Q 34: Quantum gases (Fermions) II

Time: Wednesday 14:00–16:00 Location: e214

Invited Talk Q 34.1 Wed 14:00 e214
Zooming in on Fermi Gases in Two Dimensions — •Philipp Preiss, Luca Bayha, Jan Hendrik Becher, Marvin Holten, Ralf Klemt, Philipp Lunt, Keerthan Subramanian, and Selim Jochim — Physics Institute, Heidelberg University

Interacting Fermi systems in two dimensions display interesting phenomena including strongly correlated superfluids, pseudogap physics, and collective excitations. Certain limits, such as the weakly interacting regime and the few-body case, can be modeled exactly, but for a large parameter space in particle number and interaction strength, predicting the relevant physical properties theoretically is extremely challenging.

I will report on experiments that realize tunable fermion systems with ultracold lithium and span large swaths of the interesting regime. We have assembled a complete experimental toolbox to study such systems with single-particle resolution in position and momentum space.

In the well-controlled few-body scenario, we deterministically prepare few fermions in the ground state of a two-dimensional trap and observe the formation of shell structure with stable “magic” numbers of 2,6,12 particles. Through many-body spectroscopy, we find well-defined resonances that consists of pairwise excitations and can be identified as the precursor of the Higgs amplitude mode.

Scaling the system to sizes of several hundred particles, we are able to probe strongly correlated continuum systems with the microscopic tools of particle-resolved correlation functions.

Q 34.2 Wed 14:30 e214
Direct observation of superfluidity in an ultracold two-dimensional Fermi gas — •Lennart Sobirey, Markus Bohlen, Niclas Luick, Hauke Biss, Thomas Lompe, and Henning Moritz — Institut für Laserphysik, Universität Hamburg, Deutschland

Understanding the mechanism for superfluidity in low dimensional systems with strong correlations is one of the major unsolved problems of condensed matter physics. Ultracold two-dimensional Fermi gases model these systems in a clean and controllable way, but so far, superfluidity has not been directly observed. Here, we present direct evidence of superfluidity in a strongly interacting 2D Fermi gas. We drag an optical lattice through a homogeneous 2D Fermi gas and observe no dissipation below a critical velocity, in excellent agreement with the Landau criterion. We find evidence for superfluidity across a wide range of interaction strengths in the BEC-BCS crossover.

Q 34.3 Wed 14:45 e214
An ideal Josephson junction in an ultracold two-dimensional Fermi gas — •Niclas Luick[1,2], Lennart Sobirey[1,2], Markus Bohlen[1,2,3], Vijay Pal Singh[4,2], Ludwig Mathey[4,2], Thomas Lompe[1,2], and Henning Moritz[1,2] — [1]Institut für Laserphysik, Universität Hamburg — [2]The Hamburg Centre for Ultrafast Imaging, Universität Hamburg — [3]Laboratoire Kastler Brossel, ENS-PSL Research University, CNRS, Sorbonne Université, Collège de France, 24 rue Lhomond, 75005 Paris, France — [4]Zentrum für optische Quantentechnologien, Universität Hamburg

Two-dimensional structures are present in almost all known superconductors with high critical temperatures, but the role of the reduced dimensionality is still under debate. Recently, ultracold atoms have emerged as an ideal model system to study such strongly correlated 2D systems.

Here, we present our realisation of a Josephson junction in an ultracold 2D Fermi gas. We measure the frequency of Josephson oscillations as a function of the phase difference across the junction and find excellent agreement with the sinusoidal current phase relation of an ideal Josephson junction. Furthermore, we determine the critical current of our junction in the crossover from tightly bound molecules to weakly bound Cooper pairs. Our measurements clearly demonstrate phase coherence and provide strong evidence for superfluidity in a strongly interacting 2D Fermi gas.

Q 34.4 Wed 15:00 e214
Ergodicity-breaking in tilted 1D optical lattices — •Sebastian Scherg[1,2,3], Thomas Kohlert[1,2,3], Bharath Hebbe Madhusudhana[1,2,3], Immanuel Bloch[1,2,3], and Monika Aidelsburger[1,2] — [1]Ludwig-Maximilians-Universität, Schellingstr. 4, 80799 München, Germany — [2]Munich Center for Quantum Science and Technology (MCQST), Schellingstr. 4, 80799 München, Germany — [3]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching, Germany

We study interacting ultracold Fermions in a tilted 1D optical lattice to investigate, how non-ergodic dynamics can emerge in a system even without the presence of disorder. Using a superlattice to create an initial charge-density wave, we measure the population imbalance between even and odd sites. At short times, we observe spin-resolved and parity-projected real-space Bloch oscillations, which are used as benchmark for the experimental parameters such as tunneling rate, tilt and harmonic confinement in the non-interacting regime. In the presence of interactions we observe an interaction-dependent amplitude modulation and dephasing of the Bloch oscillations. The long-time dynamics reveal a robust steady state imbalance over about 300 tunneling times, whose value depends on the interaction strength. Finally, we couple adjacent 1D systems to probe the crossover from a non-ergodic 1D to an ergodic 2D system and find a decay of the imbalance depending on the transverse coupling strength.

Q 34.5 Wed 15:15 e214
Correlation measurements of mesoscopic two-dimensional Fermi systems — •Ralf Klemt, Philipp Lunt, Jan Hendrik Becher, Ram-Janik Petzold, Philipp M. Preiss, and Selim Jochim — Physikalisches Institut der Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg

Understanding strongly correlated quantum matter on a fundamental level requires both access to microscopic correlations of individual constituents and macroscopic observables of the full system.

In recent years, we developed experimental methods to study global observables in macroscopic two-dimensional Fermi systems of ultracold ^6Li atoms in the BEC-BCS crossover by phase coherence and pairing energy measurements. Furthermore, utilizing local observables on the single atom level, we can characterize microscopic quantum systems by their correlation and entanglement properties.

Combining these two approaches, we study the crossover regime between microscopic and macroscopic systems which features already rich many-body physics, however with correlations measurements on the single particle level still feasible. In this talk, I will present first results on preparing and probing very dilute, yet strongly correlated, low entropy states of a few 100 atoms characterized by measurements on density and density correlations.

Q 34.6 Wed 15:30 e214
Strongly correlated fermions strongly coupled to light — •Hideki Konishi, Kevin Roux, Victor Helson, and Jean-Philippe Brantut — Institute of Physics, EPFL, Lausanne, Switzerland

We demonstrate strong coupling of a strongly interacting Fermi gas with light in a high finesse optical cavity. A quantum degenerate, unitary Fermi gas of lithium-6 is produced inside the cavity mode, and the transmission spectrum of the coupled system is measured. We investigate both a spin-polarized and a spin-balanced gas. In the spin-polarized case the spectrum shows a prominent anti-crossing as the cavity approaches the atomic resonance, a hallmark of strong light-matter coupling. In the spin-balanced case we observe three dressed state branches corresponding to the two internal states, in a regime where the collective Rabi frequency is larger than the hyperfine splitting. Both spectra are in good agreement with ab-initio theoretical calculations. Our system provides complete and simultaneous control over the atom-atom and atom-light interactions. It allows for the implementation of novel light-induced phases of matter as well as continuous measurements of atomic dynamics.

Q 34.7 Wed 15:45 e214
Approximate theories for an interacting wannier-stark ladder — •Bharath Hebbe Madhusudhana[1,2,3], Sebastian Scherg[1,2,3], Thomas Kohlert[1,2,3], Immanuel Bloch[1,2,3], and Monika Aidelsburger[1,2] — [1]Fakultät für Physik, Ludwig-Maximilians-Universität München, 4 Schellingstraße, 80799 München, Germany — [2]Munich Center for Quantum Science and Technology (MCQST), Schellingstr. 4, 80799 München, Germany — [3]Max Planck Institute

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The Wannier-Stark ladder is a simple 1D lattice system that features localization. Its Hamiltonian consists of a nearest neighbor hopping and a linear on-site potential resulting in a tilt . In the non-interacting case, this systems is analytically tractable. However, in the presence of Hubbard interactions, due to an exponential scaling of the dimension of the Hilbert space, theoretical and numerical computations are limited to either small system sizes or short evolution times. Here, we use an analog quantum simulator made of trapped neutral atoms to experimentally study the localization dynamics of a Wannier-Stark ladder with Hubbard interactions. Using the experimental results, we develop and benchmark an approximate theoretical model for our system and show that the experimental results are well approximated by the theory. The computational complexity of this theory is at-most linear in the system size and therefore, the system dynamics can be computed efficiently using this theory. We also apply this theory to the Aubry-André model, which is another Hamiltonian that features localization, and show a good agreement with experimental data.