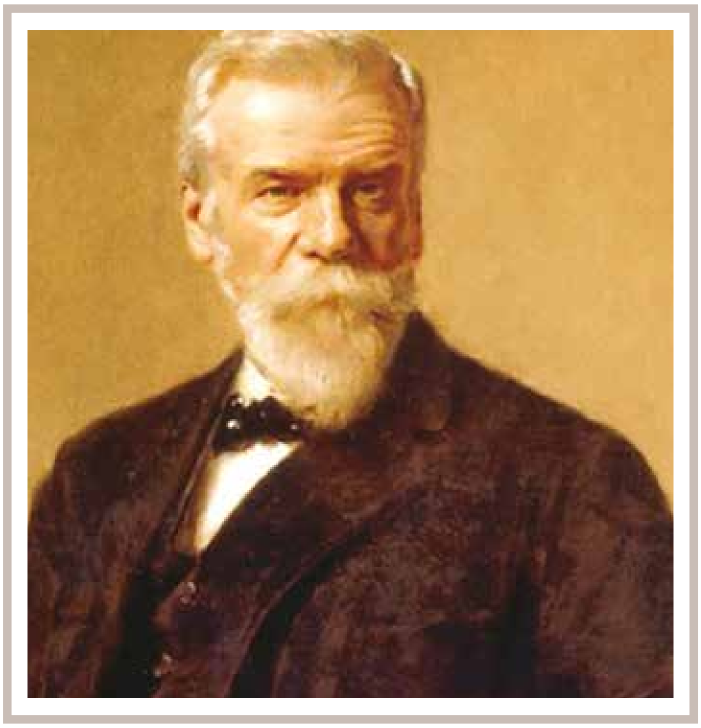
INTERNATIONAL
SOLVAY
INSTITUTES
BRUSSELS

ANNUAL REPORT 2017

Instituts Internationaux
de Physique et de Chimie
fondés par Ernest Solvay,
asbl

Internationale Instituten
voor Fysica en Chemie
gesticht door Ernest Solvay,
vzw



ERNEST SOLVAY

there are no limits
to what science can explore

The International Solvay Institutes for Physics and Chemistry,
founded by Ernest Solvay, acknowledge with gratitude the generous support of

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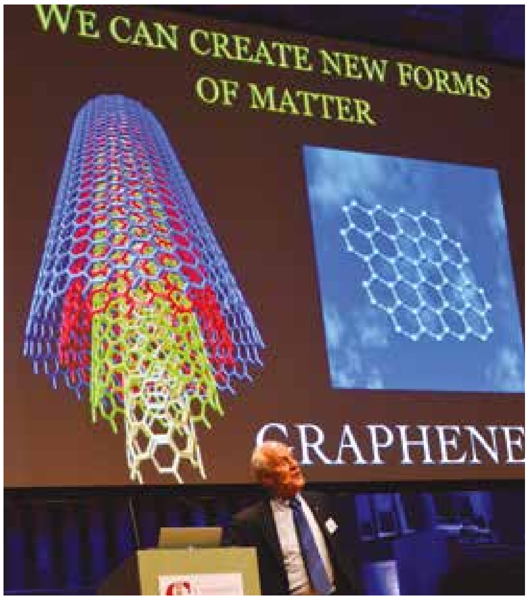
THE BELGIAN NATIONAL LOTTERY
and the International Solvay Institutes: a long-term partnership

Loterie Nationale Loterij

The Belgian National Lottery is one of the main philanthropic organizations in Belgium, which has consistently supported the activities of the International Solvay Institutes for decades. We gratefully acknowledge all those who make this support possible.

This support contributes to the international visibility of Belgium. Most of the greatest chemists and physicists of the 20th and 21st century have come to Brussels to participate in the prestigious "Solvay Congresses", the pictures of which are known worldwide and have become a symbol of excellence. The Solvay Conferences have put Brussels on the scientific world map.

The support of the National Lottery also paves the way to the future of our society. Investment in scientific knowledge and brainpower is more crucial than ever. Specific activities of the Institutes targeted to inspire the young generations towards science as well as to develop training-through-research (Colloquia, open Workshops, Public Event) directly benefit from the support of the National Lottery.



CONTENTS

A WORD from the President

This past year was another full year of workshops, colloquia and chairs organized around outstanding scientific talent: amongst the distinguished guest speakers was Professor Richard Henderson, six months before being awarded the Nobel prize in chemistry. I would like to congratulate the director, his team and the local scientific committee for the quality of their choice!

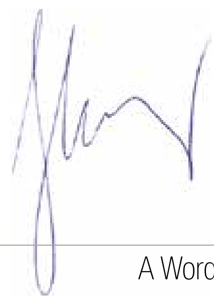
On the eve of the start of the 27th Solvay conference on Physics, while the participants were gathering in Brussels, a workshop focused on the future of Chemistry and Physics was held. The program was composed of four panel sessions staffed with distinguished scientists that were each asked to present and debate what they believed were the next scientific challenges facing humanity. As usual it was a thrill to see how the same question could trigger such a different answer depending on which community of researchers it originated from. The chemists were focused on very practical problems: they strive to understand molecular processes in order to save the planet and improve human health. The physicists were passionate about understanding universal laws, like particle physics and natural phenomena in the universe.

The next morning, the 27th conference on Physics started. The subject was: the "Physics of Living Matter: Space, Time and Information in Biology". For me, it was an outstanding event: I was impressed to see how physicists and biologists united in the common mission of understanding the wonder of life were able to thread their very lively and inspired conversations. I would like to thank Professor Boris Shraiman of the Kavli Institute, the organizer of the conference, for the quality of the contributions.

The conference concluded, as usual with the public event at the Flagey lecture Hall. The subject was: "Frontier of Science - From Physics to Biology". Nobel Laureates Professors David Gross and Eric Wieschaus made each a compelling presentation that was followed by a very lively panel discussion. Passionate students and science enthusiasts filled the hall and interacted with the panel with pointed questions. This was one of our most successful public events.

In the name of the board of directors and of all our donors, I would like to thank the director and his team, Prof. Alexandre Sevrin, Prof. Lode Wyns, Prof. Glenn Barnich, Prof. Ben Craps., Prof. Anne De Wit, Dominique Bogaerts, and Isabelle Van Geet for the outstanding work and the dedication that they bring to our mission of inspiring scientific excellence. My thanks also go to the members of our international scientific committees for their commitment and their guidance.

Jean-Marie Solvay
President



A WORD from the Director

According to its founding Fathers, "the mission of the Solvay Institutes is to support and develop curiosity-driven research in physics, chemistry and allied fields with the purpose of enlarging and deepening the understanding of natural phenomena". This broadening towards other disciplines is particularly spectacular for life science, which physics and chemistry profoundly impacted by laying the way to the development of molecular biology.

The remarkable little book "What Is Life? The Physical Aspect of the Living Cell" written in 1944 by Erwin Schrödinger, 1933 Physics Nobel Laureate, is particularly emblematic in this respect. In it, Schrödinger asks the question "How can the events in space and time which take place within the spatial boundary of a living organism be accounted for by physics and chemistry?" Both 1962 Nobel Laureates in Medicine James Watson and Francis Crick acknowledged the book as a source of inspiration for their researches that led to the discovery of the structure of DNA.

It was therefore not only very natural, but also quite important and timely, to organize a Solvay meeting in that field. The 27th Solvay Conference on Physics ("27ème Conseil de Physique Solvay") was devoted for that reason to biophysics. Entitled "The Physics of Living Matter: Space, Time and Information in Biology", the conference took place at the Hotel Métropole from 19-21 October 2017. This was a "grande première", and a very successful one. The meeting attracted in Brussels more than 50 leading scientists from all over the world who confronted their ideas on subjects ranging from "Intra-cellular Structure and Dynamics" to "Evolutionary dynamics". The International Solvay Institutes are most grateful to the conference chair, Professor Boris Shraiman from Santa Barbara, for the remarkable scientific organization of the conference.

As it is the tradition, the 27th Solvay Conference on Physics was followed by a public event on October 22, whose theme was "Frontiers of Science - From Physics to Biology". The lecturers were distinguished Professors Eric Wieschaus (1995 Nobel Laureate in Physiology or Medecine) and David Gross (2004 Nobel Laureate in Physics). Their splendid lectures, respectively devoted to "From Genes to Cell Shape: The Mechanics of Embryonic Development" and "The Many Frontiers of Physics", captivated an audience that fully packed the lecture hall. We thank the two lecturers for their very stimulating talks.

The report that follows reviews in detail the activities organized or supported by the International Solvay Institutes during the year 2017. These activities (2 chairs, 5 workshops, 16 colloquia, 1 graduate school in theoretical physics) attracted to Brussels hundreds of scientists and covered a wide spectrum of developments at the frontiers of physics and chemistry. As usual, a balance between physics and chemistry, and an opening towards promising emerging fields, inspired the 2017 program.

All the information can be found in the core of the report. I will just briefly mention in this introductory section the annual international Solvay Chairs in Physics and Chemistry, respectively created in 2006 and 2008, which are among our most successful initiatives.

The 2017 Solvay Professor in Chemistry was Professor Richard Henderson, from the University of Cambridge (UK). He gave in March a brilliant opening lecture "The cryoEM revolution in structural biology", which was attended by many students and researchers from the ULB, the VUB and other

Belgian universities. We were particularly honored and pleased to learn in October that Professor Henderson was awarded the 2017 Nobel Prize in Chemistry. Our warmest congratulations go to him!

The 2017 Jacques Solvay Chair in Physics was held by Professor Uri Alon from the Weizmann Institute (Israel). He gave a very original and inspiring opening lecture on the "Physics of joint creativity and togetherness", which was again a great attendance success.

This activity report also describes the research carried in the groups of the Director, of the deputy-Directors, and of the Scientific Secretaries of the International Scientific Committee for Chemistry and the International Scientific Committee for Physics. The research highlights of other researchers connected with the Institutes are also outlined.

The research of the group of the Director benefited from the direct and most precious support of the Solvay family and the Solvay group, as well as from generous gifts from Messrs. Collen and de Selliers de Moranville. I heartily thank them.

The activities described in this report would not have been possible without the help of the sponsors of the International Solvay Institutes, to whom I would like to express our gratitude. These are the Université Libre de Bruxelles, the Vrije Universiteit Brussel, the Solvay Company, the Belgian National Lottery, the Brussels-Capital Region, the Fédération Wallonie-Bruxelles, the Vlaamse Regering, the David & Alice Van Buuren Foundation, the Hôtel Métropole and last but not least – and as recalled above -, the Solvay family who continues with the same conviction a more than a century-old tradition of support to fundamental research.

The remarkable efficiency and dedicated commitment of Dominique Bogaerts and Isabelle Van Geet in the management of the activities of the Institutes, is again gratefully acknowledged.

Marc Henneaux
Director

GENERAL information

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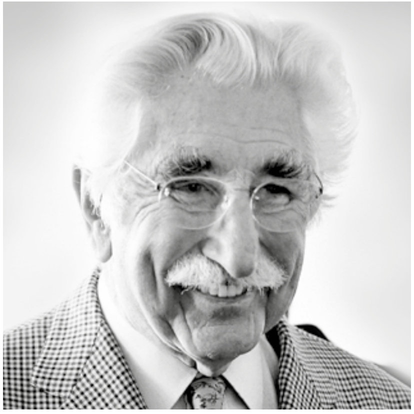

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The Director is assisted in his scientific tasks by:

- The International Scientific Committees for Physics and Chemistry, who are fully responsible for the scientific organization of the “Conseils Solvay”.
- The Scientific Assistants to the Director and the local Scientific Committees, who help him for the organization of all the other activities (workshops, colloquia, chairs).

He is assisted in his management tasks by the administrative staff.

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	Professor Klaus von Klitzing *1985 Nobel Laureate* Max-Planck-Institut, Stuttgart, Germany
	Professor Peter Zoller University of Innsbruck, Austria

The International Scientific Committees for Physics and Chemistry are responsible for the scientific organization of the "Conseils Solvay".

They are in charge of defining the general theme of the conferences and of selecting a chair person.

Members are appointed for a 6-year period term, renewable once.

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In 2008, the Board of Directors of the International Solvay Institutes decided to set up an International Advisory Committee. The International Advisory Committee of the Solvay Institutes is composed of distinguished scientists who have the task of periodically evaluating all the scientific activities of the Solvay Institutes (outside the Solvay Conferences which are run by the respective Scientific Committees), report to the Board of Directors and provide advice for future developments.

Members are appointed for a 6-year period term, renewable once.

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The local Scientific Committees help the Director for the organization of the Workshops, Colloquia, Chairs and Doctoral School.

Members are appointed for a 3-year period term

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Professor Joseph Indekeu I KU Leuven
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Professor Alexander Sevrin I VUB, Brussels
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Professor Petr Tinyakov I ULB, Brussels
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Professor Sophie Van Eck I ULB, Brussels
Professor Nicolas Vandewalle I ULg, Liège

Observer

Professor Anne De Wit
ULB, Brussels

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University of California, San Diego, USA

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1957 Nobel Laureate
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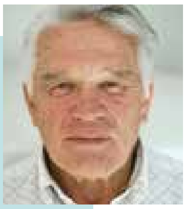

IN MEMORIAM

The Solvay Institutes mourn the loss of Professor Ludwig Faddeev (1934-2017), first holder of the International Solvay Chair in Physics and Honorary Member of the Institutes.

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19 - 21 October 2017

27th Solvay conference ON PHYSICS

" The Physics of Living Matter: Space, Time and Information in Biology"

27th Solvay conference ON PHYSICS

"The Physics of Living Matter: Space, Time and Information in Biology"

19 - 21 October 2017

The 27th Solvay Conference on Physics was a real first in the history of the Solvay Conferences: it was indeed the first one devoted to biophysics. The decision to organize the Conference in that area was taken by the International Solvay Scientific Committee for Physics chaired by Nobel laureate Professor David Gross. The Conference was chaired by Professor Boris Shraiman, from KITP and the University of California at Santa Barbara.

The Conference took place at the hotel Metropole in Brussels from October 19 through October 21, 2017. The International Solvay Institutes are grateful to the International Solvay Committee for Physics, to the Chair of the Conference, to the Session Chairs, to the Rapporteurs and to all the Participants, who contributed to make the Conference an immense success.

Scientific background

Here is how Professor Boris Shraiman describes the scientific context of the meeting and its goals:

In a series of public lectures delivered in 1943 in Dublin, which were the basis for his famous book 'What is Life', Erwin Schrödinger focused on the following important question: "How can the events in space and time which take place within the spatial boundary of a living organism be accounted for by physics and chemistry?" Since then, the advances of Molecular Biology transformed our understanding of the biochemical basis of life, providing us with rules for encoding, transmitting, and decoding genetic information, the molecular mechanisms of biological reactions, and a nearly complete catalogue of its molecular building blocks. Yet Schrödinger's question, of how these processes are integrated to create living organisms is still largely unanswered. Animate matter has astonishing features, and we are just beginning to grasp its physical basis and the collective phenomena that lead to biological functions and cellular, organismal, and evolutionary scale processes.

Physics has been remarkably successful at uncovering the laws and principles that govern inanimate matter and its emergent properties, yet living matter presents physics with new fundamental problems. For instance, the counterintuitive properties of superfluidity "emerge" from the quantum nature of a collective of identical atoms. In contrast, "living matter" is fundamentally structured and heterogeneous on all scales. In Schrödinger's words, physics has been focused on describing the emergence of "order from disorder" while living matter is in a different limit, dominated by the orderly and stable internal structure and begetting "order from order". Life "feeds on negative entropy", wrote Schrödinger, prefiguring *the quantitative concept of "information" introduced by Shannon just a few years later. The information-containing structural complexity of living matter controls its dynamics in a way analogous to information processing by computational algorithms. Hence, our outstanding challenge is to understand the dynamics of information carrying matter: a challenge that is likely to extend Physics far beyond its traditional range and possibly reveal new general principles.*

While the search for general principles continues, the interface of Physics and Biology has been a productive field for discovery, facilitated by advances in instrumentation and new quantitative approaches driven by models and theories. Progress has been made in characterizing the function of single molecules as "molecular machines". Super-resolution microscopy has revealed the unexpectedly dynamical nature of subcellular structures. Physics has provided fresh insights into the ways in which the interiors of cells are organized into compartmentalized structures that collectively enable cells to carry out a multitude of functions, from molecular manufacturing to cellular migration. Quantitative experiments uncovered the essential role that dynamics and spatial context play in intercellular signaling, and quantitative modeling has established unexpected and insightful connections between seemingly unrelated subfields: e.g. stem-cell biology and population genetics, neural networks and ecological dynamics. Ideas from statistical physics have led to major advances in understanding evolutionary dynamics of populations, establishing another exciting frontier between Physics and Biology. In many of these contexts, ideas from physics provided a unifying framework for describing phenomena at different spatio-temporal scales of organization and dynamics.

Physics of Living Matter is a burgeoning field and the goal of this meeting is not to review and to fete its accomplishments but to focus on the challenges and directions for the future, formulating both general and specific questions and seeking connections between seemingly diverse phenomena. Because the field is so vast, some difficult choices had to be made in organizing this Solvay conference. As a result, some vibrant and intellectually exciting subfields at the interface of physics and biology - including neuroscience, single molecule biophysics, advanced instrumentation and more - did not get the spotlight that they deserve. Yet the goal of the conference is to promote the intellectual unity of the subject in the broadest sense. To facilitate the latter, the meeting will focus on the broad themes of space, time and information, tackling them on different scales, from intracellular organization to evolutionary dynamics. The ambitious goal for the meeting is to identify - looking towards the future of the field - specific problems and directions that can guide progress in our understanding of living matter in general while advancing the front of knowledge in life sciences. In short, we hope to produce what might be thought of as the second edition of "What is Life", a description of the problems that we must solve to understand living matter and ideas about how to solve them.

Boris Shraiman

Comments from some participants

Truly remarkable conference at the interface of physics and biology. I was greatly inspired by the meeting […] The small number of participants is key to the success of this meeting, and sitting around a 'round' table instrumental for eye-to-eye communication. The meeting has definitely stimulated some new collaborations for me, and the friendships made will be useful for other future collaborations."

Thank you to the Solvay committee for being open to such an adventurous theme."

As a first conference of its kind, I thought the Solvay conference on biophysics went exceptionally well."

I very much enjoyed the conference and felt that it was a once-in-a-lifetime opportunity. I was extremely grateful for the opportunity, and feel that Boris Shraiman and the conference chairs did an excellent job of bringing together a brilliant set of people to discuss important questions."

Thanks very much for organizing the meeting - it was truly historic."

Reception at the Brussels City Hall

The participants of the 27th Solvay Conference on Physics were greeted on the 18th of October by the Mayor of Brussels, M. Philippe Close, in the spectacular environment of the majestic Brussels City Hall. The International Solvay Institutes acknowledge with gratitude the support of the City of Brussels and of its Mayor.

Program

Wednesday 18 October 2017

Welcome reception at the Brussels City Hall

Thursday 19 October 2017

Introduction: Biophysics and the Physics of Living Matter

Welcoming remarks: Marc Henneaux, David Gross and Boris Shraiman
Historical Perspective: J. Hudspeth (Rockefeller)

Session I: Intra-cellular Structure and Dynamics

Chair: A. Hyman (MPI-CBG, Dresden)

Rapporteurs: J. Lippincott-Schwartz (HHMI) and C. Brangwynne (Princeton)

Session II: Cell Behavior and Control

Chair: A. Murray (Harvard)

Rapporteurs: T. Hwa (UCSD) and M. Elowitz (Caltech)

Reception at the Solvays'

Friday 20 October 2017

Session III: Inter-cellular Interactions and Patterns

Chair: W. Bialek (Princeton)

Rapporteurs: G. Suel (UCSD) and E. Siggia (Rockefeller)

Banquet at the Plaza Hotel

Saturday 21 October 2017

Session IV: Morphogenesis

Chair: T. Lecuit (Collège de France)

Rapporteurs: E. Wieschaus (Princeton) and
L. Mahadevan (Harvard)

Session V: Evolutionary dynamics

Chair: D. Fisher (Stanford)

Rapporteurs: R. Neher (Biozentrum, Basel) and
A. Walczak (ENS, Paris)

End of Conference

Participants

Alon Uri (Weizmann Institute of Science, Rehovot, Israel)
Aulehla Alexander (EMBL, Heidelberg, Germany)
Bialek William (Princeton University, NJ, USA)
Blandford Roger (Stanford University, California, USA)
Brangwynne Clifford (Princeton University, NJ, USA)
Brink Lars (Chalmers U. Gothenburg, Sweden)
Chakraborty Arup (MIT, Cambridge, USA)
Chu Steven (Stanford University, California, USA)
Desai Michael (Harvard University, Cambridge, USA)
Dijkgraaf Robbert (Princeton University, NJ, USA)
Eaton Suzanne (Max Planck Institute, Dresden, Germany)
Elowitz Michael (California Institute of Technology, Pasadena, USA)
Fisher Daniel (Stanford University, California, USA)
Giardina Irene (U.di Roma, La Sapienza, Italy)
Goldbeter Albert (ULB, Brussels, Belgium)
Goodson Holly (U. Notre Dame, IN, USA)
Gordo Isabel (Instituto Gulbenkian de Ciência, Oeiras, Portugal)
Gregor Thomas (Princeton University, NJ, USA)
Grill Stephan (Technische Universität Dresden, Germany)
Gross David (Kavli Institute, Santa Barbara, USA)
Halperin Bertrand (Harvard University, Cambridge, USA)
Henneaux Marc (The Solvay Institutes & ULB, Brussels, Belgium)
Howard Jonathon (Yale University, USA)
Hudspeth James (The Rockefeller University, New York, USA)
Hwa Terence (University of California, San Diego, USA)
Hyman Anthony (Max Planck Institute, Dresden, Germany)
Jülicher Frank (Max-Planck-Institute, Dresden, Germany)
King Nicole (University of California, Berkeley, USA)
Koonin Eugene (NCBI, Bethesda, USA)
Lecuit Thomas (Parc Scientifique de Luminy, Marseille, France)
Levine Herbert (Rice University, Texas, USA)
Leyser Ottoline (University of Cambridge, UK)
Lippincott-Schwartz Jennifer (HHMI, Virginia, USA)
Mahadevan Maha (Harvard University, Cambridge, USA)
Marchetti Cristina (Syracuse University, USA)
Mayor Satyajit (NCBS, Bangalore, India)
Munro Edwin (University of Chicago, USA)
Murray Andrew (Harvard University, Cambridge, USA)
Needleman Daniel (Harvard University, Cambridge, USA)
Neher Richard (Max Planck Institute, Tubingen, Germany)
Patel Nipam (University of California, Berkeley, USA)
Perelson Alan (Santa Fe Institute, New Mexico, USA)
Phillips Rob (California Institute of Technology, Pasadena, USA)
Quake Stephen (Stanford University, California, USA)
Rainey Paul (ESPCI Paris, France)
Ramanathan Sharad (Harvard University, Cambridge, USA)
Ramond Pierre (University of Florida, Gainesville, USA)
Sevrin Alexander (The Solvay Institutes & VUB, Brussels, Belgium)
Shraiman Boris (Kavli Institute, Santa Barbara, USA)
Siggia Eric (The Rockefeller University, New York, USA)
Simons Ben (Cambridge University, UK)
Skotheim Jan (Stanford University, California, USA)
Süel Gürol (UC San Diego, La Jolla, USA)
Vergassola Massimo (UC San Diego, La Jolla, USA)
von Klitzing Klaus (Max-Planck-Institut, Stuttgart, Germany)
Walczak Aleksandra (Ecole Normale Supérieure, Paris, France)
Wieschaus Eric (Princeton University, NJ, USA)
Wingreen Ned (Princeton University, NJ, USA)
Wüthrich Kurt (Scripps Institute, USA & ETH Zurich)
Zoller Peter (Innsbruck University, Austria)

Auditors

The Conference was also attended by auditors from various Belgian universities. Auditors play an essential role in the transcription of the discussions into a publishable text.

The International Solvay Institutes are grateful to the editorial team and in particular to Professor Alexander Sevrin (Scientific Secretary of the International Solvay Scientific Committee for Physics) for his efficient handling of this difficult task.

Carlon Enrico (KU Leuven)
Craps Ben (VUB)
de Buyl Sophie (VUB)
Dupont Geneviève (ULB)
Efremov Rouslan (VUB)
Garcia-Pino Abel (ULB)
Gaspard Pierre (ULB)
Gelens Lendert (KU Leuven)
Gonze Didier (ULB)
Hertog Thomas (KU Leuven)
Lenaerts Tom (ULB/VUB)
Loris Remy (VUB)
Mognetti Bortolo (ULB)
Remaut Han (VUB)
Tempere Jacques (UAntwerp)
Van Doorslaer Sabine (UAntwerp)
Wyns Lode (VUB)

S. Ramanathan, M. Mahadevan, M. Desai, J. Skotheim, R. Neher, A. Aulehla, C. Brangwynne, S. Grill, D. Needleman
M. Elowitz, G. Süel, U. Alon, S. Quake, F. Jülicher, H. Levine, M. Satyajit, C. Marchetti, N. Patel
R. Phillips, A. Goldbeter, A. Perelson, E. Koonin, E. Siggia, B. Simons, M. Vergassola, T. Hwa, T. Gregor, A. Chakraborty, P. Rainey, S. Eaton
N. Wingreen, I. Giardina, R. Dijkgraaf, B. Halperin, H. Goodson, J. Lippincott, P. Zoller, A. Walczak, P. Ramond, O. Leyser, R. Blandford, N. King, J. Howard, I. Gordo
A. Sevrin, W. Bialek, A. Hyman, E. Wieschaus, M. Henneaux, K. von Klitzing, B. Shraiman, D. Gross, S. Chu, K. Wüthrich, D. Fisher, T. Lecuit, A. Murray, L. Brink

22 October 2017

14th Solvay PUBLIC EVENT

"Frontiers of Science from Physics to Biology"

14th Solvay PUBLIC EVENT

"Frontiers of Science - from Physics to Biology"

22 October 2017

On the day following the 27th Solvay Conference on Physics, the International Solvay Institutes organized their traditional annual public event, on the theme "Frontiers of Science - From Physics to Biology".

The event consisted in two lectures for the general public, followed by a panel debate addressing questions raised by the audience. The event closed with a drink offered to all the participants, during which the public could interact more with the speakers and the panel members.

The two lectures described some of the most fascinating questions currently explored in biology and in physics, and discussed some of the deepest challenges that these fields are facing today.

Too often, science is taught as a boring list of facts and figures to memorize. This crushes the curiosity and spirit of imagination that we are all born with. But this perception of science is not what science truly is. Science is not a dry field. The lectures vividly conveyed how imagination, creativity, intuition, quest for beauty and wonderment are driving forces behind scientific research.

They perfectly illustrated a quote from Einstein (a regular participant in the Solvay Conferences), which stresses the importance of imagination and creativity in science:

> "To raise new questions, new possibilities, to regard old problems from a new angle requires creative imagination and marks real advances in science."
>
> *A. Einstein*

And another one, from Marie Curie (also a regular participant in the Solvay Conferences), on scientific wonderment:

> "A scientist in his laboratory is not a mere technician: he is also a child confronting natural phenomena that impress him as though they were fairy tales."
>
> *M. Curie*

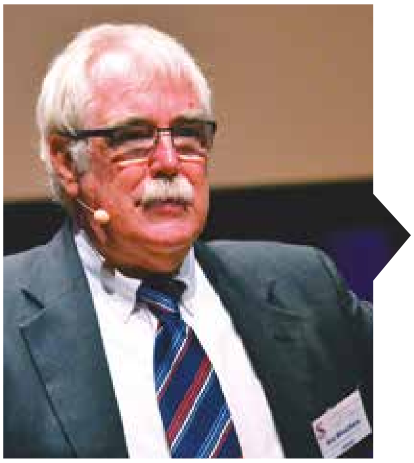
The event attracted more than 800 participants fascinated by the brilliant lectures. It is a great satisfaction to note that the Solvay annual public lectures are so well attended.

The International Solvay Institutes are extremely grateful to the two lecturers and to the panel members who made the 14th Solvay Public Event a remarkable "grand cru"!

A tradition that goes back to 2005

In 2005, the International Solvay Institutes initiated the tradition of organizing an annual public event during which distinguished scientists deliver lectures on the state-of-the-art in their field of research with an overview of the most pressing current issues. Organized jointly with the ULB, the VUB and the Solvay Group, this event popularizes science and aims at making it more attractive to the younger generations. The talks are given in English but simultaneous interpretations in Dutch and French are provided. The event closes with a drink offered to all the participants, which allows the public to interact more closely with the invited scientists. The event is free.

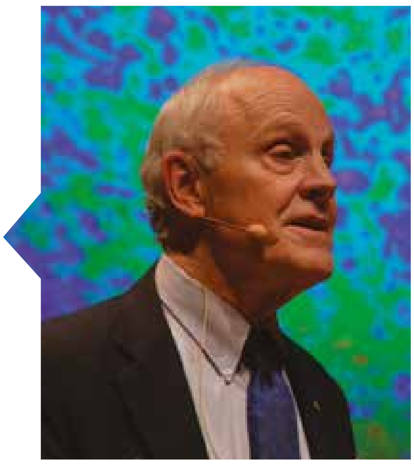
Lecturers



Both speakers received the Nobel Prize for their exceptional scientific contributions.

Professor Eric Wieschaus from Princeton University is an American evolutionary developmental biologist. In 1995, he shared the Nobel Prize in Physiology or Medicine with Edward B. Lewis and Christiane Nüsslein-Volhard, “for their discoveries concerning the genetic control of early embryonic development”.

Professor David Gross from Santa Barbara is an American theoretical physicist and string theorist. In 2004, he was awarded the Nobel Prize in Physics with Frank Wilczek and David Politzer “for the discovery of asymptotic freedom in the theory of the strong interaction”. Professor Gross chairs the Solvay International Committee for Physics since 2006.



Panel members

Professor Holly Goodson received her A.B. in molecular biology from Princeton University (1988). Her Ph.D. was awarded by Stanford University (1995) for work in the lab of Jim Spudich. She then moved to Geneva, Switzerland to do postdoctoral work in the laboratory of Thomas Kreis. Professor Goodson joined the Notre Dame faculty in January 2000.

The Goodson laboratory uses multifaceted approaches including biochemistry, molecular biology, and computational biology to address cell biological questions. A second long-term interest in the Goodson laboratory is molecular evolution.

Dr. Goodson is a member of the Harper Cancer Research Institute and is Associate Director of the Interdisciplinary Center for the Study of Biocomplexity. She was awarded the Thomas P. Madden Award for *Exceptional Teaching of First Year Students* (2012).

Professor Daniel Fisher is David Starr Jordan Professor of Science at Stanford University. He was educated at Cornell and Harvard, started his career at AT&T Bell Laboratories, and subsequently held faculty positions at Princeton and Harvard.

Professor Fisher's research has mostly been in theoretical condensed matter physics, but over the past ten years has shifted to biology, particularly dynamical processes in cells and evolutionary dynamics.

In 2013, he was awarded the Onsager Prize for his work on the statistical physics of disordered systems.

Professor Ottoline Leyser is Professor of Plant Development at the University of Cambridge and director of the Sainsbury Laboratory, Cambridge. She received her BA (1986) and PhD (1990) in Genetics from the University of Cambridge. After post-doctoral research at Indiana University and Cambridge, she took up a lectureship at the University of York.

Among her honours are the Royal Society Rosalind Franklin Award (2007) and the UK Genetics Society Medal (2016). She was appointed a Dame Commander of the Order of the British Empire (DBE) in the 2017 New Year Honours.

The Leyser Group's research is aimed at understanding the role of plant hormones in plant developmental plasticity, using the regulation of shoot branching as a model.

Professor Aleksandra Walczak is 'chargée de recherche CNRS' at the Laboratoire physique théorique de l'École normale supérieure. She received her PhD (2007) in Physics from the University of California, San Diego.

Her main interest lies in the description of systems on the cellular scale - understanding the link between function, development and evolvability of conserved pathways and their elements. Her recent focus has been on a number of concrete, not disjoint, topics: gene regulatory networks, the immune system and population genetics.

Professor Walczak was awarded the Jacques Herbrand Prize in 2014 and the Médaille de bronze 2016 du CNRS.

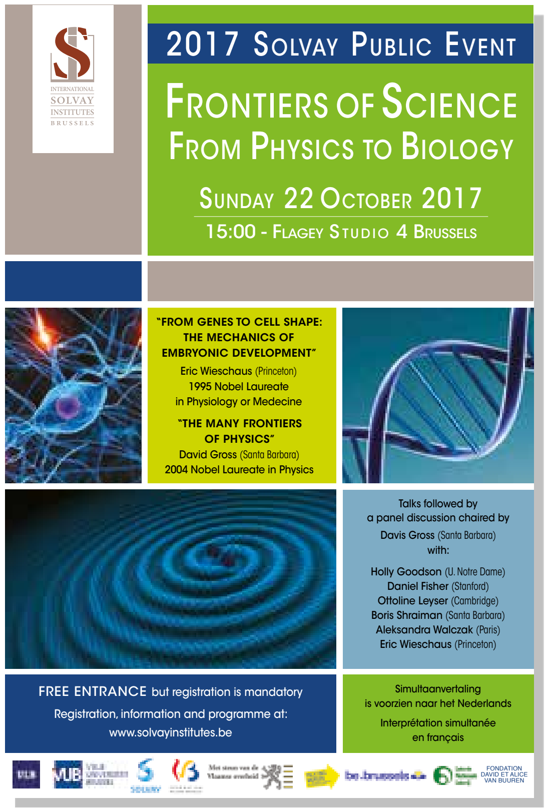
Professor Boris Shraiman is Susan F. Gurley Professor of Theoretical Physics and Biology at the Kavli Institute for Theoretical Physics. He is a theoretical physicist with background in statistical physics. He earned his PhD in theoretical physics from Harvard University in 1983.

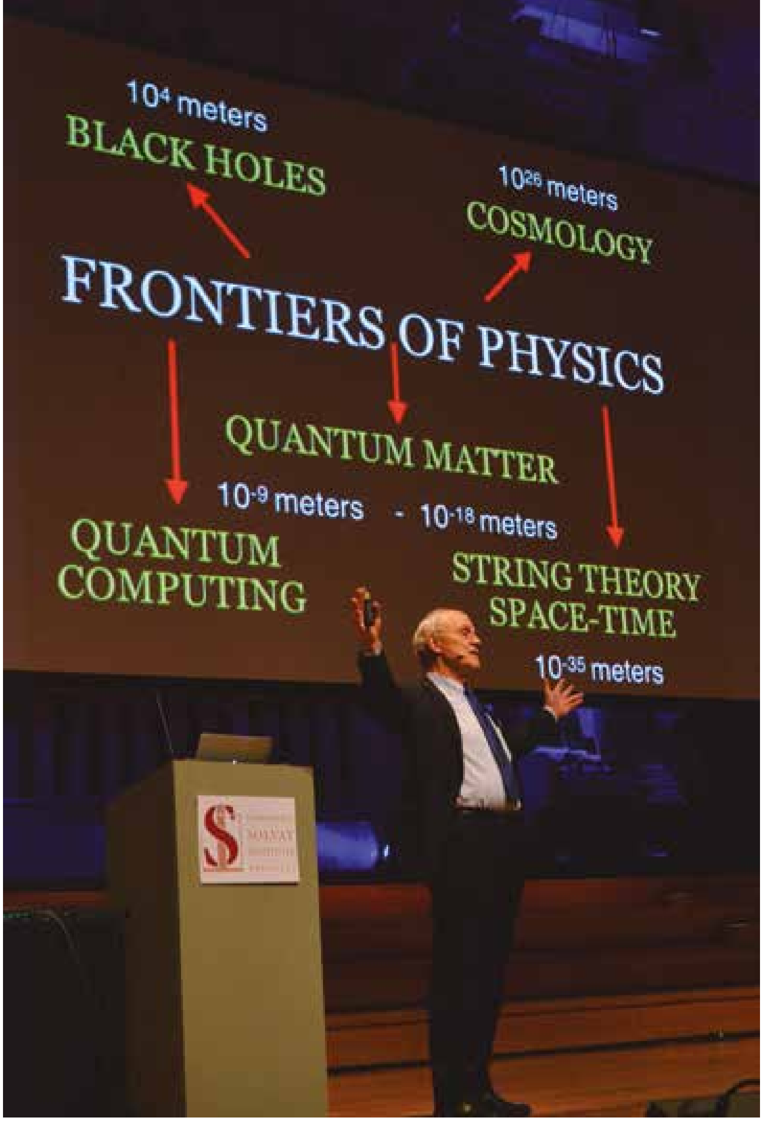
He spent 16 years with Bell Laboratories.

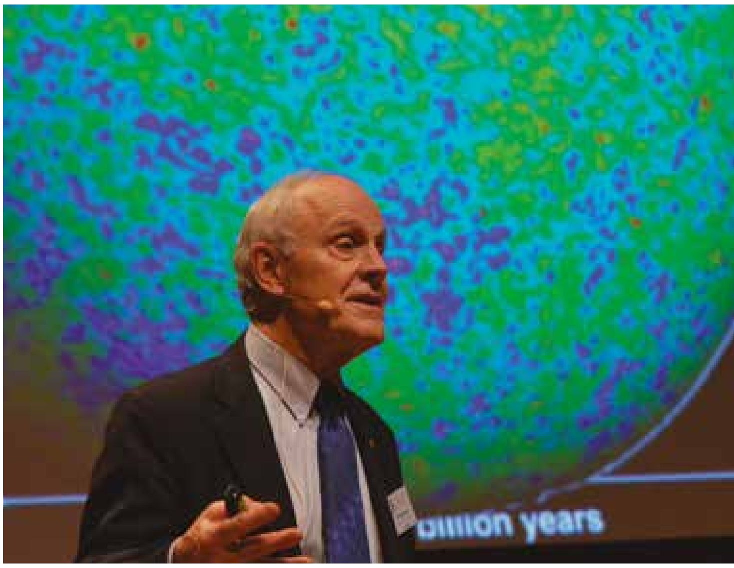
He has worked on a range of physics problems from correlated electrons and superconductivity to pattern formation and turbulence. He started working on biology problems about 15 years ago, while at Bell Labs.

Program

Moderator	Professor Franklin Lambert VUB & International Solvay Institutes
15:00 - 15:10	Opening by Professor Marc Henneaux ULB & International Solvay Institutes
15:10 - 15:55	*From Genes to Cell Shape: The Mechanics of Embryonic Development* Talk by Professor Eric Wieschaus 1995 Nobel Laureate in Physiology or Medecine
15:55 - 16:40	*The Many Frontiers of Physics* Talk by Professor David Gross 2004 Nobel Laureate in Physics
16:40 - 17:30	Discussion with Professors Daniel Fisher (Stanford U., USA) Holly Goodson (U. Notre Dame, USA) David Gross (Kavli Institute, USA) Ottoline Leyser (U. of Cambridge, UK) Boris Shraiman (Kavli Institute, USA) Aleksandra Walczak (ENS, France) Eric Wieschaus (Princeton U., USA)
17:30 - 18:00	Drink




10^{4} meters
BLACK HOLES
10^{26} meters
COSMOLOGY
FRONTIERS OF PHYSICS
QUANTUM MATTER
10^{-9} meters - 10^{-18} meters
QUANTUM COMPUTING
STRING THEORY
SPACE-TIME
10^{-35} meters




Combining anterior posterior and dorsal ventral gene expression patterns, every cell is precisely defined

international SOLVAY CHAIRS

International SOLVAY CHAIRS

The International Solvay Chair programme enables the Institutes to invite in Brussels eminent scientists for a period of one to two months in order to give lectures on their work to researchers in the corresponding fields, not only from the ULB and the VUB, but also from other Belgian universities and abroad.

The programme started in 2006 for physics. In 2011 the physics chair was renamed the International “Jacques Solvay Chair in Physics” in memory of Jacques Solvay, who was president of the Institutes for more than 50 years.

The chair programme in chemistry was launched in 2008 thanks to a generous grant from the Solvay Company, which the Institutes gratefully acknowledge.

2016 International Jacques Solvay Chair in Physics

Professor Dam Thanh Son I University of Chicago, USA

The last lectures of the 2016 Solvay Chair in Physics, held by Professor Dam Thanh Son took place in October 2017. He delivered his lectures in the context of the International Doctoral School on theoretical physics organized by the University of Amsterdam, the ULB, the VUB, a consortium of French theoretical groups led by ENS Paris, and a consortium of Swiss theoretical groups led by ETH Zurich.

Modern field-theoretical methods in condensed matter physics

Professor Dam Thanh Son’s lectures described the modern applications of quantum field theories in condensed matter physics and concentrated on the following topics:

- *Effective field theory of bosonic superfluids*
- *Fermi liquids: Landau theory, bosonization*
- *Berry phase, chiral anomaly in solids*
- *Quantum Hall effect: phenomenology, the half-filled Landau level, particle-vortex duality, Dirac composite fermion theory*

2017 International Jacques Solvay Chair in Physics

Professor Uri Alon | Weizmann Institute of Science, Israel

The 2017 International Jacques Solvay Chair in Physics was held by Professor Uri Alon from the Weizmann Institute of Science in Rehovot (Israel).

Professor Alon is a leading figure in biophysics, where he studies how cells work, using an array of tools to understand the biological circuits that perform the functions of life. His broad interests cover biological systems, protein networks, genetic circuits and collective behaviour of molecular machines. In all these areas, he made profound and very inspiring contributions.

"The physics of human behavior: improvisation and joint creativity" is another research field that Uri Alon has been pioneering. It was the subject of his fascinating inaugural lecture, which he gave on October 10, 2017.

During his stay in Brussels, Professor Alon was hosted by the groups of Professor Geneviève Dupont at the ULB and Sophie de Buyl at the VUB. The Solvay Institutes heartily thank them both, and in particular Professor Sophie de Buyl, for orchestrating Uri Alon's visit in Belgium. The stay of Professor Alon was particular fruitful in terms of interactions with Belgian groups working in the field.

Professor Uri Alon studied physics at the Hebrew University in Jerusalem, where he got his Master Degree in 1992. He received his PhD degree in physics in 1996 from the Weizmann Institute. After this initial training in Physics, Uri Alon developed a profound interest in biological systems and went to Princeton University as a postdoctoral fellow in experimental biology. He subsequently returned to the Weizmann Institute where he is now Full Professor in the Department of Molecular Cell Biology.

For his remarkable scientific achievements, Professor Uri Alon received an impressive collection of awards, among which one can mention the following two: In 2004, he was awarded the Overton Prize of the International Society for Computational Biology for "significant contributions to computational biology, particularly in the areas of network motifs and the design principles of biological networks". And more recently, in 2014, he received the "Human Frontier Science Program Nakasone Prize", "for his pioneering work in discovering network motifs".

Inaugural Lecture I 10 October 2017

Physics of joint creativity and togetherness

Can physics help us make sense of human experiences that are hard to define? In this easy to understand talk, I'll describe emerging research on moments of joint creativity that seem to occur in arts, scientific conversations and sports. The experiments use an exercise from theatre called the mirror game as a simple behavioral system in which people spontaneously create new motion without leader and follower. Precise measurements and theory help us identify how people create together.

Lecture 1 I 12 October 2017

Networks motifs: simple circuits building blocks of complex biological networks

Complex gene regulation networks seem hopelessly complicated. I will describe the discovery that complex networks in biology are much simpler than first thought, they are made of a small set of recurring interaction patterns called network motifs. These motifs include coherent and incoherent feedforward loops. I will show how each network motif carries our specific computational functions, and how motifs can be combined to generate the intricate computations of the cell. I will discuss how evolution rediscovered the same motifs again and again, evidently because they are the simplest and most robust circuits that carry out each function.

Lecture 2 I 12 October 2017

Symmetry and scaling in the sensory systems of cells and organisms

Cells and animals sense the environment and act accordingly. On the level of both cells and animals, many sensory systems share unifying features, such as exact adaptation and scaling of input signals. At the basis of these universal features is the unifying property of fold change detection (FCD): response dynamics that depend only on relative changes in input, and not absolute changes. FCD was defined about a decade ago based on symmetry considerations, and was experimentally found in diverse sensory systems including human vision, bacterial chemotaxis and major cell signaling pathways such as wnt, NFkb and TGF beta, and explains their impressive dynamic range and resistance to protein noise. A common network motif from the previous lecture, the incoherent feedforward loop, is one of the very few possible circuits that provide FCD.

Lecture 3 I 13 October 2017

Symmetry and scaling in hormone circuits and tissues

Our bodies regulate our inner states, such as our blood glucose, using hormones, which act across tissues. How hormone circuits adjust themselves to unavoidable parameter variations is a burning question: for example the parameter called insulin resistance varies by an order of magnitude across people and across time, and yet insulin keeps glucose levels and post-meal dynamics under very strict control to within 10%. I will describe design principles of hormonal circuits which use a slow feedback loop to buffer parameter variations by controlling the mass of the gland that secretes the hormone at play. I will also discuss how mathematical modelling can shed light on breakdown of such circuits, potentially leading to diseases such as type 2 diabetes in which blood glucose control fails. These breakdowns are due to mechanisms that evolved to make hormone circuits resistant to invasion by mutants that missense the feedback signal showing a tradeoff between resistance to mutants and fragility to disease.

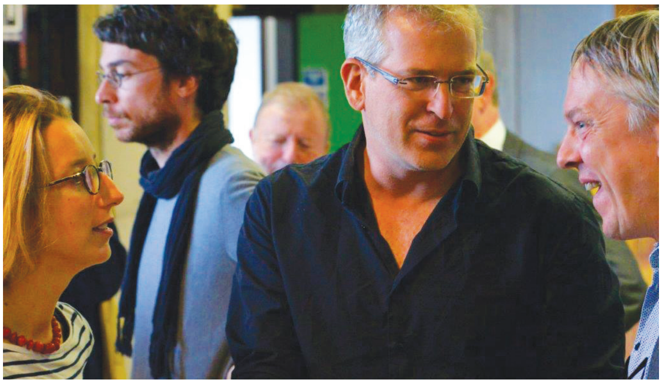
Lecture 4 I 17 October 2017

Multi-objective optimality in biology

When a biological system needs to carry out multiple tasks, it faces a fundamental tradeoff: no phenotype can be optimal at all tasks at once. I will describe a theory, called pareto task inference (ParTI), that shows how such tradeoffs lead to striking patterns in biological data. This theory employs Pareto optimality from engineering and economics. In engineering, one knows the tasks in advance, say the tasks needed from a car such as speed versus safety versus environmental friendliness but in biology we do not often know the tasks a priori. Thus ParTi allows solving the inverse problem: detecting the evolutionary tasks directly from the data. To do this, ParTi shows that when k tasks are at play, the data in trait space fills out a polytope with k vertices (or at least a shape that can be smoothly deformed to give a polytope), e.g. a triangle for three tasks and a tetrahedron for four tasks. The vertices are phenotypes optimal at each task, allowing tasks to be inferred. I will demonstrate tasks and tradeoffs in animal morphology, cancer gene expression and individual-cell transcriptomics.

It was a real pleasure to meet Uri Alon. His lectures were very inspiring and we could feel the joy he had to share his own discoveries. We could follow the whole path he undertook from finding a good question to being able to answer it beautifully both theoretically and experimentally, and finally addressing more questions by keeping wondering "why" living systems behave as observed. Moreover, he is not only teaching scientific content but also sharing his views on how the scientific community could function better by supporting each other, learning to handle failure, communicating and much more. I am looking forward to hear about his next ideas!

Sophie de Buyl



2017 International Solvay Chair in Chemistry

Professor Richard Henderson I Cambridge University, UK

The tenth International Chair in Chemistry was held by Professor Richard Henderson from the University of Cambridge (UK), one of the world leaders in molecular biology.

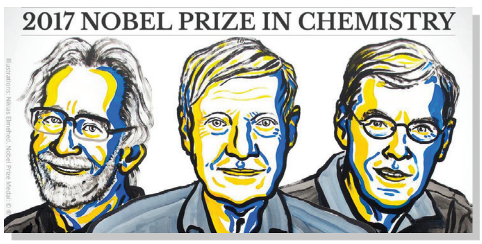
Professor Henderson is a pioneer in the field of electron microscopy of biological molecules. In particular, he made breakthough advances in the development of direct electron detectors, leading to single particle cryo-electron microscopy with spectacular potential.

His inaugural lecture, given on the 20th of March 2017, was precisely devoted to this fascinating field. During his stay in Brussels, Professor Henderson was hosted in the group of Professors Han Remaut and Lode Wyns at the VUB. The Institutes thank them for their efficient help in organizing the chair.

Professor Richard Henderson started as a physicist at Edinburgh University but switched into molecular biology at age 21. After studying at the MRC Laboratory of Molecular Biology (LMB) in Cambridge, he went on as a postdoctoral fellow at Yale University. He returned to LMB in 1973. He was Joint-Head of the Division of Structural Studies at the MRC Laboratory of Molecular Biology from 1986 until 2001, and Director from 1996 to 2006.

Professor Henderson's work solved a number of the technical and conceptual problems which limited the attainable resolution of electron crystallography. By 1990, he and his colleagues succeeded in obtaining the first atomic structure of the membrane protein by using electron microscopy and diffraction. More recently, Professor Henderson turned his attention to single particle electron microscopy, where more advanced electron cryomicroscopy offers the promise of determining atomic structures of large protein assemblies without the need first to make crystals. These methods are now being used to solve many of the outstanding problems in structural biology.

For his remarkable achievements, Professor Henderson received many Prizes. It was a great joy, pride and honour for the Institutes to hear the announcement in October of 2017 that the 2017 Nobel Prize in Chemistry was awarded to Jacques Dubochet, Joachim Frank and Richard Henderson "for developing cryo-electron microscopy for the high-resolution structure determination of biomolecules in solution". As the Nobel Committee explained, the development of cryo-electron microscopy both simplifies and improves the imaging of biomolecules. This method has moved biochemistry into a new era, and could prove crucial for many areas of research, including studying the Zika virus that causes brain damage in newborns. Using cryo-electron microscopy, researchers can freeze biomolecules mid-movement and visualise processes they have not previously seen.



Inaugural Lecture I 20 March 2017

The cryoEM revolution in structural biology

Structural biology has historically been dominated by X-ray crystallography and nuclear magnetic resonance (NMR) spectroscopy, which are incredibly powerful methods. Over 100,000 structures have been determined, with atomic coordinates deposited in the protein data bank (PDB). In the last few years, single particle electron cryomicroscopy (cryoEM), which does not require crystallisation or isotope labelling, has experienced a quantum leap in its capability, due to improved electron microscopes, better detectors and better software, and this is revolutionising structural biology. Using the technique invented by Jacques Dubochet and his colleagues, a thin film containing a suspension of the macromolecules of interest is plunge-frozen into liquid ethane at liquid nitrogen temperature, creating a frozen-hydrated sample in which individual images of the structures can be seen in many different orientations. Subsequent computer-based image analysis is then used to determine the three-dimensional structure, frequently at near-atomic resolution. I will show examples of some recent structures, and discuss remaining barriers to progress. CryoEM is already a very powerful method, but there are still many improvements that can be made before the approach reaches its theoretical limits.

Lecture 1 I 27 March 2017

Key milestones in development of electron cryomicroscopy (cryoEM)

In this lecture, I will track the different strands of research that came together to create the current enthusiasm for cryoEM. These were the development of the plunge-freezing method by Dubochet at EMBL in the 1980s, early work on frozen protein crystals by Taylor & Glaeser in the 1970s, the development of single particle computer programs on negatively stained ribosomes by Frank & van Heel, as well as the trajectory of research at the MRC-LMB in Cambridge, initiated on helical assemblies by DeRosier & Klug, icosahedral viruses by Crowther and two-dimensional crystals by Unwin & Henderson, right up to more recent developments on direct electron detectors and new programs such as Frealign by Grigorieff and Relion by Scheres.

Lecture 2 I 28 March 2017

Electron microscopy hardware and software for structural biology

As important as the conceptual and practical developments in cryoEM during the last 10 years or so, have been the steady improvements in electron microscope instrumentation (hardware) and computer programs (software). I will describe in this lecture the current status of everything from the electron sources (field emission guns), through stable columns, cold stages and vacuum systems, to new detectors that are approaching but not yet reaching perfection. Alongside this, others have developed superb computer programs that are making the practise of cryoEM possible even for beginners and those who only want to use it as one technique among many.

Lecture 3 I 29 March 2017

Sample and specimen preparation for cryoEM

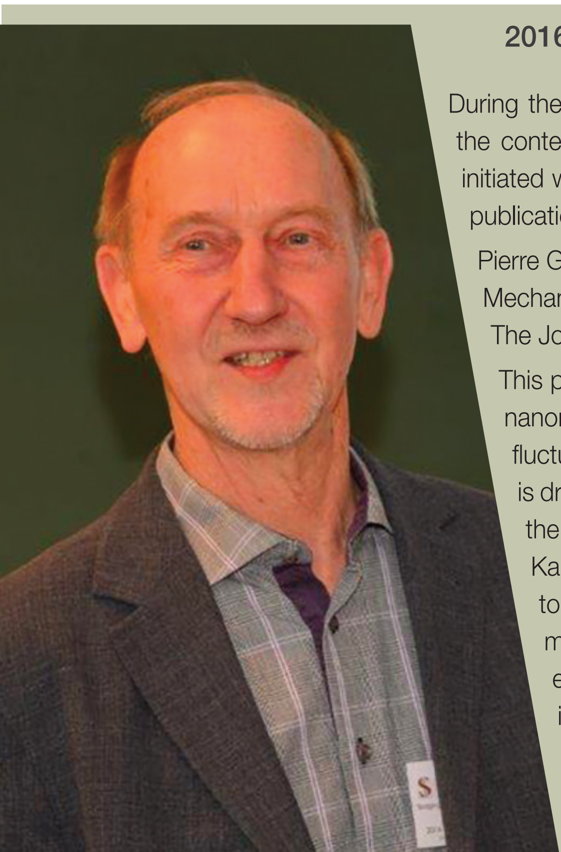
Typical structural biology research projects begin with initial biochemical characterisation of an important specimen, with the goal of answering some key biological or medical question, possibly involving the mechanism of action or the identification of a binding site on a particular macromolecular complex or individual molecule. There are many steps between such initial explorations and the successful determination of a high-resolution structure that answers the initial question. In this lecture, I plan to cover some of the keys steps, the barriers that need to be overcome and the pitfalls to avoid, on the way to a reliable structure determination.

Lecture 4 I 30 March 2017

CryoEM: future perspective

Although cryoEM is already a very powerful method, there are many improvements that still can be made before the approach reaches its theoretical limits.

In this final lecture, I will discuss the underlying theory, the fundamental limitation to the power of the method due to radiation damage, and the remaining barriers to progress. Once these problems have been overcome and generic, practical solutions have been developed, single particle cryoEM and the closely related cryoET (electron cryotomography method) may become the dominant method in structural biology.



2016 International Solvay Chair in Chemistry

During the visit in Brussels of the Professor Raymond Kapral of the University of Toronto in the context of the 2016 Solvay International Chair in Chemistry, a collaboration has been initiated with Professor Pierre Gaspard of ULB, which has already resulted into the following publication:

Pierre Gaspard and Raymond Kapral,
Mechanochemical fluctuation theorem and thermodynamics of self-phoretic motors,
The Journal of Chemical Physics vol. 147, 211101 (2017).

This paper reports a study of the implications of microreversibility on chemically powered nanomotors that are self-propelled by diffusiophoresis. Because of thermal and molecular fluctuations in the surrounding fluid, these nanomotors manifest a Brownian motion that is driven out of equilibrium by the chemical reaction taking place at the interface between the nanomotor and the fluid. In the published paper, Pierre Gaspard and Raymond Kapral have shown that the fluctuations in the motion and the reaction are coupled together and obey a mechanochemical fluctuation theorem as a consequence of microreversibility. The consistency with nonequilibrium thermodynamics predicts the existence of an effect that is reciprocal to self-propulsion by diffusiophoresis and implying that fuel can be synthesized from product, instead of being consumed, if an external force and an external torque are exerted on the nanomotor.

The Solvay Institutes are warmly thanked for their support.

P. Gaspard

WORKSHOPS and schools

organized by the Institutes

20 - 23 February 2017

WORKSHOP ON

"Ionic liquids: from fundamentals to applications"

"Ionic liquids: from fundamentals to applications"

20 - 23 February 2017

Room temperature ionic liquids (RTILs) or salts with melting points below 100 °C as well as deep eutectic solvents, have attracted attention for the development of "green chemistry" since, with their low vapour pressure and a good thermal stability, they are possible alternatives for organic solvents. The technological potentialities of ionic liquids are huge and the exploration of new technologies in fields such as electrochemistry, catalysis, purification technologies, environmental remediation, materials and sustainable energy is progressing very fast. Fundamental aspects related to the structure, properties and reactivity of these liquids are however key issues that need to be explored and discussed for the understanding of the impact of RTILs on these fields and the elaboration of new chemical strategies.

The main scientific objective of this international workshop was to generate discussions between experimentalists and theoreticians, involved in fundamental and applied research to reach some better knowledge of the reactivity of ionic liquids.

Organizing Committee

Koen Binnemans (KU Leuven, Belgium)

Claudine Buess-Herman (ULB, Brussels, Belgium) - Chairperson

Thomas Doneux (ULB, Brussels, Belgium)

Annick Hubin (VUB, Brussels, Belgium)

Zineb Mekhalif (UNamur, Belgium)

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Douglas Mac Farlane (Monash University, Australia)

Hiroyuki Ohno (Tokyo University of Agriculture and Technology, Japan)

Kenneth Seddon (Queen's University, Belfast, UK)

Herman Terryn (VUB, Belgium)

Tom Welton (Imperial College London, UK)

Speakers

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Koen Binnemans (KU Leuven, Belgium)

João AP Coutinho (University of Aveiro, Portugal)

Marta Feroci (University of Roma, Italy)

Bernard Gilbert (ULg, Liège, Belgium)

Patricia Hunt (Imperial College London, UK)

Alexei Kornyshev (Imperial College London, UK)

Corinne Lagrost (University of Rennes I, France)

Enn Lust (University of Tartu, Estonia)

Douglas Mac Farlane (Monash University, Australia)

Claudio J. Margulis (University of Iowa, USA)

Hiroyuki Ohno (Tokyo University of Agriculture and Technology, Japan)

Mathieu Salanne (Sorbonne University, UPMC, France)

Katharina Schröder (Vienna U. of Technology, Austria)

Kenneth Seddon (Queen's University, Belfast, UK)

Cristina Silva Pereira (Universidade de Lisboa, Portugal)

Tom Welton (Imperial College London, UK)

Program

Monday 20 February 2017

Welcome address by Marc Henneaux (Director of the Solvay Institutes)
and Claudine Buess - Herman (Chair of the workshop)

Chair: Claudine Buess-Herman

Bernard Gilbert	*Ionic liquids: A(n) (Hi)story*
Kenneth Seddon	*Everything you always wanted to know about ionic liquids, but were afraid to ask*

Tuesday 21 February 2017

Chair: Douglas R. MacFarlane

Barbara Kirchner	*Ionic Liquids from theoretical considerations*
Claudio J. Margulis	*Ionic Liquids Under Harsh Reactive Conditions*
Patricia Hunt	*Evaluating the valence electronic structure of [C_4C_{1l}m][SCN] gas vs liquid phase*
Tom Welton	*Ionic liquid dynamics in electrical fields*

Chair: Claudio J. Margulis

Hiroyuki Ohno	*Functional design of highly thermoresponsive phase changes in ionic/water mixed systems*
Contributed talk	
Kevin R. J. Lovelock	*A new basicity scale for ionic liquids*
Contributed talk	
Stuart Bogatko	*Ionic liquids and wavefunction in DFT embedding*

Chair: Annick Hubin

Corinne Lagrost	*Reactivity in ionic liquids from the point of view of an electrochemist*
Marta Feroci	*Azolium ionic liquids in electro-organic chemistry*
Contributed talk	
Thomas Doneux	*Electrochemical reduction of carbon dioxide in room temperature ionic liquids, at gold and copper electrodes*

Poster session

Wednesday 22 February 2017

Chair: Corinne Lagrost

Douglas R. MacFarlane	*Energy applications of ionic liquids - from global perspectives to computational approaches*
Alexei Kornyshev	*Energy harvesting and storage with ionic liquids: the essential physics at the nanoscale*
Mathieu Salanne	*Ionic liquids for supercapacitor applications*
Enn Lust	*Electrical double layer structure at metal electrodes and electrochemical characteristics of supercapacitors based on ionic liquids*

Chair: Herman Terryn

Contributed talk

Renata Costa	*Enhancement of energy storage efficiency by tuning the composition of ionic liquids mixtures*

Contributed talk

Olivier Fontaine	*Biredox ionic liquids: new opportunities toward high performance supercapacitors*
Andrew P. Abbott	*Deep eutectic solvents – towards the concept of liquid active ingredients*

Chair: Zineb Mekhalif

Contributed talk

Carlos M. Periera	*Electrodeposition from deep eutectic solvents: a nucleation study*

Contributed talk

Jon Ustarroz	*Fundamental studies on the early stages of electrochemical nucleation and growth from Deep Eutectic Solvents*

Contributed talk

Abhishek Lahiri	*Electroless deposition of metals on silicon in Ionic liquids and its application for lithium ion batteries*
Koen Binnemans	*Ionic liquid technology for recovery and separation of rare earths*

Thursday 23 February 2017

Chair: Christian Stevens

João A. P. Coutinho	*SAIL away – Exploring the potential of surface active ionic liquids: From phase diagrams to the extraction and purification of biomolecules*
Katharina Schröder	*Biomass processing with ionic liquids: Off the beaten track*

Chair: Katharina Schröder

Cristina Silva Pereira	*Ionic liquids unforeseen values in fungal biology and biotechnology*

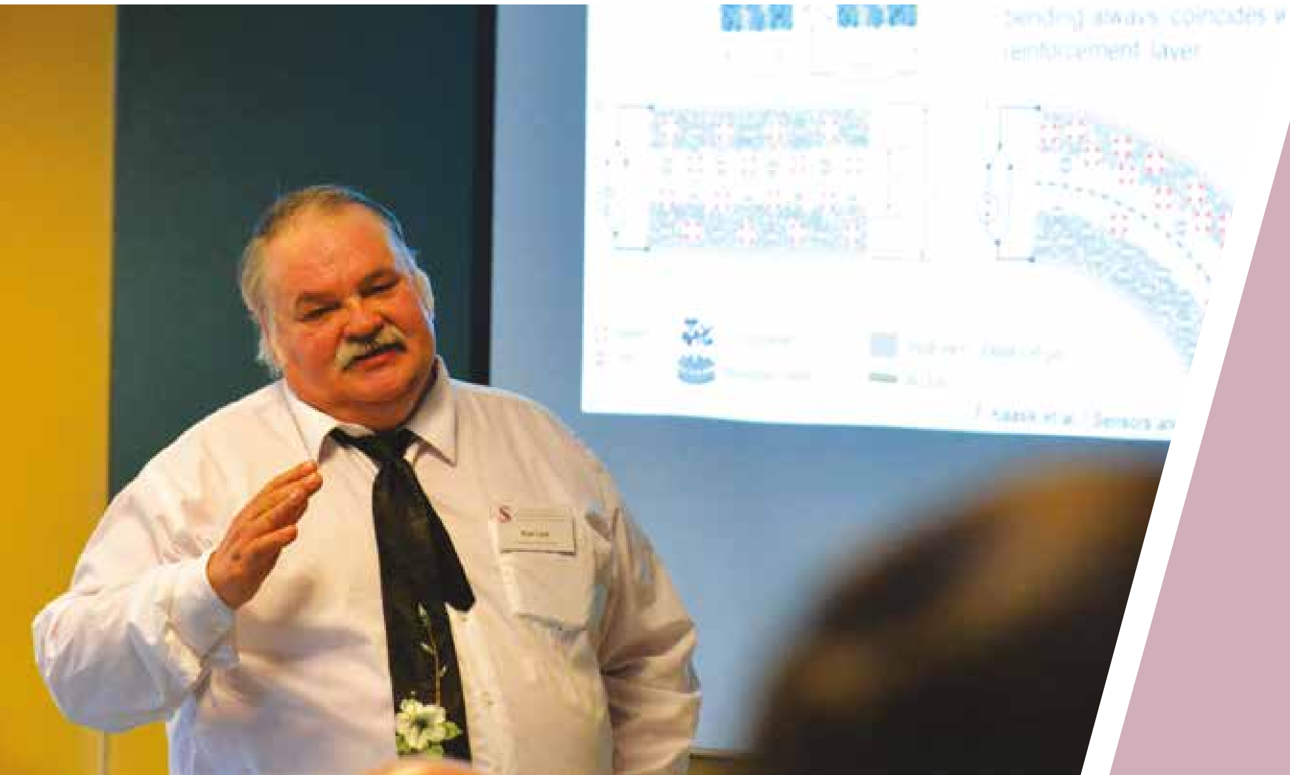
Contributed talk

Pieter Naert	*Ionic liquid ion exchange: exclusion from strong interactions leaves cations to the most weakly interacting anions*

Contributed talk

Sónia P. M. Ventura	*Impact of ionic liquids on the extraction and purification of phycobiliproteins from red seaweeds*

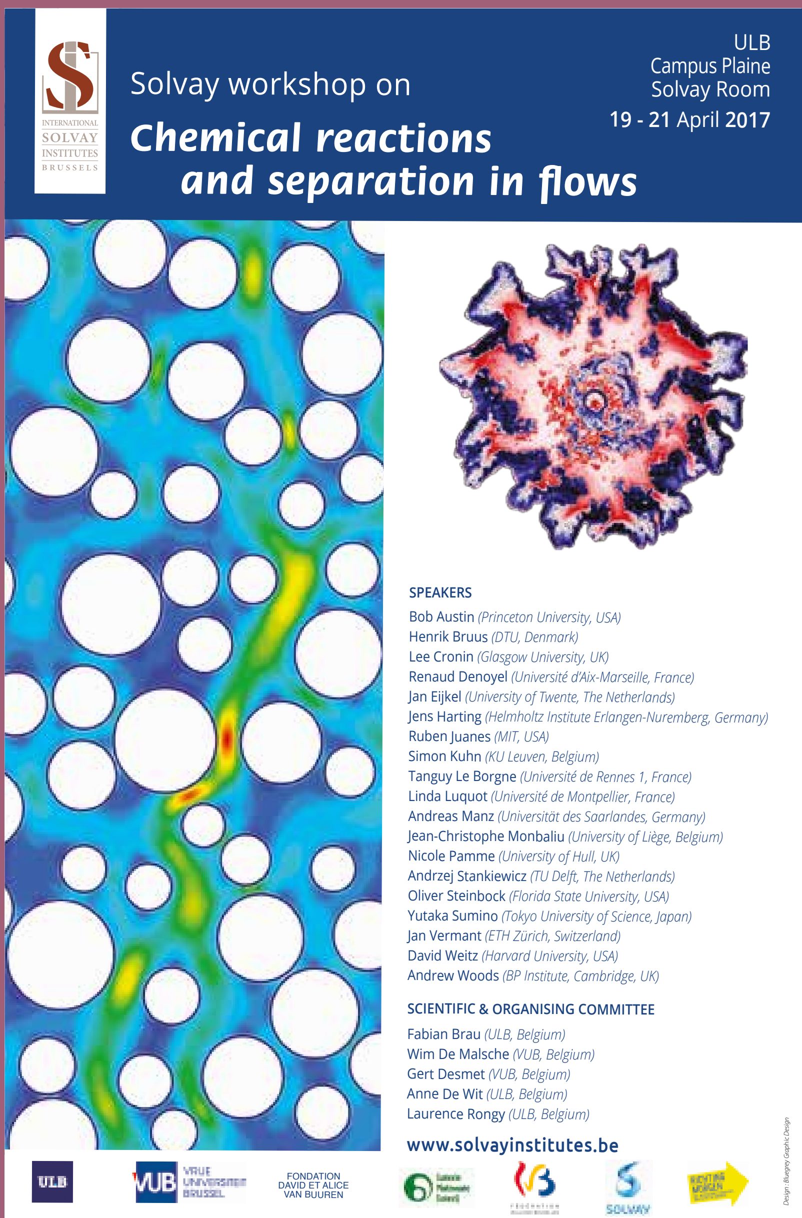
Conclusions



19 - 21 April 2017

WORKSHOP ON

“Chemical reactions and separation in flows”



“Chemical reactions and separation in flows”

19 - 21 April 2017

Chemical reactions and separation processes taking place in flows underlie many applications in environmental and industrial applications. The main ambition of this meeting was to bring together internationally acclaimed experts as well as young researchers, in order to share the latest experimental and theoretical developments in those fields. The objective was to understand how flow conditions can be used to optimize the efficiency of reactions and of separation techniques but also how chemical reactions can tune flow and mixing properties. Emphasis was put on the physical laws governing the micro- and nanoscale and the latest advancements in modelling fundamentals. The workshop consisted of a series of short sessions whose topics covered chemo-hydrodynamics, microfluidics, environmental flows, simulations and modeling, multiphase flows, new reactors and bio-inspired systems, etc. Participants discussed in a prestigious, yet relaxing atmosphere, ensuring great opportunities for networking with leading scientists from a broad range of complementary research areas.

Scientific & Organizing Committee

Gert Desmet (VUB, Belgium)
Anne De Wit (ULB, Belgium)
Fabian Brau (ULB, Belgium)
Wim De Malsche (VUB, Belgium)
Laurence Rongy (ULB, Belgium)

Speakers

Bob Austin (Princeton University, USA)
Henrik Bruus (DTU, Denmark)
Lee Cronin (Glasgow University, UK)
Renaud Denoyel (Université d’Aix-Marseille, France)
Jan Eijkel (University of Twente, The Netherlands)
Jens Harting (Helmholtz Institute Erlangen-Nuremberg, Germany)
Ruben Juanes (MIT, USA)
Simon Kuhn (KU Leuven, Belgium)
Tanguy Le Borgne (Université de Rennes 1, France)
Linda Luquot (Université de Montpellier, France)
Andreas Manz (Universität des Saarlandes, Germany)
Jean-Christophe Monbaliu (University of Liège, Belgium)
Nicole Pamme (University of Hull, UK)
Andrzej Stankiewicz (TU Delft, The Netherlands)
Oliver Steinbock (Florida State University, USA)
Yutaka Sumino (Tokyo University of Science, Japan)
Jan Vermant (ETH Zurich, Switzerland)
David Weitz (Harvard University, USA)
Andrew Woods (BP Institute, Cambridge, UK)

Program

Wednesday 19 April 2017

Welcome and introduction

Session 1: Surface tension effects (Chair: L. Rongy)

Ruben Juanes	*Impact of wettability on evaporation and condensation: phase-field modeling at the pore-scale*
Jan Vermant	*Engineering stability of fluid-fluid interfaces*
Kerstin Eckert	*Relaxation oscillations of solutal Marangoni convection at droplets and droplet chains*
Thomas Ward	*Chemically enhanced immiscible fluid displacements*

Session 2: Effect of external fields (Chair: W. De Malsche)

Andrzej Stankiewicz	*Application of alternative energy forms to reactions and separations in flow systems*
Henrik Bruus	*Microscale acoustofluidics in inhomogeneous solutions*
Ofer Manor	*Acoustic drainage*
Valentina Shevtsova	*Vibration versus diffusion in miscible liquids*

Session 3: Particles in flows (Chair: W. De Malsche)

Jens Harting	*Separation and assembly of colloidal particles by capillary, magnetic and electrostatic forces*
Jerzy Gorecki	*Chemo-mechanical signal diode and XOR gate for information coded with self-propelled particles*
Pierre de Buyl	*Passive and active colloidal chemotaxis in a microfluidic channel*

Poster Session

Thursday 20 April 2017

Session 4: Towards control of chemical reactions in flow conditions 1 (Chair: F. Brau)

Oliver Steinbock	*Chemobrionics: A gateway to a new engineering paradigm?*
Yutaka Sumino	*Confined chemical garden inspected by the change of flow rate-detailed analysis and modeling of filament pattern*
Gábor Schuszter	*Comparison of flow-controlled calcium and barium carbonate precipitation patterns for underground carbon dioxide sequestration*
Lee Cronin	*Coupling complex molecular and material systems with droplet and flow Robotics*
Simon Kuhn	*Particle formation dynamics and clogging events in microfluidics*
Ignacio Sainz-Diaz	*Nanoprecipitation in tubular materials formed in flow conditions and its interaction with organics*

Session 5: Environmental flows (Chair: A. De Wit)

Tanguy Le Borgne	*Mixing and reactive fronts dynamics in porous media*
Linda Luquot	*Role of hydrodynamic and mineralogical heterogeneities on reactive transport processes*
Andy Woods	*Mixing and reaction of two-phase turbulent jets and plumes*

Session 6: Towards control of chemical reactions in flow conditions 2 (Chairperson: A. De Wit)

Jean-Christophe Monbaliu	*Expanding chemistry's horizon with continuous-flow reactors*
Dominique Salin	*Frozen front selection in flow against self-sustained chemical waves*

Banquet

Friday 21 April 2017

Session 7: Separations in microfluidic systems (Chairperson: G. Desmet)

David Weitz	*Chemistry in drops*
Robert H. Austin	*Deterministic lateral displacements: 15 years of progress*
Nicole Pamme	*Continuous flow separations and processing harnessing magnetic forces*
Andreas Manz	*Ion separations in microfluidic systems*
Jan Eijkel	*Improving point-of-care microchip capillary electrophoresis by using a background electrolyte with integrated internal standard*

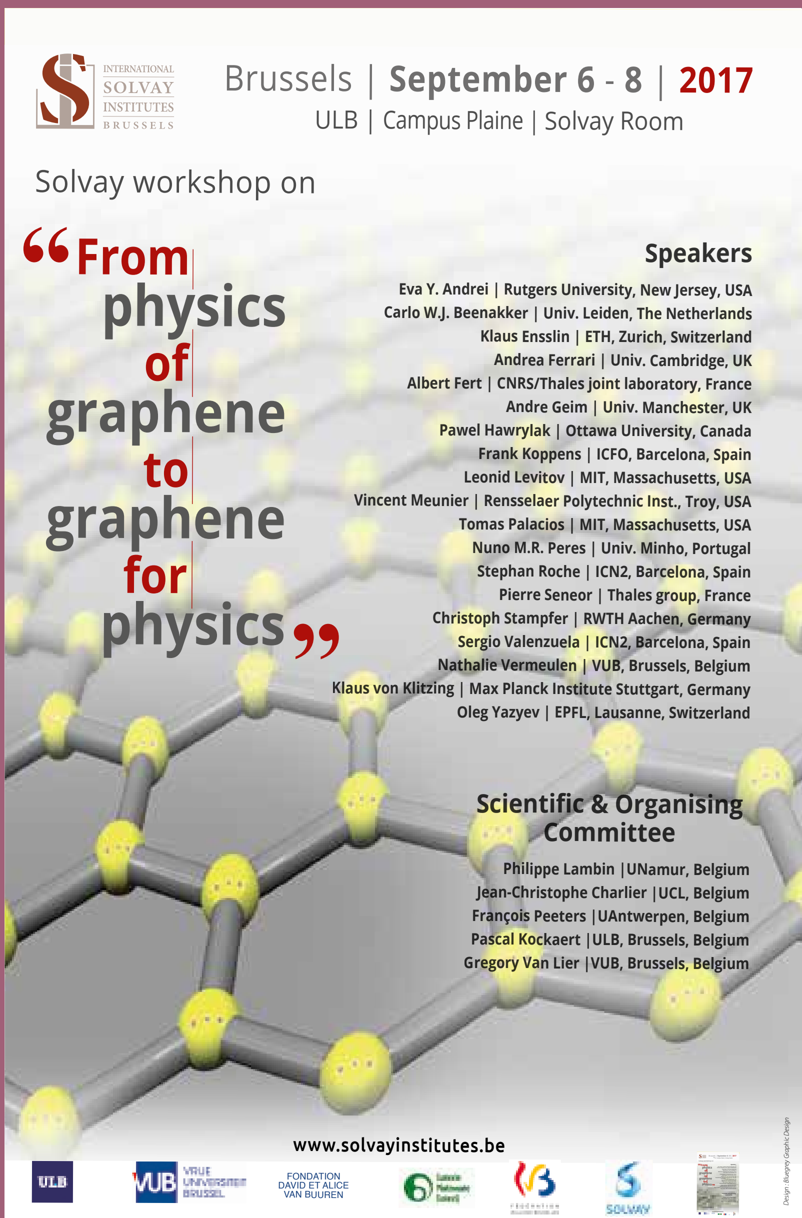
Session 8: Mass transfer properties and multiphase flows

Renaud Denoyel	*From material structure parameters to transport properties*
Marcus Hauser	*Efficient laminar mixing in the vascular tubular networks of slime moulds*
Joaquin Jimenez-Martinez	*Mixing control on fluid-fluid and fluid-solid chemical reactions in multiphase systems*
Roberta Lanfranco	*Invisible porous materials for the optical detection of molecular adsorption*
Jonas Hereijgers	*On the geometrical features of the optimal membrane contact for solvent extraction*

6 - 8 September 2017

WORKSHOP ON

"From physics of graphene to graphene for physics"



“From physics of graphene to graphene for physics”

6 - 8 September 2017

Many interesting properties of graphene put this material at the foreground of present day nanosciences. Graphene is mechanically hard, extremely flexible, chemically inert, impermeable to any atom and molecule, optically transparent. It is a zero-gap semiconductor easily made conducting by electrostatic charging, the charge carriers having then a remarkable mobility. The electronic structure of graphene near the Fermi level is remarkable: electrons and holes have a linear energy dispersion versus momentum, much like ultra-relativistic particles in free space. However, they move in a 2D periodic potential with a velocity 300 times smaller than the speed of light. Most of the remarkable properties of graphene come from its band-structure peculiarity: fractional quantum Hall effect, quantum localization, Klein paradox, small optical absorption, high carrier mobility .... Graphene is also an interesting laboratory for the illustration and sometimes verification of predictions of quantum electrodynamics. The Klein paradox, which states that relativistic particles can tunnel across large distances through a barrier potential with 100 percent probability, is one of them. Potential barriers are easily created in graphene by application of an external field making possible the study of Klein paradox. Another, still puzzling effect is the atomic collapse predicted by quantum electrodynamics for high-Z atom. The simplest theory predicts a critical Z for atom stability being the reciprocal of the fine structure constant, about 137. In graphene, the critical Z of a charged defect should be of the order of one, because the fine-structure constant is 300 larger than in conventional electrodynamics.

The workshop was the occasion to review the many interesting and exotic electronic and optical properties of graphene, and to draw a comprehensive picture of the physics that can be learned from graphene, thanks to its analogy with Dirac-Weyl relativistic fermions.

Scientific & Organizing Committee

Philippe Lambin (UNamur, Belgium)

Jean-Christophe Charlier (UCL, Belgium)

François Peeters (UAntwerpen, Belgium)

Pascal Kockaert (ULB, Brussels, Belgium)

Gregory Van Lier (VUB, Brussels, Belgium)

Speakers

Eva Y. Andrei (Rutgers University, New Jersey, USA)
Carlo W.J. Beenakker (Univ. Leiden, The Netherlands)
Klaus Ensslin (ETH, Zurich, Switzerland)
Andrea Ferrari (Univ. Cambridge, UK)
Albert Fert (CNRS/Thales joint laboratory, France)
Pawel Hawrylak (Univ. Ottawa, Canada)
Frank Koppens (ICFO, Barcelona, Spain)
Leonid Levitov (MIT, Massachusetts, USA)
Vincent Meunier (Rensselaer Polytechnic Institute,Troy, USA)
Kostya Novoselov (Univ. Manchester, UK)
Tomas Palacios (MIT, Massachusetts, USA)
Nuno M.R. Peres (Univ. Minho, Portugal)
Stephan Roche (ICN2, Barcelona, Spain)
Pierre Seneor (Université Paris-Sud, France)
Jurgen Smet (Max Planck Institute Stuttgart, Germany)
Christoph Stampfer (RWTH Aachen, Germany)
Sergio Valenzuela (ICN2, Barcelona, Spain)
Nathalie Vermeulen (VUB, Brussels, Belgium)
Klaus von Klitzing (Max Planck Institute Stuttgart, Germany)
Oleg Yazyev (EPFL, Lausanne, Switzerland)

Program

Wednesday 6 September 2017

Session 1 - Chair: F. Peeters

Welcome by Marc Henneaux (Director of the Solvay Institutes, Brussels)

Introduction by Philippe Lambin (Univ. Namur)

Kostya Novoselov	*Graphene-based heterostructures*
Eva Y. Andrei	*The physics of a vacancy in the graphene lattice*
Klaus von Klitzing	*Graphene for metrology*

Session 2 - Chair: G. Van Lier

Andrea Ferrari	*Light scattering and emission from hetero-structures*
Christoph Stampfer	*Ballistic transport and Aharonov-Bohm interference in graphene*
Oleg Yazyez	*Topological defects and topological electronic phases in 2D materials*
Klaus Ensslin	*Quantum devices in 2D materials*

Poster Session

Thursday 7 September 2017

Session 3 - Chair: C. Van Haesendonck

Leonid Levitov	*Higher-than-ballistic conduction in viscous flows of electrons*
Carlo W. J. Beenakker	*Valley-momentum locking in a graphene superlattice with Y-shaped Kekulé bond texture*
Pawel Hawrylak	*Dirac fermions in confined geometry*
Vincent Meunier	*Electron and phonon confinement in graphene nanoribbons*

Session 4 - Chair: J.C. Charlier

Albert Fert	*Spin-orbit-coupling and topology in 2D: topological insulators, interfacial skyrmions, graphene and TMD*
Pierre Seneor	*New opportunities for spintronics with graphene and other 2D materials*
Stephan Roche	*Recent theoretical advances in graphene spintronics*
Sergio Valenzuela	*Recent progress in experimental graphene spintronics*

Friday 8 September 2017

Session 5 - Chair: Ph. Lambin

Jurgen Smet	*Graphene hybrid architectures: squeezing the best out of graphene*
Nuno M.R. Peres	*Plasmonic properties of graphene*
Tomas Palacios	*Graphene (or how to reinvent engineering with extreme materials)*

Session 6 - Chair: P. Kockaert

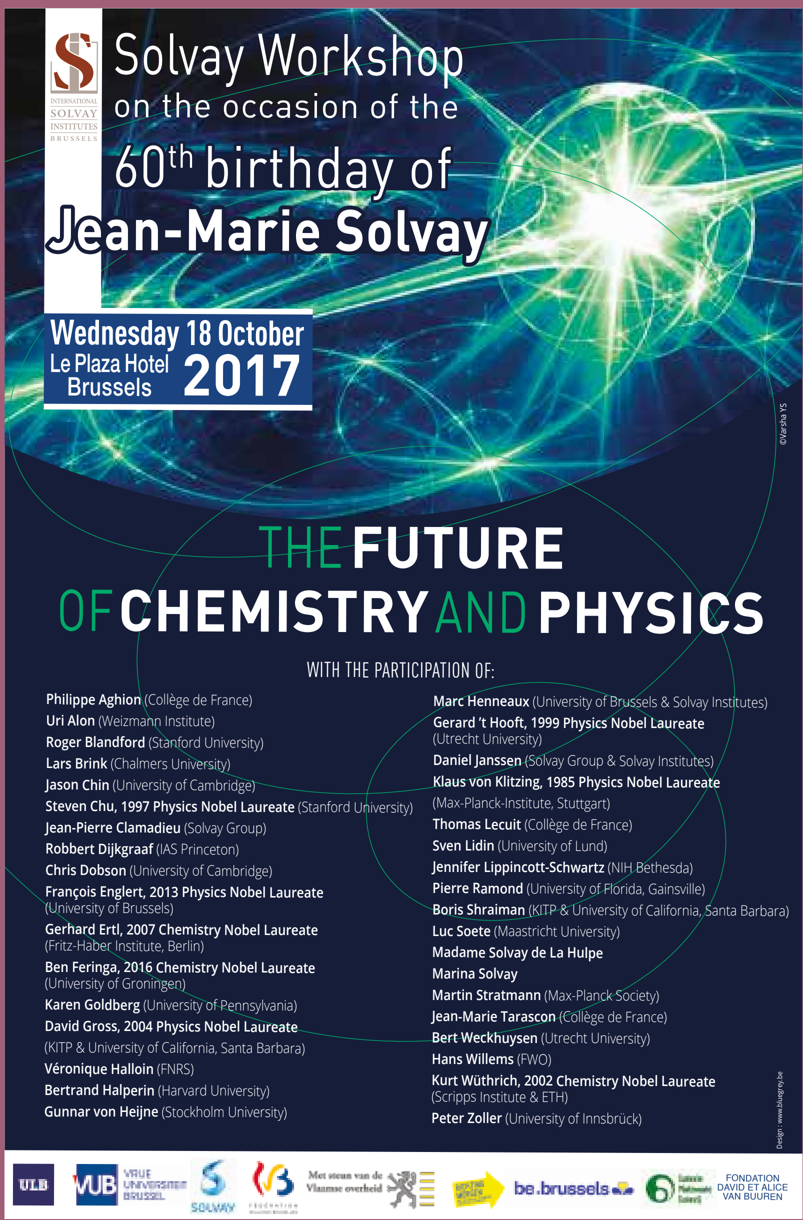
Frank Koppens	*Tuning quantum non-local effects in grapheme plasmonics*
Nathalie Vermeulen	*Nonlinearity-induced spectral broadening of laser pulses in graphene-covered waveguides*

Concluding remarks: François Peeters

18 October 2017

WORKSHOP ON

“The Future of Chemistry and Physics”



"The Future of Chemistry and Physics"

Solvay Workshop on the occasion of the 60th birthday
of Jean-Marie Solvay, President of the International Solvay Institutes

18 October 2017
Plaza Hotel, Brussels

For more than a century, the Solvay family has supported fundamental science, starting with Ernest Solvay, founder of the Solvay company. The pictures of the famous 1911 "Conseil Solvay" where Marie Curie, Einstein, Planck, Heisenberg etc confronted their views are famous worldwide and have become a symbol of scientific excellence. This first meeting was the beginning of a remarkable story.

The Solvay family is still actively supporting basic research. The current President of the Institutes, Jean-Marie Solvay, belongs to the fifth generation since Ernest Solvay.

On Wednesday October 18, 2017, the International Solvay Institutes for Physics and Chemistry organized in Brussels a one-day workshop to celebrate the 60th birthday of Jean-Marie Solvay. The theme of the workshop was "The future of Chemistry and Physics". It provided an opportunity to restate once more the importance of fundamental research for the future of our society. The workshop was attended by distinguished figures from the scientific, academic, economic and business worlds.

Program

The scientific program was ditributed among four panels:

Panel 1: The Future of Physics
Panel 2: The Future of Chemistry
Panel 3: Impact of Physics and Chemistry on Life Sciences
Panel 4: Funding Curiosity-driven Research

17 October 2017

Welcome reception and dinner
at the Le Plaza Hotel.

18 October 2017

Opening speech of Marc Henneaux, Director of the Institutes

Dear Jean-Marie,
Dear Mrs. Solvay,
Ladies and Gentlemen,
Dear Colleagues,
Dear Friends,

Good morning and welcome to everyone to the workshop "The Future of Physics and Chemistry" organized on the occasion of Jean-Marie Solvay 60th birthday.

When I told Jean-Marie that we wanted to organize such an event, he immediately said to me : "You should not do that. There are more important things to celebrate !".

I replied to him that he had no choice and that it was too late. Indeed, we had already received a very positive feedback from all the colleagues to whom we mentioned the idea. It was therefore impossible not to go ahead with the event.

Furthermore, I argued that since it is the tradition in the scientific community to celebrate colleagues who reach 60, there was no way for him to escape from such a "Fest", as we like to call such celebrations. He should be no exception.

He accepted, but he made it clear that he did not want the speakers to talk about him. And he added a condition: that the meeting should be about the future and not about the past.

So this one-day workshop is resolutely devoted to the future, to the future of physics, to the future of chemistry, to the future of their connection with life sciences, and also to the future of the funding of fundamental research.

It is always dangerous to predict the future of a scientific discipline. One way to address this issue is to list the big unsolved questions that the discipline currently faces. The more problems a field raises, the more vigorous it is. A lively field, with a bright future, is characterized by a huge collection of fascinating challenges, which will keep researchers busy for a while, and which, in turn will no doubt raise new important questions.

The program of today's event is thus structured as follows. There will be four panels, two in the morning and two in the afternoon.

The first two panels will describe what they regard as the main challenges respectively in physics and in chemistry. Panel members have been asked: "If there is one scientific question that you would like to see answered in your lifetime, what is it ?"

A third panel will then discuss the potential impact that physics and chemistry can have on life sciences, and the new ways of thinking that physics and chemistry can bring (and should bring) to the discipline. Biophysics and biochemistry are booming sciences and we expect much more to come from these interdisciplinary fields. The theme of the 27th Solvay Conference that starts tomorrow is actually precisely biophysics.

And finally, since "money is the nerve of war", a fourth panel will address how the financial future of scientific research, and in particular, basic research, should be secured. Curiosity-

driven scientific research has always been in danger because its importance is not always well understood and appreciated by the public at large. Defending basic research is a never-ending fight, a fight of yesterday, a fight of today, but also a fight of tomorrow.

The future of the Solvay Institutes depends on the vitality of science. If one day, all scientific questions were to be solved, with no answerable problem left, the Solvay Institutes would go out of business. I am convinced that one conclusion that will come out of the panel discussions is that we are not about to reach the end of science. There remain many challenges ahead of us, and we expect new equally fascinating questions, of which we have no idea now, to emerge as we progress in our understanding of Nature.

From that point of view, the International Institutes have a guaranteed long and brilliant future! We celebrated a few years ago the first hundred years of the Solvay Institutes. Perhaps we should already prepare our 200th anniversary !

Given the strict time constraints, I will not introduce one by one the members of the panels. The program gives you more information. Let me just say that all panel members are exceptional leading figures in their area, and that they complementarily cover a remarkably diverse and broad range of expertise. In the name of the International Solvay Institutes, I want to heartily thank all of them for having accepted our invitation.

When we contacted the speakers asking them to participate in the celebration of Jean-Marie 60th birthday, we received an enthusiastic and overwhelmingly positive response. This tells a lot about how much Jean-Marie's personality and action are appreciated in the community !

I would like to close this speech by disobeying the instructions of Jean-Marie and say a few words about our relationship at the Solvay Institutes. Jean-Marie became President in 2010, seven years ago. Our collaboration has been for me a very rich experience thanks to his true passion for scientific progress, his very high respect for science and the scientists, his exceptional humanity and his indefectible support. Jean-Marie is also very efficient. It has been such a great pleasure to work with him !

And last but not least, we are both convinced that the Institutes are a wonderful tool for the advancement of science. I hope to continue our collaboration towards making the Institutes even stronger for many more years to come !

I am convinced that there is no better way to celebrate Jean-Marie than to talk about science and its future. So let the "Fest" begin !

Thank you very much for your attention.

Panel 1: The Future of Physics

Chair:	Lars Brink
Panelists:	Roger Blandford, David Gross, François Englert, Bertrand Halperin, Gerard 't Hooft, Klaus von Klitzing, Pierre Ramond, Peter Zoller

Panel 2: The Future of Chemistry

Chair:	Sven Lidin
Panelists:	Jason Chin, Chris Dobson, Ben Feringa, Karen Goldberg, Jean-Marie Tarascon, Bert Weckhuysen

Panel 3: Impact of Physics and Chemistry on Life Sciences

Chair:	Gunnar von Heijne
Panelists:	Uri Alon, Steven Chu, Thomas Lecuit, Jennifer Lippincott-Schwartz, Boris Shraiman, Kurt Wüthrich

Panel 4: Funding curiosity-driven research

Chair:	Robbert Dijkgraaf
Panelists:	Jean-Pierre Clamadieu, Véronique Halloin, Luc Soete, Marina Solvay, Hans Willems, Martin Stratmann

Panelists

Uri Alon

Professor at the Weizmann Institute and holder of the 2017 Jacques Solvay Chair in Physics

Roger Blandford

Professor at Stanford University and Member of the Solvay Physics Committee

Lars Brink

Professor Emeritus at Chalmers University, former Chair of the Nobel Committee for Physics and Chair of the Solvay Advisory Committee

Jason Chin

Professor at the University of Cambridge

Steven Chu

(1997 Physics Nobel Laureate)

Professor at Stanford University and Member of the Solvay Physics Committee

Jean-Pierre Clamadieu

CEO of the Solvay Group

Robbert Dijkgraaf

Director of the Institute for Advanced Study at Princeton and Member of the Solvay Physics Committee

Chris Dobson

Professor at the University of Cambridge

Gerhard Ertl

(2007 Chemistry Nobel Laureate)

Professor Emeritus at the Fritz-Haber Institute in Berlin and Member of the Solvay Chemistry Committee

Ben Feringa

(2016 Chemistry Nobel Laureate)

Professor at the University of Groningen and Member of the Solvay Chemistry Committee

Karen Goldberg

Professor at the University of Pennsylvania and Member of the Solvay Advisory Committee

David Gross

(2004 Physics Nobel Laureate)

Permanent Member and holder of the Chancellor's Chair Professor of Theoretical Physics at the Kavli Institute for Theoretical Physics, Professor at the University of California at Santa Barbara and Chair of the Solvay Physics Committee

Véronique Halloin

General Secretary of the "Fonds de la Recherche Scientifique F.R.S.-FNRS" (Belgium)

Bertrand Halperin

Professor at Harvard University and Member of the Solvay Physics Committee

Gunnar von Heijne

Professor at Stockholm University, former Chair of the Nobel Committee for Chemistry and Member of the Solvay Advisory Committee

Marc Henneaux

Professor at the University of Brussels (ULB) and Director of the International Solvay Institutes

Gerard 't Hooft

(1999 Physics Nobel Laureate)

Professor at Utrecht University and Member of the Solvay Physics Committee

Daniel Janssen

Former CEO and Honorary Chairman of the Solvay Group and Member of the Board of Directors of the International Solvay Institutes

Klaus von Klitzing

(1985 Physics Nobel Laureate)

Director of the Max-Planck-Institute in Stuttgart and Member of the Solvay Physics Committee

Thomas Lecuit

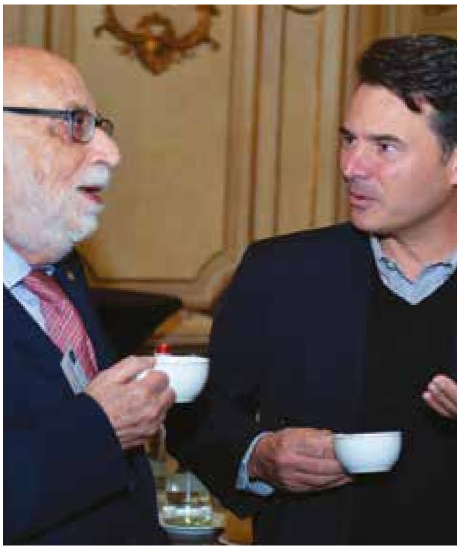
Professor at the Collège de France (Chaire "Dynamiques du vivant")

Sven Lidin

Professor at the University of Lund and former Chair of the Nobel Committee for Chemistry

Jennifer Lippincott-Schwartz

Distinguished Investigator at NIH Bethesda



Pierre Ramond

Professor at the University of Florida at Gainsville and Member of the Solvay Physics Committee

Boris Shraiman

Permanent Member at the Kavli Institute for Theoretical Physics, Professor at the University of California at Santa Barbara and Chair of the 27th Solvay Conference on Physics

Luc Soete

Former Rector Magnificus of Maastricht University

Marina Solvay

Member of the Board of Directors of the International Solvay Institutes

Martin Stratmann

President of the Max-Planck Society

Jean-Marie Tarascon

Professor at the Collège de France (Chaire "Chimie du solide et de l'énergie")

Bert Weckhuysen

Professor at Utrecht University and Member of the Solvay Chemistry Committee

Hans Willems

General Secretary of the "Fonds Wetenschappelijk Onderzoek – FWO" (Belgium)

Kurt Wüthrich

(2002 Chemistry Nobel Laureate)

Professor at the Scripps Institute, La Jolla and at ETH, Zurich, and Chair of the Solvay Chemistry Committee

Peter Zoller

Professor at the University of Innsbrück and Member of the Solvay Physics Committee

10 - 16 September 2017

MODAVE SUMMER SCHOOL
in mathematical physics

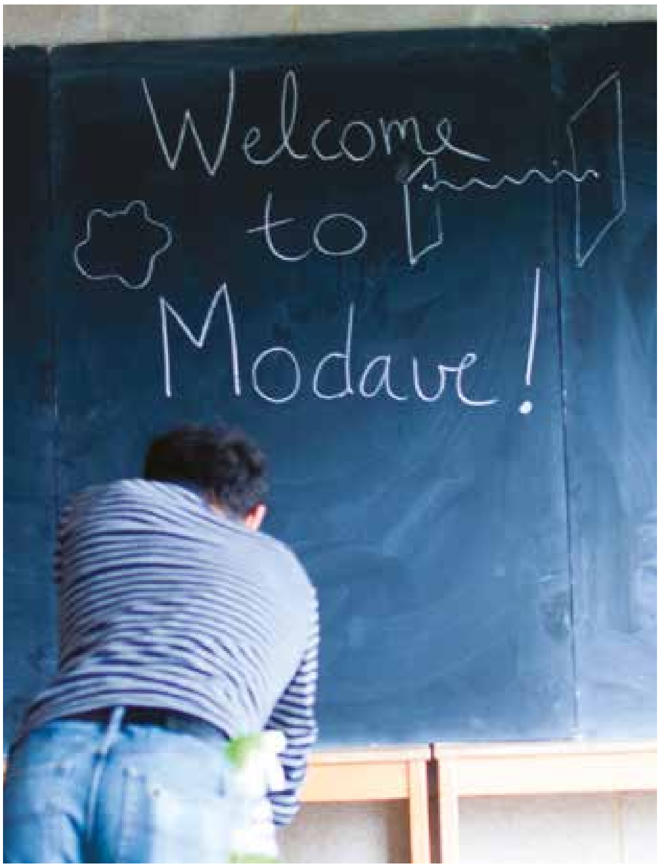
Modave Summer School in Mathematical Physics

10 - 16 September 2017

The thirteenth edition of the Modave Summer School in Mathematicals Physics took place from the 10th to the 16th of September 2017 in Modave (Belgium).

The Modave Summer School is organized by PhD students from Belgian universities (ULB, VUB, KU Leuven and UMons) for other young PhD students from all over the world. The lecturers are late PhD students or young Post-Docs, so that an informal and non-hierarchical environment is assured, facilitating fruitful interactions among young researchers of close fields. The courses consisted of pedagogical blackboard lectures on different topics in theoretical physics, ranging from introductory to advanced subjects.

Modave 2017 Organizing Committee



Tim De Jonckheere (VUB)
Saskia Demulder (VUB)
David De Filippi (UMONS)
Juan Diaz (KU Leuven)
Sibylle Driezen (VUB)
Paolo Gregori (ULB)
Eduardo Lauria (KU Leuven)
Victor Lekeu (ULB)
Tom Lemmens (KU Leuven)
Vincent Luyten (VUB)
Vincent Min (KU Leuven)
Daniel Naegels (ULB)
Kevin Nguyen (VUB)
Arash Ranjbar (ULB)
Romain Ruzziconi (ULB)
Lucas Traina (UMONS)
Guillaume Valette (ULB)
Jesse Vanmuiden (KU Leuven)
Céline Zwikel (ULB)

Lectures

Canonical Charges in Flatland

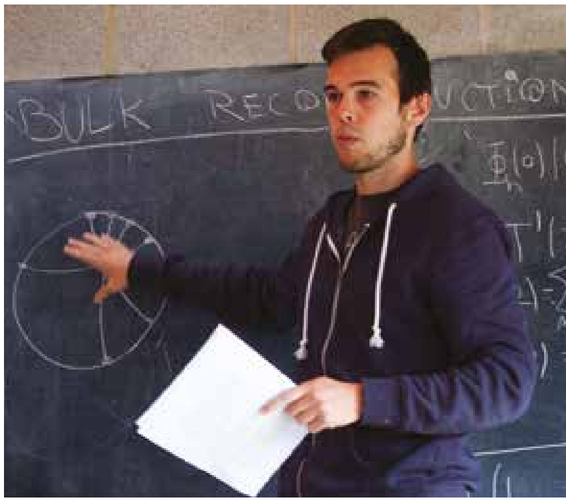
Max Riegler and Céline Zwikel (Université libre de Bruxelles)

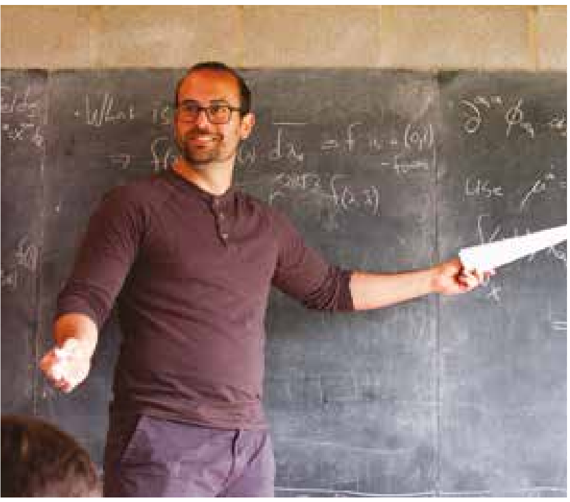
In this series of lectures, we give an introduction to the concept of asymptotic symmetry analysis with a focus on asymptotically flat spacetimes in 2+1 dimensions. We explain general ideas of quantizing gauge theories and then apply these ideas to gravity both in the metric as well as the Chern-Simons formulations. This enables one to compute the asymptotic symmetries of given gravitational configurations that in turn act as the basic underlying symmetries of a possible dual quantum field theory in the context of holography. We also briefly elaborate on the concept of "soft hair" excitations of black holes in this context.

Modave lectures on bulk reconstruction in AdS/CFT

Tim De Jonckheere (Theoretische Natuurkunde, Vrije Universiteit Brussel)

We review the construction due to Hamilton, Kabat, Lifschytz and Löwe for reconstructing local bulk operators from CFT operators in the context of AdS/CFT and show how to recover bulk correlation functions from this definition. Building on the work of these authors, it has been noted that the bulk displays quantum error correcting properties. We will discuss tensor network toy models to exemplify these remarkable features. We will discuss the role of gauge invariance and of diffeomorphism symmetry in the reconstruction of bulk operators. Lastly, we provide another method of bulk reconstruction specified to AdS_3/CFT_2 *in which bulk operators create cross-cap states in the CFT.*





Lectures on twistor theory

Tim Adamo (Theoretical Physics Group, Blackett Laboratory Imperial College London)

Broadly speaking, twistor theory is a framework for encoding physical information on space-time as geometric data on a complex projective space, known as a twistor space. The relationship between space-time and twistor space is non-local and has some surprising consequences, which we explore in these lectures. Starting with a review of the twistor correspondence for four-dimensional Minkowski space, we describe some of twistor theory's historic successes (e.g., describing free fields and integrable systems) as well as some of its historic shortcomings. We then discuss how in recent years many of these problems have been overcome, with a view to understanding how twistor theory is applied to the study of perturbative QFT today.

AdS_2 holography and the SYK model

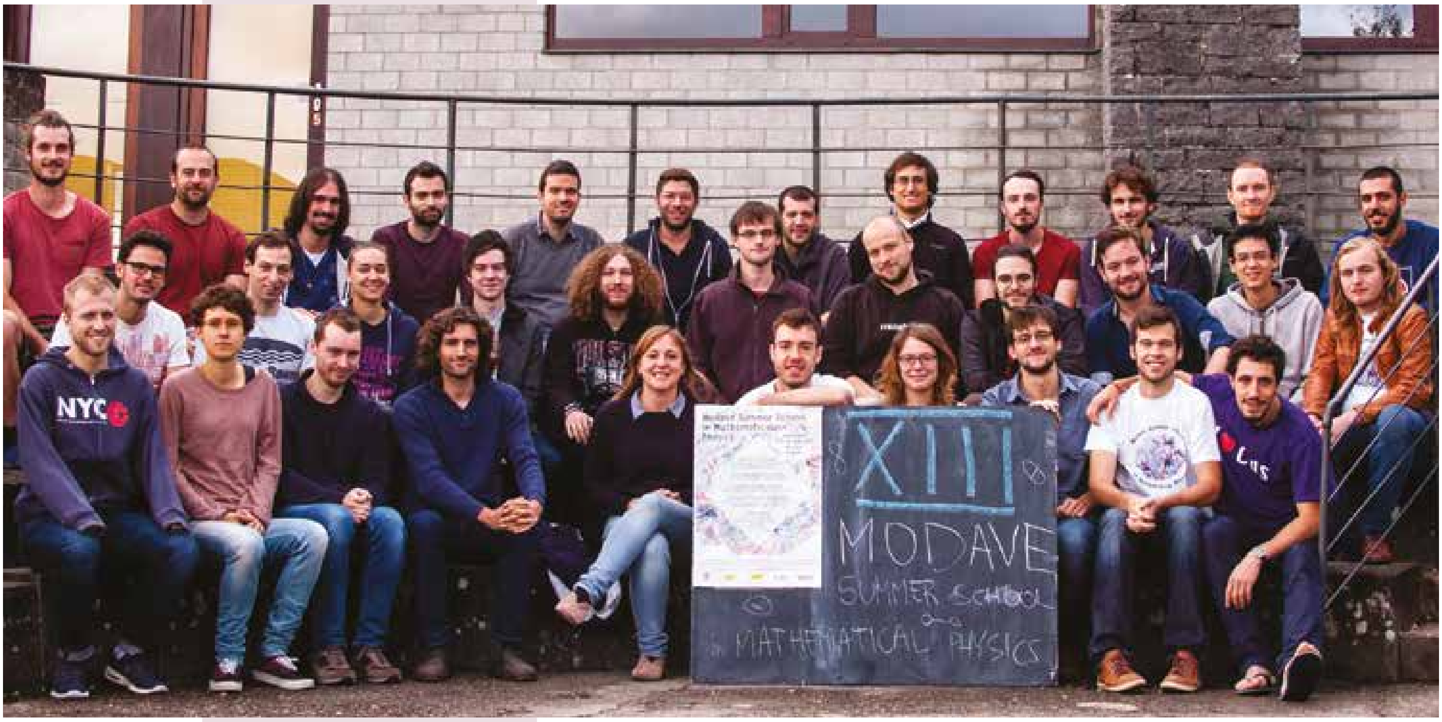
Gábor Sárosi (Theoretische Natuurkunde, Vrije Universiteit Brussels and David Rittenhouse Laboratory)

The goal is to give an introduction to some of the recent developments in understanding holography in two bulk dimensions, and its connection to microscopics of near extremal black holes. The first part reviews the motivation to study, and the problems (and their interpretations) with holography for AdS_2 spaces. The second part is about the Jackiw-Teitelboim theory and nearly-AdS_2 spaces. The third part introduces the Sachdev-Ye-Kitaev model, reviews some of the basic calculations and discusses what features make the model exciting.

Geometry and topology for physicists

Emanuel Malek (Arnold Sommerfeld Center for Theoretical Physics, Department für Physik)

These lectures will cover several topics in geometry and topology and their applications in physics, including differential manifolds, homology and cohomology and fibre bundles. Applications we consider will range from general relativity to gauge theories and string theory.



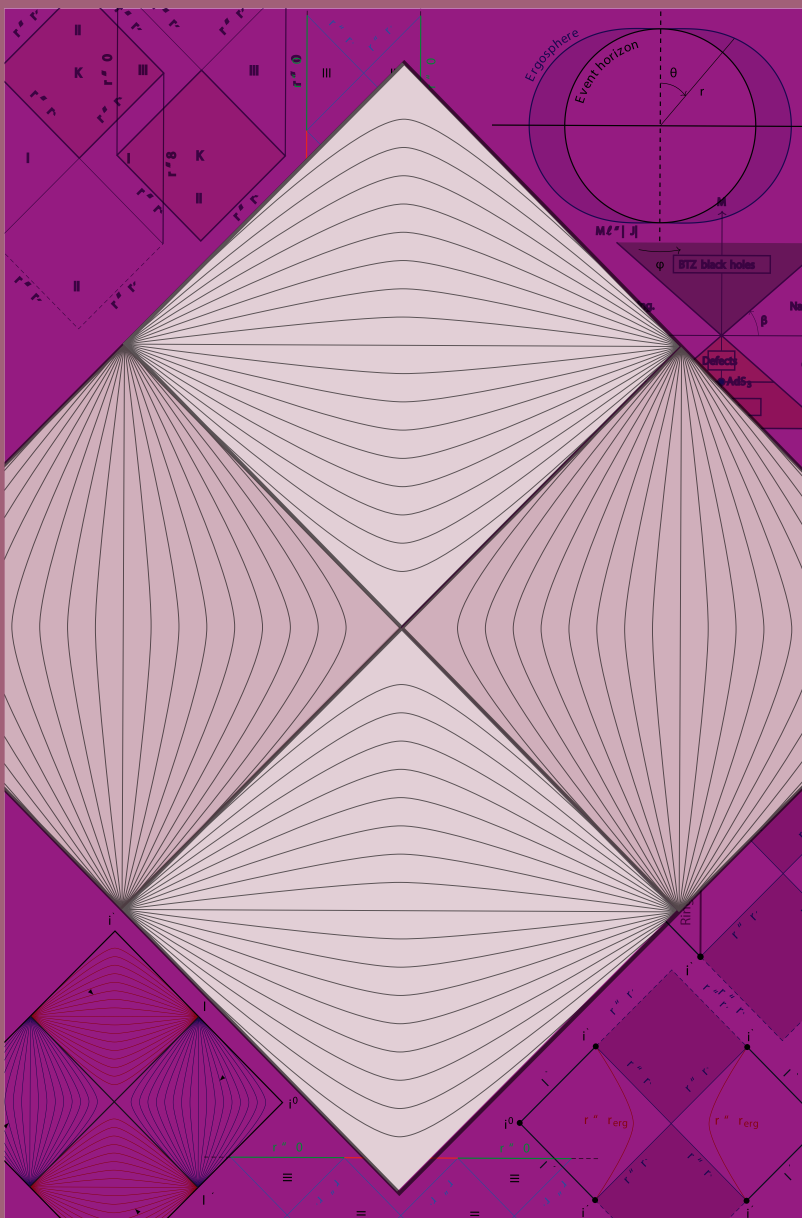
Participants

Adamo Timothy (Imperial College London)
Bomans Pieter (KU Leuven)
Ciambelli Lucas (Ecole Polytechnique Paris)
De Clerck Marine (VUB)
De Jonckheere Tim (VUB)
Del Monte Fabrizio (SISSA Trieste)
Demulder Saskia (VUB)
Driezen Sibylle (KU Leuven)
Ducobu Ludovic (UMONS)
Faller Josua (Berlin Humboldt University)
Goelen Frederik (KU Leuven)
Gregori Paolo (ULB)
Herfray Yannick (ENS Lyon)
Lekeu Victor (ULB)
Lemmens Tom (KU Leuven)
Luyten Vincent (VUB)
Malek Emanuel (Arnold Sommerfeld Center for Theoretical Physics, LMU Munich)
Martin Daniel (Durham University)
Martin Javier (Instituto de Física Teórica UAM/CSIC, Madrid)
Marzolla Andrea (ULB)
Min Vincent (KU Leuven)
Muiden Jesse (KU Leuven)
Naegels Daniel (ULB)
Nguyen Kevin (VUB)
Osten David (Max Planck Institute, Munich)
Ranjbar Arash (ULB)
Riegler Max (ULB)
Ruzziconi Romain (ULB)
Sárosi Gábor (VUB & UPenn)
Schappas Giorgios (University of Athens)
Traina Lucas (UMONS)
Valette Guillaume (ULB)
Venken Gerben (KU Leuven)
Verhellen Jonas (UGent)
Yetismisoglu Cem (Koc University, Istanbul)
Zwikel Céline (ULB)

2 - 20 October 2017

THE INTERNATIONAL doctoral school

"Quantum Field Theory, Strings and Gravity"



The International Doctoral School

"Quantum Field Theory, Strings and Gravity"

The aim of the Amsterdam-Brussels-Geneva-Paris Doctoral School on "Quantum Field Theory, Strings and Gravity" is to provide first-year PhD students with advanced courses in theoretical physics that help bridge the gap between Master-level courses and the most recent advances in the field. Responsible for the organization as well as for teaching the courses are the ULB, the VUB, the University of Amsterdam, various institutions in Paris led by the École Normale Supérieure, and various institutions in Switzerland led by ETH Zurich.

The program typically starts at the end of September/beginning of October and consists of three times three weeks of lectures in three cities among Amsterdam, Brussels, Geneva (CERN) and Paris (depending on the year), with a one-week break between the segments. This way, the students are exposed to several institutes, each with their own research and teaching culture, and to professors from the various institutes. Last but not least, they get to meet fellow students from neighboring institutes and countries, who will be their peers and colleagues throughout (and possibly beyond) their PhD studies.

Organizing Committee Brussels

Riccardo Argurio I ULB
Ben Craps I VUB
Frank Ferrari I ULB

Organizing Institutions

- Institute for theoretical physics - University of Amsterdam
- Laboratoire de physique théorique - École Normale Supérieure (Paris)
- Physique théorique et mathématique - ULB (Brussels)
- Theoretical particle physics - VUB (Brussels)
- SwissMap (ETH, U. Bern, U. Geneva, CERN)

Program

BRUSSELS

2 - 20 October 2017

String Theory I
Alberto Lerda

String Theory II
Marco Billò

Advanced Quantum Field Theory
Adel Bilal

General Relativity and Black Holes
Geoffrey Compère & Stéphane Detournay

Quantum Hall physics and field-theoretic dualities
Dam Thanh Son (2016 Solvay Chair in Physics)

PARIS

6 - 24 November 2017

Introduction to supersymmetry

Introduction to supergravity
Antoine van Proeyen

Introduction to superstrings
Costas Bachas

Lie algebras in physics
Axel Kleinschmidt

AMSTERDAM

4 - 22 December 2017

Intro to AdS/CFT
Kyriakos Papadodimas

Applied AdS/CFT
Julian Sonner

QFT on curved space
Gui Pimentel

Resurgence
Marcel Vonk

Topics in Large N
Dionysis Anninos

Participants

An Yang (Zhejiang University, China)
Chabrol Lilian (Paris-Saclay - IPhT - CEA, France)
Cheng Peng (University of Amsterdam, The Netherlands)
Christodoulidis Perseas (University of Groningen, The Netherlands)
De Clerck Marine (VUB, Belgium)
Delporte Nicolas (Université Paris-Sud, France)
Dondi Nicola Andrea (University of Southern Denmark)
Emery Yoan (Université de Genève, Switzerland)
Fiorucci Adrien (ULB, Belgium)
Fleming Claude (Ecole Polytechnique, France)
Fransen Kwinten (KU Leuven, Belgium)
Gallegos Pazos Angel Domingo (Utrecht University, The Netherlands)
Kuntz Adrien (ENS Ulm, France)
Li Songyuan (École Normale Supérieure, France)
Marcus Eric (Utrecht University, The Netherlands)
Mathys Grégoire (University of Amsterdam, The Netherlands)
Mulhmann Beatrix (University of Amsterdam, The Netherlands)
Nazari Zainab (Bogazici University, Turkey)
Niro Pierluigi (ULB & VUB, Belgium)
Pascalie Romain (Bordeaux, France and Münster, Germany)
Pasternak Antoine (ULB, Belgium)
Rodríguez Pablo (U. de Concepción / Centro de Estudios Científicos CECs, Chile)
Rotundo Antonio (University of Amsterdam, The Netherlands)
Simsek Ceyda (Groningen University, The Netherlands)
VU Dinh-Long (IPhT Saclay, France)
Zhang Yi (IPhT CEA/Saclay, France)
Zinnato Natale (Utrecht University, The Netherlands)

Student’s opinion

Last year, I had a first flavour of research in theoretical physics through my Master’s thesis. Back then, I experienced the frustration of not being able to follow some of the discussions of my research group because of a lack of what has now become basic knowledge in high energy theoretical physics. The rapid expansion of our field over the last decades has created a significant breach between what can be taught during a physics Master’s degree and what is expected from us when starting a PhD. The Amsterdam-Brussels-Geneva-Paris Doctoral School offers the opportunity to fill many of these gaps through a three-month period of intense lectures that introduce important ideas, techniques and calculations that led to present-day research areas. It builds a solid foundation to further deepen your knowledge in the subjects of your choice as well as provides you with a lot of nice references on original and more actual papers or books on the material that was presented. Along the way, different domains are connected and put into a global picture. Evidently, in addition to a great intellectual experience, it is an outstanding opportunity to meet beginning PhD students, post docs and professors from different countries at the start of our PhD. This is particularly useful because of the various conferences that gather some of the participating institutes during the year, giving us the chance to regularly meet again.

As a young physicist, it is not always simple to get a feel for the broadness and variety of subjects studied by other research groups. The doctoral school does not only bring us in contact with other beginning PhD students, which often gave rise to stimulating exchanges about our respective research interests, but it also allows us to meet experienced scientists at the other participating universities and learn more about their activities. Moreover, as the attendance to the school is not restricted to the participating institutions, I also met PhD students from the UK or even Chile. This contributes to the expansion of our network outside of Europe as well.

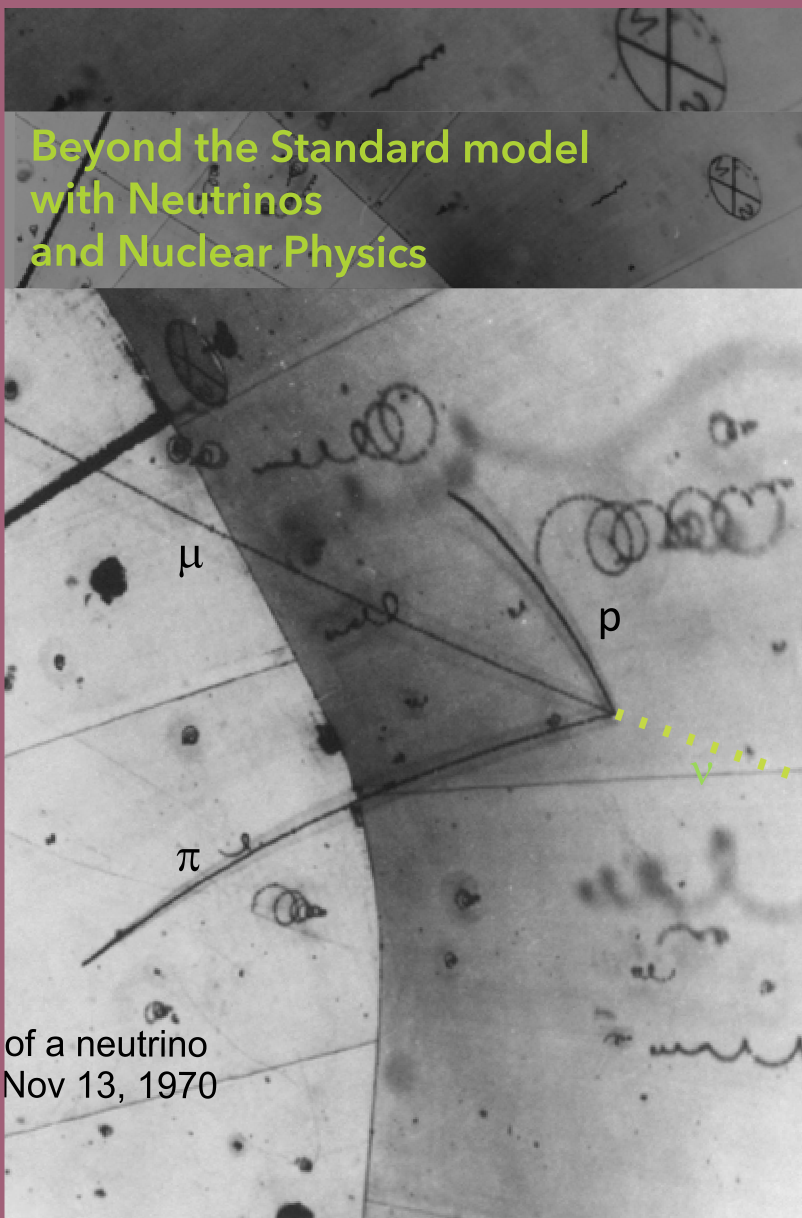
On a personal level, it was very exciting to spend three weeks in the capitals of neighbouring countries. This year, the first session was held in Brussels, my home city. We spent the second session in Paris and concluded the school in Amsterdam. It was very enjoyable to start my PhD with rich lectures accompanied by nice evenings and weekends in cities full of history.

Marine De Clerck (VUB)

29 November - 1 December 2017

WORKSHOP ON

“Beyond the standard model with Neutrinos and Nuclear Physics”



Beyond the Standard model with Neutrinos and Nuclear Physics

29 November - 1 December 2017

Organizers

Jean-Marie Frère (ULB, Brussels, Belgium)

Nathal Severijns (KU Leuven, Belgium)

Topics

The nature of the neutrino

Mass, Majorana or Dirac character

Magnetic moments

Neutrinoless double beta decay: progress in theory, g_A quenching, and experiment

Neutrino mass hierarchy: current data and planned experiments

Neutrinos from reactors

Planned and on-going experiments for fast oscillations (Solid, Stereo, ..)

Room for a sterile neutrino?

Theoretical predictions and experimental measurements (Daya Bay, Double Chooz)

CKM unitarity and CP

Electric dipole moments

Precison in CKM measurements

Other nuclear tests of the Standard Model

Speakers

Alejandro Algora (CSIC-Univ. of Valencia, Spain)
Bertram Blank (CEN Bordeaux-Gradignan, France)
Ming Chung Chu (The Chinese U. of Hong Kong, China)
Mikhail Danilov (LPI, Moscow, Russia)
Stefano Davini (INFN, Genova, Italy)
Muriel Fallot (Subatech, Nantes, France)
Alberto Garfagnini (U. of Padova, Italy)
Darren Grant (U. of Alberta, Canada)
Volker Hannen (U. of Münster, Germany)
John Hardy (Texas A&M University, USA)
Jeff Hartnell (U. of Sussex, UK)
Leendert Hayen (KU Leuven, Belgium)
Anna Hayes (LANL, Los Alamos, USA)
Julian Heeck (ULB, Belgium)
Werner Heil (U. of Mainz, Germany)
Klaus Jungmann (U. of Groningen, The Netherlands)
Boris J. Kayser (Fermilab, Batavia, USA)
David Lhuillier (CEA Paris-Saclay, France)
Manfred Lindner (Max-Planck-Institute, Germany)
Eligio Lisi (INFN, Bari, Italy)
Bastian Märkisch (Technische U. München, Germany)
Javier Menéndez (Tokyo U., Japan)
Oscar Naviliat-Cuncic (Michigan State U., USA)
Gerco Onderwater (U. of Groningen, The Netherlands)
Antonio Palazzo (Univ. of Bari, Italy)
Philipp Schmidt-Wellenburg (Paul Scherrer Institut, Switzerland)
Kate Scholberg (Duke U., USA)
Oleg Smirnov (JINR, Dubna, Russia)
Jouni Suhonen (U. of Jyvaskyla, Finland)
Rob Timmermans (U. of Groningen, The Netherlands)
Nick van Remortel (U. of Antwerpen, Belgium)

Program

Wednesday 29 November 2017

Session: Nuclear physics and the unitarity of the CKM matrix

John Hardy	*The current evaluation of |Vud| and the top-row test of CKM unitarity*
Bertram Blank	*Experimental challenges in extracting the V_ud matrix element*
Oscar Naviliat-Cuncic	*Mirror beta transitions and CKM unitarity*
Bastian Märkisch	*The neutron and CKM unitarity*

Session: Electric dipole moment searches

Rob Timmermans	*Introduction to and overview of EDM measurements*
Philipp Schmidt-Wellenburg	*Overview and status of neutron EDM experiments*
Gerco Onderwater	*EDM measurements with storage rings - the proton EDM*
Werner Heil	*EDMs of stable atoms and molecules*
Klaus Jungmann	*EDM measurements with radioactive probe nuclei*

Thursday 30 November 2017

Session: Nature of neutrinos - Dirac/majorana neutrinoless double beta decay - g_a quenching

Boris J. Kayser	*The Nature of Neutrinos*
Volker Hannen	*Direct neutrino mass measurements*
Jouni Suhonen	*Double beta decay matrix elements and quenching of gA*
Javier Menéndez	*Neutrinoless bb decay matrix elements: present and future*
Manfred Lindner	*Neutrinoless double beta decay and new physics*
Kate Scholberg	*Supernova neutrinos*

Session: Magnetic moments

Julian Heeck	*Neutrino magnetic moments*
Oleg Smirnov	*Neutrino magnetic moments (Borexino)*

Session: Mass hierarchy

Eligio Lisi	*Neutrino mass ordering: Hints and challenges*
Alberto Garfagnini	*The JUNO reactor neutrino experiment - neutrino hierarchy*
Jeff Hartnell	*The NoVA experiment - neutrino hierarchy*
Darren Grant	*The IceCube experiment*

Friday 1 December 2017

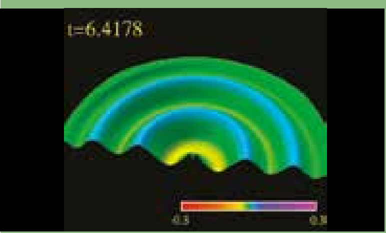
Session: Reactor neutrino spectrum and steriles - Short baseline oscillations

Muriel Fallot	*The reactor neutrino spectrum*
Anna Hayes	*Beta decay and the reactor neutrino anomaly*
Leendert Hayen	*Beta decay spectrum shape and the reactor neutrino anomaly*
Alejandro Algora	*Expt. study of the beta decay of fission fragments*
Antonio Palazzo	*Neutrino fit with steriles*
Ming Chung Chu	*The Daya Bay experiment*

Session: Short baseline oscillations

David Lhuillier	*The STEREO experiment*
Mikhail Danilov	*The DANSS experiment*
Nick van Remortel	*The SOLID experiment*
Stefano Davini	*The SOX experiment*

Closing



COLLOQUIA

Mathematical models of gene regulation: New mathematics from biology (again).

Professor Michael Mackey | *McGill University, Montreal, Canada* | 24 January 2017

Simple bacterial gene regulatory motifs can be viewed from the perspective of dynamical systems theory, and mathematical models of these have existed almost since the statement of the operon concept. In this talk I will review the three basic types of these regulatory mechanisms and the underlying dynamical systems concepts that apply in each case. In the latter part of the talk I will discuss the exciting mathematical challenges that arise when trying to make honest mathematical models of the underlying biology. These include transcriptional and translational delays, and the fact that these delays may be state dependent, as well as the interesting and often unsolved problems of characterizing the noise inherent in bacterial dynamics (which is not of the usual type).

**The Colloquium will start with a tribute to the late Professor René Thomas, an outstanding scientist, and a pioneer in the mathematical modeling of gene regulation.*

Organic bio-electronics for ultra-sensitive bio-markers detection

Professor Luisa Torsi | *University of Bari Aldo Moro, Italy* | 7 February 2017

Organic bio-electronics represents one of the most exciting directions in printable electronics, promising to deliver new technologies for healthcare and human well-being. Among the others, organic field-effect transistors have been proven to work as highly performing sensors.[1] Selectivity is achieved by integrating a layer of functional biological recognition elements, directly coupled with an electronic interface.[1-4] The devices were shown to reach detection limits down to the picomolar (10^{-12} M) range[3,4] with highly repeatable responses (within few percentage of standard deviation) even for 10^4 reiterated measurements in sea water.[5] Moreover, femtomolar (10^{-15} M, fM) detections were achieved with a graphene based FET modified with human olfactory receptors 2AG1.[6]

In this lecture the field of organic and printable electronics implemented to probe biological interfaces will be reviewed discussing the importance of the interplay among disciplines such as organic electronics, analytical chemistry and biochemistry to reach a comprehensive understanding of the phenomena. It will also be shown that applications can lead to label-free electronic biosensors with unprecedented detection limits and selectivity. Notably, the extremely good sensing performance level can be rationalized by quantifying electrostatic and capacitance contributions characterizing the surface confined biological recognition elements interacting with their affinity ligands. Examples of the detection of clinical relevant biomarkers will be provided too.

Selected bibliography

1 *Manoli, K.; Magliulo, M.; Mulla, M.Y.; Singh, M.; Sabbatini, L.; Palazzo, G.; Torsi L. Angewandte Chemie International Edition 54:2-17 2015.*

2 *Casalini, S.; Dumitru, A.C.; Leonardi, F.; Bortolotti, C.A.; Herruzo, E.T.; Campana, A.; de Oliveira, R.F.; Cramer, T.; Garcia, R.; Biscarini, F. ACS Nano 9:5051-5062 2015.*

3 *Macchia, E.; Alberga, D.; Manoli, K.; Mangiatordi, G.F.; Magliulo, M.; Palazzo, G.; Giordano, F.; Lattanzi, G.; Torsi, L. Scientific Reports 6:28085 2016.*

4 *Mulla, M.Y.; Tuccori, E.; Magliulo, M.; Lattanzi, G.; Palazzo, G.; Persaud, K.; Torsi, L. Nature Communications 6:6010 2015.*

5 *Roberts, M.E.; Mannsfeld, S.C.B.; Queraltó, N.; Reese, C.; Locklin, J.; Knoll, W.; Bao, Z. Proceedings of the National Academy of Science of USA 105:12134-9 2008.*

6 *Park, S.J.; Kwon, O.S.; Lee, S.H.; Song, H.S.; Park, T. H.; Jang, J. "Nano Letters 12:5082-5090 2012.*

SESAME
opening a source of light in the Middle East

Professor Eliezer Rabinovici | *Hebrew University of Jerusalem, Israel* | 14 February 2017

SESAME is a cooperative venture by scientists and governments of the Middle East set up on the model of CERN (European Organization for Nuclear Research).

Members of SESAME are Bahrain, Cyprus, Egypt, Iran, Israel, Jordan, Pakistan, the Palestinian Authority, and Turkey.

The synchrotron machine will be used by researchers to study a large variety of scientific questions from viruses to novel materials.

It is being constructed in Jordan and is now starting its preparations for running during 2017.

I will describe from a very personal view point how this project has come into being starting in 1995. The story will move from the CERN cafeteria through the Sinai desert to the completion of a high quality scientific electron accelerator in Jordan.

How does the Earth's atmosphere maintain its self-cleaning capacity?

Professor Jos Lelieveld | *Max Planck, Germany* | 2 March 2017

Millions of tons pollutants and greenhouse gases are emitted per year, and then photochemically oxidized. Subsequently, the oxidation products are removed by deposition processes. In the absence of this self-cleaning mechanism, or when it weakens, our atmosphere would become toxic and create a hot-house effect. The atmospheric oxidation mechanism is primarily determined by hydroxyl (OH) radicals. Key questions are: Is the oxidation capacity reduced by the worldwide growing pollution emissions? To what extent is it buffered by OH recycling? How do regions with specific photochemical and pollution characteristics act together through atmospheric transport at a global scale? Atmospheric chemistry and climate models have neglected OH recycling in the oxidation of natural hydrocarbons, which are emitted in large quantities by the vegetation. New approaches need to do justice to the intricate interactions between reactive carbon, nitrogen species and oxidants. These interactions give rise to a global buffering mechanism that can maintain the self-cleaning capacity of the atmosphere.

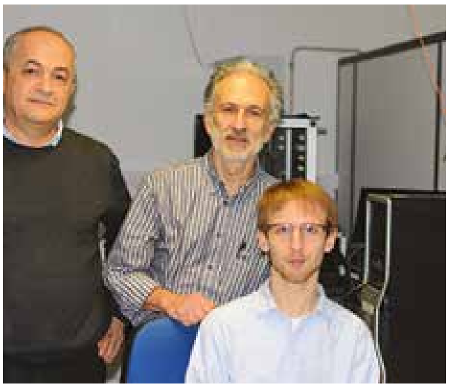
From Emergent Gravity to Dark Energy and Dark Matter

Professor Erik Verlinde | *University of Amsterdam, The Netherlands* | 14 March 2017

The observed deviations from the laws of gravity of Newton and Einstein in galaxies and clusters can logically speaking be either due to the presence of unseen dark matter particles or due to a change in the way gravity works in these situations. Until recently there was little reason to doubt that general relativity correctly describes gravity in all circumstances. In the past few year insights from black hole physics and string theory have led to a new theoretical framework in which the gravitational laws are derived from the quantum entanglement of the microscopic information that is underlying space-time. An essential ingredient in the derivation is of the Einstein equations is that the vacuum entanglement obeys an area law, a condition that is known to hold in Anti-de Sitter space due to the work of Ryu and Takayanagi. We will argue that in de Sitter space due to the positive dark energy, that the microscopic entanglement entropy also contains also a volume law contribution in addition to the area law. This volume law contribution is related to the thermal properties of de SItter space and leads to a total entropy that precisely matches the Bekenstein-Hawking formula for the cosmological horizon. We study the effect of this extra contribution on the emergent laws of gravity, and argue that it leads to a modification compared to Einstein gravity. We provide evidence for the fact this modification explains the observed phenomena in galaxies and clusters currently attributed to dark matter.

The Maxwell demon and Landuer's principle: from gedanken to real experiments

Professor Sergio Ciliberto | *ENS, Lyon, France* | 25 April 2017



During this talk we will recall the connections between information and thermodynamics. We will then discuss a specific example of the measure of the Landauer's bound. Rolf Landauer argued that the erasure of information is a dissipative process. A minimal quantity of heat, proportional to the thermal energy, is necessarily produced when a classical bit of information is deleted. A direct consequence of this logically irreversible transformation is that the entropy of the environment increases unavoidably by a finite amount. We experimentally show the existence of the Landauer bound in a generic model of a one-bit memory. Using a system of a single colloidal particle trapped in a modulated double-well potential, we establish that the mean dissipated heat saturates at the Landauer bound in the limit of long erasure cycles. This result demonstrates the intimate link between information theory and thermodynamics. For a memory erasure procedure, which is a logically irreversible operation, a detailed Jarzynski Equality is verified, retrieving the Landauer limit independently of the work done on the system.

Black holes Nature's most powerful and efficient engines

Professor Marek A. Abramowicz | *Göteborg University, Sweden* | 2 May 2017

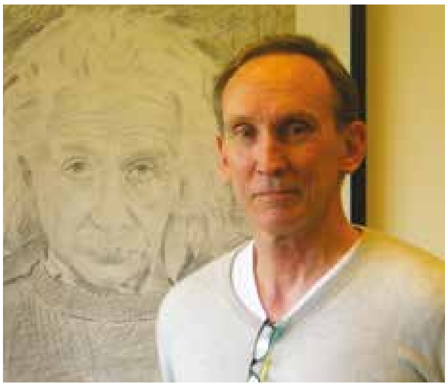
I will first discuss the observational appearance of astrophysical black holes that we know to exist in the real Universe: the "stellar" black holes with masses about 10 solar masses and the "super-massive" ones with masses from a few millions to a few tens of billions solar masses. We now observe black holes using radio, optical, X-ray, Y-ray and gravitational wave telescopes. The new Event Horizon Telescope started to collect data just this month. It is able to resolve details of matter structures around a super-massive black hole at our Galaxy centre which are comparable with the black hole size.

Black holes accrete matter from their surroundings. The black hole accretion is remarkably powerful and efficient. Indeed, there is no other non-explosive process known in the whole Universe that would surpass the black holes power and efficiency. Roger Penrose suggested the rotational energy of a spinning black hole may be, in principle, tapped. Recently it was demonstrated that an electromagnetic version of this process (the Blanford-Znajek mechanism) may power powerful jets that are observed in many black hole sources.

Collisions of black holes lead emission of gravitational waves. The gravitational wave burst detected by the LIGO interferometers in 2015 was energetically the most powerful event ever detected by the humans.

Development of Realtime Nanoscale DNA Sequencing Technology

Professor Mark Akeson | *University of California, Santa Cruz, USA* | 3 May 2017



In September 2016, astronauts aboard the International Space Station sequenced DNA using a one-Watt, 90-gram device connected to a laptop computer. This device, the MinION, decodes individual DNA strands as they are driven base-by-base through a nanoscale hole in a thin film.

In my talk, I will describe key steps in the development of this nanopore DNA and RNA strand sequencing technology from its earliest conception more than 25 years ago to its recent commercialization and application. I will then discuss features of these nanopore sequencers that will impact genomics going forward including portability, near real-time readouts, and long contiguous single strand reads exceeding 150,000 bases.

Biomimetism & Bio-inspiration : Sources of knowledge to create new materials

Professor Clément Sanchez | *U. Pierre et Marie Curie, Collège de France* | 9 May 2017

For the past five hundred million years nature has produced materials with remarkable properties and features such as the smart functionnal surfaces found in some leaves and flowers, the beautifully carved structures found in radiolaria or diatoms, the extraordinary mechanical and self-healing properties found in many composites. Another of nature's remarkable features is its ability to combine at the nanoscale (bio) organic and inorganic components allowing the construction of smart natural materials that found a compromise between different properties or functions (mechanics, density, permeability, colour superhydrophobia, porosity, etc). Such a high level of integration associates several aspects: miniaturisation whose object is to accommodate a maximum of elementary functions in a small volume, hybridisation between inorganic and organic components optimizing complementary possibilities, functions and hierarchy. Current examples of natural organic–inorganic hybrids are crustacean carapaces or mollusc shells, bone or teeth tissues in vertebrates, byssus of mussels etc… As far as man-made materials are concerned, the possibility to combine properties of organic and inorganic components for materials design and processing is a very old challenge that likely started since ages (Egyptian inks, green bodies of china ceramics, prehistoric frescos, Maya Blue pigments etc). However, to day bottum-up strategies allow to design the so-called hybrid organic–inorganic materials where organic and inorganic components are intimately mixed. It is obvious that properties of these materials are not only the sum of the individual contributions of both phases, but the role of the inner interfaces could be predominant. Hybrid materials based stategies are today generating smart membranes, new catalysts and sensors, new generation of photovoltaic and fuel cells, smart microelectronic, micro-optical and photonic components and systems, or intelligent therapeutic vectors that combine targeting, imaging, therapy and controlled release properties.

This plenary lecture will present a few striking examples of bioinspired functional materials built via bottum-up strategies. In particular analogies between, engineering and processing made by nature to construct performant materials and the today strategies used by materials chemists and engineers to produce modern materials through a kind of controlled design will be emphasized.

Computational Explorations of Flowing Matter at the Physics-Biology Interface

Professor Sauro Succi | *IAC-CNR, Rome, Italy & IACS Harvard, Cambridge, USA* | 30 May 2017

Boltzmann kinetic theory is the fundamental cornerstone of statististical mechanics, the branch of theoretical physics which endeavours to unravel the subtle connections between the microscopic world of the "things we cannot see", molecules, atoms and below, and the macroscopic world, as we perceive it through our common senses. Its mathematical cornerstone, the Boltzmann equation, describes the way how microscopic motion organizes into the flow of mass, momentum and energy, which feeds and sustains virtually all natural and industrial processes around us.

Yet, the Boltzmann equation is all but an easy piece; a non-linear integral-differential equation living in seven-dimensional phase-space time, and thus setting a formidable computational challenge even to the most advanced numerical methods, let alone analytical ones. In recent times, the Boltzmann equation has made proof of yet one more precious virtue: it (often) lends itself to minimal formulations which manage to relinquish most of the math complexity, without surrendering the essential physics at hand.

In particular, over the last three decades, the Lattice Boltzmann (LB) method has gained a prominent role as an efficient and versatile scheme for the computational exploration of complex states of flowing matter across a broad range of scales. From fully-developed turbulence in real-life geometries, to multiphase flows, all the way down to microfluidics and biopolymer translocation in nanopores. Lately, even quantum-relativistic matter, such as electron flows in graphene and subnuclear quark-gluon plasmas.

After a brief introduction to Boltzmann's kinetic theory and to the main ideas behind the LB method, in this Colloquium we shall illustrate a selected list of recent applications from the above, along with prospects for future explorations at the interface between physics and biology, such as protein folding and aggregation in the cell and the direct simulation of biological organelles on extreme-computing (Exascale) platforms.

Black Holes in the Era of Gravitational Wave Astronomy

Professor Frans Pretorius | *Princeton University, USA* | 6 June 2017

Black holes are one of the more astonishing predictions of the theory of General Relativity. The Schwarzschild black hole solution was discovered within months of Einstein publishing the field equations of general relativity, though for decades after was regarded more as a mathematical curiosity than a plausible description of any real object in the universe. This began to change in the 1960s, both through theoretical and observational discoveries, and finally in 2015 the LIGO gravitational wave detectors found the first direct evidence for the existence of black holes, having measured a signal consistent with the inspiral and merger of two black holes. In this talk I will give an overview of black holes in general relativity, the LIGO observations, and what we can hope to learn about black holes in the coming decade as a plethora of new data is gathered from ground based gravitational wave detectors, the Event Horizon Telescope, and pulsar timing arrays.

Design of Efficient Molecular Catalysts for Development of Polymeric Functional Materials

Professor Kotohiro Nomura | *Tokyo Metropolitan U., Japan* | 8 November 2017

Design of molecular catalysts plays an essential role for synthesis of (advanced) functional materials with unique properties. In this lecture, several examples developed in our laboratory will be briefly introduced.

Metal catalyzed olefin coordination/insertion polymerization is a core technology for polyolefin production. Recently, considerable attention has been paid to the synthesis of new polymers that cannot be prepared by ordinary catalysts. Nonbridged half-titanocenes containing anionic donor ligands, Cp'TiX2(Y) (Cp' = cyclopentadienyl, Y = aryloxo, ketimide etc.), are promising catalysts for syntheses of new polymers by ethylene copolymerizations especially with sterically encumbered olefins (believed to be traditionally unreactive), cyclic olefins.

Olefin metathesis is a useful method applied for synthesis of various polymeric, advanced materials. In particular, ring-opening metathesis polymerization (ROMP) has been employed for synthesis of various functional materials; both Ru-carbene (Grubbs type) and Mo-alkylidene (Schrock type) catalysts are the successful examples. (Imido)vanadium(V)-alkylidene complexes are also the promising catalysts; the fluorinated phenoxy analogue exhibited the notable activities, and the fluorinated alkoxo analogues demonstrate cis specific ROMP even at 80ºC.

Acyclic diene metathesis (ADMET) polymerization is the effective method for synthesis of defect-free conjugated polymers, and the method enables an introduction of functional groups at the chain ends. We demonstrated that the method using Mo catalysts enables quantitative introduction of different end groups into the polymer chain ends.

Functional Supramolecular Chemistry

Professor Stefan Matile | *University of Geneva, Switzerland* | 28 November 2017

This lecture will focus on functional systems that emphasize conceptual innovation, integrate unorthodox interactions,[1] and address lessons from and challenges in nature. Catalysis with anion-π interactions[2] and chalcogen bonds[3] will be introduced as recent examples for "exotic" interactions at work. Anion-π catalysts for asymmetric enolate, enamine, iminium and transamination chemistry, the first anion-π enzyme,[4] and remote control by electric fields will be presented. The more delocalized nature of anion-π interactions suggests that the stabilization of long-distance charge displacements in cascade reactions on π-acidic aromatic surfaces deserves particular attention.[5] This is almost complementary to the highly localized transition-state stabilization in the focal point of two or more chalcogen bond donors. To realize this noncovalent catalysis with chalcogen bonds, benzodiselenazoles and dithienothiophenes will be introduced as a privileged scaffold reminiscent of classics such as bipyridines or bipyrroles.[2]

A twisted dimer of same dithienothiophenes will be introduced as the first fluorescent probes that can image membrane tension in cells (unpublished). The fluorescent imaging of forces in biological systems in general is one of the central current challenges that are waiting for solutions from chemistry. Our contribution to solve this problem focuses on mechanosensitive "flipper" probes that change color like lobsters during cooking, that is by a combination of polarization and planarization of the mechanophore in the ground state.[6]

Another central, most persistent challenge in current biology concerns the question how to move across lipid bilayer membranes. To find new ways to enter cells, dynamic covalent disulfide exchange chemistry on their surface is particularly attractive. Coming from counterion-mediated uptake with cell-penetrating peptides, attention is gradually shifting over hybrid mechanisms with cell-penetrating poly(disulfide)s (CPDs) toward strain-promoted thiol-mediated uptake with asparagusic acid[7] and, most recently, epidithiodiketopiperazines (ETPs)[8] and diselenolanes (unpublished). With a CSSC dihedral angle near zero, ring tension with ETPs and diselenolanes is at the maximum, their uptake efficiency is correspondingly powerful.

1) *Zhao, Y.; Cotelle, Y.; Sakai, N.; Matile, S. J. Am. Chem. Soc. 2016, 138, 4270–4277.*

2) *Zhao, Y.; Domoto, Y.; Orentas, E.; Beuchat, C.; Emery, D.; Mareda, J.; Sakai, N.; Matile, S. Angew. Chem. Int. Ed. 2013, 52, 9940–9943.*

3) *Benz, S.; López-Andarias, J.; Mareda, J.; Sakai, N.; Matile, S. Angew. Chem. Int. Ed. 2017, 56, 812–815.*

4) *Cotelle, Y.; Lebrun, V.; Sakai, N.; Ward, T. R.; Matile, S. ACS Cent. Sci. 2016, 2, 388–393.*

5) *Liu, L.; Cotelle, Y.; Avestro, A.-J.; Sakai, N.; Matile, S. J. Am. Chem. Soc. 2016, 138, 7876–7879.*

6) *Dal Molin, M.; Verolet, Q.; Colom, A.; Letrun, R.; Derivery, E.; Gonzalez-Gaitan, M.; Vauthey, E.; Roux, A.; Sakai, N.; Matile, S. J. Am. Chem. Soc. 2015, 137, 568–571.*

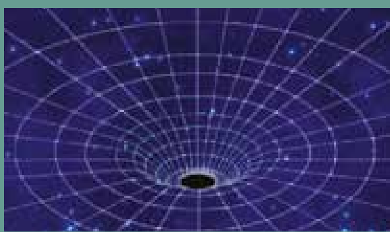
7) *Abegg, D.; Gasparini, G.; Hoch, D. G.; Shuster, A.; Bartolami, E.; Matile, S.; Adibekian, A. J. Am. Chem. Soc. 2017, 139, 231–238.*

8) *Zong, L.; Bartolami, E.; Abegg, D.; Adibekian, A.; Sakai, N.; Matile, S. ACS Cent. Sci. 2017, 3, 449–453.*

Vitrimers: principles and perspectives

Professor Ludwik Leibler | *ESPCI Paris, France* | 12 December 2017

During cooling, amorphous silica, the archetype glass-former gradually increases its viscosity over a wide temperature range and it becomes so viscous that for all practical purposes it behaves like a hard solid, the glass. In striking contrast and without exception all organic glass-formers increase their viscosity and rigidify very abruptly when cooled. Moreover, silica is not soluble. We imagined, vitrimers, organic materials that undergo gradual glass transition and are not soluble just like silica. Vitrimers are molecular networks that through thermo-activated exchange reactions are able to change their topology without changing the total number of bonds. Solid at low temperatures and malleable when heated yet insoluble whatever the temperature, vitrimers constitute the third class of polymers along with thermoplastics and thermosets (elastomers). First vitrimers were made from epoxy resins. Today most plastics and rubbers can be transformed into vitrimers. Since vitrimers can be shaped, assembled, repaired and recycled while showing exquisite chemical and thermomechanical resistance they should rapidly find applications in electronics, automotive, airplane, and coatings industries. And as for inorganic glass-formers, the question whether amorphous silica is a vitrimer opens intriguing perspectives.



WORKSHOPS & ACTIVITIES sponsored

by the Institutes

“90°South: your experiment at the South Pole?”

17 February 2017 I Brussels

Gwenhaël de Wasseige, PhD student in the IIHE IceCube group, had been selected to spend a month at the Amundsen Scott South Pole station. She proposed several ideas for outreach activities related to her trip to SP.

The main outreach activity was a contest for schools reaching students from 5th year primary school to last year secondary school. The contest was called ‘90°Zuid : jouw experiment op de Zuidpool!/ 90°Sud : ton expérience au Pôle Sud!’.

The aim was to select experiments which Gwen would take with her to SP. The students had to design an experiment for which one expects to have a different outcome in their school and at SP (‘Belgium-South Pole: what is the difference?’).

An international jury, including Francis Halzen, selected 3 of them to be re-done at the South Pole by Gwen De Wasseige:

- “De grootte van de aardmagnetische veldsterkte, richting en zin van de magnetische veldlijnen op de Zuidpool en België bepalen door middel van een magnetische kompasnaald in een spoel en de sterkte en zin van de magnetische veldlijnen aantonen m.b.v. een slinger”, by the class 6-Economie–Wetenchappen of the Lucerna College Antwerpen.
- “L’eau et ses mystères” by the 1st year Science of the Athénée Royal d’Aywaille.
- “De elektromagneet” by the 6th class of Ingeniumschool Tervuren.

All schools which made a proposal were invited to present their experiment at a public Science Fair in February 2017 in Brussels. Gwen showed the experiments she did at the South Pole, together with a testimony of her ‘life at SP’. The classes showed their experiments during the exhibition.

Five prizes were awarded: 3 for the winners selected by the international jury, and 2 prizes awarded during the expo (a prize for the scientific aspect of the projects - most of the classes who were not selected in November have continued to improve their experiment and showed new results and a communications prize for the best stand).

CONFERENCE ON

"Physics and Geometry of F-theory 2017"

27 February - 2 March 2017 I Trieste, Italy

The goal of this conference was to bring together the experts in the field of F-theory from around the globe, both from the physics and the mathematics community, in order to exchange ideas about recent progress and future endeavours. F-theory is a non-perturbative realisation of string theory that is written in the language of algebraic geometry, and has always benefited greatly from interdisciplinary interactions such as this conference.

Topics

- Phenomenological aspects of F-theory particle physics, including Grand Unification, proton decay, selection rules, Yukawa couplings.
- Analysis of effective theories arising from F-theory compactifications to various dimensions.
- Dualities to other string theories.
- New mathematical advances including geometrical aspects of elliptic fibrations, Matrix Factorisation, resolution of singular manifolds, Calabi-Yau four-folds and five-folds.

Organizers

Andres Collinucci (Université Libre de Bruxelles), Simone Giacomelli (ICTP) and Roberto Valandro (University of Trieste).

Speakers

Alessandro Tomasiello (Milano Bicocca University)
Andreas Braun (Oxford University)
Antonella Grassi (University Of Pennsylvania)
Cumrun Vafa (Harvard University)
Diego Regalado (MPI Munich)
Eran Palti (Heidelberg University)
Fabio Apruzzi (UNC Chapel Hill)
Fernando Marchesano (IFT Madrid)
Fernando Quevedo (ICPT Director)
Hirotaka Hayashi (Tokai University)
Iñaki García-Etxebarria (MPI Munich)
James Gray (Virginia Tech)
James Halverson (Northeastern University)
Jonathan Heckman (UNC Chapel Hill)
Luca Martucci (Padova University)
Marco Fazzi (Technion)
Michele Del Zotto (Suny, Stony Brook)
Mirjam Cvetic (University of Pennsylvania)
Raffaele Savelli (IFT Madrid)
Sakura Schäfer-Nameki (Oxford University)
Thomas Grimm (Utrecht University)
Timo Weigand (Heidelberg University)
Tom Rudelius (Harvard University)
Washington Taylor (MIT)

BNCPAP COLLOQUIUM

"The Physics of Living Systems"

22 March 2017 I Brussels

Biophysics has seen a tremendous growth in the last decennia. In this present Colloquium, six speakers of international standing addressed specific contributions from Physics to the domain. They have also been selected for their didactical skills, such that it is ensured that also non-specialists could get a comprehensive impression of the discipline.

Program

Introduction by Prof. Joël De Coninck, President of the Colloquium.

Prof. Daniel MÜLLER, ETH Zurich	*Imaging biological structure and functioning, with a focus on Atomic Force Microscopy*
Dr. François NÉDÉLEC, EMBL Heidelberg	*Probing the organisation principles of living matter through simulations*
Prof. Hans-Jürgen BUTT, MPIP Mainz	*Biomimetics: from nature to physical applications*

POSTER SESSION by the Belgian research teams

Prof. Antoni TOMSIA, Berkeley Lab., USA	*Biomaterials and bone reconstruction*
Prof. Liesbeth LAGAE, IMEC	*Bio-electronic tools for life science research, diagnosis and treatment*
Prof. Yves JONGEN, IBA	*Diagnostic and treatment by particle beam applications*

Conclusions, followed by a Reception

GENERAL SCIENTIFIC MEETING
of the Belgian Physical Society

17 May 2017 I Mons

The 2017 edition of the General Scientific Meeting of the Belgian Physical Society Conference took place in UMONS on the 17th of May 2017. This conference aimed at gathering all the physicists in Belgium from different disciplines. This annual one-day conference brought together physicists from Belgian universities, Belgian high schools and higher education schools, as well as from Belgian industries and companies. Its main aim was to establish links and stimulate collaborations between research groups working at different research institutions within Belgium, and to provide a platform for Belgian high school teachers to get updated on the current state of the art in physics.

Organizing Committee

Prof. Michel Voué (UMONS)
Prof. Claude Semay (UMONS)
Prof. Jozef Ongena (RMA, President of the BPS)
Prof. Gilles de Lentdecker (ULB)
Dr. Evelyne Daubie (UMONS)
Dr. Quoc Lam Vuong (UMONS)
Corentin Guyot (UMONS)
Fanny Lallemand (UMONS)

Scientific Committee

Prof. Jozef Ongena (RMA, President of the BPS)
Prof. Gilles de Lentdecker (ULB, Vice-president of the BPS)
Prof. Michel Voué (UMONS)
Prof. Claude Semay (UMONS)
Prof. Bjorn Maes (UMONS)
Prof. Yves Gossuin (UMONS)
Prof. Pascal Quinet (UMONS)
Prof. Fabrice Louche (RMA)
Prof. Mieke De Cock (KU Leuven)

Plenary Speakers

- Prof. Magali Deleuil (Laboratoire d'Astrophysique de Marseille, Marseille, France)
  Exoplanets and the search for Earth nr.2
- Prof. Bruce Allen (MPI für Gravitationsphysik, Hannover, Germany)
  Direct observations of gravitational waves with Advanced LIGO

Parallel Sessions

- *Fundamental Interactions, Particle and Nuclear Physics*
  Prof. Claude Semay, UMONS
- *Condensed Matter and Nanostructure Physics*
  Prof. Bjorn Maes, UMONS
- *Biological, Medical, Statistical, and Mathematical Physics*
  Prof. Yves Gossuin, UMONS
- *Atoms, Molecules, Optics, and Photonics*
  Prof. Pascal Quinet, UMONS
- *Astrophysics, Geophysics, and Plasma Physics*
  Prof. Fabrice Louche, RMA
- *Physics and Education*
  Prof. Mieke De Cock, KU Leuven

WORKSHOP ON

"Dynamical Systems and Brain Inspired Computing"

31 May - 2 June 2017 I Brussels

The aim of this workshop was to bring together researchers working at the interface between physics, computer science, engineering, neuroscience, in order to foster the development of novel computing architectures inspired by artificial intelligence algorithms and by how the brain processes information.

Questions of interest included:

- Novel/improved methods for using recurrent dynamical systems for information processing,
- Theoretical tools for understanding the information processing capability of recurrent dynamical systems,
- Experimental implementations of such systems, including optical and (unconventional) electronic implementations,
- Connections to other areas, including neurosciences, soft robotics, etc.

Scientific Committee

I. Fischer (Universitat de les Illes Baleares)
J. Grolier (Thales)
H. Jaeger (Jacobs University)
J-P. Ortega (University of St. Gallen, Switzerland)
P. Bienstman (Ghent University)
C. van den Broek (Universiteit Hasselt)
J. Dambre (Ghent University)
J. Danckaert (Vrije Universiteit Brussel)
M. Haelterman (Université libre de Bruxelles)
R. Lambiotte (Université de Namur)
S. Massar (Université libre de Bruxelles)
G. Van der Sande (Vrije Universiteit Brussel)
J-P. Locquet (KU Leuven)

Organizing Committee

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M. Haelterman (Université libre de Bruxelles)
R. Lambiotte (Université de Namur)
S. Massar (Université libre de Bruxelles)
G. Van der Sande (Vrije Universiteit Brussel)
J-P. Locquet (KU Leuven)

Invited Speakers

Ingo Fischer (Universitat de les Illes Baleares)
Claudio Mirasso (Universitat de les Illes Baleares)
Julie Grolier (Thales)
Herbert Jaeger (Jacobs University)
Daniel Brunner (Université de Franche Comté)
Thomas Van Vaerenbergh (HP Labs)
Vijay Balasubramanian (Penn State Univ. & VUB)
Julien Sylvestre (Sherbrook University)
Christof Teuscher (Portland State University)
Antonio Politi (Aberdeen)
Wolf Singer (Ernst Strüngmann Institute (ESI) for Neuroscience)
David Wolpert (Santa-Fe institute)
Robert Legenstein (Graz University of Technology)
Helmut Hauser (University of Bristol)
Raul Vicente (University of Tartu)
Leslie Valiant (Harvard)

THE 15TH CONFERENCE ON

"Methods and Applications in Fluorescence"

10 - 13 September 2017 I Bruges

MAF has a long-standing tradition of bringing together world-leading experts in fluorescence, one of the most powerful spectroscopic and imaging methods with applications ranging from materials research to life sciences. The unrivalled versatility of fluorescence methods relies on continuous developments in (super-resolution) fluorescence microscopy, lifetime spectroscopy, imaging and probe design, but also in nanomaterials, opto-electronics, data acquisition and data processing.

Topics covered include:

- novel developments in fluorescence spectroscopy and microscopy
- single molecule spectroscopy
- super-resolution microscopy
- photonics
- fluorescent probe development
- labels

MAF 2017 The 15th Conference on Methods and Applications in Fluorescence Bruges, Belgium, September 10 to 13, 2017!

Next to method development, MAF also focuses on applications of fluorescence based methods in biosciences and material sciences. Development and applications in both bioscience and material were well-balanced in the program of the 2017 conference.

The fact that 2015 Nobel laureate WE Moerner was one of invited speakers testifies for the outstanding reputation the meeting has in the field of fluorescence.

Local Organizing Committee

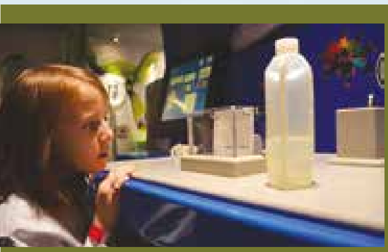
Kevin Braekmans - UGent
Peter Dedecker - KU Leuven
Eduard Fron - KU Leuven
Jelle Hendrix - UHasselt
Johan Hofkens - KU Leuven
Kris Janssen - KU Leuven
Cécile Moucheron - ULB
Maarten Roeffaers - KU Leuven
Mark Van der Auweraer - KU Leuven

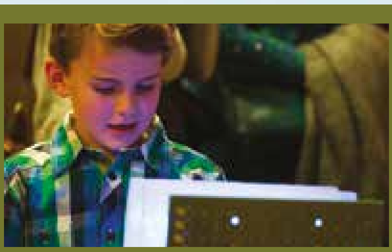
Plenary Speakers

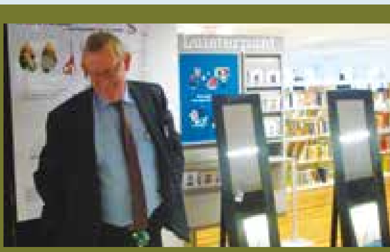
Prof. William E. Moerner - Stanford University
Prof. Petra Schwille - Max-Planck-Institut für Biochemie
Prof. Prashant Kamat - U. of Notre Dame
Prof. Luisa De Cola - Université de Strasbourg
Prof. Theo Lasser - Ecole polytechnique fédérale de Lausanne

Invited Speakers

Prof. Markus Sauer - Universität Würzburg
Prof. Jörg Enderlein - Georg August U. Göttingen
Prof. Cristina Flors - IMDEA Nanoscience
Prof. Jacob Hoogenboom - TU Delft
Prof. Enrico Gratton - University of California, Irvine
Prof. Emmanuel Beaurepaire - Ecole Polytechnique, Université Paris-Saclay
Prof. Zeger Hens - Universiteit Gent
Prof. Gonzalo Cosa - McGill University
Prof. Claus Seidel - Heinrich-Heine - Universität Dusseldorf
Prof. Marina Kuimova - Imperial College London
Prof. Yitzhak Tor - U. of California, San Diego
Prof. Xing Chen - Peking University
Prof. Julia Pérez - Universidad de Valencia
Prof. Sofie Cambré - University of Antwerp
Prof. Fred Brouwer - University of Amsterdam
Prof. Mircea Cotlet - Brookhaven National Lab.
Prof. Edwin Yeow - Nanyang Technological U.
Prof. Hiroshi Uji-i - Hokkaido University
Prof. Vasudevan P. Biju - Hokkaido University
Prof. Haw Yang - Princeton University







SCIENCE DAY

Science Day 2017

26 November 2017

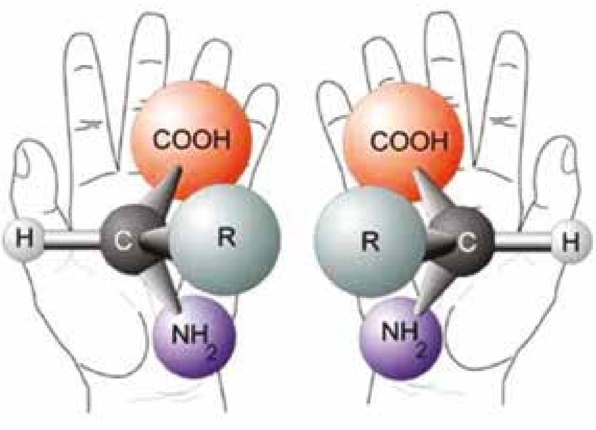
The Solvay Institutes participated to the Science Days of the Flemish Community more precisely to the Science Festival, organized in the very center of Brussels, at Muntpunt, on Sunday November 26, 2017.

The Solvay Institutes presented information about their history, mission and organization, illustrated with many pictures of past and recent activities on three posters (roll-ups).

On the other hand an introduction was given to the visitors about an intriguing concept/phenomenon in science transcending its different subdisciplines:
chirality: the remarkable fact that an object or process can be different from its mirror-image. The work by Louis Pasteur at the end of the 19th century gave a boost for the investigation of the "why and when" of chirality, which then first blossomed in chemistry. Later on it turned out that this concept also plays a fundamental role in describing processes in physics (e.g. at the level of elementary particles), in disentangling the activity of pharmaca, and even… in the definition of life. Mathematicians have been actively looking for a quantitative description of this phenomenon.

The visitors' interest was raised by mirror experiments where they could convince themselves and their friends and family that they were not identical to their mirror image, surprising especially the younger "would-be" scientists. They were encouraged to manipulate themselves molecular models and came to the conclusion that also many of these models were not identical with their mirror image. This observation then leads in a natural way to the hypothesis that these molecules most probably will also undergo different "chemical" reactions. To test this hypothesis in this mini-scientific research program the visitors conducted an "odour" experiment where they could smell that substances composed out of mirror – molecules do not always have the same odour. For the not so young-any-more visitors the link was then established with pharmacology by refreshing their minds on the Softenon tragedy in the early sixties of the previous century .

The Solvay exhibition stand received all day long many visitors enthusiastically interacting with Paul Geerlings (Emeritus Professor Chemistry at VUB and Vice-President of the Solvay Institutes) and Tatiana Wöller (Assistant Chemistry at the VUB), and it was nice to see that children as well as adults got interested in this mini scientific excursion, and were, as we could witness, sometimes really amazed by these "tales and facts from the unexpected".

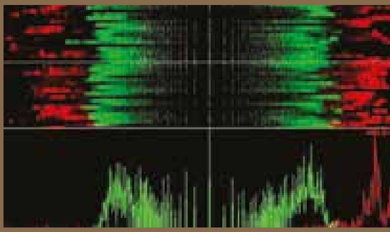


In conclusion the participation of the Solvay Institutes to the Science Days of the Flemish Community was a success. The Solvay Institutes want to acknowledge the Flemish Community for the financial support they received for this activity.


The International Institutes
for Physics and Chemistry
LOS ANGELES
14







SEMINARS

The list below gives the joint inter-university weekly seminars co-organized by the Theoretical Particle Physics Group of the VUB, the Service de Physique Théorique and the Service de Physique Théorique et Mathématique, both of the ULB, the High Energy Physics and Relativistic Field Theory group of the KUL, the Groupe de Mécanique et Gravitations at UMons, and the International Solvay Institutes. It also gives the group seminars of the research team of the Director.

January

Holography Meeting

- *String Fluctuations in Non-Conformal Holography*
  Konstantin Zarembo (Nordita, Stockholm)
- *One fish, two fish, red fish, blue fish*
  Christopher Herzog (SYNT, Stony Brook)
- *Black Holes, Matrix Models and Large D*
  Frank Ferrari (ULB, Brussels)
- *BPS Particles and Local Operators*
  Clay Cordova (IAS, Princeton)

February

On Singularities, Quantum Noise and holographic Complexity
Eliezer Rabinovici (Hebrew University of Jerusalem)

3D/4D gravity as the dimensional reduction of a theory of differential forms in 6D/7D
Kirill Krasnov (University of Nottingham)

Conformal Mass in Lovelock AdS gravity
Rodrigo Olea

March

Weak gravity conjecture, large field inflation and extremal black holes
Pablo Soler

On conformal supergravity and higher derivative invariants
Tartaglino-Mazzucchelli

From Emergent Gravity to Dark Energy and Dark Matter
Erik Verlinde

Non-Abelian black holes in String Theory
Tomas Ortin

Instanton effects in maximally supersymmetric Yang-Mills theory
Gregory Korchemsky

Black holes, Stokes Flows and Transport at Strong Coupling
Aristos Donos

Dimensional renormalization in AdS/CFT
Adam Bzowski (KU Leuven)

Gravity as a double copy of gauge theory
Ricardo Monteiro

One-loop determinants in BTZ and WCFTs
Phil Szepietowski

Multipole charges in electrodynamics and the vacuum moduli space
Ali Seraj

April

N- extended Super BMS_3 algebras
Turmoli Neogi

The geometry of fluid membranes: variational principles, symmetries and conservation laws
Jemal Guven

String field theory revisited
Ivo Sachs

A holographic perspective on phonons and pseudo-phonons
Andrea Amoretti

Boundary degrees of freedom in gauge theory and gravity
Marc Geiller

Einstein's equations, asymptotic flatness at space-like infinity, asymptotic flatness at null infinity, and their relation
Helmut Friedrich

Details on the structure of space-like infinity
Helmut Friedrich

New results in N=2 theories from non-perturbative string
Alba Grassi

Holographic Tensors
Vincent Rivasseau

May

From null geodesics to gravitational scattering
Lionel Mason

Exceptional field theory and half-maximal consistent truncations
Emanuel Malek

S-duality in N=1 orientifold SCFTs
Iñaki García-Etxebarría

Exceptional field theories and their applications
Henning Samtleben

Conformal scattering: history, principles and recent results
Jean-Philippe Nicolas

Integrable bootstrap in AdS/CFT
Alessandro Sfondrini

F-theory and AdS_3/CFT_2
Dario Martelli

Commensurate lock-in in holographic non-homogeneous lattices
Tomas Andrade

2D CFT blocks for a class of N=1 theories in 4D
Vladimir Mitev

June

BMS bootstrap
Arjun Bagchi

Non-relativistic Coset Constructions
Cynthia Keeler

Gravitational equation in higher dimensions: a case for pure Lovelock gravity
Naresh Dadhich

Gravitational dynamics of thin shells in AdS, critical behavior and chaos
Jorge V. Rocha

Backreaction Issues in Axion Monodromy and Minkowski 4-forms
Irene Valenzuela

Classical Conformal Blocks, Isomonodromy and Black Holes
Fabio Novaes

Signatures of extra dimensions in gravitational waves
Gustavo Lucena

The BMS4 algebra at spatial infinity
Cédric Troessaert

Exploring Gravitational Waves with Second-Generation Detectors
Maxime Fays

Stringy Horizons and Duality
Gaston Giribet

July

Black hole formation from pointlike particles and emerging thin shell spacetimes in AdS3
Jonathan Lindgren

On the Mutual Information in Conformal Field Theory
Bin Chen

September

Generalized global symmetries and holography
Nabil Iqbal

Generalized conformal structure and SYK
Marika Taylor

Gravity, Duality and Conformal Symmetry
Chris Hull

Multigravity theories in three dimensions
Karapet Mkrtchyan

Conformal Higher Spin Theory and Twistor Space Actions
Philipp Hähnel

October

The AdS5 non-Abelian T-dual of Klebanov-Witten as a N=1 linear quiver
Jesus Montero

Asymptotic structure of electrodynamics revisited
Andrzej Herdegen

Black hole microstates in AdS_4 and AdS_5 from supersymmetric partition functions
Kiril Hristov

On non-relativistic higher spins and massive gravity in three dimensions
Jan Rosseel

Exotic branes in exceptional field theory and U-duality orbits
Edvard Musaev

The ABC of space-time symmetry breaking
David Stefanyszyn

Gravity duals of boundary cones
Joan Camps

Duality and Extended Supersymmetry: From Interacting Theories to Free Fields
Matthew Buican

Directions in Supersymmetry Breaking
Fotis Farakos

November

Thermal Conformal Blocks and their AdS Representations
Gim Seng Ng

Asymptotic symmetries and geometry on the boundary in the first order formalism
Yegor Korovin

Local quenches: universal corrections to entanglement entropy and quantum chaos
Surbhi Khetrapal

Galilean Conformal Field Theories
Aditya Mehra

Genus two partition functions and Renyi entropies of large c CFTs
Alex Belin

Twisted BRST quantization and localization in supergravity
Sameer Murthy

Holographic models and compact stars
Carlos Hoyos

Effective holographic theory of quantum critical charge density waves
Blaise Goutéraux

Strolling along gauge theory vacua.
Dieter Van den Bleeken

The Eight field way
Shlomo Razamat

December

Tensor models and SYK
Sylvain Carrozza

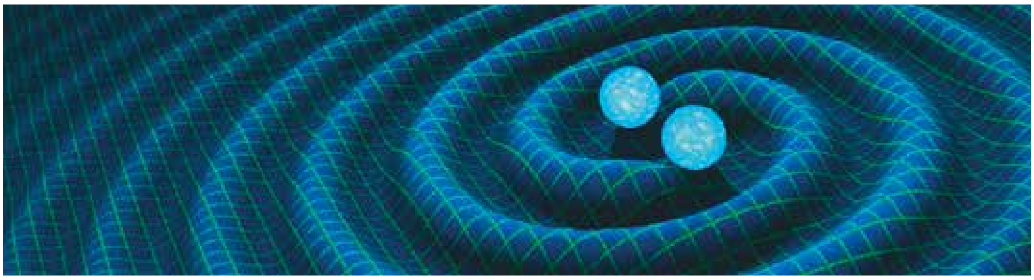
Supersymmetry and geometry of stringy corrections
Ruben Minasian

Superspace Approach to Superconformal Blocks
Israel Ramirez

Spontaneous symmetry breaking and Nambu-Goldstone bosons in quantum many-body systems
Tomas Brauner

Phase Diagram of Planar Matrix Quantum Mechanics, Tensor and SYK Models
Fidel Schaposnik

Hopf twists and marginal deformations
Konstantinos Zoubos



Gravitational Wave Seminars

April

Testing GR with GWs
Vitor Cardoso (Lisbon)

Self-similar accretion in thin disks around near-extremal black holes
Roberto Oliveri (ULB)

June

Observation of Dynamical, Strong-field Gravity
Frans Pretorius (Princeton)

Challenges in seismic isolation for the next generation of gravitational wave observatories
Christophe Collette (ULB and LIGO)

September

An astrometric search method for individually resolvable gravitational wave sources with Gaia
Chris Moore (Cambridge and LIGO)

Extreme mass ratio inspirals into near extremal Kerr black holes: orbits and gravitational waves
Jiang Long (ULB)

October

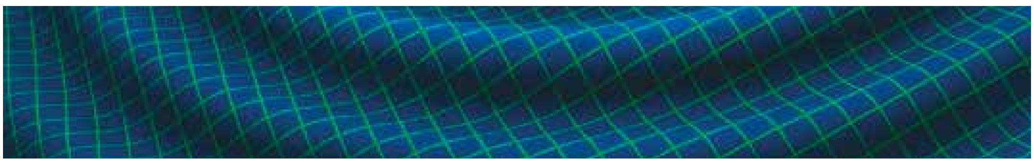
Kerr black holes with bosonic hair: theory and phenomenology
Carlos Herdeiro

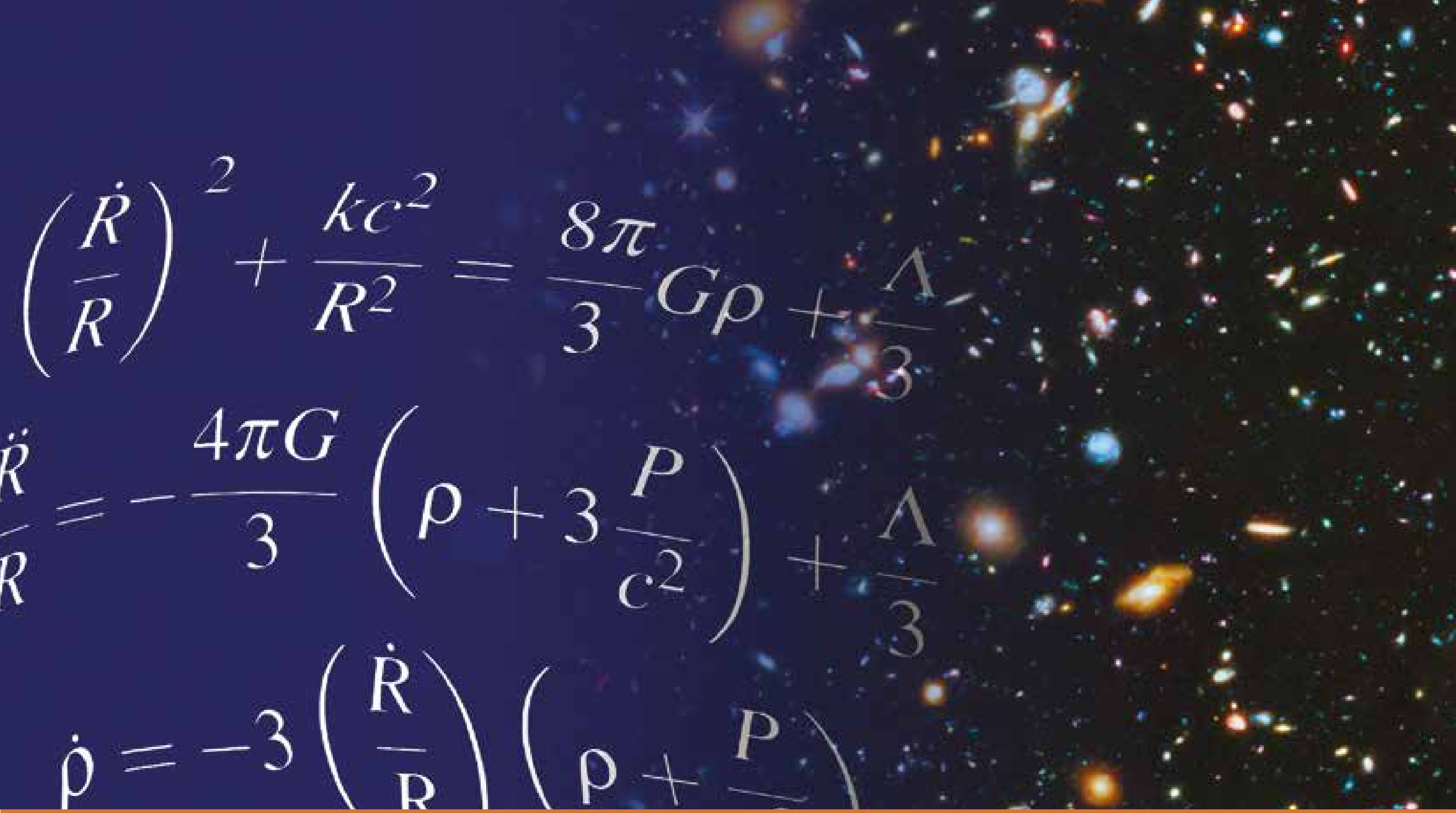
November

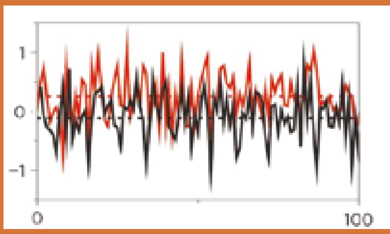
Gravitational waves: origins, detections, implications
Gustavo Romero (IAR, CONICET / University of La Plata, Argentina)

Gravitational wave astrophysics with LIGO/Virgo sources
Gijs Nelemans (RU Nijmegen & KU Leuven)

Echoes of Kerr-like wormholes
Frederik Goelen (KU Leuven)





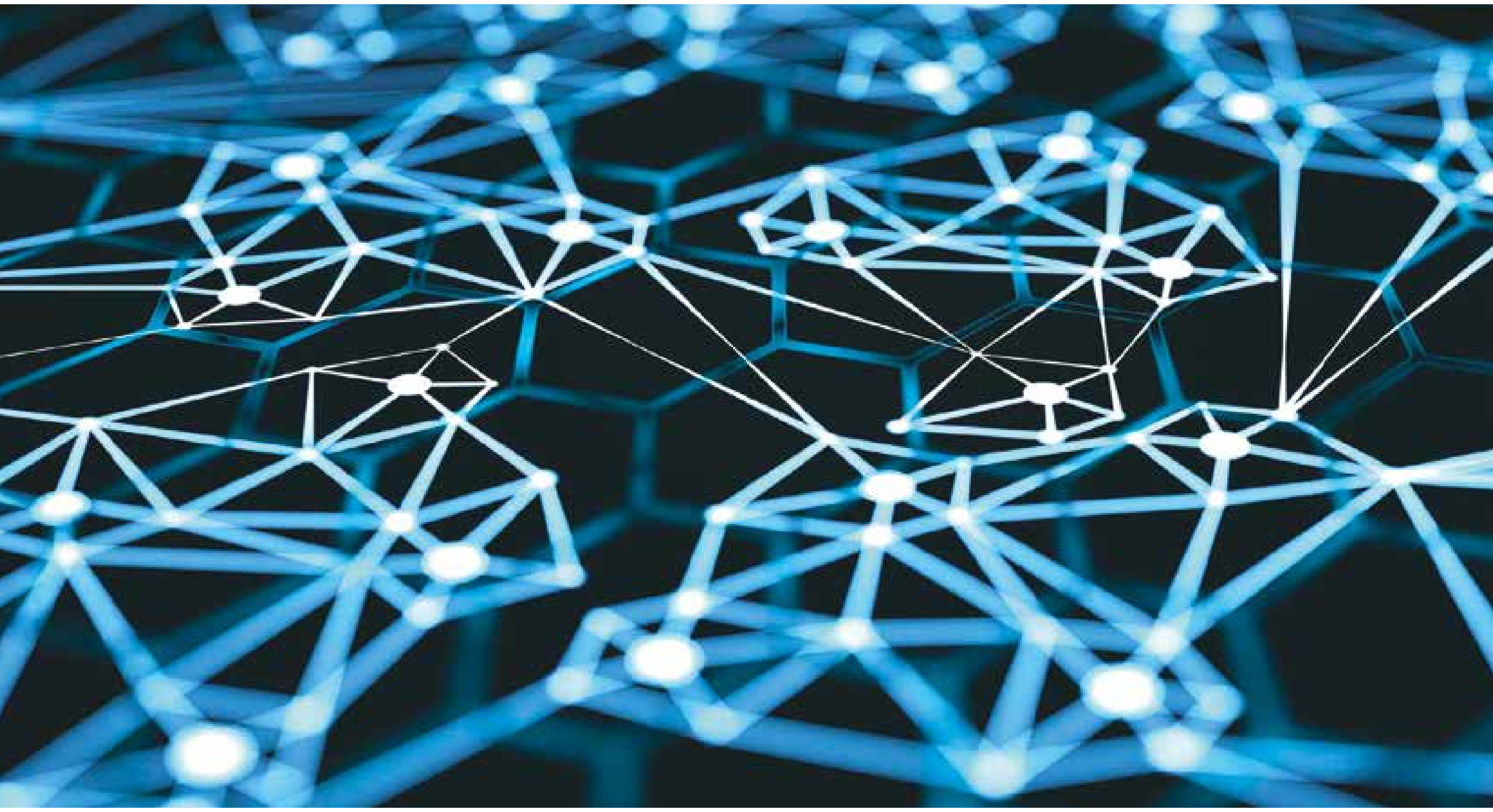


RESEARCH

Research

These sections describe successively:

- the research carried out in the groups of Professors Marc Henneaux, Director, and Alexander Sevrin, Deputy-Director for Physics and Scientific Secretary of the International Scientific Committee for Physics (Research on Gravitation, Strings and Cosmology)
- the research in Chemistry carried out in the group of Professor Anne De Wit, Scientific Secretary of the International Scientific Committee for Chemistry
- the research carried out in the group of Professors Jan Steyaert and Han Remaut (former head: Emeritus Professor Lode Wyns, Deputy-Director for Chemistry)
- the research highlights of other scientists connected with the Institutes



Research on Gravitation, String Theory and Cosmology

Groups of Professors Marc Henneaux I ULB and Alexander Sevrin I VUB

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Glenn Barnich I ULB
Chris Blair (10 %) I VUB
Andrès Collinucci I ULB
Geoffrey Compère I ULB
Ben Craps I VUB
Stéphane Detournay I ULB
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Jay Armas I ULB
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Rudranil Basu I VUB/ULB
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Adolfo Guarino I ULB
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Laetitia Leduc I ULB
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Jiang Long I ULB
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Guillaume Valette I ULB
Matthias Vereecken I VUB
Céline Zwikel I ULB

Research Summary

Of all the fundamental forces (electromagnetism, gravitation, weak and strong nuclear forces), gravity remains the most mysterious. In spite of its remarkable successes, Einstein's general theory of relativity, which has led to an unprecedented geometrization of physics, is an unfinished revolution. A major challenge of modern physics is to reconcile quantum mechanics and Einstein's gravity. This will undoubtedly need new developments that will go beyond Einstein's revolution. Fully unravelling the mysteries of the gravitational force is a long-term research goal.

The group has a long-standing interest and a demonstrated expertise in quantum gravity, quantum field theory, string theory and M-theory, black holes, cosmology, the cosmological constant problem ("dark energy") and the novel mathematical structures underlying these questions. These challenging areas raise many of the most profound issues in theoretical physics.

A central thread in the study of gravity and the fundamental interactions is the concept of symmetry (global and local). Some of the general background is given below.

General Framework

The standard model of particle physics is based on quantum field theory, a framework that reconciles Poincaré invariance with quantum mechanics and allows one to understand the electromagnetic and the two types of nuclear interactions. The fourth fundamental interaction, gravitation, is described by Einstein's theory of general relativity. Experiments as well as theoretical arguments indicate that neither the standard model, nor general relativity can be complete.

Purely theoretical attempts at generalizations are constrained, of course, by mathematical consistency and the need to incorporate the previous theories in the domains where they have been successful. Additional guiding principles are needed, though. Symmetry is such a principle and pervades most of the research carried out in theoretical high energy physics.

The Yang-Mills type theories for the three microscopic forces of elementary particle physics are invariant under Poincaré symmetries, the symmetry group of flat space-time. These theories admit in addition certain internal symmetries known as gauge symmetries. In general relativity, gravitation arises when going from a flat to a curved spacetime, and Poincaré symmetries become part of the gauge group of diffeomorphisms.

In models that go beyond the existing theories, other symmetries can come to the front.

(i) Supersymmetry

Supersymmetry is a natural extension of Poincaré symmetry in the presence of fermionic matter fields. One objective of the Large Hadron Collider at CERN in Geneva is to test supersymmetric extensions of the standard model.

Supersymmetry is also an important ingredient of string theory, a model for unification of the four fundamental interactions and for a microscopic formulation of gravity. At low energy, higher dimensional theories of gravitation emerge that include supersymmetry as part of their gauge group together with supersymmetric extensions of Yang-Mills gauge theories.

(ii) Dualities

One of the first theoretical extensions of Maxwell's theory of electromagnetism has been the inclusion of magnetic sources. The introduction of such sources is motivated by the desire to preserve invariance under duality rotations, a symmetry of the source-free equations. The solution that is dual to the Coulomb solution describing a static point-particle electron is a magnetic monopole. In some sense, black hole solutions in gravitational theories are the analog of the Coulomb solution to Maxwell's theory.

In nonlinear theories like Yang-Mills theories, dualities relate a strongly coupled regime to one at weak coupling, where standard perturbative computations may be performed. In supersymmetric situations, these dualities become tractable.

Finally, dualities between different string theories as well as holographic duality between gauge and gravity theories feature prominently in most of the recent developments. They have broadened the original scope of string theory by paving the way to applications to other fields of physics, including condensed matter theory and hydrodynamics.

(iii) Hidden symmetries:

Hidden symmetries in gravity and string theory arise in compactifications of supergravity theories and among the string duality groups. The algebraic structure of these symmetries is related to infinite-dimensional Lorentzian Kac-Moody algebras, in particular the algebras E_{10} and E_{11}.

(iv) Higher spin symmetries:

Higher spin gauge fields (massless fields with spins greater than the spin 2 of the graviton) play a central role in many searches for a quantum-mechanically consistent formulation of gravity. For instance they appear in the zero tension limit of string theory. High spin gauge field theories are described by a huge "higher spin symmetry".

The symmetries described in (i)-(iv) have strong but still somewhat mysterious connections with each other.

Research carried out in 2017

We have continued our research along the general directions outlined above. This has led to 128 published papers and preprints submitted for publication. These are listed on pages 160-167. Specific achievements by some researchers from the group are described in the subsequent pages.

Support to the research of the Director

The research of the director and of his group has benefited, as in the previous years, of gifts from the Solvay family and the Solvay Group. This support was extended by additional gifts from Messrs. Collen, and de Selliers de Moranville. This generous support was precious to cover international collaborations, the organization of workshops as well as doctoral and postdoctoral grants to researchers. It is most gratefully acknowledged.

Marina Solvay Fellowship

Thanks to a special gift of Mrs. Marina Solvay, the "Marina Solvay Fellowship" was created in 2012. The fellowship enables a brilliant young researcher to pursue her or his career as a postdoctoral fellow in the group of "physique théorique et mathématique" of the ULB.

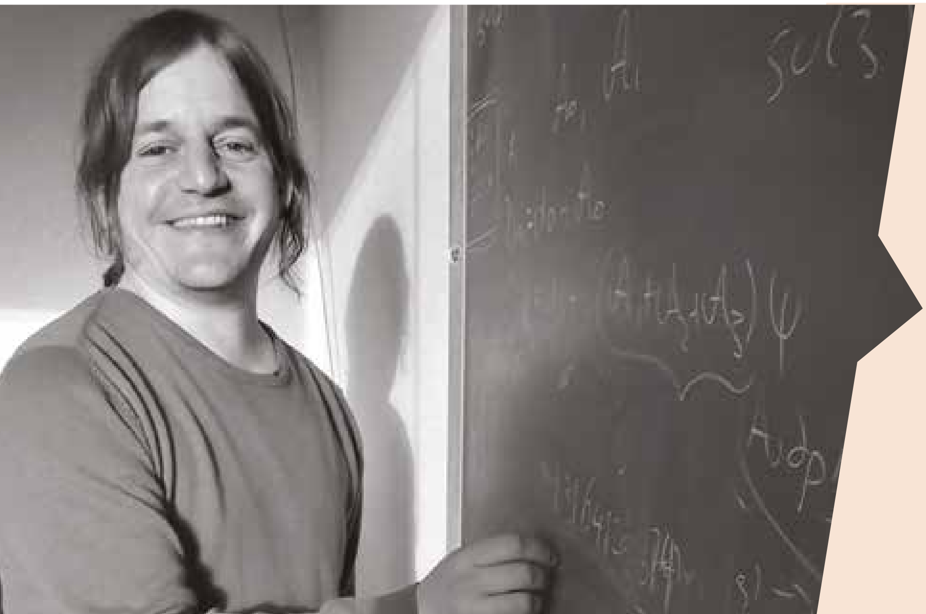
List of Marina Solvay fellows

Waldemar Schulgin (2012-2014)

David Tempo (2015)

Jelle Hartong (2016)

Adolfo Guarino (2017)



***Dr. Adolfo Guarino** was the fourth holder of the Marina Solvay fellowhip, in 2017.*

He got his PhD degree at the Universidad Autónoma de Madrid (Spain) in 2010. After postdoctoral stays at the University of Groningen (The Netherlands), at the University of Bern (Switzerland) and at NIKHEF in Amsterdam (The Netherlands), he joined the ULB group. As explained in his research description, his work deals with supergravity and black holes, a field to which he made many important contributions.

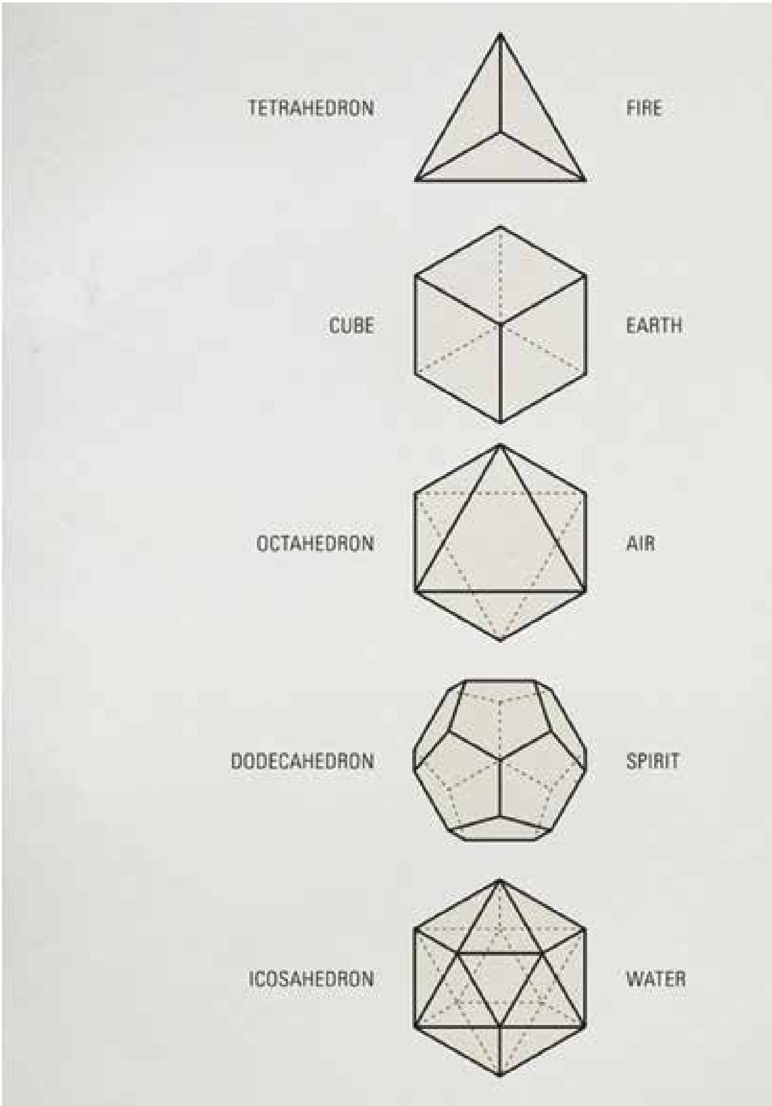
Researchers who directly benefited from the support to the research of the Director and his group.

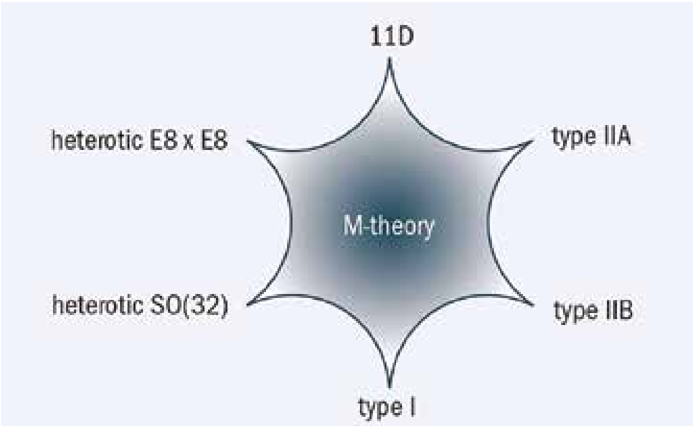
Adolfo Guarino I ULB
Postdoctoral researcher

On the Symmetries of the Big and the Small

Starting from the Platonic solids constituting the classical elements in Plato's dialogue Timaeus (360 BC), the existence of a symmetry principle underlying the physical laws has been, over history, invoked to explain the order and beauty observed in Nature. More than twenty centuries after Plato, the concept of symmetry has become a cornerstone in our understanding of forces and interactions governing physical phenomena from distances beyond the observable Universe to infinitesimal scales.

On the scale of planets and galaxies, Einstein's theory (1915) of General Relativity (GR) describes space-time in terms of a classical field, the metric. The theory rests on a symmetry principle: invariance of physical laws under local changes of reference frame. GR lies at the heart of our concordance model of modern cosmology (1990s), the so-called Λ-CDM model, which includes cold dark matter (CDM) and a positive cosmological constant Λ. In this model more is unknown that is known: the Universe is made up of 5% ordinary matter, 27% dark matter and 68% dark energy. Despite being a complete mystery, the existence of the last two is the most accepted hypothesis to explain a number of astronomical observations, like rotation curves of galaxies or the accelerating expansion of the Universe. In addition, there is also an epoch of cosmological inflation starting 10^{-36} seconds after the Big Bang. This is a short period (10^{-33}-10^{-32} seconds) in which space-time expands extremely rapidly, and is nowadays accepted as the best hypothesis to solve various cosmological puzzles like the flatness, horizon and exotic-relics problems. The detailed mechanism responsible for inflation is not yet known.





On subatomic scales, Nature becomes probabilistic and elementary particles are described as quantum fields. Leaving gravity aside, the Standard Model (SM) of Particle Physics (1960s-1970s) describes three generations of particles, quarks and leptons, interacting under the remaining fundamental forces: electromagnetism, weak and strong interactions. These three forces are mediated by gauge fields — gluons, $W^{\pm}$ and Z bosons and photons — as dictated by an $SU(3) \times SU(2) \times U(1)$ gauge symmetry. This is an internal symmetry that transforms particles into one another: electrons into neutrinos, etc. The SM has successfully explained almost all experimental results in Particle Physics and predicted new phenomena, like the existence of the Higgs boson experimentally verified (2012) at the Large Hadron Collider (LHC) at CERN. However, there are many whys and wherefores that remain unanswered: why 19 free parameters not predicted by the theory? Why three generations of fundamental particles? Why neutrinos have masses? Why the weak force is 10^{24} times as strong as gravity? Why is there a matter-antimatter asymmetry?

The above outstanding questions are nowadays viewed as indications of the need to go beyond the standard model of Cosmology and Particle Physics.

Supersymmetry and String/M-theory

Theories that lie beyond the Standard Model have been put forward based on new symmetry principles. A case that plays an important role in my research is supersymmetry (1971-1974): invariance under exchange of bosonic (integer spin) and fermionic (half-integer spin) degrees of freedom.

This symmetry can be imposed on both *gravitational* (GR-like) and *gauge* (SM-like) theories, thus restricting their matter content and interactions and yielding the so-called *supergravity* and *supersymmetric gauge theory.* Supersymmetry provides us with guidance to construct models which accurately describe universality classes of complex phenomena in gravity and Particle Physics that would be otherwise not possible to study from a theoretical perspective. It has also been essential in the search for a more fundamental theory able to unify gravitational and quantum aspects of Nature.

String theory has stand out as the best candidate for such a theory (1980s-1990s). The fundamental objects in string theory are not point-like particles but strings and membranes (called D-branes) living in a ten-dimensional space-time. There are five different versions of string theory which are unified under a single M-theory: a theory of membranes (called M-branes) living in an eleven-dimensional space-time. This has a striking consequence: the physical laws in our four-dimensional reality are encoded in the geometry (shape and size) of the extra dimensions!

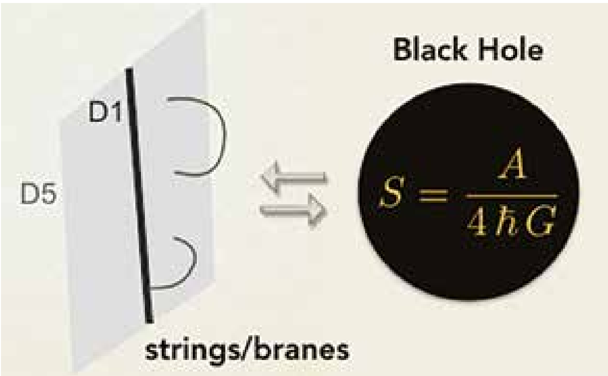
The Footprint of the Extra Dimensions

Going back to ideas by Kaluza and Klein (1920s), the extra dimensions leave a footprint in our 4D world: new (spin 0) massless fields, called *moduli fields*, that parameterise the shape and size of the extra dimensions. The dynamics of these fields is very sensitive to what are the extra dimensions filled out with: background fluxes for certain (spin1) *p*-form gauge fields that are the higher-dimensional analogue of Maxwell fields in electromagnetism, metric fluxes inducing torsion, D/M-branes, etc. Therefore, by looking at the moduli fields one can recover valuable information about the content and properties of the extra dimensions.

The study of the moduli dynamics has found applications in the area of string cosmology, for instance, to model the inflationary epoch or the late-time cosmic acceleration (moduli as dark energy). It has also been used to probe the region of space-time around a black hole: when falling into a black hole, moduli fields carry information on how the extra dimensions of string/M-theory get inevitably squeezed and stretched. This information is afterwards stored at the black hole horizon.

Black Holes in String/M-theory

A black hole is a classical solution of Einstein's theory with a curvature singularity hidden behind an event horizon. It has zero statistical entropy at the classical level but, at the quantum level, Hawking showed that it radiates as a black body with a certain temperature and an entropy (*S*) specified by the area (*A*) of its horizon. According to the thermodynamical interpretation of a black hole, it should have a microscopic origin with the entropy related to its number of indistinguishable microstates. This is a central issue to understand how Einstein's theory is reconciled with quantum gravity.



String theory and M-theory have provided a successful explanation for the black hole microstates in terms of their fundamental constituents: strings and membranes (D1-D5 branes and M-branes). In the limit where the number of microstates is large, the string/M-theory statistical entropy was shown to agree with the Hawking entropy of specific classes of supersymmetric black holes in 5D supergravity.

During 2017 my research has focused on the study of supersymmetric black holes in the context of 4D effective low-energy supergravity models arising from string theory and M-theory constructions. The presence of charged matter (moduli fields) and a cosmological constant in the classes of models we looked at makes these black holes closer to the astrophysical ones involved in the recent detection of gravitational waves (LIGO-Virgo, 2016). Even though applications in this direction are purely theoretical for the moment, the hope is that one day they will be relevant to experiment.

Irais Rubalcava-Garcia I ULB
Postdoctoral researcher

Irais Rubalcava-Garcia is a postdoctoral researcher at ULB, supported by a CONACyT Mexican grant and by ULB. She has expertise in Mathematical Physics, specially in various aspects of Einstein theory of gravity.

Symmetries in Spacetimes with Boundaries

There are interesting physical configurations where it is necessary to consider space-times with boundaries; for example, in the context of General Relativity, the asymptotically flat spacetimes are an excellent approximation to describe 'isolated' systems like the stars in the astrophysics context. Another example is black holes, which can be studied by considering them as internal boundaries of space-time. Both examples are becoming increasingly popular due to the measurement of the Gravitational Waves.

The goal of my research is to understand the relation between the bulk and boundary symmetries, for gravitation theories but also for gauge theories defined on space-times that has boundaries and whose boundary dynamics is nontrivial. It's a broad goal that touches several of the most popular and fascinating lines of research (AdS/CFT duality, BMS group, Thermodynamics of Black Holes, Loop Quantum Gravity), and also it can offer several possibilities. I'm focused on the two following lines of research.

Extend Hamiltonian Formalism to Spacetimes with Boundaries

Most of the work in the Hamiltonian context has been done in spaces without boundaries, so if we want to apply this formalism to space-times with boundaries, it would be useful besides analysing several examples, to extend the formalism itself.

For several approaches in theoretical physics, the starting point to find classical symmetries is the action principle. Also if one takes the viewpoint that at the deepest level, any physical system is quantum mechanical and can be defined by some path integral, for this to be well-defined, we need to write a meaningful, finite, action.

If the space-time has boundaries, the addition of boundary terms becomes relevant, since we want to begin with a well-posed action principle, that is finite and differentiable under the appropriate boundary conditions, which may require the addition of such boundary terms or restrict which ones are allowed to have a well-defined action principle.

So beginning with a well-posed action principle, the goal is to study how different ingredients of the Hamiltonian formalism are changing due to the presence of boundaries. In particular, I want to be able to answer the following questions. How do the bulk symmetries extend to the boundary? How to find a systematic approach to find the degrees of freedom in the boundary?

One of the goals of this approach is to see whether we can recover the BMS symmetries from a Hamiltonian analysis.

Asymptotically Flat Spacetimes in the Cartan Formalism

If we want to couple fermions to the gravitational field (a very reasonable request), then the second-order formalism does not suffice. One needs to consider the Cartan formalism or Vielbein formulation of General Relativity instead. This choice of variables is also the language and starting point of some recent theories whose aim is a quantum description of the gravitational field, such as Loop Quantum Gravity, Supergravity, Higher Spin Theories.

On the other hand, many of the most outstanding results for asymptotically flat spacetimes are formulated in the second order (metric formulation) of General Relativity. So it is relevant to see how they are translated into the Cartan language since some subtleties and potential simplifications may arise, and they will be useful for possible use in a quantum description.

This line of thought has been discussed with Yegor Korovin, also a postdoc in the group.

Early in my studies, I was inspired by Professor's Henneaux book "Quantization of Gauge Systems" and his research. Then more recently I have got inspired by the work of professor Barnich about the BMS group and symmetries on the boundary. So I am honoured to be working under their supervision.

Amaury Leonard

Amaury Leonard obtained his PhD degree under the supervision of Marc Henneaux in 2017. He is working on duality and higher spin gauge fields. He is currently establishing new collaborations with the gravitation group at the Max-Planck-Institute in Golm (Germany).

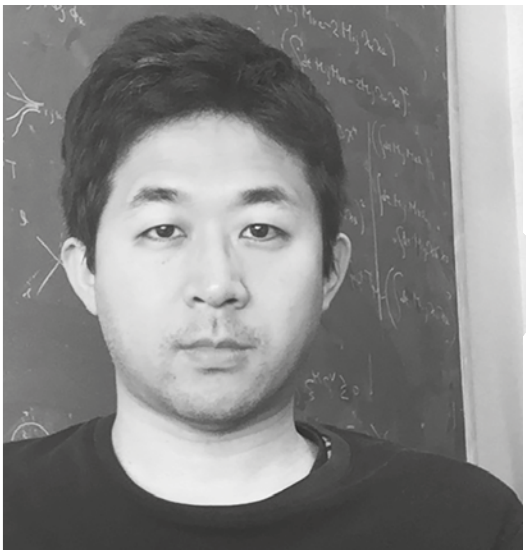
Research interests of some other members

Tatsuo Azeyanagi I ULB
Postdoctoral researcher

Black Holes in the Sky and in the Head.

Even light cannot escape once it falls into a black hole. A black hole has attracted a lot of scientists and science fiction fans. This mysterious object was first discovered by Schwarzschild theoretically and, as a consequence of recent remarkable observations, they are becoming more and more familiar objects to us. LIGO directly detected the gravitational waves emitted by a binary black hole. The observations by telescopes indicate the existence of a supermassive black hole near the center of our Milky Way galaxy. Black holes are in the sky indeed.

For theoretical physicists working towards microscopic description of gravity or quantum gravity, black holes are more than what we can observe in the sky. Last a few decades, black holes have been employed for probing the underlying microscopic theory of gravity. To understand how quantum gravity describes the time-evolution, many physicists even have dived into black holes… theoretically in their heads, of course.



Microscopic Origin of Black Hole Thermodynamics

Black holes display a more mysterious feature once quantum effects are taken into account. In 1970s, Hawking analyzed how black holes behave when quantum matters are put on them. His analysis shows that black holes behave in the same way as thermodynamic objects. This thermodynamic behavior of black holes raises a simple question: what is the microscopic origin of this thermodynamic behavior? As statistical mechanics of atoms and particles reproduces thermodynamic behavior of usual matters, microscopic theory of gravity must reproduce that of black holes. Especially, a thermodynamic object carries entropy, a measures the number of microscopic configurations associated to this object. A black hole does, too. Then, what is the microscopic origin of the black hole entropy?

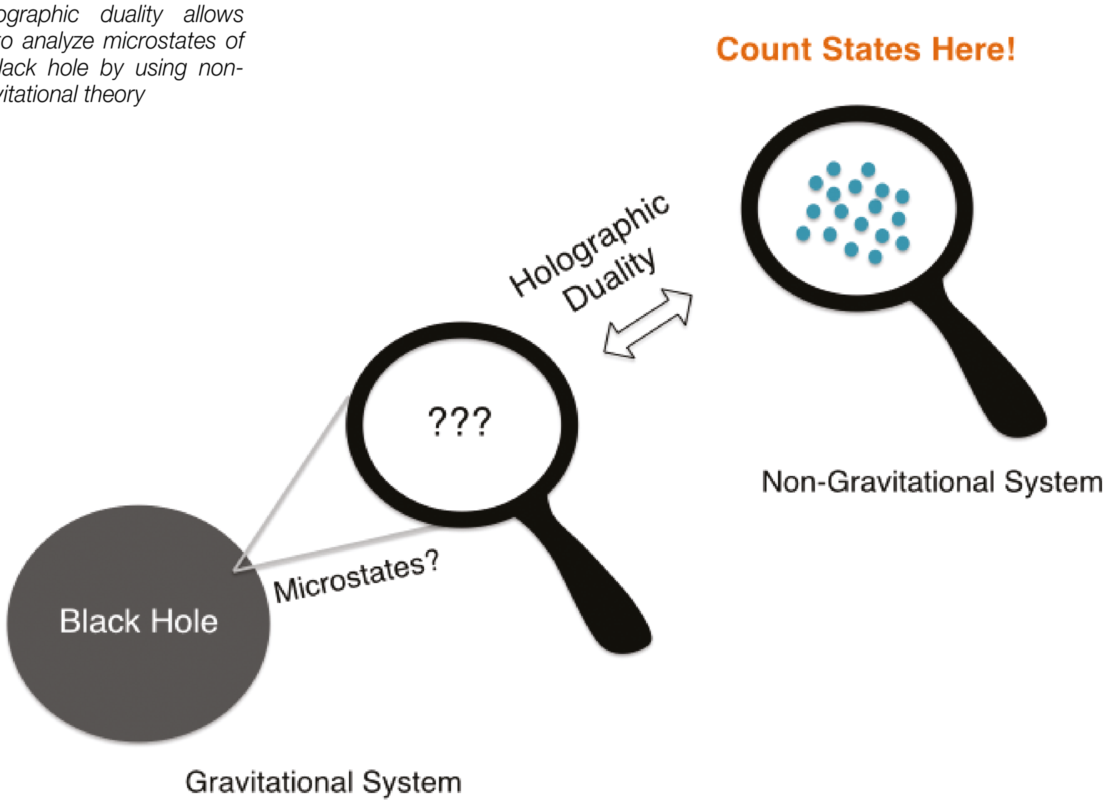
The detailed research in this direction was first carried out by Strominger and Vafa within the framework of string theory, a promising candidate for quantum gravity. They first built a black hole as a configuration of many extended objects called D-branes. Then, by using a powerful symmetry this system preserves, they counted the number of the configurations of strings attached to the D-branes and reproduced the entropy of the black hole exactly in the end. This milestone research has accelerated the analysis of black holes in string theory as well as the analysis of string theory through black holes.

Decoding Black Hole with Holographic Duality

Indeed a black hole carries entropy but its expression is in fact quite different from the one for a usual matter. Usually entropy of a matter is proportional to its volume. This can be guessed from the fact that the constituent particles spread over its volume. On the other hand, for a black hole, the entropy is proportional to its surface. This implies that the information of black hole microstates is encoded in a one-dimensional lower storage. This holographic property turns out to be the key for the modern research of quantum gravity.

The holographic property was first embodied by Maldacena in string theory. He considered a configuration of many D-branes and found a parameter region in which the system can be equivalently described by two different theories. One theory contains gravity, while another does not. The latter is one-dimensionally lower than the former. In other words, we can holographically describe the gravitational system without using gravitational theory. This holographic duality is the most powerful tool for the microscopic analysis of gravitational systems including black holes. It enables us to analyze various aspects of black holes quantitatively without directly accessing to quantum theory of gravity.

Holographic duality allows us to analyze microstates of a black hole by using non-gravitational theory



Black Hole Model Building with Holography — My Research

While holographic duality was first proposed in string theory, various applications of holographic duality imply that this duality is more general than first imagined. It is true that detailed analysis requires a rigorous underlying framework such as string theory, but we can also build simple toy models for black holes through holographic duality and play with them to understand some key properties of black holes relatively easily.

One interesting recent development in this direction is based on a one-dimensional fermionic model called the Sachdev-Ye-Kitaev (SYK) model. It has been shown that this model reproduces some important features of nearly zero temperature black holes, such as the approximate scaling symmetry in the low energy scale, maximally chaotic behavior and large degeneracy of states. The simple structure of this model allows us to carry out various computations explicitly, both analytically and numerically.

On the other hand, the SYK model takes an unusual form compared to the holographic models encountered in string theory. For example, the SYK model contains a random coupling and basic degrees of freedom are fermions only. This makes the geometric interpretation the SYK model difficult. Recently, some other models reproducing the physics of the SYK model were proposed. Among them, one of the interesting models is the large-D matrix model proposed by Ferrari in ULB. This model contains a large number of matrices as basic degrees of freedom. No random coupling is needed. Especially, the form of this model is close to the matrix models describing bound states of D-branes in string theory. Technologies developed for the latter can be applied to the former.

In my work with Ferrari, Gregori, Leduc and Valette in ULB, we constructed and analyzed various types of large-D matrix models including multi-trace deformed models, bosonic models and the ones with supersymmetry. Our analysis shows that we can define various classes of large-D matrix models consistently, and, among them, some special models show the SYK-like behavior.

In another work with Ferrari in ULB and Schaposnik Massolo in IBS, we analyzed in detail the phase structure of the simplest large-D complex matrix models with mass and a quartic interaction term. For the fermionic model, we pointed out that, between small-entropy region and large-entropy SYK-like region, there exists a second-order phase transition point with asymmetric critical exponents.

For the bosonic model, on the other hand, we have shown that the instability excludes the SYK-like region. Our analysis reveals crucial differences between the bosonic and fermionic models that were overlooked in previous works.

Our results are just a tip of the huge iceberg. Further understanding of the large-D matrix models and other holographic toy models for black holes will help us to understand microscopic nature of black holes as well as the underlying microscopic theory governing them.

Chris Blair I VUB
Faculty member (10%) - Postdoctoral Researcher (90%)

Physicists use the presence of symmetry and scales in nature to organise and formulate theories. While symmetries simplify the form of physical laws, scales — determined by the values of key physical quantities of interest — set for us the regime of validity of these laws, and indicate the sort of effects which are important, and which can be treated as irrelevant.

For instance, everyday life takes place at velocities that are small compared to the speed of light, and at lengths which are large compared to atomic distances. This allows us to use the laws of Newtonian mechanics as our description of physics. If we move to much greater speeds, then Einstein's theory of relativity supplants Newtonian ideas; while if we zoom in to very short lengthscales, such as those between the atoms in a molecule then we should use quantum mechanics.

At small scales and high velocities, the dynamics of fundamental particles is governed by "quantum field theories". We can further organise the physics of such theories by the energy of the particles that appear. By building bigger and better particle accelerators, we have been able to smash individual particles together at higher and higher energies and thereby discover new ones. The theory that describes all the particles we know, from the electron to the BEH boson, is the Standard Model. The particles of the Standard Model interact with each other via certain forces: electromagnetism, and the strong and weak nuclear forces. At low energies, these forces appear to be distinct phenomena, but as we probe physics at higher energies, electromagnetism (itself already combining electric and magnetic forces) and the weak nuclear force can be viewed as being unified into a single "electro-weak force".

It is expected that as the energies involve increase even further, there should be further unification of the laws of physics. Ultimately, this extends to the fourth force: gravitation. The gravitational pull between two particles is much, much weaker than the attraction or replusion they feel due to the other forces - but at very, very high energies this discrepancy will no longer be true. As a result, though when we theorists calculate the results of particle collisions in the LHC, we can completely ignore gravity as being irrelevant to the process, in a truly high energy process this would lead to disastrously incorrect results. A different way of looking at this problem is to say that the description of gravity provided by Einstein's general relativity is true only on large scales: famously it cannot be extended to a consistent quantum description (unlike for instance, classical electromagnetism which can be quantised as one of the ingredients of the Standard Model).

The greatest hope for a theory of fundamental physics which holds to arbitrarily high energies, and at the smallest lengthscales, is string theory. The basic idea is very simple: at short enough distances, all apparently point-like fundamental particles should turn out to in fact be extended strings. The "vibrations" of these strings at different frequencies correspond to particles of different mass, and the beauty of the theory is that strings naturally describe all the types of particles we see flying out of collision experiments, and all the types of forces we see there as well as the one we don't: gravity. Now, actually setting up a string theory description of the (relatively low energy) Standard Model has proven somewhat less straightforward than initially hoped (string theory only works in ten or twenty-six spacetime dimensions, while we only have experimental evidence so far for four), but string theory's rich internal structure, remarkable mathematical consistency and powerful insights into diverse problems in physics provide plenty of motivation to study it further.

One fascinating aspect of string theory is that it very often admits a certain fluidity when it comes to describing the theory in different regimes, or at different scales. This fluidity manifests itself in the appearance of a large number of unexpected "dualities". A duality in physics is a relationship between two different theories, or two different regimes of the same theory, which shows that they are in fact identical, describing the same phenomena in different language or different phenomena in the same language.

One regime we can study is the behaviour of strings wrapped around a circle. (If the extra spatial directions are very small circles, then at low energies the world of strings will appear effectively three-dimensional. This is a good motivation, given reality.) A remarkable fact is that string theory on a big circle is the same as string theory on a small circle, if you swap strings winding around the circle in one description for strings moving around the circle in the other.

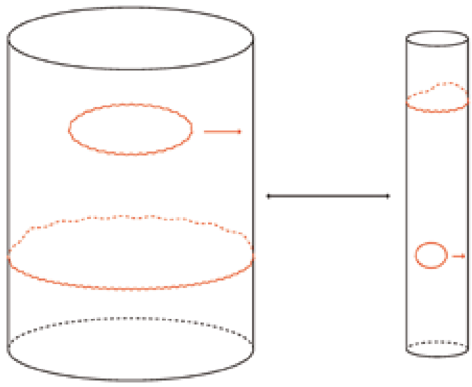


Figure 1: Depiction of T-duality in string theory: strings winding or moving around a large circle are equivalent to strings moving or winding around a small circle.

We can also consider the strength of interactions between two strings, which is measured by a quantity known as the string coupling. In one particular formulation of string theory in ten dimensions, when the string coupling becomes large, the theory appears to grow an eleventh dimension, prompting the idea that instead of a "string" theory, there is a different, still mysterious or magical, description as an eleven-dimensional "M-theory".

Notice that these duality transformations —between small and big circles, and between small and large coupling — seem to imply that a string's idea of geometry is also fluid. It does not matter whether we use a description with small or big circles. In some cases, ten dimensions are really eleven.

There is something fascinating about these relationships. The duality symmetries of string theory are nothing like the symmetries which govern the form of our conventional theories of particles. They ultimately rely on the fact the string has length — particles, which are just points, can not lead to such extra symmetries.

My research then makes use of the appearance of these extra symmetries of a "stringy" nature, and postulates that they can be used as a new organising principle for formulating and analysing string theory. This sets up the theory in a language reflecting aspects of the string that are not completely captured by our conventional geometric mathematical tools. So, for instance, to describe a string on a small circle and a big circle at once, I introduce a doubled geometry with both directions present. By introducing a more intricate set of extra coordinates, I can obtain a unified "exceptional geometry" which describes different eleven- and ten-dimensional descriptions of M-theory and string theory. In the conventional framework, duality symmetries are hidden symmetries. These extended geometry allow instead such symmetries to appear as a guiding principle in writing down string theory. These new descriptions may therefore provide a more natural language with which to formulate all of string theory, and offer hints at the sort of mathematics that the theory may really want us to use.

My recent work in Brussels has focused on exploring properties of these new geometries, which capture extra features of strings, and on demonstrating how to describe important aspects of string theory in this language in a unified manner. At VUB, I have been working with Sibylle Driezen, Alexander Sevrin and Daniel Thompson (10% VUB/Swansea) on capturing in the doubled language an elegant description of an interesting class of string theory geometries where one finds additional supersymmetries in the description of the string itself.

String theory's embarrassment of riches includes a collection of extended objects, not just strings, known generically as branes, which at low energies act as sources for generalisations of electromagnetic fields. Duality acts to relate all these branes, including the original string, to each other. I have been working on the description of such branes as objects in these new geometries, in separate collaborations with Edvard Musaev (AEI Potsdam) and Alex Arvanitakis (Imperial College London). This allows one to simultaneously describe different branes in a unified description, and in turn can be used to tell us how these different objects probe the new geometric structures. This includes both branes with which most string theorists would be familiar, and a large number of so-called "exotic" branes, which do not admit a conventional geometric description, but which are on the same footing as ordinary branes from the perspective of the extended geometry we use. The interest here is that the adjective "exotic" may be a misnomer: it has been proposed that such objects are in fact generic in string theory. As such, we should take them into account. For instance, they have been suggested as being important for understanding the fundamental properties of black holes (which I have also studied in the setting of a doubled spacetime, with Alex Arvanitakis).

This research offers glimpses into the string's geometry, and open questions remain about the precise mathematical nature of the structures that we see. At the very least, we are being provided with an elegant reformulation that somehow knows about the different pre-existing formulations in 10- and 11-dimensions. This alone deserves further study. Successful applications so far have included using this as a tool to study solutions of allowed string theory spacetime backgrounds at low energies. An important goal remains to use these new geometries to understand the connections between the world of strings and our world of things. One interesting option is to suggest that the structure of the extra six (or seven) dimensions is controlled not by ordinary geometry, but by a configuration which is intrinsically stringy and necessitates using extended geometry. This includes "exotic" configurations in which, for instance, moving in the extra directions takes you directly from a "small circle regime" to a "large circle regime", which are identified with each other. This may open up new possibilities for non-standard Standard Model model building.

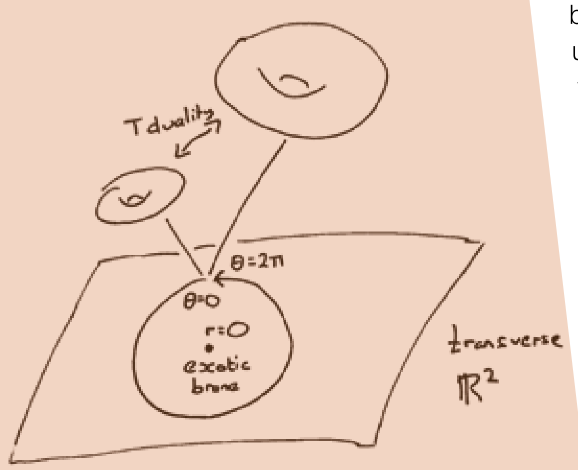


Figure 2: A schematic depiction of an "exotic geometry" in string theory: going in a circle around the location of an exotic brane takes you back not to the universe in which you started, but to a dual description in which what were originally small circles are now large circles, identified with the original small ones with (in this case) a T-duality transformation. My research offers one way to understand these features in a (generalised or extended) geometrical set-up.

Tim De Jonckheere I VUB
Doctoral researcher

Entanglement and correlations in holographic theories

The quest for a theory of quantum gravity has been a long struggle that still has no definitive outcome yet. The leading candidate today is string theory, a theory that describes elementary particles as excitations of tiny vibrating strings. While open strings give rise to particles like the photon, closed strings give rise to the graviton. As such the open string sector describes gauge theory, while the closed string sector describes gravity. String theory has a couple of remarkable and unexpected implications. One is that a description in terms of closed strings is dual to one in terms of open strings. At low enough energies, when quantum fluctuations and stringy vibrations are suppressed, a theory of gravity should be equivalently described as a gauge theory. When the gauge theory is defined in d dimensions the dual gravitational spacetime is $d + 1$ dimensional, so remarkably the duality is holographic. Moreover the duality is a strong/weak duality in the sense that gravity with a small Newton's constant is related to a strongly coupled field theory.

Up to date it is not fully understood how the extra dimension emerges from the field theory. One possibility is that the geometry of the spacetime emerges from entanglement and correlations in the field theory. This is motivated by the observation that the entanglement entropy of a subsystem of the field theory is dually described by the area of a minimal surface in the gravitational spacetime.

In my research I explore the holographic duality and study quantities that are measures of correlation and have an interesting representation in terms of geometric objects in the dual spacetime. Because of analytic tractability, I study the duality of a $d = 1 + 1$ field theory (i.e. with one spatial direction and one time direction) and a $2 + 1$ dimensional gravitational spacetime. In polar coordinates, the two spatial directions can be separated into an angular and a radial one. In this context, there exist non-trivial solutions of Einstein's equations, called conical defects, which are formed by imposing a non-trivial identification in the angular direction. Such spacetimes contain regions that are not probed by minimal surfaces which are geodesics here, and hence would not be obviously reconstructable from entanglement entropy. These regions are called entanglement shadows. They are however probed by non-minimal geodesics that wind around the defect. A quantity that computes the length of such geodesics is called entwinement and together with my collaborators we have defined a field theory quantity that computes it. We have defined entwinement as being related to the entropy of an internal set of degrees of freedom in a collection of multiwound strings, based on an ungauging and regauging of a state in the discretely gauged field theory. Spatial entanglement entropy is usually defined as the entropy of tracing out all degrees of freedom on a spatial subregion, as depicted in the black parts in the left plot of figure 1. Entwinement on the other hand is associated to tracing out all but a few internal degrees of freedom (as depicted in the right drawing of figure 1).

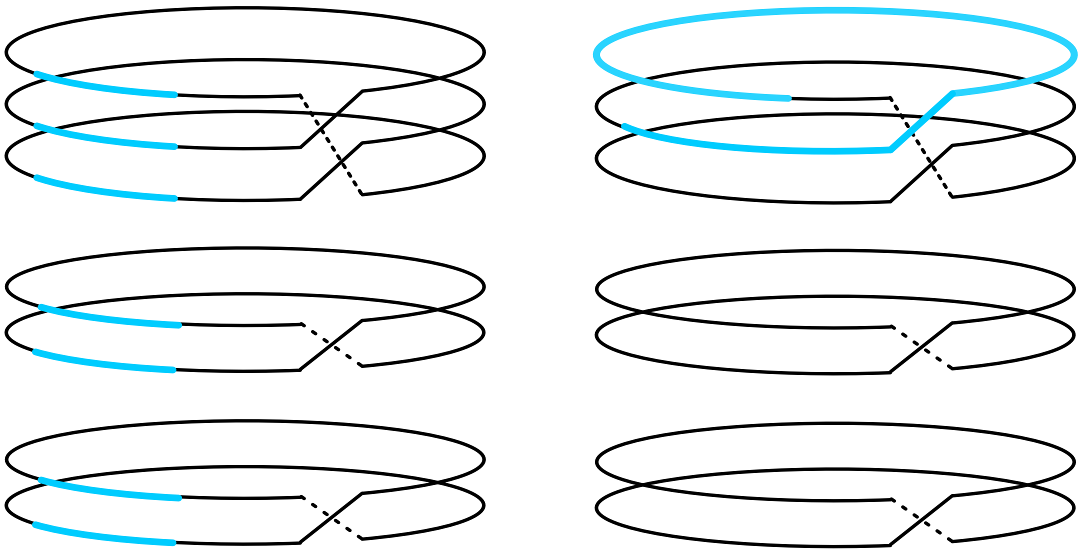


Figure 1: Spatial entanglement entropy (left) versus entwinement (right).

In holographic conformal field theory with many internal degrees of freedom, spatial entanglement entropy in excited states is often computed via a four point correlation function involving two heavy operators and two light operators. The heavy operators are typically assumed to be dual to a field that is very massive such that it backreacts and creates a conical defect geometry, while the light operator is dual to a probe field in that geometry. My collaborators and I have computed such a four point correlator in Liouville field theory, which is a possible candidate for the strongly coupled field theory dual to 2 + 1 dimensional gravity. Remarkably the correlator does not reproduce the expected behavior of entanglement entropy of a massless field theory, but is rather similar to what one would expect in a theory with a mass gap. In the bulk spacetime it has a dual interpretation as the scattering of a light field off the conical defect.

Appraisals and Prizes

- Marine De Clerck obtained a prestigious FWO “aspirant” fellowship. Besides this she also won the prize for the best graduating student of the Faculty of Sciences and Bio-Engineering Sciences of the Vrije Universiteit Brussel. Finally she also received the Brout Prize awarded by the examination committee of the Master in Physics and Astronomy of the Vrije Universiteit Brussel and the International Solvay Institutes.

- Saskia Demulder was awarded a 2-year extension of her FWO doctoral fellowship.

- Marc Henneaux was appointed “professeur du Collège de France” by decree of the President of the French Republic, on the chair “Champs, cordes et gravité”.

- Hongbao Zhang was awarded a 3-year extension of his FWO postdoctoral fellowship.

Theses defended in 2017

- Amaury Leonard I ULB – “Aspects of Higher Spin Hamiltonian Dynamics: Conformal Geometry, Duality and Charges” 3 July 2017 (thesis advisor: Prof. Marc Henneaux).

- Erik Jonathan Lindgren I ULB/VUB – “Black Hole Formation, Holographic Thermalization and the AdS/CFT Correspondence” 5 July 2017 (thesis advisors: Profs. Marc Henneaux, Ben Craps and Alexander Sevrin).

- Pablo Pais Hirigoyen I ULB – “Unconventional Supersymmetry, Massless Rarita-Schwinger Theory and Strained Graphene” 29 September 2017 (thesis advisor: Prof. Marc Henneaux).

Talks at conferences, seminars and schools

Riccardo Argurio

Sgoldstino-less inflation and low energy SUSY breaking

Lorentz Center, Leiden, The Netherlands
5 July 2017.

A holographic perspective on symmetry breaking

Università di Firenze, Italy
7 November 2017.

Advanced aspects of SUSY QFTs (3 lectures)

Università di Firenze, Italy
3, 10, 14 November 2017.

Tatsuo Azeyanagi

Large D Limit of Matrix Models

- Yukawa Institute for Theoretical Physics, Kyoto, Japan – 4 April 2017.
- University of Amsterdam, The Netherlands – 23 May 2017.

Aspects of Large D Matrix Models and Tensor Models

Yukawa Institute for Theoretical Physics, Kyoto, Japan – 7 August 2017.

Glenn Barnich

Finite BMS transformations and central extensions

Conference "Modern developments in General Relativity and their historical roots"
King's College, London, UK
12 January 2017.

BMS current algebra and central extension

- Workshop on "holography, black holes and numerical relativity"
  University of Southampton, UK
  5 April 2017.
- Conference "New Results in Quantum Field Theory and Holography"
  Trinity College, Dublin, Ireland
  2 May 2017.
- First Annual BHI Conference on Black Holes
  Harvard University, Cambridge, USA
  8 May 2017.
- Conference "Recent Trends in String Theory and Related Topics"
  IPM School of Physics, Tehran, Iran
  11 May 2017
- Conference "Recent Developments in General Relativity"
  The Hebrew University, Jerusalem, Israel
  21 May 2017.

Introduction to asymptotic current algebra

Conference "Higher Spin Theory and Holography"
Lebedev Institute, Moscow, Russia
31 May 2017.

BMS current algebra and central extension

- Conference "Ginzburg Centennial Conference on Physics"
  Lebedev Institute, Moscow, Russia
  1 June 2017.
- IMAPP Radboud University, Nijmegen, The Netherlands – 13 October 2017.
- Seminar on "Quantum Field Theory, Gravitation, and Elementary Particles"
  Leipzig University, Germany
  4 December 2017.
- Universidad Adolfo Ibáñez, Santiago, Chile
  15 December 2017.

Chris Blair

Doubled and negative strings

Banff International Research Station (Exceptional Field Theory and their Applications workshop), Banff, Canada 26 January 2017.

Double field theory and doubled geometry

Imperial College London, UK – 18 May 2017.

Doubled strings and negative branes

Rudjer Bokovi Institute (Recent Advances in T/U-dualities and Generalized Geometries conference), Zagreb, Croatia – 6 June 2017.

Particle actions and brane tensions from double and exceptional geometry

Institute for Basic Science, Seoul National University (Multi Facets of Extended Duality workshop), South Korea 29 September 2017.

Particles, branes and exceptional geometries

Max Planck Institute for Gravitational Physics, Golm, Germany – 2 November 2017.

Andrea Campoleoni

Higher-spin supertranslations and superrotations in four dimensions

Workshop "Recent developments on light front", Munich, Germany – 16 March 2017.

A glimpse into higher spin geometry from 3D black holes

Focus week "Recent developments in AdS3 black hole physics" of the GGI workshop "New developments in AdS3/CFT2 holography", Florence, Italy – 12 April 2017.

A glimpse into the infrared physics of higher-spin particles

Institut Henri Poincaré, Paris, France 4 May 2017.

Quantizing conical spaces in diagonal gauge

Workshop "New ideas on higher spin gravity and holography", Seoul, South Korea 15 July 2017.

Quantum aspects of 3D higher-spin gauge theories

ICNFP2017 Conference, Workshop on "Supergravity, Strings and related Matters", Kolymbari, Greece – 28 August 2017.

Andres Collinucci

Monopole operators, going beyond the Auslander-Reiten quiver

Simons Center for Geometry and Physics, Stony Brook, USA – 15 June 2017.

T-branes and 3d mirror symmetry: Generalizing the singularity/Lie algebra correspondence

CERN, Geneva, Switzerland 21 November 2017.

Geoffrey Compère

The E7(7) invariant black hole entropy

- University of Southampton, UK 1 February 2017.
- Conference "The String Theory Universe", Milano, Italy – 24 February 2017.

The multiple facets of symmetry in Einstein gravity

Colloquium, DAMTP, Cambridge, UK 17 May 2017.

BMS Vacua and Black Holes

- CERN, Geneva, Switzerland 28 March 2017.
- "Recent Developments in General Relativity", Hebrew University of Jerusalem, Israel – 21 May 2017.
- "Karl Schwarzschild Meeting 2017, Gravity and the Gauge/Gravity correspondence", Frankfurt, Germany – 27 July 2017.
- Niels Bohr Institute, Copenhagen, Denmark 23 November 2017.

Dries Coone

Nilpotent inflation and gauge mediation of SUSY breaking: when cosmology meets particle physics

- Kosmologietag, Bielefeld, Germany 18 May 2017.
- Planck conference, Warsaw, Poland 25 May 2017.
- Theory at sea, Oostduinkerke, Belgium 7 June 2017.

From Inflation to the LHC

Vrije Universiteit Brussel/IIHE internal seminar, Brussels, Belgium – 29 May 2017.

Ben Craps

Echoes of chaos from string theory black holes

- 6th Bangkok Workshop on High-Energy Theory, Thailand – 10 January 2017.
- Milano-Bicocca theoretical physics seminar, Milano, Italy – 8 February 2017.
- Rencontres théoriciennes, Paris, France 23 February 2017.
- IHES Conference on Black Holes, Quantum Information, Entanglement and All That, Paris, France – 30 May 2017.

Het Brout-Englert-Higgsdeeltje

- Lecture at Sint-Martinusscholen, Asse, Belgium – 14 February 2017.
- Seminarie volkssterrenwacht Urania , Hove, Belgium – 14 March 2017.

Exact LLL Solutions for BEC Vortex Precession

10th edition of the International Symposium “Quantum Theory and Symmetries”, Varna, Bulgaria – 20 June 2017.

Holography and thermalization in optical pump-probe spectroscopy

- QMUL seminar, London, UK 11 October 2017.
- Workshop on “Aspects of time-dependent holography”, Amsterdam, The Netherlands 8 December 2017.

Snaartheorie, zwarte gaten en kosmologie

Vlaams Congres van Leraars Wetenschappen, Brussels, Belgium 18 November 2017.

Tim De Jonckeere

Heavy-Heavy-Light-Light correlators in Liouville theory

Nordita, Stockholm, Sweden 15 November 2017.

Saskia Demulder

Resurgence: Uniting perturbative and non-perturbative physics

SCGSC 2017 (Institut Henri Poincaré), Paris, France – 16 February 2017.

Resurgence and integrable deformations

- XXIX Workshop Beyond the Standard Model, Bad Honnef, Germany 23 March 2017.
- Swansea University seminar, UK 26 April 2017.

Stéphane Detournay

La science d'Interstellar

Université libre de Bruxelles, Belgium
9 March 2017.

Détection des ondes gravitationnelles: Einstein et la musique des trous noirs

Hôtel de ville de Bruxelles, Belgium
25 April 2017.

Sybille Driezen

The doubled worldsheet

Theory at Sea Oostduinkerke, Belgium
8 June 2017.

N = (2,2) supersymmetric WZW models in superspace

- Swansea University, UK – 26 April 2017.
- XXIX Workshop Beyond the Standard Model, Bad Honnef, Germany
  22 March 2017.

Oleg Evnin

Nonlinear perturbations in Anti-de Sitter spacetime

Universidad Nacional Bogota, Colombia
6 April 2017.

Weak fields and effective integrability in AdS

- Universitat de Barcelona, Spain
  25 May 2017.
- Observatory of Paris, Meudon, France
  2 June 2017.
- Niels Bohr Institute, Copenhagen, Denmark
  6 June 2017.
- University of Lund, Sweden
  8 June 2017.

Periodic nonlinear dynamics of sequences

Mahidol University International College, Bangkok, Thailand – 12 July 2017.

AdS perturbations, conformal symmetry and integrability

Workshop and School "Topological Field Theories, String theory and Matrix Models" Moscow, Russia – 29 August 2017.

Weakly nonlinear dynamics of strongly resonant systems

Institute of Physics of Southern Federal University, Rostov-na-Donu, Russia
13 September 2017.

Nonlinear perturbations in Anti-de Sitter spacetime

- University of Malta, Msida, Malta
  6 October 2017.
- IFT UAM-CSIC, Madrid, Spain
  9 October 2017.

Weakly nonlinear dynamics of strongly resonant systems

Thammasat University, Bangkok, Thailand
7 November 2017.

Frank Ferrari

Black Holes, Matrix Models and Large D

Holography Meeting, KU Leuven, Belgium
27 January 2017.

The Large D Limit of Planar Diagrams

Center for Theoretical Physics of the Universe, Fields, Gravity and Strings Group, Seoul National University, South Korea
9, 10 March 2017.

Black Holes, Matrix Models and Large D

Conference "Quantum Gravity", Institut Henri Poincaré et Laboratoire de Physique Théorique d'Orsay, Paris, France
23 March 2017.

The Large D Limit of Planar Diagrams

Institut de Ciències del Cosmos, Universitat de Barcelona, Spain – 20 April 2017.

The New Large D Limit of Matrix Models: Theory and Applications

Seminar at the Korean Institute for Advanced Study, Seoul, South Korea – 23 May 2017.

New Results in Tensor Models and Large D Quantum Mechanics

Seminar at the Institute for Basic Science, Center for Theoretical Physics of the Universe, Fields, Gravity and Strings Group, Seoul National University, South Korea
25 May 2017.

The New Large D Limit of Matrix Models: Theory and Applications

Workshop “Black Holes, Quantum Information, Entanglement and All That,” IHÉS, Bures-sur-Yvette, France
30 May 2017.

On the Phase Diagram of Strongly Coupled Planar Matrix Quantum Mechanics

Seminar, XLVII ème institut d’été du Laboratoire de Physique Théorique de l’École Normale Supérieure, Paris, France
23 August 2017.

Matrix-tensor Models, Phases and Gravitational Collapse

Seminar, Theory Group Seminar, Imperial College, London, UK – 24 October 2017.

Phases of Matrix Quantum Mechanics and Quantum Gravitational Collapse from the new Large D Limit

Seminar, Triangular Seminar London in Theoretical Physics (King’s College, Imperial College and Queen Mary University), London, UK – 6 December 2017.

On Holography, Coloured Graphs and Black Holes

Seminar, École Normale Supérieure de Paris, France – 13 December 2017.

Adolfo Guarino

Double Field Theory at SL(2) angles

- Instituto Superior Técnico, Lisbon, Portugal
  17 January 2017.
- Università degli Studi di Milano – Bicocca, Milano, Italy – 21 February 2017.

Cosmological and holographical applications of string dualities

Albert Einstein Center for Fundamental Physics, Bern, Switzerland – 3 March 2017.

Holographic RG flows from massive IIA on S6

- Queen Mary University of London, UK
  6 April 2017.
- CERN, Geneva, Switzerland
  8 August 2017.

Holographic RG flows from massive IIA

Instituto de Física Teórica UAM-CSIC, Madrid, Spain – 21 December 2017.

Marc Henneaux

The 5th Conseil Solvay (1927)

Conference on “90 years of quantum mechanics”, Institute for Advanced Studies, Nanyang Technological University, Singapore
23-26 January 2017.

Chiral Tensors of Mixed Symmetry and the (4,0) Theory in 6 Dimensions

Ludwig Maximilian University, Munich, Germany – 16 March 2017.

Tools for conformal higher spins in 3 dimensions and the (4,0)-theory in 6 dimensions

Workshop “Recent developments in AdS3 black-hole physics”, Galileo Galilei Institute, University of Florence, Italy
10-14 April 2017.

Remarks on exotic theories of gravity in 6 dimensions

Workshop "Recent trends in string theory", Institute for Research in Fundamental Sciences (IPM), Tehran, Iran
8-11 May 2017.

Asymptotic Symmetries in Gravity: the Hamiltonian Approach

"Ginzburg Conference 2017", Lebedev Physical Institute, Moscow, Russia
30 May - 2 June 2017.

Asymptotic Symmetries of Gravity

CBPF, Rio de Janeiro, Brazil – 12 June 2017.

Electric-magnetic SO(2) duality for gravity and higher spin gauge fields

Instituto de Física, Universidade Federal do Rio de Janeiro, Brazil – 14 June 2017.

Three-dimensional gravity: a superb theoretical laboratory

Colloquium - University of Turin, Italy
10 November 2017.

The exotic (4,0) supergravity theory in 6 dimensions - I. The exotic graviton

Universidad de Santiago de Chile, Chile
22 November 2017.

The exotic (4,0) supergravity theory in 6 dimensions - II. The exotic gravitino

Universidad de Santiago de Chile, Chile
24 November 2017.

Three-dimensional gravity: a superb theoretical laboratory

Universidad Católica del Norte, Antofagasta, Chile – 27 November 2017.

The exotic (4,0) supergravity theory in 6 dimensions - III. Supersymmetry

Universidad de Santiago de Chile, Chile
28 November 2017.

Victor Lekeu

Exotic fields in six dimensions and the (4,0) theory

Université libre de Bruxelles, Belgium
14 December 2017.

Jonathan Lindgren

Black hole formation from pointlike particles and emerging thin shell spacetimes

University of Crete, Greece – 5 April 2017.

Laura Lopez Honorez

Minimal Dark matter Squared

IFIC, Valencia, Spain – 10 January 2017.

Dark Matter Annihilation & 21 cm Cosmology

- RWTH Aachen university, Germany 26 January 2017.
- VUB-Kobe Joint Symposium, Brussels, Belgium – 11 August 2017.
- Physics opportunities with a new universe's view: SKA telescope Valencia, Spain 7 November 2017.

Dark Matter imprint on EoR and beyond

Niels Bohr Institute, Copenhagen, Denmark
27 March 2017.

Warm Dark Matter and Epoch of Reionization

- SIDM workshop, Copenhagen, Denmark 2 August 2017.
- DM workshop @ CP3, Louvain-La-Neuve, Belgium – 8 December 2017.

Introduction to EW theory

BND School, Callantsoog, The Netherlands
12-15 September 2017.

Dark portals

IAP meeting, Brussels, Belgium
21 December 2017.

Vincent Luyten

A proof of Birkhoff's theorem

Université Libre de Bruxelles, Belgium
23 June 2017.

Alberto Mariotti

SUSY@LHC: theory perspective

CMS SUSY Workshop, Ghent, Belgium
10 April 2017.

The SUSY Twin Higgs

Aachen University, Germany – 4 May 2017.

Sgoldstinoless inflation and low energy SUSY breaking

Weizmann Institute / Tel Aviv University, Israel
17 May 2017.

SUSY@CLIC

Physics at CLIC Workshop – CERN, Geneva, Switzerland – 18 July 2017.

8h Lectures on Quantum Field Theory

BND Graduate School in Particle Physics, Callantsoog, The Nederlands
4-7 September 2017.

Andrea Marzolla

Holographic Ward identities for symmetry breaking

University of Southampton, UK
10 January 2017.

Poincaré symmetry shapes the massive 3-point amplitude

Queen Mary University of London, UK
12 January 2017.

Roberto Oliveri

Near-horizon extreme Kerr magnetospheres

University of Bremen / 7th Central European Relativity Seminars, Bremen, Germany
18 February 2017.

Self-similar accretion in thin discs around near-extremal black holes

- 16th British Gravity Meeting, University of Oxford, UK – 6 April 2017.
- Gravitational Wave Centre, KU Leuven, Belgium – 27 April 2017.
- 3rd Karl Schwarzschild Meeting, FIAS Frankfurt, Germany – 25 July 2017.
- X Black Holes Workshops, University of Aveiro, Portugal – 18 December 2017.

Charles Rabideau

Nonlinear dynamics of gravity from entanglement in conformal field theories

University of Texas, Austin, USA
7 November 2017.

Max Riegler

Spectral Flow and Flat Space Holography in 3D

- Kyoto University/Yukawa Institute for Theoretical Physics, Kyoto, Japan
  6 April 2017.
- Vienna University/Erwin Schrödinger Institute, Vienna, Austria – 2 June 2017.

Gábor Sárosi

Echoes of chaos from string theory black holes

- Yukawa Institute, Kyoto, Japan
  7 February 2017.
- Utrecht University, The Netherlands
  2 March 2017.
- University of Amsterdam, The Netherlands
  13 April 2017.

Charlotte Sleight

Interactions in Higher-Spin Gravity: a Holographic Perspective

Spring Meeting of the German Physical Society, Bremen, Germany – 16 March 2017.

Spinning (Geodesic) Witten Diagrams

GGI workshop "New Developments in AdS3 / CFT2 Holography", Florence, Italy 4 April 2017.

Spinning Witten Diagrams

- University of Rome Tor Vergata, Rome, Italy 12 April 2017.
- Ginzburg Conference 2017, Moscow, Russia – 29 May 2017.
- Workshop "New ideas on higher spin gravity and holography", Seoul, South Korea – 13 July 2017.
- PCTS workshop "20 years later: The Many Faces of AdS/CFT and Holography", Princeton, USA – 3 November 2017.

Comparing Apples and Oranges: Higher-Spins and AdS/CFT

Sommerfeld Theory Colloquium, Ludwig Maximilian University of Munich, Germany 20 December 2017.

Javier Tarrio

Holography with a Landau pole

University of Lisbon, Portugal 19 January 2017.

Cold compressible matter in holographic YM theories

University of Florence, Italy – 6 July 2017.

The path towards holographic color superconductors

University of Porto, Portugal 26 October 2017.

Towards color superconducting from strings

University of Santiago de Compostela, Spain 22 December 2017.

Dan Thompson

Chiral Tensors of Mixed Symmetry and the (4,0) Theory in 6 Dimensions

Ludwig Maximilian University, Munich, Germany – 16 March 2017.

Aspects of Integrable Deformations

Queen Mary, London, UK – 14 November 2017.

Aspects of eta and lambda models

Rudher Boskovic Institute, Zagreb, Croatia 6 June 2017.

Matthias Vereecken

High energy neutrino emission from obscured sources through the pp channel

Vrije Universiteit Brussel, Belgium 2 November 2017.

Hongbao Zhang

String Landscape, Swampland, Cosmic Censorship Conjecture, and Wald Formalism

Nanchang University, China 9 December 2017.

Cosmic Censorship Conjecture and Wald Formalism

- Hunan Normal University, Changsha, China 11 December 2017.
- South China University of Technology, Guangzhou, China – 15 December 2017.
- Sun Sat-sen University, Guangzhou, China 16 December 2017.

Dynamical Instability of Dark Soliton in Holographic Superfluids

Beijing University of Technology, China 14 September 2017.

List of Publications

[1] S. L. Adler, M. Henneaux and P. Pais, "Canonical Field Anticommutators in the Extended Gauged Rarita-Schwinger Theory," Phys. Rev. D 96 (2017) no.8, 085005 [arXiv:1708.03588 [hep-th]].

[2] N. Ambrosetti, D. Arnold, J. P. Derendinger and J. Hartong, "Gauge coupling field, currents, anomalies and $N = 1$ super-YangMills effective actions," Nucl. Phys. B 915 (2017) 285 [arXiv:1607.08646 [hep-th]].

[3] M. Ammon, D. Grumiller, S. Prohazka, M. Riegler and R. Wutte, "Higher- Spin Flat Space Cosmologies with Soft Hair," JHEP 1705 (2017) 031 [arXiv:1703.02594 [hep-th]].

[4] A. Amoretti, D. Areán, R. Argurio, D. Musso and L. A. Pando Zayas, "A holographic perspective on phonons and pseudo-phonons," JHEP 1705 (2017) 051 [arXiv:1611.09344 [hep-th]].

[5] A. Amoretti, A. Braggio, N. Maggiore and N. Magnoli, "Thermo-electric transport in gauge/gravity models," Adv. Phys. X 2 (2017) no.2, 409.

[6] A. Amoretti and N. Magnoli, "Conformal perturbation theory," Phys. Rev. D 96 (2017) no.4, 045016 [arXiv:1705.03502 [hep-th]].

[7] C. Appadu, T. J. Hollowood, D. Price and D. C. Thompson, "Yang Baxter and Anisotropic Sigma and Lambda Models, Cyclic RG and Exact S-Matrices," JHEP 1709 (2017) 035 doi:10.1007/JHEP09(2017)035 [arXiv:1706.05322 [hep-th]].

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Valérie Voorsluijs

Flow control of reactive fronts by radial injection

Reaction-diffusion (RD) fronts are ubiquitous in a wide variety of phenomena ranging from population dynamics, disease spreading, and biological pattern formation to image processing and nanotechnology to name a few. Among the large family of RD fronts, A + B → C fronts are observed when initially separated reactants A and B meet by diffusion and react to produce C. Depending on the nature of A and B, their dynamics is representative of many problems in chemistry, geochemistry, finance, particle physics, and many others. In rectilinear geometry, the temporal evolution of the front position, $x_f \sim t^{1/2}$, defined as the location of maximum C production, of the front width $w \sim t^{1/6}$, of the local production rate, $R(x_f) \sim t^{-2/3}$, and of the total amount of product $n_C \sim t^{1/2}$ has long been derived theoretically and confirmed experimentally. In such a geometry, advection at a constant velocity perpendicular to the front does not affect the dynamics in a frame moving with the advection speed. In a radial geometry, however, advection produces non-trivial effects. We have analyzed theoretically the dynamics of A + B → C fronts in the presence of passive advection when A is injected *radially* into B at a constant inlet flow rate Q. We have shown that, while advection does not change the well-known scaling exponents of the evolution of corresponding reaction-diffusion fronts, their dynamics is however significantly influenced by the injection. In particular, the total amount of product, n_C, varies as $n_C \sim Q^{1/2}\, t \sim Q^{1/2}\, V$, where V is the volume of injected reactant and the front position, r_f, as $r_f \sim Q^{1/2}\, t$, paving the way to a flow control of the amount and spatial distribution of the reaction front product. These theoretical predictions compare well with calcium carbonate precipitation experiments performed in a Hele-Shaw cell.

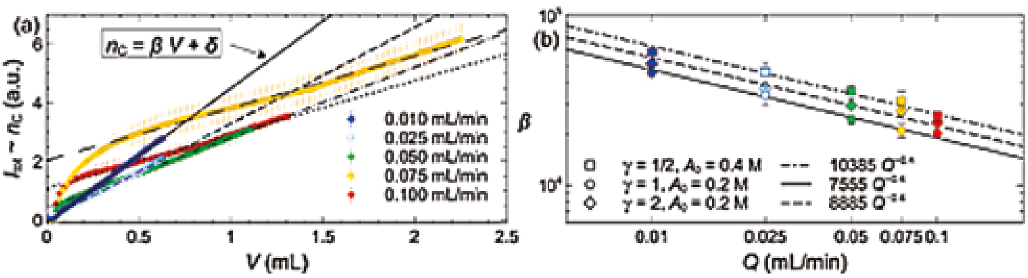


Fig.1: Precipitation reaction by radial injection in a confined quasi-2D reactor of a solution of carbonate ions (A = CO_3^{2-}) into a solution of calcium ions (B = Ca^{2+}) producing calcium carbonate (C = $CaCO_3$). (a) n_C, estimated by the intensity I_{tot} of light reflected by C, as a function of the volume V of the injected Na_2CO_3 solution for various Q and initial concentrations $A_0 = B_0 = 0.2$ M. (b) Slope β of the asymptotic linear regime shown in (a) as a function of Q for various $\gamma = B_0/A_0$.

Chemically-induced Marangoni-driven flows in exothermic reactions

Chemical reactions can induce Marangoni flows by changing the surface tension of a solution open to the air, either by changing the composition and/or by modifying the temperature. With a simple A + B → C exothermic reaction, the structure of the resulting flow can be controlled by the Marangoni numbers, quantifying the solutal and thermal effects of the reaction on the surface tension, and the Lewis number measuring the ratio between heat and mass diffusivities. Our numerical results are confirmed by analytical derivations of the surface tension profiles reconstructed from the Marangoni numbers and the reaction-diffusion concentration profiles.

Chemical fronts in microgravity

Within the framework of a European Space Agency network focusing on chemo-hydrodynamic instabilities, we have proposed a model for experiments in microgravity with an autocatalytic front. Those experiments evidence the existence of a self-organized autonomous and localized coupling of a pure Marangoni flow along the surface with the reaction in the bulk. Microgravity conditions allowed isolating the transition regime during which the surface propagation is enhanced whereas diffusion remains the main mode of transport in the bulk. This transition is typically concealed on Earth because of buoyancy-driven convection.

Role of the transport of extracellular microRNAs (miRNAs) in gene expression

Extracellular miRNAs carried by exosomes play a key role in cell-to-cell communication. We have proposed a model for the spatio-temporal evolution of protein expression in a cell tissue altered by abnormal miRNA expression in a donor cell. The resulting nonhomogeneous cellular response in the tissue is quantified with the range of action of the donor cell on the surrounding cells. The dynamics of gene expression in the tissue is robust to random changes of the parameter values showing the important role of miRNA in the propagation of a dynamical signature in gene expression (Fig.2).

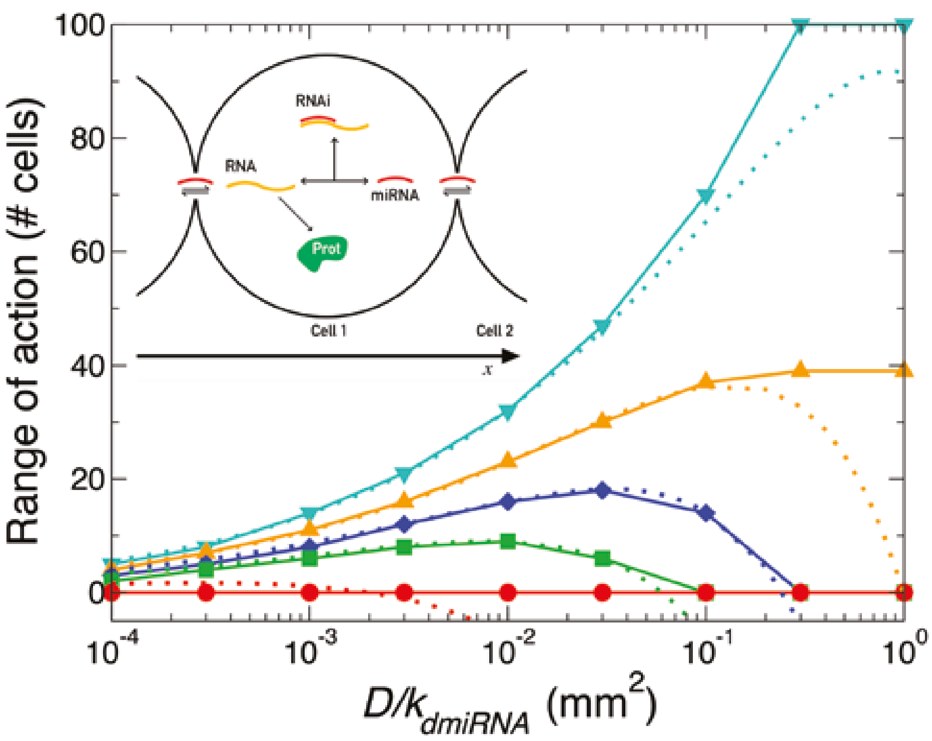


Fig.2: Extracellular microRNAs (miRNAs) carried by exosomes can play a key role in cell-to-cell communication. The range of action, defined as the distance from a source cell where protein concentration is half the basal value, depends on 3 parameters only: the synthesis rate of miRNA, its degradation constant and its transport coefficient.

Fluctuation-induced dynamics in the photosensitive Belousov-Zhabotinsky reaction

The photosensitive Belousov-Zhabotinsky reaction has been used extensively to study the properties of chemical oscillators. In particular, recent experiments revealed the existence of complex spatiotemporal dynamics for systems consisting of coupled micelles or droplets. In this work, we analyzed theoretically and investigated numerically the role of fluctuations on the dynamics in such droplets. The birhythmicity and chaotic behaviors predicted in the absence of fluctuations become transient or intermittent regimes whose lifetime decreases with the size of the droplet. Simple oscillations are more robust and can be observed in very small systems, which justifies the use of deterministic models in microfluidic systems of coupled oscillators. Simulations also revealed that fluctuations strongly affect the efficiency of inhibition by light, which is often used to control the kinetics of these systems: oscillations are found for parameter values for which they are supposed to be quenched according to deterministic predictions.

Nonlinear behavior during NO_2 hydrogenation on nanosized catalyst samples

We investigated the origin of complex kinetic phenomena observed at the nanoscale during the reduction of NO_2 on rhodium and platinum/rhodium alloy catalysts. Using field emission microscopy (FEM), we observed numerous nonlinear behaviors, including self-sustained oscillations (Fig.3). The corresponding stochastic attractors could be reconstructed with nonlinear time series analysis techniques. Combining these results with simple models we could identify the most important reaction steps involved, and we could clarify the role played by the nonlinear decomposition rate of NO_2 and by the composition of the alloys in the emergence of complex phenomena.

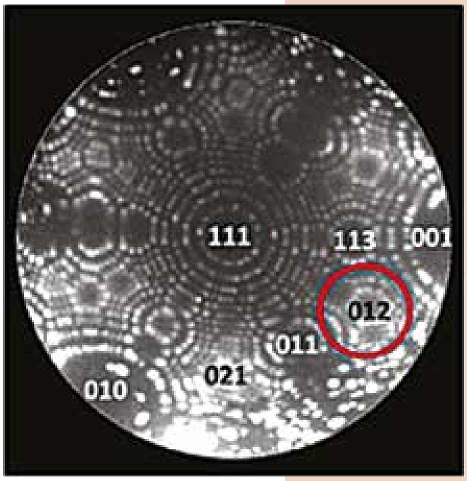
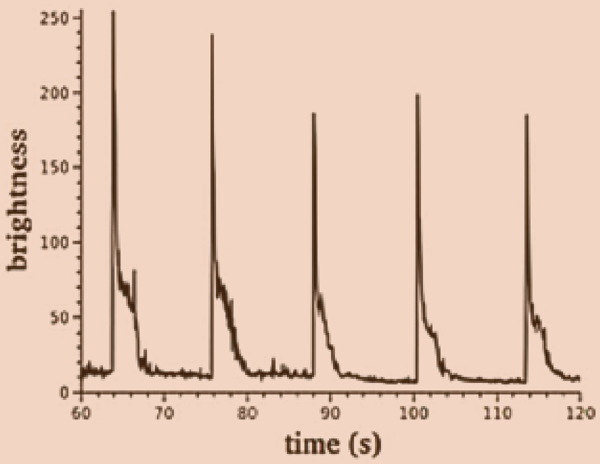


Fig.3: Left-hand side: atom micrograph of a rhodium sample at cryogenic temperature. Individual atoms appear as bright dots. Right-hand side: Oscillations during the NO_2+H_2 reaction at 390 K. The signal corresponds to the brightness averaged over the red circle as shown on the left-hand side figure.

Stochastic approach to irreversible thermodynamics

An extension of classical irreversible thermodynamics pioneered by Ilya Prigogine has been developed, in which fluctuations of macroscopic observables accounting for microscopic-scale processes are incorporated. The contribution of the fluctuations to the entropy production was derived from a generalized entropy balance equation and expressed in terms of the fluctuating variables, via an extended local equilibrium Ansatz and in terms of the probability distributions of these variables. The approach was illustrated on various systems such as the motion of a single Brownian particle, or reactions involving linear and nonlinear steps, and the role of the distance from equilibrium and of nonlinearities were assessed.



Research Interest of some other member

Jean-François Derivaux
Doctoral researcher

Progress in technology and experimental techniques made over recent years has unlocked the possibility of manipulating small systems with an accuracy and control so far inaccessible. Keeping track of a single molecular motor in a cell or measuring heat released by single electrons passing through a circuit are now daily laboratory routines (Fig.1).

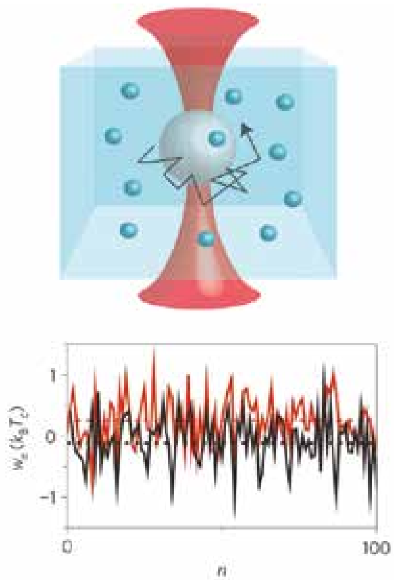


Figure 1 – Two examples of experiments in stochastic thermodynamics. Left panel: (top) Scheme of a Brownian particle in an optical trap [1] – (bottom): Experimental fluctuations of work of the Brownian particle against the trap [2]. Right panel: (top) Scheme of a single electron box – (bottom) Distribution of the entropy of a single electron in the circuit [3].

[Sources: [1] M. Y. A. Jamalabadi et al., International Journal of Optics and Applications 5, 161 (2015), [2] V. Blickle et al., Nature Physics 8, 143 (2012), [3] J. V. Koski et al., Nature Physics 9, 644 (2013).]

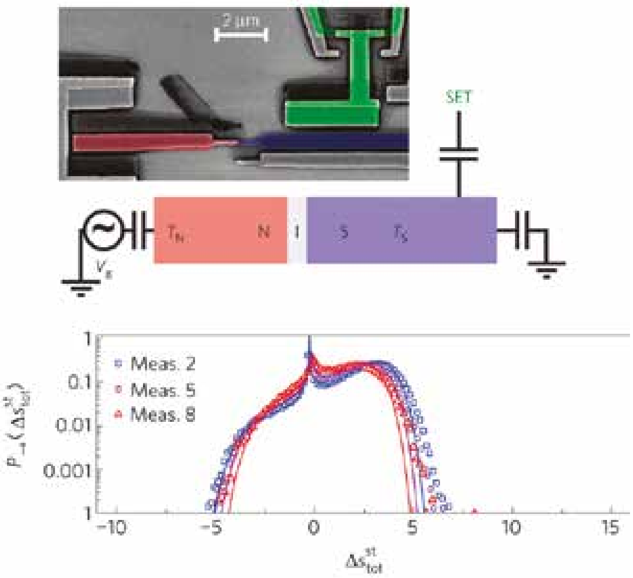
Following this evolution, the question of the possibility of defining thermodynamic quantities – originally suited for the macroscopic world- at such scales has been repeatedly stressed. Nanoscale thermodynamics would represent an invaluable tool to answer pragmatic questions related to, say, the energy budget or efficiency of small devices, but also to rationalize complex phenomena using thermodynamic arguments. A typical example of this is molecular signalling in a noisy environment, whose accuracy can be related to entropy production.

However, at small scales the fluctuations of a system's variables start to reach the same order of magnitude as the variables themselves. Deterministic descriptions should be here abandoned in favour of probabilistic approaches. Such a change in paradigm opens new questions: How to define properly stochastic thermodynamic quantities? How do the macroscopic laws of thermodynamics affect the probability distributions of those same quantities?

In my PhD thesis, I tackle those fundamental questions by developing a new general approach based on the extension to small systems of classical macroscopic non-equilibrium thermodynamics, as developed by Ilya Prigogine among others. This approach benefits from the self-consistency of the theory it is based on, and shares its broad range of applicability and the fact that complex and diverse phenomena (self-assembly, bistability, oscillations) can be treated in a unique framework.

I already applied this approach to study small chemical networks and transport phenomena at small scales. In small chemical networks, the probability distribution of fluctuating entropy production was fully characterised for different examples. Those results highlighted how the fluctuations of entropy production are connected to the macroscopic state of the system (equilibrium or non-equilibrium steady state) and how they are strongly interrelated with the dynamical behaviour of the system.

My interest has more recently focused on thermodiffusion in small devices. Thermodiffusion is the physical phenomenon where both heat and matter fluxes are established simultaneously in a system by applying temperature and density gradients. In such systems, temperature gradients can induce a flux of matter and density gradients can induce heat flux.



This coupled transport phenomenon lies at the heart of various miniaturised separation techniques and can be useful to separate matter more effectively than in the absence of coupling.

I showed that the probability distribution of the separation efficiency in such devices displays bimodality for some values of external parameters such as the temperature of the environment, indicating that different separation modes are accessible to the system. In fact, fluctuations enable the system to work in different regimes (e.g. heat pump and matter pump) simultaneously. This leads at small scales to a trade-off between an improved mesoscopic separation efficiency and efficiency losses due to the operating of the device in undesired regimes. This trade-off can be quantitatively computed and related to the different macroscopic transport coefficients specific to the system.

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Appraisals and Prizes
Theses defended in 2017

Appraisals, Prizes and Fellowships

Alexia Papageorgiou was awarded a Solvay Award for her Master Thesis.

PhD theses defended in 2017

Carelle Thomas – “Influence of chemical reactions on CO_2 convective dissolution: an experimental study” 26 June 2017 (thesis advisor: Prof. A. De Wit).

Master Thesis defended in 2017

Nathalie Ruth – “Etude expérimentale de l’effet de réactions chimiques sur la séquestration de CO_2 dans des aquifères salins” – 27 June 2017 (Advisor: Prof. A. De Wit).

Hind Saghou – “Etude d’effet de réactions chimiques sur la dissolution convective du CO_2 dans les aquifères salins : étude numérique” – 27 June 2017 (Advisor: Prof. A. De Wit).

Gauthier Hayot – “Contribution au développement d’un procédé de cristallisation du beurre de cacao sous une contrainte de cisaillement” – 8 September 2017 (Advisors: Profs Y. De Decker and F. Debaste).

Talks at conferences, seminars and schools

Anne De Wit

Invited talk at the "Mixing Day"
Université de Rennes, France – May 23.

Invited talk during the "Engineering of Chemical Complexity" Conference (ECC9)
Vilanova, Spain – June 20.

Fabian Brau

Flow control of A+B → C fronts by radial injection
Minisymposium Chemo-Hydrodynamics, XXXVII Dynamics Days Europe, Szeged, Hungary – June 7.

Laurence Rongy

Influence of chemical reactions on the convective dissolution of carbon dioxide in porous media
Interpore 9th Annual Conference on Porous Media, Rotterdam, The Netherlands – May 8.

Marcello Budroni

Cross-diffusion-driven hydrodynamic instabilities: theory and experiments
9th International Conference on Porous Media, Rotterdam, The Netherlands – May 9.

Controlling chemical chaos in the Belousov-Zhabotinsky oscillator
WIVACE-2017, Venice, Italy – September 19.

Jean-François Derivaux

Stochastic thermodynamics of reactive systems: an extended local equilibrium approach
Mathematics in (bio)Chemical Kinetics and Engineering (MaCKiE) 2017, Budapest, Hungary – May 26.

Chinar Rana

Viscous fingering instability in reactive systems
Interpore 9th Annual Conference on Porous Media, Rotterdam, The Netherlands – May 9.

Reda Tiani

Effects of Marangoni flows on A + B → C reaction-diffusion fronts
XXXVII Dynamics Days Europe, Szeged, Hungary – June 7.

Scientific stays

Marcello Budroni

Visiting researcher in the Department of Physics, University of Bayreuth, Germany – 22-28 May 2017.

Organized Conferences

F. Brau, W. De Malsche, G. Desmet, A. De Wit and L. Rongy

Solvay workshop on "Chemical reactions and separation in flows"
19-21 April 2017.

F. Brau

Co-organizer of the thematic session "From isometry to reality: Geometric principles, mechanics, and morphology of thin solid structures", APS March Meeting, New Orleans, USA – 13-17 March 2017.

M. Budroni

Organizer and chair of the mini-symposium on "Chemo-hydrodynamics" at XXXVII Dynamics Days Europe, Szeged, Hungary – 5-9 June 2017.

Press releases

"An enhanced theory for nonlinear and irreversible thermodynamics", AIP Scilight http://aip.scitation.org/doi/10.1063/1.5005502.

Cover of the journal "Reflets de la physique" (Revue de la Société française de Physique, May 2017).

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Flow control of A + B → C fronts by radial injection, Phys. Rev. Lett. 108, 134101 (2017).

A. Grau Ribes, Y. De Decker, C. Gérard and L. Rongy
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and Electrochemistry, September 2017.

C. Barroo, L. Jacobs, N. Gilis, S. V.
Lambeets, S. Owczarek, Y. De Decker
and T. Visart de Bocarmé
Field Emission Microscopy to Study the
Catalytic Reactivity of Binary Alloys at the
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Microsc. Microanal. 23, 610 (2017).

Laboratory Structural Biology Brussels I VUB

Group of Professors Jan Steyaert and Han Remaut
(former head: Emeritus Professor Lode Wyns,
Deputy-Director for Chemistry)

Peeking into the molecular mechanics of amyloid formation: lessons learned from a bacterial functional amyloid protein

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[a]*Structural Biology Brussels, Vrije Universiteit Brussel*
[b]*Structural and Molecular Microbiology, Structural Biology Research Center, VIB*

Amyloids are aggregative protein or peptide fibrils best known for their implication in (neuro)degenerative illnesses such as type 2 diabetes and Alzheimer's, Parkinson's and Huntington's diseases. However, it is now well established that the structural hallmark of amyloids, the assembly into cross-β structured fibrils, is not restricted to off-pathway protein misfolding events seen in pathological amyloidosis but is also found as the native conformation of several pro- and eukaryotic proteins referred to as "functional amyloids".

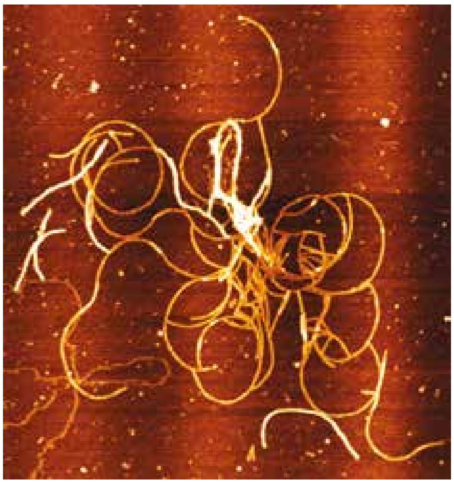

Figure 1. AFM image of curli, a bacterial functional amyloid.

Contrary to pathological amyloids, functional amyloids are the product of diverse biosynthetic pathways dedicated to the controlled aggregation of pro-amyloid subunits into surface-localized fibers. One of the most widespread functional amyloids is curli, found in the extracellular matrix of many Gram-negative bacteria, where they form non-covalent polymeric protein filaments that serve as structural scaffolds to *"glue"* together the bacteria within a protective biofilm[1]. Two gene clusters encode the curli subunits, as well as the accessory and channel proteins required for the controlled passage of pro-amyloid subunits across the cell envelope and subsequent deposition into amyloid fibrils on the cell surface[2]. The major building block of curli is CsgA, an intrinsically disordered, pseudo-repeat protein of 15,7 kDa in *E. coli,* which folds during self-assembly into fibers that exhibit the typical cross-β spine architecture and are resistant to denaturing agents[1]. In this work, we sought to understand the mechanism of nucleation and growth of CsgA molecules into amyloid fibers for two reasons.

A first reason has to do with the reported toxicity of many amyloid species. In pathogenic amyloids, cytotoxicity is ascribed primarily to soluble oligomeric species that exist as intermediates or side-products during nucleation and early fiber assembly, and to a lesser extent to the mature fibers[3].

Whether this applies to functional amyloids is not known. A pertinent question imposes itself: *How do the bacteria balance the need to quickly and efficiently produce amyloid-prone building blocks under biofilm promoting stimuli, without inducing self-inflicted cytotoxicity?* A detailed elucidation of the molecular mechanism(s) of functional amyloid formation is needed to determine whether the adapted amyloidogenesis pathways minimize cytotoxicity, or whether control mechanisms like chaperone activity and/or controlled spatiotemporal aggregation of the amyloid subunits take priority.

A second reason has to do with the apparent universality of a number of features that are shared across all amyloid species. Although the repeating units of different amyloid fibers are highly diverse in primary and tertiary structure, both functional and disease-associated amyloids all have a cross-β spine quaternary structure, and a self-assembly process that involves a usually rate-limiting nucleation step and a rapid self-catalyzed extension into linear fibrils through addition of soluble subunits to the fiber template. It stands to reason that there are a number of amyloid-specific self-assembly principles common to all proteins and peptides that are amyloid prone. If one is able to identify and understand the self-assembly mechanics of a single amyloid system, there is an implicit promise that it will advance the understanding of all amyloid systems. To that end we have focused our efforts on curli, a system that has evolutionary optimized the process.

The mechanism of curli nucleation and growth has been a subject of intense study over the last decade, albeit using bulk solvent technologies unable to discern the process at the molecular level. To resolve nucleation and elongation trajectories, and separate productive from non-productive off-pathway phenomena, a time-resolved single molecule technology is required. Looking at single fiber level with high speed atomic force microscopy, we now showed that *in vitro* curli fiber nucleation is fast and direct, i.e. the system does not transition through an intermediate, non-amyloid, oligomeric state before ending up in the amyloid phase. Thus, the formation of productive CsgA oligomers appears inherently coupled to the adoption of the amyloid fold, where the minimal curli fragment that nucleates and which can induce templated CsgA folding may be as small as a folded CsgA dimer.

On theoretical grounds, we foresee one of two possible pathways to a minimal curli fragment: (1) a “folding-binding pathway” in which transiently folded CsgA monomers can associate upon collision into a stable amyloid fragment that is rapidly extended by templated folding of new incoming subunits; or (2) a “co-incidence folding pathway” where contemporate folding of CsgA monomers leads to the formation of the minimal amyloid species that templates fiber extension (Figure 2).

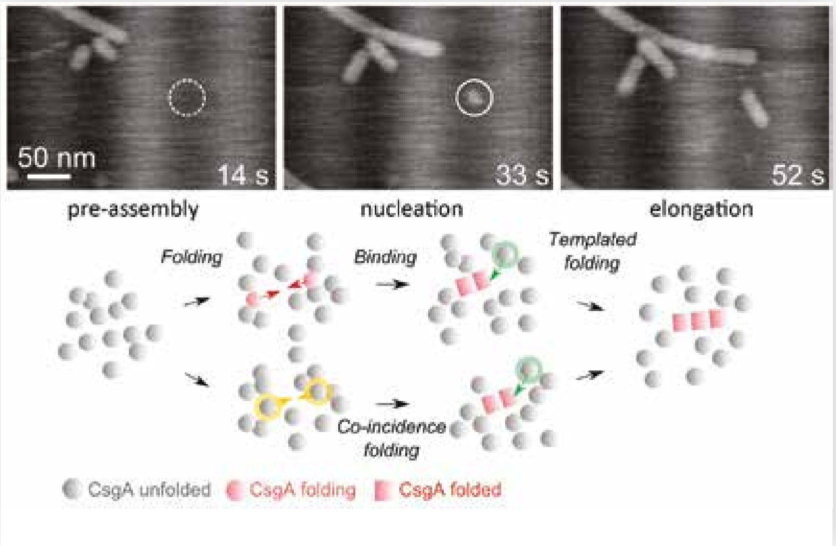

Figure 2. Nucleation and elongation of a CsgA curli fiber. High speed AFM imaging shows the evolution from an empty site to the nucleation of a minimal species with the morphological appearance and growth kinetic behavior of mature fibers

If we consider the biological context in which curli are formed, one-step direct nucleation can be considered a logical route. In the event that unfolded CsgA monomers are secreted in the extracellular milieu where convective currents may exist, long nucleation induction times seem wasteful. Although more examples are needed, the absence of a lengthy induction time could be a defining trait of functional amyloids. The reduction of the kinetic and energetic barriers for amyloid formation increase the efficiency gain of the aggregation process which fits the rationale from an evolutionary perspective. This stands in sharp contrast to the amyloid transformation of natively folded proteins where the un- and refolding steps into cross-β structures is the molecular origin of the induction time. For these cases, amyloid structures are an unwanted aberration and the large activation barriers associated with their formation are no evolutionary accident. The fast and direct nucleation of CsgA demonstrates that the apparent lag phase which is seen in bulk techniques should not be associated with a single molecular process. This point has been emphasized for pathological amyloids[38], but is reiterated here for the case of functional amyloids due to its importance.

The potency of CsgA to rapidly form amyloid structures at low concentration underlines the need for a tight spatiotemporal control of amyloid deposition during curli biogenesis. Indeed, premature, intracellular fibrillation of curli subunits before they reach the cell surface can lead to detrimental cell damage. The biological failsafe in the curli secretion-assembly pathway is CsgC, a protein residing in the periplasm, the space separating the cytoplasmic and outer membrane in diderm bacteria. CsgC has been found to inhibit CsgA fibrillation in sub-stoichiometric concentrations and can protect cells from a toxic build-up of curli subunits in case of a faulty secretion flux[3]. The mechanism of CsgC's inhibitory activity, however, remained unknown. Based on *in situ* AFM imaging and CsgA binding data, we propose that CsgC predominantly acts at the level of fiber elongation, most likely by reversibly binding to fiber termini. In doing so, it effectively acts as a fiber capping agent that blocks the further addition of new CsgA molecules to the fiber tip. This model readily explains how CsgC can function at sub-stoichiometric concentrations without invoking any enzymatic or (un)foldase activity towards conformational CsgA intermediates en route to nucleation or fiber extension, both of which would result in a thermodynamic paradox.

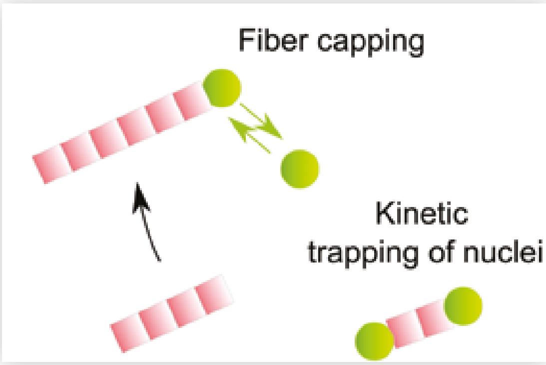

Figure 3. Curli inhibitor CsgC (green) acts by inhibiting fiber elongation, likely by shielding the fiber (red) growth poles from incoming CsgA monomers (grey).

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Sleutel, M., Van den Broeck, I., Van Gerven, N., Feuillie, C., Jonckheere, W., Valotteau, C., Dufrêne, Y.F., Remaut H. Nucleation and growth of a bacterial functional amyloid at single-fiber resolution. (2017) Nat Chem Biol 13, 902-8.

Research Highlights of other scientists connected with the Institutes

ALGC Research Group I VUB

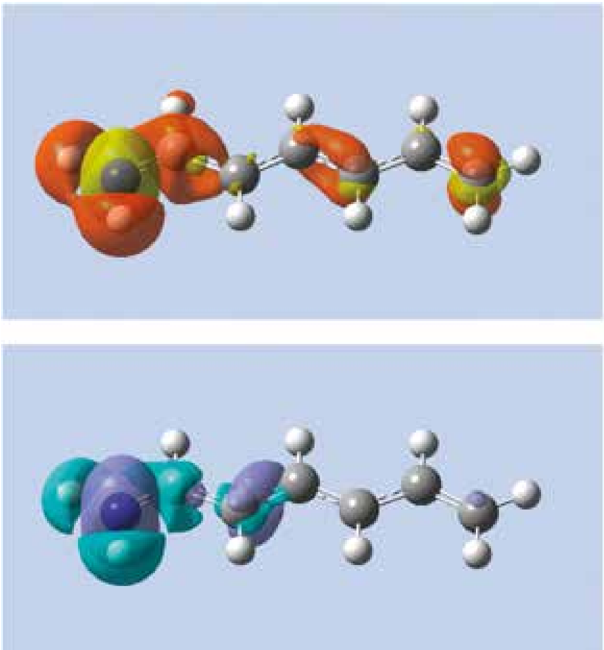
Group of Professor Frank De Proft and Emeritus Professor Paul Geerlings

In recent years the ALGC Research Group (Prof. Frank De Proft and Em. Prof. Paul Geerlings) has been extending its long-standing research interest in Conceptual Density Functional Theory [1] in a natural way along new research lines on the basis of the experience gained in various aspects of Density Functional Theory. Research Lines have been launched on Molecular Electronics, on Molecular Switching Properties, on Inverse Design and on the study of molecular behaviour in the molecules' real environment upon reactions, i.e. in most cases a solution, necessitating ab initio Molecular Dynamics and Metadynamics Simulations. Beyond and along these lines various applied quantumchemical studies are performed applying DFT based concepts on a variety of substrates most often carried out in direct interaction with experimentalists.

In this 2017 report attention is paid to fundamental work in Conceptual DFT, Molecular Electronics, Molecular Switches and Applied Quantum Chemistry .

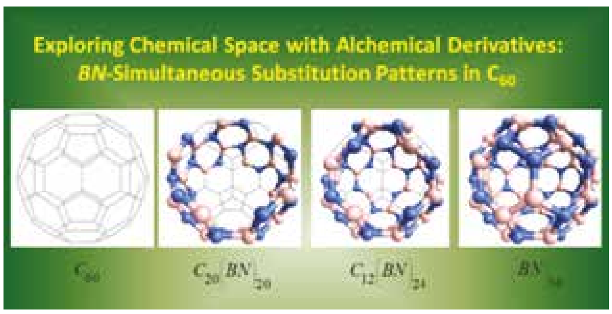
Conceptual DFT

Concerning the Conceptual DFT part particular attention was paid to the intriguing principle of the Nearsightedness of Electronic Matter (NEM) formulated some years ago by Nobel Laureate Walter Kohn [2-3].This study connects with our ongoing research on the Linear response Function [4] and was carried out by Dr.Stijn Fias in collaboration with Prof. Paul Ayers (Mc Master Canada). The NEM principle states that for many-electron systems at constant electronic potential μ the change in electron density at position $\underline{r}_{0,}$ $|\Delta\rho(\underline{r}_0)|$, induced by a perturbation at position $\underline{r}'$, $v(\underline{r}')$, with $\underline{r}'$ outside a sphere with radius R centered on $\underline{r}_0$, will always be smaller than a maximum value $\bar{\Delta}\rho(\underline{r}_0,R)$ no matter how large the perturbation is; in other words the electron density at $\underline{r}_0$ cannot "see" any perturbation beyond R with an accuracy greater than $\bar{\Delta}\rho(\underline{r}_0,R)$. Although Kohn and Prodan offered some examples on 1D systems, no numerical confirmation on this nearsightedness principle in the 3D molecular world was given hitherto. We showed that the problem can be reduced to the study of the linear response function $\chi(\underline{r}, \underline{r}') = (\delta\rho(\underline{r})/\ \delta v(\underline{r}'))_N$ but not at constant number of electrons (N) but at constant electronic chemical potential (μ) leading to the softness kernel $s(\underline{r},\underline{r}')$. We were able to show that in "gapped" systems, ergo most molecules, the decay in the charge density upon introducing a functional group as perturbation at constant chemical potential is faster than at constant number of electrons, the latter case reducing to the properties of the linear response function. The whole of our findings provides evidence for the transferability of functional groups. In this way a link was established between the physicist's view of electronic matter and the long standing chemical concept of "chemical transferability" [5].



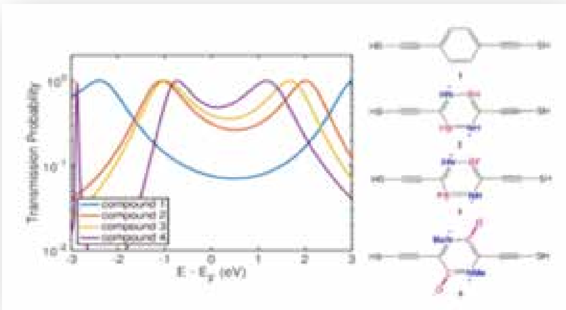
As a second example in this line of research the collaboration with Dr. Robert Balawender (Polish Academy of Sciences) should be mentioned, deepening and exploiting the concept of alchemical derivatives, i.e. derivatives of the energy of a molecule when one nucleus is replaced by another. This ansatz was previously shown to be a step forward in the exploration of the huge Chemical Compound Space [6].

We were able to show that, in the case of the gradual CC by BN substitution in C_{60}, i.e. going from C_{60} to $C_{60-2n}(BN)_n$ (n=1,2... 30) passing for example through the belt structure (n=20),the correct sequence of substitution pattern could be retrieved by a single SCF calculation on C_{60} and its alchemical derivatives up to second order, leading to an orders of magnitude decrease in computational resources as compared to a conventional procedure with one SCF calculation for each possible isomer [7].

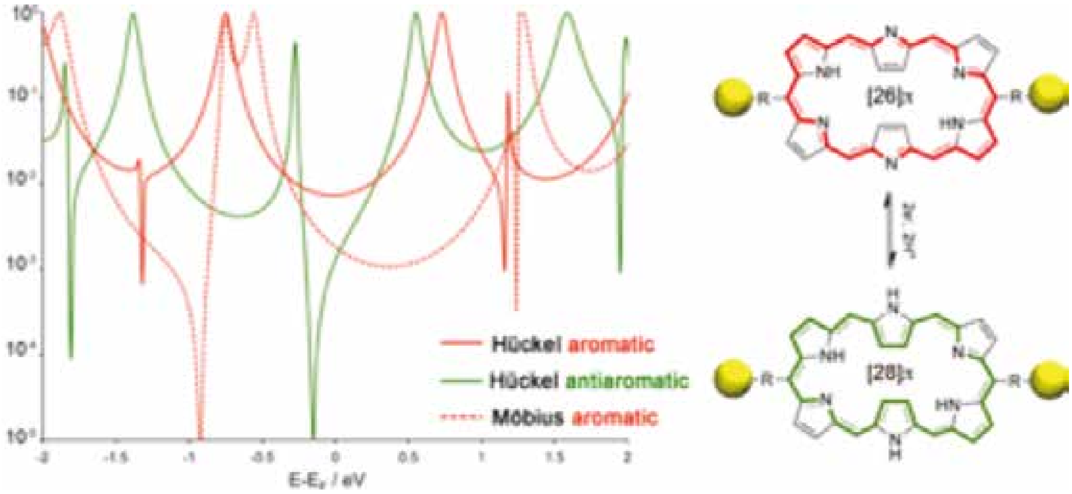


Molecular Electronics

In the Molecular Electronics research line, initiated with PhD student Thijs Stuyver and Dr. Stijn Fias, we earlier arrived at the conclusion that conductivity of molecules can be tuned by "pushing" them towards more or less diradical character [8]. This road has been exemplified by invoking the captodative effect, i.e. the stabilization of a radical center by attaching to it both an electron acceptor and an electron donor. Starting from BN substituted benzenes (2D analogues of the aforementioned BN substituted C_{60} ...) we were able to show that the conductivity can be enhanced by almost an order of magnitude under small bias and that wires can be designed showing increasing conductivity with length [9].



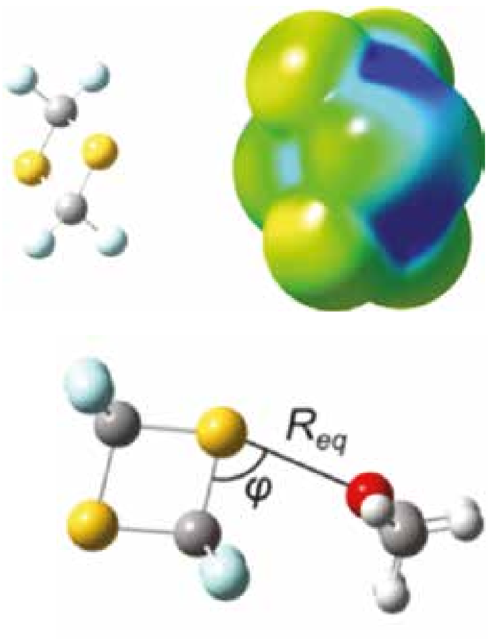
Molecular Switches



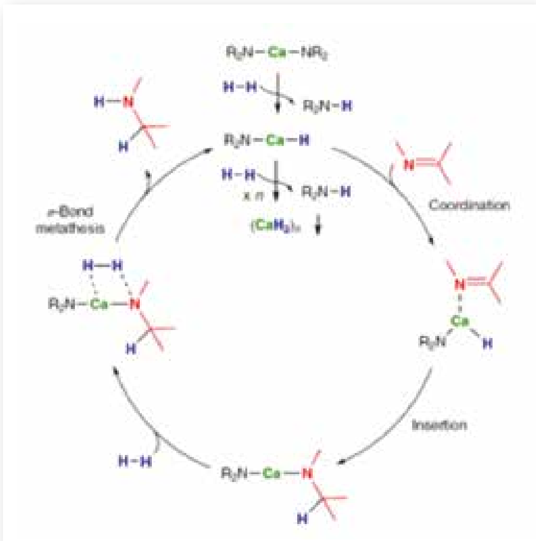
Molecular Switches have recently been explored in ALGC in the case of extended porphyrins under the impetus of Prof. Mercedes Alonso [10], with particular attention to topological switches from Hückel to Möbius rings under the influence of external stimuli. Together with Mickael Perrin, an experimentalist from Delft University, the feasibility of conductance switches based on topology and /or aromaticity changes has been assessed. When the electrodes are connected along the longitudinal axis of the macrocycle, conductance is enhanced in aromatic Hückel penta– and hexaphyrins whereas the anti-aromatic Hûckel counterparts exhibit a sharp reduction in transmission due to a destructive quantum interference. Redox-triggered aromaticity switches based on expanded porphyrins are thereby proven to be efficient conductance switching elements [11].

Applied Quantumchemistry

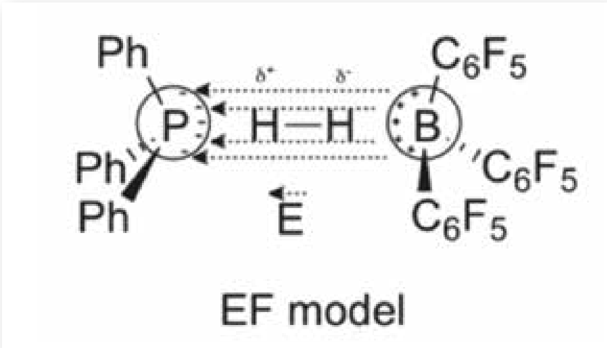
Finally, two prototype examples of applied quantumchemistry in direct interaction with experimental chemists. The collaboration with members from the experimental Spectroscopy group of the University of Antwerp (Prof. Wouter Herrebout) should be mentioned. In the context of a joint PhD UA/VUB Yannick Geboes explored the intricacies of the chalcogen bond. This "bond" results from a non-covalent interaction between positive regions in the electrostatic potential of chalcogen atoms (O,S,Se,Te), often referred to as sigma holes, and electron rich sites. It can be considered as the natural analogue of the so called halogen bond, in the picture during the last decade, and of course of the classical, century-old Hydrogen bond. Although ample theoretical evidence has been offered very recently for the existence and strength of chalcogen bonds (see for example the recent exhaustive study by Dr. De Vleeschouwer of the ALGC group [12]), experimental results remained relatively scarce. In the UA-VUB collaboration a study was made of 1:1 molecular complexes of the cyclic 2,2,4,4-tetrafluro-1,3-diethane ($C_2F_4S_2$) and dimethylether. Four equivalent sigma holes, two at each sulfur atom, were detected in the theoretical study and FTIR and Raman Spectroscopy in liquid Krypton solutions indeed revealed clear complex bands; the complexation enthalpy obtained from temperature studies turned out to be in good agreement with theoretical values [13].



In collaboration with Prof. Harder from the Inorganic Chemistry Department of the University of Erlangen-Nürnberg the catalytic activity of group 2 metals (Mg, Ca, Sr, Ba) on imine hydrogenation was investigated, in search for replacing transition metal elements by main group elements as catalysts for economic and environmental issues. The unexpected catalytic behavior of group 2 metal amides ($M[N(SiMe_3)_2]_2$, M=Mg, Ca, Sr, Ba) in the reduction of aldimines with H_2 at 80°C and at remarkably low H_2 pressure of 1-6 bar could be rationalized by the unanticipated formation of metal hydride species by deprotonation of H_2 as evidenced by DFT calculations [14].



Our interest in catalysis also transpires through a study on the activation of molecular hydrogen through Frustrated Lewis Pairs (FLP). These metal free catalysts are capable of heterolytically cleaving H_2 under mild conditions. The term "frustrated" means that the association of a Lewis acid/base pair is hindered by steric and/or electronic factors, e.g. by substitution with bulky groups such as Phenyl, from forming strong, datively bound classical Lewis adducts. Entering H_2 in the reactive pocket between base and acid ultimately yields the heterolytic cleavage of H_2 preparing it for heterolytic double bond reduction. In a series of P…B based FLP's a unified reactivity concept could be put forward hinting to the critical importance of the electrostatic field generated by the acid and base centers [15].



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Institute of Astronomy and Astrophysics I ULB

Group of Professors Sophie Van Eck and Alain Jorissen

High-resolution image of a giant star: giant bubbles on its surface

Convection plays a major role for many types of astrophysical processes including energy transport, pulsation, dynamo, wind of evolved stars, dust clouds on brown dwarfs. So far most of our knowledge about stellar convection has come from the Sun. Of the order of two million convective cells of typical size ~2000 kilometers are present on the Solar surface, a phenomenon known as granulation. But on the surface of giant and supergiant stars, which can be few hundred times larger than the Sun, the low surface gravities should engender only a few large convective cells. Deriving characteristic properties of convection (like granule size and contrast) for the most evolved giant and supergiant objects is a difficult task.

Credit: G. Hüdepohl (atacamaphoto.com) ESO

We obtained interferometric images - with the highest resolution so far - thanks to the PIONIER instrument on ESO's Very Large Telescope, of the surface of the evolved giant star π1 Gruis, of spectral type S5,7 denoting a star with strong ZrO bands in its spectrum.

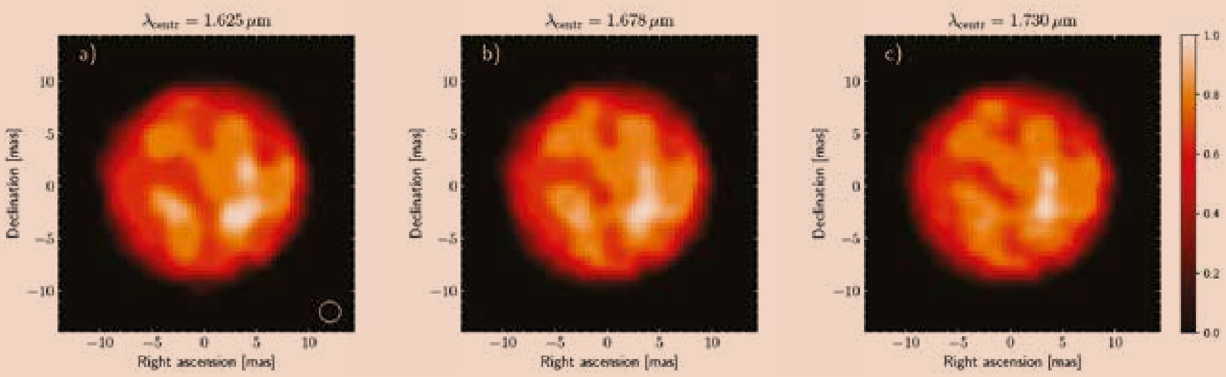
Located 530 light-years from Earth in the constellation of Grus (The Crane), π1 Gruis is a cool red giant. It has about the same mass as our Sun, but is 350 times larger and several thousand times as bright.

When π1 Gruis ran out of hydrogen to burn long ago, this ancient star ceased the first stage of its nuclear fusion programme. It shrank as it ran out of energy, causing it to heat up to over 100 million degrees. These extreme temperatures fueled the star's next phase as it began to fuse helium into heavier atoms such as carbon and oxygen. This intensely hot core then expelled the star's outer layers, causing it to balloon to hundreds of times larger than its original size. The star we see today is a variable red giant. Our Sun will swell to become a similar red giant star in about five billion years. Until now, the surface of one of these stars has never before been imaged in detail.

This project was led by Claudia Paladini, during her stay as a post-doctoral researcher at ULB Institute of Astronomy and Astrophysics (ULB-IAA); Alain Jorissen and Sophie Van Eck (ULB-IAA) contributed to this investigation.

We found that the surface of this red giant has just a few convective cells, or granules, that are each about 120 million kilometres across — about a quarter of the star's diameter. Just one of these granules would extend from the Sun to beyond Venus. The surfaces - known as photospheres - of many giant stars are obscured by dust, which hinders observations. However, in the case of π1 Gruis, although dust is present far from the star, it does not have a significant effect on the new infrared observations.

An international team of astronomers including 7 ULB researchers using ESO's Very Large Telescope have for the first time directly observed granulation patterns on the surface of a star outside the Solar System — the ageing red giant π1 Gruis. These remarkable new images from the PIONIER instrument are obtained in the spectral channels centered on 1.625 μm (a), 1.678 μm (b) and 1.730 μm (c); the angular resolution of the observations is 2 milli arcseconds and is represented with a circle at the bottom right of panel a). These images reveal the convective cells that make up the surface of this huge star, which has 350 times the diameter of the Sun. Each cell covers more than a quarter of the star's diameter and measures about 120 million kilometres across.

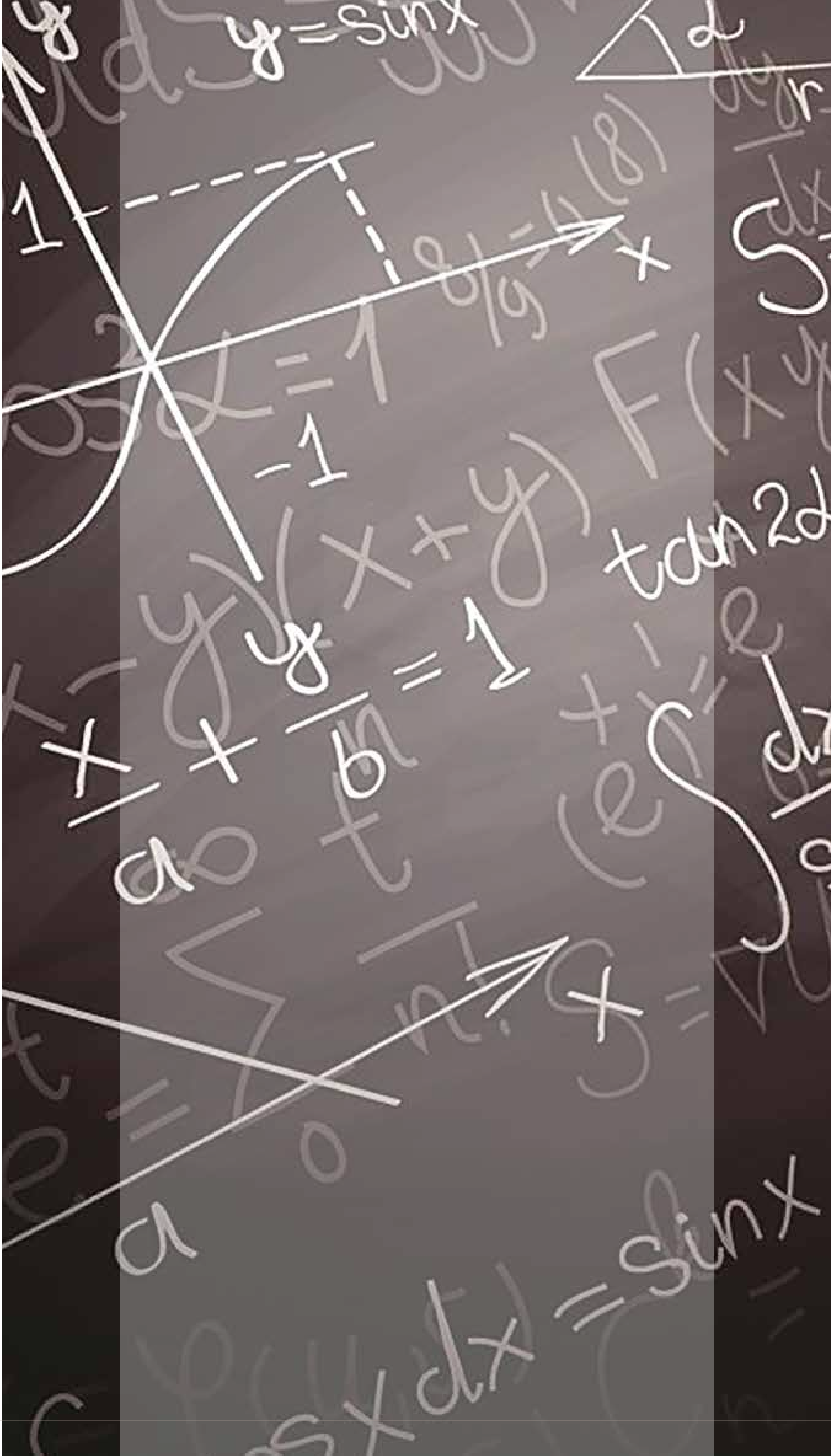


We find that the stellar surface shows a complex convective pattern with an average intensity contrast of 12% that increases towards shorter wavelengths. Through the analysis of the power spectrum of the images we derive a characteristic horizontal granulation size of (1.2 ± 0.2) x 10^{11}m, corresponding to 27% of the stellar diameter. Our measurements fall along the scaling relations between convective cell size, effective temperature, and surface gravity predicted by the mixing-length theory and multi-dimensional radiation-hydrodynamic simulations of stellar surface convection.

The vast size differences in the convective cells of our Sun and π1 Gruis can be explained in part by their varying surface gravities. π1 Gruis is just 1.5 times the mass of the Sun but much larger, resulting in a much lower surface gravity and just a few, extremely large, granules.

While stars more massive than eight solar masses end their lives in dramatic supernovae explosions, less massive stars like this one gradually expel their outer layers, resulting in beautiful planetary nebulae. Previous studies of π1 Gruis found a shell of material 0.9 light-years away from the central star, thought to have been ejected around 20 000 years ago. This relatively short period in a star's life lasts just a few tens of thousands of years – compared to the overall lifetime of several billion – and these observations reveal a new method for probing this fleeting red giant phase.

This research was presented in a paper "Large granulation cells on the surface of the giant star π^1 Gruis", by C. Paladini, F. Baron, A. Jorissen, J.-B. Le Bouquin, B. Freytag, S. Van Eck, M. Wittkowski, J. Hron, A. Chiavassa, J.-P. Berger, C. Siopis, A. Mayer, G. Sadowski, K. Kravchenko, S. Shetye, F. Kerschbaum, J. Kluska, S. Ramstedt, published in the journal *Nature* on 21 December 2017.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THE **ROBERT BROUT** AND **ILYA PRIGOGINE** prizes

Given the close ties of these two personalities with the Institutes, the International Solvay Institutes are associated with this initiative.

In order to commemorate the memory of two exceptional scientists from the University of Brussels, the juries of the masters in chemistry and in physics of the ULB and the VUB have created:

- the Ilya Prigogine Prizes, to be awarded to the best students finishing their master studies in chemistry, provided they have a brilliant curriculum (one prize at the ULB, one prize at the VUB)
- the Robert Brout Prizes, to be awarded to the best students finishing their master studies in physics, provided they have a brilliant curriculum (one prize at the ULB, one prize at the VUB).

In 2017, the prizes have been awarded to:

Lander Monné	**Antoine Aerts**	**Benoît Seron** and **Adrien Fiorucci**	**Marine De Clerck**
Ilya Prigogine Prize VUB	Ilya Prigogine Prize ULB	Robert Brout Prize ULB	Robert Brout Prize VUB


la soude et a
son nom. Elle est toujours,
demi plus tard, l'un des plus
de la chimie européenne.
surtout un savant dans l'âme,
de remarquables intuitions,
l'équivalence entre la ma-
Solvay
aujourd'hui
de la physique et de
Solvay reprend
l'idée de Nernst

APPENDIX

Le Nobel aux ondes

PHYSIQUE Weiss, Barish et Thorne ont développé le

- La découverte des trois physiciens a « bouleversé le monde ».
- Et a permis d'observer en 2015 le phénomène prédit par Einstein il y a un siècle.

Les professeurs Barry C. Barish, Kip S. Thorne et Rainer Weiss ont reçu le prix Nobel pour avoir développé le détecteur Ligo qui a permis la première observation des ondes gravitationnelles. © EPA.

Une découverte qui *« a bouleversé le monde »*, selon les termes du secrétaire général de l'Académie Nobel en annonçant que le prix 2017 de physique était attribué à Rainer Weiss, 85 ans, Barry Barish, 81 ans, et Kip Thorne, 77 ans. Ceux-ci ont permis de vérifier par l'expérience l'existence d'ondes gravitationnelles créées par les trous noirs, une révolution qui propulse notre connaissance de l'univers jusqu'au cœur du Big Bang. Un phénomène prédit par Einstein en 1915, mais que le savant doutait que l'on puisse observer un jour.

Thorne et Weiss ont créé l'observatoire Ligo (Laser Interferometer Gravitational-wave Observatory) grâce auquel la première détection directe des ondes gravitationnelles s'est produite en septembre 2015. *« Cela faisait quarante ans qu'on essayait de les détecter. Quel bonheur que nous y soyons finalement parvenus. C'est une expérience merveilleuse »*, s'est félicité Rainer Weiss. L'observatoire américain Ligo est doté de deux détecteurs, en Louisiane et dans l'Etat de Washington qui utilisent comme source lumineuse un laser infrarouge. Albert Einstein avait prédit l'existence des ondes gravitationnelles, générées par une déformation de l'espace-temps lorsque des masses, comme le Soleil, une étoile ou des trous noirs, voient modifiée leur énergie ou leur trajectoire.

Comme un filet déformé

Les ondes gravitationnelles que l'on recherche sont celles qui sont produites par des phénomènes violents comme la fusion de deux trous noirs ou encore l'explosion d'étoiles massives. Un peu semblables à la déformation d'un filet dans lequel on pose un poids, ces phénomènes ont permis les observations du Ligo en septembre 2015, juin 2016 et janvier 2017. La comparaison des temps d'arrivée des ondes dans les deux détecteurs, distants de 3.000 kilomètres et l'étude des caractéristiques des signaux mesurés ont confirmé la détection.

Et en août 2017, le détecteur européen Virgo, situé près de Pise en Italie, a lui aussi observé ce type d'ondes. Pour Benoît Mours, directeur de recherche CNRS et responsable scientifique de la collaboration Virgo pour la France, l'observation des ondes gravitationnelles représente *« une évolution fondamentale en physique. C'est comme si on ouvrait les yeux sur cette phase de l'univers qui jusqu'à présent nous était inaccessible »*.

Les astrophysiciens disposent désormais d'un nouvel outil pour observer les phénomènes violents dans l'univers, jusqu'ici inobservables. La détection de ces ondes gravitationnelles permet de voir ce qui se passe juste avant la fusion de deux trous noirs par exemple alors qu'aucune lumière ne s'en échappe.

Selon la théorie de la relativité, un couple de trous noirs en orbite l'un autour de l'autre perd de l'énergie, produisant des ondes gravitationnelles. Mais Einstein lui-même doutait qu'on détecterait un jour ces ondes, tant elles sont infimes. Puis, dans les années 1950, un physicien américain, Joseph Weber, s'est mis en tête de les débusquer en construisant les premiers détecteurs. ■

FRÉDÉRIC SOUMOIS

gravitationnelles

premier observatoire spécifique

L'EXPERTISE

« Une nouvelle fenêtre sur l'univers »

Le professeur Marc Henneaux est professeur de physique à l'ULB et directeur de l'Institut de physique et de chimie Solvay.

Que représente cette découverte ?

Elle ouvre une nouvelle fenêtre sur l'univers. La physique est une science expérimentale, ce qui signifie qu'on cherche toujours à vérifier la théorie par l'expérience. En 1915, quand Einstein formule sa théorie qui unit la relativité et la gravitation, en « corrigeant » Newton, il doute lui-même qu'on puisse un jour observer ces ondes gravitationnelles, tellement elles sont petites. Mais sans ces infimes déformations de l'espace-temps, la théorie qu'il émet ne serait pas correcte. Ici, ces chercheurs, et avec eux tous ceux qui ont contribué à élaborer la détection des ondes gravitationnelles, ont permis non seulement de les observer, mais de le faire sur la Terre. C'est un exploit scientifique considérable. Certes, une première observation avait déjà eu lieu en 1974, mais elle était indirecte, elle n'avait jamais été faite sur la Terre. Les ondes ainsi mesurées sont très petites, le « bruit » à éliminer est très important afin de les identifier clairement, car leur source est celle de la collision de deux trous noirs il y a un milliard d'années, avant de parvenir jusqu'à nous.

L'observation a-t-elle « simplement » confirmé ce qu'on savait ?

Non. Par exemple, la masse de ces trous noirs est beaucoup plus grande qu'attendu. Pouvoir mieux analyser, grâce à des outils remarquables, la création de l'univers et son fonctionnement, est une possibilité unique offerte et ce sont les travaux honorés aujourd'hui qui l'ont permis, grâce à des contributions majeures de ces trois scientifiques. Si les ondes gravitationnelles n'avaient pas existé, il aurait fallu corriger la théorie d'Einstein ! En termes d'échelle du temps en science, cela démontre bien qu'il faut de la persévérance, puisqu'un siècle sépare la théorie de l'observation expérimentale, qu'une série de chercheurs se sont passé le relais de cette tâche fabuleuse. La compréhension de ces ondes gravitationnelles, que l'on peut maintenant observer directement, ouvre une nouvelle ère de la compréhension de la formation de notre univers.

FR.SO

Le Soir - Belgium

Trento, 28 donne e un solo uomo: l'Università ribalta la celebre foto di Solvay

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Slideshow 1 di 4

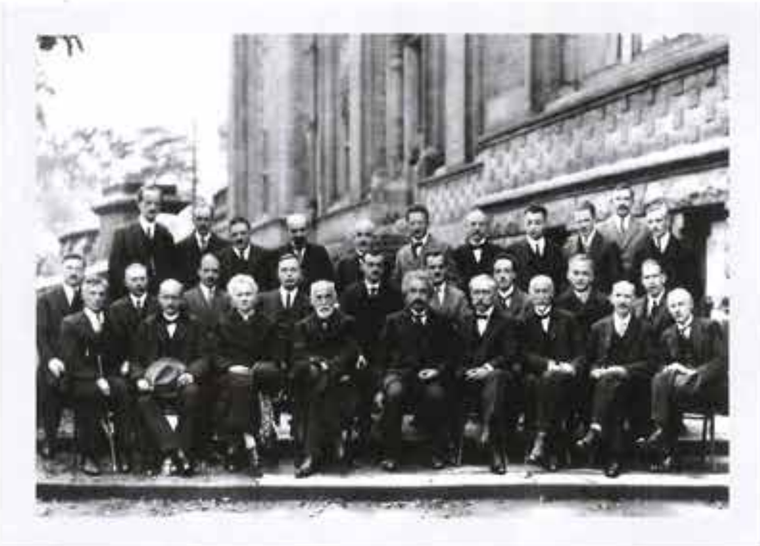
Nel 1927 una fotografia scattata durante il Congresso di Solvay a Bruxelles ritraeva 28 scienziati uomini e una sola donna: Marie Sklodowska Curie (la terza in prima fila, da sinistra). Novant'anni dopo l'Università di Trento e la Società Italiana di Fisica hanno diffuso uno scatto simile, ma che dimostra l'evoluzione dei ruoli e dei tempi. Nella foto scattata nel cortile del Polo scientifico e tecnologico Fabio Ferrari di Trento dal fotografo Giovanni Cavulli sono presenti 28 fisiche italiane e un solo uomo (il professor Guido Tonelli dell'Università di Pisa). "L'iniziativa - si legge sui siti di UniTn e SIF - è stata promossa per sensibilizzare sull'importanza di rendere visibile le tante donne che già lavorano nel campo della fisica in Italia. E per incoraggiare la diffusione di modelli femminili per quanto riguarda gli ambiti scientifici".

15 settembre 2017

www.repubblica.it – Italy

Industry Story

Électrons libres



Albert Einstein, Niels Bohr... et autres savants.

BENJAMIN COUPRIE

Benjamin Couprie serre les rangs, règle son objectif. « Ne bougeons plus ! » Le temps est maussade dans la capitale belge ce matin du 24 octobre 1927. Une heure auparavant, dans cet institut de physiologie, Hendrik Lorentz a ouvert le cinquième congrès Solvay de physique. S'y mêleront présentation des travaux et moments de détente. Cinq jours plus tard, Albert Einstein et Niels Bohr s'affronteront.

Industriel et chimiste, Ernest Solvay a toujours soutenu la recherche et l'innovation. C'est pour cela qu'il fonde, en 1911, ce congrès. Le thème de cette année : Électrons et photons. Au fil des jours, les éminents savants montent à la tribune, décrivent leur travail et avancent leurs conclusions. Schrödinger expose ses recherches sur la mécanique ondulatoire ; Louis de Broglie sur la nouvelle dynamique des quanta. Les discussions vont bon train, s'animent. Les différents travaux sont si bien avancés qu'ils autorisent l'élaboration d'une nouvelle mécanique. Pour égayer ces journées, quelques sorties sont prévues, comme une balade à vélo jusqu'à la Grand-place de Bruxelles où les sommités devisent devant le marché aux fleurs. Le 26 octobre, les représentants de l'école de Copenhague comme Heisenberg, Bohr et Born, considèrent « la théorie des quanta comme une théorie close, dont les hypothèses physiques et mathématiques fondamentales ne sont plus susceptibles d'être modifiées ». Le 29 au matin, le débat s'envenime quant à l'interprétation définitive. Si Einstein accepte les résultats, il considère que la théorie n'est pas achevée et se méfie de cette interprétation dite probabiliste. Excédé, il interpelle Bohr : « Dieu ne joue pas aux dés ! » Bohr s'agace : « Qui êtes-vous, Einstein, pour dire à Dieu ce qu'il doit faire ?! » Ils ne sont interrompus que par l'invitation du roi Albert à déjeuner.

Le soir venu, le congrès s'achève par un grand banquet organisé par Solvay. Les dissensions demeurent, mais les bases de la physique quantique sont désormais posées. Quant à Einstein et Bohr, ils se retrouveront lors du prochain congrès, en 1930. Et continueront à débattre. ■ GUILLAUME DESSAIX

L'Usine nouvelle – France

OVERVIEW OF THE INSTITUTES
through selected data

The Solvay Conferences on Physics

1911	Radiation theory and the quanta
1913	The structure of matter
1921	Atoms and electrons
1924	Electric conductivity of metals
1927	Electrons and photons
1930	Magnetism
1933	Structure and properties of the atomic nuclei
1948	Elementary particles
1951	Solid state
1954	Electrons in metals
1958	The structure and evolution of the universe
1961	Quantum Field Theory
1964	The structure and evolution of galaxies
1967	Fundamental problems in elementary particle physics
1970	Symmetry properties of nuclei
1973	Astrophysics and gravitation
1978	Order and fluctuations in equilibrium and nonequilibrium statistical mechanics
1982	Higher energy physics: What are the possibilities for extending our understanding of elementary particles and their interactions to much greater energies?
1987	Surface science
1991	Quantum optics
1998	Dynamical systems and irreversibility
2001	The physics of communication
2005	The quantum structure of space and time
2008	Quantum theory of condensed matter
2011	The theory of the quantum world
2014	Astrophysics and Cosmology
2017	The Physics of Living Matter: Space, Time and Information in Biology

Chairs of the International Scientific Committee for Physics since the first Solvay Conference on Physics

1911 - 1928	Hendrik Lorentz 1902 Nobel Laureate in Physics, Haarlem (The Netherlands)
1928 - 1946	Paul Langevin, Paris (France)
1946 - 1962	Sir Lawrence Bragg 1915 Nobel Laureate in Physics, Cambridge (UK)
1962 - 1967	Robert Oppenheimer Princeton (USA)
1967 - 1968	Christian Møller, Copenhagen (Denmark)
1969 - 1980	Edoardo Amaldi, Rome (Italy)
1980 - 1990	Léon Van Hove, Genève (Switzerland)
1992 - 2006	Herbert Walther, Munich (Germany)
2006 - present	David Gross 2004 Nobel Laureate in Physics Santa Barbara (USA)

The Solvay Conferences on Chemistry

1922 Five topical questions in chemistry
1925 Chemical structure and activity
1928 Topical questions in chemistry
1931 Constitution and configuration of organic molecules
1934 Oxygen : chemical and biological reactions
1937 Vitamins and Hormons
1947 Isotops
1950 Oxidation mechanism
1953 Proteins
1956 Some problems in mineral chemistry
1959 Nucleoproteins
1962 Energy transfer in gases
1965 Reactivity of the Photoexited Organic Molecule
1969 Phase Transitions
1972 Electrostatic Interactions and Structure of Water
1976 Molecular Movements and Chemical Reactivity as conditioned by Membranes, Enzymes and other Molecules
1980 Aspects of Chemical Evolution
1983 Design and Synthesis of Organic Molecules Based on Molecular Recognition
1987 Surface Science
1995 Chemical Reactions and their Control on the Femtosecond Time Scale
2007 From Noncovalent Assemblies to Molecular Machines
2010 Quantum effects in chemistry and biology
2013 New Chemistry and New Opportunities from the Expanding Protein Universe
2016 Catalysis in Chemistry and Biology

Chairs of the International Scientific Committee for Chemistry since the first Solvay Conference on Chemistry

1922 - 1939 Sir William Pope, Cambridge (UK)
1945 - 1958 Paul Karrer, 1937 Nobel Laureate in Chemistry, Zurich (Switzerland)
1958 - 1988 Alfred Ubbelohde, London (UK)
1989 - 2011 Stuart Rice, Chicago (USA)
2011 - present Kurt Wüthrich, 2002 Nobel Laureate in Chemistry, Zurich (Switzerland) and La Jolla (USA)

The International Solvay Chairs in Physics and in Chemistry

Jacques Solvay Chair in Physics

2006 Ludwig Faddeev, Saint-Petersburg Russia

2007 Michael Berry, Bristol, UK

2008 David Gross, Santa Barbara, USA
2004 Nobel Laureate in Physics

2009 Valery Rubakov, Moscow, Russia

2010 Serge Haroche, Paris, France
2012 Nobel Laureate in Physics

2011 Nathan Seiberg, Princeton, USA

2012 Jan Zaanen, Leiden, The Netherlands

2013 Gian Giudice, CERN, Switzerland

2014 Viatcheslav F. Mukhanov, LMU Munich, Germany

2015 Peter Zoller, Innsbruck, Austria

2016 Dam Thanh Son, Chicago, USA

2017 Uri Alon, Rehovot, Israel

Solvay Chair in Chemistry

2008 Richard Saykally, Berkeley, USA

2009 Alexander Mikhailov, Berlin Germany

2010 Weitao Yang, Durham, USA

2011 Jean-Luc Brédas, Atlanta, USA

2012 Viola Vogel, Zurich, Switzerland

2013 Egbert Meijer, Eindhoven The Netherlands

2014 Richard Schrock, MIT, USA
2005 Nobel Laureate in Chemistry

2015 Andreas Manz, KIST Europe, Saarbrücken, Germany

2016 Raymond Kapral, Toronto, Canada

2017 Richard Henderson, Cambridge, UK
2017 Nobel Laureate in Chemistry

2011 Solvay Centenary Chair

David Gross, Santa Barbara, USA
2004 Nobel Laureate in Physics

Presidents and Directors

Ernest Solvay, his son Armand Solvay and his grand-son Ernest-John Solvay successively presided over the destiny of the International Solvay Institutes until 1958. In 1958, the Institutes were restructured with the creation of the positions of "President" and "Director".

Presidents

1958 - 2010	Jacques Solvay
2010 - present	Jean-Marie Solvay

Directors

1958 - 2003	Ilya Prigogine 1977 Nobel Laureate in Chemistry Professor ULB
2003 - 2004	André Jaumotte Honorary Rector and Honorary President ULB
2004 - present	Marc Henneaux Professor ULB

The Solvay Public Lectures

22 June 2005

"From Quarks to the Quantization of Gravitation: Challenges and Obstacles in our Search for the Fundamental Forces"
by Gerard 't Hooft (Utrecht)
1999 Nobel Laureate in Physics

"From Structural Biology to Structural Genomics: New Challenges for Physics and Chemistry in the Post-Genomic Era"
by Kurt Wüthrich (Zurich and La Jolla)
2002 Nobel Laureate in Chemistry

4 December 2005
"Strings, Black Holes and the End of Space and Time"
by Robbert Dijkgraaf (Amsterdam)

"The Fabric of the Cosmos, Space, Time and the Texture of Reality"
by Brian Greene (New York)

20 May 2007

"The Origin of the Universe"
by Stephen Hawking (Cambridge, UK)

"Architecture in Nanospace"
by Harold Kroto (Brighton)
1996 Nobel Laureate in Chemistry

2 December 2007
Chemistry? More than ever!

"De la Matière à la Vie: la Chimie? La Chimie!"
by Jean-Marie Lehn (Paris and Strasbourg)
1987 Nobel Laureate in Chemistry

12 October 2008

Images from the Quantum World

"New Forms of Quantum Matter near Absolute Zero Temperature"
by Wolfgang Ketterle (Cambridge, USA)
2001 Nobel Laureate in Physics

"Visualizing Complex Electronic Quantum Matter at Atomic Scale"
by J.C. Seamus Davis (Ithaca, USA)

4 October 2009

"VIH/SIDA, une aventure scientifique et humaine en réponse à une épidémie émergente"
by Françoise Barré-Sinoussi (Paris)
2008 Nobel Laureate in Medecine

17 October 2010
Chemistry: at the crossroads of Physics and Biology

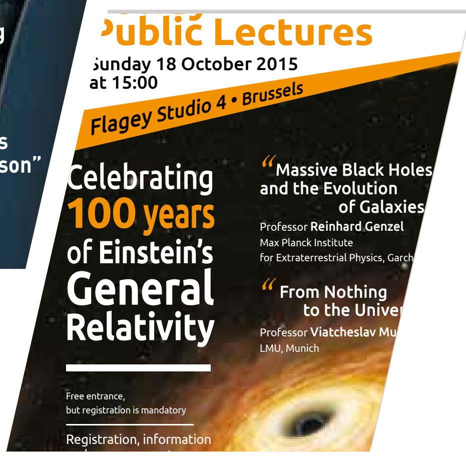
"The magnetic compass of birds and its physical basis"
by Wolfgang Wiltschko (Frankfurt am Main)

"Experimental surprises and their solutions in theory"
by Rudolph Marcus (Pasadena)
1992 Nobel Laureate in Chemistry

23 October 2011
The Future of Physics

"Time and Einstein in the 21st century"
by William Phillips (College Park)
1997 Nobel Laureate in Physics

"Quantum Beauty"
by Frank Wilczek (Cambridge, USA)
2004 Nobel Laureate in Physics



21 October 2012

"The Science of Simplicity"
by George Whitesides (Cambridge, USA)

"Will our Thinking Become Quantum-Mechanical?"
by Michael Freedman (Santa Barbara)
1986 Recipient of the Fields Medal

"Exploring the Postgenomic Protein Universe"
by Kurt Wüthrich (Zurich and La Jolla)
2002 Nobel Laureate in Chemistry

20 October 2013

"How proteins are made in the cell: Visualizing the ribosome in action"
by Joachim Frank (Columbia University, USA)

"Reprogramming the genetic code"
by Jason Chin (University of Cambridge, UK)

12 October 2014

"Starquakes and Exoplanets in our Milky Way galaxy"
by Conny Aerts (KU Leuven, Belgium)

"From a 'simple' big bang to our complex cosmos"
by Martin Rees (Cambridge, UK)

"The Brout-Englert-Higgs mechanism and its scalar boson"
by François Englert (ULB, Belgium)
2013 Nobel Laureate in Physics

18 October 2015

One hundred years of Einstein's general relativity

"Massive Black Holes and the Evolution of Galaxies"
by Reinhard Genzel (Max Planck Institute Munich, Germany)

"From Nothing to the Universe"
by Viatcheslav Mukhanov (LMU Munich, Germany)

23 October 2016

Chemistry for the World of Tomorrow

"Translation of Academic Science into the Commercial"
by Robert Grubbs (California Institute of Technology, USA)
2005 Nobel Laureate in Chemistry

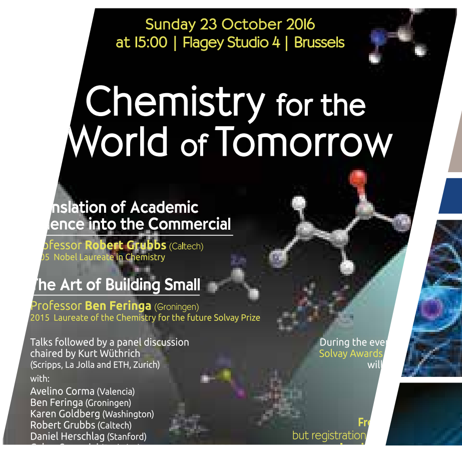
"The Art of Building Small"
by Ben Feringa (University of Groningen, The Netherlands)
2016 Nobel Laureate in Chemistry

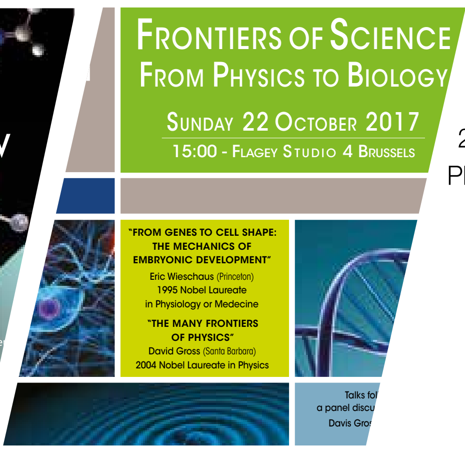
22 October 2017

Frontiers of Science from Physics to Biology

"From Genes to Cell Shape: The Mechanics of Embryonic Development"
by Professor Eric Wieschaus (Princeton U., USA)
1995 Nobel Laureate in Physiology or Medecine

"The Many Frontiers of Physics"
by Professor David Gross (Kavli Institute, USA)
2004 Nobel Laureate in Physics





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