Q 17: Quantum Gases: Bosons I

Time: Tuesday 11:00–13:00 Location: e001

Group Report Q 17.1 Tue 11:00 e001

Rosensweig instability and solitary waves in a dipolar Bose-Einstein condensate — •Matthias Wenzel, Holger Kadau, Matthias Schmitt, Igor Ferrier-Barbut, and Tilman Pfau — 5. Physikalisches Institut and Center for Integrated Quantum Science and Technology, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany

Ferrofluids show unusual hydrodynamic effects due to the magnetic nature of their constituents. For increasing magnetization a classical ferrofluid undergoes a Rosensweig instability and creates self-organized ordered surface structures or droplet crystals.
In the experiment we observe a similar behavior in a sample of ultracold dysprosium atoms, a quantum ferrofluid. By controlling the short-range interaction with a Feshbach resonance we can induce a finite-wavelength instability due to the dipolar interaction.
Subsequently, we observe the spontaneous transition from an unstructured superfluid to an ordered arrangement of droplets by in situ imaging. These patterns are surprisingly long-lived and show hysteretic behavior. When transferring the sample to a waveguide we observe mutually interacting solitary waves. Time-of-flight measurements allow us to show the existence of an equilibrium between dipolar attraction and short-range repulsion. In addition we observe interference between droplets.
In conclusion, our system shows both superfluidity and translational symmetry breaking. This novel state of matter is thus a possible candidate for a supersolid ground state.

Q 17.2 Tue 11:30 e001

Rosensweig instability due to three-body interaction or quantum fluctuations? — Vladimir Lončar[1], Dušan Vudragović[1], •Antun Balaž[1], and Axel Pelster[2] — [1]Scientific Computing Laboratory, Institute of Physics Belgrade, University of Belgrade, Serbia — [2]Physics Department and Research Center OPTIMAS, Technical University of Kaiserslautern, Germany

In the recent experiment [1], the Rosensweig instability was observed in a ^{164}Dy Bose-Einstein condensate, which represents a quantum ferrofluid due to the large atomic magnetic dipole moments. After a sudden reduction of the scattering length, which is realized by tuning the external magnetic field far away from a Feshbach resonance, the dipolar quantum gas creates self-ordered surface structures in form of droplet crystals. As the underlying Gross-Pitaevskii equation is not able to explain the emergence of that Rosensweig instability, we extend it by both three-body interactions [2-4] and quantum fluctuations [5]. We then use extensive numerical simulations in order to study the interplay of three-body interactions as well as quantum fluctuations on the emergence of the Rosensweig instability.

[1] H. Kadau, M. Schmitt, et al., `arXiv:1508.05007v2` (2015).
[2] H. Al-Jibbouri, I. Vidanović, A. Balaž, and A. Pelster, J. Phys. B **46**, 065303 (2013).
[3] R. N. Bisset and P. B. Blakie, `arXiv:1510.09013` (2015).
[4] K.-T. Xi and H. Saito, `arXiv:1510.07842` (2015).
[5] A. R. P. Lima and A. Pelster, Phys. Rev. A **84**, 041604(R) (2011); Phys. Rev. A **86**, 063609 (2012).

Q 17.3 Tue 11:45 e001

Phonon to roton crossover and droplet formation in trapped dipolar Bose-Einstein condensates — •Falk Wächtler and Luis Santos — Institut für Theoretische Physik, Leibniz Universität Hannover, Hannover, Germany

The stability, elementary excitations, and instability dynamics of dipolar Bose-Einstein condensates depend crucially on the trap geometry. In particular, dipolar condensates in a pancake trap with its main plane orthogonal to the dipole orientation are expected to present under proper conditions a roton-like dispersion minimum, which if softening induces the so-called roton instability. On the contrary, cigar-shape traps are expected to present no dispersion minimum, and to undergo phonon (global) instability if destabilized. In this talk we investigate by means of numerical simulations of the non-local non-linear Schrödinger equation and the corresponding Bogoliubov-de Gennes equations the stability threshold as a function of the trap aspect ratio, mapping the crossover between phonon and roton instability. We will discuss in particular how this crossover may be observed in destabilization experiments to reveal rotonization.
In a second part, motivated by recent experiments on droplet formation in Stuttgart, we introduce large conservative three-body interactions, and study how these forces affect the destabilization dynamics. We will discuss the ground-state physics of the individual droplets, and the crucial role that is played by the interplay between internal droplet energy, external center-of mass energy of the droplets, and energy dissipation in the nucleation of droplets observed in experiments.

Q 17.4 Tue 12:00 e001

Lattice Physics with Ultracold Magnetic Erbium — •Simon Baier[1], Manfred J. Mark[1,2], Daniel Petter[1], Kiyotaka Aikawa[1], Lauriane Chomaz[1,2], Zi Cai[2], Mikhail Baranov[2], Peter Zoller[2,3], and Francesca Ferlaino[1,2] — [1]Institut für Experimentalphysik, Universität Innsbruck, Technikerstraße 25, 6020 Innsbruck, Austria — [2]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, 6020 Innsbruck, Austria — [3]Institut für Theoretische Physik, Universität Innsbruck, Technikerstraße 21A, 6020 Innsbruck, Austria

Strongly magnetic atoms are an ideal systems to study many-body quantum phenomena with anisotropic and long-range interactions. Here, we report on the first observation of the manifestation of magnetic dipolar interaction in extended Bose-Hubbard (eBH) dynamics by studying an ultracold gas of Er atoms in a three-dimensional optical lattice. We drive the superfluid-to-Mott-insulator (SF-to-MI) quantum phase transition and demonstrate that the dipolar interaction can favor the SF or the MI phase depending on the orientation of the atomic dipoles. The system is well described by the individual terms of the eBH Hamiltonian. This includes the onsite interaction, which, additional to the isotropic contact interaction, can be tuned with the dipole-dipole interaction by changing the dipole orientation and the shape of the onsite Wannier functions. We find for the first time the presence of the nearest-neighbor interaction between two adjacent particles. Future work will investigate dipolar effects with erbium molecules and fermions as well as spin physics in our lattice system.

Q 17.5 Tue 12:15 e001

Strong-wave-turbulence character of non-thermal fixed points in Bose gases — •Isara Chantesana[1,2,3] and Thomas Gasenzer[2,3] — [1]Institut für Theoretische Physik, Ruprecht-Karls-Universität Heidelberg, Philosophenweg 16, 69120 Heidelberg, Germany — [2]Kirchhoff Institut für Physik, INF 227, 69120 Heidelberg, Germany — [3]ExtreMe Matter Institute EMMI, GSI Helmholtzzentrum für Schwerionenforschung GmbH, Planckstraße 1, 64291 Darmstadt, Germany

Far-from equilibrium dynamics of a dilute Bose gas is studied by means of the two-particle irreducible effective action formalism. We investigate the properties of non-thermal fixed points predicted previously, which are related to non-perturbative strong wave turbulence solutions of the many-body dynamic equations. Instead of using a scaling analysis, we study the Boltzmann equation of the scattering integral by means of direct integration equation for sound waves. In this way we obtain a direct prediction of the scaling behaviour of the possible fixed-point solutions in the context of sound-wave turbulence. Implication for the real-time dynamics of the non-equilibrium system are discussed.

Q 17.6 Tue 12:30 e001

Evidence of Non-Thermal Fixed Points in one-dimensional Bose gases — •Sebastian Erne[1,2,4], Robert Bücker[4], Wolfgang Rohringer[4], Thomas Gasenzer[1,2,3], and Jörg Schmiedmayer[4] — [1]Institut für Theoretische Physik, Ruprecht-Karls-Universität Heidelberg, Philosophenweg 16, 69120 Heidelberg, Germany — [2]ExtreMe Matter Institute EMMI, GSI Helmholtzzentrum für Schwerionenforschung GmbH, Planckstraße 1, 64291 Darmstadt, Germany — [3]Kirchhoff-Institut für Physik, INF 227, 69120 Heidelberg, Germany — [4]Vienna Center for Quantum Science and Technology (VCQ), Atominstitut, TU Wien, Vienna, Austria

This work investigates the rapid cooling quench over the dimensional- and quasicondensate-crossover. Analyzing experiments performed at the Atominstitut, we study the relaxation of such a far-from equilibrium system. The early stage of condensate formation is dominated by solitonic excitations, leading to a characteristic momentum distribution in agreement with a model of randomly distributed defects. The number of solitons increases with the quenchrate giving rise to an incompressible condensate. The isolated system follows a self-similar evolution governed by a universal time-independent nonthermal fixed point distribution. The dynamic universality classes of these nonequilibrium attractor solutions are relevant for a wide variety of physical systems ranging from relativistic high-energy physics to cold quantum gases. At later times of the evolution the system fully equilibrates leading to deviations from the self-similar evolution. Our results show a new way of condensation in far from equilibrium 1d Bose gases.

Q 17.7 Tue 12:45 e001

Spin phonon dynamics with classical statistical methods — •Asier Piñeiro Orioli[1,2], Arghavan Safavi-Naini[2], Michael Wall[2], and Johannes Schachenmayer[2] — [1]Institute for Theoretical Physics, Heidelberg, Germany — [2]JILA, NIST and University of Colorado, Boulder, Colorado, USA

Systems with both spin and phonon degrees of freedom are ubiquitous in physical fields ranging from condensed matter to biophysics. However, methods to compute the dynamics of such systems are scarce, especially in high dimensions. In this work, we combine the Truncated Wigner Approximation (TWA) for bosons with its recently developed discrete version (dTWA) for spins to describe the dynamics of coupled spin-phonon systems. We benchmark the method by comparing to exact results and discuss applications to trapped-ion and cavity experiments.