From N+1 to N+N: Exploring repulsive many-body states with ultracold spin mixtures

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Repulsive interactions lie at the heart of a variety of strong-correlation phenomena in condensed matter. In particular, strong repulsion between itinerant fermions fosters the emergence of ferromagnetism. We investigate many-body repulsive states within the minimal framework offered by ultracold Fermi gases with tunable short-range repulsive interactions and tunable spin polarization.

I will first report on a recent experimental study of repulsive Fermi polarons in the universal case of a mass-balanced mixture in the vicinity of a broad Feshbach resonance [1]. Understanding the properties of an impurity immersed in a degenerate quantum medium represents a fundamental problem in many-body physics. In particular, the Fermi polaron problem is centrally important for the description and the stability of correlated phases arising from repulsive interactions. We report on the observation of well-defined repulsive quasiparticles up to unitarity-limited interactions [1]. We characterize the many-body system via radio-frequency spectroscopy, extracting the elastic and inelastic properties of repulsive Fermi polarons: the energy E_+, the effective mass m^*, the residue Z and the decay rate Γ. Above a critical interaction, we find E_+ to exceed the Fermi energy of the bath, while m^* diverges and even turns negative, revealing an instability of the repulsive Fermi liquid.

In a different experiment, we probe the stability of a ferromagnetic domain wall by observing the collective spin dynamics of an initially fully magnetized spin mixture in a harmonic trap [2]. We find the spin susceptibility of the gas to significantly increase with the repulsion strength, while the two spin domains remain temporarily immiscible for critical interactions and temperatures, suggesting the presence of a Stoner-like ferromagnetic instability. Relatedly, in ongoing experiments, we investigate the evolution of the interaction energy and of the spin correlations in a balanced spin mixture after a rapid radio-frequency quench to the strongly repulsive regime.

[1] F. Scazza et al., Phys. Rev. Lett. 118, 083602 (2017)

[2] G. Valtolina et al., Nature Physics (Advance Online Publication, 24 April 2017)