TT 95: Cold Atomic Gases, Superfluids, Quantum Fluids and Solids

Time: Thursday 15:00–17:45 Location: HFT-FT 131

TT 95.1 Thu 15:00 HFT-FT 131

Vortex states in one- and two-band rotating Fermi gases in the BCS-BEC crossover — •Serghei Klimin[1], Jacques Tempere[1], and Milorad Milosevic[2] — [1]TQC, Universiteit Antwerpen, Antwerpen, Belgium — [2]Departement Fysica, Universiteit Antwerpen, Antwerpen, Belgium

Atomic Fermi superfluids can be described in terms of an effective field theory [1] for a macroscopic wave function representing the field of condensed pairs, analogous to the Ginzburg-Landau theory for superconductors. Rotation can stabilize vortices in atomic gases similarly to the magnetic field in superconductors, leading to the appearance of an effective vector potential. On the basis of the effective field theory, equilibrium vortex state diagrams are derived. They are in good agreement with available results of the Bogoliubov - de Gennes theory and with experimental data. We report also the equilibrium vortex phase diagram of a rotating two-band Fermi gas. This study is particularly focused on novel features due to interband interactions which can be experimentally resolved. We reveal the non-monotonic resonant dependence of the free energy for a two-band superfluid as a function of temperature, which is directly manifested in vortex phase diagrams, where areas of stability for both integer and fractional vortex states are found. The present investigation embraces the BCS-BEC crossover regime and the entire temperature range below the critical temperature.

[1] S. N. Klimin, J. Tempere, G. Lombardi, J. T. Devreese, EPJ B **88**, 122 (2015)

TT 95.2 Thu 15:15 HFT-FT 131

Bose-Einstein condensation of a non-ideal Bose gas of atoms with large spin — •Andrei Pavlov[1], Vladimir Babichenko[2], and Ilya Polishchuk[2,3] — [1]IFW Dresden, Dresden, Germany — [2]Kurchatov Institute, Moscow, Russia — [3]MIPT, Dolgoprudnii, Russia

A non-ideal diluted quantum Bose gas of atoms with spin-spin interaction of dipole type is described in the spin coherent states representation. Large values of spin can be treated quasi-classically up to exponentially small corrections, that allows to derive effective interaction between particles of the gas. A preferable ground state configuration of the system is determined by this effective interaction, the spin-spin coupling constant regulates whether the system takes ferromagnetic or antiferromagnetic ground state. The coupling constants of long-ranged spin-spin interaction and short-ranged scattering also define a condition when the system collapses, causing formation of molecules.

TT 95.3 Thu 15:30 HFT-FT 131

Dynamics and decay of dark solitons in superfluid Fermi gases — •Wout Van Alphen[1], Giovanni Lombardi[1], Serghei Klimin[1,2], and Jacques Tempere[1,3] — [1]Universiteit Antwerpen, B-2610 Antwerpen, Belgium — [2]State University of Moldova, 2009 Chisinau, Moldova — [3]Harvard University, Cambridge, MA 02138, USA

Dark solitons are localized solitary density dips that retain their shape while propagating at a constant velocity. In recent work, we have studied their properties and dynamics in superfluid Fermi gases by means of a recently developed effective field theory that is capable of describing fermionic superfluids across the BEC-BCS crossover regime in a wide temperature domain.

In superfluid gases, dark solitons are subject to an instability mechanism called the snake instability, which makes the soliton decay into vortices if the radial width of the atom cloud is too large. We have estimated the maximal radial size that the atomic cloud can have in order to preserve the soliton stability. An analysis of the effect of population imbalance on this critical size reveals a stabilization of the soliton with increasing imbalance.

We have also simulated the evolution of two counter-propagating solitons to investigate the properties of dark soliton collisions in different conditions of temperature and imbalance. The collisions are demonstrated to introduce a spatial shift into the soliton trajectories and become increasingly more inelastic when moving towards the unitarity regime of the interaction domain.

TT 95.4 Thu 15:45 HFT-FT 131

Manipulating the Mott lobes: optical lattice bosons coupled to atomic quantum dots — •Anna Posazhennikova[1] and Florian M. Dobler[2] — [1]Royal Holloway University of London, Egham, UK — [2]Universitaet Konstanz, Konstanz, Germany

We analyse quantum phase transitions in a system of optical lattice bosons coupled to an array of atomic quantum dots. The difference to Bose-Hubbard model is in that direct tunnelling between the lattice sites is prohibited and instead there is an assisted tunnelling via the quantum dots. We calculate the phase diagram of the combined system within the Gutzwiller-Ansatz. It turns out that the superfluid-Mott transition is still present in the system, however, the Mott lobes strongly depend on the system parameters. One can, for example, even reverse the usual hierarchy of the lobes with the first lobe becoming the smallest. We discuss the physics of the combined system in detail and overview possible applications of the model.

TT 95.5 Thu 16:00 HFT-FT 131

Noise correlations in the attractive Hubbard model — •Stephan Humeniuk — Institute for Theoretical Physics III, University of Stuttgart

In cold atom experiments, noise correlations, which can be obtained through the analysis of time of flight images, are an important probe of the quantum state inside the trap. Determinantal quantum Monte Carlo simulations of noise correlations are presented at low and experimentally relevant, high temperatures for the attractive Hubbard model, which was recently realized in optical lattices. At half filling, the Hubbard model possesses an enlarged symmetry which leads to the degeneracy of a charge density wave and superconductivity in the ground state, and both orders show characteristic peaks in the noise correlation signal. The presence of Cooper pairs with non-zero centre of mass momentum for large Hubbard attraction (in the BEC regime of strongly bound molecules) and the detectability of η-pairing are discussed.

TT 95.6 Thu 16:15 HFT-FT 131

Dynamics of the density of quantized vortices in counterflow turbulence — Emil Varga and •Ladislav Skrbek — Faculty of Mathematics and Physics, Charles University, Prague, Czech Republic

Thermal counterflow of superfluid 4He represents the most extensively studied form of quantum turbulence, initiated by pioneering experiments of Vinen, who also introduced a phenomenological model for its description based on the concept of a random tangle of quantized vortices of vortex line density L. Recently the interest in thermal counterflow has been renewed and resulted in an intense theoretical debate about what form, if any, of the so-called Vinen equation accurately captures the dynamics of L. We address this problem experimentally, in a square channel equipped by three pairs of second sound sensors. Based on large statistics of experimental data in square-wave modulated thermally induced counterflow we investigate the phase portrait of general form of the governing dynamical Vinen-like equation and conclude that for sparse tangles all proposed forms of this equation provide equally adequate description of the growth of L while for dense tangles neither of them is satisfactory and cannot account for the significant slow-down in tangle growth rate as the steady state is approached. We claim, however, that agreement with theory is recovered if geometric parameter c2 introduced in numerical studies by Schwarz is allowed to vary with vortex line density which also greatly improves the prediction of the observed decay rate.

The support of the Czech Science Foundation under project GA17-03572S is acknowledged.

15 min. break.

TT 95.7 Thu 16:45 HFT-FT 131

Anisotropic superfluidity of two-dimensional excitons in a periodic potential — •Pavel A. Volkov[1], Igor L. Kurbakov[2], and Yurii E. Lozovik[2,3] — [1]Theoretische Physik III, Ruhr-Universität Bochum, D-44780 Bochum, Germany — [2]Institute of Spectroscopy RAS, Moscow, Troitsk, Russia — [3]MIEM, National Research University Higher School of Economics, Moscow, Russia

Electrostatic potentials created with nanofabricated electrodes provide a versatile tool to control and probe excitonic systems. As a particular case, we consider the emergence of anisotropy of superfluid properties in a two-dimensional system of dipolar excitons subject to an external periodic potential. We study anisotropies of helicity modulus, excitation spectrum, sound velocity and angle-resolved luminescence spectrum. We discuss possible experiments that could detect these effects and provide estimates of their magnitude for GaAs/AlGaAs heterostructures as well as MoS_2/hBN/MoS_2 and $MoSe_2$/hBN/WSe_2 transition metal dichalcogenide bilayers.

TT 95.8 Thu 17:00 HFT-FT 131

Non-local transport properties of an excitonic insulator — •Bogusz Bujnowski[1], Jerome Cayssol[2], and Dario Bercioux[1,3] — [1]Donostia International Physics Center (DIPC), Manuel de Lardizbal 4, E-20018 San Sebastian, Spain — [2]LOMA (UMR-5798), CNRS and University Bordeaux, F-33045 Talence, France — [3]IKERBASQUE, Basque Foundation of Science, 48011 Bilbao, Basque Country, Spain

The availability of high-quality mono- and bilayer- graphene samples has motivated Coulomb drag experiments in electron/hole bilayer systems made of these materials. Such electron/hole bilayer systems have a rich and still not fully understood transport behavior and are also potential candidates to host indirect excitonic condensates. We study the ballistic transport properties within a Coulomb drag measurement set-up, assuming a coupling between sheets due to the formation of an excitonic condensate. This coupling allows a charge transfer between the sheets, which we investigate for various sheet types as a function of the distance between the contact compared to the typical coherence length of the excitonic condensate.

TT 95.9 Thu 17:15 HFT-FT 131

Out-of-bounds hydrodynamics in anisotropic Dirac fluids — Julia M. Link[1], Boris N. Narozhny[1,2], •Egor I. Kiselev[1], and Jörg Schmalian[1,3] — [1]Institute for Theory of Condensed Matter, Karlsruhe Institute of Technology, Karlsruhe, Germany — [2]National Research Nuclear University MEPhI (Moscow Engineering Physics Institute), Moscow, Russia — [3]Insitute for Solid State Physics, Karlsruhe Institute of Thechnology (KIT), Karlsruhe, Germany

We study the hydrodynamic transport in an interacting electronic system with an anisotropic dispersion, which is Dirac-like along one crystallographic direction and Newtonian-like along the other. Such a dispersion is realized in systems with merging Dirac points at charge neutrality and leads to highly anisotropic transport coefficients. The shear viscosity is a fourth-rank tensor whose distinct elements characterize the momentum flow in different directions and exhibit fundamentally different scalings with temperature. One of the viscosity coefficients violates the lower bound for the shear viscosity to entropy density ratio stemming from the AdS/CFT duality.

TT 95.10 Thu 17:30 HFT-FT 131

AC conductivity of a two-dimensional electronic fluid — Roderich Moessner, Piotr Surowka, and •Piotr Witkowski — Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Str. 38, 01187 Dresden, Germany

Motivated by experiments on a hydrodynamic regime in electron transport, we study the effect of an oscillating electric field in such a setting. We consider a long two-dimensional channel of, whose geometrical simplicity allows an analytical study as well as hopefully permitting experimental realisation. We find two, distinctive regimes: a quasi-static flow, and a boundary layer type behaviour. The latter includes a splitting of the location of maximal flow velocity from the centre towards the edges of the boundary layer, an an increasingly reactive nature of the response, with the phase shift of the response varying across the channel. In which regime we are, depends on dimensionless combination of channel width, viscosity and forcing frequency, similar to the Reynolds number. The scaling of the total optical conductance with channel width differs between the two regimes, while its frequency dependence resembles a Drude form throughout, even in the complete absence of ohmic heating, against which, at the same time, our results are stable. Current estimates for transport coefficients in graphene and delafossites suggest that the boundary layer regime should be experimentally accessible.