

europhysicsnews

THE MAGAZINE OF THE EUROPEAN PHYSICAL SOCIETY

Physics in daily life: the lustre of pearls
First result from the AMS experiment
Does water foam exist in microgravity?
Symmetry of quasi one-dimensional systems
Climate change: can we afford to wait longer?

45/3
2014

Volume 45 • number 3
European Union countries price:
100€ per year (VAT not included)



edp sciences

Built for Science. Rock Solid Performance.



Lock-In Amplifiers That Take You Further



Designed for pioneering science

When you're pushing back the frontiers of knowledge, you need the best available instrumentation. We went the extra mile in designing our 50 and 600 MHz models with fully digital signal processing to give you top performance.

Streamlined, efficient and unique to you

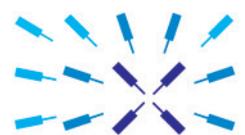
With multiple functions fully-integrated in a single elegant box, your setup complexity and everyday hassles are significantly reduced. And the powerful, intuitive graphical user interface keeps things simple – or program it the way you want, in the language of your choice.

Publish sooner, publish better

All this adds up to highly precise results, an increase in your publication rate and important steps forward for science. Discover more at www.zhinst.com.

[Your Application. Measured](#)

www.zhinst.com



Zurich
Instruments



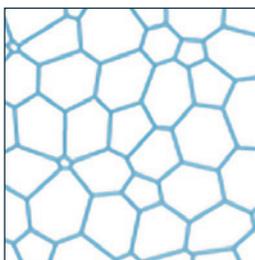
euromphysicsnews

Cover picture: Foam on a surface of water © iStockPhoto.
See “does water foam exist in microgravity?” p. 22



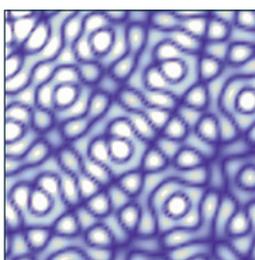
▲ PAGE 17

First result from the AMS experiment



▲ PAGE 22

Does water foam exist in microgravity?



▲ PAGE 27

Symmetry of quasi one-dimensional systems

EPS EDITORIAL

- 03 A Brussels voice for physics // J. Dudley

NEWS

- 04 Historic sites: National Physical Laboratory
06 EPS Accelerator Group Prizes 2014
08 The 2nd international symposium “Experiments in high school physics teaching”

HIGHLIGHTS

- 09 COMPASS: Radiative widths of the $a_2(1320)$ and $\pi_2(1670)$
All paths lead to Rome, even in condensed matter theory
Electrical asymmetry effect in capacitively coupled plasmas
10 Low-dimensional analogue of holographic baryons
Plasma tool for destroying cancer cells
11 Football displays fractal dynamics
Échelon cracks in soft solids
A unified approach for extrinsic loss in optical waveguides
12 Scaling up renewable energy
Making the most of carbon nanotube-liquid crystal combos
13 Spin flip in ionization of highly charged ions
Spin waves in nanowires with step-modulated thickness
14 Topological quantum phase transitions
Toward ultra-cold ion-atom chemistry

FEATURES

- 14 Physics in daily life - The lustre of pearls
T. Klein
17 First result from the AMS experiment: the beginning of a rich cosmic ray program
M. Pohl
22 Does water foam exist in microgravity?
H. Caps *et al.*
26 Crossing borders - Pride and prejudice
H.C.W. Beijerinck
27 Symmetry of quasi one-dimensional systems: line groups and applications
M. Damjanović
31 Letter - Physics and theology?
S. Holst

OPINION

- 32 Opinion - Climate change: can we afford to wait longer? // C. Rossel

Journal of Space Weather and Space Climate

SOHO (ESA/NASA), Cyril Simon Wedlund (FMJ)

A link between all communities interested in Space Weather and Space Climate including (but not limited to) solar, space, planetary and atmospheric scientists and engineers, forecasters...

An international peer-reviewed multi-disciplinary open access journal for scientists and engineers

Impact Factor Indexed in ISI Thomson Reuters JCR®

www.swsc-journal.org

OUR STATE OF THE ART ARPES SYSTEM MBS A-1 SYS GIVES YOU THE SOLUTION!

Launched Products

Sub-meV ARPES System: MBS A1SYS **NEW!**

Sub-meV PES analyser: MBS A-1

Super Intense Low Energy Photon Source:

MBS T-1

He lamp: MBS L-1

Spin detector: MUSPIN etc.

For Detailed Information **Please Contact Us:**

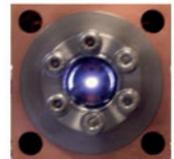
MB SCIENTIFIC AB



MBS T-1

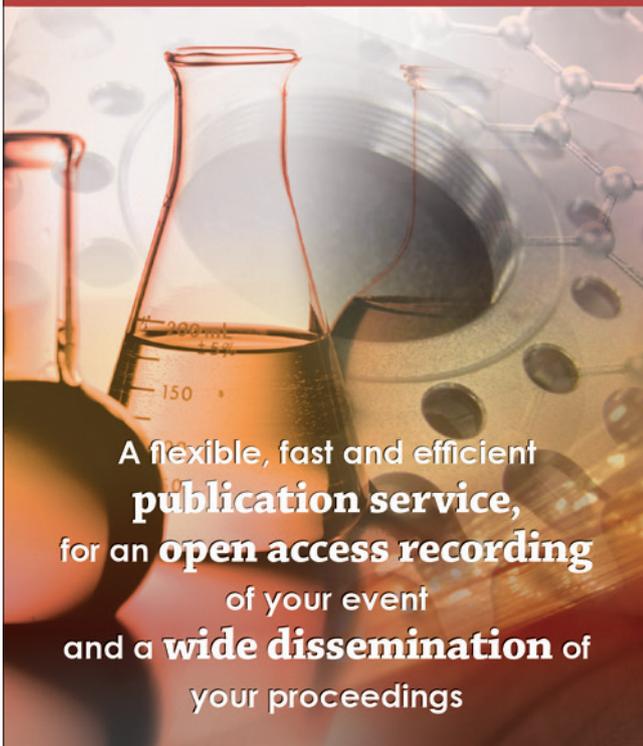
Seminariegatan 29B,
SE-752 28, Uppsala,
SWEDEN
Tel: +46 18 290960
Fax: +46 18 572683

info@mbscientific.se
www.mbscientific.se



MATEC Web of Conferences

Open access conference proceedings in Materials science, Engineering and Chemistry



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

3rd Scientific Writing for Young Astronomers

Tihany, Hungary, August 24-28, 2014

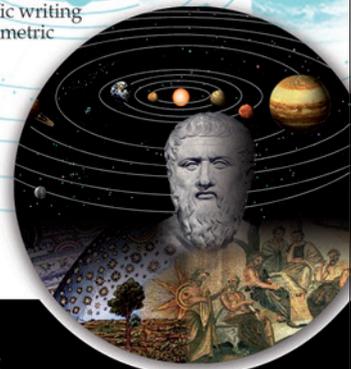
About the school

The purpose of organising an «Astronomy and Astrophysics School» is to teach beginning PhD Students how to express their scientific results through correct and efficient science writing. In other words: how to write scientific papers for different forums (journals, proceedings, thesis manuscripts, ethical aspects of scientific writing, etc.).

Lectures will be presented on:

- The Editorial Office and the Editors
- The Publisher as a service provider
- Refereed and non-refereed journals, ISI and non-ISI, etc.
- The Journal A&A
- The writing process
- Technical aspects of scientific writing
- ADS, CDS, and other bibliometric databases
- Libraries, library services and librarians
- Policies of astronomical societies
- etc.

The School is open to PhD students and young postdocs



Contact:
swya@edpsciences.org



[EDITORIAL]

A Brussels voice for physics

The European Physical Society recently held its 2014 Council at the International Centre for Theoretical Physics (ICTP) in Trieste. Councils are always busy times with many reports of the preceding year to look over and endorse, but the 2014 Council had a very forward looking agenda, as we focussed on a number of future developments: plans for the International Year of Light in 2015; the approval of an ambitious project to establish an EPS Supplementary Secretariat in Brussels; and the election of a new President-Elect!

Let me begin by offering my heartiest and sincere congratulations to Christophe Rossel who was elected to serve as the next EPS President from April 2015. Christophe has made pioneering contributions to the fields of experimental superconductivity and magnetism, and his career as a scientist working at IBM in Zurich will bring a unique perspective to how to better engage EPS with industry. Chris has worked for and supported EPS in many ways over many years, and his experience will be invaluable as we move forward to address many new challenges in the years to come.

One particular challenge is of course how to improve the broader visibility of physics, since this is crucial for the future of our discipline, and is vital in order that we continue to attract the best young minds to study physics at schools and universities. Of course this problem is well-known, and has been discussed within EPS for many years. In 2010 when the EPS Strategy Plan 2010+ was crafted, an important element of a solution to this problem was identified as an effective presence in Brussels to engage with decision-makers and other political stakeholders. Now, after detailed planning over the last twelve months, Council approved the project and business plans that will allow EPS to open a Supplementary secretariat to carry out this essential mission.

Providing a clear voice for physics to the European Commission will of course be the primary aim of the Brussels secretariat. By linking with other professional and scientific bodies in Brussels, as well as key players from the Commission including research, innovation, industry, and entrepreneurship, EPS will promote the need for continued investment in physics as a discipline, and recognition of the central role of physics in underpinning many areas of technology. A presence in Brussels will also ensure more efficient communication of calls and deadlines to all EPS members, and advance notice of policy initiatives on the European level that may have influence on national trends as well.

Providing a clear voice for physics to the European Commission will of course be the primary aim of the Brussels secretariat.

The next 18 months are really a unique chance for physics, with the extra and unique visibility that physics will have naturally during the International Year of Light, the first phases of Horizon 2020, and the natural momentum from the opening of the Brussels secretariat. EPS staff in Brussels will aim to be at the service of all EPS member societies and members in many ways such as supporting meeting organisations, arranging introductions, and facilitating partner searches for projects. But an effective voice of EPS in Brussels, however, must be the voice of all EPS members. As with all of EPS's activities, it is up to you to get involved! ■

■ **John Dudley**
President of the EPS



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/publications

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

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

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

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

Director of Publication: Jean-Marc Quilbé

Editorial Advisory Board:
Gonçalo Figueira (PT), Guillaume Fiquet (FR), Adelbert Goede (NL), Agnès Henri (FR), Martin Huber (CH), Robert Klanner (DE), Peter Liljeroth (FI), Malgorzata Nowina Konopka (PL), Mirjana Popović-Božić (RS), Stephen Price (UK), 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 Courtabœuf
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 2014 print version subscription prices available through EDP Sciences (Prices include postal delivery cost).

Institutions - European Union countries: 100 € (VAT not included, 20 %). **Rest of the world:** 119 €

Student - European Union countries: 47.50 € (VAT not included, 20 %). **Rest of the world:** 57 €

Contact: EPN Europhysics News • BP 95 • 92244 Malakoff Cedex • info@route66-agence.com or visit www.edpsciences.org

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

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

Dépôt légal: June 2014



EPS HISTORIC SITES

National Physical Laboratory

Hampton Road, Teddington, Middlesex, UK

Celebrating the Birthplace of Atomic Timekeeping

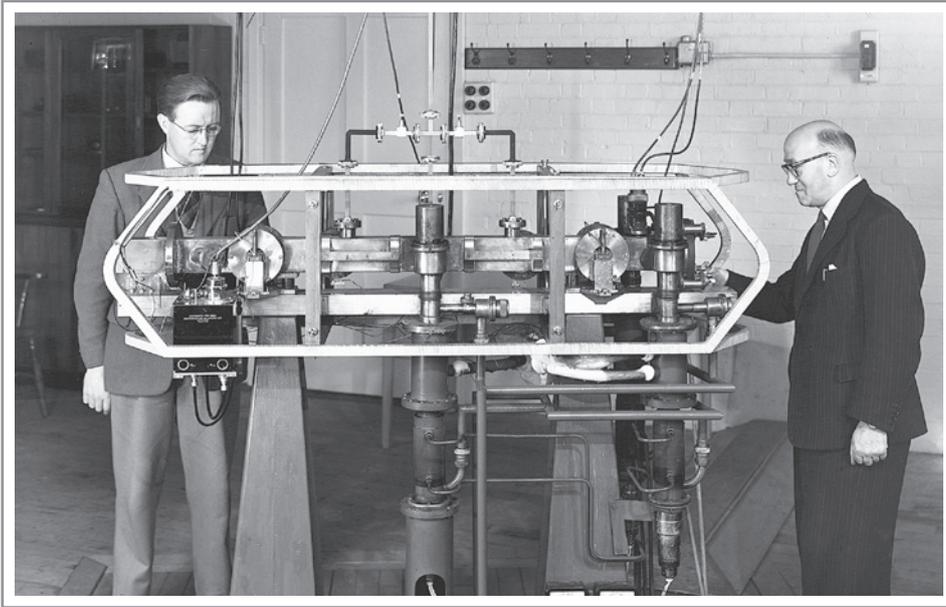
The UK National Physical Laboratory (NPL) has been officially declared a site with international significance to physics when it received the European Physical Society (EPS) 'Historic Site' Award on 31 January 2014 as the birthplace of atomic timekeeping.

The award recognises NPL as the location where the first practical atomic clock was built in 1955 by Louis Essen with support from fellow physicist, 'Jack' Parry. It was a landmark that has changed global timekeeping and made modern communications and location services possible.

About 120 people were present at the award ceremony held at the NPL site in Teddington, England. Guests included members of the Essen family and Denis Sutcliffe who worked with Louis Essen on the development of atomic clocks in the 1950s. Dr Brian Bowsher, Managing Director of NPL, gave an introduction outlining NPL's current scientific research. Dr Bowsher said: 'Being recognised by the EPS is an honour and is testament to the work of our current, as well as our past, scientists. Although invisible, atomic time has impacted the lives of all of us. What's more, ground-breaking developments continue to be made in this field, with

▼ Peter Knight and John Dudley in front of Historic Site plaque.





▲ First
Caesium-Beam
Atomic Clock

a new generation of atomic clocks on the horizon that could provide everything from improved satellite navigation systems to more sensitive tests of fundamental physical theories.'

Following Dr Bowsher's opening remarks, Professor John Dudley, President of the EPS, and Professor Sir Peter Knight FRS, former NPL Chief Scientist, unveiled a plaque which records that NPL is home to 'the world's first atomic clock to keep time better than the Earth's rotation.' It also acknowledges the current world-class research in time measurement being done at the NPL.

Professor Dudley said: 'NPL is justly recognised as a historic site. Essen's work here, as well as that of many other leading scientists, has benefited the lives of all Europeans by providing the precision of timing required for applications such as advanced telecommunications, navigation and defence systems.'

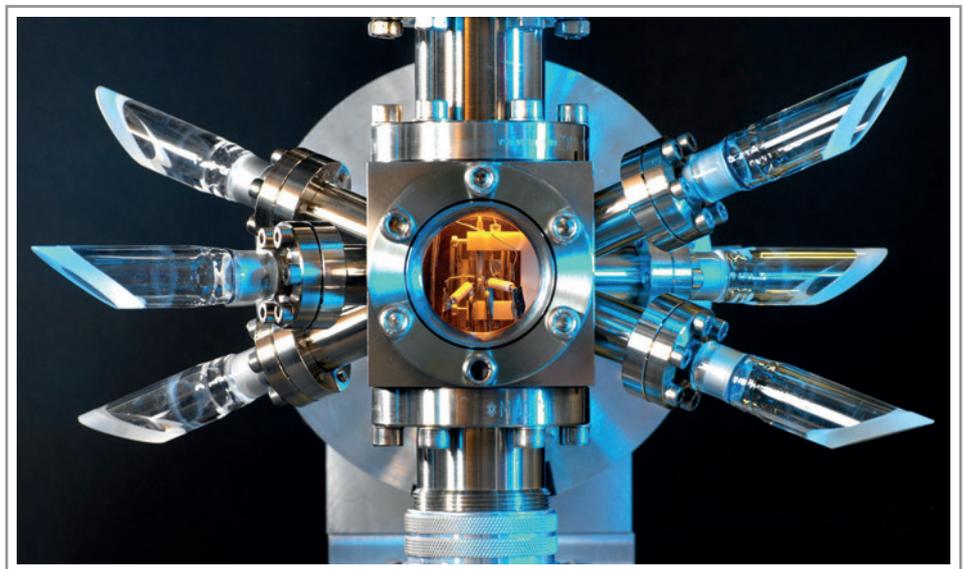
After the unveiling, a talk: NPL Time - Past, Present and Future was given by Ray Essen, son-in-law of Louis Essen, along with Professor Patrick Gill, Head of Time at the NPL. Ray covered the early part of Louis Essen's work and Patrick brought everything up to date.

The first atomic clock had an astonishing accuracy for its day and this allowed astronomers to measure perturbations in the earth's rotation

too small to be previously observed. Since then, developments in atomic clocks have been rapid and sustained - both in terms of size and accuracy. Commercially available atomic clocks are now available as chip-level components. As to accuracy, the first clock was about 1 part in 10^{10} whereas today's atomic clocks have an accuracy approaching 1 part in 10^{16} . A new service to provide time over optical fibre links to financial institutions, telecoms companies and other organisations that need accurate timing is currently being rolled out by the NPL.

After lunch guests were invited to hear Dr Leon Lobo and Peter Whibberley talk about NPL Time and Time

▼ Strontium
Ion Optical
Atomic Clock



Standards and to have a laboratory tour. In each location NPL staff were on hand to explain their latest research activities. In the National Time Scale section one could see a hydrogen maser that was the master clock and a rack of commercial atomic clocks, plus all the associated monitoring and distribution equipment. Another room housed the caesium fountain clock, the most accurate long-term timekeeper in the world. Against it is checked the hydrogen maser that generates the UK national time and frequency standard. Further along the corridor was an esoteric array of electronics and optics. This was the optical atomic clock, the leading-edge development of time measurement, potentially so accurate that the second might have to be re-defined in the future. Finally there was the femtosecond comb - a novel means to check an existing atomic clock or frequency against the new super-accurate optical ion atomic clocks.

The NPL is preparing for its biennial Open House on 20 May. EPS members may also be interested in reading *The Birth of Atomic Time*, which includes the complete memoirs of Louis Essen, to be published by Ray Essen in 2015 to coincide with the 60th anniversary of atomic timekeeping. ■

■ Ray Essen,

Son-in-law of Louis Essen

European Physical Society – Accelerator Group Prizes 2014

The EPS-Accelerator Group announced the laureates of the Rolf Wideröe Prize, the Gersch Budker Prize and the Frank Sacherer Prize. These prizes are awarded every three years for exceptional work in the accelerator field.

The **Rolf Wideröe Prize** for “outstanding work in the accelerator field without age limit” is awarded to **Professor Mikael Eriksson**, Accelerator Director of the Max-IV Laboratory, Lund, Sweden.

Professor Eriksson understands accelerator physics from the ground up. For more than four decades he has been the driving force behind the design, construction, commissioning and performance of all MAX-lab synchrotron radiation sources, from MAX I to MAX IV. With outstanding skill he has introduced simple but innovative designs and provided the technological solutions leading to their final implementation, with cutting edge performance. His special approach has brought improvement and added-value solutions, frequently challenging conventional wisdom, proposing industrial linacs as injector drivers for an FEL, or cheaper RF systems taken from mass production for other accelerators.

This enables the MAX-lab accelerators to provide users with “state-of-the-art” performance while optimizing value-for-cost. The innovations introduced by Professor Eriksson have had a substantial impact in the field of synchrotron radiation sources worldwide. The MAX IV 3 GeV storage ring design and technological implementation is paving the way for a new generation of extreme low-emittance “ultimate storage rings” for the achievement of diffraction-limited radiation sources.

Many synchrotron radiation facilities worldwide are being built or upgraded using this scheme.

In addition Professor Eriksson has served on several Machine and Scientific Advisory committees around the world. His participation has always been much appreciated and our community has profited deeply from his experience. Professor Eriksson has also devoted an important part of his time to teaching accelerator physics to students at Lund University. Many of them today play a major role in different accelerators around the world, demonstrating Professor Eriksson’s outstanding impact on the dissemination of Accelerator Science.

The **Gersch Budker Prize** for “a recent significant, original contribution to the accelerator field, with no age limit,” is awarded to **Professor Tsumoru Shintake**, Okinawa Institute of Science and Technology Graduate University, Okinawa, Japan.

Professor Shintake has led the construction of the SACLA X-Ray FEL based on novel C-Band technology in the RIKEN SPring-8 Center. The 400 m long SACLA linear accelerator, with accelerating gradients of 35 MV/m, provides 8 GeV beams with extreme energy stability better than 0.014%. Professor Shintake contributed to all aspects of the project including the



Mikael Eriksson
Lund, Sweden



Tsumoru Shintake
Okinawa, Japan

electron source, the C-Band linac and the undulator alignment. His visionary choice of a thermionic gun, with CeB₆ single crystal as cathode material, has proven to be successful in terms of emittance and stability. The first lasing of the FEL in June 2011 was the crowning achievement of numerous technological developments, and was also made possible by the successful industrialization of the C-band technology, developed from scratch. The C-band high gradient accelerator is now running stably to drive beams of low emittance electrons created by a thermionic electron source, making it possible to generate stable X-ray radiation. SACLA's novel light is expected to resolve questions in science, technology and industry, by helping to understand structure and function at the atomic level. Last but not least, Professor Shintake's numerous highly innovative ideas strongly influenced the progress and development of many areas of accelerator physics and technology over the past decades, including a beam size monitor for nanometer sized beams now called the "Shintake Monitor".

The **Frank Sacherer Prize**, for "an individual in the early part of his or her career, having made a recent significant, original contribution to the accelerator field," is awarded to **Dr Agostino Marinelli**, SLAC, USA.

Among many significant contributions in a relatively short career to date, Dr Marinelli is particularly well known for his innovative work on developments of techniques that significantly improve parameters of free electron lasers such as their spectrum and longitudinal coherence. Dr Marinelli's talents as both a theorist and an experimentalist have been demonstrated in the analysis and verification of the gain modulated FEL, a novel concept to generate two or more colors from one electron bunch – a technique that enables a new class of FEL experiments. Dr Marinelli has contributed to many other developments that are valued by the community, in particular the use of single-shot optical transition radiation diagnostics for the reconstruction of the transverse spatial structure of beam micro-bunching, the development of a kinetic model that led to the discovery of the existence of an emittance-induced anisotropy in the propagation of longitudinal plasma waves in a beam, and other techniques that have had a tremendous impact on the design of

fourth-generation linac-driven coherent light sources. In a short time, Dr Marinelli has risen to prominence as one of the most ingenious accelerator scientists at SLAC, with a highly promising research career in front of him.

The prizes will be awarded during the 5th International Particle Accelerator Conference, to be held in Dresden, Germany, from 15 to 20 June 2014. ■



[Sensofar]

New: Confocal Interferometric AND Focus Variation



Sensofar S neox for research and industry

- ⊙ Confocal, Interferometer and Focus Variation modes in the same instrument
- ⊙ Superposed high resolution color and height images
- ⊙ Roughness according ISO 25178
- ⊙ Vertical resolution down to 0.01 nm
- ⊙ Long working distance objectives

We also supply

AFMs for research, industry and teaching
Nano-/Micro- Indenter and Tribology Tester,
Nanoparticle size measurement,
LEED/AES, Stylus Profiler



Contact your nearest office

Germany	info@schaefer-tec.com +49 6103 300 980
France	info@schaefer-tech.com +33 1 6449 6350
South + East Europe	see@schaefer-tec.com +39 0425 272 28
Switzerland	ch@schaefer-tec.com +41 34 423 7070

www.schaefer-tec.com

The second international symposium “Experiments in high school physics teaching”

- Teachers for teachers - Aleksinac, Republic of Serbia, February 21st to February 23rd, 2014.

After the successful Symposium “The position of physics in secondary schools in the region”, held in Aleksinac (Serbia) from 1st - 3rd February 2013, a similar, but much larger meeting was recently held there.



The Symposium “experiments in high school physics teaching” (21-23 February 2014) was organized by: Association of physicists Niš, Agricultural School “Sumatovac”, Gymnasium and Technical School “Prota Stevan Dimitrijević” and the Union of Physics Teachers of Aleksinac, in cooperation with Physical Society Nis and the SPS division for Nisava district. General sponsor of the symposium was the Municipal Assembly of Aleksinac. There were 115 participants from FYR Macedonia, Montenegro, Republic of Srpska - Bosnia and Herzegovina, Croatia, Slovenia, Bulgaria, Serbia, Germany and Hong Kong.

The Symposium was opened by local authorities Nenad Stankovic and Slavoljub Velickovic and partners from Nis Mr. Dragoljub Dimitrijević. The main program was led and contributed by Prof. Jablan Dojcilović (Faculty of Physics Belgrade), Prof. Dragoslav Nikezic (Faculty of Sciences Kragujevac), Academician Tomislav Pavlovic and Prof. Ljubisa Nesic (Faculty of Sciences Nis), Prof. Nadezda Novakovic (State University of Novi Pazar), Prof. Bozidar Vujicic (University of Novi Sad), Prof. Mara Scepanovic and Prof. Mira Vučeljić (University of Podgorica, Montenegro).

Teachers from 7 countries in the region could follow lectures and presentations on a wide range of modern physics, experimental techniques, tools and pedagogical innovation: Renewable energy sources, School experiment in physics teaching, Modern educational technology in the teaching of physics, The detection of infrared radiation, Monte Carlo simulations, and Achievements of high school students on tests of conceptual mechanics. Short presentations were given by M. Babic (Republic of Srpska – Bosnia and Herzegovina), Dr. S. Ivkovic and J. Milisavljević (Belgrade).

Prof. Goran Djordjevic (University of Nis, Serbia), welcomed all participants, as a member of the ExCom EPS and vice-president of Balkan Physical Union on behalf of these organizations. He gave a lecture “Nobel Prize in Physics for the year 2013 - experimental techniques in the background of Higg`'s boson discovery”. Information on the forthcoming projects partially prepared by the EPS Committee of European Integration chaired by him, as well as an invitation to all teachers to join its action were delivered. The lecture “Education of the 21st century; the necessary

transformations of the teaching process”, was given by Dr. Zvezdan Curcic (Hong Kong) via video link.

On the third day of the Symposium there was a round table dedicated to the importance of the experiment in high-school physics teaching. Slavoljub Radulovic, professor of physics in Aleksinac High School, was the Moderator and almost all invited lecturers took part in it.

The format and scope of this year’s symposium, widely seen as great ideas, will be remembered as useful and attractive innovations. A competition for the best small home experiment was prepared by the Organizing Committee of the Symposium. Eleven experiments were selected out of 30 applications received. After their demonstration the top three, P. Goseva (Valandovo, FYR Macedonia), M. Ristic (Kladovo, Serbia) and V. Djordjevic (Aleksinac), were awarded. All students received copies of “Young Physicist” Journal. An exhibition of teaching aids and books with the presence of several companies from Berlin, Hamburg (Germany), Belgrade and Novi Sad (Serbia) was held. All participants found the symposium very well organized and look forward to its third edition. ■

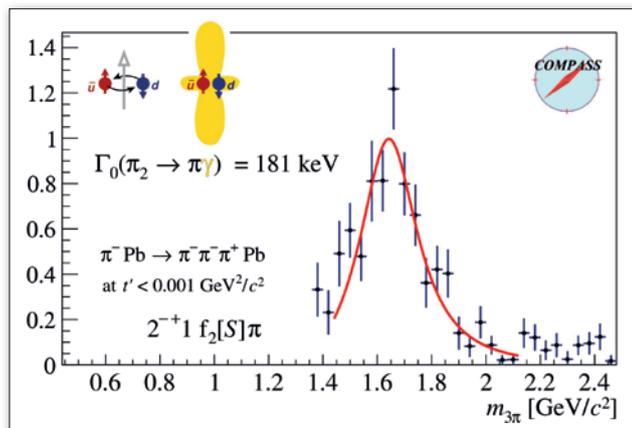
Highlights from European journals

NUCLEAR PHYSICS

COMPASS: Radiative widths of the $a_2(1320)$ and $\pi_2(1670)$

Radiative transitions are among the most important and insightful processes for the investigation of atomic, nuclear and hadronic systems. They reveal the electromagnetic substructure of the involved particles. The $a_2(1320)$ meson is known since the 1980s to decay radiatively with a branching of about 0.3% into a pion and a photon. Theoretically this can be linked, for example through the vector meson dominance model, to the main hadronic decay channels.

Experimentally, it is difficult to observe rare decays involving a single photon directly, over an abundant neutral pion background. The way out is to measure the reverse process, the production of the resonance in a pion-photon collision.



▲ Intensity of the 2^+ partial-wave in $\pi^- \gamma \rightarrow \pi^- \pi^+ \pi^0$, interpreted as radiative width of the $\pi_2(1670)$

The COMPASS experiment at CERN has taken high-statistics data of pion-nucleus collisions $\pi^- \text{Pb} \rightarrow \pi^- \pi^+ \pi^0 \text{Pb}$ of which the photon-exchange contribution, so-called Primakoff scattering, was singled out. The radiative coupling of the $a_2(1320)$ resonance was determined with unprecedented precision, employing partial-wave analysis of the three-pion final state. The latter proved the radiative coupling of the 10-times less intensive $\pi_2(1670)$ resonance, $\pi_2(1670) \rightarrow \pi \gamma$, and made possible the first measurement of its radiative width. This challenges theoretical descriptions, that aim at linking this transition intensity to the inner structure of the $\pi_2(1670)$. ■

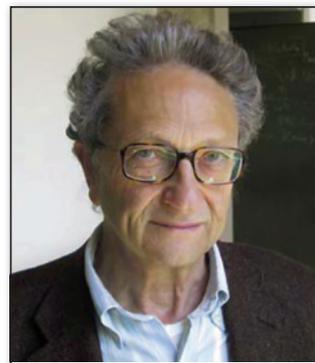
■ C. Adolph *et al.*,

'Measurement of radiative widths of $a_2(1320)$ and $\pi_2(1670)$ ', *Eur. Phys. J. A* **50**, 79 (2014)

HISTORY

All paths lead to Rome, even in condensed matter theory

The author shares his thoughts on the development of theoretical condensed matter physics in Rome from the 1960s until the beginning of this century.



▲ Carlo Di Castro.
© 2004 Humboldt Prize

This work presents his recollections of how theoretical condensed matter physics developed in Rome, starting in the 1960s. This was done in an interview in which the author reflects upon his research career.

He presents a unique, personal account of the evolution of these research fields since the 1960s. He relates the encounters he had

with those who would go on to become the next generation of condensed matter physicists and explains his involvement in setting up the 'Rome Group', an authority in his field, together with other members. ■

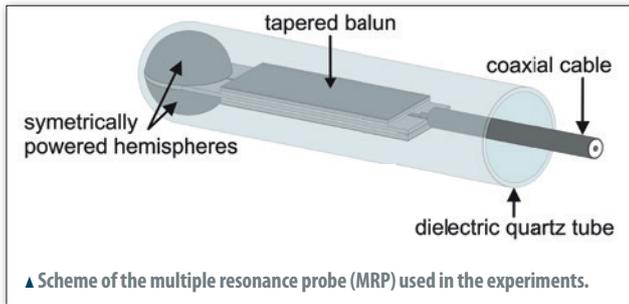
■ C. Di Castro and L. Bonolis,

'Personal remembrances of the beginnings of theoretical condensed matter physics in Rome', *Eur. Phys. J. H* **39**, 3 (2014)

PLASMA PHYSICS

Electrical asymmetry effect in capacitively coupled plasmas

In modern plasma applications an independent control of ion energy and ion flux is desirable to best meet process requirements. Using rf-plasma excitation at least two different frequencies need to be applied, which grants an independent modulation of ion flux and ion energy. By applying a fundamental frequency and at least one even harmonic, the relative phase shift between both frequencies directly influences the self-bias voltage. This effect is called the "Electrical Asymmetry Effect", since the absolute values of the minimum and maximum of the resulting waveform differ from each other depending on the relative phase shift. Using the Multipole Resonance Probe, a



constant electron density in the plasma bulk is determined over a wide range of applied relative phase shifts with constant voltage amplitudes of both frequencies. This directly leads to an ion flux towards the surface, which is independent from the relative phase shift, whereas the ion energy is set by the phase dependent self-bias voltage. Nevertheless, it is also shown, that this independent control is partly limited by self-excited harmonics in the process. ■

■ **S. Bienholz, T. Styrnoll and P. Awakowicz,**

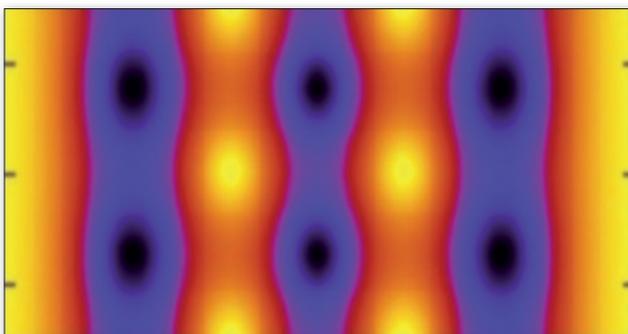
'On the electrical asymmetry effect in large area multiple frequency capacitively coupled plasmas', *J. Phys. D: Appl. Phys.* **47**, 065201 (2014)

FIELD THEORIES

Low-dimensional analogue of holographic baryons

Gauge/gravity duality provides a method to study various features of a large class of strongly coupled quantum field theories. A significant motivating application for these ideas is the physics of non-perturbative phases of Quantum Chromodynamics (QCD) and this is the subject of holographic QCD (HQCD). Within HQCD baryons are described by collective excitations, known as solitons, and the study of nuclei and dense QCD translates into the investigation of multi-soliton physics in a curved spacetime with an additional spatial dimension (the holographic direction). However, even computing the classical multi-soliton solutions is a difficult problem that has not yet been solved.

▼ A triple chain soliton solution at high density, displaying the baryonic popcorn phenomenon in the low-dimensional theory.



The authors introduce a low-dimensional analogue of holographic baryons, with the advantage that numerical computation of multi-solitons and finite density solutions is tractable. They find that many of the conjectured features of soliton physics in HQCD are realized in this model, including a series of transitions at increasing density (dubbed baryonic popcorn) where the soliton crystal develops additional layers in the holographic direction: a phenomenon that is expected to play a vital role in understanding the important issue of dense HQCD. ■

■ **S. Bolognesi and P. Sutcliffe,**

'A low-dimensional analogue of holographic baryons', *J. Phys. A: Math. Theor.* **47**, 135401 (2014)

PLASMA PHYSICS

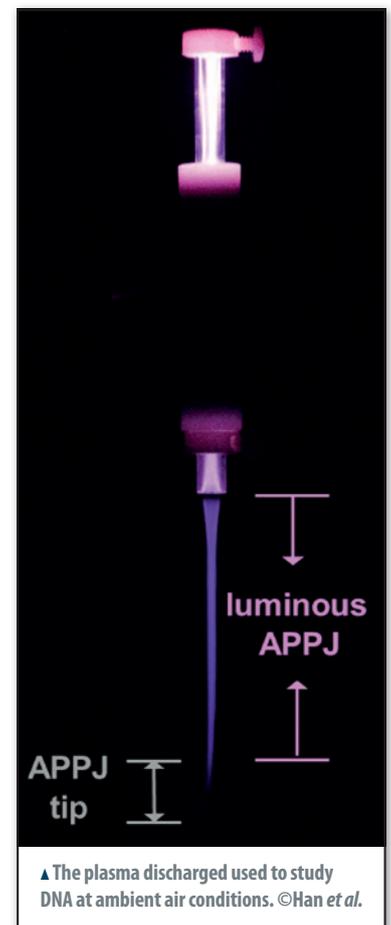
Plasma tool for destroying cancer cells

Inducing biological tissue damage with an atmospheric pressure plasma source could open the door to many applications in medicine.

The authors conducted a quantitative and qualitative study of the different types of DNA damage induced by atmospheric pressure plasma exposure. This approach, they hope, could ultimately lead to devising alternative tools for cancer therapy as well as applications in hospital hygiene, dental care, skin diseases, antifungal care, chronic wounds and cosmetics treatments.

To investigate the DNA damage from so-called non-thermal Atmospheric Pressure Plasma Jet (APPJ), the team adopted a common technique used in biochemistry, called agarose gel electrophoresis.

They studied the nature and level of DNA damage under two different conditions of the helium plasma source with different parameters of electric pulses.



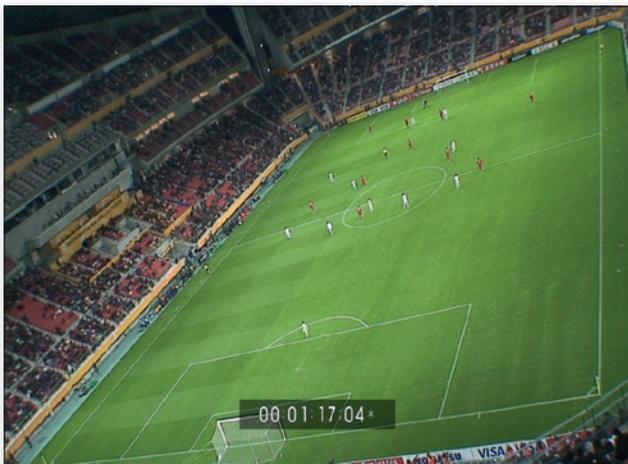
The next step would involve investigating plasma made from helium mixtures with different molecular ratios of other gases to increase the level of radical species, such as reactive oxygen species and reactive nitrogen species, known to produce severe DNA damage. These could, ultimately, help to destroy cancerous tumour cells. ■

■ **X. Han, W. A. Cantrell, E. E. Escobar and S. Ptasinska,** 'Plasmid DNA damage induced by Helium Atmospheric Pressure Plasma Jet', *Eur. Phys. J. D* **68**, 46 (2014)

STATISTICAL PHYSICS

Football displays fractal dynamics

Physicists reveal that the real-time dynamics in a football game are subject to self-similarity characteristics in keeping with the laws of physics, regardless of players' psychology and training.



▲ Players' and ball's positions captured on video. © Kijima *et al.*

Football fascinates millions of fans. Despite their seemingly arbitrary decisions, each player obeys certain rules, as they constantly adjust their positions in relation to their teammates, opponents, the ball and the goal. In this work the authors have now analysed the time-dependent fluctuation of both the ball and all players' positions throughout an entire match.

The authors considered two previous football matches. Thanks to their analysis of the time-series variation in the ball versus the front-line movements of the players, they were the first to discover that these dynamics have a fractal nature. This finding implies that the movement of the ball/front-line at any given time has a strong influence on subsequent actions. This is due to the so-called memory effect, linked to the game's fractal nature. ■

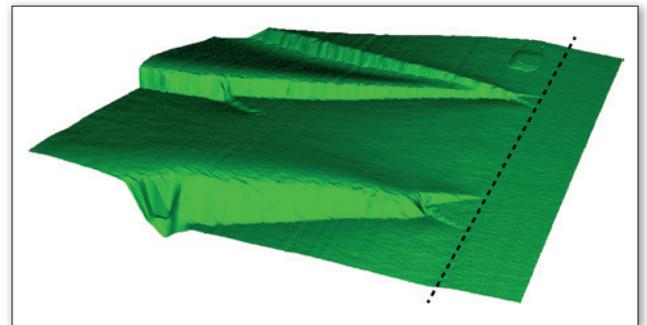
■ **A. Kijima, K. Yokoyama, H. Shima and Y. Yamamoto,** 'Emergence of self-similarity in football dynamics', *Eur. Phys. J. B* **87**, 41 (2014)

MATERIAL SCIENCE

Échelon cracks in soft solids

While under pure tension loading, crack surfaces are usually planar, whereas under superimposed shear they generally exhibit steps. Explaining the emergence of this ubiquitous instability remains a challenge in fracture mechanics. We study it here for a highly deformable solid (a hydrogel) and show that:

- échelon steps appear beyond a finite shear/tension threshold;
- contrary to linear elastic fracture mechanics predictions, they do not emerge homogeneously along the crack front via a direct bifurcation, but nucleate on local toughness/stiffness fluctuations. As such, the échelon instability continues the *cross-hatching* one, observed on soft solids under pure tension, here biased by shear loading.



▲ Stepped crack surface developing from a straight notch (dashed line).

We argue that this behaviour results from the controlling role of elastic non-linearity.

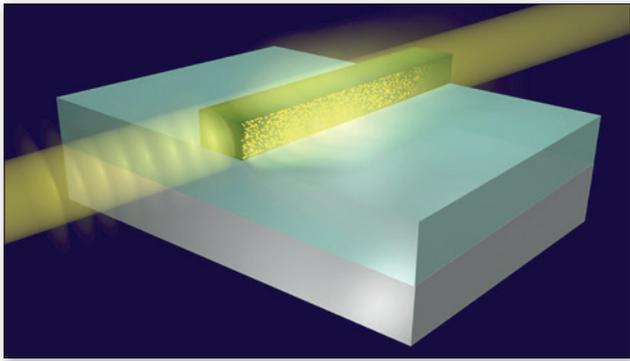
These results point to the importance of studying whether they remain relevant for stiffer materials, in order to assess the validity limit of the linear elastic approximation. ■

■ **O. Ronsin *et al.*,** 'Crack front échelon instability in mixed mode fracture of a strongly nonlinear elastic solid', *EPL* **105**, 34001 (2014)

OPTICS

A unified approach for extrinsic loss in optical waveguides

In real optical waveguides, fabrication tolerances cause the unavoidable appearance of sidewall roughness, that is a local and random deviation of the waveguide width from its nominal value. The interaction of the light propagating in the waveguide with sidewall roughness induces a coupling mechanism which transfers part of the optical power from the propagating mode(s) to other guided modes (propagating and counter-propagating) and radiative modes. Backscattered and radiated light result in what is usually referred to as extrinsic loss, which is typically the dominant loss contribution of optical waveguides.



▲ Roughness-induced radiative losses and backscattering in real optical waveguides.

In this paper, we formulate a novel unified vision for these roughness-related impairments (referred to as the n_w model), revealing for the first time that, given the roughness properties at the waveguide interface, both backscattering and radiative losses depend only on the sensitivity of the mode effective index to waveguide width perturbation. This result finds general application to both 2D and 3D waveguide structures and is not related to any particular technology or waveguide shape. Further, it provides a key instrument for a deeper understanding of roughness-induced scattering as well as simple design rules for the mitigation of waveguide extrinsic loss. ■

■ **D. Melati, F. Morichetti and A. Melloni,**

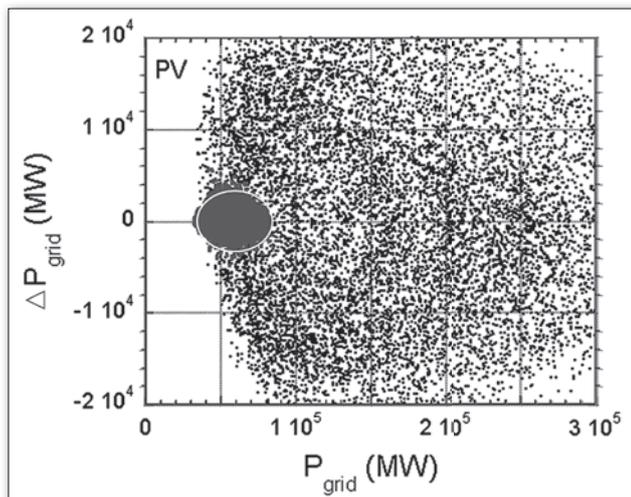
'A unified approach for radiative losses and backscattering in optical waveguides', *J. Opt.* **16**, 055502 (2014)

ENERGY

Scaling up renewable energy

A new study focuses on the feasibility of scaling up renewable energy to cover the needs of a country the size of Germany.

▼ Power increments of the grid measured every 15 minutes, against the initial grid power for solar power.



Can renewable energy adequately supply the power grid, despite its intermittent nature? This is the key question in a new study presented in this work. It outlines the key issues associated with the use of renewable energy on a large scale.

The author scaled the 2012 German national grid data—including wind (8%) and solar sources (4.8%) contributions—in such a way that renewable energy constitutes a larger than actual share of electricity production, reaching up to 100%, thus covering the country's yearly electricity needs. The power infrastructure would have to deliver three times the energy load at peak use.

This leads to excess power production, sometimes incurring negative demand-led prices when supply significantly exceeds demand. This setup still requires backup power from thermal power plants to cover periods of low wind and solar energy production. ■

■ **F. Wagner,**

'Electricity by intermittent sources: an analysis based on the German situation 2012', *Eur. Phys. J. Plus* **129**, 20 (2014)

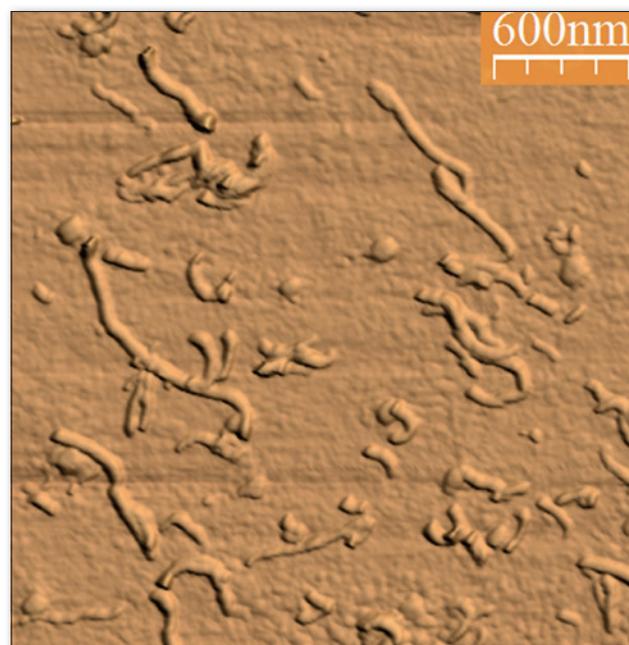
MATERIAL SCIENCE

Making the most of carbon nanotube-liquid crystal combos

A better understanding of the physical response of combination materials made of nanotubes with ferroelectric liquid crystals could soon open the door to applications as sensors or switches.

This work focuses on the influence of temperature and nanotube concentration on the physical properties of such

▼ Dispersed multi-wall carbon nanotubes on a glass surface. ©Yakemseva *et al.*



combined materials. These findings could have implications for optimizing these combinations for non-display applications, such as sensors or externally stimulated switches, and novel materials that are responsive to electric, magnetic, mechanical or even optical fields.

In this study, the authors focused on the electro-optic and dielectric properties of ferroelectric liquid crystal-multiwall carbon nanotube combinations. Specifically, they studied the influence of temperature on the compound material's main physical properties. They found that all dispersions exhibit the expected temperature dependencies with regard to their physical properties.

They also investigated the dependence of physical characteristics on nanotube concentration, which is still the subject of several contradicting reports. For increasing nanotube concentration, they observed a decrease in tilt angle, but an increase in spontaneous polarisation. ■

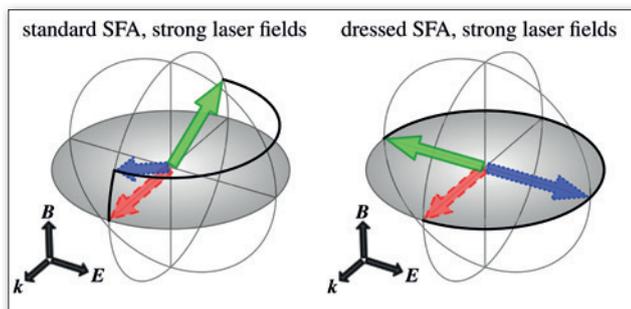
■ **M. Yakemseva, I. Dierking, N. Kapernaum, N. Usoltseva and F. Giesselmann,**

'Dispersions of Multi-wall Carbon Nanotubes in Ferroelectric Liquid Crystals', *Eur. Phys. J. E* **37**, 7 (2014)

ATOMIC AND MOLECULAR PHYSICS

Spin flip in ionization of highly charged ions

How does the electron's spin evolve during atomic ionization in a strong laser field? A new theoretical result obtained by the authors shed light on this relativistic quantum phenomenon. It was shown that even if an electron is very tightly bound by



▲ The qualitatively different behaviour of spin in strong laser fields, within SFA (left) and the proposed theory (right). Spin effects in the tunneling regime of ionization are built up in three steps: spin precession in the bound state, during tunneling, and during the motion in continuum. Only the last two steps are included in SFA. The red, blue and green arrows indicate the initial spin, the spin after the tunneling, and the final spin, respectively. The spin quantization axis is along the laser propagation direction."

the strong Coulomb field in a highly charged ion, the spin dynamics may still be crucially affected by a strong laser field of relatively moderate intensity, see figure. This effect is beyond the commonly accepted Strong-Field-Approximation

(SFA) and can be confirmed in a challenging experiment employing collisions of highly charged ions with ultra-strong laser beams. ■

■ **M. Klaiber, E. Yakoboylu, C. Müller, H. Bauke, G.G. Paulus and K.Z. Hatsagortsyan,**

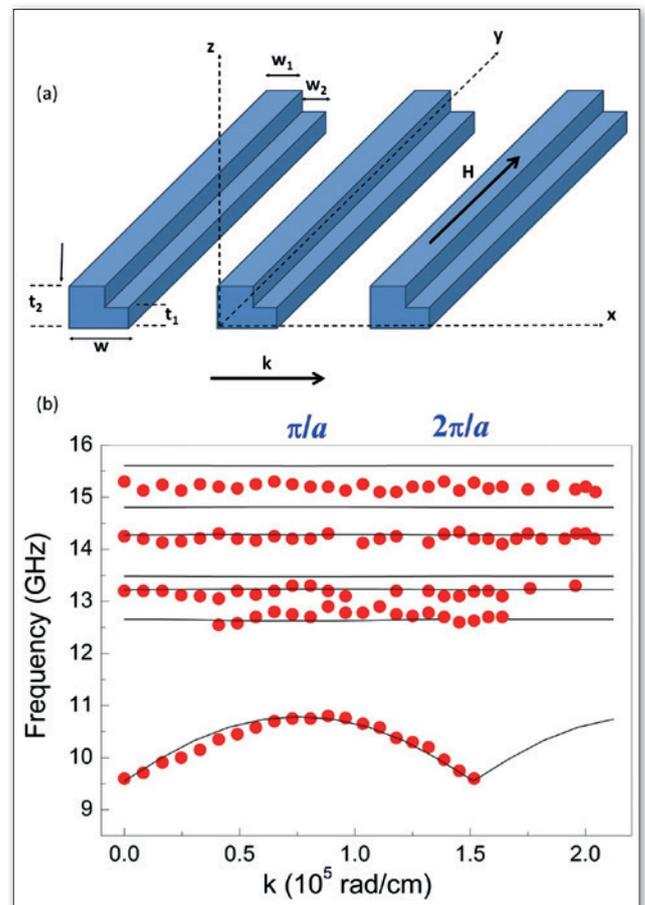
'Spin dynamics in relativistic ionization with highly charged ions in super-strong laser fields', *J. Phys. B: At. Mol. Opt. Phys.* **47**, 065603 (2014)

APPLIED PHYSICS

Spin waves in nanowires with step-modulated thickness

It is experimentally demonstrated that collective Bloch spin waves (SWs) propagate in a magnonic crystal consisting of a dense periodic array of nanowires with step-modulated thickness. The SW dispersion (frequency vs wave vector k) was measured using the Brillouin light scattering technique by sweeping the wave vector perpendicularly to the wire length. The investigated permalloy NWs have the total width of $w=300$ nm and periodicity $a=415$ nm. These nanowires consist of two

▼ (a) Schematic drawing of the nanowire array and (b) comparison between the measured (points) and calculated (curves) collective SW frequency.



sub-wires of widths $w_1=120$ nm and $w_2=180$ nm and thicknesses $t_1=25$ nm and $t_2=50$ nm, respectively. Remarkably, the lowest frequency mode has an oscillating dispersion as a function of k while modes at higher frequencies have almost constant frequency values. These results have been successfully reproduced in a numerical simulation employing two-dimensional Green's function description of the dynamic dipole field of the precessing magnetization. The theory also allowed visualizing the non-trivial distribution of dynamic magnetization across the wire cross-section and estimating the Brillouin light scattering cross-section. This work can stimulate the design, tailoring, and characterization of SWs band structure in three dimensional magnonic crystals. ■

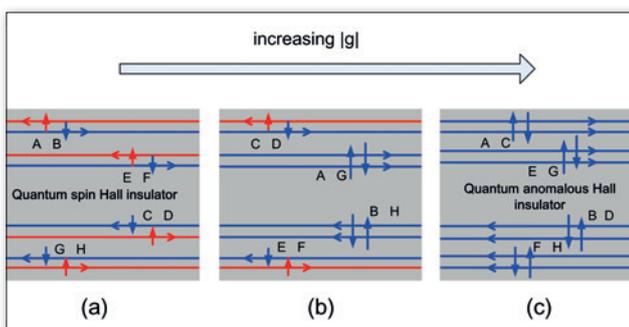
■ **G. Gubbiotti et al.**,

'Collective spin waves on a nanowire array with step-modulated thickness', *J. Phys. D: Appl. Phys.* **47**, 105003 (2014)

QUANTUM PHYSICS

Topological quantum phase transitions

The study of novel topological phases is the focus of intensive research efforts. Some theoretical works have recently been devoted to the understanding of the effect of staggered magnetic fluxes (SMFs) on the topological quantum phase transitions (TQPTs).



▲ Transformation of edge states upon increasing the exchange field. For (b), it is a new type of topological insulator, where the QSH and QAH effect appear simultaneously.

In the paper we investigate topological phases and corresponding TQPTs by introducing SMFs into the quantum spin Hall (QSH) systems. By varying the flux parameters, we find a rich variety of TQPTs between topological phases with a different number of edge states. Interestingly, some topological phases with high Chern numbers or spin Chern numbers may also appear with spin-orbit couplings.

We consider in particular the effect of exchange field and its role in driving TQPTs. It is shown that the system becomes a new type of topological insulator in a certain parameter region, where the QSH and quantum anomalous Hall (QAH) phases

coexist. It is hoped that this work will deepen the understanding of topological phases and motivate further developments in this exciting and rapidly developing field. ■

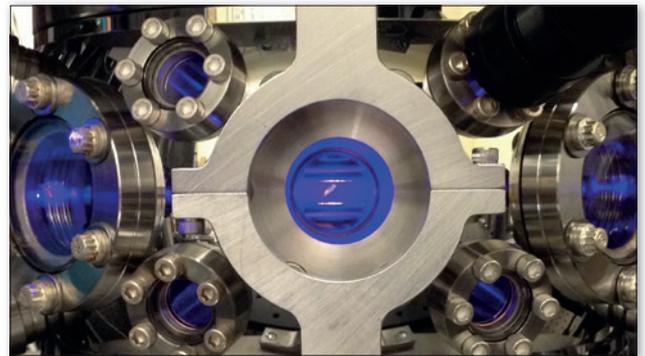
■ **Y. Yang, Y. F. Zhang, L. Sheng and D. Y. Xing**,

'Topological quantum phase transitions in a spin-orbit coupled electron system with staggered magnetic fluxes', *EPL* **105**, 27005 (2014)

ATOMIC AND MOLECULAR PHYSICS

Toward ultra-cold ion-atom chemistry

The development of cold hybrid ion-atom traps has enabled researchers to explore a new frontier; atom-ion interactions at temperatures below 1 K. In a recent theoretical study we explored the reaction pathways of cold Ca atoms in collisions with the various isotopes of the Yb ion. At cold temperatures we found that the dominant reaction mode involves the creation of the YbCa^+ molecular ion with the emission of a photon. That rate was found to be largely independent of the isotope and is consistent with Langevin behaviour which predicts a constant rate with very weak isotopic dependence. In ion-atom processes at cold temperatures Langevin behaviour is generic and has been verified in laboratory studies.



▲ Hybrid ion-atom trap setup in the Hudson lab.

In our investigation we proceeded to the ultra-cold limit and found a temperature transition region in which Langevin behaviour breaks down, and the reaction rates exhibit enhanced isotopic sensitivity. Our studies suggest that dramatic isotopic dependence in hetero-nuclear ion-atom reactions will manifest as laboratory advances coax charged gases to ever colder temperature. ■

■ **B. Zygelman, Z. Lucic and E. R. Hudson**,

'Cold ion-atom chemistry driven by spontaneous radiative relaxation: a case study for the formation of the YbCa^+ molecular ion', *J. Phys. B: At. Mol. Opt. Phys.* **47**, 015301 (2014)

By Tony Klein

The University of Melbourne - Australia - DOI: 10.1051/epr/2014301

The lustre of pearls

About 15 years ago, I learned from a gemologist friend that the value of pearls is appraised by evaluating the following factors: Size; shape; colour and lustre (a term used for the quality of shininess). The first three are easily quantified, but what about lustre? I decided to look into the problem as an intriguing piece of applied optics.

Pearlescence? Iridescence? What optical phenomenon is responsible for the unique appearance of nacre (*i.e.* mother-of-pearl)? The appearance of abalone shell, especially New Zealand Paua shell, gives a clue: Interference colours. So it must be something to do with the structure, maybe it is due to something like thin film interference?

This is confirmed by scanning electron microscopy- see Fig.1 – and explained by marine biologists as follows: Nacre consists of thin, tabular crystals of aragonite, which is Calcium Carbonate that the mollusk concentrates from seawater. But that is not all: aragonite normally forms needle-shaped crystals. However in seashells, it is constrained into tabular, platelet-shaped crystals by means of a protein secreted by the animal. This protein has dangling bonds with a spacing that is comparable with that of calcium carbonate molecules arranged in flat layers.

So the biology of the situation constrains a change in crystal 'architecture' – from acicular, *i.e.* needle-shaped, to tabular. This, incidentally, gives the resulting composite structure quite remarkable mechanical strength, apart from the interesting optical properties.

That seems to explain it, I thought: In abalone shells, the thickness of the "bricks" must be very uniform so that thin-film interference gives rise to iridescent colours. But what about ordinary nacre (mother-of-pearl) and indeed pearls themselves?

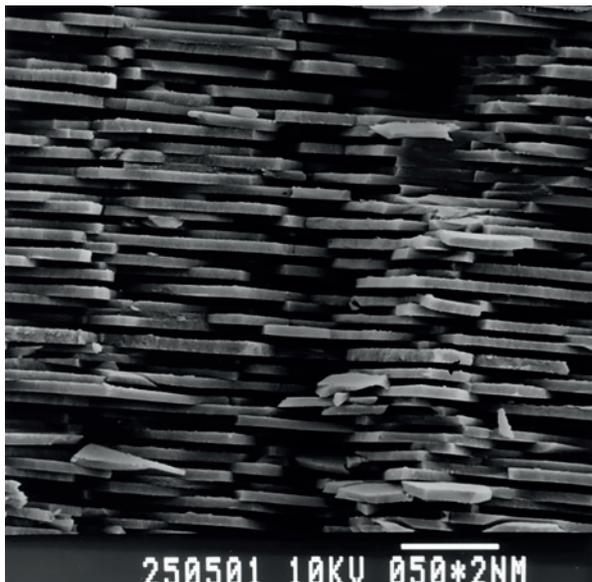
My first thoughts were that maybe the layers are too thick or maybe of non-uniform thickness in ordinary nacre. I wasted a lot of time trying to calculate the reflection properties of thin films of slightly variable (*i.e.* poly-disperse) thickness. This turned out to be an interesting exercise, rather more difficult than I thought. I even enlisted the expert help of Professor John Lekner from Victoria University, New Zealand, who spent a brief Sabbatical with us in Melbourne and is a noted specialist in reflection phenomena, random matrices and so forth. It turned out to be a wild goose chase and eventually the real answer dawned on me and turned out to be much simpler than I had thought.

Before coming to the real explanation, I must remind you why sugar, salt, snow, *etc.* are white. Rather surprisingly, many students and even more accomplished physicists are unaware of the answer. Starting with an analogy, the random walk of a drunk near a cliff-top, even if initially stepping away from the cliff face, inevitably ends up at the bottom of the cliff! In a completely analogous way, a photon (or a ray, if you prefer) entering a substance consisting of small

transparent crystals gets randomly refracted (scattered) and ends up coming back to the surface, whence it emerges in some random direction, never to return to the bulk. This is a form of diffuse reflection, which – if the crystallites are totally non-absorbing – corresponds to 100% reflection. Even better than the best metallic mirrors! So, a white surface is a better reflector than a metallic surface. Even with a certain amount of absorption caused by impurities, this gives rise to strong diffuse reflection, hence the utility of white paint. The mean depth to which the photon (or ray) penetrates depends on the scattering power of the crystallites. This, in



Cartoon by Melbourne artist Leunig



▲ FIG. 1: Scanning Electron Micrograph of a broken surface of abalone shell (Courtesy Dr R. Day, University of Melbourne).

practice, depends on the refractive index, which determines the deviation at the interfaces between the crystals. Hence, Titanium Dioxide, a material with a high refractive index, when finely powdered and suspended in a transparent carrier, makes an excellent white paint, better than Lead Oxide paint or Zinc Oxide in paint, which have smaller refractive indices and hence not as good a “covering” power. This is “the physics of paint” – apart from a supplementary section on selective absorption in pigments, which also consist of crystallites that are transparent, and hence diffuse reflectors in selected wavelength bands.

Now back to the problem of lustre. It’s simple! Imagine a photon incident on the surface of nacre. It gets scattered, *i.e.* refracted at each crystal interface, deviated before being incident on the interstitial layer of protein and scattered again and again eventually emerges from the front, just like from a surface of sugar, salt *etc.* – but with a major difference: The “random walk” that it executed is highly anisotropic: It travels much further in the lateral direction, along the tabular crystallites, rather than the thin, normal direction, before re-emerging. Thus it emerges much further from the point of incidence than it would have from a substance made of isotropic crystal grains. The net result, if you think about it, is that the splash of light reflected from the surface is much greater than it would otherwise be from, say, white paint *etc.* There is just a little more to it than that: It turns out that, in the case of spherical pearls, the crystalline platelets tiling the surface follow the curved surface so that the light diffusing sideways actually follows the contour of the surface and makes it more luminous than an isotropic scatterer. All this, therefore, creates the illusion of being whiter than white, thereby explaining why it is ‘lustrous’!

Artists such as the famous Dutch Master Johannes Vermeer (1632 – 1665) must have realised this – see Fig. 2 – “The Girl With the Pearl Earrings”. The pearl is painted as much whiter than other white surfaces in the picture.

I was quite pleased with myself when I succeeded in explaining the nature of “lustre” – at least to my own satisfaction – as diffuse reflection from a stratified, anisotropic material. But then I realised that something as simple as that must have been discovered by others before me. Indeed that is the case: It’s all there in the Scientific Papers of that doyen of light scattering, C.V. Raman (Indian Acad. of Sci. 1988 Vol. IV, 256; *The Optics of the Pearl*, 1954).

By the way: the paint industry woke up to this too, when it started to manufacture iridescent paint incorporating finely ground mica platelets, for use on luxury cars.

All this reminded me of a cartoon by Melbourne cartoonist Leunig, showing a sad little fellow looking at a sign that says “Go back. It’s all been done before!” ■

About the Author

Emeritus Professor **Tony Klein**, held a Personal Chair at the University of Melbourne (1983 – 1998) and is a Fellow of the Australian Academy of Science and a Foundation Member and a Past President of the Australian Optical Society.

▼ FIG. 2: “The Girl with a Pearl Earring” by Johannes Vermeer (1632-1664).





FIRST RESULT FROM THE AMS EXPERIMENT: THE BEGINNING OF A RICH COSMIC RAY PROGRAM

■ Martin Pohl – Center for Astroparticle Physics (CAP Genève) Université de Genève – DOI: 10.1051/epn/2014302

More than 100 years after the discovery of cosmic rays by Victor Hess, our knowledge of their sources and transport is still rather rudimentary. This does not only concern the astrophysical phenomena, which create and accelerate charged particles, but also the potential role of particle physics and cosmological mechanisms.

The Alpha Magnetic Spectrometer (AMS) [1] is a powerful and sensitive particle physics spectrometer for the observation of cosmic rays in space. As seen in Fig. 1, AMS is located on the exterior of the International Space Station (ISS). Since its installation on 19 May 2011 it has measured about 40 billion cosmic rays in the GeV to TeV energy range. Its permanent magnet and array of precision particle detectors collect and identify charged cosmic rays passing through. Over its long-duration mission on the ISS, AMS will record signals from 16 billion cosmic rays every year and transmit them to Earth for analysis by the AMS Collaboration. Beginning of April 2013, the Collaboration published its first physics result in *Physical Review Letters* [2]. Later this summer, new results were contributed to the 33rd International Cosmic Ray Conference in Rio de Janeiro. These are the first of many physics results to be reported.

The first publications from the AMS Experiment are a major milestone for the AMS international collaboration [2]. Hundreds of scientists, engineers, technicians and students from all over the world have worked together for over 18 years to make AMS a reality. The collaboration represents 16 countries from Europe, Asia and North America (Finland, France, Germany, Italy, the Netherlands, Portugal, Spain, Switzerland, Romania, Russia, Turkey, China, Korea, Taiwan, Mexico and the United States) under the leadership of Nobel Laureate Samuel C.C. Ting of M.I.T. The collaboration continues to work closely with the NASA AMS Project Management team from Johnson Space Center as it has throughout the entire process. Many countries have made important contributions to the AMS detector construction and are presently participating in the data analysis.

AMS was constructed at universities and research institutes around the world and assembled at the European Organization for Nuclear Research, CERN, Geneva, Switzerland. It was launched by NASA to the ISS as the primary payload onboard the final mission of space shuttle Endeavour (STS-134) on 16 May 2011. Once installed on 19 May 2011, AMS was powered up and immediately began collecting data from primary sources in space. Since June 2011, these are routinely transmitted to the AMS Payload Operations Control Center located at CERN, Geneva, Switzerland.

Once AMS became operational, the first task for the Collaboration was to ensure that all instruments and systems performed as designed and as tested on the ground. The AMS detector, with its multiple redundancies, has proven to perform flawlessly in space. Over more than two years in flight, AMS collaborators have gained invaluable operational experience in running a precision spectrometer in space and mitigating the hazardous conditions to which AMS is exposed as it orbits the Earth every 90 minutes. Conditions like this are not encountered by ground-based accelerator experiments or satellite-based experiments and require constant vigilance in order to avoid irreparable damage. They include the extreme thermal variations caused by illumination from the Sun and the re-positioning of ISS onboard radiators and solar arrays. In addition, the AMS operators regularly transmit software updates from the AMS Payload Operation and Control Center at CERN to the AMS computers in space in order to match the regular upgrades of the ISS software and hardware.

Positron fraction measurement

In the initial 18 months period of space operations, from 19 May 2011 to 10 December 2012, AMS analyzed 25 billion primary cosmic ray events. Of these, an unprecedented number, 6.8 million, were unambiguously identified as electrons and their antimatter counterpart, positrons, in the energy range 0.5 to 350 GeV.

Electrons and positrons are identified by the accurate and redundant measurements provided by the various AMS instruments against a large background of protons. Positrons are clearly distinguished from this background through the robust rejection power of AMS of more than one in one million. The total number of positrons identified by AMS, in excess of 400 000, is the largest number of energetic antimatter particles directly measured and analyzed from space.

In its first publication [2], AMS presents the positron fraction (ratio of the positron flux to the combined flux of positrons and electrons) in the energy range 0.5 to 350 GeV. We have observed that from 0.5 to 10 GeV, the fraction decreases with increasing energy. The fraction then increases steadily between 10 GeV and ~250 GeV. Yet the slope (rate of growth) of the positron fraction decreases by an order of magnitude from 20 to 250 GeV. At energies above 250 GeV, the spectrum appears to flatten, but to study the behaviour above 250 GeV requires more statistics – the data reported represent ~10% of the total expected. The positron fraction spectrum exhibits neither structure nor time dependence. The positron-to-electron ratio shows no anisotropy [3] indicating the energetic positrons are not coming from a preferred direction in space. Together, these features show

► FIG. 1: From its vantage point about 400 km above the Earth, the Alpha Magnetic Spectrometer (AMS) collects data from primordial cosmic rays that traverse the detector.



evidence of new physics phenomena. Fig. 2 illustrates the AMS data presented in the first publication. Even with the high statistics, 6.8 million events, and the accuracy of AMS, the fraction shows no fine structure.

The exact shape of the spectrum as shown in Fig. 2, extended to higher energies, will ultimately determine whether this spectrum originates from the collision of dark matter particles or from pulsars in the galaxy. The high level of accuracy of these data indicates that AMS may soon resolve this issue. In fact, latest results [4] confirm the finding that at high energies the positron fraction no longer increases.

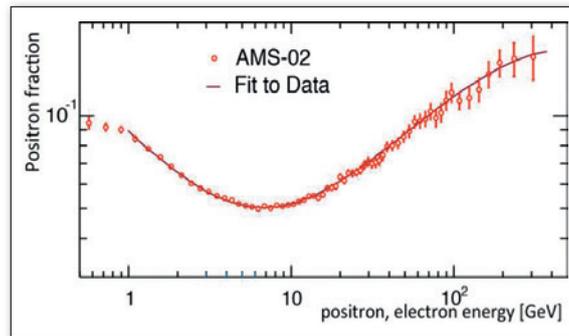
Over the last few decades there has been much interest in the positron fraction [5] from primary cosmic rays by both particle physicists and astrophysicists. The underlying reason is that by measuring the ratio between positrons and electrons and by studying the behaviour of any excess across the energy spectrum, a better understanding of the origin of dark matter and other physics phenomena may be obtained.

The first AMS result has been analyzed using several phenomenological models, one of which is described in the paper and included in Fig. 2. This generic model, with diffuse electron and positron components and a common source component, fits the AMS data surprisingly well. This agreement indicates that the positron fraction spectrum is consistent with electron and positron fluxes, each of which is the sum of a separate diffuse spectrum and a single energetic common source. In other words, a significant portion of the high-energy electrons and positrons originate from an as yet unidentified common source. This is indeed corroborated by a recent separate measurement of the absolute electron and positron fluxes [6], up to 500 GeV and 350 GeV respectively, as well as the sum of the two [7] up to 700 GeV. More specific models [8] based on dark matter self annihilation and/or pulsar sources in the Milky Way have been published immediately after the release of the AMS data.

Fluxes of cosmic nuclei

Hydrogen and Helium nuclei represent the most abundant components of cosmic rays. Their absolute flux and spectral shape are fundamental data to understand their origin and propagation history in our galaxy and to study solar phenomena. Data preceding AMS measurements have indicated that there might be variations of the spectral shape above 100 GeV [9]. Two years of data taking on the ISS permit to deliver a precision measurement of the proton [10] and Helium flux [11] for energies ranging from the geomagnetic cut-off up to several TeV. The directly measured kinematic quantity for each particle is its magnetic rigidity p/Z , *i.e.*, its momentum per unit charge.

About 1% of cosmic rays are nuclei heavier than Helium. Their absolute fluxes and the ratio of primary nuclei to the secondary nuclei produced by spallation on the interstellar medium are important input to understand



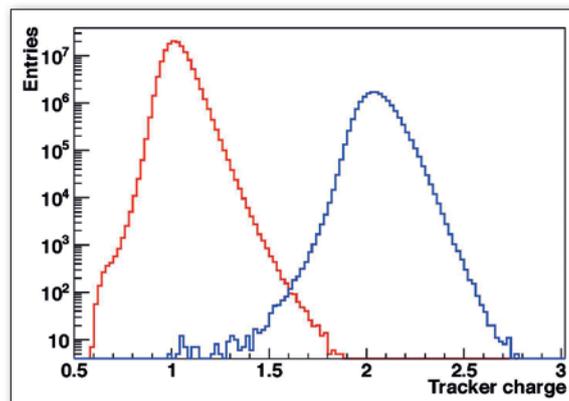
◀ FIG. 2: The positron fraction measured by AMS demonstrates excellent agreement with the simple model described in the text. It shows no fine structure.

the acceleration and propagation mechanisms of cosmic rays in our galaxy. As a first step, AMS has presented results on the ratio of Boron to Carbon fluxes [12] between a few hundred MeV and a few hundred GeV of kinetic energy per nucleon.

To differentiate between nuclei, single track events are selected, with a charge measured accurately in the tracking detector. Redundancy in charge measurement by the time-of-flight system and tracking device determines the efficiency of charge determination from data alone; it is more than 99% over the full rigidity range. Cross-feed between the two species and background from heavier ions is much below the percent level. As an example, Fig. 3 shows the nuclear charge measured by the tracker for samples of proton and Helium candidates selected using the time-of-flight scintillators.

The absolute particle flux is obtained from the raw counting rate, dividing by the exposure time, the acceptance in surface and solid angle, the trigger and identification efficiencies, as well as the interval in energy or rigidity. The AMS results represent a big leap forward in terms of statistical and systematical accuracy. Both Hydrogen and Helium nuclei show a smooth power law spectrum without features or breaks in the accessible energy region. Likewise, the ratio of the spectra for Boron and Carbon nuclei is measured with unprecedented accuracy and found to decrease smoothly from the geomagnetic cut-off all the way to energies of 670 GeV per nucleon.

The flux below 30 GV is affected by solar activity. Because of its large acceptance, AMS can determine the proton flux every day with an accuracy of about 1%.



◀ FIG. 3: Distribution of the charge measured by the tracking detector for samples of events identified as protons (red) or Helium (blue) by the time-of-flight counters.

Fig. 4 shows the time variation of the daily flux in magnetic rigidity intervals situated between 1 and 100 GV. The fluxes are normalized in the beginning of the period. A gradual decrease is observed for rigidities below about 10 GV due to solar modulation. The large spike on 7 March 2012 corresponds to an X5.4-class solar flare, which was

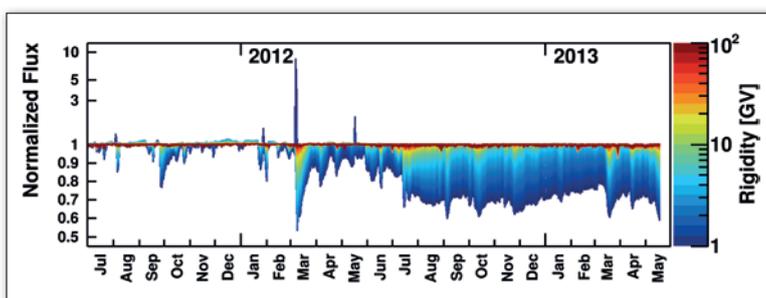
the strongest eruption in 2012. We subsequently observed a large Forbush decrease of the flux up to 30 GV, which lasted about three

weeks. A spike on 17 May 2012 corresponds to a M5.1 solar flare and the first Ground Level Enhancement event in Solar Cycle 24. A few other spikes corresponding to X-class solar events were observed on 9 August 2011 and 27 January 2012.

Outlook

As interesting as these first results may be, they are only the tip of the iceberg. AMS is a magnetic spectrometer with the ability to explore new physics because of its precision, statistics, energy range, capability to identify different particles and nuclei as well as its long data-taking period in space. AMS is designed to measure the energy- and time-dependent fluxes of cosmic nuclei to an unprecedented degree of precision, to better understand the propagation, the confinement mechanisms of cosmic rays in the Galaxy and the strength of their interactions with interstellar media. Another high-priority research topic is the indirect search for dark-matter signals based on looking at the fluxes of particles such as electrons, positrons, protons, antiprotons and photons. It is expected that hundreds of billions of cosmic rays will be measured by AMS throughout the lifetime of the International Space Station. With the wealth of data collected, the Collaboration will also explore other topics such as the search for new physics and astrophysics phenomena like residual nuclear antimatter and strangelets. AMS will thus provide new, accurate information over the lifetime of the Space Station as the AMS detector continues its mission to explore new physics phenomena in the cosmos. ■

▼ FIG. 4: Daily variation of the normalized proton flux, for the rigidity ranges specified by the color code. AMS has observed a gradual decrease in the low rigidity region as well as spikes associated with solar events.



About the author



Martin Pohl obtained his PhD from RWTH Aachen in the 1970s. He has been working on experimental particle physics at the PETRA (DESY) and LEP (CERN) colliders before turning to astroparticle physics in space. Besides AMS, his projects include the POLAR X-ray polarimeter for the Chinese space laboratory Tiangong 2; the X-ray observatory LOFT, which is an ESA M-class mission candidate; and DAMPE, a high-energy particle detector for a free flying Chinese satellite. He is the director of the department for particle and nuclear physics (DPNC) at University of Geneva, and co-founder of the Center for Astroparticle Physics, CAP Genève.

References

- [1] See: www.ams02.org
- [2] AMS Collaboration, M. Aguilar *et al.*, *Phys. Rev. Lett.* **110**, 141102 (2013)
- [3] See also <http://press.web.cern.ch/tags/ams> and M. Aguilar, CERN Courier, Sept. 27, 2013, <http://cerncourier.com/cws/article/cern/54675>
- [4] J. Casaus, "Determination of the positron anisotropy with AMS", *33rd International Cosmic Ray Conference*, Rio de Janeiro 2013, to be published in the proceedings.
- [5] A. Kounine, "Precision measurement of the positron fraction in primary cosmic rays of 0.5-350 GeV", *33rd International Cosmic Ray Conference*, Rio de Janeiro 2013, to be published in the proceedings.
- [6] TS93: R. Golden *et al.*, *Astrophys. J.* **457**, L103 (1996). Wizard/CAPRICE: M. Boezio *et al.*, *Adv. Sp. Res.* **27-4**, 669 (2001). HEAT: J. J. Beatty *et al.*, *Phys. Rev. Lett.* **93**, 241102 (2004); M. A. DuVernois *et al.*, *Astrophys. J.* **559**, 296 (2001). AMS-01: M. Aguilar *et al.*, *Phys. Lett. B* **646**, 145 (2007). PAMELA: P. Picozza, *Proc. of the 4th International Conference on Particle and Fundamental Physics in Space*, Geneva, 5-7 Nov. 2012, to be published; O. Adriani *et al.*, *Astropart. Phys.* **34**, 1 (2010); O. Adriani *et al.*, *Nature* **458**, 607 (2009). Fermi-LAT: M. Ackermann *et al.*, *Phys. Rev. Lett.* **108**, 011103 (2012).
- [7] S. Schael, "Precision measurement of the electron spectrum and the positron spectrum with AMS", *33rd International Cosmic Ray Conference*, Rio de Janeiro 2013, to be published in the proceedings.
- [8] B. Bertucci, "Precision measurement of the e+e- spectrum with AMS", *33rd International Cosmic Ray Conference*, Rio de Janeiro 2013, to be published in the proceedings.
- [9] See e.g.: Andrea De Simone, Antonio Riotto, Wei Xuec, *CERN-PH-TH/2013-054* (April 3, 2013); Tim Linden and Stefano Profumo, arXiv:1304.1791v1 [astro-ph.HE], (April 5, 2013); Peng-Fei Yin, Zhao-Huan Yu, Qiang Yuan and Xiao-Jun Bi, arXiv:1304.4128v1 [astro-ph.HE] (April 15, 2013)
- [10] PAMELA collaboration, O. Adriani *et al.*, *Science* **332**, 69 (2011)
- [11] S. Haino, "Precision measurement of the proton flux with AMS", *33rd International Cosmic Ray Conference*, Rio de Janeiro 2013, to be published in the proceedings.
- [12] V. Choutko, "Precision measurement of the cosmic ray Helium flux with AMS experiment", *33rd International Cosmic Ray Conference*, Rio de Janeiro 2013, to be published in the proceedings.
- [13] A. Oliva, "Precision measurement of the cosmic ray Boron-to-Carbon ratio with AMS", *33rd International Cosmic Ray Conference*, Rio de Janeiro 2013, to be published in the proceedings.

unbounded ultrafast potential

NEW >14 W, 12 mJ

NEW SUB-20 fs AT HIGH REP RATES

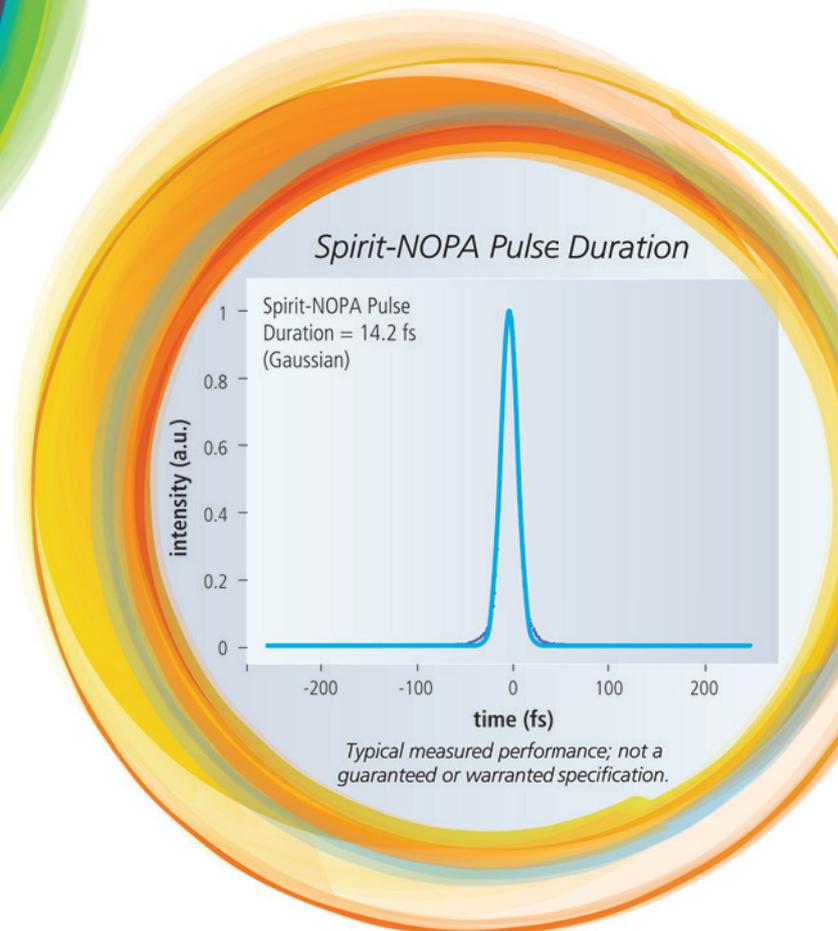


- THz generation, time resolved spectroscopy, high energy physics, etc.
- Output power range >6 W to >14 W
- High pulse energy up to >12 mJ
- Wide wavelength range UV to IR
- High repetition rate up to 1 MHz

Spectra-Physics is dedicated to breaking through boundaries and unleashing ultrafast capabilities—from THz generation and high energy physics to time-resolved spectroscopy and beyond. We recently added three new amplifiers to further extend our Ultrafast portfolio. Discover why with Spectra-Physics, the potential for Ultrafast is unbounded. For more information on our *Number 1 in Ultrafast* line of lasers, visit

www.spectra-physics.com/ultrafast-lasers

or contact us at +49 6151-708-0 or europe@spectra-physics.com.



DOES WATER FOAM EXIST IN MICROGRAVITY ?

■ H.Caps, G.Delon, N.Vandewalle, R.M.Guillermic¹, O.Pitois^{2,3}, A.L.Biance^{3,4}, L.Saulnier⁵, P.Yazhgur⁵, E.Rio⁵, A.Salonen⁵, D.Langevin⁵ – DOI: 10.1051/ejn/2014303

■ GRASP, Université de Liège, Belgium

■ ¹ Institut de Physique, Université Rennes 1, CNRS, France

■ ² LPMDI, Université Paris Est, Marne-la-Vallée, CNRS, France

■ ³ Institut Navier, Université Paris-Est, Champs-sur-Marne, France

■ ⁴ LPMCN, Université Lyon 1, CNRS, France

■ ⁵ LPS, Université Paris Sud 11, CNRS, France

Liquid foams are omnipresent in everyday life, but little is understood about their properties. On Earth, the liquid rapidly drains out of the foam because of gravity, leading to rupture of the thin liquid films between bubbles. Several questions arise: are liquid foams more stable in microgravity environments? Can pure liquids, such as water, form stable foams in microgravity whereas they do not on Earth? In order to answer these questions, we performed experiments both in parabolic flights and in the International Space Station.



Liquid foams [1] consist of gas bubbles dispersed in a liquid and stabilised by surface-active species, such as surfactants, proteins, polymers or particles. The internal structure of liquid foams – formed by the complex network of gas/liquid interfaces – leads to extremely interesting physical properties. For instance, liquid foams are soft solids and melt under the action of small forces. This is why shaving foam sticks to the face but conveniently flows under the razor blade. Foams are also strong scatterers of light and sound, which leads to remarkable optical and acoustic properties. They play important roles in detergency (shampoo, dishwashers), provide important texture properties to food (whipped cream, chocolate mousse, bread) and additional sensorial aspects to drinks (cappuccino, beer). They help extracting crude oil (oil recovery), refining minerals (flotation) or extinguishing fires.

On the other hand, many applications struggle with unwanted foams (just think of the paper and paint industry) or need to maintain the foaming properties at a

well-controlled level (washing powders), so that suitable “antifoams” need to be designed. Last but not least, most solid foams are made from liquid precursor foams. Solid foams, despite being light, are very resistant mechanically (metallic foams for cars) and are exceptionally good insulators for heat and sound (polymer foams). As a consequence of their remarkable properties, foams are omnipresent in everyday life. Despite this abundance in applications of foam, little is understood yet about their properties. In particular their stability remains mysterious: the simple question of why a soap bubble bursts is still waiting for a clear explanation [2]. As a result, empiricism is currently employed to estimate the operational window and design for foam handling in industrial processes.

Studying foam

The main difficulty of foam studies arises because they are short-lived in general. Foams are metastable systems and their formation requires energy in order to create new interfaces between liquid and gas phases: an increase in surface area of ΔA corresponds to a surface energy of $\gamma\Delta A$, with γ the surface tension. The foam then evolves with time in order to decrease this surface energy via two independent processes: *coalescence*, which is the rupture of films between bubbles, and *coarsening*, which is gas transfer between the bubbles due to their different internal pressures. Both processes lead to an increase of the bubble radius with time, but they are not easy to distinguish. A third ageing mechanism is the gravity-driven *drainage* of liquid between the bubbles. This removes liquid from the foam and influences both coarsening and coalescence. In order to disentangle the different effects, one should ideally suppress drainage. Performing experiments in microgravity is a unique way to study foams containing a substantial amount of liquid.

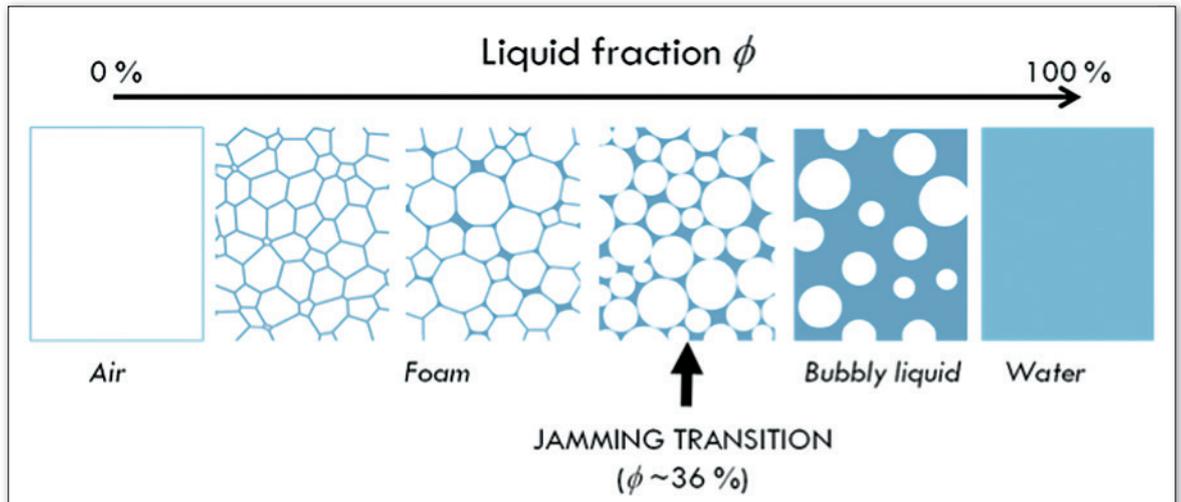
Indeed, obtaining stable foams with large liquid fraction ϕ ($\phi > 20\%$) on Earth is impossible; various hydrodynamic instabilities even accelerate drainage [1].

This prevents the study of very wet foams, formed at the beginning of the foam life and thus an important step in foaming processes. Furthermore, wet foams show a particularly interesting transition when the bubbles are closely packed, but still spherical (Fig. 1). For disordered foams this “jamming transition” occurs at a liquid fraction $\phi^* \approx 36\%$. For smaller ϕ , the bubbles are distorted into polyhedra and the foam behaves like a soft solid. By contrast, at larger ϕ the foam behaves like a viscous liquid since the bubbles are separated by enough liquid



Performing experiments in microgravity is a unique way to study foams containing a substantial amount of liquid





► FIG. 1: Scheme of foam evolution upon increasing liquid fraction ϕ . Image courtesy of Wiebke Drenckhan

to move independently. Similar jamming transitions are encountered in other assemblies of randomly packed objects, such as sand, clays, emulsions, *etc.*, which are presently the object of much interest [3].

Microgravity

Many studies of isolated bubbles in microgravity have been reported, in connection to various problems: bubbling [4], boiling [5], two-phase flow [5], electrolysis [6], combustion [7], impinging of jets [8]. However, microgravity experiments on foams are still scarce despite the promises they hold for scientists. Various foam experiments are in preparation for the Fluid Science Laboratory of the ISS, supported by the European Space agency (ESA) [9]. As part of the preparations, we benefited from opportunities offered by educational programs of ESA to tackle two long-standing questions: can we make stable wet foams in microgravity? And do pure liquids foam in these conditions? For this purpose, simple foaming experiments were performed on parabolic flight campaigns (PFC) which simulate microgravity during 15 s, and by astronauts in the ISS (Fig. 2) [10].

They showed that wet foams containing surface active agents were stable in microgravity [10].

Pure water

In this article we present results on foams made with pure water. We used three different mechanical systems for the foam production under micro-gravity conditions. In the first device, the liquid and air are rapidly pushed back and forth through a constriction between two syringes. In the second device, a porous plate moves back and forth in a cylinder containing liquid (the “mighty whipper”). The third device is the simplest to operate and was designed for use in the ISS: a heavy bead is shaken in a cylinder containing both air and liquid, in order to incorporate bubbles in the liquid. Earth-based experiments have been performed using the same foaming devices for comparison with normal gravity conditions.

Water studies in parabolic flights and aboard the ISS are fully consistent. The PFC foaming devices allowed creating foams with various liquid fractions. In the ISS less gas could be incorporated in the liquid because the energy involved in the mixing procedure was much lower; as a consequence, the liquid volume fraction remained large.

Are water foams stable?

Once formed, the bubbles remained stable over long periods of time in microgravity conditions. They may move somewhat, but not enough to coalesce (Fig. 3, left). This is due to the absence of drainage: bubbles stay sufficiently far apart, avoiding coalescence. On Earth and in the same conditions, water does not contain any bubbles (Fig. 3, right).

Foams close to the jamming transition

First of all and in line with earlier observations [10], solutions that are difficult to foam on Earth also require more vigorous shaking in microgravity, and water is no exception.

Pictures of foams made with a liquid/air volume ratio of 30% are shown in Fig. 4. One sees that the “mighty whipper” is the most efficient device: the bubbles are smaller and less polydisperse (sizes between 100 and 500 μm). With the two-syringe and bead-cylinder devices the range of sizes is wider (100 μm -1 cm).

▼ FIG. 2: Astronaut Frank de Winne with the foam cells in the ISS; a cell rack is free floating in the centre of the picture and a second rack is placed in front of a computer screen for backlight illumination during video recording. Image courtesy of ESA.



More surprisingly, it is not possible to generate a foam with $\phi < \phi^*$. Even with initial liquid/air ratio of 20 and 30%, we ended up with a dispersion of packed bubbles because we could not incorporate all the air into the liquid (Fig. 3). Only the most efficient mixing device (mighty whipper) produced foams with ϕ close to ϕ^* , although never smaller. Fast-coalescence events were observed as soon as the bubbles came close to each other whereas such events are absent in the bubbly state ($\phi > \phi^*$).

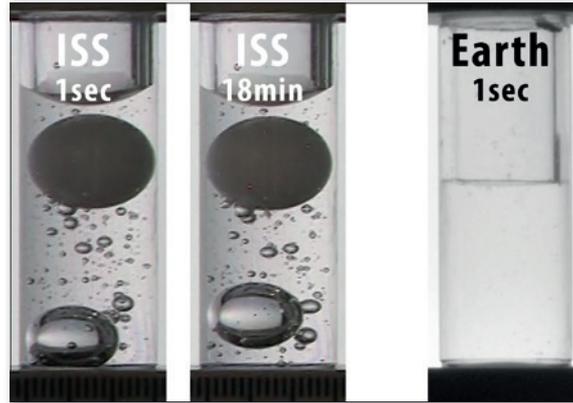
Why are foams with $\phi < \phi^*$ disappearing rapidly, as they do on Earth? We propose the following explanation: when $\phi < \phi^*$, the bubbles are distorted and films form (Fig. 1). These films are thin because of capillary suction into film borders, despite the absence of gravity drainage, as demonstrated in earlier PFCs [11]. Thinning of pure water films is extremely fast and bubbles coalesce fractions of seconds after getting into contact. Indeed, the surface energy $\gamma\Delta A$ is decreased in this process, because the area is decreased.

In summary, we showed that water foam with spherical bubbles is stable in microgravity, even in dense systems close to the jamming limit ($\phi > \phi^*$). Below this limit, the bubbles are distorted into polyhedral shapes. Films form between bubbles, they get thin rapidly due to capillary-driven drainage, followed by film rupture, as on Earth. As a result, stable foam with *polyhedral bubbles* is not formed from pure water, even in microgravity.

Apart from the scientific side, these findings are also of interest for the handling of fluids in microgravity environments. Further more elaborate experiments are planned in the Fluid Science Laboratory of the ISS in 2016. ■

Acknowledgements

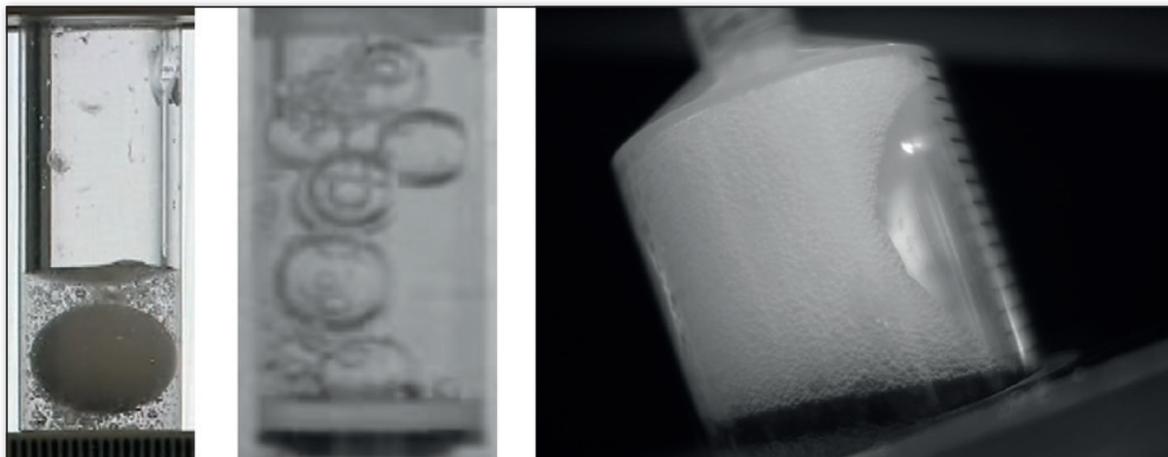
The Foam project was financially supported by ESA, CNES and BISA (Belgium Space Agency). We are grateful to Olivier Minster, Sebastien Vincent Bonniou and Bernard Zappoli for continuing support. We benefited from the help of Arnaud Saint Jalmes, Benjamin Dollet, Isabelle Cantat and of the Novespace and Astrium teams during the parabolic flights experiments. We gratefully acknowledge the astronauts who performed the ISS experiments and Wiebke Drenckhan for very constructive remarks concerning the manuscript.



◀ FIG. 3. Left: water samples made in the ISS, 1 second and 18 minutes after shaking. Right: Pure water on Earth, 1 second after shaking in the same conditions

References

- [1] D. Weaire and S. Hutzler, *The Physics of Foams*. (Clarendon press, 1999).
- [2] D. Langevin and E. Rio, in *Encyclopedia of Surface and Colloid Science* edited by P. Somasundaran (Taylor and Francis, New York, 2012), pp. 1.
- [3] A. J. Liu and S. R. Nagel, in *Annual Review of Condensed Matter Physics*, Vol 1, edited by J. S. Langer (2010), Vol. 1, pp. 347.
- [4] O. Pamperin and H. J. Rath, *Chemical Engineering Science* **50** (19), 3009 (1995).
- [5] J. F. Zhao, *International Journal of Multiphase Flow* **36** (2), 135 (2010).
- [6] H. Matsushima, D. Kiuchi, and Y. Fukunaka, *Electrochimica Acta* **54** (24), 5858 (2009).
- [7] T. Kadota and H. Yamasaki, *Progress in Energy and Combustion Science* **28** (5), 385 (2002).
- [8] F. Sunol and R. Gonzalez-Cinca, *Chemical Engineering Science* **97**, 272 (2013).
- [9] J. Banhart, F. Garcia Moreno, S. Hutzler, D. Langevin, L. Liggieri, R. Miller, A. Saint-Jalmes, and D. Weaire, *EuroPhysics News* 39/4, 26 (2008).
- [10] N. Vandewalle, H. Caps, G. Delon, A. Saint-Jalmes, E. Rio, L. Saulnier, M. Adler, A. L. Biance, O. Pitois, S. C. Addad, R. Hohler, D. Weaire, S. Hutzler, and D. Langevin, in *International Symposium on Physical Sciences in Space*, edited by A. Meyer and I. Egry (2011), Vol. 327.
- [11] A. Saint-Jalmes, S. Marze, H. Ritacco, D. Langevin, S. Bail, J. Dubail, L. Guingot, G. Roux, P. Sung, and L. Tosini, *Physical Review Letters* **98**(5) (2007).



◀ FIG. 4: Pure water foams made in microgravity with liquid/air volume ratio of 30%; Left: ISS, bead-cylinder device. Middle: PFC, two-syringe system. Right: PFC, mighty whipper.

By H.C.W. Beijerinck,

Eindhoven University of Technology - Eindhoven - the Netherlands - DOI: 10.1051/ePN/2014304

Pride and prejudice

Science and religion are two separate fields, as Dawkins clearly states in his book ‘The God delusion’¹. His crystal-clear and critical analysis shows that religion hinders the development of an independent mind in young people. More specific, it is the church with its clerics that is most guilty of this negative role. In a recent paper by Polkinghorne, the interplay of physics and religion is considered on a more philosophical basis, emphasizing the role of searching for a wider context for understanding the intelligibility of the structure of physics².

Is physics free from this pitfall of the church and its clerics? The answer is yes, most of the time, not always. When ‘believing’ hinders the dissemination of ground-breaking physics, we should investigate its cause and learn to avoid it in the future. The tale of a brilliant PhD student Hugh Everett III at Princeton University (1957) and his many-world or multi-(uni)verse interpretation of quantum mechanics is a compelling story told by Peter Byrne in Everett’s biography³.

The story of Hugh Everett III starts in 1954 in Princeton. The main characters are his advisor John Wheeler and Niels Bohr, as the proponent of the Copenhagen interpretation of quantum mechanics. Along comes an excellent student, with an out-of-the-box idea for devising a ‘universal wave function’. This approach eliminates the special treatment of observation of a system by an external observer and the corresponding collapse of the wave function. In January 1956, he submits his thesis to his advisor. At first, John Wheeler is exhilarated by this idea. With minor revisions, a final bound copy of ‘Wave mechanics without probability’ is ready and sent to a select group of physicists by Wheeler. Most likely, to probe their opinion on this new approach, as can be read in his accompanying letter³ to Niels Bohr.

Then the PhD train starts to derail. Bohr and his circle strongly oppose Everett’s approach, as becomes clear during a visit of Wheeler to Copenhagen. It is too distant from the ‘religion’ of the Copenhagen school. When you do not like the message, don’t kill the messenger. Instead of keeping in mind that a PhD thesis should be the proof that the student can perform independent research that is well documented, Everett’s work is tested on its merit to please everybody.

With an appreciable delay, in February 1957, Wheeler and Everett sit down together to rephrase the thesis. The final version ‘On the foundations of quantum mechanics’ is officially accepted on April 15, 1957.

In the meantime, Hugh Everett had left university to pursue a career with the government in Washington DC. His interest in a scientific career had been strongly damped by the unpalatable process regarding his thesis work. He had lost faith in the scientific community. Everett’s capabilities in modeling landed him in the Weapons Systems Evaluation Group at the Pentagon. Here, he worked on scenarios relating to the Cold War. One of the most important conclusions of the group is that nuclear war is fatal for *both* parties involved. A balanced capacity of mutual destruction is

the only feasible option. Again, an out-of-the-box answer was generated, which was not appreciated by the military.

In my career at university, I have seen too many research groups where the advisor insisted on running experiments and analyzing data up to the last day of the contract of the PhD student (four years in the Netherlands). In these cases, the student had to finish his thesis and related papers in his own time, writing his thesis in parallel to a job or surviving on unemployment benefits. Pride or ego of the advisor – I need as many data or papers as possible – and prejudice or self-interest – I pay for him, so he has to work for me – then play a rather negative role in educating young scientists. As senior scientists, we should know better! And behave accordingly. ■

¹ Richard Dawkins ‘The God delusion’ (Bantam Press, 2006);

² John Polkinghorne *EPN* 45, 29 (2014);

³ Peter Byrne ‘The many worlds of Hugh Everett III’ (Oxford, 2010).



SYMMETRY OF QUASI ONE-DIMENSIONAL SYSTEMS: LINE GROUPS AND APPLICATIONS

■ Milan Damnjanović – NanoLab – Faculty of Physics – University of Belgrade – Serbia – DOI: 10.1051/epn/2014305

Many of the interesting properties of stereoregular polymers, nanotubes and other nanowires exhibit quasi one-dimensionality and regularity. These specific configurations are determined by their symmetry described by line groups. Deep physical consequences of this type of symmetry are illustrated by using modified group projector technique.

More than 30 years ago it was understood that low-dimensional systems have many features which distinguish them from traditional crystals. *New physics is expected in low-dimensional matter*, was the prophetic formulation of Nobel prize winner Vitaly Ginzburg. Indeed, most contemporary condensed matter physics is focused on nanotubes, polymers, graphene and other nanowires and layers. An avalanche-like growth in research overflowed the other fields under the fashionable names nanoscience, nanotechnology, nanobiotechnology, *etc.*, all stressing the nanoscale. The interrelated classical sciences and high-tech breakthroughs are probably the first example in the history of civilization of how the

developments of fundamental and applied knowledge are interrelated through an endless series of feed-backs.

Wigner's work in the middle of the 20th century promoted symmetry, perhaps the deepest concept of science and philosophy, to one of the cornerstones and the most fruitful tool of quantum physics. It is precisely through quantum mechanics, inevitable on the nanoscale, that it penetrates physics of low dimensions. The mathematics describing symmetry is group theory, and quasi one-dimensional (Q1D) systems are related to line groups.

Some of them were first mentioned in 1923, with several important results ever since. However, following growing interest for polymers, the systematic investigation of

▲ Diffraction k-space equatorial perpendicular cross section of (8,8) carbon nanotube

line groups for physical applications did not start until 1977 at the Faculty of Physics, University of Belgrade, by Božović, Vujčić and Herbut [1], and their coworkers (presently NanoLab, www.nanolab.rs); a synthesis of the existing results was given in 2010 [2]. Simultaneously, the modified group projector technique (MGPT), enabling full symmetry calculations, and computer code POLSym, suited for symmetry assisted research of quasi one-dimensional systems, were developed [2].

Line groups

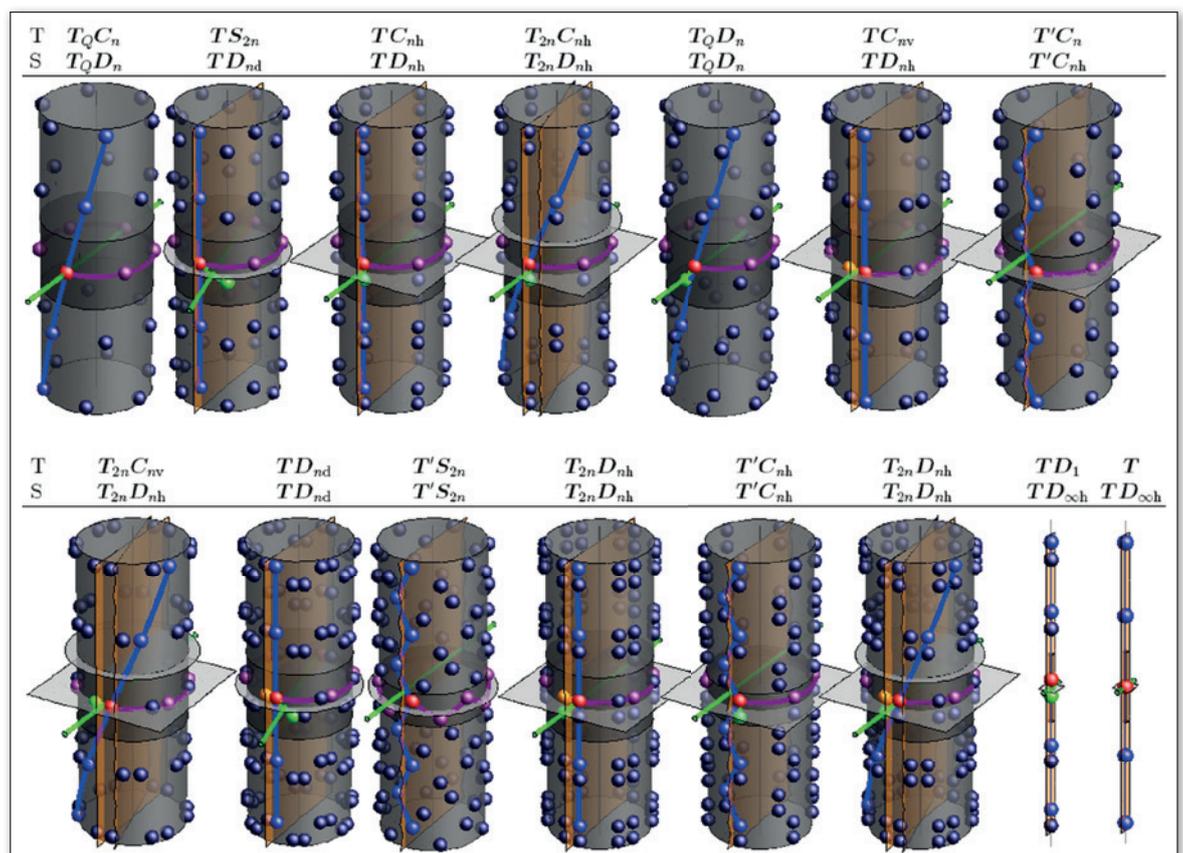
Natural insight into line groups arises from a physical point of view. The common characteristic of Q1D systems and subsystems of 3D solids is their great length compared to width. This determines the direction along which the basic constituents, identical *monomers*, are regularly repeated (*z*-axis). Accordingly, their geometrical symmetries arise in two different ways: *intrinsic symmetry* of monomer itself, and symmetry of the regular *arrangement* of monomers. This has far-reaching physical consequences.

Firstly, all line groups are obtained by independent classification of possible symmetries of monomers and symmetries of arrangements. The monomer symmetry is one of axial point groups (groups of transformations that leave *z*-axis invariant). These are C_n (successive rotations C_n , by $2\pi/n$ around *z*-axis, $n=1,2,\dots$), S_{2n} , C_{nh} , C_{nv} , D_n (which combine C_n with rotation by π/n followed by horizontal mirror reflection, horizontal and vertical mirror plane and rotation U by π around *x*-axis, respectively) and D_{nd} and

D_{nh} (vertical mirror reflection combined with S_{2n} and C_{nh}). The arrangement of monomers is described by *generalized translations*, being either glide plain or screw-axis. These are generated by $(\sigma, |f)$ and $(C_Q|f)$, vertical mirror and rotation by $2\pi/Q$ around *z*-axis (Q is a real number not less than 1), followed by translation by f along this axis. Thus, counting pairs of compatible monomer and arrangement symmetry groups, all of 13 infinite families of line groups are found. Acting on a single point, they produce two types of 1D chains and 13 types of nonlinear Q1D elementary systems, from which all Q1D systems are built (Fig. 1). Magnetic and spin groups, Jahn-Teller activity, generalized Bloch functions, symmetry of carbon and all other nanotubes, diffraction patterns, are some of the important standard symmetry tools already derived for line groups. All these results greatly facilitate analysis and prediction of physical properties of Q1D systems.

It should be emphasized that only for rational Q the compound has translational symmetry, while in other cases it has not - it is *incommensurate*. Only Q1D systems may be incommensurate. This makes them essentially different from two- and three-dimensional ones, as periodicity along two or three directions leads to translationally periodic crystalline structures. For example, numerical predictions show that in single-walled carbon nanotubes translational periodicity is broken by a small torsion. This is also the reason why there are continuously many line groups, in contrast to the finite number of crystallographic ones (rod groups).

► FIG. 1: Types of building blocks of Q1D systems. Generating line group and full symmetry group are given in the upper row. The action of the generalized translations is depicted in blue (helices for screw-axes and zig-zags for glide planes) and that of C_n and S_{2n} in purple; The U -axis and the horizontal and vertical mirror (rotoreflexional and glide) planes are green, gray and orange, respectively. The single monomer is denoted by dark gray.



Among the deepest physical consequences of symmetry are conservation laws. The described factorization shows that the conserved quantities in Q1D systems are introduced separately from the two parts of symmetry. While axial point groups build in z -component of angular momentum \tilde{m} , generalized translations contribute by quasi helical momentum \tilde{k} , canonically conjugated to the helix generated by successive application of $(C_Q|f)$. Only in commensurate systems linear momentum is conserved as well. Thus, when the system is excited by an external perturbation carrying quantum numbers \tilde{k} and \tilde{m} , the difference between helical and angular momenta in initial and final state must be \tilde{k} and \tilde{m} . When the symmetry group involves mirror planes or U symmetries, there are additional conservation laws.

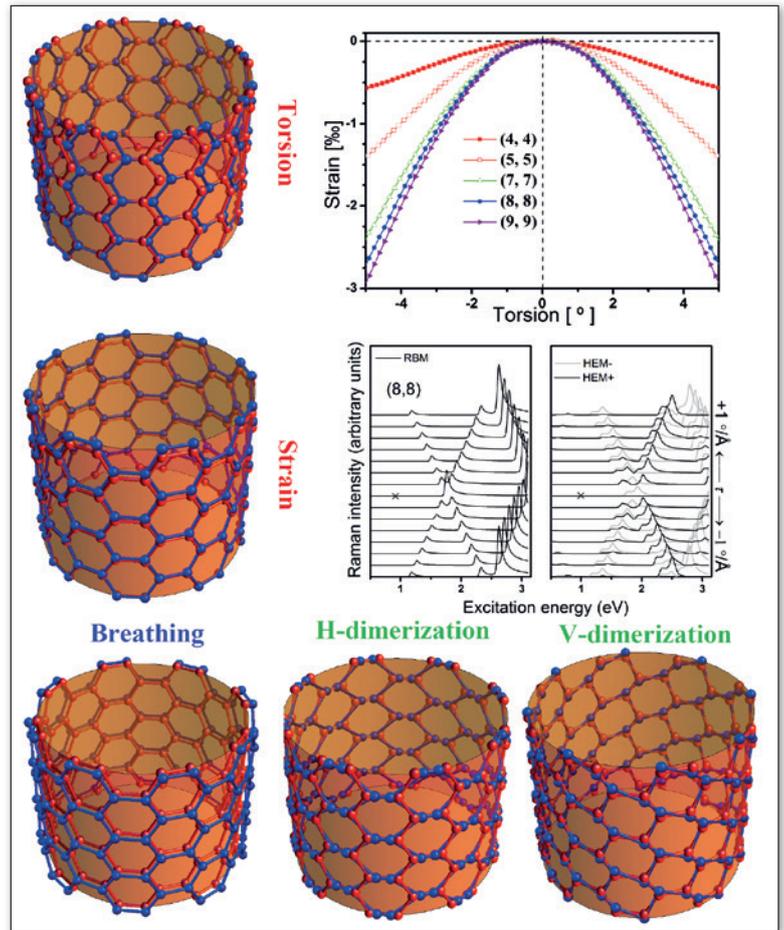
Carbon nanotubes and symmetry

Since their discovery carbon nanotubes have been in the focus of material science, with unique characteristics applicable in various fields of technology. Nanotubes are highly symmetric, to the extent that their symmetry group, completely defined through the line groups [3], generates the whole nanotube from a single atom. Thus, only symmetry and properties of the atom determine all properties of the nanotube. This is fruitfully and efficiently used in research [2,4].

Symmetries of the nanotubes are combined from $(C_Q|f)$, C_n (Q , n and f depend on the particular nanotube), U and vertical mirror reflection in achiral cases. As MGPT reduces calculations to the single atom, a stable configuration is obtained by relaxation (of the rolled graphene ribbon) over three coordinates (ρ , φ_0 , z_0) of that atom, and continual line group parameters Q and f . Some nanotubes are incommensurate [5]. Deviations of the same parameters are deformations without breaking symmetry (Fig. 2): breathing (changing of diameter), horizontal and vertical dimerization (opposite displacements of the neighboring atoms), torsion and stretching. For stable and deformed configurations electronic and phonon energy bands and many other properties are easily found [6]. Deformations have an influence on conduction, optical and Raman spectra, which are interesting for applications. For example, optical absorption can be tuned by torsion, and some tubes can be used as optical sensors covering the whole visible spectrum.

Super slippery double-walled nanotubes

Despite being huge, symmetry groups of different nanotubes are highly incompatible, with only few common elements. Thus, symmetry of double- and multi-walled nanotubes is drastically diminished, frequently to a point group only. An amazing consequence is reduced interaction between the walls. The double-wall nanotube $W@W'$ consists of coaxially positioned single-wall tubes, with line groups L and L' . Its total symmetry $L_{W@W'}$ is the



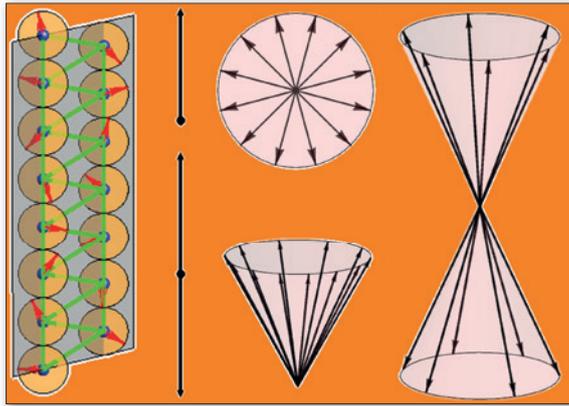
intersection of L and L' . If one wall is fixed, their relative positions are described by the angle Φ of rotation and vertical displacement Z of the other one. The energy of interaction of the walls, $E(\Phi, Z)$, is the sum of the pairwise interactions over atoms from the two walls. It is invariant under the group L_0 of all pairs of transformations, one from L and one from L' . As (Φ, Z) is not changed when an element from $L_{W@W'}$ is applied to both walls, those pairs changing (Φ, Z) form a subgroup L_V , with the number of elements equal to the ratio of the numbers of elements in L_0 and $L_{W@W'}$. Thus, the symmetry of interaction L_V exactly measures the *breaking of symmetry* produced by the interaction. Applied to any pair (Φ, Z) it generates equi-energetic positions. For incommensurate periods of walls L_V is large enough (bihelical [2]) to make $L_{W@W'}$ finite: equi-energetic positions are continual along Z , and $E(\Phi, Z)$ is constant along Z . Walls are super slippery as their mutual translation costs no energy. The same effect cannot be achieved for mutual rotation, as Q and Q' are rational. Still, the results of relaxation [5] open also this possibility, particularly important for nanomachines.

Magnetic properties

It is known that in Q1D spin systems and subsystems of 3D crystals (nanotubes, chains, spin-ladders), helimagnetic order, usually caused by Dzyaloshinskii-Moriya interaction, frequently appears. Symmetry provides the

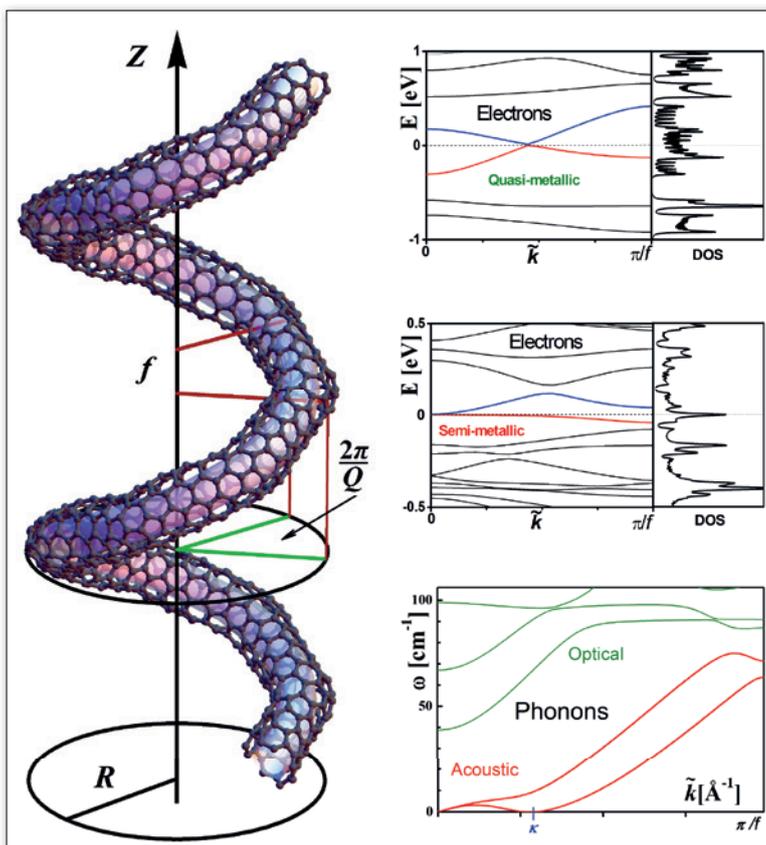
▲ FIG. 2: Deformations that do not break symmetry. Stable configuration of the armchair (8,8) nanotube is red, the deformed configuration is blue. Torsion induces strain (effect shown in upper panel for series of armchair nanotubes), and affect electro-optical: torsions (from -1 to +1 degree per Angstrom) change Raman excitation profiles of radial breathing (RBM) and high energy (HEM), central panel.

► FIG. 3: Q1D spin arrangements. Described by spin line groups they are conical, with one or two opposite cones; special cases are linear (ferromagnets, antiferromagnets) and planar helical orderings. Left: planar helical spin arrangement on zig-zag Cu chain of LiCu_2O_2 .



explanation: the χ^{xy} component of the spin susceptibility tensor χ (z -component of Dzyaloshinskii-Moriya vector), is scalar or pseudoscalar of line groups, and in the former case it can be in the Hamiltonian. In carbon nanotubes spin susceptibility is determined by RKKY interaction [7] and χ^{xy} is scalar. Particularly interesting are nanotubes composed of C^{13} isotope [8] with nuclear spin $1/2$. The analysis shows that the susceptibility tensor has a continual number of symmetries described by the spin line groups $L_{\vec{k}\tilde{m}|}$. These are derived from the line groups (Fig. 3), associating change of the spin vectors to the geometrical action of geometrical transformations. This fact tremendously simplifies ground-state determination within the classical approximation, enabling to get interesting and very precise solution: helimagnetic spin line group order is expected, and it can be controlled by an applied gate.

▼ FIG. 4: Helically coiled carbon nanotube. Electron and phonon energy bands (right) do not cross. This causes semi-metallic and quasi-metallic conduction types and low acoustic branches ($\kappa=2\pi/Qf$) reflected in the small value of Young's modulus.



Helically coiled carbon nanotubes

The existence of helically coiled carbon nanotubes was predicted in 1993, and synthesized in 1994 [9]. With periodically arranged pentagons and heptagons they are incommensurate, with fifth family line group symmetry. All of them have $n=1$, leaving exclusively $\tilde{m}=0$ quasi angular momentum. Consequently, non-crossing energy band structures (Fig. 4) are immanent (Landau's rule). Thus, there are various conducting types, from semiconducting to metallic, including interesting quasi-metallic and semi-metallic with high and low mobility. The same property based on symmetry explains that super-elasticity is more pronounced in the tubes with high Q : acoustic branches, two of which connecting Γ point with $\tilde{k}=2\pi/Qf$, cannot cross optical branches, which is, due to lower sound velocity, reflected in elasticity modules and thermal conductivity.

Conclusion

Symmetry is one of the most profound ways to understand quasi one-dimensional regular systems and efficiently predict their properties at quantum level. This class of systems includes polymers and nanotubes, which are among the most interesting challenges of contemporary science. ■

About the Author

Milan Damnjanović is Professor of Quantum mechanics and Mathematical physics at Faculty of Physics, University of Belgrade. Together with collaborators of NanoLab (Prof. Ivanka Milošević, Prof. Tatjana Vuković, Dr Božidar Nikolić, Dr Saša Dmitrović, Dr Zoran Popović and Ph.D. students Nataša Lazić and Marko Milivojević) he works on symmetry applications in quantum physics of quasi one-dimensional systems.

References

- [1] M. Vujičić, I. Božović, and F. Herbut. *J. Phys. A* **10**, 1271 (1977).
- [2] M. Damnjanović and I. Milošević, *Line Groups in Physics, Lecture Notes in Physics*, Vol. 801 (Springer, Berlin, 2010).
- [3] M. Damnjanović, I. Milošević, T. Vuković and R. Sredanović, *Phys. Rev. B* **60**, 2728 (1999).
- [4] E.B. Barros, A. Jorio, G.G. Samsonidze, R.B. Capaz, A.G.S. Filho, J.M. Filho, G. Dresselhaus, M.S. Dresselhaus, *Physics Reports* **431**, 261 (2006).
- [5] N. Lazić, T. Vuković, I. Milošević, and M. Damnjanović, *J. Phys.: Condens. Matter* **24**, 485302 (2012).
- [6] S. Dmitrović, T. Vuković, Z. Popović, I. Milošević, M. Damnjanović, *J. Phys. Cond. Matt.* **25**, 145301 (2013).
- [7] V. B. Shenoy, *Phys. Rev. B* **71**, 125431 (2005); B. Braunecker, P. Simon, D. Loss, *Phys. Rev. Lett.* **102**, 116403 (2009).
- [8] F. Simon, Ch. Kramberger, R. Pfeiffer, H. Kuzmany, V. Zolyomi, J. Kurti, P.M. Singer and H. Alloul, *Phys. Rev. Lett.* **95**, 017401 (2005).
- [9] S. Amelinckx, X.B. Zhang, D. Bernaerts, X.F. Zhang, V. Ivanov, B. Nagy, *Science* **265**, 635 (1994).

[Letter]

By Sören Holst

Department of Physics, Stockholm university

Physics and theology?

In his article “Physics and theology” (EPN issue 45/1), John Polkinghorne points out that although physics has been enormously successful in answering questions about physical phenomena, there are many related questions where answers are still lacking. How come we can understand the universe? Could the universe have been in any other way?

I agree with Polkinghorne about the importance of such questions. I also agree that they probably can't be addressed by physics alone. But his suggestion for what field that should complete physics in our search for answers is - theology! This is remarkable, since the issues that he raises are all philosophical, and so most naturally should be dealt with by philosophy (often with essential input from physics). One would therefore expect him to provide some reasons for his point of view. But on this Polkinghorne leaves us without answer.

Or maybe he provides us with a hint. At the end of the section “Cosmic fine-tuning” he refers to religious experience as a kind of legitimate evidence. Could religious experience be what makes him prefer theological explanations over philosophical? Unfortunately, religious experience has never proved to be a source of knowledge. On the contrary, there are innumerable examples of when such experience has led people astray, sometimes in bizarre ways.

One of the issues where Polkinghorne insists that theology could assist physics is the question of cosmic fine-tuning. How can it be that the parameters of our universe seem just right to support the existence of life? Polkinghorne notes that, in the context of quantum gravity, the hypothesis of a multiverse has been suggested. The idea here is that if our universe is just one out of perhaps infinitely many, then surely a few universes will be of the right kind.

Polkinghorne contrasts this hypothesis with another, suggested by theology: a divine Creator. He concludes: “there is no logically coercive principle to settle the choice between these two possibilities”.

I see at least three strong reasons to prefer one over the other:

1. *One of the hypotheses has explanatory power, the other has not.* If the multiverse hypothesis is true, that would really make the question of fine-tuning vanish. This is completely analogous to what has already happened to another similar question: that of the distance between the sun and the earth. Once we realize that there are numerous planetary systems in the universe, we no longer need to ask why the sun-earth distance is so “finely tuned” for life. On the other hand, the hypothesis of a Creator does not clear up any questions. We expect an explanation to refer to a theory which simplifies the phenomena of the world, not to lead to further confusion by introducing ill-defined concepts (such as “divine Creator”).

2. *One of the hypotheses is part of models suggested to solve also other specific problems in physics, the other is not.* Here it is important to realize that the multiverse hypothesis that Polkinghorne refers to is not just some general idea of other possible universes, but rather an implication of some specific inflationary scenarios in the context of quantum gravity. These models are supposed to solve some acute problems in theoretical physics. (Admittedly, these models must be regarded as extremely speculative, and I may add that I myself am not a proponent of any of them.) On the other hand, the hypothesis of a Creator is not part of any model supposed to solve other problems in physics.

3. *One of the hypotheses is falsifiable, the other is not.* In fact, there is plenty of hypothetical evidence that would disprove any of the suggested models for a multiverse. For example, most kinds of evidence that would falsify general relativity, quantum theory or inflation would also disprove such models. On the other hand, it is hard to imagine any empirical piece of evidence that would make the proponents of the Creator hypothesis abandon it (given that they have not already done so).

One cannot help wondering: Why did the editors of EPN choose to publish an article with such poor scientific analysis? ■



Opinion: climate change: can we afford to wait longer?

Christophe Rossel, IBM - Research Zurich, is President-elect of the EPS

Sitting in the garden and enjoying a rather hot sunny day on Sunday, April 13, I had the feeling of being in the middle of summer. In fact, according to the Swiss national weather service, April in Switzerland turned out to be 2.5°C milder than usual, with fruit trees blossoming 10 to 20 days earlier than the average measured between 1981 and 2010! Although the global warming effect may be enjoyable for many because of earlier sitting out on the terraces of restaurants or sunbathing, this trend is nevertheless a reality that can no longer be ignored. 2013 was the sixth warmest year since record-taking started more than 160 years ago, tying with 2007, based on an analysis of the World Meteorological Organization. Global warming is well explained in the synthesis of the fifth assessment report of the Intergovernmental Panel on Climate Change (IPCC), which was presented on that same Sunday, 13 April 2014, in Berlin! This report provides a clear and up-to-date view of the current state of scientific knowledge related to climate change, with a clear message: time is running out! If the countries are really willing to limit the average increase of the global surface temperature to less than 2°C by the end of this century, they have to engage in decisive political initiatives now — and not later. Today scientific consensus on the anthropogenic origin of global warming exists (*cf.* article by John Cook in *EPN* 44/6, p. 25) and also that the world emission of greenhouse gases will cause further

warming and changes in all components of the climate system. These emissions have reached unprecedented levels, and the rate of increase between 2000 and 2010 has been 2.2% each year as compared to an average of 0.4% in the three preceding decades. At this rate, the 2°C threshold might be reached already in 2030. The way to proceed is well explained by the IPCC experts: reduce the world greenhouse gas emission by 40 to 70% by 2050, and down to almost zero by the end of the century. This can only be achieved with efficient international cooperation and if all economical sectors produce more carbon-neutral energy from renewable and clean sources and improve energy efficiency. Another concern is, without doubt, the global increase of the Earth population, with individuals rightly striving for better living conditions, more food, and higher mobility. Even if we physicists may not qualify to solve such societal problems, it might still be possible to research the migration of the population from the countryside to the cities, to suggest predictive models for a more energy-efficient society.

How can the EPS contribute here? One way is to continue to publish engaged statements based on the broad scientific expertise of its members via its member societies, divisions and groups. Another one is to convince the public and governments with targeted actions that the fight against climate change must happen now — with a radical transformation in our life style and individual behaviour in

We could also use our communication skills to convince the politicians that the future of our planet is above all also their responsibility

parallel to implementing technical solutions. It is this sense of urgency that we physicists have to communicate in unison. We have been trained to address and solve complicated problems, but we could also use our communication skills to convince the politicians that the future of our planet is above all also their responsibility, before the situation becomes financially and economically impossible to remedy. Perhaps the International Year of Light 2015 could be one of many upcoming opportunities to convey this urgent message. ■

Sources

IPCC Vth assessment report (2013-2014), www.ipcc.ch/index.htm

John Cook in *EPN* 44/6, 2013 & www.theconsensusproject.com

COMING EPS EVENTS

- **9th International Summer School/Conference**
22 June / 06 July 2014,
CAMTP, University of Maribor,
Slovenia
www.camtp.uni-mb.si/chaos/2014

- **41st EPS conference on Plasma Physics**
22 - 27 June 2014,
Berlin, Germany
<http://eps2014-berlin.de/>

- **MORE ON:**
www.eps.org

TURBOVAC i

Turbomolecular pumps



A giant leap in vacuum performance!

It has never been easier to improve your processes than today! Our new TURBOVAC (T) 350 i and 450 i with integrated electronic drive will allow you to optimize pump-down times and consistently hit your target regarding pressures and gas flows. Designed to offer the best performance:size ratio available in the ISO 100/160 size range, they feature a rotor and drag stage design to achieve maximum performance and unparalleled speed, especially for light gases. This new product line is supplemented by the most flexible multi-inlet turbomolecular pumps TURBOVAC 350-400 i MI. Intended for the requirements of analytical instruments, multi-inlet pumps are prepared for individual design customization to provide an optimum process adaptation.



The TURBOVAC i series 350 i, 450 i and 350-400 i MI at a glance

Oerlikon Leybold Vacuum GmbH
Bonner Straße 498
D-50968 Köln
T +49 (0)221 347-0
F +49 (0)221 347-1250
info.vacuum@oerlikon.com
www.oerlikon.com/leyboldvacuum

oerlikon
leybold vacuum

Magnetic Field Instrumentation



Helmholtz Coil Systems

- 1, 2 and 3-axis versions available
- Field generated up to $500\mu\text{T}$ for DC and up to $100\mu\text{T}$ at 5kHz
- DC compensation up to $100\mu\text{T}$
- Option for Control Unit and National Instruments system
- 1-metre diameter coil available from September 2014



Mag-13 Three-Axis Magnetic Field Sensors

- Noise levels down to $<4\text{pTrms}/\sqrt{\text{Hz}}$ at 1Hz
- Measuring ranges from $60\mu\text{T}$ to 1mT
- Bandwidth to 3kHz
- Mag-14 version: bandwidth to 12kHz



Spacemag Three-Axis Magnetometer

- Shock and vibration tested to NASA-STD-7001
- Vacuum compatible
- 100kRad version available
- Noise: $<20\text{pTrms}/\sqrt{\text{Hz}}$ at 1Hz

www.bartington.com

Bartington Instruments Limited
5,10 &11 Thorpe Leys Business Park
Witney, Oxford, OX28 4GE, England

T: +44 (0)1993 706565
F: +44 (0)1993 774813
E: sales@bartington.com

Bartington[®]
Instruments