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Short note

The low-lying isoscalar giant dipole resonance

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Abstract. This short note is aimed to comment on the recently observed low component of the isoscalar giant dipole resonance in connection with the theoretical predictions made by microscopic and hydrodynamical models.

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Very recently, isoscalar giant dipole resonances (ISGDR) in the magical nuclei ^{90}Zr, ^{116}Sn and ^{208}Pb were investigated by inelastic scattering of 240 MeV α-particles at small angles. The α-particles beam was produced by the Texas A& M K500 superconducting cyclotron, the experimental findings being reported in a first version in ref. [1] and shortly after in a second version with additional data [2]. The authors concluded that the isoscalar $E1$ strength distribution in each nucleus contains a narrow component at $E_x \approx 72/A^{1/3}$ MeV which covers 15–28% of the total strength. There was also found a broad component at $E_x \approx 114/A^{1/3}$ MeV. The object of the present short note is to comment on the nature of the low-lying component of the ISGDR in light of the theoretical predictions.

In a series of very recent publications [3,4], the group of Münich calculated the ISGDR structure of the same nuclei as those investigated by the Texas A& M group at College Station, in the framework of a fully consistent relativistic random phase approximation. In agreement to the experiment they obtained a high-lying and a low-lying region of noticeable strength of the ISGDR. They suggested that the low-lying component might correspond to the putative "toroidal giant dipole resonance" or dipole torus mode (DTM). This kind of collective excitation for spherical nuclei can be described from a classical point of view as an in-phase motion of protons and neutrons along closed stream lines, which by rotation around the nucleus axis are generating tori. In classical hydrodynamics a similar kind of vortical flow is known under the name of Hill's vortex [5]. It was pointed out for the first time in ref. [6] that in the framework of nuclear hydrodynamics, a new non-irrotational state of the dipole electric type, with isospin $T = 0$, is occuring at energy $68/A^{1/3}$ MeV. Essential was that this state is related to the term multiplying the squared momentum transfer $k = \omega/c$ in the expansion of the dipole transversal electric form factor, known under the name of toroidal dipole moment [7]. Later on, using the method of moments of the Wigner function [8] it was obtained for the same case, *i.e.* spherical nuclei with sharp-edge surface, a 1^-, $T = 0$ resonance at $65.6/A^{1/3}$ MeV, which is very close to the one computed earlier in [6]. This was to be expected since both formalisms were based on semiclassical arguments.

Reference [9] was probably the first paper in the literature dedicated exclusively to the study of the DTM. Using the "thirteen moments approximations" of the nuclear fluid dynamics, we predicted the energy of the DTM, derived its electric form factor and evaluated its contribution to the cross-section of photoabsorbtion. It is neceessary to mention that at that time, the most recent experimental data abvailable in the literature on the dipole electric isoscalar resonances were those of the Groeningen group. According to [10], a low-energy, $1\hbar\omega$, 1^-, $T = 0$ resonance, was observed using the $(\alpha, \alpha'\gamma)$ reaction at 0°. Our estimate of 1992, lead us to the conclusion that DTM is different from the low-energy resonance $1\hbar\omega$ reported by Poelhekken *et al.* We interpreted the DTM as a $2\hbar\omega$ isoscalar dipole resonance. In the summary of our paper we also noted that *"...the torus excitation is not related to the spin and isospin degrees of freedom . This mean that the measurements with isoscalar spinless probes is presumed to be more preferable"*.

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Table 1. The lower component ISGDR energy centroids in MeV reported in experiment (Exp) and predicted by microscopical (ThII) and hydrodynamical models (ThI).

A	Exp [2]	ThI [6,8,9]	ThII [4]
^{208}Pb	12.2 ± 0.6	11–14.3	9.6–9.8
^{116}Sn	14.7 ± 0.5	13.3–17.4	11.5–12
^{90}Zr	16.2 ± 0.8	14.5–18.9	11.7–13.2

In table 1 we summarized the experimental values of the ISGDR energies reported in ref. [2] and the theoretical predictions given by the various theoretical approaches. As one can see the predictions made by the hydrodynamical models [6,8,9] are closer to the experimental values of Clark *et al.* The centroids predicted by the microscopic model of refs. [3,4] lie outside the range predicted by the macroscopic models and by 1.5–3 MeV lower than the experimental centroids. At this point one should mention the microscopical calculations performed almost two decades ago by Serr *et al.* [11] within the RPA method with the Skyrme-type interaction SGII. For the case ^{208}Pb only one 1^-, isoscalar collective vibrational state was obtained using an excitation operator $r^3 Y_{1\mu}$, which however was not corrected for the center-of-mass motion like in [6,9,4]. This state is located at 24.4 MeV and is of compressional nature. The recent calculations of Vretenar *et al.* [4] are providing a value between 14.3 and 15.6 MeV, whereas the experiment [2] reported a value of 19.9 MeV, which obviously lie between the two predicted centroids of the microscopical calculations. So even for the high-lying ISGDR, the microscopical centroids are not in a very good agreement with experiment.

In conclusion one could say that the recently computed low-lying component of the ISGDR [4], which is claimed to be of a toroidal-like resonance, is not in a very good agreement with the experimental observations. It seems that the older hydrodynamical calculations are providing ranges of values of the energy centroids which contain inside the experimental values.

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References

1. H.L. Clark *et al.*, Nucl. Phys. A **649**, 57c (1999).
2. H.L. Clark, Y.-W. Lui, D.H. Youngblood, Phys. Rev. C **63**, 031301(R) (2001).
3. D. Vretenar, A. Wandelt, P. Ring, Phys. Lett. B **487**, 334 (2000).
4. D. Vretenar, N. Paar, P. Ring, preprint `http://xxx.lanl.gov/nucl-th/0107024`.
5. Sir Horace Lamb, *Hydrodynamics*, 6th ed. (Cambridge University Press, 1932) p. 245.
6. S.F. Semenko, Sov. J. Nucl. Phys. **34**, 356 (1981).
7. V.M. Dubovik, A.A. Cheshkov, Sov. J. Part. Nucl. **5**, 318 (1975).
8. E.B. Balbutsev, I.N. Mikhailov, J. Phys. G: Nucl. Phys. **14**, 545 (1988).
9. S.I. Bastrukov, Ş. Mişicu, A.V. Sushkov, Nucl. Phys. A **562**, 191 (1993).
10. T.D. Poelhekken, S.K.B. Hesmondnalhg, H.J. Hofmann, A. van der Woude, M.N. Harakeh, Phys. Lett. B **287**, 432 (1992).
11. F.E. Serr, T.S. Dumitrescu, T. Suzuki, C.H. Dasso, Nucl. Phys. A **404**, 359 (1983).