Abstract for an Invited Paper
for the MAR09 Meeting of
The American Physical Society

Observation of Spin-Polarons in a strongly interacting Fermi liquid[1]

MARTIN ZWIERLEIN, Massachusetts Institute of Technology

We have observed spin-polarons in a highly imbalanced mixture of fermionic atoms using tomographic RF spectroscopy. Feshbach resonances allow to freely tune the interactions between the two spin states involved. A single spin down atom immersed in a Fermi sea of spin up atoms can do one of two things: For strong attraction, it can form a molecule with exactly one spin up partner, but for weaker interaction it will spread its attraction and surround itself with a collection of majority atoms. This spin down atom “dressed” with a spin up cloud constitutes the spin-polaron. We have observed a striking spectroscopic signature of this quasi-particle for various interaction strengths, a narrow peak in the spin down spectrum that emerges above a broad background. The narrow width signals a long lifetime of the spin-polaron, much longer than the collision rate with spin up atoms, as it must be for a proper quasi-particle. The peak position allows to directly measure the polaron energy. The broad pedestal at high energies reveals physics at short distances and is thus “molecule-like”: It is exactly matched by the spin up spectra. The comparison with the area under the polaron peak allows to directly obtain the quasi-particle weight Z. We observe a smooth transition from polarons to molecules. At a critical interaction strength of $1/k_F a = 0.7$, the polaron peak vanishes and spin up and spin down spectra exactly match, signalling the formation of molecules. This is the same critical interaction strength found earlier to separate a normal Fermi mixture from a superfluid molecular Bose-Einstein condensate. The spin-polarons determine the low-temperature phase diagram of imbalanced Fermi mixtures. In principle, polarons can interact with each other and should, at low enough temperatures, form a superfluid of p-wave pairs. We will present a first indication for interactions between polarons.

[1]This work was supported by the NSF, through a MURI program and the Alfred P. Sloan Foundation.