TT 9: Cold Atomic Gases and Superfluids

Time: Monday 18:00–19:15 Location: H23

TT 9.1 Mon 18:00 H23

Symmetry-protected Bose-Einstein condensation of interacting hardcore bosons — •Reja Wilke[1], Thomas Köhler[2], Felix Palm[1], and Sebastian Paeckel[1] — [1]Department of Physics, Arnold Sommerfeld Center for Theoretical Physics, University of Munich, Germany — [2]Department of Physics and Astronomy, Uppsala University, Sweden

We introduce a mechanism stabilizing a one-dimensional quantum many-body phase, characterized by a certain wave vector via the protection of an emergent $\mathbb{Z}_2$ symmetry. We illustrate this mechanism by constructing the solution of the full quantum many-body problem of hardcore bosons on a wheel geometry, which are known to form a Bose-Einstein condensate. The robustness of the condensate is shown numerically by adding nearest-neighbor interactions to the wheel Hamiltonian. We discuss further applications such as geometrically inducing finite-momentum condensates.

TT 9.2 Mon 18:15 H23

Quantum light-matter fluctuations in driven open cavity BEC systems — •Leon Mixa and Michael Thorwart — I. Institut für Theoretische Physik, Universität Hamburg

When an ultracold atom gas strongly interacts with a pumped cavity light field, effective retarded long-range interactions are induced. They give rise to non-classical states in the light sector, which do not necessarily require non-classical fluctuations in the matter sector. We study theoretically the quantum fluctuations in the light and the matter sectors in different driving regimes. In particular, the photon dissipation channel of the cavity allows for the direct nondestructive measurement of the fluctuations driving the phase transition known in this system. Light-induced density fluctuations drive a superradiant nonequilibrium Dicke quantum phase transition of the atom gas. The photon statistics in the presence of the strongly coupled, pumped atom gas is calculated within a Bogoliubov approach combined with analytic imaginary time path integrals including photon leakage of the cavity. Parameter regimes for squeezed cavity light are identified.

TT 9.3 Mon 18:30 H23

The free energy of the two-dimensional dilute Bose gas — •Andreas Deuchert[1], Simon Mayer[2], and Robert Seiringer[2] — [1]University of Zurich, Institute of Mathematics, Zurich, Switzerland — [2]Institute of Science and Technology Austria, Klosterneuburg, Austria

We prove bounds for the specific free energy of the two-dimensional Bose gas in the thermodynamic limit. We show that the free energy at density ϱ and inverse temperature β differs from the one of the non-interacting system by the correction term $4\pi\varrho^2|\ln(a^2\varrho)|^{-1}(2-[1-\beta_c/\beta]_+^2)$. Here a is the scattering length of the interaction potential, $[x]_+ = \max\{0, x\}$ and β_c is the inverse Berezinskii–Kosterlitz–Thouless critical temperature for superfluidity. The result is valid in the dilute limit $a^2\varrho \ll 1$ and if $\beta\varrho \gtrsim 1$.

TT 9.4 Mon 18:45 H23

Chaos in the three-site Bose-Hubbard model - classical vs quantum — •Goran Nakerst[1] and Masudul Haque[1,2] — [1]Institut für Theoretische Physik, Technische Universität Dresden, Dresden, Germany — [2]Max-Planck-Institut für Physik komplexer Systeme, Dresden, Germany

We consider a quantum many-body system - the Bose-Hubbard system on three sites - which has a classical limit, and which is neither strongly chaotic nor integrable but rather shows a mixture of the two types of behavior. We compare quantum measures of chaos (eigenvalue statistics and eigenvector structure) in the quantum system, with classical measures of chaos (Lyapunov exponents) in the corresponding classical system. As a function of energy and interaction strength, we demonstrate a strong overall correspondence between the two cases. In contrast to both strongly chaotic and integrable systems, the largest Lyapunov exponent is shown to be a multi-valued function of energy.

TT 9.5 Mon 19:00 H23

Out-of-equilibrium dynamics of bosons on a 2D Hubbard lattice — •Ulli Pohl, Sayak Ray, and Johann Kroha — Physikalisches Institut, Rheinische Friedrich-Wilhelms-Universität Bonn, Nußallee 12, 53115 Bonn, Germany

We study the collective excitations of bosons in two-dimensional optical Hubbard lattices, described by the Bose-Hubbard model, using the cluster mean field theory at zero temperature. The method has been shown to be very powerful to determine the phase boundaries both at zero and finite temperatures [1]. From the low-lying excitations, we identify the presence of the Higgs and the Goldstone modes of the superfluid, as well as the particle- and hole-like excitations in the Mott insulator phase and calculate their dispersion relations. The effective mass of the quasiparticles and -holes vanish at the tip of the Mott lobe where the Higgs energy gap also vanishes. Finally, we present the real time dynamics of the collective excitations, particularly, the Higgs mode. Our findings, particularly the dynamics of excitations support the previous mean-field-like calculations and can be relevant for cold-atom experiments.

[1] U. Pohl, S. Ray, J. Kroha arXiv:2106.14860