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Universality and scaling in the N-body sector of Efimov physics

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In this talk I will illustrate the universal behavior that we have found inside the window of Efimov physics for systems made of $N \leq 6$ particles [1]. We have solved the Schrödinger equation of the few-body systems using different potentials, and we have changed the potential parameters in such a way to explore a range of two-body scattering length, a, around the unitary limit, $|a| \to \infty$. The ground- (E_N^0) and excited-state (E_N^1) energies have been analyzed by means of a recent-developed method which allows to remove finite-range effects [2]. In this way we show that the calculated ground- and excited-state energies collapse over the same universal curve obtained in the zero-range three-body systems. Universality and scaling are reminiscent of critical phenomena; in that framework, the critical point is mapped onto a fixed point of the Renormalization Group (RG) where the system displays scale-invariant (SI) symmetry. A consequence of SI symmetry is the scaling of the observables: for different materials, in the same class of universality, a selected observable can be represented as a function of the control parameter and, provided that both the observable and the control parameter are scaled by some material-dependent factor, all representations collapse onto a single universal curve. Efimov physics is a more recent example of universality, but in this case the physics is governed by a limit cycle on the RG flow with the emergence of a discrete scale invariance (DSI). The scaling of the few-body energies can be interpreted as follow: few-body systems (at least up to $N = 6$), inside the Efimov window, belong to the same class of universality, which is governed by the limit cycle. These results can be summarized by the following formula

$$E_N^n/E_2 = \tan^2\xi \qquad \kappa_N^n a_B + \Gamma_N^n = \frac{\mathrm{e}^{-\Delta(\xi)/2s_0}}{\cos\xi}\,. \tag{1}$$

where the function $\Delta(\xi)$ is universal and it is determined by the three-body physics, and $s_0 = 1.00624$. The parameter κ_N^n appears as a scale parameter and the shift Γ_n^N is a finite-range scale parameter introduced to take into account finite-range corrections [2].

[1] M. Gattobigio and A. Kievsk, arXiv:1309.1927 (2013).

[2] A. Kievsky and M. Gattobigio, Phys. Rev. A **87**, 052719 (2013).