Q 11: Quantum Gases: Fermions II

Time: Monday 14:30–16:30 Location: K/HS2

Group Report Q 11.1 Mon 14:30 K/HS2

Phases of unitary imbalanced Fermi gases — •Dietrich Roscher — Institut fuer Kernphysik, Technische Universitaet Darmstadt

Apart from being interesting in their own right, "unitary" ultracold Fermi gases are receiving growing attention due to their similarity to low-energy models of QCD, such as NJL-type models. The strongly coupled nature of both systems poses a challenge to theoretical methods that is additionally complicated by deformations such as the baryon chemical potential in QCD or population and/or mass imbalance for ultracold gases, respectively. On the other hand, these modifications are prerequisites for the emergence of exotic phases associated with, e.g., a spontaneous breakdown of translational invariance. In order to gain insight into these realms, we apply functional renormalization group (FRG) techniques to the three-dimensional Fermi gas at infinite s-wave scattering length with population and mass imbalance. The resulting phase diagram will be discussed with special emphasis on the exploration of phases with broken translational invariance. Being not limited to the mean-field approximation, FRG also provides a way to test the stability and/or distortion of the phase structure upon inclusion of fluctuation effects.

Q 11.2 Mon 15:00 K/HS2

Strongly correlated states of trapped ultracold fermions in a U(2) gauge potential — Michele Burrello[1], •Matteo Rizzi[2], Marco Roncaglia[3], and Andrea Trombettoni[4] — [1]Max-Planck-Institut für Quantenoptik, Garching, Germany — [2]Johannes Gutenberg-Universität Mainz, Germany — [3]INRIM, Torino, Italy — [4]CNR-IOM DEMOCRITOS, SISSA and INFN, Trieste, Italy

We analyze the strongly correlated regime of a two-component trapped ultracold fermionic gas in a synthetic non-Abelian U(2) gauge potential, created by a magnetic field and a homogeneous spin-orbit coupling (SOC). The SOC deforms the Landau levels (DLL) and exchanges their ordering, though still allowing for a lowest DLL approximation. The corresponding Haldane pseudopotentials for interspecies contact interactions show, at sufficiently strong SOC, an unconventional non-monotonic behaviour in the relative angular momentum (NMHP). A harmonic trap combined with a Zeeman shift gives rise to a total angular momentum term, usable to experimentally test the stability of the so-obtained correlated states. In the 1st DLL we find standard Laughlin and Jain states. Instead, in the 2nd DLL, three classes of incompressible states appear: between Laughlin states and vortices of the integer QH state, the NMHPs induce two-particle correlations reminiscent of paired states such as the Haffnian one. Via exact diagonalization in the disk geometry, we compute experimentally relevant observables like density profiles and correlations, and we study the entanglement spectra to characterize the new intermediate strongly correlated states. [arXiv:1411.5962]

Q 11.3 Mon 15:15 K/HS2

Quantum Simulation of Lattice Gauge Theories Out of Equilibrium — •Valentin Kasper[1], Florian Hebenstreit[2], Markus Oberthaler[3,4], and Jürgen Berges[1,4] — [1]Institut für Theoretische Physik, Ruprecht-Karls-Universität Heidelberg, Philosophenweg 16, 69120 Heidelberg — [2]Universität Bern - Albert Einstein Center for Fundamental Physics (AEC) Sidlerstrasse 5, CH-3012 Bern, Switzerland — [3]Kirchhoff-Institute for Physics, Ruprecht-Karls-Universität Heidelberg, Im Neuenheimer Feld 227, 69120 Heidelberg — [4]ExtreMe Matter Institute EMMI, GSI Helmholtzzentrum für Schwerionenforschung, Planckstraße 1, 64291 Darmstadt, Germany

Quantum link models have been proposed as an alternative regularization of lattice gauge field theories. The U(1) quantum link models are constructed by replacing the parallel transporters of Wilsonian lattice gauge theory with quantum spin operators acting on $2S+1$ states per link. The original gauge theory is recovered in the limit of large representations $S \to \infty$. Due to the dramatic increase of the size of the Hilbert space, investigating the dynamics of these models for $S \gg 1$ becomes difficult. We study the limit of large spin representations by a functional integral approach and report on the transition from finite S to $S \to \infty$. As a specific application, we present results on the dynamical version of the Schwinger effect.

Q 11.4 Mon 15:30 K/HS2

Canonical approach to equilibrium properties of interacting fermionic quantum gases — •Quirin Hummel, Juan Diego Urbina, and Klaus Richter — Institut für Theoretische Physik, Universität Regensburg, 93053 Regensburg, Germany

It is generally accepted that the equilibrium properties of quantum gases give the same results for the canonical and grand canonical ensemble. For finite systems well below the thermodynamic limit, however, this equivalence breaks down. The total number of particles can not be fixed within the grand canonical formalism where by definition this quantity is always subject to thermal and quantum fluctuations except in the strict thermodynamic limit. This poses a serious problem, as most of the powerful techniques to deal with quantum and interaction effects in quantum gases depend in an essential way on the use of the grand canonical formalism. To the best of our knowledge, a purely canonical approach to address quantum and interaction effects on equilibrium thermodynamics of quantum gases with a fixed number of particles is not available.

In this contribution we present such an approach, with the specific intention to obtain virial-type expansions for finite fermionic systems, including the equation of state and (local and non-local) pair correlations. In our formalism the canonical partition function is given by a *finite* expansion in the inverse temperature, thus providing a closed explicit form for the quantum equation of state. We also discuss the thermodynamic limit and the effect of interactions and particle symmetry on the many-body spectra.

Q 11.5 Mon 15:45 K/HS2

Thermometry of fermionic atoms in optical lattices by modulation spectroscopy — •Karla Loida and Corinna Kollath — HISKP, Universität Bonn, Nussallee 14-16, 53115 Bonn

The possibilities to probe and accurately characterize an ultracold Fermi gas trapped in an optical lattices are still very limited. In particular, experimentalists lack reliable methods to adequately measure the temperature. We propose a scheme to directly measure the temperature of non-interacting fermionic atoms confined to a three-dimensional optical lattice by superlattice modulation spectroscopy. The superlattice modulation is applied along one direction and injects momentum into the system which strongly affects the nature of excitations. This leads to a strong temperature dependence of the spectral response such that the temperature may be easily extracted from a fit with a minimum of fitting parameters. Moreover, the experimental realization is temptingly simple since the spectral response can be determined from adiabatic band mapping when exciting to higher bands owing to the fact that the superlattice modulation only excites distinct quasimomenta. This scheme extends down to very low temperatures of about 10% of the hopping strength that have not been observed in experiment so far and that lie below the Néel temperature where antiferromagnetic ordering is expected to occur.

Q 11.6 Mon 16:00 K/HS2

Exploring topology with optical lattices: The Haldane model and beyond — •Gregor Jotzu, Michael Messer, Rémi Desbuquois, Martin Lebrat, Thomas Uehlinger, Frederik Görg, Daniel Greif, and Tilman Esslinger — Institute for Quantum Electronics, ETH Zurich, 8093 Zurich, Switzerland

The Haldane model on the honeycomb lattice is a paradigmatic example of a Hamiltonian featuring topologically distinct phases of matter and describes a mechanism through which a quantum Hall effect can appear as an intrinsic property of a band-structure. We report on the experimental realisation of the Haldane model using ultracold fermionic atoms. The model is based on breaking time-reversal symmetry, which is achieved through the introduction of complex next-nearest-neighbour tunnelling terms, which we induce through circular modulation of the lattice position. Addtionally, we create an energy offset between neighbouring sites to break inversion symmetry. Breaking either of these symmetries opens a gap in the band-structure, which is probed using momentum-resolved interband transitions. We explore the resulting Berry-curvatures by applying a constant force to the atoms and find orthogonal drifts analogous to a Hall current. The competition between both broken symmetries gives rise to a transition between topologically distinct regimes. By identifying the vanishing

gap at a single Dirac point, we map out this transition line experimentally and compare it to calculations using Floquet theory. Our approach is suitable even for interacting fermionic systems and can be extendet to create spin-dependent and spatially varying Hamiltonians.

Q 11.7 Mon 16:15 K/HS2

A quantum simulator for molecules: Imaging molecular orbitals and electronic dynamics with ultracold atoms — •Dirk-Sören Lühmann, Christof Weitenberg, and Klaus Sengstock — Institut für Laserphysik, Universität Hamburg, Germany

In the recent years, ultracold atoms in optical lattices have proven their great value as quantum simulators for studying strongly-correlated phases and complex phenomena in solid-state systems. Here, we reveal their potential as quantum simulators for molecules and propose a technique to image the three-dimensional molecular orbitals with high resolution. The outstanding tunability of ultracold atoms in terms of potential and interaction offer fully-adjustable model systems for gaining deep insight into the electronic structure of molecules. We study the orbitals of an artificial benzene molecule and discuss the effect of tunable interactions in its conjugated π electron system with special regard to localization and spin order. The dynamical timescale of ultracold atom simulators are on the order milliseconds which allow for the time-resolved monitoring of a broad range of dynamical processes. As an example, we compute the intercombination dynamics in the conjugated π system of the artificial benzene molecule.