

Soutenances de Thèses 2019

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Auditorium Irène Joliot-Curie de l'IPN

Soutenance de thèse

Many-body localization of two-dimensional disordered bosons

The study of the interplay between localization and interactions in disordered quantum systems led to the discovery of the interesting physics of many-body localization (MBL). This remarkable phenomenon provides a generic mechanism for the breaking of ergodicity in quantum isolated systems, and has stimulated several questions such as the possibility of a finite-temperature fluid-insulator transition. At the same time, the domain of ultracold interacting atoms is a rapidly growing field in the physics of disordered quantum systems.

In this Thesis, we study many-body localization in the context of two-dimensional disordered ultracold bosons. After reviewing some importance concepts, we present a study of the phase diagram of a two-dimensional weakly interacting Bose gas in a random potential at finite temperatures. The system undergoes two finite-temperature transitions: the MBL transition from normal fluid to insulator and the Berezinskii-Kosterlitz-Thouless transition from algebraic superfluid to normal fluid. At $T=0$, we show the existence of a tricritical point where the three phases coexist. We also discuss the influence of the truncation of the energy distribution function at the trap barrier, a generic phenomenon for ultracold atoms. The truncation limits the growth of the localization length with energy and, in contrast to the thermodynamic limit, the insulator phase is present at any temperature. Finally, we conclude by discussing the stability of the insulating phase with respect to highly energetic particles in systems defined on a continuum.

Directeur : Georgy Shlyapnikov

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Bertrand Lacroix à chez Toine

4 juin 2019
Auditorium Irène Joliot-Curie de l'IPN

Soutenance de thèse

Extreme value statistics of strongly correlated systems: fermions, random matrices and random walks

Predicting the occurrence of extreme events is a crucial issue in many contexts, ranging from meteorology to finance. For independent and identically distributed (i.i.d.) random variables, three universality classes were identified (Gumbel, Fréchet and Weibull) for the distribution of the maximum. While modelling disordered systems by i.i.d. random variables has been successful with Derrida's random energy model, this hypothesis fail for many physical systems which display strong correlations. In this thesis, we study three physically relevant models of strongly correlated random variables: trapped fermions, random matrices and random walks.

In the first part, we show several exact mappings between the ground state of a trapped Fermi gas and ensembles of random matrix theory. The Fermi gas is inhomogeneous in the trapping potential and in particular there is a finite edge beyond which its density vanishes. Going beyond standard semi-classical techniques (such as local density approximation), we develop a

precise description of the spatial statistics close to the edge. This description holds for a large universality class of hard edge potentials. We apply these results to compute the statistics of the position of the fermion the farthest away from the centre of the trap, the number of fermions in a given domain (full counting statistics) and the related bipartite entanglement entropy. Our analysis also provides solutions to open problems of extreme value statistics in random matrix theory. We obtain for instance a complete description of the fluctuations of the largest eigenvalue in the complex Ginibre ensemble.

In the second part of the thesis, we study extreme value questions for random walks. We consider the gap statistics, which requires to take explicitly into account the discreteness of the process. This question cannot be solved using the convergence of the process to its continuous counterpart, the Brownian motion. We obtain explicit analytical results for the gap statistics of the walk with a Laplace distribution of jumps and provide numerical evidence suggesting the universality of these results.

Directeur : Grégory Schehr

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Ivan Palaia

15 Novembre 2019

Petit Amphitheatre, batiment Pascal

Soutenance de thèse

Charged systems in, out of, and driven to equilibrium: from nanocapacitors to cement

Most systems in soft matter are immersed in solutions with charged species: some can be described by mean-field theories, others require more sophisticated techniques. In this thesis defense we focus on two such systems. Firstly, we analyze the relaxation dynamics of a nanocapacitor within the mean-field approach. We study relaxation times in the linear and nonlinear regime and characterize the behavior of the system as a function of salt density and applied voltage. The problem of designing a smart applied potential, to drive the system from an initial to a chosen final equilibrium state, is also tackled. We then discuss the physics of ionic correlations in charged systems, with particular focus on the phenomenon of like-charge attraction. We show the relevance of the strong coupling theory, that we apply to the nanoscopic constituents of cement. We demonstrate that the strong cohesion force of cement may be explained by a “dry water” picture, in excellent agreement with molecular dynamics simulations, thereby filling a gap in our understanding of the most used synthetic material in the world.

Directeur : Emmanuel Trizac

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Luca Barberi

21 novembre 2019

Petit Amphithéâtre, bâtiment Pascal

Soutenance de thèse

Inferring forces from geometry in biology

Inter-molecular forces on which we have poor prior knowledge are often essential for the stability and evolution of biological assemblies. In this thesis, we focus on two such forces that are critically involved in the deformation of either biopolymers or membranes. We infer these forces by reconciling the geometry of such deformation with simple mechanical models.

In the first part of the thesis, we consider the attractive force between DNA molecules mediated by multivalent cations. This attraction is required to compensate DNA bending rigidity when packaging large quantities of DNA in comparatively small environments, such as the nuclei of sperm cells. In vitro, multivalent cations drive DNA condensation into dense toroidal bundles. Geometrical data on DNA toroidal bundles give access to the competition between inter-helical attraction and DNA bending rigidity. From these data, we infer inter-helical forces and argue that the toroid curvature weakens the adhesion between DNA molecules.

In the second part of the thesis, we turn to the binding force of a membrane remodeling protein complex, ESCRT-III, to cellular membranes. ESCRT-III proteins assemble into membrane-remodeling polymers during many cellular processes, ranging from HIV budding to cytokinesis. The mechanism by which ESCRT-III polymers deform membranes is still unclear. In vitro, ESCRT-III polymers can reshape spherical membrane vesicles into helical tubes. We argue that helical tubes result from the peculiar positioning of membrane-binding sites on the surface of ESCRT-III polymers. Furthermore, we infer the binding force between ESCRT-III and membrane from the geometry of helical tubes.

Directeur : Martin Lenz

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