Effects of Violation of Self-consistency on Isoscalar Giant Resonances

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Here we report our investigation of the influence of violation of self-consistency on the strength function for isoscalar giant monopole resonance (ISGMR) and isoscalar giant dipole resonance (ISGDR). Before embarking upon our discussions, it may be restated (1) that most often the self-consistency is violated due to neglect of the spin-orbit, Coulomb, and momentum dependent part in the particle-hole interaction, V_{ph}. On the other hand, since the incompressibility coefficient K_{nm} depends quadratically on ISGMR centroid energy (E_0) and ISGDR centroid energy (E_1), their strength functions must be calculated very accurately. We present here HF-based continuum RPA results (2) for isoscalar giant resonances obtained using a two-body interaction V_{12} of the form,

$$V_{12} = \delta(r_1 - r_2)[t_0 + \frac{1}{6}t_3\rho^{\alpha}(\frac{r_1 + r_2}{2})] \qquad (1)$$

with $\alpha = 1$, $t_0 = -1100$ MeVfm^3 and t_3=16000 MeVfm$^{3(\alpha+1)}$. The particle-hole interaction V_{ph} then reads as

$$V_{ph} = \delta(r_1 - r_2)[\frac{3}{4}t_0 + \frac{3}{8}t_3\rho] \qquad (2)$$

We use a parameter V_{scale} needed to renormalize V_{ph} so that position of spurious state can be adjusted close to zero. To study the consequence of the violation of self-consistency we vary t_0 only in the particle-hole interaction (only in Eq. 2) by ±5% and ±10%.

Table 1:

t_0	V_{scale}	K'_{nm}	E_{ss}	E_0	E_1
-1100	1.000	408	0.1	29.70	42.26
-1045	1.000	428	5.5	31.36	43.56
-1045	1.147	484	0.1	31.57	44.08
-990	1.000	448	7.6	32.86	44.77
-990	1.325	579	0.1	33.72	46.14
-1155	1.000	389	< 0	27.84	40.86
-1155	0.878	347	0.1	28.06	40.70
-1210	1.000	369	< 0	25.72	39.36
-1210	0.777	296	0.1	26.64	39.39

In Table 1, the spurious state energy E_{ss}, centroid energies E_0 and E_1 are given in units of MeV. K'_{nm}, given in MeV is the nuclear matter incompressibility coefficient associated with t_0V_{scale} and t_3V_{scale}. Here, t_0 and t_3 are the values used in Eq. (2). Values of E_0 are obtained by integrating the energy weighted strength function from 0 to 80 MeV. In case of E_1, the lower limit of integration is so chosen that the low-lying resonance is eliminated. It can be clearly seen from the table that the centroid energies for ISGMR and ISGDR significantly differ from their corresponding self-consistent values even if V_{scale} is adjusted to give E_{ss}=0.1 MeV. One may understand this discrepancy in terms of the incompressibility coefficient. With the renormalization of V_{ph}, though, E_{ss} becomes close to zero, but value of K'_{nm} remains quite different in HF and RPA calculations. Furthermore, it is also important to

note that centroid energies for ISGDR is equally affected as that of ISGMR if the self-consistency is not maintained. But the centroid energy for isoscalar giant quadrupole resonance (not shown) reattains its self-consistent value when $t_0 = -1100 \pm 55$ is used in Eq. (2) and V_{scale} is adjusted to yield E_{ss}=0.1 MeV.

In Fig. 1, we display ISGDR strength function calculated with t_0=-990MeVfm^3. We see that if the value of t_0 in Eq. (2) is changed by 10%, the strength function $S_\eta(E)$ becomes even larger than S_3. Moreover, the strength function S_1 shows an additional peak around 12 MeV due to the fact that the self-consistency is not maintained.

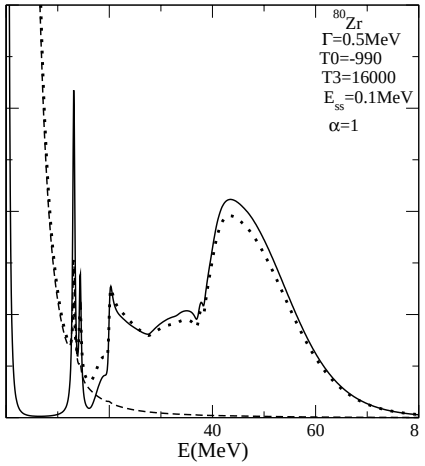

Figure 1: ISGDR strength function for F_3 (dotted), ηF_1 (long dashed), and F_η (solid line) in case ^{80}Zr nucleus.

In Fig. 2, we compare our results for t_0=-990 and -1210 with the fully self-consistent (t_0=-1100) results. For all these cases, V_{scale} is so adjusted that E_{ss}=0.1MeV (see also Table 1). We observe that the nature of compressional

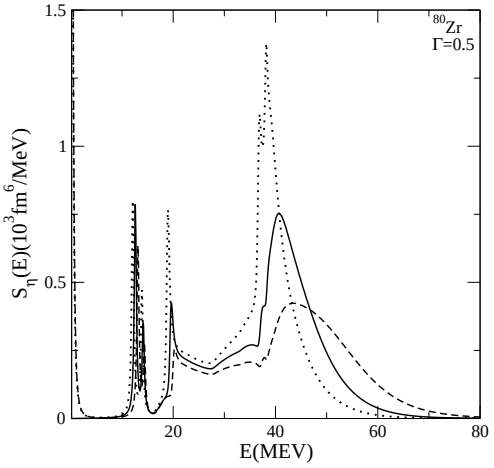

Figure 2: Influence of the variation of t_0 by +10% (dotted) and -10% (long dashed) on the strength function for F_η. Solid line represents the self-consistent result (i.e., t_0 = -1100).

We have repeated this analysis with a more realistic force taking $\alpha = 1/3$, $t_0 = -1800$, and $t_3 = 12870$. For this force we have $K_{nm} = 226$, $\rho_0 = 0.16$ and $E/A = -16.0$ MeV. With this force we find once again that the ISGMR and ISGDR strength functions get significantly affected if V_{ph} is not fully consistent with V_{12}.

References

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[2] B. K. Agrawal, S. Shlomo, and A. I. Sanzhur, to be published.