# Self-consistent RPA calculations with finite range interactions with tensor terms

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We have studied the effects of the tensor terms of interactions D1ST and D1MT [1] constructed considering global properties of the nuclei in HF+RPA self-consistent calculations for a set of nuclei in different regions of the isotope chart. This study in the excitation spectra is complex, since the effects of the tensor force in the RPA calculations add to those already present in the HF calculation which produces the s.p. bases. In our investigation we have disentangled the effects coming from these two different sources. In order to do it we have presented results where the tensor force is switched on and off in both HF and RPA calculations and we indicated as $\omega_{\rm ab}^{\rm RPA}$ the RPA excitation energies, where the first subindex, a, refers to the interaction used in the HF calculations, and the second subindex, b, to the interaction used in the RPA calculations. These indices can be t if the interaction includes the tensor term, and n otherwise. We present also results obtained by switching off the residual interaction: labelled as $\omega_{\rm a}^{\rm IPM}$, where the superscript IPM refers to Independent Particle Model. The energies produced in this type of calculations need only one subindex which indicates the presence, t, or the absence, n, of the tensor force in the HF calculation.

We present first the results related to the excitation of the first $0^-$ state in the various isotopes we are studying. The energy of this excitation in $^{16}$O has been chosen to select the strengths of our tensor forces. We have compared the excitation energies obtained by our RPA calculations with the experimental values taken from Refs. [2,3]. We found that the tensor interaction lowers the excitation energy of this state and improves the agreement in all the cases. A general view of the tensor effects in all the nuclei we have considered is given in Fig. 1. In panel (a) we show the differences $\omega_{\rm tt}^{\rm RPA} - \omega_{\rm nn}^{\rm RPA}$ for the first $0^-$ states in all the nuclei under investigation, in panel (b) the energy differences $\omega_{\rm t}^{\rm IPM} - \omega_{\rm n}^{\rm IPM}$.

In the RPA calculations, the results obtained with the tensor force are always lower than those obtained without it, and this produces negative values of the differences $\omega_{\rm tt}^{\rm RPA} - \omega_{\rm nn}^{\rm RPA}$. The only

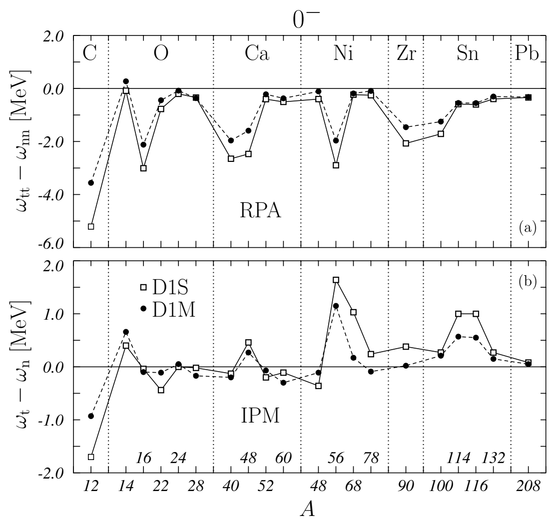


Figure 1. Differences between the energies of the first $0^-$ excited state.

exception to this general trend is that of the $^{14}$O nucleus in the case of the D1M interaction. The results presented in the two panels do not show any correlation. This indicates that the attraction is a genuine effect of the tensor force on the RPA calculations.

We studied the different role played by the tensor force in IS and IV type of excitations. To identify clearly these different type of excitation modes, we have considered nuclei with equal number of protons and neutrons and states dominated by particle-hole transitions with the same angular momentum coupling for both protons and neutrons. The effects of the tensor terms are better presented in Fig. 2. In the panels (a) and (b) we show the energy differences $\omega_{\rm tt}^{\rm RPA} - \omega_{\rm nn}^{\rm RPA}$ for IS (open squares) and IV (solid circles) states.

The results found for the various calculations have rather similar behaviours. The tensor effects are smaller on the IV states. In the panels (c) and (d) we show the differences between the energies of the IV and IS states for each multipole we have considered. We found that the IS excitations are more sensitive to the tensor force than the IV ones. The tensor force increases the energy difference between IS and IV excitations.

We made a systematic study of the effects of the tensor force on the excitation of the $1^+$ states in nuclei with different number of protons and neutrons.

The results shown in Fig. 3 indicate that the presence of the tensor force changes the s.p. energies in a way that the energy of the excitation is reduced. This is shown by the fact that all the energy differences have negative sign. These results are in agreement with the findings of Cao *et al.* [4] for the T44 interaction [5] but they are opposite to those found by the same authors for the modified SLy5 interaction [6]. With the exception of the cases where all the s.p. spin-orbit partner levels are occupied, i.e. $^{28}$O and $^{60}$Ca, the differences $\omega_{tt}^{RPA} - \omega_{nn}^{RPA}$ are noticeably larger than $\omega_t^{IPM} - \omega_n^{IPM}$.

To investigate the genuine effect of the tensor force in RPA, we have calculated the energy differences $\omega_{tt}^{RPA} - \omega_{tn}^{RPA}$ where the same s.p. basis is used for the two RPA calculations. These results are presented in Fig. 3 by solid squares. If we add incoherently the $\omega_t^{IPM} - \omega_n^{IPM}$ and the $\omega_{tt}^{RPA} - \omega_{tn}^{RPA}$ results (that are the separated effects of the tensor in HF and RPA calculation respectively), we obtain the results plotted with crosses which reproduce very well the results of the complete calculation $\omega_{tt}^{RPA} - \omega_{nn}^{RPA}$.

Now,we have limited our study to charge conserving nuclear excitations but in the next future we intend to extend this study to the charge-exchange excitations that seem to be affected by the tensor-isospin force in a more relevant way [7–9].

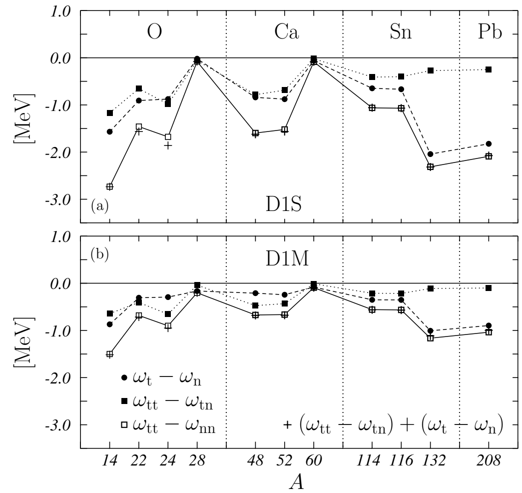


Figure 3. Differences between the energies of $1^+$ excitations having the largest $B(M1)$-value, in various nuclei.

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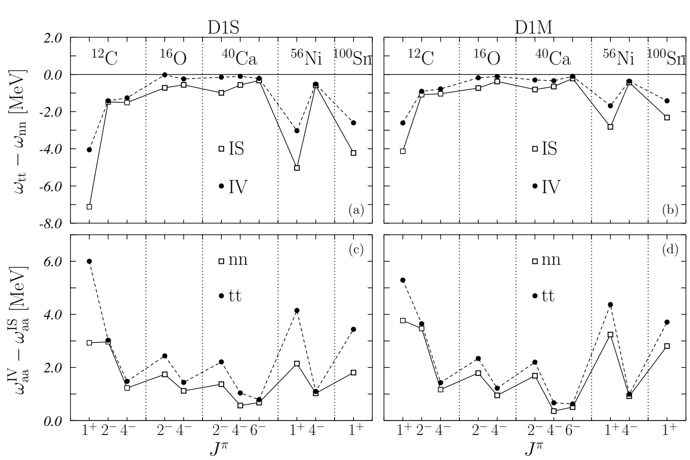


Figure 2. IS and IV excitated states.