Q 50: Quantum Gases: Fermions I

Time: Thursday 11:00–13:00 Location: F342

Q 50.1 Thu 11:00 F342

Collective excitations in mesoscopic Fermi gases — •Philipp Lunt, Paul Hill, Johannes Reiter, Philipp Preiss, and Selim Jochim — Physikalisches Institut, Universität Heidelberg

Understanding the elementary excitations of strongly interacting many-body systems in terms of the independent motion of individual particles and their collective behaviour has been a central theme in many fields ranging from nuclear physics to cold atoms [1,2].

Here, we present a study of elementary excitations of a mesoscopic Fermi system across the BEC-BCS crossover by means of spectroscopic probes. Therefore, we use an established spilling technique [3] to prepare a balanced system of few fermionic atoms in a tightly confined tweezer. We excite the quadrupole mode by interference with a Laguerre-Gaussian mode. Tuning of the interparticle interactions via a broad Feshbach resonance allows us to observe the transition from single-particle to collective excitations. Furthermore, we investigate the breakdown of collectivity by reducing the atom number gradually.

[1] B. Mottelson Science 193 (4250), 287-294 (1976) [2] S. Giorgini et al. Rev.Mod.Phys. 80, 125 (2008) [3] F. Serwane et al. Science 332 (6027), 336-338 (2011)

Q 50.2 Thu 11:15 F342

Anomalous thermoelectric transport between fermionic superfluids — Philipp Fabritius, Jeffrey Mohan, Mohsen Talebi, Simon Wili, •Meng-Zi Huang, and Tilman Esslinger — Department of Physics, ETH Zürich, 8093 Zürich, Switzerland

Thermoelectric effects in superfluid systems have been far less explored than other superfluid transport both theoretically and experimentally. Landau's two-fluid model works well in conventional superconductors, yet studies beyond the two-fluid model are scarce. Here we study the Peltier and Seebeck effects together in a superfluid system, namely transport induced by a chemical potential bias and by a temperature bias, respectively. Our system is a mesoscopic channel connecting two superfluids of ultracold fermionic atoms, where the particle current in both the Peltier and the Seebeck configurations exhibits a strong non-Ohmic character. While non-Ohmic transport is associated with superfluid features, we observe a large entropy current concomitant with the particle current, incompatible with a simple two-fluid model. On the other hand, we engineer a controlled particle loss inside the mesoscopic channel to study its influence on thermoelectric response. Surprisingly, local dissipation can enhance the particle current in a Seebeck configuration (analogous to the fountain effect). This would imply a change in the reservoir response despite the dissipation being in the channel. We present possible explanations to the observations, including non-hydrodynamic transport.

Q 50.3 Thu 11:30 F342

Observation of Cooper pairs in a mesoscopic 2D Fermi gas — •Marvin Holten[1,2], Luca Bayha[1], Keerthan Subramanian[1], Sandra Brandstetter[1], Carl Heintze[1], Philipp Lunt[1], Philipp Preiss[1,3], and Selim Jochim[1] — [1]Physikalisches Institut, Heidelberg University, Germany — [2]Atominstiut, TU Wien, Austria — [3]Max Planck Institute of Quantum Optics, Garching, Germany

The formation of strongly correlated pairs is fundamental for the emergence of fermionic superfluidity and superconductivity. To understand the pairing mechanism is an ongoing challenge in the study of many strongly correlated fermionic systems. In this talk, I present the direct observation of Cooper pairs in our experiment. We have implemented a fluorescence imaging technique that allows us to extract the full in-situ momentum distribution with single particle and spin resolution. We apply it to a mesoscopic Fermi gas, prepared deterministically in the ground state of a two-dimensional harmonic oscillator. Our ultracold gas allows us to tune freely between a completely non-interacting unpaired system and weak attractions where we find Cooper pair correlations at the Fermi surface. When increasing the interactions even further, the pair character is modified and the pairs gradually turn into tightly bound dimers. The collective behaviour that we discover in our mesoscopic system is closely related to observations in nuclear physics or metallic grains. Our method provides a new pathway to study many of the outstanding questions concerning fermionic pairing, for example in imbalanced systems or the normal phase.

Q 50.4 Thu 11:45 F342

Tunable diffusion properties of spin-polarized Fermi gases in time-dependent disorder — •Sian Barbosa, Max Kiefer-Emmanouilidis, Felix Lang, Michael Fleischhauer, and Artur Widera — Physics Department and Research Center OPTIMAS, University of Kaiserslautern-Landau, Germany

The transport of particles through disordered potential landscapes has been actively studied for the last decades. The vast majority of these studies, e.g. of Anderson localization, addressed the regime in which the disordered potential is static. However, it seems natural to investigate the influence of time-dependent disorder on transport properties. More specifically, a crossover from localization to diffusive, even hyperballistic, transport is expected to occur when the disorder varies in time. I will present the results of our experimental investigation of the dynamics of ultracold, spin-polarized fermionic lithium atoms when exposed to an optical speckle potential that can be frozen or continuously varying its random pattern in both space and time. We observe a strong dependence of the system's diffusion exponent on the so-called correlation time, a measure for the disorder's rate of change. We furthermore investigate new measures based on analysis of entropies to quantify the state of the system independent of specific models.

Q 50.5 Thu 12:00 F342

Competing antiferromagnetic and superfluid phases in the Feshbach-Hubbard model — •Victor Bezerra[1] and Axel Pelster[2] — [1]Friedrich-Engels-Gymnasium, Emmentalerstraße 67, 13407 Berlin, Germany — [2]Physics Department and Research Center OPTIMAS, Rheinland-Pfälzische Technische Universität Kaiserslautern-Landau, Germany

Competing phases play an important role in strongly interacting systems, as for example in the case of superconductivity and antiferromagnetism. Alongside condensed matter-systems ultracold atoms loaded in optical lattices have shown to be quite promising to simulate and to understand the behavior of strongly correlated systems. In this work we study a two-dimensional model that contains both the usual repulsive Fermi-Hubbard Hamiltonian and a pairing term due Feshbach bosons, and study there the competition of antiferromagnetic order and conventional pairing order within a zero-temperature mean-field theory. With this we investigate, at first, the properties of the crossover from a Bose-Einstein condensate (BEC) phase to the Bardeen-Cooper-Schrieffer (BCS)-like phase, where a reentrant behavior occurs and band-insulator lobes are obtained analytically. Secondly, concerning the antiferromagnetic (AF) order, the well-known mean-field results are reproduced. And, finally, we obtain a quantum phase diagram, which reveals an intriguing interplay from a BEC-BCS crossover to an insulating AF order.

Q 50.6 Thu 12:15 F342

Report on an Erbium-Lithium machine — •Florian Kiesel and Alexandre De Martino — Eberhard Karls Universität Tübingen, Physikalisches Institut AG Groß, Auf der Morgenstelle 14, 72076 Tübingen

Ultracold Fermions cannot be cooled below about 10% of the Fermi temperature with conventional methods. Sympathetic cooling with a classical gas as an entropy reservoir may provide a new direction to overcome the current limit. Here we report on the construction and implementation of first cooling stages of a two species apparatus for the optimized symp. cooling of fermionic Li with bosonic Er. This mixture has several promising features, that have not yet been utilized for symp. cooling in any other mixture. Pushing the temperature limit is essential for the quantum simulation of strongly correlated phenomena, in particular in optical lattice.

Q 50.7 Thu 12:30 F342

Excitation Spectrum and Superfluid Gap of an Ultracold Fermi gas — •Hauke Biss[1,2], Lennart Sobirey[1], René Henke[1], Cesar Cabrera[1,2], and Henning Moritz[1,2] — [1]Institute of Laser Physics, University of Hamburg, Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging, University of Hamburg, Hamburg, Germany

Ultracold Fermi gases with tunable interactions have allowed realizing the famous BEC-BCS crossover from a Bose-Einstein condensate

(BEC) of molecules to a Bardeen-Cooper-Schrieffer (BCS) superfluid of weakly bound Cooper pairs. In this contribution, I will present how we use Bragg spectroscopy to measure the full momentum-resolved low-energy excitation spectrum of spin-balanced strongly interacting ultracold Fermi gases. This enables us to observe the smooth transformation from a bosonic to a fermionic superfluid in the BEC-BCS crossover. We use our spectra to determine the evolution of the superfluid gap and find excellent agreement with previous experiments and theory. As a next step, we reduce the dimensionality of the gas to probe the excitation spectrum of two-dimensional (2D) Fermi gases. This allows us to demonstrate superfluidity of 2D Fermi gases and to observe the influence of the reduced dimensionality on the stability of the superfluid phase. Finally, I will present our progress towards creating and probing spin-imbalanced mixtures in 2D.

Q 50.8 Thu 12:45 F342

Towards fast, deterministic preparation of few-fermion states
— •Maximilian Kaiser[1], Tobias Hammel[1], Vivienne Leidel[1], Micha Bunjes[1], Philipp Preiss[2], Matthias Weidemüller[1], and Selim Jochim[1] — [1]Physikalisches Institut - University of Heidelberg, Heidelberg, Germany — [2]Max Planck Institute of Quantum Optics, Garching, Germany

Measurements of higher-order correlations in quantum systems, e.g. for the tomography of complex quantum states, require large data sets. This demand stands in contrast to typical cycle times of 10 seconds or more in traditional experiments with ultracold quantum gases.
We report on the ongoing development of a highly modular apparatus for fast, experimental quantum simulations using ultracold Lithium-6 with envisioned cycle times of well below 1 second. Within each run, few-fermion states are prepared in a sequence based upon [1].
The resulting high data output will especially be key for iteration-intensive research in the future, while the highly modular experimental interface allows a broad envelope of quantum systems to be realized and simulated.

[1] F.Serwane et Al., Science Vol. 332, p.336-338 (2011)