Q 31: Quantum Gases: Interaction Effects II

Time: Wednesday 14:00–16:00 Location: E 001

Q 31.1 We 14:00 E 001

Bose-Einstein condensates with induced $1/r$ interactions and embedded vorticity — •Poulcheria Christou, Patrick Köberle, Axel Keller, Jörg Main, and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart, 70550 Stuttgart

Cold quantum gases with electromagnetically induced attractive $1/r$ interaction have been proposed by O'Dell et. al. as systems in which, in addition to the short-range contact interaction a long-range interaction between the atoms is present. We study rotating Bose-Einstein condensates with $1/r$ interaction in the frame of the Gross-Pitaevskii theory by variational calculations, and by imaginary time evolution on a two-dimensional grid. We analyse the stability of the localised vortices by solving the Bogoliubov-de Gennes equations of the system numerically.

Q 31.2 We 14:15 E 001

Coherent oscillations in a many-body Wannier-Stark system — •Patrick Plötz and Sandro Wimberger — Institut für Theoretische Physik, Universität Heidelberg, Philosophenweg 19, 69120 Heidelberg

We study the effect of a many-body interaction on inter-band oscillations in a two-band Bose-Hubbard model with external Stark force. We identify a regime of strong inter-band coupling and observe an interaction-induced collapse and revival of the resonant inter-band oscillations. Effective models for oscillations in and out of resonance are presented and analytical predictions for the collapse and revival time of the oscillations are given.

Q 31.3 We 14:30 E 001

Macroscopic quantum tunnelling and bounce solutions of Bose-Einstein condensates with attractive interactions — •Rolf Häfner, Holger Cartarius, Jörg Main, and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart, 70550 Stuttgart

Solutions of the Gross-Pitaevskii equation for Bose-Einstein condensates with $1/r$ interaction reveal the existence of a metastable ground state, which can decay in the collapse of the wave function. The decay rate can be calculated from the bounce trajectory in imaginary time. Using a variational approach with a Gaussian wave function, it is possible to introduce canonical variables and to find the bounce trajectory by solving Hamilton's equations of motion in an inverted potential.

Generalizing the variational approach by the use of a wave function built from a superposition of Gaussians leads to non-canonical equations of motion for the Gaussian parameters which allow us to investigate the imaginary-time dynamics of the condensate. We show how bounce solutions in these coordinates can be found which are the prerequisite for the calculation of the decay rate of the metastable ground state.

Q 31.4 We 14:45 E 001

Variational studies of Bose-Einstein condensates with embedded vorticity — •Matthias Zimmer, Poulcheria Christou, Stefan Rau, and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart, 70550 Stuttgart

The Gross-Pitaevskii equation of condensates with embedded vortices and $1/r$ interaction is solved using a variational principle and modified Gaussian wave packets to consider the vorticity in the Bose-Einstein condensate. The result provides insight in the stability of stationary solutions with respect to the vorticity and the attractive interaction strength. Unlike the direct numerical solutions, where the Gross-Pitaevskii equation is solved at every point in the mesh, it is possible to derive not only the stable branches of the stationary solution but also the unstable which are born in a tangent bifurcation.

Q 31.5 We 15:00 E 001

Generating 'Schrödinger-cat' states via scattering of quantum matter wave solitons — •Christoph Weiss — Institute of Physics, Carl von Ossietzky University, D-26111 Oldenburg, Germany

The generation of spatial quantum superpostions via scattering solitons off a laserfocus can be understood with a mathematically justified [1] (for numeric investigations on the N-particle level see Ref. [2]).

The motion of two attractively interacting atoms in an optical lattice is investigated in the presence of a scattering potential. The initial wavefunction can be prepared by using tightly bound exact two-particle eigenfunction for vanishing scattering potential. This allows to numerically simulate the dynamics in the generation of two-particle Schrodinger cat states using a scheme recently proposed for scattering of quantum matter wave solitons.

[1] C. Weiss and Y. Castin, Phys. Rev. Lett. 102, 010403 (2009).

[2] A. I. Streltsov, O. E. Alon, and L. S. Cederbaum, Phys. Rev. A 80, 043616 (2009).

[3] C. Weiss, arXiv:0910.1162v1 [cond-mat.quant-gas] (2009).

Q 31.6 We 15:15 E 001

Pitchfork bifurcations in blood-cell shaped dipolar Bose-Einstein condensates — •Stefan Rau, Jörg Main, and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart, 70550 Stuttgart

We demonstrate that the method of coupled Gaussian wave packets is a full-fledged alternative to direct numerical solutions of the Gross-Pitaevskii equation of condensates with electromagnetically induced attractive $1/r$ interaction, or with dipole-dipole interaction. Moreover, Gaussian wave packets are superior in that they are capable of producing both stable and unstable stationary solutions, and thus of giving access to yet unexplored regions of the space of solutions of the Gross-Pitaevskii equation. We apply the method to clarify the theoretical nature of the collapse mechanism of blood-cell shaped dipolar condensates: On the route to collapse the condensate passes through a pitchfork bifurcation, where the ground state itself turns unstable, before it finally vanishes in a tangent bifurcation.

Q 31.7 We 15:30 E 001

Ultracold dipoles on a ring — •Sascha Zöllner[1], Georg M. Bruun[2], and Stephanie M. Reimann[2] — [1]Niels Bohr International Academy, Niels Bohr Institute, Blegdamsvej 17, 2100 Copenhagen, Denmark — [2]Mathematical Physics, LTH, Lund University, 2100 Lund, Sweden

Dipolar bosons and fermions in a quasi-one-dimensional (1D) ring potential have the interesting feature of combining the physics of 1D gases with anisotropic effects. Depending on the orientation of their dipole moments and the dipolar interaction strength, there may be a competition between repulsive and attractive regions on the ring. We identify three basic phases based on simulations in a few-body system:

(i) a repulsive regime resembling an inhomogeneous 1D Bose (Fermi) gas,

(ii) a Wigner-crystal-like state with a non-equidistant spatial distribution, and

(iii) bound states of identical bosons (fermions) localized in the strongly attractive regions on the ring.

We discuss how these states arise in a crossover from weak to strong dipolar interactions, with an emphasis on the particle-number dependence.

Q 31.8 We 15:45 E 001

Phonon instability and structured ground-states in multilayer stacks of dipolar Bose-Einstein condensates — •Patrick Köberle and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart, 70550 Stuttgart

Dipolar interactions between atoms in ultra-cold quantum gases are long-ranged and anisotropic. The latter feature is responsible for a wealth of effects studied in single condensates both theoretically and experimentally. The long-range nature, however, makes it possible to couple individual condensates trapped in deep optical lattices. We study the ground-state of a stack of condensates aligned in the direction of the polarization axis [1] and find a strong dependence of the phonon instability on the number of condensates, which is a direct consequence of the long-range nature of the dipole-dipole interaction. Moreover, in the very vicinity of the phonon instability, we find several types of structures in the density distribution of the atoms.

[1] P. Köberle and G. Wunner, Phys. Rev. A **80**, 063601 (2009)