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Universality of Three Identical Bosons with Large, Negative Effective Range

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A consistent nonrelativistic Effective Field Theory exists for which the scattering length a is large and the effective range r_0 is large in magnitude but negative. Such systems can for example be found in heavy mesons. Observables depend then only on the universal ratio $\xi = 2r_0/a$, with $|r_0|$ fixing the overall distance scale. The two-body scattering amplitude displays two shallow S-wave poles whose position in the complex plane is determined by ξ. We investigate here how the bound-state energies of three identical bosons depend on ξ, for a two-body system with one bound and one virtual state, or with two virtual states. We compare our results with
those of Efimov's discrete scale invariance, as $|r_0| \to 0$ is reduced. In ontradistinction to that case, no three-body interaction is needed to stabilise the system. Instead, a well-defined ground state exists for a limited range of ξ around the "quasi-unitarity point" $\xi = 0$, and excitations for even smaller ranges. Interpreting the Efimov version $r_0 = 0$ as a low-energy theory, one matches the spectra to determine its scale-breaking parameter $\overline{\Lambda}$. We also compare the phase shifts for the
scattering of a boson on the two-boson bound state with that of the equivalent Efimov system.

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