

**21ème conférence Claude
Itzykson - Dynamics, Disorder
and Localization in Interacting
Quantum Many Body Systems**

**Rapport sur les
contributions**

ID de Contribution: 18

Type: **Invited talk**

Weak Localization and Time-Reversal Symmetry: quantum simulation with ultra-cold atoms

lundi 13 juin 2016 14:30 (45 minutes)

In the early 1980's, observation of a magneto-resistance anomaly in metallic thin films was attributed to the phenomenon of weak localization of electrons and to time-reversal symmetry breaking due to a magnetic field acting upon charged particles.

We have observed weak localization of ultra-cold atoms in a 2D configuration, placed in a disordered potential created by a laser speckle. In order to manipulate time-reversal symmetry with our neutral atoms, we take advantage of the slow evolution of our system, and we observe the suppression and revival of weak localization when time reversal symmetry is cancelled and reestablished.

K. Muller, J. Richard, V. V. Volchkov, V. Denechaud, P. Bouyer, A. Aspect, and V. Josse, "Suppression and Revival of Weak Localization through Control of Time-Reversal Symmetry," Physical Review Letters 114 (20)(2015).

Orateur: ASPECT, Alain (Institut d'Optique, Palaiseau, France)

Classification de Session: Afternoon Session1

ID de Contribution: 19

Type: **Invited talk**

Thermalization and many-body localization in systems under dynamic nuclear polarization

mercredi 15 juin 2016 11:30 (45 minutes)

A generic isolated quantum system has two possible fates at long times: it thermalizes or it remains many-body localized close to its initial state. So far only few systems showing experimentally relevant consequences of many-body localization have been reported in cold atoms and in trapped ions. In this talk, we show that the phenomenon is relevant in quantum magnets, and we discuss how the two dynamical phases can affect the driven state of quantum magnets. In particular we will focus on Dynamical Nuclear Polarization - a technique used to hyperpolarize nuclear spins- and show that its efficiency strongly depends on the tendency of the interacting spins to thermalize.

Orateur: ROSSO, Alberto (CNRS and LPTMS)**Classification de Session:** Morning Session 2

ID de Contribution: 20

Type: **Invited talk**

Applying Wegner's flow equation formulation of the renormalization group method to systems with strong disorder

mercredi 15 juin 2016 14:30 (45 minutes)

The conventional formulation of the renormalization group, which works by iteratively “integrating” out high energy degrees of freedom, is aimed at describing states near the top or bottom of a spectrum. Wegner's flow equation is an alternative formulation that is aimed at describing the entire spectrum by iteratively decoupling degrees of freedom of the system that have large energy separations. We apply Wegner's flow equations to two problems: (1) Anderson localization with on-site disorder and long range power-law hopping and (2) the problem of identifying local conserved quantities in many-body localized systems.

Orateur: PEKKER, David (University of Pittsburgh)

Classification de Session: Afternoon Session1

ID de Contribution: 21

Type: **Invited talk**

Many body localization without quenched disorder?

mardi 14 juin 2016 15:15 (45 minutes)

I explore the possibility that translationally invariant quantum many body systems may undergo a transition to a localized phase where ergodicity and translational invariance break down spontaneously. This phenomenon could be regarded as an interaction-induced many-body localization on configurational (self-generated) disorder.

I will argue that such quantum glasses are indeed stable to perturbative quantum fluctuations at low enough orders. I will then discuss caveats due to high orders in perturbation theory which appear strongly suppressed but cannot be controlled. Those have interesting implications on the possible phase diagrams of systems with or without quenched disorder, as well as on the possibility of many-body mobility edges as a function of energy.

Orateur: MULLER, Markus (Paul Scherr Institute and ICTP)

Classification de Session: Afternoon Session1

ID de Contribution: 22

Type: **Invited talk**

Ergodic transition on the random regular graph: the exact diagonalization results

lundi 13 juin 2016 17:15 (45 minutes)

We show that the Anderson model on the random regular graph (RRG) possesses two transitions. One of them is the usual localization transition that happens at the disorder strength $W=W_{\{c\}} \approx 18.2$ and the other one is the first order transition between the extended ergodic and non-ergodic (multifractal) states. It happens at $W=W_{\{E\}} \approx 10.0$ and manifests itself in the sharp jump in the fractal dimensions $D_{\{1\}}$ and $D_{\{2\}}$ which is seen at a finite number of sites $N > 100\,000$ in the RRG. The results are compared with the calculations of the “Lyapunov exponent” for growing imaginary part of the particle self-energy by the generalized population dynamics method. The results are published as a preprint in arXiv:1605.02295.

Orateur: KRATSOV, Vladimir (ICTP Trieste)**Classification de Session:** Afternoon Session2

ID de Contribution: 23

Type: **Invited talk**

Probing Many-Body Localisation from an Ultracold Atom Perspective

mardi 14 juin 2016 09:30 (45 minutes)

A fundamental assumption in statistical physics is that generic closed quantum many-body systems thermalise under their own dynamics. Recently, the emergence of many-body localised (MBL) systems has questioned this concept, challenging our understanding of the connection between statistical physics and quantum mechanics. In my talk, I will report on several recent experiments carried out in our group on the observation of Many-Body Localisation in different scenarios, ranging from 1D fermionic quantum gas mixtures in Aubry-André type disorder potentials to 2D systems of interacting bosons in 2D random potentials. It is shown that the memory of the system on its initial non-equilibrium state can serve as a useful indicator for a non-ergodic, many-body localised phase.

Our experiments represent a demonstration and in-depth characterisation of many-body localisation, often in regimes not accessible with state-of-the-art simulations on classical computers.

Orateur: BLOCH, Immanuel (Max Planck Institute of Quantum Optics, Garching, Germany Ludwig-Maximilians University, Munich, Germany)

Classification de Session: Morning Session1

ID de Contribution: 24

Type: **Invited talk**

Many-body localization and global symmetries

mardi 14 juin 2016 11:30 (45 minutes)

In this talk, I will describe some general constraints on the existence of many-body localized (MBL) phases in the presence of global symmetries. I will start by considering the example of the random-bond XXZ spin chain and argue using real space renormalization group techniques that interactions drive the system into a many-body localized spin glass phase with spontaneously broken particle-hole symmetry. Based only on representation theory, I will then derive some general Mermin-Wagner-type principles governing the possible fates of non-equilibrium dynamics in isolated, strongly disordered quantum systems. In particular, I will show that MBL cannot exist in the presence of non-Abelian symmetries. Consequences for the classification of MBL protected topological phases (and Floquet phases) will be discussed.

Orateur: VASSEUR, Romain (University of California Berkeley)

Classification de Session: Morning Session 2

ID de Contribution: 25

Type: **Invited talk**

Quantum Magnetism with Trapped Ions

mercredi 15 juin 2016 09:30 (45 minutes)

Trapped atomic ions represent a very clean platform for the quantum simulation of interacting spin models. When spin-dependent optical dipole forces are applied to a collection of trapped ions, an effective long-range quantum magnetic interaction arises, with reconfigurable and tunable graphs that are determined by the spectrum of the laser forces. Recent experiments have implemented transverse Ising or XY models with up to 20 trapped ions, and this seminar will cover recent experimental results, from studies of equilibrium ground states [1,2], dynamics [3,4], and manybody localization [5] to the implementation of certain interacting spin-1 models [6] that may show certain topologically-ordered ground states. Soon these experiments will be extended to >20 spins, where no classical computer can predict its behavior, particularly the many-body dynamics. Such results are expected to shed light on the behavior of spin-liquids and other interesting forms of magnetism that feature frustration and massive entanglement.

[1] R. Islam, et al., Science 340, 583 (2013).

[2] P. Richerme, et al., Phys. Rev. Lett. 111, 100506 (2013).

[3] P. Richerme, et al., Nature 511, 198 (2014).

[4] C. Senko, et al., Science 345, 430 (2014).

[5] J. Smith, et al., arXiv 1508.07026 (to appear in Nature Physics, 2016).

[6] C. Senko, et al., Phys. Rev. X 5, 021026 (2015).

Orateur: MONROE, Christopher (JQI and University of Maryland)

Classification de Session: Morning Session1

ID de Contribution: 26

Type: **Invited talk**

Decay of correlations and absence of superfluidity in the disordered Tonks-Girardeau gas

lundi 13 juin 2016 12:15 (20 minutes)

In view of the woefully short list of rigorous results on disordered systems with interaction, limiting or integrable model systems present a testing ground for numerical works, conjectures and ideas. In the bosonic case, the limiting case of hard-core repulsive interaction is such an example: in the lattice set-up this amounts to studying the XY-spin Hamiltonian with a random magnetic field, and in the continuum this is the Tonks-Girardeau model with a random potential. Both models can be related to non-interacting fermions in an external random potential.

In this talk I will mainly report on results concerning the Tonks-Girardeau gas subject to a random external potential.

If the disorder is such that the underlying one-particle Hamiltonian displays localization, which is known to be generically the case, correlations in the many-body eigenstates are shown to decay exponentially. Moreover, there is no Bose-Einstein condensation and no superfluidity, even at zero temperature.

(This is based on joint works with R. Sims and R. Seiringer.)

Orateur: WARZEL, Simone (Technical University of Munich)

Classification de Session: Morning Session 2

ID de Contribution: 27

Type: **Invited talk**

Dicke Subradiance vs Anderson localisation: a classical many body problem

lundi 13 juin 2016 15:15 (45 minutes)

The quest for Anderson localization of light is at the center of many experimental and theoretical activities. Cold atoms have emerged as interesting quantum system to study coherent transport

properties of light. Initial experiments have established that dilute samples with large optical thickness allow studying weak localization of light.

The goal of our research is to study coherent transport of photons in dense samples. One important aspect is the quest of Anderson localization of light with cold atoms and its relation to Dicke super- or subradiance and possibly to many body physics with long range interactions.

In this talk I will give present results on past and present results on cooperative scattering of light by cold atoms.

Orateur: KAISER, Robin (CNRS and INLN, Nice)

Classification de Session: Afternoon Session1

ID de Contribution: 28

Type: **Invited talk**

Constructing Many-Body Localized Eigenstates: Questions and Answers

lundi 13 juin 2016 10:15 (45 minutes)

For a weakly interacting quantum spin chain with random local interactions, we prove that many-body localization follows from a physically reasonable assumption that limits the extent of level attraction in the statistics of eigenvalues. In a KAM-style construction, a sequence of local unitary transformations is used to diagonalize the Hamiltonian by deforming the initial tensor-product basis into a complete set of exact many-body eigenfunctions. We discuss prospects for the level-statistics problem and for results in higher dimensions.

Orateur: IMBRIE, John (University of Virginia)

Classification de Session: Morning Session1

ID de Contribution: 29

Type: **Invited talk**

Many-body localization and periodically driven systems

mardi 14 juin 2016 10:15 (45 minutes)

Periodic driving provides an efficient way of quantum control. In particular, in recent experiments driving was used to realize topological Bloch bands in optical lattices. In this talk, I will present several rigorous results regarding periodically driven many-body systems. First, I will derive strong bounds on the heating rates of generic many-body systems. I will introduce a new approach based on a series of local unitary transformations, and will use it to show that, at times shorter than the (parametrically long) heating time scale, system's dynamics is well described by a time-independent effective Hamiltonian. Our approach can be extended to analyze the effects of coupling to a heat bath and slow turn-on of the drive. Second, I will show that strong disorder can induce many-body localization (MBL) in periodically driven systems. This phase, realized at high driving frequency, is characterized by the absence of heating and emergence of a complete set of local integrals of motion. I will argue that at low driving frequency delocalization is inevitable. Therefore, there is an MBL-delocalization transition as a function of driving frequency. I will close by discussing experimental implications.

Orateur: ABANIN, Dmitry (University of Geneva)**Classification de Session:** Morning Session1

ID de Contribution: 30

Type: **Invited talk**

Probing many-body localized phase and delocalization transition with matrix elements

mercredi 15 juin 2016 12:15 (45 minutes)

Many body localization allows quantum systems to escape thermalization via emergence of extensive number of conserved quantities. I will demonstrate how the breakdown of local conserved quantities allows to probe the delocalization transition. Using statistics of matrix elements of local operators, I will define an analogue of many-body Thouless conductance which probes the response of the system to local perturbations. Its scaling allows to locate the MBL transition, and predicts onset of logarithmically slow transport at the MBL transition, consistent with results from the renormalization group. In addition, I will demonstrate the power-law form of the entanglement spectrum in the MBL phase, which follows from existence of local conserved quantities. I will discuss general implications of this result for variational studies of highly excited eigenstates in many-body localized systems, and show an implementation of a matrix-product state algorithm which allows us to access the eigenstates of large systems close to the delocalization transition.

Orateur: SERBYN, Maksym (University of California Berkeley)**Classification de Session:** Morning Session 2

ID de Contribution: 31

Type: **Invited talk**

Many-Body Localization Characterized from a One-Particle Perspective

mardi 14 juin 2016 12:15 (45 minutes)

We show that the one-particle density matrix ρ can be used to characterize the interaction-driven many-body localization transition in closed fermionic systems. The natural orbitals (the eigenstates of ρ) are localized in the many-body localized phase and spread out when one enters the delocalized phase, while the occupation spectrum (the set of eigenvalues of ρ) reveals the distinctive Fock-space structure of the many-body eigenstates, exhibiting a steplike discontinuity in the localized phase. The associated one-particle occupation entropy is small in the localized phase and large in the delocalized phase, with diverging fluctuations at the transition. We analyze the inverse participation ratio of the natural orbitals and find that it is independent of system size in the localized phase. We furthermore study the dynamical properties of the natural orbitals after a) a global quantum quench from a product state, and b) after adding or removing a natural orbital quasiparticle from an eigenstate.

Orateur: BARDARSON, Jens (MPI-PKS, Dresden)**Classification de Session:** Morning Session 2

ID de Contribution: **32**

Type: **Invited talk**

TBA

lundi 13 juin 2016 16:30 (45 minutes)

TBA

Orateur: ALTSHULER, Boris (Columbia University)

Classification de Session: Afternoon Session2

ID de Contribution: **33**

Type: **Invited talk**

TBA

mardi 14 juin 2016 16:30 (45 minutes)

TBA

Orateur: CUGLIANDOLO, Leticia (LPTHE, UPMC Paris VI)

Classification de Session: Afternoon Session2

ID de Contribution: 34

Type: **Invited talk**

Bringing together views on many-body localisation

mercredi 15 juin 2016 15:15 (45 minutes)

The phenomenon of many-body localisation received a lot of attention recently, both for its implications in condensed-matter physics of allowing systems to be an insulator even at non-zero temperature as well as - maybe most importantly - in the context of the foundations of quantum statistical mechanics, providing examples of systems showing the absence of thermalisation following out-of-equilibrium dynamics. Still, it seems fair to say that many aspects of it are still unsatisfactorily understood.

In this talk, following an introduction into recent progress on thermalisation of closed quantum systems, I will make the attempt to bring together several aspects of the phenomenology of many-body localisation, attaining new insights into the connections between seemingly unrelated features. Ideas of entanglement area laws, Lieb-Robinson bounds, filter functions, approximately local constants of motion, transport, and tensor network states such as matrix-product states and matrix-product operators will feature strongly. We will discuss experimentally accessible witnesses of many-body localisation in cold atomic quantum simulators that have the potential to clearly distinguish Anderson insulators from many-body localised models.

Orateur: EISERT, Jens (Free University, Berlin)

Classification de Session: Afternoon Session1

ID de Contribution: 35

Type: **Invited talk**

From Quantum Glass Transitions to MBL

mardi 14 juin 2016 14:30 (45 minutes)

In this talk the transition of a quantum system from an ergodic to a non-ergodic state is discussed from several different perspectives. In the first part of the talk I discuss the formation of quantum glasses in liquids with no quenched disorder. It is shown that weak quantum fluctuations can enhance the loss of ergodicity. In the second part of the talk I discuss many-body localization (MBL), with a focus on dynamics in the thermal phase as well as the question of putative MBL in systems with completely delocalized single particle states. Similarities and differences between standard glass transitions and MBL are discussed.

Orateur: REICHMAN, David (Columbia University)**Classification de Session:** Afternoon Session1

ID de Contribution: **36**

Type: **Invited talk**

TBA

mercredi 15 juin 2016 10:15 (45 minutes)

TBA

Orateur: GOPALAKRISHNAN, Sarang (California Institute of Technology)

Classification de Session: Morning Session1

ID de Contribution: 37

Type: **Invited talk**

TBA

lundi 13 juin 2016 18:00 (45 minutes)

TBA

Orateur: ALEINER, Igor (Columbia University)

Classification de Session: Afternoon Session2

ID de Contribution: 38

Type: **Invited talk**

Influence of an imperfect bath on an MBL system

lundi 13 juin 2016 11:00 (45 minutes)

In this talk, I will consider a fully MBL system coupled to an imperfect bath, representing a small (microscopic or mesoscopic) chunk of an ergodic material. This set-up arises naturally since disorder fluctuations naturally lead to the formation of such spots inside the MBL phase. My aim is to describe the intermediate region arising in the vicinity of the ergodic spot. I will provide a simple theoretical framework to do so, and present some preliminary numerical results to test the validity of the theory. This analysis has strong implications on the question of the stability of the localized phase.

From collaboration with Wojciech De Roeck

Orateur: HUVENEERS, Francois (Paris Dauphine, CEREMADE)

Classification de Session: Morning Session1

ID de Contribution: 39

Type: **Invited talk**

Discussion Session: Quantum Glasses vs MBL

mardi 14 juin 2016 17:15 (45 minutes)

Orateur: IOFFE, Lev (Rutgers University and CNRS, LPTHE UPMC)

Classification de Session: Afternoon Session2

ID de Contribution: **40**

Type: **Invited talk**

Discussion Session: New Methods for MBL

mercredi 15 juin 2016 16:00 (45 minutes)

Orateur: ALET, Fabien (CNRS and Universite' de Toulouse, LPT)

Classification de Session: Afternoon Session1