

europhysicsnews

THE MAGAZINE OF THE EUROPEAN PHYSICAL SOCIETY

Britain's nuclear secrets: inside Sellafield
Redressing scientific publishing
Slippery and never wet
"Boiling the vacuum"
Miazma: physics edutainment

48/5

48/6

2017

Volume 47 • number 5&6
European Union countries price:
104€ per year (VAT not included)

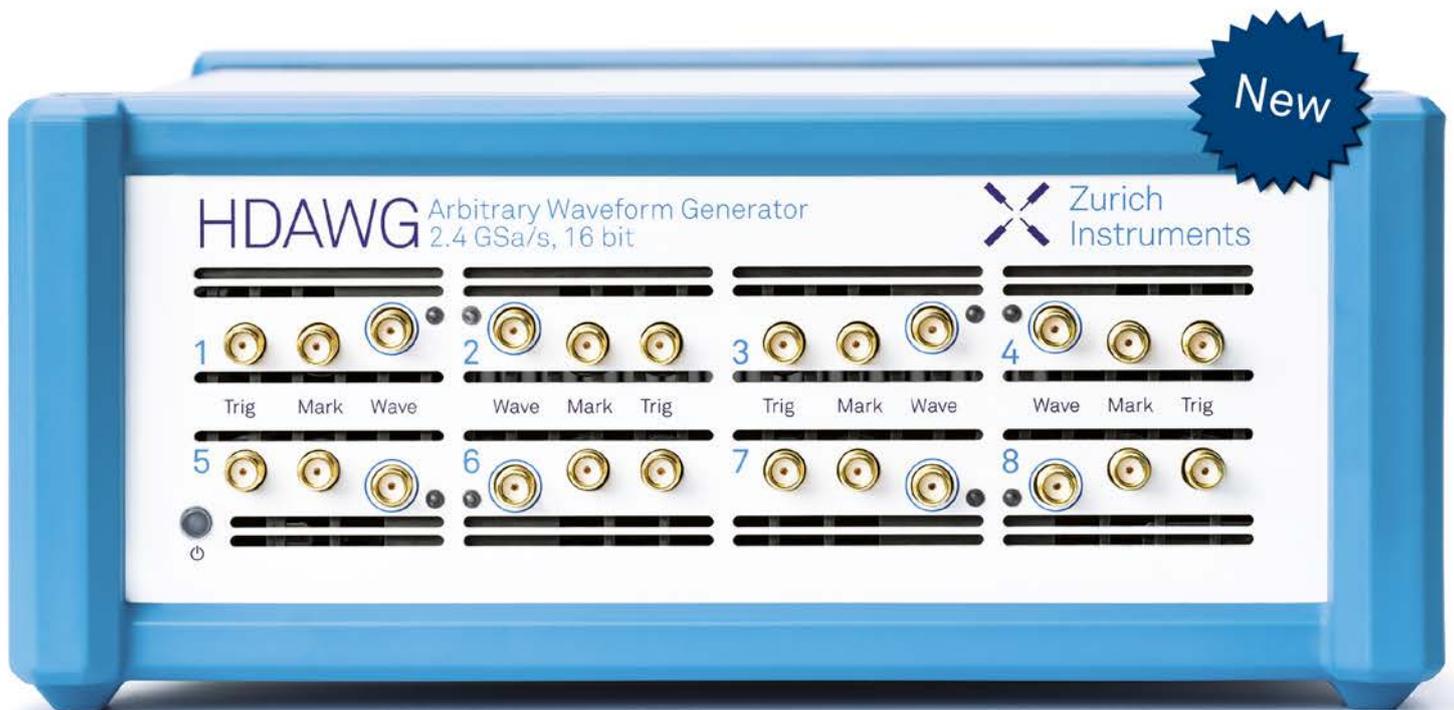


edp sciences

How many synchronous AWG channels do you need?

from less than
EUR 5.000,-
per channel

The new Zurich Instruments HDAWG is the multi-channel AWG with the highest channel density and lowest trigger latency. It comes with LabOne®, the Zurich Instruments control software, that provides easy access from any web browser. Stack multiple HDAWGs and control them with a single user interface and API.



Using the HDAWG with LabOne, you will

- learn AWG programming within minutes
- generate sophisticated waveform patterns easily and maintain the overview
- automate measurements with the parametric sweeper
- integrate it quickly into your MATLAB®, .NET, LabVIEW®, C and Python control environment

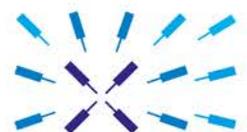
Key Features

- 4 channel and 8 channel version
- 2.4 GSa/s, 750 MHz, 16 bit
- up to 500 MSa memory/channel
- < 50 ns trigger delay
- fast waveform transfer (USB 3.0)

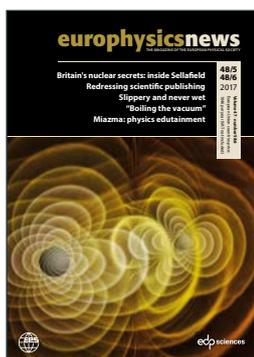
Let's talk

Intl. +41 44 515 0410
info@zhinst.com
www.zhinst.com

Your Application. Measured.



Zurich
Instruments



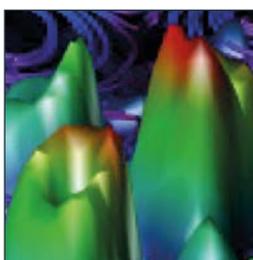
europsychysicsnews

Cover picture: Frame from a simulation of the merger of two black holes and the resulting emission of gravitational radiation (colored fields, which represent a component of the curvature of space-time). The yellow areas near the black holes do not correspond to physical structures but generally indicate where the strong non-linear gravitational-field interactions are in play. ©Credit: NASA/C. Henze See P.18 Gravitational Physics: the birth of a new era.



▲ PAGE 30

Slippery and never wet



▲ PAGE 34

"Boiling the vacuum": *in silico* plasmas under extreme conditions



▲ PAGE 42

Miazma: physics edutainment through a computer game

EPS EDITORIAL

- 03 Working together on the evidence base | R. Voss

NEWS

- 04 EPS Historic Sites: NatLab, Eindhoven, The Netherlands
 06 EPS gears up for 50th Anniversary
 08 Nobel prize in physics 2017
 09 In memoriam Prof. Alfred Zawadowski
 10 The remake of an iconic photo
 11 International conference on Strangeness in Quark Matter in Utrecht

HIGHLIGHTS

- 12 Controlling negative ions in plasma using tailored voltage
 A Fokker-Planck Model for Wealth Inequality Dynamics
 13 Magnetite or maghemite? There is a simple answer
 Best tactical approach to handling patients with simultaneous parasitic and HIV infection
 14 Highway traffic fluctuations impact congestion durations
 Like a game of 'spot the difference' for disease-prone versus healthy people
 15 Robustness of states at topological insulator interfaces
 The secret to improving liquid crystal's mechanical performance
 16 Information stored in quantum states of water fragments
 Astronauts to bring asteroid back into lunar orbit
 17 Monodisperse magnetic nanoparticles prepared from block copolymer template
 First aid kit in some living organisms helps fix DNA after lengthy sun exposure

FEATURES

- 18 Gravitational Physics: the birth of a new era | M. Sakellariadou
 21 Britain's nuclear secrets: inside Sellafield | A. Marino
 25 Redressing the inverted pyramid of scientific publishing | J.-S. Caux
 29 Physics in daily life: fascinating friction | L.J.F. Hermans
 30 Slippery and never wet | M. Backholm, J.V. I. Timonen and R.H.A. Ras
 34 "Boiling the vacuum": *in silico* plasmas under extreme conditions | L.O. Silva
 38 A Tribute to Manne Siegbahn | H. Kubbinga
 42 Miazma: physics edutainment through a computer game | Zs. Fülöp, S. Biri and G. Lévai

ANNUAL INDEX

- 47 Annual index volume 48 - 2017

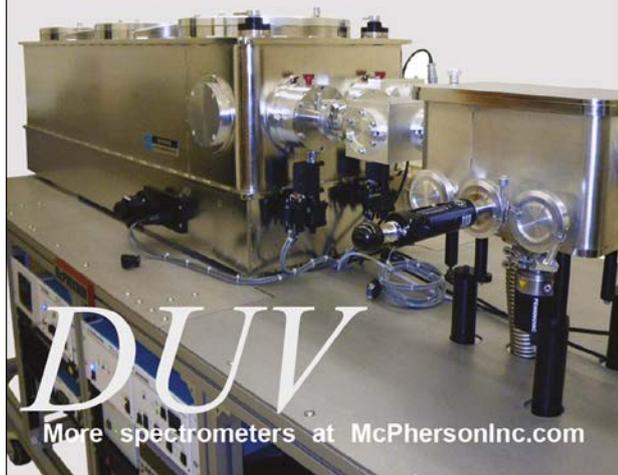
McPHERSON

DUV

Model 209V

Achieve picometer fwhm spectral resolution from 105 nanometers Deep UV and up to 20 microns LWIR. A diverse selection of diffraction gratings is available. The 1.3 meter focal-length vacuum (or purge) spectrometer provides exceptionally symmetric line profiles and easily resolves H/D ratio to baseline at Lyman-alpha.

Visit www.McPhersonInc.com today
or call 1-978-256-4512 to discuss
your spectroscopy application



DUV

More spectrometers at McPhersonInc.com

Do you do

MBS

ARPES measurements?

Analyse the **Spin** components?

Our state of the art

ARPES System with

2D Angular mapping (new!)

MBS A-1SYS + L4 lens

ARPES System with

3D VLEED Spin detector

MBS A-1SYS + MBS 3D-VLEED

Gives you the results!

MB SCIENTIFIC AB

Address: **Seminariegatan 29B,**

SE-752 28, Uppsala, SWEDEN

Tel: **+46 18 290960, Fax: +46 18 572683**

e-mail: info@mbscientific.se

Home page: www.mbscientific.se

SUBMITTING YOUR PROPOSAL BOOK

You have a scientific project
(Physics, mathematics,
Chemistry, biology ...)

In **English** or **French** language

Send a CV, Synopsis
and table of contents to:

France Citrini

Head of Books Department

france.citrini@edpsciences.org

edp sciences





[EDITORIAL]

Working together on the evidence base

To become a credible actor on the stage of science policy, the EPS needs to invest in its evidence base, with the strong support from Divisions and Groups

Not different from other learned societies, the EPS has since long organised itself in Divisions, Sections and Groups to federate its members, aggregate their expertise, and promote Europe-wide actions and initiatives in different areas of our science. Traditionally, the structure of EPS Divisions, and of divisional Sections, has followed the development of important branches of contemporary physics – the arrival of the new kid on the block, the Gravitational Physics Division, has been rapidly catalysed by the recent discovery of gravitational waves. In a complementary approach, EPS Groups have been mostly concerned with cross-cutting issues, activities and technologies such as the history of physics, accelerators, and physics for development. The excellent work of the Divisions and Groups is the scientific and social lifeblood of our society, and our most visible figurehead in the scientific community. Divisions and Groups are instrumental in promoting open scientific communication, networking, and international collaboration; they organize many of the most important conferences in our field, often drawing a global audience; through a series of prestigious prizes, they reward research excellence, raise the visibility of young talent, and promote diversity.

To safeguard the future of physics education and physics research, the EPS must not only serve the immediate scientific and professional

interests of its members, and their organisational needs. In a long-term vision, our society needs to invest in the areas of science policy, outreach, and communication, to act as the central voice of European physics, and as a credible and efficient representative of our community vis-à-vis political and institutional decision makers, the media, and the public. This insight is neither new nor is it original. Several years ago, the EPS has started to develop structures and actions to raise its science policy profile, epitomised by the development of a point of presence in Brussels and supported by the creation of a high-level Advisory Board on Science Policy. However, structures need to be filled with contents, and action and communication must be based on reliable facts and robust arguments. To this end, the EPS must invest in its evidence base. A successful example from the recent past is the study “The importance of physics to the economies of Europe” published in 2012 which was well received, but starts to become obsolete and needs to be updated. An example of a different, equally urgent project is a study of high-school physics teaching in Europe, which is of strategic importance for attracting talent, and for promoting awareness of the importance of physics for our society. The recent review “Nuclear physics for cultural heritage” published by the EPS Nuclear Physics Division sets an excellent example for topical reports which

Development of the evidence base is an excellent opportunity for the Divisions, Sections and Groups to join forces and to team up with all instances of the EPS governance, working together for a common goal.

highlight the relevance of physics research and physical methods for other branches of science, and for everybody’s daily life.

The backbone of the EPS evidence base will be the framing document “Grand challenges on the Horizon 2050” which is presently under development, designed to address both the scientific and the societal challenges which physics is expected to face between today and the middle of the twenty-first century. This paper will not only develop a strategic vision for fundamental and applied research for several decades. Equally important, it will serve as the foundation and *fil rouge* of future actions and initiatives in the science policy arena. For this ambitious project to succeed, we need to harness the full bandwidth of scientific expertise and technological know-how which the EPS represents. Nobody is better placed to deliver this expertise than our Divisions and Groups, and each of them will be called upon to contribute to this unique endeavour.

The development of the evidence base is an excellent opportunity for the Divisions, Sections and Groups to join forces and to team up with all instances of the EPS governance, working together for a common goal. It will be an equally unique opportunity to take both collaboration inside the Society and our visibility to the outside to a higher, even more rewarding level. ■

■ **Rüdiger Voss,**
EPS President

europhysicsnews

2017 - Volume 48 - number 5 & 6

Europhysics news is the magazine of the European physics community. It is owned by the European Physical Society and produced in cooperation with EDP Sciences. The staff of EDP Sciences are involved in the production of the magazine and are not responsible for editorial content. Most contributors to Europhysics news are volunteers and their work is greatly appreciated by the Editor and the Editorial Advisory Board.

Europhysics news is also available online at:

www.europhysicsnews.org

General instructions to authors can be found at:
www.eps.org/?page=publications

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

Science Editor: Ferenc Igloi (HU)
Email: igloi.ferenc@wigner.mta.hu

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

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

Director of Publication: Jean-Marc Quilbé

Editorial Advisory Board:

Tracey Clarke (UK), Gonçalo Figueira (PT),
Guillaume Fiquet (FR), Zsolt Fülöp (HU), Agnès Henri (FR),
Jo Hermans (NL), Christoph Keller (NL), Robert Klanner (DE),
Peter Liljeroth (FI), Antigone Marino (IT),
Laurence Ramos (FR), Chris Rossel (CH),
Claude Sébenne (FR), Marc Türlér (CH)

© European Physical Society and EDP Sciences

EPS Secretariat

Address: EPS - 6 rue des Frères Lumière
68200 Mulhouse - France

Tel: +33 389 32 94 40 - **fax:** +33 389 32 94 49
www.eps.org

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

EDP Sciences

Chief Executive Officer: Jean-Marc Quilbé

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

Production: Thierry Coville

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

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

Subscriptions

Individual Members of the European Physical Society receive Europhysics news free of charge.

Members of EPS National Member Societies receive Europhysics news through their society, except members of the Institute of Physics in the United Kingdom and the German Physical Society who have access to an e-version at www.europhysicsnews.org. The following are 2017 print version subscription prices available through EDP Sciences (Prices include postal delivery cost).

Institutions - European Union countries: 104 €
(VAT not included, 20 %). **Rest of the world:** 124 €

Student - European Union countries: 49.17 €
(VAT not included, 20 %). **Rest of the world:** 59 €

Contact: Europhysics News, EDP Sciences
17 avenue du Hoggar - Parc d'activités de Courtaboeuf
BP 112 - F-91944 Les Ulis CEDEX A, France
subscribers@edpsciences.org or visit **www.edpsciences.org**

ISSN 0531-7479 - ISSN 1432-1092 (electronic edition)

Printer: Fabrègue - Saint-Yrieix-la-Perche, France

Legal deposit: October 2017



EPS HISTORIC SITES

NatLab

Eindhoven, The Netherlands *Nothing ventured, nothing gained*

On October 5, 2017, NatLab in Eindhoven was inaugurated as EPS Historic Site with 80 guests from all venues in society joining the festivities. The entrepreneurs Anton and Gerard Philips founded this industrial laboratory in 1914. Their goal was to improve the production of incandescent lighting, both by fundamental and applied research in physics and engineering.

In view of the turmoil in Europe in 1914, this was a highly visionary and daring activity. While the emperors, kings, prime ministers and a single czar were busy as ego-driven warmongers, the industrialists acted as Europeans *'avant la lettre'* by their travels to Moscow and all other places to sell their lighting systems.

NatLab – short for Natuurkundig Laboratorium, *i.e.* Physical Laboratory – developed into a powerhouse of excellent research. Both the unprecedented freedom in choosing the research themes as well as the policy of inviting university physicists to NatLab (*e.g.* Albert Einstein) are at the basis of the fame and scientific standing of this institution. A comparison to Bell Labs of ATT¹ and the labs of GE is appropriate, although the former has the extra achievement of having nurtured 13 Nobel Prize winners such as Bardeen, Brattain, and Shockley in 1956 for their discovery of the transistor effect.

At the beginning of the 20th century, physics research in The Netherlands was rather academic, with small research groups consisting of a single professor with very limited academic and technical support. The exception to this rule was the group of Heike Kamerlingh Onnes in Leiden, working on the liquefaction of gases including helium. The experimental infrastructure demanded support of technicians, operators, and a large group of young scientists engaged in the experiment: the first 'big physics' venture in the Netherlands. One of these young experimental scientists was Gilles Holst, who was selected by the Philips brothers to help them

¹ https://en.wikipedia.org/wiki/Bell_Labs

² <https://www.hightechcampus.com>

³ https://en.wikipedia.org/wiki/High_Tech_Campus_Eindhoven

⁴ From harmony to chaos; J. de Heer and K. Tazelaar (publisher 1001, Amsterdam, 2013)



▲ View of entrance of NatLab, showing the protruding auditorium and the two 'pillars of science'.

in setting up the embryonic NatLab in 1914 with only a few employees. In 1923 the building of the current Historic Site at Kastanjelaan 500 in Eindhoven was opened. It was used for this purpose until 1963, when the research facilities were moved to a new site in Waalre.

It is interesting to realize that the 1914 connection between Leiden and Eindhoven in experimental research has been reestablished. As of 2017, NatLab and The Kamerlingh Onnes Laboratory/Lorentz-Institute are the only two EPS Historic Sites in the Netherlands. Planning or coincidence, who knows?

In 2003, the Waalre site of Philips Nat Lab has evolved into High Tech Campus Eindhoven^{2,3}, a research community where sharing results is the game. This initiative again has a visionary character, with a large group of small and large companies (including Philips) engaged in innovation. In 2012, High Tech Campus Eindhoven was sold to an investor who manages the site, with Philips leasing its buildings just as the other parties.

The inauguration on October 5, 2017, was a lively affair, with guests ranging from former directors of NatLab to representatives of local and national high-tech companies, including the spinouts such as ASML, FEI, NXP and Philips Lighting, as the most

recent chick that has left the nest. Politics, culture, family of Philips luminaries and even a grandson of Anton Philips also joined in.

Excellent talks by prof. Dirk van Delft, director of Museum Boerhaave in Leiden, and dr. Henk van Houten, CTO Royal Philips, discussed the past and future research of Royal Philips. EPS President Rüdiger Voss unveiled the memorial plate, together with past President Chris Rossel. The latter memorized that NatLab now is the second industrial lab that is honored as Historic Site, the other being IBM

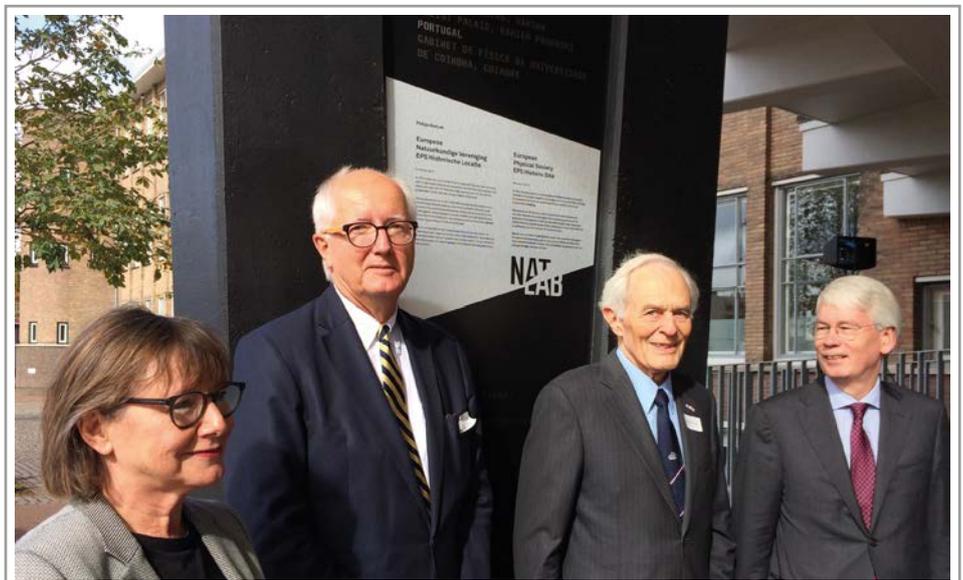
labs in Zurich since September 2017.

At lunch the guests enjoyed a preview of the reconfigured 'Le Poème Électronique' as shown at the Philips Pavilion at Expo 58 in Brussels. This version differs in such from the Expo 58 show that the visual material is much closer to the original ideas of Le Corbusier. In a clash between art and company culture at Philips, the latter emerged as the winning party⁴.

The memorial plate at NatLab is located on a pillar supporting the auditorium where all famous visitors held their talks: a 'pillar of science'. In the Netherlands we are proud of NatLab, which lies at the basis of the current position of the Eindhoven region as a kingpin in the role of The Netherlands as the Silicon Valley of the European Union. For the Netherlands, the annual contribution to the EU equals approximately 1% of the economic damages suffered during WW II. This is a very low insurance premium for avoiding war in Europe during 72 years! 'Make love, not war' can be paraphrased as 'do physics, stop quarrelling'. Join forces, think of the success of CERN. ■

■ **Herman C. W. Beijerinck**
emeritus professor Eindhoven
University of Technology

▼ Memorial plate with text (b/w) embedded in listing of other Historic Sites (grey), mounted on 'pillar of science'.
Left to right: Pauline Terreehorst (director NatLab/Plaza Futura cultural centre), Rüdiger Voss (President EPS),
Anton Philips (grandson of entrepreneur/founder Anton Philips), and Henk van Houten (CTO Royal Philips).



EPS gears up for 50th Anniversary

In 2018, the European Physical Society will celebrate its 50th anniversary. From its founding in Geneva, through the move to Mulhouse and now to the involvement of the EPS in the science policy debate in Europe, the EPS will organise a series of special events highlighting the contributions of EPS members over the past 5 decades.

A special logo will be used in 2018 on all official EPS documents. It symbolizes the deformation of the spacetime by a mass according to Einstein's general relativity theory. The presence of planets, stars and galaxies deform the fabric of spacetime like a large ball deforms a bedsheet. The logo is also a reference to our new Gravitational Physics Division.

A special session will be organised at the EPS Council meeting in Paris on 7 April 2018.

We are looking for a speaker that can summarise the 50 years of EPS, an entertaining speaker on physics in



▲ The special logo that will be used in 2018 on all official EPS documents.

everyday life, and a speaker on perspectives in physics.

The EPS was founded at the University of Geneva and a special session is planned on 28 September 2018 in the Aula Magna, where the first EPS General Meeting took place. This session will be devoted to remembering those who have contributed significantly to the EPS, and the main achievements in physics over the past 50 years.

Much has happened over the past 50 years in physics research and development, as well as in society at large. These events have had an impact on the EPS. A special booklet, outlining the major events in the developments



▲ Some of the pictures already collected on the photo archive.



of the EPS is currently being prepared. It will look at how changes in society and policy have influenced the EPS.

The EPS Young Minds sections will be organising a photo competition. It is open to everyone to show research and education in physics. The rules are given in the box.

Panels to be used as the basis for an exhibit “Physics in Your Life” are also under preparation. The panels will describe various physical phenomena in a colourful and engaging manner. The style will be loosely based on “Physics in Daily Life”, the popular column written by J. Hermans that appears in EuroPhysics News.

The EPS is inviting all EPS Member Societies and Divisions and groups to sponsor a speaker at one of their events in 2018.

Finally, a document and photo archive to collect as much material about the EPS and its history has been set up. You are invited to contribute at: <http://bit.ly/2zxonLL> ■

■ **David Lee**

EPS secretary General



EPS 50TH ANNIVERSARY PHOTO CONTEST RULES AND REGULATIONS

1. THEME

Within the 50th anniversary of the European Physical Society (EPS), the photo contest **EPS – 50years&counting** is launched. The theme is the celebration of EPS 50 anniversary. Feel free to take pictures of your lab and your colleagues, of your data analysis or your latest set-up, but don't forget to add something that recalls the 50th anniversary.

2. SPONSOR

EPS – **50years&counting** is sponsored by the European Physical Society (EPS).

3. ELIGIBILITY

- The contest is open to all, professional and amateur, regardless of age, gender or nationality.
- Only individuals who have reached the age of majority in their jurisdiction of residence at the time of entry can apply.
- The contest is open to members of the EPS or one of its Member Societies

4. SUBMISSION GUIDELINES

- Submissions must be in digital format. The pictures must be uploaded on http://www.eps.org/?page=photo_contest or sent via email to secretariat@eps.org. All digital files must be 20 megabytes or smaller, in JPEG or .jpg format, and must be at least 1,600 pixels wide (if a horizontal image) or 1,600 pixels tall (if a vertical image). Each participant can upload up to three pictures.
- The deadline for the submission is 31 January 2018.
- After deadline, all the pictures will be uploaded by the contest organizers in a specific Facebook album on EPS Facebook page.
- Both colour and monochrome images will be accepted.
- The participant has to provide: caption, name, last name, email address, telephone contact and geo-references of the photo (where it was taken).
- The submission must not contain obscene, provocative, defamatory, sexually explicit, or otherwise objectionable or inappropriate content.

5. COPYRIGHT/

INTELLECTUAL PROPERTY

- Each image submitted must be the original and unpublished work of the participant who must also be its copyright owner.
- The participant shall retain copyright to the image entered for the competition.
- By submitting an image for the competition, the participant will be regarded as having granted the organiser the right to use the image in print, broadcast and/or electronic media without any fee payment.
- Images received by the organiser through the competition will not be used by the organiser for commercial purposes.

6. JUDGING AND RESULTS

- The top 3 photos will be selected by a panel of judges and their decision is final. No correspondence pertaining to the selection process and decision will be entertained.
- The People's choice award will be granted to the picture with the largest number of “Likes” collected on Facebook.
- Images will be judged based on Artistic/visual appeal, originality, creativity and relevance to the theme.
- Results of the competition will be posted on EPS website page. The winners will be also notified via email, by the end of March 2018.

7. PRIZES

The top 3 photos plus the People's choice photo will receive a prize of 200€ and an invitation to the 50th anniversary ceremony of EPS.

8. WINNER AWARDS AND FINAL EXHIBITION

The award ceremony and the final exhibition will be held during the 50th anniversary ceremony of EPS planned for 28 September 2018 in Geneva (CH). The first 10 best images selected by the technical jury will be printed in 20 × 30 format and displayed during the ceremony. ■

Nobel prize in physics 2017

On September 14, 2015 the two detectors of the Laser Interferometer Gravitational-Wave Observatory (LIGO), located in Hanford (Washington) and Livingston (Louisiana) in the United States, observed a transient gravitational-wave signal, called the GW150914.

This is the first direct detection of gravitational waves, accomplished a century after the theoretical prediction of Albert Einstein as a consequence of his theory of general relativity. This decisive detection was the result of an international effort that lasted several decades and involved more than one thousand scientists and engineers.

Albert Einstein, only one year after formulating his theory of general relativity, had realised that in the weak-field regime, the linearised field equations admit transverse wave solutions travelling at the speed of light. He called these solutions gravitational waves. Yet the question of their existence as solutions of the fully nonlinear field equations hunted Einstein until the end of his life. The debate on the reality of gravitational waves lasted several decades and was only resolved in January 1957 during the Chapel Hill conference on “The Role of Gravitation in Physics” – known today as the GR1 meeting – during which Felix Pirani proposed a brilliant deduction on how to “measure” gravitational waves. One year earlier, in 1956, Felix Pirani had published an article entitled “On the physical significance of the Riemann tensor”, showing that gravitational waves manifest themselves as fluctuating tidal forces on masses within their path. In this work, Felix Pirani highlights the interpretation of geodesic deviation and its relation to the curvature tensor.

The first gravitational wave detector was developed in the sixties by Joseph Weber, one of the attendees of the Chapel Hill conference. The device he designed and subsequently built, consisted of massive aluminium cylinders – “antennas” – vibrating at a resonance frequency. The principle of these resonance detectors, called “Weber bars”, is based on the effect of gravitational waves on the fundamental resonant mode of aluminium bars at room temperature. By the seventies, there were developed aluminium bar systems operated at and below the temperature of liquid helium, to reduce thermal noise. However, despite several efforts, gravitational waves were not detected.

Hopes were soon raised again with the discovery of the binary pulsar system PSR B1913+16 by Hulse and Taylor in 1974 – recipients of the 1993 Nobel Prize in Physics – and the subsequent observations of its energy loss by Taylor and Weisberg. This discovery provided the first demonstration of the existence – not direct detection – of gravitational waves, leading the hunting for gravitational waves into a new phase.

The most promising design of gravitational wave detectors is laser interferometry offering a way of measuring the motion of widely separated test masses freely suspended as pendulums, produced as they interact with a gravitational wave. In the seventies, Rainer (Rai) Weiss – MIT – conceived the idea of building such a laser interferometer, and by late seventies he experimented with a modest prototype whose two L-shaped “arms” were 1.5 m long. The progress was then rapid. By 1983 Ronald Drever – Caltech – had already built an interferometer whose “arms” measured 40 m. The LIGO project saw the light in the eighties as a Caltech-MIT project funded by NSF; it was originally led by Kip Thorne, Rainer Weiss and Ronald Drever. In 1994 Barry Clark Barish, an experimental physicist – expert in high energy physics with experience in managing large projects – was appointed as the LIGO administrative leader. Barry Barish transformed the Caltech-MIT project into an international collaboration, the LIGO Scientific Collaboration (LSC), that includes today over 1200 people. Barish’s vision was to build the LIGO as an evolutionary laboratory. By the early 2000s, TAMA 300 in Japan, GEO 600 in Germany, LIGO in the United States, and Virgo in Italy were completed. Combinations of these detectors made joint observations already from 2002.

The initial LIGO, 2002-2010, did not detect any gravitational waves. The upgrade lasted five years and the advanced LIGO (aLIGO) started in February 2015. On the 14th September 2015, four days before the aLIGO starts its official run, the two interferometers detected a burst of gravitational waves from the collision of two giant black holes. In a far galaxy, 1.3 billion years ago, two black holes, of 29 and 36

solar masses, orbiting closer and closer to each other, collided and merged into a single black hole of 62 solar masses, releasing an enormous amount of energy, equivalent of an energy of 3 solar masses times the speed-of-light squared. LIGO had fulfilled its scope and the efforts of Rai Weiss, Kip Thorne and Barry Barish had paid off. The era of Gravitational Astronomy has now begun. Two more detections, the GW151226 and the GW170104, and a lower significance candidate, the LVT151012 have followed. The Advanced Virgo joined the Advanced LIGO twin interferometers on August 1, 2017. Soon afterwards, on August 12, 2017 the Advanced Virgo and the two Advanced LIGO detectors observed gravitational waves from a binary black hole coalescence. This is the first three-detectors observation, called GW170814, observed first at the LIGO Livingston and then at the LIGO Hanford and Virgo detectors, with a delay of respectively around 8 ms and 14 ms. Other detectors are planned to join the network: KAGRA is being built in Japan, and LIGO India has been recently approved. European Space Agency has selected the space-based laser interferometer, LISA, for its third large class mission, due for launch in 2034. There are also plans for the third-generation gravitational-wave, such as the Einstein Telescope or the Cosmic Explorer.

On the 3rd October 2017, the Royal Swedish Academy of Sciences has decided to award the Nobel Prize in Physics 2017, one half to Rai Weiss and the other half jointly to Barry C. Barish and Kip S. Thorne – all three members of the LIGO/VIRGO Collaboration – “for decisive contributions to the LIGO detector and the observation of gravitational waves”. The Nobel Prize acknowledges the efforts of a whole community during 45 years and the decisive contribution, vision and dedication of Barry Barish, Kip Thorne and Rai Weiss.

The years to come gravitational waves are expected to be detected from a variety of sources. Such detections will help us to better understand our universe and test the validity of our theories.

■ Mairi Sakellariadou

In memoriam

Prof. Alfred Zawadowski

One of the best known Hungarian physicists of our times, Prof. Alfred Zawadowski, – or as everybody in the international physics community knew him, 'Fred' – a former president of the Roland Eötvös Physical Society, the Hungarian member society of EPS, passed away on August 5th, 2017 in Budapest, at the age of 81.

The role played by the EPS Budapest Office for the exchanges and communication between physicists from East and West in Europe is well known.

Fred Zawadowski was a prominent member of our physics community, who played a major role in sustaining research excellence in Central Europe in communist times. Fred was born in 1936 in Budapest. He excelled in mathematics and physics already in his high-school years, and enrolled at the Roland Eötvös University in 1954 as a physics major. When getting his diploma in 1959, as the best student in his class he might have hoped – under normal conditions – to get a position at the university to work on field theory, his favourite subject. The late fifties of the last century were, however, not a normal period in Hungary. After the repression of the revolution in 1956, Fred had to accept a position at the Institute for Technical Physics of the Academy of Sciences to work on semiconductors. It was there that he became interested in the application of field-theoretical methods to solid-state physics problems.

A few years later, when the political climate got milder, he could move to the Central Research Institute for Physics of the Academy, where he got more liberty to choose his research subjects, and, at the same time, he was allowed to teach modern solid state physics at the Eötvös University. This gave him the opportunity to start to build up around himself a group of physicists, consisting of both theorists and experimentalists.

Fred Zawadowski had a broad research interest. His first breakthrough was the application of the idea of field theoretical renormalization group to the Kondo problem, much before Wilson's work. Indeed, throughout his life, he was passionately

interested in the Kondo problem, and returned to it later on several occasions. He studied it in alloys, mesoscopic structures, in the context of molecular electronics, in metallic glasses, and wrote – together with George Grüner – a well-known review paper



on the subject. But he created many important contributions in the field of correlated systems, superconductors, and one-dimensional systems, too. In a famous work with George Grüner and Paul Chaikin he gave a simple description of the dynamics and noise generation in charge-density wave systems. With his works on two-level systems and tunnelling centres in metallic glasses he established a new direction in this field, and his review on multichannel Kondo systems, written together with Daniel Cox, is a cornerstone reference today.

Fred Zawadowski was part of a lively, international network of fellow physicists. He was welcome everywhere because he was

an equal partner in scientific discussions to people like Elihu Abrahams, Phil Anderson, John Bardeen, Patrick Lee, Philippe Nozières or David Pines, just to name a few. He has spent several years at various places in the United States including Charlottesville (Virginia), Rutgers, UCLA and Urbana-Champaign. In Europe, he had extended stays at the ILL in Grenoble, and in Munich as the winner of the prestigious Humboldt Award.

One of Fred Zawadowski's major achievements was, however, not merely a scientific contribution, but the creation of a European-level Institute of Physics at the Budapest University of Technology and Economics. Although he remained a theorist throughout his life, he always liked to talk to experimentalists and tried to gather theorists and experimentalists around common subjects. He felt that it was his duty to strongly support young promising people. He was especially successful in this endeavour, when – in the early nineties – he got the possibility to reorganize completely the Institute of Physics of the Budapest University of Technology. He created a new and by now worldwide recognized institute with a strong and very successful physics program and PhD school, and with remarkable achievements in the field of statistical and condensed matter physics and optics, both in theory and experiment.

Fred Zawadowski's demise is a tragic loss to the Hungarian and international physics community. His person will be remembered and his legacy in physics will be preserved. ■

■ **Jenő Sólyom**

*Wigner Research Centre for Physics,
and Roland Eötvös University, Budapest*

■ **Gergely Zaránd**

Budapest University of Technology

The remake of an iconic photo

This year's 103rd Congress of the Italian Physical Society (SIF), which celebrated the 120th anniversary of the society, has just ended. Since its first edition in 1947 after WW2 on the occasion of the 50th anniversary of the SIF, the Congress (numbered as 33rd in order to follow the numeration of previous assemblies and meetings which had taken place since the foundation of the SIF in 1897) has been touring around Italy in various universities.

The Congress took place in Trento. This is an ancient and beautiful city in the northeast of Italy, very lively from the physics point of view, housing the Physics Department of the University, the Trento Institute for Fundamental Physics and Applications of the Italian National Institute of Nuclear Physics (TIFPA-INFN), the Centre for Materials and Microsystems of the Bruno Kessler Foundation (CMM-FBK), the European Centre for Theoretical Studies in Nuclear Physics and Related Areas (ECT*), the Bose-Einstein Condensation Centre of the Italian National Institute of Optics of the National Research Council (BEC-CNR INO@UniTn), the Centre for Neuroscience and Cognitive Systems of the Italian Institute of Technology (CNCS-IIT@UniTn), and in addition a very attractive and renowned Science Museum (MUSE).

The Congress by itself has been extremely interesting, with outstanding plenary talks as well as many invited talks and communications in the seven parallel sessions covering all branches of physics, namely: Nuclear and Subnuclear Physics; Solid State Physics; Astrophysics; Geophysics and Physics of the Environment; Biophysics and Medical Physics; Applied Physics, Accelerator Physics and Physics for Cultural Heritage; Physics Education and History of Physics.

But this year's Congress has been very special because of the commitment and

determination that the physicists of Trento have shown – with enormous success – to make their city part of the presence of hundreds of scientists coming from every corner of Italy and beyond.

The collateral programme of the Congress was splendidly named "FisiCittà". The exact translation would be "PhysiCity" but the *jeu de mots* is untranslatable since "fisicità" (with only one t) in Italian means "physicality". This programme was unique in its kind with an unprecedentedly dense series of events hosted in theatres, cinemas, museums and cafés, where the Trento people were able to meet and listen to a large number of physicists, and interact directly with them. FisiCittà has had a

of research, university, school and politics could express their views.

On the heels of these two events, the Communication Office of Trento University had the brilliant idea of immortalising 28 female speakers of the Congress, of different ages and fields of our discipline, together with only one among their male colleagues (Guido Tonelli, one of the discoverers of the Higgs boson at CERN), in a remake of the famous photo of the 1927 Solvay Conference which 90 years ago marked the birth of quantum physics. Not anymore 28 men and one woman, but the exact opposite.

The picture, taken almost for fun, had however an unexpected resonance, on all media and even on national television net-

works. I am very happy of such a resonance since it put everyone's eyes on the importance of women in physics and in scientific research. As far as I am concerned, I am very proud to be in that photo!

What came out? A provocation, of course, but something to seriously think about. The image triggers a pungent, stimulating reflection: from Madame Curie's time, much has been done to increase women's presence and careers in science. But unfortunately not enough, the road is still long ahead.

Meanwhile, let me say to my women friends and colleagues: don't fear science, don't be afraid to choose a scientific career, you have all the right credentials to do it. And Antigone Marino, a young physicist at Federico II University in Naples, former chairwoman of the Young Minds Committee of the European Physical Society, sitting in the picture in place of Albert Einstein, embodies the hope that things will change soon. ■

■ Luisa Cifarelli

Italian Physical Society, President

www.sif.it



tremendous impact, giving maximum visibility not only to the Congress but to our entire community.

To celebrate its 120th anniversary, the SIF has decided to organize the usual round table of the Congress, which normally focuses on a theme related to "Physics and Society", on the issue of women and scientific vocations. This round table, "Physics, *feminine singular*", attended by six distinguished women colleagues, was coupled to a second round table, "Research: Which spaces for women?", this time in the context of FisiCittà, where personalities from the world

International conference on Strangeness in Quark Matter in Utrecht

The 17th edition of the *International Conference on Strangeness in Quark Matter* took place from 10-15 July 2017 in Utrecht in the Netherlands (<http://sqm2017.nl>). This conference series focuses on new experimental and theoretical developments on the role of strangeness and heavy-flavour production in heavy-ion collisions, and in astrophysical phenomena related to strangeness. This year's conference attracted more than 210 participants from 25 countries, with 20% of female researchers. A two-day long graduate school on the role of strangeness in heavy ion collisions with 40 young participants preceded the conference, which was supported by the Dutch Physical Society (NNV).

The scientific programme consisted of 53 invited plenary talks, 70 contributed parallel talks and a poster session. Three discussion sessions provided scope for the necessary debates on crucial observables to characterise strongly interacting matter at extreme conditions of high baryon density and high temperature and to define possible future directions. One of the discussions centred on hadronic resonance production and their vital interactions in the partonic and hadronic phase that provide evidence for an extended hadronic lifetime even in small collision systems and might affect other observables for the quark-gluon plasma. Moreover, future astrophysical consequences for SQM following the recent detection of gravitational waves were outlined: gravitational waves from relativistic neutron star collisions can serve as cosmic messengers for the phase structure and equation-of-state of dense and strange matter, quite similar to the environment created in relativistic heavy-ion collisions.

Representatives from all major collaborations at the Large Hadron Collider (LHC) and Super Proton Synchrotron at CERN, Brookhaven's Relativistic Heavy Ion Collider (RHIC), and the Heavy Ion Synchrotron SIS at the GSI Helmholtz Centre in Germany made special efforts to release new data at this conference. Thanks to the excellent



▲ More than 210 participants attended 2017 SQM in Utrecht. [image credit: Pieter van Dorp van Vliet, Utrecht University]

performance of these accelerator facilities and detectors, a wealth of new data on the production of strangeness and heavy flavour in nuclear collisions has become available.

Among the highlights presented at the conference, the ALICE Collaboration reported new results on strange and multi-strange hyperon production in 5.02 TeV heavy-ion collisions and the first measurement of charm baryons (Λ_c and Ξ_c) in proton-proton and proton-lead collisions at the LHC. Furthermore, ALICE performed the most precise measurement of the (anti-)hypertriton lifetime, an exotic nucleus composed of a proton, a neutron and a lambda particle. The CMS Collaboration reported progress in understanding the energy loss of charm and beauty quarks in the hot QCD medium, while the STAR experiment at RHIC gave an update on global lambda polarisation, which reveals that the curl of the fluid created at RHIC is much higher than that in any fluid ever observed. Enhanced strangeness production in small systems, as reported by the HADES, NA61/SHINE and ALICE Collaborations, has also reignited the discussion surrounding strangeness production as a signature of the quark-gluon plasma.

Experimentally, the field faces high prospects for future measurements at the Facility for Antiproton and Ion Research in Darmstadt, NICA at JINR Dubna, and at CERN (namely detector upgrades at the LHC during long shutdown 2 and the AFTER programme).

On the theory side, new developments and vigorous research efforts are taking place towards a full understanding of strangeness production and open heavy-flavour dynamics in heavy-ion collisions. Global polarisation in heavy-ion collisions is also a highly debated topic since it allows studying the vorticity of the medium and the initial magnetic field.

Four young scientist prizes, sponsored by the European Physical Journal A, were awarded to the best parallel talk and poster presenters: Heidi Schuldes (Goethe University Frankfurt, Germany), Christian Bierlich (Lund University, Sweden), Yingru Xu (Duke University, US) and Vojtech Pacik (Niels Bohr Institute, Denmark).

The next edition of the SQM conference will take place in Bari, Italy, in June 2019. ■

■ **André Mischke**
conference chair

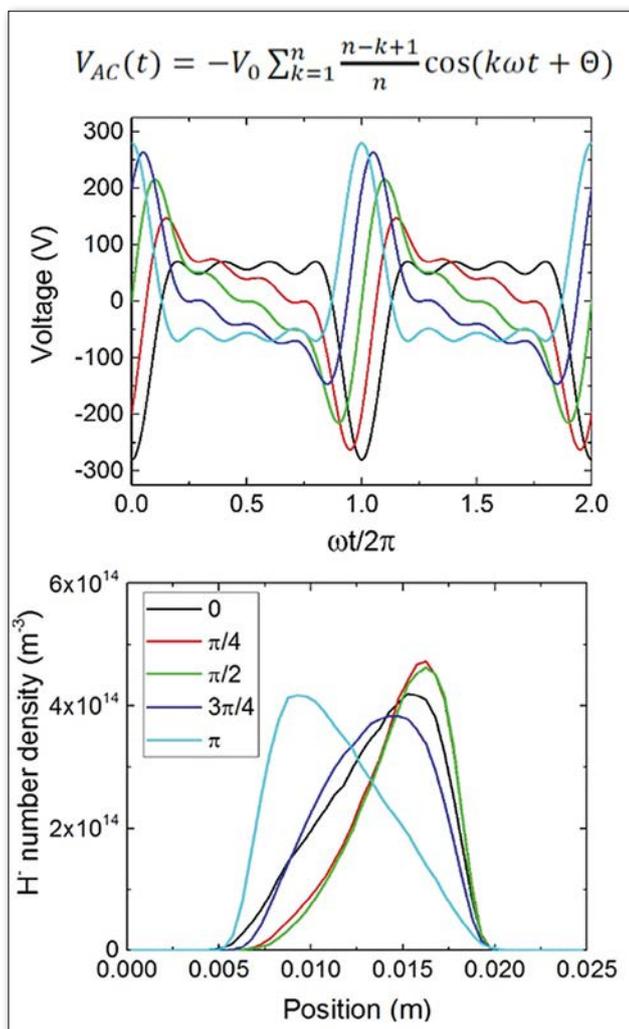
Highlights from European journals

PLASMA PHYSICS

Controlling negative ions in plasma using tailored voltage

Plasma processing of materials has wide applications in science and industry. In a capacitively coupled plasma, a feedstock gas, often diluted with hydrogen, is partially ionized with an electric discharge. In the most basic configuration, the key plasma parameters of ion flux and ion energy are strongly linked: increasing the applied sinusoidal voltage amplitude increases both. With a multiple harmonics waveform, it is possible to decouple ion flux and energy, obtaining increased processing speed while maintaining the ideal ion energy for surface reactions. This concept has been formulated and exploited for positive ions. Hydrogen plasmas, however, produce also negative ions which are important in other applications like heating systems in nuclear fusion.

▼ Calculated profile of negative ions for different voltage waveforms.



The authors investigated, using a comprehensive numerical model, the effect of tailored voltage waveforms on the location, peak density and dynamics of negative hydrogen ions and the influence of molecular physics on their production rate. They found that under appropriate conditions it is possible to concentrate negative ions in a desired position. This is due to a complex interplay between plasma electrical quantities, particle energy distributions and transport phenomena. ■

■ **P. Diomede, B. Bruneau, S. Longo, E. Johnson and J.-P. Booth,**

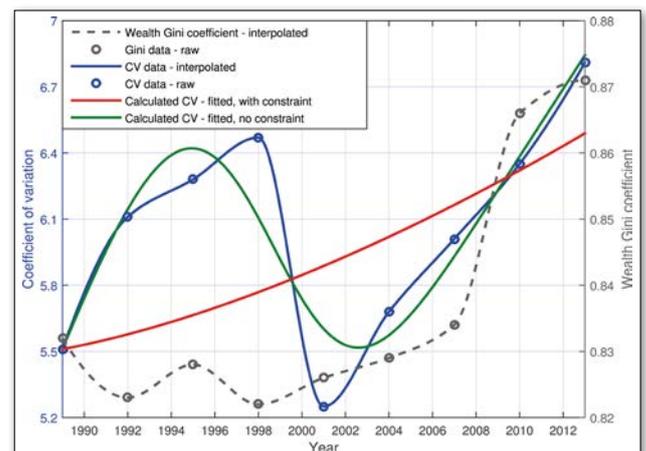
'Capacitively coupled hydrogen plasmas sustained by tailored voltage waveforms: vibrational kinetics and negative ions control', *Plasma Sources Sci. Technol.* **26**, 075007 (2017)

STATISTICAL PHYSICS

A Fokker-Planck Model for Wealth Inequality Dynamics

The growing wealth inequality in most western countries during the past several decades led to an increased interest in the nature of wealth inequality dynamics – particularly, what has driven wealth inequality upwards? Statistical mechanics can be used for addressing this question. We present a simple stochastic model for wealth and income and derive from it a Fokker-Planck equation – a standard tool in non-equilibrium statistical mechanics for studying the evolution of a distribution. Using this equation we are able to calculate the joint wealth-income distribution and its dynamics.

▼ Model comparison with data. Overall trend is well captured as well as some short-term details.



Our analysis supports empirical findings on the dynamics of wealth inequality. We find that wealth inequality inevitably tends to increase in the long run. However, even if inequality eventually goes up, we find a criterion for its possible short run decrease. This criterion is most likely to be fulfilled if the correlation between wealth and income is very low. The conditions for such a decrease are found to be met at several points during the 20th century, coinciding indeed with an observed decrease in wealth inequality. ■

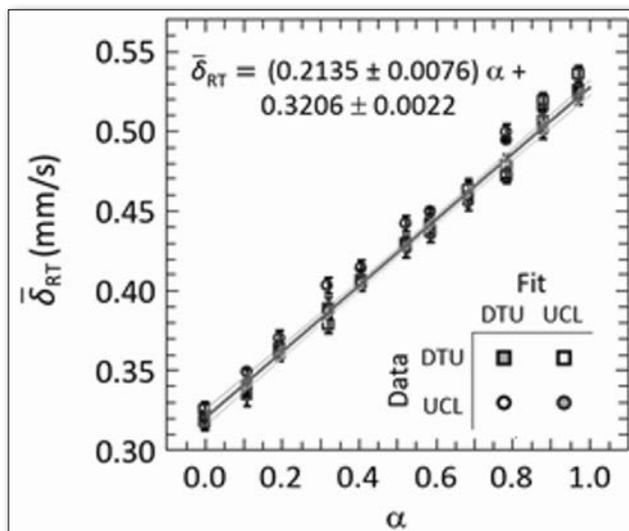
■ **Y. Berman, Y. Shapira and M. Schwartz,**

'A Fokker-Planck model for wealth inequality dynamics', *EPL* **118**, 38004 (2017)

MATERIAL SCIENCE

Magnetite or maghemite?

There is a simple answer



▲ Correlation between δ_{RT} , the 'centre of gravity' of the room temperature ^{57}Fe Mössbauer spectrum of a magnetite/maghemite sample vs. the fraction of ^{57}Fe atoms present in magnetite, α .

The composition or stoichiometry of magnetite (Fe_3O_4) and maghemite ($\gamma\text{-Fe}_2\text{O}_3$) mixtures or solid solutions is important for the physical, geological and material sciences. It is also significant in biomedical science, where magnetic nanoparticles are used both *in vitro* and clinically, and where both ferrous and ferric iron ions play active roles in the production of reactive oxygen species. However, the accurate determination of the composition/stoichiometry can be tricky, as it requires either well-crystallised samples suitable for x-ray diffraction, or it relies on chemical dissolution methods that, depending on the nature of the sample, are often either unfeasible or inappropriate. However, there is a simple answer, in the form of the recently proposed ^{57}Fe Mössbauer spectroscopic 'centre of gravity method'. The COG method is non-destructive and determines the composition/stoichiometry from the mean isomer shift, δ_{RT} . It is

well suited to nanomaterials, is simple and straightforward, and as long as appropriate measures and protocols are observed – all of which are explained in the paper – even inexperienced users will find little difficulty in its implementation. ■

■ **J. Fock, L. K. Bogart, D. González-Alonso, J. I. Espeso, M. F. Hansen, M. Varón, C. Frandsen and Q. A. Pankhurst**

'On the 'centre of gravity' method for measuring the composition of magnetite/ maghemite mixtures, or the stoichiometry of magnetite-maghemite solid solutions, via ^{57}Fe Mössbauer spectroscopy', *J. Phys. D: Appl. Phys.* **50**, 265005 (2017)

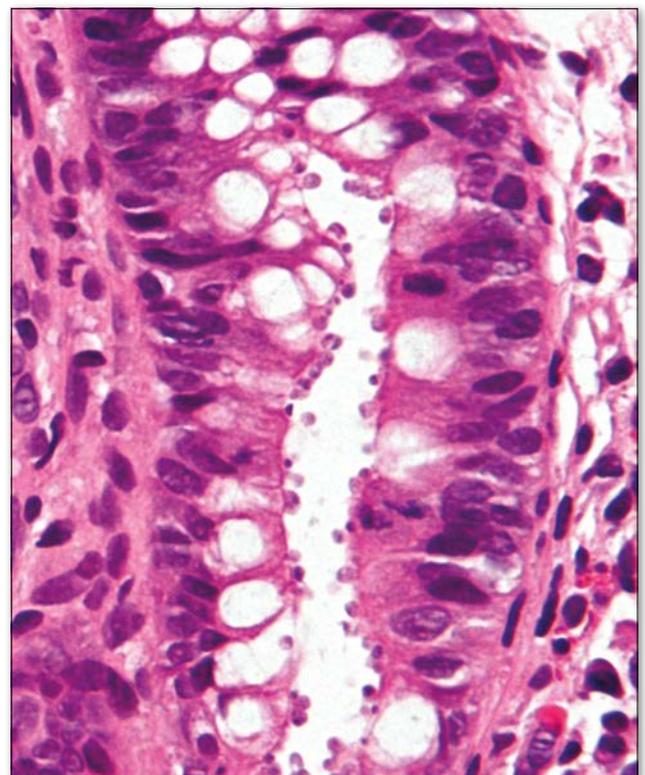
BIOPHYSICS

Best tactical approach to handling patients with simultaneous parasitic and HIV infection

New mathematical model for cryptosporidiosis - HIV co-infection explores their synergistic relationship in connection with prevention and treatment.

One of the most common waterborne diseases worldwide is cryptosporidiosis, a parasitic disease affecting the small intestine and possibly our airways. It is a common cause of diarrhoea in HIV-positive patients, who are known to have lower

▼ Cryptosporidiosis. Credit: 2012 Michael Bonert. CC BY-SA 3.0.



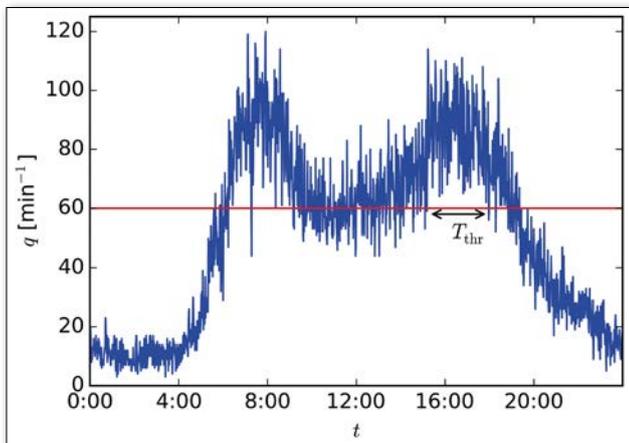
immunity. Now the authors have developed a new model and numerical simulations to determine the optimal combination of prevention and treatment strategies for controlling both diseases in patients who have been co-infected. Their results, recently published, show a positive impact on the treatment and prevention for cryptosporidiosis alone, for HIV-AIDS alone, or for both together. They found that cryptosporidiosis preventions and treatment alone had no significant impact on reducing HIV-AIDS-related problems. By contrast, the prevention and treatment strategy for HIV-AIDS had a significant positive impact on the co-infected patients. Finally, applying both strategies at the same time resulted in reduction in all cases. ■

■ **K.O. Okosun, M.A. Khan, E. Bonyah and S.T. Ogunlade,**

'On the dynamics of HIV-AIDS and cryptosporidiosis', *Eur. Phys. J. Plus* **132**, 363 (2017)

STATISTICAL PHYSICS

Highway traffic fluctuations impact congestion durations



▲ Traffic flow time series (vehicles per minute) during one day on a highway in Germany, with two rush hours and strong fluctuations.

Many highways around large cities are running above their capacity, leading to congested traffic. A useful statistical description of congestion distinguishes three phases: Free flow, synchronized traffic and wide moving jams. Traffic breakdown from free flow becomes increasingly likely around a critical flow (a certain number of vehicles per minute, specific for the highway section). Here we investigate the influence of flow fluctuations on congestion durations. As can be seen in the figure, traffic flow is antipersistent: It shows large fluctuations on short time scales which quickly trend back to the mean value, *i.e.* they reverse fast. Therefore, the duration of times with a flow above a critical value (here 60 vehicles per minute) is most often a few minutes, but sometimes it extends over longer intervals

up to several hours. We find that durations of congested traffic behave in the same way, and we conclude that traffic flow fluctuations are an important factor in congestion dynamics. The large number of short-lasting traffic jams implies a large risk for rear-end collisions. ■

■ **S. M. Krause, L. Habel, Th. Guhr and M. Schreckenberg,**
'The importance of antipersistence for traffic jams', *EPL* **118**, 38005 (2017)

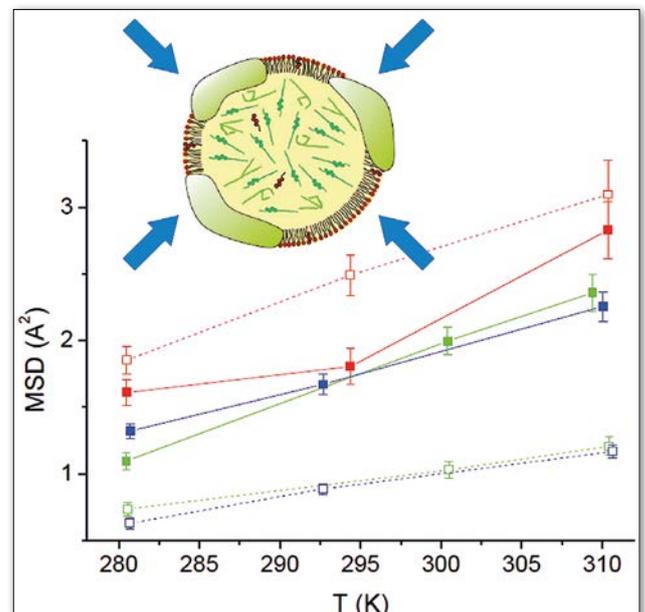
BIOPHYSICS

Like a game of 'spot the difference' for disease-prone versus healthy people

The change in behaviour of natural nanoparticles, called lipoproteins, under pressure could provide new insights to better understand the genesis of high cholesterol and atherosclerosis.

Understanding common diseases sometimes boils down to grasping some of their basic mechanisms. For instance, a specific kind of natural nanoparticles, called low-density lipoproteins (LDL), are fascinating scientists because their modification plays a key role in people affected by high cholesterol. They are also known for their role in the formation of atherosclerosis. The authors mimicked variations of LDL found in people affected by such diseases. They then compared their responses to temperature variations and increased pressure with those of lipoproteins found in healthy people. Their findings, recently published, show that the LDL

▼ Dynamical behaviour of different low-density lipoproteins as a function of temperature and pressure.



from healthy people behaved differently when subjected to high pressure compared to LDL affected by the common diseases studied. The authors found that when LDL particles were subjected to variations in temperature, their behaviour was very similar. In fact, a rise in temperature increased their dynamics at the molecular level. However, when the authors increased the pressure on LDL particles, they found that their flexibility actually increased under pressure in healthy people. By contrast, their flexibility clearly decreased for the two modified forms mimicking disease states. This difference, the authors believe, could stem from a slightly different lipid composition. ■

■ **J. Peters, N. Martinez, B. Lehofer and R. Prassl,**

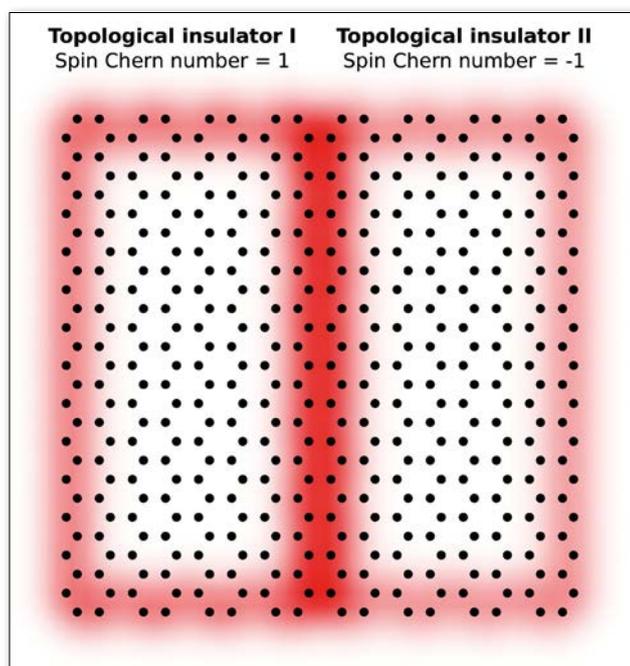
'Low-density lipoproteins investigated under high hydrostatic pressure by elastic incoherent neutron scattering', *Eur. Phys. J. E* **40**, 68 (2017)

QUANTUM PHYSICS

Robustness of states at topological insulator interfaces

Topological phases of matter are characterized by invariant numbers. In two-dimensional time-reversal symmetric electronic systems, a Z_2 valued (0 or 1) invariant distinguishes trivial insulators from non-trivial ones. Interfaces between trivial and non-trivial topological insulators are known to host conductive channels protected against disorder. The protection of these states originates from the necessity of a gap closure in order to change topology. However, if the

▼ Interface states emerging between two topological insulators with opposite spin Chern numbers.



two regions are of the same topological phase, there is no such requirement.

Using a multi-orbital model, it is shown in this study that conductive states can also emerge at the interface between two non-trivial topological insulators characterized by opposite spin Chern numbers, another invariant. In general, these states are sensitive to disorder. However, it is possible under some conditions to reduce the effect of disorder, or even to cancel it. These conditions are clarified. Since analogues of topological insulators can be presently made with polaritons, ultracold atomic gases, phononic or photonic materials, these conclusions should motivate experimental studies in many directions. ■

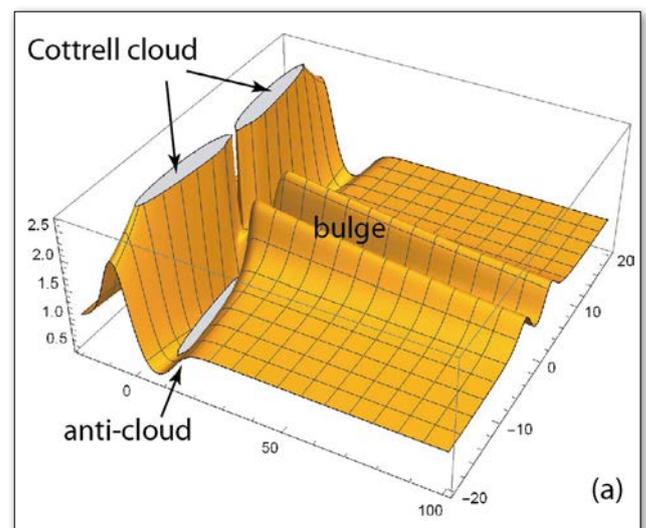
■ **A. Tadjine and Ch. Delerue,**

'Robustness of states at the interface between topological insulators of opposite spin Chern number', *EPL* **118**, 67003 (2017)

MATERIAL SCIENCE

The secret to improving liquid crystal's mechanical performance

Better lubricating properties of lamellar liquid crystals could stem from changing the mobility of their structural dislocations by adding nanoparticles.



▲ 3D plot of the concentration of nanoparticles around a moving edge dislocation in a smectic A liquid crystal.

By deliberately interrupting the order of materials—by introducing different atoms in metal or nanoparticles in liquid crystals—we can induce new qualities. For example, metallic alloys like duralumin, which is composed of 95% of aluminium and 5% copper, are usually harder than the pure metals.

This is due to an elastic interaction between the defects of the crystal, called dislocations, and the solute atoms, which form what are referred to as Cottrell clouds around them. In such clouds, the concentration of solute atoms is higher than the mean concentration in the material. In a paper published recently, the authors have now theoretically calculated the static and dynamical properties of the Cottrell clouds, which form around edge dislocations in lamellar liquid crystals of the smectic A variety decorated with nanoparticles. In this study, they demonstrate a formula previously used to approximate the mobility of dislocations in the presence of Cottrell clouds. They then perform a numerical simulation of the problem to study how the Cottrell cloud erodes when the dislocation moves at high speed. This work could be important, for example, in the context of improving the lubricating performance of such liquid crystals. ■

■ **P. Oswald and L. Lejček,**

'Drag of a Cottrell atmosphere by an edge dislocation in a smectic-A liquid crystal', *Eur. Phys. J. E* **40**, 84 (2017)

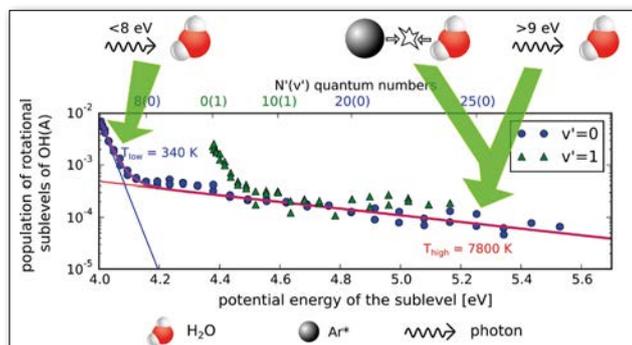
APPLIED PHYSICS

Information stored in quantum states of water fragments

Does water have memory? Well, not in the usual sense. But it is known, that if you tear water molecules apart, the remaining fragments can tell you a story about how it happened. To investigate this phenomenon, a plasma reactor producing miniature lightnings in direct contact with water level was constructed. The electrical discharges are powerful enough to cause dissociation of water molecules in various ways. To facilitate the electrical breakdown, the atmosphere in the reactor was replaced by argon.

The water molecule can be broken by impact of sufficiently fast electron, absorption of deep UV photon or previously excited argon atom. Each of these processes has a different energy balance and the remaining energy is partially conserved

▼ Typical example of a Boltzmann plot. The magenta curved line is a two-temperature fit, where the blue and red straight lines are its components.



in quantum states of the water fragments. By careful analysis of the light emitted by the relaxing OH radicals, we can disentangle the respective contributions to the total spectrum and calculate the portion of water molecules undergoing various dissociation mechanisms.

The water fragments really remember what preceded their creation and they let us know by emitting photons. The time scale for "forgetting" depends on the collisional rate, i.e. the pressure. At atmospheric pressure, the information can be kept for several nanoseconds. ■

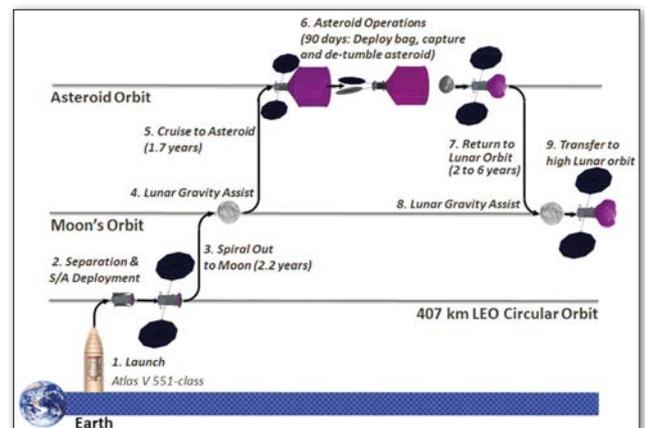
■ **J. Voráč, P. Synek, V. Procházka and T. Hoder,**

'State-by-state emission spectra fitting for non-equilibrium plasmas: OH spectra of surface barrier discharge at argon/water interface', *J. Phys. D: Appl. Phys.* **50**, 294002 (2017)

PLANETARY SCIENCE

Astronauts to bring asteroid back into lunar orbit

Italian Space Agency presents plans to develop a robotic solar-powered spacecraft capable of displacing a near-Earth asteroid towards lunar orbit for ease of study.



▲ How to bring an asteroid back nearer to lunar orbit.

Future space exploration aims to fly further from Earth than ever before. Now, Italian Space Agency scientists have expressed an interest in contributing to the development of robotic technologies to bring an asteroid from beyond lunar orbit back into closer reach in order to better study it. In a paper published recently, the authors make the case for taking part in the robotic phase of the Asteroid Redirect Mission (ARM). In addition to taking manned spaceflights deeper into space than ever before, the proposed mission would also bring some benefit for planetary science. Further, the mission has potential implications for a field called planetary defence. The next step for human space exploration after the International Space Station is to send astronauts

on a Near Earth Asteroid by 2025, as planned by NASA. This constitutes an intermediate step towards future manned missions to Mars. The planned ARM mission has been part of the NASA program since 2013. The robotic spacecraft would cruise in deep space towards a near-Earth asteroid, using a technology called advanced Solar Electric Propulsion. Under the proposed plan, Italy would contribute by enhancing the carrying capacity of that spacecraft. ■

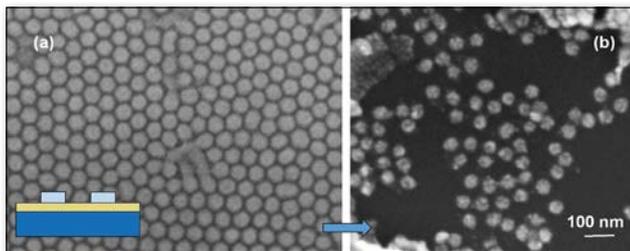
■ **M. Tantardini** and **E. Flamini**,

'Synergies between human space exploration and science in the asteroid redirect mission and the potential Italian participation in the asteroid redirect robotic mission phase', *Eur. Phys. J. Plus* **132**, 314 (2017)

MATERIAL SCIENCE

Monodisperse magnetic nanoparticles prepared from block copolymer template

Magnetic nanoparticles are playing an increasing role in biomedical applications, both for diagnosis, e.g. contrast agent in MRI (Magnetic resonance imaging) or for MPI (magnetic particles imaging) and for therapy thanks to their ability to exert forces and torques on biological species allowing for instance cancer cells destruction or oriented growth of biological tissue.



▲ SEM images of superparamagnetic nanoparticles made from self-assembled block copolymer template (a) on Si substrate, (b) after their release in solution.

In order to fabricate magnetic nanoparticles with high monodispersity, required in particular in biomedical imaging, we have developed a new preparation method based on the use of self-assembled block copolymer template.

Such techniques have already been explored for the preparation of patterned media for ultra-high density magnetic recording. However, our requirements substantially differ from those for storage media. A sacrificial layer has to be introduced between the substrate and the diblock copolymer to allow the release of the nanoparticles in solution. For that purpose, an optimized germanium oxide layer was used. The obtained superparamagnetic particles do not agglomerate in solution. They can be made of biocompatible

material (magnetite) and exhibit very narrow size dispersion ($\approx 7\%$). They can be good contrast agents for medical imaging. ■

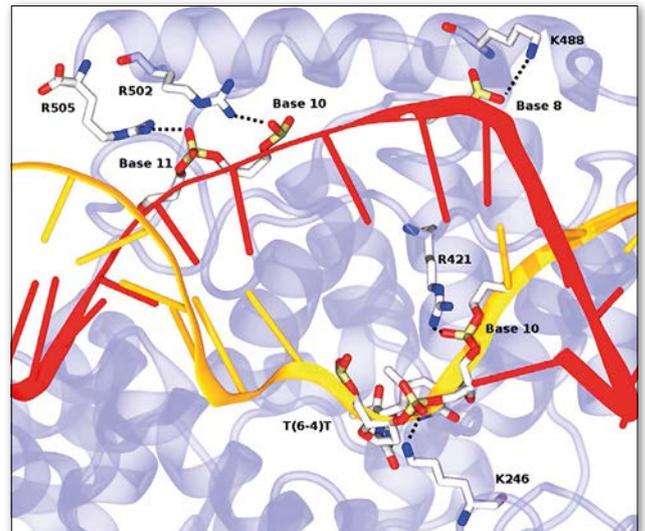
■ **M. Morcrette**, **G. Ortiz**, **S. Tallegas**, **H. Joisten**, **R. Tiron**, **T. Baron**, **Y. Hou**, **S. Lequien**, **A. Bsiesy** and **B. Dieny**,

'Fabrication of monodisperse magnetic nanoparticles released in solution using a block copolymer template', *J. Phys. D: Appl. Phys.* **50**, 295001 (2017)

BIOPHYSICS

First aid kit in some living organisms helps fix DNA after lengthy sun exposure

New study unveils the binding mechanisms of enzymes capable of repairing DNA damaged by UV light before any risk of cellular malfunction sets in.

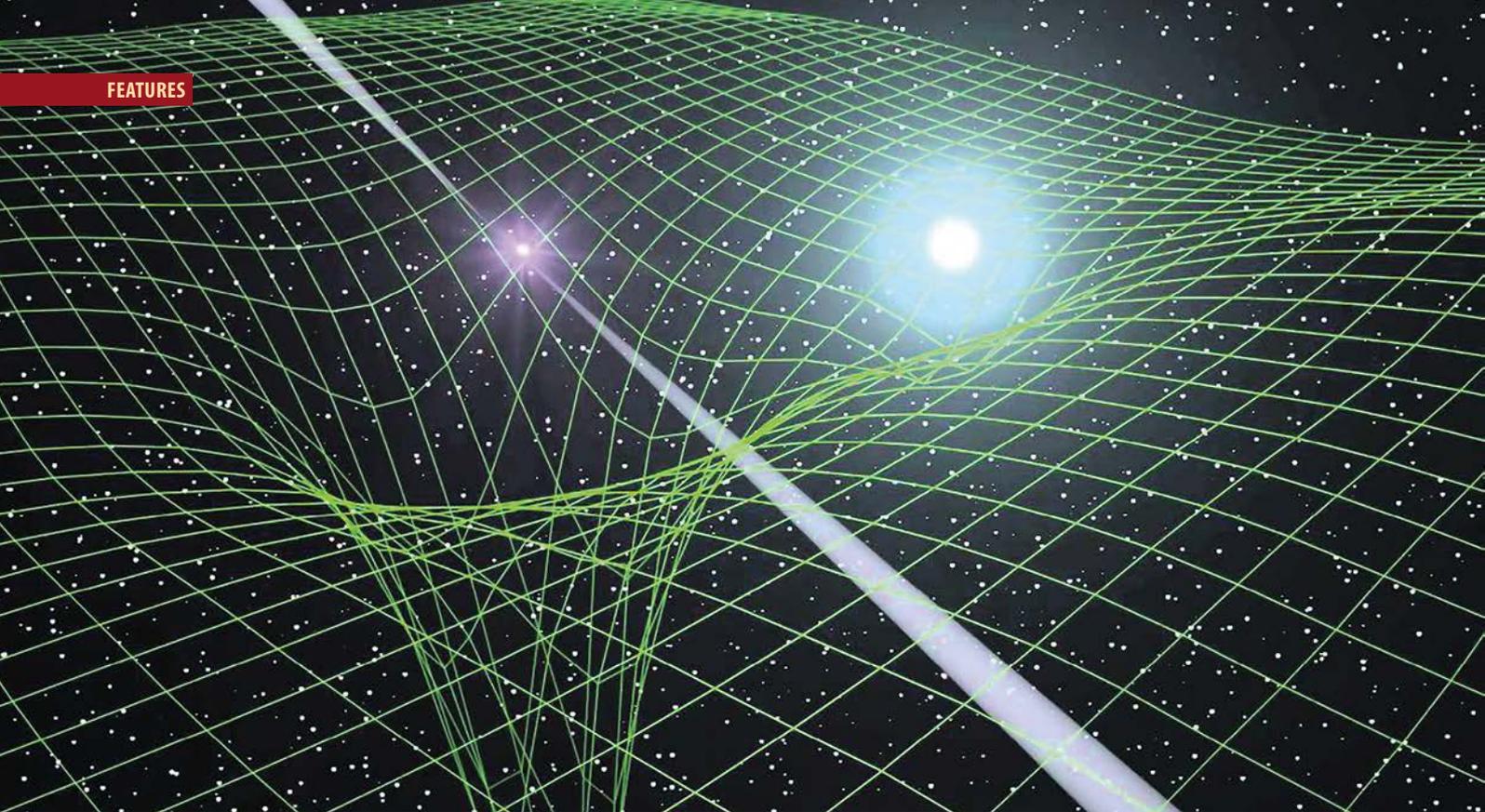


▲ Important photolyase residues for DNA binding.

Sunburn in living organisms is caused by ultraviolet (UV) light from the sun damaging the DNA in the cells. Many organisms, however, have an in-built mechanism for repairing the sun damage. This is possible thanks to an enzyme called DNA photolyase, which is so specialised that cryptochrome, a structurally similar molecule, is unable to do the same job. By comparing both types of molecule, physicists can understand precisely how the ability of our enzymes to repair DNA boils down to the most minute structural details. In a study published recently, the authors pinpoint the mechanism by which repair enzymes bind to the damaged site. ■

■ **K. Aalbæk Jepsen** and **I. A. Solov'yov**,

'On binding specificity of (6-4) photolyase to a T(6-4)T DNA photoproduct', *Eur. Phys. J. D* **71**, 155 (2017)



GRAVITATIONAL PHYSICS: THE BIRTH OF A NEW ERA

■ Mairi Sakellariadou – DOI: <https://doi.org/10.1051/epn/2017501>

We live the golden age of cosmology, while the era of gravitational astronomy has finally begun. Still, fundamental puzzles remain. Standard cosmology is formulated within the framework of Einstein's General theory of Relativity. Notwithstanding, General Relativity is not adequate to explain the earliest stages of cosmic existence, and cannot provide an explanation for the Big Bang itself. Modern early universe cosmology is in need of a rigorous underpinning in Quantum Gravity.

General Relativity, the well-known Albert Einstein's theory, describes warps in space-time, and accounts for the large-scale dynamics of the cosmos — the dynamics of galaxies and clusters of galaxies, the dynamics of black holes and even the dynamics of our Universe — with an extraordinary accuracy. General Relativity describes the way massive objects curve space-time, turning a flat landscape into curved scenery of hills and basins. NASA's Gravity Probe B mission [1], launched in April 2004, confirmed two fundamental predictions of the theory of General Relativity. With the help of very precise gyroscopes, Gravity Probe B measured the warping of space-time around the Earth, as well as the amount of space-time the Earth pulls with it as it rotates. These effects are predicted by the theory of General Relativity to be equal to 6606 milliarcsec/year and 39.2 milliarcsec/year, respectively, while Gravity Probe B measurements lead

to 6602 ± 18 milliarcsec/year and 37.2 ± 7.2 milliarcsec/year, respectively [2]. The accuracy is indeed remarkable.

In 1998, astronomical observations revealed that the Universe undergoes an accelerated expansion, while naively one would expect the expansion to be slowing down. Within the framework of General Relativity, the late acceleration originates from dark energy, with the simplest option being the cosmological constant, first introduced by Einstein. However, in order to explain the current acceleration of the Universe, the required value of the cosmological constant must be incredibly small. Alternatively, one may consider a large-distance modification to Einstein's theory of General Relativity and relax the hypothesis of dark energy. The explanation of the late-era accelerated expansion and the unknown nature of dark energy remain open questions that challenge our understanding of the Universe and question the validity or completeness of our theoretical models.

Relativity is not just an abstract mathematical theory with no applications in our daily life. Special and General Relativity play an important role in the Global Positioning System (GPS) which requires nanosecond accuracy. Combining Special and General Relativity effects implies that the atomic clocks on board of each of the GPS satellites tick faster than identical clocks on the ground by about 38 microseconds per day. If these effects were not taken into account then errors in global positions would accumulate at a rate of about 10 kilometers per day, rendering the system worthless for navigation purposes.

The theory of General Relativity predicts the existence of ripples in the fabric of space-time – called gravitational-waves – produced during a violent event of an astrophysical or cosmological origin in the faraway Universe. The existence of gravitational-waves was first demonstrated by Taylor and Weisberg who shown that the orbit of the Hulse-Taylor Pulsar (PSR 1913+16) shrinks slowly over time – only 40 seconds over 30 years – as the result of energy release in the form of gravitational-waves [3]. In 1993, the Nobel Prize in Physics was awarded jointly to Russell A. Hulse and Joseph H. Taylor Jr. *“for the discovery of a new type of pulsar, a discovery that has opened up new possibilities for the study of gravitation”*. The hunt for gravitational-waves lasted several years and the announcement of the first detection in 2016 came 100 years after Einstein’s prediction of their existence [4].

According to the theory of General Relativity, a compact binary system loses energy through gravitational-waves emission, bringing the pair of compact objects closer to each other, until a merger takes place leading to the formation of a single more massive spinning compact object and the release of energy in the form of burst of gravitational-waves. On September 14, 2015, the two detectors of the Laser Interferometer Gravitational-Wave Observatory (LIGO) [5] – located in Livingston, Louisiana, and Hanford, Washington, USA – simultaneously detected a transient gravitational-wave signal, hence confirming a major prediction of Einstein’s 1915 theory of General Relativity. These gravitational-waves were produced during the final fraction of a second of the merger of two black holes of roughly 29 and 36 solar masses – more massive than known stellar-mass black holes – which took place 1.3 billion years ago, resulting in the formation of a single black hole of 62 solar masses and the release of an energy of 3 solar masses times the speed-of-light squared, in the form of gravitational-waves [6].

The era of gravitational astronomy has then begun. Underpinning this breakthrough is a technological triumph of breathtaking capability. LIGO was able to detect movements in objects equivalent to the width of a human hair at the distance to the nearest star. The disturbances are tiny and their detection requires an exquisite sensitivity. The LIGO interferometers found a way to make measurements that go beyond the limits imposed by the Heisenberg principle of quantum physics. On the 3rd October 2017, the Royal Swedish Academy of Sciences has decided to award the Nobel Prize in Physics 2017 with one half to Rainer Weiss and the other half jointly to Barry C. Barish and Kip S. Thorne – all three members of the LIGO/VIRGO

Collaboration – *“for decisive contributions to the LIGO detector and the observation of gravitational waves”*. In announcing the award, the Royal Swedish Academy called it *“a discovery that shook the world.”*

Gravitational-waves carry information – otherwise inaccessible to us – from a variety of sources (*e.g.*, phase transitions in the early Universe, topological defects as relics of a previous more symmetric stage of the Universe, an early inflationary era which is a paradigm proposed to cure some of the pathologies that plague the standard hot Big Bang cosmological model, or mergers of compact binary systems formed by neutron stars or black holes), opening a new window on our cosmic origins, hence widening our understanding of astrophysics, cosmology, as well as fundamental physics. Gravitational-waves can be considered as the most promising cosmic relic to probe the unknown aspects of the early Universe, as they can provide information during the period that the Universe was opaque to electromagnetic radiation.

Gravitational physics is now entering a golden age of discovery. The Advanced Virgo detector [7] – located in Cascina, Italy – joined the Advanced LIGO twin interferometers on August 1, 2017. Other detectors are planned to join the network: KAGRA is being built in Japan [8], and LIGO India has been recently approved. The Microscope satellite [9], aimed to test the equivalence between gravitational and inertial mass, has been successfully launched and is now taking data. Following the highly successful LISA Pathfinder mission, the European Space Agency has selected the space-based laser interferometer, LISA [10], for its third large class mission, due for launch in 2034. LISA will open a gravitational window on the Universe in the low-frequency regime, providing the closest view of the early stages of the Universe, from its smallest scales near the horizons of black holes, all the way to cosmological scales. There are also plans for the third-generation gravitational-wave, such as the Einstein Telescope [11] or the Cosmic Explorer, reaching unprecedented sensitivities, overcoming current limitations imposed by thermal noise and quantum-optical noise. These detectors will be roughly a factor of 10 more sensitive in strain than the current generation, and be able to detect binary black hole mergers beyond a red-shift of 20.

Despite its enormous success, the theory of General Relativity has its limitations. The theory describes very well the dynamics of the Universe through Einstein’s field equations. Running these dynamic equations backwards in time, there is a finite time in the past when the Universe must have been in a state of ultra-high curvature and mass density. This is the Big Bang era, which took place about 13.8 billion years ago and is considered as the beginning of our observable Universe. At that early time, all matter and energy of our present Universe were confined into a tiny sub-atomic region of space, and the classical theory of General Relativity cannot provide the mathematical tools and physical concepts that will allow us to describe the behaviour of gravity under such extreme curvature and density conditions. Indeed, once we zoom into the microcosm, the behaviour and position of sub-atomic particles become uncertain as we enter

the realm of Quantum Mechanics, characterised by uncertainties and probabilities. To describe the Big Bang era, a quantum theory of gravity is required; such a theory is expected to cure the singularity which plagues the classical theory.

To address questions, such as what is meant by the origin of the Universe, what was the mechanism that led to its creation, whether its birth was an accidental process and whether it could have been avoided, or even what was before the Big Bang phase, requires an understanding about the state, structure and dynamics of space-time itself. Quantum Gravity is the theory aiming at explaining the shape of space-time and understanding its invisible structure, which we perceive as the force of gravity and which determines our own trajectories. Hence, modern early Universe cosmology is in the need of a rigorous underpinning in Quantum Gravity, the long-sought theory that will offer the appropriate framework to address fundamental questions such as the origin of the space-time continuum and its effective dynamics, and the pictures of the earliest moments of the Universe which emerge.

Different Quantum Gravity proposals have been made and progress has been constantly achieved. These proposals belong to two classes; they are either *top-down* (guess the structure of space-time at the Planck scale and deduce its consequences at low-energy scales) or *bottom-up* (deduce the structure of space-time at the Planck scale from our knowledge at low-energy scales at which colliders operate). In the former class belong approaches like String/M-theory or a variant of non-perturbative approach to Quantum Gravity, like Loop Quantum Gravity [12], Group Field Theory [13], Causal Sets [14], or Causal Dynamical Triangulations [15]. In the latter one belong the proposal of Non-Commutative Spectral Geometry [16] and that of Asymptotic Safety [17]. At present, Quantum Gravity has spawned many new ideas aimed at augmenting or replacing General Relativity as a theory of gravity. The low-energy limit of such Quantum Gravity theory will be the classical theory of General Relativity.

Applied to cosmology, these ideas involve dramatic departures from the standard cosmological model [18], such as *bouncing cosmological models*, where the Universe undergoes a long, *pre-big bang* contracting phase which then bounces into the expanding Universe we observe today. Another possibility is an early era of accelerated expansion without the need for a special mechanism such as inflation. These ambitious attempts to model the very early Universe mathematically have been accompanied by plans for observational tests. Searching for physical remnants of very early Universe, not to mention a possible *pre-big bang* phase, are enormously challenging, but gravitational-waves are acknowledged as the most promising. At present, even though we are not yet in a position to make any definite statement as to which – if any – Quantum Gravity proposal is viable, it is fair to say that a great progress has been made towards the goal to unify gravity with sub-atomic forces. Early Universe cosmology can shed some light on the correct Quantum Gravity theory, unweaving the fabric of the Universe and revealing the very early stages of its infancy [19]. ■

About the Author



Mairi Sakellariadou, Professor of Theoretical Physics, King's College London. Research in Early Universe Theoretical Cosmology, Quantum Gravity/Cosmology (String/Brane Cosmology, Loop Quantum Cosmology, Group Field Cosmology, Non-Commutative Geometry), Gravitational-Waves, Modified Gravity, Topological Defects.

MEMBER OF THE:

- LIGO Scientific Collaboration, GEO600 Experiment, MoEDAL at LHC Collaboration, LISA Cosmology working group, Einstein Space Team, EUCLID Consortium, Virgo Ego Scientific Forum
- Chair of the Gravitational Physics Division of the European Physical Society
- President of the Hellenic Society Relativity, Gravitation and Cosmology
- Advisory Editor for Springer Verlag books
- Co-editor of Europhysics Letters
- Member of the Editorial Advisory Board of Classical and Quantum Gravity
- Emily Noether Visiting Fellow at the Perimeter Institute, Canada
- Member of the Advisory Committee of the Research and Training Group “Models of Gravity”, Germany

References

- [1] https://www.nasa.gov/mission_pages/gpb/
- [2] C. W. F. Everitt, D. B. DeBra, B. W. Parkinson, J. P. Turneaure, J. W. Conklin, M. I. Heifetz, G. M. Keiser and A. S. Silbergleit *et al.*, *Physical Review Letters* **106** (2011) 221101
- [3] J. H. Taylor and J. M. Weisberg, *Astrophysical Journal* **253** (1982) 253
- [4] A. Einstein, *Sitzungsber. Preuss. Akad. Wiss. Berlin (Math.Phys.)* (1916) **688**
- [5] <http://www.ligo.org/>
- [6] B. P. Abbott *et al.* (LIGO Scientific Collaboration and Virgo Collaboration), *Physical Review Letters* **116** (2016) 061102.
- [7] <http://www.virgo-gw.eu/>
- [8] <http://gwcenter.icrr.u-tokyo.ac.jp/en/>
- [9] <https://microscope.cnes.fr/en/MICROSCOPE/index.htm>
- [10] <http://sci.esa.int/lisa/>
- [11] <http://www.et-gw.eu/>
- [12] A. Ashtekar, *New J.Phys.* **7** (2005) 198
- [13] D. Oriti, in *Mathematical and Physical Aspects of Quantum Gravity*, B. Fauser, J. Tolksdorf and E. Zeidler, eds., Birkhaeuser, Basel (2006).
- [14] L. Bombelli, J. Lee, D. Meyer, and Rafael D. Sorkin, *Physical Review Letters* **59** (1987) 521.
- [15] J. Jurkiewicz, R. Loll and J. Ambjorn, *Scientific American* (July 2008)
- [16] A. Connes, *J. Mathematical Physics* **41** (2000) 3832
- [17] R. Percacci, in *Approaches to Quantum Gravity: Towards a New Understanding of Space, Time and Matter*, D. Oriti, ed. Cambridge University Press (2008)
- [18] M. Sakellariadou, *Journal of Physics: Conf. Series* **880** (2017) 012003
- [19] M. Sakellariadou, in *Mathematical Structures of the Universe*, edited by the Copernicus Center for Interdisciplinary Studies (2014).

BRITAIN'S NUCLEAR SECRETS: INSIDE SELLAFIELD

■ **Antigone Marino** – DOI: <https://doi.org/10.1051/ejn/2017502>
■ Institute of Applied Sciences and Intelligent Systems, National Research Council
c/o Physics Department, University of Naples Federico II, Italy

Lying on the remote north west coast of England, Sellafield is one of the most secret places in UK, and even one of the most controversial nuclear fuel reprocessing and nuclear decommissioning sites in Britain. The film director Tim Usborne let us enter into the world's first nuclear power station, revealing Britain's attempts to harness the almost limitless power of the atom. It is precisely the simplicity and the scientific rigor used in the film to speak of nuclear, which led this documentary to win the Physics Prize supported by the European Physical Society at the European Science TV and New Media Festival and Awards 2016.



◀ **P. 21:** Jim Al-Khalili is a British Iraqi theoretical physicist, author and broadcaster. He is currently Professor of Theoretical Physics and Chair in the Public Engagement in Science at the University of Surrey. He has presented a number of science programmes on BBC television and is a frequent commentator about science in other British media.

You will be wondering if EuroPhysics News is really about to reveal the secrets of English nuclear. And that's what thousands of spectators have asked for in front of the award-winning documentary film "Britain's Nuclear Secrets: Inside Sellafield" by Tim Osborne. Winner of the Physics Prize at the European Science TV and New Media Festival and Awards 2016, the documentary brings you into one of the biggest nuclear power plants in the world, Sellafield.

Lying on the remote north west coast of England, Sellafield is one of the most secret places in UK, and even one of the most controversial nuclear fuel reprocessing and nuclear decommissioning sites in Britain. Moreover, it is the site of the world's first commercial nuclear power station to generate electricity on an industrial scale. In just one hour the nuclear physicist Professor Jim Al-Khalili presents to the general public the physics that allows UK to produce energy. The narrative rhythm is intense, the spectator discovers step by step the most dangerous substances on earth, the nature of radiation and how to split the atom. The crescendo has its maximum when cameras enter into one of the nuclear reactors. The documentary faces one of the hottest physics issues for civil society, the nuclear production of energy, revealing Britain's attempts - past, present and future - to harness the almost limitless power of the atom.

It is precisely the simplicity and the scientific rigour used in the film to speak of nuclear, which led Tim Osborne to win the Physics Prize supported by the European Physical Society. The European Science TV and New Media Festival started in 2001, as a way of recognizing

and promoting the value of science in non-science TV productions, and notably TV drama which reach large audiences. Following early success, the festival expanded its agenda and now encompasses science and technology in all genres of television and new media. Since 2015 the festival assigns a special prize to productions having physics as science subject. Andrew Millington, Festival and Awards Director, explains us that three criteria are used to judge entries. Firstly, the quality of the physics being presented. In other words, the physics message. Secondly, the production values of the films, such as the quality of the filming, pacing of the narrative and the script. And thirdly, whether it was innovative in some way, either through selection of the content or the method of presentation.

Behind a documentary like this, one wonders how much work there is. Not just for direction issues, but also for the scientific tasks needed to give scientific validation to the story. That is why we interviewed the film director, with some questions aimed at understanding what are the steps for the realization of such a bold project.

Tim Osborne is a UK based documentary film maker, mainly specialising in science. He has made films about the Nuclear Industry, Chemical Weapons, a history of Trains, Quantum Physics, Alien Life, the History of Electricity, and a 3D series about the lives of insects. His films have been broadcast by the BBC, Channel 4, Discovery, National Geographic Channel and many other UK and international broadcasters. He is currently producing BBC landmark series, *The Sky At Night*, about astronomy which has been on air for over 60 years.

▶ **FIG. 2:** On the 18th November 1983, something happened here that damaged Sellafield's reputation irrevocably. That morning scientists at Sellafield looked out to sea and saw an inky black slick. It was a slick pouring out of Sellafield. People started questioning whether the whole plant should be closed down altogether. In the picture, the troupe filming the beach where the accident took place.





◀ FIG. 3: The film Director, Tim Usborne, is a UK based documentary film maker, mainly specializing in science.

Antigone: Nowadays, scientists are asked to be good communicators. Social media and the intensive use of videos to present scientific results require specific skills. What is needed to produce a good scientific documentary is the ability to translate the scientific language into everyday life talk. How did you manage to do it? Have you had any specific studies or courses? If a young scientist decides to take this road (of documentary director) what advice would you give him/her?

Tim: I have been working in television for nearly thirty years. When I started out, I didn't have a specific idea of making science documentaries, despite having a science degree. In fact, over that time I made all sorts of television programmes - live events, sports, children's, entertainment, drama.

But then over the last ten years, I found myself making more and more documentaries and when the chance came up to make a film about science I jumped at it. And I've been working in science documentaries ever since.

I would recommend that someone starting out in TV who wants to make science films should probably first get work as a research runner at a TV production company. The BBC has work experience opportunities for instance. There are a few courses I might recommend too, for instance Imperial College London runs a master's degree in science communication which is well thought of. But don't feel that you have to start in science TV - you can learn the craft of television first, and then focus on science later.

Antigone: Your documentary deals with a very delicate and sensitive subject for society. I suppose you have a personal opinion on nuclear power. Did making this

documentary change your mind? Or has it somehow strengthened your previous idea?

Tim: I started making this film ambivalent towards nuclear, probably slightly pro, as long as it was well managed and legislated. During the filming, I saw some of the pitfalls of the industry, and have become aware that the industry is often less than perfect, so it made me think that if we are to have this industry - and there is much debate about whether that should happen or not - then the only way to manage it is extremely carefully, and with a long term view.

Antigone: I can imagine that the hardest part in making this documentary has been the bureaucracy that you and the staff had to overcome in order to enter the nuclear power plant and make the recording. Have these rules limited your creativity and the message of the documentary? Does this often happen?

Tim: It took over two years for us to get the paperwork signed to get access to Sellafield to make the film. It first had to be agreed with the nuclear industry, and the British Home Office and British government. But once this was in place, Sellafield agreed that they would have no say over the editorial of the film - so we could tell the story we felt was important. But, having said that, we knew from the start that the story we were telling was not about the pros and cons of the nuclear industry, it was always about the science and history of the industry,

Antigone: *Inside Sellafield* has two strength points: it speaks of a hot topic people like to hear, and brings the

viewer into a secret place. In your opinion, what is the one that has most fascinated the public?

Tim: I think what made this film so successful was that it gave us a chance to see inside a place which has remained secret for so long. And that was made more significant given that what happened there was so important for all of us.

Antigone: This year, the March for Science was celebrated all over the world, a global event to make governments aware of the importance of science for societies. Do you believe that scientific documentaries also have this function? And do you believe a greater interaction of the science world with that of large-scale disclosure could facilitate the transmission of this message?

Tim: Science documentaries are a chance to show the best (and sometimes the worst) of the world of science to the general public. It is our duty as science communicators to make sure we do this as effectively as possible.

And as science becomes more and more specialised - and at the same time more and more at the heart of our society - it is critical that these kinds of messages get out. Science needs to communicate or it will become estranged from society.

Antigone: Did you imagine that the documentary would win the Physics Prize by the European Physical Society? In a world where the quality of a product is measured by the number of likes or visualizations, do you think an achievement like this is unflagging or can also have a value for the documentary distribution?

Tim: Certainly winning was a great surprise - it's a great honour to win, and I know all the team involved feel very pleased to have won such a prestigious award. I hope that the prize might bring about interest in the film and the subject to new audiences.

After this interview I watched the documentary for the third time. Once again I am amazed by the clearness of the scientific message. When Jim Al-Khalili has to explain how to trigger the chain reaction he shows a box with 120 loaded mousetraps, each with a ping pong ball on it. Dropping a single ball in on top of the box, one ball triggers more and more in the mousetrap, starting the chain reaction. That's how it works in a reactor. As each uranium atom splits, it also releases neutrons. And just like the ping-pong balls triggering the mousetraps, these neutrons could split new uranium atoms. The Uranium would trigger a massive nuclear chain reaction. Plus producing enough neutrons to turn some of the Uranium into Plutonium. Historically all this science was focused on the realization of nuclear bombs. But

for nuclear physicists there's another way to use all this scientific knowledge. The same nuclear science that had split the atom to make a bomb has the potential to produce almost limitless cheap energy. Because in addition to producing Plutonium the reactor produced heat, and that heat could be harnessed. As Jim says, "The dream was that the power of the atom would come out of the shadow of the bomb, and into our living rooms. ... As electricity!". That is what happened in 1952 in Sellafield: work began on an ambitious experiment in power generation that would shape the modern world. It was called Calder Hall, opened in 1956. During the celebration the Queen said: "This new power which has proved itself to be a terrifying weapon of destruction is harnessed for the first time for the common good of our community". On 27th August 1956 heat generated from the nuclear chain reaction was used to turn water into steam that turned a turbine and made electricity. And that electricity was poured for into the National Grid, making Sellafield the world's first Nuclear Power station.

Unfortunately, the knowledge of physical processes such as those explained in this article can be used for war purposes. In times with a high tension between nuclear-armed states a clear message was given by the Norwegian Nobel Committee, which awarded Nobel Peace Prize to the International Campaign to Abolish Nuclear Weapons (ICAN) "*for its work to draw attention to the catastrophic humanitarian consequences of any use of nuclear weapons and for its ground-breaking efforts to achieve a treaty-based prohibition of such weapons*".

Thirty years ago my country (Italy) chose with a referendum to abolish nuclear facilities. It was 1987, just one year after the Chernobyl accident. I was a child. I did not know I would study physics. I just remember that the YES won, and everyone was celebrating the result. I wonder how many Italians knew at that time the difference between alpha, beta and gamma particles. I do not think this number has changed so far. That's why a documentary like this one I'm talking about has a very strong social value. Because it explains nuclear, without demonizing or taking part. The spectator will then make his choice, pro or contra. But after the documentary his/her opinion will be supported by scientific information.

That is why we don't just have to do science, but also explain it. ■

About the Author



Antigone Marino is researcher at the Institute of Applied Sciences and Intelligent Systems of the Italian National Research Council in Naples, Italy. Her research activities are concentrated on the study of soft matter optic. Since 2016 she is jury member of the European Science TV and New Media Festival and Awards.



REDRESSING THE INVERTED PYRAMID OF SCIENTIFIC PUBLISHING

■ Jean-Sébastien Caux – Institute of Physics, University of Amsterdam – DOI: <https://doi.org/10.1051/epn/2017503>

Scientific publishing is currently undergoing a progressively rapid transformation away from the traditional subscription model. With the Open Access movement in full swing, existing business practices and future plans are coming under increasing scrutiny, while new “big deals” are being made at breakneck speed. Scientists can rightfully ask themselves if all these changes are going the right way, and if not, what can be done about it.

Fortunately, in this day and age, some spheres of human activity remain anchored in rational thinking, evidence-based debate and error-corrected progress. Scientific research undoubtedly fits in this category: few scientists doubt that reason should prevail over nonsense. Yet, when it comes to publishing, the scientific world seems to be bathed in a maelstrom of irrational hogwash. What is going on? What can we do about it?

A business unlike any other

Scientific publishing, as a business, has become a truly unique inverted pyramid construction in which the “customers” pay dearly for accessing the product after actually performing themselves all the irreplaceable, not-doable-by-others steps in the manufacturing process. Historically, this tour-de-force of business abracadabra has been achieved in no small part by exploiting the other dubiously-implemented aspect of publishing,

▲ © iStockPhoto

namely impact assessment. The often-heard complaint that where you publish matters more than *what* you publish underlines the undue influence publishers now have on the lives of scientists (especially younger ones). What could be called the "impact of the impact factor" has greatly curtailed the liberty that scientists should enjoy to author their papers and evaluate their importance in a rational and collected manner. Publishing has thus become a kind of three-headed hydra which generates profit out of scientists' daily achievements and holds their career development prospects hostage, whilst discouraging them from presenting the fruits of their work in a cool, detached, scientifically professional manner.

Open Access and drifting business models

It is no wonder, then, that we have recently witnessed a great many discussions concerning reform of the whole scientific publishing edifice. Though much needs to be done, the Open Access "movement" has been at the forefront of discussions, as exemplified by a string of statements (including Budapest [1], Bethesda [2], Berlin [3] and most recently Amsterdam [4]) underlining involvement and desire for reform from interested parties at all levels. Strangely enough, the growing cacophony of voices has blurred even the very definition of "Open Access". In its simplest and most common form [5], OA simply signifies that

readers can access published material without having to pay subscription or per-view charges; but to some, it means much more. That said, much of the attention recently devoted to OA has in fact been diverted towards financial matters, with vitriol often being poured on the undeservedly high profit margins that a number of corporate publishers have historically managed to get away with. A new payment model has been developed and mandated, deprecating the journal subscription model and replacing it by an "author pays" model in which publishers require authors (or, in practice, their funders, institutions or societies) to pay an Article Processing Charge (APC) typically ranging from a thousand euros up to a large multiple of this figure to make the contents openly accessible upon publication ("Gold" OA). To facilitate rapid implementation of OA, a softer version, "Green", has also been introduced. In this version, authors deposit (after respecting eventual embargo impositions from the publisher) a version of their paper in an openly-accessible repository (institutional, or community-run like arXiv). Although solving the accessibility problem, Green OA implementations fall short of representing a full substitute and deprecator for the services publishers offer, leaving the desire for publisher reform adrift and unfulfilled.

Sportscars, jewels, rare stamps and failed markets

One of the often-mentioned rationales behind the introduction of APCs is that "opening up the market" would help drive publication costs down. However, there is a simple yet fundamental problem here, namely: scientific publishing is an industry in which prestige and reputation are at stake. Publications are not dissimilar to sportscars, jewels or rare stamps: their market price has nothing to do with their production costs. As a researcher, if I estimate that publishing in a specific journal gives me, say, 5% more probability of getting a million-level grant, then being asked to pay 1500 euro APCs seems like a bargain, since I would still evaluate it as worthwhile to pay an order of magnitude more. Of course authors cannot "buy" their way into premium journals, so this pseudo-economic calculation actually makes no sense whatsoever. As a scientist, I don't actually care what the APC is (I'll pass the bill to my funders or institutional library); I only care about the quality and reputation of the publication venue. The problem is thus that the APC model has opened a Pandora's box of potentially diverging publication costs at the high end of the market, with no mechanism to bring them down. This damaging dissociation of quality with price level has in fact had the counterproductive effect of driving some publishers to increase their APCs in order not to be viewed as lower-quality [see e.g. the Finch report [6], while fueling the proliferation

BOX 1: KARAT-LEVEL RESOLUTION FOR DEGREES OF OPENNESS

10-karat (*openness to readers: open access*):

- make full text of publications freely available to readers (Creative Commons license)

14-karat (*openness to authors: copyright, embargo*):

- copyright is given to the authors without restrictions
- publishing occurs without any embargo period

18-karat (*openness to users: reuse, remix, crawl, citations*):

- publication license allows reuse and remixing of content (Creative Commons Attribution (BY), Share-alike (SA) or Non-commercial (NC) licenses)
- publisher allows text mining (software/spiders can automatically crawl journal content)
- publisher makes its citation data publicly available (ideally via participation in I4OC)

22-karat (*openness to reviewers: open reports*):

- refereeing reports are openly visible and citable

24-karat (*openness to community: academic ownership*):

- the responsibility for publication decisions is entirely in the hands of active professional scientists.

of so-called "predatory open access" journals in which editorial processes are curtailed in order to quickly cash in on artificially-inflated APCs. When markets work, they work. When they don't, they can turn a whole industry into a disastrous and nonsensical comedy.

Big Deals and cost consciousness

Another oft-forgotten point is that markets can only work when openness reigns. One of the most criticized aspects of the old and current systems is that the actual costs of subscriptions were often negotiated and kept hidden behind closed doors due to the imposition of non-disclosure agreements on institutions by publishers. Scientists in particular were (and still are) more or less totally unaware of the sums paid by their institutions to give them access to literature. The introduction of APCs thus had some positive impact by suddenly making researchers more cost-aware, albeit in a very incomplete, incorrect but still shock-inducing manner.

On the broader economic side, much has been discussed about the non-scalability of APCs. Institutions, even top ones, will not be able to afford the sums involved in an eventual sudden transition to APCs if these remain at current levels (let alone increase!). On the other hand, the very transition from subscriptions to APCs has led to the appearance of the "double dipping" phenomenon, whereby journals that still charge subscription fees nonetheless also charge APCs to subsets of willing authors to make their particular publications openly accessible, thereby putting even more financial pressure on university libraries than in the subscription era. "Big Deals" between institutions and publishers are also often in the news these days, in which whole swathes of academics suddenly learn that they can publish "free of charge" in particular journals. Although making researchers' administration work simpler, it also makes them blind to the financial realities involved in publishing. I have often reminded colleagues that this or that journal, while perhaps "open access", is certainly not "free of charge", and that through all their Big Deals, many institutions are repeating history and condemning themselves to face increasingly severe budgetary restrictions through their lack of power in forcing reform of publishers' practices (and thus of their finances).

A better model

In a very encouraging development, alternatives to current business practices are rapidly emerging. In physics, we have for the best part of three decades benefitted from the arXiv preprint server, which is funded according to a consortial model in which many institutions provide small-scale funds that (when added to some larger institutional grants) allow the whole infrastructure to be maintained and developed. This consortial funding model is now starting to be applied with success to the

BOX 2: METALLURGY FOR OPEN ACCESS BUSINESS MODELS

Gold [Au]:

- APC-based financing

Platinum [Pt]:

- publisher does not apply any charges to authors (APCs, submission charges or any other), and is funded through a consortial model or equivalent

Palladium [Pd]:

- publisher runs a purely not-for-profit public enterprise: none of its activities generate any profit, and all financial statements are publicly disclosed.

Combinations: In this scheme, Au and Pt are incompatible; Pt naturally binds with Pd, while Au and Pd can also mix consistently.

business of publishing, the best-known example being the Open Library of Humanities [7], which gathers institutional contributions to cover publishing costs (no APCs being charged). Looking at the figures [8] makes it patently clear that overall, this model is much more economical than either subscription or APC-based ones, and is the most credible way of applying downwards price pressure in the publishing market. The real question is why this has not been implemented more broadly.

Noble metals for a noble cause

Let us briefly change tack and perform a small but worthwhile exercise, which consists of resolving the developing confusion of what Open Access actually signifies, precisely what "Gold" entails, and whether one can actually try to differentiate between its different sorts.

First, the obvious: to call itself a publisher, an entity should perform at least basic tasks, such as running a strict quality-controlled peer review process, ensuring ISSNs for its journals, running professional-level post-acceptance production, operating an online platform for its content, providing metadata handling (registration of DOIs), providing linking of funding information back to funders and ensuring perpetual availability via a dedicated, digital archiving and preservation service. None of this qualifies as rocket science.

Turning now to Open Access, expectations scale up. Since gold (as a commodity) comes in different levels of purity, let us be inspired by metallurgy and adopt karat-level resolution for Gold content¹, in order to

¹ A more technically correct and modern scheme would be to use fineness (parts per 1000), but this leaves out all the desirable poetry.

differentiate the levels of open accessibility being delivered. One could propose the requirements in Box 1. One could perhaps debate the precise contents and ordering of this list, which in any case does not include all requirements one might think of. Still, it's a good start; but is it possible to go even further? What about more details on the business model? One commonly used label is to call non-APC publishers "Platinum" instead of Gold. Box 2 extends this even further by introducing "Palladium" to denote consortial-financed, not-for-profit publishers. Possible material combinations are also given.

Though karats are not traditionally used for precious metals other than gold, let us bend the rules and characterize publishers according to their business model (Gold (Au), Platinum (Pt) and/or Palladium (Pd)) together with their openness karat rating. One can then identify some publishers as Gold 18-karat, Platinum 22-karat, etc, allowing for a simple "lifting of the degeneracy" in the current nomenclature which packs too many things under the simplistic "Gold" label. Abbreviation fans can thus argue about whether they find Au10k publishers acceptable (some would call this category "Fool's Gold"), or whether they insist that Pt/Pd24k is the *crème de la crème* and the only model worthy of their support. Funders and institutions that are sufficiently forward-thinking about meaningful mandates could decide to reimburse APCs (up to a cap) only for 18-karat and above publishers, with a lower cap for non-Pd ones. On the workforce, scientists could decide to not do any unpaid refereeing or editing work for non-Pt/Pd publishers.

For talking about Open Access to doing it: SciPost

About two years ago, after much thinking on these issues, I decided to heed my colleagues' retort "if you care so much about it, why aren't you doing anything?" and founded SciPost, a nonprofit foundation whose online portal SciPost.org (launched in 2016) offers a complete framework for publishing (according to the classification proposed here, SciPost is a fully-featured Platinum/Palladium 24-karat publisher). For many people, this has rapidly become a demonstration of the fact that scientists are most often best served by themselves. With a strong start to its publishing activities in its first year, the first journal SciPost Physics is rapidly gaining recognition as a force for innovation. The results obtained until now amply justify the interminable hours of pro-bono work that I and many others have put into it, and pave the way towards a better and healthier publishing system. With its operating costs estimated at around 300 euros per publication (about a factor of 5 lower than the current norm), SciPost is in a position to be an alternative in

the publishing industry. Having managed to convince scientists that our services constitute a proper alternative to existing practices, our next challenge is to convince funders, universities and libraries that it is in their interest to support and join our cost-slashing consortial funding model.

The driver for change

Although we are far from done (we haven't even begun discussing impact assessment!), let us end here by performing a simple thought experiment. From next January, for a period of 3 years, imagine that all scientists agreed to exclusively submit their manuscripts to new emerging not-for-profit publishers fulfilling Platinum/Palladium 18-karat and above open access criteria (simultaneously, they would exclusively perform refereeing and editorial work for such publishers). What would happen then? By simply voting with their feet, scientists could exert overwhelming influence and drive the necessary transition to open access through all currently existing or perceived obstacles. Ultimately, the power to enforce change resides in the hands of us scientists: it is up to us to decide the future we want to see in publishing, and to make it happen in the way we want; namely, in the interests of what we love the most and is only too often forgotten in Open Access discussions: science itself. ■

About the Author



Jean-Sébastien Caux is Professor of Theoretical Physics at the University of Amsterdam. His work focuses on strongly-correlated systems in magnetism, cold atoms and quantum nanostructures. Born in Canada, he pursued graduate studies in Oxford as a Rhodes Scholar, thereafter working as Postdoctoral Fellow in All Souls College, finally moving to Amsterdam in 2003. He is the recipient of the NWO Vici and ERC Advanced grants.

References

- [1] <http://www.budapestopenaccessinitiative.org/read>
- [2] <http://legacy.earlham.edu/~peters/fos/bethesda.htm>
- [3] <https://openaccess.mpg.de/Berlin-Declaration>
- [4] <https://www.government.nl/documents/reports/2016/04/04/amsterdam-call-for-action-on-open-science>
- [5] https://en.wikipedia.org/wiki/Open_access
- [6] <https://www.acu.ac.uk/research-information-network/finch-report>
- [7] <https://www.openlibhums.org>
- [8] <https://www.martineve.com/2016/06/16/consortial-purchasing-and-downward-price-pressure-for-open-access/>

by L.J.F. (Jo) Hermans

Leiden University, The Netherlands - Hermans@Physics.LeidenUniv.nl - <https://doi.org/10.1051/epn/2017504>

Fascinating friction

If surfaces are slippery, it is usually because they are wet. This is the case even for ice: our skates glide smoothly across the ice because they glide across a thin layer of water. And so does a hockey puck. Water makes slippery, this much we know. So it should not come as a surprise that oil and grease also reduce friction. After all, they form a thin layer of fluid between two solid surfaces and thus provide lubrication.

Lubrication between dry surfaces can also arise if both surfaces are covered with patches of a well-ordered smooth layer of, e.g., graphene, but with the patches randomly oriented. Think of two washboards, which glide smoothly across one another at random orientations except if the ridges happen to be aligned.

But what about the friction between two ordinary dry surfaces? Let us first remember that the friction coefficient – the ratio between the friction force and the normal force – is smaller when the surfaces are moving relative to one another than when they are static. This has an interesting consequence: the *stick-slip behaviour*. We know this phenomenon, e.g., from a bow over a violin string. The bow starts to move across the string if the driving force exceeds the static friction. It then slides over the string with the smaller dynamic friction until it reaches the point where the driving force is reduced to the level of the dynamic friction force. At this point the motion stops and driving force builds up again, making the bow ready for the next hop. The high frequency at which this entire process occurs produces the singing of the violin.

What kind of values do friction coefficients have? Obviously, they depend on the two surfaces involved. Approximate values are typically between 0.04 for Teflon on steel to 0.8 for the static friction of steel on steel.

Can the friction coefficient reach values larger than 1? Why not? In fact, in some cases it does. And you *know* it does. Everybody who has seen motorcycle racing on TV has observed that, in curves, the bike can lean over by an angle larger than 45° with respect to the surface normal. A simple force diagram shows us that, indeed, the static friction coefficient exceeds unity in this case, thanks to the silicone rubber or acrylic-rubber-coated tire surface.

Another striking property of friction, which most of us take for granted since our high-school physics, is the fact that the friction only depends on the normal force and the type of surfaces, but is independent of the surface area. If considered from a microscopic point of view, this flies in the face of common sense. The solution to this problem is that this ‘area’ is the *apparent* surface area. True atomic contact is established only in a small fraction of this area, even for polished surfaces. Elasticity of the contacting surfaces and/or their plastic response makes the true contact area approximately linear in the normal force. Problem solved.

It may be clear that much about friction is as yet poorly understood. Our present understanding is still at a semi-phenomenological level. Nobody has been able to predict the friction coefficient for a given system. Fortunately, the young and rapidly developing field of nanotribology is on course to clear up much of the friction mysteries, as is done for example by Joost Frenken and his group¹ in Leiden/Amsterdam. And since friction is responsible for a substantial fraction of the cost of mechanical equipment in wear and energy use, this work may soon save some money in our daily life... ■



¹ The physics of atomic-scale friction: basic considerations and open questions; S.Yu. Krylov and J.W.M. Frenken, Review paper (invited), *Phys. Status Solidi B* **251**, 711 (2014)

SLIPPERY AND NEVER WET

■ Matilda Backholm, Jaakko V. I. Timonen*, and Robin H. A. Ras* – DOI: <https://doi.org/10.1051/epn/2017505>

■ Department of Applied Physics – Aalto University – P.O. Box 15100, 02150 Espoo, Finland

■ * Email: jaakko.timonen@aalto.fi, robin.ras@aalto.fi

Superhydrophobic surfaces let water droplets roll off with low friction and falling droplets rebound, leaving the surfaces completely dry. Such extremely water repellent surfaces are found in nature on lotus leaves, the legs of water striders and feather coatings of birds, and portray a beautiful example of ingenious biological design. They provide an exciting research avenue for physicists and materials scientists aspiring to understand and mimic nature.

A physicist's approach to superhydrophobicity

Superhydrophobicity, that is the extreme fear of water, is a fascinating surface property found in nature on many plants and insects. The strong water repellency is often crucial for surviving in harsh conditions: the superhydrophobic surface on submerged insects, for example, traps small air pockets on their bodies that act as an

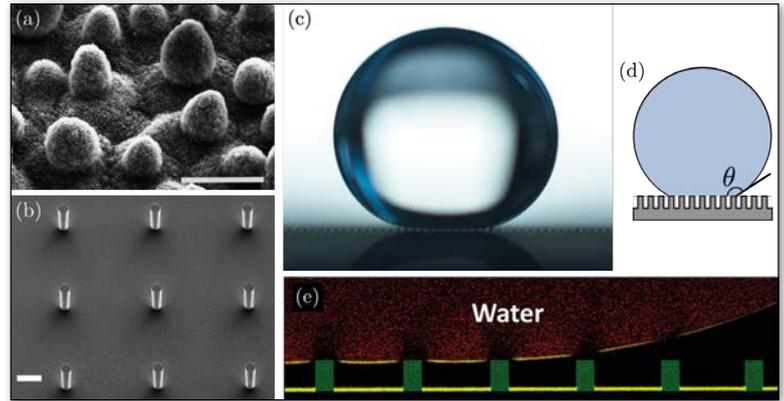
external lung to allow gas exchange and breathing underwater. Barthlott and Neinhuis realized in 1997 that the intriguing self-cleaning nature of a lotus leaf arises from the combination of surface microroughness and a low-surface-energy wax nanocrystal coating (Fig. 1a) [1]. This discovery opened an exciting avenue for scientists aspiring to mimic the designs found in nature to manufacture artificial superhydrophobic substrates.

▼ Photo by
Mika Latikka



The grand goal is to produce a world of self-cleaning, non-wetting, anti-fouling, flow-enhancing, anti-icing, and anti-fogging materials, just to name a few examples. Currently, the major bottleneck towards commercialization of superhydrophobic surfaces is the fragility of the micro/nano-structured substrate. A damaged surface region will make drops stick to the material and vastly degrade the final product. Intense research is currently being performed to create new, mechanically robust alternatives [2-3].

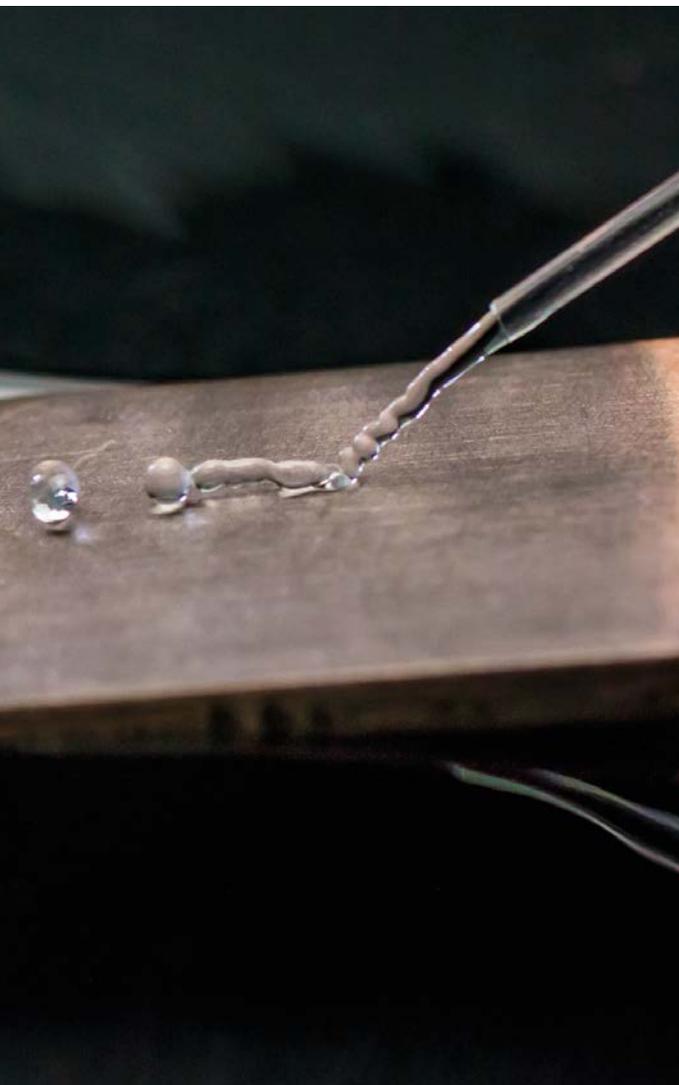
Today, the most common physical model of a superhydrophobic surface is made of an array of micron-sized pillars coated with a hydrophobic film (Fig. 1b). When a water droplet is placed on the surface, air becomes trapped within the micropillared structure (Fig. 1c-d). The droplet thus rests mostly on a cushion of air, visible as a thin ray of light between the droplet and the solid substrate. This is called the Cassie wetting state and allows for very high contact angles ($\theta > 150^\circ$) and extremely low droplet friction and adhesion. Recently, beautiful side-view projections utilizing confocal microscopy from the Butt group provided a high-resolution view of the contact line of a droplet in the Cassie state (Fig. 1e) [4]. Detailed information on the microscopic motion of the contact line was also gained, shedding light on the fundamentals



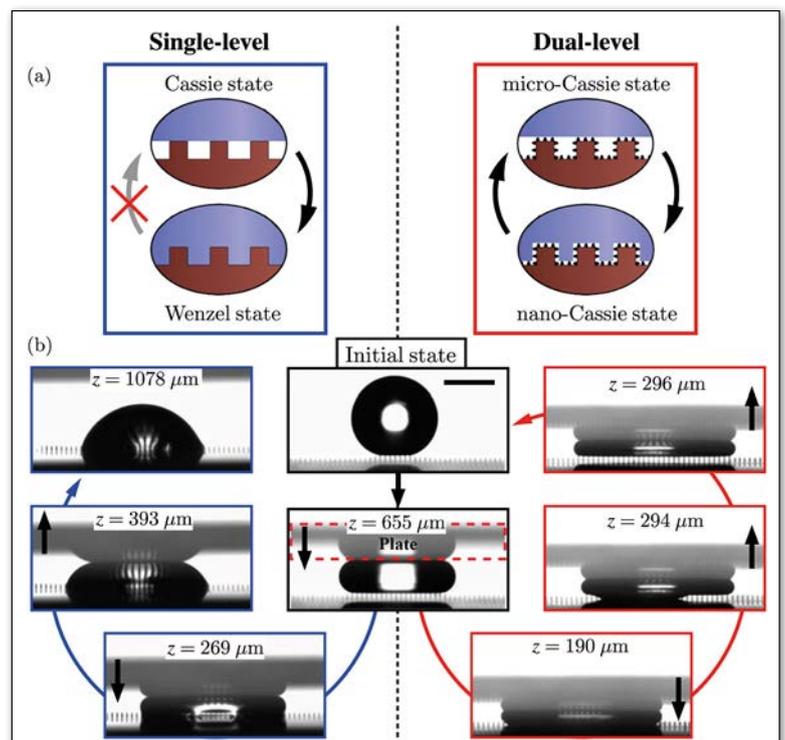
▲ FIG. 1: The physical model of a superhydrophobic surface. (a) Scanning electron microscopy (SEM) image of the surface of a sacred lotus (*Nelumbo nucifera*) leaf (scale bar 20 μm). Picture adapted from [1]. (b) SEM image of an artificial micropillared surface (scale bar 20 μm). Image by Anas Al-Azawi. (c-d) Photo and schematic illustration of a millimetric water droplet in the Cassie state on a micropillared superhydrophobic surface. An air layer is trapped within the microstructure beneath the droplet, rendering a very high contact angle θ . Photo by Mika Latikka. (e) Confocal microscopy image of the three-phase contact line of the drop (pillar spacing 30 μm for scale). Picture from [4].



The grand goal is to produce a world of self-cleaning, non-wetting, anti-fouling, flow-enhancing, anti-icing, and anti-fogging materials.



▼ FIG. 2: Transitions between wetting states. (a) Schematic illustrations of irreversible and reversible wetting transitions on a single (left) and dual-level (right) topography, respectively. (b) The compression (plate/substrate gap denoted by z , plate direction by arrow) of a droplet on a micropillared superhydrophobic surface with single (left) and dual-level (right) topography. In the former, the droplet irreversibly undergoes a transition to the Wenzel state, whereas the latter allows for a reversible transition. The two first, central images (black boxes) show experiments on a dual-level surface, but also capture the initial stages on the single-level surface. The Cassie state is noted by the bright region between the drop and the surface. Pictures in (a) adapted from [6] and (b) adapted from [7].



behind the almost unhindered dynamics of droplets on these surfaces.

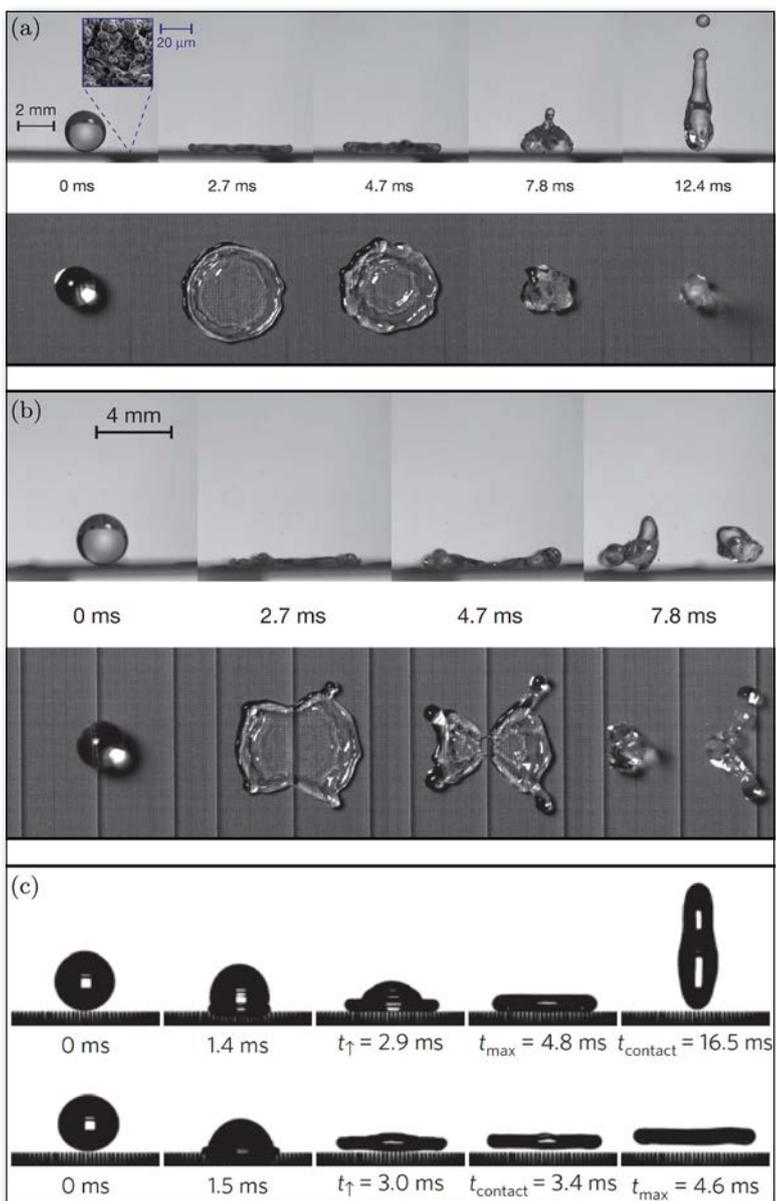
Reversible wetting transitions

The Cassie state is crucial for superhydrophobicity to arise. Unfortunately, pressure fluctuations, such as from an impacting droplet, can collapse the air cushion between the water droplet and the solid substrate, resulting in water to wet the surface completely, called Wenzel state (Fig. 2 left). This wetting transition is



The droplet thus rests mostly on a cushion of air, visible as a thin ray of light between the droplet and the solid substrate. ”

▼ FIG. 3: Bouncing droplets. (a) Conventional axisymmetric recoil of a water droplet hitting a superhydrophobic silicon surface (top: side view, bottom: top view). (b) Non-axisymmetric recoil of droplet on a macroscale textured surface (top: side view, bottom: top view). Pictures in (a-b) adapted from [8]. (c) Side view of typical bouncing (top) and unconventional pancake bouncing (bottom) of droplet on surface with tapered posts covered by nanoflowers. Picture from [9].



usually irreversible and the droplet becomes pinned to the surface. To avoid the Wenzel state, we took guidance from aquatic insects such as the water boatman *Notonecta glauca*, that can breathe underwater thanks to the air retention feature of their superhydrophobic hairy exoskeleton. Barthlott *et al.* observed that while aquatic insects with long hair can support a large volume of air, insects with small hairy structures had supreme lifetime of the air film, arguing that downward progression of the air–water interface is hindered due to the fact that it costs more energy to displace an interface with a smaller radius of curvature [5]. We introduced a dual-level topography by coating a standard, micropillared substrate with nanofilaments (Fig. 2a, right) [6]. The pressure-induced collapse of the standard “micro-Cassie” state now resulted in a Wenzel-like state that has water between the micropillars, and we call it “nano-Cassie” state because there remains a nanoscopic air layer present keeping the wetted solid fraction small. This allowed for a reversible transition back to the original state by a small input of energy in the form of suction. Recently, the Zheng group even reported on fully reversible and spontaneous (= energy input-free) transition on substrates with suitable dual-level roughness (Fig. 2b, right) [7]. The otherwise irreversible wetting transition was shown to be reversible on the dual-level surface.

Fluid dynamics of a bouncing droplet

The motion and fluid dynamics of droplets on superhydrophobic surfaces can often be both striking and unexpected (see example in Box 1). An exciting area of today’s research is in the bouncing of droplets off superhydrophobic surfaces. Typically, the drops spread out nearly axisymmetrically, retract and finally leave the surface (Fig. 3a). In doing so, there is a theoretical lower limit in the required contact time between the drop and the solid. One of the current challenges lies in finding new ways to further reduce the contact time to allow for efficient anti-icing and dropwise condensation applications. By introducing macroscale texture to the substrate, the group of Varanasi managed to break the axisymmetry involved in bouncing (Fig. 3b), resulting in redistribution of liquid mass, and thereby altering the hydrodynamics and reducing contact time by a factor of four compared to what has previously been considered the gold standard [8]. In a clever approach by the Wang group [9], a superhydrophobic surface was made of tapered, nanoflower-coated pillars with characteristic dimensions one order of magnitude larger than the conventional micropillared design. Water drops with high enough inertia were shown to spread out and then leave the surface without retracting (Fig. 3c). This “pancake” bouncing also allowed for a fourfold reduction in the contact time, compared to conventional bouncing.

Conclusions

During the last years, great advances have been made in deciphering the physics behind superhydrophobicity. A fundamental understanding of the intricate wetting characteristics is being formed and novel ways to avoid wetting or utilize its characteristics are explored. New exciting research avenues are continuously being created to get one step closer to the superrepellent materials of the future, revealing functions and features that will greatly simplify and improve our everyday lives. ■

About the authors



Matilda Backholm received her PhD in 2015 from McMaster University, Canada, and is currently working as an Academy of Finland postdoctoral researcher at Aalto University.



Jaakko V. I. Timonen is professor of the Active Matter group at Aalto University. He received his PhD from the same university in 2013 and did postdocs in the Grzybowski and Aizenberg groups at Northwestern University and Harvard, USA.



Robin H. A. Ras is professor of the Soft Matter and Wetting group at Aalto University. He received his PhD in 2003 from the University of Leuven, Belgium, and was awarded an ERC Consolidator grant in 2016.

References

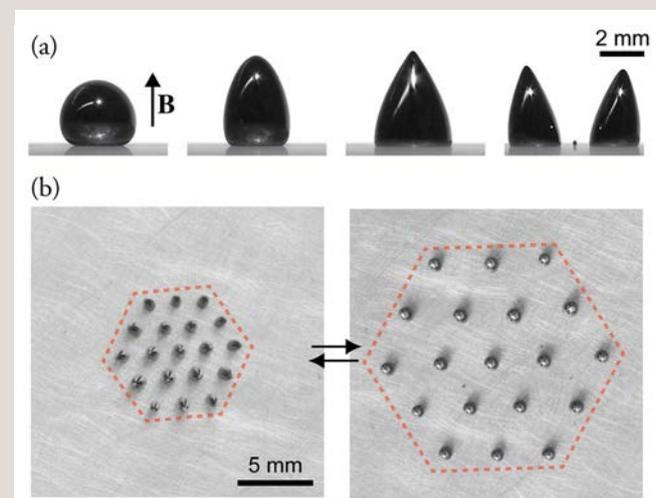
- [1] Purity of the sacred lotus, or escape from contamination in biological surfaces, W. Barthlott and C. Neinhuis, *Planta* **202**, 1 (1997).
- [2] Mechanically durable superhydrophobic surfaces, T. Verho, C. Bower, P. Andrew, S. Franssila, O. Ikkala, and R.H.A. Ras, *Adv. Mater.* **23**, 673 (2011).
- [3] Moving superhydrophobic surfaces toward real-world applications, X. Tian, T. Verho, and R.H.A. Ras, *Science* **352**, 142 (2016).
- [4] How water advances on superhydrophobic surfaces, F. Schellenberger, N. Encinas, D. Vollmer, and H.-J. Butt, *Phys. Rev. Lett.* **116**, 096101 (2016).
- [5] Dry Under Water: Comparative Morphology and Functional Aspects of Air-Retaining Insect Surfaces, A. Balmert, H.F. Bohn, P. Ditsche-Kuru, and W. Barthlott, *J. Morphol.* **272**, 442 (2011).
- [6] Reversible switching between superhydrophobic states on a hierarchically structured surface, T. Verho, J.T. Korhonen, L. Sainiemi, V. Jokinen, C. Bower, K. Franze, S. Franssila, P. Andrew, O. Ikkala, and R.H.A. Ras, *Proc. Natl. Acad. Sci. USA* **26**, 10210 (2012).
- [7] Monostable superrepellent materials, Y. Li, D. Quéré, C. Lv, and Q. Zheng, *Proc. Natl. Acad. Sci. USA* **114**, 3387 (2017).
- [8] Reducing the contact time of a bouncing drop, J.C. Bird, R. Dhiman, H.-M. Kwon, and K.K. Varanasi, *Nature* **503**, 385 (2013).
- [9] Pancake bouncing on superhydrophobic surfaces, Y. Liu, L. Moevius, X. Xu, T. Qian, J.M. Yeomans, and Z. Wang, *Nat. Phys.* **10**, 515 (2014).
- [10] Switchable static and dynamic self-assembly of magnetic droplets on superhydrophobic surfaces, J.V.I. Timonen, M. Latikka, L. Leibler, R.H.A. Ras, and O. Ikkala, *Science* **341**, 253 (2013).

SELF-ASSEMBLING MAGNETIC DROPLETS ON SUPERHYDROPHOBIC SURFACES

Ferrofluids are colloidal dispersions of magnetic nanoparticles in a carrier liquid. They exhibit a striking coupling between fluidic and magnetic properties. We asked ourselves a question: what kind of new phenomena can be observed if the fascinating features of ferrofluids are combined with the extreme non-wetting of superhydrophobic surfaces?

We tested this experimentally by placing an aqueous ferrofluid droplet on a superhydrophobic surface and subjecting it to a gradually increasing vertical magnetic field [10]. As a result, the shape of the droplet changed from nearly perfectly spherical to elongated along the field direction, until, spontaneously, the droplet split into two smaller droplets (Fig. 4a and Movie youtu.be/ehvFFbFFsjg). This splitting can be understood as the classic Rosensweig instability taking place within the droplet and is driven by the decrease of magnetic energy (at the expense of surface energy). The role of the superhydrophobic surface is to keep the droplets separated, and to allow for low-friction droplet motion to their equilibrium positions. Further increasing the magnetic field can lead to additional splitting events and nearly a hundred droplets can easily be formed. These droplets spontaneously assemble into well-defined clusters due to mutual dipolar repulsion and interaction with the spatially varying global confining magnetic field (Fig. 4b). The magnetic droplets can be used as a model system to study and visualize static and dynamic self-assembly processes.

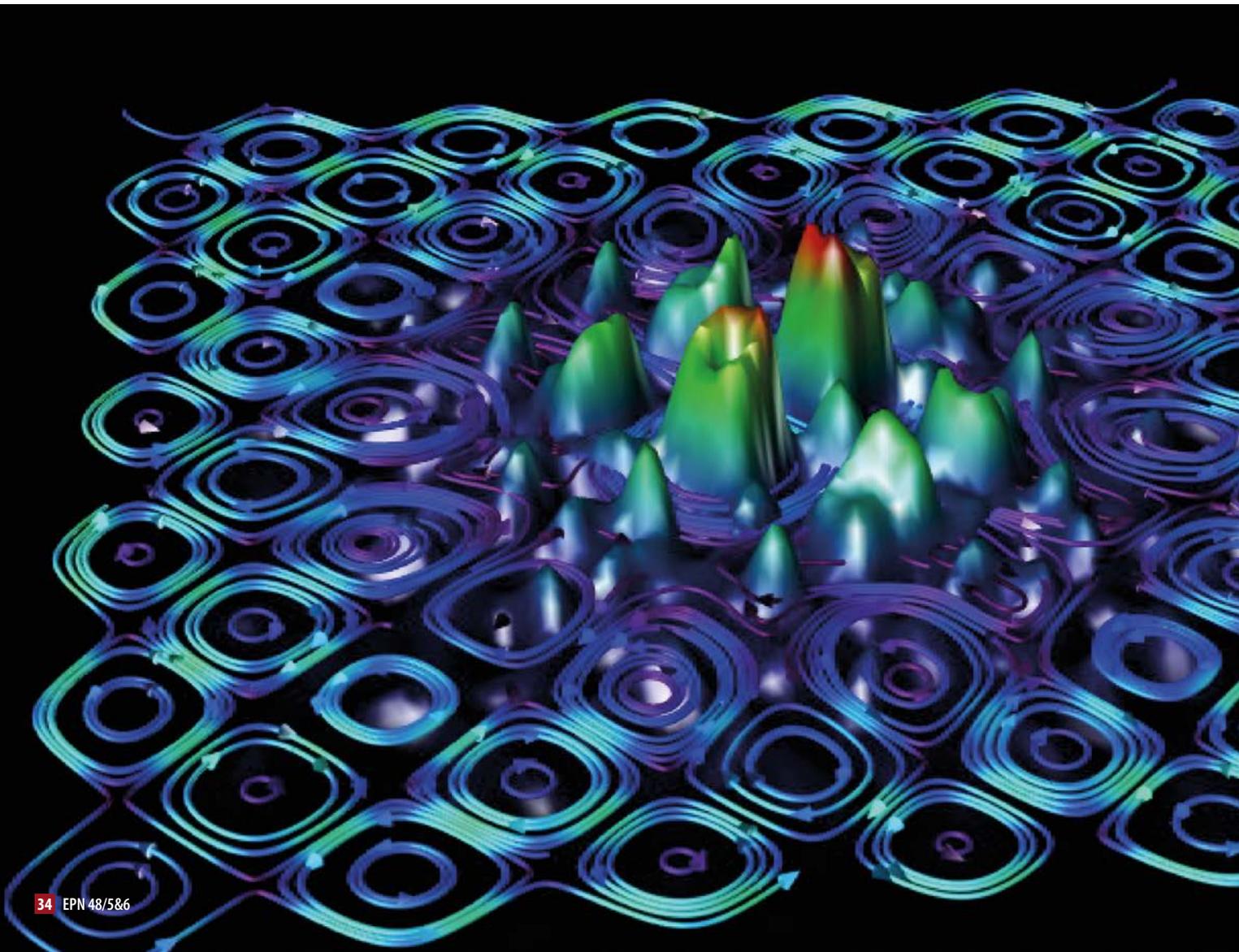
▼ FIG. 4: Magnetic droplets on superhydrophobic surfaces. (a) Profile of magnetic droplet in a gradually increasing magnetic field (from left to right). (b) Hexagonal cluster of 19 daughter droplets formed by multiple consecutive splitting events from one single mother droplet. The “lattice constant” can be tuned by adjusting the droplet-droplet repulsion and confining external potential. Pictures adapted from [10].



“BOILING THE VACUUM”: IN SILICO PLASMAS UNDER EXTREME CONDITIONS IN THE LABORATORY AND IN ASTROPHYSICS

■ Luís O. Silva – Instituto Superior Técnico, Lisbon – DOI: <https://doi.org/10.1051/epn/2017506>

Laser technology has progressed tremendously since Theodore Maiman first demonstrated the laser in 1960. One of the most striking examples of this progress is the focused intensity of lasers. Present day lasers in the near infrared frequency range can deliver intensities in excess of 10^{23} W/cm². Imagine that you have a very large and powerful lens that captures the light of the sun hitting the upper atmosphere of the Earth and focus it down to a region with the cross section of a human hair. The corresponding intensity is in the range of the most intense lasers now available.

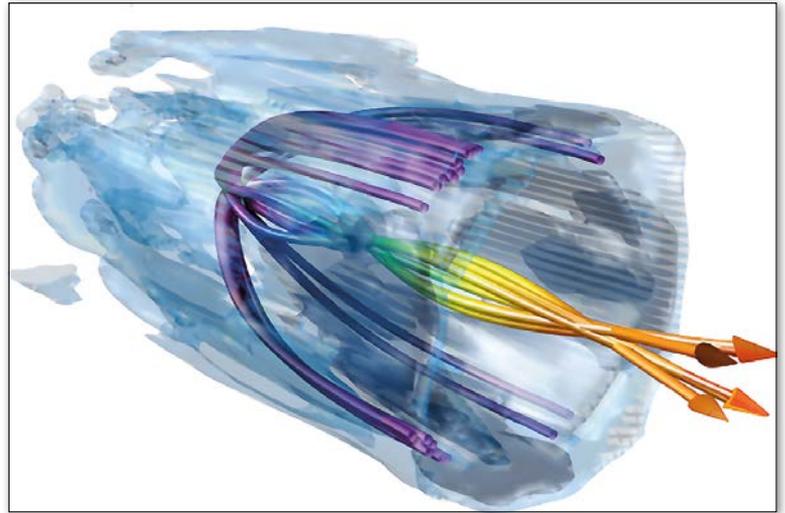


Under the action of these intense electromagnetic fields, electrons quiver at velocities close to the speed of light with Lorentz gamma factors ~ 100 . The nonlinear effects associated with special relativity determine the evolution of light-plasma interactions at these intensities. These lasers are now being explored to drive plasma accelerators [1,2], or novel light sources [3].

The interplay between lasers, experiments, simulations, and theory is well illustrated by the progress on laser-plasma interactions. *Ab initio* simulations have been at the core of plasma physics since the 50s, and this is even more striking in laser-plasma accelerators (figure 1): simulations, viewed as *in silico* experiments, have been critical to interpret and to design many landmark experiments on laser-plasma accelerators, and to predict the directions for new facilities [4].

“Boiling the vacuum”

Even more intense lasers will be available in the near future, such as the Extreme Light Infrastructure (ELI) [5]. As we move to even higher intensities the physics becomes more rich and more complex [6], and quantum effects



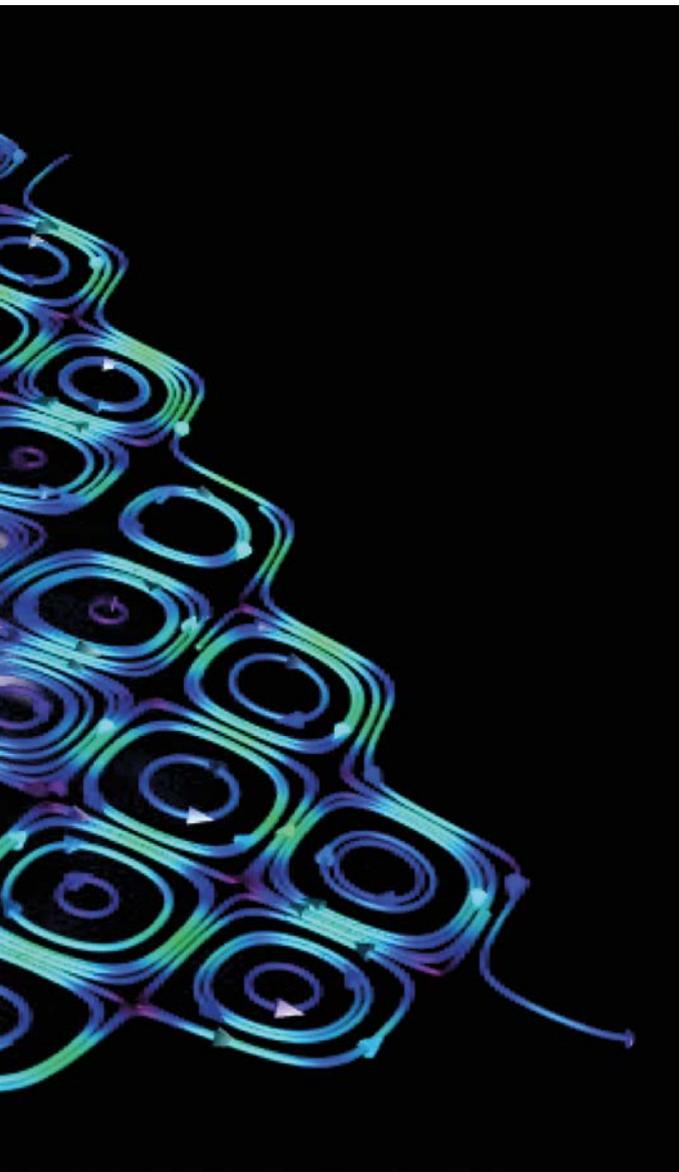
▲ FIG. 1: The accelerating structure in a laser-plasma accelerator (iso-surfaces), also with the trajectories of trapped and accelerated electrons, from low energies (blue) to high energy (red). Courtesy: Samuel F. Martins

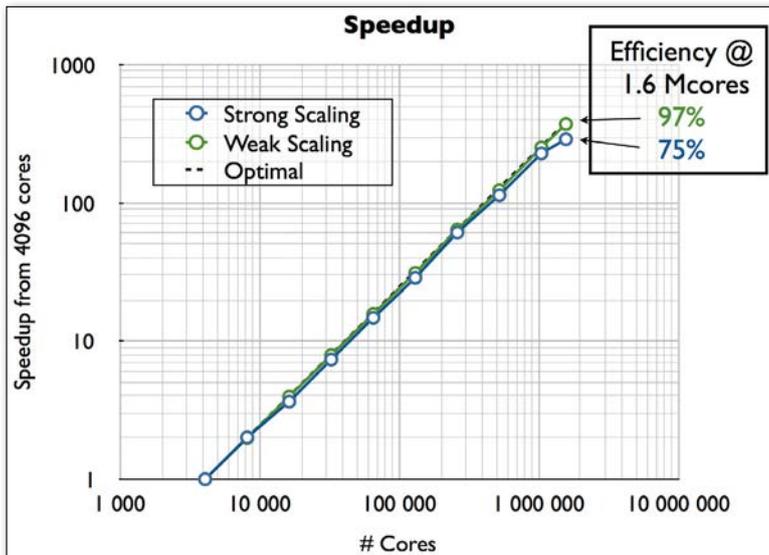
start to be important. A single ultra relativistic electron quivering in an ultra intense laser field can radiate x-rays. As the intensity is ramped up, the electron oscillating in the laser field will radiate gamma-rays. These gamma-rays can, in turn, interact with the laser and generate electron-positron pairs which, in the presence of the laser field, can again radiate strongly. An electromagnetic cascade of pairs and gamma-rays is then triggered, generating a quantum electrodynamic (QED) electron-positron plasma.

It is also possible to conceive scenarios where a static (or slowly varying) ultra strong electric field is present in a finite region of space. Let us imagine the field is so strong that, as the electron is accelerated over the distance of a Compton wavelength it gains more than $2 m_e c^2$, *i.e.* the rest mass energy of an electron and a positron. In this case, an electron-positron pair is generated, which will then interact with the ultra strong field itself, and a cascading process can also be triggered. The critical electric field for pair creation in vacuum, first identified by Sauter, is called the Schwinger critical field $E_s = 2 \pi m_e^2 c^3 / e \hbar$, where e is the electron charge, m_e the electron mass, \hbar is the Planck constant, and c the speed of light. For extreme field physics a common used dimensionless parameter is $\chi = E/E_s$, where E represents the electric field in the rest frame of the electron. χ determines the transition from the classical to the quantum dynamics; for χ on the order or higher than unity, QED effects are important and must be considered. Colloquially, when copious amounts of electrons and positrons are produced by ultra strong electromagnetic fields in vacuum, or via a cascade from a low density seed of electrons, the “vacuum is boiling”.

The prospect to reach in the laboratory these conditions in the near future is triggering many exciting developments [7, 8] at the cross roads of nonperturbative QED, plasma physics, and astrophysics. In many extreme astrophysical objects (*e.g.* pulsars, magnetars, or in the magnetosphere

◀ Optical trap: an efficient converter of light to matter. Four lasers interact with a thin wire of matter (100x thinner than a human hair). The wire is trapped in the vortexes of the electric field and radiates gamma-rays that decay into electron-positron pairs. These pairs are also trapped and radiate gamma-rays. The process continues until most of the laser energy converts to matter (or gamma-rays). Courtesy: Marija Vranic





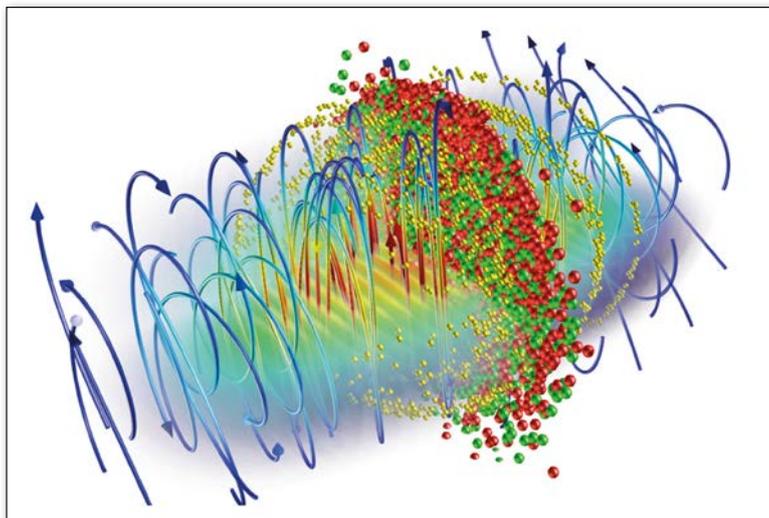
▲ FIG. 2: Strong and weak scaling of OSIRIS, a state-of-the-art PIC code, for a typical production run in the largest supercomputer in the world as of the time of the benchmark (2013) showing the measured speed-up as a function of the number of processors up to more than 1 million cpu cores. Courtesy: Ricardo A. Fonseca

of black holes), pair production, electromagnetic cascades, and strong radiation reaction are common processes that have an important impact on the properties of the emitted radiation. Therefore, understanding the interplay between the fields and the particles is very important. This renewed interest has also been an opportunity to revisit seminal foundational works, such as the Heisenberg-Euler semi-classical extension of Maxwell’s equations, or the Bohr postulate on the maximum possible physically achievable electromagnetic intensity (see [9] for a discussion).

In silico QED plasmas

The underlying physics is highly nonlinear and depends on the complicated and self-consistent trajectories of individual charged particles in extreme electromagnetic fields, including strong radiation dynamical effects, pair

▼ FIG. 3: OSIRIS simulation (the first ever) of three-dimensional QED cascades. Two laser pulses of opposite circular polarisation collide, showing the cascade (electrons – red, positrons – green, gamma rays – yellow) developing in the plane perpendicular to the laser propagation direction. Courtesy: Thomas Grismayer



production via QED processes, and, as soon as the cascades develop or if a tenuous plasma is present, collective plasma effects in complex field structures.

Although simplified analytical treatments are possible, the complexity of the systems can only be captured with computational modelling. The exponential developments of high-performance computing have set “computer simulations” as the third pillar of the scientific method, complementing theory and experiments/observation. For QED electron-positron plasmas in intense fields, where laboratory experiments have limited reach, the computational component has enhanced relevance, as a probe of the dynamics of these complex systems, as a tool to identify laboratory scenarios where bridges with the physics of extreme astrophysical environments can be established, or as a tool to model the global dynamics of astrophysical objects and make connection with observations. Therefore, the holistic comprehension of these complex scenarios requires *ab initio* fully kinetic simulations, following the trajectories of individual particles, complemented by the relevant QED processes.

Plasma physics has a long tradition of kinetic simulations: one of the first dynamical time dependent physical models explored in computers was the one dimensional plasma model, which opened the way to the particle-in-cell (PIC) model [10]. The PIC model is one of the most important computational tools in plasma and one of the most effective possibilities to follow the self-consistent dynamics of charged particles in electromagnetic fields. In the PIC method the trajectories of a large number of particles are solved self-consistently using forces calculated from field equations solved on a grid. When modelling plasmas, the field equations are the Maxwell’s equations for the electric and magnetic fields. PIC codes are also used to study a broad set of topics, including accelerator physics, cosmology, and semi-classical systems. The numerical codes based on the PIC algorithm are routinely used in some of the largest supercomputers in the World (figure 2), and thus can fully take advantage of the transformative nature that numerical simulations are bringing to the 21st century science.

It is not surprising then that a generalization of this algorithm has been recently proposed [11-13] to explore the extreme scenarios associated with the coupling of QED with plasmas. These models are computationally very demanding because the plasma scale is coupled with the QED scale via a probabilistic event generator technique. The possibility to take advantage of Peta floating point operations per second (Petaflop/s) supercomputers has already unveiled, even in the most simplified settings, the richness of the physics, ranging from radiation reaction effects in the collision of electron beams with lasers, to the self-consistent evolution of electromagnetic pair-plasma cascades, or the optimal configurations for electromagnetic cascades

Exploring extreme plasma conditions in the lab and in astrophysics

Ab initio simulations are already capturing the multidimensional collision of multi GeV electron beams with multi petawatt laser systems [14], showing this is an ideal setting to explore the transition from classical radiation reaction to quantum radiation reaction, associated with the transition of a regime with low χ to $\chi \sim 1$, opening the way to test different models for radiation reaction.

Recent three dimensional simulations have also allowed to determine the conditions for electromagnetic cascades with ELI scale lasers [15], including the radiation signatures and the properties of the associated gamma ray source, and the dependence of these processes on the configurations of the laser, taking into account the polarization or multi-beam configurations.

From a plasma physics point of view, the interplay between collective processes and QED effects associated with very high fields is relevant in high charge electron beam-electron/positron beam collisions, at the interaction point, when beam disruption can be important. Collective plasma processes are also important when the density of the self-generated plasma due to the QED cascade is so high that the plasma becomes opaque to the laser itself. In this case there is strong light absorption and efficient conversion of energy from the laser to the pair plasma and the gamma rays [13].

What is more exciting is that many of the processes that we are now exploring and understanding are at the core of some of the most exciting astrophysical objects. In magnetars, magnetic fields with magnitude close to the Schwinger field are present and the interplay between the fields, the plasma, and the QED processes remains an open question. In the magnetosphere of pulsars, electromagnetic cascades are also thought to be relevant. Global models for the magnetospheres of pulsars have been recently implemented but by coupling QED effects with the global geometry for the fields in rotating magnetospheres, as illustrated in Figure 4, it will be possible to understand the global dynamics of the system, determine radiation signatures, and identify the physical processes that determine the radiation signatures to mimic and further explore in the laboratory these physical processes, thus understanding how the “vacuum boils” in the laboratory and in astrophysics. ■

About the Author



Luís O. Silva is Professor of Physics at Instituto Superior Técnico, Lisbon, PhD and Habilitation from IST, and post-doc at UCLA (1997-2001). He was awarded two ERC Advanced Grants, among other prizes/honors. He is Fel-

low of the APS, Global Young Academy, and the EPS.

<http://web.tecnico.ulisboa.pt/luis.silva/>

<http://epp.tecnico.ulisboa.pt/>

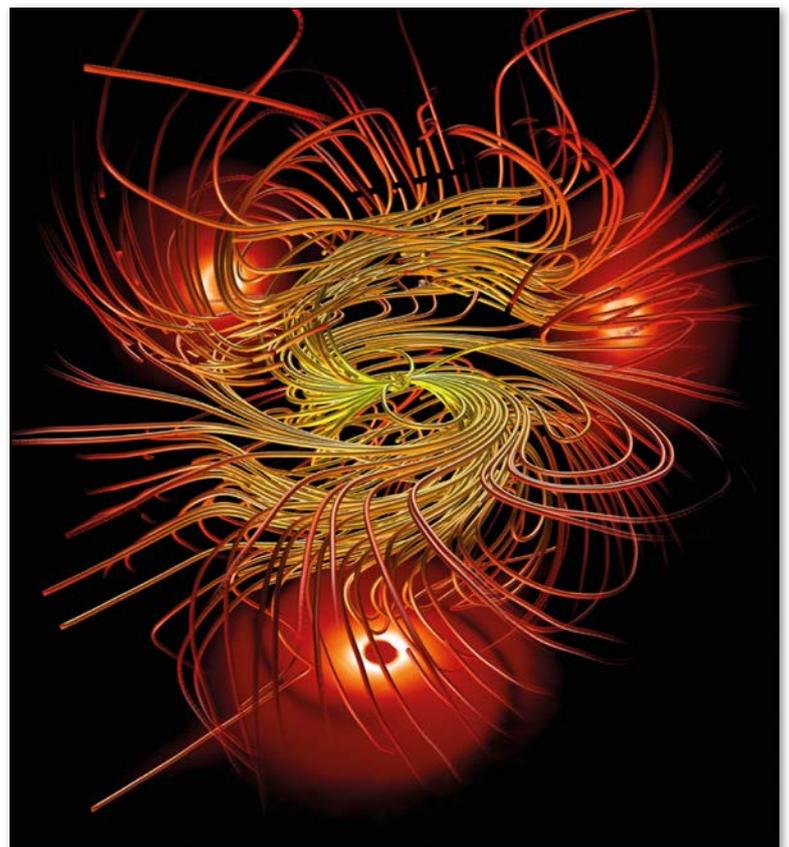
Acknowledgments

I would like to thank R. Fonseca, T. Grismayer, M. Vranic, F. Cruz, and everyone at the epp team at IST for discussions. Work partially supported by the European Research Council AdG2015 InPairs.

References

- [1] C. Joshi, *Scientific American* **294** (2), 40 (2006)
- [2] W. P. Leemans and E. Esarey, *Physics Today* **6** (3), 44 (2009)
- [3] K. Ta Phuoc *et al.*, *Nature Photonics* **6**, 308 (2012)
- [4] S. F. Martins *et al.*, *Nature Physics* **6** (4), 311 (2010)
- [5] <https://eli-laser.eu>
- [6] G. A. Mourou, T. Tajima and S. V. Bulanov, *Reviews of Modern Physics* **78** (2), 309 (2006)
- [7] M. Marklund and P. K. Shukla, *Reviews of Modern Physics* **78** (2), 591 (2006)
- [8] A. Di Piazza *et al.*, *Reviews of Modern Physics* **84** (3), 1177 (2012)
- [9] A. M. Fedotov *et al.*, *Physical Review Letters* **105**, 080402 (2010)
- [10] J. M. Dawson, *Reviews of Modern Physics* **55** (2), 403 (1983)
- [11] E. N. Nerush *et al.*, *Physical Review Letters* **106**, 035001 (2011)
- [12] C. P. Ridgers *et al.*, *Physical Review Letters* **108**, 165006 (2012)
- [13] T. Grismayer *et al.*, *Physics of Plasmas* **23** (5), 05670 (2016)
- [14] M. Vranic *et al.*, *Physical Review Letters* **113** (13), 134801 (2014)
- [15] T. Grismayer *et al.*, *Physical Review E* **95** (2), 023210 (2017)

FIG. 4: *Ab initio* simulation of a rotating magnetosphere showing the field lines of a centrifugally-driven magnetosphere, with the spiralling features already present in the density, with plasma uniformly loaded in the simulation region (projection in the top of the simulation box) Courtesy Fabio Cruz



A TRIBUTE TO MANNE SIEGBAHN

■ Henk Kubbinga – University of Groningen (The Netherlands) – DOI: <https://doi.org/10.1051/eprn/2017507>

Spectroscopy came to dominate the 19th century, with a crucial role for Swedish physicists. It was Anders Ångström who introduced the tenmillionth part of a millimeter as the wavelength unit (1868), a unit that was adopted by Rowland for his tables of the solar spectral lines (1887-1893). Janne Rydberg, then, followed in Ångström's footsteps in searching for relations between the emission spectra of the elements and their place in the Periodic Table. Röntgen's new rays became a next challenge, demanding a form of spectroscopy of their own. Manne Siegbahn, an assistant of Rydberg, then, devised appropriate instruments of ever increasing precision.



▲ FIG. 1: Manne Siegbahn by Bror Kronstrand (1936; oil on canvas, 50×60 cm; courtesy Gustavianum-Uppsala University Museum). The original version was by Sam Uhrdain, 1928. Siegbahn's desk features a self-devised X-ray tube in porcelain, for his high precision spectroscope.

Karl Manne Georg Siegbahn (1886-1978) was born in Örebro, a city in Sweden's Lake District. After graduation in 1906 he enrolled at the University of Lund, where he was charmed by the teachings of the mathematical physicist Janne Rydberg (1854-1919). From Rydberg he adopted a bent for the numerical relations between the elements' spectral lines and their place in the Periodic Table. In the year that Rydberg promulgated what came to be known as the $2x^2$ rule, with x ($= 1$ or 2) as the ordinal index of the element at the Periodic Table, Siegbahn came in. On 26 April 1911, then, he passed the doctorate on a dissertation entitled *Magnetische Feldmessungen*, which revealed his primarily experimental propensity. In hindsight an unusually short track indeed, since he made also time for two trips abroad (1908, Göttingen; 1909, Munich). Physics' Europe was in the making; in 1911 and 1914 new trips followed, to Berlin, Heidelberg and Paris.

From Barkla to Moseley; atomic number versus atomic mass

In Munich, Siegbahn had made the acquaintance of Arnold Sommerfeld and Max von Laue, who familiarized him with the particularities of Röntgen's rays. This domain lived a boost the moment, in June 1912, that Laue, Friedrich and Knipping published their epoch-making crystal-diffraction patterns. No wonder that Siegbahn came under the spell of the new rays. The Braggs subsequently introduced reflection instead of diffraction, a technique that reduced the required time significantly. For a while transverse waves, ether pulses and particles lived side by side in the physicists' minds. Laué's rather complex mathematics was exchanged, by Bragg Jr., for a straightforward expression for the

difference in path length, lattice constant, and angle of incidence:

$$n\lambda = 2d \sin\varphi$$

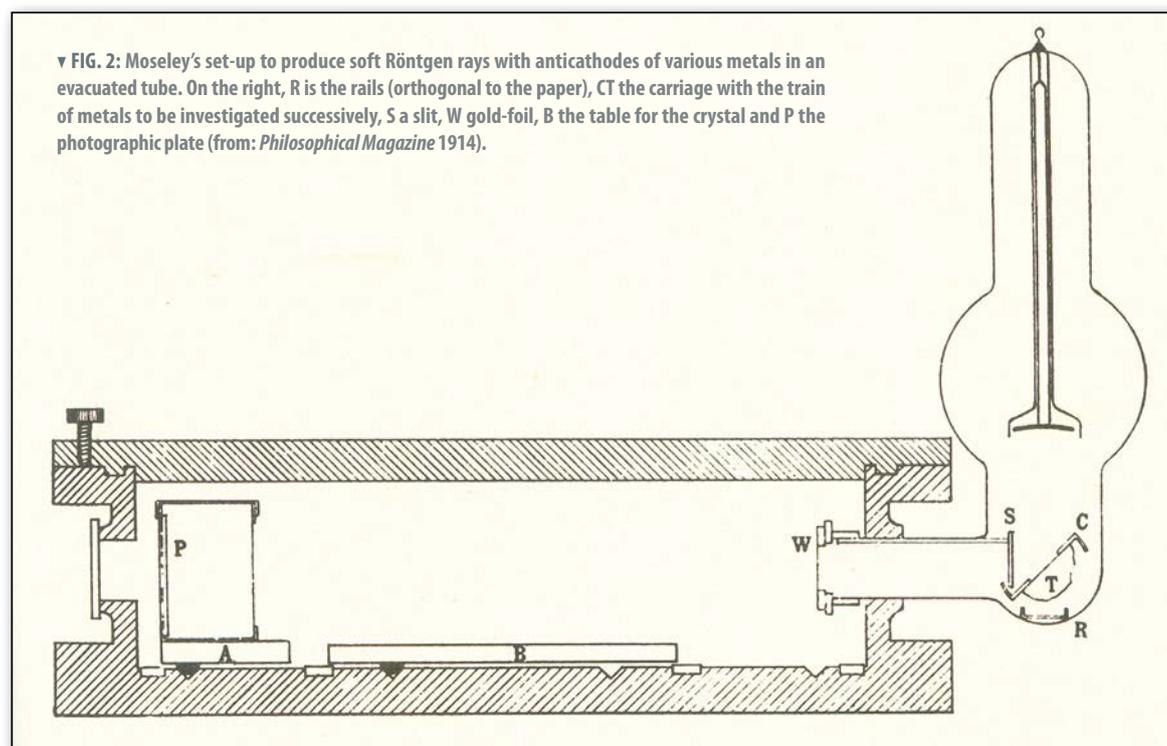
with $n = 1, 2, 3, \dots$. No doubt, there was a highly energetic electromagnetic radiation at issue, the wavelength of which could now be calculated using the available data for the crystal at stake. In case of rocksalt (NaCl) the mean distance between the constituent atoms could be calculated from the density ($\rho = 2,17 \text{ g}\cdot\text{cm}^{-3}$), the molar mass (58,5 g), and the constant N called after Avogadro: $d = 2,814 \cdot 10^{-8} \text{ cm}$. With $\varphi = 11,55$ and $n = 1$ the Braggs found $\lambda = 1,78 \cdot 10^{-8} \text{ cm}$. In October 1912, Henry Moseley, working under Rutherford at Manchester, set out to check the results reported from Munich and Cambridge. For a platinum anticathode he found, in the spring of 1913, five wavelengths, in other words, an emission spectrum consisting of five lines. Simplicity itself, compared to the traditional emission spectra, and therefore full of promises. Where others focused on the rays themselves, Moseley weighted the consequences for the ideas on atomic structure and its relation with the Periodic System. There were reasons to believe that the ordering principle of the System was not atomic mass, but the positive charge of Rutherford's nucleus. Indeed, at least three cases showed that the order did not always follow atomic mass. Moseley, then, set out to study one of these, the couple Co ($Z = 27$) and Ni (28). The idea was to study the series Ca (20) through Zn (30), all metals ready to produce sufficiently soft X-rays when used as anticathode material. The pencil of rays was reflected by a crystal of potassium ferrocyanide and detected, initially by a normal counter, but later by a photographic plate. The results were unambiguous in that the atomic number prevailed, as could be read out from the shift of the two K-lines in question. There were also

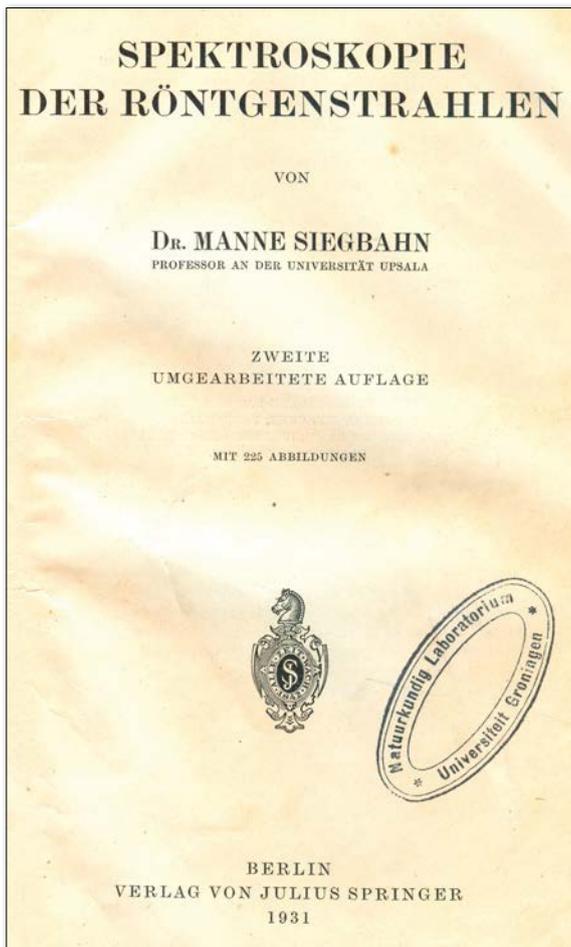
less energetic lines, it appeared; following Barkla's system (1907) they were known as L-lines. Barkla had weighted the eventuality of even higher energetic lines, to be called J, I, H, etc., but these never showed up.

X-ray-spectroscopy as such

In 1914, on the eve of the Great War, Manne Siegbahn esteemed that the utility of X-ray spectra in the identification of elements was obvious, even though the resolution of the lines left much to be desired, not unlike the precision in the wavelength determinations. While quite a lot of his colleagues got fully involved in war activities, Siegbahn could subsequently focus on the perfection of the apparatus. Initially he used an instrument similar to that of Moseley, that is, one in which a series of anticathodes could be checked in a row (Fig.2). A first advance was the integration of the reflecting crystal and the registration unit in the discharge tube in view of reducing losses of soft rays by absorption in the air. With his PhD-students he showed, for zirconium and neodymium, that the 2 K-lines were in reality doublets, a fact that again stressed the importance of precision. Next the scope of his research was greatly widened to include also lighter elements. In 1916 new series—M and N—of longer wavelength showed up. Siegbahn became the undisputed leader in the field. Students from abroad, among whom Dirk Coster from Leiden, flocked to Lund. In 1919 Siegbahn organized a first post-War congress on the topic with Sommerfeld and Bohr as key-notes; both were delighted to see their ideas on atomic structure confirmed. No wonder that Siegbahn was among the invités for the next Solvay Conference on Physics, that of 1921, which was devoted to 'Atoms and electrons'. In 1922 he moved on to the Faculty of Science

▼ FIG. 2: Moseley's set-up to produce soft Röntgen rays with anticathodes of various metals in an evacuated tube. On the right, R is the rails (orthogonal to the paper), CT the carriage with the train of metals to be investigated successively, S a slit, W gold-foil, B the table for the crystal and P the photographic plate (from: *Philosophical Magazine* 1914).





◀ FIG. 3: Spektroskopie der Röntgenstrahlen

of Uppsala University to continue his endeavours to bridge the gap between the UV-part of the normal spectrum and the X-rays. Rocksalt was exchanged for calcite, the X-unit took the place of the Ångström, with $1 \text{ \AA} = 10^3 \text{ X.U.}$ A monograph entitled *Spektroskopie der Röntgenstrahlen* (1923, 1931; Fig.3) summarized the results of a new survey of the relevant elements.

A retroactive Nobel-Prize

A rarity in the history of the Nobel Prize. For the Prize of 1924, 23 candidates had been nominated, none of whom was deemed a worthy candidate in the light of Nobel's last will, so the awarding was postponed. Siegbahn, then, was among the nominees for 1925—for the first time—and the Nobel Committee awarded him the still open Prize of 1924 “for his discoveries and research in the field of X-ray spectroscopy”. Among the nominators was Max von Laue who, in his nomination letter dated 18 November 1924, had stressed that Siegbahn was the one who had measured the wavelengths in the Röntgen spectrum with such a precision that by now the term scheme of Bohr's atomic theory could be used with full confidence, allowing us even an insight in the hitherto entirely dark structure of the heavier atoms.

From Swedish icon to global eminence

In the late 1920s the use of ruled gratings—first flat, later concave, like those of Rowland—enabled the exact

determination of wavelengths and the introduction of an absolute scale; very soft X-rays, then, came to be identified with extreme UV light. Conversely, the lattice constant of calcite could now be calibrated anew, leading to a more precise value of Avogadro's constant. Early in the 1930s Siegbahn's attention was drawn by the remarkable discoveries in the field of nuclear physics, particularly the confirmation, by Chadwick, of the existence of 'neutrons' as postulated by Rutherford and their curious behaviour as reported by Fermi. Sweden should also play a role in all this, Siegbahn esteemed, and he argued for an entirely new laboratory, at nearby Stockholm, under the wings of the Swedish Academy of Sciences. With financial support of the Wallenberg Foundation and the Swedish Government he succeeded in creating, in 1937, a Nobel Institute of Physics close to the Royal Swedish Academy of Sciences. At the new institute powerful cyclotrons were built, funded by the Wallenberg and Rockefeller Foundations. From 1988 until 2011 it was known as the Manne Siegbahn Institute of Physics and functioned under the wings of the University of Stockholm. ■

Acknowledgment

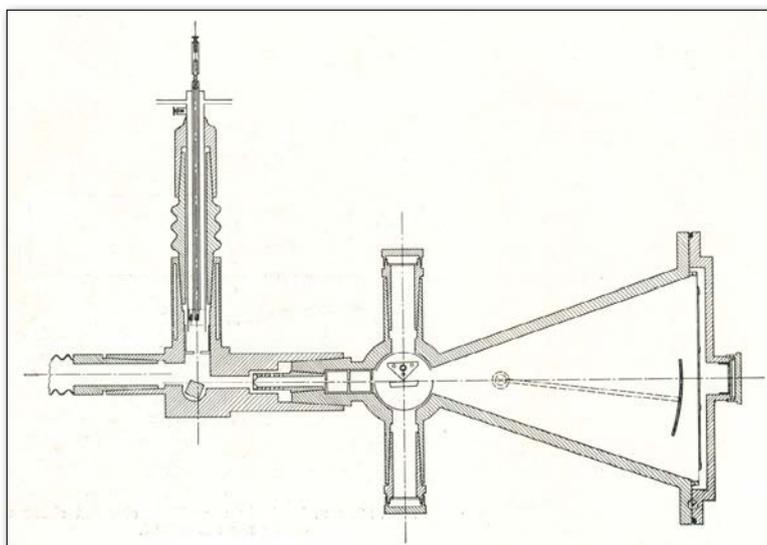
I am indebted to Karl Grandin (Royal Swedish Academy of Sciences, Stockholm; Chair EPS-HoP-Group) for kind permission to see the nomination letter by M. von Laue and to Rolf Siemssen (University of Groningen) for consultation. I am also obliged to Johanna Axné and Anna Hamberg of Uppsala University-Gustavianum for archival assistance.

About the author



Henk Kubbinga is a historian of science at the University of Groningen and member of the EPS-HoP-Group. Actually he is finishing the fifth and last volume of *The collected papers of Frits Zernike*.

▼ FIG. 4: Vacuum flat-grating spectrometer for $\lambda \geq 10^4 \text{ X.U.}$ as devised by Siegbahn et al. (1930; from *Spektroskopie der Röntgenstrahlen*, 1931, p.396). On the left the X-ray tube with the reflecting crystal, in the middle the grating with a shutter, on the right the photographic plate.



COMPANY DIRECTORY

Highlight your expertise. Get your company listed in europhysicsnews company directory
For further information please contact jessica.ekon@edpsciences.org

GOODFELLOW

www.goodfellow.com

Goodfellow supplies small quantities of metals, alloys, ceramics and polymers for research, development and prototyping applications. Our Web Catalogue lists a comprehensive range of materials in many forms including rods, wires, tubes and foils. There is no minimum order quantity and items are in stock ready for immediate worldwide shipment with no extra shipping charge. Custom-made items are available to special order.



LASER QUANTUM

www.laserquantum.com

Laser Quantum, world-class manufacturer of ultrafast and continuous wave products, provides customised solutions to meet the needs of our customers whilst supplying cutting-edge technology with industry-leading lifetimes to further research. To learn more, please visit www.laserquantum.com or contact us for a free demonstration and quotation: +44 (0) 161 975 5300.



LEYBOLD

www.leybold.com

Leybold offers a broad range of advanced vacuum solutions for use in manufacturing and analytical processes, as well as for research purposes. The core capabilities center on the development of application- and customer-specific systems for creating vacuums and extracting process gases.



MB SCIENTIFIC AB

www.mbscientific.se

MB Scientific AB is a Swedish company which develops and produces state of the art instruments for the photoelectron spectroscopy experiments. Our photoelectron energy analyser MBS A-1 gives you the opportunity to do world leading research together with MBS VUV photon sources, MBS L-1 and T-1, which produce the brightest and narrowest lines existing to be used for this type of experiments.



MCPHERSON

www.mcphersoninc.com

McPherson designs and manufactures scanning monochromators, flat-field imaging spectrographs, and vacuum monochromators and measurement systems for reflectance, transmittance, and absorbance testing. Its spectrometers and systems are built for soft x-ray, vacuum-ultraviolet, and UV/Vis and Infrared wavelengths. Applications range from lasers and lithography, solar, and energy to analytical life science and more.



METALLIC FLEX

www.metallicflex.de

METALLIC FLEX supplies vacuum equipment for research laboratories. Among the standard products as valves, flange components and sputter targets, we are specialised in

- custom designed Manipulators and Linear Translators
- custom designed welded bellows
- Vacuum chambers for HV and UHV

Articles for your success!



OPTIGRATE

www.optigrate.com

OptiGrate Corp is a pioneer and world leader in commercial volume Bragg gratings (VBGs) and VBG-based ultra-narrow band optical filters. BragGrateT Raman Filters from OptiGrate are unmatched in the industry for narrow linewidth, optical density, and optical transmission. BragGrate notch filters enable measurements of ultra-low wavenumber Raman bands in the THz frequency range down to 4 cm⁻¹.



TREK

www.trekinc.com

TREK, INC. designs and manufactures products for demanding applications in research and industry. Trek's **high-voltage amplifiers** utilize proprietary circuitry to provide a closed-loop amplifier system with exceptional DC stability and wideband performance for driving capacitive loads. Trek's novel non-contacting **electrostatic voltmeters** circumvent charge transfer issues associated with traditional contacting technology. **ESD instruments** are available for electrostatic discharge applications.



ZURICH INSTRUMENTS

www.zhinst.com

Zurich Instruments is a technology leader developing and selling advanced test & measurement instruments for dynamic signal analysis. These devices are used in many fields of application by high-technology research laboratories and industrial development sites. Zurich Instruments' vision is to revolutionize instrumentation in the high-frequency and ultra-high-frequency range by incorporating the latest analog and digital technology into powerful measurement systems.



MIAZMA: **PHYSICS EDUTAINMENT THROUGH A COMPUTER GAME**

■ Zs. Fülöp, S. Biri and G. Lévai – MTA Atomki, Debrecen, Hungary – DOI: <https://doi.org/10.1051/epn/2017508>

The beginning of the 21st century is characterised by several contradictions and challenges. One of them is that scientific and technological development has never been as important for the well-being of humankind as today. Nevertheless, these fields seem to lose the attention of talented and interested youngsters.



It is thus in the interest of all of us in science to demonstrate the beauties of scientific research to the young generation. The classical methods do not seem to be sufficient to complete this task, so new, innovative techniques have to be developed to capture the attention of the teenage generation.

The Miazma project was inspired by these ideas. Furthermore, the course of events outlined above is especially regrettable in Hungary, a country where physics and natural sciences in general, have always been highly valued. This is the reason why a group of physicists at the Institute for Nuclear Research, Hungarian Academy of Sciences (MTA Atomki), Debrecen [1] decided to address high school age students directly, through their preferred medium, a computer adventure game. It was a

long time ago, around the dawn of the personal computer era, when the present authors were in the age group of the targeted audience, so finding the right language with the latter was a real challenge. In order to facilitate the inter-generation communication, young colleagues, practicing high school teachers, as well as junior family members were asked to contribute to the efforts. The key partner, however, was a professional company, Private Moon Studios, that had extensive experience in developing computer-based adventure games, as well as tabletop and conventional strategic board games [2]. The director of this company was also a popular singer-songwriter performing under the name Pierrot, and this fact in itself helped to abolish the generation barrier to the target audience.

Needless to say, scientists and artists contemplated each other with some reservation during the early stage of the project. The two groups couldn't have differed more in their socialization, cultural background and in general, in the way they looked at the world. We, scientists, tried to resolve this shock jokingly, recalling stories from the time of the Manhattan Project, when two utterly different communities had to work jointly to reach a common aim. Nevertheless, it soon turned out that there are many common features in the thinking of scientists and artists, and that the differences also served as the source of mutual inspiration for the two groups in overcoming difficulties. In the end we all agreed that both science and developing adventure games can be considered as special forms of problem solving.

The story of Miazma [3] takes place in the present, but refers back to several historical moments from the past few hundred years. It contains both fictitious and realistic elements. Fictitious are all the characters appearing in the game in the present. However, the key characters of the past, István Hatvani, the professor of the Reformed College of Debrecen from the 18th century, and Sándor Szalay, the founding director of Atomki are real. The meteorite that landed at Kaba, near Debrecen in 1857 is also real, while the other meteorites playing role in the story are fictitious.

From the technical point of view, Miazma is an interactive film in the style of the “third person point-and-click” adventure PC Windows games. In other words, it is built of short film scenes embedded in an interactive computer game environment. Real locations are covered by live-action cinematic approach, while the narrative depends on the actions of the players themselves. Their decisions open many possible alternative routes, all from a single starting point towards one fixed ending. Besides the film and the story, puzzles provide the main motivation for players. In Miazma there are more than 30 puzzles, at varying levels of difficulty. Most of the

◀ P. 42: The fictitious meteorite on exhibition in the AGORA Science Centre, Debrecen



► **FIG. 1:** Jonathan and the head of the Radiocarbon Laboratory, with her beloved plants and animals. This laboratory is marked by green colour in the game to help the orientation.

puzzles incorporate scientific problems (fictitiously) created by Prof. Szalay several decades ago. According to the story, these problems were designed to be solvable only in a later age (the present), when the necessary technology would become available. With this, Prof. Szalay wanted to hide potentially dangerous objects in his time, and guarantee that they would be handled by trustable individuals - scientists of the 21st century. In working out the details we tried to keep scientific rigour at a sufficiently high level. However, compromise was made at several instances in order to make the storyline more fluent.

In the starting scene, a journalist, Jonathan Hunt arrives at Atomki, where he meets a young physicist, Vera. In her office the player can practice the controls of the game (selecting objects, using the inventory *etc.*). Jonathan's visit soon turns into an investigation for a missing teenage boy Balázs, Vera's younger brother. The characters of Jonathan (who already appeared in other adventure games) and Balázs represent the experienced detective and the curious teenager, whom the players can identify with during the game.

Jonathan starts the investigation by visiting the laboratories of the institute. For a better identification, each laboratory has a specific colour and decoration (see Fig. 1.). Furthermore, each scientist has some hobby, which also turns out to be useful in solving the puzzles. The following laboratories are shown and visited (some named slightly differently in the game):

- Surface Science Laboratory
- Ion beam Analysis Laboratory
- Computer Centre
- Cyclotron Control Room
- Plasma Physics Laboratory
- Radiochemistry Laboratory
- Radiocarbon Laboratory

During this stage Jonathan (and the player) gets the first impressions of the activities of the laboratories and the technologies available there.

The investigation also extends beyond the gates of the institute to the city of Debrecen, revealing some of its rich cultural heritage. It is at the visit to the Reformed College [6] when a meteorite first comes into the picture (Fig. 2.). Further pieces of information about the missing boy are collected in the College library, in an old church and in an observatory.

Meanwhile, the boy tries to escape from an underground labyrinth of cellars (Fig. 3). From this point, the storyline is temporarily no longer linear; we can follow both his escape and the investigation. In the labyrinth, common tools are to be combined and used with the laws of physics to open the next door and move on. These cover standard high-school physics topics, including mechanics, thermodynamics, electricity *etc.* A booklet is at hand to help the player, written in the style of the 1960's, in the form of a dialogue between a father and his 10-year-old son, on everyday aspects of physics.

Edutainment: The process of entertaining people at the same time as you are teaching them something, and the products, such as television programmes or software, that do this. (*Cambridge Business English Dictionary, Cambridge University Press*)

Miasma: A vaporous exhalation formerly believed to cause disease. (*Merriam-Webster Dictionary*)

Miazma: A new edutainment PC computer game developed in MTA Atomki, Debrecen, Hungary.

Finally, Jonathan's investigation reveals a secret safe in the director's office, well hidden by Professor Szalay decades before (Fig. 4). He obviously wanted to leave important messages to posterity. There are six combination locks on the safe, and a small chest with six corresponding compartments, each containing "coded messages". Using these messages (usually a set of small objects or enigmatic notes), Hunt relies on the assistance by the laboratories again in finding the combinations for the locks. From this point, the player can proceed in any order, visiting any of the labs or returning anywhere later. Solving the puzzles often requires objects or information obtained at another location earlier. The six puzzles are based on the following objects and physical methods:

1. Lapis lazuli in small bottles: element analysis and date labelling
2. Rubber bell and a bone flute: sound frequency calculation and measurement
3. Old gold-plated coin: multiple thin layers, depth analysis
4. Picture of a rainbow: plasmas from noble gases, wave lengths
5. Lead box with radioactivity sign on it: irradiation with cyclotron beam, PET camera study
6. A ring and a clock face: the Szalay-Csikai neutrino experiment in 1956 [4]

With the help of the scientists, Jonathan Hunt (and the player) figures out the next step needed to proceed with the puzzles. In this scientific investigation he uses the instruments, methods and knowledge *de facto* available in Atomki.

Finally all the puzzles are solved and the safe opens! Of course we cannot reveal what is found there and what is the end of the story. Instead, we encourage the readers to play the game and enjoy the thrill of science and adventure.

The game is a result of the long-term evolution of Atomki's outreach activities and its collaboration with high school teachers of the city. The Hungarian version of Miazma was a standalone project co-financed by the European Social Fund (grant agreement no. TÁMOP-4.2.3-12/1/KONV-2012-0057) and distributed in DVD format to the readers of a major science magazine in Hungary, available in all high school libraries. Recently, we have provided free download of the game for the entire Hungarian community. The Agora Science Centre of Debrecen [7] visited by thousands per year provides a special exhibition space for Miazma, where visitors can not only play the game, but also see the mysterious meteorite and the safe as well. The scene in which Balázs escapes from the labyrinth was also reconstructed temporarily for a science summer school, where many visiting students had the opportunity to test their skills in a realistic situation.

The Reformed College of Debrecen, founded in 1538, has always been the symbol of the Calvinist tradition of Debrecen. The college played a major role in the cultural and religious life of Hungary for centuries. Many famous Hungarian writers, poets, as well as scientists studied there. The college had strong links with universities in Switzerland, Germany and Holland: numerous graduates of the college visited these institutes, and on returning home, promoted the modern ideas learned there. The rich collection of the College Library also dates back to the time of these "peregrines", whose donations were essential in enlarging it. One of the most renowned professors of the College was István Hatvani (1718-1786), who studied mathematics, physics and medicine in Basel, Utrecht and Leiden. He refused the invitation for professorship in Leiden, and returned to Debrecen to become professor of the Reformed College. He had an extensive teaching activity, but he was most renowned for his experiments with electricity, earning him the title "Hungarian Faustus".



▲ FIG. 2: Collecting information in the library of the Reformed College.

Founded in 1954, the Institute for Nuclear Research (MTA Atomki) belongs to the network of research laboratories administered by the Hungarian Academy of Sciences. The founding director Sándor (Alexander) Szalay (1909-1987) studied nuclear physics in Cavendish Laboratory, Cambridge, where he worked with Nobel Laureate Lord Ernest Rutherford. In 1956, together with his Ph.D. student, J. Csikai, he performed a cloud chamber experiment that indirectly proved the existence of (anti)neutrino in the beta-decay of ${}^6\text{He}$. For this achievement Atomki was declared EPS Historic Site in 2013 [4]. Atomki has developed into a national accelerator centre, where about 110 researchers work in nuclear, atomic and particle physics, as well as in environmental science. The present research policy of Atomki follows the interdisciplinary approach always characterizing the institute [5].



▲ FIG. 3: Escaping from the underground labyrinth.

The international version was presented first at the 10th edition of the Science on Stage Festival in Debrecen, 2017 attended by more than 400 science teachers from all over Europe [8]. The international version of the game, however, is not public domain. It can be downloaded from the Atomki web page [9] and limited number of activation codes can be requested from the sponsors of the game: the European Physical Society [10], the Nuclear Physics European Collaboration Committee (*NuPECC*) [11] and the ENSAR2 European project [12] through the European Union's Horizon 2020 research and innovation programme under grant agreement No 654002. Negotiations are under way with major gaming download sites, e.g. STEAM, to make the game available on the European market.

As an epilogue, one may wonder whether one can really learn physics from adventure game based on a science related story. Maybe not. However, and this is the firm belief of the authors, it can help to feel the thrill of scientific investigation, to appreciate the power of high-tech instruments and, eventually, to understand the importance of evidence based research. ■

About the Authors



Zsolt Fülöp is scientific adviser at MTA Atomki working in the field of nuclear astrophysics. Former chair of the EPS Nuclear Physics Division and former member of the EPS Executive Committee.



Sándor Biri is senior researcher at MTA Atomki. His research interest is atomic plasmas, ion sources and accelerators R/D. He is presently the head of the Accelerator Center of Atomki.



Géza Lévai is scientific adviser at MTA Atomki. His field of interest is symmetry-related studies in quantum mechanics and theoretical nuclear physics. Presently he is the deputy director of Atomki.

References

- [1] www.atomki.hu/en/
- [2] <http://gamedev.privatemoon.com/en>
- [3] <https://youtu.be/tF3kHGO5MY>
- [4] R. G. Lovas, *Europhysics News* 45/1, 04 (2014)
- [5] Zs. Fülöp and G. Lévai, *Nuclear Physics News* 25/4, 05 (2015)
- [6] https://en.wikipedia.org/wiki/Debrecen_Reformed_Theological_University
- [7] <http://www.agoradebrecen.hu/en/>
- [8] <http://sons2017.eu/>
- [9] www.atomki.hu/miazmaeng
- [10] <http://www.eps.org/>
- [11] <http://www.nupecc.org/>
- [12] <http://www.ensarfp7.eu/>



Private Moon Studios [2] is an independent Hungarian game developer company specialized in computer games, board games and touristic games. They developed a range of interactive city adventure games, offering an opportunity to learn about the historic sights of a city in the course of an exciting investigation. The first interactive movie game of the company was Yoomurjak's Ring, the first in the line of Jonathan Hunt Adventures. The game's deep storyline has been subsequently extended into a novel. The protagonist, Jonathan Hunt is a young journalist from New York who has Hungarian ancestry. His first trip to Hungary begins as innocently as a vacation in the city of Eger, but soon turns into a treasure hunt for a mysterious ring and hidden messages from the past. The game features real-life locations to be discovered virtually and an immense amount of movie footage, pictures and panoramic photos.

ANNUAL INDEX VOLUME 48 - 2017

AUTHOR INDEX

- » **B**
- Backholm M.** Slippery and never wet • 48/5&6 • p.30
- Bažant Z.P.** see Le J.-L.
- Beijerinck H.C.W.** Gender diversity in STEM • 48/2 • p.16 | NatLab, Eindhoven, The Netherlands • 48/5&6 • p.04
- Benedikt M.** Can we afford to wait? Designing the collider of the future • 48/4 • p.12
- Biri S.** see Fülöp Zs.
- Bosman M.** International Day of Women and Girls in Science • 48/2 • p.05
- Bracco A.** The NuPECC Long Range Plan 2017: Perspectives in Nuclear Physics • 48/4 • p.21
- Braun H.H.** Inauguration and first beam of PSI's X-ray FEL SwissFEL • 48/1 • p.05
- Buzdin A.** See Mukhin S.
- » **C**
- Caux J.-S.** Redressing the inverted pyramid of scientific publishing • 48/5&6 • p.25
- Cifarelli L.** The remake of an iconic photo • 48/5&6 • p.10
- Crabtree G.** Where is transportation going? • 48/3 • p.21
- » **D**
- Dalnoki-Veress K.** see Salez T.
- Daruka I.** Publication stock exchange (PSX) • 48/1 • p.28
- De Natale G.** Reale Osservatorio Vesuviano, Herculaneum (Naples), Italy • 48/1 • p.06
- Dulieu O.** Ion Coulomb crystals: from quantum technology to chemistry close to the absolute zero point • 48/2 • p.17
- Duff M.** A lesson for the future of our science: my testimony on Lord Patrick M.S. Blackett • 48/3 • p.32 | Piersanti Mattarella, Tower of Thought - Erice, Sicily, Italy • 48/2 • p.04
- » **F**
- Fatta-Kassinis D.** see Fernández-Ibañez P.
- Ferdinande H.** see Pohl M.
- Fernández-Ibañez P.** Can solar water-treatment really help in the fight against water shortages? • 48/3 • p.26
- Formosa-Gauci C.** Pioneering SESAME light source circulates first beam • 48/1 • p.08
- Forrest J.A.** see Salez T.
- Fülöp Zs.** Miazma: physics edutainment through a computer game • 48/5&6 • p.42
- » **H**
- Heinz A.M.** Uddmanska House, Kungälv, Sweden • 48/1 • p.04
- Hermans L.J.F. (Jo)** Fascinating friction • 48/5&6 • p.29 | Physics formulas on Leiden walls • 48/1 • p.07 | Travel with hydrogen • 48/2 • p.32
- » **J**
- Jonson B.** see Heinz A.M.
- » **K**
- Kalda J.** First European Physics Olympiad • 48/4 • p.04
- Klein T.** Ring lasers – a brief history • 48/4 • p.25
- Kleijn A.W.** Vacuum Science and Technology • 48/4 • p.32
- Kocs E.** see Crabtree G.
- Kubbinga H.** A Tribute to Manne Siegbahn • 48/5&6 • p.38
- Kundt W.** Letter to the Editors • 48/3 • p.25
- » **L**
- Le J.-L.** Mechanics-based mathematical studies proving spontaneity of post-impact WTC towers collapse • 48/1 • p.18
- Lee D.** EPS gears up for 50th Anniversary • 48/5&6 • p.06
- Lévai G.** see Fülöp Zs.
- » **M**
- Marino A.** Britain's nuclear secrets: inside Sellafield • 48/5&6 • p.21
- McGraw J.D.** see Salez T.
- McGuigan K.G.** see Fernández-Ibañez P.
- Mischke A.** International conference on Strangeness in Quark Matter in Utrecht • 48/5&6 • p.11
- Mukhin S.** Alexei Abrikosov (1928-2017) • 48/3 • p.06
- » **N**
- Neugart R.** Properties of nuclei probed by laser light • 48/2 • p.12
- » **O**
- Ongena J.** A primer on energy from nuclear fission • 48/1 • p.30
- » **P**
- Pázsit I.** see Heinz A.M.
- Pohl M.** In memoriam: Prof. em. Dr. Ernst Heerr • 48/4 • p.07
- Poitou J.** A brief tour of the climate machine 1 - The Climate machine, a two fluids thermal engine • 48/2 • p.26 | 2 - Environment shapes the climate • 48/3 • p.17
- » **R**
- Raphaël E.** see Salez T.
- Ras R.H.A.** see Backholm M.
- Ritzmann U.** Why should one become involved in EPS Young Minds? • 48/1 • p.32
- Rossel C.** An open and peaceful world for Science • 48/1 • p.03 | Scientific and ethical responsibility • 48/2 • p.03
- » **S**
- Salez T.** Glass transition at interfaces • 48/1 • p.24
- Sauer P.** see Pohl M.
- Saunders F.** Research Ethics and Research Integrity – Why it matters • 48/4 • p.06
- Sakellariadou M.** Gravitational Physics: the birth of a new era • 48/5&6 • p.18 | Nobel prize in physics 2017 • 48/5&6 • p.08
- Silva L.O.** "Boiling the vacuum": *in silico* plasmas under extreme conditions in the laboratory and in astrophysics • 48/5&6 • p.34
- Sjøberg S.** PISA testing – a global educational race? • 48/4 • p.17
- Sólyom J.** In memoriam: Prof. Alfred Zawadowski • 48/5&6 • p.09
- Selten T.** Stella Lux: the energy-positive family car • 48/3 • p.13
- » **T**
- Tillman B.** see Crabtree G.
- Timonen J.V.** see Backholm M.
- » **V**
- van der Steenhoven G.** Trump, climate change and the EPS • 48/1 • p.28
- Varlamov A.** See Mukhin S.
- von Toussaint U.** Data Analysis: a (not so) silent revolution • 48/1 • p.15
- Voss R.** Challenging times for the EPS • 48/3 • p.03 | Election day • 48/4 • p.03 | Working together on the evidence base • 48/5 • p.03
- » **W**
- Willitsch S.** see Dulieu O.
- » **Y**
- Yeomans J.M.** Nature's engines: active matter • 48/2 • p.21
- » **Z**
- Zaránd G.** see Sólyom J.
- Zimmermann F.** see Benedikt M.

MATTER INDEX

» Annual index

Volume 48 - 2017 • 47/5&6 • p.47

» Book review

A lesson for the future of our science:
my testimony on Lord Patrick M.S.
Blackett **Duff M.**

A primer on energy from nuclear fission
Ongena J.

Vacuum Science and Technology
Kleijn A.W.

» Crossing borders

Gender diversity in STEM
Beijerinck H.C.W.

Publication stock exchange (PSX)
Daruka I.

» Editorials

An open and peaceful world
for Science **Rossel C.**

Challenging times for the EPS **Voss R.**
Election day **Voss R.**

Scientific and ethical responsibility
Rossel C.

Working together on the evidence
base **Voss R.**

» Event

First European Physics Olympiad **Kalda J.**

International conference on Strangeness
in Quark Matter in Utrecht
Mischke A.

» Everyday physics

Ring lasers – a brief history **Klein T.**

» Historic sites

NatLab, Eindhoven, The
Netherlands **Beijerinck H.C.W.**

Piersanti Mattarella, Tower of Thought -
Erice, Sicily, Italy **Duff M.**

Reale Osservatorio Vesuviano, Herculaneum
(Naples), Italy **De Natale G.**

Uddmanska House, Kungälv, Sweden
Heinz A.M., Jonson B. and Pázsit I.

» Highlights

48/1 • 13 summaries • p. 09-14

48/2 • 14 summaries • p. 06-11

48/3 • 11 summaries • p. 08-12

48/4 • 08 summaries • p. 08-11

48/5&6 • 12 summaries • p. 12-18

» Features

A brief tour of the climate machine
1 - The Climate machine, a two fluids
thermal engine **Poitou J.**
2 - Environment shapes
the climate **Poitou J.**

A Tribute to Manne Siegbahn **Kubbinga H.**

“Boiling the vacuum”: *in silico* plasmas under
extreme conditions in the laboratory
and in astrophysics **Silva L.O.**

Britain's nuclear secrets: inside Sellafield
Marino A.

Can solar water-treatment really
help in the fight against water
shortages? **Fernández-Ibañez P.,**
McGuigan K.G. and Fatta-Kassinos D.

Can we afford to wait? Designing the
collider of the future **Benedikt M.**
and **Zimmermann F.**

Data Analysis: a (not so) silent revolution
von Toussaint U.

Glass transition at interfaces
Salez T., McGraw J.D., Dalnoki-Veress
K., Raphaël E. and Forrest J.A.

Gravitational Physics: the birth
of a new era **Sakellariadou M.**

Ion Coulomb crystals: from quantum
technology to chemistry close to the
absolute zero point **Dulieu O.**
and **Willitsch S.**

Mechanics-based mathematical studies
proving spontaneity of post-impact
WTC towers collapse **Le J.-L. and**
Bažant Z.P.

Miazma: physics edutainment through
a computer game **Fülöp Zs., Biri S.**
and **Lévai G.**

Nature's engines: active matter **Yeomans J.M.**

PISA testing – a global educational
race? **Sjøberg S.**

Properties of nuclei probed by laser light
Neugart R.

Redressing the inverted pyramid
of scientific publishing **Caux J.-S.**

Slippery and never wet **Backholm M.,**
Timonen J.V. I. and Ras R.H.A.

Stella Lux: the energy-positive
family car **Selten T.**

The NuPECC Long Range Plan
2017: Perspectives in Nuclear
Physics **Bracco A.**

Where is transportation going?
Crabtree G., Kocs E. and Tillman B.

» Inside EPS

Call for Nominations, President-elect • 48/4 • p.05

EPS directory • 48/4 • p.29

EPS gears up for 50th Anniversary **Lee D.**

Highlights from EPS Council • 48/3 • p.04

» Letter

Letter to the Editors **Kundt W.**

» Obituary

Alexei Abrikosov (1928-2017)
Mukhin S., Varlamov A. and Buzdin A.

In memoriam: Prof. Alfred Zawadowski
Sólyom J. and Zaránd G.

In memoriam: Prof. em. Dr. Ernst Heer
Pohl M., Ferdinande H. and Sauer P.

» Opinion

Trump, climate change and the EPS
van der Steenhoven G.

Why should one become involved in EPS
Young Minds? **Ritzmann U.**

» Physics and Society

International Day of Women and Girls
in Science **Bosman M.**

Research Ethics and Research Integrity –
Why it matters **Saunders F.**

The remake of an iconic photo **Cifarelli L.**

» Physics in daily life

Fascinating friction **Hermans L.J.F. (Jo)**

Travel with hydrogen **Hermans L.J.F. (Jo)**

» Prizes - Awards - Medals

Nobel prize in physics
2017 **Sakellariadou M.**

» Report

Dieter Meschede becomes president
of the German Physical Society from 2018
to 2020 • 48/4 • p.07

Physics formulas on Leiden walls
Hermans L.J.F. (Jo)

» Research

Inauguration and first beam of PSI's X-ray
FEL SwissFEL **Braun H.H.**

Pioneering SESAME light source circulates
first beam **Formosa-Gauci C.**

Pioneering SESAME light source officially
opened • 48/3 • p.07

EPJ Web of Conferences

Open access conference proceedings
in Physics and Related Sciences

A flexible, fast and efficient
publication service,
for an **open access recording**
of your event
and a **wide dissemination** of
your proceedings

EPJ.org



your physics journal

www.epj-conferences.org

edp open Open Access Publishing
from **edp** sciences



Open Access publishing from EDP Sciences



**A world of opportunity
with EDP Open**

At EDP Open we publish a growing suite of international high quality Open Access journals and partner with learned societies, publishers and academics to create opportunities from Open Access.

www.edp-open.org

Your Open Access partner