Correlations among nuclear matter properties of Skyrme interactions

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Density Functional Theory is a powerful tool for the study of many body systems. The main challenge is to find the form of the energy density functional (EDF). The development of a modern and more realistic nuclear energy density functional (EDF) for accurate predictions of properties of nuclei is the subject of enhanced activity, since it is very important for the study of properties of rare nuclei with unusual neutron-to-proton ratios that are difficult to produce experimentally and likely to exhibit interesting new phenomena associated with isospin, clusterization and the continuum. In our work we consider the EDF associated with the Skyrme type effective nucleon-nucleon interaction. Adopting the standard parametrization of the Skyrme type interactions, it is common to determine the parameters of the EDF within the Hartree-Fock (HF) mean-field approximation by carrying out a fit to an extensive set of data on; (i) binding energies, (ii) single-particle energies, and (iii) charge root-mean-square (rms) radii. This approach has resulted with over 200 EDFs associated with the Skyrme type effective nucleon-nucleon interaction.

To better determine the values of the Skyrme parameters we include constraints on the values of nuclear matter (NM) properties, such as the incompressibility coefficient, symmetry energy density and nucleon effective mass. To determine the values of the NM properties, we have investigated the sensitivities of the centroid energies E_{CEN} of the isoscalar and isovector giant resonances of multipolarities $L = 0 - 3$ in ^{208}Pb to values of the NM properties. To obtain better insight into the effects of the constraint associated with properties of NM on the resulting EDF, we investigate [1] the correlations among the properties of NM, using a wide range of 34 commonly employed Skyrme type interactions. These interactions, which were fitted to ground state properties of nuclei are associated with a wide range of nuclear matter properties such as incompressibility coefficient K_{NM} = 200 - 258 MeV, symmetry energy J = 27 - 37 MeV and effective mass m* = 0.56 - 1.00. We consider the NM quantities: the effective mass m*; the incompressibility coefficient $K = 9\rho_0^2 \frac{d^2(E/A)}{d\rho^2}\Big|_{\rho_0}$; the skewness coefficient which is proportional to the third derivative$Q = 27\rho_0^3 \frac{d^3(E/A)}{d\rho^3}\Big|_{\rho_0}$; the symmetry energy coefficient $J = E_{sym}(\rho_0)$; the symmetry energy at 0.1 fm^{-3}, J(0.1) = $E_{sym}(0.1)$ the coefficient proportional to the slope, $L = 3\rho_0 \frac{d(E_{sym})}{d\rho}\Big|_{\rho_0}$, and the curvature $K_{sym} = 9\rho_0^2 \frac{d^2(E_{sym})}{d\rho^2}\Big|_{\rho_0}$ of the density dependence of the symmetry energy, respectively, κ, the enhancement factor of the energy weighted sum rule for the IVGDR, and the strength of the spin-orbit interaction W_0.

In Table I we present the Pearson Correlation Coefficients between the values of NM properties. Note the strong correlation between K and Q and between Q and m*/m, but the weak correlation between K and m*/m. J and L also have a fairly strong correlation while L and K_{sym} have a very strong correlation, and J and K_{sym} have a medium correlation. There are also medium correlations between J(0.1) and K_{sym}, m*/m and κ, and K and K_{sym}.

Table I. Pearson's correlation coefficient between NM properties.

	K	K' = -Q	J	L	K_{sym}	m*/m	J(0.1)	κ	W_0
K	1.00	-0.78	0.10	0.36	0.53	-0.39	-0.17	-0.10	0.12
K' = -Q	-0.78	1.00	0.01	-0.36	-0.63	0.83	0.36	-0.35	-0.13
J	0.10	0.01	1.00	0.72	0.45	0.03	0.36	-0.20	-0.10
L	0.36	-0.36	0.72	1.00	0.90	-0.19	-0.35	-0.11	0.22
K_{sym}	0.53	-0.63	0.45	0.90	1.00	-0.46	-0.52	-0.07	0.33
m*/m	-0.39	0.83	0.03	-0.19	-0.46	1.00	0.19	-0.59	-0.10
J(0.1)	-0.17	0.36	0.36	-0.35	-0.52	0.19	1.00	-0.18	-0.36
κ	-0.10	-0.35	-0.20	-0.11	-0.07	-0.59	-0.18	1.00	-0.18
W_0	0.12	-0.13	-0.10	0.22	0.33	-0.10	-0.36	-0.18	1.00

[1] M.R. Anders *et al.*, in preparation.