Self-consistent CRPA calculations for oxygen and calcium isotopes

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We have studied, in the Self Consistent Continuum Random Phase Approximation (CRPA) approach the 1^- and 2^+ excited states of oxygen and calcium isotopes using interactions with finite-range [1]. In our calculations we have used two different parameterizations of the Gogny interaction, the more traditional D1S force [2] and the new D1M force [3] obtained from a fit to about 2000 nuclear binding energies and 700 charge radii.

We have investigated nuclei where the hole s.p. levels are fully occupied. This eliminates deformations and minimizes pairing effects.

In the case of the oxygen we have studied the doubly magic ^{16}O nucleus, and the ^{22}O and ^{24}O isotopes.

In Fig. 1 we compare the total photoabsorption cross sections calculated for the excitation of the 1^- resonance in the three oxygen isotopes we have studied. The vertical bars show the discrete RPA results and the solid lines those of the CRPA calculations. In the upper panels we present the results obtained with the D1S interaction, and in the lower panels those obtained with the D1M interaction.

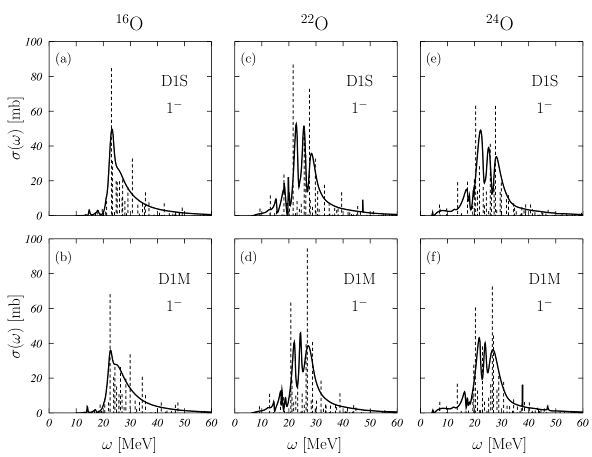

Figure 1. Total photoabsorption cross sections calculated with discrete and continuum RPA approaches.

In the ^{16}O nucleus, the agreement between the results of the two different calculations is rather good. Discrete results have their maxima in the same position of those of the continuous solutions but there are peaks around 30, 35 and 40 MeV which do not have corresponding partners in the CRPA cross sections. The D1M cross sections are slightly smaller, indicating, again, that this interaction is less attractive than the D1S force. The situation is more complicated in ^{22}O. Discrete and continuum results have similar structures, but the position of the peaks is slightly different. In any case, the cross sections show a richer structure than in the ^{16}O case. This situation is worsening in ^{24}O where the peaks of the continuous cross sections do not correspond to those of the discrete calculation.

We have done the same study for the excitation of the 2^+ resonance. In this case the results of the discrete RPA are rather different from those of the CRPA, even in the ^{16}O nucleus. The discrete calculations show clusters of peaks not present in the continuous calculations.

Another point we have investigated is related to the effects of the residual interaction in CRPA calculations.

In Fig.2 the CRPA results for ^{16}O (solid and dashed curves) are compared with the Indipendent Partcle Model (IPM) results (dotted and dashed-dotted curves), obtained by switching off the residual interaction in the CRPA calculation, and with the data of Ref. [4]. In the lower panels we present the sum rule exhaustion functions, calculated for the cross sections shown in the upper panels.

The results obtained with the D1S interaction do not show significant differences with respect to those obtained with the D1M interaction. Evidently, only the CRPA calculations predict the presence, and also the positions, of the resonances. The sum rule functions obtained with the IPM calculations are smaller than those of the CRPA.

The comparison of the CRPA results with the photoabsorption data emphasizes the well known limitations of the RPA description of the giant resonances. The strength is too concentrated in the peak region, and the data show a wider energy

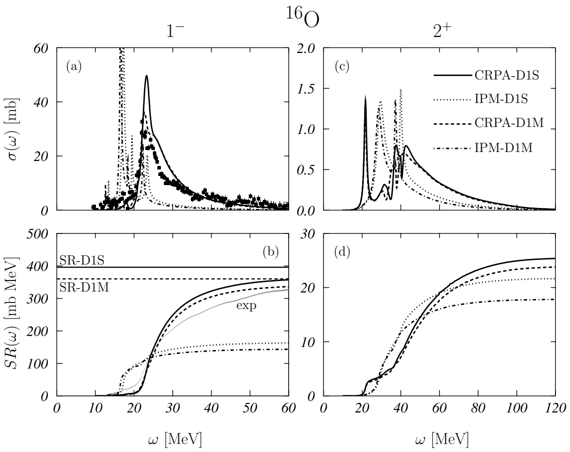

Figure 2. Total photoabsorption cross sections for the 1$^-$ (panel (a)) and 2$^+$ (panel (c)) excitations.

distribution.

The same type of investigation done for the oxygen isotopes has been repeated for three calcium isotopes: ^{40}Ca, ^{48}Ca and ^{52}Ca. The comparison between discrete and continuum RPA results is done in Figs. 3 for the 1$^-$ multipole excitation. As in the oxygen case, we show the contributions to the total photoabsorption cross sections. The agreement between the results of discrete and continuum RPA calculations is rather poor.

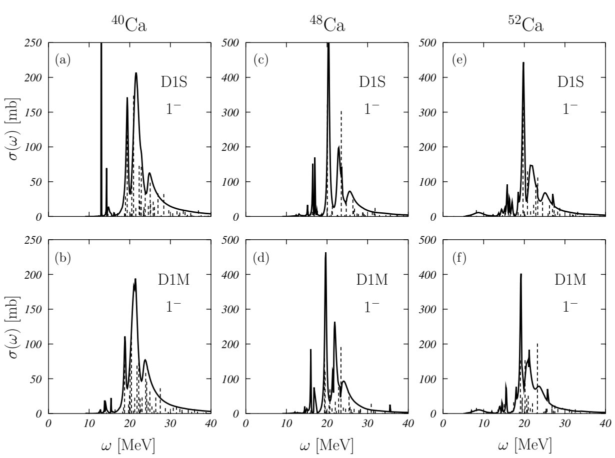

Figure 3. The same as Fig. 1 for the three calcium isotopes.

In Fig. 4 we compare our ^{40}Ca CRPA results with the total photoabsorption data of Ref. [4] and with the result of the IPM calculations. The same observations done for the oxygen case are valid also here. The IPM results are unable to describe the experimental cross section. The strengths of the IPM results are much smaller than those of the CRPA calculations. In the 1$^-$ case, the CRPA sum rule function reaches the empirical value but too early with respect to the empirical behaviour. This indicates that the strength is too concentrated in the resonance region.

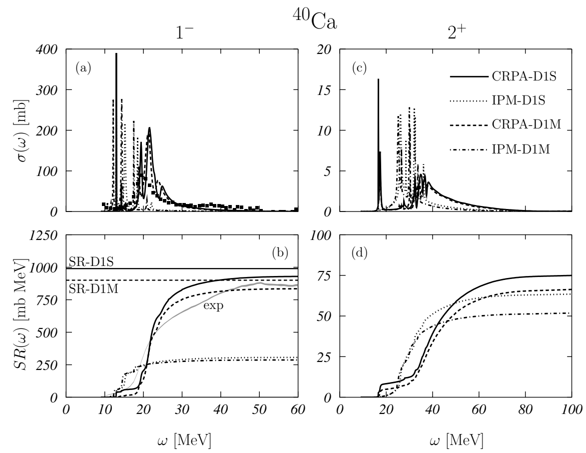

Figure 4. The same as Fig. 2 for ^{40}Ca .

We have also compared the self-consistent CRPA calculations with the phenomenological ones and we have obtained very similar results in the cases of ^{16}O and ^{40}Ca . On the contrary, when we apply this approach to the other isotopes, we found results which are rather different. This indicates the inadequacy of the phenomenological approach in the study of nuclei lying in experimentally unexplored parts of the nuclear isotope chart.

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