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EPS Strategy Plan beyond 2010

Jožef Stefan

The Croatian Physical Society

Quantum gravity

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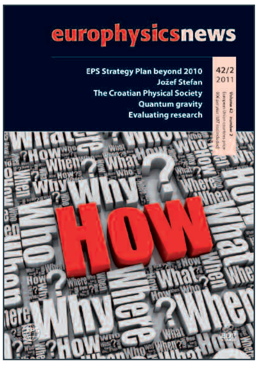

Cover picture: The interrogations of the Strategy Plan. ©iStockPhoto

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Happy Anniversary, *EPL*!

25 years ago, the British, French, and Italian physical societies and the EPS contracted a marriage of convenience with the aim of establishing *Europhysics Letters* as a competitive European letter journal. Rebranded as *EPL* in 2007, it has become the flagship journal of the EPS, owned by a partnership of 17 European physical societies, which means that it belongs not to commercial publishers but to you, the members of the EPS.

When you publish in *EPL*, your work will appear in a truly global journal. In spite of its European base, *EPL* attracts many submissions from North America, China, India, and developing countries. This globalism is reflected in the Editorial Board, whose members belong to top institutions all over the world. As active scientists they understand the needs of authors and readers. This helps considerably in the peer reviewing which many authors experienced as a constructive process fulfilling the motto expressed in the *EPL* byline: *Exploring the Frontiers of Physics*.

"Frontiers in Physics" is also the title of a symposium, with which the silver jubilee of *EPL* was celebrated at the Bavarian Academy of Sciences in Munich in May 2011. Young scientists from across Europe met distinguished physicists from all over the world. This stimulating event is described at www.epl25.org.

When you visit the *EPL* pages http://iopscience.iop.org/0295-5075, I suggest that you look for the *EPL* "Best of 2010" articles collection. It features articles highlighted as particularly interesting by the CoEditors, papers most attractive to readers as determined by the download statistics, and publications distinguished by other authors in terms of citations received. A similar compilation shows the most cited papers from the last 25 years. Further promotions cover graphene and liquid crystals. All these articles are free to read online for the entire anniversary year.

Recently iron-based superconductors have topped the list of citations. Besides this area of condensed matter physics, *EPL* has been traditionally strong in general physics, statistical physics, and interdisciplinary physics. In the future applied physics, biological physics and medical physics shall be more prominent in *EPL*. The intention is to explore the frontiers of physics, and to do so in all directions. So I ask you to submit to *EPL* (at https://www.epletters.net), irrespective of the particular field of physics. If dissemination of your work matters to you especially: *EPL* is available worldwide at over 1670 institutions, which are subscribers to the journal or to packages in which it is included. If size matters: *EPL* publishes XXL letters which, with six A4 pages, can be extra-extralarge in comparison to competing letter journals. If impact matters: the impact factor rose by remarkable 30% to the value of 2.9 for 2009, after remaining at 2.2 over several years. If speed matters: the production time from acceptance to online publication was reduced to 4 weeks.

In summary: Dear EPS members, *EPL* is your journal and you can be proud of it. You can further enhance the success of *EPL* in the years to come, if you promote *EPL*. And when you publish in *EPL* and your papers are cited more than three times in the two years after the publication year, then you will even enhance the impact factor of *EPL*. Thus I look forward to receive your excellent submissions, which I will consider as your gift to *EPL* on the occasion of its silver jubilee. ■

Michael Schreiber, Editor-in-Chief of *EPL*

EPS Strategy Plan beyond 2010

Council 2010 (in its meeting of 19-20 March) adopted a proposal to create a Strategy Working Group (SWG) to thoroughly review the EPS and propose a new plan for its mission and strategy. To ensure broad and balanced representation of the EPS membership, the SWG is composed of representatives from Member Societies (MSs), Divisions and Groups, Individual Members (IMs), Associate Members (AMs) as well as the President and Vice President of EPS.

Composition of EPS SWG

2 Executive Committee members:

President – M. Kolwas

Vice President – L. Cifarelli – Chair of EPS SWG

4 Member Societies representatives:

IOP – A. Wallard, replaced by R. Kirby-Harris

DPG – K. Meier

NNV – G. van der Steenhoven

Norwegian PS – P. Osland

3 Divisions and Groups representatives:

QEOD – J. Dudley

PDG – F. Piuzzi

EG – F. Wagner

1 Individual Members representative:

D. Nagy

1 Associate Members representative:

H. Bindslev

The present document, which has been finalized after a Council meeting in Amsterdam on 20 November 2010 is presented to the EPS Council Meeting 1-2 April 2011. Its purpose is:

1. To state the vision, mission and objectives of EPS and its key role
2. To define the activities and priorities for medium- and long-term goals of EPS
3. To identify actions, programmes and projects according to EPS priorities
4. To identify competences and responsibilities of various EPS bodies for the implementation of EPS Strategy Plan
5. To formulate financial guidelines and suggestions for the implementation of this plan.

A. Political Strategy

The European Physical Society (EPS) was established more than 40 years ago as a union of individual physicists and physical societies of European nations. At the beginning of a new decade of the third millennium, it is time for EPS to draw up a balance-sheet of its activities, and then to define its precise objectives for the coming years, taking into account the accelerating changes of political, social and economic conditions in the present world.

Since 1968, EPS has steadily increased the number of its scientific Divisions and Groups, to further assert its presence in European Physics. In the last few years the following have been established: the Physics in Life Sciences Division (2002), the Environmental Physics Division (2002), the Women in Physics Group (2002), the Solar Physics Division (2008) – replacing the Astrophysics Division – followed by the Joint Solar Physics Group (2009), and the Energy Group (2008) – formed out of the existing Technology Group.

To disseminate information about the Society and European Physics, EPS publishes Europhysics News (EPN). EPN is distributed to the members of many national physical societies in Europe. A large and influential learned society normally publishes scientific journals, and it is the case for EPS: with Europhysics Letters[1] (*EPL*), which will celebrate in 2011 its 25th anniversary, and the more education-oriented European Journal of Physics[2] (EJP).

However, it can be considered that the influence of EPS in Europe and in European Physics is not yet at the level at which it should be for a society representing 41 national physical societies and indirectly more than 10^5 physicists.

In 2001, the EPS Council approved a Strategy Plan, put forward by Martial Ducloy, who was EPS President at the time. It proposed a number of action lines which have undergone developments with variable levels of success. They should still be kept as important issues, but after 10 years, most of them need to be reconsidered and actualized.

The main objective of EPS remains as stated in the 2001 document:

"The main objective of EPS in the coming years should be to turn it into a major policy-making professional organisation in Europe – in a way complementary to the goals pursued by national physical societies. This should be carried out by increasing the European presence of EPS and its visibility in the European Union, through its executive officers, divisions and committees. Obviously, it implies that EPS fully assumes its role in public awareness of physics, demonstrating the dynamical character of Physics, and its exemplary nature as a scientific discipline with rigorous theoretical and experimental methods, as well as its "incubator" role in generating new disciplines

Notes

[1] Jointly owned by EPS, IOP, SFP, SIF, plus a pool of other societies/institutions.
[2] Owned by EPS, published by IOPP.

(Astrophysics, Biophysics, Physics in Medical Sciences, Materials Science, Information and Communication Technologies,...)".

The present document, based on an analysis of the national physical societies and EPS roles, should include some anticipation of future developments: what will be demanded in 2020 from these societies and from EPS, facing the continuing integration of Europe; the higher mobility of students trained in the "Bologna Process" frame; the expansion of the European research infrastructure in Physics; the growth in funding from the European Commission; the challenge by the USA and increasingly by the rapid development of Asia.

EPS has now a history of more than 40 years. During the next 10 years EPS should however aim at further strengthening scientific excellence in Physics (*e.g.* quality of research, researchers, networks, communication, *etc.*) through the creation of a coherent Physics community of individuals, institutions and societies that adhere to the European ideal (*e.g.* strong access networks and initiatives, educational exchanges, mobility, international research collaborations, cooperation towards less developed countries, *etc.*).

The role of EPS should demonstrate the importance of Physics (but also of Science as a whole) to scientific, technological, social and cultural development. Hence the EPS should not only be a service for physicists but it should also give them a voice outside the field, that adds value to the work of other bodies such as the European Commission and European Science institutions and organizations – as well as intergovernmental organizations (OECD, WMO, WHO, *etc.*) on the political stage of Europe. It should be stressed that the EPS as a recognized non-governmental organization (NGO) is entitled to have wide social and political aims in this context.

In addition EPS could play the fundamental role of "learned society" particularly for the members of those national physical societies (many, among the 41 affiliated to EPS) for which such a role is impossible or difficult to fully implement on a national scale.

In this perspective the mission of EPS should be:

- to pilot activities that would have additional impact if done so on a European (or possibly worldwide) scale;
- to promote activities that would be enhanced if done so through collaboration with other learned societies, whether in Physics or other scientific disciplines, whether in Europe or around the world;
- to assist its members societies (MSs) in broadening the impact of their national activities;
- to support a community of individual physicists that possibly amplifies their career development;
- to provide the opportunity and means for individual physicists to be actively involved in EPS actvities in research policy, scientific excellence and outreach;
- to support research institutes through networks for the exchange of best practice, communication and access to individual physicists;
- to monitor, communicate and provide input on Science information and Science policy.

EPS could play the fundamental role of "learned society" particularly for the members of those national physical societies

Therefore it's a two-fold role and mission that EPS should indeed aim to assume:

i) as a federation of member societies (MSs) and associate institutions (AMs), acting at the same time as an internationally enlarged scientific academy for policy statements, influence and advice, objective reports and reference papers, *etc.*;

ii) as a learned society for its individual members (IMs) through its Divisions, Groups, grants, prizes, conferences, *etc.*

This major objective of EPS should be achieved through a number of actions, as illustrated in the following.

▲ EPS building in Mulhouse

A-1. Scientific excellence and visibility

The scientific excellence of European physicists should be promoted by EPS through targeted actions, high profile activities (such as the "International Year of Light" initiative, for instance) and world leading conferences in all branches of Physics. EPS should continue to award prestigious prizes, and highlight their importance in building the European Physics community and their contribution to the career development of physicists. At the same time the visibility of EPS should be fostered by these above activities. The most modern and updated means of communication should be used to this purpose so as to ensure that the voice of EPS sounds "loud and clear" in Europe and elsewhere.

A-2. Federation and umbrella organization

The "federation and umbrella organization" functions of EPS (working on behalf of all the affiliated national physical societies and institutions) should be enhanced. EPS should bring to them an added value and give the vast scientific community of over 10^5 physicists it represents a coherent and powerful voice concerning research, education, scientific awareness and scientific policy. This action could be facilitated by improving the relationships and links with the appropriate institutions in Brussels. A proactive role of national societies, as well as of Divisions and Groups, could be very important in this respect.

A-3. Membership and recruitment

A serious attempt to increase EPS membership should be made since the weight of a learned society depends both on the scientific excellence and liveliness of its members, and also on the number of individuals they can be said to represent. With this intent, EPS should make itself more attractive and helpful to individual members and thus stimulate and encourage increased levels of member recruitment, through national societies and associate institutions, and in particular through its Divisions and Groups.

Cooperation and collaboration inside and outside Europe, in particular towards less developed and scientifically-emerging countries, should be reinforced

A-4. Cooperation and collaboration

Cooperation and collaboration inside and outside Europe, in particular towards less developed and scientifically-emerging countries, should be reinforced. A wide and powerful grants programme, for instance, could be envisaged and sustained. Also better contacts and relationships with analogous scientific societies outside Europe should be established.

B. Operational strategy

B-1. Areas of strategic importance and priorities

In order to initiate the EPS Strategy Plan and ensure its effective implementation, a number of key priorities have been identified. These are outlined below.

i) Priorities for the EPS as "federation":

- Enhance EPS visibility in the Physics and Science community, in Europe (and worldwide), by launching studies and/or surveys of general interest and by producing policy statements and position papers on relevant issues.
- Improve communication and consultation within EPS among MSs (but also AMs, IMs, Divisions and Groups), in particular concerning feedback on the above policy statements and position papers.
- Benefit and organize communication channels established by Divisions and Groups to EU/EC officials and create a contact network at the operational level.
- Invest in an effective "presence" in Brussels, directly through national Governments, based upon commonly agreed policies and also through partner organizations and alliances. The aim is to improve the engagement with the EU and its Member States in all major policy matters (such as, for instance, research infrastructures, road maps, *etc.*); this would be made easier by establishing appropriate links with European stakeholders in order to obtain direct information and response.
- Promote relevant projects/events with interdisciplinary features such as: "Physics and" Education, Society, Development, Life Sciences, Energy, Environment, Climate, Cultural Heritage, *etc.* in order to strengthen EPS influence with opinion makers and improve awareness for the greater public.

- Put special emphasis and focus on activities related to the formation of physicists and their career issues.
- Find means to increase mobility and cooperation within and outside Europe, through appropriately leveraged grants programmes, in collaboration with other pan-European and international organizations.
- Favour joint meetings with national and transnational physical societies (American, Asian, *etc.*).
- Promote the launch of e-news, for instance in the format of a fact-sheet electronic journal addressed to a large audience (possibly aiming in the future at a popular press e-journal).

ii) **Priorities for the EPS as "learned society":**

- Support the most dynamic Divisions and Groups, initiating at the same time a bottom-up revision process to revive or merge some of them or establish new ones according to specific sound proposals.
- Strengthen communication among IMs and AMs, and among Divisions and Groups, also keeping in mind the possibility to promote interdisciplinary initiatives.
- Strongly improve means and tools of communication (web page, databases, social networks, *etc.*) at all levels, in particular improving web services for all EPS members.
- Establish an internal Divisions and Groups e-bulletin for IMs, to optimize the exchange of information.
- Support relevant and prestigious conferences and prizes so as to foster the EPS scientific outreach.
- Continue to organize leading topical and general conferences in Physics in Europe.
- Plan and harmonize EPS conferences for optimal coordination with other similar initiatives in Europe and elsewhere.
- Establish a publication strategy and policy to promote high profile European publications in Physics and better coordination among European publishers (having in mind, for instance, a possible European pool of publications from publishers owned by or linked to European learned societies).
- Make EPN still more attractive and review its distribution policy.

EPS priorities are recognized, determined and monitored by the Council through an appropriate Strategy Review Group, appointed every 5 years, that would work in consultation with the Executive Committee.

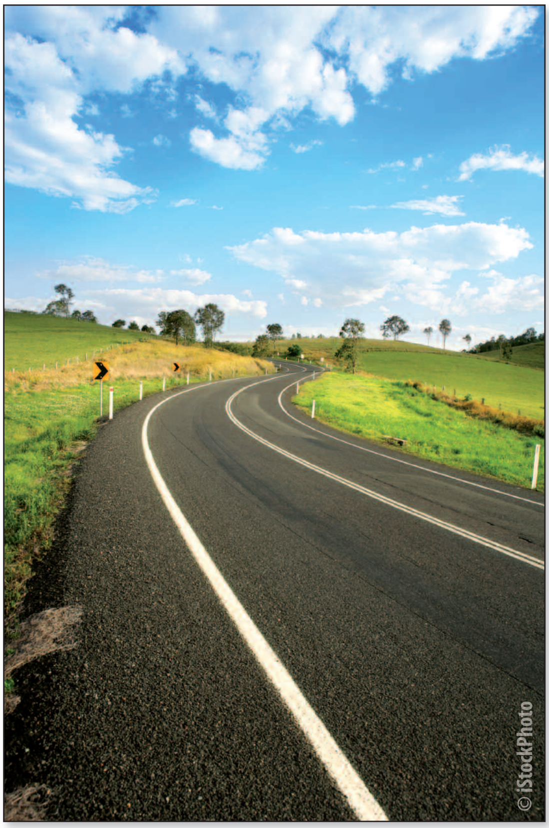
B-2. Membership

EPS maintains its membership structure consisting of member societies (MSs), individual members (IMs) and associate members (AMs).
An active campaign for recruitment of IMs should be foreseen, with the open collaboration of all MSs and AMs (formulated in case through specific agreements) to encourage their own individual members to also become EPS members. This campaign should be based on a strong effort from EPS to provide more services to IMs. The goal would be to create and enhance a spirit of belonging to the Society, in particular among early career physicists (and possibly students). Clear and well-defined benefits should be identified and then provided to individual members as added values with respect to those (non EPS) benefits already made available by their respective MSs.
In addition, the role of EPS as a federation of MSs should be duly emphasized as well as its role of "mother" learned society for those MSs which look to the EPS in this way. Regarding its explicit and effective federation role, this should be primarily achieved by means of appropriate consultation within the MSs representing, as a whole, over 10^5 individuals.
Finally, new AMs should be looked for, also in the field of industry, and new means to attract them, in view of the organization and sponsoring of special activities of common interest.

The Executive Committee, chaired by the President, is in charge of the implementation of strategy, operational matters and budget preparation through the Secretary General.

B-3. Structure and governance

EPS maintains a governance structure consisting of President, Council and Executive Committee. The Council composition based on MSs, IMs, AMs and Divisions/Groups components remains unchanged. Council decides on strategy, approves budgets, approves financial statements, and votes for and approves the President and other Executive Committee members. The Executive Committee, chaired by the President, is in charge of the implementation of strategy, operational matters and budget preparation through the Secretary General.
The Executive Committee composition should be revised to follow the evolution of EPS during the last decade (in terms of membership, activities and services), to better reflect the Council composition and to facilitate the governance of the Society enhancing its new two-fold role, as outlined in the present strategy document, of federation and learned society.
Therefore, in addition to President and Vice President (*i.e.* Past President ▸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or President Elect), the proposed Executive Committee membership is as follows:

i) 1 member from each of the largest MSs, *i.e.* those national societies with more than 10.000 effective individual members: this Executive Committee member is designated by his/her respective MS and approved by Council;
ii) 3 members elected by Council as MS representatives, from MSs other than those at point i);
iii) 4 members elected by Council as representatives of Divisions/Groups;
iv) 1 member elected by Council as representative of IMs.
v) 1 member elected by Council as representative of AMs.

On this basis the total number of Executive Committee members under this new model would currently be 13, including the President and Vice President. Such a composition is meant to strengthen interactions and communications among the different constituencies of EPS, namely MSs, IMs, AMs and Divisions/Groups, taking into account the diversity of perspectives among these constituencies, fostering at the same time a better link between the major MSs and the EPS.
The number of votes assigned to different Council members and the voting procedures in the Council, both for President and Executive Committee members, remain unchanged. For the latter, the voting procedure will be simply repeated for each list of candidates (from MSs, IMs, AMs and Divisions/Groups). Also the voting procedures for the election of IM representatives as Council members will remain unchanged.
In order for Council in 2012 to elect the members of the Executive Committee in accordance with the composition described above, an amendment to Article 17 of the EPS Constitution and to Rule 14 of the EPS By-Laws will be proposed in due time. This amendment should be approved by Council in its scheduled meeting of April 2011.

C. Financial and human resources

C-1. Financial matters

The EPS financial organisation should be matched to its new goals. Different and separate/independent "business units" should be foreseen to optimize expenditure efficiency and distribution of resources, increasing at the same time the transparency for budget presentation to Council.
As a first step, three such units could be envisaged in order to match:

i) the EPS activities related to its role of MSs (and AMs) federation;
ii) the EPS activities related to its role of learned society for IMs and AMs, and to the objectives of Divisions/Groups, including conferences;
iii) the editorial and publishing activities of EPS.

The accounts of Divisions/Groups will be treated like in the past as their property, with their full sovereignty over financial means in agreement with EPS Constitution.
A first attempt of implementation of such a new financial structure should be immediately operative and the aim should be to reach self-balancing (between income and expenditure) for the first two units (the third being in practice an income generator!) in a phased way within a reasonable number of years from the foreseen approval of the present EPS Strategy Plan by Council in its scheduled meeting of April 2011.

The various actions and steps for the implementation of the present EPS Strategy Plan within 2 years from its approval will be presented to Council

C-2. Staff and office organisation

The whole EPS office in Mulhouse will need to be reviewed so as to ensure that it fulfils the new requirements of the present EPS Strategy Plan.
In addition, we should aim to outsource activities wherever possible – profiting from the expertise and manpower of a number of MSs as far as some specific tasks are concerned (*e.g.* e-news, e-bulletin, web pages, databases, social networks, *etc.*).
A review of the EPS staff assignments and office organization will be made on a regular basis by the EPS Executive Committee.

D. Implementation of the strategy plan

The various actions and steps for the implementation of the present EPS Strategy Plan within 2 years from its approval will be presented to Council via written/oral reports of the President.
The Executive Committee will be responsible for ensuring that the actual implementation takes place within the established deadlines through the Secretary General and EPS staff. ■

▼ Some members of the Strategy Working Group after completing their last meeting, in Paris (fall 2010). Left to right: P. Osland, K. Meier, L. Cifarelli, J. Dudley, M. Kolwas, R. Kirby-Harris, R. Piuzzi and D. Nagy

EJSM, IXO and LISA

ESA presents study results on three competing Large Missions

350 scientists, science administrators and journalists gathered in early February 2011 in the impressive *Grand Amphithéâtre* of the *Institut Océanographique de Paris* to listen to the presentation of three large missions under study by the European Space Agency (ESA).

The aims and names of these missions are:

- «exploring the emergence of habitable worlds around gas giants» by the Europa Jupiter System Mission *EJSM-Laplace*;
- «revealing the physics of the hot Universe» by the International X-ray Observatory *IXO*; and
- «unveiling a hidden Universe» by the gravitational wave observatory *LISA*[1].

The potential cost of any one of these so-called L-class or large missions will exceed the amount 700 M€ set aside by the European Space Agency (ESA) for this type of mission in the long-term science programme 'Cosmic Vision'. A realisation therefore must rely on a cooperation with one or more additional space agencies, namely with NASA of the US and, in the case of *IXO*, also with JAXA of Japan.

We will describe the missions above starting with *LISA*, then go to *IXO* and finally summarise the aims of *EJSM-Laplace*. The gravitational wave observatory *LISA* is probably the mission of greatest interest to physicists — and arguably of greatest consequence for science as a whole. A concise introduction to the subject is contained in the first paragraph of the Executive Summary of the Study Report[2]:

"Einstein's theory of spacetime and gravity, general relativity, predicts that suitably accelerated masses produce propagating vibrations that travel through spacetime at the speed of light. These gravitational waves (as the vibrations are called) are produced abundantly in the Universe and permeate all of space. Measuring them will add an altogether new way to explore what is happening in the Universe: rather than studying the propagation and transformation of conventional particles and fields in spacetime, as all science has done up to now, *LISA* will sense vibrations of the fabric of spacetime itself. Studying these signals will convey rich new information about the behaviour, structure, and history of the physical universe, and about physics itself. When gravitational waves become observable they will provide a new and uniquely powerful probe of the extremes of spacetime, from the Big Bang to black holes, to address the deep questions that have emerged in mankind's never-ending quest to understand the cosmos: what powered the Big Bang, what happens to space and time in black holes and what is the mysterious dark energy accelerating the expansion of the Universe?"

To sense gravitational waves, *LISA* will use precision interferometry across 5×10^6 km of space for comparing separations between test masses that are protected by spacecraft from non-gravitational disturbances. As gravitational waves cause a strain, *i.e.* a fractional length change of 10^{-22}, *LISA* accordingly needs to be able to measure displacements of the order of fractions of a picometre. (This displacement seems small, but is orders of magnitude larger than what is routinely measured by the kilometre-sized ground-based gravitational wave detectors, which are currently under construction in Europe, Japan and the US.)

LISA thus coherently measures – along three differently oriented baselines – spacetime strain variations, including frequency, phase, and polarisation

LISA will set up three 5×10^6 km long baselines between three spacecraft placed at the corners of an equilateral triangle, each one housing two test masses. *LISA* thus coherently measures — along three differently oriented baselines — spacetime strain variations, including frequency, phase, and polarisation, all of which reflect large-scale properties of the systems that produce them, and are therefore direct traces of the motions of distant matter. As shown in the insert of Fig. 1, the triangle formed by the three spacecrafts is inclined by 60° with respect to the ecliptic, and its centre follows the Earth's orbit, but trails it by ca. 5×10^6 km. The three spacecraft orbit the Sun in natural orbits and thereby cause the triangle to rotate once in the course of one year. This rotation together with the changing orientation of the inclination with respect to the ecliptic then provides spatial information over *LISA*'s all-sky field of view.

What are the advantages of a gravitational wave observatory in space? The kilometre-sized ground-based detectors will be able to observe neutron stars or stellar-mass black holes coalescing out to distances up to ►

Notes

[1] The acronym *LISA* stands for 'Large Interferometric Space Antenna'.

[2] The three Assessment Study Reports can be downloaded as pdf-files from the web site http://sci.esa.int/science-e/www/object/index.cfm?fobjectid=47796&fbodylongid=2176.

perhaps 10^9 light-years. *LISA* in space, on the other hand, which spans the distance of 5×10^6 km — and is not subject to seismic noise — is sensitive to low-frequency gravitational waves emitted by large massive systems, such as massive black hole coalescences out to ten times this look-back time (*i.e.* red shifts up to $z \approx 10$). This will allow *LISA* to probe the earliest stages of galaxy formation.

The actual frequency band of *LISA* is 1×10^{-4} Hz to 1 Hz; and, more specifically, *LISA*'s scientific goals are

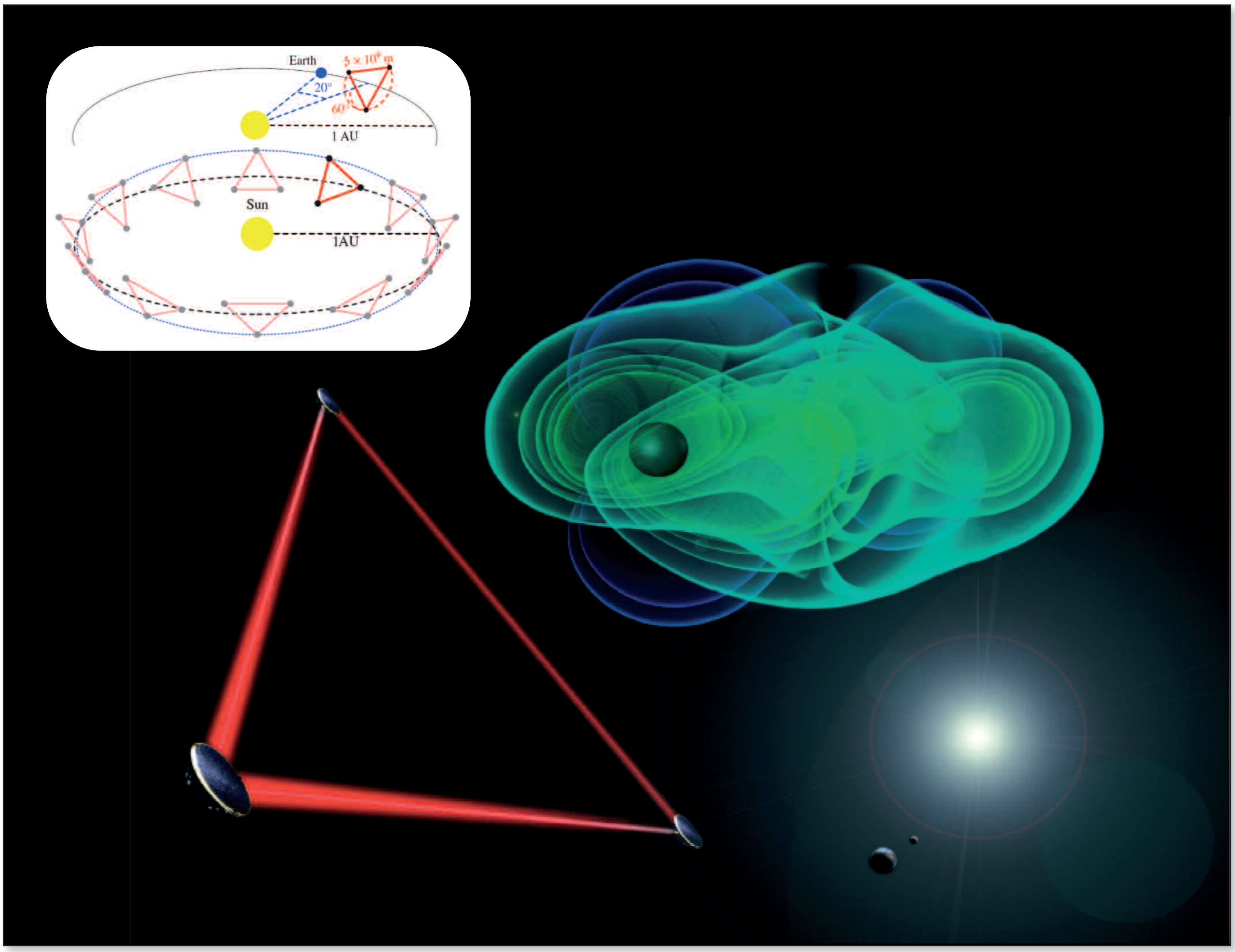
- to trace the formation, growth, and merger history of massive black holes,
- to explore stellar populations and dynamics in galactic nuclei,
- to survey compact stellar-mass binaries in our Galaxy, and
- to confront General Relativity with observations and to probe new physics and cosmology with gravitational waves.

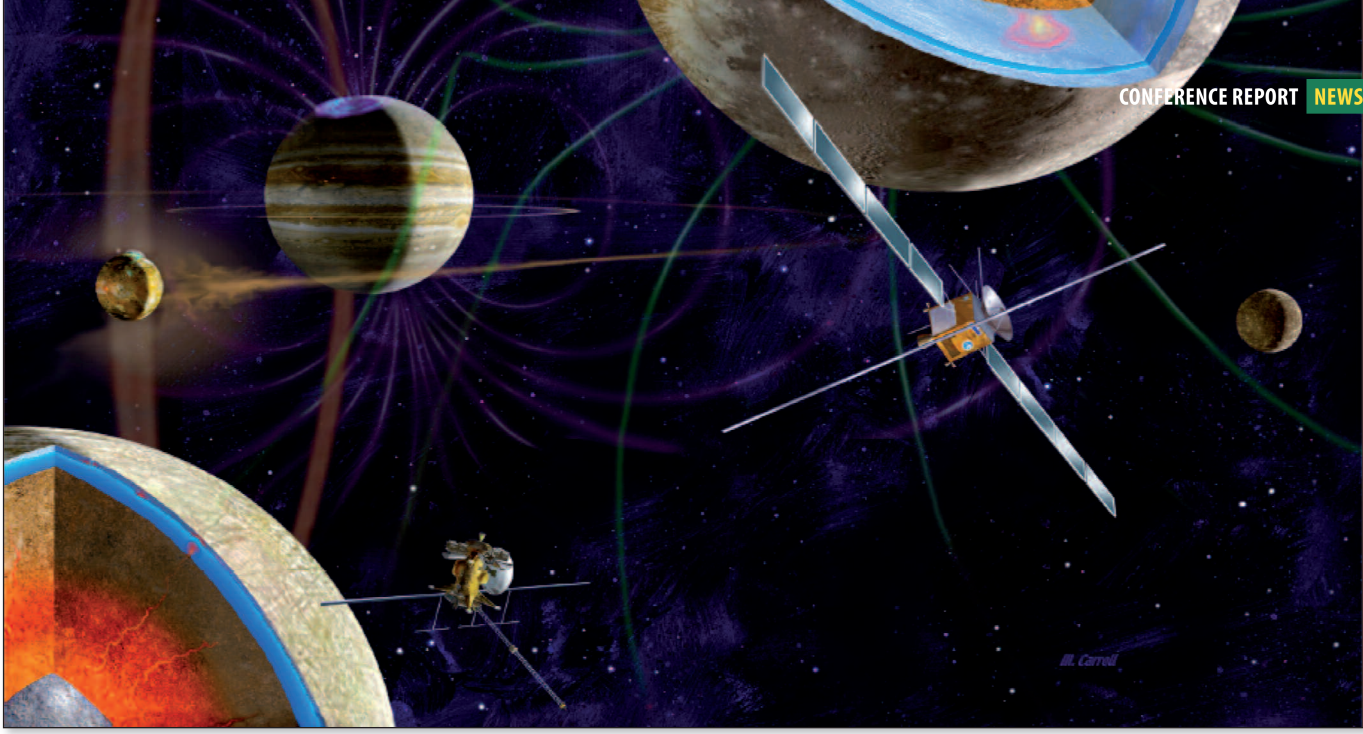
LISA records the 'sound of sirens' emitting gravitational waves

The sensitivity of *LISA* will be such that, within one year, one expects to 'see' from 1 to 1000 massive black hole mergers throughout the entire Universe and from 1 to 1000 inspirals of objects with extreme mass ratio. 'Seeing' these sources is not the right word, though, since *LISA* does not produce images. In contrast, *LISA* records the 'sound of sirens' emitting gravitational waves. But the accuracy of measurement is superior to that of electromagnetic radiation. As an example we quote from the Assessment Report a statement about the Hubble constant: "A few massive inspiral events, or a large number of extreme mass-ratio inspiral events, at redshift less than or of order unity may lead to a reliable measurement of the Hubble constant H_0 to better than 1%, about a factor of five improvement over current techniques." At the presentation in Paris, an audio simulation also vividly demonstrated how unequivocal proof is obtained that a given object has disappeared into a black hole: the 'siren's' signal suddenly stops!

The other two L-class missions presented in early February together with *LISA* — *IXO* and *EJSM-Laplace* — promise, respectively, observations of the hot Universe by a powerful X-ray telescope and an actual visit to, and exploration of the Jupiter system.

▼ FIG. 1: A collage of (i) a numerical simulation of the possible structure of gravitational wave signals caused by a collision of a black hole and a neutron star, (ii) Earth and Moon orbiting the Sun, with (iii) the triangle that is set up by the three *LISA* spacecraft trailing the Earth. The three resulting baselines of 5×10^6 km length, along which spacetime strain variations are measured by precision interferometry are shown in red. The insert in the upper left-hand corner depicts the geometrical arrangement and, below, the orbits of the three *LISA* spacecraft. (Image credit: *LISA* Assessment Study Report, ESA/SRE(2011)3). Numerical simulations provide insights into the possible structure of gravitational wave signals that can be used as templates in the search for identifying gravitational waves in the data acquired by *LISA*.





▲ **FIG. 2:** Artist's impression of the two *EJSM-Laplace* spacecraft exploring the world around a gas giant. The cuts revealing the internal structure of Europa and Ganymede show the inferred sub-surface oceans, which may harbour life, *i.e.*, may be habitats in the solar system beyond that of Earth.

The International X-ray Observatory *IXO* has its main sight on massive black holes as well. Its scientific goals are stated to be:

- The Evolving Violent Universe – finding massive black holes growing in the centres of galaxies, and understanding how they influence the formation and growth of the host galaxy;
- The Universe taking shape – revealing how the baryonic component of the Universe formed large-scale structures and understanding how and when the Universe was chemically enriched by supernovae;
- Matter under extreme conditions – studying how matter behaves in the strongest gravitational fields around black holes and at very high densities in the interiors of neutron stars and accretion disks.

IXO will use the 'Silicon Pore Optics' technology to achieve ten times more collecting area at 1 keV than any previous X-ray observatory. Its angular resolution will be 5 arc seconds.

The Europa Jupiter System Mission uses two sister spacecraft on complementary trajectories and carrying complementary instrumentation to characterise the Galilean moons Europa and Ganymede as planetary objects and potential habitats. The Jupiter Ganymede Orbiter (JGO) will be provided and launched by ESA, the Jupiter Europa Orbiter (JEO) by NASA.

The NASA mission Galileo, which had been launched in 1995 to explore Jupiter and its moons as a follow-up on the still earlier Pioneer and Voyager missions, has discovered strong evidence that sub-surface oceans could be hidden under an icy crust in Europa, Ganymede and Callisto. It was also found that strong tidal interaction and other energy make Ganymede and Europa internally active. The promoters of EJSM therefore state: «The discovery of these sub-surface oceans on these moons led to the emergence of a new habitability paradigm, which considers the icy satellites as habitats.» And the emergence of habitable worlds around gas giants is declared to be the overarching theme of *EJSM-Laplace*. From this follows the most fundamental question to be addressed: «Are there current habitats in the Solar System — besides that of the Earth — with the necessary conditions (organic matter, water, energy, stability and nutrients) to sustain life?»

Besides a solid study of the Jovian system — covering the internal structure, geology, composition, and tenuous exospheres of the icy moons; the composition of the giant planet's atmosphere, magnetosphere and plasma environment — which will also lead to conclusions on the evolution of an 'archetype of gas giants', EJSM will also provide an important link to astrobiology.

The plan is to down-select these missions in June 2011 to one for launch at the start of the next decade. Whether this is actually possible also depends on external conditions, such as the confirmation of the co-operation by the other space agencies mentioned above. Moreover, *LISA*'s technology demonstrating precursor mission, *LISA*-Pathfinder, will be launched in June 2013 only. It is possible that one would want to expect the results of that mission before making a final choice. A further consideration is the outcome of the US Decadal Survey of Astronomy and Astrophysics for the decade 2012-2021, where *LISA* was given a somewhat higher priority than *IXO*.

From Space News: "What will be decided depends on the selection made by [European] science advisory bodies and on the outcome of discussions with NASA and JAXA," said Fabio Favata, head of the science planning office at the 18-nation European Space Agency (ESA). ■

Martin Huber,
Former President of the EPS

ERRATUM

The author of the article "The appearance of the tau-neutrino" in EPN 41/6 wishes to specify that the correct caption of Fig. 2 on page 26 is "From left to right: A. Bettini, Marie-Gabrielle Philippe, sous-Préfet du Pays de Gex (FR), and L. Maiani celebrating at the "ground breaking" event for the CNGS project on 12/10/2000. Photo CERN"

Highlights from European journals

PARTICLE PHYSICS

Cosmic rays: A (partly) untold story

The work behind the discovery of cosmic rays, a milestone in science, involved many scientists in Europe and the New World fascinated by the puzzling penetrating radiation, and took place during a period characterized by lack of communication and by nationalism caused primarily by World War I.
It took eventually from the turn of the century until 1926 before the extraterrestrial nature of the penetrating radiation was generally accepted.

▲ Domenico Pacini in May 1910 (32 years old) while making a measurement. (Courtesy of the Pacini family.)

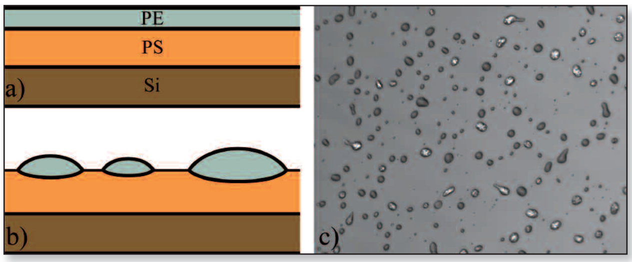
In the work that culminated with high altitude balloon flights, many important contributions have been forgotten and in particular those of Domenico Pacini, who, in June 1911, demonstrated by studying the decrease of radioactivity with an electroscope immersed in water that the radiation today called "cosmic rays" could not come from the crust of the Earth. This was the first time in which the technique of comparison of undersea measurements with measurements at sea level has been used to obtain a result in fundamental physics; this technique will be used in neutrino experiments of the near future.
This article carefully retraces the history of the discovery of cosmic rays and puts the unfolding story in both the political and scientific contexts. With the help of material previously unknown to the history of science, for example the nominations for the Nobel prizes related to cosmic ray research and the relevant internal reports of the Swedish Royal Academy of Science, and letters exchanged between Victor Hess and Pacini, a more complete view of this fascinating discovery is possible. ■

▮▮▮ **P. Carlson** and **A. De Angelis**,
'Nationalism and internationalism in science: the case of the discovery of cosmic rays', *Eur. Phys. J. H* **36**, 309 (2010)

CONDENSED MATTER

Crystal nucleation on polymer droplets

A nucleation site initiates the birth of a crystal. In most cases, take for example the dust particle in a snowflake, nucleation starts from a *heterogenous* defect. *Homogenous* nucleation is more elusive because of the prevalence of defects in any bulk sample. Crystallisation in tiny droplets alleviates this difficulty in a manner that is conceptually simple: subdivide the system into more domains than the number of defects. If the domains greatly outnumber the defects then only the homogenous mechanism can induce nucleation in a defect free compartment.
Such an approach has been used here to investigate nucleation in polyethylene (PE) droplets. At high temperatures, a thin PE film de-wets from an unfavourable surface forming tiny droplets, much like water beading up on a waxy leaf (Fig.(b)). The resulting sample geometry is ideal: thousands of droplets ranging in size can be monitored simultaneously with optical microscopy, with a nucleation event easily distinguishable by the rapid growth of the crystal (Fig.(c)). Each droplet becomes an isolated independent nucleation experiment. By investigating thousands of droplets super-cooled well below the melting temperature, studies of homogenous nucleation become straightforward.



▲ a) A Si substrate with a polystyrene (PS) layer forms an unfavourable surface for a thin PE film. b) Upon heating, the unstable film de-wets to form droplets. c) Optical microscopy image (500 µm wide). Amorphous droplets appear dark, while crystalline droplets become bright.

Relating the probability of homogenous nucleation to the size of the droplet, the authors show that nucleation is surface-activated. Stated most simply, a droplet with twice the surface area is twice as likely to nucleate, indicating that the perturbation induced by the interface reduces the intrinsic activation barrier to crystal nucleation. ■

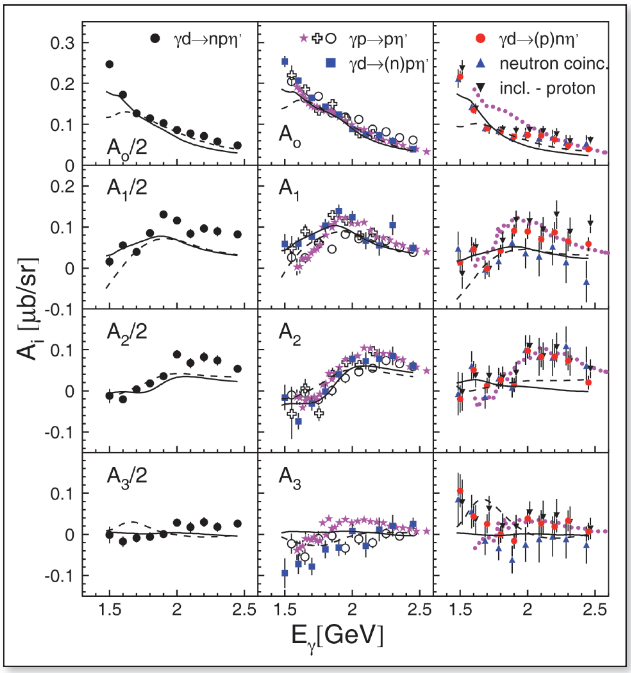
▮▮▮ **J.L. Carvalho** and **K. Dalnoki-Veress**,
'Surface nucleation in the crystallisation of polyethylene droplets', *Eur. Phys. J. E* **34**:6 (2011)

PARTICLE PHYSICS

Photoproduction of *η′*-mesons off the deuteron

A key to our understanding of Quantum Chromodynamics (QCD) in the strong regime is our ability to reproduce the hadronic excitation spectrum. Up to now, and due to their limited predictive power, quark models forecast of this spectrum at high excitation energies is unsatisfactory and is dubbed "the missing resonances problem". To explore the high excitation energies in the hadron spectrum production or scattering of heavier mesons from a nucleon target is essential.

In a recent *tour-de-force* experiment, I. Jaegle *et al.* report on an impressive first measurement of η′ photoproduction off a deuteron target at beam energies between 1.47 - 2.45 GeV at the tagged photon beam of the ELSA electron accelerator. Differential cross sections with a wide angular coverage were derived for quasi-free production both on protons and neutrons validating the quasi-free picture. And the first estimate of the coherent $\gamma d \rightarrow d\eta'$ contribution is found consistent with an impulse approximation, pointing to a viable isospin composition of model amplitudes and weak final state interactions.



▲ From left to right of panels, one has the inclusive reaction data first, then the world free and, this experiment, quasi-free proton data and last quasi-free neutron data from coincidence and an extraction of proton from deuteron inclusive data. Solid lines: solution (I) NH model, dashed lines: η′-MAID for neutron and dotted lines: CLAS proton data.

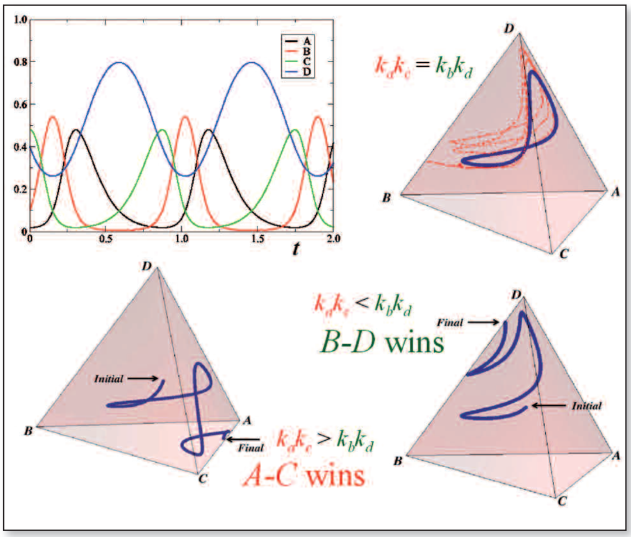
Legendre polynomials coefficients from angular distributions fits of this experiment and world data are reported in the Fig. where proton and neutron cross sections for photon energies above 2 GeV, in a region where contributions from t-channel exchange are important, display a similar behaviour. At lower photon energies from where the proton cross-section peaks, the behaviour points to different resonance contributions and would require polarization observables for future investigation. ■

I. Jaegle *et al.* (the CBELSA/TAPS Collaboration), 'Photoproduction of *η′*-mesons off the deuteron', *Eur. Phys. J. A* **47**, 1 (2011)

CONDENSED MATTER

Mean-field theory and stochastic evolution

Population dynamics is a venerable and widely applicable subject. Over the last two centuries, many studies provided valuable insights into various phenomena, *e.g.*, the emergence of biodiversity and fitness/extinction, while novelties are continually being discovered. Specifically, recent investigations of three species competing cyclically (*e.g.*, rock-paper-scissors game) revealed rich and complex behaviours, whether the populations are well-mixed or dwelling on one- or two-dimensional lattices. Indeed, the well-mixed system displayed surprising survival probabilities: The species with the slowest consumption rate wins, leading to a popularized headline "Survival of the Weakest." Fascinating properties were also found in systems with spatial structure, including formation of complex patterns and mobility effects. Many aspects can be understood by exploiting techniques from statistical physics and non-linear dynamics.



▲ Opposing pairs (A-C, B-D) of equal strength evolve deterministically on a closed orbit (blue loop), oscillating endlessly (upper left). An example of stochastic trajectories is shown in red (dashed line). Lower panels display systems with identical initial conditions but different strengths, ending at opposite edges.

The work focuses on **four** cyclically competing species. Unlike the 3-species case, ours allows final states with coexisting ▶

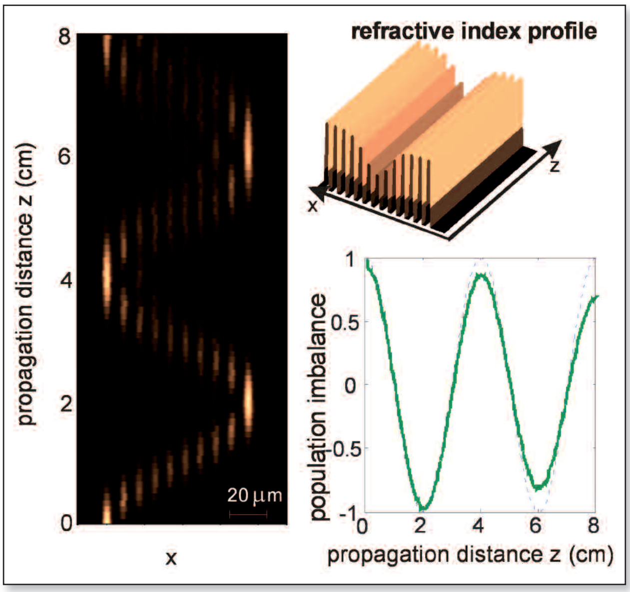
pairs. The reason is simple: Resembling the game of Bridge, the four form two opposing teams of ally-pairs. For each pair, the **product** of their consumption rates determines if it wins or loses. From a master equation for the full stochastic problem, an approximate set of rate equations (ODE's) is derived. Predictions from the latter typically agree well with simulations. Instead of the weakest surviving, the observations support a different maxim: "The prey of the prey of the weakest is the least likely to survive." Intuitively reasonable, this principle also applies to the special 3-species case! Meanwhile, a variety of intriguing extinction probabilities, discovered through simulations, provides numerous challenges for future research. ■

S.O. Case, C.H. Durney, M. Pleimling and **R.K.P. Zia**, 'Cyclic competition of four species: Mean-field theory and stochastic evolution', *EPL* **92**, 58003 (2010)

QUANTUM PHYSICS

Two-site Bose-Hubbard model in waveguides

Light transport in waveguide lattices has provided over the past decade a test bench to visualize the classical analogues of a wide variety of coherent single-particle quantum phenomena generally encountered in condensed matter or matter wave systems. Since photons in linear optical structures do not interact, it is a common belief that the use of photonics as a model system for quantum physics carries the intrinsic drawback of being limited to visualize single-particle phenomena, missing the possibility to simulate the richer physics of interacting many-particle systems.



▲ Optical realization of the two-site Bose-Hubbard model based on light transport in a waveguide array with engineered refractive index profile. The figure shows an example of Josephson oscillations in Fock space, in which light trapped in the various waveguides gives the occupation probability of the Fock states.

In this paper, the author has now pushed the realm of quantum-optical analogies beyond the single-particle phenomena, demonstrating that linear photonics can provide an accessible laboratory system to visualize in a purely classical setting the very basic dynamical aspects embodied in the physics of interacting quantum particles. In particular, a classical realization of the famous Bose-Hubbard Hamiltonian, which provides a paradigmatic model to describe the physics of strongly interacting bosons, has been theoretically proposed for light transport in engineered waveguide lattices. The author has shown that spatial propagation of light waves along the photonic crystal structure mimics in the Fock space the temporal dynamics of ultracold bosonic atoms trapped in a double-well potential, the so-called bosonic junction. While for ultracold atoms the full multi-particle dynamics is typically not accessible, the present work proposes a new route to simulate the Bose-Hubbard model which overcomes such a limitation, thus opening a new route to the realization of classical simulators of many-particle quantum physics. ■

S. Longhi,
Optical realization of the two-site Bose-Hubbard model in waveguide lattices, *J. Phys. B: At. Mol. Opt. Phys.* **44**, 051001 (2011)

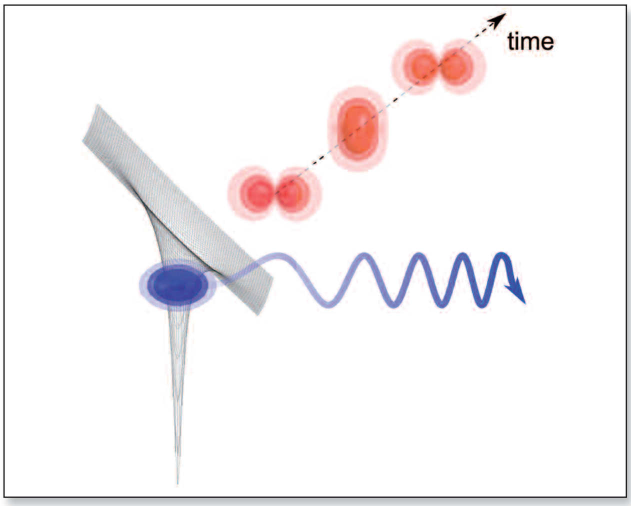
MOLECULAR PHYSICS

A tunnelling probe for molecular currents

Internal electron currents in molecules play a crucial role in chemical and biological processes, like charge transport in cellular respiration and in photosynthesis. Since electron currents can be ultrafast and escape most traditional probes, they are hard to capture. It is shown that laser-induced tunnel ionization is a powerful probe of internal currents.

An intense infrared laser field acts on a molecule essentially as the tip of a scanning tunnelling microscope (STM): it extracts a weakly bound electron through a tunnelling barrier. The electron is not equally likely to tunnel out in any direction when the orbital has an asymmetric shape – this has led to the development of the molecular STM, a probe of the static electronic structure.

Unlike in the STM, tunnelling in a laser field is an attosecond phenomenon and therefore potentially launches attosecond electron dynamics. Such dynamics has also been inferred from high-harmonic generation, but that method is insensitive to the actual degree of electronic coherence. Here, that laser-induced tunnelling is shown to directly probe time-dependent deformations of the electron cloud and map them on two complementary observables: the total tunnelling current and its momentum distribution.



▲ Laser-induced tunnelling ionization of a multi-electron system (blue wavefunction) triggers charge oscillations of the created electron vacancy (shown in red). A second tunnelling step probes the temporal rearrangement of the vacancy, enabling its characterization.

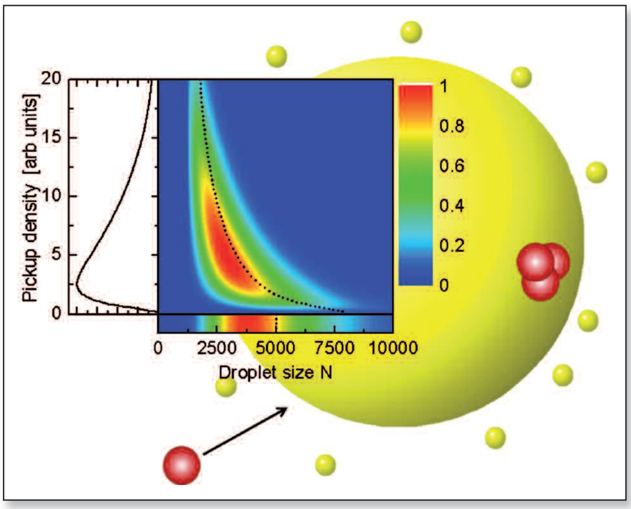
One studies spin-orbit dynamics in a rare gas ion, the simplest example of an internal electron current launched by ionization. Such currents are ubiquitous in molecules, where the sudden departure of an electron triggers an internal rearrangement. Laser-induced tunnelling is a powerful probe of such fundamental events.
A new aspect offered by the proposed concept is the control over electronic dynamics and double ionization. One shows that the spin state (*i.e.* the entanglement) of the ejected electron pair can be controlled offering interesting opportunities for quantum control. ■

▮▮▮ **H.J. Wörner** and **P.B. Corkum**,
'Imaging and controlling multi-electron dynamics by laser-induced tunnel ionization', *J. Phys. B: At. Mol. Opt. Phys.* **44**, 041001 (2011)

CONDENSED MATTER

Formation of alkali clusters **attached to helium nano-droplets**

Helium nanodroplets provide a unique matrix for the spectroscopy of embedded species. The ability to form clusters inside the droplet by successive pick-up of single atoms provides a novel method for the study of small clusters isolated in a 370 mK cold, weakly interacting environment. However, the formed clusters exist in a wide size distribution and cannot be size selected. This fact often hinders the interpretation of the experimental data.
A common technique to determine the size distribution is recording the pick-up statistics. Helium droplets collect atoms or molecules via inelastic collisions when passing a pick-up cell. Monitoring the intensity of a cluster-correlated signal as a function of the pressure in the pick-up cell gives access to the pick-up statistics. Experiments have shown that the size distribution often deviates from the expected Poissonian statistics, in particular in the case of alkali atoms. In this paper the influence of the effects of droplet shrinking, momentum transfer and cluster desorption on the pick-up statistics are simulated. Our results compare well with measured pick-up statistics of alkali clusters and demonstrate the different effects on the terminal size distributions.



▲ Illustration of cluster formation upon successive pick-up of atoms by a helium nano-droplet. The inset shows the simulated formation probability of a Na_3 cluster as a function of droplet size and the density of sodium atoms.

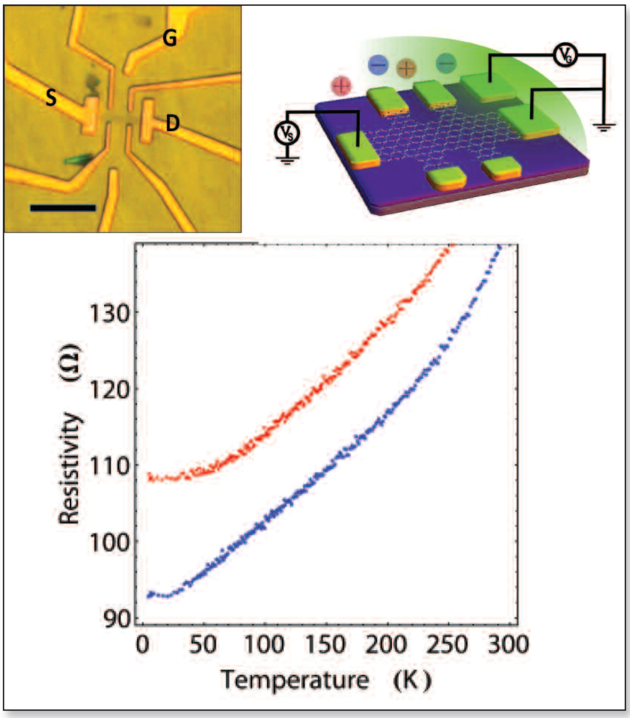
In addition information on the spin statistics of formed clusters can be derived from the presented data. ■

▮▮▮ **O. Bünermann** and **F. Stienkemeier**,
'Modelling the formation of alkali clusters attached to helium nano-droplets and the abundance of high-spin states', *Eur. Phys. J. D* **61**, 645 (2011)

APPLIED PHYSICS

Graphene transport with a polymer electrolyte gate

The electronic properties of graphene have received wide recognition, most notably the award of the 2010 physics Nobel Prize. In graphene's two-dimensional hexagonal lattice, the electrons behave as massless chiral Fermions obeying the Dirac equation. The exotic nature of these quasi-particles and their low carrier density is at the heart of several interesting phenomena, including the unconventional quantum Hall effect and Klein tunneling. Raising the density of charge carriers in graphene can have several implications including the possibility for van Hove singularity driven high-T_c superconductivity. From a fundamental point of view, the high carrier densities substantially modify the interactions between quasi-particles in this two-dimensional crystal.



▲ The figure shows the temperature dependence of graphene resistivity at high (red) and intermediate (blue) carrier densities. Since phonon modes follow the Bose-Einstein law, the scattering of electrons from acoustic phonons is strongly suppressed at low temperatures, thus leading to power-law dependence. The temperature scale that determines this suppression increases linearly with the Fermi level. At high doping, the resistivity is weakly density-dependent. A detailed analysis shows there is an important contribution from neutral weak scatterers. Top panel: Optical image and schematics of graphene device coated with polymer electrolyte gate.

In this report, graphene devices in Hall-bar geometry are gated with a polymer electrolyte to realize carrier densities an order of magnitude higher than achieved by conventional methods. At these densities, the carriers sufficiently screen the long-range interactions. This allows fully appreciating the importance of various neutral defects on the graphene lattice. In contrast to metals, the temperature scale for quantum suppression of acoustic-phonon scattering in graphene is significantly gate-tunable. The phenomenon is readily observed to high temperatures at high carrier densities. ■

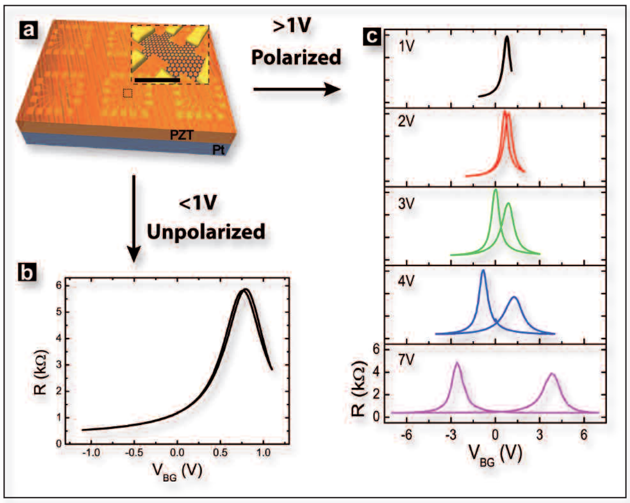
▮▮▮ **A. Pachoud**, **M. Jaiswal**, **P.K. Ang**, **K.P. Loh** and **B. Özyilmaz**, 'Graphene transport at high carrier densities using a polymer electrolyte gate', *EPL* **92**, 27001 (2010).

APPLIED PHYSICS

Graphene/ferroelectric hybrid devices

The soaring demands on non-volatile memory for ultra-portable electronic devices have grown NAND flash into a multi-billion dollar business. As a Si-CMOS based technology, NAND flash provides the most aggressive scalability, closely following the-state-of-art semiconductor manufacturing process. NAND flash also takes advantage of its relatively simple floating-gate structure and seamless integration with Si-CMOS logics, leading to significantly lower production cost over other competing non-volatile technologies such as FeRAM and MRAM.

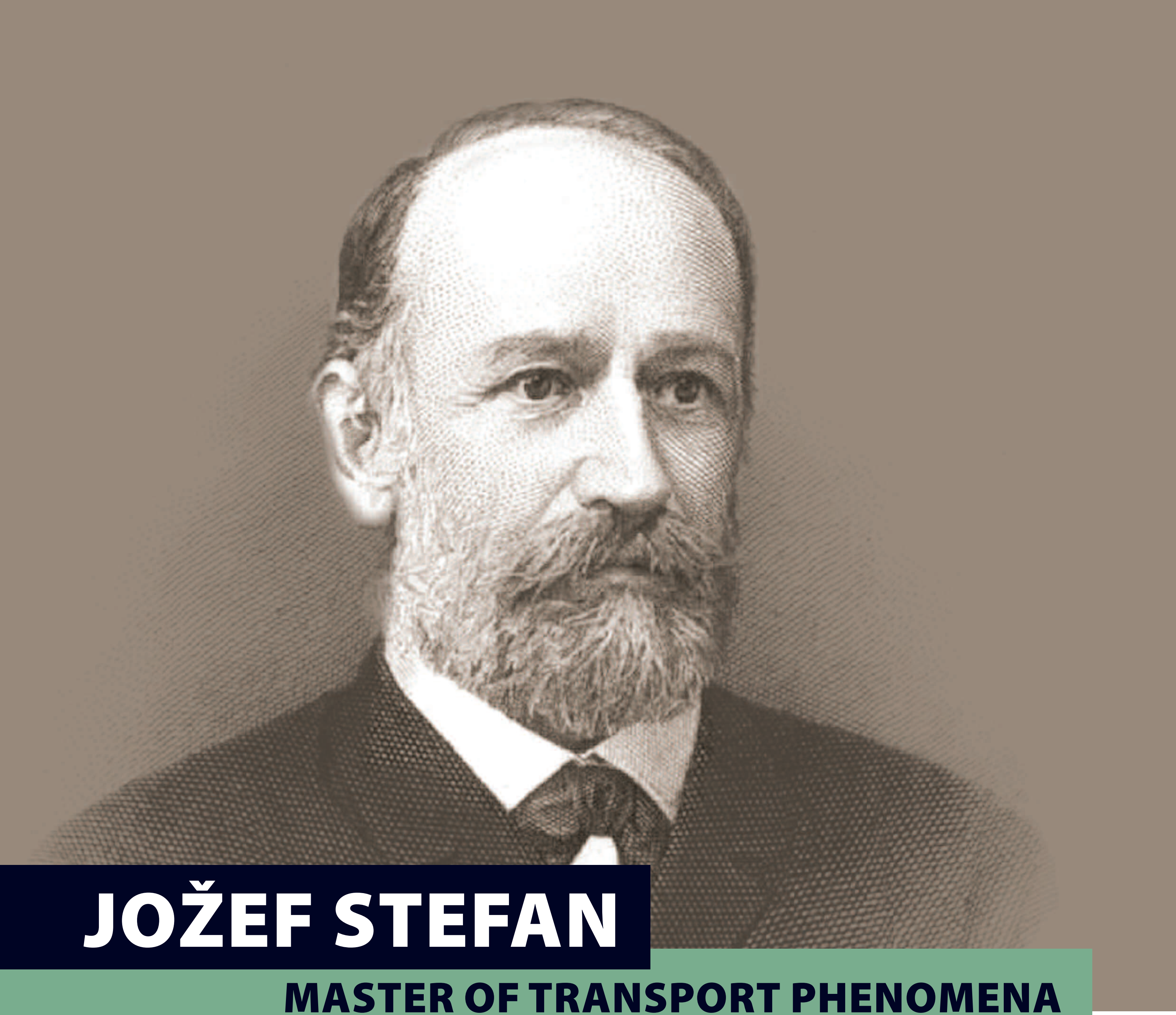
Graphene, with its ultra-high mobility and almost unlimited scalability down to atomic scale, is considered now as one of the most promising candidates for replacing Si. Graphene-based non-volatile memory has also been demonstrated very recently. However, a seamless solution for integrating graphene transistors and non-volatile memory remains a challenge.



▲ The figure shows the device operations of GFeFETs on PZT (Fig. a) with different local ferroelectric polarization magnitude. In the linear regime of PZT (Fig. b), ultra-low-voltage operation of graphene field effect transistors within ±1 V with maximum doping exceeding 10^{13} cm^{-2} and on-off ratios larger than 10 times is demonstrated. After polarizing PZT (Fig. c), switching of graphene field effect transistors are characterized by pronounced resistance hysteresis, suitable for ultra-fast non-volatile electronics.

Here, Zheng *et al.* demonstrate the wafer-scale patterning and device operations of Cu-CVD graphene-ferroelectric field effect transistors (GFeFETs) on ferroelectric $Pb(Zr_{0.3}Ti_{0.7})O_3$ (PZT) substrates, integrating both transistor and non-volatile memory functionalities on the same chip. In the linear regime of PZT, ultra-low-voltage operations of GFeFETs within ±1V can be used as controlling transistors for addressing and reading/writing of memory unit cells. After polarizing PZT, the hysteretic switching of GFeFETs is ideal for ultra-fast non-volatile data storage. The combination of high-quality Cu-CVD graphene and functional substrates will not only greatly speed up the studies of all graphene-based electronics but also open up a new route in exploring new graphene physics and functionalities. ■

▮▮▮ **Yi Zheng**, **Guang-Xin Ni**, **Sukang Bae**, **Chun-Xiao Cong**, **Orhan Kahya**, **Chee-Tat Toh**, **Hye Ri Kim**, **Danho Im**, **Ting Yu**, **Jong Hyun Ahn**, **Byung Hee Hong** and **Barbaros Özyilmaz**, 'Wafer-scale graphene/ferroelectric hybrid devices for low-voltage electronics', *EPL* **93**, 17002 (2011)



JOŽEF STEFAN

MASTER OF TRANSPORT PHENOMENA

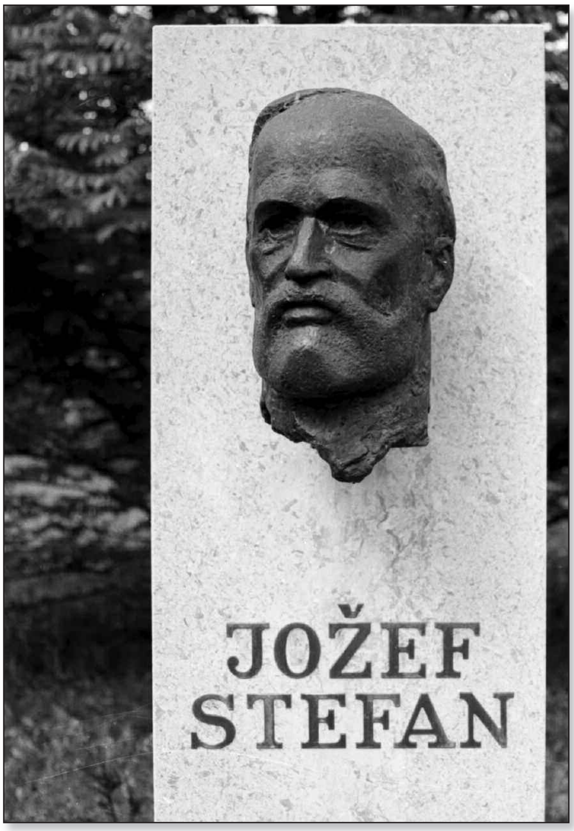
■ J. Strnad - Faculty of Mathematics and Physics, University of Ljubljana, Ljubljana, Slovenija - DOI: 10.1051/epn/2011201

Jožef Stefan is famous primarily for the Stefan-Boltzmann radiation law. But this remarkable physicist made original contributions in all fields of physics: fluid flow, mechanical oscillations, polarization of light, double refraction, interference and wavelength measurements. He also measured the heat conductivity of gases. He was among the few physicists who promoted Maxwell's electrodynamics theory.

In Stefan's life there are two distinct periods. During the first Stefan followed many interests including literature, whilst the second was devoted entirely to physics. Stefan was a Slovenian who achieved his scientific successes in Vienna as a citizen of Austria (after 1867 Austria-Hungary).

Jožef Stefan (Fig. 1) was born on March 24, 1835 at St. Peter, nowadays part of Celovec (Klagenfurt) [1]-[5]. His teachers soon noticed his talents. In 1845 he entered the gymnasium and in 1853 he went to the University of Vienna to study mathematics and physics. In his youth he loved to sing and took part in choirs which he also organized. Under the tutorship of his teacher and together with his schoolmates he founded a hand-written Slovenian literary journal. He wrote poems for it, which were later published in Slovenian journals appearing in Austria. He did not overestimate the value of his poems, but he could well have become a Slovenian poet had he not chosen ▶

▲ Jožef Stefan (1835-1893)



▶ FIG. 1: Jožef Stefan (March 24, 1835 – January 7, 1893). Bust in front of the J. Stefan Institute in Ljubljana

"This humble, hard-working scientist made a permanent impact on the field of heat transfer. It is remarkable that a single figure, about whom so little is known, could make such important contributions to conduction, convection and radiation heat transfer."

J. Crepeau [4]

▶ otherwise. In these journals he published also articles referring to a broad range of subjects from mathematics and physics to literature and society. After 1859 he did not publish any more texts in Slovenian. This was probably due to his growing involvement in physics.

In 1857 Stefan passed the teacher's examination. On his own initiative he began research in theoretical physics and sent a paper to the Academy of Science. There he held a lecture which raised the interest of Karl Ludwig, a well-known professor of physiology. Stefan accepted his invitation to collaborate in experimental work at the Institute of Physiology, as a position at the Institute of Physics did not seem within reach.

In 1858 Stefan passed the philosophical *rigorosum* at the university and obtained his PhD. In 1860 he was elected a corresponding member of the Academy. Nevertheless, the possibility for him to do experimental work at the Institute of Physics seemed very remote.

However, the situation changed in 1863. Aged 28, he became the youngest full professor in the country. He also obtained a position at the Institute of Physics and in 1865 he became its Director. He was elected a full member of the Academy of Science, and for one of his publications he was awarded the Lieben prize. At that point, all Stefan's wishes regarding his scientific carrier were accomplished.

As he dedicated himself to work, he shut himself off from the outside world. Apparently, he often did not leave the Institute staying there for days. Only after 1891, when he married a widow, it seemed that at last he relaxed and regained his cheerfulness. At the end of 1892 he had an apoplectic stroke and died on January 7, 1893.

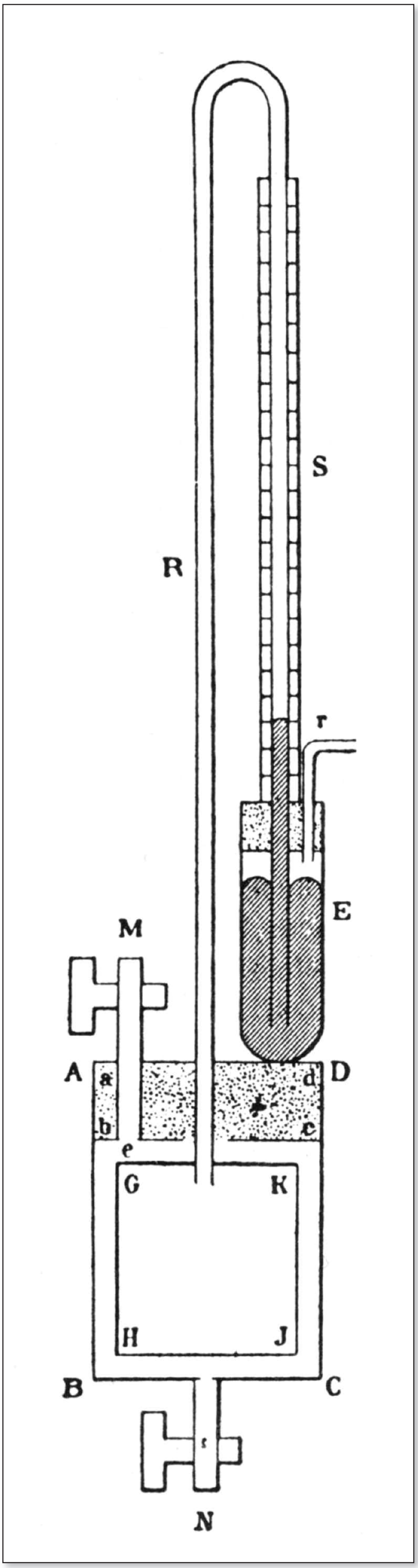
Heat conduction in gases

At the time there were doubts whether heat conduction in gases could be measured at all. After some trials in 1872, Stefan invented the "diathermometer" (Fig. 2) [6], consisting of a cylinder made of thin copper or brass sheet surrounded by a larger cylinder. The small gap between the two cylinders was filled with the gas under investigation. The temperature of the outer cylinder was controlled by a mixture of ice and water. The gas in the inner cylinder, initially at room temperature, cooled down through heat conduction across the gas-filled gap. This caused the pressure in the inner cylinder, measured by a mercury manometer, to reduce. The rate of pressure change yielded the heat conductivity of the gas in the gap. This gap was sufficiently narrow for convection not to develop. A reduction of the gas pressure inside the gap to about half the normal air pressure did not alter the result. This was in agreement with Maxwell's prediction that the thermal conductivity of gases is independent of pressure. In 1875 Stefan compared the conductivities of a number of gases [6] and obtained the values 0.0234 W/(K.m) for air and 0.188 W/(K.m) for hydrogen, the current values being 0.0241 W/(K.m) and 0.168 W/(K.m), respectively.

Stefan's radiation law

At the time, the radiation of heat was described by an equation derived by Pierre Louis Dulong and Alexis Thérese Petit. This derivation rested on observing the cooling rate of a large mercury thermometer bulb placed inside an even larger spherical vessel. The vessel was evacuated to a pressure of some millibars, such as to eliminate the influence of convection and conduction. Stefan realised that conduction still played a significant role and set out to find a better way to describe thermal radiation [7].

In 1864 John Tyndall investigated "obscure radiation", now known as infrared light, by electrically heating a platinum wire. In the part of the spectrum beyond the red he fixed a thermopile and measured the current as a



◄ **FIG. 2:** Stefan's diathermometer [6]. ABCD: hollow copper cylinder; abcd: small copper vessel filled with cork; GHKJ: smaller hollow copper cylinder; r: small tube for adjusting the initial reading of the mercury manometer SE.

function of the colour of the wire. Among his numerous data, one stated that the wire at `full white heat' radiates 11,7-times more energy than 'at faint red heat'. Adolph Wüllner included Tyndall's data in a new edition of his physics textbook, attributing to 'faint red heat' a temperature of 525 °C and to 'full white heat' a temperature of 1200 °C. Stefan used these data in 1879, transforming them to absolute temperature and observing that by raising the ratio 1473/798 = 1,85 to the fourth power it equalled 11.6. His bold conclusion was that the heat radiated is proportional to the fourth power of the absolute temperature: $j = \sigma T^4$. Here j is the energy density flow emitted by a black body at absolute temperature T. He also estimated the proportionality coefficient, the Stefan constant σ, to be $4.5 \cdot 10^{8}\,\mathrm{W/(m^2K^4)}$ compared with the current value of $5.67 \cdot 10^{-8}\,\mathrm{W/(m^2K^4)}$. For the surface temperature of the sun he obtained the first reasonable value of about 5500 °C.

Stefan was a bit lucky. Tyndall's measurement referred to infrared light and not to the radiation at all wavelengths contained in Stefan's law. Furthermore, for a platinum wire the law does not apply since its emissivity is not unity, and Wüllner's temperatures were chosen somewhat arbitrarily.

In 1884 Ludwig Boltzmann, a former student of Stefan's, deduced the law by studying an ideal thermal engine working with radiation. This law is now known as the *Stefan-Boltzmann law*. Today, Stefan's law and the Stefan constant derive from Planck's law, which launched the start of quantum physics in 1900.

Diffusion and evaporation

In the kinetic theory of gases, Stefan considered the motion of molecules in gas mixtures [8]. He studied collisions of molecules and their rates as well as the changes of velocities and discussed equations that were partially derived by Maxwell. He independently discovered the Maxwell-Stefan or Stefan-Maxwell diffusion theory which stands as a model for diffusion in multicomponent systems [9].

Evaporation of water is important for meteorologists. Stefan chose to carry out experiments with ether vapour instead. He contained ether in a vertical tube and, by observing the speed at which the surface of the liquid ►

"Stefan published in total 83 papers, almost without exception in the Proceedings of the Vienna Academy of Science. Some 13 were subsequently published in Poggendorffs and 10 later on in Wiedemanns Annalen der Physik und Chemie. A few were reported in The Philosophical Magazine [2,3]."

▲ FIG. 3: The J. Stefan Institute in Ljubljana. Thanks are due to Marjan Smerke and Marjan Verč for the preparation of figures.

▶ lowered, he came to some conclusions which nowadays are described by the diffusion law. He also measured the diffusion constant of ether vapour in air [10]. In Stefan´s experiment the air does not move while the vapour does. Thus, a macroscopic motion of the vapour, expressed by the quantity $\rho_v v$, with ρ_v the partial density of the vapour and v the centre-of-mass velocity of the mixture, is derived, known as the *Stefan flow* by contemporary meteorologists. In clouds, this represents the flow of water vapour towards growing water droplets, carrying with it aerosol particles, thereby cleansing the surrounding air. Of course, the situation in a cloud is complicated by geometry and heat released at condensation [11].

Stefan's problem

Stefan also considered heat flow in a phase change. The surface of a layer of water at temperature $T_0 = 0$ °C is brought into contact with a heat reservoir at temperature $T < T_0$. A layer of ice will now form on the water at T_0. The thickness of the ice layer and its temperature profile are to be determined. Based on the problem of heat conduction in a layer without phase change Stefan found a solution in closed form, thus solving a "problem with a moving boundary". Today this is called the *Stefan problem*.

Electrodynamics

Stefan also studied Maxwell's electrodynamics and obtained valuable results concerning the basic equations, the induction law, magnetic and electric forces, the force of electromagnets, thermo-magnetic motors, the inductivity of coils. Being appointed chairman of the scientific committee of the electrical world exhibition in Vienna 1883 he contributed six papers to the *Proceedings* in 1886, in which he considered the measurement of characteristic quantities of electric generators. He was elected the first chairman of the Austrian Society of Electrical Engineering and editor-in-chief of its publications.

Stefan was a devoted lecturer. He was extremely active, as a provisional list of his duties around 1883 shows: Vice-Chairman of the Academy of Science and secretary of its scientific-mathematical class, Rector of the Vienna University, Dean of the Faculty of Philosophy, member of the faculty board, Director of the Institute of Physics, a member of the committee on explosions of mining gases. In 1885, he was appointed chairman on the international committee defining the international normal tone. He received Austrian and international honours. He is also considered founder of the Vienna school of physics. In Ljubljana a great research institute bears his name (Fig. 3). ■

"The Stefan number S_{te} is defined in phase-change processes as the ratio between sensible heat and latent heat: $S_{te} = c_p T/L$ with c_p specific heat at constant pressure, L latent heat, T temperature difference between phases."

About the author

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Capricious suntime

At what time of the day does the sun reach its highest point, or culmination point, when its position is exactly in the South? The answer to this question is not so trivial. For one thing, it depends on our location within our time zone. For Berlin, which is near the Eastern end of the Central European time zone, it may happen around noon, whereas in Paris it may be close to 1 p.m. (we ignore the daylight saving time which adds an extra hour in the summer).

But even for a fixed location, the time at which the sun reaches its culmination point varies throughout the year in a surprising way. In other words: a sundial, however accurately positioned, will show capricious deviations through the seasons: the solar time on the sundial will almost always run slow or fast with respect to the 'mean solar time' on our watch. It's all determined by the rotation of the earth around its axis, combined with its orbit around the sun.

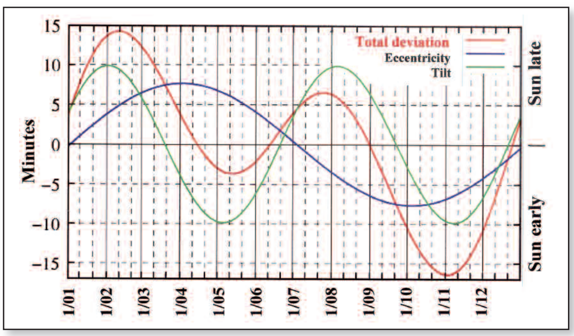
The first thing we realise is that, from one day to the next, the earth needs to rotate a bit more than 360 degrees for us to see the sun in the South again. The reason is obvious. During a day, the earth moves a bit further in its orbit around the sun and thus needs to turn a little extra to bring the sun back to the same place (remember that the rotational direction of the earth around its axis *and* of its orbit around the sun are both counterclockwise). Now, if the earth were well-behaved, and would move in a circular orbit around the sun, with its rotational axis perpendicular to its orbital plane, this would be the end of the story.

But there are two complications, both of which cause deviations. The first one is the *elliptical* orbit of the earth. In fact, the earth is 3% closer to the sun at the beginning of January than at the beginning of July. So, the globe must rotate just a bit longer in January to have the sun back in the South than in July; just think of Kepler's law. The result is that the solar time will gradually deviate from the time on our watch. We expect this 'eccentricity effect' to show a sine-like behaviour with a period of a year.

There is a second, even more important complication. It is due to the fact that the rotational axis of the earth is not perpendicular to the ecliptic, but is tilted by about 23.5 degrees. This is, after all, the cause of our seasons. To understand this 'tilt effect' we must realise that what matters for the deviation in time is the variation of the sun's *horizontal* motion against the stellar background during the year. In mid-summer and mid-winter, when the sun reaches its highest and lowest point of the year, respectively, the solar motion is fully horizontal, so its effect on time is large. By contrast, in spring and autumn, the sun's path also has a vertical component, which is irrelevant here. But it makes the horizontal component smaller in these parts of the year, and so its effect on time. This gives rise to a sine-like deviation having a period of *half* a year.

The two contributions are shown in the graph. Superposition of these 'single and double frequency' curves yields the total deviation of the 'solar noon' from the 'mean solar noon' on our watch. We see that around February 11 the sun is about 15 minutes later than average, and around November 3 about 15 minutes earlier.

So, a sundial in our front yard may be quite charming, but understanding its readings requires a scientist. ■



THE CROATIAN PHYSICAL SOCIETY

A SMALL BUT VIBRANT AND INNOVATIVE ASSOCIATION

■ Silvia Tomic - former President of the Croatian Physical Society - DOI: 10.1051/epn/2011203

The Croatian Physical Society ("Hrvatsko fizikalno drustvo"), www.hfd.hr/en/index.html, was founded in 1990 with the aim to promote and develop scientific, educational and pedagogic activities in the field of physics.

The Croatian Physical Society (CPS) gathers scientists, teachers and students of physics. Currently it has 614 members including 348 scientists, 145 physics teachers, 37 retired members and 84 students (who are not regular members and do not pay the membership fee). The number of CPS members remained steady for years and only recently it has started to show a slight increase. Most of it can be attributed to the growth of the young members category, thanks to the 2010 offer of a one-year free trial membership for freshly graduated physics students. The aim is to attract young physicists into the Society, get them active and see them continue into the regular members category. In order to fulfil its aim CPS acts either directly through its President or through the Divisions defined by the Constitution and through member-proposed projects. The bodies of the Society are President, Vice-president, Assembly, Managing Board, Supervisory Board and Court of Honor (Picture 2). The resources of the Society consist of dues paid by members, grants, gifts and donations, as well as other resources which the Society may derive from its own activities.

▲ **FIG. 1:** Members of CPS Managing Board (MB) and CPS Project Leaders. Back row (left to right): A.Hamzic (former president), B.Pivac (president), I.Aviani (E-school project leader) and M.Basletic (member of MB). Front row: I.Bogdanovic-Radovic (former member of MB), Emina Oreskovic (former member of MB), Maja Planinic (former member of MB), Zvjezdana Roller-Lutz (former vice-president), Vlasta Horvatic (former secretary, member of MB, web master), S.Tomic (past president, member of MB), D.Androic (former member of MB), K.Ilakovac (Editor in Chief of journals Fizika A and B) and Gorjana Jerbic-Zorc (past secretary, member of MB).

National activities

CPS has five divisions (D): Scientific D, Educational D, D for Industrial and Applied Physics, D for Promotion of Physics and Students D.

Scientific D is mostly concerned with questions related to research. It organizes the Scientific Meeting of CPS every two years, at which Croatian researchers gather, present newest research results and discuss issues concerning the status of the research in Croatia. Since 2007 the best physics students from four Croatian universities are invited to attend these meetings and their stay is covered by their host departments and research institutes. Educational D activities are mostly related to elementary and high school teaching. The Division organizes series of lectures on selected topics of contemporary physics for schoolteachers. Also, biannually it organizes the Croatian Symposium on Physics Education. D for Industrial and Applied Physics organizes workshops and round tables at which physicists from academic community and industry meet. D for Promotion of Physics presents the CPS projects on Croatian TV channels, radio stations and in printed and electronic newspapers. The CPS portal is regularly updated with news covering the CPS and EPS actions and events in both Croatian and English. In 2010, the CPS portal registered 27114 visits from 84 countries, out of which 25515 were from Croatia. The most popular project of the Student D is the project named Physics Express, which was initiated during the World Year of Physics in 2005. In the framework of this project, our students visit schools all around Croatia and promote physics by presenting simple experiments to show physics in daily life and by establishing a direct communication with school students. Since 2005, almost 5000 elementary and high school students in about 100 schools have attended the Physics Express presentations (Picture 3).

Since 1992 the Society edits two international peer-reviewed scientific journals FIZIKA A and FIZIKA B in which original research articles covering all branches of physics and its applications, including teaching and history of physics are published in English. The actual tendencies and strong competition in global scientific publishing, and a negative trend of the financial support, raised intense discussions whether to continue to publish national journals or to close them and merge to one of the European Physical Journals editions. As a recent outcome of thorough discussions inside CPS and consultations with EPJ publishers, the Managing Board decided to merge the journal Fizika A to EPJPlus, the electronic journal that has been released in January 2011. In cooperation with the Croatian Mathematical Society, CPS also edits a popular magazine entitled "Mathematical-Physical Journal", founded in 1950, for elementary (age 12-14) and high school students (age 14-18) and physics and mathematics teachers. Each volume (comprising four issues a year) contains articles covering various topics in mathematics, physics, astronomy and informatics, information about national and international competitions, reviews of new science books and theoretical problems addressed to curious students.

Other activities of CPS include projects and groups like Electronic-school of Physics (E-school), the Summer School for Young Physicists and Women in Physics. The latter surveys the status of female physicists in academic community, organizes round tables and search for policy priorities improving the specific situations women encounter as compared to men. E-school was established twelve years ago as a web site dedicated to

◀ **FIG. 2:** Logo of Croatian Physical Society.

the news in physics, not only for high school students and physics teachers, but also for all individuals interested in physics. In the last three years almost 100 additional Internet pages were created with new educational material. E-school Internet portal registers in average 200 visits per day that is the best sign of how popular and attractive this project is. Further, in cooperation with the Croatian Education and Teacher Training Agency and the Ministry of Science, Education and Sports, the CPS organizes elementary and high school competitions in physics at regional and national levels, and prepares as well the gifted students to participate in the international Physics Olympiad and Young ▶

▼ **FIG. 3:** Physics Express visiting an elementary school in Rijeka. Ines Filipas from Physics Express explaining the exercise entitled "Rubens tube", while one of the students is trying to induce the tube standing waves by identifying the right frequency with his voice.

▲ **FIG. 4:** Members of the Croatian team (left to right): Damir Klicek (leader), Dino Santl, Lora Grbanovic, Petra Vuckovic, Dino Halusek, Krunoslav Ljaljek and Lidia Saric (leader) at the closing ceremony of the 22nd International Young Physicists' Tournament, 21 – 28 July 2009 which was held in Tianjin, China.

▶ Physicist's Tournament. The Croatian high school students in both of these competitions usually achieve very good results: winning bronze medals is regular, making us all very proud of them (Picture 4). CPS also organizes each year the Summer School for Young Physicists dedicated to various subjects in physics: the students with the best results at the national competition are invited. CPS considers this event as a kind of reward to students that distinguished themselves and gives them the opportunity to follow the lectures of the best Croatian scientists and participate in the interactive laboratory exercises.

International activities

As an additional expression of commitment to help promote physics education, CPS took the responsibility to organize three important international events in the last three years: the 21st International Young Physicists' Tournament in 2008, the 24th International Conference of Physics Students in 2009 and the 41st International Physics Olympiad in 2010, the latter being organized in cooperation with the University of Zagreb. The 21st International Young Physicists' Tournament attracted in Trogir teams from 24 countries all over the world. The unique aspect of the Tournament, compared with other contests, is that it constitutes the competition among teams of high school students, instead of individuals. The 24th International Conference of Physics Students in Split had almost 500 students from 22 countries worldwide. It is unique as a physics conference, since it brings students of physics together with only few senior researchers guests. The third event, 41st International Physics Olympiad in 2010 was held in Zagreb. It is an international individual competition for high school students to which participated 370 of them, representing 80 countries from all over the world. We consider that this event was extremely important not only for the Croatian academic community but also for the whole country and we are very grateful to the Ministry of Science, Education and Sports, the City of Zagreb and the other sponsors from Croatia and Europe (SIF and EPS), for their valuable support without which it would not have been organized.

In coordination with the EPS, the CPS was active in the World Year of Physics in 2005 and is, since 2007 in "The implementation of the Bologna Process into Physics Studies in Europe".

Prospects

The promotion of physics and sciences becomes more and more a challenge. It is somehow paradoxical to observe a physics decline in public prestige after its historical record all along the 20th century, which demonstrates the importance of basic, curiosity-driven research for economic prosperity and justifies the belief that it should continue. This implies that we all need to pay greater attention to the way Physics should be taught to young people and future generations who have to build the civilization of the 3rd millennium, as well as to work hard achieving better support for research. It is the synergy of improved education and research that guarantees a safe and prosperous future. It is essential to make known to all that physics is a fundamental source of progress in itself as well as in broad areas ranging from energy and environment to medicine and health. CPS is a proud member of European Physical Society and International Union of Pure and Applied Physics. We are confident that in this way and only together we can forge an effective partnership for the benefit of science, education and humankind worldwide. And perhaps most importantly of all we need to understand and feel that physics and scientifically based approach to life represent a basic tool which can help humankind to create a new just and meaningful world. ■

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NOTE

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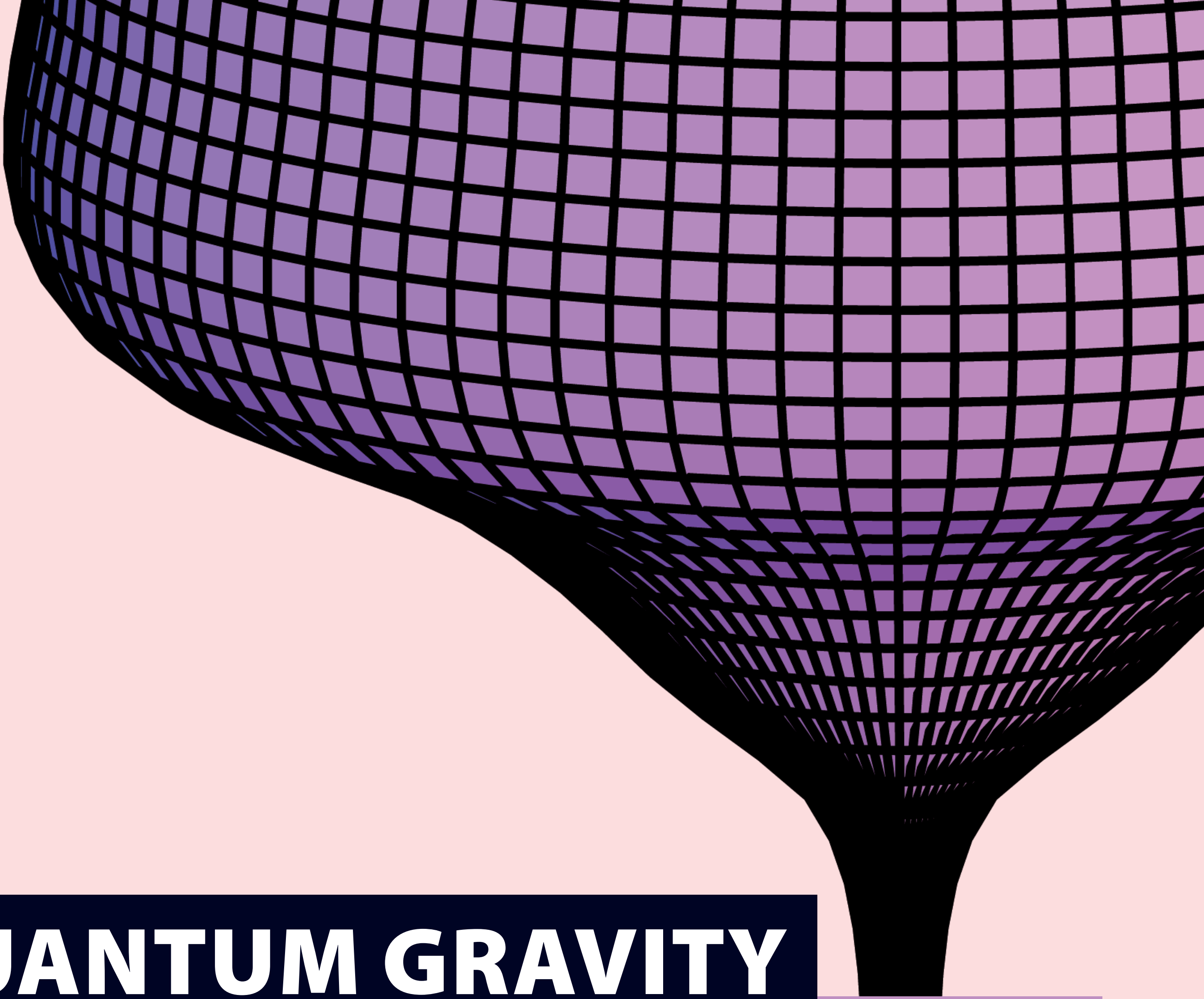

QUANTUM GRAVITY

FROM THE ENTROPY OF GEOMETRIES

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This article describes an attempt to reconcile the theory of general relativity with quantum theory from first principles. The universe is assembled from building blocks, and computer simulations reveal their collective behaviour. For small universes quantum fluctuations are large and dominant, but still some semiclassical concepts of geometry survive.

Three constants play a fundamental role in our understanding of nature: the gravitational constant G, which quantifies the strength of the gravitational forces in Newton's law, the velocity of light c appearing in Einstein's theory of Special Relativity, and Planck's constant $\hbar$, which he first introduced to describe the thermal spectrum of black-body radiation. These three constants are associated with different aspects of our universe.

Newton's law of gravity governs the motion of the solar system, which means that G is primarily associated with physics on large scales. The theory of Special Relativity determines physics at extreme velocities close to the velocity c of light. Finally, Planck's constant $\hbar$ appears in a central way in Quantum Mechanics, the laws of physics prevailing in the micro-cosmos.

▲ see fig.3

Einstein's theory of General Relativity unites the physics defined by the constants G and c. It describes how energy and matter deform ("curve") the geometry of space-time. As far as we can tell from astrophysical observations, the theory also provides us with a good description of the dynamics of our universe as a whole. On the other hand, the theories of Special Relativity and Quantum Mechanics, defined in terms of c and $\hbar$, are merged into the ▶

common theoretical framework of Quantum Field Theory. While there are many quantum field theories, the so-called Standard Model has been selected experimentally. It describes the atomic and subatomic world down to a scale of 10^{-18} m with amazing precision.

A single theory?

In view of the above description it appears natural to try and take the "final" step of unifying General Relativity and Quantum Field Theory into a single theory (Fig. 1), with all three coupling constants, G, c and $\hbar$ expected to play a role.

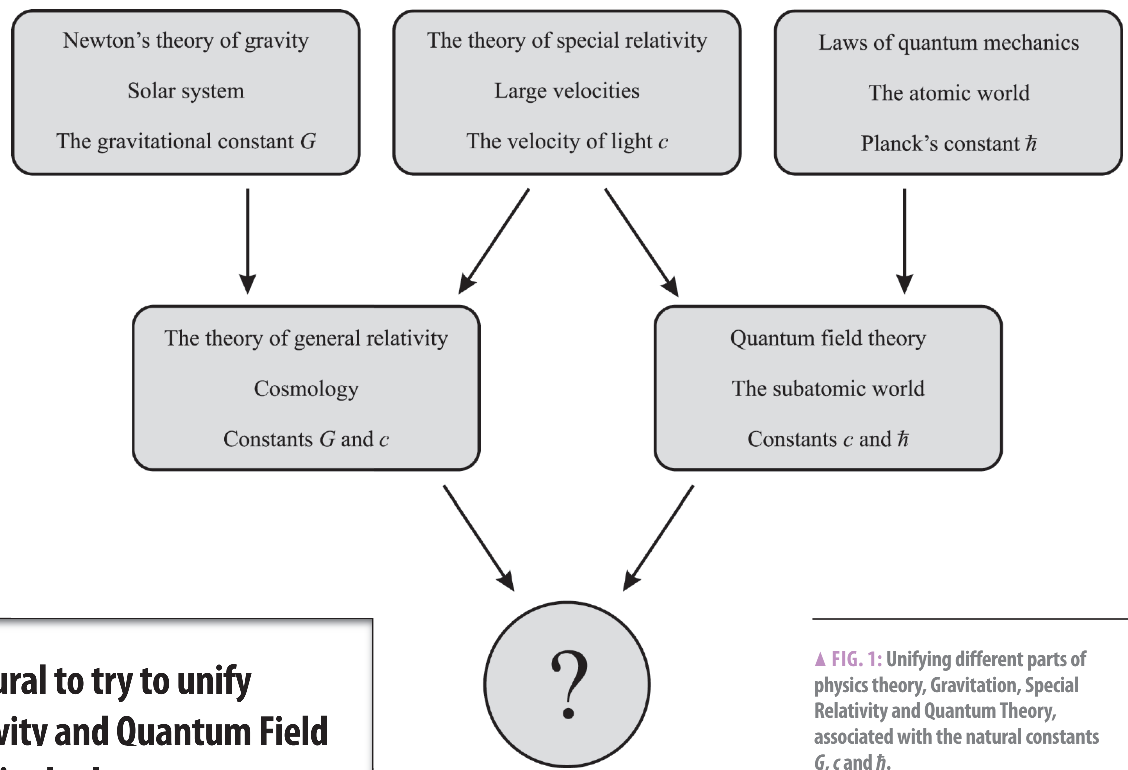
A natural unit of length in the combined theory can be obtained by multiplying appropriate powers of these three coupling constants. The resulting Planck length is unbelievably small, a mere 1.6×10^{-35} m. This should be compared with the length scale we can presently probe directly in particle accelerators, which is around 10^{-18} m. It leads us to conclude that Quantum Gravity, the sought-for theory unifying Quantum Field Theory and General Relativity, will most likely manifest itself at or near the Planck scale, which unfortunately lies far beyond the reach of any direct verification in the laboratory.

The lack of guidance from experimental or observational evidence has led researchers to consider a number of candidate theories, of which String Theory is probably the best known. While these theories provide at least partial descriptions for what may go on at the Planck scale, they have difficulties in explaining the four-dimensional world as we know it at macroscopic distances. This is a somewhat paradoxical situation since exactly at those scales we have access to experimental data.

There is an interesting precedent for this kind of situation in the theory of Strong Interactions. It describes the forces binding an atomic nucleus together, and how the proton and neutron are composed of three quarks interacting by the exchange of gluons. It is an example of a quantum theory whose short-distance, "microscopic" physics we actually understand. Although it should in principle also give an accurate description of "macroscopic" physics – by which in this context we mean the properties of the proton, the neutron and other observed hadrons – one is presently unable to perform the analytic calculations to prove it. In this situation, the computer comes to our help: we can represent the world as a lattice (with as small a lattice spacing as possible) and run computer simulations of the lattice theory. In this way we can determine the mass ratios of neutron and pion or of proton and pion, say, and check that they agree with experiments.

Amazing simplicity

Is it possible to do the same with our universe? Can we take our favorite, microscopic theory of Quantum Gravity, squeeze the whole universe into the computer and establish whether the macroscopic part of the theory gives rise to anything resembling our present universe? Surprisingly, the answer is in the affirmative, at least for the specific theory that goes by the name of "Causal Dynamical Triangulations" or "CDT" for short. One virtue of this Quantum Gravity Theory is its amazing



▲ **FIG. 1:** Unifying different parts of physics theory, Gravitation, Special Relativity and Quantum Theory, associated with the natural constants G, c and $\hbar$.

"It appears natural to try to unify General Relativity and Quantum Field Theory into a single theory."

simplicity. In it, space-time is assembled from tiny, elementary building blocks in the form of "four-simplices", four-dimensional generalizations of triangles with one time and three space dimensions. To obtain a Quantum Theory of Gravity one then performs a summation (a "quantum superposition") of all possible space-times with appropriate weights, following general principles from Quantum Field Theory.

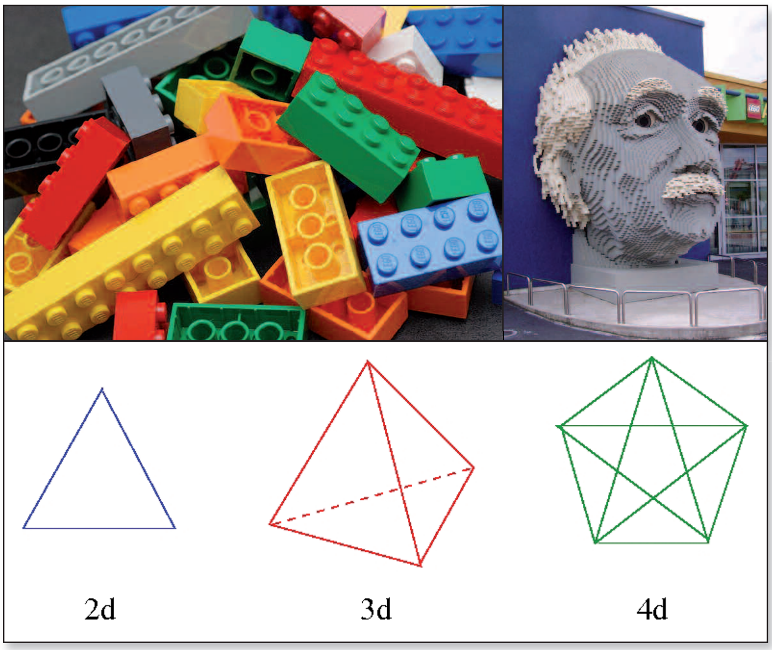
The theory could be solved analytically if one could count the number of ways of constructing different universes by gluing together four-simplices, in other words, the number of microstates the system can occupy. This state counting or *entropy* is decisive in determining the quantum dynamics of the system. Since we are unable to do the counting analytically, we let the computer take care of the task. A typical simulation uses a universe size of 40.000 to 360.000 four-simplices. It is important to appreciate that we do not consider these triangular "building blocks" as a fundamental substructure of space-time, but merely as a convenient tool for modeling its microscopic degrees of freedom. We are only interested in space-time properties that persist when the block size is shrunk to zero. This is analogous to modeling a large-scale shape, like Einstein's face shown in Fig. 2, by Lego blocks. Obviously, we will get a better and better approximation of the "real" Einstein by using ever smaller Lego blocks.

In our case, the "lattice" is therefore a four-dimensional triangulation of space-time.

Quantum fluctuations

However, unlike the lattices used in computer simulations of the Strong Interactions, this lattice is dynamical: the computer changes it all the time, reflecting the fact that in a theory of Quantum Gravity space-time itself constantly undergoes quantum fluctuations. We expect to observe an "average" macroscopic universe, where the deviations of any given computer-generated configuration from this average will constitute the quantum fluctuations. Fig. 3 shows a two-dimensional projection of such a universe as it appears in the computer.

Had we randomly selected another configuration, it would look somewhat similar but not identical. By superimposing many such configurations an "average" configuration will emerge. The beautiful surprise is that (within computing accuracy) this average configuration is a solution to the classical Einstein equations of Gravity. One may wonder why the fluctuations around the average are rather large, whereas we do not observe anything of the kind in our real universe. The point is that the (relative) magnitude of the quantum fluctuations depends on the size of the universe – the smaller the universe, the larger the fluctuations – and that our computer-generated space-times are rather small. Our computer simulations are currently limited to about 300,000 four-simplices. If one translates this into the

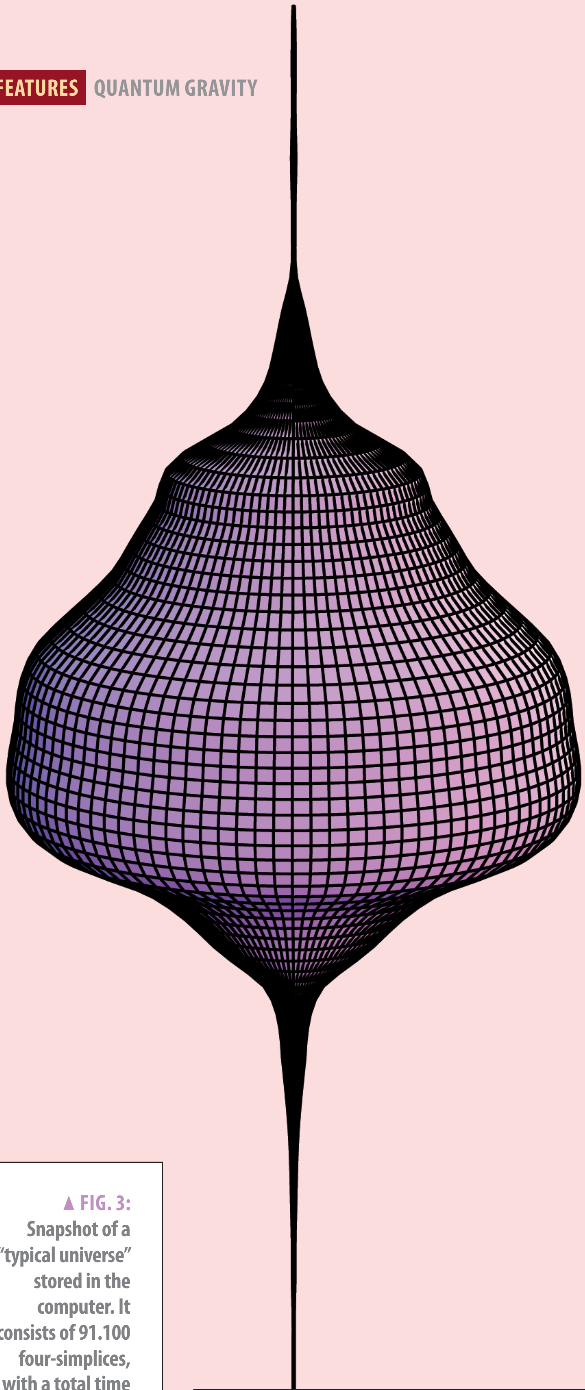


▲ **FIG. 2: Building blocks used for Einstein (Lego blocks) and, analogously, building blocks for curved geometries in dimension 2 (triangle, with one-dimensional surface formed by 3 edges), dimension 3 (tetrahedron, with two-dimensional surface formed by 4 triangles), and dimension 4 (four-simplex, with three-dimensional surface formed by 5 tetrahedra).**

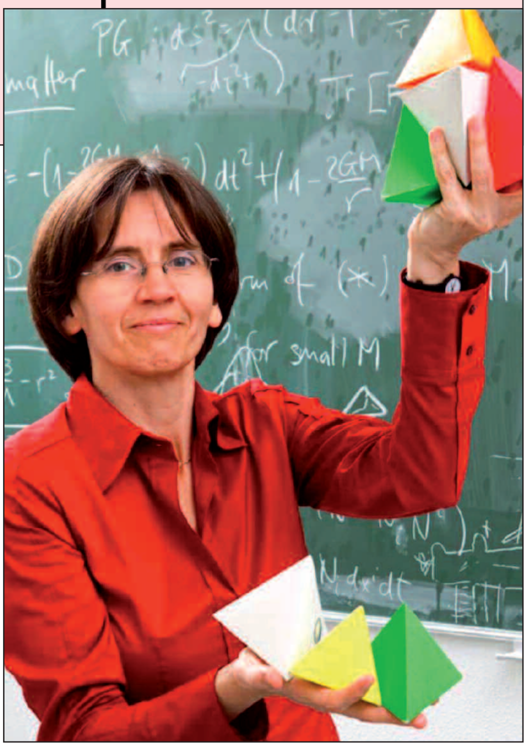
more familiar setting of a four-dimensional, regular (hyper-)cubic lattice, the triangular building blocks would approximately fill a lattice of dimensions 10^4. In fact, it is quite remarkable and encouraging that "on average" we can observe a good classical behaviour for triangulations with relatively few four-simplices.

We have not yet revealed *which* solution to General Relativity emerges from our quantum construction. If in Fig.3 we follow the development of spatial slices in time by moving upwards, we see that the universe initially has no spatial extension, after which it expands to some maximal volume, and then recontracts to a point, continuing with no spatial extension. After averaging over many such configurations, the geometry of a spatial slice within the "blob" turns out to be that of a three-dimensional sphere, whose radius changes in time such that the total blob is a perfect, round four-dimensional sphere. This one recognizes as a solution to the classical Einstein equations with a positive cosmological constant in so-called Euclidean space-time.

In *Euclidean* space-time, "time" is treated as just another spatial direction, rather than a time direction. One of the nice features of Causal Dynamical Triangulations is that to each "real" geometry with a distinct time direction one can associate a corresponding Euclidean geometry, where the time direction has been replaced by a space direction. Just as in testing the theory of strong interactions by computer simulations, also here it is convenient from a technical point of view to carry out the calculation using a four-dimensional space, rather than a true space-time.



▲ FIG. 3: Snapshot of a "typical universe" stored in the computer. It consists of 91.100 four-simplices, with a total time extent (vertical direction) of 40 discrete lattice units. The circumference at integer time s is proportional to the spatial three-volume $V_3(s)$. The surface represents an interpolation between adjacent spatial volumes, without capturing the actual four-dimensional connectivity between neighbouring spatial slices.



▶ Author Renate Loll assembling the universe from elementary blocks

Expanding universe

When we say that a classical universe emerges from the computer simulations, it is in this Euclidean sense. Upon rotating this solution back to "real" time, we obtain a real, physical solution of classical Gravity known as *de Sitter space-time*. This is a universe which expands exponentially fast, with expansion rate dictated by the cosmological constant. It does not describe our present universe accurately, because we have not yet included matter and radiation in our theory of Quantum Gravity. However, it matches perfectly with current astrophysical observations for the future of our universe, which point to an ever accelerating state of expansion, governed by a cosmological constant, and resembling more and more that of a pure de Sitter space-time.

Can CDT Quantum Gravity also give us insights into the truly nonclassical, quantum features of space-time on short scales? To address this issue we have studied a diffusion process on our ensemble of space-time geometries. One can study diffusion on very general spaces, as long as some notion of distance is present, in order to learn about their geometric properties. The manner and speed of a diffusion process can provide information about the fractal structure of the ambient space. More specifically, it allows one to extract a "dimension" of the space, called its spectral dimension. For any smooth, classical space-time this will agree with its ordinary dimension. For more general spaces, for example, fractal ones, the *spectral dimension* may assume a whole range of (typically non-integer) values. Intriguingly, while CDT's quantum space-time at large distances appears to be four-dimensional with regard to diffusion (as well as from any other point of view), when we go to small distances it appears to have spectral dimension *two*. This is a distinct quantum feature of space-time, which has since been corroborated in a different approach to Quantum Gravity, based on a renormalization group analysis. The approach is similar in spirit to ours: one assumes the existence of a Quantum Field Theory of Gravity and then applies general quantum field-theoretic techniques to explore possible consequences. The actual techniques used are very different from ours, so it is encouraging that one obtains the same result. ■

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EVALUATING RESEARCH USING IMPACT AND HIRSCH FACTORS

WHY SUCH LARGE DIFFERENCES FOR DIFFERENT FIELDS?

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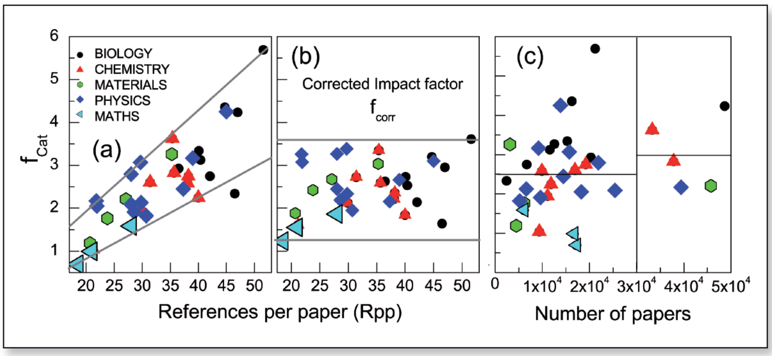
**Impact factors of the journals and Hirsch index are commonly used to evaluate researchers from close but different areas who are compelled to compete for the same funding and positions. But theses factors depend strongly on the area without a clear foundation.
A straightforward normalization would allow comparing different researchers and areas more fairly.**

It is widely admitted, from empirical evidence, that the Hirsch indexes [1], *h*, (both, mean values and top values) depend strongly on the area and that only *h* of individuals from the same area should be compared. For example, *h* indexes in biochemistry are, in general, much higher than in mathematics. But the origin of these variations from one area to the other is unclear. **Hirsch index has been criticised** and more or less complicated alternative indexes have been proposed [2,3]. But, in fact, the ***h*** **index is used every-day and everywhere because it is simple and easily obtained from databases**.

Two issues have been raised to explain the disparity of *h* indexes between different areas: the size of the community (the larger it is, the higher *h*) and the impact factors of the journals of the area. Actually, what the ▶



▲ **FIG. 1:** a) Aggregate impact factors (f_{Cat}) vs. average number of references per publication (*Rpp*) for 35 categories from JCR. The different colours correspond to categories grouped into areas (3 in Maths, 11 in Physics, 4 in Materials Sciences, 8 in Chemistry and 9 in Biology). b) Corrected impact factors as explained in the text. c) Aggregate impact factors vs. the number of publications in the category.

▸ Journal Citation Reports (JCR) from the ISI Web of Knowledge (WoK) calls "Aggregate impact factor" (f_{Cat}) of a category (which is the average impact factor of the journals of this category weighted by the number of articles in each journal) largely varies for different categories [4].

It is clear that the size of a community favours large *h* indexes for individuals since there are more candidates to cite one paper. But, when looking at mean values, this cannot explain the large differences in the factors f_{Cat} of the various categories, not even for the impact factors of individual journals with thousands of articles per year: as the community increases, the number of published articles also increases, so the ratio between the citations to theses papers and the papers themselves cannot be solely determined by the community size (or by the number of papers).

What influences the impact factors of journals and categories?

Here we show that what matters are the different habits of the different communities when writing papers: there is a **strong correlation between the average number of references included in each publication (*Rpp*) of a given category and its aggregate impact factor, f_{Cat}.** Intuitively, it is clear that the more references per article, the more overall citations and therefore the higher impact factor.

Fig. 1 (a) shows the aggregate impact factors, f_{Cat}, for 35 categories with more than 3000 articles each, published in 2008. The values of f_{Cat} vary from 0.695 for the category "Mathematics" to 5.696 for "Cell Biology", while the values of *Rpp* range from 18.5 to 51.6 references per article in these two categories. The f_{Cat} values of the different areas are plotted in different colours and all lie between two straight lines, evidencing a correlation with *Rpp*.

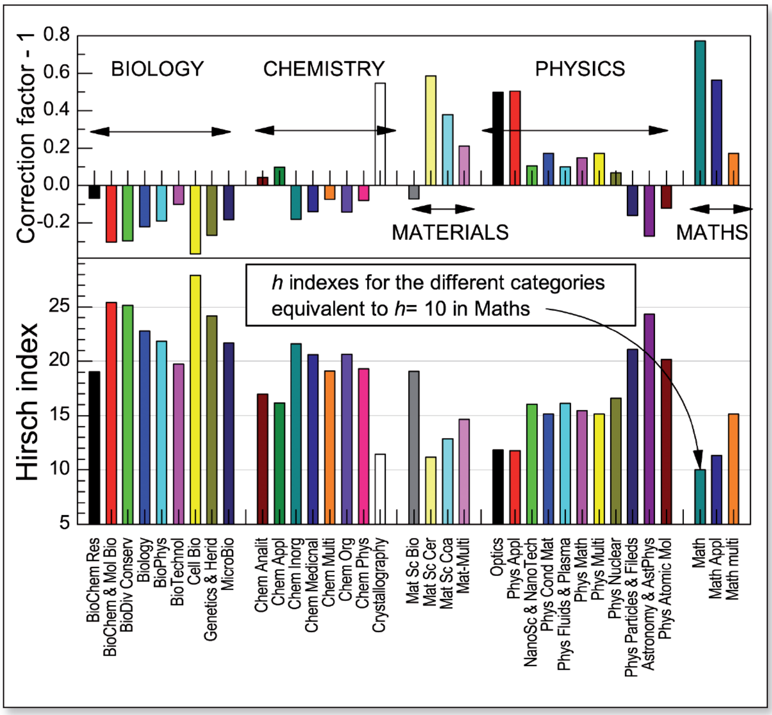
Many of these categories are not independent in the sense that i) the researchers usually publish in several categories although, in fact, mainly do it at most in two or three categories that share some journals [5]; ii) researchers from different sets of these categories are compared since they are compelled to compete for the same funding and positions. (For example, researchers that mainly publish in one or two of the following categories: "Applied Physics", "Materials Science Multidisciplinary", "Chemistry Multidisciplinary", "Physics Condensed Matter", and, recently "Chemistry Organic" are frequently compared.)

Normalization of impact factors

Here, a simple normalization is proposed to eliminate, or reduce, the biasing effect of *Rpp*. Form JCR data, the average number of references per article for all these categories can be obtained: R_{mean} = 32.8 (always weighted by the number of published items in each category). The proposed normalization is simple: for a category *i*, the corrected impact factor is defined as: $f_{Corr}(i) = f_{Cat}(i) R_{mean} / Rpp(i)$. The resulting f_{Corr} values are plotted in Fig. 1 (b). The effect is that large values of f_{Cat} related to large *Rpp* are reduced, while low values of f_{Cat} increase if they are associated to low *Rpp*. The large variation range of the impact factors is now reduced by a factor of two: from 5 (from 0.695 to 5.696) to 2.4 (from 1.2 to 3.6).

To check whether there is a correlation between f_{Cat} and the size of the community, we have plotted f_{Cat} in Fig. 1 c) vs. the number of published papers in the category (the colours correspond to the different

▼ **FIG. 2:** Upper panel: (correction factor-1) for the 35 categories. Lower panel: Hirsch index, when normalized by the correction factors, equivalent to *h* = 10 for the category "Mathematics".



areas). There is a small difference between the mean impact factor of the categories with less than 30000 publications per year (2.45) than for those (five) with more than 30000 publications per year (3.0). However, for these highly productive categories, the dispersion is too large, the number of categories too low and the difference in impact factors small to be really significant.

Normalization of Hirsch index:

For an easy visualization of the data, we have represented in the upper panel of Fig. 2 the correction factor (R_{mean} / $Rpp(i)$) – 1 for each category. Consequently, positive and negative values appear in the plot illustrating the effects of our correction on f_{Cat}: positive, the normalized factor increases, and if negative, it decreases. This correction factor may be a reasonable approach to the normalization of different areas so it can be used to compare average *h* indexes of researchers from the different categories. Using the correction factors of the upper panel we obtain the "equivalent *h* indexes" for all categories, see Fig. 2 lower panel. **It is found that *h* = 10 for the category "Mathematics", is equivalent to *h* = 28 in "Cell Biology" or that *h* = 24 for "Astronomy & Astrophysics" is equivalent to *h* = 12 for "Applied Physics".**

Temporal evolution

Also interesting is the evolution with time of the citation habits of scientists. Focussing on the category "Physics, Condensed Matter", Fig. 3 shows that in only seven years (2003 to 2009) its mean impact factor f_{CM} has increased from 1.56 to 2.34, corresponding to the increase of the mean number references per paper (*Rpp*) from 20.8 to 28. This also has implications for the comparison between the *h* indexes of researchers from different times.

The scientific community size is not relevant for mean factors

We showed in Fig.1c that the number of publications per category is not correlated with the mean impact factors (f_{Cat}). Moreover, note that the number of publications in 2008 in the categories grouped in areas of Physics, Biology and Chemistry is similar (Physics: 179558, Biology: 155076, Chemistry: 149546) while the mean impact factors of the whole areas are different (2.51, 3.93 and 2.73, respectively). So, the reason at the root of the observed differences is not in the number of papers (or the community size) but rather lies in the average number of references in each paper. **So the size does matter, but it does not correspond to the size of the community but rather to the habit of some communities to be more generous in citations than others.**

Impact factors and Hirsch index should be used carefully, at least normalized

The final remark would be that **impact and *h* factors have to be used with substantial care since this simple approach evidences that an important part of the large differences between areas are related to publication habits and do not directly reflect different scientific quality. Therefore, these factors, which are usually compared from one area to another, should not be used without some normalization.** The normalization presented here is straightforward and, even if it does not overcome other disadvantages of h (like the number and order of authors in the paper or self-citations, for example) it allows comparing different researchers and areas more fairly. ■

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About the Author

Alicia de Andrés studied Physics at the "Universidad Autónoma de Madrid" where she received her PhD in 1987. Engaged at CSIC since 1988 and research professor since 2008, her current research is focused on oxides and hybrid organic/oxide materials for spintronics and optoelectronics.

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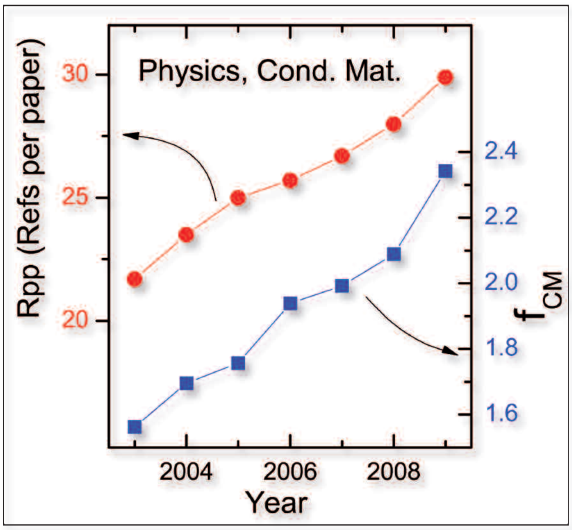

◄ FIG. 3: Evolution with time of the mean impact factor (f_{CM}) and of *Rpp* of the category "Physics, Condensed Matter"