in atomic gases, launched condensed-matter physics with tunable interactions, and transformed metrology. ■

■ **Bretislav Friedrich**
Fritz-Haber-Institut der Max-Planck-Gesellschaft, Berlin
■ **Horst Schmidt-Böcking**
Institut für Kernphysik, Goethe Univertsität Frankfurt

▲ Picture left: Historic laboratory where the Stern-Gerlach experiment was performed (left: Otfried Madelung son of Erwin Madelung director of the theoretical physics institute in 1922, right: Alan Templeton grandnephew of Otto Stern). Picture right: Past Physics building, red dot marks room of Stern-Gerlach experiment (picture taken in 2011).

Sarah Köster awarded the EPS Emmy Noether Distinction

Photo: Markus Osterhoff

Sarah Köster, a biophysics professor at the University of Göttingen, Germany [1], has been awarded the prestigious Emmy Noether Distinction of the European Physical Society for her seminal contributions to the physics of biological cells and biopolymers, in particular for the understanding of intermediate filaments, and her impressive ability in teaching and recruiting women scientists in her field of research.

Born in the south of Germany, she studied physics at the University of Ulm and performed her PhD work at the University of Ulm, Boston University and the Max Planck Institute for Dynamics and Self-Organization, Göttingen. She received her PhD from the University of Göttingen in 2006. Her thesis was awarded the Berliner-Ungewitter-Award of the Göttingen physics faculty as well as the Otto-Hahn-Medal of the Max-Planck-Society. In 2008, after two years of postdoctoral work at Harvard University with David Weitz, she returned to Göttingen as an assistant professor. In 2010 she was awarded the Helene-Lange-Award of the EWE-Foundation. In 2011 she was promoted to tenured associated professor and in 2017 to full professor in the faculty of physics of the University of Göttingen, where she leads the research group Cellular Biophysics at the Institute of X-Ray Physics. In 2016 she received an ERC Consolidator grant. Meanwhile she leads a fairly large research group in Göttingen with a surprisingly high proportion of young women scientists (14 out of 17 students and postdocs are female!). Several of these excellent students and postdocs have been awarded prices and fellowships themselves. The group works on disentangling how molecular interactions in protein filaments define their unique mechanical properties and thereby the physical properties of cells.

Sarah decided early on to focus her research on topics that were a bit off the beaten tracks. This is how she became one of the few physicists working on so-called intermediate filament, a type of biopolymers that is found inside biological cells. These protein filaments had been extensively studied by biochemist, biologists and physicians for their importance in health and disease. Their physical properties, which are equally important for the cell, have only recently been studied in detail by few groups, among them Sarah's. By combining very controlled experiments in order to measure piconewton forces on nanometre length scales, with analytical and numerical modelling they discovered very interesting materials properties: a specific molecular mechanism allows the filaments to dissipate a lot of energy, possibly a protection mechanism of the cell against strong impact, like an airbag for the cell. Furthermore, the filaments are extensible when pulled slowly, but stiff, when pulled fast, which could determine the cells flexibility when squeezing through strong constrictions, but protecting it against unwanted damage, similar to the seat belt in a car.

Sarah and her group also engaged in developing novel methods for imaging cells using x-rays, which are now established as a complementary alternative to fluorescent microscopy and electron microscopy. Through these projects, Sarah is very active in the photon science community as the experiments are typically performed at synchrotron sources.

Besides her exceptional contributions to science, Sarah has always placed emphasis on teaching. She enjoys working with young undergrad students and teaching the freshmen lecture in experimental physics, as well as educating more advanced Master's and PhD students in biophysics. Her group has always attracted many students on all levels and has considerably grown over the years. At the University of Göttingen, her students and postdocs are known for their highly cooperative and helpful attitude with each other and especially towards new members. The proportion of women among the group members is remarkable as is the high level of expertise and strong passion for science of

On the importance of the EPS Emmy Noether Distinction as an instrument to highlight the work of female physicists

"It's a great honour, which I appreciate a lot! The distinction indeed highlights our work and hopefully motivates (female and male) physics students to pursue a career in academia. I would like to stress that research is always a team effort and I have the pleasure to work with a wonderful team."

the young scientists. Clearly, this is a consequence of Sarah's own enthusiasm for her research.

Besides an excellent account of her own research group, Sarah's visibility in the biological physics community has grown during the past decade since she started her independent research group. In her department at the University of Göttingen she has always been fully involved in committee work as well as numerous collaborative research efforts such as Collaborative Research Centres (CRC) and Excellence Clusters of the DFG. As spokesperson/vice-spokesperson of two of these CRCs she was also involved in shaping the scientific directions of the centres. In 2015 the Biological Physics division of the German Physical Society (DPG) elected her vice-spokesperson and in 2017 spokesperson. Thus, Sarah has very successfully co-organized the DPG Spring Meeting, which is the largest Physics meeting in Europe, four times by now.

On how she built a research group with a large fraction of women researchers:

"I actually did not take any special measures. I got applications for PhD and postdoc positions from very talented women and was lucky and could convince them to work with me. Of course I am equally happy about applications from young male scientists. In the end, my research group does a great job in recruiting new members. They are always very welcoming and helpful with new people and manage to create an excellent work atmosphere in our lab."

With her contribution to leading research in science, her enthusiasm and passion for biological physics and her position as an important role model for young researchers, Sarah builds a bridge to the next generation of researchers. Her career is a great example for a successful women career in physics, which has been highlighted by the 2019 Emmy Noether Distinction.

Josef A. Käs
Soft Matter Physics Division of Leipzig University

Reference

[1] Prof. Dr. Sarah Köster, Institute for X-Ray Physics, Georg-August-University Göttingen. Website: www.uni-goettingen.de/en/91107.html

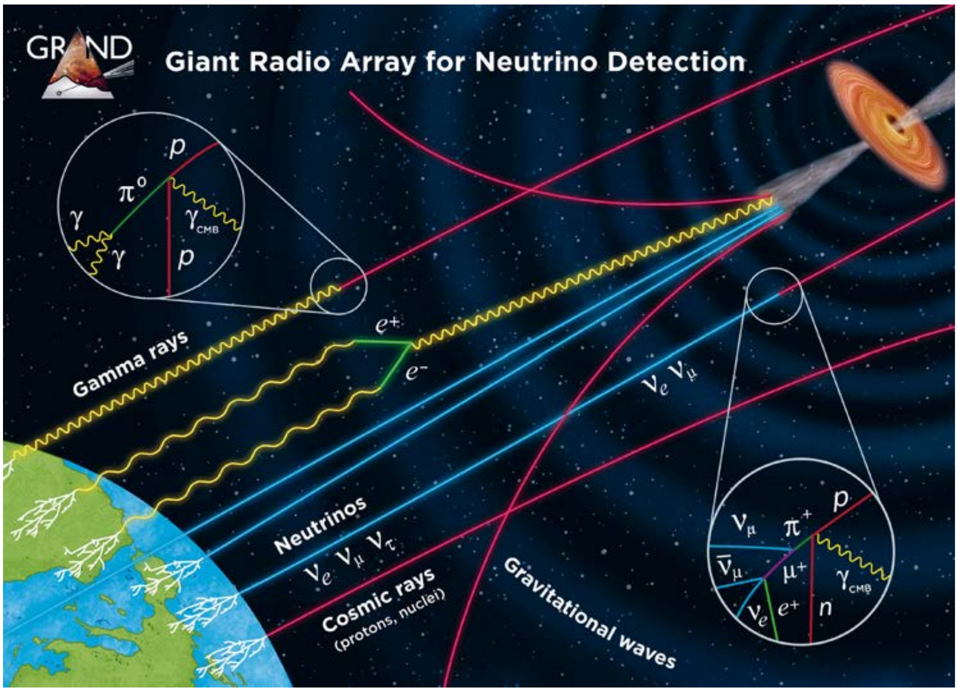
GRAND:
a Giant Radio Array for Neutrino Detection

GRAND [1] is a planned observatory for the detection of ultra-high-energetic particles raining from the cosmos down on Earth. GRAND will be a true multi-messenger observatory, detecting and identifying neutral particles such as photons and neutrinos, as well as charged nuclei, at energies exceeding 10^{17} eV.

The scale of the project, 200,000 km^2, makes GRAND the most sensitive probe for discovering neutrinos and photons at these energies, thereby unambiguously identifying the sources of ultra-high-energy cosmic rays (UHECR).

The Origin of ultra-high-energy neutrinos

When cosmic particles with energy in excess of 10^{20} eV were first detected [2], the quest for their origin started. Most recently, Pierre Auger Collaboration has analyzed the directions of the incoming UHECR and concluded that their origin is likely outside our own Milky Way [3]. Due to interactions with the cosmic microwave background, the origin of these particles is likely within 100 million light years[1], or relatively close. In their interactions with the cosmic microwave background ultra-high-energy photons and neutrinos are created that, unlike the charged cosmic rays, travel in straight lines through space before arriving at Earth (see image). Thus, the measurement of these particles will be a better probe of the origin of UHECR for more distant sources. In addition, their flux will be a good measure for the nature of the UHECR and thereby it will shed light on how nature is capable to accelerate particles to energies that are 10 million times higher than any accelerator on Earth can deliver. Although GRAND will be sensitive to all particles, this article focusses on its measurement of tau-neutrinos specifically. The IceCube collaboration has recently measured the first cosmic tau-neutrinos [4], but is too small to perform neutrino astronomy at an energy scale beyond 10^{18} eV. GRAND is the only planned observatory with the aperture and expected reconstruction accuracy to open this new window on the universe.

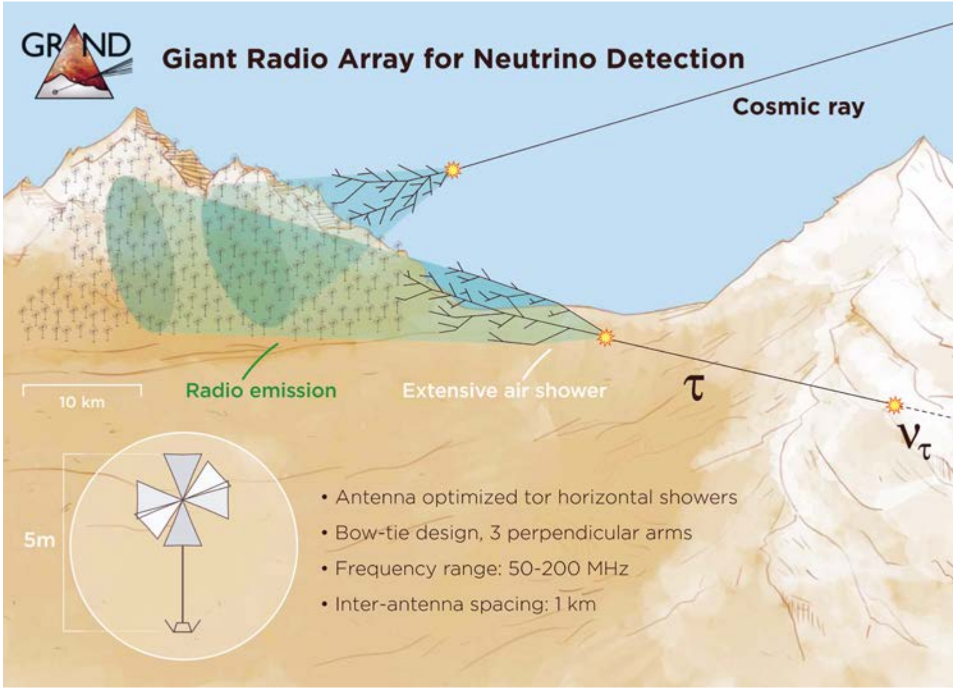


▲ The different types of cosmic particles and waves

Neutrinos are often called ghost-particles that are able to fly through the Earth and can be detected on the other side. This is no longer true at the high energy frontier that we are interested in due to the cross section rise for neutrinos interaction with matter for increasing energy. For ultra-high energies there is a high probability that a neutrino when passing through a mountain or skimming the Earth's crust interacts with the rock and thereby, in case of a tau neutrino, produces a tau-particle. This tau-lepton sometimes escapes the mountain and enters the atmosphere. As the tau-lepton has a lifetime of about 3 10^{-13} s, it will decay with an energy dependent average decay length of order 50 km. The decay products of the tau create a cascade of interactions in the atmosphere thereby producing billions of secondary particles in what is called an air shower. These secondary particles gyrate due to the Lorentz-force in the magnetic field of the Earth, which causes radiation in the MHz regime.

This radiation will be measured by cheap dipole antennas, from which the energy and direction of the tau-particle that created the air shower can be inferred.

[1] To set the scale: the typical distance between galaxies is a few million light years.

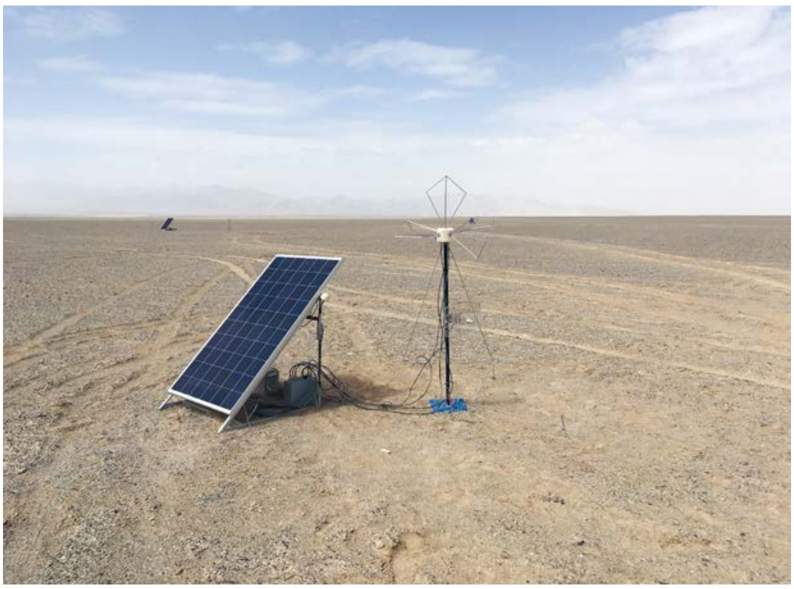


▲ GRAND detection strategy

This technique has been established in the recent past by radio arrays measuring properties of cosmic-ray-induced air showers [5], and the GRAND array can thus be used to measure all different types of ultra-high-energy particles that create air showers (see GRAND detection strategy).

The GRAND setup

GRAND will be a distributed observatory with 10-20 different sites spread over the world. Each site will cover an area of about 10,000-20,000 km^2, which is instrumented with one measurement antenna per km^2. The total project will consist of 200,000 antennas on a total area of 200,000 km^2. In order to realize such an ambitious project, we adopt a staged approach. The stage we are currently designing is GRANDProto300, a detector of 300 antennas covering an area of about 200 km^2. This stage of the detector will be deployed in the Gobi-desert at an altitude of 2800 m, nearby the town of LengHu in the QingHai province in China. On this site we recently deployed a first series of four prototypes in order to monitor the local conditions in preparation for GRANDProto300 (see picture). The main goal of GRANDProto300 is to test and optimize the detector design, trigger algorithms and reconstruction and analysis tools for GRAND. However, even this (modest-size) detector has its own physics goals. It will be used to measure the composition of charged cosmic rays in the energy region (10^{17}-10^{19} eV). At the low end of this energy region, the particles are expected to be accelerated predominantly in our own galaxy, whereas at the high end their origin is mostly outside our Milky Way. Fully understanding this transition region is very important for the study of the sources of cosmic rays as well as of the shielding effect of the galactic magnetic fields.



▶ First prototype setup in the LengHu site. This setup is used to monitor background conditions in preparation for GRANDProto300

After successfully operating and optimizing GRANDProto300 for about five years, we expect to be ready to set up the first GRAND hotspot, GRAND10K, at the same location as GRANDProto300. This 10,000 km^2 array will at that time be the largest instrumented area for the detection of ultra-high-energy particles from space and may already detect the first ultra-high-energy neutrinos.

The GRAND collaboration

The GRAND proto-collaboration is welcoming new partners. It is continuously growing, and consists at this moment of about 60 collaborators from 10 countries. A Memorandum of Understanding that will formally establish the GRAND collaboration is being drafted and the first partners are ready to sign the MoU. ■

■ **Charles Timmermans,**
Nikhef/Radboud University Nijmegen

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Improving the gender balance at a Dutch university

Photo: Rob Stork

Shortly before the 2019 summer recess, my employer – the Eindhoven University of Technology (TU/e) in the Netherlands – announced a radical plan. From July 1st onward, it would be considering *only* female applicants for any new faculty position posted [1]. The announcement quickly went viral on various social media outlets, and for a day or two the TU/e board was treated to equal measures of praise, ridicule and rage. A highly polarised reception revealing that the exclusionary hiring measures had somehow struck a deeper nerve. In a personal capacity, I'd like to take this opportunity to sketch how this extreme move came to be, what we expect from it and what's next.

The immediate cause is quite clear: The TU/e has occupied the bottom slot in the national gender rankings for some time now; it has the lowest percentage of female full professors of any university in the Netherlands. Between 2014 and 2017, the percentage of female full professors has risen from 8.6% to 12.6% (LNVH Monitor 2018, Dutch only, https://monitor.lnvh.nl). The university had set itself the target of reaching 20% in 2020; at the current rate that target will be missed. These figures appear even bleaker in European context: with an overall average of 18.7% female staff in the highest academic ranks the Netherlands is well below the EU-average of 23.7% (She figures 2018 of the EC). For more than ten years, the TU/e has worked to improve its percentages, but to little avail as evidenced by the slow rise.

Challenged by an increasing call from inside the university, and perhaps also somewhat embarrassed by the poor showing, the TU/e leadership decided to change its approach. An organisation that seeks to improve its gender balance (without laying off its male employees) needs to do one thing: hire more women. With typical Dutch directness, it was decided to do exactly that.

In some ways, this amounts to treating the symptoms rather than the cause. To be sure, the issues surrounding gender balance in academia are complex and impossible to capture in a single number or percentage. The way I see it, there are really three distinct problems which, ideally, must *all* be structurally addressed, at the same time.

- The **first** concerns recruitment and selection, and happens at the *front door*. The problem is simply that more men than women end up getting hired.
- The **second** problem is the *glass ceiling*. Once hired and 'inside the system', the progression through the academic ranks of female staff is delayed or impeded compared to the career paths of male colleagues (She Figures 2018 of the EC).
- **Thirdly**, there is the *leaky pipeline*: On average, female academics are more likely than their male colleagues to abandon their careers before they reach the highest ranks (*Why women leave academia, and why universities should be worried*, Curt Rice in The Guardian of 24 May 2012).

These three problems are well documented, and they are interrelated. Together, they have led to the skewed balance we face today. The causes for each, likewise, are largely known. The issues at the *front door* are often attributed to implicit biases in hiring and selection; subtle, unintentional or fully subconscious mechanisms by which we project stereotypes and attitudes on those we are tasked with evaluating. These biases [2,3] color our assessment, often to the disadvantage of those unlike ourselves. As a result, committees tend to select 'more of the same', which will obviously slow down the establishment of balance where balance is lacking. Another important aspect of the front door issues in STEM fields is simply that fewer women apply for faculty positions to begin with. As a result, even a fair and unbiased process would still result in gender imbalance. This 'supply side' issue is sometimes offered as an argument for the inevitability of gender imbalance in STEM, but I strongly feel we should not accept this as a *fait accompli*. Across Europe, early stage scientists in far more favourable male/female proportions are preparing for their careers in science, technology and innovation. Apparently, the women among them are more hesitant to pursue the next step than their male colleagues. Given the other two problems – which of course are well-known to applicants – I completely understand their hesitation. I too would think twice about launching myself into an environment that will hinder my career progression. I too would think twice about a job where so many colleagues have so much trouble protecting the balance between work and personal life. I too would think twice about volunteering to become the first female staff member in a research unit or an entire department, knowing full well this would entail endless quota-filler service and committee assignments. For those same reasons, I am not surprised that the career pipeline is leaky. There is no doubt that the average STEM career in the Netherlands is a profoundly different personal experience – and a considerably less enjoyable one – for women than it is for men.

The implicit biases that skew hiring and selection and the glass ceiling, likewise, share a common cause: The illusion that our current processes let us competently assess the quality and merit of candidates, both in hiring and promotion decisions. Among the most frequently raised objections to the

TU/e measures was some form of an appeal to a purely meritocratic ideal of academic organization: Obviously, its proposers would offer, any hiring procedure should only select the best qualified individual from among the candidates, regardless of anything else. The myth of this omniscient ability to single out the perfect candidate every time should be considered soundly busted by now [4,5], and we are left with the realisation that our processes are flawed and inaccurate. Despite its very best intentions, The academy is not a perfect meritocracy. For decades, appointment and promotion committees have based their decision making on noisy, biased measurements and the results are the staff compositions we see today.

For these, and many other reasons it would be short-sighted and unwise to address only the problem at the front door by just hiring only women. In Eindhoven, we are well aware that to ensure that our new colleagues remain within our university we must revisit how we support people and careers. We explore new ways of assessing and rewarding accomplishment (in line with for instance *The San Francisco Declaration on Research Assessment*, https://sfdora.org). We are setting up mentorship and coaching programmes for new staff and are addressing the mounting workloads that increasingly weigh down academic staff in the Netherlands [6]. Start-up funds were previously rare, but are now standard practice in Eindhoven and guarantee our new colleagues a fair shot, an equal playing field and (temporary) independence from the highly competitive and low success-rate external funding calls as they build their labs and their identity as independent PIs.

The understandable but unfortunately one-sided media focus on the exclusion of male candidates at TU/e stirred powerful emotions but in the end detracts from the actual job at hand. The radical hiring measure is a short sprint, aimed to get our university to a viable point of departure for its next phase. I have little doubt that we will get to that 20% in 2020 target, but I am much more excited to be a part of the larger experiment, in which we transform our university into a considerate and supportive employer that provides a career space where all of its employees may flourish. ■

Cornelis Storm
Professor of Theoretical Biophysics, Eindhoven University of Technology.

NNV DIVERSITY PRIZE 2018 AWARD GOES TO GRONINGEN

The first edition of the NNV-Diversity Prize was won by the faculty of Science and Engineering of the University of Groningen (RUG). The Netherlands Physical Society (NNV) has created the biannual prize for the physics institution that is most successful in putting an open diversity policy into practice. The prize is a tribute and an inspiring example for other institutes and/or departments.

http://www.epsnews.eu/2019/02/nnv-diversity-prize-2018-awarded-to-groningen

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The article is an adapted version of an article published in Dutch by the author in the magazine of the Netherlands Physical Society (NTvN-85/10).

[1] More precisely, the measure dictates that for every new staff vacancy, and for the first half year that it is open, only female candidates may be considered. In case no suitable female candidate is found in those first six months, the position is opened to all applicants. Target female influx figures between now and the end of 2020 are 35% at the full and associate professor level, and 50% at the assistant professor level. If these targets are realized, the TU/e will make its 20% by 2020 target.

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THE EYES
OF THE BAIKAL GVD NEUTRINO TELESCOPE

The eyes of neutrino telescopes are the photomultipliers embedded in pressure resistant glass spheres. Thousands of these are necessary to instrument the large volumes of deep ice, deep sea and – in the case of the Baikal GVD telescope – in deep lake water. That requires smooth production factories, such as the one in the picture in the Joint Institute for Nuclear Research (JINR) in Dubna, Russia. Once deployed at the bottom of Lake Baikal in Siberia they will register the Cherenkov light of charged particles produced in the collision of cosmic neutrinos with the matter in the vicinity of the telescope. An old detection technique, but still convincingly efficient.

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A personal report: setting up a junior research group in Hamburg

I am a postdoctoral researcher in theoretical physics at the Center for Free Electron Laser Science at DESY in Hamburg, Germany. Starting from January 2020, I will lead a junior research group at the Universität Hamburg funded by the Freigeist Fellowship Program of the Volkswagen Foundation.

The Volkswagen Foundation is an independent foundation that promotes science and technology in research and teaching. It shares the name of the car manufacturer for historical reasons and is not affiliated with it. I learned about the Volkswagen Foundation, when I went to a conference in Hanover in 2014 organized by the foundation. I looked into its initiatives and found out about the Freigeist Fellowship Program that funds research projects at the boundaries between established fields of research. Later, when I was shaping the idea of my research proposal for a junior research group, I realized that it matches the objectives of the program.

My research project "Seeing excitons in motion" aims to employ advances of the attosecond science for light-energy-conversion applications. This project is inspired by recent developments in the field of attosecond science. Nowadays, it is possible to produce such short light pulses that they can capture processes with sub-femtosecond temporal resolution (shorter than a millionth of a billionth of a second, 10^{-15} sec), which is a time scale relevant for electronic motion. There are a number of problems in physics, chemistry and biology, where the ability to resolve electronic motion would provide many new fascinating insights. The problem of revealing exciton formation and dynamics in the field of photovoltaics is one of the exciting examples.

Excitons are quasiparticles that describe a special state of electrons in semiconductors. They play the key role for the photovoltaic effect used by solar cells, and the ability to see how excitons are moving will enable the observation and control of mechanisms that govern the efficiency of solar cells.. The goal of this project is to invent methods to follow excitonic motion by means of ultrashort light pulses with sub-femtosecond temporal and atomic spatial resolution. The interaction of light pulses and moving electrons at sub-femtosecond time scales gives rise to quantum effects that do not appear at longer times. A rigorous quantum-mechanical analysis will be employed to describe how photovoltaic materials in the regime of exciton dynamics interact with ultrashort light pulses. This description will provide tools to extract the finest details of exciton dynamics, a very complex type of electron dynamics, from signals obtained by means of ultrashort light pulses. Based on this analysis, the project aims to propose and design novel, cutting-edge experiments that will open up new perspectives for renewable energy research.

My research project is funded for six years. The funding includes my own position and four PhD-student positions in total. Each PhD position is for three years, which means two PhD positions on average at a time. The Volkswagen Foundation also approved funds for me to stay twice for the periods of two-months at the PULSE Institute at Stanford Linear Accelerator Center in the USA. I plan to collaborate with scientists at the PULSE Institute on the development of concepts to follow electronic motion by means of ultrafast x-ray scattering at Linac Coherent Light Source at Stanford. I greatly appreciate this opportunity, since the visits of the two-months duration make it possible for me to gain additional international experience being a mother of a small child.

I was delighted to see that my request for GPU-Servers was approved. I highly acknowledge that the Volkswagen Foundation understood the need of a theoretical group for high performance computing equipment to be able to perform advanced calculations. It will enable the group to perform realistic simulations of exciton dynamics in photovoltaic materials, which are highly computationally demanding.

I have chosen the Universität Hamburg (UHH) as a host institution for my project. The UHH is one of eleven German universities that are awarded the status of a University of Excellence. The UHH has also recently won the Excellence Initiative by the German Federal and State governments to establish the cluster of excellence "CUI: Advanced imaging of matter" (AIM). The cluster of excellence AIM combines scientific teams developing technologies to explore the structure, dynamics and control of matter at the atomic scale. The goals of my project are in line with the mission of the AIM. I have already several collaborators within the cluster and there are a number of further opportunities to collaborate.

Hamburg is an excellent scientific environment. The city hosts several light source facilities that are unique among the world. There are also several research institutions in Hamburg that are partners of the UHH within the AIM: the Deutsches Elektronen-Synchrotron DESY, Max-Planck-Institute for the Structure and Dynamics of Matter and the European XFEL. I have chosen the UHH as a host institution among the other research institutions to work in a classical academic environment, which prepares to become a full professor. ■

Daria Gorelova
DESY Photon Science division

Nobel prize for Jim Peebles
for his theoretical discoveries in physical cosmology

On October 8, 2019, the Nobel Committee awarded the Nobel Prize in Physics to Phillip James Edwin Peebles, known in the scientific world as Jim Peebles or PJEP, for his theoretical discoveries in physical cosmology that contributed to our understanding of the evolution of the universe and Earth's place in the cosmos.

In the second half of the twentieth century, cosmology - the science about the Universe, its structure and evolution - ceased to be the subject of philosophical or theological speculation, or mathematical models with an obscure reference to reality, and became a precise natural science based on observations, computer simulations and solid theoretical considerations. This change was possible thanks to the close cooperation of observers and theoreticians, among them Jim Peebles.

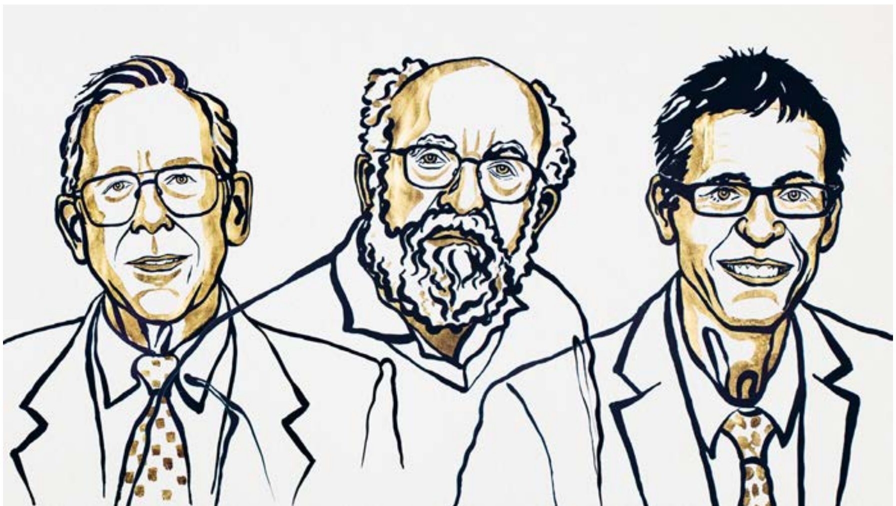
Jim Peebles was born in 1935 in Winnipeg, Canada. There he also began studying, but in 1958 he moved to Princeton in the USA, where he obtained a doctorate in physics in 1962. He remained associated with Princeton University until this day. Peebles could have been a Nobel Prize winner long ago. In the mid-1960s, together with R. Dicke and Robert Wilkinson, he contributed to building an antenna to detect microwave background radiation, the oldest light in the universe, the remnant of the Big Bang. By chance, it was recorded slightly earlier by Robert Wilson and Arno Penzias, but the theoretical explanation and cosmological connotation of the discovery came from the Princeton group. Penzias and Wilson were awarded the Nobel Prize for Physics in 1978 for their discovery. The microwave background radiation provides a "picture" of the Universe in the state it was about 300,000 years after the Big Bang, when there were no stars or galaxies - "there was nothing." However, it contains traces of unevenness in the distribution of matter, which later formed the entire large-scale structure of the Cosmos with stars and galaxies. For years, Peebles has dealt with the problem of linking what is seen in this picture with what is now seen in the distribution of matter in space. He dealt with the problem of how from an almost smooth distribution of matter after billions of years compact objects like galaxies separated from each other by almost empty space, and how it relates to this "oldest light in universe ".

The discovery of this "oldest light" marked a turning point in the development of modern cosmology. Suddenly it became a precise observational science and pure speculation and mathematical models began to be confronted with results of observations. Measurements of the microwave background radiation allowed Peebles to accurately trace the process of primordial synthesis of light chemical elements. In the beginning, after the Big Bang, "there was nothing", not even chemical elements. Everything emerged gradually. Today we know where all the elements in the Mendeleev table come from. Almost all of them were formed in crucibles, which are the interiors of hot stars, or in processes related to the evolution and end of life of stars. But the lightest, isotopes of hydrogen, helium and lithium, were created during the first three minutes of the Universe's existence, after the Big Bang. The discovery of the "oldest light" allowed Peebles to trace the process of formation of isotopes of these elements. He published the results in 1966. After working on background radiation and the formation of elements, at the age of 31 he became a classic.

Peebles contributed to other important discoveries. In the '70s, together with another prominent Princeton astrophysicist, Jeremiah P. Ostriker, he noticed that thin discs of spiral galaxies are unstable. For their stabilisation it is necessary for such galaxies to be surrounded by a vast, massive halo of dark, non-luminous matter. This was the first work proving that the universe is filled with a large amount of dark matter. Peebles and Ostriker also showed how nascent galaxies create unexpected structures that look like a bar in their midst.

For many years, Peebles' close associate was a Polish cosmologist from the Copernicus Astronomical Center in Warsaw, Roman Juszkiewicz. They were friends. Together they wrote a couple of scientific papers on "the oldest light" and on the formation of galaxies. Jim Peebles is the author of several classic monographs in the field of cosmology. As a researcher of the large-scale structure of the Universe, he once said: "Give me a thousand redshifts (a magnitude that tells you how far away a galaxy is), and I'll tell you what the structure of the Universe is". Today we know millions of redshifts and still we do not know exactly this structure. Asked if he maintained his view (that a thousand shifts would be enough), he answered "no". How so? "The universe is changing and people are changing, their views are changing and so is mine." ■

■ **Stanisław Bajtlik,**
Copernicus Astronomical Center
Polish Academy of Sciences, Warsaw



Left to right: J. Peebles, M. Mayor, D. Queloz

Nobel prize for Mayor and Queloz
as fathers of the field of extrasolar planets

Michel Mayor and Didier Queloz together received half of the Nobel Prize in Physics 2019 for arguably the most important discovery in astronomy in the past 100 years. Although it does not involve new or fundamental physics, it signaled the birth of a new research area – that of extrasolar planets. First met by much skepticism, their discovery, now almost 25 years ago, started a true revolution cumulating in the thousands of planets we know now. The initial excitement is continuing today, with some planets being surprisingly Earth-like, possibly habitable, or even inhabited. The search for signs of extra-terrestrial biological activity will start in earnest in the next decade – a direct legacy of the work by Mayor and Queloz.

The presence of planets orbiting other stars than the Sun had been speculated for hundreds of years, but stars being so distant and their orbiting planets so faint, it had not been possible to prove their existence. A number of false claims over the previous decades had made astronomers weary and cautious, and it is unlikely that the discovery of two planetary-mass objects orbiting an exotic neutron star by Alexander Wolszczan and Dale Frail in 1992, with hindsight a mere oddity, had changed this.

The detection method used by Mayor and Queloz, the radial velocity technique, measures the regular change in Doppler shift of a stellar spectrum caused by the gravitational pull of a companion object. The method was well proven and had been used to measure orbits and masses of binary stars since the early days of spectroscopy. However, Jupiter is about a thousand times less massive than a sun-like star, meaning that a Doppler shift induced by such planet would only change by a bit over twenty meters per second during its decade-long orbit – too difficult to measure. This did not defer them to start monitoring a sample of 140 stars just to see what is out there.

Using their newly-built and innovative instrument, *ELODIE*, on the 1.93m telescope at the *Observatoire de Haute Provence* in France, they began to observe targets in April 1994, and already in the autumn of that same year they noticed the velocity variations of 51 Pegasi. Since they would imply a planet of half a Jupiter mass in a 4.2 day-orbit, well within the orbit of Mercury, they were at first unsure about this result. Instead of publishing their discovery, and risking to follow the fate of some illustrious predecessors, they waited until the next observing season to monitor the star again, but continuously for eight nights. The outcome is now Nobel-prize history.

The initial reception of their announcement was bimodal, ranging from hysterical excitement that a centuries-long quest had finally delivered, to deep skepticism. Of course, the Doppler method only measures the radial component of the reflex motion of the star, so for a face-on orbit the companion could be a brown dwarf or a small star. And even if it was of planetary mass, would this really be a planet formed like those in our own solar system, or a completely different beast? Also, how sure could the team be that this was not some previously undiscovered stellar pulsation: maybe only the surface of the star is moving back and forth, not the star as a whole. The latter suggestion was the most serious one, with the eminent stellar astronomer David Gray publishing a paper in Nature early 1997, claiming that 51 Pegasi showed line shape variations pointing to stellar oscillations, not a planet. However, already before his article appeared in print, its findings were rebutted with better data: no pulsations.

Within a year, six other gas-giant planets were found, many of them by the American rivals Geoff Marcy and Paul Butler and collaborators, who had been sitting on their data (and also quickly confirmed the existence of 51 Pegasi b). This provided a powerful statistical argument against face-on orbits. Also, theoretical endeavors showed that planets could migrate inwards through early interactions with the circumstellar disk. In the following years, some planets were shown to exhibit eccentric orbits, making stellar oscillations as the origin of their Doppler variations highly unlikely. The first multiple planet systems were found. This all cumulated in the discovery of the first transiting planet in 2000, showing a dark object crossing a stellar disk by David Charbonneau and his team (which also included Mayor). This removed the last piece of doubt about the correctness of the planetary hypothesis, even from the most skeptical and conservative astronomers.

Ever since their Nobel-prize discovery, Mayor and Queloz have been at the forefront of the exoplanet field. With their team at Geneva Observatory, they developed the most stable spectrographs to date, such as HARPS and ESPRESSO at the European Southern Observatory in Chile, capable of detecting Earth-mass planets. They also had their hand in many of the transit discoveries, such as those with the CoRoT and Kepler space missions. The future is bright. Since the early years of this millennium, it is also possible to probe the atmospheres of planets, either through transit spectroscopy or direct imaging. This has resulted in increasingly detailed climatological information, such as planet temperatures, molecular abundances, clouds, global circulations and planet spin. While this is currently restricted to mostly gas-giant planets, this will soon change with the launch of the James Webb Space Telescope, and the construction of the European Extremely Large Telescope in Chile. Characterization of increasingly more Earth-like planets will be within reach, such as Proxima b, a temperate Earth-mass planet around our nearest neighbor, and the seven Earth-size planets of the TRAPPIST-1 system. Do they have atmospheres? What are their main constituencies? Are they water-rich? Or even, do they show molecular oxygen – a possible sign of biological activity? Thank you, Michel and Didier, for starting this thrilling journey. There will be many more exciting discoveries to come. ■

■ **Ignas Snellen,**
Leiden Observatory, Leiden University, The Netherlands

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OSA Frontiers in Optics 2019

A Focus on Quantum Brings to Light Innovations in Research and Applications

The international 'OSA Frontiers in Optics and Laser Science APS/DLS (FiO + LS)' conference is a joint meeting of the Optical Society (OSA) and the Division of Laser Science (DLS) of the American Physical Society.

The conference unites the OSA and APS communities for five days with a variety of high quality speakers and special events sessions. The accompanying Science + Industry Showcase features leading optics companies, technology products and programs making the conference a place where scientific ideas meet industrial interests.

▲ Ronald Hansen, plenary speaker at FiO 2019

In particular, this year's conference showed how a focus on quantum is bringing to light innovations in both research and applications. The first plenary presentation of FiO + LS, titled 'Generating High-Intensity, Ultrashort Optical Pulses' was delivered by 2013 OSA President and 2018 Nobel Laureate in Physics Donna Strickland, who discussed the foundational research that led to her award-winning development of chirped pulse amplification (CPA) and the myriad innovations it has spawned. The power of CPA comes from its ability to create incredibly powerful yet fleetingly brief bursts of laser light, which led to numerous scientific advances and to such innovations as advanced laser eye surgery and precision cutting applications for industry. Ronald Hanson, scientific director at QuTech, University of Delft, The Netherlands, provided a glimpse of future information sharing in the second plenary talk titled 'The Dawn of a Quantum Internet'. Hanson described how future quantum networks will harness the power of entanglement, potentially revolutionising the way data is stored, processed and transmitted across global networks.

◂ Ursula Gibson, president of The Optical Society

Technical sessions at this year's conference centred around four thematic areas: Autonomous Systems, Nanophotonics and Plasmonics, Virtual Reality and Augmented Vision and Quantum Technologies – the latter the first-ever cross-cutting theme at a FiO + LS conference. These themes provided opportunities for focused exploration into the compelling and promising technologies of today and tomorrow. In keeping with the conference objective to couple science and applications, two theme programs were supplemented by industry sessions on market trends and opportunities for key technologies. Each theme included an all-invited program of panel discussions and was anchored by a 45-minute talk offered by a visionary speaker from industry and research. This year's line-up included: Jeremy J. Baumberg (University of Cambridge, U.K.), Steven Cundiff (University of Michigan, U.S.A.), Bernard Kress (Microsoft Corp., U.S.A.), John Martinis (Google and University of California, Santa Barbara, U.S.A.), Toshiki Tajima (University of California, Irvine, U.S.A.), Mohan M. Trivedi (University of California, San Diego, U.S.A.) and Jelena Vuckovic (Stanford University, U.S.A.).

With about 1300 participants, the LiO+LS 2019 was a great success. The message was clear that, as an industry, optics and photonics is on the forefront of development, both in research and in translating discoveries into innovation engines. For those interested, video recordings of the plenary talks are available at the conference's website at frontiersinoptics.org. ■

(based on material provided by the OSA media relations)

▾ Young scientists at FiO 2019

Highlights from European journals

PLASMA PHYSICS

Machine Learning for Characterization and Control of Non-equilibrium Plasmas

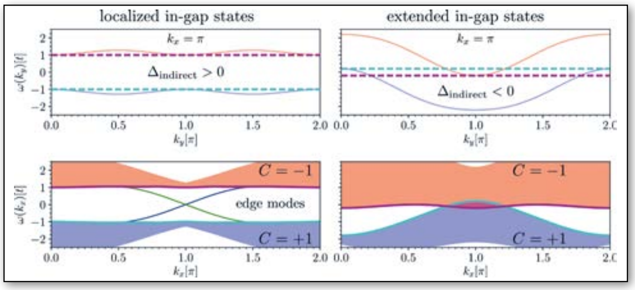
Recent breakthroughs in machine learning and artificial intelligence have created cross-disciplinary research opportunities in the field of non-equilibrium plasma (NEP) treatment of complex surfaces in applications such as plasma medicine, plasma catalysis, and materials processing. Machine learning can potentially transform modeling and simulation, diagnostics, and control of NEP. Machine learning can aid in the development of predictive models for plasma-surface interactions and plasma induced surface responses from experiments, especially when there is a lack of comprehensive theoretical models for the fundamental plasma-surface interaction mechanisms. Machine learning also holds promise for extracting the latent and often multivariate information of on-line plasma diagnostics. This can facilitate real-time inference of physical and chemical properties of NEP as well as complex surfaces interacting with NEP. Learning-based approaches to feedback control is another promising research area for NEP applications, especially when the plasma interacts with complex surfaces with time-varying and uncertain characteristics that in turn would lead to unpredictable plasma behaviour and surface responses. Learning-based process control and artificial intelligence is expected to become indispensable for reliable, flexible, and effective NEP treatment of complex surfaces in the future. ■

■ **A. Mesbah** and **D. B. Graves,**
'Machine learning for modeling, diagnostics and control of non-equilibrium plasmas', *J. Phys. D: Appl. Phys.* **52**, 30LT02 (2019)

MATERIAL SCIENCE

Delocalization of edge in topological phases

Topological properties are a hot topic currently. If the bulk of a system is topologically non-trivial (Chern number $C \neq 0$), the bulk-boundary correspondence predicts in-gap states in finite samples. These states close the energy gap between bands of different topology so that it can change at boundaries. Conventionally, the in-gap states are localized at these boundaries so that they are edge states. We show, however, that this localization only occurs for positive indirect gap. Generically, without indirect gap the in-gap states become extended by mixing with bulk states despite $C \neq 0$. This is illustrated for two fundamental lattice models (Haldane and checkerboard model) by adding terms to the Hamiltonians proportional to the identity in momentum space. Thus, the dispersions change while the topology remains unchanged. These terms can close the indirect gap and lead to delocalization of edge states in finite geometries. Thus, discrete topological invariants may exist without localized edge modes. This underlines the vital significance of indirect gaps for the existence of topological edge states and puts the bulk-boundary into perspective. ■



▲ Dispersions in a topological system with positive indirect gap and edge states (left); negative indirect gap and no edge states (right).

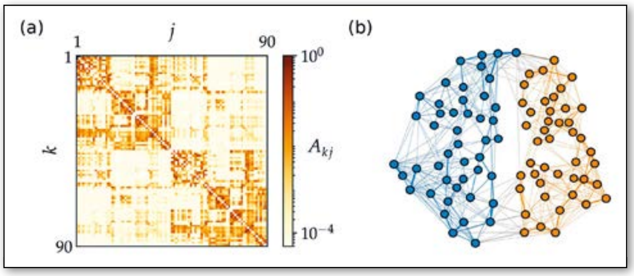
■ **M. Malki** and **G. S. Uhrich,**
'Delocalization of edge states in topological phases', *EPL* **127**, 27001 (2019)

MEDICAL PHYSICS

Partial synchronization as a model for unihemispheric sleep

Human brains exhibit a slight structural asymmetry of their two hemispheres (see Figure). We have investigated the dynamical asymmetry arising from this natural structural difference in healthy human subjects, using a minimum model which elucidates the modalities of unihemispheric sleep in human brain, where one hemisphere sleeps while the other remains awake. In fact, this state is common among migratory birds and mammals like aquatic species.

By choosing appropriate coupling parameters in a network of FitzHugh-Nagumo oscillators with empirical structural connectivity, we have observed that our brain model exhibits spontaneous symmetry breaking and bistability, where each hemisphere may engage into either of two dynamical states,



▲ Brain connectivity.

characterized by a relatively high and low degree of synchronization. However, a high degree of synchronization in one of the hemispheres always coincides with a low degree of synchronization in the other. This dynamical asymmetry can be even enhanced by tuning the inter-hemispheric coupling strength. These results are in accordance with the assumption that unihemispheric sleep requires a certain degree of inter-hemispheric separation.

The structural asymmetry in the brain allows for partial synchronization dynamics, which may be used to model unihemispheric sleep or explain the mechanism of the first-night effect in human sleep. ■

▪ **L. Ramlow**, **J. Sawicki**, **A. Zakharova**, **J. Hlinka**, **J. Ch. Claussen** and **E. Schöll**, 'Partial synchronization in empirical brain networks as a model for unihemispheric sleep', *EPL* **126**, 50007 (2019)

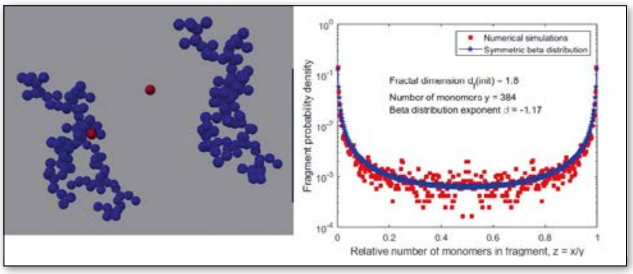
MATERIAL SCIENCE

Fractal agglomerates fragment **into dissimilar fragments**

A new study suggests the pattern of fibres in tissues is similar to the petals of a flower

Fragmentation occurs everywhere in nature: polymers degrade, soot particles break up, cells divide, volcanic ash fragments, droplets break up in turbulent flow, lung fluid fragments to generate droplets. Nevertheless, little is known about the distribution of fragment sizes when a fractal agglomerate breaks up. The fragment-size distribution upon random bond removal in a linear chain composed of identical units is uniform. How does the distribution change as the morphology of the fragmenting structure changes?

More generally, fragmentation kernels, which depend on the size distribution and the fragmentation rate, have been extensively used in population balance equations. Usually, their analytical form is dictated by homogeneity requirements (as suggested by coagulation kernels) or physical arguments. In this work, the morphology-dependent fragment-size distribution is determined from numerical simulations of fragmenting *in silico* fractal-like agglomerates. The overarching idea is to map the agglomerate onto a graph via the adjacency matrix, the matrix that specifies the monomer-monomer bonds. Fragmentation occurs via random bond removal. The simulations showed that the distribution is U-shaped, fragmentation into dissimilar fragments, accurately reproduced by a symmetric beta distribution. ■



▲ A fragmentation event and the distribution of fragment sizes upon random bond removal in a Diffusion Limited Cluster Aggregation (DLCA) cluster, EPL 127, 46002 (2019)

▪ **Y. Drossinos**, **A. D. Melas**, **M. Kostoglou** and **L. Isella**, 'Morphology-dependent random binary fragmentation of in silico fractal-like agglomerates', *EPL* **127**, 46002 (2019)

APPLIED PHYSICS

Chemotherapy drugs react differently to radiation while in water

A new study looked at the way certain molecules found in chemotherapy drugs react to radiation while in water, which is more similar to in the body, compared to previous research that studied them in gas

▲ Chemotherapy medication reacts to radiation. Image by Michal Jarmoluk from Pixabay.

Cancer treatment often involves a combination of chemotherapy and radiotherapy. Chemotherapy uses medication to stop cancer cells reproducing, but the medication affects the entire body. Radiotherapy uses radiation to kill the cancer cells, and it is targeted to the tumour site. In a recent study, published in the journal *EPJD*, the authors studied selected molecules of relevance in this context. They wanted to see how these molecules were individually affected by radiation similar to that used in radiotherapy. ■

■ **S. E. Huber** and **A. Mauracher**,
'Electron impact ionisation cross sections of fluoro-substituted nucleosides', *Eur. Phys. J. D* **73**, 137 (2019)

HISTORY

Science puts **historical claims to the test**

The latest analytical techniques available to scientists can confirm the validity of historical sources in some cases, and suggest a need for reconsideration in others

▲ Science provides valuable dating tools for artefacts

As any historian will tell you, we can rarely take the claims made by our ancestors at face value. The authenticity of many of the artefacts which shape our understanding of the past have been hotly debated for centuries, with little consensus amongst researchers. Now, many of these disputes are being resolved through scientific research, including two studies recently published in EPJ Plus. The first of these, led by Diego Armando Badillo-Sanchez at the University of Évora in Portugal, analysed an artefact named 'Francisco Pizarro's Banner of Arms' – believed to have been carried by the Spanish conquistador during his conquest of the Inca Empire in the 16th century. The second team, headed by Armida Sodo at Roma Tre University in Italy, investigated a colour print of Charlemagne – the medieval ruler who united much of Western Europe – assumed to be from the 16th century. ■

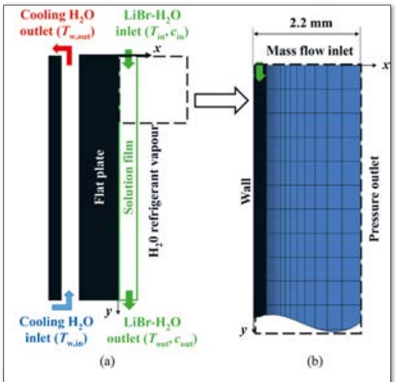
■ **D. A. Badillo-Sanchez**, **C. B. Dias**, **A. Manhita** and **N. Schiavon**,
'The National Museum of Colombia's "Francisco Pizarro's Banner of Arms": a multianalytical approach to help uncovering its history', *Eur. Phys. J. Plus* **134**, 224 (2019)

■ **A. Sodo**, **L. Ruggiero**, **S. Ridolfi**, **E. Savage**, **L. Valbonetti**, and **M.A. Ricci**,
'Dating of a unique six-colour relief print by historical and archaeometric methods', *Eur. Phys. J. Plus* **134**, 276 (2019)

MATERIAL SCIENCE

Improving heat recycling with **the thermodiffusion effect**

Numerical simulations of the thermodiffusion effect within falling film absorbers reveal that thin films composed of liquid mixtures with negative thermodiffusion coefficients enhance the efficiency of heat recycling



▲ Recycling heat using falling films.

Absorption heat transformers can effectively reuse the waste heat generated in various industries. In these devices, specialised liquids form thin films as they flow downward due to gravity. These liquid films can absorb vapour, and the heat is then extracted by a coolant so that it can be used in future processes. So far, however, there has been little research into how the performance of these films is influenced by the thermodiffusion effect – a behaviour seen in mixtures, where different types of mixture respond differently to the same temperature gradient. In a study recently published, researchers from the Fluid Mechanics group at Mondragon University and Tecnalia, pooled their expertise in transport phenomena and absorption technology. Together, they explored for the first time the influence of the thermodiffusion property on the absorption, temperature and concentration profiles of falling films. ■

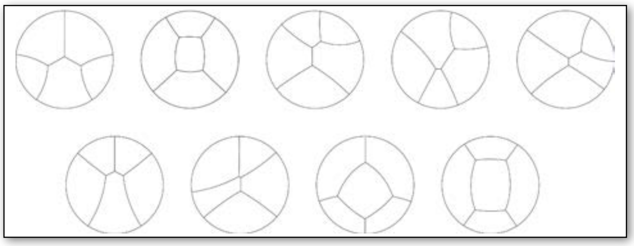
■ **P. Fernandez de Arroiabe**, **A. Martinez-Urrutia**, **X. Peña**, **M. Martinez-Agirre**, **M. M. Bou-Ali**,
'On the thermodiffusion effect in vertical plate heat exchangers', *Eur. Phys. J. E* **42**, 85 (2019)

SOFT MATTER

Optimising structures within complex arrangements of bubbles

Computer simulations reveal the secret to stronger, cheaper structures shaped like bubbly foams

While structures which emulate foam-like arrangements of bubbles are lightweight and cheap to build, they are also remarkably stable. The bubbles which cover the iconic Beijing Aquatics Centre, for example, each have the same volume, but are arranged in a way which minimises the total area of the structure – optimising the building's construction. The mathematics underlying this



▲ Optimising an arrangement of five bubbles.

behaviour is now well understood, but if the areas of the bubbles are not equal, the situation becomes more complicated. Ultimately, this makes it harder to make general statements about how the total surface area or, in 2D, edge length, or 'perimeter', can be minimised to optimise structural stability. In new research published recently, the authors explore how different numbers of 2D bubbles of two different areas can be arranged within circular discs, in ways which minimise their perimeters. ■

▮ **F. Headley** and **S. Cox**,
'Least-perimeter partition of the disc into N bubbles of two different areas', *Eur. Phys. J. E* **42**, 92 (2019)

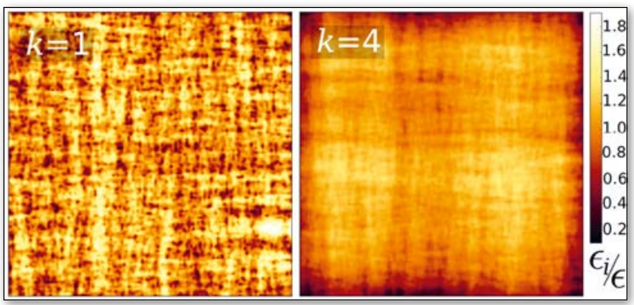
MATERIAL SCIENCE

New insights into the early stages of creep deformation

Computer simulations show that the evolution of material structures during creep deformation can modify material properties.

The properties of many materials can change permanently when they are pushed beyond their limits. When a given material is subjected to a force, or 'load', which is stronger than a certain limit, it can become so deformed that it won't return to its original shape, even after the load is removed. However, heavy loads aren't strictly necessary to deform materials irreversibly; this can also occur if they are subjected to lighter loads over long periods of time, allowing a slow process called 'creep' to take place. Physicists have understood for some time that this behaviour involves sequences of small, sudden deformations, but until now, they have lacked a full understanding of how creep deformation affects material properties over time. In new research published recently, the authors analysed the characteristic ways in which material structures evolve during the early stages of creep deformation. ■

▾ Varying strain patterns during creep deformation.

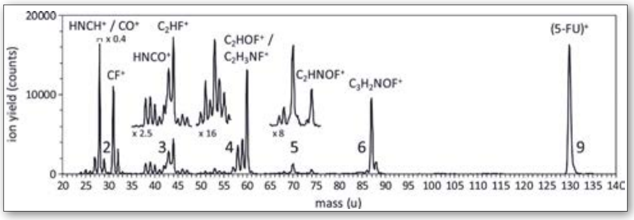


▮ **D. Fernandez Castellanos** and **M. Zaiser**,
'Statistical dynamics of early creep stages in disordered materials', *Eur. Phys. J. B* **92**, 139 (2019)

APPLIED PHYSICS

Fragmenting ions and radiation sensitizers

A new study using mass spectrometry is helping piece together what happens when DNA that has been sensitized by the oncology drug 5-fluorouracil is subjected to the ionising radiation used in radiotherapy.



▲ Mass spectrum of 5-fluorouracil showing ions produced by impact with high-energy electrons.

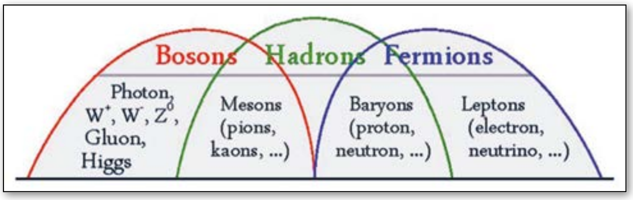
The anti-cancer drug 5-fluorouracil (5FU) acts as a radiosensitizer: it is rapidly taken up into the DNA of cancer cells, making the cells more sensitive to radiotherapy. However, little is known about the precise mechanism through which radiation damages cells. A team of scientists have now used mass spectrometry to shed some light on this process; their work was recently published in *EPJ D*. A full understanding of this process could ultimately lead to new ways of protecting normal tissues from the radiation damage caused by essential cancer treatments. ■

▮ **P.J.M. van der Burgt**, **M.A. Brown**, **J. Bockova**, **A. Rebelo**, **M. Ryszka**, **J-C. Poully** and **S. Eden**,
'Fragmentation processes of ionized 5-fluorouracil in the gas phase and within clusters', *Eur. Phys. J. D* **73**, 184 (2019)

PARTICLE PHYSICS

Improving the signal-to-noise ratio in quantum **chromodynamics simulations**

A new Monte Carlo based simulation method enables more precise simulation for ensembles of elementary particles



▲ This illustrates the fact that the fermions - the class of particle that this technique can be used to model- includes the particles that make up 'ordinary' matter (protons, neutrons and electrons). © Wikimedia Commons.

Over the last few decades, the exponential increase in computer power and accompanying increase in the quality of algorithms has enabled theoretical and particle physicists to perform more complex and precise simulations of fundamental particles and their interactions. If you increase the number of lattice points in a simulation, it becomes harder to tell the difference between the observed result of the simulation and the surrounding noise. A new study recently published in EPJ Plus, describes a technique for simulating particle ensembles that are 'large' (at least by the standards of particle physics). This improves the signal-to-noise ratio and thus the precision of the simulation; crucially, it also can be used to model ensembles of baryons: a category of elementary particles that includes the protons and neutrons that make up atomic nuclei. ■

▮ **M. Cè**,
'Locality and multi-level sampling with fermions', *Eur. Phys. J. Plus* **134**, 299 (2019)

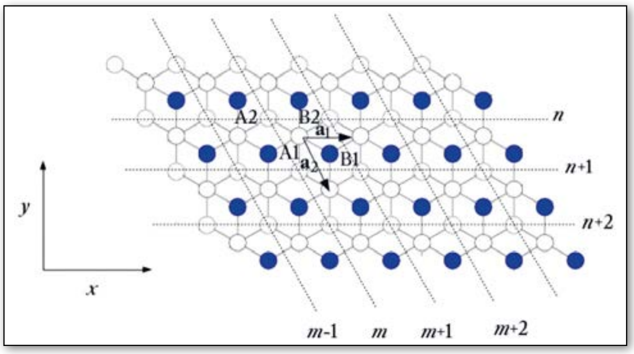
MATERIAL SCIENCE

Conductivity at the edges **of graphene bilayers**

The conductivity of dual layers of graphene greatly depends on the states of carbon atoms at their edges; a property which could have important implications for information transmissions on quantum scales.

Made from 2D sheets of carbon atoms arranged in honeycomb lattices, graphene displays a wide array of properties regarding the conduction of heat and electricity. When two layers of graphene are stacked on top of each other to form a 'bilayer', these properties can become even more interesting. At the edges of these bilayers, for example, atoms can sometimes exist in an exotic state of matter referred to as the 'quantum spin Hall' (QSH) state, depending on the nature of the interaction between their spins and their motions, referred to as their 'spin-orbit coupling' (SOC). While the QSH state is allowed for 'intrinsic' SOC, it is destroyed by 'Rashba' SOC. In an article recently published, the authors showed that these two types of SOC are responsible for variations in the ways in which graphene bilayers conduct electricity. ■

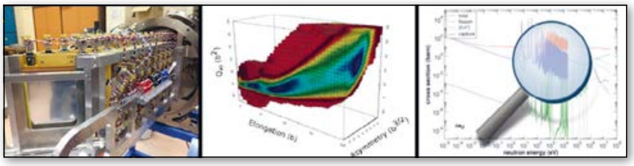
▼ Intriguing properties arise in graphene bilayers.



▮ **P. Sinha** and **S. Basu**,
'Study of edge states and conductivity in spin-orbit coupled bilayer graphene', *Eur. Phys. J. B* **92**, 207 (2019)

NUCLEAR PHYSICS

WONDER-2018: a workshop on nuclear data



▲ By combining experimental data (left, example of experimental setup) and theoretical calculations (middle, example of theoretical calculations), it becomes possible to perform an evaluation of nuclear data (right, example of evaluated cross-sections). Those evaluated nuclear data are collected in a regularly updated international library such as JEFF (Joint Evaluated Fusion and Fission).

To describe the path of neutrons in the material but also the chain reactions that take place in a reactor and the changes in the composition of matter due to nuclear reactions, neutronics uses computer codes. These codes have also acquired such a level of performance since the last two decades that the main source of uncertainty in neutronic calculations comes today from nuclear data. In this context, the 5th edition of the International **W**orkshop **O**n **N**uclear **D**ata **E**valuation for **R**eactor Applications (WONDER-2018), organized by the French Alternative Energies and Atomic Energy Commission (CEA) in collaboration with the NEA (Nuclear Energy Agency of the OECD) was held in Aix-en-Provence, France, on October 2018. The main objective was to identify future trends in the measurement, modeling and evaluation of nuclear data needed for current reactors and innovative reactor concepts. Proceedings were published in EPJ Web-of-Conferences:
(https://epjwoc.epj.org/articles/epjconf/abs/2019/16/contents/contents.html). ■

▮ **WONDER-2018 – 5th International Workshop On Nuclear Data Evaluation for Reactor applications**
EPJ Web of Conferences **211** (2019)

by Jacques Vigué
Laboratoire Collisions, Agrégats, Réactivité UMR 5589, CNRS - Université de Toulouse, UPS
DOI: https://doi.org/10.1051/epn/2019501

Some comments on the historical paper by H. Schmidt-Böcking "The Stern-Gerlach experiment re-examined by an experimenter" (EPN 50/3 pp. 15-19)

This paper is very interesting, with a large amount of poorly known or fully unknown details about this experiment. However, I would like to correct two imprecisions and add a small complementary information:

Bottom of page 15: in the sentence "Using the Molecular Beam Method (MBM) that he invented in 1919…", H. Schmidt-Bocking attributes to Stern the invention of the Molecular Beam Method. However, it is well known that the first molecular beam was built by L. Dunoyer [1] in 1911 who used it in the following years to observe the resonance fluorescence of sodium atom.

Middle of the second column of page 16: "As was typical of all experiments he [=Stern] performed, he carefully calculated the required conditions (the beam collimation parameters, the strength of the magnetic field, *etc.*) in order to be able to resolve, from the deflected beam, the tiny transverse momentum transfer due to the existence of an internal atomic magnetic moment (fig.1)". This sentence which refers to Stern 1921 paper[2] is somewhat misleading. The magnetic field gradient considered by Stern was 10^4 Gauss per centimeter (10^2T/m in SI units) and the calculated beam deflection was 1/100 mm, a lot too small to be detected. This is due to the largely underestimated value of the magnetic field gradient and the experiment was a success because the gradient was at least 10 times larger. One may wonder why Stern has made such a large underestimation of the magnetic field gradient...

The complementary information is a note in Stern 1921 paper which states (text taken from the English translation) "Mr. W. Gerlach and I have been occupied for some time with the realization of this experiment. The reason for the present publication is the forthcoming paper by Messrs. Kallmann and Reiche concerning the deflection of electrical dipolar molecules in an inhomogeneous electric field. As I understand from the proofs, which were most kindly sent to me, our considerations are mutually complementary....". This note proves that the competition was strong and, at the same time, authors were kindly communicating the proofs of their papers to possible competitors! ■

References

[1] L. Dunoyer, *Comptes Rendus Acad. Sc.* **152**, 592 (1911).

[2] O. Stern, *Z. Phys.* **7**, 249 (1921) which is available in an English translation in O. Stern, *Z. Phys. D* **10**, 114 (1988)

ANSWER by Horst Schmidt-Böcking

First I am happy and thankful that there are readers who read papers carefully and are willing to come in contact with the author.

To the history of the so-called molecular beam method MBM:

I presented in my paper the view of an experimental atomic physicist, who is performing with his group since several decades high resolution momentum imaging of atomic particles or fragments. Thus I see an important difference in the early history of the atomic beam experiments performed by Dunoyer and those performed 8 years later by Stern. Stern used the atomic beam of Dunoyer but he ennobled it to a precision method measuring tiny momentum transfers. This is for me really the beginning of the so-called **MBS**.

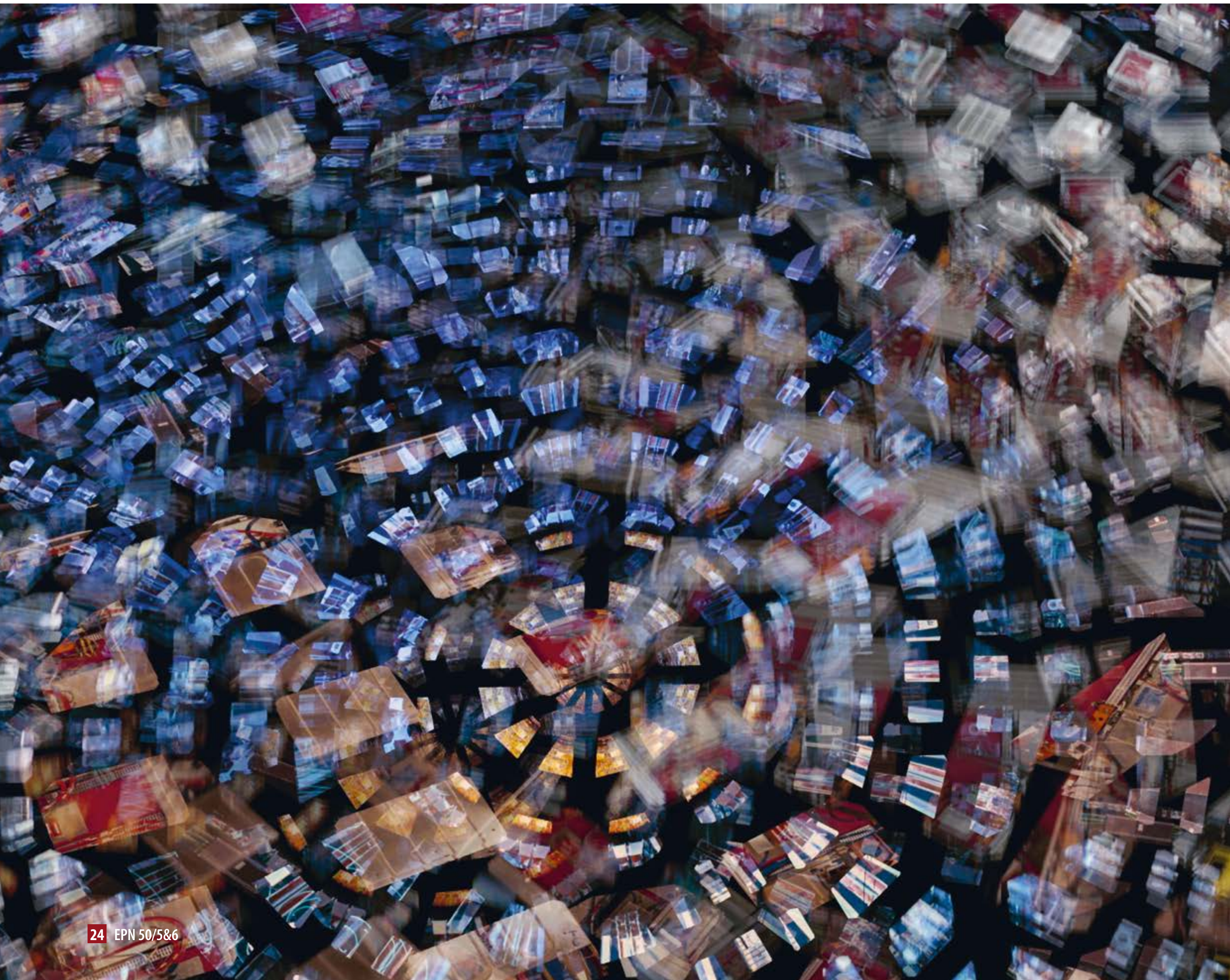
But Dunoyers work was clearly important for Stern and he mentioned it in his first publication on the Maxwell-Boltzmann velocity distribution measurement (O. Stern, Eine direkte Messung der thermischen Molekulargeschwindigkeit. *Z. Physik* **2**, 49 (1920)). We will publish in October in the German "Journal für Physik) an article, which begins with the work of Dunoyer but then the article describes the basic new features of Otto Sterns MBM.

Stern was indeed in close contact with people in the Kaiser Wilhelm Institut für Physikalische Chemie in Berlin (today the Fritz Haber Institut) and knew what Reiche and Kallmann were planning to do (electric dipole moment). Therefore Stern published very early his idea how to perform a similar experiment deflecting atoms by the interaction of the inner atomic magnetic moment with an inhomogeneous magnetic field (the idea to use inhomogeneous fields was Madelungs idea, see interview of Stern in 1961 by Jost). In Sterns first publication (Otto Stern, Ein Weg zur experimentellen Prüfung der Richtungsquantelung im Magnetfeld. *Z. Physik* **7**, 249 (1921)) his calculation was based on a magnetic field strength of about 10.000 Gauss/cm thus the predicted deflection was only 0.01mm, but later in the real experiment of Feb. 7^{th} to 8^{th} 1922 Gerlach reached fields of about 200.000 Gauss/cm, which yielded deflections of 0.1 mm or even a little more (see Walther Gerlach und Otto Stern, Über die Richtungsquantelung im Magnetfeld. *Ann. Physik* **74**, 673 (1924) and Walther Gerlach, Über die Richtungsquantelung im Magnetfeld II, *Annalen der Phys.* **76**, 163 (1925)). ■

THE STORY OF A DISCOVERY: HOW WE FOUND THE LONG-SOUGHT-AFTER HIGGS BOSON

Chiara Mariotti – INFN Torino, Italy – DOI: https://doi.org/10.1051/epn/2019502

The Higgs boson has been discovered in 2012 by the ATLAS and CMS experiments at the LHC, 50 years after its prediction. The scientific and human adventure of this discovery will be summarized in this article, going back to the search at LEP and to the foundation of the LHC Higgs Cross Section working group.

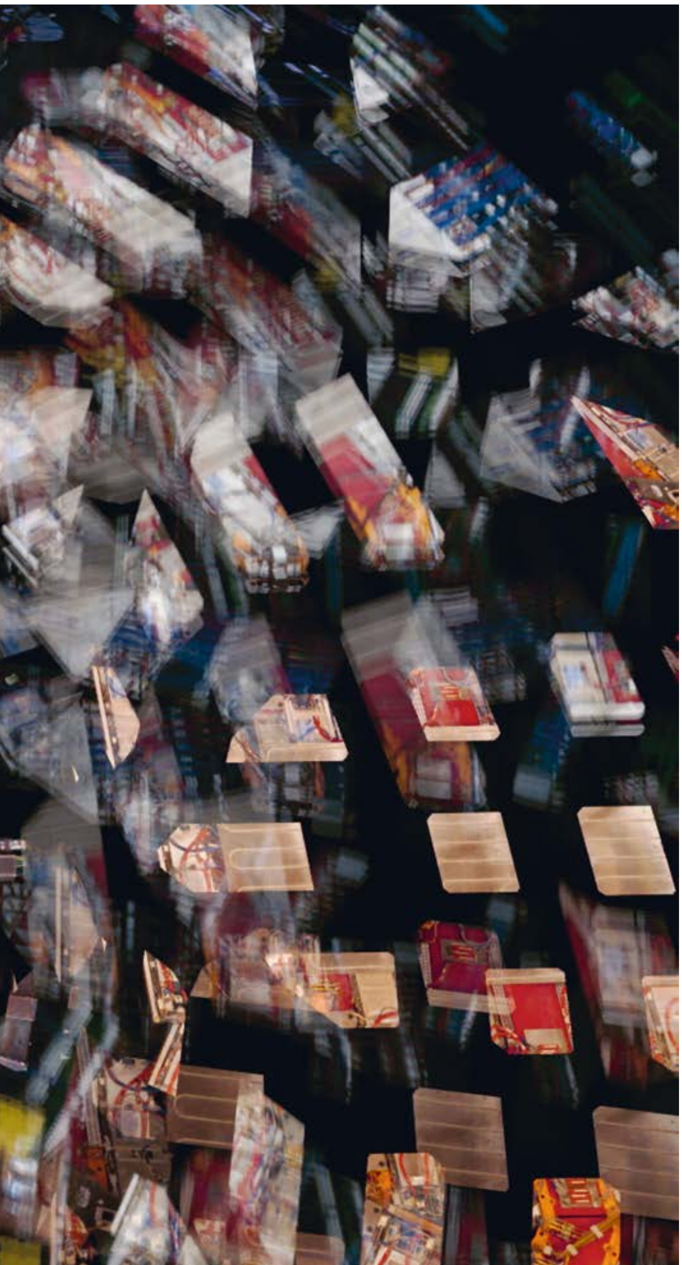


The standard model time-line

In 1954 Chen Ning Yang and Robert Mills extended the idea of a local gauge symmetry, to the case of non-abelian gauge groups. The theory required that the gauge vector bosons are strictly massless.

In 1961 Sheldon Glashow suggested that electromagnetic and weak interactions might be described by a non-abelian gauge theory, following the work of Yang and Mills, but a severe difficulty was yet to be solved: weak interactions are very short-ranged, and the corresponding intermediate vector bosons must be extremely heavy (roughly, 100 times the proton mass).

In 1964 Robert Brout, François Englert, Peter Higgs, Gerald Guralnik, Carl Richard Hagen, and Tom Kibble realized that the non-abelian gauge symmetry can be formulated in such a way that some of the gauge vector bosons acquire a non-zero mass, without spoiling the gauge symmetry. The so-called Higgs mechanism produces three massive and one massless gauge boson, plus a physical spin-0 boson (the Higgs particle.).



- In 1967-1968 Steven Weinberg and Abdus Salam, combining the theories of Yang and Mills, the Higgs mechanism and the Glashow hypothesis developed the theory of the standard model (SM) of electroweak interactions.
- In 1970 Gerardus t'Hooft and Martinus Veltman demonstrated that this new formulation of non-abelian gauge theories is perturbatively renormalizable.
- In 1973 Gargamelle, a bubbles chamber experiment at CERN, discovered the weak neutral current, using neutrino and anti-neutrino beams.
- In 1983 the UA1 and UA2 experiments at CERN discovered the W and the Z bosons.
- From 1989 to 2000 the LEP experiments at CERN signed the triumph of the standard model, by measuring its parameters with very high precisions.
- In 1995 at Tevatron the CDF and D0 experiments discovered the top quark, completing a sequence started in 1973 with the discovery of the c-quark, followed by the discovery of the b-quark in 1976.
- Only in 2012 at the large hadron collider (LHC) at CERN, the ATLAS and CMS experiments discovered the last missing piece of the standard model: the Higgs boson.

◂ Artistic view of the CMS detector, from "Subatomic desire" by Silvia Fabiani (http://www.atomesdansants.com)

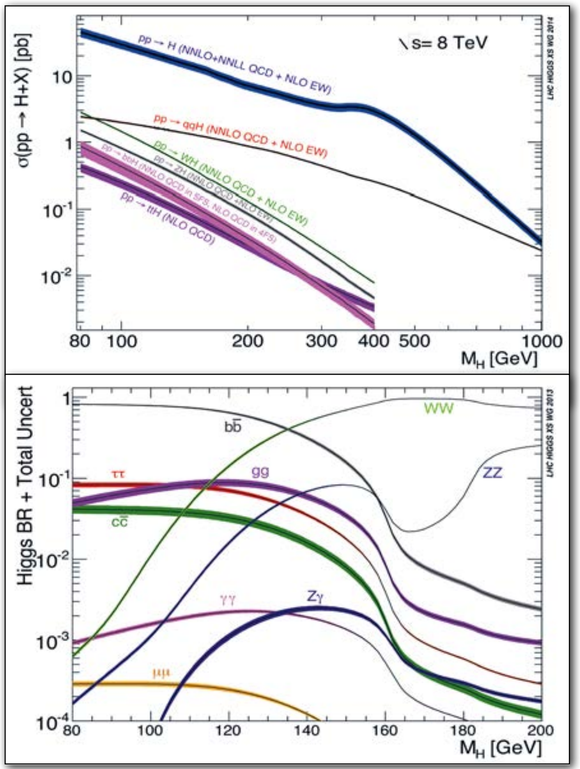
The LEP result

LEP (Large Electron Positron collider) was located in a 27 km long circular tunnel, at about 100 meters below ground, which was the largest European civil-engineering work of that time. The first interactions were delivered in August 1989 at 91 GeV. It was an amazing night, since the moment the two beams crossed in the detectors, we could observe on the display the Z decaying i n two leptons or in two jets, being the Z exchange the (almost!) only process involved at that center-of-mass energy. The four LEP experiments (ALEPH, DELPHI, L3, OPAL) took data for 12 years. When LEP stopped in 2000, it had reached the maximum center-of-mass energy of 209 GeV.

It is hard to remember how little we knew about electroweak and QCD physics before LEP started! LEP allowed a gigantic step in our knowledge.

LEP experiments could measure SM quantities with very high precision. To give an idea of the level of accuracy, at LEP we could measure changes in the accelerator circumference of a fraction of a mm! While the standard model was tested at better than per mill accuracy, what was not found at LEP was very important as well, allowing to exclude many models.

LEP was the ideal place to measure quantities with high precision: the simplicity of the electron-positron initial state is transmitted to the final state. In the case of the search of the Higgs boson, the dominant production mechanism is the "Higgs-strahlung", $e^+e^- \rightarrow Z(*) \rightarrow ZH$, allowing to produce a Higgs boson of mass $m_H < E_{cm} - m_Z$. The final state was expected to have two b-quark jets from the Higgs boson decay, and two fermions from the Z decay. The result at the end of the data taking was negative: LEP set a limit at 95%



▸ **FIG. 1: (a)** The SM Higgs production cross sections at $\sqrt{s} = 8$ TeV as a function of the Higgs-boson mass [2]. **(b)** The SM Higgs branching ratios as a function of the Higgs-boson mass [2].

CL of $m_H > 114.4$ GeV, with an expected limit of 115.3 GeV [1]. The observed limit was lower than the expected since there were four events with a non-negligible probability to be Higgs boson candidates. Indeed, immediately after the end of the run, before all the final alignments and calibrations of the detectors, there were even more significant candidates that gave a probability of 0.00065 of the fluctuation to be compatible with the background only hypothesis. The initial excitement faded after the reprocessing of the data with final calibrations, when the compatibility with the background only hypothesis became 0.0024, *i.e.* less than 2 sigma effect.

The LEP accelerator ended operation in December 2000 and the dismantling of the experiments and the accelerator started immediately.

In 1995 Siemens had offered to produce 32 Superconducting Radio Frequency cavities for 32 MCHF, in addition to the ones already ordered, before dismantling the production line. With those cavities LEP could have reached E_{cm}=220 GeV, thus $m_H < E_{cm} - m_Z \sim 129$ $(\pm \Gamma_Z)$ GeV. The CERN management, under pressure to get the LHC approved, decided not to increase the energy to more than 200 GeV and leave then the future to LHC.

In reality LEP went up to 209 GeV, because the RF cavities worked very well, and with a very ingenuous trick, that was "increasing" the radius of the collider, by moving the orbit of the electrons and positrons to the maximal possible external side of the beam pipe.

Towards LHC

In December 2000 LEP stopped and it was dismantled. LHC started the engineering work. The ATLAS detectors was built in situ in the experimental cavern, CMS on the surface and lowered between November 2006 and August 2008 to the underground cavern. The early commissioning was performed using cosmic rays. In September 2008 proton beams were circulated for the first time, but due to an accident, the first interactions were given only in November 2009, after 1 year of tremendous reparation work.

In the years 2010-2012 LHC delivered p-p collisions at energies of 7 and 8 TeV.

The LHC Higgs Cross Section working group

The same day that LHC delivered the first proton-proton collisions to the experiments, a small group of physicists met in Torino, to give birth to the group called "LHC Higgs Cross Section working group" (LHCHXSWG).

In 2008 Giampiero Passarino had the idea of the group for the first time, emphasizing the urgency, since a discovery could come sooner than expected.

In August 2009 we met at CERN with two physicists from ATLAS, and in Torino in November, the group was formed, and the program was discussed. In January 2010 the experiments formally recognized and endorsed the activities of the group. The first Yellow Report (a highly reputed CERN Report series traditionally published with a distinctive Yellow cover) was published in February 2011 [2]. This meant that since day zero the Higgs analyses from ATLAS and CMS have been using the LHCHXSWG prescriptions and results.

It was not all roses and flowers, of course! The first hard moment was between Christmas 2010 and New Year's eve 2011 when we had to submit the first Yellow Report. Some of us will hardly forget that winter break! Another hard moment was at the end of 2014, that we can summarize with this sentence: "when the battle is won the generals are coming". Thus some drastic change in the management was done.

We have published four yellow reports, that have been extensively used and cited. The group increased from ~50 authors to more than 350. The two plots of Figure 1 were the most used ones in all the Higgs boson analyses: the cross section for the Higgs boson productions at LHC and the branching ratio of its decays.

The first years of LHC data taking

The first years of data taking were a successive series of emotions; adrenaline was flowing without interruption. We (CMS) had a first spectacular four-muons events in September 2010 with a four-muons invariant mass m(4l) = 201.7 GeV, after having collected 35 pb^{-1} of luminosity[1] at 7 TeV.

[1] The luminosity is a performance parameter of the accelerator that allows to estimate how many events will be produced for a process with a given cross section. It is measured as the inverse of a cross section.

For the EPS conference in Grenoble, in July 2011 we went into panic mode because of two intriguing four leptons events at m(4l) ~ 145 GeV. We had to scrutinise the data, the Monte Carlo generators, going into the details of the diagrams, interferences, parameter setting *etc.* The collaboration put us under a tight review, but we finally were approved and (surprise!) at the EPS-2011 ATLAS presented a similar intriguing event with the same mass.

The 13 of December 2011, ATLAS and CMS presented preliminary analyses of the Higgs boson search with 4.5 fb^{-1} of luminosity at 7 TeV. Both experiments presented an exclusion at 95% CL for Higgs of masses larger than ~ 130 GeV and lighter than ~115 GeV. An excess of about 3 sigma was observed by both collaborations between ~115 and ~130 GeV.

In parallel, precision electroweak measurements from LEP and Tevatron suggested that the Higgs should be light, *i.e.* less than 130 GeV.

Both experiments decided not to look at the data in 2012 until the estimated statistics to discover an eventual Higgs boson of mass around 115-130 GeV were collected.

June and July 2012

And here comes the 14th of June 2012, in the CMS experiment. The analysis is ready, the background is under control, the statistics is enough to observe a Higgs if its mass is 115-130 GeV. It is 19:00 in a room of Building 40 at CERN and with few people connected in video conference. We run the analysis program for the first time of that year on the data, and we project the result on the screen. And there it is: a beautiful peak!

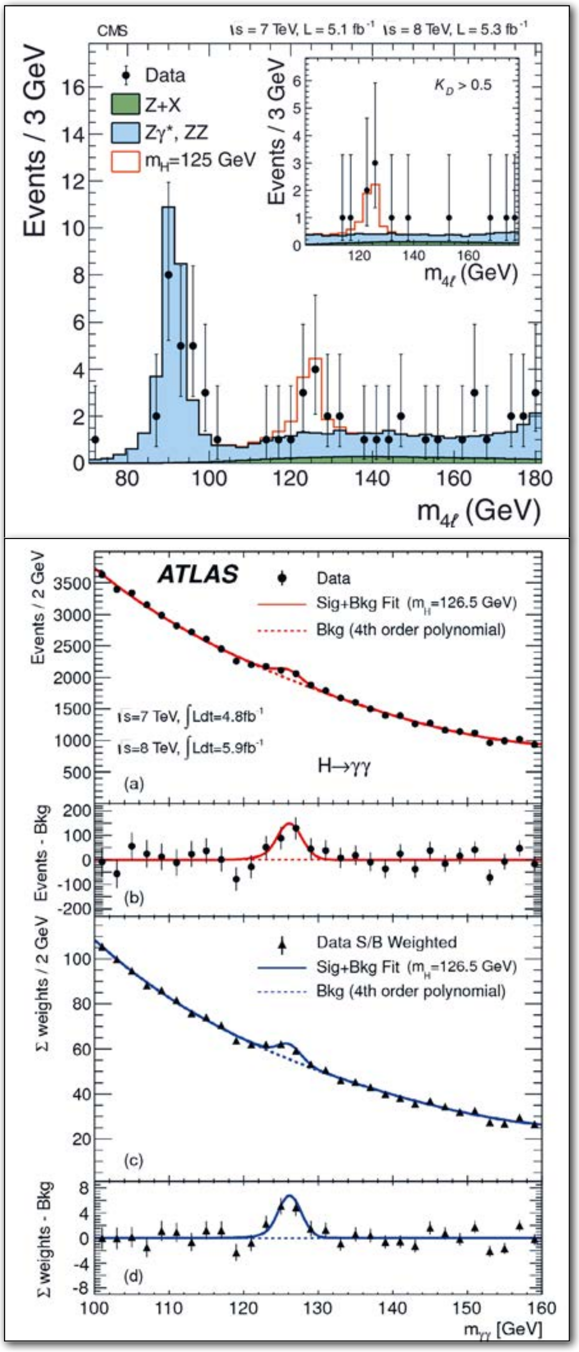
We were seeing a new particle! Maybe the Higgs boson, so much sought after. From that moment, it was a crescendo of emotions! I remember not having slept four days in a row because of too much adrenaline.

The next day, in the afternoon of the 15th of June, all the collaboration was reunited. Around the world, hundreds of physicists working in the CMS experiment connected via videoconference to a room at CERN, where the different groups showed the results. Two channels, $H \rightarrow ZZ \rightarrow 4$ leptons and $H \rightarrow 2$ photons, showed a very nice peak. The other less sensitive channels, however, gave consistent results. Since the results were only to be released on the 4th of July, we had to keep the maximum of confidentiality until then. The most difficult challenge was not smiling when going around CERN!

The 3rd of July people started to camp outside the CERN Auditorium to be able to enter first thing the following morning. On the 4th of July, the Auditorium at CERN was packed; all the former directors of CERN, Englert, Higgs, Hagen, and Guralnik were present. The first to speak was the spokesperson of the CMS experiment. The emotion was so great that we could not breathe and when he unveiled the transparency that showed the coveted 5 sigma the applause was long and loud. And then it was ATLAS, that showed a 5 sigma peak as well, at the same mass value. In Figure 2 there are the plots of two channels from the experiments [3,4].

At the end of 2012, after having collected almost 20 fb^{-1} at 8 TeV, each channel had a peak that could claim a discovery by itself. With the four-leptons final state we could measure the spin and parity to be consistent at 95% CL with the one of the SM Higgs boson. The beautiful peak that we saw for the first time on the 14th of June, was indeed the Higgs boson.

As Paul Dirac said: *"The beauty of an equation is more important than its correctness, in the sense that if an equation is beautiful, sooner or later it will be demonstrated to be correct".*



◂**FIG. 2: (a)** Distribution of the four-lepton invariant mass for the $ZZ \rightarrow 4\ell$ analysis in CMS. The points represent the data, the filled histograms represent the background, and the open histogram shows the signal expectation for a Higgs boson of mass m_H= 125 GeV, added to the background expectation. The inset shows the $m_{4\ell}$ distribution after selection of events with KD> 0.5 (*i.e.* with a high probability to be coming from signal, given their kinematic), as described in reference [4]. **(b)** The ATLAS distributions of the invariant mass of diphoton candidates after all selections for the combined 7 TeV and 8 TeV data sample [3]. The inclusive sample is shown in (a) and a weighted version of the same sample in (c). The result of a fit to the data of the sum of a signal component fixed to m_H=126.5 GeV and a background component described by a fourth-order Bernstein polynomial is superimposed. The residuals of the data and weighted data with respect to the respective fitted background component are displayed in (b) and (d).

In 2013 Prof Englert and Prof Higgs got the Nobel Prize in physics "for the theoretical discovery of a mechanism that contributes to our understanding of the origin of mass of subatomic particles, and which recently was confirmed through the discovery of the predicted fundamental particle, by the ATLAS and CMS experiment at CERN's Large Hadron Collider".

Another break-through: the Higgs boson width

In 2013, following the work of Kauer, Passarino and Caola, Melnikov, we constrained the Higgs width, Γ_H, to few tens of MeV using off-shell Higgs boson production [5]. An improvement of a factor ~200, with respect to the on-shell reconstruction, dominated by the experimental resolution limiting the measurement to few GeV.

It was an hard effort from the theoretical and experimental point of view, since we had to change all our analysis methods and Monte Carlo predictions. Thanks to many theoreticians involved in the LHCHXSWG we managed to present the first result in Moriond 2014.

The latest results with the statistics from Run 1 and half of Run 2, constrained the Higgs width to $3.2^{+2.8}_{-2.2}$ MeV.

The Higgs boson mass of the combined ATLAS and CMS Run1 data is m_H= 125.09 ± 0.24 GeV, with the statistical uncertainty of 0.21 GeV dominating over the systematic one of 0.11 GeV.

With the data collected in Run 1 and Run 2 many measurements have been possible: the Higgs boson coupling to the electroweak bosons and to all elementary fermions, differential cross sections and fiducial cross sections.

Extrapolating to the end of LHC, *i.e.* with 3 ab^{-1} of luminosity per experiment, most of the couplings will be known with at 2-4% precision, dominated by theory uncertainties.

Changing paradigm

As early as July 4th, it was clear to us physicists that our world would not be the same anymore. We now know that the Higgs boson exists and is not just an elegant and fascinating theory.

Before the discovery in 2012 the hypothesis was the SM and the unknown was the mass of the Higgs boson. Therefore, bounds on m_H were derived through a comparison with high precision data (LEP, Tevatron, LHC…).

After the discovery at LHC, given that the SM is fully specified, the possible unknowns are explored through deviations from the SM. Thus, schemas to define SM deviations are necessary. Two different approaches have been proposed, the κ-framework and the SMEFT (SM effective field theory) (see Yellow Reports [6,7] of the LHCHXSWG). The κ-framework is a procedure used at leading order (LO). It is valid only if κ~1, where κ is a multiplicative factor to the SM cross section. Thus, it can just give indications if there are deviations from the SM. The SMEFT is a methodology to study possible new physics effects from massive particles that are not directly detectable. The Lagrangian of the SM is extended by introducing additional dimension-6 (or 8) operators. The underlying assumption of an effective quantum field theory is that the scale of new physics Λ is large compared to the experimentally-accessible energies.

Moreover, we must continue to search for new particles to understand the "nature" of the newly discovered Higgs boson and try to understand if the SM is a fundamental theory. From the discovery of the neutral weak current in 1973, up to the Higgs discovery in 2012, no flaw has been detected in the SM. Is the SM just an effective field theory?

There are many open questions and many unsatisfactory explanations, and we must increase the precision of the measurements and of the predictions, especially wherever there is a little disagreement with data.

Shall we instead propose something new, completely different?

Towards a new world

We have built huge and sophisticated accelerator and detectors, "the cathedrals of science", to find an elementary particle that explain why elementary particles have mass.

The discovery of the Higgs boson is invaluable. It is a great success of a community of thousands of physicists: it is the result of a large group, where each of us has given their personal contribution. ■

About the Author

Chiara Mariotti is an elementary particles physicist of INFN-Torino. Her research activity has been focussing on data analysis in the experiments at the LEP and LHC colliders. She was one of the main actors for the Higgs boson discovery. She was awarded with the Emmy Noether Distinction for women in physics in 2018.

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CARBON NEUTRAL AVIATION

Rob Terwel[1], John Kerkhoven[1] and Frans W. Saris[2] – DOI: https://doi.org/10.1051/epn/2019503
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The aviation industry can become carbon neutral by CO_2 recycling into synthetic kerosene using renewable energy. As an example we take CO_2 emissions from Tata Steel in the Netherlands as well as Schiphol Airport's kerosene consumption.

▲ © Roya Hamburger

Modern airplanes emit CO_2 as they burn kerosene in their jet engines. Flying is therefore one of the human activities that contributes to global warming. Direct emissions from aviation are more than 2% of worldwide emissions and are set to grow by approximately 2.5 - 3.5% (including efficiency gains) every year for the next 30 years in Europe (1). Compared to 2017, kerosene usage would easily double towards 2050 and could even rise to up to 5 times current levels if efficiency targets would not be realised. In 2009 the International Air Transport Association (IATA) set a goal to halve CO_2 emissions by 2050 with respect to 2005 (2). Without additional measures projections are a factor of 6 - 10 times worse than what IATA aims for. The International Civil Aviation Organization (ICAO) launched the CORSIA program which sets out to offset any emissions above 2020 levels through emission trading (3). Participation becomes mandatory for all States committed in 2027. Given that as a society we do not seem to want to give up flying, we need to find a solution that meets – and ultimately goes beyond – IATA's long-term target and emission offsetting.

Solutions from other sectors do not work for aviation

While in other sectors technologies are available that would allow the sector to become carbon neutral, this is not likely to be the case in the aviation sector soon.

For instance, one can switch from a car with an internal combustion engine on petrol to a battery electric vehicle "fuelled" by electricity from a wind- or solar source. As a result, the activity of driving (excluding the manufacturing of the car) does not produce greenhouse gases. There is no such an electric technology for large airplanes yet, nor is it likely to arrive in the coming decades. Current electric planes can carry up to 10 passengers for up to 1 hour of flight time; in 2035, electric planes are expected to be able to transport 50-100 passengers for 1,000 km - smaller in both capacity and distance than planes on kerosene.

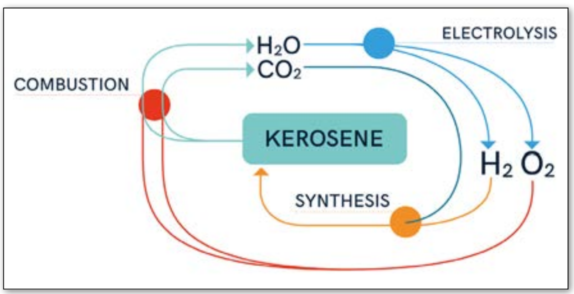
The aviation industry tries to develop, produce and buy bio-kerosene, which is kerosene produced from plant-based sources. Bio-kerosene made from biomass grown in the Netherlands typically requires over 1,000 times more fresh water and arable land than the suggested alternative we present here. To put this into perspective, supplying Schiphol Airport in 2017 with bio-kerosene would require an amount of farmland 0.5-1.8 times the size of all Dutch farmland (depending on the crop, see 6). So far aviation has also used second generation biomass such as used cooking oil, which does not compete with food production, but cannot scale up as much as the alternatives. Investigation is ongoing for third generation biofuels (from algae), but this is currently not yet a viable option from a commercial or environmental perspective. In short, it seems like bio-kerosene cannot be the ultimate solution.

Hence, we need to look for another type of solution, maybe even unique to this sector. This 'synthetic' solution would be to replace the carbon atoms present in kerosene with reusable or renewable carbon atoms from a non-plant based source.

There are various routes to make synthetic kerosene.

Kerosene is a mixture of hydrocarbons, compounds consisting of many carbon (C) and hydrogen (H) atoms. To produce this energy-dense aviation fuel, we need a source of carbon atoms and a source of hydrogen atoms. It is possible to obtain carbon atoms by capturing carbon dioxide (CO_2) from the air via a process called direct air capture (DAC). Hydrogen atoms one can obtained by splitting water (H_2O).

The technology to synthesise carbon and hydrogen atoms into kerosene exists (4,5). And so an opportunity opens up to capture carbon and use the hydrogen atoms in water to make kerosene, using solar or wind electricity as energy source. The carbon and hydrogen go back into the atmosphere by burning it: when jet engines burn kerosene, carbon dioxide (CO_2) and water (H_2O) are released. This would be a carbon neutral and circular economy solution (see figure 1).



▸ **FIG. 1:** Carbon and hydrogen cycle in synthetic kerosene production and utilisation, with the ambiant air as a CO_2 source.

An intermediate step which would roughly halve emissions would be to take the carbon atoms initially from a concentrated source of CO_2 emissions like an industrial plant and reuse the carbon. Then one would still use fossil carbon at the industrial plant from which CO_2 is captured, and emit 'new' CO_2 into the atmosphere when kerosene made from these fossil carbon atoms is burned. But because this fossil carbon is reused in synthetic kerosene, one would avoid the use of fossil kerosene and the emissions from the production of fossil kerosene - and therefore total emissions drop by 50%.

We summarised the main principles of how one makes synthetic kerosene in figure 2. Starting with carbon dioxide captured from the ambient air or an industrial plant, water and renewable electricity, a possible route would be to split the carbon dioxide into carbon monoxide + oxygen and the water into hydrogen + oxygen. There are various ways to do this. One way is to use an electrolyser that uses renewable electricity. Once one has carbon monoxide and hydrogen one has syngas and can use exactly the same process that Shell uses in its Pearl Plant in Qatar to make synthetic kerosene. The kerosene (mass) yield for this route is 61% (after recycling of light gases; the other product being diesel). The associated energy efficiency (excl. electricity generation) is 39% if diesel is considered as a 'loss' and 63% if it is considered a product.

There are other routes as well, see box. The key idea is that it is possible to convert carbon dioxide, water and renewable electricity into synthetic kerosene. In the technical report (available on the web, 6) we explain the individual process steps that jointly form the renewable synthetic kerosene production chain. For each step we describe which organisations are active in this area, how the (chemical) process works, what the costs are now and what we may expect costs to be around 2030 (7). Lastly, we describe how we use this information in the business case model (6 and 7) we have developed to flexibly calculate the costs of most major synthetic kerosene production methods. This model as well as the technical report are freely available online.

Carbon Neutral Kerosene in the Netherlands

To get an idea of how much kerosene can be produced from the emissions of an industrial plant, we consider the following scenario. We take Tata Steel in Netherlands, as an example, as well as Schiphol Airport's kerosene consumption in 2016. Tata Steel emits enough carbon atoms to fuel approximately 50% of the airplanes that fuelled at Schiphol Airport in 2016. Alternatively, if we capture the carbon atoms directly from the ambient air, there is no carbon limit and we can fuel any airplane we want at Schiphol airport. We would however also need more DAC units, water and renewable electricity – which may have a large land and/or water footprint.

To produce a large volume of hydrogen one also needs a large quantity of demineralised water. With the IJ-harbour nearby as well as the North Sea, water is not a limiting factor. One would need about 1% of the water demand of all Dutch households.

There are plans to build large offshore wind farms in the North Sea near the coast of IJmuiden, close to Tata Steel's production plant. Wind farms make electricity in variable quantities depending on how hard the wind blows. TenneT foresees that transporting that electricity (when wind farm electricity supply is high and Dutch electricity demand is low) to the rest of Europe will be quite expensive (9). Hence converting this peak supply near IJmuiden into hydrogen could be an alternative to extending the high voltage electricity grid, which may be cheaper as well.

The offshore wind electricity produced near IJmuiden around 2030 would be enough to make synthetic kerosene for approximately 1/3 of the airplanes that fuelled at Schiphol airport in 2016. Of course, this renewable electricity is not only there for the production of synthetic kerosene, and society's electricity demand may surge if various sectors electrify simultaneously. However, renewable electricity is not only produced in windfarms near IJmuiden, but also in various other places on the North Sea as well as in onshore wind farms and solar panels.

Currently, the infrastructure to transport kerosene (pipeline to Schiphol Airport) and storage terminals are already in place in the Port of Amsterdam. Hence, if we produce synthetic kerosene in the Port of Amsterdam/IJmuiden, we would not need significant additional infrastructure to secure supplies to Schiphol Airport. In fact, it would be an opportunity for regional embedding and integration of a novel cluster with a very wide reach.

Pricing Carbon Neutral Kerosene

Although we now know that we can produce semi (up to just over 50% from waste gases of an industrial plant) or fully (up to 100% for direct air capture) carbon neutral kerosene, we do not know if we can also afford it. There are many uncertainties when exploring a pathway towards 2030. The main uncertainties turn out to be the costs of crude oil (main determinant of fossil kerosene costs) and of renewable electricity (main determinant of synthetic kerosene costs).

Although the price of solar and off-shore wind electricity has dropped considerably in the last few years, we do not know for sure how much further this cost reduction will go. Also we do not know what market prices will be if all sectors in society electrify simultaneously. The crude oil price is very volatile as well – it has been between 40 and 140 dollar per barrel in recent years.

A high price of fossil oil (for example 150 dollar per barrel, excluding taxes) makes fossil kerosene just as expensive as carbon neutral kerosene in our comparison in our base scenario. Similarly, a low price of renewable electricity (1.7 eurocents per kWh, excluding taxes) also puts carbon neutral kerosene at par with fossil kerosene. Of course, a combination of a slightly higher cost of oil and a slightly lower cost of electricity also creates cost parity. This could happen, for example, with oil at 120 dollar per barrel and electricity at 3 eurocents per kWh (7).

We see that, for example, the following set of assumptions delivers carbon neutral kerosene at the same costs as fossil kerosene in 2030.

- An oil price of 98 dollar per barrel (*today's oil price is 80 dollar per barrel*)
- A fossil CO_2 tax of 20 euro per tonne (*today the CO_2 ETS price is 26 euro per tonne*)

CURRENT INTERNATIONAL DEVELOPMENTS

Recent developments have shown that large-scale synthetic kerosene production is perhaps even closer and cheaper than we thought.

Opus 12, in partnership with SoCalGas, showed that its technology can convert CO_2 in a gas mixture (biogas) to methane in a single electrochemical step. It thus does not require a clean CO_2 feed and can also produce other molecules (10). Climeworks, developer of DAC technology, built a new and more efficient DAC plant with integrated electrolysis and methanation unit, producing carbon neutral methane (11). The Opus 12 and Climeworks process could be integrated however, producing methane in a single step from water, renewable electricity and CO_2 from the air.

Sunfire in Germany developed a high temperature co-electrolysis system, which produces syngas (CO and H2) directly from CO_2, water and renewable electricity (12). This implies significant savings in investment and operating costs for synthetic kerosene production compared to a system with individual CO and H2 production units. Carbon Engineering, developer of DAC technology, published an article in a peer-reviewed journal demonstrating that DAC is feasible at costs below \$100/t CO_2 (13). This provides a stronger basis to the claim that significant cost reductions in DAC technology can be achieved.

Lanzatech, which had already successfully produced synthetic jet fuel via ethanol from waste gases, saw the ASTM certify its use for commercial flight (14), supplied sustainable jet fuel to the world's first 'steel gases' fuelled flight with Virgin Atlantic (15) and is on its way to develop a first commercial facility with a large consortium (16).

These developments combined paint a picture and envision production pathways that are closer, more cost-effective and more efficient than the ones we studied together in our research. It should therefore be exciting to see the first synthetic fuel production plants emerge. Lanzatech, Nordic Blue Crude and Carbon Engineering are amongst the first to announce the construction of synthetic fuel (pilot) production plants, while there are other consortia in the Netherlands, around the Port of Amsterdam and Rotterdam Airport, investigating this opportunity and probably others of whose existence we are not aware yet.

- An electricity price of 2.9 eurocents per kWh (*currently the average price of electricity is 4 eurocents per kWh, with solar and wind electricity sometimes pushing it towards 1 or 2 eurocents per kWh*)
- Oxygen, a by-product, is sold against production price

None of these assumptions seem very extreme. So the conclusion may be that it is possible to produce carbon neutral kerosene at (near) competitive costs in the near future.

Note that these costs are with the Netherlands as a reference point. Notably renewable electricity can be produced for lower costs in various other parts of the world. In fact, as the electricity price is the main determinant of synthetic kerosene costs, sourcing it for 2 eurocent/kWh (8) rather than for 4 eurocent/kWh could make synthetic kerosene cheaper than the fossil kerosene reference. However, transport cost to the Netherlands would then also have to be included, and the cost of capital may be higher (9).

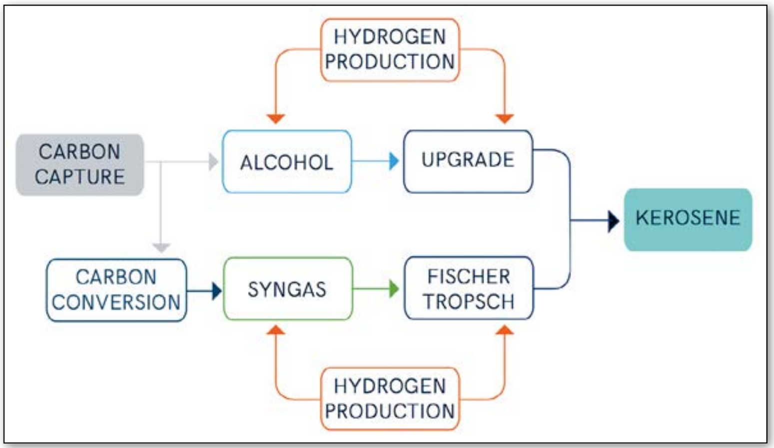
Currently fuel makes up an estimated 15 - 40% of a flight ticket's price (depending on various factors, including airline, flight distance and airports). In our base scenario for 2030 carbon neutral kerosene would add 20 - 50 % to the price of the flight ticket compared to a 'fossil kerosene' ticket. However, if cost parity is reached, tickets would cost exactly the same, irrespective of fuel choice. ■

Conclusions

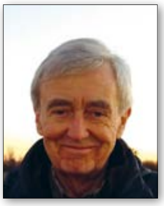
Our study shows that CO_2 recycling for synthetic kerosene production for carbon neutral aviation could become a reality around 2030. It is very likely that it can be done, and we can afford it if we assume modest changes to current prices. Furthermore, this seems the best option available for aviation to meet the goals of the Paris agreement by 2050.

CO_2 recycling for carbon neutral kerosene will however not stand on its own; instead it will be able to play a significant role in the energy system, not only by providing renewable fuels for aviation, but also in its ability to balance large variations in the supply and demand of electricity.

▼ FIG. 2: Production process



About the Authors



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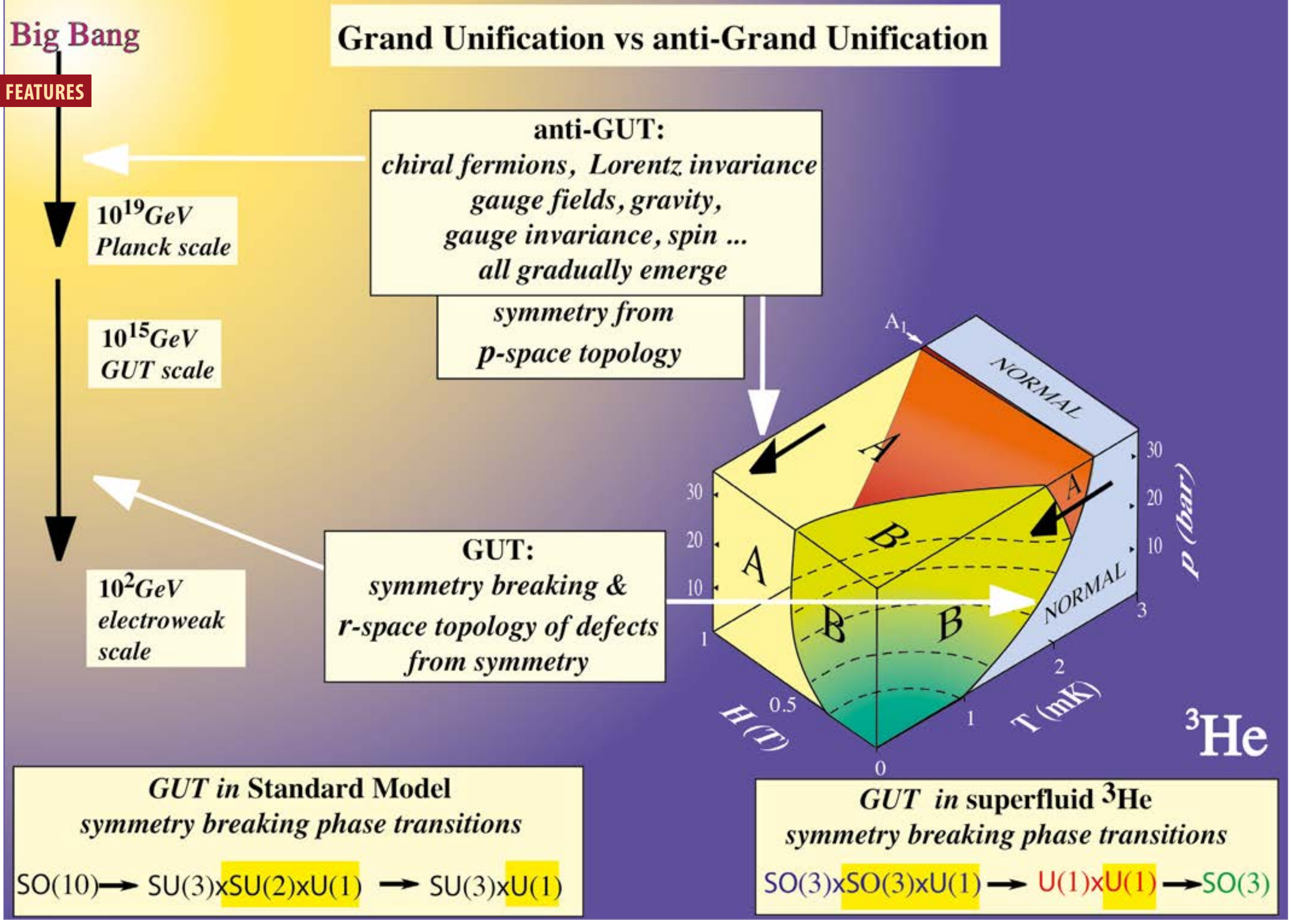

LESSONS FROM TOPOLOGICAL SUPERFLUIDS: SAFE AND DANGEROUS ROUTES TO ANTISPACETIME

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All realistic second order phase transitions are undergone at finite transition rate and are therefore non-adiabatic. In symmetry-breaking phase transitions the non-adiabatic processes, as predicted by Kibble and Zurek [1, 2], lead to the formation of topological defects (the so-called Kibble-Zurek mechanism). The exact nature of the resulting defects depends on the detailed symmetry-breaking pattern.

For example, our universe – the largest condensed matter system known to us – has undergone several symmetry-breaking phase transitions after the Big Bang. As a consequence, a variety of topological defects might have formed during the early evolution of the Universe. Depending on the Grand Unified Theory model, a number of diffierent cosmic topological defects have been predicted to exist. Among them are point defects, such as the 't Hooft-Polyakov magnetic monopole [3, 4], linear defects known as cosmic strings [1], surface defects or cosmic domain walls, continuous topological and nontopological objects (skyrmions and Q-balls), *etc.*

The model predictions can be tested in particle accelerators (now probing energy densities $>10^{-12}$s after the Big Bang) and in cosmological observations (which have not yet identified such defects to date). The same physics, however, can be probed in symmetry breaking transitions in condensed matter systems — in fermionic superfluid ^{3}He to an astonishing degree of similarity.

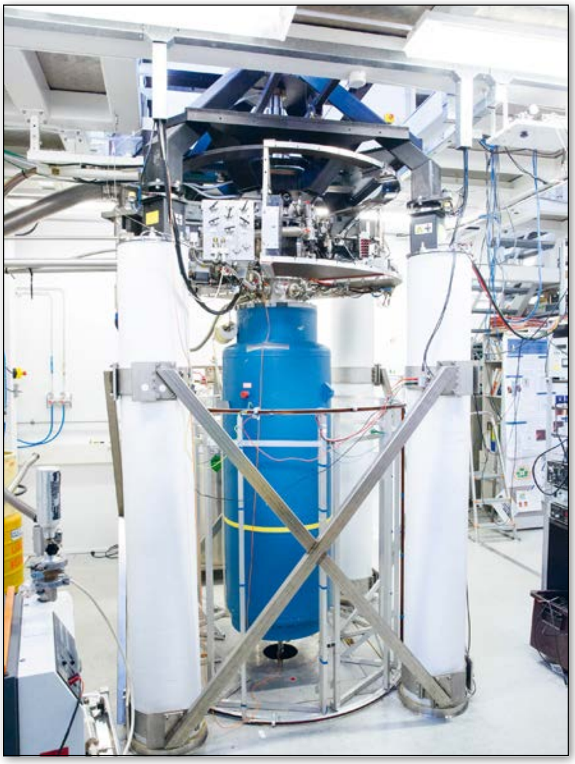
The physics of Kibble-Zurek formation of cosmic string defects during a second order phase transition was tested in superfluid ^{3}He in a rotating cryostat (Fig. 1). With neutron irradiation local mini Big-Bangs – hot spots with temperature above the superfluid transition — were created [5]. Cooling down back into the superfluid state produced topological defects – quantized vortices – in agreement with detailed theoretical predictions.

Superfluid ^{3}He as an analog of the fermionic quantum vacuum

This is but one of the many connections of the superfluid phases of liquid ^{3}He with particle physics and general relativity [6]. All superfluid phases of ^{3}He are examples of topological superfluids with emergent relativistic excitations and topological defects.

1) In the A-phase of superfluid ^{3}He (^{3}He-A) the chiral mirror symmetry is spontaneously broken, as in the vacuum of Standard Model, where the behaviour of left-handed and right-handed elementary fermions (*e.g.* quarks and leptons) is essentially different. The fermionic excitations of ^{3}He-A (called quasiparticles and -holes) are very similar to elementary particles (and antiparticles) in the early Universe, where quarks and leptons were still massless. Quasiparticles have the relativistic energy spectrum, $E^2 = g^{ik} p_i p_k$, where the anisotropy tensor g^{ik} plays the role of metric tensor in general relativity. These quasiparticles have a quantum "spin" parallel (Fig. 2 a) or antiparallel to their direction of momentum — giving the particles a handedness. The chiral right-handed particles "spin" anticlockwise whereas the left-handed clockwise (and vice versa for the chiral antiparticles).

They move in the synthetic gravitational and electromagnetic fields created by the deformations of the superfluid. Their motion is governed by an equation of the form of the relativistic Weyl equation – the linear Dirac equation applied to chiral particles. In words, the Weyl fermions of ^{3}He-A experience the same quantum effects as the elementary fermions of our Universe. Strikingly they can be created and annihilated from the quantum vacuum not only as particle-antiparticle

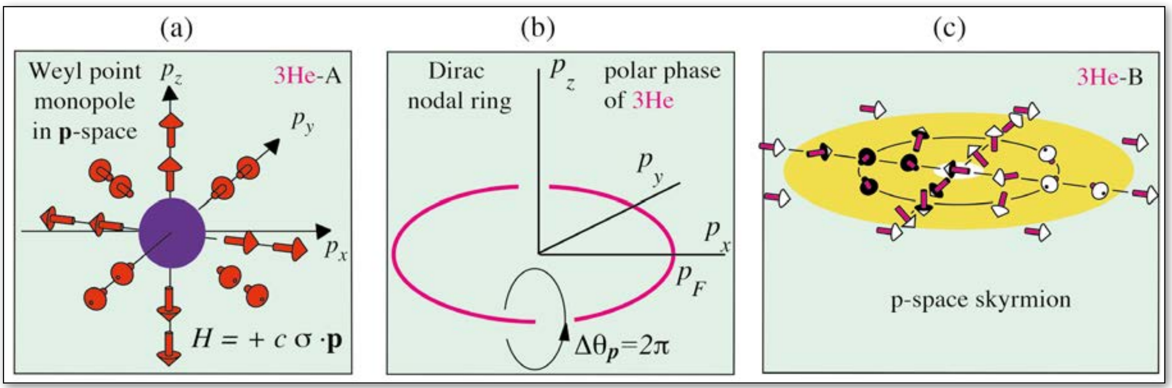


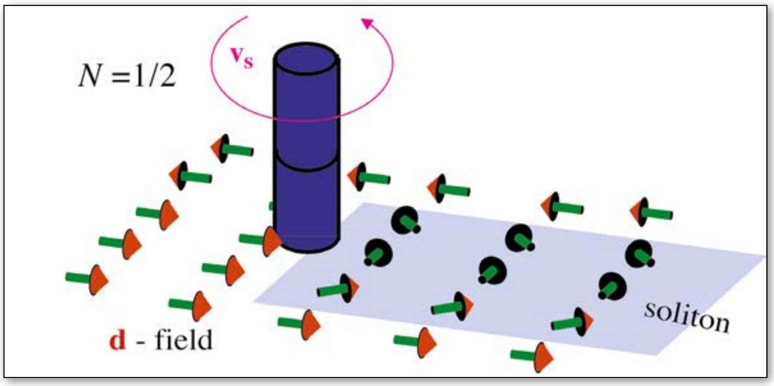
◂ **FIG. 1:** Rotating cryostat, where topological phases of superfluid ^{3}He are studied at ultralow temperature reaching 140 µK. Rotation allows to create and stabilize different types of topological objects, such as Alice strings, Witten superconducting strings, Kibble-Lazarides-Shafi walls bounded by strings, solitons, skyrmions, *etc.*, and perform "cosmological" experiments, such as simulation of the Kibble-Zurek mechanism of defect formation in early Universe, and transition from Minkowski to Euclidean spacetime.

pairs (quasiparticles and -holes), but one by one out of vacuum fluctuations, if axial "electric" and "magnetic" fields are applied. The quantum effect of creation of chiral particles from the vacuum fluctuations is known in particles physics as the chiral or axial anomaly. In ^{3}He-A the chiral anomaly has been demonstrated in experiments with skyrmions [7].

The reason for such a close and robust connection between ^{3}He-A and the quantum vacuum of Standard Model is topological. The quantum vacuum of the early Universe and ^{3}He-A belong to the same universality class of topological materials. This is the class of fermionic vacua with Weyl points – topologically protected points in momentum space, where the energy of a (quasi)particle goes to zero. The topology of this point in momentum space is similar to the topology of

▾ **FIG. 2:** Topological materials and fermionic quantum vacua as topologically stable configurations in momentum space. **(a)** Weyl point in ^{3}He-A as monopole in p-space. The hedgehog of spins in momentum space is responsible for the topological stability of elementary particles of Standard Model and Weyl quasiparticles in ^{3}He-A. **(b)** The polar phase of ^{3}He has the Dirac nodal line in the quasiparticles spectrum — the p-space counterpart of a cosmic string in real space. **(c)** Skyrmion configurations in p-space describe the topological insulators and the fully gapped topological superfluids, such as ^{3}He-B.He-A.



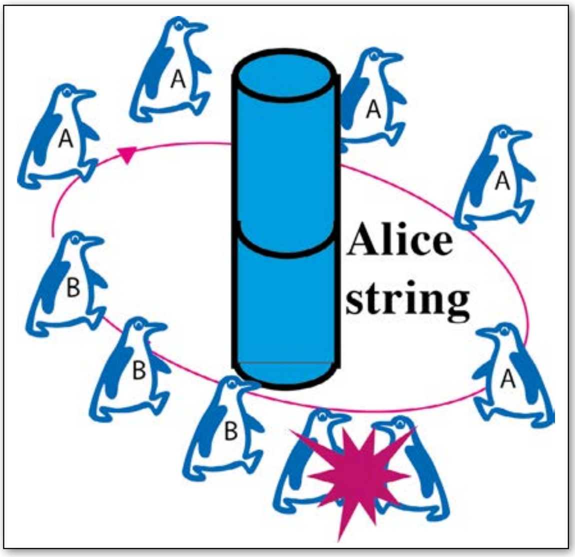


▲ **FIG. 3:** Half-quantum vortex in chiral superfluid ^{3}He-A and in the polar phase. The spin part of the order parameter in both phases has the form $\Psi = \hat{d}e^{i\Phi}$. The phase Φ of this vector order parameter changes by π around the half-quantum vortex. The change of the phase of the order parameter is compensated by the change of the direction of the spin vector $\hat{d}$ and do not produce physical jump in the order parameter Ψ. The order parameter remains continuous around the vortex. In ^{3}He-A, the spin-orbit interaction forces the change of $\hat{d}$-vector to be concentrated within the topological soliton. Across the soliton the $\hat{d}$ continuously changes the direction to the opposite. Due to the energy of the soliton attached to the vortex, the vortex is not favorable energetically. The half-quantum vortex has been observed first in the polar phase of ^{3}He confined in a nanostructured material called nafen [8]. In the polar phase the spin-orbit interaction is more favorable: in zero magnetic field or in the field along the nafen strands the solitons are absent, and the lattice of half quantum vortices becomes the lowest energy state in a rotating vessel.

a magnetic monopole in gauge theory, see Fig. 2 (a). Other condensed matter representatives of this class are solid state topological materials – Weyl semimetals and Weyl superconductors.

2) The polar phase has been realized in ^{3}He immersed in a nanostructured material called nafen, see *e.g.* Ref. [8]. Nafen is composed of nearly parallel solid strands, which are about 9 nm in diameter and are 30-50 nm apart. The nafen volume is thus mostly empty and in the experiments this empty space is filled by liquid ^{3}He.

Quasiparticles in the polar phase are also gapless, but their energy is zero along a line in momentum space — so-called Dirac nodal line in Fig. 2 (b). These quasiparticles are similar to massless quasi-two dimensional Dirac particles with one important reservation: the synthetic metric g^{ik} becomes degenerate, *i.e.* the "speed of light" vanishes in the direction along the nodal line.



▸ **FIG. 4:** Half-quantum vortex as the Alice string. Spacetime continuously transforms to its mirror image after circling an Alice string, and thus matter continuously transforms to antimatter. Two penguins, Alice and Bob, start to move in opposite directions around the string. When they meet each other again, they may annihilate. In condensed matter the vector $\hat{d}$, which is the axis of quantization for spin, changes sign around the half-quantum vortex, *i.e.* spin transforms to "antispin" – the analog of antimatter.

3) In the B phase (^{3}He-B) the spectrum of quasiparticles is similar to the spectrum of Dirac particles in the present epoch of the Universe, where all elementary particles have became massive. The fully-gapped B-phase has the topology of the so-called DIII superconducting class, which is similar to the topology of skyrmions in real space Fig. 2 (c). This topological configuration protects massless Majorana fermions living on the surface of the superfluid and in vortex cores.

Half-quantum vortex as an Alice string

One of the exotic topological objects living in ^{3}He is the half-quantum vortex (HQV) – a vortex encapsulating a fraction of the quantum of circulation, see Fig. 3. It is the analog of so-called Alice string in cosmology, where a particle encircling an Alice string continuously transforms to an antiparticle. In other words, the spacetime is continuously transformed to its mirror image — the antispacetime, see Fig. 4. In cosmology, antispacetime Universe was recently suggested as a continuation of our Universe across the Big Bang singularity [9]. This is a rather more dangerous route for Alice to travel to a mirror Universe — going around the Alice string can still be safe for Alice if she can avoid close encounter with Bob.

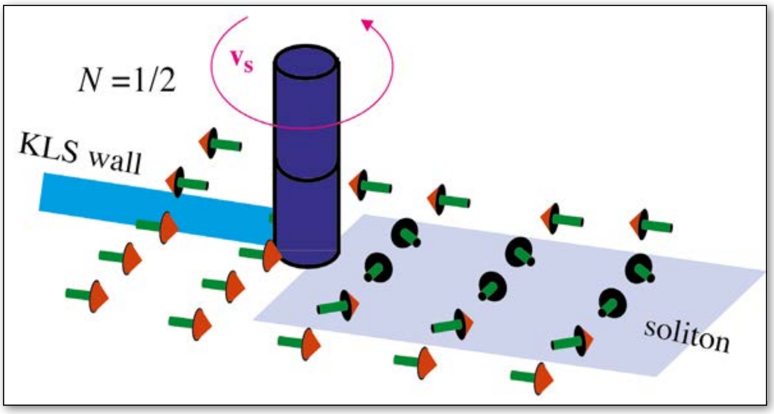
HQVs were originally predicted to exist in the chiral superfluid ^{3}He-A [10]. However, before being experimentally observed in ^{3}He-A, the HQVs were first observed in another topological phase of ^{3}He – the polar phase [11]. The reason for that is that in ^{3}He-A, the spin-orbit interaction chooses the preferable orientation for the vector $\hat{d}$ describing the spin degrees of freedom of the order parameter. This leads to formation of a soliton interpolating between two degenerate vacua in Fig. 3. The energy of the soliton prevents the nucleation of the HQVs (Alice strings) in ^{3}He-A. In contrast, in the polar phase the spin-orbit interaction can be controlled to not prohibit the formation of HQVs.

The surprise was HQVs, which are formed in the polar phase by rotation of the superfluid or by the Kibble-Zurek mechanism, surviving the transition to the ^{3}He-A. The reason for that is that the defects are pinned by the nafen strands. They remain pinned after transition to the ^{3}He-A, in spite of the formation of the energetically costly solitons and therefore effective attractive tension between vortices.

Two routes to mirror Universe

Even more surprisingly, further experiments demonstrated that the HQVs survive even the phase transition to ^{3}He-B, where such defects cannot exist as individual entities. It was found that the HQV becomes part of a composite defect: it is the boundary of a domain wall in Fig. 5. As distinct from the continuous topological soliton in Fig. 3, the wall bounded by HQV is singular: it is composed of yet a different unstable superfluid phase with a degenerate metric, and has a higher energy. But still the wall tension is not sufficiently strong to unpin the vortices.

In cosmology, the walls bounded by cosmic strings have been suggested by Kibble, Lazarides and Shafi (KLS) [12]. The KLS walls appear after two successive cosmological phase transitions. Below the first transition the topologically stable defects – cosmic strings – are formed. Below the second transition these defects lose the topological stability and become boundaries of domain walls. As we explained, the same mechanism with successive phase transitions works in superfluid ^{3}He. The composite HQV defect – the Kibble-Lazarides-Shafi wall bounded by HQVs (Alice strings) – demonstrates the two ways to enter the mirror world in Fig. 6 [13]. The safe (continuous) route is around the half-quantum vortex and the dangerous route is across the cosmic singularity of the Kibble-Lazarides-Shafi wall. In our case the dangerous route is similar to the route of our Universe from spacetime to antispacetime in Ref. [9]. ■



▲ **FIG. 5:** Further experiments demonstrated that the half-quantum vortex survives even the phase transition to ^{3}He-B, where such a vortex cannot exist as an independent topological object. The previously unobservable jump in the $\hat{d}$ field becomes physical — the domain wall between different superfluid vacua. This wall is singular as distinct from the continuous topological soliton. So, in ^{3}He-B the half-quantum vortex becomes the part of the composite defect – the domain wall terminated by the string. This is the analog of the Kibble-Lazarides-Shafi (KLS) cosmic wall bounded by cosmic string [12].

Acknowledgements

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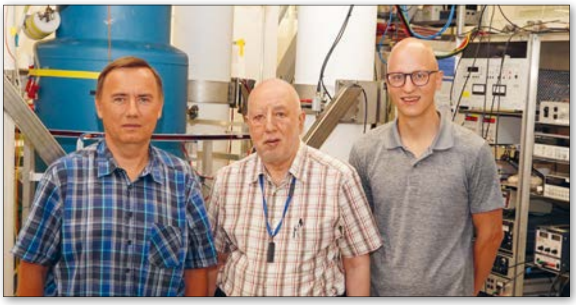
About the Authors



Grigory Volovik (middle) currently shares the position in Landau Institute (Chernogolovka, Russia) with a position in Aalto University (Otaniemi, Finland). The areas of his interests are topological defects; topological matter; connections between condensed matter physics, particle physics andcosmology. In 2003–2006 he was chairman of the European Science Foundation Programme "Cosmology in the Laboratory". He was awarded Landau Prize (1992), Simon Prize (2004) and Lars Onsager prize (2014); member of German National Academy Leopoldina.

Vladimir Eltsov (left) received his doctoral degree from the Kapitza Institute in Moscow, Russia in 1997 and then moved to Helsinki University of Technology to work on superfluid ^{3}He. Since 2010 he leads the experimental research on rotating ^{3}He at Aalto University.

Jaakko Nissinen (right) is a post-doctoral research at Aalto University. His research interests include topological phases of matter, condensed matter analogs of relativistic quantum field theory and quantum Hall physics. He obtained his Ph.D. at the University of Oslo, Norway.

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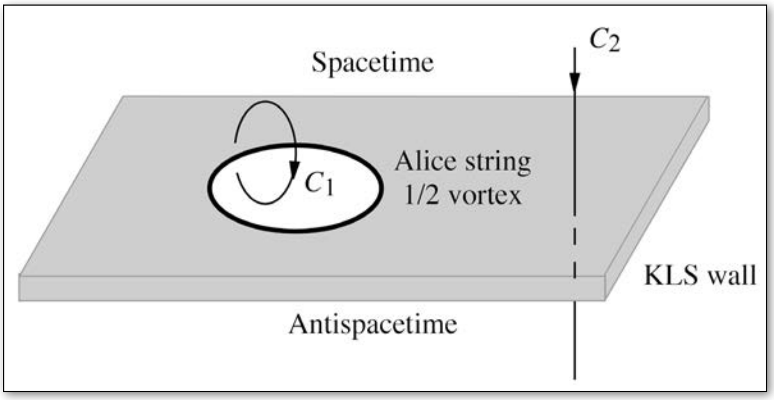
▼ **FIG. 6:** Two roads to antispacetime: the safe route around the Alice string (along the contour C_1) or the dangerous route along C_2 across the Kibble-Lazarides-Shafi wall with degenerate metric. This dangerous route through the Alice looking glass is similar to the route of our Universe from spacetime to antispacetime via Big Bang in Ref. [9].



KNOWLEDGE AND SKILLS CHANGES TO ACCREDITATION HERALD PEDAGOGICAL TRANSFORMATION IN THE UK

David Sands – University of Hull – DOI: https://doi.org/10.1051/epn/2019505

The Institute of Physics in London is changing the way it accredits degrees, which could have far-reaching consequences for the way physics is taught and assessed. Degree accreditation serves two purposes. First, it is the mechanism by which the Institute fulfils its commitment under its Royal Charter to uphold standards in physics education, and secondly, it provides a crucial step toward professional recognition for graduates.

Anyone wanting to be recognised as a Chartered Physicist has not only to be able to provide evidence of suitable professional experience, but also to show knowledge and skills appropriate to Masters level. By accrediting degree programmes, the Institute makes it much easier for graduates to be able to demonstrate the requisite educational level or knowledge level has been reached.

Those familiar with the UK system will be aware that we have two types of undergraduate degrees: the normal 3-year Bachelors and the 4-year integrated Masters. The Institute accredits both types of degree. Graduates from an accredited Bachelors degree partially meet the educational requirements for professional recognition, but graduates from an integrated Masters degree meet them in full and only have to show appropriate professional experience.

The Institute has previously approached accreditation by essentially defining what a physics degree should look like. There is a prescribed core of topics together with some attempt to define the minimum level of complexity. Referred to as the IOP Core of Physics, this content is largely delivered in the first two years. In addition to the Core, a Bachelors programme must contain at least 60 credits (CATS) of honours-level physics content. For those not familiar with the British system, honours level corresponds to the final level of a Bachelors programme. There are also suggested minimum amounts of laboratory work for experimental physics programmes, as well as a range of skills that graduates should be developing and requirements on a minimum amount of mathematics content.

What often seems like a good idea in principle can throw up difficulties in practice and there are three main drawbacks to the current approach of requiring a fairly substantial prescribed core content. First, physics degrees across the UK look remarkably similar. There are variations, of course, but as the first two years of any Bachelors degree are generally taken up with teaching the IOP Core the opportunities to be distinctive are limited to what is offered in the final year. Secondly, rather than being seen as the essential physics that every graduate should know, the Core of Physics has come to be seen as a requirement to be fulfilled and very often depth is sacrificed for breadth with some material being covered in only one or two lectures. Thirdly, the kinds of physics degrees that can meet the accreditation requirements are quite limited.

This last is a central consideration in the accreditation review. The Core contains a number of what seem at first sight to be important concepts but in fact are very specific examples of the application of more basic ideas. In degree programmes such as biological physics or environmental physics, which are concerned with the application of physics to specific areas, it might not be relevant for students to learn in depth about laser cavities, semiconductor band structure, or the role of phonons in the heat capacity of a solid. That does not mean that they do not possess a sound knowledge of physics, think like physicists or acquire the same kind of physics-related skills as graduates from more conventional physics degrees. If these kinds of degrees deliver these outcomes, graduates should be eligible for the same kind of accelerated professional recognition.

The answer to these difficulties is to shift the focus away from the degree to the graduate. The existing accreditation scheme sets out in detail what a physics degree should like, or at least those essential elements common to physics degrees across the UK, but we want instead to identify the kind of attributes a graduate should possess. It will be up to departments to decide on the details of the degree programme that will develop those attributes and this will allow for much greater flexibility, distinctiveness and inclusivity.

Our starting point for graduate attributes are the QAA benchmark statements for physics and astronomy[1]. At the end of the last century the QAA, or Quality Assurance Agency, started to lay down a set of discipline-specific statements against which the outcomes of degrees should be judged. These statements were constructed by the members of the respective academic communities, for example, lawyers, historians, mathematicians, *etc.*, and therefore reflected the thinking of that community. Regardless of the university or the discipline, it is now very unlikely that any new degree will not base its outcomes on the benchmark statements. These statements have thus become the *de facto* standards for the outcomes of degree programmes in the UK.

The last revision of the benchmark statements for physics and astronomoccurred in 2017. I was part of the review group. We came to the conclusion early on that little change was needed to the content, but it could be re-ordered and re-organized to present a much more coherent and usable account of standards. Thus, the 2017 document looks very different from its 2008 predecessor, but the changes are largely cosmetic. The long list of outcomes for both Bachelors and Masters degrees was reorganised into threshold and typical outcomes for both types of degree. The typical outcomes for a BSc build on the threshold and the threshold for integrated Masters degrees build on the typical for a Bachelors. The only change of any substance we made was to emphasise the role of computation in modern physics, which was understated in the 2008 document. Computational physics has emerged as a third way of doing physics alongside the two traditional branches of experimental and theoretical physics. In particular, computation is perhaps the only possible way to understand emergent behaviour in large systems subject to simple rules and we wanted the benchmark statement to reflect this.

Although we weren't thinking about accreditation at the time, re-organising the benchmark statements into threshold and typical levels brought the two processes into very close alignment. Accreditation is very much concerned with thresholds: every graduate from a degree programme must meet the minimum educational standard for that programme to be accredited. Therefore, we adopted and adapted the outcomes in the benchmark statement for our own purposes.

The principal adaptation has been to phrase the outcomes in a way that is clear and measurable. There are eight threshold standards for a Bachelor's degree and most can be carried across into accreditation without much adjustment or elaboration, but some are not so straightforward. For example, the first standard says that a student will have demonstrated an ability to "comprehend basic physical laws and principles", which begs two questions: what do we mean by comprehend and which basic laws?

Understanding is one of those things that we recognise when we see it but is very hard to pin down in a simple definition, yet if a department is to collect evidence that students are developing an understanding and present that in support of an accreditation application, this is precisely what must be done. Physics education research has shown repeatedly over the years that being able to state a law is not equivalent to understanding it. Students can often state Newton's three laws of motion, for example,

[1] https://www.qaa.ac.uk/docs/qaa/subject-benchmark-statements/sbs-physics-astronomy-and-astrophysics-17.pdf

but when asked to apply them in a relatively simple problem requiring qualitative reasoning, they often come up with the wrong answer. However, skill in mathematics is also not sufficient. Graduates who demonstrate mathematical facility do not always display a good grasp of the fundamentals.

If you were to have an intelligent conversation with someone about physics, you would expect the conversation to involve qualitative descriptions as well as qualitative and mathematical arguments. The last might involve, for example, limiting cases or simply interpreting trends implied by mathematical representations of the physics. You would also expect ideas to be represented in whatever way is appropriate to the discussion, including using diagrams and graphs. The ability to reason qualitatively and to translate between different representations lies at the heart of understanding and in the absence of a precise definition these will serve as good indicators. Therefore, by including understanding of basic laws and principles among the accreditation criteria we will effectively require departments to find ways to allow students to develop these abilities as well as assess them and to use both as evidence in their accreditation submission.

The question of what to include in the content is more difficult to resolve. If you were to ask your colleagues which ideas in physics a graduate must know in order to be considered a physicist, you would probably receive a variety of different answers depending on the particular specialism of the person you are asking. By way of example, a colleague of mine suggested not so long ago that the p-n junction is so central to modern technology that it ought to feature in the IOP core. It doesn't and never has, but one can easily appreciate the argument for including it. It functions as a rectifier and a voltage-dependent capacitor, but it also forms the basis of laser diodes, LEDs, solar cells, transistors and photodiodes. However, these are applications of semiconductor band theory, which in turn is arises from the application of the Pauli exclusion principle to interacting systems. If we were to pare it down to essentials, we would find that semiconductor physics is an application of quantum mechanics to interacting, multi-atom and multi-electron systems with some simplifying assumptions from classical mechanics (in the form of transport theory) and electrostatics superimposed. It might be desirable to teach these ideas via semiconductor physics, but it is not essential. What is essential, however, is that students have the skills for self-learning, so that someone who has learnt these ideas in other contexts can, if necessary, transfer them to semiconductors. The same applies to many of the ideas that would be suggested for inclusion in the core.

We have taken a quite radical approach to the IOP Core of Physics. Our intention at the outset was to make it less prescriptive and restrictive, so we have based it on the areas identified as fundamental in the benchmark statement: electromagnetism, quantum and classical mechanics, statistical physics and thermodynamics, wave phenomena and the properties of matter. Two topics currently in the Core, condensed matter and optics, no longer feature in the requirements for accreditation. We reasoned that a graduate with a sound understanding of these five basic topics should be able to pick up optics or solid state physics through self-directed learning if the need arises. Most departments are likely to continue teaching these topics but removing them from the core gives more freedom to consider whether this content is necessary for all degrees, for example mathematical physics. If taught, they would then serve as vehicles to illustrate the application of some or all of these five fundamental topics.

The main outcome of the review of accreditation procedures is that the IOP Core of Physics is no longer a list of topics that needs to be taught in the first two years. Rather, it constitutes a set of themes that will run through the entire degree and in a well-designed programme students will develop their knowledge, understanding and competence in applying that knowledge throughout the duration of the degree. This allows for a much more holistic approach to the design of the curriculum and has the additional benefit that departments can be much more distinctive in what they offer. Considerable support for these ideas has already been expressed but a formal consultation is required before the scheme is implemented. Once that happens, either towards the end of this year or early next, it will take time for departments to adjust to the new scheme, but it holds out the prospect of systematically embedding good teaching practice into the national structure of physics degrees in the UK. ■

About the Author

David Sands is chair of the Physics Education Division of the EPS. He has worked extensively with the Institute of Physics in London on accreditation, first as an assessor, then as chair of the Degree Accreditation Committee and lastly as chair of the Accreditation Review Group. He also represents the UK on Commission 14 (education) of IUPAP.

THE EXOPLANET REVOLUTION

Yamila Miguel – Leiden Observatory, Leiden, The Netherlands – DOI: https://doi.org/10.1051/epn/2019506

Hot Jupiters, super-Earths, lava-worlds and the search for life beyond our solar system: the exoplanet revolution started almost 30 years ago and is now taking off.

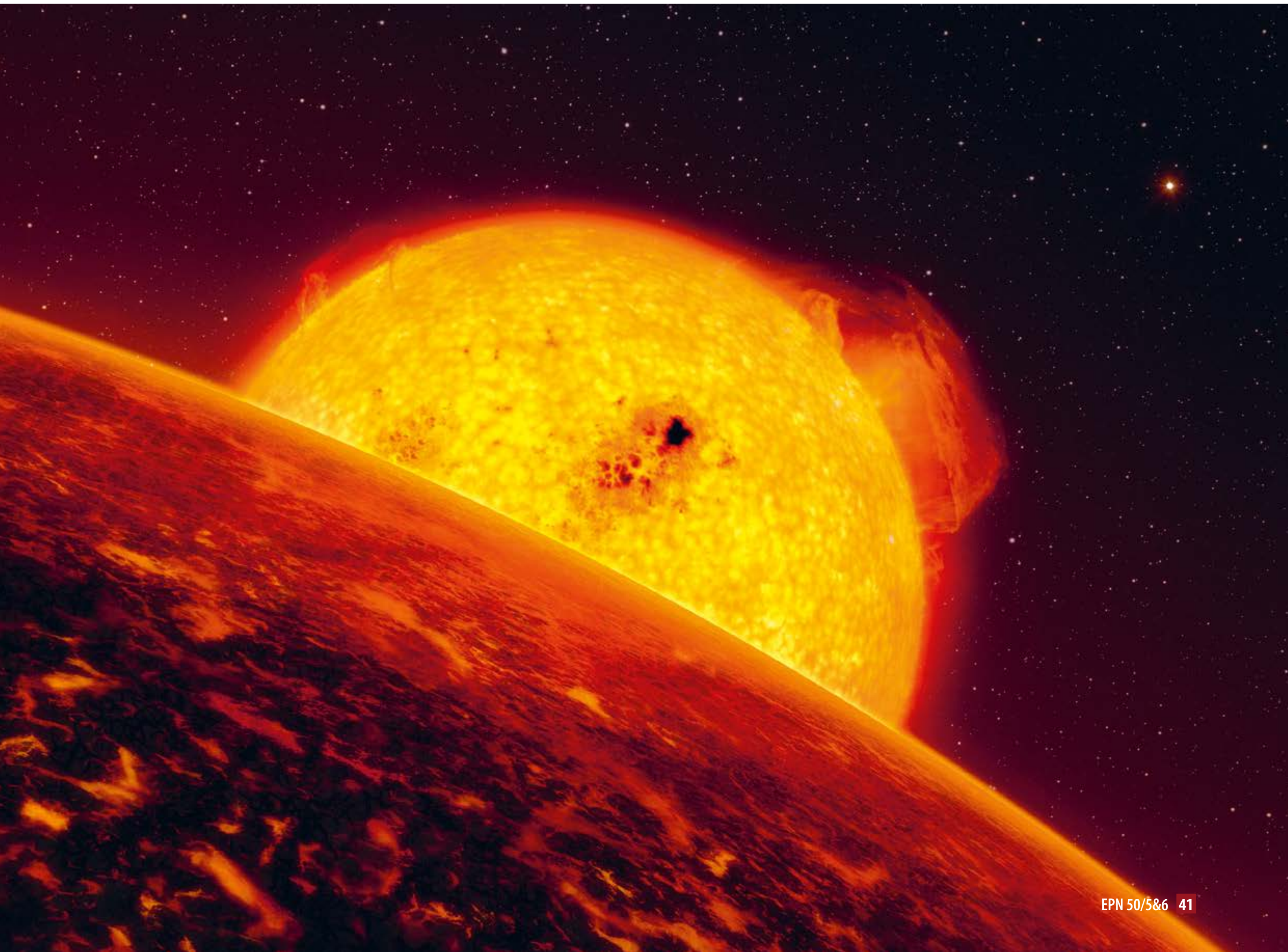
Are there other planets like the Earth out there? This is probably one of the oldest questions of humanity. For centuries and until the 90s, we only knew of the existence of 8 planets. But today we live in a privileged time. For the first time in history we know that there are other planets orbiting distant stars.

The first planet orbiting a star similar to the Sun was discovered in 1995 -only 24 years ago- and it started a revolution in Astronomy. Today astronomers have discovered the astonishing number of 4000 exoplanets, and counting. Every new discovery shows an amazing diversity that impacts in the perception and understanding of our own solar system.

How to find exoplanets?

Finding exoplanets is an extremely difficult task. These planets shine mostly due to the reflection of the stellar light in their atmospheres and their light is incredibly weak compared to that of their host stars. For this reason,

▼ Artist's impression of COROT-7b. © ESO/L. Calçada



observing exoplanets directly is extremely difficult and astronomers had to develop indirect techniques that infer the presence of the planet.

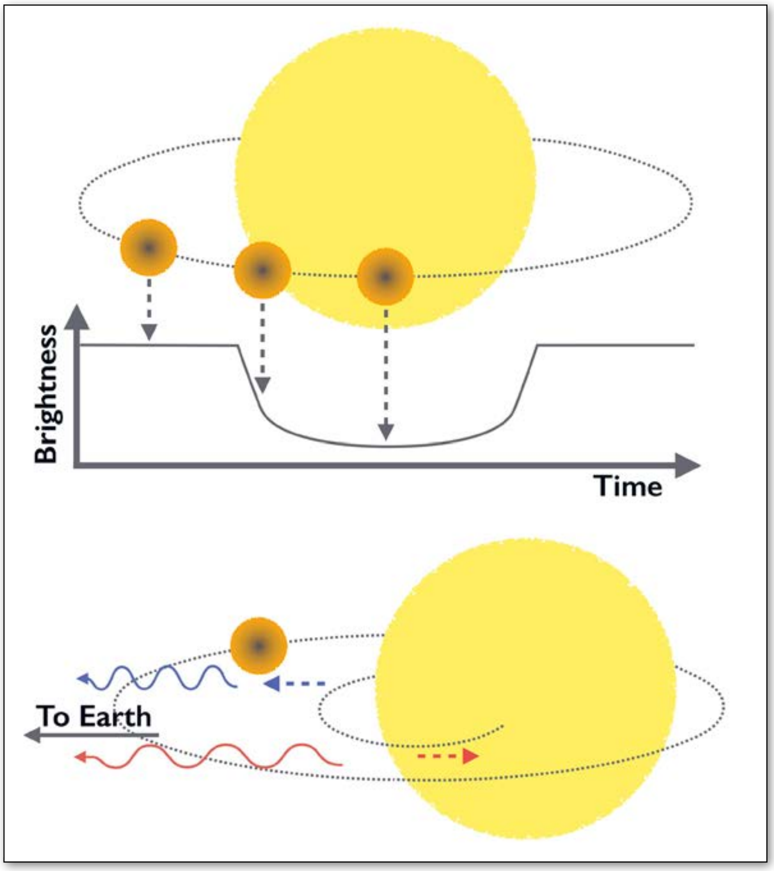
Two of the most successful techniques to discover exoplanets are the *"Transits"* and *"Radial Velocities"* techniques.

In the first one, astronomers observe the dimming of stellar light when the planet passes in front of it (figure 1, top panel). Current instrumentation allows astronomers to measure less than 1% change in stellar light. Because the portion of stellar light that diminishes is proportional to the size of the planet, this technique allows astronomers to know the planetary radius.

In the Radial Velocities technique, astronomers measure the movement of the star -the doppler shift in the stellar light- caused by the presence of a planet orbiting around it (figure 1, bottom panel). With present techniques, astronomers can measure movements of the star of less than 10cm/s (as a reference we usually walk at 1m/s) [1]. The effect on the star is larger if the planet has a high mass and is located close to the star and is smaller for small planets. Therefore, the radial velocities technique allows us to have an estimation of the mass of the planet. Other methods include direct imaging (looking at the light from the planet directly) and micro-lensing (observing gravitational lensing due to a planet).

Each one of these methods give valuable information to start understanding the variety of planets out there, in particular the combination of both techniques allows astronomers to calculate the planet's density, important to start assessing planetary compositions and diversity.

▼ **FIG. 1:** Schematic view of the transit (top panel) and radial velocities methods (bottom panel).



The Exoplanet Zoo

The population of exoplanets shows a huge diversity (figure 2). Due to observational biases, most of the planets detected so far orbit very close to their stars -in a few hours- and for this reason many of them are tidally-locked, showing always the same face towards the star, similar to the Moon-Earth system. This affects the circulation of their atmospheres and in some cases creates huge temperature differences between the dayside and dark side that can be as extreme as ~600K.

The search for exoplanets has revealed other surprises; here we describe some of the strange and unexpected worlds found.

Hot Jupiters and far-away giant planets.

Astronomers are finding giant planets -like Jupiter and Saturn- but located very close to their stars, much closer than Mercury to the Sun. One of the most famous examples of a *"hot-Jupiter"* is 51 Pegasus b, the first exoplanet detected around a Sun-type star [2], that orbits its star at a distance of 0.05 times the distance between the Earth and the Sun (Astronomical Unit), which implies that a "year" in that planet lasts 4.2 days.

Astronomers are also finding giant planets very far away from their stars, at approximately twice the distance between Neptune and the Sun, and even further out.

Both hot-Jupiters and far-away giants shook the foundation of planet formation theories, pushing the boundaries and showing that extreme scenarios are possible for the formation and evolution of planets. Today we know that planets are not located in the place where they were born, but that they "migrated" due to the interaction with the protoplanetary disk during their formation and evolution [3]. In addition, some of them might have been scattered away due to the dynamical interaction with the star and other bodies of the planetary system.

Mini-gas planets and super-Earths.

There are some planets that don't have enough mass to be a giant planet, but are more massive than small rocky planets like our own. These planets have masses of approximately 10 times that of the Earth and for this reason are usually called *"Mini-gas planets"*-those with a substantial atmosphere made of hydrogen and helium- or *"super-Earths"* -the ones that are small, and have a much smaller, potentially secondary atmosphere. Since there is no parallel to these planets in our solar system, astronomers don't know what to expect for their interiors, atmospheres or formation history. In addition, analysis of the exoplanet population shows that most of the exoplanets discovered so far belong to this category [4], and a lot of effort is going into trying to understand their nature and to know why there are no such planets in our solar System.

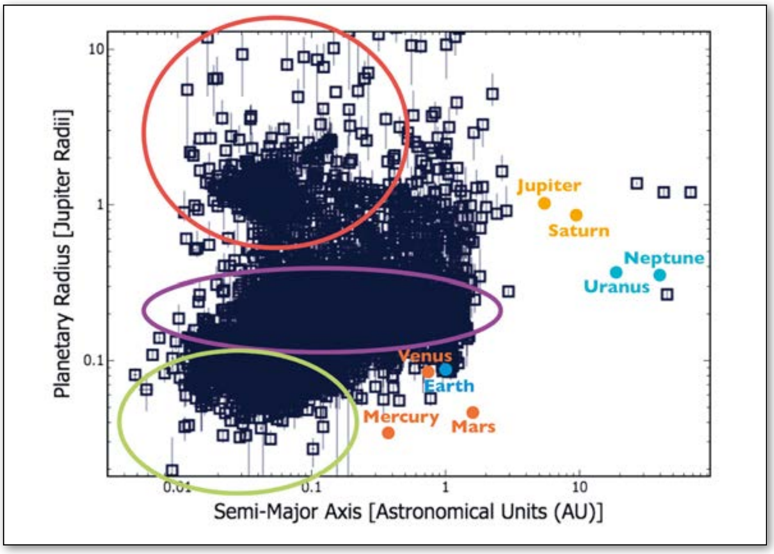
Hot rocky exoplanets or "lava worlds".

These are an intriguing class of planets that are rocky -like the Earth-, but located extremely close to their stars and that might have a magma ocean running on their surfaces. This is caused by the high temperatures on the dayside (of approximately 2000K or more) caused by stellar irradiation. In these planets, the magma ocean vaporises and forms an outgassed atmosphere mainly made of vaporised rocks [5] that is escaping the planet in what looks like a cometary tale.

Many of these planets were discovered using powerful ground-based observatories, or space missions like Corot (ESA), Kepler (NASA) or the currently on space TESS mission (NASA). Other space missions such as the upcoming Cheops (ESA, to be launched this year) and JWST (NASA, to be launched in 2021) will help to improve our knowledge on these worlds.

The search for life in the Universe and future prospects

The ultimate goal of the exploration and search for exoplanets is to know if there are other solar systems and planets like our own. We still don't know how life originated on Earth, but we do know that water is essential for life in our planet. The fact that our planet has oceans of liquid water is due to a combination of different factors, some of them being the mass of our planet, the pressure of our atmosphere and the temperature of the planet, which is a consequence of the gases present in our atmosphere and the irradiation received from the Sun. With this idea in mind, astronomers developed the concept of "habitable zone" [6]. This is the region where a planet *with an atmosphere like the Earth* should be orbiting its host star in order to maintain liquid water on its surface. Since different stars emit different energy, each star has its habitable zone located at different distances. Keep in mind that if we find an exoplanet with a mass and radius similar to the Earth and located in the habitable zone this doesn't necessarily mean that the planet will host life, it is just saying whether such planet has *any* possibility of being habitable -having liquid water on its surface- at all. Since different rocky planets might develop different atmospheres, this is just a useful concept to guide our searches, but nothing more. Our current technology allows us to measure only masses and radius of Earth-like exoplanets (and detect some chemical species in bigger, giant exoplanets atmospheres, [7]), therefore it is not yet possible to detect Earth twins and uniquely identify life-forms in exoplanets.



▲ **FIG. 2:** Exoplanets discovered by August 2019 (data from exoplanets.org). The planets in our solar system are indicated with fill circles for comparison. Main population of exoplanets are indicated with circles: hot Jupiters (red), mini-gas giants or super-Earths (purple) and hot rocky. exoplanets (green).

Nevertheless, not everything looks dark in the future, and astronomers are working towards the next generation of instruments that will make this possible [8]. An example is the Plato mission (ESA), a space telescope (to be launched in 2026) that has the goal of finding and characterising planets like the Earth. Examples from the ground, include the next generation of extremely large telescopes (Extremely Large Telescope, Giant Magellan Telescope, Thirty Meter Telescope), that will have mirrors of 30 meters and are currently under construction. These telescopes and the future space missions will lead astronomers to the next step towards finding habitable worlds, where Sci-Fi meets reality. ■

About the Author

Yamila Miguel is an assistant professor at Leiden Observatory. She completed her PhD in Argentina at La Plata University, made a first postdoctoral study at the Max Planck Institute for Astronomy (Germany) and later was a CNES postdoctoral fellow at the Observatoire de la Cote d'Azur (France).

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ADVANCED INSTRUCTIONS FOR IMPARTING KNOWLEDGE: GETTING SCIENTISTS HEARD AMIDST THE NOISE OF FAKE NEWS

A compacted re-print of an article by science writer Matthias Plüss

Swiss Science Magazine 'Horizons' of 05/06/2018 – DOI: https://doi.org/10.1051/epn/2019507

It's getting more and more difficult for experts to get their arguments across to a broad public. We investigate why, and offer six suggestions for improving things.

▲ An expert under siege by the media: German Ramirez, a specialist in tropical illnesses, reports on the successful treatment of a Spanish nurse who was infected with Ebola in 2014. © Image: Denis Doyle/Getty Images

Tom Nichols is a professor of national security affairs at the U.S. Naval War College in Newport. He says he's long had to get used to the fact that most people don't like professors. People devoid of any specialist knowledge are becoming convinced that they know better than the experts. "I don't have a problem with people being sceptical – that's actually a good thing", says Nichols. "What's bad is that people have lost all respect. We're now being challenged aggressively". With "The Death of Expertise" [1], Tom Nichols has written the ideal book for our times

Everyone's an expert

The crisis in expertise doesn't just affect science. Doctors tell of patients who don't ask for advice, but simply demand treatments they've found on Google. Architects and craftsmen tell of clients who want to dictate to them how to do their work. And teachers often have to cope with parents who aren't prepared to accept that the answers their child gave in a test are actually wrong.

The reasons for this phenomenon are as diverse as the problem is widespread. Nichols writes of a negligence that comes with prosperity: "Our highly technological world functions so smoothly that people mistakenly start to believe that everything is really simple. You click on a button, and your e-mail flies halfway round the world. No one thinks about all the experts that make it possible, from the engineers to the software designers and the diplomats". Another reason is the trend towards treating students like customers today, asking after their wellbeing instead of challenging them. This can lead to an excess of self-confidence that is coupled with less knowledge.

Two other reasons for this crisis of expertise are to be found within our science system itself. On the one hand, we are experiencing the revenge of postmodern relativism. Starting with Nietzsche – who claimed that there were no facts, just interpretations – left-wing theoreticians in particular have fundamentally questioned whether there is any such thing as objective truth. The philosopher Michael Hampe from ETH Zurich claims that this is why it's difficult to counter the arguments of those who wish to relegate the notion of man-made climate change to a mere thought-construct.

On the other hand, experts have constantly been venturing beyond their own field of competence. "Scientists can state the degree of probability that measles will break out in a kindergarten if 20 percent of the children aren't vaccinated", says Dietram Scheufele, professor of life sciences communication at the University of Wisconsin (USA). "But it's not their job to decide whether or not to introduce compulsory vaccinations". This is a political issue that can only be answered through the political process, he insists. Scientists should certainly offer their opinion, but they shouldn't claim to be acting with any authority (as they often do), as "this can only mean they lose their credibility". They should accept the fact that moral and religious notions play a role, says Scheufele. "Friedrich Dürrenmatt put it really well: 'if something affects everyone, then everyone has to solve it'".

The internet

None of these undesirable trends would have culminated in our current crisis without one decisive factor: the Internet. Today, sound knowledge and informed opinions exist on an equal footing with conspiracy theories and mere gossip. What's even worse: fake news often spreads quicker and further than facts.

Social media are intensifying these negative developments. "We're all friends on Facebook", says Tom Nichols. "That has led to the absurd notion that we all know as much as everyone else and everyone's opinion is equally valid". What's more, social media serve to promote an effect that psychologists call 'confirmation bias'. In reality, people rarely form their opinions based on facts. Instead, opinions tend to be dominant, and people then seek the facts that confirm them. The Internet makes it far easier to find such 'facts' – supported by algorithms that supply us with hits that affirm what we want to believe. "This is the paradox of our new world of information: it has never been so easy to get all the information you want", says Dietram Scheufele. "But it has also never been so easy to dodge all the information that you don't want".

The current crisis in expertise isn't actually a crisis of science. In Europe, scientists are still regarded as trustworthy, and in the USA, 90 percent of the population have a positive opinion of science. The problem is that people seek out the science that happens to suit them. And this might just turn out to be the study about alleged links between vaccinations and autism that has long been revealed to be fake.

So it is inevitable that people don't become less ideologically minded as their knowledge increases. Instead, they become even more beholden to those ideologies. This has been shown to be the case with man-made climate change. In the USA, among Democrats, the more people know about it, the more they believe it; but the opposite is the case among Republicans. The American psychologist Ashley Landrum recently reported on a fascinating experiment she conducted. She had test subjects read an article about the dangers of the Zika virus. But she had two different versions of the article: the one linked Zika to climate change, the other to migration. Republican readers showed concern when they'd read the migration article, whereas Zika in the context of climate change left them cold. The exact opposite was the case among Democrats.

In Europe, the situation does not yet seem to be as dramatic or polarised as in the USA. But a glance at the wider political situation doesn't exactly foster optimism. To give just one of many examples, we need only consider the triumph of the Movimento Cinque Stelle in Italy, which insistently supports vaccine sceptics. The concurrent crisis in journalism doesn't make things any easier. "It's already five to twelve", says Stephan Russ-Mohl, professor of journalism and media management at the Faculty of Communication Sciences, University of Lugano. "In the fight against fake news, we've got our backs against the wall". Despite all the initiatives that already exist, we can barely reach people".

Cleverer communication

Science urgently needs something along the lines of a communication strategy. It's not enough to be right in principle. Gleb Tsipursky, a science historian at Ohio State University with an interest in psychology, recommends first exploring the emotional state of your conversation partner. Why is he or she so angry? What's troubling him?

SIX COMMUNICATION TIPS FOR SCIENTISTS

- Don't moralise.
- First show empathy, then bring out the facts, but in moderation.
- Consider your audience, and choose your examples accordingly.
- State clearly where your expertise ends and your own opinions begin.
- When launching a new topic, consider early on how to frame it.
- For universities and funding organisations: offer courses in communication and create incentives for scientists to engage in PR themselves.

In a second step, you have to demonstrate sympathy for her problems. Only when you've done this groundwork should you bring your arguments – but you should do this, wherever possible, so that you don't come across as diametrically opposed to the fundamental convictions of your opposite number. By following these steps, Tsipursky claims to have been able to change the minds of several science sceptics.

Dietram Scheufele is of a similar opinion: "When I mention climate change to a Republican, the shutters come down straightaway. It's pointless for me to say anything more". So if you want to campaign for renewable energies, it's better to appeal to cross-group values. "It's best if you emphasise energy independence and global competitiveness. These are things that are important to all Americans. For example, Arnold Schwarzenegger does that very well".

Katharine Hayhoe is someone Scheufele thinks could be a role model. She's a climate scientist, the director of the Climate Science Center of Texas Tech University, and also an evangelical Christian. It's an unusual combination, but proves to be highly effective. Her religion gives her credibility in conservative circles, and her insistence that we must preserve Creation has enabled her to convince many a sceptic that climate change is real – including her husband, a pastor. The business magazine Fortune currently ranks Hayhoe at number 15 in its list of the 'World's greatest leaders'.

Getting to grips with people's values could also work in other fields. A study at Emory University in Atlanta, for example, has shown that vaccine-sceptical parents don't generally react to the value of 'fairness'. You'd have a better chance of success if you pointed out that vaccines strengthen the body's natural resistance and give you greater control over your health.

Another approach from communication psychology is so-called framing. This means the art of giving a topic a specific slant by carefully choosing your vocabulary. This can help you to shift the audience's emotions in the direction you want. It is important for scientists to consider early on how they should talk about their topics. For example, there is a new book entitled 'A Crack in Creation' about the genetic engineering method CRISPR, written by Jennifer Doudna, a researcher from Berkeley. "It sounds good", says Scheufele. "But it will tread on the toes of the almost 60 percent of Americans for whom religion is very important". It reads as if this new technology contradicts the values of a large portion of the population. "If such a notion gets established, it's almost impossible to rectify".

Together for 'truth'

Science is in the process of losing the race – even before it's really noticed that the race is on. "First, the scientists have to realise that they actually have a problem", says Gleb Tsipursky. "Then they have to stop seeing themselves as lone fighters and start to club together".

Tsipursky has set up a movement called 'Pro Truth Pledge'. It gets experts – along with journalists and interested laypersons – to commit publicly to spreading only information that's been verified; they also have to correct their own mistakes and the mistakes of others, and must always differentiate between facts and opinions. When it's suggested that science sceptics are hardly going to be won over by such a project, Tsipursky answers that there are still enough people situated between the two opposing poles who might respond to such an approach. Hardened sceptics are probably hopeless cases anyway.

Stephan Russ-Mohl has also had a similar idea. He is proposing an 'alliance for enlightenment'. "Scientists and journalists should come together in an alliance to counter the flood of disinformation and fake news". This would help journalists to get new, reliable stories, while researchers for their part would have a basis from which to communicate more with the broader public. However, at present there is nothing to suggest that such an alliance could actually come about.

But what if scientists communicated directly with the public on a more regular basis – such as via social media, blogs or newspaper articles? "That would be desirable, but there are no incentives for it", says Russ-Mohl. Scientists have enough on their plate, he says, because they need to publish in specialist journals to maintain their standing. "For as long as PR isn't explicitly rewarded by the organisations that fund science research, it's unlikely anything's going to change". Furthermore, many scientists have adapted quite comfortably to living in complete disregard of the public.

People like Nichols are lone warriors today. There are signs of a possible coordinated campaign – such as with the March for Science [2], which brought several hundred thousand people onto the streets in 2017. On the other hand, there is hardly any sign that the barrage of fake news and the vilification of experts is going to ease up.

Nichols is less optimistic. If you ask him for a general assessment of how things stand, his answers can be pretty frightening. It is tragic to think, he says, that this rampant narcissism might only disappear if it culminates in a catastrophe – such as a war or economic collapse. Because in crisis situations, people suddenly feel a need for real expertise again. "In the emergency room", says Nichols, "you don't see many people arguing with the doctor".

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[2] March for Science, https://marchforscience.org

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THANK YOU VICTOR!

Since 2014 Victor R. Velasco was the dedicated Editor of the EPN magazine. EPS and the editors of EPN are grateful to Victor for more than five years of hard work and dedication. He has passed on the baton to Els de Wolf, experimental particle physicist, retired from the University of Amsterdam and Nikhef Institute in Amsterdam.