A 15: Ultra-cold atoms, ions and BEC II (joint session A/Q)

Time: Wednesday 10:30–12:15 Location: A-H2

A 15.1 Wed 10:30 A-H2

Hole-induced anomaly in the thermodynamic behavior of a 1D Bose gas — •Giulia De Rosi[1], Riccardo Rota[2], Grigori E. Astrakharchik[1], and Jordi Boronat[1] — [1]Universitat Politècnica de Catalunya, Barcelona, Spain — [2]Ecole Polytechnique Fédérale de Lausanne, Switzerland

We reveal an intriguing anomaly in the temperature dependence of the specific heat of a one-dimensional Bose gas. The observed peak holds for arbitrary interaction and remembers a superfluid transition, but phase transitions are not allowed in 1D. The presence of the anomaly signals a region of unpopulated states which behaves as an energy gap and is located below the hole branch in the excitation spectrum. The anomaly temperature is of the same order of the energy of the maximum of the hole branch. We rely on the Bethe Ansatz to obtain the specific heat exactly and provide interpretations of the analytically tractable limits. The dynamic structure factor is computed with the Path Integral Monte Carlo method for the first time. We notice that at temperatures similar to the anomaly threshold, the energy of the thermal fluctuations become comparable with the maximal hole energy. This excitation pattern experiences the breakdown of the quasiparticle description for any value of the interaction strength at the anomaly, similarly to any superfluid phase transition at the critical temperature. We provide indications for future observations and how the hole anomaly can be employed for in-situ thermometry, identifying different collisional regimes and understanding other anomalies in atomic, solid-state, electronic and spin-chain systems. [arXiv:2104.12651 (2021)].

A 15.2 Wed 10:45 A-H2

Signatures of radial and angular rotons in a two-dimensional dipolar quantum gas — •Sean Graham[1], Jan-Niklas Schmidt[1], Jens Hertkorn[1], Mingyang Guo[1], Fabian Böttcher[1], Matthias Schmidt[1], Kevin Ng[1], Tim Langen[1], Martin Zwierlein[2], and Tilman Pfau[1] — [1]5th Institute of Physics and Center for Integrated Quantum Science and Technology IQST, University of Stuttgart, Germany — [2]MIT-Harvard Center for Ultracold Atoms, Research Laboratory of Electronics, and Department of Physics, Massachusetts Institute of Technology, Cambridge, USA

We observed signatures of radial and angular roton modes and their contribution to droplet formation in an oblate dipolar quantum gas. Roton modes have a finite momentum that can be significantly populated in dipolar quantum gases when dipole-dipole interactions are strong relative to hard-core interactions. For stronger dipole-dipole interactions the condensate will crystallize into droplets. Near this crystallization transition we extract the static structure factor from in-situ density fluctuations. We identify the presence of a radial roton by a peak at finite momentum in the radial structure factor that appears near the transition. Additional peaks are observed in the angular structure factor corresponding to the population of the angular roton mode. Finally, a comparison to simulated mode patterns from the extended Gross-Pitaevski equation shows good agreement with our results.

A 15.3 Wed 11:00 A-H2

Two-body correlations in imbalanced quantum systems — •Carl Heintze[1], Keerthan Subramanian[1], Sandra Brandstetter[1], Marvin Holten[1], Philipp Preiss[1,2], and Selim Jochim[1] — [1]Physikalisches Institut, Im Neuenheimer Feld 226, 69120 Heidelberg — [2]Max Planck Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching

Superfluidity in strongly correlated systems still poses a challenging task for experimentalists and theorists. Explaining the phenomenon with pair formation enables us to tackle the problem in the limit of strongly bound particles building up molecules (BEC limit) and delocalized zero momentum pairs (BCS limit). Nevertheless, complete and verified theories of strongly correlated regimes in between are still missing. Additionally, there are ongoing discussions about the pairing mechanisms, the breakdown of superfluidity and the rich phase diagram in imbalanced systems.

Our experiment focuses on the emergence of correlations and collective behaviour in many particle systems from the few-particle limit. The apparatus enables us to prepare small quantum systems (two to twelve particles) deterministically in a two-dimensional harmonic oscillator and to image the final state with spin and single particle resolution. Therefore, we can extract the in-situ two-body correlations in momentum as well as in real space. By using spectroscopic measurements, we are also able to measure excitation spectra.

Recently we achieved to prepare imbalanced systems (3+1, 6+3, 6+1 particles) and to measure their momentum correlations.

A 15.4 Wed 11:15 A-H2

An impurity with a resonance in the vicinity of the Fermi energy — •Mikhail Maslov, Mikhail Lemeshko, and Artem Volosniev — IST Austria, Am Campus 1, 3400 Klosterneuburg, Austria

We study an impurity with a resonance level whose energy coincides with the Fermi energy of the surrounding Fermi gas. An impurity causes a rapid variation of the scattering phase shift for fermions at the Fermi surface, introducing a new characteristic length scale into the problem. We investigate manifestations of this length scale in the self-energy of the impurity and in the density of the bath. Our calculations reveal a model-independent deformation of the density of the Fermi gas, which is determined by the width of the resonance. To provide a broader picture, we investigate time evolution of the density in quench dynamics, and study the behavior of the system at finite temperatures. Finally, we briefly discuss implications of our findings for the Fermi-polaron problem.

A 15.5 Wed 11:30 A-H2

Dynamics of atoms within atoms — •Shiva Kant Tiwari[1], Felix Engel[2], Marcel Wagner[3,4], Richard Schmidt[3,4], Florian Meinert[2], and Sebastian Wüster[1] — [1]Department of Physics, Indian Institute of Science Education and Research, Bhopal, Madhya Pradesh 462 066, India — [2]Physikalisches Institut and Center for Integrated Quantum Science and Technology, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany — [3]Max-Planck-Institut für Quantenoptik, 85748 Garching, Germany — [4]Munich Center for Quantum Science and Technology (MCQST), Schellingstr. 4, D-80799 München, Germany

Recent experiments with Bose-Einstein condensates have entered a regime in which thousands of ground-state condensate atoms fill the Rydberg-electron orbit. After the excitation of a single atom into a highly excited Rydberg state, scattering off the Rydberg electron sets ground-state atoms into motion, such that one can study the quantum-many-body dynamics of atoms moving within the Rydberg atom. Here we study this many-body dynamics using Gross-Pitaevskii and truncated Wigner theory. Our simulations focus in particular on the scenario of multiple sequential Rydberg excitations on the same Rubidium condensate which has become the standard tool to observe quantum impurity dynamics in Rydberg experiments. We investigate to what extent such experiments can be sensitive to details in the electron-atom interaction potential, such as the rapid radial modulation of the Rydberg molecular potential, or p-wave shape resonance. Finally, we explore the local dynamics of condensate heating.

A 15.6 Wed 11:45 A-H2

Quantum Rabi dynamics of trapped atoms far in the deep strong coupling regime — •Geram Hunanyan[1], Johannes Koch[1], Enrique Rico[2,3], Enrique Solano[2,3], and Martin Weitz[1] — [1]Institut für Angewandte Physik, Universität Bonn, Wegelerstr. 8, 53115 Bonn, Germany — [2]Department of Physical Chemistry, University of the Basque Country UPV/EHU, Apartado 644, 48080 Bilbao, Spain — [3]IKERBASQUE, Basque Foundation for Science, Plaza Euskadi 5, 48009 Bilbao, Spain

The coupling of a two-level system with a field mode, whose fully quantized field version is known as the quantum Rabi model (QRM), is among the central topics of quantum physics and recent quantum information technologies. When the coupling strength reaches the field mode frequency, the full QRM Hamiltionian comes into play, where excitations can be created out of the vacuum.

We demonstrate a novel approach for the realization of a periodic variant of the quantum Rabi model using two coupled vibrational modes of cold atoms in optical potentials, which has allowed us to reach a Rabi coupling strength of 6.5 times the bosonic field mode frequency, i.e., far in the so called deep strong coupling regime. For the first time, the coupling term dominates over all other energy scales.

Field mode creation and annihilation upon e.g., de-excitation of the two-level system here approach equal magnitudes, and we observe the atomic dynamics in this novel experimental regime, revealing a subcycle timescale raise in field mode excitations, in good agreement with theoretical predictions.

A 15.7 Wed 12:00 A-H2

orbital many-body dynamics of bosons in the second bloch band of an optical lattice — •JOSE VARGAS[1], MARLON NUSKE[1,2,3], RAPHAEL EICHBERGER[1,2], CARL HIPPER[1], LUDWIG MATHEY[1,2,3], and ANDREAS HEMMERICH[1,2,3] — [1]Institut für Laserphysik, Universität Hamburg, 22761 Hamburg, Germany — [2]Zentrum für Optische Quantentechnologien, Universität Hamburg, 22761 Hamburg, Germany — [3]The Hamburg Center for Ultrafast Imaging, Luruper Chaussee 149, Hamburg 22761, Germany

We explore Josephson-like dynamics of a Bose-Einstein condensate of rubidium atoms in the second Bloch band of an optical square lattice providing a double well structure with two inequivalent, degenerate energy minima. This oscillation is a direct signature of the orbital changing collisions predicted to arise in this system in addition to the conventional on-site collisions. The observed oscillation frequency scales with the relative strength of these collisional interactions, which can be readily tuned via a distortion of the unit cell. The observations are compared to a quantum model of two single-particle modes which reproduces the observed oscillatory dynamics and show the correct dependence of the oscillation frequency on the ratio between the strengths of the on-site and orbital changing collision processes.