Observation of resonances with three-body characteristics in ultracold cesium collisions

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We report on the observation of collision resonances in an ultracold optically trapped cesium gas in the presence of a laser field far blue-detuned relative to the Cs D_2 line. Both spin polarized samples consisting of atoms in the $|F = 3, m_F = 3\rangle$ state and mixed samples containing atoms the $|3,3\rangle$ and $|3,2\rangle$ states exhibit such resonances. When an external magnetic field is tuned to certain values in the region where the two-body interaction is modified due to nearby Feshbach resonances, strongly enhanced atom loss from the trap is detected in the presence of the far detuned light. The resonance positions are independent of the intensity, polarization and frequency of the probe beam and the trapping beams. The lineshapes are asymmetric and temperature broadened with an intrinsic linewidth below 10 mG.

We explain the observations as due to resonant coupling to a molecular state whose energy is tuned across that of the scattering state. The probe beam serves to detect population in the molecular state by excitation to a 6S+6P state with strongly repulsive dipole interaction, which leads to dissociation and loss from the trap. We believe that the molecular states consist of three rather than two Cs atoms based on the following observations: 1. a new very accurate calculation of the two-body Cs interaction [1] shows no binary bound states at the positions of some of the radiative resonances. 2. mixed resonances involving both $|3,3\rangle$ and $|3,2\rangle$ states exhibit a ratio of loss rates of 2:1, suggesting that two atoms in $|3,3\rangle$ and one in $|3,2\rangle$ are lost as a unit. 3. loss rates for these mixed resonances are found to be proportional to $n_3^2 n_2$, where n_i is the density of the state $|3,i\rangle$, which further supports the three-body picture.

The fact that these resonances appear in the vicinity of binary Feshbach resonances makes them promising candidates of three-body Efimov states [2]. Efimov states correspond to large three-atom molecules bound by the interaction arising from the exchange of a weakly bound two-body state. They appear when the two-body scattering length exceeds the range of the two-body potential. Efimov states were first predicted for nuclei and for the helium system, but they have never been directly experimentally verified.

[1] C. Chin, V. Vuletić, A. J. Kerman and S. Chu, *(to be submitted to PRL)*; P. J. Leo, C. J. Williams and P. S. Julienne *(to be submitted to PRL)*

[2] V. N. Efimov, *Phys. Lett.* **33B** 563 (1970)