Can Nuclear Structure Be Revealed in a Reduced Model Space?

Abstract

by

Fengqiao Luo

The limited capability of the traditional nuclear shell model in dealing with calculations for nuclei with large numbers of valence nucleons or with phenomena requiring multiple shells for their description motivated ongoing research on establishing an economical model space, one which still could reveal nuclear structural properties but in a lower dimensional space compared to the traditional shell model. Towards this goal, the generalized seniority shell model (GSSM) and the symplectic no-core shell model (Sp-NCSM) were developed. The GSSM is based on the BCS description of nucleon pairing. It is most effective for spherical and semimagic shell-configured nuclei. The Sp-NCSM is established on the SU(3) many-body basis motivated by the SU(3) symmetry structure of the harmonic oscillator many-nucleon basis states, embedded further with a higher Sp(3,$\mathbb{R}$) symmetry, as an extension of SU(3) symmetry to multiple harmonic oscillator shells.

We set up a recursive method to compute matrix elements in the GSSM basis. This method is implemented and carried out in a computer program we developed for nuclear calculations under the generalized seniority scheme. The GSSM was not previously well benchmarked, and we have used our method and code to test this model by comparing the calculated nuclear properties in the GSSM model space with calculations in the full shell model space. Such comparison is made under the same nucleon-nucleon interaction for both spaces. Meanwhile, the Sp-NCSM offers a

different approach to modeling light nuclei without the need to assume the presence of an inert core. Numerical evidence shows an important role of the symplectic Sp(3,$\mathbb{R}$) symmetry in the *ab initio* no-core shell model results for light nuclei. Therefore, the construction of Sp(3,$\mathbb{R}$) states from SU(3) states is necessary, as a prerequisite and crucial step of understanding the symplectic symmetry for those nuclei. We contribute to the Sp-NCSM by providing the numerical calculation that decomposes the basis states of Sp(3,$\mathbb{R}$) irreducible representations (irreps) in terms of the SU(3) nuclear basis.