Sensitivity of centroid energies of giant resonances to bulk nuclear matter properties

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The development of a modern and more realistic nuclear energy density functional (EDF) is the subject of enhanced activity, since it is very important for accurate prediction of properties of nuclei, such as giant resonances (GR), at and far from stability, of nuclear matter (NM) and Astrophysical phenomena. To determine constraints on bulk properties of NM, such as the incompressibility coefficient, K_{NM}, effective mass, m^*/m, symmetry energy coefficient, J, and its first, L, and second, K_{sym}, derivatives, and the enhancement coefficient, κ, of the energy weighted sum rule (EWSR) of the isovector giant dipole resonance (IVGDR), we have investigated their sensitivities to centroid energies, E_{CEN} , of isoscalar and isovector GRs with multipolarities L = 0 – 3. For this purpose we have carried out [1-4] fully self-consistent Hartree-Fock (HF) based random-phase-approximation (RPA) calculations of the strength functions *S(E)* and centroid energies E_{CEN} of GRs for a very wide range of nuclei, using 33 commonly employed effective nucleon-nucleon interaction of the Skyrme type, and determined the Pearson linear correlation coefficient *C* between each E_{CEN} and each bulk property of NM. We also determined constraints on NM properties by comparing with available experimental data on E_{CEN} of GRs.

The calculated Pearson linear correlation coefficients between different sets of NM properties are shown in Table I. We point out that the value of each NM property varies over a wide range. It is also

Table I. Calculated Pearson linear correlation coefficients, C, for NM properties. The parameters of all 33 Skyrme effective nucleon-nucleon interactions were used to calculate C.

	K_{NM}	J	L	K_{sym}	m^*/m	κ	$W_0\ (x_w = 1)$
K_{NM}	1.00	0.03	0.30	0.43	-0.37	-0.02	0.03
J	0.03	1.00	0.72	0.49	0.07	-0.24	-0.25
L	0.30	0.72	1.00	0.91	-0.15	-0.13	-0.08
K_{sym}	0.43	0.49	0.91	1.00	-0.41	-0.08	0.05
m^*/m	-0.37	0.07	-0.15	-0.41	1.00	-0.63	-0.19
κ	-0.02	-0.24	-0.13	-0.08	-0.63	1.00	-0.03
$W_0\ (x_w = 1)$	0.03	-0.25	-0.08	0.05	-0.19	-0.03	1.00

seen from Table I that there are only weak correlation between the values of K_{NM}, and m^*/m, medium correlation between m^*/m and κ, and medium correlations between the symmetry energy coefficients J, L, and K_{sym} . Table II presents the Pearson linear correlation coefficients C between each bulk property of nuclear matter at saturation density and the E_{CEN} of each GR: the isoscalar giant monopole resonance (ISGMR), isoscalar giant dipole resonance (ISGDR), isoscalar giant quadrupole resonance (ISGQR), isoscalar giant octupole resonance (ISGOR), isovector giant monopole resonance (IVGMR), isovector giant dipole resonance (IVGDR), isovector giant quadrupole resonance (IVGQR) and isovector giant octupole resonance (IVGOR). Note that it is seen from Table II that, in particular, there exist strong correlations between E_{CEN} of the ISGMR and the incompressibility coefficient, between E_{CEN} and the effective mass m^*/m for the ISGQR and between E_{CEN} of the IVGDR and the enhancement coefficient κ for the IVGDR energy weighted sum rule (EWSR) and, surprisingly, very weak correlations between E_{CEN} and the symmetry energy J or its first and second derivative, for the IVGDR. By comparing with available experimental data on E_{CEN} of GRs we obtained the following constraints on the values of : K_{NM} = 210-240 MeV, m^*/m = 0.7-0.9, and κ = 0.25-0.70.

Table II. Pearson linear correlation coefficients between the centroid energy ECEN of each giant resonance and each nuclear matter property at saturation density.

	K_{NM}	J	L	K_{sym}	m^*/m	κ
ISGMR	0.87	-0.10	0.25	0.45	-0.51	0.13
ISGDR	0.52	-0.10	0.13	0.36	-0.88	0.55
ISGQR	0.41	-0.09	0.15	0.41	-0.93	0.54
ISGOR	0.42	-0.10	0.15	0.43	-0.96	0.56
IVGMR	0.23	-0.26	-0.12	0.00	-0.70	0.86
IVGDR	0.05	-0.37	-0.42	-0.30	-0.60	0.84
IVGQR	0.18	-0.35	-0.29	-0.13	-0.74	0.80
IVGOR	0.25	-0.32	-0.19	0.02	-0.83	0.81

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