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THE MAGAZINE OF THE EUROPEAN PHYSICAL SOCIETY

2014 Nobel Prizes in Physics and in Chemistry

Showering from high-energy cosmic rays

Consumer participation in power market balancing

Extra-terrestrial Life in the Milky Way Galaxy?

EPS directory & annual index

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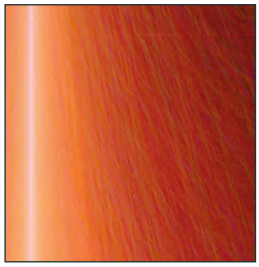
Cover picture: Atacama Large Millimeter/submillimeter Array (ALMA) and the Milky Way



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[EDITORIAL]

A short history of an International Year…

As global enthusiasm for the International Year of Light 2015 (IYL2015) rapidly develops, I am increasingly being asked where the idea actually came from. A short editorial is an ideal place to write down a brief history of the key events.

The story starts in 2009 when I proposed the idea for an International Year of Light as EPS Quantum Electronics and Optics Division (QEOD) representative to the International Council of Quantum Electronics. The idea was to follow up the Laserfest celebrations planned for 2010 (to celebrate the 50th anniversary of the laser) with something even more ambitious covering the entire field of light science and applications, and the global community of both developed and developing countries. As is often the case in a meeting, making a suggestion to do something is often followed by the task of finding out how to do it! Thus began the adventure towards IYL2015.

My first step was to meet EPS past-president Martial Ducloy (who organized the 2005 International Year of Physics). He explained that it was only the UN General Assembly that can declare International years, and he outlined how to work through UNESCO to prepare and submit a resolution. With endorsement from the EPS Executive Board, QEOD worked hard during 2010 to build a consortium amongst the major optics and physics societies to approach UNESCO. In 2011, EPS President Luisa Cifarelli brought her tremendous personal support to the initiative, and over the summer "vacation," together we drafted the prospectus and decided on 2015 as the target year based on several key scientific anniversaries. September 2011 saw the *Passion for Light* launch meeting for IYL2015 organized by SIF and EPS in Varenna where representatives of UNESCO and UNESCO-ICTP were present to learn more and to show their support for our plans.

With the help of IOP, in November 2011, EPS led a delegation to the IUPAP General Assembly in London to obtain IUPAP endorsement. From March 2012 things moved quickly. I was invited by the Director of UNESCO's International Basic Science Programme Dr Maciej Nalecz to UNESCO HQ in Paris, and his guidance was absolutely invaluable in accompanying the scientific consortium to assemble a consortium of supporting UNESCO member states. Much help was needed from a number of international partners at this stage, and it is essential (and a great pleasure) to acknowledge and thank: Francis Allotey (Ghana), Ana Maria Cetto (Mexico), Zsolt Fulop (Hungary), John Harvey and Geoff Austin (New Zealand), Joe Niemela (UNESCO-ICTP), Lluis Torner (Spain), and Victor Zadkov (Russia). There were many many more who lent their support at this stage and in another forum when I have more space I will name them all.

Obtaining the status of an International Year is absolutely not a formality!

A resolution supporting IYL2015 was adopted by the UNESCO Executive Board in 2012 which opened the gate to approach the UN General Assembly. A meeting amongst the international stakeholders in early 2013 proposed ICTP as the global coordination secretariat, and with more help from UNESCO, we were invited by Mexico to defend the proposal in full at an information meeting held at UN Headquarters in May 2013. Ana Maria Cetto and I had the great honour to lead a delegation that also represented the African Physical Society, ICTP, OSA and SPIE. Following this meeting, and after final endorsement at the 2013 UNESCO General Conference, the resolution A/RES/68/221 proclaiming the IYL 2015 was adopted during a plenary meeting of the 68th Session of the UN General Assembly on 20 December 2013.

Early on in the process, I heard it often remarked that obtaining UNESCO and UN support for an International Year was "just a formality". Nothing could be further from the truth. Getting such high-level support on a political level required extremely hard work by many people, and the development of arguments defending the proposal on all levels: from science to society to the economy to development and more…

Thanks to all who helped and supported us, we are now in a truly excellent position to ensure that 2015 is a great success! ■

John Dudley
President of the EPS

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EPS HISTORIC SITES

CERN Synchrocyclotron, Geneva Switzerland

The synchrocyclotron (SC), CERN's first accelerator, came into operation on 1st August 1957, two years before the proton synchrotron (PS), and was the highest energy particle accelerator in Europe. Its energy of 600 MeV was suggested by Enrico Fermi and is about the highest energy reasonably (and economically) achievable with a cyclotron.

The SC initially served two experimental rooms located on both sides of the accelerator hall, the "proton hall" and the "neutron hall". In 1964 the ISOLDE facility was approved (2014 is not only the 60th anniversary of CERN but also the 50th anniversary of ISOLDE), a third hall was built underground and ISOLDE experiments started in 1967.

Throughout its 33 years of operation, the SC produced many important physics results. The first one came soon after operation started, with the observation of the electron decay of the pion, which proved an important prediction of the weak interaction theory. A few others that can be mentioned are the first precision measurement of the muon anomalous magnetic moment; the first exact measurement of the decay rate of the positive pion into a positron, neutrino and neutral pion; the muon capture in hydrogen; and many others. The first bubble chamber used at CERN was operated at the SC. When the SC was shut down in December 1990, ISOLDE was moved to its present location at the PS Booster. The "proton hall" and the "neutron hall" were decommissioned and transformed into office space for the ALICE collaboration.

The SC hall was "sealed" and the residual radioactivity left to decay. As the SC is an important piece of CERN history, in 2011 a project was launched to transform the building and the accelerator into a public exhibition telling the story of the early years of the Laboratory. Before the actual project started, an extensive radiological characterization of the hall and all its content was performed, to confirm that the expected ambient radioactivity was low enough, after 25 years or so of decay, to be compatible with public access.

The "SC project", with an overall duration of two years, has consisted of three phases: 1) the radiological cleaning-up of the SC hall, with the elimination of more than 200 tons of obsolete material and equipment, and the preservation of only the accelerator itself (magnet, coils, RF system, ion source and vacuum system) and of the 50-ton overhead crane;

2) the refurbishment of the hall, which included the water-proofing of the roof, the installation of new electrical network and ventilation system, a visitor path and a new entrance, and 3) the installation of the exhibition and multimedia projection system. The first two phases were undertaken from March 2012 to September 2013, in order for the SC to be shown during the CERN Open Days at the end of September. Approximately 1500 visitors saw the SC on the weekend of 28-29 September.

Besides external contracting companies, the project involved many CERN staff from various groups. This is an excellent example of collaboration amongst several CERN groups who, in spite of their heavy involvement in the LHC, spent in parallel quite some time on a project of certainly lower priority than the LHC, but very challenging and motivating. Everybody saw the "educational" aspect and the positive impact that the future SC Visit Point would have had on CERN's public image.

Access to the accelerator hall is now via a new entrance, built inside the 4 m thick concrete shielding wall, which represents a "time tunnel" taking visitors back in time from today to the late 50's. Inside the 300 m^2 hall the visit area is defined by glass barriers, but the original floor can be seen outside the visitors' path. A section of the floor has been removed to show the entire accelerator that goes one level down from the street level.

▲ The restored SC hall will house a sound-and-light show on the story of the SC.

Old objects that were part of the SC installation or date back to that time are on display: large spammers that were used to tighten the bolts of the pieces making up the 2500-ton magnet, two control units, loudspeakers, telephones, an oscilloscope, a mechanical computer, a typewriter. A documentary projected on the back wall of the hall, telling the story of the origin of CERN and of the SC, is complemented by a light and sound show making use of the projection mapping technique, which virtually brings the accelerator back to life.

The SC was officially inaugurated and named EPS historic site on 19 June 2014, in a ceremony in the presence of the CERN Council, by CERN Director General prof. Rolf Heuer, the president of CERN Council prof. Angieszka Zalewska and prof. Luisa Cifarelli, chairperson of the EPS Historic Site Committee. The SC is now part of the new Visit Points of CERN and will be seen by many visitors in the years to come. ■

Marco Silari, *CERN*

▼ Front view of the synchrocyclotron after refurbishing.

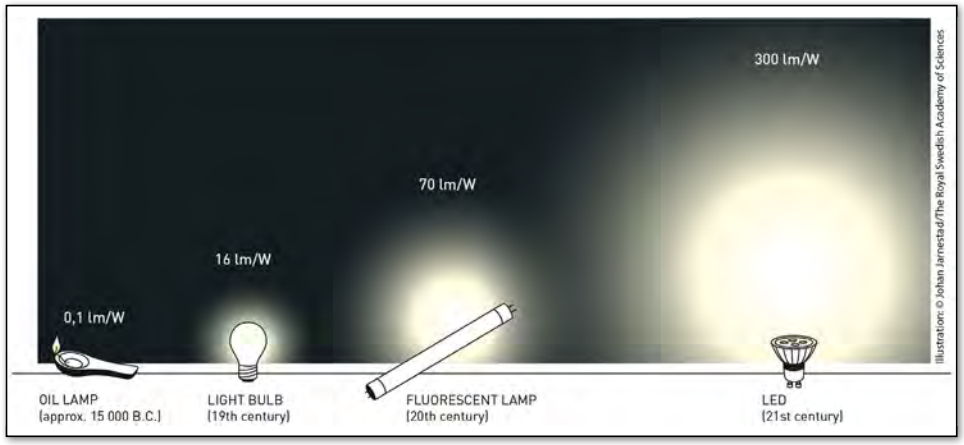
The 2014 Nobel Prizes in Physics and in Chemistry

go to revolutionary inventions based on optics and quantum electronics

During the second week of October 2014, the Swedish Academy of Sciences decided to award two practical inventions, the blue Light Emitting Diodes (LEDs) and the super-resolved fluorescence microscopy, through the attribution of the 2014 Physics and Chemistry Nobel Prizes.

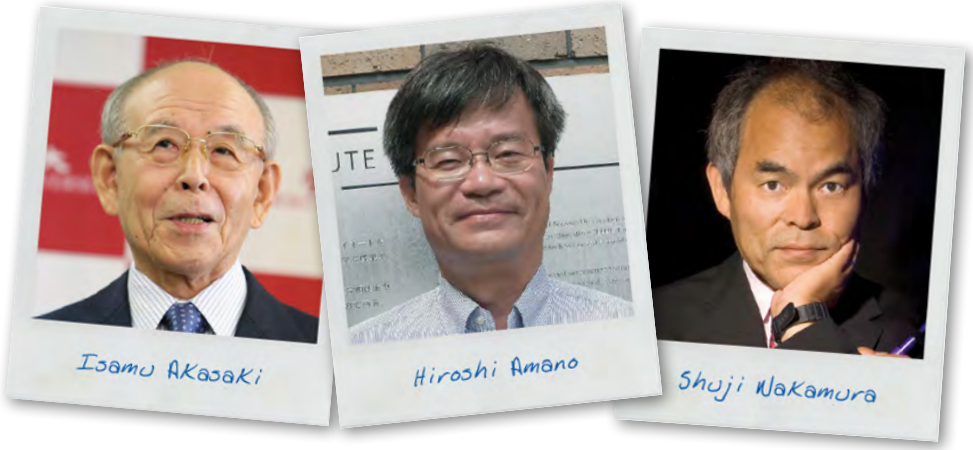
Two inventions rather than two fundamental discoveries. But those are revolutionary. They both use light to overcome technological barriers and open luminous perspectives for mankind.

The 2014 Physics Nobel Prize indeed goes to Isamu Akasaki and Hiroshi Amano from Nagoya University, Japan, and to Shuji Nakamura, University of California, USA, "for the invention of efficient blue light emitting diodes which has enabled bright and energy-saving white light sources". Producing bright visible light was routinely done in the past by manipulating groups of atoms, as those met in semi-conductors, to make electrons move and fall into holes having the right energy gap to release the photon energy corresponding to a given wavelength. This could easily be done for red, yellow or green light by doping appropriately semiconductor materials. However, blue photons that require higher energy gaps could not be created. This banned the access to bright white lamps, produced from the mixing of all colors. To create blue LEDs, Nakamura exploited special crystals, indium gallium nitrides, providing the desired range of energy gaps. He independently began to develop a blue LED in 1988. Two years later, he made high-quality gallium nitride. Asaki and Amano's seminal discovery was to prepare suitable surfaces on which these crystals could grow and supply adapted p-type layers by using sapphire as substrate. In 1986, they were the first to create a high-quality gallium nitride crystal. In 1992, they came up with the first diode that emitted blue light. The result of all these combined efforts is an invention that will benefit most people. Blue LEDs complete the rainbow of colored diodes to produce white energy-saving light sources. We find them in our cell phones, TVs, computers *etc.* These revolutionary light sources only consume 5% of the power of incandescent light bulbs and can supply four times more lumens per Watt than current fluorescent light. Nowadays, they already have such a considerable economic and environmental impact in our daily life, that, as emphasized by the Nobel Committee, "the 21st century will be lit by LED lamps".



▲ Time evolution of lighting efficiency.

The 2014 Chemistry Nobel Prize has been awarded to Eric Betzig, from Howard Hughes Medical Institute, Ashburn, USA, to Stefan W. Hell, from Max Planck Institute for Biophysical Chemistry, Göttingen, Germany, and to William E. Moerner, Stanford University, USA, "for the development of super-resolved fluorescence microscopy". So far a natural limitation of optical microscopy has consisted in the Abbe resolution limit, following which a microscope cannot discern features smaller than half the wavelength of the light used by this device. Observing submicron-sized structures such



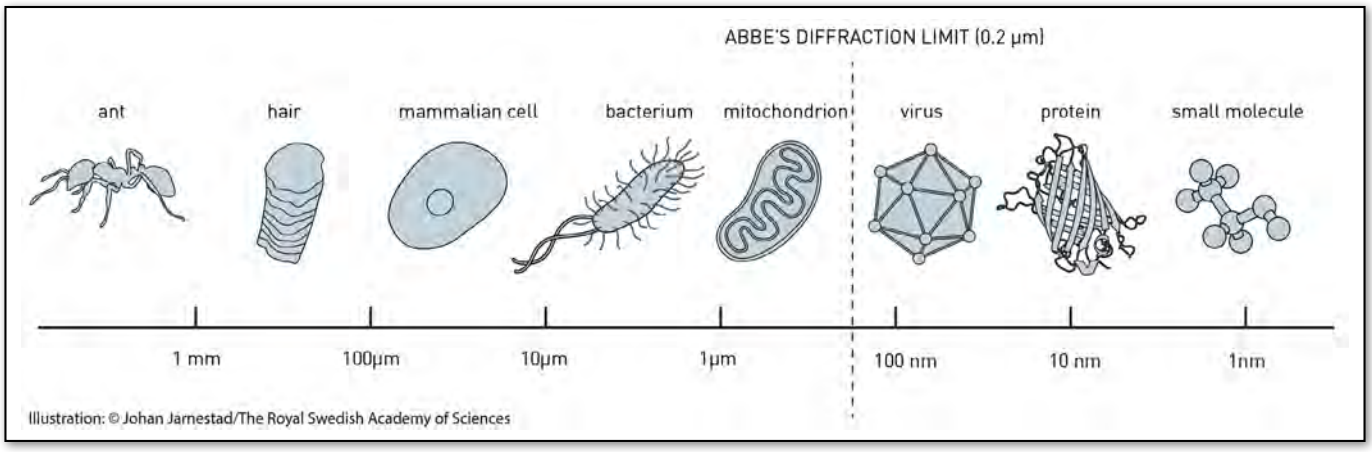
as macromolecules and proteins remained out of reach. To overcome this spatial resolution barrier, Betzig, Hell and Moerner revolutionized fluorescence spectroscopy techniques to access and see the nanoworld. Hell employed two combined near-UV and infrared laser pulses using the novel concept of stimulated emission depletion (STED) microscopy: a first laser pulse stimulates fluorescent molecules and switches on diffraction-limited distributions of excited molecules, while a second laser beam prevents the fluorescence from their outer parts. By measuring the light emitted by the central molecules only and scanning over the sample, features much smaller than the Abbe limit can be resolved. Betzig and Moerner greatly improved imagery techniques by marking biological samples with fluorescent proteins. Woerner used photorefractive polymers and organic glasses to optimize energy transfers between different laser beams to write small volume holograms; he succeeded in trapping nanoscale objects by monitoring the local Brownian motion of particles, and confined light with photonic crystal nanocavities into volumes less than the cube of the carrier laser wavelength. Betzig proposed innovative methods to overcome the electronic delocalization occurring when molecules become spatially more dense under light confinement, to prevent spontaneous spectral diffusion and light-induced spectral shifts; he moreover advanced techniques of probe design and contrast enhancement.

These combined works resulted in the single-molecule microscopy method: a pulse of light operating at an appropriate wavelength illuminates the sample, which forces a small fraction of the fluorescent molecules within it to light up. An image is taken, the light is switched off, and the procedure is repeated by means of fast and short stimulations. Each exposure triggers a different subset of the fluorescent molecules to glow. Every tagged molecule is lit up, in such a way that the built-up picture circumvents Abbe's limit. These technical breakthroughs nowadays allow us to visualize volumes extending over nanometre dimensions. Probed with femtosecond light sources, nanoscaled structures today reveal in real-time vibrational and rotational molecular motions as well as individual neurons. For comparison, the electron microscopy can resolve much smaller details, but this imaging technique needs vacuum and is thus suitable to dead samples only. In contrast, fluorescence-based optical microscopy applies to living tissues and is thus able to scan life at unprecedented levels of spatial resolution.

Two Nobel Prizes for two different scientific disciplines have been attributed to scientists working with the same matter: Light. Since the establishment of this prestigious award at the beginning of the XXth century, seventy-seven exceptional researchers have received a Nobel prize being in one way or another in connection with light. From Michelson to Townes, from Einstein to Penzias and Wilson, from Bloembergen to Zewail, all of them revealed, pushed or exploited the fascinating properties of light until its very intimate structure.

2015 will be the International Year of Light and Light-Based Technologies. The 2014 Nobel Prizes in Physics and Chemistry are brightly opening this unique event. ■

Luc Bergé
Chair of the Quantum Electronics and Optics Division
European Physical Society



▼ Beyond the Abbe resolution limit (optical microscopy).

2014 LISE MEITNER PRIZE FOR NUCLEAR SCIENCE

The 2014 Lise Meitner Prize has been jointly awarded to Johanna Stachel (University of Heidelberg), Peter Braun-Munzinger (GSI Darmstadt), Paolo Giubellino (University of Torino) and Jürgen Schukraft (CERN) for "their outstanding contributions to the experimental exploration of the quark-gluon plasma using ultra-relativistic nucleus-nucleus collisions, in particular to the design and construction of ALICE and shaping its physics program and scientific results bringing to light unique and unexpected features of a deconfined state of strongly-interacting matter at the highest temperatures ever produced in the laboratory".

▲ From left to right: Paolo Giubellino, Peter Braun-Munzinger, Johanna Stachel and Jürgen Schukraft.

The award was presented on September 3rd, 2014, at a ceremony held in the Globe of Science and Innovation at CERN. In addition to members of the ALICE collaboration, the ceremony was attended by members of the CERN Management including the Director-General, Rolf Heuer, as well as the EPS Nuclear Physics Board Chair, Douglas MacGregor.

The Lise Meitner Prize is given biennially by the Nuclear Physics Division of the European Physical Society. It recognizes outstanding work in the fields of applied, experimental or theoretical nuclear science. Initiated 14 years ago, the recipients of the award are famous European scientists and, due to them, the prize is one of the most prestigious awards in Nuclear Physics in the world.

The prize was sponsored in 2014 by Extreme Light Infrastructure – Nuclear Physics (ELI-NP) (www.eli-np.ro), Bucharest-Magurele, Romania ■

Nicolae-Victor Zamfir
2014 EPS Lise Meitner Prize Committee Chair.

EPS HISTORIC SITES

Fabra Observatory, Barcelona, Spain

The Royal Academy of Sciences and Arts of Barcelona (www.racab.es) was created in 1764 by a group of educated citizens of Barcelona under the name of "Physico-Mathematical Conference" to follow the progress of science and technology. A few years later, the "Conference" was recognized as an Academy by King Charles III.

Several years earlier, in 1717, and as a consequence of the Catalonia's stance against King Philip V at the beginning of the 18th century, the Catalan universities (including the University of Barcelona) were moved to Cervera, a town in the interior of Catalonia, where they remained until 1842. The Academy was one of the institutions created in order to substitute the academic, scientific and technical role of the University of Barcelona.

From its early years, the Academy was especially active in Astronomy, Meteorology and Seismology. That was the reason to construct two domes at the top of the rebuilt site of the Academy in the Ramblas of Barcelona, at the end of the XIX century. But in 1902 and thanks to a donation from Camil Fabra i Fontanills - the first Marquis of Alella - the Academy decided to install an observatory at the top of Tibidabo, the mountain close to the city of Barcelona. The Fabra Observatory was finished in 1904 and inaugurated by King Alfonso XIII. The building is an intrinsic part of the skyline of Barcelona and has run without interruption since its inauguration.

Within the commemoration of the 250th anniversary of the Academy, one special session took place on last 9th May at the Fabra Observatory to install the plate recognizing the Observatory as a European Physical Society Historic Site. The celebration was chaired by Andreu Mas-Colell, Minister for Economy and Knowledge of the Generalitat de Catalunya and Carmen Vela, Secretary of State of Research, Development and Innovation of the Spanish Ministry of Economy and Competitiveness. Special attendants were Luisa Cifarelli, past president of the EPS, and Peter Kennedy, from ALLEA, the federation of European Academies to which the RACAB has been admitted.

The Fabra Observatory was equipped with a Maihlat telescope, which at present has incorporated digital technology. It has the code 006 in the International Astronomic Union. With that telescope Josep

Comas, the first director, was able to discover the existence of an atmosphere in Titan, the largest of the 9 satellites of Saturn know at that time. The atmosphere was observed by purely optical means, on the night of August 13th 1907 and was published in the Astronomische Nachrichten. Comas described an object of dark edges and a central more clear part that he interpreted as the existence of a strongly absorbing atmosphere in the Titan environment. The discovery was extraordinary since it is extremely difficult to make such an observation on a body of less than one second of arc, the limit of observations in terrestrial optics. It took forty years to check his result by spectroscopic means and to confirm the existence of an atmosphere with the presence of methane. The characteristics of the atmosphere have been studied in more detail by the Huygens probe released by the Cassini spacecraft in December 25th 2005, penetrating in the atmosphere next January 14th.

The discovery of Comas has been recognized by several authors. After the analysis of the different observations by Comas, Ralph D. Lorenz concluded that they are consistent with all the details obtained by current space missions. He indicated that Comas was a keen observer able to appreciate the edge darkening and, consequently, to actually observe an effect of the atmosphere, avoiding the turbulence by making very short observations. Furthermore Comas made several other important observations. He discovered the 32P/Comas Sola comet, twelve minor planets, and some other objects.

At present the Fabra Observatory is fully operational, permanently observing small planets and comets in the framework of the Minor Planet Center. Since 2011 the observations are complemented with a new station at Montsec (at 150 km and at an altitude of 1570 m) equipped with a modified Baker-Nunn camera which can reach magnitude 21.

Following the tradition of the Academy, the meteorological observations started at the Fabra Observatory in 1913. Since then, the observations have been taken continuously and from the same place, producing a very important climatic series of data. The detection and study of earthquakes has also continued uninterrupted since 1904 and, since 1985, with a seismic detection station at 30 km connected to the Observatory.

In parallel, the Observatory has developed many outreach activities, receiving more than 2000 visitors per year and also organizes more than 10 courses per year on meteorology and astronomy. Additionally, in the last 10 years summer night sessions have collected some 50,000 persons.

▲ The Fabra observatory dome.

▼ Front row, from left to right: Mercè Durfort, Maria. J. Yzuel, Antoni Castellà, Andreu Mas-Colell, Carmen Vela, Ramon Pascual, Luisa Cifarelli, Josep M. Codina.

Ramón Pascual
Instituto de Física de Altas Energías (IFAE)
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Breaking borders, unfolding differences

The International Association of Physics Students and its success story

The International Association of Physics Students is an organisation of young volunteers whose aim is to establish a network of young scientists for both academic and social exchange beyond national borders. Its growing success is bringing together more and more students not only from Europe, but also from outside the continent, who enrich the work of the association with their activities, experience and enthusiasm about physics.

Being a good physicist sometimes is just not enough. At a time of complete internationalisation and exchanges between universities and global companies, a physics student must expand into the wider world as early as possible in his/her career. Thanks to the web and especially social networks, young scientists are able today to find out about new opportunities, people they could enjoy working with and common interests they can share.

The International Association of Physics Students (IAPS) is a simple result of these ingredients. We let a global community of students come together for physics-related events and the response is rather overwhelming. Since its foundation in 1987, IAPS has grown into a community of more than 50.000 physics students, including members organised in 15 national and 8 local societies from around the globe.

▲ Participants of the ICPS 2014 in Heidelberg

Scientific and cultural exchange

The association supports its members in their academic and professional work, discussing and acting upon scientific, social and cultural issues. Between the many activities that the organisation now leads, the annual International Conference of Physics Students (ICPS), taking place in a different country every year, is certainly a highlight. The latest, held in Heidelberg (Germany) in August, was a roaring success: about 450 international students from 36 nations took part in a one week long event, with more than 120 presentations, 80 posters and several tours of research facilities offered to all participants. These included visits of the Karlsruhe Institute of Technology (KIT), three Max Planck Institutes, local industries such as Mercedes and Bosch and many others. Distinguished scientists were invited to the conference and presented their research covering many different fields in physics. As often in its history, IAPS and its member societies were supported by the European Physical Society, as well as the host universities, the national physical society, foundations, industries and research centers.

Since its foundation in 1987, IAPS has grown into a community of more than 50.000 physics students

ICPS constitutes an important meeting point for many of our members, some of which have taken part for more than 5 years and look forward to next year's meeting from 12th to 19th August 2015 in Zagreb, Croatia. However, it is also through other activities that we aim to reach the widest possible community of physics students. We are particularly proud of some recent challenges that have been launched by member societies, such as the PLANCKS physics student competition, which featured in the previous edition of Europhysics News. We also encourage our member societies to organise binational meetings of physics students. As a very good example, the German-Hungarian autumn and spring schools in Budapest and Munich were a fascinating opportunity for exchange and sharing best practices.

A major success of IAPS in the last 5 years has also been its tour of the CERN facilities, held in April each year. Although many schools and universities organise their own trips, what we offer is a completely different deal: a place of international exchange, where new friendships and networks can always be found. The incredible demand for such visits has brought us to decide to expand in this direction as well and we hope to complete soon new agreements with the Culham Centre for Fusion Energy (UK), where the Joint European Torus is hosted, and with the Gran Sasso National Laboratories (Italy).

A voice for physics students

The Association also plays an important role in representing the physics student community at the widest levels, by taking part in multi-national meetings on scientific education and outreach. We are active members of the HoPE (Horizons of Physics Education) network and also encourage our member societies in going into schools to inspire younger minds.

Our commitment to spread passion for physics is also clear by our role in support of the International Year of Light (IYL 2015): we have recently become an official sponsor and we are in the process of developing many events involving our global community.

In its 28th year of existence, IAPS owes its success to many organisations and individuals: the first to mention are surely our volunteers, not only in the Executive Committee but also in the National and Local committees. However, we also immensely benefit from the support of the European Physical Society, as well as the Institute of Physics, the American Physical Society, the German Physical Society and the International Union of Pure and Applied Physics.

Nobody really struggles to see the importance of an organisation like IAPS, at least not after having seen the enthusiasm and creativity that its events produce in young physicists. Taking part in conferences, research tours, international forums and local meetings is always a greatly rewarding experience during the first years in a scientific career, especially if these are made in a friendly, accessible and open environment.

Why are we writing in Europhysics News? Many of the readers will not have heard of IAPS, unsurprisingly, but all of you must understand the importance of seeing beyond our national borders. We wish to address everyone with an interest in physics, its challenging advances and its understanding in society. We want to remind you that the world is wide and full of surprises and students should get to know it as early as possible. This allows for greater mobility, mutual understanding, scientific exchanges and great experiences with people who wish to improve. We hope that this article will move around your universities, your offices and laboratories, being read by as many students as possible. We hope to welcome them and make them part of a successful story very soon. ■

Francesco Sciortino
Member of the IAPS Executive Committee.

Matthias Zimmermann
IAPS president.

Links

- iaps.info
- icps2014.com
- icps2015.unizg.hr
- leiden.plancks.info

Impression of
the EPS-SIF School on Energy

The second edition of the Joint EPS-SIF International School on Energy (under the leadership of Luisa Cifarelli and Fritz Wagner, directors of the school) took place from 17 to 23 July 2014 in the beautiful Villa Monastero in Varenna on Lake Como.

The location is splendid: Varenna is undoubtedly one of the most beautiful and characteristic villages on the eastern bank of Lake Como, and Villa Monastero is one of the most ancient and famous villas of the region.

In this scenario, the European and Italian Physical Societies (EPS and SIF) have jointly taken the initiative of establishing the International School on Energy to support education and training on energy issues at post-doctoral level. The school also aims at providing a forum of discussions for an analysis of new developments and a new vision of the future for scientists interested in any aspect of physics research and development related to the supply, distribution, transformation and use of energy in society.

Sixty-five participants – lecturers and students (PhD students and young post-docs) – from all over the world including Jamaica, Japan and China attended this school.

Thirty-six lectures, followed by lively discussions which continued during breaks and dinners, focused on the most recent findings, ideas and suggestions for future developments. Topics included solar photovoltaic, wind, biomass, fossils, fission, fusion, energy saving technologies, climate issues, along with other topics where physics plays a role.

The unique feature of the school is its multidisciplinarity and interdisciplinarity, very rarely found in meetings on energy. Both aspects are vital for obtaining a global insight into the complex energy problem, for which there is no unique solution. The overview offered by the school was highly appreciated by students and teachers alike. The concepts and ideas involved in modern energy systems were clearly exposed by the lecturers, who invested every effort to be as didactic as possible. In this way knowledge gaps were filled and answers were provided to long-standing questions in the minds of the students.

▲ Participants of the EPS-SIF School on Energy in Varenna on Lake Como

The lecturers did not spare their personal criticism on currently ongoing energy reforms in Europe. This often led to an interesting confrontation of ideas that further contributed to deepen the understanding of the subject.

Security of supply, particularly in Europe, geopolitical aspects and environmental problems are once again at the top of the political agenda. Consequently, one of the central challenges of the 21st century is to ensure a sustainable energy supply for the world population and its economy.

In a world characterized by dramatic differences in per-capita energy use it will be difficult to collectively develop common responses to such a challenge. Furthermore, inequalities in energy use increase the danger of geopolitical conflicts, and foster unhealthy consumption habits throughout the developed world, while preventing entire generations in the developing world from fully realizing their potential as citizens of the modern world.

All talks may be found on the SIF website and the lectures of the school will be published by SIF as Lecture Notes, in a dedicated hardcover edition. They will be also available online in open access on the EPJ Web of Conferences, serving as a reference for years to come. ■

Gianluca Alimonti,
INFN, Sezione di Milano, Italy

(1921-2014)

Jacques Friedel

The loss of Jacques Friedel on the 27th of August 2014 is a very sad event for the worldwide community of physicists. They are all so much indebted for his exceptional contributions to the development of Condensed Matter Physics during the last 60 years.

Jacques Friedel got his PhD at the Universityof Bristol (UK) in the Sir Nevill F. Mott Laboratory and his Doctorat ès Sciences at Paris University. He became full Professor at the Paris-Sud University where he co-founded the Laboratory of Solid State Physics in 1959 with André Guinier and Raimond Castaing. This Laboratory was, from the start, very attractive to a number of well-known Professors (some of them became Nobel laureates in Physics) from the whole world as well as to many young physicists who benefitted from the high-level local environment.

Jacques Friedel was former President of the French Physical Society (1970), of the European Physical Society (1982-1984) and of the French Academy of Sciences (1992-1994). He was elected as a foreign member of the U.S. National Academy of Sciences, the Royal Swedish Academy of Sciences and the Royal Society. He had many awards: CNRS gold medal in 1970, Von Hippel award, Holweck Prize.... Finally he received the Grand Cross of the French "Légion d'Honneur" in 2013.

The contribution of Jacques Friedel to the understanding of the electronic properties of condensed matter has been extremely wide and important: the discovery of the so-called "Friedel oscillations" of the electron density characterizing the screening around impurities in metals, the demonstration of the power of the "tight binding" method, which provides a simple and useful approach to describe the chemical bond, the cohesive properties and the electronic excitations (this method is now of wide use in the theory and modelling of nanosized semiconductor devices). Furthermore any scientist interested in the plasticity of materials can find, in the highly successful book of Jacques Friedel on dislocations (published in 1956), a deep and powerful analysis of the role of extended defects in crystalline structures. Finally the different aspects of superconductivity have led him to develop again quite original points of view on this fascinating subject.

▲ Jacques Friedel at his 90 years anniversary, celebrated in June 2011 in Mercurey. © Jean Friedel

He played a very important role in the birth and further development of the European Physical Society. He participated, as a delegate of the French Physical Society, in one of the first meetings of the General Assembly, which was chaired by the Director of CERN at the time, his old friend Bernard Grégory. The young EPS had to be organized. Specialized divisions were created. Jacques Friedel participated in raising the large Condensed Matter Division, which included not only liquids and solids but also "soft matter", such as polymers and liquid crystals. He was later elected a member of the Executive Committee. During his term (1982-1984) as President of the EPS, in spite of financial difficulties, he acted efficiently to get the support of several industrial firms and to integrate all the National Societies of Europe.

To summarize, Jacques Friedel was, by far, one of the leading figures of our community. Even recently his scientific advices have been extremely valuable for many. He will be missed by all of us. ■

Michel Lannoo
Vice-President of the French Physical Society

A NEW PUBLICATION FREQUENCY FOR EPN

At the 2014 EPS Council meeting it was decided to reallocate some funds to finance EPS activities in Brussels. For EPN this means that, for 2014 and 2015, the last two issues will be merged into one 48-pages issue (5&6, published in November), which saves distribution costs. As you may have noticed already, there is now also a flip book pdf version with an html version that is indexed by Google. This user-friendly flip book will be available for all issues (see: www.zyyne.com/widgetdoc;13732).

Victor R. Velasco, *EPN Editor*

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Highlights from European journals

RELATIVITY

Electric/magnetic dipole in an electromagnetic field

How does an electric (or magnetic) dipole behave in an electromagnetic field, when its velocity becomes comparable with the speed of light?

This problem has been solved for the first time in this work, where novel relativistic effects were found. In particular, it has been shown that the concept of "hidden" momentum of magnetic dipoles in an electric field, being disputable up to date, is strongly required to derive relativistically adequate solutions. Moreover, a novel concept of "latent" momentum of electric dipole should be also involved into the description of dipoles.

As it is known, the energy and momentum constitute a four-vector in the four-dimensional space-time, which obeys Lorentz transformations. Hence, the revealing of novel components of the dipole momentum leads to the appearance of related contributions to their total energy. As a result, the energy of the ultra-relativistic electric/magnetic dipole occurs essentially depending on the mutual orientation of velocity, electric (magnetic) dipole moment and electric (magnetic) field.

Finally, the role of the known relativistic effects (contraction of scale, dilation of time, Thomas-Wigner rotation of coordinate axes of the inertial reference frame in the successive space-time transformations) is disclosed, while the force and torque on a moving dipole are calculated. ■

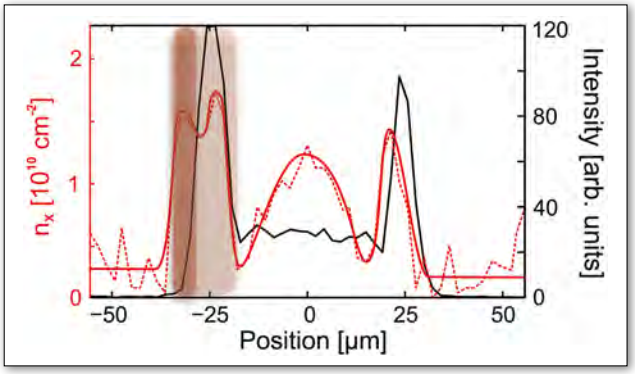
▮ **A. Kholmetskii**, **O. Missevitch** and **T. Yarman**, 'Electric/magnetic dipole in an electromagnetic field: force, torque and energy', *Eur. J. Phys. Plus* **129**, 215 (2014)

CONDENSED MATTER

Evidence for a Bose-Einstein condensate of excitons

At sufficiently low temperatures, boson-like quantum particles can condense in the ground-state of the system and then form a particular realm called a Bose-Einstein condensate.

Semiconductor excitons, *i.e.* electron-hole pairs bound by Coulomb attraction, shall undergo Bose-Einstein condensation under *a priori* easily accessible experimental conditions, *e.g.* below a few Kelvins. However, due to their composite nature, excitons exhibit a dark ground-state, *i.e.* optically inactive, which has certainly contributed to the lack of signature of exciton condensation obtained through conventional optical probes.



▲ Profiles of the photoluminescence intensity (black) and exciton density, n_x (red), at 350 mK in a spontaneously formed electrostatic trap (shaded area). Quantum statistics is signaled by the large density combined to an anomalously weak photoluminescence (darker shaded area).

In this letter, the authors reveal the dark nature of excitons Bose-Einstein condensation. They report an excitonic quantum statistical distribution marked by a dominant (~ 90%) fraction of dark excitons at sub-Kelvin temperatures. The exciton condensate emits a weak photoluminescence with macroscopic spatial coherence and linear polarization. These signal a multi-component exciton condensation, with a weak bright component coherently coupled to a dominant dark part, as theoretically predicted. ■

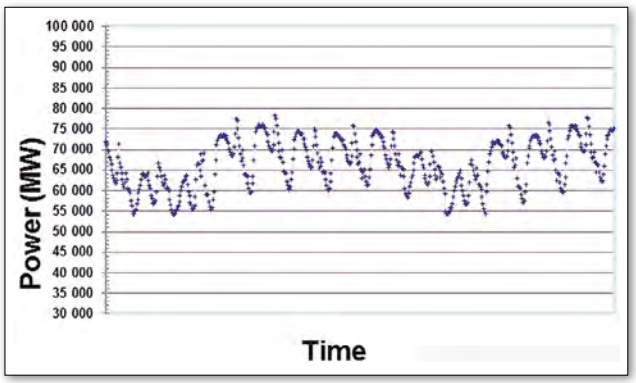
▮ **M. Alloing *et al.***, 'Evidence for a Bose-Einstein condensate of excitons', *EPL* **107**, 10012 (2014)

ENERGY

Balancing renewable energy costs

Simulating the cost of generating a combination of electricity sources while accounting for the fluctuating nature of energy production and demand provides tools to optimise such energy mix.

Increasing reliance on renewable energies is the way to achieve greater CO_2 emission sustainability and energy independence. Yet, because such energies are only available intermittently and energy cannot be stored easily, most countries aim to combine several energy sources. Now, in a new study, the authors have come up with an open source simulation method to calculate the actual cost of relying on a combination of electricity sources. They



▲ Two weeks taken from the 2011 chronicle of the time dependence of the power demand in the French metropolitan territory.

demonstrate that cost is not directly proportional to the demand level. Although recognised as crude by its creator, this method can be tailored to account for the public's interest—and not solely economic performance—when optimising the energy mix. ■

■ **B. Bonin**, **H. Safa**, **A. Laureau**, **E. Merle-Lucotte**, **J. Miss** and **Y. Richet**, 'MIXOPTIM: a tool for the evaluation and the optimization of the electricity mix in a territory', *Eur. Phys. J. Plus* **129**, 198 (2014)

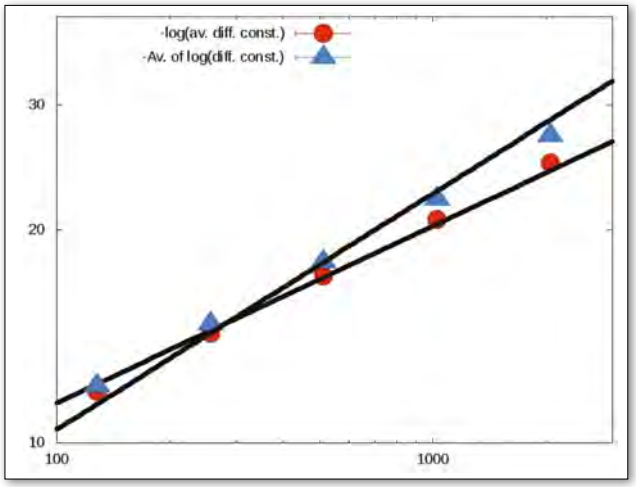
MATHEMATICAL PHYSICS

Diffusion in periodic, correlated random forcing landscapes

In measurements of physical observables, how should one correctly account for sample-to-sample variation of disorder?

A common practice is to replace an averaging over very many different samples by a single measurement for a large enough sample. This process of self-averaging often works well, while there are cases where it breaks down very strongly: rare realisations dominate the average behaviour, which therefore does not coincide with the typical behaviour obtained for a single sample. This was explicitly shown by exact analytical and numerical results in a solvable model of transport in random media. The model comprised a Brownian particle moving in a disordered potential given as a periodically-extended fractional Brownian motion with arbitrary Hurst exponent H. It was revealed that the diffusion coefficient of the particle in a potential of period L is strongly non-self-averaging, with moments supported by atypical disorder realisations: while the typical value decays as a stretched exponential in L with exponent H (blue points), the positive and the negative moments have instead the exponents H/(1+H) (red points), and 2H, respectively (see figure). This work underlines the crucial role of disorder in dictating the dynamical behaviour, thereby cautioning against naive implementation of single-sample measurements. ■

▼ Behaviour of diffusion coefficients



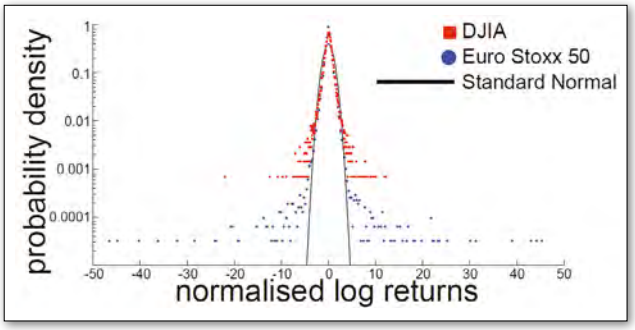
■ **D.S. Dean**, **S. Gupta**, **G. Oshanin**, **A. Rosso** and **G. Schehr**, 'Diffusion in periodic, correlated random forcing landscapes', *J. Phys. A: Math. Theor.* **47**, 372001 (2014)

STATISTICAL PHYSICS

Market crashes and the financial **data fractal landscape**

Analysing the adequation of financial data structure with its expected fractal scaling could help early detection of extreme financial events because these represent a scaling irregularity.

New research shows that the most extreme events in financial data dynamics—reflected in very large price moves—are incompatible with multi-fractal scaling. These findings have been published by the authors. Understanding the multi-fractal structure of financially sound markets could, ultimately, help in identifying structural signs of impending extreme events.



▲ Graph of the normalized empirically found distribution of the American Dow Jones Industrial Average index, DJIA (red squares), and European Euro Stoxx 50 (blue circles) index data with prices recorded every minute along with the Standard Normal curve for comparison.

In this study, the authors performed multi-fractal testing on two sets of financial data: the Dow Jones Industrial Average (DJIA) index and the Euro Stoxx 50 indexes. They demonstrate that the extreme events which make up the heavy tails of the distribution

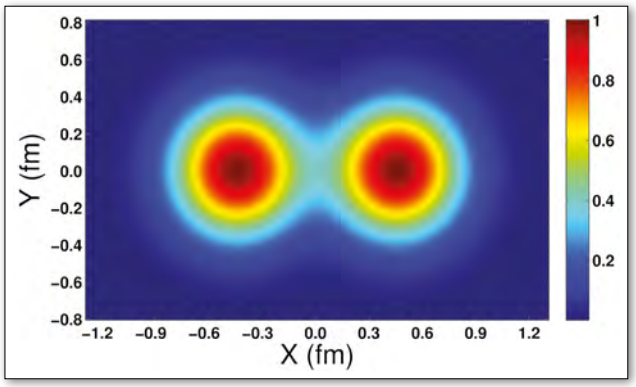
of the Euro Stoxx 50 logarithmic graph of financial returns distort the scaling in the data set. This means that most extreme events adversely affect fractal scaling. These results contrast with previous findings that extreme events contribute to multi-fractality. ■

■ **E. Green**, **W. Hanan** and **D. Heffernan**, 'The origins of multifractality in financial time series and the effect of extreme events', *Eur. Phys. J. B* **87**, 129 (2014)

THEORETICAL PHYSICS

Modern three-body forces make neutron stars collapse

Nuclear systems ranging from light nuclei to massive neutron stars can be well described by nucleons interacting through two-body and three-body forces.



▲ Density profile of the collapsed state of 10000 neutrons in the X-Y-plane along the symmetry axis Z=0 (schematic illustration). Polarized neutrons, which interact through incorrect three-body forces, concentrate in small spheres separated by 0.9 fermi.

From electrostatics we know that two identical uniformly charged spheres repel at any distance but the repulsion disappears when the spheres completely overlap. Similarly, in some modern expressions of nuclear three-body force it is assumed that the nuclear repulsion between the three nucleons is zero when they occupy the same position in space. The authors provide a mathematical proof that such form of the three-body force leads to the collapse of large neutron systems: N neutrons form a bound system with the energy growing as N^3 (the effect becomes visible for N > 10000). The density of such system is illustrated in the Figure. Thus, in order to be compatible with our knowledge of neutron stars - where the constituents form dense nuclear matter with a finite energy per particle - modern expressions for three-body nuclear forces have to be carefully assessed regarding their strong repulsive core which should not vanish even when nucleon triples overlap. ■

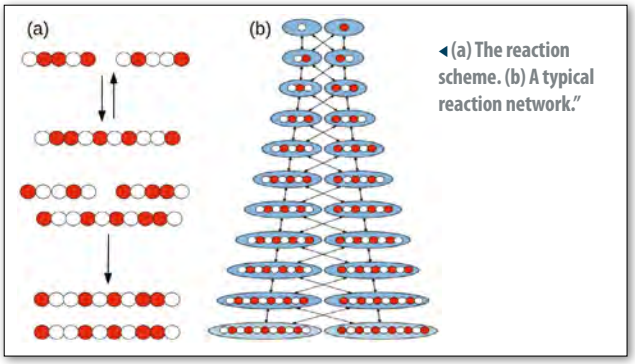
■ **D.K. Gridnev**, **S. Schramm**, **K.A. Gridnev** and **W. Greiner**, 'Nuclear interactions with modern three-body forces lead to the instability of neutron matter and neutron stars', *Eur. Phys. J. A* **50**, 118 (2014)

BIOPHYSICS

Autocatalytic binary polymer model

Template directed replication of information in polymers is at the essence of living beings, and is believed to be a cornerstone of life's origin.

Using a binary polymer model, where polymers act as templates for their autocatalytic replication, we analyze the chemical reaction network in which replicators serve as reactants of each other and compete for common resources. The involved random ligation, degradation and autocatalytic replication reactions are shown in figure (a). Our idealised model demonstrates how autocatalysis in such a molecular ecology completely alters the qualitative and quantitative system dynamics in counter-intuitive ways. We demonstrate analytically that the system features a stationary state where the concentration of polymers does not decrease with length. Numerical simulations reveal a strong intrinsic selection mechanism that favours the appearance of few population structures with highly ordered sequence patterns when starting from a pool of monomers. An example of such a cooperative structure is shown in figure (b). This selection mechanism is due to symmetries in the underlying reaction network, and we discuss how these intrinsically selected species might be in line or in conflict with other prebiotic selection mechanisms. ■



◀ (a) The reaction scheme. (b) A typical reaction network."

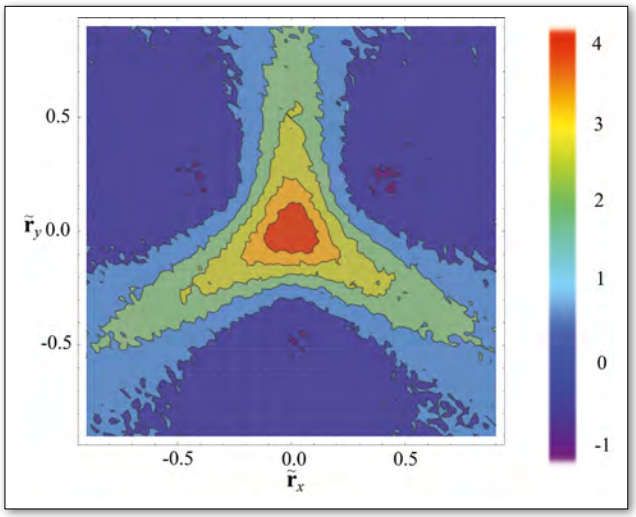
■ **S. Tanaka**, **H. Fellermann** and **S. Rasmussen**, 'Structure and selection in an autocatalytic binary polymer model', *EPL* **107**, 28004 (2014)

CONDENSED MATTER

Taking advantage of graphene defects

A new theoretical model of the effect of triangular defects in graphene provides numerical estimates of the resulting current rectification with potential applications in security screening.

Electronic transport in graphene contributes to its characteristics. Now, the author is proposing a new theoretical approach



▲ The scattering potential in real space calculated based on the Fourier image.

to describe graphene with defects—in the form of artificial triangular holes—resulting in the rectification of the electric current within the material. Specifically, the study provides an analytical and numerical theory of the so-called ratchet effect—which results in a direct current under the action of an oscillating electric field, due to the skew scattering of electronic carriers by coherently oriented defects in the material. Such theoretical studies of graphene with triangular defects could be used in the detection of terahertz radiation, which has applications in security screening detectors. These are based on the photogalvanic effect, which is the appearance of electric current as result of irradiation of a device or sample material by light. ■

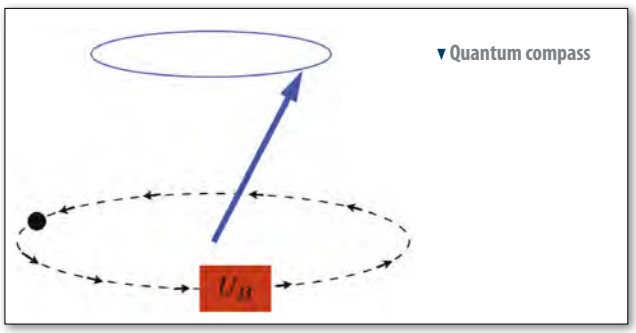
▮ **S.V. Koniakhin**,
'Ratchet effect in graphene with trigonal clusters', *Eur. Phys. J. B* **87**, 216 (2014)

MATHEMATICAL PHYSICS

Boundary dynamics driven entanglement

Quantum control in its many facets is a key notion in quantum information technologies.

Manipulating quantum states, preparing them according to given specifications, running quantum algorithms and eventually measuring certain observables are some of the main operations requested in almost all applications of quantum mechanics.



▼ Quantum compass

The quantum gates, or unitary operators, used to do these tasks can be manipulated by modifying the boundary conditions of the system. This has the advantage, over other quantum computation schemes, that no interaction with the bulk of the system is needed.

Mathematically, to address the problem of considering different boundary conditions is equivalent to address the problem of fixing different self-adjoint extensions of the corresponding symmetric operators describing the dynamics.

We study the space of self-adjoint extensions of bipartite systems and show that their space of self-adjoint extensions is much larger than the spaces of self-adjoint extensions of the separate parties. We exploit this difference to show how to generate entangled states from untentangled ones.

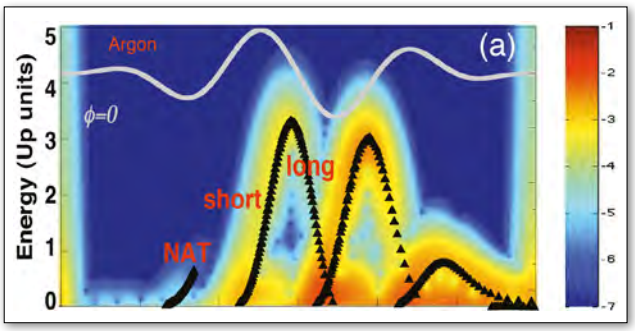
As an example we analyse the hybrid system consisting of a planar quantum rotor and a spin system under a wide class of boundary conditions. We call this bipartite system a quantum compass (see Figure). ■

▮ **A. Ibort**, **G. Marmo** and **J. M. Pérez-Pardo**,
'Boundary dynamics driven entanglement', *J. Phys. A: Math. Theor.* **47**, 385301 (2014)

BIOPHYSICS

Water window imaging opportunity

A new theoretical study elucidates mechanisms that could help in producing coherent radiations, and could ultimately help to achieve high-contrast images of biological samples.



▲ Time-frequency analysis of dipole acceleration extracted from the numerical simulations performed in argon, for three different regimes of laser intensity.

Ever heard of the water window? It consists of radiations in the 3.3 to 4.4 nanometre range, which are not absorbed by the water in biological tissues. New theoretical findings show that it is possible to develop coherent radiations within the water window. These could be the basis of an optimal technique to obtain a high-contrast image of the biological samples or to be used in high-precision spectroscopy. Now,

a new theoretical study identifies the physical mechanism needed to efficiently generate the harmonic radiations at high laser intensities that occur beyond the saturation threshold of atoms and molecules. These findings, aimed at improving conventional methods of coherent radiation production to reach the water window, were recently found by the authors. In previous similar work, studies focused on hydrogen as the atomic target. In the present work, the authors extend the study to argon atoms. ■

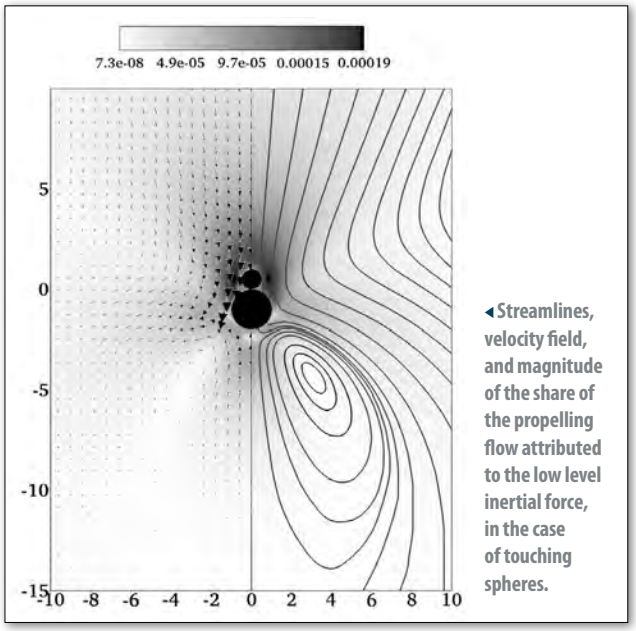
▮ **J.A. Pérez-Hernández**, **M.F. Ciappina**, **M. Lewenstein**, **A. Zaïr** and **L. Roso**,
'High-order harmonic generation at high laser intensities beyond the tunnel regime', *Eur. Phys. J. D* **68**, 195 (2014)

LIQUID PHYSICS

Nano-scale **inertial propellers**

A new study investigates the effects of small but finite inertia on the propulsion of micro and nano-scale swimming machines that could have implications for biomedical applications.

Scale plays a major role in locomotion. Swimming microorganisms, such as bacteria and spermatozoa, are subjected to relatively small inertial forces compared to the viscous forces exerted by the surrounding fluid. Such low-level inertia makes self-propulsion a major challenge. Now, the authors have found that the direction of propulsion made possible by such inertia is opposite to that induced by a viscoelastic fluid. This study could help optimise the design of self-propelled micro- and nanoscale artificial swimming machines to improve their mobility in medical applications.



◂ Streamlines, velocity field, and magnitude of the share of the propelling flow attributed to the low level inertial force, in the case of touching spheres.

The study shows that a rotating dumbbell propels with the large sphere due to inertial forces in the fluid and the small sphere ahead in a pure viscoelastic fluid. The authors then derive the optimal dumbbell geometry for a self-propelling small-scale swimmer. ■

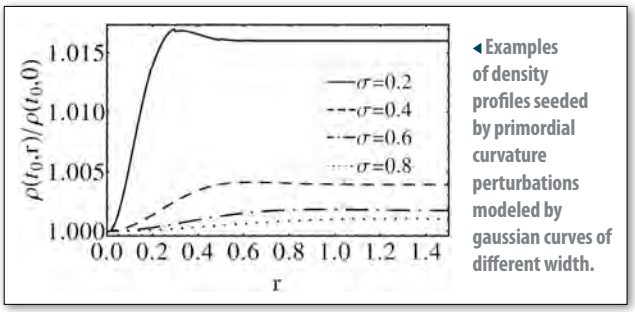
▮ **F. Nadal**, **O. S. Pak**, **L. Zhu**, **L. Brandt** and **E. Lauga**,
'Rotational propulsion enabled by inertia', *Eur. Phys. J. E* **37**, 60 (2014)

COSMOLOGY

Primordial curvature perturbations **and the cosmological constant**

The standard cosmological model is based on the assumption that the Universe is homogeneous and isotropic on a sufficiently large-scale.

Inflation can give a natural explanation to this large-scale homogeneity, through a sufficiently long period of exponential expansion of the Universe, but it also predicts the existence of perturbations of the metric, which are in good agreement with the observed anisotropy of the cosmic microwave background radiation or the large structure of the spatial distribution of galaxies.



◂ Examples of density profiles seeded by primordial curvature perturbations modeled by gaussian curves of different width.

This is the motivation to study the effects on the luminosity distance of a local inhomogeneity seeded by primordial curvature perturbations of the type predicted by the inflationary scenario. We find that a local underdensity originated from one, two or three standard deviations peaks of the primordial curvature perturbations field can induce corrections to the value of a cosmological constant of the order of 0.6%, 1%, 1.5%, respectively.

Our results can be considered an upper bound for the effect of the monopole component of the local non-linear structure which can arise from primordial curvature perturbations and requires a fully non-perturbative relativistic treatment. ■

▮ **A.E. Romano**, **S. Sanes Negrete**, **M. Sasaki** and **A.A. Starobinsky**,
'Non-perturbative effects of primordial curvature perturbations on the apparent value of a cosmological constant', *EPL* **106**, 69002 (2014)

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by Gianluca Alimonti
Teaches Fundamentals of Energy at the University of Milano and is a member of the EPS Energy Group

About "scientific consensus on climate change"

I'm writing this personal opinion about a "hot" topic: the Antropogenic Global Warming (AGW) consensus.

In EPN 44/6, John Cook presents the conclusions of a paper by himself *et al.*, published in *Environmental Research Letters* **8** (2013) doi:10.1088/1748-9326/8/2/024024, where almost 12000 abstracts of papers dealing with global warming, published since 1991, are classified depending on their position about AGW.

It is immediately clear from the abstract that two thirds of the analyzed papers do not express a position on AGW: this should be indicative of the scientific uncertainty on the issue. However, this figure is not taken into account and the authors focus on the remaining 33% of the papers.

Among these 33% papers, 97% support the AGW: papers stating that "humans are contributing to global warming without quantifying the contribution" are considered to support AGW. It is practically impossible to find a climate scientist against such a statement (it would be like saying that CO_2 is not a greenhouse gas), but this is well different from being in agreement with AGW, which – as Cook *et al.* remind us – means that "humans are contributing more than 50% of global warming, consistent with the 2007 IPCC statement that most of the global warming since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations".

Indeed, an analysis of the papers classified in the support category (which can be done by following the link "online supplementary data") shows that papers by famous climate scientists known to be against AGW (*e.g.*, Lindzen and Shaviv) fall among those in favour.

Trying to reduce the percentage of papers that do not express a position, Cook *et al.* contact the authors via e-mail: only 14% respond to such a query. At this point it would not make sense to proceed because the sample is drastically reduced and, more important, such a sample can no longer be considered "unbiased" (the analysis is based only on those who have decided to respond and it is reasonable to assume that this is a polarised sample).

J. Cook *et al.* proceed anyway and 35% of the authors, among the 14% who answered to such a query, confirm that they do not have definite position with respect to AGW: a rather high percentage to claim an almost complete consensus, as Cook *et al.* would like to do.

Finally, the reasons given by Cook *et al.* to find a justification to the high number of papers that do not take a position, show an internal logical contradiction: AGW would be such a scientific certainty that it is no longer needed to specify the authors' position in the abstract. Besides the fact that this assertion is contradicted by the 35% that confirms "no position", even if it were true, why is the research by Cook *et al.* based on such abstracts?

Given that the verification of the scientific hypothesis is not based on the level of consensus they get but on a tighter comparison with reality, all of the above has nothing to do with the consistency of AGW.

If any meaning may be given to the work about the AGW consensus, I would say it does not point to a unanimous consensus, rather to a scientifically still quite open issue, taking also into account that the percentage of papers that do not take a position grows with time. ■

John Cook responds

Gianluca Alimonti comments that because 67% of abstracts fail to state a position on anthropogenic global warming (AGW), this indicates scientific uncertainty. As discussed in Cook *et al.* (2013), this is explicitly not the case. To quantify the degree of scientific uncertainty, we re-examined 1000 of the "no position" papers and found only 5 expressed uncertainty on the issue. The relevance of "no position" papers was discussed by Naomi Oreskes in 2007. She predicted that as a consensus strengthened, less papers should see the need to restate the consensus position. For example, few astronomy papers state the consensus position that the Earth orbits the sun. Our data confirms Oreskes' prediction, with the proportion of "no position" abstracts increasing at the same time that the consensus among relevant climate abstracts increases. The significance of "no position" papers is discussed in our paper. Alimonti is correct about one point: verification of a scientific hypothesis is based on empirical confirmation, not consensus. However, the general public use expert opinion as a heuristic to guide their views on complicated scientific matters. As there is a large gap between perceived scientific agreement and the 97% reality, this necessitates communication of the overwhelming consensus. ■

SHOWERING FROM HIGH-ENERGY COSMIC RAYS

CAN BE MEASURED IN THE HIGH SCHOOL SCIENCE LAB

Henk Buisman – Leiden University – DOI: 10.1051/epn/2014501
Daniel Wilke de Souza – Trinitas College, Alkmaar
Jos Steijger – NIKHEF, Amsterdam

In particle physics a 'shower' is the avalanche of secondary particles produced by an incoming particle with high energy. This production requires the interaction with mass. A shower produced by high-energy cosmic rays usually covers a wide area, on the order of a square kilometer. The secondary particles can be observed by using scintillators. In view of the large area affected and the relatively simple equipment needed, this is an ideal project to involve high-school students and their teachers. Showering can also be observed indoors, on a much smaller scale.

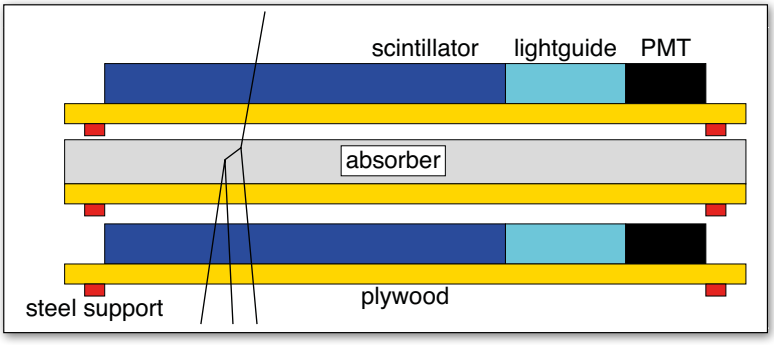
◂P.21: Simulation of an atmospheric air shower induced by a proton (E= 10^{15} eV). The shower starts high in the atmosphere at about 60 km. The shower evolves and wanes in the atmosphere, resulting in a footprint of about 10 km in diameter (simulation Arne de Laat, Nikhef).

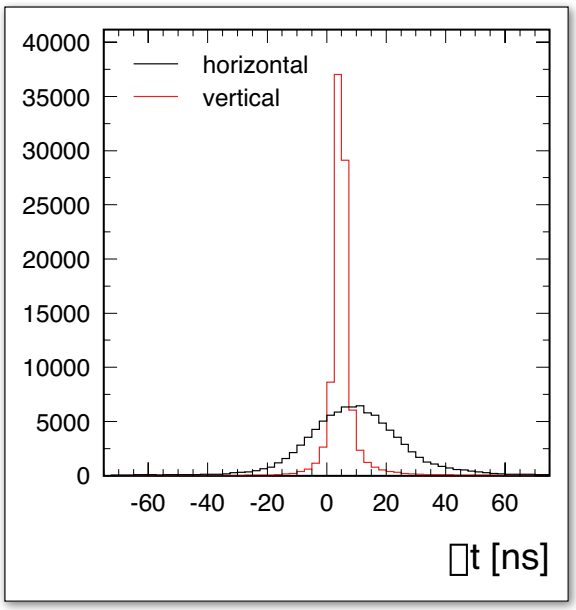
When a cosmic particle penetrates the atmosphere, its interaction with the atmospheric gas causes a so-called extensive air shower (EAS). If the energy of the particle is insufficient this shower quenches in the atmosphere. However, with sufficient energy (E >10^{14} eV) the shower can reach the earth's surface. Every square meter of the top of the atmosphere is struck by several dozens of such high-energy cosmic particles per year. Except for neutrinos, which are hard to detect and which are disregarded in this study, these particles are mainly protons (about 75%) and alpha particles (less than 25%). The rest is a small percentage of high-energy electrons, heavier nuclei and photons. The particles of the shower spread out over a surface of 10^4 – 10^7 m^2 when they reach the surface. Since a high-energy cosmic particle produces some 10^6 secondary particles, a detector of 1 m^2 at the surface of the earth is hit by about 0.1-1 particles from air showers every second. In view of the large area covered by a shower two detectors placed several meters apart can detect particles originating from the same shower. By observing coincidences of both detectors, signals originating from one shower can be distinguished from the background.

Types of showers

The strong interaction between penetrating particles (protons and α-particles) and the atmospheric gases creates large quantities of charged and neutral pions, plus the fast-moving debris of the projectile and the nucleus being struck. The average distance between two subsequent interactions of an incoming particle with the atmospheric gases is defined as the nuclear *interaction length*. In air this is 90.1 gr cm^{-2}, where gr stands for 10^{-3} kg (nuclear radiation length depends on mass, it is radiation length normalized to the density of the medium). The neutral pions decay almost instantaneously (lifetime 8.4 × 10^{-17} s) into two photons which start an electromagnetic shower. The charged pions have a larger lifetime (2.6 × 10^{-8} s). The distance that they can cover before decaying is much larger than the interaction length. Together with the fast debris of the primary interaction these particles are able to induce new interactions. The avalanche extinguishes when the energy per particle is insufficient to produce new particles. The chain of events described above is called *hadronic showering*.

▾FIG. 1: Schematic drawing of the set up. Two detectors are placed in vertical alignment with some spacing for absorber material in which showering can be induced. Both the detectors and the absorbing material are supported by plywood. A third detector is placed at several metres distance. This 'trigger detector' is used to identify Extensive Air Showers (EAS).





▴FIG. 2: Number of signals from the two detectors as a function of the time differences between the signals of two detectors. In black: time differences between two detectors that are positioned in a horizontal plane about 5 m apart. The width of the distribution is determined by the correlation between two particles in the same EAS. In red: time differences between two detectors placed in vertical alignment, separated by the absorber. The narrower distribution shows that the same particle is measured by the two detectors.

When a charged particle penetrates the electric field of an atomic nucleus a photon is emitted (*Bremsstrahlung*). If the energy of the photon is sufficient, pair production of an electron and a positron may occur. In this way the number of particles doubles with each step. This is called *electromagnetic showering*. The average distance between two such interactions is the radiation length (36.6 gr cm^{-2}).

An EAS starts off as a hadronic shower, but the high-energy photons that are produced in the hadronic shower gradually change it into an electromagnetic shower. Therefore, the particles that can be observed at the earth's surface are mainly produced by electromagnetic showers. This explains the composition of detectable particles at ground level: about 80% of the particles are photons, 20% are electrons or positrons, and about 1% are muons [1].

The experiment

To observe showering, we aim to show the production of new particles in an absorber. To this end, we used three scintillators of the type used in the High School Project on Astrophysics Research with Cosmics (HiSPARC, see Box). Two of these, the 'Trigger detectors', are placed several metres apart. The coincidence between events in these two detectors is an indicator of an EAS. Beneath one of these detectors (the 'upper detector') a third detector is installed (the 'lower detector'). Between upper and lower detector, sheets of various materials with varying thickness can be placed (Fig. 1). In this experiment we

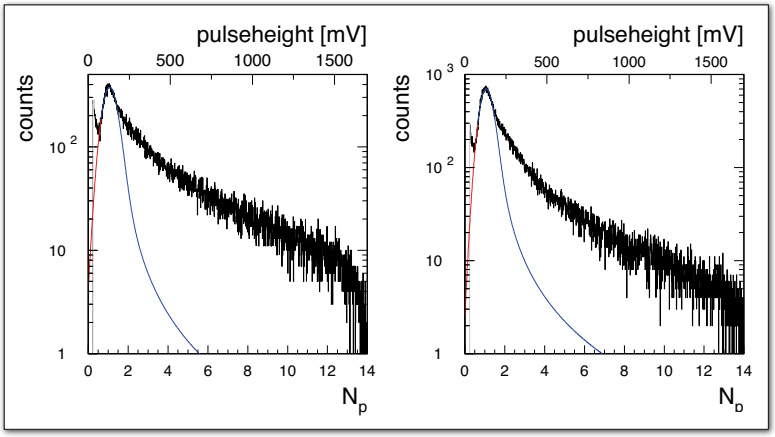
used sheets of aluminium, steel and lead. Table 1 lists the values of the radiation lengths (X_0) for these materials.

Material	X_0 [cm]
Aluminium	8.9
Steel	1.76
Lead	0.56
Plywood	56.8
BC408	42.5

◂ **TABLE 1:** Value of the radiation length for various materials [2]. The radiation length of plywood was calculated using equation (27.15) in [2]. BC408 is the scintillator material used in the detectors.

The time differences between two signals in detectors at several metres apart follow a normal distribution (Fig. 2) with standard deviation σ (= 14 ns). The time differences between two vertically aligned detectors are, of course, much smaller (σ = 2.2 ns). As described above, the time correlation between the two trigger detectors makes sure that the detectors see particles originating from the same shower. In the vertically aligned detectors either a particle is observed in both detectors, or extra particles that were created in the absorbing material are observed in the lower detector only. These signals originate from the same interaction, which results in a smaller standard deviation.

Figure 3 shows the pulse height spectra of the three detectors. The peak at $N_p = 1$ is identified with the signal caused by the passage of one charged particle. The shape of this peak is determined by the fluctuations in energy loss of this particle during its passage through the scintillator. These are described by a Landau distribution. This is a distribution in which a single parameter describes both the most probable value and the width. The resolution of the experiment is taken into account by taking the convolution of the Landau distribution with a normal distribution, where the standard deviation of the normal distribution equals the resolution of the experimental system. The result of this convolution is fitted to data near the peak. The fit yields an estimate of the horizontal scale of the spectrum in particles per event, as well as the energy resolution of the measurement.



▲ **FIG. 3:** Pulse height diagrams from events in the bottom detector. Left panel: with an absorber. In black: data as a function of pulse height (upper scale). In blue: the fit for one charged particle. In red: data without the contribution of gamma photons (at N_p <0.5). Extrapolation to zero charged particles is the result of the fit. The bottom scale indicates the pulse heights in units of Np, the number of charged particles that passes the scintillator. Right panel: same plot in absence of an absorber.

The peak at the onset of the spectrum ($N_p < 0.5$) is ascribed to photons. This part of the spectrum is replaced

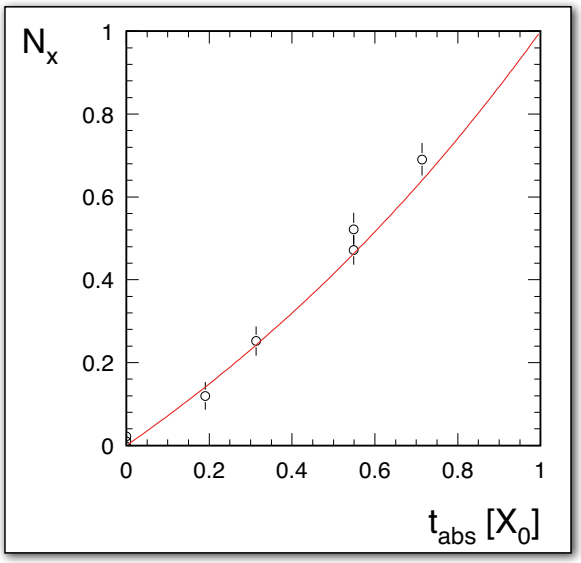
EDUCATION AND RESEARCH IN THE HISPARC PROJECT

HiSPARC (High School Project on Astrophysics Research with Cosmics) is an astrophysics experiment combining high-school education and scientific research. It consists of a physical network of more than a hundred detector stations, covering large parts of The Netherlands. Recently also several detectors in the UK have been installed. Most detectors have been built by high school students, and are installed on their schools (Fig. 5). Together these stations gather data on the interaction of high-energy cosmic particles with the atmosphere, with the aim to learn something about these cosmic particles. Many stations are equipped with a weather station, and a few have a lightning detector. The data of all stations are available for research to schools and scientific institutes.

The HiSPARC experiment achieves results in at least four fields:

1. The construction of detectors and the analysis of the data of this experiment gives pupils a taste of scientific research. After such an introduction many high-school students opt for HiSPARC for their final assignments.
2. For the pre-university level, a high-energy and particle physics course suitable for HiSPARC has been developed. This course can be used in the science and physics curricula.
3. In the 'Teachers in Research programme' (LIO) the Dutch Foundation for Fundamental Research on Matter (FOM) facilitates high school teachers to follow a research programme over the period of one year for one day per week in one of its institutes. Each year, HiSPARC offers five to ten research positions to teachers in this programme.
4. Finally, master and PhD students from various groups at Dutch universities use HiSPARC data for their research.

In the experiment described in this contribution we used a HiSPARC detector in an alternative configuration. We demonstrate the production of showers in matter in doors. It is a variation on the classical experiment by Rossi [4] in which he first demonstrated showering in 1933. This experiment is carried out in the context of the LIO-programme. With some minor changes though, this experiment could be performed or used as data-analysis project in high-schools. The data are available to high schools and the general public.



▸ **FIG. 4:** Average number of extra charged particles (Nx) in the detector under the absorber with respect to the detector above. The thickness of the absorber (t_{abs}) is expressed in radiation lengths (X_0). The red continuous line is a plot of equation 1.

by the extrapolation to zero charged particles as obtained by the fit. The average of this spectrum (without photons) between zero and fourteen particles is used as an estimate for the number of particles that passed the scintillator in each event. Figure 3 shows that the presence of an absorber increases this average for the lower detector.

Various absorbers

The space between the upper and lower detector (fig. 1) is filled with sheets of various absorber materials and of various thicknesses. With the available materials the thickness can be varied between 0.0 and 0.71 radiation lengths. The absorber may consist of several sheets of iron, lead or aluminium, but also sand or other construction material with sufficient mass may be used. The distance between the detectors should not be too large, such that the lower detector does not miss particles that passed through the upper detector.

Fig. 4 shows the average signal in the lower detector as a function of the thickness of the absorber. The extra number of charged particles seen by the lower detector is roughly proportional to the thickness of the absorber.

A simple model by Heitler [3] describes the shower as a sequence of splittings. After each radiation length the particles split into two with each secondary particle taking half the energy. This process continues until the individual particles have insufficient energy to create new ones. In a continuous version of this model the number of particles behind an absorber with thickness t is described by

$$N(t) = N(0)2^{t/X_0} - 1 \qquad (1)$$

with X_0 the nuclear radiation length. This curve is plotted in Fig. 4 as the red line, which gives a fair description of the data. ■

▾ **FIG. 5:** High school students installing a detector on a roof nearby their school.

Acknowledgements

The authors thank Bob van Eijk and David Fokkema for their constructive discussions.

About the authors

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HB an DWdS were associated with the Dutch Institute for Particle and High-Energy Physics 'Nikhef', Amsterdam through a research grant of the LIO program, in 2010-2011. The research described in this paper was done in this framework.

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CONSUMER PARTICIPATION IN POWER MARKET BALANCING

A REAL-LIFE STEP TOWARDS SMART GRIDS

Per Lund – DOI: 10.1051/epn/2014502
Chief engineer in System Development at Energinet.dk (the national Danish Transmission System Operator)

With the increasing role of wind and solar power, the power balance authorities are facing a big challenge: How to manage the increasing need for fast balancing power brought on by increased penetration of variable and difficult-to-forecast renewable generation? Could more active participation by the residential customers in managing electricity demand be a smart way to go?

This is what the EcoGrid EU field test is all about. The pilot project will introduce a market concept enabling customers to actively take part in the power market and to contribute to the power balancing. The field test is located on the Danish island of Bornholm. It involves 1,900 residential electricity consumers and up to 100 commercial customers, representing almost every tenth electricity consumer on the island.

All test households are equipped with advanced meters, collecting data about their consumption with five-minute resolution. Most of the participants or their electric appliances are "automated", *e.g.*, by various installed home automation systems and software solutions. These solutions enable participants to react to real-time price signals and adjust their electricity consumption based on their predefined comfort preferences. A manual control group of 500 participants can only respond manually to real-time price signals they receive on a dedicated web-based customer feedback system.

Integration with the Nordic electricity system

What makes Bornholm an interesting test case is that the local distribution system operator (DSO) for the island experiences actual wind power balancing challenges. On a windy day, the wind power on Bornholm can supply up to 30 MW, or more than half of the island's peak load of 55 MW. But the wind is unreliable, and this variability and unpredictability can have considerable impact on the grid's stability.

At present, cross-border interconnections provide most of the balancing of wind power generation in the Bornholm (and in the Nordic) electricity system. This is possible due to high flexibility in the Nordic hydro-based power system. There will be increased international competition for balancing capacity, and the cost of these resources is therefore expected to increase significantly.

Transition of power systems changes market conditions

Traditionally, the electricity grid has primarily been designed as a road for moving electricity in a one-way flow from large power generation plants to the customers.

Tomorrow's power system will include a variety of distributed and local energy resources as well as accommodate electric vehicles. This will require two-way flow of both electricity and information, as new technologies enable new forms of generation, supply and use.

Higher amounts of generation capacity from, *e.g.*, wind power requires a more dynamic electricity market, including mobilisation of many more resources that today are either passive or insufficiently integrated into the energy systems. This topic is addressed in the box *Modernisation of existing electricity markets*.

The EcoGrid ICT platform

The ICT system and software solutions supporting the EcoGrid real-time market concept do not start from scratch. The ICT architecture is either based on existing software solutions available on the market today, or has been tested in other field situations.

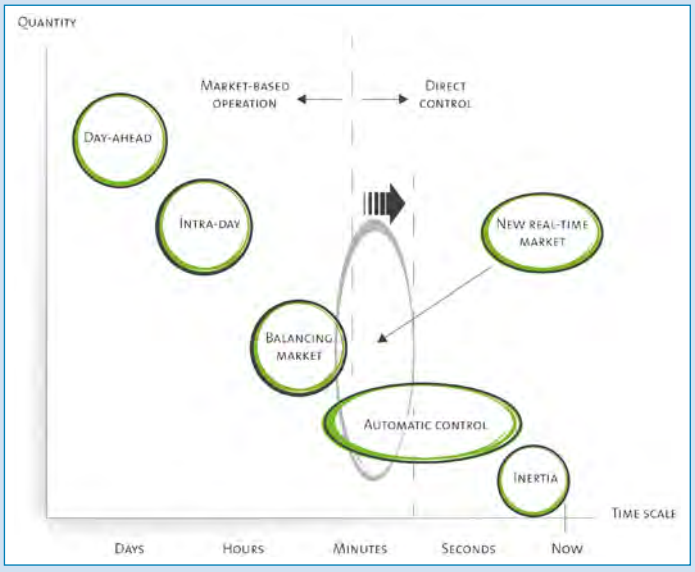
Fig. 3 shows the implementation and the key components of the ICT architecture for real-time price distribution in EcoGrid. Real-time electricity prices are generated at the price-generation module every five minutes.

The ICT implementation consists of a price-generation module and price-distribution components. The *price-generation* module takes input from i) the Transmission System Operator (TSO), ii) the electricity spot market, iii) historical metering data, and iv) weather forecasts. The generation module sends prices and price forecasts to the *price-distribution* system, which uses publish-subscribe technology to broadcast the real-time price information to the customers. The EcoGrid ICT concept describes a solution to combine publish-subscribe and so-called Internet Provider multicast technologies (a method for sending

MODERNISATION OF EXISTING ELECTRICITY MARKETS

In the existing power market, small-scale generation units and electricity consumers face considerable barriers to supply balancing services. For example, the market operation is currently based on an hourly time resolution that does not reflect the actual dynamics in the power system.

The EcoGrid project introduces a real-time market concept that is based on a 'bidless' market with price announcement beforehand ('*ex-ante*'). This implies that the final settlement price is determined by prediction of the real-time price responsiveness rather than on explicit bids as known from conventional auction-based power markets. A bidless market minimises the efforts (transaction costs) by small-scale electricity customers or small power generation units, because they must not create bids and schedules, but simply respond to the actual market prices. Small-scale electricity customers typically have the ability to ramp up or ramp down very fast, *e.g.*, by turning on/off their electrical appliances. This gives them the ability to participate in power markets with short time scales and high price volatility.



▲ **FIG. 1:** The new EcoGrid real-time market in the context of existing power-balancing markets and control systems. The five-minute real-time market will extend the market operation closer to real-time and potentially reduce the need for more expensive automatic control resources such as load-frequency control.

From the wholesale market perspective, the EcoGrid concepts imply that the power system is continuously monitored, and that a five-minute price signal is given by, for example, the transmission system operator (TSO) in order to restore the balance of the system. To do so, it is necessary to create reliable forecasts of the expected response to price changes. These will be utilised when computing the marginal price change required to trigger a response of the right size, leading to a proper rebalancing of the system.

As depicted in FIG. 1, introduction of a real-time market will be an obvious step in the further development of the existing electricity wholesale markets and balancing markets that creates more favourable conditions for the future composition of renewable generation and energy resources. This will not necessarily require a replacement of, but an extension of the current market set-up.

Internet Protocol datagrams to a group of interested receivers in a single transmission). This functionality is required for scaling the ICT system up for nationwide use.

Different *Internet Service Providers* (ISPs) of an area subscribe to the relevant price signals. Within the ISP domains, relevant price streams are multi-casted. This means that the solution can be scaled up, and in case of a massive deployment of the real-time market concept system across the EU member states, it could accommodate millions of residential electricity customers.

Smart devices or end-nodes adjust their planned consumption according to the price information. All households are connected to a smart electricity meter, which measures the power consumption of the device(s) every five minutes. The *measured power consumption data* are uploaded to the historical metering data repository every 10 minutes.

Vendor-independent solutions

EcoGrid uses different smart home solutions and different ICT control technologies. This allows for competition and freedom of choice in the hardware and software components. The challenge is of course to prove the 'smart-grid-ness' of these solutions, ensuring that the meters and the equipment installed offer interoperability with the communication technology and software solutions 'behind-the-meter'.

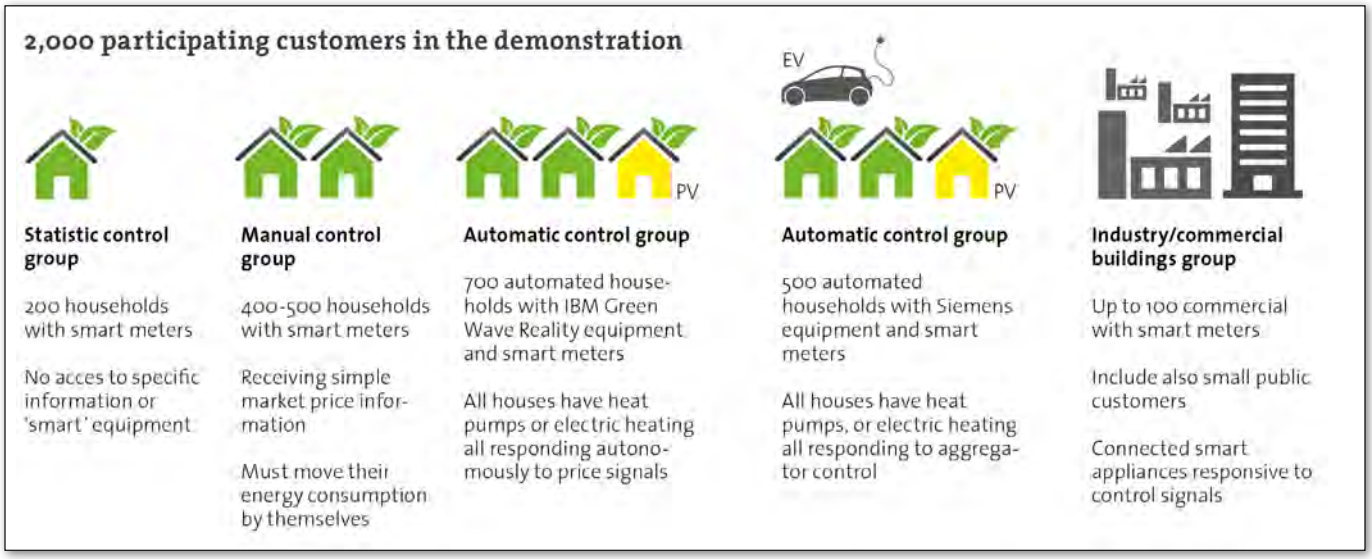
In view of rolling out a smart grid solution, standardisation of the communication and interfaces of the smart home devices need to be taken into account. Another important aspect is the security throughout the system and the use of existing standards for security as well as measures regarding privacy. Based on the demonstration experiences, the industry partners in EcoGrid will provide a framework for standards in communication and device descriptions, so an interoperable system can be assembled.

Recruitment of residential test households

Before the official recruitment to the EcoGrid field test started, activities were implemented to raise the general awareness of EcoGrid among the public on Bornholm. The target group for the first recruitment activities was the group of (potential) 'first movers' who were informed through media via press releases, invitation to visit Villa Smart (a show room for smart grid solutions on Bornholm). The key message was: "Participate in EcoGrid and make a difference – put Bornholm on the world map ….".

Recruitment of the last participants (involvement of the 'main-stream' group) was challenging. Intensive information campaigns and direct mails were required and more attention was given to the economic benefits of EcoGrid participation.

The recruitment process is considered a success. By August 2013, the objective of 1,900 test households was almost completed.



▲ **FIG. 2:** Different participating customer groups.

Consumer engagement and involvement

The establishment of Villa Smart – an EcoGrid showroom/house in Roenne city on Bornholm gives EcoGrid participants the opportunity to experience the technologies that may be installed in their houses to control part of their appliances. At the demonstration house *Villa Smart*, participants are invited to educational sessions where Oestkraft, the local DSO on Bornholm, offers EcoGrid project-specific advice/education on their participation related to the smart appliances and their customer feedback systems (developed in the EcoGrid project). The *website* www.ecogridbornholm.dk contains project news stories, FAQ, user guides, EcoGrid videos *etc.* The international audience can find information at www.eu-ecogrid.net.

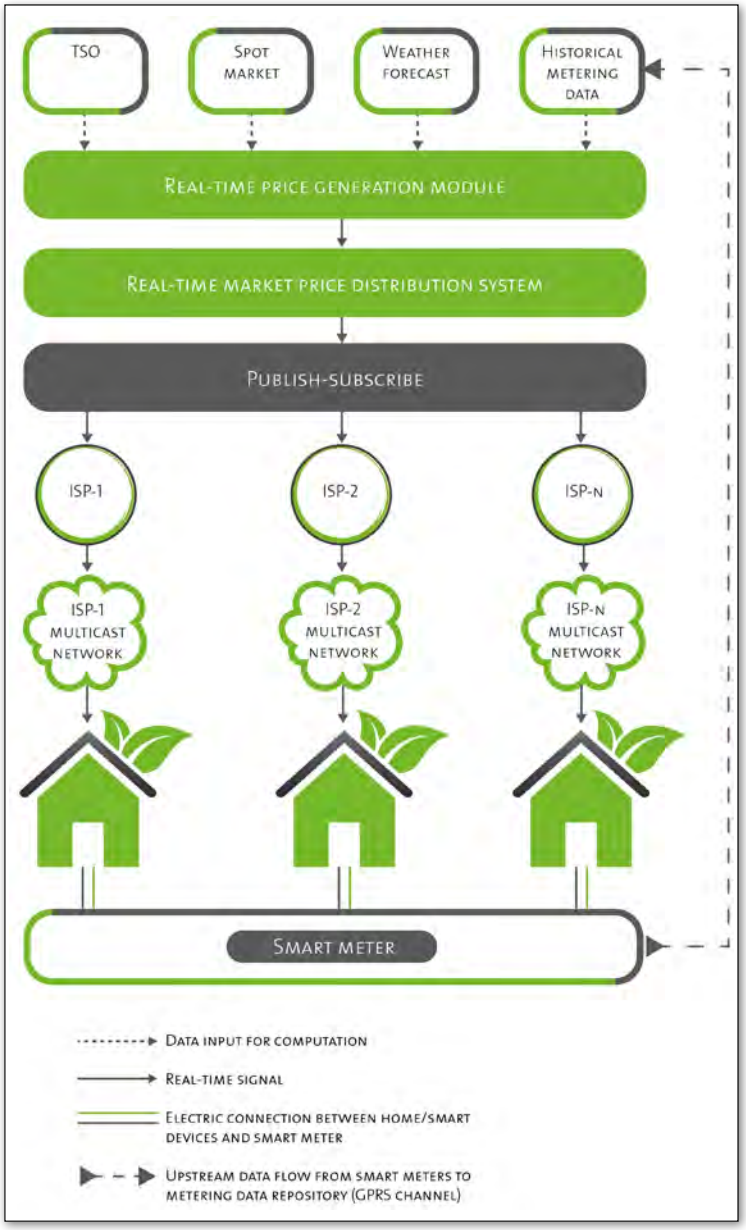
The test participants (except for the statistical control group) are introduced to the customer feedback system called 'My EcoGrid'. At 'My EcoGrid', the participants can find information about current prices and prognosis for the coming hours. Once every month the participant can find a report informing them of their performance for the past month at 'My EcoGrid', where the EcoGrid cost is compared to the cost of a non-smart grid product.

Last but not least, some of the persons closest to the EcoGrid test participants are the electricians installing the Smart Home equipment in households. It typically takes from one to three hours to install the solutions and make it fit the consumer's wishes – and this is the situation where the customers probably receive the best individual advices.

'Smartness' from the perspective of the individual customer

The demonstration of EcoGrid takes place in an innovative phase of smart grid – where the attitudes towards smart grid in general are enthusiastic and positive. This period is sometimes referred to as the 'trigger' phase of

▼ **FIG. 3:** The EcoGrid ICT architecture for price distribution. TSO is the transmission system operator and ISPs are internet service providers.



the smart grid. This is a phase that can easily generate attitudes of disillusionment, if the customers do not gain the positive outcome they were expecting.

The smart grid innovations in the EcoGrid project will be 'invisible' for most people. However, what is visible for the test participants is the EcoHome equipment, raising questions like: how does the equipment work and how appealing does it look?

In our experience, you will not only find enthusiasts, first movers or early adopters of new technology/smart grid solutions in a field test involving every tenth residential household on Bornholm. The challenging part in the next test phase (2014-2015) will be to maintain participant involvement.

Will the EcoGrid participants respond to real-time price signals?

At the time of writing this paper, the EcoGrid project was in a phase with intensive testing and tuning of all the different installed hardware (HW) and software (SW). The different project partners supplying equipment and ICT solutions have to test and tune each of their individual HW/SW parts. Full end-to-end tests of the entire demonstration set-up have to be performed in order to find and remove errors and bugs and to fine-tune for optimal price-elasticity. This is especially the case for the completely novel ICT solutions developed for the project. This is a demanding phase of the project as it involves all server-based and in-house installed SW parts and of course all HW installations in all participating houses. This is also a most critical phase of the project as the resulting level of achievable price-elasticity will be governing the resulting EcoGrid demonstration results.

During the test and tuning phase, a number of intermediate results were recorded. FIG. 4 shows the normalised price-elasticity (red curve) obtained from a group of 140 Siemens-automated houses when subjected to the shown test-price-signal. The black curve shows the simultaneous normalised base-case results from 160 non-automated houses for comparison. The grey area is the 95% confidence interval of the automated houses if they behaved as the non-automated, *i.e.*, to show true statistical price-elasticity the red curve should be outside the grey area. Hence there were still room for tuning and optimisation.

The test and tuning phase of the EcoGrid project was finalised by mid April 2014. During the summer of 2014, the real-time price generation module of FIG. 3 is to be programmed and implemented in the overall ICT server solution. All necessary closed-loop testing will be conducted and all systems will then be ready for the final EcoGrid demonstration phase to be conducted during the heating season of October 2014 through March 2015. ■

About the Author

Per Lund is Chief engineer in System Development, Energinet.dk (the national Danish Transmission System Operator). He is a Senior member of IEEE (Institute of Electrical and Electronics Engineers) and a certified European engineer in FEANI EUR ING (Federation of Professional Engineers).

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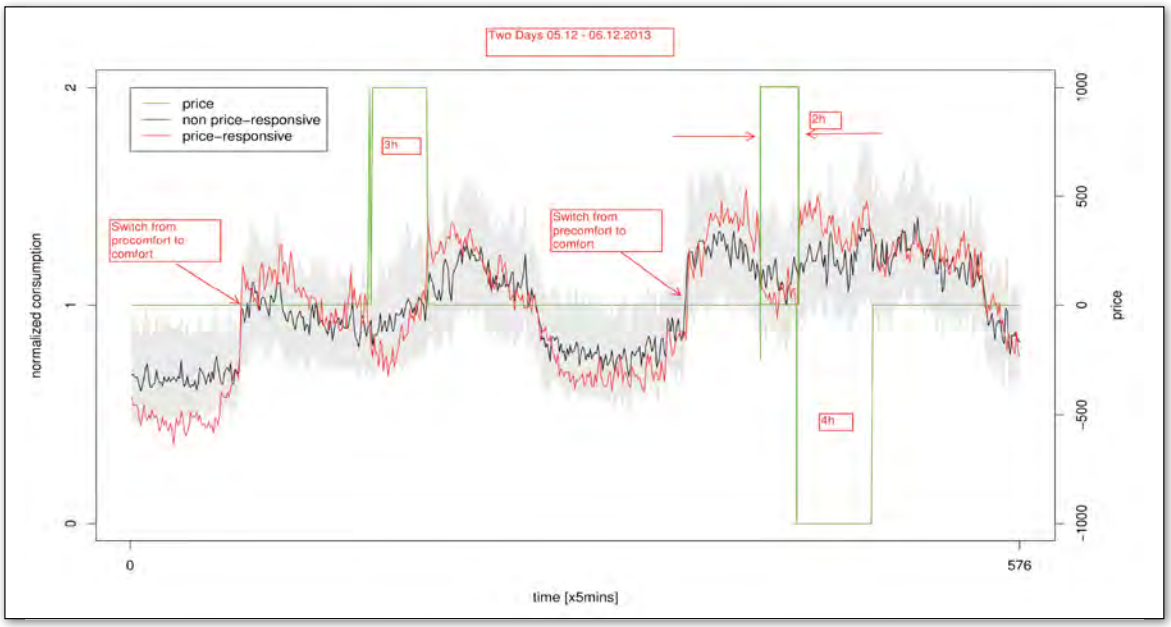

▸ **FIG. 4:** Early indications of price-elasticity of 140 automated Siemens houses. The red curve shows a distinct response to a price increase or decrease. The price at the right scale is an extremely large test price in DKK used during the test and tuning phase of the project.

by R.J. de Meijer [1,2] and W. van Westrenen [3]
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The Moon's formation revisited

The falsification of a hypothesis and its replacement by a new testable hypothesis are part of progress in science. With respect to the formation of the Moon the classic Giant Impact Hypothesis (GIH) as described in the recent article by Geiss, Huber and Rossi, *Europhysics News* **45/4**, 25-30, was developed when other hypotheses had to be discarded after the first analyses of the composition of lunar rocks, returned to Earth in the Apollo missions. The GIH appeared to explain the first-order physical and chemical features of the Earth-Moon system, including its angular momentum and the depletion of iron in the Moon compared to the Earth. The GIH was not seriously challenged for over thirty years since its inception in the mid-1970s [1].

However, over the past decade, increasingly large cracks have appeared in the armour of the GIH. More precise analytical techniques have revealed an astonishing similarity in both the elemental and isotopic composition between lunar rocks and the Earth's silicate (rocky) crust and mantle. Similarities encompass major elements including silicon and titanium [2] as well as trace elements including neodymium and tungsten [3]. Such similarity is irreconcilable with smooth-particle hydrodynamic computer simulations of the classic giant impact of a Mars-sized planet into the young Earth, because those all predict that the Moon should consist predominantly of impactor material rather than of terrestrial material [4]. Several attempts have been made to fix this fundamental problem with the GIH. One suite of models has investigated whether lunar and terrestrial mantle material can be completely homogenised elementally and isotopically after the giant impact. The answer appears to be: not for all elements that show the uncanny Earth-Moon resemblance, and not for all of the silicate Earth and the Moon [5]. Collisional parameter space for giant impact models has also been stretched to try and fit the compositional similarities [6]. Impacts in which the impactor is either significantly smaller than Mars or as large as the Earth itself lead to predicted lunar compositions which are closer to that of the silicate Earth, more consistent with observations. But such impacts only work if they are accompanied by Earth-Moon system angular momenta that are significantly larger (by about a factor of 3) than today's values. Such momenta are actually very close to the limit of rotational stability for the Earth. The main advantage of impacts accompanied by very high angular momenta is that they would release material predominantly from the proto-Earth rather than the impactor. But the disadvantage is that the high angular momentum and energy have to be syphoned off after the giant impact by a resonance involving Earth, Moon and Sun. At present it is unclear whether this mechanism can be invoked to remove the large amount of excess angular momentum that accompanies these alternative giant impact models.

Both measurements of lunar rock compositions and hydrodynamic models agree that the classic GIH, involving a Mars-sized impactor and a constant angular momentum, must be rejected. As summarised above, new impact-based hypotheses have been developed, but these require additional assumptions and a process to remove large amounts of angular momentum. Some alternative hypotheses that do not start with the premise that a giant impact caused the formation of the Moon have also been proposed. We developed a hypothesis in which the Moon is formed of terrestrial material at an angular momentum close to the present value. Our hypothesis [7] is based on the concentration of fissile material concentrated in the Core-Mantle Boundary (CMB) of the Earth by a mineral called calcium silicate perovskite. By natural concentration the fissile material gets concentrated and spontaneously leads to georeactors [8]. Triggered by a small impact or by natural concentration processes, concentration of fissile material in the georeactor causes the reactor to become supercritical leading to a nuclear explosion. This explosion produces a shock wave propagating towards the surface where it ejects iron-poor silicate material into space, from which the Moon eventually forms. The shock wave emission does not disturb the isotopic and elemental composition of terrestrial silicate rock material. The presence of georeactors has been shown to be feasible and simulations indicate that such a shock wave emission is realistic [8]. At present our hypothesis is at least as consistent with observations as the latest impact-based hypotheses.

At the moment, instead of being a done and dusted deal, the formation of our Moon remains shrouded in mystery. One reason for this may be that our present knowledge of the composition of the Moon is mainly based on the analysis of some of the 380 kg of samples collected at the Moon's surface from a small area on its near side. Future lunar missions that could bring more material

especially from the lunar far side and originating at great depths in the Moon may yield a more complete picture of the composition of the Moon. Their analysis will yield more insight in the formation of our celestial companion. ■

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The authors respond

by J. Geiss, M.C.E. Huber, A.P. Rossi

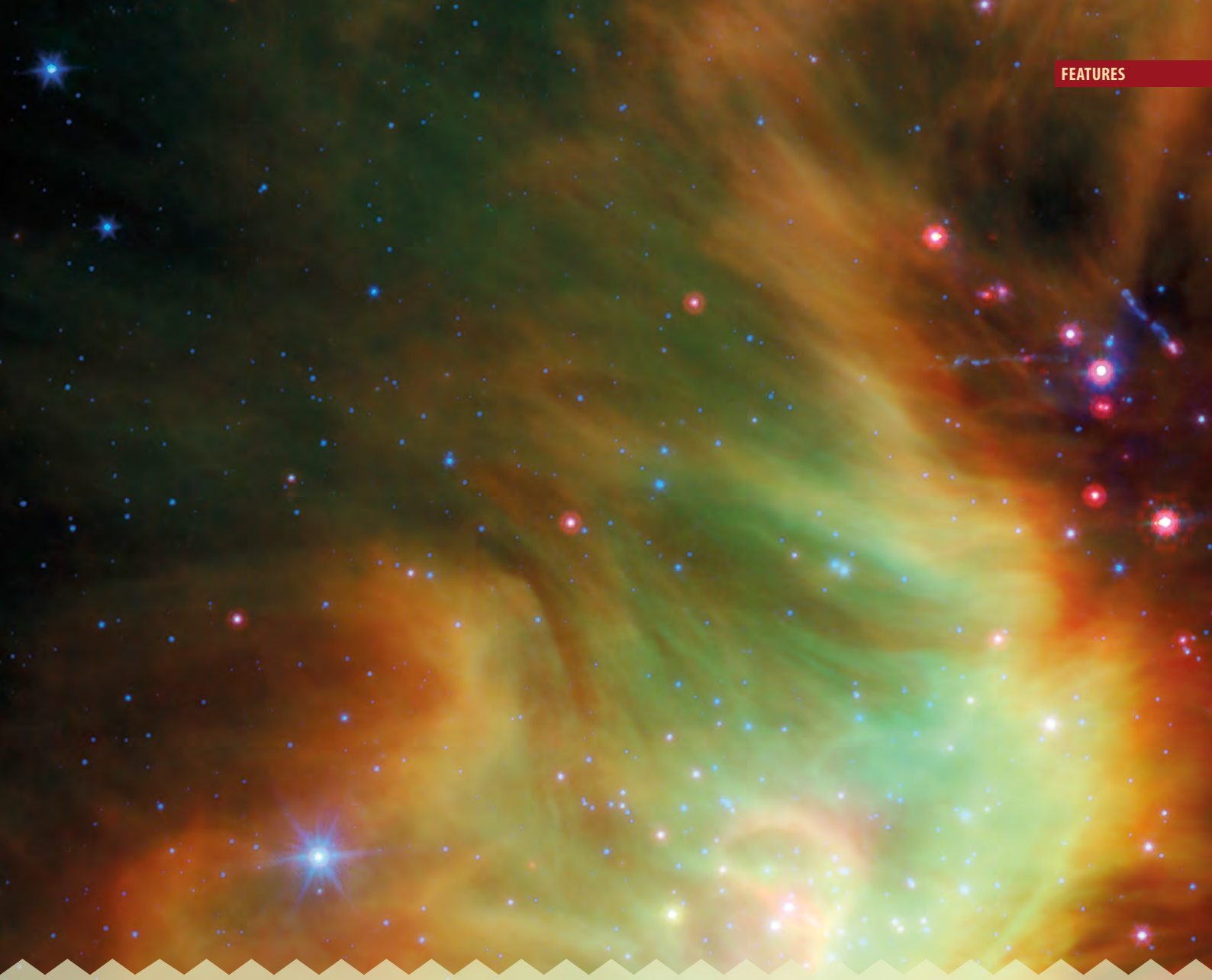
We wrote our Feature to highlight the importance of lunar research for understanding the evolution of the Solar System as a whole, and not to critically assess hypotheses on the Moon's origin. Hence our premise "… a collision of the Earth with another planet – the Giant Impact – is the most widely accepted theory for the origin of the Moon."

However, given new experimental evidence, which permits a firm differentiation between giant-impact and geo-reactor hypotheses of lunar origin, we may now directly address the issue of falsification of models raised by the authors of the above text.

Solar-System bodies are heterogeneous in their isotope composition. So, if the Moon stems from a *collision* between Earth and another body, then Moon and Earth should have retained isotopic signatures of the two original bodies. If Earth and Moon have a *common origin*, such as a Moon arising from an Earth-bound explosion, one would expect them to have identical isotopic signatures.

While our EPN article was in press, Herwartz *et al.* (2014, *Science* **344**, 1146-1150) published compelling evidence that lunar rocks contain not only matter from the Earth: Herwartz *et al.* found a distinct isotopic difference between Moon and Earth. Comparing their results with predictions of model calculations they concluded: "our triple oxygen isotope data … supports the giant-impact hypothesis of Moon formation."

On the other hand, a hypothesis like the one promoted in the Letter to the Editor, which critically depends on a nuclear explosion in the Earth's interior, needs to explain the now established difference in the triple oxygen isotope composition between Earth and Moon, while being constrained by other observations. ■



EXTRA-TERRESTRIAL LIFE

IN THE MILKY WAY GALAXY?

Neal J. Evans II – University of Texas at Austin – DOI: 10.1051/epn/2014503

Are we alone? Along with questions about black holes, this is one of the questions most commonly asked of astrophysicists. While the simple answer is that we don't know, logical and rational exploration of the question can be illuminating and a very good way to introduce non-scientists to the "scientific worldview." This short essay is based on a class for students not majoring in science, which I have taught for nearly forty years at the University of Texas at Austin.

◂ P.33: Stars are forming near the eastern rim of the molecular cloud in the direction of the Perseus constellation, as seen in this infrared image from NASA's Spitzer Space Telescope. The young stars are approximately three million years old and are shown as reddish-pink dots to the right of the image.

The basis for the class is the Drake Equation, proposed by Frank Drake over 50 years ago. While one can formulate more elaborate versions, the simple form he proposed is sufficient for our purposes (see Box).

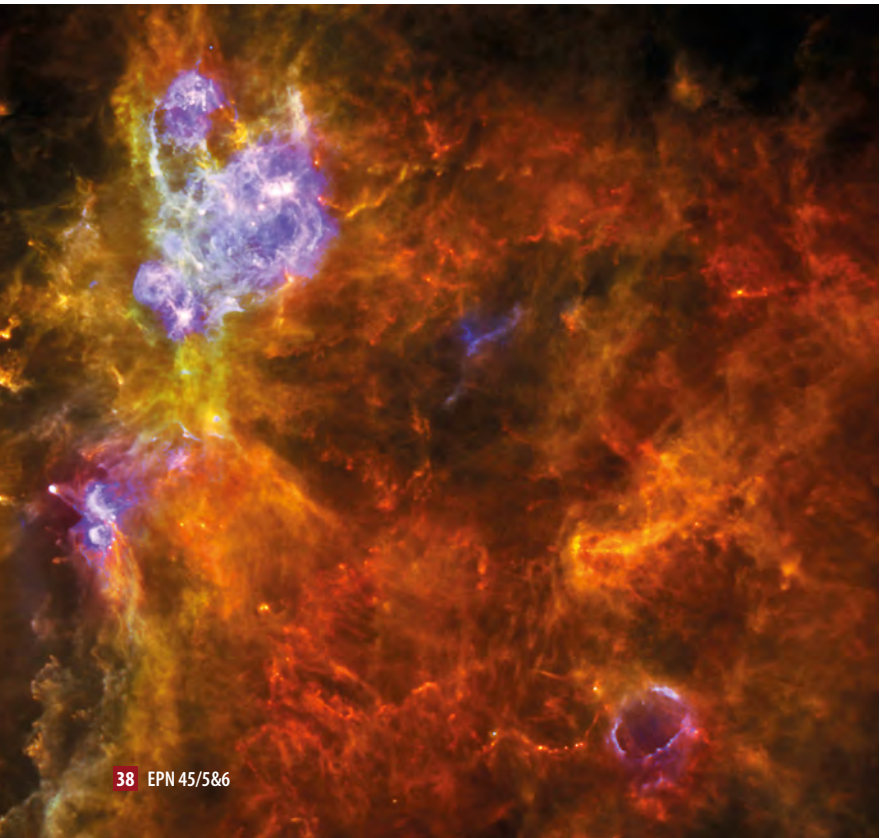
A few preliminary considerations are needed before we proceed through the factors. First, we restrict consideration to our own Milky Way galaxy simply because the light travel time for a communication from even the nearest other galaxy is millions of years. Second, we focus on communication because it is much cheaper and faster than travel; the energy required to send a single electron at v = 0.1 c is about 10^9 times the energy cost for a single photon at a frequency of 1 GHz.

The first factor, R_*, is reasonably well known. Models of the Galaxy that include dark matter and gas yield a total mass of stars of about 8×10^{10} solar masses. With an average mass of stars of 0.5 solar masses, this implies about 1.6×10^{11} stars. The age of the Galaxy is about 10^{10} years, so the average star formation rate is 16 stars per year. Star formation has slowed down in the Galaxy (as in most similar types of galaxies), and the current rate is about 4 stars per year (Fig. 1). One might consider a number between 4 and 20 stars per year.

Over 1000 planets

The next factor, f_p, was in principle completely unknown when I started teaching the class, but beginning in the mid-90s, we have discovered a large number of planets around other stars. As of June 2014, the count is 1795 planets in 1114 planetary systems. Because the methods used to find planets are strongly biased towards systems with special characteristics, large corrections for incompleteness are needed, and these suggest that at least half of all stars have planetary systems. A high value for f_p is also supported by observations of young stars, showing that rotating, circumstellar disks of gas and dust are nearly ubiquitous around the youngest stars and that half of stars retain signatures of these disks for 2 to 3 million years. Some considerably older systems show dust emission signatures, thought to be due to collisions between planetesimals that regenerate some small particles as debris. All in all, the evidence that planet formation is a common feature of star formation supports the extrapolation from the known number of planets to a value of $f_p > 0.5$.

▾ FIG. 1: Far-infrared emission from a molecular cloud, as observed with the Herschel observatory. The colours represent emission in three wavelength bands centered on 70, 160, and 250 micrometres. This region hosts a large number of forming stars. Figure is from Rivera-Ingraham *et al.*, *Astrophys. J.* **766**, 85 (2013). Copyright AAS.



Earth-like planets

There is currently intense focus on the next factor, n_e. The subscript "e" for Earth-like reflects the Earth bias usually included in this factor. Very generally, life needs a solvent, and all known life uses liquid water, and the liquid state is extremely rare in the Universe as a whole. The usual considerations assume surface water on a planet with temperature set by stellar heating balanced by thermal radiation from the planet. That leads to a range of distances from a star, called the habitable zone. Stars less massive than the Sun (the great majority of stars) are less luminous, so the habitable zone is closer to the star, and its location is more constant over long periods. Most current planet searching techniques work better for close orbits around small stars, so searches for habitable planets will probably favour lower mass stars in the near future. At present about a dozen possibly habitable planets are known, but the selection effects are strongly against small planets, so huge extrapolations are used to estimate that n_e is substantial, with most estimates from 0.5 to 1.

Considerations of habitability are very complex [1]; two complications are worth mentioning. First, about half of stellar systems are binaries or higher multiples. If the stellar separation is near what would otherwise be the habitable zone, planets are likely to be ejected and may not even form in the first place. About half of binaries may have such a problem, decreasing n_e. On the other hand, greenhouse effects can greatly affect the temperature of a planet, and different planet atmospheres can allow habitable planets closer (relatively dry atmosphere) or much farther (hydrogen-rich atmosphere) from the star than calculated with simple assumptions[2]. Finally, habitable zones may be extended by considerations of sub-surface water kept liquid by internal heat (*e.g.*, Europa and some other moons of giant planets) and other solvents (*e.g.*, Titan with methane lakes).

Life

Now we move into much less certain territory in thinking about f_l. While it is generally accepted by scientists that life began on Earth through a gradual increase in complexity from simple molecules to the ability to metabolize and replicate, there is no completely satisfactory

▲ **FIG. 2:** Currently living stromatolites in Australia. These are microbial mats of cyanobacteria, anaerobic organisms whose waste product of oxygen made more complex life possible. The oldest certain evidence of life is a fossilized stromatolite about 3.5 billion years old.

theory for how this happened. Even if a convincing model for the origin of life on Earth eventually emerges, it will be difficult to extrapolate to other planets to compute f_l. However, if clear evidence can be found for extraterrestrial life anywhere, we could at least be sure that f_l is not vanishingly small. Consequently, it is tempting to search for signs of life outside the Earth. The most obvious target is Mars. Although searches for microbial life by the Viking landers in the 1970s turned up no convincing evidence, we now know that any life (or molecular fossils of early, but now extinct life) would need to be buried under about a metre of soil to avoid degradation by highly reactive molecules on the surface. A series of increasingly sophisticated probes have found strong evidence for sub-surface water. A probe using newer techniques to search for past of current life in samples excavated from deeper soil levels could be sent within a decade [3]. To ensure that any life on Mars arose independently, terrestrial contamination must be convincingly disproved. Missions to penetrate the ice and search for life in the sub-surface oceans of Europa have been considered, but they are more challenging.

To extend the search for life beyond our solar system, we could search for biomarkers in the atmospheres of planets around other stars. The oxygen in the Earth's atmosphere arose from photosynthetic activities by past life, and the current co-existence of oxygen and methane is considered a sign of current life. Studies of atmospheres of planets that transit (pass in front of) their stars have begun, but atmospheric studies of smaller, Earth-like planets are extremely challenging and will require a new generation of telescopes and instruments. At this point, possible values for f_l range from very small (*e.g.*, 10^{-9}) to unity.

Intelligence

Moving on to f_i leads us into evolutionary biology, where once again, we have only our terrestrial experience to guide us. The facts are fairly clear. Life arose between 3 and 4 billion years ago and remained strictly prokaryotic, unicellular life ('microbial' for short) for most of Earth's history (Fig. 2). Multicellular, differentiated life appears between 500 and 600 million years ago and diversified in the Cambrian explosion beginning around 543 million years ago. Most of today's phyla, including ours (Chordata) trace to that period.

An interesting feature is that the timescale to evolve human level intelligence through biological evolution (5×10^9 years) is comparable to the timescale for stellar evolution. If our evolution to intelligence has been twice as fast as on other planets, no other planets with life would have developed complex life. The likely cause of the long period was the need for microbial photosynthesis to produce an oxygen-rich atmosphere. A still more fundamental question is whether intelligent life with the characteristics needed for the next stage (technology) is a likely outcome on another planet. A diverse and changing environment is often invoked to select for intelligence, and it may have played a role in the evolution of Homo sapiens from a diverse array of hominids over the last few million years.

As with f_l, evidence for intelligent life on another planet would provide some constraints on f_i. Unfortunately, prospects for doing this are slim. Complex, non-technological life does not seem to produce any obvious atmospheric biomarkers.

Communication capability

Now we come to f_c, which assumes we have human level intelligence and is the fraction of planets with that level of intelligence that become "communicable." Since tool use is essential, purely aquatic planets that might have dolphin or whale intelligence probably need to be rejected at this point. While no such water worlds exist in our solar system, there is evidence for some around other stars. As long as we focus on stone-age or metal-age technology, we have several independent "experiments" on Earth. While cultural diffusion confuses the issue for the Africa-Eurasia land-mass, the Americas and Australia/New Guinea provide reasonably isolated cultures. The basis for all technological cultures is the development of agriculture, which allowed settled lifestyles, surpluses, and specialization of roles. It also triggered written language (for business records and taxes), metal extraction from ores, and observational astronomy for calendrical purposes. All these appear to have developed independently at least several times, providing some evidence that f_c is not very small. Of course, no evidence exists for independent origins of higher technology because of the rapid diffusion of such technology around the world.

To engage in interstellar communication, a society must understand the nature of the Universe. For almost all of "Western" intellectual history, the Universe was conceived as geocentric and stars were assumed to be different from the Sun. While this was less true in some other cultures, none developed a correct world-view until the chain of events known as the Copernican Revolution proceeded to a reasonably correct understanding of the Milky Way in the early 20th century. The connections between evolving worldview and technology are intriguing. The telescope played a major role in worldview evolution, while the Galilean and Newtonian revolution in physics was stimulated in part by trying to understand the cosmos. One can argue that technology and worldview (capability and interest in the Drake equation) are coupled, but one can perhaps imagine advanced civilizations on cloudy planets with incorrect worldviews.

The timescale for technology to develop is negligible compared to that for biological evolution. Advanced technological civilizations may produce planet-wide signatures. Ours has introduced novel chemicals, such as CFCs, into the atmosphere, for example. On one of the passages near Earth of the Galileo spacecraft as it was being boosted for its journey to Jupiter in 1990, its instruments were pointed at the Earth. Even with a resolution of 1 km, the cameras found no clear indications of technological civilization; in contrast the radio emission from the Earth provided unambiguous evidence of advanced technology[4]. While no existing radio telescopes on Earth could detect current levels of this "leakage radiation" from extrasolar planets, it would not be prohibitively expensive to build such a telescope. However, the transition to fiber and digital transmission may mean that "radio-loud" planets are short-lived.

Lifetime of Civilizations

Once a communicable civilization arises on a planet, how long does it last? On this question, even our one example that we have used for the previous three factors fails us; we are still here! Technically speaking, a civilization needs only to lose interest in communicating to limit L,

▼ FIG. 3: Communication with extraterrestrial advanced civilisations is usually assumed to use radio wavelengths. Radio telescopes can be quite large as their requirements on surface accuracy are much lower than for telescopes operating at visible wavelengths. This telescope at the Dwingeloo Radio Observatory is 25 metres in diameter. After retirement from active astronomy use, it has become a Dutch industrial heritage monument. It has been refurbished by volunteers and there is some discussion about using it to search for signals from extraterrestrial civilisations.

but it is more interesting to consider what might end the civilization altogether. We can divide the threats to our civilization to human-caused and natural threats. The human-driven threats all arise from the nature of technological civilizations, broadly conceived. Agriculture allows population growth, which leads to resource depletion and pollution. The main resource depletion issue is energy, actually low-entropy sources of energy. While the timescale for fossil fuel depletion is uncertain and contentious, it is probably measured in centuries, after which time, solar energy in various forms provides the only truly long-term source, with nuclear as an important bridging technology. Burning fossil fuels of course increases the greenhouse effect, which may provide some brake on fossil fuel use, but not enough to extend the reserves very much longer. The most apocalyptic possibility is all-out nuclear war, with arsenals like those of the US and USSR during the height of the cold war. Such an exchange could lead to "nuclear winter," causing crop failures and famine. Any survivors might well be disinclined toward, or incapable of, redeveloping such technology. It seems likely that either civilization will collapse or that a new, long-term worldview will emerge within centuries to millennia.

The most immediate natural threat is impact by asteroids or comets, as the recent Siberian incident has reminded us. There are dedicated efforts to find and catalog Near Earth Objects; with sufficient notice, we could modify the orbits of dangerous asteroids. Large objects, like the asteroid that may have finished the extinction of dinosaurs, have timescales of about 10^8 years. The only truly certain natural threat is the evolution of our Sun. While the main sequence of a star is relatively stable, the star increases slowly in luminosity. In about 1 billion years, the rising luminosity will cause the loss of our oceans. In about 5 billion years, when the Sun becomes a red giant, the Earth is likely to spiral into the Sun. The only escape will be to send some people to a habitable planet around another star. Possible values for L range from decades to 5 $\times$ 10^9 years. A few long-lived civilizations will completely dominate the average lifetime. This logic indicates that the civilizations we might communicate with are very likely to be much older and presumably more advanced. (The latter presumption depends on an assumption of continued progress, which is debatable.) The fact that our searches have listened for, rather than broadcasted, messages is based on the conclusion that we are the less advanced civilization. If we mark our emergence by our first attempt to listen for a signal, that was about 60 years ago, so we would be one of the youngest civilizations in the Galaxy.

Armed with all the estimates, anyone can calculate his or her own estimate for N.

If none of f_l, f_i, or f_c is very small, the answer will depend primarily on the choice of L. Of course, the ultimate test of any estimate of N would be to detect signals from an extraterrestrial civilization (Fig. 3). The Milky Way "society" will be dominated by the civilizations that develop the "long-view" before they destroy themselves. ■

THE DRAKE EQUATION

The number of civilizations in our Galaxy with which we could communicate is given by

$$N = R_* f_p n_e f_l f_i f_c L, \text{ where}$$

- R_* is the rate of star formation,
- f_p is the fraction of stars with planetary systems,
- n_e is the number of habitable (Earth-like) planets per planetary system,
- f_l is the fraction of habitable planets where life begins,
- f_i is the fraction of planets with life that evolves to a level of intelligence comparable to that of humans,
- f_c is the fraction of those that develop a technological civilization with the capability and interest in interstellar communication, and
- L is the lifetime of such civilizations.

The first three factors are astrophysical, while f_l lies at the transition from chemistry to biology, f_i is biological, and the last two factors involve history and predictions about technological developments and social interactions. The value of the Drake equation is in organizing our thinking rather than in providing an answer.

About the author

Neal Evans obtained his doctorate in physics at the University of California, Berkeley working with Nobel laureate Charles Townes. Evans joined The University of Texas at Austin faculty in 1975, where he teaches several astronomy courses, including a class about extraterrestrial life. Evans has led large programs on both the Spitzer and Herschel space telescopes, studying the formation of stars and planet-forming disks. He is currently the Edward M. Randall, Jr., MD Centennial Professor at the University of Texas at Austin and the Oort Professor for 2014 at Leiden University.

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SUGGESTION FOR FURTHER READING:

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Opinion: Science and innovation

Erich Griesmayer is CEO of CIVIDEC Instrumentation, Austria, and associated professor at the Vienna University of Technology

CERN's story has been one of continued success since its creation 60 years ago, culminating in the world-leading LHC (Large Hadron Collider), the LHC experiments and the Higgs boson discovery. The success of CERN can be attributed to many things, but CERN's liberal organisational structure is high on the list. CERN is open-minded, politics plays no role in the daily work, and its funding is both stable and sufficient for its mission.

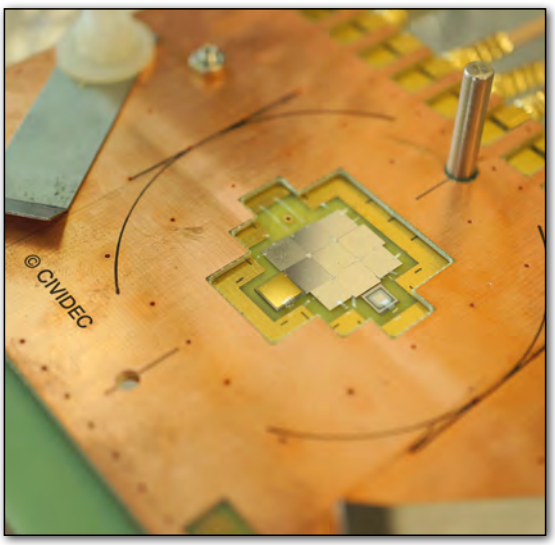
For more than twenty years CERN was completely focused on the Higgs search. Each engineer and scientist, including the associated universities and research laboratories, had this single goal in mind. Technological barriers such as the superconducting magnets (it was not clear in 1989 how to build 8.4 T magnets on an industrial scale), the world-wide-web (the proposal by Tim Berners Lee dates back to 1989) and grid computing, to allow global data processing, were all overcome with dedication and enthusiasm. The motivation of the employees and users of CERN and their technological excellence, in combination with sufficient funds and the freedom endowed by the liberal organizational structure, built success on success leading ultimately to the Nobel Prize in 2013.

CERN also supports innovation even when it is not directly related to its main objective of high-energy physics. One of several examples is related to hadron therapy.

In the early 1990s my former boss, Meinhard Regler from the Austrian Academy of Sciences, initiated the AUSTRON project where the idea of an Austrian Radiobiological Facility was first published as part of a proposed research centre of excellence for the central European region. Later this idea was revived and in collaboration with the Italian group *Centro Nazionale di Androterapia Oncologica* (CNAO), CERN was approached to host an international study group to investigate the feasibility of a medical synchrotron for a hadron therapy centre.

In 1996, under the patronage of CERN and its former Director of Accelerators, Kurt Hübner, the PIMMS (Proton Ion Medical Machine Study) was officially launched under the superior scientific leadership of Phil Bryant, the intellectual father of this particular machine design. After the PIMMS report was published in 2000, CERN continued its support and technology transfer to the respective national projects in Italy (CNAO) and Austria (MedAustron).

Innovation is driven by pioneers who are willing to devote their professional lives to the generation of new ideas and technologies, a task which requires courage.



▼ The CIVIDEC Diamond Mosaic-Detector as used at the CERN n_TOF experiment.

After the funding for the Austrian project was settled, the MedAustron design team went to CERN to work under the guidance of Michael Benedikt in 2008. The technology was later successfully transferred to Austria where the MedAustron project is now a reality.

The Austrian hadron therapy project might not have become a reality without the innovative character of the PIMMS design. The combination of medical cancer treatment and non-clinical research proved to be the convincing argument during funding negotiations with ministries, government departments and politicians as well as civil servants.

Innovation is driven by pioneers who are willing to devote their professional lives to the generation of new ideas and technologies, a task which requires courage. Innovation also requires political independence, structural freedom and a solid financial basis. Current approaches in science policy, which pressure scientists to become self-funding either through commercial partnerships or applied research contracts, are against the intrinsic freedom of scientific research and can only lead to disappointment, malfunction and finally to the emigration of intellectual potential.

Political influence in science will inevitably suppress the natural development of innovative ideas. Only a politically and financially independent and structurally liberal system can be sustainably innovative.

CERN should remain a blazing example of that. ■

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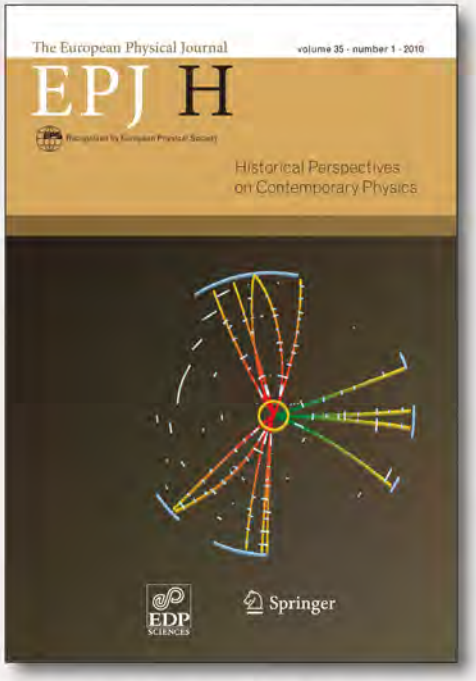

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A second purpose of the journal is to serve as a bridge between the working physicists and the professional historians and philosophers of science interested in the most recent developments in physics. Not only theory (e.g. quantum field theory), but also experiments and observations become so involved that a deeper understanding of the fundamental ideas requires the help of professional physicists. Here, historians will benefit from the physicists' own analysis of their quest for a better understanding of their field and for the subsequent historian's work.

Accordingly and importantly, the journal will not insist in a particular style of presentation. Articles may be as non-technical or as technical as they need to be, both in terms of their mathematical content and in relation to the technical jargon a community uses to convey precise meanings. However, in the latter case, the editors of this journal will insist that a substantial non-technical introduction and conclusion is provided.

Given that the language of the journal is English, a third feature will be to publish (annotated/commented) translations of historical documents, initially written in a different language, of relevance to the aims and scope of the journal.

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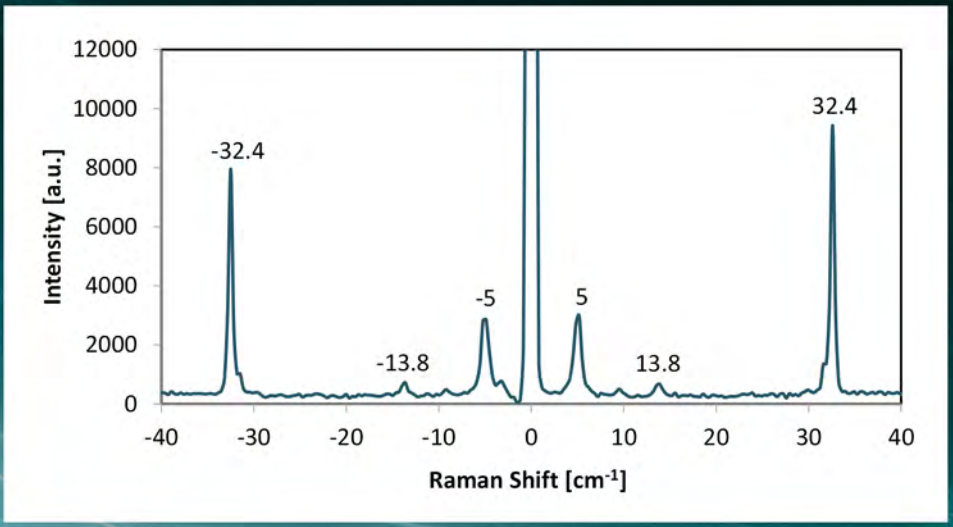

Raman spectrum of MoS_2 flakes measured at 633 nm with BragGrate™ Notch filters and single stage spectrometer

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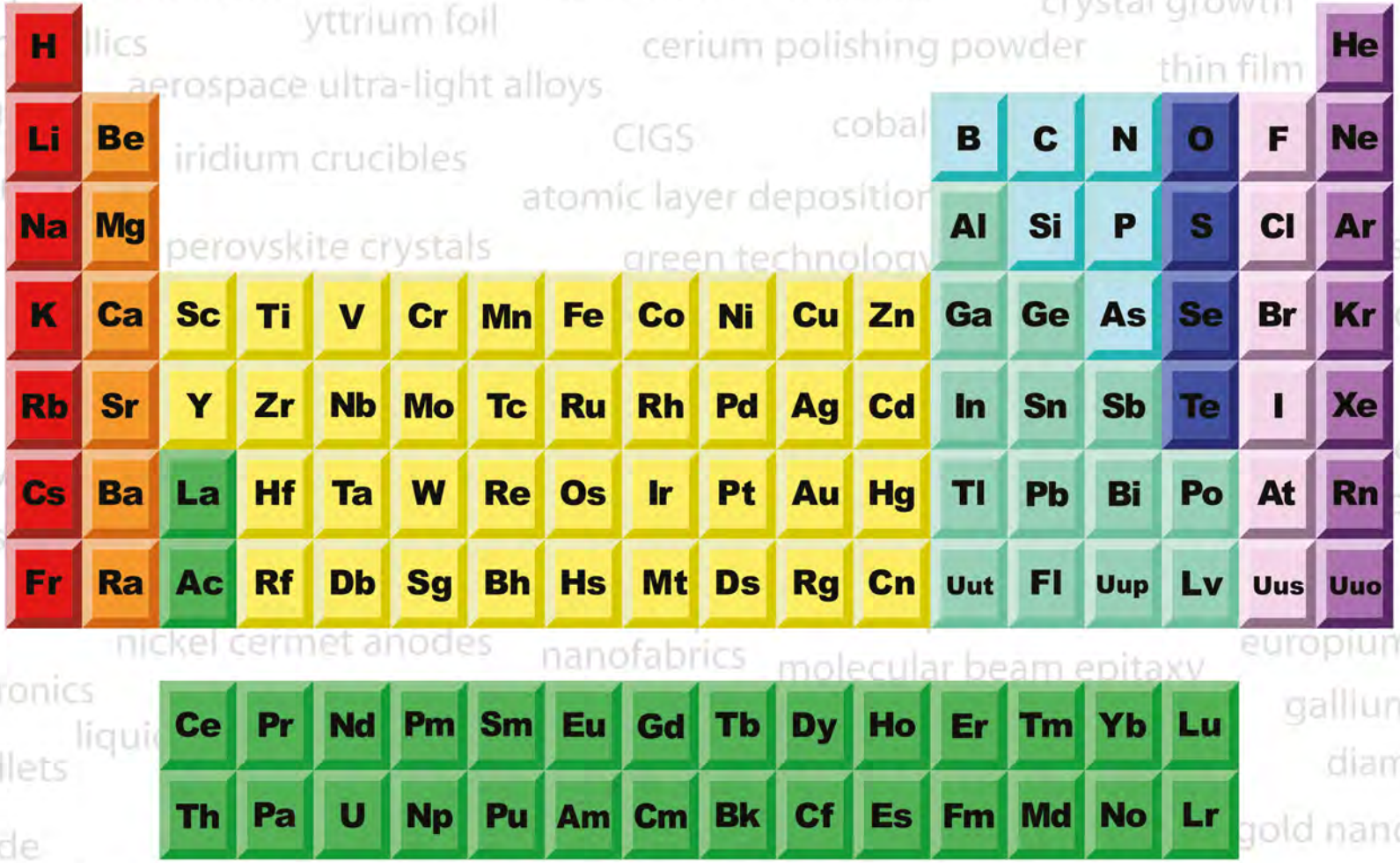

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