**Symmetry-adapted no-core shell model for light nuclei**
**– $^{12}$C and $^{16}$O –**

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Symmetry-adapted, no-core shell-model calculations show that bound states of light nuclei are dominated by low-spin and high-deformation configurations. This result is independent of whether the system Hamiltonian is phenomenological in nature or derived from realistic interactions. It implies that only a small fraction of the full model space is needed for a description of low-lying states in these nuclei, and this in turn points to the importance of using a symmetry-adapted, no-core shell-model framework for describing such nuclei, one based on an LS coupling scheme with spatial configurations organized according to deformation.

The results confirm the relevance of the pioneering work of early developers of the field, J. P. Elliott and his SU(3) model [1] and M. Moshinsky with his U(3) many-body oscillator work [2], extended to open, multi-shell environments. Specifically, they demonstrate the relevance of these algebraic methods in this region, and in particular, how they can be used to quell the combinatorial growth in the dimensionality of the problem with the addition of higher oscillator shells to the model space. Indeed, the results show the utility of a symmetry-adapted, no-core shell-model approach for light nuclei that takes maximum advantage of group theoretical methods as well as advanced computational techniques.

The theory is applied to a study of the structure of $^{12}$C and $^{16}$O. Comparisons with results from no-core shell model analyses illustrate the efficacy of the symmetry-adapted framework. In addition, a simple algebraic interaction, which reduces to the Elliott model in its single-shell limit, is shown to reproduce all features of the elusive Hoyle state in $^{12}$C, as well as corresponding first excited $0^+$ in neighboring nuclei, such as $^{16}$O. While this requires that the no-core underpinning of the model be extended beyond the current reach of the standard no-core shell model to excitations as high as 18 (eighteen) major oscillator shells, only the most deformed configurations in the extended region are required. This further affirms the importance of exploiting algebraic methods in exploring special correlations in many-particle and multi-shell environments. The latter also suggests a possible path forward for realizing macroscopic theories that target collective degrees of freedom in terms of more microscopic ones that build forward from the nucleon-nucleon interaction itself.

1. Group Theory and Special Symmetries in Nuclear Physics; Proceedings of the international symposium in honor of K.T. Hecht, 19-21 September 1991, Ann Arbor, MI; edited by J. P. Draayer and J. Janecke (World Scientific, 1992).
2. Computational and Group Theoretical Methods in Nuclear Physics; Proceedings of the Symposium in Honor of Jerry P. Draayer's $60^{th}$ Birthday, 18-21 February 2003, Playa del Carmen, Mexico; edited by J. Escher, O. Castaños, J. G. Hirsch, S. Pittel, and G. Stoichevia (World Scientific, 2004).