EnIQMa 2017

ABSTRACTS

Bruno Laburthe-Tolra (Paris XIII)

Out-of-equilibrium magnetism of tilted dipoles

We have studied spin mixing dynamics in a chromium dipolar Bose-Einstein Condensate, after tilting the atomic spins by an angle θ with respect to the magnetic field. Spin mixing is triggered by dipole-dipole interactions. However, once dynamics has started, dynamics is mostly driven by contact interactions. We have found that, surprisingly, the initial ferromagnetic character of the gas is locally preserved, an unexpected feature that we have attributed to large spin-dependent contact interactions.

We have performed additional experiments for bosonic Chromium atoms loaded into deep optical lattices. The system then consists of an array of localized spins interacting at a distance by dipole-dipole interactions. We have compared our experimental results with numerical simulations developed in the group of A. M. Rey at Boulder, Colorado, together with Johannes Schachenmayer. We find that our experimental results disagree with the simple classical equations, but find significantly better agreement with simulations taking into account quantum correlations.

Johannes Schachenmayer (Université de Strasbourg)

Simulating quantum many-body dynamics with discrete Wigner functions

Novel experiments with e.g. ultracold atoms offer platforms for studying non-equilibrium dynamics of large quantum many-body models in controlled environments. Thus, also numerical methods for simulating such dynamics are of great importance. While in 1D techniques based on matrix product states have been very successful, computing dynamics in higher dimensions remains to be a challenge. Here, I present the DTWA, a semi-classical method based on the well-known truncated Wigner approximation. This method has been surprisingly successful in predicting dynamics of lattice spin-1/2 models, particularly in high dimensional systems. I show how this method can be generalized to study dynamics of arbitrary discrete lattice models.

Laurent Sanchez-Palencia (Ecole Polytechnique, Palaiseau)

Universal scaling laws for correlation spreading in quantum systems with variable-range interactions

In quantum systems with short- or long-range interactions, the spreading of information is constrained by the so-called Lieb-Robinson (LR) bounds, also known as the causality cone. For long-range interactions, the bounds are super-ballistic and the cone is bent. Recent experimental and numerical work has demonstrated bounded propagation of information. However, the observed propagation does not fit the known bounds and show ballistic or slower-than-ballistic behavior. The known LR bound thus appear to loose. Here, we show that, after a quantum quench, the causality cone features a double structure whose scaling laws can be related to a set of universal microscopic exponents that we determine. When the system supports excitations with a bounded group velocity, we find that the correlation edge moves ballistically, with a velocity equal to twice the maximum group velocity, while the dominant correlation maxima propagate with a different velocity that we derive. When the maximum group velocity diverges, as realized with long-range interactions, we show that the correlation edge is *slower than ballistic*. The motion of the maxima is, instead, either *faster than ballistic*, for gapless systems, or *ballistic*, for gapped systems. Our results have fundamental consequences on information spreading in correlated quantum systems and shed new light on existing experimental and numerical observations, for which our analysis provides a unified picture.

References

. [1] G. Carleo et al., "Light-cone effect and supersonic correlations in one- and two-dimensional bosonic superfluids", Phys. Rev. A 89, 031602(R) (2014).

. [2] L. Cevolani, G. Carleo, and L. Sanchez-Palencia, "Protected quasi-locality in quantum systems with long-range interactions", Phys. Rev. A 92, 041603(R) (2015).

. [3] L. Cevolani, G. Carleo, and L. Sanchez-Palencia, "Spreading of correlations in exactly-solvable quantum models with long-range interactions in arbitrary dimensions", New J. Phys. 18, 093002 (2016).

. [4] L. Cevolani, J. Despres, G. Carleo, L. Tagliacozzo, and L. Sanchez-Palencia, "Universal scaling laws for correlation spreading in quantum systems with short- and long-range interactions", arXiv:1706.00838.

Tarik Yefsah (ENS Paris)

Probing Local Correlations in a Unitary Fermi gas

We will present a measurement of local correlations in a Unitary Fermi gas, where immersed Bose impurities are used as a probe. We will first show that the three-body recombination rate in a Bose-Fermi mixtures, can be quantitatively related to the Contact of the Unitary gas. Second, I will present our measurements on a 7Li/6Li mixture, where we probe the recombination rate in both the thermal and dual superfluid regimes. At unitarity where the fermion-fermion scattering length diverges, we find that the loss rate is proportional to the 4/3 power of the fermionic density. This unusual exponent signals non-trivial two-body correlations in the system. Furthermore, we obtain a local measurement of the homogeneous contact at low temperature, in agreement with previous measurements based on thermodynamics and Bragg spectroscopy. Our results demonstrate that few-body losses can be used as a quantitative probe of quantum correlations in many-body ensembles. Specifically, it opens the possibility to measure quantitatively the Contact of the Unitary Fermi gas through the Normal-to-Superlfluid transition, where several theoretical models disagree.

Fabien Alet (Univ. Paul Sabatier - Toulouse)

Many-Body Localization: overview and some recent developments

I will try to provide a brief, most likely biased and incomplete, overview on the topic of many-body localization, including open questions in the field. If time allows, I will also present preliminary results on the possibility of many-body localization in dimension larger than one.

Nicolas Regnault (ENS Paris)

Many body localization and thermalization: (machine) learning from the entanglement spectrum

We numerically explore the many body localization transition through the lens of the entanglement spectrum, i.e. the spectrum of the reduced density matrix. We show that a simple artificial neural network trained on entanglement spectra of individual states of a many-body quantum system can be used to determine the transition between a many-body localized and a thermalizing regime.Furthermore, we analyze the network operation using the dreaming technique to show that the neural network correctly learns by itself the power-law structure of the entanglement spectra in the many-body localized regime.

Giuliano Orso (Paris VIII)

2D Anderson transitions of ultracold atoms with synthetic spin-orbit interactions

We investigate the impact of spin-orbit interactions on the transport properties of cold atoms moving in a correlated 2D disorder potential generated by laser speckles.
By combining a high order discretization scheme for the Schrodinger equation with the transfer matrix method, we show that the system exhibits anti-localization and 2D Anderson transitions driven by spin-interference effects. We calculate the precise position of the mobility edge and show that the transition disappears when the Rashba and Dresselhauss spin-orbit couplings become equal, due to a change of the universality class.

Nicolas Cherroret (Paris VI)

Novel perspectives from Anderson localization of matter waves

In the last decades, the field of atom optics has allowed for accurate experimental investigations of quantum transport with cold atoms. In this context, the physics of Anderson localization (AL) of interacting and non-interacting waves in disordered environments can today be finely studied, using tunable atomic matter waves in well controlled optical random potentials.
After briefly introducing the main concepts of atom optics in random optical potentials, I will address the problem of the out-of-equilibrium evolution of a non-interacting matter wave in a random potential. The discussion will be focused on two different dynamical scenarios where unexpected and somehow counter-intuitive manifestations of AL show up. The first scenario will be concerned with the spatial spreading of a narrow wave packet of zero mean velocity. AL then manifests itself as a "mesoscopic echo" effect in the density distribution, a phenomenon which has been first observed experimentally with cold atoms only recently. In the second scenario, I

will consider the evolution of a wave packet to which a finite mean velocity has been impulsed. In this case, AL leads to a surprising "quantum boomerang" effect of the center of mass, signaling a retro-reflection of the wave packet in the random potential.

Radu Chicireanu (Univ. Lille)

Symmetry and localization in a disordered quantum system

TBA

Patrizia Weiss (Univ. Nice)

Interplay of subradiance and radiation trapping in cold atom clouds

Radiation trapping [1,2] as well as subradiance [3] lead to significantly slower decay times in cold atomic clouds compared to the single atom fluorescence decay time. Even though both show similar signatures the origin of the slowed down decay is different. Radiation trapping occurs close to resonance as an effect of multiple scattering and can be described with classical scattering in a random walk model without any interference effects. While subradiance is also visible for large detuning and is due to cooperative effects of the atoms one need the electric field and has to take into account interference effects.
We want to show what is the interplay between both effects in a cold cloud of rubidium atoms and further how to distinguish between both.

References

1. G. Labeyrie, E. Vaujour, C.A. Müller, D. Delande, C. Miniatura, D. Wilkowski, R.Kaiser, Phys. Rev. Lett. **91**, 223904 (2003)
2. G. Labeyrie, R. Kaiser, D. Delande Appl. Phys. B **81**, 1001 (2005)
3. W. Guerin, M. O. Araújo, R. Kaiser Phys. Rev. Lett. **116**, 083601 (2016)

Cristiano Ciuti (Paris VII)

Critical slowing down in driven-dissipative Bose-Hubbard lattices

The manybody physics of photons is the subject of fundamental theoretical studies and experimental investigations in a wide variety of nonlinear optical platforms including semi-conductor microcavities, superconducting quantum circuits and atomic Rydberg gases. In the broader context of open manybody systems, a growing interest is emerging for dissipative phase transitions, i.e., critical phenomena affecting the manybody mixed steady-state. Here, we will present our recent theoretical results [1] predicting the dynamical properties of a first-order dissipative phase transition in coherently driven Bose-Hubbard systems, describing, e.g., lattices of coupled optical cavities with on-site Kerr nonlinearity. Via stochastic trajectory calculations based on the truncated Wigner approximation, we predict the size-dependent physics in 1D and 2D lattices in the regime where mean-field theory predicts nonlinear bistability. We show that a critical slowing down emerges in 2D lattices for increasing lattice size, while it is absent in 1D arrays. We characterize the peculiar properties of the collective phases in the critical region.

[1] F. Vicentini, F. Minganti, R. Rota, G. Orso, C. Ciuti, arXiv:1709.04238 and references therein.

Frédéric Hébert (Univ. Nice)

Collective behavior of light and matter

We will present two examples of collective behaviors of matter interacting with light. We will first study an assembly of Rabi systems, several two level systems with fixed positions being coupled to modes of an electromagnetic field, which describres the physics of circuit QED systems. At equilibrium we will show that the system shows a physics similar to the Dicke model. Second, we will study itinerant bosons interacting with an electromagnetic field mode, which describes recent experiments of cold atoms in cavities and show that, through a long range interaction mediated by the field, the bosons can adopt a supersolid phase.

Guido Pupillo (Univ. Strasbourg)

Cavity-enhanced transport of charge

We discuss the effects on charge conductivity in a molecular semiconductor of coupling intra-molecular electronic transitions to the bosonic field of a cavity or of a plasmonic structure prepared in its vacuum state [1]. We present a proof-of-principle model where this coupling leads to a light-matter hybridization - the dressed fermionic bands interact via absorption and emission of dressed cavity-photons - that ultimately provides an enhancement of charge conductivity in the steady-state. We discuss the role of the finite electronic band-width in the dressing, and explain how this affects the current enhancement. We demonstrate that under certain experimentally relevant conditions the enhancement can reach orders of magnitudes and discuss the relevance of these results to recent experiments with organic semi-conductors, where a dramatic enhancement of charge conductivity was demonstrated [2]. We conclude with a discussion of open questions.

[1] Cavity-enhanced transport of charge, D. Hagenmueller, J. Schachenmayer, S. Schuetz, C. Genes, and G. Pupillo, arXiv:1703.00803 (2017).
[2] Conductivity in organic semiconductors hybridized with the vacuum field, E. Orgiu et al., Nature Materials 14, 1123-1129 (2015).

Jakob Reichel (ENS Paris - Paris VI)

Generating multiparticle entanglement with optical fiber microcavities

Multiparticle entanglement is a key feature of quantum many-body dynamics and a resource for quantum technologies. High-finesse optical cavities are a powerful tool to produce and detect such entanglement in ultracold atoms. I will show some examples from recent experiments in our group with fiber microcavities on atom chips. One application is quantum metrology, and I will describe progress towards a spin-squeezed atomic clock on a chip.

Guillaume Roux (Univ. Paris Sud)

Spin models emulated on an analog quantum simulator with circular Rydberg states

A proposal for a novel quantum analog simulator based on trapped circular Rydberg states is introduced. After presenting the envisioned experimental setup and its main assets, we discuss the model corresponding to a trapped spin chain. Next, we show how the residual motion of the atoms, treated classically, can be almost decoupled from the spin dynamics. The example of the adiabatic preparation of the ground-state through a quantum phase is discussed. Last, we draw some perspectives on possible problems that could be addressed with such device.
Ref: arXiv:1707.04397.

Marc Cheneau (Institut d'Optique, Palaiseau)

Two-particle, four-mode interferometer for atoms

The demonstration of non-classical interference effects has been a crucial enterprise in the history ofquantum physics. This has played a role in stimulating quantum information theories, but has also providedbenchmarking experiments for quantum information protocols. Two examples are the observation of theHong–Ou–Mandel effect and the violation of Bell's inequalities using photons. Thanks to recent progress,similar experiments have become possible using massive particles (e.g. atoms or electrons).
In this talk, I will present a recent experiment performed with metastable Helium-4 atoms. We implemented atwo-atom, four-mode interferometerwhose geometry was inspired by the Rarity–Tapster Bell inequality violation experiment. Our observations yields firstindications that the atom pairs are entangled [1]. Such experiment brings rare demonstrations of two-particleinterferences formassive particles and open the way to a genuine test of a Bell inequality using themomentum degree of freedom.

[1] P. Dussarrat et al., "Two-atom, four mode interferometer", arXiv:1707.01279.

Jérôme Dubail (Univ. Nancy)

Generalized Hydrodynamics of the 1d Bose gas in the Quantum Newton Cradle setup

The theory of generalized hydrodynamics (GHD) [Castro-Alvaredo, Doyon, and Yoshimura, Phys. Rev. X **6**, 041065, 2016; Bertini, Collura, De Nardis, Fagotti Phys. Rev. Lett. **117**, 207201, 2016] was recently developed as a new tool for the study of time evolution of inhomogeneous many-body interacting systems with infinitely many conserved charges. It supersedes the widely used conventional hydrodynamics of one-dimensional Bose gases, and offers an efficient quantitative description of experimental setups that were previously beyond the reach of modern analytical and numerical methods. I will illustrate this in the setup of the Quantum Newton Cradle experiment [Kinoshita, Wenger and Weiss, Nature 440, 900, 2006].

Based on work with B. Doyon and T. Yoshimura (London), R. Konik (Brookhaven), and J.-S. Caux (Amsterdam).

David Clément (Institut d'Optique, Palaiseau)

Single-atom-resolved probing of lattice gases in momentum space

Measuring the full distribution of individual particles is of fundamental importance to characterize many-body quantum systems through correlation functions at any order. Real-space probes of individual quantum objects -- ions, superconducting qbits, Rydberg atoms or neutral atoms throuhg a quantum gas microscope -- have paved the way to unprecedented investigations of many-body physics. Here I will present an experiments that provides the possibility to reconstruct the momentum-space distribution of three-dimensional interacting lattice gases atom-by-atom [1]. This is achieved by detecting individual metastable Helium atoms [2,3] in the far-field regime of expansion, when released from an optical lattice. We benchmark our technique with Quantum Monte-Carlo calculations, demonstrating the ability to resolve momentum distributions of superfluids occupying 10^5 lattice sites. It permits a direct measure of the condensed fraction across phase transitions, as we illustrate on the superfluid-to-normal transition. Our single-atom-resolved approach opens a new route to investigate interacting lattice gases through momentum correlations.

[1] H. Cayla, C. Carcy, Q. Bouton, R. Chang, G. Carleo, M. Mancini and D. Clément, submitted (2017).
[2] Q. Bouton, R. Chang, L. Hoendervanger, F. Nogrette, A. Aspect, C. Westbrook and D. Clément, Phys. Rev. A 91, 061402(R) (2015).
[3] F. Nogrette, D. Heurteau, R. Chang, Q. Bouton, C. Westbrook, R. Sellem and D. Clément, Rev. Scient. Instrum 86, 113105 (2015).

Nicola Dupuis (Paris VI)

Kosterlitz-Thouless signatures in the low-temperature phase of layered three-dimensional superfluid systems

TBA

Fred Jendrzejewski (Uni Heidelberg)

Observation of the phononic Lamb shift

In this talk, we will present our observation of the phononic Lamb shift with a synthetic vacuum. We engineer the synthetic vacuum, building on the properties of ultracold atomic gas mixtures and observe the phononic Lamb shift using high-precision spectroscopy. Our observations establish this experimental platform as a new tool for precision benchmarking of experimental set-ups that mimics quantum electrodynamics with increasing sophistication.

Anna Minguzzi (CNRS Grenoble)

Tan's contact for one-dimensional multi-component Fermi gases

A universal decay power-law of the large-momentum tails of the momentum distribution, fixed by Tan's contact coefficients, constitutes a direct signature of strong correlations in a short-range interacting quantum gas. For a one-dimensional multi-component Fermi gas under harmonic confinement we derive the Tan's contact. We find a direct correspondence between the value of the Tan's contact and the magnetic symmetry of the state. We show that a local density approximation (LDA) on the Bethe-Ansatz equation of state for the homogeneous gas is in excellent agreement with numerical DMRG results for the harmonically confined gas and predicts a scaling behavior of the Tan's contact. This provides useful analytical expressions for the dependence on the number of particles, number of components and on interaction strength.

Jean-Marie Stephan (Univ. Lyon 1)

Inhomogeneous quantum quenches in the XXZ spin chain via statistical mechanics

I consider a simple out-of-equilibrium setup where a 1d quantum spin system on the infinite lattice is prepared in a domain wall product state, and then let evolve unitarily with the Hamiltonian of the XXZ spin chain. I show how a few simple observables may be computed analytically at all times, a very rare instance after such quantum quench protocols in strongly interacting systems. These exact results are then used to get some more general hindsights into inhomogeneous quenches, and transport properties of the XXZ spin chain, some of which still remain poorly understood.

Crucial to the whole analysis is the relation to the 2d classical six-vertex model with domain wall boundary conditions, and the beautiful phenomenon of arctic curves for dimer coverings. These results also serve as an opportunity to mention alternative approaches such as the generalized hydrodynamic treatment of integrable systems, and conformal field theory description of 1d inhomogeneous systems. I will also discuss the crucial role played by integrability, and its spectacular effect on entanglement growth after inhomogeneous quench protocols.

Grégoire Misguich (CEA Saclay)

Dynamics of the Heisenberg spin chain initialized from a domain-wall initial condition

We study the dynamics of an isotropic spin-1/2 Heisenberg chain starting from a domain-wall initial condition, where the spins are initially up on the left half-line and down on the right half-line.
Using time-dependent DMRG simulations we analyze the long-time behavior of the magnetization and entropy profiles.
We find that the data are compatible with a diffusive behavior for the isotropic model.
The situation where the anisotropy parameter (Delta) is greater than 1 will also be discussed.

Reference: G. Misguich, K. Mallick and P. L. Krapivsky, arXiv:1708.01843

Fabrice Gerbier (ENS Paris)

Clock spectroscopy of ytterbium atoms in optical lattices

I will describe our experimental project aiming at the realization of an optical lattice with a “built-in” effective magnetic field coupling to the atomic motion-the so-called Hofstadter optical lattice. Our experimental scheme uses an ultra-narrow optical transition (the ``clock'' transition) linking the ground state to a long-lived excited state. Coherent driving of the clock transition impart a geometric phase on the external wavefunction that can be tailored to replicate the Aharnonov-Bohm phase experienced by charged particles moving in a magnetic field. I will present the current status of the experiment, includinghigh-resolution spectroscopy on the clock transition and the observation of coherent Rabi oscillations.

Leonardo Mazza (ENS Paris)

Laughlin-like physics in bosonic and fermionic 1D gases with synthetic dimension

The combination of interactions and static gauge fields plays a pivotal role in our understanding of strongly-correlated quantum matter. Cold atomic gases endowed with a synthetic dimension are emerging as an ideal platform to experimentally address this interplay in quasi-one-dimensional systems. A fundamental question is whether these setups can give access to pristine two-dimensional phenomena, such as the fractional quantum Hall effect, and how.

Using numerical simulations based on matrix-product states, we show that signatures of bosonic and fermionic Laughlin-like states can be observed and characterized in synthetic ladders. We theoretically diagnose these Laughlin-like states focusing on the chiral current flowing in the ladder, on the central charge of the low-energy theory, and on the properties of the entanglement entropy. Moreover, by introducing periodic boundary conditions in the synthetic dimension, we show that these systems can be used to implement topological fractional pumping.

Our work provides a qualitative and quantitative guideline towards the observability and understanding of strongly-correlated states of matter in synthetic ladders. In particular, we unveil how state-of-the-art experimental settings constitute an ideal starting point to progressively tackle two-dimensional strongly interacting systems from a ladder viewpoint.

Refs:
- Topological fractional pumping with alkaline-earth(-like) ultracold atoms
L. Taddia, E. Cornfeld, D. Rossini, L. Mazza, E. Sela, R. Fazio, Phys. Rev. Lett. 118, 230402 (2017)
- Laughlin-like states in bosonic and fermionic atomic synthetic ladders
M. Calvanese Strinati, E. Cornfeld, D. Rossini, S. Barbarino, M. Dalmonte, R. Fazio, E. Sela, L. Mazza, Phys. Rev. X 7, 021033 (2017)

Loïc Henriet (Ecole Polytechnique, Palaiseau)

Dynamics and topology of a dissipative spin

Abstract : The notion of topology plays a key role in condensed matter systems, from the study of the hydrodynamic behavior in superfluid helium 3 to the quantization of transport in quantum (spin) Hall systems. In this talk, we analyze the topological deformations of a spin-1/2 in an effective magnetic field induced by an ohmic quantum dissipative environment at zero temperature. This model is known to display a Kosterlitz-Thouless quantum phase transition from a delocalized to a localized phase when increasing the coupling with the environment. From Bethe Ansatz results and a variational approach, we confirm that the Chern number is preserved in the delocalized phase (low coupling) and we report a divergence of the Berry curvature at the equator at the transition.
Recent experiments in quantum circuits have engineered non-equilibrium protocols in time to access topological properties at equilibrium from the measure of the (quasi-)adiabatic out-of-equilibrium spin expectation values. Applying a numerically exact stochastic Schrodinger equation we find that, for a fixed sweep velocity, the bath induces a crossover from (quasi-)adiabatic to non-adiabatic dynamical behavior when the spin bath coupling increases. Then, we provide an intuitive physical explanation of the breakdown of adiabaticity in analogy to the Faraday effect in electromagnetism. We demonstrate that the driving of the spin leads to the production of a large number of bosonic excitations in the bath, which in return strongly affect the spin dynamics.