TT 24: Symposium "Condensed Matter Phases in Ultracold Atoms"

Time: Thursday 9:30–12:50 Location: H20

Invited Talk TT 24.1 Thu 9:30 H20
Probing interacting systems of cold atoms using interference experiments — •Eugene Demler — Harvard University, Cambridge, MA 02138, USA

This talk will review how interference experiments can be used to analyze equilibrium and non-equilibrium phenomena in interacting systems of cold atoms. This includes analysis of correlation functions based on measuring interference amplitude for independent condensates and analysis of phase dynamics in coupled condensates.

Invited Talk TT 24.2 Thu 10:00 H20
Criticality and correlations in cold atomic gases — •Michael Köhl — University of Cambridge, Department of Physics, J J Thomson Avenue, Cambridge CB3 0HE, UK — ETH Zürich, Institute of Quantum Electronics, 8093 Zürich, Switzerland

Phase transitions are among the most dramatic phenomena in nature. Minute variations in the conditions controlling a system trigger a fundamental change of its properties. In the critical regime near a second-order phase transition point the fluctuations of the order parameter are so dominant that they completely govern the behavior of the system on all length scales. Using cold atomic gases, we have directly observed critical fluctuations of the order parameter near the phase transition of Bose-Einstein condensation. From the divergence of the correlation length versus temperature we have determined its critical exponent ν. Despite our densities being nine orders of magnitude smaller and our interactions considerably weaker, we find a remarkable similarity to case of the λ-transition of Helium-4.

TT 24.3 Thu 10:30 H20
Bose gas in Flatland — •Zoran Hadzibabic, Peter Kruger, Marc Cheneau, Baptiste Battelier, Patrick Rath, and Jean Dalibard — Laboratoire Kastler Brossel, 24 Rue Lhomond, 75005 Paris, France

Physics of a Bose gas in 2D is quite different from the usual 3D situation. In a homogeneous 2D fluid of identical bosons long-range order is always destroyed by long wavelength thermal fluctuations, but the system can nevertheless become superfluid at a finite critical temperature. This phase transition does not involve any symmetry breaking and in the Berezinskii-Kosterlitz-Thouless (BKT) paradigm it is explained in terms of binding and unbinding of pairs of vortices with opposite circulations. Above the critical temperature, proliferation of unbound vortices is expected.

Using optical lattice potentials we can create two parallel, independent 2D atomic clouds with similar temperatures and chemical potentials. When the clouds are suddenly released from the trapping potential and allowed to freely expand, they overlap and interfere. This realizes a matter wave heterodyning experiment which gives direct access to several features of the phase distributions in the two planes. Long wavelength phase fluctuations create a smooth and random variation of the interference fringes and free vortices appear as sharp dislocations in the interference pattern. Temperature study of these effects supports the BKT picture of the development of quasi-long-range coherence in these systems.

15 min. break

TT 24.4 Thu 11:10 H20
Simulations of ultra-cold atom gases on frustrated optical lattices — •Stefan Wessel — Institut für Theoretische Physik III, Universität Stuttgart

We review results from recent quantum Monte Carlo simulations of ultra-cold bosonic atoms on frustrated optical lattices such as the triangular and the Kagome lattice. For the triangular lattice case a supersolid state of matter emerges, resulting from a novel order-by-disorder effect in the strongly interacting regime. On the Kagome lattice the atoms form exotic valence-bond-solids with local bosonic resonances. We discuss the quantum melting transitions of these solids, the connection to the recently proposed deconfined quantum criticality scenario, as well as the relation to frustrated quantum magnetism.

TT 24.5 Thu 11:35 H20
Multicolor Hubbard models with ultracold atoms — •Carsten Honerkamp — Universität Würzburg, Am Hubland, D-97074 Würzburg

In ultracold atomic systems, the hyperfine states provide an internal degree of freedom which may allow for the realization of novel many-particle states without obvious ancestors in solid state physics. Here we review our results (most recent: A. Rapp, G. Zarand, C. Honerkamp, W. Hofstetter, cond-mat/0607138) on fermionic SU(N)-Hubbard models on optical lattices where N denotes the number of hyperfine states (colors) loaded into the lattice. In the case of repulsive interactions on the half-filled square lattice, staggered current phases replace generalized antiferromagnetic ordering above a critical color number. For the attractive case we focus on $N = 3$, as this can be possibly realized using ^{6}Li. For weak attractions and generic densities, the variational ground-state is a color-superfluid with an ungapped branch of single-particle excitations. For increasing attraction, an extended variational ansatz reveals a continuous quantum phase transition toward a color-confining heavy-fermion phase with bound states of three particles, mimicking the QCD phase transition a high matter density. For low densities in our lattice model, this transition can be interpreted in simple two-fluid model.

TT 24.6 Thu 12:00 H20
Fermionic Superfluidity with Imbalanced Spin Populations — •Martin Zwierlein — MIT, Cambridge, MA, USA — Johannes-Gutenberg Universität Mainz, Germany

Whether it occurs in superconductors, helium-3 or inside a neutron star, fermionic superfluidity requires pairing of fermions. For an equal mixture of spin up and spin down fermions, pairing can be complete and the entire system will become superfluid. If the two fermion populations are imbalanced, not every particle can find a partner. Will the system nevertheless stay superfluid?

In this talk I will present our studies of this intriguing question in an unequal mixture of strongly interacting, ultracold fermionic atoms. We establish the phase diagram for the superfluid and the normal state as a function of population imbalance and interaction strength. Due to strong interactions near a Feshbach resonance, the superfluid state is remarkably stable in response to population imbalance. The final breakdown of superfluidity at large imbalance marks a phase transition, the Pauli or Clogston limit of superfluidity.

TT 24.7 Thu 12:25 H20
Vortex Matter in Optical Lattices — •Michiel Snoek — Institut für Theoretische Physik, Universität Frankfurt, Frankfurt am Main, Deutschland

A Bose-Einstein condensate responds to rotation by forming quantized vortices. The quantum fluctuations of these vortices are greatly enhanced by slicing the Bose-Einstein condensate into a stack of two-dimensional pancake-condensates by means of an optical lattice.

A single vortex line in this setup has bosonic fluctuations and is equivalent to a bosonic string. By trapping fermionic atoms in the vortex cores, a superstring can be realized.

Multiple vortex lines order in a Abrikosov lattice. We have investigated the excitations of the vortex lattice; in particular we studied the Bloch bands of the Tkachenko modes. Vortex fluctuations melt the vortex crystal after which higly correlated quantum liquids are formed. Because of the small number of particles in the pancake Bose-Einstein condensates at every site of the optical lattice, finite-size effects and effects of the inhomogeneous density are important. As a result, the melting of the lattice occurs from the outside inwards. We studied the melting of the vortex lattice as a function of rotation frequency, temperature, and strength of the optical lattice.