Q 9: Cold atoms II - interactions (joint session A/Q)

Time: Monday 10:30–12:00 Location: K 2.019

Q 9.1 Mon 10:30 K 2.019

Dimensional Crossover for the Beyond-Mean-Field Corrections in the Weakly Interacting Bose Gas — •Tobias Ilg, Jan Kumlin, and Hans Peter Büchler — Institute for Theoretical Physics III, University of Stuttgart, 70569 Stuttgart, Germany

We investigate the beyond-mean-field corrections in a confined weakly interacting Bose gas at zero temperature. The system is elongated along one direction and tightly confined along the transverse directions. The confined gas can exhibit three-dimensional as well as quasi-one-dimensional behavior. We use the field-theoretic approach of Hugenholtz and Pines to include beyond-mean-field corrections. The field-theoretic treatment allows us to connect the three-dimensional regime to the quasi-one-dimensional regime and to describe a dimensional crossover of the system. We show that the inclusion of the beyond-mean-field terms leads to a correction of the coupling constant in the quasi-one-dimensional regime due to the presence of the confinement. Thus, the confinement-induced shift of the ground state energy appears naturally in our approach.

Q 9.2 Mon 10:45 K 2.019

Time-dependent variational Monte Carlo method for interacting Bosons in continuous space — •Markus Holzmann — LPMMC, UMR 5493 of CNRS, Université Grenoble Alpes, F-38042 Grenoble, France

I will describe time-dependent Variational Monte Carlo method for continuous-space Bose systems based on a systematic truncation of the many-body wave function [1]. We have benchmarked the method by studing the Lieb-Liniger model of one dimensional Bosons interacting by a delta potential. We have calculated static ground state properties, as well as the unitary dynamics after a sudden quench in the interaction strength and compared to Bethe ansatz results wherever available.

[1] G. Carleo, L. Cevolani, L. Sanchez-Palencia, and M. Holzmann, Phys. Rev. X 7, 031026 (2017).

Q 9.3 Mon 11:00 K 2.019

Commensurate-Incommensurate Transition in Optical Cavities — •Andreas Alexander Buchheit[1], Haggai Landa[2], Cecilia Cormick[3], Thomas Fogarty[4], Eugene Demler[5], and Giovanna Morigi[1] — [1]Saarland University, 66123 Saarbrücken — [2]IPhT, CEA Saclay, France — [3]IFEG, CONICET and Universidad Nacional de Cordoba — [4]Okinawa Institute of Science and Technology, Japan — [5]Department of Physics, Harvard University, Cambridge, MA 02138, USA

We theoretically analyse the equilibrium configuration of an ion chain which interacts with the optical lattice of a cavity mode. We assume the lattice periodicity is almost commensurate with the interparticle distance of the ions and determine the resulting configuration as a function of their ratio. In the limit of small cooperativity, when cavity backaction is negligible, we show that this system simulates the commensurate-incommensurate phase transition. We derive a field theory for the kinks that are created in the incommensurate phase and determine the effects of the Coulomb repulsion on the phase diagram. When instead the cavity strongly couples to the ions motion we show that the commensurate-incommensurate transition becomes of first order and is associated with bistable behaviour of the cavity field. We characterize the kinks and their interactions and determine the properties of the light at the cavity output across the phase transition.

Q 9.4 Mon 11:15 K 2.019

Observation of the Higgs mode in a strongly interacting fermionic superfluid — •Martin Link[1], Alexandra Behrle[1], Timothy Harrison[1], Johannes Kombe[2], Kuiyi Gao[1], Jean-Sebastien Bernier[2], Corinna Kollath[2], and Michael Köhl[1] — [1]Physikalisches Institut, University of Bonn, Wegelerstrasse 8, 53115 Bonn, Germany — [2]HISKP, University of Bonn, Nussallee 14-16, 53115 Bonn, Germany

Higgs and Goldstone modes are possible collective modes of an order parameter upon spontaneously breaking a continuous symmetry. Whereas the low-energy Goldstone (phase) mode is always stable, additional symmetries are required to prevent the Higgs (amplitude) mode from rapidly decaying into low-energy excitations. In the realm of condensed-matter physics, particle-hole symmetry can play this role and a Higgs mode has been observed in weakly-interacting superconductors. However, whether the Higgs mode is also stable for strongly-correlated superconductors in which particle-hole symmetry is not precisely fulfilled or whether this mode becomes overdamped has been subject of numerous discussions. Here, we observe the Higgs mode in a strongly-interacting superfluid Fermi gas. By inducing a periodic modulation of the amplitude of the superconducting order parameter Δ, we observe an excitation resonance at frequency $2\Delta/h$. For strong coupling, the peak width broadens and eventually the mode disappears when the Cooper pairs turn into tightly bound dimers signalling the eventual instability of the Higgs mode.

Q 9.5 Mon 11:30 K 2.019

Breaking of SU(4) symmetry and interplay between strongly correlated phases in the Hubbard model — •Agnieszka Cichy[1,2] and Andrii Sotnikov[3,4] — [1]Faculty of Physics, Adam Mickiewicz University, Umultowska 85, 61-614 Poznan, Poland — [2]Umultowska 85 — [3]Institute of Solid State Physics, TU Wien, Wiedner Hauptstr. 8, 1040 Wien, Austria — [4]Akhiezer Institute for Theoretical Physics, NSC KIPT, 61108 Kharkiv, Ukraine

We study the thermodynamic properties of four-component fermionic mixtures described by the Hubbard model using the dynamical mean-field-theory approach. Special attention is given to the system with SU(4)-symmetric interactions at half filling, where we analyze equilibrium many-body phases and their coexistence regions at nonzero temperature for the case of simple cubic lattice geometry. We also determine the evolution of observables in low-temperature phases while lowering the symmetry of the Hamiltonian towards the two-band Hubbard model. This is achieved by varying interflavor interactions or by introducing the spin-flip term (Hund's coupling). We observe a strong effect of suppression of ferromagnetic order in comparison with previous studies that were usually performed by restricting to density-density interactions. By calculating the entropy for different symmetries of the model, we determine the optimal regimes for approaching the studied phases in experiments with ultracold alkali and alkaline-earth-like atoms in optical lattices.

Q 9.6 Mon 11:45 K 2.019

Polaron physics with ultracold atoms and beyond — •Richard Schmidt — Department of Physics, Harvard University, Cambridge, MA 02138, USA — ITAMP, Harvard-Smithsonian Center for Astrophysics, Cambridge, MA 02138, USA — Max-Planck-Institut für Quantenoptik, 85748 Garching, Germany

When an impurity interacts with an environment, it changes its properties and forms a polaron. Depending on the character of the environment, various types of polarons are created. In this talk, I will review recent progress on studying the physics of polarons in cold atoms [1], and discuss related phenomena in semiconductors and the study of rotating molecules in Helium droplets [2]. Then I will show that Rydberg excitations coupled to BECs are a new, exciting playground for the study of polaronic physics. Here the impurity-bath interaction is mediated by the Rydberg electron. This gives rise to a new polaronic dressing mechanisms, where molecules of gigantic size dress the Rydberg impurity. We develop a functional determinant approach [3] which incorporates atomic and many-body theory. Using this approach we predict the appearance of a superpolaronic state, recently observed in experiments [4,5].

References: [1] R. Schmidt, et al, arXiv:1702.08587 (2017). [2] R. Schmidt, and M. Lemeshko, Phys. Rev. Lett. 114, 203001 (2015); [3] R. Schmidt, H. Sadeghpour, and E. Demler, Phys. Rev. Lett. 116, 105302 (2016). [4] F. Camargo et al., arXiv:1706.03717 (2017). [5] R. Schmidt et al., arXiv:1709.01838 (2017).