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Four-body Efimov effect

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The few-body problem with resonant two-body s-wave interaction (that is with an infinite scattering length) can now be studied experimentally with ultracold atomic gases. In particular, the three-body Efimov phenomenon (Efimov, 1971), consisting in the existence of an infinite number of trimer states with an asymptotically geometric spectrum in the vicinity of a zero energy accumulation point, has now obtained experimental evidence. On the contrary, the four-body Efimov effect has remained elusive, both theoretically and experimentally. Strictly speaking, for same spin state bosons, as pointed out by Amado and Greenwood (1973), it is *a priori* excluded by the existence of the three-body Efimov effect: A tetramer state with an energy arbitrarily close to zero has eventually an energy larger than an Efimov trimer state and may decay into this trimer plus a free atom. We have found a system where a four-body Efimov effect takes place: It is made of three same spin state fermions of mass M interacting only with a lighter particle of mass m. The mass ratio $\alpha = M/m$ is used as a control knob: This system experiences a three-body Efimov effect if and only if $\alpha > \alpha_c(2;1) \simeq 13.607$ (Efimov, 1973; Petrov, 2003). Using a combination of symmetry arguments and a numerical solution of an integral equation,we show that Efimov tetramers exist over the interval of mass ratio $\alpha_c(3;1) < \alpha < \alpha_c(2;1)$, with $\alpha_c(3;1) \simeq 13.384$. The four-body Efimov exponent $|s|$ is also calculated as a function of α over that interval, and the experimental feasibility is discussed.