Q 4: Quantum Gases: Fermions I

Time: Monday 11:30–13:00 Location: K/HS2

Q 4.1 Mon 11:30 K/HS2

Observation of Leggett-Rice effect in a unitary Fermi gas — •Tilman Enss[1], Stefan Trotzky[2], Scott Beattie[2], Chris Luciuk[2], Scott Smale[2], Alma Bardon[2], Edward Taylor[3], Shizhong Zhang[4], and Joseph Thywissen[2] — [1]Universität Heidelberg — [2]University of Toronto, Canada — [3]McMaster University, Canada — [4]University of Hong Kong, China

We observe that the diffusive spin current in a strongly interacting degenerate Fermi gas of ^{40}K precesses about the local magnetization. As predicted by Leggett and Rice, precession is observed both in the Ramsey phase of a spin-echo sequence, and in the nonlinearity of the magnetization decay. At unitarity, we measure a Leggett-Rice parameter $\gamma = 1.08(9)$ and a bare transverse spin diffusivity $D_0^{\perp} = 2.3(4)\,\hbar/m$ for a normal-state gas initialized with full polarization at $T/T_F = 0.2$. Tuning the scattering length a, we find that a sign change in γ occurs near unitarity. We argue how γ reveals the effective interaction strength of the gas, such that the sign change in γ indicates a switching of branch, between a repulsive and an attractive Fermi gas.

Q 4.2 Mon 11:45 K/HS2

Exploring a strongly interacting 2D Fermi gas — •Mathias Neidig, Luca Bayha, Dhruv Kedar, Puneet Murthy, Martin Ries, Andre Wenz, Gerhard Zürn, and Selim Jochim — Physikalisches Institut, Universität Heidelberg

In this talk, we present our current progress investigating a strongly interacting cloud of paired ultracold ^{6}Li-fermions in a strongly anisotropic confinement.

Our starting point is a quasi-2D gas of deeply bound bosonic dimers trapped in a single layer of a red-detuned standing wave trap. We are able to directly access the in-situ momentum distribution of this system and observe the emergence of a low-momentum condensate at low temperatures. From the momentum distribution, we extract a trap averaged g_1 correlation function which for low temperatures shows a region of algebraically decaying phase. This hints towards a Berezinskii-Kosterlitz-Thouless (BKT)-like phase transition which is expected in a two-dimensional system.

Recently we added an optical square lattice to the setup and we are currently loading this BKT-type superfluid into this lattice. Progress on this will be reported.

Q 4.3 Mon 12:00 K/HS2

Non-linear superlow of strongly interacting Fermions in a quantum point contact — •Dominik Husmann[1], Sebastian Krinner[1], Martin Lebrat[1], Jean-Philippe Brantut[1], Shun Uchino[2], Thierry Giamarchi[2], and Tilman Esslinger[1] — [1]Institut für Quantenelektronik, ETH Zürich, Schweiz — [2]Department of Quantum Matter Physics, University of Geneva, Schweiz

Superfluids, like superconductors, are characterised by their strong, non-linear response to a bias. Here we report on the measurement of the non-linear current-bias relation of a strongly interacting Fermi gas flowing through a narrow constriction. We prepare a cigar-shaped cloud of ultracold ^{6}Li close to a Feshbach resonance where the scattering length diverges and the system behaves as a unitary Fermi gas. The cloud is then narrowed down in the center by means of repulsive laser beams, creating a system of two separate clouds connected by a one-dimensional constriction, a quantum point contact (QPC). By imposing a chemical potential bias between the two clouds and observing the dynamics of particle flow, we analyse the current-bias characteristics of our system and find nonlinear behaviour indicating superfluid behaviour. The results agree quantitatively with a biased superfluid point contact model treated with the Keldysh formalism, suggesting that the supercurrent originates from multiple Andreev reflections. We study the influence the density in the QPC and investigate the effect of finite temperature effects on the current-bias characteristics.

Q 4.4 Mon 12:15 K/HS2

Many-Body Localisation of Fermions in a Quasi-Random 1D Lattice — •Michael Schreiber[1,2], Pranjal Bordia[1,2], Henrik Lüschen[1,2], Sean Hodgman[1,2], Ulrich Schneider[1,2], Immanuel Bloch[1,2], Mark Fischer[3], Ronen Vosk[3], and Ehud Altman[3] — [1]Ludwig-Maximilians-Universität, Schellingstrasse 4, 80799 München — [2]Max-Planck-Institut für Quantenoptik, Hans Kopfermann Str. 1, 85748 Garching b. München — [3]Weizmann Institute of Science, Rehovot 76100, Israel

While Anderson localisation of non-interacting particles has been studied extensively, much less is known about localisation in interacting systems. As an experimental probe, we study the breakdown of ergodicity and the resulting absence of thermalisation, which is one key feature of localised systems. We have investigated the many-body localisation transition for interacting ultracold fermions in a quasi-random 1D lattice by measuring the relaxation dynamics of an initial Charge Density Wave (CDW). Utilising a band mapping technique in an additional superlattice, we can measure the relative imbalance between atoms on even and odd sites, which serves as our CDW order parameter. While the imbalance quickly decays in the thermalising case, a CDW persisting for long evolution times reveals the breakdown of ergodicity and many-body localisation.

Q 4.5 Mon 12:30 K/HS2

Pairing in the vicinity of the BEC-BCS crossover — •Daniel Hoffmann[1], Thomas Paintner[1], Stefan Häussler[1], Wladimir Schoch[1], Wolfgang Limmer[1], Benjamin Deissler[1], Cheng Chin[2], and Johannes Hecker Denschlag[1] — [1]Universität Ulm, Institut für Quantenmaterie, Ulm, Deutschland — [2]University of Chicago, James Franck Institute, Chicago, USA

We investigate a mixture of paired (molecules or Cooper pairs) and unpaired atoms in the BEC-BCS crossover regime. For a given temperature, a thermodynamic equilibrium forms between atoms and pairs.

We use a 50-50 (30-70) mixture of the two lowest ^{6}Li hyperfine spin states and set their interaction strength by adjusting the scattering length with the help of the Feshbach resonance at 832 G.

We then determine the temperature T* at which pair creation sets in. To do so we use RF spectroscopy as well as a magnetic field projection technique to determine the fraction of paired atoms at different temperatures.

Since T* differs from the critical temperature T_c for the superfluid transition it holds additional information on mixed systems. Therefore our results provide a deeper insight into pairing and pair-correlations.

Q 4.6 Mon 12:45 K/HS2

Towards single-site resolved imaging of ^{40}K in an optical lattice — •Thomas Lompe, Lawrence Cheuk, Matthew Nichols, Melih Okan, and Martin Zwierlein — Massachusetts Institute of Technology

Ultracold atoms in optical lattices are an ideal system to study quantum many body physics in a clean and well-controlled environment. Recently, experiments at Harvard and MPQ Munich using bosonic 87Rb atoms have established the ability to locally probe and manipulate such systems with single site resolution.

The goal of our experiment is to achieve such single-site resolution for a quantum gas of fermionic atoms. This would allow to directly observe microscopic density or spin correlations which are difficult to extract from bulk measurements. This technique could for example be used to directly observe magnetic ordering in a fermionic Mott insulator. The ability to locally address and probe the system could also be used to create and detect sharply localized quantum states such as edge states at the boundary of topological states of matter.

As the starting point for our experiments we prepare a 2D Fermi gas trapped in a single node of an optical standing wave seven micrometers below a solid immersion microscope. We then freeze the distribution of the atoms by ramping up a deep 3D optical lattice and use Raman sideband cooling to perform fluorescence imaging. In this talk we will report on our progress towards using this scheme to achieve single-site resolved imaging of fermionic atoms in an optical lattice.