

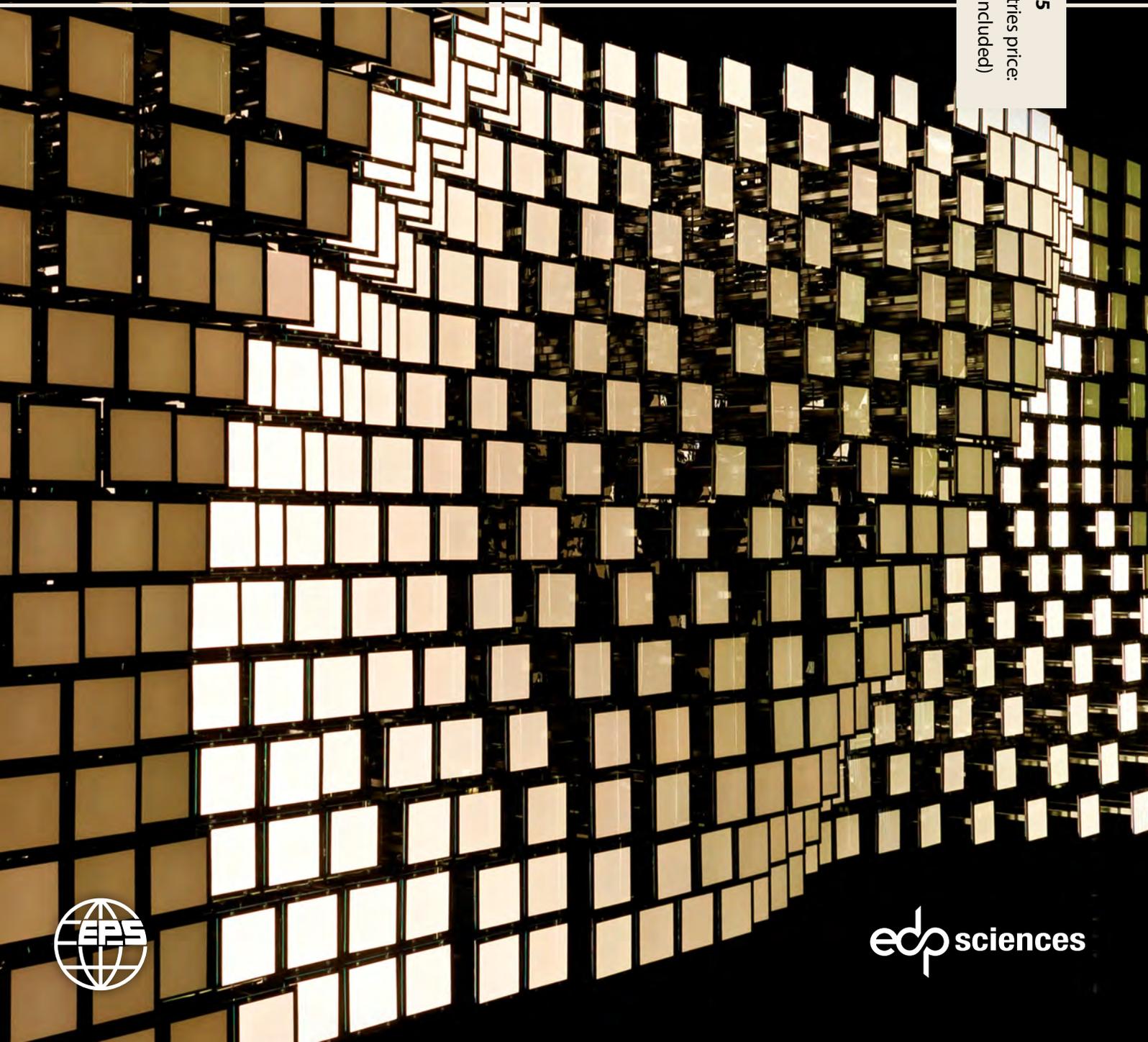
# europhysicsnews

THE MAGAZINE OF THE EUROPEAN PHYSICAL SOCIETY

**A look inside white OLEDs**  
**On inverse problems in physics**  
**Water lenses**  
**A tribute to Jean Perrin**  
**The challenge of Open Access**

**44/5**  
**2013**

**Volume 44 • number 5**  
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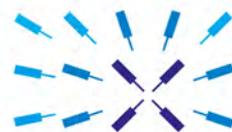
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**Cover picture:** OLED Lighting, LivingSculpture, 3D module system. Designed by Christopher Bauder/WHITEvoid © Philips / www.lumiblade-experience.com See p.21 'A look inside white OLEDs'



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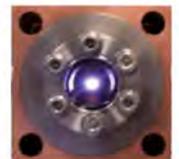
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[EDITORIAL]

## Future focus

**Physics has a wonderful history, and we are proud of the great achievements of the past. Indeed, the very successful EPS Historic Sites Award was created to recognize places associated with significant events, discoveries, or bodies of work. Moreover, as I write this editorial, it is only a few weeks before the announcement of the Nobel Prize in Physics. As we know, this is often awarded for research initiated many years ago, and the details of the history behind the Prize, which is awarded each year, are always fascinating.**

**A**s tempting as it may be, however, we must not fall into the trap of studying history only to celebrate what was achieved in the past. After all, we certainly don't want to give the impression that the best days of physics are over! And moreover, past successes do not by themselves convince decision-makers of the need to support future physics research and to provide necessary investment. Whilst stories of past accomplishments may be attentively listened to, these historical stories are very likely to have been heard before! What we must do to focus the interest of political decision-makers is to describe our vision for the future of physics, and explain why this is worthwhile and important for both science and society.

In a sense, we are all ourselves very aware of these issues every time we write or review a funding application. We know that track records are important, but we also know how vital it is that vision and originality are also stressed. Of course we can use examples from history to demonstrate how fundamental research in physics has been influential in science and technology, but we need to describe our future plans in a very clear way. We need to explain precisely the important open questions, how and why they need to be solved, and the need for flexibility and freedom to follow up

unexpected discoveries and to explore new directions. Physicists are not always comfortable with this as we prefer not to speculate too much without justification, and we are naturally cautious when describing potential future results. But if we do not argue forcefully and with conviction for the continued centrality of physics, we run the risk that we will be considered less and less relevant to the future of science.

This is a challenge of course, but when one looks at history one finds that physicists in the past have also

faced many difficulties and challenges. Yet thanks to their passion and commitment, they succeeded in creating the knowledge that we now benefit from. We must now work as hard as they did, to continue to create and discover new physics and to demonstrate its benefit for all.

We have inherited a great legacy and tradition from the past. It is not enough to celebrate it – we must show that we deserve it. ■

▼ Portrait of a physicist oriented toward the future with an eye on the past © Quinn Dombrowski, via Flickr, under creative commons licence

■ **John Dudley**  
*President of the EPS*



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## EPS HISTORIC SITES

# The Villa Griffone in Pontecchio Marconi, near Bologna (IT)

**On the gentle hills in the Bologna neighborhoods there is a magnificent country house and park, once inhabited by Guglielmo Marconi father's family, whose name is Villa Griffone(\*). It is now a State property hosting the Marconi monumental grave, and, in the restored villa, the Marconi Foundation offices and an historical museum. Visiting the museum, which collects what is left of the instrumentation used by 21 years young Marconi for his experiments on the electromagnetic waves propagation, one has a strong perception of his value as an experimental physicist.**

It has been therefore a very felicitous initiative from the European Physical Society to mark as an "EPS Historic Site" Villa Griffone where, with many experiments conducted along the year 1895, Marconi eventually succeeded to produce a long range electromagnetic wave and to detect it with a receiver on the other side of a hill named in Italian "collina dei Celestini". This historic experiment can be considered the starting point of over a hundred years of studies in radio waves physics which have led both to unique discoveries for the understanding of our universe, like the Cosmic Microwave Background (CMB) radiation, and to unbelievable engineering applications, like the current mobile phone wireless communications. The new EPS Historic Site was inaugurated on 26 May 2013 in Pontecchio di Sasso Marconi (Bologna), Italy, the sixth since the beginning of this EPS initiative.

The ceremony, which coincided with the closure of a popular annual festival on wireless communications, called "Marconi Radio Days", took place in a crowded Aula Magna at Villa Griffone, in the presence of local authorities: the Mayor of Sasso Marconi, the Pro Vice-Chancellor of the University of Bologna, and Councillors of the Province of Bologna and of the Region of Emilia-Romagna. The ceremony started with the grant to young postgraduate students and PhD graduates, of various awards for original work done in the field of communications and informatics.

\* [www.panoramio.com/photo/2265367](http://www.panoramio.com/photo/2265367)

Introducing the plaque unveiling, Marconi Foundation President Gabriele Falciasecca declared to be particularly proud for the EPS recognition of the importance for physics of young Marconi's work at Villa Griffone. If in fact the development of radio communications at the dawn of the 20<sup>th</sup> century was an engineering enterprise, the early experiments which led to the 1895 successful transmission of a radio signal beyond the Celestini hill were genuine physics research. Marconi, with extraordinary intuition and constant application, took advantage of all the experimental work and theoretical knowledge of renowned physicists like Hertz and Righi (the latter at Bologna University).

The text of the plaque, which was placed in the front wall of the Aula Magna, is the following:

#### European Physical Society – EPS Historic Site

##### *The Villa Griffone in Pontecchio Marconi*

*Here, in summer 1895, at the age of 21 Guglielmo Marconi established the first long range electromagnetic wave communication between the loft of Villa Griffone and a place out of sight behind the Celestini hill about 2 km away using a transmitter and receiver made by himself. This experiment started in the last century the fundamental studies of the radio waves physics and the developments of today's worldwide wireless communication technology.*



▲ A. Zichichi, G. Falciasecca, F. Palmonari and L. Cifarelli (left to right) unveiling the EPS Historic Site plaque

EPS Vice-President Luisa Cifarelli, in her presentation, explained the scope of the EPS Historic Sites initiative, addressed to the whole European community, to remember all places where outstanding progresses in scientific knowledge have been achieved. She mentioned that Villa Griffone was the third EPS Historic Site in Italy, after the Arcetri Hill of Galileo Galilei in Florence and the goldfish fountain of Enrico Fermi in the old Physics Institute at Via Panisperna in Rome. Former EPS President Antonino Zichichi finally delivered a special lecture. Its title "The great

achievements in science from Marconi to the Superworld" was meant to emphasize the importance in the modern world of a widespread correct scientific culture and to remember the Italian scientists' contribution of theoretical and experimental discoveries to the advancement of physics. In particular Zichichi recalled the high consideration of Marconi for the most outstanding 20<sup>th</sup> century Italian physicist Enrico Fermi. As President of the Italian National Scientific Council CNR, Marconi actually promoted the experimental work on radioactive nuclei of the group led by Fermi at the Physics Institute in Rome up to his death in 1938.

A long and enthusiastic applause of the audience in the Aula Magna concluded the ceremony. Finally, everybody was invited in the magnificent park surrounding the Villa to attend a presentation, "Notes on Marconi", which was crowned by a joyous toast. The afternoon was particularly sunny and clear (but chilly!). ■

#### ■ Federico Palmonari,

INFN & University, Bologna (IT)  
<http://www.linkedin.com/pub/federico-palmonari/29/807/69a>

▼ Villa Griffone



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# Interview of **Alessandra Gatti**

**Interview between Alessandra Gatti (AG), first winner of the EPS Emmy Noether Distinction for Women in Physics (see EPN 44/2, p. 6 to 8) and Jo Lister (JBL), chair of the Equal Opportunities Committee of the EPS, May 2013.**

*JBL: Alessandra, please let me add my own congratulations on this award. One of our aims in making this award is to provide some excellent role models for young female physicists, so I would like to concentrate our discussions on early career issues. So let me start right at the beginning. I would like to understand at what point in your education you considered a career in physics and what the main motivations were?*

**AG:** Actually, the start of my career happened very late. When I was a child, I was very good at mathematics and I dreamed about being a scientist (well, as a matter of fact I dreamed about being an astronaut!). However, at that time good students in Italy, especially girls, were often oriented towards the humanities. So in my high school I studied a lot of ancient Greek, Latin, and literature but no science at all. It was all very interesting, but also became rather boring. Then, when it came to the time to choose a university course, I started a degree in architecture! This was also not so exciting for me, but by now I was grown up enough to realise that it wasn't worth spending all my life working on something which was really not interesting enough for me, so I came back to my first passion and I started a degree in physics. In the beginning it was hard, I had no serious background in mathematics (I did not even know what a logarithm was!), but slowly I recovered and I became really passionate about my physics studies.

However, it was only after my first degree, when I won a competition to start a PhD in physics, that the possibility of realising my dreams and launching a career in physics became a reality for me.

*JBL: That is amazing, an obstacle course for anyone. While you were being oriented towards your studies, did you find any resistance to girls succeeding in science?*

**AG:** Not really, I can only remember some funny episodes. For example a teacher

insisted on giving a very good report to my male neighbour, because in his mind a girl couldn't have been the author of such good work. But these were really very isolated cases since normally there is not any particular discrimination in the education of boys and girls in Italy.

*JBL: That was from the teachers' point of view, but did other girls at school find it strange for you to want to do science?*

**AG:** No, normally girls do not find it strange, but sometimes boys do find it a bit odd! But in Italy, there is no particular discrimination, neither is science considered a field for males only. In fact, to tell you the whole truth, my mother, who was born in 1932, has a degree in mathematics, and this was not considered so strange even at that time. However, I have the impression that this situation is peculiar to Italy, where any science is considered a strange choice, for anyone, independently of gender, because my country is very humanities oriented. Looking from a more basic perspective, it may also derive from the fact that salaries in science are low and the career is long and hard.

Even now, when I first meet someone, I am still a little hesitant to say I am a physicist, because people may look at me oddly. I was even asked whether there was a misspelling; perhaps I meant a "physician" instead?

*JBL: I think that Italy is probably culturally different, as you say, but this difference itself appears to have its positive and negative aspects, although science does thrive in Italy and women are perhaps more visible than in many other countries. In order to make the best use of talented young female scientists, do you believe that physics should positively discriminate in favour of women?*

**AG:** This is rather a difficult question to answer. On the one side, I would not be

in favour of any discrimination between women and men, because we all have the same basic capability, women should certainly not be considered as weaker! On the other side, women may have a legitimate aspiration to become mothers and to take care of their family, a role which is fundamental in any society. This may discourage them from taking on particularly hard careers, especially when they see that there is not much help from society in general to reconcile the two things.

More importantly, I am aware that these arguments apply well to developed countries, where women have reasonable possibilities to study and choose a career, but there is still a huge part of the world where these possibilities are excluded, women are considered to be not much more than slaves. In this sense, any effort that could favour women living in such situations should be made. Prizes like the one I have the honour to receive from the EPS may really help, because by highlighting the role of women in science, the perception that women are as capable and good as men can take root in the whole world. This might encourage girls who have found a passion for science to launch themselves in this career.

*JBL: That really does express what is behind the Emmy Noether Award for Women in Physics. Please let me ask you one final question: would you choose the same career again?*

**AG:** I would choose the same career every single day of my life. Physics was the best choice I ever made. I think it's a real privilege to have your passion as a job.

*JBL: Alessandra, our thanks for being so frank and exposing your personal views. Once again, may I congratulate you on the award and our interview can only underline its appropriateness. ■*

# Inspiring science education: eLearning tools to promote IBSE

**The project Inspiring Science Education [ISE] - funded by the European Commission under the CIP-ICT-PSP programme - aims to encourage the use of eLearning tools for promoting inquiry-based science education [IBSE] across European schools.**

Running from April 2013 until July 2016, the project brings together a multi-stakeholder partnership, including the European Physical Society [EPS], and aims to reach 10,000 teachers and 100,000 students in 5,000 primary and secondary schools in 14 European countries (Belgium, Bulgaria, Croatia, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Portugal, Romania, Spain and United Kingdom). The project's final goal is to make available to all European science teachers a common framework for the design, development, organisation and sharing of resources, methods and tools that promote IBSE.

**The ISE project will be organised into four main lines of action:**

- The ISE consortium will prepare a series of scenarios that will guide the teachers in the application of eLearning tools in innovative teaching practices that will demonstrate the potential of these tools to qualitatively upgrade the current practice.
- The creation of a structured inventory of eLearning tools that will comprise, among others, interactive simulations, educational games and Virtual Reality [VR] and Augmented Reality [AR] applications developed by research organisations as well as by outreach infrastructures of universities. The repositories developed will be eventually integrated into the Open Discovery Space Portal ([www.opendiscoveryospace.eu](http://www.opendiscoveryospace.eu)).
- The project will run large-scale pilots in European schools during three academic years. The implementation in each school will follow a progressive approach, with the engagement of pioneering groups of 2-3 teachers setting up the schools roadmap to the science learning innovation and moving on with the involvement of student groups and the use of more advanced tools. The final goal is to establish, organise and support a community of teachers that will act as leaders in producing meaningful change in contexts of teaching practices and will influence policy making.
- Finally, the mainstreaming process that will help to increase the potential of the main project outcomes, making them useful at a both micro- and macro-level of the European education systems.



Among these initiatives, the EPS will lead the integration of the proposed project's methodology in the evolution of the European Science Education Academy [ESEA] (for more information about the ESEA initiative, see an e-EPS item on this month's issue ([www.epsnews.eu/2013/08/esea-workshop/](http://www.epsnews.eu/2013/08/esea-workshop/))) in the framework of the development of the Inspiring Science Education Federation.

For more information, you can visit the ISE webpage on the EPS website ([www.eps.org/?page=edu\\_ise](http://www.eps.org/?page=edu_ise)). ■

## EPS EUROPHYSICS PRIZE

The EPS Europhysics Prize for Outstanding Achievement in Condensed Matter Physics is acknowledged internationally as one of the most prestigious awards for condensed matter physics. It recognises recent work by one or more individuals in the area of physics of condensed matter, which, in the opinion of the Society's selection committee, represents scientific excellence. Recent work is defined to mean completed within 5 years prior to the award. The award can be given for either pure or applied research.

Nominations are now being sought for the 2014 Award. For a nomination to be complete, it must include:

- a completed nomination form from the EPS web pages
- a complete CV
- a publication list (5 pages maximum)
- an indication of the three most relevant papers to the nomination
- a description of the work justifying the nomination (2 pages maximum)
- a suggested short citation.

The deadline for the receipt of nominations is 15 January 2014 and should be sent to the EPS Secretariat, 6 rue des Frères Lumière, F-68200 Mulhouse, France, or by email to [s.loskill@eps.org](mailto:s.loskill@eps.org).

The 2014 Award will be presented at a session of the 25<sup>th</sup> General Conference of the EPS Condensed Matter Division which will take place in Paris from 24 to 29 August 2014. <http://cmd25jmc14.sciencesconf.org> ■

# Highlights from European journals

## STATISTICAL PHYSICS

### Calculation of the connective constant for self-avoiding walks

Self-avoiding walks are walks on a lattice, which are not allowed to self-intersect. Despite the apparent simplicity of the self-avoiding walk model, it is an important model of polymers, and over the past 60 years it has resisted all attempts to find an exact solution.

One of the basic features of self-avoiding walks is the number of walks for a given number of steps. The number of walks grows exponentially with length, and the rate of exponential growth, called the connective constant, is a quantity of fundamental interest.

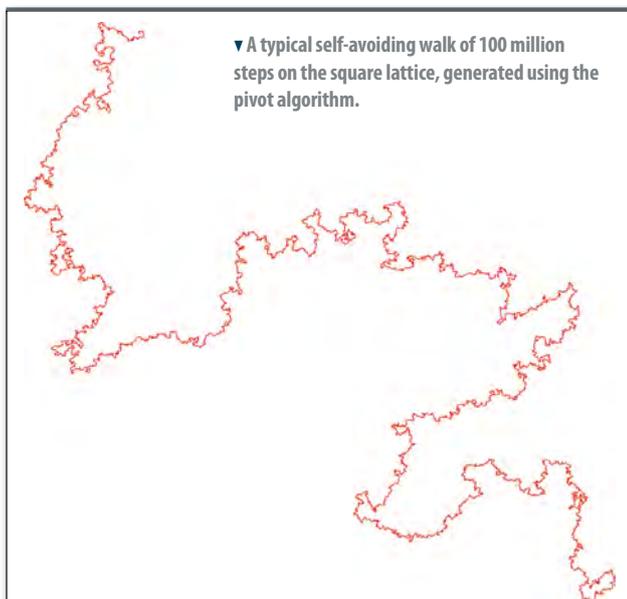
Using a novel divide-and-conquer Monte Carlo algorithm, the number of self-avoiding walks on the simple cubic lattice for selected lengths of up to 38 million steps were estimated to high precision. For instance, the number of walks with 606 207 steps is  $7.7 \times 10^{406.5351}$ . Using these estimates the connective constant was found to be  $4.684\,039\,931 \pm 0.000\,000\,027$ , which is significantly more accurate than estimates obtained via alternative methods.

A key open question is whether similarly powerful enumeration methods can be found for other models in statistical mechanics. ■

#### ■ Nathan Clisby,

'Calculation of the connective constant for self-avoiding walks via the pivot algorithm',

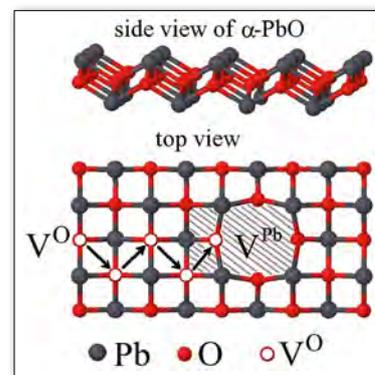
*J. Phys. A: Math. Theor.* **46**, 245001 (2013)



## PHYSICS FOR MEDICINE

### Self-passivation of vacancies in $\alpha$ -PbO

Polycrystalline Lead Oxide (PbO) is one of the most promising materials for application in radiation medical imaging. At the current stage of technology, electronic grade PbO is not achievable because of large defect concentration. Defects act



▲ Migration of oxygen vacancy towards lead vacancy followed by pair formation

as traps for x-ray generated charge carriers during their transit across PbO layers: average distance drifted before trapping is smaller than layer thickness. Therefore, suppression of the effect of defects on carrier transport is an important challenge in PbO technology.

In metal oxides, vacancies are the main source of traps. The authors have shown that in thermally deposited PbO layers both Pb and O vacancies appear primarily in charged states of opposite sign. As a result, neighbouring vacancies can form a neutral pair, which no longer acting as trapping centre. This finding offers a practical way to improve the transport properties. The post-growth annealing would initiate migration of the O vacancies towards Pb vacancies and facilitate their merging and neutral pair formation. The reduction in an amount of ionized centres increases carrier mobility and suppresses recombination thus improving x-ray generated charge collection. ■

#### ■ J. Berashevich, J. A. Rowlands and A. Reznik,

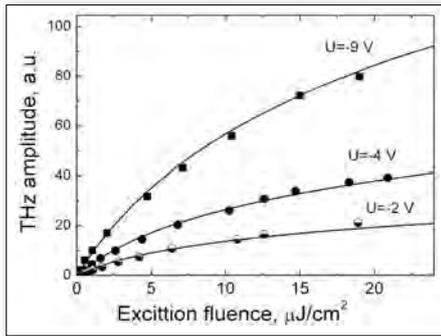
'Self-passivation of vacancies in  $\alpha$ -PbO',

*EPL* **102**, 47002 (2013)

## APPLIED PHYSICS

### Dynamic screening and GaAs/AlGaAs quantum wells

The article reports results of investigations of generation of coherent terahertz (THz) radiation from 29 nm thick GaAs/Al<sub>0.37</sub>Ga<sub>0.63</sub>As quantum wells (QWs) with transverse electric



◀ Dependences of the THz amplitude on the excitation fluence at different bias voltages. The solid curves are results of calculations by the developed model with the following parameters:  $m^* = 0.065m_0$ ,

$m_h = 0.5m_0$ ,  $\epsilon = 12.9$ ,  $\alpha_0 = 1.8 \times 10^4 \text{ m}^{-1}$  (electron and hole effective masses, dielectric constant and bulk optical absorption coefficient for  $\hbar\omega_{ex} = 1.56 \text{ eV}$ , respectively). The initial electric field  $F_0$  in the QWs was supposed to be equal to the averaged electric field in the structure part containing QWs.

bias under interband femtoseconds laser photoexcitation at room temperature. The detected THz radiation is attributed to the excitation of time-varying dipole moment induced by polarization of non-equilibrium electron-hole pairs in QWs. Noticeable sub-linearity in the dependence of THz amplitude on excitation density is observed. A theoretical model, which accounts for the dynamic screening of the electric field in wide GaAs QWs by nonequilibrium carriers, has been developed. The model describes well the properties of the observed THz signal. ■

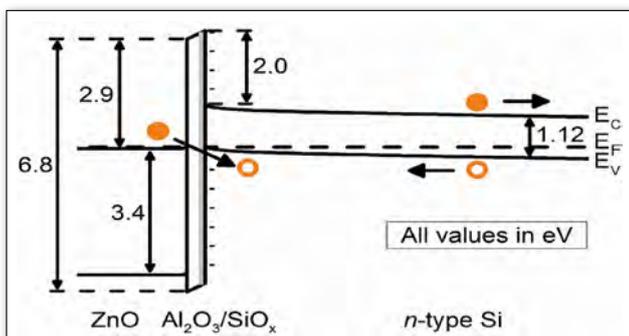
■ **A.V. Andrianov, P.S. Alekseev, G.V. Klimko, S.V. Ivanov, V.L. Tscheglov, I.V. Sedova, and A.O. Zakhar'in,** 'Influence of dynamic screening effect on coherent terahertz radiation from biased GaAs/AlGaAs quantum wells', *Semicond. Sci. Technol.* **28**, 105012 (2013)

## APPLIED PHYSICS

### Passivated tunneling contacts for c-Si solar cells

$\text{Al}_2\text{O}_3$  nanolayers are well-known for their ability to reduce recombination losses at crystalline silicon surfaces, making  $\text{Al}_2\text{O}_3$  an attractive material for passivation of the next-generation high efficiency solar cells. In this work, we try to take the application of  $\text{Al}_2\text{O}_3$  one step further: when  $\text{Al}_2\text{O}_3$  is deposited

▼ Band diagram of the proposed novel front contact



on n-type silicon, a high concentration of holes accumulates at the surface due to the high density of negative charges in the  $\text{Al}_2\text{O}_3$ . Consequently a  $pn$ -junction is formed which can replace the traditional front side  $p$ -doped region made by high temperature diffusion.

The idea presented in the article is to deposit a stack consisting of an  $\text{Al}_2\text{O}_3$  and ZnO layer on the silicon. The holes separated from the electrons at the junction can tunnel through the  $\text{Al}_2\text{O}_3$  into the transparent conductive ZnO where they are collected with minimal energy loss when the  $\text{Al}_2\text{O}_3$  charge density and ZnO doping density are properly tailored. Using atomic layer deposition, it was demonstrated that  $\text{Al}_2\text{O}_3$  and Al-doped ZnO films deposited with sub-nanometer precision can be used for this purpose with sufficiently high tunneling currents when the  $\text{Al}_2\text{O}_3$  is about 1-2 nm thick. ■

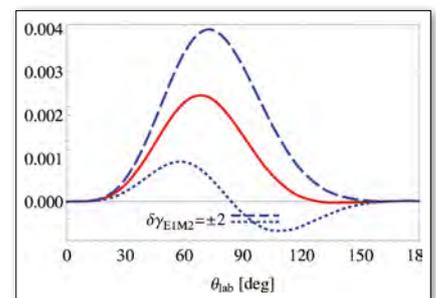
■ **D. Garcia-Alonso, S. Smit, S. Bordihn and W.M.M. Kessels,**

'Silicon passivation and tunneling contact formation by atomic layer deposited  $\text{Al}_2\text{O}_3/\text{ZnO}$  stacks', *Semicond. Sci. Technol.* **28**, 082002 (2013)

## PARTICLE PHYSICS

### Dissecting deuteron Compton scattering I

The electromagnetic polarisabilities of the nucleons characterise their responses to external fields. The simplest are the electric and magnetic polarisabilities that describe the induced dipole moments. For spin-1/2 particles there are also four spin polarisabilities, analogous to rotations of the polarisation of light by optically active media. The best experimental window on them is Compton scattering of photons, which has provided good determinations of



▲ Sensitivity of a double-polarisation-asymmetry observable to the E1-M2 spin polarisability.

the electric and magnetic polarisabilities of the proton. Future experiments with polarised protons will give access to its spin polarisabilities. In contrast, much less is known of about the neutron since it does not exist as a stable target. Nonetheless, its properties can be obtained from Compton scattering on light nuclei, most notably the deuteron -- a weakly bound proton and neutron. A new generation of experiments is planned to provide beams of polarised photons on targets of polarised deuterons. If the spins of the final particles are not observed, there are 18 independent observables. This work provides,

for the first time, the complete set of these, which will be needed for the experimental analyses. More importantly, it also examines their sensitivities to the various polarisabilities, which will be crucial for the design of the experiments. ■

■ **H. W. Griebhammer,**

'Dissecting Deuteron Compton Scattering I: The Observables with Polarised Initial States',  
*Eur. Phys. J. A* **49**, 100 (2013)

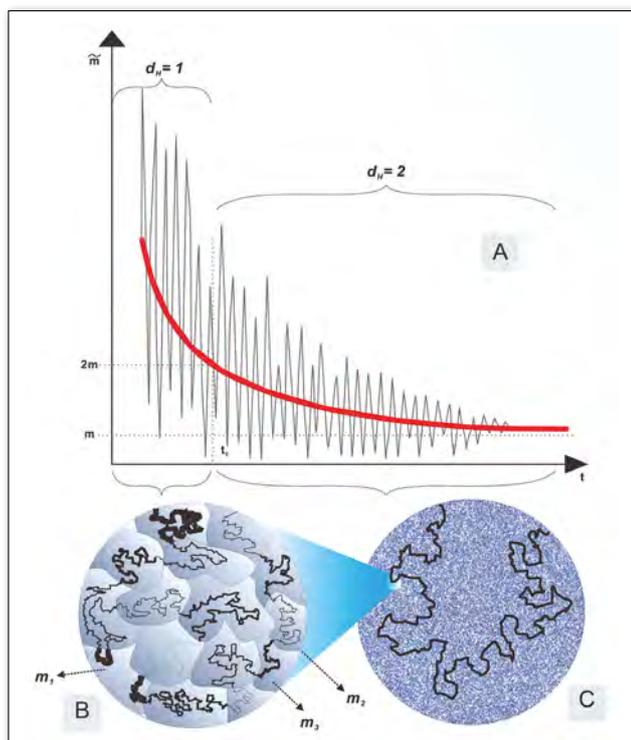
## COSMOLOGY

### Removing complexity layers from the universe's creation

Understanding complexity in the early universe may require combining simpler models to interpret cosmological observations. The authors publish results pertaining to theoretical predictions of cosmological systems' dynamics.

They found that the combination of Einstein's special relativity and quantum-mechanical dynamics is mathematically identical to a complex dynamical system akin to two interlocked processes with different energy scales. To model it, the authors consider a quantum mechanical dynamics in a background polycrystalline space where particles exhibit a Brownian motion. The observed relativistic dynamics then comes solely from a particular grain distribution in this space. In cosmology, such distribution might stem from early universe's formation.

▼ A schematic depiction of the combined motion that a Brownian particle executes in a background polycrystalline space.



This new interpretation focuses on the interaction of a quantum particle with gravity. The non-existence of the relativistic dynamics leads to a natural mechanism for the *formation* of particles-antiparticles *asymmetry*. When coupled with cosmology, the authors' approach predicts that a charge asymmetry should have been produced at ultra-minute fractions of seconds after the Big Bang, in agreement with constraints born out of recent cosmological observations. ■

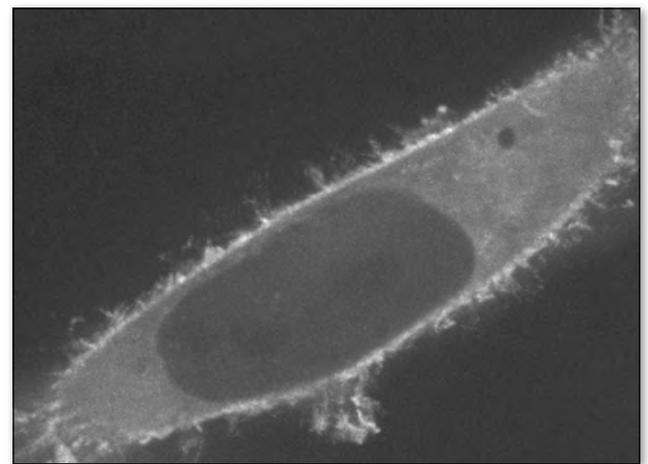
■ **P. Jizba and F. Scardigli,**

'Special relativity induced by granular space',  
*Eur. Phys. J. C* **73**, 2491 (2013)

## BIOPHYSICS

### How cells get a skeleton

Stress generated by nano-motors within animal cells can lead to the creation of a condensed layer of filaments beneath the outer cell membrane.



▲ Microscopy image of a cell.

The authors have found that a well-defined layer beneath animal cells' outer membrane forms beyond a certain critical level of stress generated by motor proteins within the cellular system. They have created hydrodynamic models of active gels to model the cell cortex. They first derived the equations providing a coarse-grained description of cortical dynamics, then calculated the configuration in which their model was in a steady state.

They found that for sufficiently high levels of contractile stress it consisted of a dense layer near the membrane, which abruptly cut off beyond a certain thickness. The key advance in their model is the inclusion of gel disassembly throughout the system, and the contractility due to molecular motors. ■

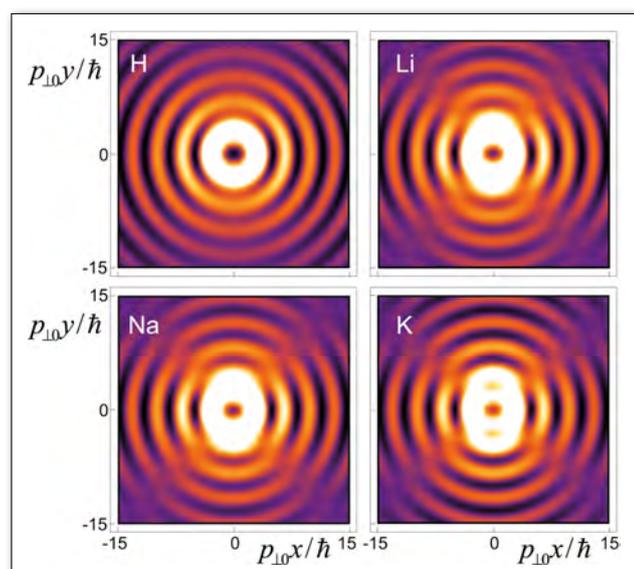
■ **J.-F. Joanny, K. Kruse, J. Prost and S. Ramaswamy,**

'The actin cortex as an active wetting layer',  
*Eur. Phys. J. E* **36**, 52 (2013)

## ATOMIC AND MOLECULAR PHYSICS

## Novel beams made of twisted atoms

Scientists can now theoretically construct atomic beams of a particular kind, which may apply in fields like quantum communication. The present paper presents a theoretical construct of beams made of twisted atoms. These so-called atomic Bessel beams can, in principle, have potential applications in quantum communication as well as in atomic and nuclear processes.



▲ ‘Snapshot’ of atomic Bessel beam profiles.

The authors focused on a beam made of twisted two-level atoms, which are driven by a laser field. They created a theoretical construct by using an equation, referred to as the non-relativistic Schrödinger equation, for atoms which are moving much slower than the speed of light. The authors solved this equation by taking into account the propagation directions of both the atomic and laser beams. By superimposing a multitude of plane waves with well-defined amplitudes, they produced Bessel beams for two-level atoms that resonantly interact with the laser field. ■

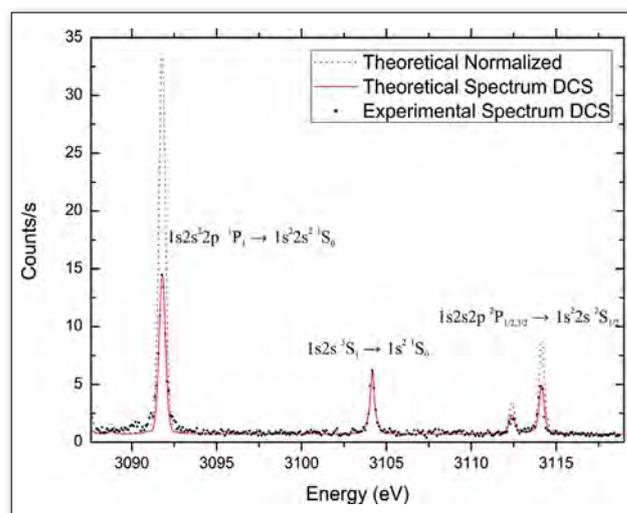
■ **A.G. Hayrapetyan, O. Matula, A. Surzhykov and S. Fritzsche,**

‘Bessel beams of two-level atoms driven by a linearly polarized laser field’, *Eur. Phys. J. D* **67**, 167 (2013)

## PLASMA PHYSICS

## Analysis of the charge state distribution in Ar plasma

Investigation of charge state distributions (CSD) in astrophysical as well as laboratory plasmas, such as those provided by electron-beam ion traps, electron – cyclotron-resonance ion



▲ Double crystal X-ray spectrum showing Ar<sup>12+</sup> to Ar<sup>14+</sup> transitions.

source (ECRIS) and tokamaks, is very important for the understanding of plasma processes. This knowledge is crucial for the optimization of a given ion source so that higher yields of higher charge states can be obtained. Furthermore, characterization of the CSD enables precise diagnostics of injected elements and impurities, which are important for the performance of fusion devices.

In this work, we have determined the CSD of an Ar plasma through the analysis of x-ray spectra obtained with a double crystal spectrometer. It is the first time that such a spectrometer is used coupled to an ECRIS for measuring inner-shell transitions in highly charged ions. The very high resolution of this apparatus enables us to correctly obtain the CSD of the plasma from x-ray spectra, even in highly populated energy regions. Comparison to extracted ion currents show that the CSD in the center of the plasma can be quite different from the ion beam yields, due to the fact that the ions are extracted from the plasma edges. ■

■ **M. Guerra, P. Amaro, C.I. Szabo, A. Gumberidze, P. Indelicato and J.P. Santos,**

‘Analysis of the charge state distribution in an ECRIS Ar plasma using high-resolution x-ray spectra’, *J. Phys. B: At. Mol. Opt. Phys.* **46**, 065701 (2013)

## APPLIED PHYSICS

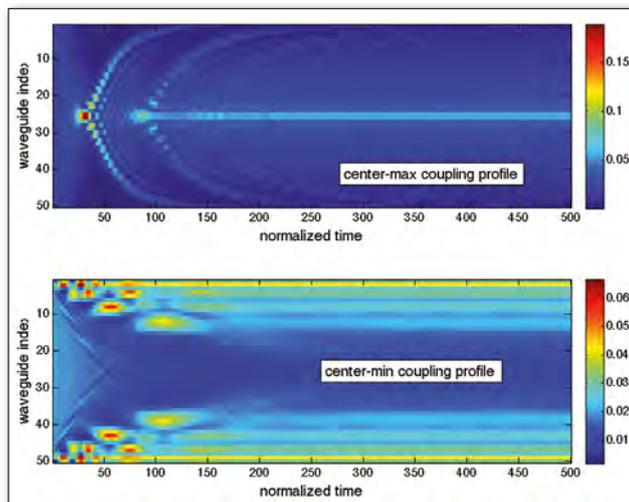
## Optical waveguide arrays

Over the past few years, advances in fabrication have made possible arrangements of coupled optical waveguides with tailored specifications. Such waveguide arrays are indispensable for building a scalable photonic quantum computer or creating novel optical elements.

The present paper summarizes the properties of light propagation in such an array with position-dependent coupling between adjacent waveguides. It shows that such arrays have

properties that are markedly different from those of constant-coupling arrays. One such property is the formation of mirror-symmetric intensity profile in an array with a centre-maximum coupling profile. Another, shown in the figure, is the disorder-induced localization of a broad-input light to the centre of the array for centre-maximum coupling profiles and to the array edges, which occurs for centre-minimum coupling profiles. These results, along with novel properties of light propagation in the presence of balanced, spatially separated absorption and amplification, indicate the wealth of tunability that is offered by coupled optical waveguides. ■

■ **Y.N. Joglekar, C. Thompson, D.D. Scott and G. Vemuri,** 'Optical waveguide arrays: quantum effects and PT symmetry breaking', *Eur. Phys. J. Appl. Phys.* **63**, 30001 (2013)



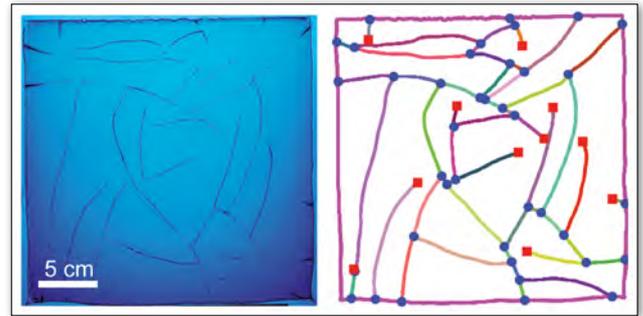
▲ Centre or edge localization in tunable waveguide arrays.

## GEOPHYSICS

# Topology of fluid drainage fracture networks

Fluid generation in rocks is a common phenomenon: generation of hydrocarbons (oil\gas) from source rocks during diagenesis, dehydration of sedimentary and metamorphic rocks during burial and partial melting of the Earth's mantle. Fluid generation leads to local increase in fluid pressure. If the rate of fluid production is high compared to the rate at which fluids can escape by flow through the initial permeability, the fluid pressure increases and may cause fracturing and creation of new fluid transport pathways.

This paper presents the development of fracture networks in a simple quasi-2D system consisting of a confined layer of gelatine containing yeast that consumes sugar to produce CO<sub>2</sub>. The topological properties of the emerging fracture networks were found to be intermediate between the tree-like structure of river networks and the fragmentation cracking patterns observed



▲ Drainage fractures in gelatine layer. Blue circles – nodes, red squares – dead ends.

in drying muds, domain splitting during rock weathering and fracturing of cooling basalts. The ratio of the number of dead ends to the amount of nodes is  $\sim 0.4$ , between the ratio for rivers ( $=1$ ) and fragmentation crack patterns ( $=0$ ). Understanding of fluid drainage network topology is crucial for uncovering the mechanisms which lead to its formation. ■

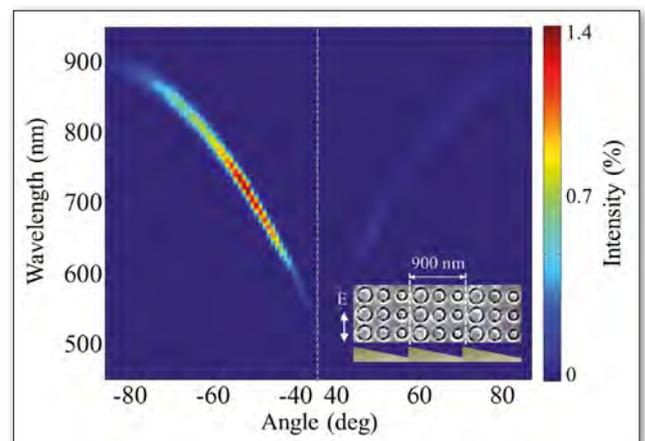
■ **M. Kobchenko, A. Hafver, E. Jettestuen, O. Galland, F. Renard, P. Meakin, B. Jamtveit and D. K. Dysthe,** 'Drainage fracture networks in elastic solids with internal fluid generation', *EPL* **102**, 66002 (2013)

## OPTICS

# A meta-diffraction-grating for visible light

Metamaterials — artificially engineered structures with building blocks smaller than the wavelength of light — have delivered a new way to design and make materials with exotic electromagnetic properties. The current challenge is to make these metamaterials into meta-devices that convert the promising research into practical applications. Nanotechnology has made it possible to fabricate ultrathin metamaterials — less than a 15<sup>th</sup> of the wavelength — shrinking conventional optical devices

▼ Intensities diffracted into first diffraction order. Inset: SEM image of the planar meta-grating mimicking a bulk blazed grating profile.



into planar form. In the coming years, research in metamaterials, plasmonics and nanofabrication will revolutionize device form and function throughout the electromagnetic spectrum. This paper reports experimental demonstration of a planar ultrathin (50 nm) gold diffraction grating, mimicking the function of a bulk dielectric grating but tens of times thinner. It uses the resonant properties of individual sub-wavelength meta-atoms to change the phase of the light passing through it, in the same way as a blazed diffraction grating. It functions throughout the visible region of the spectrum (400 – 900 nm), with peak efficiency at 736 nm, and exhibits asymmetric diffraction, sending 25 times more light to the left than the right. ■

■ **T. Roy, A.E. Nikolaenko and E.T.F. Rogers,**  
'A meta-diffraction-grating for visible light', *J. Opt.* **15**,  
085101 (2013)

### STATISTICAL PHYSICS

## When diffusion depends on chronology

The present work shows that the order of events taking place in complex networks may dramatically alter the way diffusion occurs in them. The Internet, motorways and other transport systems as well as many social and biological systems are composed of nodes connected by edges, and can be represented as networks.



▲ Motorways are examples of nodes connected by edges studied as complex networks. (Photo Credit: Highways Agency)

Scientists studying diffusion over such networks over time have now identified the temporal characteristics that affect their diffusion pathways. In this paper, the authors show that one key factor that can dramatically change a diffusion process is the order in which events take place in complex networks. They developed an analytical model to better understand the properties of time-dependent networks that either accelerate or slow down diffusion. Their study focused on different classes of popular models for diffusion, namely random walks and epidemic spread models, and found the way in which the temporal ordering of events matters. They expect these results to help in building more appropriate metrics to understand real-world complex network data. ■

■ **R. Lambiotte, L. Tabourier and J.C. Delvenne,**  
'Burstiness and spreading on temporal networks',  
*Eur. Phys. J. B* **86**, 320 (2013)

### PHYSICS AND SOCIETY

## Studying emotions causing opinions to change

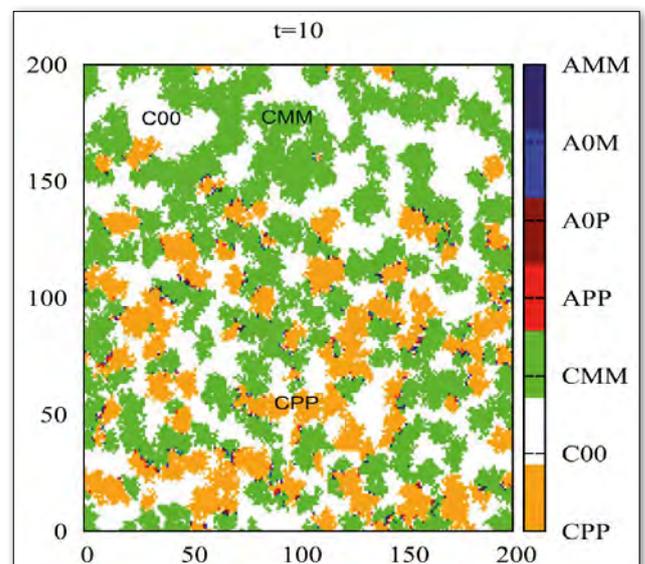
Physicists can use their tools to help understand how, in real life, opinions form and change by modelling the complex interactions between information and emotion. Social phenomena fascinate with their complexity, but are not easily understood. The author of the present article has developed a model to study the dynamic of 'agents' and their response to a given piece of information, depending on their emotional state. He shows that opinion dynamics differ depending on whether the agent is agitated or not.

The premise for this study was to consider that a given agent opinion about a particular issue is determined by both its information about the issue and its subsequent emotional response. The author assumes the possibility of the same information leading to different opinions when agents are agitated. This results in an individual opinion dynamics.

The author's findings, relevant to a simplified social environment, are directly comparable with social observations. These include the stability of minority groups surrounded by enemies and the fact that so many elections have results close to the 50/50 ratio. ■

■ **P. Sobkowicz,**  
'Minority persistence in agent based model using  
information and emotional arousal as control variables',  
*Eur. Phys. J. B* **86**, 335 (2013)

### ▼ Example of evolution of agent opinions.



L.J.F. (Jo) Hermans

Leiden University, The Netherlands – [Hermans@Physics.LeidenUniv.nl](mailto:Hermans@Physics.LeidenUniv.nl) – DOI: 10.1051/epn/2013501

## Water lenses

Sometimes nature provides us with convenient optical instruments, for free. Take, for example, a rain droplet on a leaf, or on any flat surface. It is a rather strong converging – or convex – hemispherical lens. Indeed, some people use a water droplet on their mobile phone screen to examine its miniature structure.

But what about a whole, completely spherical water droplet? If we take the spherical aberration for granted it forms a beautiful converging lens with an even higher refracting power than the hemisphere mentioned above. So, could it perhaps be converging to the point that, if exposed to a parallel beam of light like sunrays, the focus is *inside* the droplet?

Interesting question. And, even more interesting, we have a clue to the answer at hand. Just think of our eyeball. It can be considered as a sphere of fluid having a refractive index equal to that of water (1.33), with two exceptions. First, the very front of our eye – the cornea – is curved more strongly than the rest of the eyeball. Second, there is the lens itself, which has a relatively large refractive index (about 1.40). Both effects produce a higher degree of focussing than a pure sphere of water would. And since our eye is capable of focusing a parallel beam of light onto the retina, we may expect that the focal point would be located *behind* the eyeball if the eye did not have these two extras. In other words, we have a strong suspicion that a pure water droplet has a

focal length  $f$  exceeding its diameter. We arrive at the same conclusion if we use the famous lens maker's equation applied to a sphere,  $1/f = (n-1)(2/R)$ , which relates  $f$  to the radius of curvature  $R$  and the refractive index  $n$ . But it may not be safe to rely on this equation for such an extreme case.

So why not do the experiment? It is easily done if we take a cylindrical glass, fill it with water and put it in direct sunlight. Since the thin glass layer can be neglected for this proof-of-principle, we have an object which acts as a spherical water lens in the horizontal plane. And indeed: what we see is a vertical bright line (the 'focal line') a centimetre or so behind the glass.

Once we have this set-up, it is tempting to do a simple, yet charming, demonstration. Take a piece of paper and draw an arrow on it. If we put the paper behind the glass with the arrow pointing upwards, not much happens: the arrow remains upwards, whatever the distance between the paper

and the glass. But if we have the arrow horizontal, it reverses its direction if we slowly move it away from the glass. The physics behind this becomes obvious if we do some elementary ray tracing: we change from a situation with the object between the glass and the focal point (virtual image, same orientation) to a situation with the object placed beyond the focal point (real image, inverted orientation).

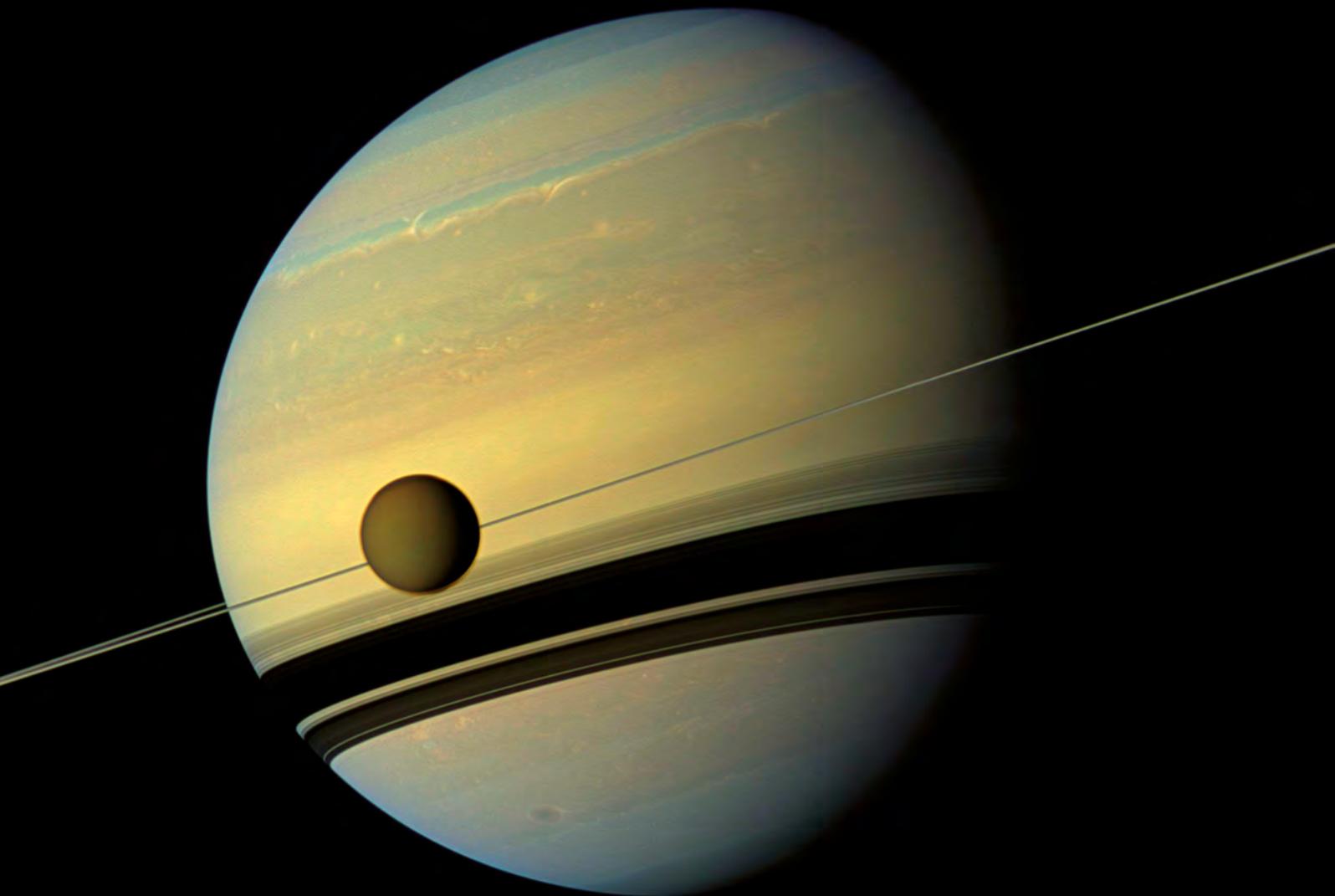
This elegant demonstration may well serve to illustrate the wonders of optics to a layman, or to our children. For free. ■



# A TRIBUTE TO JEAN PERRIN

■ Henk Kubbinga - University of Groningen (The Netherlands) - DOI: 10.1051/eprn/2013502

Nineteenth century's physics was primarily a molecular physics in the style of Laplace. Maxwell had been guided by Laplace's breathtaking nebular hypothesis and its consequences for Saturn. Somewhat later Van der Waals drew upon his analysis of capillarity. The many textbooks of Biot perpetuated the molecularism involved in all this. Jean Perrin, then, proposed a charmingly simple proof for the well-foundedness of the molecular theory (1908).



Jean [Baptiste] Perrin enrolled in 1891 at the Ecole Normale Supérieure de Paris, the nursery of France's academic staff. The new 'normalien' came from Lyon and had passed a typically French parcours: primary school and collège 'en province', lycée at Paris. The 'normaliens' of the time were left-winged politically, but wore uniforms, though, and despised their Sorbonne fellow students. Mathematics made the difference; Perrin had passed without any trouble. He was lucky to follow in the footsteps of the great Marcel Brillouin (1854-1948), who had introduced Boltzmann's classical *Vorlesungen über Gastheorie* in France.

In preparing his doctorat ès sciences, Perrin made his international debut as a talented experimentalist in 1895, when he published a straightforward demonstration that the charge of (the particles of) cathode rays is negative (Figure 1). With other work on Röntgen's new rays, it earned him in 1896 the Joule Prize of the Royal Society of London. What a start for this lad of scarcely 26 year of age!

### From physico-chemistry back to physics

Perrin was charged with something new at the Sorbonne: a course of physico-chemistry, the new science that had been inaugurated by Van 't Hoff, Ostwald and Arrhenius. It brought him to write down his lectures in the form of a textbook: *Traité de chimie physique. Les principes'* (1903). Among his friends were Pierre and Marie Curie-Sklodowska, his neighbours at Boulevard Kellermann, Paris, and Pierre Langevin, a former student of Pierre Curie. These were sober living people, not unlike the Perrins, Jean and his Henriette. They regularly met, mostly at the Perrins', where Jean often played the piano. The nature of the atom was hotly discussed on such occasions. Perrin weighted the solar system as a model—a positively charged 'sun' with negatively charged 'planets' around it—but did not insist. An important turn came by a new invention, that of the ultramicroscope by Henry Siedentopf and Richard Zsigmundy (1903), an instrument which allowed for the first time to study the details of an age-old but still riddle-like phenomenon: Brownian motion. Discovered in the late 1820's by the English naturalist Robert Brown, the phenomenon implied the incessant, unperturbable zig-zag motion of tiny particles suspended in a liquid. In Brown's case there were pollen grains in water at stake. About 1903 it was a matter of what were called colloidal particles. The irregular motion also strongly reminded of a similar motion postulated in gas theory for the molecules describing their free paths between two collisions: the bigger the particles and/or the lower the temperature, the slower the motion. It was otherwise the time that Perrin had to answer pressing questions from Sorbonne's philosophers: "was it allowed, for a scientist, to make use of invisibly small particles like molecules (and atoms)?" Perrin's answer was a stroke of genius. He referred to the microbes of Louis Pasteur

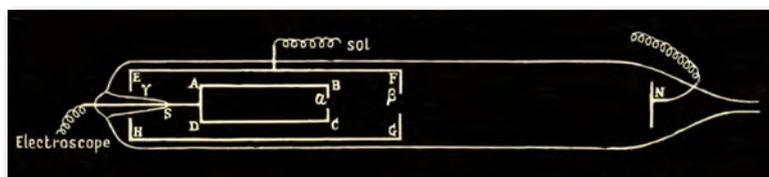
and Robert Koch and fancied a state of science in which *the microscope had not yet been invented*. In such a situation Pasteur and Koch—let's say, medical science in general—might have concluded all the same that contagious diseases were caused by invisibly small living beings which infect a victim and set out immediately to multiply, before attacking subsequent victims *etc.* Effective countermeasures might have been developed in that very same hypothesis, by trying all kinds of chemicals on infected materials. However, the microscope was there all the same and had hugely simplified the research. In the case of the molecules, though, the situation was quite the reverse: *there was not yet a microscope to make them visible*, but scientists had nonetheless succeeded in building an impressive whole of thoroughly consistent physics and chemistry, fully based on the idea of molecules composed of atoms. In our age of monomolecular if not monoatomic microscopy, it is easy to grasp the appropriateness of Perrin's reasoning.

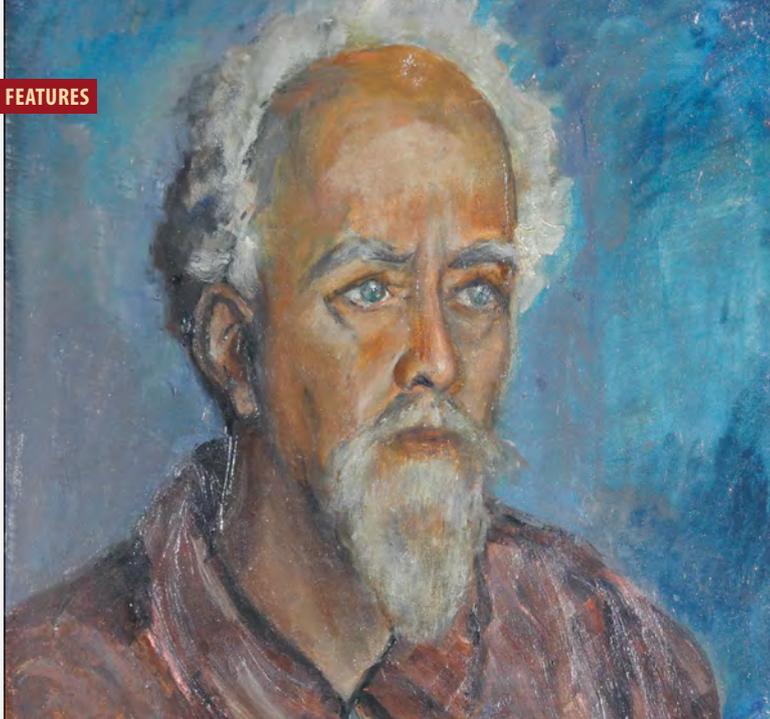
### Brownian motion

Siedentopf and Zsigmundy's invention opened new alleys to assess colloidal particles, among which gold granules dispersed in glass. But, irresistibly, Brownian motion, with its direct bearing on the hard core of contemporary physics, that is: the kinetic theory of gases, came to the fore. In 1905-1906 Einstein and Smoluchowski published their analyses. Einstein showed that the observed zig-zag route of colloidal particles could be deduced from what he called the 'molecular-kinetic theory of heat'. One of his arguments derived from the osmotic pressure to be expected from suspensions: after all, the only difference between dissolved molecules and suspended particles is their bigness. And hence, when molecules move haphazardly hither and thither, those particles should move in very much the same way, be it on a smaller scale. Something similar holds for diffusion. The translation and rotation of such particles ought to be analyzed, of course, in terms of Maxwell's statistical physics. In principle, then, the thermal velocity of any particle may be calculated in advance, provided that its mass is known and that it is in the gaseous state. Once suspended in a viscous liquid there is, of course, friction tending to slow down the particle. Application of the law of Stokes then allows for a quantitative evaluation. Marian Smoluchowski, in 1906, worked the other way around: he stressed the importance of the collisions between the liquid molecules and the suspended particles. Against this background Jean Perrin set out to experimentally investigate Brownian motion.

◀ P.16: Saturn (with Titan) edge-on as viewed by the Hubble Telescope (2012; courtesy: NASA).

▼ FIG. 1: Perrin's demonstration of the negative charge of the particles involved in gas discharge tubes. N is the cathode; cylinder EFGH is the (earthened) anode. Through the openings  $\beta$  and  $\alpha$  the unperturbed pencil of cathode rays reaches the Faraday cylinder ABCD which is connected to a gold foil electroscope. With an electromagnet the pencil can be directed at FG, such that it doesn't reach ABCD.





▲ FIG. 2: Jean Perrin by his daughter Aline Lapique-Perrin (oil on canvas; about 1926; courtesy Perrin family, Paris).

### Laplace, Perrin: granules and molecules

In his magnum opus *Traité de mécanique céleste* Laplace had deduced a formula for the observed decrease in air pressure with height. The essence was that that decrease would obey a logarithmic law:  $\ln(p_0/p) = C \cdot h$ . Constant  $C$  in Laplace's formula had been checked by measuring the air pressure at the foot and on top of a duly famous mountain of known height, the Puy de Dome (Auvergne). It had allowed the first scientific 'aironauts', the ballooners Gay Lussac and Biot (1804), to calculate the height they had attained: 6977 m above Paris.

Perrin had noticed that resting suspensions of gamboge in water—let's say, in a test tube—because of sedimentation, feature a vertical colour intensity gradient, which reminded him of Laplace's logarithmic law. If the analogy between granules and molecules be correct, then, the number of granules should decrease as  $\ln(n_0/n) = C \cdot h$ . The new ultramicroscope of Zsigmundy and Siedentopf allowed him to test the formula: because of its weak focal depth Perrin could simply take photographs, count the number of granules in the field of view and follow its variation with height. The number of granules appeared to half every 10  $\mu\text{m}$ . Wonderful! The analogy, then, was justified indeed. And, the other way around, since granules definitely exist, so do the molecules. Through his granules Perrin even succeeded in determining the number of molecules in a 'grammolecule', today's

mole ( $6.7 \cdot 10^{23}$ ). Perfectly conscious of the importance of his find, Perrin took the liberty to call it after the Italian gas specialist Amedeo Avogadro (1776-1856).

### The new light: nothing but physics

In Perrin's work there is a direct link with Laplace's physics: both were essentially *molecular*. Perrin, however, did what Laplace had neglected: he found a new way to assess molecular dimensions. At the time the philosophers tried to mix in and impose their terminology, but in vain. Physics is self-sufficient: it provides for its own philosophy. Perrin's brilliant assessments earned him the Nobel Prize for Physics of 1926.

### Science and politics in the 1930's

Later, Perrin and his socialist *compagnons* joined the French government. It was Perrin who, as under-State Secretary of Scientific Research (1936-1938), imposed the creation of the Centre National de la Recherche Scientifique (CNRS) in an attempt to reinvigorate academic life at the top. In 1941, the war was raging, Perrin and his family moved to the United States, where he died the next year. ■

### About the author

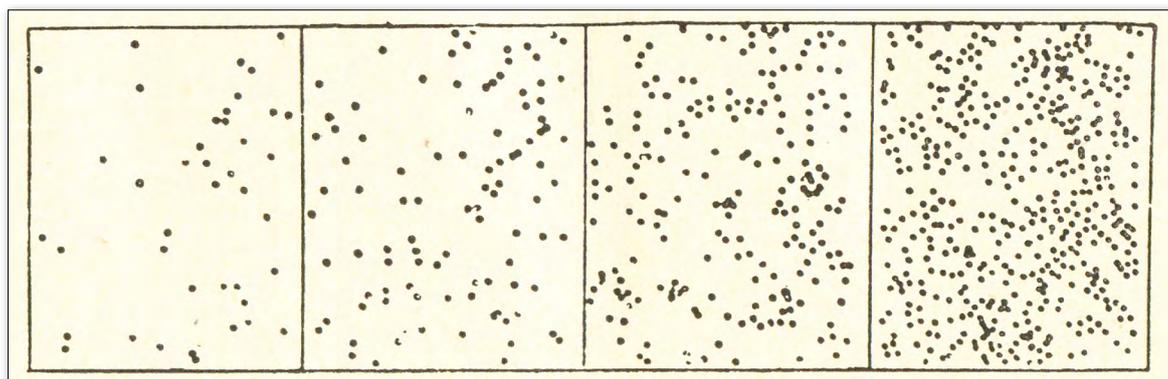
**Henk Kubbinga** is a historian of science at the University of Groningen and member of the EPS-History of Physics Group. He recently co-edited, with Paul Bronsveld, the *Festschrift in honor of Jeff Th.M. De Hosson* (Groningen University Press, 2012).

### Acknowledgment

I am greatly indebted to Guy Laval, Foreign Secretary of the Académie des Sciences of the Institut de France, who kindly allowed me to consult the Archives of the Académie. Courtesy photographs: Académie des Sciences.

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► FIG. 3: Drawings made after photographs taken at heights differing 10  $\mu\text{m}$ ; The mean diameter of the grains was 0.6  $\mu\text{m}$  (from Ref. 3).

## [ Letter to the Editor ]

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## Can comments cause citations?

### Yes, they can!

**Commented EPL papers attract more citations than the average number of citations to EPL publications.**

Should an author of a publication be worried or thankful, when the Editorial Office sends him a Comment for consideration? [1] The usual initial reaction is probably concern, because such a Comment normally contains criticism of the original paper. On the other hand it means that the author of the Comment has seriously examined the paper and found it worth the effort to prepare a Comment. Moreover, a published Comment increases the visibility of the original publication and draws the attention of other colleagues to the paper. This means that Comments can be expected to enhance the impact of a publication and result in additional citations. Moreover, a Comment and the subsequent Reply by the author of the commented paper are likely to provoke a scientific dispute which would further enhance the citation count. Nowadays citation counts are often taken as a measure of scientific achievements and considered for allocating research resources and in academic appointment processes. Although these practices are questionable, it is a matter of fact that they are widespread in use. Thus it is interesting to investigate, whether Comments indeed lead to higher citation counts.

Recently Radicchi [1] has analyzed the citation statistics of commented papers in 13 journals published by the American Physical Society. He found that commented papers have high scientific impact in terms of citation frequencies. I have done a similar analysis for the flagship journal of the European Physical Society, *i.e.* *EPL*

(formerly *Europhysics Letters*). The results are unequivocal: Most commented papers are highly cited. This is visualized in Figure 1 where the symbols appear dominantly on the right hand side.

In scientometrics or bibliometrics it has become a standard procedure to compare the citation count of a paper with the citation frequencies of an appropriate reference set. For the present purpose I have therefore downloaded the citation report comprising all *Europhysics Letters/EPL* papers from the ISI Web of Knowledge on 4 June 2013. This constitutes the references set. The data are analyzed separately for each year, because obviously older papers have had more time to receive citations and it is therefore dangerous to compare large publication windows. The papers in each year are sorted by (increasing) number of citations. The thus obtained rank is used to determine a percentage and thus to define a

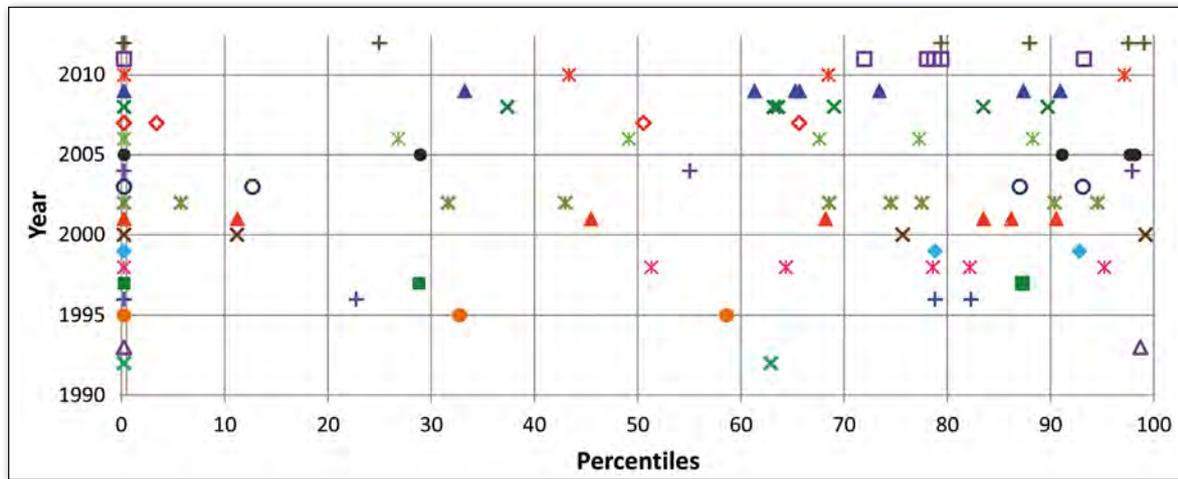


percentile that reflects the number of papers which have obtained less or equally many citations. In recent years there has been a controversy in bibliometrics how to treat tied papers, *i.e.* papers with the same number of citations in the dataset [2]. For the present purpose it is sufficient to average the ranks of the tied papers and utilize the corresponding percentile [3].

The citation frequency of the investigated commented paper is now compared with the reference dataset and ▶

\* Former Editor in Chief of EPL

## [ Letter to the Editor ]



**▲ FIG. 1:** Position of commented papers according to the number of received citations in comparison with all papers published in Europhysics Letters/EPL in the respective year. (Early years are not plotted, because I found only one commented paper that was published before 1992. It was the most cited one in 1986.) Percentiles reflect the percentage of papers which have received less or equal numbers of citations than the paper in question. The left-most symbols do not represent papers, but are plotted to make it easy to attribute symbols and years.

thus attributed a percentile value which is presented in figure 1. It is obvious that most commented papers are found in the range of rather high percentiles, *i.e.* they are highly cited. To be precise, there are 2, 3, 5, 4, 4, and 4 papers in the first 6 deciles, respectively, and 13, 13, 11, 18 papers in the top 4 deciles. Altogether there are 77 Comments, so that one would expect 7.7 commented papers in each decile if their citation frequencies were evenly distributed. But this is clearly not the case in Figure 1. Radicchi [1] made a similar observation, namely that with nearly 10% the commented papers are overrepresented among the top-5% highly cited papers in most of the 13 investigated journals. In figure 1 one can find even more than 10%, namely 13% (10 out of 77) in the top-5% region. It may be worthwhile to note that I have excluded the references from the Comment and Reply to the commented paper from its citation count in order to avoid a possible bias. Thus a zero citation count is possible but occurs only once in 2007, although the symbol in Figure 1 is not found at the zero percentile, but rather at 3%, because this is the average rank of all uncited papers in that year.

One could also compare the average citation frequency of the commented papers with that of all papers in each year. However, due to the strongly skewed citation distribution (many uncited or lowly cited papers versus a long tail of few highly cited papers) it is dangerous to utilize averages and therefore the above employed procedure of comparing percentiles is much more justified.

In contrast to the observation by Radicchi [1], namely that the proportion of commented papers has drastically decreased in recent years for all 13 investigated APS journals, this is not the case for Europhysics Letters/EPL. Since 1998 there have been on average 4.5 commented papers per year with minima of 2 in 1999 and 2004 and maxima with 8 in 2002 and 7 in 2009. Due to the somewhat increasing number of papers per year the proportion of commented papers has somewhat decreased, but the effect is certainly not as drastic as observed in the APS journals.

In conclusion, as an author you should be grateful if you receive a Comment, because this means that your paper is rather likely a candidate to become highly cited. This is the reason why I answered the title question whether Comments can cause citations with a clear “Yes”. But in fact it is not so obvious. As already mentioned, the Comment already means a distinction, because who would comment on an uninteresting or mediocre paper? But of course Europhysics Letters/EPL does not publish uninteresting or mediocre manuscripts anyhow. ■

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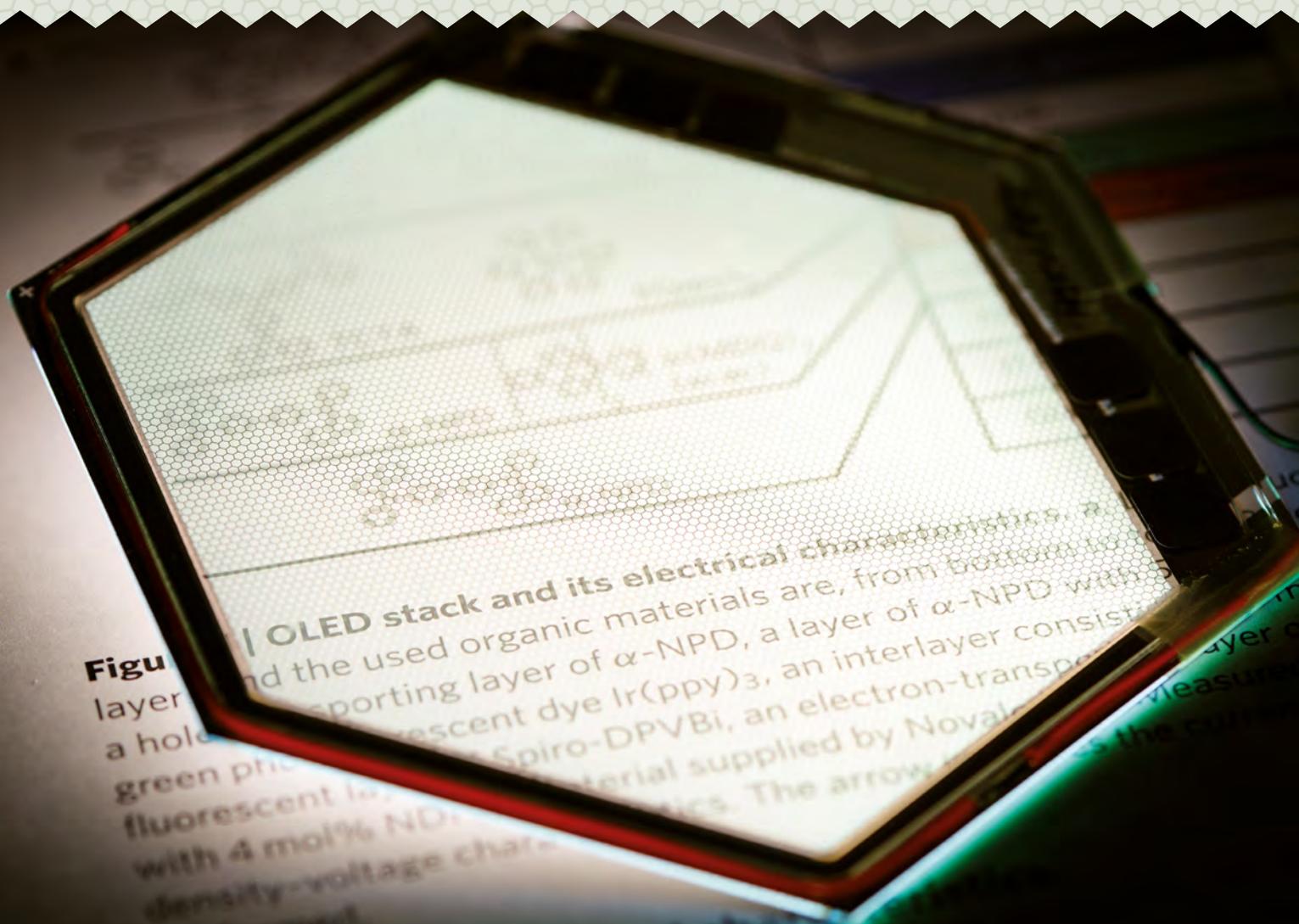
# A LOOK INSIDE WHITE OLEDs

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White organic light-emitting diodes (OLEDs) for lighting are finding their way to the market. These OLEDs have organic layers only a few nanometres thick. Improving their efficiency and stability requires nanometre-precision information about where the light is emitted. Reconstruction of the emission profile from the measured emission and molecular-scale modelling provide a unique nanoscale look inside white OLEDs.



**Figure**

layer  
a hole

green ph  
fluorescent  
with 4 mol% ND  
density-voltage char  
performed.

**OLED stack and its electrical characteristics.** The used organic materials are, from bottom to top: supporting layer of  $\alpha$ -NPD, a layer of  $\alpha$ -NPD with 5% fluorescent dye  $\text{Ir}(\text{ppy})_3$ , an interlayer consisting of Spiro-DPVBi, an electron-transporting material supplied by Novaled. The arrow indicates the direction of the current flow.

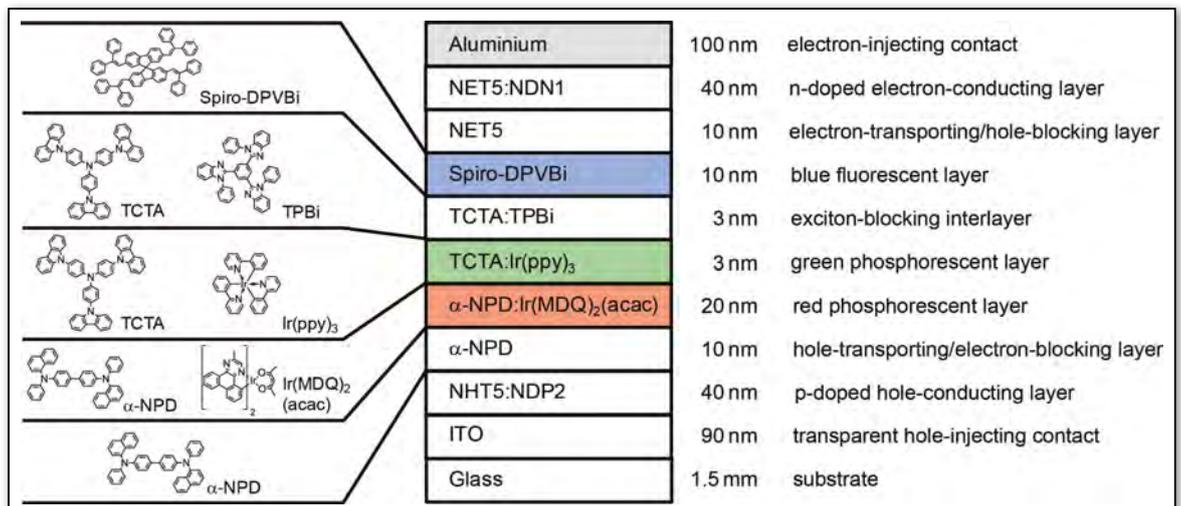
Almost everyone nowadays is familiar with the high-quality OLED displays of recent generations of smart-phones. The breakthrough of OLED TVs seems a matter of time. Advantages of OLED displays over the ubiquitous liquid-crystal displays (LCDs) are evident. LCDs require a permanently emitting white back-light, illuminating an array of switchable liquid-crystal cell pixels with colour filters, which tune brightness and colour of the transmitted light. Hence, LCD technology is based on light absorption. In contrast, OLEDs actively emit light of the desired colour from pixels of organic semiconductors. This leads to higher contrast ratios (“black” is really black) and lower power consumption. OLEDs for lighting applications [1] are presently under development, not in the first place because of power efficiency – present-day commercial inorganic LEDs are still more efficient – but because they are unique in being ultrathin large-area light sources which can be flexible and transparent. Therefore, an OLED lamp needs no special luminaire: it is its own luminaire. And as luminaire losses are avoided, the efficiency at a system level is expected to be competitive over a wide range of applications. The required broad-spectrum white light could in principle be obtained from a Red-Green-Blue pixelated OLED display with all pixels switched on. However, the lateral structuring needed for this would be unnecessarily complicated and expensive. White-OLED research therefore focuses on vertical multilayer structures, pioneered in Japan [2]. Light of different colours is emitted in different organic layers stacked on top of each other, together composing white light. It is important that a large fraction of the light actually leaves the structure and can be used for illumination. An excellent review of the efficiency of the *light outcoupling* from OLEDs was given two years ago in this journal by Brütting *et al.* [3]. Here, we focus on the *light generation*, and in particular on the question *where* in these structures emission of the different colours takes place. There is an intimate relation between this question and the question of outcoupling, since the position where emission takes place directly determines the light outcoupling efficiency.

◀ P.21:  
A transparent  
white OLED  
made by Philips

### A hybrid white OLED

In recent work together with the Institut für Angewandte Photophysik (IAPP) of the *Technische Universität Dresden* and Philips Research Aachen, our groups studied within the European FP7 project AEVIOM (Advanced Experimentally Validated Integrated OLED Model) the multilayer white-OLED stack shown in Fig. 1 [4]. The OLED has been fabricated at the IAPP by thermal evaporation in ultra-high vacuum of the organic materials displayed in this figure. The structure is ideal for a fundamental study, because most of the used materials have been well characterized in literature and all relevant processes can be addressed. The generation of the primary colours in this OLED is based on a hybrid principle, used extensively nowadays in commercially available white OLEDs. Green and red light are generated in layers of a host organic semiconductor doped by green and red phosphorescent dyes. The use of this dye-doping for light generation in OLEDs has been pioneered by researchers from the US [5]. A heavy metal atom in such dye molecules (in this case iridium) opens up – by its strong spin-orbit coupling – a radiative decay pathway for excitons (Coulombically bound electron-hole pairs) with a triplet spin configuration (parallel spins of electron and hole) next to singlet excitons (antiparallel spins). Hence, almost all excitons formed in such layers decay under the emission of a photon. Hybrid OLEDs avoid the use of blue phosphorescent dyes – of which the stability is still an issue – by using instead blue-emitting molecules without a heavy metal atom, at which only the singlet excitons decay radiatively (fluorescence). This compromises the internal quantum efficiency, because the triplet excitons – 75% of all formed excitons – have no efficient radiative decay pathway and are thus wasted. Still, the power efficiency of today’s commercial hybrid white OLEDs is already a factor of three to four higher than that of incandescent light bulbs (~40-60 lm/W vs. ~15 lm/W), combined with operational lifetimes exceeding 10,000 hours. Of crucial importance to the functioning of multilayer OLEDs is that excitons are generated at the right place

▶ FIG. 1:  
Schematic of the studied multilayer white OLED stack. Given are the chemical structures of the used organic molecular semiconductors and dyes (apart from proprietary materials from the company Novaled), and the thickness and function of the layers. See Ref. [4] for more details.

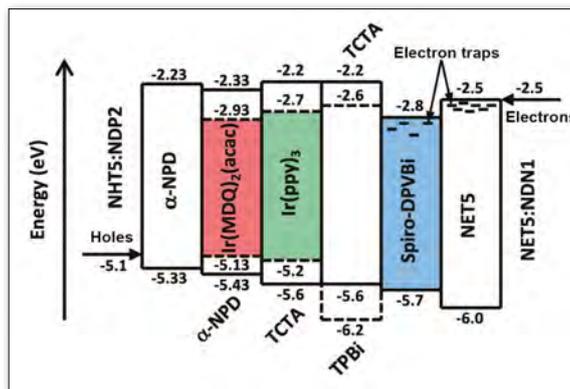


by encounter of electrons and holes, and that their subsequent motion until the moment of radiative decay is precisely controlled. In the OLED of Fig. 1 an exciton-blocking interlayer has been inserted in between the blue and green layer. This interlayer prevents the motion of singlet excitons from the blue to the green layer as well as that of triplet excitons from the green to the blue layer. These are unwanted energetically downward processes that have to be blocked. On the other hand, motion of excitons from the green to the red layer can take place because of the direct contact between these layers. This is a desired process, because it leads to the right colour balance in this OLED, as will become clear.

Next to the control of the exciton motion, the control of the motion of electrons and holes is crucial. This control occurs by using organic semiconductors with appropriate energy levels of electrons and holes; see Fig. 2. First, electrons and holes have to be injected from suitable electrodes (of which at least one has to be transparent, in this case indium-tin-oxide, ITO) into the organic layers. In the early days of OLEDs, researchers struggled with the difference in energy between charges in the electrodes and in the organic semiconductor, leading to large barriers for charge injection. This problem has practically disappeared by an invention of the group at the IAPP. They introduced the use of highly n- and p-doped organic layers adjacent to the electron- and hole-injecting contacts [6]. These layers behave as good electron and hole conductors, providing an almost barrier-free contact with the electrodes. From these doped layers the electrons and holes smoothly enter the electron- and hole-transporting layers, via which they move to the inner layers of the stack. The electron and hole energies of the organic semiconductors used in the transport layers are such that charge carriers of only one polarity can enter these layers. This guarantees that electrons and holes meet in the inner emissive layers of the stack and form excitons there. The OLED functions as an optical microcavity, in which exciton formation close to metallic electrodes must be avoided because this would lead to non-radiative decay. By carefully tuning the thicknesses of all layers, the outcoupling efficiency can be optimized [3]. A special role is again played by the interlayer between the green and blue layer. This very thin (3 nm) layer should block excitons, but allow passage of both electrons and holes, in order to guarantee exciton formation in both the green and blue layer. In order to achieve this, the interlayer consists of a mixture of an electron transporter and a hole transporter, where the electron energy of the former matches well to that of the blue fluorescent material, while the latter material is the same as the hole-transporting host in the green layer.

### Reconstructed light-emission profile

So, how does the OLED of Fig. 1 work? To answer this question, one would have to “look inside” the OLED, in order to find out where in the OLED the light is emitted.



◀ FIG. 2: Energy-level scheme of the OLED at open circuit. Indicated are the hole and electron energies of the highest occupied and lowest unoccupied molecular orbitals of the corresponding molecules, in eV. Due to disorder, these energies are actually broadened by approximately 0.1 eV. Electron traps are indicated in the two layers where they matter.

Here, the link with the light-outcoupling problem comes into play. If it is known where in the OLED the emission takes place, the external emission can be readily calculated by optical microcavity modelling, using the known dielectric properties of all layers in the stack and representing a radiatively decaying exciton as a classical dipole antenna [3]. The *total* outcoupled radiation of the OLED is the sum of the outcoupled radiation of all dipoles in the stack. However, it is also possible to solve the inverse problem, that is, to reconstruct the emission profile of all dipoles in the stack from knowledge of the total outcoupled radiation field [7]. Solving such an inverse problem is similar to reconstructing the three-dimensional (3D) inner structure of the earth from seismic signals (see the Feature by Jobert in this issue), or the 3D structure of a patient's body by X-ray Computed Tomography (CT) scanning. Here, we make use of the strong dependence of the emission pattern on the distance of the dipole emitter to the aluminium cathode layer (see box). The information contained in the angle-, wavelength-, and polarization-dependent emitted light intensity is sufficiently rich to determine the dipole-emission profile of the primary colours with a nanometre-scale precision. The result for the OLED of Fig. 1 at a typical operating bias voltage is given in Fig. 3(a). The balance between emission of the primary colours, with a strong red component, leads for this OLED to the emission of pleasant warm-white light. Resolution of the emission profile within the very thin (3 nm) green layer is just beyond the limits of the approach. The profiles in the red and blue layer are on the scale of a few nanometres confined to the interfaces with the green layer and interlayer, respectively.

### Simulations at the molecular scale

Unique insight in the interplay of the processes leading to the emission profile can be obtained from molecular-scale simulations. Whereas inorganic LEDs are based on crystalline semiconductors, in which the electronic and excitonic wave functions are delocalized, OLEDs are based on amorphous materials, in which the electronic contact between the molecules is weak. The quantum-mechanical wave functions of electrons, holes, and excitons in such disordered materials are localized on the molecules. Their motion involves sudden hops from one ▶

molecule to another by an incoherent phonon-assisted tunnelling process. This motion can ideally be simulated by Monte Carlo methods, where at every time step a possible hop is chosen according to a randomly drawn number [8]. We have performed such simulations by modelling the OLED stack as an array of hopping sites representing all the different molecules in the stack, including the dyes [4]. Electron traps occur in many organic semiconductors. These are taken into account in the layers where they matter: the electron-transporting and blue fluorescent layers. The inter-site distance is taken to be 1 nm, which is the typical distance between the molecules. All molecules are given an electron and a hole energy according to the energy-level scheme of Fig. 2, with a random energy due to disorder added. The doped electron- and hole-conducting layers are modelled as metallic-like contacts. The hopping rates are chosen to reproduce available experimental information about the mobility of electrons, holes, and excitons in each material in the stack. Coulomb interactions between all charges are taken into account. Electrons and holes attracting each other by the Coulomb force form excitons. Subsequent

exciton motion is simulated within the green and red layer, and, importantly, from the green to the red layer. Excitons formed in the blue layer will stay there, because of the adjacent exciton-blocking interlayer. Information about the radiative decay efficiencies of the blue fluorescent and the green and red phosphorescent emitters, determining the fraction of excitons that decay by emitting a photon, is taken from experiments. This information is needed to predict the light-emission profile from the simulations. Excitons formed in the interlayer are assumed to be lost.

A first check of the validity of the simulations is the comparison between the calculated and measured current in the OLED. At the operating voltage of 3.6 V the current densities agree to within 25% [4], which is a gratifying result in view of the rather drastic approximations and assumptions made. In Fig. 3(b) the simulated exciton generation profile is given. We find that indeed almost all injected electrons and holes form excitons. As desired, most excitons form in the emissive layers, with the majority of excitons (54%) formed in the blue layer. Also, a considerable fraction of excitons is formed in the

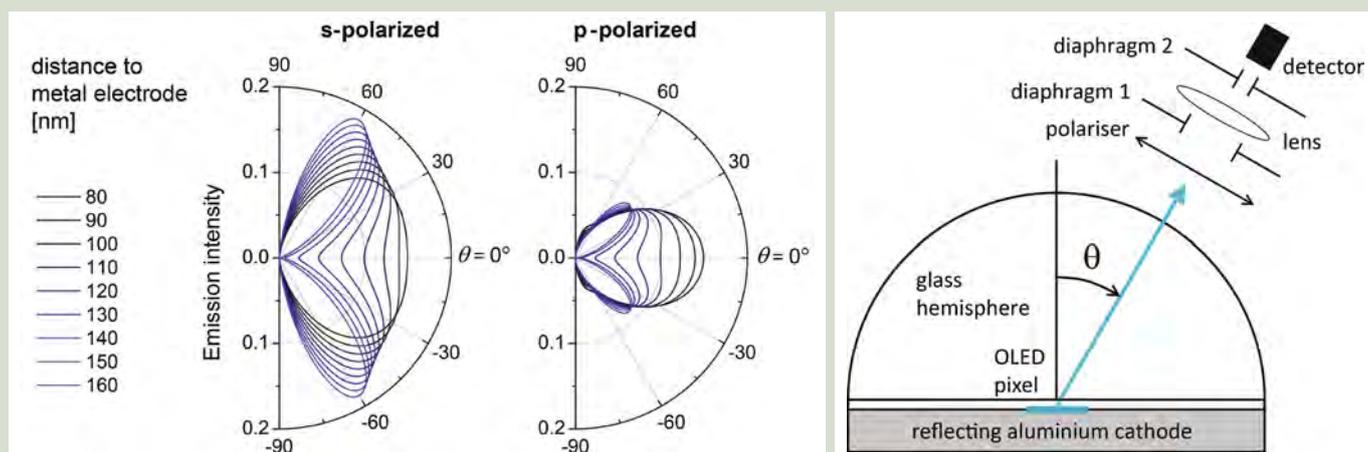
## BOX 1: RECONSTRUCTION OF THE LIGHT-EMISSION PROFILE

The light-emission profile in OLEDs can be determined with nanometre-scale resolution, far below the diffraction limit [7]. That is possible due to the interference of directly emitted light from a dipole and light emitted from its image dipole in the highly conducting aluminium cathode layer. The left figure shows the angular dependence of the emission from a randomly oriented green emitter in glass, at varying distances from the cathode, for the two polarization directions. Due to interference, the

perpendicular emission intensity oscillates as function of distance to the cathode with a periodicity  $\lambda/(2n) \cong 177$  nm, where  $\lambda$  is the wavelength in vacuum (530 nm) and  $n$  is the refractive index of glass (1.5). In the distance range from 80 to 160 nm (approximately from the first maximum, near  $\lambda/(4n)$ , to the first minimum, near  $\lambda/(2n)$ ) the emission profile depends for both polarizations strongly on the emission angle. Although the emission in actual OLEDs is influenced by the more

complex layer structure, the dominant role of the metal cathode on the light emission pattern is preserved. In order to prevent loss of information due to internal reflection at the interface between the glass substrate and air, a glass hemisphere is used to extract also emission at large internal angles (figure on the right). Optical microcavity modelling and least-squares fitting methods are used to obtain the emission profile in the OLED from the measured angle-, wavelength- and polarization-dependent emission. ■

▼ LEFT: Polar diagrams of the normalized s and p-polarized emission from a randomly oriented dipole emitter in glass as a function of distance to an aluminium layer. RIGHT: Measurement configuration. A glass hemisphere is put on top of the OLED to extract also light which is internally emitted under angles larger than the critical angle for full internal reflection,  $\theta_c \approx 42^\circ$ .



green layer (22%), while almost no excitons are formed in the red layer (3%). Fig. 3(b) reveals an important loss mechanism caused by excitons formed in the interlayer (21%). This leads to a somewhat suboptimal efficiency, as is indeed observed.

After taking into account the excitonic motion and radiative decay efficiencies the simulated light-emission profile of Fig. 3(c) is obtained. We observe the same large component of emitted red light as found in the reconstruction of the experimental light-emission profile of Fig. 3(a), which is almost completely caused by transfer of excitons from the green to the red layer. Also the green and blue component of the simulated emission profile are in fair agreement with the reconstructed emission profile. Like the reconstructed profiles, the simulated profiles are confined to nanometre-scale regions close to the interfaces. The overall agreement between the reconstructed and simulated emission profiles is striking.

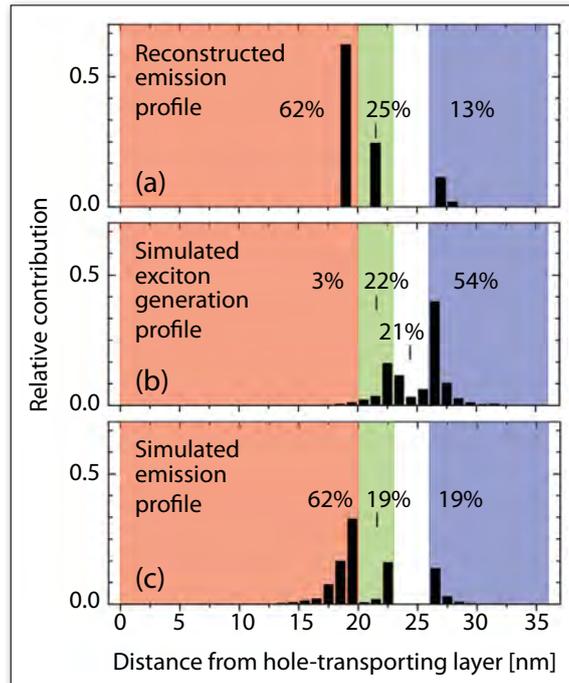
### A bright future

The experimental and simulation tools discussed here provide a unique way to “look inside the OLED” and can be fruitfully used in the further development of white OLEDs, which show ever more complex layer structures. They could help in identifying what processes limit their efficiency and lifetime. An important current issue is to what extent interactions between two excitons and between excitons and charges lead to exciton quenching, and thereby to a loss of efficiency. It is found that at high voltages the efficiency of OLEDs drops (an effect called “role-off”), which is presumably caused by these interactions. We are presently investigating this issue using our tools. With all-phosphorescent OLEDs, power efficiencies beyond 100 lm/W have been demonstrated in laboratory experiments, even exceeding those of fluorescent lamps (~90 lm/W), while operating at a high luminance [9,10]. Novel concepts for efficient and stable organic light emitters are also emerging, such as organic emitters in which the energies of singlet and triplet excitons are almost identical [11]. These emitters allow a transformation of non-emissive triplet excitons into emissive singlet excitons, providing an alternative to phosphorescent emitters. Use of these emitters could lead to a radical redesign of OLEDs, to which our tools can also be applied. But whatever turn this will take, the future of OLEDs is bright. ■

### About the authors



**Peter Bobbert** (1960) studied and obtained his PhD (cum laude) in Theoretical Physics in Leiden. After a postdoc in Delft as Royal Dutch Academy of Sciences Fellow he joined Eindhoven University in 1991. He presently works on various aspects of the theory of Organic Electronics, among which OLED modelling.



◀ **FIG. 3:** (a) Reconstructed light-emission profile of the OLED, at a bias voltage of 3.6 V. (b) Simulated exciton generation profile. (c) Simulated light-emission profile. The difference between (b) and (c) is caused by motion of excitons from the green to the red layer and by radiative emission probabilities smaller than unity. Excitons generated in the interlayer (white) are lost.



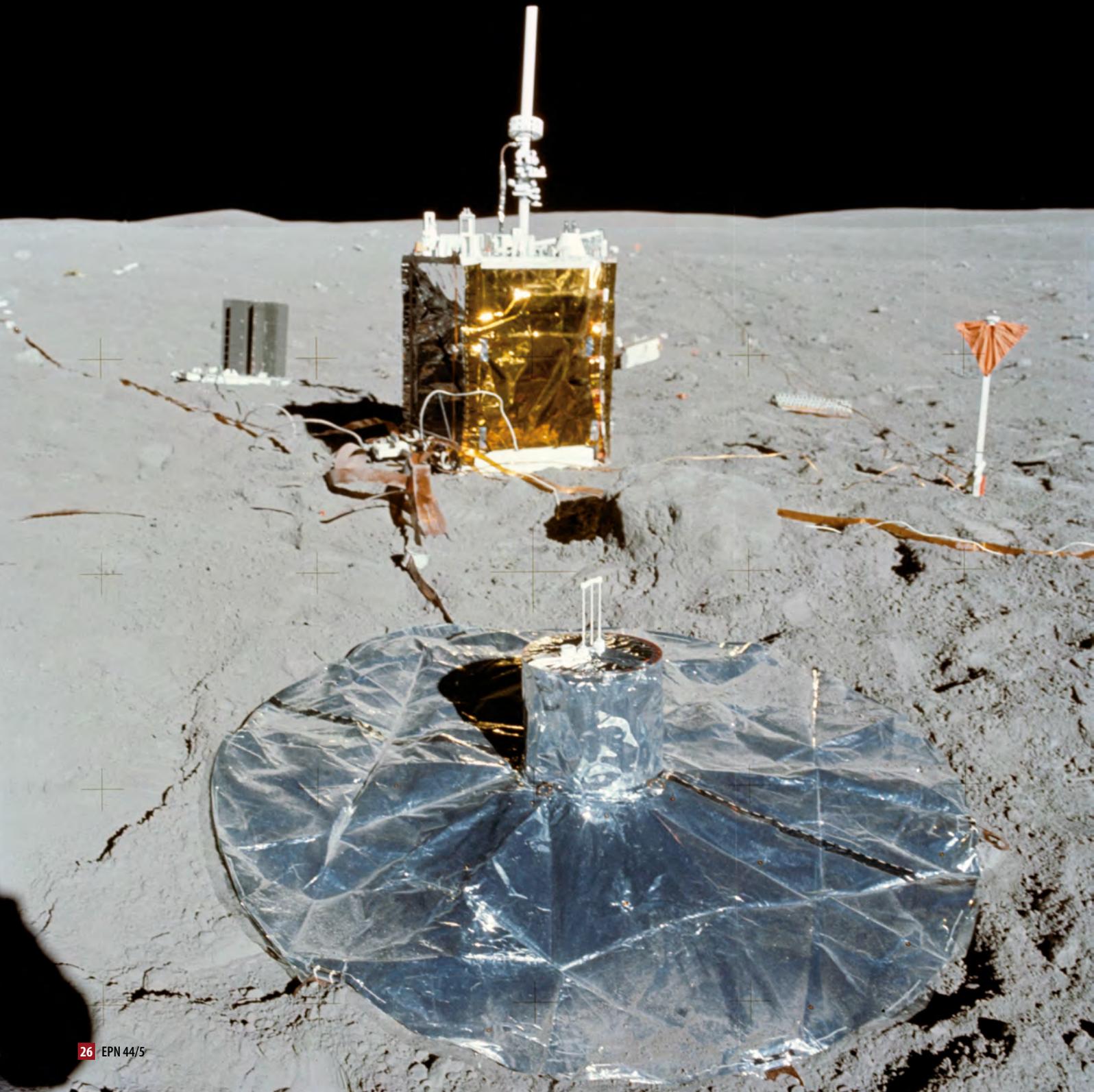
**Reinder Coehoorn** (1956) studied experimental physics in Amsterdam and obtained his PhD in Groningen. Since 1985, he is employed at Philips Research, working on permanent magnets, magnetic multilayers, and presently on OLEDs. He is part-time professor at the Eindhoven University, and an elected member of the Royal Netherlands Academy of Sciences.

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# ON INVERSE PROBLEMS IN PHYSICS

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**Despite its great practical importance, the theory of inverse problems remains poorly known. Indeed, physics was built by solving *direct* problems: from a given model to the corresponding measurable data. The opposite approach: from observed data to model parameters – the solution of an ‘inverse’ problem – is not so easy. It is, however, essential in many fields.**

The announcement made on September 22, 2011 by researchers of the OPERA [1] experiment, that the speed of observed neutrinos seemed to exceed the speed of light, acted as a bombshell, not only in scientific circles, but also in the press. Our purpose is to show that a very general theory was discreetly at work here, as in dozens of applications in everyday life. Let us first recall that the experiment was based on the creation of neutrinos at CERN near Geneva and on the detection of their arrival at a station under the Gran Sasso in Abruzzo. Neutrinos followed straight-line paths in the terrestrial crust, the length of which – about 730 km – was determined by GPS measurements having extreme precision [2]. But GPS tracking, medical engineering (echography, tomography,...), detection of flaws in devices by non-destructive techniques, pattern and characters recognition, detection of new planets, determination of the internal structure of the Earth [3] and stars, oil and gas research, and many other applications – from the diffraction of particles in quantum mechanics [4] to econometrics – would not be possible without the progress made during the past fifty years in the theory of inverse problems (and without the explosion of computing power required for their solution). A striking example of the determination of the internal structure of Tibet is shown in Fig. 1. In the case of GPS, it has been first necessary to solve the inverse problem of determining the gravity field of the Earth from the observation of trajectories of many satellites (first the Moon, then artificial satellites). Once this field known, the trajectories of a group of satellites equipped with transmitters and very accurate clocks can be determined. The position of a point on the surface of the Earth can then be calculated from the time of arrival of the waves transmitted by the satellites. Actually, improving the models of the

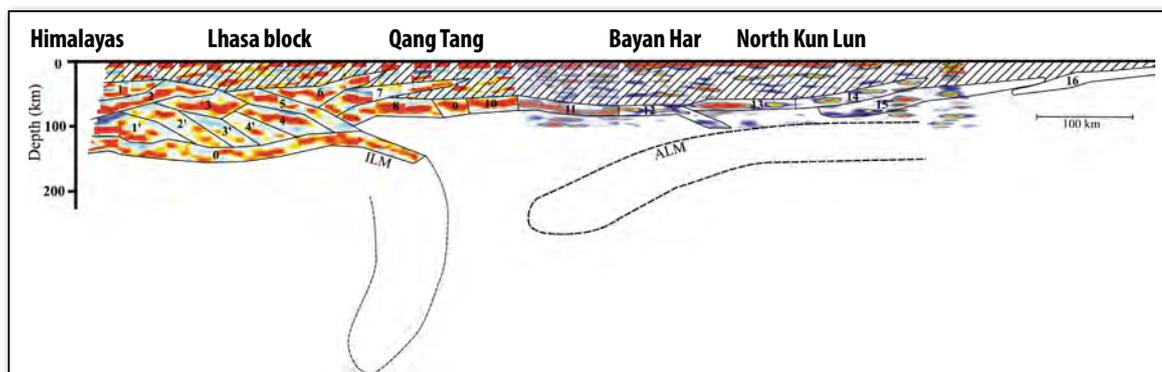
gravity field is obtained by simultaneously treating both problems: computing trajectories and positioning stations. This is a particularly interesting aspect of the theory of Albert Tarantola, summarized in box 1 (see also ref. [9]).

### On the theory of inverse problems

The usual approach of experimental science can be described as follows: The observed phenomena lead to formulate hypotheses and to develop a theory, in which a model of the system is built, characterized by some relevant parameters. The theory is then used to solve the ‘direct’ problem, *i.e.*, to calculate, from the values chosen for these parameters, the values of the measurable data, which will be compared to experiment. In short, a theory is the formulation of a direct problem. Consider for example a problem studied by Abel in 1826: on the line of greatest slope of a hill (assumed of known shape and perfectly smooth) a vehicle is launched upwards. Knowing the profile and the initial velocity of the vehicle, find the duration of a round trip. By comparing the calculated values to the observed ones (or to the result of experiments programmed for this purpose) one can check the validity of the theory.

To determine the properties of the studied system from the observed data, *i.e.*, to solve an inverse problem, is an otherwise difficult operation because it proceeds opposite to the normal process of experimental science. For the above case studied by Abel, the inverse problem is to find the shape of the hill profile, knowing the time taken for a round trip of the mobile, as a function of its initial speed. In mathematics it is, for example, the famous problem of the drum: find its form knowing the sound that it produces. One has then to search the coefficients of a differential equation or of a PDE, knowing the spectrum of the eigenvalues. One encounters this problem in particular when one wants

◀ Seismometer on the Moon (©NASA)



◀ FIG. 1: S-N section of Tibet obtained from seismological INSU expeditions between 1981 and 1998 (A.Hirn). The base of the crust (Mohorovicic's discontinuity, between 50 and 70 km) is not plane and seems often multiple. Also deeper interfaces appear.

to determine the properties of a medium that is inaccessible to direct observation, from observations made outside the medium. This is obviously the case in internal geophysics. It is therefore not surprising that many geophysicists have contributed to the progress of this discipline, by developing a variety of methods to solve their problems.

### Inverse problems in geophysics

The first inverse problem studied in this field was the determination of the source (position, time) of seismic waves, from their arrival time at a number of locations. If it can be assumed that the propagation speed is constant on a flat surface, this problem can be treated by the least squares method developed by Gauss in the early nineteenth century. Once the source is determined, the time it takes for a wave to reach a given point on the surface can be calculated. On the (almost) spherical Earth, this time depends (almost) only on the distance between the source and the station, but the apparent velocity of the signal is greater than if the propagation were along the surface. Hence another inverse problem: how to determine the wave velocity as a function of depth (if it may be assumed to be a function of depth only). In 1910, Batemann, Herglotz and Wiechert applied the method used by Abel for the equivalent problem mentioned above. In practice, however, many difficulties are encountered. The solution actually requires the calculation of the derivative of the transit time over the distance, an operation unreliable because of the large experimental uncertainties. In addition, as shown by Gerver and Markushevitch [5] in 1967, it is unique only if the velocity law meets certain conditions. But this method has shown that, overall, the velocity increases with depth, with

some discontinuities about twenty miles deep, as highlighted by Mohorovičić in 1909. Gutenberg showed the existence of the Earth's core in 1913. More detailed models were then obtained. In 1967, G. Backus and F. Gilbert developed [6] a general theory which led to a revolution in the field.

### Discretisation and successive approximations

The properties of a medium depend in principle on position and time. So its full description generally requires an infinite amount of information. In practice, by studying only static problems and fragmenting the medium, discrete and finite sequences of parameters remain. For example, by defining an Earth model by the density of homogeneous elementary volumes, the attraction it exerts on its exterior may be deduced from the Newtonian theory of gravitation. One then proceeds by successive adjustments of the parameters until an agreement between calculated and observed values is reached that is consistent with the instrumental precision. This is the classic approach by successive approximations, applied until the middle of last century.

### Existence, uniqueness, stability of solutions for a linear problem

Linear problems – where the data depend linearly on the parameters – are the only ones for which the theory can be fully developed. It is easy [7] to show that three main difficulties are encountered. The solution may or may not exist, may be unique or not, may be stable or not when the data or the theory are slightly varied. In the last case, the problem is called "ill-posed".

## BOX 1: THE PROBABILISTIC APPROACH OF ALBERT TARANTOLA

Let us assume that, before applying the inversion, we have at our disposal a probability distribution  $\rho_D(\mathbf{d})$  on the observable  $\mathbf{d}$ , and some *a priori* information on the model  $\mathbf{m}$  (e.g., parameters being between certain values), represented by a law of probability  $\rho_M(\mathbf{m})$ . Data and parameters being independent, the *a priori* information we have on the system is represented by the product law:  $\rho(\mathbf{d}, \mathbf{m}) = \rho_D(\mathbf{d}) \cdot \rho_M(\mathbf{m})$ .

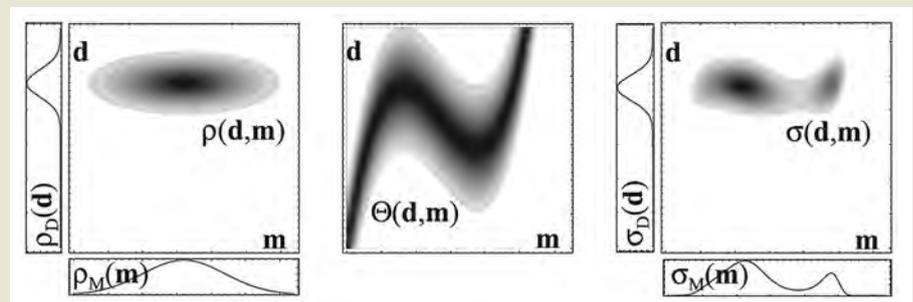
For the direct problem, a theory gives  $\mathbf{d}$  knowing  $\mathbf{m}$ . It may also be known only approximately – because of the physical constants used (always determined experimentally), or due to modelling errors (e.g., spherical model for the flattened Earth) – and must therefore be represented by a probability

distribution  $\Theta(\mathbf{d}, \mathbf{m})$ . By combining these two states of independent information one obtains the resulting probability on the data:  $\rho_D(\mathbf{d}) = \Theta(\mathbf{d}, \mathbf{m}) \cdot \rho_M(\mathbf{m})$ .

The observation leads to the definition of the law  $\sigma_D(\mathbf{d})$ . The solution of the inverse problem is given by

$\sigma_M(\mathbf{m}) = \Theta(\mathbf{d}, \mathbf{m}) \cdot \sigma_D(\mathbf{d})$ . We see (fig.2) how the knowledge of the model has been improved thanks to the data used. The *a posteriori* information on the system is now represented by the product law:  $\sigma(\mathbf{d}, \mathbf{m}) = \sigma_D(\mathbf{d}) \cdot \sigma_M(\mathbf{m})$ . Two types of solutions appear possible. ■

▼ FIG. 2: (Fig.1.12 of Tarantola's book [9]). The grey areas correspond to the values of the functions, taking the uncertainties into account.



## The progress

In any case one should not look for a solution dependent on a number of parameters greater than that of the data. This is a form of the principle of parsimony (or Ockham's razor). But all the data do not have the same importance. One must take into account the information available on their probable errors, giving more weight to those that are more accurate. To this end, data covariance and parameters covariance matrices are introduced. From these a generalized reverse is built that is, in a sense, the best solution available. G. Backus and F. Gilbert have shown in particular that, before any effective measure, the number of independent pieces of information contained in a collection of data may be estimated. In principle one can thus determine, before any experiment, which ones provide the most interesting information. In parallel one can assess the resolving power which can then be obtained for the values of model parameters. A local value for a parameter can be regarded as an average weighted by a filter, the resolving power corresponding to the width of the optimal filter, which can be evaluated from the data.

The results of experimental data have an imprecision both due to errors in the data and to a finite resolving power. One can try to minimize a quantity that combines these effects. For linear problems one shows that, when the experimental error is decreased by increasing the measurement accuracy, the resolving power decreases. Inversely, searching a better localisation for a parameter leads to an increase in its error. This is a form of the uncertainty principle.

## Non-linear problems

Nonlinear problems do not allow this kind of analysis. For a given model one can evaluate the difference between observed and calculated data – for example by calculating the sum of the squares (the method of least squares), or of the modules of the differences – and look for the solution in the direction where the difference decreases fastest (gradient method). However, this often leads to secondary minima which do not give the lowest value. Two other methods can be used:

**a) Linearisation.** If previous studies provide a result valid in first approximation, one can search a solution in the vicinity of this model. Writing the relationship between data  $\mathbf{D}$  and model  $\mathbf{M}$  as  $\mathbf{D} = \mathbf{G}(\mathbf{M})$ , if  $\mathbf{M}_0$  is the initial model and  $\epsilon$  the deviation from the final solution, we may write:  $\mathbf{D} = \mathbf{G}(\mathbf{M}_0 + \epsilon) = \mathbf{G}(\mathbf{M}_0) + \mathbf{G}'(\mathbf{M}_0)\epsilon + \mathcal{O}(\|\epsilon\|^2)$  where  $\mathbf{G}'$  is a function that can be constructed from  $\mathbf{G}$ . We then seek the solution of the linear problem:  $\mathbf{D} = \mathbf{G}(\mathbf{M}_0) + \mathbf{G}'(\mathbf{M}_0)\epsilon$ . This process can be iterated.

**b) Monte Carlo method.** If the computational cost of the solution of the direct problem is not excessive, one may conduct a random exploration of the parameter domain. This avoids the difficulties mentioned above. But when the number of parameters is large, the research quickly becomes very costly.

A detailed description of these methods can be found in the works of A. Tarantola [8,9]. In ref. [9], he proposed a probabilistic approach based on Bayes (1702-1761) assumption (see box 1). In this approach, the direct problem and the inverse problem lose their specificity and are in fact replaced by the search for the state of a system. This also corresponds to the evolution of research, for example in seismology where one is no longer trying to separately determine the parameters of the seismic source (origin and focal mechanism) and those of the Earth interior. All these parameters are searched simultaneously using not only the arrival time of the waves but also the shape of the signals. For A. Tarantola, the *a priori* information on the parameters of the studied model is defined as a probability distribution on the space of models. This distribution is transformed into an *a posteriori* information, by incorporating on one hand a physical theory linking the parameters to observable quantities – which themselves should be defined by a probability distribution – and on the other, the information provided by the observed data. The knowledge of the system state is thus revised. ■

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# Opinion: The challenge of Open Access

Agnès Henri is Publishing Director at EDP Sciences, an international publisher in Scientific, Technical & Medical areas

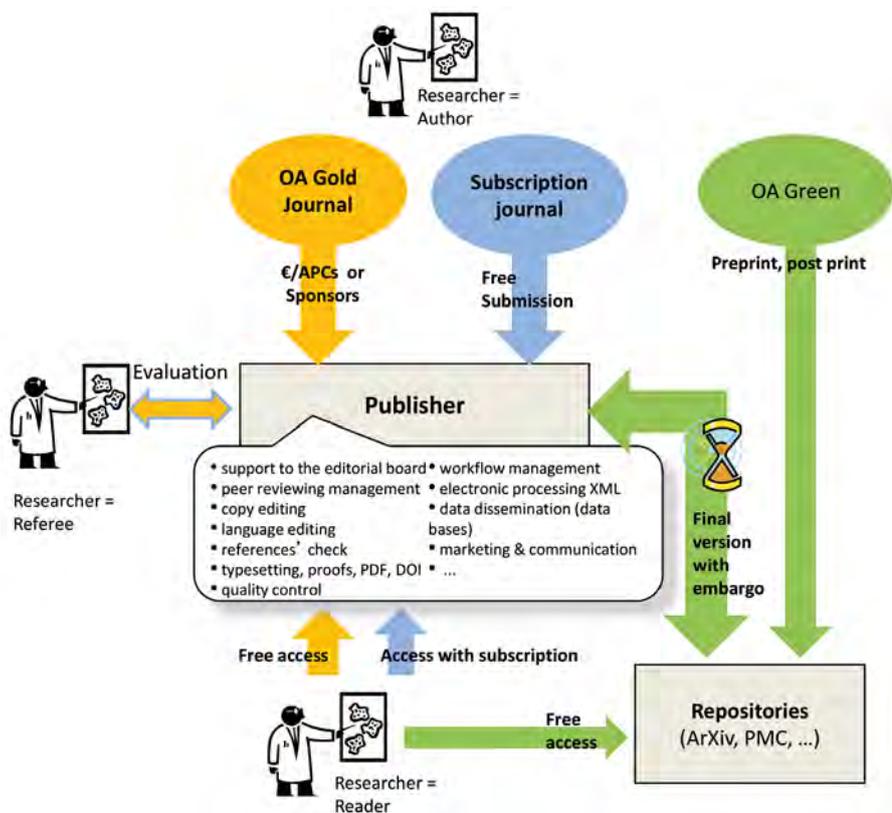
Alex Brashaw argues in a previous opinion [EPN 44/4, p.29] that “Learned Societies should accept the challenge and participate actively in shaping the transition into the new Open Access era”. EDP Sciences is a publishing company belonging to several French learned societies, and has actually been concerned about OA for a number of years. Open Access may be the best and most efficient way to disseminate research, but there are numerous roadblocks that are difficult to overcome. Green OA is the option chosen by most physicists and also advocated by some governments (US, France, EC, ...). EDP Sciences is certainly one of the few [pilot] publishers in the world that allow authors to post the final (reviewed and copy-edited) version of a paper on green repository, without any embargo period. However, if all publications can be accessed via green repositories, why would libraries continue to subscribe to journals? Today, subscriptions support a sustainable peer-review system (including

management tools and secretarial assistance to the editorial board), copy-editing, web platforms, etc. A Green OA manuscript could never exist without the professional support by the publishers to maintain scientific quality. To summarize, today’s repositories depend on subscriptions! In this subscription-based economic model, the library’s budget has become a large problem, due to a number of different factors. First, a few (but not all) commercial publishers are raising journal subscriptions excessively. Secondly, subscription prices in general continue to rise simply because the number of articles published each year has been growing steadily over the years, by about 3% per year<sup>1</sup>. Finally, more and more submissions come from countries that do not buy subscriptions (as an example, in EDP Sciences journals, there is a disproportionate number of submissions from China compared to its small number of subscriptions). As a result, the volume of published research rapidly outweighs library budgets’ growth.

Apart from the undeniable benefits that freely accessible research output has, “Gold Open Access” seems to be the easiest and simplest model because each country automatically pays its own share. Gold OA also forces a publisher to reconsider its role and to be more transparent in its costs. Finally, Gold does not exclude Green, and publishers can actually collaborate closely with repositories (for example, all medical papers from the EDP Open<sup>2</sup> platform are automatically deposited in PubMed Central<sup>3</sup>). Nevertheless, some risks remain in Gold OA:

- “Predatory” publishers<sup>4</sup>: in Gold OA, the more a journal publishes, the more money it makes, a tempting argument to accept bad papers, as already emphasized by EPS<sup>5</sup>. The learned societies should play a significant role to protect researchers from such predators, and to help them identify the best journal for their papers.
- The problem of “prestige”: a journal with a high impact factor could be tempted to always raise its fees, open access or not, simply because authors will accept the cost. It is important to remember that OA allows a wide dissemination, and the quality of a specific paper becomes more independent from the quality and prestige of the journal.

One should always keep in mind that Publishers are service providers for researchers; they must adapt to the researchers’ needs to offer the best services at the best prices. ■



<sup>1</sup> The STM report, An overview of scientific and scholarly journal publishing, Ware & Mabe, 2012 [www.stm-assoc.org/2012\\_12\\_11\\_STM\\_Report\\_2012.pdf](http://www.stm-assoc.org/2012_12_11_STM_Report_2012.pdf)

<sup>2</sup> [www.edp-open.org](http://www.edp-open.org)

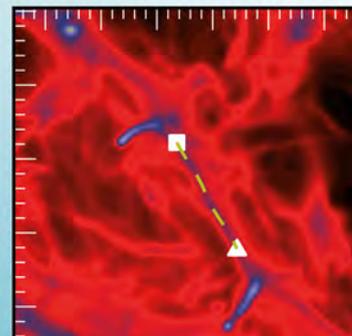
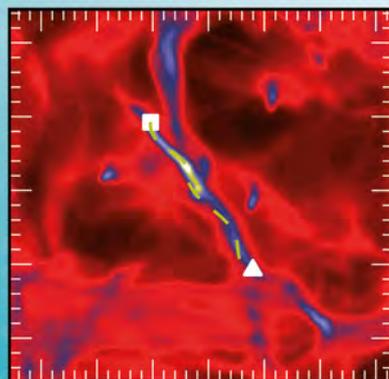
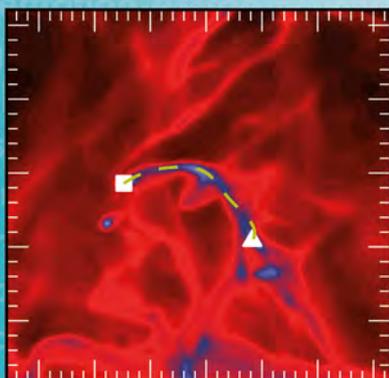
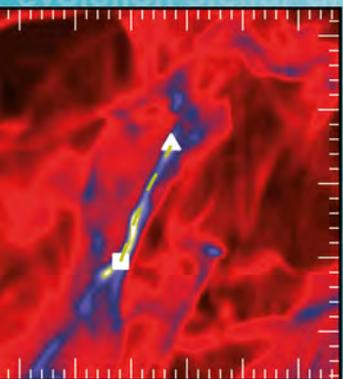
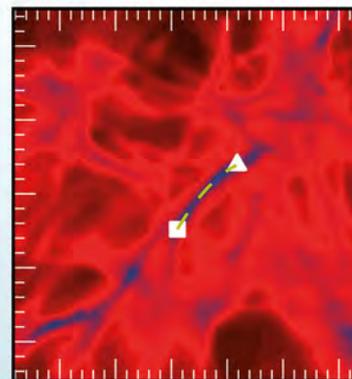
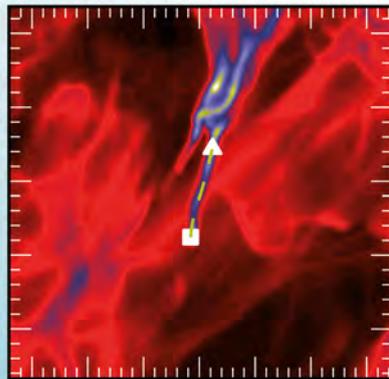
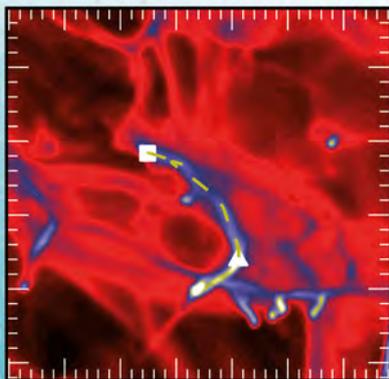
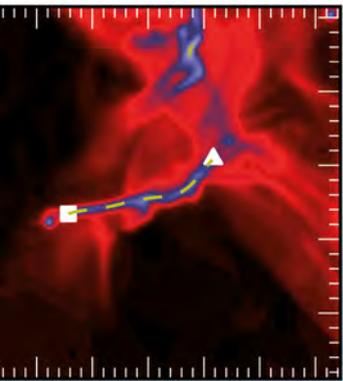
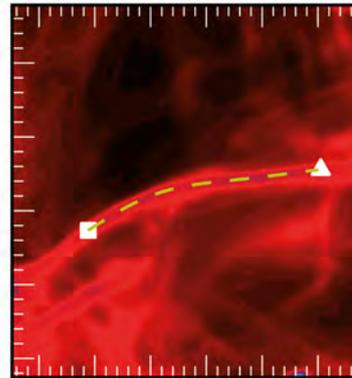
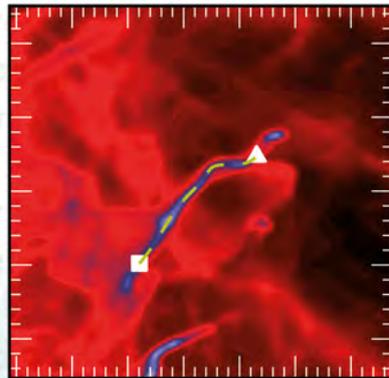
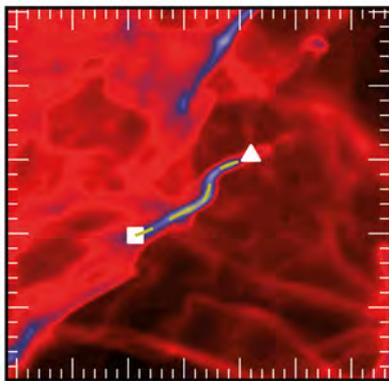
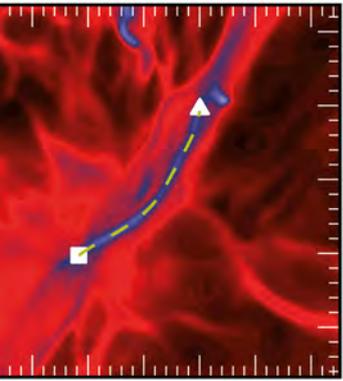
<sup>3</sup> PubMedCentral is a biomedical repository developed by the U.S. National Library of Medicine

<sup>4</sup> <http://scholarlyoa.com/2012/12/06/bealls-list-of-predatory-publishers-2013/>

<sup>5</sup> “Open Access – A position paper of the EPS”, [www.eps.org/resource/resmgr/policy/eps\\_pp\\_oa\\_2009.pdf](http://www.eps.org/resource/resmgr/policy/eps_pp_oa_2009.pdf)

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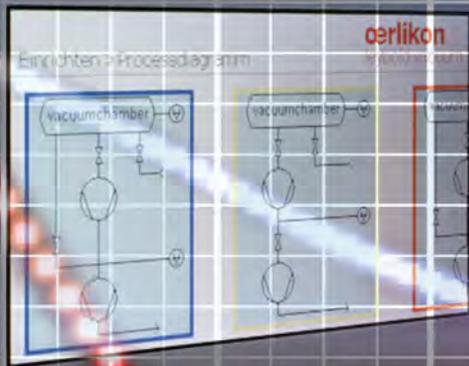
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