Magnetic dipole excitations in nuclei with neutron excess

G. Co' and V. De Donno [1] [2] and M. Anguiano and A. M. Lallena [3]

[1]Dipartimento di Fisica, Università del Salento, Italy

[2]Istituto Nazionale di Fisica Nucleare sez. di Lecce, Italy

[3]Departamento de Fisíca Atómica, Molecular y Nuclear, Universidad de Granada, Granada, Spain

The possibility offered by the new radioactive ion beam facilities to produce nuclei with neutron excess opens new perspectives in the study of nuclear excitations. After having studied the electric excited states of different nuclei [1], we illustrate here the most important results about our recent study of magnetic dipole excitation [2] of various oxygen and calcium isotopes. We have analyzed the evolution of the magnetic resonances with the increasing number of neutrons, the relevance of collective effects, the need of a correct treatment of the continuum and the role of the tensor force. Our approach is based on self-consistent continuum RPA (CRPA) theory with an effective interaction which has both finite-range and tensor components. We show here results obtained with the traditional D1S [3] interaction and with the D1ST force that we have recently constructed by adding a finite-range tensor-isospin term to the former parameterization [4].

An example of the comparison between discrete and continuum calculations can be seen in Fig. 1 where we compare the $B(\mathcal{M}1)\uparrow$ results for four oxygen isotopes in discrete RPA (DRPA) (dashed vertical lines) and CRPA (full lines) calculations. The positions of the peaks of the DRPA results correspond to that of the continuum responses. The CRPA results of the ^{28}O nucleus show a very broad continuum response that the discrete calculations can hardly reproduce.

The $B(\mathcal{M}1)\uparrow$ strengths in the ^{16}O and ^{28}O nuclei are orders of magnitude smaller than those of the other two isotopes. In our model, the 1^+ excitation in ^{16}O and ^{28}O is generated by $2\hbar\omega$ particle-hole (p-h) configurations, since, in the ground states of these nuclei, the nucleons fully occupy all the spin-orbit partner levels below the Fermi surface. On the contrary, in ^{22}O and ^{24}O the neutron $(1d_{3/2})$ level is empty, while the $(1d_{5/2})^{-1}$ level is occupied. In this last case, since a 1^+ transition between these two states, a $0\hbar\omega$ transition, is allowed, the corresponding $B(\mathcal{M}1)\uparrow$ strengths are much larger than those of ^{16}O and ^{28}O.

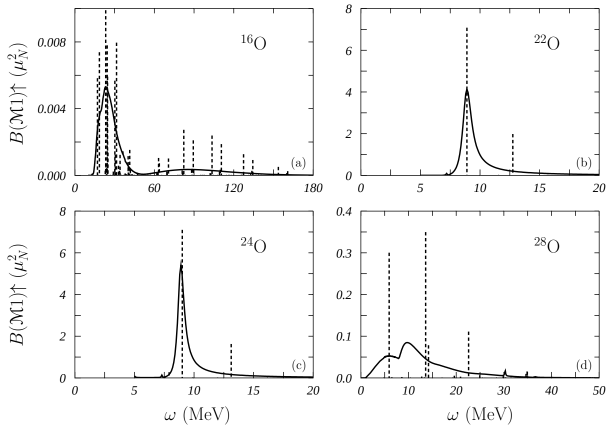

Figure 1. $B(\mathcal{M}1)\uparrow$ values for oxygen isotopes with CRPA (full lines) and DRPA (vertical dashed lines) calculations.

An example of the role of the residual interaction on the energy distribution of the $B(\mathcal{M}1)\uparrow$ strengths is shown in Fig. 2 where we compare the results of continuum indipendent particle model (CIPM) (dashed lines) and CRPA calculations (full lines). We observe an almost exact overlap of the two results in ^{16}O and ^{28}O nuclei. The situation is more interesting for the other two oxygen isotopes where the effective interaction pushes the peak position at higher energies and, at the same time, spreads the strength.

After discussing the role of the continuum and that of the residual interaction, we show an example of the effects of the tensor part of the residual interaction. In Fig. 3 we compare CRPA results indicating with nn the results of calculations done without tensor force, with tn those where the tensor force is used only in HF calculations and not in RPA, and with tt the results obtained by using the tensor force in both HF and RPA calculations.

The results of these three calculations almost overlap for the ^{16}O and ^{28}O nuclei. We have observed that already the results of Fig. 2 indicated a small sensitivity to the full residual interaction of the 1^+ excitation in these two nuclei, therefore, it is not surprising that the inclusion of the tensor force does not change the situation. In addition, these results confirm that in HF calcula-

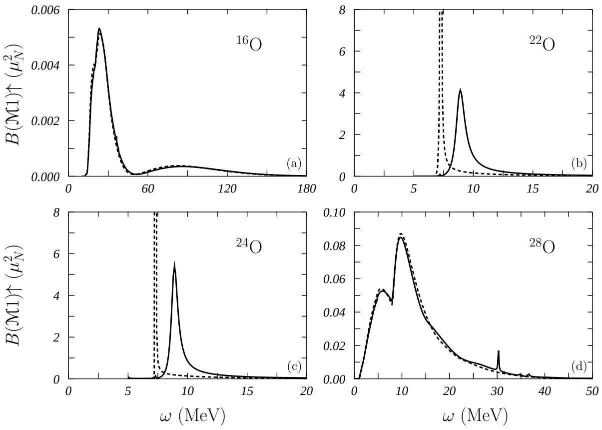

Figure 2. $B(\mathcal{M}1)\uparrow$ values for the oxygen isotopes with CRPA (full lines) and CIPM (dashed lines) calculations.

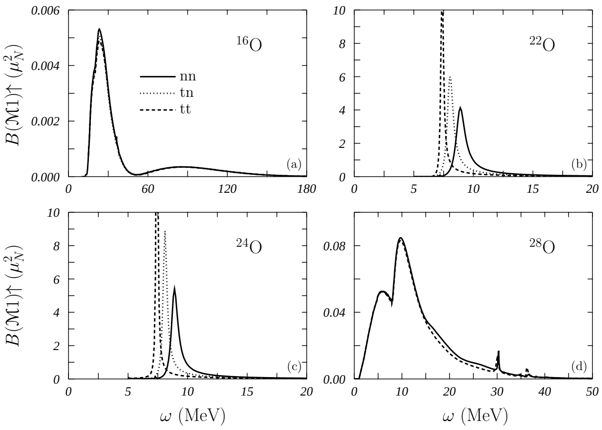

Figure 3. The CRPA results for the $B(\mathcal{M}1)\uparrow$ strengths of oxygen isotopes. The different calculations are indicated by nn (obtained with the D1S interaction in both HF and CRPA calculations), tn (with D1ST interaction in the HF calculation and the D1S force in the CRPA one) and tt (with D1ST interaction in both HF and CRPA calculations).

tions the tensor effects are irrelevant when all the spin-orbit partner levels are occupied. The situation changes for ^{22}O and ^{24}O. In these cases, the effect of the tensor force consists in lowering the position of the peaks of the response. It is possible to identify two different sources of this effect. A first one is already present at the HF level, as we can see by comparing nn and tn results: the proton s.p. energies are affected by Otsuka [5,6] effect. This effect appears in nuclei where not all the spin-orbit partner levels of a certain type of nucleons (protons or neutrons) are occupied and affects the s.p. energies of the nucleons of the other type. Further we find another similar effect that applies to nucleons of the same type. The second source is a genuine RPA effect, as we deduce by observing the tt results, that is attractive in the 1^+ excitation.

The study of the tensor effect has been done also by investigating the electron scattering responses: the tensor force quenches the proton contribution, enhancing the role of the main neutron excitation.

The study of the 1^+ excitation has been carried on also for calcium isotopes. The main features pointed out in the discussion regarding the oxygen isotopes have been found also in this case.

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