2023

Instituts Internationaux
de Physique et de Chimie
fondés par Ernest Solvay ASBL

Internationale Instituten
voor Fysica en Chemie
gesticht door Ernest Solvay VZW

ANNUAL REPORT

INTERNATIONAL SOLVAY INSTITUTES BRUSSELS

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ANNUAL REPORT

There are no limits to what science can explore

ERNEST SOLVAY

The International Solvay Institutes for Physics and Chemistry,
founded by Ernest Solvay,
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Merci à tous les joueurs de la Loterie Nationale. Grâce à eux, les Instituts Internationaux Solvay peuvent mener des activités de recherche et sensibiliser le public aux grandes questions scientifiques contemporaines.
Et vous, vous jouez aussi, non ?
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BIEN PLUS QUE JOUER
Bedankt aan alle spelers van de Nationale Loterij. Dankzij hen kunnen de Internationale Solvay Instituten onderzoeks-activiteiten uitvoeren en het publiek bewust maken van de grote heden-daagse wetenschappelijke vragen.
Jij speelt toch ook?
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The Belgian National Lottery and the International Solvay Institutes: a long-term partnership

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 20^{th} and 21^{st} 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 for 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 Lectures) directly benefit from the support of the National Lottery.

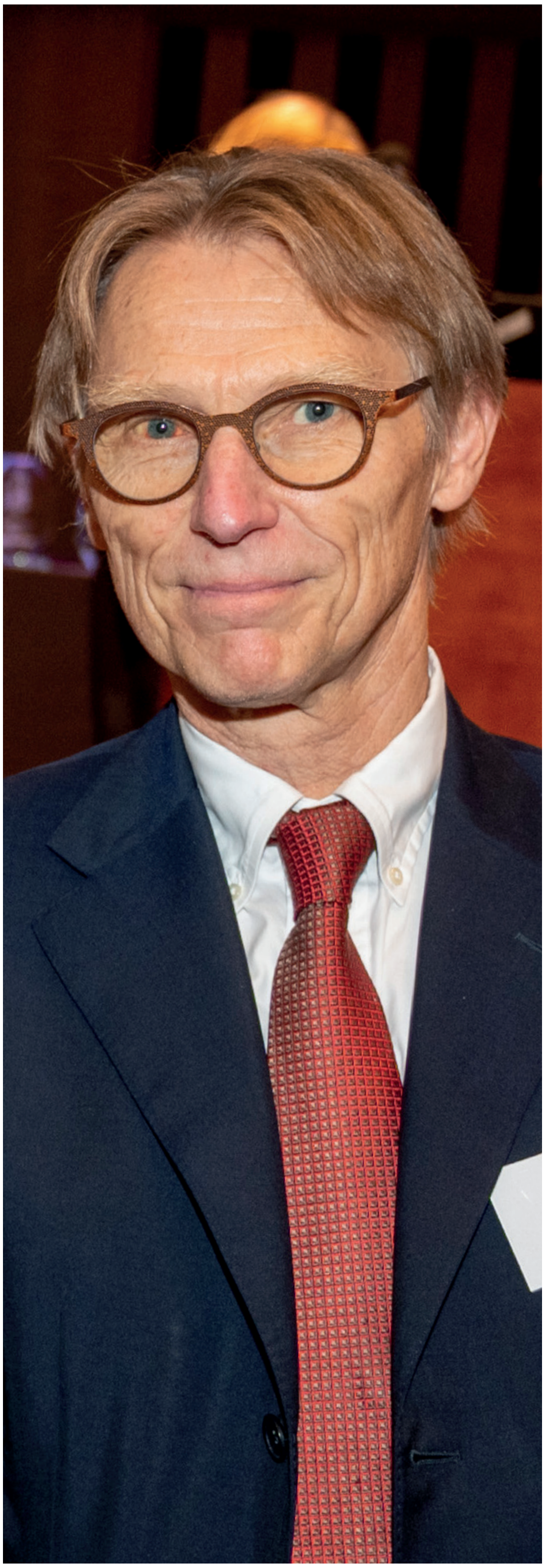
CONTENTS

A word from the President

The year 2023, was the year that the International Solvay Institutes caught up with its pre-pandemic schedule of scientific activities. This is an achievement that I want to celebrate: the director and his team, managed the uncertainty of the crisis, the many rescheduling of events and ancillary activities, with an unyielding will to deliver the program and the wisdom to make the right bets at the right time.

Looking back at these years starting back in early 2020 when we went into lock down, I am grateful to the director and his team for bringing us through this period with unscathed optimism in the excellence and dynamism of the Institutes going forward. I extend my heartfelt gratitude to Professor Marc Henneaux (Director), Dominique Bogaerts (Office Manager) and Isabelle Van Geet (Project Coordinator), Alexander Sevrin and Anne de Wit (Conference Scientific Secretaries) and all the other members of the executive committee that assists the director in planning the scientific program (Professors Glenn Barnich, Ben Craps, Gert Desmet and Yves Geerts).

Amongst the many activities that were organised in 2023, the 29th physics conference on the structure and dynamics of disordered systems stands out to me. It was a privilege to hear about the future and limits of computer science and machine learning at a time where AI is perceived as the new ultimate frontier.



The conference was preceded by a workshop titled « Perspectives in fundamental physics » to honour the memory of our dear friend Lars Brink who left us in October 2022. It was very moving to hear from the distinguished guests that were invited to recount their cherished experiences with Lars. I had met Lars in 2006 when I became a member of the board of directors of the Institutes. I appreciated his personality as a calm generous thinker. I had never imagined the vastness of his intellectual curiosity and the incredible generosity with which he supported scientific talent in a wide variety of fields.

In that sense, over the years, Lars as the chair of our Advisory Committee, was a precious guide to the Solvay Institutes, providing benevolent support and challenging us to develop ambitious dreams. We owe it to Lars to have challenged us to embark on the new journey of biology.

My sincere appreciation goes to the members of our board for their council and wisdom.

I am also grateful to our sponsors, the Université Libre de Bruxelles, the Vrije Universiteit Brussel, the Solvay company, the UCB company, the Belgian National Lottery, the FWO, the FRS-FNRS, BNP Paribas Fortis company, the Brussels-Capital Region, the Fédération Wallonie-Bruxelles, the Solvac company and the very supportive Solvay family.

Without them none of this would be possible.

Jean-Marie Solvay | President

A word from the Director

For the International Solvay Institutes, the year 2023 has meant a very welcome complete return to normality after the sanitary crisis. In addition to the normal program of 2023, the last two Covid-postponed activities did take place: the 2021 New Horizons Lectures in Chemistry were delivered in May and the 2022 New Horizons Lectures in Physics took place in March.

We have thus successfully overcome the delays due to the difficult times through which we went in the past years. We can now definitely look towards the future with great optimism and renewed energy.

And this is what we actually did in 2023! One of the most noticeable achievements is that we have put the last hand to a project that will mark a new era in the life of the Institutes and which will materialize in 2024: the beginning of a new cycle of Solvay conferences devoted to Biology.

Many scientists are convinced that biology is on the eve of major developments in the years to come - one sometimes even hears the statement that “the 21st century will be the century of biology”. It was the right time for the Solvay Institutes to become actors in that new revolution and to start initiatives in biology. The first Solvay Conference in Biology will take place in April of 2024, after seven years of careful preparation based on the advice of many scientific leaders worldwide.

Pursuing activities in physics, chemistry and biology reflects the interdisciplinarity character of science. It is also a way for the Solvay Institutes to stress the unity of rational thinking across scientific disciplines.

The biology initiative would not have been possible without the enthusiastic support of our President, of the entire Solvay family and the company UCB. More information on our biology conference will be given in the 2024 activity report!

The present report describes at length the activities organized or supported by the International Solvay Institutes during the year 2023. These activities covered a wide spectrum of developments at the frontiers of physics and chemistry. We had:

- the 29th Solvay Conference on Physics, on “The Structure and Dynamics of Disordered Systems”, co-chaired by Professors David Gross (Santa Barbara), Marc Mézard (Milano) and Giorgio Parisi (Roma);
- the 2023 Jacques Solvay Chair in Physics held by Professor Subir Sachdev from Harvard University;
- the 2023 Solvay Chair in Chemistry held by Professor Ehud Gazit from Tel-Aviv University;
- the 2023 New Horizons Lectures in Chemistry given by Professor Danna Freedman from MIT;
- the 2023 New Horizons Lectures in Physics given by Professor Alexander Zhiboedov from CERN;
- our traditional public event with popular lectures on October 22;
- as well as more than ten workshops and colloquia, the annual Amsterdam-Brussels-Paris doctoral school etc

All the detailed information can be found in the core of the report.

Besides the activities of the Institutes, the report describes the research carried in the groups of the Director, of the deputy-Directors, and of the Scientific Secretaries of the International Scientific Committees. The research highlights of other researchers connected with the Institutes are outlined too.

I would like to express our gratitude to the individuals and institutions who subsidize the Institutes and stimulate their mission, which are the Université Libre de Bruxelles, the Vrije Universiteit Brussel, the Solvay company, the UCB company, the Belgian National Lottery, the FWO, the FRS-FNRS, BNP Paribas Fortis company, the Brussels-Capital Region, the Fédération Wallonie-Bruxelles, the Solvac company, and last but not least, the Solvay family who continues with the same conviction a more than a century-old tradition of support to fundamental research.

The Solvay family also supports directly the research of the group of the Director. I heartily thank them for this most precious help and trust.

Finally, I want to thankfully praise the commitment and the exceptional sense of responsibility of Dominique Bogaerts and Isabelle Van Geet, who have as usual managed with remarkable efficiency and dedication the logistics of our activities.

Marc Henneaux | Director

01

2023

GENERAL INFORMATION

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Management and staff

The Director is assisted in his scientific tasks by:

- The International Scientific Committees for Physics and Chemistry, which are fully responsible for the scientific organization of the "Conseils Solvay".
- The Executive Committee and the Local Scientific Committees, which help him for the organization of all the other activities (workshops, colloquia, chairs, new horizons lectures).

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Director

Professor Alexander Sevrin | VUB
Deputy Director for Physics

Professor Gert Desmet | VUB
Deputy Director for Chemistry

Professor Glenn Barnich | ULB

Professor Anne De Wit | ULB

Professor Ben Craps | VUB

Professor Yves Geerts | ULB

Administrative Staff

The Director is assisted in his management tasks by the administrative staff.

Ms Dominique Bogaerts
Office Manager

Ms Isabelle Van Geet
Project Coordinator

Mr Tahar Hmida
Accounting Officer

International Scientific Committee for Physics

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.

Chair

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2004 Nobel Laureate
Kavli Institute for Theoretical Physics,
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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.

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2002 Nobel Laureate
Scripps Research Institute
La Jolla, USA and ETH Zurich
Switzerland

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1957 Nobel Laureate
Chinese University Hong Kong
& Tsinghua University, Beijing
China

In Memoriam

The International Solvay Institutes mourn the passing away on 3 August 2023, at the age of 93, of Professor Prof. Victor P. Maslov, Russian mathematical physicist and member of the Russian Academy of Sciences. Professor Maslov has been honorary member of the Institutes for more than 25 years.

Local Scientific Committee for Physics

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

Chair

Professor Marc Henneaux I ULB, Brussels

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Professor Han Remaut
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Professor Marc Henneaux I ULB, Brussels

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Wielemans Patrick
Willems Hans
Willox Ralph

02
20
23

29th SOLVAY CONFERENCE ON PHYSICS

"The Structure and Dynamics of Disordered Systems"

19-21 October 2023

The study of disordered systems, which are omnipresent in physics, is a profound and challenging research area where spectacular understanding has been achieved in recent years. Furthermore, methods and concepts from the physics of disordered systems have led to remarkable applications in mathematics, computer sciences, biology, neuroscience, optimization, economics and so forth. In 2021, the Swedish academy rewarded the Nobel Prize to Professor Giorgio Parisi, one of the chairs of the conference, for his revolutionary contributions to the subject.

That disordered systems constitute the subject of the 29th Solvay Conference was therefore quite timely. 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 from KITP and the University of California at Santa Barbara.

The conference took place at the hotel "Le Plaza" in Brussels. It was chaired by Professors David Gross, Marc Mézard (Milano) and Giorgio Parisi (Roma). As it is the tradition, the Conference was also attended by auditors from various Belgian universities.

The International Solvay Institutes are grateful to the International Solvay Committee for Physics, to the Conference Chairs, to the Session Chairs, to the Rapporteurs and to all the participants, who contributed to make the Conference an immense success.

Great thanks also go to the editorial team headed by Professor Alexander Sevrin, for their diligent work in producing the conference proceedings, which will include the vivid and informative discussions that took place during the meeting.

Scientific background

Most solid-state textbooks are almost entirely devoted to ordered systems. The reason is obvious: while the theory of crystals is fully developed, the theory of amorphous solids is still incomplete. Yet most of the solid matter in Nature is amorphous: one can think of glasses, foams, pastes, granular materials, plastics, and possibly even proteins. All these materials are extremely important for practical applications in everyday life.

Amorphous solids display all kinds of anomalies with respect to crystals. For example, they are formed through complex non-equilibrium processes that are very different from standard phase transitions.

In disordered systems, like glasses of all sorts, the equilibration time may be extremely large, so we can only observe an off-equilibrium behavior where the probability distribution is different from the usual Boltzmann-Gibbs one. Many other off-equilibrium phenomena, like fracture, are dominated by disorder in the physically interesting region. These problems are not restricted to the classical world. In quantum systems, new phenomena are also present.

In the past decades, a lot of progress has been made in the understanding of these problems:

- Building from the mean field theory of spin glasses developed in the 80s, an exact solution for the mean field theory of particle glasses, in the limit of infinite dimensions, has been derived. While this mean field theory reproduces all known basic facts about glasses, the finite-dimensional corrections around it (in the Renormalization Group sense) are expected to be quite large, and many non-trivial effects appear in low dimensions.

- The off-equilibrium dynamics (mainly in the aging regime) has been studied in simplified models since the 90s. Phenomenological concepts such as the effective temperature have been put on firm ground. Yet, many open problems in the dynamics of glasses remain, most notably connected to the rheology of these materials, i.e. their dynamical response to external perturbations.

- The concept of "dynamical heterogeneity", i.e. strong spatial correlations of the dynamics upon approaching the glass transition, was discovered at the beginning of this century. These correlations are extremely interesting because they show that the glass transition is a collective phenomenon. However, different origins for these heterogeneities have been proposed, and it is yet unclear which one is the correct one.

- Finally, the notion that glasses are "marginally stable" has been proposed in the last decade. Marginal stability means that glasses respond extremely strongly to external perturbations. An infinitesimal perturbation is enough to destroy the metastable glass state and force the system to jump to another glass state. It implies the existence of extremely soft vibrational modes, avalanches, and diverging (elastic) susceptibilities. While one may hope that the idea of marginal stability could provide a unifying principle to understand all the low temperature anomalies of glasses, very recent numerical results suggest that marginal stability is present only in some classes of glasses, and not in others.

- Related to marginality is the fact that glasses become 'soft' with respect to time reparametrizations. This phenomenon has formally the same origin as the emergence of an infrared `gravity-like' theory in SYK systems.

A lot of research activity is ongoing on all these topics, and progress is being made at a fast pace. This research has also a strong influence on other fields. To properly cover this exciting activity, the program of the 29th Solvay Conference on Physics was divided in five sessions listed in the next pages.

The Conference opened with a lecture by Professor Giorgio Parisi who gave a broad view of the current status and challenges of the field and set the stage for the meeting. This opening lecture was attended by the Solvay family and Dr. Ilham Kadri, CEO of the Solvay company.

Programme

Thursday 19 October 2023

Welcome remarks and perspective by Marc Henneaux, David Gross, Marc Mézard and lecture by Giorgio Parisi.

Session I: Mean field theory of glasses and beyond, marginal stability

Chair: Peter Wolynes

Rapporteurs: Giulio Biroli and Francesco Zamponi

Scientific secretaries: Federico Caporaletti and Nathan Dupont

Reports and discussions

Session II: Dynamics of glasses, in and out of equilibrium, and rheology of glasses

Chair: Ludovic Berthier

Rapporteurs: Jean-Philippe Bouchaud and Peter Sollich

Scientific secretaries: Simone Napolitano and Cedric Schoonen

Reports and discussions

Friday 20 October 2023

Session III: Shaping disorder for material design: metamaterials and proteins

Chair: Andrea Liu

Rapporteurs: Xiaoming Mao and Arvind Murugan

Scientific secretaries: James F. Lutsko and Patricia Maria Losada Perez

Reports and discussions

Reception organised at the Brussels City Hall

Saturday 21 October 2023

Session IV: Quantum glasses, reparameterization invariance, Sachdev-Ye-Kitaev models

Chair: Giorgio Parisi

Rapporteurs: Jorge Kurchan and Subir Sachdev

Scientific secretaries: Nathan Goldman and Jacques Tempere

Reports and discussions

Session V: Computer science, inference, machine learning, and statistics

Chair: Cris Moore

Rapporteurs: Andrea Montanari and Lenka Zdeborova

Scientific secretaries: Lucila P. Gavensky and Bortolo M. Mognetti

Reports and discussions

Closing round

Note:
Professor Leticia Cugliandolo carefully prepared the 4th session as chair before the conference took place. However, she had to cancel her participation at the last minute and was replaced by Professor Giorgio Parisi.

Conference room at the Le Plaza Hotel, Brussels

Participants

Berthier Ludovic
Université de Montpellier, France

Biroli Giulio
LPENS, Paris, France

Blandford Roger
Stanford University, USA

Bouchaud Jean-Philippe
Capital Fund Management S.A.
Paris, France

Chaikin Paul
NYU, New York, USA

Charbonneau Patrick
Duke University, Durham, USA

Cugliandolo, Leticia
Sorbonne University, Paris
France

Ediger Mark
University of Wisconsin, Madison
USA

Gamarnik David
MIT, Cambridge, USA

Georges Antoine
Collège de France, Paris, France

Gross David
KITP, UC Santa Barbara, USA

Halperin Bertrand
Harvard University, Cambridge
USA

Henneaux Marc
Solvay Institutes & ULB
Brussels, Belgium

Kabashima Yoshiyuki
University of Tokyo, Japan

Katifori Eleni
University of Pennsylvania
Philadelphia, USA

Kurchan Jorge
ENS, Paris, France

Liu Andrea
University of Pennsylvania
Philadelphia, USA

Lubchenko Vassiliy
University of Houston, USA

Mao Xiaoming
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Mehta Pankaj
Boston University, USA

Mertens Stephan
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Stanford University, USA

Moore Cris
Santa Fe Institute, USA

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Murugan Arvind
University of Chicago, USA

Nagel Sid
University of Chicago, USA

Nemenman Ilya
Emory College, Georgia, USA

Nishimori Hidetoshi
Tokyo Institute of Technology
Japan

Onuchic Jose
Rice University, Houston, USA

Parisi Giorgio
Università di Roma
La Sapienza, Italy

Popovic Dragana
Florida State University, USA

Procaccia Itamar
Weizmann Institute of Science
Israel

Reichman David
Columbia University, New York
USA

Sachdev Subir
Harvard University, Cambridge
USA

Sastry Srikanth
JNCASR, Karnataka, India

Scardicchio Antonello
ICTP, Trieste, Italy

Sethna Jim
Cornell University, Ithaca, USA

Sevrin Alexander
VUB, Brussels, Belgium

Sollich Peter
Göttingen University, Germany

Wolynes Peter
Rice University, USA

Wyart Matthieu
EPFL, Lausanne, Switzerland

Zamponi Francesco
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Zdeborova Lenka
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Zoller Peter
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Simone Napolitano (ULB)

Lucila Peralta Gavensky (ULB)

Cedric Schoonen (ULB)

Jacques Tempere (UAntwerp)

Reception organised at the Brussels City Hall

03

2023

OUTREACH
ACTIVITIES

Solvay Public Lectures

22 October 2023

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. Organised 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.

The list of all our public events is given at the end of this report.

On the day following the 29th Solvay Conference on Physics, the International Solvay Institutes organized their traditional annual public event, on the theme “Complex systems and collective behaviors”.

The event was preceded by a short Solvay Awards Ceremony (see information given separately). The program continued with 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 study of disordered systems, which are complex systems omnipresent in physics, is a profound and challenging research area where spectacular understanding has been achieved in recent years. Furthermore, methods and concepts from the physics of disordered systems have led to remarkable applications in mathematics, computer sciences, biology, neuroscience, optimization, economics; the list is long! In 2021, the Swedish academy awarded the Nobel Prize to Professor Giorgio Parisi, one of the chairs of the conference and a member of the panel, “for the discovery of the interplay of disorder and fluctuations in physical systems from atomic to planetary scales”. The two lectures illustrated this fascinating area of physics.

Programme

Moderator	Prof. Alexander Sevrin VUB & International Solvay Institutes
15:00 - 15:10	Opening by Prof. Marc Henneaux ULB & International Solvay Institutes
15:10 - 15:35	Solvay Awards ceremony
15:35 - 16:15	"Computational optimization: from glasses to black holes" Lecture by Prof. Leticia Cugliandolo (Sorbonne University, Paris, France)
16:15 - 16:55	"How many candies are in that jar? A dynamical phase transition." Lecture by Prof. Paul Chaikin (New York University, USA)
16:55 - 17:55	Panel discussion with Profs. David Gross (2004 Physics Nobel Laureate) Paul Chaikin Leticia Cugliandolo Andrea Liu Marc Mézard Giorgio Parisi (2021 Physics Nobel Laureate) Dragana Popovic
17:55 - 18:00	Closing by Prof. Marc Henneaux
18:00	Drink

The event took place in presence of the Solvay family, the ULB and VUB authorities, the Solvay group representatives.

Lecturers

The lectures were delivered by two of the leading world experts in the field who made major contributions to various aspects of complex disordered systems.

The panel debate that followed, in which took part some of the participants in the 29th Solvay Conference on Physics, addressed questions on topics ranging from phase transitions, complexity and emergence to artificial intelligence.

The international Solvay Institutes are most grateful to the lecturers and the panellists for their active involvement in the success of the event.

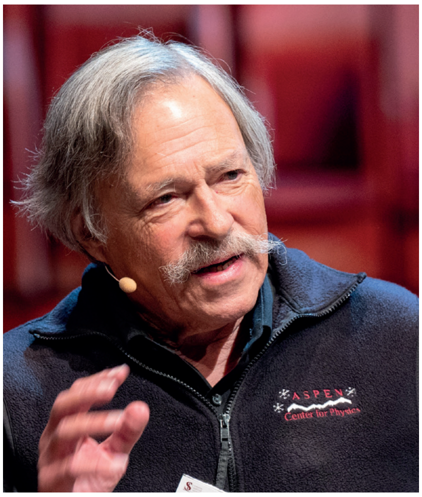
Leticia Cugliandolo

Sorbonne University, Paris, France

Leticia Cugliandolo earned a degree in physics from the National University of Mar del Plata in 1988, and completed a doctorate at the National University of La Plata in 1991, under the supervision of Fidel A. Schaposnik. She earned a habilitation at Pierre and Marie Curie University in 2000.

After completing her doctorate, she was a postdoctoral researcher at the National University of La Plata, Sapienza University of Rome, and Pierre and Marie Curie University, before becoming a researcher for the French National Centre for Scientific Research (CNRS) in 1996, associated with the laboratory for theoretical physics of the École normale supérieure (Paris). She became an associate professor at the École normale supérieure in 1997, returned briefly to the CNRS in 2002, and in the same year visited Harvard University as a Guggenheim Fellow. In 2003 she became a full professor with Pierre and Marie Curie University. She was also director of the École de physique des Houches from 2007 to 2017, and worked half-time for the CNRS from 2009 to 2014. In 2018, Pierre and Marie Curie University merged with several other institutions to become Sorbonne University, where she continues as a full professor.

She won the Prix Paul Langevin in 2002, and in the same year won the Marie Curie award of the European Commission. She won the Irène Joliot-Curie Prize for female scientist of the year in 2015.



Professor Paul Chaikin

New York University, USA

After graduating from Stuyvesant High School in New York City, Paul Chaikin earned his B.S. in physics from California Institute of Technology in 1966, and his Ph.D. in physics from the University of Pennsylvania in 1971 working with Kondo superconductors. He joined the physics faculty at the University of California, Los Angeles in 1972 and studied thermopower, density waves, and high field phenomena mostly in organic superconductors.

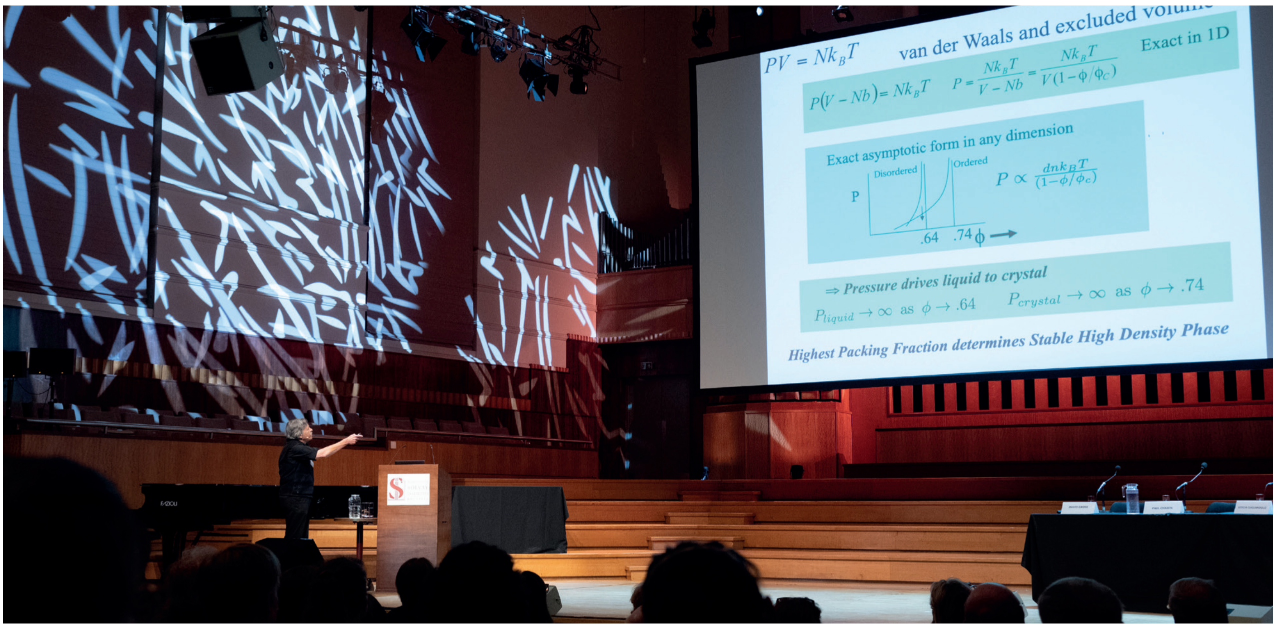
The lure of actually seeing the microscopics of a system led him to soft matter. He helped develop techniques to measure elasticity and motion and understand colloidal interactions. Hard and soft matter interests continued after joining the faculty at UPenn (1983), the staff at Exxon Research (1983) and the faculty at Princeton University (1988).

His interests in geometry/topology led to his founding contributions to diblock copolymer nanolithography, and studies of defects, annealing, and pattern formation. He helped demonstrate and explain why ellipsoids pack more densely than spheres.

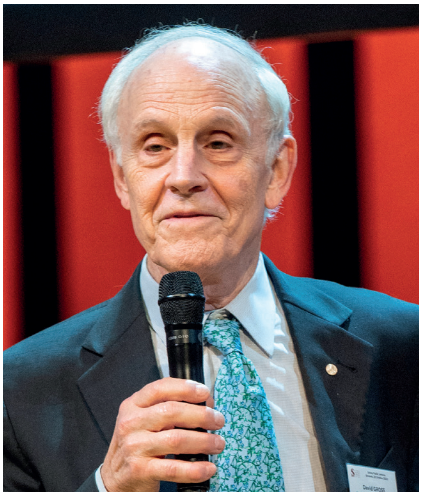
His more recent research centers on artificial self-replication, self-assembly, active matter, DNA nanotechnology, topological defects on curved surfaces, and quantifying order far from equilibrium.

He has been awarded the 2018 Oliver Buckley Prize with the citation “for pioneering contributions that opened new directions in the field of soft condensed matter physics through innovative studies of colloids, polymers, and packing.”

He is currently a Silver professor of physics at New York University.



Panel members



Professor David Gross

2004 Nobel Prize in Physics
UC Santa Barbara, USA
Chair of the panel

Professor Gross is the Chancellor's Chair Professor of Theoretical Physics and former Director of the Kavli Institute for Theoretical Physics at UCSB. He received his Ph.D. in 1966 at UC Berkeley and was previously Thomas Jones Professor of Mathematical Physics at Princeton University.

He has been a central figure in particle physics and string theory. His discovery, with his student Frank Wilczek, of asymptotic freedom - the primary feature of non-Abelian gauge theories - led Gross and Wilczek to the formulation of Quantum Chromodynamics, the theory of the strong nuclear force. Asymptotic freedom is a phenomenon where the nuclear force weakens at short distances, which explains why experiments at very high energy can be understood as if nuclear particles are made of non-interacting quarks. The flip side of asymptotic freedom is that the force between quarks grows stronger as one tries to separate them. This is the reason why the nucleus of an atom can never be broken into its quark constituents. QCD completed the Standard Model, which details the three basic forces of particle physics - the electromagnetic force, the weak force, and the strong force.

Professor Gross was awarded the 2004 Nobel Prize in Physics, with Politzer and Wilczek, for this discovery

Professor Andrea Liu

University of Pennsylvania, USA

Professor Liu is the Hepburn Professor of Physics at the University of Pennsylvania, where she holds a joint appointment in the Department of Chemistry. She is a theoretical physicist studying condensed matter physics and biophysics. She is particularly known for her study of jamming, a phenomenon in which disordered materials become rigid with increasing density and stress.

Professor Liu graduated from the University of California, Berkeley in 1984, and earned a Ph.D. in 1989 from Cornell University under the supervision of Michael Fisher. After postdoctoral studies at Exxon and the University of California, Santa Barbara, she joined the faculty at the University of California, Los Angeles in 1993, and moved to the University of Pennsylvania in 2004.

Professor Marc Mézard

Bocconi University, Milan, Italy

Professor Mézard graduated from the École normale supérieure in 1976 and earned the agrégation in Physics. He earned a PhD in Physics from University of Paris 6 in 1980

He joined the Centre national de la recherche scientifique (CNRS) as a researcher in 1981. He was a professor of Physics at the École Polytechnique. In 2001, he joined the Center for Theoretical Physics and Statistical Models at the University of Paris-Sud, and he serves as its director. Since 2012 to 2022, he had also served as the director of his alma mater, the ENS. In 2022 he joined the Department of the Computing Sciences at the Bocconi University in Milan.

He won the Prize Ampère in 1996, the Humboldt Prize in 2009, and the Lars Onsager Prize in 2016.

Professor Giorgio Parisi

2021 Nobel Prize in Physics
Sapienza University, Rome, Italy

Professor Parisi received his degree from the University of Rome La Sapienza in 1970. He was a researcher at the Laboratori Nazionali di Frascati (1971–1981) and a visiting scientist at the Columbia University (1973–1974), Institut des Hautes Études Scientifiques (1976–1977), and École Normale Supérieure (1977–1978). From 1981 until 1992 he was a full professor of Theoretical Physics at the University of Rome Tor Vergata and he is now professor of Quantum Theories at the Sapienza University of Rome. His main activity has been in the field of elementary particles, theory of phase transitions and statistical mechanics, mathematical physics and string theory, disordered systems (spin glasses and complex systems), neural networks theoretical immunology, computers and very large-scale simulations of QCD (the APE project), non-equilibrium statistical physics.

He received among others the Dirac medal and prize in 1999, the Enrico Fermi Prize in 2003, the Dannie Heineman Prize in 2005, the Nonino Prize in 2005, the Galileo prize in 2006.

Professor Parisi was awarded the 2021 Nobel Prize in Physics.

Professor Dragana Popovic

Florida State University, USA

After undergraduate studies at the university of Belgrade (Yugoslavia) and Brown University (US), Dragana Popovic obtained her PhD degree at Brown University in 1989. She then held various postdoctoral positions before joining the National High Magnetic Field Laboratory (NHMFL) in Florida where she is now Senior Scientist. She is also Research Professor at Florida State University since 2017.

Professor Popovic is a leading world expert in Experimental condensed matter physics, where she made highly visible contributions.

Her research interests cover the effects of disorder and strong electronic correlations in two-dimensional (2D) and quasi-2D systems, primarily using electrical transport and resistance noise spectroscopy techniques; phase transitions (metal-insulator, superconductor-insulator, structural, and Berezinskii-Kosterlitz-Thouless transitions), charge dynamics (glassy freezing and other out-of-equilibrium behavior), superconducting fluctuations, mesoscopic effects.

The materials she has investigated include in particular semiconductor heterostructures, layered transition-metal dichalcogenides, copper-oxide high-temperature superconductors, iron pnictides, and quasicrystals.

Professor David Gross, 2004 Nobel Prize in Physics, Professor François Englert, 2013 Nobel Prize in Physics and Professor Giorgio Parisi, 2021 Nobel Prize in Physics.

Flagey Studio 4 - Brussels

Solvay Awards Ceremony

One of the goals of the Solvay public event is to stimulate interest for science and scientific research, especially among the young generations. In that spirit, the event started with a Solvay Awards Ceremony. These Solvay awards are given by the Solvay Company.

Mrs Michèle Huart
Chairwoman of the Solvay Awards Jury

Awarding young STEM Ph.D. to contribute to societal progress

On an annual basis, the Solvay Group presents "Solvay Awards" to Ph.D. graduates who have successfully defended their theses the previous year at the Faculty of Sciences or Engineering School of the Université Libre de Bruxelles (ULB) or the Vrije Universiteit Brussel (VUB).

Our aim in awarding this prize is to encourage young people to train and undertake research in the fields of science and technology, where research is essential for the development of current and future industrial activities. Solvay's intent is to stimulate the inventiveness of talented Ph.D. graduates and encourage them to think of ways their work can contribute to societal progress.

Solvay Company

Laureates 2022

Iacobellis Nicolas
Mannes Morgane
Themelis Thomas
Van Oene Thomas
Waeytens Jehan

Science Days

26 November 2023

In collaboration with the VUB, the Solvay Institutes participated in the Science Days of the Flemish Community more precisely in the Science Festival, organized on Sunday November 26, 2023, at Muntpunt in the center of Brussels.

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

On the other hand a workshop was organized by Paul Geerlings (Emeritus Professor Chemistry at VUB and Vice-President of the Solvay Institutes) 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 "odor" experiment where they could smell themselves that substances composed out of mirror-molecules do not always have the same odor. 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. Finally, even the presence of chirality in architecture was addressed as witnessed in the spirality of skyscrapers.

The Solvay/VUB exhibition stand received all day long many visitors enthusiastically interacting with Eline Desmedt, Jochen Eeckhoudt and Thibault Cauwenbergh (predoctoral researchers at the Chemistry Department of 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".

04

2023

UNESCO RECOGNITION

UNESCO Memory of the World Register

The United Nations Educational, Scientific and Cultural Organization (UNESCO), born after the Second World War, is the agency of the United Nations conceived to contribute to building peace through international cooperation in education, the sciences, and culture. The UNESCO program known as Memory of the World (MOW) aims at facilitating the preservation of the world's documentary heritage, enabling universal access to documentary heritage worldwide, and enhancing awareness among the general public of the importance of documentary heritage.

On May 24, 2023, the Executive Council of UNESCO inscribed the Archives of Solvay Councils in Physics and Chemistry (1910-1962) to the Memory of the World Register.

The archives bring to light the scientific internationalism organized at the beginning of the 20th century and the perpetuation of a tradition of international cooperation. The Solvay Conferences, a privileged meeting place for leading members of the scientific community, marked an era when the foundations of classical science were being challenged by the advent of quantum physics, the birth of the theory of relativity and the emergence of a new chemistry based on the exploration of the structure of the atom and chemical bonds. The collection is composed of the archives of the International Solvay Institutes for Physics and Chemistry (from the period 1910-1962) deposited at the Free University of Brussels (ULB) and the archives of Paul Langevin (section dedicated to the Solvay Conferences) kept at the École Supérieure de Physique et de Chimie Industrielles de la ville de Paris (ESPCI Paris) – PSL University.

The Vrije Universiteit Brussel (VUB) and the Université Libre de Bruxelles (ULB) submitted the application with the support of the Solvay Science Project.

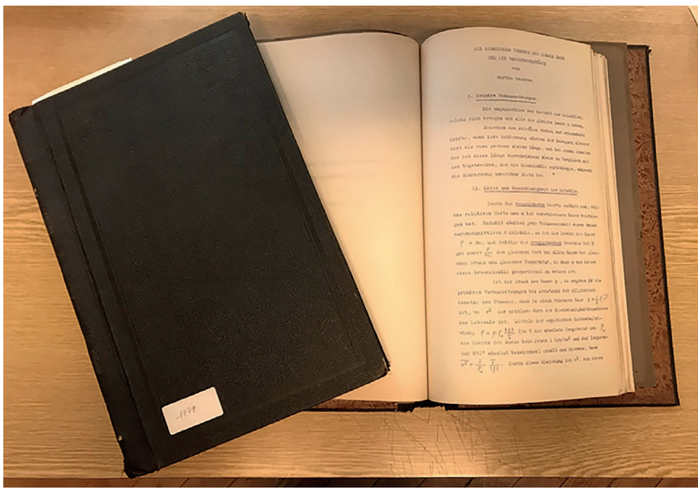
Every scientist knows two surnames: Nobel and Solvay. Nobel needs no explanation. Solvay refers to the Solvay Conferences for Physics and Chemistry that have been held here in Brussels every three years since 1911", says VUB rector and physicist Jan Danckaert.

"These meetings were the first international scientific conferences, similar to what we would call workshops today. The councils held between 1911 and 1927 established the interpretation of, among other things, quantum mechanics, which was a turning point for physics in the 20th century."[1]

The councils were also privileged meeting places for leading figures in the scientific community, who witnessed the birth of the theory of relativity and the emergence of a new chemistry, based on exploring the structure of the atom and chemical bonds. The documents from these historic Solvay Conferences are a reflection of the history of physics and chemistry in the 20th century, and are therefore a unique source for analysing the development of modern physics and chemistry.

Part of the collection that will become part of the UNESCO Memory of the World Register are the archives of the International Solvay Institutes for Physics and Chemistry (VUB-ULB) from the period 1910-1962, which are kept by ULB. The other part is the archives of Paul Langevin (a section dedicated to the Solvay Conferences) which are kept at ESPCI Paris-PSL. The collection includes manuscripts, printed documents, drawings and postcards, photographs on paper and digital images including photographs signed by participants. Both archives are free to view on the website of the Solvay Science Project and via the digital library of the Université Paris Sciences et Lettres.

With the recognition as Unesco World Heritage, VUB and ULB hope to further digitise the archives and learn even more about how those conferences came about. Who was invited, and who wasn't? What role did the two World Wars play?
This is the history not only of science, but also of thought," says Danckaert.[1]



The original report discussed at the first Solvay Council.

Joint initiative by VUB and ULB

The application for recognition by Unesco was a joint project by VUB and ULB, with the support of the department of libraries and scientific information at ULB (DBIS ULB), the École Supérieure de Physique et de Chimie Industrielles (ESPCI Paris-PSL) and the Université Paris Sciences et Lettres (PSL).

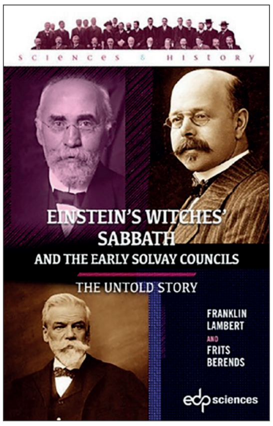
Renaud Bardez, head of Archives, Heritage and Special Collections at ULB, led the application process.

> *This recognition by Unesco is the result of a proactive institutional policy to preserve and promote both our heritage and history," he says.*[1]

Joint coordinator and ULB professor of contemporary history Kenneth Bertrams adds:

> *This is great recognition for our two universities and great recognition for the work carried out by the ULB archives"*[1]

As for the VUB, it should be noticed that research work carried out by Franklin Lambert, co-author of a book[2] which served as guide in the drawing up of the candidacy file for Unesco, and by Alessio Rocci, a historian of science and post-doc VUB researcher, enabled the Institutes to identify important Solvay documents in custody of the ESPCI, a discovery which gave rise to the idea of a joint UNESCO candidacy, involving both the Institutes and the Paris School.



The most updated historical study on Solvay's project

Solvay Science Project

The International Institute for Physics and Chemistry, established by Ernest Solvay and managed by VUB, ULB and the Solvay family, are currently involved in a project that aims at tracing and recovering Solvay archival documents that are scattered around the world. This endeavour is part of the Solvay Science Project, a collaboration between VUB and ULB established in 2018.

The managing of the Solvay Science Project had been entrusted to a Committee which comprised: Yoanna Alexiou, Brigitte Van Tiggelen, Anne de Wit, Renaud Bardez, Nicolas Coupain, Kenneth Bertrams and Franklin Lambert.

The project is supported by the VUB fund for Natural Science in Society, a Fund created by Krist'l Vanouytsel, a former VUB student in physics, and managed by the VUB Foundation philantropy service.

One of the goals of the fund was to gain recognition by UNESCO of the historical importance of the Solvay Conferences. This recognition is a step that will facilitate the necessary contacts, and collaborations between the Institutes and foreign archival centra identified as custodians of Solvay documents.

I welcome the opportunity to pay tribute to Stéphanie Manfroid, who now heads the "Commission Francophone et Germanophone Belge pour l'Unesco", for her inspiring ideas, and concrete help in the realisation of an initiative that required the drawing up of a virtual exhibition entitled "The Solvay Science Project". The initiative benefited from the enthusiastic support of Jean-Marie Solvay and Marina Solvay and the enlightened advice provided by Philippe Busquin, the former president of the above Commission for Unesco[3].

Mrs Marina Solvay, on behalf of the Solvay Institutes received a UNESCO certificate from Mr. Yves Rouyet, President of the Belgian Committee for Unesco.

To celebrate the inscription of the Archives of the International Solvay Conferences on Physics and Chemistry on the Memory of the World International Register, a reception was organized at the Brussels City Hall in presence of the participants of the 29th Solvay Conference on Physics.

The International Solvay Institutes are very grateful to:

The project and the candidacy enjoyed the precious support of several distinguished people: Mr. Philippe Busquin, Mr. Roger Roberts, Belgian Committee for Unesco, Mrs. Stéphanie Manfroid, President of the Belgian French- and German speaking Committee, Mr. Vincent Croquette, Director of the ESPCI, Mrs. Catherine Kounelis, Director the Archives of the ESPCI, Mr. Renaud Bardez, Director of the ULB Archives, and many others.The Solvay Institutes wish also to thank Mrs. Agnès Magnien, General inspector of cultural affairs (France) and Mr. Yves Rouyet, President of the Belgian Committee for Unesco.

1 *VUB and ULB press releases*

2 *Franklin Lambert and Frits Berends, Einstein's Witches' Sabbath and the Early Solvay Councils, the Untold Story, Les Ulis, EDP Sciences, 2021*

3 *Franklin Lambert's address on the occasion of the celebration of the registration of the Archives of the International Solvay Institutes of Physics and Chemistry in Unesco's Register "The Memory of the World". Brussels City Hall – 19 octobre 2023.*

05 2023

SCIENTIFIC ACTIVITIES

INTERNATIONAL SOLVAY

CHAIRS

International Solvay Chairs

The International Solvay Chair programme enables the Institutes to invite to 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 program in chemistry was launched in 2008 thanks to a generous grant from the Solvay Company, which the Institutes gratefully acknowledge.

2023 International Jacques Solvay Chair in Physics

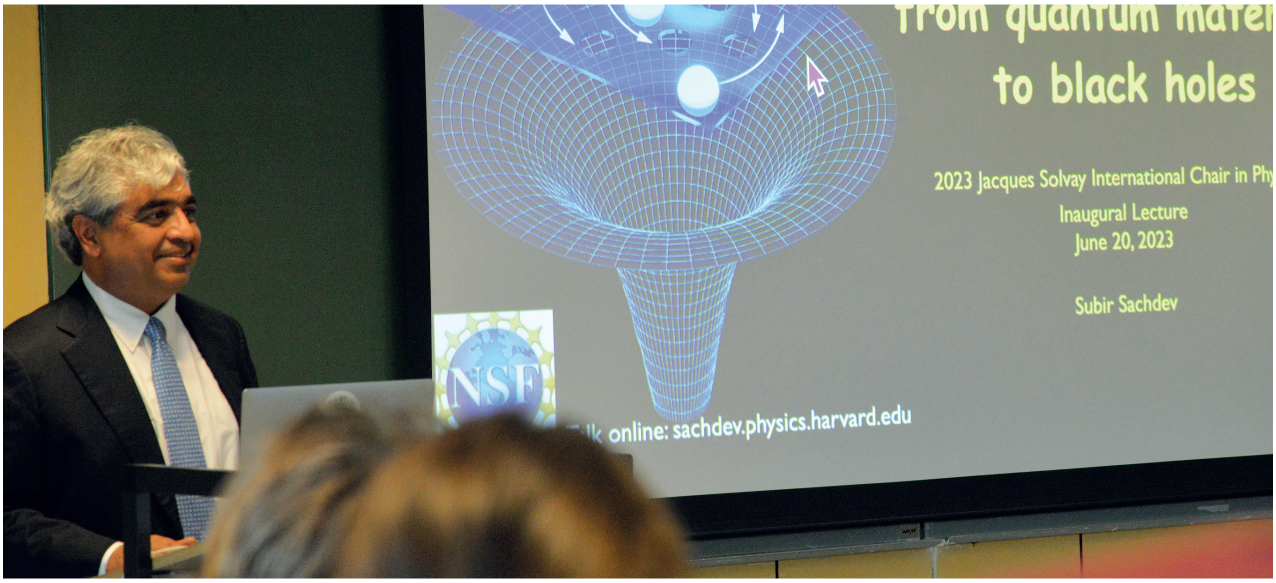
The 2023 International Jacques Solvay Chair in Physics was held by **Professor Subir Sachdev** from Harvard University (USA).

Subir Sachdev is a leading figure in condensed matter theory. Among his most notable recent contributions is the construction of a solvable model of a strange metal, a variant of which is now called the Sachdev–Ye–Kitaev (SYK) model. Remarkably, there is an intimate connection between the quantum physics of strange metals found in modern materials and quantum entanglement near black holes of astrophysics. This has led to valuable insights both on the properties of electronic quantum matter, and on the nature of Hawking radiation from black holes. This fascinating topic was precisely the subject of Professor Sachdev's brilliant inaugural lecture, delivered on June 20, 2023.

Subir Sachdev studied physics at MIT and at Harvard University. He obtained his PhD at Harvard in 1985 for his research on “Frustration and Order in Rapidly Cooled Metals”. He then held positions successively at the Bell Laboratories and at Yale University where he became Professor of Physics and Applied Physics, before moving to Harvard in 2005 where he is now Herchel Smith Professor of Physics.

Subir has made pioneering advances to theoretical condensed matter theory. He developed in particular the theory of quantum phase transitions. He also made seminal contributions to strange metals, which exhibit complex quantum entanglement. He was one of the key contributors to the now called Sachdev–Ye–Kitaev (SYK) model, which is a solvable model fror strange metals. This model has an exceptional impact, not only in condensed matter, but also in gravity theory.

For his work, Subir Sachdev received numerous honors and awards. The ones mentioned here are only a sample that illustrates the remarkable visibility of Subir’s contributions to physics. In 2014, Subir was elected to the U.S. National Academy of Sciences. He received the Lars Onsager Prize from the American Physical Society and the Dirac Medal from the ICTP in 2018. He was appointed Honorary Fellow of the Indian Academy of Sciences and Foreign Fellow of the Indian National Science Academy in 2019. This year (2023), he was elected Foreign Member of the Royal Society, “for his profound contributions to theoretical condensed matter physics research. Professor Sachdev’s main interests have been in quantum magnetism, quantum criticality, and perhaps most innovative of all, links between the nature of quantum entanglement in black holes and strongly interacting electrons in materials.”



Programme

Inaugural Lecture

20 June 2023

When nature entangles millions of particles: from quantum materials to black holes

Entanglement is the strangest feature of quantum theory, which Einstein dubbed "spooky action at a distance”. Quantum entanglement can occur on a macroscopic scale with millions of electrons, leading to “strange metals” and novel superconductors which can conduct electricity without resistance even at relatively high temperatures. Remarkably, related entanglement structures also arise across the horizon of a black hole, and give rise to Hawking’s black hole entropy. I will describe a simple model of many particle quantum entanglement which has shed light on long-standing problems in these distinct physical systems.

SYK Tutorial

22 June 2023

Part 1
Large N theory of the SYK model
Finite N theory of the SYK model

Part 2
Quantum Einstein gravity theory of charged black holes
Universal theory of strange metals

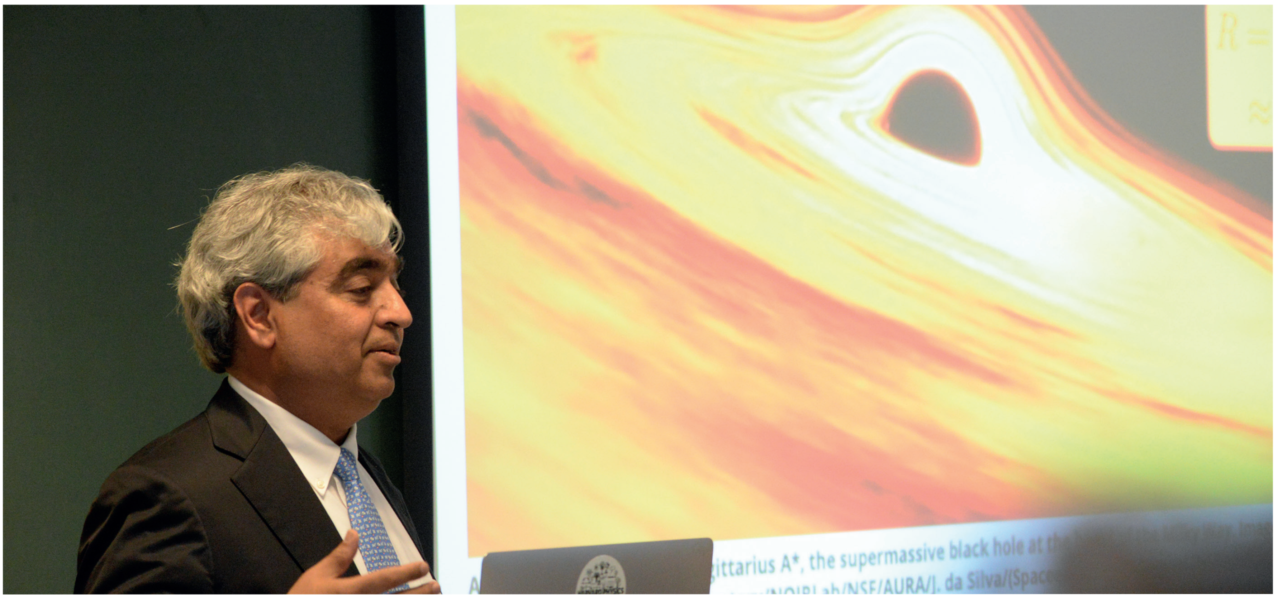
Colloquium at KU Leuven

23 June 2023

Quantum statistical mechanics of charged black holes and strange metals

Complex many-particle quantum entanglement is a central theme in two distinct major topics in physics: the strange metal state found in numerous correlated electron compounds, and the quantum theory of black holes in Einstein gravity. I will describe recent progress on both topics.

Hawking’s result on black hole entropy has now been improved to a universal, low energy density of quantum states of non-supersymmetric charged black holes in 3+1 dimensional asymptotically Minkowski space. A model of a metal with fermionic excitations on a Fermi surface with a spatially random Yukawa coupling to a critical boson provides a universal theory of strange metals which matches numerous observations. This progress has relied upon insights gained from the Sachdev-Ye-Kitaev model of many-particle quantum states without quasiparticle excitations.



The purposes of the chair were thus particularly met in 2023!
Many thanks go to Professor Sachdev for his exceptional availability.

The inaugural lecture was part of a very rich program that covered the period mid-June to mid-July 2023.

- June 22: A half-day tutorial
- June 23: Colloquium at KU Leuven
- June 26: Lecture at UAntwerp
- 27-28 June: Workshop “SYK models: from strongly correlated systems to quantum gravity”
- July 3: A colloquium in Würzburg
- July 5: A colloquium in Leiden

Many colleagues from various Belgian universities have been instrumental in the scientific organization of Professor Sachdev’s visit: Ben Craps (VUB), Frank Ferrari (ULB), Nathan Goldman (ULB), Christian Maes (KUL), Alex Sevrin (VUB), Eugene Skvortsov (UMONS), Jacques Tempere (UAntwerpen) and Frank Verstraete (Ugent).

The International Solvay Institutes are most grateful to all of them.

Publications

The Solvay chairs initiates or strengthens collaborations between the chair holder and Belgian scientists, resulting in common research papers in competitive journals.

The 2023 chair (held by Subir Sachdev) has led to:

"Connecting the Many-Body Chern Number to Luttinger's Theorem through Streda's Formula"
Lucila Peralta Gavensky, Subir Sachdev, and Nathan Goldman

Phys. Rev. Lett. 131, 236601 – Published 4 December 2023
https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.131.236601.

The 2021 chair (held by Jean Dalibard) has led to:

"Cold-atom elevator: From edge-state injection to the preparation of fractional Chern insulators"
Botao Wang, Monika Aidelsburger, Jean Dalibard, André Eckardt, and Nathan Goldman

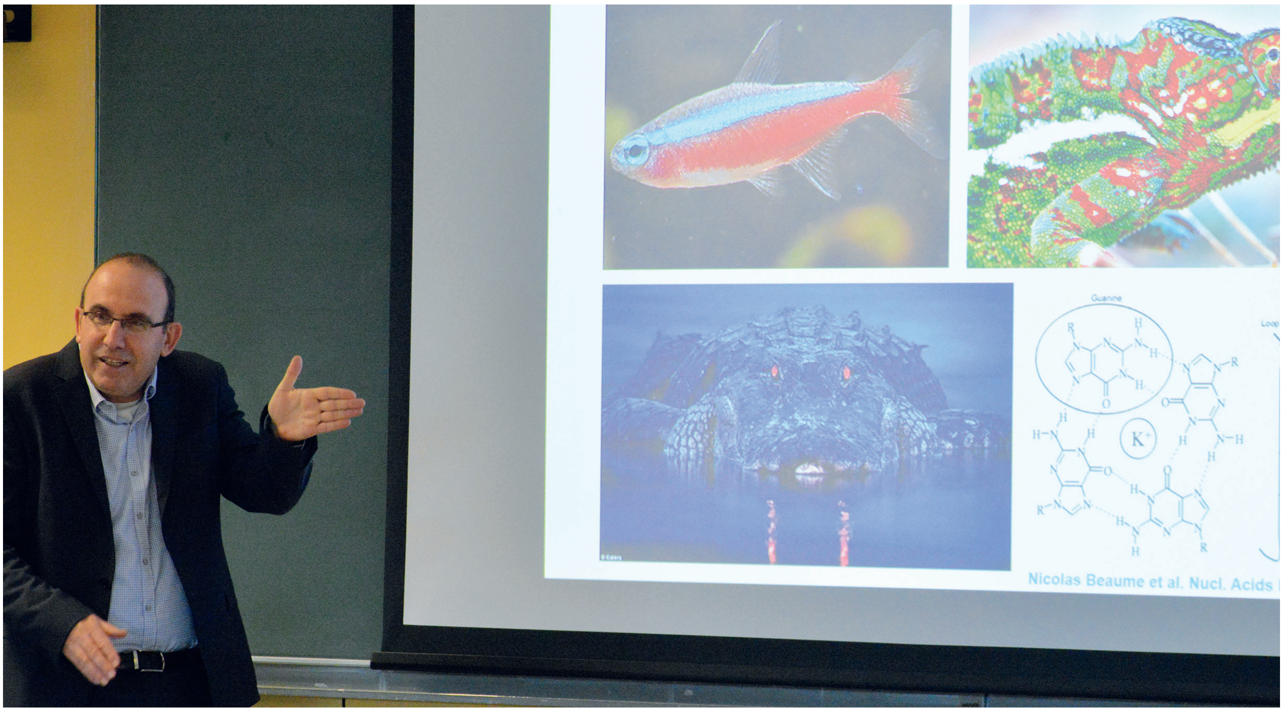
Phys. Rev. Lett. 132, 163402 (2024)
https://journals.aps.org/prl/pdf/10.1103/PhysRevLett.132.163402.

2023 International Solvay Chair in Chemistry

The 2023 International Chair in Chemistry was held by **Professor Ehud Gazit** from Tel-Aviv University (Israel).

Professor Gazit is a world-leading expert on biomolecular self-assembly. He transformed the field of molecular medicine by his work and discoveries on ordered supramolecular assemblies and their connection with human diseases. His remarkable achievements have far-reaching impact on revolutionary new therapeutic treatments. Professor Gazit's laboratory has also acquired a unique expertise in the identification of minimal recognition elements that facilitate the assembly of new large molecules. The potential of these nano-assemblies for ultra-sensitive biosensors applications, energy-storage devices, and the fabrication of metallic nanowires has been demonstrated.

Professor Gazit also served and continues serving on various positions related to science and technology at the national and international levels.



Professor Gazit received his B.Sc. after completing his studies at the Special Program for Outstanding Students of Tel Aviv University, and his Ph.D. (with highest distinction) as a Clore Fellow at the Department of Membrane Research and Biophysics, Weizmann Institute of Science in 1997. For his Ph.D. work, he received the John F. Kennedy Award. He has been a faculty member at Tel Aviv University since 2000, after completing his postdoctoral studies as a European Molecular Biology Organization (EMBO) and Human Frontiers Science Program (HFSP) fellow at Massachusetts Institute of Technology (MIT) where he also had held a visiting appointment (2002–2011). He also had a visiting appointment at St John's College, Cambridge University, UK (2016), a Senior Visiting Professor appointment at Fudan University, China (2018-2019) and a Guest Professor appointment at Umeå University, Sweden (2019-2021). He is a Professor and Endowed Chair at both the Faculties of Life Sciences and Engineering of Tel Aviv University and a member of the Executive Council of the University. Professor Gazit is also the founding director of the BLAVATNIK CENTER for Drug Development. From 2012-2014 he served as the Chief Scientist of the Israeli Ministry of Science and Technology (MOST) and the coordinator of the forum of Chief Scientists of the Israeli ministries. In 2015, he was knighted by the Italian Republic for his service to science and society. He had received numerous awards and honors.

Programme

Professor Ehud Gazit spent the period mid-September to mid-October 2023 in Belgium. During his stay, Ehud was hosted by Professor Han Remaut at the VUB, who has played a central role in the scientific organization of the chair, and to whom the Institutes are very grateful.

Ehud's inaugural lecture dealt with molecular self-assembly of biological, bio-inspired and other organic building blocks. This fascinating subject, connected with the understanding of life itself, has an enormous potential for therapeutic applications.

The inaugural lecture was followed by three other more specialized lectures given at the VUB.

Inaugural Lecture

19 September 2023

From Molecule to Mosaic:
Where Life's Puzzles Find Assembly

For over two decades, we have delved into the fundamental building blocks of nature, identifying the minutest biomolecular elements capable of forming ordered nano-scale structures. Adopting a minimalist approach, we've identified the essential modules that promote molecular self-assembly across proteins, peptides, metabolites, and lipids.

With this systematic methodology, we've unraveled the mechanisms leading to the formation of cerebral amyloid nano-deposits in severe disorders including Alzheimer's and Parkinson's diseases. Our novel mechanistic understanding has culminated in the development of therapies now in advanced clinical trials. In the domain of nanobiotechnology, our research illuminates how basic biochemical modules can forge versatile nanostructures with unique properties encompassing optics, mechanics, piezoelectricity, and semiconductivity.

We've deciphered and emulated nature's utilization of these physical and chemical principles in captivating phenomena, such as the night vision of nocturnal animals and chameleons' color-changing abilities.

Our most recent exploration has broadened the amyloid narrative, unveiling that even individual metabolites can assemble into amyloidlike structures. This discovery has implications for important genetic disorders, including Phenylketonuria, diagnosed via a simple heel prick test in every newborn. Fascinatingly, our understanding of metabolite assembly in physiology and pathology is highly important for numerous age-related maladies allowing us to clarify previously unexplained epidemiological associations. Taken together, we chart the assembly protocols and rules of the biomolecular mosaic across physiology, pathology, and nanotechnology defining the intricate dance of assembly that shapes the vast and diverse biomolecular landscape.

Lectures at the VUB

25 September 2023

Molecular Self-Assembly (I) Principles and Physiology

From molecular principles to biological optics: The role of self-assembly in night vision, chameleon camouflage and beyond.

27 September 2023

Molecular Self-Assembly (II) Nanotechnology

From peptide semiconductors to steel-like rigidity: The role of self-assembly in designing biomolecular materials with unique physical properties.

2 October 2023

Molecular Self-Assembly (III) Pathology

From age-related neurodegeneration to inborn metabolic disorders and back: The pathological implications of molecular self-assembly.

WORKSHOPS

ORGANISED BY THE SOLVAY INSTITUTES

“Progress on gravitational physics: 45 years of Belgian-Chilean collaboration”

11 - 14 April 2023

This workshop provided the opportunity to celebrate 45 years of Belgian-Chilean collaboration in theoretical gravity (CECs - ULB - Solvay Institutes).

Organising and Scientific Committee

Riccardo Argurio (ULB, Belgium)
Glenn Barnich (ULB, Belgium)
Geoffrey Compère (ULB, Belgium)
Stéphane Detournay (ULB, Belgium)
Marc Henneaux (ULB, Belgium)

Invited Participants

Max Bañados (UC, Chile)
Fabrizio Canfora (CECs, Chile)
Laura Donnay (SISSA, Italy)
Adrien Druart (ULB, Belgium)
Jose Edelstein (U. Santiago de Compostela, Spain)
Oscar Fuentealba (ULB, Belgium)
Gaston Giribet (NYU, USA)
Andres Gomberoff (U. Mayor, Chile)
Hernán Gonzalez (UAI, Chile)
Lorenzo Küchler (ULB, Belgium)
Cristián Martínez (CECs, Chile)
Javier Matulich (IFT-UAM/CSIC, Spain)
Olivera Misković (PUC Valparaíso, Chile)
Rodrigo Olea (UNAB, Chile)
Alfredo Perez (CECs, Chile)
Miguel Pino (USACH, Chile)
Francisco Rojas (UAI, Chile)
Patricio Salgado-Rebolledo (Wrocław UT, Poland)
David Tempo (UC Temuco, Chile)
Cédric Troessaert (HERS, Belgium)
Ricardo Troncoso (CECs, Chile)
Alejandro Vilar Lopez (ULB, Belgium)
Jorge Zanelli (CECs, Chile)
Raphaela Wutte (ULB, Belgium)

Programme

11 April 2023

Welcome address	
Jorge Zanelli	*Unconventional unification*
Gaston Giribet	*The 2D quantum gravity partition function*
Hernán Gonzalez	*A holographic model for soft gluon interactions*
Miguel Pino	*1/c deformations of AdS_3 boundary conditions*
Lorenzo Küchler	*Waveforms from compact binaries: the gravitational self-force Approach*
Patricio Salgado-Rebolledo	*Non-relativistic 3D gravity and higher-spin fields in the fractional quantum Hall effect*

12 April 2023

Max Bañados	*A new dynamics for Weyl connections, and a new Weyl invariant gravity*
Jose Edelstein	*Beyond General Relativity: causality, cosmology and astrophysics*
Alfredo Perez	*Carrollian/Fractonic elementary particles*
Francisco Rojas	*Strings on the celestial sphere*
Adrien Druart	*Spinning test bodies around Kerr black holes*
Javier Matulich	*Superrotations at spatial infinity*

13 April 2023

Ricardo Troncoso	*BMS (Carollian) field theories in 2D of electric and magnetic type from finite current-current deformations*
Andres Gomberoff	*The Implications of a Positive Cosmological Constant on Electromagnetic Theory*
Laura Donnay	*Constraints for flat space holography from asymptotic symmetries*
Olivera Misković	*Infinite-dimensional symmetries of the gauge theories in the light front*
David Tempo	*Nonlinear automorphism of the conformal algebra in 2D and continuous $\sqrt{TT}$ deformations*
Alejandro Vilar Lopez	*Entwinement: a tool for bulk reconstruction in AdS3/CFT2*

14 April 2023

Fabrizio Canfora	*Analytic hadronic condensates at finite Baryon density and their electronic fields*
Rodrigo Olea	*Conformal Renormalization and gravitational instantons in anti-de Sitter gravity*
Alberto Faraggi	*Interpolating Boundary Conditions on AdS2 and Supersymmetric Wilson Loops*
Oscar Fuentealba	*The BMS group in higher spacetime dimensions*
Cédric Troessaert	*BMS4 and logarithmic supertranslations*
Raphaela Wutte	*Hyperbolic mass and gluings of initial data*

“New ways to do chemistry - Emerging technologies for synthetic methodology”

24 - 26 April 2023

In the spirit of Ernest Solvay, the Solvay Institutes invited world leading scientists in the field of synthetic methodologies that is currently undergoing a revolution thanks to emerging chemical technologies.

The workshop focused on five specific topics:

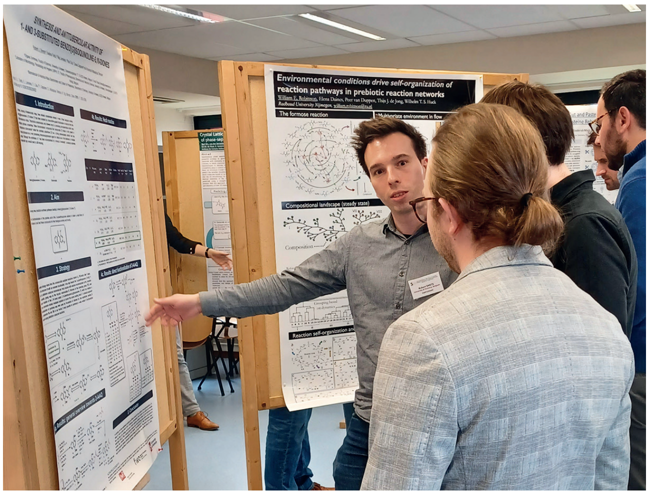
- AI-assisted synthesis
- Photo/electrochem Electron transfer
- Automated synthesis, robotics
- High throughput/flow, microfluidics
- Theory, data analysis/predictive reaction development

Scientific and Organising Committee

Gert Desmet (VUB, Belgium)
Ben Feringa (U. of Groningen, The Netherlands)
Yves Geerts (ULB, Belgium)
Patrick Maestro (Solvay SA, Belgium)
Hennie Valkenier (ULB, Belgium)

Invited Speakers

Phil Baran (Scripps Research, USA)
Richard Brown (U. of Southampton, UK)
Martin Burke (U. of Illinois, USA)
Lee Cronin (Glasgow U., UK)
Amandine Cuenca (Solvay SA, France)
Andrew J. De Mello (ETH Zurich, Switzerland)
Anne De Wit (ULB, Belgium)
Tim Donohoe (Oxford U., UK)
Frank Glorius (U. of Münster, Germany)



Corinne Gosmini (I. Polytechnique de Paris, France)

Véronique Gouverneur (Oxford U., UK)

Bartosz Grzybowski (Ulsan Inst., Republic of Korea)

Klavs F. Jensen (MIT, USA)

Burkhard König (U. Regensburg, Germany)

Pascal Miéville (EPFL, Switzerland)

Jean-Christophe Monbaliu (U. Liège, Belgium)

Robert Pollice (U. of Groningen, The Netherlands)

Philippe Schwaller (EPFL, Switzerland)

Peter Seeberger (Max-Planck, Germany)

Matt Sigman (U. of Utah, USA)

Berend Smit (EPFL, Switzerland)

Ludovic Troian-Gautier (UCLouvain, Belgium)

Véronique Van Speybroeck (Ghent U., Belgium)

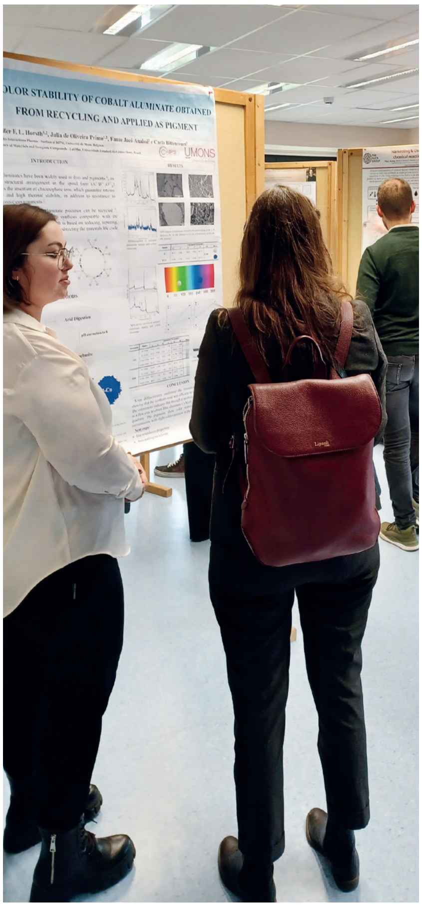
Programme

24 April 2023

Chairman Patrick Maestro

Ben Feringa & Marc Henneaux	*Introduction and context*
Franck Glorius	*On discovery and sensitivity in (photo) catalysis*
Veronique Van Speybroeck	*Resolving complex catalytic cycles with modeling techniques bridging length and time scales*
Véronique Gouverneur	*New ways to do chemistry - Emerging technologies for Synthetic methodology*
Lee Cronin	*Foundations of Digital Chemistry – Chemputation*
Bartosz Grzybowski	*Algorithmic synthesis planning and reaction discovery*
Andrew J. De Mello	*Microfluidics for high-throughput chemistry & biology*
Philippe Schwaller	*AI-accelerated Organic Synthesis Chemistry*

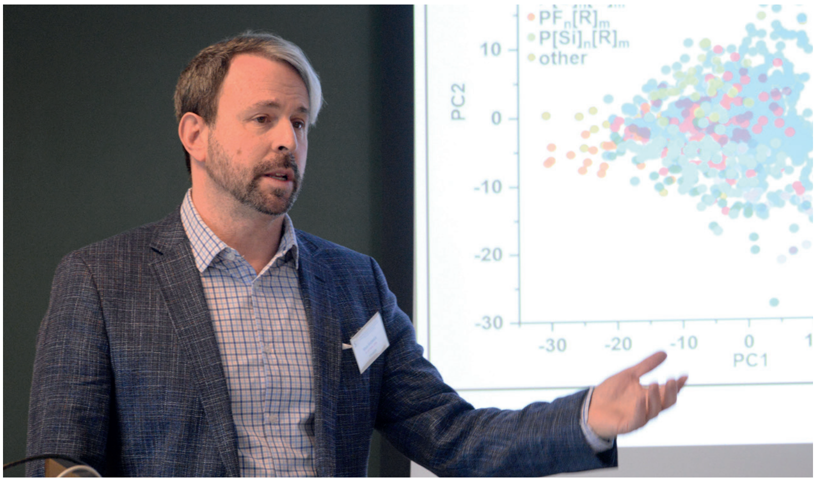
Poster session



25 April 2023

Chairwoman Hennie Valkenier

Peter Seeberger	*Automated Glycan Assembly as a Basis for Life and Material Science Applications*
Tim Donohoe	*To Leave and then Return? Hydrogen Borrowing Catalysis and Organic Synthesis*
Berent Smit	*Capturing chemical intuition*
Matt Sigman	*Data Science meets Reaction Optimization*
Klavs Jensen	*Accelerating chemical discovery and development with machine learning and automation*
Burkhard König	*Chemical Photosynthesis - towards ideal chemical transformations*
Martin Burke	*Generalizing small molecule synthesis*
Phil Baran	*Simplifying Synthesis with Electricity*
Corinne Gosmini	*Cobalt-catalyzed cross-coupling reactions*
Amandine Cuenca	*Applications of robotics and high throughput screening for industrial R&D*



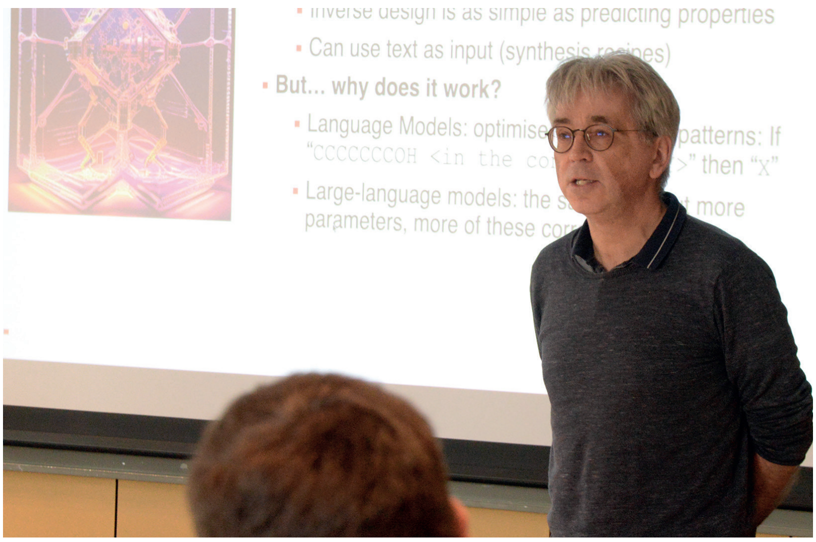
Many thanks for the organization of a great workshop. I received a lot of very positive responses, participants were excited about the science and the discussions about the future of synthesis, the labs of the future AI etc. I think it was worth every minute. Many thanks especially to the Solvay Institutes to make this possible".

Ben Feringa

26 April 2023

Chairman Gert Desmet

Pascal Miéville	*Multidisciplinary challenges on the way to a fully autonomous chemistry laboratory at Swiss CAT+*
Richard Brown	*Organic electrosynthesis in flow reactors*
Jean-Christophe Monbaliu	*New perspectives at the confluence of technology and organic synthesis*
Anne De Wit	*Chemical pattern formation in flows*
Ludovic Troian-Gautier	*Controlling Excited-State Reactivity Towards More Efficient Energy Conversion*



“SYK models: from strongly correlated systems to quantum gravity”

27 - 28 June 2023

This workshop was organized in the context of the 2023 Jacques Solvay Chair in Physics held by Subir Sachdev (Harvard).

Organising and Scientific Committee

Ben Craps (VUB, Belgium)
Frank Ferrari (ULB, Belgium)
Nathan Goldman (ULB, Belgium)
Marc Henneaux (ULB, Belgium)
Christian Maes (KUL, Belgium)
Alex Sevrin (VUB, Belgium)
Eugene Skvortsov (UMONS, Belgium)
Jacques Tempere (UAntwerpen, Belgium)
Frank Verstraete (UGent, Belgium)

Invited Speakers

Dario Benedetti (CPHT, France)
Mike Blake (U. of Bristol, UK)
Jean-Philippe Brantut (EPFL, Switzerland)
Leticia Cugliandolo (LPTHE, France)
Sebastian Diehl (U. of Cologne, Germany)
Giuseppe Di Giulio (U. Würzburg, Germany)
Blaise Goutéraux (CPHT, France)
Felix Haehl (U. of Southampton, UK)
Sean Hartnoll (U. of Cambridge, UK)
Jorge Kurchan (ENS, France)
Andreas Läuchli (EPFL, Switzerland)
Andrew Lucas (U. of Colorado Boulder, USA)
Thomas Mertens (UGent, Belgium)
Koenraad Schalm (Leiden University, The Netherlands)
Mathias Scheurer (U. Innsbruck, Austria)

Programme

27 June 2023

Welcome addresses by Marc Henneaux & Subir Sachdev

Jean-Philippe Brantut	*All-to-all interacting quantum gases*
Sebastian Diehl	*Phases and phase transitions in non-unitary quantum dynamics*
Jorge Kurchan	*A few surprising analogies between models of Black Holes and glasses*
Koenraad Schalm	*T-linear resistivity, optical conductivity and Planckian transport for a holographic local quantum critical metal in a periodic potential*
Mathias Scheurer	*Correlated many-body physics in van der Waals moiré Superlattices*
Andreas Läuchli	*Thermalization Dynamics in Quantum Spin Chains*
Leticia Cugliandolo	*Slow dynamics: aging, weak long-term memory & time reparametrization invariance*
Andy Lucas	*Disordered quantum critical fixed points from holography*

28 June 2023

Felix Haehl	*Effective description of sub-maximal chaos and stringy effects from SYK models*
Mike Blake	*The Page curve from the entanglement membrane*
Blaise Goutéraux	*Towards effective actions for critical holographic matter*
Sean Hartnoll	*Emergent area laws from entangled matrices*
Dario Benedetti	*Tensor models: from quantum gravity to SYK and beyond*
Giuseppe Di Giulio	*Symmetry-resolved modular correlation functions in free fermionic theories*
Thomas Mertens	*Double-scaled SYK, quantum groups, and JT gravity*

Alex Fest: “Strings, Branes and Gravitational Waves”

22 August 2023

Scientific workshop in honour of Alex Sevrin’s 60th birthday.

Organising and Scientific Committee

Ben Craps (VUB, Belgium)
Marc Henneaux (ULB, Belgium)
Alberto Mariotti (VUB, Belgium)
Antoine Van Proeyen (KU Leuven, Belgium)
Nick Van Remortel (U. Antwerpen, Belgium)

Invited Speakers

Eric A Bergshoeff (U. of Groningen, The Netherlands)
Christopher Blair (UAM Madrid & VUB)
Anna Ceresole (INFN Torino, Italy)
Jan de Boer (U. of Amsterdam, The Netherlands)
Frederik Denef (Columbia U., USA)
Chris Hull (Imperial College London, UK)
Niels Obers (NBI, Denmark and Nordita, Sweden)
Kareljan Schoutens (U. of Amsterdam, The Netherlands)
Kostas Skenderis (U. of Southampton, UK)
Marika Taylor (U. of Southampton, UK)
Daniel Thompson (Swansea U., UK)
Paul Townsend (U. of Cambridge, UK)
Jan Troost (ENS Paris, France)
Nick Van Remortel (U. Antwerpen, Belgium)

Programme

22 August 2023

Welcome address	
Kareljan Schoutens	*Supersymmetric brick wall quantum circuits*
Anna Ceresole	*Surfing superspace, branes and gravitational waves*
Jan de Boer	*Title TBA*
Eric A Bergshoeff	*Carroll Fermions*
Chris Hull	*Chiral p-form Gauge Theory*
Niels Obers	*Carroll symmetry in field theory, gravity and string theory*
Kostas Skenderis	*CFT in momentum space*
Frederik Denef	*Title TBA*
Jan Troost	*Topological Symmetric Orbifolds: An Example of Simplicity*
Marika Taylor	*Celestial Shock Waves*
Daniel Thompson	*Title TBA*
Paul Townsend	*Trirefringence and the M5-brane*
Christopher Blair	*Strings, Branes and Generalised Dualities*
Nick Van Remortel	*Title TBA*

“Dissipative solitons, turbulence and extreme events in nonlinear photonics”

6 - 8 September 2023

The study of the confinement of light in one or more dimensions leading to the formation of conservative and dissipative solitons has revolutionized nonlinear optics and photonics. New classes of ultrafast lasers have also been created, making a wide range of interdisciplinary applications possible. Key studies in the field of optical communications as well as many areas of ultrafast photonics, including laser design, frequency comb generation, and interdisciplinary studies related to the complexity of producing extreme events, turbulence, and spatiotemporal chaos, are now supported by soliton physics. This workshop covered the most recent advances in the following active areas of study while describing the state of the art, recent developments, new perspectives, and cutting-edge methods:

- Spatial and temporal localized structures of light
- Laser mode locking
- Machine learning and networks with photonic devices
- Microresonator frequency comb technologies
- High-precision spectroscopy
- Generation and propagation of pulses in fiber lasers and optical waveguides
- Stability, interaction, and mobility of optical solitons
- Extreme events, turbulence, and spatiotemporal chaos in photonic devices

Scientific and Organising Committee

Marcel Clerc (U. of Chile, Santiago, Chile)
Saliya Coulibaly (U. of Lille, France)
Pascal Kockaert (ULB, Brussels, Belgium)
Bilal Kostet (ULB, Brussels, Belgium)
René Lefever (ULB, Brussels, Belgium)
Krassimir Panajotov (VUB, Brussels, Belgium)
Majid Taki (U. de Lille, France)
Mustapha Tlidi (ULB, Brussels, Belgium)
Guy Verschaffelt (VUB, Brussels, Belgium)

Invited Speakers

Nail Akhmediev (Australian National U. Canberra, Australia)

Lies Bahloul (U. of Science & Technology Houari Boumediene, Algeria)

Uwe Bandelow (Weierstrass Institute, Berlin Germany)

Stefano Boccaletti (Institute of Complex Systems, Florence, Italy)

Amin Chabchoub (Kyoto U., Japan & U. of Sydney, Australia)

Marcel Clerc (U. of Chile, Santiago, Chile)

Lina Grineviciute (FTMC, Vilnius, Lithuania)

Luigi Lugiato (U. of Insubria, Como, Italy)

Boris Malomed (Tel Aviv U., Israel)

Andrey Matsko (California Institute of Technology, USA)

Ziad Musslimani (Florida State U., USA)

Arnaud Mussot (U. of Lille, France)

Marco Piccardo (Harvard U., USA)

Nathalie Picqué (Max Planck Institute, Garching, Germany)

Stefania Residori (U. of Nice-Sophia Antipolis, Nice, France)

Nikolay Rosanov (Ioffe Institute, St. Petersburg, Russia)

Dmitry Skryabin (U. of Bath, UK)

Kestutis Staliunas (ICREA, Barcelona, Spain)

Guy Van der Sande (VUB, Brussels, Belgium)

Andrei Vladimirov (Weierstrass Institute, Berlin, Germany)

Stefan Wabnitz (La Sapienza U., Rome, Italy)

Programme

6 September 2023

Marc Henneaux	*Opening and welcome speech*
Luigi Lugiato	*The cavity Kerr medium model and the surprising history around it*
Stefan Wabnitz	*Wave turbulence, thermalization and multimode locking in optical fibers*
Dmitry Skryabin	*Moulding light on a ring*
Andrey Matsko	*Time crystals as regenerative frequency dividers*
Nikolay Rosanov	*Dissipative optical solitons: From 1D- scalar to 2D-and 3D-, topological and vector solitons*
Boris Malomed	*Multidimensional dissipative solitons - a survey*
Amin Chabchoub	*Extreme waves in the presence of wave reflection*

7 September 2023

Stefano Boccaletti	*The transition to synchronization of networked systems*
Guy Van der Sande	*Opto-electronic Ising machines*
Stefania Residori	*Optically addressed liquid crystal light valves for the generation of nonlinear optical structures and control of their dynamics*
Marcel Clerc	*Optical turbulence in liquid crystal*
Kestutis Staliunas	*Fano resonances at the edge of a continuum: fundamentals and applications in microlasers*
Lina Grineviciute	*Nanostructured dielectric coatings for anisotropy and Fano-like resonances*
Uwe Bandelow	*Unusual scenarios in the context of the modulation Instability*
Ziad Musslimani	*PT symmetry, nonlocal integrable models and physical applications*
Marco Piccardo	*A journey in ring quantum cascade lasers: From phase turbulence to driven solitons on a laser chip*

8 September 2023

Nathalie Picqué	*Interferometry with soliton frequency combs and Microcombs*
Andrei Vladimirov	*Neutral delay differential equation Kerr cavity Model*
Arnaud Mussot	*Recent results on fiber Fabry Perot resonators for frequency comb generation*
Nail Akhmediev	*Passive mode-locking and self-Q-switching in terms of the cubic-quintic Ginzburg-Landau equation*

"Perspectives in fundamental physics" Meeting in memory of Lars Brink

17 - 18 October 2023

The International Solvay Institutes and the Arnold Sommerfeld Center organized this meeting to commemorate Professor Lars Brink who passed away on 29 October 2022.

Lars Brink was an emeritus professor at Chalmers University Göteborg, Sweden and a member of the Royal Swedish Academy. He was a world class physicist, with numerous essential contributions to supergravity, superstring theory and quantum field theory. In particular, he pioneered maximal supersymmetric Yang-Mills theory which has been inspirational to many modern developments of theoretical physics. He served on the Nobel Committee for Physics, which he chaired in 2013. He chaired since its creation the International Advisory Committee of the Solvay Institutes.

His advice has been key to the development of the Institutes in the last 20 years.

Invited Speakers

Erik Aurell
(KTH, Stockholm, Sweden)

Costas Bachas
(ENS, Paris, France)

Åsa Brink (Sweden)

Maria Brink (Sweden)

Jenny Brink (Sweden)

Radu Constaninescu
(U.of Craiova, Romania)

Ulf Danielsson
(Uppsal U., Sweden)

Paolo Di Vecchia
(Niels Bohr Institute, Denmark)

François Englert
(ULB/Solvay Institutes)

Cesar Gomez
(UAM, Madrid, Spain)

Michael Green
(Cambridge U., UK)

David Gross (Kavli Institute
Santa Barbara, USA)

Gerard 't Hooft (U. Utrecht
The Netherlands)

Marc Henneaux
(ULB/Solvay Institutes)

Måns Henningson
(U. of Gothenburg, Sweden)

Jean Iliopoulos
(ENS, Paris, France)

Bernard Julia
(ENS, Paris, France)

Mats Larsson
(Stockholm U., Sweden)

Sucheta Majumdar
(ENS, Lyon, France)

Marc Mézard (Bocconi U., Italy)

Slava Mukhanov (LMU, Germany)

Holger Nielsen
(Niels Bohr Institute, Denmark)

Bengt Nilsson
(Chalmers U., Sweden)

Eva Olsson
(Chalmers U., Sweden)

Alexander Polyakov
(Princeton U., USA)

Pierre Ramond
(U. of Florida, USA)

Alexander Sevrin
(VUB/Solvay Institutes)

Jean-Marie Solvay
(Solvay Institutes)

Misha Vasiliev (Lebedev Physical
Institute, Moscow)

Peter Zoller
(U. Innsbruck, Austria)

Programme

17 October 2023

Session: A glimpse into physics
Chair: Bernard Julia

Paolo Di Vecchia	*Gravitational observables from scattering amplitudes*
Bengt Nilsson	*Lars Brink: "my baby" N=4 super-Yang-Mills*
Sucheta Majumdar	*BMS symmetry in light-cone gravity*

Session: Lars Brink and the Swedish Academy
Chair: Alexander Sevrin

Mats Larsson	*The quantum mechanics Nobel Prizes in 1932/33 to Heisenberg, Schrödinger and Dirac*
Eva Olsson	*Lars - the teacher, fellow panel chair and academy Member*

Session: Reminiscences from colleagues, friends and family
Chair: Slava Mukhanov

Jean Iliopoulos	*Lars Brink and the École Normale Supérieure*
Michael Green	*Learning from Lars*
Pierre Ramond	*Lars Brink Friend and Physicist*
Family testimony	

18 October 2023

Session: Göteborg
Chair: Holger Nielsen

Måns Henningson	*Lars Brink and fundamental physics in Göteborg*

Session: Lars and international collaboration
Chair: Costas Bachas

Marc Henneaux	*From Chile to the International Solvay Institutes*
Radu Constantinescu	*Lars Brink - Honorary member of Physics communities from Romania and from other South-Eastern European Countries*
Cesar Gomez	*Lars: an altruist engagement with the Spanish Scientific politics*
Misha Vasiliev	*Lars Brink and International Center for Fundamental Physics in Moscow*

Round table on Why fundamental physics
Chair: Ulf Danielsson

Participants: François Englert, Sasha Polyakov, Ulf Danielsson, Gerard ’t Hooft and Jean-Marie Solvay

Round table on Perspective in physics
Chair: Slava Mukhanov

Participants: Eric Aurell, Peter Zoller, David Gross, Marc Mézard and Slava Mukhanov

“ Solvay Workshop on History: Embedding the Solvay Science Project in a Global Framework ”

9 November 2023

On Thursday, 9 November, the Solvay Science Project, the collaboration between ULB and VUB, organized the first Solvay Workshop on History with the logistic help of the Solvay Institutes and the general support of the Science History Institute. The organizers invited five international speakers and the one-day workshop was hosted by the ULB at the Hall of Marbles.

The workshop was organized in the context of the celebrations for the inscription of the Archives of Solvay Councils in Physics and Chemistry (1910-1962) in UNESCO’s Memory of the World Register.
Ernest’s Solvay initiative were tackled in a global framework by discussing the concept of international scientific collaboration, the history of international organizations, the role of women in science, and the social and political aspects of the conferencing practice.

The attendees contributed with questions, observations, or remarks after every lecture and during the closing roundtable discussion.

Organising and Scientific Committee

Anne De Wit (ULB - Solvay Institutes, Belgium)
Kenneth Bertrams (ULB, Belgium)
Brigitte Van Tiggelen (Science History Institute, Belgium)
Alessio Rocci (VUB, Belgium)

Invited Speakers

Danielle Fauque (Université Paris-Saclay, France)
Luca Forgiarini (Utrecht University, The Netherlands)
Ernst Homburg (Maastricht University, The Netherlands)
Annette Lykknes (Norwegian University of Science & Technology, Norway)
Geert J. Somsen (Maastricht University and Vrij Universiteit Amsterdam, The Netherlands)

Programme

Brigitte Van Tiggelen	*The History of Historic Conferences: Embedding the Solvay Science Project in a Global Framework*
Anne De Wit	*Today Solvay Chemistry Council*
Geert J. Somsen	*Witches' Sabbath, Parliament, or Debating Club? The Solvay Councils in the History of Scientific Conferences*
Danielle Fauque	*From the IACS to the first International Solvay Council of Chemistry (1910-1922)*
Ernst Homburg	*The Solvay Chemistry Councils and the social and theoretical evolution of chemistry, 1922-1938*
Kenneth Bertrams	*Solvay's 1913 Jubilee: a Conflation of Business, Science, and Family*
Annette Lykknes	*Cutting-edge research, interdisciplinarity and international networking: Women in radioactivity research in the beginning of 20th century*
Luca Forgiarini	*Unstable bonds: CERN's relations with some of its smaller member states in the 1950s and 1960s*
Alessio Rocci	*The Solvay Science Project and its legacy*

Round table - Moderated by Alessio Rocci and Brigitte Van Tiggelen

The workshop concluded with a round-table between the invited speakers, the organizers, and the participants.

Scientific internationalism and excellence concepts were discussed, along with the possibilities of new directions and future collaborations.

A strong characterization of the workshop was the presence of two different approaches: a Solvay-centered perspective, on the one hand, and a more general point of view, on the other.

The discussion showed that these two approaches are compatible but, require further interaction and convergence.

WORKSHOPS

SPONSORED BY THE SOLVAY INSTITUTES

General Scientific Meeting 2023 of the Belgian Physical Society

University of Namur, 17 May 2023

The General Scientific Meeting of the Belgian Physical Society covered all main fields of physics research in Belgium. The target groups for this activity were all Belgian physicists, irrespective of their scientific sub-discipline.

The aim was to create awareness about the research that is done in the different institutes and to stimulate collaborations among Belgian institutes. All speakers were asked to make their presentation accessible for a broad audience and to encourage interactions between scientists of different sub-disciplines. Also recent scientific developments and trends in physics education were discussed with this year a special emphasis and invitation to Belgian teachers.

The scientific committee of the 2023 BPS Meeting consisted of researchers from UNamur, UMons, ULB, and the Royal Military Academy in Brussels.

Parallel sessions and poster sessions were organized about:

- Astrophysics, Geophysics, and Plasma Physics
- Biophysics and medical physics
- Condensed Matter and Nanophysics
- Fundamental interactions, Particle and Nuclear Physics
- Mathematical and statistical physics, theoretical astronomy
- Physics and Education
- Quantum Physics, Atoms, Molecules, and Optics

Plenary Lecture 1

Martine de Mazière (BIRA-IASB)

Monitoring the Earth atmosphere composition using infrared spectrometry

Plenary Lecture 2

Olivier Deparis (UNamur)

Parchments & skins: physical methods for the identification of animal species in historical manuscripts

Invited Speakers

The young speaker contest highlighted the tree following talks:

- *Photonics for personal thermal regulation* by Muluneh G. ABEBE (UMons);
- *Exploring the Higgs sector at LHC and Future Colliders* by Paola MASTRAPASQUA (UCLouvain);
- *Mechanisms of DNA-mediated allostery* by Midas SEGERS (KULeuven).

“Exploring low-energy nuclear properties: latest advances on reaction mechanisms with light nuclei”

Brussels, 1-2 June 2023

Nuclear reactions are one of the most important topics in nuclear physics. Their study is essential to deepen our knowledge about the nuclear interaction or about the structure of radioactive nuclei, especially far from stability. This also enables the experimental or theoretical determination of reaction rates, used as inputs in other fields of physics such as nuclear astrophysics, nuclear power generation, or radioactive isotope production.

The aim of this workshop was to discuss the latest advances in the field of nuclear reactions, covering both theoretical and experimental developments, fundamental and applications to astrophysics. Recent progresses on low-energy reactions between light nuclei were, in particular, highlighted. The main topics of this workshop were:

- exotic nuclei via direct and indirect reactions: theory and experiments;
- microscopic models for structure and reactions;
- clustering effects in bound states, resonances, and collisions;
- ab initio description of few-body reactions;
- nuclear reactions relevant for astrophysics and cosmology.

Organising and Scientific Committee

Jérémy Dohet-Eraly (ULB)
Claude Semay (UMONS)
Michele Sferrazza (ULB)
Jean-Marc Sparenberg (ULB)

“Beyond Boundaries Arts, Sciences & Society”

Brussels, 3 November 2023

The Collegium of the Royal Academy of Belgium organized the first edition of "Beyond Boundaries: Art, Science & Society", which took place on November 3rd, 2023 at Studio 4 Flagey (Brussels).

On the occasion of the first anniversary of the creation of the Collegium, this event brought together scientists and artists to question the interactions between artificial intelligence algorithms and artistic and scientific creativity. It included three presentations by scientists specializing in different disciplines concerned with artificial intelligence, two artistic performances, and a debate with all the speakers.

Programme

Antoinette Rouvroy (FNRS/UNamur)	*AI and law: two ways of straddling the ungovernable*
Olga Kisseleva (Art&Science Intern. Institute)	*From swarm intelligence to AI, and vice versa*
César Hidalgo (Univ. Toulouse)	

Musical performances:

- *BIAS II* by Artemi-Maria Gioti (live electronics) & Stéphane Ginsburgh (piano)
- *Umbraphonics - Bach / Bartok* by Vincent Caers (live electronics) and Julien Libeer (piano)

NEW HORIZONS

LECTURES

New Horizons Lectures

The "New Horizons Solvay Lectures" were launched in 2018. The object of the program, which benefits from the generous financial support of the Solvay Group is to invite a brilliant young scientist (PhD + 12 years maximum) with already high visibility and well-established stature to give a series of lectures in Brussels and in other Belgian universities.

Through this program, the Solvay Institutes wishes to strengthen collaborations between Belgian research teams. Young researchers are the special target, and interactions between them and the Solvay lecturer are maximized.

Past New Horizons Lectures

New Horizons Lectures in Chemistry

2018 Lecturer: Alexandre Tkatchenko from U. of Luxemburg

2019 Lecturer: Rafal Klajn from Weizmann Institute, Israel

2020 Lecturer: Hans Jakob Wörner from ETH Zürich, Switzerland

2021 Lecturer: Ying Diao from University of Illinois, USA (postponed in 2023)

2022 Lecturer: Cornelia Meinert from CNRS, Université Côte d'Azur, France

2023 Lecturer: Danna Freedman from MIT, USA

New Horizons Lectures in Physics

2018 Lecturer: Zohar Komargodski from Weizmann Institute, Israel & Simons Center U. of NY, Stony Brook, USA

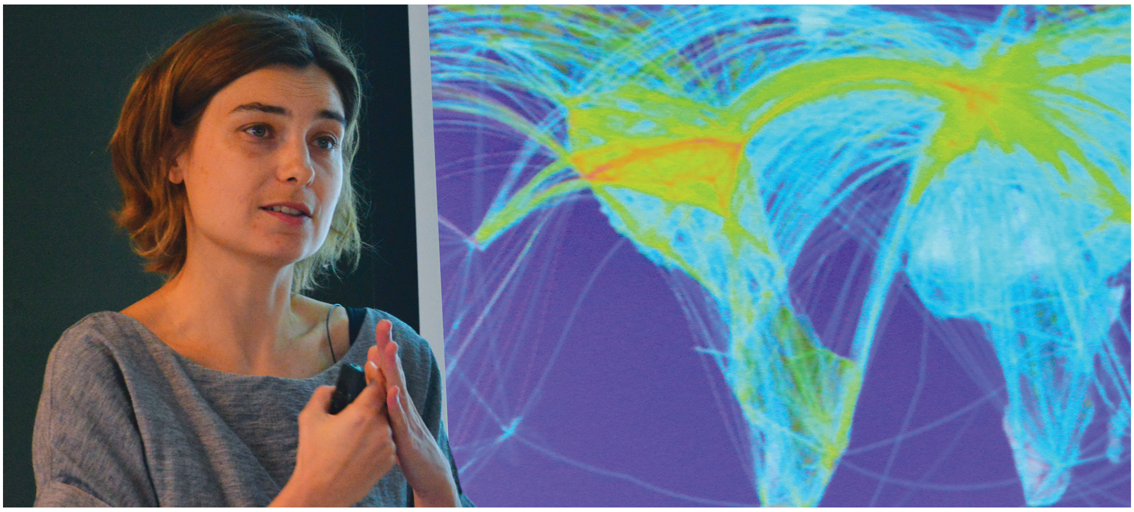
2019 Lecturer: Aleksandra Walczak from LPT ENS, Paris, France

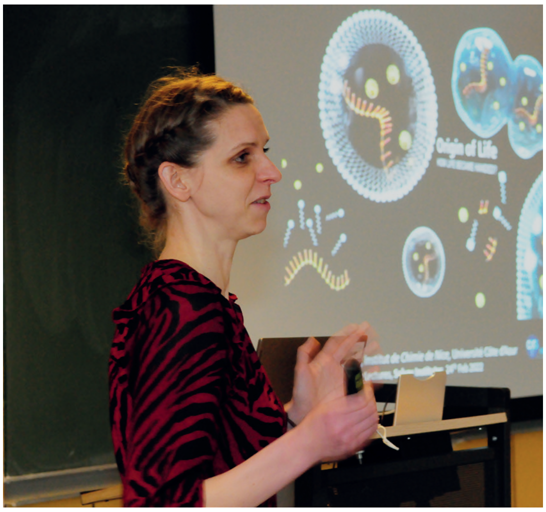
2020 Lecturer: Douglas Stanford from Stanford University, California, USA

2021 Lecturer: Maria Bergemann from Max Planck Institute, Heidelberg, Germany

2022 Lecturer: Nir Navon from Yale University, USA (postponed in 2023)

2023 Lecturer: Alexander Zhiboedov from CERN, Genève, Switzerland





2021 New Horizons Lectures in Chemistry (postponed in 2023)

Professor Ying Diao

University of Illinois, USA

Professor Diao is a Beckman Fellow, Dow Chemical Company Faculty Scholar, Lincoln Excellence for Assistant Professor (LEAP) Scholar at University of Illinois at Urbana- Champaign.

She received her Ph.D. degree in Chemical Engineering from MIT in 2012. Her doctoral thesis was on understanding heterogeneous nucleation of pharmaceuticals by designing polymeric substrates. In her subsequent postdoctoral training at Stanford University, she pursued research in the thriving field of printed electronics. Diao group, started in 2015 at Illinois, focuses on understanding assembly of organic functional materials and innovating printing approaches that enable structural control down to the molecular and nanoscale.

She is named to the MIT Technology Review's annual list of Innovators Under 35 as a pioneer in nanotechnology and materials.

She is also a recipient of NSF CAREER Award, NASA Early Career Faculty Award, 3M Non-Tenured Faculty Award and was selected as a Sloan Research Fellow in Chemistry as one of the "very best scientific minds working today".

Lecture

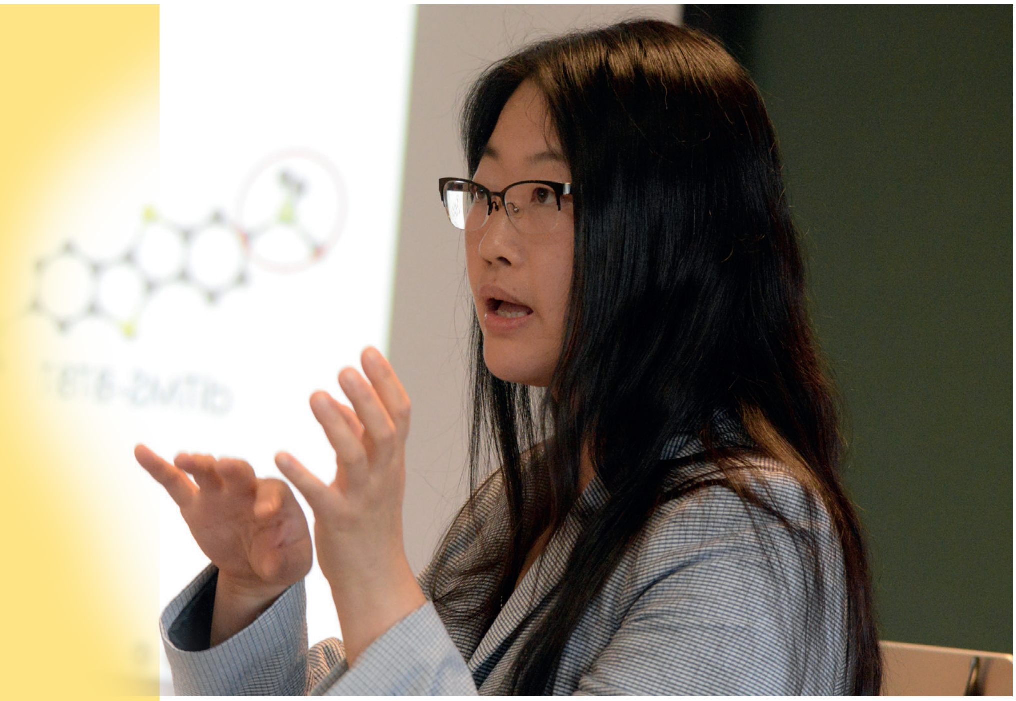
2 May 2023

Cooperative Polymorphic Transitions for Dynamic Electronic Crystals

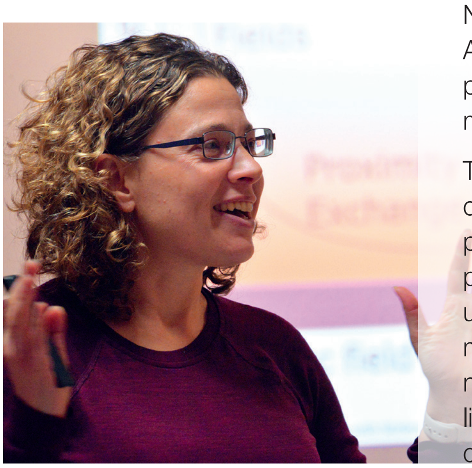
Controlling crystal polymorphism represents a long-standing challenge in solid-state chemistry. Molecular packing sensitively modulates properties of crystalline solids from solubility, bioavailability of pharmaceuticals to charge transport and energy conversion in organic electronics.

I will discuss understanding molecular mechanisms of polymorph transitions to dynamically modulate electronic properties in organic semiconductor single crystals. In particular, we are deciphering the molecular origin of cooperativity in polymorph transitions, a phenomenon long used by living systems for circumventing energetic and entropic barriers to yield highly efficient molecular processes. Combining in situ polarized microscopy, single crystal X-ray diffraction, Raman spectroscopy and solid-state NMR, we discovered a molecular-machine-like gearing mechanism for triggering cooperative transitions in several classes of organic semiconductors. This phenomenon led to pronounced shape and function memory effect whereby rapid, reversible switching of electronic properties were realized with low energy input.

This molecular design rule further enabled mechanically-induced cooperative transitions, which serves as a new stress-relieving mechanism and leads to unprecedented strain-tolerance in single crystal electronic devices. We further leverage this phenomenon for actuatable electronic devices.



2023 New Horizons Lectures in Chemistry



Professor Danna Freedman

MIT, USA

Danna Freedman is the F. G. Keyes Professor of Chemistry at MIT. After high school, she left upstate NY to head to Harvard University in Cambridge, MA. At Harvard, Danna performed research in Prof. Hongkun Park's laboratory studying defect engineering in single-walled carbon nanotubes. During her time as an undergraduate researcher she had the opportunity to learn about magnetic molecules through a fortuitous collaboration between Prof. Park and Prof. Jeffrey R. Long.
After graduation, Danna decided to pursue her interest in magnetic molecules and moved across the country to obtain a Ph.D. in Prof. Jeffrey Long's lab at the University of California, Berkeley. For her postdoctoral research she moved back to Cambridge, MA to work in Prof. Daniel G. Nocera's laboratory at the Massachusetts Institute of Technology.
After completing her postdoctoral research at MIT, Danna accepted a position as an Assistant Professor at Northwestern University. She recently moved to MIT.

The Freedman Group applies the atomistic control inherent to synthetic chemistry to address fundamental questions in physics. Within this paradigm, the group is focused on three vital areas of contemporary physics: advancing quantum information science, creating and understanding new magnetic materials, and designing new emergent materials. The researchers harness synthetic inorganic chemistry to target new systems, spectroscopy to probe compounds, and use fundamental ligand field considerations to aid in interpretation of emerging physico-chemical phenomena.

Professor Danna Freedman spent one week in Belgium in December and interacted with research groups from several universities (ULB, KU Leuven and UMONS).

At the ULB Professor Freedman was hosted by Prof. Yves Geerts who organized discussions with colleagues and young researchers.

Lecture

12 December 2023

Chemistry for the Second Quantum Revolution

The unique combination of atomic-scale tunability, reproducibility, and chemical specificity make paramagnetic molecules a paradigm-shifting category of materials for quantum information science. This capability has the potential to be transformative for developing a bespoke quantum ecosystem, as, for example, the requirements for a node within a quantum communications network are distinct and potentially orthogonal to those for a quantum sensor.

Our team imbued molecular qubits with the same read-out approach as defect-based systems. To achieve this, we envisioned an inverse design problem whereby we mimicked the electronic structure with an orthogonal physical structure. Using transition metal chemistry, we designed the ground state, excited states and dynamics based on straightforward ligand field analysis. By coupling optical read-out with spatial precision, we seamlessly integrated a new class of materials with existing read-out technology.

- Visit to KUL, hosted by Profs. Steven De Feyter, Johan Hofkens, Jeremy Harvey.
  Nano(bio)chemistry on surfaces is the core activity of the group.
  Lecture and discussions.
- Visit to UMONS, hosted by Profs. David Beljonne, Jérôme Cornil, Roberto Lazzaroni, and Yoann Olivier who are quantum chemists.
  Lecture and discussions.

2022 New Horizons Lectures in Physics (postponed in 2023)

Professor Nir Navon

Yale University, USA

Nir Navon is an Assistant Professor of Physics at Yale University. He received his undergraduate degree from the Université Libre de Bruxelles (Belgium) with a Master's degree from the Ecole Polytechnique (Palaiseau, France). In 2011, he obtained his Ph.D degree from the Ecole Normale Supérieure (Paris, France), where he developed novel methods to probe the thermodynamics of ultracold strongly correlated gases. He went on to a visiting stay at the Weizmann Institute of Science (Rehovot, Israel), where he developed high-fidelity entangling gates between trapped ions. He was then elected a Junior Research Fellow at Trinity College (Cambridge, UK), and joined the Cavendish Laboratory. During that period, he investigated the equilibrium and non-equilibrium behavior of homogeneous gases of weakly interacting bosons using groundbreaking advances in optical box trapping of atoms. He joined the Department of Physics at Yale in 2017. He has been awarded a 2017 Packard Fellowship for Science and Engineering.

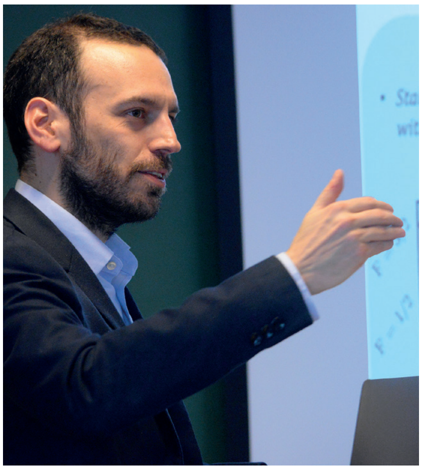
Nir Navon's research focuses on various aspects of the quantum many-body problem; his lab uses synthetic ultracold matter in programmable traps as a versatile experimental platform for this exploration. His lab's interests revolve around two broad axes: the study of the emergence of order and collective phenomena in homogeneous quantum matter, and the understanding of far-from-equilibrium turbulent dynamics of quantum fluids.

At the ULB, Professor Navon was hosted by Professor Nathan Goldman (Physics of Complex systems and Statistical Mechanics).

Lecture

20 March 2023

Many-body Physics with Fermions in an Optical Box



For the past two decades harmonically trapped ultracold atomic gases have been used with great success to study fundamental many-body physics in flexible experimental settings. However, the resulting gas density inhomogeneity in those traps makes it challenging to study paradigmatic uniform-system physics (such as critical behavior near phase transitions) or complex quantum dynamics. The realization of homogeneous quantum gases trapped in optical boxes has marked a milestone in the quantum simulation program with ultracold atoms[1].

These textbook systems have proved to be a powerful playground by simplifying the interpretation of experimental measurements, by making more direct connections to theories of the many-body problem that generally rely on the translational symmetry of the system, and by altogether enabling previously inaccessible experiments.

I will present a set of studies with ultracold fermions trapped in a box of light. This platform is particularly suitable to study problems of Fermi-system stability, of which I will discuss two cases: the spin-1/2 Fermi gas with repulsive contact interactions[2], and the three-component Fermi gas with spin-population imbalance[3]. Both studies lead to surprising results, highlighting how spatial homogeneity not only simplifies the connection between experiments and theory, but can also unveil unexpected outcomes.

Finally, I will discuss two ongoing efforts to tackle far-from-equilibrium dynamics of uniform fermions. One focuses on an impurity embedded in a Fermi bath and strongly driven between internal states; the second one aims at understanding the nonlinear density-density response of the weakly and strongly interacting Fermi gases.

- Visit to Antwerp University

  hosted by Prof. Jacques Tempere (Theory of Quantum systems and Complex systems).

- Visit to Ghent University

  visit of the laboratory of Prof. Karel Van Acoleyen (Department of Physics and Astronomy).

- Meetings of the Belgian Quantum Physics Initiative.

[1] N. Navon, R.P. Smith, Z. Hadzibabic, Nature Phys. 17, 1334 (2021).
[2] Y. Ji et al., Phys. Lev. Lett 129, 203402 (2022).
[3] G.L. Schumacher et al., arXiv:2301.02237.

Colloquium - Académie Royale de Belgique.

23 March 2023

Quantum Gases in Optical Boxes

Optical boxes have had a transformative impact on experiments with ultracold atoms[1]. They have allowed inter alia the creation of homogeneous-density quantum gases, a milestone in quantum many-body physics with ultracold atoms. These uniform gases have since opened many new research avenues by simplifying the interpretation of complex measurements and by enabling previously inaccessible experiments. In this short course, I will give a selected overview of exciting recent results on this topic, ranging from the thermodynamics of strongly correlated systems, to collective excitations across normal-superfluid transitions, to far-from-equilibrium dynamics.

[1] N. Navon, R.P. Smith, Z. Hadzibabic, Nature Phys. 17, 1334 (2021)

2023 New Horizons Lectures in Physics

Professor Alexander Zhiboedov

CERN, Genève, Switzerland

Fields of interest:

- Gravity
- Mathematical Physics
- QCD
- Quantum Field Theory
- String Theory

Alexander Zhiboedov is interested in understanding the space of quantum field theories (QFTs), especially the strongly coupled models. He applies and develops nonperturbative methods of the conformal and S-matrix bootstrap which rely on general principles, such as symmetry and quantum mechanics. One motivation for this work is holography which relates QFTs to quantum gravity in spacetimes with one extra dimension.

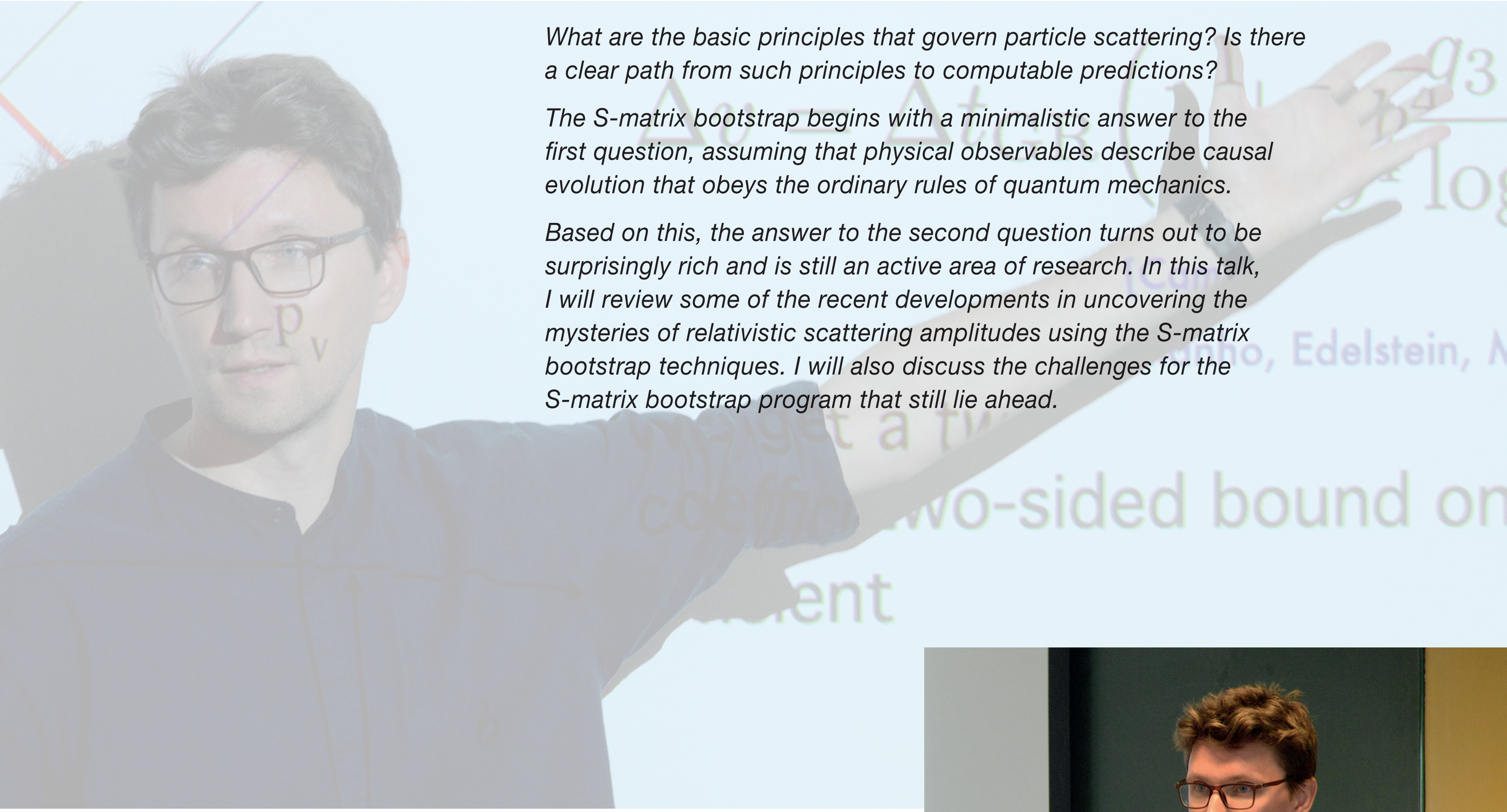
By understanding the space of consistent QFTs via bootstrap methods one hopes to get profound insight into nonperturbative aspects of quantum gravity and string theory, which are hard to probe otherwise.

In 2022, he was awarded the Prix Philippe Meyer «...for outstanding contributions to our understanding of the operator structure of quantum field theories with conformal invariance. His foundational work has applications to the search for new non-perturbative quantum field theories and to the analysis of Quantum Chromodynamics at particle colliders.»

Lecture

23 May 2023

The S-matrix Bootstrap: Exploring Everything, Everywhere, All at Once



What are the basic principles that govern particle scattering? Is there a clear path from such principles to computable predictions?

The S-matrix bootstrap begins with a minimalistic answer to the first question, assuming that physical observables describe causal evolution that obeys the ordinary rules of quantum mechanics.

Based on this, the answer to the second question turns out to be surprisingly rich and is still an active area of research. In this talk, I will review some of the recent developments in uncovering the mysteries of relativistic scattering amplitudes using the S-matrix bootstrap techniques. I will also discuss the challenges for the S-matrix bootstrap program that still lie ahead.

Mini-workshop "Strings, higher spins and amplitudes"

Mons, 25 May 2023

UMONS hosted a mini-workshop associated to the New Horizons Solvay Chair held by Sasha Zhiboedov. The goal of the workshop was to allow young researchers currently working in various Belgian universities to interact in an informal way with the Solvay chair holder.

Organizers

Nicolas Boulanger
Andrea Campoleoni
Evgeny Skvortsov

Programme

Lecture by Sasha Zhiboedov (CERN)

Massive and spinning colliding strings
Lecture by Chrysoula Markou (UMONS)

AdS_7 Black Holes from Rotating M5-branes
Lecture by Marina David (KUL)

Non-invertible symmetries along supersymmetric RG flows
Lecture by Jeremias Aguilera Damia (ULB)

Non-invertible symmetry, topological defects, and hamiltonian mechanics
Lecture by Alex Arvanitakis (VUB)

Near-extremal black holes in de Sitter space
Lecture by Francesca Mariani (UGent)

COLLOQUIA

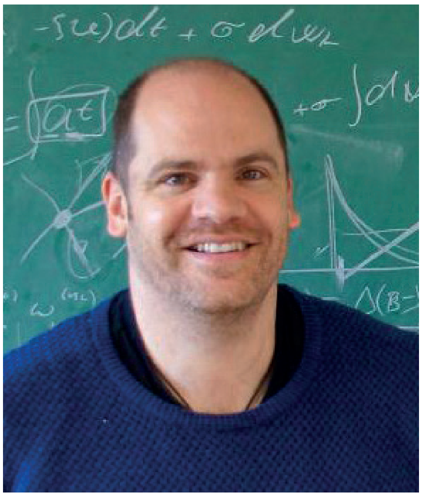
AI-accelerated Organic Synthesis

24 April 2023

Professor Philippe Schwaller
École Polytechnique Fédérale de Lausanne (EPFL), Switzerland

AI-accelerated organic synthesis is an emerging field that uses machine learning algorithms to improve the efficiency and productivity of chemical synthesis. Modern machine learning models, such as large language models, can capture the knowledge hidden in large chemical databases to rapidly design and discover new compounds, predict the outcome of reactions, and help optimise chemical reactions. One of the key advantages of AI-accelerated organic synthesis is its ability to make vast chemical data accessible and predict promising candidate synthesis paths, potentially leading to breakthrough discoveries. Overall, AI is poised to revolutionise the field of organic synthesis, enabling faster and more efficient drug development, catalysis, and other applications.

Towards a Nonequilibrium Thermodynamics of Complex Systems



9 May 2023

Professor Massimiliano Esposito
University of Luxembourg, Luxembourg

Equilibrium thermodynamics emerges from equilibrium statistical mechanics as the most likely behavior of a system in the macroscopic limit. Over the last two decades, enormous progress has been made in formulating statistical mechanics for small systems operating far-from-equilibrium. The resulting theory is called stochastic thermodynamics. I will show that taking the macroscopic limit of stochastic thermodynamics enables to formulate a nonequilibrium thermodynamics of large systems typically described by nonlinear deterministic dynamics which can also capture macroscopic fluctuations around it [1].

This macroscopic stochastic thermodynamics gives rise to novel fundamental results (for instance, once can bound nonequilibrium steady state fluctuations using the entropy production along deterministic relaxation trajectories [2]) and enables to recover many classical phenomenological results in macroscopic irreversible thermodynamics within well controlled approximations. It also opens the way to study the energetics of many complex nonlinear phenomena in a broad range of systems such as chemical reaction networks (CRNs), nonlinear electrical circuits, and Potts models. For systems displaying a modular structure, one can go even further and formulate a thermodynamic circuit theory, which, similarly to electrical circuit theory, uses the analogue of current-voltage characteristics and Kirchhoff's laws. I will focus on CRNs [3] and illustrate these ideas in the context of metabolism [4].

[1] G. Falasco and M. Esposito, "Macroscopic stochastic thermodynamics", to appear.
[2] N. Freitas and M. Esposito, "Emergent second law for non-equilibrium steady states", Nature Communications 13, 5084 (2022).
[3] F. Avanzini, N. Freitas and M. Esposito, "Circuit Theory for Chemical Reaction Networks", arXiv:2210.08035.
[4] A. Wachtel, R. Rao and M. Esposito, "Free-Energy Transduction in Chemical Reaction Networks: From Enzymes to Metabolism", J. Chem. Phys. 157, 024109 (2022).


Sortie de secours

Information processing in prebiotic reaction networks

14 November 2023

Professor Wilhelm T. S. Huck

Institute for Molecules and Materials
Radboud University, Nijmegen, The Netherlands

In life, the flow of information is as important as the flow of energy. Inspired by the unique ability of living systems to process information (in homeostasis, sensing, adaptation, growth) we are exploring routes to construct synthetic systems that capture some of the complexity of living systems.

Our focus is on complex networks of chemical reactions. We are familiar with the metabolic networks studied in biochemistry, and in recent decades many regularly recurring network motifs have been uncovered that are responsible for much of the functional behaviour in signalling or genetic networks. However, molecular 'circuits' are very delicate, and sensitive to changes in concentration, temperature, and so on.

In this lecture, I will discuss strategies to 'synthesize' programmable reaction networks in microfluidic flow reactors, and how to use these networks as powerful reservoir computers.

Some relevant publications:

[1] S.N. Semenov, et al. Nature Chemistry, 2015, 7, 160-165.

[2] A.S.Y. Wong, et al. J. Am. Chem. Soc. 2017, 139, 8146-8151.

[3] te Brinke, et al. Nature Nanotech. 2018, 13, 849.

[4] Zheng, L. et al. Nature Chemistry, 2019, 11, 359–366.

[5] Robinson, et al. Nature Chemistry 2022, 14, 623-631.

[6] van Duppen, et al. J. Am. Chem. Soc. 2023, 145, 13, 7559–7568.

DOCTORAL
SCHOOLS

XIX Modave Summer School in Mathematical Physics

4-9 September 2023

The Modave Summer School in Mathematical Physics is a summer school organised by and aimed at Ph.D. students. The school provides blackboard lectures given by young researchers. The lectures cover core subjects that contribute to the backbone knowledge of the participants working in the field of theoretical and mathematical physics, which includes topics in General Relativity, Quantum Field Theory and String Theory.

This year marks the 19th edition of the school! As for the previous years, the ULB, VUB, KUL and UMONS will join their forces to propose a unique scientific and human experience in the heart of the Belgian countryside.

Organising Committee

Ankit Aggarwal (ULB)
Sergio Ernesto Aguilar Gutierrez (KUL)
Ismael Ahlouche Lahlali (UMONS)
Lorenzo Cimino (UMONS)
Cyrille Chevalier (UMONS)
Victor Dehouck (UMONS)
Arnaud Delfante (UMONS)
Shailesh Dhasmana (UMONS)
Vasko Dimitrov (KUL)
Adrien Druart (ULB)
José Figueroa Silva (ULB)
Dima Fontaine (ULB)
Yegor Goncharov (UMONS)
Philip Hacker (VUB)
Dongming He (VUB)
Sahaja Kanuri (ULB)
Joel Karlsson (KUL)
Maria Knysh (VUB)
Lorenzo Küchler (ULB/KUL)
Guillaume Lhost (UMONS)
Simon Maenaut (KUL)
Ludovico Machet (ULB/KUL)
Louan Mol (ULB)
Josh O'Connor (UMONS)
Arthur Offermans (KUL)
Noémie Parrini (UMONS)
Gabrielle Pascuzzi (VUB)
Maxim Pavlov (VUB)
Simon Pekar (UMONS)
Sébastien Reymond (KUL)
Mattia Serrani (UMONS)
Antoine Somerhausen (ULB)
Colin Sterckx (ULB)
Arsenii Sukhanov (UMONS)
Wendi Tan (ULB)
Rob Tielemans (KUL)
Richard van Dongen (UMONS)
Romain Vandepopeliere (ULB)
Quentin Vandermiers (ULB)
Vincent Van Hemelryck (KUL)
Annelien Vekemans (KUL)
Milan Wils (KUL)
Xuao Zhang (KUL)
Sofia Zhidkova (VUB)

Lectures: topics and speakers

Introduction to AKSZ sigma models

by Thomas BASILE (UMONS)

The AKSZ construction (for Alexandrov, Kontsevich, Schwarz and Zaboronsky, authors of the seminal paper [hep-th/9502010] in which it was first introduced), allows one to define an action functional for a topological sigma model out of any graded symplectic manifold equipped with a compatible cohomological vector field, action which satisfies the classical master equation of the BV-BRST formalism. We will review this construction, along with the necessary background in graded geometry, and illustrate it by detailing the examples of the Poisson sigma model and Chern-Simons theory from this standpoint.

Carrollian Physics: Flat Spacetime as the Hologram of the Wonderworld

by Adrien FIORUCCI (Technische Universität Wien)

This series of lectures aims at introducing key concepts of Carrollian physics that emerges as the limit of Einstein's relativity in the vanishing speed of light regime. On the geometric side, the contraction induces the closure of light-cones along a timelike direction and the resulting manifold is equipped with a degenerate metric. Such geometric structures, which can be conveniently described as fibre bundles, are analysed in detail, as well as convenient choices of coordinates and connections. Carrollian isometries, which correspond to the contraction of the Poincaré algebra, are discussed and some elements of their representation theory are provided.

Next, a catalogue of Carrollian physical theories of particles and fields is compiled to further explore the interesting and peculiar features of this regime at both classical and quantum levels. Finally, the exploration of the Carrollian world culminates in a briefly discussion of its most important field of application, namely the formulation of a holographic description of asymptotically flat spacetime in the spirit of the celebrated AdS/CFT correspondence.

Field exploration in phases of matter

by Antoine PASTERNAK (INFN Milan)

A new look has been given to symmetries in quantum field theory in the last ten years. Generalized symmetries broadened our vision of their role in constraining the renormalization group flow. Together with the knowledge of their anomalies, they can be used to classify phases of matter that fall outside the scope of Landau's paradigm with ordinary symmetries. Examples include topological field theories, symmetry-protected topological phases, or deconfined phases of gauge theories. These lectures will introduce these notions and work out examples of quantum field theories that exhibit such phases.

Introduction to Exceptional field theory and its applications

by Colin STERCKX (ULB, Oviedo U.)

Supergravities are the low energy effective theories of the different possible superstrings. These supergravities are 10 or 11-dimensional theories, locally supersymmetric and with fluxes degree of freedom. The compactification of these theories, à la Kaluza-Klein, reveals unexpected exceptional symmetries descending from the superstring U-duality. It is a famously hard problem to consistently compactify supergravities in presence of fluxes to build new solutions in supergravity. In these lectures, we will see how Exceptional Field Theory makes these hidden symmetries explicit by expressing the degrees of freedom of supergravity in a U-duality covariant way and how it can be used to build consistent compactifications and truncations of different supergravities. More precisely, we will focus on compactifications of type IIB supergravity down to four dimensions maximal supergravity using E7(7)-Exceptional Field Theory.

Thermodynamics and Holography for de Sitter Space

by Manu VISSER (Cambridge U., DAMTP)

In this course I will survey some classical and quantum features of de Sitter space. The first part of the lectures is devoted to the thermodynamics of de Sitter horizons. In pioneering work from 1977 Gibbons and Hawking demonstrated that the static patch of de Sitter space has an associated entropy and temperature. I will review their paper and recent interpretations of their results in terms of operator algebras and thermodynamic ensembles. Secondly, I will discuss two different proposals for holography of de Sitter space: the dS/CFT correspondence and static patch holography. Even though there is not yet a precise dual description of de Sitter space, I will lay out some features that it has to satisfy.

Participants

Aguilar Gutierrez Sergio (KU Leuven)
Ahlouche Lahlali Ismael (UMONS)
Basile Thomas (UMONS)
Delfante Arnaud (UMONS)
Dhasmana Shailesh (UMONS)
Druart Adrien (ULB)
Ecker Florian (Technische Universität Wien)
Figueroa Silva Jose (ULB)
Fiorucci Adrien (Technische Universität Wien)
Fontaine Dima (ULB)
Guarini Robin (UMONS)
Knysh Maria (VUB)
Lhost Guillaume (UMONS)
Machet Ludovico (ULB/KU Leuven)
Mariani Francesca (UGent)
Mele Lea (UMONS)
Mol Louan (ULB)
O'Connor Josh (UMONS)
Parrini Noémie (UMONS)
Pasternak Antoine (INFN Milan)
Pavlov Maxim (VUB)
Serrani Mattia (UMONS)
Somerhausen Antoine (ULB)
Sterckx Colin (ULB, Oviedo U.)
Sukhanov Arsenii (UMONS)
Tan Wendi (ULB)
Thomée Sylvain (UMONS)
Van de Popoliere Romain (ULB)
Van Dongen Richard (UMONS)
Vandermiers Quentin (ULB)
Vilatte Matthieu (École Polytechnique, Palaiseau)
Visser Manu (Cambridge U.,)

Doctoral School on "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 Ecole Normale Supérieure, and various institutions in Switzerland led by the Swiss network "SwissMap" (ETH, U. Bern, U. Geneva, CERN).

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.

Participating 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

Organising Committee Brussels

Riccardo Argurio (ULB)

Ben Craps (VUB)

Frank Ferrari (ULB)

Isabelle Van Geet (Solvay Institutes)

Paris I 9 October - 27 October 2023

Alberto Lerda	*Introduction to String Theory*
Marco Billo	*Introduction to String Theory*
Geoffrey Compère	*Advanced General Relativity*
Adel Bilal	*Advanced Quantum Field Theory*

Geneva I 6 November - 24 November 2023

Domenico Orlando	*Introduction to Superstring Theory*
Silvia Penati	*Introduction to Supersymmetry*
Antoine van Proeyen	*Supergravity*
Susanne Reffert	*D-branes and Superstring Dualities*

Amsterdam I 4 December - 22 December 2023

Kyriakos Papadodimas	*AdS/CFT (Part 1)*
Lorenz Eberhardt	*AdS/CFT (Part 2)*
Balt van Rees	*CFT and bootstrap*
Migeul Monteiro	*Swampland*

Guest lectures

Andrea Puhm	*Celestial Holography*
Jeremy van der Heijden	*Algebraic Quantum Field Theory*
Marcel Vonk	*Non-perturbative Methods and Resurgence*

Participants

Afxonidis Evangelos (University of Oviedo, Spain)
Acalapati Madani Muhammad Ezra (ENS/ Sorbonne, France)
Ambrosini Marco (University of Geneva, Switzerland)
Arbalestrier Adrien (Université Libre de Bruxelles, Belgium)
Armanini Elisabetta (CERN and EPFL, Switzerland)
Bakker Maaike (Utrecht University, The Netherlands)
Basilavecchia Augustin (Université Libre de Bruxelles, Belgium)
Beauvillain Mathieu (École Polytechnique, Palaiseau, France)
Belaey Andreas (Ghent University, Belgium)
Corbeel Aude (University of Amsterdam, The Netherlands)
de Groot Jort University of Amsterdam, The Netherlands)
Douaud Simon (École Normale Supérieure, France)
Fumagalli Alessandro (University of Amsterdam, The Netherlands)
Girault Bastien (ENS Paris, France)
Heide Wallberg Anders (CERN and EPFL, Switzerland)
Hergueta Blanca (Universität zu Köln, Germany)
Honet Loïc (Université Libre de Bruxelles, Belgium)
Jansen Sarah (University of Amsterdam, The Netherlands)
Leflot Damien (Université Savoie Mont Blanc, France)
Lefundes Gabriel (IPhT, France)
Löwenberg Robin (University of Geneva, Switzerland)
Martina Adrien (École Polytechnique Fédérale de Lausanne, Switzerland)
Massidda Anthony (Università degli Studi dell'Insubria, Italy)
Mele Lea (University of Mons, Belgium)
Moran Claire (Utrecht University, The Netherlands)
Nenmeli Vijay (University of Edinburgh, UK)
Paznokas Elise (Université Libre de Bruxelles, Belgium)
Pochart Thomas (IP Paris, France)
Raj Rishi (Sorbonne Université, LPTHE, Jussieu, France)
Ramakrishnan Shradha (Utrecht University, The Netherlands)
Rieth Lizzy (University of Amsterdam, The Netherlands)
Rodrigues Ricardo (University of Porto, Portugal)
Scali Federico (University of Insubria, Italy)
Serrano Filipe (University of Porto, Portugal)
Smoes Thomas (Université Libre de Bruxelles, Belgium)
Suchel Noé (ENS Paris, France)
Supiot Clément (Institut Polytechnique de Paris, France)
Tappeiner Thomas (Ghent University, Belgium)
Thomée Sylvain (University of Mons, Belgium)
Tu Jingxin (University of Amsterdam, The Netherlands)
Varrone Mattia (EPFL, Switzerland)

Student's Opinion

Elise Paznokas

Postdoctoral student I Université Libre de Bruxelles, Belgium

The 2023 Solvay Doctoral School brought with it a journey across three countries, exposure to various physics topics taught by experts in each field, and assembled a community of doctoral students. Beginning this year at ENS (Paris), the lectures set a solid foundation, which included advanced QFT, string theory, and advanced GR. The following stints included a stay at CERN (Geneva) and then subsequently the University of Amsterdam, where we were able to get increasingly specialized lectures on topics from AdS/CFT, to D-Branes, the Swampland, and so much more.

The schedule is demanding, one can expect typically six hours of lectures per day. However, this is complimented by a good deal of bonding with other students and exploring the respective cities. Some of the most memorable moments for me over these few months included a guided tour of ATLAS while visiting at CERN and playing board games after lectures.

The opportunity to participate in this doctoral school was an invaluable experience for me. Academically, it allowed me to be immersed in high-level courses that bridged the gap between master's courses and doctoral research. It also introduced me to many of my fellow doctoral students across Europe, making not only a collaborative network of scholars but also a group of friends.

Overall, I would highly recommend the Solvay school to any incoming Theoretical Physics PhD students.

Student's Opinion

Andreas Belaey

Postdoctoral student I UGent, Belgium

The Solvay Doctoral Schools are the perfect way to break the ice in the first year of your PhD, and bridge the gap between master's level courses and advanced state-of-the art topics. The curriculum is thoughtfully structured, starting with introductory courses on subjects like supersymmetry and string theory, and progressing to more advanced topics such as supergravity, superstring theory, and conformal field theory.

This approach presented us with the unique opportunity to learn about a variety of subjects in the field of high-energy physics in a pedagogical manner from experts in the field.

The knowledge gained from these courses has already proven to be invaluable in shaping my own doctoral research endeavors.

One of the main assets of this school is its international character. During a nine-week period, we spent consecutive three-week-long programs in Paris, Geneva (CERN) and Amsterdam. This allowed us to get acquainted with the various cities and local research groups. Additionally, the social networking during the school has forged lasting friendships among fellow physicists from all over the world. Informal gatherings over dinner and spontaneous outings during weekends further enriched the experience, whether it is climbing the Eiffel Tower in Paris or visiting the Van Gogh Museum in Amsterdam. Of course, a three-week stay in Geneva would not have been complete without a visit to the nearby Alps, adding a touch of adventure to the academic journey.

Organized social activities by the school, such as a visit to the ATLAS experiment at CERN, certainly made lasting impressions on everyone, offering insights into cutting-edge research activities.

Not only could we socialize among fellow students, but the lecturers too were eager to discuss physics during the coffee breaks, or to go for an annual pizza dinner in town with the entire class. During these conversations, we could learn from their experience and expertise in academia.

From the comprehensive courses, to the unforgettable social interactions, I am grateful for the opportunity to have learned and grown alongside fellow physicists from all over the world.

06
2023

RESEARCH
AND RESEARCHERS

GRAVITATION, STRING THEORY AND COSMOLOGY

Research on Gravitation, String Theory and Cosmology

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

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Faculty Members

Riccardo Argurio (ULB)
Vijay Balasubramanian (VUB)
Glenn Barnich (ULB)
Vladimir Belinski (ICRAN, Italy)
Andrès Collinucci (ULB)
Geoffrey Compère (ULB)
Ben Craps (VUB)
Nathalie Deruelle (ULB & CNRS)
Stéphane Detournay (ULB)
François Englert (ULB, Honorary Member of the Institutes)
Oleg Evnin (VUB)
Frank Ferrari (ULB)
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Sudipta Dutta (ULB)
Camille Eloy (VUB)
Oscar Fuentealba (ULB)
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Marius Gerbershagen (VUB)
Juan Hernandez (VUB)
Ondra Hulik (VUB)
Mikhael Khramtsov (VUB)
Salvatore Mancani (ULB)
Kévin Nguyen (ULB)
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Alba Romero (VUB)
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Miguel Vanvlasselaer (VUB)
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Adrien Druart (ULB)
Hannah Duval (VUB)
José Figueroa Silva (ULB)
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Seppe Geukens (VUB)
Dongming He (VUB)
Loïc Honet (ULB)
Niranjan Kamath (VUB)
Sahaja Kanuri (ULB)
Maria Knysh (VUB)
Lorenzo Küchler (ULB)
Ludovico Machet (ULB)
Louan Mol (ULB)
Xander Nagels (VUB)
Gabriele Pascuzzi (VUB)
Maxim Pavlov (VUB)
Elise Paznokas (ULB)
Aäron Rase (VUB)
Thomas Smoes (ULB)
Antoine Somerhausen (ULB)
Colin Sterckx (ULB)
Wendi Tan (ULB)
Kevin Turbang (VUB)
Romain Vandepopeliere (ULB)
Quentin Vandermiers (ULB)
Sofia Zhidkova (VUB)

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). Two lines of investigation have been in particular vigorously pursued recently: developing flat space holography and understanding the role of quantum information and complexity in quantum gravity.

The direct detection of gravitational waves has opened in the last years a spectacular new window on the universe. The group has also invested efforts towards developing new analytical and numerical tools for analyzing gravitational radiation and is involved as well in the development of new detectors.

In 2023, we have continued our research along the general directions outlined above. This has led to 107 published papers and preprints submitted for publication. These are listed on pages163-173. Specific achievements by some researchers from the group are described in the subsequent pages.

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 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.

Previous Marina Solvay Fellows

- Waldemar Schulgin (2012-2014)
- David Tempo (2015)
- Jelle Hartong (2016)
- Adolfo Guarino (2017)
- Charlotte Sleight (2018)
- Sucheta Majumdar (2019)
- Oscar Fuentealba (2020)
- Luca Ciambelli (2021)
- Jakob Salzer (2022)
- Oscar Fuentealba (2023)

2023 Marina Solvay Fellow

Oscar Fuentealba

Postdoctoral researcher I ULB

Oscar Fuentealba got his PhD degree at the University of Concepción (Chile) in 2015. After a postdoctoral stay at CECs (Valdivia), he joined the group of the Director at ULB.

His research deals with Einstein theory of gravity: black hole solutions, black hole thermodynamics, supersymmetric models. More recently, he worked on asymptotic symmetries of gravity in the asymptotically flat space context, where infinite dimensional groups appear at infinity. He already held the Marina Solvay fellowship in 2020, and got it for a second time in 2023.

Asymptotic structure of spacetime, logarithmic supertranslations and the problem of the angular momentum ambiguity in General Relativity

Last century witnessed two major scientific revolutions. On one hand, we have Einstein's Theory of General Relativity, which brings an elegant geometrical description of the gravitational interaction. In spite of its impressive achievements, the theory is provided with a number of interesting puzzles, in particular when we try to place it in the same framework as the remaining fundamental interactions. This framework refers to the other revolution in Physics, which arises in order to understand our world in a microscopic scale, that is to say, the renowned Quantum Mechanics. The different efforts made with the aim to find a quantum description of the gravitational interaction has triggered the development of new mathematics and useful concepts in the description of emergent phenomena at rather diverse scales.
A beautiful example is the Post-Newtonian approximation in the merging of two black holes, i.e., describing the transition from inspiral to plunge in binary black hole coalescences, which is strongly inspired on Quantum Field Theory technics. This model played a key role in the first observation of gravitational waves by the LIGO-Virgo collaboration (see Figure 1). Nowadays, these developments allow us to observe the universe and the stellar dynamical processes by making use not only of the electromagnetic spectrum, but also the gravitational one.

Nonetheless, the interesting puzzles that remain open in the context of Einstein's theory have led to explore several aspects of it. Among them, we can find the problem of the infrared structure and its connection with an accurate characterization of the global properties of the spacetime. The latter is subordinated to a rigorous study of the asymptotic structure of the theory, which would bring the observables of a plausible quantum description of spacetime. This exploration has shown to be of a great relevance in the context of the holographic principle through the famous AdS/CFT correspondence. This conjecture claims that a quantum theory of gravity with negative cosmological constant (Anti-de Sitter or AdS spaces) should be equivalent to Conformal Field Theory (CFT) living in the spacetime boundary.

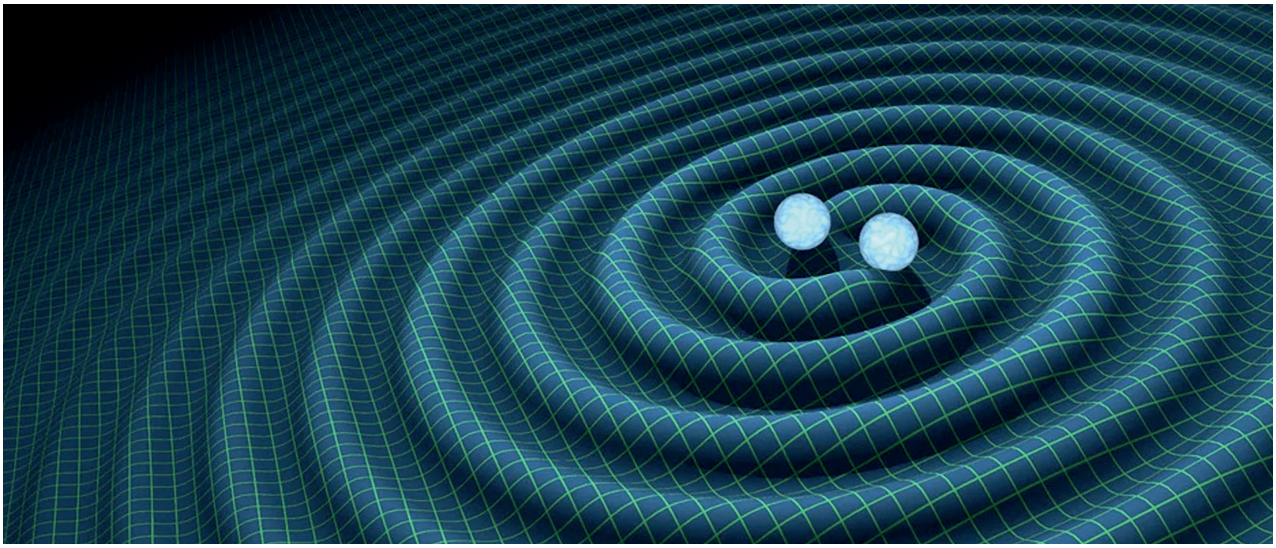
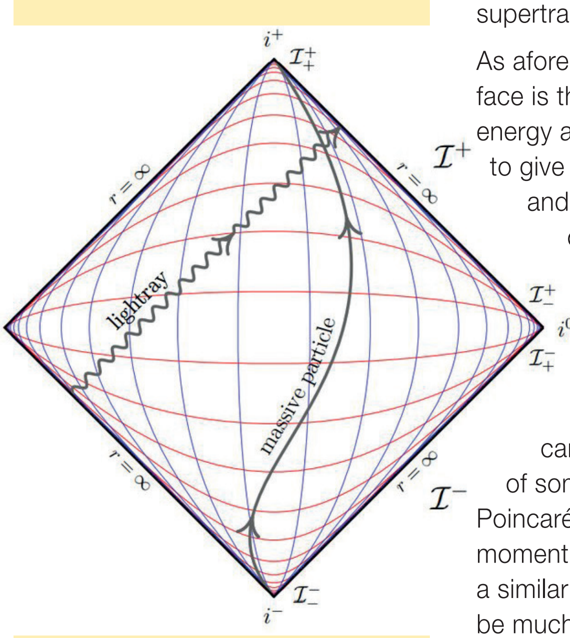


Figure 1:
The collaboration between LIGO (The Large interferometer Gravitational-Wave Observatory) and Virgo (named after the Virgo cluster) performed the first detection of a gravitational wave signal on September 2015, almost one hundred years after the publication of Einstein's Theory of Gravitation. These gravitational waves can be seen as ripples in spacetime made by the merging of two black holes (Credit figure: Caltech).

An explicit realization of this conjecture was found almost 12 years before of its publication, in the precursor work by J. David Brown and Marc Henneaux. They showed that the conformal symmetry in two dimensions (described by two copies of the infinite-dimensional Virasoro algebra) can be obtained from the canonical realization of the asymptotic symmetries of three-dimensional AdS spacetimes. General Relativity in four spacetime dimensions possesses also a very rich asymptotic structure, which reflects on the existence of the BMS group, named after Bondi, van der Burg, Metzner and Sachs in the 60's. BMS is an infinite-dimensional group that turns out to be an enhancement of the Poincaré group with a generalization angle-dependent (coordinates of the sphere at infinity) translations, known as *supertranslations*.
In the last 10 years this asymptotic symmetry group has attracted a great deal of attention. This because of the intriguing connection, found by the Harvard school, of BMS symmetry with Weinberg's soft theorems (within the context of scattering amplitudes) through Ward identities, which has led to a deeper physical understanding of classical and quantum properties of gravity (see, e.g., [1]).

Figure 2:
Penrose's diagram represents the conformal compactification of the Minkowski space. This diagram is useful to describe the casual structure of spacetime and to visualize its different asymptotic regions. (Past and future) null infinities, denoted by I±, correspond the regions that can only be reached by lightrays (electromagnetic or gravitational radiation), while (past and future) timelike infinities i± stand for the asymptotic region reached by massive particles. Finally, spatial infinity i0 denotes a set of points causally disconnected from any physical event in the manifold, so that it can be regarded as the "distant" asymptotic region of the spacetime (Credit figure: [1]).



These last interesting developments have driven in—so far—two possible holographic descriptions of asymptotically flat spacetimes (by flat we refer to a theory devoid of a cosmological constant).
One alternative is the Celestial Holography proposal, which is based on the technical fact that the elements of the gravitational scattering matrix written in terms boosts eigenstates take the form of conformal correlation functions. Thus, the dual boundary theory can be seen as a Celestial Conformal Field Theory in two dimensions. The second alternative corresponds to a three-dimensional dual theory invariant under the BMS symmetry initially defined in an asymptotic region of the spacetime called null infinity (see Figure 2), which can only be reached by electromagnetic or gravitational radiation. It has been shown that the BMS group is isomorphic to the conformal Carroll group in three dimensions, this is why this dual theory can be also understood as a Conformal Carrollian Field Theory.

There are still a number of questions that require a more careful study of the asymptotic structure of General Relativity and in particular of the BMS group. For instance, in spite of the BMS group was first discovered in the asymptotic region known as null infinity, and it was only recently (in 2018) that was found at spatial infinity (see Figure 2) in [2].
The presence of the BMS symmetry at spatial infinity allowed to apply all the available machinery to construct well-defined canonical generators for supertranslation charges.

As aforementioned, another problem that Einstein's gravity has had to face is the one related to a precise definition of global quantities, as energy and angular momentum of the spacetime. It took some decades to give a precise definition of energy for asymptotically flat spacetimes and to show its positivity since the publication of the Einstein theory of gravity at the beginning of the 20th century. The case of angular momentum in General Relativity is even more dramatic, whose definition is still a matter of cutting-edge research.
The *problem* lies on the fact that its known definition is not invariant under the aforementioned BMS supertranslations. The angular momentum ambiguity under ordinary translations can be solved by defining an intrinsic angular momentum in terms of some quantities called Casimirs (invariants under the action of the Poincaré group). The latter is indeed equivalent to compute the angular momentum with respect the center of mass wordline. However, a similar construction for the case of BMS supertranslations has shown to be much more involved.

Recently, in a collaboration with Marc Henneaux and Cédric Troessaert in [3], we were able to relax the asymptotic conditions that define an asymptotically flat spacetime by accommodating terms that behave logarithmically (in the radial coordinate) at spatial infinity. This led us to unveil a brand-new class of supertranslations, called *logarithmic supertranslations*, which form a conjugate pair with the usual BMS supertranslations.

Mathematically, the above statement means that the Poisson brackets (or commutators at quantum level) between the canonical generators associated to these transformations give an invariant quantity (under all symmetry transformations) known as central charge. We then say that *all* supertranslations form a centrally extended Abelian algebra. Notably, the presence of this invariant quantity in the algebra of the asymptotic symmetries allowed us to find a definition for the Lorentz canonical generators that is invariant under all supertranslations. In consequence, we constructed an appropriate redefinition of the angular momentum that is invariant supertranslations, solving in this way “the problem of the angular momentum ambiguity in General Relativity”. In a recent article [4], we showed explicitly the equivalence of our definition for the angular momentum with analogue expressions in the no-radiative phase of future null infinity (asymptotic region denoted by $\mathscr{I}^+_-$ in Figure 2).

It must be stressed that the new set of asymptotic conditions introduced in [3] leads to a new algebra of asymptotic symmetries for Einstein’s gravity, which is given by the direct sum of the Poincaré algebra and the (centrally extended) Abelian algebra of all (logarithmic and BMS) supertranslations.

This decoupling mechanism of infinite-dimensional symmetries from the Poincaré algebra is not a peculiarity of Einstein gravity in four spacetime dimensions. Indeed, in [5], we generalized this statement to the case of Maxwell electromagnetism, where in addition to the *logarithmic* infinite-dimensional gauge transformations, we found that Maxwell theory is also invariant under a new infinite-dimensional symmetry generated by a parameter with a linear asymptotic behaviour (in the radial coordinate). We have also explored the generalization of these results in higher dimensions, specifically in the context of electromagnetism in [6] and (super)gravity theories in [7] and [8].

These novel results trigger challenging new questions in the field, as for instance, the intriguing connection with null infinity, which includes the analysis of the existence of logarithmic supertranslations at null infinity and new possible symmetries of the gravitational scattering matrix, in the line of Strominger’s proposal in [1]. Specifically, it would be interesting to carry out the study of new memory effects (infrared gravitational effect that has been associated to the BMS supertranslations) and to explore the Ward identities associated to these new symmetries.

References

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[3] O. Fuentealba, M. Henneaux and C. Troessaert, ``Logarithmic supertranslations and supertranslation-invariant Lorentz charges," JHEP 02, 248 (2023) [arXiv:2211.10941 [hep-th]].

[4] O. Fuentealba, M. Henneaux and C. Troessaert, ``Asymptotic Symmetry Algebra of Einstein Gravity and Lorentz Generators," Phys. Rev. Lett. 131, no.11, 111402 (2023) [arXiv:2305.05436 [hep-th]].

[5] O. Fuentealba, M. Henneaux and C. Troessaert, ``A note on the asymptotic symmetries of electromagnetism," JHEP 03, 073 (2023) [arXiv:2301.05989 [hep-th]].

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[7] O. Fuentealba and M. Henneaux, ``Simplifying (super-)BMS algebras," JHEP 11, 108 (2023) [arXiv:2309.07600 [hep-th]].

[8] O. Fuentealba and M. Henneaux,``The BMS group in D= 6 spacetime dimensions," [arXiv:2312.12627 [hep-th]].

Research Interests and Achievements of some other members

Maria Knysh

Doctoral researcher I VUB

The 20th century witnessed two paramount scientific achievements—general relativity and quantum mechanics. General relativity elegantly captures the macroscopic fabric of the universe, while quantum mechanics delves into the microscopic intricacies of nature. Despite their successes, the seamless fusion of these theories into a unified framework, quantum gravity, remains an ongoing pursuit. This quest sparks the curiosity of today's scientists, urging them to explore the fascinating realm where the grand structures of general relativity collide with the intriguing quantum details exposed by quantum mechanics.

In the theater of the cosmos, black holes are one of the most important protagonists. Black holes are often described as remarkable solutions to Einstein's equation: special geometries characterized by the existence of a singularity and a surface of no return called a horizon. The first indirect evidence of a real black hole dates back to 1964. In April 2019, the first images of a black hole shadow were revealed. Yet, black holes are more than just observational curiosities. They transform into theoretical laboratories and provide interesting insights into quantum field theory and quantum gravity.

The link emerges through the holographic principle, which was explicitly realized by Maldacena in the anti-de Sitter/conformal field theory (AdS/CFT) correspondence in 1997. This principle conjectures that a theory of gravity is equivalently described through a lower-dimensional quantum field theory residing on its boundary. Specifically, it establishes a remarkable duality linking a theory of fields endowed with conformal invariance on d-dimensional flat space to a dynamic theory of gravity in a (d + 1)-dimensional AdS space. Notably, within this framework, black holes in AdS are dual to thermal CFT states. Consequently, questions about the dynamics of black holes can be translated into inquiries about the dynamics of thermal fields through the holographic dictionary, and vice versa.

One intriguing question relates to quantum chaos and the response of black holes to small perturbations. As thermal quantum objects, black holes should relax back to equilibrium when perturbed slightly. Classically, such thermalization processes are expected to be driven by dynamical chaos. A natural inquiry arises: does this extend to quantum systems as well? Defining and characterizing chaos in thermal quantum systems has been an active research area of the past few decades.

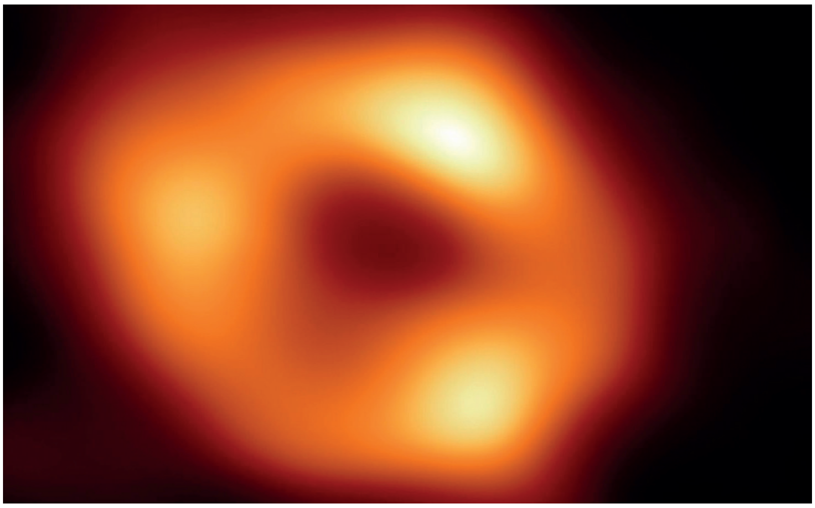


Figure 1:
The first image of the supermassive black hole in the middle of our galaxy, released on May 12th, 2022 by the Event Horizon Telescope collaboration.

A source of inspiration is the characterizing feature of classical chaos, a trajectory diverges exponentially fast from the reference trajectory when initial conditions change slightly. Existing probes of quantum chaos mimic this classical butterfly effect reflecting that an initially small perturbation will spread exponentially fast amongst the other degrees of freedom after which it gets scrambled and hidden to local measurements. Studying aspects of quantum chaos in holographic thermal quantum systems through various probes on both sides of the duality is one of my main research interests.

In collaboration with researchers at MIT and UniFI (Hong Liu and Natalia Pinzani-Fokeeva), our work aims to unravel the mechanisms rendering a thermal quantum system chaotic. Recent efforts on the field theory side, led by Hong Liu and collaborators, propose a universal description for systems exhibiting quantum chaotic behavior.
According to their insights, quantum chaos emerges due to the invariance of the theory under a specific symmetry. Our work focuses on solidifying the foundation of this postulated symmetry, identifying its dual counterpart as a symmetry of the horizon in the dual black hole description, and mapping it to the field theory.

In parallel, with colleagues from Ben-Gurion University and VUB (Shira Chapman, Ben Craps, Saskia Demulder and Andrew Rolph), we investigate the implications of this symmetry on Krylov complexity —a novel probe of quantum chaos. This quantity measures how fast quantum operators grow in Krylov space spanned by nested commutators of the Hamiltonian of the system and the operator in question. For chaotic systems, Krylov complexity is expected to grow exponentially in time, also mimicking the classical butterfly effect.
We aim to determine how the postulated symmetry influences the growth patterns within Krylov space, unraveling the connection between the symmetries of the system, quantum chaos, and the dynamic behavior of thermal quantum systems.

Another prominent area of research is the statistical origin of the Bekenstein - Hawking black hole entropy and its interpretation as an entanglement entropy defined in the dual CFT. Entanglement entropy, a concept borrowed from quantum information theory, quantifies the correlation of a subset of degrees of freedom in a given system with the rest of the system. Over the years, (holographic) entanglement entropy has seen remarkable advancements, playing a crucial role in resolving longstanding problems such as the black hole information paradox, at least in some simple, lower dimensional gravity theories. Yet, many puzzles remain, including the finite nature of the black hole entropy which suggests that there are finitely many states, black hole microstates, that span the Hilbert space describing the quantum dynamics of black holes.

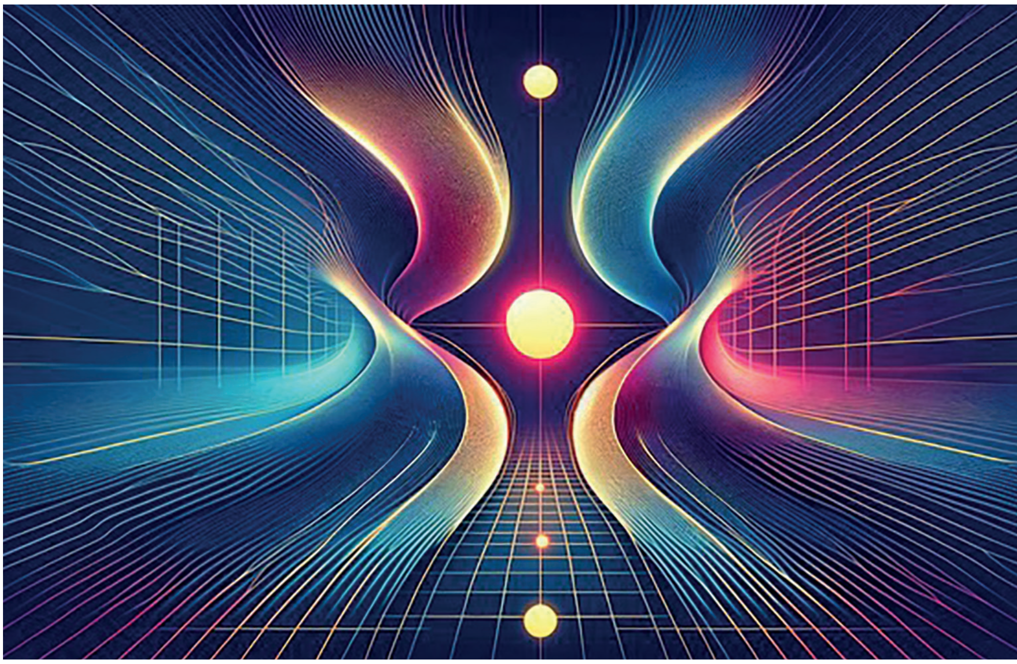
With collaborators at VUB (Vijay Balasubramanian, Ben Craps, Juan Hernandez and Mikhail Khramtsov) we are building upon the work of Vijay and collaborators to gain more insight into the dimension of the black hole Hilbert space. A black hole can develop from many initial states that differ in their late-time interior, these are examples of different microstates. However, one can construct infinitely many geometries that are a solution to Einstein's equations and look like the same black hole from the outside but have different interiors behind the horizon.
Yet, these solutions are not all independent, they overlap quantum mechanically. With the correct counting prescription, one can find that these states span a finite-dimensional Hilbert space with dimension in agreement with the black hole entropy. We are interested in expanding these results and constructing microstates for a black hole that grows or evaporates, by including states with infalling or outgoing shells of matter. The aim is to refine the counting prescription, making it applicable to more intricate scenarios. By accurately counting the dimensionality of the Hilbert space governed by these newly constructed states, we expect to reproduce the change in black hole entropy that occurs when adding or removing these shells of matter. Once the microstate construction and the counting prescription are perfected, these methods can be applied to other open questions, such as the understanding of the de Sitter horizon entropy or equivalently, the dimension of the Hilbert space of a ball of space in general relativity with a positive cosmological constant.

Luigi Tizzano

Postdoctoral researcher I ULB

Quantum field theory is the language adopted in theoretical physics to explain a broad spectrum of natural phenomena ranging from the interactions of elementary particles in colliders to the microscopic changes in the phases of matter. Even though such a powerful idea has led to impressive discoveries, many systems in nature cannot be described with our current knowledge of quantum field theory.
A prominent example of such limitation appears in the study of quantum chromodynamics, the physical theory underlying the structure of nuclei. At low energy, quarks are so tightly bound together that it is not possible to separate them into elementary constituents.
This phenomenon, which has many experimental confirmations, is known as confinement, and it is one of the most elusive problems in theoretical physics. Theories that exhibit similar puzzling phenomena are ubiquitous in physics, illustrated by a wide range of phenomena such as high-temperature superconductivity and the behavior of gravity at the Planck scale. Being able to understand even the most basic properties of strongly coupled systems is thus an essential step in the solution of these fundamental physics problems.

My research aims to develop new non-perturbative techniques to enhance our current understanding of the dynamics of strongly coupled theories, including gauge theories with a mass gap as well as conformal quantum field theories (CFTs). Over the last few years, I have been particularly interested in studying these systems by adopting a viewpoint deeply focused on modern generalizations of global symmetries and their dynamical implications.



Symmetry is a fundamental concept in physics that has been used to guide research and development for a very long time. It is the foundation of key discoveries such as Noether's theorems, which link symmetries and conservation laws, and Landau's theory of phase transitions. The fundamental forces of Nature are represented by local gauge interactions. In this framework, a useful mathematical concept known as gauge redundancy is introduced to maintain consistency with the principles of locality and Lorentz invariance in relativistic quantum field theory. However, it is well appreciated that these gauge redundancies do not lead to any physically observable effects.
On the contrary, global symmetries have consequences for the spectrum of physical observables in a given theory, they can be spontaneously broken and are very useful even if only approximate. Examples of this are the approximate but unbroken symmetries of SU(3) flavor and SU(2) isospin in QCD, as well as the approximate discrete symmetries C and P. QCD also breaks its approximate chiral quark flavor symmetries.
The resulting particle excitations are known as Nambu-Goldstone bosons or pions and have played an essential role in our understanding of QCD.

The understanding of global symmetries in quantum field theory has recently been subject to a profound revolution. The modern point of view on symmetries is based on the notion of extended topological operators also known as defects. These operators are supported on a codimension-(p+1) manifold in spacetime, on which they depend 1 only topologically, that act on extended p-dimensional objects giving rise to the so-called p-form global symmetries.

A surprising realization that follows from this analysis is that not all topological defects form a group. There exist defects that do not have an inverse and whose fusion algebra involve more than one operator. These non-invertible topological operators should also be seen as novel generalizations of global symmetries. The study of topological symmetry defects and their general properties is by now a very active area of research that is focused on identifying generalized global (categorical) symmetries of a rapidly growing list of theories.

Most of the studies available in the literature do not analyze the broader dynamical implications of these symmetries. The main objective my research is to fill this gap and explore how generalized global symmetries can be leveraged to impose new constraints on the renormalization group (RG) flows of various quantum field theories (QFTs). The key tools that we will adopt are the study of anomalies and symmetric deformations of a given model to analyze its long distance behavior.

Highlighted below is a curated selection of my research contributions as a Solvay Fellow:

- In collaboration with J. Aguilera Damia (ULB), R.Argurio (ULB), F. Benini (SISSA), S. Benvenuti (SISSA) and C. Copetti (SISSA) we presented novel constraints on partial supersymmetry breaking RG flows of N=4 SYM theory, drawing on non-invertible symmetries and their anomalies. This research also shed light on the concept of spontaneously broken non-invertible symmetries and offered a microscopic description of the gapped vacua in N=1* SYM using purely field-theoretical methods. This represents one of the earliest applications of dynamical constraints from non-invertible symmetries in four-dimensional gauge theories.
- In collaboration with J. Aguilera Damia (ULB) and R.Argurio (ULB) we established the existence of continuous 2-groups in three-dimensional quantum field theory which were previously thought not to occur. Thanks to a novel gauging procedure that has been introduced in that paper we also uncovered novel examples of non-invertible symmetry defects for continuous symmetries which have been one of the main focuses of the high-energy theory community in the past year.
- In collaboration with K. Ohmori (U. of Tokyo) we used anomalies to establish non-perturbatively the value of certain transport coefficients that are widely studied in finite temperature quantum field theory. This analysis can also be applied to supersymmetric quantum field theories to study their Cardy limits behavior which is important in the study of BPS black holes of relevance for the AdS/CFT correspondence.
- In collaboration with P. Benetti Genolini (King's College) we analyzed the role of generalized global symmetries in five-dimensional quantum field theories. We found a new mixed anomaly between the ordinary instantonic symmetry and the 1-form center symmetry. First, this anomaly can be used to investigate the phase diagram of non-supersymmetric Yang-Mills theory at finite temperature which is of interest for lattice simulations. At the same time, the anomaly can be applied to supersymmetric quantum field theories that are UV completed by 5d superconformal field theories. In this context, we presented a novel non-perturbative argument for the pattern of global symmetry enhancement that these theories should exhibit. This work has sparked a lot of interest in communities interested in 5d SCFTs that have been studying intensely the problem of global symmetry enhancement in recent years.

Soumyadeep Chaudhuri

Postdoctoral researcher I ULB

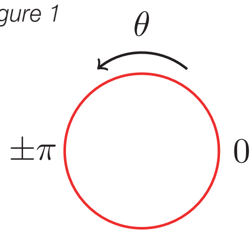
The framework of quantum mechanics provides the foundation of our current understanding of the different phenomena in nature. To describe some of the fundamental interactions between particles, one needs to extend this framework to fields defined on the continuum of spacetime. Over the last few decades, the theories of such 'quantum fields' have become crucial tools to study the dynamics of a broad class of systems going far beyond the original domain of particle physics. Hence, it has become imperative to develop a deeper understanding of these theories.

One of the key features of quantum field theories (QFTs) that guides us in understanding them is the presence of global symmetries, i.e. transformations of the degrees of freedom of a system that leave its dynamics invariant. Such symmetries often provide analytic handles to study different aspects of the system. Moreover, there are also interesting scenarios where the action of such symmetry transformations do not leave the vacua (the lowest energy states) of the theory invariant – a phenomenon known as 'spontaneous symmetry breaking'. Determining whether a symmetry in a system is spontaneously broken or not provides a ways to classify the different phases of the system.

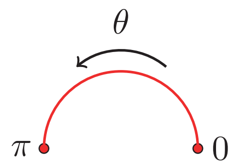
Traditionally, the symmetry transformations that have been explored by physicists are ones that act locally on the fields. Furthermore, they constitute certain mathematical structures called 'groups' which, in particular, means that for every symmetry transformation, there is an inverse transformation which brings the system back to the original configuration. In recent years, the above notion of symmetries has been extended significantly to include firstly, transformations that do not act locally on the fields, and secondly, transformations that are not invertible. The latter generalization is particularly remarkable as it requires going beyond the above-mentioned group structure and developing a mathematical framework for dealing with these symmetries. The relevant mathematical framework is the theory of categories which is presently being extended to incorporate the various novel features of non-invertible symmetries. Aside from the interest in the underlying mathematics, a lot of effort is also being invested to understand the different physical implications of such non-invertible symmetries. For the last year and a half, in collaboration with Jeremias Aguilera Damia and Prof. Riccardo Argurio, I have been studying the spontaneous breaking of such non-invertible symmetries in certain quantum field theories and its implication for the vacuum structure of those theories.

The simplest theory which can be tweaked to obtain such non-invertible symmetriesis that of of a free compact scalar field φ in three or more spacetime dimensions. Such a theory usually emerges as the effective dynamics of a Nambu-Goldstone boson in the event of spontaneous breaking of a $U(1)$ global symmetry in a QFT. The effect of the spontaneous breaking of this symmetry is that instead of a single vacuum, there is a moduli space of vacua of the theory which takes the form of a circle parameterized by $\theta \in [-\pi, \pi)$ as shown in figure 1(a). The $U(1)$ symmetry transformation implements shifts in this moduli space. In addition to this $U(1)$ symmetry, there is also a global Z_2 charge conjugation symmetry in the model which takes φ to $-\varphi$. Now, one can gauge this Z_2 symmetry which tantamounts to identifying the field configurations that are obtained from each other by local transformations of the form $\varphi \to -\varphi$. The gauging of the Z_2 symmetry does not completely destroy the aforementioned shift symmetry in the model but makes it non- invertible.

Figure 1



(a) Moduli space of vacua before Z_2 gauging



(b) Moduli space of vacua in the Z_2 gauged theory

We showed that this non-invertible symmetry is spontaneously broken leading to the emergence of a moduli space of vacua which takes the form of an S^1/Z_2 orbifold as shown in figure 1(b). The regular points on this orbifold are parameterized by $\theta \in (0, \pi)$, while the end-points, $\theta = 0$ and $\theta = \pi$, are the singular points of the orbifold. We identified certain operators that implement translations between the regular points and showed that these operators act trivially on the singular points, i.e. they leave these vacua invariant. We also showed that the non-invertible symmetry transformations can implement transitions from the singular points to the regular points and vice versa. Furthermore, we found that these distinctions between the two classes of vacua lead to an essential difference in the Hilbert spaces built upon them. On the one hand, the states built upon the vacua at the regular points of the orbifold are quite similar to those in the original theory before gauging the Z_2 symmetry. In particular, there is no constraint on the number of Nambu-Goldstone bosons for these states. On the other hand, the Hilbert spaces built upon the vacua at the singular points are distinguished by the absence of all states with odd number of Nambu- Goldstone bosons. Such a distinction between the states living on the different vacua of a theory is a unique feature of the spontaneous breaking of non-invertible symmetries. I am interested in exploring further consequences of such spontaneous breaking of non-invertible symmetries and in finding their phenomenological implications in physical systems.

Apart from the above-mentioned work on quantum field theories, I am also trying to understand some aspects of 2-dimensional theories of quantum gravity. At a classical level, Einstein's theory of general relativity provides a clear description of gravity in terms of the geometry of spacetime. However, unlike the other fundamental interactions (electroweak and strong interactions), coming up with a quantum theory of gravity that describes our Universe still remains an open problem. To make headway in solving this problem, it is useful to study consistent theories of quantum gravity where one can employ some analytic techniques to do concrete computations. Certain 2-dimensional models of quantum gravity provide precisely such a setting and allow one to explore some possibly more general aspects of quantum gravity. One such model that has been studied extensively for the last few decades is commonly known as 'Liouville gravity'. It is a theory where the metric of a 2-dimensional space is allowed to fluctuate and the quantum path integral involves summing over the contributions of all such metric configurations. In recent years, a new class of models of 2d quantum gravity has received considerable attention. This class of models is known as 'Jackiw-Teitelboim gravity' or JT gravity in short. These models are distinguished from Liouville gravity by the constraint that the allowed metrics correspond to constant bulk curvature.

The interest in these models arose from the observation that in the negative curvature case, a certain limit of JT gravity (known as the 'Schwarzian limit') is holographically dual to the low energy regime of some quantum mechanical systems (SYK and tensor models). Moreover, in the same limit, it was also found that JT gravity provides an effective description of the near-horizon regime of higher dimensional black holes. These observations have led to a lot of research on the negative curvature case of JT gravity with particular emphasis on the duality with the quantum mechanical models mentioned earlier. However, very little is known about what happens in the negative curvature case beyond the Schwarzian limit, and even less is known about JT gravity with zero or positive curvature. Furthermore, we lack an understanding of the behaviour of these theories in the presence of matter coupling to the metric. For the last few months, in collaboration with Prof. Frank Ferrari, I have been working on filling these gaps in the understanding of these theories.

To address the above-mentioned issues, we coupled JT gravity (with positive, negative or zero curvature) defined on a space with the topology of a disk to conformal matter with central charge c.

We considered a regime where c is a large negative number, while the cosmological constant scales linearly with $|c|$ and the boundary of the disk is fixed at a finite length. In the negative curvature case, this regime is away from the Schwarzian limit due to the finite length of the boundary. The advantage of working in this regime is that it allows for a perturbative expansion of the free energy in powers of the small parameter $\frac{1}{|c|}$. At leading order in this expansion, the contributions come from certain saddle point configurations. We identified these configurations for each of the cases of negative, positive and zero curvature, and computed their contributions to the free energy. Moreover, we calculated the first subleading corrections to these leading order values that arise due to the quantum fluctuations of the metric over the saddle point configurations. These results provide some initial insight into the features of these theories away from the Schwarzian limit. Furthermore, the general framework provides a systematic way to perturbatively compute the effects of the quantum fluctuations of the metric. In the future, I would like to go beyond this perturbative regime and extract some non-perturbative (exact) features of these models. It would also be very interesting to find holographic duals of these models which may lead to discovering novel quantum mechanical systems and offer fresh insights on some general aspects of quantum gravity.

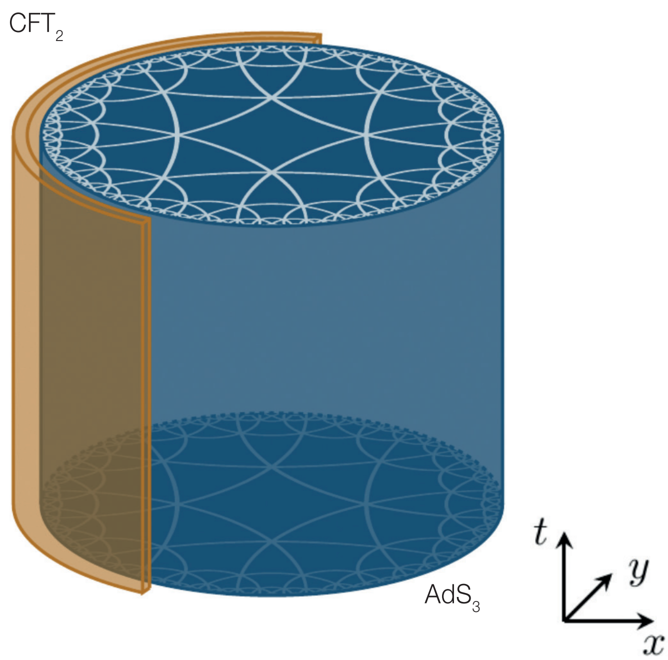
Camille Eloy

Postdoctoral researcher I VUB

A fundamental challenge in modern physics is the construction of a consistent theory of quantum gravity. Such a construction builds on general relativity, devoted to the study of gravitational interactions, and quantum field theory, which describes physics at small length scales. The scopes of these two theories are very different: the former is about solar systems, galaxies and the universe, while the latter focuses on electrons, atoms and particle physics. Although these domains of validity are usually well-separated, there are particular situations where quantum corrections to general relativity are needed, such as the studies of the birth of our universe and of the interior of black holes. However, these situations are not reproducible as laboratory experiments, nor accessible to astronomical observations (although recent progresses indicate that gravitational wave experiments will provide powerful tool to explore extensions of general relativity). The search for a consistent theory of quantum gravity is thus quite peculiar, compared to how research in theoretical physics is usually conducted.

The need for a new theory is typically motivated by an experiment whose results do not fit into any existing model. The new model is validated if it can explain the initial experiment while remaining consistent with the pre-existing results, and can then be used to predict new physical phenomena. This often requires several back and forth between experiments and theory. On the contrary, theoretical physicists searching for quantum gravity must rely on theoretical thinking only, building the theory from what they think it should be. The theory is not constrained by some experimental results, but by its conceptual and mathematical consistency. Of course, one can base one's thinking on well-established theories, like quantum theory and general relativity. However, naively applying to gravitation the recipe that succeeded for particle physics leads to problems that cannot be resolved in the usual framework, so that the resulting theory fails to predict anything.

String theory is a proposal that approaches quantum gravity from a radically different perspective. It trades the concept of point-like elementary particles for one-dimensional extended objects, called strings. This paradigm shift radically changes the way physical interactions are described. In particular, particle states are interpreted as excitation modes of the string. Among those states, there is a spin-2 mode which corresponds to the graviton. Quantum gravity is thus built in to string theory. Furthermore, classical general relativity (with additional ingredients) arises as a point particle limit of the theory. This limit can be viewed as the leading term in an expansion in the inverse string tension α', and sub-leading terms in this expansion correspond to corrections to general relativity, in the form of additional higher-derivative terms in the usual two-derivative Einstein-Hilbert action. These corrections are essential as they result in deviations from the predictions of general relativity, that could eventually be tested in gravitational wave experiments.



However, the consistency of string theory imposes constraints. It requires supersymmetry, a symmetry that relates bosonic (i.e. associated to physical interactions) and fermionic (i.e. associated to matter) degrees of freedom. This yields new particles and couplings in the form of supergravity, the supersymmetric extension of general relativity. Six additional spatial dimensions are also needed, giving rise to a ten-dimensional spacetime. Due to these self-consistency requirements, there are five different versions of string theory. To describe our four-dimensional universe, the extra dimensions have to be compactified (they are considered compact and small enough that they are invisible on all currently experimental accessible scales), which together with the existence of multiple string theories appears to lead to a large variety of solutions, thus losing predictability.

In fact, on top of inducing gauge symmetries and physical interactions in low dimensions, this compactification is the source of so-called dualities: novel symmetries that link the seemingly different string theories which are, in turn, not truly distinct but rather provide complementary descriptions of each other. These dualities are one of the most important properties of string theory, as they give various and complementary ways to study the same phenomena. The most simple example of a duality is T duality. It relates a string moving around a circle of radius R to a string winding around a circle of radius α'/R. Combined with S duality, which exchanges strongly and weakly coupled theories, it gives rise to a non-perturbative duality known as U duality. These new symmetries provide strong constraints on the structure and solutions of string theory.

Both the existence of higher-derivative corrections and of dualities are core properties of string theory. My expertise lies in the study of dualities, with special focuses on their use to find and study new supergravity solutions and on the interplay between dualities and higher-derivative corrections. The relevant and most efficient framework to implement dualities is Exceptional Field Theory (ExFT), which provides a duality covariant formulation of the higher-dimensional supergravities prior to any compactification. I am developing and using ExFT to study one of the major development of string theory, the so-called AdS/CFT correspondence. This is a holographic correspondence, conjecturing equivalence between certain solutions of string theories describing a d-dimensional spacetime of negative curvature, named anti de Sitter (AdS), and *d-1*-dimensional conformal field theories (CFT) defined on the edge of the AdS spacetime (see the figure 1 for an illustrated description). The crucial point of this correspondence is that it links a theory of gravitation to a field theory, without gravitation. It thus enables us to learn about quantum gravitation from the traditional tools of field theory (and *vice versa*).

Practical description of the correspondence requires knowledge of supergravity solutions of the form $AdS_d \times K$ with AdS_d an AdS spacetime of dimension d and K a compact space. Once explicitly compactified, the properties of the resulting theory in low dimension can be mapped to the characteristics of the dual CFT. Thus, to explore the AdS/CFT correspondence, one needs to build $AdS_d \times K$ solutions and to extract the relevant quantities from the compactification. However, standard techniques apply only to very specific backgrounds that feature a large number of symmetries. Both steps become quickly unreachable once supersymmetry and symmetry is (partially) broken. One major achievement of ExFT is to have provided efficient and powerful tools to construct and study solutions relevant to the AdS/CFT correspondence, and this even for solutions preserving few or no (super)symmetries. I have contributed to these developments, in particular for the AdS_3/CFT_2 correspondence. With my collaborators Michele Galli (Humbold Universität zu Berlin), Gabriel Larios (Texas A&M), Emanuel Malek (Humbold Universität zu Berlin) and Henning Samtleben (ENS de Lyon) we have revealed a wide set of deformations of the $AdS_3 \times S^3 \times T^4$ and $AdS_3 \times S^3 \times S^3 \times S^1$ solutions and explored their properties in details.

The ExFT techniques are however restricted to the two-derivative truncation of string theory. An other facet of my research interests lies in extending this duality covariant approach to include higher-derivative corrections. This requires to study the interplay between dualities and those corrections, which remains mainly unexplored.

I have recently achieved a first step by exposing explicitly how U duality of half-maximal supergravity in three dimensions interact with four-derivative corrections. Extension of this work will provide the necessary framework to explore higher-derivative corrections to the AdS/CFT correspondence.

Achievements & Awards

- Dr. Marius Gerbershagen was awarded a prestigious FWO junior postdoctoral fellowship.
- Ms. Maria Knysh wins with her poster “Horizon supertranslations lead to chaos” the Poster Award at EuroStrings 2023 (Gijón, Spain).
- Gabriele Pascuzzi was awarded a prestigious FWO Aspirant PhD fellowship.
- Dr. Alba Romero-Rodriguez won the 2023 edition of the Virgo Award, given by the international Virgo Collaboration, every year, to young scientists of the collaboration, for their significant contribution to the operation of the experiment and to the results of the Virgo Collaboration.
- Prof. Mairi Sakellariadou was elected President of the European Physics Society.

Theses defended in 2023

- Ankit Aggarwal (ULB)

  “Near Extremal Aspects of Warped Black Holes and Warped CFT’s”
  7 September 2023 (Thesis’ advisor: Prof. S. Detournay).
- Adrien Druart (ULB)

  “The Motion of Test Bodies around Kerr Black Holes”
  27 June 2023 (Thesis’ advisor: Prof. G. Compère).
- Philip Hacker (VUB)

  “Complexity, Chaos and Black Hole Microstates”
  29 June 2023 (Promotor: Prof. dr. Ben Craps).
- Colin Sterckx (ULB)

  “Type IIB S-folds: an exceptional approach”
  29 June 2023 (Thesis’ advisor: Prof. R. Argurio).
- Lorenzo Küchler (ULB)

  “Inspiral, transition and plunge: a framework for complete waveforms in the small-mass-ratio expansion”
  4 September 2023 (Thesis’ advisor: Prof. G. Compère).

Talks at Conferences, Seminars and Schools

Riccardo Argurio

Non invertible generalized symmetries in various dimensions
Milano-Bicocca University, Italy
16 January 2023.

Alexandros Spyridon Arvanitakis

Non-invertible symmetries, topological defects, and hamiltonian mechanics

- Regular seminar at the Asia Pacific Center for Theoretical Physics (APCTP), Pohang South Korea - 18 April 2023.
- Regular Seminar at Sogang University Seoul, South Korea - 28 April 2023.
- "Mini Workshop Strings, higher spins and amplitudes" at U. Mons, Belgium 25 May 2023.
- "Mini-Symposium on Geometry and Physics 2023" at RBI Zagreb, Croatia - 6 June 2023.
- "Gravity Beyond Riemannian Paradigm" CQUeST-APCTP Workshop, Jeju Island South Korea - 22 June 2023.
- "Integrability, Dualities and Deformations 2023" Workshop at U. Durham, UK 26 July 2023.

Glenn Barnich

Geometric actions for gravity

- MITP, Johannes Gutenberg University Mainz Program on Higher Structures, Gravity and Fields – Mainz, Germany - 9 January 2023.
- IMAPP, Radboud University CDT & Friends Jubilee edition Nijmegen, Netherlands 27 January 2023.
- Collège de France, Paris France 31 May 2023.
- Université de Tours, Journées Relativistes de Tours, France - 2 June 2023.
- Asia Pacific Center for Theoretical Physics XV International Conference on Gravitation Astrophysics and Cosmology (ICGAC15) Gyeongju, Korea - 6 July 2023.

Introduction à la théorie quantique des champs à température finie et à l'effet Casimir
Les Samedis de la Physique
à Bruxelles, Belgium 4,11,18 February & 18 March 2023.

Photons and gravitons in a Casimir box. Scalar field partition functions on tori
MITP, Johannes Gutenberg University Mainz Program on Thermalisation in Conformal Field Theories - Mainz, Germany - 11 July 2023.

Lessons from DLCQ for celestial holography
Aristotle University of Thessaloniki 3rd Carroll Workshop Thessaloniki Greece
2 October 2023.

Lessons from DLCQ for gravity

- Centre de Physique Théorique Luminy Marseille, France - 10 November 2023.
- Iranian Conference on High Energy Physics 1402 (on-line) School of Physics IPM, Tehran 21 November 2023.
- Xmas Theoretical Physics Workshop University of Athens Greece 22 December 2023.

Soumyadeep Chaudhuri

Goldstone bosons arising from the spontaneous breaking of continuous non-invertible symmetries
KU Leuven, Belgium - 19 May 2023.

Andres Collinucci

CY3s and nilpotent spectral data
University of British Columbia Okanagan
Kelowna, Canada - 29 May 2023.

5^d SCFT's from non-toric CY threefold
International Institute for Theoretical Physics
Trieste, Italy - 20 June 2023.

Ben Craps

Definitions of entwinement

- Quantum Information Meets Gravity
  Würzburg, Germany - 28 March 2023.
- Eurostrings 2023, Gijón, Spain
  24 April 2023.

Integrability and complexity in quantum spin chains
Complexity: Between Field Theory and Gravity
Madrid, Spain - 22 May 2023

Quantum complexity of integrable and chaotic time evolution
Quantum information: Theory and Applications
Cergy-Pontoise France
2 November 2023.

Stéphane Detournay

An introduction to The Solitary One: Wandering around a Black Hole
MUDAC, Lausanne, Switzerland
9 December 2023.

Camille Eloy

Higher-derivative corrections and duality invariance
Mainz Institute & for Theoretical Physics,
Mainz, Germany - 11 January 2023.

Reductions to AdS3 through exceptional field theory
Humboldt Universität zu Berlin Germany
2 June 2023.

Supergravité – Une (très) brève introduction
ENS de Lyon, France - 13 September 2023.

Non-supersymmetric stable marginal deformations in AdS3/CFT2

- Rencontres théoriciennes (LPTHE, LPENS CPHT, IphT) Paris, France
  19 October 2023.
- LAPTH Annecy, France
  14 December 2023.

Supergravity – A (very) brief introduction
African Institute of Mathematical Sciences
Kigali, Rwanda - 15 November 2023.

Oleg Evnin

De Sitter bubbles from anti-de Sitter fluctuations

- University of Catania, Italy - 11 April 2023.
- Rikkyo University, Tokyo, Japan
  19 October 2023.

Geometry and physics of exponential random gaphs
University of Leiden, The Netherlands
31 May 2023.

Quantum evolution complexity, hands-on

- Joint Israel Theory Seminar Neve Shalom, Israel - 13 June 2023.
- Yukawa Institute for Theoretical Physics
  Kyoto, Japan - 13 October 2023.

Frank Ferrari

Conférence pour des élèves de fin de collège et de lycée
Du Big-Bang aux trous noirs, par la pensée
Institut Henri Poincaré, Paris France
30 January 2023.

Jackiw-Teitelboim Quantum Gravity from First Principles
Workshop on Tensor Models and Holography
Institut Henri Poincaré, Paris, France
6 February 2023.

Random Disks of Constant Curvature

- Workshop Random Geometry in Math & Physics - Radboud University, Nijmegen The Netherlands - 30 March 2023.
- Seminar - Asia Pacific Center for Theoretical Physics (APCTP) Pohang, South Korea 11 April 2023.
- Seminar - Korea Institute for Advanced Study (KIAS), Séoul, South Korea 17 April 2023.

Random Disks of Constant Curvature (matrix model formulation)
Seminar - Asia Pacific Center for Theoretical Physics (APCTP) POSTECH, Pohang South Korea - 13 April 2023.

Random Disks of Constant Curvature: the Conformal Gauge Story
Seminar, CP7 Quantum Geometry and Topological Methods in Physics Seminar series, Ruprecht-Karls-Universität Heidelberg Germany - 14 June 2023.

Random Geometries of Constant Curvature: from Condensed Matter Physics to the Combinatorics of Self-Overlapping Curves through Black Holes.
Seminar series, Ruprecht-Karls-Universität Heidelberg, Germany - 15 June 2023.

Oscar Fuentealba

The asymptotic structure of spacetime in higher dimensions
Universidad de Concepción, Chile
3 April 2023.

The BMS group in higher spacetime dimesions
Université Libre de Bruxelles Belgium
14 April 2023.

Logarithmic supertranslations and supertranslation-invariant Lorentz charges
Universidad de Santiago de Chile, Chile
20 October 2023.

Marius Gerbershagen

Distance measures for quantum circuits in AdS3 /CFT2

- University of Würzburg, Germany 30 March 2023.
- University of Jena, Germany - 24 May 2023.

Generalized entanglement measures in AdS3/CFT2
University of Jena, Germany - 23 May 2023.

Quantum circuits in AdS/CFT
Theory@sea, Oostende, Belgium
8 June 2023.

Marc Henneaux

Supertranslation-invariant Lorentz charges
2nd workshop on "Asymptotic Symmetries & Holography", Universidad Adolfo Ibañez Santiago, Chile - January 2023.

The logarithmic BMS(4) algebra
Workshop «NordGrav@ICEN»
Universidad Arturo Prat, Iquique, Chile
18 January 2023.

Gravitation einsteinienne, une centenaire dynamique
"Journée SFP 2023 (champs et particules)", University of Paris-Sorbonne - 10 July 2023.

L'espace et le temps en physique: de Newton à Einstein et au-delà
Université de Lorraine, Nancy, France
21 September 2023.

The relevance of surface terms in the action principle
Closing ceremony of graduate school "Particles & Interactions" (DKPI) TU Vienna Austria - 28 September 2023.

Asymptotic Structure of Gravity and Gauge Theories
Series of 8 lectures given at the Universidad Católica de Chile,Santiago, Chile
6, 8, 13 and 15 November 2023.

Juan Hernandez

Chiral hydrodynamics in strong magnetic fields
ECTstar, Trento, Italy - 15 March 2023.

Entanglement entropy and complexity in various holographic models
HoloTube, Online - 2 May 2023.

Holographic entanglement entropy and complexity in the context of braneworld models
IFT, Madrid, Spain - 24 May 2023.

Semiclassical black hole microstates
Jena University, Germany - 7 December 2023.

Mikhael Khramtsov

Lloyd bound in holographic complexity = volume conjecture
Steklov Mathematical Institute, Moscow, Russia - 31 August 2023.

Dropping a diary into semiclassical black hole microstates
Steklov Mathematical Institute (online) Moscow, Russia - 6 December 2023.

Towards semiclassical black hole S-matrix in AdS
Steklov Mathematical Institute Moscow, Russia 28 December 2023.

Maria Knysh

The Love Triangle of Quantum Chaos
Theory at sea 2023, Oostende, Belgium
8 June 2023.

Laura Lopez Honorez

Cosmology probes of decaying DM

- Dark Matter beyond the Weak Scale workshop, Liverpool, UK 28 March 2023.
- Technical University, Munich Germany 29 June 2023.

(Non Cold) Dark Matter: at the interface between Particle physics & Cosmology
Theory at Sea 2023, Oostende, Belgium
9 June 2023.

Future 21cm-cosmology probe of decaying DM
Corfou 2023 - Workshop on the Standard Model and Beyond Greece
1 September 2023.

FIMPs imprint on Cosmology as Non Cold Dark Matter
LLP Bethe Forum, Bonn, Germany
23 November 2023.

(Non Cold) Dark Matter: at the interface between Particle physics & Cosmology
Johannes Gutenberg University, Mainz Germany - 29 November 2023.

Andrew Rolph

Page curves and replica wormholes from chaotic dynamics
University of Chicago, USA
5 December 2023.

Alexander Sevrin

Gravitational Waves: from Cosmic Origins to Extreme Precision Optics
VUB/Light Night, Brussels, Belgium
18 March 2023.

De EinsteinTelescoop: een nieuw venster op ons heelal
Universiteit Hasselt/Grijze Cellen & EOS Hasselt, Belgium - 16 May 2023.

Wat willen wetenschappers zien met een telescoop van 10km lang?
Universiteit van Vlaanderen Hasselt, Belgium
26 November 2023.

Luigi Tizzano

Non-invertible symmetries along 4d RG flows

- Theory Seminar - University of Padova, Italy May 2023.
- Workshop on Categorical Aspects of Symmetries Nordita - August 2023.
- Theory Seminar - CERN Geneva, Switzerland September 2023.
- Theory Seminar - University of Birmingham UK - December 2023.

Modern Applications of Symmetries in Quantum Field Theory
Theory Colloquium, University of Bologna, Italy November 2023.

Kevin Turbang

Gravitational-wave background: searches and implications
Caltech, Pasadena, USA - 30 March 2023.

Stochastic search for intermittent backgrounds
LVK meeting (stochastic F2F) Evanston, USA 14 March 2023.

Probing early Universe first order phase transitions with gravitational-wave data
Theory@Sea, Oostende, Belgium 8 June 2023.

Inferring the time-delay distribution and metallicity dependence of BBHs
Maastricht University, The Netherlands 23 October 2023.

Christoph Uhlemann

Splitting interfaces in N=4 SYM
"Defects, Strings and Fields 2023" APCTP workshop, Jeju, South Korea 19 September 2023.

Alejandro Vilar Lopez

Multipartite information in conformal field theories
Iberian Strings 2023, University of Murcia Spain - 13 January 2023.

Entwinement and bulk reconstruction in AdS3/CFT2

- Cosmos Sciences Institute - University of Barcelona, Spain - 6 March 2023.
- Brandeis University, Boston USA 28 March 2023.

Entwinement: a tool for bulk reconstruction in AdS3/CFT2
Solvay Workshop - Université Libre de Bruxelles, Belgium - 13 April 2023.

An information theoretic approach to conformal field theories
Be.HEP Summer Solstice 2023, University of Mons, Belgium - 23 June 2023.

Raphaela Wutte

Hyperbolic Mass and Gluings of Initial Data

- Arizona State University, Tempe, USA 27 & 31 January 2023.
- University of Chicago, Chicago, USA 7 February 2023.
- "Junior scientist workshop: Mathematical General Relativity", Universitaet Tuebingen Wildberg, Germany - 8 March 2023.
- Université libre de Bruxelles, Belgium 4 April 2023.

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GENERAL

CHEMISTRY

RESEARCH GROUP (ALGC)

General Chemistry Research Group ALGC - VUB

Group of Professors Frank De Proft, Frederik Tielens, Mercedes Alonso, Freija De Vleeschouwer, Ionut Tranca and Professor Emeritus Paul Geerlings

The ALGC research group is active in the field of quantum and computational chemistry. It is composed of two intertwined and mutually reenforcing research subgroups: the *Chemical Theory group* (F. De Proft, M. Alonso and F. De Vleeschouwer) and the *Materials Modeling group* (F. Tielens, I. Tranca). The ALGC research activities focus on a broad range of topics going from fundamental contributions to applications, the latter very often conducted in direct interaction with experimentalists. A broad variety of substrates, ranging from atoms, small and medium-size molecules, polymers to solids and materials are thereby treated.

A first topic which remains an important interest of the *Chemical Theory group* involves conceptual quantum chemistry, i.e. the development and application of chemical concepts rooted in quantum mechanics to describe molecular and material properties and chemical reactivity. Of particular importance for the group are the concepts rooted in Density Functional Theory (DFT), giving rise to the field of Conceptual DFT (or CDFT).[1] Other important and research lines in the group focus on molecular electronics, singlet fission, molecular switches and inverse design of chemical compounds. The group additionally investigates many topics in applied quantum chemistry, modelling as realistically as possible many (complex) chemical systems and reactions. In addition, the group is active in the scrutiny of complex chemical systems and reactions and attempts of simulating processes as closely as possible to experimental conditions.

The *Materials Modelling group* is renowned for its groundbreaking contributions in the field of biological minerals. Their multidisciplinary approach combines theoretical modeling, experimental techniques, and spectroscopic analysis to elucidate molecular mechanisms underlying mineral formation and function in biological systems. The research spans various topics, including the role of minerals in bone formation and the formation of pathological calcifications like kidney stones. Through innovative investigations, light is shed on fundamental questions in biomineralization with implications for medicine, materials science, and environmental science. The group's work represents a pioneering effort to unravel the intricate interplay between minerals and living organisms. The research efforts have profound implications for understanding biological systems and developing novel therapeutic interventions.

In this report, we highlight a few recent studies illustrating the broad and diverse research activities of ALGC in both fundamental and applied quantum chemistry.

Conceptual DFT and Chemical Reactivity

One of the recent research activities of the ALGC group has involved the evaluation of the effect of mechanical forces,[2,3] electric [2,4] and magnetic fields [2,5] and pressure [6] on CDFT based reactivity indices. Very recently, the group has reviewed its research activities in the field of mechanochemistry in an invited contribution in the themed collection "Fundamental Basis of Mechanochemical Reactivity" of the journal Physical Chemistry Chemical Physics [7] (Figure 1).

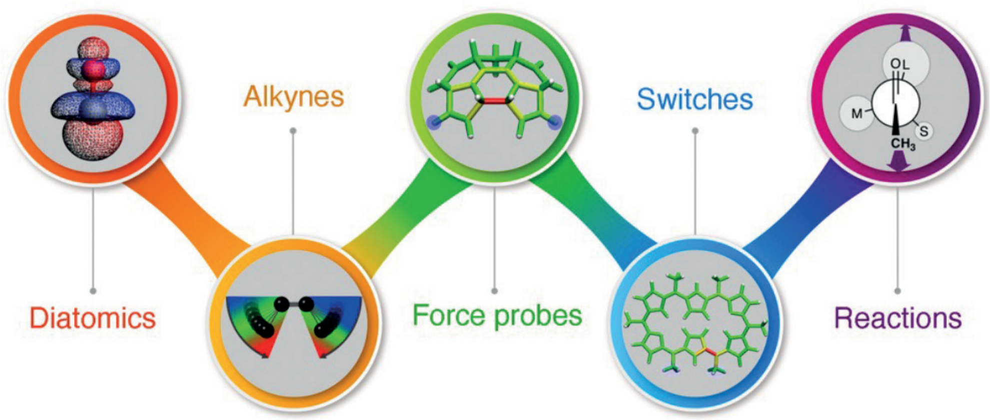


Figure 1. Graphical abstract illustrating the research activities of the ALGC group in quantum mechanochemistry [7].

In the field of chemical reactivity, we highlight the recent combined computational and conceptual scrutiny of the electrophilic aromatic substitution reaction mechanism of benzenes.[8] This is a well-known reaction in organic chemistry and is part of any undergraduate organic chemistry textbook. It turns out however that the mechanism of this reaction, and more specifically the presence of the so-called Wheland intermediate, is still under discussion. Based on our calculations of the reaction path of bromination of benzene, anisole and nitrobenzene, we discovered a clear kinetic preference for an addition-elimination mechanism, rather than substitution, irrespective of the aromatic compound considered (Figure 2). Also, it was found that both mechanisms did not involve a charged Wheland-like intermediate, not in the gas phase nor in the solvents that were investigated. We furthermore gained insight into the regioselectivity of the bromination through the combined use of conceptual DFT reactivity indices, aromaticity indices, bond orders and the non-covalent interaction index. The ortho/para directing effect of the methoxy-group in anisole was explained through the synergy between strong electron delocalisation and attractive interactions. However, the preferred meta-addition on nitrobenzene could not be traced back to any of these effects but could be rationalized through the electrostatic clash between the *ipso*-carbon of the ring and the nitrogen atom resulting from the late nature of the rate-determining step.

Figure 2. Journal cover of our recent publication on the mechanism of electrophilic aromatic substitution.[8]

Aromaticity

In collaboration with Prof. Tiznado (Universidad Andrés Bello, Chile), the ALGC group has recently proposed an advanced analysis of the magnetically induced current densities (GIMIC) that allows for determining the most appropriate combination of ring current circuits within a specific system.[9] Within this method, the current strengths susceptibilities through selected chemical bonds are computed making it possible to quantify the strength of local, semilocal, and global ring currents in both the ground (S_0) and lowest triplet (T_1) states (Figure 3). Our investigation reveals that the analyzed polycyclic systems display a prominent global ring current, contrasting with subdued semi-local and local ring currents. This method can be applied to materials with complicated fused ring structures that cannot be characterised with the popular NICS-based indices due to the superposition of local magnetic responses. With this method, a detailed understanding of the magnetic properties of novel diradicals based on difluorenopyrrole was attained, showing that the diradical character of these structures can be modulated by isomerism.[10]

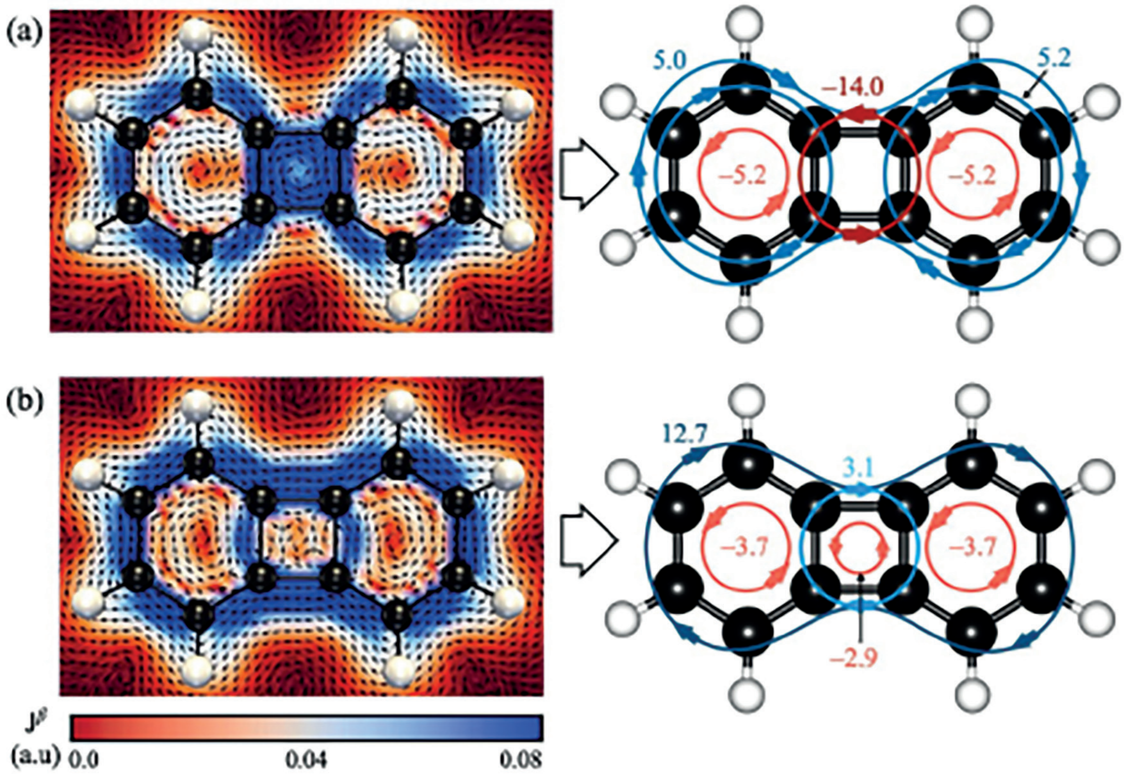


Figure 3. GIMIC analysis of biphenylene in the S_0 (a) and T_1 (b) states with an schematic representation of the local and global current flows and their respective intensities in nA/T.

Molecular Switches

Molecular switches, in which a stimulus induces a large and reversible change in molecular properties, are of significant interest in the domain of photonics. Due to their commutable redox states with distinct nonlinear optical (NLO) properties, hexaphyrins have emerged as a novel platform for multistate switches in nanoelectronics. We employed an inverse design algorithm to find functionalized hexaphyrin-based redox switches with maximal β_{HRS} contrast (Figure 4). We succeeded in enhancing the NLO efficiency by at least an order of magnitude and identified some key players influencing the NLO contrast, i.e., the electronic character of meso-substituents and the centrosymmetry of the OFF state. [11,12] Remarkably, both redox switches unveil very distinct design rules. When optimally combining those rules, even performant three-state switches can be designed. [12] We are currently adopting explainable machine-learning techniques to gain better insights into why certain functionalized switches perform better than others, and what sets both redox switches apart.

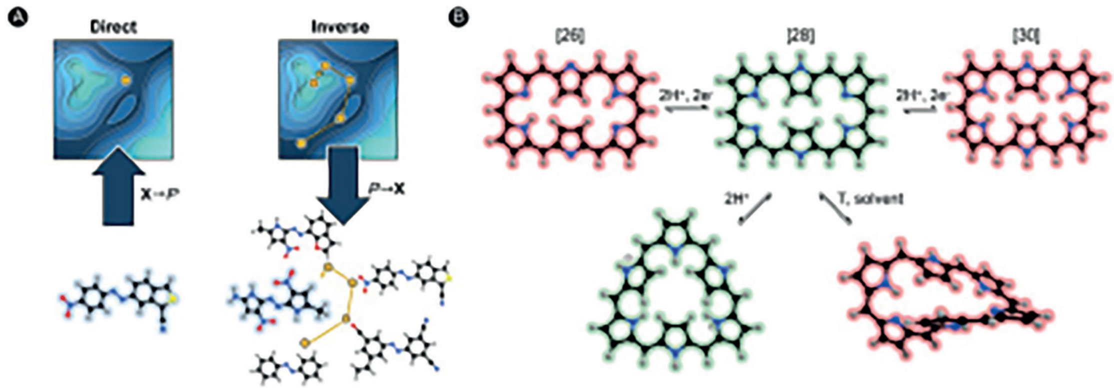


Figure 4.

(A) Schematic representation of direct and inverse design approaches. Inverse design follows the reverse design protocol starting with the property of interest and ending in the optimal structure.

(B) Different structures in hexaphyrin macrocycles interconvertible upon redox and protonation reactions as well as changing solvation and temperature.

Self healing materials

In collaboration with the Physical chemistry and polymer science (FYSC) group of the VUB, improved self-healing and recyclability of materials via crosslinked, reversible Diels-Alder (DA) bonds is being studied using theoretical and computational chemistry (Figure 5). In a first phase, focus was put on the construction of a large DA chemistry database, with attention for forward and retro kinetics and thermodynamics for all possible stereochemical outcomes. This database is first of its kind in terms of size and data completeness and aims at providing alternatives to currently employed DA components in covalent adaptable networks.[13] Next, as these Diels-Alder bonds are part of a polymer network, the influence of the linkers to the network on the DA reactivity has been analyzed for a wide variety of linkers. Our findings suggest that conformer ensembles need to be considered for a proper description of the DA reaction.[14] To consider full flexibility in atom movements, reactive molecular dynamics simulations, for which a reactive force field needed to be parametrized, are currently being exploited with the aim to study the resulting material behavior during the healing process.[15]

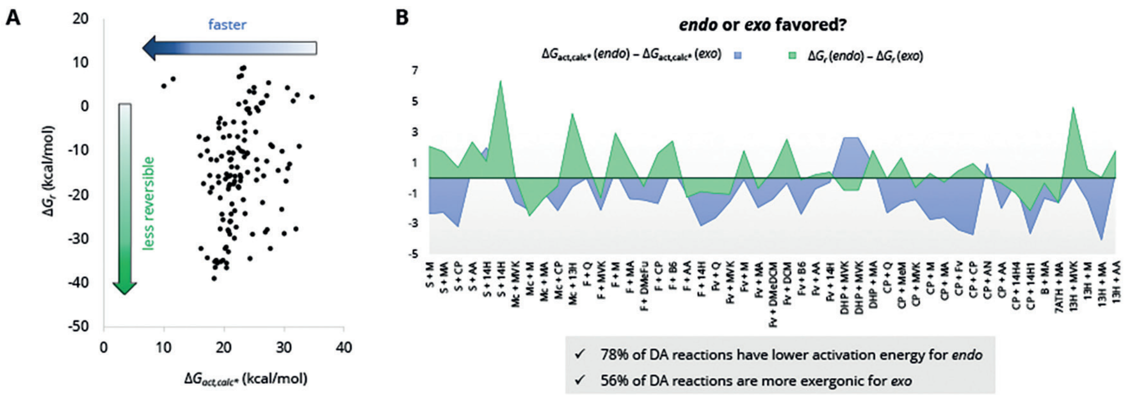


Figure 5.

(A) correlation between the Gibbs free energy of the reaction and the Gibbs free energy of activation for 131 DA reactions;

(B) endo and exo preference in terms of kinetics (blue color) and thermodynamics (green color); positive values refer to exo being favored whereas negative values refer to endo.

Materials Modelling

Oxalate and hydroxyapatite (HAp) are pivotal compounds in biomedical and materials science research, each playing crucial roles in various applications. Oxalate, a common organic acid found in many biological systems, interacts with minerals like calcium oxalate, influencing pathological calcifications such as kidney stone formation. On the other hand, HAp, a calcium phosphate mineral, is a fundamental component of bone tissue and a key material in dental and orthopedic applications.

This study [16] delved into the molecular understanding of citrate adsorption on calcium oxalate polyhydrates, crucial for advancing our knowledge of pathological calcifications, particularly in kidney stone formation. By examining citrate's influence on calcium oxalate crystal morphology, the research offered insights into therapeutic applications for inhibiting pathological calcifications. Combining theoretical and experimental approaches, the study provided a comprehensive analysis of citrate's interaction with calcium oxalate, shedding light on medical applications for treating pathological calcifications. The impact of citrate ions on calcium oxalate mineral formation was explored, focusing on crystal morphology. Utilizing advanced computational modeling and scanning electron microscopy (SEM) imaging, the citrate-calcium oxalate interaction was analyzed.

The findings revealed citrate's significant effect on calcium oxalate dihydrate (COD) crystallite morphology, resulting in larger, disk-shaped crystallites with altered surface planes. This suggests citrate's potential role in inhibiting pathological calcifications by stabilizing specific COD crystallite planes.

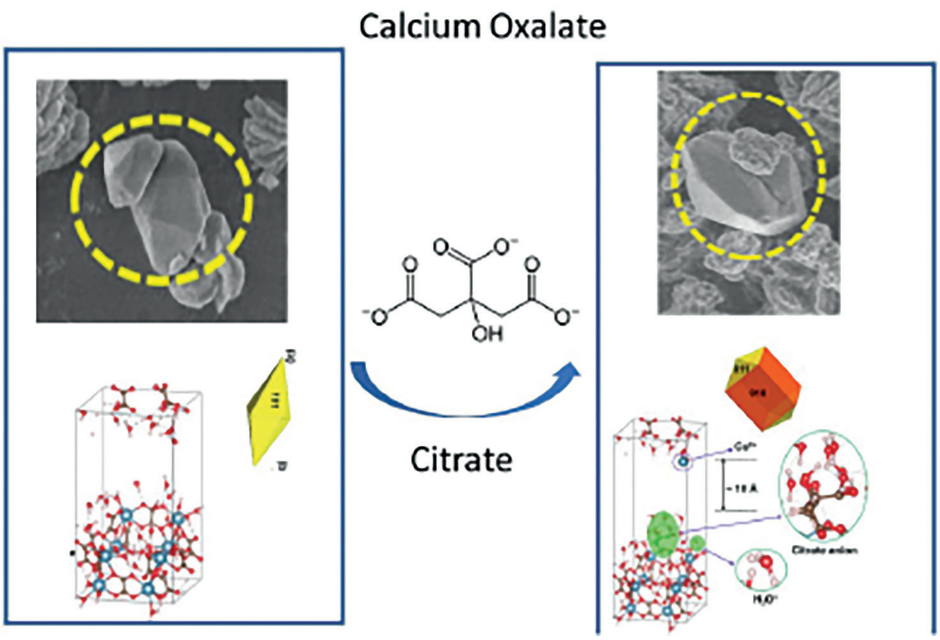


Figure 6. Investigation of citrate adsorption on calcium oxalate polyhydrates: scrutiny of interactions at the molecular level.

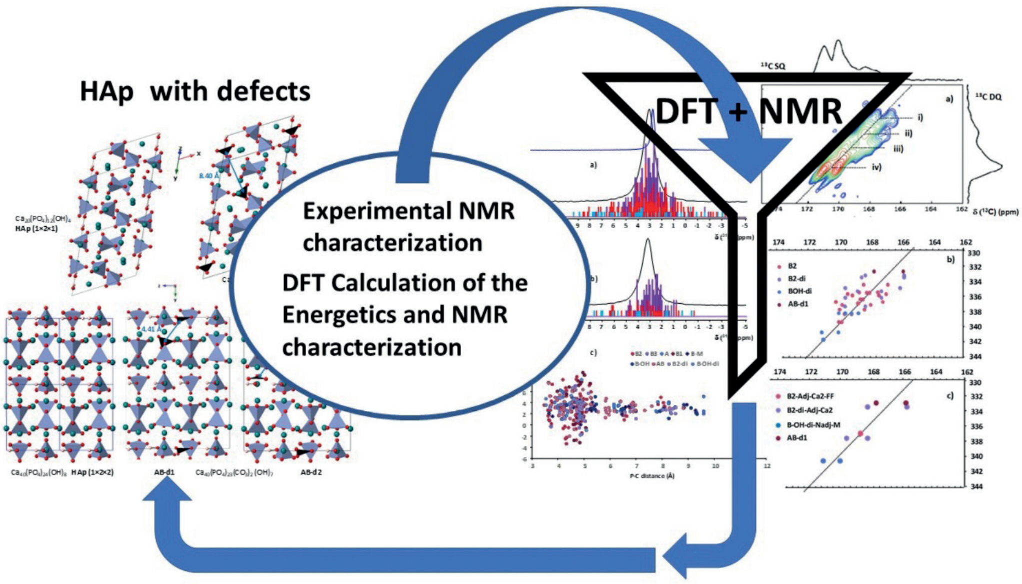
Additionally, insights into molecular-level interactions between citrate and calcium oxalate surfaces, offering potential therapeutic applications for treating pathological calcifications, were gained. This underscores the importance of understanding biological mineral behavior and interactions with biological ions, providing avenues for targeted interventions.

A second study (Figure 7) focused on applying GIPAW NMR calculations to various structural models of carbonate-substituted apatites, aiming to interpret experimental NMR spectra for better understanding carbonate substitution mechanisms. Addressing four main challenges in NMR spectra interpretation, the research provided valuable insights into carbonate-substituted hydroxyapatite's structural and dynamical properties. Utilizing advanced NMR calculations, the study reproduced experimental data and interpreted carbonate substitution effects, contributing to a better understanding of carbonate-substituted apatites' complex structural characteristics.

Investigating carbonate substitution in hydroxyapatite (HAp) using solid-state NMR and DFT calculations, the study explored various carbonate-substituted apatite models and their structural parameters, providing insights into stable arrangements of carbonate sites in experimental 13C NMR spectra. Addressing challenges related to NMR data interpretation, the study offered insights into carbonate substitution's impact on apatite reactivity in geochemistry and biomedicine. Additionally, the study discussed potential implications of different substitution mechanisms, providing a comprehensive analysis of carbonate substitution in HAp. Overall, the research contributed to understanding carbonate-substituted HAp's structural and dynamical properties, essential for various applications in materials science and biomedicine. Using cutting-edge techniques, the study unraveled carbonate substitution complexities in HAp, shedding light on its implications across
various fields.

Figure 7.

Combined theoretical/experimental study on the NMR characterization of carbonate-substituted apatites.



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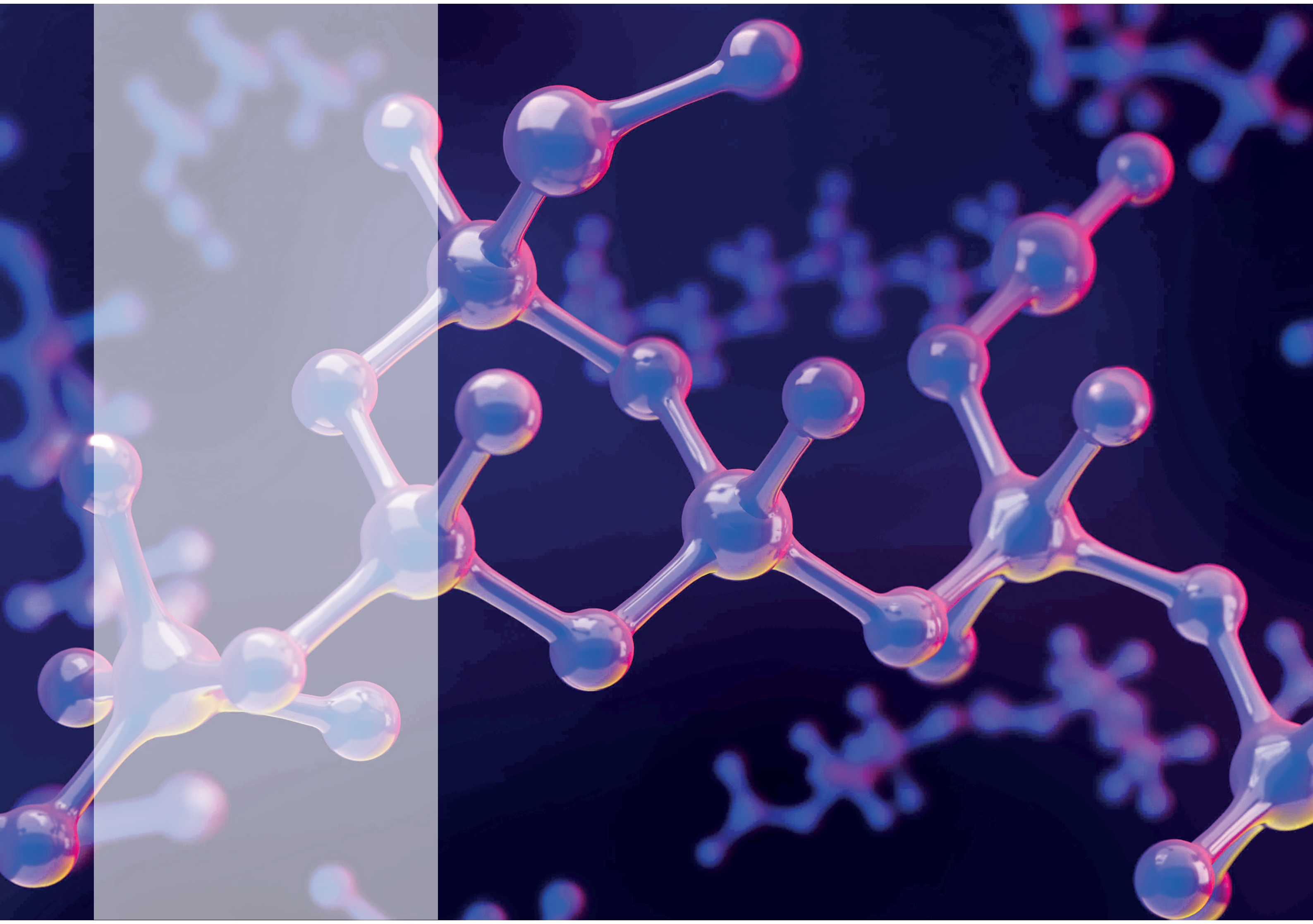


INSTITUTE OF

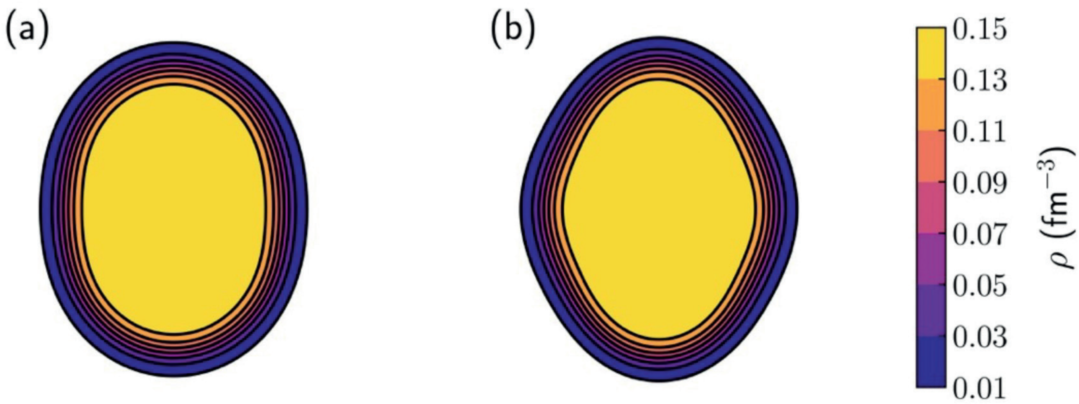
ASTRONOMY AND ASTROPHYSICS

Institute of Astronomy and Astrophysics (IAA) - ULB

The shape of 238U from relativistic collisions

Atomic nuclei are not all perfect spheres: many of them resemble a rugby ball, a pancake or even a pear. The shape of a nucleus has enormous impact on its structural properties and the way it reacts with other nuclei on earth or in stellar interiors; predicting it based on only proton and neutron number is the challenge of low-energy nuclear structure. Put more precisely: the distribution of nucleons is often not spherically symmetric. The deformation of a nucleus can be quantified by decomposing its nuclear density into multipole components: quadrupole deformation is usually dominant, but octupole and hexadecapole components are important for many heavy nuclei such as Uranium isotopes and other actinides.

On the other hand, relativistic collisions of heavy nuclei have long been used to produce quark-gluon plasma at colliders such as the LHC. Only recently however, did theorists realize that the deformation of the collision partners gets imprinted on the spatial distribution of the plasma! The key question in this –now suddenly multidisciplinary – field is: can we recognize the shape of a nucleus across energy scales, i.e. is the shape of the nucleus the same when probed at low energies (nuclear physics) and at high energies (collisions)?



Caption:

2D contour plots for two different deformed densities (ρ, the number of nucleons per volume) for U238; with only quadrupole deformation in panel (a) and with quadrupole and hexadecapole deformation in panel (b). Experimental evidence from both low energy nuclear physics and high-energy collisions indicate the latter is more realistic.

The collisions of 238U nuclei at RHIC (BNL, USA) posed a puzzle in this context; our experimental and theoretical knowledge of this nucleus is rather complete, yet detailed simulations of the collisions could only match the observations qualitatively. Wouter Ryssens - then a postdoc at IAA developing nuclear structure models for astrophysical purposes - pointed out that all collision simulations only consider quadrupole deformation and improperly account for hexadecapole deformation, which is sizeable for 238U. Working with experts from Heidelberg and BNL, he showed that simulations can quantitatively reproduce the data if they start from a complete description of 238U such as that provided by IAA-built models.

By resolving the tension between data and simulations for 238U, IAA has contributed to the development of high-energy collisions as an entirely novel way to determine the shape of a nucleus. Since this type of experiment is complementary to existing experimental techniques in nuclear physics, it will likely teach us much on nuclear shapes and in turn improve our nuclear models.

Synthesis of Thorium and Uranium in Asymptotic Giant Branch stars

Actinides (e.g. thorium and uranium) are generally thought to be synthesized exclusively by the rapid neutron capture process (r-process) during explosive events such as the fusion of two neutron stars.

Together with S. Goriely and L. Siess, Arthur Choplin (a post-doctoral researcher at IAA-ULB) proposed in [2] that actinides can also be significantly synthesized in asymptotic giant branch (AGB) stars, which correspond to the last life stages of stars between 1 and 8 solar masses. He has run the STAREVOL stellar evolution code using a nuclear network of 1160 species from H to Cf coupled to transport processes. Models with different resolutions (temporal and spatial) using different nuclear data sets were considered for the analysis.

During the AGB phase, the star is composed of a carbon-oxygen core, surrounded by a helium-burning shell, a hydrogen-burning shell and a large convective envelope. When active, the helium-driven convection zone may penetrate the hydrogen-rich layers and ingest protons. The ensuing proton ingestion leads to a strong neutron burst with neutron densities of the order of 10^{15} cm^{-3}, giving rise to the intermediate process of neutron capture (i-process). The i-process is characterized by neutron densities N_n intermediate between the slow neutron capture process (s-process, $N_n = 10^6 - 10^{10}$ cm^{-3}) and the r-process ($N_n > 10^{20}$ cm^{-3}), which is just enough to bypass the Lead-Bismuth region (atomic number Z = 82 and 83) and build actinides, in particular Thorium (Th, Z = 90) and Uranium (U, Z = 92). They have shown that the surface enrichment in Th and U in AGB stars is subject to nuclear and astrophysical model uncertainties that could be lowered in the future, in particular by a detailed analysis of the nuclear inputs that affect the neutron capture rates of neutron-rich isotopes between Lead (Z = 82) and Pa (Z = 91).

A stellar candidate that may confirm actinide production by the i-process is the star RAVE J094921.8-161722, whose observation was reported in [3]. This star shows a chemical pattern midway between the s- and r-processes and thorium lines in its spectrum. Its surface abundances were shown to be reasonably well reproduced by our AGB model, although the abundances of elements with atomic numbers 38 < Z < 46 remain underestimated.

With this work, Arthur Choplin has shown that AGB stars are therefore potential contributors to galactic enrichment in actinides (such as Th and U), and that the r-process may not be the only production mechanism.

Binarity of evolved stars and its impact on their evolution

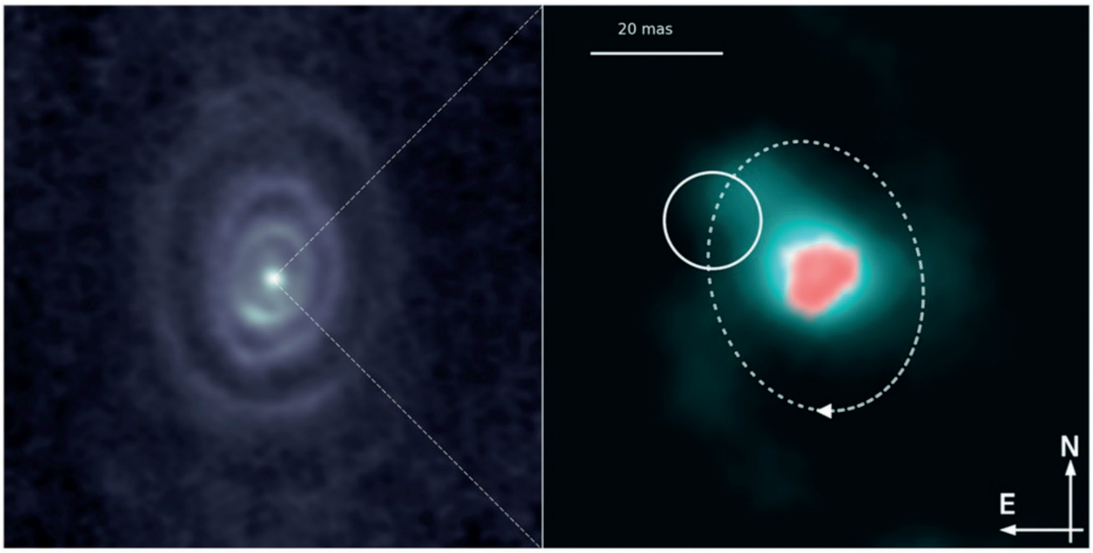
In our understanding of the agony of Sun-like stars - and more specifically their short-lived transition from the spherical Asymptotic Giant Branch (AGB) stars phase to the bipolar planetary nebula phase - the star V Hydrae stands as the missing link. Its unique behavior - from regular dimming events reported since 1926 [4] to the hourglass-shaped structure embedded in a multiring nebula [5] - is suspected to be caused by the presence of an unseen stellar companion gravitationally bound to the dying giant. However, until now, evidence of such a companion was still lacking, and its link with regular visual obscuration was not fully understood…

In this research project, by taking a multi-epoch and multi-instrumental approach, Léa Planquart, a PhD student working at IAA with A. Jorissen, tried to assess the existence of this suspected companion by by taking the closest look into the circumstellar nebula, down to the stellar surface (see Figure below).

In the first step [6], she obtained the orbit of the system using decade-long radial-velocity monitoring with the high-resolution HERMES spectrograph mounted on the Mercator telescope. Combined with astrometric measurements, the proposed orbital model, compatible with regular obscuration events, unveils the presence of a gaseous jet attached to the companion.

Caption: A close look into V Hydrae system.

Left: the molecular multi-ring nebula from the ALMA radio-interferometer [2]. Right: the infrared MATISSE image of the giant and its circumstellar envelope. The orbital motion of the companion is represented by the dashed ellipse, and its predicted position is drawn as the white circle. The scale is expressed in milliarcsecond ("mas") corresponding to an angular distance on the sky-plane of 2.7 × 10-7 (1/3600000) degrees.



Many thanks to Wouter Ryssens, Arthur Choplin and Léa Planquart for their contributions.

In the second step [7], the stellar surface and its surroundings were resolved for the first time, using the MATISSE infrared interferometer at the Very Large Telescope (VLT). The dusty wind of V Hydrae exhibits an asymmetric shape, where an enhanced dust clump is detected in the vicinity of the giant, and at the predicted position of the invisible companion. This confirms – by independent means - the presence of the faint stellar companion and explains, in the meantime, the origin of dimming events.
This extended dust clump, moving along with the companion and its gaseous jet, is responsible for the stellar light periodic fainting, each time it passes in front of the giant.

By connecting the orbit-scale properties of the binary system with previous large-scale observations of the hourglass nebula, the work of Léa Planquart gives further evidence that close-by companions are an essential ingredient to shape the wind of bipolar pre-planetary nebulae.

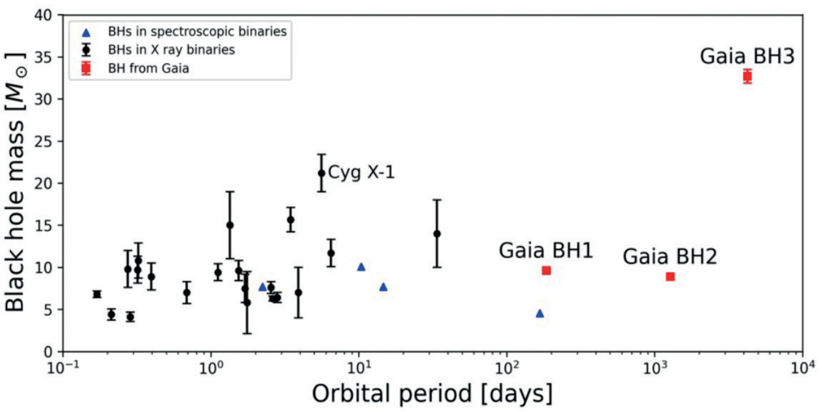
ESA's Gaia satellite spots the most massive stellar dormant black hole in our Galaxy [8]

Wading through the inestimable wealth of data from ESA's Gaia mission, scientists from the Gaia Collaboration, including several from ULB's *Institut d'Astronomie et d'Astrophysique* (IAA-ULB), uncovered a 'sleeping' giant. A large black hole, with a mass of nearly 33 times the mass of the Sun, was hiding in the constellation Aquila, less than 2000 light-years from Earth. This is the first time a black hole of stellar origin this big has been spotted so close to home. The discovery challenges our understanding of how massive stars develop and evolve.

The great majority of stellar-mass black holes that we know of are gobbling up matter from a nearby stellar companion. The captured material falls onto the compact object at high speed, becoming extremely hot and releasing X-rays. These systems belong to a family of celestial objects named X-ray binaries. However, when a black hole does not have a companion close enough to steal matter from, it does not generate any light and is extremely difficult to spot. These black holes are called 'dormant'.

To prepare for the release of the next Gaia catalogue, Data Release 4 (DR4) planned for the first quarter of 2026, scientists are checking the motions of billions of stars, carrying out complex tests to ¬see if anything is out of the ordinary. The motions of stars can be affected by companions: light ones, like exoplanets; heavier ones, like stars; or very heavy ones, like black holes. Dedicated teams are in place in the Gaia Collaboration to investigate any 'odd' cases. One such team, involving A. Jorissen from IAA-ULB, stumbled upon an old giant star in the constellation Aquila whose wobbling path on the sky revealed the presence of a dormant black hole of exceptionally high mass, about 33 times that of the Sun [9].

This is the third dormant black hole found with Gaia and was aptly named 'Gaia BH3'. Its discovery is very exciting because of the mass of the object. So far, black holes this massive have only been detected in distant galaxies, by the LIGO–Virgo–KAGRA collaboration thanks to observations of gravitational waves. The average mass of known black holes of stellar origin in our Galaxy is around 10 times the mass of our Sun. Until now, the weight record was held by a black hole in an X-ray binary in the Cygnus constellation (Cyg X-1), whose mass is estimated to be around 20 times that of the Sun. The quality of Gaia data enabled scientists to pin down the mass of the Gaia BH3 black hole with unparalleled accuracy.



Caption:
The masses of known black holes are given here against their orbital periods. All of these black holes are part of a binary system. While black holes in X-ray binaries are typically detected due to the X-rays they emit when the matter of their neighbouring star is 'eaten', the black holes found by Gaia are all dormant. Gaia BH3 clearly stands out, both with its mass as well as with its orbital period.
Credits: ESA/Gaia/DPAC - CC BY-SA 3.0 IGO. Acknowledgement: Created by Pasquale Panuzzo.

Astronomers face the pressing question of explaining the origin of black holes as massive as Gaia BH3. Our current understanding of how massive stars evolve and die does not immediately explain how these types of black holes came to be.

Most theories predict that, as they age, massive stars shed a sizable part of their material through powerful winds; ultimately, they are partly blown into space when they explode as supernovae. What remains of their core further contracts to become either a neutron star or a black hole, depending on its mass. Cores large enough to end up as black holes of 30 times the mass of our Sun are very difficult to explain.

Yet, a clue to this puzzle may lie in the star orbiting Gaia BH3 at about 16 times the Sun–Earth distance. It is rather uncommon: an ancient giant star, that formed in the first two billion years after the Big Bang, at the time our Galaxy started to assemble. It belongs to the family of the Galactic stellar halo and is moving in the opposite direction to the stars of the Galactic disc. Its trajectory indicates that this star was probably part of a small galaxy, or a globular cluster, engulfed by our own galaxy more than eight billion years ago.

The companion star has very few elements heavier than hydrogen and helium, indicating that the massive star that became Gaia BH3 could also have been very poor in heavy elements. This is remarkable as it supports, for the first time, the theory that the high-mass black holes observed by gravitational-wave experiments were produced by the collapse of primeval massive stars poor in heavy elements. These early stars might have evolved differently from the massive stars we currently see in our Galaxy.

The discovery of Gaia BH3 is only the beginning and much remains to be investigated about its baffling nature. The next release of Gaia data, foreseen during the first quarter of 2026, promises to be a goldmine for the study of binary systems and the discovery of more dormant black holes in our Galaxy is expected.

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[6] Planquart, L., Jorissen, A., Escorza, A., Verhamme, O., & Van Winckel, H. 2024, A&A, 682, A143.

[7] Planquart, L., Paladini, C., Jorissen, A., et al. 2024, A&A, submitted.

[8] adapted from the ESA Press Release ‘Sleeping_giant_surprises_Gaia_scientists’, published April 16, 2024, https://www.esa.int/Science_Exploration/Space_Science/Gaia/ Further information about this discovery may be found at https://www.cosmos.esa.int/web/gaia/iow_20240416.

[9] Gaia Collaboration, P. Panuzzo, T. Mazeh, F. Arenou, B. Holl, E. Caffau, A. Jorissen, et al. 2024, Astronomy & Astrophysics Letters, in press https://doi.org/10.1051/0004-6361/202449763.

LABORATORY OF

POLYMER CHEMISTRY

Laboratory of Polymer Chemistry ULB

Group of Yves Geerts and Guillaume Schweicher

Organic materials are of particular interest to us because their solid-state properties can be nearly infinitely varied by engineering molecular structures and supramolecular order. This is particularly true for organic semiconductors that are made of pi-conjugated molecules in which electrons are substantially delocalized. We have modified state-of-the-art organic semiconductors to make them chiral to test the chiral-induced spin selectivity effect and the electrical magneto-chiral anisotropy in field-effect transistors.

Let us recall that transistors are three-electrode devices that act as electronic switches.[1] Surprisingly, a huge magnetoresistance has been observed when ferromagnetic source and drain electrodes are used. The effect is so large that transistors can be switched on/off with an external magnetic field oriented parallel or antiparallel to the charge transport direction.[2] These results document the intimate and intriguing link between molecular handedness and the spin of electrons. In parallel, we carried out research towards the elucidation of charge transport mechanisms in organic semiconductors, notably by using Terahertz spectroscopy.[3]

The most recent results confirm that charge are transiently delocalized over large clusters of molecules and highlight the electron-phonon coupling.[4] Phonons are collective excitations in a periodic, elastic arrangement of atoms or molecules. Intramolecular and intermolecular phonons coexist in organic crystals, but they are generally weakly coupled because they have their own frequency domains.

To complement our approach, we investigated the dynamics of crystals.[5] Clearly, intermolecular phonons are not all equal, some are more non-harmonic than others, meaning that their oscillation around an equilibrium position cannot simply be described by a harmonic energy potential ($y = x^2$) as generally assumed. The non-harmonic character of intermolecular vibrations manifests itself strongly around phase transitions, and sometimes even triggers them.[6,7]

Intermolecular phonon modes contributes to heat transport by diffusion mechanism. A higher level of complexity is present when an external thermal gradient is imposed to crystallizing systems because heat is forced to flow in a specific direction. In other words, phonons acquire a directionality. Heat flow unexpectedly controls the fate of molecular systems that crystallize in more than one form, a phenomenon known as polymorphism that is largely ill-understood. As illustrated in Figure XX, we investigated the directional crystallization of ROY, i.e. the most polymorphic molecular systems know to date with up to thirteen crystal forms.

Curiously, we obtained only one polymorph over thirteen in presence of a thermal gradient. The mechanism by which the polymorphic selection operates remain elusive for the moment. Simple thermodynamic and kinetic arguments do not suffice to rationalize our observations.[8] However, our results are of practical importance for the field of pharmacy because polymorphic forms have different solubility and hence various bioavailability.

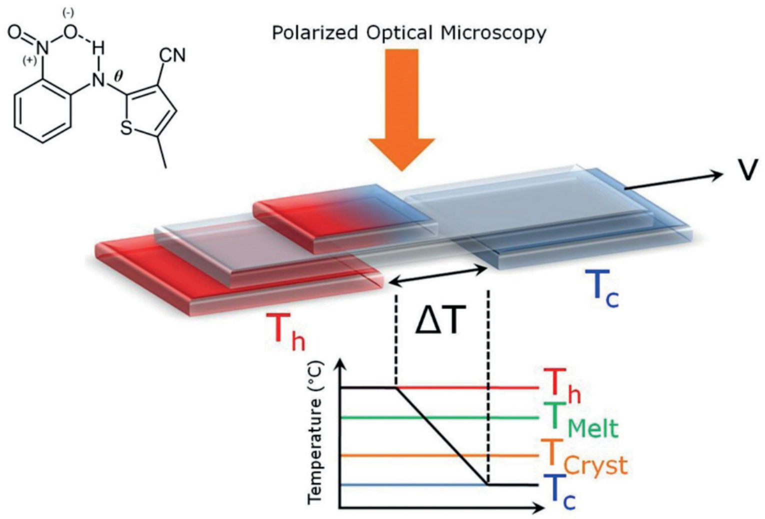


Figure XX. Directional crystallization of ROY reproducibly affording one polymorphic form over thirteen possible one.

[1]*"From synthesis to device fabrication: elucidating the structural and electronic properties of C7-BTBT-C7" Priya Pandey, Lamiaa Fijahi, Nemo McIntosh, Nicholas Turetta, Marco Bardini, Samuele Giannini, Christian Ruzié, Guillaume Schweicher, David Beljonne, Jérôme Cornil, Paolo Samori, Marta Mas-Torrent, Yves Henri Geerts, Enrico Modena, Lucia Maini, J. Mater. Chem. C, 2023, 11, 7345.*

[2] *"Enantiopure Dinaphtho[2,3-b:2,3-f]thieno[3,2-b]thiophenes: Reaching High Magnetoresistance Effect in OFETs" Martina Volpi, Rémy Jouclas, Jie Liu, Guangfeng Liu, Luca Catalano, Nemo McIntosh, Marco Bardini, Christos Gatsios, Federico Modesti, Nicholas Turetta, David Beljonne, Jérôme Cornil, Alan R. Kennedy, Norbert Koch, Peter Erk, Paolo Samorì, Guillaume Schweicher, Yves H. Geerts, Adv. Sci. 2023, 10, 2301914.*

[3] *"Molecular semiconductors and the Ioffe–Regel criterion: A terahertz study on band transport in DBTTT" P. Riederer, F. Devaux, G. Schweicher, Y. H. Geerts, R. Kersting, Appl. Phys. Lett. 2023, 123, 032103.*

[4] *"Transiently delocalized states enhance hole mobility in organic molecular semiconductors" Samuele Giannini, Lucia Di Virgilio, Marco Bardini, Julian Hausch, Jaco J. Geuchies, Wenhao Zheng, Martina Volpi, Jan Elsner, Katharina Broch, Yves H. Geerts, Frank Schreiber, Guillaume Schweicher, Hai I. Wang, Jochen Blumberger, Mischa Bonn, David Beljonne, Nat. Mater. 2023, 22, 1361-1369.*

[5] *"Phonon–Phonon Interactions in the Polarization Dependence of Raman Scattering" Nimrod Benshalom, Maor Asher, Remy Jouclas, Roman Korobko, Guillaume Schweicher, Jie Liu, Yves Geerts, Olle Hellman, Omer Yaffe, J. Phys. Chem. C 2023, 127, 18099-18106.*

[6] *"Mechanistic View on the Order–Disorder Phase Transition in Amphidynamic Crystals" Maor Asher, Marco Bardini, Luca Catalano, Remy Jouclas, Guillaume Schweicher, Jie Liu, Roman Korobko, Adi Cohen, Yves Geerts, David Beljonne, and Omer Yaffe. J. Phys. Chem. Lett. 2023, 14, 1570-1577.*

[7] *"Interlayer Sliding Phonon Drives Phase Transition in the Ph-BTBT-10 Organic Semiconductor" Elena Ferrari, Lorenzo Pandolfi, Guillaume Schweicher, Yves Geerts, Tommaso Salzillo, Matteo Masino, Elisabetta Venuti, Chem. Mater. 2023, 35, 5777-5783.*

[8] *"Accessing Selective Crystallization of ROY Polymorphs Using Directional Crystallization from the Melt" Jie Liu, Sylvain Kabbadj, Guangfeng Liu, Lygia S. de Moraes, Gabin Gbabode, Guillaume Schweicher, Roland Resel, Yves Geerts, Cryst. Growth Des. 2023, 23, 8565-8574.*

THE ROBERT BROUT AND THE ILYA PRIGOGINE

PRIZES

The Robert Brout Prizes and the Ilya Prigogine Prizes

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).

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

In 2023, the prizes have been awarded to:

- Thomas Debing (Ilya Prigogine Prize VUB)
- Chris Sauber (Ilya Prigogine Prize ULB)
- Adrien Arbalestrier (Robert Brout Prize ULB)
- Dimitri Kanakaris Decavel (Robert Brout Prize VUB)

07

2023

APPENDIX

Press and Newspapers

L Quand Oppenheimer, père de la bombe atomique, dormait au Palais royal de Bruxelles et dînait à l'Atomium

Robert Oppenheimer, le père de la bombe atomique, avait d'étroits liens avec la Belgique. Ce scientifique de génie, popularisé par le film de Christopher Nolan, a été actif durant vingt ans au Conseil Solvay, qui rassemble tous les trois ans l'élite mondiale de la physique à Bruxelles. Plongée dans un morceau d'histoire de notre pays, entre 1948 et 1967.

Sophie Devillers
Journaliste service Planète

Publié le 08-10-2023 à 12h00

Enregistrer

Robert Oppenheimer, le père de la bombe atomique, avait d'étroits liens avec la Belgique ©BATISTA

La scène se passe en 1958, à Bruxelles, année de l'Exposition universelle. La Belgique est au centre du monde et à Bruxelles, tous les hôtels sont pleins. Robert Oppenheimer, arrivé dans la capitale belge pour participer au Conseil Solvay, qui rassemble pour des présentations et des débats l'élite mondiale de la physique tous les trois ans depuis 1911, découvre qu'il se retrouve logé dans une minuscule chambre d'un des rares hôtels pas encore bondé. Il contacte alors Ernest John Solvay, l'organisateur des conférences et lui confie qu'il est très mal logé. Une alternative de luxe sera vite trouvée.

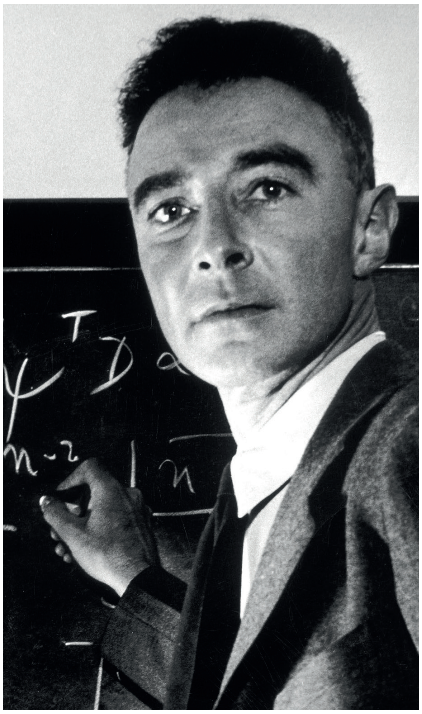
Mon grand-père, très fâché de voir que cet homme qu'il trouve extraordinaire et qui nous fait l'honneur de sa présence se trouve si mal logé, cherche des alternatives, nous raconte Marina Solvay, présidente des Archives des Instituts Solvay. *Il pense d'abord à accueillir Robert Oppenheimer au château de La Hulpe, mais le scientifique se serait alors trouvé assez loin de Bruxelles et de la conférence Solvay… Mon grand-père contacte ensuite le Palais royal. Par son entremise, c'est finalement au Palais royal même, place des Palais, qu'Oppenheimer logera. Il passera un très bon séjour ! De là, il avait en outre la possibilité de se rendre facilement à pied à la Fondation universitaire, où avaient alors lieu certaines des réunions scientifiques…"*

Reconnaissance

Être présent au Conseil est un adoubement pour un scientifique : *"cela représentait déjà à l'époque la réunion la plus importante du domaine de la physique moderne. Soit ces conseils montrent qu'il y a des questions importantes qu'on ne comprend pas, soit ils closent des débats. Tous les prix Nobel du XX*^e^ *siècle sont passés par Bruxelles pour assister à ces réunions. Ce sont des réunions sur invitation, donc la recevoir est déjà une reconnaissance"*, complète le physicien Marc Henneaux, professeur à l'ULB et directeur des Instituts Solvay.

En 1958, c'est en fait déjà la deuxième fois que Robert Oppenheimer assiste aux Conseils Solvay. Sa première visite a eu lieu en 1948, où il arrivait des États-Unis auréolé de gloire, avec son frais statut de "père de la bombe atomique" et accompagné de plusieurs de ses collègues ayant travaillé également sur la bombe, dont Edward Teller. Sur la photo de groupe traditionnelle du Conseil de cette année-là, Oppenheimer, sûr de lui, rayonne, fait remarquer Marina Solvay : *"Il est au sommet de sa gloire"*. Sa venue fait d'ailleurs les titres des journaux belges. Et l'un des participants écrit même un poème, lu à l'un des banquets, célébrant "Oppie" (son surnom) et sa présence à ce Conseil Solvay.

Congrès Solvay de 1948 en présence de Robert Oppenheimer. ©Archives Instituts Solvay



Oppenheimer dans le laboratoire de Los Alamos.

À ce congrès dédié aux particules élémentaires où il est vu comme une star, "Oppie" peut en remontrer sans peine à sa némésis, Patrick Blackett, également présent à Bruxelles et qui avait été son "tuteur" lors de son doctorat à Cambridge vingt ans plus tôt. C'est à ce physicien britannique charismatique que, comme le montre le film de Christopher Nolan, Oppenheimer avait destiné une pomme empoisonnée avant, pris de remords, de l'alerter par télégramme de ne pas croquer le fruit. Prévenus du scandale, les parents d'Oppenheimer doivent intervenir en sa faveur à Cambridge. *"Blackett était très beau et tout lui réussissait. À l'époque, Robert Oppenheimer était très dépressif parce qu'il n'avait pas d'amis. Il était très mal dans sa peau et était très jaloux de Blackett, retrace Marina Solvay. Sa personnalité s'est ensuite ouverte : il était chimiste de formation quand il est arrivé à Cambridge, mais il y a entendu toutes ces nouvelles théories physiques… Il s'est lancé dans la physique quantique et il est reparti aux États-Unis avec cela : cela l'a sauvé, il est sorti de sa dépression."*

La mécanique quantique est en effet alors principalement développée en Europe. C'est en octobre 1927 qu'a d'ailleurs lieu l'un des plus célèbres Congrès Solvay qui cimente la théorie de cette bizarre discipline étudiant le monde à l'échelle de l'infiniment petit et où les particules perdent la position et la vitesse "définies" qu'elles avaient dans la physique classique.

Reparti d'Europe à l'été 1927 – et de toute façon encore trop peu connu- Oppenheimer n'y assiste pas. Mais aux États-Unis, il commence à enseigner la mécanique quantique et en devient le principal "importateur". "*Et sans mécanique quantique, pas de bombe atomique,* résume Marc Henneaux. *Dans le projet Manhattan, Oppenheimer a un rôle de coordinateur génial mais il était un physicien complet et ses connaissances de la physique lui ont permis de choisir les bons physiciens. Et comme il travaillait dans le domaine des électrons, des positrons, des particules élémentaires, il connaissait bien les problèmes à résoudre pour que des réactions nucléaires puissent avoir lieu, qu'une réaction en chaîne puisse se produire. C'est un domaine où l'apport est surtout collectif, et on ne peut donc pas isoler sa contribution, mais ses pairs* (du projet Manhattan) *le reconnaissaient aussi comme brillant car c'était lui qui avait apporté des idées de la mécanique quantique en Amérique. Et la mécanique quantique, pour fabriquer la bombe, c'était indispensable…"*

"Sa personnalité était une remarquable combinaison d'intelligence, d'éloquence et d'arrogance, selon mes collègues plus âgés qui m'en ont beaucoup parlé, décrit pour La Libre David Gross, prix Nobel de physique 2004, président des conseils Solvay et grand admirateur d'Oppenheimer. *J'ai un très profond respect pour lui pour de nombreuses raisons : cette brillance, cette éloquence, son rôle dans la création en Amérique de la physique théorique et son leadership magistral du Manhattan Project. Il fut aussi un excellent leader des Conférences Solvay."*

Période de cauchemar

En effet, après le Congrès Solvay de 1948, Robert Oppenheimer est nommé au conseil scientifique qui choisit les sujets et les invités des conférences bruxelloises. Il en deviendra ensuite le président. Mais il sera dans l'impossibilité de revenir en Belgique pendant dix ans; il manquera ainsi deux congrès de physique, en 1951 et 1954. Robert Oppenheimer vit en effet là ce qui sont sans doute les années les plus douloureuses de sa vie. En plein maccarthysme, il est soupçonné par le gouvernement américain de sympathie communiste et de transfert d'informations aux Russes, et subira l'épreuve d'un procès très médiatisé en 1954.

Robert Oppenheimer ne plaît en effet plus aux autorités car il veut alors limiter le développement des armes nucléaires dans le monde et refuse de contribuer à la conception de la bombe H. Son collègue Edward Teller, qui lui soutient l'idée de cette bombe plus puissante que la bombe A, n'hésitera pas à témoigner contre Oppenheimer à son procès. *"Il a été persécuté. On a mis sa loyauté en doute, on lui a retiré sa clearance* (son autorisation d'accès aux documents sensibles sur le nucléaire, NdlR), précise Marina Solvay. *Il a été dévasté par cette trahison.*

Marina Solvay et Marc Henneaux, encadrant une photo d'un Congrès Solvay où Oppenheimer a participé. ©Sophie Devillers

Une anecdote : un soir au Conseil de 1958 où il fait son grand retour, après l'un des dîners de gala donnés pour les scientifiques, mon père intrigué demande à ma mère de quels sujets Oppenheimer et elle ont si longuement parlé pendant toute la soirée, car elle n'a pas de formation scientifique… Ma mère a expliqué avoir parlé avec lui de son procès, des accusations de trahison… Elle a confié à mon père qu'Oppenheimer lui paraissait extrêmement affecté et avoir compris à quel point celui-ci avait été blessé par ce retrait de clearance. Je crois que ma mère, parce qu'elle avait grandi à New York comme Oppenheimer et connaissait bien les États-Unis, a réellement pu l'écouter avec l'empathie nécessaire, et prendre la mesure de cette blessure patriotique."

Cette chute brutale laisse aussi des traces physiques. Sur les photos du Conseil 1958, à l'inverse de dix ans plus tôt, on le voit marqué, préoccupé. L'accueil est pourtant chaleureux, autant de la Belgique que de ses confrères physiciens au Conseil. Reste ainsi dans les archives un banquet dans le restaurant l'Atomium qui venait d'être construit. Le thème du Conseil est aussi abordé pour la fois et un des thèmes de pédilection de Robert Oppenheimer : l'astrophysique et la cosmologie. C'est en effet moins connu, mais le père de la bombe atomique est aussi *"le père des trous noirs"*, relève Marc Henneaux. *"Il a compris des choses sur les trous noirs avant la guerre de 40. En 1939, il a publié un article justement pour montrer qu'une étoile va s'effondrer sur elle-même pour former un trou noir si elle est trop massive. Il y a deux articles de lui extrêmement importants à ce niveau. C'est peut-être sa découverte la plus importante – car sa contribution peut ici vraiment être isolée – et la plus originale parce que c'était absolument hors des sentiers battus pour l'époque.*

Congrès Solvay de physique de 1958 en présence de Robert Oppenheimer. ©Archives Instituts Solvay

D'ailleurs, cela a été très controversé et au Conseil de 58, certaines personnes n'étaient pas d'accord avec lui. Dans la transcription des débats, on lit que certains scientifiques disent : 'mais non, un trou noir ne peut pas se former ; quelque chose doit se passer qui empêche la formation de cet objet bizarre'. Mais c'est Oppenheimer qui avait raison."

Soutien de Georges Lemaître

À l'inverse, parmi ses supporters se trouvait le Belge Georges Lemaître, père du Big Bang, également présent au Conseil cette année-là. Il est très probable que les deux sommités aient échangé, peut-être en français, langue qu'Oppenheimer parlait couramment. La lecture des débats menés aux Conseils confirme en tout cas qu'Oppenheimer *"aimait les idées originales"*, poursuit Marc Henneaux. Toujours à ce même congrès, il interpelle par exemple le grand physicien suédois Oskar Klein après sa présentation sur le développement des galaxies sur la question du multivers, une multitude d'Univers parallèles, un audacieux concept scientifique toujours très critiqué mais devenu depuis un des ressorts scénaristiques favoris d'Hollywood. *"Il pose toujours des questions "cash",* remarque Marc Henneaux. *Il demande à Klein : y a-t-il plusieurs univers ? Je pense que vous estimez que c'est le cas… L'autre répond oui. Immédiatement, Oppenheimer enchaîne : "Pourrait-on voir hors de notre Univers ? Je pense que vous espérez qu'on soit capable de le faire".* L'autre acquiesce, admettant cependant que ce sera probablement très compliqué…

Ce type de discussions et d'échanges directs après chaque exposé scientifique reste une marque de fabrique des Conseils Solvay. *"Ces discussions sont peut-être plus importantes maintenant qu'à l'époque,* juge Marc Henneaux. *Parce qu'il reste très peu de conférences où il y a vraiment des débats. Les gens font leur présentation, écoutent un petit peu celui avant et celui après, puis s'en vont. Nous, nous imposons aux scientifiques qui viennent au Conseil Solvay de rester du début à la fin…"* GSM et tablettes doivent en outre être éteints et il a même été envisagé par David Gross de couper le wifi… Chaque soir, tout le monde – en compagnie des époux et épouses – dîne ensemble : à l'Atomium, chez les Solvay, au Palais royal… C'est ainsi qu'Oppenheimer dîne par exemple à l'Atomium à côté de Mme Prigogine, l'épouse du prix Nobel belge Ilya Prigogine.

Mais les Conseils le lieront aussi à ceux qui théoriquement auraient dû être ses ennemis à vie. À la table du comité scientifique des Conseils Solvay qu'il intègre en 1948, Oppenheimer se trouvera en effet avec l'Allemand Werner Heisenberg, principal cerveau du programme nucléaire nazi, et le physicien japonais Shinichiro Tomonaga, compatriote des victimes de Nagasaki et Hiroshima qui, après la guerre, a dû survivre avec sa famille dans un laboratoire bombardé par les Américains. *"Ils ont travaillé ensemble, ils étaient capables de construire une réunion scientifique,* commente Marc Henneaux. *Quand on est scientifique, on ne se pose même pas la question de savoir ce que pense l'autre d'un point de vue politique. On est immédiatement passionné par ce qu'il apporte sur le plan scientifique. C'est pour cela que la recherche peut contribuer à la paix entre les peuples : finalement, on se rend compte qu'on suit la même démarche, rationnelle, scientifique. Et donc on peut se parler…"*

En 1961, c'est Robert Oppenheimer lui-même qui organise la conférence. *"C'est clair qu'il a mis un temps énorme à la préparer, il y a un immense travail en amont"* car les scientifiques doivent avoir connaissance des exposés à l'avance. Il emmène à ce conseil avec les "Oppenheimer boys", ces jeunes qui avaient travaillé avec lui à Los Alamos ou qui avait bénéficié de son soutien scientifique – et qui deviendront quasi tous prix Nobel ! – et en 1964, il devient en outre le président du Conseil Solvay. En 1967, une semaine avant sa mort le 18 février, il espérait encore pouvoir assister à la conférence d'octobre qu'il met aussi sur pied, mais qui ne pourra finalement que rendre hommage à ce *"grand fils de l'Amérique"*, *"qui a souvent répété tout ce qu'il devait à la culture européenne".*

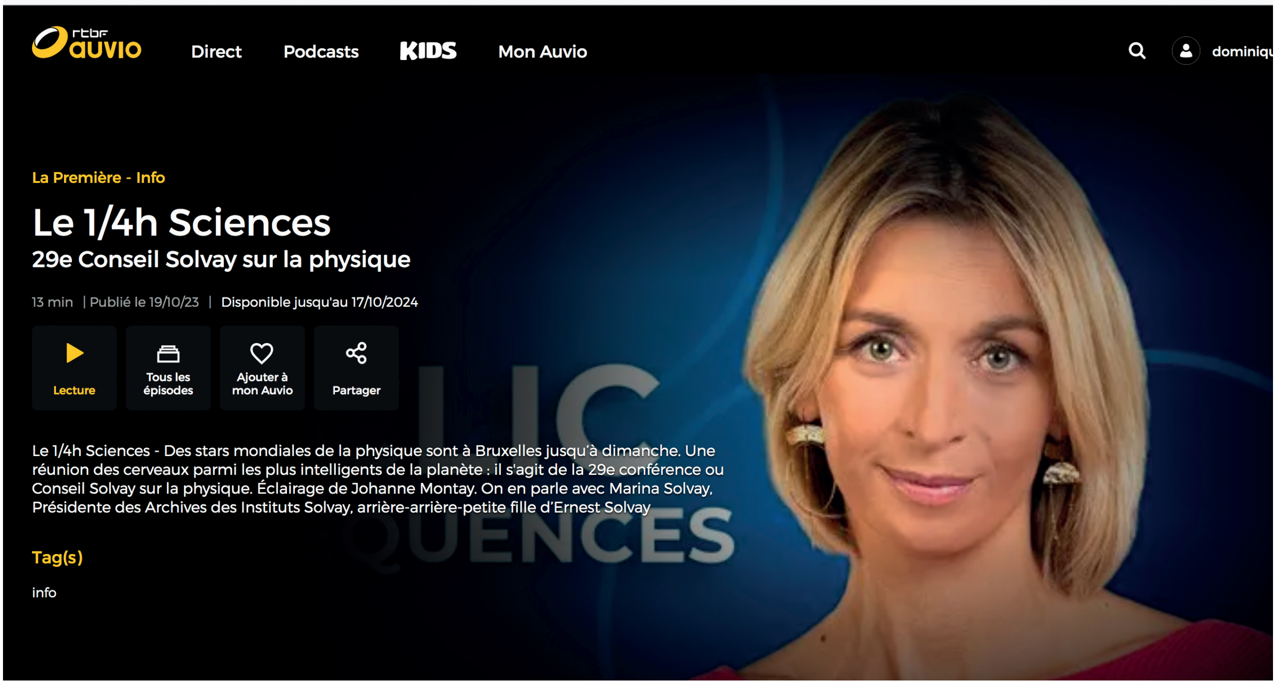
"Ce format inhabituel produit souvent des réunions mémorables"

Les Conseils Solvay ont été lancés en 1911 par le mécène Ernest Solvay, le chimiste et industriel belge. *"Les Conférences Solvay jouent toujours un rôle important dans le domaine scientifique (physique et chimie), même si bon nombre de leurs innovations originales sont devenues monnaie courante,* explique le président actuel du Conseil Solvay David Gross, prix Nobel de physique 2004. *Ce format inhabituel (un groupe sélectionné de scientifiques accomplis, choisis sans distinction de nationalité, réunis en séances à huis clos pour discuter de questions cruciales dans des domaines prometteurs de la recherche actuelle, toutes les discussions étant enregistrées puis publiées) produit souvent des réunions mémorables qui font progresser la science. Cela fournit aussi un compte rendu historique des délibérations des scientifiques en action."*

Cette année, le 29e Conseil de Physique Solvay se déroulera du 19 au 21 octobre à l'hôtel Plaza (c'était au Métropole jusqu'à sa fermeture). Dans la foulée, sera organisé un exposé scientifique destiné au grand public, une activité… lancée par Robert Oppenheimer lui-même qui souhaitait vulgariser les découvertes scientifiques au maximum. Cette présentation aura lieu le 22 octobre à 15 heures au Studio 4 de Flagey, avec (entre autres) les deux Nobel de physique David Gross et Giorgio Parisi. Gratuit mais inscriptions obligatoires sur www.solvayinstitutes.be < https://www.solvayinstitutes.be/ >

Notons que les Archives des Conseils internationaux de physique et de chimie Solvay sont inscrites au Patrimoine mondial de l'Unesco depuis mai 2023. Une cérémonie à l'Hôtel de Ville de Bruxelles célébrera cette inscription en compagnie des scientifiques du Conseil le 19 octobre.

La libre - 12 February 2023



October 2023 - Marina Solvay's interview

INSTITUT INTERNATIONAL DE CHIMIE-SOLVAY

PREMIER CONSEIL DE CHIMIE. - BRUXELLES, 21-27 AVRIL 1922.

BENJAMIN COUPRIE, PHOTO. 28, AVENUE LOUISE, BRUXELLES

G. CHAVANNE O. DONY-HÉNAULT F. SWARTS CH. MAUGUIN E. HERZEN L. FLAMACHE E. HANNON AUG. PICCARD

M. DELÉPINE E. BIILMANN H. WUYTS T.-M. LOWRY G. URBAIN J. PERRIN F.-M. JAEGER A. DEBIERNE H. RUPE A. BERTHOUD R.-H. PICKARD

CH. MOUREU F.-W. ASTON Sir W.-H. BRAGG H.-E. ARMSTRONG Sir W. POPE E. SOLVAY A. HALLER S. ARRHÉNIUS F. SODDY

De eerste Solvay-raad voor Chemie in 1922, tevens de laatste vergadering die Ernest Solvay zelf bijwoonde. Zoals veel foto's van de Solvay-vergaderingen is deze genomen in het Leopoldpark in Brussel (ULB, Solvay-archief).

Het Solvay Science Project

De Solvay-archieven als geheugen van de wetenschap

Alessio Rocci

"Er zijn geen grenzen aan wat de wetenschap kan onderzoeken."
Ernest Solvay

Op 24 mei 2023 heeft de Uitvoerende Raad van UNESCO de "Archives of Solvay Councils in Physics and Chemistry" (1910-1962) ingeschreven in het Memory of the World Register. De Organisatie van de Verenigde Naties voor Onderwijs, Wetenschap en Cultuur (UNESCO), ontstaan na de Tweede Wereldoorlog, is het agentschap van de Verenigde Naties dat is opgericht om bij te dragen aan het opbouwen van vrede door internationale samenwerking op het gebied van onderwijs, wetenschappen en cultuur. Het UNESCO-programma dat bekend staat als MoW (Memory of the World) wil het behoud van het documentaire erfgoed van de wereld vergemakkelijken, toegang tot documentair erfgoed wereldwijd mogelijk maken en het grote publiek bewuster maken van het belang van documentair erfgoed.

België is lid van UNESCO sinds 1946. De erkenningen in ons land omvatten vijftien Werelderfgoedsites, zestien elementen die zijn ingeschreven op de lijst van immaterieel erfgoed, één World Book Capital Network en zes inschrijvingen in het MoW-register.[1] Volgens de definitie van UNESCO worden al deze benoemingen beschouwd *als van uitzonderlijke waarde voor de mensheid.* De "Archives of Solvay Councils in Physics and Chemistry (1910-1962)", hierna het Solvay-archief, maken nu dan ook deel uit van het MoW-register.

Het MoW-programma werd in 1992 gelanceerd om collectief geheugenverlies tegen te gaan, waarbij het een oproep deed om waardevolle archiefbezittingen en bibliotheekcollecties te behouden en ervoor te zorgen dat deze op grote schaal worden bekendgemaakt. De achterliggende gedachte is dat het documentaire erfgoed van de wereld aan iedereen toebehoort, dus moet het volledig worden bewaard en zonder belemmeringen voor iedereen permanent toegankelijk zijn. Het UNESCO-programma wordt uitgevoerd door commissies en ondersteuningsmechanismen op internationaal, regionaal en nationaal niveau.

Het MoW-register geeft een overzicht van historische gegevens van wereldbelang en is een bron voor onderwijs en interculturele dialoog. Leraren en opvoeders kunnen het MoW-register gebruiken om de jonge generatie te helpen meer te leren over andere culturen en hun realiteiten en identiteiten in de geschiedenis te verankeren. Het register bevat film, epische poëzie, overheidsdocumenten of, zoals in het geval van het Solvay-archief, een verzameling documenten bestaande uit brieven, ansichtkaarten, geschetste portretten, memoires, officiële rapporten, foto's, poëzie, financiële registers, ongepubliceerde wetenschappelijke bijdragen, projecten, verslagen van vergaderingen en historische studies.

Het Solvay Science Project

De evaluatie van UNESCO bevestigde dat het materiaal dat wordt bewaard in het Solvay-archief een schat uit het verleden is. De archiefstukken vertellen ons het verhaal van de mensen die hebben bijgedragen aan wat we nu, naar een definitie bedacht door de Nederlandse Nobelprijswinnaar Hendrik Antoon Lorentz, "The Solvay Science Project" noemen.

Vlaams-Nederlands tijdschrift voor industriecultuur (2023 – Nummer 4)

Alessio Rocci

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
2022	The Physics of Quantum Information
2023	The Structure and Dynamics of Disordered Systems

Chairs of the International Scientific Committee for 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
2019	Computational Modeling: From Chemistry to Materials to Biology
2022	Chemistry Challenges of the 21st Century

Chairs of the International Scientific Committee for 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 - 2022	Kurt Wüthrich, 2002 Nobel Laureate in Chemistry Zurich (Switzerland) and La Jolla (USA)
2022 - present	Professor Ben Feringa, 2016 Nobel Laureate University of Groningen, The Netherlands

The International Solvay Chairs in Physics and in Chemistry

Jacques Solvay Chairs 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
2018	Bernard Derrida, Collège de France, France
2019	Gary Gibbons, Cambridge, UK
2020	Roger Blandford, Stanford University, USA
2021	Jean Dalibard, Collège de France, France
2022	Juna Kollmeier, Canadian Institute for Theoretical Astrophysics, Toronto, Canada
2023	Subir Sachdev, Harvard University, USA

Solvay Chairs 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 Royce Schrock, 2005 Nobel Laureate in Chemistry MIT, USA
2015	Andreas Manz, Saarbrücken, Germany
2016	Raymond Kapral, Toronto, Canada
2017	Richard Henderson, 2017 Nobel Laureate in Chemistry Cambridge, UK
2018	Ben Feringa, 2016 Nobel Laureate in Chemistry U. of Groningen, The Netherlands
2019	Gernot Frenking, Philipps-U. Marburg, Germany
2020	Joanna Aizenberg, Harvard, USA
2021	Omar Yaghi, Berkeley, USA
2022	Daniel Jacob, Harvard University, USA
2023	Ehud Gazit, Tel-Aviv University, Israel

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

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 (University of 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 Eric Wieschaus (Princeton U., USA)
1995 Nobel Laureate in Physiology or Medecine

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

21 October 2018

"De novo protein design: bringing biology out of the Stone Age"
by David Baker (University of Seattle, USA)

"Random Walk to Graphene"
by Andre Geim (University of Manchester, UK)
2010 Nobel Laureate in Physics

20 October 2019 | "Frontiers of Chemistry"

"Optical microscopy: the resolution revolution"
by Stefan Hell, (Max Planck Institute, Öttingen, Germany)
2014 Nobel Laureate in Chemistry

"To get to know biological molecules, freeze them and photograph them!"
by Eva Nogales (UC Berkeley, USA)

12 September 2021 | "Physics, Chemistry and Life Sciences"

"How personalised is your immune repertoire?"
by Aleksandra Walczak (ENS, Paris, France)

"Why we cannot make artificial life in a laboratory"
by Bert Meijer (Eindhoven, The Netherlands)

"Steps towards complex matter: chemistry!"
by Jean-Marie Lehn (Strasbourg, France)
1987 Nobel Laureate in Chemistry

24 October 2021

"Exoplanets or the Quest for Life around Another Sun"
by Michaël Gillon (Liège University, Belgium)

22 May 2022 I "The New Quantum Revolution"

"The Strangeness and the power of quantum physics"
by Serge Haroche (Collège de France, Paris)

"Quantum computing and the entanglement frontier"
by John Preskill (Caltech, USA)

16 October 2022

"Water Harvesting from Air Anytime Anywhere"
by Omar Yaghi (Berkeley, USA)

"What is Life?"
by Paul Nurse (Crick Institute, UK)

22 October 2023 | "Complex systems and collective behaviors"

"Computational optimization: from glasses to black holes"
by Leticia Cugliandolo (Sorbonne Université, Paris)

"How many candies are in that jar? A dynamical phase transition."
by Paul Chaikin (New York University)

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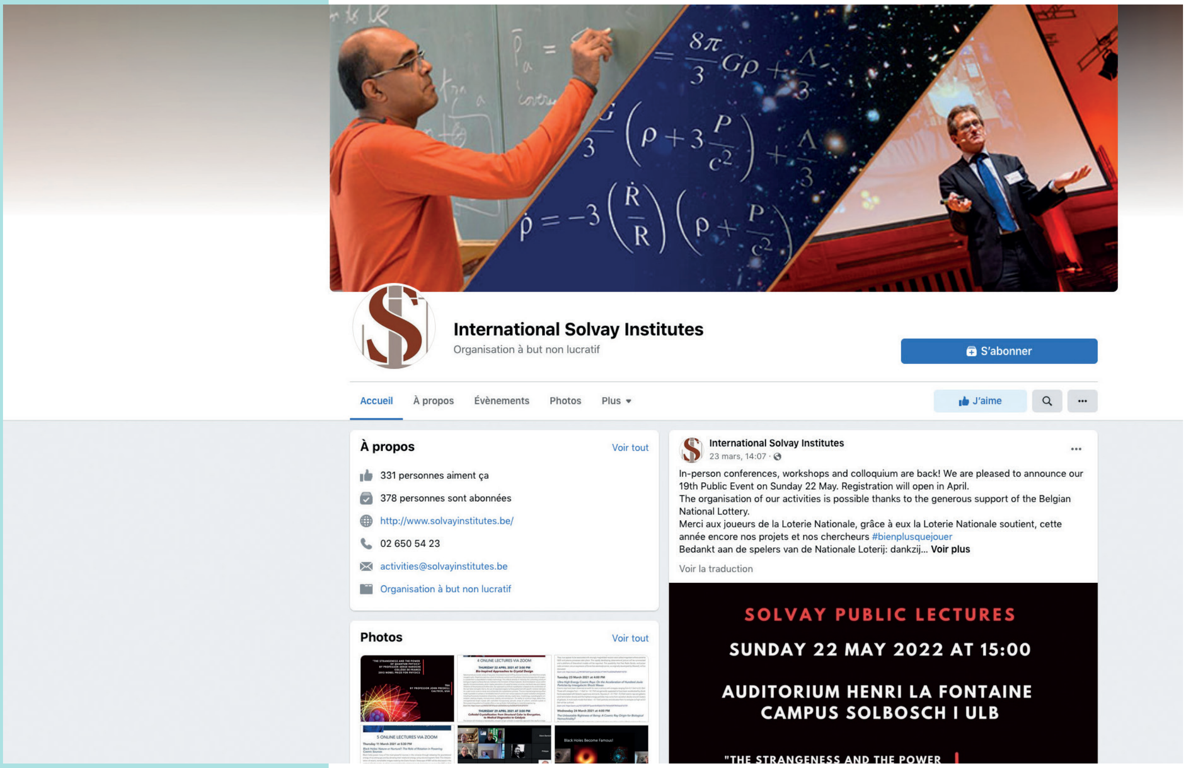

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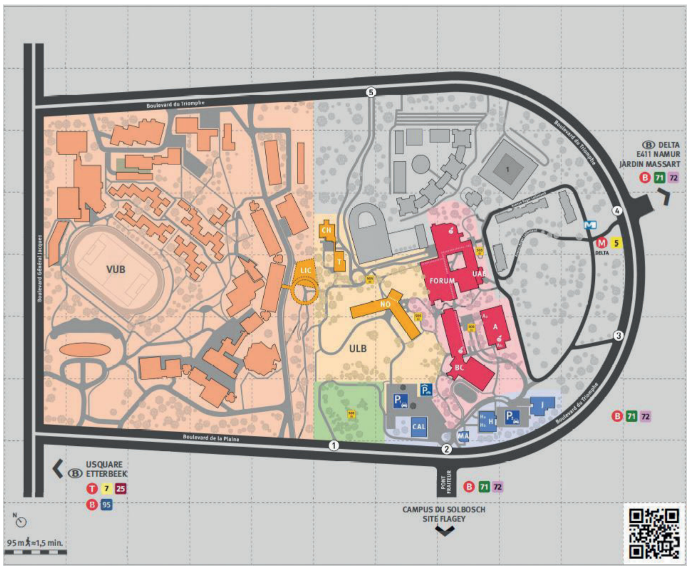

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