Q 25: Quantum gases (Bosons) IV

Time: Wednesday 11:00–13:00 Location: e214

Q 25.1 Wed 11:00 e214

Exciting an interaction-tuneable uniform Bose gas confined in flatland — •Julian Schmitt, Panagiotis Christodoulou, Maciej Galka, Nishant Dogra, Jay Man, and Zoran Hadzibabic — Cavendish Laboratory, University of Cambridge, UK

Dimensionality plays a crucial role in governing the nature of phase transitions in a system. The marginal case of two dimensions is especially interesting, where an interacting Bose gas exhibits superfluidity via the Berezinski-Kosterlitz-Thouless (BKT) topological phase transition mediated by the binding of vortices.

In this talk, I will present our recent experimental investigations to probe the collective excitations in a two-dimensional uniform Bose gas trapped in an optically sculpted box potential. Our system is derived from a Bose-Einstein-condensate of ^{39}K atoms with tuneable interactions due to a broad Feshbach resonance. Subsequently, the atoms are confined in a two-dimensional homogeneous optical box created using two different digital micromirror devices. By applying temporally changing spatial potentials, we force the superfluid out of equilibrium and monitor its density response. The emergent sound modes in the system are studied as a function of interaction strength and temperature. Importantly, the tuneability of the interactions allows us to explore the behaviour of the elementary excitations near the BKT phase transition under hydrodynamic conditions. Our system provides an ideal platform to study out-of-equilibrium situations with externally controlled dissipation channels, paving the way for studies of turbulent cascades in two-dimensional systems.

Q 25.2 Wed 11:15 e214

Single-atom quantum probes for ultracold gases using nonequilibrium spin dynamics — •Daniel Adam[1], Quentin Bouton[1], Sabrina Burgardt[1], Jens Nettersheim[1], Tobias Lausch[1], Daniel Mayer[1], Felix Schmidt[1], Eberhard Tiemann[2], and Artur Widera[1] — [1]Department of Physics and Research Center OPTIMAS TU Kaiserslautern, Germany — [2]Institut für Quantenoptik, Leibniz Universität Hannover, 30167 Hannover, Germany

Quantum probes are atomic-sized devices mapping information of their environment to quantum mechanical states. By improving measurements and at the same time minimizing perturbation of the environment, they form a central asset for quantum technologies. Here, we present a realization of single-atom quantum probes for local thermometry based on the spin dynamic of individual neutral Caesium (probe) atoms in an ultracold gas (bath) of Rubidium atoms. The competition of inelastic endo- and exoergic spin-exchange processes map the temperature onto the quasi-spin population of the probe. The sensitivity of the thermometer can be adjusted via the external magnetic field changing the Zeeman energy splitting. Sensitivity can also be enhanced, if temperature information is obtained from the nonequilibrium dynamic, instead of the steady-state distribution, of the probe, maximizing the information obtained per inelastic collision and thus minimizing the perturbation of the bath. We will discuss the latest state of the experiment to include coherence of the probe for further quantum probing approaches.

Q 25.3 Wed 11:30 e214

Dynamical structure factors of dynamical quantum simulators — Maria Laura Baez[1,2], Marcel Goihl[2], Jonas Haferkamp[2], Juan Bermejo-Veja[2,3], •Marek Gluza[2], and Jens Eisert[2,4] — [1]Max Planck Institute for the physics of complex systems, Dresde, Germany — [2]Dahlem Center for Complex Quantum Systems, Berlin, Germany — [3]Institute for Theoretical and Computational Physics, Granada, Spain — [4]Helmholtz-Zentrum Berlin für Materialien und Energie, Germany

The dynamical structure factor is one of the experimental quantities crucial in scrutinizing the validity of the microscopic description of strongly correlated systems. Despite its long-standing importance, it is exceedingly difficult in generic cases to numerically calculate it, ensuring that the necessary approximations involved yield a correct result. We discuss in what way results on the hardness of classically tracking time evolution under local Hamiltonians are precisely inherited by dynamical structure factors; and hence offer in the same way the potential computational capabilities as dynamical quantum simulators do. Furthermore, we improve upon a novel, readily available, measurement setup allowing for the determination of the dynamical structure factor in different architectures, including arrays of ultra-cold atoms, trapped ions, Rydberg atoms, and superconducting qubits. Our results suggest that quantum simulations employing near-term quantum devices allow for the observation of dynamical structure factors of correlated quantum matter in the presence of experimental imperfections, for larger system sizes than what is achievable by classical simulation.

Q 25.4 Wed 11:45 e214

Dissipation induced structural instability and chiral dynamics in a quantum Gas — •Nishant Dogra[1,2], Manuele Landini[1,3], Katrin Kroeger[1], Lorenz Hruby[1], Francesco Ferri[1], Rodrigo Rosa-Medina[1], Fabian Finger[1], Tobias Donner[1], and Tilman Esslinger[1] — [1]Institute for Quantum Electronics, ETH Zurich, CH-8093 Zurich, Switzerland — [2]Cavendish Laboratory, University of Cambridge, J. J. Thomson Avenue, Cambridge CB3 0HE, United Kingdom — [3]Institut für Experimentalphysik und Zentrum für Quantenphysik, Universität Innsbruck, 6020 Innsbruck, Austria

Dissipative and unitary processes define the evolution of a many-body system. Their interplay gives rise to dynamical phase transitions and can lead to instabilities. In this talk, I will present our recent observation of a non-stationary state of chiral nature in a synthetic many-body system with independently controllable unitary and dissipative couplings. Our experiment is based on a spinor Bose gas interacting with an optical resonator. Orthogonal quadratures of the resonator field coherently couple the Bose-Einstein condensate to two different atomic spatial modes whereas the dispersive effect of the resonator losses mediates a dissipative coupling between these modes. In a regime of dominant dissipative coupling we observe the chiral evolution and relate it to a positional instability.

[1] N. Dogra et al, arXiv:1901.05974 (2019).

Q 25.5 Wed 12:00 e214

Realizing the Deep Strong Coupling Regime of the Quantum Rabi Model with Ultracold Rubidium Atoms — •Geram Hunanyan, Johannes Koch, and Martin Weitz — Institut für Angewandte Physik Bonn

The dynamics of a two-level system interacting with a single bosonic mode is well described by the quantum Rabi model (QRM). Although a fair quantity of experiments explore the strong coupling regime of the QRM, where due to limited coupling strength the widely known Jaynes-Cummings model breaks down, researchers are just beginning to exploit the regime where the full QRM must be considered. Our experimental implementation to simulate the full QRM uses ultracold rubidium atoms in a 1D optical lattice potential, with the effective two-level quantum system being realized by different Bloch bands in the first Brillouin zone. The bosonic mode is represented by a vibrational mode of atoms oscillating in an optical dipole trapping potential. We experimentally observe the atomic dynamics in the deep strong coupling regime. The present status of experimental results will be presented.

Q 25.6 Wed 12:15 e214

Strongly interacting bosons in a synthetic magnetic field — •Julian Léonard, Robert Schittko, Sooshin Kim, Joyce Kwan, and Markus Greiner — Harvard University, Cambridge, MA, USA

The interplay between magnetic fields and interacting particles can lead to exotic phases of matter that exhibit topological order and high degrees of entanglement. Although these phases were discovered in a solid-state setting, recent innovations in systems of ultracold neutral atoms allow the synthesis of artificial magnetic fields. However, so far these experiments have mostly explored the regime of weak interactions, which precludes access to correlated many-body states.

We demonstrate the controlled generation of strongly correlated many-body states of bosons in a magnetic field. We use a bottom-up strategy based on quantum state engineering in the interacting Harper-Hofstadter model with tunable flux. Starting from a Fock state with a fixed number of particles, we perform a quantum annealing ramp that adiabatically connects the initial state with the target state. This allows us to reach quantum states of different fillings, particle numbers, and system sizes.

Q 25.7 Wed 12:30 e214

Bose Gases on Spheres and Ellipsoids — •Natália Móller[1], Ednilson Santos[2], Vanderlei Bagnato[3], and Axel Pelster[1] — [1]Physics Department and Research Center OPTIMAS, Technische Universität Kaiserslautern, Germany — [2]Departamento de Fisica, Universidade Federal de Sao Carlos, Brazil — [3]Instituto de Fisica de Sao Carlos, Universidade de Sao Paulo, Brazil

Due to the prospect of experimentally realizing a Bose-Einstein condensate in a bubble-trap [1], we are interested in studying the behavior of a Bose gas on the surface of a curved manifold. The simplest geometric form approximately describing this type of trap is a spherical one, which has gained much attention in the literature and for which we have computed the low-lying excitation modes [2]. To this end we have performed a dimensional reduction of the 3D Gross-Pitaevskii (GP) equation, leading to an effective two-dimensional GP equation for the condensate wave function on the sphere and a separated equation determining the radial width, which have to be solved self-consistently. However, a more appropriate manifold to describe a bubble trap is an ellipsoid. For this case, the two-dimensional GP equation turns out to have an effective potential which results in a non-uniform ground state along the surface together with an angle-dependent width.

[1] N. Lundblad, R. A. Carollo, C. Lannert, M. J. Gold, X. Jiang, D. Paseltiner, N. Sergay, and D. C. Aveline, arXiv:1906.05885.

[2] N. S. Móller, F. E. A. dos Santos, V. S. Bagnato, and A. Pelster, in preparation.

Q 25.8 Wed 12:45 e214

NOON states with ultracold bosonic gases via resonance-assisted tunneling — •Guillaume Vanhaele and Peter Schlagheck — University of Liège, Liège, Belgium

NOON states are maximally entangled many-body states that represent an important resource for quantum information processing. In the context of ultracold bosonic atoms, they can in principle be created through quantum tunneling within a two-mode system in the self-trapping regime, where an initial |N,0> state undergoes a tunneling process towards |0,N> passing via the coherent superposition |N,0> + |0,N>. However, the time scales of such tunneling processes are in general prohibitively long for typical experimental configurations and parameters. In this talk, we show that a periodic driving of this two-mode system with suitably chosen amplitudes and frequencies can give rise to a significant enhancement of this tunneling rate. We specifically focus on the mechanism of resonance-assisted tunneling which is particularly suited for this purpose, and discuss to what extent microscopic NOON states with N=5 atoms can thereby be created on experimentally realistic time scales.