⟨S|P|S⟩
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SPG MITTEILUNGEN
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Annual Meeting of the
Swiss Physical Society

June 21 - 22, 2012 , ETH Zürich

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Call for Abstracts:
Submission Deadline March 15, 2012

Detailed information on page 3

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Annual Meeting of the SPS, June 21 - 22, 2012, ETH Zürich

Like every other year the annual meeting 2012 of our society is organized jointly with the current NCCRs in physics. This year we welcome also the Swiss Society for Crystallography (SGK) as our special guest, to celebrate together the centenary of the discovery of X-rays diffraction in crystals by Max von Laue.

Scientific Program

Plenary Session
Five plenary talks, adressing latest advancements in different research fields will be presented in the morning sessions.

- Jürg Fröhlich, ETHZ: *From the QHE to Topological Insulators and on to Cosmic Magnetic Fields - a Unified Perspective*
- Thierry Giamarchi, Uni Genève: *Quantum physics in one dimension*
- Dieter Schwarzenbach, EPFL: *From Laue's discovery and the Braggs' key to the world of atoms to service crystallography*
- Jörg Peter Kotthaus, Uni München: *Nanomechanical Resonators - coherent control of nanomechanical motion*
- Majed Chergui, EPFL: *Ultrafast dynamics of complex systems probed with light from the visible to the X-ray domain*

A public tutorial is planned for June 22 on "Ultrafast Biology" (see next page for details).

Topical Sessions
The following parallel sessions will be held in the afternoons:

- Applied Physics
- Atomic Physics and Quantum Photonics
- Careers for Physicists
- Earth, Atmosphere and Environmental Physics
- History of Physics
- Magnetism at Interfaces
- NCCR MaNEP
- NCCR MUST
- NCCR Nano
- NCCR QSIT
- Nuclear, Particle- & Astrophysics
- Theoretical Physics
- 100 Years of Diffraction: Historical highlights and a look into the next 100 years
- Teacher's Afternoon: Nanophysik am Gymnasium

Dependent on the number and contents of the contributed papers, each topical session will be split into special thematic subsessions.

Poster Session and Conference Dinner

The poster session will start in the evening of June 21, in the frame of an apéro. Subsequent to the postersession a grillparty will be organized on campus, allowing everybody to meet with colleagues in a relaxed and nice atmosphere.

The poster session is continued on June 22 at lunch time, where a buffet is offered.

The maximum poster size is A0 (portrait).

Vendors Exhibition

A vendors exhibition will be organized in parallel to the sessions. An invitation letter will be mailed within the next weeks to interested companies. If your company would like to join the exhibition, but did not receive the letter, please contact: *sps@unibas.ch*

Award Ceremony

As every year three outstanding scientific works will be honoured with the SPS awards, in the respective fields of General Physics (sponsored by ABB Research Center), Condensed Matter Physics (sponsored by IBM Zürich Research Laboratory), and Applied Physics (sponsored by OC Oerlikon), each granted with CHF 5000.- .

The ceremony will be held on June 21, 2012.

General Assembly

The general assembly is scheduled for June 21, 2012. The agenda will be published in the next issue of the SPS Communications. We encourage all members to actively participate and contact the committee if special points of interest should be discussed at the assembly.

Abstract Submission

You can submit abstracts to all topical sessions. The choice between an oral or a poster presentation of your contribution is possible. Due to the limited number of time slots the session organizers might however be forced to change oral presentations into posters. If possible, please mark both options in your submission.

The submission of abstracts must be done online. Visit our webpage *www.sps.ch* and follow the link to the submission form. Further explanations are available there.

The full conference program will be available in May 2012 on *www.sps.ch*.

IMPORTANT: The submission deadline for abstracts is March 15, 2012 !

Conference Fees, Registration and Payment

The conference fees cover the participation to all sessions, including coffee breaks (both days), apéro (Thursday), and the lunchbuffet on Friday (no "one-day tickets").
The grillparty on Thursday evening will be charged separately.

Pay your conference fee in time and save money !

The regular fees, as shown in the table below, hold for payments reaching us before June 1, 2012. Please make sure that your name and the purpose of the payment are indicated.
Payments can be made to the following account:

Swiss Post - Postfinance, Account 80-8738-5, for Swiss Physical Society, 4056 Basel

If you pay from abroad, please use the following data:
IBAN: CH59 0900 0000 8000 8738 5
BIC: POFI CH BE

Category (all prices in CHF):	*Regular*
SPS Members	100.-
Ph.D. Students (*)	100.-
Students before Master/Diploma degree (*)	30.-
Plenary / invited speakers, awardees	0.-
Other persons	140.-
"Not yet" members special offer (see below)	150.-
Grillparty (**)	90.-

(*) Students licence required
(**) free for plenary /invited speakers and awardees

For payments made later than June 1 a surcharge of CHF 20.- will be added. This applies also for participants paying cash at the conference. Credit cards are not accepted.

Attention: Fees are not refundable in case of cancellation.

Registration Deadline: June 1, 2012

Registration is also done completely online on *www.sps.ch*. The only exception is the admission form for new members, see below.

Group registrations

If several members (≥ 5) of your group or laboratory want to participate in our meeting, you don't have to fill out the online registration form for every person. Please contact the SPS-Secretariat (*sps@unibas.ch*). We will then send you a special electronic form where you can insert the required data.

Special offer for non-members:

Do you plan to participate in our meeting and want also to become a member of the SPS ? Then take advandage of our special offer of CHF 150.- covering the conference fees and the membership for 2012. (CHF 170.- after June 1) ! Just fill out the online-registration form, choose the option "Special offer", then download, print, fill and sign the admission form for new members, and return it as soon as possible to the SPS Secretariat.

The membership admission form is available on *www.sps.ch/uploads/media/anmeldeformular_d-f-e.pdf* .

(This offer does not apply for students and Ph.D. students. They still profit from the free first-year-membership and have only to pay the conference fee shown above.)

Additional information for selected sessions

NCCR MUST

The NCCR MUST (Molecular Ultrafast Science and Technology) will participate at our annual meeting for the first time. Besides the plenary talk given by Majed Chergui (see page 3), the following invited speakers will present highlights from their fields:

- Fabrizio Carbone, EPFL: *Real-time oscillations of the superconducting condensate in a high-T_c superconductor*
- Peter Hamm, University of Zürich: *Multidimensional IR spectroscopy of water*
- Steve Johnson, Physics Department, ETH Zürich: *Femtosecond dynamics of atomic structure in solids*
- Hans Jakob Wörner, Lab. für Physikalische Chemie, ETH Zürich: *Probing electron dynamics during chemical reactions*

Furthermore a public tutorial is planned:
Gebhard F. X. Schertler, Department of Biology, ETH Zürich and Laboratory of Biomolecular Research, PSI, Villigen will talk about *Ultrafast Biology*.
This tutorial addresses the physics community and should explain why ultrafast processes in biology are important and give some examples of the open questions that we hope we can address within NCCR MUST and the SwissFEL (Swiss Free Electron Laser).

Contact: Jürg Osterwalder, Uni Zürich (osterwal@physik.unizh.ch), Thomas Feurer, Uni Bern (thomas.feurer@iap.unibe.ch), Ursula Keller, ETH Zürich (keller@phys.ethz.ch)

NCCR QSIT

The NCCR QSIT (Quantum Science and Technology) will, also for the first time, organize a session during our meeting. The presentations (oral and poster) will cover results from quantum optics, condensed matter physics, experiment and theory. For the opening of this session J. P. Kotthaus from the University of Munich will give a plenary lecture with the title "Nanomechanical Resonators - coherent control of nanomechanical motion".

Contact: Klaus Ensslin, ETH Zürich, (ensslin@phys.ethz.ch), Richard Warburton, Uni Basel (richard.warburton@unibas.ch)

NCCR NANO

The NCCR NANO will participate this year with three dedicated sessions:

Nanophotonics

The interaction of light with structures much smaller than the wavelength gives rise to a broad range of effects, where light can be used to probe the response of matter at the nanoscale. The session covers the different facets of nanophotonics, from theory to experimental realizations, including plasmonics, optical metamaterials and near-field optics. Applications range from metrology to biosensing, integrated optical nanosources, security applications and novel devices for energy-harvesting at the nanoscale.

Contact: Olivier J. F. Martin, EPFL (olivier.martin@epfl.ch)

Nanomechanics

Mechanics on the nanometer scale procures insights into the basic processes in mechanics. The session covers elastic, thermal and kinetic properties of physical systems at the nanometer scale. These nanomechanical investigations deliver information on the materials itself and its properties on a macroscopic scale. The second includes contributions on miniaturization, instrumentation and possible future applications.

Contact: Martino Poggio, Uni Basel (Martino.Poggio@unibas.ch)

Nanobiophysics

The session focuses on Nanophysics applied to biological objects like enzyms, organelles and the cell. The field is strongly driven by advances in physical measurement and biological preparation techniques. Recent scientific findings are presented as well as their possible application in medicine.

Contact: Roderick Lim, Uni Basel (roderick.lim@unibas.ch)

Magnetism at Interfaces

The ability to control the properties of interfaces has lead to important applications in nowadays electronic and magnetic devices. The continuing demand on miniaturization will further stimulate intense research efforts on interfaces in the field of condensed matter physics. This session focuses at magnetic phenomena at interfaces in systems with different length scales ranging from thin films to nanostructures, clusters or molecules on surfaces. The meeting aims to provide a platform for interdisciplinary discussions and will consist of invited and contributed presentations.

Contact: Armin Kleibert, PSI (Armin.Kleibert@psi.ch)

100 Years of Diffraction: Historical Highlights and a Look Into the Next 100 Years

The 2012 annual meeting of the Swiss Society for Crystallography (SGK/SSCR) will take place on Thursday 21st June, 2012. The meeting will be held in conjunction with that of the Swiss Physical Society. There will be a joint plenary lecture (Dieter Schwarzenbach) and a two-hour microsymposium on the history of crystallography to commemorate 100 years of the experiments by the team of von Laue.

In addition, the SGK/SSCR will have its general assembly and a further session focussing on exciting new developments in the field of crystallography as we head into the next 100 years.
SGK/SSCR posters will be up all day, and there will be a joint poster session with the SPS in the late afternoon.

Contact: PD Dr Anthony Linden, Institute of Organic Chemistry, University of Zürich (alinden@oci.uzh.ch)

Earth, Atmosphere and Environmental Physics

This year at the SPS annual meeting, following the success of last year's session on geophysics, we will host session(s) on the novel theme "Earth, Atmosphere and Environmental Physics". The aim is to bring together scientists whose research and activities employ physically-based approaches and methods. This theme encompasses many different topics, spanning from energy issues, resources, waste management, to observations and numerical modelling of earth-atmosphere systems.
The topics may cover theoretical geophysics, engineering and applied geophysics (geological resources, hazards, waste storage, monitoring of contaminated sites), extraterrestrial geophysics, as well as meteorological and climatological methods of the atmosphere and ocean.

Contact: Stéphane Goyette, Uni Genève (stephane.goyette@unige.ch), Antoine Pochelon, CRPP-EPFL (Antoine.Pochelon@epfl.ch)

Careers for Physicists

The majority of physicists are not working in academia, but are joining industry at one point in their career. Therefore physics students and young professionals are always interested in getting to know, what are possible options for them. After the great success encountered at the last meeting in Lausanne and also at the symposium organized in Zürich with PGZ and some student organizations, another session is planned. It will give the opportunity to professional physicists of the industry to present their work and give advice on the successful step from academic to industrial research.

Contact: Kai Hencken, ABB Baden(kai.hencken@ch.abb.com)

Teacher's Afternoon: Nanophysik am Gymnasium

Die ersten Anwendungen der Nanotechnologie haben Einzug in das tägliche Leben der Schülerinnen und Schüler gehalten. Gleichzeitig sind in der Schweiz und im angrenzenden Europa verschiedene Bildungsprojekte im Bereich der Nanowissenschaften entstanden. Die Palette reicht von Infobroschüren über multimediale Lehrmittel bis zur Vermietung einer kompletten Schullabor-Infrastruktur. Wir stellen auf die Sekundarstufe II abgestimmte Lehrmittel vor und zeigen Möglichkeiten auf, Nanotechnologie und Nanowissenschaften in den gymnasialen Physik-Unterricht zu integrieren.

Kontakt: Tibor Gyalog, Uni Basel (tibor.gyalog@unibas.ch), Andreas Vaterlaus, ETH Zürich (vaterlaus@solid.phys.ethz.ch)

The Swiss Institute of Particle Physics CHIPP

Martin Pohl, CHIPP Chairman 2010-11

The Swiss Institute of Particle Physics, CHIPP, is a bottoms-up organization of physicists active in nuclear, particle and astroparticle physics in Switzerland. Current membership statistics are shown in the adjacent map. Detailed information about CHIPP and its activities are available on the web site *www.chipp.ch*.

CHIPP has been founded in October 2003, superseding the 'Forum of Swiss High Energy Physicists'. In 2011, CHIPP has acquired legal personality by transforming itself into an association according to Swiss law. This step was a milestone in CHIPP's history, since it allows the association to conclude employment contracts and sign other legal documents. Furthermore, acquiring legal personality was a prerequisite to become a member of the Swiss Academy of Natural Sciences, SCNAT. Consequently, CHIPP has joined the platform MAP (Mathematics, Astronomy, Physics) of SCNAT as a member society in 2011, thus strengthening the representation of physics in the Academy.

The purpose of the CHIPP association is to strengthen particle, astroparticle and nuclear physics in Switzerland by the following lines of action:

- To help towards a successful participation of Swiss groups in projects;
- To advise the Universities and Swiss Federal Institutes of Technology on vacant professorships and academic strategies, and help coordinate teaching activities;
- To ensure a proper Swiss representation in relevant national and international bodies; and
- To promote public awareness on particle, astroparticle and nuclear physics.

Since the goals of CHIPP and the SPS overlap, both societies have decided to work more closely together. As a first step, CHIPP regularly presents a candidate for the SPS committee, and SPS sends a representative to relevant CHIPP meetings as an Observer to the CHIPP Board.

The science behind and our way to promote it

Particle physics and neighboring fields explore the most fundamental laws of Nature. Their questions are of a fundamental nature and their answers are in the best case simple and unique. However, the process of finding these answers is difficult, at the edge of technological achievements, and has a cost, for we are probing the frontier of our knowledge. While experimental particle physics indeed requires costly infrastructure, this does not prevent university groups of modest size and reasonable funding to make an impact, provided their effort is well imbedded in a national as well as international context.

In order to structure and federate Swiss efforts, CHIPP has undertaken to formulate a Roadmap[1] in 2003. It identifies three strategic research directions:

- Particle physics at the frontier of high energy and high precision, as represented by experiments at the LHC and at PSI;
- Neutrino physics, using accelerator beams as well as astrophysical neutrino sources; and
- Astroparticle physics, addressing both astrophysics and particle physics questions in a systematic way.

These pillars are complemented by some technology transfer activities, mainly into spin-offs, as well as educational and outreach activities.

A recent review and update of the Roadmap[2] has led to explicitly include particle theory, PSI activities and accelerator research as part of the CHIPP activities, and has indeed confirmed its general validity and its value for both decision makers and our own planning.

The FAST detector at PSI: Small precision experiments like this by a dozen physicists can contribute to particle physics in a way complementary to large high energy collider experiments. Theoretical activities are even more individual in nature.

What we do and how we do it

CHIPP is organized as a two-level structure:

- The strategic level is formed by the plenary meeting of its members – the supreme body of the Association – and the Board, where all professors active in particle, astroparticle and nuclear physics assemble. Several subcommittees are dealing with specific issues like outreach or computing. The annual plenary meeting reviews all scientific activities and takes the role of a small national conference on the field.

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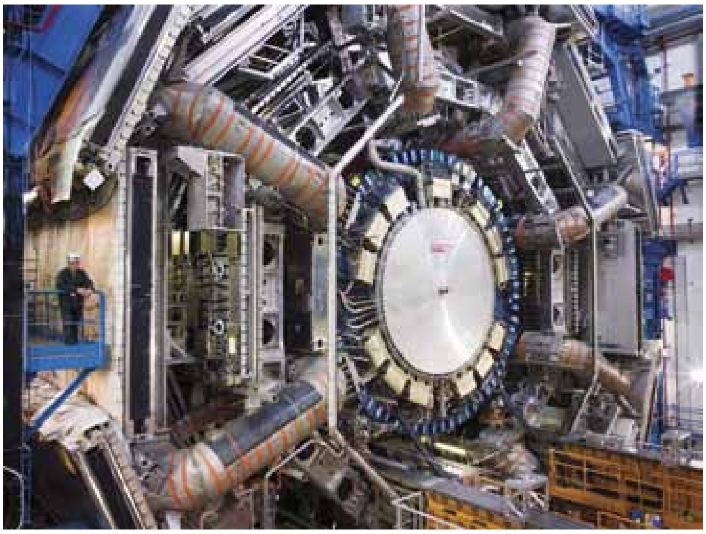
[1] Particle Physics in Switzerland, Status and Outlook of Research and Education, CHIPP 2004

[2] Particle Physics in Switzerland, Achievements, Status and Outlook: Implementation of the Road Map 2005-2010, CHIPP 2011

- An Executive Board of typically four members, headed by a chairperson and assisted by a part time administrator, takes care of the day-to-day operations of the organization.



The ATLAS detector at the CERN Large Hadron Collider: Experiments at the forefront of high energies require a large international effort, with the participation of several thousand physicists. CHIPP works to make the Swiss contribution strategically important and visible. (Photo: © CERN)

The activities of the Association are very diverse. To name but a few examples:

- CHIPP attributes a yearly price of for the best PhD student among its members.
- It organizes a yearly CHIPP PhD School and several topical Workshops per year to support communication among its members.
- In a rolling forward planning, CHIPP establishes an annual update of the foreseeable participations of Swiss groups in particle, astroparticle and nuclear physics in international projects. This table serves as input to the financial planning of the funding agencies (State Secretariat for Education and Research SER, Swiss National Science Foundation SNF).
- Each year, CHIPP submits joint funding requests to cover the Swiss contribution to the Maintenance and Operations cost of the LHC experiments, as agreed at an international level in the CERN Resource Review Board, as well as the Swiss cost for LHC GRID Computing.
- CHIPP runs an Innovation and Cooperation Project for the period 2008-2012 of the Swiss University Conference SUK, called the Swiss Centre for Advanced Studies in Particle Physics in the LHC Era. The project has filled nine PostDoc positions in international competition. In parallel, CHIPP is actively participating in ProDoc set up by the Swiss National Science Foundation SNF during the same period.

The key to success of CHIPP lies with its members, who are very actively supporting its activities, participate in lively discussions at its meetings and workshops and thus form a solid network of competence and cooperation. It also lies in embedding the association into the national and international context, without which particle physics cannot exist. The contributions of CHIPP to its mother and sister organizations, SCNAT and SPS, will strive to strengthen science in general and physics in particular in a country, where brain power is one of the rare natural resources.

CHIPP
Swiss Institute of Particle Physics
an Association according to Swiss law

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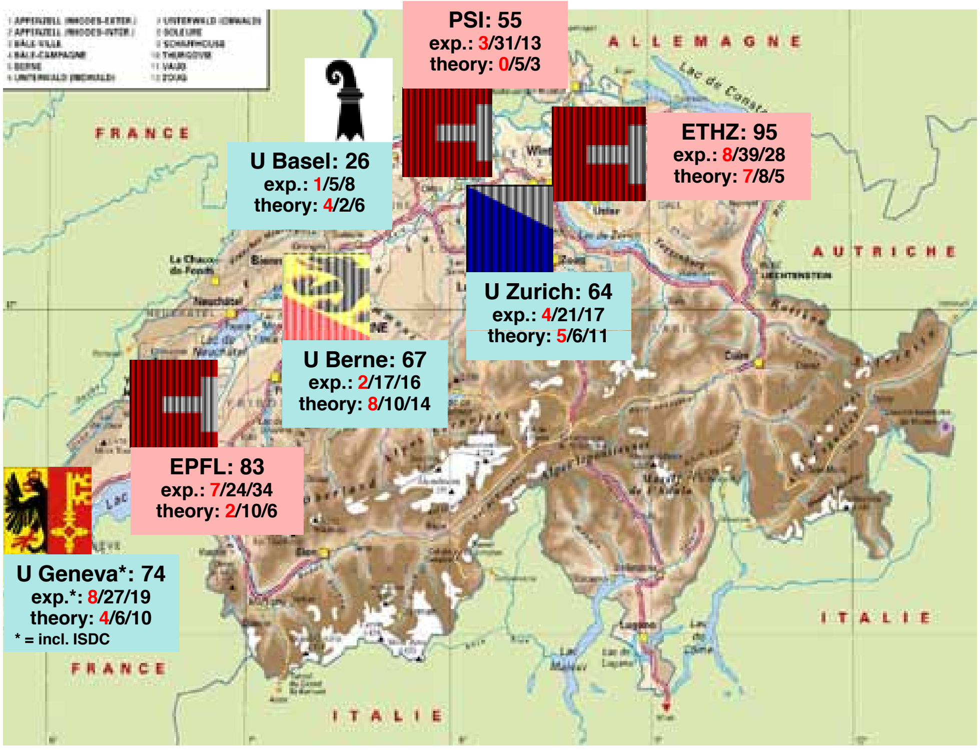
Member of the Swiss Academy of Sciences

Swiss Particle Physics Landscape in 2011

Total Scientific personnel:
Total 409

Professors / staff / PhD students
Total 60/175/174

(admin. & technical staff not included: hard to quantify)



PSI: 55
exp.: 3/31/13
theory: 0/5/3

ETHZ: 95
exp.: 8/39/28
theory: 7/8/5

U Basel: 26
exp.: 1/5/8
theory: 4/2/6

U Zurich: 64
exp.: 4/21/17
theory: 5/6/11

U Berne: 67
exp.: 2/17/16
theory: 8/10/14

EPFL: 83
exp.: 7/24/34
theory: 2/10/6

U Geneva*: 74
exp.*: 8/27/19
theory: 4/6/10
*** = incl. ISDC**

Source: CHIPP Membership Database, 14 Nov 2011
Author: J.P. Ruder

Review of "Careers for Physicists"

Joint Symposium of SPS, PGZ, VMP, FPU and FG14 at ETH Zürich, 25th October 2011

Kai Hencken, SPS, "Physik in der Industrie"

The majority of students in physics will join industry after their graduation and is therefore quite interested in the tasks and activities they have to perform later in industry. On the other side, what are the expectations of industry on the job beginners? These questions were addressed in a symposium organized jointly by the "Swiss Physical Society" (SPS), the "Physikalische Gesellschaft Zürich" (PGZ) and the student organizations of the ETH Zürich (VMP), the university of Zürich (FPU) and the university of Basel (FG14).

Four experts from industry with different background in physics and working in different fields reported about their experiences and what they do recommend to their younger colleagues. After shortly presenting their own career steps from university to industry, they described the challenges of their daily work and what skills are needed to manage arising problems. After the presentations, the students could discuss many details with the speakers at an apéro.

Adrian Honegger, Co-Head of IT at *Baloise Insurance* noted that physicists are generally well prepared for the business world of tomorrow due to their broad education and their flexibility. He started his career as an experimental nuclear physicists, moved to applied biology and then to the IT area. He considers physicists as being strong in "mental intelligence", but pointed out how import it is to properly communicate with people, which also requires "emotional intelligence". Physicists are good conceptual and systematical thinkers, therefore he recommends to never stop questioning the reasons behind decisions.

Marc von Waldkirch, Vice President Research and Development of *Sensirion*, told the students how he contributed to push a startup-company to a successful business case. His company, which develops integrated microelectronical sensor systems, is a success story. The advantage of joining a small company is the opportunity to become responsible for research and development in a short time. The physicists at Sensirion work in many areas ranging from sensor physics and fluid dynamics to software and electronics development.

Rolf Kaufmann, Project Manager at the *CSEM* talked about working in the interface region between university & industry. This is the area of "applied research & development", research results from universities are moved to industry for product manufacturing. CSEM is a research institution working on micro-, nano- and information technologies, where the knowledge transfer is performed either by the contractual work with companies or by founding spin-off companies, when the basic idea has reached industrial maturity. Working in this area has the advantage to stay in contact with research and also to acquire practical experience by the industrial contacts.

Finally **Kai Hencken** from *ABB* explained his work as "theoretical physicists in industry". While academic research is focused more on pure and fundamental questions, research in industry is driven by economical pragmatism with focus on product reliability and cost reduction. Theoretical physicists find good possibilities in industry, for example as experts for numerical simulations, which allows them to predict results instead of performing expensive experiments. Transferring their theoretical findings into usable models is therefore an effective and efficient method in product development. Due to the large scale dimensions of most industrial products the methods of classical physics are more often needed.

The event was well attended by a large number of students, indicating the importance for them. It should be considered as part of some ongoing actions of the SPS to respond to this need. One other major activity is the "SPS Young Physicists Forum", which organizes visits to research institutions and companies in Switzerland. And finally, a follow-up "career event" will be organized at the next annual SPS meeting in June 2012 at the ETH Zürich.

The New International System of Units based on Fundamental Constants

Beat Jeckelmann, Chief Science Officer, Federal Office of Metrology METAS, Bern-Wabern; beat.jeckelmann@metas.ch

At its 24th meeting in October 2011, the General Conference on Weights and Measures (CGPM) approved possible changes to the International System of Units, including new definitions for the kilogram, ampere, kelvin and mole. The final approval of the new SI will be made by the CGPM after its prerequisite conditions have been met. The earliest date for this change is 2014.

The International System of Units, known as the SI, is used throughout the world to express the results of measurements in almost all aspects of modern society, from advanced science and technology, via precision manufacturing to daily life. The roots of the SI go back to the Metre Convention signed in 1875 by 17 countries and now consisting of 55 signatories, but being applied in almost all countries of the world. The Convention established the General Conference of Weights and Measures (CGPM), a diplomatic body of representatives of each member state which meets usually every four years and has the authority to decide on any changes or extensions to the SI. In October 2011, the CGPM adopted a resolution [1] paving the way to a major revision of the SI.

The building blocks of the SI are the seven base units: second, metre, kilogram, ampere, kelvin, mole and candela. In recent years, possible new definitions of the base units were intensively discussed among specialists. In the course of the planned changes, especially the unit of mass, the kilogram, which is the last remaining unit defined in terms of an artefact, should be based on fundamental physical constants. The responsible committees of the Metre Convention have worked out a detailed proposition for the new SI which includes new definitions for the base units kilogram, ampere, kelvin and mole.

Why do we need a redefinition of SI base units?

In the current SI, the only unit still based on an artefact is the unit of mass. The kilogram is defined as the mass of a particular cylinder of an alloy of platinum (Pt) and iridium (Ir) conserved and used at the International Bureau of Weights and Measures (BIPM) in Sèvres, France. Copies of this kilogram prototype are kept by many National Metrology Institutes (NMI) around the world. Since 1889, these copies were compared three times with the international prototype. A series of copies was produced later and was compared only twice with the prototype. For both groups it has turned out that on average the mass of the national copies has increased with respect to the international prototype [2].

The relative change of about 50 µg/100 years on average is very small, but scientifically unsatisfactory and a possible problem and obstacle in the future. Due to the definition of the ampere, the electrical units are related to force and thus to the kilogram. A drift of the kilogram would induce a similar drift in the electrical units.

In modern electrical metrology, however, the Josephson and quantum Hall effects are used to realize very reproducible voltage and resistance values [3, 4] which, to our current knowledge, depend only on fundamental physical constants. To be used as practical standards, the value of the Josephson constant $K_J = 2e/h$ and the von-Klitzing constant $R_K = h/e^2$ have to be known in SI units. Unfortunately, the best realizations of the volt and the ohm in the SI according to the current definitions are about two orders of magnitude less accurate than the reproducibility of quantum standards based on the Josephson and the quantum Hall effects. As a consequence, conventional values for R_K and K_J were introduced in 1990 ($R_{K\text{-}90}$ = 25812.807 Ω and $K_{J\text{-}90}$ = 483597.9 GHz V^{-1}). This step drastically improved the worldwide consistency of electrical measurements. On the other hand however, it led to a practical subsystem in the SI which is unsatisfactory from the conceptional point of view.

Attempts to replace the kilogram

Much effort is being made to replace the kilogram artefact by a procedure relating the unit of mass to fundamental constants [5]. In the Avogadro experiment, the Avogadro constant N_A is measured with high accuracy by counting atoms in a nearly perfect Si crystal. Combining the constant with other physical constants, N_A can be linked to Planck's constant h. Hence the Avogadro experiment offers the opportunity to relate the kilogram either to an atomic mass or to the Planck constant. Another promising experimental approach is the so called "watt balance". It equalises mechanical and electrical power. When the electrical power is measured with quantum standards, mass can be related to Planck's constant h [5] (see also box 3).

The 7 fixed constants, setting the scale of the SI

The International System of Units, the SI, will be the system of units in which [1]:

- the ground state hyperfine splitting frequency of the caesium 133 atom $\Delta\nu(^{133}\mathrm{Cs})_{\mathrm{hfs}}$ is exactly 9 192 631 770 hertz, Hz,
- the speed of light in vacuum c is exactly 299 792 458 metre per second, m s^{-1},
- the Planck constant h is exactly 6.626 06X $\times 10^{-34}$ joule second, J s,
- the elementary charge e is exactly 1.602 17X $\times 10^{-19}$ coulomb, C,
- the Boltzmann constant k is exactly 1.380 65X $\times 10^{23}$ joule per kelvin, J K^{-1},
- the Avogadro constant N_A is exactly 6.022 14X $\times 10^{23}$ reciprocal mole, mol^{-1},
- the luminous efficacy K_{cd} of monochromatic radiation of frequency 540 $\times 10^{12}$ hertz is exactly 683 lumen per watt, lm W^{-1}.

Note: see Box 2

Proposed new definitions of the seven base units.

- The **second**, **s**, is the unit of time; its magnitude is set by fixing the numerical value of the ground state hyperfine splitting frequency of the caesium 133 atom, at rest and at a temperature of 0 K, to be equal to exactly 9 192 631 770 when it is expressed in the unit s^{-1}, which is equal to Hz.
- The **metre**, **m**, is the unit of length; its magnitude is set by fixing the numerical value of the speed of light in vacuum to be equal to exactly 299 792 458 when it is expressed in the unit m s^{-1}.
- The **kilogram**, **kg**, is the unit of mass; its magnitude is set by fixing the numerical value of the Planck constant to be equal to exactly $6.626\,06X \times 10^{-34}$ when it is expressed in the unit s^{-1} m^{2} kg, which is equal to J s.
- The **ampere**, **A**, is the unit of electric current; its magnitude is set by fixing the numerical value of the elementary charge to be equal to exactly $1.602\,17X \times 10^{-19}$ when it is expressed in the unit s A, which is equal to C.
- The **kelvin**, **K**, is the unit of thermodynamic temperature; its magnitude is set by fixing the numerical value of the Boltzmann constant to be equal to exactly $1.380\,6X \times 10^{-23}$ when it is expressed in the unit s^{-2} m^{2} kg K^{-1}, which is equal to J K^{-1}.
- The **mole**, **mol**, is the unit of amount of substance of a specified elementary entity, which may be an atom, molecule, ion, electron, any other particle or a specified group of such particles; its magnitude is set by fixing the numerical value of the Avogadro constant to be equal to exactly $6.022\,14X \times 10^{23}$ when it is expressed in the unit mol^{-1}.
- The **candela**, **cd**, is the unit of luminous intensity in a given direction; its magnitude is set by fixing the numerical value of the luminous efficacy of monochromatic radiation of frequency 540×10^{12} Hz to be equal to exactly 683 when it is expressed in the unit s^{3} m^{-2} kg^{-1} cd sr, or cd sr W^{-1}, which is equal to lm W^{-1}.

Note: the symbol X in the presentation of the constants represents one or more additional digits to the numerical values of the constants, using values based on the most recent CODATA adjustment.

Of course, the results of the individual experiments and the two different approaches should agree. At present the CODATA task group on fundamental constants, taking into account all relevant experimental data available by the end of 2010, attributes an uncertainty of 44 parts in 10^9 to the value of the Planck constant [6]. An improvement of a factor of two is needed before the redefinition of the kg will be decided.

Concept of the new SI

With the recent progress made in the experimental determination of the Planck constant, the replacement of the last artefact within the SI is within reach. For the first time, it becomes possible to base the whole system on a set of exactly known values of fundamental constants. All units, base or derived, can then be constructed by consulting the laws of physics. In the SI, we have chosen to fix the size of seven base units by convention. For this reason, seven constants have to be selected. The set, proposed in this form for the first time in [7], is shown in box 1. From the point of view of fundamental physics one might argue that the SI is unnecessarily complicated and that basic units for time, length and mass would be sufficient. Indeed, in the view of many physicists it would be simpler to measure electrical quantities in terms of these three basic mechanical units. The kelvin and the mole are not essential since thermodynamic energy and the number of particles could be measured without introducing any special units. The candela, finally, is related to the sensitivity of the human eye and as such not necessarily related to physics. However, it should be realized that the SI should serve practical measurements as well as fundamental physics. The ampere, kelvin, mole and candela would not be necessary to make all the associated quantities measurable. But for practical applications, it is much more convenient to have these basic units. Along these lines it is not surprising that the constants listed in box 1 do not all have the same importance. The speed of light c and the Planck constant h are truly fundamental constants in modern physics as they are related to fundamental limitation principles described in the theories of special relativity and quantum mechanics. The Boltzmann constant k can be seen as conversion factor relating temperature and energy. The ground state hyperfine splitting frequency of the caesium 133 atom $\Delta\nu(^{133}\mathrm{Cs})_{\mathrm{hfs}}$ is the property of a specific atom. It cannot be expressed by more fundamental quantities in a simple way. The accuracy of the realization of the unit second linked to this constant is limited by the natural line width of the atomic transition. Considerable efforts are being made to define the unit of time through a more fundamental constant in the foreseeable future. The Avogadro constant N_A and the luminous efficacy K_{cd} are chosen for practical reasons; they are usually not considered as "fundamental" by physicists.

With the fixed constants and with the help of the laws of physics, all units in the SI may be realized. The constants set the scale for the entire system. They are the building blocks and, as a consequence, it is no longer necessary to make a distinction between base and derived units. Nevertheless, for reasons of continuity with the past, the organs of the Metre Convention decided to keep the concept of base units and to propose formal definitions for them as listed in box 2 (see also [8] for more background information).

Benefits of the new SI

The proposed changes make the SI fit for the future measurement needs. Replacing the kilogram prototype by a unit based on fundamental constants makes the system invariable over time. The electrical units can directly be realized through quantum effects within the SI with the highest accuracy and the conventional values R_{K-90} and K_{J-90} become obsolete. In addition, the uncertainties of important fundamental constants are either eliminated or appreciably reduced.

Next steps

The proposed changes will be implemented as soon as the experimental results for the Planck constant are consistent and accurate enough. The target relative uncertainty for h is < 20 parts in 10^9.

There is concern about the proposed wording in the definition of the base units [see e.g. 9]. As they stand now, the definitions are hardly understandable for the non-expert reader. This is especially true for the units where the fixed constant does not belong to the same quantity as the unit to be defined (e.g. the unit of mass, the kg, is defined by a fixed value of h which is an angular momentum). For this reason, the CGPM invites the relevant committees [1] "*... to continue the work towards improved formulations for the definitions of the SI base units in terms of fundamental constants, having as far as possible a more easily understandable description for users in general, consistent with scientific rigour and clarity.*" In this context, it is of great importance that the wider public and the user communities express their opinion about the proposed new SI. Feedback addressed to the author of this article is welcome.

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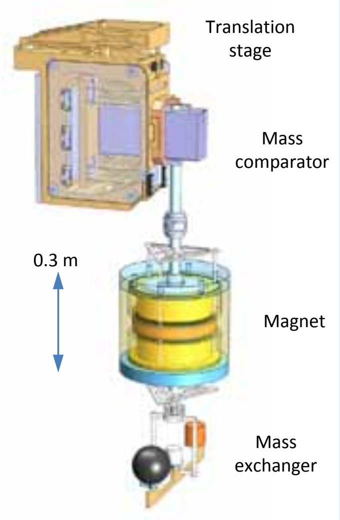
METAS operates a watt balance experiment to contribute to the efforts leading to a new definition of the kilogram based on fundamental constants. In the watt balance, electrical power and mechanical power are compared in a two phase measurement sequence. First results of the experiment were published in 2011 [10]. Currently, METAS is developing an improved apparatus, designed to reach the required relative uncertainty of < 20 parts in 10^9.



Sketch of the Mark II watt balance apparatus at METAS.

METAS is the National Metrology Institute of Switzerland, located in Bern-Wabern. Reliable, comparable and, internationally recognized metrology is an essential prerequisite for trade in measurable goods, industrial manufacturing, research, measurable services, transportation and the protection and safety of people and environment. To fulfil this mission, METAS focuses on two main objectives:

- The measurements required for the protection and safety of our society are always completed correctly and according to legal regulations - in trade, transportation, public safety, healthcare and environmental protection.
- The measurement, verification, and certification infrastructure is available to the Swiss economy and to industry for research, production, and services as required for scientific, technical or economic reasons and for quality assurance.

Therefore, the metrological activities of METAS mainly focus on measurement units and the testing of measurement equipment. The activities of METAS are designed to enable its customers to measure, verify, or evaluate conformity correctly and as accurately as possible.

Progress in Physics (26)

Improving energy confinement in fusion plasmas by plasma shaping and current profile tailoring in the TCV tokamak

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Introduction

The search for an abundant, sustainable, environmentally clean and climatically neutral energy source is more important than ever. Mankind is facing the challenge of a growing energy demand, particularly under the form of electricity, with a typical growth of a factor 4-5 expected from now to the end of the century [1, 2]. The fusion of light atomic elements like in the stars is an attractive option for several reasons, listed in box 1.

The most promising reaction is the fusion of deuterium and tritium (isotopes of hydrogen), which requires temperatures of the order of 10-20 keV (100-200 million °C) to bring the nuclei together. At these high temperatures, the gas is ionized, i.e. in a *plasma* state, macroscopically neutral but formed of electrically charged particles, which allows confining it with magnetic fields of a few Teslas. In magnetically confined fusion plasmas the density is very low and the pressure comparable to the pressure in a bicycle tire. For economic efficiency, it is important to have a confining "tire" that is not loosing too much pressure through heat and particle losses, keeping the plasma energy in "a well-insulating magnetic bottle". These losses have to be compensated by additional heating to maintain the required high temperatures. In standard plasmas, the losses are typically 50 times too high to be explained by inter-particle collisions alone and are due mainly to turbulence. But there are methods to reduce turbulence, as shown in the two next examples from the TCV tokamak experiment and numerical simulations in Lausanne.

Tokamak plasma shaping

The tokamak concept, invented in Russia in 1955, stands for "*toroidalnaya kamera magnitnaya katushka*", a toroidal chamber with magnetic coils. Tokamaks are used to create torus-like hot plasmas confined by magnetic fields. The plasma is embedded in a toroidal magnetic field (generated by a toroidal solenoid) and a poloidal field produced by a toroidal plasma current, itself induced by outside primary transformer coils. The superposition of these two fields forms a helical magnetic field, which confines the plasma. The magnetic helicity (or "rotational transform" of the field lines) is a key parameter for plasma confinement and was given the name of "safety factor" by early engineers.

These initial Russian tokamaks quickly showed excellent confinement properties but the results were not well known or accepted outside the USSR. In 1969, thanks to the development of high power lasers, the high electron temperature reached was confirmed by an international independent team using Thomson scattering. The news rapidly spread and led to the multiplication of tokamak experiments worldwide. In these initial tokamaks, the torus-like plasmas had a simple circular cross-section and the plasmas were heated Ohmically by the current flowing in the plasma.

Fusion energy basics

- The most attractive reaction is the fusion of deuterium and tritium: D + T -> He + n + 17.6 MeV.
- Deuterium is abundant, found in any water, thus well distributed geographically and practically inexhaustible. Doing the reaction with the deuterium found in one litre of water is equivalent to 300 litres of petrol.
- Tritium is produced by breeding lithium, also abundant on Earth, using the fast neutrons (14 MeV) produced in the reaction above. Another comparison: the deuterium of your bath (45 l) and the lithium of the battery of your laptop is equivalent to 40 tonnes of petrol.
- Interestingly, the reaction above is not a chain reaction. Thus, a “runaway” reaction and the resulting uncontrolled production of energy is not possible with fusion. Fusion reactions cannot be maintained uncontrollably: any disturbance or failure stops the reaction. This is why fusion is inherently safe.
- Nuclear fusion reactors produce no high activity/long life radioactive waste. The "burnt" fuel is helium, a non-radioactive gas. Radioactive substances in the system are the fuel (tritium) and materials activated while the machine is running. The goal of the ongoing R&D programme is for fusion reactor material to be recyclable after 100 years.
- Nuclear risks associated with fusion relate to the use of tritium, which is a radioactive form of hydrogen. However, the amount used is limited to few grams of tritium for the reaction and a few kilograms on site. During operation, the radiological impact of the use of tritium on the most exposed population is much smaller than that due to natural background radiation. For the reactor ITER, no accident scenario has been identified that would imply the need to take countermeasures to protect the surrounding population.
- Risks of nuclear proliferation are extremely weak (no uranium, no plutonium, etc.). Fusion research was declassified in 1958 in the middle of the cold war.
- Low CO_2 emission.

The TCV device (Tokamak à Configuration Variable) at the Centre de Recherches en Physique des Plasmas (CRPP) at EPFL, which is part of the Association Suisse-EURATOM-

Fusion, has been built to study the properties of shaped plasmas cross-sections, i.e. of different elongation, triangularity, and squareness [3]. TCV with its 16 independently supplied shaping coils, is a worldwide unique device for its flexibility in plasma shaping, see Fig.1. TCV for instance is the only tokamak that can generate negative triangularity plasma shapes (inverse Dee-shaped, symmetric to the plasma shape in Fig.1). In addition, the machine is equipped with an intense microwave power system [4], which allows heating the plasma through electron cyclotron resonance heating (ECRH). This heating method provides localized power deposition and is an important tool for controlling pressure and current profiles.

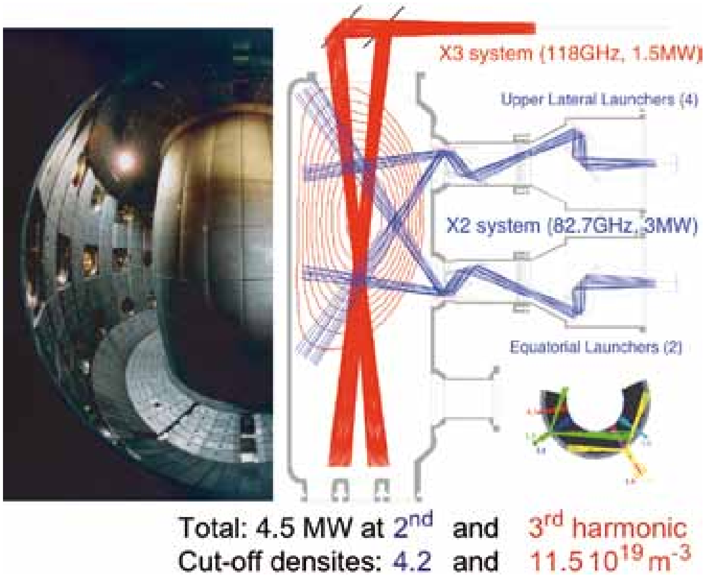

Fig. 1). TCV facility. Left: view of the inside of the vacuum vessel covered by carbon tiles with ports for heating and diagnosing the plasma. Right: cut of the vacuum vessel with a schematics of the micro-wave heating beams at the 2nd and 3rd electron cyclotron harmonics, directed to a Dee-shaped plasma (i.e positive triangularity $\delta > 0$*)*

Improved heat confinement found at negative triangularity

Varying the plasma triangularity in TCV ECRH plasmas, it was found for the first time that the energy confinement time (the ratio of the energy in the plasma to the power used to heat it, a confinement figure of merit) nearly doubles from positive to negative triangularity δ [5]. ECRH, with its local power deposition property, enabled us to undertake local heat transport measurements over a large range of plasma parameters. This made it possible to separate the effects of plasma shape and collisionality on heat transport: transport decreases towards low triangularity and high collisionality [6]. The measurements show that heat transport is reduced by a factor up to two at mid-radius going from positive to negative triangularity. These experimental heat transport results are supported by linear and non-linear gyrokinetic simulations [7]. The micro-instabilities developing in these plasma conditions, the "trapped electron modes" (TEM), have essentially shorter radial wavelengths at negative triangularity, Fig.2a, compared to positive triangularity, Fig.2b. Recent non-linear calculations showed the relevance of such linear calculations in the specific case of TEM [8].

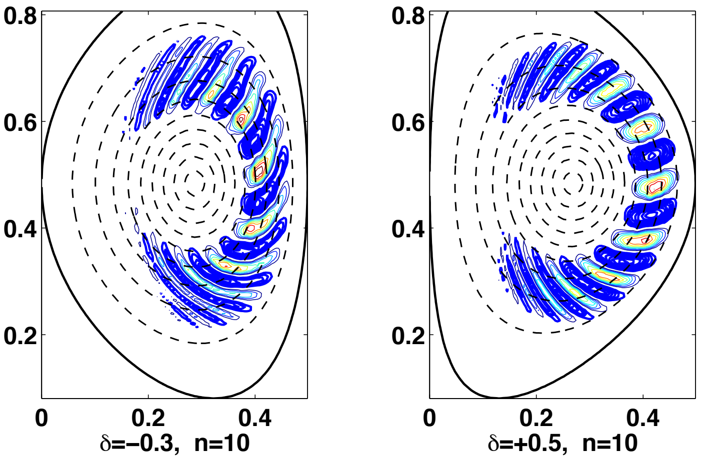

Fig. 2). Effect of ***triangularity plasma shape*** *on the poloidal cross-section of electrostatic potential cells from linear gyrokinetic calculations, for negative (left) and positive triangularity* δ *(right). This shows a reduction of the radial wavelength* $\lambda_\perp \sim 1/k_\perp$ *at* $\delta < 0$*, clearly identifiable in the midplane of left subplot, reducing transport [6]. The tokamak axis is on the left of the plasma cross-section, solid lines correspond to the plasma edge, dashed lines to the different magnetic surfaces in the plasma and* ***n*** *represents the toroidal mode number of the mode shown.*

Let's draw an analogy for the role of the radial wavelength on transport by comparing radial turbulent transport in tokamak plasma with the vertical transport in meteorology. In the summer, in the absence of wind, large vertical convection cells can develop – large cumulus - leading to vertical transport and finally storms. In the presence of wind, shearing the development of vertical cells, the vertical wavelength is reduced, leading to a reduction of the vertical transport: no storms are formed.

This analogy is suggestive and *sheared flows* are indeed known to reduce transport in tokamak plasmas. The full picture is however more complex and for instance the *shearing of the magnetic field lines* with radius, which by changing direction with radius, opposes like a braided net to radial convection, also has a beneficial effect on transport reduction.

Transport Barriers by current profile shaping

Internal transport barriers (ITB) are regions of reduced heat transport of energy and particles, which essentially allow for larger temperature and density gradients to develop while keeping the particles and the heat losses at a low level. The creation and control of ITBs are strongly related to the profile shape of the current density flowing along the torus, which determines the shearing of the magnetic field lines. In particular, ITBs tend to appear where the rotational transform profile has a local maximum (the cyan contour in Fig. 3a), At this radial location in the plasma, gyrokinetic simulations show that the radial size of the potential cells is largely reduced, Fig.3a, compared to the case of a monotonic rotational transform profile [9], Fig.3b. Appropriate current density profile tailoring can be used to control the position and strength of the ITB.

The TCV microwave power system can be employed for an accurate current density profile control through the generation of current from the waves, the so-called electron cyclotron current drive (ECCD). Thus, ITBs have been generated and studied in TCV in a variety of conditions [10], reaching electron temperatures up to 18 keV, typically one order of magnitude higher than the corresponding Ohmic condition. In TCV, ITBs can be generated in both electron temperature and density profiles.

ECCD was also used in TCV to produce for the first time in the world steady fully non-inductive discharges, in which all the current is driven by EC microwaves [11,12], an important step in the direction of the steady-state tokamak.

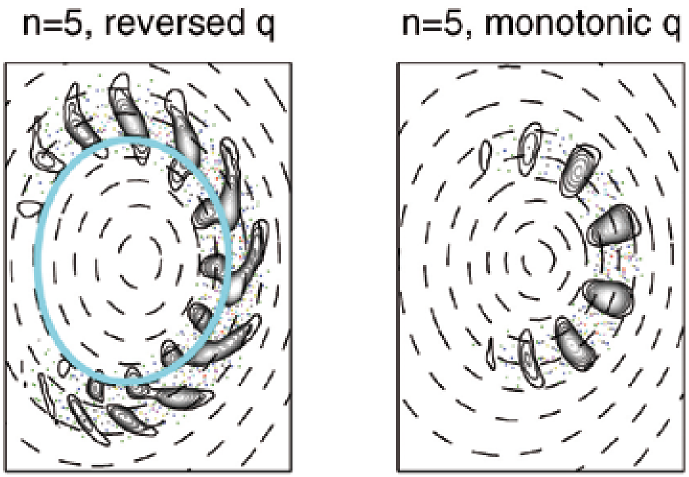

*Fig. 3). Effect of **current profile** on the poloidal cross-section of the electrostatic potential for the n = 5 mode, in the case of*

- *a current density profile with a local off-axis maximum (indicated by the solid cyan line, left subplot) and*
- *a peaked, monotonic current density profile, from [9].*

In the vicinity of the local off-axis maximum (left subplot), the electrostatic potential eddies are distorted and the radial extent of the mode is reduced, reducing transport.

Conclusion

From the experience over the years in plasma shaping and current density profile tailoring, we have learned at TCV not only to develop interesting ways of improving confinement performance, but also – through comparison of modelling and experiment - found powerful tests of theoretical models of plasma stability and confinement [e.g. 13-15].

The comparison of plasma confinement, transport and, more recently, turbulence of TCV plasmas with results from gyrokinetic codes gives strong indications on the nature of turbulent transport. More crucially, this allows testing and improving the codes that will be applied to the computationally much more demanding cases of ITER, the International Thermonuclear Experimental Reactor in construction in the South of France [16] (see box 2).

There are various other issues that still need to be tackled in view of the development of a magnetic fusion reactor, such as the very large power loads on walls resulting from relaxation instabilities of edge plasma profiles. These aspects need skills from domains extending from plasma stability, transport, control, to materials. In this view, the flexibility in plasma shaping of TCV has allowed us to test for the first time a so-called "snow flake" divertor [17,18]. This new divertor concept has recently been proposed [19] with the aim of reducing heat loads on the first wall by spreading the power over a larger surface. This is an example of the various plasma geometries and concepts to test and develop, and which a machine like TCV can economically address owing to its relative small size and its flexibility in shaping and heating systems. Improved heating power systems, also delivering power to the ions instead of only to the electrons as presently, will open new fields of research relevant to reactor physics.

High power computation

The complexity of the systems under investigation implies that numerical computations are often the only way to make a quantifiable theoretical prediction. Stimulated by the fast growing performance of High Performance Computing (HPC) platforms, there has been in recent years a vigorous development in the development of codes devoted to fusion plasma physics. Among the still largely open and most challenging problems is the question of plasma turbulence. There has been dramatic improvement in first-principles based simulations of such phenomena. Thanks to the application of massively parallel algorithms that scale up to tens of thousands of processors computations of turbulence in the whole core of tokamaks such as TCV is now feasible. In order to be able to simulate the whole ITER plasma scalable computations up to hundreds of thousands of processors will be required. The CRPP is actively pursuing research in this field, notably in the frame of the HP2C initiative (Swiss Platform for High Performance High Productivity Computing).

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Progress in Physics (27)

Brownian Motion beyond Einstein

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Brownian Motion and Diffusion

The observation of the erratic motion of microscopic particles suspended in a liquid dates back to the invention of optical microscopy in the 17th century. This phenomenon was later named after the Scottish botanist Robert Brown who published in 1827 his observation of random and apparently inexhaustible motions in a wide range of suspensions. From then on, understanding the origin of Brownian motion was under debate [1], until 1905, when Einstein gave a convincing theoretical description. He assumed that the fluctuations of small-sized spherical particles floating in a fluid are caused by momentum transfer from thermally excited fluid molecules. He identified the mean square displacement (MSD) of the particle as the characteristic experimental observable of Brownian motion, and showed that it grows linearly with time, $\langle \Delta x^2(t) \rangle = 2Dt$, thereby introducing the diffusion coefficient $D = k_BT/6\pi\eta R$, where R is the particle's radius, η the viscosity of the fluid, T its temperature, and k_B the Boltzmann constant [2]. Attempts to measure velocities of a Brownian particle in experiments had failed so far because these velocities were too high and changed too rapidly.

In 1908, Langevin adapted Newton's force balance equation to the problem of Brownian motion, by introducing a random thermal force F_{th} that arises from random fluctuations of the fluid molecules excited by the thermal energy k_BT [3]. The particle's motion is then on one hand driven by collisions with the fluid molecules, and on the other hand strongly damped by the Stokes friction force $F_{fr} = -6\pi\eta Rv$ of the surrounding viscous fluid, which is instantaneously linear with the particle's velocity v [4].

Experimental verification of the theoretical framework, developed in parallel by Einstein, Smoluchowski and Langevin, was soon possible thanks to several technical breakthroughs. It was Langevin's friend, Jean Perrin and his students who employed a combination of the both newly invented "Ultramicroscope" [5] and film camera to precisely determine the sizes of thousands of colloidal resin spheres and record each of their trajectories. Careful analysis confirmed that at equilibrium, i.e. times larger than $\tau_P = m/6\pi\eta R$ (m being the particle's mass), particle motion was completely diffusive as predicted by Einstein. Perrin's experiments related diffusion, an observable bulk phenomenon, to the non-observable fluctuations of the molecules constituting the fluid [6]. He was awarded the Nobel prize in 1926 for proving the existence of molecules and atoms.

Short-time dynamics of Brownian Motion

Throughout the 20th century the theory of Brownian motion was generalized, in particular for all times and at non-equilibrium. Therefore, the forces involved in the Langevin equation had to be defined more carefully. $F_{th}(t)$ was associated to a Dirac delta distribution, hence a Gaussian white noise spectrum, which means that the force spectrum is constant over a wide range of frequencies [7, 8]. As a result for short times, the particle, kicked by the surrounding fluid molecules, moves with a mean velocity $\overline{v}(0) = \sqrt{k_BT/m}$ and motion is ballistic with $\langle \Delta x^2(t) \rangle_{t\to 0} = (k_BT/m)t^2$. At long times, diffusive motion according to Einstein is recovered. The exponential transition from ballistic to diffusive motion occurs at the characteristic timescale τ_P (Fig. 1, left).

Uhlenbeck and Ornstein [9] further provided a solution of the Langevin equation for a harmonically bound Brownian sphere exposed to an external harmonic force $F_{ext}(t) = -Kx$, with K the force constant. Motion becomes that of an overdamped harmonic oscillator reaching at long times the constant value $\langle \Delta x^2(t) \rangle_{t\to\infty} = 2k_BT/K$. The transition from diffusive to confined motion is then characterized by $\tau_K = 6\pi\eta R/K$ (Fig. 1, right).

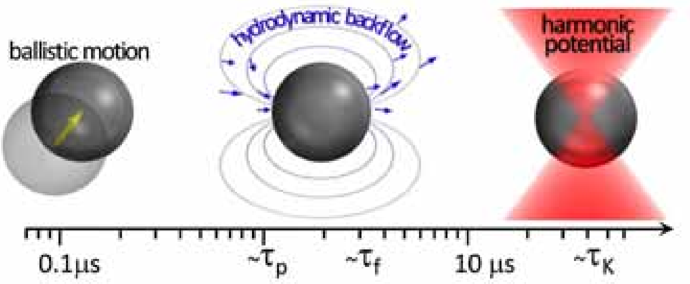

Fig 1: Characteristic time scales of a Brownian particle confined by a harmonic potential. On very short timescales ($t << \tau_P$), the particle undergoes ballistic motion governed by its mass (left). On timescale τ_f, hydrodynamic backflow develops (centre; solid lines show the emerging fluid velocity field). Finally, for $t \geq \tau_K$, the harmonic potential sets in and confines particle diffusion (right).

Also $F_{fr}(t)$ had to be refined, as the Stokes force only applies for steady flow at long times and for particles, which are much denser than their medium. However, in most experiments (also Perrin's) neutrally buoyant particles are used implying that the particle has a density similar to the surrounding medium. When the particle receives momentum from the fluctuating fluid molecules, it displaces fluid in its immediate vicinity. The non-negligible inertia of entrained fluid acts back on the sphere. As a consequence, the fluid bears a memory on the particle's past motion. The time needed by the perturbed fluid flow field to diffuse over one particle radius is then given by $\tau_f = R^2\rho_f/\eta$, with ρ_f the density of the fluid (Fig. 1, middle). The phenomenon is well known for macroscopic objects. For example, when a swimmer stops his movement abruptly, he can still feel the ongoing drag of the water.

Following Navier-Stokes hydrodynamics, the complete expression for $F_{fr}(t)$ was already given in the late 19th century by Boussinesq [10] and Basset [11], but yielded a complicated Langevin equation, which was only solved in 1945 by Vladimirsky and Terletzky who provided the exact expression for the MSD [12]. However their contribution, published in Russian, remained largely ignored. In 1967, Alder and Wainwright discovered, in numerical simulations, that the particle's velocity autocorrelation function (VAF, another characteristic observable of Brownian motion) displays a power-law decay [13] instead of an exponential relaxation, as expected for simple Stokes friction. These simulations led theoreticians in the 1970's to reconsider the contribution of fluid mechanics to Brownian motion [14, 15 and many others]. In 1992, Clercx and Schram provided the full theoretical description of a harmonically bound Brownian sphere including hydrodynamic memory [16].

Indirect experiments using dynamic light scattering in colloidal suspensions confirmed that the diffusion of colloidal particles is influenced by fluid mechanics [17, 18 and many others]. However, to achieve a high enough resolution, averaging over an ensemble of different particles was necessary.

Direct observation of Brownian Motion at ballistic and hydrodynamic timescales

This year, about 100 years after Perrin's pioneering experiments, again recent technical improvements and a careful consideration of theoretical predictions led to the experimental verification of the short-time behavior of a single micrometer sized Brownian particle. For such a particle, ballistic motion exists at timescales significantly faster than τ_P = 100 ns, and the corresponding average displacement is of the order of 1 Å.

This extraordinary high spatial and temporal resolution was achieved by optical trapping interferometry. A resin sphere (R = 1.5 µm) immersed in a fluid was held in the well-defined harmonic potential of a laser trap (also called optical tweezers). The interference pattern created between the laser light scattered by the fluctuating sphere and the non-scattered light was recorded on a high-bandwidth position detector [19]. The optical trap provided thereby the light source for illuminating the particle and, at the same time, ensured that it remained within the detector range [20]. Such configuration allowed reaching the early ballistic regime of Brownian motion, characterized by a t^2-dependence in the MSD (Fig. 2a) [21]. Also the VAF became measurable, displaying an initial exponential decay determined by the particle's mass and followed by the predicted, but up to now never measured, $t^{-3/2}$ power-law decay [21, 22] (Fig. 2b).

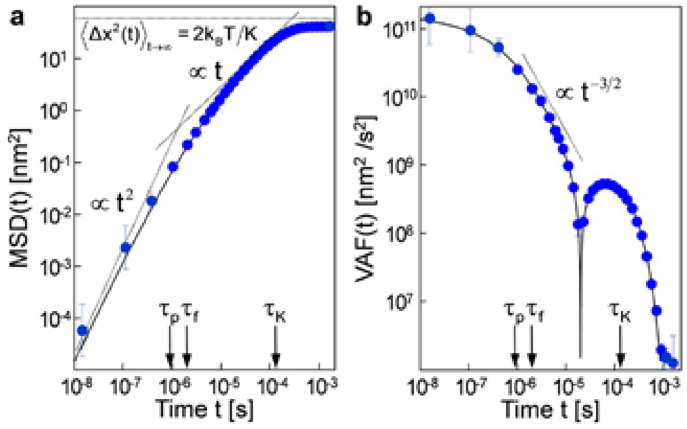

Fig 2: MSD (a) and VAF (b) of a single resin sphere (m = 21 pg, R = 1.5 µm) in water (ρ_f = 1000 g/l) for K = 0,2 mN/m. Calibration of the particle's trajectory and optical trap is achieved by fitting the theory (black continuous line) to the measured data (blue dots).

Resonances and the Color of Thermal Noise

According to the fluctuation-dissipation theorem [23], a direct consequence of the hydrodynamic coupling between sphere and fluid is that $F_{th}(t)$ is not only characterized by a delta-correlated white noise term, but has also a colored, frequency-dependent component. By increasing the trapping force $F_{ext}(t)$ and decreasing the viscosity of the fluid, i.e. reducing $F_{fr}(t)$, it could be shown that the spectrum of the thermal force indeed grows with increasing frequencies (Fig. 3a) [24].

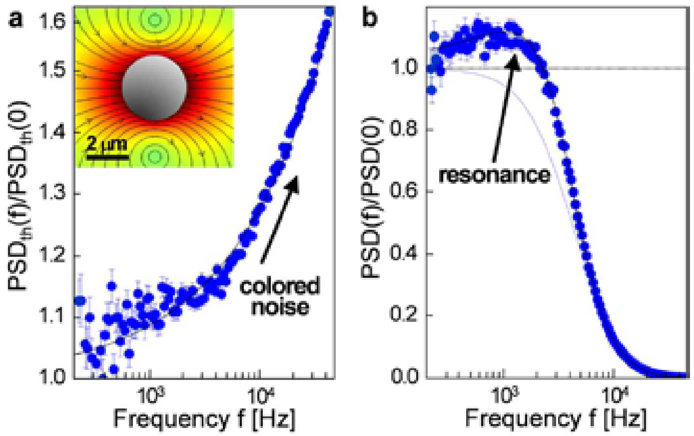

Fig 3: (a) Normalized power spectral density (PSD) of the thermal force. Deviations from Gaussian white noise are towards the blue end of the spectrum at frequencies that are much smaller than the collision rate of the solvent molecules, and reflect the color of thermal force. Inset: Corresponding fluid velocity field developing around the sphere. (b) Normalized PSD of the position fluctuations of the resin sphere. The blue line indicates exponential relaxation when overdamped motion, according to Uhlenbeck and Ornstein, is assumed. The black lines correspond to the full hydrodynamic theory.

The colored thermal noise led to a resonance in the spectrum of the bead's positional fluctuations (Fig. 3b). The appearance of such peak was up to now overlooked since hydrodynamic memory is commonly neglected and the paradigm of overdamped Brownian motion dating back to Uhlenbeck and Ornstein is assumed in optical trapping experiments. Interestingly, resonances disappeared when bringing the particle close to a hard surface. Due to the increased surface friction, the diffusion of the hydrodynamic backflow was hindered [supplementary information in 24, 25, 26].

Stronger and narrower resonances could be obtained, but yet only theoretically or in computer simulations, by increasing and modulating the trap strength through parametric excitation (Fig. 4a) [24]. It was found that the amplitude of the resonance is strongly sensitive to the stiffness of the harmonic potential, the boundary conditions at the fluid-particle interface, the fluid properties, as well as the size and mass of the particle.

A Brownian Nanoresonator

Inspired by microcantilever-based sensors [27], the particle-fluid-trap system has the potential to turn into a nanomechanical resonator to characterize fluid properties, detect the presence of analytes and probe even deeper into the molecular world (Fig. 4b). Here also theoretical predictions and new instruments will pave the way for new exciting and challenging experiments on Brownian motion.

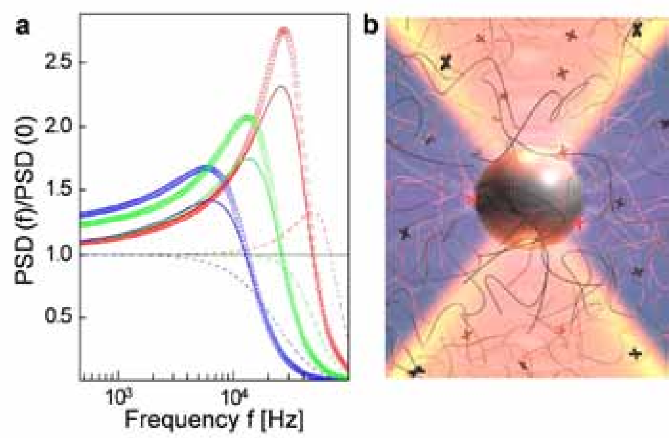

Fig 4: (a) Theoretical PSD of a resin sphere in very strong traps (blue: K=1.02 mN/m, green: 2.04 mN/m, red: 4.07 mN/m). The dashed lines give a damped harmonic oscillator. The colored dots represent the corresponding PSD after modulating the trap strength at frequency $f_{exc}=2f_{peak}$ demonstrating the possibility of parametric excitation of the Brownian resonator. (b) A Brownian nanomechanical resonator sensing molecules within its fluid environment.

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Cooper-Pair Splitter: towards a source of entangled electrons

Christian Schönenberger, Uni Basel

In quantum mechanics the properties of two and more particles can be entangled. In basic science pairs of entangled particles, so called Einstein-Podolsky-Rosen (EPR) pairs, play a special role as toy objects for fundamental studies [1]. They provide such things as "spooky interaction at distance" [2], but they also enable through their entanglement secure encoding and teleportation and are thus important for applications in quantum information technology. While EPR pairs of photons can be generated by parametric down conversion (PDC) in a crystal, a similar source for EPR pairs of electrons does not exist yet. In the solid state, electrons can be entangled by interactions. In principle it is enough to overlap two electrons in separate quantum dots to form a molecular state similar to the bonding state of the H_2 molecule. This chemical bond is formed by a pair of electrons with opposite spin. Because nature cannot decide on whether the spin up electron should sit on atom A and the spin down one on atom B, it opts for a compromise, which is a symmetric superposition. This superposition is an entangled state, an EPR pair of electrons. This state forms the ground state of a double quantum dot.

There is another system where entangled EPR pairs of electrons come almost for free. The superconducting ground state is formed by a condensate of so-called Cooper-pairs which are electron pairs in a spin-singlet state. Since there are many Cooper pairs in a metallic superconductor like Al, the main task is to extract Cooper pairs one by one and to split them into different arms as illustrated schematically in the figure. This has recently be demonstrated by two groups [3,4] using hybrid quantum-dot devices with both superconducting and normal metal contacts. The quantum dots were realized in semiconducting nanowires [3] and carbon nanotubes [4].

The first step in this source of EPR electrons is the extraction of single Cooper pairs one-by-one from the superconducting contacts. This is well known and works by tunneling. If the tunneling barrier is sufficiently opaque ($\Gamma < \Delta$) and quasiparticle tunneling is prohibited (low enough temperatures and an applied bias eV << Δ), only Cooper pairs tunnel and they tunnel well separated in time. Here, Delta

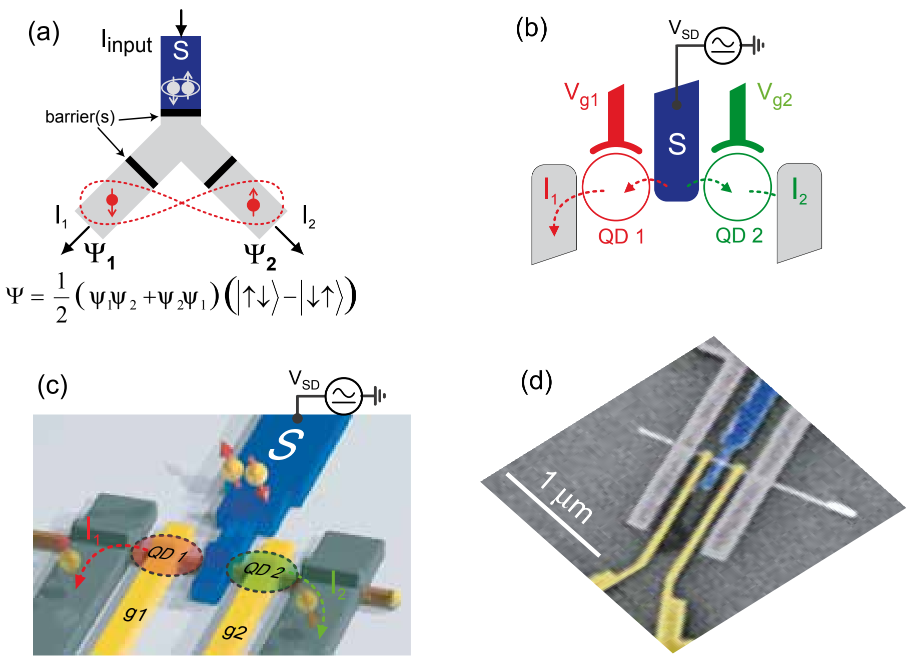

Figure (a) Illustration of Cooper pair splitting in a Y-junction with a superconducting (S) source contact injecting Cooper pair into the central branch. (b) Adding quantum dots (QDs) to the two arms increases the efficiency of Cooper pair splitting. The two QDs together with the S injector can be realized in a nanowire [3] and a nanotube [4]. An SEM image of a nanowire device is shown in (d).

and Gamma denote the superconducting gap and the tunneling rate, respectively.

The real challenge lies in the separation of the two electrons that make up a Cooper pair. The desired process is schematically shown in Fig. a. When a Cooper pair is approaching the Y branch, the two particles can stay together emanating at the left or at the right arm, or they can split. In a mesoscopic device with many channels, the desired Cooper-pair splitting has in general a weight comparable to the other undesired processes. However, theory has proposed a concept that can drastically enhance Cooper pair splitting [5]. The proposition is to make use of electron-electron interaction by introducing two quantum dots, one into each arm of the Y branch. This brings us to the device schematically shown in figure b) - c) with the two quantum dots QD1 and QD2. The enhancement of Cooper pair splitting follows, because the transfer of a Cooper pair through a single QD costs twice as much charging energy than the transfer of two split electrons traversing the two arms separately. At low temperatures, this selection rule can lead to a 100% efficient Cooper pair splitter [5]. However, the driving force of the selection rule can be infiltrated if the two electrons of a single Cooper pair tunnel sequentially, one after the other through the same QD. This unwanted channel can be suppressed if Δ is chosen sufficiently larger than Γ (albeit at the cost of the total current, which is then also reduced).

The two recent experiments demonstrated a remarkably high efficiency of up to 50%. This has to be contrasted with optical PDC where efficiencies of only < 10^{-6} are achieved. This result is remarkable, because theory predicts an inconvenient suppression factor p_S, which could easily amount to 10^{-4} or less [5]. This factor has the following origin: when the two electrons of the Cooper pair tunnel into the two different QDs, they tunnel from different geometrical positions because one QD is on the left and the other on the right side of the S contact. The efficiency is governed by a prefactor $p_S(k_F\delta r)$ which depends on $k_F\delta r$, where k_F denotes the Fermi wavevector in S and δr the lateral distance between the two tunneling events. Because the S contact has been evaporated in both existing experiments over the nanowire or nanotube, δr is expected to be of the order of the width of this contact. This would result in a strong suppression, which, however and to the surprise of the experimentalists, is absent in the experiment. If, as the experiments seem to suggest, the prefactor $p_S(k_F\delta r)$ is inactive, a fidelity near 100% should be possible if the device is operated in the ideal parameter regime. These results provide an important milestone in the realization of a solid-state source of entangled electron pairs [6]. Such a source will make new experiments possible aiming at properties of solid-state devices beyond single electron physics. Furthermore, if one is able to convert electrons into photons without loosing entanglement, this approach may even provide a source of EPR photon pairs on demand with unprecedented efficiency.

This research has led to a collaborative European project, funded by the EC under the scheme ICT within FET-Open. The project was launched in August 2011 and runs under the name SE2ND, which stands for *Source of Electron Entanglement in Nano Devices*. The principle investigators of the consortium are: Christian Schönenberger (Uni Basel), Szabolcs Csonka (BME, Budapest), Jesper Nygard (Niels Bohr, Copenhagen), Takis Kontos (ENS, Paris), Christoph Strunk (Uni Regensburg), Alfredo Levy-Yeyati (UAM, Madrid), Jan Martinek (IFM PAN, Poznan), and Patrik Recher (Uni Würzburg).

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Physik Anekdoten (15)

Anlässlich des 100. Geburtstags von Carl Friedrich von Weizsäcker veranstaltet die Deutsche Akademie der Naturforscher Leopoldina, Nationale Akademie der Wissenschaften, in Halle vom 20. bis 22. Juni 2012 eine Tagung zum Thema "Physik, Philosophie und Friedensforschung". Unter anderem wird auch das Verhältnis Heisenbergs zu von Weizsäcker untersucht, das anscheinend nicht immer spannungsfrei war, wie sich im jüngst veröffentlichten Band zeigt: "Werner Heisenberg, Elisabeth Heisenberg: Meine liebe Li!. Der Briefwechsel 1937-1946". Herausgeben von Anna Maria Hirsch-Heisenberg. Residenz Verlag St. Pölten 2011. 349 Seiten, zahlreiche Abbildungen. 29.90 Euro.

Neues zum Verhältnis von Werner Heisenberg und Carl Friedrich von Weizsäcker?

Dieter Hoffmann, MPI für Wissenschaftsgeschichte Berlin

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Carl Friedrich von Weizsäcker. (Quelle: Uni Göttingen)

Kennen gelernt hatte man sich bereits in jungen Jahren, im Winter 1926/27 in Kopenhagen, wo Carl Friedrich von Weizsäckers Vater als Diplomat in der deutschen Botschaft arbeitete. Werner Heisenberg lehrte damals als Gastdozent an der Kopenhagener Universität und war gerade dabei, zusammen mit seinem Mentor Niels Bohr, die Grundlagen der Quantenmechanik zu formulieren und damit die klassische Physik endgültig aus den Angeln zu heben. Dem gerade erst 14jährigen und bereits an philosophischen Fragen interessierten Gymnasiasten gab Heisenberg den Rat: "Physik ist ein ehrliches Handwerk; erst wenn Du das gelernt hast, darfst Du darüber philosophieren." Weizsäcker ist diesem Rat gefolgt, studierte Physik und konnte sich zu einem der führenden Physiker seiner Zeit, aber auch zu einem hoch anerkannten Wissenschaftsphilosophen und Friedensforscher des zwanzigsten Jahrhunderts profilieren. Aus der Kopenhagener Begegnung wurde so eine lebenslange wissenschaftliche Partnerschaft und Freundschaft, über der jedoch seit jüngstem ein großes Fragezeichen steht. Im soeben erschienenen Briefwechsel zwischen Heisenberg und seiner Frau Elisabeth findet sich ein Brief vom Herbst 1943, in dem sich Heisenberg höchst kritisch über seinen ehrgeizigen und sich zuweilen sehr aristokratisch, wenn nicht gar arrogant gebärenden Meisterschüler und Freund äußert:

> *"Ich verstehe mich im Grunde überhaupt nicht mit ihm; diese Art, alles prinzipiell zu nehmen und überall die 'letzte Entscheidung' zu erzwingen, ist mir so völlig fremd. Weizs. kann so Sätze sagen, wie etwa: er wäre in einer total zerstörten Stadt ganz zufrieden, denn dann wisse man sicher dass das nicht wiederkäme und dass die Menschen, aus dem Erlebnis von Schuld und Strafe reif würden zu einer anderen Art zu denken – womit dann der neue Glaube gemeint ist, zu dem er sich selbst bekennt. Dann sagt er weiter, dass dieser Glaube natürlich dem der alten Welt, d.h. der Angelsachsen, unversöhnlich feind sei und dass ja auch Christus gesagt habe, er sei nicht gekommen, den Frieden zu bringen, sondern das Schwert -, worauf man dann wieder so weit ist, wie am Anfang, d.h. wer nicht das Gleiche glaubt, wie ich, muss ausgerottet werden. Mir ist dieser ewige Zirkel von Glauben an die heiligsten Güter, die mit Feuer u. Schwert verteidigt werden müssen, ganz unerträglich; offenbar bin ich darin ganz undeutsch, und ich gerate in einer solchen Diskussion entgegen sonstiger Gewohnheit in so heftige Opposition, dass ich am Schluss nur noch das langweilige Spießertum verteidigen kann." (14.10.1943)*

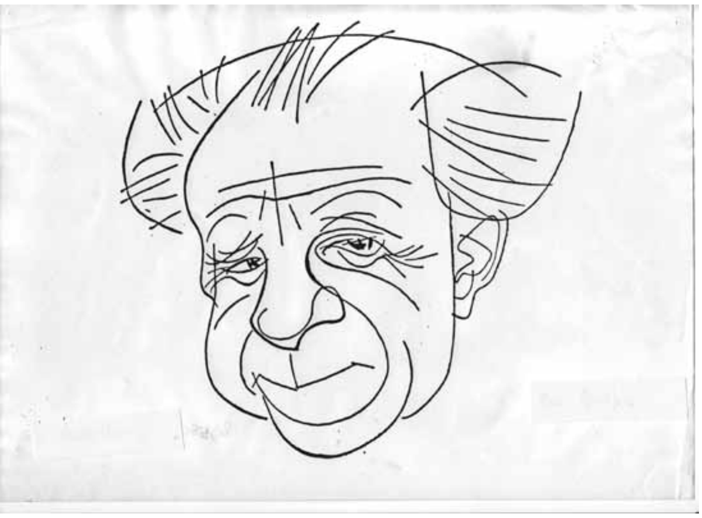
In der vorliegenden Literatur zu beiden Gelehrten ist von einem Dissens keine Rede. Vielmehr wird ihr Verhältnis als harmonisch und freundschaftlich beschrieben, wobei Wolfgang Pauli in Weizsäcker aber auch eine Art 'schwarzer Schatten' sah und manche Biographen in ihm den "Advocatus Diaboli" Heisenbergs zu sehen meinen. Gegenüber seiner Mutter hatte Heisenberg selbst im Herbst 1934 bekannt:

> *"Zu der uns umgebenden äusseren Welt habe ich wohl beinahe die gleiche Stellung wie Du. Nur die Freundschaft mit Carl Friedrich, der sich mit dem ihm eigenen Ernst mit der Umwelt auseinandersetzt, lässt mir einen kleinen Zugang in das mir sonst fremde Gebiet offen." (8.10.1934)*

Von Heisenbergs "lebensweltlichem oder gar politischem Gewissen" weiß man, dass Weizsäcker nach der nationalsozialistischen Machtübernahme zunächst gewisse Sympathien für den Nationalsozialismus empfunden hatte, glaubte er doch, dass dieser dem krisengeschüttelten Deutschland neue Hoffnung und Perspektiven geben sowie das nationale Selbstbewusstsein stärken würde. Allerdings verachtete er Hitler und lehnte die NS-Rassenlehre mit ihrem militanten Antisemitismus kategorisch ab. Dies schütze ihn davor - im Gegensatz zu vielen seiner Zeitgenossen und Kollegen - Mitglied der NSDAP zu werden. Seine Haltung im Dritten Reich und zum Nationalsozialismus gründete sich so auf ein elitäres Selbstverständnis und auf ein sich nicht zuletzt auf Stefan George beziehende zivilisationskritische Überzeugung, dass der Untergang der bürgerlichen Gesellschaft bevorstünde und die künftige Gesellschaft von einer elitären Minderheit zu gestalten sei. Mit letzterer waren mitnichten die Nationalsozialisten gemeint und deshalb sollte auch im oben zitierten Brief der dort erwähnte "neue Glaube" nicht unbedingt und kurzschlüssig als Nationalsozialismus gelesen werden. Dagegen spricht auch der explizite Christusbezug und die Herausstellung religiöser Elemente, die für die NS-Ideologie und -Weltanschauung eher untypisch waren. Weizsäcker selbst und der ihm umgebende Kreis von Vertrauten wie z.B. der spätere Pädagoge und Religionsphilosoph Georg Picht verstanden sich als Mitglieder einer elitären Minderheit und vielleicht auch als Träger eines "neuen Glaubens". Von Weizsäckers diesbezüglichem Selbstbewußtsein zeugen seine Gespräche mit seinem Freund und Gesinnungsgenossen im Winter 1938/39 über die Konsequenzen der Uran-Kernspaltung, bei deren Entdeckung er gewissermaßen Augenzeuge gewesen war. Man erkannte sofort, dass die Jahrhundert-Entdeckung eine Waffe mit bislang unbekannter Zerstörungskraft möglich machen würde und die Menschheit nur die Wahl habe, die Institution des Kriegs entweder zu überwinden, oder sich selbst zu vernichten; man verstieg sich sogar zu der wahnwitzigen Hybris, auch Hitler - quasi mit dem Bauplan der Atombombe in der Hand - davon überzeugen zu wollen, deshalb von seinen Kriegsplänen abzulassen. Als Experte und Elite wollte man schließlich gehört werden und Zugriff auf die politischen Macht gewinnen!

Fachliche Kompetenz und Überzeugung führten Weizsäcker so in den deutschen Uranverein, der ab 1940 von seinem wissenschaftlichen Mentor Heisenberg geleitet wurde und sich mit der Entwicklung einer Uranmaschine, d.h. eines Atomreaktors beschäftigte. Dass man in diesem wohl auch intensiv und sehr konkret über Atombomben nachgedacht hatte, machen nicht zuletzt Weizsäckers Arbeiten zum Plutonium als Kernsprengstoff und mehrere damit im Zusammenhang stehende Patentanmeldungen für eine Plutoniumbombe deutlich. Ein anderes Dokument von Weizsäckers damaligen politischen Illusionen bzw. Fehlurteilen ist die Reise, die ihn zusammen mit Heisenberg im Herbst 1941 zu Niels Bohr ins besetzte Kopenhagen führte. Sollte sie Weizsäcker zufolge die mögliche Einflussnahme der Physiker auf die weltweite Entwicklung von Nuklearwaffen ausloten, so wurde sie von Bohr als Kollaborationsangebot empfunden. Ob letzteres tatsächlich zu den Intention der beiden deutschen Physiker gehörte oder doch eine "Internationale der Physiker" geschmiedet werden sollte, darüber gibt es bis heute sehr emotional geführte Diskussionen unter Physikern und Historikern. Auf jeden Fall war die vermeintlich so apolitische Physik und selbst die Freundschaft ihrer Protagonisten damals zu einer hochpolitischen Angelegenheit geworden.

Keineswegs zufällig gehörte Weizsäcker zu jenen deutschen Atomphysikern, die von den Alliierten nach Kriegsende interniert wurden. Im englischen Farm Hall erfuhr man vom Abwurf amerikanischer Atombomben auf Japan, was für Weizsäcker zum "Höhepunkt des Katastrophenerlebens" wurde. In Farm Hall wurde aber auch ganz wesentlich durch Weizsäcker jene Sprachregelung gefunden, dass in Deutschland die Atombombe nicht entwickelt wurde, weil man sie nicht entwickeln wollte. Dieser absichtsvollen Schutzbehauptung stehen nicht nur Weizsäckers Bombenpatente, sondern auch andere Forschungsbemühungen deutscher Physiker entgegen. Weizsäckers Haltung im Dritten Reich führte so dazu, dass in der Nachkriegszeit insbesondere in den angelsächsischen Ländern einige Kollegen zu ihm auf Distanz gingen und er erst relativ spät zu Vorträgen in die USA eingeladen wurde; von solchen Ressentiments ebenfalls beeinflusst, ist wohl die Tatsache, dass ihm für seine Aufklärung der Energieproduktion in Sternen (Bethe-Weizsäcker-Zyklus) und anderer herausragender wissenschaftlicher Leistungen trotz wiederholter Nominierungen der Nobelpreis versagt blieb.


Werner Heisenberg (Zeichnung von H. E. Köhler, um 1970)

Weizsäcker hat sich nach dem zweiten Weltkrieg aber nicht nur zu obiger Schutzbehauptungen verstiegen, sondern sich auch zu seinem Konformismus im Dritten Reich bekannt und als seinen größten Fehler bezeichnet, gedanklich u.a. im folgenden, in Farm Hall geschriebenen Sonett verarbeitet:

Ich ließ mit sehendem Aug in dunklen Jahren
Schweigend geschehn Verbrechen um Verbrechen.
Furchtbare Klugheit, die mir riet Geduld!
Der Zukunft durft ich meine Kraft bewahren,
Allein, um welchen Preis! Das Herz will brechen.
O Zwang, Verstrickung, Säumnis! Schuld, o Schuld!

Die im Dritten Reich gemachten schuldvollen Erfahrungen haben sicherlich ganz wesentlich dazu beigetragen, dass Weizsäcker nach dem zweiten Weltkrieg in Deutschland zum Prototyp des politischen Wissenschaftlers wurde. Als solcher bezog er zu zahlreichen zeitgenössischen Kontroversen und wichtigen Problemen wiederholt und pointiert in der Öffentlichkeit Stellung. Am bekanntesten wurde seine Initiative, die 1957 zur Erklärung der "Göttinger Achtzehn" führte und vehement jede Beteiligung an der Entwicklung einer deutschen Atombombe ablehnte. Von der Sorge um einen Atomkrieg getrieben, hat er auch später immer wieder die Möglichkeiten einer dauerhaften Kriegsverhütung und Friedenssicherung hinterfragt - u.a. in dem von ihm gegründeten und bis 1980 geleiteten Max-Planck-Institut zur Erforschung der Lebensbedingungen der wissenschaftlich technischen Welt. Sowohl die Gründung des Starnberger Instituts als auch die Göttinger Erklärung wurden im Übrigen ganz wesentlich von Werner Heisenberg mitgetragen, so dass die größere Verstimmung beider Gelehrter vom Herbst 1943 anscheinend nur temporär war und offenbar keine nachhaltigen Auswirkungen auf ihre Zusammenarbeit und Freundschaft gezeigt hat.

Physik und Gesellschaft

Nationale Förderinitiativen zur Stärkung des Wissenstransfers zwischen Hochschule und Industrie

Bernhard Braunecker

Die Wohlfahrt eines Staates hängt vom Erfolg seiner Wirtschaft ab. Sie erlaubt ihm die Finanzierung der Hochschulen, deren Forschungsergebnisse wiederum Grundlagen zukünftiger industrieller Produktentwicklungen bilden. Die in der Schweiz traditionell praktizierte Gleichbehandlung von Denk- und Werkplatz hat zur heutigen Prosperität entscheidend beigetragen. Der Wissenstransfer zwischen den beiden muss jedoch permanent optimiert werden, und zwar in *beiden Richtungen*. Dafür bestens geeignet sind nationale Schwerpunktsprogramme.

Bidirektionaler Wissenstransfer

Ausgangspunkt der folgenden Überlegungen ist, dass im Gegensatz zur reinen Hochschulforschung, deren Ziele langfristig und primär auf Innovationen ausgerichtet sind, die Industrie ihre Hauptressourcen in kurzfristig angelegte Produktentwicklungen stecken muss. Massgebliches Kriterium für den industriellen Markterfolg ist der mit den Produkten zu erzielende Kundennutzen, der immer öfters nur durch den Einsatz komplexer neuer Technologien erbracht werden kann. Die Industrie verfügt jedoch meist nicht über die erforderlichen freien Kapazitäten und oft auch nicht mehr über die Fähigkeiten, die Grundlagen für neue Technologieansätze selbst zu entwickeln. Sie ist daher auf eine Kooperation mit Hochschulen und nationalen Forschungsstätten wie CSEM oder EMPA angewiesen.

Andererseits ist die industrielle Technologieumsetzung Teil einer langfristig angelegten und global ausgerichteten Marktstrategie, deren Kenntnis für die Hochschulen durchaus nützlich ist. Sie kämen bei einer Kooperation mit Problemstellungen in Kontakt, deren Lösungen in drei bis fünf Jahren von wirtschaftlicher und damit gesellschaftlicher Bedeutung sein werden. Das würde nicht nur ihre Chancen erhöhen, leichter an Drittmittel zu gelangen, sondern käme vor allem der Qualität der Ausbildung ihrer Studenten zugute, da diese gut vorbereitet in die Industrie überwechseln können. Kurzum, eine enge Verzahnung von Hochschule und Industrie unter Beachtung gegenseitiger Interessen würde allen Beteiligten zum Vorteil gereichen.

Erfolgreiche Schwerpunktsprogramme

Die nationalen Schwerpunktsprogramme hatten ihre Blütezeit in der Dekade nach 1990 und gelten rückblickend aus Sicht damals beteiligter Firmen als nachhaltiger Erfolg. An Programmen wie *Optique I / II*, *LESIT*, *Top Nano21* etc. beteiligten sich nahezu alle Hochschulen (nicht nur die ETHs) und viele Firmen aus allen Landesteilen der Schweiz. In den Programmen wurden Grundlagen für neue Technologien in einer Vielzahl von Dissertationen erarbeitet, deren Fortschritte von Hochschule und Industrie laufend gemeinsam beurteilt wurden. In *Optique II* beispielsweise wurde die Montage komplexer Optiksysteme auf nur 1 cm^2 Fläche mit von der EPFL entwickelten Minirobotern zu industrieller Reife gebracht, eine Technologie, die heute zur serienmässigen Fertigung von Präzisionsinstrumenten eingesetzt wird (Figur). Die in *Top Nano21* behandelten Grundlagenprojekte führten zu einem profunden physikalischen Verständnis der Nano-Welt mit Auswirkungen auf die moderne Chemie, Biologie, Medizin und Ingenieurwissenschaft.

Vorteile der Förderprogramme

Die Programme wurden trotz allgemein positiver Beurteilung unverständlicherweise zurückgefahren, vermutlich aufgrund massiver finanzieller Beteiligungen der Schweiz an EU-Programmen. Eine aktive Teilnahme an diesen ist jedoch zumindest für kleinere Industriebetriebe wegen des erforderlichen Aufwands an Administration und politischem 'Lobbying' oft nicht lohnend. So wurden in der Folge die Industriebelange auf rein problemfokussierte KTI-Projekte reduziert, die bilateral zwischen einzelnen Firmen und Instituten durchgeführt werden. Sie sind zweifelsohne notwendig, aber für die Grundlagenentwicklung nur bedingt geeignet.

Die Industrie reagierte nur verhalten auf das Auslaufen der Schwerpunktsprogramme. Ein wesentlicher Grund war, dass damals die Umsetzung der erarbeiteten Technologien in Produkte anstand, was alle Ressourcen band, und die bei grösseren Firmen zunehmend mit Firmenkollegen in aller Welt geschah. Das brachte zwar wertvolle Erfahrungen wie die über moderne Fertigungsmethoden im asiatischen Raum, aber es ging auch klar zu Lasten der Zusammenarbeit mit schweizerischen Hochschulen. Andererseits zeigte sich auch bald, dass im Fall der Grundlagenentwicklung, wo es primär um die Grenzen der physikalisch-technischen

Nationale Förderprogramme sind ein bewährtes Mittel, die wissenschaftliche Kompetenz der Hochschulen und die Wettbewerbsfähigkeit der Industrie zu erhöhen. Gefördert werden sollte die Entwicklung von Zukunftstechnologien, die von der Industrie aufgrund von Marktvorhersagen und von den Hochschulen aufgrund von Machbarkeitsanalysen gemeinsam als aussichtsreich beurteilt werden. Den Hochschulen sind dabei der nötige Freiraum und die erforderliche Finanzierung vom Staat zu gewähren, während die Industrie nicht direkt finanziell unterstützt werden sollte, da dies zu Abhängigkeiten und Interessenskonflikten führen würde. Hingegen soll und muss sie Zugriff auf die Hochschulergebnisse bekommen. Die schweizerischen Akademien können aufgrund ihrer Kenntnis beider Parteien und ihrer gesellschaftlichen Verankerung eine wichtige begleitende Rolle spielen.

Machbarkeit geht, die unterschiedlich kulturellen Hintergründe eher behindernd als fördernd waren. Das gern zitierte Beispiel, wonach ein Entwicklerteam in der Schweiz ein Projekt mit 1% Genauigkeitsanforderung durchzieht, dies im gleichen Zeitraum in USA aber für zehn Projekte mit 10% Genauigkeit geschieht, illustriert, wenn auch vereinfachend, das Konfliktpotential.

Da nunmehr der Zeitpunkt gekommen ist, neue Technologieentwicklungen anzugehen, sollte man sich der Vorteile der nationalen Schwerpunktsprogramme erinnern. Neben dem eigentlichen Wissenstransfer erwies sich vor allem die *Netzwerkbildung* innerhalb der Schweiz, also innerhalb kurzer informeller Wege, als sehr wertvoll. Im Folgenden sei deshalb für eine Renaissance der Schwerpunktsprogramme geworben, um anstehende wichtige Fragestellungen mit der nötigen Effizienz anzugehen. Die dazu erforderliche Fachkompetenz auf beiden Seiten kann von *Physikern* erbracht werden.

Die Rolle der Physiker in der Industrie

Industriephysiker sind oft als Vorentwickler im Bereich zwischen Technologie- und Produktentwicklung tätig und müssen somit die Grundlagenstudien über neue Technologieansätze verfolgen. Sie können deshalb die eigentliche Technologieentwicklung an den Hochschulen aktiv begleiten, zum Beispiel durch Mitbetreuung von Doktoranden und Post-Docs an den Hochschulen oder direkt in der Industrie. Zeichnen sich fundamental neue Technologieansätze ab, war und ist es durchaus üblich, diese, sofern sie noch produkt- und marktfern sind, innerhalb einer Interessengemeinschaft ('Community') gemeinsam mit Kollegen anderer Firmen zu untersuchen, ein Vorgehen, das in anderen Ländern die Regel ist. Dadurch lassen sich Risiken und Chancen für die geplante eigene Produktreihe im Voraus besser abschätzen. Das kann aber nur - und hier schliesst sich der Kreis - innerhalb national aufgesetzter, staatlicher Förderinitiativen geschehen. Dazu sollten jedoch gewisse Verhaltensregeln beachtet werden.

Kulturkonflikte

Jede Zusammenarbeit zwischen Partnern aus verschiedenen Lagern bedarf des Verstehens der 'Kultur' der Gegenseite, also der Erfolgskriterien, denen diese in ihrem Umfeld unterstellt ist. Diese erscheinen beim Wissenstransfer zwischen Hochschule und Industrie zunächst als unvereinbar, denn steht bei den Hochschulen die Publikation der Forschungsergebnisse im Vordergrund, unterliegt die Industrieforschung in der Regel der Geheimhaltung. Auch kann sich die Industrie nur dann aktiv in eine Kooperation einbringen, wenn sich ein wirtschaftlicher Nutzen zumindest mittelfristig erwarten lässt, während für die Hochschule die Forschung auftragsgemäss zweckfrei sein soll.

Als Beispiel eines solchen 'Kulturkonflikts' sei die Publikation einer von der Hochschule im Rahmen einer Kooperation erfolgreich durchgeführten Technologieentwicklung genannt, die von ihr spätestens zum Zeitpunkt der Übergabe an die Industrie vorgenommen werden muss. Aber selbst dieser späte Zeitpunkt ist für die Industrie immer noch denkbar unpassend, da sie gerade ab dann mit der ingenieurmässigen und damit oft hochsensitiven Umsetzung in ein Produkt beginnen kann. Das offensichtliche Dilemma ist, dass innerhalb der Wertschöpfungskette von der Technologie- zur Produktentwicklung Hochschule und Industrie zu völlig verschiedenen Zeiten an die Öffentlichkeit gehen können. Dieser Konflikt lässt sich jedoch lösen, wenn bestimmte Randbedingungen bei der Gestaltung der Programme beachtet werden.

Gestaltung staatlicher Förderinitiativen

Die Erfahrung mit den Schwerpunktsprogrammen zeigt, dass bei deren Konzipierung folgende Grundsätze eingehalten werden sollten:

- *Die Themenstellung muss einvernehmlich von Industrie und Hochschule formuliert werden*. Wie bereits angesprochen, kennt die Industrie aufgrund ihrer weltweiten Präsenz die marktspezifischen Erwartungen und Möglichkeiten und kann daraus Spezifikationen der zu entwickelnden Technologien ableiten. Gerade in der Definitionsphase braucht es neben dem hochschulspezifischen 'Technology Push' den industriellen 'Market Pull'.
- *Die Förderung muss breit angelegt sein*, sollte also viele KMUs und 'Spin-off' Firmen einbinden, um eine vollständige Abdeckung des notwendigen Kompetenzspektrums zu erreichen. Kleinere Firmen sind oft gerne bereit mitzuwirken, wenn sie administrativ entlastet werden. Ihre Teilnahme führt über das Programmende hinaus zu der erwähnten Netzwerkbildung.
- *Die Förderung muss Kontinuität gewährleisten*, denn Technologieentwickung ist ein evolutionärer, Kontinuität erfordernder Vorgang. Erfahrungsgemäss entwickeln sich aus gut laufenden Projekten wiederum Erkenntnisse, die zu neuen signifikanten Fragestellungen führen. Jede bedeutende Technologieentwicklung war ein mehrfaches Pendeln zwischen Methodik und Applikation, und dieser Prozess darf nicht unterbrochen werden.
- *Die Förderung muss in geeigneter Form die Kompetenzen von Industrie und Hochschule verbinden*. Zwar ist in der Startphase eher das Innovationsvermögen der Hochschule gefragt, während die Umsetzung in Produkte und Applikationen dann mehr die Aufgabe der Industrie ist. Dennoch muss die Industrie die Startphase mit Eigenleistungen begleiten, und umgekehrt muss während der Produktisierung der Kontakt zu den Hochschulen weiterhin gewährleistet sein, um bei Problemen prinzipieller Art weiter zu kommen.
- *Die Förderung muss den Erwartungen von Industrie und Hochschule genügen*. Hier kommen wir zum oben erwähnten Publikationsproblem zurück. In der Regel wird eine Zusammenarbeit so ablaufen, dass die beteiligten Industrien primär ihre Applikationen definieren und diese, basierend auf dem gewählten Technologieansatz, für ihr spezifisches Anwendungsfeld ('Field of Use') patentieren. Die Hochschulen, denen die Grundlagenentwicklung obliegt, müssen wählen, ob sie ihre Ergebnisse publizieren oder patentieren wollen. Falls letzteres der Fall sein sollte, geben sich beide Seiten das Recht der lizenzfreien Benutzung beider Patente unter Respektierung des jeweiligen Anwendungsfeldes der anderen Seite.

Vorwärtsstrategie zur Lösung des Kulturkonflikts

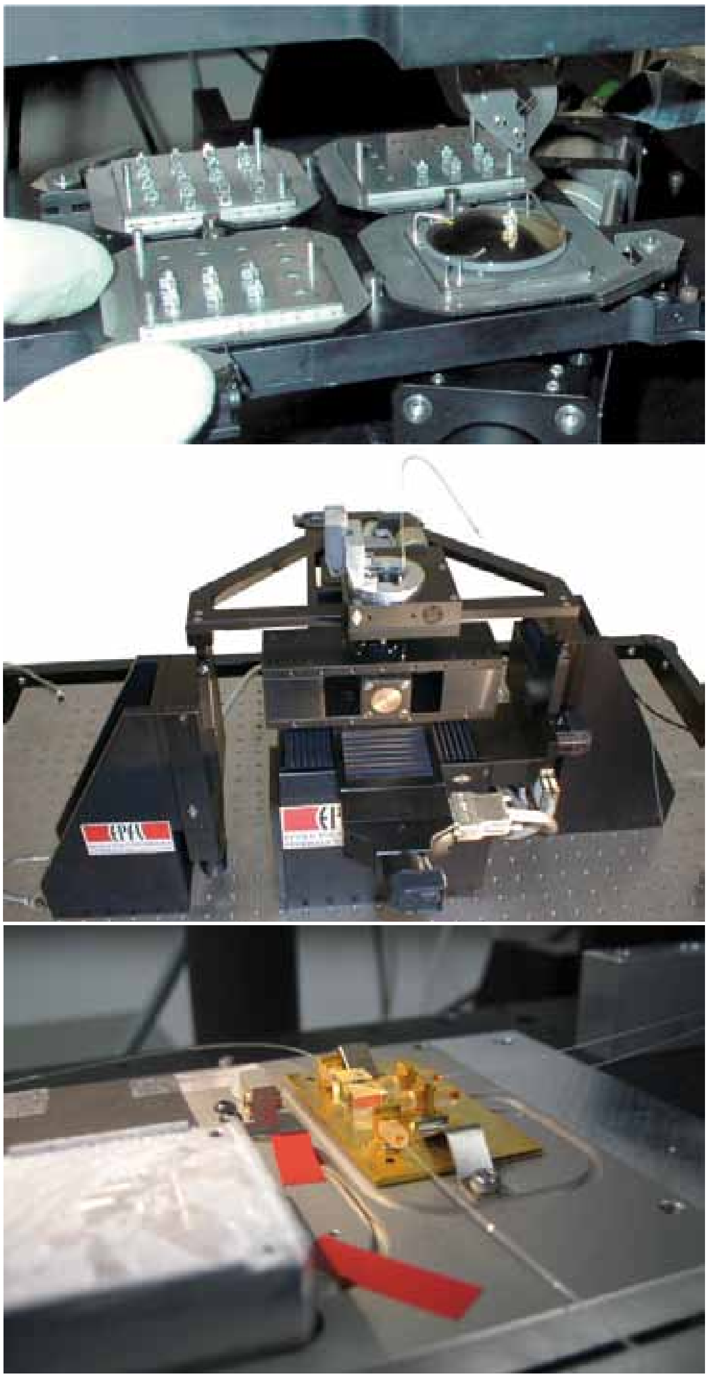
Durch die Patentierung wird nicht nur das Publikationsproblem entschärft, sondern auch ein neuer positiver Aspekt eingebracht: Jede Technologie sollte möglichst breit angewendet werden, denn sie zum Eigengebrauch allein einzusetzen, schöpft meist das ihr inne liegende Potential nicht aus. Deshalb praktizieren gerade High-Tech-Firmen die weltweite Vermarktung einer beherrschten Technologie als *OEM-Modul* ausserhalb ihres Produktspektrums unter Erhebung von Lizenzgebühren. Somit wird die von der Hochschule angestrebte internationale Publizierung der Technologie zum wertvollen Werbe- und Marketingfaktor einer Lizenzierung, und dies zum Vorteil beider Parteien.

Allerdings sei nicht verhehlt, dass die Frage, ob die Hochschulen aus der Forschungskooperation mittels Patentlizenzen Geld verdienen, also unternehmerisch tätig sein sollen, wie es mittlerweile auch in der Schweiz üblich ist, von der Industrie mit gemischten Gefühlen betrachtet wird. Denn die Gefahr besteht, dass trotz der erwähnten Patentabgrenzung Hochschule und Industrie sich irgendwann ins Gehege kommen, da sich die ursprünglich fixierten Anwendungsfelder aus Gründen der Erhaltung der Konkurrenzfähigkeit verschieben und somit überlappen können. Die Hochschulen würden dann zur staatlich finanzierten und oft steuerfrei agierenden Konkurrenz, was nicht nur einer Missachtung wirtschaftsliberaler Grundsätze gleichkäme, sondern auch die Nützlichkeit der nationalen Kooperationen für die Industrie infrage stellen könnte. Denn dann müsste man konsequenterweise das 'asiatische' Beispiel übernehmen, wo die Industrie in der Anfangsphase einer Technologie- oder Produktentwicklung vom Staat massiv unterstützt wird. Nur stünde dies quer zu den bewährten liberalen Wertvorstellungen der schweizerischen Industrie.

Vorgehen

Als Beispiele für neue Schwerpunktsprogramme seien die auf der Nanotechnologie aufbauenden *multifunktionalen Werkstoffe auf Keramik- oder Polymerbasis*, die *Substituierung Seltener Erden*, sowie neue *hoch integrierte Sensorkonzepte für satellitenbasierte Erdbeobachtung* oder auch die *industrielle Umsetzung der Physik der Kurzzeitphänomene* genannt. Bei der Auswahl sollte zum einen die physikalische Verifizierung der Grundlagen erfolgt sein, um für den nötigen 'Technology Push' zu sorgen, zum Beispiel durch vorangehende Programme des Schweizerischen Nationalfonds, zum anderen sollte die Marktattraktivität hinsichtlich einer angestrebten industriellen Realisierung gesichert sein.

Bei der Beurteilung beider Faktoren können die *schweizerischen Akademien* eine wichtige Rolle spielen. Sie sind im Gebiet der Naturwissenschaften, Technologie und Medizin gut untereinander vernetzt, und sie kennen sowohl die Kompetenzen der Hochschulinstitute als auch die Bedürfnisse der Wirtschaft. So wird zum Beispiel in der neuen *Forum Serie* der Schweizerischen Akademie der Technischen Wissenschaften SATW das Chancenpotential neuer Technologieansätze mit Hochschul- und Industrievertretern diskutiert, um gegebenenfalls die Bildung einer Interessengemeinschaft zu initiieren. In den Akademien werden auch in eigenen Kommissionen *ethische* Fragen behandelt. Deren Erkenntnisse sollten gewichtig in die Programmdefinitionen einfliessen, um später eine nachhaltige Akzeptanz der Programmergebnisse durch Politik, Gesellschaft und Öffentlichkeit zu gewährleisten.



Industrielle Technologieumsetzung aus dem Grundlagenprogramm Optique II: Optische Minibaugruppen (oben) werden mit dem EPFL-Roboter (Mitte) auf einer Saphirscheibe mit sub-mue Genauigkeit positioniert und von unten mit einem Laser fixiert. Unten ein so montiertes Interferometer auf einer kostengünstigeren Invarscheibe für den industriellen Einsatz.
(Foto: Leica Geosystems AG)
http://www.leica-geosystems.com/de/TRIMO-SMD_3837.htm

Optique II Programm des ETH Rates von 1996-1999:

Anzahl durchgeführter Projekte:	36
Anzahl teilnehmender Industrien:	32
Öffentliche Mittel (CHF in 4 Jahren):	32 Mio
Eigenleistungen der Industrie (CHF):	19 Mio
Anzahl durchgeführter Doktorarbeiten:	80
Anzahl wissenschaftlicher Publikationen:	490
Anzahl Patente:	26
Anzahl gegründeter Start-Up Firmen:	7

History of Physics (3)

Which physics for a new institute?
Albert Gockel, Joseph Kowalski and the early years of the Fribourg Institute of Physics

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The first decades of the existence of the Fribourg's Institute of Physics witnessed an impassioned opposition between two visions of science, those of Albert Gockel and Joseph Kowalski - the first two ordinary professors to serve there. This confrontation had a substantial impact on the subsequent evolution and the orientation of the institute in the first half of the 20th century.
Some accounts of the early years of Fribourg physical Institute described the distinction between Kowalski and Gockel as a genuine opposition between applied and fundamental physics. There are indeed many differences between Gockel's and Kowalski's physics but the "pure" versus "applied" science dichotomy hardly exhausts the description of the deep divide between Gockel's and Kowalski's styles of physics.

The creation of the Fribourg Institute of Physics

The University of Fribourg is quite recent. It started in 1889 with three faculties (Law, Humanities, and Theology in 1890); the Faculty of Science was added 7 years later in 1896. The Fribourg University owes much to Georges Python, the State counselor elected in 1886 and in charge of the public instruction between 1886 and 1927 [1]. In 1895, the project, the building and the founding of the Faculty of Science had all been approved thanks to Python's strong commitment. The last task, and not the least, as Python stated to the High Council was "to find good professors" [2]. This is where Joseph Kowalski (1866-1927) enters the stage.

Kowalski, born in the Russian occupied part of Poland, studied initially in Warsaw. In 1884, he enrolled in Göttingen to study mathematics and physics. He stayed there for four years and obtained his Ph.D. in 1889. He prepared his dissertation on the resistance properties of glass [3] under the supervision of the leading Göttingen physicist Woldemar Voigt [4]. As his ensuing career shows, Kowalski did not inherit Voigt's passion for theoretical physics; however, since his Göttingen years, he kept high respect for German teaching and especially German technical schools – the models that later inspired him to shape the Fribourg Institute of Physics.

In 1889 Kowalski went to Paris to attend the International Electrical Congress. He extended his Parisian stay to visit Gabriel Lippmann's laboratory on industrial electricity [5]. Later this year, he left for Berlin where he worked under the direction of Kundt and Helmholtz. In 1890 he became assistant in the Würzburg physical laboratory [6]. He transferred next to Switzerland where, the following two years, he taught successively at the Zürich Polytechnicum and Bern University where he obtained his habilitation in physics and in physical chemistry, in general physics and in analytical mechanics [7].

Joseph Kowalski's scientific trajectory and merits attracted Python's attention at the time when he was looking for a competent scientist that could help him build the Faculty of Science. In 1895, after a few exchanges with Kowalski, and impressed with the training that the latter has received in Germany and France, Python went convinced that he held the right man: he hired Kowalski as the first professor of the Faculty of Science [8] and asked him to take care of the recruitment of all the other eleven professors for the new Faculty [9].
Kowalski was certainly a versatile physicist. Judging from his educational trajectory, he could have chosen theoretical as well as experimental physics to shape his career. As Python described him "Joseph de Kowalski is an erudite man, but also a very practical one" [10]. It is hence difficult to tell what eventually motivated Kowalski's choice favoring his practical side over the other. Indeed, when Kowalski came to Fribourg, he took a radical shift toward "applied" physics. Thanks to Kowalski, the Institute became one of the best equipped in Switzerland [11]. His researches were

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[1] Georges Python played a major role in Fribourg's political landscape from the last decade of the 19th century until his death in 1927. See the article devoted to Python in the *Historical Dictionary of Switzerland*, also online at *http://www.hls-dhs-dss.ch/textes/f/F3943.php*.

[2] For a detailed account of the creation of the Faculty of Science and the political debate it raised at the time, see: *Histoire de l'Université de Fribourg Suisse, 1889-1989 : institutions, enseignement, recherches*, éd. Roland Ruffieux et al, Fribourg, Ed. universitaires, 1991, vol.2, pp.776-783.

[3] Kowalski, J., "Untersuchungen über die Festigkeit des Glases", *Wied. Ann.*, vol. XXXVI, p. 307, 1889, see also a reproduction in *Journal de Physique Theorique et Appliquée*, vol. 9, 1890, pp.166-167.

[4] Voigt joined Göttingen in August 1883 to serve as ordinary professorship for theoretical and mathematical physics, see Jungnickel, C., and McCormmach, R., *Intellectual mastery of nature, Theoretical physics from Ohm to Einstein*, Chicago: University of Chicago Press, vol.2, pp.115-119.

[5] A well-known anecdote reports that he brought Marie Sklodowska, whom he knew from Poland, in touch with her future husband Pierre Curie. Be it as it may, the close ties that he kept since then with the Curies explain that he could later obtain some radium for Gockel's laboratory.

[6] He worked probably under the direction of Röntgen.

[7] *Curriculum vitae de Joseph Kowalski*, Dossier Kowalski, Archives d'Etat de Fribourg (AEF); *Notice sur les travaux scientifiques de Joseph Kowalski*, Dossier Kowalski, AEF

[8] He was actually already teaching at Fribourg University two years before the official creation of the Science Faculty with such general lessons as "Energy and its transformations", "Cosmogonic hypothesis", and "Light" – dispensed in the Faculty of Humanities. *Histoire de l'Université de Fribourg Suisse, 1889-1989 : institutions, enseignement, recherches*, éd. Roland Ruffieux et al, Fribourg, Ed. universitaires, 1991, vol.2, p.785.

[9] Kowalski for physics, H. Baumhauer for mineralogy, M. Arthus for physiology, M. Westermaier for botanic, A. Bistrzycki for chemistry, J. Brunhes for geography, M. F. Daniëls for mathematics, R. de Girard for geology, R. Thomas-Mamert for chemistry, M. Lerch for mathematics, L. Kathariner for zoology, *Ibid*, pp.783-785.

[10] Letter from Python to the State Council, *Lettre du 20.11.1915*, AEF.

[11] "Das hiesige physikalische Institut gehörte zweifellos zu den best eingerichteten der Schweiz, und ich erinnere mich noch wohl wie der später berühmt gewordene Ophthalmologe Vogt den Wunsche äusserte im hiesigen Physikalischen Institut arbeiten zu können, weil er die gewünschten Einrichtungen sonst nicht fand.", Urspung, A., "Ein Tag mit Westermaier", *Beitrag zum 50jährigen Bestehen der Universität Freiburg,*

devoted mainly to electrical phenomena, which involved, among others the study of capacitors and electrical arcs (Kowalski made also some researches on phosphorescence).

Albert Gockel (1860-1927) is today mostly known for his pioneering role in the discovery of the cosmic rays [12]. He started his studies in Konstanz gymnasium. He continued his training in the Universities of Freiburg im Breisgau, Würzburg and Karlsruhe. He obtained his doctorate in 1885 in Heidelberg under the direction of Ferdinand Braun, with his work on the Peltier's effect [13].
Gockel taught for a few years at the Ladenburg gymnasium in his native Baden state. During that time he investigated extensively the phenomena related to lightning and storm [14]. In a series of meticulous measurements he monitored the potential of atmospheric electricity and reported his results in great detail comparing them with the observations of the Karlsruhe's meteorological station and with other investigations, and especially those of Elster and Geitel [15]. Gockel summed up his researches in a book published in 1895 and entitled *Das Gewitter* [16] that received a warm welcome and which was reedited several times.
When Gockel came to Fribourg in 1896 to become Kowalski's assistant he was already 36 while Kowalski was only 29 [17]. Over the next four years, Gockel worked on his habilitation work entitled "*On the relationship between polarization and current density in solid and molten salts*" [18]. Such a topic, at odds with Gockel's actual research interests may appear surprising. It becomes less so when one takes into account how much the director of the habilitation work, in the present case Kowalski, had a say in the choice of the subject and in its orientation [19]. Be it as it may, Gockel did never come back to his habilitation topic in his further research. In meanwhile, the acceptance of Gockel's habilitation gave rise to a first conflict between both men.

The Kowalski – Gockel opposition

The acceptance of Gockel's habilitation depended on Daniëls', professor of mathematics, and Kowalski's *reports*. While Daniëls judged Gockel's work "good and appropriate", Kowalski found it too vague and inaccurate [20].
It took Gockel one year to answer Kowalski's criticisms and see his habilitation finally accepted. Soon after, the Faculty proposed him as extraordinary professor for physics and meteorology [21]. He was assigned to teach meteorology and "other selected topics in physics", subjected, of course to the prior approval of Kowalski [22]. The latter was definitely not willing to give up his grasp over Fribourg's physics. Thus, the decision of Gockel's nomination was shortly supplemented with some official clauses severely restraining Gockel's status and role in the Institute of Physics: Indeed, in the next protocol Nr 267 of the State council one reads:
"The Faculty wished to clarify the rules applying to the relations between the Institute of Physics and Dr Gockel. The holder of the physics chair, Dr. Kowalski has agreed to the following arrangement: 1. The Institute of Physics concedes to Mr. Gockel the exclusive use of room Nr 24 [...] 3. Mr. Dr. Gockel has the right to use for research or teaching, instruments from the collection of the Physics Institute, but after having made the prior special request to the Director of the Institute of Physics and provided that the latter does not wish to reserve the same equipment for its own research or teaching. [...]" [23]
The room Nr 24 was actually a small room secluded from the rest of the physical Institute. Moreover, no assistant or other technical help was attributed to Gockel. Actually, over the years when Kowalski directed the Institute of Physics, and even later on, Gockel was never granted, on a regular basis, the appropriate resources required by his researches. He had instead to write directly to the state education authorities, to ask for more funds for particular researches. While such extra funds were often granted to him, his fixed funds remained the same since his initial nomination as an extraordinary professor in 1903 [24]; the amount he could invest in his research was actually even less given that a part had to be allocated to his students' laboratory work. [25]

Over the next years Kowalski continued to counter any ini-

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i.d. Schweiz, 1947

[12] An account of Gockel's crucial role in the cosmis ray discovery and the rivalry that opposed Gockel and the Austrian Hess will be covered in a forthcomming article. The present paper intends rather to put emphasis on the confrontation between Kowalski and Gockel, but see two articles already devoted respectively to Gockel's and Hess' investigations in the series “Physics Anecdotes” by Hansruedi Völkle and Peter Maria Schuster in Communications of the SPS, July 2009; see also Schneuwly, H., *Albert Gockel et la découverte du rayonnement cosmique*, Fribourg, Edition Universitaire de Fribourg, 1990.

[13] *Actes de la Société Helvétiques des Sciences Naturelles*, vol.108, 1827, pp.3-9 / Beziehungen der Peltierwärme zum Nutzeffekt galvanischer Elemente, *Annalen der Physik und Chemie*, Bd.XXIII, Leipzig 1885.

[14] Schneuwly, H., *Albert Gockel et la découverte du rayonnement cosmique*, Fribourg, Edition Universitaire de Fribourg, 1990, p.6

[15] *Ibid*, p.7; Gockel, A., "Messungen des Potentialgefälles der Luftelectizität in Ladenburg a. Neckar", *Meteorologische Zeitschrift*, 1898, pp.281-297

[16] Gockel, A., *Das Gewitter*, Köln, Bachem, 1895

[17] The exact circumstances of Gockel's arrival to Fribourg are unclear. Maybe Kowalski knew Gockel's *Das Gewitter*, or maybe Gockel chose Fribourg and Kowalski because electrical phenomena were at that time at the focus of the Fribourg institute of physics, but such was also the case for many other institutes. Another reason could be related to religious affinity: Gockel was catholic and the Fribourg University was at the time proudly displaying its status of the only catholic university in Switzerland.

[18] Gockel, A., "Über die Beziehungen zwischen Polarisation und Stromdichte in festen und geschmolzenen Salzen", *Zeitschrift für Physikalische Chemie*, Leipzig, XXXIX/5, 1900, pp.529-559.

[19] *Règlement relatif à l'examen de doctorat*, Protocoles de la Faculté des Sciences, Cahier 1, 1896-1906, Archives de la Faculté des Sciences (AFS).

[20] Kowalski's main griefs were that Gockel's handling of data was inappropriate and incomplete.

[21] This was certainly a welcome decision given Gockel's recent wedding (1902) with Paula Baumhauer, daughter of Heinrich Baumhauer, Fribourg professor of mineralogy.

[22] *Extrait du protocole du conseil d'Etat n°266*, 29 février 1903, Dossier Gockel, AEF.

[23] "La Faculté s'est préocupée du règlement des rapports entre l'Institut de physique et M. le Dr Gockel ; le titulaire de la chaire de physique, M. le Dr Kowalski, a donné son adhésion à l'arrangement suivant : 1. L'Institut de physique concède à M. Gockel l'usage exclusif de la salle N°24. [...] 3. M. le Dr Gockel aura le droit de se servir, pour ses recherches ou son enseignement, des instruments de la collection de physique, mais après en avoir formulé, au préalable, la demande spéciale auprès du directeur de l'Institut de physique et pour autant que celui-ci ne désire pas se réserver les mêmes appareils pour ses propres recherches ou son enseignement.", *Extrait du protocole du conseil d'état, 267*, 29 février 1903.

[24] Namely 500 francs per year, *protocole n°266, ibid*.

[25] Some studies suggest that this lack of funding was one of the major reasons why Gockel “lost” the run for the cosmic ray discovery against Hess: "[Gockel] didn't have the material means to challenge and compete with [Hess]", Schneuwly, H., *Albert Gockel et la découverte du rayonnement cosmique*, Fribourg, Edition Universitaire de Fribourg, 1990.

tiative aiming at strengthening Gockel's effective situation. When, in December 1909, the Faculty of Science proposed to promote Gockel to an ordinary professorship [26], Kowalski fought back arguing that the Institute of Physics was not intended to have two ordinary professors and that he wanted to remain the only examiner for the physics degree and the doctorate. Significantly, Kowalski wished moreover "that the laboratory of M. Gockel not be named 'a physical institute' at all" [27]. Gockel got eventually promoted but again under restrictive clauses: In the Faculty meeting protocol stating his nomination (February 18th, 1910) the Faculty narrows the scope of Gockel's promotion making clear that " […] there is no question of creating a second ordinary professorship for physics, but to recognize the number and quality of the services that Mr. Gockel did and the considerable amount of his works, while not causing any prejudice to the rights and privileges of the holder of the ordinary professorship of physics […] The title of professor is conferred with rights attached thereto, ad personam, to Dr. Albert Gockel." [28]

Thus, in spite of his promotion, Gockel's effective position and status in the Faculty did not see much improvement. His situation, his salary and the funds granted to his Institute did not change until the 1920's, more than five years after Kowalski left Fribourg and returned to Poland [29].

Different ideas of physics

Kowalski's and Gockel's teachings were not that different and both men were working in rather similar fields. However, and this may explain their problematic relationship, Gockel and Kowalski had very dissimilar visions of science and pursued different objectives in their research. As Schneuwly stated: "with Gockel and Kowalski, we are facing two worlds, two radically different visions of research and science" [30]

In 1905, Kowalski co-authored an article on "the teaching of applied sciences in the Fribourg Institute of physics" [31]. In a form of a genuine *manifesto*, it puts forth Kowalski's vision of what science is all about and helps to understand how the latter intended to develop the Fribourg Institute of physics.

The article starts with a firmly stated premise: science should be at the service of industry. Thus, investigations in physics are to be judged relative to their utility and the latter can be secured linking physics to industrial development. In that respect, he wished physical sciences in Fribourg to develop in full acknowledgment of the growing Swiss industry.

Kowalski distinguished consequently different categories of physicists. The ones he valued most were those professionals that he dubbed *Wissenschaftliche Hilfsarbeiter* of the industry [32]: Their role was to provide assistance to industry and to alleviate its potential development. These were, to his opinion, just the physicists that the Fribourg Institute of Physics was endeavoring to train: "Without competing with our leading Swiss technical schools in Zürich and Lausanne, we provide students with a culture, possibly less technical, but which is nevertheless very useful in industries whose development depends largely on that of physical sciences." [33]

On the opposite side of Kowalski's categorization there were those physicists that he regarded as least important for the advancement of science. This category, where he undoubtedly situated Gockel, regroups scholars that are investigating the laws of nature for the sake of knowledge for knowledge. The superiority of the Wissenschaftliche Hilfsarbeiter over the latter is made clear in another strong statement where Kowalski concludes that “within an industrial environment [the physicist] no longer appears as an estranged being, looking for laws with no purpose or use. [...] His efforts are constantly aimed at specific needs and his findings are [thus] unlikely to remain buried in the files of some great Academy; they are on the spot magnified by the practical collaboration of which he is part of." [34]

One can better grasp Kowalski's precepts examining how he himself followed them in his and his collaborators' research on electricity. In 1899, Kowalski found out that "the rate of production of nitrous vapors obtained by electrical discharges in the air increases considerably with the frequency of the alternating current producing the latter" [35]. He then asked Ignacy Moscicki (1867-1946), his new assistant who replaced Gockel, to study not the causes of the phenomenon but the actual effects and relations that he could observe. In the following years Moscicki prepared a thesis on "The atmospheric nitrogen and its fixation by the electric arc", and Kowalski, while supervising him, took

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[26] *Réunion de la Faculté des Sciences*, 4 décembre1909, Protocole de la Faculté des Sciences, Cahier 2, Archives de la Faculté des Sciences (AFS)

[27] The proposal to promote Gockel and Kowalski's reactions to it are stated in a letter from the Faculty of science dean (Dr. Daniëls) to the director of Fribourg's State education dated December 9, 1909. *Correspondance du doyen de la Faculté des Sciences*, AFS.

[28] "Il est réservé qu'il n'est pas question de créer un second ordinariat pour la physique, mais bien de reconnaître le nombre et la qualité des services rendus par M. le Dr Gockel, ainsi que la quantité considérable de ses travaux sans porter aucun préjudice aux droits et prérogatives du titulaire de l'ordinariat de physique. […] Le titre de professeur est conféré avec les droits qui s'y rattachent, à titre personnel, à M. le Dr Albert Gockel". *Extrait du protocole du conseil d'Etat n°284*, 18 février 1910, Dossier Gockel, AEF.

[29] Kowalski kept his influence over the Faculty of Science even years after his departure. It can be witnessed for example in the controversy between his successor Paul Joye and Gockel.

[30] Schneuwly, H., *Albert Gockel et la découverte du rayonnement cosmique*, Fribourg, Edition Universitaire de Fribourg, 1990.

[31] Kowalski, J., and Dalemont, J., "L'enseignement des sciences appliquées à l'Institut de Physique de l'Université de Fribourg", *Revue Générale des sciences pures et appliquées*, n°17, 15 septembre 1905, pp.773-776.

[32] In French :"Savants associés à l'oeuvre industrielle", *ibid*, p.774.

[33] "Sans donc faire concurrence à nos grandes écoles techniques suisses de Zürich et de Lausanne, nous donnons aux étudiants une culture moins technique, sans doute, mais qui est néanmoins d'une grande utilité dans les industries dont le développement dépend en grande partie de celui de la science physique." *ibid*, p.776.

[34] "Ainsi placé au milieu d'un organisme industriel en pleine activité, le savant n'apparaît plus comme un être hors cadre, cherchant des lois sans utilité ou sans utilisation. Son effort est orienté sans cesse par des besoins précis et ses découvertes ne risquent pas de rester enfermées dans les dossiers de quelque grande Académie; elles sont imédiatement mises en valeur par la collaboration pratique dont il est entouré.", *ibid*, p.775.

[35] "Déjà, en 1899, j'avais remarqué que le rendement des vapeurs nitreuses produites dans l'air par des décharges électriques augmente beaucoup avec la fréquence du courant alternatif employé pour produire ces décharges. Cette influence de la fréquence sur la quantité des vapeurs nitreuses produites par les décharges, qui n'a été, que je sache, remarqué par aucun autre chercheur, peut être expliquée de différentes manières." Kowalski, J., «Production de l'acide nitrique par des décharges éléctriques», *Société Internationale des Electriciens. Extrait du Bulletin*, 2e série, tome III n°26, p.3.

a deeper look at these effects [36]. He investigated what improvements could increase the rate of the nitrous production and realized that more efficient capacitors were needed. Even before Moscicki finished his doctorate in 1903, Kowalski founded with him and Jan Modzelewski (1875-1947), another of his assistants, the *Fabrique Suisse de Condensateurs* in Fribourg. Another research spin off created at the time that resulted from Kowalski's team activity was the *Societé de l'Acide Nitrique* initiated and later run by Moscicki after he left the Fribourg's institute.

From that moment on the number of Kowalski's publications decreased sharply. After Moscicki and Modzelewski left the University to run their industries Kowalski kept in touch with his former students until 1915 when he himself left his Institute to come back to Poland.

Gockel wrote conversely quite a large number of papers between 1901 and 1927. These publications report mostly his observations of atmospheric electricity and radioactivity. Gockel's experimentation proves as meticulous as Kowalski's, to witness his study "On diurnal variation of the loss of electricity in the atmosphere" [37], where Gockel did several hundreds of measurements over three years at different time of the day before he felt ready to report on his results. In this work he carefully discussed all the circumstances of his experiments and the instruments he used. Indeed, Gockel kept up a correspondence with many physicists over the working of his instruments and was anxious about cases where the latter could prove defective [38]. He and Kowalski were both relishing precise measurements.

Gockel versus Kowalski, an opposition between pure and applied physics?

Kowalski's 1905 *manifesto* indeed suggests this way to differentiate Kowalski's and Gockel's research. But, if we understand "applied" as characterizing the transfer of an existing knowledge, from a theoretical to a practical level, then "applied physics" does not characterize aptly Kowalski's scientific undertakings.

In Kowalski's study of the rate of production of nitrous vapors, the discovery of the increase in the vapors production with the frequency of the current was not an application of former knowledge but a genuine *creation* of knowledge, indeed of *practical* knowledge. The *Fabrique Suisse de Condensateurs*, as well as the *Societé de l'Acide Nitrique* that Kowalski created with his collaborators could indeed be characterized as "applications", but not the work they did at the Fribourg Faculty of Science. Their research does not appear as more "applied" than Gockel's.

On the other hand, Gockel's research displays the same typical experimental moves as found in Kowalski's. Judging from the point of view of Kowalski's and Gockel's laboratory practices, there is not much difference either.

Actually, one meets in their case the difficulty which makes contemporary historians and philosophers of science wary of hasty distinctions in terms of "applied" and "pure" science: it is just impossible to draw a clear line between the activities supposedly belonging to one or the other.

Yet, there is a difference between Gockel and Kowalski, a definite polarization in their science views. Gockel was interested in the very causes of natural phenomena, and tried to identify the circumstances and parameters best suited to understand them. Kowalski, on the other hand, aimed mostly at gaining practical knowledge, in a form of rules that enable action, namely handling and manipulating a physical object to one's advantage.

Thus, in the end, the difference between Kowalski's and Gockel's physics did not lie in their activities or the objects of their investigations. It was primarily a matter of inclination toward explanatory knowledge or useful knowledge that gave a specific turn to their research, and influenced the organization of their inquiry as well as their choice of what they thought relevant arguments, good explanation methods, etc. [39].

Epilogue

In 1915, Kowalski took a leave of absence from the Fribourg Institute to come back to Poland and definitely resigned his chair in 1919. During these years, serving as its first physics professor, he helped to shape Warsaw's new polytechnic school apparently following the same precepts that guided his action in Fribourg. From 1919 on, Kowalski turned to diplomacy; when his former student Moscicki became president of Poland in 1926 [40], Kowalski was invited to join the government.

Kowalski's departure did not enable Gockel to promote at last his own vision of physics. Paul Joye (1881-1955), Kowalski's *protégé* since 1910, replaced his mentor at the direction of the Fribourg Institute where he remained faithful to Kowalski's ideas and was almost equally successful in enforcing them in the subsequent development of Fribourg physics.

After Gockel's death in 1927 his laboratory was shut down and no effort was done to find a successor. Paul Joye remained the only professor of the Physical Institute until his departure for the *Entreprises Electriques Fribourgeoises* in 1932. The Physical Institute stayed in line with Kowalski's ideas until 1943 when a second chair of physics was created. As elsewhere in Switzerland, the post-war years proved decisive in shaping new directions for Fribourg physics: in 1952 André Houriet was thus inaugurating the Fribourg Theoretical Physics Institute founded with the support of the Swiss National Science Foundation [41].

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[36] Kowalski, J., "Quelques applications des oscillations électriques lentes", *Congrès de l'Association française pour l'avancement des sciences, Angers*, 4 au 11 Août 1903.

[37] Gockel, A., "Sur la variation diurne de la déperdition de l'électricité dans l'atmosphère", *Archives des sciences physiques et naturelles,* 1904.

[38] See Schneuwly, H., *Albert Gockel et la découverte du rayonnement cosmique*, Fribourg, Edition Universitaire de Fribourg, 1990.

[39] One could say that their « styles of scientific thinking » were ultimately opposed, see Crombie, A. C., *Styles of scientific thinking in the European tradition*, London, Duckworth, vol.1-3, 1994.

[40] Moscicki returned to Poland in 1913.

[41] It might be conforting to know that between 1927 and 1952 Friedrich Dessauer, that held the Fribourg chair of physics between 1937 and 1953 took genuine interest in Gockel's life and work, see *Histoire de l'Université de Fribourg Suisse, 1889-1989 : institutions, enseignement, recherches*, éd. Roland Ruffieux et al, Fribourg, Ed. universitaires, 1991, vol.2, pp.806-808.

The 2011 Nobel Prize in Physics

Norbert Straumann, Uni Zürich

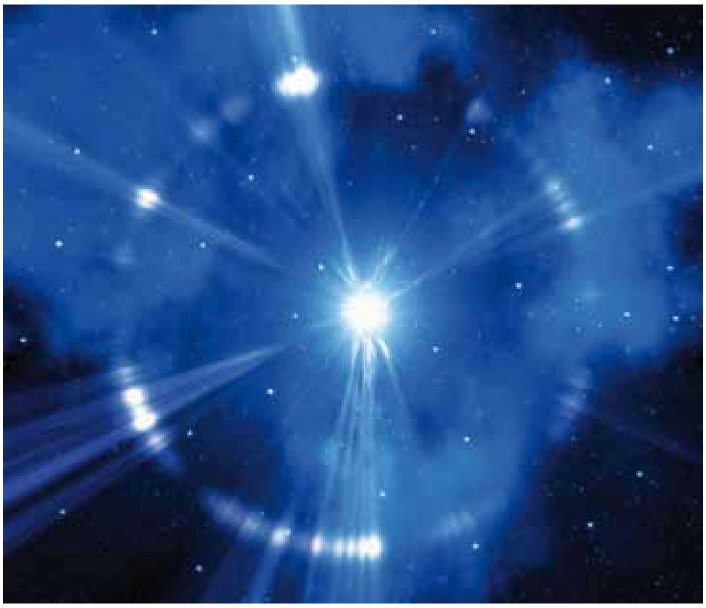
Press release on 4 October 2011

"The Royal Swedish Academy of Sciences has decided to award the Nobel Prize in Physics for 2011 with one half to **Saul Perlmutter** and the other half to **Brian P. Schmidt** and **Adam G. Riess** 'for the discovery of the accelerating expansion of the Universe through observations of distant supernovae'."

Type Ia supernovae as standard candles

It has long been recognized that supernovas of type Ia are excellent standard candles and are visible to cosmic distances. In 1979 Tammann [1] and Colgate [2] independently suggested that at higher redshifts this subclass of supernovae can be used to determine also the deceleration parameter. In the 1990's this program became feasible thanks to the development of new technologies which made it possible to obtain digital images of faint objects over sizable angular scales, and by making use of big telescopes such as Hubble and Keck.

In the standard scenario of Type Ia supernovae a white dwarf accretes matter from a nondegenerate companion until it approaches the critical Chandrasekhar mass and ignites carbon burning deep in its interior of highly degenerate matter. This is followed by an outward-propagating nuclear flame leading to a total disruption of the white dwarf. Within a few seconds the star is converted largely into nickel and iron. The dispersed nickel radioactively decays to cobalt and then to iron in a few hundred days. (A lot of effort has been invested to simulate these complicated processes, but for the cosmological applications this may not be so relevant.) In view of the complex physics involved, it is not astonishing that Type Ia supernovae are not perfect standard candles. Their peak absolute magnitudes have a dispersion of 0.3-0.5 mag, depending on the sample. The research teams of the Nobel Prize winners have, however, learned over the years to reduce this dispersion by making use of empirical correlations between the absolute peak luminosity and light curve shapes. Examination of nearby SNe showed that the peak brightness is correlated with the time scale of their brightening and fading: slow decliners tend to be brighter than rapid ones. There are also some correlations with spectral properties. Using these correlations it became possible to reduce the remaining intrinsic dispersion, at least in the average, to $\simeq 0.15$ mag. Other corrections, such as Galactic extinction, have been applied, resulting for each supernova in a corrected (rest-frame) magnitude. The redshift dependence of this quantity is compared with the theoretical expectation within the class of cosmological models independently found by Friedmann and Lemaître.



Results

The Nobel laureates are leaders of the two major teams investigating highredshift SNe Ia: the 'Supernova Cosmology Project' (SCP) and the 'High-Z Supernova search Team' (HZT)[1]. Each team has found a large number of SNe, and both groups have published almost identical results. In 1998 the Hubble diagram for Type Ia supernovae gave, as a big surprise for many cosmologists, the first serious direct evidence for an accelerating Universe. After the classic papers [3], [4], [5] significant progress has been made by both teams. (For up-to-date information, see the home pages [6] and [7].) Possible systematic uncertainties due to astrophysical effects have been discussed extensively in the literature. The most serious ones are (i) *dimming* by intergalactic (grey) dust, and (ii) *evolution* of SNe Ia over

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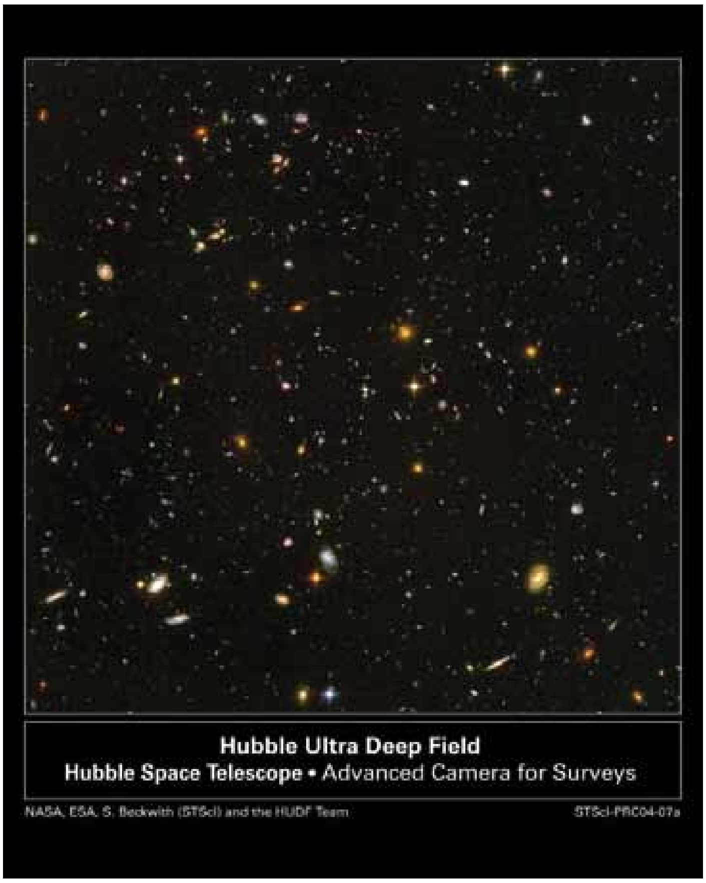
[1] An active member of this team – since its constitution – is the Swiss astronomer Bruno Leibundgut (ESO).

cosmic time, due to changes in progenitor mass, metallicity, and C/O ratio. Because of such worries, astronomers were for quite some time sceptical and doubted that the observations definitely established a non-vanishing cosmological constant or some more general (dynamical) form of *Dark Energy*. By now the results from the supernovae are well established, and are in addition strongly supported by other completely independent cosmological observations, in particular by precision measurements of the microwave background and large scale surveys of galaxy distributions. The evidence that about 70% of the matter-energy density of the Universe consists of what is called (somewhat misleadingly) "dark energy" is now really strong. There are, however, attempts to explain the observations differently, for instance by modifying general relativity.



Some historical remarks

1. Most cosmologists repeat again and again that it was Hubble who discovered the expansion of the Universe. This is a myth that was first propagated by Humason in 1931. After first tentative steps toward the discovery of the velocity-distance relationship by Wirtz and Lundmark in the early 1920's, it was Lemaître who established in 1927 the expansion of the Universe and interpreted it as a consequence of general relativity (GR). In his crucial paper [8] he derived the general redshift formula for an expanding Universe, and showed that it leads for small distances to a linear relation, known as Hubble's law. He also estimated the Hubble constant H_0 based on Slipher's redshift data. Two years before Hubble he found a value only somewhat higher the one of Hubble from 1929. (Actually, Lemaître gave two values for H_0.) In a public talk on January 1929 in Brussels, Lemaître employed the same balloon model we use today. Hubble, on the other hand, nowhere in his famous 1929 paper even mentions an expanding Universe. In addition, Hubble never claimed to have discovered the expanding universe, he apparently never believed this interpretation. That Hubble was elevated to the discoverer of the expanding universe belongs to sociology, public relations, and rewriting history. These and related facts are in detail documented in the recent excellent book [9] of our Swiss colleagues Harry Nussbaumer and Lydia Bieri.

2. It is well-known, that Einstein realized the freedom to introduce the cosmological term in his field equations only when he applied GR to cosmology. GR is a classical field theory with *two free constants* – the gravitational constant *G* and the cosmological constant Λ – that have to be determined from observations. This was the point of view of several leading cosmologists, among them Lemaître, Eddington and Tolman. When Einstein dropped in 1931 the cosmological term, just for simplicity reasons, many influencial colleagues (for instance Pauli) followed him.
Lemaître was the first who associated in 1933 the cosmological constant with vacuum energy. Today, this confronts us with the profound mystery that the energy scale belonging to Λ is so tiny by particle physics standards. From quantum fluctuations in known fields up to the electroweak scale, contributions to the vacuum energy density are expected to be vastly larger (more than 50 orders of magnitude) than the observed dark energy density. In spite of many attempts, no convincing proposal out of this dilemma has emerged. Einstein's so called "biggests blunder" was not that he introduced the cosmological term – actually he should have done that already in his 'final' field equations in November 1915 – but that he did not realize that even with this term there are no *stable* static cosmological solutions (for dust).

In the next issue of this journal, we shall indicate the interesting early history of cosmology, beginning with Einstein's model of 1917, up to the point when the majority of cosmologists accepted Lemaître's ideas on the expanding Universe.

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[9] H. Nussbaumer and L. Bieri, *Discovering the Expanding Universe*, Cambridge University Press (2009).

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Une rencontre entre les sommités de la physique et l’élite européenne de demain

Martin C. E. Huber, ancien président du comité de l‘Association Europhysics Letters (EPLA)

Pour fêter le 25e anniversaire du journal *EPL*, les sociétés membres de l’*Association Europhysics Letters*, ainsi que la Société Suisse de Physique ont invité des étudiants de toute l’Europe au Symposium International EPL25 où ils pouvaient rencontrer des physiciens de tout premier rang et assister à leurs conférences. Le congrès proposait une revue de domaines choisis de la physique pure et appliquée contemporaine [1].

Laissons parler ***Gaëlle Giesen***, dont la participation au Symposium EPL25 était soutenue par la SSP:

> «En tant qu'étudiante en master de physique à l'École Polytechnique Fédérale de Lausanne (EPFL), j'ai eu la chance de pouvoir participer au Symposium EPL25, célébrant le 25ème anniversaire du journal scientifique *Europhysics Letters (EPL)*. L'événement de grande ampleur s'est déroulé en mai 2011 dans les locaux de l'Académie Bavaroise des Sciences à Munich (Allemagne). Durant les deux jours du congrès, j'ai pu découvrir un grand nombre de domaines différents de la physique, tous explorés à un très haut niveau. En effet, il ne s'agissait pas seulement d'une discussion internationale de nouveaux résultats et découvertes scientifiques, mais également d'une rencontre interdisciplinaire entre chercheurs, doctorants et étudiants avancés. De la supraconductivité à l'astrophysique en passant par l'océanographie et la spectroscopie, toutes les facettes de la physique y étaient abordées.
>
> Tout a commencé par un repas le soir même de mon arrivée dans la capitale bavaroise, au cours duquel j'ai pu échanger avec des étudiants et doctorants venus de toute l'Europe : Suède, France, Grande-Bretagne, Croatie, Espagne, etc. Presque tous les participants étaient spécialisés dans des domaines différents de la physique théorique, expérimentale ou appliquée. Nous avons ainsi pu partager nos savoirs et projets d'avenir, tout comme les résultats les plus récents dans notre champ ; toutefois, cela n'offrait en réalité qu'un avant-goût des présentations et débats des jours suivants.
>
> Le lendemain matin, nous avons pu visiter les instituts et laboratoires de l'Université de Munich (Technische Universität München). Personnellement, j'ai pu découvrir le département d'optique non-linéaire qui effectue des recherches notamment dans la dynamique moléculaire grâce à des lasers femtoseconde. De par là, un nouveau domaine de la physique s'est ouvert à moi. Ce n'est qu'après cette visite qu'a débuté le symposium à proprement parler. La présidente de l'EPS, Luisa Cifarelli, nous a dispensé une leçon sur le Large Hadron Collider (LHC). D'autres physiciens de grande renommée mondiale ont présenté leurs derniers résultats durant la session scientifique. Le soir nous étions tous conviés au dîner du symposium pour nous familiariser avec certaines coutumes bavaroises, ainsi que pour faciliter la communication entre chercheurs, doctorants et étudiants. Le lendemain matin et après-midi nous avons assisté à deux séances scientifiques. Parmi les nombreux orateurs je retiens en particulier la professeure Katherine Richardson Christensen, une océanographe, qui nous a exposé la dynamique des petits organismes aquatiques. Je n'oublierai pas non plus notre compatriote, le professeur Nicolas Gisin, décrivant les applications de la non-localité quantique.
>
> Ma participation à ce symposium exceptionnel m'a non seulement permis de découvrir une grande variété de secteurs de la physique et d'en approfondir certains, mais aussi d'avoir une expérience extrêmement enrichissante en termes d'échanges avec d'autres étudiants et doctorants, voire avec des chercheurs déjà établis et de réputation internationale. On ne peut rêver meilleure motivation pour aller de l'avant en physique.»

Fig. 1 : Au cours des 25 premières années, le nom du journal a passé de «Europhysics Letters» à «EPL - a Letters Journal Exploring the Frontiers of Physics». La couverture s’est également modernisée et reproduit une illustration d’un article récent. Elle change chaque trimestre avec le numéro du volume.

Un peu d’histoire…

EPL a été fondée il y a 25 ans, en 1986, par la Société Européenne de Physique (EPS), l’Institut de Physique (IOP) du Royaume Uni, la Société Française de Physique (SFP), la Société Italienne de Physique (SIF) et, avec un engagement moindre, par 15 autres sociétés et organisations nationales de physique en Europe. A ses débuts, le journal réunit les deux publications *Journal de Physique Lettres* et *Lettere Al Nuovo Cimento* sous le nom *Europhysics Letters*, ce qui soulignait l’aspect européen de la publication. Dès 2007 le journal prend le nom *EPL* et inclut les «Letters» publiées jusqu’alors dans le *Journal of Physics*. De son côté, l’IOP participe, avec les trois anciens partenaires EPS, SFP et SIF, à la production du journal. C’est à ce moment que la connotation européenne a délibérément été supprimée du nom afin de privilégier la mission mondiale du journal. Quatre ans après ce changement d’identité, la répartition géographique des auteurs de l’EPL reflète effectivement sa

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[1] http://www.epl25.org/programme

mission globale puisque seuls 48 % des articles proviennent d'Europe (38 % d'Asie, 13 % des Etats-Unis et 6 % du reste du monde).

Du manuscrit à la publication

La publication d'un article dans *EPL* se déroule comme suit: les manuscrits arrivent au bureau de rédaction de l'*EPL* qui se trouve au secrétariat de l'EPS à Mulhouse. Ce bureau suit les manuscrits durant toute la phase de production. Chaque article est envoyé à un membre du comité rédactionnel familier avec le sujet en question. Le comité rédactionnel est couramment composé de 51 co-rédacteurs sélectionnés par le rédacteur en chef et agréés par le Comité Exécutif de l'EPS. Tous les co-rédacteurs d'*EPL* sont des physiciens actifs de renommée mondiale - la plupart d'entre eux a un indice 'Hirsch' $h > 30$ [2]. C'est à eux qu'il revient de décider si un article sera publié ou non. Le co-rédacteur choisit les noms et le nombre de rapporteurs qu'il veut consulter. Dans des cas exceptionnels il accepte (ou refuse) un article immédiatement, sans consultation des rapporteurs, ce qui réduit le délai de publication en ligne à quelques jours.

Fig. 2 : La table «Robert Boyle» pendant le dîner : étudiants en pleine discussion avec le rédacteur en chef Michael Schreiber (Photo : Graeme Watt)

Les manuscrits des articles acceptés sont transmis à Bologne, où la SIF édite le texte, les tables et les illustrations et s'assure que le format corresponde aux standards du journal. Le document est ensuite transmis à Paris et à Bristol. L'EDPS (Edition Diffusion Presse Sciences) à Paris, qui appartient à la SFP, met le journal sous presse et prend en charge sa distribution et l'IOPP (IOP Publishing) à Bristol met les articles en ligne. L'EDPS et IOPP sont de surcroît responsables du marketing d'*EPL* - une activité aujourd'hui indispensable dans le monde de la publication scientifique. La gestion de la publication entre les quatre partenaires domiciliés à travers toute l'Europe, est coordonnée par un comité de régie dont les membres communiquent fréquemment entre eux par courriel et téléphone et, le cas échéant, règlent les éventuels problèmes.

Le journal est accessible sous forme imprimée et électronique dans 1670 institutions à travers le globe. Les articles mis en ligne sont accessibles gratuitement durant 30 jours. Si un auteur désire offrir l'accès libre à son article, l'*EPL*, en tant que journal hybride, perçoit une taxe de 1000 Euros.

Contenu rédactionnel

Nous avons observé que le domaine de la Physique Générale (PACS 00) [3], la Matière Condensée (PACS 60 et 70) et la Physique Interdisciplinaire (PACS 80) occupent traditionnellement une place plus importante dans l'*EPL* que dans la revue nord-américaine *Physical Review Letters*. Nous avons cependant mis en place des mesures tendant vers un meilleur équilibre rédactionnel, tout en maintenant l'accent mis sur PACS 00 et PACS 80. Pour l'anecdote, durant le centenaire de l'*annus mirabilis* d'Einstein, nous avons reçu un certain nombre de manuscrits proposant des théories parfois très fantaisistes sur la théorie de la relativité. Ils ont tous été refusés. Les expériences du LHC ont de leur côté engendré deux articles publiés récemment.

Le taux d'acceptation entre les articles soumis et ceux publiés est actuellement bien en dessous de 50 % et il varie en fonction des domaines. Selon la stratégie élaborée par le comité directeur, l'objectif à moyen terme est d'améliorer encore la qualité et d'arriver à un taux de 33 %.

La concurrence entre les publications scientifiques est sévère et le but d'*EPL* est de soutenir ses auteurs, de leur donner un excellent service rédactionnel et éditorial, et de publier rapidement leurs manuscrits. Nous espérons ainsi attirer toujours plus d'auteurs originaux et créatifs.

L'événement organisé par l'*EPL* à l'occasion de son 25e anniversaire s'adressait à la future élite des physiciens européens. Espérons que le *goodwill* créé par cet événement, mais surtout aussi la qualité des acteurs de cette entreprise mèneront l'*EPL* sur le chemin de son 50e anniversaire.

Fig. 3 : Le comité de l'Association «Europhysics Letters (EPLA)» avant le dîner des étudiants, de gauche à droite : Martin Huber (EPS), Angela Oleandri (SIF), Sir John Enderby (IOP, Président du comité scientifique EPL25), Agnès Henri (EDPS/SFP), David Lee (Secrétaire du comité et Secrétaire Général de l'EPS), Markus Schwoerer (Président du comité, DPG). (Photo : Graeme Watt)

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[2] Un chercheur avec un indice de *h* a publié *h* articles qui ont été cités *h* fois.

[3] 'PACS' est le schéma de classification de physique et astronomie (Physics and Astronomy Classification Scheme) de l'Institut de Physique Américain (AIP), cf. http://publish.aps.org/PACS .

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