TT 37: Cold Atomic Gases

Time: Tuesday 9:30–12:45 Location: HSZ 304

Invited Talk TT 37.1 Tue 9:30 HSZ 304
Superfluidity and Collective Pairing in Polariton Microcavities — •Francesca Maria Marchetti — Departamento de Fisica Teorica de la Materia Condensada & IFIMAC, Universidad Autonoma de Madrid, Madrid 28049, Spain

Matter-light systems such as semiconductor microcavities have been witnessing remarkable advances, promoting them as ideal environments where to engineer and study novel collective quantum states. Since the first realisation of a polariton Bose-Einstein condensate, the field has grown at a high rate. Superfluid behaviour, the observation of full and half quantum vortices and solitons, the optical spin Hall effect, are just few examples of the most seminal results for polaritonic fluids obtained only in the last few years, a brief account of which will be given in the introduction of this presentation. Most recently, it has been possible to tune the interaction strength between polaritons with opposite polarisations via a bipolariton Feshbach resonance mechanism. This allows to access regimes of tunable pairing and strong correlations, opening a wealth of interesting possibilities. I will in particular show that microcavity polaritons present an ideal opportunity to study bosonic collective pairing phases: Exploring the theoretical phase diagram, I will show that, by using the photon-exciton detuning as the interaction tuning parameter, a novel phase transition between the regular polariton superfluid phase and a "molecular" (i.e. bipolariton) superfluid phase can be realised. Temperatures and detunings required for typical materials such as GaAs and ZnO are attainable, and I will discuss experimental signatures for detecting such novel phases.

TT 37.2 Tue 10:00 HSZ 304
Transport with ultra-cold atoms at constant density — •Christian Nietner, Gernot Schaller, and Tobias Brandes — Institut für theoretische Physik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany

We investigate the transport through a few-level quantum system described by a Markovian master equation with temperature- and particle-density dependent chemical potentials. From the corresponding Onsager relations we extract linear response transport coefficients in analogy to the electronic conductance, thermal conductance and thermopower. Considering ideal Fermi and Bose gas reservoirs we observe steady-state currents against the thermal bias as a result of the non-linearities introduced by the constraint of a constant particle density in the reservoirs. Most importantly, we find signatures of the on-set of Bose-Einstein condensation in the transport coefficients.

TT 37.3 Tue 10:15 HSZ 304
Relaxation towards negative temperatures in bosonic systems: generalized Gibbs ensembles and beyond integrability — Stephan Mandt[1], Adrian E. Feiguin[2], and •Salvatore R. Manmana[3] — [1]Princeton Center for Complex Materials and Department of Physics, Princeton University, NJ 08544, USA. — [2]Department of Physics, Northeastern University, Boston, MA 02115, USA. — [3]Institute for Theoretical Physics, University of Göttingen, D-37077 Göttingen, Germany.

Motivated by the recent experimental observation of negative absolute temperature states in systems of ultracold atomic gases on optical lattices [Braun et al., Science 339, 52-55 (2013)], we investigate theoretically the formation of these states. More specifically, we consider the relaxation after a sudden inversion of the external parabolic confining potential in the one-dimensional inhomogeneous Bose-Hubbard model. First, we focus on the integrable hard-core boson limit which allows us to treat large systems and arbitrarily long times, providing convincing numerical evidence for relaxation to a generalized Gibbs ensemble at negative temperatures $T < 0$, being defined by us in this context. Second, going beyond one dimension, we demonstrate that the emergence of negative temperature states can be understood in a dual way in terms of positive temperatures, which relies on a dynamic symmetry of the Hubbard model. We complement the study by exact diagonalization simulations at finite values of the on-site interaction.

TT 37.4 Tue 10:30 HSZ 304
Spin-Imbalanced Fillings for Fermions in a Trap — •Denis Morath, Stefan Söffing, and Sebastian Eggert — TU Kaiserslautern, 67663 Kaiserslautern, Germany

Recently it has become experimentally feasible to realize tunable few-fermion systems in an ultra cold gas setup. Besides the huge variability in interaction using the Feshbach Resonance people are now able to control the filling of different pseudo-spin species independently. This leads to interesting local magnetizations i.e. spin resolved local densities. We calculate these quantities on a discretized, one dimensional system using a Quantum Monte Carlo algorithm called Stochastic Series Expansion. This offers the opportunity to perform complete quantum many-body simulations in order to study the influence of finite interactions, filling and temperature on the density-distribution. We observe the formation of an anti-ferromagnetic arrangement, but this is only stable for small and intermediate interactions and small spin imbalances. For higher interactions a Wigner crystal forms, which has regular peaks in the density, that are independent of spin. Hence the density of one spin species typically has more peaks in the particle density than the actual number of particles in this case.

TT 37.5 Tue 10:45 HSZ 304
Zitterbewegung in the honeycomb lattice — •Michael Hauber[1], Benjamin Deissler[2], Johannes Hecker Denschlag[2], and Alejandro Muramatsu[1] — [1]Institut für Theoretische Physik III, Universität Stuttgart — [2]Institut für Quantenmaterie, Universität Ulm

We present simulations of the dynamics of relativistic fermions on a honeycomb lattice to investigate the Zitterbewegung in 2+1 dimensions under real conditions, such as finite lattice size and external potentials. Our results serve as a guide for an experimental realization of such systems with ultracold fermionic atoms (^6Li) on an optical lattice. From our simulations, Zitterbewegung should be observable in such a system with site-resolved imaging capabilities.

15 min. break.

TT 37.6 Tue 11:15 HSZ 304
2D Phase Space Crystals: artificial gauge fields in phase space — •Lingzhen Guo[1,2], Michael Marthaler[1,2], and Gerd Schön[1,2] — [1]Institut für Theoretische Festkörperphysik, Karlsruhe Institute of Technology(KIT), Karlsruhe, Germany — [2]DFG-Center for Functional Nanostructures (CFN), Karlsruhe Institute of Technology, Karlsruhe, Germany

We propose a new paradigm to study the properties of driven systems. We find the driving field in fact induces a lattice structure in phase space, which we call phase space crystals [1]. The discrete sysmmetry of phase space lattice allows us to apply the Bloch theorem in solid state physics to the study of driven systems. From this point of view, we investigate the gap openning mechanism of quasienergy spectrum different from that in solid state physics. Interestingly, because the two dimensions of phase space are intrinsically noncommutative, there exists an effective magnetic field in phase space. We explore the related physics due to the existence of this artificial magnetic field.
[1] Phys. Rev. Lett. 111, 205303 (2013)

TT 37.7 Tue 11:30 HSZ 304
Haldane phases of SU(N) spin chains and their realization in ultra-cold atom gases — •Thomas Quella — University of Cologne, Cologne, Germany

The general classification of SU(N) spin chains of Duivenvoorden and Quella predicts the existence of up to N-1 distinct non-trivial topologically protected phases. Each phase is characterized by a specific type of non-local string order and the emergence of fractionalized SU(N) spins at the boundary of the system.

In this talk, we analyze model Hamiltonians of AKLT type in which these phases are realized and discuss their relation to the Heisenberg Hamiltonians that arise as certain limits of suitably chosen Hubbard models. Our results indicate that it should be possible to realize at least one of the non-trivial topological phases in ultra-cold alkaline-earth atom gases if N is even. We also comment on the modifications of the previous Hamiltonians which are required to realize the remaining non-trivial topological phases.

TT 37.8 Tue 11:45 HSZ 304
Quantum phases of one-dimensional soft-core systems —

•Marion Moliner, Davide Vodola, and Guido Pupillo — IPCMS (UMR 7504) and ISIS (UMR 7006), Université de Strasbourg and CNRS, 67000 Strasbourg, France

Rydberg-excited atoms trapped in optical lattices have provided an experimental realization of strong repulsive non-local van der Waals interactions [1]. These soft-core interactions engender exotic phases such as supersolid states in two and three dimensions. In one dimension, a very recent theoretical study showed the existence of critical quantum liquids beyond the Tomonaga-Luttinger liquid picture [2]. The particular feature of these liquids is the formation of clusters due to frustrating interactions.

In the present work, we investigate the effects of adding a 'spin' degree of freedom in order to mimic a magnetic behaviour. Such systems are described by a longer-range extended Hubbard model with frustrating couplings. By means of analytical and numerical methods we show the existence of other 'cluster Luttinger liquids' exhibiting different types of magnetic orders.

[1] N. Henkel, R. Nath, and T. Pohl, Phys. Rev. Lett. 104 195302 (2010)
[2] M. Mattioli, M. Dalmonte, W. Lechner and G. Pupillo, Phys. Rev. Lett. 111, 165302 (2013)

TT 37.9 Tue 12:00 HSZ 304

Repulsive to attractive interaction quenches for bosons in a one-dimensional trap — •Wladimir Tschischik, Roderich Moessner, and Masud Haque — Max-Planck-Institut für Physik komplexer Systeme, Dresden

We present a study of the non-equilibrium dynamics of attractively interacting bosons in a one-dimensional harmonic trap. We describe the physics in terms of many-body spectra. We focus on the highly excited 'super-Tonks-Girardeau' state that is accessed through a sudden quench from a positive to a negative interaction. We describe both lattice (Bose-Hubbard) and continuum (Lieb-Liniger) cases.

Topical Talk TT 37.10 Tue 12:15 HSZ 304

Mesoscopic Transport of Heat in Trapped-Ion Crystals — •Martin Bruderer[1], Alejandro Bermudez[1,2], and Martin B. Plenio[1] — [1]Institut für Theoretische Physik, Albert-Einstein-Allee 11, Universität Ulm, 89069 Ulm, Germany — [2]Instituto de Fisica Fundamental, IFF-CSIC, Calle Serrano 113b, Madrid E-28006, Spain

Measuring and controlling heat flow on the nanoscale poses formidable practical difficulties as elementary devices such as switches and 'ampere meters' for thermal currents are not available. We propose to overcome this problem by realizing heat transport through a chain of trapped ions, where steady-state currents of local vibrations (vibrons) are induced by a constant temperature difference between the edges of the chain. We show how to efficiently control and measure these currents by coupling vibrons to internal ion states, which can be easily manipulated in experiments. Trapped-ion crystals therefore provide a promising platform for studying heat transport, e.g., through thermal analogues of quantum wires and quantum dots. Specifically, elusive phenomena such as the onset of Fourier's law may be observable in trapped-ion systems.

[1] A. Bermudez, M. Bruderer and M. B. Plenio, Phys. Rev. Lett. **111**, 040601 (2013)