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Study of nuclear structure with a generalized Skyrme functional

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In the framework of the KIDS generalized energy density functional (EDF), the nuclear equation of state (EoS) is expressed as an expansion in powers of the Fermi momentum or the cubic root of the density. Although an optimal number of converging terms was obtained in specific cases of fits to empirical data and pseudodata, the degree of convergence remains to be examined not only for homogeneous matter but also for finite nuclei. One goal of the present work is to validate the minimal and optimal number of EoS parameters required for the description of homogeneous nuclear matter over a wide range of densities relevant for astrophysical applications. The major goal is to examine the validity of the adopted expansion scheme for an accurate description of finite nuclei. To this end we vary the values of the high-order derivatives of the EoS, namely the skewness of the energy of symmetric nuclear matter and the kurtosis of the symmetry energy, at saturation and examine the relative importance of each term in density expansion for homogeneous matter. For given sets of EoS parameters determined in this way, we define equivalent Skyrme-type functionals and examine the convergence in the description of finite nuclei focusing on the masses and charge radii of closed-shell nuclei. The EoS of symmetric nuclear matter is found to be efficiently parameterized with only 3 parameters and the symmetry energy (or the energy of pure neutron matter) with 4 parameters when the EoS is expanded in the power series of the Fermi momentum. Higher-order EoS parameters do not produce any improvement, in practice, in the description of nuclear ground-state energies and charge radii, which means that they cannot be constrained by bulk properties of nuclei.

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