Charge exchange excitations with finite range interactions

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

[1]Dipartimento di Matematica e Fisica “E. De Giorgi”, 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 study of spin-isospin excitations in neutron-rich nuclei is presently an important problem not only from the nuclear structure point of view but also for the special role they play in many astrophysical processes. Many fundamental issues depend on our quantitative understanding of phenomena like beta decays of nuclei, nuclear electron capture or the r-process in nucleosynthesis. It is desirable to have theoretical models which can describe the data wherever they can be measured and which can predict the properties related to spin-isospin excitations in systems too short-lived to allow for experimental studies. It has been known that the random phase approximation (RPA) is an appropriate microscopic model for charge-exchange giant resonances [1]. The self-consistency is an extremely important requirement for the analysis of long isotopic chains toward the drip line and the predictions of new collective modes in unstable nuclei without introducing any adjustable parameter. Recently many studies have been conducted with the zero-range Skyrme interaction for the charge-exchange excitations [2], [3] and zero-range tensor terms were introduced to study the effects of tensor forces on the Gamow-Teller (GT) transitions in ^{90}Zr and ^{208}Pb (Refs.[4], [5]) and on the charge-exchange Spin-Dipole (SD) excitation in ^{208}Pb [6]. So far no studies of the charge exchange calculations have been conducted with a finite range interaction like Gogny interaction. In this work we have analysed the SD and GT excitation in ^{90}Zr and ^{208}Pb with finite range interactions with and without tensor channels and we have extracted informations about neutron skin thickness and on the effects of the tensor. Here we present only a selection of our results refferred to ^{90}Zr nucleus. We have used three different interactions: the D1M [7], the D1MT [8] and the D1ST2a [9]. Tensor terms of the interaction are present in the last two forces. In particular the D1MT has a tensor-isospin channel only, the D1ST2a also a pure tensor channel.

The SD operator is defined as:

$$\hat{A}_{\pm} = \sum_{im\mu} t^i_{\pm} \sigma^i_m r_i Y^{\mu}_1(\hat{r_i}), \tag{1}$$

where $t_3 = t_z$, $t_{\pm} = (t_x \pm i t_y)$ are the isospin operators and σ the Pauli matrix operator acting on the spin variable. The model independent sum rule for the SD operator can be written as:

$$A_- - A_+ = \frac{9}{4\pi}(N < r^2 >_n - Z < r^2 >_p), \tag{2}$$

that is the difference between the mean square radius of neutrons and protons with weighted with the neutron and proton numbers. For the GT operator

$$\hat{A}_{\pm} = \sum_{im} t^i_{\pm} \sigma^i_m \tag{3}$$

the sum rule for a parent nucleus with Z protons and N neutrons is the Ikeda sum rule:

$$A_- - A_+ = 3(N - Z). \tag{4}$$

In Table 1 we show the sum rule values A$_-$ − A$_+$ compared with the equations (2) and (4). In all the case the sum rules are properly exhausted.

λ^π	A$_-$	A$_+$	Δ A
		D1M	
SD	276.42	135.37	141.05
GT	31.10	1.12	29.98
		D1MT	
SD	277.82	139.85	137.91
GT	31.26	1.15	30.11
		D1ST2a	
SD	285.41	135.41	150.00
GT	30.72	0.82	29.90

Table 1
SD and GT sum rules. Experimental SD values: $A_- = 271 \pm 14$, $A_+ = 124 \pm 11$, $\Delta A = 147 \pm 13$. Theoretical GT value: $\Delta A = 30$

In Fig. 1 we present the RPA SD and GT strengths for the ^{90}Zr (p,n)^{90}Nb reaction smoothed by a Lorentzian function with a width of 1.0 MeV. The black lines are the SD responses

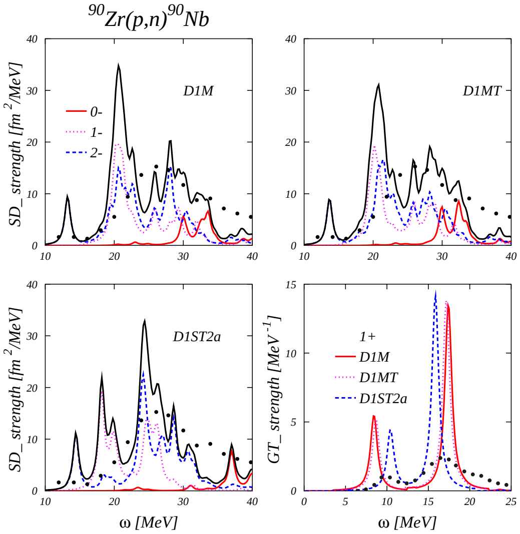

Figure 1. The responses for the SD and GT excitations. The experimental data shown by the black dots are taken from ref. [10] for the SD excitation and from refs.[11], [12], [13] for the GT.

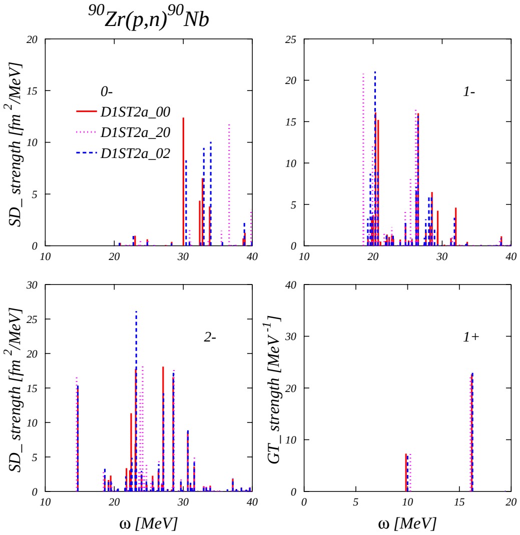

Figure 2. Tensor effects.

obtained summing the 0^-, 1^- and 2^- strengths. These lines are compared with the experimental data. In the fourth panel we present the GT response. We can see that the D1ST2a interaction is able to reproduces the position of the experimental maximum.

In Fig. 2 we present for all the multipole excitations, the effect of the tensor on the RPA calculations. All the calculations are obtained using the D1ST2a interaction in HF calculations and switching off the tensor channels in RPA calculations (D1ST2a00) or switching on only the tensor channel (D1ST2a20), or only the tensor-isospin channel (D1ST2a02). First of all we see that no sensitivity is shown to the isospin-tensor channel in all the cases. On the other hand we notice a significant effect of the pure tensor channel on the strength, in particular on the SD mode, more evident in 0^- and 2^- multipolarities.

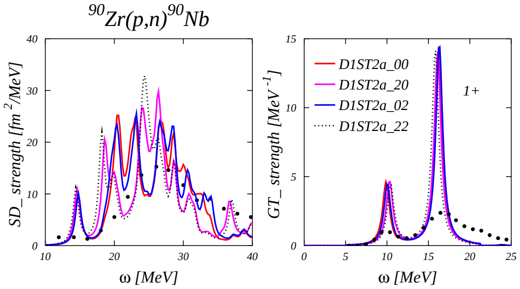

Figure 3. Global tensor effects compared with experimental data.

The global effect on the strengths is shown in Fig. 3 where the strengths are smoothed by a Lorentzian with a width of 1.0 MeV. The dotted black lines represent the case where both tensor channels are active. No effect can be seen in GT strength. Different is the case of the SD excitation: only with the pure tensor channel we can obtain a good comparison with the position of the maximum of the experimental data. These characteristics can be used as costraints to fix the tensor channels of the interactions on the available empirical informations.

REFERENCES

1. N. Auerbach, A. Klein, and N. Van Giai, Phys. Lett. B106, 347 (1981).
2. I. Hamamoto and H. Sagawa, Phys. Rev. C 62, 024319 (2000)
3. S. Fracasso and G. Colò, Phys. Rev. C 76, 044307 (2007).
4. C.L. Bai *et al.*, Phys. Lett. B 675, 28 (2009).
5. C.L. Bai *et al.*, Phys. Rev. C 79, 041301(R)(2009).
6. C. L. Bai *et al.*, Phys. Rev. Lett. 105, 072501(2010).
7. S. Goriely, S. Hilaire, M. Girod, S. Peru, Phys. Rev. Lett. 102 (2009) 242501.
8. M. Anguiano, G. Co', V. De Donno, A. M. Lallena , Phys. Rev. C 83 (2011) 064306.
9. M. Anguiano, M. Grasso, G. Co', V. De Donno, A. M. Lallena, Phys. Rev. C 86 (2012) 054302
10. K. Yako, H. Sagawa, H. Sakai,
11. T. Wakasa, M. Okamoto, M. Dozono, *et al.*, Phys. Rev. C 85 (2012) 064606.
12. T. Wakasa, H. Sakai, H. Okamura, *et al.*, Phys. Rev. C 55 (1997) 2909.
13. T. Wakasa, M. Ichimura, H. Sakai, Phys. Rev. C 72 (2005) 067303(R).