Q 22: Ultracold Matter (Bosons) II (joint session Q/A)

Time: Tuesday 11:00–13:00 Location: HS I PI

Q 22.1 Tue 11:00 HS I PI

Exploring Frustration Effects of Strongly Interacting Bosons via the Hall Response — •Catalin-Mihai Halati and Thierry Giamarchi — Department of Quantum Matter Physics, University of Geneva, Geneva, Switzerland

We investigate the Hall response of interacting bosonic atoms on a triangular ladder in a magnetic field, making inroads in understanding the meaning of the Hall response for many-body quantum phases, by analyzing the effects of frustration effects and phase transitions. We show that the nature of the underlying chiral phases has an important influence on the behavior of the Hall polarization, both in its saturation value and in the short-time dynamics. In particular, we find correlations between the Hall response and the features of the underlying phase diagram stemming from the interplay of interactions and geometric frustration. Thus, one can employ the Hall response as a sensitive probe of the many-body chiral quantum phases present in the system.

Q 22.2 Tue 11:15 HS I PI

Dipolar supersolid in a toroidal trap — •Paul Uerlings[1], Kevin Ng[1], Fiona Hellstern[1], Alexandra Köpf[1], Michael Wischert[1], Tanishi Verma[1], Philipp Stürmer[2], Koushik Mukherjee[2], Jens Hertkorn[4], Stephan Welte[3], Ralf Klemt[1], Stephanie Reimann[2], and Tilman Pfau[1] — [1]5. Physikalisches Institut and Center for Integrated Quantum Science and Technology IQST, Universität Stuttgart — [2]Division of Mathematical Physics and NanoLund, LTH, Lund University — [3]5. Physikalisches Institut and Center for Integrated Quantum Science and Technology IQST and QPhoton,Universität Stuttgart — [4]Department of Physics, MIT

A supersolid is a phase of matter that combines the ordered, periodic density modulation of a solid with the frictionless flow of a superfluid, simultaneously breaking both the global U(1) gauge symmetry and the translational symmetry. This symmetry breaking gives rise to three types of collective excitations: the first and second-sound branch and the amplitude Higgs modes. In harmonic traps the Higgs excitations couples strongly to other modes making it hard to detect experimentally. In this work, we theoretically explore the excitation spectrum of a dipolar quantum gas trapped in a toroidal trap. In contrast to previous studies in a harmonic confinement. Our findings reveal decoupled sound and amplitude modes. In the low-momentum limit we find an isolated and massive Higgs excitation. We show how we can selectively excite individual modes of the supersolid. In order to observe these excitations experimentally, we prepare an ultracold gas of 162Dy atoms in a tunable toroidal trap.

Q 22.3 Tue 11:30 HS I PI

Magnetically ordered flux-supersolids with magnetic atoms in an anti-magic wavelength optical lattice — •Michele Miotto — Technische Universität Berlin — Politecnico di Torino

Supersolidity is one of the most fascinating and investigated states of matter. In this work, we prove that the combination of geometrical frustration and strong long-range interactions can give rise to this many-body phase. In particular, we design an experimental platform where a Raman coupled mixture of bosonic magnetic atoms is trapped in a 1D anti-magic wavelength optical lattice. We model this setup by means of a frustrated extended Bose-Hubbard model and we explore its ground-state properties by means of DMRG simulations. We obtain a rich phase diagram, where we observe well-known insulating phases along with interesting gapless states: a chiral superfluid phase and a supersolid phase. The latter can also be characterized by non-trivial order in the current patterns, which can be related to magnetically ordered states such as ferrimagnets and ferromagnets.

Q 22.4 Tue 11:45 HS I PI

Observation of localization in quasidisordered optical lattices — •David Gröters[1,2], Lee Reeve[1], Zhuoxian Ou[1], Qijun Wu[1], Emmanuel Gottlob[1], Yong-Guang Zheng[1], Bo Song[1], and Ulrich Schneider[1] — [1]Cavendish Laboratory, University of Cambridge, J.J. Thomson Avenue, Cambridge CB3 0HE, United Kingdom — [2]Max-Planck-Institut für Quantenoptik, 85748 Garching, Germany

Quasidisordered materials constitute a unique class of systems that are not periodic yet long-range ordered. They can exhibit localized phases of matter, known as the Bose glass, in which thermalization and transport are inhibited. While the Bose glass has recently been observed, an understanding of how localization prevents transport in quasicrystals in the presence of interactions remains unclear.

In this talk, we present recent results of our optical lattice-based quantum simulator on localization of interacting ^{39}K atoms in 2D. We directly observe a suppression in transport rate by three orders of magnitude in a quasicrystal potential that we compare to numerical exact-diagonalization results. Furthermore, we investigate the quasiperiodic Aubry-André model in which transport characteristics are expected to be strikingly different. Using coherence measurements, we map the disorder vs. interaction strength phase diagram and find signatures of the Bose glass phase. Our results demonstrate robust localization in quasicrystalline lattices in the presence of interactions that renders these systems a valuable platform for future studies of many-body localization.

Q 22.5 Tue 12:00 HS I PI

Designed Potential Edges for Phonon-Based Quantum Simulations — •Jelte Duchene, Nikolas Liebster, Marius Sparn, Elinor Kath, Helmut Strobel, and Markus Oberthaler — Kirchhoff-Institut für Physik, Heidelberg, Deutschland

Experimental quantum simulation has become an important tool for the study of quantum fields out of equilibrium. Often, theoretical models are studied with infinite extension or periodic boundary conditions, which makes comparisons with finite-size experiments challenging. In our quantum field simulator, based on phononic excitations of a two-dimensional Bose-Einstein condensate of potassium-39 atoms, we effectively mimic an infinitely extended system by suppressing coherent reflections of phonons at the edges of the trap while still conserving the atom number. This is achieved using a so-called slanted box (Slox) potential, which is flat in the center and has linearly rising slopes at the edges. Experimentally, this is implemented with a Digital Micromirror Device, enabling us to produce various light potentials. We study wave packet dynamics in 2D experiments and 1D simulations as well as the influence of the Slox parameters on the emergence and stability of spontaneously formed density patterns in an interaction-driven situation. Our observations suggest that spatial noise in the light potential is crucial for the efficient suppression of coherent reflections.

Q 22.6 Tue 12:15 HS I PI

Solidity and Smecticity of a Driven Superfluid — •Nikolas Liebster, Marius Sparn, Elinor Kath, Jelte Duchene, Helmut Strobel, and Markus Oberthaler — Kirchhoff-Institut für Physik, Universität Heidelberg, Im Neuenheimer Feld 227, 69120 Heidelberg, Germany

In recent years, a wealth of studies have surrounded the budding field of supersolids, which are systems that are simultaneously superfluid and crystalline. A consequence of the two spontaneously broken symmetries is an enriched excitation spectrum with distinct Goldstone modes. This generic behavior can be derived hydrodynamically by considering only broken symmetries and conserved quantities. Here, we probe the hydrodynamic excitations of a superfluid with density patterns stabilized by driving the interaction strength. We probe both stripe patterns as well as two-dimensional crystals, observing propagating sound modes in each configuration. Using anisotropic response of the stripe (i.e. smectic), we experimentally determine the relevant hydrodynamic parameters. Additionally, we probe transverse sound modes of a two-dimensional crystal to investigate the symmetry breaking processes of the pattern.

Q 22.7 Tue 12:30 HS I PI

Understanding Phonon Pair Production as 1d Scattering Problem — •Elinor Kath, Marius Sparn, Nikolas Liebster, Jelte Duchene, Helmut Strobel, and Markus K. Oberthaler — Kirchhoff-Institut für Physik, Universität Heidelberg

Non-adiabatically changing the interatomic interaction strength of a Bose-Einstein Condensate produces pairs of phonons, which interfere with the background condensate and become visible as density fluctuations. The resulting density fluctuation power spectrum depends on the details of the temporal shape of the interaction strength and, because the phonons were produced coherently, will still oscillate when the interaction strength is held constant again. This process of quasiparticle production can be mapped onto a quantum-mechanical scattering problem in 1d, where the time dependence of the interaction strength sets the height and shape of the scattering potential. We demonstrate how to apply this mapping to intuitively understand the shape and time dependence of produced phonon spectra.

Q 22.8 Tue 12:45 HS I PI

Deterministic Generation of Topological Spin Excitations in a Bose-Einstein Condensate — •Yannick Deller, Alexander Schmutz, Raphael Schäfer, Alexander Flamm, Helmut Strobel, and Markus K. Oberthaler — Kirchhoff-Institut für Physik, Universität Heidelberg, Deutschland

Spinor BEC experiments are an ideal platform for quantum field simulations far from equilibrium with exquisite control over the initial state as well as the readout. The spin-1 system supports a wealth of localized nonlinear excitations, classified by the spatial structure of the spin observables and the atomic densities [1,2,3].
We report on the deterministic generation of topological spin excitations by utilizing a spatially controlled spinor phase imprinting scheme in a quasi one-dimensional ferromagnetic spin-1 BEC. We track their time evolution in all relevant observables by employing a generalized POVM readout scheme [4] and study key properties like propagation speed and lifetime.

1 Lannig et. al., PRL 125, 170401 (2020)
2 Chai et. al., PRL 125, 030402 (2020)
3 Yu and Blakie, PRL 128, 125301 (2022)
4 Kunkel et. al., PRL 123, 063603 (2019)