Impurities strongly interacting with Bose gases

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Emergent polaronic quasiparticle descriptions underpin our understanding of conventional quantum many-body systems, a paradigm first introduced by Landau and Pekar. Here, I will showcase a series of recent experiments on mobile impurities in homogeneous ^{39}K Bose gases. We study the impurities both spectroscopically and interferometrically, and explore a wide range of impurity-bath interactions as well as bath densities and temperatures.

We first show that the behavior of impurities in weakly interacting degenerate baths is remarkably universal, controlled only by the bath density and a single dimensionless interaction parameter. For attractive interactions, the impurity spectrum features a single branch, which away from the resonance corresponds to a well-defined attractive polaron; near the resonance we observe dramatic broadening of this branch, suggesting a breakdown of the quasiparticle picture. Instead, for repulsive interactions, the spectrum features two branches: the attractive branch, that is dominated by excitations with energy close to that of the Feshbach dimer but has a many-body character, and the repulsive polaron branch.

We then study the fate of the quasiparticle branches as we heat the system and cross the BEC transition temperature of the bath. Counterintuitively, we find that for strong impurity-bath interactions the spectra narrow with increasing temperature, while the impurity energy shift is suppressed. Near the critical temperature for condensation, many-body effects still play an important role, and only for a nondegenerate bath, the system approaches the classical Boltzmann-gas behavior. We compare our results to bosonic functional determinant approach (FDA) calculations for an ideal Bose polaron, finding excellent qualitative agreement.