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A Rydberg Impurity in a Bose-Einstein Condensate

Rydberg atoms in dense clouds contain more than one background gas atom that interacts with the Rydberg electron. The low-energy interaction between the Rydberg electron and the background gas perturber leads to energies much larger than typical chemical potentials of a Bose-Einstein condensate (BEC) over the spatial extent of the Rydberg wavefunction, which is much larger than typical healing lengths. The Rydberg atom impurity can therefore have significant non-equilibrium effects on the many-body state of the background gas. We study this system using spectroscopy of a single Rydberg atom in a BEC. Collisions between the Rydberg electron and background neutral atoms, lead to a mean field density shift for Rydberg atoms, which is of the order 10MHz/ 1014 cm-3 for 87Rb triplet s-wave scattering. We exploit this density shift to characterize the mean density of our quantum gas and to monitor the dynamics of the BEC phase transition, by analyzing the center of gravity of Rydberg spectra. We also observe an n-dependent line broadening due to the p-wave shape resonance relevant for electron-neutral atom scattering of 23meV, near the Rydberg ionic core, for 87Rb. We simulate the spectroscopic line shapes using the full potentials of the s- and p-wave electron-neutral scattering. We discuss the implications of these results on experiments on charged impurities in quantum gases as well as wavefunction imaging based on electron-phonon coupling in a BEC.

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