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Towards quantum magnetism with ultracold atoms

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Spin ordering or quantum magnetism can be realized with both ultracold bosons and fermions. We have studied ultracold fermions with strong repulsive interactions. When a Feshbach resonance is approached, a two-component Fermi gas shows non- monotonic behavior of lifetime, kinetic energy and size. This provides strong evidence for a phase-transition to a ferromagnetic state, or a state with strong ferromagnetic fluctuations. A two component Mott insulator of bosons in an optical lattice should show spin ordering at sub-nanokelvin temperatures. As a step towards this goal, we have developed a novel method of thermometry, spin gradient thermometry. In this method, the two states are pulled towards opposite sides of the trapped sample by a magnetic field gradient. The width of the domain wall is proportional to the temperature. Using this method, we optimized the temperature in a Mott insulator to 1 nK, the lowest measured temperature in a lattice, indicating that the system has reached the quantum regime, where insulating shells are separated by superfluid layers.