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The Microscopic Link Between Deformation and the Nuclear Force

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Abstract

State-of-the-art *ab initio* nuclear structure calculations highlight the critical importance of emergent symmetries to nuclear dynamics, especially collective phenomena [1]. The near-perfect shape-preserving symmetry described by the symplectic Sp(3,R) group, and the deformation-preserving SU(3) symmetry embedded within, lead to highly-regular patterns in nuclear shapes and their allowed vibrations and rotations [2]. The symmetry-adapted no-core shell model, which reorganizes no-core shell model bases into subspaces which respect these symmetries, reveals that light- to medium-mass nuclei across the chart are dominated by a few highly-deformed configurations spanning a fraction of the model space [3]. I will discuss results that combine this many-body framework with global sensitivity analysis in order to determine which low energy constants (LECs) in chiral effective nucleon-nucleon interactions have the greatest impact on collectivity and deformation [4]. Specifically, we find that the electric quadrupole moments of low-lying ^{6}Li and ^{12}C states are overwhelmingly sensitive to two LECs which both exhibit a strong linear correlation with the quadrupole moments. Further, those LECs have a profound and direct influence over the deformation content of the nucleus, affecting which vibrations of the dominant shape are energetically preferable, while leaving the total probability of this shape largely untouched [5]. This suggests that we have found a vital link between quadrupole deformation in nuclei and the effective fundamental forces between quarks and gluons in the low-energy limit where nucleons and pions dominate the dynamics, bringing us closer to a microscopic understanding of emergent collective behavior informed by elementary particle physics.

References

[1] K. D. Launey, A. Mercenne, and T. Dytrych, *Annu. Rev. Nucl. Part. Sci.* **71**, 253–277 (2021).

[2] T. Dytrych, K. D. Launey, J. P. Draayer, D. Rowe, J. Wood, G. Rosensteel, C. Bahri, D. Langr, and R. B. Baker, *Phys. Rev. Lett.* **124**, 042501 (2020).
[3] A. C. Dreyfuss, K. D. Launey, T. Dytrych, J. P. Draayer, R. B. Baker, C. M. Deibel, and C. Bahri, *Phys. Rev. C* **95**, 044312 (2017).
[4] A. Ekström and G. Hagen, *Phys. Rev. Lett.* **123**, 252501 (2019).
[5] K. S. Becker, K. D. Launey, A. Ekström, T. Dytrych, *Front. Phys.* **11** (2023).