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Strongly Interacting Fermi Gases of Atoms and Molecules

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In recent years, ultracold gases of fermionic atoms have become a new platform for the realization of paradigmatic forms of strongly interacting matter. Feshbach scattering resonances allow to tune the interactions between atoms at will and to realize the crossover from Bose-Einstein condensation of molecules to Bardeen-Cooper-Schrieffer superfluidity of long-range Cooper pairs. On resonance, we encounter the unitary Fermi gas, with universal properties that closely correspond to those of dilute neutron matter in the crust of neutron stars, and to nuclear matter. I will present our recent study of solitonic excitations in this novel superfluid, the creation of planar solitons and the subsequent cascade into vortex rings and solitonic vortices. In the presence of spin imbalance, solitons are predicted stabilize, a hallmark of the Larkin-Ovchinnikov phase. To induce strong interactions one may also quench the atoms' kinetic energy in optical lattices. Of great interest here is the realization of the Fermi-Hubbard model, believed to hold the key to understanding high-temperature superconductors. We recently realized imaging of fermionic atoms with single-site resolution in optical lattices, an important step towards the direct observation of magnetic order. Finally, strong, long-range dipolar interactions can lead to novel states of fermionic matter such as topological superfluids. We have created chemically stable, strongly dipolar fermionic molecules, opening up prospects for observing a strongly interacting degenerate Fermi gas with dominant dipolar interactions.