ANNUAL REPORT

2022

INSTITUTS INTERNATIONAUX DE PHYSIQUE ET DE CHIMIE
FONDÉS PAR ERNEST SOLVAY ASBL

INTERNATIONALE INSTITUTEN VOOR FYSICA EN CHEMIE
GESTICHT DOOR ERNEST SOLVAY VZW

INTERNATIONAL SOLVAY INSTITUTES BRUSSELS

ANNUAL REPORT

2022

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GESTICHT DOOR ERNEST SOLVAY VZW

There are no limits to what science can explore

ERNEST SOLVAY

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

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Progress beyond

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FÉDÉRATION WALLONIE-BRUXELLES

fnrs

LA LIBERTÉ DE CHERCHER

fwo Opening new horizons

BNP PARIBAS FORTIS


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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 ?
loterie nationale
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?
nationale loterij
MEER DAN SPELEN

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 20th and 21st century have come to Brussels to participate in the prestigious "Solvay Congresses", the pictures of which are known worldwide and have become a symbol of excellence. The Solvay Conferences have put Brussels on the scientific world map.

The support of the National Lottery also paves the way 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

Let us reflect on the year 2022, which was exceptional in many ways. A year that saw the emergence out of the covid confinement and out of the uncertainty that ruled over all activities that thrive on the meeting of people face to face. In these difficult and uncertain circumstances, the team, led by the director was able to, nimbly, organize successfully the 28th Solvay Conference on Physics in May, the longtime planned 26th Solvay Conference on Chemistry in October, followed by the celebration of the 100-year anniversary of the first Conference on Chemistry in October 1922.

Let us add that 2022 was also the anniversary year of the death of Ernest Solvay.

Going back to the vision that Ernest had about science, physics and chemistry, which were unique for him because of his passion for curiosity driven research and because he saw the potential impact of these two fundamental sciences through industrialization as an avenue to bring prosperity, education, and a better life to humanity.

We wanted to celebrate the two anniversaries in a special event: an Academic Session in celebration of the vision and values that Ernest Solvay demonstrated in his life. How would he look upon his legacy at this time? The program of the Academic Session, "Chemistry and the Future of Society" was structured around the impact of Chemistry as a science in today's world and what could be our ambition for the future?

The 26th Solvay Conference on Chemistry and the Academic Session brought much of these themes together: inventing new sustainable chemistry as an answer to climate change, new chemistry to optimize industrial processes, RNA chemistry to fight viral pandemics and a world science-based culture as a driver for global peace were debated in panels.

A special panel was held with bright young scientists to peer into the future of chemistry. We heard that the passion and ambition of curiosity driven research is very much alive and that our founder would find the pursuit of science for the benefit of humanity as compelling as ever.

This was a year of re-emergence and ambition. I extend my heartfelt gratitude to the executive team for their amazing agility, Professor Marc Henneaux (Director), Dominique Bogaerts (Office Manager) and Isabelle Van Geet (Project Coordinator), Alexander Sevrin and Anne de Wit (Conference Scientific Secretaries).

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

I am also grateful to our sponsors, the ULB and the VUB universities, the Solvay Company, the Belgian National Lottery, the Brussels-Capital Region, the Fédération Wallonie-Bruxelles, the FWO, the FRS-FNRS, the Solvac company and the very supportive Solvay family.

Whitout them none of this would be possible!

Jean-Marie Solvay | President

A word from the Director

The year 2022 has been at the same time very busy and very gratifying: we have been able to catch up with the backlog of delayed activities accumulated during the Covid-19 crisis and can now turn the page of the pandemic with reasonable confidence.

The policy of the International Solvay Institutes for coping with the restrictions imposed by the sanitary crisis has been to avoid cancellations of our activities by postponing our programs to times where restrictions would be removed. Some activities were held in a virtual or hybrid mode, but only in a minority of cases. The Solvay Institutes are an activity-based institution where face-to-face interactions between researchers are essential. We wanted to privilege this invaluable working mode and succeeded in doing so.

The lift of the sanitary restrictions in 2022 enabled us to continue the effort began in 2021 and to hold not only our planned 2022 program, but also all the remaining activities postponed from 2020 and 2021 to 2022. This led to a very busy year indeed, with two Solvay conferences (28th Solvay Conference on Physics in May and 26th Solvay Conference on Chemistry in October), two public events, two chairs in physics, three chairs in chemistry etc. Only two activities from 2021 and 2022 are still to be held in 2023, the 2021 New Horizons Lectures in Chemistry which will take place in May of 2023 and the 2022 New Horizons Lectures in Physics which will take place in March of 2023 (by the time this report is released, both programs will be completed).

The overall impact of the sanitary crisis on our activities has thus successfully been kept to a minimum. We can start anew the year 2023 with optimism and I look forward to it.

This report describes at length the activities organized or supported by the International Solvay Institutes during the year 2022. These activities covered a wide spectrum of developments at the frontiers of physics and chemistry. All the detailed information can be found in the core of the report.

To be particularly mentioned is the special Academic Session "Chemistry and the Future of Society" that took place on the occasion of the 100th anniversary of the first Solvay Conference on Chemistry. Distinguished scientists and economists, high-level executives from industry as well as representatives of funding agencies and of the political world stressed the importance of fundamental research - and in particular fundamental research in chemistry - for the future of humanity. The event was honored by the presence of His Majesty the King, Minister Valérie Glatigny and State Secretary in charge of Science Policy Thomas Dermine.

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 Belgian National Lottery, the FWO, the FRS-FNRS, the Brussels-Capitale Region, the Fédération Wallonie-Bruxelles 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.

The Institutes would not have successfully gone through the sanitary crisis without the remarkable dedication and commitment of Dominique Bogaerts and Isabelle Van Geet. The Covid times have been very demanding – and sometimes frustrating - for them. Dominique et Isabelle have been able to masterly manage the complicated logistics due to the numerous reschedulings of our activities. I want to thankfully praise their diligent efficiency and their exceptional sense of responsability.

Marc Henneaux | Director

01

GENERAL INFORMATION

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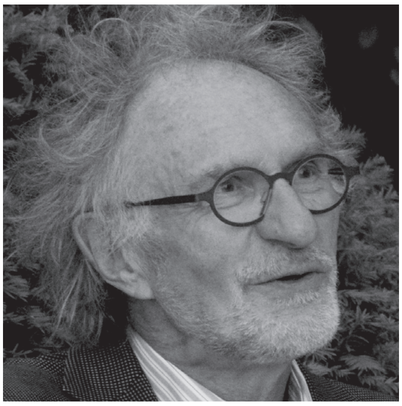

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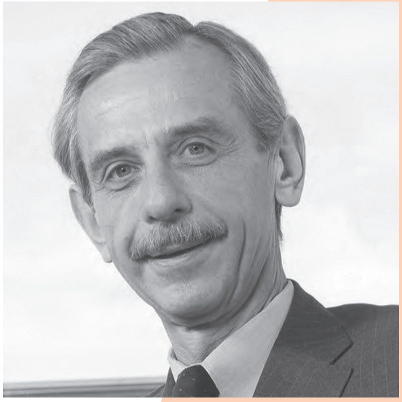

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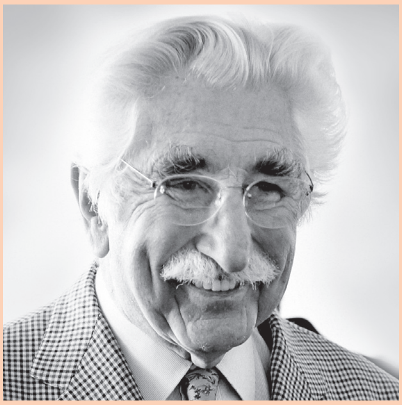

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Scientific Secretary of the International
Committee for Physics

Marina Solvay
Chairwoman of the Archives Committee
of the Solvay Institutes

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Secretary of the Royal Academy for Science
and the Arts of Belgium

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).

Executive Committee

Professor Marc Henneaux | ULB
Director

Professor Alexander Sevrin | VUB
Deputy Director for Physics

Professor Gert Desmet | VUB
Deputy Director for Chemistry

Professor Glenn Barnich | ULB

Professor Ben Craps | VUB

Professor Anne De Wit | ULB

Professor Yves Geerts | ULB

Administrative Staff

He 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.

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Professor David Gross
2004 Nobel Laureate
Kavli Institute for Theoretical Physics,
Santa Barbara, USA

Scientific Secretary

Professor Alexander Sevrin
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1997 Nobel Laureate
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Università La Sapienza, Roma, Italy

Professor Peter Zoller
University of Innsbruck, Austria

International Scientific Committee for Chemistry

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2002 Nobel Laureate
Scripps Research Institute, La Jolla, USA
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2016 Nobel Laureate
University of Groningen, The Netherlands

Professor Stefan Hell
2014 Nobel Laureate
Max Planck Institute, Göttingen, Germany

Professor JoAnne Stubbe
Massachusetts Institute of Technology, USA

Professor Bert Weckhuysen
University of Utrecht, The Netherlands

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Harvard University, USA

International Advisory Committee

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.

Chair

Professor Lars Brink
Chalmers University of Technology, Göteborg, Sweden († 29 October 2022)

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Eindhoven University of Technology, The Netherlands

Professor Hirosi Ooguri
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Professor Gunnar von Heijne
Stockholm University, Sweden

In Memoriam

The International Solvay Institutes mourn the passing away of Professor Lars Brink on 29 October 2022 at the age of 78.

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 super-symmetric 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.

Through his invaluable advice based on his broad knowledge of physics and of the physics community, Lars Brink has been instrumental in the revival of the Solvay Institutes. The detailed constructive reports of the international advisory committee which he chaired since its creation have been of enormous guidance and inspired many decisions made by the direction of the Institutes. In spite of his illness, he kept his influential and much appreciated advisory role until his death, through regular Zoom videoconferences. Lars also gave critical advice for setting up the governing rules of the “Chemistry for the Future Solvay Prize” created by the Solvay company.

The International Solvay Institutes have benefitted for many years of the vision of Professor Lars Brink.

We owe him very much. We miss a great supporter and friend.

1 - One-day fest in honor of Mrs Solvay (July 2019)
2 - 26th Solvay Conference on Physics (October 2014)
3 - 25th Solvay Conference on Physics (October 2011)
4 - Workshop “Le charme discret de la Symétrie” in honor of Prof. Marc Henneaux (March 2015)

Local Scientific Committee for Physics

Chair

Professor Marc Henneaux I ULB, Brussels

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Professor Conny Aerts I KU Leuven
Professor Nicolas Boulanger I UMONS
Professor Giacomo Bruno I UCL, Louvain
Professor Ben Craps I VUB, Brussels
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Professor Han Remaut I VUB, Brussels
Professor Marlies Van Bael I UHasselt
Professeur Lode Wyns I VUB, Brussels

Observers

Professor Pierre Gaspard I ULB, Brussels
Professor Marc Henneaux I ULB, Brussels

Honorary Members

Professor Claudio Bunster
Centro de Estudios Científicos, Valdivia, Chile

Professor Claude Cohen-Tannoudji
1997 Nobel Laureate
École Normale Supérieure, Paris, France

Professor Robbert Dijkgraaf
Minister of Education, Culture and Science, The Netherlands

Professor François Englert
2013 Nobel Laureate
Université Libre de Bruxelles, Belgium

Professor Graham Fleming
University of Berkeley, USA

Professor Gerard 't Hooft
1999 Nobel Laureate
Spinoza Instituut, Utrecht, The Netherlands

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Former CEO Solvay Group, Belgium

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2006 Nobel Laureate
Stanford University, USA

Professor Jean-Marie Lehn
1987 Nobel Laureate
Collège de France, Paris, France

Professor Henk N.W. Lekkerkerker
Utrecht Universiteit, The Netherlands

Professor Victor P. Maslov
Moscow State University, Russia

Professor Hermann Nicolai
Max-Planck-Institut für Gravitationsphysik, Golm, Germany

Professor Kyriacos Costa Nicolaou
University of California, San Diego, USA

Professor Jacques Prost
Institut Curie, Paris, France

Professor Pierre Ramond
University of Florida, Gainesville, USA

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University of Chicago, USA

Professor Victor A. Sadovnichy
Moscow State University, Russia

Professor Roald Sagdeev
University of Maryland, College Park, USA

Madame Solvay de la Hulpe, Belgium

Professor Irina Veretennicoff
Emeritus Professor VUB, Belgium

Professor Klaus von Klitzing
1985 Nobel Laureate
Max-Planck-Institut, Stuttgart, Germany

Professor Chen Ning Yang
1957 Nobel Laureate
Chinese University Hong Kong & Tsinghua University, Beijing, China

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02

28th SOLVAY
CONFERENCE ON PHYSICS

28th Solvay Conference on Physics "The Physics of Quantum Information"

19 - 21 May 2022

The 28th Solvay Conference on Physics was initially scheduled to take place in October of 2020. Because of the pandemic it was rescheduled twice, first to October of 2021, and then to May of 2022.

It was the third time in the history of the Solvay conferences that the normal periodic cycle of one conference every three years was interrupted. The first two instances were the two world wars, during which Solvay meetings were just canceled. The recent pandemic also took its toll, but in a lighter way since it only forced us to postpone the conference.

We feared until the very last day that the conference would have to be rescheduled again. It was therefore a big relief and a real pleasure when the conference did start on May 19, with all participants physically present in the conference room!

"The Physics of Quantum Information" is a field that has witnessed remarkable developments in the last decade and that naturally imposed itself as the subject of the 28th Conference. 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 Châtelain" in Brussels. It was chaired by Professors David Gross and Peter Zoller from the University of Innsbruck. A welcome reception was given by the Mayor of Brussels at the City Hall on the 18th of May in the evening. 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. They have produced in a record time the conference proceedings, which include the vivid and informative discussions that took place during the meeting.

Scientific background

The development of quantum mechanics is one of the most extraordinary intellectual conquests of humanity. It has completely revolutionized our view of Nature. Furthermore, it has led to numerous applications which have dramatically changed our way of living. The transistor, the integrated circuit and electronics, the laser have grown out of our understanding of quantum mechanics and have become familiar devices that have invaded our everyday life.

Solvay Conferences played a key role in deciphering the mysteries of the quantum world during the 20th century, going back to the very first one in 1911.

But quantum mechanics has not revealed all its secrets yet. New remarkable developments, which constitute what is sometimes called "The new quantum revolution", have taken place in the last decades. These developments were precisely the subject of the 28th Solvay conference, "The Physics of Quantum Information".

The meeting covered four areas where far-reaching advances have taken place recently: quantum matter, quantum gravity, quantum computer science and quantum hardware. These were discussed in the corresponding sessions.

Programme

Thursday 19 May 2022

Session I: Opening / Overview - Chairs: Marc Henneaux and John Preskill

Welcome remarks: Marc Henneaux, David Gross and Peter Zoller

Overview by John Preskill, David Wineland and Peter Shor

Session II: Many-Body Entanglement - Chair: Ignacio Cirac

Rapporteurs:

Misha Lukin	*Programmable Quantum Machines for Probing Entanglement in Many-Body Systems*
Frank Verstraete	*Quantum Information and Many-Body Systems*

Reports and discussions

Friday 20 May 2022

Session III: Quantum Information and Spacetime - Chair: Juan Maldacena

Rapporteurs:

Netta Engelhardt	*The Entropy of Hawking Radiation*
Douglas Stanford	*Quantum information and spacetime*

Reports and discussions

Saturday 21 May 2022

Session IV: Quantum Platforms - Chair: Steven Girvin

Rapporteurs:

Rainer Blatt	*The Trapped-Ion Platform for Quantum Information Processing*
Robert Schoelkopf	*Superconducting Qubits as a Platform for QC*

Reports and discussions

Session V: Quantum Algorithms - Chair: Umesh Vazirani

Rapporteurs:

Scott Aaronson	*How Much Structure Is Needed for Huge Quantum Speedups?*
Daniel Gottesman	*Opportunities and Challenges in Fault-Tolerant Quantum Computation*

Reports and discussions

Participants

Aaronson Scott
University of Texas, USA

Aharanov Dorit
Hebrew University, Jerusalem, Israel

Almheiri Ahmed
IAS, Princeton, USA

Altman Ehud
University of California, Berkeley, USA

Blatt Rainer
Universität Innsbruck, Austria

Bloch Immanuel
Max-Planck-Institut München, Germany

Browaeys Antoine
Institut d'Optique, Palaiseau, France

Calabrese Pasquale
SISSA, Trieste, Italy

Cirac Ignacio
Max Planck, Garching, Germany

Engelhardt Netta
MIT, USA

Farhi Edward
Google/MIT, USA

Fisher Matthew
Kavli Institute, Santa Barbara, USA

Gambetta Jay
Thomas J. Watson Research C., Yorktown Heights, USA

Girvin Steven
Yale University, USA

Gottesman Daniel
Perimeter Institute, Canada

Gross David
Kavli Institute, Santa Barbara, USA

Halperin Bertrand
Harvard University, USA

Harlow Daniel
MIT, USA

Haroche Serge
Collège de France, Paris, France

Henneaux Marc
Solvay Institutes & ULB, Brussels, Belgium

Hubeny Veronika
UC Davis, California, USA

Jiang Liang
University of Chicago, USA

Ketterle Wolfgang
MIT, USA

Khemani Vedika
Stanford University, USA

Lukin Misha
Harvard University, USA

Mahadev Urmila
CALTECH, USA

Maldacena Juan
IAS, Princeton, USA

Marcus Charles
Niels Bohr Institute, Denmark

Martinis John
UC Santa Barbara, USA

Nakamura Yasunobu
University of Tokyo, Japan

Penington Geoffrey
University of California, Berkeley, USA

Pollmann Frank
TUM, Germany

Preskill John
CALTECH, USA

Rey Ana Maria
University of Colorado, Boulder, USA

Schoelkopf Robert
Yale University, USA

Sevrin Alexander
VUB, Brussels, Belgium

Shor Peter
MIT, USA

Simmons Michelle
UNSW Sydney, Australia

Stanford Douglas
Stanford University, USA

Terhal Barbara
Delft University of Technology,
The Netherlands

Troyer Matthias
One Microsoft Way, USA

Vazirani Umesh
University of California, Berkeley, USA

Verstraete Frank
U. Gent, Belgium

Vidick Thomas
CALTECH, USA

Wall Aron
University of Cambridge, UK

Wen Xiao-Gang
MIT, USA

Wiebe Nathan
University of Washington, USA

Wineland David
University of Oregon, USA

Zoller Peter
Universität Innsbruck, Austria

Auditors

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

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

Nicolas Cerf (ULB)
Ben Craps (VUB)
Frank Ferrari (ULB)
Nathan Goldman (ULB)
Jacques Tempere (UAntwerp)
Karel Van Acoleyen (UGent)
Jutho Haegeman (UGent)
Marco Di Liberto (University of Innsbruck)
Nader Mostaan (University of Munich)
Thomas Mertens (UGent)
Marine De Clercq (VUB)
Juan Hernandez (VUB)
Laurens Vanderstraeten (UGent)
Jacob Bridgeman (UGent)
Kristiaan De Greve (IMEC)

The conference was one of the best I have ever attended.

Scott Aaronson

19th Solvay Public Lectures "The New Quantum Revolution"

22 May 2022

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

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

Two public events took place in 2022. The first one was organized on 22 May 2022 in the ULB auditorium Henri Lafontaine, immediately after the Solvay Conference on Physics. It is described in this section. The second one was part on the chemistry centenary celebrations and can be found in the corresponding section.

The 19th Solvay public event was entitled "The New Quantum Revolution". Even though quantum mechanics is part of the cultural heritage of humanity and has led to so many applications, the general public knows very little about it. This is perhaps because the behaviour of the quantum world conflicts with our intuition: Nature at the microscopic scale exhibits strange behaviours which appear to be in complete conflict with common sense. It was the purpose of the 19th public event to give to the general public a good idea and a good feeling of the fundamental features of the strange quantum behaviour of Nature and its peculiar beauty.

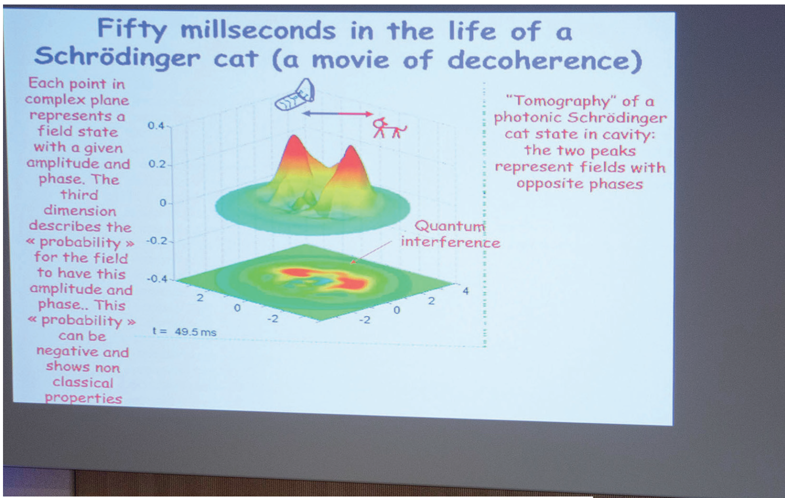
The lectures were delivered by two of the leading world experts in the field, who made major contributions to various aspects of quantum mechanics. Their lectures were followed by a panel discussion in which took part some of the participants in the 28th Solvay Conference on Physics. Topics addressed by the lecturers and the panellists ranged from fundamental principles of quantum physics to quantum communication and quantum computing.

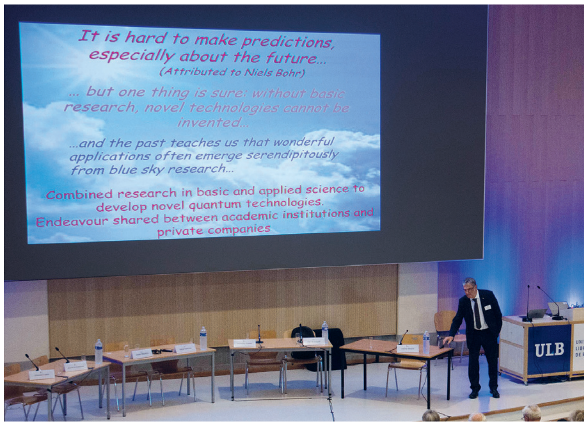
The international Solvay Institutes are most grateful to them.

Programme

Moderator	Prof. Alexander Sevrin VUB & International Solvay Institutes
15:00 - 15:10	Opening by Prof. Marc Henneaux ULB & International Solvay Institutes
15:10 - 16:00	“The Strangeness and the power of quantum physics” by Prof. Serge Haroche (Collège de France, Paris)
16:00 - 16:50	“Quantum computing and the entanglement frontier” by Prof. John Preskill (Caltech, USA)
16:50 - 17:50	Panel Discussion with Profs. David Gross, Edward Farhi, Serge Haroche, Veronika Hubeny, John Preskill, Michelle Simmons and Peter Zoller
17:50 - 18:00	Closing by Prof. Marc Henneaux
18:00	Drink

Lecturers





Professor Serge Haroche

Collège de France, France
2012 Nobel Laureate for Physics

Professor Serge Haroche graduated from École Normale Supérieure (ENS), receiving his doctorate from Paris VI University in 1971. After a post-doctoral visit to Stanford University, he became full professor at Paris VI University in 1975, a position he held until 2001, when he was appointed Professor at Collège de France (in the chair of quantum physics). He has been Maitre de Conference at Ecole Polytechique (1974-1984), visiting professor at Harvard (1981), part time professor at Yale University (1984-1993), member of Institut Universitaire de France (1991-2000) and chairman of the ENS Department of Physics (1994-2000). His research has mostly taken place in laboratoire Kastler Brossel at ENS. He developed new methods for laser spectroscopy, based on the study of quantum beats and superradiance. He then moved on to Rydberg atoms, giant atomic states particularly sensitive to microwaves, which makes them well adapted for studying the interactions between light and matter. He showed that such atoms, coupled to a superconducting cavity containing a few photons, are well-suited to the testing of quantum decoherence and to the realization of quantum logic operations necessary for the treatment of quantum information.

Serge Haroche has received many prizes and awards, including the Grand Prix Jean Ricard of the French Physical Society and the Humbold Award.

On 9 October 2012, Professor Haroche was awarded the Nobel Prize in Physics, together with the American physicist David Wineland, for their work regarding measurement and manipulation of individual quantum systems.

In 2020, Professor Haroche was appointed by European Commissioner for Innovation, Research, Culture, Education and Youth Mariya Gabriel to serve on an independent search committee for the next president of the European Research Council (ERC), chaired by Helga Nowotny.

Professor John Preskill

Caltech, USA

Professsor Preskill is the Richard P. Feynman Professor of Theoretical Physics at the California Institute of Technology, where he is also the Director of the Institute for Quantum Information and Matter.

He graduated summa cum laude from Princeton University with an A.B. in physics in 1975, completing his senior thesis, titled “Broken symmetry of the Pseudoscalar Yukawa theory”, under the supervision of Arthur S. Wightman. He received his Ph.D. in the same subject from Harvard University in 1980 and became Associate Professor of Theoretical Physics at Caltech in 1983, rising to full professorship in 1990. Since 2000 he has been the Director of the Institute for Quantum Information at Caltech.

In recent years most of his work has been in mathematical issues related to quantum computation and quantum information theory. He is a leading scientist in the field of quantum information science and quantum computation, and he is known for coining the term “quantum supremacy” and that of “noisy intermediate-scale quantum (NISQ)” devices.

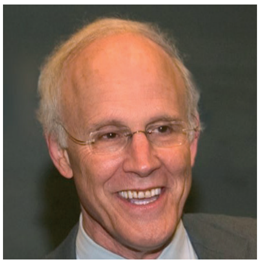
Professor Preskill was elected as a Fellow of the American Physical Society in 1991 and a member of the National Academy of Sciences in 2014.

Panel members

Professsor Edward Farhi

MIT, USA

Professor Farhi went to the Bronx High School of Science and Brandeis University before getting his Ph.D. from Harvard in 1978. He was then on the staff at the Stanford Linear Accelerator Center and at CERN in Geneva Switzerland before coming to MIT, where he joined the faculty in 1982. From 2004 until 2016, he served as Director of MIT's Center for Theoretical Physics. He was trained as a theoretical particle physicist but has also worked on astrophysics, general relativity, and the foundations of quantum mechanics. His present interest is the theory of quantum computation.



Professor David Gross

Kavli Institute for Theoretical Physics at UCSB, USA
2004 Nobel Laureate for Physics

Professor David Gross is the Chancellor's Chair Professor of Theoretical Physics and former Director of the Kavli Institute for Theoretical Physics at UCSB (see CV on pages 44-45).

Professor Veronika Hubeny

UC Davis, California, USA

Professor Hubeny is a theoretical physicist, currently a Professor in the Department of Physics and Astronomy at UC Davis and a founding member of the Center for Quantum Mathematics and Physics (QMAP). Her research interests lie mainly in areas of string theory and quantum gravity. Much of her past work has been set in the context of the gauge/gravity duality and black holes. More recently, she has been focusing on the fascinating connections to quantum information theory, in particular on the relation between entanglement structure and emergence of dual spacetime.

Professor Michelle Simmons

UNSW Sydney, Australia

Professor Simmons is Director of the Centre of Excellence for Quantum Computation and Communication Technology and an Australian Research Council Laureate Fellow. She has pioneered unique technologies internationally to build electronic devices in silicon at the atomic scale, including the world's smallest transistor, the narrowest conducting wires, 3D atomic electronics and the first two qubit gate using atom-based qubits in silicon. As founder of Silicon Quantum Computing Pty Ltd, her team is at the forefront of developing a silicon-based quantum computer. Professor Simmons is one of a handful of researchers in Australia to have twice received an Australian Research Council Federation Fellowship and now a Laureate Fellowship.

Professor Peter Zoller

Universität Innsbruck, Austria

Professor Peter Zoller is a Professor for theoretical physics at the University of Innsbruck, and Scientific Director at IQOQI Innsbruck. His research interests include atomic physics and theoretical quantum optics, and many-body quantum physics with quantum gases, and quantum information, in close collaboration with experiment. He has written major works on the interaction of laser light and atoms. In addition to fundamental developments in quantum optics he has made major contributions in the field quantum information. The model of a quantum computer, suggested by him and Ignacio Cirac in 1995, is based on the interaction of lasers with cold ions confined in an electromagnetic trap. The principles of this idea have been implemented in experiments over recent years and it is considered one of the most promising concepts for the development of a scalable quantum computer. Professor Zoller and his researcher colleagues have also managed to link quantum physics with solid state physics. One of his suggestions has been to build a quantum simulator with cold atoms.

David's Fest

17-18 May 2022

Professor David Gross served as member, and then as chair, of the International Solvay Scientific Committee for Physics since 2004. Through his scientific vision, his communicative energy and his constant support, David has played a key role in shaping the Solvay Institutes during the first quarter of the 21st Century. His influence will clearly last for much longer!

The International Solvay Institutes owe immensely to him.

In order to pay tribute to his essential role in the revival of the Solvay Conferences and Institutes, we organized the "David's Fest" on 17-18 May. The celebration was initially scheduled to take place in 2021 so as to coincide with David's 80th birthday. But Covid 19 decided otherwise and forced us to reschedule the event to May of 2022. Members of the Solvay family and of the Board of Directors of the Solvay Institutes, as well as selected scientists from all over the world, participated in the meeting.

The event took place in two different venues related to the history of the Institutes. It started on the first day in the magnificent setting of the Solvay Library, a key building of the city of science project that Ernest Solvay envisioned more than a century ago. It continued on the second day in sumptuous decor of the "Maison Ernest Solvay", where Ernest Solvay lived and which still belongs to the Solvay Company.

Invited Speakers

Kenneth Bertrams (ULB, Brussels, Belgium)
Edouard Brézin (ENS, Paris, France)
Rajesh Gopakumar (ICTS-TIFR, Bengaluru, India)
Bertrand Halperin (Harvard University, USA)
Marc Henneaux (Solvay Institutes, Belgium)
Wolfgang Ketterle (MIT, USA)
Igor Klebanov (Princeton University, USA)
Juan Maldacena (IAS, Princeton, USA)
Eliezer Rabinovici (Racah Institute of Physics, Israel)
Boris Shraiman (Kavli Institute, Santa Barbara, USA)
Marina Solvay (Solvay Institutes, Belgium)
Spenta Wadia (ICTS-TIFR, Bengaluru, India)
Peter Zoller (Universität Innsbruck, Austria)

Ms Marina Solvay, Mrs Solvay, Prof. David Gross, Prof. Eliezer Rabinovici, Prof. Marc Henneaux, Prof. Rajesh Gopakumar and Prof. Spenta Wadia.

Programme

Tuesday 17 May 2022 at the Solvay Library

16:40 - 16:50	*Welcome remarks* by Marc Henneaux
16:50 - 17:20	*Ernest Solvay's Scientific Patronage between Internationalism and Patriotism* by Kenneth Bertrams
17:20 - 17:35	*David's role in the Solvay Institutes* by Marc Henneaux
17:35 - 17:45	*David's role in the Solvay Institutes* by Jean-Marie Solvay
17:45 - 18:05	*David's international involvement in the development of science in India* by Spenta Wadia & Rajesh Gopakumar
18:05 - 18:20	*David's international involvement in the development of science in Israel* by Eliezer Rabinovici
18:20 - 18:30	*Closing words* by Marc Henneaux
19:30	*Banquet* (talks by Edouard Brézin and Igor Klebanov)

Wednesday 18 May 2022 at the Maison Ernest Solvay

14:00 - 14:15	*Presentation of the session* by Marc Henneaux
14:15 - 15:00	*The Solvay Conferences since 2004* by Bertrand Halperin and Boris Shraiman
15:00 - 16:00	*The future of the Solvay Conferences* - Panel with the Solvay scientific committee members: David Gross, Bertrand Halperin, Wolfgang Ketterle, Juan Maldacena, Peter Zoller chaired by Eliezer Rabinovici, preceded by a Zoom oral intervention by Lars Brink
16:00 - 16:30	Coffee break
16:30 - 17:30	*Some of the biggest challenges of physics* - Questions to David by Wolfgang Ketterle, Juan Maldacena and Peter Zoller
17:30 - 17:40	*Closing words* by Jean-Marie Solvay

David's CV

David 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. He has also made seminal contributions to the theory of Superstrings, a burgeoning enterprise that brings gravity into the quantum framework. With collaborators, he originated the «Heterotic String Theory,» the prime candidate for a unified theory of all the forces of nature. He continues to do research in this field at the KITP, a world center of physics.

He holds honorary degrees from the US, Britain, France, Israel, Argentina, Brazil, Belgium, China, the Philippines and Cambodia. His membership includes the US National Academy of Science, the American Academy of Arts and Sciences, the American Philosophical Society, the Indian Academy of Science, the Chinese Academy of Science, the Russian Academy of Sciences and TWAS.

Prof. Ariela Gross (David's daughter), Prof. David Gross and Mrs Solvay.

His awards include the Sakurai Prize, MacArthur Prize, Dirac Medal, Oscar Klein Medal, Harvey Prize, the EPS Particle Physics Prize, the Grande Médaille d'Or, the Nobel Prize in Physics in 2004, and the Medal of Honor of the Joint Institute for Nuclear Research, Dubna.

In 2016, he began a four-year term in the Presidential Line of the American Physical Society, where he is currently Past President.

03

26th SOLVAY CONFERENCE ON CHEMISTRY AND CENTENARY CELEBRATION

Centenary Celebration Week

The first Solvay Conference on Chemistry took place a century ago, in 1922. How much revolutionary scientific understanding has been gained during these one hundred years!

All the major discoveries in chemistry that occurred in that century were actively debated at the Solvay conferences.

To celebrate this centenary, the International Solvay Institutes organized the following events:

- Sunday 16 October 2022: Public event at Flagey with two lectures for the general public.
- Monday 17 October - Wednesday 19 October: 26th Solvay Conference on Chemistry entitled "Chemistry Challenges of the 21st Century".
- Thursday 20 October: Academic session "Chemistry and the Future of Society" emphasizing the importance of scientific research for the future of humanity.

These three events are described in the pages that follow, following the chronological order of the celebrations.

Background information

The first Solvay Conference on Chemistry "Cinq questions d'actualité" (1922)

The year 1922 was not an easy time for organizing international conferences since the wounds of the first World War were still open and German scientists were banned from international meetings. In spite of these adverse conditions, the first Solvay conference was a great scientific success. Many renown scientists actively participated in it.

The conference addressed five important topics:

- "Isotopes and radioactivity" with reports by 1921 Nobel laureate Frederick Soddy, by 1922 Nobel laureate Francis Aston, by 1926 Nobel laureate Jean Perrin and by Georges Urbain.
- "Analysis of molecular structure by X-rays" with a report by 1915 Nobel laureate William Bragg.
- "Molecular structure and optical activity" with reports by William Pope and by Thomas Lowry.
- "Valence" with a report by Charles Mauguin.
- "Chemical mobility" with a report by André Job.

Among the participants, 1903 Nobel laureate Svante Arrhenius and Auguste Piccard should also be mentioned.

20th Solvay Public Lectures

16 October 2022

The 20th Solvay public event opened the centenary celebration week. It took place in the Studio 4 of Flagey on Sunday 16 October afternoon.

Two splendid lectures on different fascinating topics illustrated not only the breadth of chemistry but also the spectacular advances made in one century, since many of the topics addressed in the lectures could not even have been formulated without the new knowledge that has been gained since the first Solvay conference of 1922.

Professor Omar Yaghi has pioneered the science of building chemical structures from molecular building blocks; a field referred to as Reticular Chemistry. His research has led to the discovery of several classes of new porous crystalline materials with remarkable applications such as harvesting water in the desert, the topic of his lecture.

Professor Paul Nurse has made fundamental contributions to revealing how living cells work. Based on his experience, he explained what it means to be alive in a way adapted to the general public, illuminating five great ideas key to life—the Cell, the Gene, Evolution by Natural Selection, Life as Chemistry, and Life as Information.

As usual, the event attracted a great attendance. The International Solvay Institutes are extremely grateful to the two lecturers who made this event a great success.

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 - 16:20 "Water Harvesting from Air Anytime Anywhere" by Prof. Omar Yaghi (Berkeley, USA)
- 16:20 - 16:30 Questions
- 16:30 - 17:15 "What is Life?" by Prof. Paul Nurse (Crick Institute, UK)
- 17:15 - 17:25 Questions
- 17:25 - 17:30 Closing by Prof. Marc Henneaux
- 17:30 Drink

Lecturers

The two lecturers are outstanding world leaders in their fields.

Professor Paul Nurse
Francis Crick Institute, UK

2001 Nobel Laureate in Physiology or Medecine

Professor Nurse received a degree in biology at the University of Birmingham in 1970 and a PhD in 1973 from the University of East Anglia. He went to the laboratory of Murdoch Mitchison at the University of Edinburgh for postdoctoral studies on the cell cycle. Here, between 1973-1979, he used a classical genetic approach to study the cell cycle by identifying and studying a set of cell cycle defective mutants that have formed the basis of much of his future work. In 1979 he set up his own laboratory at the University of Sussex.

In 1984, Professor Nurse joined the Imperial Cancer Research Fund (ICRF, which became Cancer Research UK in 2002). He left ICRF in 1988 to chair the Department of Microbiology at the University of Oxford. Here he continued his work on the cell cycle and also initiated new research areas to study cell form and genomics. He returned to the ICRF as Director of Research in 1993, and in 1996 became Director General of the ICRF and in 2002 the Chief Executive of Cancer Research UK.

In 2003, he became President of Rockefeller University in New York City where he continued to work on the cell cycle, cell form and genomics of fission yeast.

In 2010, he became the first Director and Chief Executive of the Francis Crick Institute in London and in addition for 5 years was President of the Royal Society. Professor Nurse was awarded the 2001 Nobel Prize in Physiology or Medicine along with Leland Hartwell and Tim Hunt for their discoveries of protein molecules that control the division (duplication) of cells in the cell cycle.

In 1989 he was elected a Fellow of the Royal Society (FRS) and in 1995 he received the Royal Society Royal Medal and became a foreign associate of the US National Academy of Sciences. He received the Albert Lasker Award for Basic Medical Research in 1998 and was knighted in 1999. He was awarded the French Légion d'Honneur in 2002, the Royal Society Copley Medal in 2005, and the Japanese Order of the Rising Sun in 2018. He was a member of the Council for Science and Technology advising Prime Ministers from 2000 to 2015. In 2013 he became the winner of the Albert Einstein World Award of Science conferred by the World Cultural Council, and since 2017 has been a Chief Scientific Advisor of the European Commission.

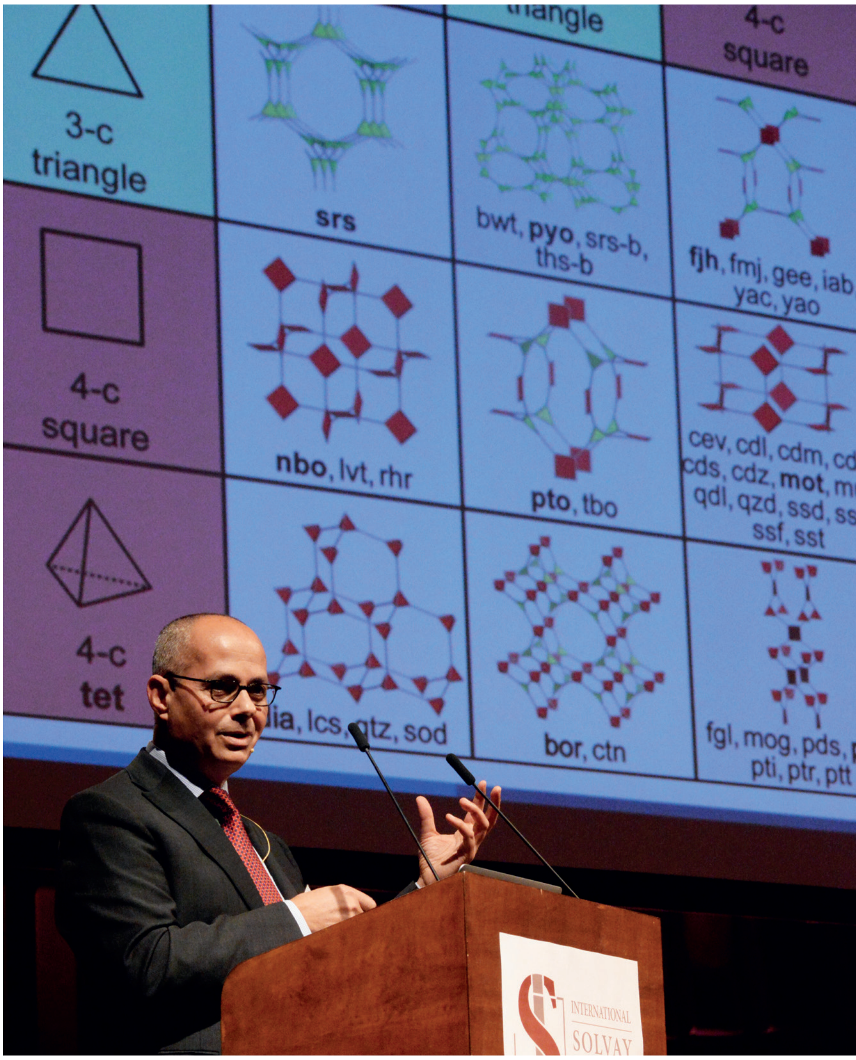
Professor Omar Yaghi
Berkeley UC, USA

Professor Yaghi is among the top five most highly cited chemists worldwide.

He received his B.S. degree from State University of New York-Albany (1985), and Ph.D. from the University of Illinois-Urbana (1990).

He is currently the James and Neeltje Tretter Chair Professor of Chemistry at UC Berkeley, and a Senior Faculty Scientist at Lawrence Berkeley National Laboratory.

He is the Founding Director of the Berkeley Global Science Institute.



His work encompasses the synthesis, structure and properties of inorganic and organic compounds and the design and construction of new crystalline materials. The building block approach he developed has led to an exponential growth in the creation of new materials having a diversity and multiplicity previously unknown in chemistry.

He is the recipient of numerous prizes and awards among which the Wolf Prize in Chemistry (2018).

Solvay Awards Ceremony

One of the goals of the Solvay public events 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. The ceremony celebrated students in physics, chemistry and engineering at the ULB and the VUB who had been distinguished for their work.

These Solvay awards are given by the Solvay Company.

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

Mrs Michèle Huart
Chairwoman of the Solvay Awards Jury

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.

On October 16, 2022 in Brussels, the ceremony celebrates the PhD laureates of the 2021 session.

PhD work submitted for evaluation can be of a basic or applied nature but must have focused, from a physical or chemical perspective, on one of the following themes:

- *the investigation and understanding of matter (structure, properties, transformation, chemical reactivity, material science),*
- *the study of the mechanisms and chemistry of life,*
- *new production technologies,*
- *new resources, energy storage and generation,*
- *environmental sciences and sustainable development.*

Solvay Group

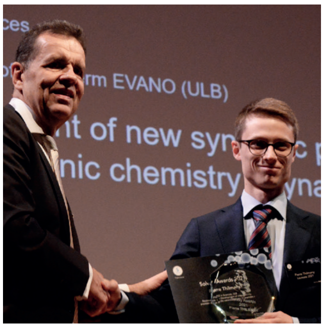
M. Hervé Tiberghien
Chief People Officer and member of the Executive Committee at Solvay

Laureates 2021


Diederik Coppitters (VUB)


Maria Teresa Scelzo (ULB)


Giuseppe D'Alessio (ULB)


Pierre Thilmany (ULB)


Dieter De Baere (VUB)


Ludovico Zanus (ULB)

26th Solvay Conference on Chemistry "Chemistry Challenges of the 21st Century"

17 - 19 October 2022

The 26th Solvay Conference on Chemistry covered a broad range of topics, illustrating the far-reaching spectrum of chemistry, from physics to the life sciences. The meeting was deliberately turned towards the future and to the great challenges that drive the field.

The themes of the conference and of the various scientific sessions were chosen by the International Solvay Scientific Committee for Chemistry chaired by Nobel laureate Professor Kurt Wüthrich, from the Scripps Research Institute and the ETH.

The Conference took place at the hotel Plaza in Brussels from October 17 through October 19, 2022. Leading chemists from all over the world discussed challenges and perspectives in their own area triggering numerous fruitful exchanges across disciplines. A welcome reception at the Brussels City where the Mayor greeted the participants was organized on October 17.

The meeting was chaired by Professor Kurt Wüthrich and co-chaired by Professor Ben Feringa (Groningen, 2016 Nobel laureate in chemistry). Together with the chairs of the various sessions, they put up a splendid program. The International Solvay Institutes express their deepest thanks to all of them for the definite success of the Centenary Solvay Conference on Chemistry.

Reception at the Brussels City Hall.

Mr Philippe Close, Mayor of the City of Brussels.

Professor Kurt Wüthrich

ETH Zurich, Switzerland

Nobel laureate Kurt Wüthrich joined the Solvay Scientific Committee for Chemistry in 2005 and became its chair in 2011. Thanks to his vigorous action at the head of the committee, the Solvay conferences on chemistry are back on the tracks of scientific excellence, attracting the best chemists from all over the world. The rhythm of one conference every three years has also been consolidated.

The 26th Solvay conference was the last one organized under the direction of Professor Wüthrich. The International Solvay Institutes are most grateful to him for his help and scientific guidance. He paved the way for a bright future!

Kurt Wüthrich is a Swiss chemist/biophysicist and Nobel Chemistry laureate, known for developing nuclear magnetic resonance (NMR) methods for studying biological macromolecules.

Born in Aarberg, Switzerland, Wüthrich was educated in chemistry, physics, and mathematics at the University of Bern before pursuing his Ph.D. at the University of Basel.

He currently maintains a laboratory at the ETH Zürich, at The Scripps Research Institute, in La Jolla, California and at the iHuman Institute of ShanghaiTech University. He has also been a visiting professor at the University of Edinburgh (1997–2000), the Chinese University of Hong Kong (where he was an Honorary Professor) and Yonsei University.

He was awarded the Louisa Gross Horwitz Prize from Columbia University in 1991, the Louis-Jeantet Prize for Medicine in 1993, the Otto Warburg Medal in 1999 and half of the Nobel Prize in Chemistry in 2002 for "his development of nuclear magnetic resonance spectroscopy for determining the three-dimensional structure of biological macromolecules in solution". He received the Bijvoet Medal of the Bijvoet Center for Biomolecular Research of Utrecht University in 2008. He was elected a Foreign Member of the Royal Society (ForMemRS) in 2010. He was also awarded the 2018 Fray International Sustainability Award at SIPS 2018 by FLOGEN Star Outreach.

Scientific themes

The scope of the 26th Solvay Conference encompassed many frontier subjects. Sustainability and applications to health science were in particular given a prominent role and constituted recurrent themes in all the sessions, which were:

- "Catalysis for Sustainable Chemistry"
- "From Molecules to Dynamic Supramolecular Systems"
- "Reticular Chemistry and New Materials"
- "New Chemistry for Renewable Energy to Fuels"
- "Directed Protein Evolution for Green Chemistry"
- "RNA Chemistry to Explore our Origins and Fight Viral Pandemics"

Programme

Monday 17 October 2022

Welcome addresses by Marc Henneaux, Director of the Solvay Institutes and by Kurt Wüthrich, Chair of the conference and of the Scientific Committee for Chemistry of the International Solvay Institutes.

Historical Background by Franklin Lambert, Emeritus Professor VUB

Session 1: Catalysis for Sustainable Chemistry - Chair: David MacMillan

Introductory statement by David MacMillan

Statements: Karen I. Goldberg, Rob Knowles, Karthish Manthiram, Sir Martyn Poliakoff

Discussion

Session 2: From Molecules to Dynamic Supramolecular Systems - Chair: Ben Feringa

Introductory statement by Ben Feringa

Statements: Nicolas Giuseppone, Nathalie Katsonis, Bert Meijer, Andrew Turberfield

Discussion

Tuesday 18 October 2022

Session 3: Reticular Chemistry and New Materials - Chair: Omar M. Yaghi

Introductory statement by Omar M. Yaghi

Statements: Makoto Fujita, Chad Mirkin, Joachim Sauer, Arne Thomas, Todd Yeates, Xiaodong Zou

Discussion

Session 4: New Chemistry for Renewable Energy - Chair: Dan Nocera

Introductory statement by Dan Nocera

Statements: Dame Clare Grey, Sossina Haile, Matthew Kanan, James Liao, Henry Snaith, Andreas Züttel

Discussion

Wednesday 19 October 2022

Session 5: Directed Protein Evolution for Green Chemistry - Chair: Sabine Flitsch

Introductory statement by Sabine Flitsch

Statements: Bernhard Hauer, Don Hilvert, Stefan Lutz, Alison Narayan, Silvia Osuna, Nicholas Turner

Discussion

Session 6: RNA Chemistry to Explore our Origins and Fight Viral Pandemics - Chair: Gerald Joyce

Introductory statement by Gerald Joyce

Statements: Andrew Fire, Claudia Höbartner, Karla Kirkegaard, Peter Palese, John Sutherland, Jack Szostak

Discussion

BertWeckhuysen @BWeckhuysen · 18 oct.
Impressions from the 26th Solvay Conference on Chemistry (2)

(1)Group picture in the hall of the hotel
(2)Dan Nocera in action

Today we had excellent symposium sessions & related discussions on reticular chemistry and renewable energy, chaired by Omar Yaghi and Dan Nocera.

Participants

De Wit Anne
ULB, Brussels, Belgium

Ebbesen Thomas
University of Strasbourg, France

Feringa Ben
University of Groningen, The Netherlands

Fire Andrew
Stanford University, USA

Flitsch Sabine
University of Manchester, UK

Fujita Makoto
University of Tokyo, Japan

Grey Clare
Cambridge University, UK

Giuseppone Nicolas
University of Strasbourg, France

Goldberg Karen I.
University of Pennsylvania, USA

Haile Sossina
Northwestern University, USA

Hilvert Don
ETH Zurich, Switzerland

Höbartner Claudia
Julius-Maximilians-U. of Würzburg, Germany

Joyce Gerald
The Salk Institute for Biological Studies, USA

Kanan Matthew
Stanford University, USA

Katsonis Nathalie
University of Groningen, The Netherlands

Kirkegaard Karla
Stanford University, USA

Knowles Rob
Princeton University, USA

Krishnan Yamuna
University of Chicago, USA

Liao James C.
Academia Sinica, Taiwan

Lutz Stefan
Codexis, Inc., USA

MacMillan David
Princeton University, USA

Manthiram Karthish
CALTECH, USA

Meijer Bert
Eindhoven, The Netherlands

Mirkin Chad
Northwestern University, USA

Narayan Alison
University of Michigan, USA

Nocera Dan
Harvard University, USA

Osuna Silvia
University of Girona, Spain

BertWeckhuysen @BWeckhuysen · 17 oct.
Impressions from 26th Solvay Conference on Chemistry

Theme: "Chemistry Challenges of the 21st Century"

1) Delegation from the Netherlands

2) Welcome reception in City Hall with Jean-Marie Solvay & Mayor of Brussels

3) Wandering in the centre of Brussels with some colleagues

Palese Peter
Icahn School of Medicine at Mount Sinai, USA

Poliakoff Martyn
University Park Nottingham, UK

Rongy Laurence
ULB, Brussels, Belgium

Sauer Joachim
Humboldt University of Berlin, Germany

Snaith Henry
University of Oxford, Clarendon Laboratory, UK

Sutherland John
MRC Laboratory of Molecular Biology, UK

Szostak Jack
University of Chicago, USA

Thomas Arne
TU Berlin, Germany

Turberfield Andrew
University of Oxford, UK

Turner Nicholas
Manchester Institute of Biotechnology, UK

von Heijne Gunnar
Stockholm University, Sweden

Weckhuysen Bert
Utrecht University, The Netherlands

Wüthrich Kurt
Scripps Research, La Jolla, CA, USA &
ETH Zurich, Switzerland

Yaghi Omar
UC Berkeley, USA

Zou Xiaodong
Stockholm University, Sweden

Züttel Andreas
EPFL, Switzerland

Auditors

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

The International Solvay Institutes are grateful to the editorial team and in particular to Professors Anne De Wit (Scientific Secretary of the International Solvay Scientific Committee for Chemistry) and Laurence Rongy for their efficient handling of this difficult task.

- Aprile Carmela (UNamur, Belgium)
- Back Olivier (Solvay Company)
- Ballet Steven (VUB, Brussels, Belgium)
- Baron Gino (VUB, Brussels, Belgium)
- Debroye Elke (KU Leuven, Belgium)
- Elias Benjamin (UCLouvain, Belgium)
- Geerts Yves (ULB, Brussels, Belgium)
- Govaerts Cédric (ULB, Brussels, Belgium)
- Gueydan Cyril (ULB, Brussels, Belgium)
- Hennecke Ulrich (VUB, Brussels, Belgium)
- Kapelyushko Valeriy (Solvay Company)
- Luhmer Michel (ULB, Brussels, Belgium)
- Maestro Patrick (Solvay Company)
- Marion Philippe (Solvay Company)
- Martens Chloé (ULB, Brussels, Belgium)
- Mastroianni Sergio (Solvay Company)
- Meegan Jonathan (Solvay Company)
- Remaut Han (VUB, Brussels, Belgium)
- Rocci Alessio (ULB, Brussels, Belgium)
- Surin Mathieu (UMons, Belgium)
- Theunissen Cédric (ULB, Brussels, Belgium)
- Tielens Frederik (VUB, Brussels, Belgium)
- Valkenier Hennie (VUB, Brussels, Belgium)
- Van Assche Guy (VUB, Brussels, Belgium)
- Vorobieva Anastassia (VUB & VIB Brussels, Belgium)

Academic session “Chemistry and the Future of Society”

20 October 2022

To conclude the celebrations of the centenary of the first Solvay Conference on Chemistry, the International Solvay Institutes organized in the afternoon of October 20, 2022 a special academic session, entitled “Chemistry and the Future of society”.

The event was open to the public and devoted to the importance of fundamental research - and in particular fundamental research in chemistry - for the future of society.

It was structured around four panels:

- “From fundamental chemistry to sustainable development”
- “From fundamental chemistry to human health”
- “Economic impact and funding of fundamental research”
- “Future and social responsibility of chemistry: the view of the young generation”

as well as a special session devoted to “Why basic research” with three lectures by distinguished scientists.

The panels were composed of world-class scientists, high-level executives from industry and environmental foundations, as well as people from funding agencies and from the political world.

The International Solvay Institutes express their gratitude to the lecturers and panellists for their decisive contributions to the success of the meeting.

His Majesty the King, Minister Valérie Glatigny, State Secretary Thomas Dermine and Philippe Close, Mayor of Brussels honored the event by their presence.

The event took place under the auspices of the UNESCO.

Mrs Ilham Kadri (CEO of the Solvay Company), Minister Valérie Glatigny, Mr Jean-Marie Solvay, His Majesty the King, Professor Marc Henneaux and Mr Philippe Close, Mayor.

Opening Address by Professor Marc Henneaux

For more than a century, the International Solvay Institutes have supported curiosity-driven research in physics and chemistry. Through the celebrated Solvay Councils, the International Solvay Institutes have become one of the most visible Belgian scientific institutions, attracting periodically at their renowned conferences and activities the best scientists from all over the world, including many Nobel laureates. They undoubtedly contribute to the prestige of our country.

The first Solvay physics council took place in 1911, while the first Solvay chemistry council, delayed by the first world war, took place in 1922. It is the centenary of this conference that we are celebrating today, and through it, the importance of basic research – and more particularly, basic research in chemistry – for the future of our society.

Understanding the world around us, from the constituents of matter and how they assemble, to the universe itself, has always been a quest of humanity. This research, pursued for the sole purpose of gaining new knowledge, has been extremely successful in leading to applications that have revolutionized our way of living. New understanding opens new doors, very often in directions that could not have been anticipated before reaching the new vantage point.

Chemistry has been at the heart of this revolution, to such an extent that the 19th and 20th centuries have sometimes been called the "chemical age".

And the story is not finished! Our society is confronted with enormous challenges (drug design, energy, recycling, sustainability, batteries, new materials, etc). It is my conviction that it is only with the help of science and chemistry that these challenges will be solved.

But the interest and importance of science and scientific research go beyond discovering new applications for the benefit of mankind. The scientific methodology, based on rational thinking and experimentation, has a clear educational value. May reason and critical analysis of the facts be more prevalent in our social relationships! Science is also a universal human enterprise common to all cultures. It has no borders. It is the same science all over the globe, independently of nationality or religion.

All these topics – and more – will be addressed in the panels and lectures of today's event. I do not want to make any predictions on the outcomes of the discussions, but I think that I can safely bet that one conclusion will be:

> *We need science – and in particular, chemistry – more than ever!*

Programme

Moderator	Gert Desmet, Deputy-director for chemistry of the International Solvay Institutes
13:30 - 13:55	**Opening session** • Marc Henneaux, Director of the International Solvay Institutes • Thomas Dermine, State Secretary in charge of Science Policy (Belgium) • Yves Rouyet, President of the Belgian French-speaking and German-speaking Commission for UNESCO
13:55 - 14:35	**Panel 1:** From fundamental chemistry to sustainable development
14:35 - 15:15	**Panel 2:** From fundamental chemistry to human health
	Arrival of his Majesty the King
15:20 - 15:50	**Why basic research?** Marc Henneaux: Presentation and background • *Chemistry at the center of solutions to mitigate climate change* Karen Goldberg (Chemistry department, University of Pennsylvania, USA) • *From the laboratory to the bedside; from basic research to medical applications* Jean-Marie Lehn (1987 Chemistry Nobel Laureate, Strasbourg, France) • *Nurturing and Harnessing Global Talent in an Equitable World* Sossina Haile (Chemistry department, Northwestern University, USA)
15:50 - 16:30	Break
16:30 - 17:10	**Panel 3:** Economic impact and funding of fundamental research
17:10 - 18:00	**Panel 4:** Future and social responsibility of chemistry: the view of the young generation
18:00 - 18:30	**Closing session** • Ilham Kadri, CEO of the Solvay Company • Jean-Marie Solvay, President of the International Solvay Institutes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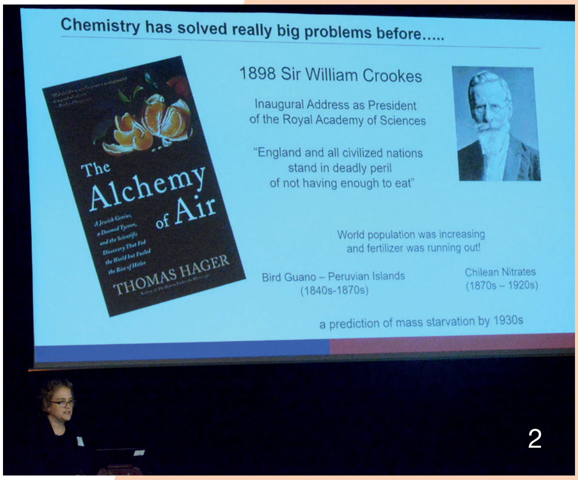

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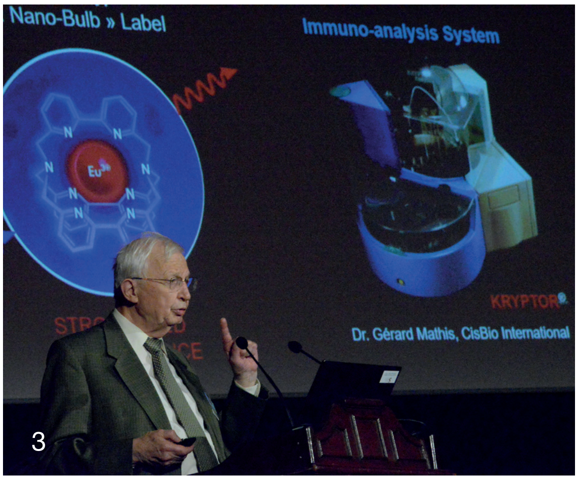

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5

1 - Thomas Dermine (State Secretary in charge of Science Policy)
2 - Prof. Karen Goldberg (University of Pennsylvania, USA)
3 - Prof. Jean-Marie Lehn (University of Strasbourg, France)
4 - Prof. Sossina Haile (Northwestern University, USA)
5 - Mrs Ilham Kadri (CEO of the Solvay Company)

Composition of the panels

CV's of the panelists can be found on pages 212-233.

Panel 1: From fundamental chemistry to sustainable development

Chair: Ben Feringa
2016 Chemistry Nobel Laureate, Groningen, The Netherlands

Panel members:

Nicolas Cudré-Mauroux (Solvay General Manager for Research & Innovation)

Karen Goldberg (Chemistry department, University of Pennsylvania, USA)

Bertrand Piccard (Solar Impulse Foundation Chairman)

Omar Yaghi (Laureate of the 2018 Wolf Prize, University of California at Berkeley, USA)

Panel 2: From fundamental chemistry to human health

Chair: Gunnar von Heijne
Former chair of the Nobel Chemistry Committee

Panel members:

Andrew Fire (2006 Physiology or Medicine Nobel Laureate, Stanford, USA)

Stefan Lutz (Senior VP Research, Codexis Company, USA)

Jean Stéphenne (Chairman of the Board of Directors of CureVac and of Nanocyl)

Jack Szostak (2009 Physiology or Medicine Nobel Laureate, Harvard, USA)

Panel 3: Economic impact and funding of fundamental research

Chair: Gerald Joyce
Professor at Salk Institute, director at the Novartis Research Foundation, USA

Panel members:

Philippe Aghion (Professor of economy, Collège de France and London Business School)

André Hoffmann (Board of Directors, Hoffmann-La Roche, former vice-president of WWF)

Jean-Marie Lehn (1987 Chemistry Nobel Laureate, Strasbourg, France)

Maria Leptin (ERC president)

Panel 4: Future and social responsibility of chemistry: the view of the young generation

Chair: Bert Meijer
Chemistry Department, Eindhoven University of Technology, The Netherlands

Panel members:

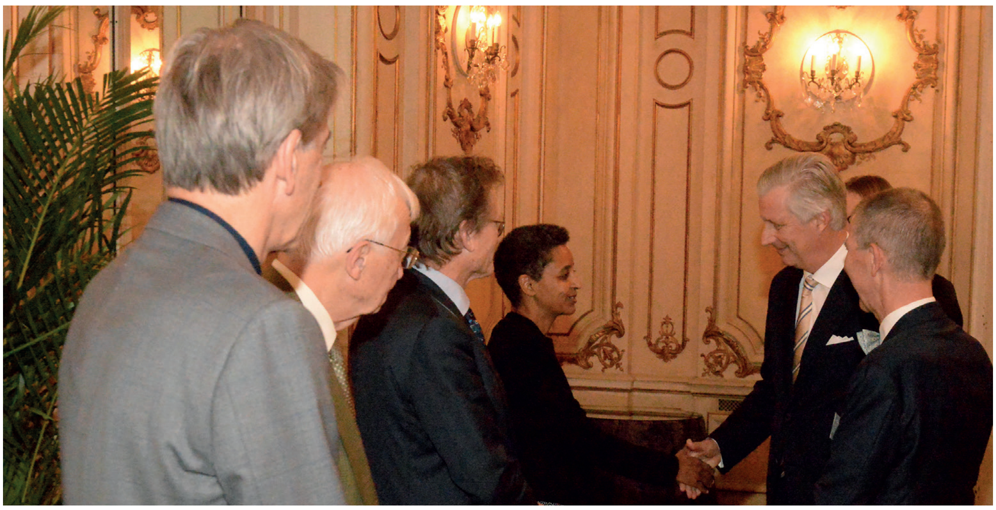
Alena Budinska (PhD Student in Chemistry, ETH Zurich, Switzerland)

Thomas Ebbesen (Strasbourg Institute for Advanced Study, France)

Yamuna Krishnan (Chemistry Department, University of Chicago, USA)

Pablo Serna Gallén (PhD Student in Chemistry, Castellon, Spain)

Hennie Valkenier ("Chercheuse Qualifiée F.R.S.-FNRS", ULB, Belgium)



04

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.

Because of the pandemic and the ensuing reschedulings, the chair programme was particularly intense in 2022. Not only did the 2022 chairs took place as normal, but also the 2021 Jacques Solvay chair in physics as well as the closing lectures of the 2020 and 2021 chairs in chemistry.

Prof. Paul Geerlings (VUB and Solvay Institutes), Mr Patrick Maestro (Solvay Company), Ms Marina Solvay and Mr Jean-Marie Solvay.

2021 International Jacques Solvay Chair in Physics

Professor Jean Dalibard

Collège de France,
Paris, France

Professor Dalibard is a world-leading expert in quantum optics, atomic physics and cold atoms. He participated in the experiments of Alain Aspect (2022 Nobel laureate in physics) which superbly confirmed quantum mechanics; he made decisive contributions to laser-cooling and the remarkable applications of this revolutionary technique.

The fascinating subject of laser cooling and cold atoms was precisely the theme of Professor Dalibards's brilliant inaugural lecture, which he gave on September 6, 2022. The inaugural lecture was followed by a series of more technical lectures developing various aspects of quantum matter, from the exploration of systems in reduced dimension to the notion of scale invariance and solitonic matter waves.

The chair's lectures were preceded by a workshop on "Quantum Simulation" which was part of the chair program, and which is described in the section on workshops.

Our colleague Nathan Goldman (ULB) has been instrumental in the scientific organization of Professor Dalibard's visit. The International Solvay Institutes are most grateful to him.

Jean Dalibard studied physics at the École Normale Supérieure and the Université Paris 6, before getting a PhD degree (doctorat du 3e cycle) in 1981 under the direction of Claude Cohen-Tannoudji. He then joined the group of Alain Aspect at the Institut d'Optique. He became in 1989 Professor at the Ecole Polytechnique and, since 2013, he holds the chair "Atomes et rayonnement" at the Collège de France.

Professor Dalibard pioneered many developments in the understanding of quantum matter and the interaction of matter with light. For his achievements, he received many distinctions and prizes. He was elected member of the French Academy of Sciences in 2004. In 2009, he received the Blaise Pascal medal of the European Academy of Sciences for "his outstanding and influential works in atomic physics and quantum optics". In 2012, he received the Max Born Award and Davisson–Germer Prize « for his seminal contributions to the physics of light-atom interactions and cold atomic gases ». In 2020, he was elected international member of the National Academy of Sciences of the United States. In 2021, he received the CNRS Gold Medal, the highest distinction in France.

Inaugural Lecture

6 September 2022

A brief history of cold atoms

A laser beam can heat, burn, or even destroy ... but also allows to reach the lowest temperatures ever measured. The cooling of matter by light is undoubtedly one of the most paradoxical applications of the laser. It makes it possible to considerably reduce the disordered motion of particles in a gas and to achieve a near perfect order: the temperatures obtained are a billion times lower than the usual ones!

This inaugural lecture will present the general ideas at the basis of this unexpected use of laser light. It will also describe a few perspectives among the numerous research avenues opened by cold atoms. One emblematic example concerns the measurement of time: modern clocks, our "time keepers" which use atoms as pendulums, are all the more accurate when the atomic motion is reduced. The cooling of gases by light has thus allowed a spectacular improvement of the clock precision, which finds applications for instance in navigation, positioning by satellite, or geodesy.

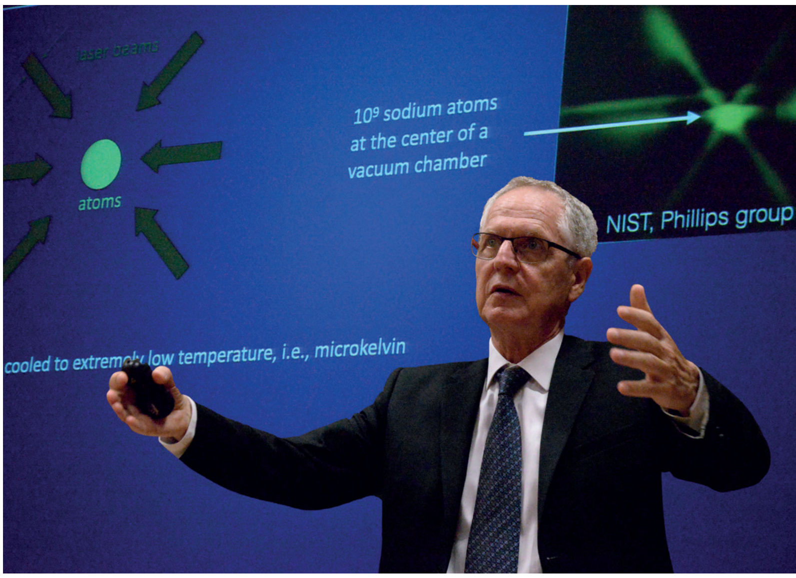
In this lecture, I will also explain why these assemblies of cold atoms constitute a "quantum matter" with fascinating properties, radically different from usual fluids. Then, the following lectures will be devoted to a more detailed investigation of some facets of this quantum matter, from the exploration of systems in reduced dimension to the notion of scale invariance and solitonic matter waves.

Subsequent lectures

- **20 September 2022**
  "From Bose-Einstein condensation to Kosterlitz-Thouless physics"

- **23 September 2022**
  "Controlling atomic interactions: Scale invariance tested in the laboratory"

- **28 September 2022**
  "A droplet of spin-1 atoms: the simplest many-body system"



2022 International Jacques Solvay Chair in Physics

After undergraduate and graduate studies at Caltech and the Ohio State University, Professor Kollmeier was a Hubble Fellow and a Carnegie Princeton Fellow before joining the staff at the Carnegie Institution for Science in 2008 as researcher at the Carnegie Observatories.

She has outstanding leadership capabilities and is playing a remarkable role in the collective development of astrophysics: she is the founding director of the Carnegie Theoretical Astrophysics Center and director of the Sloan Digital Sky Survey.

In 2021, she was appointed Director of the Canadian Institute for Theoretical Astrophysics.

Juna Kollmeier is world leader in astrophysics and cosmology. She combines a use of cosmological hydrodynamic simulations with analytic theory to understand how galaxies and black holes formed from fluctuations in the density of the early universe. The breadth of her interests is unusually large since she studies everything from the Intergalactic medium to the Milky Way and supermassive black holes.

She is also remarkably committed to public outreach, through Ted talks, documentaries or public lectures.

Professor Juna Kollmeier

Canadian Institute for Theoretical Astrophysics, Toronto, Canada

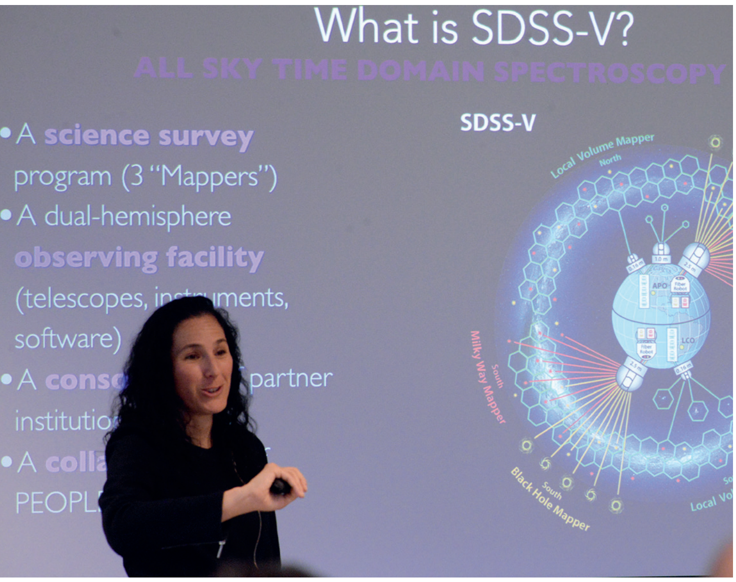
Professor Kollmeier is an observationally-oriented theorist who made key contributions to the formation of structure within the universe.

The Sloan Digital Sky Survey is a truly exceptional program that has provided a map of the cosmos (from stars to black holes to galaxies) of unprecedented scope. What we are learning from it was the subject of the beautiful inaugural lecture which took place on June 28, 2022. Nobody was in a better position to speak about it than Juna Kollmeier, director of the project.

This inaugural lecture was accompanied by two lectures on astrophysical foundations, from stellar astrophysics and supermassive black holes to galaxies and cosmology.

The scientific programme of Professor Kolllmeier's visit was organized by Professors Sophie Van Eck (ULB) and Conny Aerts (KUL), to whom the International Solvay Institutes are very thankful.

Professor Juna Kollmeier visited the "Institut d'Astronomie et d'Astrophysique de l'ULB" (IAA) during June 27-29, 2022. Several common interest research topics were discussed during three informal meetings that took place in between the Solvay Chair Lectures of Professor Kollmeier. The topics covered in particular the current involvement of IAA in the Gaia (ESA) mission, and the synergies with SDSS, given that Professor Kollmeier is currently leading the SDSS-V, a robotic spectroscopic survey in the optical and the infrared. Several research projects, combining the strengths of both surveys, were discussed and could lead to future collaborations. The topic of Machine Learning within large spectroscopic surveys was also discussed, in particular within the Gaia-ESO Survey in which IAA is involved. Interesting discussions about detection of peculiar stars (for example enriched in s-process elements) with these new methods took place.



Juna Kollmeier also dedicated her time to discuss with young researchers from the ULB Physics department, PhD students and young post-docs (all fields included), starting with a presentation on: "Strategies for the 21st Century Scientist: Defining and Realizing Scientific Self-Actualization". The goal was to offer junior scientists a chance to exchange informally with Prof. Kollmeier and benefit from her expertise on how to become an outstanding scientist. Themes such as "setting priorities" and "formulating good research questions" as well as "developing collaborations" were developed and the exchanges proved to be very interactive and inspiring.

On July 8, Professor Kollmeier visited the astronomy and astrophysics group of the University of Ghent.

Finally, during the week 11-15 July, Professor Kollmeier actively participated in the TASC6/KASC13 workshop in Leuven "Asteroseismology in the Era of Surveys from Space and the Ground: Stars, Planets, and the Milky Way", where she delivered one of the plenary talks on "The SDSS-V Milky Way Mapper: Asteroseismology X Cosmology".

Inaugural Lecture

28 June 2022

Mapping Our Universe: The Sloan Digital Sky Survey

For millennia, humans, limited by the optics of their eyes and the reach of their feet evolved beautifully to probe the Earth and its contents. This changed only recently, but dramatically, when humanity mastered optics, gravity, and quantum mechanics. Today, we survey the skies at all wavelengths and in all directions. This great capacity to map the heavens, has brought new challenges. What are we learning about the universe, its fundamental structure, and our place within it? I will present what we have learned from the Sloan Digital Sky Survey the largest map of the cosmos to date. I will describe its fifth phase, mapping of over six million objects, from stars, to black holes, to Galaxies. SDSS is designed to decode the history of the Universe and the galaxies within it, trace the emergence of the chemical elements, reveal the inner workings of stars, and investigate the origin of planets. I will explain why we do this and how taking on this massive, complex, and seemingly esoteric undertaking, humanity ultimately benefits. While our place in the cosmos is not special, it is precious and this inaugural lecture will explore the underpinnings of how we understand physical reality and why it is so critically important at this point in the evolution of our species.

Lecture 1

27 June 2022

Astrophysical Foundations I: Stellar Astrophysics and Supermassive Black Holes

Stellar and black hole astrophysics are both currently in a wonderful period of scientific explosion. Stars and black holes, in many ways, form the bedrock of our astrophysical knowledge base. And yet, we still have critical uncertainty about how stars and black holes form and critical uncertainty about their evolution during different phases. I will discuss these puzzles where I believe there is the opportunity for transformative change over the next 5 years.

Lecture 2

29 June 2022

Astrophysical Foundations II: Galaxies and Cosmology

In this lecture, I will move to the larger scales of galaxies and cosmology. I will discuss the state-of-the art in these areas and my work related to each. I will describe what the era of precision cosmology has told us about our universe, and what it has not yet revealed. I will highlight the puzzle of why galaxies are so dark and go over possible changes to the cosmic picture that could be probed within the next 15 years. I will challenge the audience to "think big" while also thinking deeply about these puzzles.

2020 International Solvay Chair in Chemistry

Professor Joanna Aizenberg

Harvard University, USA

Professor Aizenberg, 2020 Solvay chemistry chair holder, completed her cycle of lectures given on line in 2021 (see 2021 activity report of the Solvay Institutes) by coming to Brussels for one week in May of 2022. She gave her closing lecture in person on May 4, 2022.

Closing Lecture

4 May 2022

New bio-inspired materials: When chemistry meets optics, surface science, and mechanics

Living systems sense, respond to, and harvest energy from the changing environment by interweaving chemistry, mechanics, optics, electronics, and fluid dynamics across time and length scales. In this lecture, materials chemist Joanna Aizenberg will give us a taste of how the inspiration from nature teaches us to break barriers between these fields and leads to fascinating new concepts in materials design. She will look at a deep sea sponge and envision a green, illuminated skyscraper that harvests energy from the wind. The brittle star's intricate skeleton will inspire dynamic optical systems that can collect light. She will present cilia-inspired adaptive hairy surfaces that alter their wetting, optical, and adhesive behavior via chemomechanical reconfiguration of tiny nanostructures. Creating liquid-sensing "noses" and novel catalytic materials from chemically patterned photonic crystals inspired by butterflies, or ultra-slippery surfaces that prevent icing and biofouling inspired by pitcher plant – these are just the beginning of the multifunctional, dynamic materials possibilities waiting to be explored at the interdisciplinary border between chemistry, biology, and physics.

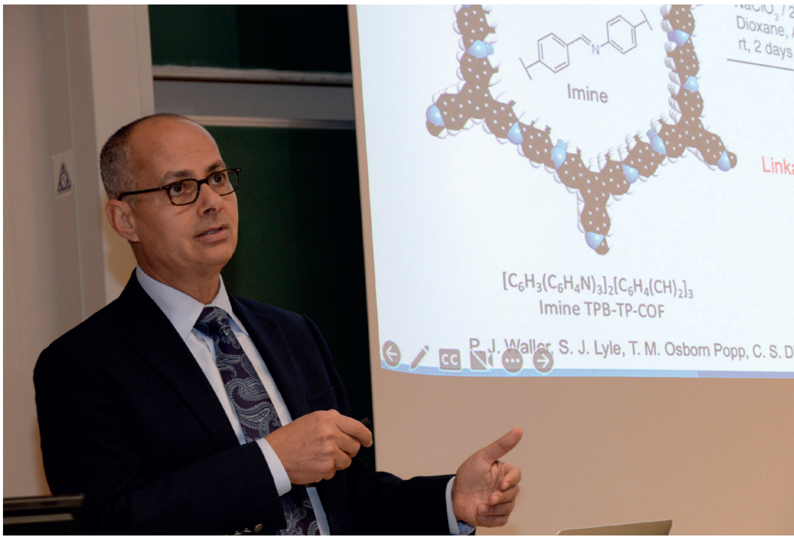
2021 International Solvay Chair in Chemistry

Professor Omar Yaghi

University of California at Berkeley, USA

Professor Yaghi, 2021 Solvay chemistry chair holder, completed his cycle of lectures given on line in 2021 (see 2021 activity report of the Solvay Institutes) by coming to Brussels for one week in October of 2022 on the occasion of the 26th Solvay Conference on Chemistry where he played a very active role. He delivered one of the public lectures at our October public event.

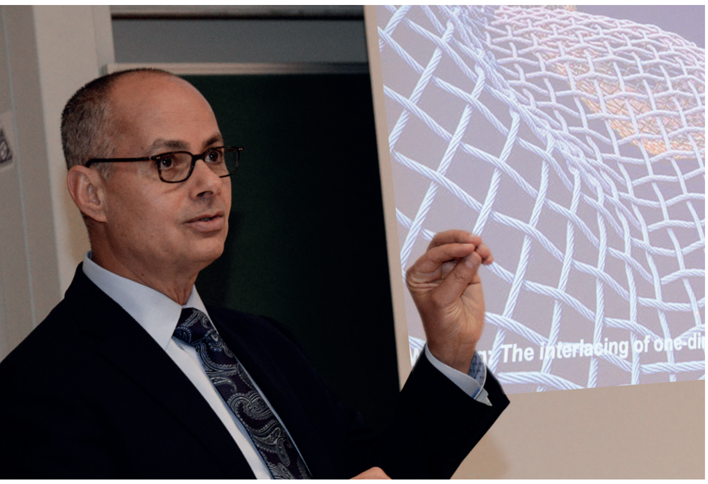
He gave his closing lecture in person on October 21, 2022.



Closing Lecture

21 October 2022

Extending Organic Chemistry into Infinite Two- and Three-dimensions



The covalent bond occupies a central role in building up organic molecules leading to polymers and pharmaceuticals. With the advent of covalent organic frameworks (COFs), the chemistry of the covalent bond has been extended to crystalline two- and three-dimensional frameworks. Here, organic molecules are stitched together with covalent bonds to make crystalline, porous frameworks of high architectural and chemical robustness. This opened the way to carrying out chemistry on frameworks (i.e. the development of precision chemistry beyond the molecule). The union of the covalent and the mechanical bond gives way to incorporating flexibility and dynamics into frameworks, and this provides a whole new way of thinking about materials beyond molecules.

2022 International Solvay Chair in Chemistry

Professor Daniel Jacob

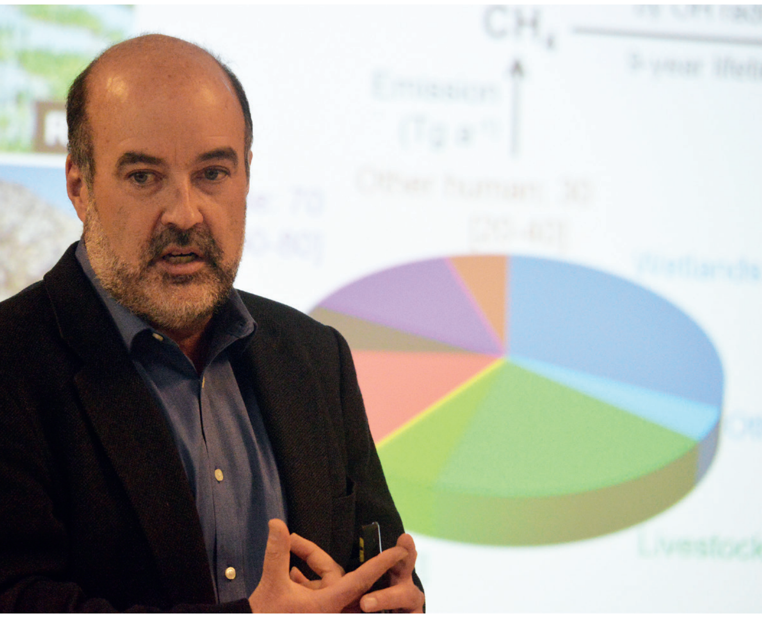
Harvard University, USA

The fifteenth International Chair in Chemistry was held by Professor Daniel Jacob from Harvard University (USA).

Professor Jacob is a world-leading expert on air pollution, atmospheric transport, regional and global atmospheric chemistry, biosphere-atmosphere interactions and climate change.

Professor Jacob spent six weeks in Brussels in 2022, three in May (8-29) and three in October (3-21). During his stay in Brussels, he was hosted in the group of Professor Pierre-Yves Coheur, with whom fruitful collaborations were developed. The Institutes thank Professor Coheur for his very useful help in organizing the chair.

The subject of Professor Jacob's splendid inaugural lecture "Methane in the climate system: mapping emissions from satellites", given on May 10, was the crucial topic of controlling methane emissions. The inaugural lecture was followed by two other more specialized lectures on May 13 and May 17. A closing lecture on "The obsessive problem of ozone air pollution" was given on October 7.



Professor Jacob took advantage of his stay in Belgium to visit various institutions.

18 May 2022

Visit in Paris hosted by Cathy Clerbaux's group (Laboratoire Atmosphères & Observations Spatiales (LATMOS)/Institut Pierre Simon Laplace).

19 October 2022

Visit at the KU Leuven hosted by Jérôme Loreau (Chemical Dynamics and Astrochemistry Research group).

Daniel Jacob received his B.S. in 1981 in Chemical Engineering from the École Supérieure de Physique et Chimie Industrielles (ESPCI) in Paris, and his Ph.D. in Environmental Engineering in 1985, from the California Institute of Technology. After his PhD, Daniel Jacob went to Harvard University as a postdoc and he joined there the faculty in 1987, successively as Assistant Professor, Associate Professor, Professor, Gordon Mc Kay Professor. He is currently the Vasco McCoy Family Professor of Atmospheric Chemistry and Environmental Engineering in the School of Engineering and Applied Sciences at Harvard University.

Daniel Jacob received an impressive number of prizes and honors over the course of his career, among which -in the recent years- the Haagen Smit Prize, the NASA Distinguished Public Service Medal and the NASA Julian Allen Award. He is also reknown for his teaching, for which he has received a number of Distinguished Lecturer awards from various Institutes around the World.

Professor Jacob's research covers a range of topics in atmospheric chemistry. He has led the development of the GEOS-Chem global 3-D model of atmospheric composition, has served as Mission Scientist on eight NASA aircraft missions around the world, and is a member of several satellite Science Teams. He has trained over 100 Ph.D. students and postdocs over the course of his career. Daniel Jacob has authored or co-authored close to 500 papers (H-index of 176 for 2014-2021 publications) in the best journals. He is today the #1 environmental scientist in the world according to research.com.

Inaugural Lecture

10 May 2022

Methane in the climate system: mapping emissions from satellites

Methane is a major greenhouse gas, and controlling methane emissions is central to a climate policy of avoiding two degrees of danger. But the sources of methane and the causes of the current rise are poorly understood. Here I will show how new satellite observations of atmospheric methane can play a crucial role in better quantifying methane emissions from the global scale down to point sources, providing a global monitoring system in support of climate action.

Lecture 1

13 May 2022

The tropospheric ozone saga

Tropospheric ozone is of central interest for atmospheric chemistry as an air pollutant, as a greenhouse gas, and as the primary precursor for the main atmospheric oxidant (OH). Despite decades of extensive observations and modeling, there are still fundamental gaps in our understanding of global tropospheric ozone and its trends. Here I will review current understanding of the mechanisms controlling tropospheric ozone including new developments related to precursor emissions, heterogeneous chemistry, and halogen chemistry.

Lecture 2

17 May 2022

Evolving understanding of air pollution: lessons from East Asia

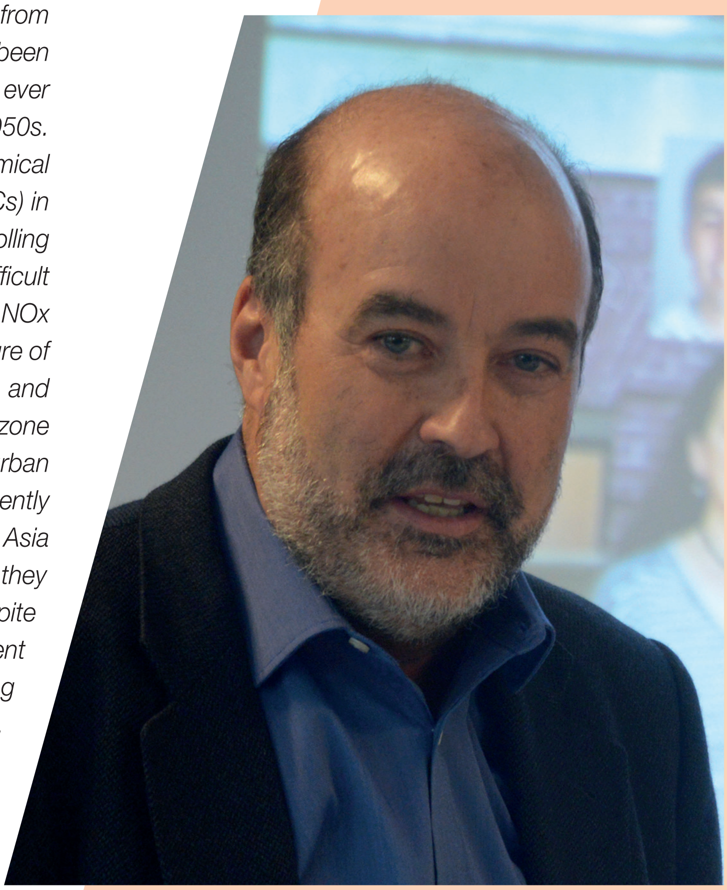
High pollutant concentrations and rapidly changing emissions in China and Korea offer new insights into the chemical processes driving air pollution and the highly non-linear relationships between emissions and concentrations. Here I will present an overview of air pollution chemistry including new developments motivated by the interpretation of pollutant trends in East Asia. I will discuss the transformative potential of new geostationary satellite observations for air pollution monitoring.

Closing Lecture

7 October 2022

The obsessive problem of ozone air pollution

Damage to human health and vegetation from high ozone concentrations in surface air has been a worldwide focus of air pollution research ever since its discovery in Los Angeles in the 1950s. Ozone is produced in polluted air by photochemical oxidation of volatile organic compounds (VOCs) in the presence of nitrogen oxides (NOx). Controlling ozone pollution has been an exceedingly difficult problem because of the range of VOC and NOx emission sources, the complex nonlinear nature of the chemical mechanisms producing ozone, and the importance of atmospheric transport of ozone and its precursors on scales ranging from urban to global. Ozone concentrations are presently exceedingly high and increasing in East Asia despite new efforts to control emissions, and they remain high in Europe and North America despite decades of such efforts. In this talk I will present the chemistry behind ozone formation including new developments in our understanding, examine the causes of rising ozone in East Asia, and discuss the chemical pathways driving the intercontinental transport of ozone pollution.



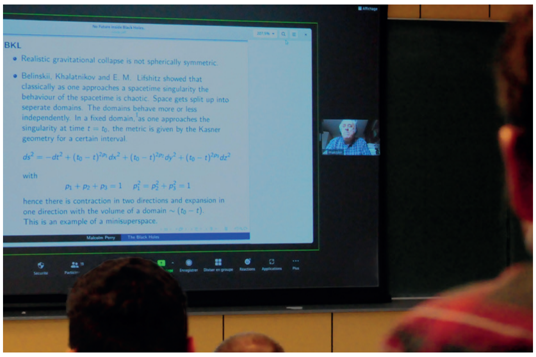
WORKSHOPS ORGANIZED
by the Solvay Institutes

“Selected topics on quantum gravity”

21 - 22 February 2022

This Solvay workshop was the first of a series of meetings devoted to new developments in quantum gravity. Topics addressed in this first session included: information in quantum gravity, wormholes, dynamics of entanglement in QFT and AdS/CFT, complexity in QFT and holography, quantum chaos, soft hair, asymptotic symmetries, symmetries at the horizon, insights from the Wheeler-De Witt equation, quantum de Sitter space, bounds on quantum gravity and holography from amplitudes.

Physical presence was favoured but given the sanitary situation, the workshop adopted a hybrid format with online and physical participation.



Organising and Scientific Committee

Costas Bachas (ENS, France)

Vijay Balasubramanian (University of Pennsylvania, USA)

Ben Craps (Solvay Institutes & VUB, Belgium)

Jan de Boer (UvA, The Netherlands)

Marc Henneaux (Solvay Institutes & ULB, Belgium)

Kyriakos Papadodimas (CERN, Switzerland)

Giuseppe Policastro (ENS, France)

Invited Speakers

Shira Chapman (Ben-Gurion University, Israel)

Frederik Denef (Columbia University, USA)

Netta Engelhardt (MIT, USA)

Elias Kiritsis (CNRS, France & Uoc, Greece)

Adam Nahum (ENS, France)

Malcolm Perry (Cambridge, UK)

Andrea Puhm (CPHT, France)

Suvrat Raju (ICTS, India)

Leonardo Rastelli (Yang I. for Theoretical Physics, Stony Brook, USA)

Julian Sonner (University of Geneva, Switzerland)

Herman Verlinde (Princeton University, USA)

Erik Verlinde (UvA, The Netherlands)

Alexander Zhiboedov (CERN, Switzerland)

Programme

21 February 2022

Welcome speech	
Elias Kiritsis (ONLINE)	*Wormholes and holography*
Shira Chapman	*On holographic flow geometries*
Suvrat Raju (ONLINE)	*Failure of the split property in gravity and the information Paradox*
Alexander Zhiboedov	*Gravitational Regge bounds*
Leonardo Rastelli (ONLINE)	*Carving out the space of gravitational effective field Theories*
Herman Verlinde	
Netta Engelhardt (ONLINE)	*Canonical purification of evaporating black holes*

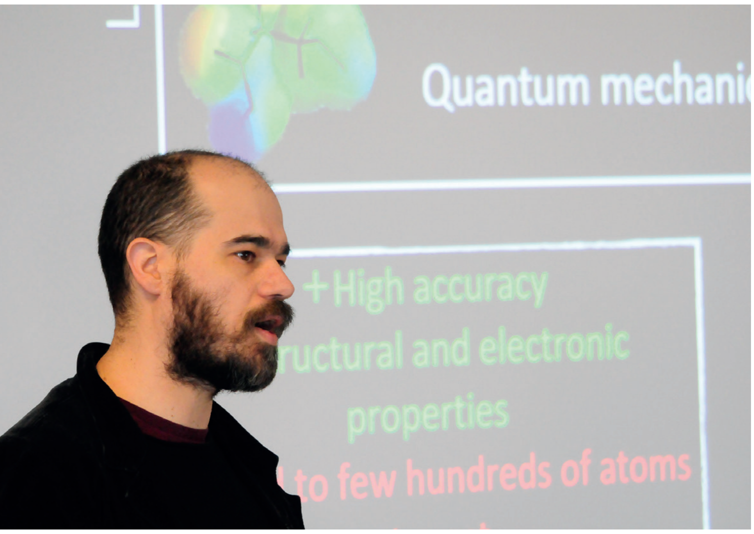
22 February 2022

Adam Nahum	*Quantum dynamics with an observer: the measurement phase transition*
Julian Sonner	*Quantum ergodicity and quantum gravity*
Malcolm Perry (ONLINE)	*Is there a future in black holes?*
Andrea Puhm	*Goldilocks modes in celestial CFT*
Frederik Denef	*Quantum de Sitter Entropy and the QGT Loopstrap*
Erik Verlinde	*A Universal String Field Theory for Quantum Chaos*

"From 2D to 3D Crystals: A Multi-Scale, Multi-Technique and Multi-System Approach of the Crystallization of Organic Molecules on Tailored Carbon Surfaces"

21 - 23 March 2022

An international workshop, which put together experts on crystal growth, polymorphism, epitaxy, surface modifications, and characterization methods. Participants and speakers were welcome to attend in person or remotely. The goal of the meeting was to discuss the latest results of the 2Dto3D project in an international context.



Organising and Scientific Committee

Steven De Feyter (KU Leuven, Belgium)
Yves Geerts (ULB, Belgium)
Roberto Lazzaroni (UMons, Belgium)
Roland Resel (U. of Graz, Germany)
Sandra Van Aert (U. of Antwerp, Belgium)

Invited Speakers

David Amabilino (Nottingham U., UK)
Cinzia Casiraghi (Manchester U., UK)
Neil Champness (Birmingham U., UK)
Shelley Claridge (Purdue U., USA)
Steven De Feyter (KU Leuven, Belgium)
Roman Forker (Friedrich Schiller U., Germany)
Jean Gillet (ULB, Belgium)
Andreas Hirsch (FAU, Germany)
Stefan Kowarik (U. of Graz, Germany)
Markus Lackinger (TUM, Germany)
Tom Leyssens (UCLouvain, Belgium)
Jim Lutsko (ULB, Belgium)
Andrea Minoia (UMONS, Belgium)
Klaus Müllen (Max Planck, Germany)
Josep Puigmartí-Luis (UB, Spain)
Roland Resel (U. of Graz, Germany)
Francesco Tassinari (Weizmann Institute of Science, Israel)
Sandra Van Aert (U. of Antwerp, Belgium)
Omer Yaffe (Weizmann Institute of Science, Israel)

Programme

21 March 2022

Chairman Steven De Feyter

Yves Geerts	*Introduction and context*
Klaus Müllen	*In and out of graphene flatland*
Shelley Claridge	*Phospholipids on carbon: A bridge from 2D to 3D*
Markus Lackinger	*Synthesis of 2D polymers by on-surface photopolymerization*
Andreas Hirsch (online)	*Chemical Patterning of 2D-Materials*
Cinzia Casiraghi (online)	*Crystallization of organic molecules templated by graphene*
Neil Champness (online)	*Molecular Organisation: A Journey Through Complex Structures*
Roman Forker (online)	*Correlation between 2D and 3D crystallographic lattices using LEED and rotated GIXD*
Sandra Van Aert	*Visualisation of light-element atomic structures by advanced transmission electron microscopy*
Poster session	

22 March 2022

Chairman Roland Resel

Omer Yaffe	*The Interplay Between the Molecular Structure and Lattice Thermal Fluctuations in Organics Crystals – A Raman Spectroscopy Study*
Steven De Feyter	*2D crystallization on pristine and chemically modified carbon surfaces*
Roland Resel	*Substrate-Induced Crystallisation of Molecular Crystals: Examples from the 2Dto3D Network*
Andrea Minoia	*On the foundations of supramolecular self-assembly and polymorphism on surfaces: a molecular modeling exploration*
Jean Gillet	*From Pasteur's molecular dissymmetry to homochirality: an introduction to experimental & theoretical works*
Francesco Tassinari	*Spin-polarized surfaces as resolving agents for enantiomeric resolutions*
Yves Geerts	*Tentatives of spin-induced deracemizations*
Jim Lutsko	*Mesoscopic Nucleation Theory: a nanoscale approach to understanding crystallization*
Stefan Kowarik	*Growth of the first monolayer and beyond: X-ray scattering, artificial intelligence analysis and growth models*

23 March 2022

Chairman Kunal Mali	
Josep Puigmartí-Luis	*Simulated microgravity conditions for materials synthesis*
David Amabilino	*Hierarchical supramolecular chemistry at the carbon-molecule interface*
Tom Leyssens	*The importance of nucleation the appropriate crystal form for the development of multi-component resolution processes*
Yves Geerts	*Concluding remark*
Informal discussions	

"Cosmological Frontiers in Fundamental Physics 2022 Workshop"

26 - 28 April 2022

This workshop was part of the `Cosmological Frontiers in Fundamental Physics' series of annual workshops which rotate between the Perimeter Institute in Waterloo, Canada, the Laboratoire APC in Paris, and the International Solvay Institutes in Brussels. This 2022 edition in Brussels was a topical edition centered around the prospects for fundamental physics of observations of long-frequency gravitational waves. It was organized under the umbrella of the Fundamental Physics working group of LISA but the workshop was open to all interested scholars.

Organising Committee

Niayesh Afshordi (PI, Canada)

Geoffrey Compère (ULB, Belgium)

Thomas Hertog (KU Leuven, Belgium)

Philippe Jetzer (Zurich U., Switzerland)

Tjonnie Li (KU Leuven, Belgium)

Alberto Mariotti (VUB, Belgium)

Alexander Sevrin (VUB, Belgium)

Daniele Steer (APC, France)

Nicolas Yunes (Illinois Urbana-Champaign U., USA)

Invited Speakers

Enrico Barausse (SISSA, Italy)

Diego Blas (UAB/IFAE, Spain)

Richard Brito (Técnico Lisboa, Portugal)

Sébastien Clesse (ULB, Belgium)

Katy Clough (Oxford U., UK)

Daniela Doneva (Tuebingen U., Germany)

Jose Maria Ezquiaga (U. of Chicago, USA)

Gabriele Franciolini (Sapienza U. Roma, Italy)

Jonathan Gair (Max Planck, Germany)

Archisman Ghosh (Ghent University, Belgium)

Lavinia Heisenberg (ETH Zurich, Switzerland)

Carlos Herdeiro (Aveiro U., Portugal)

Tanja Hinderer (Universiteit Utrecht, The Netherlands)

Paolo Pani (Sapienza U. Roma, Italy)

Mairi Sakellariadou (King's College London & VUB, UK & Belgium)

Thomas Sotiriou (Nottingham U., UK)

Filippo Vernizzi (IPhT, Saclay, France)

Programme

26 April 2022

Welcome speech

Session 1 - Tests of General Relativity

Convener: Thomas Sotiriou	*Tests of GR with LISA I*
Convener: Daniela Doneva	*Tests of GR with LISA II*
Focus talk: Diego Blas	*Propagation effects, Lorentz violation and memory in MG*
Discussion	

Session 2 - Lambda CDM and Dark Energy

Convener: Filippo Vernizzi	*Testing LCDM model and dark energy with LISA*
Convener: Jose Ezquiaga	*Testing LCDM with LISA*
Focus talk: Archisman Ghosh	*H0 from GWs*
Discussion	

27 April 2022

Session 3 - Nature of Black Holes

Convener: Carlos Herdeiro	*Testing the Kerr hypothesis: universality, imitators and dynamical signatures*
Convener: Paolo Pani	*Black Hole Microstates & LISA*
Focus talk: Richard Brito	*Inspiralling compact objects with generic Deformations*
Discussion	

Session 4 - Model-independent Tests

Convener: Mairi Sakellariadou	*Model-independent tests of Gravity with LISA*
Convener: Lavinia Heisenberg	
Discussion	

28 April 2022

Session 5 - Dark Matter and Primordial Black Holes

Convener: Katy Clough	*Particle dark matter, opportunities and challenges*
Convener: Gabriele Franciolini	*Testing primordial black holes as dark matter with LISA*
Focus talk: Sébastien Clesse	*Key questions on Primordial Black Holes*
Discussion	

Session 6 - Astrophysics and Waveform systematics

Convener: Jonathan Gair	*LSG*
Convener: Enrico Barausse	*Environmental effects and matter systematics for LISA*
Convener: Tanja Hinderer	
Closing Discussion	

"Quantum Simulation - 2021"

29 - 31 August 2022

The Workshop was organized in the context of the 2021 International Jacques Solvay Chair in Physics attributed to Prof. Jean Dalibard.

It put a special emphasis on out-of-equilibrium phenomena and dissipation. Principal topics included:

- Quench dynamics in many-body quantum systems
- Quantum trajectories and open-system dynamics
- Dissipative preparation of strongly-correlated states
- Entanglement and topology in quantum matter
- Quantum transport

Scientific Committee

Ehud Altman (Weizmann I., Israel)
Rainer Blatt (University of Innsbruck)
Immanuel Bloch (MPQ, Garching)
Ignacio Cirac (MPQ, Garching)
Jean Dalibard (Collège de France, Paris)
Maciej Lewenstein (ICFO, Barcelona)
Jean-Michel Raimond (UPMC, Paris)
Uwe-Jens Wiese (University of Bern)

Organising Committee

Nathan Goldman (ULB, Brussels)
Ben Craps (VUB, Brussels)
Wojciech De Roeck (KU Leuven)
Jacques Tempere (U. of Antwerp)
Frank Verstraete (UGent)
Peter Zoller (IQOQI, University of Innsbruck)

Invited Speakers

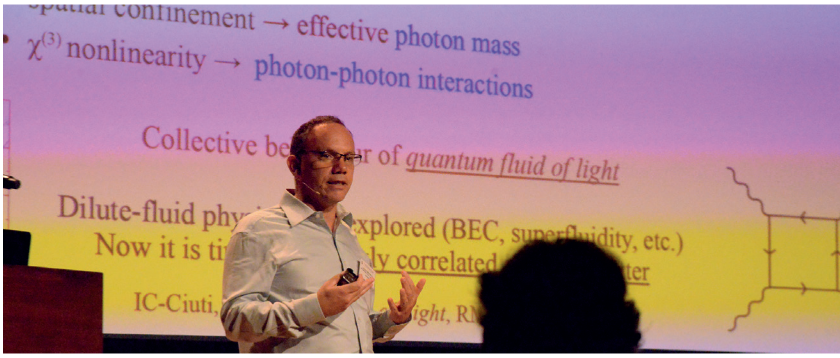
Monika Aidelsburger (LMU, Munich)
Jacqueline Bloch (LPN, CNRS, Paris)
Antoine Browaeys (Institut d'Optique, Palaiseau)
Iacopo Carusotto (INO-CNR BEC Center, Trento)
Nigel R. Cooper (University of Cambridge)
Andrew Daley (University of Strathclyde, Glasgow)
Sebastian Diehl (University of Cologne)
Tilman Esslinger (ETH Zurich)
Leonardo Fallani (UNIFI, Florence)
Francesca Ferlaino (University of Innsbruck)
Zoran Hadzibabic (University of Cambridge)
Julian Leonard (TU Wien, Vienna)
Klaus Mølmer (Aarhus University)
Sylvain Nascimbene (Collège de France, Paris)
Frank Pollmann (TUM, Munich)
Ana María Rey (U. of Colorado, Boulder)
Christian Roos (University of Innsbruck)
Giulia Semeghini (Harvard University)
Leticia Tarruell (ICFO, Barcelona)
Vladan Vuletic (MIT, Cambridge)
Martin Zwierlein (MIT, Cambridge)

Programme

29 August 2022

Opening - welcome speech by Marc Henneaux, Director of the Solvay Institutes

Klaus Mølmer	*Monte Carlo wave functions – a never ending story*
Andrew Daley	*Propagation of information and errors in analogue quantum simulators*
Nigel Cooper	*Steady states and long-range entanglement in locally driven many-body systems*
Zoran Hadzibabic	*Shaken 2D Bose gases*
Sebastian Diehl	*Measurement induced phase transitions: from theory to observability*
Frank Pollmann	*Efficient classical simulation of quantum transport*
Francesca Ferlaino	*Supersolidity and vortices in dipolar quantum gases*
Christian Roos	*Learning entanglement in a trapped-ion quantum simulator*

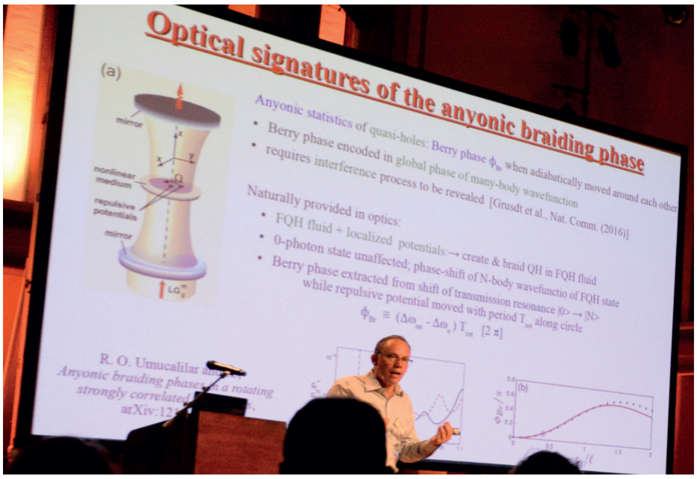


30 August 2022

Sylvain Nascimbene	*Realisation of an atomic Hall system in four dimensions*
Leonardo Fallani	*Flavour-selective localization of interacting fermions and universal Hall response in synthetic dimensions*
Julian Leonard	*Quantum simulation with optical lattices: avalanche thermalization and fractional quantum Hall physics*
Iacopo Carusotto	*Excitations and dynamics of fractional quantum Hall fluids of light and of atoms*
Martin Zwierlein	*Geometric squeezing and crystallization of Bosonic Quantum Hall states*
Monika Aidelsburger	*Simulating synthetic gauge fields with cold atoms*
Tilman Esslinger	*Self-oscillating and interacting topological pumps*
Leticia Tarruel	*Engineering a topological gauge theory in an optically coupled Bose-Einstein condensate*

31 August 2022

Antoine Browaeys	*Many-body physics with atoms in resonant interaction*
Vladan Vuletic	*Quantum simulation and computation with Rydberg atoms*
Ana María Rey	*Tunable-spin-model generation with spin-orbit-coupled fermions in optical lattices*
Jacqueline Bloch	*KPZ universality in driven dissipative polariton condensates*



"Nucleation: multiple pathways multiple outcomes"

7 - 9 December 2022

The workshop aimed to be a forum for lively exchange of ideas between chemists and physicists, experimentalists and theorists in pursuit of fundamental understanding of classical and non-classical crystallization, polymorphism, crystal structure selection, and other related topics.

Organising and Scientific Committee

Tom Leyssens (UCLouvain, Belgium)

Jim Lutsko (ULB, Brussels, Belgium)

Dominique Maes (VUB, Brussels, Belgium)

Peter Vekilov (U. of Houston, USA)

Invited Speakers

Dwaipayan Chakrabarti (U. of Birmingham, UK)

Aurora Cruz-Cabeza (Durham U., UK)

Robin Debuysschère (ULB, Brussels, Belgium)

James de Yoreo (PNNL, Washington, USA)

Yves Geerts (ULB, Brussels, Belgium)

Jerry Heng (Imperial College London, UK)

Bart Kahr (New York U., USA)

Fiona Meldrum (U. of Leeds, UK)

Jianwei Miao (UCLA, Los Angeles, USA)

Sally Price (UCL, London, UK)

Susan Reutzel Edens (Cambridge Crystallographic Data Centre, UK)

Jeffrey Rimer (U. of Houston, USA)

Frank Schreiber (U. Tübingen, Germany)

Joop Ter Horst (U. de Rouen Normandie, France)

Peter Tompa (VIB-VUB, Brussels, Belgium)

Chantal Valeriani (UCM, Madrid, Spain)

Programme

7 December 2022

Opening Remarks	
Jeffrey Rimer	*Nucleation and Polymorphism of Open Frameworks:Navigating the Voids*
Yves Geerts	*Towards spin-directed enantiomeric excess by biased nucleation*
Susan Reutzel Edens	*Crystal polymorphs: Now you see them, now you don't*
Chantal Valeriani	*Nucleation: a simple and a complex case study*
Aurora Cruz-Cabeza	*Thermodynamics vs. Kinetics: Who wins the crystallisation race?*
Poster Session	

8 December 2022

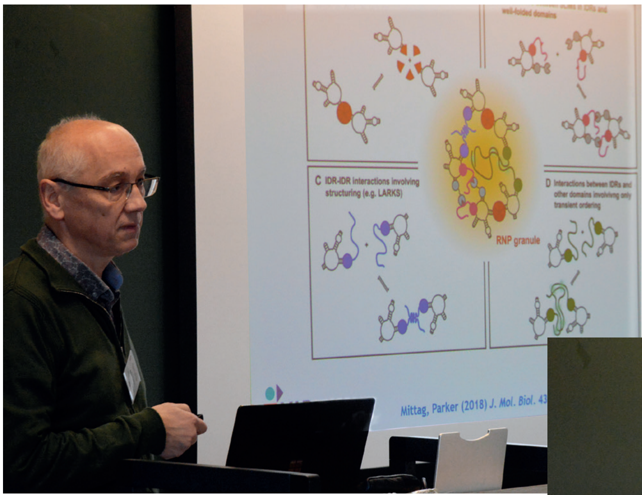
Sally Price	*How can we find more polymorphs?*
Jerry Heng	*A Selective Nucleation Approach for the Purification of Proteins from Impure Solutions*
Peter Tompa	*Biophysical basis of LLPS in the formation of cellular membraneless Organelles*
Dwaipayan Chakrabarti	*Programming crystal clear pathways for colloidal open Crystals*
Fiona Meldrum	*Controlling crystallization using confinement and surface topography*

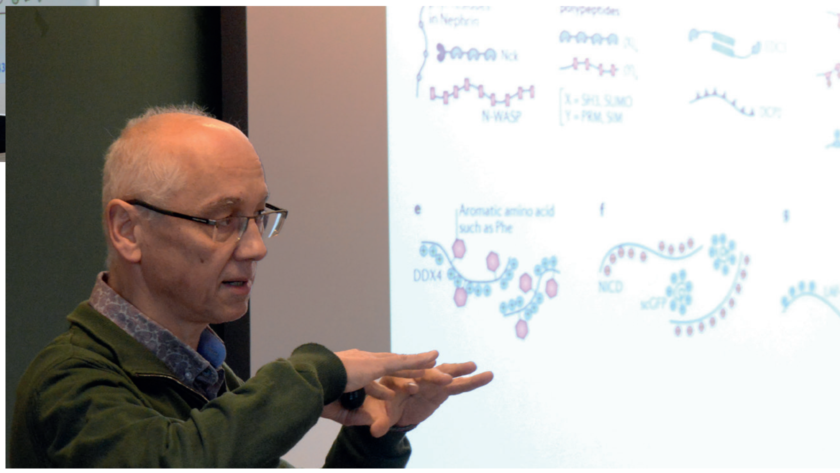
Solvay Colloquium

James De Yoreo	*Emulating Nature's Way of Making Materials*

9 December 2022

Joop Ter Horst	*The unexpected dominance of secondary over primary nucleation*
Frank Schreiber	*Tuning protein aggregation and crystallization by charges*
Bart Kahr	*Mosquito meets crystal*
Robin Debuysschère	*Analysis of non-classical shear-induced nucleation mechanism*
Concluding remarks	


C IDR-IDR interactions involving structuring (e.g. LARKS)
D Interactions between IDRs and other domains involving only transient ordering
RNP granule
Mittag, Parker (2018) J. Mol. Biol.


Nck
N-WASP
X = SH3, SUMO
Y = PRM, SIM
e
Aromatic amino acid such as Phe
DDX4
f
NICD

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Colloquium Gravitational Waves and Exoplanets

2 April 2022

The colloquium was organised by the National Committee for Pure and Applied Physics and took place at the Royal Academies for Science and the Arts of Belgium in Brussels.

Programme

Prof. Christoffel Waelkens (KU Leuven)	**Introduction**
Prof. Gabriela Gonzales (Louisiana State University)	*Basics and Detection of Gravitational Waves*
Prof. Jo van den Brand (NIKHEF and University of Maastricht)	*Gravitational Waves: what lies in the future?*
Poster session by the Belgian research institutions	
Prof. Michel Mayor (Nobel Laureate 2019, University of Geneva)	*Discovering Exoplanets*
Prof. Lisa Kaltenegger (Cornell University)	*Habitability of Exoplanets*
Prof. Yaël NAZE (ULiège)	**Conclusions**

19th International Conference on Density-Functional Theory and its Applications in 2022 in Brussels (DFT2022)

28 August – 2 September 2022

Density functional theory (DFT) is today's most widely used method for practical computational electronic structure calculations across chemistry, physics and materials science. The conference covered a broad range of topics in the field, from the latest theoretical developments to cutting-edge applications in chemistry and physics, bringing together scientists from all over the world. The scientific program extended over five days, and consisted of 10 plenary and 15 invited lectures by internationally renowned speakers, presenting the current state-of-the-art in the field. In addition, a total of 33 slots for contributed talks provided the opportunity to present your research at the world's largest platform for DFT developers and users.

Contributions to the following topics were warmly welcome:

- New fundamental developments in density functional theory
- New developments for exchange-correlation functionals
- Time-dependent and real-time density functional theory
- Chemical concepts and conceptual DFT
- DFT and machine learning
- Applications of DFT in chemistry, condensed matter physics and materials science

Organising Committee

Prof. Frank De Proft
Vrije Universiteit Brussel

Prof. Mercedes Alonso
Vrije Universiteit Brussel

Prof. Freija De Vleeschouwer
Vrije Universiteit Brussel

Dr. Jan Turek
Vrije Universiteit Brussel

Sabrina Vanoppen
Vrije Universiteit Brussel

Fabienne Morren
Vrije Universiteit Brussel

Prof. Frederik Tielens
Vrije Universiteit Brussel

Prof. Jeremy Harvey
Katholieke Universiteit Leuven

Prof. Toon Verstraelen
Ghent University

Prof. Benoît Champagne
University of Namur

Prof. Nathalie Vaeck
Université Libre de Bruxelles

Baryon and Lepton Number Violation (BLV2022)

5 - 8 September 2022

The 2022 International Workshop on Baryon and Lepton Number Violation (BLV2022) was hosted by the Service de Physique Théorique of the Université Libre de Bruxelles (ULB).

After Berkeley (2007), Madison (2009), Gatlinburg (2011), Heidelberg (2013), UMass (2015), Cleveland (2017) and Madrid (2019) this was the eighth edition of this workshop.

The 5 main topics of this workshop were:

- baryogenesis mechanisms
- baryon lepton number violation
- lepton number and lepton flavor violation
- neutrinos
- dark matter

so that it covered a wide range of BSM physics, with both a theoretical and an experimental component.

50 years of VUB-ULB Interuniversity Institute for High Energies

14 September 2022

The anniversary was celebrated on Wednesday 14 September with a Colloquium at the Royal Academies for Science and the Arts of Belgium in Brussels.

> *"The IIHE is the first joint research institute between the two Brussels universities, ULB and VUB. It was created in 1972. We are very happy to celebrate today the 50th anniversary of the Institute. During these 50 years of research, important discoveries have been made at the IIHE to better understand the world around us. If we celebrate today this important moment and look back at the path we have taken, it is also and above all to look forward, to the missions ahead. To further unravel the mysteries of physics, we need to keep innovating. Only then can we make visible what is otherwise invisible. Moreover, these technological innovations are always finding their way into various applications in society, thus permanently changing it.*
>
> *Barbara Clerbaux (ULB) - IIHE director*

Programme

Marius Gilbert	*Welcome from the ULB vice-rector of research and valorisation*
Karin Vanderkerken	*Welcome from the VUB rector*
Daniela Bortoletto	*Inspirational talk: the landscape of high energy physics*
Daniel Bertrand	*The birth of the institute*
Laurent Favart	*IIHE: 50 years of scientific exploration*
Caroline Volckaert	*Words from the funding agencies - FWO science policy advisor*
Véronique Halloin	*Words from the funding agencies - Secretary General F.R.S-FNRS*
Luca Malgeri	*The CMS experiment at CERN*
Francis Halzen	*The IceCube experiment at the South Pole*
Ian Shipsey	*Instrumentation for HEP and society*
Julia Tjus Becker	*The high-energy universe*
Wim Leemans (VUB alumnus)	*Plasma accelerators: can small be the next big thing*
Frédéric Hemmer (ULB alumnus)	*Data processing for large research infrastructures*

NEW HORIZONS LECTURES

New Horizons Lectures

The “New Horizons Solvay Lectures” were launched in 2018. The object of the program 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.

The success of the 2018 edition convinced the board of the Institutes to continue on a yearly basis.

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

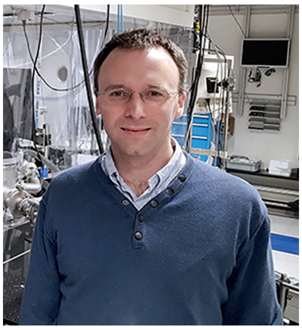
• New Horizons Lectures in Physics

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

As the pages that follow illustrate, the year 2022 was also impacted by the pandemic.
We expect to make up the backlog (2021 Lectures in Chemistry and 2022 Lectures in Physics) by May of 2023.

2020 New Horizons Lectures in Chemistry

Professor Hans Jakob Wörner
ETH Zurich, Switzerland



Professor Wörner, 2020 New Horizons lecturer for chemistry, completed his cycle of lectures given on line in 2021 (see 2021 activity report of the Solvay Institutes) by coming to Brussels in June of 2022. He gave his closing lecture in person on June 14, 2022.

Hans Jakob Wörner was born in Freiburg, Germany, in 1981. He studied chemistry at ETH Zurich, graduating in 2003 and obtaining a doctorate in physical chemistry in 2007. From 2007, he worked as a postdoc at the Laboratoire Aimé Cotton of the CNRS (Centre national de la recherche scientifique) in Orsay, France, and the National Research Council in Ottawa, Canada.

He has been an Assistant Professor at the Laboratory of Physical Chemistry in the Department of Chemistry and Applied Biosciences of ETH since 2010.

Hans Jakob Wörner's main research focus is the ultra-fast spectroscopy of molecules with an attosecond time resolution (1as = 10-18 s) and the development of new experimental methods to characterize the structure and dynamics of the valence shell of molecules.

Closing Lecture

14 June 2022

Attosecond spectroscopy and dynamics

Electrons in matter move on attosecond (1 as = 10-18 s) time scales. Attosecond pulses of light are the shortest events that humans can control today. Attosecond spectroscopy is therefore providing unprecedented insights into the electronic dynamics of matter, which are advancing fundamental knowledge and have the potential of generating new technologies. I will discuss the principles of attosecond spectroscopy and its recent extensions from atoms to molecules, clusters and liquids. These developments reveal how the dynamics of photoionization evolve from isolated particles over finite-sized systems to the bulk. I will then describe the recent development of attosecond soft-X-ray spectroscopy and how it overcomes the complexity gap. I will describe the first direct observation of attosecond charge migration in molecules, as well as its dephasing and revival driven by femtosecond structural dynamics. The lecture will conclude with an outlook on the possibilities offered by attochemistry.

2022 New Horizons Lectures in Chemistry

Professor Cornelia Meinert
CNRS, Université Côte d'Azur, France

Professor Meinert is a CNRS Research Director at the Université Côte d'Azur, Nice. After completing her chemistry studies at the universities of Rostock and Leipzig, she obtained her PhD on characterizing complex environmental samples with Werner Brack at the Helmholtz-Centre of Environmental Research in Leipzig. In 2013, after 4 years of PostDoc at the University of Nice, working on the asymmetric origins of amino acids, she has been nominated a permanent Research Scientist in physical chemistry by the French National Centre for Scientific Research (CNRS).

She was awarded the CNRS Bronze Medal in 2018 and an ERC Starting Grant exploring a unified hypothesis of the emergence of biological homochirality (A-LIFE).

Thank you very much for the hospitality you showed me during my week in Belgium.
It was an incredible time for me to interact with one of the best scientists. I am honored to have had the chance to visit the KU Leuven, UCL Louvain and both ULB and VUB. Time is very precious; therefore, I am very grateful for the time you spent to introduce me to your research and your well-equipped laboratories!
Thank you for the papers you gave or sent me as well as for the many questions, I have already received, including those from young researchers.

I would like to express my gratitude to the wonderful and brilliant PhD and Post-doc students I had the chance to meet last week for making your science accessible to me.
I wish you all the best for your future and hope that some of you will have the passion, drive and ambition for an academic career.

This opportunity was clearly a moment I will never forget in my life! New collaborations have already been initiated and I look forward to discussing the beauty of science with you again in the future! I wish you all the very best for your upcoming experiments and research activities.

Thanks again for making me feel so welcome!

Cornelia

Lecture

24 February 2022

The cosmic origin of biomolecular chirality

'How did life choose its handedness?' Just like our hands mirror each other, but cannot be superimposed on each other, amino acids and sugars exist in left- and right-handed forms. Even if there appears to be no biochemical reason to favor one enantiomer over the other, life on Earth uses almost exclusively left-handed amino acids and right-handed sugars. This is called biological homochirality and it is inevitable for building functional proteins and RNA/DNA. Numerous experiments have confirmed that simple prebiotic molecules could have been synthesized both in space as well as on the early Earth. However, the preferential selection of one enantiomer over the other remains to date most likely explained by asymmetric interactions of stellar ultraviolet circularly polarized light (UV CPL) with chiral organics. The astrophysical origin of homochirality is strengthened by i) the detection of L-enriched amino and D-enriched sugar acids in meteoritic samples, ii) the detection of CPL in several star-forming regions as well as iii) experiments studying the interaction of UV CPL with prebiotically relevant chiral species. In this talk, I will highlight significant results on our on-going cometary ice simulation experiments (Fig. 1) as well as on circular dichroism andanisotropy spectroscopy as a key tool to decipher the response of chiral molecules to UV CPL.

Moreover, I will present our major findings on recent asymmetric photosynthesis/photolysis experiments to discuss whether stellar UV CPL could have induced a common chiral bias across molecular families?

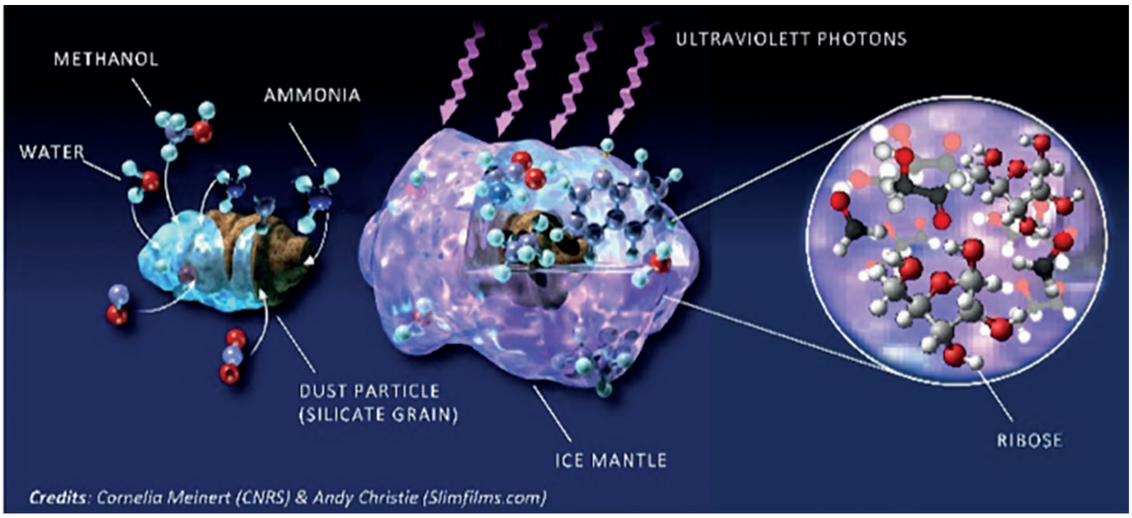
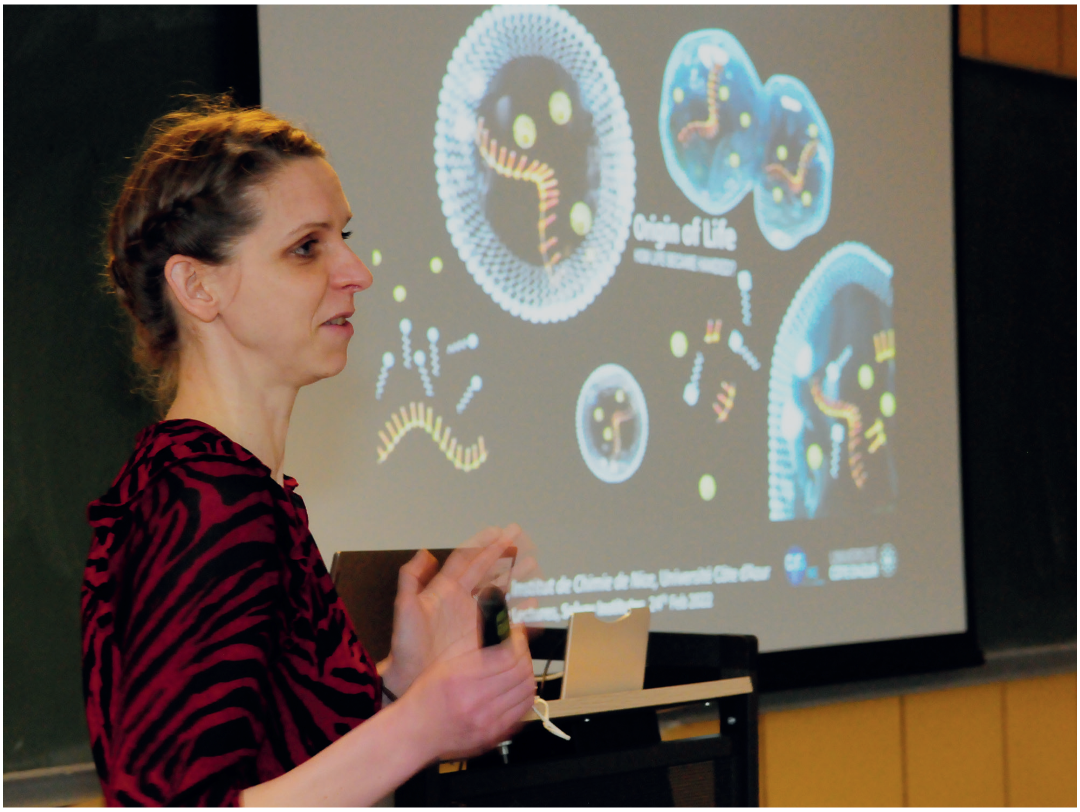


Figure 1: Ribose forms in the icy mantles of interstellar dust grains from simple precursor molecules (water, methanol, and ammonia) under high energy radiation.

Interactions with research groups from several universities

Professor Cornelia Meinert spent one week in Belgium and interacted with research groups from several universities (ULB, VUB, KU Leuven and UCL Louvain).



- **Visit to KU Leuven**

  hosted by Profs Steven De Feyter, Johan Hofkens, Jeremy Harvey. Nano(bio)chemistry on surfaces is the core activity of the group.

- **Visit to UCL**

  hosted by Profs Sophie Hermans, Benjamin Elias et Clément Lauzin.

  The research group of Prof. Sophie Hermans develops expertise in inorganic chemistry, heterogeneous catalysis and functional nanomaterials for specific applications.

- **Discussion with ULB colleagues and young researchers**

  Prof. Bartik's group - The EMNS laboratory has extensive know-how in the experimental study of the structure, stability and dynamics of molecular complexes, and in the synthesis and functionalization of nanoparticles.

  Profs Yannick De Decker, Laurence Rongy, Anne De Wit: Nonlinear Physical Chemistry Unit.

  Prof. Vinciane Debaille: geochemistry. Her current interest is the study of the planet Mars, either through chemical analyzes of martian meteorites, or by participating to the Mars 2020 mission as return sample scientist.

  Prof. Alain Jorissen: Institut d'Astronomie et d'Astrophysique.

  Young researchers: Cédric Theunissen (Collaborateur scientifique F.R.S.-FNRS), Stefano Perusko (PhD Student/Researcher at Brussels and Antwerp Universities), Lizzie Killalea (Postdoctoral researcher), Pamela Knoll (Postdoctoral Fellow), Jean Gillet (Doctoral Researcher · F.R.S. - FNRS).

- **Discussion with VUB colleagues and young researchers**

  Prof. De Proft's group (General Chemistry): the central research topic of the General Chemistry Research group is quantum chemistry., i.e. the application of quantum mechanics to chemical problems such as the structure, stability and reactivity of molecules.

  Prof. Ulrich Hennecke's group: the Hennecke's group is interested in research within the areas of synthetic organic and bioorganic chemistry. A key component of research focuses on organohalogen compounds, especially of the heavier halogens chlorine, bromine and iodine.

2022 New Horizons Lectures in Physics

The visit of Professor Nir Navon (Yale University, USA) has been rescheduled to March of 2023.

COLLOQUIA

Developing mRNA for therapy

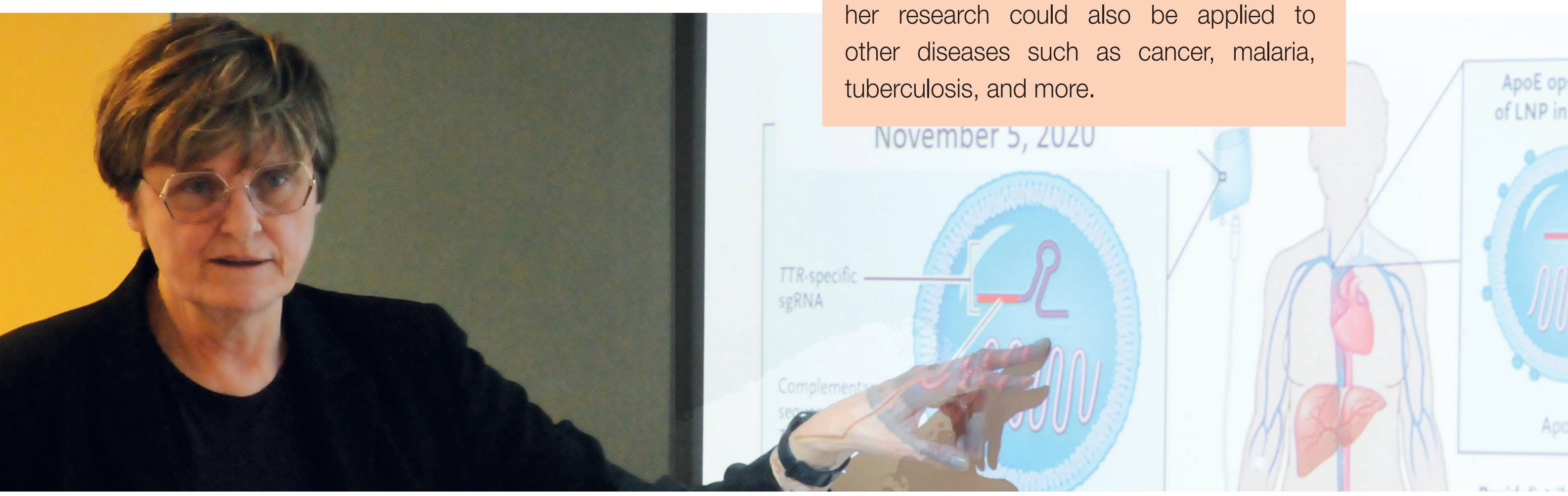
Professsor Katalin Karikó
University of Pennsylvania, USA

30 March 2022

Messenger RNA was discovered in 1961 and it took six decades until the first mRNA became FDA-approved product in the form of COVID-19 mRNA vaccine. During those years a lot of progress has been made but the inflammatory nature of the mRNA hampered its medical use. We achieved a great milestone when we warded off the response by replacing uridine with pseudouridine in mRNA. We further demonstrated that modified mRNA formulated with LNP can be a potent vaccine.

These discoveries eventually led to the development of the mRNA vaccine that has now helped to fight the pandemic and opened the door for developing breakthrough therapeutics for unmet medical needs.

The 2022 Solvay Prize was awarded to Professor Katalin Karikó. She won the prize for her research, which led to the creation of the messenger RNA covid-19 vaccine. She found a way to use chemistry to modify the mRNA so that the immune system won't reject it. And this is just the beginning: her research could also be applied to other diseases such as cancer, malaria, tuberculosis, and more.

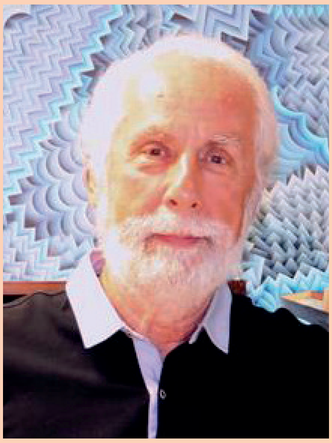


Neutrino: chronicles of an aloof protagonist

Professor Goran Senjanovic
LMU, München, Germany

24 May 2022

We give a brief account of the history of neutrino, and how this most aloof of all particles has shaped our search for a theory of fundamental interactions ever since it was conceived. We introduce the necessary concepts and phenomena in a non-technical language aimed at a physicist with some basic knowledge of quantum mechanics. It is argued that neutrino mass offers an ideal door into new physics and that the Large Hadron Collider could open that door. We show finally then that the Minimal Left-Right Symmetric model is a complete theory of the origin and nature of neutrino mass, with testable predictions at present and near future experiments. This is the theory that led originally to neutrino mass and the seesaw mechanism behind its smallness, but even more important, the theory that sheds light on a fundamental question that touches us all: the symmetry between left and right.



Driven open quantum systems from micro- to macrophysics

Professor Sebastian Diehl
University of Cologne, Germany

1 - 2 September 2022

The two lectures were organized in the context of the Solvay Workshop on Quantum Simulation.

Recent experimental developments in areas - ranging from cold atomic gases over light driven semiconductors to NISQ platforms - move systems into the focus, which are located on the interface of quantum optics, condensed matter physics and statistical mechanics. These systems realize instances of driven open quantum matter: Coherent and driven-dissipative quantum dynamics occur on an equal footing, and they are operated in the thermodynamic limit.

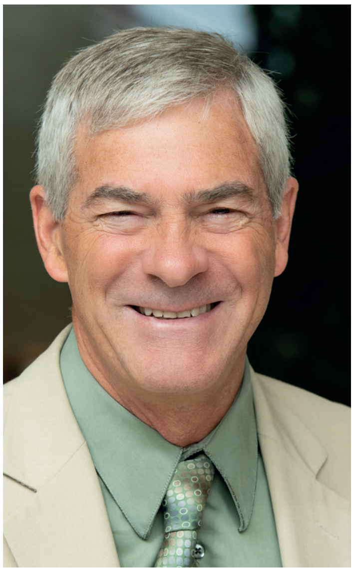
In these lectures, we will develop the tools to understand such systems based on a field theory approach to the many-body Lindblad equation, which is particularly well suited to perform the transition from microscopic physics to macroscopic observables, thereby distilling universal aspects of such setups. In particular, we will make precise in which way these systems qualify as "non-equilibrium" on the microscopic scale. Based on this understanding, we will then focus on two applications: First, we investigate the fate of the famous Kosterlitz-Thouless phase transition under driving conditions. We show that an infinitesimal non-equilibrium perturbation is sufficient to suppress this transition in large systems. On the other hand, we point out a new intrinsic non-equilibrium phase transition characterized by the onset of defect chaos. Second, we argue that drive and dissipation can be harnessed to create various forms of quantum mechanical correlations such as phase coherence, entanglement or topological order.

We will concentrate on topology, and zooming out, discuss universal aspects of topology in mixed quantum states and far from equilibrium.

Emulating Nature's Way of Making Materials

Professor James De Yoreo
PNNL, Washington, USA

8 December 2022



From harvesting solar energy to capturing CO_2 to purifying water, living organisms have solved some of the most vexing challenges now faced by humanity. They have done so by creating a vast library of proteins and other macromolecules that can assemble into complex architectures and direct the mineralization of inorganic components to produce materials characterized by a hierarchy of structure. While the high information content contained within the intricate sequences of the proteins is crucial for accomplishing these tasks, self-assembly and mineralization are nonetheless constrained to proceed according to the physical laws that govern all such processes, even in synthetic systems. An understanding of the mechanisms by which biological systems successfully manipulate those laws to create hierarchical materials would usher in an era of materials design to address our most pressing technological challenges.

In this talk, I will present the results of recent research using in situ atomic force microscopy and in situ transmission electron microscopy to directly observe interfacial structure, protein self-assembly, and nanocrystal formation in biomolecular and biomimetic systems, including protein-directed nucleation of calcium carbonate and calcium phosphate and mineral-directed nucleation of two-dimensional assemblies of proteins. The results elucidate the mechanisms by which biomolecules and interfaces direct crystallization processes, leading to unique materials and morphologies. The results reveal the importance of surface charge, facet-specific binding, solvent organization near interfaces, and, more generally, the balance of protein-substrate-solvent interactions in determining how ordered materials emerge in these systems.

DOCTORAL SCHOOLS

XVIII Modave Summer School in Mathematical Physics

4 - 10 September 2022

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 18th edition of the school! As for the previous years, the ULB, VUB, KUL and UMONS joined their forces to propose a unique scientific and human experience in the heart of the Belgian countryside.

Organizing Committee

Ankit Aggarwal (ULB), Sergio Ernesto Aguilar Gutierrez (KUL), Akshay Bedhotiya (UMONS), Martin Bonte (ULB), Lorenzo Cimino (UMONS), Cyrille Chevalier (UMONS), Arnaud Delfante (UMONS), Shailesh Dhasmana (UMONS), Vasko Dimitrov (KUL), Adrien Druart (ULB), Ludovic Ducobu (UMONS), Kwinten Fransen (KUL), Yegor Goncharov (UMONS/U. de Tours), Philip Hacker (VUB), Maria Knysh (VUB), Lorenzo Küchler (ULB/KUL), Yan Liu (ULB), Ludovico Machet (ULB/KUL), Louan Mol (ULB), Daniel Naegels (ULB), Josh O'Connor (UMONS), Noémie Parrini (UMONS), Maxim Pavlov (VUB), Simon Pekar (UMONS), Mattia Serrani (UMONS), Antoine Somerhausen (ULB), Colin Sterckx (ULB), Wendi Tan (ULB), Rob Tielemans (KUL), Richard van Dongen (UMONS), Jesse van Muiden (KUL), Romain Vandepopeliere (ULB), Quentin Vandermiers (ULB), Vincent Van Hemelryck (KUL), Annelien Vekemans (KUL), Xuao Zhang (KUL) and Sofia Zhidkova (VUB).

Lectures: topics and speakers

Asymptotic symmetries from a geometric point of view

by Luca Ciambelli (ULB, Brussels)

This lecture consists of three main parts. The first is devoted to Noether theorems and their underlying framework, the covariant phase space, with special focus on gauge theories. Surface charges are introduced and their algebra is shown to projectively represent the asymptotic symmetry algebra. Integrability and conservation of charges are addressed. In the second part, we introduce the universal corner symmetry and enunciate the corner proposal. The last part of this lecture is about the extended phase space, and, time permitting, scattered recent advancements in the understanding of gauge symmetries. Various exercises are proposed, to accompany and elucidate the arguments exposed.

Noncommutative Geometry with applications to physics

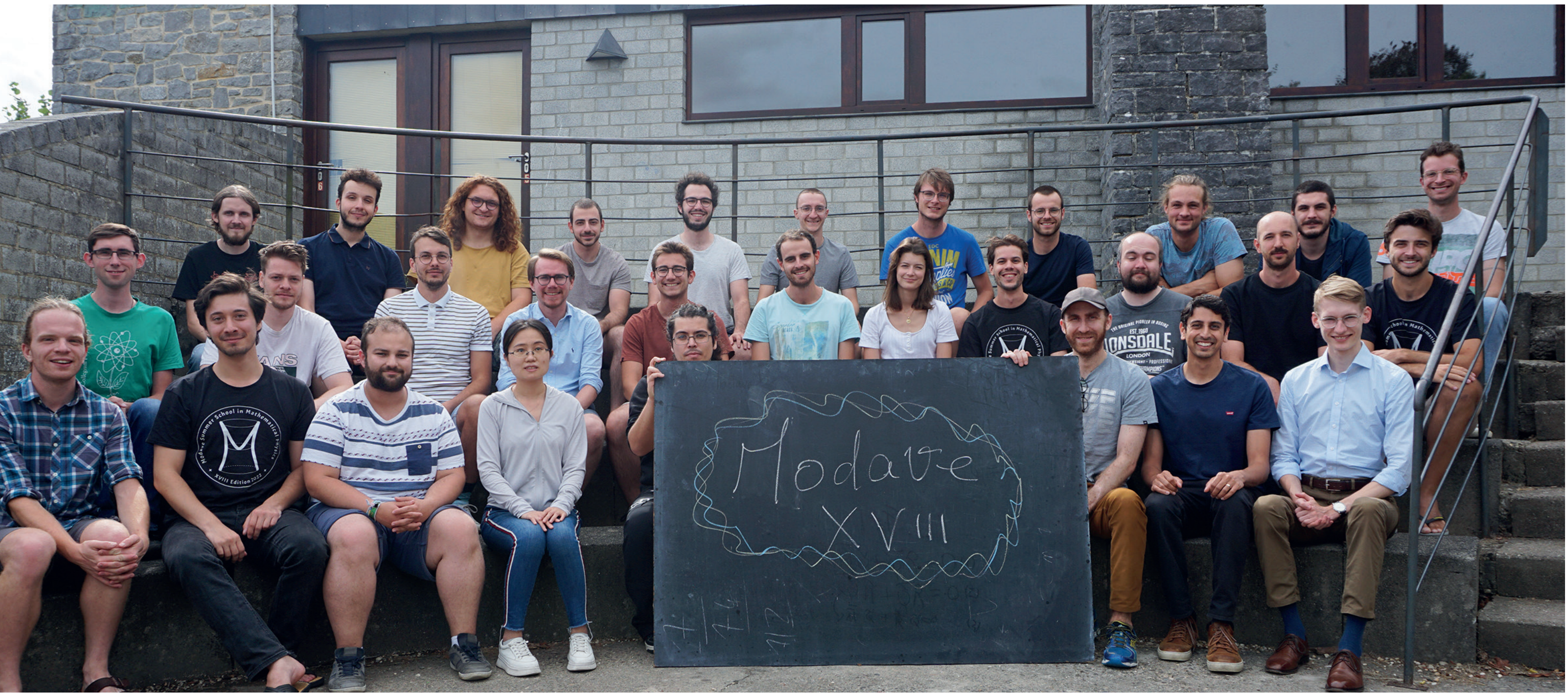
by Arkadiusz Bochniak (Jagiellonian University, Kraków)

Noncommutative Geometry: I give a series of lectures dedicated to Noncommutative Geometry and its applications to physics. I motivate the use of Noncommutative Geometry, ending up with the notion of a spectral triple, describing the correspondence between vector bundles and modules, and discussing the notion of noncommutative differential calculus. Then I present different additional structures that can be added on top of a bare spectral triple. The example of the canonical spectral triple as a link with classical geometry is described. I then answer the question of how one can derive physical action out of the geometric data. These methods are then used to describe the Standard Model of particle physics.

De Sitter space & holography

by Damian Galante (King's College London)

We provide an overview of different aspects of de Sitter space and their plausible holographic interpretations. We start with a general description of the classical spacetime. We note the existence of a cosmological horizon and its associated thermodynamic quantities, such as the Gibbons-Hawking entropy. We discuss two simple probes, geodesics and shockwaves, that might be relevant in holography. Finally, we discuss different approaches to quantum theories of de Sitter space, with an emphasis on recent discussions on static patch holography.



Geometric Quantization

by Konstantin Wernli (University of Southern Denmark, Odense)

Geometric Quantization is a mathematical way of trying to satisfy Dirac's axioms for quantization. It is formulated in the language of phase spaces or symplectic geometry. One of its main advantages is the possibility to quantize a large class of symplectic manifolds. I will give a pedestrian introduction to the subject, with the goal of discussing some applications to (topological) quantum field theory.

Introduction to higher-spin theories

by Simon Pekar (UMONS)

These lectures will be an introductory course to higher- spin theories. We start with the basics of group theory allowing one to define higher-spin fields, then discuss the free theory in the metric-like and the frame-like formulations. We end with the construction of higher-spin symmetry algebras and emphasise the link between them and the free theory, as well as the considerations that allow one to construct the former from the symmetries of the latter.

Participants

Aggarwal Ankit (ULB, Belgium & Amsterdam U., The Netherlands)

Aguilar Gutierrez Sergio Ernesto (KU Leuven, Belgium)

Ahlouche Ismaël (UMons, Belgium)

Beauvillain Mathieu (École Normale Supérieure Paris and CPHT Polytechnique, France)

Bochniak Arkadiusz (Jagiellonian University, Poland)

Ciambelli Luca (ULB, Belgium)

Delfante Arnaud (UMons, Belgium)

Druart Adrien (ULB, Belgium)

Furlan Manuel (University of Trieste, Italy)

Galante Damian (King's College London, UK)

Hacker Philip (VUB, Belgium)

Karlsson Joel (KU Leuven, Belgium)

Lemut Timotej (University of Ljubljana, Slovenia)

Lhost Guillaume (UMons, Belgium)

Machet Ludovico (KU Leuven, Belgium)

Mol Louan (ULB, Belgium)

O'Connor Josh (UMons, Belgium)

Parrini Noémie (UMons, Belgium)

Pavlov Maxim (VUB, Belgium)

Pekar Simon (UMons, Belgium)

Raml Thomas (Max Planck Institute for Physics, Germany)

Rivera David (École polytechnique, France)

Scalea Adrien (UMons, Belgium)

Serrani Mattia (UMons, Belgium)

Sheorey Sameer (King's College London, UK)

Sterckx Colin (ULB, Belgium)

Tan Wendi (ULB, Belgium)

van Dongen Richard (UMons, Belgium)

Vandepopeliere Romain (ULB, Belgium)

Vandermiers Quentin (ULB, Belgium)

Vilatte Matthieu (CPHT-École Polytechnique, France)

Wernli Konstantin (Syddansk Universitet, Denmark)

Zalecki Paweł (Jagiellonian University, Poland)

Doctoral School on "Quantum Field Theory, Strings and Gravity"

Brussels, 3 - 21 October 2022

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

Organizing Committee

Brussels

- Riccardo Argurio (ULB)
- Ben Craps (VUB)
- Frank Ferrari (ULB)

Brussels | 3 - 21 October 2022

Adel Bilal	*Advanced Quantum Field Theory*
Alberto Lerda	*String Theory I*
Marco Billò	*String Theory II*
Silvia Penati	*Introduction to Supersymmetry*
Geoffrey Compère	*Gravitational waves*

Paris | 31 October - 18 November 2022

Domenico Orlando	*Introduction to Superstrings*
Susanne Reffert	*D-branes and Superstring Dualities*
Antoine van Proeyen	*Introduction to Supergravity*
Andrea Puhm	*Infrared aspects of gravity and holography*

Geneva | 28 November - 16 December 2022

Victoe Gorbenko	*Cosmology*
Kyriakos Papadodimas	*Introduction to AdS/CFT*
Eric Perlmutter	*Holographic CFTs*
Julian Sonner	*AdS/CFT*
Erik Tonni	*Entanglement in QFT and holography*

Participants

Barriga Gonzalo (Universidad de Concepción, Chile)
Baumgartner Rahel (University of Geneva, Switzerland)
Baune Konstantin (ETH Zurich, Switzerland)

Bedhotiya Akshay (UMons, Belgium)
Bendriss Khalil (Montpellier University, France)
Benizri Lior (École Normale Supérieure, France)
Boura De Matos José Guilherme (EPFL, Switzerland)
Chen Zhongwu (ENS/PSL, France)
Dhasmana Shaileh (UMons, Belgium)
Dongming He (Vrije Universiteit Brussel, Belgium)
Fontaine Dima (Université Libre de Bruxelles, Belgium)
Franken Victor (École Polytechnique, France)
Hollander Jildou (University of Amsterdam, The Netherlands)
Kanuri Sahaja (Université Libre de Bruxelles, Belgium)
Leuthner Markus (TU Wien, Austria)
Maisel Licerán Lucas (Utrecht University, The Netherlands)
Mariani Francesca (Ghent University, Belgium)
Milam Michael (Université Paris-Saclay, France)
Nairz Beat (ETH Zurich, Switzerland)
Oyarzo Marcelo (Universidad de Concepción, Chile)
Parrini Noémie (UMons, Belgium)
Pascuzzi Gabriele (Vrije Universiteit Brussel, Belgium)
Planella Planas Guim (Utrecht University, The Netherlands)
Reymond Sébastien (KU Leuven, Belgium)
Sanhueza Mardones Leonardo (Universidad de Concepción, Chile)
Selle Matteo (University of Cologne, Germany)
Serrani Mattia (UMons, Belgium)
Shieber Andrei (University of Oxford, UK)
Van Dongen Richard (UMons, Belgium)
Van Vliet Mick (Utrecht University, The Netherlands)
Vuignier Antoine (EPFL, Switzerland)

Student’s opinion

Sahaja Kanuri
ULB

The Solvay Doctoral School is an intense 3 months-long school spread over 3 cities with 3 weeks spent at each city. This year, it took place at ULB (Brussels), ENS (Paris) and CERN (Geneva). The school, with an international set of students and lecturers who are leading researchers from various European universities, was rewarding on multiple levels:

Firstly, the courses are advanced, ranging from topics such as an introduction to Conformal Field Theories, Superstring Theory, Supergravity, the AdS/CFT correspondence, and Celestial Holography. These formed the perfect bridge between Master-level courses and the comprehension required to embark on a PhD in Theoretical Physics. These lectures were taught by researchers with expertise in a variety of areas. The conversations with the professors during coffee breaks also allowed us to better understand their research and their experience in academia so far. This was even complemented by a couple of group dinners with some of the professors.

Secondly, the duration of the school spanning over the different cities allowed me to form deep bonds with fellow PhD students. From attending lectures together, to spending time together at the end of the day, we got to know each other better over time. Moreover, we were able to have new experiences together thanks to travelling to different places: we did activities such as going to orchestras in Paris, bouldering (yes, Physicists love to boulder!), hiking around Geneva, behaving like tourists, and numerous dinners! Some of us now even get to meet each other often at seminars and the reunion is always special! I am grateful to be able to call them my friends and not just colleagues.

> *Overall, the environment of the school was incredibly conducive to growth, both on a personal and a professional level. I highly recommend it to future PhD students!*

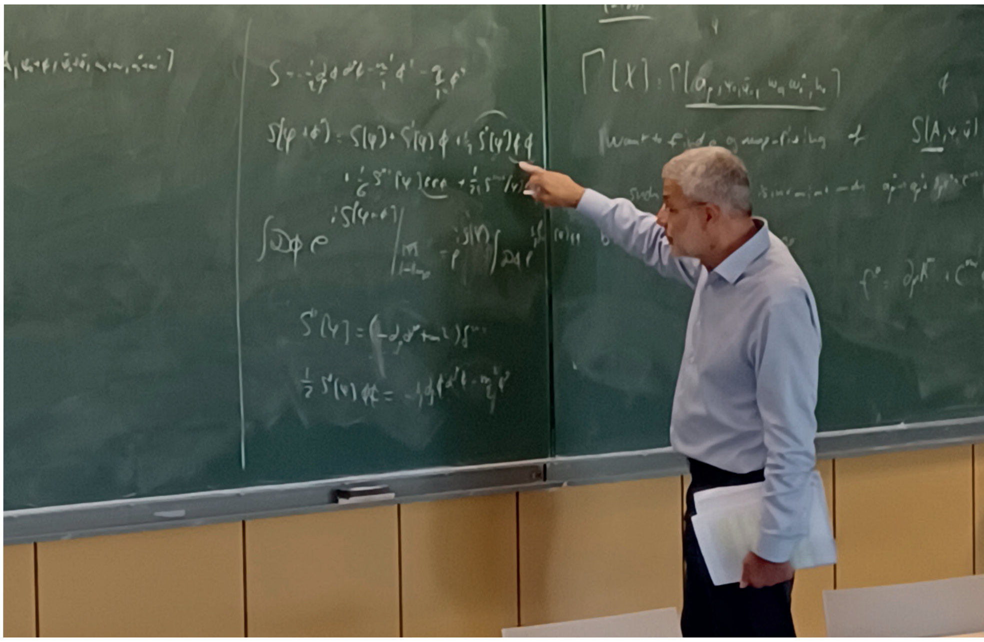
Student's opinion

Dima Fontaine
ULB

The Solvay Doctoral School is an ideal start for a PhD journey on many levels. Purely academically, three blocks of 3 weeks of high-quality lectures, given by renowned experts in all areas of theoretical physics, is a must-have for any student willing to fill the gap between masters studies and the exciting - but demanding - world of research. From rigorous foundations to recent ideas from vibrant modern areas of research, this 9-week course has been a very useful platform to get started in my PhD, expand my knowledge of theoretical physics and exchange ideas.

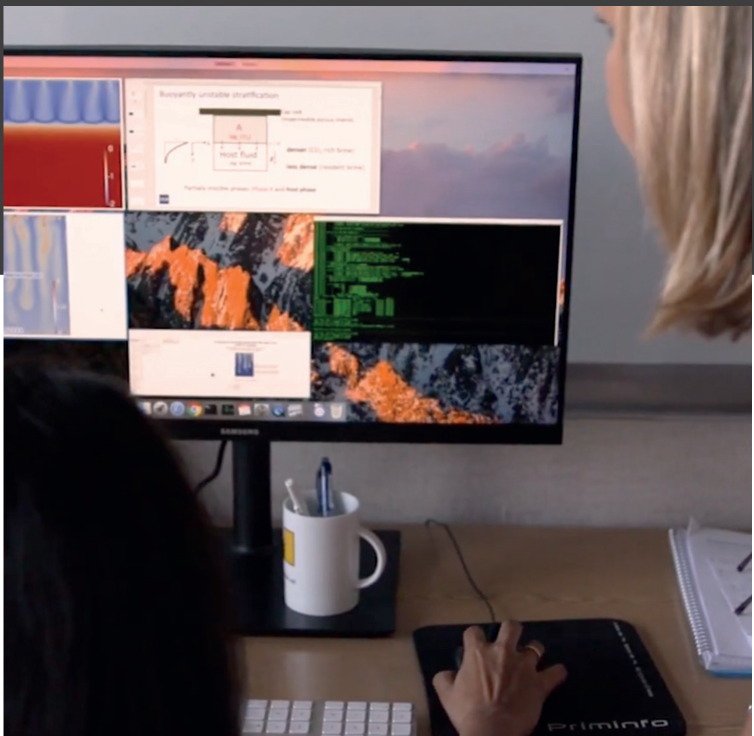
On the humane level, joining tens of other students, from all around the world, starting their voyage in sometimes remote, sometimes connected, topics of theoretical physics has also been a pleasure, and a great way to get acquainted with the people that I will undoubtedly meet again in conferences, such as the Belgian Joint Seminars held weekly in Brussels.

From Brussels to Paris, to Geneva, one gets a once-in-a-lifetime occasion to deepen their understanding of the mysteries of nature in historic locations, surrounded by young and brilliant minds. I am most grateful for this opportunity offered by the Solvay Institutes, and without a shadow of a doubt, do recommend any future PhD candidate to partake in this unique event.



05

RESEARCH AND RESEARCHERS



RESEARCH ON GRAVITATION, STRING THEORY & COSMOLOGY

Research on Gravitation, String Theory and Cosmology

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

Researchers

Faculty Members

Riccardo Argurio (ULB)

Vijay Balasubramanian (VUB)

Glenn Barnich (ULB)

Vladimir Belinski (ICRAN, Italy)

Chris Blair (VUB)

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)

Marc Henneaux (ULB)

Axel Kleinschmidt (Max-Planck-Institute, Potsdam, Germany)

Laura Lopez Honorez (VUB)

Alberto Mariotti (VUB)

Mairi Sakellariadou (VUB)

Alexander Sevrin (VUB)

Dan Thompson (VUB)

Postdoctoral Researchers

Jeremias Aguilera-Damia (ULB)

Alexandros Spyridon Arvanitakis (VUB)

Simone Blasi (VUB)

Sumyadeep Chaudhuri (ULB)

Luca Ciambelli (ULB)

Camille Eloy (VUB)

Oscar Fuentealba (ULB)

Eduardo García-Valdecasas (ULB)

Marius Gerbershagen (VUB)

Juan Hernandez (VUB)

Ondra Hulik (VUB)

Mikhael Khramtsov (VUB)

Javier Matulich (ULB)

Turmoli Neogi (ULB)

Romain Pascalie (ULB)

Alba Romero (VUB)

Jakob Salzer (ULB)

Ali Seraj (ULB)

Luigi Tizzano (ULB)

Miguel Vanvlasselaer (VUB)

Alejandro Vilar López (ULB)

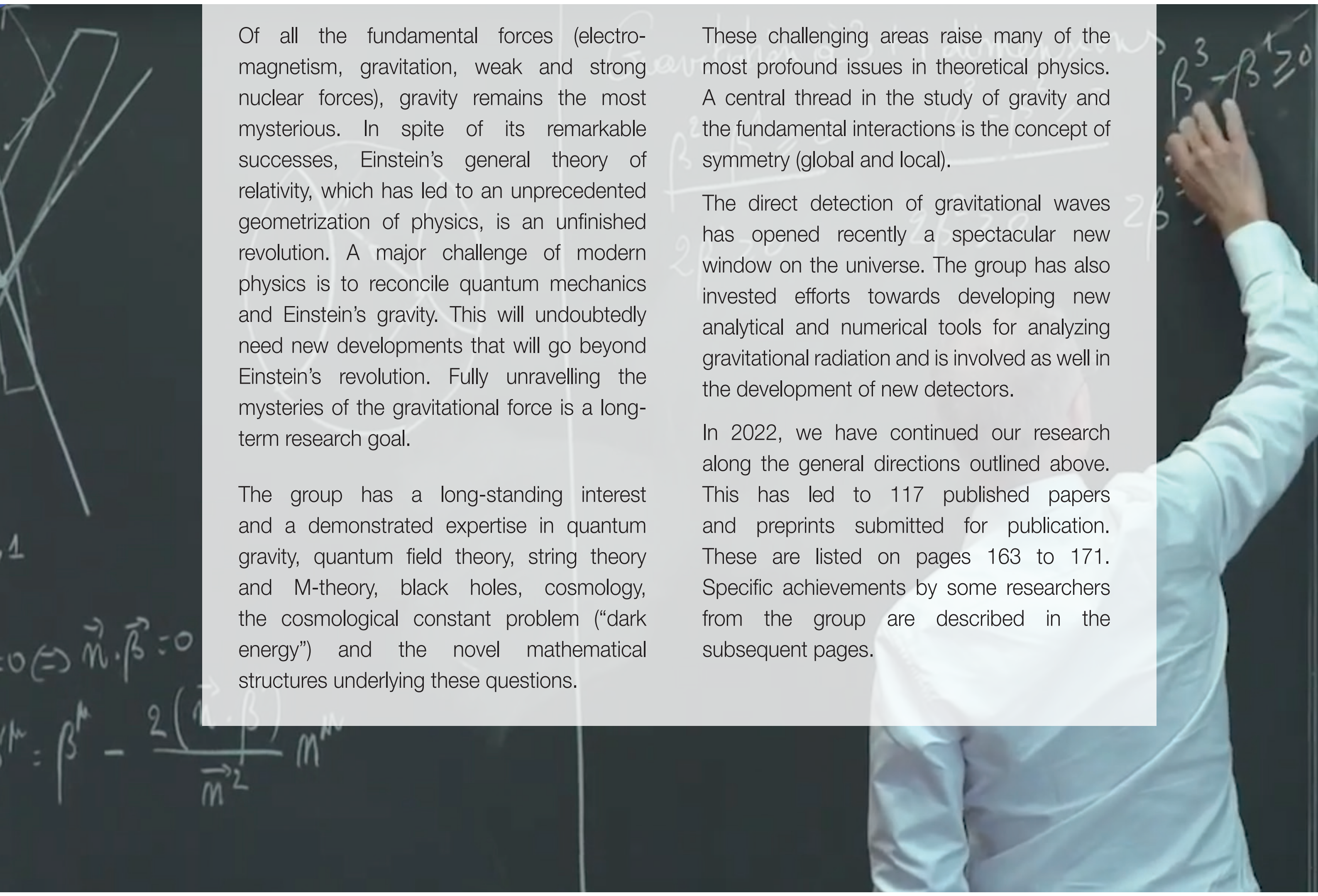
Raphaela Wutte (ULB)

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.

Doctoral Researchers

- Ankit Aggarwal (ULB)
- Martin Bonte (ULB)
- Adrien Druart (ULB)
- Hannah Duval (VUB)
- José Figueroa Silva (ULB)
- Dima Fontaine (ULB)
- Philip Hacker (VUB)
- Dongming He (VUB)
- Sam Junius (VUB)
- Sahaja Kanuri (ULB)
- Maria Knysh (VUB)
- Lorenzo Küchler (ULB)
- Ludovico Machet (ULB)
- Louan Mol (ULB)
- Daniel Naegels (ULB)
- Xander Nagels (VUB)
- Gabriele Pascuzzi (VUB)
- Maxim Pavlov (VUB)
- Aäron Rase (VUB)
- Antoine Somerhausen (ULB)
- Colin Sterckx (ULB)
- Wen-di Tan (ULB)
- Kevin Turbang (VUB)
- Romain Vandepopeliere (ULB)
- Quentin Vandermiers (ULB)
- Sofia Zhidkova (VUB)

Research Summary



Of all the fundamental forces (electro-magnetism, 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).

The direct detection of gravitational waves has opened recently 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 2022, we have continued our research along the general directions outlined above. This has led to 117 published papers and preprints submitted for publication. These are listed on pages 163 to 171. Specific achievements by some researchers from the group are described in the subsequent pages.

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

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

2022 Marina Solvay Fellow

Jakob Salzer I ULB

Jakob Salzer got his PhD degree at the “Technische Universität” in Vienna (Austria) in 2018. After two postdoctoral stays at the University of Barcelona (Spain) and the University of Harvard (USA), he joined ULB in the group of the Director. His research deals with a wide range of questions related to the Einstein theory of gravity: asymptotic symmetries and infrared theorems, infinite-dimensional algebras, lower dimensional models, non-relativistic modifications of Einstein’s theory.

He held the Marina Solvay fellowship in 2022.

Running to stay in the same place: Carrollian symmetries.

According to Philip Anderson, it is only slightly overstating the case to say that physics is the study of symmetry. The study of symmetries goes back to the very beginnings of modern physics, when Galilei observed that the description of physical systems is *invariant* under certain *transformations*. Most physical systems behave (approximately) in the same way when moved to a different place, studied at a different time or in a uniformly moving laboratory. For instance, we perceive no change in the laws of physics when we sit on board of a (non-accelerating) train. We conclude that the laws of physics of our everyday life possess a certain *symmetry* known as the *Galilei transformations*. One can understand these transformations as the symmetries of a world in which every observer measures the same time, i.e., time is absolute.

While this description is completely adequate for our everyday life, it became clear that this notion of absolute time is just an approximation. The theory of Special Relativity led to a unification of space and time into a four-dimensional entity, called Minkowski space, that is invariant under the *Poincaré transformations*. In contrast to Galilean transformations, Poincaré symmetries allow to transform space and time into each other. The effects of special relativity, that run against our intuition from everyday life and originate in this mixing of space and time, become important only at velocities that are comparable to the speed of light. Put differently, Galilean symmetries with its absolute notion of time can be regarded as the limit of Poincaré symmetries when all velocities are infinitesimally small compared to the speed of light. Since the speed of light sets the upper bound on causal relations, in a Galilean world every point can influence any other point instantaneously.

Already at this point one may wonder whether one can also take the opposite limit, that is can we consider a world in which the speed of light is zero. Inverting the logic of the above discussion, one would expect a world in which space is absolute and no point can causally influence any other point. In other words, one considers an *ultrarelativistic* world in which every point moves with the speed of light. A space with these properties is called *Carrollian space* and the respective symmetries are called *Carrollian transformations*. It is amusing to note that the name "Carrollian" derives from a quote in the book "Through the Looking-Glass" by Lewis Carroll, the pen name of the mathematician Charles Dodgson *(cf. Fig. 1)*. It might seem that Carrollian spaces are of little physical relevance and should be regarded as a mathematical curiosity. However, it turns out that these spaces are in fact ubiquitous in General Relativity.

Figure 1: "Now, here, you see, it takes all the running you can do, to keep in the same place."
Illustration by John Tenniel.

The asymptotic structure of flat spacetimes.

In the above we saw that the symmetries of physical systems derive from the symmetries of its non-dynamical background, i.e., a fixed spacetime the theory is put on. However, if one considers gravity, spacetime itself becomes dynamical. Consequently, the definition of a symmetry for a gravitational system becomes quite subtle. Nevertheless, in most physical problems one is not interested in arbitrary spacetimes but just in spacetimes that obey certain *asymptotic conditions*, i.e., one considers only spacetimes that look very similar once one moves sufficiently far away from all matter sources. The symmetries preserving this asymptotic form are called the *asymptotic symmetries* of the gravitational theory. Interestingly, one usually encounters infinitely many symmetries in this way. An important example of this set-up is the study of spacetimes that describe the gravitational field of isolated sources in a universe with zero cosmological constant. The asymptotic symmetries of this set of spacetimes is the famous, infinite-dimensional Bondi–van der Burg-Metzner-Sachs (BMS) group.

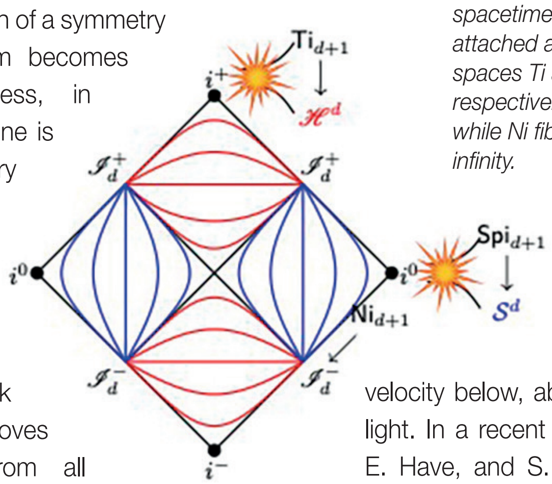


Figure 2:
The Penrose diagram of Minkowski spacetime M with its hyperbolic slicing and attached asymptotic regions. The carrollian spaces Ti and Spi arise as the blow-ups of, respectively, timelike and spacelike infinities, while Ni fibers over J describing lightlike infinity.

Interestingly, Carrollian spaces provide another point of view on the above. In order to discuss the asymptotic regions of a spacetime and their symmetries, it is often useful to consider a *compactification* of the spacetime. In the same way that one can turn an infinitely-extended two-dimensional plane into a sphere by adding a single point "at infinity", one can add certain *asymptotic regions* to asymptotically flat spacetimes. The form of these asymptotic regions depends on whether one approaches infinity on a time-, space-, or lightlike trajectory, i.e., roughly with a velocity below, above or exactly at the speed of light. In a recent work with J. Figueroa-O'Farrill, E. Have, and S. Prohazka we showed that all of the asymptotic regions of asymptotically flat spacetimes can be understood as specific Carrollian spaces; *see Fig. 2*. The symmetries of these Carrollian spaces can be regarded as the asymptotic symmetries of asymptotically flat spacetimes. In particular, the infinite BMS symmetries arise as *conformal symmetries* of the carrollian space at light-like infinity.

In a related work with the same authors we also studied gravitational theories that are inherently Carrollian, i.e., that can be regarded as an ultrarelativistic limit of General Relativity. While the construction of such theories is of interest in itself, it was shown by Marc Henneaux that close to gravitational singularities, as they appear at the beginning of the universe, gravity becomes essentially Carrollian or ultrarelativistic. Together with Oscar Fuentealba, M. Henneaux, and P. Salgado-Rebolledo we also constructed an appropriate set of asymptotic conditions for a particular example of these ultrarelativistic gravitational theories and discovered a certain ultrarelativistic version of the BMS group as asymptotic symmetry group for these Carrollian spacetimes.

Towards flat space holography.

Of the two pillars of modern physics, quantum mechanics and gravity, we have discussed so far only the latter. A unification of quantum theory and gravity in a theory of quantum gravity has been one of the major challenges of theoretical physics in the past hundred years. For gravity in a universe with negative cosmological constant, the so-called *Anti-de Sitter/Conformal Field Theory* (AdS/CFT) duality allows to map problems in quantum gravity to computations in a lower-dimensional non-gravitational quantum field theory that is much better understood. One therefore argues that this set-up provides a holographic definition of quantum gravity in asymptotically AdS spaces. However, much less is understood about the holographic principle and quantum aspects of gravity in spacetimes other than AdS, in particular in asymptotically flat (AF) spacetimes, that provide a much better approximation to our universe with its positive, yet tiny, cosmological constant.

The subject of flat space holography has grown into a very active area of research in the past decade. Two main approaches have been proposed in recent times: *celestial holography* and *conformal carrollian field theories*. The former approach is based on the following simple picture. In a typical scattering event, one considers a set of particles, that may include gravitons if one is interested in quantum gravitational processes, coming in from infinity, interacting for a relatively short time, and then moving again outward to infinity. The directions from which particles enter or leave the scattering process can be labelled by points on a sphere, the celestial sphere. The goal of the celestial holography program is then to describe scattering events in a four-dimensional asymptotically flat spacetime in terms of a two-dimensional theory on this *celestial sphere*.

Due to the above-mentioned infinitely many asymptotic symmetries of asymptotically flat spacetimes, one expects this theory to be highly constrained by symmetries. Most of the present results on celestial holography concern only scattering processes that do not take into account quantum effects. Nevertheless, together with Adam Ball, Sruthi Narayanan, and Andrew Strominger, we showed that quantum effects on celestial holography can be studied in a certain simplified version of General Relativity called *self-dual gravity*.

In the other approach to flat space holography, one instead aims to define a holographic dual on one of the above-mentioned carrollian asymptotic regions of asymptotically flat spacetimes. Again due to the analysis of asymptotic symmetries in flat spacetimes, one expects the dual theory to be a so-called *conformal carrollian theory*. These theories are still not well-understood. In a recent paper, I was able to obtain a better understanding of these theories by studying the form of simple correlation functions, that constitute basic building blocks for any physical theory.

The question which of these two approaches will lead to a simple realization of flat space holography is far from being decided. Very likely, some other, new ideas will be needed in this endeavour. However, it is quite clear that symmetries will continue to be guiding stars on this journey.

Research interests and Achievements of some other members

Raphaela Wutte | Postdoctoral researcher I ULB

On May 12th, 2022 the Event Horizon Telescope collaboration announced the first image of the supermassive black hole in the middle of our galaxy. It is the second image of a black hole, the first-ever image of the supermassive black hole in the Virgo constellation having only been announced in April 2019. These outstanding experimental results come mere years after the LIGO and VIRGO collaboration recorded gravitational waves sent out by the merger of two black holes in September 2015. General relativity has surpassed all our expectations, it has passed every experimental check, the images of black holes and the detection of gravitational waves being only the latest results in a very long list.

While the classical theory of gravitation, general relativity, has celebrated many successes in recent years, the problem of combining general relativity with quantum mechanics into a theory of quantum gravity is unsolved as experimental guidance towards a solution is currently out of reach. Not knowing which features the theory of quantum gravity, which describes our universe, exhibits, one is forced to appeal to purely theoretical guidelines such as consistency with the semiclassical approximation and internal mathematical consistency. A guiding principle in the search for such theories is the existence of properties that are preserved in the quantum theory. Amongst these properties are conservation laws and associated conserved quantities. A quantity of particular importance is the energy of the gravitational field.

In general relativity, unlike in other field theories, the very definition of energy is a delicate issue. In particular, there does not exist a meaningful local energy expression – an energy per point – of the gravitational field. However, despite the absence of a local energy expression, there exists an appropriate and meaningful expression for the total energy of an isolated system – a system far away from gravitational sources such as matter. Although no physical system can ever truly be regarded as isolated, for many situations of interest this is a good approximation. To give an example, imagine you would like to study the structure of a star. It seems reasonable to ignore the influence of distant matter and small cosmological constant and treat the star as if it were situated in a universe which becomes flat at large distances, i.e. has vanishing gravitational field in the far away region. Spacetimes with such behavior are referred to as asymptotically flat spacetimes. When the cosmological constant is negative, to study the analog situation, one considers spacetimes which approach Anti-de Sitter (AdS) spacetime at large distances. These spacetimes in turn are referred to as asymptotically AdS spacetimes.

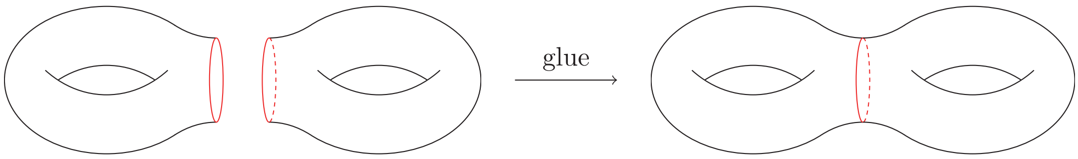


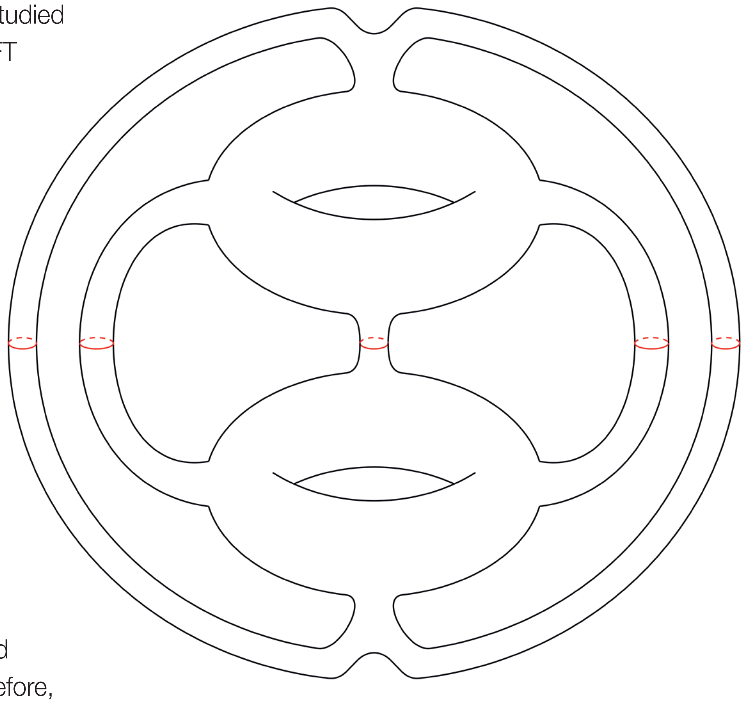
Figure 1: Gluing two tori 1

While the cosmological constant of our universe is very small and positive, asymptotically AdS spacetimes are ubiquitous in nowadays theoretical high-energy physics. They have received a surge of attention due to the so-called Anti-de Sitter/conformal field theory (AdS/CFT) correspondence, which conjectures that quantum gravity on d–dimensional asymptotically AdS spacetimes is equivalent to a $(d-1)$–dimensional quantum field theory with conformal invariance. To obtain a better grasp of the AdS/CFT correspondence, it is crucial to have absolute control over the classical properties of asymptotically AdS spacetimes. However, to this day, many classical features are not fully understood. In particular, it is not known in general whether the energy of asymptotically AdS spacetimes is bounded from below. As these spacetimes are the main object of study within the AdS/CFT correspondence, it is clear that bounds on the energy for such spaces will have potential implications for the correspondence. Indeed, boundedness of mass for negative cosmological constant is often required within the framework of the AdS/CFT correspondence. On the one hand, positive energy theorems in general relativity for negative cosmological constant can be used to restrict the energy spectrum in a conformal field theory and make predictions regarding aspects of the AdS/CFT correspondence.

On the other hand, the duality may be used to form new conjectures regarding the boundedness of energy in general relativity. One example of this is the Horowitz-Myers conjecture which has received much attention over the last twenty years, both in the AdS/CFT, as well as in the mathematical general relativity community.
In 1998 Horowitz and Myers studied implications of the AdS/CFT correspondence.
They found a novel solution to general relativity, the so-called Horowitz-Myers soliton, and computed that the lowest energy in the conformal field theory precisely matches the negative energy of the Horowitz-Myers soliton. Given that the energy in the conformal field theory is bounded from below, also the energy in the dual gravitational setup should be bounded from below. Therefore, Horowitz and Myers conjectured that a new positive energy theorem in general relativity with negative cosmological constant must hold. While various results in favour of the conjecture exist, the conjecture remains unproven to this day and may be viewed as – citing the original paper – "a highly nontrivial prediction of the AdS/CFT correspondence".

My research revolves around understanding the notion of energy for general relativity with a negative cosmological constant. How is the energy defined? Is the energy bounded from below? Can the energy be lower than the energy of local Anti-de Sitter spacetime? Together with Piotr T. Chruściel and Erwann Delay, we proved existence of certain initial data sets for general relativity with particular boundary geometry and negative mass.

Figure 2: A genus-6 geometry



This shows that if the energy is bounded from below, then in this case the bound must be negative – a result which was previously unknown.

To prove this result we used a certain gluing construction, which was developed by my collaborators in a previous paper. We glued two Horowitz–Myers solitons, which both have negative mass individually and toroidal geometry at infinity, together to obtain an initial data set with genus-two (two holes) geometry at infinity and negative mass, *see Fig. 1*. This construction can be iterated to obtain initial data sets with higher-genus geometry at infinity and negative mass, *see Fig. 2*.

Another line of research I am currently pursuing concerns itself with developing a complete description of the geometry and asymptotic structure of so-called warped spacetimes. Warped spacetimes appear in the near-horizon region of extremal astrophysical black holes and have been used for various considerations by the AdS/CFT community. Currently, with Stéphane Detournay, Philippe Spindel and Pierre Beliavsky, we are investigating the structure of so-called warped AdS spacetimes. These spacetimes may be obtained by deforming Anti-de Sitter spacetime in an appropriate manner. Previous studies about related spacetimes, so-called warped flat spacetimes, suggested that these spacetimes do not admit a conformal completion, a standard mathematical procedure to define the asymptotic behavior of the gravitational field. For this reason, we are currently using and developing novel methods to study the asymptotic behavior of the gravitational field for the specific example of warped AdS spacetimes. Clarifying these issues will shed further light on the geometry of extremal astrophysical black holes.

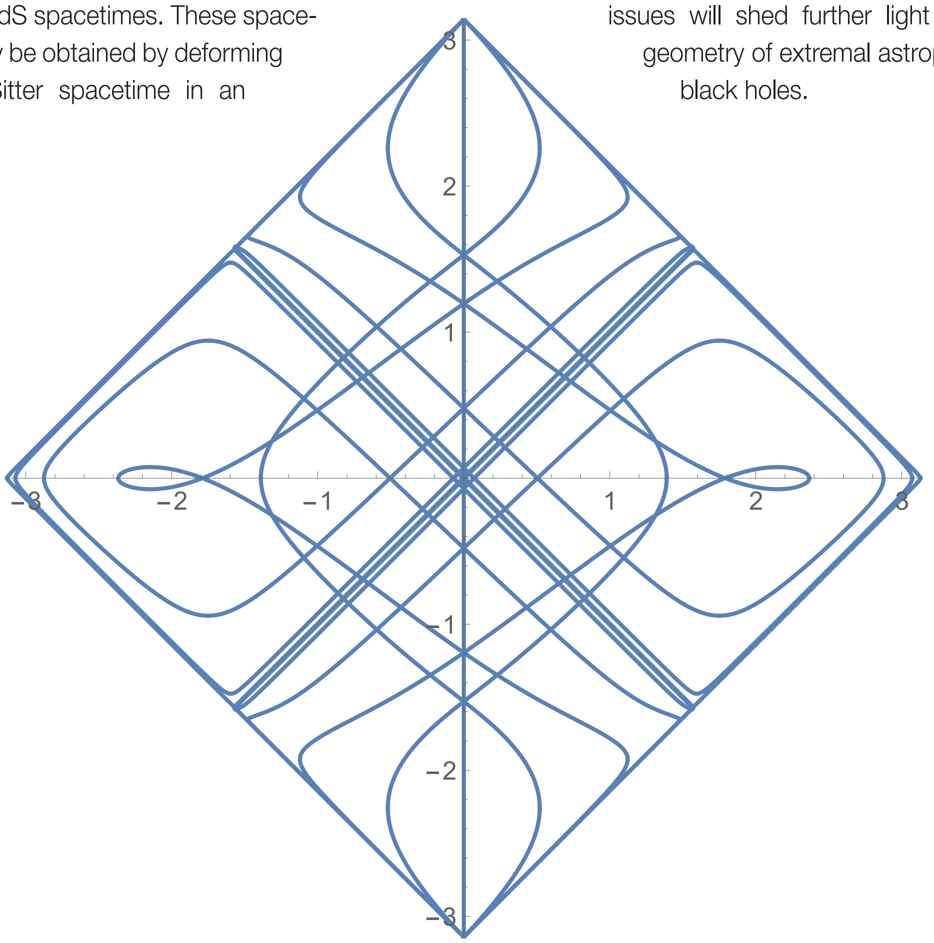


Figure 3: A visualization of coordinate lines in warped flat space

Juan Hernandez | Postdoctoral researcher I VUB

In the last few decades, an influx of concepts from quantum information theory has led to exciting new insights into quantum gravity, especially in the framework of gauge/gravity duality, a realization of the holographic principle. A lot of the lessons we have learned from these new tools are summarized in the motto that 'entanglement builds spacetime'.

The holographic principle states that a theory of quantum gravity is dual (or equivalent) to a lower dimensional quantum theory, usually considered to be at the boundary of the quantum gravity region. As a consequence, everything in our universe can be thought of as an exotic lower dimensional quantum mechanical theory living somewhere far away at the edge of the universe. The two sides of this duality (gravity theory and quantum mechanical theory) are related by a holographic dictionary, which translates quantities from one theory to the other.

One of the most useful tools borrowed from quantum information theory so far has been (holographic) entanglement entropy, a quantity that determines how much entanglement (or correlation) there is between a subset of degrees of freedom in a system and the rest of the system. By analyzing entanglement entropy in the setting of holography, it was argued that quantum entanglement is essential for the emergence of classical spacetime geometry in the bulk. Further, it was shown that the linearized Einstein equations in the bulk emerge as a consequence of the 'first law' of entanglement entropy. More insights into the emergence of spacetime comes from the entanglement wedge reconstruction protocols, where it was shown that bulk operators can be reconstructed in the boundary – in parallel to quantum error correcting codes. Considered in the opposite direction, those results show that a boundary subregion contains the information needed to reconstruct a certain bulk gravitational

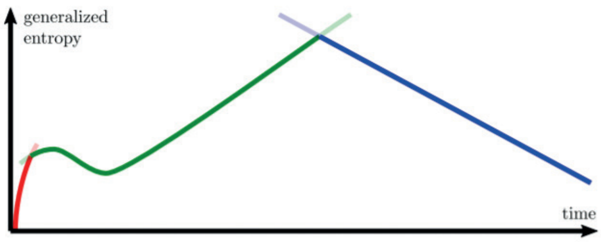


Fig. 1 Entanglement entropy of an evaporating two dimensional black hole. Recently discovered corrections lead to the phase in blue in which entanglement entropy decreases, solving the information paradox in that setting.

subregion, called its entanglement wedge. This is a direct example of spacetime and gravitational dynamics emerging from a non-gravitational system and its entanglement structure. In turn, attempts at arriving at a better understanding of quantum gravity have led to refinements of our understanding of (holographic) entanglement entropy. Examples include the addition of quantum corrections to holographic entanglement entropy and the island rule for gravitational theories. This improved understanding of entanglement entropy has finally led to the resolution of the black hole information paradox (an open problem that had puzzled theoretical physicists for several decades), at least in some simple, lower dimensional gravity theories.

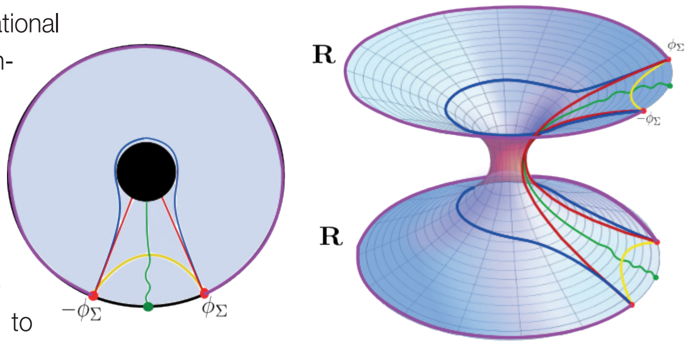


Fig. 2 In the holographic dictionary, the entanglement entropy of a boundary subregion (in violet) is given by the length of geodesics connecting its boundaries. In the example above, there are three competing geodesics shown in yellow, blue and red.

Studying aspects of entanglement entropy in holography is one of my main research interests. With collaborators at VUB (Vijay Balasubramanian, Ben Craps, Mikhail Khramtsov and Maria Knysh) we are working on extending previous results by Vijay and collaborators in which they provide a semiclassical description of the black hole microstates in general relativity. Their results showed that for a countably infinite basis of states, exponentially small but universal overlaps in the states imply that they span a finite dimensional Hilbert space with dimension in agreement with the black hole entropy. We are now interested in expanding these results for a basis of states which allow the black hole to grow or evaporate, by including states with infalling or outgoing shells of matter and seeing how the dimensionality of the resulting Hilbert space gets modified. We expect that the dimension of the Hilbert space will change in relation to the change in black hole mass (and entropy) as one adds or removes these shells of matter.

In another project with collaborators at KU Leuven (Sergio Aguilar-Gutierrez) and VUB (Mikhail Khramtsov and Maria Knysh), we intend to further explore the fine grained structure of information in various black hole models in which the information paradox can be studied. In these models, it was already shown that if one takes all of the Hawking radiation, information about the interior of the black hole can be deciphered. We aim to look at how smaller portions of the Hawking radiation can contain enough information to decipher the black hole interior, and in so doing discover something about how the information is transferred during the black hole evaporation process.

Another exciting concept imported from quantum information theory has been quantum circuit complexity, and its conjectured holographic duals. The motivation behind studying complexity is the need to have well defined quantities on both sides of the holographic dictionary that thermalize at very late times, in contrast with entanglement entropy. The strongest arguments for entanglement building spacetime and gravitational dynamics are restricted to the entanglement wedge of boundary regions. This is clear from the entanglement wedge reconstruction picture described above, as well as the fact that the gravitational dynamics have been shown to emerge from entanglement entropy thermodynamics. However, there are models where certain regions of the bulk spacetime are inaccessible to the aforementioned entanglement wedges. In contrast, the proposed holographic duals to circuit complexity are able to access these regions deep in the bulk. For this reason, it is interesting to attempt to establish a well defined formalism to deal with circuit complexity for arbitrary quantum field theories. There has been some recent progress in this area, but there is still much to learn from this direction. The hope is that by learning some general rules for complexity in quantum field theory, a similar picture of "geometry from entanglement" can arise from complexity considerations.

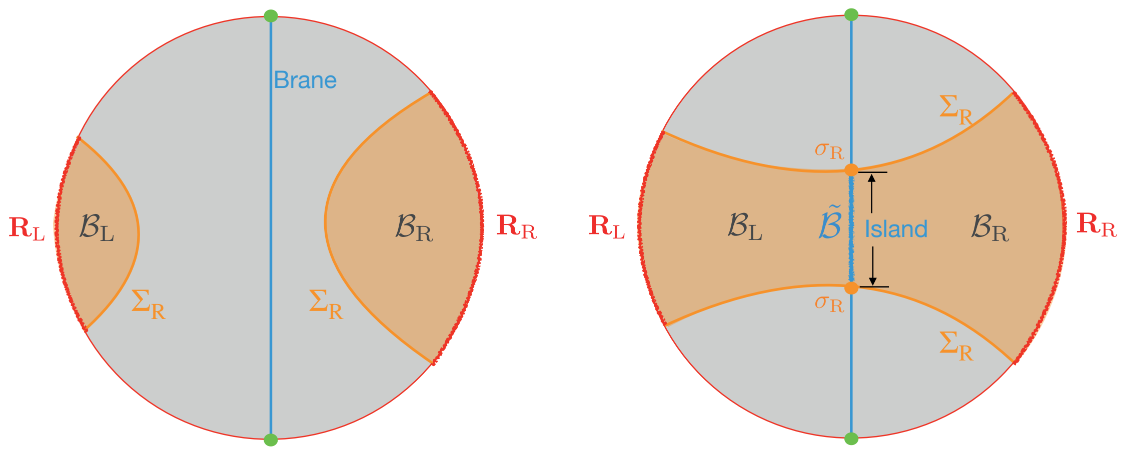


Fig. 3 The complexity of a subregion (in red) is conjectured to be equal to geometric quantities associated to the entanglement wedge (in orange). The size of the entanglement wedge is discontinuous during phase transitions such as the one above. This implies a discontinuity in the subregion complexity.

In a project with colleagues from École Polytechnique (Ashish Shukla) and KU Leuven (Sergio Aguilar-Gutierrez) and VUB (Ben Craps, Mikhail Khramtsov and Maria Knysh), we are exploring the consequences of an upper bound on complexity growth - known as the Lloyd bound - on the types of systems that can be sustained in a particular surface inside the gravitational theory, called an end-of-the-world brane. End-of-the-world branes are commonly used features that can be added to holographic models to describe systems with boundaries, or more recently to model black hole microstates, something that still remains to be understood.

An open question in the holographic complexity literature concerns the proper definition of subregion complexity on both sides of the holographic duality. Some proposals have been suggested for subsystem complexity both in the quantum mechanical side as well as in the gravity side. Moreover, there is a universal discontinuity in holographic subregion complexity as certain well known phase transitions occur. However, in the quantum mechanical definition of subregion complexity it is less clear how such a discontinuity would arise. This is a question I am addressing with collaborators at VUB (Marius Gerbershagen, Mikhail Khramtsov and Maria Knysh) by expanding a framework in which both definitions of complexity can be related in a controlled way.

Alba Romero-Rodríguez | Postdoctoral researcher I VUB

The current description of the evolution of our Universe (cosmology) and of the astrophysical objects populating it is based on the Einstein theory of General Relativity (GR) which, among others, predicts the existence of gravitational waves (GWs). These are deformations of space-time that travel at the speed of light. Usually, the sources of GWs are categorised in four groups, compact binary coalescences (CBCs), continuous waves (CW), bursts and sources of the gravitational wave background (GWB). Their characteristic strain amplitudes, h, vary by orders of magnitude from source to source, with signals as loud as CBCs and as faint as the GWB.

The detection of GWs relies on the effect they have on the proper distance between free falling particles (particles exempt from the effect of any force). For a set of free falling masses separated by a distance L, a GW characterised by a strain amplitude h will modify the proper distance between the particles by $\Delta L \sim hL$. Assuming $L \sim 1$ m and $h \sim 10^{-21}$, in order to detect the effect of the GWs, a detector sensitive to variations of space-time of the order of $\Delta L \sim 10^{-21}$ m is required, which is the case of an improved version of a Michelson interferometer (IFO). The first GW detection was made on September 14th 2015 by the LIGO IFOs. After a thorough analysis, it could be concluded that the source of these gravitational waves was the merger of a binary of black holes (BBHs), named after its detection date, GW150914. To this date, roughly 100 detections of CBCs have been claimed by the network of two LIGO IFOs and the Virgo IFO. These detections have been possible thanks to the increased sensitivity of the detectors, the result of several upgrades the IFOs have undergone. At this point we are about to begin the fourth observational run (O4), planned to last for at least 1 year.

The sensitivity of the current IFOs is highly compromised by different sources of noise which can be classified according to different criteria. The first criterion is stationarity. If a noise's statistical properties do not vary much over time, the noise is said to be stationary. Non-stationary noise is difficult to characterise and subtract, but new methods have been developed in recent years. Another criterion by which to characterise noise is its origin. There are noises intrinsic to the detector and noises introduced in the system or amplified by control loops used to maintain the IFO in a correct working point.

Another type are the technical noises, coming from the implementation of the IFO, such as power noises. There are also many environmental (ENV) noises, such as magnetic fields that couple to the detector or scattered light (light from the laser that does not follow the designed path in the optical system). I have personally worked on the detection of ENV noise sources and their mitigation. I mainly contributed to the development of a novel instrument capable of intercepting and absorbing scattered light (SL), known as baffle, which will also help in further understanding the source of the SL thanks to the photodiodes installed on its surface. However, not all the noise sources can be mitigated or understood, so data analysis techniques have been developed to "clean" the data and not bias the results of the analysis.

One of these techniques is based on a machine learning algorithm that detects and subtracts non-linear noise. I am currently assessing the effect this subtraction method can have in the search for an isotropic GWB, which is my main field of research and is described in what follows.

Gravitational waves are not just important probes of massive asymmetric astrophysical bodies, as mentioned above, but they can also probe models Beyond the Standard Model (BSM) in the early Universe, up to the limits of the Planck era.

These cosmological models, alongside the contribution from a large number of unresolved astrophysical objects such as binary neutron stars and BBHs, are known to source the GWB already introduced above. The detection of this background would provide essential information about the very early Universe, such as inflation, cosmic strings, domain walls and first order phase transitions (FOPTs), among others. However, its amplitude is various orders of magnitude below that of gravitational waves coming from mergers of BBHs and also, its random nature could be confused with noise. Hence, a search method consisting of cross-correlating data from different interferometers is performed assuming noise between interferometers is uncorrelated, increasing the effective sensitivity to the detection of the background. In the last year we have developed a user-friendly Python-based cross-correlation code that has just been made public and has become the official LIGO-Virgo-KAGRA isotropic GWB search pipeline: pygwb.

Even though the sensitivity of the current interferometers is still not enough to detect the GWB, it is expected to be done by the proposed new generation of GW detectors (3G detectors), which will hopefully start operating around the 2040s. This 3G network will be composed by the European Einstein Telescope, the US funded space based LISA and the ground based Cosmic Explorer. Nevertheless, despite not being able to make a detection with our current 2G detectors, the search for a GWB can still have implications in the population of CBCs and on different cosmological sources. We have been able to constraint the merger rate of CBCs at large redshifts, which direct detections of CBCs cannot do. Furthermore, by performing Bayesian inference analysis we have been able to constraint regions in parameter space of models BSM that could not be probed by other means, such as with particle accelerators. For instance, we have been able to constraint FOPTs taking place at very large scales above 10^7 GeV, which is unreachable by colliders.

However, even once a detection is made, the primordial background will remain hidden by the contribution of unresolved CBCs to the background. With the increased sensitivity of the 3G gravitational-wave detectors, it will be possible to detect and resolve almost all of the BBH mergers, even the ones at high redshifts. This will allow us to have a further understanding of the population of CBCs and hence subtract most of the astrophysical foreground. Several techniques have been proposed to do so. Nevertheless, one of the biggest challenges in some of these methods is performing parameter estimation (PE) over the huge amount of signals, of the order of 10^4 that are expected to be detected with 3G detectors. Some new PE methods have been proposed, and their objective is generating mock posteriors for all the resolved sources, without actually having to run a full Bayesian inference PE over each event. I have started working with one of these new methods with the aim of calibrating it and eventually using it to help subtract the astrophysical foreground of the GWB.

To sum up, the detection of GWs allows us to study the Universe and its content in a novel way that relies on very accurate and sensitive interferometers. The continuous upgrades seek to mitigate sources of noise, which will progressively allow us to increase the sensitivity. The future generation of GW detectors will grant us access to part of the history of the Universe never “seen” before, allowing us to probe cosmological models such as inflation or first order phase transitions.

Jeremias Aguilera-Damia | Postdoctoral researcher I ULB

Since its advent more than 100 years ago, Quantum Mechanics has been proven to be one of the most accurate descriptions of Nature. A more elaborate version of Quantum Mechanics, embodied by Quantum Field Theory (QFT), has been target of impressive developments in the last century, consequently playing a central role in our modern conception of physics. Even if the ultimate microscopic theory describing the dynamics at the Planck scale is still out of reach, there is no doubt that Quantum Field Theory is the appropriate framework to describe physical processes taking place at energies ranging from well below the electronic scale up to the largest energy achieved in current colliders. Remarkable examples of its success are, for instance, the unprecedented accuracy for the prediction of the electron gyromagnetic moment, the effective description of macroscopic systems and phase transitions and, needless to say, the incommensurable achievements of the celebrated Standard Model of Fundamental Interactions.

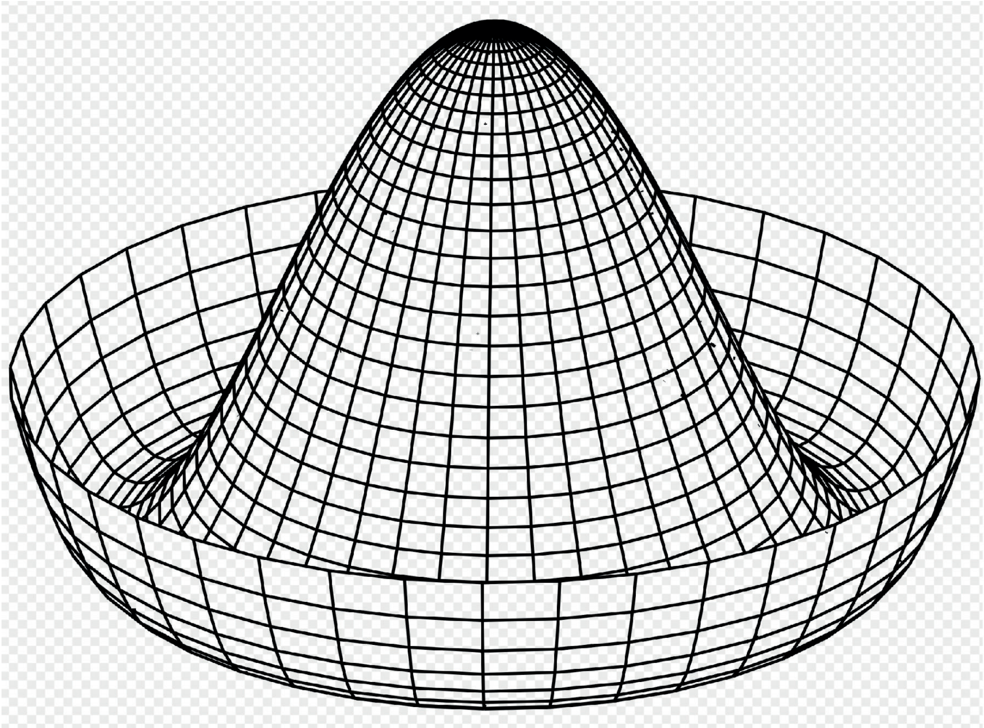
This high rate of success may be thought to be rooted in several added values of QFT. Two prominent and complementary features are predictability and universality. The former states that a "good" microscopic description, often referred to as a renormalizable QFT, only depends on a limited (and usually small) amount of phenomenological parameters which need to be adjusted to experimental data. With this mild external input, one is in principle capable to extract valuable phenomenological predictions which may be contrasted with further experiments. On the other hand, universality stems from the fact that the relevant dynamics of a large set of manifestly distinct microscopic systems is usually captured by a smaller set of theories as the reference energies are taken to zero.

Remarkably, these two notable attributes have been put on equal footing under a single revolutionary mathematical framework envisioned by K. Wilson, the so called Renormalization Group (RG) flow. The main idea behind the power of the RG is that most of the detailed microscopic structure of a given physical system has gradually lower impact on the dynamical processes occurring at lower energies. As such, its effective low energy physics is accounted for by a QFT describing a simpler universal sector, shared by a large variety of systems. Moreover, this dynamical "mutation" suffered by a given physical system along the RG flow is precisely quantified in terms of the RG equations. All in all, this framework traced a solid bridge between theory and observation.

Nevertheless, there are still very important longstanding problems calling for a resolution. Indeed, an immediate obstruction to achieve full analytical understanding of the processes undertaken along the RG flow is that most physical systems of interest become strongly coupled at low energies (at least in four or lower spacetime dimensions). This difficulty lies at the core of many currently open questions: How are the mechanisms of confinement in Quantum Chromodynamics, which underlies the formation of stable baryons, like protons and neutrons? What are the possible realizations of critical phenomena? What is the effective description of the dynamics taking place in strongly coupled electronic systems, like High Critical Temperature Superconductors? And many more. As a consequence, in the last decades, the community experienced an exciting development of a large variety non-perturbative techniques in QFT, tailored to appropriately deal with strong coupling dynamics. It is within this general program that most of my recent research activities might encompassed, as I will describe now.

Symmetries and Dualities in QFT

In general, symmetries in physics are associated to conservation laws, by means of which several global quantities associated to a particular system, like the energy or the total electric charge, are preserved. Furthermore, symmetries are known to be an either exactly or approximately realized in Nature and, as such, impose strong constraints on the possible dynamical processes kicking in along the RG flow. At low energies, symmetries may be implemented in several ways and, moreover, there might be emergent symmetries as a consequence of the RG flow. This paradigm dates back to L. Landau, who proposed that infrared phases of matter should be classified in terms of how they realize the global symmetries. In addition, a quantum system may fail to be exactly symmetric. However, as originally observed by G. 't Hooft, this failure, also called anomaly, is highly constrained by global aspects of the theory and, what is more, it remains invariant across the RG. Accordingly, symmetries stand as a key instrument to open a window into the non-perturbative structure of QFT.



In the last few years, there has been intense research on this field, inspired by the seminal work of D. Gaiotto, A. Kapustin, N. Seiberg and B. Willet. In the modern perspective, all aspects related to symmetries (including anomalies), are captured by a topological sector in QFT. Being topological, this sector is transparent to local dynamical processes, hence remaining invariant at any step of the RG flow. Remarkably, this framework opened up the possibility of detecting novel forms of global symmetries. Besides the ordinary ones that usually act on particles, the concept of higher form symmetry incorporated symmetries that are naturally realized on extended objects. Last but not least, this extended notion of global symmetry allows to include more exotic structures lying beyond group theory, hence called non-invertible symmetries. Technically, the latter are described by Category Theory, a pushing topic in both physics and mathematics.

Within this field, and in collaboration with R. Argurio (ULB) and L. Tizzano (ULB), we published an article exploring the incidence of some intricated symmetry structures, including both higher groups and non-invertible symmetries, occurring in certain gauge theories in three spacetime dimensions. In addition, with R. Argurio (ULB) and E. Garcia-Valdecasas (ULB), we carried on a project studying a particular set of non-invertible symmetries arising in Maxwell-Chern-Simons theories in five dimensions, together with its potential implications in holographic setups.

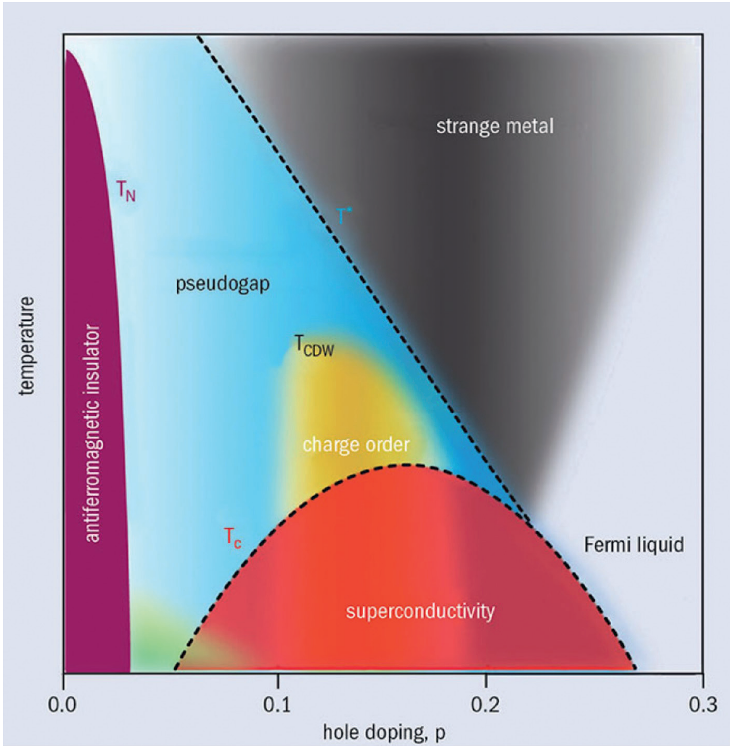
Finally, close to the concept of symmetry, there is the powerful notion of duality. Duality stems from the fact that certain seemingly different Quantum Field Theories are actually equivalent descriptions of the same physical system. This should not be confused with the previously mentioned property of universality. Indeed, duality generally relate theories which are often tractable in complementary regions of parameter space, hence many times stablishing a map between strongly and weakly coupled models. Due to this remarkable property, the concept of duality played a central role in past and present developments within both QFT and String Theory. More recently, it has been noticed that, under certain conditions, duality may in turn be regarded as a novel form of global symmetry, hence being incorporated as a natural technique to explore non-perturbative physics. In this context, I am currently involved in a project, together with R. Argurio (ULB), L. Tizzano (ULB), Christian Copetti (SISSA), F. Bennini (SISSA) and S. Benvenuti (SISSA), with the aim of characterizing the realization of interesting duality symmetries across supersymmetric RG flows. For this kind of systems, supersymmetry (again, a symmetry) provides a valuable set of exact results which can be used to unravel all the implications of the non-invertible symmetries on the infrared structure of the theories.

Non-perturbative techniques applied to Condensed Matter physics

According to the general framework described previously, QFT may be regarded as a primary tool for the study of universal macroscopic phenomena, making it extremely appealing for applications in Condensed Matter physics. Crucial implementations along these lines were, for instance, the incorporation of Fermi Liquid theory within the RG formalism (remarkably with the resolution of the Kondo model) and the identification of Conformal Field Theory (CFT), or more generally scale invariant theories, as the appropriate description of the dynamics of second order phase transitions. From this perspective, one may contemplate Condensed Matter physics as the most dynamical and pushing laboratory for testing Quantum Field Theory.

However, this archetype does not lack of interesting challenges. Indeed, there is a large compendium of samples presenting some singular phenomenological features which still evade any solid theoretical understanding. The main reason behind these complications is, not surprisingly, the proliferation of strong coupling dynamics. An iconic example of this kind comprises the so called Strange Metals, namely metallic samples whose typical properties strongly deviate from the paradigm stablished by Landau's Fermi Liquid theory. Indeed, Fermi Liquid theory stablishes that ordinary metallic systems, i.e. in which the main degrees of freedom are electrons primarily surjected to Coulomb interactions, are effectively described by an almost free theory at low energies.

In spite of its simplicity, this scenario turned out to be extremely accurate in predicting the behavior of many metallic samples above the onset of superconductivity. Starting in the late 80's, a series revolutionary experiments carried on High Critical Temperature Superconductors uncovered a variety of novel metallic states whose transport properties would never be accounted for by Fermi Liquid theory. Most remarkably, a universal linear scaling of the resistivity, which may persist down to very low temperatures, is currently target of intense research and may be considered as one of the main fundamental questions in modern theoretical and applied Condensed Matter physics.



In the last few years, part of my research has been focused on problems of this kind. More precisely, on the study of metallic systems presenting strong deviations from Fermi Liquid theory due to the effect of strong interactions. With a notable lack of creativity, these models have been dubbed non-Fermi Liquid metals and are believed to provide a theoretical explanation to the phenomenology observed in Strange Metals. Precisely due to their strongly interacting nature, solving these models is an extremely challenging task, and any attempt of achieving some (partial) analytical resolution would demand resorting to non-perturbative techniques in QFT. Accordingly, this is one of the main scenarios out of which many of recent theoretical developments find a natural application.

Along these lines, in collaboration with S. Kachru (Stanford U.), Srinivas Raghu (Stanford U.) and G. Torroba (Balseiro Institute), we proposed a model for a non-Fermi liquid which can nevertheless be exactly solved within some region in parameter space. It consists of a spinless Fermi Surface coupled to an order parameter through strongly relevant interactions and its resolution is attained by certain non-perturbative diagrammatic resumations. Later on, with G. Torroba (Balseiro Institute) and M. Solis (Balseiro Institute), we carried on two projects exploring the finite temperature behavior of these models, together with the interplay between decoherence and superconductivity naturally induced by non-Fermi liquid dynamics. It remains as an interesting open question to discern whether non-Fermi liquid behavior plays any central role in the onset of High Critical Temperature Superconductivity, as it is commonly believed. This task would demand a meticulous analysis of the transport properties of several models of this kind, a subject on which we expect to report in the foreseeable future.

Fellowships

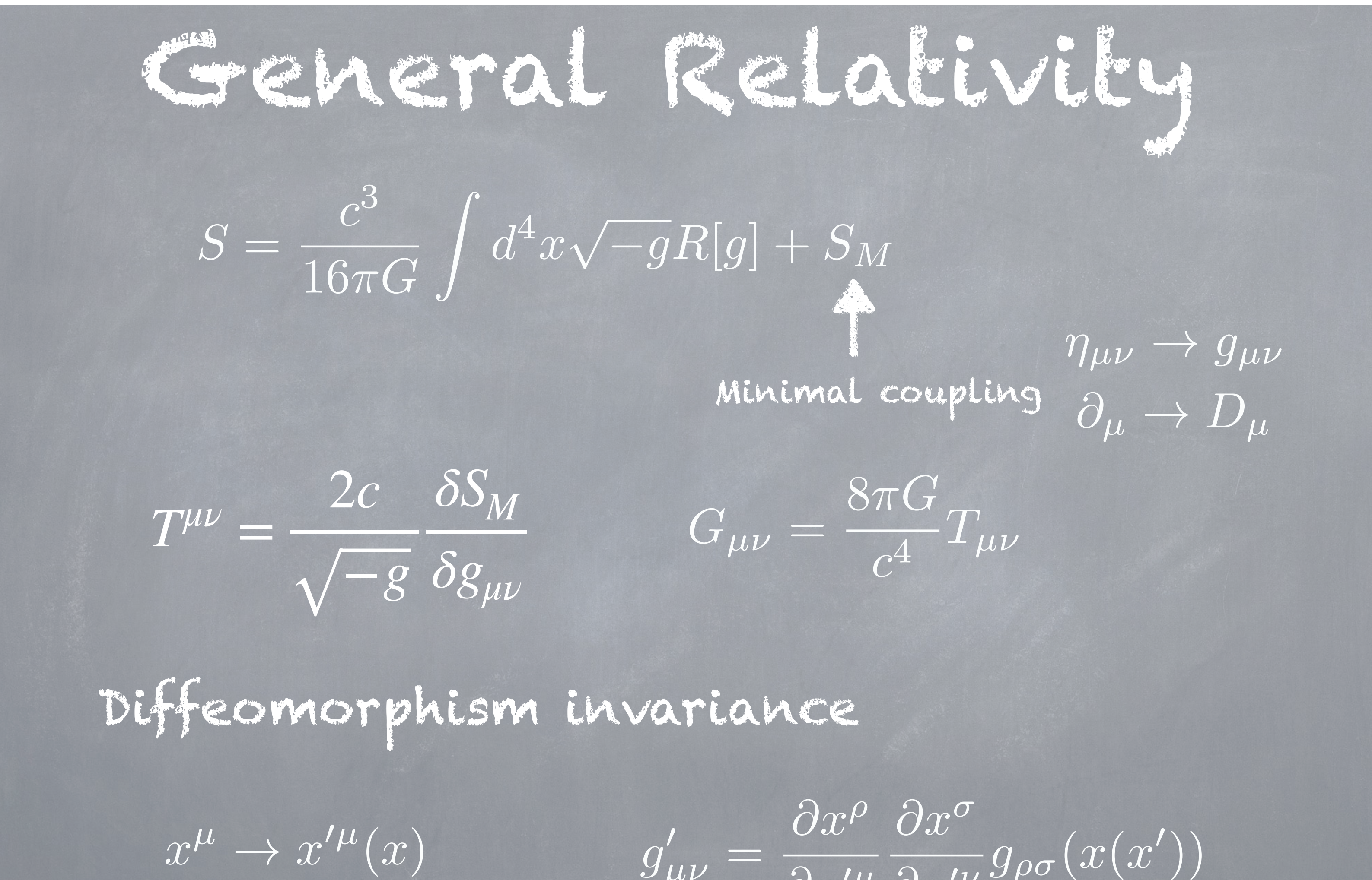
- Dr. Juan Hernandez (VUB) and Dr. Simone Blasi (VUB) received a prestigious FWO postdoctoral fellowship.

- Mr. Maxim Pavlov (VUB) and Mr. Aäron Rase (VUB) received an FWO Aspirant fellowship while Ms Sofia Zhidkova (VUB) obtained the extension of her FWO Aspirant fellowship.

Theses defended in 2022

- Martin Bonte (ULB)
  "Degrees of freedom and partition functions of gauge theories with planar boundaries"
  30 June 2022 (thesis advisor: Glenn Barnich).

- Daniel Naegels (ULB)
  "Perturbative and holographic study of symmetry breaking in non-relativistic theories"
  14 June 2022 (thesis advisor: Riccardo Argurio).



Talks at Conferences, Seminars and Schools

Jeremias Aguilera Damias

Non-invertible Symmetry defects in 5d
SISSA, Trieste, Italy – 19 October 2022.

Generalized symmetries in QFT and Adjoint QCD2
Swansea University, Swansea, Wales
23 November 2022.

Non-invertible Symmetry defects in 5d
Swansea University, Swansea, Wales
23 November 2022.

Riccardo Argurio

SUSY breaking in branes at singularities (or: The octagon rising from the swamp)
INFN Strings Web Seminars, online, Italy (organization) – 15 February 2022.

SUSY breaking in branes at singularities (or: The Rise of the Octagon)
Quiver Meeting online, UK (organization)
9 September 2022.

Non invertible symmetries in a simple 5d theory
Università di Firenze, Firenze, Italy
13 October 2022.

Alexandros Arvanitakis

On topology change in Poisson-Lie duality

- Aristotle University Thessaloniki (online), Greece – 21 January 2022.
- RBI Zagreb, "Mini-Symposium on Geometry and Physics 2022", Zagreb, Croatia
  8 June 2022.
- Orthodox Academy Kolymbari, conference "12th Crete Regional Meeting in String Theory", Kolymbari, Greece – 6 July 2022.
- U. Warsaw, conference "STRINGMATH 2022", Warsaw, Poland – 13 July 2022.
- U. Hradec Králové, workshop "Differential Geometry and its Applications 2022", Hradec Králové, Czech Republic
  21 July 2022.

Glenn Barnich

Coadjoint representation of BMS4 on celestial Riemann surfaces
Technical University Vienna/ Carroll Workshop, Vienna, Austria – 16 February 2022.

A phase transition of photons and gravitons in a Casimir box
Beijing Institute of Mathematical Sciences and Applications/ Physics @ Boundaries Workshop, Beijing, China – 17 March 2022 (online).

A quantum phase transition of photons and gravitons in a Casimir box
Pontificia Universidad Catolica de Valparaiso/ Kickoff Meeting HolographyCL, Valparaiso, Chile – 5 April 2022.

Asymptotic symmetries and conserved charges in gravity
3rd Meeting of the GPD of the EPS, Nice, France – 23 May 2022.

Photons and gravitons in a Casimir box: Modular invariance and phase transitions
Centro de Ciencias de Benasque Pedro Pascual/Gauge theories, supergravity and superstrings, Benasque, Spain
27 June 2022.

Asymptotic symmetries and current algebras at null infinity
Institute for Fundamental Physics of the Universe, SISSA/ Holography and gravitational waves, Trieste, Italy – 11 July 2022.

Coadjoint representation of BMS4 on celestial Riemann surfaces
Banach Center/ The 8th Conference of the Polish Society on Relativity, Warsaw, Poland
21 September 2022.

Geometric actions for BMS4

- Perimeter Institute/ Quantum Gravity Around the Corner, Waterloo, Canada
  4 October 2022.
- Mons University/ Higher symmetries and field theory, Mons, Belgium
  22 December 2022.

Luca Ciambelli

Carroll Limit of Fluid/Gravity
Conference in Vienna, Austria
21 February 2022.

Universal Symmetries of Gravity
École Polytechnique, Paris, France
20 March 2022.

Building the Corner Proposal
Nordita, Stockholm, Sweden – 20 May 2022.

Exploring Corners of the Covariant Phase Space
Conference Notre Dame, London, UK
18 August 2022.

Asymptotic Symmetries from a Geometric Viewpoint
Lecture, Modave, Belgium
5-9 September 2022.

Andres Collinucci

5d beyond toric

- Utrecht University, Utrecht, The Netherlands
  5 May 2022.
- Tsinghua University (Remote talk), Beijing, China – 15 December 2022.

Geoffrey Compère

Tails and memories: Monsieur Théophile de Donder meets Sir Hermann Bondi
Yangi Lake Beijing Institute of Mathematical Sciences and Applications, Beijing, China
14 March 2022.

Metric reconstruction from celestial multipoles

- Conception University, Conception, Chile
  28 November 2022.
- University of Crete, Heraklion, Crete
  6 December 2022.

Asymptotically matching the inspiral to the transition-to-plunge
Albert Einstein Institute, Potsdam, Germany
30 November 2022.

Ben Craps

Bounds on quantum evolution complexity via lattice cryptography

- Topics in Quantum Gravity (Collège de France and IPM, ENS), Paris, France
  23 June 2022.
- Henri's conference (in honor of Henri Verschelde), Ghent, Belgium – 4 July 2022.
- Online International Workshop on BPS State Counting, Holography and Quantum Information, Lisbon, Portugal
  1 September 2022.
- Utrecht University, Utrecht, The Netherlands
  10 November 2022.

Panel discussion: observable microstructure?
Black-Hole Microstructure IV: 26th Rencontres Itzykson, Saclay, France – 8 June 2022.

Bounds on quantum evolution complexity via lattice cryptography
Black-Hole Microstructure IV: 26th Rencontres Itzykson, Saclay, France – 8 June 2022.

Stéphane Detournay

Non-Conformal Symmetries and Near-Extremal Black Holes
Collège de France, Paris, France
8 June 2022.

Near-extremal limits of WAdS3 Black Holes and Warped CFTs
- Niels Bohr Institute, Copenhagen, Denmark 16 June 2022.
- BHI/CMSA Workshop on Flat Holography, Harvard, USA – 21 June 21.

Camille Eloy

AdS3 × S3 reductions through exceptional field theory
- Joint Belgian HEPTH Seminar (VUB, ULB, KUL, UMONS), Brussels, Belgium 26 January 2022.
- ENS de Lyon, France 30 September 2022.

Supergravity: a (very) brief introduction
African Institute for Mathematical Sciences Kigali, Rwanda – 9 November 2022.

Oscar Fuentealba

Asymptotic structure of Carrollian limits of Einstein-Yang-Mills theory
Technische Universität Wien (TU Wien), Vienna, Austria – 15 February 2022.

The asymptotic structure of spacetime in diverse dimensions
Universidad Católica de la Santísima Concepción (UCSC), Concepción, Chile
25 October 2022.

Marius Gerbershagen

A gravity dual to computational complexity from first principles
ULB, Brussel, Belgium – 23 November 2022.

Philip Hacker

Slow scrambling in extremal BTZ and microstate geometries
University of Amsterdam, The Netherlands
12 May 2022.

Marc Henneaux

L'espace et le temps en physique: de Newton à Einstein et au-delà
Online talk given at the "Collège Belgique" (inauguration 2022 du cycle "Le Collège Belgique reçoit le Collège de France"), Académie Royale de Belgique, Bruxelles, Belgique – 18 January 2022.

Asymptotic structure of gravity in five spacetime dimensions
Online seminar given at the University of Vienna, Austria – 28 January 2022.

Carroll invariant field theories
- University of Barcelona, Spain 3 February 2022.
- First Carroll workshop, TU Wien, Vienna, Austria – 15 February 2022.

Asymptotic structure of gravity in five (and higher) spacetime dimensions at spatial infinity
Kickoff Meeting Holography@CL – PUCV, Valparaiso, Chile – 4 April 2022.

Introduction to the Hamiltonian formulation of gauge systems
Pontificia Universidad Católica de Chile, Santiago, Chili – 8 April 2022.

The BMS algebra at spatial infinity (D=4 and D>4)
Conference "Eurostrings 2022", ENS Lyon, France – 26 April 2022.

Three-dimensional gravity on spaces with multiple boundaries
Workshop "Topics in Quantum Gravity", Collège de France & École Normale Supérieure, Paris, France – 22 June 2022.

The asymptotic structure of gravity at spatial infinity (D=4 and D> 4)
Ludwig Maximilian University,
Munich, Germany – 13 July 2022.

Three-Dimensional Gravity - review and some recent developments
Charles University, Prague, Czech Republic
21 September 2022.

The asymptotic structure of gravity at spatial infinity
Teaching given at the school "Gravity@Prague 2022", Prague, Czech Republic
23 September 2022.

Spacelike (cosmological or black hole) singularities
Charles University, Prague, Czech Republic
27 September 2022.

Description of the BMS symmetry at Spatial infinity
Massachusetts Institute of Technology, MIT, USA – 12 October 2022
(online seminar).

Description of the BMS symmetry at spatial infinity in four and higher spacetime dimensions
University of the Witwatersrand, Johannesburg, South Africa
14 November 2022.

Spacelike singularities and infinite-dimensional exceptional symmetries of gravity
University of Cape Town, South Africa
16 November 2022.

Singularités cosmologiques et symétries cachées de la gravitation
Meeting "Horizon Maths 2022: Mathématiques et gravitation", Sorbonne université, Paris, France – 6 December 2022.

Mikhail Khramtsov

Delicate windows into evaporating black holes (seminar)
University of Pennsylvania, Philadelphia, USA
1 June 2022.

Delicate windows into evaporating black holes (poster)
University of Vienna, Austria
18 July 2022.

Delicate windows into evaporating black holes (online conference)
Steklov Mathematical Institute, Moscow, Russia
11 November 2022.

Black hole information paradox
University of Torino, Italy
21 December 2022.

Aspects of subregion complexity (seminar)
Steklov Mathematical Institute, Moscow, Russia
29 December 2022.

Maria Knysh

Delicate windows into evaporating black holes
BEL mini-workshop at KU Leuven, Leuven, Belgium – 28 October 2022.

Laura Lopez Honorez

Feebly Interacting Dark Matter a Non Cold Dark Matter candidate
King's College London, UK – 27 April 2022.

Non Cold Dark Matter from Freeze-in & SuperWIMP
Synchretism conference, Chania, Greece
20 June 2022.

Cosmology versus Colliders: Dark Matter as an illustrative case
ECT workshop, Trento, Italy
29 August 2022.

Dark Matter at Cosmic Dawn
Scuela Normale, Pisa, Italy
21 & 22 February 2022.

Alberto Mariotti

Ripples in spacetime from broken SUSY
MPI Heidelberg, Heidelberg, Germany
7 February 2022.

Romain Pascalie

JT gravity at finite cut-off
University of Heidelberg, Germany
18 May 2022.

Maxim Pavlov

Bounds on quantum evolution complexity via lattice cryptography (poster)
- UvA, Amsterdam, The Netherlands
  12 May 2022.
- University of Vienna, Austria
  18 July 2022.

Quantum chaos in quantum resonant systems
UA, Antwerp, Belgium – 14 November 2022.

Jacob Salzer

IR divergences and the effective action of supertranslation modes
University of Vienna/TU Vienna, Austria
5 April 2022.

w-infinity Symmetry of Quantum Self-Dual Gravity
King's College London, UK – 4 May 2022.

An effective action for superrotation vacua at null infinity
UMons (Carroll Workshop), Mons, Belgium
13 September 2022.

Carrollian Spaces at Infinity: An Embedding Space Picture
Perimeter Institute (Quantum Gravity around the Corner Workshop), Waterloo, Canada
7 October 2022.

Luigi Tizzano

Anomaly matching across dimensions and supersymmetric Cardy formulae
- Online Seminar Series on String Phenomenology – 8 February 2022.
- King's College London, UK
  16 March 2022.

Continuous Generalized Symmetries in Three Dimensions
- SISSA, Trieste, Italy – 18 May 2022.
- Ghent University, Ghent, Belgium
  21 June 2022.
- Imperial College, London, UK
  16 September 2022.
- University of Cambridge, UK
  17 November 2022.
- University of Amsterdam, The Netherlands
  29 November 2022.

2 Lectures on Generalized Global Symmetries
University of Parma, Italy – 1 December 2022.

Kevin Turbang

Probing Early Universe Supercooled Phase Transitions with Gravitational Wave Data
LVK Stochastic telecon, online
2 August 2022.

Gravitational-wave backgrounds from first order phase transitions
Cargèse summer school, Cargèse, France
3 August 2022.

Stochastic search for intermittent backgrounds (poster)
UCLouvain, Louvain, Belgium
9 September 2022.

Stochastic search for intermittent backgrounds
LVK Stochastic telecon, online
13 December 2022.

Raphaela Wutte

Hyperbolic Mass and Gluings of Initial Data
Université libre de Bruxelles, Belgium
8 November 2022.


Gravitation à 3 + 1 d
$\beta^2 - \beta^1 \geq 0$
$2\beta^1 \geq 0$
H^2
H^M

Publications

[1] R. Abbott, ... , K. Turbang et al. [KAGRA, LIGO Scientific and VIRGO], "Search for continuous gravitational wave emission from the Milky Way center in O3 LIGO-Virgo data," Phys. Rev. D 106 (2022) no.4, 042003 doi:10.1103/PhysRevD.106.042003 [arXiv:2204.04523 [astro-ph.HE]].

[2] R. Abbott, ... , K. Turbang et al. [KAGRA, VIRGO and LIGO Scientific], "First joint observation by the underground gravitational-wave detector KAGRA with GEO 600," PTEP 2022 (2022) no.6, 063F01 doi:10.1093/ptep/ptac073 [arXiv:2203.01270 [gr-qc]].

[3] R. Abbott, ... , K. Turbang et al. [KAGRA, VIRGO and LIGO Scientific], "Search for gravitational waves from Scorpius X-1 with a hidden Markov model in O3 LIGO data," Phys. Rev. D 106 (2022) no.6, 062002 doi:10.1103/PhysRevD.106.062002 [arXiv:2201.10104 [gr-qc]].

[4] R. Abbott, ... , K. Turbang et al. [KAGRA, LIGO Scientific and VIRGO], "All-sky search for continuous gravitational waves from isolated neutron stars using Advanced LIGO and Advanced Virgo O3 data," Phys. Rev. D 106 (2022) no.10, 102008 doi:10.1103/PhysRevD.106.102008 [arXiv:2201.00697 [gr-qc]].

[5] R. Abbott, ... , K. Turbang et al. [LIGO Scientific, KAGRA and VIRGO], "Narrowband Searches for Continuous and Long-duration Transient Gravitational Waves from Known Pulsars in the LIGO-Virgo Third Observing Run," Astrophys. J. 932 (2022) no.2, 133 doi:10.3847/1538-4357/ac6ad0 [arXiv:2112.10990 [gr-qc]].

[6] R. Abbott, ... , K. Turbang et al. [KAGRA, VIRGO and LIGO Scientific], "All-sky search for gravitational wave emission from scalar boson clouds around spinning black holes in LIGO O3 data," Phys. Rev. D 105 (2022) no.10, 102001 doi:10.1103/PhysRevD.105.102001 [arXiv:2111.15507 [astro- ph.HE]].

[7] R. Abbott, ... , K. Turbang et al. [LIGO Scientific and VIRGO], "Search of the early O3 LIGO data for continuous gravitational waves from the Cassiopeia A and Vela Jr. supernova remnants," Phys. Rev. D 105 (2022) no.8, 082005 doi:10.1103/PhysRevD.105.082005 [arXiv:2111.15116 [gr-qc]].

[8] R. Abbott, ... , K. Turbang et al. [LIGO Scientific, VIRGO and KAGRA], "Searches for Gravitational Waves from Known Pulsars at Two Harmonics in the Second and Third LIGO-Virgo Observing Runs," Astrophys. J. 935 (2022) no.1, 1 doi:10.3847/1538-4357/ac6acf [arXiv:2111.13106 [astro- ph.HE]].

[9] R. Abbott, ... , K. Turbang et al. [LIGO Scientific, VIRGO and KAGRA], "Search for Gravitational Waves Associated with Gamma-Ray Bursts Detected by Fermi and Swift during the LIGO–Virgo Run O3b," Astrophys. J. 928 (2022) no.2, 186 doi:10.3847/1538-4357/ac532b [arXiv:2111.03608 [astro-ph.HE]].

[10] R. Abbott, ... , K. Turbang et al. [KAGRA, Virgo and LIGO Scientific], "All-sky, all-frequency directional search for persistent gravitational waves from Advanced LIGO's and Advanced Virgo's first three observing runs," Phys. Rev. D 105 (2022) no.12, 122001 doi:10.1103/PhysRevD.105.122001 [arXiv:2110.09834 [gr-qc]].

[11] R. Abbott, ... , K. Turbang et al. [LIGO Scientific, VIRGO and KAGRA], "Search for Subsolar-Mass Binaries in the First Half of Advanced LIGO's and Advanced Virgo's Third Observing Run," Phys. Rev. Lett. 129 (2022) no.6, 061104 doi:10.1103/PhysRevLett.129.061104 [arXiv:2109.12197 [astro- ph.CO]].

[12] R. Abbott, ... , K. Turbang et al. [LIGO Scientific, VIRGO and KA- GRA], "Search for continuous gravitational waves from 20 accreting millisecond x-ray pulsars in O3 LIGO data," Phys. Rev. D 105 (2022) 022002 doi:10.1103/PhysRevD.105.022002 [arXiv:2109.09255 [astro-ph.HE]].

[13] R. Abbott, ... , K. Turbang et al. [LIGO Scientific, VIRGO and KAGRA], "Search for intermediate-mass black hole binaries in the third observing run of Advanced LIGO and Advanced Virgo," Astron. Astrophys. 659 (2022), A84 doi:10.1051/0004-6361/202141452 [arXiv:2105.15120 [astro-ph.HE]].

[14] R. Abbott, ... , K. Turbang et al. [LIGO Scientific, KAGRA and Virgo], "Constraints on dark photon dark matter using data from LIGO's and Virgo's third observing run," Phys. Rev. D 105 (2022) no.6, 063030 doi:10.1103/PhysRevD.105.063030 [arXiv:2105.13085 [astro-ph.CO]].

[15] F. Acernese, ... , K. Turbang et al. [Virgo], "The Virgo O3 run and the impact of the environment," Class. Quant. Grav. 39 (2022) no.23, 235009 doi:10.1088/1361-6382/ac776a [arXiv:2203.04014 [gr-qc]].

[16] F. Acernese, ... , K. Turbang et al. [VIRGO], "Calibration of advanced Virgo and reconstruction of the detector strain h(t) during the observing run O3," Class. Quant. Grav. 39 (2022) no.4, 045006 doi:10.1088/1361-6382/ac3c8e [arXiv:2107.03294 [gr-qc]].

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[21] R. Argurio, M. Bertolini, S. Franco, E. García-Valdecasas, S. Meynet, A. Pasternak and V. Tatitscheff, "The Octagon at large M," JHEP 11 (2022), 114 doi:10.1007/JHEP11(2022)114 [arXiv:2207.00525 [hep-th]].

[22] R. Argurio and A. Caddeo, "Comments on holographic level/rank dualities," JHEP 08 (2022), 097 doi:10.1007/JHEP08(2022)097 [arXiv:2205.06115 [hep- th]].

[23] K. G. Arun et al. [LISA] (G. Compère), "New horizons for fundamental physics with LISA," Living Rev. Rel. 25 (2022) no.1, 4 doi:10.1007/s41114- 022-00036-9 [arXiv:2205.01597 [gr-qc]].

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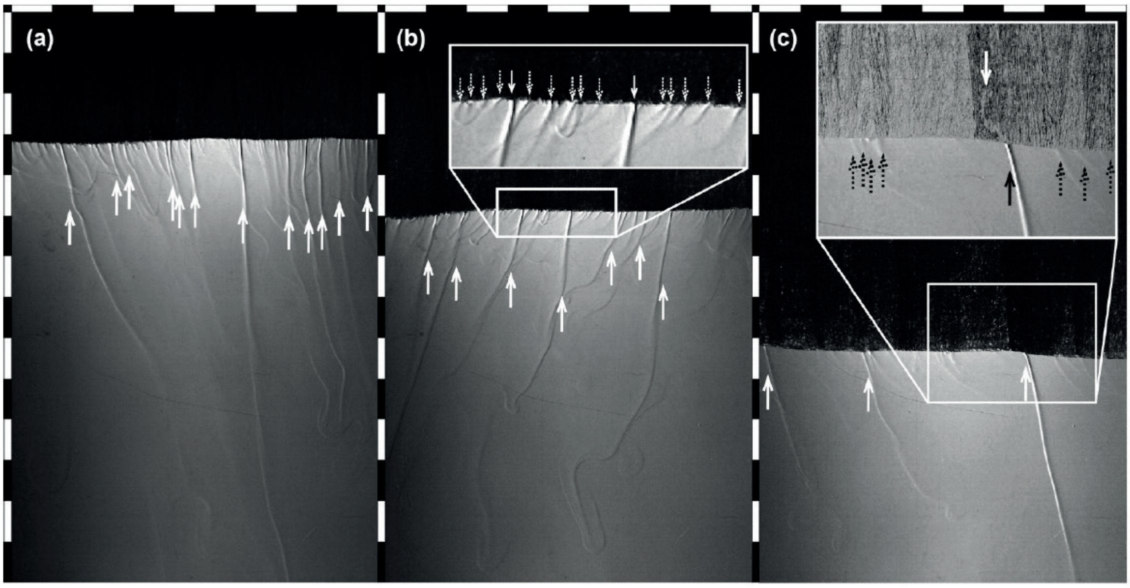
Convection below growing sea ice

C. A. Middleton, S. S. Gopalakrishnan, I. Berenstein, B. Knaepen , J.-L. Tison, and A. De Wit

Convective dynamics developing below growing sea ice have been studied experimentally by freezing salt water from above in a quasi-two-dimensional reactor *(Fig.)*.

Observations of the convective processes are made with Schlieren and direct imaging systems, allowing visualization both under and within the growing ice. Buoyancy-driven flows are seen to develop under the ice layer via two different mechanisms: on one hand, brine diffuses out from the ice layer creating a denser boundary layer of enhanced salinity, which triggers boundary layer convection resulting in small-scale interfacial fingers. On the other hand, internal flow within brine drainage channels inside the ice is observed flushing out longer-scale convective streamers at given locations at the ice-water interface.

Streamers descend in the bulk aqueous layer faster and for longer distances than fingers. Understanding such convective transfer processes from the ice towards the underlying water gives insight into important fluxes of matter between sea ice and oceans.



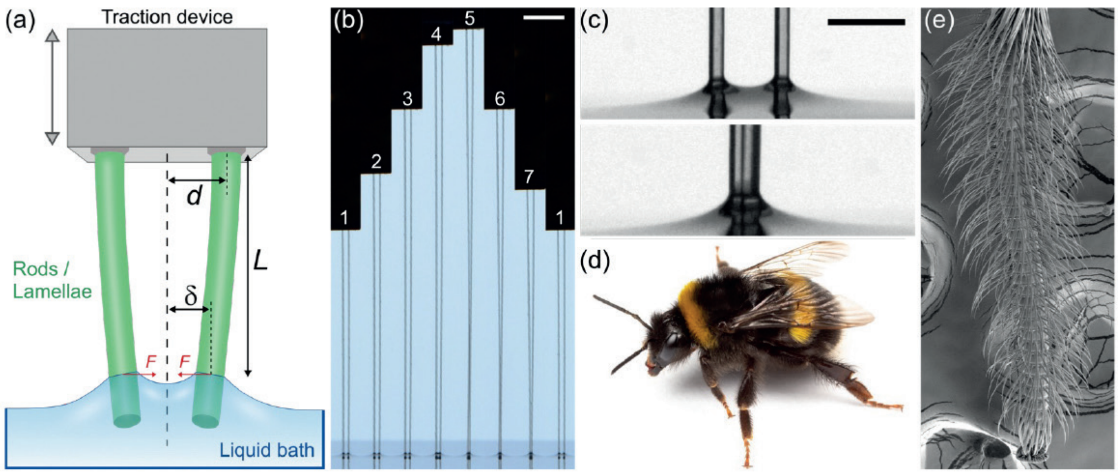
Schlieren images of the convective dynamics for an ice thickness of (a) 30 mm, (b) 50 mm, and (c) 80 mm when a 35 ppt NaCl solution is cooled at –20° C from above in a chamber kept at 0° C. The dark region at the top is the ice layer, and the gray area is the underlying water. Long streamer positions are marked with solid arrows while the zoom insets in (b) and (c) also indicate short finger positions with dashed arrows. The inset in (c) is a composite figure, where the direct imaging view of the ice layer is superimposed on the Schlieren image, allowing the streamer in the water to be linked to a channel structure in the ice layer, indicated by the solid white arrow. Alternate black and white border scales are in cm.

Capillary coalescence of two partially immersed slender structures

Emmanuel Siéfert, Hoa-Ai Béatrice Hua and Fabian Brau

Many bees possess a tongue resembling a brush composed of a central rod (glossa) covered by elongated papillae, which is dipped 5 times per second into nectar to collect this primary source of energy.

During this dipping process, the papillae unfold when immersed in the nectar like the hairs of a paintbrush. When the tongue is withdrawn from the nectar, the papillae collapse on the glossa due to the capillary force. During such a process, some papillae may also form bundles like wet hairs (coalescence). To rationalize this phenomenon, we have studied the onset of coalescence between two slender structures (rods or lamellae) quasi-statically withdrawn from a liquid bath. When partially immersed, they interact with each other through the capillary force induced by their menisci. As they are removed from the bath, their dry length increases and they become easier to bend until the capillary force is strong enough to trigger contact. Surprisingly, the structures snap to contact from a finite distance at a critical dry length. The transition to coalescence is thus subcritical and exhibits a large hysteresis loop between two stable states. We have derived an analytical coalescence criterion which agrees well with experimental data for rods and lamellae. This simple elastocapillary model is a first step to better understand the elastocapillary coalescence of slender structures in fluid capture systems such as the bee's tongue.



(a) Schematic of the experimental setup where two partially immersed slender structures with a dry length L are clamped at a distance 2d to a traction device and deflected by the capillary force F induced by the menisci. (b) Snapshots of an experiment cycle where two rods coalesce when the dry length is large enough (step 5) and detach at a much smaller dry length (step 1) illustrating the large hysteresis loop. (c) Fluid interface distortion induced by two rods when separated (top) or in contact (bottom). (d) Image of a Bombus terrestris (credit-Nicolas Vereecken). (e) Electron Microscopy Image of a bee's papillae (Megachile rotundata).

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Spatio-temporal oscillations in A + B → C reactive systems: The role of natural convection

Adam Bigaj, Reda Tiani and Laurence Rongy

Spatio-temporal oscillations are common examples of self-organization in complex reactions involving nonlinear chemical or thermal feedbacks. Recently, it was shown that local oscillations of the product concentration can be induced for simple bimolecular A + B → C reactions provided they are actively coupled to self-induced flows. When two reactants A and B, initially separated in space, react upon diffusive contact, damped spatio-temporal oscillations in the concentration of the product C can develop when the surface tension increases sufficiently in the reaction zone. Additionally, if the density decreases, the coupling of both surface tension- and buoyancy-driven contributions to the flow can further sustain this oscillatory instability.

We have studied the opposite case of a reaction inducing a localized decrease in surface tension, showing that no oscillations are observed for pure chemically-driven Marangoni flows. It is, however, possible to create oscillatory dynamics either by differential diffusion effects *(Fig. 1A)* or through the competition with antagonistic buoyancy-driven flows *(Fig. 1B)*. In the former case, the surface tension is found to oscillate in space and time *(Fig. 1A)*. We have studied numerically the different scenarios in a two-dimensional system by integrating the incompressible Navier-Stokes equations governing the flow evolution coupled to reaction-diffusion-convection equations for the chemical species concentrations. We show how those scenarios are controlled by the key parameters, i.e., the surface tension and density variations during the reaction, the layer thickness, the diffusion coefficients ratios, and the initial concentrations ratio.

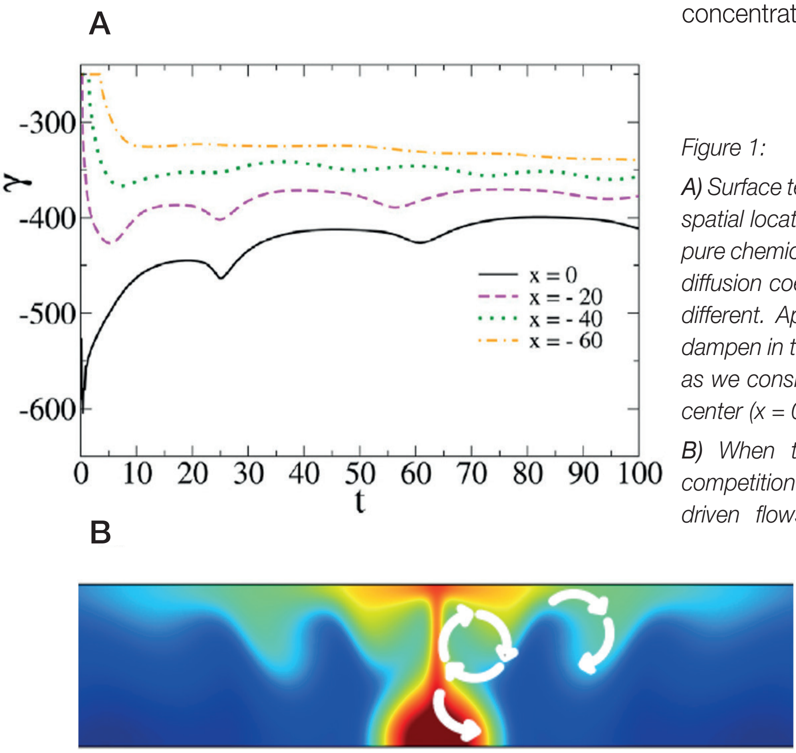


Figure 1:

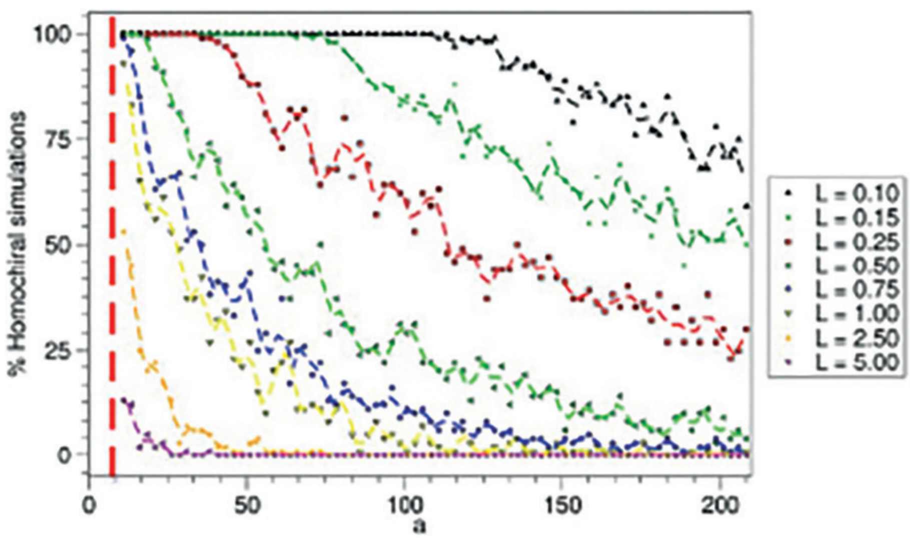
A) Surface tension γ (x, t) as a function of time at various spatial locations for representative parameter values of pure chemically-driven Marangoni convection when the diffusion coefficients of the three chemical species are different. Aperiodic temporal oscillations emerge and dampen in the course of time with reducing amplitudes as we consider spatial locations further away from the center (x = 0).

B) When the diffusion coefficients are equal, the competition between Marangoni-driven and buoyancy-driven flows can lead to local oscillations of the product concentration. The red (blue) zones represent the zones of maximum (zero) concentration of the product C. The reaction A + B → C decreases the surface tension of the solution locally in the reaction zone and increases its density.

Spontaneous mirror symmetry breaking in reaction–diffusion systems

Jean Gillet, Laurence Rongy and Yannick De Decker

The behaviour of a Frank-like chemical network model featuring autocatalytic production of chiral enantiomers from achiral reactants has been studied numerically in one-dimensional and two-dimensional systems using fluctuating initial conditions and accounting for diffusion processes. Our results reveal that the achiral substrate concentration can play an ambivalent role. When the achiral reactant concentration is maintained constant and homogeneous in 1D systems, global homochirality is not systematically reached when the size of the system or the achiral reactant concentration are increased *(Figure)*. However, with a fixed concentration gradient, coexisting homochiral domains of opposite handedness are no longer observed and homogeneous homochirality, i.e. the presence of a single stable homochiral domain, is recovered. In 2D systems, reaching global homochirality is just a matter of time. This time is dramatically increased when insufficient or excessive amount of achiral reactant is used. An optimal amount of achiral material is observed to maximise the enantiomer production rates.



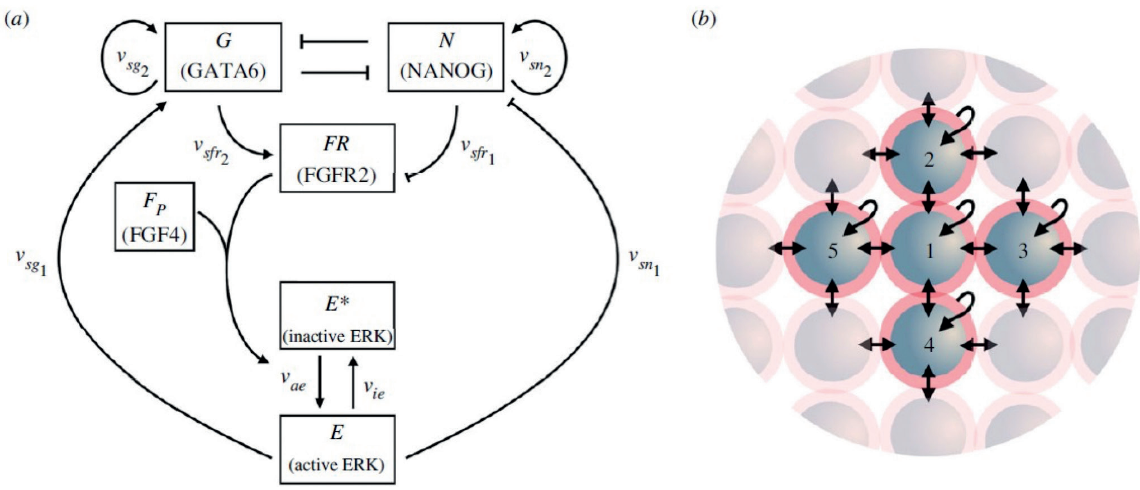
Percentage of simulations exhibiting homogeneous homochirality as a function of the concentration, a, of the achiral reactant at various system sizes L, increasing from right to left. Each point in the figure is calculated from 100 simulations where the initial distributions of the enantiomeric excess are randomly distributed following a Gaussian distribution centered around zero. Those initial conditions correspond to globally racemic mixture with local fluctuations.

Initial source of heterogeneity in a model for cell fate decision in the early mammalian embryo

Corentin Robert, Francisco Prista von Bonhorst, Yannick De Decker,
Geneviève Dupont and Didier Gonze

During development, cells from a population of common progenitors evolve towards different fates characterized by distinct levels of specific transcription factors, a process known as cell differentiation. This evolution is governed by gene regulatory networks modulated by intercellular signalling. In order to evolve towards distinct fates, cells forming the population of common progenitors must display some heterogeneity.

We applied a modelling approach to obtain insights into the possible sources of cell-to-cell variability initiating the specification of cells of the inner cell mass into epiblast (EPI) or primitive endoderm (PrE) cells in early mammalian embryo. At the single-cell level, these cell fates correspond to three possible steady states of the model. A combination of numerical simulations and bifurcation analyses predicts that the behaviour of the model is preserved with respect to the source of variability and that cell–cell coupling induces the emergence of multiple steady states associated with various cell fate configurations, and to a distribution of the levels of expression of key transcription factors. Statistical analysis of these time-dependent distributions reveals differences in the evolutions of the variance-to-mean ratios of key variables of the system, depending on the simulated source of variability, and, by comparison with experimental data, points to the rate of synthesis of the key transcription factor NANOG as a likely initial source of heterogeneity.



(a) A graphical representation of the gene regulatory network controlling the specification of cells from the inner cell mass into Epi and PrE cells. GATA6 and NANOG proteins inhibit each other and self-activate. FGF/ERK signalling, via FGFR2, activates GATA6 and inhibits NANOG. The synthesis of the receptor FGFR2 is activated by GATA6 and inhibited by NANOG.

(b) To simulate the emergence of Epi and PrE cells in a population, we consider a static network of 25 cells, disposed on a 5 × 5 square lattice with periodic boundary conditions. Intercellular signalling is achieved through the secretion of FGF4 in the extracellular medium. Each cell synthesizes and releases FGF4 at a rate proportional to its level of NANOG and senses the (average) level of FGF4 produced by the neighbouring cells and by itself.

Pamela Knoll | Postdoctoral researcher

I joined the Nonlinear Physical Chemistry Unit in the Université libre de Bruxelles as a postdoctoral scientist in December 2021. In March 2022, I was awarded a fellowship by the Belgian American Education Foundation to continue my research studying mineralization reactions for the safe and long-term storage of carbon dioxide.

My research project investigates the reaction of carbonate-rich liquids or of carbon dioxide gas into solutions containing calcium and/or magnesium *(Figure 1)*. The goal is to obtain insights into the effect of experimental parameters on precipitation to understand and enhance CCS methods.

Since the industrial revolution, there has been increasing levels of pollution entering Earth's atmosphere. The biggest culprit is carbon dioxide and the largescale anthropogenic release into the air has led to a significant change in the current climate with dangerously high predicted temperatures in the future. Current research is working to diminish our carbon footprint by finding solutions to store this greenhouse gases.

One method is carbon, capture, and storage (CCS) where CO_2 is collected from factories before entering the atmosphere and then trapped as carbonate minerals. There are currently several project sites around the world where industrial CO_2 waste is injected into mineral-rich geological settings. The goal is a reaction with abundant elements in these locations such as calcium and magnesium to form stable carbonate crystals which will safely sequester the CO_2 indefinitely.

However, there is little known about the actual physicochemical processes occurring within these sites nor the optimal parameters for achieving the highest yield of carbonate materials.

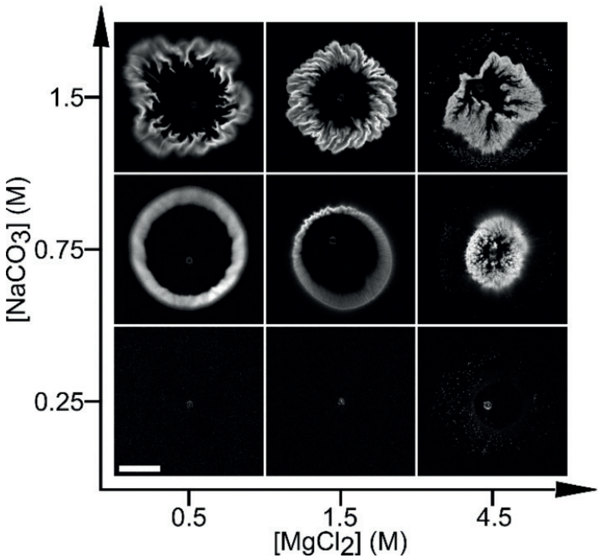


Figure 1 Precipitation patterns from the injection of sodium carbonate into magnesium chloride.

Talks at conferences, seminars and schools

Fabian Brau

Invited seminar at Transfers, Interfaces & Processes (TIPs), ULB - March 2022.

Invited seminar at Institut Jean Le Rond d'Alembert, Paris (France) - April 2022.

Invited talk at the Académie royale des Sciences, des Lettres et des Beaux-Arts de Belgique June 2022.

Alessandro Comolli

Oral talk, 1st IF@ULB Symposium, Brussels (Belgium) - May 2022.

Solicited oral talk, European Geosciences Union General Assembly, Vienna (Austria) - May 2022.

Oral talk, Conference on Computational Methods in Water Resources (CMWR), Gdansk (Poland) June 2022.

Oral talk, Interpore Annual Meeting, online June 2022.

Anne De Wit

Invited talk, CEPULB conference, Waterloo (Belgium) - April 2022.

Invited plenary talk, Gordon conf. on Oscillations and Dynamic Instabilities in Chemical Systems, Stonehill College, Easton (USA) - July 2022.

Invited talk, 16th International Conference on Fundamental and Applied Aspects of Physical Chemistry (Online), Society of Physical Chemists of Serbia - September 2022.

Invited talk, COST Chemobrionics meeting, Pisa (Italy) - September 2022.

Invited Altaïr conference, ULB (Belgium) October 2022.

Dario Escala

Oral talk, EGU22-10079, Copernicus Meetings, Wien (Austria) - May 2022.

Invited oral talk, Geochemobrionics, 2022 COST Action Chemobrionics Workshop, Edinburgh (UK) - June 2022.

Oral talk, Gordon Research Seminar on Oscillations and Dynamic Instabilities in Chemical Systems, Easton (USA) - July 2022.

Oral talk, Gordon Research Conference on Oscillations and Dynamic Instabilities in Chemical Systems, Easton (USA) - July 2022.

Invited Department Seminar, Universidad Nacional de General Sarmiento, Buenos Aires (Argentina) - December 2022.

Giulio Facchini

Oral talk, 25th Rencontre du Non-Linéaire, Paris (France) - March 2022.

Oral talk, 16th Physics of Living Matter, Marseille (France) - September 2022.

Invited Department Seminar, IUSTI laboratory, Université Aix-Marseille, Marseille (France) November 2022.

Jean Gillet

Oral talk at Solvay workshop “From 2D to 3D Crystal”, Brussels (Belgium) - March 2022.

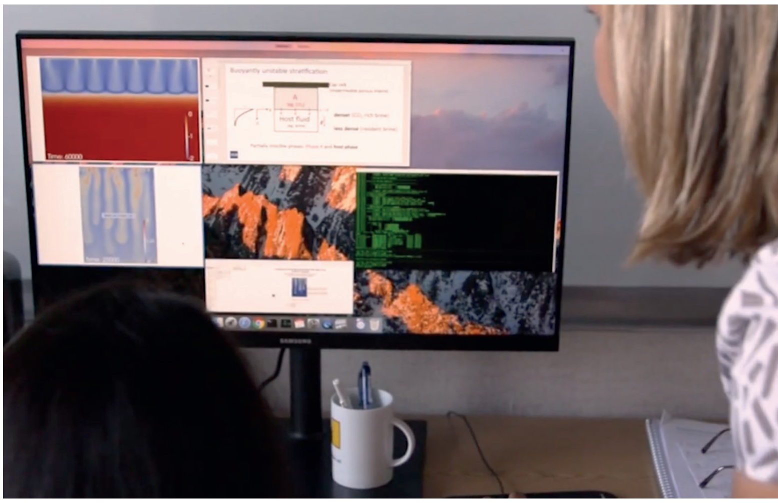
Oral talk, Gordon Research Seminar on Oscillations and Dynamic Instabilities in Chemical Systems, Stonehill College, Easton (USA) July 2022.

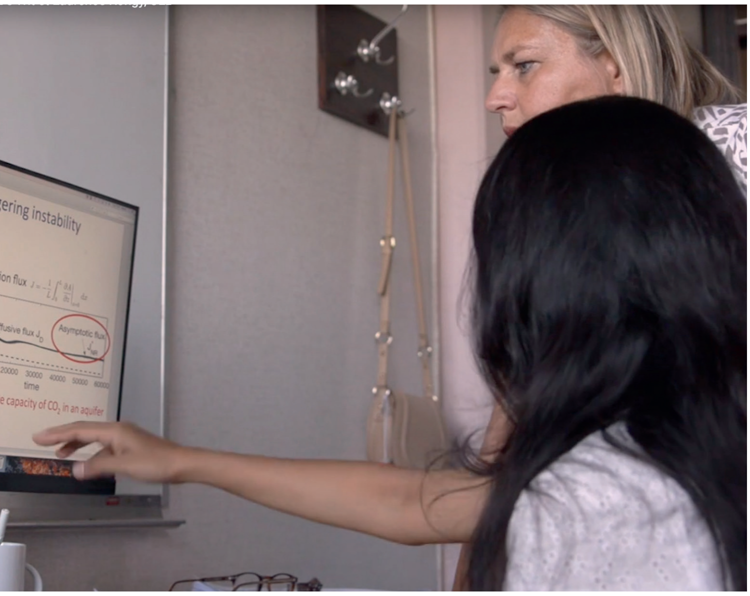
H.-A. B. Hua

Oral talk, Rencontres du Non-Linéaire 2022, Paris (France) - March 2022.

Department Seminar of Bio-inspired Fluid Flow and Multiphase and Multiscale Flow laboratories, University of California Santa Barbara, Santa Barbara (USA) - April 2022.

Oral talk, European Solid Mechanics Conference, Mechanics and Physics of Structures symposium, Galway (Ireland) - July 2022.





Pamela Knoll

Oral talk, European Geosciences Union, General Assembly, Vienna (Austria) - May 2022.

Oral talk, COST Action Chemobrionics, Geochemobrionics Workshop, Edinburgh (UK) June 2022.

Oral talk, COST Action Chemobrionics, Annual Meeting, Pisa (Italy) - September 2022.

Laurence Rongy

Talk at the 20th European Conference on Composite Materials, ECCM20, Lausanne (Switzerland) - June 2022.

Invited courses at the Summer school “Fluid flow and phase change of a solid”, Udine (Italy) July 2022.

Prizes & Awards

Anne De Wit has been elected Member of the Belgian Royal Academy of Sciences, Arts and Letters.

Hadrien Bense received the Seal of Excellence from the European Commission Horizon Europe.

Posters

A. Bigaj, M.A. Budroni and L. Rongy, "Flow competition to make a bimolecular reaction oscillate", Gordon Research Seminar & Gordon Research Conference – Oscillations & Dynamic Instabilities in Chemical Systems, Easton (USA) 16 - 22 July 2022.

D.M. Escala, L. Negrojevic, F. Brau, and A. De Wit.
"Effect of a radial geometry on the dynamics of A + B → C chemical fronts", Gordon Research Conference on Oscillations and Dynamic Instabilities in Chemical Systems. Stonehill College, Easton (USA), 16 - 22 July 2022.

J. Gillet, L. Rongy, and Y. De Decker, "Emergence of homochirality in reaction diffusion systems: effect of precursor concentration and enantiomer asymmetric diffusion rates". Gordon Research Conference on Oscillations and Dynamic Instabilities in Chemical Systems, Stonehill College, Easton (USA) 16 - 22 July, 2022.

S. Kabbadj, L. Rongy and A. De Wit, "Effect of variable solubility on reactive dissolution in partially miscible systems", Gordon Research Seminar & Gordon Research Conference – Flow and Transport in Permeable Media, Les Diablerets Conference Center (Switzerland) 16 - 22 July 2022.

P. Knoll, S. Nótte, A. De Wit, "Precipitation of Carbonate Minerals in Confined Geometries", Gordon Research Conference – Oscillations & Dynamic Instabilities in Chemical Systems, Easton, MA (USA), 16 - 22 July 2022.

A. Lechantre, A. Draux, H.-A. B. Hua, D. Michez, P. Damman and F. Brau, « Relaxation d'une tige élastique dans un fluide visqueux : application à la capture de nectar chez les abeilles » , Rencontres du Non-Linéaire 2022, Paris (France) 29 - 31 March 2022.

L. Negrojevic, A. Comolli, F. Brau, A. De Wit, "Influence of radial advection on properties of autocatalytic fronts", Gordon Research Seminar & Gordon Research Conference – Oscillations & Dynamic Instabilities in Chemical Systems, Stonehill College, North Easton (USA) 16 - 22 July 2022.

L. Negrojevic, A. Comolli, F. Brau, A. De Wit, "Influence of radial advection on properties of autocatalytic fronts", Chemobrionics Meeting, Pisa, Italy, 6 - 9 September 2022.

J. Oyero and A. De Wit, "Scaling of Buoyancy-Driven Instabilities in Bulk Flow", Gordon Research Seminar & Gordon Research Conference – Flow and Transport in Permeable Media, Les Diablerets Conference Center in Les Diablerets (Switzerland), 16 - 22 July 2022.

C. Robert, F.Prista von Bonhorst, Y. De Decker, G.Dupont, D.Gonze, "Initial source of heterogeneity in a model for cell fate decision in the early mammalian embryo", ICSB 2022 : The 21st International Conference On Systems Biology, Berlin (Germany), 08 - 12 October 2022.

Publications

Y. Stergiou, M. J. B. Hauser, A. De Wit, G. Schuszter, D. Horváth, K. Eckert, and K. Schwarzenberger
Chemical flowers: Buoyancy-driven instabilities under modulated gravity during a parabolic flight,
Phys. Rev. Fluids 7, 110503 (2022)

R. M. Lucena, J. Pontes, A. De Wit, G. R. Anjos, N. Mangiavacchi
Linear stability analysis and nonlinear simulations of convective dissolution in an inclined porous layer between impermeable surfaces,
Chaos 32, 113110 (2022)

J. Gillet, L. Rongy, Y. De Decker
Spontaneous mirror symmetry breaking in reaction–diffusion systems: ambivalent role of the achiral precursor,
Phys. Chem. Chem. Phys. 24, 26144 (2022)

J. Wei, F. Brau, P. Damman, A. Draux, H.-A. B. Hua, Z. Wu, J. Wu
Trade-off mechanism of honey bee sucking and lapping,
Soft matter 18, 5568 (2022)

E. Siéfert, H.-A. B. Hua, F. Brau
Capillary coalescence of two partially immersed slender structures,
Extreme Mech. Lett. 55, 101823 (2022)

R. Tiani, J. A. Pojman, L. Rongy
Critical Role of Layer Thickness in Frontal Polymerization,
J. Phys. Chem. B 126, 3607 (2022)

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Effects of gravity modulation on the dynamics of a radial A+ B → C reaction front,
Chem. Eng. Sci. 257, 117703 (2022)

R. Tiani, L. Rongy
Spatial and Temporal Oscillations of Surface Tension Induced by an A + B → C Traveling Front,
Front. Phys. 10, 860419 (2022)

C. A. Middleton, S. S. Gopalakrishnan, I. Berenstein, B. Knaepen, J.-L. Tison, A. De Wit
Relative role of short interfacial fingers and long internally driven streamers in convective flows below growing sea ice,
Phys. Rev. Fluids 7, 043503 (2022)

P. M. J. Trevelyan, A. De Wit, J. Kent
Rayleigh-Taylor instability of classical diffusive density profiles for miscible fluids in porous media: a linear stability analysis,
J. Eng. Math. 132, 1 (2022)

C. Robert, F. Prista von Bonhorst, Y. De Decker, G. Dupont, & D. Gonze (2022).
Initial source of heterogeneity in a model for cell fate decision in the early mammalian embryo.
Interface Focus, 12(4), 20220010 (2022).

GENERAL CHEMISTRY RESEARCH GROUP (ALGC)

General Chemistry Research Group (ALGC)

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

The main research activities of the ALGC research group are in the field of quantum chemistry. The group focuses on a diverse series of research topics investigating chemical systems ranging from atoms to small, middle sized and large (macro)molecules to extended systems and materials.

An important research interest of the group remains the development, implementation, and use of chemical concepts rooted in quantum mechanics, with special interest for the concepts introduced in the so-called Conceptual Density Functional Theory (CDFT).[1] Recently, the group has focused on extending the CDFT framework to include external variables enabling the conceptual study of chemical reactivity in the presence of e.g., a mechanical force, electric or magnetic fields. [2] Other important research lines in the group focus on molecular electronics, molecular switches and inverse design.

The group additionally investigates many topics in applied quantum chemistry, modelling as realistically as possible many (complex) chemical systems and reactions. ALGC's Materials Modelling group specializes in researching metal oxides, molecular self-assembly on surfaces, and materials from biological mineralization. They continue, among others, to focus on the characterization of silica-based materials, used as support for nano-catalysts and as adsorbents. [3] The amorphous character of silica materials makes their characterization complex and the complexity of the system further increases when liquid water is added, creating an interface between two amorphous phases. Studying this interface at the atomic level experimentally is challenging, and computational chemistry tools are used to explain its physical and chemical properties. In addition, the group is active in the simulation and interpretation of spectroscopical data, e.g., from Raman spectroscopy, is achieved to investigate the structure of both bulk and surfaces.

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

Conceptual DFT and Chemical Reactivity

The ALGC group has focused attention on extending the CDFT framework to include the effect of mechanical forces,[4] electric [5] and magnetic fields [6] on chemical reactivity. In a very recent application in the field of mechanochemistry,[7] performed within the framework of the Ph.D. work of Tom Bettens, mechanochemical nucleophilic additions to chiral carbonyl compounds were investigated, putting forward the ability to lock a molecule into one particular conformation using a mechanical force.[8] This study thus put forward mechanochemical activation as a powerful strategy to obtain otherwise forbidden (diastereomeric) products *(Fig. 1)*, in line with previously shown mechanochemical anti Woodward-Hoffmann electrocyclizations.

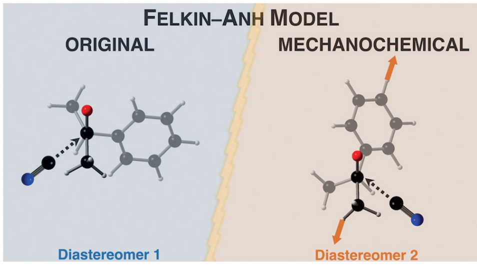


Figure 1. Illustration of the principle of mechanochemical diastereoselectivity in the nucleophilic additions studied in reference [8].

As a continuation of our work on confinement effects on chemical reactivity, we performed a proof-of-concept study investigating the effect of pressure on atomic CDFT properties in view of the many possibilities high pressure chemistry offers to control both chemical properties and reactivity. Pressure was included in the quantum chemical calculations using the eXtremePressure-(XP-PCM) model of Cammi and co-workers [9] and the influence of the pressure on atomic ionization energies, electron affinities, electronegativities, hardness and softness, polarizability and electron density was investigated. As an example, the dependence of the electronegativity on the pressure of the atoms H through Kr is shown in *Figure 2*.

The atomic properties investigated in this work will be of utmost importance to rationalize the effect of pressure on molecular charge distributions and reactivities.[10]

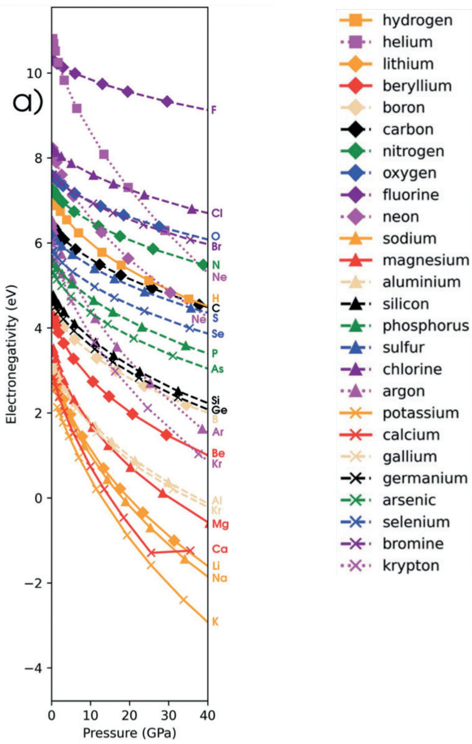


Figure 2.
Dependence of the atomic electronegativity of the elements H-Kr on external pressure.
Reproduced from reference [10].

Molecular Switches

In our long-standing interest on the description of aromaticity of challenging macrocycles, we have evaluated the performance of different descriptors to assess the local and global aromaticity of neutral and charged expended porphyrins.[11] We investigated different conjugation pathways in a set of neutral, anionic, and cationic expanded porphyrins by means of several aromaticity indices rooted in the structural, magnetic, and electronic criteria. Our results reveal that the predominance of the annulene-type conjugation pathway is only fulfilled in planar neutral macrocycles.

Figure 3. Cover work illustrating our research on the quest for the most aromatic pathway in macrocycles.

Applied Quantum Chemistry

Self-healing network materials have the potential to entirely change the way we view and use materials. Self-healing through Diels-Alder (DA) chemistry will play a large role in the development of these materials, with current innovative applications in self-healing robotics and coatings. However, the major issue is the slow kinetics of the material. Elevating the temperature to ensure proper healing can be, in the less severe case, unpractical but also lead to loss of mechanical strength or unwanted side reactions.

Research suggests that alternative and potentially non-covalently catalysed DA reactions, compared to the conventionally used furan-maleimide system, may be the answer. In this research, computational, going from static density functional theory calculations to reactive molecular dynamics, and conceptual approaches are used to study the kinetics and thermodynamics of alternative Diels-Alder systems.[12]

Also, we scrutinized the origin of non-covalent catalysis of (hetero-)DA reactions via an energy decomposition analysis and confirmed the general believe that improved orbital interactions are key for catalysis to occur, sometimes assisted with decreased Pauli repulsion. [13] Currently, a large database is being constructed in which the kinetics and thermodynamics of potential DA reaction candidates is described in detail for applications ranging from self-healing soft robotics to recyclable windmill blades.

This research track is conducted in close collaboration with the Physical Chemistry (FYSC) group from the Engineering Department of the VUB. This joint work, in which static and dynamic quantum-chemical modelling methods are combined with experimental data on Diels-Alder crosslinking reactions, is new in its field.

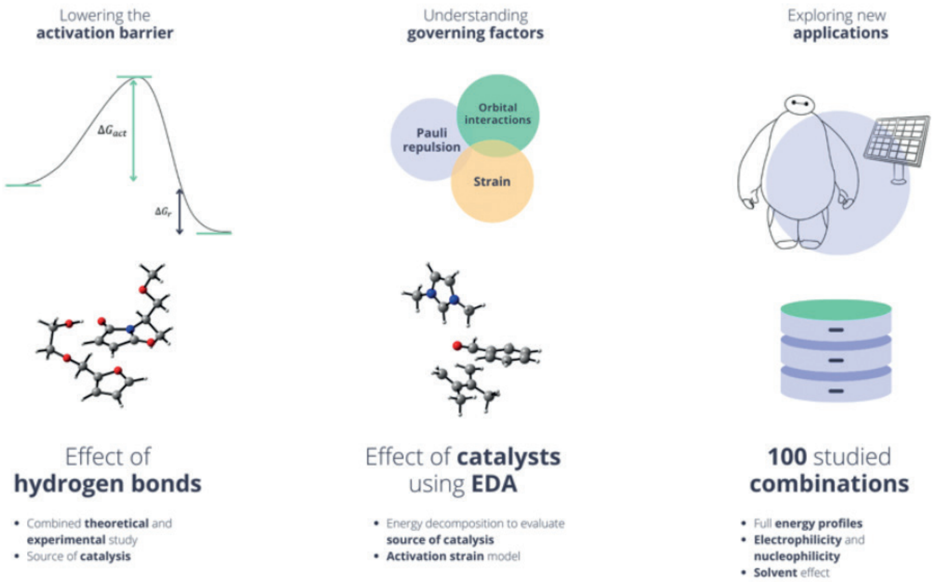


Figure 4. Overview of recent developments in modelling the kinetics of self-healing network polymers via reversible Diels-Alder reactions.

In close collaboration with the experimental group of Prof. Chaplin (University of Warwick, UK), and within the framework of our recently established Eutopia Connected Research Community "Sustainable Catalysis by Design", our group explored the metal carbonyl stretching frequencies across the homologous series of rhodium(I) carbonyl complexes **1–3** *(Fig. 5)*.[14] Advanced DFT-based molecular dynamics simulations revealed a correlation between the conformation of the flanking aryl-substituted oxazoline donors and the carbonyl stretching frequency ν(CO). These findings are reconciled by local changes in the magnitude of the electric field that is projected along the metal-carbonyl vector, namely the internal Stark effect. We are currently developing a model to describe the CO frequency shifting behaviour of a large dataset of $[M(L)_n(CO)]^m$ compounds by combining the extent of π back-donation of the metal to the CO together with the dipole moment of the $[M(L)_n]^m$ fragment.

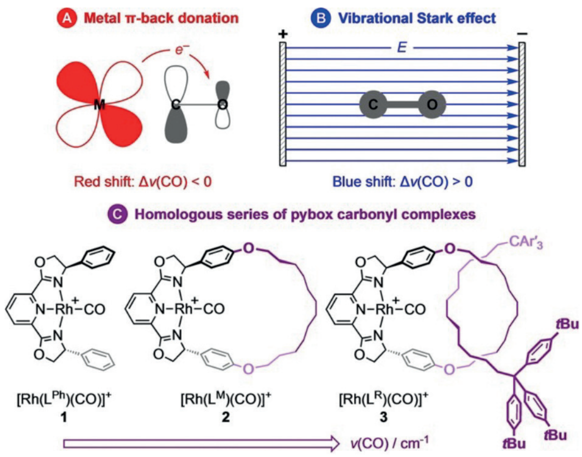


Figure 5. (A, B) Metal-based interactions with carbon monoxide and their effect on the carbonyl stretching frequency; C) structures of the pybox carbonyl complexes studied, with $[BAr^F_4]^-$ counterions omitted for clarity (Ar^F=3,5-$(CF_3)_2C_6H_3$) Reproduced from reference [14].

A new transformation based on sulfur(VI) fluoride exchange (SuFEx) chemistry represents another prominent research example in which ab initio MD simulations constitute the next step in understanding complex chemical processes, enabling the explicit treatment of solvent and challenging conformational dynamics.[15] SuFEx has emerged as a next generation click reaction, designed to assemble functional molecules quickly and modularly. In this synergistic experimental-computational study, we report a new SUFEx protocol that allows to efficiently synthesize a diverse library of triflates and triflamides, often without the need for further purification. *ab initio* metadynamics (AIMtD) simulations offered insight into the reactivity of the CF_3SO_2F triflylation with secondary amine nucleophiles. The simulations for amines suggested a formal S_N3 mechanism with a termolecular transition state that relies on hydrogen bond formation between base and nucleophile.

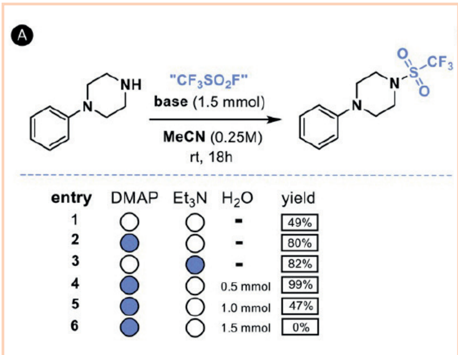
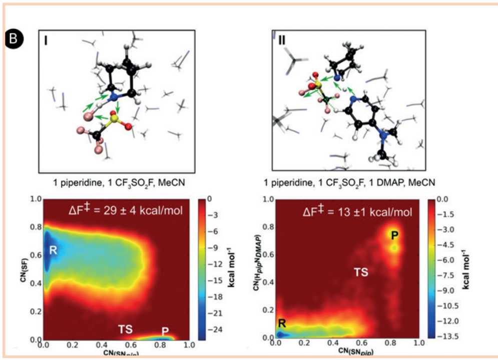


Figure 6. (A) Triflylation of phenylpiperazine as model reaction varying the base, solvent and relative amounts of substrate and CF_3SO_2F.



(B) Transition states obtained through metadyna-mics simu-lations for the diffe-rent SuFEx reactions: (I) the non-activated CF_3SO_2F-triflylation of piperidine in acetonitrile and (II) the DMAP-activated CF_3SO_2F-triflylation of piperidine in acetonitrile (DMAP: 4-dimethylaminopyridine).

Reproduced in part from reference [15].

Materials Modelling

In the field of materials modelling, we highlight a study investigating the NO dissociation reaction on Pt12M with M: Rh, Ir, Ru type clusters inside an MCM-41 pore.[16] The dissociation of environmentally hazardous NO through dissociative adsorption on supported metallic clusters is receiving growing attention. The study considered bimetallic Pt12M (M = Rh, Ru, or Ir) clusters, and the adsorption energy and activation energy of NO dissociation on the clusters were calculated using Kohn-Sham DFT in vacuum. Reactivity indices such as molecular electrostatic potential and global Fermi softness were used to rationalize their trends. Reactivity indices were also calculated to estimate the performance of the clusters in realistic amorphous silica pores (MCM-41) through ab initio molecular dynamics simulations. This recent study demonstrates the group's continued dedication to research that can have a positive impact on the environment.

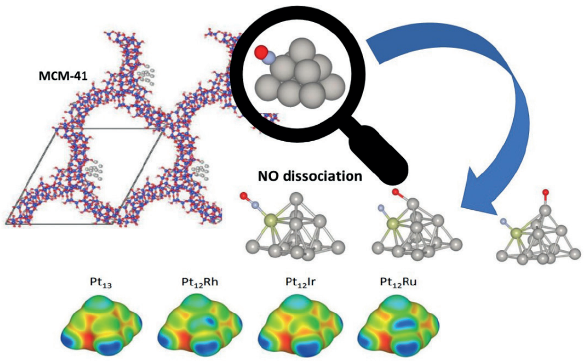


Figure 7. Graphical abstract representing the conducted research on NO dissociation on metallic clusters of Pt doped with Rh, Ir and Ru. From reference [16].

Over the years, the focus of the research efforts in materials has shifted towards the study of biological mineralization, a complex phenomenon that is widespread in living species on Earth. With over 60 different minerals from biological origin, including silicates, carbonates, and phosphates, this field of study has gained a lot of attention. These materials have a complex structure, typically constructed hierarchically, showing a macro, micro, and nano assembly. As a result, their characterization and chemistry pose a challenging task that requires a multidisciplinary network of researchers.

Our team collaborates with clinicians, physicists, chemists, and fellow materials modelers from France, Argentina, UK, and China. We have worked on oxalates, whitlockite, cystine, and cysteine. We would like to highlight our work on cystine/cysteine characterization.[17] Genetic diseases affecting the metabolism of cysteine and kidney function lead to two different kinds of pathologies, namely cystinuria and cystinosis, which generate L-cystine crystals. Therefore, the study of cystine and cysteine is important for providing a better understanding of cystinuria and cystinosis. We elucidated the discrepancy between L-cystine and L-cysteine by investigating theoretical and experimental infrared spectra (IR), X-ray diffraction (XRD), as well as Raman spectra, aiming to obtain a better characterization of abnormal deposits related to these two genetic pathologies.

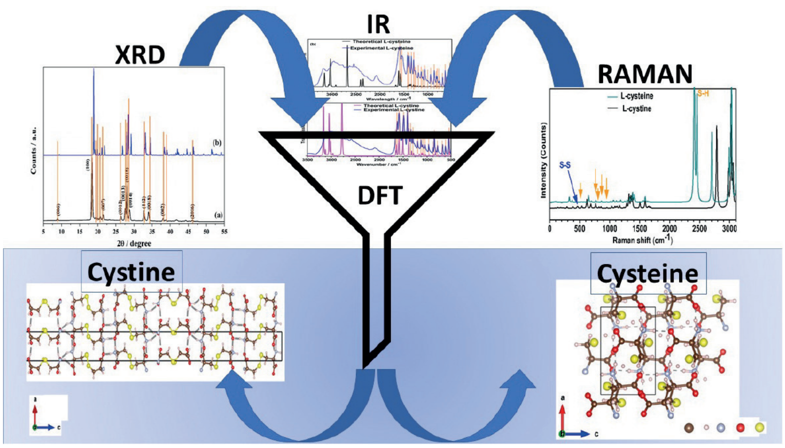


Figure 8. Spectroscopic quantities obtained through DFT to gain insight into the structure of cysteine and cystine. [17].

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"19th International Conference on Density-Functional Theory and its Applications" (DFT2022).

From August 28 until September 2, 2022, the ALGC group organized the DFT2022 conference at the Square Brussels Convention Centre; this conference is the most important conference in the field of Density Functional Theory (DFT). It was the most recent edition in a series of biennial meetings, which have taken place in Paris (1995), Vienna (1997), Rome (1999), Madrid (2001), Brussels (2003), Geneva (2005), Amsterdam (2007), Lyon (2009), Athens (2011), Durham (2013), Debrecen (2015), Tällberg (2017) and Alicante (2019). The conference was attended by 212 participants from over 21 countries.

The main objective of the conference was to provide a state-of-the-art overview and update of the most recent and exciting scientific activities and breakthroughs in the field of Density Functional Theory: topics included Density Functional Theory: new fundamental developments and new developments of exchange-correlation functionals, Time-dependent and real-time density functional theory, Chemical concepts and conceptual DFT, Applications of DFT in chemistry, catalysis, condensed matter physics and materials science, Computational aspects of DFT and DFT and machine learning.

A series of 10 plenary lectures (45-50 minutes plus 15-10 minutes of discussion) and 15 invited lectures (25 minutes and 5 minutes of discussion) were delivered by international leading experts in the field addressing a large diversity of topics and challenges in the research field. Also, the opportunity was given to apply for a contributed talk during the conference, providing a platform to other active (young) researchers in the field to present their research. A total of 33 contributed talks (12 minutes and 3 minutes of discussion) were delivered.

On Thursday, September 1, a session on "DFT in industry" was organized with representatives from industry discussing the relevance of DFT for their industrial activities.

On Tuesday, August 30, a poster session was organized where a total of 105 posters were presented; 11 poster awards could be granted among the presenters thanks to contributions of sponsors; sponsorship of the conference was provided, among others, by the International Solvay Institutes and the Solvay Company.

CHEMICAL ENGINEERING
RESEARCH GROUP

Chemical Engineering Research group

Group of Professor Gert Desmet I VUB

Demonstrating the benefits of order and confinement in chemical engineering

Rooted in chemical engineering, with a long standing specialization in microfluidics and analytical separation science (chromatography, DNA hybridization assays, microfluidic membrane separations…), the Desmet group is reputed for the development of novel analytical separation devices, as well as for its know-how on the modeling and understanding of flow effects in laminar flow systems.

The group is also internationally reputed for its know-how on miniaturization and has over the last 20 years established an extensive set of microfluidics capabilities. Harvesting from this unique combination of know-how, our group was the first to show the dramatic acceleration in chromatographic separation that can be achieved by working at the nanoscale. Whereas conventional chromatographic separations are conducted with particles of a few micrometer and typically take minutes to be completed, moving to nanochannels with a height of only 100 nm enabled to do the same separation on the order of milliseconds.

The group also realized an important breakthrough in the development of perfectly ordered separation beds. While flow heterogeneities are the enemy of separation processes, conventional separation beds are still filled with randomly packed spherical particles. Using advanced silicon micromachining (= a combination of the photolithography and Deep Reactive Ion Etching processes originally developed for the micro-electronics industry) allowed to develop microfluidic channels filled with perfectly ordered arrays of cylindrical micro-pillars. Because of the order, separation efficiencies are more than doubled compared to the standard technology.

In this research track, we have now proposed a groundbreaking novel concept to produce ordered beds of spherical HPLC particles in a format that suitable for liquid chromatography *(Fig. 1)*. In this concept, spherical particles are either positioned individually (single layer column) or stacked (multi-layer column) in micro-machined pockets that are interconnected to form an interconnected array of micro-grooves acting as a perfectly ordered chromatographic column filled with spherical particles. As first step towards the realization of this concept we report on the breakthrough we realized by obtaining a solution to uniformly fill the micro-groove arrays with spherical particles.

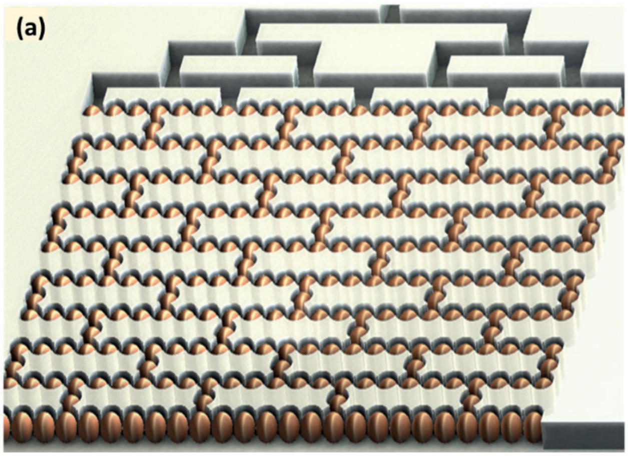
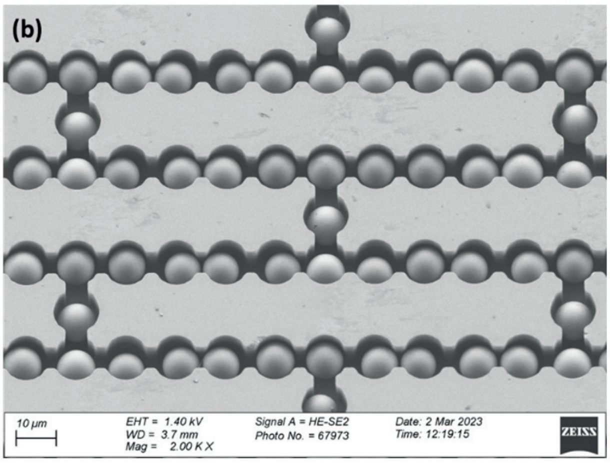


Figure 1.
(a) Conceptual image showing the principle underlying the new concept wherein a micro-groove template is used to perfectly organize arrays of chromatographic particles.



(b) SEM images of micro-groove network columns filled with calibrated 10 µm silica particles, where each pocket is filled with exactly one particle.

We show this can be achieved in a few sweeps using a dedicated rubbing approach wherein a particle suspension is manually rubbed over a silicon chip. In addition, numerical calculations of the dispersion over a unit cell have been carried out and demonstrate the combined advantage of order and reduced flow resistance the newly proposed concept has over the conventional packed bed. Due to their interconnected design, the microgrooves also have an inherent mechanism for the correction of velocity differences among the different branches. Because of the increased order, significantly larger separation efficiencies (>factor 2 increase in theoretical plates) can be obtained. Combining this with the lower flow resistance (originating from the fact that the inescapable vicinity of the column leads to higher external porosities than those prevailing in random packed beds), significant gains in separation speed (order of factor 10 when neglecting groove-to-groove packing density differences).

In our research line on the theoretical modelling of dispersion of matter through ordered and random porous media, we have, in collaboration with colleagues Adrover and Cerbelli of La Sapienza University di Roma, developed new mathematical insights into how the local velocity fluctuations in randomly packed media influence the dispersion of a passive tracer over different length scales and how this leads to a near-logarithmic dependency between the eddy-dispersion and the velocity.

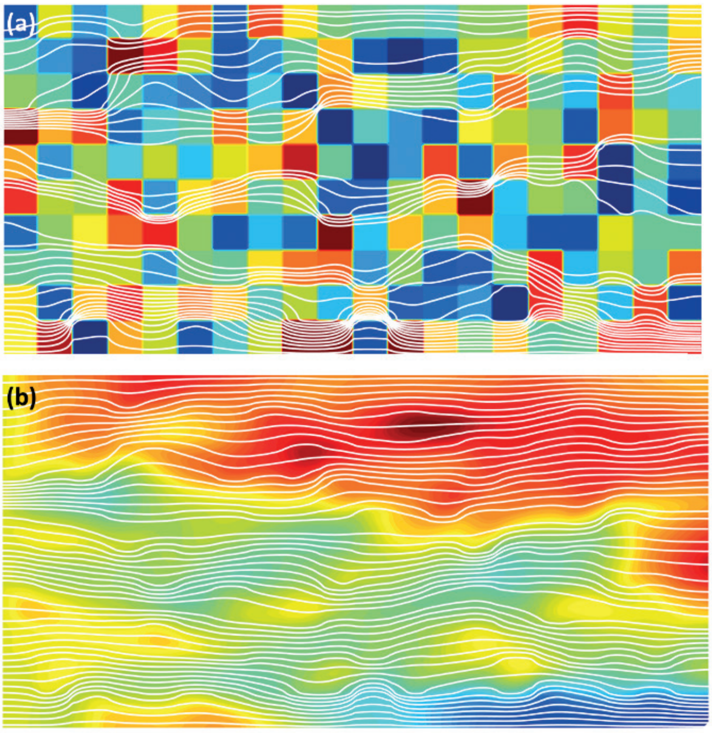


Figure 2.

(a) Flow streamlines in a synthetic patchwork of flow resistances for the study of the dispersion of matter through random porous media.

(b) Relative age distribution field (red=old relative age, blue=young relative age).

The study consists of two parts. First, numerical computations of the tracer dispersion in synthetic media consisting of 2D and 3D ordered patchworks of zones with a different permeability have been conducted using the age distribution-approach. The latter turns the original transient advection-diffusion tracer dispersion problem into a steady-state problem, thus greatly reducing the computational effort with respect to the conventional time-dependent simulations and hence opening the road to studying a sufficiently large number of different random seeds and sufficiently large flow domains to arrive at a statistically meaningful average that is furthermore devoid of finite width and length effects.

Secondly, the data are interpreted using a Fourier series expansion of how the local velocity biases (represented by a classic Giddings-coupling or finite-parallel zone model terms) interact over different length scales, treating the velocity fluctuations as white noise. This analysis shows the observed velocity-dependency can, especially in 3D, to a very high degree of accuracy be described using a logarithmic law depending on only two fitting parameters. The law remains accurate over a much wider range of velocities than Knox' classic empirical power law.

In our microfluidics track, we also started the development of a radically novel approach for the size separation of micro- and nano-particles based on a combination of open-tubular chromatography and the process of Brownian sieving (Hydrodynamic Chromatography-Brownian Sieving).

This work occurs in collaboration with the MESA+ Institute for Nanotechnology from the University of Twente and the La Sapienza University di Roma. The theoretical foundation and elaboration for this approach has been laid using a series of Lagrangian particle flow simulations in parallel arrays of interconnected micro-channels *(Fig. 3)*. These simulations show this technology has the potential to improve the current technology (i.e., open-tubular hydrodynamic chromatography) with a factor of about 10 in both required channel length and time. The microfluidic devices required to demonstrate the practical feasibility of the concept *(Fig. 4)* have been produced using a combination medium-range UV photolithography and cyclic deep reactive ion etching (Bosch etching).

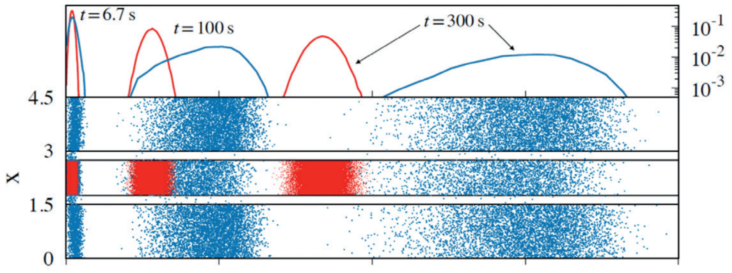


Figure 3. Lagrangian particle flow simulations of the separation of a mixture of 100 and 200 nm particles using the Hydrodynamic Chromatography-Brownian Sieving (HDC-BS) principle developed by our group.

Unique to the design of the device is a double flow distributor, one on each side of the silicon wafer, and forming a series of interdigitated feed channels: one feeding the sample to a series of central separation channels and one feeding a carrier liquid to a set of parallel peripheral channels.

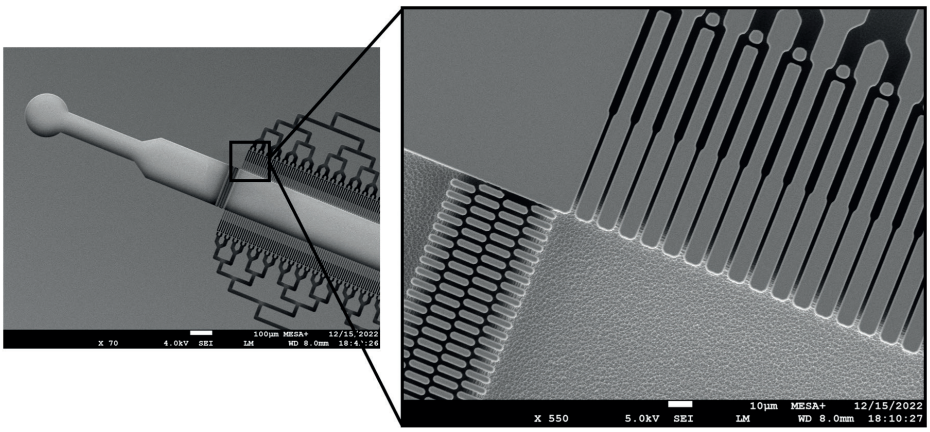


Figure 4. Silicon etched device produced by medium-range UV photolithography and cyclic deep reactive ion etching for the experimental exploration of the possibilities of the novel Hydrodynamic Chromatography-Brownian Sieving (HDC-BS) nanoparticle separation scheme developed by our group.

LABORATORY OF POLYMER CHEMISTRY

Laboratory of Polymer Chemistry

Group of Professors Yves Geerts and Guillaume Schweicher I ULB

Our research activities have focused on functional molecular materials to tailor their structural, thermal, optical, and electronic properties. We have designed, synthesized, and characterized organic semiconductors for charge transport and humidity sensors. We have also progressed in the understanding of polymorphism of molecular systems by investigating the dynamics of crystals and substrate-induced phases. Finally, we have contributed by a synthetic approach towards the obtaining of functional nanodiamonds.

Organic semiconductors are made of aromatic molecules that have delocalized electrons over their entire structures. In crystals, electrons are even partially shared by adjacent molecules and the materials become semiconducting, i.e. their electrical conductivity can be varied by injecting charges.[1,2,3] The variable conductivity is exploited in field effect transistors and in sensors. We have achieved humidity sensors reaching state of the art performances.[4] Our work contributes elucidating the transport properties of electrons, but also of protons at the interface with a dielectric layer.

Polymorphism is the formation of more than one crystal structure for a given molecule. Crystal structures rule solid-state properties and hence semiconductor properties.[5,6] The solubility and thus the bioavailability of pharmaceutical drugs depends also on their crystal structures that play a truly pivotal role. Nowadays, a fundamental understanding of polymorphism still lacks. Some organic molecules exhibit many polymorphs whereas others do not show any. Polymorphism is sometimes hard to control and the reproducible obtaining of a desired form is compromised,

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1 "Dinaphthotetrathienoacenes: Synthesis, Characterization, and Applications in Organic Field-Effect Transistors" Rémy Jouclas, Jie Liu, Martina Volpi, Lygia Silva de Moraes, Guillaume Garbay, Nemo McIntosh, Marco Bardini, Vincent Lemaur, Alexandre Vercouter, 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. 2022, 9, 2105674

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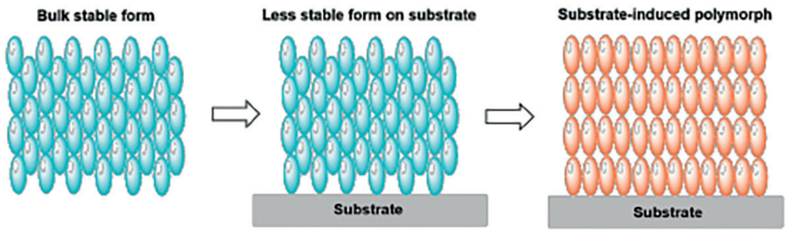
3 "Charge transfer complexes of a benzothienobenzothiophene derivative and their implementation as active layer in solution-processed thin film organic field-effect transistors" Lamiaa Fijahi, Tommaso Salzillo, Adria´n Tamayo, Marco Bardini, Christian Ruzié, Claudio Quarti, David Beljonne, Simone d'Agostino, Yves H. Geerts, Marta Mas-Torrent, J. Mater. Chem. C, 2022, 10, 7319-7328

4 "High-Performance Humidity Sensing in pi-conjugated molecular assemblies through the Engineering of Electron/Proton Transport and Device Interfaces" Nicholas Turetta, Marc-Antoine Stoeckel, Rafael Furlan de Oliveira, Félix Devaux, Alessandro Greco, Camila Cendra, Sara Gullace, Mindaugas Gicevičius, Basab Chattopadhyay, Jie Liu, Guillaume Schweicher, Henning Sirringhaus, Alberto Salleo, Mischa Bonn, Ellen H.G. Backus, Yves H. Geerts, Paolo Samorì J. Am. Chem. Soc. 2022, 144, 2546-2555

5 "Discovering Crystal Forms of the Novel Molecular Semiconductor OEG-BTBT" Priya Pandey, Nicola Demitri, Lara Gigli, Ann Maria James, Félix Devaux, Yves Henri Geerts, Enrico Modena, Lucia Maini, Cryst. Growth Des. 2022, 22, 1680-1690

6 "Discovering Crystal Forms of the Novel Molecular Semiconductor OEG-BTBT" Priya Pandey, Nicola Demitri, Lara Gigli, Ann Maria James, Félix Devaux, Yves Henri Geerts, Enrico Modena, Lucia Maini, Cryst. Growth Des. 2022, 22, 1680-1690 such as the sad example of ritonavir. In the summer of 1998, a sudden change in the solubility of this drug, which is a HIV protease inhibitor, brought its production to a halt and led to an interruption affecting the millions of HIV patients under medical care. The crystal form of Ritonavir had unexpectedly changed to a less soluble polymorph. So far, efforts to shed light over polymorphism have mainly focused on solution-based crystallization processes, namely through screening of solvent and temperature effects on the thermodynamics and kinetics of crystallization. We approach the issue of polymorphism differently, notably by searching for substrate-induced phases, i.e. crystal phases that exist only in contact or in vicinity of rigid substrates.[7,8,9,10] Substrate-induced polymorphs cast a completely different light on heterogeneous nucleation since the crystal forms that nucleate on the surface of a rigid body, e.g. a dust particle, differ from those in bulk. In parallel, we study the dynamics within crystals because intermolecular vibrations contribute to the entropic term of the Gibbs free energy and thus on the overall stability of crystals.[11]

Functional nanodiamonds, are nanometer size diamonds containing NV- vacancies that confer them extraordinary properties, for example they serve to measure temperature, locally in cells with unprecedented resolution and accuracy. Nanodiamonds are, however, very difficult to synthesize because they require high temperature (800-1000 K) and high pressure conditions (at least 10 000 atm). We aim to synthesizing nanodiamonds in milder conditions allowing a better control of their size, structure and performances by starting with tailored molecular precursors. To this end, we have synthesized a library of molecular systems that we are now converting into nanodiamonds.[12]



7 "Molecular Packing of Phenoxazine: A Combined Single-Crystal/ Crystal Structure Prediction Study" Martin Kaltenegger, Louis Delaive, Sai Manoj Gali, Patrick Brocorens, Oliver Werzer, Hans Riegler, Yves Henri Geerts, Roberto Lazzaroni, Roland Resel, Jie Liu Cryst. Growth Des. 2022, 22, 1548-1553

8 "From 2D to 3D: Bridging Self-Assembled Monolayers to a Substrate-Induced Polymorph in a Molecular Semiconductor" Yansong Hao, Gangamallaiah Velpula, Martin Kaltenegger, Wolfgang Rao Bodlos, Francois Vibert, Kunal S. Mali, Steven De Feyter, Roland Resel, Yves Henri Geerts, Sandra Van Aert, David Beljonne, and Roberto Lazzaroni, Chem. Mater. 2022, 34, 2238-2248

9 "Engineering of a kinetically driven phase of phenoxazine by surface crystallisation" Martin Kaltenegger, Sebastian Hofer, Roland Resel, Oliver Werzer, Hans Riegler, Josef Simbrunner, Christian Winkler, Yves Geerts, Jie Liu, CrystEngComm, 2022, 24, 4921-4931

10 "Temperature-induced polymorphism of a benzothiophene derivative: reversibility and impact on the thin film morphology" Shunya Yan, Alba Cazorla, Adara Babuji, Eduardo Solano, Christian Ruzié, Yves H. Geerts, Carmen Ocal, Esther Barrena, Phys. Chem. Chem. Phys., 2022, 24, 24562–24569

11 "Chemical Modifications Suppress Anharmonic Effects in the Lattice Dynamics of Organic Semiconductors" Maor Asher, Remy Jouclas, Marco Bardini, Yael Diskin-Posner, Nitzan Kahn, Roman Korobko, Alan R. Kennedy, Lygia Silva de Moraes, Guillaume Schweicher, Jie Liu, David Beljonne, Yves Geerts,Omer Yaffe ACS Mater. Au 2022, 2, 6, 699-708

12 "Synthesis and Structural Properties of Adamantane-Substituted Amines and Amides Containing an Additional Adamantane, Azaadamantane or Diamantane Moiety" Maxime Bonsir, Alan R. Kennedy, and Yves Geerts ChemistryOpen 2022, e202200031

THE ROBERT BROUT PRIZES 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 2022, the prizes have been awarded to:

- Luka Dockx (Ilya Prigogine Prize VUB)
- Jérôme Bailly (Ilya Prigogine Prize ULB)
- Simone Vitale et Nicolas De Ro (Robert Brout Prizes ULB)

06

APPENDIX

CURRICULUM VITAE OF THE ACADEMIC SESSION PANELISTS

Philippe Aghion

Philippe Aghion is a French economist who is a Professor at College de France, at INSEAD, and at the London School of Economics and a fellow of the Econometric Society and of the American Academy of Arts and Sciences. His research focuses on the economics of growth. With Peter Howitt, he pioneered the so-called Schumpeterian Growth paradigm which was subsequently used to analyze the design of growth policies and the role of the state in the growth process.

Much of this work is summarized in their joint book *Endogenous Growth Theory* (MIT Press, 1998) and *The Economics of Growth* (MIT Press, 2009), in his book with Rachel Griffith on Competition and Growth (MIT Press, 2006), and in his survey “What Do We Learn from Schumpeterian Growth Theory” (joint with U. Akcigit and P. Howitt.)

In 2001, Philippe Aghion received the Yrjo Jahnsson Award of the best European economist under age 45, in 2009 he received the John Von Neumann Award, and in March 2020 he shared the BBVA “Frontier of Knowledge Award” with Peter Howitt for “developing an economic growth theory based on the innovation that emerges from the process of creative destruction.”

Alena Budinská

Alena Budinská is a PhD student in the group of Prof. Dr. Helma Wennemers at the ETH Zürich, Switzerland. She was Intern in Roche Center of Excellence for Catalysis, F. Hoffmann-La Roche AG, Basel, Switzerland. She studied a MSc in Chemistry at ETH Zürich, Switzerland and undertook a Master Thesis in the group of Dr. Dmitry Katayev and Prof. Dr. Antonio Togni, titled *Application of N-Nitroheterocycles in the Synthesis of Nitro(hetero) arenes*.

She has a BSc studies in Chemistry from the University of Chemistry and Technology, Prague, Czech Republic and a Bachelor Thesis in the group of Dr. Petr Beier at Institute of Organic Chemistry and Biochemistry, Prague, Czech Republic.

Nicolas Cudré-Mauroux

Nicolas Cudré-Mauroux is the Solvay General Manager for Research & Innovation since 2015. He has a MS and a PhD in Materials Science from the Swiss Institute of Technology (EPFL) in Lausanne, Switzerland. He spent the first part of his career with DuPont, starting in 1988 as a researcher at the Experimental Station, DuPont's central research facility in Wilmington, Delaware (USA).

Until 2006, he has held a range of R&D, technical, marketing and new business development leadership roles in the United States, Canada and Europe.

In 2006, Nicolas was named Regional Business Director for the Advanced Fibers Systems and Nonwovens businesses in EMEA.

In 2011, he joined the DuPont-Danisco integration team and, in 2012, moved to Denmark to become the Technology & Innovation Director for the food ingredient business that DuPont formed following this acquisition.

In 2015, Nicolas joined Solvay where he focuses on maximizing the impact of Research & Innovation investments. He is based at the corporate headquarters in Brussels, Belgium.

He is passionate about innovation management, focusing specially on value creation at the interface between R&D and markets. He is a member of the Royal Academy of Belgium, of the Board of Directors of CNRS (France) and of the Board of Governors of the Argonne National Lab (US).

In 2019, he received the "European CTO of the Year Award" from EIRMA.

Thomas Ebbesen

Thomas Ebbesen is professor of physical chemistry at the University of Strasbourg in France, known for his pioneering work in nanoscience. He received a Bachelor's degree from Oberlin College (USA) and a PhD in the field of photo-physical chemistry from the Pierre and Marie Curie University in Paris.

He is currently the director of the International Center for Frontier Research in Chemistry (ICFRC), and the University of Strasbourg Institute for Advanced Study (USIAS). For his pioneering and extensive contribution to the field of carbon nanotubes, he shared the 2001 EuroPhysics Prize with Sumio Iijima, Cees Dekker and Paul McEuen. Thomas Ebbesen received the 2014 Kavli Prize in Nanoscience together with Stefan Hell and Sir John Pendry for their transformative contributions to the field of nano-optics.

In 2015, Thomas Ebbesen was given an honorary Doctorate of Science by Oberlin College, in the presence of the First Lady of the United States, Michelle Obama, and was awarded an honorary doctorate by the University of Leuven in 2018.

He also received the Quinquennial Anniversary Award of the European Materials Research Society (E-MRS) in 2018. Thomas Ebbesen is a member of the Institut Universitaire de France (IUF), the Norwegian Academy of Science and Letters, the French Academy of Science and the Royal Flemish Academy of Belgium, and was made Knight of the French Legion of Honour in 2017.

He held the Liliane Bettencourt Chair of Technological Innovation at the Collège de France in 2017-2018. In 2019, he received the Grand Prix from the Fondation de la Maison de la Chimie for the development of the field of polaritonic chemistry, and the Gold Medal of the CNRS, the French National Centre for Scientific Research.

Ben Feringa

Ben Feringa was awarded the Nobel Prize in Chemistry in 2016 for the design and synthesis of molecular machines. He obtained his PhD degree at the University of Groningen in the Netherlands. After working as a research scientist at Shell in the Netherlands and at the Shell Biosciences Centre in the UK, he was appointed lecturer and in 1988 full professor at the University of Groningen and named the Jacobus H. van't Hoff Distinguished Professor of Molecular Sciences in 2004.

He was elected Foreign Honory member of the American Academy of Arts and Sciences and is member and vice-president of the Royal Netherlands Academy of Sciences. In 2008 he was appointed Academy Professor and was knighted by Her Majesty the Queen of the Netherlands.

Feringa's research has been recognized with a number of awards including the Koerber European Science Award (2003), the Spinoza Award (2004), the Prelog gold medal (2005), the Norrish Award of the ACS (2007), the Paracelsus medal (2008), the Chirality medal (2009),the RSC Organic Stereochemistry Award (2011), Humboldt Award (2012), the Grand Prix Scientifique Cino del Duca (French Academy 2012), the Marie Curie medal (2013) and the Nagoya Gold Medal (2013). The research interest includes stereochemistry, organic synthesis, asymmetric catalysis, optopharma, molecular switches and motors, self-assembly and molecular nanosystems.

Sossina M. Haile

Sossina Haile received her B.S and Ph.D (1992) from the Massachusetts Institute of Technology, and M.S. from the University of California, Berkeley. She carried out postdoctoral research at the Max Planck Institut für Festkörperforschung [Institute for Solid State Research], Stuttgart, Germany (1992-1993) as a Humboldt Fellow.

Haile joined Northwestern University in 2015, after having served 18 years on the faculty at the California Institute of Technology.

Sossina Haile's research broadly encompasses solid state ionic materials and devices, with particular focus on energy technologies. She has established a new class of fuel cells based on solid acid electrolytes and demonstrated record power densities for solid oxide fuel cells. Her more recent work on water and carbon dioxide dissociation for solar-fuel generation by thermochemical processes has created new avenues for harnessing sunlight to meet energy demands.

She is the recipient of several awards, including in 2008 an American Competitiveness and Innovation (ACI) Fellowship from the National Science Foundation in recognition of "her timely and transformative research in the energy field and her dedication to inclusive mentoring, education and outreach across many levels," the 2010 Chemical Pioneers Award of the Chemical Heritage Foundation, and the 2012 International Ceramics Prize for the World Academy of Ceramics.

In 2016 she was inducted into the African Academy of Sciences.

Andrew Fire

Andrew Fire enrolled at the University of California at Berkeley in 1975, receiving an AB degree in Mathematics in 1978. He then entered the Ph.D program in Biology at Massachusetts Institute of Technology as a National Science Foudation Fellow in 1978. From 1983 to 1986, he received training in the *Caenorhabditis elegans* group at the Medical Research Council Laboratory of Molecular Biology in Cambridge, England as a Helen Hay Whitney Foundation Fellow. During this time, he initiated research directed toward improvement of microinjection technology and development of assays for expression of foreign DNA in *C. elegans* worms.

During his last year at the MRC lab, he applied for a research position at the Carnegie Institution of Washington's Department of Embryology in Baltimore Maryland, also applying for an independent research grant from the US National Institutes of Health. Both applications were successful and he moved to Baltimore in 1986. In 1989, Fire was appointed as a regular staff member at the Carnegie, with his group continuing to develop DNA transformation technology and collaborating on a number of studies to understand the molecular basis of gene activation in muscle cells. Along with the appointment as a full staff member at Carnegie Institution, Fire also acquired an adjunct appointment as a faculty member in the Department of Biology at Johns Hopkins, where he was involved in both graduate and undergraduate teaching and mentoring.

In 2003, Dr. Fire moved to Santa Clara County, taking a position at the Stanford University School of Medicine, where he currently holds the title of Professor of Pathology and Genetics.

Andrew Fire was awarded the Nobel Prize in Physiology or Medicine in 2006.

Karen Goldberg

Karen Goldberg received her A.B. degree from Barnard College of Columbia University in New York City. As an undergraduate, she pursued research projects with Professor Roald Hoffmann at Cornell University, Professor Stephen Lippard at Columbia University, and Drs. Tom Graedel and Steven Bertz at AT&T Laboratories.

She then went on to the University of California at Berkeley where she earned her Ph.D. in Chemistry working with Professor Robert Bergman. Following a postdoctoral year with Professor Bruce Bursten at The Ohio State University, she joined the faculty at Illinois State University, a primarily undergraduate institution in Normal, IL.

In 1995, she moved to the University of Washington (UW) as Assistant Professor of Chemistry. She was awarded tenure at UW and rose through the ranks to full Professor.

In 2007 she became the first Raymon E. and Rosellen M. Lawton Distinguished Scholar in Chemistry, and in 2010 she became the first Nicole A. Boand Endowed Professor of Chemistry. She served as Director of the first National Science Foundation-funded Phase II Center for Chemical Innovation (CCI), the Center for Enabling New Technologies through Catalysis (CENTC) from 2007-17.

In 2107, she moved to the University of Pennsylvania as a Vagelos Professor of Energy Research and is the inaugural Director of the Vagelos Institute of Energy Science and Technology (VIEST).

André Hoffmann

Andre Hoffman is the Vice-Chairman of the Board of Roche Holding Ltd., Basel, Switzerland. Andre Hoffman is the great-grandson of Fritz Hoffmann-La Roche who founded the drug company Roche Holding in 1896, he is currently the vice-chairman of the company and as of November 2020.

He studied economics at the University of St. Gallen, and holds an MBA from INSEAD, completed in 1990.

André Hoffmann is an environmentalist, involved in a number of not-for-profit organizations and initiatives related to sustainability and nature conservation. In 1998, he joined the WWF and served as vice-president of the organization from 2007 to 2017.

Since 2010, he has served as president of the MAVA Foundation, a major foundation in the field of nature preservation. In 2016, he was appointed President of Fondation Tour du Valat, a French research institute dedicated to Mediterranean wetland conservation.

He has also served on the boards of Wetlands International, Global Footprint Network and FIBA. In August 2018, Hoffmann and his wife Rosalie made a €40 million commitment to INSEAD, establishing the Hoffmann Global Institute for Business and Society. He is currently the chairman of its Advisory Board.

Gerald Joyce

Gerald Joyce is a professor in the Jack H. Skirball Center for Chemical Biology and Proteomics at the Salk Institute in La Jolla, California. He also is institute director of the Genomics Institute of the Novartis Research Foundation (GNF).

He received his B.A. from the University of Chicago in 1978 and both an M.D. and a Ph.D. from the University of California, San Diego in 1984. He carried out postgraduate medical training at Scripps Mercy Hospital in San Diego and postdoctoral research training at the Salk Institute before joining the faculty of the The Scripps Research Institute in 1989. In 2017 he moved his laboratory to the Salk Institute.

Gerald Joyce has published over 150 scientific papers and is the inventor of 11 issued patents. He is a member of the U.S. National Academy of Sciences, the U.S. National Academy of Medicine and the American Academy of Arts and Sciences. In 2005 he received the H.C. Urey Award, presented every six years by the International Society for the Study of the Origin of Life; in 2009 he received the Dannie Heineman Prize, presented every two years by the Göttingen Academy of Sciences; and in 2010 he received the U.S. National Academy of Sciences' Stanley Miller Medal, presented every five years in association with the Award in Early Earth and Life Sciences. He has lectured extensively around the world, including at the Pontifical Academy and the Royal Swedish Academy of Sciences.

Yamuna Krishnan

Yamuna Krishnan is a professor at the Department of Chemistry, University of Chicago, where she has worked since August 2014. She was earlier a Reader in National Centre for Biological Sciences, Tata Institute of Fundamental Research, Bangalore, India. Krishnan won the Shanti Swarup Bhatnagar Prize for science and technology, the highest science award in India in the year 2013 in the Chemical Science category.

Krishnan earned her Bachelor's in Chemistry from the University of Madras, Women's Christian College, Chennai, India in 1993. She secured a Master of Science in Chemical Sciences in 1997 and a PhD in Organic Chemistry in 2002, both from the Indian Institute of Science, Bangalore. Krishnan worked as a postdoctoral research fellow and an 1851 Research Fellow from 2001 to 2004 at the Department of Chemistry at the University of Cambridge, UK.

Krishnan was a Fellow 'E' at National Centre for Biological Sciences from 2005 to 2009, at the TIFR in Bangalore, India, and then tenured Reader 'F' from 2009 to 2013 at the National Centre for Biological Sciences, TIFR, Bangalore, India. In 2013, she was promoted to Associate Professor 'G' at the National Centre for Biological Sciences, TIFR, Bangalore, India and moved to University of Chicago as a Professor of Chemistry in August 2014.

Krishnan was a recipient of the Wellcome Trust -DBT Alliance Senior Research Fellowship in 2010, the Indian National Science Academy Young Scientist Medal in 2007, Innovative Young Biotechnologist Award from the Dept. of Biotechnology, Govt. of India, in 2006, and the Infosys Prize 2017 in the Physical Sciences category.

Maria Leptin

Professor Maria Leptin is the President of the European Research Council (took office from 1 November 2021).

Prior to that, Professor Leptin served as Director of EMBO from 2010-2021. She also established a research group in Heidelberg at the European Molecular Biology Laboratory (EMBL).

The group studies the mechanics of shape determination during development. After completing her studies in mathematics and biology at the University of Bonn and the University of Heidelberg, Professor Leptin worked for her PhD at the Basel Institute for Immunology, Switzerland (1979-1983) studying B-lymphocyte activation under the supervision of Fritz Melchers.

In 1984 she moved, as a post-doctoral fellow (1984-1987) to the Laboratory of Molecular Biology (LMB), Cambridge, UK, where she started her research on the embryonic development of Drosophila, joining the laboratory of Michael Wilcox. This work laid the foundations for her future work in the field of molecular morphogenesis. In 1988, she was appointed as staff scientist at the same institution. As visiting scientists in Pat O'Farrell's lab at the University of California, San Francisco (UCSF) she began her work on gastrulation which became the core of her research interests at the Max Planck Institute for Developmental Biology in Tübingen, Germany, where she worked as group leader (1989-1994).

In 1994, Maria Leptin became Professor at the Institute of Genetics, University of Cologne, Germany, where she still leads a research group. She spent sabbaticals as a visiting Professor at the École Normale Supérieure, Paris, France (2001) and as visiting scientist at the Wellcome Trust Sanger Institute, Hinxton, UK (2004-2005).

Professor Leptin is an elected member of EMBO, the Academia Europaea and the German National Academy of Sciences (Leopoldina), and an Honorary Fellow of the Academy of Medical Sciences. She is also Foreign Member of the Royal Society since May 2022.

Stefan Lutz

Stefan Lutz joined Codexis in 2020 as the Senior Vice President of Research to lead the company's research team advancing the discovery of proteins. Prior to his arrival in Redwood City, he was a Professor and Chair of the Chemistry Department at Emory University, having joined the university in 2002 and ascending to Chemistry Department Chair in 2014.

In addition to his academic work, he has consulted for AgriMetis and served on the scientific advisory boards of ZuvaChem, CODA Genomics Inc. and SynBioX Inc.

Stefan has co-authored more than 65 articles published in peer-reviewed journals and six technical books and journals. He holds six patents and is a frequent lecturer and speaker. Dr. Lutz received a B.Sc. in chemistry/chemical engineering from the Zurich University of Applied Sciences, an M.Sc. in Biotechnology from the University of Teesside and a Ph.D. in chemistry from the University of Florida. He was a postdoctoral fellow at Pennsylvania State University.

Jean-Marie Lehn

Jean-Marie Lehn is Professor at the University of Strasbourg Institute for Advanced Study (USIAS), Emeritus Professor at the University of Strasbourg, and Honorary Professor at the Collège de France in Paris. In 1968, he achieved the synthesis of cage-like molecules (cryptands) containing a cavity (crypt) into which another entity, molecule or ion of specific nature, can be lodged, forming a cryptate.

In 1987, Jean Marie Lehn was awarded the Nobel Prize in Chemistry, together with Donald Cram and Charles J. Pedersen.

Professor Lehn founded the *Institute of Supramolecular Science and Engineering* (ISIS) in Strasbourg in 2002. He has been involved in a large number of public and private boards and committees and also participated in several start-up companies. As president of the non-governmental International Organization for Chemical Sciences in Development (IOCD), he aims, together with a group of dedicated colleagues, to contribute to helping chemists in developing countries. He is the author of over 1000 scientific publications and two books, and member of many academies and institutions. He has received numerous international honours and awards, among them *Officer of the French National Order of Merit* (1993), *Grand Officer of the French Legion of Honour* (2014), *Österreichisches Ehrenzeichen für Wissenschaft und Kunst*, (Austrian Decoration for Science and Art -first class, 2001), the *Grosses Verdienstkreuz mit Stern der Bundesrepublik Deutschland* (Knight Commander's Cross of the Order of Merit of the Federal Republic of Germany - 2009), and was conferred the Order of the Rising Sun, Second Class, Gold and Silver Star by the Government of Japan (2019).

Bert Meijer

E.W. "Bert" Meijer is Distinguished University Professor in the Molecular Sciences, Professor of Organic Chemistry at the Eindhoven University of Technology and co-director of the Institute for Complex Molecular Systems. After receiving his PhD degree at the University of Groningen with Hans Wynberg, he worked for 10 years in industry (Philips and DSM).

In 1991 he was appointed in Eindhoven, while in the meantime he has part-time positions in Nijmegen, MPI-Mainz, and Santa Barbara, CA. Bert Meijer is a member of many editorial advisory boards, including Advanced Materials and is associate editor of the Journal of the American Chemical Society.

Bert Meijer has received several awards, including the Spinoza Award in 2001, the ACS Award for Polymer Chemistry in 2006, the AkzoNobel Science Award 2010, the International Award of the Society of Polymer Science Japan in 2011, the Cope Scholar Award of the ACS in 2012, the Prelog Medal in 2014, the Nagoya Gold Medal in 2017 and the Chirality Medal in 2018. In 2020 he is knighted by the king to be Commander in the Order of the Netherlands Lion. He is an honorable member of several academies and societies, including the Royal Netherlands Academy of Science, where he is appointed to Academy Professor in 2014. Since 2022 he is also a visiting professorial fellow of the University of New South Wales in Sydney, Australia.

Bertrand Piccard

Bertrand Piccard is a Swiss explorer, psychiatrist and environmentalist. Along with Brian Jones, he was the first to complete a non-stop balloon flight around the globe, in a balloon named Breitling Orbiter 3. He was the initiator, chairman, and pilot, with André Borschberg, of Solar Impulse, the first successful round-the-world solar-powered flight. In 2012 Piccard was designated as a Champions of the Earth by the UN Environment Programme.

As a child, Piccard was taken to the launch of several space flights from Cape Canaveral. He developed early interests in flight and human behaviour in extreme situations. He received a degree from the University of Lausanne in psychiatry. He has since become a lecturer and supervisor at the Swiss Medical Society for Hypnosis (SMSH).

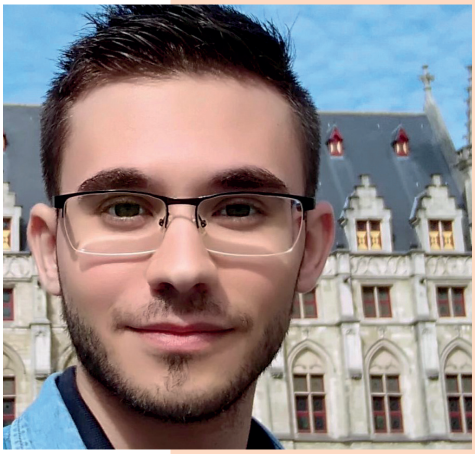
Piccard obtained licences to fly balloons, airplanes, gliders, and motorized gliders. In Europe, he was one of the pioneers of hang gliding and microlight flying during the 1970s. He became the European hang-glider aerobatics champion in 1985.

Founder and Chairman of the Solar Impulse Foundation, he has succeeded with his team to select 1000 efficient solutions to protect the environment in a profitable way. Whether it is to protect the environment or to reduce inequalities, Bertrand seeks to highlight solutions by developing synergies where others see only oppositions. To support his approach, he strives to unite the forces involved, raise public awareness and encourage political action.

Bertrand has become a prominent speaker, invited to express his vision of the pioneering spirit at public, private and institutional events. Bertrand is currently United Nations Ambassador for the Environment and Special Advisor to the European Commission.

Pablo Serna Gallén

Pablo Serna Gallén is a Ph.D. student at the University Jaume I (UJI) of Castellón (Spain) in the area of Inorganic Chemistry. He obtained the Bachelor's Degree in Chemistry (2018, awarded with special honors) and the Master's Degree in Applied and Pharmacological Chemistry (2019) with further specialization in Advanced Materials at UJI. Over the last years, he has obtained more than 20 national and regional awards and distinctions for his academic, research, or dissemination career.



Pablo develops his work in the Solid State Chemistry group of the UJI, where he has studied multifunctional and technological materials with optical and electrical properties, as well as the development of new sustainable and advanced ceramic pigments with remarkable industrial applications. Currently, his main lines of research are based on the design, preparation, and characterization of lanthanide ion-doped fluorides coated with plasmonic nanoparticles that have important luminescent applications.

In 2020 Pablo was appointed member of the Governing Board of the Official Chemists College of the Valencian Community, where he boosts his collaborations and links with the chemical industrial sector. Furthermore, he has been recently appointed Delegate in Castellón of this institution, so he represents and leads it in the Province of Castellón.

Jean Stéphenne

Jean, Baron Stéphenne is a Belgian businessman. He studied chemistry and bioindustries and obtained an MSc degree at the Faculté universitaire des sciences agronomiques de Gembloux in 1972 and an MBA degree from the Université catholique de Louvain in 1982.

Jean Stéphenne joined Smith Kline-RIT (now Glaxo Smith Kline Biologicals) in 1974 as head of bacterial and viral vaccines production, he became vaccine production director in 1980.

From 1981 to 1991, he served as vaccine plant director and R&D director.

From 1988 to 1991, he was vice president of human vaccines research and development and production. From 1991 to 1998 he led the vaccines division, first as vice president and general manager, then senior vice president and general manager, until his appointment as president and general manager in 1998. Since 1998, Jean Stéphenne is president and general manager of GlaxoSmithKline Biologicals.

In 2001, Stéphenne was raised into the Belgian nobility by King Albert II and given the noble title Baron for life.

Since 2013, Jean Stéphenne is shareholder and chairman of OncoDNA.

Since September 2015 he was a member of the supervisory board of CureVac, a German biopharmaceutical company specialising in mRNA-based drugs. In April 2020, he was appointed as the chairman of the company.

Jack Szostak

Jack Szostak is a biochemist and geneticist who was awarded the 2009 Nobel Prize for Physiology or Medicine, along with American molecular biologists Elizabeth H. Blackburn and Carol W. Greider, for his discoveries concerning the function of telomeres (segments of DNA occurring at the ends of chromosomes), which play a vital role in determining cell life span.

Szostak also investigated the process of chromosomal recombination during cell division and conducted studies into the role of RNA in the evolution of life on early Earth.

Szostak received a bachelor's degree in cell biology from McGill University in Montreal in 1972 and received a Ph.D. in biochemistry from Cornell University in Ithaca, N.Y., in 1977. After working as a research associate at Cornell from 1977 to 1979, Szostak took a position as assistant professor in the department of biological chemistry of the Sidney Farber Cancer Institute (now the Dana-Farber Cancer Institute) at Harvard Medical School.

In 1998 he became a Howard Hughes Medical Institute investigator and was elected a member of the National Academy of Sciences. He was also elected a member of the American Academy of Arts and Sciences and a fellow of the New York Academy of Sciences. In addition to the 2009 Nobel Prize, he received a variety of other awards during his career, including the Albert Lasker Basic Medical Research Award in 2006 (shared with Blackburn and Greider).

Hennie Valkenier

Hennie Valkenier studied Chemistry at the University of Groningen (NL) and obtained her PhD from this university in 2011 with a thesis on Molecular Electronics. After a year of teaching in West-Africa, she joined the group of Tony Davis at the University of Bristol as a post-doc to develop transmembrane transporters for chloride.

In 2015, she moved to Brussels where she worked for a year on the functionalisation of gold nanoparticles, before returning to transmembrane transport research as Postdoctoral Researcher (Chargée de Recherches), funded by the FRS-FNRS.

In 2018, she has obtained a permanent position as FNRS Research Associate at the Université libre de Bruxelles and has been awarded an ERC starting grant to develop new classes of transporters for ions and nucleotides (ORGANITRA).

Gunnar von Heijne

Professor Nils Gunnar Hansson von Heijne is a Swedish scientist working on signal peptides, membrane proteins and bioinformatics at the Stockholm Center for Biomembrane Research at Stockholm University.

Gunnar von Heijne graduated in 1975 with a Master of Science degree in chemistry and chemical engineering from the Royal Institute of Technology (KTH). He then became a doctoral student in theoretical physics at KTH, in a research group focussing on statistical mechanics and theoretical biophysics, and was awarded his Ph.D. in 1980.

In 1983 he was made docent in theoretical biophysics at KTH, where he remained until 1988. 1982-1985 he was active as a science reporter at Sveriges Radio. 1989-1994 he was active at Karolinska Institutet, and in 1994 he was made a professor in theoretical chemistry at Stockholm University.

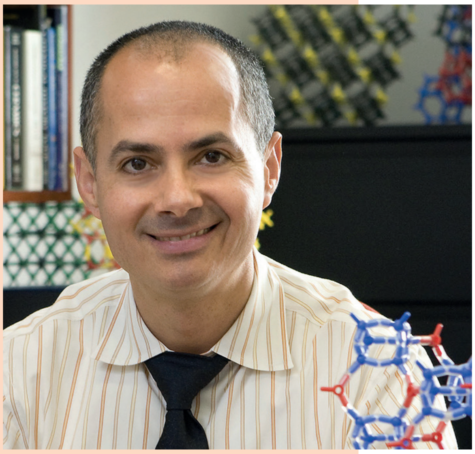
In 2012 he was awarded the Accomplishment by a Senior Scientist Award by the International Society for Computational Biology.

von Heijne is a member of the Royal Swedish Academy of Sciences since 1997 and a member of the Nobel Committee for Chemistry from 2001 to 2009, and the Committees chairman from 2007 to 2009. In 2008, he received an honorary doctorate at Åbo Akademi.

He was the director of the Center for Biomembrane Research, from 2006 to 2015, Vice Director at the Science for Life Laboratory Stockholm from 2009 to 2015. And Director of the SciLifeLab National Cryo-EM Facility, from 2016 to 2021.

Omar M. Yaghi

Omar M. Yaghi received his B.S. degree from State University of New York-Albany (1985), and Ph.D. from the University of Illinois-Urbana (1990) with Professor Walter G. Klemperer. He was an NSF Postdoctoral Fellow at Harvard University (1990-92) with Professor Richard H. Holm. He has been on the faculties of Arizona State University (1992-98), University of Michigan (1999-2006), and UCLA (2007-2011). He is currently the James and Neeltje Tretter Chair Professor of Chemistry at UC Berkeley, and a Senior Faculty Scientist at Lawrence Berkeley National Laboratory. He is the Founding Director of the Berkeley Global Science Institute. He is also the Co-Director of the Kavli Energy NanoScience Institute, and the California Research Alliance by BASF.



The building block approach to chemistry that he developed has led to an exponential growth in the creation of new materials having a diversity and multiplicity previously unknown in chemistry. He termed this field 'Reticular Chemistry' and defines it as 'stitching molecular building blocks into extended structures by strong bonds'

His work on hydrogen storage was recognized by Popular Science Magazine which listed him among the 'Brilliant 10' scientists and engineers in USA (2006), and the US Department of Energy Hydrogen Program Award for outstanding contributions to hydrogen storage (2007). He is also the recipient of numerous awards, among which the American Chemical Society Chemistry of Materials Award (2009), the United Kingdom's Royal Society of Chemistry Centenary Prize (2010), the King Faisal International Prize in Science (2015), the King Abdullah II Order of Distinction of the First Class (2017), the Japan Society of Coordination Chemistry International Award (2017), the Kuwait Prize in Fundamental Sciences (2017), the Albert Einstein World Award of Science conferred by the World Cultural Council (2017), the BBVA Foundation Frontiers of Knowledge Award in Basic Sciences (2018), and the Wolf Prize in Chemistry (2018). He published over 250 articles, which have received an average of over 300 citations per paper. He is among the top five most highly cited chemists worldwide.

OVERVIEW OF THE INSTITUTES

through selected data

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

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 - present	Kurt Wüthrich, 2002 Nobel Laureate in Chemistry, Zurich (Switzerland) and La Jolla (USA)

The International Solvay Chairs in Physics and in Chemistry

Jacques Solvay Chair in Physics

2006	Ludwig Faddeev Saint-Petersburg, Russia
2007	Michael Berry, Bristol, UK
2008	David Gross, Santa Barbara, USA 2004 Nobel Laureate in Physics
2009	Valery Rubakov, Moscow, Russia
2010	Serge Haroche, Paris, France 2012 Nobel Laureate in Physics
2011	Nathan Seiberg, Princeton, USA
2012	Jan Zaanen, Leiden, The Netherlands
2013	Gian Giudice, CERN, Switzerland
2014	Viatcheslav F. Mukhanov LMU Munich, Germany
2015	Peter Zoller, Innsbruck, Austria
2016	Dam Thanh Son, Chicago, USA
2017	Uri Alon, Rehovot, Israel
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

Solvay Chair in Chemistry

2008	Richard Saykally, Berkeley, USA
2009	Alexander Mikhailov, Berlin, Germany
2010	Weitao Yang, Durham, USA
2011	Jean-Luc Brédas, Atlanta, USA
2012	Viola Vogel, Zurich, Switzerland
2013	Egbert Meijer Eindhoven, The Netherlands
2014	Richard 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

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"
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2014 Nobel Laureate in Chemistry

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by Eva Nogales (UC Berkeley, USA)

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

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by Aleksandra Walczak (ENS, Paris, France)

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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

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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)

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"What is Life?"
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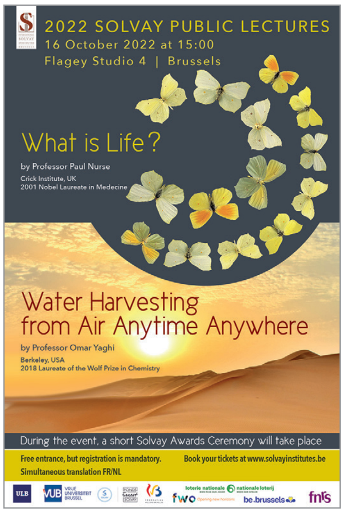

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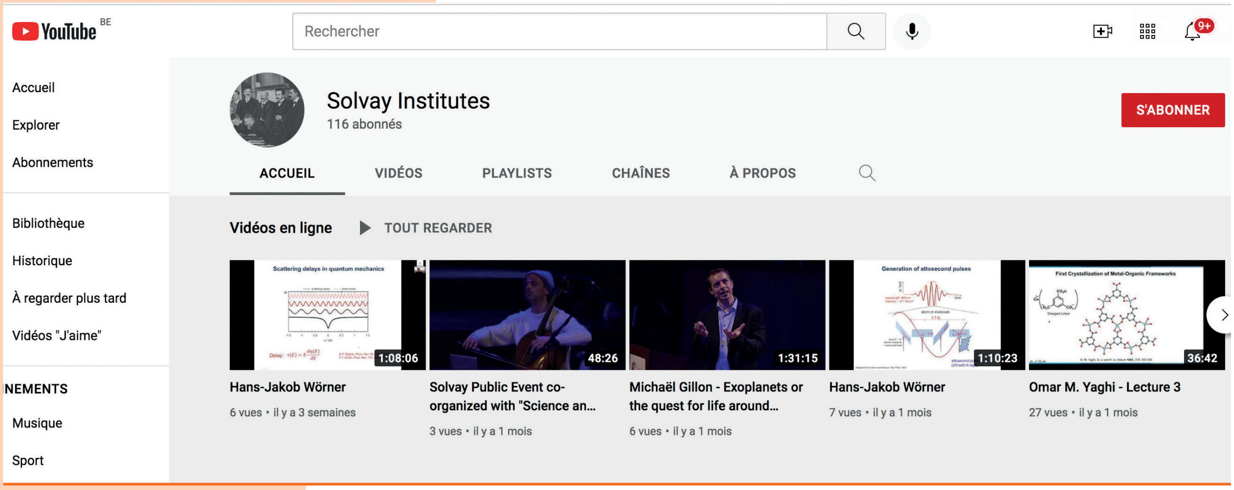

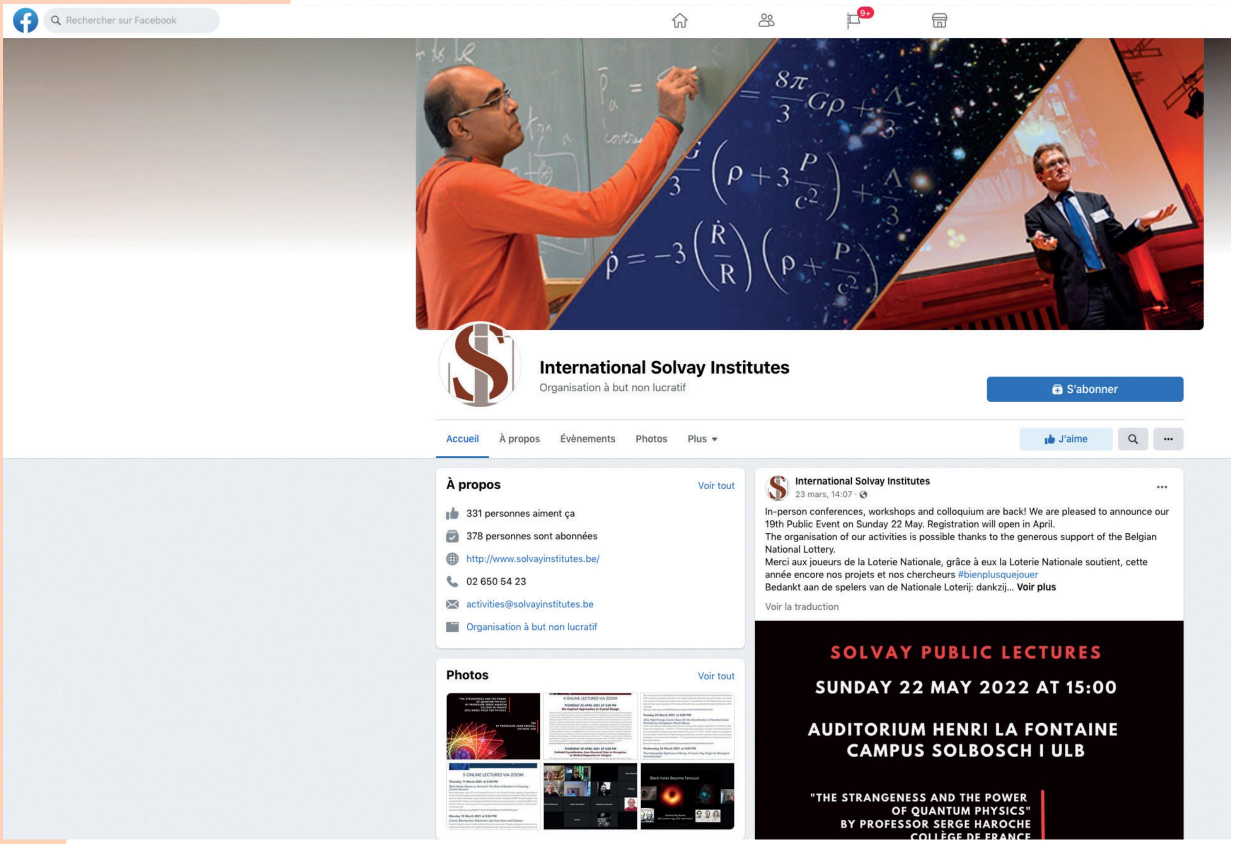

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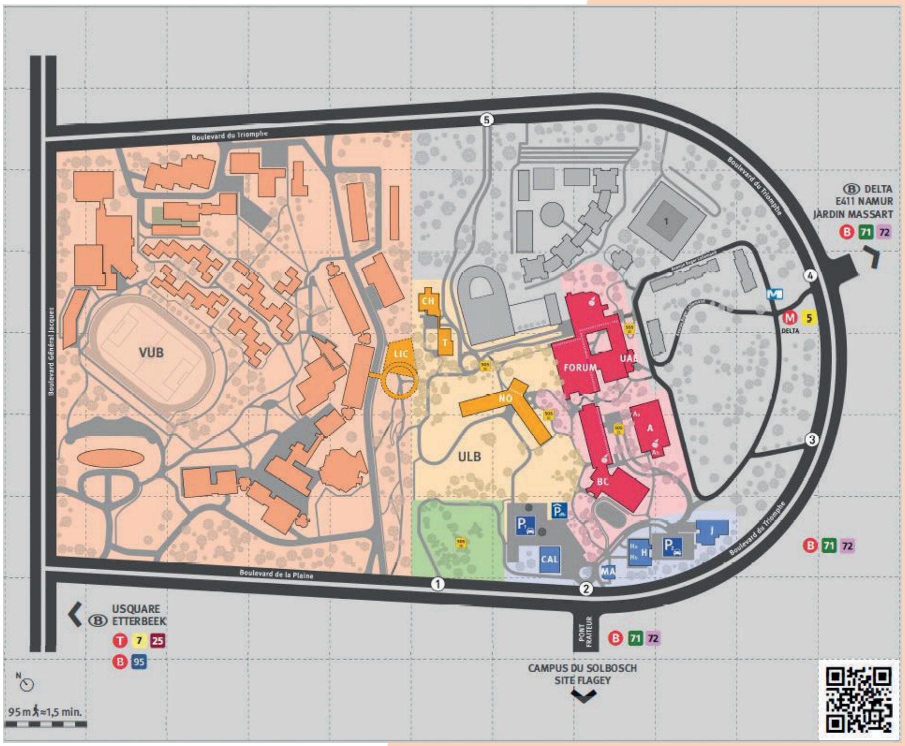

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