A Bose-Fermi Superfluid Mixture

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In recent years, ultra-cold atoms have established a very fruitful connection with condensed matter physics, nuclear physics, and astrophysics. Thanks to the tunability of the atomic interactions offered by magnetic Feshbach resonances, Bose and Fermi gases can be brought to the strongly correlated regime and simulate outstanding problems in quantum many-body physics.

One of them deals with the possibility to produce a mixture of Bose and Fermi superfluids, a long-standing challenge in Helium 4 -Helium 3 mixtures. Using lithium 7 and lithium 6 isotopes, we have produced a quantum gas mixture where both the Bose species and the Fermi species are superfluid [1]. We probe the collective dynamics of this system by exciting center-of-mass oscillations that exhibit extremely low damping below a certain critical velocity. Using high precision spectroscopy of these low-lying modes we observe coherent energy exchange and measure the coupling between the two superfluids. Our observations can be captured theoretically using a sum-rule approach that we interpret in terms of two coupled oscillators. We have also measured the critical velocity for superfluid counterflow in the Bose-Fermi mixture as a function of temperature and interaction strength between fermions. In in the phonon-dominated regime and for weak Bose-Fermi coupling, the critical velocity is predicted to be given by the sum of the sound velocities in the Bose gas and in the Fermi gas [2]. In some parameter range of the BEC-BCS crossover, our observations are consistent with this prediction

[1] I. Ferrier-Barbut, M. Delehaye, S. Laurent, A.T. Grier, M. Pierce, B.S. Rem, F. Chevy, C. Salomon, A Mixture of Bose and Fermi Superfluids , Science **345**, 1035 (2014)

[2] Y. Castin, I. Ferrier-Barbut, and C. Salomon, the Landau critical velocity for a particle in a Fermi superfluid, Comptes-rendus Physique **16**, 241, (2015)