Exploring the rod-shaped nucleus

In terms of mass, carbon is the fourth most abundant element in the universe after hydrogen, helium, and oxygen, and the second most abundant element in the human body (approximately 18.5%) after oxygen. Carbon's formation from helium is an essential gateway in stellar nucleosynthesis, which is responsible for the galactic abundance of elements ranging from carbon to iron. Carbon can be synthesized via the triple-alpha process by exploiting the Hoyle state, i.e., the second $J^\pi=0^+$ excited state with 7.65 MeV in carbon-12. The existence of the Hoyle state has been confirmed experimentally; however, its precise properties continue to be investigated. In particular, the possible exotic shapes for the Hoyle state, e.g., a rod shape (linear three-alpha chain) or a gas-like state of three alpha particles, have become a hot topic in recent nuclear structure studies.

Recently, a group of researchers at Peking University, China, led by Professor Jie Meng in collaboration with Professor Naoyuki Itagaki from Kyoto University, Japan, and Professor Joachim Maruhn from Goethe University in Frankfurt, Germany, developed a microscopic and self-consistent approach to investigate exotic shapes of nuclei. By overcoming variational collapse and fermion-doubling problems with the inverse Hamiltonian and Fourier spectral methods as well as avoiding occupation of unphysical continuum, they have established a cranking covariant density functional theory in three-dimensional lattice space that properly accounts for the spin-orbit potential and time-odd fields [1].

Considering individual nucleons as fundamental building blocks and without *a priori* assumption of the existence of alpha clusters, the authors in this work found stable three-alpha linear chain structures in carbon-12 in a microscopic and self-consistent manner. These linear chains are stable against bending and fission with a rotational frequency of 2.0 to 3.5 MeV/ $\hbar$.

The newly developed cranking covariant density functional theory in three-dimensional lattice space allows the elucidation of the exotic shapes in whole nuclear chart. The interesting results here are expected to stimulate future experimental investigations in this field as well as in related topics [2].

Gui-Lu Long

Department of Physics, Tsinghua University, Beijing 100084, China

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- 2 U. G. Meißner, *Sci. Bull.* **60**, 43 (2015).