Q 22: Quantum Gases: Bosons II

Time: Tuesday 14:30–16:30 Location: e001

Q 22.1 Tue 14:30 e001

Inducing Bose condensation with a hot needle — •Alexander Schnell[1], Daniel Vorberg[1], Roland Ketzmerick[1,2], and André Eckardt[1] — [1]Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Straße 38, 01187 Dresden, Germany — [2]Technische Universität Dresden, Institut für Theoretische Physik, 01187 Dresden, Germany

A quantum system exchanging energy with a thermal bath will assume an equilibrium state that is completely determined by the bath temperature. In contrast, when the system is driven out of equilibrium, e.g. by coupling it to two baths of different temperatures, the system will assume a non-equilibrium steady state that does not only depend on the bath temperatures, but on the very details of the system bath coupling.

This offers great freedom to tailor the properties of a system by bath engineering and can also give rise to counter intuitive effects. We consider an ideal one-dimensional Bose gas immersed in a cold bath. We show that the coherence length of the system can be increased by several orders of magnitude by coupling it additionally to a "hot needle" (a second, spatially localized bath that is much hotter than the first one). As a consequence, Bose condensation can be induced by a hot needle in a system of finite extent.

Q 22.2 Tue 14:45 e001

Interplay between statistics and interactions in 1D few-boson systems — •Quirin Hummel, Benjamin Geiger, Juan Diego Urbina, and Klaus Richter — Institut für Theoretische Physik, Universität Regensburg, Germany

The theoretical study of quantum few-body systems poses a fundamental challenge since the absence of a large number of particles makes the usually simplifying description within the grand canonical formalism invalid. We analytically address the fundamental interplay between indistinguishability and interactions in systems where the total number of particles is strictly fixed, quantum statistics is treated exactly and interparticle forces are described non-perturbatively, by introducing a set of techniques based on neglecting the discreteness of spectra at the level of a cluster expansion of the canonical partition function. Our approach is specially suitable for the few-body case as it generates thermodynamic and spectral properties in terms of a *finite* set of permutation and interaction events thus overcoming the inappropriate use of virial expansions. For 1D systems with short range interactions we found analytical expressions applicable to both integrable and realistic non-integrable models with harmonic confinement.

Q 22.3 Tue 15:00 e001

Ramsey Interferometry with squeezed collective spin states under decoherence — •Björn Schrinski[1], Stefan Nimmrichter[2], and Klaus Hornberger[1] — [1]Fakultät für Physik, Universität Duisburg-Essen — [2]Centre For Quantum Technologies, National University of Singapore

We discuss the non-unitary time evolution of number-squeezed collective spin states in Ramsey interferometry. We focus on decoherence models as proposed by the CSL model [1] or utilized by macroscopicity measures [2]. Exemplary experimental realisations are BEC superpositions with ultracold Rubidium atoms in double [3] and single-well [4] potentials. Our analytical results are based on a continuous-variables approach in the basis of Dicke states and are verified using exact numerical simulations in cases when the particle number is conserved.

[1] Bassi et al., Rev. Mod. Phys. 85, 471-527 (2013)
[2] Nimmrichter et al., Phys. Rev. Lett. 110, 160403 (2013)
[3] Berrada et al., Nat. Commun. 4, 2077 (2013)
[4] S. van Frank et al., Nat. Commun. 5, 4009 (2014)

Q 22.4 Tue 15:15 e001

Short time propagation in interacting bosonic systems — •Benjamin Geiger, Quirin Hummel, Juan-Diego Urbina, and Klaus Richter — Institut für Theoretische Physik Universität Regensburg, 93040 Regensburg, Germany

In order to investigate general properties of interacting bosonic gases we present a formalism to calculate thermodynamic properties as well as the smoothed density of states by means of short-time propagation and compare our analytical predictions against quantum integrable models that allow for an exact analysis by means of Bethe ansatz techniques. As an essential input of our approach, we were able to construct the many-body propagator for a one-dimensional free bosonic gas with delta interactions of variable strength. Using this propagator we can give short-time approximations for the Lieb-Liniger model and non-integrable systems including external harmonic potentials. Furthermore we can think of using the spatial information and the time dependence of the propagator to calculate e.g. two-point correlations or to investigate quantum quenches.

Q 22.5 Tue 15:30 e001

Many-particle quantum dynamics after an interaction quench for ground state quantum bright solitons — •Christoph Weiss[1] and Lincoln Carr[2] — [1]Joint Quantum Centre (JQC) Durham-Newcastle, Department of Physics, Durham University, United Kingdom — [2]Colorado School of Mines, Golden, USA

We investigate strongly attractively interacting bosons in a (quasi-)one-dimensional waveguide initially prepared in the ground state of an additional harmonic potential, a quantum bright soliton. An interaction quench that increases the interaction by a factor of four combined with switching off the potential leads to a higher-order soliton for which the mean-field description via the Gross-Pitaevskii equation predicts oscillations of the variance of the single particle density. We investigate the quantum many-particle dynamics after such an interaction quench numerically via TEBD and back our interpretation of the data by calculations based on the Lieb-Linger model with attractive interactions.

Q 22.6 Tue 15:45 e001

Long-range correlations and superfluidity of the one-dimensional quasi-condensate — •Hansjörg Polster and Carsten Henkel — Institute of Physics and Astronomy, University of Potsdam, Germany

A Bose gas confined to two or one dimensions does not show any phase transition. Still, due to interactions, a smooth cross over is found when the density increases, signalled by a reduction of density fluctuations and an increase in the phase correlation length. We discuss exact results for correlation functions of the Bose field, obtained with the help of a mapping to a random walk in the complex plane [1,2].

When the Bose gas is rotated in a closed ring, discrete peaks emerge in the momentum distribution, defined by the winding numbers of the complex field. We discuss the disappearance of these peaks when the rotation velocity is increased and compare to Landau's scenario of the breakdown of superfluidity. Full distribution functions are obtained for both local and global quantities like current density and total momentum.

[1] L. W. Gruenberg and L. Gunther, *Phys. Lett. A* **38** (1972) 463; D. J. Scalapino, M. Sears, and R. A. Ferrell, *Phys. Rev. B* **6** (1972) 3409
[2] I. Carusotto and Y. Castin, *C. R. Physique* **5** (2004) 107

Q 22.7 Tue 16:00 e001

Towards the Bose Polaron in an ultracold gas — •Lars J. Wacker, Nils B. Jørgensen, Kristoffer T. Skalmstang, Rasmus S. Christensen, Georg Bruun, and Jan Arlt — Department of Physics and Astronomy, Aarhus University, Ny Munkegade 120, 8000 Aarhus C, Denmark

An impurity interacting with its surroundings leads to the formation of a quasi particle, called a polaron. This was first described by Landau as a bosonic phonon gas, formed in a solid by the interaction of an electron with the lattice displacements. Ultracold gases with their high degree of control allowed for first experimental investigations of the Fermi polaron in ultracold Fermi gases.

Likewise, bosonic polarons can be investigated using mixtures of ultracold bosonic gases. I present our study of the Bose polaron, employing a magnetic Feshbach resonance to tune the interaction between two spin states of ^{39}K. We record the energy spectrum of the impurity for different interaction strengths, allowing us to distinguish between the mean field energy regime and the appearance of the polaronic signature in the spectrum.

Q 22.8 Tue 16:15 e001

Dynamics of Bose polarons in a BEC — •Fabian Grusdt[1],

Yulia Shchadilova[1], Richard Schmidt[1,2], and Eugene Demler[1] — [1]Department of Physics, Harvard University, Cambridge, Massachusetts 02138, USA — [2]ITAMP, Harvard-Smithsonian Center for Astrophysics, Cambridge, MA 02138, USA

When neutral impurity atoms are placed in a Bose-Einstein condensate (BEC), they become dressed by a cloud of phonons and form a polaron. We calculate the spectral function of the impurity, which serves as a fingerprint of polarons in experiments with strongly imbalanced atomic mixtures. We also study the dynamics of polaron formation in the time domain, after a sudden quench of the interaction strength which can be realized using Feshbach resonances. For finite initial velocities of the impurity atoms we predict strong deceleration for long times and find non-trivial transient polaron trajectories.

We analyze the BEC polaron using an extension of the renormalization group (RG) approach [Grusdt et al., Sci.Rep.5:12124, 2015] to far-from equilibrium dynamics. Fröhlich polarons are considered first, but we also apply the RG method to go beyond the Fröhlich approximation. This is necessary to describe experiments in the strong-coupling regime.