LOW DIMENSIONAL QUANTUM SYSTEMS

Schedule

Thursday, November 8 :

14 – 14 : 30	Johannes Schachenmayer (Université de Strasbourg, France)
14 : 30 – 15	Takis Kontos (Ecole Normale Supérieure, Paris, France)
15 – 15 : 30	Isabelle Bouchoule (Institut d'Optique, Palaiseau, France)
15 : 30 – 16	*Coffee break*
16 – 16 :30	Romain Dubessy (Université Paris XIII, Villetaneuse, France)
16 : 30 – 17	Tommaso Roscilde (Ecole Normale Supérieure, Lyon, France)
17 – 17 : 30	Gabriel Dufour (University of Freiburg, Germany)

Friday, November 9 (morning) :

9 – 9 : 30	Leonardo Mazza (Université Paris XI, Orsay, France)
9 : 30 – 10	Nicolas Regnault (Ecole Normale Supérieure, Paris, France)
10 – 10 : 30	Jutho Haegemann (Ghent University, Belgium)
10 : 30 – 11	*Coffee break*
11 – 11 :30	Sebastian Eggert (Universität Kaiserslautern, Germany)
11 : 30 – 12	Christophe Mora (Ecole Normale Supérieure, Paris, France)
12 – 12 : 30	Kristof Moors (Université du Luxembourg, Luxembourg)

Friday, November 9 (afternoon) :

14 – 14 : 30	Grazia Salerno (Université Libre de Bruxelles, Belgium)
14 : 30 – 15	Jacopo de Nardis (Ghent University, Belgium)
15 – 15 : 30	Rebecca Kraus (Universität des Saarlandes, Saarbrücken, Germany)
15 : 30 – 16	*Coffee break*
16 – 16 :30	Imke Schneider (Universität Kaiserslautern, Germany)
16 : 30 – 17	Benoit Estienne (Sorbonne Université, Paris, France)
17 – 17 : 30	Andreas Buchheit (Universität des Saarlandes, Saarbrücken, Ger.)

Abstracts

Isabelle Bouchoule « Generalised Hydrodynamics on an atom chip »

Describing the out-of-equilibrium dynamics of many-body quantum systems is a priori a tremendously difficult task. However, a recent theoretical development provides an ab-initio description of the long wavelength dynamics of 1D integrable quantum systems, the so-called Generalised Hydrodynamics (GHD). In contrast to conventional hydrodynamics, GHD does not assume that gas is locally described by the Gibbs ensemble but it keeps track of all conserved quantities of the integrable system. In cold atom experiments, 1D bosonic gases are realised, which are well described by the famous integrable Lieb-Liniger model. Cold atom experiments thus offer an ideal platform to test GHD.

We use the atom-chip experiment of LCF, where 1D gases of ^{87}Rb are realized, to test experimentally GHD. Starting from a cold atomic cloud at thermal equilibrium, dynamics is generated by a sudden quench of the longitudinal potential. The measured time evolution of the density profiles are in excellent agreement with predictions from GHD. We also compare our data with predictions from the conventional hydrodynamics method, which assumes locally a thermal equilibrium described by a Gibbs ensemble. Except for the special case of harmonic potentials, we find that conventional hydrodynamics completely fails to reproduce our data. Hydrodynamics even predicts the development of sharp structures leading to a chock phenomena, such a phenomena being absent in the data and in the GHD description.

Grazia Salerno « The quantized Hall conductance of a single atomic wire: A proposal based on synthetic dimensions »

We propose a method by which the quantization of the Hall conductance can be directly measured in the transport of a one-dimensional atomic gas. Our approach builds on two main ingredients: (1) a constriction optical potential, which generates a mesoscopic channel connected to two reservoirs, and (2) a time-periodic modulation of the channel, specifically designed to generate motion along an additional synthetic dimension. This fictitious dimension is spanned by the harmonic-oscillator modes associated with the tightly-confined channel, and hence, the corresponding "lattice sites" are intimately related to the energy of the system. We analyze the quantum transport properties of this hybrid two-dimensional system, highlighting the appealing features offered by the synthetic dimension. In particular, we demonstrate how the energetic nature of the synthetic dimension, combined with the quasi-energy spectrum of the periodically-driven channel, allows for the direct and unambiguous observation of the quantized Hall effect in a two-reservoir geometry. Our work illustrates how topological properties of matter can be accessed in a minimal one-dimensional setup, with direct and practical experimental consequences.

Johannes Schachenmayer « Semi-classical perspective on dynamics of correlations in quantum spin models with long-range interactions »

Experimental setups with ultracold atoms, molecules or ions offer platforms for studying coherent non-equilibrium dynamics of long-range interacting quantum many-body spin-models in controlled environments. We developed a semi-classical technique that makes it possible to study many-body evolution in these models numerically, also for large system sizes. Here we show how many aspects of such dynamics, such as correlation spreading, can be remarkably well captured with our semi-classical approach.

Kristof Moors « Electron transport in low-dimensional metallic systems »

For the very-large-scale integration of two-dimensional and topological materials in electrical circuits, a proper understanding of the transport properties as well as accurate models are paramount. I will present some of our recent work on two low-dimensional metallic systems with very promising features. First, I will discuss graphene (nano)ribbons and the impact of edge scattering on their transport properties, being one of the major sources of conductivity degradation. Second, I will present the magnetotransport properties of 3D topological insulator nanowires and wire circuits with kinks and junctions.

Gabriel Dufour « Signatures of (in)distinguishability in the dynamics of (interacting) bosons »

The interference of two photons on a balanced beamsplitter reveals their mutual degree of indistinguishability, with the probability of measuring one photon in each output mode going from zero if the photons are indistinguishable to one half if they are fully distinguishable, as demonstrated by Hong, Ou and Mandel. We extend this line of thought to the realm of many interacting bosons evolving continuously in a multimode setting, for example in a Bose-Hubbard lattice. In particular, we show how the dynamics of bosons changes when they are split into mutually distinguishable species.

(in collaboration Tobias Brünner, Alberto Rodríguez, Andreas Buchleitner)

Jutho Haegemann « Topological order in tensor networks »

I will give a brief overview of how tensor networks are used as a theoretical tool to characterise topological order (and symmetry protected topological order) in gapped phases of matter.

Jacopo de Nardis « Hydrodynamic diffusion and super-diffusion in integrable models »

I will show how hydrodynamic diffusion is generically present in many-body one-dimensional interacting quantum and classical integrable models. I will extend the recently developed generalised hydrodynamic (GHD) to include terms of Navier-Stokes type which lead to positive entropy production and diffusive relaxation mechanisms. These terms provide the subleading diffusive corrections to Euler-scale GHD for the large-scale non-equilibrium dynamics of integrable systems, and arise due to two-body scatterings among the quasiparticles of the model. Moreover I will show how with some particular choice of Hamiltonian interactions, the diffusion constant relative to the spin or charge degrees of freedom diverges, signaling the presence of super diffusive transport.

Benoit Estienne « Area law in the integer quantum Hall effect »

Ideas coming from quantum information theory have provided invaluable insights and powerful tools for quantum many-body systems. One of the most basic tools in the arsenal of quantum information theory is (entanglement) entropy. A particularly striking phenomenon is the the “area law” of the entanglement entropy, which has been widely discussed in recent years in condensed matter and quantum field theories. Typically, one considers a many-particle state and a geometric partition of the space in two sub-regions. The von Neumann entropy of the reduced state of a sub-region measures the degree of entanglement between the two regions. The area law states that this entanglement entropy is proportional to the volume of the boundary of the sub-region.
I will then present some recent results in the context of the quantum Hall effect.

Andreas Buchheit « Commensurate-incommensurate transition with long-range interactions and simulation thereof in trapped chains of ions »

We show that a one-dimensional chain of trapped ions in a periodic optical lattice displays the commensurate-incommensurate transition (CIC) predicted at the interface of two crystal surfaces. We determine the properties and derive the phase diagram of the CIC in the presence of long-range interactions, proving the existence of a devil's staircase in the deep substrate limit, analyze the modifications of the phase diagram for a finite trapped chain and demonstrate that the CIC can be observed in chains of dozen of ions in a harmonic trap at finite temperatures. Our study provides the foundations for simulating structural transitions in crystal layers in a well-controlled setting, possibly in the quantum regime.

(in collaboration with H. Landa, C. Cormick, T. Fogarty, E. A. Demler, G. Morigi)

Imke Schneider « Decoherence of charge density waves in beam splitters for interacting quantum wires »

Simple intersections between one-dimensional channels can act as coherent beam splitters for non-interacting electrons. Here we examine how coherent splitting at such quantum wire crossings is affected by inter-particle interactions. We derive an effective impurity model which represents the intersection within Luttinger liquid theory at low energy. For Luttinger K=1/4, we compute the exact time-dependent expectation values of the charge density as well as the density-density correlation functions. In general a single incoming wave-packet will split into four outgoing wave-packets with transmission and reflection coefficients depending on the effective strength of the relevant tunneling processes. We find that when multiple charge density wave packets from different directions pass through the intersection at the same time, reflection and splitting of the packets depend additionally on their relative phases. In an extreme scenario the incoming four wave-packets would all annihilate each other with no outgoing packets surving. Active use of this phase dependent splitting of wave-packets may make Luttinger interferometry possible. We also find that coherent incident packets suffer partial decoherence from the intersection, with some of their initially coherent signal being transferred into correlated quantum noise.

Leonardo Mazza « Tight-binding models of parafermions »

Parafermions are emergent excitations with intriguing anyonic properties that generalize Majorana fermions and have been predicted to appear in some condensed-matter devices. Here, we study the simplest number-conserving model of particle-like Fock parafermions, namely a one-dimensional tight-binding model. By means of numerical simulations based on exact diagonalization and on the density-matrix renormalization group, we prove that this quadratic model is not integrable and displays bound states in the spectrum, due to its peculiar anyonic properties. Moreover, we characterize its anyonic correlation functions and discuss the underlying low-energy theory. When Fock parafermions behave as fractionalized fermions, our tight-binding model shows, on a lattice, the low-energy properties of two counter-propagating edge modes belonging to two neighboring Laughlin states at filling 1/3.

(Joint work with Davide Rossini, Matteo Carrega and Marcello Calvanese Strinati, to appear soon on the arXiv)

Tommaso Roscilde « Quantum quench dynamics in systems with unconventional excitations »

In this talk I will explore the unconventional quench dynamics driven by linear excitations of quantum spin models, using three remarkable examples: 1) systems with long-range interactions, featuring a divergent group velocity in the dispersion relation of elementary excitations; 2) systems with competing interactions, featuring (nearly) flat bands of excitations due caging effects; and 3) systems with disordered interactions, featuring (Anderson) localised modes or coexistence between localised and extended modes. In all three cases a very rich dynamics is shown to occur, going beyond the paradigm of linear light-cone spreading of correlations.

Sebastian Eggert « Floquet induced superfluidity »

We consider the one-dimensional Hubbard model with periodically modulated repulsive interactions, which is equivalent to two species of hard-core bosons in a one-dimensional optical lattice. Using Floquet theory the periodic model can be mapped to an effective Hamiltonian for high frequencies, which is described by a static interaction and hopping parameters that depend on the local densities. In particular, if the density difference of one species is non-zero on neighboring sites, the effective hopping of the other species is reduced and can even take on negative values. Using a combination of analytic calculations and different advanced numerical simulations we establish the full quantum phase diagram for half-integer filling for this system. Surprisingly, the density-dependent reduction of hopping drives a quantum phase transition into a superfluid phase. For negative hopping a previously unknown state is found, where one species induces a gauge phase of the other species, which leads to a superfluid phase of gauge-dressed particles. The corresponding experimental signatures in time-of-flight experiments are calculated and show characteristic signatures of the different phases. The phase transition line between the two superfluid phases corresponds to an exactly solvable model with high degeneracy.

Christophe Mora « Parafermions and symmetry-enriched Majorana fermions in one-dimensional fermionic models »