Q 19: Quantum Gases: Fermions III

Time: Tuesday 11:00–12:30 Location: K/HS2

Q 19.1 Tue 11:00 K/HS2

Exploring the Ionic-Hubbard model with ultracold fermions — •Michael Messer, Gregor Jotzu, Rémi Desbuquois, Thomas Uehlinger, Frederik Görg, Daniel Greif, Sebastian Huber, and Tilman Esslinger — ETH Zurich, 8093 Zurich, Switzerland

The Ionic Hubbard model is a fundamental model that describes the competition between different density-ordered phases, which originate from the interplay of the underlying geometry and inter-particle interactions. Depending on the energy scales, it can feature a charge-density-wave ordered state or a Mott-insulating state.

In our experiment we realize the Ionic Hubbard model on a honeycomb lattice by loading a two-component interacting Fermi gas into an optical lattice with a staggered energy offset on alternating sites. We characterize the state of the system by performing noise correlation measurements of the atomic momentum distribution. For large energy offsets we observe a staggered density ordered state, which is suppressed when increasing the repulsive on-site interactions. We additionally characterize the staggered density order by measuring the double occupancy as a function of interaction and energy offset. Furthermore, we explore the distinct response of the charge excitation spectrum for different strengths of the energy offset using lattice modulation spectroscopy and find gapped excitation spectra in the Mott-insulating regime.

Q 19.2 Tue 11:15 K/HS2

Formation and dynamics of anti-ferromagnetic correlations in tunable optical lattices — •Daniel Greif, Gregor Jotzu, Michael Messer, Frederik Görg, Rémi Desbuquois, and Tilman Esslinger — Institute for Quantum Electronics, ETH Zurich, 8093 Zurich, Switzerland

The observation of anti-ferromagnetic spin correlations of ultracold fermions in optical lattices is an important milestone towards an experimental study of the Hubbard model. In this model many questions on the low-temperature phase diagram still remain open, both for simple cubic and square configurations, as well as for more complex lattice geometries. Additionally, for creating an equilibrated low-temperature state and a successful implementation of advanced cooling schemes based on entropy redistribution, an understanding of the formation time for spin correlations is of paramount importance.

In our experiment we load a two-component, repulsively interacting fermionic quantum gas into an optical lattice of tunable geometry. For very low temperatures we observe anti-ferromagnetic correlations on neighbouring sites in both isotropic 3D cubic and 2D square lattices. We also study the strength of the spin correlations in more complex lattice geometries, such as honeycomb, 1D-dimerized and spin-ladder configurations. Furthermore, we investigate the characteristic formation time of spin correlations in optical lattices by changing the lattice geometry on variable timescales.

Q 19.3 Tue 11:30 K/HS2

Breakdown of quantized conductance with interacting ultracold fermions — •Martin Lebrat, Sebastian Krinner, Dominik Husmann, Charles Grenier, Jean-Philippe Brantut, and Tilman Esslinger — Institut für Quantenelektronik, ETH Zürich, Schweiz

We study the transport of ultracold fermions through a one-dimensional structure in the presence of strong attractive interparticle interactions. While conductance is quantized in steps of $1/h$ for weak interactions, as predicted by the Landauer-Büttiker theory of transport, this feature vanishes with increasing interactions.

Experimentally, we pinch off at its center an elongated cloud of ultracold ^{6}Li atoms, effectively splitting it into two macroscopic reservoirs. The precise geometry of the junction is defined through a set of repulsive and attractive optical potentials, similarly to the gate potentials of an electronic quantum point contact. Upon inducing a population bias between the reservoirs, which can be addressed independently for different hyperfine species, a current sets in to restore thermal equilibrium. Measuring its magnitude for both spin states allows to access particle and spin conductance. Both show opposite behaviors as the atoms enter in the strong superfluid regime, delivering further insights on the breakdown of the quantized conductance.

Q 19.4 Tue 11:45 K/HS2

Local Probing of a Fermionic Mott Insulator — •Marco Koschorreck, Luke Miller, Eugenio Cocchi, Jan Drewes, Daniel Pertot, Ferdinand Brennecke, and Michael Köhl — Rheinische Friedrich-Wilhelms-Universität Bonn

Systems of interacting Fermions are ubiquitous in nature. They exhibit fascinating phenomena like superconductivity, quantum magnetism, and the superfluidity of 3He. Ultracold atomic Fermi gases allow for a particularly clean experimental realization of these quantum many-body systems and for addressing long-standing open questions.

In this talk, we focus on situations in which the motion of particles is confined to two-dimensional layers. In particular, we will report on the realization of the two dimensional Fermi-Hubbard model with repulsive interactions by loading degenerate Fermi gases of Potassium 40 atoms into a three dimensional optical lattice. Exploiting high-resolution imaging combined with radio-frequency spectroscopy enables us to go beyond the standard of global measurements. We observe the formation of Mott insulating domains by in-situ imaging a single two-dimensional layer. Having access to local properties we can identify different quantum phases.

Q 19.5 Tue 12:00 K/HS2

Emergence of orthogonality in the Fermi impurity problem — •Simon Murmann, Andrea Bergschneider, Vincent M. Klinkhamer, Gerhard Zürn, and Selim Jochim — Physikalisches Institut der Universität Heidelberg, Heidelberg, Deutschland

In quasi one dimensional systems, the ground-state wavefunction of an impurity particle interacting with a Fermi sea is orthogonal to the wavefunction of the non-interacting system. In this case the squared overlap between the interacting and the non-interacting systems, which is defined as the quasiparticle residue, is zero.

Here, we report on measurements of the residue of a single fermionic impurity particle interacting with an increasing number of majority particles. To probe the system, we flip the spin of the impurity particle by driving a radio frequency (RF) transition. In a previous experiment we used RF spectroscopy to measure the interaction energy in this system while increasing the number of majority particles one atom at a time and thereby observed the crossover from few to many-body physics [1]. Now, we measure how the wavefunction overlap between initial and final states changes both as a function of interaction strength and the number of majority particles. Our goal is to extend these measurements into the crossover region between few and many-body physics by increasing the number of majority particles and thereby observe the emergence of the orthogonality catastrophe.

[1] Wenz et al. Science 342, 457 (2013)

Q 19.6 Tue 12:15 K/HS2

Quantum state preparation, manipulation and detection in a double well — •Vincent M. Klinkhamer[1], Marius M. Rimmler[1], Andrea Bergschneider[1], Simon Murmann[1], Gerhard Zürn[1], Thomas Lompe[2], and Selim Jochim[1] — [1]Physikalisches Institut der Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany — [2]Department of Physics, Massachusetts Institute of Technology, Massachusetts Avenue 77, Cambridge, MA, USA

Initializing, manipulating and detecting quantum systems with high fidelity is essential for quantum simulation and quantum computation.

Here, we present our system of two interacting fermions in a double-well potential. It can be described by a two-site Fermi-Hubbard model which depends on the tunnel coupling, on-site interaction and Zeeman energy. We control these parameters over several orders of magnitude through the confining potential, magnetic field offset and magnetic field gradient. This allows us to prepare and manipulate quantum states with fidelities of over 98%. For example, we use this to observe singlet-triplet oscillations or prepare spin-ordered states. Currently, we are implementing a new, site-resolved imaging system for the detection of the final state.

We aim to use this double well as a starting point for preparing low-entropy states in larger finite lattice systems. Furthermore, our double-well system is equivalent to a single qubit with universal single-qubit quantum gates. We can implement two qubits and two-qubit operations by coupling to a second double well.