MAR14-2013-020402

Abstract for an Invited Paper
for the MAR14 Meeting of
the American Physical Society

**Spin-Orbit Coupled Fermi Gases and Solitons in Fermionic Superfluids**

LAWRENCE CHEUK, MIT

The coupling of the spin of electrons to their motional state lies at the heart of topological phases of matter. We have created and detected spin-orbit coupling in an atomic Fermi gas via spin-injection spectroscopy, which characterizes the energy-momentum dispersion and spin composition of the quantum states. For energies within the spin-orbit gap, the system acts as a spin diode. To fully inhibit transport, we open an additional spin gap with radio-frequency coupling, thereby creating a spin-orbit coupled lattice whose spinful band structure we probe. In the presence of s-wave interactions, spin-orbit coupled fermion systems should display induced p-wave pairing and consequently topological superfluidity. Such systems can be described by a relativistic Dirac theory with a mass term that can be made to vary spatially. Topologically protected edge states are expected to occur whenever the mass term changes sign. A system that similarly supports edges states is the strongly interacting atomic Fermi gas near a Feshbach resonance. Topological excitations, such as vortices - line defects - or solitons - planar defects - have been described theoretically for decades in many different physical contexts. In superconductivity and superfluidity they represent a defect in the order parameter and give rise to localized bound states. We have created and directly observed solitons in a fermionic superfluid. These are found to be stable for many seconds, allowing us to track their oscillatory motion in the trapped superfluid. Their trapping period increases dramatically as the interactions are tuned from the BEC to the BCS regime. At the Feshbach resonance, their period is an order of magnitude larger than expected from mean-field Bogoliubov-de Gennes theory, signaling strong effects of quantum fluctuations and possible filling of Andreev bound states. Our work paves the way towards the experimental study and control of fermionic edge states in ultracold gases.