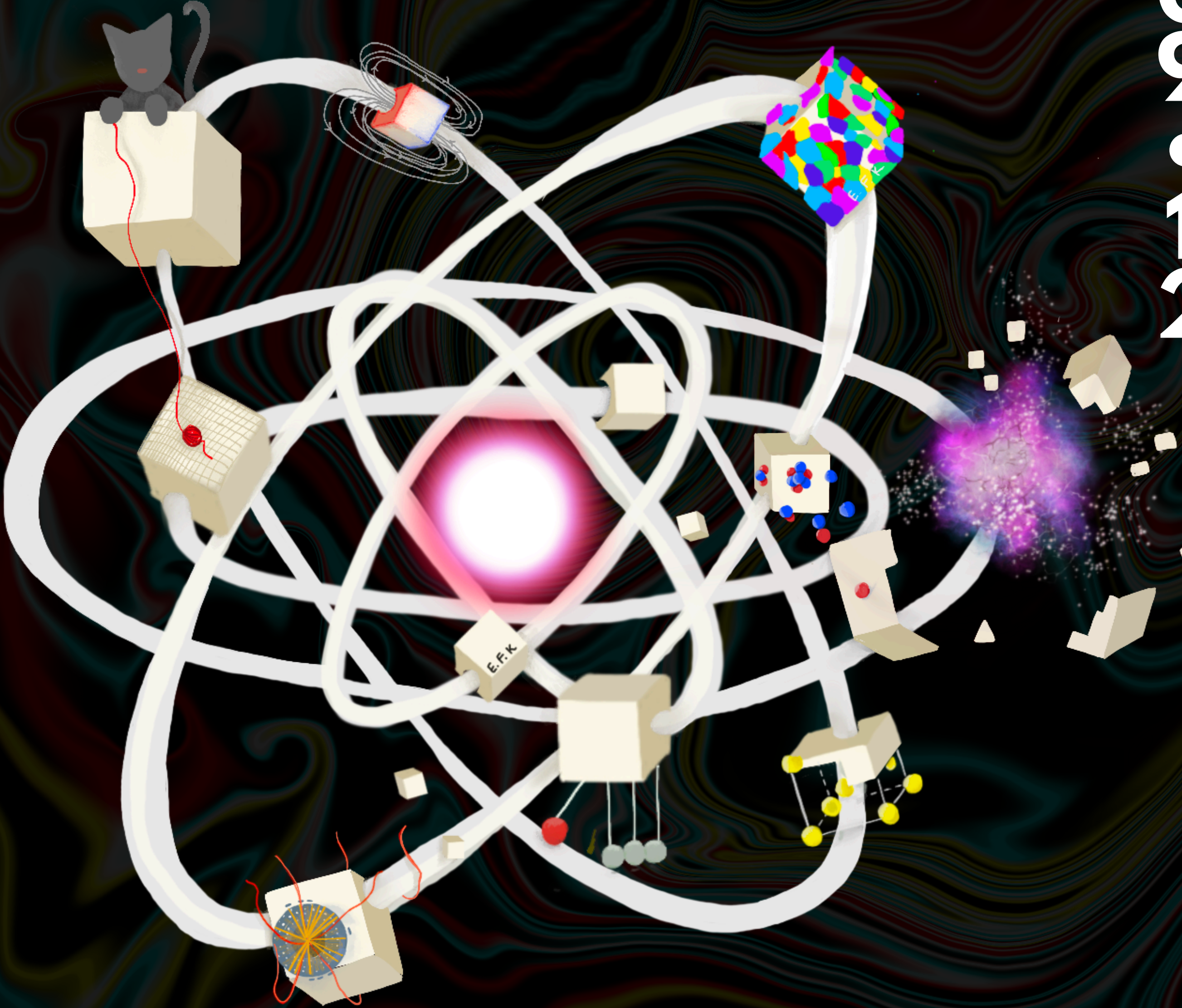
RENCONTRE DES JEUNES PHYSICIEN.E.S – ÉDITION 2024

Société Française de Physique

RJP

09.12
2024

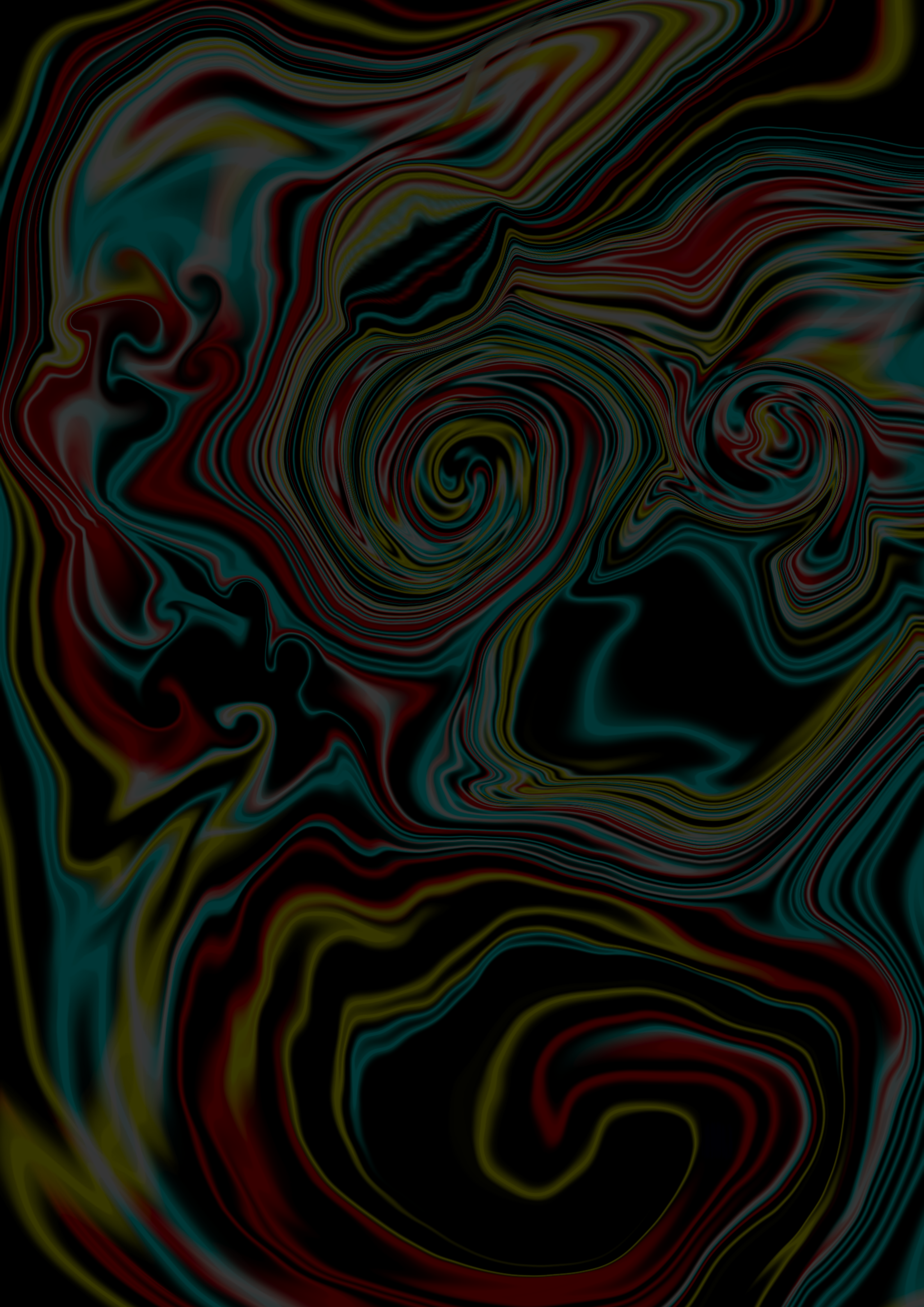


Book of Abstracts

Monday December 9th, 2024

9h-17h30, Auditorium CICSU, Campus Jussieu

4 place Jussieu, 75005 Paris



Société Française de Physique
RÉSEAU JEUNES

DETAILED PROGRAM

This detailed program is subject to limited modifications to accommodate speakers and attendees.

The up-to-date version is accessible on our website at the address:
https://rjp-paris.jeunes.sfpnet.fr/program/

RJP – Paris 09.12.2024

8.30 am	Welcome and breakfast		
9 am	Introduction		
Session 1			
9.15 am	**Symbolic regression in photonics**	– *Julian SIERRA VELEZ* (L2n)	
9.30 am	**A nitrogen emission puzzle in star formation**	– *Guillaume VIGOUREUX* (LPENS)	
9.45 am	**Synthesizing gold-based perovskites**	– *Ange CHAMBISSIE* (IPVF)	
10.00 am	**Quantum sensing with diamond**	– *Grégoire LE CARUYER* (LuMIn)	
10.15 am	Coffee break & posters	with 10.25am-10.55am – a social game around physics	
Session 2			
11.15 am	**On the structure of amorphous sulfide electrolytes**	– *Louis-Martin POITRAS* (LPTMC)	
11.30 am	**High-energy emission of gamma-ray bursts**	– *Mouad GNAOUI* (IAP)	
11.45 am	**Microtubule-based active nematic droplets**	– *Romain LEROUX* (LJP)	
12.00 pm	**Quantum frustrated spin lattices**	– *Thibault NOBLET* (LPTMC)	
12.15 pm	Speed-poster presentations on stage		
12.30 pm	Lunch & posters	and a poster bingo	
Session 3			
2.15 pm	**Making a surface bubble evaporate fast**	– *Xue MA* (MSC)	
2.30 pm	**Quantum linear time invariant systems**	– *Jacques DING* (APC)	
2.45 pm	**Laser-plasma interactions in fusion**	– *Kévin VILAYPHONE* (CEA)	
3.00 pm	**Ants and quantum trails**	– *Magali KOROLEV* (CPhT)	
3.15 pm	**Characterizing a gas phase and microdroplets**	– *Ayoub BADRI* (LPL)	
3.30 pm	Coffee break & posters		
Session 4			
4 pm	**Greenhouse gases in real time**	– *Cannelle CLAVIER* (LATMOS)	
4.15 pm	**The fast dynamics of a phase transition**	– *Ilaria DELBONO* (SU)	
4.30 pm	**Faraday effect and drift currents in optics**	– *Romeo ZAPATA* (INSP)	
4.45 pm	**Unblurring images using entanglement**	– *Yanis TROUYET* (INSP)	
5 pm	SFP PhD thesis prizes ceremony & talks (2)		
5.45 pm	Conclusion of the day	& reflections on moving forward a young researchers' community	
5.50 pm	Cocktail		
7 pm	Evening continues at a local bar		

MORE INFORMATION

Monday December 9th, 2024

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Detailed Program

	Time	Presentation	Speaker	Affiliation (lab, ED)	Field
Session 1	9.15am	**Symbolic regression: an alternative method to model the optical response of photonic biological and bio-inspired structures**	Julian SIERRA VELEZ	L2n, Université de Technologie de Troyes	Photonics
	9.30am	**The nitrogen tracer emission puzzle in star formation**	Guillaume VIGOUREUX	LPENS, ENS-PSL, ED127 Astro	Astrophysics
	9.45am	**From lead to Gold: Investigating the Synthesis and Characterization of Gold-Based Double Perovskites for Optoelectronic Applications**	Ange CHAMBISSIE	IPVF, Ecole polytechnique, ED IP Paris	Materials science
	10.00am	**Quantum sensing at extreme conditions using defects in diamond**	Grégoire LE CARUYER	LuMIn, Université Paris-Saclay, ED Ondes et Matière	Condensed matter
Session 2	11.15am	**Advances in Amorphous Sulfide Electrolytes: Structural Insights and Ionic Conductivity Perspectives**	Louis-Martin POITRAS	LPTMC, Sorbonne Université, EDPIF	Physico-chemistry
	11.30am	**The high energy emission from Gamma-Ray Bursts**	Mouad GNAOUI	Institut d'Astrophysique de Paris, ED127 Astro	Astrophysics
	11.45am	**Microtubule-based active nematic droplets: from patterns to motion**	Romain LEROUX	Laboratoire Jean Perrin, SU, EDPIF	Biophysics
	12.00pm	**Perturbative theory on quantum frustrated spin lattices**	Thibault NOBLET	LPTMC, Sorbonne Université, EDPIF	Statistical physics
Session 3	2.15pm	**Surface Bubble with a Vapor Fountain Accelerates Evaporation**	Xue MA	MSC, Université Paris-Cité, EDPIF	Soft matter
	2.30pm	**Quantum Linear Time Invariant Systems : from Group Theory to Quantum-enhanced Gravitational Wave Detectors**	Jacques DING	APC, Université Paris-Cité, ED Step'Up 560	Quantum physics
	2.45pm	**From the Sun to the Earth: experimental study of laser-plasma interactions in laser inertial confinement fusion**	Kévin VILAYPHONE	CEA, ED Ondes et Matière	Plasma physics
	3.00pm	**Quantum Trails: Ants and the Physics of One-Dimensional Matter**	Magali KOROLEV	Centre de Physique Théorique (CPhT), Ecole polytechnique, ED IP Paris	Quantum physics
	3.15pm	**Laser desorption on water microdroplets for gas phase characterization**	Ayoub BADRI	Laboratoire de Physique des Lasers, Ecole Doctorale Galilée USPN	Laser physics
Session 4	4.00pm	**A new disruptive approach of observing greenhouse gases in near-real time**	Cannelle CLAVIER	LATMOS, ED127 Astro	Climate physics
	4.15pm	**Ultrafast dynamics of the phase transition in vanadium dioxide**	Ilaria DELBONO	ED 397 - Physique et Chimie des Matériaux	Materials science
	4.30pm	**All-Optical Generation of Drift Currents Trough Inverse Faraday Effect**	Romeo ZAPATA	Institut des nanosciences de Paris, SU, EDPIF	Electro-optics
	4.45pm	**Unblurring microscope images using entanglement**	Yanis TROUYET	Institut des nanosciences de Paris, SU, EDPIF	Quantum optics

Contents

Abstracts for oral presentations

Session 1

- Author: **Julian Sierra Velez**
  Title: "Symbolic regression: an alternative method to model the optical response of photonic biological and bio-inspired structures."
  Doctoral school: *Université de technologie de Troyes*
  Affiliation: *L2n, UTT*

  The optical properties of photonic biological structures often inspire advanced material designs but present big challenges for analytical modeling due to their complex geometries. In our work, we explore symbolic regression (SR), an artificial intelligence (AI) technique, as an alternative to traditional machine learning methods. Unlike neural networks, which operate as "black boxes," SR generates physically plausible, dimensionally homogeneous closed-form expressions that explicitly relate structural and illumination parameters to observed optical phenomena. Moreover, SR serves as a computationally efficient meta-model, reducing the need for resource-intensive simulations.

  We show the potential of our approach using two case studies: the colorful plumage of the "Tersina viridis" bird and the whiteness of a bio-inspired porous polymer film based on the "Cyphochilus insulanus" beetle's scales. Using experimentally or numerically obtained reflectance spectra as inputs, SR effectively retrieves functions that match observed spectral features with high accuracy. For example, SR successfully predicts the angular dependence of the bird's coloration and the relationship between the polymer film's structural parameters and its reflectance.

  This study highlights SR's ability to produce consistent and accurate models, positioning it as a promising tool for both theoretical understanding and practical applications in optics, materials science, and biomimetics.

  (This work has been accepted for publication. The DOI 10.1364/OL.541279

has been registered for this article. It will be pusblished on Vol. 49, No. 23 / 1 December 2024 / Optics Letters)

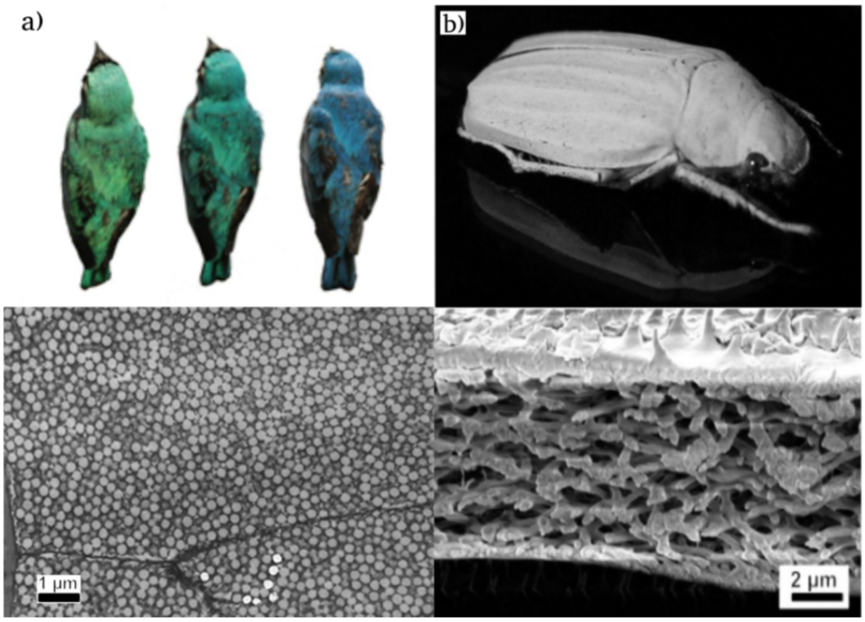

Figure 1: Two examples of photonic biological structures found in nature and the structural morphology responsible for their coloration. (a) Male Tersina viridis bird, with a TEM image of a transversal cut section of a barb from a back feather. (b) White beetle Cyphochilus insulanus, with a sectional view of an SEM image of the white scales that cover its body.

- Author: **Guillaume Vigoureux**
  Title: "The nitrogen tracer emission puzzle in star formation"
  Doctoral school: *ED127 : Astronomie Et Astrophysique D'Ile De France*
  Affiliation: *LPENS, ENS-PSL*

  Context: Stars are formed in the cold neutral regions of a galaxy. Therefore, understanding star formation not only requires assessing the mass and volume budgets of neutral and ionised phases in galaxies but also characterizing the mechanisms responsible for the ionisation and heating of interstellar matter. It is usually admitted that ionised regions are mostly produced by the ionising radiation emitted by massive stars. However, recent observations led by P.Goldsmith reveal that the emission of N+, a tracer of fully ionised regions, originates from specific environments that challenge the range of physical conditions typically expected in ionised phases surrounding massive stars.

  Aims: My goal is to see to what extent the explosions at the end of the massive stars' life (known as "supernovae") could reproduce the measured quantity of N+ in the Milky Way.

  Methods: To do so, I have first modeled the galactic distribution of supernova. Then I used the Paris-Durham shock code to model the N+ formation during the propagation of high velocity (30 to 400km/s) shocks in diffuse medium (0.01 to 100 particles/cm3).

  Results: Combining these two modelisations, I was able to estimate the N+ abundance in the Milky Way. My modelisation is at the moment able to reproduce between 10% and 50% of the observed N+ emission.

  Conclusions: This work, which is still ongoing, shows that the ionisation of interstellar matter in our Galaxy probably result from a mix of the ionising radiation emitted by massive stars and collisional ionisation induced by the release of mechanical energy at the end of their lives.

From lead to Gold: Investigating the Synthesis and Characterization of Gold-Based Double Perovskites for Optoelectronic Applications.

Ange Bernardin CHAMBISSIE KAMENI[1], Alexandre Py[1], Jean-François GUILLEMOLES[1], Géraud DELPORT[1].

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Abstract: The development of innovative materials is essential to support the energy transition and meet the demands of sustainable energy technologies. Lead-based halide perovskites ($APbX_3$, *A = Cs, MA, FA; X = Cl, Br, I*) have emerged as a leading contender for photovoltaic technologies, thanks to their excellent charge-carrier mobility, low defect density and can be easily synthesized using conventional synthesis techniques. However, their toxicity and environmental instability limit their scalability. In this study, we explore **Gold-based Double Perovskites**, $\mathbf{Cs_2Au_2X_6}$ (*X = Cl, Br, I*), as a non-toxic and potentially more stable alternative, where lead is replaced by Au^{1+} and Au^{3+}. These materials feature tunable energy gaps in the near-infrared range (1–1.6 eV), aligning with requirements for photovoltaic and X-ray detector applications. Our research focuses on an innovative synthesis method tailored to create high-quality thin films. Optical characterization, including photoluminescence and absorption spectroscopy, reveals strong electron-phonon coupling in these materials, which directly affects their charge transport and energy dissipation properties. Structural and chemical analyses, performed through X-ray diffraction, Raman spectroscopy, SEM, and EDX, provide further insights into their fundamental characteristics. This study fundamentally investigates whether substituting lead with gold enables the necessary optoelectronic properties for photovoltaic applications. By identifying either the performance-enhancing traits or the physical limitations of these materials, it offers critical insights into their potential for sustainable energy applications.

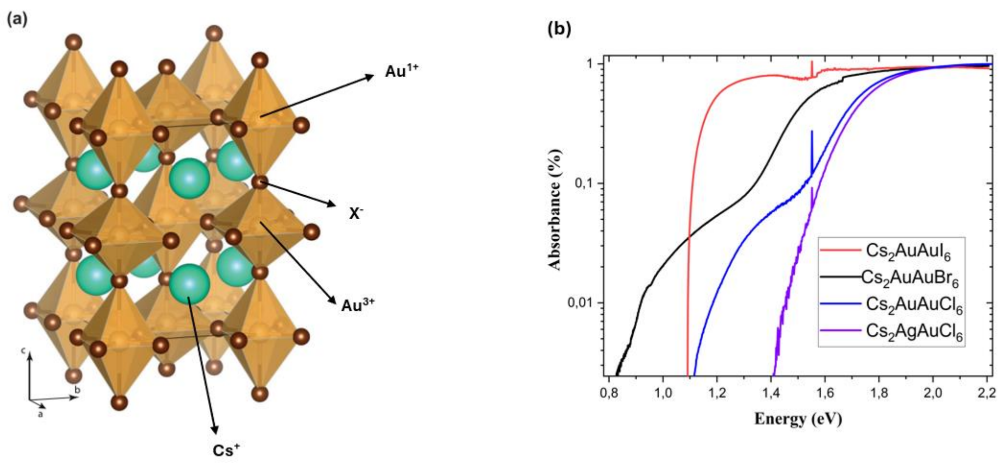

Figure: a) Cristal Structure of the Gold-based double perovskite b) Absorption spectra of the Gold Perovskite family showing the variation of the gap with the halogens.

Quantum sensing at extreme conditions using defects in diamond

Grégoire Le Caruyer[1], Cassandra Dailledouze[1], Claire Roussy[1], Loïc Toraille[2,3], Antoine Hilberer[2,3], Florent Occelli[2,3], Valentin Schmidt[2,3], Martin Schmidt[1], Kin On Ho[1], Marie-Pierre Adam[1], Paul Loubeyre[2,3], Jean-François Roch[1]

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Abstract

Understanding the fundamental properties of matter under extreme conditions is essential in various fields of physics, from planetary science to quantum behavior of electrons in high-density solids. Among these topics, hydrogen and its compounds have raised particular theoretical interest. In 1935, Wigner and Huntington predicted the existence of metallic hydrogen—a phase [1] that would exhibit superconductivity at room temperature. It took nearly a century to confirm part of this prediction experimentally. In 2020, a team led by Paul Loubeyre at CEA observed the transition from insulating molecular hydrogen to metallic hydrogen at a pressure of approximately 425 GPa (4.25 Mbar) using a diamond anvil cell (DAC) at 80 K at Synchrotron SOLEIL [2]. Achieving such extreme pressures poses significant challenges, and probing the fundamental properties of matter under these conditions requires innovative techniques. Our team has developed methods leveraging defects in diamond to explore these extreme environments [3]. Specifically, we have utilized nitrogen-vacancy (NV) centers to probe the superconducting transition of a mercury dopped cuprates [*in preparation*] and are now focusing on group-4 vacancies (G4V) in diamond [4]. In this talk, I will discuss the ongoing development of a novel platform designed to investigate the optical properties and sensing capabilities of G4V centers under extreme conditions, including high pressures using DAC, temperatures of a few kelvins in a helium cryostat, and high magnetic fields.

References

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Session 2

- Author: **Louis-Martin Poitras**
  Title: "Advances in Amorphous Sulfide Electrolytes: Structural Insights and Ionic Conductivity Perspectives"
  Doctoral school: *EDPIF*
  Affiliation: *LPTMC*

  Fast-ion batteries have revolutionized energy storage systems for applications ranging from mobile devices to electric vehicles. However, dependence on flammable liquid electrolytes and limited lithium resources underscore the urgent need for safer, more sustainable alternatives. Amorphous or glassy sulfide electrolytes have emerged as promising candidates due to their high ionic conductivity and structural tunability. In contrast to their crystalline counterparts, these materials offer the possibility of combining an almost infinite combination of components, thus optimizing key properties such as ionic conduction and mechanical stability. This presentation will cover recent advances in characterizing the structural and dynamic properties of sulfide glasses using spectroscopic and scattering techniques, as well as classical and ab initio molecular dynamics techniques. Emphasis will be placed on the role of polarizable sulfur atoms, the depolymerization process and its impact on ion transport. The potential for optimizing Na-based glassy electrolytes for solid-state battery applications will be explored, paving the way for safer and more cost-effective energy storage solutions.

- Author: **Mouad Gnaoui**
  Title: “The high energy emission from Gamma-Ray Bursts”
  Doctoral school: *Astronomie et Astrophysique d’Île de France (ED127)*
  Affiliation: *Institut d’Astrophysique de Paris*

  Gamma-Ray Bursts (GRBs) are some of the most luminous and energetic phenomena in the universe. They are believed to originate from catastrophic events like the collapse of very massive stars at the end of their lives or the collision of two neutron stars. These events expel a relativistic jet that emits energetic gamma-ray. I will briefly go over how these GRBs were discovered by VELA in the seventies and present the standard model — prompt and afterglow emission, particle acceleration and radiation mechanisms — in a simple way so as to emphasise some of the most important aspects of GRB physics and their surprising properties. My presentation will be in English.

Microtubule-based active nematic droplets: from patterns to motion

Romain Leroux*, Nicolas Lobato-Dauzier, Samuel Bell, Guillaume Sarfati, André Estévez-Torres, Jean-Christophe Galas

Laboratoire Jean Perrin (LJP), Institut de Biologie Paris-Seine (IBPS),
Sorbonne Université, CNRS, F-75005, Paris
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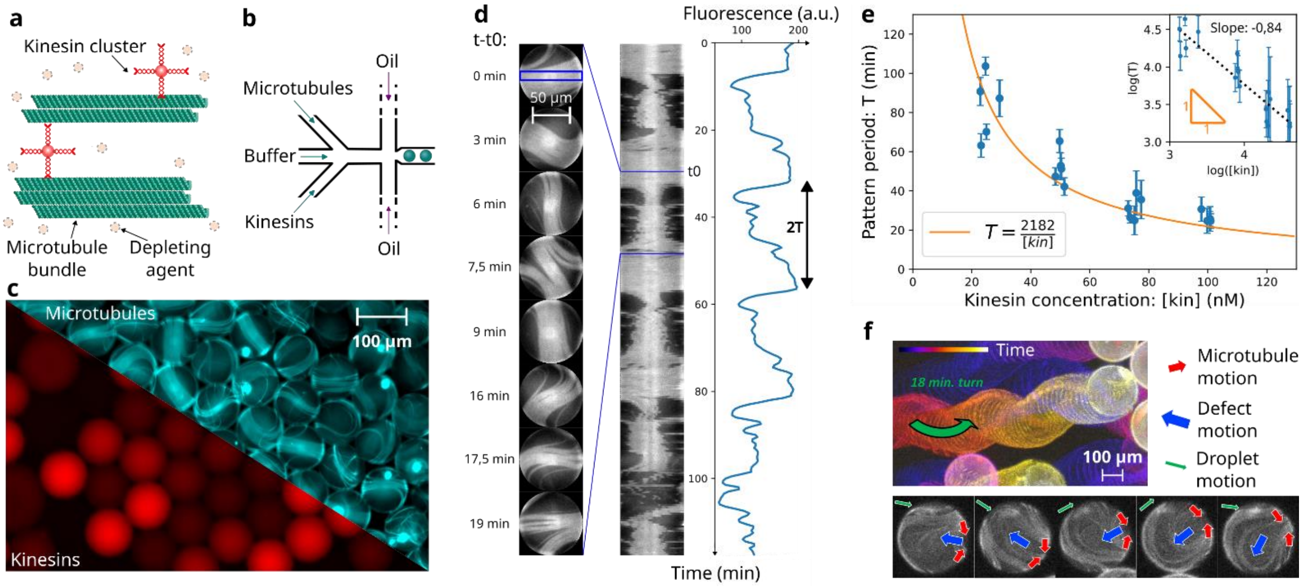
Known as the cytoskeleton, networks of active biopolymers dynamically shape the cell membrane. Described by active matter physics, the cytoskeleton has gained the attention of both theorists and experimentalists who developed filament-motor model systems that exhibit remarkable self-organizations [1, 2]. It is also a source of inspiration for the development of self-propelled objects in the biomimetic robotics field.

Here, we encapsulate a microtubule-kinesin based active matter inside water-in-oil droplets. The microtubule bundles spontaneously migrate to the oil-water interface and form an active nematic. Movements of the microtubules on the droplet surface are analyzed by following the movements of topological defects. Repeated sequences of movements are revealed by studying hundreds of droplets layered in a two-dimensional tissue. Once squeezed in between two parallel planes, the droplets acquire motility. Sinusoidal trajectories are observed that matches the nematic motion.

In addition to revealing the self-organization of the microtubule/kinesin system when constrained on a sphere, these results contribute to the engineering challenge of developing and controlling the motion of self-propelled micro-objects.



A spherically constrained microtubule/kinesin active matter exhibits periodic patterns of microtubule movement. (a) Scheme of the active matter formed by nongrowing microtubules bundled together by a depletion agent, and clusters of kinesin motors. (b) Scheme of the microfluidic device used to generate droplets with a fixed concentration of microtubules and a varying concentration of kinesin motor clusters. (c) Fluorescence two-color images of droplets showing microtubules (blue) and a reporter dye standing for the concentration of kinesin clusters (red). (d) Timelapse images showing a period of microtubule movement (left), kymograph showing repetitive sequences of microtubule movement (center), and plot extracted from kymograph, used to determine the pattern period (right). (e) Period of microtubule movement as a function of kinesin concentration, and *1/x* fit determined from a log-log plot (inset). (f) Squeezed droplets move. Sinusoidal trajectories match the periodic microtubule motion.

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- Author: **Thibault Noblet**
  Title: “Perturbating theory for quantum frustrated spin lattices”
  Doctoral school: *EDPIF*
  Affiliation: *Laboratoire de Physique Théorique de la Matière Condensée (LPTMC)*

  In theoretical physics, one powerful tool available is the perturbation theory. For a large set of systems, models and problems, this technique allows to simplify the analytical derivation and gives qualitative results, if it’s not even quantitative for particular cases. In this talk, this perturbative approach will be briefly explained using some simple and visual analogies. We will see that it can be seen as a Taylor expansion for which all the terms of the series are not computed with derivatives, but using diagrammatical methods as Feynman diagrams. In the end, we will see how does it apply to the topic of my PhD, the quantum frustrated spins on lattices.

Session 3

- Author: **Xue Ma**
  Title: "Surface Bubble with a Vapor Fountain Accelerates Evaporation"
  Doctoral school: *EDPIF*
  Affiliation: *Laboratoire Matière et Systèmes Complexes*

  A volatile liquid evaporating inside a cylindrical tube follows a pure diffusion process, known as Stefan problem (Mitrovic, 2012). We monitor the mass and the liquid height variation over time, and find that introducing a bubble at the liquid surface significantly changes the evaporation dynamics. We quantify this effect by extracting the evaporation mass flow rate when the interface recedes, with bubbles of different sizes. We report that the larger the bubble, the larger the evaporation rate. These bubbles can persist viably up to 2000 seconds at the air/liquid interface, following the liquid recession in the tube. As demonstrated recently by Menesses et al., the stability of bubbles of volatile liquids arises from a cooling effect: evaporation cools down the bubble cap more rapidly than the surrounding bath, thus increasing the surface tension locally. This replenishes the bubble by driving thermo-capillary liquid flows upward against the gravitational drainage (Menesses et al., 2019).

  In our work, upward flows are observed both in the liquid phase and the gas phase near the bubble. We track the flow in the bubble cap by seeding the liquid with insoluble solid particles. We report on thermo-capillary flows oriented from the bubble base to its apex, with typical velocity $\tilde{0}.1$ m/s. These flows are triggered by the evaporation-driven cooling, drawing the surrounding vapor upward with them, which can be visualized using Schlieren imaging. The entrained upward vapor flows converge at the bubble apex, forming a vapor fountain as illustrated in Figure 1. This fountain denotes a forced convection flow, efficiently evacuating the vapor. Piercing through the vapor cloud accumulated near the interface, the vapor fountain provides an upward mass evacuation pathway between the liquid surface and the atmosphere. As a result, liquid evaporation is no longer limited by diffusion alone, but markedly promoted by convection driven by the surface bubble.

  We define the fountain height as the distance between the bubble apex and the fountain top, and show that it remains roughly constant with time, despite the interface recession within the tube. Moreover, this height increases with the bubble size. By comparing this vapor fountain with classic fountains (Hunt, Burridge, 2015), we relate the fountain height to the vapor flow velocity and the mass rate. We consistently find that the larger the bubble, the higher the fountain, and the faster the evaporation.

Our system relies on a coupling between evaporation and flows in the liquid and the vapor phases. Evaporation induces temperature differences at the bubble surface, triggering upward flows at the bubble interface. These flows replenish the bubble, extending its lifespan, but also drag vapor upward, forming the vapor fountain. The latter markedly strengthens evaporation,which sustain this cycle.

The bubble and its fountain eventually disappear (after a few thousands seconds), when the cycle breaks. This occurs when the top of the vapor fountain recedes below the tube top border. Moreover, this cycle is never observed with low-volatility liquids or with bubbles smaller than the capillary length, that cannot host large enough temperature difference.

Keywords: evaporation, bubble, convection flow, free surface

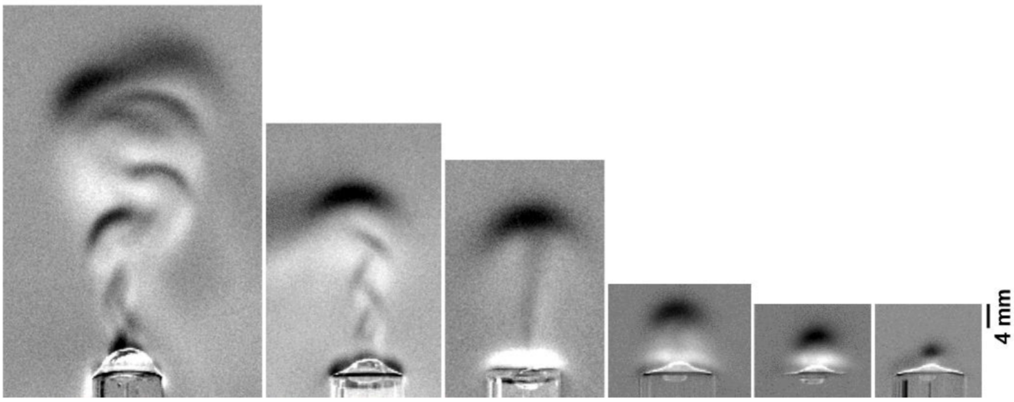

Figure 2: Vapor fountains, visualized with Schlieren imaging technics, with surface bubbles sitting at octane/air interface. Bubble radius ranges from 4.3 mm to 1.2 mm (left to right)

Quantum Linear Time Invariant Systems : from Group Theory to Quantum-enhanced Gravitational Wave Detectors

Jacques Ding*
Laboratoire Astroparticule et Cosmologie, Université Paris Cité, Paris, 75000, France

A general problem in science is to produce a minimal model of a "black box" system based on a set of response measurements from its inputs to its outputs. The classical theory of linear time-invariant (LTI) systems has been widely successful in classical engineering, but does not account for fundamental quantum noise sources, which must be added to preserve the canonical commutation relations of the output quadratures. Previous attempts at a quantum LTI theory have relied on restrictive hypotheses such as Markovianity or a well-defined state-space representation of the inaccessible internal modes of such a "black box" [1–3].

In this talk, I will present the results of a recent theoretical paper [4], and highlight its implications for current quantum-enhanced sensors such as Gravitational Wave interferometers by explaining the experimental challenges encountered when implementing frequency dependent squeezing [5].

I will first pedagogically introduce the framework developed in [4] which provides a quantization scheme for a general multimode LTI system. Identifying the Lie group structure of all quantum LTI transformations, this framework unifies the quantum linear response theory developed by the quantum control community [6], with the matrix group theory approach of gaussian quantum information [7, 8] and the recent developments in integrated quantum photonics [9].

Then, I will report on the experimental status of the current generation of Gravitational Wave detectors (LIGO/Virgo), which have recently undergone improvements in quantum noise reduction. Finally, I will provide insights into how our formalism allows to better understand the propagation and degradation of quantum noise in such detectors.

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- Author: **Kévin Vilayphone**
  Title: "From the Sun to the Earth: experimental study of laser-plasma interactions in laser inertial confinement fusion"
  Doctoral school: *Ondes et Matière (EDOM)*
  Affiliation: *CEA, LMCE*

  In today's search for new, clean and sustainable sources of energy, thermonuclear fusion often stands out as the Holy Grail of this quest, seemingly as miraculous as it is unattainable. After all, we are talking about reproducing on Earth the physical reactions that have powered our Sun for billions of years. Currently, one of the main methods used to achieve thermonuclear fusion is indirect-drive Inertial Confinement Fusion (ICF). Here, a capsule of deuterium-tritium (D-T) is placed at the center of a millimeter-sized cavity, usually made of gold. More than a hundred laser beams are fired at the inner walls of the cavity. The target is immediately pulverized, becoming a plasma – a gas composed of ions and electrons. The laser energy deposited on the walls is converted into X-rays, which compress and heat the D-T capsule until it reaches extreme pressures and temperatures – about a hundred million degrees – typical of the core of a star. Triggering fusion reactions requires, among other things, perfectly symmetrical irradiation of the D-T capsule. However, numerous complex physical phenomena make this a difficult task. These include the so-called "laser-plasma interactions", resulting from the propagation of the lasers through the plasma. These lead to laser energy losses and, a fortiori, to irradiation asymmetries. In this talk, we will look at how the problems associated with laser-plasma interactions are being addressed experimentally, at large-scale laser facilities such as OMEGA and the National Ignition Facility in the USA, or the Laser MegaJoule in France. To do this, we will take the example of one of the most problematic phenomena: stimulated Raman scattering.

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Quantum Trails: Ants and the Physics of One-Dimensional Matter

Presentation by Magali KOROLEV for the RJP 2024

When ants march they follow a narrow (one-dimensional) trail, and their constrained motion and collective behavior (guided by the strong interactions between them – their pheromones) offer an intuitive window into the fascinating world of one-dimensional quantum systems.

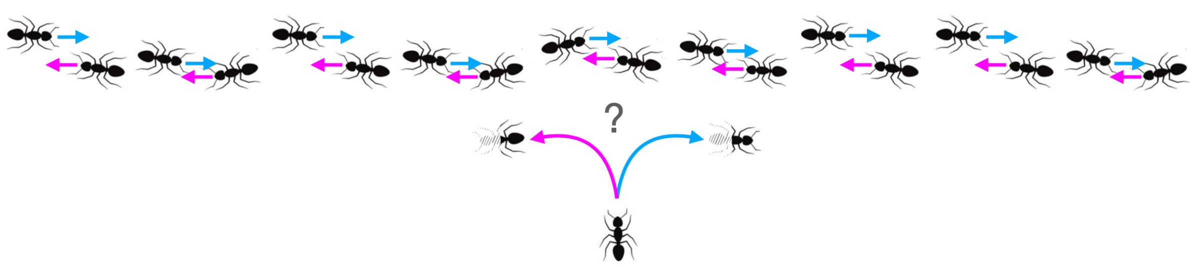
In one-dimensional (1D) quantum systems, electronic interactions give rise to unique and paradigmatic phenomena not observed in higher-dimensional systems. Unlike two- (2D) or three-dimensional (3D) systems, the electron-electron interactions are enhanced in 1D, the low-energy properties of 1D systems are dominated by collective rather than individual excitations, and the concept of quasiparticles break down which makes them indescribable by the celebrated *Fermi liquid theory* and a new theory, so-called *Luttinger liquid theory* (LLT) has to be used.

In this framework, new special phenomena can occur, in particular the so-called *charge fractionalization*, where an electron in a 1D quantum system (a quantum wire described by LLT) splits into separate, fractional, charge excitations. This phenomenon is a hallmark of 1D systems and challenges the conventional understanding of charge carriers. Charge fractionalization is particularly compelling because it defies the intuitive notion of electron indivisibility and highlights the richness of quantum behaviors in reduced dimensions.

In this talk, using the behavior of ants as a guiding metaphor (because it seems quantum physicists like animals), we will explore how one-dimensional systems defy the conventional rules of higher-dimensional quantum physics, unveiling unique phenomena like charge fractionalization.

Schrödinger's cat

Quantum ants



ÉCOLE DOCTORALE GALILÉE Université Sorbonne Paris Nord

LPL UNIVERSITÉ SORBONNE PARIS NORD

Laser desorption on water microdroplets for gas phase characterization

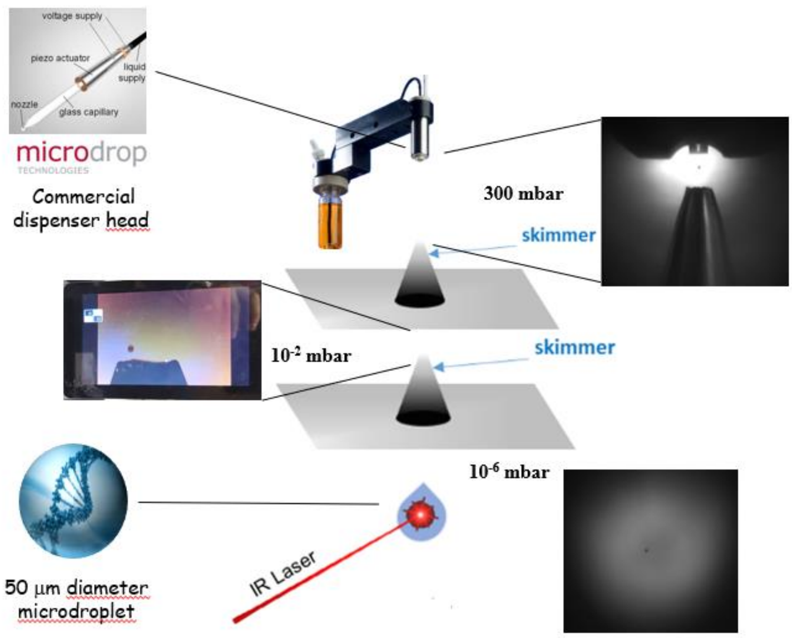
Ayoub Badri[1], Manal Al Sahmarani[1], Charles Desfrancois[1], Frederic Lecomte[1], Bruno Manil[1], Nicolas Nieuwjaer[1]

1 : Laboratoire de Physique des Lasers, Villetaneuse, France

Abstract :

The biological functions of biomolecules (proteins, DNA, RNA) are intimately linked to their secondary or tertiary structure. We investigate this topic using the powerful tools of the gas phase, namely mass spectrometry and action spectroscopy. The gas phase desorption of large biomolecules has been made possible by the advent in the last decades of soft sources, such as electrospray ionization or matrix assisted laser desorption sources. Even if these sources have the capability to preserve low interactions in the gas phase, the desorption process might generate structural changes of the biomolecules and relevance for biological understanding is not always assessed.

In this context, we have started the development of a very new source : the laser induced liquid bead ion desorption (LILBID). Liquid micro droplets (50 µm diameter), containing the biomolecules of interest, are laser ablated directly under vacuum. This innovative source allows to benefit from the gas phase advantages (stoichiometric control for a better control for the ions manipulation and trapping) while preserving the biomolecules native structure. The analysis is made by mass spectrometry. We have, recently, obtained a pure water microdroplets under vacuum. We are now coupling our system with a new infrared desorption laser, narrower and more powerfull, to study the desorption phenomenon in detail. To potentially confirm the desorption possibility of hydrated species and with the perspective to better preserve the native structure of the biomolecules. Finally, we will couple this source with a cold trap, for biomolecules structural analysis by IR spectroscopy.



The LILBID source developed during my thesis

Session 4

- Author: **Cannelle Clavier**
  Title: "A new disruptive approach of observing greenhouse gases in near-real time"
  Doctoral school: *Ecole doctorale Astronomie Astrophysique d'Ile de France*
  Affiliation: *Laboratoire Atmosphères, Milieux, Observations Spatiales*

  Since the early 2000s, many space missions have been launched to observe greenhouse gases (GHGs). These missions have made it possible to monitor GHG emissions on a global scale, and to identify the various sources of anthropogenic emissions on a regional scale. It is now necessary to maintain these time series and to improve the spatial and temporal resolution. The current observation satellites are limited in their capacity for detecting sporadic sources of greenhouse gases, due to a lack of sufficient revisit time to enable real-time detection. It is necessary to develop new satellite resources. The Uvsq-Sat NG is a CubeSat developed by LATMOS to identify local sources of GHGs with a 2 km spatial resolution and with absolute accuracies of 4 ppm for CO2 and 25 ppb for CH4. For this purpose, the satellite is equipped with a miniaturized near-infrared spectrometer with a spectral resolution of 6 nm. Validating the instrumental concept proposed for Uvsq-Sat NG would make it possible to consider setting up a constellation of CubeSats to study CO2 and CH4 in real time. The enhancement of the temporal resolution of GHGs emissions monitoring represents a significant research challenge in understanding the impact of anthropogenic emissions on the natural carbon and methane cycles.

- Author: **Ilaria Delbono**
  Title: "Ultrafast dynamics of the phase transition in vanadium dioxide"
  Doctoral school: *ED 397 - Physique et Chimie des Matériaux*
  Affiliation: *Sorbonne University*

Transition metal oxides are compounds consisting of elements from groups 3 to 12 of the periodic table (such as titanium, vanadium, iron, and nickel) combined with oxygen. These materials exhibit a wide range of structural, electronic, and magnetic properties, making them important for numerous scientific and technological applications. Among them, vanadium dioxide (VO_2) has gained considerable attention due to its remarkable phase transition behavior. At around 68 °C (341 K), VO_2 undergoes a reversible phase transition from an insulating phase at low temperatures to a metallic phase at higher temperatures. This phase transition causes a drastic modification in the electrical conductivity, which increases by several orders of magnitude, as well as changes in other physical properties. Although the exact mechanisms behind this transition are not yet fully understood, VO_2 continues to generate significant scientific interest for its potential in developing advanced materials and devices.

There are two primary methods to trigger the phase transition in VO_2: thermal excitation, where the material is heated above the transition temperature, and optical excitation, where it is illuminated with intense, ultrafast laser pulses.

The photoinduced phase transition is typically investigated using the pump-probe technique, a powerful method for studying ultrafast dynamics in materials, molecules, and biological systems. In this approach, an ultrashort laser pulse (about 80 fs), called the pump, excites the material, creating a non-equilibrium state. A second, delayed pulse, known as the probe, then measures the resulting changes in the material's optical properties, such as reflectance and transmittance. By varying the time delay between the pump and probe pulses, the response of the material can be mapped out over time, capturing processes that occur on femtosecond to picosecond timescales.

One key finding from pump-probe studies on VO_2 is that the transition to the metallic state can occur in about 300 fs after photo-excitation, much faster than the thermally induced phase change.

Studying such fast phenomena provides deeper insights into non equilibrium behavior, helping unravel the intricate interplay between electronic and structural changes in VO_2. Additionally, this ultrafast phase transition opens up possibilities for developing new electronic and photonic devices, such as ultrafast switches, infrared sensors, modulators, and transistors.

Finally, understanding the phase transition in VO_2 is crucial for advancing fundamental knowledge of this type of systems, and it unlocks new possibilities in developing electronic and photonic devices, making it an exciting subject of ongoing investigation.

All-Optical Generation of Drift Currents Trough Inverse Faraday Effect

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The inverse Faraday effect allows the generation of stationary magnetic field through optical excitation only. This light-matter interaction in metals results from creating drift photocurrents via non-linear forces that light applies to the conduction electrons. In our group, we recently described the theory underlying the generation of drift currents in metals, particularly its application to plasmonic nanostructures using numerical simulations. We have also recently demonstrated that drift currents in a gold nanorod can be controlled by manipulating the polarization of light incident on photonic nanostructures [1]. In this work, we used this property to generate and control drift photocurrents in a gold strip with nanorods placed next to it (see Figure 1). We demonstrate theoretically and experimentally that by controlling the linear polarization incident on these structures we can manipulate the direction of the created photocurrents in the gold strip. The ability to generate photocurrents at nanoscale and potentially at ultra-fast timescales opens the way to the generation of nanoscale THz sources, with possible applications in the detection and recognition of molecules in extremely small volumes, or in the design of nanodevices with electric circuitry but optically driven.

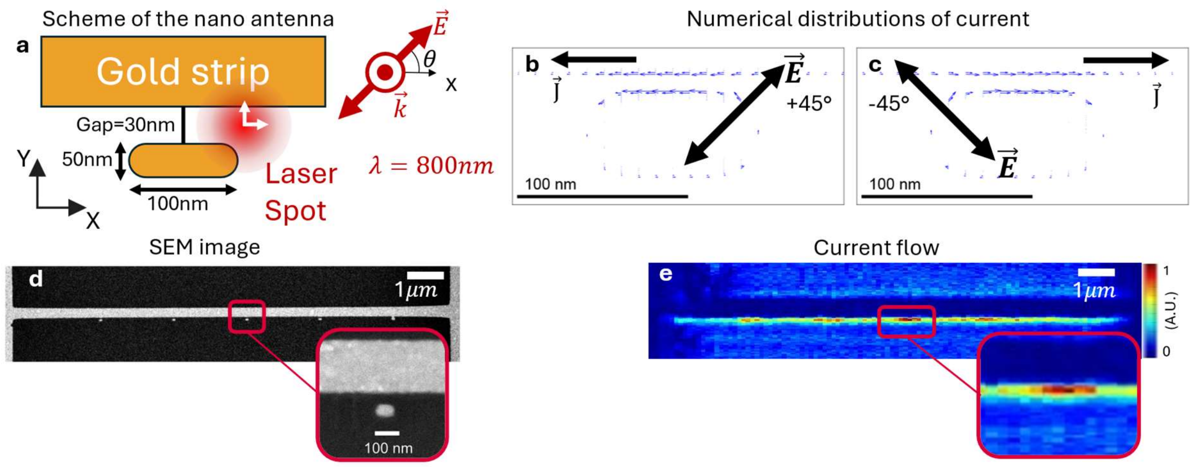

Figure 1: a) scheme of the nanoantenna with the main geometrical parameters close a nanostrip. b,c) Numerical distribution of the drift currents close to a nanorod for the polarizations ±45°. d) SEM image of the nanoantenna. e) Experimental map of the detected current flowing through the gold strip according to the position of the laser beam.

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Unblurring microscope images using entanglement

Yanis Trouyet[1], Patrick Cameron[2], Pedro Ornelas[3], Isaac Nape[3], Andrew Forbes[3] and Hugo Defienne[1] [1]*Sorbonne Université, CNRS, Institut des NanoSciences de Paris (France);* [2]*Laboratoire Kastler Brossel, ENS-Universite PSL, CNRS, Sorbonne Universite, College de France (France);* [3]*University of the Witwatersrand (South Africa)*

Wavefront shaping is a crucial technique in optics, traditionally used to correct aberrations and scattering that an optical beam may encounter along its propagation path [1, 2]. In a conventional wavefront shaping architecture, the optical signal passes through the complex medium, and an aberration correction device - typically a spatial light modulator (SLM) - is positioned along the same optical path (Figure 1a). One challenge of this approach is to properly integrate the SLM into the optical system to efficiently correct aberrations by developing suitable algorithms. To overcome this challenge, and also explore a new avenue in optical wavefront control, we developed a *non-local* wavefront shaping approach using entangled photons (Figure 1b). This approach decouples the wavefront shaping from the system containing the aberrations, enabling the development of new correction algorithms that may surpass existing methods and opening up new possibilities for applications in communication and imaging.

In our experiment, the photon pairs are produced by Spontaneous Parametric Down Conversion, therefore exhibiting strong spatial correlations. One of the photon of the pair is sent through a scattering medium, while its twin propagates through a SLM. Figure 1d shows the distorded correlation images caused by the aberration. By shaping the photon that hasn't interacted with the medium to mimic the scattering effects experienced by its pair, we demonstrate the restoration of strong correlations and entanglement between the pairs. Figure 1c shows the evolution of the coincidence rate at the target with respect to the optimization steps, leading to a correlation image with a sharp correlation peak shown in Figure 1f.

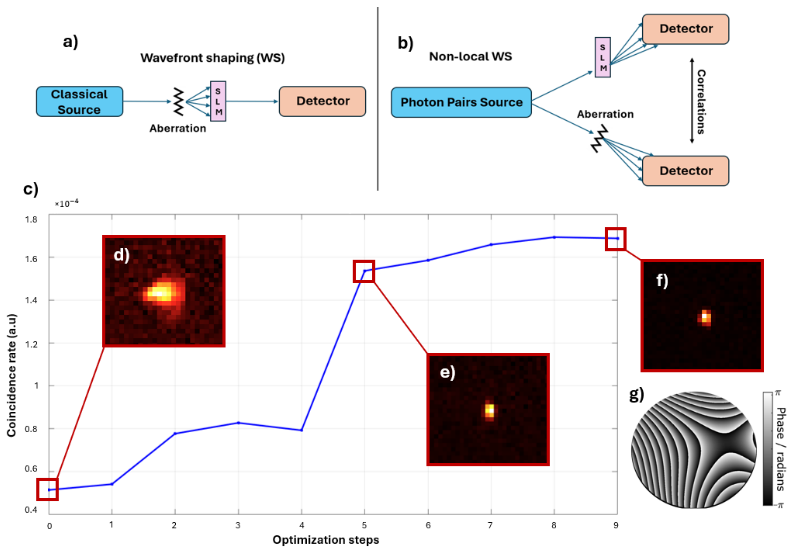

FIGURE 1. Simplified schemes of a **(a)** classical wavefront shaping (WS) configuration and a **(b)** non-local WS configuration. **(c)** Evolution of coincidence rate at the target (central pixel) with respect to the number of optimization steps. Correlation images **(d)** before correction, **(e)** at the fifth step and **(f)** a the end of the process. The narrower the peak, the stronger the spatial correlations between the pairs. **(g)** Correction phase pattern displayed on the SLM at the end.

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Poster abstracts

- Author: **Greivin Alfaro Miranda**
  Title: "SWAP algorithm for lattice spin models"
  Doctoral school: *EDPIF*
  Affiliation: *Laboratoire de Physique Theorique et Hautes Energies*

  We adapted the SWAP molecular dynamics algorithm for use in lattice Ising spin models. We dressed the spins with a randomly distributed length and we alternated long-range spin exchanges with conventional single spin flip Monte Carlo updates, both accepted with a stochastic rule which respects detailed balance. We show that this algorithm, when applied to the bidimensional Edwards-Anderson model, speeds up significantly the relaxation at low temperatures and manages to find ground states with high efficiency and little computational cost. The exploration of spin models should help in understanding why SWAP accelerates the evolution of particle systems and shed light on relations between dynamics and free-energy landscapes.

- Author: **Weipeng Yao**
  Title: "Laboratory investigation of CR origin via the interaction of high-power lasers and magnetized plasmas"
  Doctoral school: -
  Affiliation: *LERMA, Observatoire de Paris*

  The origin of non-thermal energetic particles in the Universe, or Cosmic Rays (CRs), has posed significant challenges to the astrophysical community since their discovery over a century ago. The most widely accepted sites for CR acceleration are supernova remnants (SNRs), where strong shocks interacting with magnetized turbulent plasmas are believed to underpin the acceleration process. With the advent of high-power lasers, it is now possible to replicate such extreme plasma conditions in the laboratory, offering valuable insights into astrophysics, space physics, and planetology. This rapidly growing research field enables the investigation of extreme astrophysical processes, including the origin of CRs, in a controlled and reproducible environment. However, current laser-driven shocks are limited in their strength, as measured by their Mach number, i.e., the ratio of the shock velocity to the magnetosonic velocity of the ambient plasma. Additionally, generating plasma turbulence with lasers, which is crucial for studying shock interactions, remains a major challenge. In this talk, I will present our efforts made in the last few years aiming to overcome these difficulties by coupling emerging multi-petawatt (PW) lasers with strong external magnetic fields, in order to generate powerful shocks interacting with laser-driven magnetized turbulent plasmas. This approach will advance our understanding of the microphysics in the CRs origin.

- Author: **Trisha Debnath**
  Title: "A case of di-boson production in the LHC"
  Doctoral school: *Institute Polytechnique de Paris*
  Affiliation: *Laboratoire Leprince Ringuet, Ecole polytechnique, IP Paris*

  The production of $W^{\pm}\gamma$ in proton-proton collisions is being studied using 34.6 fb^{-1} of data recorded by the CMS detector at $\sqrt{s}$= 13.6 TeV in 2022 (and 27.2 fb^{-1} in 2023) at the Large Hadron Collider of CERN, in order to measure the inclusive and differential cross sections. Utilising the effective field theory (EFT) approach, higher-dimensional operators will be introduced into the standard model (SM) Lagrangian, parameterising potential beyond SM interactions. The use of multivariate techniques will be explored to improve our sensitivity to new physics effects in the triple gauge couplings, potentially unveiling new facets of particle physics.

- Author: **Istiak Akib**
  Title: "An intriguing coincidence between the majority of the VPOS dwarfs and a recent major merger at the Andromeda position"
  Doctoral school: *ED127 - Ecole Doctorale Astronomie et Astrophysique d'Ile de France*
  Affiliation: *GEPI, Observatoire de Paris*

  A significant part of the Milky Way (MW) dwarf galaxies are orbiting within a Vast POlar Structure (VPOS) that is perpendicular to the Galactic disk, whose origin has not been identified yet. It includes the Large Magellanic Cloud (LMC) and its six dynamically associated dwarf galaxies. Besides this, the Andromeda Galaxy (M31) has experienced a major merger two to three billion year ago, and its accurate modelling predicts that an associated tidal tail is pointing toward the Galaxy. Here, we have tested a possible association between M31 tidal tail particles and MW dwarf galaxies, focusing first on the LMC and its associated dwarfs since they are less affected by ram pressure. To do so, we have traced back these dwarf galaxy orbits by one billion year in time, and calculated their association to tidal tail particles in the 6D phase space, on the basis of their Gaia DR3 proper motions. We find that for low-mass MW models (total mass smaller than 5×1011 M$\odot$), the separation in the 6D space can be less than 1σ for most of the M31 modelling, while an important degree of freedom is provided by the still unknown proper motion of M31. We further discover that many other dwarfs could be also associated to M31 tidal tails if their motions have been radially slowed-down, as expected from ram pressure exerted by the MW corona. This intriguing coincidence could explain the VPOS origin that would come from a matter exchange between the M31 and the MW.

- Author: **Afonso Ribeiro**
  Title: “Dissipation-induced order in the one-dimensional Bose-Hubbard model”
  Doctoral school: *EDPIF*
  Affiliation: *Laboratoire Léon Brillouin, CEA*

  Understanding the stability of strongly correlated phases of matter when coupled to environmental degrees of freedom is crucial for identifying the conditions under which these states may be observed. Here, we focus on the paradigmatic one-dimensional Bose-Hubbard model, and study the stability of the Luttinger liquid and Mott insulating phases in the presence of local particle exchange with site-independent baths of non-interacting bosons. We perform a numerically exact analysis of this model by adapting the recently developed wormhole quantum Monte Carlo method for retarded interactions to a continuous-time formulation with worm updates; we show how the wormhole updates can be easily implemented in this scheme. For an Ohmic bath, our numerical findings confirm the scaling prediction that the Luttinger-liquid phase becomes unstable at infinitesimal bath coupling. We show that the ensuing phase is a long-range ordered superfluid with spontaneously broken U(1) symmetry. While the Mott insulator remains a distinct phase for small bath coupling, it exhibits diverging compressibility and non-integer local boson occupation in the thermodynamic limit. Upon increasing the bath coupling, this phase undergoes a transition to a long-range ordered superfluid. Finally, we discuss the effects of super-Ohmic dissipation on the Luttinger-liquid phase. Our results are compatible with a stable dissipative Luttinger-liquid phase that transitions to a long-range ordered superfluid at a finite system-bath coupling.

Plasmonic enhancement of single molecule emission in DNA origamis

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[1] Institut Langevin - ESPCI Paris – PSL

[2] CBS - Centre de Biochimie Structurale, Univ. Montpellier

[3] CEA Saclay - Univ. Paris-Saclay

Abstract

We leverage the precise nanoscale control of DNA origamis to position a single fluorescent molecule between two plasmonic nanospheres (figure 1-a-b-c), creating an optimized platform for enhanced interactions between light and single fluorescent molecules. Our study demonstrates that plasmonic nanosphere dimers strongly modify single-molecule photon emission under non-cryogenic conditions. In order to minimize the distance between gold nanospheres and maximize the local field enhancements, the ionic strength is increased around these self-assembled nanostructures, resulting in a reduced fluorescence lifetime compared to isolated molecules (Figure 1-d) and corresponding to an increased Purcell factor. This approach highlights the potential of plasmonic nanostructures for the study of coherent light-matter interactions at room temperature using fluorescent molecules as single quantum emitters.

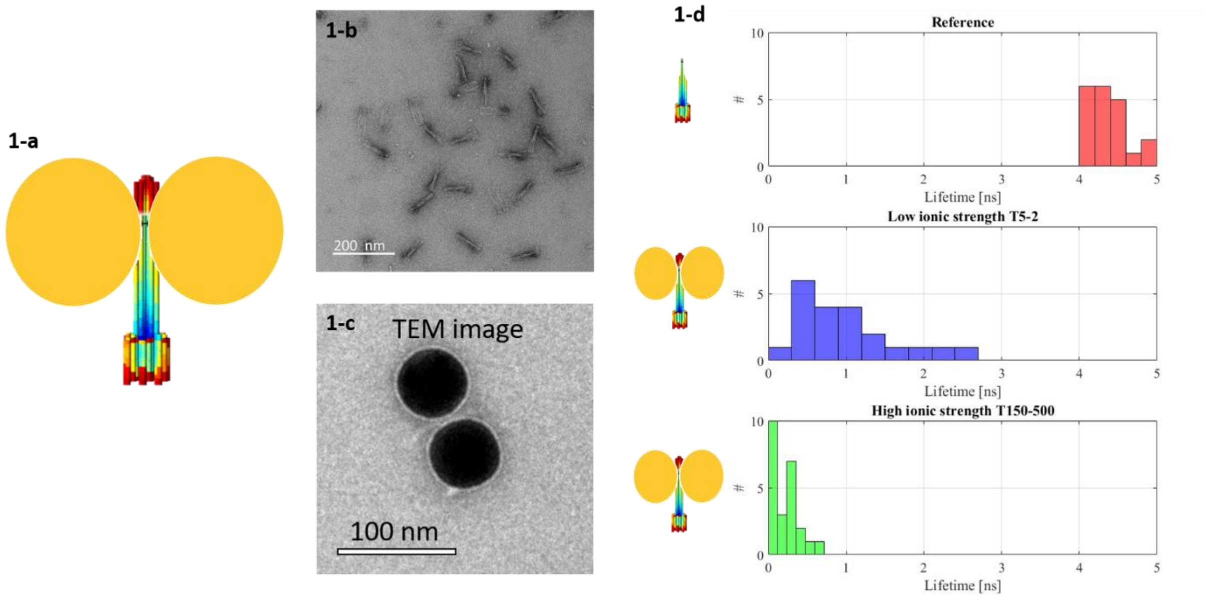

Figure 1: Schematic representation of a gold nanosphere dimer assembled around a DNA origami (a) and TEM images of the DNA origamis (b) and of a self-assembled dimer (c). (d) Distributions of fluorescence lifetimes of single molecules without (top) and with the nanosphere dimer at low (centre) and high (bottom) ionic strengths.

- Author: **Alessandro Santini**
  Title: "-"
  Doctoral school: *École polytechnique*
  Affiliation: -

  We introduce novel hybrid approaches that integrates tensor network methods with the stabilizer formalism to tackle the challenges of simulating many-body quantum systems. These methods improve the ability to accurately model unitary dynamics and compute expectation values of observables while mitigating the growth of entanglement typically encountered in classical simulations. By leveraging the strengths of both techniques, we present Hybrid Stabilizer Matrix Product Operators [1] and Clifford Dressed Time-Dependent Variational Principle [2] for the dynamics of many-body quantum systems.

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PHOTOELECTRIC DETECTION OF NITROGEN-VACANCY CENTER MAGNETIC RESONANCE USING SCHOTTKY CONTACTS

Xuan Phuc LE [(1)]; Ludovic MAYER [(1)] ; Simone MAGALETTI [(1)]; Martin SCHLIDT [(2)]; Jean-François ROCH [(2)]; Thierry DEBUISSCHERT [(1)]

[(1)]Thales Research and Technology;

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Keyword's: NV center, Diamond, Quantum sensing, Spin readout, Photoelectric detection

Nitrogen-vacancy (NV) centers in diamond provide a unique platform for quantum sensing due to their ability to polarize and read out electronic spin states optically, as well as manipulate them at room temperature. Recently, an alternative to the standard optical detection method (ODMR), known as photoelectric detection of magnetic resonance (PDMR), has gained attention for its potential to enable more compact device designs.

PDMR relies on the correlation between photocurrent intensity and the NV spin state when the diamond is illuminated with an intense green laser. The photocurrent is measured using graphitic electrodes fabricated via focused-ion-beam (FIB) techniques. This setup functions as a back-to-back Schottky diode system, differing from earlier approaches that detected photoconductive currents using ohmic contacts. Given that ODMR is a more established technique, a combined system has been developed to facilitate direct comparisons between ODMR and PDMR. The PDMR signal was observed to be localized near the reverse-biased contact, corresponding to the positive electrode in the experiment. This localization is related to the Schottky barrier modulation, resulting in a PDMR contrast of up to 17%, exceeding previously reported values for systems with ohmic contacts.

This research highlights the potential of PDMR through Schottky contacts for achieving high contrast and precise signal localization, marking a significant step toward compact, high-performance quantum sensors.

Monochromatic source of ions and electrons for nanosciences

Clélia Bastelica[1], *Matthieu Viteau*[2], *Martin Schmidt*[3], *Daniel Comparat*[1], *Yan Picard*[1]

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Electron and ion beams have become indispensable tools in surface and material sciences, with the demand for ever-increasing resolutions. This project aims to develop a Focused Ion Beam (FIB), called FIBback, leveraging two innovative concepts:

- A correlated source of ions and electrons that demonstrates, among other applications, complete trajectory control of the ion using information from its correlated electron [1, 2].
- A FIB (called COldFIB) based on a cesium atoms beam collimated by laser, excited to a Rydberg state then ionized by field [3, 4].

We aim to enhance the resolution of ColdFIB by enabling the collection and detection of each electron created during the ionization process. To achieve this, we have developed several optical elements and a detector that will be incorporated into the FIB column. These additions will allow us to maintain the existing correlation between the electron on its detector and the ion on the sample, both coming from the same atom. The coincidence detection ion/electron provided information on both correlated particles which can be used to enhance beam properties. The beam resolution will be improved either by using the real-time trajectory control of each ion [1] or using ghost imaging [2]. This new FIB prototype will also provide a deterministic ion source.

With this innovative FIB, we aim to achieve nanometer-scale resolution at low energy, paving the way for high-resolution non-destructive imaging applications and deterministic implantation experiments.

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Laser induced liquid bead ioniation desorption

M. Al Sahmarani[1], A. Badri[1], C. Desfrançois[1] , F. Lecomte[1], A.Macario[1], B. Manil[1], N. Nieuwjaer[1]

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The desorption of large biomolecules in the gas phase has become feasible in recent decades thanks to the development of soft ionization techniques such as electrospray ionization (ESI) and matrix-assisted laser desorption ionization (MALDI). While these methods are designed to maintain weak intermolecular interactions in the gas phase, the desorption process can still induce structural changes in the biomolecules, raising questions about their biological relevance.

In this context, we have developed a new gas-phase ionization source: LILBID (Laser Induced Liquid Bead Ionization Desorption). This method involves the generation of microdroplets approximately 50 micrometers in diameter, which are then introduced into a secondary vacuum. A tunable infrared laser, operating around 3 micrometers, is used to desorb the microdroplets under vacuum while preserving the native structure of the biomolecules.

The objective of my thesis is to conduct structural studies of biomolecules using IR spectroscopy and to investigate radical chemistry by irradiating the droplet with an ion beam during its descent. Initially, I am developing a new source that will enable interaction with the droplet during its trajectory in a vacuum. This will allow the droplet to be irradiated with an ion beam before desorption by the IR laser. This instrumental development will facilitate radical chemistry studies through liquid-phase irradiation followed by gas-phase analysis.

Conception of a new electron microscope for surface science

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[3]*SPEC, CEA, Orsay France*
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By combining a monochromatic electrons source with high performance detectors, we build with the laboratories ISMO and SPEC a unique electronic microscope call HREELM. This microscope is able to make spatial imagery and analyse the surface vibrations interactions simultaneously. Applications include nanophysics, nanochemistry and photonics.

One of the most important things for HREELM is the electron source. The flux must be higher than 100 pA and the energy dispersion must be lower than 10 meV to be able to resolve phonons, plasmons, etc... To satisfy these criteria, we choose the Rydberg atom ionization. We use a caesium jet and three lasers to excite the atoms into a Rydberg state. Centrally drilled electrodes are used to impose an electric field on the Rydberg atoms.

The manipulation and the detection of the electrons after the sample interaction is also crucial and requires special attention. The electron energy loss spectra will be given by a time-of-flight measurement. For this reason, we need to use a special sensor who is able to measure the position and the time of arrival of the electron.

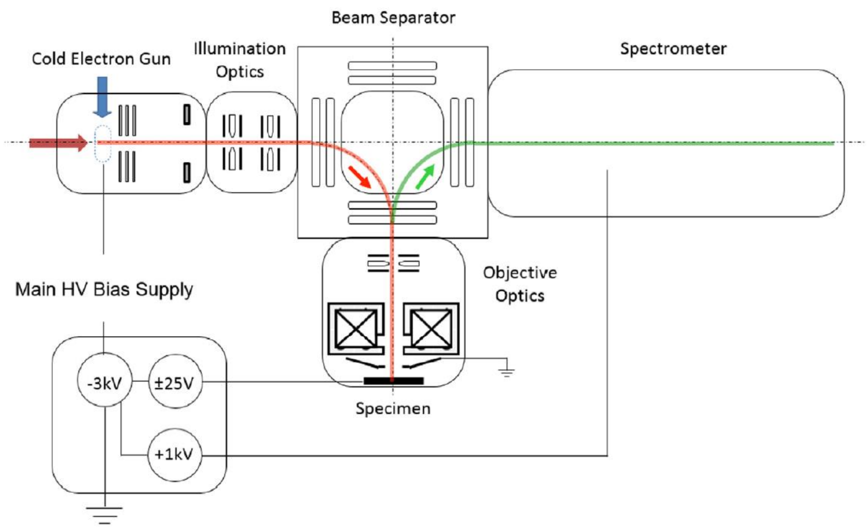

Fig.1. Final HREELM version scheme.

[1] High repetition rate sub-ns electron pulses from resonant pulsed Rydberg field-ionization R.Hahn, D.Comparat: https://arxiv.org/abs/2308.15333
[2] Cesium Rydberg-state ionization study by three dimensional ion-electron correlation : Toward monochromatic electron source R.Hahn, D.Comparat DOI : 10.1103/PhysRevA.103.042821

- Author: **Maxence Tabary**
  Title: "The Interplay Between Cosmic Ray-Driven and Weibel Instabilities in Astrophysical and Laboratory Plasmas"
  Doctoral school: *ED127*
  Affiliation: *LERMA*

  Shocks are ubiquitous in astrophysical environments and exist across a wide range of scales, and are the site of efficient particle acceleration, yielding the well-known energy distribution of cosmic-rays (CR). This acceleration is mediated by a strong, large scale and turbulent magnetic field that scatters the CR across the shock. This magnetic field that must exist around shocks is rather different from the one of the Interstellar Medium (ISM), and results from its amplification by plasma instabilities, stemming from the streaming of the super-alfvenic CR into the ambient plasma. Often studied on their own in idealized conditions, these instabilities are in fact expected to coexist and interplay with each-other, greatly enriching the physics at play. The aim of this thesis is to provide an analytical model, reinforced by numerical simulations of the interplay between various instabilities, in order to achieve a more realistic model of the magnetic field amplification in collisionless shocks, which is needed to explain the observed particle acceleration.

- Author: **Thershi Seebaruth**
  Title: "Simulations and experiments of shocks in weakly collisional plasmas"
  Doctoral school: *ED127*
  Affiliation: *LERMA*

  Shock waves are pervasive phenomena occurring in a variety of environments, from astrophysics to inertial confinement fusion. The microphysics of shocks varies greatly depending on the collisionality regime[1]. In our work, we focus on understanding shocks in weakly collisional plasma, where kinetic effects, such as energetic ions[2, 3] and instabilities, may be important in determining the shock structure. We present Particle-in-Cell and MHD simulations, as well as experiments on high power laser facilities,, exploring the impact of the laser ablated plasma and the background plasma on the shock structure and dynamics.

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  [1] Bret, Antoine & Pe'er, Asaf. (2021). Bridging the gap between collisional and collisionless shock waves.

  [2] Hua, R. et al. Structures of strong shocks in low-density helium and neon gases. Physical Review Letters (2023)

  [3] Rinderknecht, H. G. et al. Highly Resolved Measurements of a Developing Strong Collisional Plasma Shock. Physical Review Letters 120 (2018).

Reconfigurable integrated thermo-optics: towards applications in endoscopy

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Wavefront shaping includes a variety of techniques that involves controlling and manipulating the phase of light waves to achieve specific outcomes, e.g. refocusing, or correcting optical aberrations. It could play a crucial role in various applications, enhancing the exploration of different types of biological tissues and environments, particularly in the field of endoscopy.

Here we propose a method to shape optical wavefronts using planar microresistors to locally modify the refractive index distribution and produce controlled wavefronts through thermo-optical effects, i.e. the temperature dependence of the refractive index [1,2]. These devices, coined as SmartLenses, combine several sets of independently addressable micro-resistive loops (4 ITO resistors here, as shown in Fig. 1a), that can be activated separately by applying a voltage. The temperature change induced in PDMS (Fig. 1b, c) locally changes the refractive index, thus allowing optical wavefront modifications (Fig. 1c).

Applying the appropriate voltages to each pre-designed resistor allows to produce a variety of wavefronts, enabling the correction of different optical aberrations, such as defocus and spherical aberration. By tuning these voltages, it is also possible to tune, modify and reconfigure this optical function, and adapt it dynamically to the needs of the user.

We will present applications of SmartLenses in a micro-endoscopy context (Fig. 1d, e), and we will discuss their potential applications in the field of neurosciences.

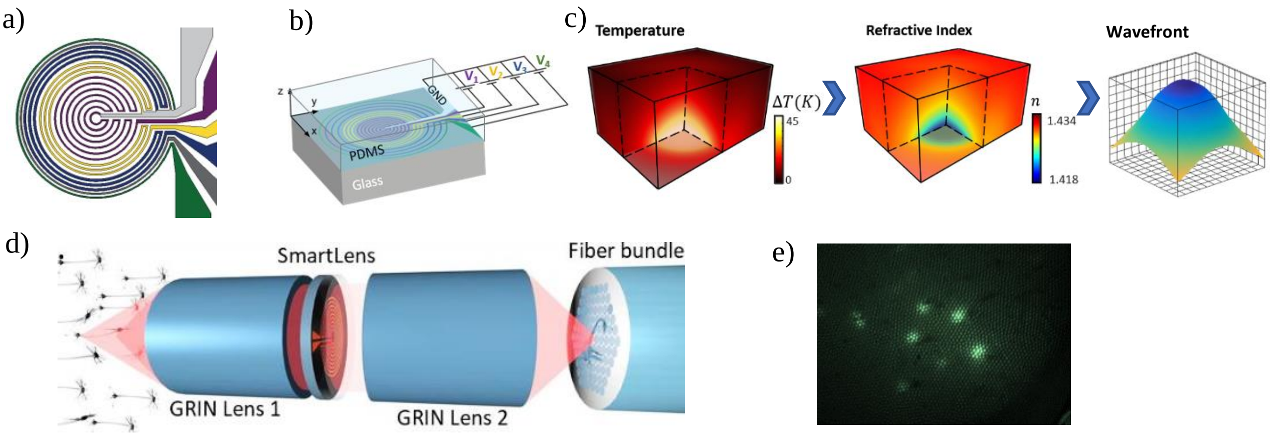

Figure 1: a) SmartLens resistor design. b) Resistive element covered by a layer of thermo-optical material. c) Local change in temperature and refractive index, producing a controlled wavefront. d) Endoscopic system, with the SmartLens in the Fourier plane between two GRIN lenses. e) Fluorescent image of 10 µm rhodamine-coated beads, obtained with the SmartLens system.

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[1] Berto, P., Philippet, L., Osmond, J. et al. Tunable and free-form planar optics. Nat. Photonics 13, 649–656 (2019)
[2] Panadés, J., Rutz, N., Robert, H., et al. Reconfigurable Integrated Thermo-Optics for Aberration Correction. ACS Photonics, 4804- 4811 (2024)

Effective (field) theory for collective motion in atomic nuclei

E. Thiriont–Bernolle, J.P. Ebran
CEA DAM

November 25, 2024

Structure of the atomic nuclei and energy scales

The atomic nucleus is at the crossroads of many interactions, Electromagnetism, and nuclear forces being the principal ones. We are here dealing with a mesoscopic object, making theoretical study very close to what we can find in condensed matter theory. The main difference is that the finiteness of the system is hard to avoid in the case of the atomic nucleus. In previous years, and still today, members of the community of theoretical nuclear physicists have chosen to follow the path of the BCS theory and more specifically the effective approximation of the Hamiltonian further developed by Bogoliubov-De Gennes and Andreev. It turns out that this approach is actually the one that makes the strongest and most consistent results for now. The previous studies carried by all the great theoretical physicists that work, and have worked, on this field have allowed us to extract relevant energetic scales that take place in the atomic nucleus. Thus, imposing a hierarchy of the different degrees of freedom entering the nucleus becomes possible. One part of my work is to follow the path of Effective Field Theory, which is the perfect tool you want to use if the physical playground is clearly defined in terms of energy scales.

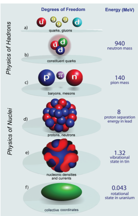


Figure: Energy scales from the most (top) to the lowest (bottom) energetic degrees of freedom identified in the atomic nucleus. Picture taken from [**F1**]

Symmetry breaking and Lagrangian of the left-coset space $SO(3)/K_4$

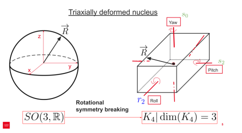


Figure: Discrete K_4 symmetry breaking from rotationnal incariance

We use symmetry breaking approach and especially the formalism of non linear σ models of QFT. The theory is SO(3) invariant and the ground state is invariant under $K_4 \in SO(3)$, which is a non-normal closed Lie subgroup of SO(3). The result is that this quotient space is not a Lie group. The coset space is the space of the equivalence classes identifying elements that differ only from elements of K_4.
We then, describe a spherical shape where deformation occur on the three cartesian axis. The Symmetry breaking is expressed through Nambu-Goldstone modes, that are generated from the operator,

$$
\begin{aligned}
U &= g(\alpha,\beta,\gamma)u(x,y,z)\\
&= e^{-i\alpha(t)J_z}e^{-i\beta(t)J_y}e^{-i\gamma(t)J_z}e^{-ix(\theta,\phi,t)J_x-iy(\theta,\phi,t)J_y-iz(\theta,\phi,t)J_z}
\end{aligned}
$$

The Lagrangian is build from SO(3) invariant expressed through the pullback of the Maurer-Cartan form. This tool allow to express element living in the tangent bundle of the coset space to the lie algebra $\mathfrak{so}(3)$ (near identity), which is the space of left invariant vector fields.

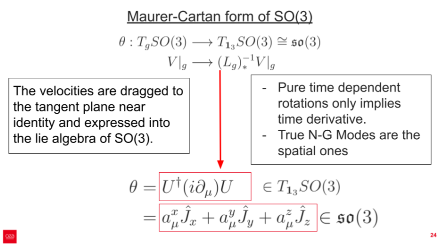
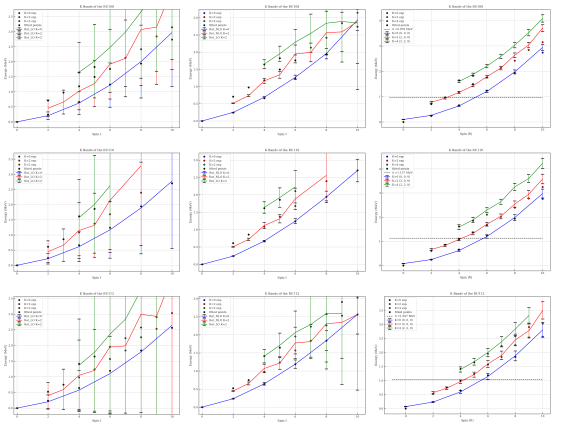


Figure: We search for components of the velocities that are expressed in $\mathfrak{so}(3)$, ie, for left invariants vector fields. The $a_\mu^{x,y,z}$ are then invariant under SO(3) for all $\mu \in \{t,x,y,z\}$. The pure time dependent components ($\mu = t$) are specific to finite systems and are singled out from the theory, these modes are the pure rotational degrees of freedom.

Results: 108-110-112 Ruthenium



LEFT: Application of the Leading order rotional Hamiltonian.
CENTER: NLO rotational Hamiltonian.
RIGHT: rot-vib Hamiltonian at leading order.
Uncertainties are considered as degrees of belief coming from bayesian uncertainties from the truncation of the Hamiltonians. Here we consider a normal distribution of 68%

Rotational Hamiltonian LO and NLO

At leading order, the lowest spectrum is generated by rotation only and involve pure time components. After considering all the invariants entering in the Lagrangian at leading order (LO), identified from a power counting procedure, one recover through Legendre transformation and identification of angular momenta, the well known rotor Hamiltonian found by and Bohr-Mottelson.

$$\mathcal{H}_{LO} = \frac{I_1^2}{2\mathcal{J}_1} + \frac{I_2^2}{2\mathcal{J}_2} + \frac{I_3^2}{2\mathcal{J}_3} \tag{1}$$

where the coefficients $\mathcal{J}_k$ are seen as the moments of inertia about the 3 principal axis and are of dimension $\hbar^2/MeV$ from simple dimensionnal analysis.
The next-to-leading order is obtained from considering the next invariants ordered by the power counting,

$$
\begin{aligned}
\mathcal{H}_{NLO} = &\frac{1}{2\mathcal{J}_1}I_1^2 + \frac{1}{2\mathcal{J}_2}I_2^2 + \frac{1}{2\mathcal{J}_3}I_3^2 - \frac{\mathcal{M}_1}{4\mathcal{J}_1^4}I_1^4 - \frac{\mathcal{M}_2}{4\mathcal{J}_2^4}I_2^4 - \frac{\mathcal{M}_3}{4\mathcal{J}_3^4}I_3^4\\
&- \frac{\mathcal{M}_4}{4\mathcal{J}_2^2\mathcal{J}_3^2}\{I_2^2,I_3^2\} - \frac{\mathcal{M}_5}{4\mathcal{J}_1^2\mathcal{J}_3^2}\{I_1^2,I_3^2\} - \frac{\mathcal{M}_6}{4\mathcal{J}_1^2\mathcal{J}_2^2}\{I_1^2,I_2^2\}
\end{aligned}
\tag{2}
$$

The power counting allow to identify the following pattern,

$$
\begin{aligned}
[\mathcal{H}] &\approx \sum_{n=1}^{3}[\mathcal{J}_n]\,[\xi]^2 + \sum_{n=1}^{6}[\mathcal{M}_n]\,[\xi]^4 + \mathcal{O}\left([\xi^6]\right)\\
&\approx [\mathcal{H}_{NLO}] + \mathcal{O}\left([\xi^6]\right)
\end{aligned}
\tag{3}
$$

Where ξ refer to the typical rotationnal energy of the studied nucleus and Ω the typical vibrational energy. This theory specifically hold for all $\xi << \Omega$ and die at the cutoff $\Lambda \approx \Omega$ where the first phonon appear.

Rot-Vib Hamiltonian LO - U(n) infinite anisotropic quantum oscillator basis

To refine the theory, vibration must be included, this allow to push the Λ cutoff further to the first non bands level or near $\Lambda \approx 3\Omega$ dependeing on the size of the nucleus. The leading order Lagrangian is solved by considered infinite harmonic oscillators on each axis, the Hamiltonian read,

$$
\begin{aligned}
H_{LO} = &\frac{(I_1-I_1)^2}{2A_a} + \frac{(I_2-I_2)^2}{2A_b} + \frac{(I_3-I_3)^2}{2A_c}\\
&+ \sum_{\lambda\mu}\left\{\frac{(p^x_{\lambda\mu})^2}{2B_a} + \frac{(p^y_{\lambda\mu})^2}{2B_b} + \frac{(p^z_{\lambda\mu})^2}{2B_c}\right\}\\
&+ \sum_{\lambda\mu}\left\{\frac{1}{2}\lambda(\lambda+1)[D_a x^2_{\lambda\mu} + D_b y^2_{\lambda\mu} + D_c z^2_{\lambda\mu}] + \frac{1}{2}\mu^2[D_d x^2_{\lambda\mu} + D_e y^2_{\lambda\mu} + D_f z^2_{\lambda\mu}]\right\}\\
&\sim [A_i]\xi\Omega\left(\sqrt{\xi/\Omega}\right)^2 + [B_i]\xi\Omega\left(\sqrt{\xi/\Omega}\right)^0 + [D_i]\xi/\Omega\left(\sqrt{\xi/\Omega}\right)^0 + [\mathcal{C}_{LO}]\xi\Omega\left(\sqrt{\xi/\Omega}\right)^3
\end{aligned}
\tag{4}
$$

For practical computation we truncated the sum at $\lambda = 2$, which introduce a regulator on the infinite sum.
The last line is the dimensional analysis that i have done in order to explicit the power counting for the application of uncertainties.

Bayesian analysis and truncation uncertainties

These Hamiltonians are truncated version of an infinite polynomials. Physical model impose convergence of these series and we are able to estimate the predictive loss with bayesian inference. For the three Hamiltonian the uncertainties are introduced as follow,

$$\Delta\mathcal{H}_{LO} = <\mathcal{H}_{LO}> \frac{Q^2}{\xi}\begin{cases}2p\% & \text{if } p \leq \frac{1}{2}\\ \frac{1}{2(1-p\%)} & \text{if } p > \frac{1}{2}\end{cases} \tag{5}$$

$$\Delta\mathcal{H}_{NLO} = max\left(\frac{<\mathcal{H}_{LO}>}{Q^2\xi}, \frac{<\mathcal{H}_{NLO}>}{Q^4\xi}\right)Q^6\begin{cases}\frac{3}{2}p\% & \text{if } p \leq \frac{2}{3}\\ \left(\frac{1}{3(1-p\%)}\right)^{1/2} & \text{if } p > \frac{2}{3}\end{cases} \tag{6}$$

$$\Delta H_{LO} \approx \pm\Omega\overline{c_3}\left(\sqrt{\frac{\xi}{\Omega}}\right)^3\begin{cases}\frac{3}{2}p\% & ,p \leq \frac{2}{3}\\ \frac{1}{3(1-p\%)} & ,p > \frac{2}{3}\end{cases} \tag{7}$$

where $\overline{c_3}$ is a complicated function which also take the maximum of the previous dimensionless constants in the power counting. The degrees of belief are fixed for a given p% distribution.

Références

More to be done

Exploring Ultrafast Photoswitching and Ligand Structure-Dependent Thermal Recovery in Red-Absorbing Photochromic Proteins

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Photochromic proteins are a specific subset of molecular photoswitches found in biological systems. These proteins undergo a typically reversible conformational change upon absorbing light, leading to photoproducts with optical properties and absorption spectra distinct from their initial state. This change is often driven by the photoisomerization of an embedded chromophore, also known as a protein cofactor, which serves as the light-absorbing entity [1]. Their ability to reversibly switch between states with different absorption spectra makes photochromic proteins highly valuable for diverse applications in the biological sciences [2]. However, for many of these applications, red-absorbing, reversible photochromic proteins with high photoswitching quantum yield (QY) and prolonged photoproduct lifetimes are highly desirable but remain scarce. Recently, a new type of reversibly photoswitchable protein was reported. It consists of a red-absorbing intermolecular charge transfer (CT) complex formed between a flavin cofactor and a substrate-analog inhibitor in monomeric sarcosine oxidase (MSOX). This system photoswitches in a few hundred femtosecond timescale in a barrierless way and with a near unity QY, yielding a CT dissociated state. The photoproduct lifetime extends to a few nanoseconds near room temperature and the initial state recovery (CT recombination) was shown to be thermally activated [3].

In this study, we employ multi-timescale transient absorption spectroscopy, spanning from the picosecond to millisecond range, to investigate the processes following the photoactivation of the charge transfer (CT) complex. Using two different ligands (inhibitors), methylthioacetate (MTA) and methylselenoacetate (MSeA), we first analyze the forward photoswitching reaction and determine the associated quantum yield (QY). Subsequently, we study the thermal recovery process of the back reaction by precisely monitoring transient kinetics at various temperatures. Notably, despite differences in molecular weight between the inhibitors and distinct steady-state absorption spectra for the CT complexes (MSOX:MTA and MSOX:MSeA), both systems exhibit the same activation energy for recovery. However, they display significantly different extrapolated recovery rates at extremely high temperatures. These findings indicate that the weight of the isomerizing atom controls the shape of the potential energy surface of the recovery process, but not the activation barrier, as had been suggested previously.

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[3] Zhuang, Bo, and Marten H. Vos. "Photoswitching Behavior of Flavin–Inhibitor Complex in a Nonphotocatalytic Flavoenzyme." Journal of the American Chemical Society 144.26 (2022): 11569-11573.

- Author: **Tristan Cerdin**
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  Affiliation: *PHENIX, FAST*

  Quantifying particle dynamics through microscopy has generally been of great interest to the scientific community studying active matter. Indeed information on the movement in complex ircumstances is essential to better understand the way active particles evolve in their environment, and quantifying their displacement is traditionally done by studying their trajectories.

  Trajectories can however be difficult to obtain, especially in situations with large concentration heterogeneities that are a generic feature of active matter as seen with behaviours such as MIPS (Motility Induced Phase Separation). Recent work suggest an alternative strategy to quantify dynamics by counting particles in boxes, which removes the need for obtaining trajectories but is for the moment limited to the study of passively diffusing colloidal systems. Here I develop a method to obtain the dynamic properties of active particle from counts by studying Active Brownian Particles, and aim to obtain the quantities defining their movement, their self propulsion speed and their translational and rotational diffusion coefficients. For that we study data from experiments and simulations and, using stochastic density field theory and a Dean-Kawasaki formalism to derive equations describing the evolution of the hydrodynamic fields of the problem, I uncover 3 regimes in the counts at low, intermediate, and long times, similarly to the behavior of the mean squared displacement of those particles. These results could help us to later be able to directly extract dynamic parameters from experiments using this counting method.

By: Pascale Nasr

Title

Harvesting the Magnetic Field of Light at the Nanoscale

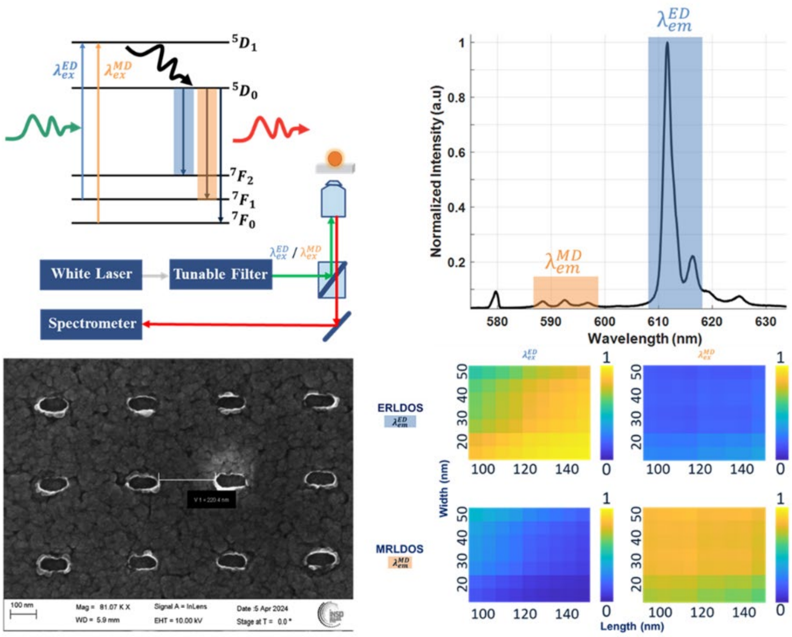
Abstract

While the electric field is often the primary focus in light-matter interactions, the optical magnetic response—typically overlooked in optics—also plays a vital role in various phenomena, such as circular dichroism, transitions in lanthanide ions, and chiral light-matter interactions.

In this study, we use Finite Difference Time Domain (FDTD) simulations to demonstrate that plasmonic nanoantennas in the form of nanoslits selectively enhance the magnetic component of light relative to the electric component. By embedding trivalent europium ions, which are well-known for their strong magnetic dipole transitions, within the nanostructure, we achieve a significant enhancement of their magnetic emission.

Our findings reveal that this enhancement is driven by an increase in the magnetic local density of optical states (LDOS), particularly its radiative component. By tailoring the structural dimensions of the nanoantennas, we control both the Purcell factor and the relative LDOS, enabling the selective isolation of magnetic emission. Furthermore, by carefully tuning the excitation conditions, we achieve precise magnetic excitation of the emitters.

This approach provides a pathway for advanced control and manipulation of magnetic fields at the nanoscale, paving the way for novel magnetic nanosources. Potential applications include improved quantum emitters for quantum information processing, nanoscale sensing with enhanced magnetic resolution, and the development of chiral photonic devices for molecular analysis and light-driven enantioselective chemistry.



Partial band diagram, a spectrum of Europium ions representing magnetic and electric transitions, and the experimental set-up. Scanning electron microscope image of the plasmonic nanoantenna. Relative local density of state in the function of the dimensions and excitation wavelength.

Cold ytterbium atoms' source for atom interferometry

Oscar BOUCHER[1], Pierre CLADE[1], and Saïda GUELLATI-KHELIFA[1, 2]

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[2]*Conservatoire National des Arts et Métiers, 75003 Paris, France*

Atom interferometry using continuous laser light is a well-developed technique which enable us to measure with very high accuracy velocities, accelerations, rotations, gravity or gravity gradients. It is now used in many tests of fundamental physics, such as the detection of gravitational waves, testing the equivalence principle or measuring fundamental constants. The new measurement of h/m_{Rb} made by our group in 2020 improved the relative accuracy of the value of the fine structure constant (alpha) to 81 parts per trillion [1][1]. However, a discrepancy of 5.6 sigma in the determination of alpha was observed with the measurement of h/m_{Cs}, made by the group of H. Müller in 2018. Both measurements were performed using atom interferometry on alkaline atoms with two-photon diffraction techniques.

In this context, we have started developing a new source of cold ytterbium (Yb) atoms. This alkaline-earth-like atom opens new possibilities for measuring the atomic recoil using one-photon diffraction on the $^1S_0$-$^3P_0$ clock transition. Furthermore, the studies of Bragg diffraction performed on the $^1S_0$-$^1P_1$ and $^1S_0$-$^3P_1$ transitions could lead to a better determination of the systematic effects on recoil measurements. Additionally, the diffraction using a frequency comb, first implemented on the 780 nm transition of Rubidium atoms [2][2], could be extended to the near-UV region using this platform.

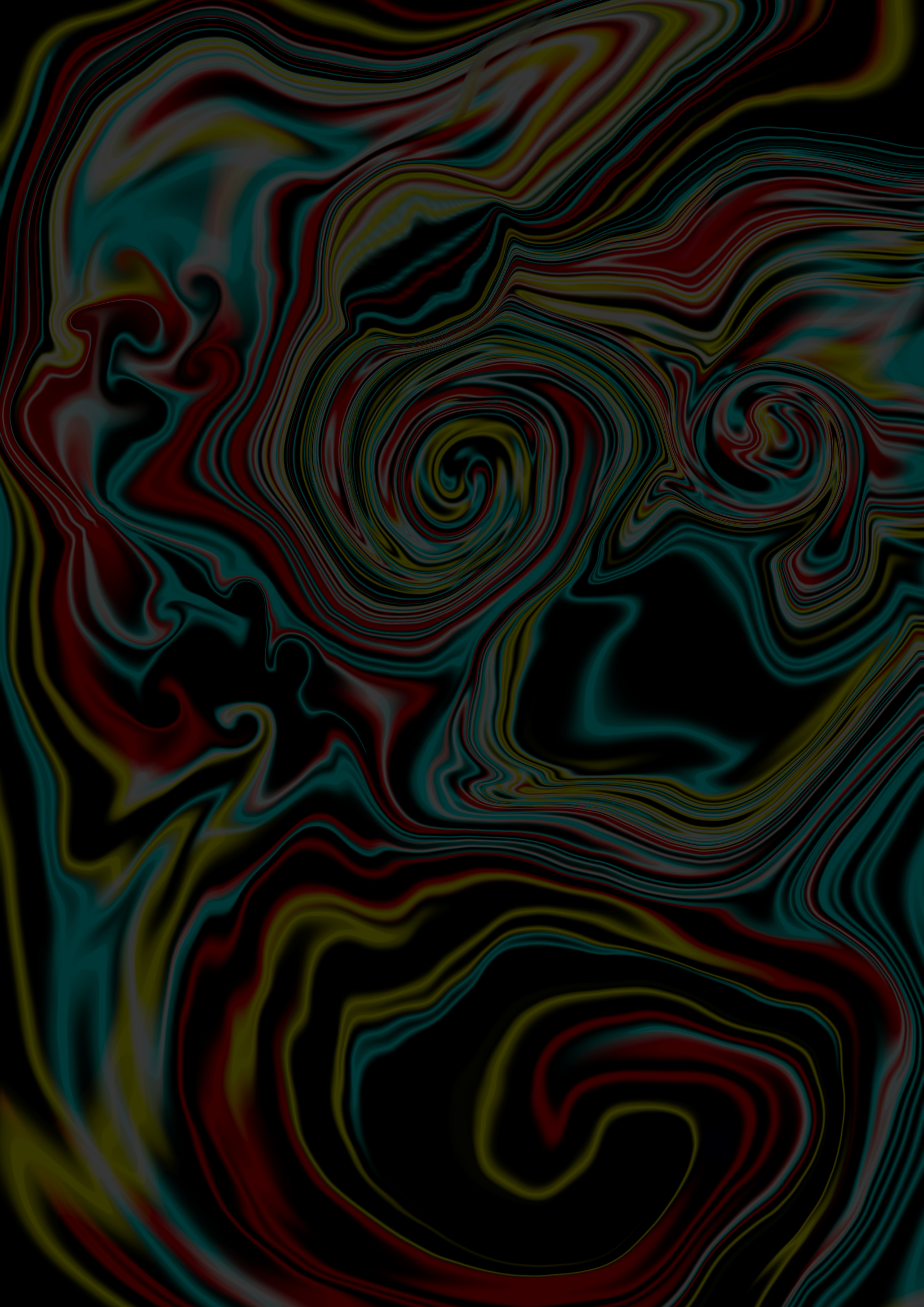
In this poster, we will present the development of the cold atom apparatus. Currently, an oven produces an atomic beam at 400°C. A laser at 399 nm is locked using the fluorescence of the atomic beam. For the 556 nm laser, we locked it with a saturated absorption setup on iodine, which exhibits strong transitions at around 1 GHz from the $^1S_0$-$^3P_1$ transition of ^{174}Yb. We recently added a Zeeman slower to the setup to slow down the atomic beam using the 399 nm laser and are in the process of putting it into operation. The beam will then be cooled in the transversal directions in a 2D magneto-optic trap (MOT) on the same transition. Finally, a 3D-MOT will be implemented on the narrower transition at 556 nm, which has a Doppler temperature of 4,4 µK.

[1] Morel, L., Yao, Z., Cladé, P. *et al*. Determination of the fine-structure constant with an accuracy of 81 parts per trillion. *Nature* **588**, 61–65 (2020). https://doi.org/10.1038/s41586-020-2964-7

[2] C. Solaro et al., "Atom interferometer driven by a picosecond frequency comb", Physical Review Letters 129, 173204 (2022)

- Author: **Guido Giachetti**
  Title: "Elusive phase transition in the replica limit of monitored systems"
  Doctoral school: *PSL - Ecole Normale Superieure*
  Affiliation: *Laboratoire de Physique de l'Ecole Normale Superieure*

  The possibility of a phase transition between a low-entanglement and a high-entanglement phase in quantum systems due to the presence of external measurement has sparked a lot of interests in recent years. As a paradigmatic example, we studied an exactly solvable model of monitored dynamics in a system of N spin 1/2 particles with pairwise all-to-all noisy interactions, where each spin is constantly perturbed by weak measurements of the spin component in a random direction. We make use of the replica trick to account for the Born's rule weighting of the measurement outcomes in the study of purification and other observables, with an exact description in the large-N limit. We find that the nature of the phase transition strongly depends on the number n of replicas used in the calculation, with the appearance of non-perturbative logarithmic corrections that destroy the disentangled / purifying phase in the relevant $n \to 1$ replica limit. Specifically, we observe that the purification time of a mixed state in the weak measurement phase is always exponentially long in the system size for arbitrary strong measurement rates.



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