Observation of Fermi Polarons in a tunable Fermi liquid of Ultracold Atoms

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We have observed Fermi polarons, dressed spin down impurities in a spin up Fermi sea of ultracold atoms [1]. Feshbach resonances allow to freely tune the interactions between the two spin states involved. For weak attraction the impurity propagates freely in the spin up medium, merely experiencing the familiar mean field energy shift (see Fig. 1a). However, as the attractive interaction grows, the impurity can undergo momentum changing collisions with environment atoms, and thus starts to attract its surroundings (Fig. 1b). The impurity ``dressed" with the localized cloud of scattered fermions constitutes the Fermi polaron.

We have observed a striking spectroscopic signature of this quasiparticle for various interaction strengths, a narrow peak in the spin down spectrum that emerges above a broad background. The peak position and its weight allow us to determine the polaron energy and the quasiparticle residue. The energy is found to be largely insensitive to the impurity density, thus polarons are weakly interacting. Hence, the strongly interacting spin mixture can be described as an essentially non-interacting Fermi gas of renormalized quasi-particles.

The polaronic state is stable until the attraction is strong enough to bind the impurity to a single environment atom, thus forming a molecule (Fig. 1c). We observe this transition from polaronic to molecular binding at a critical interaction strength. Here, the imbalanced Fermi liquid undergoes a phase transition into a Bose liquid coexisting with a Fermi sea.

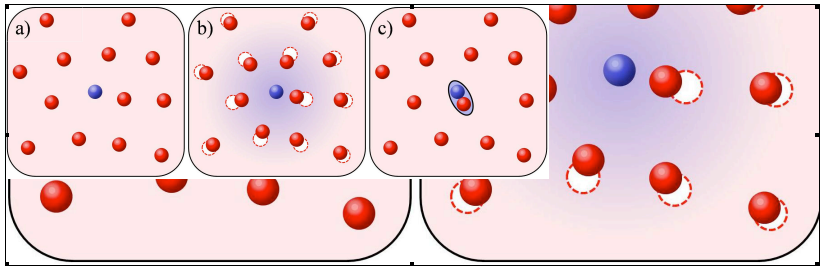

Fig. 1: From polarons to molecules. a) For weak attraction, an impurity (blue) experiences the mean field of the medium (red). b) For stronger attraction, the impurity surrounds itself with a localized cloud of environment atoms, forming a polaron. c) For strong attraction, molecules form despite Pauli blocking from the environment.

[1] André Schirotzek, Cheng-Hsun Wu, Ariel Sommer, and Martin W. Zwierlein, submitted to PRL, preprint cond-mat arXiv:0902.3021 (2009)