Shell Evolution in Exotic Nuclei

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In recent years, the understanding of the shell evolution in exotic nuclei has been advanced considerably. I will present an overview on the shell evolution in exotic nuclei due to 2- and 3-body nuclear force, with perspectives over the future directions.

The shell evolution due to the proton-neutron interaction has the major origin in the central and tensor forces. The indispensable role of the tensor force has been established not only from the comparison to experimental data but also from modern microscopic theories on the hard-core effects and in-medium corrections. Renormalization process is shown not to change the monopole part of the tensor force, and the bare tensor force obtained from one-pion and one-rho-meson exchanges is a good approximation, explaining/predicting changes of the spin-orbit splitting in a robust and well-defined quantitative manner. The central force is, at present stage, more phenomenological as it is changed largely through the renormalization. On the other hand, the resultant central force appears, at least in its monopole part, with a very simple form with Gaussian range of 1 fm. By using such a proton-neutron monopole interaction, one can describe or predict many phenomena by a single fixed interaction: transition from the N=20 island of inversion to normal structure at 40Ca, breaking of Z=28 around N=50, transition from 90Zr to 100Sn structures with very different single particle orderings, with more interesting cases over the periodic table [PRL 104, 012501].

The interaction between valence neutrons has been clarified more recently with additional new aspects. The bare 3-body interaction, particularly the one originating in Delta particle excitation (Fujita-Miyazawa (FM) force), induces an effective interaction between valence neutrons. This interaction between two neutrons is due to the third nucleon in the core, and its monopole part is shown to be robustly repulsive. This repulsive contribution solves a long-standing problem in the shell-model interaction: the origin of repulsive modification to the T=1 monopole part. This 3-body-induced 2-body interaction, combined with an effective interaction from bare 2-body force, indeed reproduces many properties which are otherwise open questions. This interaction is related to and consistent with neutron matter/star. The dripline and magic structure of oxygen isotopes are an example. The dripline can be predicted naturally, and the new magic numbers N=14 and 16 arise. The major ingredients of such a 3-body-induced 2-body interaction will be discussed with perspectives over unexpected structures of exotic nuclei. [arXiv nucl-th: 0908.2607]