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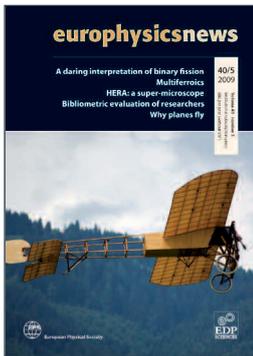
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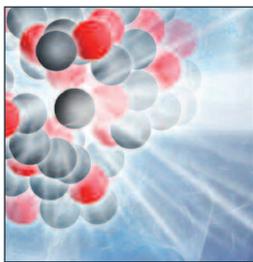
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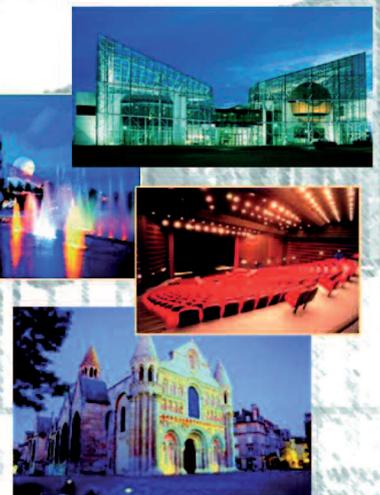
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Full-length paper submission deadline:
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THE NEED FOR THE DEVELOPMENT OF A EUROPEAN SCIENCE EDUCATION ACADEMY

Teachers are the key in the renewal of science education. The effective widespread use of inquiry- and problem-based science-teaching techniques in primary and secondary schools heavily depends on them. There are many constraints in the adoption of inquiry-based (ib) methods in science teaching and the science education community is using the term “inquiry” in different ways including inquiry as content and inquiry as instructional technique, making the term's meaning unclear. The evidence indicates that “although teachers made positive statements about the value of inquiry, they often felt more responsible for teaching facts, ‘things which show up on tests,’ ‘basics’ and structure and the work ethic”¹.

Teaching *ib* science poses unique and sometimes complex challenges for the teacher. What exactly is the difference between “traditional teaching and learning” and “*ib* teaching and learning” practices? Inquiry learning requires active participation of the students; they need to be more responsible, self-directed and self regulated². A great deal of the understanding of both scientific ideas and scientific practices is gained through collaboration with peers in collecting and analyzing data, and through classroom discourse. The teachers need to coach the students – to provide scaffolding for the inquiry and sense-making process, and reduce confusion by modelling practices, to provide feedback and help students plan and perform investigations. Teachers need to successfully shift their traditional roles and become comfortable in their new roles in the classroom.

In order for teachers to fully realize the potential of *ib* education, the potential fears and negative preconceptions related to the proposed approach need to be addressed. Teachers also need assistance in every step of the process. In our view there are two key points where we need to focus our full attention:

- **Using *ib* methods:** Albeit very effective, *ib* methods in science education constitute a major paradigm shift for teachers: they need to acquire new skills, abandon long standing practices and move away from their professional “comfort zone”, thereby exposing themselves to perceived, or real, risks.
- **Assisting behavioural change:** Apart from their training, in order for teachers to introduce *ib* methods and activities into their everyday routine, they will have to adopt a new culture and philosophy. In order to assist this change, we must introduce a solid theoretical framework and underline the main actions that need to be taken.

Following the recommendations of the “*Science Education Now: A renewed Pedagogy for the Future of Europe*” report³, the European Physical Society aims to add its contribution towards the effective widespread use of inquiry- and problem-based science-teaching techniques in secondary schools in Europe and beyond, through support for a European Science Education Academy. The aim of the European Science Education Academy is to set the pathway toward a standard-based approach to teaching science by inquiry, to disseminate methods and exemplary cases of both effective introduction of inquiry to science classrooms and professional development programmes, to support the adoption of *ib* teaching by demonstrating ways to reduce the constraints presented by teachers and school organisation and finally to deliver a set of guidelines for the educational community to further explore and exploit the unique benefits of the proposed approach in science teaching. To realize this vision the European Physical Society proposes to bring together experts in the field of science-education research and technology-enhanced science education, scientists and researchers involved in pioneering scientific experiments, teachers’ communities, policy makers and curriculum developers. ■

■ ■ ■ Sofoklis Sotiriou,
Ellinogermaniki School, Athens, Greece

notes

¹ Rodger W. Bybee, Leslie W. Trowbridge, Janet Carlson Powell: Teaching Secondary School Science: Strategies for Developing Scientific Literacy (9th Edition). ISBN-13: 978-0-13-230450-4

² Blumenfeld, P.C., Kempler, T.M., Krajcik, J.S. & Blumenfeld, P. (2006). Motivation and Cognitive Engagement in Learning Environments. In Sawyer, R. K. (Ed.), the Cambridge handbook of the learning sciences. New York: Cambridge

³ Rocard M. *et al.*, EC High Level Group on Science Education (2007). Science Education NOW: A Renewed Pedagogy for the Future of Europe, ISBN 978-92-79-05659-8.

NOVEL DIRECTIONS IN EUROPEAN RESEARCH ON LIQUID CRYSTALLINE SOFT MATTER

If the amount of discussions could be used as unit of measurement for the success of a conference, then the European Science Foundation (ESF) exploratory workshop “Frontiers in European Research on Liquid Crystalline Soft Matter”, Bandol, France, 27-29 May, saturated the scale. Liquid crystals (LCs) are widely known for their use in display technology, for long the main research interest in the LC community.

But LC research is much broader than this and one of the main goals of the workshop was to touch different topics in the “realm of soft condensed matter, that address, apply or rely on aspects of the liquid-crystalline state of matter”, as the organizers expressed it.

A restricted number of scientists, in conformity with the ESF rules, were invited to represent the full breadth. The twenty-six participants came from eight European countries with an good representation of female scientists. The farsighted vision of the organizers brought together researchers from the LC field and scientists from other communities, contiguous or working on topics relevant in emerging LC fields, with a general intent of exchange of knowledge. Questions followed each presentation but time was also specifically allocated for common discussions in which almost everybody took part, in a truly multi-disciplinary spirit, finding common problems and new ideas relevant for joint projects or networks. It is well known that people are affected by their working envi-



▲ The participants in the ESF exploratory workshop “Frontiers in European Research on Liquid Crystalline Soft Matter”.

ronment, thus the location of the workshop certainly had a positive contribution to the event. Benefits came from the beautiful surroundings and from the science-soaked air of the workshop venue, the LC Lab with its research equipment, demonstrators and insects that reflect multiple colours (due to their LC-like photonic crystal shells).

The main organizer of the workshop, Jan Lagerwall, with the co-organization of Sven T. Lagerwall, had realized a program outside the well-established LC research, identifying five areas in strong development: *Liquid crystals*

in and from living matter and in medicine; Drops, bubbles, tubes, foams and films; Colloidal liquid crystals and liquid crystal colloids; Liquid crystals for new functional materials, organic electronics and photovoltaics and Liquid crystals in sensors, actuators and novel optic and electrooptic devices. ■

■ Giusy Scalia,

ENEA, Department of Physical Technologies and New Materials, C. R. Portici, Portici (Naples), Italy

For more information:

www.workshop.lcsoftmatter.com

Nominations for Editor in Chief of EPL

Nominations are requested for the Editor in Chief of EPL, a letters journal owned and published by a consortium of national physical societies. The Editor in Chief (EiC) needs to be a recognised authority and leading researcher in a field of physics, and have a broad knowledge and interest in physics and its frontiers. The EiC will need to demonstrate strong commitment and leadership to develop further EPL into a top-ranking jour-

nal. To this end, a proven ability to interact with senior scientists is required. Experience with the editorial process for a physics journal is also essential. The EiC will play a key role in making EPL a leading global physics letters journal with high impact and high visibility that publishes high-quality articles across all of physics. The term of office of EPL Editor in Chief is three and a half years. A job description is available at www.epletters.net.

Nominations may be made by the individual concerned, or by third parties not later than 15 November 2009. Nominations should include a CV, publication list and a brief covering letter explaining their interest and qualifications for the post of the person being nominated. Nominations should be sent to the chair of the selection committee care of the EPL Editorial Office. (editorial.office@epletters.net).

IAPS: SURVIVAL AGAINST THE ODDS

The International Association of Physics Students (IAPS) turned 21 last year. The odds against the survival of such an organisation – an entirely student-run body, whose leading members have no more than a year or two to spare before moving on – must have been huge, but survived it has. Here is the story of the Association, and of the remarkable people who made it happen.

On the afternoon of Saturday October 18th 1986, four physics students at Eötvös Loránd University (ELTE) sat in a room in Budapest feeling tired, but rather pleased with themselves. Their project – which many must have thought impossible – had been a success. In the room with them were 25 fellow physics students from all over Europe, including both sides of the Iron Curtain – the participants in the first ever International Conference for Students of Physics, which the four had spent the previous few months organising.

Great changes were taking place in Hungary at that time. János Kádár had ruled with an iron fist ever since the 1956 uprising, but paradoxically – or perhaps *because of* the excesses of the repression – the country had evolved its own brand of communism, sometimes described as “goulash communism”, in which private enterprise was tolerated to a degree unknown in the rest of the Eastern bloc. When, in 1985, Mikhail Gorbachev became General Secretary of the Soviet Communist Party, and ushered in the age of *perestroika* (restructuring), therefore, Hungary had a head start; it was Hungary that would precipitate the fall of the Ber-

lin Wall, along with the rest of the Iron Curtain, by opening its border with Austria in September 1989.

Against that background, opportunities were opening up in the country for resourceful and creative people who wanted to do something for their fellow citizens; such an individual was Péter Ván.

“I wanted to do something for the sake of our small society – a kind of social work”, he says. “This is still a principle for me. I try to do things, beyond my work and my family. To do something for the other humans around”. What he and his three colleagues at ELTE – Patroklosz Budai, Ákos Horváth and Péter Lévai – decided to do was to hold an international conference.

The four made up the foreign affairs group of the youth organisation of physics students, itself a sub-group of the Kommunista Ifjúsági Szövetség (KISZ), the Communist Youth Association. “It was obvious that we needed experience in English; to be a physicist is an international job”, says Ván. So they became interested in summer job-related exchange visits, and also had the idea of organising a conference, and a meeting of all physics students at the university endorsed this plan. With help from the uni-

versity, from the Central Research Institute for Physics of the Hungarian Academy of Sciences, and from their parents, they started planning. Invitation letters were sent to physical societies and universities all over Europe (these were pre-email days), as a result of which bookings came in from eight different countries, covering both sides of the Iron Curtain.

The first ICSP (the name was later changed to ICPS: International Conference of Physics Students) covered three full days. There were student lectures, guest lectures, scientific visits (including an opportunity to observe a well-timed eclipse of the moon), and parties. At the end of the conference, everyone felt it had been a success and should be repeated, not just next year but every year; there were also suggestions for other activities such as summer and winter schools, and scholarships.

But the organisers knew that something else was needed to make it all happen – an international organisation. *“We saw immediately... that what we had done would not be enough in the future”*, says Péter Ván. At the end-of-conference meeting, attended by some invited adults from the university and the

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▲ IAPS EC 2008-9
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 (Norway), Anton
 Muskeyev (Ukraine),
 Silvia Franklim
 (Portugal, President),
 Marko Banusic
 (Croatia), Jessica
 Stanley (UK & Ireland,
 Secretary), Jelmer
 Renema (Nether-
 lands, Treasurer).

government as well as the participants and organisers, he dropped a small bombshell. “We promoted the idea of an international physics organisation. They were surprised. You may imagine – you come to eat a pizza and they want you to build an oven...”. However, the response was enthusiastic, at least among the students; and over the next year, the new organisation – as well as a follow-up conference – began to take shape.

ICSP 1987 was held in Debrecen, eastern Hungary. Eleven different countries sent delegates, the total attendance being about 40. As well as all the academic, social and cultural activities that had been included the previous year, there was a formal meeting on the last day – Saturday September 12th – at which IAPS was born.

Among the participants that year was a second-year student from Budapest called Tamás Fülöp. He had been present during the first conference, but, as a very new student, he says, “my contribution to the organising work was making coffee for the participants”. Even at Debrecen he played a fairly minor rôle, but was inspired by the ideas and visions of the older organisers, and became the first secretary of IAPS, with Budai as president. These two set about the task of drawing up the first Charter and Regulations of the new body; these

documents, says Fülöp, provided IAPS with a “permanent backbone” which would hold it together in the face of the constant changes of personnel which are inevitable in a student organisation: when members of the group moved on, they would leave something behind for others to build on.

1988 saw ICPS moving out of Hungary for the first time; it took place in Prague, Czechoslovakia. Since then the conference has been hosted by a different country every year (several countries have held it more than once, but never consecutively). In 1989 it moved into Western Europe, crossing the swiftly-disintegrating Iron Curtain. The conference opened in Freiburg, West Germany, on Monday August 28th; two weeks later, on September 11th, Hungary opened its borders and hastened the collapse of the Eastern bloc. Twenty-three conferences have now been held, in a total of 20 cities and 16 countries.

The number of ICPS participants grew steadily in its first few years. In 1989, there had been about 50 participants; the following year, the Dutch organisers planned for 125, but were swamped with applications and had to allocate places on a system of quotas for each country. Numbers eventually levelled out at about 350, which is a natural limit inasmuch as there are

few lecture theatres that will hold more, and it is important for everyone to be able to attend the guest lectures and the ceremonies.

The conference grew in duration too, from a few days to a week, and it also evolved. The basic elements were there from the start: student and guest lectures, scientific and cultural visits, and, of course, the parties. In addition, IAPS needed to hold an annual general meeting, and the conference was the natural venue for that too. By 1989, poster sessions had been introduced, and later other activities were added, some of which became regular features of ICPS, such as the National Party (introduced in 1996), team sports, and (from 2005) a Costume Party. Other events, such as workshops and debates, have appeared from time to time.

IAPS membership grew over the years, with national and local committees being set up in more and more countries. With the help of the European Physical Society, IAPS was registered as an international organisation, and a bank account was set up. The association established its own Journal (JIAPS), and organised summer schools, exchange visits and short trips to scientific places of interest such as CERN; however, ICPS remained the jewel in its crown. The secret of ICPS’s success is its unique blend of the conventional components of a conference

(lectures, posters, excursions etc) with the social side. At ICPS, almost every night is a party. One of these, the National Party, encapsulates, in one evening, the spirit of ICPS. It would be more accurate to call it the International Party, as it is a celebration of the national food and culture of each participating nation. First, stalls are set out, and each national group presents samples of food and drink (usually alcoholic), having prepared the former using whatever kitchen facilities can be found – anything from the main university refectory to a tiny hired kitchen in a backstreet. Later in the evening, preferably when most of the food, and especially the drink, have been consumed, each group is called to the stage to perform some act, which may be song, dance, drama, mime, comedy, or any other kind of performance.

Not surprisingly, organising ICPS is the biggest challenge of all. The fee is deliberately kept low, so that students from poorer countries can attend. That means that most organisers will face a huge sponsorship target, amounting to perhaps half, or even two-thirds, of the total budget. And when the

money has been found, there are all kinds of things to sort out – student accommodation, lecture theatres, guest lecturers, excursions, the conference handbook, the IAPS AGM, sporting events, lab tours, food, bars... and not forgetting those parties.

Jelmer Renema, a student at the University of Leiden in the Netherlands, is the current Treasurer of IAPS. “Looking back on the rich history of IAPS”, he says, “we can only admire the pioneering spirit of our predecessors, as they realised their vision in the aftermath of communism. These people deserve our respect, and it's great to hear that those who have been instrumental in making IAPS a success feel that they have gotten so much out of it. Our conference, ICPS, continues in the spirit of openness and friendship that has made it so successful in the past. In the future, IAPS will continue its efforts to create a truly international network of physics students from all corners of the globe.”

The pioneers of ICPS and IAPS do indeed look back on their work with fond memories, and are pleased to see their creations looking so healthy. Tamás Fülöp is currently

working in Prague, researching the physical aspects of boundary conditions in quantum mechanics. He says he learned a lot from the five ICPSs he attended between 1986 and 1990 – about physics, and about people: “*The atmosphere of the conferences was very warm and friendly. It impressed me very seriously that, irrespective of linguistic, cultural or other differences, people gather to be together, to scientifically interact, and to cooperate in an open way. It opened my personality a lot, too*”. And Péter Ván, when I first contacted him, was busy organising another conference, which he hoped would “*build a bridge between engineering, applied and fundamental theoretical research*”. It will be a small conference, he said, “*but we are a good team, and want to set up an international organization...*”. ■

■ ■ ■ **Jim Grozier**,
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Acknowledgements:

Norman Davies: *Europe: A History* (OUP, 1996); Péter Ván, Tamás Fülöp, Jelmer Renema – personal communications; IAPS archive.

European Physical Society Nuclear Physics Board

► CALL for nominations for the 2010 Lise Meitner Prize for Nuclear Science

The Nuclear Physics Board of the EPS invites nominations for the “Lise Meitner Prize” for the year 2010. The award will be given to one or several individuals for outstanding work in the fields of experimental, theoretical or applied nuclear science. The Board welcomes proposals which represent the breadth and strength of European nuclear science.

Nominations need to be accompanied by a completed nomination form, a brief curriculum vitae of the nominee(s) and a list of major publications. Letters of support, from authorities in the field, that outline the importance of the work of the nominee(s) will also be helpful.

Nominations will be treated in strict confidence. While all nominations will be acknowledged, there will be no further communication from the selection committee, till the announcement of the prizewinner. Nominations should be sent to:

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For the nomination form and more detailed information go to the web site of the EPS Nuclear Physics Division <http://nuclear.epsdivisions.org/> or the web site of the EPS www.eps.org (activities, EPS Prizes, Lise Meitner Prize)
The deadline for the receipt of nominations is 8 January 2010.

■ ■ ■ **Matti Leino**,
Chairman EPS-Nuclear Physics Division

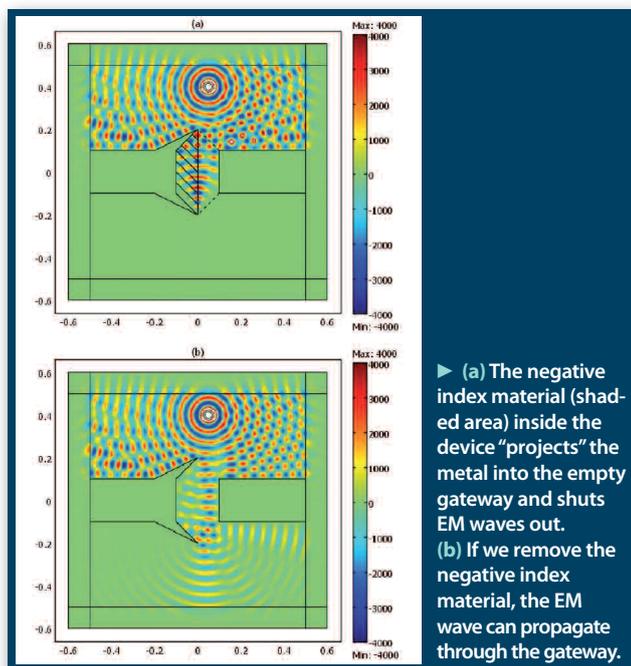
Electromagnetic gateway

It is well known that a piece of metal can block electromagnetic waves. When some special form of “negative refractive index” material is placed next to a piece of metal, the metal will appear to be bigger than its true physical size. The negative index material behaves as some sort of “passive” projector (which does not require power to operate), and it can project the metal optically into a near-by channel to block waves, even though the channel is actually “open”.

The consequence is that we have a device which acts like the “railway platform 9 3/4” that Harry Potter uses to get to Hogwarts. The “amplification” functionality of negative index media is noted before, but the feasibility of such devices is limited by the very complex material parameters and the narrow bandwidth. Here, we show that such gateway-type devices can actually be realized with simple parameters and they can have wider bandwidths such that the concept is closer to reality than previously thought. The structure can be implemented by using magnetic photonic crystal structures that are periodic (*i.e.* each unit cell is the same). In addition, the effect is field tunable in microwave frequencies, resulting in an electromagnetic gateway that can be open or shut using external fields.

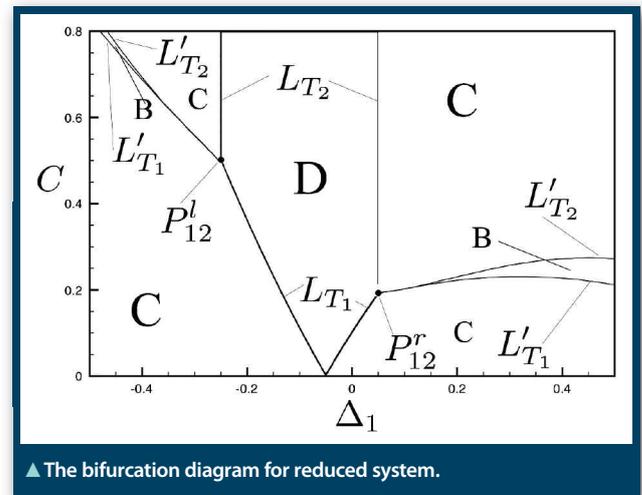
The only essential component is a negative refractive index layer with a refractive index of approximately -1. As there is extensive work on the design of the negative refractive index materials, it would be reasonably feasible for the present gateway to be realized in the near future. ■

■■■ Huanyang Chen, Che Ting Chan, Shiyang Liu and Zhifang Lin, ‘A simple route to a tunable electromagnetic gateway’, *New Journal of Physics* 11, 083012 (2009).



Coupled oscillators under periodic force

In the classical theory of synchronization of periodic oscillations, the bifurcational mechanism of this phenomenon was strictly established. Nowadays, the theory of chaotic synchronization develops intensively. However, the synchronization of quasi-periodic self-sustained oscillations is insufficiently studied and the strict bifurcation theory is not built yet.



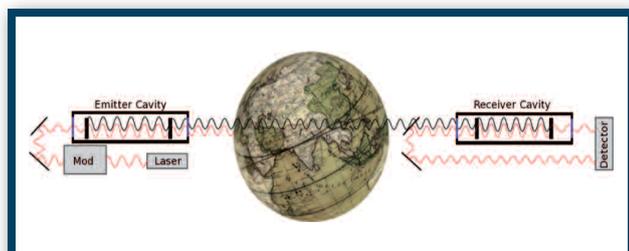
In the present paper, we propose and study a relatively simple model that describes phase dynamics of coupled quasi-harmonic oscillators under external periodic forcing in a vicinity of 1 : 1 resonance. On the basis of analytical and numerical studies, the bifurcational mechanisms of external partial and complete synchronization of two-frequency self-sustained oscillations have been established. We show that the transition from a single-frequency oscillation (corresponds to region D in the figure) to a three-frequency self-sustained oscillation (region B in the bifurcation diagram) in the source system is based on the following sequence of saddle-node bifurcations in the reduced system obtained using phase approach. The pair-wise tangential bifurcations of four equilibria appear simultaneously, and two closed invariant curves appear when crossing lines $L_{T1,2}$. This corresponds to the tangential bifurcations of four limit cycles and appearance of two two-dimensional tori lying on the surface of a three-dimensional torus as the result. Then, when crossing lines $L'_{T1,2}$ the tangential bifurcation of invariant curves appears in phase approach that corresponds to the saddle-node bifurcation of two-dimensional tori in the complete system. ■

■■■ V. Anishchenko, S. Astakhov and T. Vadivasova, ‘Phase dynamics of two coupled oscillators under external periodic force’, *EPL* 86, 30003 (2009).

Hidden laser communications through matter

Extensions of the standard model of particle physics - like string theory - predict and/or require the existence of hidden sectors, sets of new particles not participating in the strong or electroweak interactions. Still, these particles can have feeble interactions with our known sector through gravity or suppressed quantum effects. If very heavy, hidden particles don't have any impact in our everyday life, but if they are light - also a likely possibility - this might not be the case. One of these candidates, hidden photon (a hidden $U(1)$ gauge boson) with mass around the meV is proposed here as a way to establish secure optical communications through dense matter.

Hidden photons (γ') can mix quantum mechanically with ordinary photons (γ) leading to the inter-conversion of photons and hidden photons of identical characteristics. This effect, $\gamma \leftrightarrow \gamma'$ oscillations, can be used to produce beams of hidden photons by using laser beams, being the former fainter copies of the mother photonic ones. Current technology of optical communications can now be applied to these hidden beams, with the advantage that they interact so weakly with dense matter that they can be used to carry signals across dense matter; the denser the medium, the lesser the distortions/losses.



▲ A way to send hidden information across the Earth

Current constraints on the existence of hidden photons bound the $\gamma \rightarrow \gamma'$ probability (in vacuum, where it is more efficient) to be smaller than 10^{-12} demanding very intense lasers and sensitive photo-detectors. However, with the use of optical resonators in the emitter and receiver, a transmission rate of more than 1 bit/s is achievable in a link across the Earth's globe (Figure). Possible applications include communication between submarines, mines or to the backside of the moon. One could also contemplate the possibility of sending encryption keys directly through Earth thereby making it more difficult to eavesdrop. ■

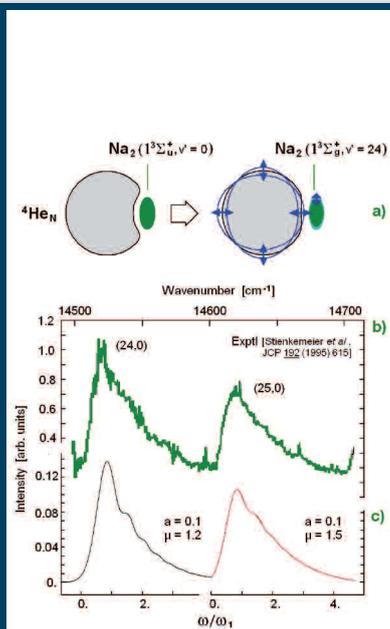
■ J. Jaeckel, J. Redondo and A. Ringwald, 'Hidden laser communications through matter - An application of meV-scale hidden photons', *EPL* **87**, 10010 (2009).

Optical transitions probe surface collective excitations

Collective excitations in confined quantum systems can be probed by the optical spectroscopy of doping chromophores [Szalewicz: *Superfluid He nano-droplets: the Franklin Physics Medal to G. Scoles and J.P. Toennies*, doi:10.1016/j.jfranklin.2008.04.008]. The lucky circumstance that alkali molecules can be trapped at the surface of ^4He droplets offers a unique tool to explore their surface excitations. In Na_2 an optical transition between triplet states [F. Stienkemeier *et al.*, *J. Chem. Phys.* **102**, 615 (1995)] determines a spectacular contraction of the molecule, with a sudden weakening of the molecule-surface interaction and a conversion of the ^4He -droplet collective excitations localized around the sodium dimer into much softer, delocalized excitations of the droplet surface, similar to tidal waves. The authors show that in this model case the spectral function can be derived analytically within the Lax formalism, and that the localized phonon zero-point energy released in this process yields a peculiar asymmetric triangular shape of the surface-phonon sideband of the molecular vibronic lines, with suppression of the zero-phonon line. The good agreement with experiment shows that the structure of the vibronics line carries information on the dynamics of the droplet surface, with a negligible perturbation of the probe molecule. Thus a surface-excitation optical spectroscopy of quantum droplets appears to be feasible. ■

■ V. Hizhnyakov, I. Tehver and G. Benedek, 'Theory of the optical spectrum of Na_2 on ^4He droplets: effects of the zero-point energy of the nearest atoms', *Eur. Phys. J. B* **70**, 507 (2009).

▲ An optical transition between triplet states of a Na_2 molecule trapped at the surface of a ^4He droplet, besides leaving it in a high vibronic state v , generates surface collective excitations through the release of ground-state zero-point energy of droplet localized excitations (a). Theory (c) predicts a peculiar triangular shape of the molecular vibronic lines in agreement with Stienkemeier experiments (b), the sidebands being due to low-energy surface-phonons.

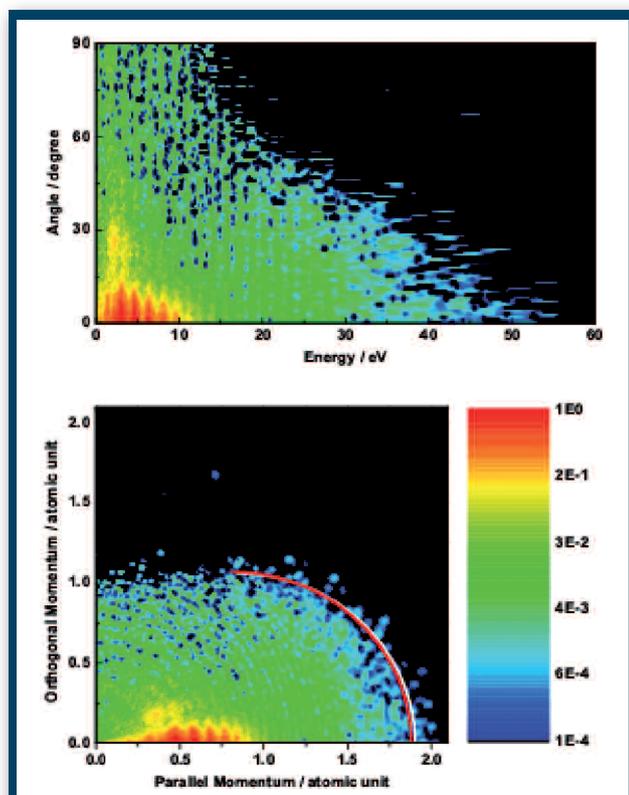


Electron-molecular ion elastic scattering

Electron-ion scattering phenomena are of great interest in plasma and planetary atmosphere physics and chemistry [A.D. Williams, *Rep. Prog. Phys.* **62**, 1431 (1999)]. The short-range interaction leads to elastic scattering differential cross sections which are noticeably different from the Rutherford formula for backscattered electrons. The related experimental measurements are very demanding due to very low densities of ion beams and difficulties to build electron spectrometers for large deviation angles. Following the proposal of Lin and co-workers [T. Morishita *et al.*, *New J. Phys.* **10**, 025011 (2008)], **it is now possible to extract elastic scattering differential cross sections from the high energy cut-off of photoelectron spectra** measured in laser-induced ionization of neutral molecules (figure). The underlying tunnel ionization and re-scattering mechanisms may lead to time-resolved studies of structural changes in molecules with sub-femtosecond resolution. ■

■ ■ ■ C. Cornaggia,

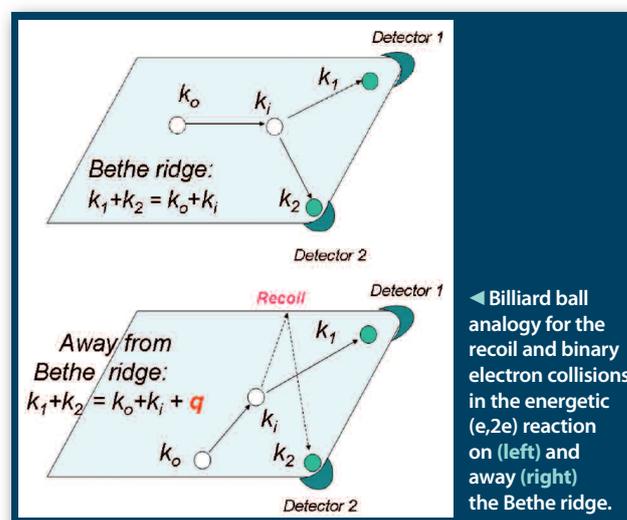
'Electron-molecular ion elastic scattering probed by laser-induced ionization of neutral molecules', *J. Phys. B: At. Mol. Opt. Phys.* **42**, 161002 (2009).



◀ Photoelectron spectra recorded in CO_2 at 800 nm and $8.3 \times 10^{13} \text{ Wcm}^{-2}$. **Top:** Angle-resolved energy spectrum. **Bottom:** Momentum spectrum. The angle and momentums are relative to the laser polarization direction.

Energetic (e, 2e) reaction away from Bethe ridge

We analyse the recoil-to-binary peak ratio in an energetic (e,2e) reaction on the valence ns sub-shell of noble gas atoms. Dramatic qualitative change in this ratio dependence on the ejected electron energy can be explained by variation of reflectivity of the short-range target potential. The reflectivity increases profoundly from lighter (He) to heavier (Ne and Ar) noble gas atoms because of modification of the scattering phases due to occupation of the target np orbitals (Levinson theorem). This effect is further modified due to strong inter-shell correlations in Ar. These theoretical predictions are confirmed experimentally.



◀ Billiard ball analogy for the recoil and binary electron collisions in the energetic (e,2e) reaction on (left) and away (right) the Bethe ridge.

This effect can be illustrated using a simple billiard-ball analogy as is shown in the figure. Binary (e,2e) reaction satisfies the momentum conservation also known as the Bethe ridge condition (upper diagram). Accordingly, the ejected electron is well confined within a narrow angular range in the forward direction (binary peak). If the Bethe ridge condition is no longer satisfied, there is a need for a momentum exchange with the nucleus (lower diagram). This results in an additional recoil peak roughly in the direction opposite to the binary peak. Conventionally, it was believed that the relative recoil peak intensity would fall with increase of the projectile energy which is indeed the case in light atoms like H and He. This happens because the bare nucleus Coulomb barrier ("billiard wall") is a poor reflector of energetic electrons. This, however, changes in many-electron noble gases. **In these systems, electron reflection from the target core potential is increasing with energy because of occupied target orbitals which change profoundly the scattering phases of the ejected electron.** ■

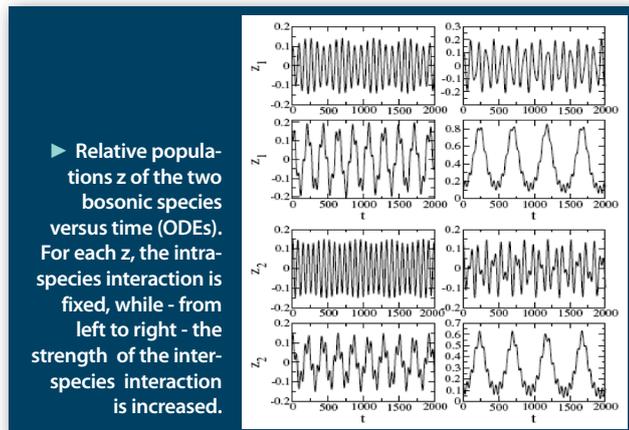
■ ■ ■ A. S. Kheifets, A. Naja, E. M. Staicu Casagrande and A. Lahmam-Bennani,

'An energetic (e, 2e) reaction away from the Bethe ridge: recoil versus binary', *J. Phys. B: At. Mol. Opt. Phys.* **42**, 165204 (2009).

Josephson junction with 2 bosonic species

Atomic Josephson junctions (AJJs) keep in touch ultracold atoms and superconductivity. Josephson predicted the macroscopic quantum tunneling of Cooper pairs occurring in superconductor-oxide-superconductor junctions in 1962. This work is a contribution to the study of the atomic counterpart of the Josephson effect.

Here, the analysis of AJJs performed with a single Bose-Einstein condensate (BEC) is extended to the case of two species of Bose-Einstein condensed atoms. The two BECs are trapped by means of a one-dimensional double-well potential and are interacting with each other; their spatio-temporal evolution is controlled by two coupled Gross-Pitaevskii equations (GPEs). Performing the so-called two mode approximation, AJJs temporal evolution can be described by a system of four coupled ordinary differential equations (ODEs), whose mechanical analog are coupled pendula. By these ODEs the oscillations of the relative population of each species are determined.



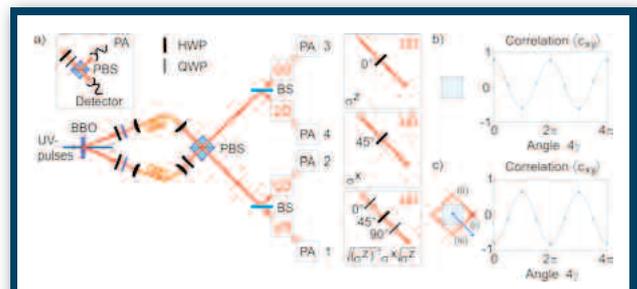
The main points of the paper are three:

- 1) The agreement between the oscillations predicted by the GPEs and by the ODEs.
- 2) By solving the ODEs, it is proved that even if the intra-species interaction is not strong enough to ensure the oscillations of the relative populations around a non-zero time averaged value, if the inter-species interaction is greater than a certain value, this phenomenon occurs.
- 3) The possibility to establish links with the current experiments on the ultracold atoms. In the paper, are derived analytical formulas for the frequencies of the relative populations oscillations around stable equilibrium points. Such formulas can be used to address measures of the inter-species inter-atomic scattering length. ■

■ G. Mazzarella, M. Moratti, L. Salasnich, M. Salerno and F. Toigo,
'Atomic Josephson junction with two bosonic species',
J. Phys. B: At. Mol. Opt. Phys. **42**, 125301 (2009).

Revealing anyonic features

In Nature particles appear in two distinct types according to their statistics: bosons and fermions. This is due to the fact that in three dimensions the observable particle statistics is limited to these two cases. In two-dimensional systems, the situation changes drastically: anyons can appear which exhibit fractional statistics ranging continuously from bosonic to fermionic.



▲ Echo spectroscopy Ramsey fringes as a function of the time separation between two light pulses around the echo pulse.

Amongst others, anyons can be realized as quasiparticles in highly entangled, two-dimensional many-body lattice systems. In our work, we encode the corresponding relevant many-body state of a simple anyonic model in the multi-partite state of polarization entangled photons. This physical realization, Fig. (a), allows the demonstration of anyonic statistics in the minimal instance of a square plaquette of the lattice, Fig.(b). There, an anyon and the path of a second anyon circulating it, can be encoded, Fig.(c). As the circulation of one particle around another is equivalent to two successive exchanges of these particles it is possible to probe the exotic statistical behaviour of these anyons with our experimental implementation.

Our experiment demonstrates the presence of fractional statistics by the manipulation of entangled quantum states. For future applications one would like to employ anyons to perform error-free quantum computation by exploiting their topological properties. This is the first in-principle demonstration for the implementation of such anyonic quantum processing. ■

■ J. K. Pachos, W. Wieczorek, C. Schmid, N. Kiesel, R. Pohlner and H. Weinfurter,
'Revealing anyonic features in a toric code quantum simulation', *New Journal of Physics* **11**, 083010 (2009)

Erratum

In the Highlight EPN 40/4, p.11, right, the title should be 'Field-free molecular alignment probed by FLASH' and the reference at the bottom should be: M.J.J. Vrakking, 'Field-free molecular alignment probed by the free electron laser in Hamburg (FLASH)', *J. Phys. B: At. Mol. Opt. Phys.* **42**, 134017 (2009)".

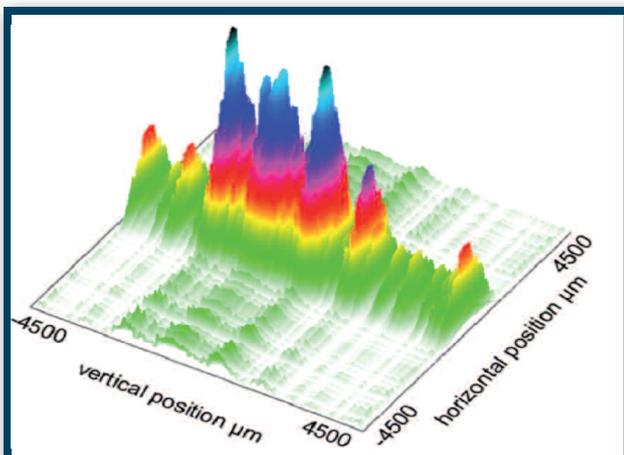
Miniature electron beam pumped laser

In 1894, P. Lenard developed a technique to send electron beams through thin metal foils into dense gases. This technique was later used for particle beam pumped laser experiments with MV and kA beams. Replacing the classical "Lenard windows", which are several μm thick, by very thin (300nm) silicon-nitride membranes allows a drastic reduction of the electron energy to typically 12 keV. The short range of low energy electrons and the stability of the ceramic membranes with respect to high beam currents result in high power densities in the target gas. Using this technique, brilliant electron beam induced vacuum ultraviolet excimer light sources have been developed, which have commercial applications.

The high power density can also be used to build extremely compact laser devices. There is an entire class of gas laser systems such as the widely used excimer lasers, which can be pumped ideally by particle beams at elevated gas density. An atomic Xe laser line at a wavelength of $1.73 \mu\text{m}$ emitted from a 12 keV electron beam pumped argon-xenon mixture was used to demonstrate the concept. This is a miniature version of the large transversely pumped electron beam pumped lasers. The threshold pumping power was only 37 mW and the dimensions of the laser cell and electron gun only a few cm. It could be demonstrated that the $1.73 \mu\text{m}$ Ar-Xe laser can be operated fully continuously and, by pulsing the electron beam, we showed that it is clearly a recombination laser. The gain medium is almost spherical, which leads to the multi-mode beam pattern shown in the figure when the laser mirrors are tilted with respect to the optical axis. ■

■ C. Skrobol, T. Heindl, R. Krücken, A. Morozov, R. Steinhübl, J. Wieser and A. Ulrich,

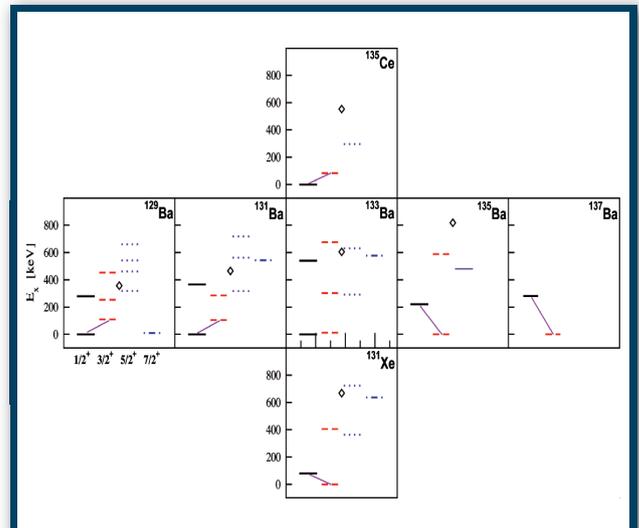
'A miniature electron beam pumped laser', *Eur. Phys. J. D* **54**, 103 (2009).



▲ Example of the beam profile for a strongly de-aligned laser cavity. It shows that many off axis modes develop due to the almost spherical gain medium.

The ^{133}Ba nucleus with the (d,p) reaction

In a recent article Suliman et al. present a study of the single-neutron levels of the ^{133}Ba nucleus using the $^{132}\text{Ba}(d,p)^{133}\text{Ba}$ reaction with a polarised deuteron beam. Many unambiguous spin-parity assignments were made, up to an excitation energy of 2.2 MeV, due to the sensitivity of the angular distributions of the vector analysing powers to the total spin, J , of the final state (it will be recalled that angular distributions of the differential cross section are only sensitive to the transferred angular momentum, L). These assignments enabled a detailed comparison with the results of different structure models.



▲ The evolution of the experimental low-lying positive-parity states in the Ba isotopes and the $N = 77$ isotones around ^{133}Ba .

Along the chain of odd- A Ba isotopes it is conspicuous that the lowest $1/2^+$ and $3/2^+$ states cross each other, the ^{133}Ba nucleus forming the point at which these states are almost degenerate. It thus forms a severe constraint on structure models in this mass region. It may also be considered as a single fermion (a neutron hole) coupled to a nearly $E(5)$ ^{134}Ba core, making it a suitable nucleus for comparison with IBFM (Interacting Boson-Fermion Model) calculations.

Suliman *et al.* show that in fact none of the IBFM schemes that they investigated was able to provide a satisfactory description of the low-lying levels of ^{133}Ba , suggesting that the structure is rather more complicated than this simple picture suggests. This conclusion seems to be borne out by spherical shell model calculations, which provided the best overall description of the low-lying levels. ■

■ G. Suliman *et al.*,

'Study of the ^{133}Ba nucleus with the (d,p) reaction', *Eur. Phys. J. A* **41**, 299 (2009).



A DARING INTERPRETATION

OF BINARY FISSION

* R.A. Ricci * INFN, Laboratori Nazionali di Legnaro e Dipartimento di Fisica, Università di Padova, Padova, Italy * DOI: 10.1051/epn/2009701

Seventy years ago, on the seventeenth of December 1938, O. Hahn and F. Strassmann discovered that barium is formed in uranium irradiated by neutrons, and concluded from the chemical evidence that a new type of nuclear process exists. This tremendous discovery of fission opened a new area, that of nuclear energy, and gave an extraordinary stimulus to the development of scientific research in an immense variety of fields. Astonishingly enough, sixty-nine years of intensive research by physicists and chemists in the whole world did not permit to explain why light actinide nuclei fission asymmetrically and why ^{258}Fm and heavier nuclei fission symmetrically, nor to explain the observed width of the regions of appreciable yield and its variation as a function of the mass A_F of the fissioning nucleus.

Now, after a long wait, a quite new hypothesis, able to live up to this expectation, has recently been formulated. But by its real nature, this hypothesis is much more than just an answer to the above questions: Its novelty is that it assumes the existence of a new state of nuclear matter, “the nucleon phase”. The nucleon of such a phase could be a “third constituent” of the atomic nucleus, to be added to the proton of Rutherford and to the neutron of Chadwick...if it could exist other than in very extreme conditions. This hypothesis is made of several elements (I through VI). Let us examine them successively (a), and compare them every time with possible arguments in their favor (b).

Reaction time of the major step

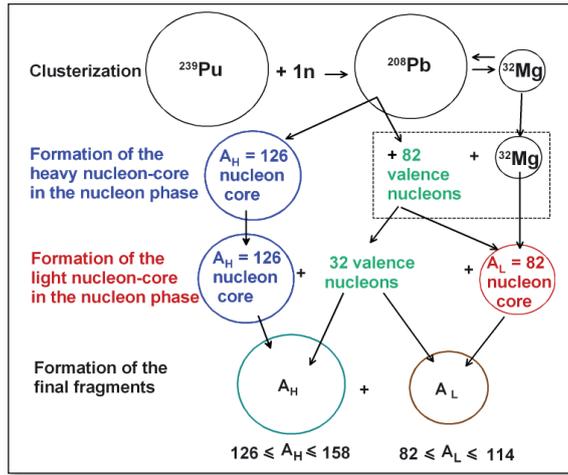
I-a This hypothesis first concerns the “reaction time” Δt of the major step of the fission process. This time should be as short as $1.77 \cdot 10^{-25}\text{s}$. According to the energy-time uncertainty relation $\Delta E \cdot \Delta t \geq \hbar$, this means that any discrete mass value should be replaced by a “mass spectrum”, having a width of 4 atomic mass units (u); it

means furthermore, that an energy as large as 3.72 GeV should be available, and a temperature as high as 10^{13} K , i.e. 10^5 times higher than the temperature needed for the onset of a thermonuclear reaction, should be reached.

I-b In favor of this almost dismaying hypothesis, C. Ythier and G. Mouze, of the Chemistry Department of the University of Nice, France, have since 1991 found several arguments. They first found clear evidence, in the slope of the mass distribution of the fission of ^{235}U induced by thermal neutrons, that this distribution, in the region $A \sim 132$, can be obtained by adding Gaussian distributions centered on $A = 132, 133$ and so on and having a width of 5u; but they had not taken into account the very small contribution of symmetric fission at thermal energies [1]. In 1992, in their study of the fine structure discovered at Saclay by C. Signarbieux in the mass distribution of the same fissioning system (but obtained in the conditions of a “cold fission” experiment [2]) they found again clear evidence that the uncertainty in the mass is equal, more precisely, to 4u. Later on, they found another opportunity to verify this

▲ A concept image of the process of nuclear fission of uranium atoms.
© iStockPhoto

► **FIG. 1:** Description of the asymmetric fission of $^{239}\text{Pu} + n_{\text{th}}$ in the nucleon-phase model by the sharing-out of a number of valence nucleons equal to A_{cl} between the nucleon cores.



value of $4u$. They found that the width of $8u$ of the mass distribution of ^{258}Fm measured by D.C. Hoffman could be obtained by adding four Gaussian distributions centered on $A = 126, 128, 130$ and 132 , if their width is taken equal to $4u$. But recently Ythier and Mouze realized that the extreme brevity of the fission process is related to its localization in the extremely narrow region of space occupied either by the valence shells of the deep-lying ^{132}Sn core of the fissioning nucleus, or better by the valence shells of a now postulated “ $A = 126$ nucleon core” of the nascent heavy fragment [see II-a]. Indeed, the width Δl of this region of space should be as small as only $5.3 \times 10^{-17} \text{ m}$ [3] and correspond to a minimum reaction time $\Delta t = \Delta l/c$ of $1.77 \times 10^{-25} \text{ s}$.

The nucleon phase hypothesis

II-a As a consequence of these extreme conditions, it is further assumed that the distinct proton phase and neutron phase, which coexist in ordinary nuclear matter, disappear and are replaced by a unique “nucleon phase”. Here the distinction between proton and neutron is abolished, but the nucleons form closed shells for the same magic numbers as those of the proton- and neutron-phases, in particular for $A = 82$ and $A = 126$, as if “magic mass numbers” should exist: the organization of matter in closed “shells” should be a universal law!

II-b The strongest argument in favor of the existence of a nucleon phase is the equation of James Terrell [4], which was never explained so far:

$$\bar{\nu} = 0.08 (A_L - 82) + 0.10 (A_H - 126), \quad (1)$$

giving the mean value of the prompt-neutron yield of systems as different as $^{233}\text{U} + n_{\text{th}}$, $^{235}\text{U} + n_{\text{th}}$, $^{239}\text{Pu} + n_{\text{th}}$ and ^{252}Cf as a function of the mass numbers A_L and A_H of the light and heavy fission fragments, respectively.

In a communication at the 46th International Winter Meeting on Nuclear Physics [3] held in Bormio in January 2008, Ythier and Mouze pointed out that the formation, in the nascent light and heavy fragments, of an $A = 82$ nucleon core and of an $A = 126$ nucleon core,

surrounded by their valence nucleons, could explain 1°) why no prompt neutron is emitted by a fragment having a mass number equal to 82 or 126 and 2°) why the prompt neutron yield increases approximately as a function of the mass number A_L or A_H for $A > 82$ and $A > 126$.

Nature of the rearrangement

III-a The hypothesis in question implies that an “ignition step” precedes the step of the nucleon phase. As heavy nuclei have a great tendency to dissociate internally with a great energy-release, e.g. 59.49 MeV for $^{235}\text{U} + n_{\text{th}}$, this ignition step can be that of the “clusterization”. Indeed, this energy is large enough for inducing a kind of “core-cluster collision”.

The hypothesis is further that this collision creates in the heavy part of the “dinuclear system” an “ $A = 126$ nucleon core”, and that the $208 - 126 = 82$ “extra-nucleons” can be partially transferred from this core to the primordial cluster. There, this transfer allows the formation of an “ $A = 82$ nucleon-core”. However, in a fissioning system such as ^{252}Cf , and in heavier systems, the transfer of nucleons can lead to the formation of an “ $A_L = 126$ nucleon-core”: It is the closure of such a shell in the nascent light fragment which explains the occurrence of the “symmetric” fission mode.

III-b There are several arguments in favor of the clusterization of the fissioning system. One of them was put into evidence by Ythier and Mouze [5] as far back as 1988; it is the law of Flynn, Glendenin *et al.*, according to which “the mean mass of the light fragments varies linearly as a function of the mass A_F of the fissioning system” [6]. Indeed, this law was then interpreted as a law of formation of the light fragment by the transfer of an almost constant number of protons and neutrons from a ^{208}Pb core to its cluster, of mass A_{cl} .

An argument in favor of the creation of an $A_L = 82$ nucleon core is furnished by the mass spectrum of the light fragments [7]. One observes that the fission yield decreases abruptly below $A = 82$, as if the valence shells of the primordial cluster had a tendency to form a closed $A = 82$ nucleon shell with the nucleons released by the nascent heavy fragment (where an $A = 126$ nucleon core has been formed), as shown by Ythier *et al.* at the Strasbourg Meeting of May 2008.

But the best argument for these $A = 82$ and $A = 126$ nucleon cores is the observed “width” of the mass distribution of the light or heavy fragments. Ythier *et al.* have demonstrated that, if the broadening of the distribution due to the uncertainty in the mass is neglected, this width must be equal to exactly “ A_{cl} ” u in asymmetric fission, and to exactly $(A_{cl} - 44) u$ in symmetric fission. Indeed, this width is equal to $\Delta A_L = A_L^{\text{MAX}} - A_L^{\text{MIN}}$ for light fragments; so it must be equal either to $(A_{cl} + 82) - 82$ in asymmetric fission, or to $(A_{cl} + 82) - 126$ in symmetric fission.

But if the broadening due to the uncertainty on the mass is taken into account, these two widths become $(A_{cl} + 2)u$ and $[(A_{cl} - 44) + 2]u$, respectively, as is observed experimentally. For example, for the spontaneous fission (s.f.) of ^{258}Fm in which $A_{cl} = 50$, one finds a width of only $6 + 2 = 8u$, as was discovered, in 1977, by D.C. Hoffman [8].

One sees that the shell closure at $A = 126$ in the nascent light fragment explains the “narrow symmetric” mass distribution of ^{258}Fm (s.f.). So it explains the appearance of symmetric fission! And the nucleon-phase hypothesis explains, at the same time, the asymmetric and the symmetric fission mode!

A distribution law for 82 nucleons

IV-a The nucleon-phase hypothesis allows to describe the main step of the fission reaction as a simple chemical process: it is the distribution of 82 nucleons between two different valence shells, those of the primordial cluster, and those of the $A_H = 126$ nucleon core of the nascent heavy fragment. And for the now well-known asymmetrically-fissioning systems, it can be characterized by a constant “distribution coefficient”.

IV-b The argument in favor of this very new point of view is furnished by the law of Wahl. In 1965, A. C. Wahl, co-discoverer of plutonium, pointed out that the mean mass of the heavy “fission product” is constant and equal to $\sim 138 u$ for fissioning systems as different as $^{233}\text{U} + n_{th}$, $^{235}\text{U} + n_{th}$ and ^{252}Cf (s.f.) [9]. Nowadays, and for fission fragments, this constant value is taken $\overline{A_H} = 140u$. This fact can be interpreted as follows: on an average, and whatever the fissioning system may be, $140 - 126 = 14$ nucleons remain in the heavy fragment. But the number of nucleons to be distributed is constant and equal to $208 - 126 = 82$. So, on an average, the number of nucleons remained in the valence shells of the primordial cluster is $82 - 14 = 68$. Ythier and Mouze concluded that, on the average, the mean mass of the light fragment $\overline{A_L}$ is equal to $(A_d + 68)u$: it is the modern expression of the linear law of K.F. Flynn, L.E. Glendenin *et al.* [6]. But this result can also be written as follows: “the ratio of the mean number of nucleons remaining on the $A_H = 126$ core to the mean number of nucleons transferred to the primordial cluster A_{cl} is constant, and equal to $14/68 = 0.206$.” Thus it is nothing else but a Nernst-distribution law, similar to that established in 1891 for describing the distribution of one and the same body between two unmiscible liquids [10].

The phenomenon of barrier-free fission

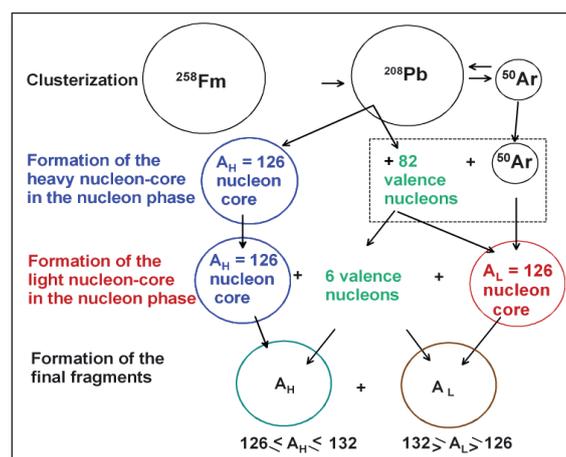
V-a Nowadays it is no longer possible to correctly describe the symmetric-fission mode without referring to the discoveries made in 2005 by Mouze [11]. First, ^{258}Fm and heavier nuclei can fission “barrier-free”, because, in these nuclei, several fragments pairs have a fission energy large enough for overcoming their own Coulomb barrier; this increases the fission yield of such pairs considerably. Secondly, this

situation leads to the definition of an “external” fission barrier B_C^f as being the difference between the Coulomb barrier $B_C(i)$ of a given pair i and the fission energy $Q_{tot}(i)$ of this pair. As the most energy-rich fragment pairs contain “spherical” nuclei such as Sn-nuclei, a “sphericity correction” has to be applied to their $B_C(i)$. Ythier and Mouze found that the usual fission barrier B^f is nothing else but the external fission barrier of the most energy-rich fragment pair after sphericity correction: B^f can now be calculated without reference to a model! Third, the barrier-free fission decides on the “profile” of the mass distribution of all heavier and superheavy fissioning systems, in the limits determined by the nucleon phase.

V-b All fragment pairs of all actinide nuclei lighter than ^{258}Fm have a positive $B_C^{f,corr}$ -value, their corrected Coulomb barriers being greater than their fission energy: the fission of these nuclei is “confined”.

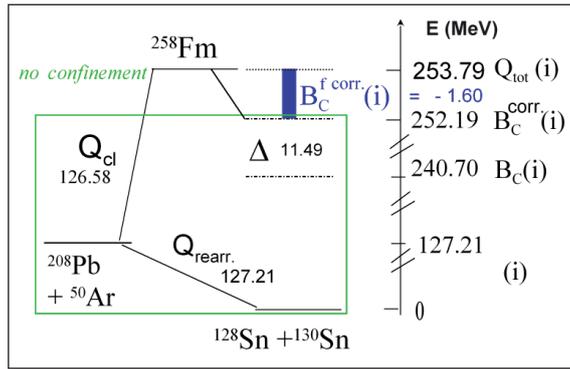
In ^{258}Fm , in the region of appreciable yield predicted by the nucleon phase, having a width of $6u$, only two pairs, $^{128}\text{Sn}-^{130}\text{Sn}$ and $^{126}\text{Sn}-^{132}\text{Sn}$ have a negative $B_C^{f,corr}$. The two other fragment pairs, $^{127}\text{Sn}-^{131}\text{Sn}$ and $^{129}\text{Sn}-^{129}\text{Sn}$, have a positive $B_C^{f,corr}$ -value. Thus it may be concluded that the high yield measured in the peak at symmetry by Hoffman in 1977 [8] was due essentially to these two most-energy-rich pairs $^{128}\text{Sn}-^{130}\text{Sn}$ and $^{126}\text{Sn}-^{132}\text{Sn}$. This explains also the presence of a high-energy component in the energy spectrum reported by E.K. Hulet *et al.* [12]. The lower-energy component can be explained by the “thermalization” of the other still confined pairs.

For heavy symmetrically fissioning nuclei, Ythier *et al.* made the observation that the different profiles of their mass distributions, either narrow and almost Gaussian, *e.g.* for ^{258}Fm , or broadly symmetric [13], *e.g.* for ^{266}Hs , or even double-humped [13], *e.g.* for $^{286}(112)$, all result from the barrier-free fission, but that the limits of these distributions remain those predicted by the nucleon phase, if the broadening due to the uncertainty on the mass is taken into account.



◀ FIG. 2: Description of the symmetric fission of ^{258}Fm in the nucleon-phase model by the sharing-out of 6, *i.e.* of $(A_{cl} - 44)$, valence nucleons between the nucleon cores.

▲ FIG. 3: Discovery of the barrier-free fission of ^{258}Fm into ^{128}Sn + ^{130}Sn (ref.11).



The best argument in favor of the new definition of the fission barrier B^f as being the corrected external barrier B_C^f of the most energy-rich fragment pair, is that it explains why almost all actinide nuclei have B^f - values of ~ 6 MeV. Indeed, this pair always contains a tin nucleus or another “spherical” nucleus and has an almost constant $(B_C^{f\text{corr.}} - Q)$ -value. For example, the external fission barrier of $^{235}\text{U} + n_{\text{th}}$, which corresponds to the most energy-rich pair $^{132}\text{Sn} - ^{104}\text{Mo}$, is positive and equal to 2.73 MeV. But after a plausible sphericity correction of ~ 3 MeV, it becomes equal to the quite commonly accepted B^f value of 5.80 MeV.

The symmetric fission mode, observed in ^{258}Fm and in heavier spontaneously fissioning nuclei, and which results from the laws of the nucleon phase, has to be distinguished from the phenomenon of appearance of an increased yield at symmetry observed in asymmetrically fissioning systems at higher energies. Ythier *et al.* have interpreted this situation as resulting from a kind of hindered barrier-free fission: the increase of E_{exc} in the expression of the fission barrier

$$B_f = B_C^{f\text{corr.}}(i) - [Q_{\text{tot}}(i) + E_{\text{exc}}] \quad (2)$$

diminishes the still positive value of B^f , and makes the emission (by tunnel effect) of the most energy-rich pairs easier. However, the latter are precisely those having mass numbers close to $A_F/2$; hence the increased yield at symmetry.

The end of the nucleon phase

VI-a The nucleon-phase hypothesis raises a number of interesting questions. It may be asked what happens to the quarks as the distinction between proton and neutron disappears. It may especially be asked what happens at the end of this phase, and whether the appearance of phenomena related to the double giant dipole resonance could be the last expression of this nucleon phase.

VI-b In 1996, Mouze made the observation that the “missing energy” necessary for explaining the emission of alpha particles and other low-energy light charged particles could be furnished by the double giant dipole resonance (DGDR). Indeed, their maximal energy cor-

responds to the DGDR-energy minus the binding energy of the ternary particle [14]. And the DGDR-energy is large enough for setting free a small number of prompt neutrons from the valence shells of the $A = 82$ and $A = 126$ nucleon cores, for example the 3.76 prompt neutrons emitted on average by a ^{252}Cf nucleus, having a DGDR-energy of 26.4 MeV^{-1} .

I thought it would be important to bring to light the quite novel ideas of Ythier and his coworkers on the mechanism of binary fission. Their description of this reaction might appear too daring, because it clearly rejects a number of widely accepted concepts.

However, their description is not only the outcome of a tenacious reflection conducted step by step in the last twenty years, it is also now a coherent representation, since the nucleon-phase hypothesis provides a joint explanation of the most enigmatic experimental facts of binary fission, those revealed by A.C. Wahl, by K.F. Flynn and L.E. Glendenin, by C. Signarbieux, by J. Terrell, by D.C. Hoffman, by E.K. Hulet and by M.G. Itkis. ■

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References

- [1] C. Ythier and G. Mouze, *Workshop on Dynamical Aspects of Nuclear Fission*, Smolenice, C.S.F.R., June 17-21, 1991, Dubna (Russia), 1992, p.203.
- [2] C. Signarbieux, *ibidem*, p.19.
- [3] G. Mouze and C. Ythier, *46th intern. Winter Meeting on Nuclear Physics*, Bormio (Italy), January 20-26, 2008, Università di Milano, 2008, p.230.
- [4] J. Terrell, *Phys. Rev.* **127** (1962), 880.
- [5] C. Ythier and G. Mouze, *J. Nucl. Materials* **166** (1989), 74.
- [6] K.F. Flynn *et al.*, *Phys. Rev. C* **5** (1972), 1725.
- [7] G. Mouze, S. Hachem and C. Ythier, *Int. J. Modern Phys. E*, in press.
- [8] D.C. Hoffman *et al.*, *Los Alamos Scientific Lab. Report LA-UR677* (1977), 2901.
- [9] A.C. Wahl, *I.A.E.A. Symposium Phys. Chem. Fission*, Salzburg (1965), I.A.E.A., Vienna, vol.1, p.317.
- [10] G. Mouze, S. Hachem and C. Ythier, private communication, 2008.
- [11] G. Mouze, *43th Intern. Winter Meeting on Nuclear Physics*, Bormio (Italy), March 14-19, 2005, Università di Milano, 2005, p.250.
- [12] E. K. Hulet *et al.*, *Phys. Rev. C* **40** (1989), 770.
- [13] M.G. Itkis *et al.*, *Fusion 06, AIP Conference Proceedings* **853** (2006), p.231.
- [14] G. Mouze, *Workshop on Dynamical Aspects of Nuclear Fission*, Casta Papiernicka (Slovakia), August 30-September 4, 1996, Dubna (Russia) 1996, p.338.
- [15] G. Mouze and R.A. Ricci, *European Physical Journal A* **21**(2004), 179.

note

¹ It was not possible to take into account here the work devoted by Ythier and Mouze (at times in collaboration with me) [15] to the various kinds of ternary fission and to their competition with cluster-radioactivity; the study of their relation to the nucleon-phase hypothesis is not completed yet.

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MULTIFERROICS

THE CHALLENGE OF COUPLING MAGNETISM AND FERROELECTRICITY

The origin and understanding of coupling phenomena between different physical properties within one material is a central subject of solid state science. It has fascinated physicists for decades. Multiferroics possess several so-called ferroic properties: ferromagnetism, ferroelectricity, and/or ferroelasticity. Their cross-coupling reflects interesting electron-phonon interactions, and they have great potential for new spintronic devices.

A material is generally considered functional if it possesses a physical property that is usable in applications. A considerable amount of research currently concentrates on multifunctional materials in which several physical properties could potentially be used simultaneously [1-5]. One of the key questions for the future development and understanding of multifunctional materials concerns the mutual coupling between the properties, its underlying mechanism and whether it can be used in applications. Multiferroics are multifunctional materials *par excellence*, because they simultaneously possess several so-called ferroic orders such as ferromagnetism, ferroelectricity and/or ferroelasticity. The class of ferroics is also commonly extended to anti-ferroics: antiferromagnetism and antiferroelectricity. Note that the prefix *ferro* refers historically to iron (*ferrum* in Latin), which shows a spontaneous magnetization M that can be controlled (and namely reversed) by the application of a magnetic field. In analogy, the electrical polarization P of a ferroelectric material can be controlled by the application of an electric field, and the ferroelastic deformation e by a mechanical strain (Figure 1). Ferroelectric-ferroelastic materials have been extensively studied and are at the origin of numerous applications. The showcase example - and industrial standard - is PZT, in which the coupling between deformation and electric polarization leads to a remarkable piezoelectric response, much larger than in quartz.

Ferroelectric and magnetic?!

Although ferroelectric-ferroelastic materials also belong to the class of multiferroics, the community uses the term “multiferroic” currently for magnetoelectric (ME) multiferroics which are both ferroelectric and magnetic, but not necessarily ferromagnetic. In the past ferroelectric-magnets have been much less studied due to their scarcity and indeed they seem to exclude each other, at least at first sight. First, it has been argued that the presence of electrons in the d -orbitals of transition metals (favorable for magnetism) inhibits hybridization with the p -orbitals of the surrounding oxygen-anions and thus a cation displacement (necessary for ferroelectricity) [6]. Second, a ferroelectric has to be a good insulator so that mobile charges do not neutralize ferroelectric polarization, but most ferromagnets are rather conducting. In fact, even though ferroelectric-magnets are rare, those which present a direct coupling (magnetoelectric multiferroics) are even rarer. As a consequence, the research for both new materials systems and new coupling mechanisms are the *sine qua non* conditions for a better understanding of magnetoelectric coupling mechanisms and the development of future applications in the field of spintronics.

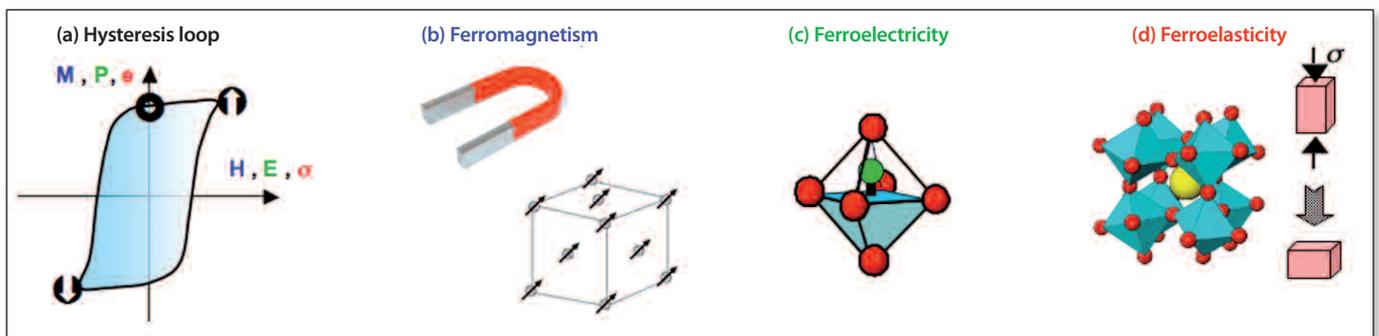
Different materials – different coupling

The known multiferroic materials can be classified into three different classes depending on the microscopic mechanism of ferroelectricity. Ferroelectricity arises because

▲ Piezo-Force Microscopy (PFM) image of the domain structure in the model multiferroic BiFeO₃. © F. Zavaliche *et al.*, Multiferroic BiFeO₃ Films: Domain Structure and Polarization Dynamics, *Phase Transitions* 79, 991 (2006)

■ of either (i) hybridization effects, (ii) geometric constraints and/or (iii) electronic degrees of freedom (spin, charge or orbital). All three classes attract an intense research interest: (i) In this class of multiferroic, the magnetic and ferroelectric ordering are associated with two chemically different cations [6], which can lead to both strong magnetic and ferroelectric properties, but their coupling is unfortunately not necessarily strong. The best example of this class of multiferroic is probably BiFeO₃ (BFO). This is perhaps the only material that is both magnetic and a strong ferroelectric at room temperature, making it the preferred model system for fundamental and theoretical studies of multiferroics. Its impact on the field of multiferroics is comparable to that of yttrium barium copper oxide (YBCO) on superconductors [7]. In BFO the magnetism is associated with the 3*d* electrons of the Fe³⁺ cations. The ferroelectricity arises from the hybridization between the oxygen 2*p* orbitals and the empty Bi 6*p* orbitals, which are low lying in the conduction band and spatially extended due to the presence of the so-called lone-pair 6*s*² electrons. A recently observed electric-field-induced spin flop in BFO single crystals demonstrates that the antiferromagnetic and ferroelectric order parameters in BFO are coupled [8]. It has been argued that the magneto-electric coupling in BFO is intimately related to the presence of a magnetic cycloid structure that allows a coupling of *M* and *P* on an atomic level even in antiferromagnetic structures where on average the linear ME-effect is forbidden.

(ii) In geometric multiferroics, the ferroelectric instability has its origin in the topology of the chemical structure, and the ferroelectric distortions are driven by ionic size effects. In contrast to covalent-bond driven ferroelectrics, geometric ferroelectrics feature no significant hybridization effects or significant charge transfer between cations and anions. The first material identified as a geometric ferroelectric was the hexagonal manganite YMnO₃ [9], illustrated in Figure 2. Ferroelectricity in YMnO₃ arises from the rotation of MnO₅ bipyramids which separate two-dimensional triangular planes of Y ions. Because of the topology of differently charged ions in the chemical lattice, this rotation leads to ferroelectric polarization even in the absence of charge transfer from one ion or bond to another. (iii) In correlation-induced ferroelectrics, the ferroelectric polarization results from long-range order of an electronic degree of freedom such as orbital, charge or spin. In this class of multiferroics, magnetically-induced ferroelectrics such as TbMnO₃ and Ni₃V₂O₈ are probably the best understood [10]. Ferroelectricity in these two materials arises from a magnetic spiral structure that breaks inversion symmetry and creates a polar axis (Figure 3). Magnetic order and ferroelectricity are thus directly coupled because there is not ferroelectric polarization without magnetic order. Changing the symmetry of the magnetic order can switch or suppress ferroelectricity. Competing magnetic interactions seem to play a key role in the emergence of magnetically-induced ferroelectricity, as they do not clearly favour a fully ordered magnetic state at low temperatures. Ferroelectricity in



▲ FIG. 1: Ferroic materials

- (a) The term **ferroic** unifies common characteristics of ferromagnetic, ferroelectric and ferroelastic materials. A shared key property of these three ferroics is the hysteresis loop (cf. Figure) which describes the control of the macroscopic physical property (magnetization, polarization, deformation) by an external field (magnetic, electric, mechanical), leading to two important characteristics: 1) The macroscopic property remains different from zero - remanent or spontaneous - under zero field (●) and 2) reversing the field allows the inversion of the physical property (◐◑).
- (b) **Ferromagnetism** was in ancient times the first identified ferroic property, used for example in a compass by Chinese 100BC. A ferromagnet presents a spontaneous magnetization *M* that can be driven by a magnetic field *H*. The electrons' orbital angular momentum is responsible for so called orbital-magnetism, while the spin of an electron is responsible for spin-magnetism, which is often preponderant for the magnetic structure.
- (c) Although studied since the 17th century, the term **ferroelectricity** has been introduced by Erwin Schrödinger only in 1912. Initially considered as a rare phenomenon, a vast number of ferroelectrics is known today, namely in form of the ABO₃ perovskite. A ferroelectric material is characterized by an electric polarization *P* of which the direction can be reversed by an electric field. In a schematic picture the macroscopic polarization is on the microscopic level related to a displacement of positively charged cations (in green) with respect to the centre of gravity of negatively charges anions (in red).
- (d) The **ferroelastic** deformation has long been considered as a property linked to ferromagnetism (leading to magnetostriction) or to ferroelectricity (electrostriction). It is only in the 70'ties that the ferroelastic deformation *e* has been recognized as an independent property of which the direction can be controlled by a mechanical stress *σ*. The Figure illustrates the microscopic mechanism of a spontaneous ferroelastic deformation, even in absence of stress, for the example of the perovskite SrTiO₃ (Sr in yellow, oxygen in red and Ti in the centre of the octahedra). A mechanical stress can modify the angle of the octahedra tilting (left) and thus the state of macroscopic deformation (right). Just as for the other ferroic properties a hysteresis loop can be obtained by applying a uniaxial stress.

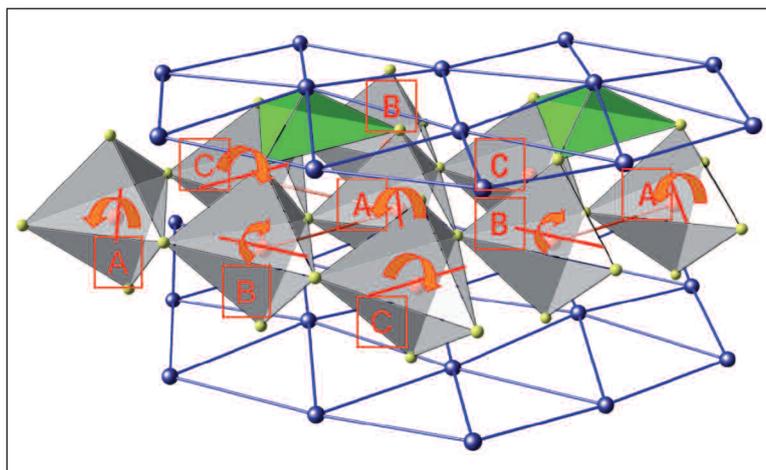
these systems is driven by a lattice distortion that allows Dzyaloshinskii-Moryia interactions which stabilize a magnetic spiral, thereby reducing the magnetic entropy. Some of the electric polarization may also arise from the so-called spin-current effect where the exchange of electrons from a non-collinear structure leads to electric polarization from a distortion of electronic orbitals without ion displacements. The maximum ferroelectric polarization that has been observed in spin-spiral ferroelectrics is rather small and of the order of $0.2 \mu\text{C}/\text{cm}^2$, probably due to the small size of the magneto-electric coupling that is mediated by spin-orbit interactions.

Ferroelectric polarization on the order of $2\text{--}6 \mu\text{C}/\text{cm}^2$ has been predicted for another class of magnetically-induced ferroelectrics which feature commensurate collinear magnetic order [11]. Ferroelectricity in collinear spin ferroelectrics is mediated by symmetric exchange strain which does not depend on the presence of spin-orbit in interactions and can be of the order of the dominant exchange interactions in a material. Examples of this class include orthorhombic HoMnO_3 , TmMnO_3 but also rare-earth-nickelates ReNiO_3 in their charge ordered state. These materials are difficult to produce as single crystals, but powder measurements provide evidence for ferroelectric polarization that is larger than any previously observed ferroelectric polarization in a magnetically-induced ferroelectric.

Probably the most promising class of correlations-induced ferroelectrics are charge-order induced ferroelectrics. These are materials with competing charge interactions or charge frustration that leads to a charge instability that carries ferroelectric polarization. An example of this class of ferroelectrics is LuFe_2O_4 [12] where competing charge interactions arise from an intermediate valence iron ion which is arranged in bi-layers of triangular lattices. The lowest energy state of this strongly-correlated charge lattice appears to be a charge-ordered state which carries ferroelectric polarization. Because the charge order is driven directly by charge-charge interactions, the ordering temperature and ferroelectric polarization can be high. Magnetic order is established at low temperature due to the magnetic degrees of freedom associated with the charge ordered iron ions, and increases the ferroelectric polarization.

Composite multiferroics

So far we have discussed intrinsic multiferroics, where the different ferroic properties are united within *one* material (single-phase multiferroics). To overcome the shortage of single-phase multiferroics and to provide new magnetoelectric coupling mechanisms, recent work also concentrates on the class of *artificial* multiferroics in the form of composite-type materials or thin film nano-/hetero-structures [5,13]. It was shown that composite-type multiferroics, which incorporate both ferroelectric and magnetic phases, can yield a giant



magnetolectric (ME) coupling response even above room temperature. In such systems neither the ferroelectric (thus piezoelectric) nor the magnetic phase shows the ME effect, but composites of these two phases have a remarkable ME effect. Thus the ME effect is a result of the product of the magnetostrictive effect (magnetic/mechanical effect) in the magnetic phase and the piezoelectric effect (mechanical/electrical effect) in the piezoelectric one [13], *i.e.* the coupling between both components is mediated by strain: for instance the magnetic phase changes its shape magnetostrictively when a magnetic field is applied and, in turn, the strain is passed along to the piezoelectric phase giving rise to an electric polarization. Thus, the ME effect in composites is extrinsic. This field remains full of scientific challenges and certainly deserves a particular attention in view of future applications of multiferroics.

Applications

Most of the research in multiferroics has been curiosity-driven basic research, but there are a number of ideas for device applications based on multiferroic materials. One of the more popular ideas is that multiferroic bits may be used to store information in the magnetization M and the polarization P . The feasibility of such a 4 stage memory (two magnetic $M_{\uparrow\downarrow}$ and two ferroelectric $P_{\uparrow\downarrow}$) has been demonstrated recently [14]. Such a memory does not require the coupling between ferroelectricity and magnetism; a cross coupling would be even disastrous. If magneto-electric coupling is present, device applications could be realized where information is written magnetically, but stored in the electric polarization, leading to non-volatile memory. Multiferroics bits could also be used to increase the magnetic anisotropy to increase the decay time for magnetic storage. Other applications include magnetically field-tuned capacitors with which the frequency dependence of electronic circuits could be tuned with magnetic fields, or multiferroic sensors which measure magnetic fields through a zero-field current measurements.

▲ **FIG. 2:** Ferroelectricity in YMnO_3 arises because of the cooperative rotation of the bipyramids indicated by the axes and by the arrows. All oxygen (in yellow) of the green YO_6 pyramid move closer together, leading to a uniform shift of ions perpendicular to the triangular planes. Because of the symmetry of the chemical lattice, this thus leads to a overall shift of positively and negatively charged ions in the opposite direction [9]. The Y ions are shown in blue, the Mn ions in red and the O ions in yellow.

Outlook

The rapid development in the field of multiferroics in the last few years has been exciting and revealed fascinating physics in condensed matter. There are several important conclusions that we can draw regarding future directions of research. A first important question is what multiferroic mechanisms can lead to high ferroelectric polarization. Many of the investigated materials like the spin-spiral ferroelectrics are far away from charge instabilities, and magnetoelectric interactions are mediated by spin-orbit interactions. This combination naturally limits the ferroelectric polarization to relatively small values. Theory gives us a good guide in what type of materials we can expect larger polarizations and larger coupling effects. These are materials where magneto-electric effects are mediated by symmetric exchange or materials with intrinsic charge instabilities. However, experimental work has been limited due to a lack of novel materials.

A second important issue will be to develop further techniques allowing to provide experimental evidence for magnetoelectric coupling and to estimate its strength. One promising way may be the investigation of magnetic spin waves which couple to optical phonons (lattice vibrations). Such novel excitations - called electromagnons - are directly related to electromagnetic coupling and reflect the intimate relationship between magnetic and ferroelectric magnetic orders in multiferroic materials. The study of electromagnons may thus shed light on the strength of magnetoelectric coupling interactions. Electromagnons probably belong to the most challenging open questions in the field and are currently under intense investigation.

Another key question is in what kinds of other materials we can also expect multiferroic behavior. With a few exceptions, the multiferroics materials that have been investigated are transition metal oxides. It will be interesting to see how different types of magnetic and electric interactions found in rare-earth insulators without transition metal oxides, in organo-metallic materials, in

magnetic chalcogenide-based phase-change material or in polymer-based magnets affect the magnetic and ferroelectric properties, and the magneto-electric coupling. Finally, it remains a challenge to recreate some of the fascinating multiferroic properties in artificially engineered thin films and heterostructures. Without doubt, the study of such materials will be an important pillar of multiferroic research towards applications and for basic research, particularly for key model materials that cannot be grown as clean single-crystals. ■

About the authors

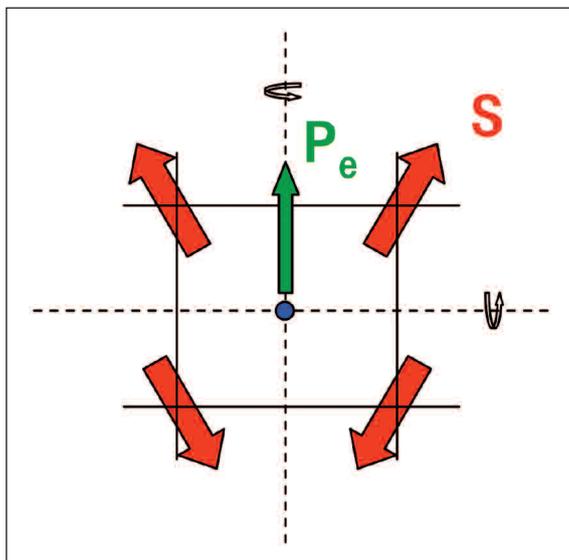
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References

- [1] M. Fiebig, T. Lottermoser, D. Fröhlich, A.V. Goltsev, and R.V. Pisarev, *Nature* (London) **419**, 818 (2002).
- [2] W. Eerenstein, N.D. Mathur and J.F. Scott, *Nature* (London) **442**, 759 (2006).
- [3] S.W. Cheong and M. Mostovoy, *Nature Materials* **6**, 13 (2007).
- [4] T. Kimura, T. Goto, H. Shintani, K. Ishizaka, T. Arima, and T. Tokura, *Nature* (London) **426**, 55 (2003).
- [5] R. Ramesh and N.A. Spaldin, *Nature Materials* **6**, 21 (2007).
- [6] N.A. Hill, *J. Phys. Chem. B* **104**, 317 (2000).
- [7] G. Catalan and J.F. Scott, *Advanced Materials* **21**, 1 (2009).
- [8] D. Lebeugle, D. Colson, A. Forget, M. Viret, A.M. Bataille and A. Gukasov, *Phys. Rev. Lett.* **100**, 227602 (2008).
- [9] B.B. Van Aken, T.T.M. Palstra, A. Filippetti and N.A. Spaldin, *Nature Materials* **3**, 164 (2004).
- [10] M. Kenzelmann, A.B. Harris, S. Jonas, C. Broholm, J. Schefer, S.B. Kim, C.L. Zhang, S.W. Cheong, O.P. Vajk and J.W. Lynn, *Phys. Rev. Lett.* **95** (2005)
- [11] S. Picozzi, K. Yamauchi, B. Sanyal, I. A. Sergienko and E. Dagotto, *Phys. Rev. Lett.* **99**, 227201 (2007).
- [12] N. Ikeda, H. Ohsumi, K. Ohwada, K. Ishii, T. Inami, K. Kakurai, Y. Murakami, K. Yoshii, S. Mori, Y. Horibe and H. Kito, *Nature* (London) **436**, 1136 (2005).
- [13] C.W. Nan, M.I. Bichurin, S.X. Dong, D. Viehland and G. Srinivasan, *J. Appl. Phys.* **103**, 35 (2008).
- [14] M. Gajek, M. Bibes, S. Fusil, K. Bouzehouane, J. Fontcuberta, A. Barthélémy and A. Fert, *Nature Materials* **6**, 296 (2007).

► **FIG. 3:** A generic example of a magnetic structure that breaks the inversion symmetry of the lattice: The magnetic structure is even under a two-fold rotation around the vertical direction and odd under a two-fold rotation around the horizontal axis, allowing ferroelectricity along the vertical direction [10].





HERA:

A SUPER-MICROSCOPE FOR THE PROTON AT THE ENERGY FRONTIER

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Some 40 years ago the inner structure of the proton was revealed by the first 'deep-inelastic scattering' experiments at SLAC near Stanford. Energies were so large that the proton was decomposed, yielding evidence of point-like particles inside the proton, the so-called "partons". Now the electron-proton collider HERA in Hamburg is yielding new and precise information on proton structure.

We know today that the partons are fundamental particles called quarks, interacting via vector bosons called gluons. They form the proton and the neutron, that are both baryons ('heavy particles', derived from the Greek *barus*, or heavy). Baryonic matter, that dominates the mass of the visible Universe, is therefore mostly composed of quarks and gluons. These carry an essential quantum number named "colour" and are the main characters of the theory of strong interactions: Quantum Chromo-Dynamics (QCD). This picture emerged in the seventies and eighties from many deep-inelastic scattering (DIS) experiments [1] that consolidated and refined the first discoveries.

A decisive step in the understanding of the proton structure was the arrival of the unique electron-proton collider HERA (Hadron Electron Ring Accelerator) at DESY (Deutsches Elektronen-SYNchrotron), in Hamburg, Germany. The centre-of-mass energy available at HERA of up to 320 GeV results from collisions of 27.5 GeV electrons or positrons with 920 GeV protons. The collider experimental program was developed with two multi-purpose,

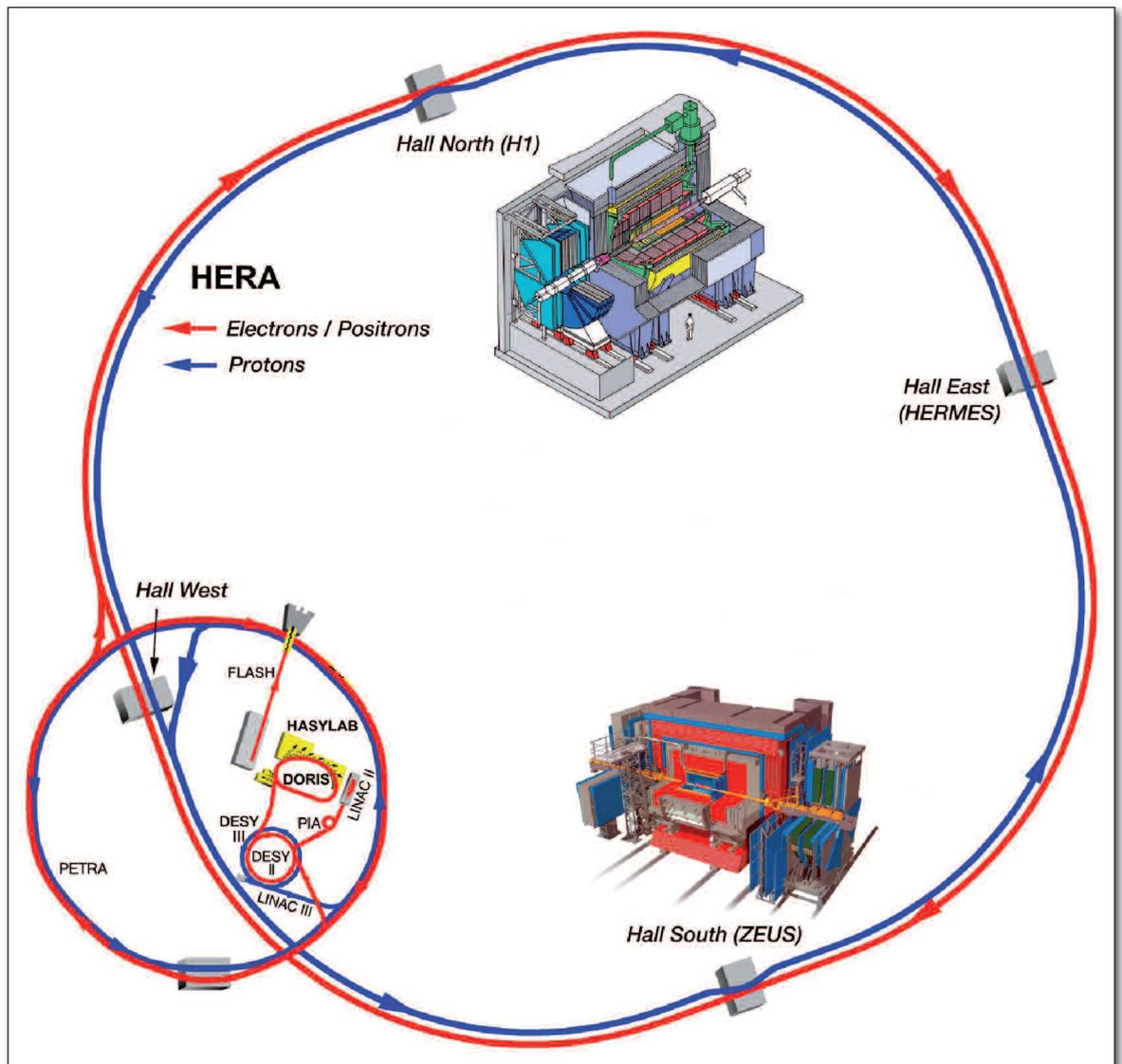
hermetic detectors, H1 [2] and ZEUS [3], designed to measure particles produced in each electron-proton interaction and operated by two collaborations of more than 300 physicists, from 90 institutes and 30 countries. The detectors contained internal trackers able to measure charged particle momenta, and calorimeters completing the measurement of the energy flow. A scheme of the HERA collider, together with the location of the H1 and ZEUS detectors is shown in Figure 1. The collisions started in 1992 and the data-taking ended June 30, 2007. The final precision analyses using the collected data are currently in progress. A few recent results, demonstrating the scientific reach of the HERA programme, are presented here.

Proton structure measurements

The collision of an electron with a proton is generally mediated by a photon, emitted from the incident electron. The distance δ probed into the proton by this photon is of the order of its wavelength which, following the Heisenberg's uncertainty principle, is inversely proportional to the amount of momentum transfer Q between the

◀ **P23:**
Inside the tunnel of the electron-proton collider HERA.

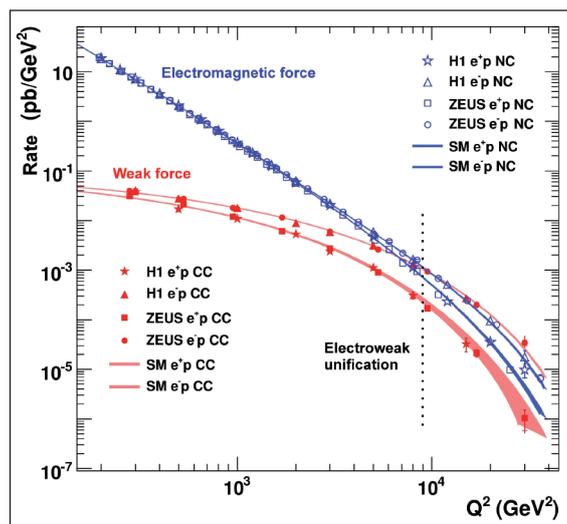
▶ **FIG. 1:**
A schematic view of the HERA accelerator ring, including the injectors and the two collider mode detectors H1 and ZEUS. The accelerator ring as a circumference of 6.3 km and is situated at 30 m under Hamburg city. The detectors have a typical size of 10 m and are shown in a longitudinal section displaying the multiple detection technologies installed around the interaction point.



electron and the proton $\delta[\text{fm}] = 0.2 / Q$ [MeV]. This relation suggests that the spatial precision δ is improved by increasing the momentum transfer, which can be achieved by increasing the collisions energies. This explains why high energy colliders act as powerful microscopes. Since the energy available at HERA is 320 GeV it is easy to see that the probed distances are of order 10^{-18} m. This means resolving details of a size that is 1000 times smaller than the size of the proton, measured already in the fifties to be around 10^{-15} m. At such small distances, the photon can directly interact with the constituents quarks of the proton. The reaction reveals how the quarks compose the proton, via measurement of the fraction x of the proton's momentum carried by the struck quark. The accessed domain extends to very low values of x , in a region never explored before. Moreover, the large amount of momentum transferred allows also the exchange of the so-called weak bosons, carriers of another type of force, the weak force. While photons are massless, the weak bosons are rather heavy, with masses of the order of 100 GeV, such that they can occur as mediators of the electron-proton interaction only if the momentum transfer approaches their mass.

Unlike photons, which are sensitive to the electromagnetic charge only, the weak bosons couple differently to the various types of quarks. They induce processes with different strengths when positrons or electrons are used to probe the proton. If the exchanged boson is neutral, the process is said to proceed via the neutral current (NC) interaction and the scattered electron or positron is measured in the final state. In contrast, the charged current (CC) process, due to the exchange of the charged weak boson W^\pm , converts the initial positron or electron into a neutrino. The CC events exhibit an imbalance in the detected final state, since the produced neutrinos do not interact with the apparatus and escape undetected. The measurement of the rate of the neutral and charged current processes at HERA, expressed as a function of the transferred momentum squared Q^2 , is shown in Figure 2. At low values of Q^2 the rate of CC interactions is much smaller than for NC, reflecting the nature of the pure weak interactions. However, at values of Q^2 close to the squared mass of the weak bosons, the rates become comparable, demonstrating the similar nature of the electromagnetic and weak interactions at high energies and pointing to the unification of forces, predicted by the theory.

The kinematic domain probed at HERA extends also to very low x values, around 10^{-5} , where the partons carry only a tiny fraction of the proton momentum. This regime was probed for the first time at HERA and revealed a surprising picture: more and more partons are found in the proton as x decreases. QCD explains this intriguing cloud of partons as quarks produced by gluons, which are abundant in the low x regime and fluctuate to quark-antiquarks pairs. These quarks interact with the incoming electron within a laps of time that is also inversely pro-

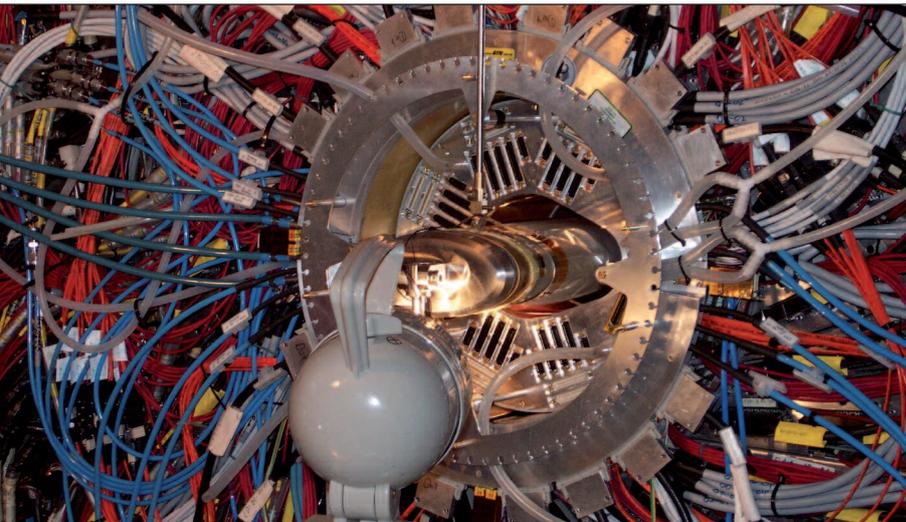


◀ FIG. 2: Rates, in picobarn ($1\text{pb}=10^{-36}\text{cm}^2$) per GeV^2 , of neutral (NC) and charged (CC) boson exchange processes as a function of the transferred momentum squared Q^2 performed by the H1 and ZEUS experiments at HERA, using electron- and positron-proton collision data. The measurements are in excellent agreement with the theory (Standard Model SM), which is shown as a shaded band.

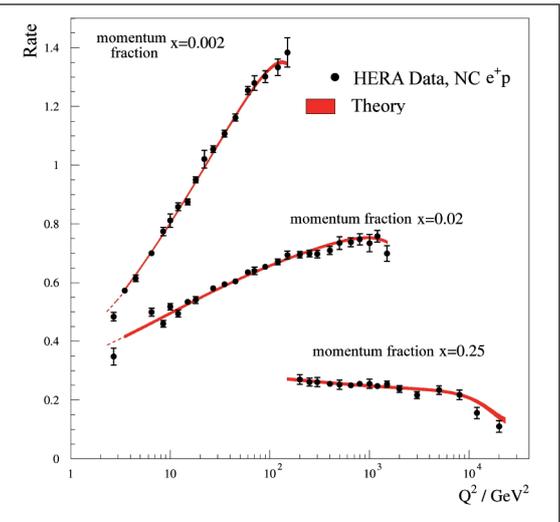
portional to the momentum transfer Q . Therefore the amount of partons at low x also increases with Q : the higher Q , the shorter the time of interaction, increasing thereby the chances to reveal the gluon-to-quarks fluctuations. This behaviour is observed in Figure 3. The variation with Q^2 of the rate of the NC interactions is increasingly violent for lower x and the precise data obtained at HERA is well described by the theory.

There is however one component of the DIS process that cannot be predicted and is still a puzzle in contemporary physics, namely the dynamics of the quarks and gluons inside the proton; in short: the proton structure. This lack of predictability is the consequence of a peculiar property of the strong force: the asymptotic freedom. Whereas the other forces tend to decrease when the distance between the interacting particles increases, for the strong force the behaviour is reversed: two quarks are rather free while close in space and their interaction becomes stronger as they get separated. This property is described perfectly by QCD and also explains why quarks cannot exist in a free state and are always confined in color-neutral particles (hadrons). However, the unfortunate consequence of such a behaviour is that, given the size of the proton, the typical distance between the quarks is such that the coupling constant is large. Therefore, the usual calculation methods based on perturbative developments, successfully used in the case of a small coupling at high energies, are not applicable.

A way to simplify the problem is provided by a factorisation theorem, which separates the calculable part and allows for robust predictions. The physical observables (rates of physical processes) can be described as a convolution between the parton distribution functions (PDFs), describing the distributions of quarks and gluons in the proton, and some coefficients that are calculable in QCD. Even if the exact shape of the PDF's cannot be predicted, their evolution with Q^2 is calculable. It is therefore sufficient to consider a set of



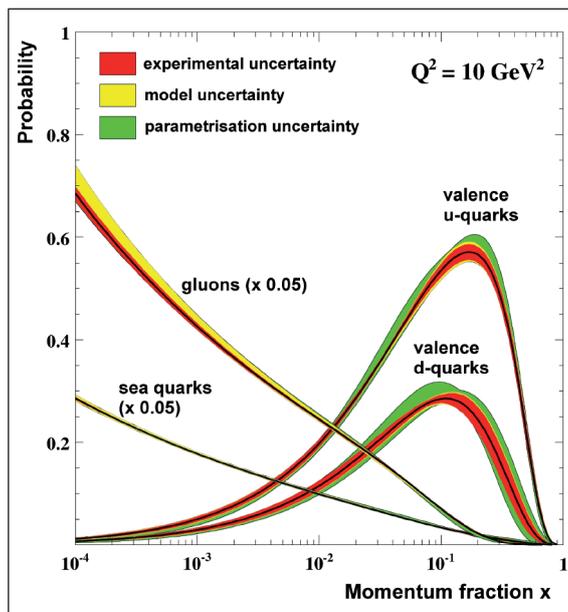
▲ Light on the heart of the H1 detector at HERA



► FIG. 3: Examples of rates of neutral boson exchange (NC) measured as a function of the transferred momentum Q squared at a given x . The evolution as a function of Q^2 is described by the theory and is a clear sign of the gluon contributions to the proton structure.

unknowns PDFs for the quark $q(x, Q^2)$ and gluon $g(x, Q^2)$, parameterized as a function of x at a given value of $Q^2 = Q_0^2$. Since the theory predicts both the insertion of these functions into the observable rates and also their evolution from Q_0^2 to any Q^2 , all measurements over the large range in x and Q^2 available at HERA can be used to constrain the unknown PDFs. A recent determination of these functions describing the proton structure is shown in Figure 4, as obtained from a global fit of more than 600 measurements, resulting

from combining H1 and ZEUS data. The HERA data uniquely constrain the proton structure at low x , where the gluon largely dominates the partonic content. HERA DIS measurements provide therefore fundamental and unique knowledge for the understanding of the proton structure. Beyond the intrinsic value of the research in this domain, the measurements are particularly important for experiments involving protons, in particular for the Large Hadron Collider (LHC), the powerful proton-proton collider to start operations this year at CERN at an energy of 14 TeV (Terra Electron-Volts), seven times larger than the present similar collider running at Fermilab, Chicago in the United States.



▲ FIG. 4: Distribution of quarks and gluons in the proton as a function of the carried proton momentum fraction x . The “valence” quark distributions peak is around $x = 1/3$, as expected for the three constituents quarks building the proton. The distribution of the gluon as well as that of quarks occurring from gluon fluctuations (“sea”) dominate the proton content at low x (these distributions are shown after division by a factor 20). The obtained precision is impressive, in particular at low x , below ~ 0.01 , where no data was available before HERA.

Strong interaction probes

During the DIS experiments the scattered quark produces a jet of particles in the detector, due to the hadronisation process, which leads to the production of a statistically variable number of particles grouped in a jet. The scattered quark may also radiate high-energy gluons, which in turn can also produce a jet of particles. DIS events with more than one jet are therefore a clear signature of gluon radiation. Since this phenomenon involves the coupling between the quarks and gluons, the strength of the strong interactions (the so-called strong coupling α_s) can be measured from the rate of multi-jet events produced at HERA. In addition, HERA provides a way to test the strong interaction at various scales. Due to the correspondence between the transferred momentum Q and the distance probed, the measurement domain in Q allows the investigation, within a single experiment, of the strong coupling variation as a function of the typical distance between the particles interacting strongly. A recent measurement of the strong coupling as a function of the interaction scale is shown in Figure 5. The data displays the so-called

“running” of the strong coupling over about two orders of magnitude in Q , as predicted by QCD. The coupling is indeed observed to be larger at low Q (*i.e.*, large distances) while it decreases at high Q , where particles interact over smaller distances. This is the property of asymptotic freedom, which is spectacularly confirmed by this complex and precise measurement.

On the energy edge

The present understanding of the particle physics is summarised in a theory called the Standard Model. This theory emerged in the last decades as a result of spectacular advances in experiment and theory. It includes quarks and leptons (particles similar to the electron) and their interactions via electromagnetic, weak and strong forces. Perhaps the most puzzling experimental observation successfully accommodated in the Standard Model is the organisation in three families of the known quarks and leptons, as well as their mass hierarchy. This apparent and unexplained ordering may be the result of a substructure, in the same way as Mendeleev’s periodic table of the elements is explained by the content in protons and nucleons of the atomic nuclei. The electron-proton collisions at the highest momentum transfer are ideal to reveal new substructures inside the proton, probing this time the partons or even the incoming electrons. No significant discrepancy between the data and the Standard Model has been observed, in spite of extensive searches in a large number of channels (Figure 6). The results confirm that the known elementary particles are indeed point-like, with a size in any case smaller than the experimental resolution of 10^{-18} m. However, HERA allows also to substantially broaden the range of validity of the Standard Model and to restrict the possible phase space for new phenomena, new particles or new interactions.

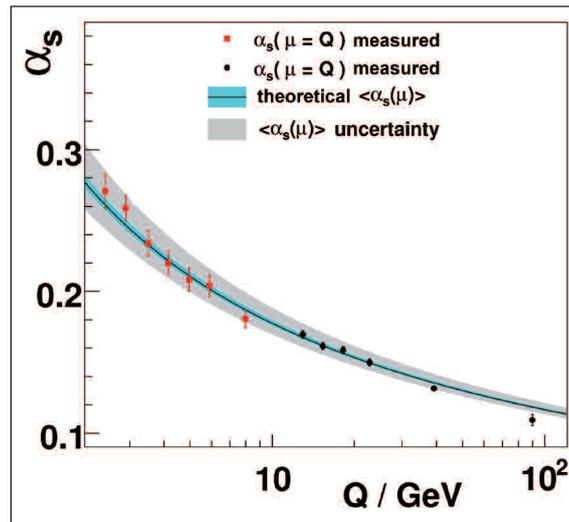
Outlook

Understanding of the structure of matter is a fundamental scientific goal. Tremendous progress has been made due to the experimental program at the HERA collider, which continues to deliver scientific results of high precision, probing the proton structure and investigating the energy frontier in a unique configuration. ■

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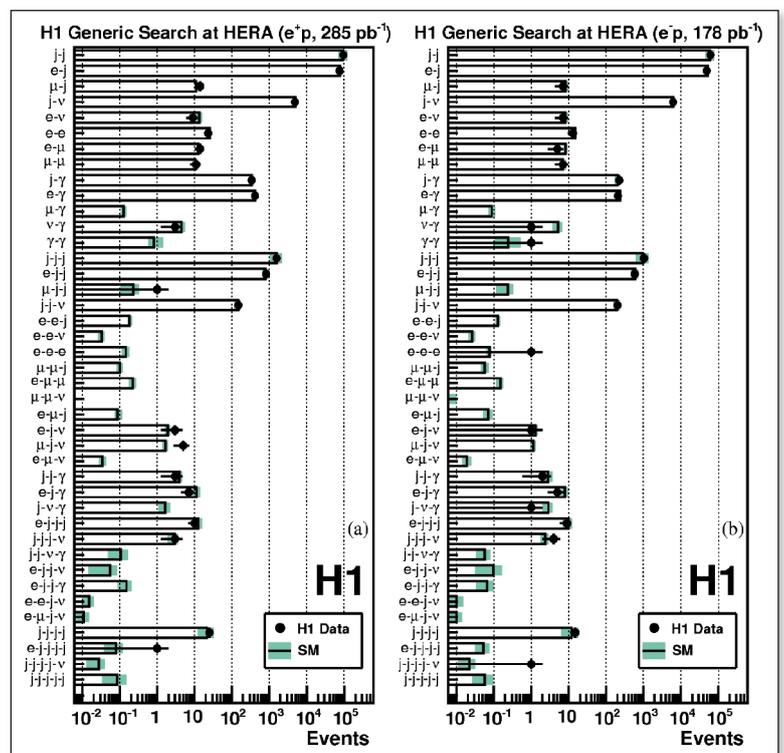


◀ **FIG. 5:** The dependence of the strong coupling constant α_s on the energy scale represented by Q compared with the expectation of quantum chromodynamics. At large momentum transfers (short distances), the strong force becomes increasingly weak, clearly displaying the property of asymptotic freedom.

structure of exotic neutron rich nuclei. Presently, he is co-responsible of the H1 working group searching for new phenomena and leads the H1 group of the CPPM.

References

- [1] R. Devenish and A. Cooper-Sarkar, *Deep Inelastic Scattering*, Oxford University Press, ISBN13: 978-0-19-850671-3, (2005).
- [2] H1 experiment and its scientific results are described at : www-h1.desy.de
- [3] ZEUS experiment and its scientific results are described at : www-zeus.desy.de



▲ **FIG. 6:** Total event yield observed for each type of events in a general, model-independent search for new phenomena at HERA. Various event classes are defined as combinations of jets (j), electrons (e), muons (μ), photons (γ) and neutrinos (ν). The observed event rates, represented as full dots, for positron-proton scattering (left) and electron-proton scattering (right) agree well with the predictions of the Standard Model SM (histogram) leaving no room for new physics effects at HERA.

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N.A. Hill, J. Phys. Chem
7] G. Catalan and J.F. Scott,
[8] D. Lebeugle, D. Colson, A.
B.B. Van Aken, T.T.M. Pal
Kenzelmann, A.P.

okura, Nature (Lo
A. Gukasov, Phys. Rev. I
, Nature Materials 3, 164
efer, S.B. Kim, C.L. Zhang, S
E. Dagotto, Phys. Rev. Lett. 99
akurai, Y. Murakami, K. Yos
nivasan, J. Appl. Phys. 10
A. Barthélemy and A

[0] M.
[11] S. P
[12] N.
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BIBLIOMETRIC EVALUATION OF INDIVIDUAL RESEARCHERS:

NOT EVEN RIGHT... NOT EVEN WRONG!

Scientific research is probably, among the various human activities, one of those that are most subject to benchmarking and evaluation (refereeing of articles, research contracts, evaluation of laboratories, etc.). In recent years, an increasing weight has been given to bibliometry, yielding various rankings and numbers. While such data may sometimes bring useful information, in case of evaluation of individuals, sadly the implementation often seems to arise from a loss of critical and rational mind.

Nobody would suggest that the long-term artistic impact of contemporary writers, composers, painters, etc. should be assessed by using quantitative methods (number of books sold in bookshops, tickets in concerts, number of paintings, etc.). One would in this way get some information on the quality of the artistic production, but also mostly detect other characteristics of the productions, as well as fashions; the most creative artists, those who will remain famous for decades or centuries, would probably not emerge. Neither would anyone suggest evaluating quantitatively the efficiency of state officers by the number of administrative reports they write!

Although scientific research is neither art nor administration, quantitative methods of evaluation of individual scientists suffer from the same problem: they contain some information, but with only a relatively small part that corresponds to scientific quality. The use of indices such as the H-index¹ at the level of individuals is easy and therefore attractive, but mostly unscientific. An even more serious problem is that the generalization of quantitative evaluation of research will create (and actually is already creating) perverse feedback effects, decreasing the quality of publications and therefore affecting the general functioning of research.

Wolfgang Pauli

It is reported that Wolfgang Pauli, one of the geniuses who created quantum mechanics, was very irritated after reading an uninteresting article and exclaimed: “*it is not right, and not even wrong!*”. Verification and falsification are indeed at the heart of Nature sciences. Pauli’s remark could apply as well to many applications of bibliometry, proposed by those who believe that, as soon as numbers are manipulated, they create scientific reasoning.

The bibliometric evaluation of researchers is “not even wrong”: yes, if we compare an internationally well-known scientist to an eccentric who has never been cited by anyone but himself, the bibliometric indices of the former will be much better than for the latter; no doubt about it. Therefore, if the purpose was to distinguish between exceptional from mediocre scientists, it would undoubtedly be possible to use bibliometric methods. One would then find again... what was known before. But, if the idea is to obtain really useful information, for instance to rank researchers within a relatively homogeneous group (members of a laboratory for instance), then the situation is different: one immediately notices the existence of large fluctuations of the indices^{1,2} (H, G, etc.) that are surprising. Significantly different values are obtained by scientists whose production is judged similar by the scientific community. Why?

Extracting signal from noise

Several reasons explain why bibliometric methods provide a simplistic view of individual scientific contributions. They do contain information about scientific quality, but this “signal” is buried in a “noise” created by a dependence on many other variables. Let us take for instance the H-index, which is a function of a first variable X that we assume to correspond more or less to the scientific quality, of a variable Y related to the personal style of the person (working in collaboration or not, preference for “fashionable” scientific subjects, interest in applications, etc.), of a variable Z related to the publication style (preference for short letters or long, more developed, articles; for prestigious journals of general interest such as Nature or Science, even if they are not much used in the domain), and of a variable W

- (does the person belong to a prestigious school of research, or has preferred to try and create a new field of research?). Obviously, this list of variables is not limitative; one could for instance add the taste of the person for scientific congress, which is not always connected with creativity. Any scientist knows that the only way to determine the target variable X from H is to eliminate the noise by averages. If they are performed over a large sample of persons, variables Y, Z, ... will take all possible values and their influence will average out, leaving the target variable X to emerge. This is the reason why bibliometric methods allow one to obtain relevant data at large scales, for instance the comparison between two big fields of research in different countries. Nevertheless, using H to determine X with a single statistical sample is merely a scientific error that would not be accepted in any serious laboratory.

Real purpose of references

Moreover, this evaluation method relies on an implicit postulate that, actually, is by no way obvious. The idea is that the references contained in all scientific articles should be some sort of prize list among all published articles in the relevant scientific domain; this ranking could then be used as measure of quality averaged over the opinion of many authors. But this is certainly not the way authors create the list of references in their articles: including them is a scientific act, which has little to do with bibliometry or ranking. The real purpose is to give the reader the information that is needed to understand the article. This is also a strongly contextual process: for instance, an article will be cited by convenience, because it allows a shortening of the article under writing - review articles will then be preferred to the original sources. Similar articles are also preferred, independently of their scientific interest, because they simplify the writing... and avoid tensions with colleagues. Authors may even cite articles that they consider as wrong, because they wish to correct their errors. In experimental disciplines, articles describing methods and apparatuses are also favoured. By contrast, big scientific discoveries, abstract new ideas, are rarely cited through the big original article, but rather through daughter publications inspired by the first. It is therefore a very indirect use of citations, probably even a

complete misunderstanding of their function, to take them as the only basic element for evaluating scientific quality. What is even worse, it creates perverse side effects since this method of evaluation tends to react back on the way scientific citations are given in articles, in a way that does not improve the quality of scientific communication.

Various bias

In "hard" sciences, the data base that is used for bibliometry is mostly the SCI³. A first problem immediately comes to mind: books are not taken into account in the calculation of the H factor that this basis provides in 2 clicks! This is very strange, since most scientists agree that one of the best ways for a creative researcher to influence a scientific domain is precisely to publish books.

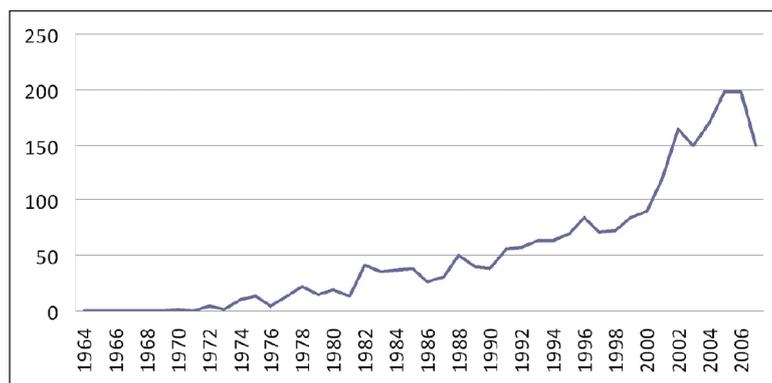
A second problem: the indices G, H, etc. that are usually used to rank individuals are as biased as the well-known Shanghai ranking. In these indices, the contribution of an author is exactly the same whether he/she is the only author, or if he/she has 10 co-authors! Calculating indices G', H', etc... from the number of citations divided by the number of authors may look elementary and even more logical, but no one seems to be doing the calculation in this way with the SCI⁴. The biasing problem is then obvious: if three friends decide to put together all their publications during their entire career, all their H-index will be strongly increased.

Third problem: the prominent weight of short term in bibliographic indices. In many scientific domains, minor technical breakthroughs create a flurry of publications, which may sometimes become quickly forgotten. As a consequence, the bibliometric indices are very sensitive to fashions. This problem could also easily be cured: it would be easy to calculate indices that favour articles that have a long term influence, for instance by including only articles that are still cited after 3 of 5 years; but no one seems to be doing it. A striking illustration of the long time constants involved in the citation rate of very influential articles in physics is given in Figure 1.

Fourth problem, rather technical but nevertheless real: the SCI data basis is not homogeneous, since the entry of data has fluctuated in time with the persons in charge of it. It therefore requires a specialist to make the necessary series of corrections, which we cannot discuss here, but who cares: it is so much easier to get a ranking with three mouse clicks!

In addition to being of mediocre quality, this superficial use of bibliometry creates more serious problems at a deeper level than just biased evaluation. It may affect the quality of scientific communication between researchers, and therefore in the long run the quality of research itself. It is clear that, if the criteria for selection favour the short term bibliometric impact, most scientists will adapt to this fact and orient their work in a direction that will provide good indices, even at the

▼ FIG. 1: Number or citations per year of the famous article by John Bell "On the Einstein-Podolsky-Rosen paradox" (Physics, vol. 1, 195-200 (1964) until mid 2007. While this article was almost not cited for many years, 30 years later it became more and more cited. In particular, this article would have not contributed at all to the IF (impact factor) of the journal in which it was published!



expense of scientific quality. Since the process of scientific communication is directly at the heart of the functioning of science, it will shift the general effort towards short term impact, reducing the progress of knowledge in the long run. This is actually already happening: some scientific journals, in order to improve their “Impact factor”, implement a biased citation policy, by letting the authors know that “if your manuscript contains at least 4 citations of articles in our journal, it will be more easily accepted”. What can be worse for scientific quality and clarity?

Conclusions

This leads us to the following conclusions about these indices for evaluation of an individual:

1. They have not been rationally tested with sufficient care, in comparison with other methods of evaluation. Paradoxically, the methods for evaluating research have escaped the scientific selection that is applied in all disciplines! Even elementary consistency checks as those mentioned above (e.g. effect of dividing by the number of authors) have not been performed; no one really understand the influence of the arbitrary method of calculation on the final result.
2. No one seems to have had the time to honestly try to obtain indices that are more closely related to the quality and long-term relevance of science.
3. They are “not even wrong” since they undoubtedly do contain some information on individuals, mostly when this information is trivial and already known. When the indices are used in real life in a homogeneous population, they give more information on other variables than the quality of the work, such as the style of work of the evaluated person.
4. Their success is not related to the quality of the information they provide, but more on the facility: a saving of the time necessary to make a real evaluation.
5. Finally, it seems that the faith in these indices is not very different from something that escapes rationality. One could compare this with astrology and numerology, which pretend to be scientific but have never gone through the process of scientific selection.

A recipe

If you are a bad researcher, there is probably no way to get a good H-index, so this is not for you. If you are a good researcher, and if you want a better H-index, here is some advice:

1. Choose to work in a group of at least 5 or 6 colleagues, if possible more, who publish all their articles in common; this should allow you to significantly increase your index (you will all have the same index, but who cares?). Moreover, this will allow you to share material and human benefits (postdocs, for instance) which may also increase your real productivity. No

need to mention that, the more prominent these colleagues are, the more you will improve your H!

2. Favour big scientific domains over smaller ones; since small domains cite more large domains than the converse, a positive correlation exists between the citation rate of articles and the size of the scientific domain. Above all, avoid choosing subjects that are not mainstream; even if you are a genius, it will take at least 10 years to see your work appreciated. Moreover, your articles will not be cited more than those which your article has stimulated. In short, do not take too much scientific risk!
3. Above all, do not waste your time in publishing books, whatever their international intellectual impact is; they play no role in the usual H factor.
4. Do not give too much importance to what was initially your motivation to do science, namely the production of new and original knowledge, in particular when you write articles; keep in mind that public relations are more important. ■

Big scientific discoveries are rarely cited through the original article

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notes

¹ The H-index attempts to measure both the scientific productivity and the apparent scientific impact of a scientist, a group, a laboratory, etc. J.E. Hirsch introduced it in 2005 and defined it in the following way: “A scientist has index h if h of [his/her] N_p papers have at least h citations each, and the other $(N_p - h)$ papers have at most h citations each”. The “Web of Science” now gives direct access to the H index in a few mouse clicks.

² The G index was introduced in 2006 by L. Egge, as an alternative to the H index. Its definition is “Given a set of articles ranked in decreasing order of the number of citations that they received, the g -index is the (unique) largest number such that the top g articles received on average at least g citations”.

³ SCI is for “Science Citation Index”, the data base on which the commercial service of the WOS (Web of Science) is offered by ISI/Thomson.

⁴ Our point is not to imply that this method would solve all problems, and even that it would be sufficient. The indices G , H , ... would not necessarily be more relevant than G , H , ...; what is interesting is that they would change the results of rankings, illustrating the arbitrary character of the final result.

PHYSICS IN DAILY LIFE:

WHY PLANES FLY

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Ask any physicist how the wings of an aircraft work, and most probably he or she will come up with the popular explanation based on Bernoulli's law. The idea is that the cross section of a wing is curved along the upper side, and more or less flat at the bottom. Air hitting the front of the wing, the 'leading edge', is split in two, and the two air masses meet up again at the rear of the wing, the 'trailing edge'. Since the distance along the upper surface is longer, the air speed along the upper side must be greater. And according to Bernoulli's law, larger speeds imply lower pressures, and so there is a net upward force on the wing. It sounds simple and logical. But it's wrong. We *know* it must be wrong. If this were the correct explanation, how on earth would planes be able to fly upside down? So what *is* it that produces lift on a wing? It turns out that all we need is for the air flow to be deflected downward by the wing profile. As shown elegantly by Holger Babinsky from Cambridge back in 2003 (*Physics Education* 38, p. 497-503), streamline curvature is the key. Think of a sailing boat, and forget the mast for a second. The sail can be seen as a vertical wing. It works beautifully propelling the boat, but its shape is nowhere near that of a traditional wing. There is no difference in path length along the two sides of the sail, so the Bernoulli explanation invoking different path lengths fails. Yet the sail is very efficient, simply because it creates curvature in the air flow. If we work it out, we

find a simple relation between the curvature of the flow and the pressure gradient perpendicular to the streamlines: $dp/dn = \rho v^2/R$, with coordinate n normal to the streamlines, ρ the air density, v the speed and R the radius of curvature. The sign is such that the pressure decreases toward the center of curvature. This yields a pressure decrease at the convex side of the sail, and a pressure increase at the hollow side.

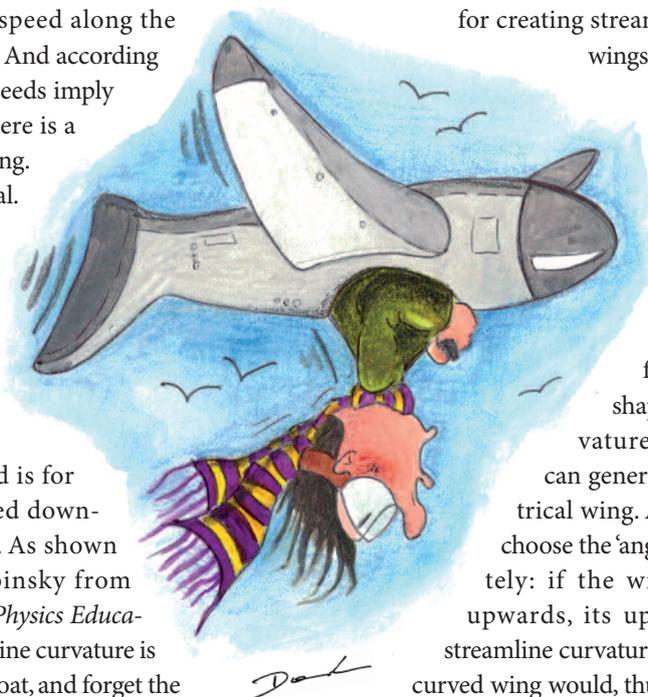
Indeed, thin curved wings like those of a sail are ideal for creating streamline curvature. Birds'

wings tend to be like that. For

aircraft, this is not an attractive option: thin curved wings would not meet structural demands and, in addition, would have no useful volume for storing fuel. Fortunately, *any*

shape that introduces curvature into the flow profile can generate lift, even a symmetrical wing. All we have to do is to choose the 'angle of attack' appropriately: if the wing is slightly tilted upwards, its upper side will create streamline curvature as effectively as a thin curved wing would, thus giving by far the largest contribution to the lift. Below the wing there are regions of different senses of curvature, creating a net effect which is close to zero.

So, for a symmetrical wing the amount of lift – positive or negative – is purely a matter of adjusting the angle of attack, obviously within certain limits. And flying upside down is now a piece of cake. If you feel like it, of course. ■



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Announcement of an open position at the Institute of General Physics, (renamed to "Applied Physics" from October 1st, 2009) Faculty of Physics, Vienna University of Technology (TUW)

Full Professorship in Biophysics

The successful applicant is expected to have outstanding academic credentials and an excellent track record of scientific accomplishments in the field of experimental biophysics, e. g. in the fields of biomaterials, bio-related soft matter, bio-inspired materials and/or of molecular and supra-molecular structures. Synergies with relevant research at TUW are desirable. Adequate participation in the teaching duties of the relevant curricula is expected. After a transition period, lectures are expected to be given in German. Links to further information can be found at: <http://www.iap.tuwien.ac.at/biophysics/>

Special consideration will be given to the ability to cooperate with national and international scientific institutions, including institutions outside academia. Experience with the acquisition of research grants, including grants for applied research will be expected. The contribution of aspects of biophysics to the cooperation centre "functional matter" would be highly desirable.

A more detailed announcement and information on how to apply can be found at: <http://info.tuwien.ac.at/dektnf/Ausschreibungen.html>

Application deadline: **October 30th, 2009**



Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Assistant Professor (Tenure Track) of Experimental Solid State Physics

The Department of Physics at ETH Zurich (www.phys.ethz.ch) invites applications for an assistant professorship in Experimental Solid State Physics. The successful candidate is expected to sustain a strong research program in modern solid state physics, for example by complementing or expanding the current research programs at the Laboratory for Solid State Physics in the fields of semiconductors, magnetism, superconductivity, correlated electrons and manipulation of quantum systems. ETH Zurich offers a stimulating research and teaching environment with excellent on-site infrastructure and access to first class experimental facilities at the near-by Paul Scherrer Institute. Teaching involves contributions to the physics curriculum of the Bachelor and Master's program. The new professor will be expected to teach undergraduate level courses (German or English) and graduate level courses (English).

Assistant professorships have been established to promote the careers of younger scientists. The initial appointment is for four years with the possibility of renewal for an additional two-year period and promotion to a permanent position.

Please submit your application, together with a curriculum vitae, a list of publications, and a brief statement of present and future research interests **to the President of ETH Zurich, Prof. Dr. Ralph Eichler, Raemistrasse 101, 8092 Zurich, Switzerland, no later than January 31, 2010.** With a view towards increasing the proportion of female professors, ETH Zurich specifically encourages female candidates to apply.

Europhysics News Recruitment

Contact **Jessica Ekon** • e-mail advertisement@edpsciences.org

EDP Sciences • www.edpsciences.org • Phone: +33 (0)1 69 18 92 40 • Fax: +33 (0)1 69 18 18 15



EUROMAGNET CALL FOR PROPOSALS FOR MAGNET TIME

The next deadline for applications for magnet time at the **LABORATOIRE NATIONAL DES CHAMPS MAGNETIQUES INTENSES** (ex GHMLF & LNCMP / <http://lncmi.cnrs.fr>) the **HIGH FIELD MAGNET LABORATORY** (www.hfml.science.ru.nl) and the **HOCHFELD LABOR DRESDEN** (www.fzd.de/hld) is November 15th, 2009.

Applications can be done through an on-line application form on the web site: <http://www.euromagnet.org>.

Scientists of EU countries and Associates States* are entitled to apply under FP7 for financial support according to the rules defined by the EC.

*listed on ftp://ftp.cordis.europa.eu/pub/fp7/docs/third_country_agreements_en.pdf

For further information concerning feasibility and planning, please contact the facility of your choice.



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Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Professor of Mathematical Physics Assistant Professor (Tenure Track) of Mathematical Physics

The Department of Physics of ETH Zurich (www.phys.ethz.ch) invites applications for a Professorship / Assistant Professorship (Tenure Track) in Mathematical Physics.

The Department offers a stimulating environment in mathematical, theoretical, and computational physics, as well as in experimental high energy physics, condensed matter physics, quantum optics, astrophysics, and neuroinformatics. Furthermore, ETH Zurich has a thriving Department of Mathematics.

The successful candidate should sustain a strong research program in some area of mathematical physics, for example in the context of statistical physics, many-body theory, quantum field theory, or string theory. Teaching duties involve the theoretical physics curriculum at the undergraduate level and advanced courses in the Master's program. The new professor will be expected to teach undergraduate level courses (German) and graduate level courses (English).

Assistant professorships have been established to promote the careers of younger scientists. The initial appointment is for four years with the possibility of renewal for an additional two-year period and promotion to a permanent position. ETH Zurich offers substantial support associated with this appointment.

Please submit your application together with a curriculum vitae, a list of publications, and a brief statement of present and future research interests to the President of ETH Zurich, Prof. Dr. Ralph Eichler, ETH Zurich, Raemistrasse 101, 8092 Zurich, Switzerland, no later than December 15, 2009. With a view toward increasing the number of female professors, ETH Zurich specifically encourages qualified female candidates to apply.



Universität Hamburg



Hamburg

Ph. D. Positions and Research Associate Positions

for Fundamental Studies of Spin Systems at the Atomic Level

In the framework of the recently granted **Cluster of Excellence "NANO-SPINTRONICS"**, the Department of Physics at the University of Hamburg is seeking outstanding and enthusiastic young researchers with a strong record of creativity and achievements. Positions are available in the following research areas:

- **Metal-based NANO-SPINTRONICS**
- **Semiconductor-based NANO-SPINTRONICS**
- **Molecular-based NANO-SPINTRONICS**
- **Atom-based SPINTRONICS**
- **Nano- and atomic-scale SPINTRONIC DEVICES**
- **Theory and advanced simulations for NANO-SPINTRONICS**

Appointments should begin as soon as possible. To apply, send a resume including a statement of research experience and interests, and a list of publications and presentations to:

Prof. Dr. Roland Wiesendanger

Scientific Coordinator of the Cluster of Excellence "NANO-SPINTRONICS"
Institute of Applied Physics and Interdisciplinary Nanoscience Center Hamburg

University of Hamburg

Jungiusstraße 11, D-20355 Hamburg, Germany, EU

Email: wiesendanger@physnet.uni-hamburg.de

Web: www.nanoscience.de

The University of Hamburg is an equal opportunity employer and welcomes applications from all qualified individuals. It aims at increasing the representation of women among the staff and therefore explicitly encourages applications from female scientists. Disabled persons are given priority over applicants of equal suitability, qualification and degree of specialized knowledge.

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October 25 – 31 '09 Orlando, Florida,

<http://www.nss-mic.org/2009/NSSMain.asp>