Olivier GIRAUD

7 avril 2015 Salle des conseils de l'IPN **Soutenance Habilitation à diriger des recherches**

Critical systems and quantum multifractality

Martin LENZ

19 juin 2015 Salle des conseils de l'IPN **Soutenance Habilitation à diriger des recherches**

On the microstructure of active cellular processes

Eukaryotic cells use a multitude of protein machines to regulate their own structure. In this thesis, we study how the geometrical arrangement of these interacting microscopic active elements sculpt the cell's own internal microstructure and its membrane enclosure.

We first focus on the mechanisms generating actomyosin contractility, a crucial driver of cell motion and organization. We question the current position of highly organized, sarcomeric contractility as the only possible mechanism to drive contractility. We propose an alternative mechanism, and show that only it can account for the observed contractility of disordered actomyosin assemblies. It moreover yields qualitatively new effects in intracellular force transmission, including stress reversal and amplification, consistent with experimentally observations in fiber networks.

We next elucidate some of the mechanisms through which the cell deforms and cuts its own membrane, thus enabling exchanges with the extracellular medium as well as between its internal compartments. We find that the function of the proteins responsible for this remodeling is strongly influenced by the mechanics of the membrane, and use these effects to elucidate the modes of operation of proteins clathrin and dynamin, as well as of protein complex ESCRT-III.

Anthony PERRET

22 juin 2015 Auditorium de l'IPN **Soutenance de thèse**

Statistique d'extrêmes de variables aléatoires fortement corrélées

La statistique des valeurs extrêmes est une question majeure dans divers contexte scientifiques. Cependant, la description de la statistique d'un extremum global est certainement une caractéristique importante mais celle-ci ne décrit la fluctuation que d'une seule variable, parmi un grand nombre de variables aléatoires. Une question naturelle qui se pose alors est la suivante: ces valeurs extrêmes sont-elles isolées, loin des autres variables ou bien au contraire existe-t-il un grand nombre d'autres variables proches de ces valeurs extrêmes ? Ces questions ont suscité l'étude de la densité d'état de ces événements quasi-extrêmes. Il existe pour cette quantité peu de résultats pour des variables fortement corrélées, qui pourtant est le cas de nombreux modèles fondamentaux. Deux pistes de modèles physiques de variables fortement corrélées pouvant être étudiés analytiquement se démarquent alors: les positions d'une marche aléatoire et les valeurs propres de matrice aléatoire. Ce sont les deux modèles que j'ai étudiés dans ma thèse et que je vais présenter durant cette soutenance.

Caterina DE BACCO

8 septembre 2015 Auditorium de l'IPN **Soutenance de thèse**

Decentralized network control, optimization and random walks on networks

In the last years several problems been studied at the interface between statistical physics and computer science. The reason being that often these problems can be reinterpreted in the language of physics of disordered systems, where a big number of variables interacts through local fields dependent on the state of the surrounding neighborhood. Among the numerous applications of combinatorial optimisation the optimal routing on communication networks is the subject of the first part of the thesis. We will exploit the cavity method to formulate efficient algorithms of type message-passing and thus solve several variants of the problem through its numerical implementation. At a second stage, we will describe a model to approximate the dynamic version of the cavity method which allows to decrease the complexity of the problem from exponential to polynomial in time. This will be obtained by using the Matrix Product State formalism of quantum mechanics. Another topic that has attracted much interest in statistical physics of dynamic processes is the random walk on networks. The theory has been developed since many years in the case the underneath topology is a d-dimensional lattice. On the contrary the case of random networks has been tackled only in the past decade, leaving many questions still open for answers. Unravelling several aspects of this topic will be the subject of the second part of the thesis. In particular we will study the average number of distinct sites visited during a random walk and characterize its behaviour as a function of the graph topology. Finally, we will address the rare events statistics associated to random walks on networks by using the large-deviations formalism. Two types of dynamic phase transitions will arise from numerical simulations, unveiling important aspects of this problems. We will conclude outlining the main results of an independent work developed in the context of out-of-equilibrium physics. A solvable system made of two Brownian particles surrounded by a thermal bath will be studied providing details about a bath-mediated interaction arising for the presence of the bath.

Silvia GRIGOLON

14 septembre 2015 Salle E de l'IPN **Soutenance de thèse**

Modeling and inference for biological systems: from auxin dynamics in plants to protein evolution

All biological systems are made of atoms and molecules interacting in a non-trivial manner. Such non-trivial interactions induce complex behaviours allowing organisms to fulfill their many vital functions. These features can be found in all biological systems at different levels, from molecules and genes up to cells and tissues. In the past few decades, physicists have been paying much attention to these intriguing aspects by framing them in network approaches for which a number of theoretical methods offer many powerful ways to tackle systemic problems. At least two different ways of approaching these challenges may be considered: *direct* modeling methods and approaches based on *inverse* methods. In this defense I am going to show how we made use of both approaches to study three different problems occurring on three different biological scales. The first part concerns the very early stages of tissue development in plants; it covers the model we proposed for understanding which features drive the spontaneous collective behaviour in space and time of the transporters which pump the phytohormone auxin out of plant cells. Then, at the cell level, I will go through my study of the intracellular molecular networks that implement auxin signaling in plants, examining how network structures affects network functions. Finally, I will talk about inference problems on structural properties of proteins. I will introduce a method we introduced to understand how conservation of protein function across different organisms constrains the evolution of protein sequences and their diversity.

Clélia DE MULATIER

12 octobre 2015 Auditorium de l'IPN **Soutenance de thèse**

Some contributions of the random walk theory to the study of stochastic neutron transport

One of the key goals of nuclear reactor physics is to determine the distribution of the neutron population within a reactor core. This population indeed fluctuates due to the stochastic nature of the interactions of the neutrons with the nuclei of the surrounding medium: scattering, emission of neutrons from fission events and capture by nuclear absorption. Due to these physical mechanisms, the stochastic process performed by neutrons is a branching random walk. For most applications, the neutron population considered is very large, and all physical observables related to its behaviour, such as the heat production due to fissions, are well characterised by their average values. Generally, these mean quantities are governed by the classical neutron transport equation, called linear Boltzmann equation.

During my PhD, using tools from branching random walks and anomalous diffusion, I have tackled two aspects of neutron transport that cannot be approached by the linear Boltzmann equation. First, thanks to the Feynman-Kac backward formalism, I have characterised the phenomenon of "neutron clustering" that has been highlighted for low-density configuration of neutrons and results from strong fluctuations in space and time of the neutron population. Then, I focused on several properties of anomalous (non-exponential) transport, that can model neutron transport in strongly heterogeneous and disordered media, such as pebble-bed reactors. One of the novel aspects of this work is that problems are treated in the presence of boundaries. Indeed, even though real systems are finite (confined geometries), most of previously existing results were obtained for infinite systems.

Ricardo MARINO ABASOLO

16 octobre 2015 Auditorium de l'IPN **Soutenance de thèse**

Number statistics in random matrices and applications to quantum systems

Random matrix theory has found many applications spanning a vast number of fields in physics and mathematics in the last two decades. Most recently, the equivalence between the statistics of eigenvalues of Gaussian Hermitian matrices and the position of ground-state harmonically confined 1-D fermionic particles has been studied to obtain many interesting and universal results in cold atoms. In my thesis, I explore this connection to solve the problem of determining quantum fluctuations of cold fermions using techniques from random matrix theory, expanding previous results that were restricted only to specific scaling limits of the spectrum to yield a full picture of the behavior of fluctuations of fermionic particles in one dimensional traps.

Andrii GUDYMA

28 octobre 2015 Auditorium de l'IPN **Soutenance de thèse**

Non-equilibrium dynamics of a trapped one-dimensional Bose gas

A study of breathing oscillations of a one-dimensional trapped interacting Bose gas is presented. Oscillations are initiated by an instantaneous change of the trapping frequency. In the thesis a 1D quantum Bose gas in a parabolic trap at zero temperature is considered, and it is explained, analytically and numerically, how the oscillation frequency depends on the number of particles, their repulsive interaction, and the trap parameters. We have focused on the many-body spectral description, using the sum rules approximation. The oscillation frequency is identified as the energy difference between the ground state and a particular excited state.

The existence of three regimes is demonstrated, namely the Tonks regime, the Thomas-Fermi regime and the Gaussian regime. The transition from the Tonks to the Thomas-Fermi regime is described in the terms of the local density approximation (LDA). For the description of the transition from the Thomas-Fermi to the Gaussian regime the Hartree approximation is used. In both cases the parameters where the transitions happen are found. The extensive diffusion Monte Carlo simulations for a gas containing up to N = 25 particles is performed. As the number of particles increases, predictions from the simulations converge to the ones from the Hartree and LDA in the corresponding regimes. This makes the results for the breathing mode frequency applicable for arbitrary values of the particle number and interaction. The analysis is completed with the finite N perturbative results in the limiting cases. The theory predicts the reentrant behavior of the breathing mode frequency when moving from the Tonks to the Gaussian regime and fully explains the recent experiment of the Innsbruck group.