Testing the universality of three-body interactions near narrow Feshbach resonances

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We study properties of Efimov states and explore their dependence on the strength of the underlying Feshbach resonance. Within a two-channel model for the interatomic interactions, we calculate the energies of the Efimov ground and exited states to test the van der Waals universality expected for strong (broad) Feshbach resonances. By varying the position and strength of the two-body coupling between the channels, we modify the strength/width of the Feshbach resonance, as measured by the s_{res} parameter [1]. Investigating across a range of Feshbach resonance widths, we showcase the appearance of non-universal behavior of the Efimov trimer in the ground and excited states, likely emergent from a repulsive interaction in the atom-dimer channel, which appears for narrow resonances [2].

The interplay between the length-scales describing the short-range, exchange, and the van der Waals interaction across a series of alkali-metal, homonuclear samples is likely an important factor determining the universal behavior of the Efimov spectrum. Thus, we compare the Efimov spectra dependence on the s_{res} parameter for systems with varying strength of the Feshbach resonance across a range of atomic species [3]. Interestingly, we also show how the non-universal behavior changes upon switching the resonance across many closed-channel bound states, which gives insights about the nature of the repulsive interaction and provides a way to measure the influence of the coupling position on the non-universal behavior of the resonance.

Acknowledgments

Financial support from the National Science Centre Poland (Grants No.2016/23/B/ST4/03231 and 2023/49/N/ST2/03439) and the Foundation for Polish Science within the First Team program co-financed by the European Union under the European Regional Development Fund is gratefully acknowledged. The computational part of this research has been partially supported by the PL-Grid Infrastructure. This research was supported in part by the National Science Foundation under Grant No. NSF PHY-1748958 to the Kavli Institute for Theoretical Physics (KITP).

References

[1] C. Chin, R. Grimm, P. S. Julienne, and E. Tiesinga, *Feshbach resonances in ultracold gases*, Rev. Mod. Phys. 82, 1225 (2010).

[2] Y. Yudkin, R. Elbaz, J. P. D'Incao, P. S. Julienne, L. Khaykovich, *The reshape of three-body interactions: Observation of the survival of an Efimov state in the atom-dimer continuum*, Nature Communications 15, 2127 (2024).

[3] Roman Chapurin, X. Xie, M. J. Van de Graaff, J. S. Popowski, J. P. D'Incao, P. S. Julienne, J. Ye, and E. A. Cornell, *Precision Test of the Limits to Universality in Few-Body Physics*, Phys. Rev. Lett. 123, 233402, (2019)