Ground states of odd-mass nuclei in nuclear density-functional theory under a time-odd external field

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As a microscopic input for astrophysical simulations such as the nucleosynthesis and the evolution of massive stars, higher accurate and reliable nuclear data for thousands of nuclides are desired. For exotic nuclei those are not accessible experimentally, one should rely on a microscopic calculation.

Density functional theory (DFT) is an approach that describes ground-state properties of quantum many-body systems such as atomic nuclei in terms of the particle density. Since the computational cost does not depend on the number of nucleons, it can be applied to from light to superheavy nuclei by combining a universal energy density functional for all the nuclei.

Deformation and superfluidity of nuclei are a key for describing the nuclear structure. Especially for weakly bound nuclei near drip lines, these many-body correlations have important roles since they determine whether the system is bound or not. In addition, the superfluidity makes a decisive difference between nuclei with even number of protons and neutrons (even-even nuclei) and those with odd number of protons or neutrons (odd-mass, odd-odd nuclei). Whereas the spin and parity of the ground state of even-even nuclei is 0^+ without exception and they have the time-reversal symmetry, odd nuclei generally have finite spins and break the time-reversal symmetry. Therefore, in order to systematically describe even- and odd-mass nuclei including stable and unstable nuclei, it is essential to simultaneously deal with the nuclear deformation, superfluidity, and breaking of the time-reversal symmetry. A method that can handle these three ingredients on the same footing in the framework of DFT is known as the Hartree-Fock-Bogoliubov (HFB) method in nuclear physics.

There have been few studies of odd nuclei using the HFB method, while the nature of even-even nuclei has been studied a lot. This is because the conventional description of odd nuclei by the HFB method is complicated compared with that of even-even nuclei; odd nuclei are obtained as an excited state from the neighboring even-even nuclei. We propose a novel method to describe odd nuclei as a ground state under an appropriate external field that breaks the time-reversal symmetry in the HFB method. One can then describe odd-mass nuclei with the same procedure as for even-even ones in the framework of DFT.