Exploring Quantum Antiferromagnets with single-site resolution

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Strongly correlated electron systems such as high-temperature superconductors, pseudo-gap states or spin liquids are a cornerstone of modern condensed matter research. A promising approach to studying solid-state systems is to build an experimentally tunable quantum system, which qualitatively describes these materials and is thought to capture the essential physical mechanisms. Ultracold fermionic quantum gases in optical lattices provide a clean and tunable implementation of the Hubbard model. At the same time, optical microscopy in these systems gives access to single-site observables and correlation functions, and provides dynamic control of the potential landscape at the single-site level. However, so far ultracold atom experiments have not been able to reach the low-temperature regime of the doped Hubbard model, where a number of complex many-body systems are expected.

In this talk I will report on the observation of antiferromagnetic long-range order in a repulsively interacting Fermi gas of Li-6 atoms on a 2D square lattice. The ordered state is directly detected from a peak in the spin structure factor and a diverging correlation length of the spin correlation function. When doping away from half-filling into a numerically intractable regime, we find that long-range order extends to doping concentrations of about 15%. I will also show how we can use entropy redistribution to create ultra-low entropy states of fermionic atoms. Furthermore, I will discuss recent efforts on detecting spinon-hole string states when hole-doping the Hubbard model.