A modern nuclear energy density functional

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Density functional theory, which is based on a theorem for the existence of a universal energy density functional (EDF) that depends on the densities of the constituents and their derivatives, provides a powerful approach for theoretical calculations of properties of many body systems. However, the main challenge is to find the EDF. The development of a modern and more realistic nuclear EDF for accurate predictions of properties of nuclei is of the highest priority for the worldwide nuclear physics community.

Starting from the EDF associated with the Skyrme effective nucleon-nucleon interaction [1], we aim to construct a more realistic EDF with improved predictive power for properties of nuclei at and away from the valley of stability. It should be emphasized that in earlier attempts to determine a more realistic interaction, the main objective has been that the experimental data on ground state properties of nuclei be reproduced by the mean-field theory. In our approach we use the effective interaction to determine the properties of giant resonances within the RPA theory and thus introduce RPA correlations into the ground state. Therefore, for consistency, we must require that the comparison with data be made after the inclusion of the effects of RPA correlations in the ground states of nuclei, i.e. going beyond mean-field theory.

Recently, we have determined within the Hartree-Fock (HF) approximation a new and more realistic Skyrme interaction (named KDE0) by fitting [2] a set of extensive data on binding energies, "bare" single particle energies, charge radii, and radii of valence nucleon density distribution of nuclei. We have included in the fit, for the first time, the data on the energies of the isoscalar giant monopole resonances (ISGMR) of nuclei and imposed additional constraints, such as a non-negative value for the slope of the symmetry energy density at high nuclear matter (NM) density (at three times the saturation density of NM) and the Landau's stability constraints on nuclear matter. We have implemented, for the first time, the simulated annealing method together with an advanced least square method to search for the global minima. We have continued our work [3] to further improve our EDF by *addressing the following tasks:*

- *(i)* Modifying the isospin dependence of the spin-orbit interaction in order to better reproduce the spin-orbit splitting of single particle orbits in neutron-rich and proton-rich nuclei.
- *(ii)* Including in the fit for determining the EDF additional experimental data on ground state properties of nuclei, such as binding energies and radii.
- *(iii)* Including in the fit for determining the EDF the data on giant resonances, such as the ISGMR and the isoscalar giant dipole resonance (ISGDR), which are sensitive to the NM incompressibility coefficient *K*, the isovector giant dipole resonance (IVGDR), which is sensitive to the symmetry energy density, and the isoscalar giant quadrupole resonance (ISGQR), which is sensitive to the effective mass.

[1] T. H. R. Skyrme, Phil. Mag. **1**, 1043 (1956); Nucl. Phys. **9**, 615 (1959).
[2] B. K. Agrawal, S. Shlomo and V. Kim Au, Phys. Rev. C **72**, 014310 (2005).

[3] D. C. Fuls, V. K. Au and S. Shlomo (to be published).