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THE MAGAZINE OF THE EUROPEAN PHYSICAL SOCIETY

Accretion and evolution of the Moon
The Earth's magnetic field
Mental ability in an artificial society
EPS Council report
Interview with Rumiana Dimova

45/4
2014

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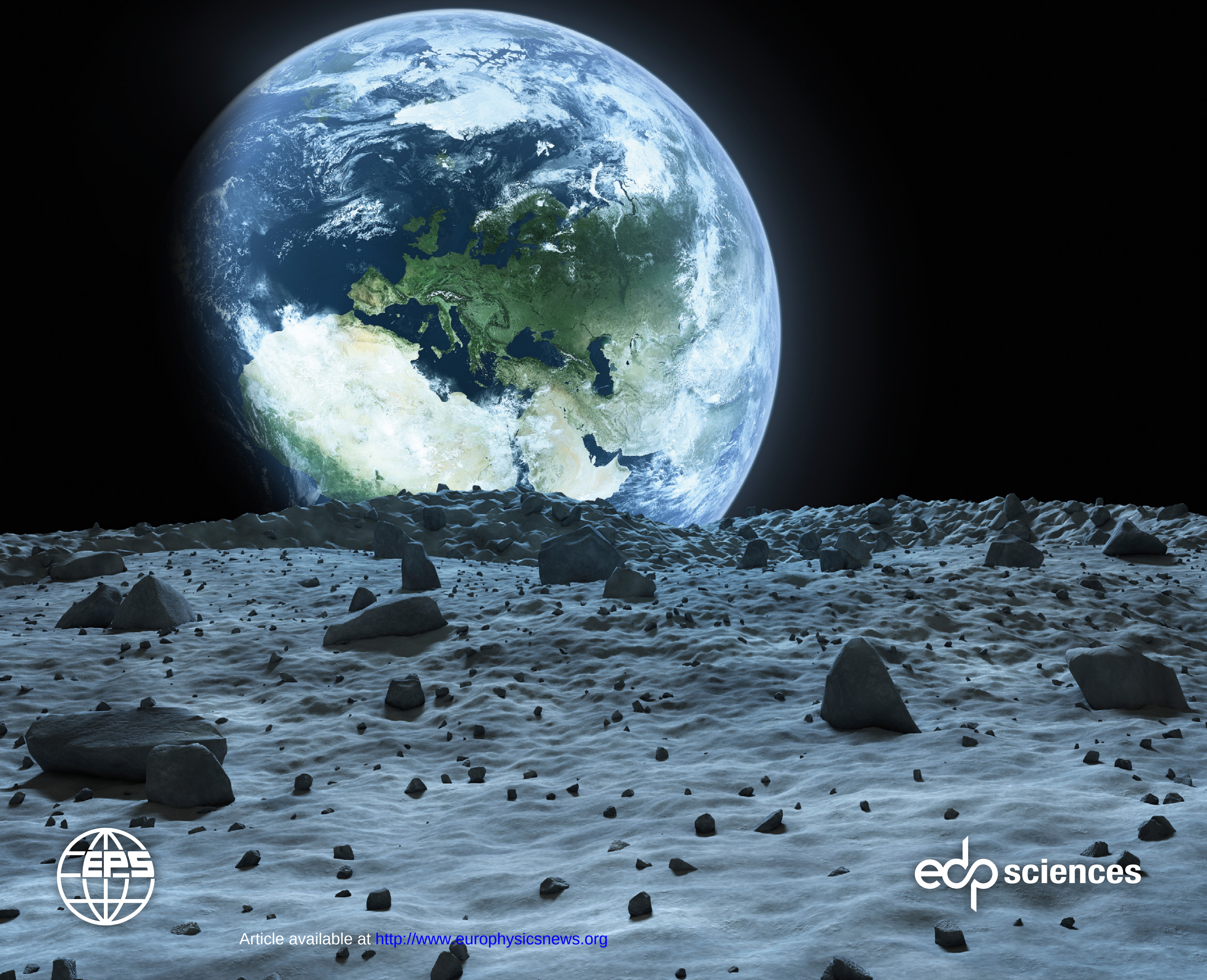

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Article available at http://www.europhysicsnews.org

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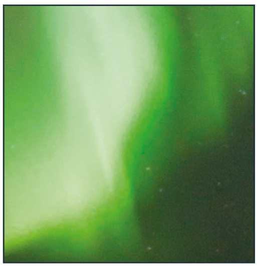
Cover picture: Europe seen from the moon.



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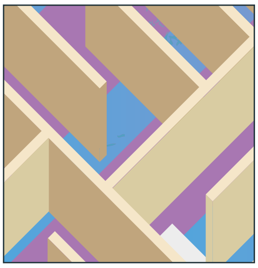
Unravelling the mystery of the Earth's magnetic field



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Mental ability and common sense in an artificial society

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Giant impact: accretion and evolution of the Moon


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[EDITORIAL]

Science and sport, similar integration factors?

Fascination football! In the months of June and July, the whole world vibrated at the Brazilian rhythm for the World Championship 2014. National flags proudly displayed in the streets or on balconies, large-screen public viewings, dins of horns, fireworks… Sports, and in particular football, is indeed a great society phenomenon, bringing people together in a big wave of enthusiasm and frenzy.

Can one say the same for science and physics? Interestingly enough, the International Year of Physics in 2005 ran in parallel to the International Year of Sport and Physical Education. Two events with different impact, but similar goals, namely to raise awareness among the general public and encourage organizations and individuals to share their knowledge on values relevant for our society.

Well, next to the Mundial, politics in Europe is not at rest this summer. After the election of the EU parliament, strong debates on many issues were ongoing, including the election of the new president of the EU Commission. An agreement of association for Moldavia and Georgia was just signed on 27th June, following the one with Ukraine. According to José Manuel Barroso, this could be the main historical event in Europe after the fall of the wall in Berlin! Optimism and hope for a well-integrated and peaceful Europe? Let's believe it, especially as we scientists have long been a great integration factor with the development of international scientific networks and collaborations in research, technology and education. One nice example is CERN, which celebrates its 60th anniversary this year with several events and which in many ways can be viewed as a model of what Europe can do in bridging nationalities and bringing different cultures to work together. The EPS, born at CERN in 1968, was indeed created in the same spirit of international cooperation. Now that EPS Council has decided to be more proactive in Brussels, it is our unique chance to look for novel paths and be innovative in communicating with the new generation of EU politicians, not only to improve the image of physics, but more importantly to share with them our expertise and provide them with the required scientific evidences.

The EPS, born at CERN in 1968, was indeed created in the same spirit of international cooperation.

In this respect the recent advice of Anne Glover, the chief scientific advisor to the president of the EU commission, has been a great help to us. Let's only hope that also under the new presidency her advisory office will remain, in order to strengthen our links with the EU further and to help bridge the divide between policymakers and scientists. According to some investigations by John H. Marburger III, who served as scientific advisor to George W. Bush, it seems indeed that government officials might tend to ignore or alter scientific advice and that science's authority in governmental circles is often of a more charismatic than of rational or legal nature [1].

So, let's go and score a goal for science! ■

Christophe Rossel
EPS President Elect

[1] see the article *Why don't they listen* by Robert P. Crease in *Physics World*, May 2014, p. 19

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EPS HISTORIC SITES

The Blackett Laboratory: EPS site of historical interest

On April 30, 2014, Professor Tom Kibble unveiled the plaque that recognized The Blackett Laboratory, Imperial College London, as a European Physical Society Historic Site.

The Lab has been the home of Imperial's Department of Physics since 1961 and named The Blackett Lab in 1975 after one of its distinguished former Heads of Department, Lord Patrick Blackett, who was responsible for its building. Blackett was a Nobel Laureate, President of the Royal Society and scientific advisor to Prime Minister Harold Wilson, who delivered The Blackett Memorial Lecture at the 1975 renaming.

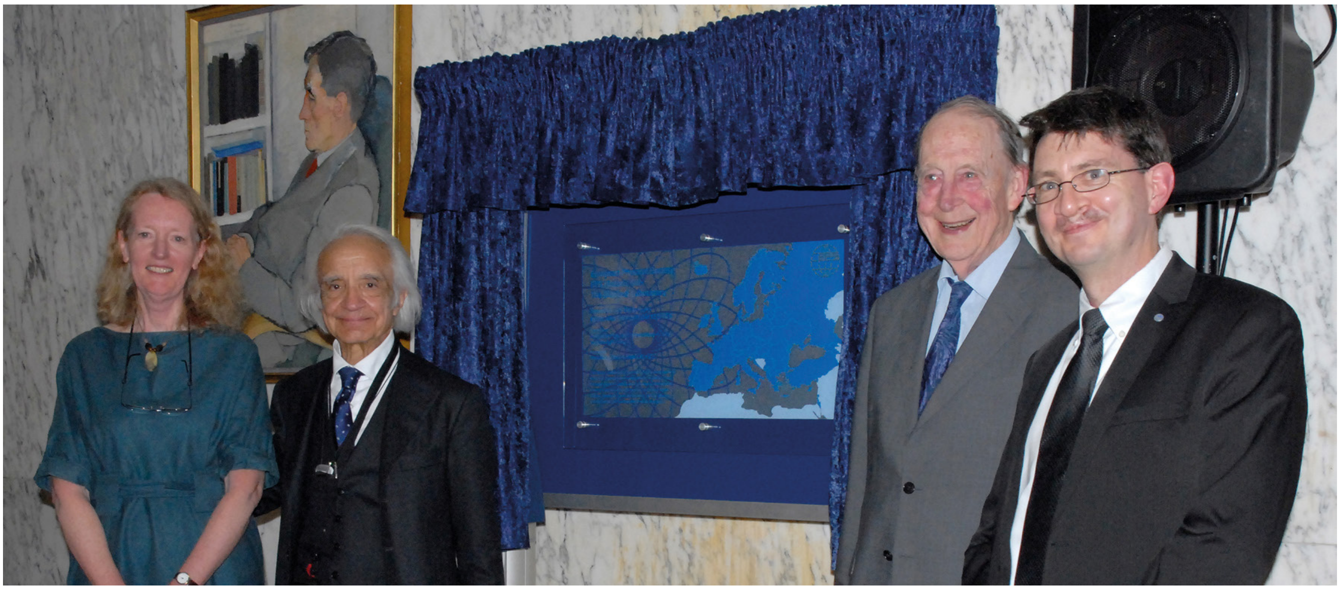
History could have turned out very differently, however, since J. Robert Oppenheimer is alleged to have left a poisoned apple on Blackett's desk while a postdoc in Cambridge in 1926. (*Blackett: Physics, War, and Politics in the Twentieth Century*, Mary Jo Nye).

At the unveiling ceremony on April 30, on her final day as Department Head, Professor Joanna Haigh recalled some of the scientific triumphs that have taken place there during the period 1961-2000. "We are proud of the significant contributions that our academics, past and present, have made to the field and this commemorative plaque is a testament to their achievements." she said.

Professor John Dudley, EPS President, said: "The advances made at the Blackett Laboratory have impacted on all fields of physics, and the laboratory continues today to produce results at the highest level and to turn out exceptional young physicists."

Examples of these achievements, garnering a Nobel Prize and 26 elections to Fellowship of the Royal Society, include:

- **1960s Sir Clifford Butler FRS, Steve Goldsack:** Design of the British National Hydrogen Bubble Chamber Measuring Machine – the first standard measuring device for particle tracks.
- **1969 Reginald Garton FRS:** Experimental discovery of quantum chaos.
- **1968 Harold H. Hopkins FRS:** Mathematical analysis for modern optical design including fibre optics .
- **1960s – 70s Patrick Blackett OM CH FRS, Harry Elliot CBE FRS:** Fundamentals of cosmic rays and development of particle detectors at the dawn of the space age - the Ariel Programme.
- **1964 Tom Kibble FRS:** Defined the mechanism by which gauge bosons acquire mass via the spontaneous symmetry breaking. Brout, Englert, Higgs, Kibble, Guralnik and Hagen were awarded the 2010 Sakurai Prize for spontaneous symmetry breaking. Higgs and Englert won the 2013 Nobel Prize.



▲ Professors Joanna Haigh, Antonino Zichichi, Tom Kibble and John Dudley

- **1968 Abdus Salam FRS:** The unification of the weak and electromagnetic forces. Glashow, Weinberg and Salam were awarded the Nobel Prize in 1979.
- **1960s – 1970s Bryan Coles FRS, David Sherrington FRS:** Coles named the magnetic property in disordered systems as 'Spin Glasses'; the Sherrington-Kirkpatrick paper on the theory of spin glasses inspired neural networks.
- **1970s Daniel J. Bradley FRS:** Development of tunable ultra short pulse lasers.
- **1980s Peter Dornan FRS, David Binnie:** High energy particle detection: first silicon microstrip and production of first drift wire chambers.
- **1980s David Olive FRS:** Fundamental contributions to string theory.
- **1980s-1990s Michael Duff FRS, Kellogg Stelle :** Laid the foundations of supermembranes, leading to the M-theory unification of gravity and quantum mechanics.
- **1990s Sir Peter Knight FRS, Vlatko Vedral:** Frontier studies on theoretical quantum optics & measures of quantum correlations.
- **1999 Sir John Pendry FRS, David Smith:** Creation of meta-materials and the field of meta-material research; theory of the perfect lens; invisibility cloaking.

Before unveiling the plaque, Tom Kibble paid homage to P. M. S. Blackett and his contributions to Imperial College Physics.

Earlier in the day, Professor Antonino Zichichi, President of the World Federation of Scientists and former EPS President, gave a Distinguished Lecture entitled "My testimony on Lord Patrick Blackett". As his former student, Professor Zichichi gave a personal recollection of Blackett's life and work: his Nobel-Prize winning discoveries in subatomic physics, his contribution to operational research as advisor to the Admiralty during the Second World War and his promotion of scientific culture, in particular Blackett's role in the establishment of the Ettore Majorana Centre for Scientific Culture in Erice, Sicily. It is here that students at the annual summer school on subnuclear physics attend lectures in the Blackett Institute and where the best ones are awarded the Blackett Diploma. The P. M. S. Blackett plaque was unveiled in Erice in 1991 by… Tom Kibble. ■

■ **Michael Duff FRS,**
Abdus Salam Professor of Theoretical Physics - Imperial College London

EPS PRIZE FOR RESEARCH IN THE SCIENCE OF LIGHT

The European Physical Society (EPS) Prize for Research into the Science of Light is awarded on behalf of the European Physical Society through its Quantum Electronics & Optics Division (QEOD).

The prize is awarded every 2 years in recognition of recent work by one or more individuals (no more than three) for scientific excellence in the area of electromagnetic science in its broadest sense, across the entire spectrum of electromagnetic waves.

The first Prize for Research into the Science of Light was awarded during Nanometa 2013, January 3rd 2013, Seefeld, Austria to **Philip StJ Russell**, from the *Max Planck Institute for the Science of Light in Erlangen, Germany*.

The 2015 Edition of the Prize for Research into the Science of Light is now open for nominations. Please use the link below to access the submission site: http://qeod.epsdivisions.org/QEOD%20Prizes/european-physical-society-quantum-electronics-and-optics-division-prizes-2015 ■

Initiative of students Utrecht University
First international physics competition huge success

From Friday 23 May to Sunday 25 May, 32 teams of students from 14 countries participated in PLANCKS, the first international physics competition. PLANCKS was initiated and organised by students of Utrecht University in the Netherlands. The opening symposium made national headlines when they successfully signed on Stephen Hawking to give a lecture. Participants are now looking forward to the next edition.

"We want to say *Dank u wel*[1]! We had an amazing weekend here in Utrecht and we were truly impressed by the excellent organisation. The only thing we can blame you for is the fact that half of our group is now seriously considering to delay their graduation in order to be allowed to participate in PLANCKS 2015!" Thus read one entry in the guest book, but there were many more in the same spirit.

▸ (p.07) The contestants from all 32 teams together.

PLANCKS

The Physics League Across Numerous Countries for Kickass Students, (PLANCKS), was set up by students of A-Eskwadraat, the study association of Utrecht University for students of Mathematics, Computer Science, Information Science, Physics and Astronomy. The association is a member of SPIN, the umbrella organisation for Dutch study associations in the field of physics. In 2012, the newly installed and ambitious SPIN committee expressed its ambition to revamp the annual Dutch national physics competition, PION, which had existed since 1995. Thus PLANCKS was born.

This first edition attracted no less than 32 teams of three to four students from 14 countries, even as far away as China. The actual competition took place in the morning after the opening symposium. The teams were given 10 challenging assignments[2] which had been meticulously composed by scientists from different institutes. The event was sponsored by Utrecht University, several companies and funding agencies.

Stephen Hawking

Since they wanted the best publicity for their initiative, the organising committee decided to send an email to Professor Hawking, inviting him to the opening symposium. Much to their surprise, a reply arrived almost by return saying he would be delighted to attend.

When the news of Hawking's attendance was made public, it soon became clear that many people wanted to attend the symposium. Therefore, the students decided to rent a theatre auditorium for the symposium with a seating capacity of 1,500 and to expand their eight-strong organising team by four. The 500 tickets for the general public were sold out within a minute.

Professor Hawking took the stage to a reception the Rolling Stones would have been jealous of. He had written a new lecture especially for the opening symposium which included recent work on BICEP (Background Imaging of Cosmic Extragalactic Polarization).

When posed the question, after his lecture, "Do you think scientists

▾ (left) The winners of PLANCKS 2014: Roy Figiel, Ruben Doornenbal, Martijn van Kuppenvelt and Joost Houben receive their prize, with Nobel laureate Gerard 't Hooft at the left.

▾ (right)The three lecturers: Stephen Hawking, Immanuel Bloch and Gerard 't Hooft.

have an obligation to convey their knowledge to a general audience and why?", Hawking answered: "It is important, that we all have a good understanding of science and technology. Science and technology are changing our world dramatically, and it is important to ensure that these changes are in the right directions. In a democratic society, this means that we all need to have a basic understanding of science, so we can make informed decisions ourselves, rather than leave them to the experts."

In addition to Stephen Hawking, the PLANCKS organisation also managed to sign on theoretical physicist and Nobel Prize Laureate Gerard 't Hooft[3] of Utrecht University, and experimental physicist Professor Immanuel Bloch, Director of the Max Planck Institute in Munich, recipient of the Körber European Science Prize 2013.

Winners

Professor 't Hooft presented the prizes at the award ceremony. The third prize was shared between Smoluchowski's Team from the Jagiellonian University in Poland and NOFY066 from the Charles University in Prague, Czech Republic. The second prize went to Tena, a home-grown mixed team from Utrecht, Nijmegen and Eindhoven Universities, and the winner was another mixed home-grown team, Dutch Physics Olympiad from Utrecht and Nijmegen Universities. The winning students, Troy Figiel, Ruben Doornenbal, Martijn van Kuppenvelt en Joost Houben had not expected to achieve such a high score. Even so, they won by a considerable margin. The first prize included a € 2,109.14 cheque ($h/\pi \cdot 10^{37}$ with h being the Planck's constant), and a trophy in the form of a plank.

At the end of the award ceremony, the baton was passed on to Irene Haasnoot of Leiden University, which will organise PLANCKS 2015. The Dutch initiators hope PLANCKS will start touring the world from 2016 onward.

Websites:

PLANCKS 2014: http://www.plancks.info.

Utrecht University: www.uu.nl/en

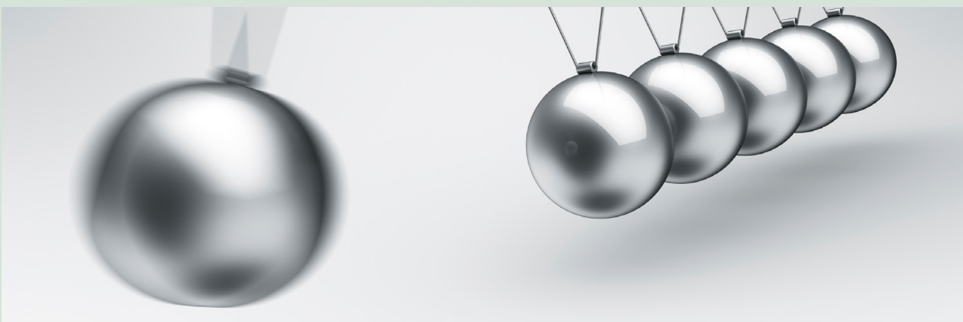
John Donnelly
Utrecht University - The Netherlands

[1] Thank you
[2] See Box for an example
[3] Professor Gerard 't Hooft and Professor Martinus J.G. Veltman were awarded the 1999 Nobel Prize in Physics for elucidating the quantum structure of electroweak interactions in physics. 't Hooft is still actively involved in the Utrecht University's Physics Department.

ASSIGNMENT EXAMPLE: NEWTON'S CRADLE

JAN VAN RUITENBEEK, LEIDEN UNIVERSITY

Newton's cradle is a well-known gadget and physics demonstration. It is usually described as demonstrating the laws of conservation of energy and conservation of momentum.
For simplicity we take the motion to be one-dimensional and the collisions to be elastic.
1. (5 points) We launch a single ball onto the other balls that are at rest, and consider the situation just after the collision. For any number N of balls (including the launched ball) in the cradle how many solutions do the laws of conservation of energy and momentum permit? For $N = 2$ and $N = 3$ describe the set of allowed solutions in N-dimensional velocity space.
2. (5 points) When we perform the experiment for $N = 3$ we find that only one solution is realised. Which solution is this, and explain why.
The solution can be downloaded from the website 2014.plancks.info



European Physical Society – Council

4-5 April 2014 - Trieste - Italy

The EPS Council was held at the International Centre for Theoretical Physics (ICTP) in Trieste, Italy on 4-5 April 2014. Over 60 delegates attended representing the 42 EPS Member Societies, Divisions, Groups, Individual Members and Associate Members.

Fernando Quevedo, the ICTP Director welcomed the EPS Council. ICTP is celebrating its 50th anniversary, following its creation in 1964 under the guidance of Abdus Salam. The mission of ICTP is to support high level research and education in the physical and mathematical sciences in the developing countries. As an institution led by scientists, it has many programmes in fields such as high energy physics, computational and mathematical physics, climate change, entrepreneurship, *etc.* that bring together top scientists from developing countries and around the world to engage in high level research. ICTP is supported by International Atomic Energy Agency (IAEA), UNESCO and the Italian government.

L. Cifarelli, immediate past EPS President, and President of the Italian Physical Society also welcomed the EPS. Trieste is host to many other prestigious scientific institutions, including University of Trieste, laboratories of the CNR and INFN, as well as the Elettra Synchrotron, and SISSA (International School for Advanced Studies).

President's Report

John Dudley began his report with a summary of facts and figures for the EPS. The EPS has 42 Member Societies, that represent amongst them over 130,000 physicists in Europe. There has been an increase of 16% in the number of Individual Members (IMs), now totalling over 3200. IMs are part of the historic development of the EPS, and are a unique feature of the EPS, as well as the main actors in the 17 EPS Divisions and Groups.

The Executive Committee, elected by Council and charged with oversight and implementation of EPS activities met 4 times since Council 2013. The meetings were efficient in discussing EPS priorities, as well as meeting with various EPS Member Societies and Divisions and Groups. Summaries of Executive Committee meetings are prepared by the Honorary Secretary, and are available to all EPS members.

EPS engages in a number of activities, consistent with its role as a learned society. Publication is one important activity. EPL is the EPS flagship letters journal, publishing high quality content in all fields of physics. Over 2000 manuscripts were submitted in 2013, and 868 were published. The quality of the content and the visibility of the journal has been enhanced, thanks to the hard work of the outgoing Editor in Chief Michael Schreiber. Giorgio Benedek, whose proven dedication to EPL will be an asset in its continued development, will replace him. With the rapid growth of open access publications, EPL is looking at different models to take advantage of the opportunities that are presented in terms of speed of access to high quality research, and visibility.

▾John Dudley, EPS President

Claude Sebenne, the editor of Europhysics News, the EPS magazine, retired in 2013. His hard work and dedication to the magazine, and EPS were recognised by Council. Victor Velasco, from the CSIC in Madrid, and former Honorary Secretary of the EPS Executive Committee has replaced him. EPN is distributed in 25,000 copies 6 times a year to 40 EPS Member Societies. It publishes review articles on trends in physics, as well as articles of general interest to the physics community.

The EPS electronic newsletter, e-EPS is published monthly. It is distributed to over 35,000 readers around the world. It contains news items about important developments in physics, as well as items of interest to the general community. Council formally thanked Luisa Cifarelli for creating e-EPS, and recognised its role in increasing the visibility of the EPS.

EPS Divisions and Groups organised 14 of the world's best conferences in physics in 2013. These included CLEO/Europe – EQEC, the largest conference on optics and photonics in Europe, coupled with the world's largest industrial exhibit in the field. The Executive Committee was particularly involved in the organization of the 3rd European Energy Conference in Budapest in October 2013. This high level conference attracted attention from the EU Director General of Innovation, Robert Jan Smits, and the Hungarian Minister of state for Energy Affairs, Pal Kovac.

EPS was also involved in the organization of the 3rd Asia-Europe Physics Summit (ASEPS 3) which took place in Chiba, Japan, from 16 to 19 July 2013. Jointly organized by the Association of Asian Pacific Physical Societies [AAPPS] and the EPS, ASEPS 3 aimed to continue the work in reinforcing cooperation in physics research between Asia and Europe started in the two previous editions: ASEPS 1, Tsukuba, Japan (2010) and ASEPS 2, Wroclaw, Poland (2011). At the conclusion of the 2013 ASEPS 3 meeting, a "Chiba Statement" was signed by AAPPS President Shoji Nagamiya and EPS President John Dudley, expressing the determination of the two societies to continue organising such fruitful ASEPS meetings in the future.

The EPS Young Minds initiative introduces young researchers to the EPS, and encourages them to organise outreach activities in their universities and communities. There are currently 22 sections in 12 countries.

International Year of Light

The International Year of Light is a global initiative that will highlight to the citizens of the world the importance of light and optical technologies in their lives, for their futures, and for the development of society.

Since 2009, the EPS has been spearheading the initiative to declare 2015 as the International Year of Light. These efforts were rewarded, first by a resolution welcoming and endorsing an International Year of Light in 2015 adopted by the UNESCO Executive Board in October 2012. With this support, the UNESCO General Conference in November 2013 confirmed support for a formal resolution before the United Nations General Assembly, and the formal adoption of 2015 as the International Year of Light and Light Based Technologies (IYL2015) was made during a General Assembly Plenary meeting on 20 December 2013.

The International Year of Light was co-sponsored by more than 35 countries in both UNESCO and the UN. In addition to international sponsorship from countries around the world, the international scientific community brings grass roots support to IYL2015 through more than 100 societies and unions in over 85 countries. This impressive number of co-sponsoring nations and institutions reflects the truly international and inclusive nature of the theme of an International Year of Light.

The Proclamation of an International Year of Light by the United Nations has provided the EPS and its Member Societies, as well as international partners an unprecedented platform to explain the importance of light and its potential applications. Light science is one of the most accessible themes to promote cross-disciplinary education understanding of science. Light has been a major factor in the evolution of humankind and our biosphere. Light- based technology is a major economic driver with potential to revolutionize the 21st century as electronics did in the 20th century.

IYL2015 will consist of coordinated activities on international, national, and regional levels. Activities will be planned so that people of all ages and all backgrounds from all countries enjoy and appreciate the central role of light in science and culture, and as a cross-cutting scientific discipline that can advance sustainable development.

For more information, please see: www.eps.org/light2015

EPS Study on the Importance of Physics to the Economies of Europe

The EPS commissioned an independent economic analysis from the Centre for Economics and Business Research (Cebr), using statistics available in the public domain. This study includes data from 29 European countries – the EU27 countries, plus Norway and Switzerland – and examines the 4-year period 2007-2010 (2010 being the most recent year for which official data are simultaneously available for all these countries.)

▲ Christophe Rossel, EPS President elect

The study uses statistics filed by European companies and collected by Eurostat. The activity of European companies is described using the NACE codes. Within the NACE codes classification, 77 out of more than 700 correspond to physics-related sectors, *i.e.* where there is a critical use of physics in terms of associated technology, expertise and skills. It is important to note that universities, and national and international research facilities are not included in the study. The study looked at various indicators and clearly demonstrates that physics makes an important contribution to the economy and is not limited to a few high-profile examples.

Presented for the first time at the EPS Council 2013, the EPS has actively encouraged its Member Societies to use the study in their national contexts. One positive result is that the Società Italiana di Fisica has commissioned a similar report in Italy. Presentations of the EPS report were made to the CERN Council, to European Commission and representatives for the European Research area, to the EU Science Advisor, the OECD Forum on the Knowledge Economy, and to the American Physical Society.

An Executive Summary presents the main findings, and a more detailed report, including notes on methodology can be found here: www.eps.org/physicsandeconomy

◂ The EPS Edison Volta Prize 2014 ceremony (left to right) Sergio Zannella, Giulio Casati, Jean-Michel Raimond (Laureate of the Prize), John Dudley,

EPS Statements

EPS Council discussed the opportunity for the EPS to make statements as a means to communicate to policy makers and the general public about physics and how it relates to important issues. The EPS issued 2 statements in 2013. The first discusses Education and Research Opportunities for Innovation in Horizon 2020, and the second "Managing the Transition to Open Access" presents the results of a broad consultation by the EPS concerning open access and physics publications.

Statements, whether they are bottom up proposals, for example by EPS Divisions and Groups, or top down, mandated by the Executive Committee require approval by the Executive Committee. A consultation loop with Council delegates is also necessary. This will be the case with two statements currently under consideration on energy, and the importance of support to fundamental research.

Round table on Developing Physics

A Round table on Developing Physics was moderated by JM Gago. The questions posed were related to how to develop physics, and how physics contributes to development. E. Griesmayer, CEO of CIVIDEC, associate professor at the University of Vienna and researcher at CERN discussed physics as an economic driver. H. Bruhns gave an overview of physics and its contributions to energy policy and research. J. Niemela from ICTP provided insight into the work at ICTP for development.

Elections

EPS Council 2014 elected the incoming members of the Executive Committee. The EPS would like to congratulate the incoming members:

- Angela Bracco
- Lucia Di Ciaccio
- Ari Friberg
- Gerd Leuchs
- Elisabeth Rachlew
- Marian Reiffers

The Members of the Executive Committee Elected for a second term were:

- Zsolt Fulop
- James Hough
- Carlos Hidalgo
- Thomas Muller
- Sofoklis Sotiriou

John Dudley continues as EPS President for a second year, until Council 2015, when Christophe Rossel, currently EPS President – elect will take up office.

Council warmly thanked the outgoing members of the Executive Committee for their hard work and dedication to the EPS:

- Caterina Biscari
- Luisa Cifarelli
- Goran Djordjevic
- Els de Wolf
- Martina Knoop
- Colin Latimer
- Jo Lister

Decisions

Council approved the following individuals as Honorary Members of the EPS:

- François Englert,
- Peter Higgs

(more information: www.eps.org/directory/honorary-members)

Council approved the following individuals as fellows of the EPS:

- Peter Fulde, Germany
- Markus Pollnau, Netherlands
- Thomas Kibble, UK

Council approved the award of the Gero Thomas Memorial Medal to Robert Lambourne.

Council approved the modifications of the Constitution proposed by the Executive Committee including section 6 of Annexe 1 to the Constitution and By-laws, below:

§6 Membership fee of Individual Members

The membership fee for members according to Art.3 a) … e) is calculated as the average unit fee multiplied by the number of units given in TABLE 3:

▾ Updated table 3 of the Constitution and By-laws

CATEGORY	MEMBER	UNITS
3.3 a	Full	2.5
	Below 30 years of age	1.8
	Retired	1.8
	Teachers/Students	1.8
3.3 b	Full	5
	Below 30 years of age	2.5
	Retired	2.5
	Teachers/Students	1.8
3.3 c	Full	7
	Below 30 years of age	3.5
	Retired	3.5
3.3 d	Student	1.8
3.3 e	Teacher	1.8

This modification will apply to membership fees invoiced in 2015.

Invited Speaker

Jean-Michel Raimond, recipient of the 2014 EPS Edison Volta Prize, gave an invited talk to Council Members. ■

Highlights from European journals

THEORETICAL PHYSICS

Photocouplings at the pole from pion photoproduction

While the strong force is well understood at high energies in terms of perturbative QCD, the precise mechanism responsible for the confinement of quarks and gluons in color-neutral hadrons at low energies remains a mystery to date. The intermediate energy region is characterized by rich and complex spectra of excited baryons and mesons. Its phenomenology provides a key to our understanding of the fundamental properties of matter.

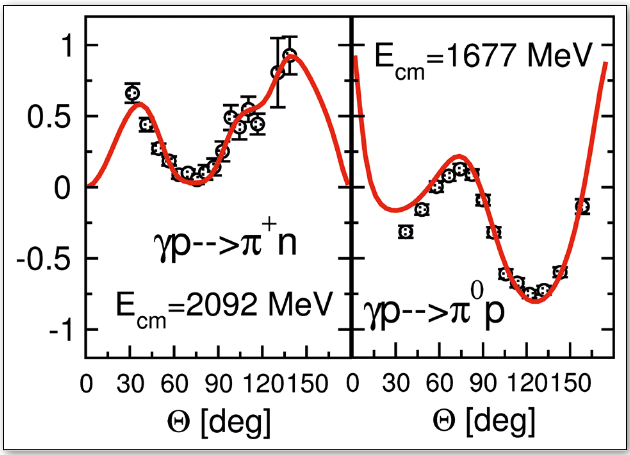
This theoretical interest has triggered large-scale experimental programs. Extracting the spectrum of baryon resonances from experimental data is a theoretical challenge, since the resonances are unstable and exhibit different decay patterns into different final states. Moreover, many resonances are broad and overlap in energy. Accordingly, a global multi-channel partial-wave analysis is required.

To this purpose, a theoretical model of meson-baryon interactions has been developed and resonance parameters were determined in the analysis of the reactions $\pi N \to \pi N$, $\pi N \to \eta N$, $\pi N \to K\Lambda$ and $\pi N \to K\Sigma$.

The present paper extends this analysis to single pion-photoproduction data - including over 20,000 measurements of cross sections and single- and double-polarization observables - from which the electromagnetic resonance properties are then extracted. ■

■ **D. Rönchen *et al.***,
'Photocouplings at the pole from pion photoproduction',
Eur. Phys. J. A **50**, 101 (2014)

▾ Selected fit results for the beam asymmetry Σ (left) and the double polarization E (right).



MATERIAL SCIENCE

Transparent conducting device **for electromagnetic waves**

It is highly desirable to make a metal transparent for electromagnetic waves, owing to many application requests for transparent metals in optoelectronics devices. However, it is well known that a high-conducting metal with a high electron density is generally opaque for electromagnetic waves, since the metal's permittivity is generally very negative at optical frequencies. Here, a freestanding transparent conducting device based on multilayer metamaterials is theoretically demonstrated at terahertz frequencies. It is realized by depositing periodic metallic patches on top and bottom of the subwavelength metallic mesh. The high transmission of the designed system is attributed to the impedance matching to the vacuum. This design of a transparent conducting device opens a high transmission window within the technologically relevant THz frequency range. This device may find plenty of applications in optoelectronic electrodes, micro-electronic displays, and the miniaturization and integration of THz components, where both high electrical conductivity and high optical transmission are desirable. ■

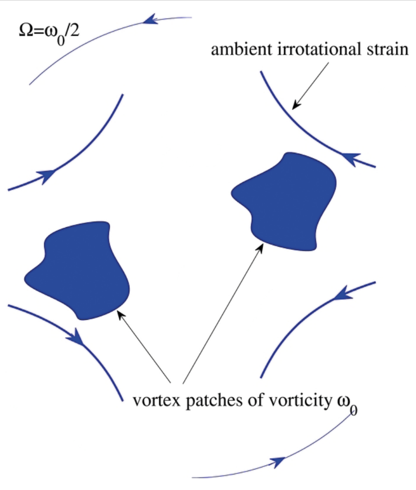
■ **Z. Song**, **Z. Gao**, **Y. Zhang** and **B. Zhang**,
'Terahertz transparency of optically opaque metallic films',
EPL **106**, 27005 (2014)

MATHEMATICAL PHYSICS

A vortex of eigenvalues

As the size of a random normal matrix grows, so does the number of its eigenvalues. As this number tends to infinity (with the mutual "repulsion" of eigenvalues reducing simultaneously) the eigenvalues "clump together" into a finite collection of dense, uniform, regions. Here we demonstrate the surprising result that exactly the same phenomenon pertains to rotating equilibrium arrangements of vorticity - so-called "vortex patches" or "V-states" – whose dynamics are governed by the famous Euler equations for ideal fluids. The underlying mathematical structure in these quite distinct areas of physics turns out to be identical.

The connection is made via an inverse moment problem in which the geometry (of either the limiting eigenvalue distribution, or the vortex patches) is dictated by an imposed background



▲ Rotating vortex patches behave like clumps of eigenvalues for random matrices

potential, but in an indirect way that must be decoded. This analogy is significant not only because it links two erstwhile unconnected areas of study, but also because it affords valuable mathematical "technology transfer", especially with respect to decoding the shape of what we might now call the limiting "vortex of eigenvalues" in random matrix theory. ■

▮ D.G. Crowdy,
'Vortex patch equilibria of the Euler equation and random normal matrices', *J. Phys. A: Math. Theor.* **47**, 212002 (2014)

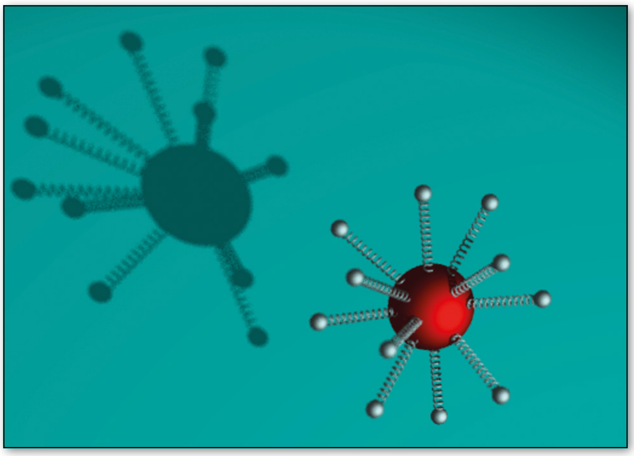
CONDENSED MATTER

Particles near absolute zero **do not break the laws of physics**

A change of models demystifies anomalous particle behaviour at very low temperatures, confirming that the third law of thermodynamics cannot be violated

In this work, the authors have demonstrated that a theoretical model of the environment's influence on a particle does not violate the third law of thermodynamics, despite appearances to the contrary. These findings are relevant for systems at the micro or nanometer scale that are difficult to decouple from the heat or the quantum effects exerted by their environment.

▼ A free particle strongly coupled to a heat bath. Credit: Adamietz *et al.*



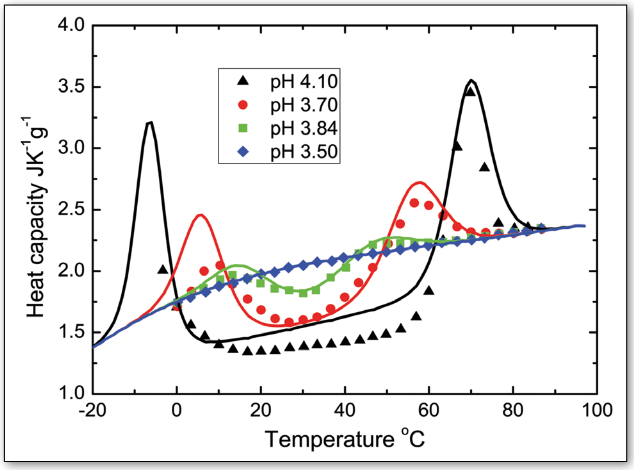
Previous theoretical predictions suggested that, under certain circumstances, the specific heat—the amount of energy needed to raise the temperature of a particle coupled to a heat bath by a certain amount—can decrease below zero at strictly zero temperature (–273.15 °C). This prediction appears to breach the third law of thermodynamics, indicating that the specific heat must drop to zero value at strictly zero temperature. Yet, these findings show that previous studies need to be modified in order to account for a spatial confinement of the particle. ■

▮ R. Adamietz, **G.-L. Ingold** and **U. Weiss**,
'Thermodynamic anomalies in the presence of general linear dissipation: from the free particle to the harmonic oscillator', *Eur. Phys. J. B* **87**, 90 (2014)

STATISTICAL PHYSICS

Deeper insights **into protein folding**

Physicists have published a new theory explaining the mechanism of protein folding and unfolding in water.



▲ Structure of staphylococcal nuclease. Credit: Yakubovich *et al.*

The authors have produced a new theoretical study of a protein macromolecules changing from a coil structural formation to a globular one. Their statistical mechanics model describes for the first time the thermodynamic properties of real proteins in aqueous environments using a minimal number of free physical parameters.

In this work, the authors confirmed the validity of their theoretical calculation of dependencies of the protein heat capacities on temperature by comparing it with the corresponding experimental measurements for two proteins, namely an enzyme called staphylococcal nuclease and an oxygen and iron carrier protein called metmyoglobin. Sudden changes in temperature could result in the loss of proteins' three-dimensional structure, and of their function. Thus, these findings could contribute to our understanding of high-energy ion therapy for biological cells. ■

A. V. Yakubovich and **A. V. Solov'yov**,
'Quantitative thermodynamic model for globular protein folding', *Eur. Phys. J. D* **68**, 145 (2014)

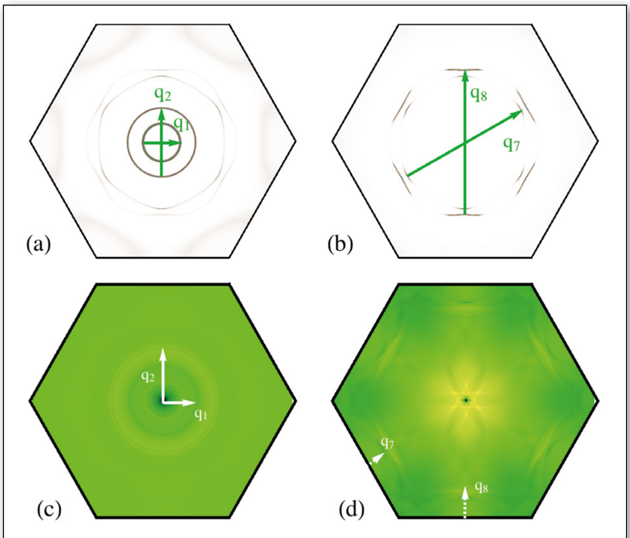
MATERIAL SCIENCE

Gap function of hexagonal pnictide superconductor SrPtAs

The pnictide superconductor SrPtAs has a hexagonal layered structure that breaks in-plane inversion symmetry while overall the crystal is still centrosymmetric. This has peculiar consequences for the electronic structure as well as the Cooper pairing. It leads to a strong Rashba spin orbit coupling and splitting of quasi-2D 5d Pt bands that dominate the Fermi surface. Although the superconducting gap functions are even or odd under inversion the in-plane pairing is nevertheless a mixture of singlet and triplet pairs due to the large Rashba coupling. Microscopic theories have obtained possible s+f and p+d wave candidates with unconventional nodal structure. We propose to apply Bogoliubov quasiparticle interference (QPI) technique to SrPtAs which records the spectral density fluctuations at the surface due to impurities. We show that their analysis can give important clues on the nodal structure of the unknown SrPtAs gap function. ■

A. Akbari and **P. Thalmeier**,
'Gap function of hexagonal pnictide superconductor SrPtAs from quasiparticle interference spectrum', *EPL* **106**, 27006 (2014)

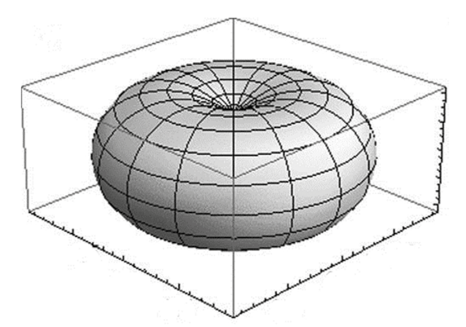
▼ Above: Quasiparticle equal energy (ω) surfaces for A_{1g} (a) and E_g (b) gap functions at ω/Δ_0=0.5 (Δ_0 is the gap amplitude). Below: QPI spectrum (c,d) for corresponding gap functions. The scattering vectors $\mathbf{q}_i$ are characteristic for the nodal gap structure.



APPLIED PHYSICS

Anisotropic light emission from aligned luminophores

Organic dichroic dyes are neither isotropic in absorption nor in emission. By aligning the fluorophores using liquid crystals, for example, one may gain a degree of control over both the absorption and emission directions of the light. Controlling of light emission directions could have significant impact on the performance of devices such as organic LEDs or luminescent solar concentrators, the latter of which have potential for use as solar energy generators in the built environment.



◀ Calculated emission profiles from homeotropically aligned dichroic luminophores illuminated from directly overhead with an order parameter of $S_{2,opt}$=0.6.

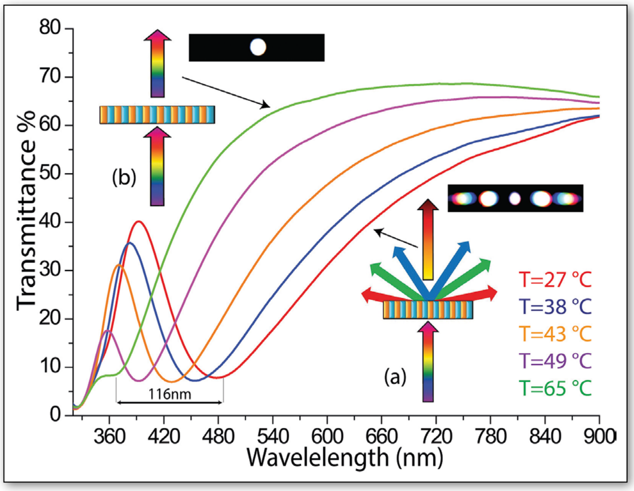
Commercial ray tracing software does not take this dichroism into account, and thus cannot model these devices correctly. In this paper, we develop a simple formalism to describe the resulting emission from a collection of dichroic dyes with arbitrary alignment, including the extremes of planar and homeotropic, and for various degrees of disorder about this alignment. We demonstrate close agreement of the calculations with experimental studies. We close the discussion by accentuating the importance of incorporating these calculations into functioning simulation systems to allow *in silico* optimization of the devices which will accelerate their entrance into the commercial sphere. ■

P.P.C. Verbunt, **T.M. de Jong**, **D.K.G. de Boer**, **D.J. Broer** and **M.G. Debije**,
'Anisotropic light emission from aligned luminophores', *Eur. Phys. J. Appl. Phys.* **67**, 10201 (2014)

OPTICS

Tuneable broadband optical filter based on soft-composite materials

We realized a free-space, polarization sensitive, broadband, widely tunable, optical filter by exploiting a micro-composite holographic grating made of polymer slices alternated with films of aligned Nematic Liquid Crystals (NLC). Impinging probe light (*p*-polarized) experiences a refractive index modulation (Δn_g); thus, it is transmitted/diffracted and, consequently, angularly separated into its fundamental colours, according to the



▲ Spectral response versus temperature and schematic rapresentation of the filter mechanism in states ON (a) and OFF (b).

sketch of Figure (a). This diffraction effect induces a band-gap behaviour (filter in the ON state) in the transmission properties featured by the structure (Figure (a), red curve) and in the corresponding far field diffraction pattern. Both electric fields and temperature variations can be exploited to tune the position of the diffractive band-gap; in particular, by increasing the sample temperature, a nematic to isotropic transition of the NLC component gradually reduces Δn_g, with a resulting blue shift and a gradual suppression of the diffraction band (Figure (a), green curve). Under these conditions, light is almost completely transmitted (filter in the OFF state) as shown in the far field diffraction pattern and in the corresponding sketch reported in Figure (b). ■

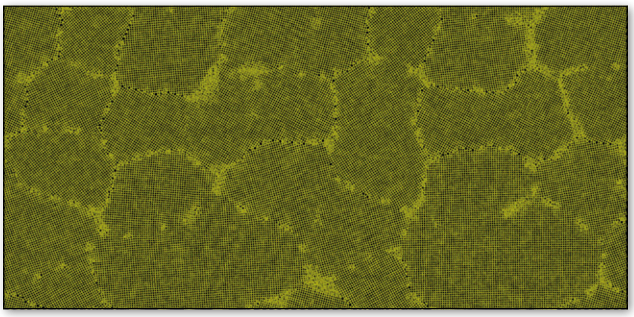
▮ **L. De Sio**, **V. Caligiuri** and **C. Umeton**,
'Tuneable broadband optical filter based on soft-composite materials', *J. Opt.* **16**, 065703 (2014)

MATERIAL SCIENCE

Nanoscale heat flow predictions

A new study predicts that heat flow in novel nanomaterials could contribute to creating environmentally friendly and cost-effective nanometric-scale energy devices.

▼ Snapshot of the final configuration of a nc-Si sample. Credit: Melis *et al.*



Physicists are now designing novel materials with physical properties tailored to meet specific energy consumption needs. Before these so-called materials-by-design can be applied, it is essential to understand their characteristics, such as heat flow. Now, the authors have developed a predictive theoretical model for heat flux in these materials, using atom-scale calculations. These findings could have implications for optimizing the thermal budget of nanoelectronic devices or in the production of energy through thermoelectric effects in novel nanomaterials.

The authors adopted a method called approach equilibrium molecular dynamics (AEMD), which is robust and suitable for representing large systems to deliver trustworthy predictions on thermal transport. Ultimately, the model could be applied to semiconductors used as high-efficiency thermoelectrics, and to graphene nanoribbons used as heat sinks for so-called ultra large scale integration devices, such as computer microprocessors. ■

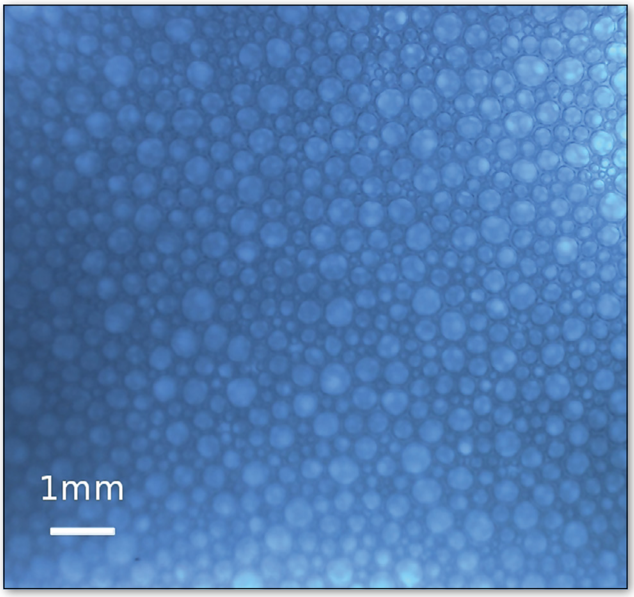
▮ **C. Melis**, **R. Dettori**, **S. Vandermeulen** and **L. Colombo**
'Calculating thermal conductivity in a transient conduction regime: theory and implementation',
Eur. Phys. J. B **87**, 96 (2014)

CONDENSED MATTER

Microgravity and aqueous wet foams

Foams and foaming processes pose interesting questions for both fundamental research and practical applications. Although foams are a familiar thing, both in our everyday lives and in industry, many aspects of foam physics and chemistry still remain unclear.

▼ Foam made in the device elaborated by Astrium for the future foam studies in the ISS.



This work comprehensively reviews the studies of foams under microgravity, including studies conducted in parabolic flights, in sounding rockets and in the International Space Station.

Experiments on foams performed under microgravity can be extended far beyond the conditions of experiments carried out on Earth. In particular, when gravity is minimized, it is possible to observe the behaviour of wet foams obtained during the foaming process. On Earth, foams at this stage evolve too quickly due to gravity drainage and cannot be studied. ■

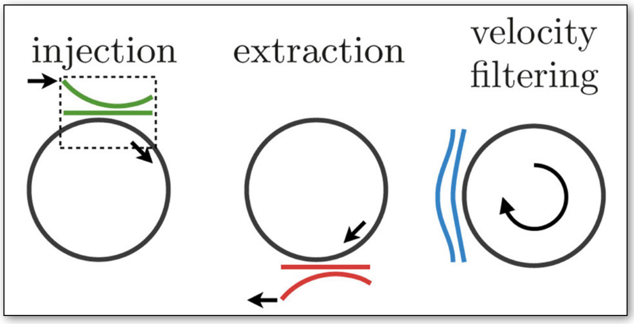
■ **D. Langevin** and **M. Vignes-Adler**,
'Microgravity studies of aqueous wet foams',
Eur.Phys. J. E **37**, 16 (2014)

ATOMIC AND MOLECULAR PHYSICS

Ultra-cold atom transport made simple

New study provides proof of the validity of a filtering device for ultra-cold neutral atoms based on tunnelling.

A new study gives a proof of principle, confirmed by numerical simulations, of the applicability to ultra-cold atoms of a very efficient and robust transport technique called spatial adiabatic passage (SAP). The authors have, for the first time, applied SAP to inject, extract, and filter the velocity of neutral atoms from and into a ring trap.



▲ Schematic representation of the physical system consisting of a ring trap and two dipole waveguides for injecting neutral atoms into, extracting them from, and velocity filtering them in the ring waveguide. Credit: Loiko *et al.*

They focused on controlling the transfer of a single atom between the outermost waveguides of a system composed of two dipole waveguides and a ring trap, using the SAP technique. They calculated the explicit conditions for SAP tunnelling, which depend on two factors: the atomic velocity along the input waveguide and the initial atom population distribution among what physicists refer to as the transverse vibrational states.

To check the performance of the proposed approach, they relied on a numerical integration of the corresponding equation with parameter values for rubidium atoms and an optical dipole ring trap. ■

■ **Y. Loiko**, **V. Ahufinger**, **R. Menchon-Enrich**, **G. Birkl** and **J. Mompart**
'Coherent injecting, extracting, and velocity filtering of neutral atoms in a ring trap via spatial adiabatic passage',
Eur. Phys. J. D **68**, 147 (2014)

CONCLUSION OF THE INTERNATIONAL CONFERENCE SIGMAPHI2014

The International Conference on Statistical Physics -SigmaPhi2014- took place in Rhodes (Greece) during the second week of July 2014 (from 7th to 11th July).

SigmaPhi2014 was organized by the Polytechnic of Turin (Italy) in collaboration with the Nonlinear and Statistical Physics Division of the European Physical Society (NSP-EPS).

The Conference was established in 2005 and currently represents the largest European event in the field of Statistical Physics. The conference is organized with three-year periodicity by the Polytechnic of Turin in collaboration with NSP-EPS.

The Chairman of the Conference Giorgio Kaniadakis (Polytechnic of Turin) was opening the Conference sessions in the presence of the Mayor of Rhodes and the President of NSP-EPS Jerzy Luczka (University of Silesia).

More than 400 papers, selected as oral or poster, were presented during the Conference. More than 65 invited talks were presented in various fields of Statistical Physics.

The Conference, in addition to regular sections, also hosted 8 parallel workshops dedicated to some important topical applications of Statistical Physics involving physical and non-physical systems (including Biophysics, Econophysics, Physics for Sociology, Complex Networks). For the first time the Conference dedicated a specific workshop on Quantum Computing and Quantum Information gathering great success.

On July 8th the Board of NSP-EPS held its annual meeting and during the closing session of the Conference on July 11th three awards for young scientists were presented, each of 500 Euros, for the best work on the Foundations of Statistical Physics offered by the Polytechnic of Turin, for the best work on Complexity offered by the Publisher Elsevier and finally for the best poster presentation offered by the National Center for Scientific Research Demokritos.

Three awards were won by three young scientists from Russia, Hungary and Japan, respectively.

The date for the next edition of the SigmaPhi Conference is set for July 2017. ■

UNRAVELLING THE MYSTERY OF THE EARTH'S MAGNETIC FIELD

Henri-Claude Nataf – Univ. Grenoble Alpes/CNRS/IRD, ISTerre
F-38000 Grenoble, France – DOI: 10.1051/epn/2014401

Slow convective motions in the liquid iron core of the Earth give birth to its magnetic field. How do these motions get organized under the combined effects of the Coriolis and Lorentz forces? Lab experiments reveal a peculiar behaviour. They also suggest that we need to reconsider what turbulence means in these conditions. Our better understanding of the dynamics of the core, and ever more precise observations have led to the recent discovery of a spectacular phenomenon: the propagation of torsional Alfvén waves, which jerk the core every 3-4 years.

The Earth's remote ocean

Because it is remote, invisible and unreachable, we tend to forget that the largest ocean on Earth is not at its surface: it is deep inside the Earth. The Earth's liquid core is an ocean of liquid iron more than 2000 km thick. It lies between the central solid inner core (at radius 1220 km) and the base of the silicate mantle (at radius 3500 km). Hot as hell (T>5000°C) and under horrendous pressures (from 135 to 360 GPa), iron in these conditions is nearly as fluid as water [1]. It flows easily and, as its surface cousin, it strongly feels the rotation of the Earth: fluid motions organize in large columnar eddies with their axis aligned with the rotation axis of the Earth. These are called quasi-geostrophic motions. Purely azimuthal geostrophic motions are also expected, similar to the winds that form the bands in the atmosphere of Jupiter.

There is a big difference though: fluid motions in the core generate a magnetic field, whose strength reaches 0.5 mT at its surface (down to 0.05 mT at the surface of the Earth). How? By the self-excited dynamo mechanism proposed by Larmor [2] in 1919. Take a tenuous seed of magnetic field, and let the electrically conducting liquid iron flow across its field lines. It induces electric currents. In turn, these currents generate a magnetic field. If that field reinforces the seed field, exponential growth of the magnetic field occurs.

With this mechanism, it is not so easy to produce a large-scale almost dipolar magnetic field, aligned with the rotation axis, as we observe on Earth and several planets. And it was a relief when the first consistent numerical simulation of the geodynamo produced such a field, in 1995 [3]. At least as exciting were the first experimental demonstrations of dynamo self-excitation by a fluid flow, in Riga and in Karlsruhe, in the year 2000 (see [4] for an overview of dynamo experiments).

A changing magnetic field

The magnetic field of the Earth is not static. Back in the 17th century, when maps of the magnetic field were essential for navigators, it was observed that magnetic features drift on secular time-scales. Using these long historical time series, and combining them with recent more global satellite observations, scientists infer the large-scale flow in the core. Velocities of about 1 mm/s are typical. One key observation is that magnetic energy is more than a thousand times larger than the kinetic energy of these large-scale motions. Numerical dynamo simulations are not able to reproduce this surprising result. One consequence is that the dominant forces in the Earth's core are the Lorentz force – due to the interaction of the flow with the magnetic field – and the Coriolis force – due to the rotation of the Earth. We call this the magnetostrophic regime.

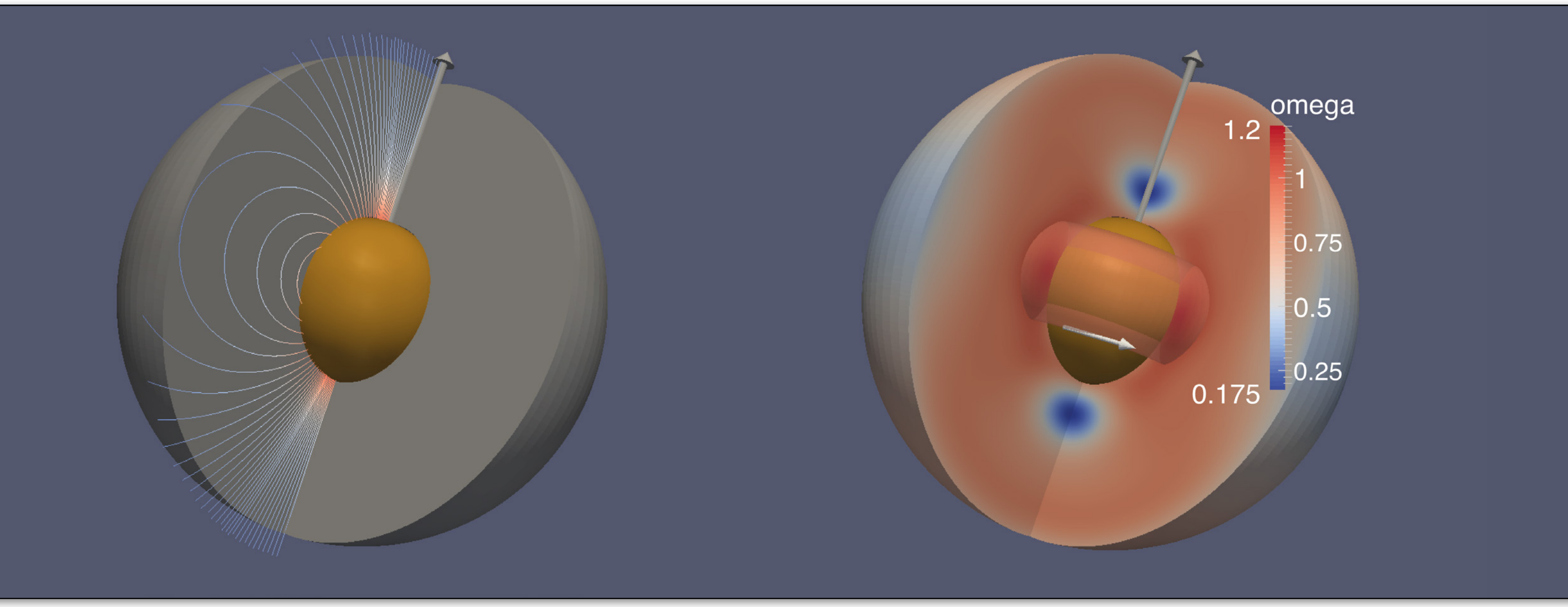
We know that the Coriolis force tends to organize flows into quasi-geostrophic columns and large azimuthal winds. The Lorentz force behaves similarly, inhibiting flows that would cross magnetic field lines. So, how do flows get organized when both rotation and strong magnetic field are present?

DTS: a magnetostrophic experiment

Nothing better than an experiment to explore the physics in these conditions. Take a spherical shell with a spinning inner sphere to force a spherical Couette flow, *i.e.*, a shear flow between concentric spherical shells. Allow rotation of the outer sphere around the same vertical axis to get the Coriolis force. Add a strong dipolar magnetic field by enclosing a big magnet inside the copper inner sphere. And fill the shell with the liquid that has the largest electrical conductivity to get the Lorentz force: you get the "Derviche Tourneur Sodium" (DTS) experiment (fig. 1) that my team has built to investigate the magnetostrophic regime [5].

◂ Silent and invisible, the magnetic field of the Earth reveals its presence when particles from the solar wind break their way through its protective shield, producing beautiful auroras. ©iStockPhoto

▾ **FIG. 1:** the DTS experiment installed in our Lab in Grenoble. The action takes place in the sphere, which contains 40 litres of liquid sodium.



▲FIG. 2: The initially dipolar magnetic field imposed in the DTS experiment (left) is sheared by motions in the sodium, which is dragged along by the inner sphere spinning at 30 Hz (middle; colours indicate the angular velocity of the fluid, normalized by that of the inner sphere. The values exceeding 1 in the torus correspond to super-rotation). The magnetic field lines are twisted by the flow (right).

One might have expected the flow to be hindered by the Lorentz force. For the mean flow, we observe the opposite. In the absence of a magnetic field and with the outer shell at rest, viscous friction on the inner sphere drags the fluid along at angular velocities that stay below one third of that of the inner sphere Ω_i. With the imposed magnetic field, the fluid spins much faster: its angular velocity even gets 20% larger than Ω_i: super-rotation! It spins so fast that the Coriolis force is strong even when the outer sphere is kept at rest. We have been able to reconstruct the mean flow, using ultrasound Doppler velocimetry (sodium is opaque), and measurements of the induced magnetic field (fig. 2). Isovalues of the angular velocity tend to follow the field lines of the imposed magnetic field around the inner sphere, where the Lorentz force is the largest, obeying Ferraro's law of isorotation. The torus drawn around the spinning inner sphere demarcates the region where sodium is super-rotating. At larger radii, the Coriolis force dominates and the mean flow is geostrophic. The field lines of the imposed dipolar magnetic field are twisted by the shear.

Lessons on turbulence from experiments

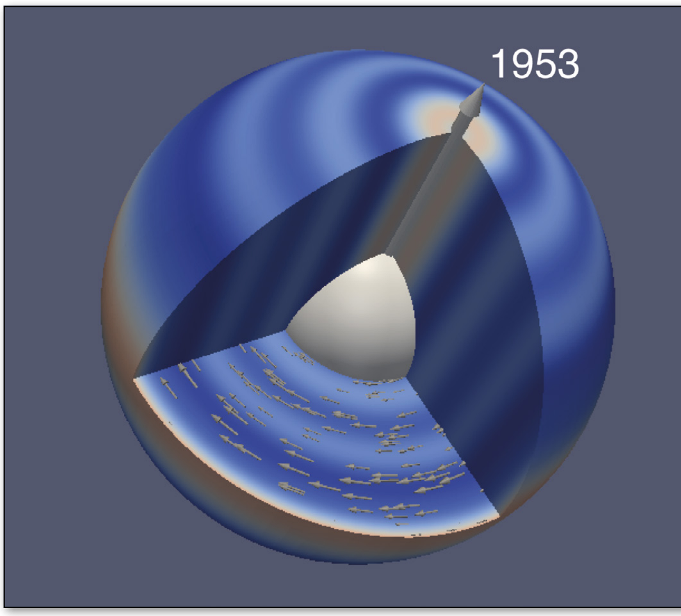
Our most striking observation is that turbulent fluctuations are very small despite the large values of the Reynolds number (Re~10^6). Under the combined action of the Lorentz and Coriolis forces, the fluid has little freedom to fluctuate.

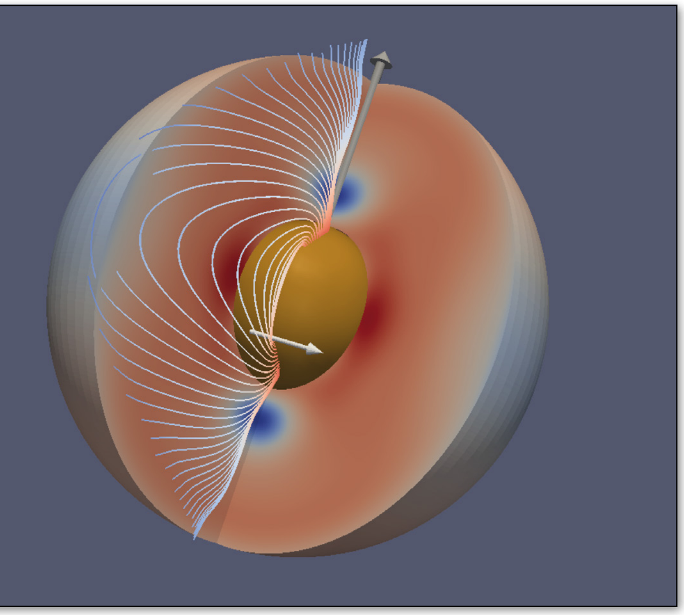
We think that this mechanism could help to explain why the large-scale magnetic energy is so large in the Earth's core. Indeed, if the magnetic field were following a classical turbulent cascade from large scales down to small scales, where Joule dissipation occurs, one would await a total power in excess of 1000 TW, while we know that the total power transmitted by the core to the mantle is no more than 15 TW.

It swings in the Earth's core

Great progress has been made in reconstructing flow inside the core from the analysis of the secular variation of the magnetic field. This led to the recent discovery [6] of a spectacular ballet inside the core: geostrophic motions propagate in a wave-like fashion from the inner core to the equator of the outer core (fig. 3). The journey takes 3-4 years, and it repeats itself again and again for decades. These waves are Alfvén waves: they initiate some motion that distorts magnetic field lines, which swing back to their initial position, thus propagating the motion further.

The Coriolis force inhibits Alfvén waves in the core, except for this particular kind, called torsional oscillations, on which it has no effect. The stronger the magnetic field, the faster the wave. This way, we





get the first measure of the intensity of the magnetic field hidden inside the core: almost 3 mT, some six times larger than the field that makes it out of the core.

Sceptical? Remember that torsional waves carry angular momentum. Since the total angular momentum of the Earth is conserved, the mantle of the Earth has to swing in the opposite direction when the wave travels. This should modulate the length-of-day, which astronomers measure very precisely. And indeed it does: the modulation is only ±0.2 milliseconds, but the prediction is right on [6]!

More fun to come?

It would be nice to observe these waves in our Lab experiments. Unfortunately, they are heavily damped by magnetic diffusion, and die away before they can get anywhere. But there is still hope: our DTS experiment now has a big sister: a 3 m-diameter sphere, containing 12,000 litres of liquid sodium, which has just been launched by Dan Lathrop and his team, at the University of Maryland [4]. And we all hope that this experiment will create its own magnetic field, by the dynamo mechanism. Stay tuned!

About the Author

Henri-Claude Nataf studied Physics and Geophysics at the University Paris-South in Orsay, where he obtained a PhD in 1980. He is now a CNRS Research Director at ISTerre in Grenoble, where he co-founded the 'geodynamo team' in 1997.

Acknowledgments

I thank all present and past actors of the DTS adventure for their contribution to this exciting project. Nicolas Gillet kindly provided the data used for Figure 3, and David Cébron helped with handling the Paraview software for Figures 2 and 3.

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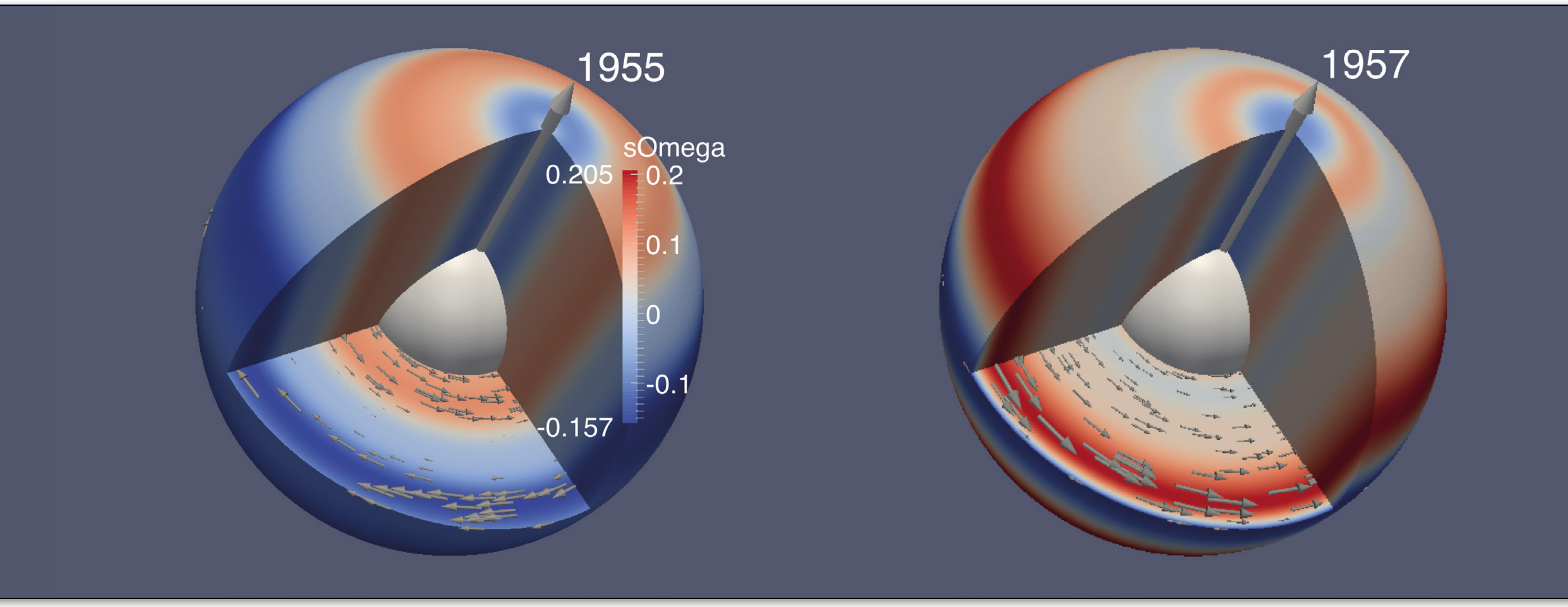
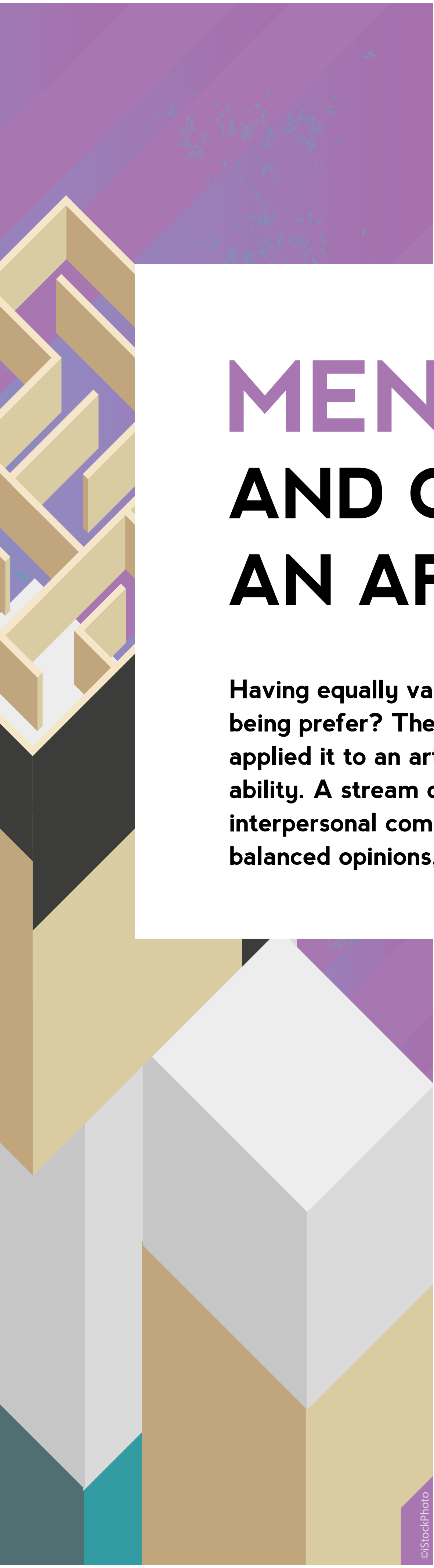
[6] N. Gillet, D. Jault, E. Canet and A. Fournier, *Nature* **465**, 74 (2010).

▼ **FIG. 3:** Torsional waves in the Earth's core, as discovered in 2010 by Gillet et al [6]. These geostrophic motions (arrows and colours with scale in km/year) are a particular kind of Alfvén waves. It takes them a few years (here from 1953 to 1957) to travel from the inner core to the outer core equator.





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MENTAL ABILITY AND COMMON SENSE IN AN ARTIFICIAL SOCIETY

Having equally valid premises pro and contra, what does a rational human being prefer? The answer is: nothing. We designed a test of this kind and applied it to an artificial society, characterized by a given level of mental ability. A stream of messages from media is supplemented by ongoing interpersonal communication. The result is that high ability leads to well-balanced opinions, while low ability produces extreme opinions.

How we decide what is right or wrong

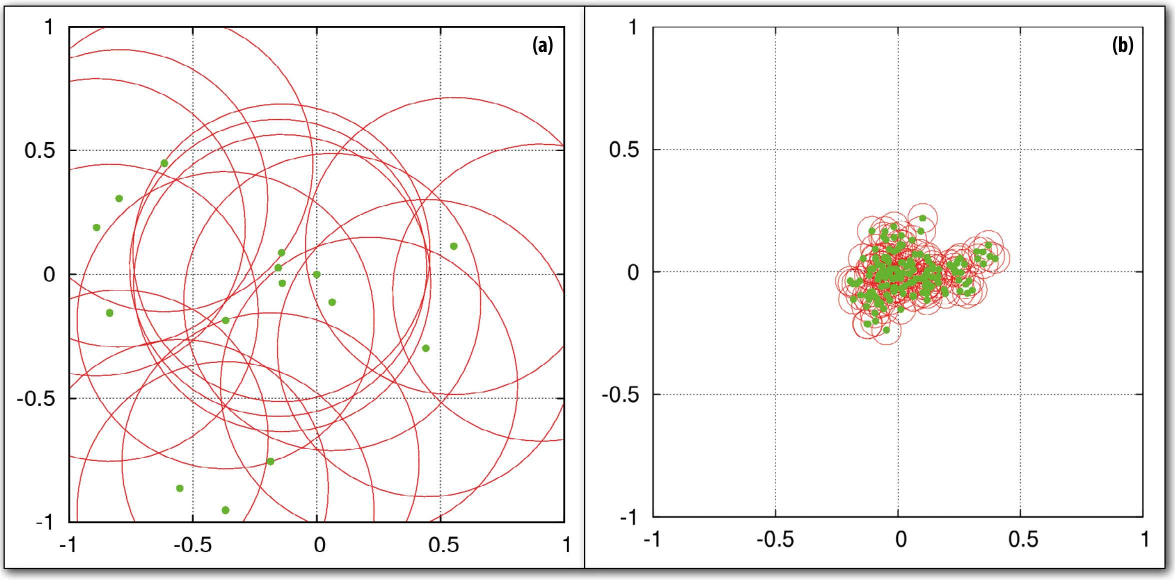
We read newspapers and watch TV every day. There are many issues and many controversies. Since media are free, we can hear arguments from every possible side. How do we decide what is wrong or right? The first condition to accept a message is to understand it; messages that are too sophisticated are ignored. So it seems reasonable to assume that our understanding depends on our ability and our current knowledge. Here we show that the consequences of this statement are surprising and funny.

How do we learn?

To demonstrate this, we propose a computational model with two assumptions [1]. The first is that messages can be represented as points on a plane of a finite area, say, a square $a \times a$. Consequently, we can measure the distance between messages. The second assumption is that we can understand a message if it is not too far from what we already know.

As a direct consequence of these two assumptions, we obtain a simple model of learning. In this model the mind is represented by an area around the messages understood by the mind's owner. Her/his ability is represented by a critical distance D_c. A new message can be grasped if its distance to the closest previously understood message is shorter than D_c. If this distance is longer, the message is ignored.

Let us consider a new area of experience: differential calculus, traffic regulations, stock market, foreign policy or classic Latin grammar can serve



▸ FIG. 1: The 'mental history' of a single actor: positions of understood messages for a) $D_c/a = 0.3$ and b) $D_c/a = 0.03$. Each actor starts from one message at the center of the square. In case a) the actor understands almost all messages after a few steps. In case b) the actor remains confined with her/his knowledge, with a bias towards right (the bias direction is random).

as examples. Initially we know a small area on a square. Step by step, we expand our knowledge each time when a new message is found to be comprehensible. The speed at which the known area expands is determined by the parameter D_c. If it is comparable with size a of the square, the mind understands everything after a few messages. However, if D_c/a is small, initially most of the incoming messages are ignored, and the area of understanding expands very slowly. This is demonstrated in Fig. 1, where we see an area equivalent to the gained knowledge for D_c/a =0.3 after 10 messages in panel a), and for D_c/a =0.03 after 100 messages in panel b). In Fig. 2 we show the fraction of messages that are understood as a function of the number of all messages, also for these two values of D_c/a.

An example - how we think about politics

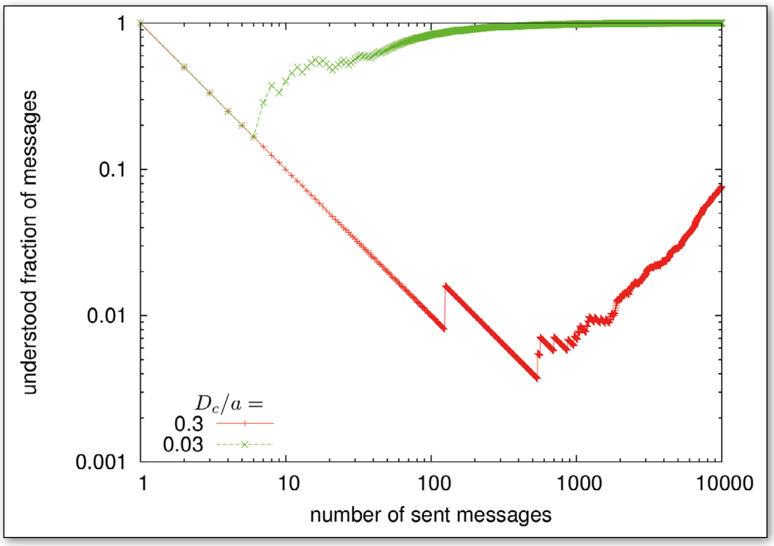
As we are political animals, let us apply the model to our political beliefs. In this field, public discussions are most aggressive and arguments least convincing. Trying to be objective – as scientists should be – we choose our square to be symmetrically divided between two orientations: Left and Right. The vertical axis can be interpreted as a measure of the distance between Authoritarian and Libertarian, as in [2].

Let us suppose that our model mind is target of a stream of messages, evenly distributed in the square. Again, if D_c/a is close to 1, the situation is rather trivial; the model mind quickly arrives at full understanding. However, for small values of the ratio D_c/a the situation is less trivial because bias comes into play. Let us assume at first that our mind is initially unbiased; its owner accepts the first message if it appears within a circle of radius D_c around the square centre. Yet we can expect that a certain degree of bias will soon develop: it is unlikely that the Left-Right symmetry is preserved for the trajectory of a single mind. An example of this effect is shown clearly in Fig. 1b.

To explain this, we refer to theory of random walk [3]. Suppose that our model is simplified to one dimension, with steps towards left and right at discrete times with equal probabilities. Suppose also that our mind made a step in a given direction. We can then ask the question: how long will it take until it returns? The theory tells us: infinitely long on average.

Here we touch upon an important feature of our model. It is clear that each mind will reach full understanding after a sufficiently long time. However, the difference between able (large D_c) and less able (small D_c) minds manifests itself always within a finite time. It is just our own lifetime which is finite, and its length provides a time scale for everything we do, including understanding things. Compared with the 'infinitely long' case from the previous paragraph, this means that, once biased, many of us will never reach objectivity again.

▾ FIG. 2. The fraction of messages understood as a function of the number of incoming messages, for D_c/a =0.3 (upper, green curve) and D_c/a = 0.03 (lower, red curve). Each actor starts from one message at the center of the square. In this log-log plot, the lower curve shows a vertical step between two subsequently understood messages. Initially, such events are rather rare.



The test

To generalize our model, let us consider a large number of minds, each of which is target of a stream of messages. As we have seen, whether we include an initial bias or not is of secondary importance. Now we are going to design a test of social common sense in our artificial society.

As the messages are evenly distributed, neither Left nor Right arguments prevail. Knowing this, we can expect that a reasonable person remains objective. What is the result?

To answer this, let us introduce a probability p that a given mind's owner, when asked about her/his preference, is going to answer "Right". Likewise, a probability q is assigned to the answer "Left", with the obvious condition $p + q = 1$. For each mind, the probability p will be calculated as follows. The number of all messages he or she understood within a given time is N. This set is divided into $N(L)$ and $N(R)$, where $N(L)$ is the number of understood messages placed on the left part of the square, and $N(R)$ for the right part. Obviously, $N(L) + N(R) = N$. Then, $p = <x(R)>/<|x|>$, where

$$<x(R)>=\sum_{i}^{N(R)} x(i)$$

is the mean x-coordinate of messages on the right half-plane, and

$$<|x|>=\sum_{j}^{N}|x(j)|$$

is the mean absolute value of the x-coordinate of all messages. Probability p is now calculated separately for each mind [1].

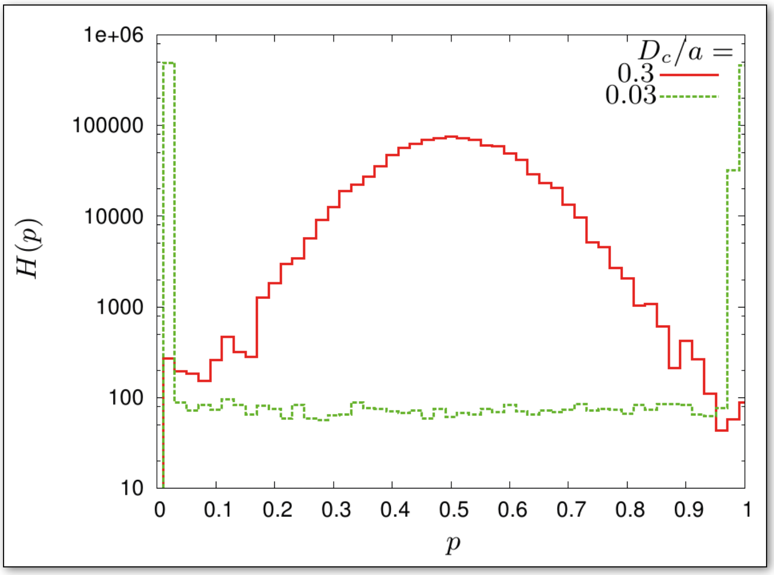
What is the probability distribution of p itself? The answer is shown in Fig. 3, for different values of the ability parameter D_c. As we see, both plots preserve the Left-Right symmetry within the accuracy of statistical errors. For large values of D_c the resulting probability distribution is centered around the value $p = 0{,}5$. By contrast, for small D_c the distribution consists of two sharp maxima close to $p = 0$ and $p = 1$. In other words, in the former case of large ability a statistical mind answers "Left" and "Right" with equal probabilities. This is equivalent to the answer "I don't know", the only reasonable answer because the incoming messages do not provide arguments for a more decisive statement. However – and this is our most important result – for a society characterized with small ability D_c a statistical mind answers either surely "Left", or surely "Right". In other words, in the case of small mental ability all opinions are extreme.

Additional remarks

The model [1] has been further developed to include consequences of interpersonal communication: minds not only hear but also articulate their opinions, which are included to the stream of messages. To mention two main results, we note that an intensive communication leads to a clustering of opinions, which become more extreme even for the case of moderate ability [4]. On the other hand, the latter unanimity disappears if messages are addressed to minds which are neighbors in the square of issues. Then, again, the opinions are less extreme [5]. These results lead one to be cautious about situations in which unanimity is treated as good and conflict as evil.

Alas, in our world unanimity is almost always against somebody else. In that case the contradistinction is not "unanimity *vs.* conflict", but rather "diversity *vs.* extreme".

Paraphrasing Paul Géraldy, one could say that it is the political party who chooses the man who will choose her. This means that everybody will be chosen by some party. Yet a simple "I don't know" seems a good remedy against an extreme "Yes" or an extreme "No". What is funny (at least for us) is that this is the result of a model based on statistical mechanics. ■



▲ **FIG. 3.** Histogram $H(p)$ of the individual probabilities p for $D_c/a = 0.3$ (central peak) and $D_c/a = 0.03$ (binomial curve). The small asymmetry of the latter is a statistical fluctuation. The results are averaged over 10^3 actors, 100 messages and 10^3 runs; one run means one set of messages, the same for all actors. Here, initial positions of actors (their first understood messages) are evenly distributed on the square.

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GIANT IMPACT:

ACCRETION AND EVOLUTION OF THE MOON

IMPLICATIONS FOR EARTH, MARS AND THE SOLAR SYSTEM AS A WHOLE[1]

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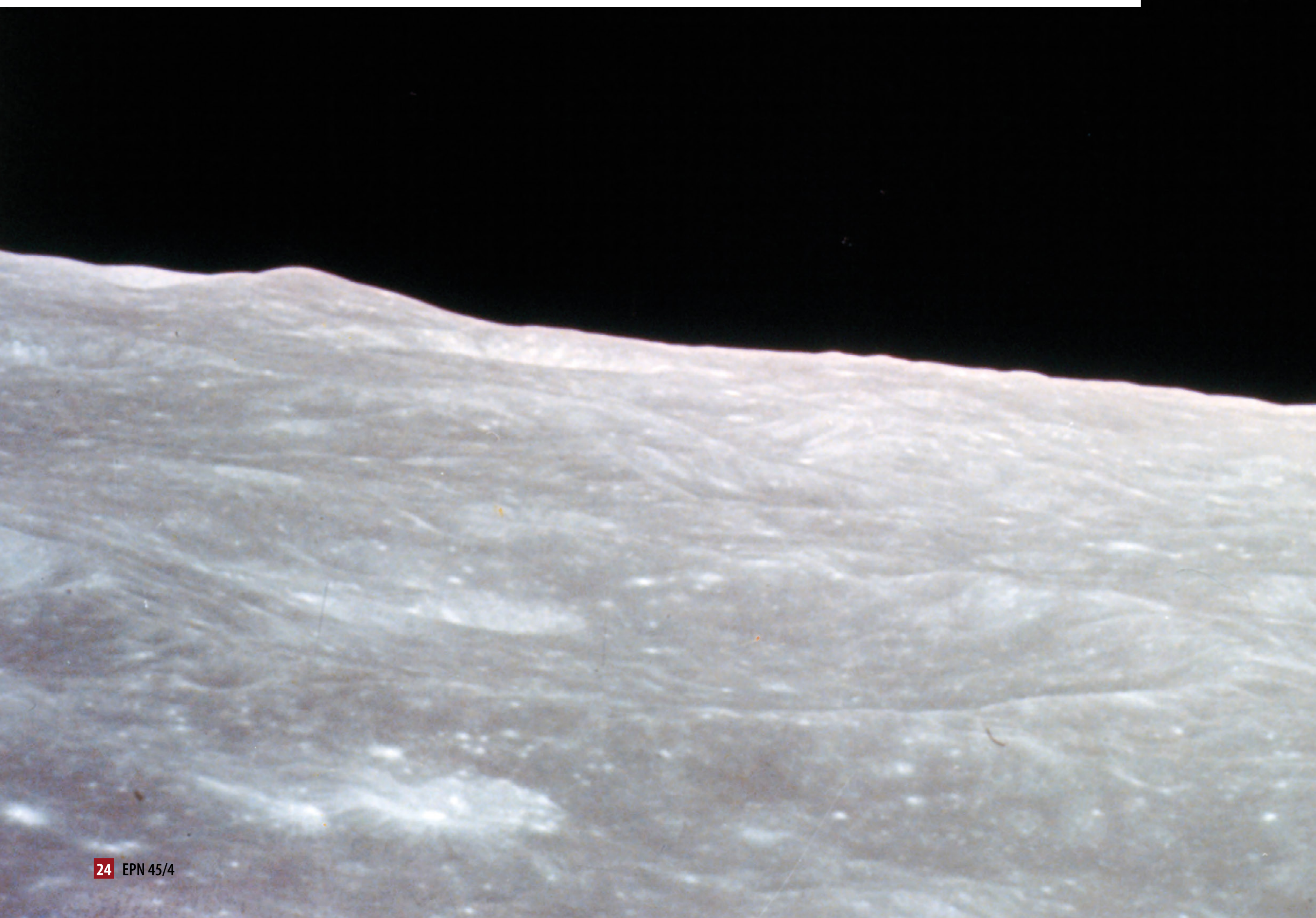
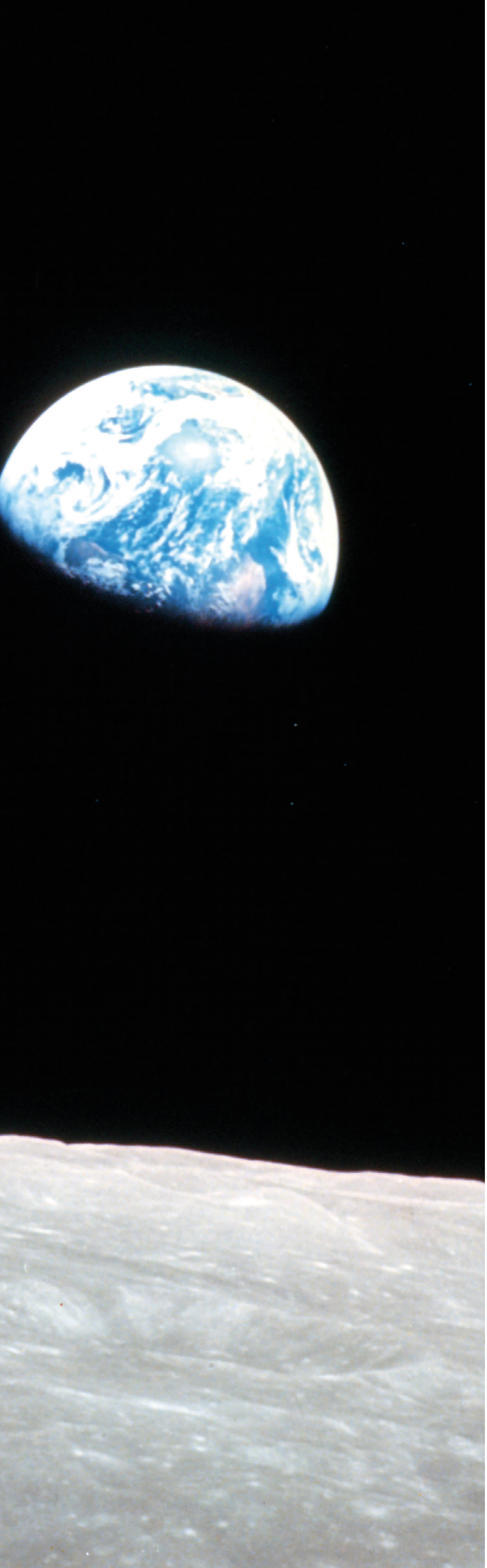
Our planetary system has not always been as serene as it appears to us today. Exploration of the Moon has shown that disastrous collisions and violent epochs have occurred in the early part of its history. Indeed, a collision of the Earth with another planet – the Giant Impact – is the most widely accepted theory for the origin of the Moon. Several hundred million years later, Moon and Earth received a *Late Heavy Bombardment* that created the large basins on the Moon and must have devastated the atmosphere and hydrosphere of the Earth.





The exact place and time of such disastrous events are impossible to accurately retrace in time, but that does not mean they are unlikely. It has been proposed, for example, that the high density of Mercury is due to a giant impact as well, or that Uranus and Neptune migrated outwards, ravaging small-object populations until reaching their final positions several hundred million years after their formation. Also the existence of extra-solar "*Hot Jupiters*" – large planets circling close to a star – is explained by planet migration.

Obviously, the chance for life to form and survive on Earth, on Mars or on exo-planets is affected by the intensity of such violent epochs in their history.

The Giant Impact

The Giant Impact (depicted in Fig. 1) is consistent with major lunar observations, namely (i) the Moon's exceptionally large size relative to its host planet; (ii) the high angular momentum of the Earth-Moon system; (iii) the Moon's extreme depletion of volatile elements; and (iv) a differentiated global crust and mantle of the Moon that had quickly followed its delayed formation.

For the most part, the latter two findings are based on chemical analyses and age determinations of lunar rocks that had been brought back to Earth by the Apollo astronauts between 1969 and 1972.

The Giant Impact set the initial conditions for the formation and evolution of the Moon. The impactor – sometimes called Theia – is assumed to have had at least the size of Mars and to have hit the Earth at an oblique angle. The collision produced a dense protolunar cloud. Fast accretion of the Moon from this cloud assured an effective storage of gravitational energy as heat, producing early melting. A *Magma Ocean* of global dimensions formed, and upon cooling, solidified into a crust[2] and a mantle[3] (*cf.* left-hand part of Fig. 2).

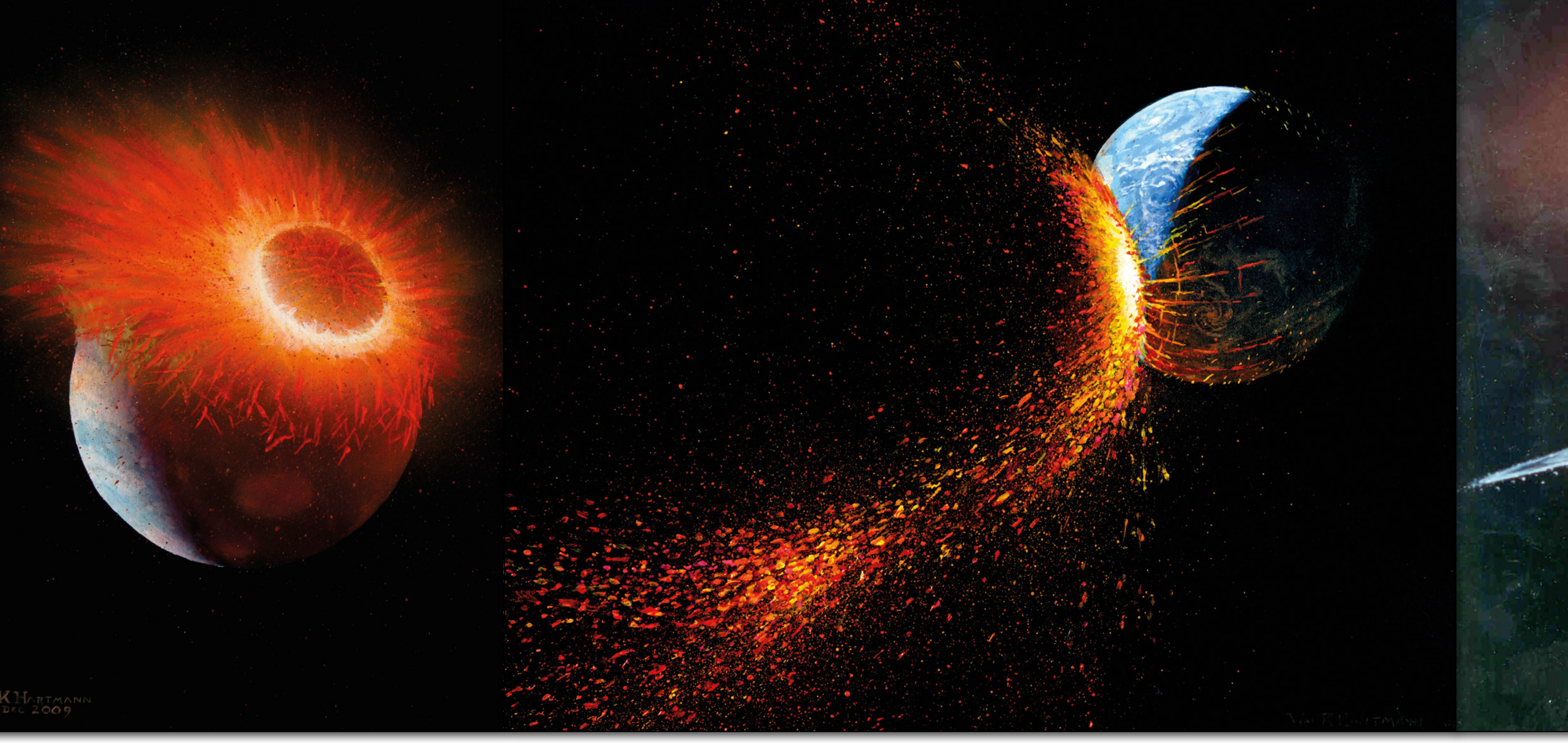
The Giant Impact occurred between 70 Ma and 110 Ma after the solar-system matter had become isolated from galactic nucleosynthesis [1]. At that time, heat and accretion were the only energy sources capable of providing the energy for melting and differentiation of a lunar-sized body[4]. Heating occurs near its surface and thus much heat

[1] Editor's Note: This special Feature is an updated summary of a paper in which J. Geiss and A.P. Rossi [*The Astronomy and Astrophysics Review* (2013) On the chronology of lunar origin and evolution – Implications for Earth, Mars and the Solar System as a whole, **21**:68 (54 pp)] covered the development of lunar science over the past half-century and underlined the importance of understanding the Moon's history for the history of the Solar System as a whole. Detailed physical arguments, models, numerical estimates and references can be found in the review paper itself. ***Jo Hermans, EPN Science Editor***

[2] The lunar crust is feldspar-rich, composed mainly of anorthite $CaAl_2Si_2O_8$, with a density of $\rho = 2.67$ g cm^{-3}.

[3] The mantle is composed mainly of olivines and pyroxenes $(Mg,Fe)SiO_3$ and $(Mg,Fe)_2SiO$ etc, with densities of $\rho \approx 3.5$ g cm^{-3} and $\rho \approx 3.6$ g cm^{-3}, respectively.

[4] Decay of ^{26}Al with a half-life of 0.7 Ma was the principal energy source for melting and differentiating asteroids very early in Solar-System history. At the time of the formation of the Moon, however, ^{26}Al had disappeared and the long-lived isotopes of K, U and Th with half-lives between 0.7 Ga and 14 Ga are much too slow to produce the fast melting that is inferred from the ages of lunar crust material.



▲ **FIG. 1:** Origin of the Moon in a Giant Impact. Paintings by William Hartmann depicting the Earth– Moon system at 30 min, 5 h and 1000 a, respectively, after impact (©William K. Hartmann).

is lost by radiation with increasing temperature unless a very fast accretion "buries" the heat as it is produced. Accretion times as short as ≈ 10^3 a are needed, and model calculations show that this is achieved at the high density existing in the protolunar cloud that had been created as a consequence of the Giant Impact.

During the formation of the Moon a poorly defined intermediate layer rich in incompatible elements called KREEP developed between crust and mantle[5].

The maria: basins being filled by lava

Several 100 Ma after the Moon's accretion, the decay of the long-lived isotopes (^{40}K, ^{232}Th, ^{235}U and ^{238}U) that were concentrated in the KREEP-rich layer below the crust had generated enough internal heat to induce partial melting in the mantle. Lava extruded into large basins – *i.e.*, into the depressions that had been excavated on the Moon as part of the Late Heavy Bombardment. Upon cooling, the lava solidified into titanium-rich mare basalt (*cf.* right-hand part of Fig. 2). This era of rock formation may actually have lasted for nearly 3 Ga, from about 3.9 Ga before the present until *ca.* 1 Ga ago.

Mare basalt surfaces and other geologic units have been identified on the lunar near side by use of chemistry data from lunar orbit (*i.e.*, from remote sensing in spectral domains ranging from γ- and X-rays to the infrared). How a relative timescale was established through crater counting, and how this timescale was then calibrated by radiometric dating of rocks returned from six Apollo landing regions and three Luna[6] landing spots is presented in Box B. Detailed results, including geographical information are shown in Fig. 3.

The general, coherent explanation of the lunar origin and evolution sketched above is by and large complete. There remain some questions that still need to be resolved. In the following we briefly mention two such issues. The first one shows the precision of some lunar measurements, the second one also sheds light on early technological accomplishments.

Constraints from isotopes: the "Oxygen Isotope Puzzle"

The abundances of the chemical elements and their isotopes – as measured in the returned lunar samples – are generally compatible with the fractionation processes that go along with, and follow the Giant Impact origin of the Moon. But there remains an odd agreement of isotope ratios, the so-called *Oxygen Isotope Puzzle*, which might not *a priori* be expected as a consequence of that scenario.

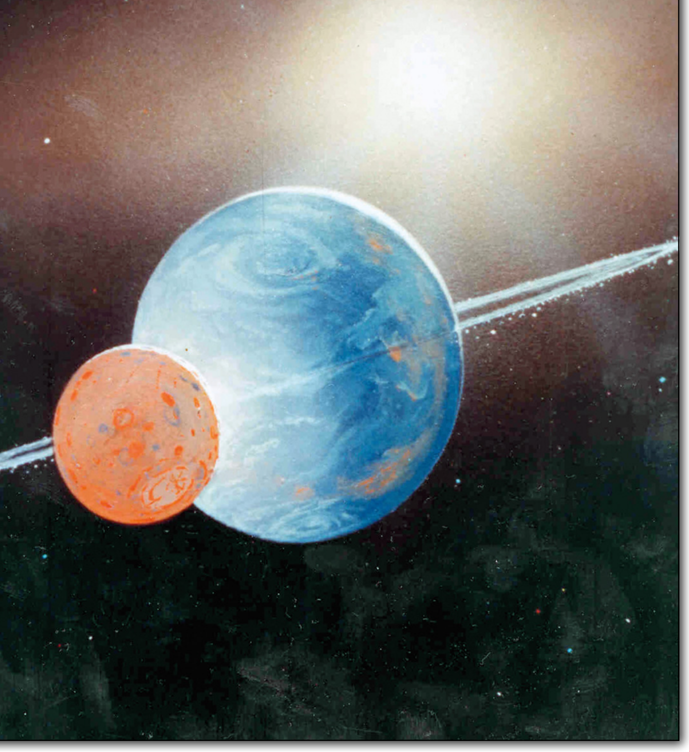
The "intrinsic" isotopic composition of an object is commonly represented as Δ^{17}O, the excess – or deficit – of ^{17}O, relative to its terrestrial abundance[7]. For solar-system objects, $|\Delta^{17}O|$ values are very small, typically 1‰ or less. For Mars, for example, $\Delta^{17}O = 0.3$ ‰ has been determined[8]. Surprisingly, however, there is no significant difference in the oxygen isotopic composition between Moon and Earth.

Models have been presented indicating that this puzzle is probably not severe enough for falsifying the Giant Impact scenario. In any case, the need for explanation would be less severe if $|\Delta^{17}O|$ of Theia was smaller than the Martian value of 0.3 ‰. This is quite possible, since Theia, by definition, crossed the Earth orbit during the later phase of planet accretion, while Mars accreted its matter farther away from Earth. So it is quite possible that Theia's $|\Delta^{17}O|$ was very small.

[5] KREEP stands for potassium (K), rare earth elements (REE) and phosphorus (P), which together with uranium and thorium had accumulated between crust and mantle.

[6] Three of the USSR Luna spacecraft returned samples that they had collected at their landing spots.

[7] Δ^{17}O is defined such as to be unaffected by mass dependent chemical or physical processes.



The lunar dichotomy – scientific and political surprise

In October 1959, only two years after the USSR had launched the first artificial satellite, Sputnik 1, into orbit, another Russian spacecraft, Luna-3, took images of the far side of the Moon – and that side turned out to be very different from the near side![9] Most notably, the typical *maria* seen on the near side (*cf.* Fig. 3) are almost absent.

Photographing the far side of the Moon was a technological feat: it meant on-board developing and scanning of the exposed film, so that the images could be sent back to Earth by telemetry[10].

Some of the suggested explanations for the dichotomy can be further tested by altimetry, and by gravimetric and chemical analysis from lunar orbit. However, to definitely decide what caused the dichotomy and when it happened might require the return and analysis of documented samples from the far side of the Moon[11].

We now turn to the use of the lunar timescale for other planets, in this case Mars, and finally discuss the lunar evidence for the Late Heavy Bombardment.

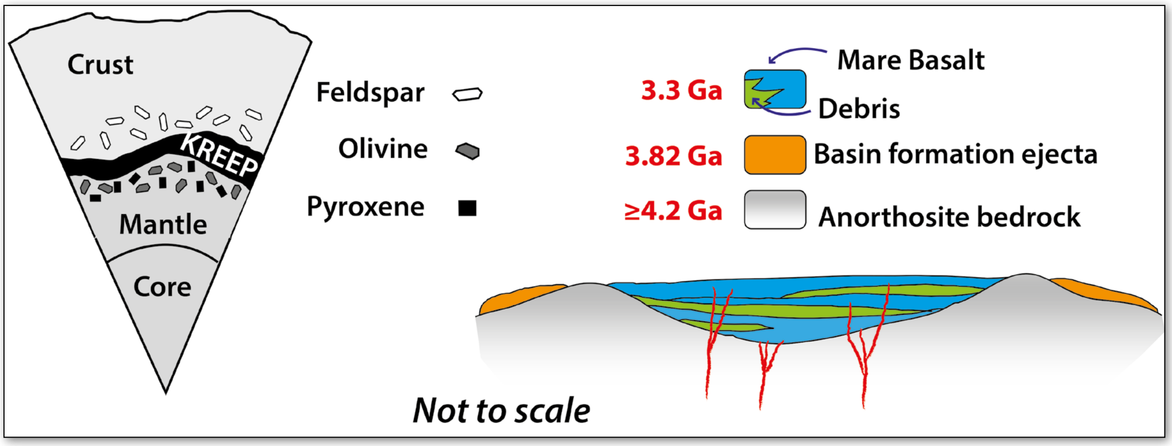
Towards a Chronology of Mars

The spatial density of craters (the 'crater frequency') can be used to infer information about the age of surfaces. Crater frequency ages and ages of Martian meteorites provide growing evidence for young lava flows, fluvial activity and aeolian deposition on Mars. In Fig. 4 plots of cumulative crater frequency[12] *vs.* diameter are shown for the ejecta blanket of the lunar North Ray Crater and for a young volcanic area on Mars.

The crater frequency age of 46.5 Ma for the lunar North-Ray Crater is in good agreement with its exposure age of 50 Ma. Due to "resurfacing", the cumulative crater frequency levels off at small diameters in both plots, but as expected, "resurfacing" for Martian areas is much faster than it is for lunar areas.

Establishing a relative timescale for Mars is now progressing fast: in the absence of documented samples from Mars, crater frequencies are being provisionally converted to actual ages (in Ma) by use of a theoretical Mars Production Function.

So far, calibration of crater frequency ages with radiometric ages or exposure ages of meteorites has not been achieved, but this is beginning to change. In a recent paper [5] it is concluded that the 55 km wide Martian Mojave Crater is the source of many Shergottites[8],



◂ **FIG. 2 (left)** The fast accretion following the Giant Impact led to a Magma Ocean covering the lunar surface, partly or fully. Before the magma solidified, light minerals (feldspar) moved towards the surface and the heavier minerals (pyroxene, olivine) sank towards the centre. The incompatible KREEP elements remained enriched in an intermediate layer. **(right)** Several 100 Ma after lunar accretion, lava that was melted in the mantle by the decay of long-lived isotopes of K, U and Th extruded into large basins and solidified as titanium-rich *mare* basalt. The ages indicated refer to the *Mare Imbrium* and to *mare* basalt samples collected at the Apollo 15 landing site (*cf.* Fig. 3).

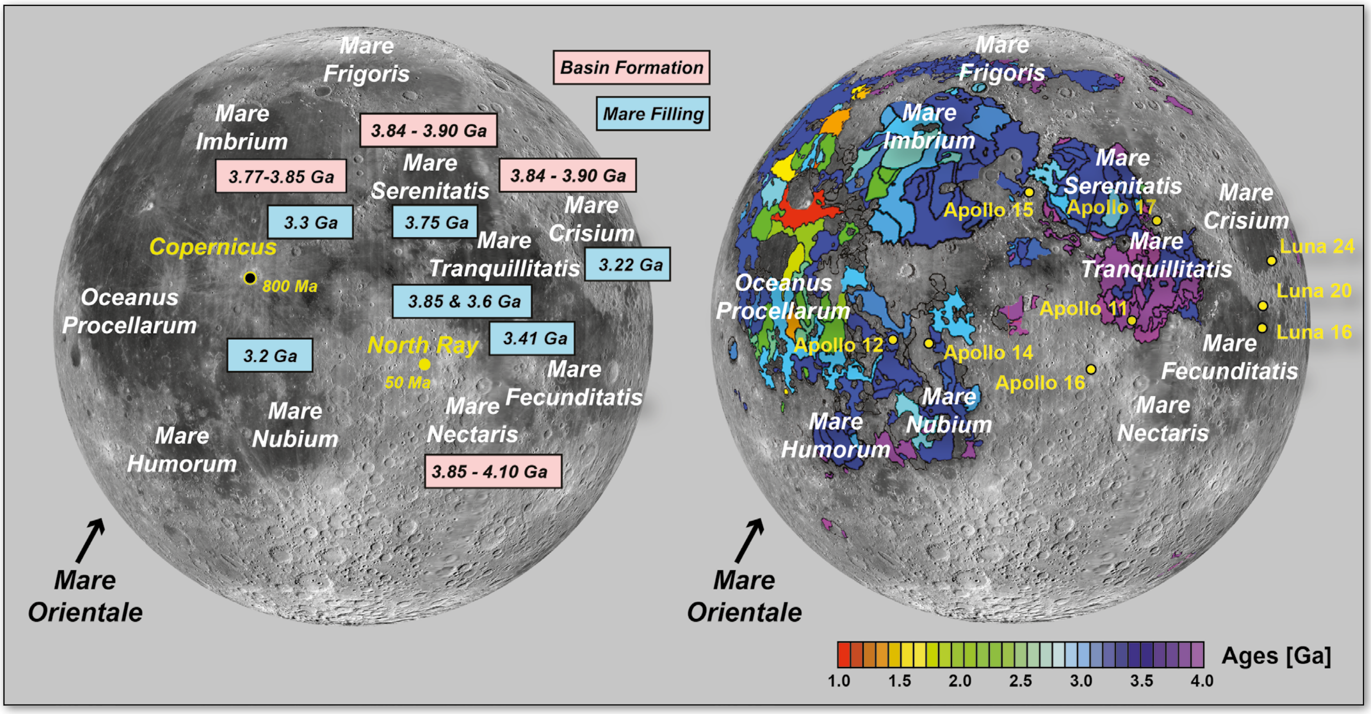
[8] So far no samples have been returned from Mars, but the rare SNC meteorites are known to come from Mars. (SNC stands for the meteorite classes named after the place where the first examples had been found: Shergotti, Nakhla, Chassigny.)

[9] The Moon's rotation is tidally locked, *i.e.*, its orbital and rotational periods are the same; so there is a 'far side' of the Moon, which we never see from Earth.

[10] This happened long before today's ubiquitous CCDs were available!

[11] Detailed exploration of the lunar far side is not straightforward. It will most likely require telecommunication via a lunar relay satellite, since electromagnetic waves from the far side of the Moon do not reach the Earth.

[12] Note that crater frequencies are spatial frequencies (normally they have the dimension km^{-2}).



because the meteorite ejection ages coincide with the crater frequency age of that crater as calibrated with a theoretical Mars Production Function. Both ages cluster around 3 Ma. The expected production rate on Mars for Craters with a diameter D > 55 km is less than one in 10 Ma. Thus having a competitor for the Mojave Crater as source for the 3-Ma-Shergottites is rather unlikely. In fact, the ample ejection of meteorites from the young Mojave Crater might be the reason why in our epoch there are more Martian meteorites than lunar ones!

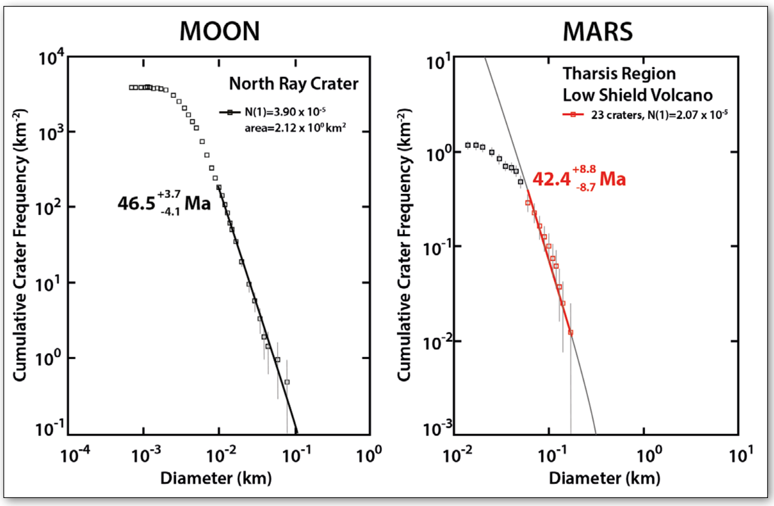
Clustering of exposure ages is observed not only for Shergottites, but also for other meteorite classes, suggesting that crater production rates are likely to vary on timescales of tens of Ma. For older surfaces such variations will be evened out when observing Cumulative Crater Frequencies.

The Late Heavy Bombardment

Radiometric dating revealed that four of the prominent large lunar basins were created during a relatively short time interval, about 4.1 Ga to 3.8 Ga before present (*cf.* Fig. 3 and the illustration in Box A). When stratigraphic observations showed that many of the other large basins on the near side of the Moon were also excavated during or close to this period, it was realised that the Moon had received a *Late Heavy Bombardment* (LHB), about 0.5 Ga to 1.6 Ga after the Moon had been accreted. Such a late clustering of major impacts must have been caused by a special phase in the history of the solar system, separate from the main accretion period. Was there a major perturbation in the planetary system so late in its history, and what could have been its cause?

Three discoveries, the lunar LHB, Trans-Neptunian objects, and Jupiter-sized Exoplanets unexpectedly close to their central stars[6] have renewed interest in planet

▲ **FIG. 3** Two images of the near side of the Moon with chronological information. **(left)** Radiometric ages of four large basins (purple) and basalt samples from six *mare* areas (blue) derived from analyses of samples collected in the Apollo landing areas and the Luna landing spots (both of them are marked on the right-hand image). **(right)** Crater frequency ages of *mare* areas from high-resolution crater counting and mapping. The youngest mare areas are in the *Oceanus Procellarum* to the West of *Mare Imbrium*; they correspond to mare areas with a high KREEP content.



◂ **FIG. 4** Crater frequency ages for the lunar North Ray Crater [2] and a young volcanic area on Mars.[3] Images used were from the NASA Lunar and Mars Reconnaissance Orbiters, respectively. The Crater Frequency ages given in these plots were calculated by using the theoretical Production-Function and Chronology-Function given by Ivanov [4] (see Box B).

migration, and led to the development of Nice Models[13] for explaining late heavy bombardment epochs by planet rearrangement well after the birth of the Solar System.

The classical Nice model assumes planets to have been accreted from the proto-planetary disc more closely together than we find them today. After dissipation of the gaseous portion of the solar nebula, the planets slowly migrated, due to their interacting with the remaining planetesimals. Saturn moved away from Jupiter, increasing the ratio between the periods of the two planets (P_S and P_J), until they got into the 1:2 resonance at $P_J/P_S = 1/2$ (today, we have $P_J/P_S = 1/2.48$). The orbit of Saturn became very eccentric, causing close encounters among large planets and "a massive delivery of planetesimals to the inner solar system" that could have caused the lunar LHB.[7]

For comparisons with specific Nice-model predictions, the lunar LHB would have to be better defined than it is today. The Orientale basin is the youngest among the major lunar basins and may mark the end of the lunar LHB. Its beginning is difficult to measure and even to define. Determining instead the declining phase of the bombardment by measuring the number of basin-forming impacts in a given time interval near 4 Ga would be easier and could significantly constrain theories of LHB origin. Geiss & Rossi[1] suggest that two rover/sample-return missions would do the job, one sampling the blanket of the *Orientale* basin and the other exploring a region to the Southeast of *Mare Nectaris*[14].

The heavy bombardment of the Moon about 4.1 Ga to 3.8 Ga ago must have hit the Earth as well, causing lasting devastation of our atmosphere and hydrosphere[15]. Quantitative comparison of the effects of bombardment of Moon and Earth depends on the origin of the impactor. For objects arriving with high energy from, *e.g.*, the region beyond Uranus, impact energies on the Earth are only modestly increased, and the Moon and Earth ratio of impact rates are nearly proportional to their geometrical cross sections (1: 13.4). On the other hand, for objects coming from the inner edge of the asteroid belt, focussing and acceleration by the terrestrial gravitational field strongly increases the relative flux and also the impacting energy hitting the Earth.

Remnants of basins produced on Earth during the Archean and Proterozoic epochs have been wiped out by plate tectonics. However, the distribution of spherule beds, interpreted as ejecta from large impacts, indicate

[13] Nice models were first developed in Nice (France).

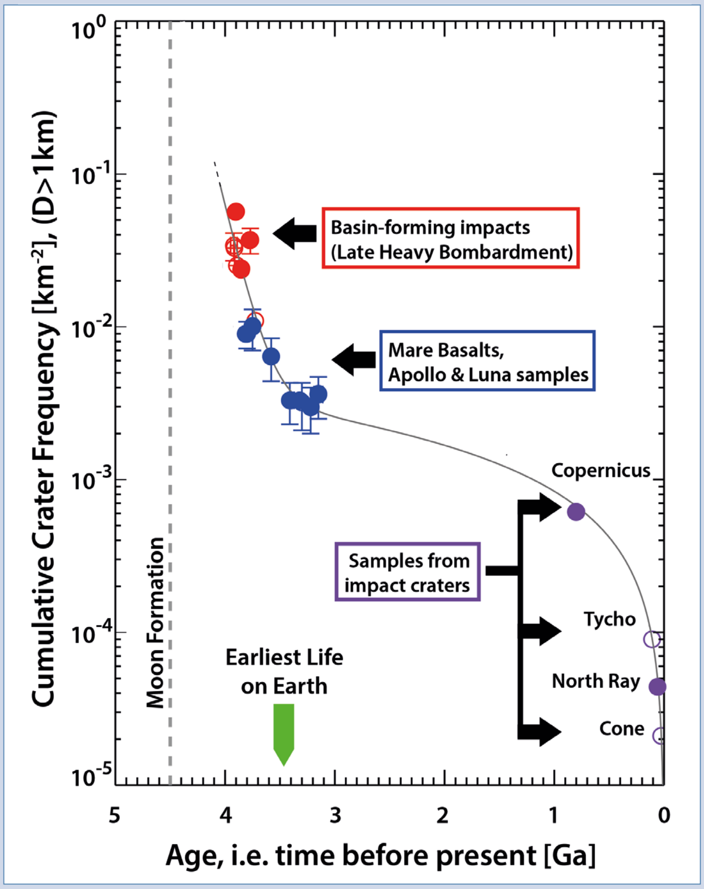
[14] Following the delivery to the lunar surface of the Chinese rover Chang'e 3 in December 2013, a sample return mission, Chang'e 5 is scheduled for 2017.

[15] The energy of the Imbrium impact on the Moon was roughly a thousand times higher than the energy of the Chixculub impact on Earth that caused the mass extinction at the K/T boundary.

BOX A: TIMESCALES AND CHRONOLOGIES[9]

On Earth, a global relation was found in the 19th century between fossil species and sedimentary rock strata, establishing a relative chronology from the Cambrian to the present. In the 20th century this chronology was calibrated by radiometric dating and extended deep into the Precambrian. On the Moon, where there are no fossils, relative timescales are based on the observed impact crater frequencies. Crater count ages have now been determined for a large portion of the lunar surface and calibrated with radiometric and some exposure ages of lunar samples returned from six Apollo landing areas and three Luna landing spots. Even from the rather limited geographical coverage available after the Apollo and Luna missions, it was concluded that the crater production rate decreased strongly for ages larger than 3.2 Ga and remained approximately constant afterwards. By approximating the crater production rate by a constant plus an exponential, Neukum, Ivanov and Hartmann[10] introduced the Cumulative Crater Frequency Timescale shown in the illustration below; this has since been the standard. The timescale is well established only in the time interval 4 Ga to 3 Ga. It cannot be much extended beyond 4 Ga, because there the crater frequency is approaching saturation. Samples from the young areas to the West of Mare Imbrium (*cf.* Fig. 3) could close the gap in the calibrated timescale from 3 Ga to 1 Ga. Completing the lunar crater count timescale is of foremost importance, because it will remain indispensable for quite some time, as it can help for transferring absolute timescales to Mars and other solar system bodies.

▼FIG. 5: Timescale of events on the Moon, traced by the relative scale established by crater counting, which was calibrated by radiometry of lunar rock samples. Red, blue and purple data points represent the Late Heavy Bombardment, the *maria* and relatively young craters, respectively.



that basin forming impacts on Earth lasted to 3 Ga before the present and beyond.[8] The *lunar* LHB ended earlier, as inferred from the crater frequency curve in the illustration of Box A or from the estimated age of the Orientale basin.

The earliest, well-established traces of life appeared about 3.5 Ga ago. The analysis of spherule beds implies, however, that the epoch of heavy bombardment on Earth had not yet ended at that time. Further data on the LHB and post-LHB epochs on Moon, Earth and Mars as well as on early traces of life on Earth might tell us whether a heavy bombardment had delayed the creation of life on our planet, whether all life was extinguished that had existed before, or whether a primitive life form managed somehow to survive the epoch of heavy bombardment. ■

BOX B: AGE DETERMINATION

Radiometric Ages are determined by radioactive dating. This technique is based on a comparison between the observed abundance of naturally occurring radioactive isotopes and their decay products, by use of the known decay rates.

Cosmic Ray Exposure Ages are based on the following model: a collision excavates a rock that was buried and screened from cosmic rays and ejects it into an orbit around the Sun, where it is fully exposed to cosmic rays. Eventually, the orbiting rock will collide with the Earth, where cosmic-ray exposure will virtually cease. The time of exposure to cosmic rays is determined from nuclides produced by cosmic-ray-induced nuclear reactions.

An exposure age (T_{EXP}) is calculated from the abundances of a pair of a stable (N_{ST}) and a radioactive (N_{RAD}) cosmic-ray-produced nuclide, the corresponding production rates P_{ST} and P_{RAD}, and the decay constant λ of the radioactive nuclide. If P_{ST} and P_{RAD} were constant over the time interval T_{EXP} to T_0, then for the simple case of $\lambda T_0 = 0$ and $\lambda T_{EXP} >> 1$, the exposure age is given by

$$T_{EXP} = \frac{1}{\lambda}\frac{P_{RAD}}{P_{ST}}\frac{N_{ST}}{N_{RAD}}$$

This relation is valid only if the irradiation conditions (cosmic-ray intensity and energy spectrum, heliospheric modulation, shielding by atmosphere or overlying solid material) were constant from T_{EXP} to T_0. These conditions are usually met when calculating the time of ejection of a meteorite from an asteroid, Mars or Moon.

Crater Count Ages are defined as the Cumulative-Crater-Frequency [km^{-2}] = Production-Function (D) x Chronology-Function (T) [km^{-2}]. Because it is possible to separate the variables, the data can be presented in two types of plots:

- Cumulative-Crater-Frequency versus Age (see graph in BOX A) and
- Cumulative-Crater-Frequency versus D, *i.e.*, the lower integration limit for the crater diameter.

The slope of the plot (*cf.* Fig. 4) determines the age of the cratered area. This must, however, be calibrated by radiometric or exposure ages of rocks, determined in the laboratory.

About the Authors

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Interview with Rumiana Dimova

Rumiana Dimova (RD) is winner of the Spring 2014 EPS Emmy Noether distinction for Women in Physics. This interview was taken in June 2014 by Ana Proykova (AP), member of the Equal Opportunity Committee of the EPS.

AP: How did you learn that you have been awarded and what was your first reaction? Where were you at the time of learning that you've been awarded?
RD: The answer to this question is boring. I was sitting at my desk and answering work emails. Of course, I was excited and instantly forwarded the message to my husband, and since he was also sitting behind his desk answering emails, he instantly answered with "Bravo! Shall we celebrate? Tonight? Champagne, may be?" We didn't. We got trapped in our daily routine of playing with and finally putting the kids to bed.

AP: What were your main motivations to choose a career in Physics?
RD: Actually, at the university I opted for theoretical and physical chemistry but then slowly and steadily I was converted to biophysics during my PhD. Understanding how things work was always the main driving question. And all the laws in nature, and also the answers to these questions, are provided by Physics.

AP: Were you influenced by some outstanding teacher or researcher?
RD: Yes. Looking back, I realize that I was lucky with all the supervisors I had. They were not only great physicists, but also men with character and an excellent example to follow. I learned a lot from Prof. P. Kralchevsky at Sophia University who introduced me to the world of chemical physics and ignited the academic spark. Prof. B. Pouligny at the Research Center Paul Pascal in Bordeaux with his enlightening table-corner experiments formed me as an experimentalist but also as a person setting an excellent example of being above everyday clutter and of being honest in science. Finally, Prof. R. Lipowsky from the Max Planck Institute of Colloids and Interfaces in Potsdam, my current mentor, is an inspiring and great theoretical physicist who in my eyes still seems to have almost all the answers to the questions I address in my research.

AP: During your studies, did you feel that there were equal opportunities for boys and girls?
RD: Yes. Both in Bulgaria and in France.

AP: Competition for a tenure-track position: any comment on fair/unfair selection criteria like gender-biased requirements?
RD: I have not experienced an incidence where gender had played a role.

AP: Did your colleagues appreciate the results of your scientific research? Did they neglect your achievements in comparison with your male peers?
RD: I hope that my colleagues appreciate the results of my research. With respect to the second part of the question, honestly, I was never concerned about this and haven't given it a serious thought. I assume that every scientist reads and cites the papers of others as long as their work is relevant and interesting, irrespective of the gender of the authors.

AP: Salaries: are they gender dependent in your view at universities and research institutes?
RD: I am not aware of such differences and have not tried to find out whether they exist in my institute, and simplemindedly assume that they don't.

AP: Is there any positive correlation between achievements in science and salaries or number of grants?
RD: Yes, I believe most of the time.

AP: You have worked in different countries. Have you found differences about the role of women physicists in these countries?
RD: The first time I was faced with this question was when I came to work in Germany and saw that only some 10 % of the members of my department were female. This was in sharp contrast to the environment to which I was exposed both in Bulgaria and in France. The situation now, 10 years later, is much better and realistic – around 30 % of the researchers in our department are women. Curiously and also unfortunately, in my group the number is currently much lower because of some unusual drop down in the number of applications from women.
It is true that for women, family and career are more difficult to synchronize, but I became aware of the issue of women in science only in Germany. I also think that the current national programs attempting to support women in Physics have a dual effect. On the one hand, they do support women, but on the other, they may damage the image of a woman who has achieved a position via such support in the sense that she might not be considered as an equally well performing counterpart of her male peers.

AP: Do you have some advice for young women starting Physics careers?
RD: Do not be scared of possible conflicts between career and family. Combining the two is possible, even though sometimes tough.

AP: I want to congratulate you on this award and also to thank you for letting us know your personal views in this interview. ■

Opinion:
Do-it-yourself breakthrough

Sanli Faez - Faez@physics.leidenuniv.nl - is a Post-doc at Leiden University and founder of touchablephysics.com

How should we determine the relevance of a research activity? This is a key question when limited resources have to be distributed between disciplines or institutions. One answer, which is hard to argue against when spending the taxpayers' money, is to look at its impact on the society. However, it is often impossible to grade the current relevance of fundamental research because its future impact is unforeseeable.

Seeking relevance is also vital for institutes or individuals who need to justify their professional existence. The well-established and successful have to continuously use their influence and credit to define their impact as high. This game, however, extremely disfavors the newcomers, particularly those who take pride in originality; something we attribute to the big names in the history of science that saw no point in just following the mainstream.

Fortunately, a new path of scientific conduct is emerging in form of community-supported open collaborations. Here, a relatively large group of like-minded people dare to share all their knowledge to realize a big goal. Such open collaborations, rooted in the free and open source software (FOSS) movement, are getting increasingly active in hardware-based scientific areas such as experimental physics or biology. The story of the Arduino microcontroller, for example, is really appealing. It was introduced in 2005 as a student project at the Interaction Design Institute Ivrea in Italy. Interestingly, the school has ceased its operation after five years due to lack of funding, but the project continued to expand and half a million boards are now produced globally each year. Arduino is the central part of some 3D-printable equipment listed on appropedia.org, a wiki dedicated to collaborative solutions.

Some may claim that open collaborations can only address "simple" problems and will not result in any breakthrough. They would argue that a large investment on individual labs is the only way to push the frontiers of science forward. At least George Whitesides does not seem to agree. In a recent lecture in Amsterdam [1], the highest-cited living chemist expressed his worries that "the real world puts up reluctantly with what current academics like: complexity and emergence". In his words, what the society really needs is simplicity. He emphasized that "simplicity" relates to function, not mechanism, and "function" includes cost.

The current exclusive emphasis on "outstanding" principal investigators (PI) is totally at odds with open collaboration, for which the credit is highly distributed and where there is no individual to stand out. With this super-sized PI approach, the winner takes it all [2] and efforts of hundreds who have paved the way to the shiny discoveries, stone by stone, are neglected. It is a pity, and a guaranteed loss of talent, that support for the young enthusiasts is placed second to financing grandiose grants for a few.

It is a pity, and a guaranteed loss of talent, that support for the young enthusiasts is placed second to financing grandiose grants for a few.

Maybe ten years from now, when the entry barrier to high-tech research is further reduced by open-source hardware and community support, we will worry less about finding (non-academic) jobs for trained-to-be-researcher PhDs [3]. The enthusiastic PhDs will find their creative ways of producing knowledge in garage labs or, wishfully-thinking, in open-to-public research facilities. The big establishments of science will then have no choice but to adapt to the vibrant and energetic open-innovation community. Perhaps they can already join the movement by contributing to open science, from their publicly funded subsidies, as several prominent individuals are already doing.

Keeping Wikipedia in mind, and how it forced the longstanding Britannica foundation to adapt, our academia may need to get prepared for new ways of seeking relevance. ■

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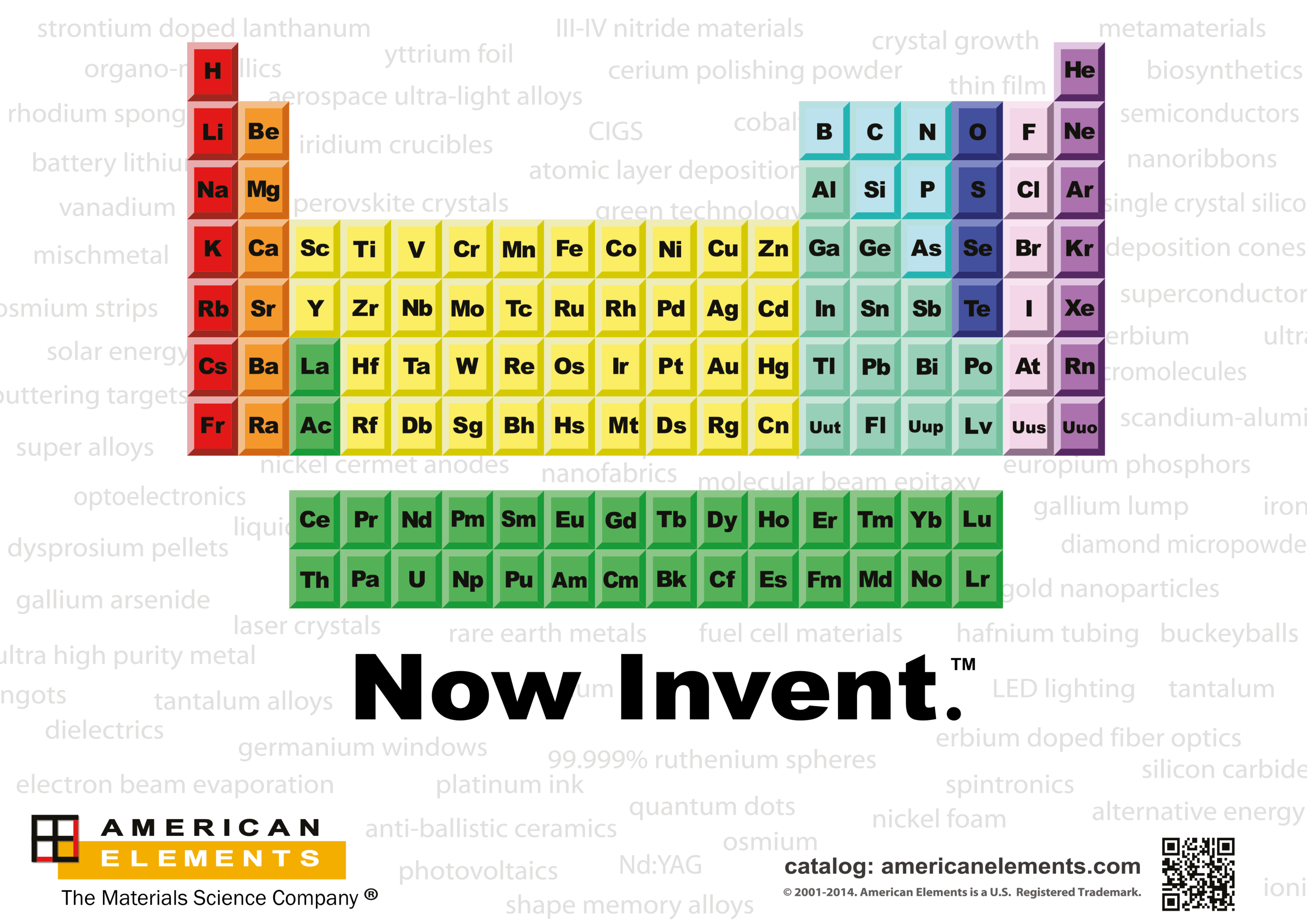

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