Q 46: Quantum Gases: Fermions I

Time: Thursday 11:00–13:00 Location: P 204

Group Report Q 46.1 Thu 11:00 P 204

Observation of antiferromagnetic long-range order in the Hubbard model with ultracold atoms — •Daniel Greif, Anton Mazurenko, Christie S. Chiu, Geoffrey Ji, Maxwell F. Parsons, Fabian Grusdt, Richard Schmidt, Marton Kanasz-Nagy, Eugene Demler, and Markus Greiner — Department of Physics, Harvard University, Cambridge, Massachusetts 02138, USA

Quantum gas microscopy of ultracold fermionic atoms in optical lattices opens new perspectives for addressing long-standing open questions on strongly correlated low-temperature phases in the Hubbard model. For example, the precise character of the phases emerging when doping an antiferromagnet away from half-filling is still not well understood. We report on the observation of antiferromagnetic long-range order in a repulsively interacting Fermi gas of Li-6 atoms on a 2D square lattice of approximately 80 sites at temperatures $T/t = 0.25$. Using single-site resolution, the ordered state is directly detected from a peak in the spin structure factor and a diverging correlation length of the spin correlation function. In the long-range ordered state we measure staggered magnetizations exceeding 50% of the ground-state value. When doping away from half-filling into a numerically intractable regime, we find that long-range order extends to doping concentrations of about 15%. Our results pave the way for directly addressing open questions on pseudo-gap states and high-temperature superconductivity.

Q 46.2 Thu 11:30 P 204

Floquet engineering of a two-body system in an array of double wells — •Michael Messer, Rémi Desbuquois, Frederik Görg, Kilian Sandholzer, Gregor Jotzu, and Tilman Esslinger — Institute for Quantum Electronics, ETH Zurich, Switzerland

Periodically driving a system of ultracold fermions in an optical lattice allows for implementing a large variety of effective Hamiltonians through Floquet engineering. A crucial question is whether this method can be extended to interacting systems. By driving a two-body system on an array of double wells we measure the double occupancy and the spin-spin correlator as a function of shaking frequency and strength. We analyze the importance of micromotion to describe the exact time evolution of the system and compare it to numerical theory. In addition we investigate the experimental timescales needed to adiabatically connect the emerging states of the driven system to states of the initial Hamiltonian. We find an adiabatic regime in which the double occupancy and spin-spin correlations of the Floquet Hamiltonian can be exactly compared to theory. This hierarchy of different energy scales allows us to implement driven systems with strong interactions.

Q 46.3 Thu 11:45 P 204

Floquet engineering of unconventional Hubbard terms in an interacting fermionic system — •Frederik Görg, Michael Messer, Gregor Jotzu, Kilian Sandholzer, Rémi Desbuquois, and Tilman Esslinger — Institute for Quantum Electronics, ETH Zurich, 8093 Zurich, Switzerland

Periodically modulated systems have recently attracted much interest both from a theoretical and experimental perspective, since they can be used to create novel effective Hamiltonians which feature terms that are not accessible in static systems. For cold atoms in optical lattices, this approach has, among others, been used to dynamically control the tunnelling amplitude, create artificial gauge fields and spin-dependent lattices. Recently, we experimentally demonstrated how Floquet engineering can be used to create unconventional Hubbard terms for interacting Fermions in an optical lattice. By modulating the lattice position at a frequency close to the interaction energy of a two-body system, we can change both the sign and magnitude of the magnetic exchange energy. For an inhomogeneous cold atom system in a trap, this method can be used to independently tune the exchange coupling and the single particle tunnelling, therefore providing a possible entropy redistribution scheme. An open question in this context is if experimental heating timescales are favourable enough to study this driven interacting many-body system.

Q 46.4 Thu 12:00 P 204

Vanishing order parameter oscillations of the Higgs mode in a cigar-shaped ultracold Fermi gas — •Simon Hannibal[1], Peter Kettmann[1], Mihail Croitoru[2], Vollrath Martin Axt[3], and Tilmann Kuhn[1] — [1]Institute of Solid State Theory, University of Münster — [2]Condensed Matter Theory, University of Antwerp — [3]Theoretical Physics III, University of Bayreuth

Ultracold Fermi gases in optical traps provide a unique system to study the many body physics of systems composed of fermionic constituents. Both, the BEC and the BCS superfluid state are observed. Furthermore, the transition between these states is well controllable by means of a Feshbach resonance, which allows to tune the scattering length over a wide range from negative to positive values.

We employ an inhomogeneous BCS mean field theory and calculate the dynamics of the BCS gap of a confined ultracold Fermi gas after an interaction quench. Due to the spontaneously broken U(1) symmetry in the superfluid phase two fundamental modes of the BCS gap evolve, i.e., the amplitude (Higgs) and phase (Goldstone) mode. Here, we focus on the Higgs mode on the BCS side of the BCS-BEC crossover.

We investigate the dynamics after a large quench from strong to weak interactions. For large aspect ratios we find a dynamical vanishing of the order parameter similar to what has been predicted in the case of a homogeneous system. However, for smaller aspect ratios transverse trap modes are excited preventing a complete vanishing of the order parameter.

Q 46.5 Thu 12:15 P 204

Pair formation in a fermionic system — •Thomas Paintner[1], Daniel Hoffmann[1], Wladimir Schoch[1], Wolfgang Limmer[1], Cheng Chin[2], and Johannes Hecker Denschlag[1] — [1]Universität Ulm, Institut für Quantenmaterie, Deutschland — [2]University of Chicago, James Franck Institute, USA

We investigate the pair formation in a fermionic system at the BEC-BCS crossover. For a given temperature and interaction strength a thermodynamic equilibrium forms between atoms and pairs.

We use a 50-50 mixture of the two lowest ^{6}Li Zeemann 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 fraction of paired atoms at different temperatures and interaction strengths using optical spectroscopy. The results are compared with a classical calculation [1]. Since the pair formation sets in for higher temperatures than the critical temperature T_c for superfluid transition our results provide a deeper insight into pairing and the pseudo-gap in fermionic systems.

[1] C. Chin et al., *Physical Review A* 69, 033612 (2004).

Q 46.6 Thu 12:30 P 204

Phase Separation in a Bose-Fermi Mixture of ^{41}K and ^{6}Li — •Rianne S. Lous[1,2], Bo Huang[1], Isabella Fritsche[1,2], Fabian Lehmann[1,2], Michael Jag[1,2], Emil Kirilov[1,2], and Rudolf Grimm[1,2] — [1]IQOQI, Austrian Academy of Sciences, Innsbruck, Austria — [2]Institute for Experimental Physics, University of Innsbruck, Innsbruck, Austria

We report on the observation of phase separation between a ^{41}K Bose-Einstein condensate (BEC) and a ^{6}Li Fermi sea with strong repulsive interspecies interactions. After evaporation in an optical dipole trap, we obtain 10^4 ^{41}K atoms with a 55 % BEC fraction and a Fermi sea of 10^5 ^{6}Li atoms with a $T/T_F < 0.07$. We explore this double-degenerate mixture by tuning the heternonuclear interaction with the use of a Feshbach resonance at 335.8 G. We observe the phase separation by measuring the breathing-mode frequency of the bosons and their lifetimes for varying interaction strength. We see an increase in frequency when interactions become strongly repulsive and a decrease in loss rate. To understand our loss rate results, we calculate the spatial overlap between the two components with a mean-field model beyond local density approximation (LDA) and attribute the losses to the three-body recombination. We also calculate the breathing-mode frequency on a LDA level. Both theoretical models fit nicely to our experimental results. This work is supported by the Austrian Science Fund FWF within SFB FoQuS.

Q 46.7 Thu 12:45 P 204

High-momentum tails as magnetic-structure probes for strongly correlated SU(N) fermionic mixtures in one-

dimensional traps — Jean Decamp[1], •Johannes Jünemann[2,3], Mathias Albert[1], Matteo Rizzi[2], Anna Minguzzi[4], and Patrizia Vignolo[1] — [1]Université Côte d'Azur, CNRS, INLN, France — [2]Johannes Gutenberg-Universität, Mainz, Germany — [3]MAINZ-Graduate School Materials Science in Mainz, Mainz, Germany — [4]Université Grenoble-Alpes, CNRS, LPMMC, Grenoble, France

We consider the experimentally feasible setup of a repulsively interacting multi-component Fermi gas under harmonic confinement exhibiting a SU(N) symmetry. Here, we concentrate on the density- and momentum-distributions of the particles, and in particular on their Tan contact (weight of a k^{-4}-scaling in the tails of the mom.-distribution).

For infinite interactions, we show a direct correspondence between the value of the Tan contact for each of the N components of the gas and the Young tableaux for the S_N permutation symmetry group. A mapping to an effective spin-model allows us to identify the corresponding magnetic structure. Measurement of the Tan contact therefore opens an alternative route to the experimental determination of magnetic configurations in cold atomic gases, employing only standard (spin-resolved) time-of-flight techniques.

For finite interactions, we present an analytical scaling prediction for the Tan contact. We confirm the prediction through MPS/DMRG-calculations and show their qualitative agreement with recent experiments.