Observation of attractive and repulsive polaron in a Bose-Einstein condensate

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Abstract

The problem of an impurity particle moving through a bosonic medium plays a fundamental role in physics, ranging from organic electronics to the Standard Model. However, despite intense theoretical investigation, the canonical scenario of a mobile impurity immersed in a Bose-Einstein condensate (BEC) has not yet been realized.

Here, we use radio frequency spectroscopy of ultracold bosonic 39K atoms to experimentally demonstrate the existence of a well-defined quasiparticle state of an impurity interacting with a BEC. We measure the energy of the impurity both for attractive and repulsive interactions, and find excellent agreement with theories that incorporate three-body correlations. The spectral response consists of a well-defined quasiparticle peak at weak coupling, while for increasing interaction strength, the spectrum is strongly broadened and becomes dominated by the many-body continuum of excited states.

Crucially, no significant effects of three-body decay are observed. Our results open up exciting prospects for studying mobile impurities in a bosonic environment and strongly interacting Bose systems in general.

N. B. Jørgensen et al., arXiv:1604.07983

Experimental procedure

Sympathetic Cooling of 39K with 87Rb

State Preparation of 39K in Optical Dipole Trap

Feshbach Resonance Structure

Spectroscopy scheme

Quantitative data evaluation

Average Energy of Impurity State

Width of the Spectrum

Polaron fraction

Outlook

• Canonical study of strongly interacting Bose systems
• Probe the coherence properties of the polaron by measuring the quasiparticle residue
• Investigate the characteristics of polarons as the BEC melts
• Explore the properties of mixtures with unitary interactions
• Observe the effect of Efimov physics in a BEC

Spectral response of an impurity in a BEC

White dots: independently measured molecular binding energy
Solid lines: calculated signal using a truncated basis method including three-body correlations
Dashed lines: calculated signal excluding three-body correlations