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Bose polarons in a homogeneous Bose-Einstein Condensate

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We experimentally study the paradigmatic many-body problem of mobile impurities interacting with a homogeneous Bose-Einstein condensate (BEC). We use a combination of injection spectroscopy and many-body interferometry to access the injection spectrum (frequency domain) and the impurity-coherence function (time domain). Our experiments start with a spin-polarized BEC confined in an optical box trap and we use rf pulses to transfer a fraction of atoms into the target spin state. We map out the polaron energy and spectral response from weak to strong impurity-bath interactions (characterized by the interstate scattering length a) and study the effects of varying condensate properties, changing both the condensate (intrastate) interactions (a_{b}) and density n. While we observe that most of the physics is universally set by n and a, we find a clear dependence on a_{b} for the attractive polaron branch. For strong repulsive interactions, we observe two distinct spectral features, corresponding to a repulsive polaron and a many-body state related to the Feshbach dimer, whose energy shifts with density. Curiously, despite the significantly reduced inhomogeneous-density broadening in our system, we observe that even at weak interactions the spectra have significant widths proportional to their shifts. Finally, our many-body interferometry provides new insights into the formation dynamics of the Bose polaron.

Primary author: EIGEN, Christoph (University of Cambridge)

Co-authors: Mr ETRYCH, Jiri (University of Cambridge); Mr CAO, Alec (University of Colorado); Mr MARITROSYAN, Gevorg (University of Cambridge); Dr HO, Christopher (University of Cambridge); Prof. HADZIBABIC, Zoran (University of Cambridge)

Presenter: EIGEN, Christoph (University of Cambridge)

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