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Rosetta's journey to Comet
How many gold atoms make gold metal?
Light – cosmic messages from the past
PLANCKS 2015 second edition
EPS directory

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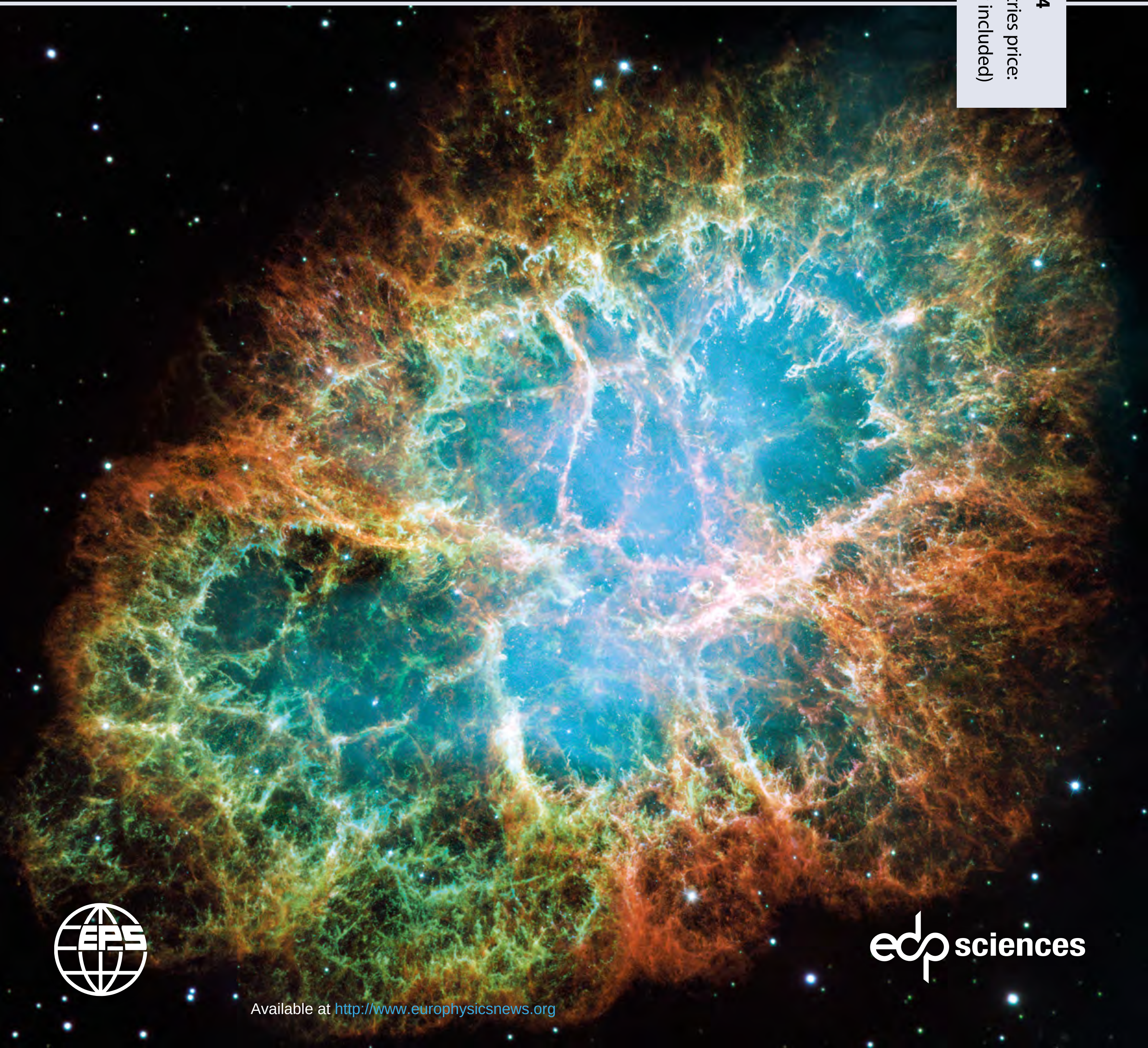

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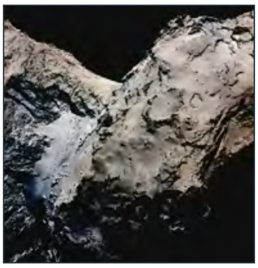
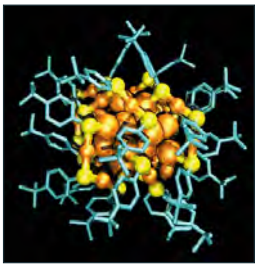
Cover picture: The Crab Nebula is a six-light-year-wide expanding remnant of a star's supernova explosion. Japanese and Chinese astronomers recorded this violent event nearly 1000 years ago in 1054.



▲ PAGE 19

Rosetta's journey to Comet Churyumov-Gerasimenko



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How many gold atoms make gold metal?

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Light – cosmic messages from the past

[EDITORIAL]

Advising on Science

One essential question today is how much responsibility scientists must take in advising politicians on science policy issues and other society challenges.

In an article that appeared in EPN 45/3 in 2014, entitled 'Climate change: can we afford to wait longer?' I expressed my personal view on the needs to communicate on important environmental issues. This was an easy process since it was the opinion of a single author. In the meantime EPS published a position paper written by its Energy Group on the 'European Energy Policy and Global Reduction of CO_2 emissions: Towards an effective sustainable electricity production in Europe'. The document focuses on electricity production by non-fossil sources. It puts the European Energy Policy in the broader context of the world energy and climate problem and highlights important points in the discussion on a greener energy future. Merging the different points of view of all parties involved appeared to be an almost impossible task, but a final version was agreed on and sent out to policy makers in Brussels and to all presidents of our Members Societies. Indeed, the need to reach a consensus on critical science-related issues is very important but has the drawback of being too slow. In this particular case let's hope that a measurable impact will be achieved before the UN Conference on Climate Change to be held in December in Paris. A more radical impact in the media has certainly been the announcement on 18 June of Pope Francis' encyclical on climate change, a 180-page letter addressed to "every single person on the planet" and stating that global warming is one of the world's most pressing moral, ethical and religious challenges.

A positive development, after the turmoil generated in 2014 by the suppression of the chief scientific advisor position at the EU Commission, was the proposal soon after by president Jean-Claude Juncker to set up a European Political Strategy Centre (EPSC), a revamped version of the former Bureau of European Policy Advisers. This Centre would focus on economic and social issues, sustainable development, institutional policy, and communications, with a particular emphasis on foresight studies. In May of this year a press release announced that a group of eminent scientists had been invited at a meeting with Juncker and Commissioner Carlos Moedas 'to exchange views on how to ensure that Europe remains a center of excellence for science, foster innovative ideas that are brought to market, and ensure that EU policy benefits from the best scientific advice'. Thus the idea of a science advisory panel at the European level is back on track and the EPS should aim at becoming an active partner. I am thus convinced that producing objective scientific advices, based on careful studies should be among the duties of learned societies, thus demonstrating that scientists are concerned by today's great challenges. But the communication requires on both sides attentive, competent, and engaged interlocutors, with better scientific literacy among politicians and more political interest among scientists.

Another point to consider is the scientific misconduct of a few who might discredit the majority of scientists in front of the public opinion. Scientific misconduct is the violation of the standard codes of scholarly conduct and ethical behaviour in scientific research. It includes negligence in the research process with fabrication, falsification or simply embellishment of data, plagiarism in addition to false credit. All that is essentially due to career pressure – after the motto publish or perish - and eased by today's informatics tools.

It is therefore essential that advising on science is done showing the good example and following the code of ethics. The many science advisory boards should consider all these aspects when addressing relevant questions in research and technology and interacting with policymakers, media and the public in general.

Christophe Rossel
President of the EPS

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Editor: Victor R. Velasco (SP)
Email: vrvr@icmm.csic.es

Science Editor: Jo Hermans (NL)
Email: Hermans@Physics.LeidenUniv.nl

Executive Editor: David Lee
Email: d.lee@eps.org

Graphic designer: Xavier de Araujo
Email: x.dearaujo@eps.org

Director of Publication: Jean-Marc Quilbé

EPS Secretariat

Address: EPS • 6 rue des Frères Lumière
68200 Mulhouse • France
Tel: +33 389 32 94 40 • **fax:** +33 389 32 94 49
www.eps.org

Secretariat is open 09.00–12.00 / 13.30–17.30 CET except weekends and French public holidays.

EDP Sciences

Chief Executive Officer: Jean-Marc Quilbé

Publishing Director: Agnès Henri
Email: agnes.henri@edpsciences.org

Production: Thierry Coville

Advertising: Jessica Ekon
Email: jessica.ekon@edpsciences.org

Address: EDP Sciences
17 avenue du Hoggar • BP 112 • PA de Courtabœuf
F-91944 Les Ulis Cedex A • France
Tel: +33 169 18 75 75 • **fax:** +33 169 28 84 91

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EPS HISTORIC SITES

The Residencia de Estudiantes,
Madrid, Spain

It was a pleasure to be with the president of the EPS, Dr. Christophe Rossel, to commemorate the role of the *Residencia de Estudiantes* in the development of physics during the so-called Silver Age of Spanish Science, 1910-1936.

As the plaque declaring this place European Physical Society Historic Site states, the *Residencia*, under the supervision of Blas Cabrera (director of the neighbouring Laboratory of Physics Research and a former president of the Spanish Royal Physics Society), contributed strongly to the development of modern physics in Spain. Many illustrious physicists came to speak at the *Residencia* as, for instance, Einstein (his German being translated by the philosopher Ortega y Gasset), Marie Curie, Maurice de Broglie, Arthur Eddington or Paul Scherrer; the Spanish physicists Cabrera, Julio Palacios, Miguel Catalán, the physical chemist Enrique Moles, and many others also participated at the Residencia's evening seminars.

I would like to stress that the present occasion does justice both to the *Residencia* and to physics and science in general. To the *Residencia*, because it recognizes its important role -not widely known- in fostering the advance of modern physics in Spain. It is easy to understand why science usually fades away when thinking of the *Residencia*: first, science is usually harder to grasp than humanities (*La Natura è scritta in lingua matematica* and too often mathematics becomes a barrier) and, secondly, the *Residencia* also hosted, to name just three, luminaries such as the poet and playwright Federico García Lorca, the painter Salvador Dalí or the filmmaker Luis Buñuel. But, precisely by having humanities as a reference frame, we are also doing justice to physics and to the scientists around the *Residencia* by recognizing science as a fundamental part of culture, on a par with literature or art. We might go even further: after all, as Ortega y Gasset said to and of Einstein himself, great scientists are "the magicians of our day, those who dictate the laws that Nature obeys". Uncovering these laws is the privilege of the very few, but it is a feat of paramount importance: as Richard Feynman said of Maxwell equations in his famous *Lectures on Physics*, with the passing of time even "the American Civil War

▲ EPS President Chris Rossel and Prof. J. Adolfo de Azcárraga unveil the commemorative plaque. To the right Prof. Emilio Lora-Tamayo (CSIC's President) and Alicia Gómez-Navarro (Director of the Residencia de Estudiantes).

will pale into provincial insignificance in comparison with this important scientific event of the same decade" (the 1860s).

The founders of the *Institución Libre de Enseñanza* (ILE, *Free Institution for Education*), and the *Junta de Ampliación de Estudios e Investigaciones Científicas* (JAE, *Board for Further Studies and Scientific Research*, est. 1907), understood well the role of science. They thought of it as an essential ingredient of knowledge, culture and -last but by no means least- of social progress. The JAE, presided by the Nobel prize (in Physiology or Medicine, 1906) Santiago Ramón y Cajal until his death in 1934, created the *Residencia de Estudiantes*. Other illustrious members of the JAE's governing board included Joaquín Costa (more of him below); María de Maeztu, the driving force behind the *Residencia de Señoritas*, the sister of the *Residencia de Estudiantes*; and the engineer, excellent mathematician and also Nobel prize (of Literature!) José de Echegaray who, let me say in passing, was the first president of our Society (at that time, both of Physics and Chemistry and not yet Royal until 1928). He must have been a bigger than life character: the RSEF is still receiving letters addressed to president *Echegaray*!

Under Cajal's leadership of the JAE, it is not surprising that the *Residencia* soon became the hub of exchange and diffusion of new scientific ideas, of physics in particular, that we commemorate today. But science does need time to develop fully: the *Silver Age* came to an abrupt end in 1936, with the civil war. Of course, physics in Spain has come a very long way since the best years of the *Residencia* almost a century ago. But, in spite of the enormous development of physics and other branches of knowledge, Spanish science is now at a crossroads, damaged by the crisis, by dwindling economic support, plagued by bureaucracy and, further, by the loss of brilliant, young scientists who are emigrating -for good- to other countries. This trend needs being reversed without delay.

More than a century ago, at the time of the Spanish *regenerationist movement*, which overlapped with the 'Silver Age' of Spanish Science and the golden years of the *Residencia*, a motto of Joaquín Costa was often repeated: "bread, school, and double lock to the Cid's grave", implying that Spain was lagging behind the rest of Europe and that this could not be hidden under her past glories. Present times are of course very different but, in some respects, a new *regenerationist* spirit is necessary today. Spain sorely needs a much healthier public life, an improved secondary education, truly first class universities and much more support for science. As it was obvious to the leaders of the ILE and the JAE a century ago, education and science play a central and always increasing role in the development and well-being of society. Let this happy occasion, in which we recognize the *Residencia* as an *EPS Historic Site*, remind us that scientific progress is rather hard to achieve, that it takes a long time to set it on track but that, unfortunately, it may be derailed and halted very easily. ■

■ **J. Adolfo de Azcárraga**
President of the Spanish Royal Physics Society
Univ. de Valencia and IFIC (CSIC-UV)

▼ From left to right C. Rossel, E. Lora-Tamayo, A. Gómez-Navarro and J. Adolfo de Azcárraga during the opening ceremony.

EPS HISTORIC SITES

The Physics Faculty Ludwig-Maximilians-University
Munich, Germany

On the 6th of May, the Ludwig-Maximilians-University Munich (LMU) has been named a "Historic Site" by the European Physical Society (EPS). After the Physikalisch Technische Bundesanstalt (PTB) in Berlin in 2013, LMU is the second German institution to receive this honour.

As mentioned on the commemorative plaque, which is mounted on a boulder of granite in the courtyard of the LMU, its Physics Faculty has been distinguished because here, "at the beginning of the twentieth century, pioneers of modern theoretical and experimental physics taught and performed scientific research". "Ludwig Boltzmann, Wilhelm Wien, Max Planck, Arnold Sommerfeld, Werner Heisenberg, Wolfgang Pauli and Karl Schwarzschild laid foundations of statistical mechanics, thermodynamics, atomic physics, quantum mechanics and the theory of relativity. Through their invention and application of X-rays, Wilhelm Conrad Roentgen and Max von Laue revolutionized medical diagnostics and the analysis of atomic structures in physics, chemistry and biology."

▼ S. Bethke (DPG), C. Rossel (EPS, President), R. Bender (LMU, Dean), B. Huber (LMU, President), A. Schenzle (LMU, previous dean). In the back you see the old lecture hall, where also A. Sommerfeld lectured in front of his students like Heisenberg and Pauli.

The award ceremony took place in the faculty's historic lecture hall, where Arnold Sommerfeld held his lectures in front of students like Heisenberg and Pauli. Welcome addresses were delivered by Prof. Ralf Bender, dean of the faculty for physics, Prof. Bernd Huber, president of LMU and Prof. Siegfried Bethke, representing the Deutsche Physikalische Gesellschaft (DPG). Dr. Christophe Rossel, president of the EPS, praised the mentioned scientists for their fundamental contributions and emphasised the importance of appreciating historical achievements for future developments in science and society. In his enjoyable speech, Prof. Axel Schenzle, who presided as dean over the faculty for many years, outlined the history of physical research in Munich. He also included scientists who are not mentioned on the plaque explicitly but were of importance at various times. His anecdotes and side remarks not only made us smile, they also inspired further reflections upon science and those who perform it. ■

Siegfried Bethke
Director Max Planck Institut für Physik, Munich

PLANCKS 2015

Second edition of international physics competition great success

From the 22nd to the 24th of May 2015, the second edition of the international physics competition PLANCKS was held in Leiden, the Netherlands. A total of 28 teams from 18 different countries took up the challenge for the title of "Best Physics Students of the World".

"*Good afternoon, and welcome to the opening symposium of the second edition of PLANCKS 2015. We have gathered here today to listen to five leading physicists who will talk about their outstanding research...*" With these words the second edition of the Physics League Across Numerous Countries for Kick-ass Students (PLANCKS) had started. We, as the organizing committee, are grateful for a great weekend and think that PLANCKS 2015 was a huge success!

PLANCKS

In 2012 PLANCKS was set up by students of the University of Utrecht in cooperation with SPIN, the umbrella organization for Dutch student associations in the field of physics. The idea was to create an international version of the annual Dutch national physics competition, PION, which had existed since 1995. The first edition of PLANCKS in 2014 was a great success and that is why a second edition was organized in Leiden, the Netherlands, by students of Leiden University. With PION as a leading example, also other countries organized a national physics competition and the winners of these preliminaries participated in PLANCKS 2015. In countries where no national competition was organized teams were able to sign up for PLANCKS directly. This resulted in 28 teams of three or four students from 18 different countries.

▲ Lecture hall during the Opening Symposium

Opening symposium

The day prior to the competition itself there was an opening symposium where 5 leading physicists talked about their research. We started with a brief talk about physics in Leiden by our host Eric Eliel, scientific director of the Leiden Institute of Physics. He spoke about the research of Kamerlingh Onnes, Albert Einstein and Hendrik Lorentz and elaborated on the structure of the institute, so that the international visitors would get an idea of how a Dutch physics institute is organized. He was followed up by Carlo Beenakker, *Leiden University*, who spoke about quantum computing. He focused mainly on the conceptual part of this wildly complicated topic so that the audience got a basic understanding of what quantum computing is, what the main ideas are and why we need it. His talk was largely complemented by the next speaker, prof. Leo Kouwenhoven, *Delft University of Technology*, who became famous in 2012 by being the first to observe Majorana fermions. This time around he spoke about the practical problems of building a quantum computer, and

ONE OF THE TEN CHALLENGING PROBLEMS: FALLING SLINKY

Consider a slinky (*i.e.* a flexible open spring) suspended from its top and at rest. When you release the top end the time evolution of the slinky is fascinating, as shown in the series of pictures below. To describe this phenomenon, we consider an ideal uniform slinky of mass m, and negligible rest length, for which each segment obeys Hooke's law (force $\propto$ extension) $F = kL$. We will consider both its static shape and its dynamic evolution in free fall.

(3.1) [3 points] Describe the (vertical) shape of the slinky at rest (left frame). Hint: denote points on the slinky by a dimensionless variable x, ranging from $x = 0$ at the bottom to $x = 1$ at the top and describe its shape by specifying the height $L(x)$ of each segment above the bottom of the slinky

(3.2) [1 point] Explain in words why the slinky behaves the way it does while falling.

(3.3) [5 points] How long will it take for the top of the slinky to reach the bottom of the slinky? How does this result compare with the fall time of a small object falling from the same height L?

(3.4) [3 points] Derive equations (you don't have to solve them) to describe the distance $\Delta L(t)$ travelled by the top of the slinky at a time t after 'launch', up to moment when it reaches the bottom of the slinky.

went in detail about where we are currently in this long process. After these talks the floor was given to two speakers from London.

John Ellis, *King's college London*, lectured on his specialty: particle physics. The talk was interspersed with anecdotes from his own time at CERN, where he was head of the theoretical physics department for several years, and full with puns like *Higgsteria*, *Higgsdependenceday* and *The particle Higgsaw puzzle*. The other speaker from London was John Pendry, *Imperial College London*, the holder of the Lorentz chair for 2015 in Leiden. He explained his research in optics and meta materials. Using self-made materials with special properties such as reverse light refraction you can bend light around an object, which results in an "invisibility cloak". The final talk was given by Erik Verlinde, *University of Amsterdam*. His talk mixed a wide range of topics to elucidate a new perspective of the widely known phenomena called gravity. Instead of explaining it by general relativity, he has a theory in which he combines entropy, string theory and quantum information.

Competition

In the remaining part of the weekend, we focused on the most important goal of the whole event: bringing together physics students from all over the world. On Saturday the competitors solved challenging problems in the morning and enjoyed one of the several excursions in the afternoon.

◂ The contestants of PLANCKS 2015

▴ The winners of PLANCKS 2015: Roy Figiel, Ruben Doornenbal, Martijn van Kuppenvelt and Joost Houben.

▸ John Ellis explaining particle physics using his shirt)

The day was closed by a barbecue and a party. The next morning the closing ceremony was held in museum Boerhaave, the Leiden Museum of the History of Science. Jan van Ruitenbeek, the chairman of the Dutch Physical Society, presented the prizes to the winners of this year. The third prize went to the Czech team *Charles' Angels* (74.5 out of 120 points), the second prize went to the Dutch team *Tena* (81 out of 120 points) and the first prize of € $(h/\pi) \cdot 10^{37}$ = €2109,14 went to the Dutch team *Strength in Unitarity* (88.5 out of 120 points).

SOLUTION: FALLING SLINKY

(3.1) [3 points] The pulling force in each part of the slinky is determined by its relative local extension, such that Hooke's law can be written as $F(x) = k\frac{dL}{dx}$. As this force has to lift the lower part of the slinky $F(x) = mgx = k\frac{dL}{dx}$. Integration of this equation yields the shape of the slinky $L(x) = \left[\frac{mg}{2k}\right]x^2$. The total length of the slinky is $L_0 = \frac{mg}{2k}$ is needed for later reference.

(3.2) [1 point] When the top part of the slinky is falling, **the bottom part doesn't notice yet when its local shape hasn't changed yet.** The acceleration of the top part is faster than that of a free-falling object, as this top experiences the pulling force of the lower part.

(3.3) [5 points] In order to calculate how long it takes for the top of the slinky to reach the bottom of the slinky, you don't need to solve its full equation of motion. It is enough to **consider the motion of the center of mass of the slinky**, which is originally positioned at $\frac{L_0}{3}$ above the bottom of the slinky. This center of mass moves as any free falling object does and reaches the bottom at a time t_{fall} that obeys the equation $\frac{L_0}{3} = \frac{g}{2}t_{fall}^2$. This yields $t_{fall} = \sqrt{\frac{2L_0}{3g}}$, which is a factor $\sqrt{3}$ shorter than the fall time $\sqrt{\frac{2L_0}{g}}$ of a point-like object falling over a distance L_0.

(3.4) [3 points] We can derive an equation for the distance $\Delta L(t)$ travelled by the top of the slinky at a time t after 'launch', up to the moment when it reaches the bottom of the slinky, by combining the equation for the motion of the center of mass with the observation that a compression wave travels neatly from top to bottom through the slinky. When at a time t a fraction $y = 1 - x$ of the top of the slinky has collapsed, the position of the center of mass with respect to the bottom of the slinky can be written as $\frac{L_0}{3} - \frac{1}{2}gt^2 = L_0(x^2 - \frac{2}{3}x^3)$. This equation describes how the slinky contracts in time, but the solution $x(t)$ is far from trivial. Its time derivative yields the expression $\frac{dx}{dt} = \frac{-gt}{2L_0 x(1-x)}$ and the real speed $\upsilon = -\frac{dL}{dt} = -2L_0 x\frac{dx}{dt} = \frac{gt}{1-x}$. As an alternative approach towards the solution, we can consider the acceleration of the contracted top section of the slinky, which goes as $\frac{d\upsilon}{dt} = \frac{g}{1-x}$.

The next edition of PLANCKS will take place in Romania and will be organized by students of the University of Bucharest. We hope it will be just as big a success as the previous editions, and that the competition will develop into a big event which will be known among all physic students across the world. ■

Reference: http://plancks.info

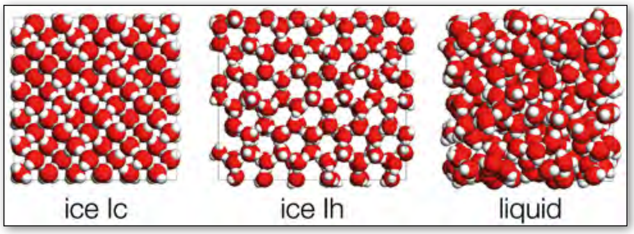
■ **Irene Haasnoot**
President of the Organizing Committee of PLANCKS 2015 / Student at Leiden University

Highlights from European journals

SOFT MATTER

How supercooled water is prevented **from turning into ice**

Calculating the energy barrier that keeps liquid water below zero from immediately turning into ice provides the key to understanding its ability to be compressed as temperature drops



▲ Representative configurations of ice in its Ic format, which is a simulation in a cube with 216 molecules, Ih format, which is in a rectangular cell with 432 molecules, and in liquid water.

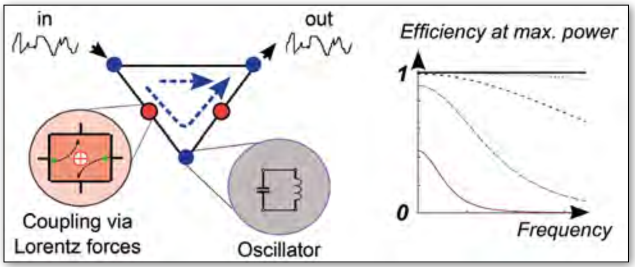
Water behaves in mysterious ways. Especially below zero, where it is dubbed supercooled water, before it turns into ice. Physicists have recently observed the spontaneous first steps of the ice formation process, as tiny crystal clusters as small as 15 molecules start to exhibit the recognisable structural pattern of crystalline ice. This is part of a new study, which shows that liquid water does not become completely unstable as it becomes supercooled, prior to turning into ice crystals. The team reached this conclusion by proving that an energy barrier for crystal formation exists throughout the region in which supercooled water's compressibility continues to rise. Previous work argued that this barrier vanished as the liquid gets colder. ■

■ **C.R.C. Buhariwalla**, **R.K. Bowles**, **I. Saika-Voivod**, **F. Sciortino** and **P.H. Poole**,
'Free energy of formation of small ice nuclei near the Widom line in simulations of supercooled water',
Eur. Phys. J. E **38**, 39 (2015)

MATHEMATICAL PHYSICS

How linear networks become exciting

Oscillator networks are omnipresent; they occur, *e.g.*, in electric devices, in mechanical systems, and in biochemistry. However, purely linear networks have limited capabilities. Diode-like, monodirectional transport is usually impossible. Also, maximum power can not be transmitted with an efficiency larger than 1/2. Therefore, engineered networks often contain active or non-linear elements such as transistors. As a possible alternative, the authors investigated purely linear networks containing Lorentz-force-like couplings that break time-reversal symmetry. These networks allow to construct linear diodes with frequency-independent isolation properties. Also, the efficiency at maximum power can approach unity. We show that this surprising system behaviour requires a combination of network loops with magnetic time-reversal symmetry breaking. ■



▲ Left: Exemplary linear network containing a loop. Blue dots represent oscillators, red dots represent magnetic couplings that break time-reversal symmetry, *e.g.*, Hall elements. Tuning the system parameters allows to force destructive interference of all signals that propagate from the right port around the two sides of the network. Thus, the system acts as a frequency-independent linear diode. Right: In contrast to systems without magnetic couplings, maximum power can be transferred here with an efficiency that is higher than the fundamental limit of 0.5.

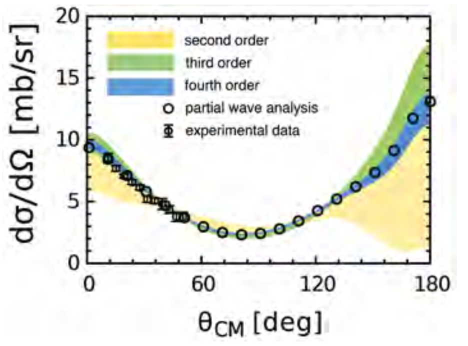
■ **B. Sabass**,
'Network topology with broken Onsager symmetry allows directional and highly efficient energy transfer', *EPL* **110**, 20002 (2015)

NUCLEAR PHYSICS

A new generation of **chiral nuclear forces**

Chiral effective field theory provides a systematically improvable perturbative approach to deriving nuclear forces in harmony with the symmetries of Quantum Chromodynamics. Combined with modern few- and many-body methods, this framework represents a commonly accepted procedure for ab initio studies of nuclear structure and reactions.

In this work, the authors introduce a new generation of nucleon-nucleon forces up to fourth order in the chiral expansion. By employing an appropriate regularization in coordinate space, which maintains the analytic structure of the amplitude, the authors succeed in significantly reducing the amount of finite-cut-off artefacts. In addition, a simple approach to estimating the



◂ Neutron-proton differential cross section at E_{lab}=143 MeV up to fourth order in the chiral expansion.

theoretical uncertainty in few- and many-nucleon calculations from the truncation of the chiral expansion is formulated. By calculating various two-nucleon scattering and bound-state observables, the authors verify that the results at different chiral orders and for different values of the regulator are indeed consistent with each other and with the experimental data.

The new generation of chiral nuclear forces is expected to provide an excellent starting point for applications in nuclear physics. ■

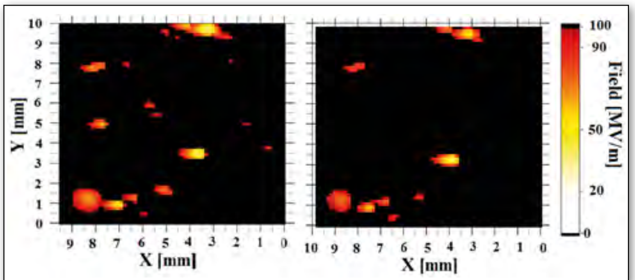
▪ **E. Epelbaum**, **H. Krebs** and **U.-G. Meißner**, 'Improved chiral nucleon-nucleon potential up to next-to-next-to-next-to-leading order', *Eur. Phys. J. A* **51**, 53 (2015)

CONDENSED MATTER

Prevention of dark currents from photocathodes

Alkali-based photocathodes deposited in the centre of molybdenum substrates are used as pulsed electron sources in linear particle accelerators. Operation at high electric dc or rf fields is required to obtain a low beam emittance, thus increasing the probability of unwanted dark currents from the cathode surface. Therefore, a field emission scanning microscope was used to localize parasitic electron emitters on single crystal and polycrystalline Mo plugs. In contrast to well-polished and dry-ice cleaned Mo surfaces with native oxide, strong field emission occurred after heat treatments above 400 °C (see figure), which are usually applied before the coating process. Thermal oxidation,

▾ Field emission maps of an annealed oxide-free (left) and thermally oxidized Mo surface (right). Obviously, the number of emitters providing 1 nA current at fields up to 100 MV/m is reduced by the oxide."



however, partially weakened the emitters. X-ray photoelectron spectroscopy confirmed the corresponding changes of the surface oxide layer. These results suggest a selective removal of the native Mo oxide prior to the photocathode deposition to prevent the dark currents in accelerators. ■

▪ **S. Lagotzky**, **R. Barday**, **A. Jankowiak**, **T. Kamps**, **C. Klimm**, **J. Knobloch**, **G. Müller**, **B. Senkovskiy** and **F. Siewert**, 'Prevention of electron field emission from molybdenum substrates for photocathodes by the native oxide layer', *Eur. Phys. J. Appl. Phys.* **70**, 21301 (2015)

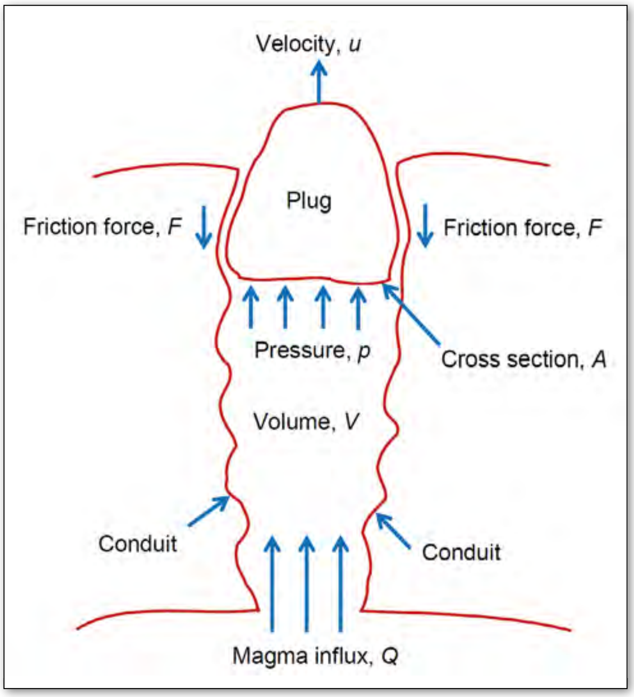
MATHEMATICAL PHYSICS

Noise produces volcanic seismicity, akin to a drumbeat

A new study shows that relatively small external disturbances play a crucial role in chaotic phenomena like the recent Calbuco volcanic eruption in Chile, leading to drum-beat-like seismicity.

Volcanoes are considered chaotic systems. They are difficult to model because the geophysical and chemical parameters in volcanic eruptions exhibit high levels of uncertainty. Now, the authors have further extended an eruption model—previously developed by other scientists—to the friction force at work between the volcanic plug and volcanic conduit surface. The results provide evidence that volcanic activity can be induced by external noises that would not otherwise have been predicted by the model. The authors show that the external noise is also linked to the appearance of large-amplitude oscillations in the volcanic plug and high seismicity. An increase in noise intensity

▾ A diagram showing the plug dynamics and the various friction forces at work.



leads to drumbeat-type plug movement, exhibiting irregular periodicity dependent on noise. Such beat-type behaviour is a building block for understanding the physical mechanisms of volcanic drumbeat seismicity. ■

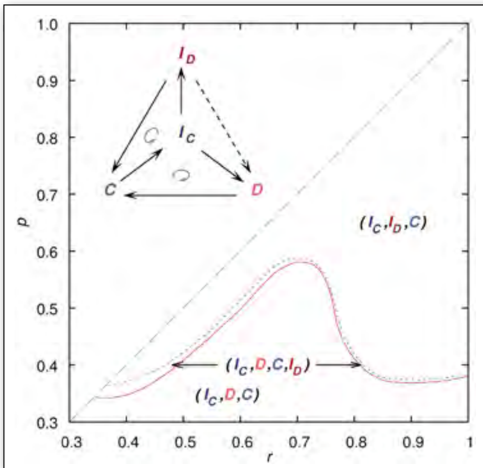
▮ **D. V. Alexandrov**, **I. A. Bashkirtseva** and **L. B. Ryashko**, 'How a small noise generates large-amplitude oscillations in the volcanic plug and produces high seismicity', *Eur. Phys. J. B* **88**, 106 (2015)

STATISTICAL PHYSICS

Does knowing the opponent's strategy guarantee **optimal play?**

Methods of statistical physics are proving indispensable for the study of evolutionary games in structured populations. The evolution of cooperation and the phase transitions leading to favorable evolutionary outcomes depend sensitively on the structure of the interaction network and the type of interactions, as well as on the number and type of competing strategies. Now, physicists have solved the puzzle of the availability of information in evolutionary games. In a new theoretical model, the authors answer whether knowing the strategy of an opponent is indeed the holy grail of optimal play in social dilemmas, or whether the situation is in fact more complex. It is indeed the latter, as final evolutionary outcomes depend sensitively not just on individual relations between the competitors as determined by payoff elements, but equally strongly on the spatiotemporal dynamics of defensive alliances that emerge spontaneously as a result of strategic complexity. Reentrant phase transitions highlight the fact that the viability of an alliance depends sharply on the invasion speeds between group members who cyclically dominate each other. ■

▮ **A. Szolnoki** and **M. Perc**,
'Reentrant phase transitions and defensive alliances in social dilemmas with informed strategies',
EPL **110**, 38003 (2015)

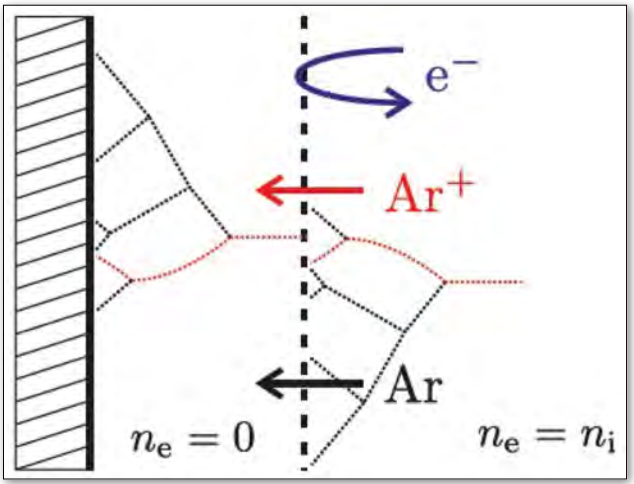


◂ Reentrant phase transition between two cyclically dominant strategy triplets who form alliances against the fourth strategy. The triplets are indicated by curved arrows in the inset.

PLASMA PHYSICS

Novel plasma diagnostics method

Physicists have now devised an elegant plasma pressure diagnostic method by studying forces akin to the pressure change at the inner walls of energy saving light bulbs when the light is switched on.



▴ Sketch of the momentum fluxes across the sheath edge.

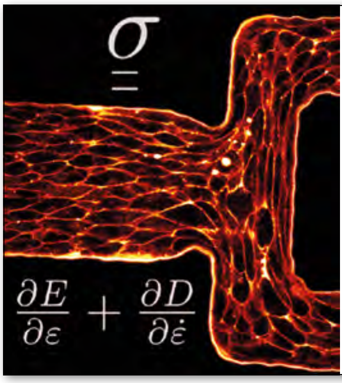
Could the mundane action of switching on an energy saving light bulb still hold secrets? It does, at least for physicists. These bulbs are interesting because they contain low-temperature plasma—a gas containing charges from ions and electrons. Now, the authors have developed a method that could be used for measuring the increase in the plasma force on the inner side of such a light bulb when the light is switched on. These findings have implications for plasma diagnostics concerning plasma-wall interactions used in surface modification and the production of thin-film solar cells and microchips. This could lead to a promising new kind of plasma diagnostics, providing insights into processes that conventional electrical probes can't detect. ■

▮ **T. Trottenberg**, **T. Richter** and **H. Kersten**,
'Measurement of the force exerted on the surface of an object immersed in a plasma', *Eur. Phys. J. D* **69**, 91 (2015)

BIOPHYSICS

The importance of rheology in tissue development

Our understanding of biomechanics increasingly improves through the use of physics models. There are some intriguing biological questions regarding the interplay between the behaviour of cells and the mechanics at the level of tissues. For example, how does a collective behaviour, not apparent at the



◂ The dissipation function formalism helps construct constitutive equations relating the mechanical stresses with intracellular variables such as cell deformations and intercellular variables such as cell velocities and cell neighbour changes. Experiments where cells are forced to flow in a narrow geometry and where these variables are measured help to infer and/or test such equations.

cell scale, emerge at the tissue level? Or how can the mechanical state of a tissue affect the cell division rate or the orientation of cells undergoing division?

The authors think that the interplay between genes and mechanics is key to understanding how the adult shape emerges from a developing tissue.

They construct rheological diagrams based on insights concerning the mechanics of the biological tissue. One of the main insights is a distinction between intra-cellular and inter-cellular mechanism. The local rheological equations obtained allow to generate a complete spatial model expressed as a set of partial differential equations. This procedure is conducted not only in the case of small elastic deformations, but also in the relevant, less discussed, case of large elastic deformations. The authors provide a functional and versatile toolbox for tissue modelling and propose a framework for a tensorial treatment of heterogeneous tissues. Although the simplest applications concern in-vitro experiments, the same approach may be used for many other living tissues including animal tissues during development, wound healing, or carcinogenesis. ■

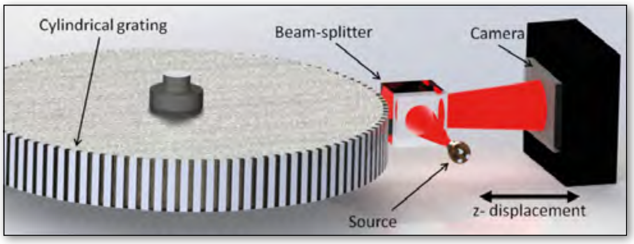
▪ **S. Tlili**, **C. Gay**, **F. Graner**, **Ph. Marcq**, **F. Molino** and **P. Saramito**,
'Colloquium: Mechanical formalisms for tissue dynamics',
Eur. Phys. J. E **38**, 33 (2015)

OPTICS

Self imaging process of **cylindrical convex gratings**

Diffraction gratings have become one of the most used optical elements. Their behaviour has been extensively analysed from many diverse points of view. From a general sight, diffraction gratings produce diffraction orders at the far field and self-images at the near field. The applicability of diffraction gratings is quite extensive. They can be found as fundamental parts of many different devices such as telescopes, spectrometers, optical encoders, *etc.*

One particular kind of optical encoder uses cylindrical convex gratings. The authors show the near-field diffraction



▴ Experimental set-up used to obtain the near field diffraction pattern.

of cylindrical convex gratings illuminated by a general source that can be punctual or finite, monochromatic or polychromatic. They analyse how the size and polychromatism of the source affect the self-imaging process of cylindrical convex gratings. A decrease in the self-images contrast is produced for finite non-punctual sources. On the other hand, polychromaticity of the source produces quasi-continuous diffraction fringes from a certain distance forward.

All the results have been proven by experiments and could be helpful in applications that include convex diffraction gratings. ■

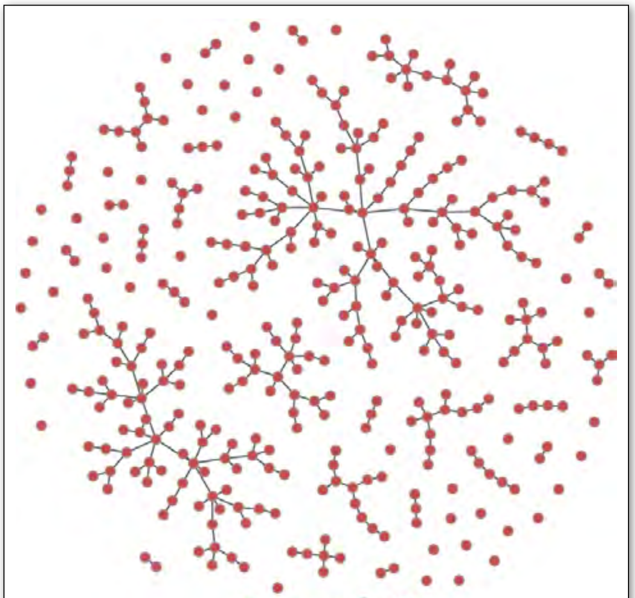
▪ **F.J. Torcal-Milla**, **L.M. Sanchez-Brea** and **E. Bernabeu**,
'Near field diffraction of cylindrical convex gratings,
J. Opt. **17**, 035601 (2015)

MATHEMATICAL PHYSICS

Fragmentation of random trees

Networks are ubiquitous, appearing in the study of subjects as diverse as gene-protein interactions, power grids, and algorithms.

The function of a network is closely linked to its structure. For instance, in biochemical reaction networks, removal of a species or reaction can dramatically change the output of the system.



▴ The random forest

Evolving networks often undergo degradation, making it important to understand how the structure breaks apart when components are randomly removed, also revealing how resilient a network is to attacks.

We studied the fragmentation of a random tree, a network formed by repeatedly attaching new nodes to an existing node chosen uniformly randomly.

We present exact equations governing the evolution of fragment sizes after a fraction of the nodes are removed at random, along with asymptotic solutions. For very large trees, fragment size distribution decays as a power law, with an exponent of $1+1/m$, m being the fraction of remaining nodes. This implies that a few very large fragments coexist with many small ones (see figure).

Our findings reveal unusual fragmentation kinetics, where the fragment size distribution is characterized by a time-dependent exponent, and can provide insight into other fragmentation processes where dynamic parameters are observed. ■

Z Kalay and **E Ben-Naim**,
'Fragmentation of random trees',
J. Phys. A, *Math. Theor.* **48**, 045001 (2015)

CONDENSED MATTER

Organic nanoparticles, **more lethal to tumours**

Carbon-based nanoparticles could be used to sensitize cancerous tumours to proton radiotherapy and induce more focused destruction of cancer cells, a new study shows.

Radiotherapy used in cancer treatment is a promising treatment method, albeit rather indiscriminate. Indeed, it affects neighbouring healthy tissues and tumours alike. Researchers have thus been exploring the possibilities of using various radio-sensitizers; these nanoscale entities focus the destructive effects of radiotherapy more specifically on tumour cells. In a

▼ Man receiving radiation therapy for cancer treatment. ©Mediteraneo / Fotolia

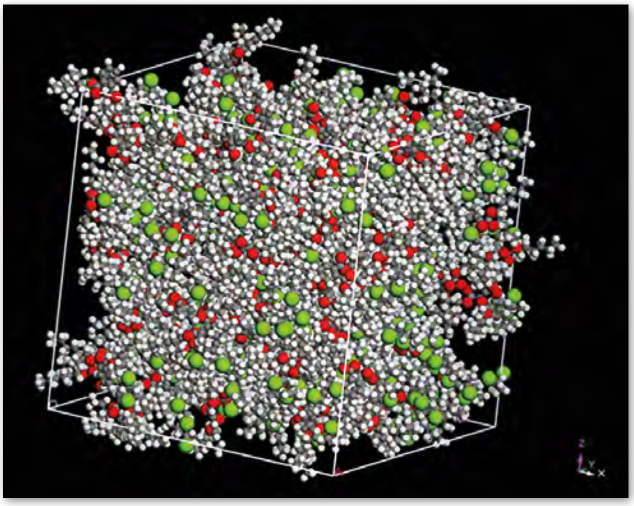
study published recently, the authors have now shown that the production of low-energy electrons by radio-sensitizers made of carbon nanostructures hinges on a key physical mechanism referred to as plasmons—collective excitations of so-called valence electrons; a phenomenon already documented in rare metal sensitizers. This reseach may lead to the development of novel types of sensitizers composed of metallic and carbon-based parts. ■

■ **A. Verkhovtsev**, **S. McKinnon**, **P. de Vera**, **E. Surdutovich**, **S. Guatelli**, **A. V. Korol**, **A. Rosenfeld** and **V. Solov'yov**,
'Comparative analysis of the secondary electron yield from carbon nanoparticles and pure water medium', *Eur. Phys. J. D* **69**, 116 (2015)

SOFT MATTER

A "green" plasticiser makes **my PVC more flexible**

A study of an eco-friendly solvent helping to make PVC plastic more flexible reveals the molecular-level interaction of hydrogen bonds between the two ingredients



▲ A snapshot of the simulated PVC/DOP system at a 30 wt% PVC concentration after minimization. Red, green, yellow and blue spheres represent O, Cl, C, and H atoms, respectively.

What gives plastic objects their flexibility and reduces their brittleness is the concentration of plasticiser. For example, a chemical solvent of the phthalate family called DOP is often used. The trouble is there are concerns that phthalates present health risks. So there is a demand for more alternatives. Now, the authors have examined the effect of using DEHHP, a new eco-friendly plasticiser, used in combination with PVC. For a plasticiser to work, there has to be adequate hydrogen bonding with the plastic. By combining experiments and simulations, the team revealed why the polymer-solvent hydrogen bonding interaction's strength decreases with dilution at a molecular level—which is a phenomenon also observed in the DOP-PVC combination. These findings have been published in the present work. ■

■ **Y. Liu**, **R. Zhang**, **X. Wang**, **P. Sun**, **W. Chen**, **J. Shen** and **G. Xue**,
'Hydrogenation induced deviation of temperature and concentration dependences of polymer-solvent interactions in poly(vinyl chloride) and a new eco-friendly plasticizer', *Eur. Phys. J. Plus* **130**, 116 (2015)

MATHEMATICAL PHYSICS

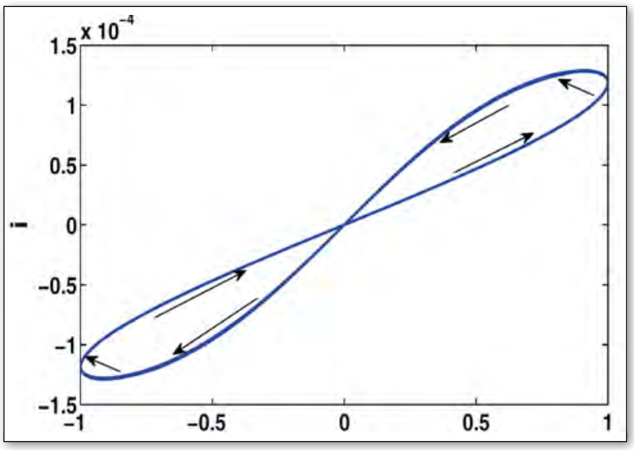
Brain learning simulated via electronic replica memory

A new study shows how a new way of controlling electronic systems endowed with a memory can provide insights into the way associative memories are formed by mimicking synapses.

Scientists are attempting to mimic the memory and learning functions of neurons found in the human brain. To do so, they investigated the electronic equivalent of the synapse, the bridge, making it possible for neurons to communicate with each other. Specifically, they rely on an electronic circuit simulating neural networks using memory resistors. Such devices, dubbed memristor, are well-suited to the task because they display a resistance, which depends on their past states, thus producing a kind of electronic memory. The authors have developed a novel adaptive-control approach for such neural networks, presented in this study. Potential applications are in pattern recognition as well as fields such as associative memories and associative learning. ■

■ **H. Zhao**, **L. Li**, **H. Peng**, **J. Kurths**, **J. Xiao** and **Y. Yang**,
'Anti-synchronization for stochastic memristor-based neural networks with non-modeled dynamics via adaptive control approach, *Eur. Phys. J. B* **88**, 109 (2015)

▼ Typical current-voltage (i-v) characteristics of a memristor; the pinched hysteresis loop is due to the nonlinear relationship between the memristance current and voltage.



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President
C. Rossel
IBM Research GmbH - Zurich Research Laboratory
Science and Technology Dept.
Säumerstrasse 4
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TEL/FAX +41 44 724 8522 or 8238 / +41 44 724 8956
EMAIL rsl@zurich.ibm.com or president@eps.org

Vice-President
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FEMTO-ST / CNRS UMR 6174
15B avenue des Montboucons
F-25030 Besançon cedex, France
TEL/FAX +33 (0)3 81 66 64 94 / +33 (0)3 81 66 64 23
EMAIL john.dudley@univ-fcomte.fr

Secretary
L. Di Ciaccio
University of Savoie and LAPP laboratory
9 Chemin de Bellevue – BP 110
F-74941 Annecy-le-Vieux, France
TEL/FAX +33 (0)4 50 09 16 24 / +33 (0)4 50 27 94 95
EMAIL lucia.di.ciaccio@cern.ch

Treasurer
G. Leuchs
Max-Planck-Institut für die Physik des Lichts
Günther-Scharowsky-Straße 1/ Bau 24
D-91058 Erlangen, Germany
TEL +49 09131 - 6877 503
EMAIL leuchs@physik.uni-erlangen.de

Executive Committee Members
A. Bracco
Universita degli Studi di Milano - Dipartimento di Fisica, LITA
Via Celoria 16
I-20133 Milano, Italy
TEL/FAX +39 02503 17252 / +39 02503 17487
EMAIL Angela.Bracco@mi.infn.it

A. T. Friberg
University of Eastern Finland
Dept. of Physics and Mathematic - P. O. Box 111
FI- 80101 Joensuu, Finland
TEL + 358 503 591 238
EMAIL ari.friberg@uef.fi

Z. Fülöp
ATOMKI - POB 51 - Debrecen
HU-4001 Debrecen, Hungary
TEL +36-52-509-200
EMAIL fulop@atomki.hu

C. Hidalgo
Laboratorio Nacional de Fusion Euratom-Ciemat
Av. Complutense 22
ES-28040 Madrid, Spain
TEL +34 91 3466498
EMAIL carlos.hidalgo@ciemat.es

J. Hough
Kelvin Building - School of Physics & Astronomy
University of Glasgow
UK-Glasgow G12 8QQ, Scotland, United Kingdom
TEL/FAX + 44 (0)141 330 4706 / + 44 (0)141 330 6833
EMAIL James.Hough@glasgow.ac.uk

T. Müller
Institut fuer Experimentelle Kernphysik
Karlsruher Institut fuer Technologie KIT
Wolfgang-Gaedestrasse 1
D-76131 Karlsruhe, Germany
TEL +49-721-608-43524, 0049-721-608-25968
EMAIL Thomas.Mueller@kit.edu

E. Rachlew
KTH, Department of Physics
Roslagstullsbacken 21
SE- 10691 Stockholm, Sweden
TEL +46 8 5537 8112
EMAIL rachlew@atom.kth.se

M. Reiffers
University of Presov
Faculty FHPV
Ul. 17 novembra č. 1
SK- 08116 Presov, Slovakia
TEL/FAX +421 (0)51 75 70 604 / +421 (0)51 77 25 547
EMAIL reiffers@saske.sk

S. Sotiriou
D. Panageas Str.
Pallini, Attika
GR-15351 Pallini, Attika, Greece
TEL +30 2108176797
EMAIL sotiriou@ea.gr

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European Physical Society
6 rue des Frères Lumière
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TEL/FAX + 33 389 329 440 / + 33 389 329 449
WEBSITE www.eps.org

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O. Fornari • **EMAIL** o.fornari@eps.org

Graphic designer
X. de Araujo • **EMAIL** x.dearaujo@eps.org

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A. Ouarab • **EMAIL** a.ouarab@eps.org

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P. Padovani • **EMAIL** p.padovani@eps.org

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F. Burr • **EMAIL** burr@epletters.net

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Chief Executive Officer
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EDP Sciences
17 avenue du Hoggar - BP 112 • PA de Courtaboeuf
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Publishing Director
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R. Galvao
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Cidade Universitaria - Institute of Physics
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TEL + 55 (11) 30917069
EMAIL rgalvao@if.usp.br

C. Hirlimann
IPCMS / DSI
23 rue du Lœss - BP 43
F- 67034 Strasbourg, France
TEL +33 (0)3 88 10 71 39 / +33 (0)3 88 10 72 48
EMAIL Charles.Hirlimann@ipcms.unistra.fr

G. Rosner
FAIR
Alfred-Nobel-Str. 53
DE-55124 Mainz, Germany
TEL +49 6131474880
EMAIL guenther.rosner@fair-center.eu

A. Weis
Université de Fribourg
Département de Physique - Off. 1.68
Chemin du Musée 3
CH-1700 Fribourg, Switzerland
TEL/FAX +41 26 300 9030 / +41 26 300 9631
EMAIL antoine.weis@unifr.ch

V. Zadkov
International Laser Center
M. V. Lomonosov Moscow State University
RU-119991 Moscow, Russian Federation
TEL/FAX +7 (495) 939 23 71 / +7 (495) 932 98 02
EMAIL zadkov@phys.msu.ru

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Piazzale Aldo Moro, 2
IT-00186 Roma, Italy
TEL/FAX +39 06 6840031 / +39 06 68307924
EMAIL speranza.falciano@presid.infn.it

M. Krisch
ESRF – The European Synchrotron
71 Avenue des Martyrs
F-38043 Grenoble, France
TEL/FAX +33 (0)47688 2374/ +33 (0)47688 2160
EMAIL krisch@esrf.fr

M. Meedom Nielsen
Technical University of Denmark
Department of Physics - Building 307
253 Fysikvej
DK-2800 Kgs. Lyngby, Denmark
TEL +45 253226
EMAIL mmee@fysik.dtu.dk

E. Puppin
Politecnico di Milano - Dipartimento di Fisica
Piazza L. Da Vinci, 32
IT-20133 Milano, Italy
TEL/FAX +39 02 2399 6138 / +39 02 2399 6126
EMAIL ezio.puppin@polimi.it

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Physics Department - CERN
CH-1211 Geneva 23, Switzerland
TEL/FAX +41 22 767 6447 / +41 22 766 9519
EMAIL rudiger.voss@cern.ch

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4 Place Jussieu
F-75252 Paris Cedex, France
TEL +33 (0)144 274 518
EMAIL dominique.vernhet@insp.jussieu.fr

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99 Avenue J.-B. Clément
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EMAIL martial.ducloy@univ-paris13.fr

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University of Savoie and LAPP laboratory
9 Chemin de Bellevue – BP 110
F-74941 Annecy-le-Vieux, France
TEL/FAX +33 (0)4 50 09 16 24 / +33 (0)4 50 27 94 95
EMAIL lucia.di.ciaccio@cern.ch

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IT-80126 Napoli, Italy
TEL/FAX +39-081-676851 / +39-081-676346
EMAIL antigone.marino@na.infn.it

DIVISIONS & SECTIONS

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CHAIR D. Vernhet
Institut des Nanosciences de Paris - UPMC
4 Place Jussieu
F-75252 Paris Cedex, France
TEL +33 (0)14427 4518
EMAIL dominique.vernhet@insp.jussieu.fr

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Department Physics and Mathematics
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Cottingham Road
Hull HU6 7RX, United Kingdom
TEL +44 (0)1482 465826
EMAIL D.Sands@hull.ac.uk

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CHAIR H. Fischer
Institut für Meteorologie & Klimaforschung-IMK
Forschungszentrum Karlsruhe GmbH
Hermann-von-Helmholtz-Platz 1
D-76344 Eggenstein-Leopoldshafen, Germany
TEL/FAX + 49 7247 82 3643 / + 49 7247 4742
EMAIL herbert.fischer@imk.fzk.de

High Energy & Particle Physics

CHAIR Y. Sirois
Laboratoire Leprince-Ringuet - École Polytechnique
Avenue Chasles
F-91128 Palaiseau, France
TEL +33 (0)16933 5566
EMAIL yves.sirois@in2p3.fr

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CHAIR I. J. D. Macgregor
School of Physics and Astronomy
University of Glasgow - Kelvin Building
Glasgow G12 8QQ, United Kingdom
TEL +44 (0)1413 304468
EMAIL douglas.macgregor@glasgow.ac.uk

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CHAIR F. Ritort
University of Barcelona
Departament de Fisica Fondamental
Avinguda Diagonal 647
ES-08028 Barcelona, Spain
TEL + 34-934035869 / +34-934021149
EMAIL ritort@ffn.ub.es

Plasma Physics

CHAIR S. Jacquemot
LULI - École Polytechnique
F-91128 Palaiseau Cedex, France
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EMAIL sylvie.jacquemot@polytechnique.fr

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F-91297 Arpajon, France
TEL +33169267376
EMAIL luc.berge@cea.fr

Solar Physics

CHAIR M. K. Georgoulis
RCAAM of the Academy of Athens
4 Soranou Efesiou Street
GR- 11527 Athens, Greece
TEL/FAX +30 210 6597103 / +30 210 6597602
EMAIL manolis.georgoulis@Academyofathens.gr

Statistical & Nonlinear Physics

CHAIR J. Luczka
Faculty of Mathematics, Physics and Chemistry
University of Silesia
ul. Bankowa 14
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ROSETTA'S JOURNEY TO COMET CHURYUMOV-GERASIMENKO

AN ENCOUNTER TO EXPLORE THE BEGINNING OF THE SOLAR SYSTEM

H. Balsiger[1] and G. Schwehm[2] – DOI: 10.1051/epn/2015401
[1] Physikalisches Institut University of Bern, Bern – [2] European Space Agency (retired)

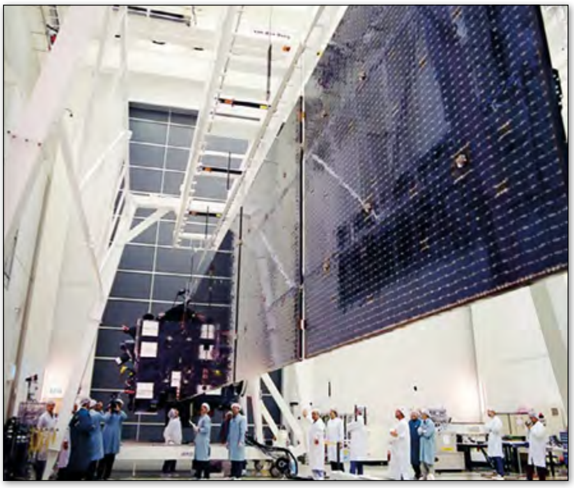
On 6 August 2014, finally the big day had come: ESA's Rosetta mission went into an orbit around comet 67P/ Churyumov-Gerasimenko to start its actual science mission. More than ten years after the launch on 2 March 2004 and more than 6 billion km cruise, the science phase, for which a large number of scientists had worked since the mid-nineties of the last century, did start.

Actually, the preparation work for the mission had already started in 1985, originally perceived as a Comet-Nucleus Sample-Return mission, the fourth cornerstone in ESA's new long- term programme Horizon 2000 [1] jointly with NASA.

However, in the aftermath of the explosion of the shuttle Challenger on 28 January, NASA had to restructure their programme and Europe had to define a mission that could be done by ESA alone. Rosetta re-emerged as a comet rendez-vous mission with asteroid fly-bys: 'If we cannot bring back material out of a comet nucleus to our laboratories on Earth, we will bring the laboratory to the comet' became the new slogan.

In 2002 spacecraft and payload were ready (Fig. 1) and tested for the launch in early 2003 with the Ariane 5 from Kourou to comet 46P/Wirtanen. The spacecraft was already in Kourou and fueled, when the improved version of the Ariane 5 exploded on her maiden flight, shortly after lift off just before Christmas 2002. As a consequence the launcher was grounded until the problem had been identified and resolved.

In a very short time an alternative mission scenario was found: the next opportunity with an Ariane 5 was the mission to comet 67P/Churyumov-Gerasimenko with a launch in March 2004.



▸ FIG. 1: The flight model of the Rosetta spacecraft during a deployment test of the solar panels (Courtesy ESA)

The Mission

On 2 March 2004 the journey to the comet started. It took more than ten years, with three Earth gravity assists and one at Mars to gain sufficient orbital energy, to get Rosetta to its rendez-vous with 67P/ Churyumov-Gerasimenko.

On its long journey the mission returned the first exciting science from the two asteroid flybys at 2867 Steins in September 2008 and at 21 Lutetia in July 2010, respectively.

Mid 2011 Rosetta was put into a 30 months hibernation as, despite the huge solar arrays, at a distance beyond 4 a.u. from the Sun, not enough energy could be generated to operate the spacecraft under all conditions.

On 20 January 2014 Rosetta woke up by its internal wake-up call and the most important phase of its mission was about to begin. On 6 August 2014 it entered the orbit around the nucleus at a distance of 100 km. An extensive science and reconnaissance phase started with the initial prime objective to select a landing site for its surface science laboratory Philae.

The first soft landing on a comet nucleus occurred on 12 November, 2014. At 8:35 UTC the Lander was released with a relative velocity $\Delta v = 0.1876$ m/s about 20.5 km from the nucleus surface. After 6:59:04 hours of ballistic descent Philae landed on the comet at 15:34:03.97 UTC with a touchdown speed relative to the surface of about 1 m/s. Since the anchor harpoons did not fire upon touchdown and the hold-down thrust of the cold-gas system did not work either, the lander bounced several times until it came to rest after 1:57 hours of ballistic flight at its final landing site.

Science goals

Already late in the 17th century Edmond Halley and Isaac Newton had independently proposed that comets may have played an important role in the development of planets [2]. Whereas Halley thought that a collision with a comet could have caused a biblical flood on Earth, Newton proposed that the vapours from comet tails could have been collected by planetary atmospheres, thereby delivering the water necessary for terrestrial life. These were quite bold suggestions if one considers that, at the time, nobody knew the chemical composition or the structure of comets. Later, after detection of carbon-bearing radicals in the spectra of comets, it was speculated that their parent molecules could have been the source of the pre-biotical chemistry that ultimately resulted in the development of life on Earth.

The two open questions, origin of water and life on Earth, are still drivers for comet science together with the question how the solar system has been formed and developed. That comets play an important role in this basic question is taken for granted. The fact that they represent the most primitive material found in the solar system and hence are witnesses of the very early history has already been demonstrated by composition measurements during the Giotto mission [3]. The role of comets in the formation history of the solar system has been the subject of numerous models and speculations. Of the two families, the Comets in the Oort Cloud and those in the Kuiper Belt, at least the latter formed beyond the orbit of Neptune at very low temperatures. They are considered to originate from the family of icy planetesimals that have contributed to the volatile inventory of the planets, including the terrestrial planets. Impacts of comets must have brought some water and other volatiles to the Earth and the inner planets. However the magnitude of their contribution is debated.

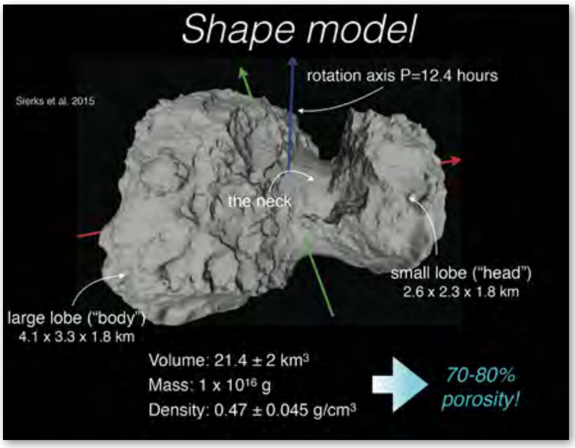
The Rosetta mission [4] to 67P/Churyumov-Gerasimenko, a "Jupiter-family comet" (originating in the Kuiper belt) has the prime goal to solve as many of the basic open questions as possible by accompanying the comet from aphel through perihel and monitoring its development and activity. For this purpose a suite of twelve sophisticated instruments covering all conceivable aspects was selected for Rosetta's orbiter. Ten more instruments on the lander Philae are characterizing structure and composition of the surface of the nucleus.

First results

The first results of the measurments in October/November 2014 are already very exciting and in part also quite surprising. Due to the fact that the comet's activity was substantial and the search of the Philae landing site was performed in a bound orbit of 10 km altitude, a first science campaign could be carried out, which has led to a Special Issue of Science with unprecedented details of a comet nucleus [5]. We will here give a summary of these first results.

Shape, Density and Surface Structure

Already during approach it became clear that this comet has a funny shape and a wealth of surface structure elements which are not easily explained, considering its low gravity forces. Its duck-like shape (Fig. 2) raises the question whether the two lobes represent a contact-binary or a single body where a gap has evolved via mass loss. The duck rotates in 12 hours around the axis shown in Fig. 2, and this axis appears to be stable (<0.3°). The total volume is currently estimated to be 21.4 ± 2.0 km^3, whereby the uncertainty reflects the fact that the entire nucleus has not yet been seen). This leads to a mean density of 470 ± 45 kg/m^3. Assuming that this density is homogeneous, a high porosity of 70 – 80% is implied.

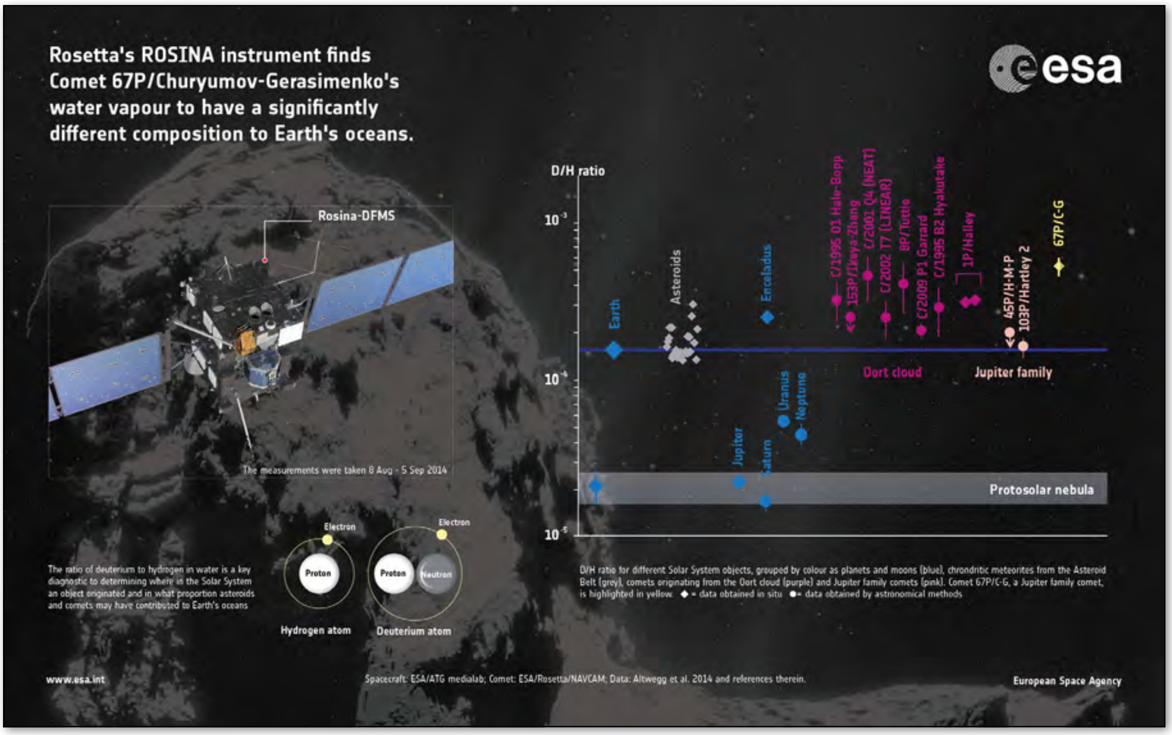


◂ **FIG. 2:** Stereophotogrammetric shape model of the nucleus, supplemented with vital statistics (5) (Courtesy ESA)

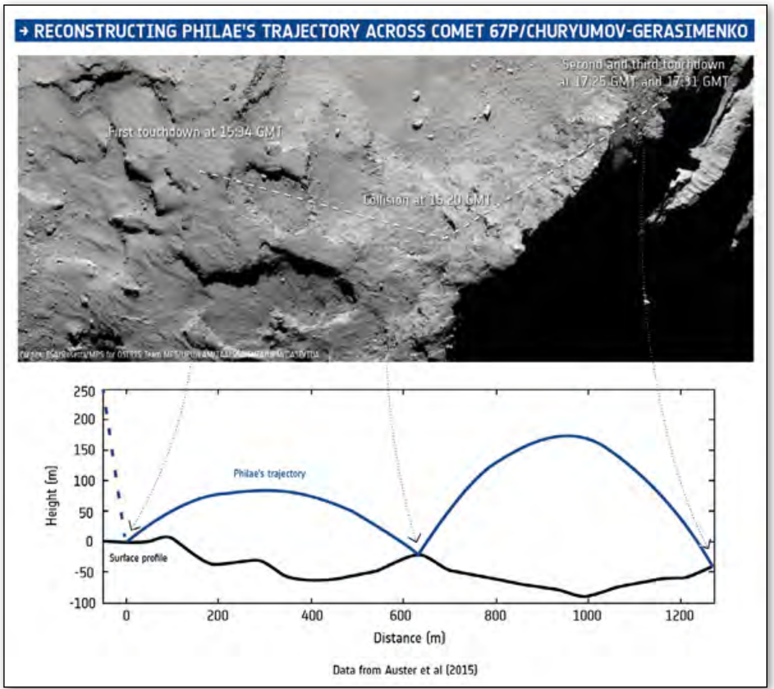
High resolution pictures (0.8 m/Pixel) reveal an amazing variety of surface textures. Cliffs as high as 900 m, several hundred meters long fractures, circular pits and boulders up to several meters are just some of the impressive features. Their origin can result from the thermal shock by the very large variation in temperatures (150 K) seen by comet nuclei or collapse of internal reservoirs of volatiles. But only the development during approach of the Sun will give more evidence on the mechanisms in place.

Composition of nucleus and coma

Remote-sensing instruments have measured the progression of the H_2O production rate. It has developed from 0.3 kg/s in June 2014 to 1.2 kg/s in late August. With an albedo of 0.060, the comet is very dark. Broad absorption features taken in radiation with low micrometer wavelengths that are present across the entire illuminated surface, are compatible with



◂ **FIG. 3:** The isotopic ratio between deuterium and hydrogen (D/H) measured after the rendez-vous with comet 67P/Churyumov-Gerasimenko in comparison with that of other bodies belonging to the solar system, including our Earth (Courtesy ESA)



▲ **FIG. 4:** A reconstruction of the trajectory by the lander 'Philae' after first contact with the comet (Courtesy ESA)

opaque minerals associated with nonvolatile macromolecular materials (carbon-hydrogen and/or oxygen-hydrogen groups). The coma as monitored by a total gas pressure gage and two mass spectrometers shows substantial time variability and heterogeneity in total gas production and composition, both diurnal and seasonal. The main constituents are H_2O, CO and CO_2 in variable proportions, but a large zoo of molecules, containing various combinations of H, C, O, N, S and P atoms (as they were partially already known from the Giotto mission) have been identified. For the first time N_2 could be measured and as the first of the noble gases Ar was clearly identified. The D/H ratio in water was found to be three times as high as in terrestrial sea-water (Fig. 3). The comet's water production, at this time of the mission, is not yet fully developed, and the coma may not yet be representative for the inner of the nucleus. Hence firm conclusions still have to wait for the next phase of the mission. Nevertheless the clear identification and relative abundances of the very volatile N_2 and Ar strongly suggest that cometary grains formed at very low temperatures (below 30 K), and the D/H ratio together with the relatively high abundance of Ar tell us that comets of the type of Churyumov-Gerasimenko were not the main providers of the Earth water and volatiles.

Surface science by Philae

After Philae had come to rest, the attempt to take material out of the nucleus with the drill and hammering of MUPUS into the surface failed, most probably due to the unexpected hardness of the upper surface. As predicted, Philae ceased operations after about 60 hrs, when the primary battery was depleted. Analysis of the data, taken during this period, will soon appear in a second Special Issue of Science. The unexpected flight provided a unique opportunity for a joint measurement of the magnetometers on the orbiter and the one on the Lander. Not only could they determine that the nucleus was not magnetized [6], but the measurements helped to reconstruct Philae's trajectory across the surface, including the precise timing of the touchdown points (Fig. 4).

Already this first part of the mission has demonstrated the potential of the payload to achieve its ambitious goals. Its continuation while the comet fully develops its coma promises substantial progress in understanding these messengers from the Solar System's genesis. ■

About the Authors

Hans Balsiger was Professor of Physics at the University of Bern (1984-2003). He was PI and CoI on several space missions of ESA and NASA, in particular PI on Giotto to Comet Halley and on Rosetta to Comet Churyumov-Gerasimenko. He chaired the Solar System Working Group and the Space Science Advisory Committee of ESA and was chairman of ESA's Space Science Program Committee SPC (1996-1999). He is member of the Academia Europea and of the International Academy of Astronautics IAA, from which he received the Basic Science Award 2004. For his contribution to Apollo 11 he received the NASA Apollo Achievement Award.

Gerhard Schwehm has been the Rosetta Study and Project Scientist for the mission since the start of the mission studies until 2006, in addition he led Rosetta as Mission Manager from 2004 until 2013. He has also been Deputy Project Scientist for the Giotto mission (1985-1988) and subsequently Project Scientist for the Giotto Extended Mission that passed by comet Grigg-Skjellerup in July 1992.

He headed the Planetary Missions Division in ESA's Science Directorate (2002-2007) in ESTEC, Noordwijk, and spent four years at ESAC, Madrid, as Head of the Solar System Science Operations Division (2007-2011). He retired from ESA in March 2014 but remained involved in the Rosetta Mission as an Advisor.

He has been a member of the Advisory Board of the Ernst-Mach-Institute of the Fraunhofer Society and is a Member of the International Academy of Astronautics and its "Basic Science Commission".

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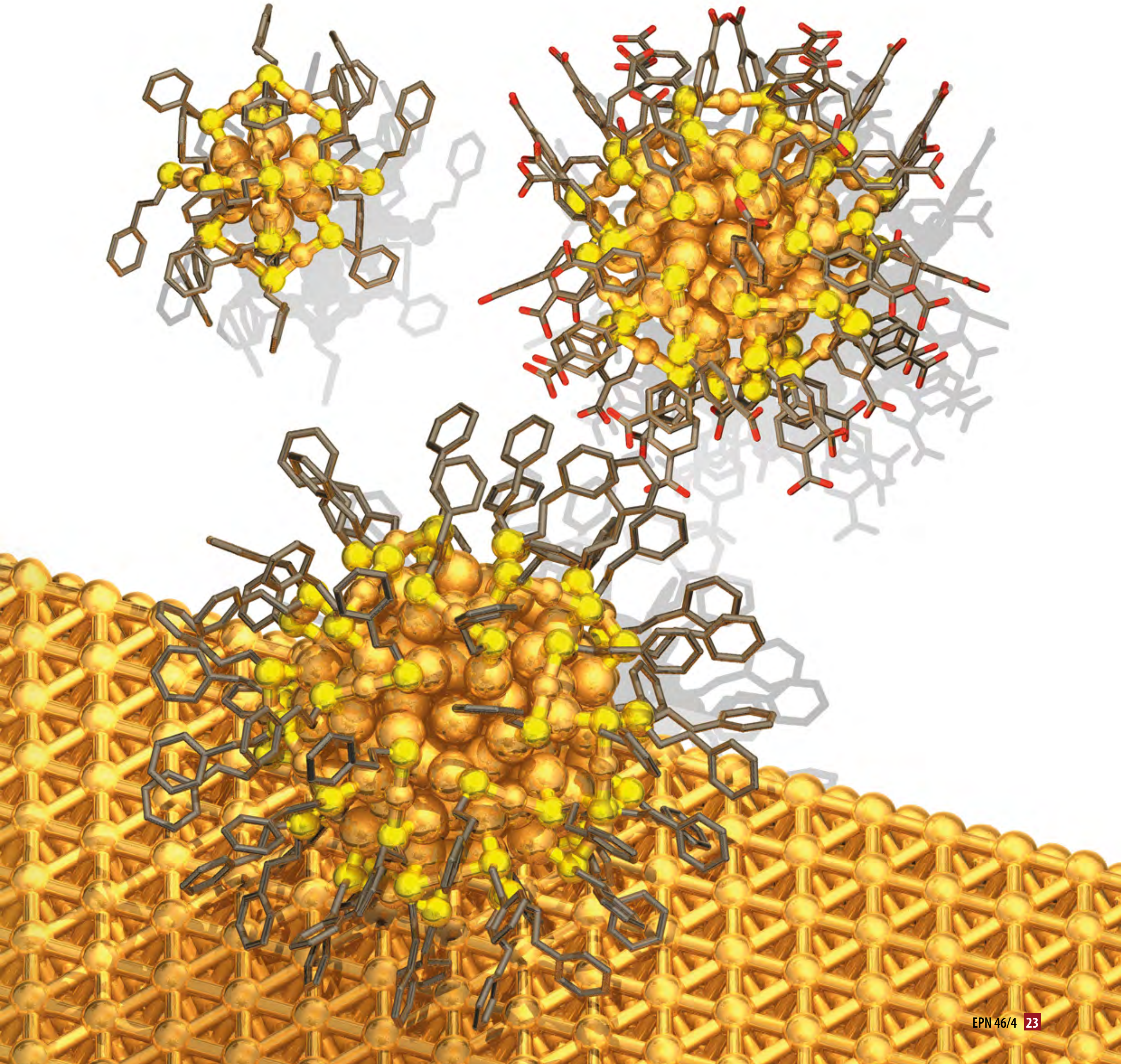
HOW MANY GOLD ATOMS MAKE GOLD METAL?

Sami Malola and Hannu Häkkinen – DOI: 10.1051/epn/2015402

Departments of Physics and Chemistry, Nanoscience Center – University of Jyväskylä, FI-40014 Jyväskylä, Finland

It is well known that a piece of gold is an excellent metal: it conducts heat and electricity, it is malleable to work out for jewellery or thin coatings, and it has the characteristic golden colour. How do these everyday properties – familiar from our macroscopic world – change when a nanometre-size chunk of gold contains only 100, 200 or 300 atoms?



These simple but fundamental questions can now be answered due to recent developments in synthesis, characterization and theory of finely dispersed, ambient-stable gold nanoparticles with atom-precise composition and structure.

Quantum size effects

Every undergraduate textbook of solid state physics contains a discussion of a "perfect theorist's metal": the three-dimensional electron gas model for a monovalent metal. When electrons are confined in a small volume, the solutions of the Schrödinger equation describing their possible quantum states correspond to discrete energies (Fig. 1). The quantum states are filled according to the Pauli principle up to the highest possible energy, called the Fermi energy E_F. When the number of electrons increases, the average spacing Δ between the quantum states decreases. In the limit when Δ approaches zero (*e.g.*, $\Delta < 25$ meV which is the thermal energy at room temperature), minute external stimuli create immediate response of the electrons and the system becomes "metallic" in nature. For a macroscopic piece of metal $\Delta = 0$ (Fig. 1) which makes the material responsive to extremely small external electromagnetic fields and/or to temperature.

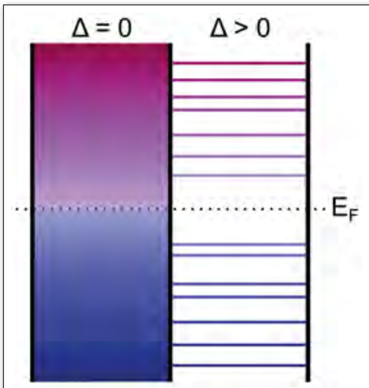
The critical nanoparticle size, where the crossover between non-metallic and metallic behaviour happens, can be estimated from the following simple consideration. The density of electron states $D(E)$ of a three-dimensional electron gas follows a square-root behaviour as a function of the electron energy E which leads to a simple estimate of D at the Fermi energy

$$D(E_F)=\frac{3N}{2E_F} \quad (1)$$

for N electrons. The mean spacing Δ of electron energy levels at E_F is then

$$\Delta=1/D(E_F)=\frac{2E_F}{3N} \quad (2)$$

Clearly, Δ approaches zero as N grows. Plugging the Fermi energy of gold metal (about 5.5 eV) in Eq. (2) yields $N > 150$, or in terms of the nanoparticle diameter d, $d > 1.7$ nm, for the crossover where $\Delta < 25$ meV.



◄ **FIG. 1:** Electron energy levels form a continuum in a macroscopic metal (left), with no energy gap ($\Delta = 0$) at the Fermi energy E_F whereas the states have discrete energies in a nanometre-sized particle (right) with a finite energy gap at E_F.

Breakthroughs in synthesis and structural characterization of gold nanoparticles

Small pure gold and gold-containing particles have been used in glass-making and in art since ancient times [1]. Finely-dispersed gold particles suspended in solutions ("colloidal gold") have been known since the days of Michael Faraday, who marvelled at their beautiful ruby colour that results from their strong absorption of light around the wave length of 520 nm [2]. Faraday himself described the particles "very minute in their dimension"; later work by Turkevich concluded that Faraday's gold particles were indeed in the nanometre-range with average diameter of 6 ± 2 nm [2], *i.e.*, well in the metallic side of the crossover region discussed above.

In 1994-1995 Brust, Schiffrin and collaborators published recipes [3] for a synthesis that gives a control of the size of gold nanoparticles in the important 1 – 3 nm region, and these methods have been used widely ever since. The methods produce ambient-stable particles capped at the surface by thiols, that are organic molecules containing a sulphur headgroup binding to gold.

Since late 1990's, several stable gold nanoparticle sizes were synthesized. However, it took until 2007 before the first atomic structure of such nanoparticle was solved via X-ray diffraction. This was achieved by the group of R.D. Kornberg from a sample that contained single crystals made out of identical nanoparticles – a method completely analogous to what was used in early 1900's to discover the atomic structures of solids made out of ordinary elements. The particle has a chemical formula of $Au_{102}(pMBA)_{44}$, *i.e.*, 102 gold atoms and 44 para mercapto benzoic acid (pMBA) molecules at the surface [4]. Special to this structure and to many structures of other gold nanoparticles that have been solved since 2007 is the existence of gold atoms in two distinct parts of the nanoparticle: in the compact all-gold core and mixed with thiols in the ligand shell (Fig. 2). This chemical structure was predicted theoretically in 2006 [5]. Interestingly, a very similar mixed metal-thiol overlayer forms when thiol molecules self-assemble on a macroscopic flat gold surface and seems thus to be a universal structural feature of the gold-sulfur interface [6].

Small gold nanoparticle: Molecule or metal?

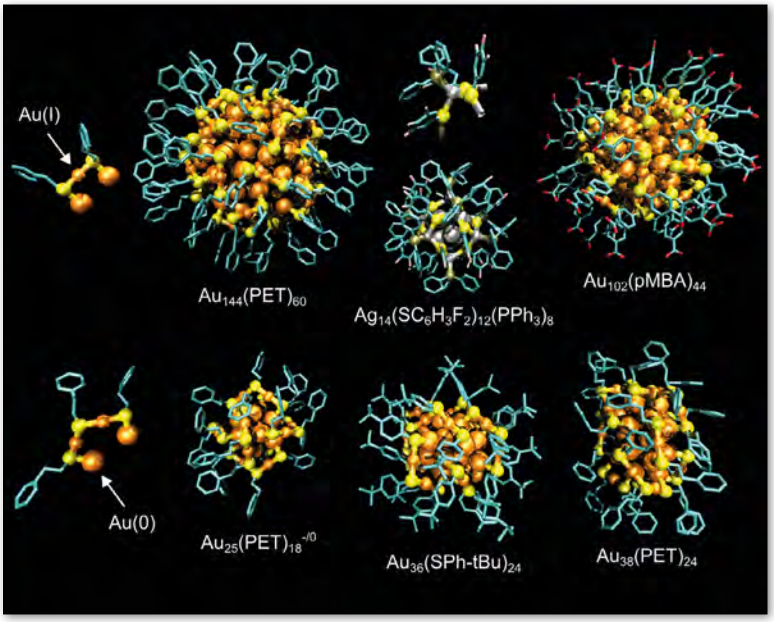
Macroscopic metals are good conductors for energy in many forms such as electricity and heat. In the nanoscale, "conducting" properties can be studied by pumping energy into a nanostructure and monitoring how it is transferred to the environment. Recent spectroscopic measurements at the Nanoscience Center in the University of Jyväskylä have shed light onto this question and shown how two different, but almost same-size nanoparticles dissipate energy in drastically different ways. One can be defined as a "molecule", the other one as "metal" [7a,b].

Two nanoparticles, $Au_{102}(pMBA)_{44}$ and $Au_{144}(PET)_{60}$, that are close in size and composition (Fig. 2), were recently studied by shining visible or infrared light into the nanoparticle solution and monitoring how fast the excitation energy transfers from the particles to the solution. The energy of the photons is initially absorbed by the metal centre of the particle, and then transferred to the solution through the layer of the ligand molecules. The experiments yielded time constants for this energy transfer process by monitoring how the transient absorption by the ligand molecules changes in time. When the absorbed energy is dissipated through the ligand molecules to the surrounding solvent, shifts in typical eigenmodes for ligand vibrations take place. This generates a "hot band", *i.e.*, shift of the vibration mode to a slightly lower frequency due to increased anharmonicity, and "bleach" of the initial frequency at the thermal equilibrium.

Temporal data of the observed hot band and bleach dynamics of $Au_{102}(pMBA)_{44}$ and $Au_{144}(PET)_{60}$ nanoparticles is shown in Figure 3. The slightly larger nanoparticle $Au_{144}(PET)_{60}$ exhibits a fast thermalization in about 50 – 60 ps timescale when both hot and bleach bands have disappeared. This agrees with the expected behaviour for a metallic system and is in fact a manifestation of rapid "heat conductance" on nanoscale. Other recent spectroscopy experiments from other laboratories agree with this result [7c]. Theoretical calculations on the electronic structure of this nanoparticle also implicate metallic behaviour, *i.e.*, rather continuous density of available electron states close to the Fermi energy.

The excitation dynamics of the smaller $Au_{102}(pMBA)_{44}$ nanoparticle is drastically different. The decay dynamics has several different time scales, and particularly interesting are a medium-time scale of about 84 ps and an extremely long component with an estimated decay time of 3.5 ns for the hot band dynamics. These interesting time scales could be explained by help of theoretical calculations taking into account the electronic structure of the nanoparticle.

The excitation takes the system from its initial spin-singlet ground state S_0 to a highly excited state over the fundamental energy gap beyond the first excited singlet state S_1 (Fig. 3). The excitation can decay by rapid electronic relaxation down to the first excited singlet state or by crossing over to a manifold of magnetic states such as the lowest energy triplet state T1 on a time scale of about 1 ps. The magnetic state is transient with a decay time to the singlet ground state of about 84 ps. The long decay time, 3.5 ns, is assigned to the transition from S_1 back to S_0 over the fundamental energy gap $E(S_1) - E(S_0)$. This long decay time is a direct manifestation of the existence of a sizable fundamental gap, which has been determined to be about 0.5 eV by earlier theory and spectroscopic measurements, [7d] and thus confirms that this nanoparticle behaves like a huge gold-rich molecule. It is quite remarkable that both basic types of nanoparticle behaviour are found in these gold nanoparticles that differ just by a few tens of gold atoms.

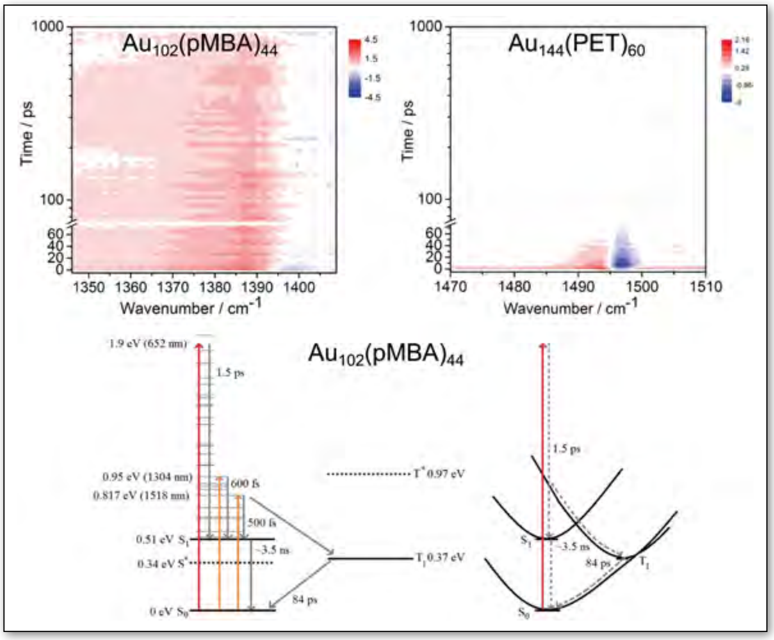


▲ **FIG. 2:** Assembly of typical molecular structure found in nanometre-size gold and silver nanoparticles. Gold: orange, silver: grey, sulphur: yellow, carbon: cyan, oxygen: red. The particle fragments on the left demonstrate the existence of gold in "metallic" Au(0) and "oxidised" Au(I) forms. PET = phenylethylthiol, Ph = phenyl, pMBA = para mercapto benzoic acid and tBu = tert-butyl.

Collective electronic excitations and development of the localized surface plasmon

Faraday's liquid samples containing "very minute" gold nanoparticles had a beautiful ruby colour due to an interesting collective excitation of the nanoparticles' electron cloud, called a surface plasmon resonance (LSPR). It forms when the energy of the incoming light photon enhances the natural oscillations of the freely moving electrons of a metal. In metal nanoparticles this leads to density changes of the electron cloud near the metal surface. The resonance energy of this oscillation is well known for gold corresponding to a wave length of light close to 520 nm. The LSPR phenomenon shows up when the electronic properties of the nanoparticle become similar to macroscopic metals and is thus considered as the sign of emergence of metallic properties when nanoparticles grow in size.

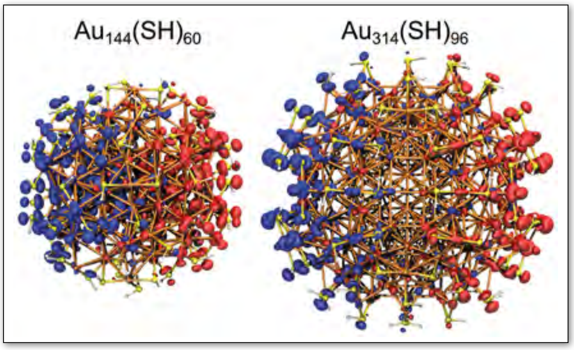
Recent theoretical work in our laboratory has established that the "birth" of the LSPR takes place when the metal core of gold nanoparticles grows from 1.5 nm to 2 nm [8]. The response of two model nanoparticles ($Au_{144}(SR)_{60}$ and $Au_{314}(SR)_{96}$ with metal cores of 1.5 nm and 2 nm, respectively) to light was calculated. The larger particle shows a strong absorption of light at around 540 nm, close enough to the limit for large colloidal gold particles. Analysis of the oscillations of the electron cloud (Fig. 4) shows that they are localized at the surface of the particle. The smaller particle shows a collective dipole-like oscillation as well but it is not localized at the surface. When the excitation is localized at the surface, the transition dipole moment increases, thus making the absorption stronger. These differences demonstrate for the first time a plausible mechanism of a developing surface plasmon from atomic-scale calculations.



▲ **FIG. 3: Top:** Comparison of the transient absorption spectra of $Au_{102}(pMBA)_{44}$ (left) and $Au_{144}(PET)_{60}$ (right) obtained with excitation at 652 nm (visible light). The "hot bands" are shown in red and the "bleach bands" in blue. **Bottom:** Schematic energy diagram that explains the observed long lifetimes in $Au_{102}(pMBA)_{44}$ after excitation by visible light or near-infrared radiation (for details see the text). Reproduced by permission from ref. [7a]. Copyright 2015 American Chemical Society.

Prospects

The field of molecularly precise noble metal nanoparticles is still in a discovery phase. Due to increased interest in this field, new ambient-stable particles and their atomic structures are reported several times every year, not only on gold but also on silver and intermetallic particles containing gold, silver and copper. Biological imaging techniques have yielded new recent breakthroughs for nanoparticle structural characterization [9].



▶ **FIG. 4:** Visualisation of the response of the electron "cloud" to an excitation by light around 540 nm in two model gold nanoparticles $Au_{144}(SH)_{60}$ and $Au_{314}(SH)_{96}$. The metal cores of these particles have diameters of 1.5 nm and 2 nm, respectively. Red and blue areas depict the oscillatory changes in the electron density under the excitation.

All this activity will provide an excellent set of realistic data revising our understanding on principles how matter, atoms and molecules, assemble from molecular to more macroscopic architectures in the nanoscale. Aside from being of great fundamental interest, ambient-stable, atomically precise noble metal nanoparticles of 1 – 3 nm size are still little-explored, but promising materials for several applications for instance in the field catalysis, biological imaging and sensing or even medical use [10,11]. ■

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The authors wish to thank both the in-house and external collaborators in refs. 7 – 10 contributing to synthesis, characterization and application of ligand-stabilized gold nanoparticles.

About the Authors

Sami Malola (top) and **Hannu Häkkinen** (bottom) are computational physicists working at the Nanoscience Center (NSC) in the University of Jyväskylä. Häkkinen is a professor in computational nanoscience since 2007 and the Scientific Director of the NSC since 2012. His research interests include electronic, optical, magnetic, chemical and catalytic properties of bare, supported, and ligand-stabilized metal nanoparticles, electrical conductivity of molecule-metal interfaces in nanostructures and structural and chemical properties of metal nanoparticle / bionanoparticle hybrids. Malola is a senior scientist working in the Häkkinen group.

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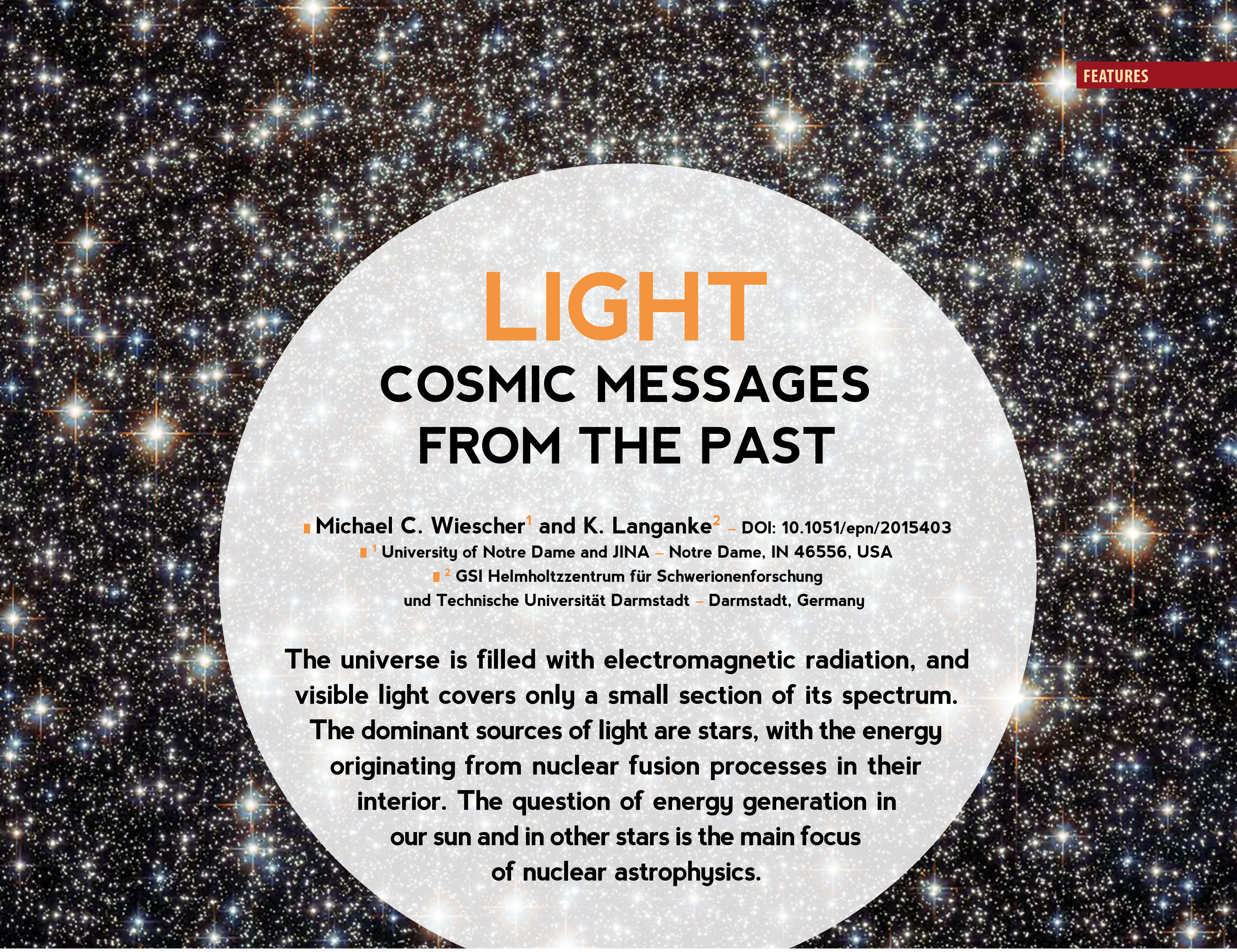


LIGHT
COSMIC MESSAGES FROM THE PAST

Michael C. Wiescher[1] and K. Langanke[2] – DOI: 10.1051/epn/2015403
[1] University of Notre Dame and JINA – Notre Dame, IN 46556, USA
[2] GSI Helmholtzzentrum für Schwerionenforschung und Technische Universität Darmstadt – Darmstadt, Germany

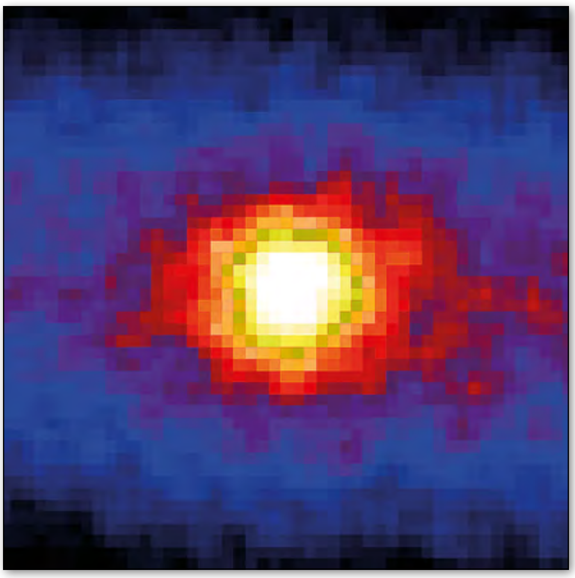
The universe is filled with electromagnetic radiation, and visible light covers only a small section of its spectrum. The dominant sources of light are stars, with the energy originating from nuclear fusion processes in their interior. The question of energy generation in our sun and in other stars is the main focus of nuclear astrophysics.

▲ The crammed centre of Messier 22. This image shows the centre of the globular cluster Messier 22, also known as M22, as observed by the NASA/ESA Hubble Space Telescope. Globular clusters are spherical collections of densely packed stars, relics of the early years of the Universe, with ages of typically 12 to 13 billion years. © ESA/Hubble & NASA

The field of nuclear astrophysics addresses the nature of the nuclear reactions, and reaction sequences that generate stellar energy and drive the evolution of stellar life from birth to death. The field also addresses the origin of the elements, during the evolution of our universe from its beginning 13.7 billion years ago to the present time. Nuclear reaction processes represent the engine for the evolution of stars and the chemical evolution of our universe. The light from distant stellar objects provides us with the information that tests the theories and guides the experiments of the nuclear astrophysics community. Thus light observed today allows us to look back into the past and to unravel the evolution of our universe. In this article we provide an overview of selected astrophysical sources of light and what they tell us about the history of our universe.

Light from our Sun

Without light from our sun and far distant stars, the earth would be cold and dark. Our sun provides the light and heat that drive the evolution of our planet, it is the key to climate evolution, and provides the energy for most of the geo-chemical and bio-chemical processes that make earth a habitable planet. Light is radiated from the outer atmosphere – the photosphere – of the sun, having an average temperature of about 5500°C. The energy heating the solar surface is, however, generated deep in the solar interior through nuclear fusion and is being transported by radiative and convective processes to the solar surface. The light reaches earth with the characteristic Planck blackbody distribution from the ultraviolet to the infrared

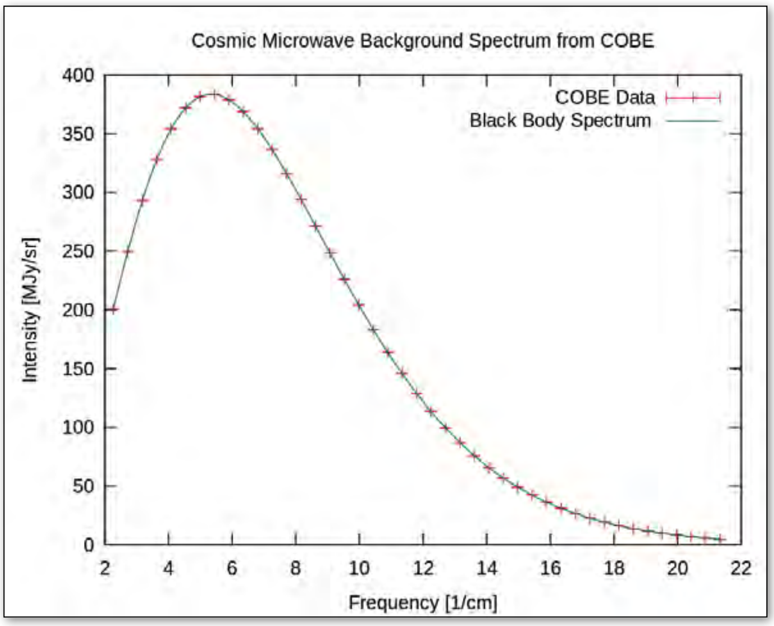


◄ **FIG. 1:** Our sun observed in neutrinos. Image Credit: http://apod.nasa.gov/apod/ap980605.html range of the electromagnetic spectrum, peaking in the wavelength range of visible light. Evolution has made our eyes, our main organs for detecting electromagnetic radiation, most sensitive to exactly this range of visible light transmitted by the sun to our planet.

Besides light, the second messenger indicating the existence of solar fusion reactions are neutrinos. These weakly interacting neutral particles are being produced in enormous quantities by weak interaction processes in the core of the sun. Unlike electromagnetic radiation, neutrinos can penetrate matter without much interaction and reach earth with (nearly) the speed of light. They are measured by deep underground neutrino detectors, typically large vessels filled with water or scintillator liquids, which detect a few of the enormous flux of neutrinos that daily penetrate earth (Fig. 1).

Through the intensity of solar light emission and the measurements of solar neutrino flux we have obtained a detailed understanding of the nuclear reaction processes that power not only our sun but also the earth as part of the planetary system [1]. The main energy source consists of the pp-chains (proton-proton chains): a sequence of nuclear reactions fusing four protons into helium (4He), under the release of energy in the form of photons, neutrinos, and the kinetic energy of other reaction products. The first reaction in the sequence is the extremely slow p+p⇒d conversion from two protons to a deuteron. As this reaction is based on the weak interaction, which converts one proton into a neutron, it is very slow and causes the long life of our sun. The various reactions associated with the pp-chains are being studied in deep underground laboratories in order to determine the lifespan of our sun and the amount of luminosity our sun will produce over the next few billion years before running out of hydrogen fuel.

▼**FIG. 2:** The Cosmic Microwave Background Radiation as observed by the COBE satellite constitutes a perfect blackbody spectrum with temperature *T*=2.725 K. Image Credit: Wikipedia



Light in the early universe

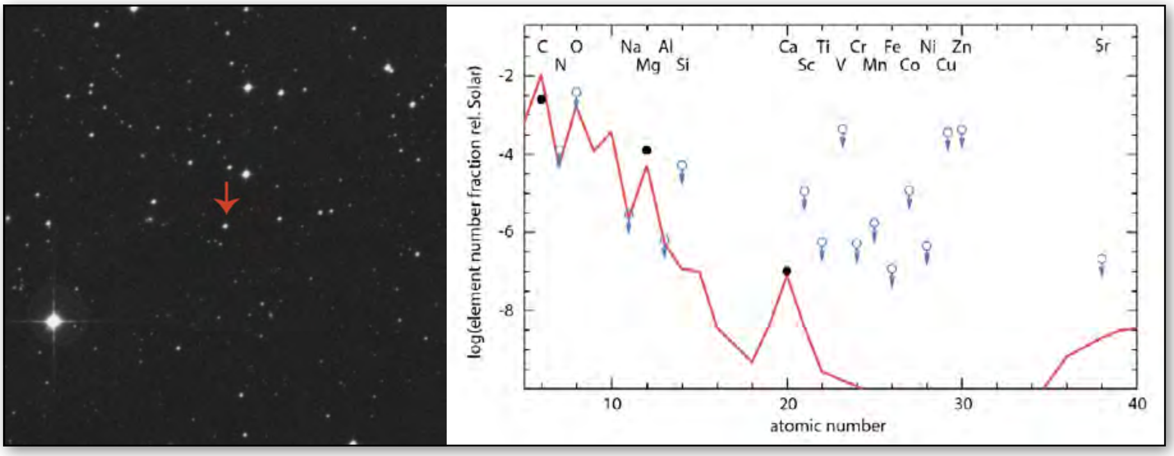
The dominant source of photons in our universe is the Big Bang, which took place about 13.7 billion years ago and is considered to be the birth of our rapidly expanding universe. The early universe was filled with different kinds of matter, including free protons and neutrons. Dominant components were photons, intense electromagnetic radiation that cooled with the expansion. After the first minute the energy of the photons was reduced to a sufficiently low level, allowing deuterium nuclei, which were continuously formed by fusion of protons and neutrons, to survive against photodisintegration. This initiated primordial nucleosynthesis, forming nuclei up to helium and lithium. After 400 Million years of expansion the photon energy was reduced further to the electronvolt (eV) level, insufficient for atomic ionization and excitation processes. Photons and baryons decoupled, and the first generation of stars was formed. Photons cooled further to ever expanding wavelengths until today, when the universe has cooled to a temperature of 3 Kelvin. These photons are visible with radio telescopes as 3K background radiation. The structure and distribution of this radiation provides insight into the early Big Bang development [2] (Fig. 2).

Light of early stars

Over the last decade remarkable results have been obtained in the discovery and spectroscopic analysis of light of early-generation stars. These stars emerged through gravitational contraction about 13 billion years ago, after the photons and baryons decoupled. In their interior these first stars offered the first site with sufficient temperature and density conditions to allow for nuclear reactions that form heavier elements. The respective nucleosynthesis was driven by the pp-reactions on the hydrogen-helium fuel that was provided by the Big Bang. With the contraction of the stellar core, helium burning by fusion between three helium nuclei – the triple alpha process – becomes possible. It forms ^{12}C and by subsequent alpha-capture ^{16}O, the two most critical elements for the development of biological life [3]. Indeed, recent spectroscopic analysis – based on Hubble or other space or ground based observatories – of the light that reaches us from these first stars indicates primordial elements as well as carbon and oxygen abundance (Fig 3). These observations provide a story of the first origin of carbon and oxygen, key elements and stepping stones for subsequent nucleosynthesis patterns that emerged in the following generations of stars.

Light from old metal-poor stars

Stellar light provides a tantalizing glimpse on the unique origin of heavy elements. The spectroscopy of light from old stars indicates only very few heavy elements. These stars are named metal-poor. Large



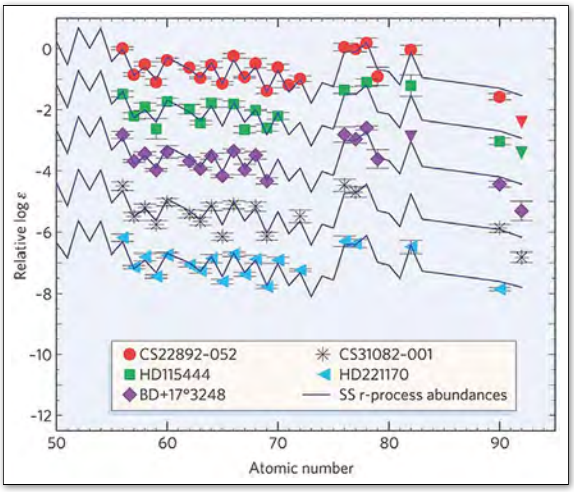
▸ **FIG. 3:** The oldest known star (arrow in left picture) with an age of about 13.6 billion years is located in our Milky Way at a distance of 6000 light years from the sun [4]. Its abundance pattern (right picture) proves early stellar nucleosynthesis of light elements like carbon and oxygen.

galactic surveys of thousands of stars have helped to identify a fairly large number of metal-poor stars. High-resolution spectroscopy of these stars revealed an abundance distribution pattern of heavy elements from about barium to lead and uranium that closely mapped the so-called r-process abundance pattern of our sun (Fig. 4). This is often viewed as proof that there is one unique site for r-process production of the heavy elements, with other sites contributing to lower-mass elements.

The r-process or rapid neutron capture process is one of the main sources for heavy element production in our universe. The r-process is envisioned as a process taking place in stellar explosions, which releases a large flux of neutrons that rapidly (within a second) convert the existing abundance distribution of the star into heavy elements. The particular structure of the r-process abundance pattern is closely correlated with the shell structure of massive nuclei and is one of the prime signatures for the importance of microscopic nuclear effects impacting the chemical evolution of the universe. The nuclei encountered during r-process nucleosynthesis are exotic with large neutron excesses and have to be artificially produced in the laboratory to determine their properties. To achieve this goal, large radioactive beam facilities such as FAIR in Germany and FRIB in the United States are currently being built. They will provide the refined nuclear data needed to identify the astrophysical site of the r-process which is currently unknown [6]. For decades supernovae were considered to be the prime candidate. However, recent supernova simulations indicate that this site is not likely. Merging neutron stars are presently viewed as a very suitable site for the r-process revealing astrophysical conditions that seem to match those required for r-process nucleosynthesis to produce the observed abundance patterns. The collision and merging of two neutron stars is, however, not a particularly likely event and it is not clear yet whether they have occurred frequently enough to explain the amount of heavy elements observed in the old stars.

Light and stellar evolution

Stars are traditionally classified by their light characteristics – the absolute luminosity or magnitude and the colour or spectroscopic classification – ranging from blue to red. Sorting each star according to these two parameters gives the so-called Hertzsprung-Russell (HR) diagram (Fig. 5). Most of the stars line up in a diagonal line stretching from bright blue stars to dim red stars. Our sun is in the yellow range. This is the main-sequence of the HR diagram. Other stars cluster in two areas: red bright stars which represent the red giant (RG) branch in the diagram and bright stars stretching over the colour range from blue to red, the so-called asymptotic giant branch (AGB) stars. There are also a number of dim white-bluish stars, which resemble the white dwarfs (WD) branch in the HR diagram. While this diagram was originally only developed for classification reasons, it was later realized that each of these branches corresponds to an evolutionary stage of stellar life. Main sequence stars are in the first phase of hydrogen burning. For lower mass stars such as our sun, this fusion process is facilitated by the pp-chains, described above. For more massive stars, the pp-chains do not produce enough energy to stabilize the star against gravitational contraction and the CNO cycle, which is based on a sequence of proton capture processes on carbon, nitrogen, and oxygen as catalytic elements, becomes



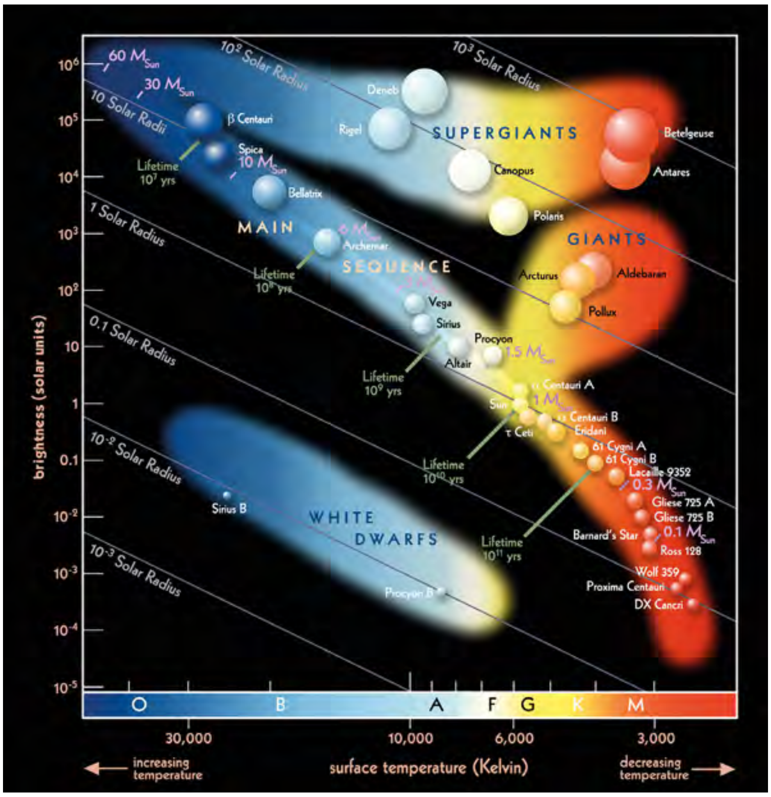
▸ **FIG. 4:** Abundance pattern of heavy elements in old, metal-poor stars compared to the relative solar r-process distribution (solid lines) [5], where r-process stands for rapid neutron capture process. The absolute scales have been chosen arbitrarily for better presentation.

dominant. The CNO cycle provides only a few percent to the energy generation of our sun, but dominates the energy production in more massive main sequence stars such as the well-known Sirius in Canis Major, Vega in Lyra, and Spica in the Virgo constellation.

When hydrogen fuel is exhausted, the stellar core that contains mainly helium as ashes of the hydrogen burning, contracts under its weight and the hydrogen burning zone expands outward, causing an expansion of the outer layers. This shifts the colour of the star towards red and it emerges as Red Giant. The contraction of the core continues until the temperature and density condition in the center of the star are sufficiently high to trigger helium burning. An example of a red giant in the helium burning phase is Betelgeuse in Orion, a star that is suspected to be close to the end of its helium burning phase. This end occurs when all of the helium in the core is converted to carbon and oxygen. Further energy production comes from the fusion reaction of these two nuclei, followed by a number of subsequent rapid evolution phases that convert these elements by a number of characteristic burning processes to iron and nickel in the stellar core. Stars in these final phases of their life show up as AGB or giant stars in the HR diagram.

The nuclear reactions that determine the stellar energy production, lifetime, and the development of chemical composition have extremely low cross sections, that need to be determined with high accuracy at stellar energy conditions. Enormous progress has been made over the last decade in developing new techniques for these studies, but many critical questions remain primarily associated with the nuclear processes at the final stages of stellar life [7]. The main obstacle is that reliable measurements are not only handicapped by extremely low cross sections but also by large amounts of detector background, due to cosmic-ray interaction with the detector material. This limits the experimental range to energies that are well above the stellar energy range. Their study at stellar energies is presently being pursued at the LUNA accelerator that is located deep underground in the Gran Sasso laboratory in Italy, exploiting the large background shielding by the rocks of the Apennine Mountains.

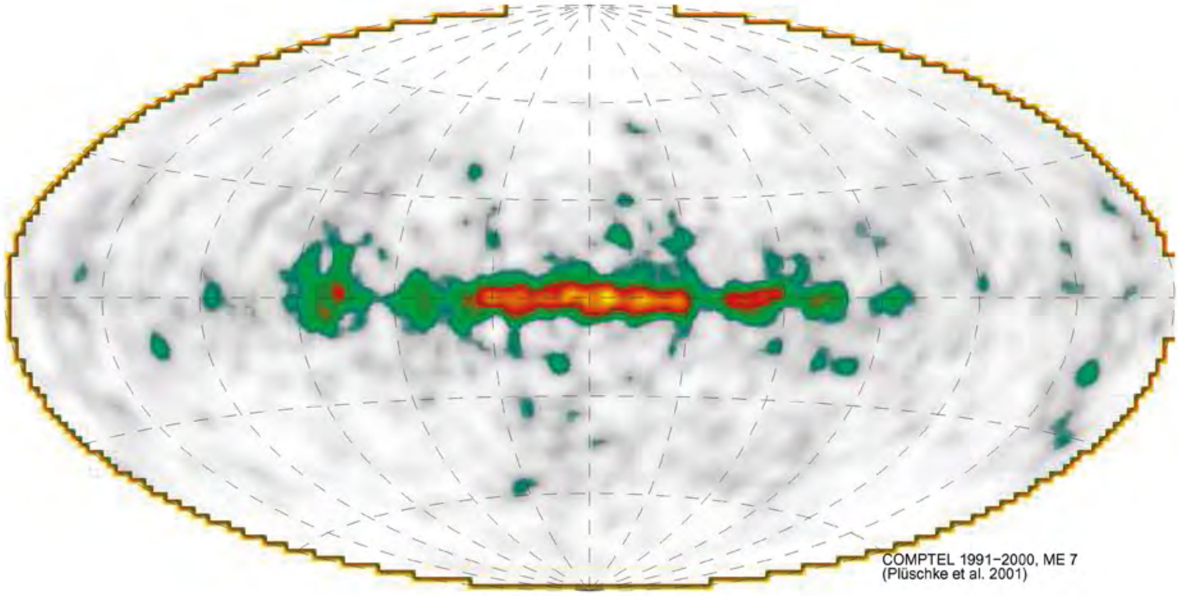
▼ FIG. 5: The Hertzsprung-Russell diagram displays the luminosity of a star against its colour (spectral class). The location in the diagram provides information about the mass of a star and characterizes the evolutionary phase on its journey through life. Image Credit: Wikipedia



Light from stellar explosion

Classical and medieval astronomers observed stars which suddenly developed enormous brightness; they called these stars novae or supernovae (new stars). Today, astronomers observe supernovae in far distant galaxies, with a luminosity that parallels the luminosity of the entire host galaxy. Supernovae (SN) are classified by their spectroscopic appearance and are sorted (roughly speaking) in two main classes: SN type I, by the lack of hydrogen lines in the spectrum of the emitted light, and SN type II which does show hydrogen lines. While the sub class SN type Ia is considered to be a gigantic thermonuclear explosion of a star that is triggered by accretion processes in a white dwarf double star system, SN type II basically represents the violent death of a massive star as a consequence of the gravitational collapse of the stellar core [8].

Associated with the rapid energy release in a supernova explosion is an enormously high emission of light or luminosity over the entire electromagnetic spectrum within seconds. The light emission associated with the actual explosion rapidly declines, but multiple new radioactive elements such as ^{56}N and ^{44}Ti have been formed as a consequence of the nuclear processes occurring during the explosion, and the associated decay energy is slowly released with the characteristic nuclear half-lives. The time correlation between the luminosity and the radioactive decay has been particularly observed for the light curve of recent supernovae such as SN 1987a, which is associated with the violent death of the blue supergiant star Sanduleak in the Tarantula Nebula of the Large Magellanic Cloud. The light curve matches successively the decay of ^{56}N, its daughter nucleus ^{56}Co and other radioisotopes that are being produced in the explosion. These observations are mirrored by studies on other supernova remnants such as Cas A in the constellation Cassiopeia, that was first observed in 1680. For Cas A satellite-based X-ray and γ-ray observatories directly observed the characteristic γ-lines associated with the decay of ^{44}Ti and delivered direct evidence for the existence of this relatively short-lived isotope [9]. Mapping the sky with γ-telescopes such as INTEGRAL reveals the image of a radioactive universe resulting from the slow radioactive decay processes associated with supernova remnants along the galactic plane of our Milky Way (Fig. 6).



◂ **FIG. 6:** All-sky map of ^{26}Al activities as observed by the COMPTEL and INTEGRAL satellites. © R. Diehl

This demonstrates that the synthesis of new elements is an on-going process, continuously changing the element budget and distribution in our universe.

The sequence of nuclear reactions that develop during supernova explosions involve many short-lived nuclei far beyond the limits of nuclear stability. A study of these reactions and of the nuclei along the reaction path provides fundamental insight into the nature of these processes, the rapid timescale and dynamics of the explosion, the associated energy release and, of course, the synthesis of new elements. While experimental techniques are being developed now, the next-generation radioactive beam facilities, such as FAIR and FRIB, will generate the intensity necessary to produce key nuclei and to determine their properties. This will provide crucial input constraining the conditions during the explosion and will help to reliably model such events.

The origin of the elements

Recent years have witnessed impressive advances in the understanding of the microscopic processes that initiate and drive the evolution of the elements, through multiple sites, over the history of our universe. Light with its spectroscopic characteristics is the main signature for mapping and analyzing this evolution. The spectroscopy of stellar light with high resolution ground- and space-based telescopes indicates a gradual growth in the number of elements and in the increase of their abundances with time, confirming their continuous production in stars. The detailed structure of the elemental abundance distribution reflects the structure of nuclei participating in the various nucleosynthesis processes. These elements that have been built in the past are not only in stars, but also provide the chemical building stones of our planets, our earth, and ourselves. Carl Sagan summarized this remarkable development: "*We are made of star stuff* [10]". The observation and analysis of stellar light has confirmed this statement. ■

About the Authors

Michael Wiescher is an experimental nuclear physicist and the Director of the Nuclear Science Laboratory at the University of Notre Dame, USA. Previously he held positions at the University of Mainz, the California Institute of Technology and at the Ohio State University. He has been the founding Director of the Joint Institute for Nuclear Astrophysics and is the recipient of the 2003 APS Bethe Prize.

Karlheinz Langanke serves presently as Director of the GSI *Helmholtzzentrum für Schwerionenforschung* and is Professor at the Technical University of Darmstadt, working in theoretical nuclear astrophysics. Previously he held positions at the University of Aarhus in Denmark and at the California Institute of Technology. He is the recipient of the 2012 EPS Lise-Meitner Prize.

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Opinion: Rankings, reputation and prestige

Martina Knoop is CNRS researcher at Aix-Marseille University and *chargée de mission* for scientific publications at CNRS Institute of Physics

Among the ingredients heating up the debate about the publication landscape stands prominently today's strong entanglement of assessment and publications. A long time ago, scientists were either writing books to communicate about their findings, or they wrote short (!) contributions about their results, with a large part of discussion taking place at conferences or by correspondence. Today, publications are one of the fundamental factors in assessment, be it for the evaluation of projects and collaborations, or to promote one's personal career. Striking here is the hunt to publish in high-impact-factor journals, whose editorial policy is unfortunately governed by commercial impact rather than by scientific dissemination. In this context, time dedicated to research has been converted into communication time, and sometimes research funds in communication funds.

It is intriguing to remark that this evolution has taken place in the frame of the peer-review process. Projects, papers, and also personal promotion are judged in a large majority by scientists for scientists. In considering our research or those of others, we try to be objective, find arguments, look into the context, and get rid of environmental influences – so what makes the name of the chosen journal so important? It is probably not the wider audience that attracts so much, as a physics paper will be of interest primarily for physicists. Could it be that the main attraction is the idea of having passed not only the eye of a fellow colleague, but also the narrow funnel of an editorial policy oriented towards harvesting a maximum of citations?

Going further, it becomes clear that the notion of prestige is not limited to publications. Many actual assessments are "reputation" based. This means that a panel of evaluators is asked to rank institutions, journals, *etc.* These rankings are built on a sandy ground, but still they are put forward on many occasions. First, the group of evaluators is rarely chosen on completely random terms, sometimes even advertised as "invitation only". If your panel is composed of a majority of astrophysicists, you will eventually not end up having only solid-state research groups cited in the first place. Second, "reputation based" implies that you recall the name of the institution (or journal) which clearly favors those which have short, historically long-standing names, or an active public relations department. Third, in general we work on small numbers, and as physicists we know that this will increase the error bar. To add a flavor of statistics, the answers of all evaluators are then averaged, and the outcome is presented as a "research indicator" (or "journal index"). This reputation-based sorting finds its way (partially) into the Shanghai ranking, or the Nature index.

As scientists, we should consider these lists at least as being biased. If your undergrad intern would come up with a study as described above, you would certainly protest – at least about methodology! We very well know, that in order to have a serious idea of the scientific quality of something, we need to invest time and look into the contents.

To add a flavor of statistics, the answers of all evaluators are then averaged, and the outcome is presented as a "research indicator".

At almost all levels we are the evaluators, reviewers and assessors. It is up to the scientific community to be critic about ranking, reputation and prestige. It should be our task to defend the independence of the scientific judgment. Today, the majority of scientists is aware of this, but there is still a small margin for improvement. There are many scientific ways to bring research results to a large readership, and it is up to us to promote these values. ■