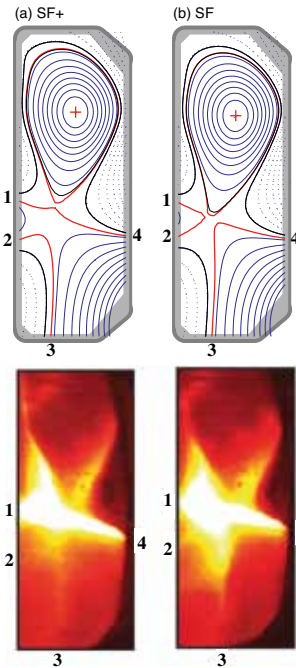


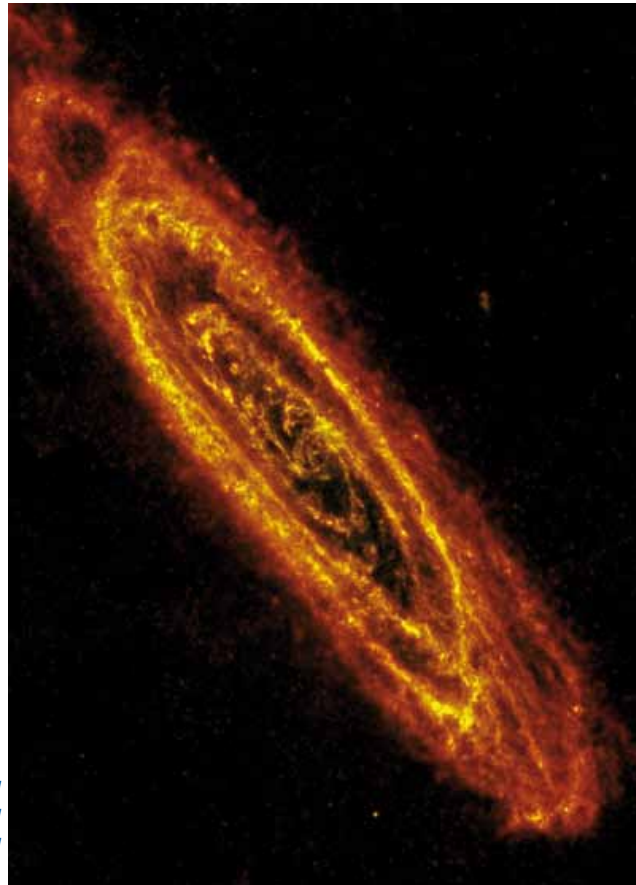
# SPG MITTEILUNGEN

## COMMUNICATIONS DE LA SSP



*What have snowflakes to do with a hot plasma? Find out on p. 36.*

*Four years after its launch the Herschel space observatory completed its observations about how stars and galaxies are formed. The successful mission is described on p. 42.*



*The scientific community celebrates this year the centenary of the Atomic Model of Niels Bohr. Read more (on p. 52) about the history of this outstanding event in physics, which is also the topic of the SCNAT Annual Congress (see p. 60).*

### Joint Annual Meeting of the Austrian Physical Society and Swiss Physical Society

with

### Austrian and Swiss Societies for Astronomy and Astrophysics

### September 3 - 6, 2013, JKU Linz

**General information: page 10, preliminary program: page 12**

# Inhalt - Contenu - Contents

Gemeinsame Jahrestagung in Linz, 03. - 06. September 2013 - Réunion annuelle commune à Linz, 3 - 6 septembre 2013	3
Vorwort; Preisverleihung, Generalversammlung - Avant-Propos; Cérémonie de remise des prix, Assemblée générale	3
Informationen für die Mitglieder - Informations pour les membres	4
Zum Tod von Nobelpreisträger Heinrich Rohrer	9
Allgemeine Tagungsinformationen - Informations générales sur la réunion	10
Vorläufige Programmübersicht - Résumé préliminaire du programme	12
Aussteller - Exposants	24
Open Access, where do we stand today?	25
Kurzmitteilungen - Short Communications	25, 45
19 <sup>th</sup> Swiss Physics Olympiad 2013 (SPHO) in Aarau	26
Das Rennen um die Industrieproduktion der Zukunft	27
First result from the AMS experiment	28
Progress in Physics (33): Outreach: Can Physics Cross Boundaries?	30
Progress in Physics (34): On the development of physically-based regional climate modelling	32
Progress in Physics (35): A snowflake in a million degree plasma	36
Physics Anecdotes (17): IBM Research – Zurich, a Success Story	40
Goodbye Herschel	42
Structural MEMS Testing	44
Physique et la Société: Quand la Physique rejoint le Sport	46
History of Physics (8): On the Einstein-Grossmann Collaboration 100 Years ago	48
Histoire de la Physique (9): Le modèle atomique de Bohr: origines, contexte et postérité (part 1)	52
Buchbesprechung: Geschichte des SIN	56
Lehrerfortbildung: 18 Deutschschweizer Lehrer im Herz von CERN	58
Annual Congress of SCNAT	60

## Vorstandsmitglieder der SPG / Membres du Comité de la SSP

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Dr. Andreas Schopper, CERN, [Andreas.Schopper@cern.ch](mailto:Andreas.Schopper@cern.ch)

### Vize-Präsident / Vice-Président

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### Kassier / Trésorier

Dr. Pascal Ruffieux, EMPA, [pascal.ruffieux@empa.ch](mailto:pascal.ruffieux@empa.ch)

### Kondensierte Materie / Matière Condensée (KOND)

Prof. Christian Rüegg, PSI & Uni Genève, [christian.rueegg@psi.ch](mailto:christian.rueegg@psi.ch), [christian.rueegg@unige.ch](mailto:christian.rueegg@unige.ch)

### Angewandte Physik / Physique Appliquée (ANDO)

Dr. Ivo Furno, EPFL-CRPP, [ivo.furno@epfl.ch](mailto:ivo.furno@epfl.ch)

### Astrophysik, Kern- und Teilchenphysik /

*Astrophysique, physique nucléaire et corp. (TASK)*

Prof. Martin Pohl, Uni Genève, [martin.pohl@cern.ch](mailto:martin.pohl@cern.ch)

### Theoretische Physik / Physique Théorique (THEO)

Prof. Gian Michele Graf, ETH Zürich, [gmggraf@phys.ethz.ch](mailto:gmggraf@phys.ethz.ch)

### Physik in der Industrie / Physique dans l'industrie

Dr. Kai Hencken, ABB Dättwil, [kai.hencken@ch.abb.com](mailto:kai.hencken@ch.abb.com)

### Atomphysik und Quantenoptik /

*Physique Atomique et Optique Quantique*

Prof. Antoine Weis, Uni Fribourg, [antoine.weis@unifr.ch](mailto:antoine.weis@unifr.ch)

### Physikausbildung und -förderung /

*Education et encouragement à la physique*

Dr. Tibor Gyalog, Uni Basel, [tibor.gyalog@unibas.ch](mailto:tibor.gyalog@unibas.ch)

### Geschichte der Physik / Histoire de la Physique

Prof. Jan Lacki, Uni Genève, [jan.lacki@unige.ch](mailto:jan.lacki@unige.ch)

### Physik der Erde, Atmosphäre und Umwelt /

*Physique du globe et de l'environnement*

Dr. Stéphane Goyette, Uni Genève, [stephane.goyette@unige.ch](mailto:stephane.goyette@unige.ch)

## SPG Administration / Administration de la SSP

*Allgemeines Sekretariat (Mitgliederverwaltung, Webseite, Druck, Versand, Redaktion Bulletin & SPG Mitteilungen) /*

*Secrétariat générale (Service des membres, internet, impression, envoi, rédaction Bulletin & Communications de la SSP)*

S. Albietz, SPG Sekretariat, Département Physik,

Klingelbergstrasse 82, CH-4056 Basel

Tel. 061 / 267 36 86, Fax 061 / 267 37 84, [sps@unibas.ch](mailto:sps@unibas.ch)

### Buchhaltung / Service de la comptabilité

F. Erkadoo, SPG Sekretariat, Département Physik,

Klingelbergstrasse 82, CH-4056 Basel

Tel. 061 / 267 37 50, Fax 061 / 267 13 49, [francois.erkadoo@unibas.ch](mailto:francois.erkadoo@unibas.ch)

### Protokollführerin / Greffière

Susanne Johner, [SJO@zurich.ibm.com](mailto:SJO@zurich.ibm.com)

### Wissenschaftlicher Redakteur/ Rédacteur scientifique

Dr. Bernhard Braunecker, Braunecker Engineering GmbH,

[braunecker@bluewin.ch](mailto:braunecker@bluewin.ch)

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### Verlag und Redaktion:

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SATW

Schweizerische Akademie der Technischen Wissenschaften  
Académie suisse des sciences techniques  
Accademia svizzera delle scienze tecniche  
Swiss Academy of Engineering Sciences

# Gemeinsame Jahrestagung in Linz, 03. - 06. September 2013

## Réunion annuelle commune à Linz, 3 - 6 septembre 2013

### Vorwort

Im Zweijahresrhythmus organisiert die SPG ihre Jahrestagung gemeinsam mit der Österreichischen Physikalischen Gesellschaft (ÖPG) sowie den Schweizerischen und Österreichischen Gesellschaften für Astronomie und Astrophysik (SGAA und ÖGAA). Dieser Modus hat sich in den vergangenen Jahren bei den sehr erfolgreichen Tagungen in Innsbruck (2009) und Lausanne (2011) bewährt. Die diesjährige Tagung in Linz soll diese Tradition fortsetzen und den Dialog zwischen Physikern beider Länder weiter vertiefen.

Mit rund 400 eingereichten Abstracts in 15 Fachsitzungen, 9 Plenarvorträgen und zwei öffentlichen Abendvorträgen, einer davon von Serge Haroche (Physiknobelpreisträger 2012), steht ein sehr attraktives Programm zur Verfügung. Zudem findet vor der gemeinsamen Jahrestagung noch ein spezieller Energietag statt, zu dem alle Tagungsteilnehmer herzlich willkommen sind.

Im Folgenden finden Sie die für die SPG-Mitglieder relevanten Gesellschaftsnachrichten, die wichtigsten Tagungsinformationen sowie eine vorläufige Programmübersicht. Das definitive Programm wird in Kürze auf der SPG-Webseite verfügbar sein.

Der SPG-Vorstand hofft auf eine rege Teilnahme an der Tagung und freut sich auf Ihren Besuch.

### Avant-Propos

Tous les deux ans, la SSP organise sa réunion annuelle en collaboration avec la société autrichienne de physique (ÖPG) et les deux sociétés nationales d'astronomie et d'astrophysique (SSAA et ÖGAA). Ce modèle a fait ses preuves au cours des dernières années de rencontres très fructueuses à Innsbruck (2009) et à Lausanne (2011). La conférence de cette année à Linz a comme but de poursuivre cette tradition et d'approfondir le dialogue entre les physiciens de ces deux pays.

Avec environ 400 résumés soumis à 15 séances, 9 conférences plénières et deux conférences publiques, l'une par Serge Haroche (Prix Nobel de physique 2012), un programme très attrayant a été mis en place. En outre, une journée spéciale de l'énergie aura lieu avant la réunion annuelle commune, à laquelle tous les participants de la conférence sont les bienvenus.

Vous trouverez ci-dessous les nouvelles de la société d'intérêt pour les membres, ainsi que les informations les plus importantes sur la conférence et sur le programme provisoire. La version finale sera accessible sous peu sur le site de la SSP.

Le comité de la SSP compte donc sur une participation active et nombreuse à notre réunion annuelle et nous réjouissons de votre visite.

## Preisverleihung - Cérémonie de remise des prix

**Mittwoch 04. September 2013, 11:30h - Mercredi 4 septembre 2013, 11:30h**  
**Johannes Kepler Universität Linz, Keplergebäude, Hörsaal 1**

Es werden alle Preise von SPG und ÖPG in einer gemeinsamen Zeremonie verliehen.

Tous les prix de la SSP et l'ÖPG seront remis dans une cérémonie commune.

## Generalversammlung 2013 - Assemblée générale 2013

**Donnerstag 05. September 2013, 12:00h - Jeudi 5 septembre 2013, 12:00h**  
**Johannes Kepler Universität Linz, Keplergebäude, Hörsaal 4**

<b>Traktanden</b>	<b>Ordre du jour</b>
1. Protokoll der Generalversammlung vom 21. Juni 2012	Procès-verbal de l'assemblée générale du 21 juin 2012
2. Kurzer Bericht des Präsidenten	Bref rapport du président
3. Rechnung 2012, Revisorenbericht	Bilan 2012, rapport des vérificateurs des comptes
4. Wahlen	Elections
5. Projekte	Projets
6. Diverses	Divers

## Statistik - Statistique

### Neue Mitglieder 2012 - Nouveaux membres en 2012

Acremann Yves, Adams Jonathan, Ancu Lucian Stefan, Andreussi Oliviero, Antognini Aldo, Bachmann Maja, Barhoumi Rafik, Bernard Laetitia, Bettler Marc-Olivier, Bigler Matthias, Bonvin Camille, Braun Oliver, Brunner Bernhard, Casadei Diego, Castiglioni Luca, Cepellotti Andrea, Chandrasekaran Anand, Cheah Erik, Cholleton Danaël, Cohen Denis, Crivelli Paolo, Doglioni Caterina, Dragoni Daniele, Ehtesham Alireza, Fantner Georg, Fernandes Vaz Carlos Antonio, Gibertini Marco, Goyette Stéphane, Havare Ali Kemal, Herzog Benedikt, Huppert Martin, Issler Mena, Jaffe Arthur, Jordan Inga, Knabenhans Mischa, Knopp Gregor, Kraus Peter, Krauth Felix, Küçükbenli Emine, Kuhn Felix Arjun, Laine Mikko, Leindl Mario, Locher Reto, Mariotti Nicolas, Marzari Nicola, Mathys Christoph, Mermoud Philippe, Miguel Sanchez Javier, Montaruli Teresa, Moutafis Christoforos, Müller Andreas, Nguyen Ngoc Linh, O'Regan David Daniel, Pizzi Giovanni, Pozzorini Stefano, Rakotomiarimana Barinjaka, Reinle-Schmitt Mathilde Léna, Ries Dieter, Rochman Dimitri, Rønnow Henrik Moodysson, Rückauer Bodo, Sabatini Ricardo, Salman Zaher, Schwarz Sacha, Silatani Mahsa, Strassmann Peter, Südmeyer Thomas, Šulc Miroslav, Tehlar Andres, Tiwari Rakesh, Tolba Tamer, Tourneur Stéphane, van Megen Bram, Vaniček Jiří, Vindigni Alessandro, Walter Manuel, Wyszynski Grzegorz, Zimmermann Tomáš

### Ehrenmitglieder - Membres d'honneur

Prof. Hans Beck (2010)  
 Dr. J. Georg Bednorz (2011)  
 Prof. Jean-Pierre Blaser (1990)  
 Prof. Jean-Pierre Borel (2001)  
 Prof. Jean-Pierre Eckmann (2011)  
 Prof. Charles P. Enz (2005)  
 Prof. Øystein Fischer (2010)  
 Prof. Hans Frauenfelder (2001)  
 Prof. Jürg Fröhlich (2011)  
 Prof. Hermann Grunder (2001)  
 Prof. Hans-Joachim Güntherodt (2010)  
 Dr. Martin Huber (2011)  
 Prof. Verena Meyer (2001)  
 Prof. K. Alex Müller (1991)  
 Prof. Hans Rudolf Ott (2005)  
 Prof. T. Maurice Rice (2010)  
 Dr. Heinrich Rohrer (1990)  
 Prof. Louis Schlapbach (2010)

### Assoziierte Mitglieder - Membres associés

#### A) Firmen

- F. Hoffmann-La-Roche AG, 4070 Basel

#### B) Universitäten, Institute

- Albert-Einstein-Center for Fundamental Physics, Universität Bern, 3012 Bern
- CERN, 1211 Genève 23
- Département de Physique, Université de Fribourg, 1700 Fribourg
- Departement Physik, Universität Basel, 4056 Basel
- Departement Physik, ETH Zürich, 8093 Zürich
- EMPA, 8600 Dübendorf
- Lab. de Physique des Hautes Energies (LPHE), EPFL, 1015 Lausanne
- Paul Scherrer Institut, 5332 Villigen PSI
- Physik-Institut, Universität Zürich, 8057 Zürich
- Section de Physique, Université de Genève, 1211 Genève 4

#### C) Studentenfachvereine

- AEP - Association des Etudiant(e)s en Physique, Université de Genève, 1211 Genève 4
- Fachschaft Physik und Astronomie, Universität Bern, 3012 Bern
- Fachschaft Physique, Université de Fribourg, 1700 Fribourg
- Fachverein Physik der Universität Zürich (FPU), 8057 Zürich
- FG 14 (Fachgruppe für Physik-, Mathematik- und Versicherungswissenschaft), Universität Basel, 4056 Basel
- Les Irrationnels, EPFL, 1015 Lausanne
- Verein der Mathematik- und Physikstudierenden an der ETH Zürich (VMP), 8092 Zürich

### Verteilung der Mitgliedskategorien - Répartition des catégories de membres (31.12.2012)

Ordentliche Mitglieder	726
Doktoranden	55
Studenten	80
Doppelmitglieder DPG, ÖPG oder APS	164
Doppelmitglieder PGZ	41
Mitglieder auf Lebenszeit	144
Assoziierte Mitglieder	19
Bibliotheksmitglieder	2
Ehrenmitglieder	18
Beitragsfreie (Korrespondenz)	7
<b>Total</b>	<b>1256</b>

## Jahresbericht 2012 des Präsidenten - Rapport annuel 2012 du président

The major event of our society in 2012 was once more the annual SPS meeting that took place from 21-22 June 2012 at the Höggerberg campus of the ETHZ, jointly organized with the four National Centres of Competence in Research (NCCR) MaNEP, MUST, Nano and QSIT as well as with the Swiss Society for Crystallography. More than 550 persons attended the meeting. The scientific program was rather dense with 6 plenary talks, 237 talks distributed over 14 parallel sessions and 170 posters. Worth mentioning is the successful session of the new section "Earth, Atmosphere and Environmental Physics" and a dedicated session to celebrate the birth of crystallography in 1912 "100 Years of Diffraction". It was very satisfying to observe a large participation of young enthusiastic physicists sharing their research results and their experiences in a lively manner. The interest by the commercial exhibitors was once more well demonstrated by the attendance of 21 companies. As every year, the annual meeting was also the occasion to announce and present the winners of the SPS Awards in General Physics, Condensed Matter Physics and Applied Physics.

It became a tradition that SPS organises in collaboration with the Physikalische Gesellschaft Zürich PGZ a joint symposium every year. In September 2012, PGZ and SPS celebrated together the 125 years of PGZ with a meeting in Zürich on "General relativity and its applications".

Fostering its international relations, every other year the SPS organises its annual meeting together with the Austrian Physical Society ÖPG that will take place in Linz in 2013. The SPS maintained tight links to the European Physical Society EPS, participating in its Council and in various activities of its groups. In 2012 our society also welcomed its first international Associate Member with domicile in Switzerland, namely CERN.

In view of promoting young scientists, the SPS Young Physicist Forum YPF, that was created in 2010 and that regroups most of the Swiss physics student associations,

has been accepted as a Commission of SPS in 2012. In the framework of this very active forum, the young physicists had organised a SPS sponsored visit to the International Laboratory for Particle Physics CERN at Geneva. As every year, our society also sponsored activities of the Swiss Young Physicists Tournament SYPT as well as of the Swiss Physics Olympiads SPhO, with two SPS prizes awarded to the best male and female finalists of SPhO.

Furthermore, our society also supported Swiss students for attending the 13<sup>th</sup> IONS (International OSA Network of Students) conference, that was jointly organized by PhD students from EPFL and ETH and that took place in Zürich and Lausanne from 9-12 Jan, 2013.

Three times per year the SPS publishes its "Communications", which is the most important SPS publication to disseminate information about on-going activities within the society and to review scientific progress in various areas. High-class articles have been published in the various, now well established rubrics. A paper copy is distributed to all members, whilst open access to this publication is also granted to the entire Swiss scientific community via the SPS homepage.

SPS is a member organization of the Swiss Academy of Science SCNAT and part of the platform Mathematics, Astronomy and Physics MAP. With two SPS representatives in the organising committee, our society is supporting the platform MAP actively in organising the "SCNAT-Jahreskongress 2013" on the occasion of the jubilee of "100 Jahre Bohr'sches Atommodell".

We are grateful to the organizational and financial support of SCNAT and acknowledge also support of the Swiss Academy of Engineering Science SATW. Thanks to a well-balanced program the Swiss Physical Society could once more close its budget with a positive balance for 2012.

*Andreas Schopper, SPS President, May 2013*

## Protokoll der Generalversammlung vom 21. Juni 2012 in Zürich Protocole de l'assemblée générale du 21 juin 2012 à Zürich

### Traktanden

1. Protokoll der Generalversammlung vom 16.06.2011
2. Bericht des Präsidenten
3. Rechnung 2011 & Revisorenbericht
4. Anpassung der Statuten
5. Neue Sektion und Kommission
6. Projekte
7. Wahlen

Der Präsident, Christophe Rossel, eröffnet die Generalversammlung um 12:00 Uhr. Anwesend sind 41 Mitglieder.

### 1. Protokoll der letzten GV vom 16.6.2011 in Lausanne

Herrn Peter Wolff beanstandet den ihn betreffenden ersten Satz unter Traktandum „6. Diverses“ und verweist auf das GV-Protokoll 2010 (Basel). Da keine Neuformulierung vorliegt, wird über die in den SPG-Mitteilungen veröffentlichte Version abgestimmt und diese mit 35 Stimmen genehmigt, bei 5 Enthaltungen und 1 Gegenstimme.

*(Siehe dazu den NACHTRAG am Schluss dieses Protokolls).*

### 2. Bericht des Präsidenten

Der Jahresbericht 2011 des Präsidenten wurde auf Seite 5 der "SPG Mitteilungen Nr. 37" im Mai 2012 veröffentlicht. Christophe Rossel erläutert kurz einige Punkte:

- Die gemeinsame Jahrestagung mit der Österreichischen Physikalischen Gesellschaft (ÖPG) und den beiden nationalen Gesellschaften für Astronomie und Astrophysik (SGAA und ÖGAA) vom 15.-17. Juni 2011 in Lausanne war wiederum ein Erfolg mit rund 650 Teilnehmenden, 10 Plenarvorträgen, 470 Beiträgen verteilt auf 10 Parallel-Sitzungen, dazu zahlreichen Postern und 22 Ausstellern.
- Die Generalversammlung 2011 ernannte vier neue Ehrenmitglieder: Dr. J. Georg Bednorz, Prof. Jean-Pierre Eckmann, Prof. Jürg Fröhlich und Dr. Martin Huber.
- Die Mitgliederzahl ist auf etwa 1'250 gestiegen, was einer Zunahme von rund 10% gegenüber dem Vorjahr entspricht. Bei den 18 Kollektiv- (neu: assoziierten) Mitgliedern ist bei den Firmen ein Rückgang zu verzeichnen, dafür sind mehr Universitäten und Studentenorganisationen vertreten.

### 3. Rechnung 2011 & Revisorenbericht

Der Kassier, Pierangelo Gröning, präsentiert und erläutert die Jahresrechnung 2011, die detailliert in den "SPG-Mitteilungen Nr. 37" auf Seite 7 veröffentlicht wurde. Sie schliesst mit einem Gewinn von CHF 17'200.36 und einem Vereinsvermögen von CHF 36'606.87.

Der Empfehlung der Revisoren folgend genehmigt die Generalversammlung die Jahresrechnung 2011 und der Kassier wird mit bestem Dank für die gute Rechnungsführung entlastet.

### 4. Anpassung der Statuten

Die Generalversammlung stimmt der auf Seite 9 der "SPG-Mitteilungen Nr. 37" veröffentlichten Anpassung der Statuten einstimmig zu. Somit wird der Begriff "Kollektivmitglieder" durch "Assoziierte Mitglieder" ersetzt und in Art. 2 die Definition der Gruppe B um "überstaatliche bzw. internationale" erweitert.

### 5. Neue Sektion und Kommission

Die Generalversammlung stimmt folgenden Neugründungen einstimmig zu.

- Neue Sektion:  
*Physik der Erde, Atmosphäre und Umwelt - Earth, Atmosphere and Environmental Physics - Physique du Globe et de l'Environnement*
- Neue Kommission:  
*Young Physicists Forum*

### 6. Projekte

- Im September 2013 soll die nächste gemeinsame Jahrestagung mit der ÖPG in Linz stattfinden.
- In Zusammenarbeit mit der PGZ wird am 29.9.2012 das Symposium „Allgemeine Relativitätstheorie und ihre Anwendungen“ an der Universität Zürich, organisiert.
- Das neu als Kommission integrierte „Young Physicists Forum“ wird Aktivitäten, Betriebsbesichtigungen und Exkursionen für Studenten organisieren.
- Die Final-Runde der Schweizer Physik-Olympiade hat am 21./22. April 2012 in Aarau stattgefunden. Die Goldmedaillen-Gewinner Thanh Phong Lê und Lau-

ra Gremion wurden zusätzlich mit den beiden SPG-Nachwuchspreisen ausgezeichnet. Die Internationale Physik-Olympiade findet im Juli in Estland statt.

- Ebenfalls im Juli 2012 wird das „International Young Physicists Tournament“ (IYPT) in Bad Sulgau (D) stattfinden.
- Die SPG könnte sich am Swiss Young Physicists' Tournament 2013 beteiligen. Im Jahr 2016 wird das IYPT möglicherweise in der Schweiz organisiert.
- Im 2013 wird das Jubiläum "100 Jahre Bohr'sches Atommodell" gefeiert.
- 2015 wurde zum „Internationalen Jahr des Lichts“ bestimmt. Dann wird die SCNAT auch ihr 200jähriges Bestehen feiern.

### 7. Wahlen

Der Präsident dankt den beiden ausscheidenden Vorstandsmitgliedern Urs Staub (Kondensierte Materie) und Pierangelo Gröning (Kassier) für Ihren langjährigen Einsatz. Und der Vizepräsident, Andreas Schopper, dankt dem zurücktretenden Präsidenten, Christophe Rossel, für seine vierjährige Amtszeit.

In corpore werden einstimmig gewählt:

- Präsident (bisher Vizepräsident): Dr. Andreas Schopper, CERN
- Vize-Präsident (bisher Präsident): Dr. Christophe Rossel, IBM Research Zurich
- Kassier (bisher Revisor): Dr. Pascal Ruffieux, EMPA
- Kondensierte Materie (neu): Dr. Christian Rüegg, PSI
- Theoretische Physik (bisher ad interim): Prof. Gian Michele Graf, ETH Zürich
- Physik der Erde, Atmosphäre und Umwelt (neu): Dr. Stéphane Goyette, Universität Genf

Die übrigen Vorstandsmitglieder bleiben für ihre restliche Amtszeit unverändert.

Der neue Präsident dankt den Anwesenden für ihr Erscheinen sowie den Delegierten und seinen Vorstandskollegen für ihren Einsatz und die gute Zusammenarbeit.

Ende der Generalversammlung: 12:45 Uhr.

Zürich, 21. Juni 2012  
Die Protokollführerin: Susanne Johner

### NACHTRAG zu Punkt 1, Protokoll der letzten GV vom 16.06.2011 in Lausanne

Nach der GV stimmt Herr Peter Wolff folgender Neuformulierung zu:

Der erste Satz unter Traktandum "6. Diverses" wird ersetzt durch:

*"Herr Peter Wolff erinnert an sein Anliegen betreffend die Schwierigkeiten, nicht-englische Artikel in wissenschaftlichen Zeitschriften zu publizieren, welches er an der GV 2010 in Basel geäußert hatte."*

## Jahresrechnung 2012 - Bilan annuel 2012

Bilanz per 31.12.2012		
	Aktiven	Passiven
<b>Umlaufvermögen</b>		
Postscheckkonto	55733,76	
Bank - UBS 230-627945.M1U	14378,51	
Debitoren - Mitglieder	6450,00	
Debitoren - SCNAT/SATW u.a.m.	39180,80	
Transitorische Aktiven	2853,81	
<b>Anlagevermögen</b>		
Beteiligung EP Letters	15840,00	
Mobilien	1,00	
<b>Fremdkapital</b>		
Mobiliar		1,00
Mitglieder Lebenszeit		59824,50
Transitorische Passiven		10729,25
<b>Eigenkapital</b>		
Vefügbares Vermögen		36606,87
<b>Total Passiven</b>	<b>134437,88</b>	<b>107161,62</b>
<b>Gewinn</b>		<b>27276,26</b>
<b>Total</b>	<b>134437,88</b>	<b>134437,88</b>
<b>Verfügbares Vermögen per 31.12.12 nach Gewinnzuweisung</b>		<b>63883,13</b>

Erfolgsrechnung per 31.12.2012		
	Aufwand	Ertrag
<b>Gesellschaftsaufwand</b>		
EPS - Membership	14364,81	
SCNAT - Membership	8400,00	
SATW-Mitgliederbeitrag	1750,00	
<b>SCNAT und SATW Zahlungs- und Verpflichtungskredite</b>		
SPG-Jahrestagung	18240,86	
Schweizer Physik Olympiade	4000,00	
SPG Young Physicist's Forum	1180,80	
SCNAT/SPG Bulletin	9627,00	
SCNAT Periodika (SPG-Mitteilungen, Druckkosten)	15720,20	
SCNAT Int. Young Phys. Tournament	5500,00	
SCNAT Entdeckungen des Jahres 1912	4142,90	
SATW Earth Sciences	2350,00	
SATW Light and Sound Exhibition	3000,00	
<b>Betriebsaufwand</b>		
Löhne	11909,76	
Sozialleistungen	1806,60	
Porti/Telefonspesen/WWW- und PC-Spesen	814,95	
Versand (Porti Massensendungen)	7080,30	
Unkosten	3395,85	
Büromaterial	4492,30	
Ausserordentlicher Aufwand	4536,70	
Bankspesen	138,00	
Debitorenverluste Mitglieder	1665,00	
Debitorenverlust SCNAT/SATW u.a.m.	5319,20	
Sekretariatsaufwand extern	12375,00	
<b>Ertrag</b>		
Mitgliederbeiträge		98826,30
Inserate/Flyerbeilagen SPG Mitteilungen		5170,00
Aussteller		12744,94
Zinsertrag		99,80
Ertrag aus EP Letters Beteiligung		2745,45
<b>SCNAT und SATW Zahlungs- und Verpflichtungskredite</b>		
SPG-Jahrestagung (SCNAT)		15000,00
Schweizer Physik Olympiade		4500,00
SPG Young Physicist's Forum		6000,00
SCNAT Entdeckungen des Jahres 1912		4000,00
SPG Bulletin (SCNAT)		5500,00
Periodika (SPG-Mitteilungen, Druckkosten) (SCNAT)		4000,00
SCNAT Int. Young Phys. Tournament		5500,00
SATW Earth Sciences		2000,00
SATW Light and Sound Exhibition		3000,00
<b>Total Aufwand / Ertrag</b>	<b>141810,23</b>	<b>169086,49</b>
<b>Gewinn</b>	<b>27276,26</b>	
<b>Total</b>	<b>169086,49</b>	<b>169086,49</b>



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## Revisorenbericht zur Jahresrechnung 2012

Die Jahresrechnung 2012 der SPG wurde von den unterzeichneten Revisoren geprüft und mit den Belegen in Übereinstimmung befunden.

Die Revisoren empfehlen der Generalversammlung der SPG, die Jahresrechnung zu genehmigen und den Kassier mit bestem Dank für die gute Rechnungsführung zu entlasten.

*Die Revisoren der SPG:*

Prof. Dr. Philipp Aebi

Dr. Pierangelo Gröning

Basel, 04. April 2013

## News from SPS committee meetings (February & April)

**Annual Meetings:** The SPS meeting in 2014 will be held in Fribourg beginning of July, together with the National Centres of Competence in Research (NCCRs). The meeting in 2015 is planned with the Austrian Societies in Wien.

**Communications:** The SPS has two major means of communication, the "SPG Mitteilungen" ("Communications de la SSP") and the SPS homepage ([www.sps.ch](http://www.sps.ch)). To further improve communication, from now on, we will report about decisions from the executive committee meetings in the "SPG Mitteilungen". The editorial board is being enlarged, with the entire committee contributing to articles of the specific rubrics. With the aim of better publicizing colloquia, talks and seminars of general interest in Swiss academic centres and universities, a list of these events and their links will be provided on the SPS website. You are most welcome to communicate events of interest to the SPS Secretariat ([sps@unibas.ch](mailto:sps@unibas.ch)).

**Projects:** One of the main emphases of the SPS is to promote young academics through a variety of activities and projects. The Young Physicists Forum (YFP), a commission of SPS also represented in the executive committee, organized a 2-day meeting on "Physics and Sport". (see p. 46 for a detailed report). Another continuous endeavour of the SPS is to improve the contact between the teachers and the organizers of courses or training for secondary school teachers. The involvement of teachers varies from canton to canton, due to very different levels of encouragement (from the obligation of following paid courses during teaching time to the encouragement of following only courses at one's expense and outside working time). In view of this year's discovery of the

Higgs particle, a visit to CERN took place in cooperation with H. P. Beck and [www.teilchenphysik.ch](http://www.teilchenphysik.ch), in particular for teachers from the Swiss German. For the enlargement of outreach to all domains of physics, it is felt that similar activities should develop over the next years in other fields of physics.

This year the SPS was once more involved in the Swiss Physics Olympiad (SPHO) by awarding 4 prizes, in the special recipients' configuration of 2013 including Liechtenstein in the winners. For the first time, Switzerland and Liechtenstein will organise the 2016 International Physics Olympiad (typically 400 participants from 95 countries), which will require additional organisational and scientific forces to be involved.

There exists a demand from secondary schools students to become members of the Society: as a very first action, we will try to establish an e-mail list, with the link to the electronic version of "SPS Communications" to be sent for each new publication.

**Contact to Academies:** The SATW has new structures and commissions (scientific advisory board, topical platforms, etc.) in which now more physicists can take part as experts; SPS will spread the information to its members. The SCNAT encourages participation to the "200 years SCNAT" Jubilee in 2015; the SPS will support the "Pop-up Lab" for this event, a project supported by AGORA, which is a SNF tool to intensify and fund dialogue between science and public.

**Contact to EPS:** SPS has submitted a nomination to the EPS Physics Education Division Award. A delegation has participated to the Energy Group Meeting. A variety of SPS actions have been defined to follow-up on the outcome of the EPS council meeting.

## Zum Tod von Nobelpreisträger Heinrich Rohrer

Mit grosser Bestürzung und Trauer musste die SPG vom Tod ihres Ehrenmitglieds Heinrich Rohrer erfahren, der am 16. Mai im Alter von 79 Jahren verstarb. Er war von 1963 bis 1997 am IBM Forschungszentrum in Rüschlikon tätig und gilt als einer der massgebenden Pioniere der Nanowissenschaften, deren Werdegang aus dem Forschungsstadium heraus zur mittlerweile alle Bereiche des täglichen Lebens erfassenden Nanotechnologie er aktiv mitgestalten konnte. Für seine Erfindung des Rastertunnelmikroskops wurde er 1986 zusammen mit Gerd Binnig mit der höchsten Auszeichnung in Physik, dem Nobelpreis, geehrt.

Eine der letzten beeindruckenden Anwendungen seiner Pionierarbeit ist der kurze Film "a Boy and his Atom" über einen Jungen, der mit einem Atom spielt, und der als kleinster Film der Welt kürzlich von Wissenschaftlern am IBM Forschungslabor Almaden / San Jose (USA) produziert wurde. Im gewissen Sinn eine Parabel über Heini, der gerne seine Begeisterung für die Nanowissenschaft weltweit an die junge Generation weitergab.

Das mag auch noch folgende kleine Begebenheit illustrieren: Als eine Gruppe von Leica-Physikern gegen Ende der 80er Jahre während einer Zugfahrt von Lausanne nach



Image courtesy of IBM Research – Zurich

Heerbrugg unerwartete technische Schwierigkeiten in einem Gemeinschaftsprojekt mit der EPFL lautstark beklagte, kam Heini Rohrer aus dem Nebenabteil überraschend zu uns und meinte schelmisch, dass wir die Beschäftigung mit Problemen im Submikrometerbereich doch positiv als Chance für den Einstieg in den Nanobereich mit all seinen ungeahnten Möglichkeiten sehen sollten! Während wir Älteren noch recht skeptisch blickten, wurden unsere jüngeren Kollegen durch diese ermunternden Worte sichtbar aufgerichtet.

Seine Persönlichkeit und die Bedeutung seines Wirkens werden von IBM unter folgendem Link <http://www.research.ibm.com/articles/heinrich-rohrer.shtml>

eindrücklich geschildert.

So verlieren wir Physiker einen liebenswerten Freund und Kollegen, dessen bescheidene Art, sein subtiler Humor, seine grossartigen wissenschaftlichen Leistungen und vor allem seine stete Hilfsbereitschaft uns in bester Erinnerung bleiben werden.

C. Rossel (IBM Research - Zurich) und B. Braunecker (früher Leica Geosystems)

## Allgemeine Tagungsinformationen - Informations générales sur la réunion

### Konferenzwebseite und Anmeldung

Alle Teilnehmeranmeldungen werden über die Konferenzwebseite vorgenommen.

[www.sps.ch](http://www.sps.ch) oder [www.jku.at/hfp/oepgsps13](http://www.jku.at/hfp/oepgsps13)

Anmeldeschluß: 1. August 2013

### Tagungsort

Johannes Kepler Universität Linz, Keplergebäude

### Tagungssekretariat

Das Tagungssekretariat befindet sich beim Haupteingang zur Tagung, vor dem Hörsaal 1.

Öffnungszeiten:

Di 03.09.	09:00 - 19:00
Mi - Do 04. - 05.09.	08:00 - 19:00
Fr 06.09.	08:00 - 15:00

Alle Tagungsteilnehmer melden sich bitte **vor** dem Besuch der ersten Veranstaltung beim Sekretariat an, wo Sie ein Namensschild und allfällige weitere Unterlagen erhalten sowie die Tagungsgebühr bezahlen.

**Wichtig:** Ohne Namensschild ist kein Zutritt zu einer Veranstaltung möglich.

Wir empfehlen Ihnen, wenn möglich den Dienstag Nachmittag für die Anmeldung zu nutzen. So können Sie am Mittwoch direkt ohne Wartezeiten die Vorträge besuchen.

**Achtung:** Das Tagungssekretariat gibt kein technisches oder Büromaterial ab. Jeder Teilnehmer ist für seine Ausrüstung (Mobilrechner, Laserpointer, Adapter, Scheere, Reissnägel, Folien usw.) selber verantwortlich !

### Hörsäle

In allen Hörsälen stehen Beamer und Hellraumprojektoren zur Verfügung. Bitte bringen Sie Ihre eigenen Mobilrechner und evtl. Adapter und USB Stick/CD mit.

### Postersession

Die Postersession findet am Mittwoch und Donnerstag Abend sowie am Freitag während der Mittagspause in der Halle statt. Bitte bringen Sie Befestigungsmaterial (Reissnägel, Klebestreifen) selbst mit. Die Posterwände sind entsprechend diesem Programm nummeriert, sodaß jeder Teilnehmer "seine" Wand leicht finden sollte. Alle Poster sollen an allen drei Tagen präsentiert werden.

Maximale Postergröße: A0 Hochformat

### Zahlung

Wir bitten Sie, die Tagungsgebühren im Voraus zu bezahlen. Sie verkürzen damit die Wartezeiten am Tagungssekretariat, erleichtern uns die Arbeit und sparen darüber hinaus noch Geld !

Die Angaben zur Zahlung werden während der Anmeldung direkt auf der Webseite angezeigt.

### Site web de la conférence et inscription

L'inscription des participants se fait sur le site web de la conférence.

[www.sps.ch](http://www.sps.ch) ou [www.jku.at/hfp/oepgsps13](http://www.jku.at/hfp/oepgsps13)

Délai d'inscription: 1<sup>er</sup> août 2013

### Lieu de la conférence

Johannes Kepler Universität Linz, Bâtiment "Kepler"

### Secrétariat de la conférence

Le secrétariat de la réunion se trouve juste à l'entrée, devant l'auditoire 1.

Heures d'ouverture :

Mar 3.9.	09:00 - 19:00
Mer - Jeu 4. - 5.9.	08:00 - 19:00
Ven 6.9.	08:00 - 15:00

Tous les participants doivent se présenter **en premier lieu** au secrétariat de la conférence afin de recevoir leur badge et les divers documents ainsi que pour le paiement des frais d'inscription.

**Attention:** Sans badge, l'accès aux sessions de la manifestation sera refusé.

Nous vous recommandons de vous inscrire déjà mardi après-midi afin d'éviter des temps d'attente inutiles mercredi matin.

**Attention:** Le secrétariat de la conférence ne met aucun matériel technique ni matériel de bureau à disposition. Chaque participant est responsable de son équipement (ordinateur, pointeur laser, adaptateurs, ciseaux, punaises, ...) !

### Auditoires

Les auditoires disposent tous d'un projecteur multimédia (beamer) et d'un projecteur pour transparents. Veuillez apporter votre ordinateur portable ainsi que d'éventuels accessoires tels que clé USB ou CD.

### Séance posters

Les posters seront présentés dans le hall le mercredi et jeudi soir et pendant la pause de midi de vendredi. Veuillez amener vous-même le matériel nécessaire pour fixer les posters (punaises, ruban adhésif). Les panneaux de posters seront numérotés suivant le numéro de l'abstract indiqué dans le programme. Tous les posters devraient rester installés pendant les trois jours.

Dimension maximale: A0, format portrait

### Paiement

Nous vous prions de régler d'avance vos frais d'inscription. De cette manière vous éviterez des files d'attente et vous nous facilitez notre travail. En plus vous pourrez faire des économies !

Les informations pour le paiement sont indiquées directement sur la page web lors de l'enregistrement.

**Preise gültig bei Zahlung bis 1. August - Prix valable pour des paiements avant le 1er août**

Kategorie - Catégorie	EUR
Mitglieder von SPG, ÖPG, SGAA, ÖGAA - Membres de la SSP ÖPG, SSAA, ÖGAA	90.-
Doktoranden, die in einer der obigen Gesellschaft Mitglied sind - Doctorants qui sont membres d'une des sociétés mentionnées ci-dessus	70.-
Doktoranden, die NICHT Mitglied sind - Doctorants qui ne sont PAS membres	90.-
Studenten VOR Master/Diplom Abschluß - Etudiants AVANT le degré master/diplôme	30.-
Plenar-/Eingeladene Sprecher, Preisträger - Conférenciers pléniers / invités, lauréats	0.-
Andere Teilnehmer - Autres participants	120.-
Konferenz Abendessen - Dîner de la conférence	70.-
<b>Zuschlag für Zahlungen nach dem 1. August sowie Barzahler an der Tagung - Supplément pour paiements effectués après le 1er août et pour paiements en espèces à la conférence</b>	<b>20.-</b>

Am Tagungssekretariat kann nur bar bezahlt werden (in EUR). Kreditkarten können leider nicht akzeptiert werden.

ACHTUNG: Tagungsgebühren können nicht zurückerstattet werden.

**Kaffeepausen, Mittagessen**

Die Kaffeepausen und die zur Postersitzung gehörenden Apéros finden in der Halle bei Händlerausstellung statt. Diese Leistungen sind in der Konferenzgebühr enthalten.

Die Mensen auf dem Campus sowie umliegende Restaurants stehen zum Mittagessen zur Verfügung.

**Konferenz-Abendessen**

Das Abendessen findet am Donnerstag im Anschluß an die Postersession statt. Der Preis beträgt EUR 70.- pro Person (beinhaltet Transfer, Menü und Getränke) Bitte registrieren Sie sich unbedingt im Voraus, damit wir disponieren können. Eine Anmeldung vor Ort ist nicht möglich !

**Hotels und Anreise**

Alle Informationen finden Sie auf der Konferenzwebseite: [www.jku.at/hfp/oepgsps13](http://www.jku.at/hfp/oepgsps13)

Les paiements lors de la conférence ne pourront être effectués qu'en espèces (EUR). Les cartes de crédit ne pourront malheureusement pas être acceptées.

ATTENTION: Les frais d'inscription ne pourront pas être remboursés.

**Pauses café, repas de midi**

Les pauses café, et les apéros pendant la séance posters se dérouleront dans le hall près des exposants. Ces prestations sont incluses dans les frais d'inscription.

Les restaurants du campus ainsi que des restaurants autour de l'université sont disponible pour les repas de midi.

**Dîner de la conférence**

Le dîner se tiendra le jeudi soir après la séance posters. Le prix est de EUR 70.- par personne (transfert, repas et boissons inclus). Veuillez s.v.p. absolument vous enregistrer d'avance pour des raisons d'organisation. Il n'est plus possible de s'inscrire sur place.

**Hôtels et Arrivée**

Tous les informations se trouvent sur le site web de la conférence: [www.jku.at/hfp/oepgsps13](http://www.jku.at/hfp/oepgsps13)


**Neuer MANTIS Kontakt für die Schweiz und Österreich**

Das britische Unternehmen Mantis Deposition Ltd. ist seit dem 1. Oktober 2012 in Deutschland mit einer eigenen Niederlassung in Mainz vertreten, die für die Betreuung der Kunden in Deutschland, Österreich und der Schweiz zuständig ist.

Mantis wurde im Jahre 2003 in Oxford von Wissenschaftlern mit Erfahrung in den Bereichen Nanotechnologie sowie Mess- und Dünnschichttechnik gegründet. Ein Team von erfahrenen und hochqualifizierten Mitarbeitern trägt in Entwicklung, Produktion, Beratung, Installation und Service zum Erfolg des Unternehmens bei. Heute steht das Unternehmen für die Herstellung qualitativ hochwertiger Beschichtungskomponenten und Vakuumabscheideanlagen. Die Produkte werden sowohl in der innovativen Materialforschung (Nanobeschichtungen, Molekularstrahlhexpitaxie, Sputterprozessen uvm.)

als auch in Pilot-Produktionsbeschichtungsanlagen mit Erfolg eingesetzt und stehen an der Spitze der Dünnschicht-Beschichtungstechnologie. Die Firma hat in kürzester Zeit mehr als 60 komplette Anlagen weltweit verkauft.

Neben universellen Standard Beschichtungssystemen werden auch Anlagen nach Kundenspezifikationen angeboten. Als besondere Dienstleistung wird ein Entwicklungsbeschichtungsservice unter Verwendung der eigenen Nanopartikel- Abscheidungsquelle angeboten.

**Mantis Deposition GmbH**  
Alte Fahrkartendruckerei  
Mombacher Straße 52  
55122 Mainz  
Deutschland

Tel: +49(0)6131-3272520  
OfficeDE@mantisdeposition.com  
[www.mantisdeposition.de](http://www.mantisdeposition.de)



## Vorläufige Programmübersicht - Résumé préliminaire du programme

Das vollständige Programm wird allen Teilnehmern am Tagungssekretariat abgegeben sowie auf der SPG-Webseite publiziert.

Hinweise:

- Je Beitrag wird nur der präsentierende Autor aufgeführt.
- Die Postersitzung ist am Mittwoch und Donnerstag von 18:30 - ca. 20:00 (mit Apéro) sowie am Freitag von 12:00 - 13:30.
- (p) = Plenarsprecher, (i) = eingeladener Sprecher

Le programme final complet sera distribué aux participants au stand du secrétariat de la conférence et sera publié sur le site de la SSP.

Indication:

- seul le nom de l'auteur présentant la contribution a été indiqué.
- la session poster a lieu le mercredi et jeudi de 18.30 à env. 20.00 (avec apéro) ainsi que le vendredi de 12:00 à 13:30.
- (p) = orateur de la session plénière, (i) = orateur invité

### Special: Energy Day 2013

Tuesday, 03.09.2013, HS 1

Time	ID	ENERGY DAY Chair: Werner Spitzl
10:00	21	Energiespeicherung: Das Vorwort zum Energietag 2013 Norbert Pillmayr
10:15	22	Zukünftiges Energiesystem benötigt neue Lösungsansätze besonders bei der Speicherung Horst Steinmüller
10:45	23	Herausforderungen für den Betrieb des kontinentaleuropäischen Verbundnetzes Martin Geidl
11:15		<b>Coffee Break</b>
11:30	24	Smart Grid und das Hauskraftwerk Michael Zahradnik
12:00	25	Wieviel erneuerbare Energie muss zukünftig gespeichert werden? Analyse des zukünftigen Speicherbedarfs in Österreich mit einem hohen Anteil an erneuerbarer Energie. Gerfried Jungmeier
12:30		Diskussion
12:45		<b>Lunch</b>
		Chair: Brigitte Pagana-Hammer
13:30	26	Technologische und Ökonomische Aspekte der Elektrochemischen Energiespeicherung Stefan Koller
14:00	27	Wasserstoffspeicherung durch Magnesiumhydrid Iris Bergmair
14:30	28	Superconducting Magnetic Energy Storage Bartłomiej A. Glowacki
15:00	29	Die Lithium-Ionen Batterie – von der Knopfzelle zur Traktionsbatterie Michael Sternad
15:30		Diskussion
15:50		Schlußbemerkungen Norbert Pillmayr
16:00		<b>END</b>
18:00		<b>RECEPTION</b>
19:00		<b>OFFICIAL OPENING OF THE JOINT ANNUAL MEETING OF ÖPG, SPS, ÖGAA AND SSAA</b>
		<b>PUBLIC LECTURE</b> Chair: Günther Bauer, JKU Linz
19:15	11	Using Nanostructures toward Achieving Energy Sustainability Mildred Dresselhaus, MIT (p)
20:30		<b>END</b>

### Special: Thermoelectrics

Tuesday, 03.09.2013, HS 4

Time	ID	THERMOELECTRICS Chair: Armando Rastelli, JKU Linz
15:15	31	From Superconductivity Towards Thermoelectricity: Germanium Based Skutterudites E. Bauer (i)
15:45	32	Half-Heusler compounds for thermoelectricity Sascha Populoh
16:00		<b>Coffee Break</b>
16:30	33	Seebeck Effect in the Kondo Insulator CeRu <sub>4</sub> Sn <sub>8</sub> under Magnetic Field Valentina Martelli
16:45	34	Seebeck-effect in organic semiconductors Kristin Willa
17:00	35	Crucial role of surface-segregation-driven intermixing on the thermal transport through planar Ge/Si superlattices Peixuan Chen
17:15	36	X-ray characterization of Si/Ge thermoelectric structures Tanja Etzelstorfer
17:30	37	Intermetallic transition metal clathrates Andrey Prokofiev
17:45		<b>END</b>

ID	THERMOELECTRICS POSTER
41	Influence of process variables of ball milling and hot pressing on the thermoelectric performance of type I clathrates Xinlin Yan
42	Development of a Measuring Platform for Thermoelectric Properties of Nanowires Günther Lientschnig
43	Thermoelectric properties of melt-spun SPS sintered type-VIII Ba <sub>3</sub> Ga <sub>16</sub> Sn <sub>30-x</sub> Ge <sub>x</sub> clathrates Petr Tomes
44	Experimental setup and sample processing for direct measurements of the cross-plane Seebeck coefficient of nanostructured Si/Ge materials Lukas Nausner
45	Melt spinning of CoSb <sub>3</sub> : e <sub>ect</sub> of microstructure on phonon thermal conductivity Matthias Ikeda
46	Thermoelectric properties of the anisotropic Kondo insulator CeRu <sub>4</sub> Sn <sub>8</sub> Jonathan Haenel
47	Resonant scattering induced thermopower peak in one dimensional disordered systems Daniel Müller

Thursday, 05.09.2013, HS 1

**Special: Photovoltaics**

Tuesday, 03.09.2013, HS 5

Time	ID	PHOTOVOLTAICS Chair: Markus Clark Scharber, JKU Linz
14:45	51	Theory of light-harvesting in photosynthesis: From structure to function Thomas Renger
15:15	52	Artificial Photosynthesis for the Storage of Chemical Energy Kerstin Oppelt
15:30	53	Ultrathin, lightweight, and flexible organic solar cells Matthew White
15:45	54	Colloidal Quantum dot photovoltaics: Tuning optoelectronic properties Philipp Stadler
16:00		Coffee Break
16:30	55	Organic nanocrystals from latent pigments for environmentally-friendly and biocompatible electronics Mykhailo Sytnyk
16:45	56	Metal sulfide nanoparticle/polymer hybrid solar cells Gregor Trimmel
17:00	57	Flexible Monograin Membrane Photovoltaic Membranes Axel Neisser
17:15	58	15 years of research on organic solar cells: lessons learned from 1 % to 10 % efficiency Christoph J. Brabec (i)
18:00		END

**Plenary Session**

Wednesday, 04.09.2013, HS 1

Time	ID	PLENARY SESSION I Chair: NN
08:55		Welcome note
09:00	1	Plasmons, forces and currents in atomic and molecular contacts Richard Berndt, Uni Kiel (p)
09:40	2	Quantum simulation with Atoms, Ions and Molecules Peter Zoller, Uni Innsbruck (p)
10:20		Coffee Break
		Chair: NN
10:50	3	The Quantum Way of Doing Computations Rainer Blatt, Uni Innsbruck (p)
11:30		Award Ceremony
12:30		Lunch
13:30		Topical Sessions
18:30		Postersession and Apéro
		PUBLIC LECTURE Chair: Rainer Blatt, Uni Innsbruck
20:00	12	Manipulation of single quantum systems Serge Haroche, Collège de France (p)
21:15		END

Time	ID	PLENARY SESSION II Chair: NN
09:00	4	100 years Bohr's Atomic Model: Its birth and its importance in the rise of QM Jan Lacki, Uni Genève (p)
09:40	5	Exoplanets and their atmospheres Lisa Kaltenegger, MPI Heidelberg (p)
10:20		Coffee Break
		Chair: NN
10:50	6	GEO: Using Earth observation for Integrated Water Resources Management Douglas Cripe, GEOSS Genève (p)
11:30	16	Winner of the ÖPG Boltzmann Award
12:00		General Assemblies
12:30		Lunch
13:30		Topical Sessions
18:30		Postersession (continued)
20:00		Conference Dinner

Friday, 06.09.2013, HS 1

Time	ID	PLENARY SESSION III Chair: NN
09:00	7	LHC - The first three years Rainer Wallny, ETH Zürich (p)
09:40	8	Quantum phase transitions in condensed matter Silke Bühler-Paschen, TU Wien (p)
10:20		Coffee Break
		Chair: Georg Pabst, Uni Graz
10:50	9	Theoretical Insights into Structure of Animal Tissues Primoz Zihelr, Uni Ljubljana (p)
11:30	17	Winner of the SPS ABB Award
12:00		Best Poster Awards
12:15		Postersession (continued), Lunch
13:30		Topical Sessions
15:30		END

**Careers for Physicists**

Thursday, 05.09.2013, K001A

Time	ID	CAREERS FOR PHYSICISTS Chair: Kai Hencken, ABB Baden
14:00	71	"Advanced Manufacturing", ein interessantes Feld für Physikerinnen und Physiker? Bernhard Braunecker (i)
14:30	72	What does a physicist do at ETH Zürich if he is not in research? Bernd Rinn (i)
15:00	73	On the Cutting Edge: Publication Dynamics and the Society of Scientific Journals Istvan Daruka
15:30		Coffee Break

16:00	74	<b>A new generation of Physicists</b> <i>Stefano Verginelli (i)</i>
16:30	75	<b>Workshop: Wie? Mit Physik Karriere machen?</b> <i>Josef Siess (i)</i>
17:00		<b>END</b>
18:30		<b>Postersession and Apéro</b>
20:00		<b>Conference Dinner</b>

### Physik und Schule

Wednesday, 04.09.2013, K269D

Time	ID	PHYSIK UND SCHULE <i>Chair: Engelbert Stütz, JKU Linz</i>
13:15	81	<b>Sexl-Preisträger: Preisvortrag 1</b>
13:35	82	<b>Sexl-Preisträger: Preisvortrag 2</b>
14:00	83	<b>Hat Aristoteles doch recht?</b> <i>Siegfried Bauer (i)</i>
		<b>PRÄMIERTE FACHBEREICH SARBEITEN</b> <i>Chair: Leopold Mathelitsch, Uni Graz</i>
15:00	84	<b>Introduction to Rutherford Backscattering Spectrometry (RBS)</b> <i>Maximilian Heinz Ruep</i>
15:15	85	<b>Schwerelosigkeit und Mikrogravitation</b> <i>Bianca Neureiter</i>
15:30		<b>Coffee Break</b>
16:00	86	<b>Stringtheorie; Grundgedanken und ihr Einfluss auf Teilchenphysik und Kosmologie</b> <i>Stefan Purkhart</i>
16:15	87	<b>Bildsensorik. Physikalische und technische Grundlagen am Beispiel des CCD</b> <i>Stefan Janisch</i>
		<i>Chair: Engelbert Stütz, JKU Linz</i>
16:30	88	<b>Präsentation des österreichischen Teams des IYPT 2013</b>
16:50	89	<b>Präsentation des österreichischen Teams der IPhO 2013</b>
17:10		<b>Sitzung des FA Physik und Schule</b>
18:00		<b>ENDE</b>
18:30		<b>Postersession and Apéro</b>

ID	PHYSIK UND SCHULE POSTER
91	<b>Construction, development and tests of a cost-effective force platform</b> <i>Florian Rieder</i>
92	<b>Schülervorstellungen zum Thema Strahlung</b> <i>Martin Hopf</i>
93	<b>Astrobiology as an Interdisciplinary Starting Point to Natural Sciences</b> <i>Johannes Leitner</i>
94	<b>Let's Play Physics! Making physics education physically - A project on the transit of the venus</b> <i>Christina Rothenhäusler</i>
95	<b>Nanophysik am Beispiel eines Rastertunnelmikroskops in der Schule</b> <i>Thomas Möst</i>
96	<b>Professionswissen Physiklehramtsstudierender in Österreich</b> <i>Ingrid Krumphals</i>

### KOND

Wednesday, 04.09.2013, HS 5

Time	ID	MAGNETISM, SUPERCONDUCTIVITY AND QUANTUM CRITICALITY <i>Chair: Silke Bühler-Paschen, TU Wien</i>
13:30	101	<b>Superconductivity in Materials without Inversion Symmetry</b> <i>Ernst Bauer (i)</i>
14:00	102	<b>Quantum criticality of the heavy-fermion compound CeCoGe<sub>2.2</sub>Si<sub>0.8</sub></b> <i>Julio Larrea</i>
14:15	103	<b>Strong Pressure Dependence of the Magnetic Penetration Depth in Single Crystals of the Heavy-Fermion Superconductor CeCoIn<sub>5</sub> Studied by Muon Spin Rotation</b> <i>Ludovic Howald</i>
14:30	104	<b>Electric and magnetic coupling of quantum-critical materials to a microwave coplanar waveguide resonator at milli-Kelvin temperatures</b> <i>Diana Geiger</i>
14:45	105	<b>Superconductivity and Quantum Criticality</b> <i>Johan Chang (i)</i>
15:15	106	<b>About the origin of frustration in the magnetism-driven multiferroic YBaCuFeO<sub>5</sub></b> <i>Marisa Medarde</i>
15:30		<b>Coffee Break</b>
		<b>NEUTRONS AND SYNCHROTRON RADIATION FOR CONDENSED MATTER</b> <i>Chair: Oskar Paris, Uni Leoben</i>
16:00	111	<b>X-ray absorption spectroscopy for element selective investigations of structure, valence and magnetism in doped oxides</b> <i>Andreas Ney (i)</i>
16:30	112	<b>Growing semiconductor nitrides into spintronic and magneto-optic materials</b> <i>Alberta Bonanni</i>
16:45	113	<b>X-ray strain microscopy of inhomogeneously strained Ge micro-bridges</b> <i>Tanja Etzelstorfer</i>
17:00	114	<b>A New Crystalline Phase of Gallium Phosphide: Wurtzite Nanowires Investigated by X-ray Diffraction</b> <i>Dominik Kriegner</i>
17:15	115	<b>In-situ synchrotron SAXS studies on Colloidal Nanocrystal Formation</b> <i>Rainer T. Lechner</i>
17:30	116	<b>In-situ and ex-situ study of mesostructured silica synthesized in the gas phase</b> <i>Barbara Sartori</i>
17:45	117	<b>Humidity Driven Pore-Lattice Deformation in Ordered Mesoporous Thin Films</b> <i>Parvin Sharifi</i>
18:00	118	<b>Radiation assisted material synthesis and processing by deep X-ray lithography</b> <i>Benedetta Marmiroli</i>
18:15	119	<b>Novel insights into photoemission from solids: Surface RABBITT yields absolute delays and reveals temporal structure beyond transport phenomena.</b> <i>Luca Castiglioni</i>
18:30		<b>Postersession and Apéro</b>
20:00		<b>Public Lecture</b>

Thursday, 05.09.2013, HS 5

Time	ID	<b>SOFT MATTER AND OTHER SYSTEMS I</b> (SHARED WITH THE BIOPHYSICS SESSION) Chair: Georg Pabst, Uni Graz
13:30	121	Equilibrium and flow of cluster-forming complex fluids <i>Christos N. Likos (i)</i>
14:00	122	Optimized Fourier Monte Carlo Simulation of Solid and Hexatic Membranes <i>Andreas Troester</i>
14:15	123	Biomimetic folding particle chains <i>Peter Oostrum</i>
		<b>SOFT MATTER AND OTHER SYSTEMS II</b> Chair: Oskar Paris, Uni Leoben
14:30	124	Small Angle Scattering Study of the self-assembly of an amphiphilic designer peptide from the monomer to a helical superstructure <i>Heinz Amenitsch</i>
14:45	125	Liquid Structure and the Noncoincidence Effect of Liquid Dimethyl Sulfoxide Revisited <i>Maurizio Musso</i>
15:00	126	Generation of multiply twinned Ag clusters (n<6000) in superfluid helium nanodroplets <i>Philipp Thaler</i>
15:15	127	The characterization of defects in silicon by Electron Beam Induced Current (EBIC) measurements <i>Peter Hadley</i>
15:30		<b>Coffee Break</b>
		<b>SEMICONDUCTORS</b> Chair: Peter Hadley, TU Graz
16:00	131	Structural Investigation of Novel Semiconductor Systems by Transmission Electron Microscopy <i>Heiko Groiss (i)</i>
16:30	132	Harnessing nuclear spin polarization fluctuations in a semiconductor nanowire <i>Phani Peddibhotla</i>
16:45	133	Structural and magnetic properties of ZnO with doping beyond the coalescence limit <i>Verena Ney</i>
17:00	134	$\mu$ -Raman investigation of heterogeneously strained Si nanostructures <i>Martin Süess</i>
17:15	135	Normally-off GaN MOSHEMTs with thin barrier on Si substrate <i>Alexander Alexewicz</i>
17:30	136	Spin dependent electron response functions <i>Raphael Hobbiger</i>
17:45	137	Creation and detection of entanglement in helical edge states using a single-electron source <i>Patrick Hofer</i>
18:00	138	Experimental observation of the even-denominator fractional quantum-Hall effect in suspended graphene bilayers <i>DongKeun Ki</i>
18:15	139	Magneto-optical spectroscopy of epitaxial graphene <i>Iris Crassee (talk given by Alexey Kuzmenko)</i>
18:30		<b>Postersession and Apéro</b>
20:00		<b>Conference Dinner</b>

Friday, 06.09.2013, HS 5

Time	ID	<b>CONDENSED MATTER COMPUTATIONAL AND THEORY</b> Chair: Christian Rüegg, PSI Villigen & Uni Genf
13:30	141	Computer simulations of strongly correlated quantum matter <i>Andreas Läuchli (i)</i>
14:00	142	A variational cluster approach to strongly correlated quantum systems out of equilibrium <i>Martin Nuss</i>
14:15	143	Exotic Bound States in Low Dimensions <i>Jelena Klinovaja</i>
14:45	144	Berry Phase Effect in Solids <i>Gerhard Brunthaler</i>
15:00	145	First-principle investigation of topological transition in $\alpha$ -Sn nanocrystals <i>Sebastian Kufner</i>
15:15	146	A modified Griffith model for explaining Liquid Metal Embrittlement in the Fe/Zn system <i>Klaus-Dieter Bauer</i>
15:30		<b>END</b>

ID	<b>KOND POSTER</b>
151	Conduction and Valence Band States of Sb-Mediated Ge Quantum Dots in n-type Si Studied by Deep Level Transient Spectroscopy <i>Victor Tapio Rangel Kuoppa</i>
152	Ultra-small-angle polarised neutron scattering on magnetic structures <i>Erwin Jericha</i>
153	Low temperature magnetic structure of multiferroic YBaCuFeO <sub>5</sub> <i>Mickael Morin</i>
154	Dynamic stabilization of nonequilibrium domain configurations in magnetic squares with high amplitude excitations <i>Stephanie Stevenson</i>
155	Parametric polariton scattering in coupled planar microcavities <i>Patrick Mai</i>
156	Magnetism on the route of compensated to remnant magnetism: SQUID- and Raman-data on NiO-nanoparticles <i>Julia Weber</i>
157	Skyrmion Dynamics in Perpendicular Magnetic Anisotropy Nanostructures <i>Christoforos Moutafis</i>
158	Neutron diffraction study of lattice damage induced by tritium decay in palladium tritide <i>Gerhard Krexner</i>
159	Effects of Geometrical Confinement on Li and Na in Nanoporous Glasses <i>Gerhard Krexner</i>
160	SiGe self-assembled nanostructures: from surface science to quantum transport <i>Georgios Katsaros</i>
161	Enhanced 1.54 $\mu\text{m}$ -Er <sup>3+</sup> photoluminescence through contact coupling with Ge nanostructures <i>J. Martín-Sánchez</i>
162	Refinement of the eutectoid region of the Fe-Ru phase diagram using thermodynamic and metallurgical approaches <i>Gabriela Schimo</i>
163	Conducting Cellulose Fiber Networks as Flexible Substrate for Optoelectronic Applications <i>Bettina Friedel</i>

## Surfaces, Interfaces and Thin Films

Wednesday, 04.09.2013, HS 1

Time	ID	<b>SURFACES + ORGANIC THIN FILMS</b> Chair: Christian Teichert, Uni Leoben
13:30	201	Isolated Pd Sites on PdGa Model Catalyst Surfaces Jan Prinz
13:45	202	Metal clusters and simple adsorbates on ultra-thin ZrO <sub>2</sub> /Pt <sub>3</sub> Zr Joong Il J. Choi
14:00	203	Mechanics of single molecules Ernst Meyer (i)
14:30	204	Initial steps of indigo film growth on silicon dioxide Boris Scherwitzl
14:45	205	Tuning the 1D-self-assembly of dicyano-functionalized helicene building-blocks Aneliia Shchyrba
15:00	206	Using polarized light in PEEM Thorsten Wagner
15:15	207	Substrate enhanced intermolecular dispersion: Pentacene on Cu(110) Thomas Ules
15:30		<b>Coffee Break</b>
		<b>THEORY + CLUSTERS</b> Chair: Ernst Meyer, Uni Basel
16:00	211	Ohmic contacts for resistance measurements of ultra-thin metal-on-silicon layers Bernhard Lutzer
16:15	212	Electrical and Physical Characterization of Interfacial Germanates in Ge-based MOS devices Ole Bethge
16:30	213	Numerical Simulations of a Capillarity Driven Morphological Transition on the Nanoscale Istvan Daruka
16:45	214	Reflectance Anisotropy spectrum of water covered Cu(110) surface studied from first principles Amirreza Baghbanpourasl
17:00	215	Organic Semiconductors Interfaces Explored With Ab-initio Electronic Structure Methods Peter Puschnig (i)
17:30	216	Solid-solid interfaces in metal oxide nanoparticle ensembles Oliver Diwald
17:45	217	Single gold nanoparticles as nanoscopic pH-sensors Cynthia Vidal
18:00	218	Efficient random lasing from star-shaped nanoparticles Johannes Ziegler
18:15	219	Growth of in-plane SiGe nanowires Hannes Watzinger
18:30		<b>Postersession and Apéro</b>
20:00		<b>Public Lecture</b>

Thursday, 05.09.2013, HS 1

Time	ID	<b>METHODES</b> Chair: Peter Zeppenfeld, Uni Linz
13:30	221	On-surface magnetochemistry: controlling spins in adsorbed molecules by a chemical switch Christian Wäckerlin (i)

14:00	222	Electronic and Magnetic Properties of Surface-Supported Hydrocarbon Radicals Studied by Low-Temperature Scanning Tunneling Microscopy Stefan Müllegger
14:15	223	Using AFM nanoindentation to investigate mechanical properties of cellulose fibers in controlled humidities Christian Ganser
14:30	224	Helium Atom Scattering Measurements of the Sb(111) Surface Markus Polanz
14:45	225	Formation of HCN <sup>+</sup> in Heterogeneous Reactions of N <sup>2+</sup> and N <sup>+</sup> with Surface Hydrocarbons Martina Harnisch
15:00	226	Hydrogen Induced Buckling of Gold Films Baran Eren
15:15		<b>ÖPG-OGD Division Meeting</b>
15:30		<b>Coffee Break</b>
		<b>OXIDES</b> Chair: Ulrike Diebold, TU Wien
16:00	231	Growth and Morphology of Epitaxial MgO Films on GaAs(001) Anirban Sarkar
16:15	232	Compositional and structural study of homoepitaxial-STO based oxides heterostructures Mathilde L. Reinle-Schmitt
16:30	233	Single Metal Adatoms on Fe <sub>3</sub> O <sub>4</sub> (001)-(√2x√2)R45° Gareth Parkinson (i)
17:00	234	Water Gas Shift Chemistry at the Fe <sub>3</sub> O <sub>4</sub> (001) Surface Oscar Gamba
17:15	235	STM and photoemission study of vacancies and hydroxyls at the SrTiO <sub>3</sub> (110)-(4x1) surface Stefan Gerhold
17:30	236	Interface Fermi states of LaAlO <sub>3</sub> /SrTiO <sub>3</sub> and related heterostructures Claudia Cancellieri (i)
18:00	237	Combined Spectroscopic Study of the Evolution from the Metallic Surface State on SrTiO <sub>3</sub> to the Interface of LaAlO <sub>3</sub> /SrTiO <sub>3</sub> Nicholas Plumb
18:15	238	Field-induced migration of oxygen vacancies towards the surface of TiO <sub>2</sub> anatase(101) Martin Setvin
18:30		<b>Postersession and Apéro</b>
20:00		<b>Conference Dinner</b>

Friday, 06.09.2013, HS 1

Time	ID	<b>GRAPHENE + FLEXIBLE ELECTRONICS</b> Chair: Adolf Winkler, TU Graz
13:30	241	Observing Graphene grow: In-situ metrology for controlled growth of graphene and carbon nanotubes Bernhard Bayer
13:45	242	Optical characterization of atomically precise graphene nanoribbons Richard Denk
14:00	243	Electronic Structure of Atomically Precise Graphene Nanoribbons Pascal Ruffieux
14:15	244	Modification of exfoliated graphene: a case study Markus Kratzer (i)

14:45	245	In-situ thin film transistor fabrication: Electrical and surface analytical characterization <i>Roman Lassnig</i>
15:00	246	Valve metal anodic oxides for flexible electronics <i>Andrei Ionut Mardare</i>
15:15	247	Direct writing of high-k metal oxide dielectrics for flexible large area electronics <i>Christian M. Siket</i>
15:30		<b>END</b>

ID SURFACES, INTERFACES AND THIN FILMS POSTER		
251		Stabilization mechanisms at polar ZnO surfaces in ideal vacuum conditions: a SCC-DFTB study <i>Stefan Huber</i>
252		Shockley Surface States Revisited: A Comprehensive Density Functional Study <i>Bernd Kollmann</i>
253		Molecule-Substrate Hybridization Revealed by Angle-Resolved Photoemission Spectroscopy <i>Dario Knebl</i>
254		Initial growth of quinacridone on Ag(111) <i>Thorsten Wagner</i>
255		Adsorption of quinacridone on Cu(110) and Cu(110)-(2x1)O surfaces <i>Harald Zaglmayr</i>
256		Attachment-limited nucleation and growth of organic films: Pentacene on sputter modified mica (001) <i>Levent Tümbek</i>
257		Interfacial structure and device efficiency of an organic bilayer heterojunction solar cell <i>Michael Zawodzki</i>
258		Adsorption of pentacene and perfluoro-pentacene on Cu(110) studied by reflectance difference spectroscopy <i>Johannes Gall</i>
259		Influences of rippled titania surfaces on to the growth morphologies of 6P thin films <i>Reinhold Wartbichler</i>
260		Hydrogen adsorption on TiO <sub>2</sub> anatase(101) <i>Benjamin Daniel</i>
261		Optical properties of metal doped ZnO thin films on glass and polymer substrates <i>Meirzhan Dosmailov</i>
262		Negative muonium as a local probe for the detection of the photo-induced inversion of a Ge surface layer <i>Thomas Prokscha</i>
263		Short-Term Metastable Effects in Amorphous Silicon Solar Modules <i>Ankit Mittal</i>
264		Oxide diffusion barriers on GaAs(001) <i>Shibo Wang</i>
265		Formation of Tungsten Oxide Nanolayers by (WO <sub>3</sub> ) <sub>3</sub> Cluster Condensation on Ag(100) <i>Thomas Obermüller</i>
266		Influence of the Ni content in AlCu alloy using the combinatorial approach. <i>Martina Hafner</i>
267		Susceptibility measurements of Ni clusters embedded in organic matrices <i>Mariella Denk</i>
268		Investigation of Single Ni Adatoms on the Magnetite (001) Surface <i>Roland Bliem</i>
269		Investigation of Exchange Coupled Composites with Scanning Transmission X-ray Microscopy <i>Phillip Wohlhüter</i>

270		Spin resolved photoemission spectroscopy of Fe <sub>3</sub> O <sub>4</sub> : The effect of surface structure <i>Jiri Pavelec</i>
271		Charge behavior on insulating monocrystalline surfaces by Kelvin probe force microscopy <i>Monika Mirkowska</i>
272		Stabilization of explosive compounds on metallic surfaces <i>Stefan Ralser</i>
273		Characterizations of HOPG and Graphene Treated with Low Temperature Hydrogen Plasma <i>Baran Eren</i>
274		Characterization of thin two-element compound material films by time-of-flight Low Energy Ion Scattering <i>Dietmar Roth</i>
275		Indication of phonon-assisted electron-hole relaxations on Sb(111) and Bi(111) in iHAS measurements <i>Patrick Kraus</i>
276		Determination of atmospheric corrosion of coated steel surfaces by in situ infrared reflection absorption spectroscopy (IRRAS) <i>Maurizio Musso</i>
277		Al-Si thin films for hydrogen reference materials <i>Cezarina Cela Mardare</i>

## Nuclear, Particle- and Astroparticle Physics

Wednesday, 04.09.2013, HS 6

Time	ID	I: LHC PHYSICS I Chair: Martin Pohl, Uni Genève
13:30	301	Search for a Higgs-like Boson decaying into bottom quarks <i>Philipp Eller</i>
13:45	302	Search for long lived charged and massive particles at LHCb detector <i>Thi Viet Nga La</i>
14:00	303	Measurement of differential isolated diphoton production cross section at CMS <i>Marco Peruzzi</i>
14:15	304	Search for Higgs boson production in supersymmetric cascades using fully hadronic final states <i>Mario Masciovecchio</i>
14:30	305	Search for supersymmetry in hadronic final states with MT2 at CMS <i>Hannsjörg Weber</i>
14:45	306	Search for supersymmetry in events with two opposite-sign same-flavor leptons, jets and missing energy <i>Marco - Andrea Buchmann</i>
15:00	307	Application of CMS and ATLAS Simplified Models Results to Theories Beyond the Standard Model (BSM) <i>Ursula Laa</i>
15:15	308	Measurement of quarkonium polarization at CMS <i>Valentin Knünz</i>
15:30		<b>Coffee Break</b>
		II: ASTROPARTICLE AND NON-ACCELERATOR PHYSICS Chair: Eberhard Widmann, ÖAW Wien
16:00	311	Neutron Capture Measurements on <sup>62</sup> Ni, <sup>63</sup> Ni and <sup>197</sup> Au and their Relevance for Stellar Nucleosynthesis <i>Claudia Lederer (i)</i>

16:30	312	Latest Results of Searches for Point and Extended Sources with Time Independent and Time Dependent emissions of Neutrinos with the IceCube Neutrino Observatory <i>Asen Christov (i)</i>
17:00	313	High resolution 3D-simulations of galactic cosmic ray propagation using GALPROP <i>Michael Werner</i>
17:15	314	The cosmological constant puzzle: Vacuum energies from QCD to dark energy <i>Steven Bass</i>
17:30	315	Numerical 3D-hydrodynamic modelling of colliding winds in massive star binaries: particle acceleration and gamma-ray emission <i>Klaus Reitberger</i>
17:45	316	High precision tests of the Pauli Exclusion Principle for Electrons at LNGS <i>Johann Marton</i>
18:00	317	Search of neutrinoless double beta decay with the GERDA experiment <i>Giovanni Benato</i>
18:15	318	qBounce: A quantized frequency reference with gravity-resonance-spectroscopy <i>Gunther Cronenberg</i>
18:30		<b>Postersession and Apéro</b>
20:00		<b>Public Lecture</b>

Thursday, 05.09.2013, HS 6

Time	ID	III: PROTONS AND NEUTRONS <i>Chair: Johann Marton, ÖAW Wien</i>
13:30	321	Spectroscopy apparatus for the measurement of the hyperfine structure of antihydrogen <i>Chloe Malbrunot (i)</i>
14:00	322	A progress report on detector and analysis development for the Hbar-HFS experiment within the ASACUSA collaboration <i>Clemens Sauerzopf</i>
14:15	323	Beamline Simulations for cold Antihydrogens <i>Bernadette Kolbinger</i>
14:30	324	Gravitational interaction of antihydrogen: the AEGIS experiment at CERN <i>Michael Doser</i>
14:45	325	Design of the downstream interface in the AEGIS beamline <i>Sebastian Lehner</i>
15:00	326	Ultracold neutrons for fundamental physics experiments at the Paul Scherrer Institute <i>Bernhard Lauss (i)</i>
15:30		<b>Coffee Break</b>
		IV: PROTONS AND NEUTRONS, FLAVOR PHYSICS <i>Chair: Christoph Schwanda, ÖAW Wien</i>
16:00	331	Comparison of the Larmor precession frequencies of $^{199}\text{Hg}$ and ultracold neutrons in the nEDM experiment at PSI <i>Beatrice Franke</i>
16:15	332	Vector Cesium Magnetometer for the nEDM Experiment <i>Samer Afach</i>
16:30	333	The future neutron beta decay facility PERC <i>Jacqueline Erhart</i>
16:45	334	Tailoring of polarised neutron beams by means of spatial magnetic spin resonance <i>Erwin Jericha</i>
17:00	335	Flavour GUT models with $\theta_{13}^{\text{PMNS}} = \theta_c / \sqrt{2}$ <i>Constantin Sluka</i>

17:15	336	Angular analysis of $B_d \rightarrow K^* \mu^+ \mu^-$ with the ATLAS detector <i>Emmerich Kneringer</i>
17:30	337	Measurement of $B(B_s^0 \rightarrow J/\psi \phi)$ , $B(B_s^0 \rightarrow J/\psi f_2(1525))$ and $B(B_s^0 \rightarrow J/\psi K^* K^0)$ and a determination of the $B_s^0 \rightarrow J/\psi \phi$ polarization at the Belle experiment <i>Felicitas Thorne</i>
17:45	338	Measurement of $ V_{cb} $ through exclusive semileptonic $B \rightarrow D   \nu$ decays with a tagged fully reconstructed B meson at the Belle experiment <i>Robin Glattauer</i>
18:00	339	Monte Carlo simulation for Kaonic deuterium studies <i>Carolina Berucci</i>
18:15		
18:30		<b>Postersession and Apéro</b>
20:00		<b>Conference Dinner</b>

Friday, 06.09.2013, HS 6

Time	ID	V: LHC PHYSICS II AND DETECTORS <i>Chair: Rainer Wallny, ETH Zürich</i>
13:30	341	Measurement of Charged Particle Multiplicities with the ATLAS detector at the LHC <i>Wolfgang Lukas</i>
13:45	342	Jet production in association with a Z boson at CMS <i>Andrea Carlo Marini</i>
14:00	343	The Readout System of the Belle II Silicon Vertex Detector <i>Richard Thalmeier</i>
14:15	344	Interstrip capacitance of double sided silicon strip detectors <i>Bernhard Leitl</i>
14:30	345	Over Saturation Behaviour of SiPMs at High Photon Exposure <i>Lukas Gruber</i>
14:45	346	FLUKA studies of hadron-irradiated scintillating crystals for calorimetry at the High-Luminosity LHC <i>Milena Quittnat</i>
15:00	347	Studies of radiation hardness of diamond strip trackers. <i>Felix Bachmair</i>
15:15	348	Irradiation Studies with the New Digital Readout Chip for the Phase I Upgrade of the CMS Pixel Detector <i>Jan Hoss</i>
15:30		<b>END</b>

ID	NUCLEAR, PARTICLE- AND ASTROPHYSICS POSTER	
351	Measurement of the thermal neutron flux at the source for ultracold neutrons at the Paul Scherrer Institute <i>Dieter Ries</i>	
352	An uncompensated magnetic field drifts in a search for an electric dipole moment of the neutron (nEDM) carrying out at Paul Scherrer Institute (PSI). <i>N Prashanth Pataguppi</i>	
353	High-volume production of Silicon strip detectors for particle physics experiments <i>Thomas Bergauer</i>	
354	Bethe-Salpeter Description of Light Pseudoscalar Mesons <i>Wolfgang Lucha</i>	
355	Lock-in based detection scheme for a hydrogen beam <i>Michael Wolf</i>	
356	Spin polarized atomic hydrogen beam source <i>Martin Diermaier</i>	

357	A neutron interferometric measurement and calculation of a phase shift induced by Laue transmission <i>Thomas Potocar</i>
358	Development of a novel muon beam line for next generation precision experiments <i>Kim Siang Khaw</i>
359	Measurements and simulations of magnetic field inside the ASACUSA Antihydrogen spin-flip cavity <i>Nazli Dilaver</i>
360	Neutron Reflectometry as Matura project - Verifying the Wave-Particle Dualism at the NARZISS Instrument at the Paul Scherrer Institut. <i>Carla Kreis</i>

### Theoretical Physics

Wednesday, 04.09.2013, K034D

Time	ID	THEORETICAL PHYSICS I <i>Chair: Jakob Yngvason, Uni Wien</i>
14:00	401	Lattice effects on vortex dynamics in strongly correlated electron systems <i>Sebastian Huber (i)</i>
14:30	402	Strongly Interacting Dipolar Quantum Gases <i>Robert Zillich (i)</i>
15:00	403	On currents, anomalies and the RG-behaviour of supersymmetric gauge theories. <i>Jean-Pierre Derendiger (i)</i>
15:30		<b>Coffee Break</b>
16:00	404	Maximally entangled sets <i>Barbara Kraus (i)</i>
16:30	405	Geometry as a Semiclassical Effect in a Quantum World - Emergent gravity from matrix models <i>Daniel Blaschke</i>
16:45	406	Electrostatic Interactions with Dielectric Samples in Scanning Probe Microscopies <i>Alexis Baratoff</i>
17:00		
18:30		<b>Postersession and Apéro</b>
20:00		<b>Public Lecture</b>

Thursday, 05.09.2013, K034D

Time	ID	THEORETICAL PHYSICS II <i>Chair: Gian Michele Graf, ETH Zürich</i>
13:30	411	Exterior Navier-Stokes problems in two dimensions: results and open questions <i>Peter Wittwer (i)</i>
14:00	412	Quantum many-body effects in transport through quantum dots: renormalization-group approaches <i>Sabine Andergassen (i)</i>
14:30	413	Atomic clocks: A mathematical physics perspective <i>Martin Fraas (i)</i>
15:00	414	Non-local perturbations of hyperbolic PDEs and QFT models on non-commutative spacetimes <i>Gandalf Lechner (i)</i>
15:30		<b>Coffee Break; END</b>

### Applied, Plasma and Geophysics

Wednesday, 04.09.2013, K153C

Time	ID	APPLIED PHYSICS <i>Chair: Ivo Furno, CRPP-EPFL</i>
13:30	451	Analysis of the Microscopic Fluid Flow of State-of-the-art Absorption Heat Pump Working Pairs under Operational Conditions <i>Johann Emhofer</i>
13:45	452	Entwicklung eines Kondensationswindkanals zur Untersuchung des Wärme- und Massetransports an Wärmeüberträgern <i>Sanda Seichter</i>
14:00	453	Precision Metrology with a Diode-Pumped Solid-State Laser Optical Frequency Comb <i>Stephane Schilt</i>
14:15	454	Identifying Photoreaction Products in Cinnamate-based Photoalignment Materials <i>Daniele Passerone</i>
14:30	455	Experimental and simulated results on adsorption of molecules on fullerenes. <i>Alexander Kaiser</i>
14:45	456	Dual-Comb Spectroscopy based on Mid-IR Quantum-Cascade-Lasers Frequency-combs <i>Gustavo Villares</i>
15:00	457	Coincidence Time Resolution(CTR) of PMT and SiPM and readout components <i>Albulena Berisha Shabani</i>
15:15		
15:30		<b>Coffee Break</b>
		GEOPHYSICS AND APPLIED PHYSICS <i>Chair: Stéphane Goyette, Uni Genève</i>
16:00	461	Towards an integrated Observation System of the Black Sea catchment <i>Nicolas Ray (i)</i>
16:30	462	Cs-137 in Wildpilzen in Österreich: Verteilung und zeitliche Trends <i>Herbert Lettner</i>
16:45	463	Simulation of microwave propagation and absorption in heterogeneous rocks <i>Ronald Meisels</i>
17:00	464	Calculation of atom evaporation rates using entropy production maximisation <i>Frank Kassubek</i>
		PLASMA PHYSICS <i>Chair: Ivo Furno, CRPP-EPFL</i>
17:15	465	Zeitaufgelöste schnelle Messungen von Wachstumsrate und Teilchentransport in HIPIMS-Plasmen <i>Christian Maszl</i>
17:30	466	Plasma fluctuations study in the new closed flux-surfaces configuration of the TORPEX experiment <i>Fabio Avino</i>
17:45	467	Simulating the effect of fine radial structures resulting from non-adiabatic passing electrons on turbulent transport in the ITG and TEM regimes <i>J. Dominski</i>
18:00	468	Characterization of rf discharges in non-thermal atmospheric pressure plasma jets using helium <i>Johann Laimer</i>
18:15		<b>END</b>
18:30		<b>Postersession and Apéro</b>
20:00		<b>Public Lecture</b>

ID	APPLIED, PLASMA AND GEOPHYSICS POSTER
481	Simulated insertion loss of noise barriers using the boundary element method <i>Holger Waubke</i>
482	In-line measurements of chlorine containing polymers in an industrial waste sorting plant by laser-induced breakdown spectroscopy <i>Norbert Huber</i>
483	Element analysis of complex materials by calibration-free laser-induced breakdown spectroscopy <i>Johannes D. Pedarnig</i>
484	Variable Capacitance Energy Harvesting <i>Robert Pichler</i>
485	Photoluminescence enhancement of Double-Walled Carbon Nanotubes filled with linear carbon chains <i>Philip Rohringer</i>
486	Inter-atomic Coulombic Decay (ICD) of clusters upon electron impact <i>Elias Jabbour Al Maalouf</i>
487	The Inner Structure of Jupiter's Moon Europa – Estimations on the Physical Conditions at the Sea Floor of its Potential Subsurface Ocean <i>Susanne Pollack-Drs</i>
488	The evolution of hotspots on Earth and Venus <i>Elisabeth Fahrngruber</i>
489	Comparing Characteristics of Polygonal Impact Craters on Mercury and Venus <i>Gerhard Weihs</i>
490	Modeling the evolution and fate of early Mars' hypothesized ocean <i>Gabor Imre Kiss</i>

### Atomic Physics and Quantum Optics

Wednesday, 04.09.2013, HS 4

Time	ID	ATOMIC PHYSICS AND QUANTUM OPTICS I <i>Chair: NN</i>
13:30	501	Measuring higher-order interferences with a five-path interferometer <i>Thomas Kauten</i>
13:45	502	Extraction of Ionic Cores From Charged Helium Nanodroplets <i>Michael Renzler</i>
14:00	503	Probing Non-Equilibrium Dynamics of Isolated Quantum Many-Body Systems <i>Bernhard Rauer</i>
14:15	504	Buffer gas cooling of atoms and molecules <i>Sarah Skoff</i>
14:30	505	Spectroscopic and Theoretical Studies of Chromium Doped Helium Nanodroplets <i>Andreas Kautsch</i>
14:45	506	A graph state formalism for mutually unbiased bases <i>Christoph Spengler</i>
15:00	507	Strong coupling between single atoms and non-transversal photons <i>Christian Junge</i>
15:15	508	Interactions of He <sup>-</sup> in doped He droplets <i>Michael Neustetter</i>
15:30		Coffee Break

Time	ID	ATOMIC PHYSICS AND QUANTUM OPTICS II <i>Chair: NN</i>
16:00	511	Decoration of anionic and cationic fullerenes with polar and apolar molecules. <i>Nikolaus Weinberger</i>
16:15	512	Nonequilibrium dynamics, Optimal Control and Nanofibers on an Atom Chip <i>Dominik Fischer</i>
16:30	513	A Spin Polarised Temperature Controlled Atomic Hydrogen Beamline <i>Peter Caradonna</i>
16:45	514	Theoretical Investigation of Excited States of the Diatomic Molecule LiCa <i>Johann Pototschnig</i>
17:00	515	Single atom cavity quantum electrodynamics with non-transversally polarized light fields <i>Michael Scheucher</i>
17:15	516	Mapping Magnetic Nanostructures Using Radical Pair Reactions <i>Jofre Espigule Pons</i>
17:30	517	Merging two immiscible BECs of Rb and Cs for optimized production of RbCs ground-state molecules <i>Lukas Reichsöllner</i>
17:45	518	Cavity cooling of free silicon nanoparticles in high vacuum <i>Peter Asenbaum</i>
18:00	519	Integrated Mach-Zehnder interferometer for Bose-Einstein condensates <i>T. Berrada</i>
18:15	520	Entanglement Swapping over a 143 km free-space link <i>Thomas Herbst</i>
18:30		Postersession and Apéro
20:00		Public Lecture

Thursday, 05.09.2013, HS 4

Time	ID	ATOMIC PHYSICS AND QUANTUM OPTICS III <i>Chair: NN</i>
13:30	521	Tenfold reduction of Brownian noise in high-reflectivity optical coatings <i>Garrett D. Cole</i>
13:45	522	Doublon stability and decay mechanisms <i>M. J. Mark</i>
14:00	523	Cavity cooling of an optically levitated nanoparticle <i>Nikolai Kiesel</i>
14:15	524	Entanglement properties of locally maximally entangleable states <i>Martí Cuquet</i>
14:30	525	Decrease in query complexity for quantum computers with superposition of circuits <i>M. Araujo</i>
14:45	526	Optimal state reconstruction for cavity-optomechanical systems via Kalman filtering <i>Jason Hoelscher-Obermaier</i>
15:00	527	Quantum Entanglement of High Angular Momenta <i>Robert Fickler</i>
15:15	528	Cooling-by-measurement and mechanical state tomography via pulsed optomechanics <i>M. R. Vanner</i>
15:30		Coffee Break

Time	ID	<b>ATOMIC PHYSICS AND QUANTUM OPTICS IV</b> <i>Chair: NN</i>
16:00	531	Einstein-Podolsky-Rosen correlations from colliding Bose-Einstein condensates <i>M. Ebner</i>
16:15	532	Real-Time Imaging of Quantum Entanglement <i>Robert Fickler</i>
16:30	533	Creation of nitrogen-vacancy centres for cavity QED <i>Kathrin Buczak</i>
16:45	534	Studies of Quantum Entanglement in 100 Dimensions <i>Mario Krenn</i>
17:00		<b>END</b>
18:30		<b>Postersession and Apéro</b>
20:00		<b>Conference Dinner</b>

ID	<b>ATOMIC PHYSICS AND QUANTUM OPTICS POSTER</b>	
541	Coupling Spins and Diamond Color Centers to Superconducting Cavities <i>Stefan Putz</i>	
542	Dipole-dipole influenced Ramsey interferometry <i>Laurin Ostermann</i>	
543	Ultracold atoms on a superconducting Atomchip <i>Stefan Minniberger</i>	
544	Coherent manipulation of cold cesium atoms in a nanofiber-based two-color dipole trap <i>Daniel Reitz</i>	
545	Coherence properties of cold cesium atomic spins in a nanofiber-based dipole trap <i>Rudolf Mitsch</i>	
546	<i>see talk 516</i>	
547	Photonic platform for experiments in higher dimensional quantum systems <i>Christoph Schaeff</i>	
548	Loophole-free Einstein Podolsky Rosen Experiment via Quantum Steering <i>Bernhard Wittmann</i>	
549	Quantum communication with satellites, its preparatory terrestrial free-space demonstrations and future missions <i>Thomas Scheidl</i>	
550	Laser desorption/vaporization/ionization techniques for matter-wave interferometry <i>Ugur Sezer</i>	

### Infrared Optical Nanostructures

Wednesday, 04.09.2013, HS 3

Time	ID	<b>I: QUANTUM CASCADE LASERS</b> <i>Chair: Karl Unterrainer, TU Wien</i>
13:30	601	Quantum cascade laser frequency combs: spectroscopy and novel developments <i>Jerome Faist (i)</i>
14:00	602	Bi-functional Quantum Cascade Laser/Detectors for Integrated Photonics <i>Gottfried Strasser (i)</i>
14:30	603	Broadband external cavity tuning of a quantum cascade laser in the 3 - 4 $\mu\text{m}$ window <i>Sabine Riedi</i>

14:45	604	Terahertz spectroscopy of coupled cavity quantum cascade lasers <i>Dominic Bachmann</i>
15:00	605	Terahertz Photonic Crystal Quantum Cascade Laser Coupled to a Second Order Bragg Vertical Extractor <i>Christopher Bonzon</i>
15:15	606	From photonic crystal to micropillar terahertz quantum cascade lasers and recent progress towards nanowire-based devices <i>Michael Krall</i>
15:30		<b>Coffee Break</b>
		<b>II: NANOCRYSTALS</b> <i>Chair: Gunther Springholz, JKU Linz</i>
16:00	611	Ultra strained Si and Ge for device applications <i>Hans Sigg (i)</i>
16:30	612	Nanowires for solar cell applications <i>Knut Deppert (i)</i>
17:00	613	On polytypism in III-V nanowires <i>Friedhelm Bechstedt (i)</i>
17:30	614	PbS nanocrystal photodetectors with inorganic ligands <i>Wolfgang Heiss (i)</i>
18:00	615	X-ray analysis of nanowires <i>Julian Stangl</i>
18:15	616	Towards group IV direct gap semiconductors <i>Martin Glaser</i>
18:30		<b>Postersession and Apéro</b>
20:00		<b>Public Lecture</b>

Thursday, 05.09.2013, HS 3

Time	ID	<b>III: QUANTUM NANOSTRUCTURES</b> <i>Chair: Jérôme Faist, ETH Zürich</i>
13:30	621	Superconducting Split Ring Resonators for Ultrastrong Coupling <i>Curdin Maissen</i>
13:45	622	Terahertz-induced nonlinear intersubband dynamics. <i>Daniel Dietze</i>
14:00	623	Symmetric farfield, short-wavelength ( $\lambda = 4.53 \mu\text{m}$ ) MOPA quantum cascade lasers with Watt-level optical output power <i>Borislav Hinkov</i>
14:15	624	Optically pumped QD VECSEL for the Mid-Infrared <i>Amir Khier</i>
14:30	625	Intersublevel transition study of InAs/AlInAs quantum dashes by absorption, electroluminescence and magneto-tunneling spectroscopy <i>Gian Lorenzo Paravicini Bagliani</i>
14:45	626	Erasing the exciton fine structure splitting in semiconductor quantum dots <i>Rinaldo Trotta</i>
15:00	627	Grating-design based polarization modifications of ring cavity quantum cascade lasers <i>Rolf Szedlak</i>
15:15	628	Active control of THz-waves by coupling large-area CVD-graphene to a THz-Metamaterial <i>Federico Valmorra</i>
15:30		<b>Coffee Break; END</b>
18:30		<b>Postersession and Apéro</b>
20:00		<b>Conference Dinner</b>

ID		INFRARED OPTICAL NANOSTRUCTURES POSTER
631		Enhancement of light extraction from aligned SiGe-based photonic crystal slabs <i>Magdalena Schatzl</i>
632		Optically driven current turnstile based on self-assembled semiconductor quantum dots <i>Giancarlo Cerulo</i>
633		PbS quantum dots - silicon on insulator hybrid photonics <i>Markus Humer</i>
634		Electronic and optical properties of strained and unstrained group-IV semiconductor Germanium alloys <i>Kerstin Hummer</i>
635		Enhanced photoluminescence efficiency of SiGe islands integrated into large area photonic crystals <i>Elisabeth Lausecker</i>
636		Tuning the emission properties of single semiconductor quantum dots via electro-elastic fields <i>Johannes Wildmann</i>
637		High power terahertz quantum cascade laser for 63 $\mu\text{m}$ <i>Dana Turcinkova</i>
638		Quaternary Barrier InGaAs/AlInGaAs Terahertz Quantum Cascade Laser <i>Keita Ohtani</i>
639		Distributed-Feedback Quantum Cascade Laser at 3.2 $\mu\text{m}$ <i>Johanna Wolf</i>
640		Tuning of resonances in photonic crystal photodetectors <i>Andreas Harrer</i>
641		Frequency noise in mid-infrared quantum cascade lasers <i>Lionel Tombez</i>
642		Observation of THz Photo-luminescence from Multilayer SiC Epitaxial Graphene Pumped by a Mid-infrared Quantum Cascade Laser <i>Peter Qiang Liu</i>

## Biophysics and Medical Physics

Thursday, 05.09.2013, K153C

Time	ID	SOFT MATTER (SHARED WITH THE CONDENSED MATTER SESSION) Go to HS 5 Chair: Georg Pabst, Uni Graz
13:30	121	Equilibrium and flow of cluster-forming complex fluids <i>Christos N. Likos (i)</i>
14:00	122	Optimized Fourier Monte Carlo Simulation of Solid and Hexatic Membranes <i>Andreas Troester</i>
14:15	123	Biomimetic folding particle chains <i>Peter Oostrum</i>
14:30		GO BACK TO K153C
		BIOPHYSICS Chair: Georg Pabst, Uni Graz
14:30	701	Fluorescence and atomic force microscopy to visualize the interaction of HDL particles with lipid membranes <i>Gerhard J. Schütz (i)</i>
15:00	702	Characterization of Curli A Production on Living Bacterial Surfaces by Scanning Probe Microscopy <i>Yoojin Oh</i>

15:15	703	Innovating nanosensing technique to detect living bacteria and reveal resistance to antibiotics <i>Justin Notz</i>
15:30		Coffee Break
		BIOPHYSICS/MEDICAL PHYSICS Chair: Giovanni Dietler, EPF Lausanne Georg Pabst, Uni Graz
16:00	711	Cell mechanics measured with Atomic force microscopy <i>Jose Luis Toca-Herrera</i>
16:15	712	Measuring the stability of lipid membrane domains with nanometer resolution. <i>Georg Fantner</i>
16:30	713	Protein partitioning in liquid-ordered (Lo) / liquid-disordered (Ld) domains <i>Benjamin Kollmitzer</i>
16:45	714	Filter gate closure inhibits ion but not water transport through potassium channels <i>Peter Pohl</i>
17:00	715	Core-shell nanoparticles and their assembly <i>Erik Reimhult</i>
17:15	716	Characterization of augmented bone structures with $\mu$ -computed tomography and Raman spectroscopy <i>Johann Charwat-Pessler</i>
17:30	717	Raman spectroscopic investigation of urinary calculi and salivary stones <i>Matthias Eder</i>
17:45	718	Saving Joint with Aerosolphysics <i>Karoline Mühlbacher</i>
18:00	719	Probing metabolism <i>in vivo</i> in real time via hyperpolarized NMR <i>Arnaud Comment (i)</i>
18:30		END; Postersession and Apéro
20:00		Conference Dinner

ID		BIOPHYSICS AND MEDICAL PHYSICS POSTER
721		Photomodification and Nanopatterning of Polystyrene for Bioapplications <i>R. A. Barb</i>
722		Fractal characterization of tissue with the new Pyramid Method <i>Michael Mayrhofer-Reinhartshuber</i>
723		The open pore of SecYEG does not show physiologically relevant ion selectivity <i>Denis Knyazev</i>
724		Advancing high resolution structural analysis of lipid membranes using a generic algorithm <i>Peter Heftberger</i>
725		Studies on the Cherenkov effect for improved TOF-PET <i>Stefan Brunner</i>
726		Progress in the Structure-based Simulation of Plant Light-Harvesting Complexes <i>Frank Müh</i>
727		The density and distribution of sacrificial bonds in polymer chains determines the amount of dissipated energy <i>S. Soran Nabavi</i>
728		STED-lithography nano-anchors with single protein capacity <i>Richard Wollhofen</i>
729		These IgGs are made for walkin': Random antibody movement on bacterial and viral surfaces <i>Johannes Preiner</i>
730		Chemically tagged DNA tetrahedra as linker for single molecule force spectroscopy <i>Michael Leitner</i>

731	Long and short lipid molecules experience the same inter-leaflet drag in lipid bilayers <i>Andreas Horner</i>
732	Bachelor thesis: Hyper Spectral Imaging with Two-Photon Microscopy <i>Harald Razum</i>
733	Investigation of the pH stability of avidins and newly developed avidin mutants with atomic force microscopy based on single molecule sensors <i>Melanie Köhler</i>
734	Electrokinetic Trap <i>Metin Kayci</i>
735	Towards a Non-Perturbative Theory of Optical Spectra of Pigment Protein Complexes: Application to the Water Soluble Chlorophyll Protein. <i>Thanh-Chung Dinh</i>

17:15	820	Dynamical atmospheres of earth-like protoplanets <i>Ernst Dorfi</i>
17:30	821	Constraining stellar wind properties in habitable zones <i>Colin Johnstone</i>
17:45	822	The analysis of young solar-like stars and their stellar winds observed with the EVLA to define mass loss rates <i>Bibiana Fichtinger</i>
18:00	823	Stellar magnetic fields and their potential influence on planetary surroundings <i>Theresa Lüftinger</i>
18:15	824	Photometry of different Minor Bodies and comparisons <i>Mattia Galazzo</i>
18:30		<b>END; Postersession and Apéro</b>
20:00		<b>Conference Dinner</b>

## Astronomy and Astrophysics

Thursday, 05.09.2013, K269D

Time	ID	ASTRONOMY AND ASTROPHYSICS
11:00		<b>General Assembly ÖGAA</b>
12:30		<b>Lunch</b>
		<b>SELECTED ÖGAA TALKS</b> <i>Chair: NN</i>
13:30	801	Talk 1 <i>NN</i>
13:45	802	Talk 2 <i>NN</i>
14:00	803	Talk 3 <i>NN</i>
14:15	804	Talk 4 <i>NN</i>
		<b>HABITABLE WORLDS: FROM DETECTION TO CHARACTERIZATION</b> <i>Chair: NN</i>
14:30	811	Observing Exoplanet Atmospheres: Recent Results from ESO and National Facilities <i>Monika Lendl</i>
14:45	812	A massive stars' view on carbon-to-oxygen abundance ratios in exoplanet host stars <i>Norbert Przybilla</i>
15:00	813	Composition of extrasolar planets <i>Amaury Thiabaud</i>
15:15	814	The effect of metallicity in the envelope of protoplanets <i>Julia Venturini</i>
15:30		<b>Coffee Break</b>
16:00	815	Pathways to Habitability (Path): An Austrian National Research Network <i>Manuel Güdel</i>
16:15	816	Long term evolution of protoplanetary disks <i>Alexander Stökl</i>
16:30	817	Formation of Chondrules in radiative shock waves <i>Helmut Joham</i>
16:45	818	Formation of terrestrial planets in binary stellar systems <i>Zsolt Sándor</i>
17:00	819	A possible model of water delivery by collisions in early planetary systems <i>Thomas I. Maindl</i>

ID	ASTRONOMY AND ASTROPHYSICS POSTER
831	BRITE-Constellation and the chances for detecting exoplanets <i>Werner Weiss</i>
832	Simulations of Prebiotic Chemistry under Post-Impact Conditions on Titan <i>Johannes Leitner</i>
833	On the Internal Structure of Enceladus <i>Ruth-Sophie Taubner</i>
834	Kepler-62 e and Kepler-62 f: The Potential Internal Structure of these habitable worlds <i>Ruth-Sophie Taubner</i>
835	Theoretical models of planetary system formation <i>David Swoboda</i>

## History of Physics

Thursday, 05.09.2013, K012D

Time	ID	HISTORY OF PHYSICS
		<i>Chair: Heinz Krenn, Uni Graz</i>
13:30	901	Die Untersuchung planetarer und interplanetarer Magnetfelder: von den ersten Satellitenmissionen bis zur Landung auf Asteroiden und Kometen <i>Konrad Schwingenschuh</i>
14:00	902	Die Novara-Weltumsegelung (1857-1859): Wendepunkt für Geophysik / Meteorologie / Ozeanographie in Österreich <i>Bruno Besser</i>
14:15	903	Eine frühe Anwendung radioaktiver Tracer <i>Heinrich Mitter</i>
14:30	904	G. E. Rosenthal, a follower of Deluc in northern Germany <i>Jean-François Loude</i>
14:45	905	Die steinernen Schattenlinien der Sonne: Die Sonnenuhren des Andreas Pleningner <i>Reinhard Folk</i>
15:00	906	The Inconsistencies of the Lorentz transformations first formulated by Woldemar Voigt in 1887 <i>Hartwig Thim</i>
15:15		<i>Discussion</i>
15:30		<b>Coffee Break</b>

Time	ID	Chair: Reinhard Folk, Uni Linz
16:00	911	Physics in magnetic fields from Faraday to Pierre Weiss and his contemporaries <i>Jean-François Loude</i>
16:30	912	Zur Erfindung des Magnetinduktions-Zeigertelegraphen durch Charles Wheatstone <i>Franz Pichler</i>
16:45	913	The Effective Mass Concept <i>Gerhard Brunthaler</i>
17:00	914	Das Elektrotechnische Institut der Universität Innsbruck, 1907 – 1946. Ein 'vergessenes' Institut <i>Armin Denoth</i>
17:15	915	Die Kommentare in Le Seurs und Jacquiers Ausgabe von Newtons Principia <i>Harald Iro</i>
17:30	916	Viktor von Lang und Ernst Lecher – die Säulen des I. Physikalischen Institutes <i>Franz Sachslehner</i>
17:45	917	Das wissenschaftliche Exil in Großbritannien <i>Wolfgang L. Reiter</i>
18:00	918	The *Squinting* in the Doppler-effect and the Hidden Ether-drifts <i>Karl Mochnik</i>
18:15		<b>END</b>
18:30		<b>Postersession and Apéro</b>
20:00		<b>Conference Dinner</b>

## Aussteller - Expositants

Agilent Technologies, Vacuum Products Division,  
DE-60528 Frankfurt  
[www.agilent.com](http://www.agilent.com)

Anton Paar GmbH, 8054 Graz;  
[www.anton-paar.com/](http://www.anton-paar.com/)

attocube systems AG, DE-80539 München  
[www.attocube.com](http://www.attocube.com)

CryoVac GmbH & Co. KG, DE-53842 Troisdorf  
[www.cryovac.de](http://www.cryovac.de)

Dr. Eberl MBE-Komponenten GmbH, DE-71263 Weil der Stadt  
[www.mbe-komponenten.de](http://www.mbe-komponenten.de)

EPL-IOP, UK-Bristol  
[www.iop.org](http://www.iop.org)

Finetech GmbH & Co. KG, DE-12681 Berlin  
[www.finetech.de](http://www.finetech.de)

Goodfellow GmbH, DE-61213 Bad Nauheim  
[www.goodfellow.com](http://www.goodfellow.com)

Hositrad Deutschland Vacuum Technology,  
DE-93047 Regensburg  
[www.hositrad.com](http://www.hositrad.com)

Mad City Labs GmbH, CH-8302 Kloten  
[www.madcitylabs.eu](http://www.madcitylabs.eu)

Mantis Deposition GmbH, DE-55122 Mainz  
[www.mantisdeposition.com](http://www.mantisdeposition.com)

MaTeCK GmbH, DE-52428 Jülich  
[www.mateck.de](http://www.mateck.de)

Nanosurf AG, CH-4410 Liestal  
[www.nanosurf.com](http://www.nanosurf.com)

Pfeiffer Vacuum Austria GmbH, AT-1150 Wien  
[www.pfeiffer-vacuum.com](http://www.pfeiffer-vacuum.com)

Physik Instrumente (PI) GmbH & Co.KG, DE-76228 Karlsruhe  
[www.pi.ws](http://www.pi.ws)

SPECS Surface Nano Analysis GmbH, DE-13355 Berlin  
[www.specs.com](http://www.specs.com)

VAQTEC - Scientific, DE-13189 Berlin  
[www.vactec-scientific.com](http://www.vactec-scientific.com)

VAT – Deutschland GmbH, DE-85630 Grasbrunn bei München  
[www.vatvalve.com/de/contacts/vat-deutschland](http://www.vatvalve.com/de/contacts/vat-deutschland)

VIDEKO GmbH, AT-2512 Oeynhausen  
[www.vacuumtechnology.at](http://www.vacuumtechnology.at)

Zurich Instruments, CH-8005 Zürich  
[www.zhinst.com](http://www.zhinst.com)

# Open Access, where do we stand today?

## Your opinion interests us.

Christophe Rossel, SPS Vice-President

With the development of Open Access (OA) where the research papers become freely accessible by the readers, the academic publishing scheme is changing rapidly all over the world. The general consensus is that the results of research should be accessible in the public domain so that they will bring benefits for public services and economic growth. They need nevertheless to undergo some quality control for relevance and reliability reasons and for avoiding misleading statements and erroneous conclusions. Open Access is not strictly speaking free access because somewhere time and money must be found to make it functioning. Any new business model, different from the conventional subscription-based model must then be robust and sustainable.

In 2009 the European Physical Society (EPS) published a position paper, declaring its support, like other organizations, to the 2003 Berlin Declaration on Open Access to Knowledge in the Sciences and Humanities (<http://oa.mpg.de/openaccess-berlin/berlindeclaration.html>).

The ongoing discussions are based on several critical issues. Whereas most researchers are essentially concerned about publishing their results in the journal of their choice without concerns about any business models, librarians who are facing decreasing budgets and increasing journal prices are ready for alternatives to the subscription-based model. But how to meet publication costs if the subscription income is removed?

Part of the debate is to decide whether the *Gold OA* model where publishers get their revenues from authors rather than from readers is preferable to the *Green OA* model where the final refereed article is placed temporarily in their institutional repository, in a central repository, or on some other OA archive like arXiv for physics. Critical voices claim that some detrimental embargo time of 6–12 months or longer might be associated with the Green OA model, as done already by some non-OA journals.

Funding is therefore a critical issue for research agencies and academic institutions, which will have to subsidize not only the work of editors but also support charges related to Gold OA. This leads to another concern, namely the academic freedom. Critics claim indeed that full Open Access

model will see universities, not readers, pay for articles to be published in journals, meaning the decision on how to publish new research will rest with university and funding agencies administrators and not academics themselves.

Science Europe ([www.scienceeurope.org](http://www.scienceeurope.org)), an umbrella organization of the most important research and funding institutions in Europe, has published in April 2013 a declaration entitled *Principles for the Transition to Open Access to Research Publications*. It describes the benefits of OA and proposes a set of common principles agreed by all its members to support the transition to full OA. It is stated that each organization will have to implement policies according to their own needs but in agreement with the proposed principles, viewed as a contribution to a global dialogues and cooperation with other stakeholders in Europe and worldwide.

Funding organizations, including the Swiss National Science Foundation, endorse both publications in open-access journals and second publications on document servers. However, they are explicitly against supporting so-called hybrid publication models offered by most large commercial publishers. Indeed in the case of hybrid journals, the authors can, in exchange for a fee, place the article with publishers on OA. This model might result in double charges since on one side libraries still pay for the journal subscriptions and licenses and, on the other, for the OA publication fees of the authors

The OA policies of all participating institutions, including those in Switzerland, are published in the Registry of Open Access Repository Mandatory Archiving Policies (ROAR-MAP) and can be found under <http://roarmap.eprints.org/>.

Since the active debate on the economics and reliability of OA continues among researchers, librarians, universities and funding agencies administrators, government officials, and commercial publishers, the SPS Board would be very interested in collecting comments by its members in order to evaluate the general opinions prevailing in the Swiss scientific community. Please send your comments to [sps@unibas.ch](mailto:sps@unibas.ch).

## Kurzmitteilungen - Short Announcements

### Initiative for Science in Europe

The Initiative for Science in Europe is an independent platform of European learned societies and scientific organizations whose aim is to promote mechanisms to support all fields of science at a European level, involve scientists in the design and implementation of European science poli-

cies, and to advocate strong independent scientific advice in European policy making. In Winter 2012/13, ISE has coordinated the campaign "No-Cuts-On-Research.EU". More Info: <http://www.initiative-science-europe.org/>

## 2013 PSI Summer School on Condensed Matter Research: Materials - structure and magnetism August 17-23, 2013, Lyceum Alpinum, Zuoz, Switzerland

The 12<sup>th</sup> edition of the PSI summer school on condensed matter physics is open for registration. This year the school will be dedicated to some of the main topics addressed at large scale user facilities such as neutron and muon sources or synchrotron photon sources: **Materials - structure and magnetism**.

International experts and PSI staff members will introduce and deepen your knowledge not only about these scientific topics but also about the main methods applied to understand the phenomena, which are presently at the forefront of modern solid state physics and chemistry.

The school is fully open to the national and non-national public and the language of the school is English.

Following the school a practical training is offered at PSI. It will allow a limited number of participants to get hands-on experience with state-of-the-art instrumentation using photons, neutrons, and muons.

More information, the school's programme and online registration is available from the school's webpage:

<http://www.psi.ch/summerschool>

## 19<sup>th</sup> Swiss Physics Olympiad 2013 (SPhO) in Aarau

*Antoine Pochelon, SPS Secretary*

The final round of the Swiss Physics Olympiad took place on March 23/24 in Aarau at the Neue Kantonsschule. The competition was held between twenty-four students from Switzerland and two from Liechtenstein.

The selection process began in January with a preliminary round with a record participation of over 100 students, a success with 50% more participation than in earlier years. The students, aged between 16 and 20, had the chance to prepare for the final round at a three day training session at EPFL. The final round consisted of two challenging days, totalling no less than six and a half hours of theoretical and experimental exams, something like a Marathon! The top five participants – gold medals - will have the unique opportunity to travel to Denmark to represent Switzerland at the International Physics Olympiad in July.

The award ceremony was a dedicated moment with talks and piano pieces, where one could feel the mood of the accomplished effort. After an excellent pedagogical talk by Gabriel Palacios on Fraunhofer lines, president of SPhO, it was the tour of the Swiss Physical Society – who is sponsoring the event – to present the mission and vision of the Society, and to proceed to the awards distribution.

The absolute best was Lukas Lang, from Liechtenstein. Followed just next by Sven Pfeiffer, from Münsingen (BE) and Rafael Winkler, from Mettauertal (AG). The SPS was happy to deliver the woman award to Viviane Kehl, from Küsnacht (ZH) who already illustrated herself in the preliminary round as 4<sup>th</sup> and at the time best of the present Swiss winner group.

Such an event is the opportunity to strengthen contact with offspring and teachers in a nice and stimulating climate. As summarized by Markus Meier, the local organizer: I hope and believe that this event (with SPS presentation and award giving) is the first and also successful contact of the SPS to future physicists. And truly, at this occasion young people of 15 or 16 were asking how to become member of the SPS and how they could be better informed about courses, seminars, ateliers ... : a hint for the SPS to be well present for the young leaves.

PS: Let us note that in Switzerland such Olympiads - in addition to Physics ([www.swisspho.ch](http://www.swisspho.ch)) - are also organized in Biology, Chemistry, Informatics, Mathematics, Philosophy ([www.olympiads.ch](http://www.olympiads.ch)).



The four recipients of the SPS awards: Sven Pfeiffer (first Swiss), Rafael Winkler (second Swiss), Viviane Kehl (first woman) and Lukas Lang (first Liechtensteiner and absolut best)

# Das Rennen um die Industrieproduktion der Zukunft

Rolf Hügli, SATW Generalsekretär

Die Schweiz gehört bekanntlich zu den innovativsten Ländern der Welt. Die Ausgaben für die Forschung sind hoch und auf Jahre hinaus gesichert. Wenn die Schweiz aber eine bedeutende Industrienation bleiben will, muss auch der Produktionsstandort Schweiz eine Zukunft haben. Produktions-Knowhow gehört zu den Schlüsselkompetenzen für die "alten Industrienationen", die nicht auf billige Arbeitskräfte setzen können.

In den letzten 5 Jahren hat die EU 10% ihrer Industrieproduktion und 3 Millionen Jobs verloren. Zumindest vorderhand hat sich die Schweiz gut behaupten können, weil ihre Industriegüter hochspezialisiert sind. Diese Produkte sind weniger preissensitiv und ihre Herstellung ist sehr anspruchsvoll. Ob dies in Zukunft hilft, ist ungewiss. Die Währungssituation ist nach wie vor angespannt und Länder wie China und Indien sind im Begriff, immer komplexere Eigenprodukte zu entwickeln und herzustellen.

Hinzu kommt, dass sich bedeutende Neuerungen bei den Herstellungsverfahren abzeichnen. Die massgeblichen Treiber dafür sind:

- weitgehende Digitalisierung der Wertschöpfungskette (Herstellungsdaten werden verschickt, nicht physische Produkte)
- präzisere Verfahren bei der automatischen maschinellen Bearbeitung (schnelle, hochwirksame Korrekturalgorithmen verbessern die automatisierte mechanische Bearbeitung)
- völlig neue, additive Herstellungsverfahren (z.B. 3D Printing).

Dadurch wird eine kostengünstige Produktion anspruchsvoller Komponenten an einem beliebigen Ort der Welt denkbar. Auch die rentable Produktion von Kleinstserien oder Einzelstücken könnte damit gelingen.

Während diese Entwicklung für qualifizierte Facharbeiter eine Gefahr darstellen könnte, bietet sie den westlichen Industrienationen die Möglichkeit, dank kostengünstiger Produktion einen Teil des verlorenen Marktes zurückzuerobieren. Welcher Aspekt dominieren wird, ist völlig unklar. Für den

Werkplatz Schweiz ist es von grosser Bedeutung, diese Trends zu verstehen und richtig darauf zu reagieren.

Die SATW hat kürzlich ein Forum unter dem Titel "advanced manufacturing" veranstaltet. Unter den Teilnehmern waren Produktions- und Materialexperten, Wissenschaftler und Repräsentanten von Verwaltung und Industrieverbänden. Auch unter den Anwesenden herrschte keine Einigkeit, in welche Richtung sich die Dinge entwickeln werden. Klar herausgeschält haben sich jedoch zwei Dinge:

- Die neuen Verfahren bestehen aus einzelnen Komponenten und Arbeitsschritten, die aufeinander abgestimmt sein müssen. Es ist daher empfehlenswert, diese Verfahren „vertikal integriert“, d.h. in Konsortien zu entwickeln, welche die ganze Wertschöpfungskette abdecken.
- C. M. Clayton hat den Begriff der "disruptiven" Innovation geprägt. Gemeint sind damit Veränderungen, die auf (vom Markt) unerwarteten, neuen Prinzipien beruhen und die die Spielregeln einer ganzen Branche verändern können. Die erwähnten neuen Herstellungsmethoden haben das Potential dazu. Allerdings ist unklar, welche Verfahren sich wo durchsetzen werden. Damit entstehen grosse Investitionsrisiken. Da nicht gewartet werden kann, bis völlige Klarheit darüber herrscht, ist zu prüfen ob eine finanzielle Förderung von Pilotprojekten durch Bundesmittel (evtl. im Rahmen KTI oder SNF) im Sinne eines Schwerpunktprogrammes angezeigt wäre.

Die SATW wird dieses Thema weiter bearbeiten. Im Verbund der europäischen technischen Akademien (Euro-CASE) ist sie an einem Diskussionspapier für die EU-Kommission beteiligt. Sie verfolgt zudem den Jahreskongress der Canadian Academy of Engineering (CAE), an dem ähnliche Fragen diskutiert werden. Die SATW plant ausserdem im Herbst ein Folgemeeting mit einzelnen Teilnehmern des Forums, um praktische Handlungsoptionen zu bestimmen. Zusätzlich möchte die SATW ihr Netzwerk mit Produktionsexperten aus der Industrie verstärken. Gerne nimmt sie auch Beiträge oder Anregungen von Mitgliedern der SPG entgegen.

## "Advanced Manufacturing", ein interessantes Feld für Physikerinnen und Physiker?

Moderne Produktionsmethoden beruhen auf der *durchgängigen Digitalisierung* nahezu aller Prozessschritte, vom Design über die eigentliche Fertigung bis zur Auslieferung. Dabei umfasst der Begriff Digitalisierung sowohl computergesteuerte Datenerfassung, numerische Modellierung wie Echtzeit-Kommunikation. Weist das zu fertigende Gerät ab einer gewissen Fertigungsstufe einen bestimmten Grad an interner Digitalisierung auf, kann es -ab dann- selber mit den Produktionswerkzeugen kommunizieren, was zu Genauigkeitssteigerungen und Durchlaufzeitverkürzungen führt. Im gleichen Sinne kann die interne Digitalisierung später im Einsatz beim

Kunden die Kommunikation mit der Herstellfirma oder einem Provider ermöglichen, um die Dienstleistung des Gerätes nur dann und dort abzurufen, wann und wo es vom Kunden benötigt wird. Für den Kunden bedeutet das eine deutliche Effizienzsteigerung seiner Arbeit und eine Senkung der Betriebskosten.

Im Mittelpunkt all dieser Ansätze steht die Erfassung der realen Fertigungsabläufe und deren mathematische Modellierung ('Virtuelle Fabrik'). Das erfordert ein profundes physikalisches Verständnis, wenn man an die technischen Machbarkeitsgrenzen gehen will. Für Industriephysiker öffnen sich attraktive Betätigungsfelder

B. Braunecker

# First result from the AMS experiment

Martin Pohl, Center for Astroparticle Physics, CAP Genève

Beginning of April 2013, the Alpha Magnetic Spectrometer (AMS) Collaboration published its first physics result in *Physical Review Letters*<sup>1</sup>. The AMS experiment is a powerful and sensitive particle physics spectrometer. As seen in Figure 1, AMS is located on the exterior of the International Space Station (ISS). Since its installation on 19 May 2011 it has measured over 30 billion cosmic rays in the GeV to TeV energy range. Its permanent magnet and array of precision particle detectors collect and identify charged cosmic rays passing through. Over its long duration mission on the ISS, AMS will record signals from 16 billion cosmic rays every year and transmit them to Earth for analysis by the AMS Collaboration. This is the first of many physics results to be reported.



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

The first publication from the AMS Experiment is a major milestone for the AMS international collaboration. Hundreds of scientists, engineers, technicians and students from all over the world have worked together for over 18 years to make AMS a reality. The collaboration represents 16 countries from Europe, Asia and North America (Finland, France, Germany, Italy, the Netherlands, Portugal, Spain, Switzerland, Romania, Russia, Turkey, China, Korea, Taiwan, Mexico and the United States) under the leadership of Nobel Laureate Samuel Ting of M.I.T. The collaboration continues to work closely with the NASA AMS Project Management team from Johnson Space Center as it has throughout the entire process. Many countries have made important contributions to the AMS detector construction and presently to the data analysis. These include two groups from Switzerland, University of Geneva and ETHZ, supported by federal and cantonal authorities as well as the SNF.

AMS was constructed at universities and research institutes around the world and assembled at the European Organization for Nuclear Research, CERN, Geneva, Switzerland. It was launched by NASA to the ISS as the primary payload

onboard the final mission of space shuttle Endeavour (STS-134) on 16 May 2011. Once installed on 19 May 2011, AMS was powered up and immediately began collecting data from primary sources in space and these were transmitted to the AMS Payload Operations Control Center located at CERN, Geneva, Switzerland.

Once AMS became operational, the first task for the AMS Collaboration was to ensure that all instruments and systems performed as designed and as tested on the ground. The AMS detector, with its multiple redundancies, has proven to perform flawlessly in space. Over the last 22 months in flight, AMS collaborators have gained invaluable operational experience in running a precision spectrometer in space and mitigating the hazardous conditions to which AMS is exposed as it orbits the Earth every 90 minutes. Conditions like this are not encountered by ground-based accelerator experiments or satellite-based experiments and require constant vigilance in order to avoid irreparable damage. They include the extreme thermal variations caused by solar effects and the re-positioning of ISS onboard radiators and solar arrays. In addition, the AMS operators regularly transmit software updates from the AMS POCC at CERN to the AMS computers in space in order to match the regular upgrades of the ISS software and hardware.

## Positron fraction measurement

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

Electrons and positrons are identified by the accurate and redundant measurements provided by the various AMS instruments against a large background of protons. Positrons are clearly distinguished from this background through the robust rejection power of AMS of more than one in one million.

Currently, the total number of positrons identified by AMS, in excess of 400,000, is the largest number of energetic antimatter particles directly measured and analyzed from space. The first paper can be summarized as follows:

AMS has measured the positron fraction (ratio of the positron flux to the combined flux of positrons and electrons) in the energy range 0.5 to 350 GeV. We have observed that from 0.5 to 10 GeV, the fraction decreases with increasing energy. The fraction then increases steadily between 10 GeV to ~250 GeV. Yet the slope (rate of growth) of the positron fraction decreases by an order of magnitude from 20 to 250 GeV. At energies above 250 GeV, the spectrum appears to flatten but to study the behavior above 250 GeV requires more statistics – the data reported represents ~10% of the

<sup>1</sup> AMS Collaboration, M. Aguilar et al., *First Result from the Alpha Magnetic Spectrometer on the International Space Station: Precision Measurement of the Positron Fraction in Primary Cosmic Rays of 0.5–350 GeV*, *Phys. Rev. Lett.* **110**, 141102 (2013)

total expected. The positron fraction spectrum exhibits neither structure nor time dependence. The positron to electron ratio shows no anisotropy indicating the energetic positrons are not coming from a preferred direction in space. Together, these features show evidence of a new physics phenomena. Figure 2 illustrates the AMS data presented in the first publication.

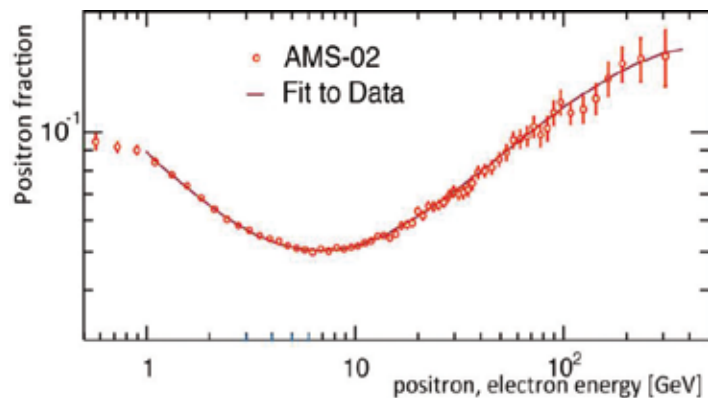


Figure 2: The positron fraction measured by AMS demonstrates excellent agreement with the model described below. Even with the high statistics, 6.8 million events, and accuracy of AMS, the fraction shows no fine structure.

The exact shape of the spectrum, as shown in Figure 2, extended to higher energies, will ultimately determine whether this spectrum originates from the collision of dark matter particles or from pulsars in the galaxy. The high level of accuracy of this data indicates that AMS may soon resolve this issue.

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

The first AMS result has been analyzed using several phenomenological models, one of which is described in the paper and included in Figure 2. This generic model, with diffuse electron and positron components and a common source component, fits the AMS data surprisingly well. This agreement indicates that the positron fraction spectrum is consistent with electron positron fluxes each of which is the sum of its diffuse spectrum and a single energetic common source. In other words, a significant portion of the high-energy electrons and positrons originate from a common source. More specific models<sup>2</sup> based on dark matter self annihilation and/or pulsar sources in the Milky Way have been published immediately after the release of the AMS data.

As shown in Figure 3, the accuracy of AMS and the high

<sup>2</sup> See e.g.: Andrea De Simone, Antonio Riotto, Wei Xuec, CERN-PH-TH/2013-054 (April 3, 2013). Tim Linden and Stefano Profumo, arXiv:1304.1791v1 [astro-ph.HE], (April 5, 2013). Peng-Fei Yin, Zhao-Huan Yu, Qiang Yuan and Xiao-Jun Bi, arXiv:1304.4128v1 [astro-ph.HE] (April 15, 2013)

statistics available distinguish the reported positron fraction spectrum from earlier experiments<sup>3</sup>, by extending the energy range and improving the precision by an order of magnitude.

## Outlook

AMS is a magnetic spectrometer with the ability to explore new physics because of its precision, statistics, energy range, capability to identify different particles and nuclei and its long duration in space. It is expected that hundreds of billions of cosmic rays will be measured by AMS throughout the lifetime of the Space Station. The volume of raw data requires a massive analysis effort. The parameters of each signal collected are meticulously reconstructed, characterized and archived before they undergo analysis by multiple independent groups of AMS physicists thus ensuring the accuracy of the physics results.

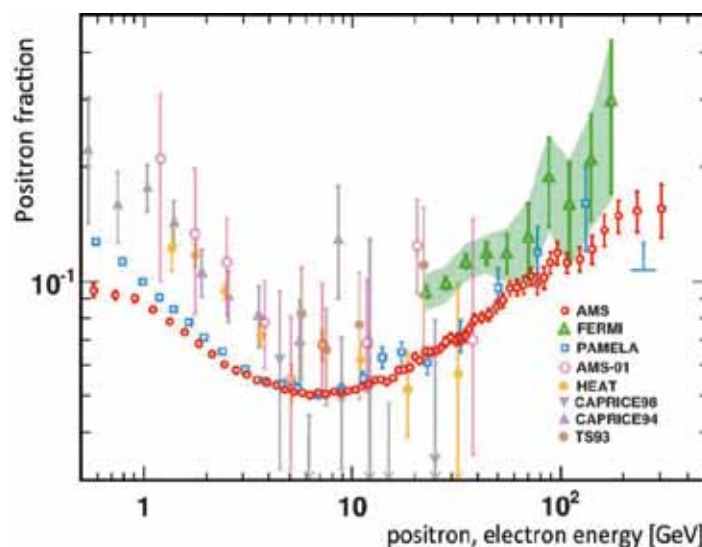


Figure 3: A comparison of AMS results with recent published measurements.

With the wealth of data emitted by primary cosmic rays passing through AMS, the Collaboration will also explore other topics such as the precision measurements of the boron to carbon ratio, nuclei and antimatter nuclei, and anti-protons, precision measurements of the helium flux, proton flux and photons, as well as the search for new physics and astrophysics phenomena such as strangelets.

The AMS Collaboration will provide new, accurate information over the lifetime of the Space Station as the AMS detector continues its mission to explore new physics phenomena in the cosmos.

(This article is based on <http://press.web.cern.ch/tags/ams/>)

<sup>3</sup> TS93: R. Golden *et al.*, *Astrophys. J.* **457** (1996) L103. WIZARD/CAPRICE: M. Boezio *et al.*, *Adv. Sp. Res.* 27-4 (2001) 669. HEAT: J. J. Beatty *et al.*, *Phys. Rev. Lett.* **93** (2004) 241102; M. A. DuVernois *et al.*, *Astrophys. J.* **559** (2001) 296. AMS-01: M. Aguilar *et al.*, *Phys. Lett.* **B 646** (2007) 145. PAMELA: P. Picozza, *Proc. of the 4<sup>th</sup> International Conference on Particle and Fundamental Physics in Space*, Geneva, 5-7 Nov. 2012, to be published. O. Adriani *et al.*, *Astropart. Phys.* **34** (2010) 1; O. Adriani *et al.*, *Nature* **458** (2009) 607. Fermi-LAT: M. Ackermann *et al.*, *Phys. Rev. Lett.* **108** (2012) 011103.

# Progress in Physics (33)

## Outreach: Can Physics Cross Boundaries?

Jean-Pierre Eckmann, Département de Physique Théorique et Section de Mathématiques, Université de Genève

Recently, physical thinking has been making progress in domains at which it did not aim originally. In this contribution, I want to sketch some examples of what can be done. The method consists of finding systems which originate in complex or complicated structure or dynamics, and which can profit from questions physicists ask. The examples I want to present comprise biology, language and the World-wide-web (WWW).

I find it fascinating that relatively simple methods, questions, and techniques from the exact sciences seem to be able to shed new light, and also new insight, into structures which are mostly self-generated. I want to suggest and illustrate that questions outside physics proper can be developed fruitfully by physicists. My story is neither totally new (see, e.g., [14]) nor as revolutionary as it may seem. I just want to convey my interest and pleasure in addressing "esoteric" questions with the tools of mathematics and physics.

The discussion will be in the subject of "network theory," and I first summarize some of its literature [1, 12]: With the advent of powerful computers on every scientist's desk, it has become easy to analyze large data sets. These data sets come often, and quite naturally, in the form of large networks (graphs, directed or undirected), where the nodes of the graph are certain objects, and the edges are certain binary relations between them. For example, the nodes could be individual researchers, and the links could signify that they either co-author a paper, or cite each other. Other examples are pages and links in the WWW, which connect two pages; airports and connections provided by commercial airlines; words and links between these words and their definition in a dictionary. I will call such graphs real-life graphs<sup>1</sup>. Experimental automation, and the availability of large databases through the internet provide many interesting networks for analysis. The most useful ones are obtained in collaboration with experimental scientists.

Continuing a long tradition in statistical physics, the studies of large networks often concentrate on their statistical properties. Erdős and Rényi described a set of random graphs which are built as follows [3]: Take  $N$  nodes ( $N$  very large) and assume that the mean degree (number of links coming out of a node) is  $k > 0$ , independently of  $N$ . Then, paraphrasing Erdős and Rényi, one can make two statements:

1. Such a graph looks locally like a tree (i.e., it has very few loops, and these loops are all very long) [4].
2. The expected number of triangles is  $k^3/6$ , (i.e., this number does *not* grow with  $N$ ). (Longer loops are also rare<sup>2</sup>.)

<sup>1</sup> One may legitimately ask why only binary relations seem important, but I will argue later that triangles in these graphs play the role of three-body-interactions and are the main indicators of semantic contexts.

<sup>2</sup> It is actually quite easy to prove these statements, although, at first, they certainly seem totally anti-intuitive.

The first surprise was the discovery that real-life graphs are *not* random in the above sense. In contrast to general results on random graphs, the graphs of "affinities" or "connections" between "authors," "entities" have very specific general properties, namely power law behavior over several decades [1]. By this, one means the statistics of the number  $N(j)$  of nodes which are attached to exactly  $j$  others (the degree of the node). In formulas,  $N(j) \approx \text{const.} \cdot j^{-\gamma}$  for large  $j$ . The point here is that the decay is a power law, and not an exponential, pointing to the important feature of nodes in the graph with very many connections, many more than a Gaussian, or Poisson distribution would allow for. In many real-life graphs  $\gamma$  takes a value between 2 and 3.

What this means is that there are a few nodes which have a really high degree. For example, in studying the connections in Twitter, one finds that there are a few nodes with over 100'000 "friends" (these are usually politicians, perhaps also singers), the interesting question here is whether they are friends (the singers) or whether they think they have friends (the politicians...).

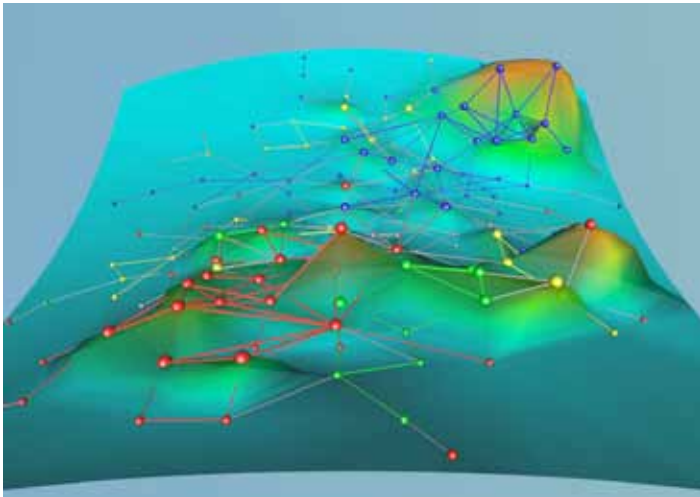
Many studies then concentrate on the dynamics of how such networks come into being. This is usually called the "preferential attachment"<sup>3</sup> problem [2], namely the idea that the networks build up in time, and that people have a tendency to connect to well-known other people (or services). These models have successfully explained how long-range (scale-free) properties of graphs come about.

Another important aspect of network studies is summarized under the term of "clustering coefficient" [18]. In contrast to the power laws described above, this is a local property of any graph. In mathematical terms, if a node  $n$  has  $j$  neighbors, then you count the number  $t$  of triangles which have the node  $n$  as a corner. Obviously, there cannot be more than  $T(j) = j(j-1)/2$  such triangles, and the clustering coefficient is defined as  $t/T(j)$ , which is a number between 0 and 1. A high clustering coefficient means that many of the possible triangles are actually realized.

When I started to study real-life graphs [7], I was puzzled by the abundance of triangles, which appear orders of magnitude above  $\mathcal{O}(k^3)$  predicted by Erdős and Rényi. What does this mean? It soon turned out that triangles play a strong semantic role. In other words, in all studies of this type, one can attach meaning to this abundance.

The first case where we discovered this phenomenon was the set of links in the WWW [7]. While there are many links which seem irrelevant, we found that those links which form triangles relate to common interests of the owners of the pages involved. Carrying this idea further, we found that triangles of connections among neurons of *C. Elegans* (a little worm with 302 neurons) organize their function. Another example is provided by triangles of e-mail messages sent between people, and this determines their social grouping [8].

<sup>3</sup> also called "rich get richer"

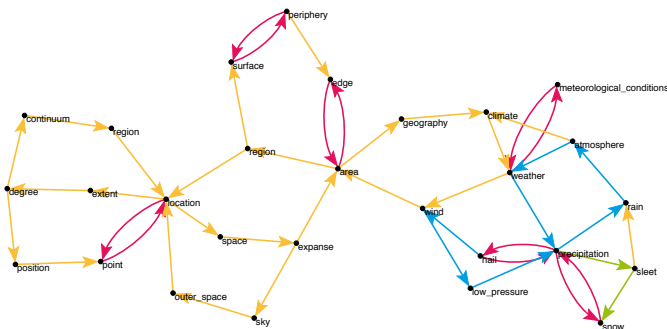


The neurons of *C. Elegans* and their connections: Height is clustering coefficient, color codes function (motor, sensory,...)

My final example is the appearance of loops in the definitions of words in a dictionary [10]. Here, the graph is formed by arrows pointing from each word (actually nouns) to the words in their definition. One finds not only triangles, but also bi-angles, back-and-forth, (which are synonyms) and also longer loops. When the loops are too long, there might be a jump in interpretation, such as at the broken arrow in

*railcar*  $\Rightarrow$  *rails*  $\Rightarrow$  *bar*  $\Rightarrow$  *weapon*  $\Rightarrow$  *instrument*  $\Rightarrow$   
*skill*  $\Rightarrow$  *train*  $\Rightarrow$  *railcar*.

But the surprising fact is that the medium size loops are semantically coherent, and their words form the core of the language. (We checked that by comparing the core-words to those of [13].) And furthermore, as a bonus, one can show that they are related to the historical appearance of new concepts in language [9].



The structuring of words in a dictionary.

What fascinates me in all this is that questions and methods from physics can shed new light on several systems with complex dynamics or structure. The most accessible among such systems are those where sub-units are assembled without a master building plan.

The common structure which appears in such studies is that the more "interesting dynamics" (biochemistry, feedback) [16], the "meaning" (language) [5] or "mechanisms" (emergent life) are all revealed by deviations from the natural statistical structures of random assemblies. In general, the connected objects have some "deeper" identity (meaning, semantics) that curves the pathways back to some originating node, in contrast to the "rich get richer" scenario. So far, these methods have allowed to give some insight into realms outside of physics proper. I am convinced that

this outreach has an interesting future, and will penetrate further new domains.

Where does all this lead? The studies I have presented all use only the *topology* of the network, but never the *metrics*, namely the way some real-life networks are embedded in the space in which we live. Adding this component opens new possibilities, especially in studying aspects of life. This is so because many aspects of life are about spatial connections, organisms are a linked set of individual units that have to interact well and "intelligently" in order to function. It is too early to make strong methodological statements about how mathematics and physics can play a role in studying such problems, but certainly, a few studies on neuronal networks [6, 17], or the interaction of ants in colonies [11, 15] seem to me promising beginnings in developing a methodology for studies in living systems.

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# Progress in Physics (34)

## On the development of physically-based regional climate modelling

Stéphane Goyette

Institute for Environmental Sciences, University of Geneva, 7 route de Drize, Geneva

There are huge scientific and technical challenges in research directed towards understanding climate and climate change. No clear picture of how the weather and climate system works emerged prior to the 20<sup>th</sup> century because of the lack of connection between atmospheric variables. In fact, there was still some doubt about deriving a theory about how to interpret daily weather patterns, general circulation of the atmosphere, and the global climate. Atmospheric physics reached a landmark in the early 20<sup>th</sup> century when empirical climatology, theoretical meteorology and forecasting were about to converge into a conceptualisation of this "vast machine" (Edwards, 2010). The problem of understanding the causes of weather, climate and climate change is not one to be solved quickly or easily, but contributing to its solution is particularly worthwhile. In fact, the status of the climate results from the complex interactions between the atmosphere with the physical and biological systems which bound it - the lakes and oceans, ice sheets, land and vegetation through a spectrum of temporal and spatial scales. These elements all determine the state and the evolution of the Earth's weather and climate, owing to a particular influence of the general circulation of the atmosphere which redistributes energy, along with the ocean currents, from the Tropics to the Poles. This highly-coupled system presents a genuine challenge for modellers, and this has led to a body of literature which details the range and hierarchy of numerical climate models (e.g. Trenberth, 1996, Schlesinger, 1988).

Back in 1904, Vilhelm Bjerknes recognised that a physically-based weather forecast is a fundamental initial-value problem in the mathematical sense; this was later classified as predictability of the first kind according to Lorenz (1975). The foundation of what became a framework of studying the geophysical fluid motions in order to predict the state of the atmosphere was shaping up. The derivation of the equations of motion began in the 17<sup>th</sup> century with Newton's Laws of Motion, which were later applied for fluid flow purposes by Euler and Bernoulli in the 18<sup>th</sup> century. The modern conservation of momentum formulation consists of a form of the Navier–Stokes equations, an extension of Euler's (but for viscous flow), that describe hydrodynamical flow. A continuity equation, also accredited to Euler, represents the conservation of mass. Hadley in 1735, and Ferrel, around 1850, showed that the deflection of rising warm air is due to the Coriolis effect, a force that began to be used in connection with meteorology in the early 20<sup>th</sup> century. The first law of thermodynamics, a version of the law of conservation of energy, was codified near the end of the 19<sup>th</sup> century by a number of scientists, but the first full statements of the law came earlier from Clausius and Rankine. This led to the thermal energy equation relating the overall temperature of the system to heat sources and sinks. The gas state variables were related in 1834 when, Clapeyron combined Boyle's Law and Charles' law into the first statement of the

ideal Gas Law. The basic ingredients employed to approximate atmospheric flow were then gathered to progress from concepts to operational computer forecasting, thus aiming at representing weather by numbers (Harper, 2008). The partitioning of the atmospheric fluid into a dry and water vapour mixture, according to the Dalton's law, was later included in numerical models; this premise led to a genuine improvement when the water cycle and its associated energy exchange was introduced as an extra equation, describing the transport of water vapour handling the effects of changes of water phases for calculating precipitation. All of the above form the basic equations used today for weather forecasting and climate prediction. The conservation equations are partial differential equations. For a unit mass, with a frame of reference attached to the Earth and the origin at its centre, these equations may be written as follows (e.g. Washington and Parkinson, 1986, Henderson-Sellers and McGuffie, 1987, Jacobson, 1998, Coiffier, 2011):

$$\frac{d\mathbf{V}}{dt} = -2\boldsymbol{\Omega} \times \mathbf{V} - \frac{1}{\rho} \nabla p - \nabla \Phi + \mathbf{F} \quad \text{momentum equation (1)}$$

$$\frac{dT}{dt} = \frac{1}{c_p} \left( \frac{dp}{dt} + Q \right) \quad \text{thermodynamic equation (2)}$$

$$\frac{d\rho}{dt} = -\rho \nabla \cdot \mathbf{V} \quad \text{continuity equation (3)}$$

$$\frac{dq}{dt} = M \quad \text{water vapour equation (4)}$$

$$p = \rho RT \quad \text{equation of state (5)}$$

which gives us a set of seven equations with seven unknowns, where  $\mathbf{V}$  represents the three-dimensional wind velocity,  $T$  is the air temperature,  $p$  is the pressure,  $q$  is the specific humidity, and  $\rho$  is the air density, all varying in space and in time. The other quantities are:  $\boldsymbol{\Omega}$  is the angular of rotation of the Earth,  $\Phi$  is the geopotential defined as the product of geometric height above the surface  $z$  by the acceleration due to gravity  $g$ , (the latter including the Newtonian gravity and the centrifugal acceleration),  $R$  and  $c_p$  are the specific gas constant and the specific heat at constant pressure, and  $t$  is the time.  $\mathbf{F}$ ,  $Q$  and  $M$  represent the sources and sinks of momentum (e.g. frictional forces), heat (e.g. solar and infrared radiation, and latent heat release) and moisture (e.g. evaporation and condensation), respectively, and their expression depends on the scale of the atmospheric motion the model aims to describe, and they represent subgrid-scale processes commonly expressed in terms of resolved quantities. In the prognostic equations (1-4), the derivative of any scalar quantities  $\psi$  with respect to time taken following the fluid is expressed as

$$\frac{d\psi}{dt} = \frac{\partial \psi}{\partial t} + \mathbf{V} \cdot \nabla \psi \quad (6)$$

where the first term on the right is a local partial deriva-

tive at a fixed point in the chosen frame of reference and the second the advection of the same quantity. Advection that induces non-linear effects is a transport mechanism of a quantity by a fluid due to its bulk motion. Simplification and transformation are required in order to resolve for some analytical solutions or the numerical methods used to seek numerical solutions. The discretization of these continuous equations would render them amenable, using appropriate algorithms, to a numerical solution of the continuous behaviour of the circulating atmosphere.

Around 1920, Richardson, who may be considered as the father of today's models for weather and climate, tried to solve a simplified set of equations using numerical methods "by hand and step-by-step". However, his 6-hour "retrospective forecast" proved unrealistic. Computational instability and imbalance in the initial data set were later found to be the cause of this "setback". However, in 1928, Courant, Friedrichs, and Lewy showed that a time step must be less than a certain value in explicit time-marching schemes to warrant stable numerical solutions using the method of finite differences. Then, Richardson realised that *64'000 computers* [human automata] *would be needed to race the weather for the whole globe*, but by the time he published "Weather Prediction by Numerical Process" in 1922, fast computers were unavailable. The development of complex models remained dormant until the development of electronic computers handling self-programmed sequences of instructions. In 1950, Charney, Ragnar Fjörtoft, and von Neumann made the first numerical weather prediction (NWP) using "simplified" equations to represent large-scale eddy motion. This accomplishment then fostered the development of more complex prediction models of even greater spatial resolution, allowing small scales of motion to be resolved. In 1956, Phillips developed a model which could realistically depict monthly and seasonal patterns in the troposphere, which became the first successful climate model. Following Phillips' work, several groups began working out General Circulation Models (GCMs) of the atmosphere of increasing complexities, including the effects of sub-systems such as these induced by oceans. The challenge of numerical models is to run forward in time much faster than the real atmosphere and oceans with available electronic computers. To do this, they must make a large number of simplifying assumptions. Although there have been great advances made in the discipline of climate modelling over the last fifty years, the most sophisticated models remain very much simpler than that of the full climate system (McGuffie and Henderson-Sellers, 2001). The first atmospheric general circulation model applied for long-term integrations, were derived directly from numerical models designed for short-term numerical weather forecasting, which did not have a global coverage at this time. Then, the advance of computing technologies, along with the requirements of weather predictions needing hemispheric or even global computational domains, the longer integration periods became a matter of availability of computer resources. The early climate model grid spacing was very coarse in the horizontal and vertical dimensions. The evolution towards greater resolution and increased complexity has been the rule since. This has been facilitated by the availability of large computing technologies and by new algorithms and numerical methods thus allowing

longer numerical time-stepping (Mote and O'Neil, 2000). To this day, climate modelling and weather forecasting groups co-exist, but the needs and focus of the two disciplines differ. For climate modelling, long-term mass, energy and moisture conservation is an important issue. This may thus be considered as a fundamental boundary-value problem in the mathematical sense, classified as predictability of the second kind according to Lorenz (1975). Not all climate models originated from weather forecast models, however. Simpler models based on global energy conservation are collectively called Energy Balance Models, or EBMs (Henderson-Sellers and McGuffie, 1987). They take into account the different forms of energy driving the climate system and look for a steady state solution for the surface temperature. Their main advantage is that they can be extensively used to do sensitivity studies of the role of external forcing on the surface temperature (that of the greenhouse gases, of the Earth's orbital parameters in the very long term, the impacts of volcanic eruptions, etc.), which can thus be investigated at a low computational cost. However, the atmospheric circulation is not explicitly resolved so they cannot be used neither to forecast daily conditions nor the general circulation of the atmosphere.

During the early days of weather forecasting, the computational domains were restricted to an area of interest. These Limited Area Models (LAMs) were developed to enable short range predictions to be made over a large domain. Their major drawback is that flow field values have to be specified at the area boundary for each time step. Later on, to overcome this problem, these field values were interpolated from those obtained from a global larger-scale model. This technique has led to "nested models" that are the basis of operational prediction systems in most meteorological services. Following the pioneering work in the U.S. in the 1980s (e.g. Giorgi et al., 1989), the approach, consisting of driving a high resolution LAM lateral boundaries with low-resolution GCM flow fields, entered the scene (Laprise, 2008). In practice, one order of magnitude in resolution can be gained with this approach, so the small-scale structures of atmospheric circulation can be reproduced. One advantage of such a LAM is that it can also be driven by atmospheric reanalyses (data derived from global observations using data assimilation schemes and models), rather than by GCM outputs; this feature is very convenient for development and validation purposes. When LAMs are applied to long time scales, they are referred to as Regional Climate Models (RCMs). They are now exploited in a number of research centres around the world and used in a wide range of climate applications, from palaeoclimate to anthropogenic climate change studies (IPCC, 2007). The development and application of such numerical tools has been motivated by the needs of assessing what the impact of global climate will be in different regions. This downscaling approach is very versatile since RCMs are locatable in any part of the world. Moreover, simulating climate and climate change at the regional and national levels is of paramount importance for policymaking. Any regional climate modelling approach affords focusing over an area of the globe with a regional grid-point spacing of a few tens of kms in the horizontal, for operational use on climate timescales. Furthermore, even when the increase of computing power will permit the operational use of GCMs at a resolution of a few tens of km,

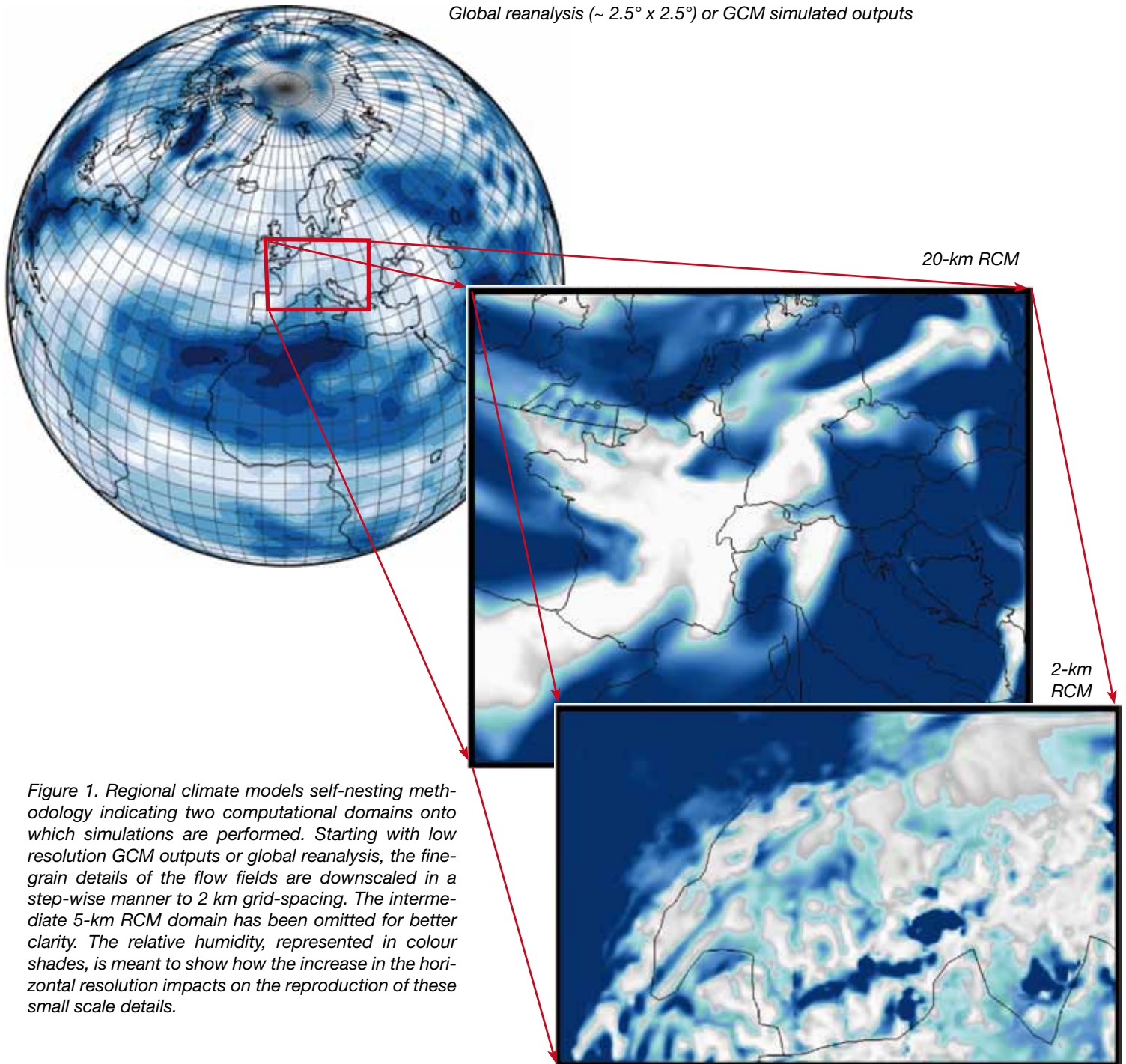
Global reanalysis ( $\sim 2.5^\circ \times 2.5^\circ$ ) or GCM simulated outputs

Figure 1. Regional climate models self-nesting methodology indicating two computational domains onto which simulations are performed. Starting with low resolution GCM outputs or global reanalysis, the fine-grain details of the flow fields are downscaled in a step-wise manner to 2 km grid-spacing. The intermediate 5-km RCM domain has been omitted for better clarity. The relative humidity, represented in colour shades, is meant to show how the increase in the horizontal resolution impacts on the reproduction of these small scale details.

the RCM approach could still be useful, allowing reaching resolution of a few kms for a similar computational load. In principle, specific physical parameterizations for the sources and sinks of momentum, heat and moisture, respectively  $F$ ,  $Q$  and  $M$  as depicted in Eqs (1) - (2), and (4) are scale dependent. In the historical development of RCMs, these parameterisations often benefited from packages coming from either NWP or from GCMs. Improvements to existing schemes and also new developments were nevertheless deemed necessary. This enables RCMs to be applied to a large range of atmospheric flows. This downscaling technique can be further extended to finer detail with the cascade self-nesting capability as shown in Fig 1 (Goyette et al., 2001). The enhancement of horizontal resolution, also prompted for on the specification of surface boundary conditions as a sizeable portion of the performance of RCMs relies on the surface forcing not captured by GCMs. Their success depends on their ability to respond to these

forcing factors in a realistic manner in space and time. An important surface forcing not captured by GCMs (Fig 2.) which has received much attention lately is the regional influence of inland water bodies (Goyette et al., 2000). Also, much attention is being paid to the capability of RCMs to reproduce extreme events. Wind gusts are fundamental characteristics of the variability of wind climate; physically-based parameterization to simulate gusts has been developed to better capture the effects of extremes associated with these features (Goyette et al., 2003).

There is also a need for future climate projection at local and regional scales. In addition, climate models, either global or regional, are constantly improved so as to include state-of-the-art numerical schemes, physical parameterizations, new scenarios for greenhouse gas forcing, etc. to warrant realistic simulations at an ever-increasing spatial resolution. For example, the European project "PRUDENCE" was

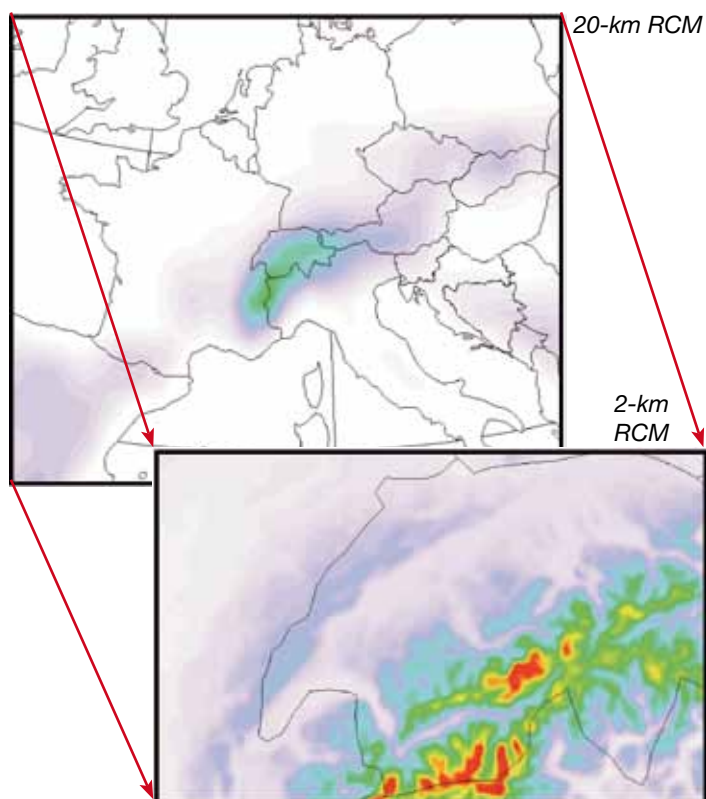


Figure 2. Surface topography prescribed as a lower boundary condition in a 20- and a 2-km RCM. Local weather and climate are significantly influenced by local topographical features such as mountains. Small-scale topographical features are not resolved by GCMs neither by low resolution RCMs (e.g. 20-km RCM) due to the coarse resolution of their computational grids.

aimed at quantifying confidence and uncertainties in predictions of future European climate and its impacts using a suite of high resolution RCMs driven by a coarser resolution GCM (Christensen et al., 2002).

Ultra-high climate simulations, i.e. 30 years or more with an horizontal grid spacing on the order of one kilometre, is not foreseen in the near future due to as yet inadequate computational resources. Some specific case studies using RCMs with 2 and even 1 km grid spacing have been carried out for short term integrations to test the downscaling ability of such an approach (Goyette, 2001). The analysis has shown that the model cannot overcome the massive increase in resolution from coarse resolution GCM or reanalysis data down to these fine scales without introducing intermediate steps (Fig 1). The cascade self-nesting method requires, for long-term simulations, that the ratio between successive grid meshes should range between 3 and 5 to avoid numerical inconsistencies. However, 2.2-km numerical weather predictions do exist and this model is particularly aimed at assisting in short-term local forecasting, showing skill for a 24-h forecast (COSMO<sup>1</sup>). Much research remains to be done, despite all the post World War II achievements. There are still many scientific and technical challenges in weather and climate research, and contributing to these innovations and findings is indeed worthwhile.

1 [www.meteosuisse.admin.ch/web/fr/meteo/previsions\\_numeriques/cosmo.html](http://www.meteosuisse.admin.ch/web/fr/meteo/previsions_numeriques/cosmo.html)

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# Progress in Physics (35)

## A snowflake in a million degree plasma

Y. Martin, B. Labit, H. Reimerdes, W. Vijvers

CRPP, EPFL, Association EURATOM – Confédération Suisse, CH-1015 Lausanne

### Introduction

Fusion is the energy that powers the stars. Harnessing fusion on Earth would offer the world almost inexhaustible, environmentally clean and safe energy, see box 1. Research and development performed during a few decades already brought significant results. In the domain of magnetic confinement, for instance, 16MW of fusion power have been produced in the JET tokamak [1] in 1997. Since then an international collaboration was set to build the next step device, ITER <sup>1</sup>, the first fusion reactor that would deliver 500 MW of fusion power, 10 times the power injected into the device, see box 2. Recently, the European fusion scientists, under the banner of European Fusion Development Agreement <sup>2</sup> (EFDA), developed and published a roadmap <sup>3</sup> that describes the steps and the challenges to achieve the production of electricity from fusion before 2050, see box 3. The steps consist in completing the construction of ITER, operating ITER, designing, building and operating DEMO, a prototype reactor that would provide the electrical network

<sup>1</sup> ITER: [www.iter.org](http://www.iter.org)

<sup>2</sup> EFDA: [www.efda.org](http://www.efda.org)

<sup>3</sup> Fusion roadmap: <http://www.efda.org/efda/activities/the-road-to-fusion-electricity/>

with several hundreds of MW. The roadmap is divided into 8 missions, including the 'heat exhaust' issue: if one extrapolates from the present devices to a reactor grade device, the heat flux density produced by particles escaping from the plasma would reach levels that may exceed the material capabilities. To mitigate the heat flux impact several strategies are proposed. One of these strategies aims at the exploration of the so-called snowflake configuration. The scientists of the CRPP-EPFL were the first to realise a snowflake configuration in a tokamak, thanks to the high shaping capability of the TCV tokamak but especially to the hard work of these dedicated scientists. It should be emphasized that this work was subsequently awarded the R&D100 prize in 2012 <sup>4</sup>. This paper presents the achieved snowflake configuration and its advantages with respect to heat exhaust.

### Plasma configuration

The TCV tokamak is equipped with 16 independently driven poloidal field coils that are used for shaping the plasma. Depending on the combination of coil currents, the plas-

<sup>4</sup> R&D magazine: <http://www.rdmag.com/award-winners/2012/08/high-performance-tokamak-exhaust>

### Fusion

The fusion of hydrogen isotopes, deuterium and tritium, is the easiest reaction that could be implemented on Earth, because of its higher cross section at a lower temperature than other possible reactions.

Temperatures of about 100 M°C must be achieved so that fusion power becomes exploitable. Before reaching these temperatures, a gas turns to plasma wherein particles are ionised.

Magnetic fields then provide a good way to guide the ionised particles.

The most attractive magnetic confinement device so far is the tokamak, a toroidal device wherein a poloidal field, induced by a toroidal current, is superimposed to a toroidal magnetic field to form the magnetic structure that guides and maintains the plasma away from the vacuum vessel walls. In addition poloidal field coils are used to shape the plasma.

To reach the required temperatures, the plasma is heated by either energetic neutral particles or by microwaves delivering their power in the plasma through different possible resonant schemes.

The CRPP-EPFL tokamak, called TCV <sup>1</sup> for 'Tokamak à Configuration Variable' has a high shaping capability and an Electron Cyclotron Heating (ECH) system of 4.5 MW.

<sup>1</sup> [http://crpp.epfl.ch/research\\_TCV](http://crpp.epfl.ch/research_TCV)

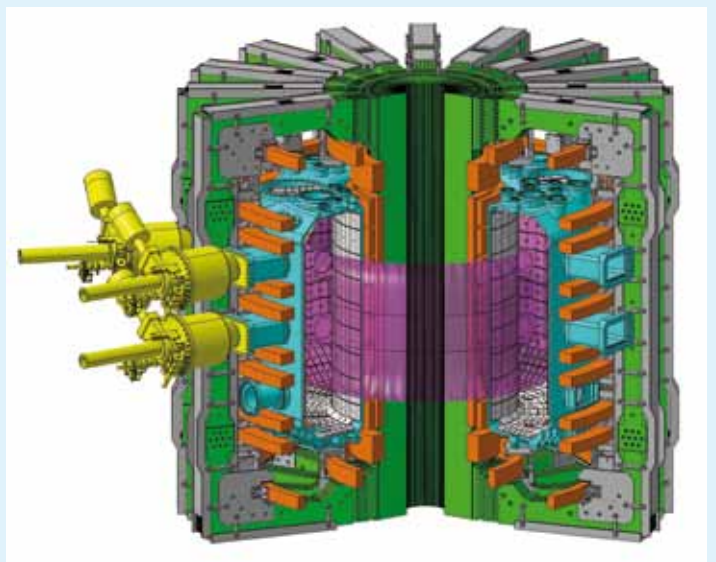


Figure: The CRPP-EPFL Tokamak à Configuration Variable (TCV). Cyan: vacuum vessel; green: main toroidal field coils; orange: poloidal field coils (for plasma current induction and plasma shaping); yellow: microwave launchers; pink: plasma. TCV diameter: 3.3m

ma either lies against the carbon tile covered wall of the vacuum vessel, the so-called limited configuration, or is fully detached from the wall thanks to the presence of a null point in the poloidal field (X-point) and the resulting separatrix that delimits the plasma as shown in Fig. 1. In the latter configuration, the so-called divertor configuration, the plasma is not in immediate contact with the wall. Particles that escape from the plasma are diverted towards the vessel wall, along the 'separatrix legs', towards a more remote position than in the limited configuration. In addition, the journey of particles escaping from a diverted plasma is particularly long because the low value of the poloidal field in the vicinity of the X-point leads to almost entirely toroidal trajectories. For these reasons, higher performances can be achieved in diverted plasmas, making this configuration most suitable for fusion reactors.

However, those escaping particles may damage the surface of the divertor because they deposit their significant energy on a relatively small area leading to unacceptably high heat flux densities. The snowflake configuration has been proposed as a potential solution to mitigate the strong heat flux in the divertor.

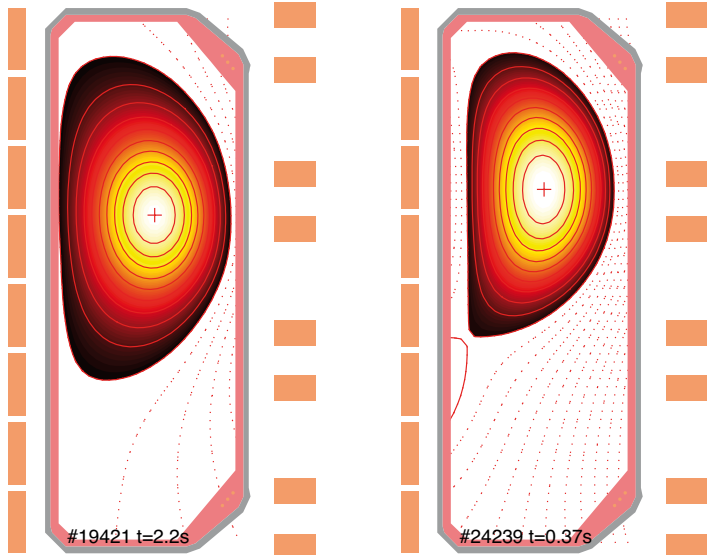


Figure 1: Comparison of plasma cross-sections in the limited (left, #19421) and diverted (right, #24239) configurations. Also shown are the vessel and plasma shaping coils cross-sections.

### Snowflake configuration

A snowflake configuration is obtained when not only the poloidal field vanishes, as in the diverted configuration, but also its first derivatives. This second order null implies that six separatrix sprout from the X-point instead of four for the diverted configuration, as shown in sketch (b) of Fig. 2. The name 'snowflake' comes from this 6-fold geometry. In the sketch, the upper lobe represents the plasma enclosed in its separatrix while the lower lobes encompass two poloidal field coils. The vacuum vessel then cuts both lower lobes resulting in four separatrix legs instead of two. It directly reveals the advantage of such a configuration: the heat flux power may be diverted towards four sections of the vacuum vessel walls, thereby reducing the heat flux densities onto the divertor plates. If the configuration slightly deviates from the perfect snowflake shown in Fig. 2b, it produces the other configurations shown in Fig. 2. These variants of the snowflake configuration are labelled SF+ (snowflake plus)

and SF-, reflecting the excess or lack of current flowing in the conductors, respectively. The distance between the two X-points, indicated by the green crosses, normalized by the minor radius of the plasma torus, is used as the measure, denoted  $\sigma$ , of the proximity to the perfect snowflake.

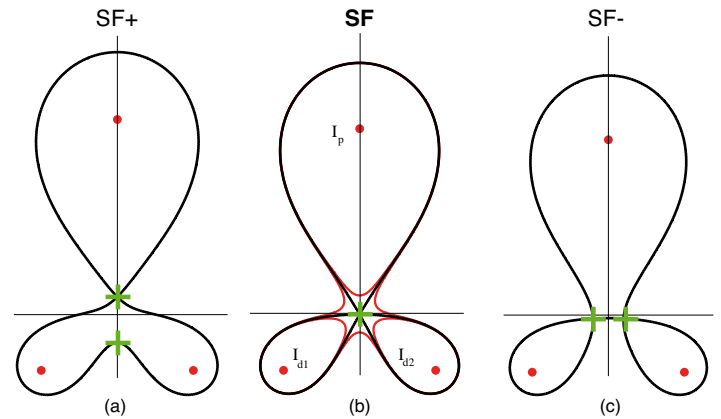


Figure 2: Schematic representation of a perfect snowflake configuration (b). Upper lobe represents the plasma while the lower lobes encompass the current conductors. A small vertical displacement of the plasma would generate the (a) or (c) configurations depending of the direction of the displacement.

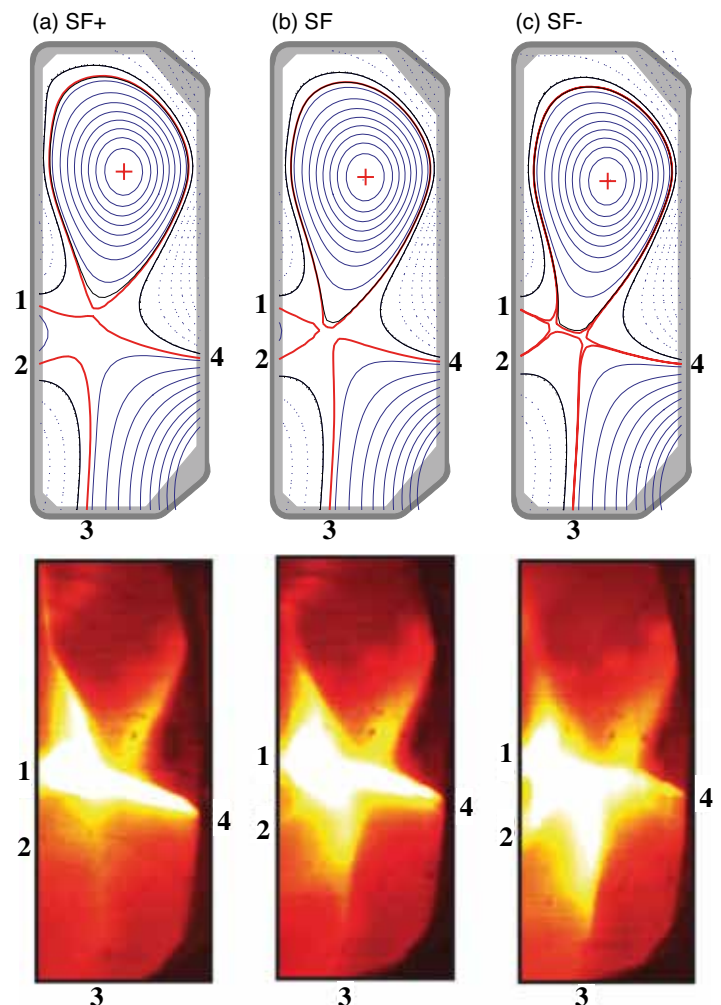


Figure 3: Equilibrium reconstruction and tangential views of the plasma obtained with a CCD camera at three different times during a plasma discharge in which the plasma was vertically displaced to go through the variant configurations shown in Fig. 2.

The snowflake configuration was proposed by Ryutov et al [2,3]. It was experimentally realised for the first time in the TCV tokamak at the CPPP-EPFL [4] and then reproduced in the NSTX spherical tokamak at the Princeton Plasma Physics Laboratory [5] and more recently in the DIII-D tokamak at General Atomics [6].

Fig. 3 shows an example of a TCV discharge wherein the plasma was vertically shifted to reveal the different snowflake configurations described in the schematic representation (Fig. 2). The plasma equilibrium reconstructions, based on magnetic measurements, are shown in the first row. The numbering 1-4 helps to identify the regions where the separatrix legs reach the vacuum vessel walls. Locations 1 & 4 are called primary locations since they correspond to the divertor legs of the traditional divertor configuration (field lines surrounding the plasma hit the wall at the primary lo-

cation). In opposition locations 2 & 3 are called secondary regions due to the absence of direct connection with the vicinity of the plasma.

The second row exhibits tangential views of the plasma obtained with a CCD camera. Since most line radiation originates from relatively "cold" plasma, the measurement of the emitted visible light provides an excellent mean to locate the edge of the plasma as well as the separatrix legs. This series of measurements shows a clear agreement between both information sources.

In all three cases shown in Fig. 3, the emitted light clearly reveals that all separatrix become active. This suggests that the low poloidal field in the vicinity of the null point enhances the cross-field transport. If this transport were sufficiently large it could not only distribute the heat among four divertor legs instead of two, but also widen the power flux

## ITER

ITER, currently under construction in the south of France, aims to demonstrate that fusion is an energy source of the future. ITER is a collaboration between European Union, including Switzerland, Japan, South Korea, China, India, Russia and United States.

### Main goals

- Ratio of fusion power to input power larger than 10 ( $Q > 10$ )

- Fusion power up to 500 MW
- Test of key technologies such as divertor materials and blanket modules wherein neutrons will deliver their energy and breed tritium

### Main parameters

- Plasma major & minor radii: 6.2 m & 2 m
- Toroidal field: 5.3T
- Plasma current: 15 MA
- Plasma duration: 500 s

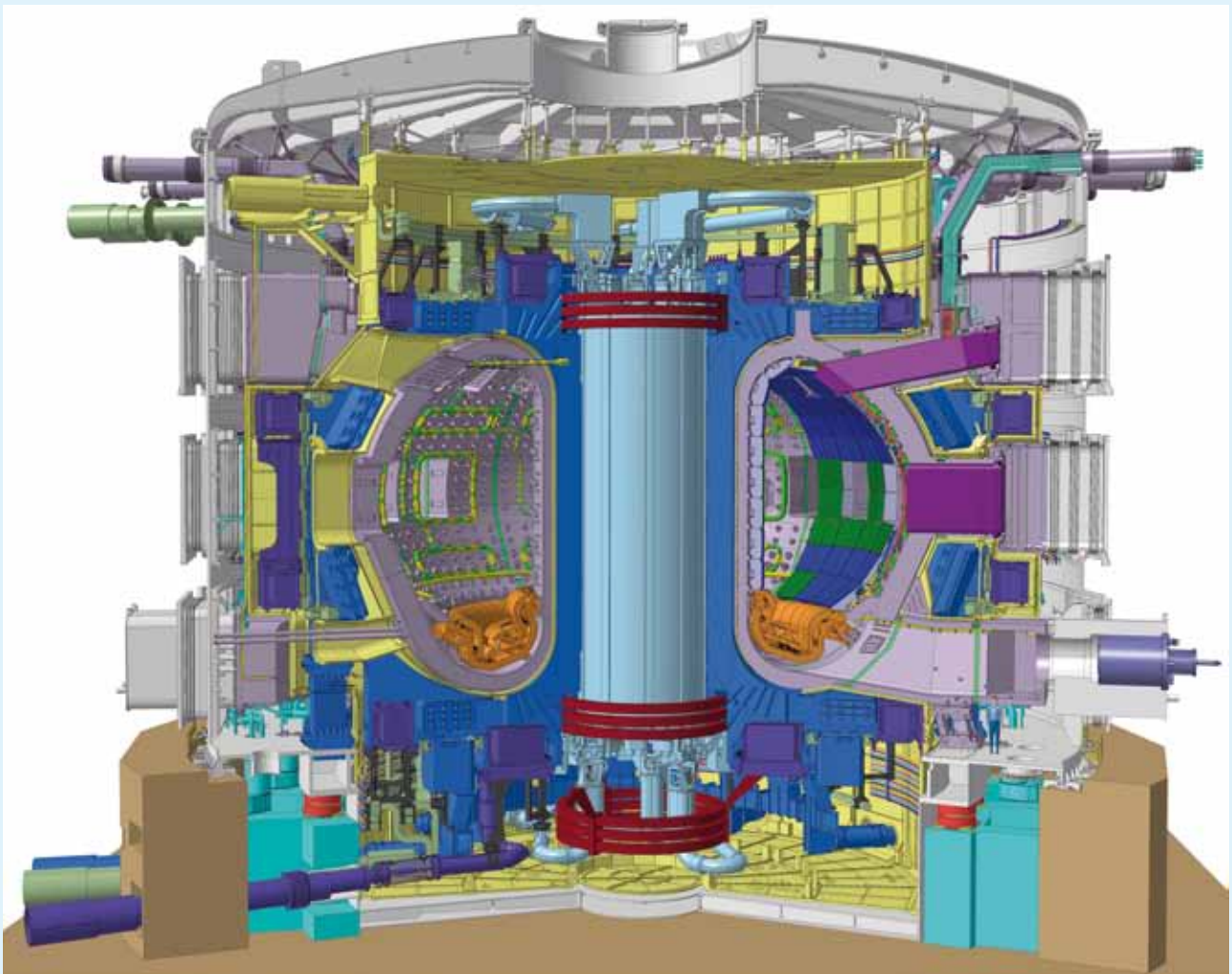


Figure: ITER. Orange: divertor; dark blue: blanket modules. ITER diameter: 28.6m

channel at each leg and thereby further reduce the power flux density onto material surfaces. Dedicated measurements were done in the most promising scenario for ITER: the H-mode.

### H-mode and snowflakes

In the early 1980's, tokamak experiments performed in diverted configuration revealed the existence of an operational regime wherein the confinement of particles and energy suddenly increases by a factor of two [7]. It was called H-mode regime (H for 'high') and has since been obtained in most tokamaks. By comparing results obtained in several devices it was shown that the additional heating power should exceed a threshold that depends on the plasma density, the plasma size and the main toroidal field [8]. The improvement in the plasma confinement properties observed in this H-mode regime makes it the selected operational mode for the ITER baseline scenario. Unfortunately, H-modes are generally accompanied with plasma edge instabilities (ELM) that repeatedly release particles towards the divertor in sharp bursts that threaten the divertor material.

H-modes are also regularly obtained and investigated in TCV diverted plasmas. Soon after the realisation of the first snowflake in TCV, efforts have been dedicated to the search for H-modes in snowflake configuration and results came soon: the access to the H-mode regime occurs at approximately the same power as in the quadrupole diverted configuration. The confinement improvement is similar or even slightly better.

Regarding the heat flux to the divertor, dedicated measurements were performed. The high pressure observed near

the second order null even increased the cross-field transport relative to the conventional configuration. This resulted in an efficient distribution of the power on the secondary divertor regions as shown in Fig. 4. The power deposited onto the divertor tiles, measured in regions labelled 1 and 3 in Fig. 3, shows a strong reduction in the primary divertor region while the secondary zone receives a significantly larger fraction. [9].

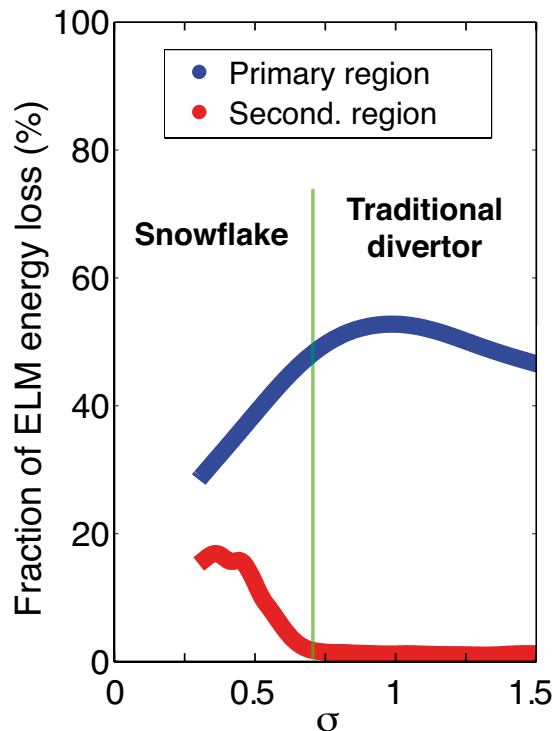


Figure 4: Fraction of the ELM energy loss reaching two of the divertor plates as a function of  $\sigma$ , the measure of the proximity to the perfect snowflake (perfect at  $\sigma=0$ ). When the snowflake is formed by decreasing  $\sigma$  below 0.75, up to 20% of the power (red curve) reaches the divertor at the additional location (label 3 in Fig. 3) while the power decreases (blue curve) at the primary location (label 1 in Fig. 3).

### Fusion electricity – EFDA roadmap

European scientists established the necessary steps and challenges that should be solved in order to realise a fusion reactor that would provide the electrical network with electricity before 2050.

#### Steps

- 2012-2020: Construction of ITER
- 2020-2030: Exploitation of ITER
- 2030-2050: Construction and exploitation of DEMO

#### Challenges

- Plasma regimes of operation
- Heat exhaust
- Neutron resistant materials
- Tritium self-sufficiency
- Integration of intrinsic safety features
- Integrated DEMO design
- Competitive cost of electricity
- Stellarator

The roadmap to fusion electricity can be downloaded from: <http://www.efda.org/efda/activities/the-road-to-fusion-electricity/>

### Conclusions

CRPP-EPFL scientists have demonstrated the feasibility of the snowflake configuration and shown the advantage of the corresponding increase of the number of separatrix legs, in the form of a significant reduction of the heat flow onto the divertor plates. While snowflakes will not likely be achievable in ITER, design studies for the subsequent device, DEMO, are evaluating the snowflake configuration as a potential divertor solution.

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# Physics Anecdotes (17)

## IBM Research – Zurich, a Success Story

Chris Sciacca and Christophe Rossel

### An Industrial Lab Grows in Switzerland

As the Zurich Lab recognizes its 50<sup>th</sup> year in the leafy Zurich suburb of Rüschlikon, a closer look inspects the details of how this lab became the home of four Nobel Prize laureates and countless innovations spanning material sciences, communications, analytics and Big Data.

There are several reasons why IBM was considering a research lab outside of the United States in the 1950s. At this time IBM was in its heyday. The company was financially strong, and the success of the recently opened San Jose lab made the management realize the benefits of having research conducted with the support of headquarters in New York, but without the local stress and peer pressure.

Switzerland wasn't IBM's first option for a European research lab; London and Amsterdam were also on the short list, and in 1955 an IBM electrical engineer named Arthur Samuel was tasked with scouting the three cities.

While officials in England were receptive to the idea, the proposed location was in the suburbs of London that he described as, "the most dismal places that I have ever seen." And shortly after, Samuel passed on England and travelled to Switzerland, to a completely different experience - he never made it on to Amsterdam.

Simultaneously, as Samuel was visiting Switzerland, Ambros Speiser, a young Swiss electrical engineer from ETH Zurich, had applied for positions at Remington Rand and IBM. He never got a response from Rand, but by that summer Speiser became an IBMer.

### How to Build a Research Lab

Now that Speiser was on board he was tasked with building a new laboratory, and the challenges he faced were immense.

As he tells it in the *IEEE Annals of the History of Computing* [1], "There was no established pattern to follow - an industrial laboratory, separate from production facilities, did not exist in Switzerland."

But Speiser knew he needed to be close to Zurich, its universities and within reach of public transport. After viewing a number of locations, he decided to rent the wing of a Swiss stationary company in Adliswil, which was at the end of a tram line and only a few kilometers from the city.

Having the building for the new lab, Speiser needed brilliant scientists and engineers. Leveraging his acquaintances, professional societies and contacts at ETH, he began a recruiting campaign and quickly amassed a team from all parts of Europe.

The goal set by IBM management was to build new and better computer hardware. At the time everyone knew that vacuum tubes would be replaced by solid-state circuits,



Fig. 1. The building of IBM Research in Adliswil in 1956. Inset: Ambros Speiser, first lab director, in discussion with Thomas Watson Jr., CEO of IBM

so it was obvious that IBM should begin developing transistors and magnetic devices, but this was never formalized.

This lack of direction weighed heavily on Speiser's mind because he knew that similar research was being conducted inside and outside of IBM and that they would never achieve the global recognition he so desired by doing the same science as everyone else.

After building a stronger rapport with Research's new management team in 1958, Speiser was given new direction for the Zurich Lab to change from electronics to physics, with a focus on solid-state as the basis for electronic devices of the future.

Once again Speiser went on recruiting missions across Europe to find young, creative physicists. Little did he know at the time that he was also laying the groundwork for what would become a renowned team for decades to come.



Fig. 2. Hans Peter Louis one of the earlier research staff members in the 50's, in front of a prototype technology called the phototron, which was never finished.

## Moving to Rüschnikon

In addition to electrical engineering and physics, Speiser soon added a mathematics department, and quickly the lab was outgrowing its modest space in Adliswil. Knowing that the growth would continue and to establish a more stable reputation, he requested approval from Thomas Watson Jr., IBM's CEO at the time and son of the founder, to look for a new location where the lab would have its own facilities.

Again, Speiser knew the new lab had to be close to the city, the airport, but most importantly to ETH Zurich, and after some debate a 10-acre site was purchased in Rüschnikon for \$400,000.

As for the actual design of the lab, Speiser's main tenant was that it created spaces for personal interaction, which he referred to as "a vital process for a research laboratory". To assure this idea, instead of building up, he wanted the lab to be horizontal with long corridors to encourage chance meetings, similar to the design of Bell Laboratories in New Jersey. It was also important for the lab to have a proper cafeteria for informal discussion and an auditorium for guest lectures. While initially this was met with some skepticism because of its costs, he eventually got his wish and construction started in 1961. The lab was officially inaugurated in front of several hundred guests on 23 May 1963, that is, 50 years ago.



*Fig. 3. Introduced in 1956, the IBM 305 RAMAC (Random Access Memory Accounting System) was an electronic general purpose data-processing machine that maintained business records on a real-time basis. The 305 RAMAC was one of the last vacuum tube systems designed by IBM, and more than 1000 of them were built before production ended in 1961.*

## Impacting the Future of the Lab

In the coming decade, the groundwork of Speiser and his successor began to bear fruit. The idea to start a physics department resulted in the hiring of Heinrich Rohrer and Karl Alex Müller, who through their research and subsequent publications began to cement a strong reputation for the Zurich Lab, which reached its apex in the mid-80s when these two scientists and their colleagues Gerd Binnig and Georg Bednorz were recognized with the Nobel Prize for Physics in 1986 and 1987.

This period also saw the addition of a new line of research in communications. Once again the lab succeeded with the

development of the token ring and trellis-coded modulation, each playing a critical role in making the Internet what it is today.

By 1987 the lab also had its own manufacturing line for semiconductor lasers which were used by telecommunication equipment manufacturers. The research became so successful that the Uniphase Corporation acquired the technology and the people from IBM for \$45 million, a huge sum for the future telecommunications giant with only 500 people at the time.

## The Crash and Recovery

With the end of the 80s, towards the mid-90s, IBM found itself in a dire position. IBM's near-death experience was caused by its failure to recognize that the 40-year-old mainframe computing model was out of touch with the needs of clients, and other firms like Sun Microsystems pounced on the opportunity.

This experience also impacted IBM Research. Throughout the 1970s IBM Research was corporate funded, it had its own research agenda and occasionally it did some technology transfer, but it was not done in a very coordinated manner because the funding kept coming every year and the profit margins were strong. This afforded the scientists the freedom they needed.

By the 1980s IBM began doing more applied research, and management took a more active role in influencing the direction in which the developments had to go. For example, IBM started joint programs between Research and the product divisions with a shared agenda that both parties, Research and Development, had to agree upon. IBM also created collaborative teams to accelerate the transfer of research results which went into products spanning from storage to personal computers. It's strange to look back at this now, as today this seems so obvious.

In the 1990s change truly came. To preserve Research, scientists in Zurich tried to become more proactive in working on actual customer problems. At the time this was unheard of at IBM and a large reason why the company stumbled. The idea was to interact with clients, gain insights into their challenges, and find solutions. The concept was a great success, and in 2000 the Zurich Lab opened up a dedicated facility called the Industry Solutions Lab (ISL), with the goal of hosting and interacting with clients on a daily basis.

Today, there are similar facilities around the world hosting hundreds of clients every month and working directly with clients. This is a fundamental strategy across all twelve IBM Research labs on the six continents. "The world is now our lab," as says Dr. John E. Kelly III, IBM senior vice president and director of Research.

## IBM Research in Zurich Today

Under the direction of seven successive lab directors, the expansion in Zurich continued well into 2000s. Today, there are five departments, namely, storage, computer science and systems in addition to physics (science and technology) and mathematics (mathematics and computational sciences).

In addition, the lab has a new cutting-edge facility called the Binnig and Rohrer Nanotechnology Center, named for the two Nobel Laureates. When the current lab director requested the funding to upgrade the existing clean rooms on the campus he was greeted with a pleasant surprise: "I was told to make it much bigger and to find a partner. ETH Zurich was an obvious and logical choice," says Dr. Matthias Kaiserswerth, the current director of IBM Research - Zurich.

No one could have predicted it, but Speiser's intuition to keep the lab close to ETH Zurich was a fortuitous decision. Nobel Laureates K. Alex Müller, Georg Bednorz and Heinrich Rohrer all came from ETH. And now nearly 60 years later, the partners built a \$90 million facility, which features



Fig. 4. The newly built Binnig and Rohrer Nanotechnology Center and as inset an example of the complete atomic structure of a pentacene molecule resolved by AFM [2]. The extreme resolution of the C, H atoms and chemical bonds is achieved by the CO molecule attached to the tip.

a large clean room and in particular six Noise Free Labs unlike any in the world.

Outside of the nano world, IBM scientists are working on some of the greatest challenges of our society today.

On Earth Day 2013, scientists in Zurich announced that they will be building an affordable photovoltaic system capable of concentrating solar radiation 2,000 times and converting 80 percent of the incoming radiation into useful energy. The system can also provide desalinated water and cool air in sunny, remote locations where both are often in short supply.

Another team is collaborating with a consortium of scientists in the Netherlands and South Africa on extremely fast, but low-power exascale computer systems aimed at developing advanced technologies for handling the Big Data that will be produced by the Square Kilometer Array (SKA), the world's largest and most sensitive radio telescope that consortium will build.

And to improve the much-strained energy grid, IBM scientists are collaborating with utility companies in Denmark, Austria and Switzerland to improve to balance between demand and the supply of renewable energy.

While much has changed at IBM Research – Zurich, the essence of collaboration and the spirit of innovation and excellence that Speiser envisioned remains true to this day.

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## Goodbye Herschel

Arnold Benz, ETH Zürich

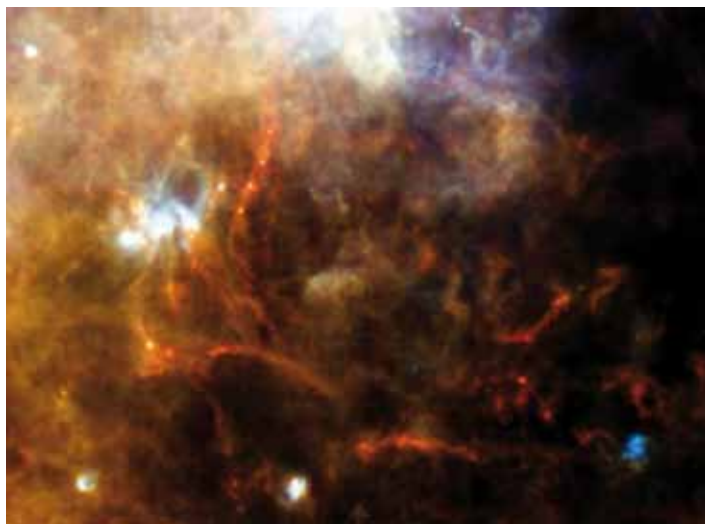
On April 29 this year the Herschel space observatory exhausted its supply of helium that cooled the sensors in the far-infrared and submillimeter range, wavelengths that cannot be observed from the ground. Herschel was put into the Lagrange position L2 in the Sun-Earth system, 1.5 million kilometres from us. Four years after its launch by the European Space Agency (ESA), the mission completed its novel observations about how stars and thus galaxies form and evolve throughout the universe. The Herschel observatory was sent to space with 2,300 litres of superfluid helium. The helium was pumped around the spacecraft in such a way as to cool the three observing instruments and gradually evaporated in the process. Herschel cannot observe without cooling below 1 K in the most critical components, but the amount was limited and chosen to outlast the expected lifetime of the cutting-edge, but new-to-space electronics.

Herschel exceeded expectations both in technology and science. The technical developments required by the unusual observing wavelengths delayed the start by more than two years. Swiss industry provided the large cryostat and

the optical assemblies for the HIFI instrument; the low-noise low-power indium phosphide amplifiers for HIFI (Heterodyne Instrument for the Far Infrared) were developed at ETH Zürich, software for HIFI at the Fachhochschule FHNW in Windisch. After four years in space all three instruments on board were still fully operational.

Herschel's observations have revealed the cosmos in unprecedented detail at these wavelengths. This raised interest in the astronomical community and resulted in 160 "first results papers" within the first four months of scientific data taking. However, most results emerged and still do so after careful data analysis, modelling and interpretation. Some highlights of my personal selection are described below.

Herschel observations allowed studying galaxies in the early universe that form stars at prodigious rates and apparently also in the absence of mergers. Other processes like inflowing intergalactic streams of cold gas may thus be equally effective. In nearby active galaxies, on the other



The Herschel image is a composite of observations at 70 (blue), 160 (green), and 250 – 500  $\mu\text{m}$  (red) wavelengths indicating hot, warm and cold regions, respectively. The image size is  $2 \times 2$  degree in the constellation of the Southern Cross. Note cloud cores (white dots) located on filaments (Credit: ESA and the SPIRE & PACS consortia).

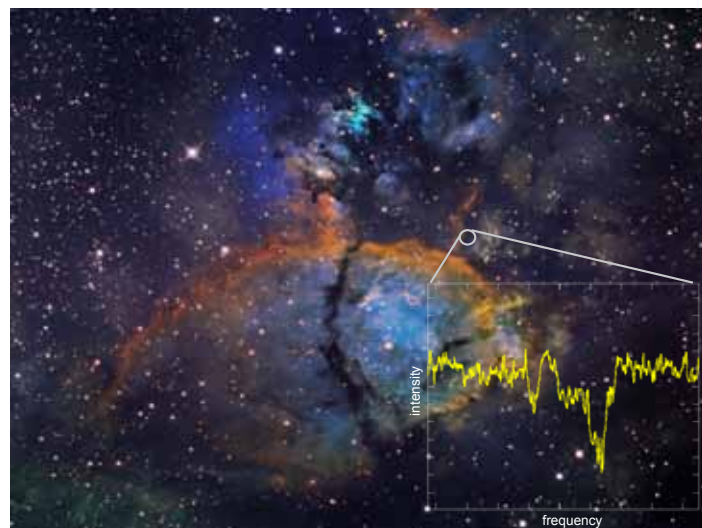
hand, Herschel found for the first time vast amounts of out-flowing molecular gas that may deplete a galaxy's supply to form new stars.

In observations of our own galaxy, Herschel identified the presence of a filamentary network in the gas of molecular clouds, filaments which contain cloud cores that will collapse under their own weight to form stars. Herschel demonstrated that filaments are nearly everywhere in clouds and that they are a key to star formation. It is not clear how filaments originate; intersecting shock waves and magnetic fields are proposed.

A chief goal of Herschel is the study of the chemical composition of cosmic objects through high-resolution spectroscopy, and in particular the search for water in the gas state, which cannot be observed from the ground. Of special interest at ETH Zürich were the chemical network of water in star formation and the evolution of protostellar disks. Herschel found gaseous water already in a cold pre-stellar core before the start of star formation. It amounts to a few million times the amount of water in the Earth's oceans. The 10 million year old disc surrounding nearby star TW Hydrae still contains a water supply equivalent to several thousand times Earth's oceans. Disks older than some 60 million years were observed to contain not enough gas to form new planets. These findings suggest that water played an important role throughout the formation of the solar system.

Several molecules were discovered in interstellar clouds for the first time. We modelled the chemistry in regions of star formation in an attempt to predict which molecules – especially ionised ones – exist there and could be used to infer the physical conditions. In particular, ultraviolet and X-ray irradiation change the chemistry and heat the collapsing envelope and its walls to the outflows. The surprise: new molecules in interstellar space, like  $\text{SH}^+$ ,  $\text{OH}^+$ , and  $\text{H}_2\text{O}^+$  were discovered to be more abundant than expected.

The region of ionized molecules in the inner parts of star and planet forming regions is certainly a field of future research. On the other hand,  $\text{O}_2$ , also not observable from the ground, was much harder to detect than predicted. Free oxygen, not bound to carbon monoxide, doesn't seem to be in molecular gas form, but might hide in silicates of the interstellar dust.



The Herschel space observatory has discovered ionized water,  $\text{H}_2\text{O}^+$ , in absorption at a location where a massive star is forming in the W3 molecular cloud. The star-forming region in the Perseus spiral arm of the Milky Way galaxy is completely opaque in visual light shown as background in colour (Diameter of image: 500 light years; credit: ESA/ETH Zürich/Sierra Remote Observatories, Don Goldman, CA, USA).

The water profile in the atmospheres of Mars is studied at the University of Bern. For the first time the water vapour was determined from a global perspective yielding a view on overall seasonal changes. The group was also part of the team that discovered  $\text{O}_2$  in the Mars atmosphere.

Two weeks after the end of the helium the Herschel observatory was moved away from the Lagrange point and the communication was terminated. The loss of pointing control ends the direct contact with Herschel. The observatory will slowly drift away from Earth and orbit indefinitely the Sun like a small planet.

Herschel has observed more than we expected, but the project is not over yet. More than 35,000 scientific observations were executed with Herschel, and more than 50,000 lines have been detected with the HIFI instrument alone. They will eventually be identified, analyzed in more detail, and modelled. Only limited parts of the data are fully exploited. It will probably be a long time before the next opportunity to gather this kind of data in space. Due to the breadth and completeness throughout the entire wavelength range, the Herschel data are bound to be unparalleled for many years to come. In a year, all the data will become a public legacy. Most important will be their combination with observations at other wavelengths, such as the millimetre/submillimetre telescope ALMA in Chile. ESA has just announced a Herschel data analysis course for beginners.

# Structural MEMS Testing

Alex Dommann and Antonia Neels\*

EMPA, Lerchenfeldstrasse 5, 9014 St. Gallen, [alex.dommann@empa.ch](mailto:alex.dommann@empa.ch)

\*CSEM, Microsystems Technology Division, 2002 Neuchâtel

In single crystal silicon (SCSi) based devices, stress and loading in operation introduces defects during the **Micro-ElectroMechanical Systems (MEMS)** life time and increases the risk of failure. Reliability studies on potential failure sources have an impact on MEMS design and are essential to assure the long term functioning of the device. Defects introduced by Deep Reactive-Ion Etching (DRIE), thermal annealing, dicing and bonding and also the device environment (radiations, temperature) influence the crystalline perfection and have a direct impact on the mechanical properties of MEMS and their aging behavior. Defects and deformations are analyzed using High Resolution X-ray Diffraction Methods (HRXRD) such as Reciprocal Space Maps (RSM). Micro systems technology can be highly reliable, but can be different from those of solid-state electronics. Therefore testing techniques must be developed to accelerate MEMS-specific failures [1 - 4].



Figure 1: Diffractometer used for HRXRD applications.

HRXRD allows measuring the strain of a crystal with high resolution (Fig. 1). We use HRXRD to assess the strain in DRIE etched processed silicon beams. Strain deforms the silicon beam leading to an appreciable sample curvature

which is detected via the broadening of the X-ray peak in a "rocking-curve" (RC) measurement. Analysis is performed with high resolution X-ray diffraction. The set-up is composed by curved multilayer x-ray mirrors named after Herbert Göbel (Göbel mirror) in front of the X-ray tube, followed by a monochromator for monochromatization and collimation of X-ray beams by using a 4-Crystal monochromator with two channel-cut Ge [220] called Bartels monochromator (Fig. 2). Two configurations are possible for the diffracted beam side, depending on the methods applied: Rocking curve (RC) or Reciprocal space map (RSM). Both methods allow measuring strain and defects concentration in a crystal. The instrument used for HRXRD is shown (Figure 1).

New MEMS fabrication processes and packaging concepts find applications in areas where a high reliability is needed such as in aerospace, automotive or watch industry. This creates a strong demand in quality control and failure analysis and also brings new challenges, particularly in the fields of testing and qualification. Non-destructive HRXRD methods are applied to monitor the mobility of defects and strain

A rocking curve (RC) is obtained as angular distribution of the reflected X-ray beam, when the detector is set at a specific Bragg angle and when the sample is rotated about small angles normal to the Bragg plane axis. The rocking curve is broadened by disruptions of the plane parallelity and by crystal defects like those introduced by mechanical stress. Reciprocal space mapping (RSM) adds, by the restriction of the angular acceptance of the detector, another dimension to the information available from the HRXRD experiment. Strain and tilt elements being present in a sample are identified separately. An excellent introduction to both analytical methods can be found at <http://prism.mit.edu/xray/tutorials.htm>. See 'Basics of High Resolution X-Ray Diffraction for Studying Epitaxial Thin Films'.

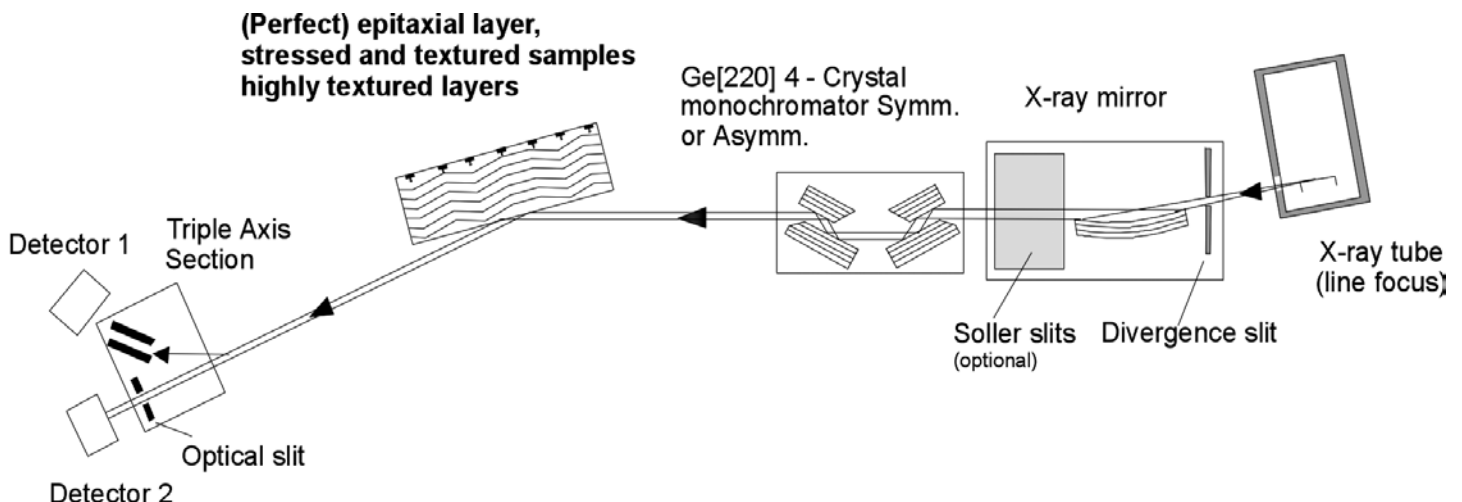


Fig 2: Diffractometer setup for RSM's (detector position 1) and RC's (detector position 2)

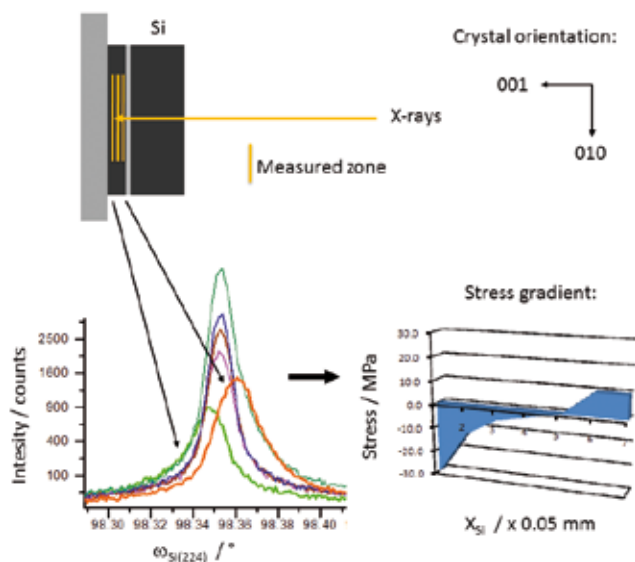


Figure 3: Schematic HRXRD measurement setup and silicon crystal orientation (top) and measured rocking curves RC's from the bonding interface 1 of the device layer to the bonding interface 2 (bottom) resulting in a stress profiling.

and along the MEMS fabrication and packaging processes. RSM is a powerful tool for evaluating the strain state of the entire structure. Due to the much more limited vertical divergence and the very small horizontal divergence of the RSM settings, it is possible to get a ' $\gamma$ -function like' reciprocal-space probe which is almost invariant over the Ewald sphere. Figure 2 shows a setup used for measuring such RSMs.

HRXRD is a very sensitive and non-destructive technique for determining the strain in MEMS devices.

An example of such a test structure is a silicon based piezoelectric resonator (Fig. 3), developed at CSEM, targeting vacuum hermetic wafer-level packaging technology [5]. The monitoring of quality factors (Q) for the resonators permits to evaluate the pressure level (hermeticity) of the device cavity and the leakage rate.

As the Q-factor is not only dependent on the vacuum level of the MEMS cavity but also on the strain state of the de-

vice, the simultaneous data collection for the Q factor determination and the strain state is evident. The packaging induced strain created at the important interfaces such as the interfaces close to the bonding material and more importantly to the device layer has been analyzed by means of X-ray Rocking Curves (Fig. 3). The stress profile can be determined. Especially the strain close to the functional device is important as the strain state influences the application relevant physical parameters such as the resonance frequency and the Q factor in resonator.

The combination of functional testing with state-of-the-art X-ray methods for the evaluation of defect and strain gradients will serve as a useful tool for setting up a fundamental understanding of the reliability and also aging problems of MEMS.

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**Alex Dommann's** research concentrates on the structuring, coating and characterization of thin films, MEMS and interfaces. In July 2013 he was appointed Head of Departement "Materials meet Life" at Empa, Swiss Federal Laboratories for Materials Science and Technology. He is member of different national and international committees.

**Antonia Neels** is heading the XRD Application Lab of CSEM's Microsystems Technology Division. She has a broad experience in the application of X-ray diffraction methods for microsystems (MEMS) and thin films with respect to quality control and failure mode analysis.

## Kurzmitteilungen (Fortsetzung)

### Felicitas Pauss und Karl Gademann neu im Vorstand SCNAT

Die Physikerin Felicitas Pauss und der Chemiker Karl Gademann sind an der Delegiertenversammlung der Akademie der Naturwissenschaften Schweiz (SCNAT) am 24. Mai 2013 in Bern neu in den Vorstand gewählt worden. Zudem wurde der Verein Schweizerischer Naturwissenschaftslehrerinnen und -lehrer in die Akademie aufgenommen. Die Professorin für Experimentelle Teilchenphysik, Felicitas Pauss, forscht an der ETH Zürich und am CERN in Genf, wo sie die «Internationalen Beziehungen» führt. Karl Gade-

mann ist Professor für organische Chemie an der Universität Basel und aktueller Präsident der Platform Chemistry der SCNAT. 2012 wurde er mit dem renommierten Latsis-Preis ausgezeichnet. Felicitas Pauss nimmt ab Juni 2013 Einsitz im Vorstand, Karl Gademann ab Januar 2014. In den Vorstand wiedergewählt wurde Helmut Weissert von der ETH Zürich.

Quelle: SCNAT Newsletter Juni 2013

## Paul Scherrer Institute: User facilities - calls for proposals

The Paul Scherrer Institute (PSI) in Villigen operates four major user laboratories: a third generation X-ray synchrotron source (SLS), the only continuous spallation neutron source worldwide (SINQ), the world's most powerful continuous-beam  $\mu$ SR facility ( $S\mu S$ ) and a meson factory for fundamental nuclear and elementary particle physics (LTP). In fact, PSI is the only place worldwide to offer the three major probes for condensed matter research (synchrotron X-rays, neutrons and muons) on one campus.

The installations are all open access user facilities and offer regular calls for proposals.

More information is available here:

<http://www.psi.ch/useroffice/proposal-deadlines>

Contact address:

Paul Scherrer Institute  
User Office  
5232 Villigen PSI

phone: +41-56-310-4666  
email: [useroffice@psi.ch](mailto:useroffice@psi.ch)

User facility	Proposal submission deadline
<b>SLS</b>	
all beamlines, except PX-I,-II,-III	Mar 15, Sep 15
PX beamlines	Feb 15, Jun 15, Oct 15
<b>SINQ</b>	
all beamlines	May 15, Nov 15
<b><math>S\mu S</math></b>	
DOLLY, GPD, GPS, LEM and LTF	Dec 10
GPD, GPS and LTF	June 11
<b>PARTICLE PHYSICS</b>	
all	Dec 10

## Physique et la Société

### Quand la Physique rejoint le Sport

*Christophe Rossel*

Une quarantaine d'étudiants et étudiantes en physique des universités suisses se sont réunis les 17 et 18 mai 2013 à Macolin pour un atelier de travail sur le thème Physique et Sport. Organisée dans le cadre du Forum des Jeunes Physiciens (YPF) en collaboration avec la Société Suisse de Physique (SSP) et l'office fédéral du sport (OFSP) cette réunion a permis à ces jeunes de se rencontrer dans une atmosphère amicale.

L'YPF a été créé en 2009 à l'instigation de la SSP, grâce au soutien financier de l'Académie suisse des sciences naturelles (SCNAT) et de sa plateforme MAP. Les buts du Forum sont d'encourager la communication entre les sociétés d'étudiants en physique entre elles, avec les physiciens professionnels membres de la SSP ainsi que de créer une plateforme pour discuter des sujets d'intérêts communs et organiser des événements divers tels que visites ou séminaires.

C'est dans ce contexte qu'a eu lieu ce premier workshop sur le splendide site de la Haute école fédérale de sport (HEFS) de Macolin. Arrivés le vendredi soir les étudiants ont été reçus officiellement par le recteur de cette école, Walter Mengisen, qui leur a décrit la fonction et les activités de l'OFSP qui est un centre de prestations, de formation et d'entraînement au service du sport d'élite, du sport de compétition et du sport populaire.

Après une soirée conviviale de discussion et de jeux au bar et la nuit passée au Grand Hôtel, les participants se sont retrouvés le samedi matin pour la série de conférences prévues au programme. Après une introduction générale sur le thème et l'organisation du workshop par Christophe Rossel, le premier conférencier, Didier Staudenman du département de médecine de l'université de Fribourg a présenté le sujet de la biomécanique et de l'activation musculaire à une audience attentive. En particulier, il a décrit la tech-



Une partie des participants réunis devant le Grand Hôtel de Macolin avec une vue imprenable sur les alpes

nique d'électromyographie (EMG) qui permet d'enregistrer et d'analyser les signaux électriques produits par les variations physiologiques des fibres musculaires.

Dans une seconde présentation Pierre Cornu, avocat et conseiller juridique pour les affaires d'intégrité et de régulations à l'UEFA ainsi qu'au Centre international d'étude du sport (CIES) de Neuchâtel a développé le sujet des manipulations dans les compétitions sportives et la bonne gouvernance. De manière captivante avec maints exemples il a évoqué les paris illégaux, les manipulations en football, le dopage et ses effets pervers ainsi que les méthodes de contrôle et de sanctions disciplinaires.

Pascal Arnold, doctorant à l'Institut des systèmes mécaniques de l'ETHZ nous a ensuite expliqué les défis humains et technologiques dans le bobsleigh de compétition. De manière remarquable il nous a décrit toutes les étapes techniques dans la construction d'un bob professionnel qu'il a développé dans le cadre de sa thèse de doctorat. Par chance un exemplaire d'un tel bob a été exposé en présence du pilote professionnel Rico Peter de l'équipe Suisse. Il qui a aussi répondu aux nombreuses questions.



*Pascal Arnold présentant les caractéristiques techniques du bob Suisse II en présence de son pilote Rico Peter*

Tous les secrets de la mesure de position en sport nous ont été révélés par Martin Rumo de la Haute école fédérale de sport de Macolin. Il a expliqué les développements récents dans les instruments d'analyse de performance dans les sports d'élite et en particulier les méthodes de mesures locales de la position des joueurs de football et du ballon. En effet les données 3D obtenues en temps réel permettent un entraînement précis, une observation exacte et une analyse de chaque joueur et de l'équipe.

Finalement le dernier conférencier, Benedikt Fasel du Laboratoire de mesure et d'analyse des mouvements de l'EPFL s'est exprimé sur les méthodes d'analyse du mouvement et en particulier sur la prévention des accidents dans les compétitions de ski alpin. Il a expliqué l'utilisation de senseurs inertiels placés sur le skieur, de caméras 3D ou du GPS pour mesurer la trajectoires, les forces et la dynamique du corps pendant la descente et comment utiliser les données pour optimiser la géométrie des skis.



*Démonstration d'agilité sur la slackline*

Changement de décors l'après-midi où l'occasion a été donnée de passer de la théorie à la pratique grâce au soutien organisationnel de Bruno Tschanz. Sous un soleil radieux et en tenue sportive les participants se sont rendus à la salle et au stade de la Fin du Monde pour tester différentes installations. Par exemple ils ont pu se mesurer aux professionnels de l'équipe de bob du Lichtenstein à la poussée d'engins d'entraînement similaires sur roues ou encore tester leur habileté d'équilibristes en slackline, ou littéralement corde souple. Dans ce sport créé dans les années 80, l'objectif est de se déplacer ou de faire des figures sur une sangle légèrement élastique et ceci sans aucun accessoire. Un autre clou des activités sportives a été sans conteste le football joué avec analyse des performances de chaque joueur, visionné sur petit écran après la partie. Enfin chacun a aussi pu tester les signaux induits par le mouvement de leur biceps grâce à un système de mesure électriques avec électrodes multiples et en comprendre les principes avec les explications de Didier Staudenman.



*Un bel exercice sportif, la poussée du bob à deux*

C'est enthousiastes et presque à regret que les participants ont quitté le site en fin d'après-midi pour retourner chez eux après une journée riche en information scientifique et technique et en activités sportives.

# History of Physics (8)

## On the Einstein-Grossmann Collaboration 100 Years ago

Norbert Straumann, Institute for Theoretical Physics, Uni Zürich

### Introduction

Einstein's path to general relativity (GR) meandered steeply, encountered confusing forks, and also included a big U-turn. In this brief account I discuss in some detail Einstein's remarkable progress beginning in August 1912, after his second return to Zürich, until Spring 1913. Before we come to this, some indications of what he had already achieved until this period are necessary.

In 1907, while writing a review article on special relativity (SR), Einstein speculated – attempting to understand the empirical equality of inertial and gravitational mass – on the possibility of extending the principle of relativity to accelerated motion, and added an important section on gravitation in his review [2]<sup>1</sup>. With this "basic idea", which he referred to as *principle of equivalence*, he went beyond the framework of SR. His (special formulation) of the equivalence principle – "the most fortunate thought of my life" – became the guiding thread in his search for a relativistic theory of gravitation. Until 1911 Einstein worked apparently mainly on the quantum puzzles and did not publish anything about gravitation, but continued to think about the problem. In [3] he writes: "Between 1909-1912 while I had to teach theoretical physics at the Zürich and Prague Universities I pondered ceaselessly on the problem". When Einstein realized in 1911 that gravitational light deflection should be experimentally observable [4], he took up the problem of gravitation again and began to "work like a horse" in developing a coherent theory of the static gravitational fields. Since he had found that the velocity of light depends on the gravitational potential, he concluded that the speed of light plays the role of the gravitational potential, and proposed a non-linear field equation, in which the gravitational energy density itself acts as a source of the gravitational potential. Therefore, the field equation implied that the principle of equivalence is valid only for infinitely small spatial regions. In the second of his Prague papers on "gravito-statics" [5] he also showed how the equations of electrodynamics and thermodynamics are modified in the presence of a static gravitational field. At this point he began to investigate the dynamical gravitational field.

### Einstein gains Marcel Grossmann as a collaborator

When Einstein arrived in Zürich in early August, he was convinced that a metric field of spacetime, generalizing the Minkowski metric to a pseudo-Riemannian dynamical metric, was the right relativistic generalization of Newton's potential. The main question was to find the basic equation for this field. But how to achieve this was in the dark and he looked for mathematical help. Fortunately, Marcel Grossmann, his old friend since his student time, was now also professor at the ETH and Einstein succeeded in gain-

ing him as a collaborator in his search for the gravitational field equation. In a 1955 reminiscence, shortly before his death, Einstein wrote [3]:

*I was made aware of these [works by Ricci and Levi-Civita] by my friend Grossmann in Zürich, when I put the problem to investigate generally covariant tensors, whose components depend only on the derivatives of the coefficients of the quadratic fundamental invariant.*

*He at once caught fire, although as a mathematician he had a somewhat sceptical stance towards physics. (...) He went through the literature and soon discovered that the indicated mathematical problem had already been solved, in particular by Riemann, Ricci and Levi-Civita. This entire development was connected to the Gaussian theory of curved surfaces, in which for the first time systematic use was made of generalized coordinates.*

Louis Kollros, another student friend of Einstein, who was also mathematics professor at the ETH during this time, remembered also in 1955 [6]:

*[Einstein] spoke to Grossmann about his troubles and said one day: "Grossmann, you must help me, otherwise I'll go crazy!".*

The fruitful collaboration of Einstein and Grossmann led to the famous joint article with the modest title "Outline of a Generalized Theory of Relativity and a Theory of Gravitation" [7], one of the most important physics papers in the twentieth century. A lot of additional insight can be gained from Einstein's detailed 'Zürich Notebook' [8]. It is really fascinating to study these research



Figure 1: Marcel Grossmann.

notes, because one can see Einstein at work, and theoretical physics at its best: A delicate interplay between physical reasoning, based on an intuitive estimate of the most relevant empirical facts, and – equally important – mathematical structural aspects and requirements. We shall see that already late in 1912 Einstein came very close to his final theory, but physical and conceptual arguments, that will be discussed later, convinced him for a long time that – with "heavy heart" – he had to abandon the general covariance of the gravitational field equation. In a letter to Lorentz [9] he called this the "ugly dark spot" of the theory. With this decision, based on erroneous judgement, Einstein lost almost three years until physics and mathematics came into harmony in his beautiful general theory of relativity. The Einstein-Grossmann theory, published almost exactly hundred years ago, contains, however, virtually all essential elements of Einstein's definite gravitation theory.

<sup>1</sup> References to papers that have appeared in the *Collected Papers of Albert Einstein* (CPAE) [1] are always cited by volume and document of CPAE.

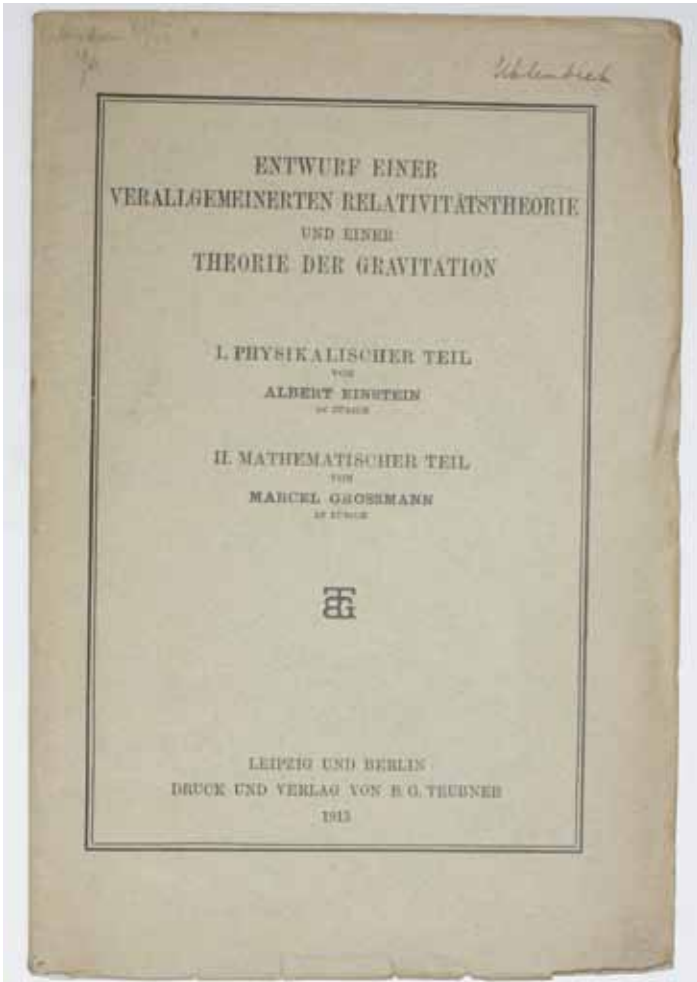


Figure 2: Cover sheet of the Einstein-Grossmann "Entwurf" paper.

### Requirements to be satisfied by the future theory

The following mixture of physical and mathematical properties of a relativistic theory of gravitation are among Einstein's main guiding principles:

- The theory reduces to the Newtonian limit for weak fields and slowly moving matter.
- Conservation laws for energy and momentum must hold.
- The equivalence principle must be embodied.
- The theory respects a generalized principle of relativity to accelerating frames, taking into account that gravitation and inertia are described by one and the same metric field  $g_{\mu\nu}$ . Einstein expressed this by the requirement of general covariance of the basic equations (to become a much debated subject).

### Non-gravitational laws in external gravitational fields

The easier part of the new theory was to describe the coupling of external gravitational fields to matter and electromagnetic fields. In one of the Prague papers Einstein had derived the equation of motion for a point particle in a static field from a variational principle, which is now generalized in a natural manner to

$$\delta \int ds = 0, \quad ds^2 = g_{\mu\nu} dx^\mu dx^\nu. \quad (1)$$

The corresponding Euler-Lagrange equation is the geodesic equation of motion for a point particle. Considering an incoherent dust distribution as an ensemble of particles, Einstein guesses that the energy-momentum conservation law of special relativity,  $\partial_\nu T^{\mu\nu} = f^\mu$ , with the energy-stress tensor  $T^{\mu\nu} = \rho_0 u^\mu u^\nu$  ( $\rho_0 =$  rest-mass matter density,  $u^\mu =$  four-velocity field) and an external force density  $f^\mu$ , should be replaced by

$$\frac{1}{\sqrt{-g}} \partial_\nu (\sqrt{-g} g_{\mu\lambda} T^{\lambda\nu}) - \frac{1}{2} \partial_\mu g_{\alpha\beta} T^{\alpha\beta} = 0 \quad (2)$$

( $g := \det(g_{\mu\nu})$ ). The details of Einstein's considerations are described in his Part I, Sect. 4 of the "Entwurf" paper by Einstein and Grossmann [7]. This is just an explicit form of the equation  $\nabla_\nu T^{\mu\nu} = 0$ , as stated by Grossmann in his Part II of [7]. Later in Sect. 6 of [7] Einstein generalizes Maxwell's equations in generally covariant form. This part has survived in GR. The coupling of electromagnetic fields to external gravitational fields is not yet formalized to the " $\partial \rightarrow \nabla$ " rule, as a mathematically precise expression of a local version of the equivalence principle.

### In search of the gravitational field equation

Soon, Einstein begins to look for candidate field equations. The pages before 27 of the Zürich Notebook show that he was not yet acquainted with the absolute calculus of Ricci and Levi-Civita. On p. 27, referring to Grossmann, Einstein writes down the expression for the fully covariant Riemann curvature tensor  $R_{\alpha\beta\gamma\delta}$ . Next, he forms by contraction the Ricci tensor  $R_{\mu\nu}$ . The resulting terms involving second derivatives consist, beside  $g^{\alpha\beta} \partial_\alpha \partial_\beta g_{\mu\nu}$ , of three additional terms. Einstein writes below their sum: "should vanish" ["sollte verschwinden"]. The reason is that he was looking for a field equation of the following general form:

$$\Gamma^{\mu\nu}[g] = \kappa T^{\mu\nu}, \quad (3)$$

with

$$\Gamma^{\mu\nu}[g] = \partial_\alpha (g^{\alpha\beta} \partial_\beta g^{\mu\nu}) + \text{terms that vanish in linear approximation.} \quad (4)$$

After long complicated calculations, Einstein discovers that the Ricci tensor is of the desired form, when the coordinates are assumed to be *harmonic*. (Readers who are not familiar with this may regard this as a kind of gauge condition, analogous to the Lorentz condition in electrodynamics.) This seems to look good, and Einstein begins to analyse the linear weak field approximation of the field equation <sup>2</sup>

$$R_{\mu\nu} = \kappa T_{\mu\nu}. \quad (5)$$

(Readers, familiar with GR, know that Einstein has to run into problems, because of the contracted Bianchi identity.)

<sup>2</sup> Never before had Einstein used in his work such advanced and complex mathematics. This is expressed in a letter to Arnold Sommerfeld on 29 October 1912 (CPAE, Vol. 5, Doc. 421): "But one thing is certain: never before in my life have I toiled any where near as much, and I have gained enormous respect for mathematics, whose more subtle parts I considered until now, in my ignorance, as pure luxury. Compared with this problem, the original theory of relativity is child's play."

### The weak field approximation

The linearized harmonic coordinate condition becomes for  $h_{\mu\nu} := g_{\mu\nu} - \eta_{\mu\nu}$  ( $\eta_{\mu\nu}$ : Minkowski metric)

$$\partial_\mu (h^{\mu\alpha} - \frac{1}{2} \eta^{\mu\alpha} h) = 0 \tag{6}$$

( $h := h^\mu_\mu$ , indices are now raised and lowered by means of the Minkowski metric). This is nowadays usually called the *Hilbert condition*, but Einstein imposed it already in 1912. The field equation becomes an inhomogeneous wave equation:

$$\square h_{\mu\nu} = -2\kappa T_{\mu\nu} \tag{7}$$

Einstein takes for  $T_{\mu\nu}$  his earlier expression for dust.

But now he runs into a **serious problem**:

From  $\partial^\nu T_{\mu\nu} = 0$  in the weak field limit, it follows that  $\square(\partial_\nu h^{\mu\nu}) = 0$  hence the harmonic coordinate condition requires  $\square(\partial_\nu h) = 0$ , and therefore the trace of the the field equation implies  $\square h = -2\kappa T = const., T := T^\mu_\mu$ . For dust this requires that  $T = -\rho_0 = const.$  This is, of course, unacceptable. One would not even be able to describe a star, with a smooth distribution of matter localized in a finite region of space.

### Einstein's modified linearized field equation

Now, something very interesting happens. Einstein avoids this problem by modifying the field equation (7) to

$$\square (h_{\mu\nu} - \frac{1}{2} \eta_{\mu\nu} h) = -2\kappa T_{\mu\nu} \tag{8}$$

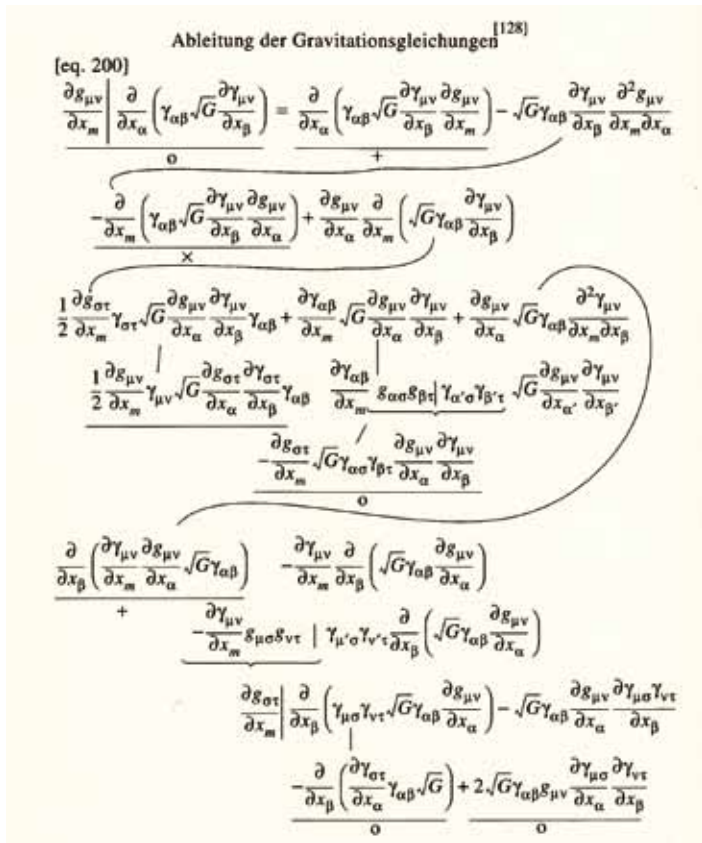


Figure 3: A typical page in Einstein's 'Zürich Notebook', CPAE, Vol. 4, Doc. 10, p.262.

Then the harmonic coordinate condition (6) is compatible with  $\partial_\nu T^{\mu\nu} = 0$ . Remarkably, (8) is the linearized equation of the final theory (in harmonic coordinates). One wonders why Einstein did not try at this point the analogous substitution  $R_{\mu\nu} \rightarrow R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R$  or  $T_{\mu\nu} \rightarrow T_{\mu\nu} - \frac{1}{2} g_{\mu\nu} T$  in the full non-linear equation (5), which would have led to the final field equation of GR. One probable reason for this is connected with the Newtonian limit.

### The problem with the Newtonian limit

The problem with the Newtonian limit was, it appears, one of the main reasons why Einstein abandoned the general covariance of the field equation. Apparently, (8) did not reduce to the correct limit. That it leads to the Poisson equation for  $g_{00}(x)$  is fine, but because of the harmonic coordinate condition the metric can **not be spatially flat**. (The almost Newtonian approximation of (6) and (8) is derived in textbooks on GR; see, e.g., [11], Sect. 4.2.) Einstein found this unacceptable. He was convinced that for (weak) static gravitational fields the metric must be of the form  $(g_{\mu\nu}) = \text{diag}(g_{00}(x), 1, 1, 1)$ , as he already noted on p. 1 of his research notes. I wonder why he did not remember his cautious remark in one of his Prague papers [12] on static gravitational fields, in which – while assuming spatial flatness – he warned that this *may very well turn out to be wrong*, and says that actually it does not hold on a rotating disk. Since a non-flatness would not affect the geodesic equation in the Newtonian limit, there is actually, as we all know, no problem. But Einstein realized this only three years later<sup>3</sup>. Well(!): "If wise men did not err, fools should despair" (Wolfgang Goethe).

At the time, Einstein arrived at the conviction that there were other difficulties implied by generally covariant field equations. One was connected with energy-momentum conservation (see [10].)

### The 'hole' argument against general covariance

At the time when he finished the paper with Grossmann, Einstein wrote to Ehrenfest on May 28, 1913: "The conviction to which I have slowly struggled through is that *there are no preferred coordinate systems of any kind*. However, I have only partially succeeded, even formally, in reaching this standpoint." (CPAE, Vol. 5, Doc. 441.) In a lecture given to the Annual Meeting of the Swiss Naturforschende Gesellschaft in September 1913, Einstein stated: "It is possible to demonstrate by a general argument that equations that completely determine the gravitational field cannot be generally covariant with respect to arbitrary substitutions." (CPAE, Vol. 4, Doc. 16.) He repeated this statement shortly afterwards in his Vienna lecture [13] of September 23, 1913.

The so-called "hole" ("Loch") argument runs as follows (instead of coordinate transformations, I use a more modern language): Imagine a finite region  $\mathcal{D}$  of spacetime – the 'hole' – in which the stress-energy tensor vanishes. Assume that a metric field  $g$  is a solution of a generally covariant field equation. Apply now a diffeomorphism  $\varphi$  on  $g$ ,

<sup>3</sup> In his calculation of the perihelion motion (on the basis of the vacuum equations  $R_{\mu\nu} = 0$ ) it became clear to him that spatial flatness did not hold even for weak static fields.

producing  $\varphi^*g$  (push-forward), and choose the diffeomorphism such that it leaves the spacetime region outside  $\mathcal{D}$  pointwise fixed. Clearly,  $g$  and  $\varphi^*g$  are different solutions of the field equation that agree outside  $\mathcal{D}$ . In other words, generally covariant field equations allow huge families of solutions for one and the same matter distribution (outside the hole). At the time, Einstein found this unacceptable, because this was in his opinion a dramatic failure of what he called the law of causality (now usually called determinism). He then thought that the energy-momentum tensor should (for appropriate boundary or initial conditions) determine the metric *uniquely*.

It took a long time until Einstein understood that this non-uniqueness is an expression of what we now call *gauge invariance*, analogous to the local invariance of our gauge theories in elementary particle physics. On January 3, 1916 he wrote to Besso: "Everything in the hole argument was correct up to the final conclusion."

The role of diffeomorphism invariance of GR, especially for the Cauchy problem, was first understood by Hilbert.

### Final remarks

When Einstein was finishing his work on GR under great stress and was suspending all correspondence with col-

leagues, he still found time to communicate with Michele Besso. On November 17, 1915 he mailed a postcard from Berlin, that contains the great news:

*I have worked with great success during these months. General covariant gravitational equations. Motions of the perihelion quantitatively explained. (...) You will be amazed. I worked horribly strenuously [schauderhaft angestrengt], [it is] strange that one can endure that. (...) (CPAE, Vol. 8, Part A, Doc. 147).*

Besso passed this card on to Zangger: "I enclose the historical card of Einstein, reporting the setting of the capstone of an epoch that began with Newton's 'apple'."

The discovery of the general theory of relativity has often been justly praised as one of the greatest intellectual achievements of a human being. At the ceremonial presentation of Hubacher's bust of A. Einstein in Zürich, W. Pauli said:

*The general theory of relativity then completed and - in contrast to the special theory - worked out by Einstein alone without simultaneous contributions by other researchers, will forever remain the classic example of a theory of perfect beauty in its mathematical structure.*

### Auszug aus einem Interview von Res Jost mit Otto Stern, der mit Einstein von Prag nach Zürich kam und zwei Jahre später an der ETH (mit einem Gutachten von Einstein) habilitierte:

In Zürich war's natürlich sehr schön (...) und besonders deswegen interessant, weil Laue an der Universität war. Ausserdem waren Ehrenfest und Tatjana (...) mindestens ein Vierteljahr, vielleicht auch etwas länger zu Besuch (...). Das gab natürlich immer herrliche Diskussionen im Kolloquium (...). Wir waren auch ein paar jüngere Leute, die ganz eifrig waren. Ehrenfest nannte uns immer den 'Dreistern'. Das waren der Herzfeld und der Kern (und ich). (Kern hatte den Doktor bei Debye gemacht.) Debye war ja der Vorgänger von Laue an der Universität (...). Nur der Weiss (...), Pierre Weiss war damals Experimentalphysiker und Institutsdirektor, der kam nie ins Kolloquium. Er verbot auch das Rauchen, das war furchtbar (...). Dem Einstein konnte man das aber nicht verbieten. Infolgedessen, wenn es eben zu schlimm war, dann bin ich einfach ins Einstein'sche Zimmer gegangen (...) und konnte mich mit ihm unterhalten (...). Das gab dann immer lebhaftere Diskussionen (...) über damals völlig ungelöste Rätsel der Quantentheorie. Das einzige, was man über Quantentheorie wirklich wusste, war die Planck'sche Formel, Schluss (...). Ich bin auch ins Kolleg zu Einstein gegangen (...), das war (...) auch sehr schön, aber nicht für Anfänger. Einstein hat sich ja nie richtig vorbereitet auf die Vorlesung, aber er war eben doch Einstein (...), wenn er da so herumgemarkt hat, war es doch sehr interessant (...), immer sehr raffiniert gemacht und sehr physikalisch vor allen Dingen (...).

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# Histoire de la Physique (9)

## Le modèle atomique de Bohr: origines, contexte et postérité (part 1)

Jan Lacki, Uni Genève

Nous célébrons cette année le centième anniversaire du modèle atomique de Niels Bohr. Pour le physicien, il est le commencement de la route qui allait mener à la formulation de la mécanique quantique; pour l'homme de la rue, il symbolise à lui tout seul la nature quantique du monde atomique. Nombre de ses particularités sont depuis passées dans les esprits et se sont banalisées: c'est oublier combien ce modèle a été révolutionnaire à son époque et combien il reste encore aujourd'hui paradoxal, mais de ces paradoxes profonds et fructueux qui ont pavé la voie de la physique contemporaine. L'atome de Bohr appartient ainsi à cette classe restreinte de grandes idées qui ont fait basculer le cours de la science. Malgré cette importance, peu de personnes, y compris les physiciens, connaissent le contexte précis de la découverte de Bohr et la formulation qu'il donna à ses idées. Son article, tout comme, pour donner un autre exemple notable, celui d'Einstein initiant la relativité en 1905, est aujourd'hui peu connu et encore moins lu. Le centenaire du modèle de Bohr offre une excellente occasion de revenir sur cet épisode capital de l'histoire de la physique quantique.

### 1 Une courte histoire de la spectroscopie

Quand Bohr entre en scène, l'étude des spectres est vieille de plus d'un demi-siècle, et ses racines remontent encore plus loin <sup>1</sup>. L'histoire commence avec l'observation du spectre solaire par le britannique William H. Wollaston, qui relève en 1802 l'existence des raies sombres; elles intrigueront ensuite fortement Joseph v. Fraunhofer qui en comptera 476 entre 1814 et 1815. Fraunhofer introduira aussi dans le champ de la spectroscopie l'usage des réseaux et obtiendra ainsi des résultats remarquables sur la relation entre l'angle d'observation et la longueur d'onde des raies. Il se livrera également à l'étude des spectres d'émission provenant de flammes colorées ou encore d'étincelles produites par décharge des machines électrostatiques. L'étude des spectres électriques se poursuivra et se systématisera avec l'utilisation des bobines d'induction et, dans les années 1845-1850, de la bobine de Ruhmkorff.

Il reviendra à Gustav Kirchhoff (1859) d'apporter des arguments décisifs en faveur de l'interprétation des raies sombres du soleil comme des raies d'absorption. Observons que c'est dans le contexte de ces travaux que Kirchhoff parviendra à une découverte capitale pour le développement ultérieur de la physique. Réfléchissant sur le rapport entre les pouvoirs d'émission et d'absorption d'un

corps à une longueur d'onde et température données, Kirchhoff obtient son fameux résultat affirmant son universalité pour tout corps. C'est le début de la problématique du rayonnement du corps noir qui amènera à la toute fin du siècle à la loi du rayonnement de Planck et la découverte des quanta.

À défaut d'une correspondance stable entre les éléments et leurs spectres (on a réalisé dans les années 1870 qu'un élément peut produire plusieurs spectres selon les conditions physiques ce qui met fin à l'espoir d'une spectrochimie), on observe tout de même d'autres régularités. On remarque des analogies entre les spectres d'éléments aux mêmes propriétés chimiques et on relève des rapports numériques entre raies d'un même élément (Mascart 1869, Lecoq de Boisbaudrant 1869, Cornu 1885). L'observation des doublets et triplets suggère que l'on a affaire à des harmoniques. Les tentatives d'expliquer les spectres sur la base d'une mécanique de vibrations en analogie avec les phénomènes sonores s'en trouvent renforcées. Les spectres à raies correspondraient aux vibrations internes des molécules alors que leur interaction dans les liquides et les solides conduirait aux spectres continus (Clifton 1866, Stoney 1868, 1871). L'hypothèse d'harmoniques perd cependant de son attrait à partir des années 1880: certaines raies seraient associées à des harmoniques d'ordre trop élevé par rapport à ce qui est physiquement plausible. Alors que l'on ne croit plus à une explication aussi simple des spectres, la conviction de l'existence de lois bien définies régissant les fréquences spectrales et susceptibles de renseigner sur les mécanismes internes à l'atome va cependant croissant. L'histoire de la spectroscopie franchit une étape capitale avec l'obtention de premières lois empiriques pour les longueurs d'onde des raies. La formule de Balmer (1885) pour les raies d'Ångström de l'hydrogène (1868), d'une précision remarquable, donne une impulsion forte à la recherche de formules empiriques de plus en plus générales. Celles-ci culminent avec les contributions de Rydberg (1890) et bien sûr de Ritz avec son principe de combinaisons (1908). Ces travaux s'appuient de manière fondamentale sur la découverte récente, pour des éléments chimiquement semblables, de l'existence de séries homologues aux propriétés communes comme celles de présenter un point d'accumulation vers les hautes fréquences avec des intensités de raies allant décroissant.

### 2 La spectroscopie et la structure de l'atome: questions et enjeux au tournant du siècle

L'obtention de formules empiriques pour les fréquences de séries de raies ne pouvait qu'aviver les tentatives pour concevoir un modèle de l'atome. Des modèles dynamiques avaient été proposés bien avant l'avènement de la théorie des quanta et la découverte de l'électron. La conception de la lumière comme ondulation d'un éther élastique suggérait que les spectres résultaient de vibrations moléculaires transmises mécaniquement à l'éther (Stokes 1852, Stoney 1868). La question de la structure atomique qui permettait

<sup>1</sup> Pour des études détaillées de l'histoire de la spectroscopie, on consultera H. Dingle, *A Hundred Years of Spectroscopy*, *British Journal of History of Science*, vol. 1 (1963), 199-216 ; M.C. Lawrence, *The Role of Spectroscopy in the Acceptance of an Internally Structured Atom (1860-1920)*, thèse de doctorat, University of Wisconsin, 1964 ; W. McGucken, *Nineteenth-Century Spectroscopy : development of the understanding of spectra, 1802-1897*, Johns Hopkins Press, 1969 ; J. C. D. Brand, *Lines of Light: The Sources of Dispersive Spectroscopy, 1800-1930*, Gordon & Breach Science Pub., 1995 ou encore M. Saillard, *Histoire de la spectroscopie*, Cahiers d'histoire et de philosophie des sciences, no 26 (1988).

ces vibrations ne pouvait donner lieu qu'à des spéculations. Suivant les travaux de Helmholtz sur l'hydrodynamique des vortex dans un fluide idéal (1858), William Thomson (Lord Kelvin) proposait déjà en 1867 un modèle de l'atome comme un vortex de l'éther. Plus que les résultats de la spectroscopie, la découverte de l'électron (1896) rendit obsolètes ces premières tentatives. Avec l'idée d'électrons comme corpuscules fondamentaux de la matière, et donc de l'atome, on disposait d'un nouveau principe de sa construction en prenant en compte l'émission de rayonnement électromagnétique par des charges en accélération. Le mécanisme d'excitation mécanique de l'éther était remplacé par celui de l'excitation électromagnétique par le mouvement de l'électron devenu oscillateur hertzien (Larmor 1897, pressenti par Stoney 1889). La difficulté principale consistait alors à concilier les conditions assurant les stabilités mécanique et radiative de l'atome. En effet, on savait depuis longtemps (Earnshaw 1831) qu'un système de corpuscules sous l'effet mutuel des forces en inverse du carré de la distance ne pouvait donner lieu à des configurations statiques stables: il fallait donc que les électrons de l'atome soient en mouvement. Cela impliquait à son tour que ces électrons devaient, pour rester confinés et assurer la permanence de l'atome, subir nécessairement des accélérations et donc rayonner de l'énergie électromagnétique, ce qui hypothéquait de nouveau la stabilité de l'atome par perte de son énergie.

Larmor montrait cependant en 1897 que les déperditions d'énergie pour un système de charges accélérées pouvaient être limitées, voire nulles, si la somme vectorielle des accélérations était nulle. On le voit, la satisfaction simultanée de conditions assurant la stabilité constituait déjà en soi un problème formidable mais il fallait encore que les solutions de ce problème soient en nombre suffisant pour expliquer la variété d'éléments chimiques connus. Comme si ces défis ne suffisaient pas, tout modèle stable de l'atome devait de surcroît rendre compte des raies spectrales en accord avec les formules empiriques de Rydberg et Ritz.

Au vu de ces multiples exigences, souvent contradictoires, il n'est pas étonnant que peu de modèles atomiques réussissaient à les satisfaire toutes et encore, ils ne le faisaient qu'au prix d'hypothèses au caractère *ad hoc* marqué<sup>2</sup>. En 1901, James H. Jeans proposait pour chaque électron de l'atome l'existence d'un partenaire positif de même masse. Dans l'état normal de l'atome, la configuration d'ensemble pouvait être stable grâce à l'hypothèse d'une force compensant l'interaction électrostatique ; le spectre résultait des oscillations électroniques autour des positions d'équilibre. Avec ses "dynamides", Philipp Lenard concevait au contraire des paires de charges où le partenaire de l'électron avait une masse sensiblement plus grande (1903). Nous nous souvenons mieux aujourd'hui des conceptions de Jean Perrin qui, en 1901, suggérait un atome planétaire avec une charge positive retenant les charges négatives en orbite. Le Japonais Hantaro Nagaoka 1904 s'inspirait pour sa part des réflexions de jeune Maxwell sur la stabilité gravitationnelle des anneaux de Saturne (1860) pour proposer un modèle saturnien où des anneaux de charges négatives en orbite présentent des oscillations responsables des

raies. Comme il s'avéra rapidement, le modèle de Nagaoka, basé sur les forces électrostatiques et non gravitationnelles, présentait en fait des problèmes de stabilité mécanique, un handicap plus sérieux que celui de la déperdition d'énergie par rayonnement qui pouvait être résolu selon les lignes suggérées par Larmor.

Dès 1903, J. J. Thomson concevait à son tour un modèle qui marqua pendant quelques années les esprits. Selon sa conception, la charge positive de l'atome était distribuée de manière uniforme dans tout le volume de l'atome. Les électrons, distribués en anneaux, tournaient à l'intérieur. S'appuyant sur les observations de Larmor, Thomson mettait beaucoup d'espoir dans le fait que ses configurations électroniques, pourvu qu'un nombre suffisant d'électrons soit considéré, présentaient un moment dipolaire total nul, ce qui assurait, à cet ordre, l'absence de rayonnement électromagnétique. Peu de temps après le même Thomson montrait cependant que le nombre d'électrons dans l'atome devait être de même ordre de grandeur que le nombre atomique (1906). Cela mettait fin à de nombreux modèles qui multipliaient le nombre des électrons à outrance, à commencer par le sien.

La contrainte sur le nombre d'électrons présents dans l'atome permit à l'époque de trancher aussi l'importante question de savoir si l'ensemble de raies du spectre pouvait être imputé à une seule source, un atome dans une seule configuration, ou si des configurations différentes d'un même atome, voire des variétés atomiques différentes, devaient être envisagées pour chaque raie. Comme les solutions à une seule source pour l'ensemble du spectre impliquaient un nombre prohibitif d'électrons<sup>3</sup>, on finit par pencher en faveur de configurations atomiques différentes pour chaque raie.

Une étude des modèles atomiques ne devrait pas à ce stade omettre les conceptions du suisse Walter Ritz et de son compatriote Arthur Schidlof. Comme j'eus déjà l'occasion de traiter du parcours scientifique de ces deux pionniers de la physique théorique suisse dans les *Communications*<sup>4</sup> je terminerai juste sur une remarque. Les modèles de Ritz étaient caractéristiques de leur temps. Tout comme ceux de ses contemporains, ils étaient a posteriori handicapés par la conjonction d'une physique classique et d'hypothèses *ad hoc*. Schidlof, en prenant en compte l'existence du quantum d'action (1911), apparaît au contraire se mettre résolument du côté d'une physique nouvelle<sup>5</sup>. Sa pensée est pourtant encore insuffisamment affranchie de la tradition classique: elle ne visait pas tant l'obtention d'un modèle quantique de l'atome qu'une explication de l'existence et de la valeur du quantum d'action de Planck. Ce sera tout le contraire avec la contribution de Bohr.

### 3 L'avancée de Niels Bohr

Quand Bohr propose son modèle, les quanta viennent à peine d'être acceptés comme une réalité physique incon-

<sup>3</sup> Voir Carazza et Robotti, *op. cit.*, pp. 313-315.

<sup>4</sup> J. Lacki, Arthur Schidlof, un pionnier de la physique théorique suisse, *Communications de la SSP*, no 34, mai 2011, 48-51; Walter Ritz (1878-1909), the revolutionary classical physicist, *Communications de la SSP*, no 35, septembre 2011, 26-29.

<sup>5</sup> A. Schidlof, Zur Aufklärung der universellen elektrodynamischen Bedeutung der Planckschen Strahlungskonstanten  $h$ , *Annalen der Physik*, vol. 340 (1911), 90-100.

<sup>2</sup> Pour une étude des modèles atomiques proposés dans le cadre de la physique classique, voir Bruno Carazza et Nadia Robotti, Explaining Atomic Spectra within Classical Physics: 1897-1913, *Annals of Science*, vol. 59 (2002), 299-320.

tourable. Autant on salue en 1900 la loi du rayonnement du corps noir de Planck comme une grande réussite, autant on fait peu de cas, pour ne pas dire qu'on rejette, l'explication ("désespérée" comme l'avait qualifiée lui-même Planck) de cette loi en termes de discontinuités dans les échanges énergétiques entre matière et rayonnement. Des années après la découverte de Planck on en cherchera encore une justification "classique". Il y a pourtant des esprits qui prennent les quanta d'emblée au sérieux, ainsi le jeune Einstein qui contribuera pour beaucoup à leur donner une respectabilité. Dans l'un des articles de sa "merveilleuse année" 1905 Einstein montre que dans le régime de Wien (grandes fréquences/petites températures) les propriétés thermodynamiques d'un volume d'énergie électromagnétique monochromatique de fréquence  $\nu$  sont *thermodynamiquement semblables* à celles d'un gaz de corpuscules d'énergie individuelle  $h\nu$ <sup>6</sup>. Ces "grains" d'énergie, dont Einstein se garde encore bien d'affirmer l'existence physique autonome, signalent un aspect corpusculaire de la lumière: plus tard Einstein montrera, toujours dans le cadre d'une analyse de propriétés énergétiques, que cet aspect cohabite avec celui, classique et familier, des phénomènes ondulatoires<sup>7</sup>. C'est l'application de la nature "granulaire" de l'énergie électromagnétique à l'explication de l'effet photoélectrique, plutôt que la relativité, qui apportera à Einstein son prix Nobel<sup>8</sup>. En 1907 Einstein récidive sur le chemin de l'exploration des conséquences "quantiques" de la loi de Planck: si on comprend cette dernière comme remplaçant l'énergie moyenne classique d'un oscillateur unidimensionnel,  $kT$ , par l'expression:

$$kT \rightarrow \frac{h\nu}{e^{\frac{h\nu}{kT}} - 1}$$

alors pourquoi ne pas opérer cette substitution pour les oscillateurs matériels modélisant la matière dans les solides ?<sup>9</sup> Le résultat permet d'expliquer immédiatement la décroissance des chaleurs spécifiques à basse température, l'une des énigmes qui, vers la fin du XIX<sup>e</sup> siècle, constituait un argument puissant contre la théorie cinétique des gaz et contre toute reconstruction de la thermodynamique sur la base d'une mécanique des constituants atomiques: grâce à Einstein, on comprend que ce n'était pas tant cette approche qui était fautive, mais les lois mécaniques sur les-

6 Über einen die Erzeugung und Verwandlung des Lichtes betreffenden heuristischen Gesichtspunkt, *Annalen der Physik*, vol. 17 (1905), pp. 132-148

7 Entwicklung unserer Anschauungen über das Wesen und die Konstitution der Strahlung, *Physikalische Zeitschrift*, vol. 10 (1909), 817-825, conférence donnée lors du 81<sup>e</sup> congrès de la *Gesellschaft Deutscher Naturforscher* à Salzburg. Einstein y argumente aussi en faveur d'un quantum de lumière aux propriétés résolument corpusculaires. Il faudra cependant encore des années avant que l'idée ne s'impose: les expériences de la diffusion de Compton (1923) jouèrent ici un rôle décisif. Il est intéressant d'observer que Niels Bohr lui-même rejettera initialement la réalité des corpuscules de lumière préférant dans un premier temps voir dans les aspects corpusculaires une manifestation de l'insuffisance, à l'échelle atomique, des descriptions spatio-temporelles, voir par exemple Dugald Murdoch, *Niels Bohr's philosophy of physics*, Cambridge University Press, 1989.

8 On connaît bien les hésitations du comité du Nobel de physique à récompenser Einstein sur la relativité, voir R. M. Friedman, *The Politics of Excellence: Behind the Nobel Prize in Science*, W. H. Freeman Books, 2001.

9 Die Plancksche Theorie der Strahlung und die Theorie der spezifischen Wärme, *Annalen der Physik*, vol. 22 (1907), 180-190.

quelles elle s'appuyait<sup>10</sup>.

Ces deux succès, où le génie d'Einstein se révèle autant que dans son article sur l'électrodynamique des corps en mouvement, contribuent plus que tout autre, à convaincre la communauté de l'intérêt de l'hypothèse quantique et, progressivement, de l'existence réelle des quanta. La première conférence Solvay en 1911 dont nous connaissons la photographie emblématique est consacrée à "La théorie du rayonnement et les quanta": on peut dire que ses travaux officialisent les quanta comme partie intégrante de la physique<sup>11</sup>. Cependant, nous sommes encore loin d'une modification que les quanta opéreraient sur les lois des systèmes individuels: dans ses deux travaux Einstein tire les conséquences de l'existence des quanta à partir d'un travail d'analyse des lois phénoménologiques obtenues par ses prédécesseurs (Wien, Planck, etc.) mais il ne les dérive pas d'une modification postulée des lois de base de la mécanique ou de l'électrodynamique affectant les constituants élémentaires<sup>12</sup>. Bohr se confrontera en revanche frontalement à ces lois classiques et c'est précisément pour cette raison que sa contribution est une étape capitale sur le chemin de la mécanique quantique.

A l'époque de la formulation de son modèle Niels Bohr est depuis mars 1912 collaborateur au laboratoire de Rutherford à Manchester. Il vient à peine de défendre sa thèse à Copenhague sur "la théorie électronique des métaux" (1911). Après un séjour décevant chez J. J. Thomson à Cambridge qui voit les deux hommes s'affronter à propos du... modèle atomique de Thomson, Bohr se tourne vers Rutherford<sup>13</sup>. Celui-ci vient à l'époque d'apporter des arguments décisifs contre la conception de Thomson en montrant que les expériences de la diffusion à large angle des particules alpha concluent aux effets d'une déflexion unique sur des centres de diffusion intraatomiques: le noyau atomique est découvert<sup>14</sup>. L'accueil que Bohr reçoit de la part du Néo-zélandais est d'emblée meilleur que celui que lui a réservé Thomson. Rutherford est convaincu de l'importance des idées de Planck et encourage les efforts de son jeune collègue. Dans son laboratoire Bohr travaille sur l'absorption des particules alpha par la matière et c'est pour lui l'occasion de se rapprocher encore plus de la pro-

10 Pour les critiques de la théorie cinétique au XIX<sup>e</sup> siècle, voir S. Brush, *The kind of motion we call heat. A History of the Kinetic Theory of Gases in the Nineteenth Century*, North Holland, 1986.

11 C'est Walter Nernst, impressionné par les travaux d'Einstein, qui persuade le riche industriel Ernest Solvay de financer une conférence solennelle consacrée à la physique quantique, voir D. Kormos Barkan, *The Witches' Sabbath: The First International Solvay Congress in Physics*, *Science in Context*, vol. 6 (1993), 59-82. aussi M.-C. Bustamante, Paul Langevin et le Conseil Solvay de 1911, *Images de la physique*, 2011, 3-9.

12 Cela permet de comprendre comment Einstein est dans ces années indiscutablement un père fondateur de la théorie quantique alors qu'il deviendra, un dizaine d'années plus tard, un féroce critique de la mécanique quantique. L'existence des quanta n'entraîne à ce moment pas en conflit avec les convictions profondes d'Einstein sur la réalité et sur la manière dont nous devrions la décrire: les thèmes d'indéterminisme, de l'inexistence de propriétés objectives des systèmes, contre lesquels Einstein se battra jusqu'à la fin, n'étaient pas (encore) affleurants à la surface de la nouvelle physique quantique. Tout changera avec la mécanique quantique et surtout l'interprétation qu'en prônera Bohr.

13 Dans son survol "60 years of quantum mechanics", E. U. Condon rapporte que Bohr, suite à son désaccord avec Thomson, avait été "poliment invité" à aller voir ailleurs, voir *Physics Today*, vol. 15 (1962), 45.

14 The scattering of alpha and beta particles by matter and the structure of the atom, *Philosophical Magazine*, vol. 21 (1911), 669-688.

blématique de l'atome <sup>15</sup>. Le modèle nucléaire de l'atome suggéré par Rutherford offre un cadre prometteur mais entraîne aussi son lot de problèmes. En particulier, Bohr réalise que les lois dynamiques classiques sont impuissantes à fixer seules une échelle pour sa taille. En termes d'analyse dimensionnelle, il manque un ingrédient: le modèle de Rutherford faisant intervenir les masses et les charges des électrons, on peut se convaincre qu'il est impossible de construire à partir de là une constante ayant la dimension d'une longueur. Tout change cependant si l'on introduit la constante de Planck: on peut alors former l'expression  $h^2/me^2$  qui a non seulement la bonne dimension mais aussi le bon ordre de grandeur atomique ( $h^2/me^2 \approx 2 \cdot 10^{-10}$  m). La stratégie de Bohr allait dès lors différer considérablement de celle de ses prédécesseurs comme Schidlof. Alors que ce dernier espérait, comme on l'a vu, justifier la valeur de la constante  $h$  sur la base d'un mécanisme atomique décrit en termes classiques, Bohr renverse la perspective en prenant acte de l'existence du quantum d'action et de sa valeur  $h$  pour rendre compte de la structure de l'atome et dériver les propriétés de son spectre. Il fallait encore qu'il comprenne comment lier la constante de Planck au champ de ses recherches. De retour à Copenhague dès septembre 1912, Bohr ne prenait pas encore en considération ce que les données spectroscopiques pouvaient lui enseigner mais dès qu'il eut compris l'importance des formules établies par Balmer, Rydberg et Ritz, les pièces du puzzle commencent à s'assembler: "dès que je pris connaissance de la formule de Balmer, toute cette affaire devint claire" <sup>16</sup>. Nous pouvons maintenant examiner les idées fortes du modèle de Bohr, non pas tant pour les découvrir (elles sont passées largement dans notre culture), mais pour examiner comment Bohr les exposa à l'origine dans sa publication <sup>17</sup>. Pour un atome constitué d'une charge positive  $E$  autour de laquelle orbite une charge égale mais de signe opposé  $e$ , l'énergie totale est:

$$W = T + V = \frac{1}{2}mv^2 + \frac{Ee}{r^2}$$

La condition de stabilité pour une orbite circulaire de rayon  $r$  et fréquence  $\nu$  donne

$$\frac{mv^2}{r} = -\frac{Ee}{r^2} \Leftrightarrow m\omega^2 r = -\frac{Ee}{r^2},$$

et, pour l'atome d'hydrogène ( $E = -e$ ),

$$m\omega^2 r = \frac{e^2}{r^2} \Rightarrow \omega^2 = \frac{e^2}{mr^3} = (2\pi\nu)^2.$$

$$\text{Ainsi } W = -\frac{e^2}{2r}, \text{ alors que } \nu^2 = -\frac{8W^3}{4\pi^2 e^4 m}.$$

<sup>15</sup> On the theory of the decrease of velocity of moving electrified particles on passing through matter, *Philosophical Magazine*, vol. 25 (1913), 10-31.

<sup>16</sup> "As soon as I saw Balmer's formula, the whole thing was immediately clear to me", cité par Max Jammer, *The conceptual development of quantum mechanics*, McGraw Hill, 1966, p. 77.

<sup>17</sup> On the constitution of atoms and molecules, *Philosophical Magazine*, vol. 26 (1913), 1-25, 476-502, 857-875.

La donnée de l'énergie détermine donc entièrement l'orbite circulaire correspondante <sup>18</sup>.

Mais comment faire entrer l'hypothèse des quanta, et la dimension de  $h$ , dans le problème de la structure de l'atome ? Certes, la quantification des échanges énergétiques entre la matière et le rayonnement doit avoir une conséquence au niveau de la structure atomique, mais comment faire le lien ? Bohr propose de considérer le processus de la formation de l'atome par la capture d'un électron par le noyau. Infiniment loin du noyau l'électron est libre,  $W = 0$ . Supposons qu'il soit capturé sur une orbite d'énergie  $W$  négative (état lié !). Par la conservation de l'énergie, une quantité d'énergie positive,  $-W$ , doit être libérée dans le processus: Bohr, suivant l'hypothèse quantique, suppose que c'est sous la forme d'un rayonnement d'un certain nombre  $\tau$  (entier !) de quanta d'énergie. Il pose:

$$-W = \tau h \nu' \equiv \tau h \frac{\nu}{2}, \quad (1)$$

avec la fréquence du quantum rayonné  $\nu'$  posée égale à la moitié (!) de la fréquence de révolution mécanique de l'orbite de capture. L'hypothèse de Bohr fixe, parmi le continuum des énergies un nombre infini, mais néanmoins discret, d'entre elles :

$$-W = \frac{2\pi^2 e^4 m}{h^2} \frac{1}{\tau^2}. \quad (2)$$

La différence des énergies, pour deux nombres  $\tau_1$  et  $\tau_2$  donnés est alors :

$$\Delta W = -\frac{2\pi^2 e^4 m}{h^2} \left( \frac{1}{\tau_2^2} - \frac{1}{\tau_1^2} \right);$$

Si de tels processus de changement de niveau énergétique surviennent dans l'atome, on doit supposer, avec Bohr, qu'ils donnent lieu à une émission/absorption de quanta d'énergie de rayonnement électromagnétique de fréquence  $\nu'$  donnée par la formule

$$h\nu' = -\Delta W = \frac{2\pi^2 e^4 m}{h^2} \left( \frac{1}{\tau_2^2} - \frac{1}{\tau_1^2} \right).$$

En posant  $\tau_2 = 2$ , et  $\tau_1 = 3; 4; 5; \dots$  la formule ci-dessus reproduit les valeurs des fréquences des raies spectrales de la série de Balmer (1885) exprimée, dans la formule de Rydberg (1890), par:

$$\nu' = R c \left( \frac{1}{\tau_2^2} - \frac{1}{\tau_1^2} \right).$$

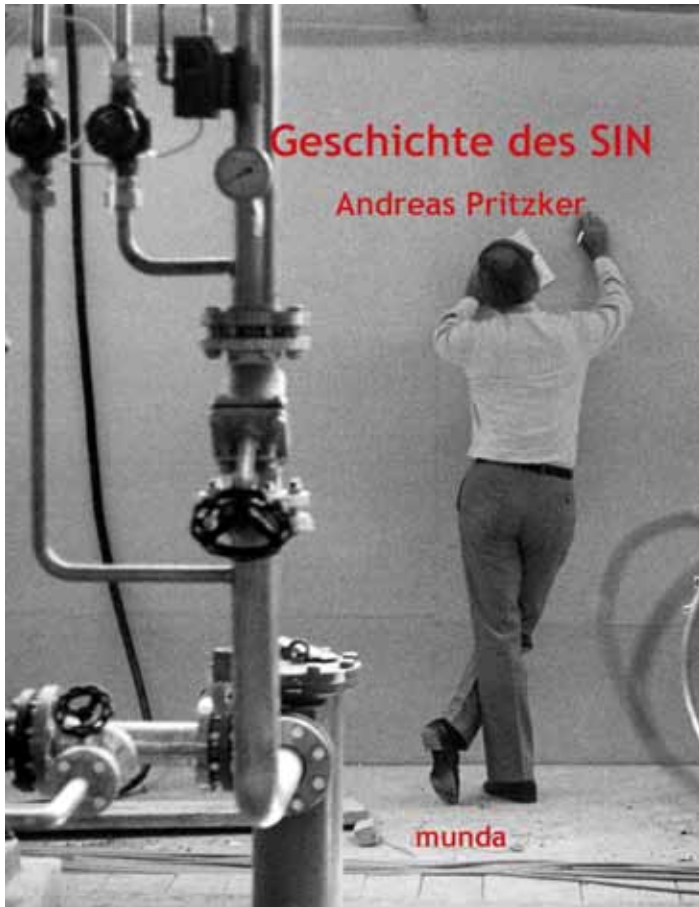
Bohr avait donc réussi à obtenir la valeur de la constante de Rydberg  $R$  à partir de constantes élémentaires,

$$R = \frac{2\pi^2 e^4 m}{ch^3}.$$

<sup>18</sup> En fait on peut montrer que le résultat s'applique aussi aux orbites elliptiques: leur grand axe  $2r$  et la fréquence de rotation de l'électron  $\nu$  sont déterminés par la donnée de l'énergie de l'orbite et ne dépendent pas de la valeur de l'excentricité.

# Geschichte des SIN

Buchbesprechung von Andreas Pritzker



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Das Buch erzählt die Geschichte des Schweizerischen Instituts für Nuklearforschung (SIN). Das Institut wurde 1968 gegründet und ging 1988 ins Paul Scherrer Institut (PSI) über. Die Gründung des SIN erfolgte in einer Zeit, als die Physik als Schlüsseldisziplin für die technologische und gesellschaftliche Entwicklung galt. Der Schritt war für ein kleines Land wie die Schweiz ungewöhnlich und zeugte von Mut und Weitsicht. Ungewöhnlich waren in der Folge die Leistungen des SIN im weltweiten Vergleich sowie sein Einfluss auf die schweizerische, teils auf die internationale Wissenschaftspolitik.

Die Ausgangslage war günstig. Die ETH Zürich war bereits in den 1930er Jahren führend im Gebiet der Kernphysik. Zudem wurde in den 1950er Jahren das CERN in Genf gegründet. An beidem war Paul Scherrer, Leiter des Physikalischen Instituts der ETH, massgeblich beteiligt. Er sorgte früh dafür, dass an der ETH Teilchenbeschleuniger als Forschungsinstrumente eingesetzt wurden. Eines davon war das berühmte ETH-Zyklotron. Als sich dessen Nutzungsmöglichkeiten in den 1950er Jahren allmählich erschöpften, gründete Scherrer die Zyklotronplanungsgruppe, welche den Bau einer leistungsfähigeren Maschine für die Kernphysik zum Ziel hatte. Bereits diese hätte den Rahmen eines einzelnen Hochschulinstituts gesprengt. In der Planungsgruppe waren denn auch die Universitäten von Basel und Zürich vertreten.

Im Hinblick auf Scherrers Emeritierung 1960 wählte der Bundesrat 1959 Jean-Pierre Blaser zu dessen Nachfolger an der ETH. Blaser "erbte" die Zyklotronplanungsgruppe. Unter dem Eindruck der weltweiten Entwicklung strebte Blaser allerdings anstelle eines Zyklotrons für die Kernphysik eine Maschine an, die den Einstieg in die Hochenergiephysik ermöglichte. Er wurde dabei unterstützt durch den Theoretiker Res Jost, der die Hochenergiephysik als fruchtbares künftiges Arbeitsgebiet betrachtete.

Blaser, der Ende Februar 2013 seinen 90. Geburtstag feiern konnte, verfolgte dabei die Idee eines grossen Teilchenbeschleunigers, den die ETH für sämtliche schweizerischen Universitäten betreiben sollte. In den 1950er Jahren waren weltweit mehrere Maschinen im Bereich um 500 MeV gebaut worden. Sie ermöglichten es, Mesonen künstlich zu erzeugen und vorerst als solche zu studieren. Der nächste Schritt war die Idee, Mesonen als Werkzeuge einzusetzen. Die Mesonen wurden mit Protonenbeschleunigern erzeugt. Für die sogenannten Mesonenfabriken waren hohe Protonenströme - man sprach von 100 Mikroamp - notwendig.



Der Ringbeschleuniger des SIN mit seinen Erbauern im September 1973

Hans Willax, den bereits Scherrer als Physiker angestellt hatte, entwarf das zweistufige Zyklotron-Konzept, das später unter seiner Leitung verwirklicht wurde. Obschon dem Projekt, wie bei solchen Vorhaben üblich, Opposition aus Hochschulkreisen erwuchs, waren Bundesrat Tschudi und ETH-Präsident Pallmann entschlossen, es zu verwirklichen, weil sie sich starke Impulse für den Forschungsstandort Schweiz versprochen. Die Eidgenössischen Räte bewilligten 1965 (im Rahmen einer Baubotschaft, welche auch die ersten Bauten der ETH-Hönggerberg umfasste) einen Baukredit von beinahe 100 Millionen Franken. Und auf Anfang 1968 wurde das SIN als Annexanstalt der ETH gegründet. Von 1966 an entwickelten zumeist junge, begabte Physiker unter der Leitung von Blaser und Willax an der ETH, dann bei der Maschinenfabrik Oerlikon das SIN-Zyklotron, und ab 1968 wurde das Institut auf der grünen Wiese in Villigen, gegenüber dem ebenfalls zur ETH gehörenden Eidgenössischen Institut für Reaktorforschung (EIR) erbaut. Im Februar 1974 war es dann soweit: das SIN produzierte die ersten Pionen.



Gute Stimmung im Kontrollraum des SIN am 24. Februar 1974, als die ersten Pionen produziert wurden.

Die Beschleunigeranlage erfüllte sämtliche Erwartungen. Sie wurde in den folgenden Jahrzehnten laufend ausgebaut und erreichte in ihrem Einsatzbereich die Weltspitze. Ihre Qualität lag aber darin, dass sie, als die Teilchenphysik an Aktualität verlor, zusätzlich für viele weitere Forschungsprogramme in Medizin und Materialwissenschaften eingesetzt werden konnte. Sie ist heute noch ein Standbein des PSI. Dass diese Geschichte nun in allgemein verständlicher Form vorliegt, ist das Verdienst einiger von Anfang an am Projekt beteiligter Physiker, welche die Initiative dazu ergriffen, solange noch Zeitzeugen befragt werden konnten. Wie immer zeigen die offiziellen Dokumente nur einen Ausschnitt der Wirklichkeit. Will man den Menschen, die ihren Beitrag zum Gelingen leisteten, nahe kommen, braucht es persönliche Erinnerungen. Der Text stützt sich auf beides. Er hält zudem die Geschehnisse in zahlreichen (schwarz-weiß) Bildern fest.

### Widerstand gegen das SIN-Projekt

Das Projekt der Mesonenfabrik traf teilweise bei den Physikern auf Widerstand. Besonders die Kernphysiker hätten lieber eine Maschine gehabt, wie sie von der ursprünglichen Zyklotron-Planungsgruppe ETH-Uni Zürich-Uni Basel geplant gewesen war. Die Projektleiter der Mesonenfabrik gingen daher einen Kompromiss ein, indem sie als Injektor für den Ringbeschleuniger das Philips-Zyklotron wählten. Da dieses nicht geeignet war für den späteren Hochstromausbau, entwickelte das SIN schon bald den Injektor II nach demselben Prinzip wie für den Ringbeschleuniger. Im Hinblick auf den SIN-Baukredit in der ETH-Baubotschaft 1965 wandte sich eine Gruppe von Physikern an Bundesrat Tschudi, um das Projekt zu verhindern. Tschudi und ETH-Präsident Pallmann liessen sich nicht beirren. Tschudi meinte Blaser gegenüber, dass ein Projekt, das dermassen auf Opposition stosse, gut sein müsse; er solle weiterfahren damit.

Der Autor arbeitete in den 1980er Jahren selbst am SIN, später beim ETH-Rat und schliesslich in der Direktion des PSI.

Die Opposition flammte in den Eidgenössischen Räten nochmals beim teuerungsbedingten Zusatzkredit in der ETH-Baubotschaft 1972 auf. Sprecher der Opposition war der Basler Standesherr Wenk, der sich wohl auf eine Intervention von Basler Physikern stützte. Das veranlasste Bundesrat Tschudi zur Erklärung:

*"Die Finanzverwaltung ist in der Lage, dieses Kreditbegehren zu beurteilen, weil die Direktion der Finanzverwaltung in der Baukommission für das Schweizerische Institut für Nuklearforschung mitwirkt. Ich muss - Herr Wenk hat das schon gesagt - unterstreichen: die Finanzverwaltung ist der Meinung, dass hier ein besonders mustergültiger Bau erstellt wird, der in bezug auf Planung des Baus, auf sparsame Bauausführung andern als Modell dienen kann, dass also in Bezug auf die Sparsamkeit und die gute Bauorganisation, die gute Planung des Baues der Baukommission, die unter Leitung des früheren Direktors der Brown Boveri, Herrn Dr. Seippel, steht, das beste Zeugnis ausgestellt werden kann."*

Andreas Pritzker hat mit Unterstützung von Kollegen aus dem ehemaligen Schweizerischen Institut für Nuklearforschung (SIN) die Vorgeschichte, Gründung und Forschungsaktivitäten des SIN nachgezeichnet. Es wird lebendig, mit zahlreichen Anekdoten umrahmt beschrieben, wie die erste Schweizer Grossforschungsanlage, eine "Mesonenfabrik", mit dem von Hans Willax entworfenen zweistufigen Protonenbeschleuniger mit Injektor- und Ringzyklotron, in Zusammenarbeit mit der Industrie realisiert wurde. Eng verbunden mit der Geschichte des SIN ist das Wirken von Prof. Dr. Jean-Pierre Blaser. Er war Initiator dieser strategischen Forschungsinitiative, die den Aufbau eines nationalen Forschungslabors für universitäre Forschungsbedürfnisse auch ausserhalb der Grundlagenphysik zum Ziel hatte. Er war Gründer und Direktor des SIN während den 20 Jahren seines Bestehens. Und er war auch einer der Hauptinitiatoren für die Zusammenführung des SIN mit dem Eidgenössischen Institut für Reaktorforschung (EIR) zum Paul Scherrer Institut (PSI) im Jahre 1988. Andreas Pritzker zeigt in der Nachzeichnung der SIN-Geschichte wie die breiten naturwissenschaftlichen Interessen von Jean-Pierre Blaser über die Physik hinaus zur Realisierung und Förderung von einzigartigen Projekten im Bereich der Medizin (Krebstherapie und -diagnostik), der Material- und Festkörperforschung (Spallationsneutronenquelle, Supraleitung) und der Energieforschung (Kernfusion) führten. Das Buch über das SIN gibt einen guten Einblick in den Forschungsbetrieb einer Institution, die grosse Forschungsanlagen kreiert und betreibt und diese auch externen Forschenden zur Verfügung stellt. Das Buch ist sehr lesenswert. Es ist auch eine Hommage an Jean-Pierre Blaser, der dieses Jahr bei guter Gesundheit seinen 90. Geburtstag feiern konnte.

Martin Jermann, Paul Scherrer Institut

# Lehrerfortbildung: 18 Deutschschweizer Lehrer im Herz von CERN

Christine Plass (Text und Bilder)

Im Rahmen der Nachwuchsförderung setzt sich die SPG für die Lehrerfortbildung im Gebiet der Physik ein. Im Frühjahr wurde aus aktuellem Anlass, im Zusammenhang mit der Higgs-Entdeckung am CERN, eine Lehrerfortbildung mit Schwerpunkt Teilchenphysik zusammen mit [teilchenphysik.ch](http://teilchenphysik.ch) durchgeführt. Anfang Juni 2013 reisten 18 Lehrerinnen und Lehrer aus der Deutschschweiz nach Genf. Der Weiterbildungstag am CERN vermittelte ihnen Anschauungsmaterial und Experimente, um Hochenergiephysik zu unterrichten.

"Das ist eine einmalige Gelegenheit, den Detektor zu besichtigen!", erkannten acht Physiklehrer der Kantonsschule Zug, als ihr Kollege Markus Schmidinger ihnen von seiner Einladung ans CERN erzählte. Schmidinger hatte an einer Fortbildung zu Teilchenphysik in Bern teilgenommen und war zur Folgeveranstaltung ans CERN nach Genf eingeladen worden. Höflich fragte er an, ob seine Kollegen wohl mitkommen dürften? Initiator Hans Peter Beck, Physiker am CERN und Dozent der Uni Bern, überlegte nicht lange. Er konzipierte sein Programm so um, dass es auch ohne Vorbildung verständlich war. Insgesamt nahmen 18 Lehrerinnen und Lehrer aus der Kantonsschule Ausserschwyz, dem Gymnasium Oberaargau, dem Gymnasium Rämibühl in Zürich und dem Gymnasium Biel die Chance wahr, das CERN von innen kennen zu lernen. Um trotz längerer Anreise einen vollen Tag am CERN zu erleben, waren sie bereits am Tag zuvor angereist und konnten kostenlos im CERN-Hostel übernachten.



Hans Peter Beck erklärt das CERN und wie Lehrer ihre Schüler mit einfachen Modellen und Experimenten an Teilchenphysik heranführen können.

Es gehört zum Verständnis des Conseil Européen pour la Recherche Nucléaire (kurz CERN) die Schulbildung zu unterstützen. "Wir möchten, dass moderne Physik in die Schulen Einzug findet und der Unterricht nicht bei der schiefen Ebene aufhört", erklärt Hans Peter Beck. Aus aller Welt kommen Lehrkräfte ans CERN um sich dort tage- und wochenlang fortzubilden oder gemeinsam mit ihren Schü-

lern eines der faszinierendsten Forschungszentren der Welt kennen zu lernen.



Im Herz von CERN, der Protonenquelle. Am Modell erklärt Mick Storr, wie dem Wasserstoffgas hier die Protonen entzogen werden, die dann im Large Hadron Collider (LHC) miteinander kollidieren.

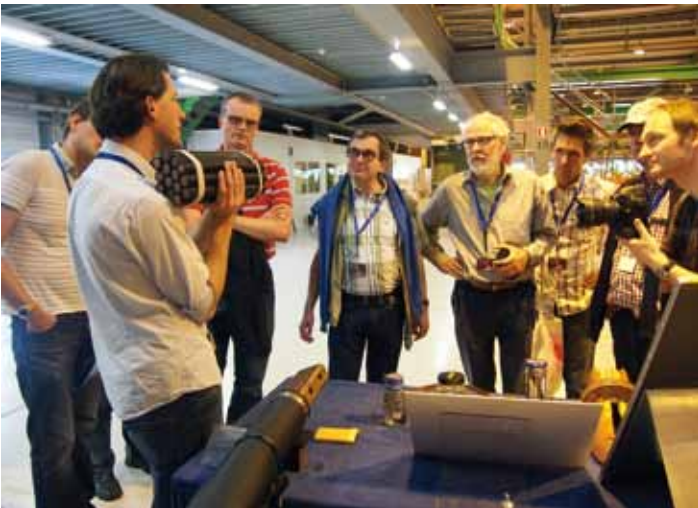
Nach der kurzen Einführung durch Hans Peter Beck geht es direkt ins Herz von CERN, den LINAC2. Hier werden die Protonen bereitgestellt, die sie im Large Hadron Collider aufeinander schießen. "Welcome to the Star Trek Enterprise", scherzt Mick Storr, als wir den Vorraum zur Protonenquelle betreten. Er erstrahlt im Design der 70er Jahre, und das ist kein Retro, sondern Original. Fehlt nur noch, dass Captain Kirk um die Ecke kommt. Mick Storr weiss, wie er seinen Besuchern die Scheu vor der High-End-Physik nehmen kann. Doch was vielleicht noch viel wichtiger ist, er schätzt sehr, was die Lehrer in den Schulen leisten: "Die physikalischen Grundlagen, die Sie an Ihren Schulen vermitteln, sind die Grundlage von allem, was hier im CERN passiert", sagt Mick Storr und lädt seine Zuhörer ein, das, was sie heute sehen, auch einmal mit ihren Schülern zu besichtigen.



Original-Kontrollraum der Protonenquelle.

Mit dem Bus geht es zur nächsten Station, dem LHCb-Experiment. "Sie haben ein Riesenglück, dass Sie direkt in den Detektor reingehen können! Das hab ich selbst seit zehn Jahren nicht mehr gemacht", begrüsst Andreas Schopper seine Besucher. Der Physiker am CERN hat das LHCb Experiment mit aufgebaut und ist Präsident der Schweizerischen Physikalischen Gesellschaft (SPG). Sie hat die Reisekosten für die Lehrer ans CERN übernommen. Bevor ein Fahrstuhl die Reisegruppe 100 Meter ins Erdinnere befördert, erklärt Schopper an einem Modell, was das Besondere am LHCb ist. 700 Wissenschaftler aus 61 Institutionen und 16 Ländern forschen dort nach den Unterschieden zwischen Materie und Antimaterie. Aus der Schweiz sind die ETH Lausanne und die Universität Zürich am Experiment beteiligt. So untersuchten die Forscher erstmals den Zerfall eines weiteren Teilchens, dessen Messung abermals beweist, dass Materie und Antimaterie nicht exakt symmetrisch sind.

Nach einer zügigen Fahrt in 100 Meter Tiefe wartet die nächste Schleuse. Radioaktivität, vor der auf der Tür gewarnt wird, herrscht zur Zeit des Shutdowns hier unten zwar nicht. Trotzdem hat Schopper ein Dosimeter dabei, da es sich um eine kontrollierte Zone handelt, für die bestimmte Sicherheitsvorkehrungen gelten. Langweilig wird es den Physikern während des Shutdowns übrigens trotzdem nicht, denn es gibt noch riesige Datenmengen, die auf ihre Auswertung warten, wie Markus Joos erklärt. Der Informatiker arbeitet an der Software, die die Messergebnisse aufzeichnet, filtert und speichert. 100 Petabyte Rohdaten sind auf 40.000 Festplatten und 40.000 Bandkassetten gespeichert. Bandkassetten? Tatsächlich setzten die Informatiker am CERN auf diese vermeintlich veralteten Speichermedien, da sie die Daten 100 Mal sicherer aufbewahren als eine Festplatte.



*Gerfried Wiener von der Uni Wien erklärt, warum Supraleitungen im LHC zum Einsatz kamen. Alle dürfen mal testen, wie schwer konventionelle Kupferkabel sind, die in der Lage wären, 13000 Ampère zu leiten, ohne zu schmelzen.*

Danach geht es weiter zur Magnestesthalle. Anhand einiger Modelle erklärt Gerfried Wiener von der Universität Wien, wie der LHC gebaut wurde und welche Hürden dabei zu bewältigen waren. Allein die Kabel! 13000 Ampère laufen

durch den LHC hindurch. Gäbe es keine Supraleitungen müsste der LHC den Umfang des Äquators haben.

Unsere vorletzte Station ist der Kontrollraum des Alpha Magnetic Spectrometer (AMS2). Der schüttelsichere Detektor wurde 16 Jahre lang gebaut und getestet, mit dem letzten Spaceshuttle zur Internationalen Raumstation (ISS) geschossen und von NASA Astronauten auf der ISS installiert. Dort jagt er nach Antimaterie. Wenigstens ein einziges Anti-Helium. Noch besser zwei. Zehn, um ein Paper zu veröffentlichen. Die Wissenschaftler gehen nämlich davon aus, dass beim Urknall riesige Mengen von Materie und Anti-Materie freigesetzt wurden, um sich sogleich wieder gegenseitig zu zerstören. Nach dieser Theorie dürfte es keine stabile Antimaterie in unserem Universum geben – es sei denn, AMS2 lieferte den Gegenbeweis. Bislang hat AMS2 noch keine Antimaterie dingfest gemacht. Dafür fanden Wissenschaftler signifikante Hinweise auf unbekannte Quellen kosmischer Strahlung, die beantworten könnten, was es mit der dunklen Materie auf sich hat.

Doch man braucht gar nicht ins All oder ans CERN reisen, um Teilchen zu sehen. Wie sie ihren Schülern Elektronen und Alphateilchen in einem Experiment zeigen können, erfahren die Lehrer am Nachmittag beim Bau einer Nebelkammer. Rasch ist klar, hier sind Profis am Werk. In Windeseile haben sie die Nebelkammern fachgerecht aufgebaut und die Gardinen zugezogen. Dann lauern sie auf Teilchen, die sich im Licht der Taschenlampe zeigen. "Joh, jetzt seh' ich eins", ruft einer. "Was für ein dicker Brummer!", stellt ein anderer fest. Kleine wurmförmige Partikel bewegen sich horizontal und vertikal durch den Lichtstrahl. Das einfache wie eindruckliche Experiment lässt sich sogar mit Plastikbecher und Alu-Aschenbecher durchführen. Trockeneis ist allerdings unentbehrlich.

Die Lehrer sind von ihrem abwechslungsreichen Tag am CERN sichtlich begeistert. Als "sehr eindrucklich", beurteilt Markus Schmindinger den Tag am CERN: "Es ist etwas anderes, wenn man das Experiment vor Ort sieht und Zutritt zu einer Welt erhält, die einem sonst verborgen bleibt". Er nimmt viele Anregungen mit nach Hause, die er gleich umsetzen will: "Zum Beispiel bei der Lorentzkraft im Unterricht zeigen, dass es keine blosse Theorie ist, sondern Ingenieure am CERN damit arbeiten."

Das von PD Dr. Hans Peter Beck (Universität Bern/CERN) initiierte 1. Deutschschweizer Lehrerprogramm am CERN wurde, in Zusammenarbeit mit [www.teilchenphysik.ch](http://www.teilchenphysik.ch), durch die fachliche und finanzielle Unterstützung von CERN und der Schweizerischen Physikalischen Gesellschaft (SPG) ermöglicht. In regelmässigen Abständen werden weitere Programme für Schweizer Lehrer/innen folgen. Anmeldungen zu einer weiteren Fortbildung am **8./9. November** zu diesem Thema, inklusive CERN Besuch, werden schon jetzt unter [indico.cern.ch/event/swissteachers](http://indico.cern.ch/event/swissteachers) entgegengenommen.

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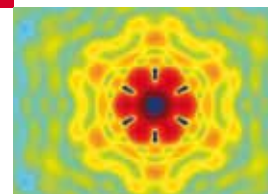
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