Q 17: Fermi Quantum Gas

Time: Tuesday 10:30–12:45 Location: BAR Schön

Q 17.1 Tue 10:30 BAR Schön

Exploring Many-Body Interaction in a Strongly Interacting ^{6}Li-^{40}K Fermi-Fermi Mixture — •Christoph Kohstall[1,2], Andreas Trenkwalder[1], Matteo Zaccanti[1], Devang Naik[1], Andrei Sidorov[3], Florian Schreck[1], and Rudolf Grimm[1,2] — [1]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, Innsbruck, Austria — [2]Institut für Experimentalphysik und Zentrum für Quantenphysik, Universität Innsbruck, Innsbruck, Austria — [3]Swinburne University of Technology, Melbourne, Australia

We have realized the first strongly interacting ^{6}Li-^{40}K Fermi-Fermi mixture by means of an interspecies Feshbach resonance. Measurements on the expansion of this resonantly interacting Fermi-Fermi mixture reveal its collisionally hydrodynamic behavior [1]. In present experiments, we explore the many-body interaction by determining the interaction energy, which we extract from expansion measurements and from radio frequency spectroscopy. These studies will shed light on the formation dynamics of polarons or pseudo-gap pairs in the strongly interacting regime. An intriguing prospect is to individually control the optical potentials of the two components, opening the new possibility to investigate systems with selectively adjusted Fermi surfaces or with mixed dimensionality.

[1] A. Trenkwalder et al., arXiv:1011.5192 (2010).

Q 17.2 Tue 10:45 BAR Schön

Deterministic preparation and control of a few-fermion system — •Gerhard Zürn[1,2], Thomas Lompe[1,2,3], Timo Ottenstein[1,2,3], Martin Ries[1,2], Friedhelm Serwane[1,2,3], Andre Wenz[1,2], and Selim Jochim[1,2,3] — [1]Physikalisches Institut, Universität Heidelberg — [2]MPI für Kernphysik, Heidelberg — [3]ExtreMe Matter Institute EMMI, GSI, Darmstadt

Systems composed of only few interacting fermions are common in nature. The most prominent examples are atoms and nuclei. However, these systems have limited tunability. In contrast microscopic quantum systems consisting of ultracold atoms can provide tunable artificial atoms if they can be prepared in well defined quantum states. To prepare such systems we load a micrometer-sized trap from a shallow optical dipole trap containing a two-component degenerate Fermi gas. To control the number of atoms in the microtrap we spill the excess atoms from the upper levels of the microtrap potential by applying a magnetic field gradient. Using this technique, we have prepared ground state samples of one to ten atoms with fidelities of $\sim 90\%$. Due to the tunability of the interaction strength our system is suited for quantum simulation with fully controlled few-body systems.

Q 17.3 Tue 11:00 BAR Schön

Local observation of density and fluctuations in a trapped Fermi gas — •David Stadler[1], Torben Müller[1], Bruno Zimmermann[1], Jakob Meineke[1], Jean-Philippe Brantut[1], Henning Moritz[2], and Tilman Esslinger[1] — [1]Institut für Quantenelektronik, ETH Zürich, Schweiz — [2]Institut für Laser-Physik, Universität Hamburg, Deutschland

We present in-situ observations of density and density fluctuations in a two-component Fermi gas of Lithium atoms.

These observations are performed in an apparatus, which features two microscope objectives, allowing high-resolution (about 1 micrometer) in-situ optical detection of the cloud. By measuring the number of atoms in small regions of the cloud on many realisations of the experiment, we locally measure the mean and the variance of the atomic density. For a non-degenerate, weakly interacting gas, we observe density fluctuations proportional to the mean cloud density (atomic shot-noise), in agreement with classical statistics. In a degenerate, weakly interacting fermi gas, we observe a strong reduction of density fluctuations compared to the classical limit. This represents a direct manifestation of Fermi-Dirac statistics, complementary to the Hanbury-Brown and Twiss observations performed with cold atoms after time-of-flight.

In addition we present an interferometric detection scheme that allows to extend fluctuation measurements to the magnetic properties of a two-component Fermi gas.

Q 17.4 Tue 11:15 BAR Schön

Impurities in a 2D Fermi Gas — •Sascha Zöllner[1], Georg M. Bruun[2], and Christopher J. Pethick[1] — [1]Niels Bohr Institute, Copenhagen, Denmark — [2]Aarhus University, Aarhus, Denmark

We study an impurity atom in a two-dimensional (2D) Fermi gas using variational wave functions for (i) an impurity dressed by particle-hole excitations (a so-called polaron) and (ii) a dimer consisting of the impurity and a majority atom. In contrast to 3D, where similar calculations predict a sharp transition to a dimer state with increasing interspecies attraction, the 2D polaron ansatz always gives a lower energy. However, the exact solution for a heavy impurity reveals that both a two-body bound state and distortions of the Fermi sea are crucial. This reflects the importance of particle-hole pairs in lower dimensions and makes simple variational calculations unreliable. Moreover, we show that the energy of an impurity gives important information about its dressing cloud, and what can be learned about the more general case of many (fermionic or bosonic) impurities.

Q 17.5 Tue 11:30 BAR Schön

The density profile of interacting Fermions in a one-dimensional optical trap — Stefan Söffing and •Sebastian Eggert — Fachbereich Physik und Research Center OPTIMAS, Univ. Kaiserslautern, Germany

The density distribution of the Hubbard model in a one-dimensional external harmonic potential is investigated in order to study the effect of the confining trap. The broadening of the Fermion cloud with increasing interaction is analyzed in detailed, which can be described by a surprisingly simple scaling form. Strong superimposed "Friedel" oscillations are always present despite the absence of any hard wall boundaries. The wavelength of the dominant oscillation changes with interaction, which indicates the crossover to a spin-incoherent regime. We present an analytical formula, which describes the behavior of the oscillations very well for all interactions strengths and in return gives some insight for the use of bosonization in a trapping potential.

Q 17.6 Tue 11:45 BAR Schön

Double-degenerate Bose-Fermi mixture of strontium — •Simon Stellmer[1,2], Meng Khoon Tey[1], Mark Parigger[1,2], Rudolf Grimm[1,2], and Florian Schreck[1] — [1]Institut für Quantenoptik und Quanteninformation, 6020 Innsbruck, Austria — [2]Institut für Experimentalphysik und Zentrum für Quantenphysik, Universität Innsbruck, 6020 Innsbruck, Austria

We report on the achievement of a double-degenerate Bose-Fermi mixture of strontium. A sample of fermionic ^{87}Sr atoms is spin-polarized and sympathetically cooled by interisotope collisions with the bosonic isotope ^{84}Sr. At the end of evaporation, 2×10^4 ^{87}Sr atoms at a degeneracy of $T/T_F = 0.30(5)$ co-exist with a BEC of ^{84}Sr. Fermions with two valence electrons have a rich electronic structure, which comprises metastable states, narrow intercombination lines, and a nuclear spin that can be as large as 9/2 in ^{87}Sr. These properties are at the heart of recent proposals for quantum simulation, especially the study of $SU(N)$ magnetism. Loading the fermions into a lattice is the next step towards the realization of such systems. Furthermore, we report on BEC of ^{86}Sr with an unusually large scattering length of $\sim 800\, a_0$.

Q 17.7 Tue 12:00 BAR Schön

Radio-Frequency Association of Efimov Trimers — •Thomas Lompe[1,2,3], Timo Ottenstein[1,2,3], Friedhelm Serwane[1,2,3], Andre Wenz[1,2], Gerhard Zürn[1,2] und Selim Jochim[1,2,3] — [1]Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Germany — [2]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany — [3]ExtreMe Matter Institute EMMI, GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany

Since the first signatures of Efimov states were found in the rate of inelastic collisions of an ultracold atomic gas, such systems have been used to study Efimov physics with great success. However, until recently experiments have been limited to observations of the crossings of Efimov states with the continuum. In this talk we report on the first direct observation of an Efimov state with RF association spectroscopy. We have measured the binding energy of this Efimov state as a function of interaction strength and found good agreement with theoretical predictions. This work opens the door for both precision studies and coherent manipulation of Efimov trimers.

Q 17.8 Tue 12:15 BAR Schön

Loschmidt Echo of a Trapped Fermi Gas — •Thomas Fogarty[1], Thomas Busch[1], and John Goold[2] — [1]Physics Department, University College Cork, Ireland — [2]Department of Atomic & Laser Physics, Clarendon Laboratory, University of Oxford

The process of decoherence in quantum systems is an substantial area of study with implications for quantum computing. This importance has led to a rich area of study that encompasses decoherence in spin environments. It has been shown that the coherence of a qubit coupled to an environment directly influences the entanglement of the qubit with the environment and can result in quantum phase transitions. Here we study the decoherence of a one dimensional Fermi gas in a harmonic trap undergoing a sudden perturbation. The decoherence is studied by calculating the Loschmidt echo which is the overlap of the initial state evolving according to two different hamiltonians, one with and one without the perturbation. We show that revivals of the coherence occur based on the trap frequency of the harmonic oscillator and that the decoherence is directly influenced by the Anderson orthogonality catastrophe. Anderson proved that the overlap of two many body ground states tends to zero as the number of fermions are increased and here we provide detailed analysis of the catastrophe and derive a perturbative scheme which holds for a small perturbation.

Q 17.9 Tue 12:30 BAR Schön

Far-From-Equilibrium Dynamics of Ultracold Fermi Gases — •Matthias Kronenwett[1,2], Sebastian Bock[1,2], and Thomas Gasenzer[1,2] — [1]Institut für theoretische Physik, Philosophenweg 16, 69120 Heidelberg — [2]ExtreMe Matter Institute EMMI, GSI Helmholtzzentrum für Schwerionenforschung GmbH, Planckstr. 1, 64291 Darmstadt

Equilibration of an isolated Fermi gas in one spatial dimension after an interaction quench is studied. Evaluating Kadanoff-Baym dynamic equations for correlation functions obtained from the two-particle-irreducible effective action in nonperturbative approximation, the gas is seen to evolve to states characterized by thermal as well as nonthermal momentum distributions, depending on the assumed initial conditions. At sufficiently low total energies a violation of the fluctuation-dissipation relation in the tail of the Fermi-Dirac distribution indicates equilibration to a nonthermal state.