GDR DynQua : Book of abstracts

Angers : 4-6 2025 February

Speakers

Federica Agostini : Trajectory-based methods for photoinduced ultrafast processes
In this talk, I will discuss some theoretical and computational approaches to simulate the coupled electronic and nuclear dynamics underlying photoinduced processes.
The photoexcitation of a molecule by a femtosecond UV-visible laser triggers an ultrafast response characterized by the nonadiabatic coupling between electronic and nuclear motion. The photoexcited system relaxes either over time scales of the order of femtoseconds to picoseconds via non-radiative pathways, eg, conical intersections, or over longer time scales via radiative pathways, for instance via fluorescence. These relaxations bring the molecule to explore the nuclear configurations in the electronic excited states and to experience de-excitations mediated by the nuclear motion towards lower-lying states.
While this picture is quite clear in terms of quantum mechanics, simulations of realistic/complex molecules cannot be performed by solving the time-dependent Schrödinger equation due to the exponential scaling of the computational cost with the number of degrees of freedom. Therefore, a practical and widely-used solution is to mimic the nuclear dynamics using classical-like trajectories that are coupled to quantum electrons. However, there is not a unique way to introduce this quantum-classical perspective and to describe the coupling between classical nuclei and quantum electrons in nonadiabatic conditions.

Cristina Caraci : Quantum Fluctuations of Many-Body Dynamics around the Gross-Pitaevskii Equation
In this talk, we consider the evolution of a gas of N bosons in the Gross-Pitaevskii regime in three-dimensions, in which particles are initially trapped in a volume of order one and interact through a repulsive potential with scattering length of order 1/N. We construct a quasi-free approximation of the many-body dynamics, whose distance to the solution of the Schrödinger equation converges to zero as the number of particles goes to infinity, in the L^2-norm. As an application of this result, we show a central limit theorem for fluctuations of bounded observables around their expectation with respect to the Gross-Pitaevskii dynamics. This is a joint work with Jakob Oldenburg and Benjamin Schlein.

Laure Dumaz : Some aspects of the Anderson Hamiltonian in 1D
In this talk, we will present several results on the Anderson Hamiltonian with white noise potential in dimension 1. This operator formally writes « minus Laplacian plus white noise ». It arises as the scaling limit of various discrete models and its explicit potential allows for a detailed description of its spectrum. We will discuss localization of its eigenfunctions as well as the behaviour of the local statistics of its eigenvalues. Around large energies, we will see that eigenfunctions are delocalized and the operator limit takes a simple form "J ∂_t + 2*2 noise matrix" that can be linked to the hyperbolic carousel operators introduced in the random matrix context by Valko and Virag. Based on joint works with Cyril Labbé.

Antide Duraffour : Agmon estimates and spectral consequences
I will present my Ph.d contribution on the spectral analysis of 1d pseudodifferential operators. The presentation is twofold. First with Nicolas Raymond I adapted the Helffer-Sjöstrand method to tackle a specific class of pseudodifferential operators appearing after a microlocal reduction of the magnetic laplacian. Second I will present a work in progress with San Vu Ngoc and Yannick

Guedes-Bonthonneau where we interest ourselves in estimating with exponential sharpness the Bohr-Sommerfeld spectrum of non self-adjoint pseudodifferential operators under a specific condition on the energy sets.

Hugo Eulry : Gibbs measures in singular environments
Invariant measures play a crucial role in understanding the long-term behavior of dynamical systems, as they describe the statistical properties of the system's evolution over time. In this talk, we will focus on dynamics driven by a singular operator: the Anderson Hamiltonian, a Schrödinger operator where the potential is the spatial white noise, reflecting the roughness of the environment in which the system evolves.
We will study dynamics governed by this operator and investigate the construction of invariant measures in this singular framework. After introducing the corresponding Gaussian measure, the Anderson Gaussian Free Field, we will consider the associated quantization equation. Once the Gibbs measure is constructed using variational methods, we will explore the dynamical consequences for the Anderson Φ_2 model: invariance, probabilistic and deterministic globalization, the strong Feller property and ergodicity.
This is based on joint work with Antoine Mouzard (Université Paris-Nanterre) and Tristan Robert (Université de Lorraine)."

Maxime Ingremeau : Mini-course Random limits of highly oscillatory deterministic functions
The aim of these lectures is to present the notion of local weak limits. Such limits allow to understand the asymptotic properties of highly oscillatory functions (typically, solutions of PDEs with some small (or large) parameters), by comparing them with random functions. After presenting the construction of these limits, I will explain how they can be used to formulate Berry's random waves conjecture in quantum chaos. I will finish by presenting some situations where an analogue of Berry's conjecture can be proven, either for eigenfunctions on the torus (thanks to results by Bourgain), or for long-time propagated Lagrangian states on manifolds of negative curvature (results by Rivera, Vogel and myself).

Lucien Jezequel : The "Mode-Shell" correspondence, a unifying concept in topological waves
In quantum or classical wave systems, some properties of wave systems are known to be topologically protected. Due to their increased robustness, such properties have attracted much interest among physicists but also mathematicians.
The most studied case is the existence of unidirectional edge states in the quantum Hall effect and, more generally, the existence of protected states at the edges of topologically insulators. An important result is then the bulk-edge correspondence that links the existence of topological edge states to a topological index defined in the volume of the material.
This is not the only case studied in topological physics and different, yet similar, results have been obtained fior topological semimetals, higher order insulators or continuous wave systems. A link can also be made with much older mathematical results such as the Atiyah-Singer theorem of the Callias index formula. In this talk I will explain how all these results can be understood in a unifying theory using the mode-shell correspondence formalism which relates the existence of isolated topological modes in phase space, to a topological invariant defined in the surface which encloses these modes in phase space. Invariant that reduces to Chern or winding numbers in the semiclassical limit.

Jacquelin Luneau : Topological coupling between slow and fast quantum systems
We consider two slow bosonic modes coupled to a fast two-level system. We can interpret this system as a quantum simulator of a single particle in a two dimensional lattice by considering the number of photons in the two modes as synthetic dimensions. With a suitable coupling between the modes and the qubit, we obtain a quantum optical simulation of a Chern insulator under an electric field. The adiabatic dynamics leads to a topological pumping of energy between the two modes, also called topological frequency conversion (1,2).
However, the Hamiltonian is not properly translationnally invariant in the synthetic lattice. This leads to topologically distinct domains in the space of number of photons. The transition lines are associated to conical intersections leading to non-adiabatic Landau-Zener transitions. We show that the dynamics and the eigenstates lying in the topologically non trivial domain display quantum signatures of chaos (3).
Motivated by these recent works, we study the spectral properties of a topological insulator under a strong electric field. We show how the electric field hybridizes the edge modes with the bulk states. We describe this hybridization as an extension in energy of the spectral flow of edge modes (4).
(1) I. Martin, G. Refael, B. Halperin, Phys. Rev. X 7, 041008 (2017).
(2) J. Luneau, B. Douçot, D. Carpentier, SciPost Phys. 17, 112 (2024).
(3) J. Luneau, HAL Id: tel-04351529, https://theses.hal.science/tel-04351529 (2023).
(4) J. Luneau, T. Roscilde, B. Douçot, D. Carpentier, in preparation.

Ngoc Nhi Nguyen : Spectral cluster bounds for orthonormal functions on compact manifolds with non-smooth metrics There has been substantial recent interest in functional inequalities for systems of orthonormal functions. This talk focuses on a family of inequalities called "spectral cluster bounds", which concern L^p norms of eigenfunctions of the Laplace-Beltrami operator on a compact closed manifold. Since the seminal work of Sogge in the 1980's, these bounds have been generalized in various directions. Frank and Sabin recently established a version of Sogge's bounds for systems of orthonormal functions for smooth metrics. We will show that the same result holds for less regular metrics. The talk is based on joint ongoing work with Jean-Claude Cuenin.

Coni Rojas Molina : Spectral properties of the fractional Anderson model: conjectures, localization and local eigenvalue statistics
We review recent results on the spectral and dynamical properties of the fractional Anderson model, part of a research program on non-local Hamiltonians with diagonal disorder. We report on on-going work in collaboration with P. Hislop on the local eigenvalue statistics of the fractional Anderson model and the conjectures involving the spectral and dynamical transition expected in this setting.

Julien Royer : Energy decay for the wave equation in the asymptotically Euclidean setting
We consider the question of energy decay for the (possibly damped) wave equation in the asymptotically Euclidean setting. In even dimensions, we prove optimal estimates and provide the asymptotic profile of the solution for large times. In odd dimensions, we improve the best known estimates, and in particular we go beyond the decay rate which is optimal in even dimensions. The proof is based on resolvent estimates for the corresponding Helmholtz equation near energy 0. This is a joint work with Rayan Fahs.

Euan Spence : A case study in using semiclassical analysis in the numerical analysis of high-frequency wave problems

For the last 10 years, the main focus of my research has been in using tools from semiclassical analysis in the numerical analysis of high-frequency wave problems.

This talk will showcase a recent result in this research direction, namely, the first frequency-explicit convergence results about domain-decomposition methods for the high-frequency Helmholtz equation.

No knowledge of any numerical analysis/domain decomposition will be needed to understand this talk!

Posters

Mirna Charif : Asymptotic Behavior of Large Eigenvalues of the Two-Photon Asymmetric Quantum Rabi Model

The quantum Rabi model describes the simplest interaction between a two-level atom and a single-mode quantized radiation field. It is fundamental and widely used in quantum physics. The two-photon asymmetric quantum Rabi model is another type of quantum Rabi model in which the interaction occurs through the exchange of two photons, and the static bias is not necessarily zero. This model has been applied to describe the interaction between a two-level atom and squeezed light, quantum dots embedded in a cavity, trapped ion experiments, and superconducting circuits. The asymptotic formula for the m-th eigenvalue is obtained with a remainder estimate of the form $O(m^{-1}\ln m)$ as tends to infinity, which corresponds to the first-order approximation of large eigenvalues for this model.

Armand Coudray : Peeling-off behaviour of the wave equation on the Vaidya spacetime

In this poster I will present the results I have obtained on the asymptotic regularity of the scalar waves in a curved spacetime representing a dynamical spherical black hole. The regularity of the field is characterised in terms of Sobolev spaces instead of C^k spaces. This study is based on two aspects : on the one hand, I used the conformal methods developed by Penrose in the 60's, on the other hand, I worked with a Morawetz vector and I obtained energy estimates to control the norm (given by the energy of the field) of the asymptotic of the field by the norm of the initial data.

Viviana Grasselli : Number of bound states for fractional Schrödinger operators

We study the number of negative eigenvalues, counting multiplicities, of the fractional Schrödinger operator $H_s = (-\Delta)^s - V(x)$ on $L^2(\mathbb{R}^d)$ for any $d \geq 1$ and $s \geq d/2$. Our proof relies on a splitting of the Birman-Schwinger operator associated to this spectral problem into low- and high-energies parts, a projection of the low-energies part onto a suitable subspace, and, in the critical case $s = d/2$, a Cwikel type estimate to handle the high-energies part. In collaboration with Sébastien Breteaux and Jérémy Faupin.

Emma Grugier : Small eigenvalues of non-reversible metastable diffusion processes with Neumann boudary conditions

Let $\Omega \subset \mathbb{R}^d$ be a bounded smooth domain and $b : \Omega \to \mathbb{R}^d$ be a smooth vector field. We focus on the associated overdamped Langevin equation :

$$\dot{X}_t = b(X_t) + \sqrt{h}\dot{B}_t$$

in the low regime temperature where $h \to 0$ and in the case where b admits the decomposition $b = -\nabla f - l$ with :

- l a smooth vector field ;
- f a Morse function on $\overline{\Omega}$ admitting several local minima ;
- $\nabla f \cdot l = 0$ on $\overline{\Omega}$.

In this framework, minima of the function f correspond to metastable states for this Langevin dynamics. In this context, we analyse the spectrum of the infinitesimal generator of the dynamics :

$$L_h = -\frac{h}{2}\Delta + \nabla f \cdot \nabla + l \cdot \nabla$$

with Neumann boundary conditions. In this case, moving particles will remain trapped inside the domain. More specifically, we will consider additional hypotheses ensuring that the measure $e^{-\frac{2f}{h}}dx$ is invariant.

Diwakar Naidu : Momentum distribution of a high density Fermi gas in random phase approximation
The poster is about the momentum distribution of an interacting Fermi gas on a 3D torus in the mean field regime. The key tool for deriving the distribution is a rigorous bosonization method. I will start with the construction of a natural trial state and then show the implementation of the bosonization procedure. Finally, I will sketch how we obtain the momentum distribution in the mean-field approximation. The expression for the momentum distribution contains the contribution collective excitations above the Fermi-surface going beyond the precision of Hartree-Fock theory. This result is an extension of the previous result for the momentum distribution by Benedikter-Lill.

Éric Vacelet : Semiclassical measure of the propagation between two topological insulators
We study the propagation of a family of initial conditions in the presence of two topological insulators without magnetic field where the interface is a smooth connected curve not compact without boundaries. The solution is governed by an adiabatic modulation of a Dirac operator with a variable mass. We determine the evolution of the semiclassical measure of the solution with a two-scale Wigner measure method by reducing the Dirac operator to a normal form.

Michele Zaccaron : Bending and twisting in electromagnetic waveguides

Abstract: We investigate the effects of the geometrical deformations of bending and twisting on the propagation of electromagnetic waves in a guided structure. We do so by analyzing the corresponding Maxwell operator and providing conditions at infinity for the curvature and twist in order to preserve the essential spectrum, using a Birman-Schwinger type principle. We also discuss the possibility of existence of discrete eigenvalues in the perturbed waveguide, and provide a sufficient condition on the curvature for their existence.