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Smooth Polaron-Molecule Transition in a Degenerate Fermi Gas with Multiple Impurities (ONLINE presentation)

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Understanding the behavior of a spin impurity strongly-interacting with a Fermi sea is a long-standing challenge in many-body physics. For short-range interactions and zero temperature, most theories predict a first-order phase transition between a polaronic ground state and a molecular one. We study this question with an ultracold Fermi gas [1]. Experimentally, the impurity problem poses a challenge: the signals from the minority atoms are inherently very weak. To overcome this difficulty, we have developed novel sensitive rf and Raman spectroscopic techniques, which are based on fluorescence detection. Raman spectroscopy allows us to isolate the quasiparticle contribution and extract the polaron energy [2-3]. As the interaction strength is increased, we observe a continuous variation of all observables, in particular a smooth reduction of the quasiparticle weight as it goes to zero beyond the transition point. Our observations are explained by a theoretical model where polaron and molecule quasiparticle states are thermally occupied according to their quantum statistics. At the experimental conditions, polaron states are hence populated even at interactions where the molecule is the ground state and vice versa. The emerging physical picture is thus that of a smooth transition between polarons and molecules and a coexistence of both in the region around the expected transition. A smooth transition happens even at zero temperature, while a true first-order transition occurs only in the single impurity limit.

[1] G. Ness et. al., Phys. Rev. X 10, 041019 (2020)

[2] C. Shkedrov, Y. Florshaim, G. Ness, A. Gandman, and Y. Sagi, PRL 121, 093402 (2018).

[3] C. Shkedrov, G. Ness, Y. Florshaim, and Y. Sagi, PRA 101, 013609 (2020).

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