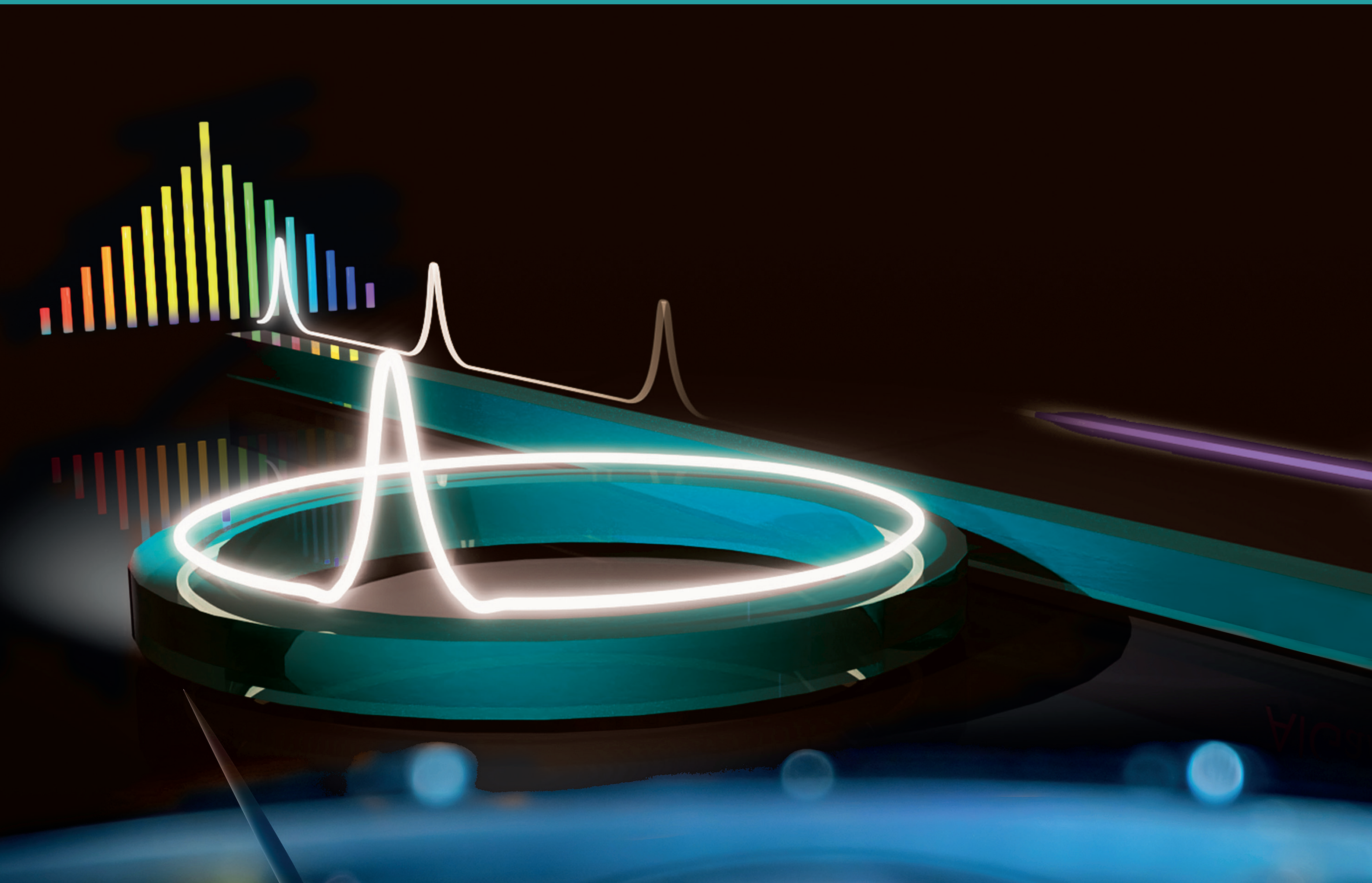
2021

ANNUAL REPORT

Instituts Internationaux de Physique et de Chimie fondés par Ernest Solvay asbl
Internationale Instituten voor Fysica en Chemie gesticht door Ernest Solvay vzw



2021

ANNUAL REPORT

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

Internationale Instituten voor Fysica en Chemie
gesticht door Ernest Solvay vzw

THERE ARE NO LIMITS TO WHAT

ERNEST SOLVAY

SCIENCE CAN EXPLORE

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

THE SOLVAY FAMILY

loterie nationale
BIEN PLUS QUE JOUER
nationale loterij
MEER DAN SPELEN

VUB
VRIJE UNIVERSITEIT BRUSSEL

ULB

SOLVAY

Progress beyond

be.brussels

FÉDÉRATION
WALLONIE-BRUXELLES

fnrs
LA LIBERTÉ DE CHERCHER

fwo Opening new horizons


STED
MINFLUX
PALM/STORM
1 nm
10 nm

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.

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A WORD FROM THE PRESIDENT

This year again, we spent much of our energies managing the uncertainties created by the pandemic that was obstinate in its grip on our society. We were left with shots in the dark, hoping for a reprieve during the summer and fall. Indeed, luck was with us, the virus relented for a short while and we were able to organize during a three-month window, a significant number of activities, among which two public events for which we had made our calculated bets. Thus, we were able to bring our community of science driven enthusiasts together to meet our outstanding speakers. I will focus here on the two public events, which constitute a key element of our mission.

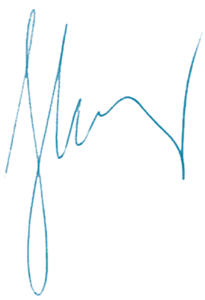
The first event happened on September 12th: Solvay's CEO's Ilham Kadri made the opening address and presided over the celebration of the Solvay awards. Then three distinguished scientists, Professor Jean Marie Lehn (U. de Strasbourg), Professor Bert Meijer (TU. Eindhoven) and Professor Aleksandra Walczak (École Normale Supérieure, Paris) each presented their latest research topics ranging from complex chemistry, the creation of artificial life to immunology. The public reacted fondly to the scientific presentations in person and in particular during the Q & A sessions, after months of virtual interactions.

The second event was held on 24 of October: we were able to repeat the in-presence gathering at the Flagey conference hall. This time with an even more relax format: science and cocktails!

In other words, science and art, and in this case: music. The scientific presentation was done by Professor Michael Gillon (U. Liège) that kept us on the edge of our seats with exoplanets. The music piece was performed by Benjamin Glorieux. The two events were separated by a gathering at the bar, the first such gathering for most participants in 18 months. Needless to say that the spirits were high!

In the end, this was a year of resilience and determination in tackling many obstacles. My sincere thanks go to the executive team for their unbending spirit and professionalism: Professor Marc Henneaux (Director), Dominique Bogaerts (Office Manager) and Isabelle Van Geet (Project Coordinator).

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



Jean-Marie Solvay | President

The year 2021 was the second year in which the activities of the International Solvay Institutes were impacted by the Covid-19 pandemic. Due to the positive evolution of the sanitary restrictions during and after the Spring, we could nevertheless hold a significant fraction of our scheduled program face-to-face, before the Omicron variant struck the world in December. We have been able in that manner, sometimes by using virtual or hybrid modes, to catch up with our 2020 program and to hold most of our scheduled 2021 activities.

A notable exception is the 28th Solvay conference on physics. Initially planned to take place in October of 2020, it was successively postponed to October of 2021 and now to May of 2022. We very much look forward to this important event and hope that by the end of 2022, we will be back to a normal state and will have almost entirely caught up with the backlog.

This report describes the activities organized or supported by the International Solvay Institutes during the year 2021. 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. I would just like to stress here how cheerful it was to see the studio 4 of Flagey filled up again with our loyal public, who came with the same enthusiasm to attend our two public events on September 12 (which was actually our postponed 2020 event) and on October 24 (our annual 2021 event). We were overcome by the same feelings of joy and relief at the first scientific activities that could physically take place in the Solvay room, marking the re-start of our in-person program.

A WORD FROM THE DIRECTOR

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 also outlined.

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 Brussels Capitale Region, the Fédération Wallonie-Bruxelles, the FWO, the FNRS, the Solvac holding, 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 remarkable efficiency and dedicated commitment of Dominique Bogaerts and Isabelle Van Geet whose involvement has been key in managing this difficult and tiring period, with repeated reschedulings, is again gratefully acknowledged.

Marc Henneaux | Director

01

GENERAL INFORMATION

BOARD OF DIRECTORS

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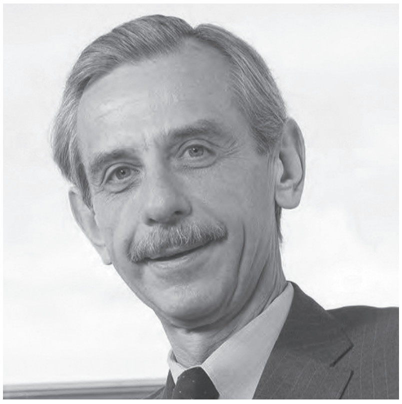
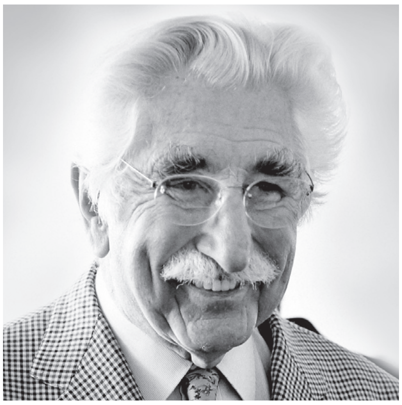


Eric Boyer de la Giroday
| Honorary Chairman of the Board of Directors ING Belgium sa/nv



Daniel Janssen
| Former Chairman of the Board of Directors of the Solvay Group

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Former Deputy Director for Chemistry
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Freddy Dumortier
Secretary of the Royal Flemish Academy for Science
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Marc Henneaux
Professor ULB
Director

Franklin Lambert
Emeritus Professor VUB

Alexander Sevrin
Professor VUB
Deputy Director for Physics and Scientific Secretary
of the International Committee for Physics

Marina Solvay
Chairwoman of the Archives Committee
of the Solvay Institutes

Didier Viviers
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

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Deputy Director for Physics
Secretary of the International Scientific Committee for Physics

Professor Gert Desmet VUB
Deputy Director for Chemistry

Professor Glenn Barnich ULB
Solvay Colloquia in Physics

Professor Ben Craps VUB
Doctoral School

Professor Anne De Wit ULB
Archives and Secretary of the International Scientific Committee for Chemistry

Professor Yves Geerts ULB
Solvay Colloquia and New Horizons Lectures in Chemistry

Administrative Staff

Ms Dominique Bogaerts
Office Manager

Ms Isabelle Van Geet
Project Coordinator

Mr Tahar Hmida
Accounting Officer

INTERNATIONAL SCIENTIFIC COMMITTEE FOR PHYSICS

Congratulations

The International Solvay Institutes were particularly honored and pleased to congratulate **Professor Parisi** who was awarded the 2021 Nobel Prize in Physics "for groundbreaking contributions to our understanding of complex systems", and in particular, “for the discovery of the interplay of disorder and fluctuations in physical systems from atomic to planetary scales”. Professor Parisi has been an active member of our International Scientific Committee for many years. His pioneering scientific contributions have opened entirely new fields in statistical mechanics and in the study of complex systems.

Chair

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

Scientific Secretary

Professor Alexander Sevrin
Vrije Universiteit Brussel, Belgium

Members

Professor Roger Blandford
Stanford University, USA

Professor Steven Chu
1997 Nobel Laureate
Stanford University, USA

Professor Fabiola Gianotti
CERN, Switzerland

Professor Bertrand Halperin
Harvard University, USA

Professor Wolfgang Ketterle
2001 Nobel Laureate
Massachusetts Institute of Technology, USA

Professor Juan Maldacena
IAS Princeton, USA

Professor Giorgio Parisi
2021 Nobel Laureate
Università La Sapienza, Roma, Italy

Professor Peter Zoller
University of Innsbruck, Austria

INTERNATIONAL SCIENTIFIC COMMITTEE FOR CHEMISTRY

In Memoriam

The International Solvay Institutes mourn the passing away of **Robert Grubbs** on December 19, 2021. Professor Robert Grubbs was a member of the international scientific committee for chemistry of the Institutes since 2011. He co-chaired the 24th Solvay Conference on Chemistry "Catalysis in Chemistry and Biology" which took place in 2016 and gave then one of the public lectures entitled "Translation of Academic Science into the Commercial". In 2005, he received the Chemistry Nobel Prize for chemistry with Yves Chauvin and Richard Schrock "for the development of the metathesis method in organic synthesis". He had accepted to participate in the forthcoming Solvay conference in October. We will deeply miss him.

Chair

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

Scientific Secretary

Professor Anne De Wit
Université Libre de Bruxelles, Belgium

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Harvard University, USA

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1989 Nobel Laureate
Boulder, Colorado, USA

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2007 Nobel Laureate
Fritz-Haber-Institut der Max-Planck-Gesellschaft
Berlin, Germany

Professor Ben Feringa
2016 Nobel Laureate
University of Groningen, The Netherlands

Professor Robert H. Grubbs †
2005 Nobel Laureate
California Institute of Technology, Pasadena, USA

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

Professor George M. Whitesides
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

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École Normale supérieure (ENS), Paris, France

Professor Leticia Cugliandolo
Université Pierre et Marie Curie – Paris VI, France

Professor Thomas Ebbesen
Université de Strasbourg, France

Professor Karen I. Goldberg
University of Pennsylvania, USA

Professor Bert Meijer
Eindhoven University of Technology, The Netherlands

Professor Hirosi Ooguri
California Institute of Technology, Pasadena, USA

Professor Gunnar von Heijne
Stockholm University, Sweden

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FOR PHYSICS

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Professor Giacomo Bruno I UCL, Louvain
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Professor Jean-René Cudell I ULg, Liège
Professor Jan Danckaert I VUB, Brussels
Professor Pierre Gaspard I ULB, Brussels
Professor Michaël Gillon I ULg, Liège
Professor Joseph Indekeu I KU Leuven
Professor Philippe Lambin I FUNDP, Namur
Professor Jean Manca I UHasselt
Professor Dirk Ryckbosch I UGent
Professor Alexander Sevrin I VUB, Brussels
Professor Jacques Tempere I UAntwerp
Professor Petr Tinyakov I ULB, Brussels
Professor Sophie Van Eck I ULB, Brussels
Professor Frank Verstraete I UGent

Observer

Professor Anne De Wit I ULB, Brussels

FOR CHEMISTRY

Chair

Professor Gert Desmet I VUB, Brussels

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Professor Benoît Champagne I FUNDP, Namur
Professor Pierre-François Coheur I ULB, Brussels
Professor Frank De Proft I VUB, Brussels
Professor Anne De Wit I ULB, Brussels
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Professor Han Remaut I VUB, Brussels
Professor Marlies Van Bael I UHasselt
Professor Lode Wyns I VUB, Brussels

Observers

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

HONORARY MEMBERS

In Memoriam

Tito Arecchi (11 December 1933 – 15 February 2021), honorary member of the International Institutes, left us in 2021. Renowned expert in laser physics and quantum optics, he actively served for an extended period as member of our international scientific committee for physics. His help and support are remembered with emotion.

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

Christian Jourquin,
Former CEO Solvay Group, Belgium

Professor Roger Kornberg
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

Professor Stuart Rice
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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

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

SOLVAY PUBLIC LECTURES

SOLVAY PUBLIC LECTURES

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.

Because of the pandemics, the 2020 annual public event could not take place as planned. It was rescheduled in 2021, which has therefore been an exceptional year with two public events, the 2020 and 2021 ones.

These events were our first completely in-person meetings since the beginning of the sanitary crisis. Physical presence in the lecture hall was, however, only allowed in reduced gauge. In spite of this restriction, the public responded with enthusiasm to our initiative.

The lecturers were world-leading experts of exceptional stature, working at the forefront of the research in their fields. The International Solvay Institutes warmly thank them for having accepted our invitation in times of travel uncertainties and praise their patience and their understanding with the various reschedulings.

The restart of our program of lectures popularizing science was a great and encouraging success.

17TH SOLVAY PUBLIC LECTURES - 12 September 2021

"Physics, Chemistry and Life Sciences"

The 17th Solvay public event took place on September 12th. It was a clear celebration of science at a time when social media and other communication means are unfortunately invaded by messages of rejection of science, and more generally, of rejection of rational thinking based on objective facts. We need to listen to science!

Three splendid lectures on subjects of very timely interest exemplified how the scientific method can unravel the mysteries of Nature and at the same time arouse wonder and amazement.

Programme

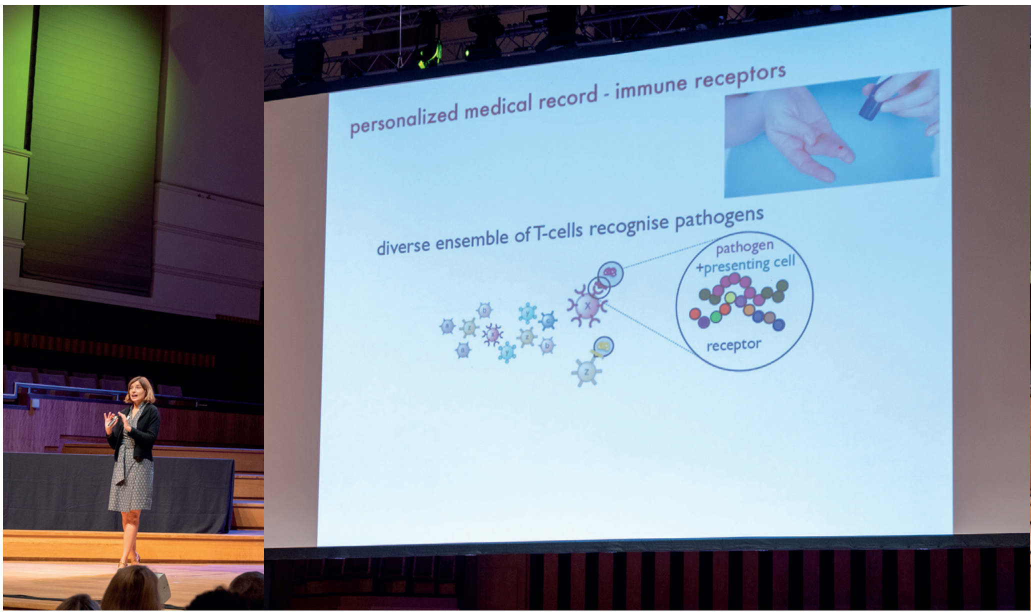
15:00 - 15:10	Opening by Professor Marc Henneaux (ULB & International Solvay Institutes)
15:10 - 15:45	Address by Ilham Kadri, CEO of the Solvay Company followed by Solvay Awards ceremony
15:45 - 16:30	"How personalised is your immune repertoire?" Lecture by Professor Aleksandra Walczak (École Normale Supérieure, Paris, France)
16:30 - 17:15	"Why we cannot make artificial life in a laboratory" Lecture by Professor Bert Meijer (TU Eindhoven, The Netherlands)
17:15 - 18:00	"Steps towards complex matter: chemistry!" Lecture by Professor Jean-Marie Lehn (USIAS, Strasbourg, France) 1987 Nobel Laureate in Chemistry

The traditional drink offered after the lectures could unfortunately not take place due to the sanitary constraints.

The Lecturers

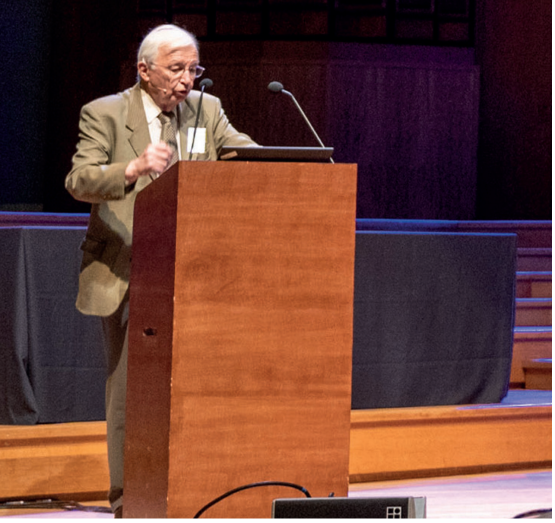
Professor Aleksandra Walczak

received her PhD in physics at the University of California (USA), working on models of stochastic gene expression. After a graduate fellowship at the Kavli Institute for Theoretical Physics (California), she worked on applying information theory to signal processing in small gene regulatory networks at the Princeton Center for Theoretical Science. Currently based at the École Normale Supérieure as a CNRS researcher, she studies the effects of selection on population genealogies, collective behaviour of bird flocks and statistical descriptions of the immune system. Dr Walczak was awarded the “Grand Prix Jacques Herbrand de l’Académie des sciences" in 2014 and the bronze medal of CNRS in 2016. Her ERC project 'RECOGNIZE' focuses on the self-organization of the immune repertoire at the molecular and evolutionary level, by using a combination of data analysis and statistical mechanics modelling. Dr Walczak aims to shed light on the diversity and complexity of immune receptors on the surfaces of B and T cells, which interact with pathogens, recognize them and initiate an immune response.



Professor Bert Meijer

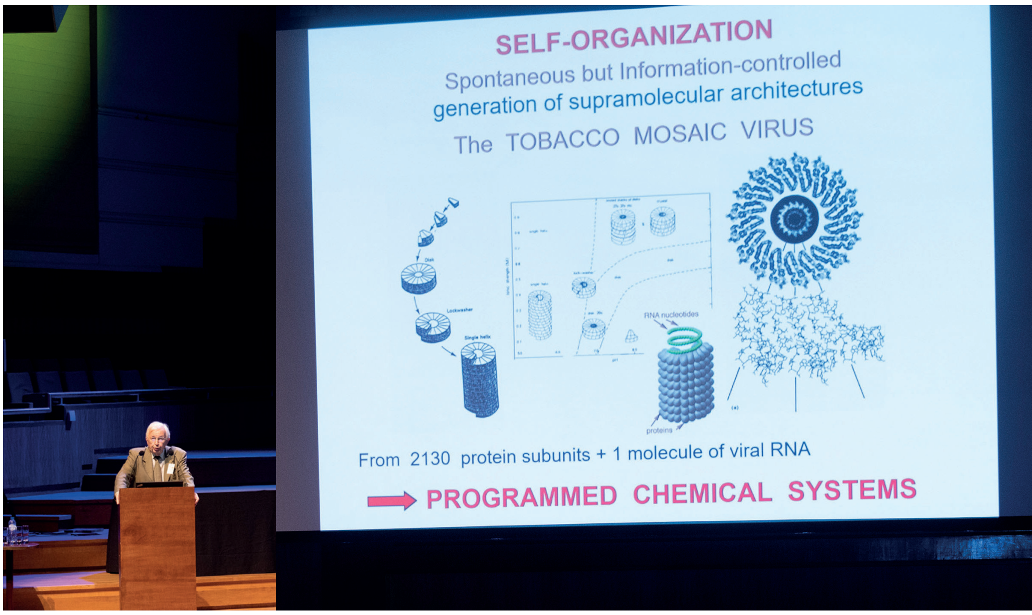
is Distinguished University Professor and Professor of Organic Chemistry at the Institute for Complex Molecular Systems of the Eindhoven University of Technology. After receiving his PhD degree at the University of Groningen, he worked for 10 years in industry (Philips and DSM). In 1991 he was appointed in Eindhoven, while he has part-time positions in Nijmegen, Santa Barbara, and Mainz. He is member of many editorial advisory boards, including the Journal of the American Chemical Society, and received a number of awards, including the Spinoza Award in 2001, the ACS Award for Polymer Chemistry in 2006, the ACS Cope Scholar Award in 2012, the Prelog medal in 2014, the Nagoya Gold medal in 2017, and the Chirality medal in 2018. He is a member of a number of academies and societies, including the American Academy of Arts and Sciences and the Royal Netherlands Academy of Arts and Sciences. He was appointed lifetime Academy Professor by the Royal Netherlands Academy of Arts and Sciences in 2014.



Professor 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. This work expanded into the investigation of the chemical basis of "molecular recognition" (the way in which a receptor molecule recognises and selectively binds a substrate), which plays a fundamental role in biological processes. Over the years these studies led to the definition of a new field of chemistry, which he called "supramolecular chemistry". It deals with the complex entities formed by the association of two or more chemical species held together by intermolecular forces.

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



SOLVAY AWARDS: A POOL OF SCIENTIFIC TALENTS FOR INNOVATION

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

The Solvay Awards rewarded 13 PhD students and bright minds from the Faculty of Sciences and the Faculty of Engineering of both Université Libre de Bruxelles (ULB) and Vrije Universiteit Brussel (VUB), renewing Solvay's commitment to open innovation to help address shared future challenges with the best of scientific advancement.

The selection is done by the Solvay Awards Jury and takes into account the work submitted for evaluation both for basic or applied research focusing on one of the following fields:

- 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

The nominators also evaluate the ability to summarise and communicate to making main scientific messages intelligible by non-specialists. Furthermore, the candidates are invited to present their own view on the potential contribution of their work to society, contributing to the great advancement of humankind for a better future.

2019 AND 2020 SOLVAY AWARDS LAUREATES

“These brilliant scientists hold the key to the future because without science, there will be no sustainable future. We count on you. Our children count on you!”

Ilham Kadri , Solvay CEO

Bariselli Federico

Colomer Martinez Frederic

De Clercq Jarne

Grauwels Glenn

Hebborn Chloë

Li Zhiyi

Retout Maurice

Scholl Daniel

Shetye Shreeya

Tossounian Maria

Uchanski Tomasz

Van Hoorick Jasper

Zhu Xinhua

18TH SOLVAY PUBLIC LECTURE – 24 October 2021

"Exoplanets or the quest for life around another sun"

by professor Michaël Gillon

The 18th Solvay public event was co-organized with the non-profit initiative Science & Cocktails, which has been active in Brussels since 2017 and has been able to consistently put up a remarkable program since it began its activities.

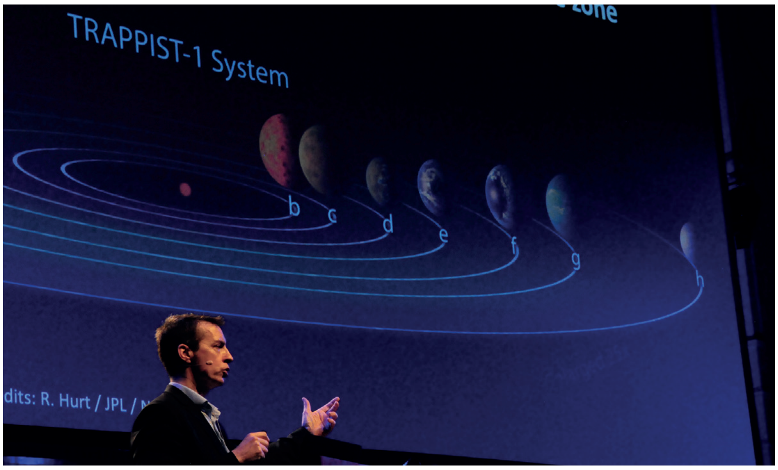
The lecture, given by one of the leading world-experts in the field, addressed a subject that has sparked curiosity and imagination since the beginning of mankind: "the quest for life around another Sun".

The format of the Science & Cocktails events combines scientific presentations with musical performances in harmony with the theme of the scientific talk. This format was adopted for our 18th public event. The lecture was indeed followed by a special musical creation of a new piece for a string orchestra by Benjamin Glorieux et al. with video artist Klaas Verpoest.

The Lecturer

Professor Michaël Gillon

is a Senior Research Associate at the FNRS (Belgian national fund for scientific research) and works on the detection of exoplanets and their physicochemical characterization. He is the scientific leader of the exoplanets part of the TRAPPIST project, which has participated in the detection of more than one hundred transiting exoplanets, including the now famous exoplanetary system TRAPPIST-1, revealed to the public on 22 February 2017 during an international press conference at NASA headquarters and through a publication in the scientific journal Nature. He also launched the SPECULOOS project, which targets nearby ultra-cold red dwarfs to detect potentially habitable planets. He received in 2017 the Balzan Prize for "his innovative and fruitful searches for planets around nearby stars, milestones on the way towards finding life signatures beyond our solar system". He was also awarded the Francqui Prize in 2021 for his pioneering contributions.



03

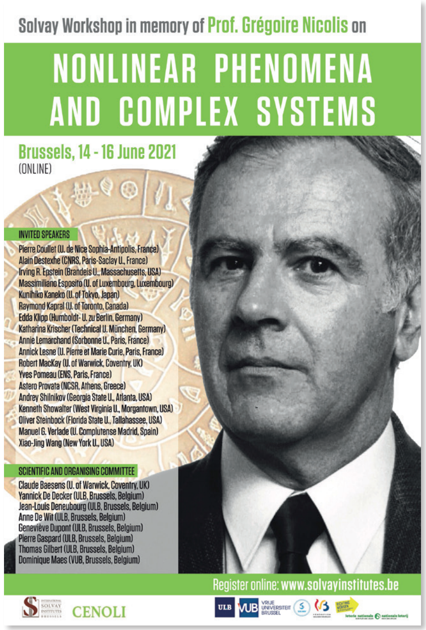
SCIENTIFIC ACTIVITIES

WORKSHOPS ORGANISED BY THE SOLVAY INSTITUTES

Workshop on "NONLINEAR PHENOMENA AND COMPLEX SYSTEMS"

in memory of Prof. Grégoire Nicolis

Brussels, 14 - 16 June 2021 (online)



This workshop was dedicated to the memory of Grégoire NICOLIS who passed away on October 18, 2018. Grégoire Nicolis was a pioneer in the science of nonlinear phenomena and complex systems, who published many influential publications in this area. His contributions are known worldwide for having initiated a vast field of research unifying the physical sciences in our understanding of the emergence by nonlinear bifurcations of stationary, oscillating, and chaotic spatio-temporal structures from chemistry and physics to biological systems, neuroscience, meteorology and climate science. Today, this vast field is blossoming internationally and we hoped to commemorate Grégoire Nicolis' contributions to these advances at this workshop. The workshop had also the aim to establish the state of the art for future research in this multidisciplinary area.

Scientific and Organising Committee

Claude Baesens (U. of Warwick, UK)
Yannick De Decker (ULB, Brussels, Belgium)
Jean-Louis Deneubourg (ULB, Brussels, Belgium)
Anne De Wit (ULB, Brussels, Belgium)
Geneviève Dupont (ULB, Brussels, Belgium)
Pierre Gaspard (ULB, Brussels, Belgium)
Thomas Gilbert (ULB, Brussels, Belgium)
Dominique Maes (VUB, Brussels, Belgium)

Invited Speakers

Pierre Coullet (U. de Nice Sophia-Antipolis, France)
Alain Destexhe (CNRS, Paris-Saclay U., France)
Irving R. Epstein (Brandeis U., Massachusetts, USA)
Massimiliano Esposito (U. of Luxembourg)
Kunihiko Kaneko (U. of Tokyo, Japan)
Raymond Kapral (U. of Toronto, Canada)
Edda Klipp (Humboldt- U. zu Berlin, Germany)
Katharina Krischer (Technical U. München, Germany)
Annie Lemarchand (Sorbonne U., Paris, France)
Annick Lesne (U. Pierre et Marie Curie, Paris, France)
Robert MacKay (U. of Warwick, Coventry, UK)
Yves Pomeau (ENS, Paris, France)
Astero Provata (NCSR, Athens, Greece)
Andrey Shilnikov (Georgia State U., Atlanta, USA)
Kenneth Showalter (West Virginia U., Morgantown, USA)
Oliver Steinbock (Florida State U., Tallahassee, USA)
Manuel G. Velarde (U. Complutense Madrid, Spain)
Xiao-Jing Wang (New York U., USA)

Programme

Monday 14 June 2021

Welcome and Introduction

In memoriam

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

Session 1: Hydrodynamics, chaos and atmospheric science - Chair: Pierre Gaspard

Yves Pomeau	Turbulence in fluids: from deterministic equations to statistical picture
Yves Elskens	Critical exponent for the Lyapunov exponent and phase transition
Benoit Scheid	Dripping or not dripping in suspended falling films
Priya Verma	Chemical Reaction Induced Viscous Fingering in a Radial Displacement Flow
Stéphane Vannitsem	Extratropical low-frequency variability with El-Niño-Southern Oscillation forcing: A reduced-order coupled model study

Session 2: Reaction-diffusion patterns and nonlinear oscillations - Chair: Anne De Wit

István Szalai	Reaction-diffusion patterns in a simple hydrogel device with flow-through channels
Judit Horváth	A New Aldehyde – Sulfite – Lactone Type pH-Oscillator
Ljiljana Kolar-Anic	Investigation of the Bray-Liebhafsky oscillatory reaction
Dezsó Horváth	Oscillatory dynamics in the model of reactive oxygen species in the rhizosphere
Irving Epstein	Turing patterns on growing domains
Kenneth Showalter	Transition from spiral wave chimeras to phase cluster states
Raymond Kapral	Active matter meets nonlinear dynamics
Marcello Budroni	Between dissipative structures and applied processes: chemohydrodynamic (and not only) oscillatory systems
Seth Fraden	The Symmetry Basis of Pattern Formation in Reaction-Diffusio Networks with Heterogeneity

Personal testimonies - Chair: Claude Baesens

Tuesday 15 June 2021	
Session 3: Regulatory networks and biocomplexity - Chair: Geneviève Dupont	
Kunihiko Kaneko	Macroscopic Theory for Adaptation and Evolution: Multilevel Consistency, Dimensional Reduction, and Fluctuation-Response Relationship
Annie Lemarchand	A thermostatted kinetic theory model of tumor growth
Edda Klipp	Entropic regulation of dynamical metabolic processes
Session 4: Complex systems - Chair: Thomas Gilbert	
Annick Lesne	Concepts from nonlinear dynamics for the analysis of symbolic sequences
Robert MacKay	Thermoeconomics
Igor Franovic	Emergent Dynamics in Populations of Active Rotators, with Diversity
Session 5: Synchronization and chimera states - Chair: Jean-Louis Deneubourg	
Astero Provata	Complex synchronization patterns in spatially correlated networks of coupled Oscillators
Katharina Krischer	Between Synchrony and Turbulence: Intricate Hierarchies of Coexistence Patterns
Maximilian Patzauer	Self-Organized Multifrequency Clusters in an Oscillating Electrochemical System with Strong Nonlinear Coupling
Maria Masoliver	Embedded Chimera States in Recurrent Neural Networks
Session 6: Self-organization, from chemistry to biology - Chair: Dominique Maes	
Oliver Steinbock	From Chemobrionics to Self-propelled Tubes
Peter Vekilov	Harnessing the complexity of crystal nucleation: nucleation control by manipulating the amorphous precursors
John Tyson	A Dynamical Paradigm for Molecular Cell Biology
Personal testimonies - Chair: Claude Baesens	

Wednesday 16 June 2021

Session 7: Thermodynamics and non-equilibrium systems - Chair: Yannick De Decker

Massimiliano Esposito	Stochastic Thermodynamics from the mid 80s to now
Valérie Voorsluijs	Energetic cost of the cross-talk between calcium dynamics and mitochondrial Metabolism
Sandip Saha	Suppressing birhythmicity by parametrically modulating nonlinearity in limit cycle oscillators
Enrique Abad	Peculiarities of nanoparticle diffusion in polymer melts

Session 8: Spatially extended systems and networks - Chair: Yannick De Decker

Manuel G. Velarde	Variations on the quasiparticle (dressed particle) concept: from entropy to polaron and to solectron (with a bonus: a novel field effect transistor)
Hans Dierckx	A novel view on the topology of wave patterns in the heart
Jerzy Gorecki	Information processing with networks of coupled chemical oscillators
Jean-François Kemmeter	Symmetry breaking induced by self-recruitment random walks on regular Networks

Session 9: Nonlinear dynamics and beyond - Chair: Claude Baesens

Pierre Coullet	Ibn Sahl and Kepler: the search for « Anaclastic » and the refraction law
Jean-Marc Ginoux	A physical memristor based Muthuswamy–Chua–Ginoux system
Juan Perez-Mercader	From Equations to Artificial Life in a Test Tube
Yannis Kevrekidis	Disentangling (the parametrization of) relations
Léon Brénig	On an equivalence between deterministic nonlinear dynamical systems and stochastic urn processes

Session 10: Neural networks - Chair: Claude Baesens

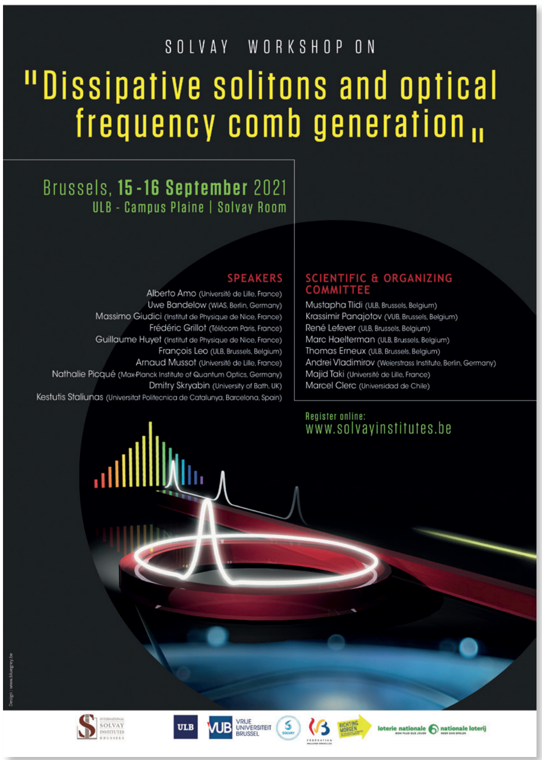
Xiao-Jing Wang	Slope bifurcation: how cognitive functions arise from canonical cortical Microcircuits
Alain Destexhe	Complexity of spontaneous and evoked brain dynamics
Andrey Shilnikov	Cooperative Rhythm Generation in Neural Networks

Conclusions

Workshop on

"DISSIPATIVE SOLITONS AND OPTICAL FREQUENCY COMB GENERATION"

Brussels, 15 - 16 September 2021



Optical frequency combs generated by optical resonators have revolutionized many fields of science and technology, such as high-precision spectroscopy, metrology, and photonic analog-to-digital conversion. A particular interest was paid to the soliton frequency combs associated with the formation in the time domain of the so-called temporal dissipative solitons.

Scientific and Organising Committee

Mustapha Tlidi (ULB, Brussels, Belgium)

Krassimir Panajotov (VUB, Brussels, Belgium)

René Lefever (ULB, Brussels, Belgium)

Marc Haelterman (ULB, Brussels, Belgium)

Thomas Erneux (ULB, Brussels, Belgium)

Andrei Vladimirov (Weierstrass Institute, Berlin, Germany)

Majid Taki (Université de Lille, France)

Marcel Clerc (Universidad de Chile)

Invited Speakers

Alberto Amo (Université de Lille, France)

Uwe Bandelow (WIAS, Berlin, Germany)

Massimo Giudici (Institut de Physique de Nice, France)

Frédéric Grillot (Télécom Paris, France)

Guillaume Huyet (Institut de Physique de Nice, France)

François Leo (ULB, Brussels, Belgium)

Arnaud Mussot (Université de Lille, France)

Nathalie Picqué (Max-Planck Institute of Quantum Optics, Germany)

Dmitry Skryabin (University of Bath, UK)

Kestutis Staliunas (U. Politecnica de Catalunya, Barcelona, Spain)

Programme

Wednesday 15 September 2021

Welcome speech

Nathalie Picqué	Frequency combs for spectroscopy and 3D imaging
Alberto Amo	Driven-dissipative solitons in topological lattices
Massimo Giudici	Time-Localized Fourier modes in Vertical External-Cavity Surface-Emitting Lasers (VECSELs)
François Leo	Solitons in coherently driven active fiber cavities
Dmitry Skryabin	CHI-2 frequency conversion and solitons in microresonators

Thursday 16 September 2021

Frédéric Grillot	Mode locking and frequency comb generation by four-wave mixing in a semiconductor quantum-dot active medium
Arnaud Mussot	Non-invasive distributed characterization method in phase and intensity of breathers along an optical fiber
Uwe Bandelow	Ultrashort Solitons in the regime of Event Horizons in nonlinear dispersive optical Media
Guillaume Huyet	Dark solitons in a long laser
Kestutis Staliunas	Turbulence control by non-Hermitian potentials

Workshop on

"PLASMA TECHNOLOGY AND OTHER GREEN METHODS FOR NITROGEN FIXATION"

Brussels, 15 - 17 November 2021

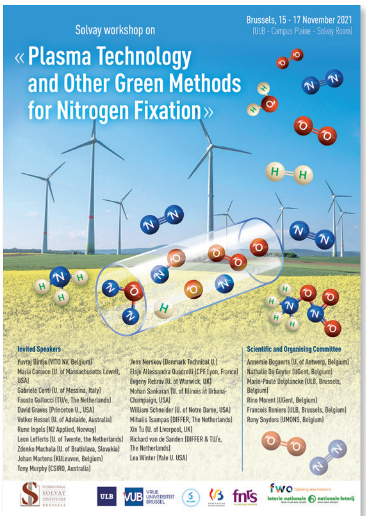
Nitrogen, the main constituent of the Earth's atmosphere, is a crucial element in the growth of plants and living organisms. Unfortunately, atmospheric nitrogen (N_2) is hardly accessible to most living beings, because of its extremely stable N≡N bond, which demands very high activation energies to break. To become accessible, N_2 must thus be chemically bonded to oxygen or hydrogen through a process, which is called N_2 fixation. Since the beginning of the 20th century, people have put a lot of effort in developing chemical processes to fix N_2. In 1903, Birkeland and Eyde successfully developed thermal arc plasmas to convert air into nitrogen oxides. This process was, however, quickly abandoned by industry due to its low NO_x yield and low energy efficiency. In 1908, an alternative N_2 fixation technique, known as the Haber-Bosch (H-B) process, was successfully developed, in which NH_3 is synthesized from N_2 and H_2 using iron as a catalyst at relatively high temperature (400-500°C) and high pressure (150-250 bar). The H-B process was commercialized in 1913 and gradually took over the Birkeland-Eyde process, because of its comparatively lower energy consumption and high NH_3 production. As a result, the H-B process has been extensively used over the last century. Unfortunately, it consumes almost 2% of the world's total energy production, emits 300 million metric tons of CO_2 and utilizes 3-5% of the total natural gas output. Significant optimization efforts have been done over the last 100 years to reduce the environmental footprint and increase the energy efficiency of the H-B process, resulting today in a modern approach, which almost reaches its theoretical limits. As a result, further improvements in the environmental impact of N_2 fixation processes can only be reached by searching for approaches very different from the H-B process.

A lot of research is therefore carried out on novel green methods for N_2 fixation that eliminate or minimize the need for fossil fuels, based on heterogeneous catalysis, electro- and photo-catalysis, nitrogenase enzymes and plasma. This workshop focused on these novel methods, with primary focus on plasma-based N_2 fixation, but placing it in the wider context of other green methodologies.

Non-thermal plasma (NTP) indeed appears to be a promising alternative for N_2 fixation. It is a partially ionized gas consisting of electrons, ions, excited molecules, ground state molecules, atoms, radicals, …

It is of great interest for N_2 fixation because of its thermodynamically non-equilibrium nature, as only the electrons have a temperature of thousands of degrees, while the bulk gas remains close to room temperature. The plasma generates highly reactive and energetic plasma species, which can activate the N_2 molecules through vibrational-vibrational collisions and electron impact processes. Thus, plasma-based N_2 fixation can in principle occur at low reaction temperature and low energy consumption. In addition, plasma can easily switched on/off, making it in principle suitable for using intermittent renewable electricity. This can open new paths for renewable electricity driven chemistry. However, more fundamental research is needed to understand the underlying mechanisms, in order to really exploit this application.

Several types of plasmas have been used in recent years for N_2 fixation. Both N_2 reduction (into NH_3) and oxidation (into NO_x) are of interest. NH_3 synthesis is mainly carried out in dielectric barrier discharges (DBDs) by plasma catalysis, while NO_x synthesis has been investigated in several types of plasmas, including DBD, gliding arc, and microwave plasmas. However, it is not yet clear which plasma type is the most promising. Furthermore, a lot of fundamental research is needed to improve the conversion and energy efficiency of the process in the various plasma types, as well as to design catalysts most suitable for the plasma conditions. This fundamental insight can be obtained by plasma diagnostics experiments and computer modeling. In addition, a lot of insight can be gained from other catalytic approaches, including heterogeneous catalysis, electro- and photo-catalysis, to design the best types of catalysts. Therefore, this workshop also included speakers from heterogeneous, electro- and photocatalysis, also to place plasma (catalysis) in a broader perspective.



Scientific and Organising Committee

Annemie Bogaerts (U. of Antwerp, Belgium)
Nathalie De Geyter (UGent, Belgium)
Marie-Paule Delplancke (ULB, Brussels, Belgium)
Rino Morent (UGent, Belgium)
Francois Reniers (ULB, Brussels, Belgium)
Rony Snyders (UMONS, Belgium)

Invited Speakers

Yuvraj Birdja (VITO NV, Belgium)
Maria Carreon (U. of Massachusetts Lowell, USA)
Gabriele Centi (U. of Messina, Italy)
Fausto Gallucci (TU/e, The Netherlands)
David Graves (Princeton U., USA)
Volker Hessel (U. of Adelaide, Australia)
Rune Ingels (N_2 Applied, Norway)
Leon Lefferts (U. of Twente, the Netherlands)
Zdenko Machala (U. of Bratislava, Slovakia)
Johan Martens (KULeuven, Belgium)
Tony Murphy (CSIRO, Australia)
Jens Norskov (Denmark Technical U.)
Elsje Allessandra Quadrelli (CPE Lyon, France)
Evgeny Rebrov (U. of Warwick, UK)
Mohan Sankaran (U. of Illinois at Urbana-Champaign, USA)
William Schneider (U. of Notre Dame, USA)
Mihalis Tsampas (DIFFER, The Netherlands)
Xin Tu (U. of Liverpool, UK)
Richard van de Sanden (DIFFER & TU/e, The Netherlands)
Lea Winter (Yale U., USA)

Programme

Monday 15 November 2021

Welcome speech

Morning session - Chair: Annemie Bogaerts

Tony Murphy (Online)	Plasma catalytic production of ammonia: prospects, problems and possible solutions
Volker Hessel (Online)	Economic and Environmental Assessment of Small-scale Plasma-Assisted Ammonia Production Pathways – ‘at-Farm’
Rune Ingels	Can we manage without Haber Bosch?
Johan Martens	Green ammonia synthesis on a NOx trap fed with NOx from plasma-driven nitrogen gas oxidation from air (PNOCRA Process)

Afternoon session - Chair: Marie-Paule Delplancke

Xin Tu	Plasma catalysis: An emerging technology for decentralized ammonia synthesis
Leon Lefferts	Reaction Pathways in Plasma-Catalytic Ammonia Synthesis
David Graves (Online)	Plasma Technology and Nitrogen Fixation at Scale
Maria Carreon	Cold plasma ammonia synthesis: the search for a suitable Catalyst

Poster session

Tuesday 16 November 2021

Morning session - Chair: Nathalie De Geyter

Mihalis Tsampas	Synergistic combination of plasma activation and electrocatalysis for nitrogen fixation by water
Jens Norskov (Online)	Electrochemical nitrogen activation
Gabriele Centi	Electrocatalytic direct nitrogen fixation: perspectives and gaps
Yuvraj Birdja	Electrocatalytic nitrogen fixation: perspectives, challenges and recent advances

Afternoon session - Chair: Francois Reniers

Lea Winter (Online)	Electrifying nitrogen transformations: Decarbonizing ammonia using plasma catalysis and electrochemical reduction of nitrate in wastewaters
Mohan Sankaran (Online)	Catalyst-free, electrolytic synthesis of ammonia from nitrogen and water by atmospheric-pressure plasma processes
William Schneider	Models and Opportunities in Plasma Catalysis
Senne Van Alphen	Plasma-based NOx formation: potential avenue for sustainable N2 fixation
Kevin van 't Veer	Plasma-catalytic NH3 production in DBD plasma: Chemical kinetics modeling

Wednesday 17 November 2021

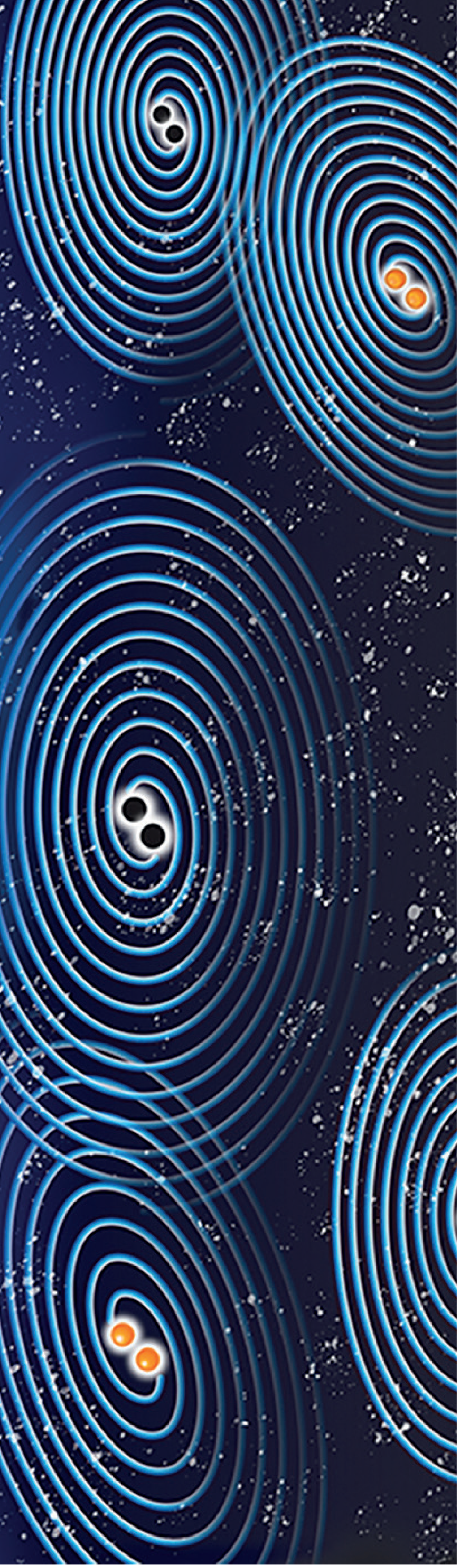
Morning session - Chair: Rony Snyders

Fausto Gallucci	Nitrogen fixation in plasma assisted catalytic reactor system
Anton Nikiforov	N_2 fixation in ns-discharge above water: from kinetics to energy costs
Zdenko Machala	Pulsed plasma discharges in air as an efficient strategy of nitrogen fixation and (H)NOx transport into water
Richard van de Sanden	Plasma-electrochemical conversion processes using ion conducting membrane: a playground for detailed studies on the role of surface charge and electric fields on plasma-electrocatalytic processes
Elsje Allessandra Quadrelli	Mechanistic Aspects of Dinitrogen Cleavage and Hydrogenation to Ammonia in Catalysis and Organometallic Chemistry

Afternoon session - Chair: Rino Morent

Evgeny Rebrov	Plasma assisted synthesis of plasmonic titanium nitride nanoparticles and thin films
Omid Samadi Bahnamiri	Nitrogen fixation in a pulsed microwave discharge: combining experiment and modelling
Kevin Rouwenhorst	Reaction mechanisms and process considerations for plasma-driven nitrogen fixation

WORKSHOPS SUPPORTED BY THE SOLVAY INSTITUTES



BELGIAN GRAVITATIONAL-WAVE MEETING

Brussels, 3 November 2021

Organized by the ULB and VUB with support from the International Solvay Institutes

Since the first observation of gravitational waves by LIGO in 2015, gravitational wave physics has grown explosively. The current generation of gravitational wave interferometers, LIGO/Virgo/Kagra (LVK), has clearly demonstrated that gravitational waves truly opened a new window on our Universe enabling us to address problems and observe novel phenomena otherwise inaccessible. The future 3rd generation observational facilities, such as the Einstein Telescope (ET) in Europe and Cosmic Explorer in the USA, expected to come online in the mid-thirties, will realize a breathtaking and ground breaking scientific program.

The meeting was held both in person and on Zoom.

Programme

Update by group leaders

KULeuven - Orator: Li Tjonnie, UCLouvain - Orator: Giacomo Bruno,
UGent - Orator: Archisman Ghosh, ULiège - Orator: Maxime Fays,
UAntwerp - Orator: Nick Van Remortel,
UNamur - Orator: André Füzfa,
VUB - Orators: Alberto Mariotti & Alexandre Sevrin,
ULB - Orators: Geoffrey Compère, Nicolas Chamel, Sébastien Clesse

Session 1. Detectors, instrumentation and new methods of data analysis

Exploring the Phase Camera at Adv. Virgo and in the Lab
Ricardo Cabrita (UCLouvain)

A superconducting inertial sensor for low-frequency and cryogenic gravitational wave detectors
Elvis Ferreira (UCLouvain)

ALBUS: Anomaly detector for Long duration BUrst Searches
Vincent Boudart (ULiège)

Detecting planetary-mass primordial black holes with resonant electromagnetic gravitational-wave detectors
Nicolas Herman (UNamur)

Session 2. Gravitational-wave backgrounds: sources and analysis

A boosted gravitational wave background for primordial black holes with broad mass distributions and thermal features
Eleni Bagui (ULB)

Direct constraints on planetary-mass primordial black holes using data from LIGO/Virgo's third observing run
Andrew Miller (UCLouvain)

Interferences in the Stochastic Gravitational Wave Background
Disrael Cunha (UCLouvain)

Jointly setting upper limits on multiple components of a stochastic gravitational wave background
Jishnu Suresh (UCLouvain)

A Search for Intermittent Gravitational Wave Backgrounds
Kevin Turbang (VUB, Brussels)

Session 3. Early Universe cosmology and Black Hole Theory

Ringing of rotating black holes in higher derivative gravity
Kwinten Fransen (KULeuven)

Observable effects of equatorial symmetry breaking for EMRIs
Daniel Mayerson (KULeuven)

Exploring the early Universe with numerical General Relativty
Cristian Joana (UCLouvain – CURL)

Discussion & final words

GENERAL SCIENTIFIC MEETING 2021 OF THE BELGIAN PHYSICAL SOCIETY

Hasselt University, 2 December 2021

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.

2020 INTERNATIONAL JACQUES SOLVAY CHAIR IN PHYSICS

Professor Roger Blandford

Kavli Institute for Astrophysics and Cosmology, Stanford University, USA

The fifteenth International Jacques Solvay Chair in Physics was held by professor Roger Blandford from Stanford University. Professor Blandford gave 5 lectures online in March 2021. Then, he also spent 3 weeks in November in Brussels and gave his closing lecture on November 10 at the ULB. During his stay in Belgium, professor Blandford was also hosted in research groups at the KU Leuven and at Liège University.

After undergraduate and graduate studies at Cambridge University under the supervision of Martin Rees, Roger Blandford held postdoctoral research positions at Cambridge, Princeton and Berkeley before taking up a faculty position at Caltech in 1976. In 2003 he moved to Stanford University to become the first Director of the Kavli Institute of Particle Astrophysics and Cosmology (KIPAC) and the Luke Blossom Chair in the School of Humanities and Science.

Professor Blandford is a leading figure in astrophysics and cosmology. His research interests include black holes, white dwarfs, gamma ray bursts, gravitational lensing and the evolution of the universe. He is famous for the Blandford-Znajek Process, the leading model that explains how energy can be extracted from a rotating black hole, producing jets of plasma that travel near the speed of light. It is one of the best explanations for the way quasars are powered.

Among his notable recognitions, he is a Fellow of The Royal Society and the American Academy of Arts and Sciences, and a Member of the National Academy of Sciences. He received the Dannie Heineman Prize for astrophysics in 1998, a Humboldt Award in 2011 and the Gold Medal of the Royal Astronomical Society in 2013, the Shaw Prize in Astronomy 2020, along with the Solvay Chair of Physics 2020.

Lecture 1 I 11 March 2021 (online)

Black Holes: Nature or Nurture?: The Role of Rotation in Powering Cosmic Sources

Black holes power many of the most powerful sources in the universe through releasing the gravitational energy of accreting gas and by donating their rotational energy using electromagnetic field. The interpretation of recent, remarkable images made by the Event Horizon Telescope of M87 will be discussed in the context of both modes. It will be proposed that the rotational mode dominates in sources like M87 so that the black hole spin drives away the accreting gas as a powerful hydromagnetic wind that collimates a pair of relativistic jets.

Lecture 2 I 15 March 2021 (online)

Cosmic Blowtorches: Relativistic Jets from Stars and Galaxies

Powerful relativistic jets are made by black holes and neutron stars. They are prodigious emitters from the lowest radio frequencies to the highest energy gamma-rays. They may also create high energy cosmic raysand neutrinos. They are remarkably persistent as they escape from collapsing stars, active galaxies and merging neutron stars. It will be argued that their collimation, resilience and emission is generically due to the tensile action of electromagnetic field.

Lecture 3 I 19 March 2021 (online)

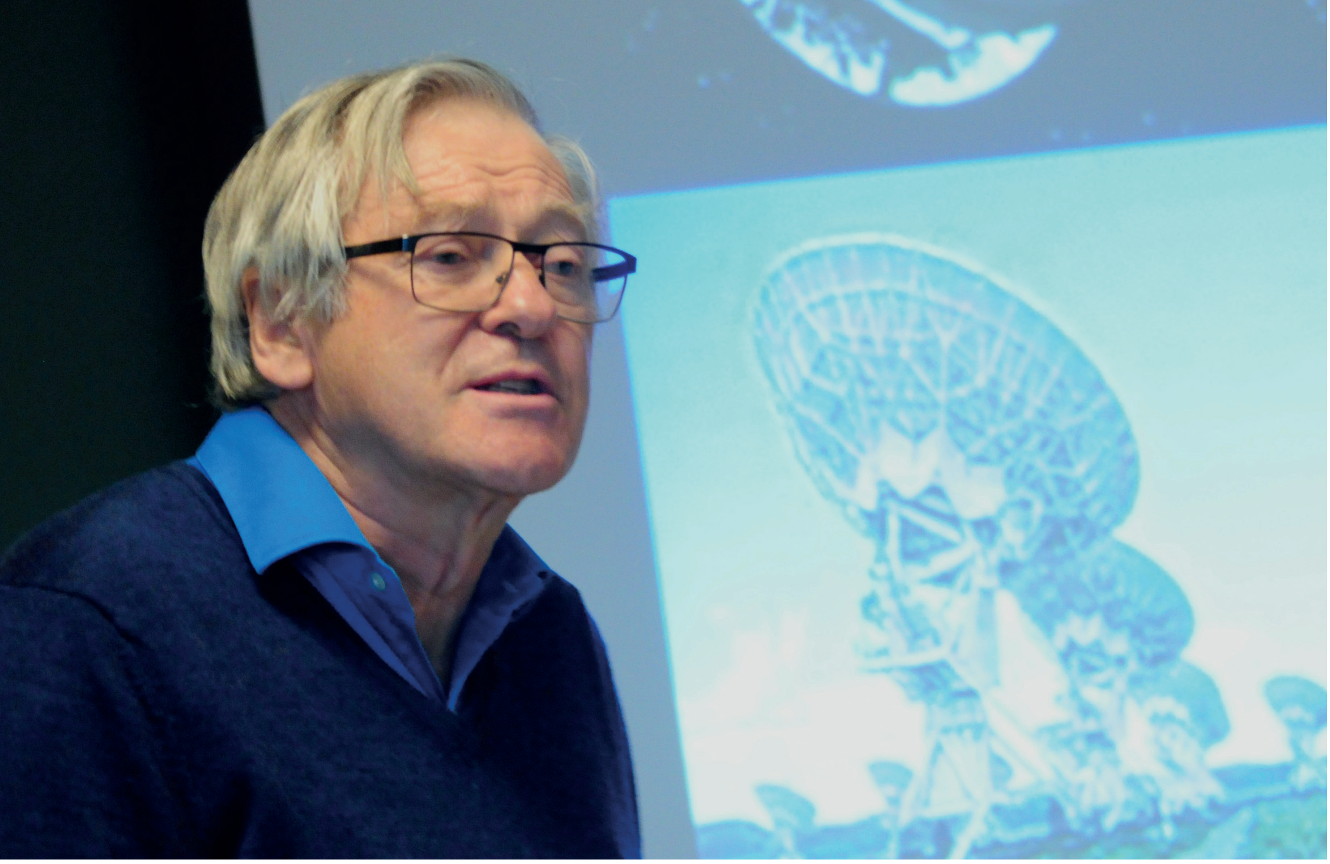
Fast Radio Bursts: ElectroMagnetic Pulses from Cosmologically Distant Neutron Stars with Hundred GigaTesla Magnetic Field?

For over a decade, radio astronomers have been observing millisecond pulses of intense radio emission. They now appear to be associated with strongly magnetized neutron stars called magnetars where extreme QED and plasma processes take place. The rapidly developing observational picture will be summarized and a plethora of theoretical models will be reported. The possibility that Fast Radio Bursts, and pulsar radio emission, are an expression of force-free electrodynamics, as originally developed by Maxwell, will be discussed.

Lecture 4 I 23 March 2021 (online)

Ultra High Energy Cosmic Rays: On the Acceleration of Hundred Joule Particles by Intergalactic Shock Waves

Cosmic rays have been observed at earth for over a century with energies ranging from 0.1 GeV to 0.3 ZeV. Those with energies from ~ 1 GeV to ~ 0.1 PeV are generally supposed to have been accelerated by shock fronts associated with Galactic supernova remnants. Sources of ~ 0.1 PeV - 0.3 EeV cosmic rays are galactic wind termination shocks and the highest energy particles may come from accretion shocks around clusters of galaxies. A multi-scale model that takes ~ 0.1 GeV particles and elevates them to energies as high as 0.3 ZeV will be outlined.



Lecture 5 I 24 March 2021 (online)

The Unbeatable Rightness of Being: A Cosmic Ray Origin for Biological Homochirality?

The laws of physics were long thought to be unchanged when viewed in a mirror. We have known for over sixty years that they are not. As Sakharov first explained, this asymmetry, in action during the first moments of the universe, may account for the prevalence of matter over antimatter today. Likewise, as Pasteur first showed, the laws of biology are similarly asymmetric, as is exhibited by the structure of DNA. In this talk, a possible causal connection between these two asymmetries, mediated by cosmic rays, will be discussed.

Closing Lecture at ULB I 10 November 2021

Confirmation, Conviction and Cosmology

The past sixty years have seen the transformation of cosmology from a weakly constrained metaphysics to a scientific description based on careful observation and accurate measurement. We now know that the universe expanded from a hot beginning to its present state, dominated by an unidentified "dark matter" and an enigmatic "cosmological constant". In a similar fashion to what has happened with particle physics, this "standard model" provides a basis for relating the narrative history of galaxies, stars and planets.

It also establishes a foundation for discussion of more fundamental issues. In this talk, I will discuss how large observational programs as well as some simpler investigations of existing data may affirm or confront our current understanding.

Seminar I 4 November 2021 at Liège University
and 19 November 2021 at KU Leuven

Extreme Astrophysics

The electromagnetic spectrum has been opened up from meter radio waves to ~ PeV photons and augmented with 10 - 300 Hz gravitational wave, MeV - PeV neutrinos and MeV - ZeV (160 J) cosmic ray messages. Consequently, there is a high rate of discovery and understanding of phenomena whose explanation invokes accepted physics - classical (including general relativity), atomic, nuclear and particle (including QED) processes - in extreme environments. The richness of the discovery space can be epitomized by describing some new observations and ideas pertaining to relativistic outflows formed by spinning black holes and neutron stars, Ultra High Energy Cosmic Rays accelerated by strong shock waves surrounding rich clusters of galaxies and Fast Radio Bursts, generated by neutron stars with 100 GT magnetic fields.

2020 INTERNATIONAL SOLVAY CHAIR IN CHEMISTRY

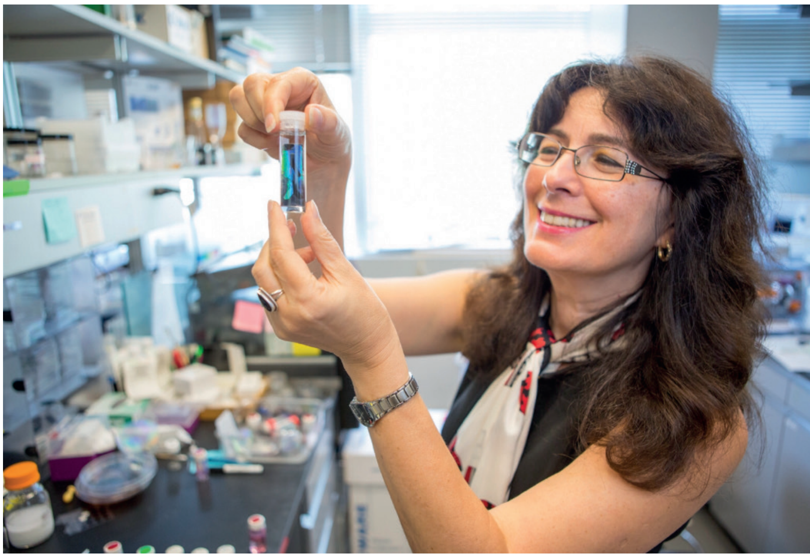
Professor Joanna Aizenberg

Harvard University, USA

The thirteenth International Solvay Chair in Chemistry was held by professor Joanna Aizenberg from Harvard University, USA. Due to the sanitary situation, the Solvay Institutes could not host professor Aizenberg currently in Belgium.

Instead, we had the pleasure to listen to her four inspiring lectures via zoom.

She will be come to Brussels in May 2022 to give her closing lecture.

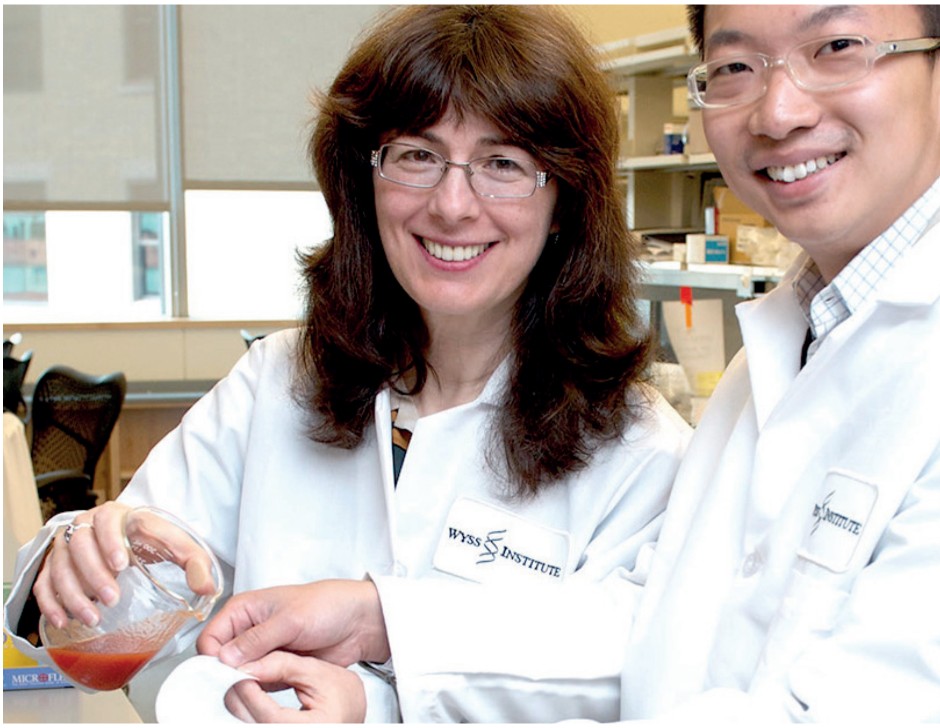


Professor Aizenberg is the Amy Smith Berylson Professor of Material Sciences at Harvard John A. Paulson School of Engineering and Applied Sciences, a Professor of Chemistry and Chemical Biology in the Department of Chemistry and Chemical Biology, and Co-Director of the Kavli Institute for Bionano Science and Technology.

She received the B.S. degree in Chemistry in 1981, the M.S. degree in Physical Chemistry in 1984 from Moscow State University, and the Ph.D. degree in Structural Biology from the Weizmann Institute of Science in 1996. She then went to Harvard University where she did postdoctoral research with George Whitesides on micro/nanofabrication and near-field optics.

Professor Aizenberg is a pioneer in the rapidly developing field of bio-inspired materials science and engineering — a branch of science that uses biological principles as guides in developing advanced, adaptive materials and devices. Her work focuses on understanding the unique architectural principles found in nature that enable living organisms to assemble themselves into structures with high functionality. These principles offer important clues into economical ways of solving complex materials and design problems. In Adaptive Material Technologies, Professor Aizenberg's team is experimenting with materials systems that emulate the design principles and versatility of a deep-sea sponge known as Venus' Flower Basket and of a brittle star that have uniquely evolved highly performing optical fibers and lenses, of a carnivorous Pitcher plant that has an adaptive slippery surface allowing it to catch prey, and of a number of organisms exhibiting sophisticated structural color that has advantages over traditional pigments. Using these principles, she has designed nanostructured materials that repel water droplets before they freeze and are resistant to biofouling, bioinspired periodic photonic structures possessing adaptive color features, dynamic and responsive surfaces that can sense and respond to changes in their environment, transduce different types of energy, and on-demand catch and release biomolecules. Such materials have a variety of potential applications in a number of medical and industrial areas.

Professor Aizenberg has been elected to the National Academy of Sciences, National Academy of Engineering, American Academy of Arts and Sciences, American Philosophical Society, American Association for the Advancement of Science. Dr. Aizenberg's select awards include: MRS Medal; Kavli Innovations in Chemistry Leader Award, ACS; Fred Kavli Distinguished Lectureship in Nanoscience, MRS; Ronald Breslow Award for the Achievement in Biomimetic Chemistry, ACS; Arthur K. Doolittle Award in Polymeric Materials, ACS; ACS Industrial Innovation Award, as well as ~50 Named and Distinguished Lectureships, Harvard's Ledlie Prize for the most valuable contribution to science, and she was recognized with two R&D 100 Awards for best innovations in 2012 and 2013 for the invention of a novel class of omniphobic materials and watermark ink technologies.



Lecture 1 l 22 April 2021 (online)

Bio-Inspired Approaches to Crystal Design

Nature produces a wide variety of exquisite mineralized tissues fulfilling diverse functions, and often from simple inorganic salts. Organisms exercise a level of molecular control over the physico-chemical properties of inorganic crystals that is unparalleled in today's technology. This reflects directly or indirectly the controlling activity of biological organic surfaces that are involved in the formation of these materials. Biomineralization occurs within specific microenvironments, which implies stimulation of crystal formation at certain interfacial sites and relative inhibition of the process at all other sites. Our approach to artificial crystallization is based on the combination of the two latter concepts: that is, the use of organized organic surfaces patterned with specific initiation domains on a sub-micron scale to study and orchestrate the crystallization process. This bio-inspired engineering effort made it possible to achieve a remarkable level of control over various aspects of crystal nucleation and growth, including the precise localization of particles, nucleation density, crystal sizes, morphology, crystallographic orientation, arbitrary shapes, microstructure, stability and architecture. The ability to construct large, defect-free, micropatterned single crystals with controlled microporosity; periodic arrays of uniform, oriented crystals or films presenting patterns of crystals offers a new synthetic methodology to materials engineering.

Lecture 2 l 29 April 2021 (online)

Colloidal Crystallization: from Structural Color to Encryption, to Medical Diagnostics to Catalysis

This lecture will introduce a reproducible, one-pot sol-gel colloidal co-assembly approach that results in large- scale, highly ordered inverse opal films with embedded, uniformly distributed, and accessible nanoparticles. The unique coloration of these inverse opals combines iridescence with plasmonic effects. When locally functionalized, these films exhibit a sharply defined threshold wettability for infiltration that couples to macroscopic color changes. This approach may find applications in a broad range of technologies, including a convenient and direct method for liquid detection and encryption, or as a tag for low-cost monitoring of tampering or material aging. Extension of this methodology to create a new class of highly stable heterogeneous catalysts will also be discussed.

Lecture 3 I 6 May 2021 (online)

Hydrophobicity, Icephobicity and Oleophobicity: from Lotus to Pitcher Plant

This lecture will describe chemical and physical principles of liquid-phobic surfaces. Creating a robust synthetic material with antifouling properties would have broad technological implications for areas ranging from biomedical devices to fuel transport to architecture but has proven to be extremely challenging. Inspirations from natural nonwetting structures, particularly the lotus, surged the development of liquid-repellent microtextured surfaces that rely on the formation of a stable air-liquid interface. Despite over a decade of intense research, these surfaces are, however, still plagued with problems that restrict their practical applications: they show limited oleophobicity with high contact angle hysteresis; do not prevent ice formation; fail under pressure and upon any physical dam- age; cannot self-heal, and are expensive to produce. To address these challenges, I will introduce a new strategy to create self-healing, Slippery Lubricant-Infused Porous Surfaces (SLIPS) that outperform state-of-the-art synthetic surfaces in their ability to resist ice and microbial adhesion and repel various simple and complex liquids.

Lecture 4 I 20 May 2021 (online)

Actuated 'Hairy' Surfaces: En Route for Adaptive, Homeostatic Materials

Dynamic structures that respond reversibly to changes in their environment are central to self-regulating thermal and lighting systems, targeted drug delivery, sensors, and self-propelled locomotion. Since an adaptive change requires energy input, an ideal strategy would be to design materials that harvest energy directly from the environment and use it to drive an appropriate response. This lecture will present the design of a novel class of reconfigurable materials that use 'hairy' surfaces bearing arrays of nanostructures put in motion by environment- responsive gels. Their unique hybrid architecture, and chemical and mechanical properties can be optimized to confer a wide range of adaptive behaviors. Using both experimental and modeling approaches, we are developing these hydrogel-actuated integrated responsive systems (HAIRS) as new materials with reversible optical and wetting properties, as a multifunctional platform for controlling cell differentiation and function, and as a first homeostatic system with autonomous self-regulation.

2021 INTERNATIONAL SOLVAY CHAIR IN CHEMISTRY

Professor Omar Yaghi
Berkeley UC, USA

The 2021 International Solvay Chair in Chemistry was held by professor Omar Yaghi from Berkeley who gave four online lectures in November 2021. He will complete the last part of his Solvay chair in-person in Brussels at the time of the 2022 Solvay Conference in Chemistry of which he is one of the participants.

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 with Professor Richard H. Holm. He has been on the faculties of Arizona State University, University of Michigan and UCLA. 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.

His work encompasses the synthesis, structure and properties of inorganic and organic compounds and the design and construction of new crystalline materials. He is widely known for pioneering several extensive classes of new materials termed metal-organic frameworks, covalent organic frameworks, and zeolitic imidazolate frameworks. These materials have the highest surface areas known to date, making them useful in clean energy storage and generation. Specifically, applications of his materials are found in the storage and separation of hydrogen, methane, and carbon dioxide, and in clean water production and delivery, supercapacitor devices, proton and electron conductive systems. 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 termed this field 'Reticular Chemistry' and defines it as 'stitching molecular building blocks into extended structures by strong bonds'.

He is among the top five most highly cited chemists worldwide.

He is the recipient of the American Chemical Society Chemistry of Materials Award (2009), Izatt-Christensen International Award (2009), United Kingdom's Royal Society of Chemistry Centenary Prize (2010), China Nano Award (2013), King Faisal International Prize in Science (2015), Mustafa Prize in Nanoscience and Nanotechnology (2015), TÜBA Academy Prize in Basic and Engineering Sciences (2016), Royal Society of Chemistry Spiers Memorial Award (2017), King Abdullah II Order of Distinction of the First Class (2017), Japan Society of Coordination Chemistry International Award (2017), Bailar Medal in Inorganic Chemistry (2017), Kuwait Prize in Fundamental Sciences (2017), Albert Einstein World Award of Science conferred by the World Cultural Council (2017), BBVA Foundation Frontiers of Knowledge Award in Basic Sciences (2018), and Wolf Prize in Chemistry (2018).

Lecture 1 I 9 November 2021 (online)

The Discovery of Covalent Organic Frameworks

The synthesis of covalently-linked organic extended structures has been a long-standing objective. The fundamental problem is that attempts to link organic molecular building blocks into extended structures often led to intractable amorphous solids and ill-defined materials, thus impeding development of this field. This changed when the reaction and crystallization conditions for making covalent organic frameworks (COFs) were worked out and reported in 2005 for 2D COFs and 2007 for 3D COFs. This advance extended the field of organic chemistry beyond discrete molecules (0D) and polymers (1D) to infinite layered (2D) and network (3D) extended structures. The discovery of reactions and crystallization conditions for making COFs using reversible as well as what is traditionally considered irreversible linkages (e.g. dioxin, olefin) will be outlined. The recent developments in (1) making large single crystals of COFs, (2) the first molecular weavings, and (3) greatly expanding structural complexity of COFs through building high valency nodes will be presented.

Lecture 2 I 16 November 2021 (online)

Molecular Weaving

The ability to combine the strong bond approach of reticular chemistry with the mechanical bond results in unprecedented class of molecularly woven structures. This presentation will outline the strategies for carrying out molecular weaving using covalent organic framework building blocks. The result is a vast chemical space in which robustness and porosity are combined with flexibility to yield materials of exceptional resiliency and mechanical properties. The reaction chemistry and crystallization methodologies for producing woven structures in which threads are interlaced, and rings and polyhedra are interlocked will be discussed. The inclusion chemistry and evolution of dynamics in these systems will also be presented.

Lecture 3 I 23 November 2021 (online)

Reticular Chemistry: System of Sequences in Multivariate Metal-Organic Frameworks

Linking of molecular building blocks by strong bonds into crystalline extended structures (reticular chemistry) has resulted in metal-organic frameworks and made available precisely designed infinite 2D and 3D materials. Reticular chemistry has been focused on making simple structures in which a few kinds of component are linked to make crystals such as metal-organic frameworks MOFs. While this chemistry has grown into a large field, a more extensive area with fascinating directions is emerging through the introduction of multiplicity and variation into the components of these frameworks. When the framework's backbone is composed of more than two kinds of building unit, the resulting backbone multiplicity is regular repeats of those units.

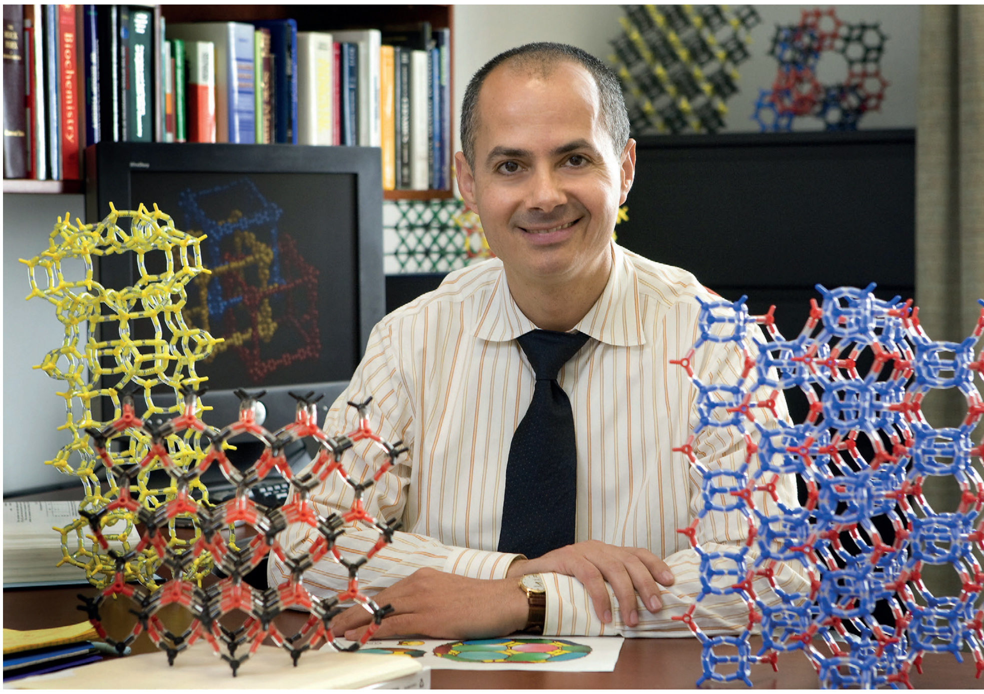
However, when variations involve multiple functionalization of the organic linkers or multiple metalation of metal-containing building units, it results in an aperiodic spatial arrangement of these variations, without altering the regularity of the MOF backbone.

Such variance is represented by unique sequences of functionality or metal, and the very aperiodic nature of their spatial arrangement give rise to sequences and anisotropy. This presentation will be focused on how to recognize, study, and use multivariate MOF structures.

Lecture 4 I 30 November 2021 (online)

Water Harvesting from Air Anytime Anywhere

Water is essential to life. It is estimated that by 2050 nearly half of the world population will live in water stressed regions, due to either arid conditions or lack of access to clean water. This presentation outlines the parameters of this vexing societal problem and presents a solution to the global water challenge. Metal–organic frameworks (MOFs) have emerged as a unique class of porous materials capable of trapping water at relative humidity levels as low as 10%, and doing so with facile uptake and release kinetics. From laboratory testing to field trials in the driest deserts, kilogram quantities of MOFs have been tested in several generations of devices. We show that the vision of having clean water from air anywhere in the world at any time of the year is potentially realizable with MOFs and so is the idea of giving "water independence" to the citizens of the world.



NEW HORIZONS LECTURES IN PHYSICS AND IN CHEMISTRY

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

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

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

Due to the pandemic, some lectures (2020/2021) were given online or were postponed.

2020 NEW HORIZONS LECTURES IN CHEMISTRY

Professor Hans Jakob Wörner

ETH Zurich, Switzerland

Professor Wörner gave three online lectures in October 2021 and will come to Brussels in 2022 to give his last lecture and to interact with belgian researchers.

5 October 2021 (online)

"Attosecond charge migration and its interaction with nuclear motion: towards attochemistry"

Charge migration is a periodic rearrangement of the charge distribution in molecules, driven by a coherent superposition of electronic states. It can be prepared in a variety of ways, including temporally confined ionization, excitation or through electron correlation. In this lecture, I will discuss the experimental measurement and re-construction of attosecond charge migration in spatially oriented molecules [1].

These measurements revealed the essentially complete migration of an electron hole from one side of the iodoacetylene cation to the other in less than one femtosecond. Turning from high-harmonic spectroscopy to attosecond transient-absorption spectroscopy, I will discuss the experimental observation of decoherence and revival of attosecond charge migration driven by nuclear motion in the neutral silane molecule [2].

These results demonstrate a broadly applicable approach to inducing and probing charge migration in molecules, opening the door to controlling molecular dynamics on the electronic time scale. An outlook on the prospects of attochemistry will be given.

[1] P. M. Kraus, B. Mignolet, D. Baykusheva, A. Rupenyan, L. Horný, E. F. Penka, G. Grassi, O. I. Tolstikhin, J. Schneider, F. Jensen, L. B. Madsen, A. D. Bandrauk, F. Remacle, H. J. Wörner, Science 350, 790 (2015).

[2] D. Matselyukh, V. Despré, N. V. Golubev, A. I. Kuleff, H. J. Wörner, submitted (2021)

12 October 2021 (online)

"Attosecond time delays in molecules, clusters and liquids: towards electronic dynamics in solutions"

Attosecond spectroscopy has enabled the observation of ionization dynamics on their natural time scale. These delays convey rich information on the scattering potential of the ionized system, as well as electronic correlations. In this lecture, I will discuss the experimental measurement of time delays in molecules [1]. Turning from gases to liquids, I will discuss the measurement of photoionization delays from liquid water [2] and the development of theoretical methods for their interpretation. Extending attosecond spectroscopy to size-resolved water clusters provided a bridge between the gas and liquid phases and yielded a molecular-level understanding of the mechanisms governing photoionization dynamics in the condensed phase [3]. A systematic correlation between the ionization delay and the spatial extension of the electron hole has been found, which suggests the possibility of studying electron-hole dynamics in weakly bound clusters and liquids with attosecond temporal resolution. These methods establish an experimental pathway to time-resolved studies of electronic dynamics in (micro-)solvated molecules.

[1] M. Huppert, I. Jordan, D. Baykusheva, A. von Conta, H. J. Wörner, Phys. Rev. Lett. 117, 093001 (2016)

[2] I. Jordan, M. Huppert, D. Rattenbacher, M. Peper, D. Jelovina, C. Perry, A. von Conta, A. Schild, H. J. Wörner, Science 369, 974 (2020)

[3] X. Gong, S. Heck, D. Jelovina, C. Perry, K. Zinchenko, H. J. Wörner, submitted (2021), arxiv.org/abs/2106.09459

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.

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

19 October 2021 (online)

"Attosecond soft-X-ray and high-harmonic spectroscopies: bridging the complexity gap"

One of the remaining challenges for attosecond spectroscopy is its extension to complex systems, such as large molecules, molecular aggregates or nanoparticles in solution. X-ray spectroscopy offers an attractive approach to this goal, owing to its element specificity and site sensitivity. In this lecture, I will discuss the development of table-top soft-X-ray spectroscopy and its application to observing the rearrangement of unoccupied molecular states during chemical reactions [1]. The generation of isolated attosecond soft-X-ray pulses with a duration of only 43 attoseconds has established the current world record of the shortest light pulse ever measured [2]. The spectroscopic application of such pulses has revealed the fastest conical-intersection dynamics observed to date, i.e. the sub-7-femtosecond electronic relaxation from the A to the X state in the ethylene cation [3]. Turning from the gas phase to the liquid phase, I will discuss recent results including the observation of suppressed dissociation of ionized pyridine in solution, as well as the ultrafast proton transfer of ionized urea dimers in aqueous solution. These results demonstrate the potential of attosecond soft-X-ray spectroscopy in addressing complex systems.

[1] Y. Pertot, C. Schmidt, M. Matthews, A. Chauvet, M. Huppert, V. Svoboda, A. von Conta, A. Tehlar, D. Baykusheva, J.-P. Wolf, H. J. Wörner, Science 355(6322), 264-267 (2017)

[2] T. Gaumnitz, A. Jain, Y. Pertot, M. Huppert, I. Jordan, F. Ardana-Lamas, H. J. Wörner, Opt. Exp. 25(22), 27506 (2017)

[3] K. S. Zinchenko, F. Ardana Lamas, I. Seidu, S. P. Neville, J. van der Veen, V. Utrio Lanfaloni, M. S. Schuurman, H. J. Wörner, Science 371 (6528), 489 (2021)

2020 NEW HORIZONS LECTURES IN PHYSICS

Professor Douglas Stanford

Stanford University, USA

Professor Standford gave one online lecture in June 2021 and two online lectures in January 2022.

He will come to Brussels in May 2022 to participate in the 28th Solvay Conference on Physics "The physics of quantum information". He will present a report and will be therefore one of the youngest rapporteurs of the history of the Solvay conferences.

8 June 2021 (online)

"Spacetime wormholes and their baggage"

We review the definition of spacetime wormholes and their interpretation by Coleman as describing an average over couplings. We describe the factorization paradox associated to wormholes in AdS/CFT.

Douglas Stanford is a professor at Stanford University. As a member of It from Qubit, he was a postdoc at the Institute for Advanced Study, in Princeton, New Jersey. He received his Ph.D. from Stanford University under the supervision of Leonard Susskind. His recent work has focused on the quantum properties of black holes and on chaotic dynamics in systems with many degrees of freedom. With Juan Maldacena and Stephen H. Shenker, he proved a bound on many-body chaos that is saturated by black holes. Stanford was awarded the 2018 New Horizons in Physics Prize by the Fundamental Physics Prize Foundation for his work on improving the understanding of quantum mechanics of black holes via chaos theory.

2021 NEW HORIZONS LECTURES IN PHYSICS

Professor Maria Bergemann

Max Planck Institute, Heidelberg, Germany

Dr. Maria Bergemann, leading the research group “Stellar spectroscopy and stellar populations” at the Max Planck Institute of Heidelberg (Germany) was the 2021 New Horizon Lecturer in Physics.

Maria Bergemann’s research span a broad range of observational and theoretical topics in modern astrophysics, from numerical modelling and physics of stellar atmospheres to quantitative spectroscopy, detailed studies of chemical and dynamical structure of the Milky Way, cosmic nucleosynthesis and star forming galaxies. She is particularly interested in non-equilibrium radiative transfer modelling using 3-dimentional convective atmospheres. She develops models in quantitative studies of stellar atmospheres, including for Sun-like stars, red giants and supergiants, M dwarfs, and planets. Her group is actively involved in major large-scale astronomical programs like the Gaia-ESO, WEAVE, PLATO, 4MOST and MSE.

Maria Bergemann studied physics at the Kazan State University in Russia, and was then offered a PhD position in geophysics at Cornell University, but chose to pursue doctoral studies in astronomy at Ludwig Maximilian University in Munich. She then moved to post-docs at the Max-Planck Institute for Astrophysics, Garching (Germany), and at the Cambridge University (UK). Since 2014, she is an independent Research Group Leader at the Max Planck Institute for Astronomy, Heidelberg (Germany). She has been selected as a Group Leader in 2019 in the framework of the Lise Meitner Excellence Program. She benefited on 2020 from an ERC starting grant “ELEMENTS”. She is author of more than 200 publications.

18, 20 and 22 October 2021 at ULB

"Reading physics from stellar spectra"

The Milky Way galaxy is host to a few hundred billion stars. Of them, about 10 million, less than 0.01%, have so far been mapped by large-scale spectroscopic surveys. Major progress in the quantity and/or quality of data is expected with next generation astronomical facilities.

In this colloquium, I will focus on the frontiers in diagnostic stellar spectroscopy.

First, I will summarize the physical principles behind models that allow us to extract physical parameters of stars from their observed spectra. 3D non-equilibrium models are poised to become workhorses of astronomy in the next decade.

Second, I will show how we overcome another challenge: the innovative combination of the models and complex noisy data.

Third, I will demonstrate how new data, new models, and new statistics drive progress in the areas that rely on stellar parameters and chemical composition of stars. These include studies of exoplanets, stellar evolution, nucleosynthesis, gravitational wave sources, and Galaxy formation. I will close with a personal view of perspectives opening with large facilities of the next decade, such as SDSS-V, 4MOST, and ELT.

- Discussions with young researchers on topics as diverse as cosmic nucleosynthesis, stellar atmospheres and evolved phases of stellar evolution were organized during these days.
- Discussions with the group of Pascal Quinet (Mons University) took place on October 20, focused on spectrophysics and atomic data of astrophysical interest.
- A young researcher workshop on "How to become a better (funded) scientist" was also organized on October 18 and 22 (moderator: Wouter Ryssens).

Visit at KU Leuven (hosted by the group of Conny Aerts)

19 October 2021

Attendance of Maria Bergemann as guest during the bi-weekly 2-hour meeting of the asteroseismology group, including progress talks by 3 PhD students, followed by joint sandwich lunch.
Afternoon: interactions with the 12 PhD students on the bridging of TESS, Gaia, and Large ESO spectroscopy programs for OBAF-type stars.

20 October 2021

3-hour discussion meeting with staff, postdocs, and PhD students of Profs Conny Aerts and Jon Sundqvist on NLTE spectroscopic line-profile fitting in high-precision spectroscopy of hot massive stars with radiation-driven winds. Maria's visit ended with a joint lunch.

Visit at Liège University - 21 October 2021

Professor Maria Bergemann was hosted in the group of Professor Marc-Antoine Dupret (Department of Astrophysics, Geophysics and Oceanography).

Lecture and discussions with young researchers.

COLLOQUIA

BLACK HOLES, INFORMATION AND WORMHOLES

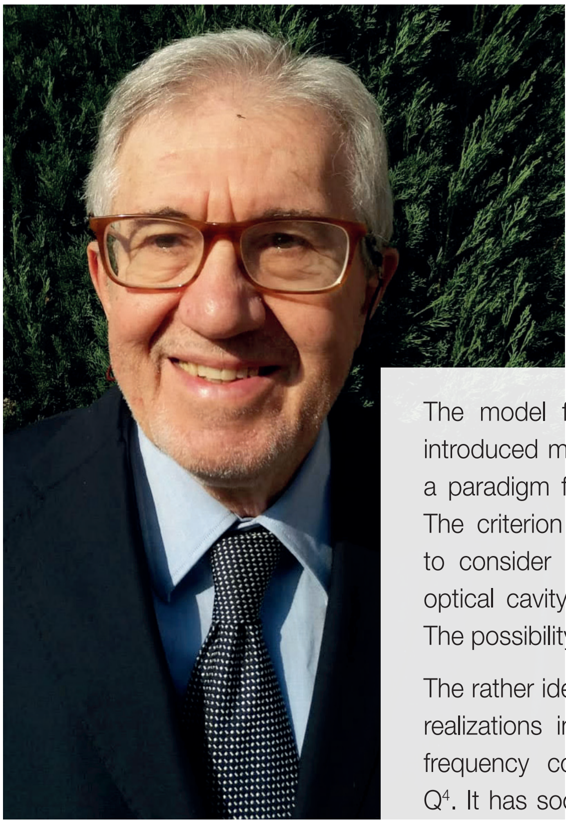
Professor Geoff Penington

UC Berkeley, USA

30 March 2021 (online)

In the 1970s, Hawking showed that black holes, like any finite-temperature system, radiate energy and so eventually evaporate away entirely. However, his calculations showed something very weird: unlike any other physical system, the radiation seemed to contain no information about the initial state of the black hole. Instead the information that fell into the black hole was simply lost forever. This contradiction between Hawking's calculations and the ordinary rules of quantum mechanics has been a driving force behind much of the research in quantum gravity over the ensuing decades.

Finally, in the last couple of years, we have begun to understand where Hawking's calculation went wrong, and to derive precise predictions, consistent with unitary quantum mechanics, for the information content of Hawking radiation. However, the new calculations, which involve weird spacetime topologies called 'spacetime wormholes', lead to as many new questions as answers.



THE CAVITY KERR MEDIUM MODEL AND THE SURPRISING HISTORY AROUND IT

Professor Luigi Lugiato
Università dell'Insubria, Italy

13 April 2021 (online)

The model formulated in[1] (called LLE in the following) was introduced more than thirty years ago with the aim of providing a paradigm for pattern formation in nonlinear optical systems. The criterion of simplicity followed in formulating the LLE led to consider a Kerr medium enclosed in a nonlinear bistable optical cavity of high quality driven by a coherent light beam. The possibility of localized solitonic structures was predicted in[2].

The rather idealized conditions assumed in the LLE met physical realizations in a passive fiber cavity[3] and in broadband Kerr frequency combs in driven microresonators with very high Q[4]. It has soon become clear that the LLE is the model for the description of Kerr combs; the history that starts from the LLE and goes to soliton-based Kerr frequency combs is described in[5].

These results have led to worldwide research activity on this topic. Today Kerr frequency comb generation is a mature field and the technology has been applied to numerous areas, including coherent telecommunications, spectroscopy, atomic clocks as well as laser ranging and astrophysical spectroscopic calibration.

A companion paper to[1], published in 1988[6], extended the LLE concept to the case of a laser instead of a passive system. A very recent paper[7] indicates that a model formulated in[6] is closely linked to quantum cascade lasers.

1 *L. Lugiato and R. Lefever, Spatial dissipative structures in passive optical systems, Phys. Rev.Lett. 58, 2209 (1987)*

2 *A. Scroggie, W.J. Firth, G. McDonald, M. Tlidi, R. Lefever, L. Lugiato, Pattern formation in a passive Kerr cavity, Chaos, Solitons, fractals 4, 1323 (1994)*

3 *S. Coen and M. Haelterman, Continuous-wave ultrahigh-repetition-rate pulse-train generation through modulational instability in a passive fiber cavity,Opt.Lett. 26, 39 (2001)*

4 *P. Del'Haye, A. Schliesser, O. Arcizet, T. Wilken, R. Holzwarth and T.J. Kippenberg, Optical frequency combs generation from a monolithic microresonator, Nature 450, 1214 (2007)*

5 *L. Lugiato, F. Prati, M.L. Gorodetsky and T.J. Kippenberg, From the Lugiato-Lefever equation to microresonator-based soliton Kerr frequency combs, Phil.Trans. Roy.Soc.A 376, 20180113 (2018), theme issue "Dissipative structures in matter out of Equilibrium: from chemistry, photonics and biology (part 2), in honour of Ilya Prigogine.*

6 *L. Lugiato, C. Oldano and L.M. Narducci, Cooperative frequeny locking and stationary spatial structures in lasers, J. Opt. Soc. Am. B 5, 879 (1988)*

7 *M. Piccardo, B. Schwartz, D. Kazakov, M. Beiser, N. Opacak, Y. Wang, S. Jha, M.T amagnone, W. Ting Chen, A.Y. Zhu, L. Columbo, A. Belyakin and F. Capasso, Frequency combs induced by phase turbulence, submitted for publication.*

A JOURNEY IN EXPERIMENTAL TOXICOLOGY, WITH A TWIST OF CHEMISTRY

Professor Dominique Lison
UCLouvain, LTAP, Belgium

11 May 2021 (online)

The general scope of toxicology is to study the adverse effects of natural and manmade chemicals on human health. Experimental toxicologists investigate the molecular and biological mechanisms that drive the toxicity of chemicals. Unravelling these mechanisms is crucial to identify subgroups of the population who are more susceptible, to possibly develop treatments and antidotes, and ideally to support safer-by-design strategies for a sustainable development of chemicals. Investigators at LTAP have identified the mechanisms driving the toxicity of several important industrial chemicals, including the elective respiratory toxicity of cemented carbides used for the manufacturing of hard metals[1], the liver toxicity of hydrogenated compounds proposed for the replacement of ozone-depleting CFCs[2], and the lung toxicity of carbon nanotubes[3,4] and silica dusts[5]. A close inter-disciplinary dialogue between chemists and biologists has always been the key to decipher these mechanisms of toxicity. These examples also illustrate the need, early in the process of discovery and development of new industrial chemicals, for a parallel consideration of technological applications but also implications for human health and the environment.

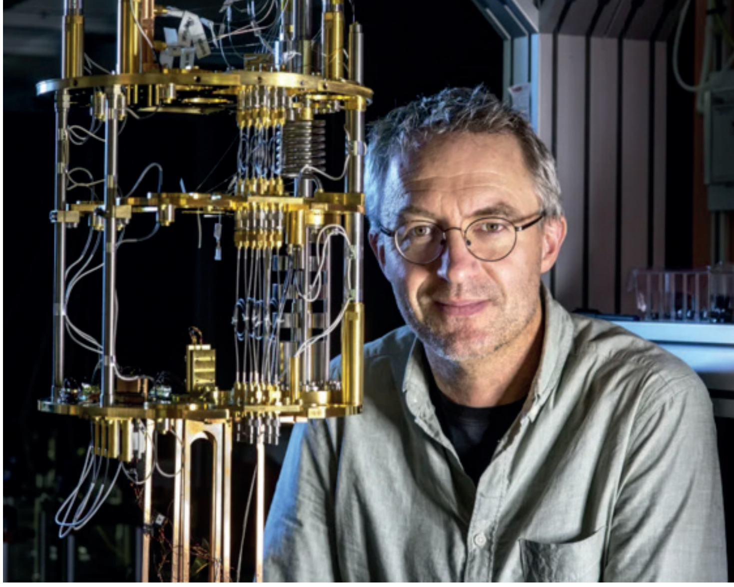
1. Lison D (1996) Human toxicity of cobalt-containing dust and experimental studies on the mechanism of interstitial lung disease (hard metal disease). Crit Rev Toxicol 26:585-616.
2. Hoet P, Graf MLM, Bourdi M, Pohl LR, Duray PH, Chen W, Peter RM, Nelson SD, Verlinden N, Lison D (1997) An epidemic of liver disease caused by hydrochlorofluorocarbons (HCFCs) used as ozone-sparing substitutes of chlorofluorocarbons (CFCs). The Lancet 350:556-559.
3. Muller, J., Huaux, F., Fonseca A., B. Nagy J., Moreau N., Delos M., Raymundo-Piñero, E., Béguin, F., Kirsch-Volders M., Fenoglio I., Fubini B. and Lison D. (2008) Structural defects play a major role in the acute lung toxicity of multi-wall carbon nanotubes: toxicological aspects. Chem. Res. Toxicol. 21(9):1698-705 (JCR 06: 3.162).
4. Fenoglio, I., Greco, G., Tomatis, M., Muller J., Raymundo-Pinero, E., Béguin, F., Fonseca A, B.Nagy, J., Lison D, and Fubini, B. (2008) Structural defects play a major role in the lung toxicity of multi-wall carbon nanotubes: physicochemical aspects. Chem. Res. Toxicol. 21(9):1690-7.
5. Pavan C, Santalucia R, Leinardi R, Fabbiani M, Yakoub Y, Uwambayinema F, Ugliengo P, Tomatis M, Martra G, Turci F, Lison D, and Fubini B (2020) Nearly free surface silanols are the critical molecular moieties that initiate the toxicity of silica particles. Proc Nat Acad Sci 117 (45) 27836-27846.

HYDRODYNAMICS BEYOND HYDRODYNAMICS

Professor Pavel Kovtun
University of Victoria, Canada

18 May 2021 (online)

Hydrodynamics is a well-established field with a venerable history. In this talk, I will focus on foundational aspects of hydrodynamics which came to light in recent years. Do the equations of hydrodynamics even make sense? To what degree can the crudeness of hydrodynamics be improved? What about the phenomena that hydrodynamics should describe but fails to? And what about the phenomena that hydrodynamics shouldn't describe, but does?



QUANTUM HARDWARE FOR QUANTUM COMMUNICATION

Professor Val Zwiller
KTH, Stockholm, Sweden

1 June 2021 (online)

We develop single photon sources based on semiconductor quantum dots to generate single photons as well as photon pairs at telecom wavelengths that ultimately, enable the implementation of long distance quantum communication in optical fibers. Operation at telecom wavelengths also allows us to implement experiments at the single photon level with off-the-shelf components such as modulators.

Schemes to manipulate light on-chip, allowing for integration, scalability and higher reliability are also carried out with the aim of operating at telecom frequencies as well. Last but not least, single photon detectors with high efficiency, low noise and high time resolution are required to realize quantum communication experiments. For this purpose, we develop NbTiN superconducting nanowire single photon detectors. To allow for complex systems, integrated quantum optics circuits where we combine quantum sources and superconducting detectors are under development.

Finally, we demonstrate single photon transmission over 32 km of deployed SMF28 fibers, paving the way to secure telecommunication links using quantum technologies.

HABITABILITY OF MARS AND ELSEWHERE IN THE SOLAR SYSTEM

Professor Véronique Dehant
Royal Observatory of Belgium &
U. Catholique de Louvain

28 September 2021

The habitability of planets is directly related to their evolution, which is mainly driven by their internal energy sources and depends on the composition, structure, and thermal state of their interior. There is no direct access to planetary interiors but observations of their rotation for instance provide indirect information on their interiors, in the same way as a raw (liquid) egg and a cooked (solid) egg rotate differently. In this conference, we will discuss both the Earth and Mars from which we have rotation data and the consequences for their deep interiors in terms of core flows.

Véronique Dehant works at the Royal Observatory of Belgium, where she is Responsible for the Operational Directorate “Reference Systems and Planetary Science”. She is also Extraordinary Professor at the Université Catholique de Louvain. She is Academician (Royal Academy of Belgium, Science class) since 2010 and was awarded with several prizes, including the Descartes Prize of the European Union in 2003. In 2015, she has obtained a European Research Council (ERC) Advanced Grant, with the project RotaNut: Rotation and Nutation of a wobbly Earth and in 2020, a second ERC Grant (Synergy), with the project GRACEFUL (GRavimetry, mAgnetism, rotation and CorE Flow).

In December 2020, she got the Prix Dr A. De Leeuw-Damry-Bourlart of the FNRS.

THE BELGIAN PHYSICAL SOCIETY & THE INTERNATIONAL SOLVAY INSTITUTES JOINT WEBINARS ON NUCLEAR FUSION RESEARCH

29 September 2021

"Introduction to nuclear fusion research"

Dr. Julien Hillairet, Directeur de Recherches, Institut de Recherche sur la Fusion Magnetique, CEA Cadarache, France

5 October 2021

"Objectives and status of the ITER project, the first fusion reactor under construction"

Dr. Alberto Loarte, Head of the ITER Science Division, Science, Controls and Operation Department, ITER Organization, Cadarache, France

13 October 2021

"The long way to steady-state fusion plasmas
The superconducting stellarator experiment Wendelstein 7-X"

Prof. Dr. Thomas Klinger, Director of the Division Stellarator Dynamics and Transport, Director of the Project Wendelstein 7-X, Max Planck Institute for Plasma Physics, Greifswald, Germany

20 October 2021

"Materials research for fusion: availability of fusion relevant neutron sources"

Dr. Juan Knaster, Deputy Head of ITER Programme Department, F4E at ITER Organisation, Cadarache, France

27 October 2021

"Inertial fusion research: physics, status and latest results"

Prof. Dr. Vladimir Tikhonchuk, Centre Lasers Intenses et Applications, Université de Bordeaux, France

DOCTORAL SCHOOLS

XVII MODAVE SUMMER SCHOOL ON MATHEMATICAL PHYSICS

Brussels, 13 - 17 September 2021

The Modave Summer School on Mathematical Physics is a yearly summer school in topics of theoretical physics ranging from quantum gravity and cosmology to theoretical particle physics and string theory. For this 2021 edition, the school exceptionally took place in Brussels as opposed to its traditional venue in Modave, a charming village in the Belgian countryside close to Huy. The Modave School is organised by PhD students for PhD students, and this makes it rather unique. The courses are taught by Post-Docs or late PhD students, and they are all made of pedagogical, basic blackboard lectures about recent or fundamental topics in theoretical physics. Lectures of the seventeen edition are centered around the following subjects: Integrability in field theory, Horizon-scale microstructure of black holes, Goldstone boson physics and Interplays between cosmology, string theory and the Swampland program.

Organizing Committee

Ankit Aggarwal (ULB), Sergio Ernesto Aguilar Gutierrez (KUL),
Martin Bonte (ULB), Lorenzo Cimino (UMONS), Marine De Clerck (VUB),
David De Filippi (UMONS), Arnaud Delfante (UMONS),
Vasko Dimitrov (KUL), Adrien Druart (ULB), Ludovic Ducobu (UMONS),
Adrien Fiorucci (ULB), 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), Daniel Naegels (ULB),
Pierluigi Niro (ULB/VUB), Antoine Pasternak (ULB),
Maxim Dmitrievich Pavlov (VUB), Simon Pekar (UMONS),
Antoine Somerhausen (ULB), Colin Sterckx (ULB),
Rob Tielemans (KUL), 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

Classical Integrability in 2d Field Theories

by Sibylle DRIEZEN
(Universidad de Santiago de Compostela)

In these lectures, I will introduce the salient features of 2d classical integrable field theories. These models are distinguished by the rare property of having an infinite tower of conserved charges that are in involution and, therefore, in a certain sense completely solvable. In particular, I will cover the notions of Lax connections, monodromy matrices and Maillet brackets. I will illustrate these concepts with the Principal Chiral Model which is a two-dimensional integrable sigma model relevant for string theory and the AdS/CFT correspondence. At the end I will give a broad overview of deformations of sigma models of which the integrable structure is preserved.

Horizon-Size Microstructure, Fuzzballs and Observations

by Daniel MAYERSON (CEA Saclay)

In these lectures, we will discuss various aspects of the fuzzball paradigm. We will briefly introduce the information paradox and discuss how the fuzzball paradigm aims to resolve it. Then, we will explore in some detail the two most important and well-known families of explicit fuzzball solutions in supergravity (generically called microstate geometries): multicentered geometries and superstrata. Finally, we will review some very recent developments of the gravitational phenomenological study of fuzzballs and delineate the exciting opportunities as well as the limitations of studying fuzzballs as alternatives to black holes in current and future observations.

Cosmology, String Theory and the Swampland

by Alex COLE (University of Amsterdam)

The swampland program studies universal aspects of quantum gravity, with particular interest in how these aspects descend to constraints on low-energy physics. In these we will introduce, motivate, and study the consequences of several conjectured swampland constraints. We will see how perturbative string theory, extremal black holes, asymptotic limits in moduli spaces, and holography can be used to test conjectures.

A rough breakdown of topics:

- → introduction, EFT, global symmetries and completeness;
- → weak gravity conjecture;
- → swampland distance conjecture;
- → cosmological consequences?
- → the weak gravity conjecture and black hole corrections.

Goldstone Boson Physics and Effective Field Theories

by Daniel NAEGELS (ULB, Brussels)

The lecture will start by briefly stating Goldstone theorem and emphasize the motivations behind Goldstone physics; the main asset being the universality of spontaneous symmetry breaking (SSB), the fundamental hypothesis of Goldstone theorem. Once we clarified/reviewed the different notions of SSB, Goldstone theorem will be presented and proved. A prediction of this theorem is the existence of gapless particles, called Nambu-Goldstone (NG) modes. From the discussion on Goldstone results, some aspects of the NG modes will emerge. Beside to be massless, there are systematically weakly coupled at low energy. Therefore, an effective field theory (EFT) building tool called "coset construction" will be presented to explicitly display these specific features of NG modes. Coset construction suits for our goal since it is mainly based on the symmetry realizations of the perturbed theory around the background inducing SSB. From the general obtained EFT, a counting rule for the NG modes will be derived. The limitations of this rule as well as the still ongoing research generalization will be discussed (cf. spacetime symmetries). This will allow to a smooth transition to a brief state of the art of Goldstone physics. Finally, if time allows it, the tools developed during this course will be illustrated with a concrete example in physics.

Participants

Ankit Aggarwal (ULB Brussels and UvA Amsterdam)

Sergio Ernesto Aguilar Gutierrez (KU Leuven)

Cyrille Chevalier (UMons)

Lorenzo Cimino (Université de Mons)

Alex Cole (University of Amsterdam)

Kamil Cwiklinski (UMons)

Marine De Clerck (VUB)

David De Filippi (UMons)

Arnaud Delfante (UMons)

Vasil Dimitrov (KU Leuven)

Sibylle Driezen (Universidade de Santiago de Compostela)

Adrien Druart (ULB)

Kwinten Fransen (KU Leuven)

Philip Hacker (VUB)

Abdelhamid Haddad (Aix-Marseille University)

Caroline Jonas (Max Planck Institute for Gravitational Physics)

Joel Karlsson (KU Leuven)

Maria Knysh (VUB)

Quim Llorens (University of Barcelona)

Ludovico Machet (KUL-ULB)

Simon Maenaut (KU Leuven)

Daniel Mayerson (CEA Saclay)

Daniel Naegels (ULB)

Dušan Novičić (Ludwig Maximilian University of Munich)

Josh O'Connor (UMons)

Noémie Parrini (UMons)

Maxim Pavlov (VUB)

Simon Pekar (UMons)

Ahmed Rakin Kamal (Université de Bourgogne Franche-Comte)

Mattia Serrani (UMons)

Colin Sterckx (ULB)

Sayeda Tashnuba Jahan (Université Paris Saclay)

Simon Theil (FAU Erlangen-Nürnberg)

Romain Vandepopeliere (ULB)

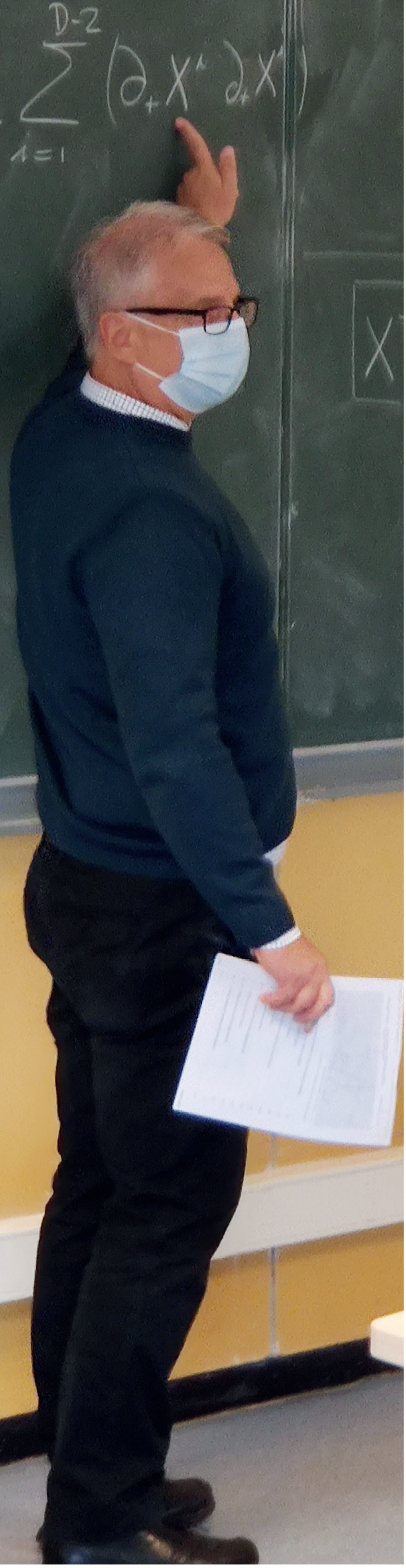
Quentin Vandermiers (ULB)

Richard van Dongen (UMons)

Vincent Van Hemelryck (KU Leuven)

Annelien Vekemans (KU Leuven)

Xuao Zhang (KU Leuven)



DOCTORAL SCHOOL ON "QUANTUM FIELD THEORY, STRINGS AND GRAVITY"

Brussels, 4 - 22 October 2021

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.

Programme

Brussels | 4 - 22 October 2021

Adel Bilal	*Advanced Quantum Field Theory*
Alberto Lerda	*String Theory I*
Marco Billò	*String Theory II*
Geoffrey Compère	*Gravitational waves & Advanced Lectures on General Relativity*

Paris | 2 - 19 November 2021

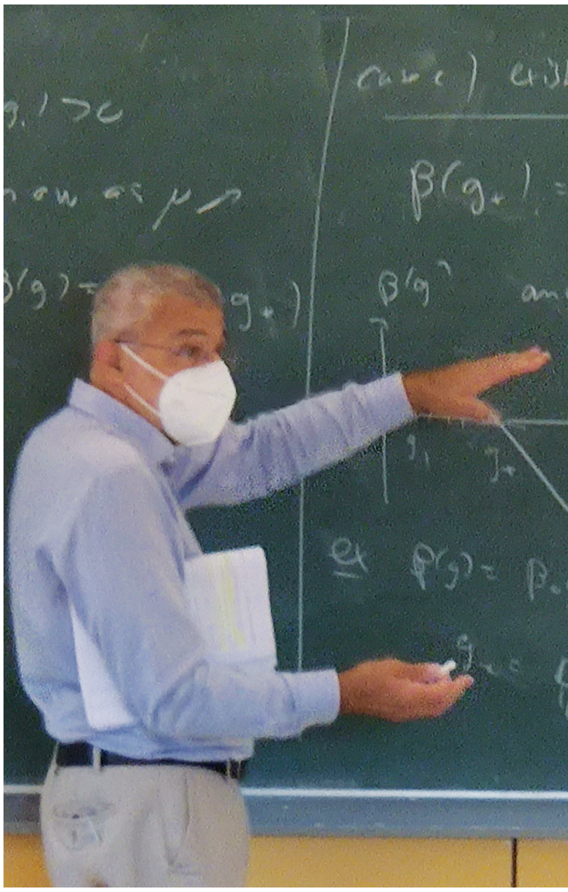
Silvia Penati	*Introduction to Supersymmetry*
Domenico Orlando	*Introduction to Superstrings*
Susanne Reffert	*D-branes and Superstring Dualities*
Julian Sonner	*AdS/CFT*
Antoine van Proeyen	*Introduction to Supergravity*

Amsterdam | 29 November - 17 December 2021

Kyriakos Papadodimas	*AdS/CFT*
Andrea Puhm	*A celestial holography primer*
Jan Pieter van der Schaar	*Cosmology*
Erik Verlinde	*Quantum Gravity and Quantum Information*
Michael Walter	*Quantum Information and Quantum Gravity*

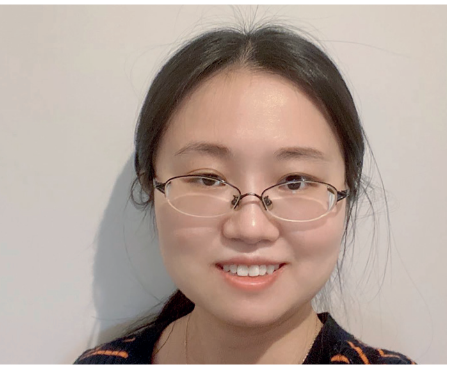
Participants

Boruch Jan (University of Warsaw, Poland)
Casagrande Gabriele (École polytechnique, Paris, France)
Duarte Mourão Paulo (University of Geneva, Switzerland)
Figueroa Silva José Pablo (Universidad de Concepción, Chile / ULB, Belgium - cotutelle)
Figueroa Vilar del Valle Felipe (LAPTh, Annecy, France)
Gkountoumis Georgios (Utrecht University, The Netherlands)
Grinko Dmitry (University of Amsterdam, The Netherlands)
Groenenboom Nico (Utrecht University, The Netherlands)
Guillen Anthony (Sorbonne Université, Paris, France)
Guoen Nian (Utrecht University, The Netherlands)
Hoefnagels Arno (Utrecht, The Netherlands)
Horer Ludwig Sebastian (Technical University of Vienna, Austria)
Im Egor (ETH Zurich, Switzerland)
Karlsson Joel (KU Leuven, Belgium)
Klisch Sonja (University of Edinburgh, UK)
Kodžoman Toni (Ruđer Bošković Institute, Zagreb, Croatia)
Loparco Manuel (EPFL, Lausanne, Switzerland)
Loty Adrien (École Polytechnique, Paris, France)
McDonald Ross (University of Edinburgh, UK)
Mol Louan (Université Libre de Bruxelles, Belgium)
Naderi Kiarash (ETH Zürich, Switzerland)
Post Boris (University of Amsterdam, The Netherlands)
Radhakrishnan Bharathkumar (University of Geneva, Switzerland)
Rost Facundo Emanuel (University of Amsterdam, The Netherlands)
Sriprachyakul Vit (ETH Zurich, Switzerland)
Strittmatter Benjamin (University of Edinburgh, UK)
Sueiro Arthur (École Normale Supérieure, Paris, France)
Tan Wen-Di (Université Libre de Bruxelles, Belgium)
Vilatte Matthieu (École Polytechnique de Paris, France & Aristotle University of Thessaloniki, Greece)
Viswanathan Karthik (University of Amsterdam, The Netherlands)



Student's opinion

Wendi Tan
PhD student I ULB



The Solvay Doctoral School is the beginning of my PhD journey. This program covers a lot of subjects such as superstring theory and advanced general relativity in order to provide with us not only the knowledge we should gain as a first-year PhD student, but also lead us to know something about the frontier of different aspects of theoretical high-energy physics. Moreover, first-year PhD students from different universities in Europe gathered during these three blocks of lectures, we discussed with each other, exchanging our understanding about physics and spent very wonderful time together. So this is also a very important opportunity for us to get acquaintance with peers cultivating in similar fields.

Although it turned to the hybrid form in Amsterdam period. As an international student who is from east Asia and has never been to Europe before, taking part in such a doctoral school is quite a novel experience for me. During these periods, I visited three important universities in three different cities, namely Brussels, Paris and Amsterdam which I have never been to before. I took courses in very different styles comparing with the courses I took before. I knew something about the frontier of some fields such as celestial holography although sometimes taking courses given in English and without lecture notes provided after class can be a little bit challenging for me. I also exchanged my opinions about physics with other students and we worked together to read and present a paper in the field which I have never dabbled in before. All of these can be very useful experience for me to continue my PhD career in Europe.

Thus, the Solvay School is quite a fitted program to get started with my PhD. And the organizers and lectures' diligent work needed to be acknowledged!

Wendi Tan

Student's opinion

José Pablo Figueroa Silva
PhD student I ULB

Being a new PhD student at ULB coming from abroad as part of a cotutelle agreement, it was a tremendous opportunity to participate in the Solvay School. The program exposes students to a wide variety of topics in physics, from the building blocks of theoretical high energy physics to the current frontiers and new developing research lines.

The School allowed me to learn about fields in physics that I could not cover during my Master in Chile, and to reinforce the ones in which I am most interested in and that I have worked on, leaving me well prepared to continue with my PhD and research projects. It also gave me the possibility to learn of different ways of doing research and teaching, from each of the different three universities involved in this version. And, one of the most important things for me was to be able to interact with classmates again and to discuss physics face to face at the blackboard, something I have not done since before the pandemic. This gave me an immense amount of motivation, and reminded me of one of the main reasons why I love Physics.

In that sense I am very grateful to the organizers, who put their best effort into making everything go well and smoothly. And of course to the lecturers, who in the best way and with great motivation brought us knowledge that before seemed quite distant.

The 2021 version of the Solvay School met all my high expectations and was the perfect way to start my doctorate.

José Pablo Figueroa Silva

SEMINARS

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

JANUARY

Horizons 2020
Shahin Sheikh-Jabbari

Misaligned Supersymmetry in String Theory
Susha Parameswaran

FEBRUARY

Toward a 3d Ising Model with a weakly coupled string dual
Nabil Iqbal

Nonperturbative structures in the SYK model
Mikhail Khramtsov

MARCH

The cosmological constant in supergravity and string theory
Ignatios Antoniadis

Discreteness and Integrality in Conformal Field Theory
Justin Kaidi

Crossing the Horizon: Using Soft Hair to Evade a Firewal
Sabrina Pasterski

A Momentum/Complexity correspondence
Javier Martin

Geometric constraints on the space of 4d theories
Mario Martone

APRIL

Grigory Tarnopolski

MAI

Remarks on thermal one-point functions in CFTsat 3PM as usual.
Anastasios Petkou

Matthew Roberts

The EFT stringy viewpoint on large distances
Stefano Lanza

Chiara Toldo

Magnetic Quivers and Phase Diagrams — New ways of thinking about moduli spaces of supersymmetric gauge theories
Amihay Hanany

SEPTEMBER

Steve Abel

OCTOBER

Towards Solving CFTs with Artificial Intelligence
Costis Papageorgakis

Monica Pate

Eric Perlmutter

The anomaly that was not meant IIB
Miguel Montero

NOVEMBER

Fractons and D-branes
Shamit Kachru

Liouville and JT quantum gravity
Thomas Mertens

G-algebroids, a unified framework for exceptional and generalised geometry
Ondřej Hulík

Johannes Lahnsteiner

Diego Hofman

Davide Cassani

Juan Pedraza

DECEMBER

The string dual of free N=4 SYM
Matthias Gaberdiel

The Cardy-like limit of the superconformal index
Marco Fazzi [BEL-center:theory]

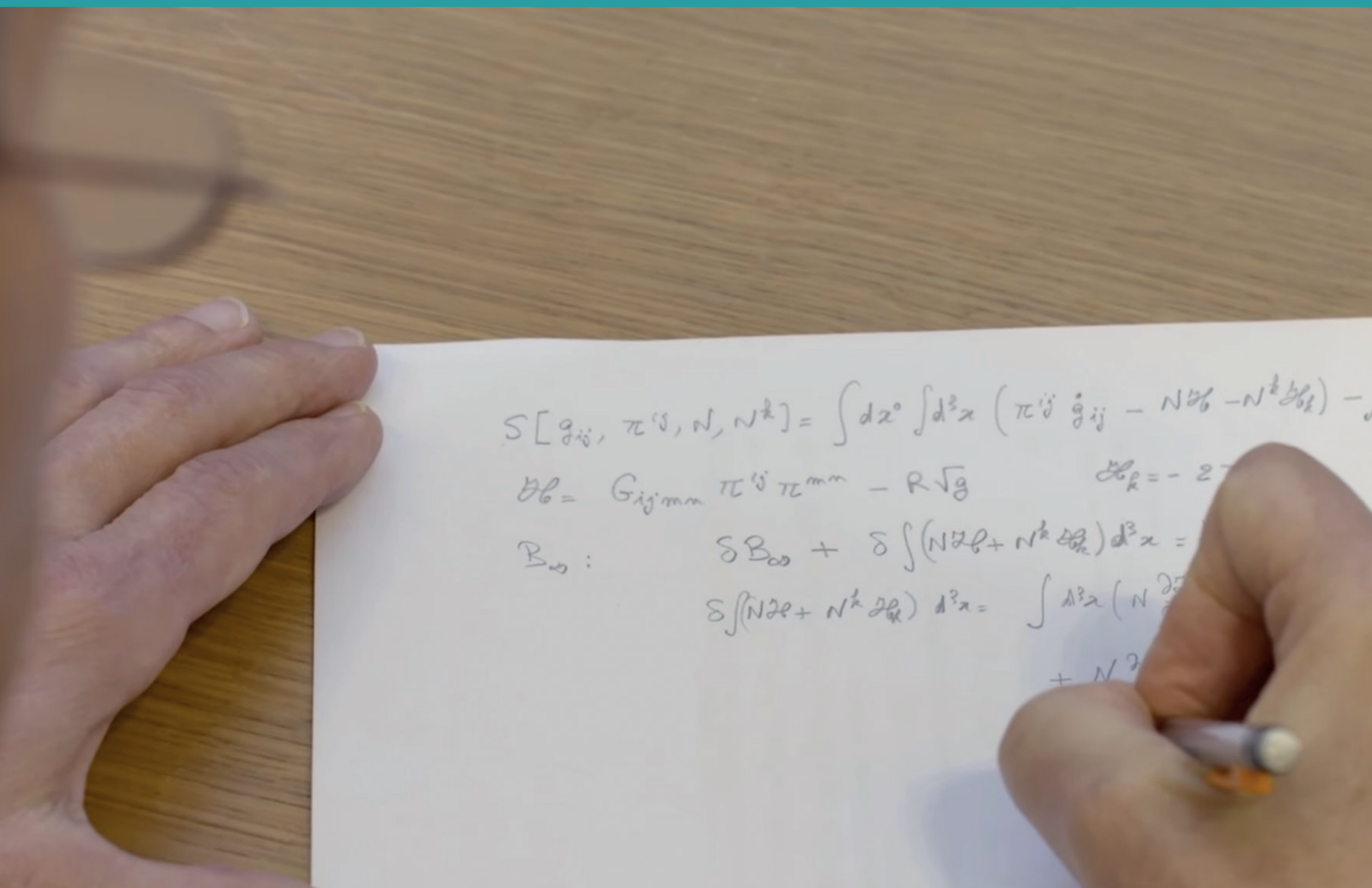
Alexander Ochirov

Conformal renormalization in AdS gravity
Rodrigo Olea

Conformal boundary conditions for free fields
Edoardo Lauria

04

RESEARCH



RESEARCH ON GRAVITATION, STRING THEORY AND COSMOLOGY

GROUPS OF PROFESSORS MARC HENNEAUX | ULB AND ALEXANDER SEVRIN | 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)
Alberto Mariotti (VUB)
Mairi Sakellariadou (VUB)
Alexander Sevrin (VUB)
Dan Thompson (VUB)

Postdoctoral Researchers

Jeremias Aguilera-Damia (ULB)
Francesco Alessio (ULB & Naples)
Alexandros Spyridon Arvanitakis (VUB)
Simone Blasi (VUB)
Luca Ciambelli (ULB)
Marine De Clerck (VUB)
Camille Eloy (VUB)
Oscar Fuentealba (ULB)
Eduardo García-Valdecasas (ULB)
Juan Hernandez (VUB)
Ondra Hulik (VUB)
Mikhael Khramtsov (VUB)
Sucheta Majumdar (ULB)
Javier Matulich (ULB)
Wout Merbis (ULB)
Turmoli Neogi (ULB)
Romain Pascalie (ULB)
Patricio Salgado-Rebolledo (ULB)
Jakob Salzer (ULB)
Ali Seraj (ULB)
Luigi Tizzano (ULB)
Alejandro Vilar López (ULB)

Doctoral Researchers

Ankit Aggarwal (ULB)
Martin Bonte (ULB)
Adrien Druart (ULB)
Adrien Fiorucci (ULB)
Philip Hacker (VUB)
Sam Junius (VUB)
Maria Knysh (VUB)
Lorenzo Küchler (ULB)
Yan Liu (ULB)
Ludovico Machet (ULB)
Abbas Mirahmadi (ULB)
Louan Mol (ULB)
Daniel Naegels (ULB)
Pierluigi Niro (ULB/VUB)
Antoine Pasternak (ULB)
Maxim Pavlov (VUB)
Aäron Rase (VUB)
Antoine Somerhausen (ULB)
Colin Sterckx (ULB)
Kevin Turbang (VUB)
Wen-di Tan (ULB)
Romain Vandepopeliere (ULB)
Quentin Vandermiers (ULB)
Sofia Zhidkova (VUB)

Research Summary

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

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

In 2021, we have continued our research along the general directions outlined above. This has led to 124 published papers and preprints submitted for publication. These are listed on pages 117-118. Specific achievements by some researchers from the group are described in the subsequent pages.

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

MARINA SOLVAY FELLOWSHIP

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

Previous Marina Solvay Fellows

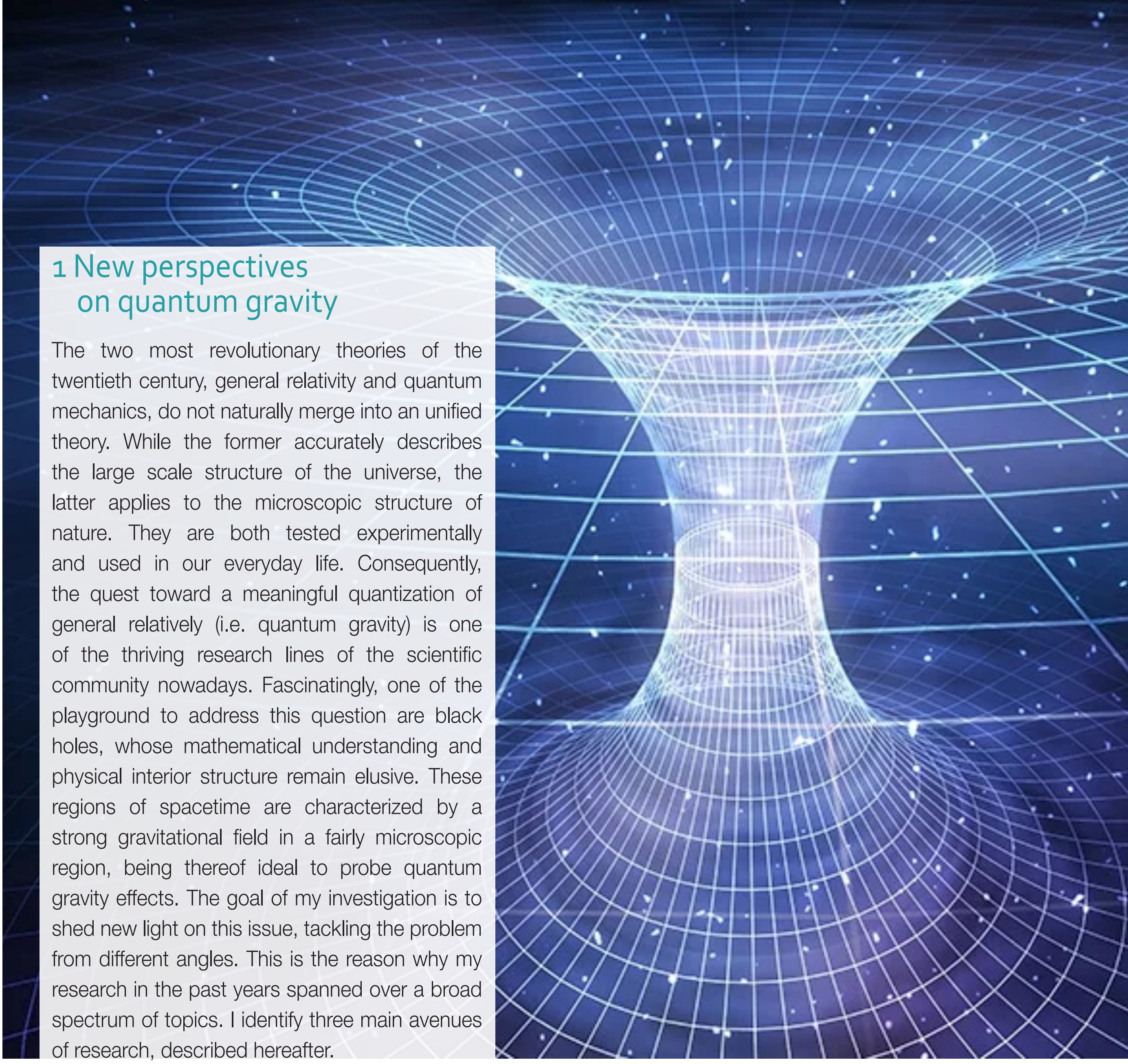
2012 - 2014	2015	2016	2017	2018	2019	2020	2021
Waldemar Schulgin	David Tempo	Jelle Hartong	Adolfo Guarino	Charlotte Sleight	Sucheta Majumdar	Oscar Fuentealba	Luca Ciambelli

Luca Ciambelli

Postdoctoral Researcher ULB

Luca Ciambelli got his PhD degree at the Ecole Polytechnique in Paris (France) in 2019 before joining the group of the Director at ULB. His research deals with the algebraic structure of gauge theories and a wide range of aspects of Einstein theory: black hole thermodynamics, ultrarelativistic limit, asymptotic symmetries and infinite dimensional groups. He is also involved in the swampland program.

He held the Marina Solvay fellowship in 2021.



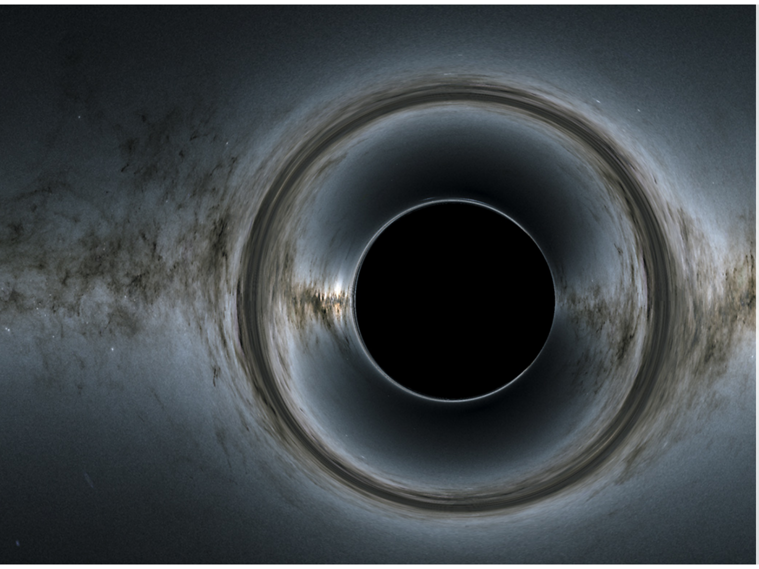
1 New perspectives on quantum gravity

The two most revolutionary theories of the twentieth century, general relativity and quantum mechanics, do not naturally merge into an unified theory. While the former accurately describes the large scale structure of the universe, the latter applies to the microscopic structure of nature. They are both tested experimentally and used in our everyday life. Consequently, the quest toward a meaningful quantization of general relatively (i.e. quantum gravity) is one of the thriving research lines of the scientific community nowadays. Fascinatingly, one of the playground to address this question are black holes, whose mathematical understanding and physical interior structure remain elusive. These regions of spacetime are characterized by a strong gravitational field in a fairly microscopic region, being thereof ideal to probe quantum gravity effects. The goal of my investigation is to shed new light on this issue, tackling the problem from different angles. This is the reason why my research in the past years spanned over a broad spectrum of topics. I identify three main avenues of research, described hereafter.

1.1 Three-dimensional models

In the search for toy models able to capture the main features of the most salient black hole conundrums, and of quantum gravity thereof, lower-dimensional theories have always stood out. Indeed, simplified models of quantum gravity are of great relevance, for they can potentially unveil universal features that are impossible to address in more realistic configurations. This led researchers to focus on toy models in three-dimensional gravity, particularly in Einstein-Hilbert gravity in (2+1) dimensions with a negative cosmological constant. Albeit without propagating degrees of freedom, this theory contains black hole solutions — the famous BTZ black holes. In the by now classic Brown and Henneaux paper, it has been shown that the phase space of AdS_3 gravity admits a non-trivial action of the 2-dimensional conformal group, pioneering in three dimensions what later was found out to be the AdS/CFT correspondence, explained in greater detail below. Supplementing a gravitational Chern-Simons term to Einstein-Hilbert gravity gives rise to Topologically Massive Gravity (TMG), a model enriched with propagating degrees of freedom. In this context, I, Stephane Detournay, Ankit Agarwal, and Antoine Somerhausen, found new boundary conditions such that the holographic field theory, called Warped CFT, is naturally found in the so-called quadratic ensemble. In this setup, we proved that the counting of asymptotic degeneracy of states reproduces correctly the black hole entropy, via the Warped Cardy formula.

This added a step in the understanding of this simplified model of quantum gravity. We plan in the future to add supersymmetry, and study how this affects the result mentioned. In particular, these models are realized in the near horizon region of certain classes of black holes. We therefore hope to be able to provide new insights on black hole physics from a better understanding of these models in the future.

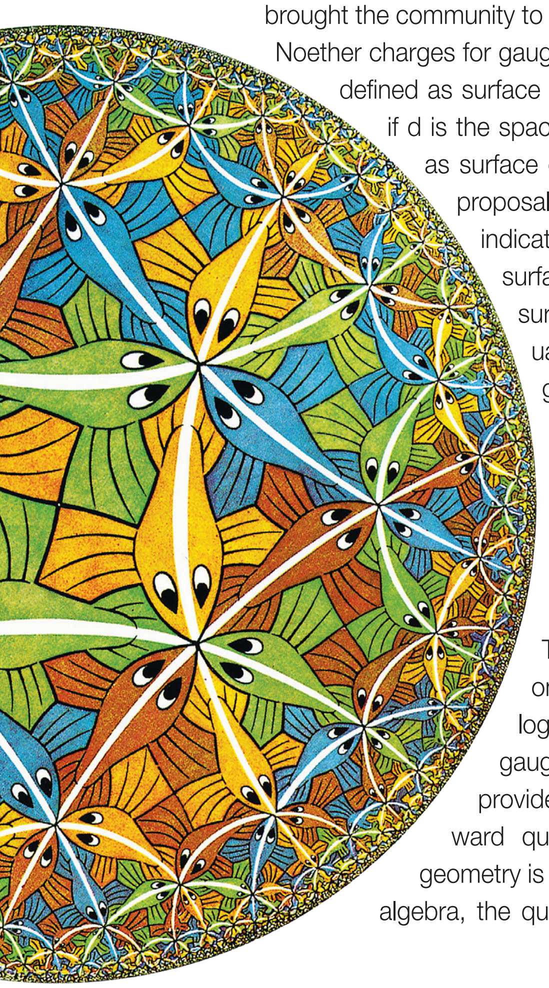


1.2 Fluid/Gravity Correspondence

Another avenue of research I am currently exploring is the fluid/gravity correspondence, a spinoff of the AdS/CFT correspondence. The latter is the prime example of a duality. Dualities are crucial ingredients in modern era physics, allowing to relate two seemingly uncorrelated theories. The importance of this transversality in physics cannot be stressed enough, incorporating the modus operandi of researchers nowadays. In a nutshell, the AdS/CFT correspondence, states that (quantum) gravity on a d-dimensional asymptotically anti-de Sitter (AdS) spacetime is dual to a conformal field theory (CFT) in one dimension less, living on the boundary of AdS. In order words, this correspondence relates a dynamical theory of gravity with a seemingly very different theory, a theory of fields (without gravity) possessing conformal invariance. This powerful duality is permeating all aspects of high-energy physics. In practice, nonetheless, the AdS/CFT is hard to handle, and sometimes it is too complicated to grasp useful predictions. This explains why I, Marios Petropoulos, Anastasios Petkou, Konstantinos Siampos, and Charles Marteau, considered the fluid/gravity spinoff, where we perform the hydrodynamic long wavelength limit in the boundary field theory, that gives rise to a relativistic fluid, whose equations of motion translates directly into Einstein equations for the dual gravitational theory. It is in this framework that we found new results, especially concerning the flat limit. The latter is achieved sending the cosmological constant to zero on the gravity side. Until some years ago, it was not clear what was the counterpart of this procedure on the boundary. We showed that the relativistic fluid becomes an ultra-relativistic one in this limit, exhibiting conformal Carroll symmetries. This opened the door to new promising results in the understanding of asymptotically flat holography. The latter, now revitalized thanks to the celestial holography proposal, is among the best setups we currently have to unveil quantum gravity predictions, such as scattering amplitudes. In the future, we will keep investigating the still puzzling Carroll physics, which is the correct background structure for flat holography, and which has attracted lot of attention lately.

1.3 Corner Physics

A different, yet ultimately connected, idea in quantum gravity is the corner proposal. This proposal is more recent, and is developing a fresh perspective on old unanswered questions in the field. Symmetries in gauge theory have been the subject of intense study since the work of Madame Noether, arguably one of the most pioneering paper in theoretical physics. While the first Noether theorem deals with global symmetries, that is, symmetries associated to transformations applied simultaneously at all points of spacetime, Noether herself remarked that for a gauge symmetry, defined as a local symmetry acting differently at different spacetime points, Noether's first theorem gives a current associated to the symmetry that necessarily vanishes on-shell up to total derivatives, which naively seems an unpleasant feature. It is this "up to total derivatives" remark that brought the community to the understanding that Noether charges for gauge symmetries must be defined as surface integrals of d-2 forms, if d is the spacetime dimension, i. e., as surface charges. In the corner proposal, the term "corner" indicates a codimension-2 surface on which these surface charges are evaluated. The non-trivial gauge symmetry algebra is an essential tool to reformulate geometrical observables in an algebraic language amenable to quantization.



This proposal is based on the idea of local holography, in which the gauge symmetry algebra provides a clear pathway toward quantization, where the geometry is encoded into a charge algebra, the quantum kinematics into its representations, and the quantum dynamics into fusion properties. A complete understanding of the geometry of corners is thus an essential starting point in this proposal. In a longstanding collaboration between me and Robert Leigh, we recently provided such a geometric picture, unveiling an universal algebra associated to spacetime diffeomorphisms at corners, that we named the maximal embedding algebra. This algebra is expected to hold also in the putative quantum gravity theory, and to organizes the transformation rules of quantum gravity observables, providing deep predictions thereof. We, together with Pin-Chun Pai, then returned to classical analysis and found an extension of the well-known covariant phase space analysis for gravity, such that the Noether charges are always integrable. This comes about thanks to a scrupulous analysis of embeddings of corners, and the effects that the embedding map has on the field space. We are still exploring the far-reaching consequences of our mathematical result, testing it in specific physics setups. The corner proposal is ultimately connected with another recent idea on quantum gravity, celestial holography. In the latter, the bulk gravitational information in asymptotically flat spacetimes is encoded in the properties of a 2-dimensional CFT living on the celestial sphere, a sphere on null infinity. Here also, the geometric data are related to algebraic properties of operators. We are currently exploring how the corner proposal marries with celestial holography, and our expectation is that eventually these two theories are two sides of the same coin.

RESEARCH INTERESTS AND ACHIEVEMENTS OF SOME OTHER MEMBERS

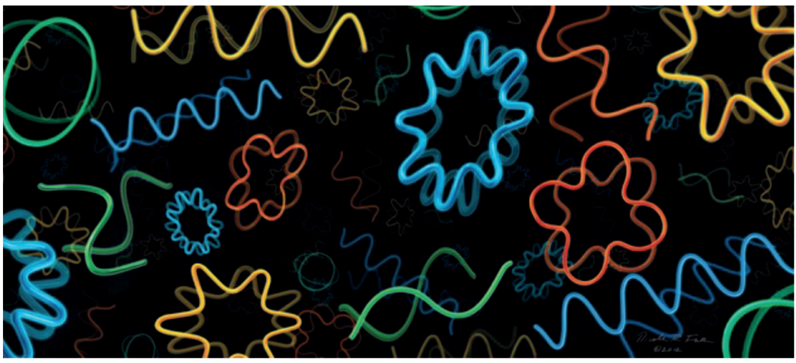
Eduardo García-Valdecasas
Postdoctoral Researcher ULB

String theory

The two pillars of our understanding of the universe are Quantum Mechanics and General Relativity. Quantum Mechanics, embodied in Quantum Field Theory, allows us to describe the world of the tiniest constituents of matter. It implies that the subatomic world is rather chaotic, lumpy and discrete. On the other hand, General Relativity is a theory of gravity which describes the dynamics of spacetime as a smooth arena where planets and stars move. While these two theories have allowed us to describe the history of the Universe with surprising success, it is difficult to put them together. In particular, we find ourselves with lumpy, discrete matter moving in a smooth arena. The simplest way out is to build a quantum theory of spacetime, a theory of quantum gravity. This is easier said than done and is one of the main challenges in fundamental physics to this day.

Our best candidate for such a theory is String Theory, which aims to unify all knows forces and particles as different vibration modes of only one object, a filament of energy, an string. While this theory has been around some time already, it is still greatly unknown and has yet to bear any verifiable connection to experiments.

There are two important ingredient of String Theory that we will mention later. The first one is Supersymmetry. This symmetry with a fancy name is a symmetry between the bosons and the fermions of the theory and it is unavoidable for the consistency of the theory. The second one is extra dimensions because... well String Theory is consistent only in 10 dimensions, 6 of which are compact and tiny. Nonetheless, this happens to be a blessing, since one can use the 6 extra dimensions to give rise to different universes by curling them in different ways (geometries).



Vibrating strings

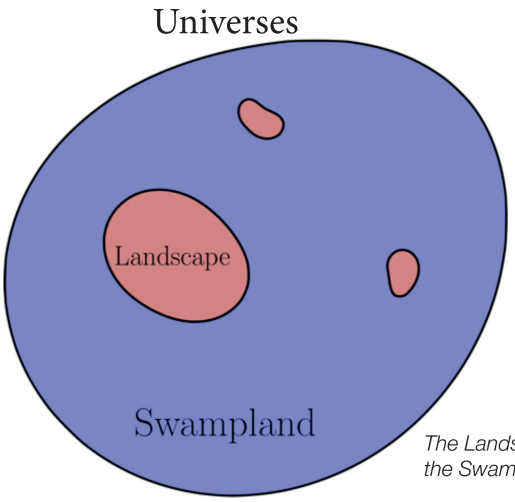
Quantum gravity in a box

In Physics, when something is complicated, we approximate it using harmonic oscillators. And then, we put it in a box. It is complicated to make a box of which gravity can't escape. In fact, we need to create a whole universe which behaves like a box. It is called AdS space. As any other box, AdS has a boundary. It is a remarkable fact that, upon placing Quantum Gravity in such a box, a Conformal Quantum Field Theory lives in its boundary. Even more remarkably, we believe that the boundary theory fully encodes the theory on the bulk. This phenomenon is known as holography and we say that the boundary theory, without gravity, and the bulk theory, with gravity, are dual. Hence, we can use the boundary theory, which does not have gravity, to study Quantum Gravity!

The landscape and the swampland

Quantum Gravity (or String Theory) can produce many low energy Quantum Field Theories, each of which corresponds to a possible universe. The set of such universes is called the Landscape. A reasonable question then, given a universe is whether it may arise from a theory of quantum gravity. In fact, we believe that most universes are in contradiction with some generic properties of quantum gravity. We say that they lie in the Swampland. Finding these properties of Quantum Gravity, that allow to tell good universes from bad ones is an ongoing effort dubbed "The Swampland Program".

Probing the swampland with holography

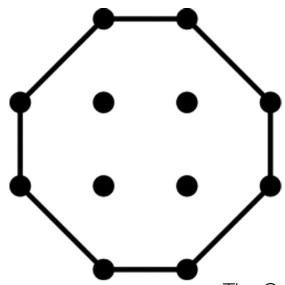


The Landscape and the Swampland

A possible way of studying which universes may be realized in Quantum Gravity and String Theory is through the holographic setup explained above. In this way we may use powerful tools from Quantum Field Theory to directly study Quantum Gravity! This is precisely what I do in my research.

Recently we have studied whether a stable universe, also called vacua, with broken supersymmetry may exist, at least if we put Quantum Gravity in a box (AdS). This is a very important question, because Supersymmetry is a fundamental ingredient of String Theory and it must be necessarily broken at low energies, since we do not observe it. Furthermore, depending on how stable these vacua are, they may be used to achieve inflation and dark energy, two fundamental ingredients of our current description of cosmology. The rough idea is that one may use a non-supersymmetric AdS solution of String Theory to build a deSitter (dS) solution, which is how a universe with Dark Energy looks like.

In a recent series of papers, we were able to find the first instance of a String Theory construction of fully stable quantum gravity in AdS with broken supersymmetry. Such a model is realized by taking String Theory on a beautiful geometry that can be encoded in the diagram below. Showing an obvious lack of creativity, we called the model "The Octagon".


The Octagon

Romain Pascalie
Postdoctoral Researcher ULB

Developing a quantum description of gravity is one of the most challenging problem in fundamental physics. Such a description would be particularly relevant in the context of black holes. There exist many approaches that try to provide a unified description of gravity and quantum mechanics, in the simpler case of 2 dimensional quantum gravity, matrix models have been a successful attempt.

This description is based on a representation of discrete gravity in terms of random matrices. From a mathematical point of view, this representation requires to triangulate Riemann surfaces. A dual point of view consists in encoding the information coming from the triangulation into ribbon graphs, which are exactly the Feynman graphs generated by the matrix model.

One of the main results of matrix models was the discovery of the 1/N expansion by 't Hooft, where N represent the size of the matrix. At large N, matrix models are dominated by planar diagrams which correspond to triangulation of the sphere and the 1/N expansion is indexed by the genus of the Riemann surfaces dual to the ribbon graphs.

At first glance, a natural generalisation of matrix models in higher dimensions can be achieved with the use of tensor models. They were first introduced as such in the '90s, with the idea that similarly to ribbon graphs, tensor graphs are dual to discretization of higher dimensional spaces. Nevertheless, the original development of tensor models was impaired by the lack of large N expansion. This changed after almost twenty years, when the large N expansion of random tensors was established for the first time. Similarly to matrix models, tensor models are dominated by a class of graphs called melonic graphs.

Another approach to quantum gravity, which is one of the most far reaching, is the holography principle. It postulates a correspondence between a gravitational theory in Anti-de Sitter (AdS) space-times and a conformal quantum field theory (CFT) on its boundary. This is the AdS/CFT correspondence which is supposed to give a quantum description of gravity through the quantum field theory.

In this context, a model of N fermions considered originally by Sachdev and Ye received considerable attention, after a simple variant of this model was proposed by Kitaev as a toy model of holography. This Sachdev-Ye-Kitaev (SYK) model has several remarkable properties, it is solvable at large N and at strong coupling, it exhibits a maximally (quantum) chaotic behaviour, similar to quantum black holes, and it has an emergent conformal symmetry. Surprisingly, at large N the dominant Feynman graphs are the same melonic graphs that appeared in tensor models. And naturally it is possible to reformulate the SYK model into a tensor model.

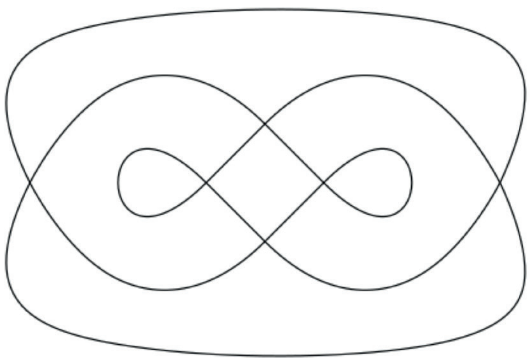


Figure 1: This curve represents the boundary of two inequivalent immersed disks [1].

Dual gravitational models of the above-mentioned microscopic theories are derived from the near-horizon limit of near-extremal black holes in various dimensions. The resulting models are two-dimensional dilaton gravity models. The most important class of these models, which captures all the interesting physics, is the Jackiw-Teitelboim (JT) gravity. In the so-called Schwarzian limit, which is a large cut-off limit for which only certain geometries obtained by reparameterization of the boundary are kept, the JT gravity model reproduces all the low energy properties of SYK/tensor models.

Nevertheless, many fundamental issues remain to be understood. In particular, there is not a clear derivation from first principles that reduce the path integral of JT gravity to the Schwarzian theory. And beyond the extensively studied Schwarzian limit, the precise definition of the theory is not known. Neither is a microscopic description of the model.

My research is at the interplay between tensor/SYK models and JT gravity. In particular, in collaboration with Frank Ferrari and Nicolas Delporte, I am currently focusing on developing a rigorous analysis of JT quantum gravity models from first principles. One of the striking feature of JT gravity at finite cut-off, is that the geometries we need to consider are immersions. A puzzle then arises on how to describe the model, since contrary to the Schwarzian limit where each geometry in the theory is characterised by its boundary curve, several inequivalent immersed geometries can have the same boundary curve (see figure 1 where the curve is the boundary of two inequivalent immersed disks). Hence, we need to understand how to go beyond the description of JT gravity in terms of boundary curves and find the appropriate variables to formulate the theory at finite cut-off.

References
[1] Valentin Poénaru. Extension des immersions en codimension 1. In Séminaire Bourbaki : années 1966/67 1967/68, exposés 313-346, number 10 in Séminaire Bourbaki. Société mathématique de France, 1968. talk:342.

Kevin Turbang
Doctoral Researcher VUB

Gravitational waves were predicted more than a century ago by Einstein as part of his theory of general relativity. These waves are deformations of spacetime itself that travel at the speed of light and can be emitted during e.g. binary black hole mergers. It is exactly these spacetime deformations that interferometer experiments attempt to detect by using the effect of these deformations on the interferometer's laser beams. However, it was not until 2015, a hundred years after their prediction, that gravitational waves were actually detected by the LIGO-Virgo-Kagra (LVK) collaborations. To this day, many gravitational wave events have been discovered by the LVK collaborations, corresponding to binary black hole mergers, binary neutron star mergers and black hole-neutron star mergers.

Beyond the individually detectable events, it is expected that there exists a background of gravitational waves, forming the analogue of the Cosmic Microwave Background (CMB) for gravitational waves. In contrast to the CMB, probing the gravitational wave background would allow us to learn more about times prior to recombination and thus, study the very early stages of the Universe.

Due to the weak nature of the gravitational wave background, it would appear as noise inside a detector. However, if such a background is present, it will appear in all detectors. Therefore, by using a network of interferometers, such as the LVK network, one can rely on cross-correlation of the data between interferometer baselines to distinguish the background from the detector noise. Indeed, the background would be correlated across detectors, whereas the noise typically is not.

One usually distinguishes two contributions to the stochastic background: an astrophysical component and a cosmological component. The former is expected to arise from the superposition of astrophysical events, such as the merger of binary black holes and binary neutron stars, but also pulsars, for example. Indeed, beyond the many merger events detected by the LVK collaboration, many more, weaker mergers are expected to have taken place, contributing to an overall gravitational wave background. Detecting this astrophysical component would teach us more about the population, the mass distribution, etc. of binary black holes, binary neutron stars and black hole-neutron star mergers in the Universe.

On the other hand, the cosmological background of gravitational waves could have arisen during the very early stages of the Universe.

Various processes are expected to give rise to a cosmological gravitational wave background, among which are inflation, primordial black holes, cosmic strings, domain walls, and phase transitions. Most of these processes take place within the context of particle physics models at varying energy scales. Therefore, using the gravitational wave background to study these processes forms a unique and novel way to probe these particle physics theories, some of which are happening at energy scales that are unattainable by particle accelerators on Earth. For example, a gravitational wave background from phase transitions happening at energy scales up to O(10^8-10^9 GeV) can be sought for at the LVK detectors, offering an unprecedented window to high energy particle physics.

With the increasing sensitivity of gravitational wave interferometers and the upcoming so-called third generation detectors such as the Einstein Telescope or the Laser Interferometer Space Antenna, we are getting closer to the detection of a stochastic background every day. Therefore, it is of the utmost importance to understand the various contributions to the gravitational wave background, as well as to have the necessary data-analysis tools available to detect such a background.

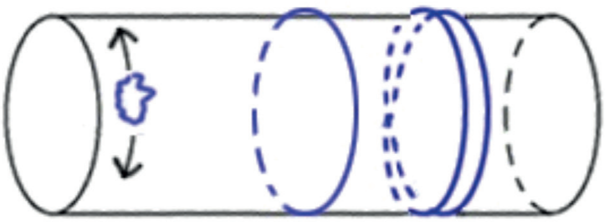
Within this context, my work is two-fold. One part of it consists of investigating several beyond the Standard Model particle physics models and the stochastic background of gravitational waves of cosmological origin that could have resulted from them. More specifically, I am interested in gravitational wave backgrounds from phase transitions and domain walls. Furthermore, I am developing a data-analysis technique that takes into account the intermittent nature of the astrophysical background. Indeed, a background of gravitational waves coming from the mergers of binary black holes is expected to be intermittent, i.e. popcorn-like. Developing a method that correctly takes this behavior into account and thus, goes beyond the usual assumption that the astrophysical background is continuous in time, will significantly improve the search compared to currently employed methods, decreasing the time until detection of the stochastic background.

The Virgo interferometer in Cascina, Italy, near Pisa.

Ondra Hulik
Postdoctoral Researcher VUB

> *“String theory is a truly mysterious theory. Continued research being conducted in this direction uncovers how little we know about even about the most fundamental features of it while at the same time, all the deepest findings about the inner workings of our universe can be traced to a stringy origin.”*

String theory is a truly mysterious theory. Continued research being conducted in this direction uncovers how little we know about even about the most fundamental features of it while at the same time, all the deepest findings about the inner workings of our universe can be traced to a stringy origin. Despite its complexity string theory is based on a simple premise: the fundamental constituents of matter are not particles, but instead one dimensionally extended objects called strings. Like the strings on a guitar these strings can vibrate at different frequencies, and it is exactly these different frequencies which give rise to the plethora of particles we see in our universe. However, there is more to strings than their frequencies, strings can also wind in the space which is a novel feature unknown to the realm of particles. The windings of the strings are in many ways indistinguishable from the vibrations of the string and there is an obscure symmetry exchanging these two distinct types of states called T duality.



Strings can wind around compact directions.

It is T duality which drives my interest in string theory, in particular its geometric underpinning. As it turns out, the implications of this duality are rather obscured in the modern language of physics (differential geometry) which begs the question: “what is the correct geometry that the strings perceive?”

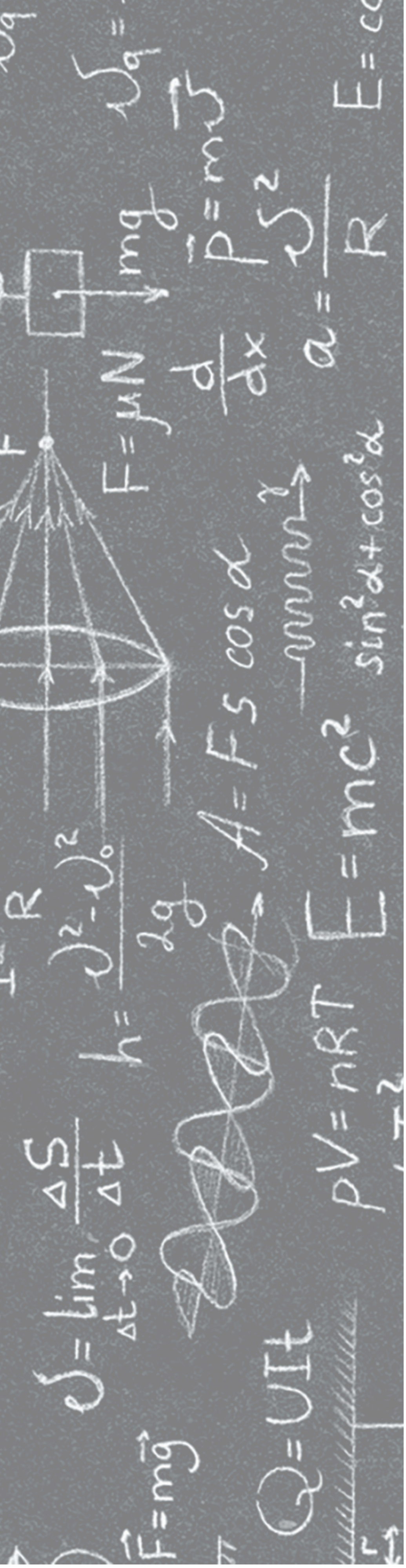
We call this geometry a generalized geometry (GG). Generalized geometry started as a purely mathematical theory, introduced by N. Hitchin, but soon after its connection to string theory has been realized. Most of the physical theories we know have an elegant geometric formulation which allows us to see various phenomena more clearly, for instance the Einstein’s general theory of relativity is best understood within the so-called Riemannian geometry setup. General relativity is in turn related to the dynamics of particle like objects in the curved space, however it is insufficient for studying the same dynamics of strings. The appropriate generalization of the general relativity theory is a theory of supergravity (SUGRA). Although originally formulated in the language of Riemannian geometry it turns out that SUGRA is better understood in the framework of generalized geometry.

This language of GG now helps us understand the theory at a geometric level. In particular T duality becomes an obvious symmetry of the reformulated theory and as such it allows us to study relations between various solutions of SUGRA which originally appeared distinct. In an ongoing project with colleagues from VUB (Chris Blair, Dan Thompson and Camille Eloy) we are studying higher modes of these solutions in the duality covariant description of generalized geometry.

Every consistent formulation of string theory we know exhibits another interesting feature called supersymmetry. This is a symmetry unlike any others we know from basic courses of physics as it exchanges the statistics of the particles involved, bosonic (such as photons) with fermionic (such as electrons). To this day, however, we don't know how to successfully marry ideas of supersymmetry with generalized geometry. Together with colleagues from the VUB (Chris Blair, Alex Sevrin, Dan Thompson) I am trying to investigate this connection.

In another project in collaboration with colleagues form Imperial College London (Fridrich Valach and Dan Waldram) I am investigating the extension of this story to the dynamics of branes and their effective action called M theory. This is a higher dimensional extension of string theory where the elementary constituents are multi-dimensional membranes rather than one-dimensional strings moving in space. These objects are even less manageable than strings and very little is known about the full theory. This is due to the fact that higher dimensional objects such as branes have more frequency modes and more ways to wrap compact directions. However, we can still distil interesting information when trying to identify a proper extension of generalized geometry to encompass the geometry of these membrane objects. We call these types of geometries exceptional generalized geometries (EGG).

As we know so little about membrane dynamics and M theory, the information uncovered by utilizing EGG is even more valuable, for instance we can study membrane analogue of T duality (called U duality). Another way both GG and EGG proved to be useful is by studying so called generalized parallelizable spaces which are the most symmetric spaces on which we can formulate SUGRA and M theory respectively. Studying dynamics on these space helps us understand the full theory in a simplified setup.



THESES DEFENDED IN 2021

- **Marine De Clerck I VUB**

  'Integrable structures and probes of quantum chaos in resonant systems, spin chains and holography'

  26 May 2021 (Promotor: Prof. dr. Ben Craps)

- **Adrien Fiorucci I ULB**

  “Leaky covariant phase spaces: Theory and application to Λ-BMS symmetry”

  30 June 2021 (Promotors: Prof. dr. Geoffrey Compère and Prof. dr. Glenn Barnich)

- **Pierluigi Niro I VUB/ULB**

  “Strong coupling in 2+1 dimensions from dualities, holography, and large N”

  13 July 2021 (Promotors: Prof. dr. Ben Craps, Prof. dr. Alexandre Sevrin, Prof. dr. Riccardo Argurio)

- **Antoine Pasternak I ULB**

  “Dimers, Orientifolds, and Dynamical Supersymmetry Breaking”

  8 July 2021 (thesis advisor: Prof. dr. Riccardo Argurio)

TALKS AT CONFERENCES, SEMINARS AND SCHOOLS

Riccardo Argurio

Goldstones, or not, from relativistic to non-relativistic
City University of New York, City College (virtual), New York, USA - 14 May 2021

SUSY breaking in branes at singularities (or: The octagon rising from the swamp)
KULeuven (virtual), Belgium - 5 July 2021

Phases and dualities of 3d gauge theories and their brane constructions
Galileo Galilei Institute, Florence, Italy
21 September 2021

Alex Arvanitakis

Lectures on homotopy algebras in field theory
Online "Junior Duality and Integrability Workshop" - 15 February 2021

Double field theory via homotopy transfer
Hybrid "Homotopy algebra of QFT and its application" conference Kyoto (online), Japan
29 March 2021

Brane current algebras, generalised geometry, and QP manifolds
Online "Exceptional geometry seminar series"
11 June 2021

A BFV perspective on brane currents
Online conference "Higher Structures in QFT and String Theory" - 14 July 2021

Doubled spacetime from higher algebra
Workshop on "New Developments in Quantum Gravity and String Theory",
Corfu, Greece - 14 September 2021

Doubled Spacetime, Homotopy Algebras, and Puzzles of String Fields on Tori
Online workshop "SFT@Cloud 2021"
24 September 2021

What have the String Theorists been doing?
(HEP@VUB colloquium), Brussels, Belgium
16 November 2021

A QP perspective on topology change in Poisson-Lie duality
Imperial College London, UK
29 November 2021

Glenn Barnich

Coadjoint representation of BMS4 on celestial Riemann surface

- Okinawa Institute of Science and Technology, Flat Asymptotia workshop online, Japan
  16 March 2021
- Quarks-2020 Online Workshops-2021: Integrability, Holography, Higher-Spin Gravity and Strings, Pereslavl, Russia
  1 June 2021

Photons & gravitons in a Casimir box
Albert Einstein Institute, Potsdam, Germany
22 June 2021 - online

Gravity with boundary conditions: From asymptotic symmetries to discrete dualities
Corfu Summer Institute 2021, Celestial Amplitudes and Flat Space Holography On-line Workshop, Panel discussion, Corfu, Greece - 2 September 2021

Photons & gravitons in a Casimir box. Massless scalar partition functions & Eisenstein series

- A Gauge Summer with BV, Scalea, Italy
  6 September 2021 - in person
- Higgs Centre Workshop "Celestial Sphere: holography, CFT and amplitudes, Edinburgh, UK - 15 September 2021 - online

Glenn Barnich

- Corfu Summer Institute 2021. Humboldt Kolleg on Quantum Gravity and Fundamental Interactions, Corfu, Greece
20 September 2021 - in person

ESI programme: Geometry for Higher Spin Gravity: Conformal Structures, PDE's, and Q-manifolds, Vienna, Austria

- *From finite temperature Casimir effect to massless scalar partition functions*
13 September 2021 - in person
- *Massless scalar field partition functions & real analytic Eisenstein series*
14 September 2021 - in person
- *Gravitons in a Casimir box*
16 September 2021 - in person

Massless scalar partition functions on flat backgrounds, Eisenstein series and modular invariance in higher dimensions
Iranian Conference on High Energy Physics 1400, IPM School of Physics, Tehran, Iran
9 November 2021 - online

Massless scalar partition functions, modular invariance & Eisenstein series
PTM retreat ULB, Brussels, Belgium
3 December 2021 - online

Chris Blair

Introduction to T/U-duality invariant formalisms (invited review talk)
Junior Duality and Integrability Workshop (Online)
16 February 2021

Simone Blasi

Beyond the Standard Model with Pulsar Timing

- University of Liverpool, UK - 4 March 2021
- VUB, Brussels, Belgium - 25 March 2021

Cosmic Strings and Gravitational Waves
University of Heidelberg, Germany
29 April 2021

Cosmic Strings and Pulsar Timing
16th Marcel Grossmann Meeting online
7 July 2021

Luca Ciambelli

Lie Algebroids and BRST

- Edinburgh Mathematical Physics Group, UK
7 April 2021
- Perimeter Institute, Waterloo, Canada
10 April 2021

Geometry of Corners
School of Physics HEP, Tehran, Iran
21 September 2021

New Perspectives on (Quantum) Gravity

- Charles University, Prague, Czech Republic
30 September 2021
- Milano Statale, Milano, Italy
15 December 2021
- Perimeter Institute, Waterloo, Canada
16 December 2021

Geoffrey Compère

Asymptotic Symmetries
Celestial Holography Princeton, Princeton, USA
5 February 2021

Self-consistent adiabatic inspiral and transition motion
LISA waveform working group meeting, online
11 March 2021

Centerless BMS4 charge algebra, the quantized angular momentum and (A)dS uplift
"Flat Asymptotia" Virtual Workshop Okinawa, Japan - 15 March 2021

Centerless BMS4 charge algebra and (A)dS uplift
Spanish-Portuguese Relativity Meeting (EREP2021), Porto, Portugal
13 September 2021

Advanced Lectures on General Relativity
Amsterdam-Brussels-Geneva-Paris Doctoral School on "Quantum Field Theory, Strings and Gravity", Brussels, Belgium - 5 October 2021

Kerr Geodesics and Self-consistent match between Inspiral and Transition-to-plunge

- Harvard CMSA math group, Boston, USA 2 December 2021
- Michigan particle theory group, Michigan, USA - 10 December 2021

Ben Craps

Slow scrambling in extremal BTZ and microstate geometries

- University of Crete, Heraklion, Greece 12 January 2021
- University of Ljubljana, Slovenia 4 March 2021

Scrambling and tidal disruption
Saclay, Paris, France - 11 June 2021

Scrambling in rotating BTZ from CFT
Saclay, Paris, France - 11 June 2021

Quantum chaos, black holes and microstate geometries
KU Leuven, Belgium - 6 July 2021

Submerging islands through thermalization

- University of Kentucky, Lexington, USA 6 October 2021
- Université de Genève, Switzerland 18 November 2021

Marine De Clerck

Time-periodicities in quantum resonant systems
International Congress on Mathematical Physics 2021, Geneva, Switzerland - 4 August 2021

Quantum resonant systems
University of Pennsylvania, Philadelphia, USA 15 December 2021

Stéphane Detournay

The 3d black string and its dual

- ICTS String Theory and Quantum Gravity, TIFR, Bangalore (India, zoom) - 16 June 2021
- Workshop on Black Holes, BPS and Quantum Information, ICT Lisbon (Portugal, zoom) - 23 September 2021
- IIT Kanpur Seminar series (India, zoom) 16 November 2021

Black Hole Information
Master class at LUCA School of Arts
7 October 2021

Oleg Evnin

The birth of geometry in random graphs
Radboud University, Nijmegen, The Netherlands
29 October 2021

Frank Ferrari

Gauge Theory Formulation of Hyperbolic Gravity
School of Theoretical Physics, Dublin Institute for Advanced Study, Ireland - 17 February 2021

On Jackiw-Teitelboim Quantum Gravity at Finite Cut-Off
Workshop on Quantum Geometry, Field Theory and Gravity, Corfu, Greece - 26 September 2021

Marc Henneaux

Asymptotic symmetries of electromagnetism and gravity: a Hamiltonian study
University of Padova, Italy - 14 January 2021

Super-BMS algebras and the asymptotic structure of supergravity at spatial infinity
Talk given online at the workshop "Flat Asymptotia", OIST, Okinawa, Japan
18 March 2021

Introduction to asymptotic symmetries - General formalism
Talk given at the workshop "Geometry for Higher Spin Gravity: Conformal Structures, PDEs, and Q-manifolds", Erwin Schrödinger Institute, Vienna, Austria - 30 August 2021

Marc Henneaux

Introduction to asymptotic symmetries – Examples
Talk given at the workshop "Geometry for Higher Spin Gravity: Conformal Structures, PDEs, and Q-manifolds", Erwin Schrödinger Institute, Vienna, Austria - 31 August 2021

The BMS superalgebra at spatial infinity
Talk given at the workshop "Geometry for Higher Spin Gravity: Conformal Structures, PDEs, and Q-manifolds", Erwin Schrödinger Institute, Vienna, Austria - 1 September 2021

Analysis of asymptotic symmetries at spatial infinity
Talk given at the online workshop "Celestial Amplitudes and Flat Space Holography", Corfu, Greece - 1-3 September 2021

The Latest News About Black Holes
Public Lecture - Science & Cocktails, Brussels, Belgium - 4 October 2021

Asymptotic symmetries of electromagnetism and gravity
Division of Theoretical Physics, Rudjer Bošković Institute, Zagreb, Croatia - 7 October 2021

Ultrarelativistic Limit of Gravity, Spacelike Singularities and E(10)
Talk given at the conference "Damour Fest: Adventures in Gravitation", IHES, Bures-sur-Yvette, France - 13 October 2021

La construction européenne de la physique: des premiers Conseils Solvay aux grandes infrastructures d'après 1945
Talk given at the "Colloque de rentrée 2021 du Collège de France: Inventer l'Europe" - Collège de France, Paris, France - 21 October 2021

Carroll invariant field theories
Talk given at the Zoom meeting on "Non-Lorentzian geometries and their applications to theoretical physics", University of Groningen, The Netherlands - 10 November 2021

The Bondi-Metzner-Sachs group in five spacetime dimensions
Online talk given at the workshop on "Asymptotic Symmetries and Holography", Universidad Adolfo Ibañez, Santiago, Chile
9 December 2021

Le défi de la gravitation quantique
Online talk given at the workshop "Les deux infinis", Musée Curie, Paris, France
13 December 2021

Juan Hernandez

Complexity of Islands
KU Leuven, Belgium - 7 December 2021

Holographic entanglement entropy and complexity of islands
UCL, Louvain, Belgium - 22 December 2021

Mikhail Khramtsov

Submerging islands through thermalization
(online seminar), IPM, Tehran, Iran
28 September 2021

Nonperturbative structures in the SYK model
Journal club, KU Leuven, 19 October 2021

Submerging islands through thermalization
Poster, It from Qubit collaboration meeting, Simons foundation, New York, USA
9 December 2021

Laura Lopez Honorez

From WIMPs to FIMPs through co- scatterings

- Albert-Ludwigs-Universität (online), Freiburg, Germany - 3 February 2021
- Theory Division of the National Centre for Nuclear Research (online), Warsaw, Poland, 17 March 2021

Freeze-in Cosmology and displaced signals
Rencontres de Moriond (online), La Thuile, Italy
27 March 2021

Non Cold Dark Matter: Particle physics vs Cosmology
Observatoire Astronomique de Strasbourg (online), Strasbourg, France - 28 May 2021

Feebly Interacting Dark Matter a Non Cold Dark Matter candidate
Heidelberg University, Germany
16 December 2021

Dark matter particle (production) models: a status
News from the Dark 6, Annecy, France
22 November 2021

Sucheta Majumdar

Asymptotic symmetries at spatial infinity
LETHEP online seminar series, India
2 February 2021

BMS symmetry in light-cone gravity
TU Wien, Vienna, Austria - 22 April 2021

Alberto Mariotti

Ripples in spacetime from broken SUSY

- Karlsruhe University, Karlsruhe, Germany
  17 May 2021
- Durham University, Durham, UK
  20 May 2021
- Heidelberg University, Germany
  17 June 2021

Round Table SUSY @ Muon Collider
Muon collider Physics Potential Meeting, CERN, Switzerland - 24 June 2021

Javier Matulich

Asymptotic symmetries at spatial inifinity

- Universidad de Concepción, Chile
  16 September 2021
- Instituto de Física Teórica (IFT), Madrid, Spain
  15 October 2021

Romain Pascalie

JT gravity at finite cut-off
ULB, Brussels, Belgium - 3 December 2021

Jakob Salzer

Effective Theory of Superrotation Vacua
Perimeter Institute, Waterloo, Canada
10 June 2021

Ali Seraj

Breathing memory effect and dual symmetries

- Institute for Cosmology and Fundamental Physics (CEICO), Czech Academy of Sciences, Prague, Czechoslovakia
  10 March 2021
- CENTRA/Instituto Superior Técnico (IST), Lisbon, Portugal - 5 July 2021

Gravitational memory effect

- Belgian-Dutch GW meeting, Brussels, Belgium - 18 June 2021
- Inst. for Advanced Studies in Basic Sciences, Zanjan, Iran - 11 June 2021

Gyroscopic Gravitational Memory

- Université Libre de Bruxelles, Brussels, Belgium - 3 December 2021
- Perimeter Institute, Waterloo, Canada
  9 December 2021

Alexander Sevrin

Gravitational Wave Physics at the VUB
Université Libre de Bruxelles, Belgium
3 November 2021

Luigi Tizzano

Supersymmetric AdS5 Black Holes and the Superconformal Index
Columbia University, New-York, USA
22 November 2021

Kevin Turbang

Updating the Virgo non-discrimination policy
Virgo week, Online - 19 April 2021

Update on the Stochastic Search for Intermittent backgrounds
Stochastic F2F meeting - LVK meeting, Online
7 September 2021

A search for intermittent gravitational wave backgrounds
ULB (BeGWaMe 2022), Brussels, Belgium
3 November 2021

PUBLICATIONS

[1] R. Abbott et al. [KAGRA, VIRGO and LIGO Scientific], "All-sky search for long-duration gravitational-wave bursts in the third Advanced LIGO and Advanced Virgo run," Phys. Rev. D 104 (2021) no.10, 102001 doi:10.1103/PhysRevD.104.102001 [arXiv:2107.13796 [gr-qc]].

[2] R. Abbott et al. [KAGRA, VIRGO and LIGO Scientific], "All-sky search for short gravitational-wave bursts in the third Advanced LIGO and Advanced Virgo run," Phys. Rev. D 104 (2021) no.12, 122004 doi:10.1103/PhysRevD.104.122004 [arXiv:2107.03701 [gr-qc]].

[3] P. Akara-Pipattana, T. Chotibut and O. Evnin, "The birth of geometry in exponential random graphs," J. Phys. A 54 (2021) no.42, 425001 doi:10.1088/1751-8121/ac2474 [arXiv:2102.11477 [cond-mat.dis-nn]].

[4] H. Al Ali, N. Arkani-Hamed, I. Banta, S. Benevedes, D. Buttazzo, T. Cai, J. Cheng, T. Cohen, N. Craig and M. Ekhterachian, et al. "The Muon Smasher's Guide," [arXiv:2103.14043 [hep-ph]].

[5] F. Alessio, G. Barnich and M. Bonte, "Gravitons in a Casimir box," JHEP 02 (2021), 216 [erratum: JHEP 03 (2021), 228] doi:10.1007/JHEP02(2021)216 [arXiv:2011.14432 [hep-th]].

[6] F. Alessio, G. Barnich and M. Bonte, "Notes on massless scalar field partition functions, modular invariance and Eisenstein series," JHEP 12 (2021), 211 doi:10.1007/JHEP12(2021)211 [arXiv:2111.03164 [hep-th]].

[7] F. Alessio, G. Barnich, L. Ciambelli, P. Mao and R. Ruzziconi, "Weyl charges in asymptotically locally AdS3 spacetimes," Phys. Rev. D 103 (2021) no.4, 046003 doi:10.1103/PhysRevD.103.046003 [arXiv:2010.15452 [hep-th]].

[8] S. Ananth, L. Brink and S. Majumdar, "Bondi-Metzner-Sachs algebra as an extension of the Poincaré symmetry in light-cone gravity," JHEP 07 (2021), 129 doi:10.1007/JHEP07(2021)129 [arXiv:2012.07880 [hep-th]].

[9] S. Ananth, L. Brink and S. Majumdar, "BMS algebra from residual gauge invariance in light-cone gravity," JHEP 11 (2021), 008 doi:10.1007/JHEP11(2021)008 [arXiv:2101.00019 [hep-th]].

[10] R. Argurio, M. Bertolini, S. Franco, E. García-Valdecasas, S. Meynet, A. Pasternak and V. Tatitscheff, "The Octagon and the Non- Supersymmetric String Landscape," Phys. Lett. B 815 (2021), 136153 doi:10.1016/j.physletb.2021.136153 [arXiv:2005.09671 [hep-th]].

[11] R. Argurio, M. Bertolini, S. Franco, E. García-Valdecasas, S. Meynet, A. Pasternak and V. Tatitscheff, "Dimers, Orientifolds and Stability of Supersymmetry Breaking Vacua," JHEP 01 (2021), 061 doi:10.1007/JHEP01(2021)061 [arXiv:2007.13762 [hep-th]].

[12] R. Argurio, M. Bertolini, S. Franco, E. García-Valdecasas, S. Meynet, A. Pasternak and V. Tatitscheff, "Dimers, Orientifolds and Anomalies," JHEP 02 (2021), 153 doi:10.1007/JHEP02(2021)153 [arXiv:2009.11291 [hep- th]].

[13] R. Argurio, C. Hoyos, D. Musso and D. Naegels, "Fractons in effective field theories for spontaneously broken translations," Phys. Rev. D 104 (2021) no.10, 105001 doi:10.1103/PhysRevD.104.105001 [arXiv:2107.03073 [hep-th]].

[14] A. S. Arvanitakis, "Brane current algebras and generalised geometry from QP manifolds. Or, "when they go high, we go low"," JHEP 11 (2021), 114 doi:10.1007/JHEP11(2021)114 [arXiv:2103.08608 [hep-th]].

[15] Z. Avetisyan, O. Evnin and K. Mkrtchyan, "Democratic Lagrangians for Nonlinear Electrodynamics," Phys. Rev. Lett. 127 (2021) no.27, 271601 doi:10.1103/PhysRevLett.127.271601 [arXiv:2108.01103 [hep-th]].

[16] V. Baibhav, L. Barack, E. Berti, B. Bonga, R. Brito, V. Cardoso, G. Compère, S. Das, D. Doneva and J. Garcia-Bellido, et al. "Probing the nature of black holes: Deep in the mHz gravitational-wave sky," Exper. Astron. 51 (2021) no.3, 1385-1416 doi:10.1007/s10686-021-09741-9 [arXiv:1908.11390 [astro-ph.HE]].

[17] V. Balasubramanian, B. Craps, M. Khramtsov and E. Shaghoulian, "Submerging islands through thermalization," JHEP 10 (2021), 048 doi:10.1007/JHEP10(2021)048 [arXiv:2107.14746 [hep-th]].

[18] V. Balasubramanian, M. De Cross, A. Kar, Y. Li and O. Parrikar, "Complexity growth in integrable and chaotic models," JHEP 07 (2021), 011 doi:10.1007/JHEP07(2021)011 [arXiv:2101.02209 [hep-th]].

[19] V. Balasubramanian, J. J. Heckman, E. Lipeles and A. P. Turner, "Statistical Coupling Constants from Hidden Sector Entanglement," Phys. Rev. D 103 (2021) no.6, 066024 doi:10.1103/PhysRevD.103.066024 [arXiv:2012.09182 [hep-th]].

[20] V. Balasubramanian, A. Kar and T. Ugajin, "Islands in de Sitter space," JHEP 02 (2021), 072 doi:10.1007/JHEP02(2021)072 [arXiv:2008.05275 [hep- th]].

[21] V. Balasubramanian, A. Kar and T. Ugajin, "Entanglement between two disjoint universes," JHEP 02 (2021), 136 doi:10.1007/JHEP02(2021)136 [arXiv:2008.05274 [hep-th]].

[22] V. Balasubramanian, A. Kar, O. Parrikar, G. Sárosi and T. Ugajin, "Geometric secret sharing in a model of Hawking radiation," JHEP 01 (2021), 177 doi:10.1007/JHEP01(2021)177 [arXiv:2003.05448 [hep-th]].

[23] I. Baldes, S. Blasi, A. Mariotti, A. Sevrin and K. Turbang, "Baryogenesis via relativistic bubble expansion," Phys. Rev. D 104 (2021) no.11, 115029 doi:10.1103/PhysRevD.104.115029 [arXiv:2106.15602 [hep-ph]].

[24] S. Bansal, O. Evnin and K. Mkrtchyan, "Polynomial Duality-Symmetric Lagrangians for Free p-Forms," Eur. Phys. J. C 81 (2021) no.3, 257 doi:10.1140/epjc/s10052-021-09049-0 [arXiv:2101.02350 [hep-th]].

[25] G. Barnich and R. Ruzziconi, "Coadjoint representation of the BMS group on celestial Riemann surfaces," JHEP 06 (2021), 079 doi:10.1007/JHEP06(2021)079 [arXiv:2103.11253 [gr-qc]].

[26] A. Biasi, O. Evnin and B. A. Malomed, "Fermi-Pasta-Ulam phenomena and persistent breathers in the harmonic trap," Phys. Rev. E 104 (2021) no.3, 034210 doi:10.1103/PhysRevE.104.034210 [arXiv:2106.03870 [nlin.PS]].

[27] L. Blanchet, G. Compère, G. Faye, R. Oliveri and A. Seraj, "Multipole expansion of gravitational waves: from harmonic to Bondi coordinates," JHEP 02 (2021), 029 doi:10.1007/JHEP02(2021)029 [arXiv:2011.10000 [gr- qc]].

[28] C. D. A. Blair, D. Gallegos and N. Zinnato, "A non-relativistic limit of M- theory and 11-dimensional membrane Newton-Cartan geometry," JHEP 10 (2021), 015 doi:10.1007/JHEP10(2021)015 [arXiv:2104.07579 [hep-th]].

[29] C. D. A. Blair, G. Oling and J. H. Park, "Non-Riemannian isometries from double field theory," JHEP 04 (2021), 072 doi:10.1007/JHEP04(2021)072 [arXiv:2012.07766 [hep-th]].

[30] Q. Bonnefoy, L. Ciambelli, D. Lust and S. Lust, "The swampland at large number of space-time dimensions," JHEP 07 (2021), 009 doi:10.1007/JHEP07(2021)009 [arXiv:2011.06610 [hep-th]].

[31] G. Bossard, F. Ciceri, G. Inverso, A. Kleinschmidt and H. Samtleben, "E9 exceptional field theory. Part II. The complete dynamics," JHEP 05 (2021), 107 doi:10.1007/JHEP05(2021)107 [arXiv:2103.12118 [hep-th]].

[32] G. Bossard, A. Kleinschmidt and E. Sezgin, "A master exceptional field theory," JHEP 06 (2021), 185 doi:10.1007/JHEP06(2021)185 [arXiv:2103.13411 [hep-th]].

[33] L. Calibbi, F. D'Eramo, S. Junius, L. Lopez-Honorez and A. Mariotti, "Displaced new physics at colliders and the early universe before its first second," JHEP 05 (2021), 234 doi:10.1007/JHEP05(2021)234 [arXiv:2102.06221 [hep- ph]].

[34] R. Caroca, P. Concha, J. Matulich, E. Rodríguez and D. Tempo, "Hyper-symmetric extensions of Maxwell-Chern-Simons gravity in 2+1 dimensions," Phys. Rev. D 104 (2021) no.6, 064011 doi:10.1103/PhysRevD.104.064011 [arXiv:2105.12243 [hep-th]].

[35] H. Casini, J. M. Magan and P. J. Martinez, "Entropic order parameters in weakly coupled gauge theories," JHEP 01 (2022), 079 doi:10.1007/JHEP01(2022)079 [arXiv:2110.02980 [hep-th]].

[36] L. Ciambelli, C. Corral, J. Figueroa, G. Giribet and R. Olea, "Topological Terms and the Misner String Entropy," Phys. Rev. D 103 (2021) no.2, 024052 doi:10.1103/PhysRevD.103.024052 [arXiv:2011.11044 [hep-th]].

[37] L. Ciambelli and R. G. Leigh, "Lie algebroids and the geometry of off-shell BRST," Nucl. Phys. B 972 (2021), 115553 doi:10.1016/j.nuclphysb.2021.115553 [arXiv:2101.03974 [hep-th]].

[38] L. Ciambelli and R. G. Leigh, "Isolated surfaces and symmetries of gravity," Phys. Rev. D 104 (2021) no.4, 046005 doi:10.1103/PhysRevD.104.046005 [arXiv:2104.07643 [hep-th]].

[39] A. Collinucci, M. De Marco, A. Sangiovanni and R. Valandro, "Higgs branches of 5d rank-zero theories from geometry," JHEP 10 (2021) no.18, 018 doi:10.1007/JHEP10(2021)018 [arXiv:2105.12177 [hep-th]].

[40] A. Collinucci, A. Sangiovanni and R. Valandro, "Genus zero Gopakumar-Vafa invariants from open strings," JHEP 09 (2021), 059 doi:10.1007/JHEP09(2021)059 [arXiv:2104.14493 [hep-th]].

[41] G. Compère and L. Küchler, "Self-consistent adiabatic inspiral and transition motion," Phys. Rev. Lett. 126 (2021) no.24, 241106 doi:10.1103/PhysRevLett.126.241106 [arXiv:2102.12747 [gr-qc]].

[42] N. Craig, N. Levi, A. Mariotti and D. Redigolo, "Ripples in Spacetime from Broken Supersymmetry," JHEP 21 (2020), 184 doi:10.1007/JHEP02(2021)184 [arXiv:2011.13949 [hep-ph]].

[43] B. Craps, S. Khetrapal and C. Rabideau, "Chaos in CFT dual to rotating BTZ," JHEP 11 (2021), 105 doi:10.1007/JHEP11(2021)105 [arXiv:2107.13874 [hep-th]].

[44] B. Craps, M. De Clerck and O. Evnin, "Time-periodicities in holographic CFTs," JHEP 09 (2021), 030 doi:10.1007/JHEP09(2021)030 [arXiv:2103.12798 [hep-th]].

[45] B. Craps, M. De Clerck, P. Hacker, K. Nguyen and C. Rabideau, "Slow scrambling in extremal BTZ and microstate geometries," JHEP 03 (2021), 020 doi:10.1007/JHEP03(2021)020 [arXiv:2009.08518 [hep-th]].

[46] E. D'Hoker, A. Kleinschmidt and O. Schlotterer, "Elliptic modular graph forms. Part I. Identities and generating series," JHEP 03 (2021), 151 doi:10.1007/JHEP03(2021)151 [arXiv:2012.09198 [hep-th]].

[47] L. Di Pietro, E. Lauria and P. Niro, "3d large N vector models at the boundary," SciPost Phys. 11 (2021) no.3, 050 doi:10.21468/SciPostPhys.11.3.050 [arXiv:2012.07733 [hep-th]].

[48] D. Dorigoni and A. Kleinschmidt, "Resurgent expansion of Lambert series and iterated Eisenstein integrals," Commun. Num. Theor. Phys. 15 (2021) no.1, 1-57 doi:10.4310/CNTP.2021.v15.n1.a1 [arXiv:2001.11035 [hep-th]].

[49] C. Eloy, G. Larios and H. Samtleben, "Triality and the consistent reductions on AdS_3 X S^3," JHEP 01 (2022), 055 doi:10.1007/JHEP01(2022)055 [arXiv:2111.01167 [hep-th]].

[50] O. Evnin, "Resonant Hamiltonian systems and weakly nonlinear dynamics in AdS spacetimes," Class. Quant. Grav. 38 (2021) no.20, 203001 doi:10.1088/1361-6382/ac1b46 [arXiv:2104.09797 [gr-qc]].

[51] O. Evnin, V. Massart and K. Nguyen, "Robustness of the cosmological constant damping mechanism through matter eras," Class. Quant. Grav. 38 (2021) no.17, 17 doi:10.1088/1361-6382/ac1851 [arXiv:2010.05927 [gr-qc]].

[52] O. Evnin, "Melonic dominance and the largest eigenvalue of a large random tensor," Lett. Math. Phys. 111 (2021), 66 doi:10.1007/s11005-021-01407-z [arXiv:2003.11220 [math-ph]].

[53] F. Ferrari, "Gauge Theory Formulation of Hyperbolic Gravity," JHEP 03 (2021), 046 doi:10.1007/JHEP03(2021)046 [arXiv:2011.02108 [hep-th]].

[54] A. Fiorucci and R. Ruzziconi, "Charge algebra in Al(A)dSn spacetimes," JHEP 05 (2021), 210 doi:10.1007/JHEP05(2021)210 [arXiv:2011.02002 [hep- th]].

[55] O. Fuentealba, H. A. González, A. Pérez, D. Tempo and R. Troncoso, "Superconformal Bondi-Metzner-Sachs Algebra in Three Dimensions," Phys. Rev. Lett. 126 (2021) no.9, 091602 doi:10.1103/PhysRevLett.126.091602 [arXiv:2011.08197 [hep-th]].

[56] O. Fuentealba, M. Henneaux, S. Majumdar, J. Matulich and T. Neogi, "Asymptotic structure of the Rarita-Schwinger theory in four spacetime dimensions at spatial infinity," JHEP 02 (2021), 031 doi:10.1007/JHEP02(2021)031 [arXiv:2011.04669 [hep-th]].

[57] O. Fuentealba, M. Henneaux, S. Majumdar, J. Matulich and T. Neogi, "Local supersymmetry and the square roots of Bondi-Metzner- Sachs supertranslations," Phys. Rev. D 104 (2021) no.12, L121702 doi:10.1103/PhysRevD.104.L121702 [arXiv:2108.07825 [hep-th]].

[58] E. García-Valdecasas, S. Meynet, A. Pasternak and V. Tatitscheff, "Dimers in a Bottle," JHEP 04 (2021), 274 doi:10.1007/JHEP04(2021)274 [arXiv:2101.02670 [hep-th]].

[59] J. Gomis, D. Hidalgo and P. Salgado-Rebolledo, "Non-relativistic and Carrollian limits of Jackiw-Teitelboim gravity," JHEP 05 (2021), 162 doi:10.1007/JHEP05(2021)162 [arXiv:2011.15053 [hep-th]].

[60] J. Gomis, E. Joung, A. Kleinschmidt and K. Mkrtchyan, "Colourful Poincaré symmetry, gravity and particle actions," JHEP 08 (2021), 047 doi:10.1007/JHEP08(2021)047 [arXiv:2105.01686 [hep-th]].

[61] D. Gourevitch, H. P. A. Gustafsson, A. Kleinschmidt, D. Persson and S. Sahi, "Eulerianity of Fourier coefficients of automorphic forms," Represent. Theory 25 (2021) no.16, 481-507 doi:10.1090/ert/565 [arXiv:2004.14244 [math.NT]].

[62] A. Guarino and C. Sterckx, "Flat deformations of type IIB S-folds," JHEP 11 (2021), 171 doi:10.1007/JHEP11(2021)171 [arXiv:2109.06032 [hep-th]].

[63] A. Guarino and C. Sterckx, "S-folds and holographic RG flows on the D3-brane," JHEP 06 (2021), 051 doi:10.1007/JHEP06(2021)051 [arXiv:2103.12652 [hep-th]].

[64] M. Henneaux and P. Salgado-Rebolledo, "Carroll contractions of Lorentz- invariant theories," JHEP 11 (2021), 180 doi:10.1007/JHEP11(2021)180 [arXiv:2109.06708 [hep-th]].

[65] M. Ipinza and P. Salgado-Rebolledo, "Gravitating Meron-like topological solitons in massive Yang–Mills theory and the Einstein–Skyrme model," Eur. Phys. J. C 81 (2021) no.7, 654 doi:10.1140/epjc/s10052-021-09444-7 [arXiv:2005.04920 [hep-th]].

[66] A. Kleinschmidt and H. Nicolai, "Generalised holonomies and K(E9)," JHEP 09 (2021), 054 doi:10.1007/JHEP09(2021)054 [arXiv:2107.02445 [hep-th]].

[67] L. Machet and J. Wang, "On the horizon entropy of a causal set," Class. Quant. Grav. 38 (2021) no.8, 085004 doi:10.1088/1361-6382/abe957 [arXiv:2012.06212 [gr-qc]].

[68] J. M. Magan, "Proof of the universal density of charged states in QFT," JHEP 12 (2021), 100 doi:10.1007/JHEP12(2021)100 [arXiv:2111.02418 [hep- th]].

[69] E. Malek, Y. Sakatani and D. C. Thompson, "$E_{6(6)}$ exceptional Drinfel'd algebras," JHEP 01 (2021), 020 doi:10.1007/JHEP01(2021)020 [arXiv:2007.08510 [hep-th]].

[70] P. Salgado-Rebolledo and G. Palumbo, "Extended Nappi-Witten Geometry for the Fractional Quantum Hall Effect," Phys. Rev. D 103 (2021), 125006 doi:10.1103/PhysRevD.103.125006 [arXiv:2102.03886 [cond-mat.mes-hall]].

[71] L. Schepers and D. C. Thompson, "Resurgence in the bi- Yang-Baxter model," Nucl. Phys. B 964 (2021), 115308 doi:10.1016/j.nuclphysb.2021.115308 [arXiv:2007.03683 [hep-th]].

[72] K. Shi, X. Wang, Y. Xiu and H. Zhang, "Covariant phase space with null boundaries," Commun. Theor. Phys. 73 (2021) no.12, 125401 doi:10.1088/1572-9494/ac2a1b [arXiv:2008.10551 [hep-th]].

[73] A. Seraj, "Gravitational breathing memory and dual symmetries," JHEP 05 (2021), 283 doi:10.1007/JHEP05(2021)283 [arXiv:2103.12185 [hep-th]].

Preprints

[74] R. Abbott et al. [LIGO Scientific, VIRGO and KAGRA], "Search for gravitational waves from Scorpius X-1 with a hidden Markov model in O3 LIGO data," [arXiv:2201.10104 [gr-qc]].

[75] R. Abbott et al. [LIGO Scientific, VIRGO and KAGRA], "All-sky search for continuous gravitational waves from isolated neutron stars using Advanced LIGO and Advanced Virgo O3 data," [arXiv:2201.00697 [gr-qc]].

[76] R. Abbott et al. [LIGO Scientific, VIRGO and KAGRA], "Narrowband searches for continuous and long-duration transient gravitational waves from known pulsars in the LIGO-Virgo third observing run," [arXiv:2112.10990 [gr-qc]].

[77] R. Abbott et al. [LIGO Scientific, VIRGO and KAGRA], "Tests of General Relativity with GWTC-3," [arXiv:2112.06861 [gr-qc]].

[78] R. Abbott et al. [LIGO Scientific, VIRGO and KAGRA], "All-sky search for gravitational wave emission from scalar boson clouds around spinning black holes in LIGO O3 data," [arXiv:2111.15507 [astro-ph.HE]].

[79] R. Abbott 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," [arXiv:2111.15116 [gr-qc]].

[80] R. Abbott 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," [arXiv:2111.13106 [astro-ph.HE]].

[81] R. Abbott et al. [LIGO Scientific, VIRGO and KAGRA], "GWTC-3: Compact Binary Coalescences Observed by LIGO and Virgo During the Second Part of the Third Observing Run," [arXiv:2111.03606 [gr-qc]].

[82] R. Abbott et al. [LIGO Scientific, VIRGO and KAGRA], "The population of merging compact binaries inferred using gravitational waves through GWTC-3," [arXiv:2111.03634 [astro-ph.HE]].

[83] R. Abbott 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," [arXiv:2111.03608 [astro-ph.HE]].

[84] R. Abbott et al. [LIGO Scientific, VIRGO and KAGRA], "All-sky, all-frequency directional search for persistent gravitational-waves from Advanced LIGO's and Advanced Virgo's first three observing runs," [arXiv:2110.09834 [gr-qc]].

[85] R. Abbott et al. [LIGO Scientific, VIRGO and KAGRA], "Search for subsolar-mass binaries in the first half of Advanced LIGO and Virgo's third observing run," [arXiv:2109.12197 [astro-ph.CO]].

[86] R. Abbott et al. [LIGO Scientific, VIRGO and KAGRA], "Search for continuous gravitational waves from 20 accreting millisecond X-ray pulsars in O3 LIGO data," [arXiv:2109.09255 [astro-ph.HE]].

[87] R. Abbott et al. [LIGO Scientific and VIRGO], "GWTC-2.1: Deep Extended Catalog of Compact Binary Coalescences Observed by LIGO and Virgo During the First Half of the Third Observing Run," [arXiv:2108.01045 [gr-qc]].

[88] R. Abbott 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," [arXiv:2105.15120 [astro-ph.HE]].

[89] R. Abbott et al. [LIGO Scientific, Virgo and KAGRA], "Constraints on dark photon dark matter using data from LIGO's and Virgo's third observing run," [arXiv:2105.13085 [astro-ph.CO]].

[90] A. Aggarwal, L. Ciambelli, S. Detournay and A. Somerhausen, "Boundary Conditions for Warped AdS3 in Quadratic Ensemble," [arXiv:2112.13116 [hep-th]].

[91] P. B. Aneesh, G. Compère, L. P. de Gioia, I. Mol and B. Swidler, "Celestial Holography: Lectures on Asymptotic Symmetries," [arXiv:2109.00997 [hep- th]].

[92] A. Angelescu, A. Bally, S. Blasi and F. Goertz, "Unification of Gauge Symmetries... including their breaking," [arXiv:2109.14538 [hep-ph]].

[93] A. Angelescu, A. Bally, S. Blasi and F. Goertz, "Minimal SU(6) Gauge-Higgs Grand Unification," [arXiv:2104.07366 [hep-ph]].

[94] A. S. Arvanitakis, C. D. A. Blair and D. C. Thompson, "A QP perspective on topology change in Poisson-Lie T-duality," [arXiv:2110.08179 [hep-th]].

[95] A. S. Arvanitakis, E. Malek and D. Tennyson, "Romans massive QP manifolds," [arXiv:2201.07807 [hep-th]].

[96] A. S. Arvanitakis, O. Hohm, C. Hull and V. Lekeu, "Homotopy Transfer and Effective Field Theory II: Strings and Double Field Theory," [arXiv:2106.08343 [hep-th]].

[97] V. Balasubramanian, A. Kar and T. Ugajin, "Entanglement between two gravitating universes," [arXiv:2104.13383 [hep-th]].

[98] A. Ball, S. A. Narayanan, J. Salzer and A. Strominger, "Perturbatively exact w1+ asymptotic symmetry of quantum self-dual gravity," [arXiv:2111.10392 [hep-th]].

[99] N. Banerjee, A. Bhattacharjee, S. Biswas and T. Neogi, "Dual Theory for maximally N extended flat Supergravity," [arXiv:2110.05919 [hep-th]].

[100] L. Ciambelli, R. G. Leigh and P. C. Pai, "Embeddings and Integrable Charges for Extended Corner Symmetry," [arXiv:2111.13181 [hep-th]].

[101] G. Compère and A. Druart, "Complete set of quasi-conserved quantities for spinning particles around Kerr," SciPost Phys. 12 (2022) no.1, 012 doi:10.21468/SciPostPhys.12.1.012 [arXiv:2105.12454 [gr-qc]].

[102] G. Compère and L. Küchler, "Asymptotically matched quasi-circular inspiral and transition-to-plunge in the small mass ratio expansion," [arXiv:2112.02114 [gr-qc]].

[103] G. Compère, Y. Liu and J. Long, "Classification of radial Kerr geodesic motion," [arXiv:2106.03141 [gr-qc]].

[104] G. Compère and D. A. Nichols, "Classical and Quantized General- Relativistic Angular Momentum," [arXiv:2103.17103 [gr-qc]].

[105] N. B. Copland, G. Piccinini and D. C. Thompson, "The Duality Symmetric String at Two-loops," [arXiv:2110.14481 [hep-th]].

[106] Q. Decant, J. Heisig, D. C. Hooper and L. Lopez-Honorez, "Cosmological imprints of non-thermalized dark matter," [arXiv:2112.08853 [hep-ph]].

[107] Q. Decant, J. Heisig, D. C. Hooper and L. Lopez-Honorez, "Lyman-α constraints on freeze-in and superWIMPs," [arXiv:2111.09321 [astro-ph.CO]].

[108] S. Deser and M. Henneaux, "Higher spin m/= 0 excitations on curved back- grounds and cosmological supergravity," [arXiv:2112.09870 [gr-qc]].

[109] D. Dorigoni, A. Kleinschmidt and O. Schlotterer, "Poincaré series for modular graph forms at depth two. I. Seeds and Laplace systems," [arXiv:2109.05017 [hep-th]].

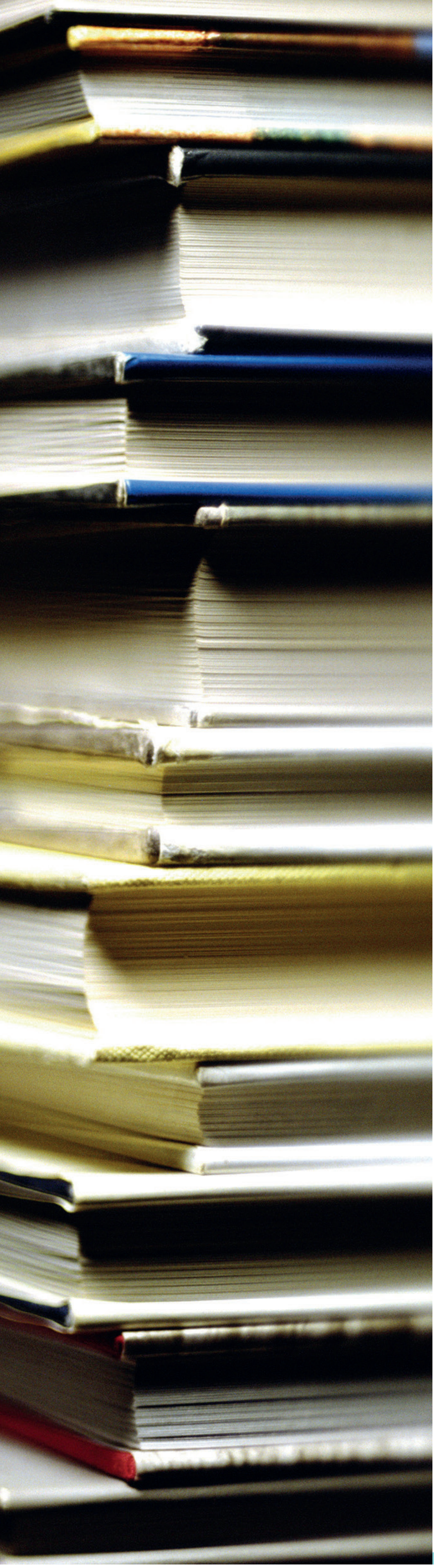
[110] D. Dorigoni, A. Kleinschmidt and O. Schlotterer, "Poincaré series for modular graph forms at depth two. II. Iterated integrals of cusp forms," [arXiv:2109.05018 [hep-th]].

[111] K. Farnsworth, K. Hinterbichler and O. Hulik, "Scale vs. Conformal Invariance at the IR Fixed Point of Quantum Gravity," [arXiv:2110.10160 [hep-th]]. [38]

[112] J. Figueroa-O'Farrill, E. Have, S. Prohazka and J. Salzer, "Carrollian and celestial spaces at infinity," [arXiv:2112.03319 [hep-th]].

[113] O. Fuentealba, M. Henneaux, J. Matulich and C. Troessaert, "The Bondi- Metzner-Sachs group in five spacetime dimensions," [arXiv:2111.09664 [hep- th]].

[114] A. Giambrone, A. Guarino, E. Malek, H. Samtleben, C. Sterckx and M. Trigiante, "Holographic Evidence for Non-Supersymmetric Conformal Mani- folds," [arXiv:2112.11966 [hep-th]].



[115] O. Hulik and F. Valach, “Exceptional algebroids and type IIA superstrings,” [arXiv:2202.00355 [hep-th]].

[116] A. Kleinschmidt, R. Köhl, R. Lautenbacher and H. Nicolai, “Representations of involutory subalgebras of affine Kac-Moody algebras,” [arXiv:2102.00870 [math.RT]].

[117] D. Naegels, “An introduction to Goldstone boson physics and to the coset construction,” [arXiv:2110.14504 [hep-th]].

[118] K. Ohmori and L. Tizzano, “Anomaly Matching Across Dimensions and Supersymmetric Cardy Formulae,” [arXiv:2112.13445 [hep-th]].

[119] P. Salgado-Rebolledo and J. K. Pachos, “Simulating quantum gravity with optical lattices,” [arXiv:2109.07552 [quant-ph]].

[120] P. Salgado-Rebolledo and G. Palumbo, “Non-Relativistic Supergeometry in the Moore-Read Fractional Quantum Hall State,” [arXiv:2112.14339 [cond- mat.mes-hall]].

[121] A. Seraj and B. Oblak, “Gyroscopic Gravitational Memory,” [arXiv:2112.04535 [hep-th]].

Books and Collective works published in 2021

[122] A. Fiorucci, “Leaky covariant phase spaces: Theory and application to Λ- BMS symmetry,” [arXiv:2112.07666 [hep-th]], PhD Thesis

[123] P. Niro, “Strong coupling in 2+1 dimensions from dualities, holography, and large N,” PHD Thesis

[124] A. Pasternak, “Dimers, Orientifolds, and Dynamical Supersymmetry Breaking,” PhD Thesis

NONLINEAR PHYSICAL CHEMISTRY UNIT

GROUP OF PROFESSOR ANNE DE WIT I ULB

Researchers

Faculty Members

Fabian Brau
Anne De Wit
Yannick De Decker
Laurence Rongy

Postdoctoral Researchers

Alessandro Comolli
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Satoshi Izumoto
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Emmanuel Siéfert

Doctoral Researchers

Adam Bigaj
Jean Gillet
Hoa-Ai Béatrice Hua
Luka Negrojévic
Johnson Oluberi Oyero
Dimitra Spanoudaki
Reda Tiani

Oscillatory growth of a chemical garden in a co-flow injection of reactants

Fabian Brau and Anne De Wit

Engineering strategies for designing functional materials with complex shapes are of fundamental interest in materials science. In this context, we have studied experimentally the growth of chemical garden tubes within the co-flow of cobalt chloride and sodium silicate solutions in a microfluidic device for large reactant concentrations. The reactor consists of two concentric capillaries that allow to control the relative speed at which the two reactants are put in contact by tuning the flow rate in each inlet capillary. Thanks to the confined space within the microfluidics capillaries and the co-flow, the oscillatory growth of the budding regime is tamed and gives periodically spaced membranes on the precipitate surface *(Figure 1)*. A theoretical model is developed to explain the dependence of the pattern wavelength, of the velocity of the structure growth and of the period of oscillations on the velocities within the two flows.

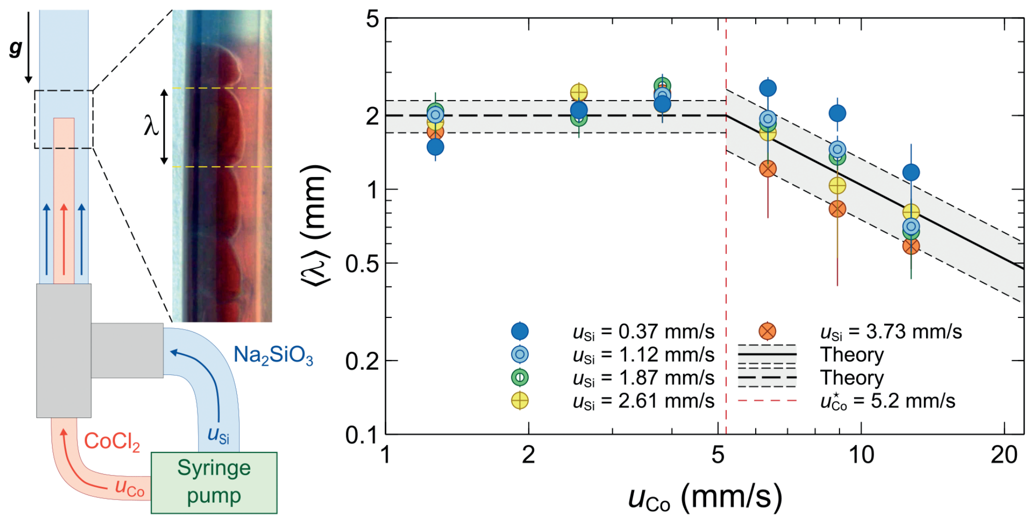


Figure 1: Chemical garden tube grown in a co-flow reactor and scaling of the wavelength of the striped pattern at the surface of the tube as a function of the velocity injection of the cobalt chloride solution.

Influence of a viscosity contrast on the Rayleigh-Taylor instability

Anne De Wit

The Rayleigh-Taylor (RT) instability is a buoyancy-driven instability developing when a denser fluid is accelerated against a less dense fluid. It favors mixing between the two fluids and is genuinely observed in inertial confinement fusion, plasmas, liquid films, material deformation, oceanography, and astrophysics, to name a few. Motivated by the interest to control this mixing, universal scalings, quantifying the interpenetration of the two fluids as a function of the acceleration or the density and viscosity differences across the interface, are of tantamount importance. Through 2D numerical simulations, we have shown for porous media flows that large viscosity contrasts profoundly affect the RT instability as a breaking of symmetry of the buoyancy-driven fingers occurs above a critical value of the viscosity ratio M. The fingers extend then preferably in the fluid of lower viscosity, which has an impact on the mixing. We have quantified the effect of the viscosity contrast on the RT convection across a wide range of viscosity ratios (up to M $\approx$ 3000) and have obtained new scaling relations, characterizing the fingers spreading around the initial interface of fluids. In particular, we have derived scalings of the spreading rates of fluids and of their convective mass flux as a function of M. We have also characterized a new fingering mechanism observed at large viscosity ratios, which enlightens hitherto unexplained previous experiments *(Figure 2).*

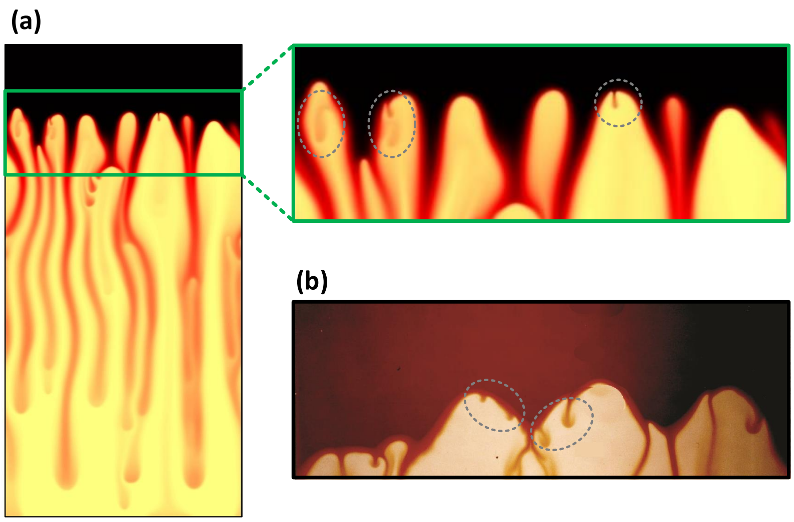


Figure 2: Asymmetric Rayleigh-Taylor instability observed when a denser and very viscous fluid overlies a less dense and less viscous fluid in the gravity field. A high viscosity contract induces locally small dips at the tip of the rising fingers as observed numerically (a) and experimentally (b).

Role of papillae flexibility in nectar capture by bees

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 *(see Figure 3)*. In vivo measurements show that the amount of nectar collected per lap remains essentially constant for sugar concentrations lower than 50% but drops significantly for a concentration around 70%. To understand this variation of the ingestion rate with the sugar content of nectar, we have investigated the dynamics of fluid capture by Bombus terrestris as a model system. During the dipping process, the papillae unfold when immersed in the nectar (see snapshots, Δt=20 ms). Combining in vivo investigations, macroscopic experiments with flexible rods, and an elastoviscous theoretical model, we have shown that the capture mechanism is governed by the relaxation dynamics of the bent papillae, driven by their elastic recoil slowed down through viscous dissipation. At low sugar concentrations, the papillae completely open before the tongue retracts out of nectar and thus, fully contribute to the fluid capture. In contrast, at larger concentrations corresponding to the drop of the ingestion rate, the viscous dissipation strongly hinders the papillae opening, reducing considerably the amount of nectar captured. This study shows the crucial role of flexible papillae, whose aspect ratio determines the optimal nectar concentration, to understand quantitatively the capture of nectar by bees and how physics can shed some light on the degree of adaptation of a specific morphological trait.

Figure 3: Motion of the tongue of a bee when dipping into nectar. Right: close-up on the papillae covering the tongue.

Oscillations of surface tension in simple reactive systems

Reda Tiani and Laurence Rongy

A new mechanism for the emergence of oscillatory dynamics in simple A + B -> C chemical systems has been found to be driven by the interaction of hydrodynamic flows and reaction-diffusion processes. No autocatalytic feedback nor prescribed hydrodynamic instability are involved but differential diffusion plays a key role. We have numerically studied the dynamics of an A + B -> C reaction-diffusion front in the presence of chemically-driven Marangoni flows for arbitrary initial concentrations of reactants and diffusion coefficients of all species. All the species are assumed to affect the solution surface tension thereby inducing Marangoni flows at the air-liquid interface. Spatial and temporal oscillations of surface tension are triggered by differential diffusion effects of surfactant species coupled to the chemically-induced Marangoni effect. Such oscillations are related to the discontinuous traveling of the front along the surface *(Figure 4)* leading to the progressive formation of local extrema in the surface tension profiles as time evolves.

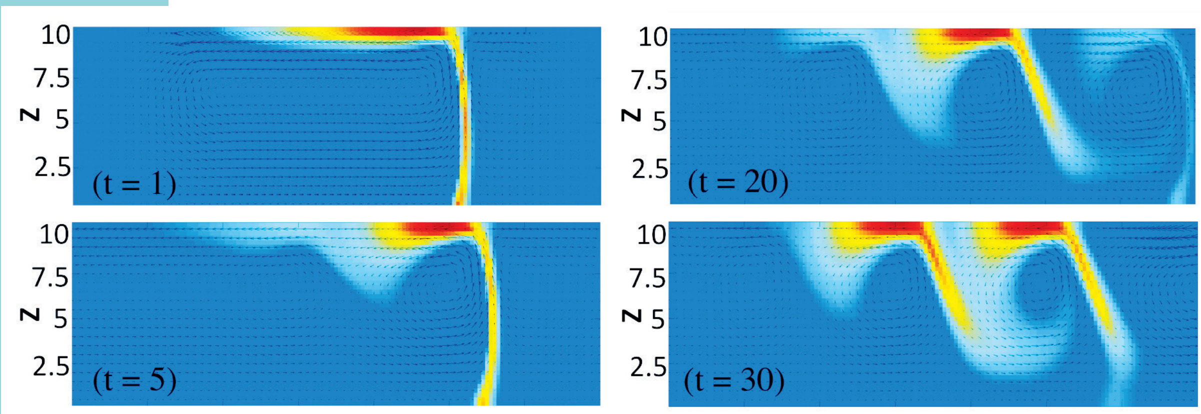


Figure 4: Focus on the convective rolls centered on the reaction front at different times. The fluid velocity field is superimposed on a 2D plot of the production rate, defined as the product of the concentrations of A and B, which ranges between its maximum value shown in red and its minimum value (0), shown in blue.

Critical role of layer thickness in frontal polymerization

Reda Tiani, John Pojman, and Laurence Rongy

Thermal frontal polymerization (FP) is a chemical process during which a cold monomer-initiator mixture is converted into a hot polymer as a polymerization front propagates in the system due to the interplay between heat diffusion and the exothermicity of the reaction. The theoretical description of FP generally focuses on one-dimensional reaction-diffusion models where the effect of heat losses is encoded into an effective parameter in the heat equation. We have shown that the layer thickness, a parameter that cannot be accounted for in 1D models, is a crucial parameter controlling not only the dynamics of the front but also determining its very existence. We have found that a minimum value of the layer thickness is required for front propagation as recently observed in frontal polymerization experiments of 2D thin films on wood. Moreover, when the layer thickness exceeds a critical value, the front is observed to survive independently of the rate of heat losses *(Figure 5)*. Those results cannot be predicted with 1D models, where front extinction is always possible, and bears important consequences for the existence of the front, and hence the use of FP in applications such as coatings or greener synthesis of materials.

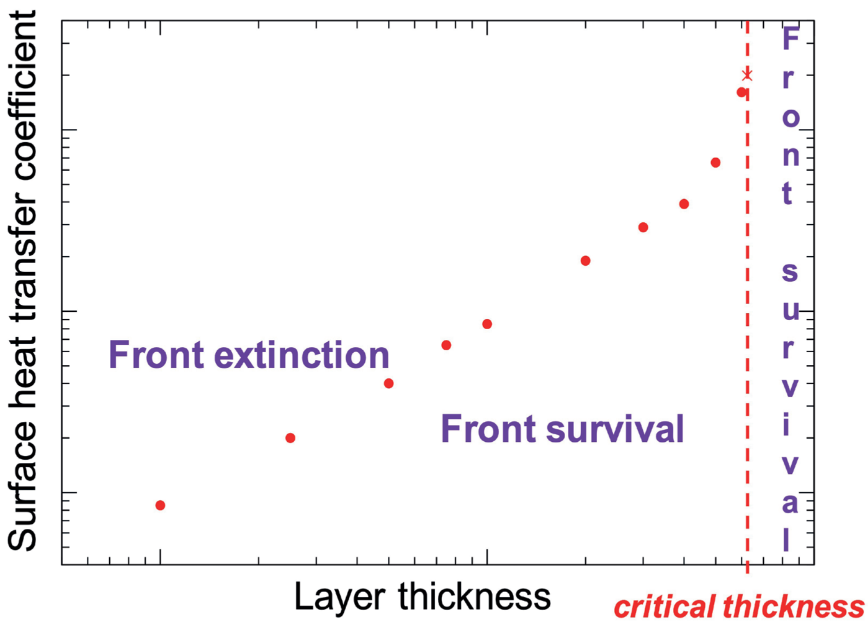
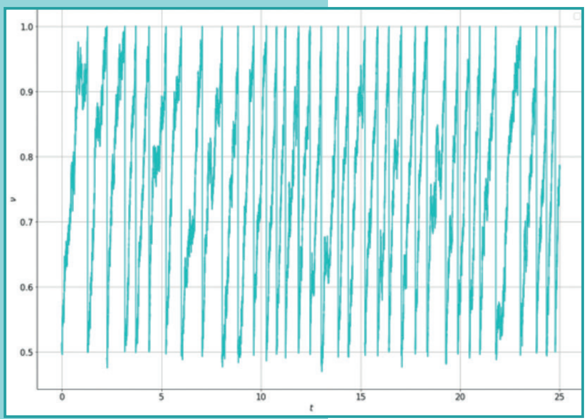


Figure 5: Typical parameter space diagram indicating when the polymerization front survives and when it is quenched by heat losses.

Stochastic thermodynamics of the growth and reproduction of supramolecular assemblies

Romain Haag, Yannick De Decker



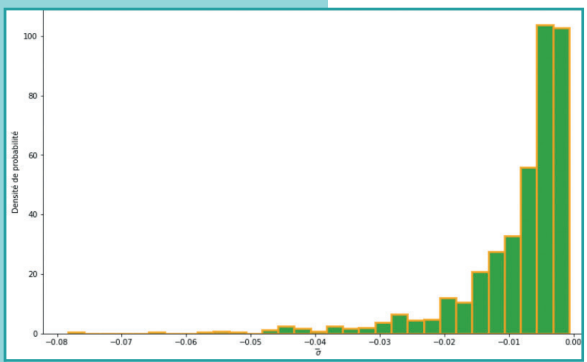
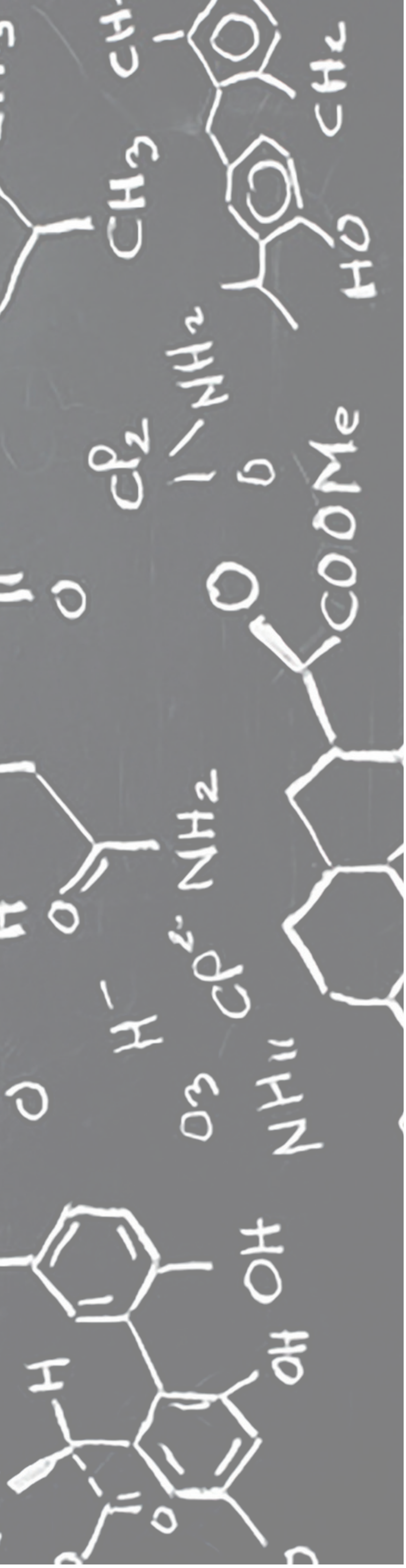


Figure 6: Top: Fluctuation-induced self-reproduction cycles in the simple model (v is the relative size of the micelle and t stands for a non-dimensional time). Bottom: probability distribution of entropy production (σ) during the cycles. Note that σ takes negative values only.

Supramolecular assemblies often form through the addition of simple, monomeric units to pre-existing seeds. In many situations, the assemblies can break down once they reach a large enough size, which gives rise to new seeds. If this process can be maintained, the supramolecular entities thus become capable of self-reproduction. These systems often need to be kept very far from equilibrium in order for the growth process to take place spontaneously. We have analyzed a simple stochastic example for the growth of such self-assemblies to assess how fluctuations might affect the need for strong non-equilibrium constraints. We show that the system under consideration presents fluctuation-induced growth, which takes place even close to equilibrium *(Figure 6)*. Consequently, assemblies can grow when macroscopic conditions are unfavorable. This leads to the possibility of having assemblies self-reproduce even when macroscopic thermodynamics predicts that they should not be doing so.



THESES DEFENDED IN 2021

PhD theses

- **A. Papageorgiou,**

  "Influence of proton transfer kinetics and natural convection on Proton-Coupled Electron Transfer reactions"
  Supervisors: T. Doneux and L. Rongy, ULB (2021).

- **R. Tiani**

  "Dynamics of chemical fronts driven by reaction-diffusion processes and convective effects"
  Supervisor: L. Rongy, ULB (2021).

Master Theses

- **S. Kabbadj**

  « Effet d'une solubilité variable sur la dissolution réactive du CO_2 dans des solutions aqueuses : étude théorique»
  - Promotors: A. De Wit and L. Rongy (2021).

- **C. Robert**

  « Dynamique et robustesse de réseaux de régulation génétique minimaux gouvernant la différenciation cellulaire »
  Promotors: Y. De Decker and D. Gonze (2021).

- **R. Haag**

  « Thermodynamique stochastique des cycles de reproduction d'un assemblage supramoléculaire »
  Promotor: Y. De Decker (2021).

- **P. Bryssinck**

  « Étude de la dynamique de relaxation d'une tige élastique déformée dans un fluide visqueux appliquée à la capture de nectar chez les abeilles »
  Promotor : F. Brau (2021).

PUBLICATIONS

M. A. Budroni, F. Rossi, L. Rongy

From Transport Phenomena to Systems Chemistry: Chemohydrodynamic Oscillations in $A + B \rightarrow C$ Systems,
ChemSystemsChem 3, e2100023 (2021).

M. A. Budroni, A. Polo, V. Upadhyay, A. Bigaj, L. Rongy

Chemo-hydrodynamic pulsations in simple batch $A + B \rightarrow C$ systems,
J. Chem. Phys. 154, 114501 (2021).

A. Comolli, A. De Wit, F. Brau

Dynamics of $A + B \rightarrow C$ reaction fronts under radial advection in a Poiseuille flow,
Phys. Rev. E 104, 044206 (2021).

A. Draux, H.-A. B. Hua, P. Damman, F. Brau

Relaxation dynamics of a flexible rod in a fluid,
Phys. Rev. Fluids 6, 114102 (2021).

S.S. Gopalakrishnan, B. Knaepen, A. De Wit

Scalings of the mixing velocity for buoyancy-driven instabilities in porous media,
J. Fluid Mech. 914, A27 (2021).

M. Jotkar, A. De Wit, L. Rongy

Control of chemically driven convective dissolution by differential diffusion effects,
Phys. Rev. Fluids 6, 053504 (2021).

A. Lechantre, A. Draux, H.-A. B. Hua, D. Michez, P. Damman, F. Brau

Essential role of papillae flexibility in nectar capture by bees,.
Proc. Nat. Acad. Sci. USA 118, e2025513118 (2021).

N. Sabet, H. Hassanzadeh, A. De Wit, J. Abedi

Scalings of Rayleigh-Taylor instability at large viscosity contrasts in porous media,
Phys. Rev. Lett. 126, 094501 (2021)

D. Spanoudaki, F. Brau, A. De Wit

Oscillatory budding dynamics of a chemical garden within a co-flow of reactants,
Phys. Chem. Chem. Phys. 23, 1684 (2021).

TALKS AT CONFERENCES, SEMINARS AND SCHOOLS

Alessandro Comolli

Online talk at the 2021 EGU (European Geophysical Union) conference - April 2021

Online poster at the InterPore 2021 conference - May 2021

Yannick De Decker

Online talk at Dynamics Days, Nice (France) August 2021

Invited seminar, IAS, University of the Basque Country (Spain) - October 2021

Online talk at the VIRTUAL ICTAM 2020 +1 Congress - August 2021

Invited talk, Annual meeting of the Belgian Royal Society of Chemistry, Brussels (Belgium) - October 2021

CEPULB invited conference, Nivelles (Belgium) - November 2021

Talk at the "Physics of Life" meeting, KULeuven, Leuven (Belgium) - November 2021

Anne De Wit

Online talk at the 2021 EGU (European Geophysical Union) conference - April 2021

Online talk at the InterPore 2021 conference - May 2021

Online invited talk, Classe des Sciences de l'Académie royale des Sciences, Arts et Lettres - June 2021

Invited talk at the Summer school "Mixing in porous media", Cargèse, Corsica (France) - July 2021

Laurence Rongy

Online invited talk at the First Virtual International Symposium on Frontal Polymerization - April 2021

Online invited talk at Dynamics Days, Mini-symposium on Instabilities and patterns in extended systems and their control, Nice (France) - August 2021

ORGANIZED CONFERENCES

- Solvay Workshop in memory of Prof. Grégoire Nicolis on "Nonlinear Phenomena and Complex Systems" (Online), Brussels, 14 - 16 June 2021.
  Members of the Scientific and Organising Committee: Y. De Decker and A. De Wit.

- Symposium " Data-based analysis of complex dynamical systems " at the 2021 Dynamics Days. Organizing Committee: Y. De Decker (ULB), F. Dietrich (Technical University of Munich) and C. Siettos (University of Naples Federico II).

ALGC RESEARCH GROUP

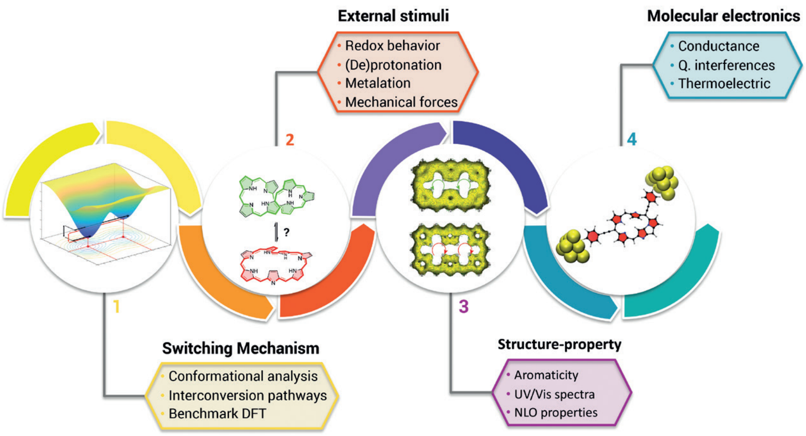
GROUP OF PROFESSORS FRANK DE PROFT, FREDERIK TIELENS, MERCEDES ALONSO, FREIJA DE VLEESCHOUWER AND PROFESSOR EMERITUS PAUL GEERLINGS I VUB

Besides extending its long-standing research interest in Conceptual Density Functional Theory, the ALGC Research Group has in recent years launched several new research lines in more applied domains of quantum chemistry such as Molecular Opto-electronics, under the impetus of Professor Mercedes Alonso and Materials Modelling, a new line created by Professor Frederik Tielens since his appointment in 2017.

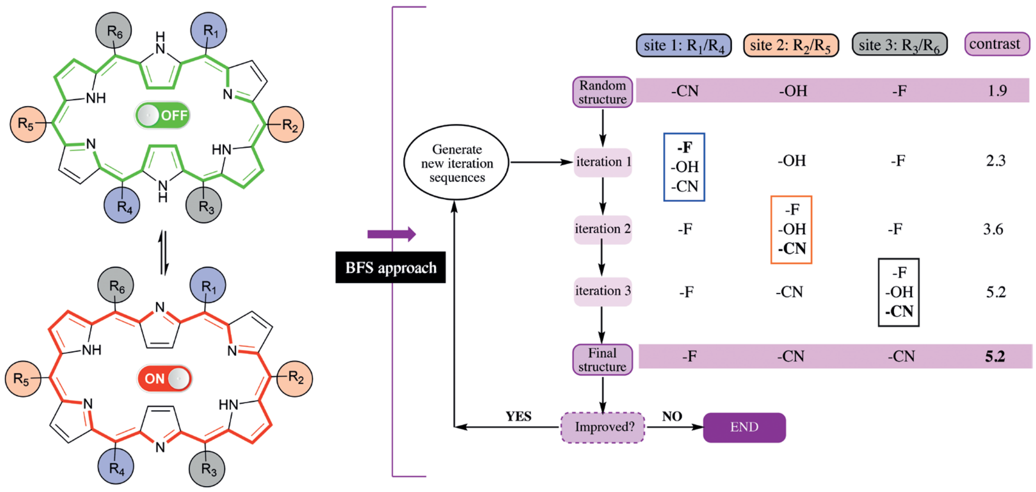
This 2021 Report highlights the contributions of these two colleagues

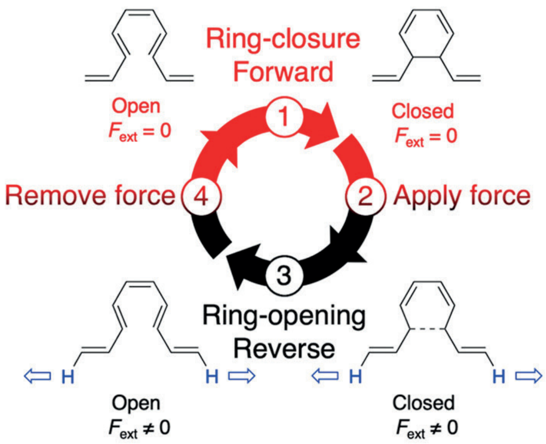
In recent years, we have developed and implemented in the Molecular Optoelectronics line a bottom-up modelling approach to design efficient nanoscale devices. In this approach, different computational and conceptual techniques are combined, including first-principle quantum chemistry methods, non-equilibrium Green´s function theory, molecular dynamics simulations and inverse design approaches.

Particular attention is devoted to the design of molecular switches from π-extended macrocycles since these responsive molecules are key building blocks to accomplish new functions beyond silicon-based technologies. We recently proposed a novel type of molecular switches based on redox and topology interconversions in expanded porphyrins for different nano-electronic applications, including conductance switching,[1] bithermoelectric devices[2] and nonlinear optical (NLO) switches.[3] New selection rules were devised to predict the occurrence of quantum interference around the Fermi level for Hückel and Möbius π-systems.[4]



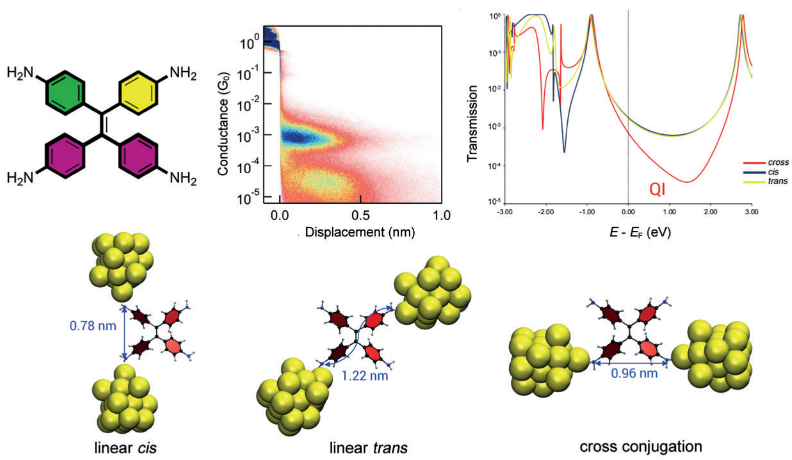
To accelerate the discovery of functionalized expanded porphyrins with improved switching properties, we recently incorporated inverse design approaches, building on the expertise of the ALGC research group in implementing, developing and applying property-optimization algorithms.[5,6] Within inverse design, the calculation of certain properties is used to derive new molecular structures with an optimal target property/functionality. The ratio and the difference of the first hyperpolarizabilities of the ON and OFF states of the switches were introduced as new figures of merit. The application of the best-first-search algorithm on a substituent library resulted in redox and topological switches with extremely large NLO contrasts and highlighted the electronic nature of the substituents and molecular symmetry as pivotal key players for fine-tuning the first hyperpolarizability and NLO contrasts.[7]





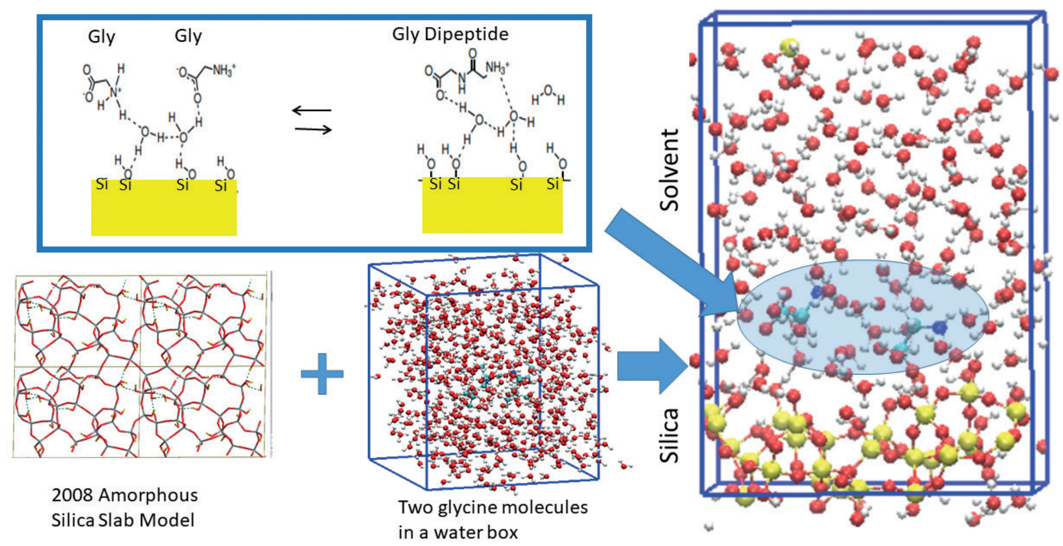
Besides understanding the switching properties of porphyrinoid-based switches, we aim to identify effective external stimuli for triggering the molecular interconversions. The connection between our work in mechanochemical reactivity[8] and molecular switches naturally led to the research question if the conformational preferences of porphyrin-based macrocycles can be controlled by external forces. Our work proved that mechanical force is an effective stimulus to trigger the interconversion between Hückel and Möbius topologies in [28]hexaphyrin, making these expanded porphyrins suitable to act as conformational mechanophores operating at mild (sub-1nN) force conditions.[9,10] It was shown that an external pulling force is an effective stimulus for reverting a 6π-electrocyclic reaction under identical thermal reaction conditions. Force-distribution analyses illustrate that the application of a mechanical force at the ends of the polyene chain transfers the mechanical stress efficiently to the target C–C σ-bond triggering the ring-opening reaction.

A final illustrative example is our recent work in molecular electronics on the impact of the competition between *linear*- and *cross*-conjugations in the molecular conductance of a tetra (aminoaryl)ethene.[11]



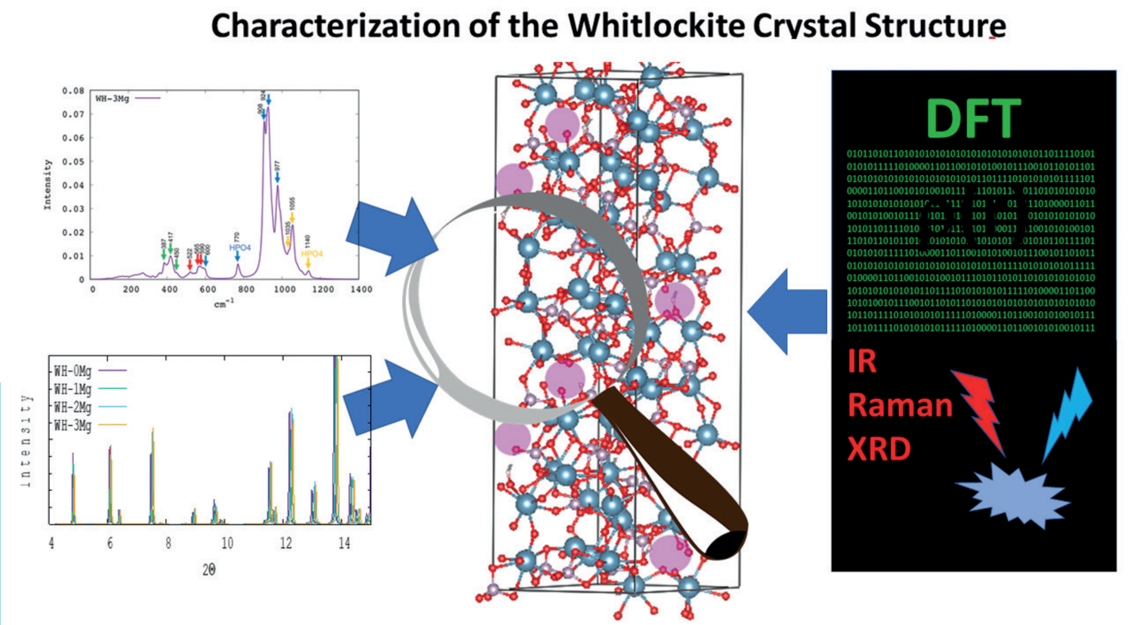
Despite the possibility of three modes of connection to the gold electrodes, only two regimes of conduction are found experimentally. Modelling of the molecular junction provides insight in the conduction mechanisms. Around the Fermi level, the cis- and trans-versions promote conductance by through-bond transmission. In the cross-conjugated channel, through-space transmission adds to the through-bond channel, which partially alleviates the destructive quantum interference typical of cross-conjugated molecules. This study represents one of the simplest cases of cross-conjugation conductance, demonstrating that the combination of several forms of conjugation in π-conjugated systems confers greater versatility and multifunctionality to molecules.

The Materials Modelling group of ALGC is specializing in metal oxides, molecular self-assembly on surfaces, and materials originating from biological mineralization, For some 15 years F. Tielens has been active in the characterization of silica-based materials, that find their application as support for nano-catalysts but also as adsorbent, as meso-porous materials and other complex nano hybrid objects. The complexity of their characterization resides in their amorphous character. The silica material used in these materials are SiO_2 tetrahedrals connected with each other via their vertices oxygen atoms, with no particular structure but terminated with hydroxyl groups, called silanols. Two or three main groups of silanols have been identified on the amorphous hydrated surface of silica: isolated, geminal and vicinal silanols. On the SiO_2 surface a distribution over these types of silanol has been observed depending on the degree of hydration of the silica. The system becomes even more complex when liquid water is put on top of the amorphous surface. This situation yields a particular interface where two amorphous phases are in contact. The study of this interface is very difficult to characterize experimentally at the atomic level and the only way to explain its physical chemical properties is using computational chemistry tools and in particular quantum chemical solid-state calculations. Already in 2008, we published the first paper on hydroxylated silica studied using periodic DFT calculations [12] and we were able to describe the individual pKa's of the surface silanols a few years later.[13] Since then a series of papers were published on the topic including silica supports for transition metal atoms and oxide catalysts including the famous Philips catalyst, functionalized silicas, MCM-41 models, vectorization of drugs, and bulk properties[14] After a decade of work, the condensation reaction path of the amino acid glycine on Silica was published this year in ACS Catalysis.[15] The amino acid condensation reaction on a heterogeneous mineral surface has been regarded as one of the important pathways for peptide bond formation. In this work ab initio molecular dynamics calculations are coupled with enhanced sampling methods such as meta molecular dynamics and umbrella sampling. The model includes a periodically repeated slab of amorphous SiO_2 forming an interface with explicit liquid water, technically and theoretically challenging due to the silica water interface and the multi transition state reaction path of the reaction that had to be calculated using advanced meta-molecular dynamics approaches.



The adopted simulation method allowed reconstruction of a prejudice-free reaction mechanism of glycine dimerization and quantification of the corresponding free energy profile, with a detailed characterization of transition states and of the role of water. The resulting three-step mechanism features an overall free energy barrier of 155 kJ/mol at 300 K. In comparison to the bulk liquid phase, our results indicate that the interface has a strong catalytic effect on the condensation reaction, which we trace back to the capability of the silica–water interface in promoting an addition reaction by a transition state stabilization. The silica–water interface is found to behave as a less-polar reaction medium with respect to bulk water, promoting addition reactions and disfavoring elimination reactions.

Concentrating now on our work on materials originating from biomineralization it should be noticed that biological mineralization is a very complex phenomenon, very widely spread in the living species on earth. Moreover, organisms have been producing mineral skeletons for over 550M years, mainly made from calcification of phosphates and carbonates. One can find over 60 different minerals from biological origin, including silicates, carbonates and phosphates as the most evident examples. Moreover, pathological calcification and mineralizations exist as well, such as kidney stones, extra skeletal calcification, brain, gal, tumor, etc. These materials have all in common to have a complex structure, typically constructed hierarchally showing a macro, micro and nano assembly. Therefore, the characterization and their chemistry are a challenging task needed to be characterized within a multidisciplinary network of researchers. We actually work with clinicians, physicist, chemists and fellow materials modellers, from France, Argentina, UK, and China. In particular, we worked on oxalates[16], cystine, cysteine[17], and whitlockite.[18] The latter is a calcium phosphate phase of crucial interest in various pathologies.



It appears in abnormal calcification such as dental calculi, kidney stones, or dystrophic calcifications of tuberculous origin. It is a complex material which involves cation substitutions, cation vacancies, and protonation of phosphate groups. In the literature, there is a lack of theoretical characterization of such materials originating from biological calcifications. By means of DFT calculations, we were able to quantify the ability of whitlockite to hold these substitutions and vacancies in preferential sites. The impact of Ca^2+/Mg^2+ substitutions on characterizations (IR, RAMAN, and XRD) was also investigated in the scope of DFT.

The sections on Molecular Electronics and Materials Modelling illustrate that in its applied quantum-chemical research ALGC is on the road to a multiscale approach allowing, together with the more fundamental issues in the Conceptual DFT part, to address a broad spectrum of problems/issues in the Chemistry of today and tomorrow.

1. *T. Stuyver, M. Perrin, P. Geerlings, F. De Proft, M. Alonso, J. Am. Chem. Soc. 140, 1313 (2018).*
2. *T. Stuyver, P. Geerlings, F. De Proft, M. Alonso. J. Phys. Chem. C 122, 24436 (2018).*
3. *T. Woller, P. Geerlings, F. De Proft, B. Champagne, M. Alonso. J. Phys. Chem. C 123, 7318 (2019).*
4. *T. Stuyver, S. Fias, P. Geerlings, F. De Proft, M. Alonso. J. Phys. Chem. C 122, 19842 (2018).*
5. *F. De Vleeschouwer, P. Geerlings, F. De Proft. ChemPhysChem 17, 1414 (2016).*
6. *J. L. Teunissen, F. De Proft, F. De Vleeschouwer. J. Chem. Theory Comput. 13, 1351 (2017).*
7. *E. Desmedt, T. Woller, J. L. Teunissen, F. De Vleeschouwer, M. Alonso. Front. Chem. 9, 786036 (2021).*
8. *T. Bettens, M. Alonso, P. Geerlings, F. De Proft, Chem. Sci., 11, 1431 (2020).*
9. *T. Bettens, M. Hoffmann, M. Alonso, P. Geerlings, A. Dreuw, F. De Proft, Chem. Eur. J. 27, 3397 (2021).*
10. *T. Bettens, J. Eeckhoudt, M. Hoffmann, M. Alonso, P. Geerlings, A. Dreuw, F. De Proft, J. Org. Chem. 86, 7477 (2021).*
11. *S. Medina Rivero, P. García Arroyo, L. Li, S. Gunasekaran, T. Stuyver, M. J. Mancheño, M. Alonso, L. Venkataraman, J. L. Segura, J. Casado, Chem. Com. 57, 591 (2021).*
12. *F. Tielens, C. Gervais, J.-F. Lambert, F. Mauri, D. Costa, Chem. Mater. 20, 3336 (2008).*
13. *M. Pfeiffer-Laplaud, D. Costa, F. Tielens, M.-P. Gaigeot, M. Sulpizi, , J. Phys. Chem. C 119, 27354 (2015).*
14. *F. Tielens, M. Gierada, J. Handzlik, M. Calatayud, Catal. Today 354, 3 (2020).*
15. *F. Siro Brigiano, M. Gierada, F. Tielens, F. Pietrucci, ACS Catal. 12, 2821 (2022).*
16. *J. Vekeman, F. J. Torres, C. David, E. Van de Perre, K.M. Wissing, E. Letavernier, D. Bazin, M. Daudon, A. Pozdzik, and F. Tielens, Nanomaterials 11, 1763 (2021).*
17. *T. Debroise, E. Colombo, G. Belletti, J. Vekeman, Y. Su, R. Papoular, N.S. Hwang, D. Bazin, M. Daudon, P. Quaino, and F. Tielens, Crystal Growth & Design, 20, 2553 (2020).*
18. *Y. Su, E. Hessou, E. Colombo, G. Belletti, A. Moussadik, I. Lucas, V. Frochot, M. Daudon, D. Bazin, P. Quaino, F. Tielens, Amino Acids, online.*

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).

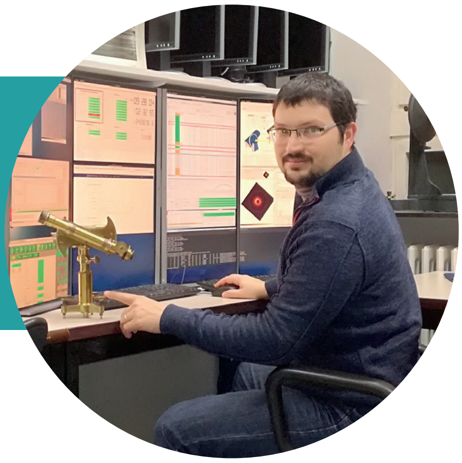
Given the close ties of these two personalities with the Institutes, the International Solvay Institutes are associated with this initiative.

In 2021, the prizes have been awarded to:

- Jochen Eeckhoudt (Ilya Prigogine Prize VUB)
- Victor Lepeintre (Ilya Prigogine Prize ULB)
- Floriano Tori (Robert Brout Prize VUB)

INSTITUTE OF ASTRONOMY AND ASTROPHYSICS

GROUP OF PROFESSORS SOPHIE VAN ECK AND ALAIN JORISSEN I ULB



Thibault Merle
Postdoctoral Researcher

Stellar Multiplicity

Stars like company, and in contrast with our Sun, most of the stars in the Galaxy have stellar companions. Multiple systems may follow a complex evolution leading to mergers that are possible progenitors of Type Ia supernovae. In addition, binary stars allow us to derive fundamental stellar parameters like masses, radii and luminosities with a better accuracy compared to single stars. They represent the gems on which various astrophysics topics rely.

During my long-term postdoctoral position at the Institut d'Astronomie et d'Astrophysique, I became more and more interested in the study of binaries detected with spectrographs: the spectroscopic binaries (SB). Such binaries can be characterized by measuring their radial velocities as a function of time. I led and participated in the investigations on interesting families of binary stars that allow us to constrain their evolutionary pathways (binaries with an Helium white dwarf companion, Barium and CH stars [1], AGB-manqué family, carbon-enriched metal poor stars, etc.).

These investigations were done through the analysis of spectra obtained with the high-resolution echelle spectrograph HERMES mounted on Mercator telescope at La Palma (Canary Islands) and partly funded by the FNRS. I have also joined the large public spectroscopic survey Gaia-ESO (GES) which targeted 100 000 stars of the Milky Way. I have developed an innovative automated method to detect SB based on the successive derivatives of the cross-correlation of spectra with templates; this allows to reveal the presence of close companions [2]. The characterisation of their statistical properties was performed in terms of binary fraction, orbital period, temperature and metallicity distributions, showing that the fraction of close binaries increases with decreasing stellar metallicity [3]. My automated method was also applied in the context of a larger Anglo-Australian spectroscopic survey, GALAH, targeting about half a million stars, revealing the existence of more than 12 000 SB [4].

A progenitor of type Ia supernovae?

While binaries have received much attention so far, higher-order stellar systems show a wide variety of interactions especially in tight systems, like long-term gravitational effects playing a key role in triple and quadruple systems.

Among the SB detected in the GES, an interesting quadruple candidate emerged [2]. Stellar quadruples only represent a marginal fraction (a few percent) of all multiple systems. Nevertheless, the complex evolution of such high-order multiples involves mass transfer and collisions, leading to mergers that are possible progenitors of Type Ia supernovae. The progenitors of such explosions are still highly debated.

I obtained spectroscopic follow-up observations of this system (HD 74438) with the Southern African Large Telescope in South Africa, the Mount John Observatory from University of Canterbury in New Zealand and archival observations from ESO. These observations allowed us to demonstrate that the system consists in a 2+2 bound hierarchical stellar system, i.e. two gravitationally bound binaries. We derived orbital *(Figure 1)* and astrophysical parameters for the two inner pairs and found that their orbits are non-coplanar. The membership of this system in the open cluster IC 2391 makes it the youngest spectroscopic quadruple discovered so far. Using an innovative combination of high-resolution spectroscopy and Gaia/Hipparcos astrometry, we showed that this system is undergoing secular interaction that likely pumped the eccentricity of one of the inner orbits higher than expected for the spectral types of its components. We computed the future evolution of HD 74438 by considering gravitational dynamics, stellar evolution, and binary interactions, and showed that this system is an excellent candidate progenitor of sub-Chandrasekhar Type Ia supernova through white dwarf mergers *(Figure 2)*. This specific type of SNIa better accounts for the chemical evolution of iron-peak elements in the Galaxy. This discovery led to a publication in Nature Astronomy [5].

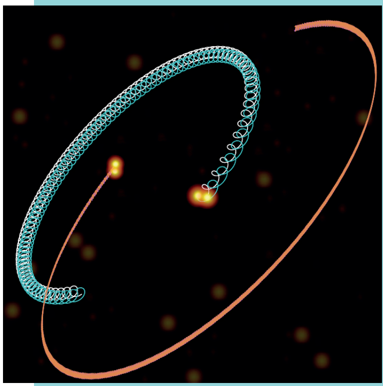


Figure 1. Trajectories of the quadruple stellar system HD 74438: the two close pairs, having orbital periods of 21 and 4 days, orbit around their center of mass in 6 years.

Figure 2. One of the possible fates of the quadruple system HD74438 is to form a thermonuclear supernova Ia that can temporarily be as bright as the hosting galaxy, as illustrated by the example shown here, the supernova SN 1994D in the NGC 4526 Galaxy. Credit: NASA/ESA/HST.

[1] T. Merle, S. Van Eck, A. Jorissen et al., To Ba or not to Ba: Enrichment in s-process elements in binary systems with WD companions of various masses, Astronomy & Astrophysics, 586, A151 (2016)

[2] T. Merle, S. Van Eck, A. Jorissen et al., The Gaia-ESO Survey: double-, triple-, and quadruple-line spectroscopic binary candidates, Astron. Astrophys., 608, A95 (2017)

[3] T. Merle, M. Van der Swaelmen, S. Van Eck et al., The Gaia-ESO Survey: detection and characterisation of single-line spectroscopic binaries, Astron. Astrophys., 635, A155 (2020)

[4] G. Traven, S. Feltzing, T. Merle et al., The GALAH survey: Multiple stars and our Galaxy. I. A comprehensive method for deriving properties of FGK binary stars, Astron. Astrophys., 638, 145 (2020)

[5] T. Merle, A. S. Hamers, S. Van Eck et al., A spectroscopic quadruple as a possible progenitor of sub-Chandrasekhar Type Ia supernovae, Nature Astronomy, accepted (2022)

LABORATORY OF POLYMER CHEMISTRY

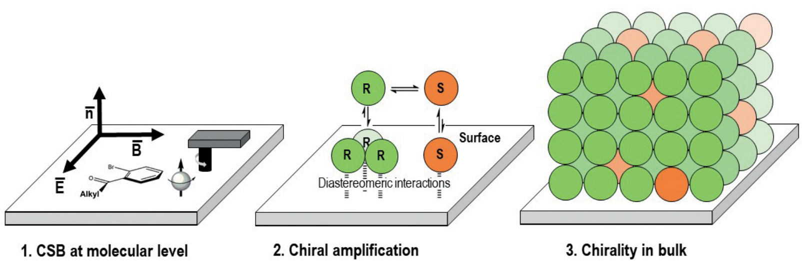
GROUP OF YVES GEERTS I ULB AND GUILLAUME SCHWEICHER[1]

In 2021, we have pursued our research activities on functional molecular materials to tailor their structural, thermal, optical, and electronic properties. Advances have been made in the understanding and control of polymorphism[2,3], and polyamorphism[4]. The role of interfaces,[5] disorder,[6] and structural defects[7] have been investigated.

Polymorphism that is the occurrence of more than one crystal structure for a given compound is very common for molecular crystals. Some organic molecules exhibit many polymorphs whereas others do not show any. Nowadays, a fundamental understanding of polymorphism still lacks, although it has a pivotal role in pharmaceutical sector because it determines the bioavailability and hence the efficiency of drugs. Our work hypothesis is that non-equilibrium conditions and particularly heat transfer processes rules,[8] at least in part, polymorphism. We use a temperature gradient setup that decouple nucleation from growth phenomena.[9] Thin films of periodic and controlled morphologies have been obtained even for binary-systems where an electron transfer occurs.[10] Polymorphism is evidently also influenced by the molecular structure of the compounds, although the scientific community does not understand how.

Polyamorphism, which has been coined by analogy to polymorphism, refers to the existence of different amorphous states of a given compound. We have shown that a memory of previous crystal forms remains in glassy state and impact its mechanical properties, far below the glass transition temperature (T_g).[4] Glass transition is similar in appearance to a second-order phase transition, but it is not a true thermodynamic phase transition. This is because the transition temperature depends on the rate at which the experiment is done. Below T_g, the system can no longer reach equilibrium on the timescale of experiment. Some degrees of freedom can no longer contribute to the values of thermodynamic quantities as they are measured in the experiment. The memory effect can, however, be erased by prolonged thermal annealing above the melting point.[4]

Interfaces between molecular or macromolecular materials and a rigid substrate imposes new thermodynamic and geometrical constrains to which systems adapt by changing their structures or/and dynamics.[5] We have shown that a metastable crystal phase can grow on the surface of a stable one, in thin films.[3]



In the frame of the Excellence of Science (EOS) program, a high-scale financing has been obtained by Yves Geerts for a project to be carried out in close collaboration with Belgian and foreign groups, of which the one of Ben Feringa. CHISUB is an ambitious collaborative research project that span over 4 years (2022-2025) and that puts together 6 research groups. As illustrated in the figure, CHISUB features a multidisciplinary approach, towards crystallization mechanisms of molecules, which uses chiral symmetry breaking as local probe of ordering phenomena and as a tool for enantiomeric separation. Crystallization often starts on surfaces of rigid substrates with the formation of 2D self-assembled molecular layers and then extends to bulk phases. CHISUB intends to design, synthesize, and characterize a library of molecular systems tailored to break chiral symmetry at different time- and length-scales. These systems will be studied by scanning probe microscopy at 2D and by electron microscopy and diffraction techniques when extending to 3D. Chiral symmetry breaking towards specific handedness will be directed by external stimuli, such as a combination of electric and magnetic fields, spin polarization, and even rotation of molecular machines. Theoretical and experimental studies will be carried out in synergy to explore ordering phenomena and chiral selectivity processes from first principles and reach a fundamental understanding beyond specific systems.

1. Guillaume Schweicher has been appointed as an FNRS Research Associate (Chercheur Qualifié) in October 2021. His research interests aim at developing novel organic and hybrid semiconducting materials for a greener and more sustainable electronics. Since October 2019, he started to interact with Ohme, a Belgian transdisciplinary and creative label, as an Associate Researcher on the establishment of art and sciences contents in accessible, educational and interactive formats. So far, the most notable outcome from this collaboration is the realisation of the audiovisual performance: "Tales of Entropy", staging the irresistible beauty and poetry of an organic compound changing its physical state in a thermal gradient, under polarized light, premiered 2020/10/23, Pilar, Brussels.

2. The Polymorphism of 2-Benzoyl-N,N-diethylbenzamide" Lygia S. de Moraes, Jie Liu, Elumalai Gopi, Ryusei Oketani, Alan R. Kennedy, Yves H. Geerts, Crystals 2021, 11, 1004.

3. "Phase Transition toward a Thermodynamically Less Stable Phase: Cross-Nucleation due to Thin Film Growth of a Benzothienobenzothiophene Derivative" Sebastian Hofer, Andreas Hofer, Josef Simbrunner, Michael Ramsey, Martin Sterrer, Alessandro Sanzone, Luca Beverina, Yves Geerts, and Roland Resel J. Phys. Chem. C 2021, 125, 28039-28047.*

4. "Memory Effect and Crystallization of (R, S)-2-Chloromandelic Acid Glass" Jie Liu, Guangfeng Liu, Zijian Song, Martin Kaltenegger, Lygia Silva de Moraes, Elumalai Gopi, Simone Napolitano, and Yves Henri Geerts, J. Phys. Chem. B 2021, 125, 13339-13347.

5. "1D-Confinement Inhibits the Anomaly in Secondary Relaxation of a Fluorinated Polymer" David Nieto Simavilla, Anabella A. Abate, Jie Liu, Yves H. Geerts, Patricia Losada-Peréz, Simone Napolitano, ACS Macro Lett. 2021, 10, 649-653.

6. "Molecular Disorder in Crystalline Thin Films of an Asymmetric BTBT Derivative", Sebastian Hofer, Johanna Unterkofler, Martin Kaltenegger, Guillaume Schweicher, Christian Ruzié, Adrián Tamayo, Tommaso Salzillo, Marta Mas-Torrent, Alessandro Sanzone, Luca Beverina, Yves Henry Geerts, and Roland Resel, Chem. Mater. 2021, 33, 1455-1461.

7. "Exhaustive One-Step Bridgehead Methylation of Adamantane Derivatives with Tetramethylsilane" Maxime Bonsir, Christian Davila, Alan R. Kennedy, Yves Geerts, Eur. J. Org. Chem. 2021, 5227-5237.

8. "Thermal conductivity of benzothienobenzothiophene derivatives at the nanoscale", Magatte N. Gueye, Alexandre Vercouter, Rémy Jouclas, David Guérin, Vincent Lemaur, Guillaume Schweicher, Stéphane Lenfant, Aleandro Antidormi, Yves Geerts, Claudio Melis, Jérôme Cornil, Dominique Vuillaume, Nanoscale 2021, 13, 3800.

9. "Directional crystallization of C8-BTBT-C8 thin films in a temperature gradient" Guillaume Schweicher, Guangfeng Liu, Pierre Fastre, Roland Resel, Mamatimin Abbas, Guillaume Wantz, Yves Henri Geerts. Mater. Chem. Front. 2021, 5, 249-258.

10. "Directional Crystallization from the Melt of an Organic p-Type and n-Type Semiconductor Blend" Guangfeng Liu, Jie Liu, Andrew S. Dunn, Peter Nadazdy, Peter Siffalovic, Roland Resel, Mamatimin Abbas, Guillaume Wantz, Yves Henri Geerts, Cryst. Growth Des. 2021, 21, 5231-5239.

05

APPENDIX

STEL ZELF JE VRAAG
EN STEM OP BRUZZ.BE

Wat zijn de Solvay-conferenties?

— ALBERT UIT OLMEN

De eerste Solvay-conferenties in 1911, met als derde van links zittend Ernest Solvay. Ook op de foto Albert Einstein (staand, twee van rechts) en Marie Curie (zittend, tweede van rechts). © BELGA

Albert Einstein en Marie Curie zijn in Brussel nog slimmer geworden dan ze al waren. Dat komt door de Solvay-conferenties, waaraan ze vaste deelnemers waren. Voor wetenschapsdummies zijn zij waarschijnlijk de bekendste namen op die bijeenkomsten over fysica en chemie, maar het summum van de natuurkundige wetenschappers van de negentiende en twintigste eeuw nam er deel aan. Onder anderen de grote Franse wiskundige Henri Poincaré, Max Planck en Niels Bohr, allebei grondleggers van de kwantumfysica, en nog meer knappe koppen uit die tijd. In november 1911 kwamen ze voor het eerst samen in Brussel in Hotel Métropole.

De man die de vierentwintig topwetenschappers samen rond een chique tafel kreeg, was Ernest Solvay. Een ingeweken Brusselaar van wie de naam op verschillende plekken in Brussel opduikt. Hij bouwde een fortuin op omdat hij gevonden had hoe in grote hoeveelheid natriumcarbonaat of sodazout kon worden geproduceerd. Die stof kan voor heel wat doeleinden gebruikt worden, in de glasindustrie, de gietijzerindustrie, maar ook de chemische industrie. Zijn ontdekking maakte hem door die grote toepassingsmogelijkheden slapend rijk. Dat hij van Solvay et Compagnie een wereldbedrijf maakte, dat vandaag nog altijd in de Brusselse beursindex Bel-20 staat, maakt dat we zijn naam niet alleen linken aan de wetenschap, maar ook aan de economie. Zo draagt de opleiding voor economische wetenschappen aan de ULB zijn naam. Hij investeerde zijn geld ook in het door Victor Horta getekende, prachtige Hotel Solvay op de Louizalaan en de indrukwekkende Solvay Bibliotheek in het Leopoldspark.

TIEN NOBELPRIJZEN

Behalve al die verwezenlijkingen is er nog die andere onmiskenbare verdienste voor de wetenschap. Solvay had een grote passie voor fysica en chemie. Hij kwam op het idee om de grootste wetenschappers van dat moment samen te brengen om bevindingen en inzichten uit te wisselen, en zo tot nieuwe ontdekkingen te komen. De aanwezigen in 1911 kwamen op uitnodiging en het waren niet de minste, het was een gezelschap ter waarde van tien Nobelprijzen. De vierentwintig wetenschappers discussieerden vijf dagen aan een stuk, met uitzonderlijk resultaat.

Op de agenda van de eerste conferentie stond het thema 'De theorie van de straling en de quanta'. De wetenschappelijke uitleg laten we even achterwege, maar die conferentie werd een belangrijk keerpunt in de kwantumfysica, niet alleen wetenschappelijk, het smeedde ook banden tussen de verschillende wetenschappers. Voor herhaling vatbaar dus en dat gebeurde ook. Solvay stichtte het Instituut voor Fysica, dat later het Instituut voor Fysica en Chemie werd. Via die instelling werden nog veel edities van de Solvay-conferenties georganiseerd. De groep wetenschappers breidde steeds uit, en sommige figuren werden vaste waarden op de bijeenkomsten.

Ook na de dood van Solvay werden de conferenties georganiseerd. Een andere conferentie die de geschiedenis inging, was de vijfde editie die het begin markeerde van de nieuwe kernfysica. Maar in het algemeen kan worden gesteld dat de Solvay-conferenties wereldwijd zijn uitgegroeid tot de belangrijkste conferenties over fysica en chemie. Ze vinden trouwens nog altijd plaats. Hoewel ze minder ingrijpend zijn, blijven het vaste waarden in bepaalde domeinen van de wetenschap en hebben de conferenties de fundamenten gelegd van de moderne natuurkunde.

BRUZZ - 31 March 2021

« L'ERC est une belle réussite européenne »

avec Marc Henneaux

Le Pr Marc Henneaux, physicien théoricien, a remporté le Prix Francqui en 2000 ainsi que le Prix Quinquennal FNRS « Dr A. De Leeuw-Damry-Bourlart » en Sciences Exactes Fondamentales en 2015. Il est professeur au Collège de France depuis 2017 et membre de l'Académie royale de Belgique . Depuis 2011, il a bénéficié de deux ERC Advanced Grant. Pour le chercheur, ce programme de financement européen est incontestablement une réussite, gage de tranquillité et d'indépendance pour la recherche.

Comment résumeriez-vous votre parcours ?

En deux mots, je peux simplement dire que je suis heureux de faire de la recherche. C'est une chance. Les distinctions que j'ai reçues sont liées à mes travaux relatifs à la théorie de la gravitation d'Einstein qui ont un impact sur notre compréhension des trous noirs, d'une part, et sur la construction d'une théorie cohérente de la gravitation quantique d'autre part.

Est-ce que ces subventions de l'ERC ont joué un rôle majeur dans votre carrière de chercheur ?

Oui, pour moi l'ERC est une belle réussite européenne. C'est un financement important qui permet notamment d'engager des collaborateurs. Et c'est aussi une bourse individuelle, qui donne une très grande liberté dans la manière de conduire ses recherches.

Un des défauts de l'évolution du financement de la recherche est que nous sommes amenés de plus en plus souvent à demander de l'argent, parce que les financements sont de plus en plus réduits et morcelés. Cela a pour conséquence que le chercheur passe une fraction significative de son temps à postuler pour des crédits et rédiger des rapports. Ce qui entraîne une charge de travail administratif qui se fait au détriment de la recherche.

L'avantage de l'ERC est donc double : le financement est important et il est de longue durée (cinq ans). C'est extrêmement précieux puisque cela nous libère de ce travail administratif pesant et nous permet de consacrer plus de temps à la recherche.

Êtes-vous malgré tout inquiet face à la tendance annoncée au niveau des budgets européens de réduire le financement de la recherche fondamentale pour l'orienter davantage vers la recherche appliquée ?

Oui. Cela m'inquiète. Des pétitions de chercheurs ont été lancées, et je les ai signées à deux mains.

D'abord, je pense qu'il ne faut pas opposer recherche appliquée et recherche fondamentale car elles se nourrissent l'une l'autre. Je crains ensuite que si l'on diminue la recherche fondamentale, la recherche appliquée se tarisse. Beaucoup d'applications actuelles sont dérivées de résultats obtenus en recherche fondamentale.

Qu'est-ce qui motive, selon vous, ce changement de cap ?

Il y a des problèmes budgétaires évidents, vu la crise sanitaire. Je pense également que nos dirigeants, excepté des personnes comme Philippe Busquin, par exemple, qui a fait beaucoup pour la recherche fondamentale au niveau européen, comprennent mal l'importance de la recherche fondamentale.

Un très beau discours du Roi Albert 1er prononcé à Seraing en 1927, qui marque d'ailleurs les débuts du FNRS, résume l'importance de la recherche fondamentale : « *Le public ne comprend pas assez chez nous que la science pure est la condition indispensable de la science appliquée et que le sort des nations qui négligent la science et les savants est marqué pour la décadence.* »

> **« Je pense qu'il ne faut pas opposer recherche appliquée et recherche fondamentale car elles se nourrissent l'une l'autre. Je crains que si l'on diminue la recherche fondamentale, la recherche appliquée se tarisse.**

Quels sont les défis du financement de la science dans le contexte actuel ?

Le défi est d'abord politique, puisque – nous venons de le dire – nos dirigeants ne comprennent pas toujours l'importance de la recherche fondamentale. Ensuite, la recherche n'est pas assez plébiscitée auprès du grand public. Il faut mieux communiquer afin de convaincre le grand public de l'intérêt de la science.

Laurent Zanella

Marc Henneaux, Membre titulaire de la Classe des Sciences de l'Académie royale des Sciences, des Lettres et des Beaux-Arts de Belgique.

FNRS NEWS February 2021

OVERVIEW OF THE INSTITUTES

THROUGH SELECTED DATA

THE SOLVAY CONFERENCES ON PHYSICS

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

CHAIRS OF THE INTERNATIONAL SCIENTIFIC COMMITTEE FOR PHYSICS

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

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

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

2011 Solvay Centenary Chair

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

PRESIDENTS AND DIRECTORS

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

Presidents

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

Directors

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

THE SOLVAY PUBLIC LECTURES

22 June 2005

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

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

4 December 2005

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

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

20 May 2007

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

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

2 December 2007 | "Chemistry? More than ever!"

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

12 October 2008 | "Images from the Quantum World"

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

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

4 October 2009

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

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

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

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

23 October 2011 | "The Future of Physics"

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

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

21 October 2012

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

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

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

20 October 2013

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

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

12 October 2014

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

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

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

18 October 2015 | One hundred years of Einstein's general relativity

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

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

23 October 2016 | Chemistry for the World of Tomorrow

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

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

22 October 2017 | Frontiers of Science from Physics to Biology

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

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

21 October 2018

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

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

20 October 2019 | Frontiers of Chemistry

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

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

12 September 2021 | Physics, Chemistry and Life Sciences

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

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

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

24 October 2021

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

SOCIAL MEDIA

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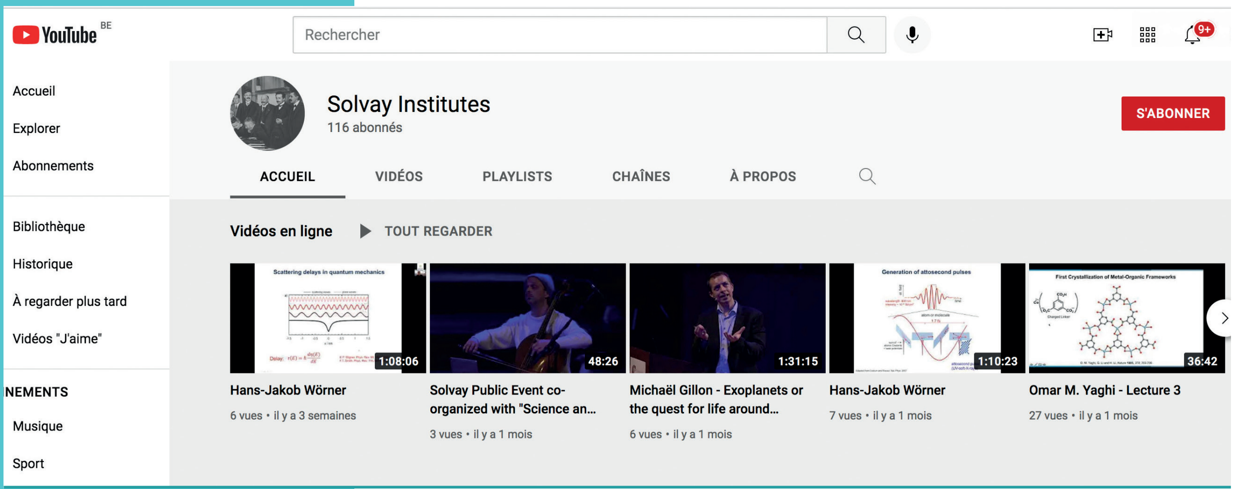

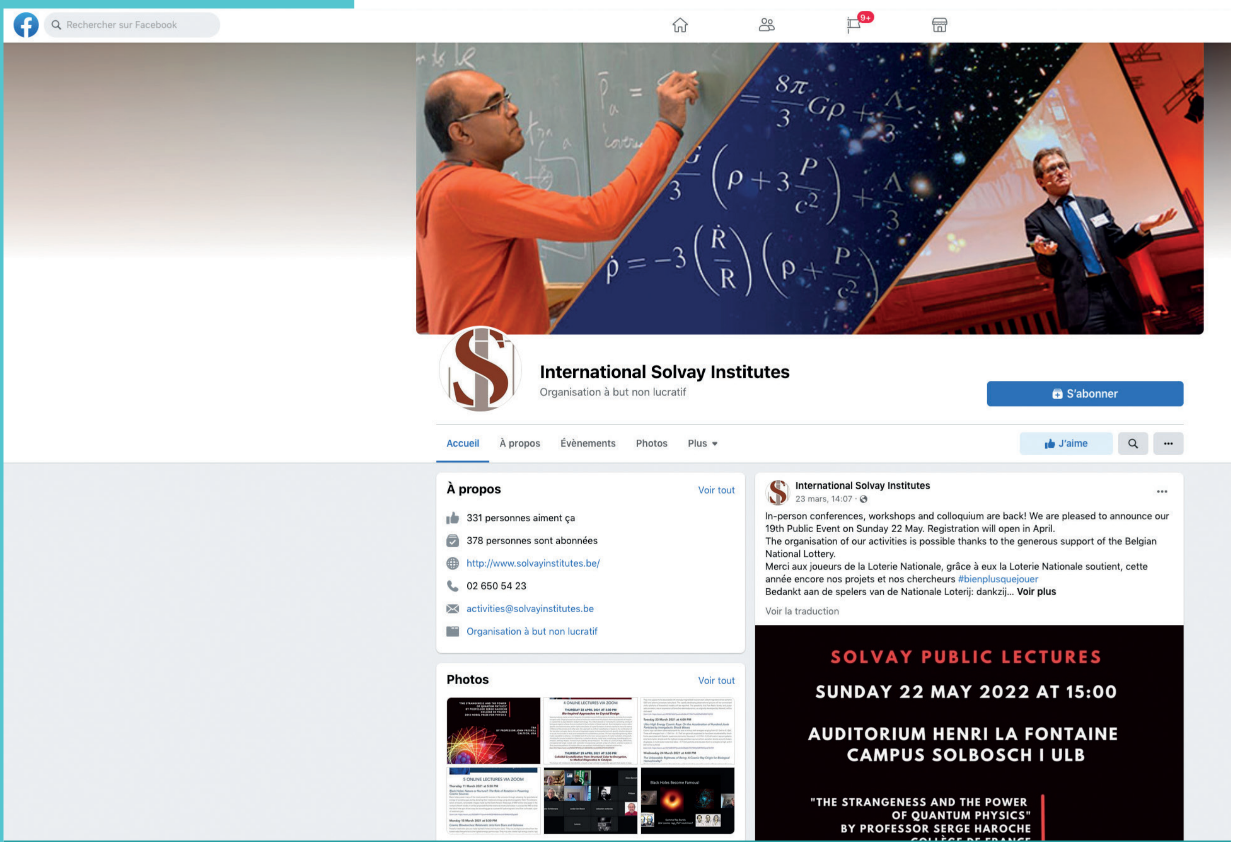

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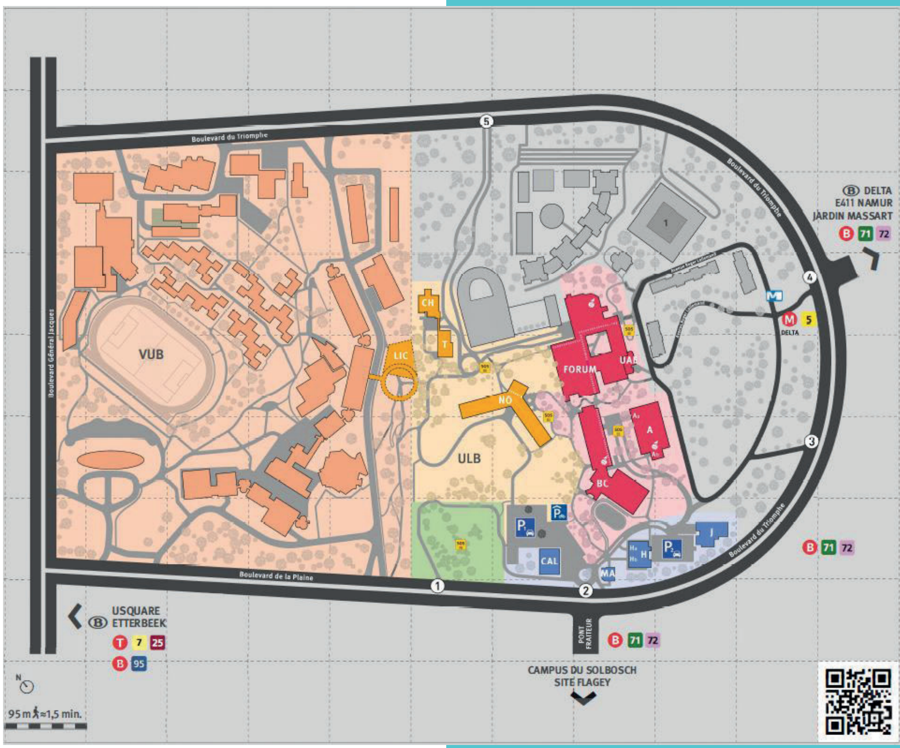

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