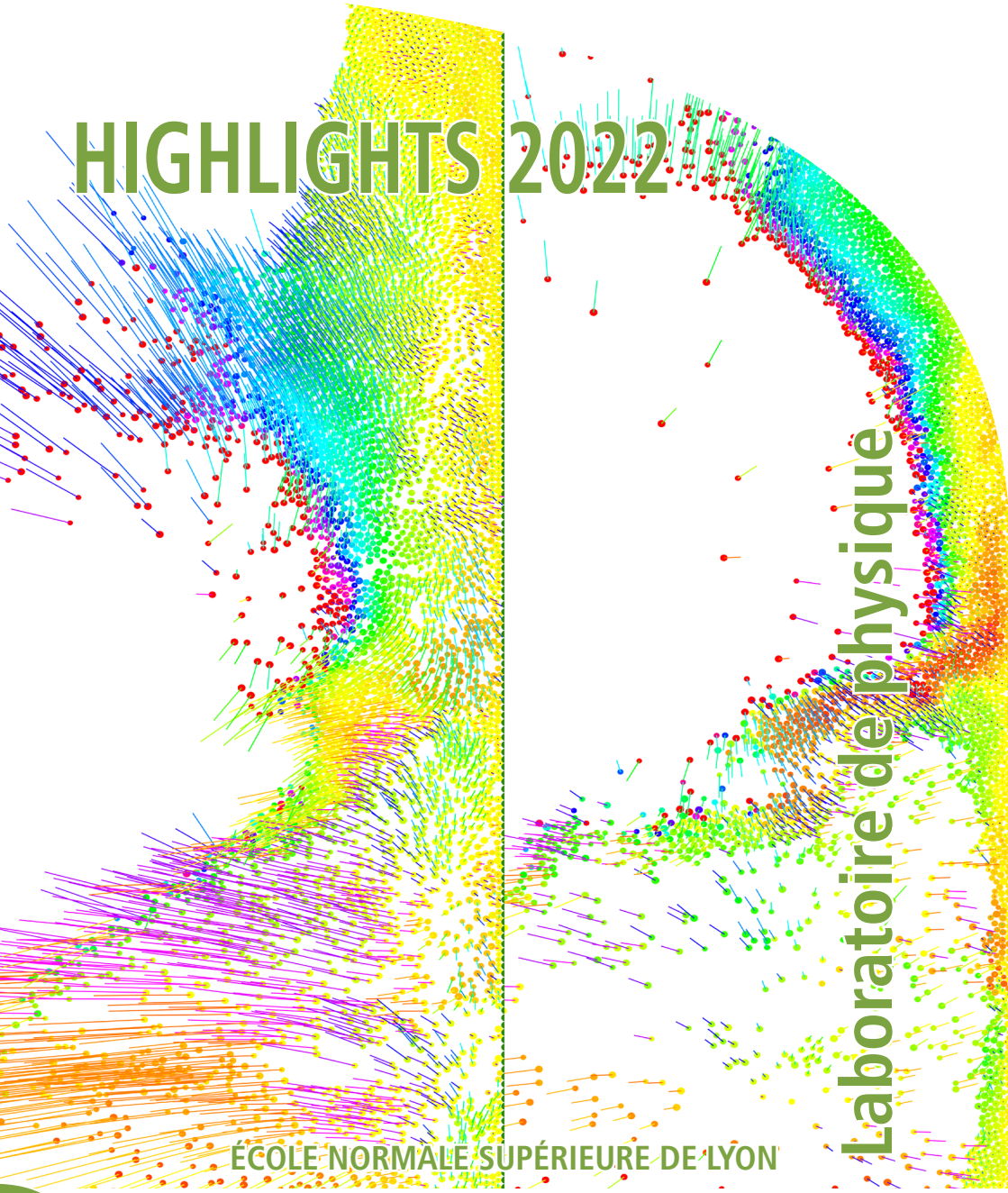
HIGHLIGHTS 2022



Laboratoire de physique

ÉCOLE NORMALE SUPÉRIEURE DE LYON

cnrs

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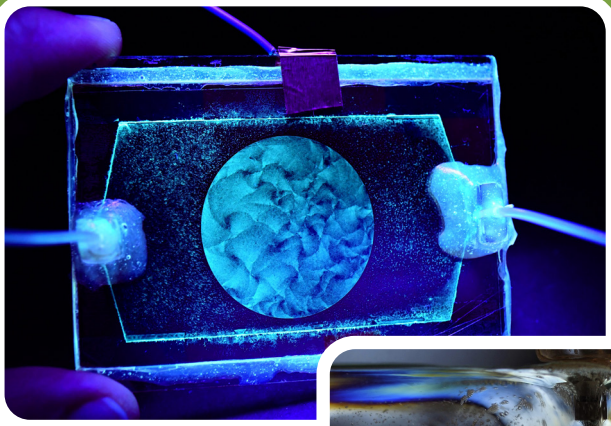
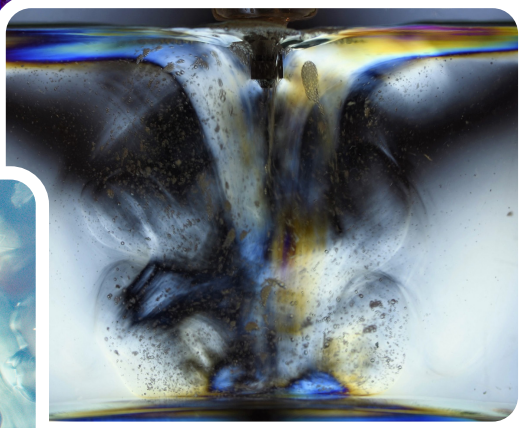
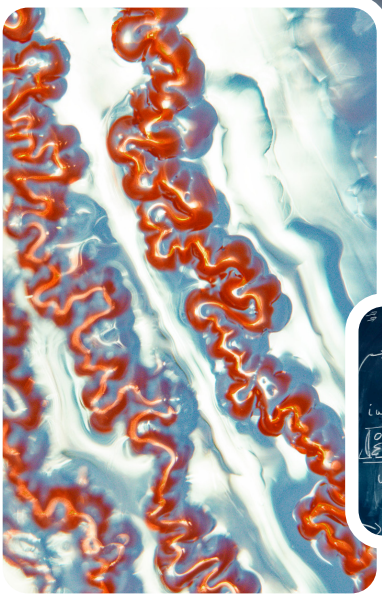
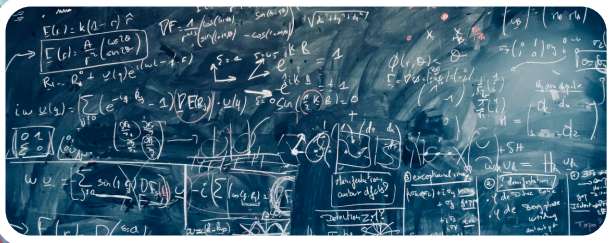
ENS DE LYON









The lab organizes every year a photography contest, in which all the members can submit pictures and vote. The results are announced at the annual lab meeting in December. We present here a patchwork of the recent winners in the categories “experiments” and “theory”.

Top to bottom:

- Amélie Chardac, Collective motion in an assembly of active colloids
- Lise Morlet-Décarnin, Giant micellae as seen between crossed polarizers
- Ariane Gayout, Meanders on a miniature glacier
- Denis Bartolo, Blackboard

Jean-Christophe Géminard
Director of the lab

Foreword

The present booklet gathers a selection of facts, events or research achievements of the Laboratoire de Physique since the "Highlights 2020", published before Thierry Dauxois handed over to me the management of the laboratory in March 2020.

It is impossible to ignore the health situation that has altered our personal lives and that of the laboratory since 2020. We have done our best, under the guidance of our tutelages, to aliviate the consequences for the most vulnerable, especially the postdoctoral fellows and the PhD students. I would like to thank here the colleagues and the tutelages who financed extensions of the grants for those who needed it. We overcame the situation thanks to the involvment of all the members of the laboratory, whom I want to deeply thank as well.

Despite the sanitary situation, the laboratory can boast of nice successes. Several members have been awarded distinctions and prizes. Ariane Gayout, Samuel Boury and Théau Peronnin have been distinguished for their PhD works. Antoine Venaille received the CNRS bronze medal. Patrice Abry was awarded the Michel Monpetit - INRIA prize, and Denis Bartolo the Louis Ancel prize. Henning Samtleben was named Senior Member of the IUF. Patrick Flandrin was elected president of the Académie des Sciences, and Thierry Dauxois was named director of the Institute of Physics of the CNRS. An emotional thought also goes to Krzysztof Gawędzki, who passed away shortly before receiving the 2022 Dannie Heineman prize.

The purpose of this booklet is also to present some examples of recent scientific achievements. You can read about the work of Audrey Bienfait and Denis Bartolo, who have been awarded ERC grants. We also chose to put the spotlight on research directions pertaining to the COVID-19 pandemic, climate science, biophysics, and finally quantum technologies.

Finally, we gather here interesting facts about our laboratory, including its international relationships, key figures, book releases, PhD and HDR defenses and, last but not least, a presentation of the administrative, scientific, and technical staff.

Contents

Lab Presentation

The Laboratoire de Physique (LPENSL) is affiliated to the École normale supérieure de Lyon (ENS de Lyon) and the Centre national de la recherche scientifique (CNRS). Its activities cover various fields, from statistical physics to hydrodynamic turbulence, including mathematical physics and signal processing, as well as soft and condensed matter. The emergence of multidisciplinary approaches is particularly fostered by the association with the teaching activities at ENS de Lyon, within the Master "Sciences de la Matière".

In a broad range of topics, our laboratory tackles both established and emerging problems with the highest quality modeling and experimental techniques. Our diverse expertise enables to achieve exact theoretical results, to use the most advanced numerical methods, and to perform groundbreaking experiments for which we often create innovative instrumentation.

Research topics can be gathered into seven themes: "Hydrodynamics and Geophysics", "Soft Matter", "Physics of Biological Systems", "Mathematical Physics and Fundamental Interactions", "Condensed Matter and Quantum Information", "Infophysics, Signal and Systems", and "Statistical Physics". From the administrative point of view, the laboratory is organized into four research teams: "Matter and Complexity", "Waves, Flows and Fluctuations", "Signals, Systems and Physics" and "Theoretical Physics". Thus, research topics are transverse to the teams, and researchers all contribute to different themes through very dynamic and efficient collaborations.

The scientific outcomes of the laboratory are the culmination of the efforts of 75 permanent researchers or faculty members, who benefit from the expertise of the 16 members of the technical staff working in four invaluable services: "Mechanical Engineering", "Electronical Engineering", "Systems Engineering", and "Administration and Finances''. Last, but not least, a large part of the dynamism of the laboratory must be attributed to the 60 PhD students and 30 postdoctoral fellows, whose enthusiasm, talent, and dedication help drive us forwards into new areas of research.

Samuel Boury

Ariane Gayout

Théau Peronnin

Samuel Boury
Ariane Gayout
Théau Peronnin

PhD excellence

A large proportion of lab members are PhD students, who all contribute invaluably to its high level of scientific output. Over the period 2019 - 2021, three students have been awarded specific young investigator (PhD and postdoctoral fellow) prizes.

Samuel Boury worked on the transport of energy and momentum in the oceans through axisymmetric internal waves. He was also involved in oceanographic measurements performed during a research campaign in the Arctic. He was awarded the Prix de thèse Daniel Guinier by the Société Française de Physique, and also the Prix de thèse Systèmes Complexes from the Institut des Systèmes Complexes. He is now an Assistant Professor at the Courant Institute of Mathematical Sciences (New York University).

Ariane Gayout has studied fluid-structure interactions on a bistable pendulum. Coupled with her long-standing interest for animal flight, this research led her to develop a project on the flight of butterflies in microgravity, funded by the CNES. She received the 2021 Amelia Earhart fellowship for her work on aerodynamics. This international prize is awarded yearly to about 35 women in doctoral studies in the field of aeronautics and space sciences.

Théau Peronnin's PhD work was focused on the study of quantum circuits and quantum technologies. He was awarded the Grand prix i-PhD 2019 for his creation of the startup project "Alice & Bob", whose goal is to build a universal quantum computer using new qubit technologies.

- S. Boury, PhD, 2020, http://www.theses.fr/248611240
- A. Gayout, PhD, 2022, http://www.theses.fr/s236270
- T. Peronnin, PhD, 2020, http://www.theses.fr/248741713

Antoine Venaille

CNRS Bronze Medal

Geophysical fluid dynamics

Antoine in 5 dates

2009 PhD LEGI Grenoble

2011 Postdoc Princeton

2012 CNRS researcher ENS de Lyon

2017 HDR ENS de Lyon

2020 CNRS Bronze Medal

Antoine Venaille works at the interface between theoretical physics and geophysical fluid dynamics. With his colleagues, he uses tools of nonlinear physics and statistical mechanics to understand phenomena that take place in atmospheres and oceans. He is fascinated by the fact that the seemingly complex behavior of winds and ocean currents can sometimes be understood by examining the basic symmetries and physical invariants. Together with Pierre Delplace and Brad Marston, Antoine has discovered an unexpected formal analogy between equatorial waves involved in El Niño and electronic waves in topological insulators. Since then, they have developed a new line of research on the topological origin of geophysical and astrophysical waves. On the applied side, Antoine found with Louis-Philippe Nadeau and Antoine Renaud a route to chaos in simple models of the stratosphere, based on wave-mean flow interactions. This could explain the unanticipated 2016 observation of periodicity disruption in quasi-biennial equatorial wind reversal.

Antoine Venaille is a former physics student from ENS de Lyon. He defended his PhD in 2008 at the Laboratoire des Ecoulements Géophysiques et Industriels (Grenoble), on the statistical mechanics of ocean currents, followed by a two-year postdoc at the Geophysical Fluid Dynamics Laboratory of Princeton University. He was hired as a CNRS researcher in 2012, and awarded the Bronze Medal of CNRS in 2020.

More and references

- P. Delplace *et al.*, Science, 358,1075-1077 (2017)
- A. Renaud *et al.*, Physical Review Letters, 122, 214504 (2019)

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- web: http://perso.ens-lyon.fr/antoine.venaille

Denis Bartolo

ERC Advanced Grant, Fellow of the APS

Active matter

Denis in 5 dates
2012 Prof. ENS de Lyon
2016 de Gennes prize
2019 Louis Ancel Prize (SFP)
2020 ERC advanced grant
2021 Fellow of the APS

We are active matter. Unlike inanimate materials, we can move without resorting to external forces to push, pull, stretch or squeeze our body. This remarkable property is however not unique to living creatures. Over the past decade, physicists, chemists and material scientists set out to turn passive fluids and soft solids into active matter animated by spontaneous flows and deformations. The basic strategy consists in seeding fluids with units that locally convert chemical or electric energy into translational motion. As they interact, these self-propelled units assemble into dazzling coherent structures which steadily drive the host fluid out of equilibrium. To understand the lively structure and flows of active matter, Denis and his group combine experiments, simulations and theory to get at general principles. For exemple they explained the robustness of flocking motion to disorder, and inferred a predictive hydrodynamic description of pedestrian crowd from experimental data. Their work was distinguished by the Louis Ancel prize from the Société Française de Physique.

Until now, however, virtually all realizations of synthetic active matter have been limited to two dimensional model systems. In 2020, Denis was awarded an ERC advanced grant to let active matter explore the third dimension. Denis and his group expect to upgrade the status of synthetic active matter from aesthetic 2D experiments to genuine 3D materials with unanticipated engineering applications.

His involvement in editorial activities resulted in him being appointed editor in chief at Physical Review X.

- A. Chardac *et al.*, PNAS, 9, 118 (2021)
- N. Bain, Science, 363, 46-49 (2019)

- email: denis.bartolo@ens-lyon.fr
- web: http://bartololab.com

Audrey Bienfait

ERC Starting Grant

Detecting and imaging spin signals

Audrey in 5 dates

2016 PhD SPEC CEA-Saclay

2017 Postdoc University of Chicago

2019 Michelson Postdoctoral Prize

2019 CNRS researcher ENS de Lyon

2021 ERC starting grant

Electron spin resonance is a powerful technique to identify paramagnetic species present in a material, and to quantify their interactions with their environment. It usually relies on detecting the absorption or emission of microwaves by the spins when embedded in a resonator. In the last decade, the field of quantum circuits has demonstrated that resonators can have high quality factors, and are able to concentrate the microwave field at the micron-scale by using superconducting films and by working at millikelvins temperature. When combined with quantum-limited amplifiers, another common element of quantum circuitry, these resonators have achieved a drastic sensitivity enhancement when detecting spin signals: 10 spins within 5 femto-liters! These experiments were however realized in very restrictive conditions, namely in low magnetic fields, with implanted species, and with lossless samples.

Audrey's ERC project aims at pushing these proof-of-concept experiments beyond the comfort zone of operation for quantum circuits, and thereby render this quantum-enabled spectrometer compatible with a large scope of samples, spanning applications in chemistry, biology and condensed matter science. This versatility will be achieved by using recently developed superconducting materials and by engineering resilience within the resonator design. A second step in the project is dedicated to bringing spatial resolution to the detection of these nanoscale spin signals using gradient and near-field imaging techniques.

More and references

- A. Bienfait *et al.*, Nature Nanotechnology, 11,253–257 (2015)
- V. Renjan *et al.*, Applied Physics Letters, 116, 184002 (2020)

- email: audrey.bienfait@ens-lyon.fr
- web: http://physinfo.fr

Henning Samtleben

Senior Member of Institut Universitaire de France

String theory and supergravity

Henning in 5 dates

1998 PhD U. Hamburg

2004 Junior Professor U. Hamburg

2006 Prof. ENS de Lyon

2010 Junior Member IUF

2021 Senior Member IUF

Henning's fields of research are supergravity and string theory: fundamental theories to describe nature at its smallest length scales. String theory replaces the concept of point-like elementary particles by extended strings, and proposes a unification of the fundamental interactions, including the gravitational force. Mathematical consistency of the theory predicts the existence of six extra spatial dimensions, curled up or "compactified" at length scales undetectable at the currently achievable energies. Much of Henning's work has been devoted to studying the possible types of such compactifications, drawing on the historical work by Kaluza and Klein which attempts to unify gravity and electromagnetism by introducing a fifth dimension to Einstein's general relativity.

More recently, Henning's work has focused on so-called generalized and exceptional geometry: new mathematical structures that have emerged as powerful tools in the analysis of extra dimensions. They give a new twist to Kaluza and Klein's old ideas. Notably, the extended nature of the fundamental objects gives rise to a "stringy" generalization of Riemannian geometry based on the exceptional duality groups appearing in string theory.

Henning received his PhD in 1998 from the University of Hamburg, and worked as a postdoc at the ENS Paris and Utrecht University. He became junior professor at the University of Hamburg, and then joined the ENS de Lyon in 2006 as a professor of physics. He has held a Chair d'Excellence by the ANR and was appointed junior member of the Institut Universitaire de France in 2010. In 2021 he was appointed senior member of the IUF.

- E. Malek *et al.*, Physical Review Letters, 124, 101601 (2020)
- O. Hohm *et al.*, Physical Review Letters, 111, 231601 (2013)

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Krzysztof Gawędzki

Dannie Heineman Prize

Major contributions to physics

Krzysztof in 5 dates

1971 PhD U. of Warsaw

1982 CNRS researcher

1984 Joins IHES

2001 Joins ENS de Lyon

2022 Dannie Heineman Prize

Born on July 2nd 1947 in Żarki, Poland, Krzysztof Gawędzki obtained his PhD in 1971 from the University of Warsaw. Early in his career his research focused primarily on quantum field theory. With Antti Kupiainen he developed rigorous renormalization group methods for quantum field theory and statistical physics. He also made major contributions to conformal field theory. During the 1990s he became interested in the problem of turbulence and described the abnormal scale behavior of the advection of a passive scalar field. In recent years Krzysztof made outstanding contributions to a wide variety of fields, ranging from experimental physics to mathematics.

From 2001 onwards, Krzysztof strongly contributed to the development and recognition of Theoretical Physics at ENS de Lyon. The breadth of his spectrum of activity, combined with his insatiable curiosity, benevolence and kindness, meant that he played a crucial role in the activities of Lyon's scientific life in Theoretical Physics and its interactions with Mathematics. His notoriety contributed to the recognition of ENS de Lyon at both national and international levels in these fields. Krzysztof's international stature can be illustrated by the numerous invitations to prestigious conferences and institutions that he received. He is the recipient, together with Antti Kupiainen, of the 2022 Dannie Heineman Prize from the American Physical Society for Mathematical Physics.

Krzysztof Gawędzki passed away in Lyon in January 2022, and will be greatly missed by his colleagues.

remembering

More and references

- bibliography: http://inspirehep.net/authors/1008738
- web: http://en.wikipedia.org/wiki/Krzysztof_Gawedzki

Thierry Dauxois

Patrick Flandrin

Thierry Dauxois
Patrick Flandrin

Executive appointments at CNRS and Académie des Sciences

Thierry Dauxois was appointed director of the Institut de Physique (INP) of the CNRS on July 1st 2021. Prior to that, he has served as the director of the Laboratoire de Physique from January 2012 to March 2020, and then held the position of vice-president of research at the ENS de Lyon. His role in this new position at INP is to lead and coordinate all the scientific actions being done in CNRS involving physics. Thierry Dauxois' work in science covers a wide range of subjects such as chaos in dynamical systems, solitons, and internal waves in stratified fluids.

Patrick Flandrin was elected president of the Académie des Sciences for the period 2021 - 2022. He organizes the scientific life and the work of the Academy and ensures its proper functioning. Patrick Flandrin's work involves the use of theoretical methods in order to decipher and process various signals. All this work has led to numerous applications in fields ranging from mechanics to astrophysics, biomedical engineering, computational metrology, and urban mobility.

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- web: http://perso.ens-lyon.fr/patrick.flandrin

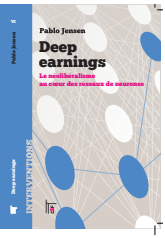
International Collaborations

international

The Laboratoire de Physique has numerous connections abroad, on all continents, and 25% of its academic collaborations happen internationally. This non-exhaustive map was built with the data registered by the researchers on http://www.ens-lyon.fr/cartographie-dai.

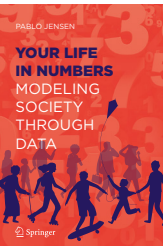
- web: http://www.ens-lyon.fr/cartographie-dai
- web: http://www.ens-lyon.fr/lecole/international

Book releases

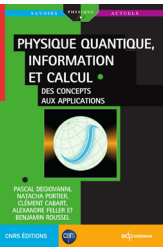


P. Jensen

Artificial intelligence, neural networks, and deep learning are at the forefront of technology. But which vision of society underlies these themes? How are politics, computer science, algorithms and financial markets intertwined? *Deep Earnings* explores these topics in a fascinating investigation.



Driven by the digital revolution, modern scientists are creating complex models of society to shed light on topics such as epidemic outbreaks and economic growth. Our lives are being increasingly captured in numbers. But how do these scientists gather and interpret their data? How accurate are their models? Can we trust the numbers? These are the type of questions addressed in *Your Life in Numbers*.



P. Degiovanni, N. Portier, C. Cabart, A. Feller, B. Roussel

Quantum theory has recently entered a renewal phase, characterized by the developemnt of new quantum technologies exploiting the full power of quantum interferences to measure, simulate, communicate, and compute. The goal of this book is to present this "second quantum revolution", that of quantum technologies, by focusing on the relationship between quantum theory, information theory, and computer science. It also discusses in details the interepretation of quantum theory. It is the first book in French to present a detailed overview of these topics.

Jolidon

The Jolidon team is composed of several former PhD students from the lab, and some of their colleagues. In this book, aimed at students and teachers alike, they present 25 experiments in several fields of physics, focusing for each of them on the theoretical underpinnings and presenting a detailed experimental protocol. The measures obtained in the lab are compared to the theoretical predictions, and the book also contains numerous illustartions and Python codes dealing with numerical aspects.

- http://cfeditions.com/deep-earnings
- http://link.springer.com/book/10.1007/978-3-030-65103-9
- http://laboutique.edpsciences.fr/produit/1109/9782759824137
- http://laboutique.edpsciences.fr/produit/1157/9782759825233

Focus

COVID-19 Pandemic

Diary of a pandemic in the lab

COVID-19 times in the lab

Just like in other workplaces, the first lockdown in Lyon in March 2020 resulted firstly in an abrupt stop of all research projects. Yet, thanks to remote communication technologies, science found new ways to diffuse among researchers of the lab. Partial lifting of the lockdown allowed in particular PhD students and postdocs to go back part-time at the lab benches, contributing effectively to the fitness of research projects. New ways of performing remote teaching were also successfully explored. Among the noticeable things, the mechanics workshop produced 3D printed masks during the hardest times of the pandemic.

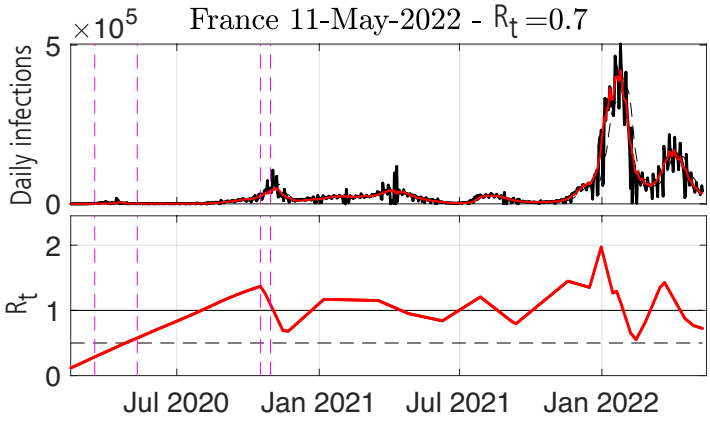
Orienting research projects toward COVID-19

In the stunning context of the early stages of the COVID-19 pandemic and lockdown, an interdisciplinary team of researchers, with first physicists and specialists in information theory from the lab, quickly joined by scientists from other labs at ENS de Lyon (computer scientists, cartographers, sociologists, philosophers...), already used to conduct interdisciplinary research through previous collaborations at the Rhône-Alpes Institute of Complex Systems, decided to investigate the possibility of designing a robust tool for quantifying the spatio-temporal evolution of the intensity of the pandemic, and of making such estimations available for the general public and for citizens.

The team was not specialized in epidemiology at the time of the first lockdown. However, an intense bibliographic research work quickly allowed us to imagine that the use of a model developed by epidemiologists during the previous pandemics, combined with signal and image analysis tools, which were recently developed for the detection of gas bubbles in a filmed recording of liquid flow, would allow to measure the intensity of the pandemic. Monitoring the intensity of a pandemic relies fundamentally on regular observation of the counts of new infections. However, the COVID-19 pandemic data made available by health authorities is very scarce and of limited quality, in all countries of the world. Even after two years of pandemic, the quality of the data remains limited, which is one of the major difficulties in achieving reliable and robust estimates of the evolution of the intensity of the pandemic. Therefore, surveillance in an intra-pandemic context is often carried out using a robust model focused on a single parameter: the pandemic reproduction rate R_t, which measures the number of individuals who will, on average, be infected by one and the same already infected person. The tool we have designed aims at estimating the temporal and spatial R_t in spite of the limited quality of the available COVID-19 data.

Further, and with the objective of a free and direct transfer of information on the state of the pandemic to society and citizens, these estimates, automatically updated daily and representing the evolution over time of the pandemic, are available publicly. They are also available via interactive maps (the country of interest can be chosen) and animated maps (the evolution in time can be activated) allowing to visualize jointly the evolution in time and space of the pandemic in the world and in France.

Estimation of R_t



Legend: COVID-19 in France
Top plot: Raw (black) and corrected (red) counts of daily infections.
Bottom plot: estimated R_t value.

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Collaborators: P. Abry, P. Borgnat, P. Flandrin, N. Garnier, R. Gribonval, É. Guichard, P. Jensen, C.-G. Lucas, N. Pustelnik, S. Roux

References:

- P. Abry *et al.*, PLoS ONE 15(8): e0237901, (2020)
- World interactive map: http://barthes.enssib.fr/coronavirus/cartes/Rmonde
- France interactive map: http://barthes.enssib.fr/coronavirus/cartes/RFrance

Climate Sciences

Theoretical challenges for climate sciences

An interdisciplinary approach

The newly created research group (GDR) "Défis théoriques pour les sciences du climat" gathers a community of theoreticians with common interests in climate sciences. This comprises in particular physicists, climate and atmosphere scientists, oceanographers, mathematicians, computer scientists, machine learning experts, and statisticians.

The aim of this GDR is to improve and develop new theoretical and numerical tools in order to foster major advances in the field of climate sciences. Using approaches merging statistical physics, the modelling of turbulence, mathematics, and machine learning, will enable to obtain a better understanding of the fundamental mechanisms underlying and driving climate change, and also to improve the models. In addition, these combined methods will enhance our ability to better predict extreme climate events, in order to reduce the risks and the uncertainties in predicting the impacts of climate change. This GDR is highly interdisciplinary by design. It involves researchers coming from many of the CNRS institutes, from other French universities and organisations, as well as companies.

Foundation and organisation

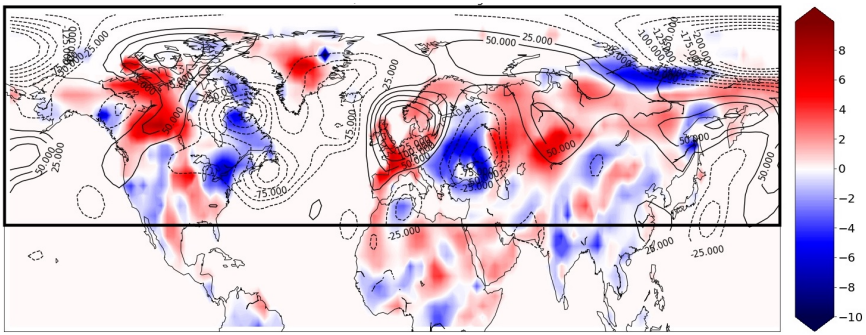
This new GDR was created in January 2022 on the impulse of Freddy Bouchet and of the Institut de Physique (INP) of CNRS. It is also supported, among others, by the INSMI (Institut des Sciences Mathématiques et de leurs Interactions), and the INSU (Institut des Sciences de l'Univers).

The LPENSL has played a major role in the creation of this GDR, in particular through the involvement of Freddy Bouchet (coordination), Corentin Herbert (head office), Antoine Venaille (scientific board), and Fatiha Bouchneb (financial and administrative aid). Many members of the LPENSL are also members of the GDR, and contribute through several of the laboratory's research groups: statistical physics, turbulence, non-linear dynamics, machine leaning and signal processing. Finally, the GDR is also working closely with the GDR on turbulence TurBullet coordinated by Michael Bourgoin, another member of the LPENSL.

Topics covered by the GDR

- Dynamics of the climate
- Dynamics of the oceans and the atmosphere
- Machine learning and climate
- Mathematics and climate: Statistics
- Mathematics and climate: Data and numerical analysis
- Stochastic modeling
- Physics, non-linear dynamics, and climate
- Statistical physics and climate
- Turbulence and geophysical flows
- Relationship between observations, data, and integration into models

Modeling the evolution of global temperature



Legend: Simulated map of the fluctuations of temperature (colors, Kelvin) and of the geopotential hight at 500 hPa (lines, meters) in the Northern hemisphere. (Taken from first reference below.)

Contact: freddy.bouchet@ens-lyon.fr

Collaborators at LPENSL: F. Bouchet, M. Bourgoin, L. Couston, C. Herbert, A. Venaille

References:

• V. Jacques-Dumas *et al.*, Frontiers in Climate, 02 (2022)
• C. Herbert *et al.*, Journal of the Atmospheric Sciences, 77(1), 31-49 (2022)
• F. Ragone *et al.*, PNAS, 115 (1) 24-29 (2017)

Optical Tweezers

Touching living things to understand them better

Manipulate with light

Mechanically manipulating living organisms with the help of light. Such is the possibility offered by the system (C-Trap, Lumicks) that has just been set up at the Laboratoire de Physique of the ENS de Lyon. To achieve this feat, the researchers use the phenomenon of optical trapping. A laser beam focused on a dielectric microbead induces a restoring force which acts like a spring. By moving the trap, it is possible to exert forces of the order of pico-Newtons on the environment of this bead, equivalent to those present within animal cells. We can also collect the light diffracted by the bead to trace the force felt by the trap. To adapt this phenomenon to the study of living organisms, the trap was coupled to a confocal microscope which allows the study area to be observed and the spatial reorganization of the biological system to be measured under force. It also includes a microfluidic control that allows to bring to the optical clamp the proteins or nucleic acids on which mechanical constraints are to be exerted.

A robust and adaptable system

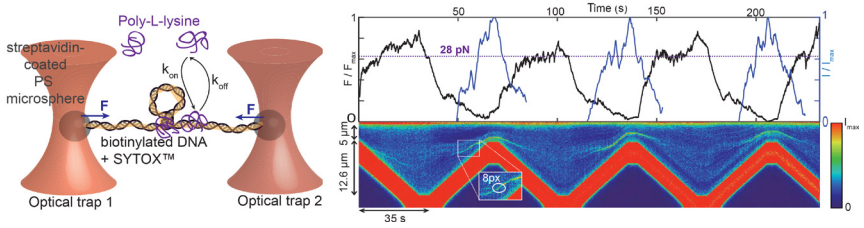
The strengths of this system are numerous. First of all, it is a system coupling ultra-stable optical tweezers with a microfluidic system (5 coflows) and a confocal. It is extremely robust and also adapted to many biological systems, from single molecules to tissues. It is very easy to use and can be scripted to automate experiments. Its temporal and force resolution is unequalled today, and it is the only system of this type in France.

A collaboration on the scale of ENS de Lyon

The purchase of this equipment, financed by the ENS de Lyon, is complementary to the optical tweezer systems already present in the department, which are adapted to the study of soft matter. This new system will allow the realization of 8 well-defined scientific projects from 3 departments (LPENSL: Montel, Lecuyer, and Moskalenko - LBMC: Rety, Vanoosthuyse, and Yvert - RDP: Bendahmane and Hammant). These projects range from the manipulation of individual molecules (DNA-protein or DNA-RNA interaction) to the manipulation of plant or animal cells or tissues. The long-term objective is to create scientific synergies between physicists and biologists using the same equipment.

One of the projects in which the Laboratoire de Physique is involved concerns directional transport in nanopores. This equipment has already made it possible to measure the forces involved in directional transport in artificial nanopores. The objective is to use it later to measure these forces in a system mimicking the nuclear pore. Moreover, a partnership has been set up between the company that markets this instrument and the ENS de Lyon. The C-Trap will be available for 8 weeks a year so that the company can demonstrate it to other French laboratories.

A versatile tool in biophysics



Legend: DNA molecules are tethered by their ends to microbeads. Using two laser beams focused on the beads, one can trap and exert extension forces on the DNA molecule. In presence of a polycation (polylysine) we observed the formation of a DNA loop that can be resolved by an extension of the DNA molecule. In our setup the fluorescence signal is recorded at the same time as the force signal, which enables to correlate mechanical and localisation signals.

Contact: fabien.montel@ens-lyon.fr

Collaborators: F. Montel, C. Moskalenko, S. Lecuyer

References:

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- B. Molcrette *et al.*, PNAS, 119 (30) e2202527119 (2022)
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Quantum Technologies

Computing, sensing, and simulation enhanced by quantum physics

Which applications for quantum physics?

Despite being more than a century old, quantum physics is still intriguing. Fascinating questions remain open such as: Is there a maximum size, weight or complexity for quantum superposition or entanglement? How do thermodynamical laws apply to quantum information? Such questions start to be addressed thanks to the level of control that experiments have recently reached on many systems: photons, ions, nuclear spins, neutral atoms, spin defects, superconducting circuits, electrons... These developments have motivated a new wave of applications of quantum physics. Some have already come into play, such as random number generation or quantum enhanced magnetometry. Yet, many applications are still under development, such as quantum enhanced simulation and computing. Activities in the laboratory focus on both fundamental quantum physics and quantum technologies. Research towards the latter is supported by strong national (France 2030, ANR) and European (Quantum Flagship, Quantera, ERC) fundings.

Quantum computing

By exploiting the massive parallelism enabled by the superposition principle, quantum computing promises to tackle problems which are currently out-of-reach for classical computers. Yet for any useful application to be possible, quantum bits must be able to retain their information long enough for an algorithm to run. Using superconducting circuits, we encode quantum bits into so-called cat states and develop quantum error correction protocols on them. In this direction, we partner with the Alice & Bob startup, whose CEO and co-founder is a former PhD student of the lab. We also develop new superconducting circuits that offer some level of protection against errors. Finally, using semiconductors, we explore the potential of coherent single electron excitations for a flying qubit architecture.

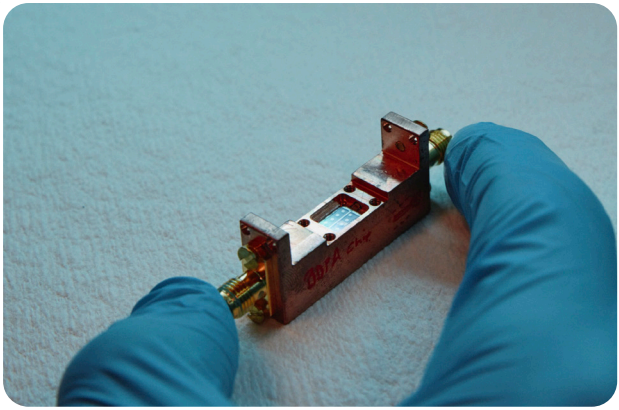
Quantum simulation

Controlled quantum systems, such as cold atoms, offer an interesting platform to experimentally simulate quantum many-body systems. Our theoretical work focuses on quantum simulators of strongly interacting quantum systems based on ultracold atoms, and in particular on the dynamics of many-body quantum entanglement.

Quantum sensing

The lab has several activities on quantum sensing. Using a superconducting circuit, we realized the number-resolved photo-counters for microwaves, and demonstrated a quantum speedup in microwave radar for the first time. We are also building tools to perform electron spin resonance on microscale samples using superconducting circuits. We are also working on entanglement-assisted sensing in quantum many-body systems. Based on recent progress in the generation and characterization of single electron excitations in quantum Hall edge channels, we also work on using single electron excitations to feed an interferometric device for measuring quantum electromagnetic fields with a ps to ns time resolution, thereby realizing the quantum electronic version of a radar which probes matter using electromagnetic waves.

Quantum theory and applications



Legend: Superconducting device which is able to perform electron spin resonance on microscale samples.

Contacts: benjamin.huard@ens-lyon.fr

Collaborators: A. Bienfait, P. Degiovanni, B. Huard, F. Mezzacapo, T. Roscilde, startup "Alice & Bob"

References:

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Lab PHYS
ENS de LYON

Research teams
- Matter and complexity
- Waves, flows, and fluctuations
- Signals, systems, and physics
- Theoretical physics

Interdisciplinary topics
- Condensed matter and quantum information
- Hydrodynamics and geophysics
- Soft matter
- Physics of biological systems
- Mathematical physics
- Statistical physics
- Data science and signal processing

Equipment

Research at the Laboratoire de Physique relies on the highest quality and up-to-date tools and technologies, whose use is made possible with the help of the associated technical staff. This includes a team of project, mecanical, and electrical engineering experts. A non-exhaustive list of the equipements available at the laboratory includes:

- Atomic force microscope, electron microscope
- Rotating table for fluid mechanics, wind tunnel
- High frequency and high resolution optical and infrared imaging
- High frequency ultra-sound imaging
- White room, anechoic Faraday cage
- 20mK cryostat
- Rheometers
- Optical tweezers
- Micro milling machines, 3D printing

Key figures

The Laboratoire de Physique hosts around 180 members, with 75 permanent researchers, around 90 postdoctoral fellows and PhD students, and 16 administrative and technical staff members. Over the past five years, this team has produced high quality work illustrated by the following key figures:

- 25 prizes and distinctions, including 2 CNRS medals, 4 IUF nominations, and 1 membership of the Academy of Science
- 825 publications
- 76 public funding contracts, including 5 ERC grants, 5 Horizon 2020 grants, and 61 ANR grants
- 34 private funding contracts
- 10 equipment and software patents

- web: http://www.ens-lyon.fr/PHYSIQUE

Staff

The administrative, scientific and technical staff provides a unique environment to achieve the best of our research.

staff

PhD

- A. Barbe - *Diffusion Wasserstein distances for attributed graphs.* (P. Borgnat)
- S. Boury - *Energy and buoyancy transport by inertia-gravity waves in non-linear stratifications.* (D. Carpentier / P. Delplace)
- E. Brillaux - *Relativistic phases in condensed matter.* (D. Carpentier)
- F. Bunel - *Effet Leslie chimique dans les monocouches de Langmuir et les films libres de smectique C chiraux.* (P. Oswald)
- F. Cabrera - *Setting of particles in quiescent and turbulent flows. From ground conditions to micro-gravity.* (M. Bourgoin / N. Plihon)
- Y. Carrasco-Salas - *Physical properties of R-Loops and viral capsids: a single molecule approach based on AFM high resolution imaging and nanoindentation.* (C. Mosalenko)
- A. Chardac - *Matière active polaire: ordre, désordre et défauts topologiques.* (D. Bartolo)
- N. Dages - *Matériaux rhéo-acoustiques.* (S. Manneville)
- L. Deunneulin - *Avancée en traitement du signal pour la caractérisation des environnements circumstellaires par imagerie directe avec l'instrument ESO/VLT-SPHERE.* (N. Pustelnik)
- D. Dumont - *Etudes des échanges énergétiques en convection thermique turbulente.* (F. Chilla)
- C. Eloy - *Supergravité : vides AdS3 et corrections en dérivées d'ordre supérieur.* (H. Samtleben)
- A. Essig - *Photon counting with a multiplexed dispersive readout.* (B. Huard)
- L. Favreau - *Ecoulements forcés par gravité de fluides simples et fluides complexes.* (E. Freyssingeas)
- A. Fontana - *Thermal fluctuations of stationary out-of-equilibrium system.* (L. Bellon)
- T. Jules - *Géométrie et mécanique des origamis.* (M. Adda-Bedia)
- Y. Kaloga - *Apprentissage de représentations de graphes attribués.* (P. Borgnat)
- M. Le Blay - *Effets collectifs dans la dynamique d'émulsions confinées : transition de dépiégeage et fonte hydrodynamique.* (D. Bartolo)
- L. Lemahieu - *De la physique à la pratique physique : la promotion du sport chez les personnes en situation de handicap.* (J.-C. Géminard)
- D. Lucente - *Predicting probabilities of climate extremes from observations and dynamics.* (F. Bouchet)
- C. Madec - *Dynamique de bulles isolées et interactions de bulles multiples dans des suspensions granulaires confinées entre deux plaques.* (S. Joubaud)
- L. Menou - *Elasticité de capsides virales et défauts topologiques.* (M. Castelnovo)

defenses

PhD

- R. Menu - *Gaussian state approaches to quantum spin systems away from equilibrium.* (T. Roscilde)
- B. Molcrette - *Transport directionnel dans un nanopore.* (F. Montel)
- B. Pascal - *Estimation régularisée d'attributs fractals par minimisation convexe pour la segmentation de textures.* (P. Abry)
- H. Piot Durand Lecomte - *Pelage de rubans adhésifs sur substrats mous micro-texturés.* (S. Santucci)
- J. Sautel - *Ségrégation granulaire dans les astéroides lâchement agglomérés.* (N. Taberlet)
- M. Z. Sheikh - *Sedimentation and collision of anisotropic particles in turbulence.* (A. Pumir)
- J. Stevens - *Effect of the environment on fluxonium qubits and thermodynamics of quantum measurements.* (B. Huard)
- L. Thorens - *Unstable drainage of frictional fluids and magnetic control of the mechanical behavior of confined granular media.* (S. Santucci)
- L. Vignoli - *Quantum separation of variables in higher rank and supersymmetric integrable models.* (G. Niccoli)
- S. Vincent - *Modification par injection de courant d'ondes azimuthales dans une colonne de plasma magnétisée.* (N. Plihon / V. Dolique)

Habilitations à diriger des recherches (HDR)

- P. Delplace - *Topological properties of waves.*
- T. Divoux - *On the yielding dynamics of amorphous soft solids.*
- A. Naert - *Physique statistique hors équilibre : expériences dans des systèmes macroscopiques.*
- N. Pustelnik - *Variational approaches for solving inverse problems and machine learning.*
- L. Savary - *Transport and correlations in quantum materials.*

HIGHLIGHTS 2022

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