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Universality in Three and Four-Body Efimov States[1]

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Ultracold atomic gases are clean, well-characterized systems, whose versatility for elucidating fundamental behavior extends from condensed matter to nuclear physics. In the past several years, ultracold atomic Bose gases with tunable interactions have established a remarkable prediction in few-body physics made by V. Efimov nearly 30 years. Efimov contended that in a resonantly interacting system, three-body bound states could be formed even in regions where two-body bound states cannot form. Furthermore, he showed that these three-body trimers occur in a repeating sequence where the binding energy of the next trimer in the sequence would be $(22.7)^2$ smaller than the previous one. This prediction was universal, in the sense that the three bodies could be nucleons, quarks, atoms, or molecules, as long as their interactions were strong. We have used a Feshbach resonance in ^{7}Li, a composite boson, to verify the universal prediction of Efimov [1]. The large width of the ^{7}Li Feshbach resonance facilitates precise tuning of the s-wave scattering length a. We previously showed that a could be tuned over a range of at least seven decades, from 0.01 a_o to $10^5 a_o$, where a_o is the Bohr radius [2]. The presence of 3-body bound states is manifested in the rate of inelastic collisions that lead to loss of atoms from a Bose-Einstein condensate. We find features in the rate of three-body inelastic loss that we ascribe to Efimov trimers. In addition, we find features in the four-body decay rate that are due to the presence of four-body Efimov states. A total of 11 features on both sides of the Feshbach resonance are observed. The features on either side of the Feshbach resonance agree well with current theories, but there is disagreement on the relative location of features *across* the resonance. This discrepancy may be due to beyond mean-field effects influening the measured location of the Feshbach resonance.

[1] S. E. Pollack, D. Dries, and R. G. Hulet, *Science* **326**, 1685 (2009).
[2] S.E. Pollack *et al*, Phys. Rev. Lett. **102**, 090402 (2009).

[1]Work done in collaboration with S. Pollack and D. Dries.