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Accurate relativistic exchange energy functional for atomic nuclei

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The shell evolution towards the extreme neutron-to-proton ratio has been a pivotal focus in nuclear physics over recent decades, since it is crucial to understand the effective nucleon-nucleon interactions and the r-process. Significant efforts have been devoted to deciphering the mechanism behind the shell evolution, such as the spin-orbit interaction, the tensor force, and the pseudospin symmetry. This motivates us to include the exchange energy in the relativistic density functional theory to simultaneously consider the important mechanisms in a self-consistent way.

The inclusion of nucleonic exchange energy has been a long-standing challenge for the relativistic density functional theory in nuclear physics. We propose an orbital-dependent relativistic Kohn-Sham density functional theory to incorporate the exchange energy with local Lorentz scalar and vector potentials. The relativistic optimized effective potential equations for the local exchange potentials are derived and solved efficiently. The obtained binding energies and charge radii for nuclei are benchmarked with the results given by the traditional relativistic Hartree-Fock approach, which involves intractable nonlocal potentials. It demonstrates that the present framework is not only accurate but also efficient. An extension to three-dimensional coordinate space is also realized, which would have great potential for wide applications.

Primary author(s) : Dr ZHAO, QIANG (Research Center for Nuclear Physics, Osaka University)

Presenter(s) : Dr ZHAO, QIANG (Research Center for Nuclear Physics, Osaka University)

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