A 30: Ultra-cold Atoms, Ions and BEC IV (joint session A/Q)

Time: Thursday 14:30–16:30 Location: GrHS Mathe

A 30.1 Thu 14:30 GrHS Mathe

Dark energy search using atom interferometry in microgravity — •Sukhjovan Singh Gill[1], Magdalena Misslisch[1], Charles Garcion[1], Alexander Heidt[2], Ioannis Papadakis[3], Vladimir Schkolnik[3], Christoff Lotz[2], Sheng-Wey Chiow[4], Nan Yu[4], and Ernst Rasel[1] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Hannover, Germay 30167 — [2]Institut für Transport- und Automatisierungstechnik, Leibniz Universität Hannover, Hannover, 30167, Germany — [3]Institut für Physik, Humboldt Universität zu Berlin, Berlin, Germany 12489 — [4]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, USA 91109

The nature of dark energy is one of the biggest quests of modern physics and is crucial for explaining the accelerated expansion of the universe. In the chameleon theory, a scalar field is proposed, which is hidden due to a screening effect in the vicinity of bulk masses to make the model concord with observations. DESIRE project studies the chameleon field model using Bose-Einstein condensates of ^{87}Rb atoms as a source in a microgravity environment. The Einstein-Elevator at Leibniz University Hannover provides 4 seconds of microgravity time for multi-loop atom interferometry to search for phase contributions induced by chameleon fields influenced by variations in mass density.
Bloch oscillations are intended to transport the BEC from the atom chip to the test-mass to perform atom interferometry. Landau-Zener and Wannier-Stark models are employed to simulate losses during transport for precise selection of the lattice depth, detuning, and pulse shape for an efficient transport.

A 30.2 Thu 14:45 GrHS Mathe

Quantum Monte Carlo simulations of hardcore bosons with repulsive dipolar density-density interactions on two-dimensional lattices — •Robin Rüdiger Krill[1,2], Jan Alexander Koziol[2], Calvin Krämer[2], Anja Langheld[2], Giovanna Morigi[1], and Kai Phillip Schmidt[2] — [1]Theoretische Physik, Universität des Saarlandes, 66123 Saarbrücken, Germany — [2]Department für Physik, Friedrich-Alexander Universität Erlangen-Nürnberg, Staudtstraße 7, 91058 Erlangen, Germany

We study the extented Bose-Hubbard model, describing bosons in optical lattices that interact with long-range repulsive forces. The forces are algebraically decaying with the distance, the Bose-Hubbard model is extended by adding a repulsive density-density interaction term. We determine the quantum phase diagram for hard-core bosons using a Stochastic Series Expansion quantum Monte Carlo algorithm, where we develop a sampling procedure to account for the long-range interactions in directed loop updates. We then determine the phase diagram on the two-dimensional square and triangular lattice, where a mean-field study predicts rich quantum phase diagrams including a devil's staircase of solid phases and a plethora of exotic lattice supersolids [1].

[1] J. A. Koziol, G. Morigi, K. P. Schmidt, SciPost Physics 17.4 (2024)

A 30.3 Thu 15:00 GrHS Mathe

Engineering Atomic Interactions using Floquet-Feshbach Resonances — •Alexander Guthmann, Felix Lang, Louisa Marie Kienesberger, Krishnan Sundararajan, and Artur Widera — Physics Department and Research Center OPTIMAS, University of Kaiserslautern-Landau, Germany

Scattering resonances are fundamental in physics, governing dynamics from high-energy nuclear fusion to the low-energy regime of ultracold quantum gases. Magnetically tunable Feshbach resonances have revolutionized the study of ultracold atomic systems by enabling precise control over interaction strengths. However, their dependence on static magnetic fields limits their flexibility, particularly in complex systems such as multi-component quantum gases. In this talk, we present the experimental realization of Floquet-Feshbach resonances in a gas of lithium-6 atoms, achieved through strong magnetic field modulation at MHz frequencies. This periodic modulation creates new scattering resonances where dressed molecular states intersect the atomic threshold. Furthermore, using a two-color driving scheme, we demonstrate tunable control over resonance asymmetries and suppress inelastic two-body losses caused by Floquet heating. These advancements offer a versatile tool for tailoring atomic interactions, paving the way for quantum simulations of complex many-body systems and the exploration of exotic quantum phases.

A 30.4 Thu 15:15 GrHS Mathe

Constrained dynamics in the two-dimensional quantum Ising model — •Luka Pavesic[1,2], Daniel Jaschke[1,2,3], and Simone Montangero[1,2] — [1]Dipartimento di Fisica e Astronomia 'G. Galilei', via Marzolo 8, I-35131 Padova, Italy — [2]Istituto Nazionale di Fisica Nucleare (INFN), Sezione di Padova, I-35131 Padova, Italy — [3]Institute for Complex Quantum Systems, Ulm University, Albert-Einstein-Allee 11, 89069 Ulm, Germany

We numerically investigate the dynamics of the quantum Ising model on two-dimensional square lattices up to 16x16 spins. In the ordered phase, the model is predicted to exhibit dynamical constraints. This leads to confinement of elementary excitations and slow thermalization.

The dynamical constraints are strongly related to the presence of domain walls. We explore how the nature of confined excitations governs the evolution of domain walls, and investigate quantum coarsening of competing domains.

The results demonstrate the ability to numerically capture dynamics of large two-dimensional interacting systems. We foresee many interesting extensions of the presented work, numerically or experimentally. As the most direct avenues, we propose the investigation of quantum coarsening, and false vacuum decay in two dimensions.

A 30.5 Thu 15:30 GrHS Mathe

Quasiparticle Properties of Long-range Impurities in a Bose Condensate — •Taha Alper Yogurt and Matthew Eiles — Max Planck Institute for the Physics of Complex Systems Nöthnitzer Straße 38 01187 Dresden

Atomic impurities inside of a Bose condensate facilitated the study of Fröhlich polarons, wherein impurity-bath interactions are considered only to linear order. The tunability of interactions enabled the exploration of attractive and repulsive polaron regimes, requiring interactions beyond Fröhlich (BF) model. In this regime, polaron dynamics intertwine with few-body physics, as short and long-range impurities support single or multiple bound states. Characterizing an impurity as a quasiparticle across various regimes and the determination of its quasiparticle properties have attracted significant interest. Here we employ two complementary methods to compute the quasiparticle properties of the contact, ion, and Rydberg impurities in the BF model. First, we use an ansatz in the form of a coherent state of the condensate excitations. The coherent-state amplitudes for zero momentum are calculated to determine the energy and quasiparticle weights, followed by solving the implicit equation for a moving impurity to obtain the effective mass. The second method treats the impurity as a slowly moving external potential and solves the Gross-Pitaevskii (GP) equation, assuming small perturbations around a uniform density. By expanding the GP energy in powers of the impurity velocity, we derive an analytical expression for the BF effective mass of the contact impurities, consistent with the former approach.

A 30.6 Thu 15:45 GrHS Mathe

Engineering tunable synthetic fluxes with Raman-coupled Bose mixtures in an accordion optical lattice — •Andreas Michael Meyer[1], Ignacio Pérez-Ramos[1], Rémy Vatré[1], Sarah Hirthe[1], and Leticia Tarruell[1,2] — [1]ICFO - Institut de Ciencies Fotoniques, The Barcelona Institute of Science and Technology, 08860 Castelldefels (Barcelona), Spain — [2]ICREA, Pg. Lluís Companys 23, 08010 Barcelona, Spain

The Harper-Hofstadter model describes two-dimensional charged particles in a lattice in a perpendicular magnetic field. For interacting particles, it features exotic phases like the lattice analog of the fractional quantum Hall states. So far, realizations of these strongly-interacting systems using neutral cold atoms have been limited to few particles.

We report on our progress towards an interacting many-body realization of the Harper-Hofstadter model. It is based on a Raman-coupled bosonic spin mixture where the two spin states can be thought of as lattice sites in a synthetic dimension. Placing the spin mixture in a one-dimensional optical lattice, we can obtain a ladder system and realize a minimal instance of the model. The Raman coupling further results in complex tunneling rates giving rise to a synthetic flux through the ladder. It is governed by two competing length scales: the lattice spacing and the wavelength of the recoil momentum of the Raman transition.

Here, we present our experiment with optical lattices of adjustable lattice spacing. We can thus realize ladder systems pierced by arbitrary fluxes and probe their spectrum using spin-injection techniques.

A 30.7 Thu 16:00 GrHS Mathe

Parallel entangling gates on a 2D ion-trap lattice — •Lennart Kämmle, Ralf Riedinger, and Ludwig Mathey — University of Hamburg

In current trapped-ion quantum computers ion traps are commonly arranged in a (quasi-)linear configuration. However, this setup is hardware-intensive, limiting the scalability.

In this project we study several versions of 2D geometrics and control setups to improve the efficiency and scalability of trapped-ion quantum computers.

Specifically, we explore the geometric constraints of a 2D ion-trap lattice as well as schemes to apply the Mølmer-Sørensen entangling gate on multiple individual lattice sites in parallel by using local rotations.

Going forward we point out strategies regarding beam leakage and single-site selectivity, to improve the fidelity of parallel quantum entanglement gates in trapped-ion systems.

A 30.8 Thu 16:15 GrHS Mathe

Phase transitions and dissipation in one-dimensional supersolids. — •Chris Bühler, Alicia Biselli, and Hans Peter Büchler — Institute for Theoretical Physics III and Center for Integrated Quantum Science and Technology, University of Stuttgart, DE-70550 Stuttgart, Germany

Quantum fluctuations in one dimensions prevent the appearance of long-range order for a continuous symmetry even at zero temperature. Furtherure, the nucleation of quantum phase slips can have significant influence on the phase diagram and transport properties. Here, we study the influence of quantum phase slips on the phase diagram of a one-dimensional supersolid as they can be realized with Dysprosium atoms. We demonstrate the appearance of a novel quantum phase transition from the supersolid to the superfluid phase and study in detail its influence on transport properties.