Q 29: Quantum Gases: Bosons IV

Time: Tuesday 14:30–16:45 Location: P 204

Q 29.1 Tue 14:30 P 204

Non-equilibrium condensation of weakly interacting bosons in the presence of thermal baths: treating temperature-dependent dissipation — •Alexander Schnell and André Eckardt — Max-Planck-Institut für Physik komplexer Systeme, Dresden, Germany

When a quantum system is coupled weakly to a rapidly relaxing thermal bath of inverse temperature β, a simple description of this open system is given by the Born-Markov approximation. Within this framework, the bath induces quantum jumps between energy eigenstates, whose rates depend the bath temperature through the product $\beta\Delta E$ involving the energy change ΔE. Taking into account this form of temperature-dependent dissipation for a many-body system far from equilibrium is challenging. Already on the level of a simple mean-field approximation, it requires the diagonalization of the mean-field Hamiltonian in every step of the time integration. We propose and test a scheme to circumvent this problem by treating the system-bath coupling semi-classically and apply it to describe non-equilibrium Bose condensation in weakly interacting Bose gases in contact with two thermal baths of different temperature.

Q 29.2 Tue 14:45 P 204

Center of mass dynamics across the superfluid to Mott insulator phase transition in an optical lattice. — •Andreas Müllers[1], Christian Baals[1,5], Bodhaditya Santra[1,3], Ralf Labouvie[1,5], Thomas Mertz[2], Arya Dhar[2], Ivana Vasic[4], Agnieszka Cichy[2], Walter Hofstetter[2], and Herwig Ott[1] — [1]Research Center OPTIMAS and Fachbereich Physik, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany — [2]Institut für Theoretische Physik, Goethe-Universität Frankfurt, D-60438 Frankfurt/Main, Germany — [3]Zentrum für Optische Quantentechnologien, Universität Hamburg, 22761 Hamburg, Germany — [4]Scientific Computing Laboratory, Institute of Physics Belgrade, University of Belgrade, 11080 Belgrade, Serbia — [5]Graduate School Materials Science in Mainz, Staudingerweg 9, 55128 Mainz, Germany

We study the relaxation dynamics of a many-body quantum system after forcing it out of equilibrium by displacing an underlying potential. We adiabatically load ^{87}Rb atoms into a 3D optical lattice superimposed on an optical dipole trap and then shift the trapping potential by $1\,\mu$m. Using a scanning electron microscope, we image the center of mass motion of the atoms during relaxation for various depths of the optical lattice, spanning the superfluid to Mott-insulator phase transition. We observe varying dynamics across the transition and by piecewise analysis of the system, we can also identify a thermal phase at the edges which moves with velocities in between those of the superfluid and the insulating phase. We present our measured data and the results of theoretical modeling currently in progress.

Q 29.3 Tue 15:00 P 204

Density ordering dynamics at an insulator to insulator transition — •Lorenz Hruby, Nishant Dogra, Katrin Kröger, Manuele Landini, Tobias Donner, and Tilman Esslinger — Institute for Quantum Electronics, ETH Zurich, 8093 Zurich, Switzerland

Engineering of open quantum many-body systems allows for new insights into the dynamics of complex quantum phases. Here we experimentally explore the phase transition between two insulating phases of Mott type with different density ordering. The transition is driven by competing on-site and global-range interactions. We monitor the temporal dynamics of the density order parameter in real-time and we observe a hysteresis loop and the emergence of two distinct timescales in the ordering dynamics. We explain our findings using a mean-field approach featuring metastable many-body states. Our system is based on a Bose-Einstein condensate trapped in a three-dimensional optical lattice which controls the on-site interaction strength. Tunable atom-atom interactions of global-range are mediated by coupling the condensate to a single mode of an optical cavity.

Q 29.4 Tue 15:15 P 204

Models for a multimode bosonic tunneling junction — •David Fischer[1] and Sandro Wimberger[1,2,3] — [1]Institut für Theoretische Physik, Philosophenweg 12, Universität Heidelberg, 69120 Heidelberg, Germany — [2]Dipartimento di Scienze Matematiche, Fisiche e Informatiche, Università degli Studi di Parma, Parco Area delle Scienze 7/a, 43124 Parma, Italy — [3]INFN, Sezione di Milano Bicocca, Gruppo Collegato di Parma,Italy

We discuss the relaxation dynamics for a bosonic tunneling junction with two modes in the central potential well. We use a master equation description for ultracold bosons tunneling into two central modes in the presence of noise and incoherent coupling processes. The master equation is solved exactly with quantum jump simulations. Whilst we cannot quantitatively reproduce the experimental data of the setup reported in [1], we find a reasonable qualitative agreement of the refilling process of the initially depleted central site. Furthermore an analysis of the time scale of the refilling shows a power-law behavior with respect to the decoherence rates, with *similar exponents* for all analyzed processes. Our results may pave the way for the control of bosonic tunneling junctions by the simultaneous presence of decoherence processes and atom-atom interaction.

[1] R. Labouvie, B. Santra, S. Heun, S. Wimberger, and H. Ott, Phys. Rev. Lett. **115**, 050601 (2015).

Q 29.5 Tue 15:30 P 204

A Bosonic Josephson Junction with an Impurity — •Maximilian Dirkmann, Gabriel Dufour, and Andreas Buchleitner — Institute of Physics, University of Freiburg, Germany

We study the dynamics of a Bose-Einstein condensate in a double-well potential, or bosonic Josephson junction [1], in the presence of a mobile impurity particle. This allows us to test the practicability of a quantum probe scheme, where measurements are performed on the impurity in order to obtain information about the rest of the system.

The system is described using a two-site Bose-Hubbard Hamiltonian which accounts for tunneling between the wells and on-site interactions between the particles. We observe a variety of dynamical regimes as the relative strength of tunneling and interactions is changed. In particular, we study the entanglement of the impurity particle with the rest of the system. In the weakly interacting regime, we demonstrate that the amplitude of impurity's oscillations between the two wells is related to the purity of its reduced density matrix.

[1] G.J. Milburn et al. *Phys. Rev. A* **55**, 4318-4324 (1997).

Q 29.6 Tue 15:45 P 204

A path-integral approach to composite, rotating impurities — •Giacomo Bighin and Mikhail Lemeshko — Institute of Science and Technology Austria, Am Campus 1, 3400 Klosterneuburg, Austria

The study of composite, rotating impurities interacting with a quantum many-body environment is extremely important for the description of several experimental settings: cold molecules in a Bose-Einstein condensate or embedded in helium nanodroplets, electronic excitations in a BEC or in a solid. In all these cases the vibrational and rotational degrees of freedom create an involved energy level structure, with a continuous exchange of angular momentum with the surrounding environment. The recently-introduced angulon quasiparticle [1] formalises the concept of a rotating, interacting impurity. In this talk we introduce an alternative approach to the angulon problem making use of the path integral formalism, extending Feynman's treatment for the polaron. A clear advantage is that the bath degrees of freedom and the interaction can be integrated out exactly, resulting in an effective, single-particle description for the angulon in which the many-body character of the original problem is encoded in an interaction term. This alternative, effective treatment for the angulon is, in principle, valid at arbitrary coupling and at arbitrary temperature. The results obtained will be compared with existing state-of-the-art theories for composite impurities and with experimental data from the rotational spectrum of molecules embedded in helium nanodroplets.

References: [1] R. Schmidt and M. Lemeshko, Phys. Rev. Lett. 114, 203001 (2015) and Phys. Rev. X 6, 011012 (2016).

Q 29.7 Tue 16:00 P 204

Anomalous screening of quantum impurities by a neutral environment — •Enderalp Yakaboylu and Mikhail Lemeshko — Institute of Science and Technology Austria (IST Austria), Klosterneuburg, Austria

We investigate the dynamics of a rotating impurity interacting with a neutral many-body bosonic bath in the presence of an oscillating electric field. Even though light cannot interact with the neutral bath, we show that the neutral bath itself is capable to induce a drastic screening of the impurity's dipole moment and polarizability due to angular momentum transfer between the impurity and the bath. Consequently, all phenomena related to the light-molecule interaction can be generalized to the interaction in the presence of a neutral many-body environment by means of the screened dipole moment and the screened polarizability of the impurity. In particular, we showed how a neutral many-body environment affects the effective Rabi frequency, the geometric phase, and the molecular alignment.

Q 29.8 Tue 16:15 P 204

Dimensionally Induced Phase Transition of the Weakly Interacting Ultracold Bose Gas — •Bernhard Irsigler[1,2] and Axel Pelster[3] — [1]Institut für Theoretische Physik, Johann Wolfgang Goethe-Universität, Germany — [2]Institut für Theoretische Physik, Freie Universität Berlin, Germany — [3]Fachbereich Physik und Forschungszentrum OPTIMAS, Technische Universität Kaiserslautern, Germany

We investigate the dimensionally induced phase transition from the normal to the Bose-Einstein condensed phase for a weakly interacting Bose gas in optical lattices. To this end we make use of the Hartree-Fock-Bogoliubov-Popov theory, where we include numerically exact hopping energies and effective interaction strengths. At first we determine the critical chemical potential, where we find a much better agreement with recent experimental data than a pure Hartree-Fock treatment [1]. We ascribe this finding to the dominant role of quantum fluctuations in lower dimensions. Furthermore, we determine for the 1D-3D-transition the power-law exponent of the critical temperature for two different non-interacting Bose gas models yielding the same exponent of 1/2 which indicates that they belong to the same universality class. For the weakly interacting Bose gas we find for both models that this exponent is robust with respect to finite interaction strengths.

[1] A. Vogler, R. Labouvie, G. Barontini, S. Eggert, V. Guarrera, and H. Ott, Phys. Rev. Lett. **113**, 215301 (2014)

Q 29.9 Tue 16:30 P 204

Observing the Goldstone and the amplitude mode in a supersolid quantum gas — •Julian Léonard, Andrea Morales, Philip Zupancic, Tilman Esslinger, and Tobias Donner — Institute for Quantum Electronics, ETH Zurich, Switzerland

A phase transition with continuous symmetry breaking of a scalar quantum field can give rise to excitations of its phase and amplitude. A supersolid presents an intriguing example for such an excitation spectrum, as both continuous gauge symmetry of the superfluid phase and the translational symmetry of the lattice modulation are broken simultaneously.

We investigate the interplay of these symmetries by studying the elementary excitations across the superfluid-supersolid phase transition. The supersolid phase is realized by coupling a Bose-Einstein condensate with the fields of two crossed cavity modes. We perform cavity-enhanced Bragg spectroscopy on the quantum gas to measure its excitation spectrum. In the superfluid phase, we observe two independent modes that soften upon approaching the critical point. Inside the supersolid phase the modes split into a low-energetic Goldstone mode and a high-energy amplitude mode.