A Microscopic Description of the Elusive Hoyle State

ALISON DREYFUSS, Keene State College, KRISTINA LAUNEY, Louisiana State University, CAIRO BAHRI, University of Notre Dame, TOMAS DYTRYCH, JERRY DRAAYER, Louisiana State University — Using the symplectic $\text{Sp}(3,\mathbb{R})$ symmetry inherent to nuclear dynamics together with a novel many-nucleon interaction, we are able to reproduce low-lying spectral features of $^{12}\text{C}$, including the Hoyle state energy, and to gain a further understanding of the underlying physics. We employ a no-core symplectic model for symmetry-preserving interactions—with $\text{Sp}(3,\mathbb{R})$ the underpinning symmetry—that offers a microscopic description of nuclei in terms of mixed shape deformations and allows for the inclusion of higher-lying configurations currently inaccessible to ab initio shell models. Our interaction is effectively realized by an exponential dependence on the quadrupole-quadrupole two-body interaction. We were able to reproduce the energies of the ground state rotational band, the Hoyle state, and the next excited $0^+$ state, along with the $B(E2 : 2^+_1 \rightarrow 0^+_{\text{stat}})$ transition strength for $^{12}\text{C}$. The success of this work indicates the importance of alpha-cluster structures in the $^{12}\text{C}$ nucleus and the inclusion of hierarchical many-body interactions.

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