A New Quantum Monte Carlo Method for the Nuclear Shell Model

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Résumé

Despite considerable progress in computational power and memory capacity in recent years, the applicability of the nuclear Shell Model remains limited because of the exponential growth of the size of the many-body Hilbert space, which increases with the nucleon number and/or the number of valence shells. Quantum Monte Carlo (QMC) methods can be considered as a possibly attractive alternative to direct diagonalization of the Hamiltonian matrix. Indeed, the quantum many-body problem is then reduced to a set of one-body problems, describing particles in fluctuating external fields. However, the sampling is in general contaminated by the emergence of configurations with "negative weights" degrading the signal-to-noise ratio: this is the well-known fermion sign problem. Up-to-date QMC methods applied to the Shell Model only provide the ground state and the thermodynamical properties of nuclei, subject to a more or less well-controlled removal of these pathological configurations. We will present an original QMC method inspired by approximations used in the ab initio calculations of nuclear and condensed matter physics, developed to reproduce the "yrast" spectroscopy of nuclei. The sign problem is avoided by using a Hartree-Fock state with restored symmetries before variation to initialize and constrain the projection onto the desired state. To illustrate this method, we will show promising results for sd-shell nuclei.

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