On the "authentic damping mechanism" of the phonon damping model

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(Received 11 October 2001; published 5 February 2003)

Some general features of the phonon damping model are presented. It is concluded that the fits performed within this model have no physical content.

DOI: 10.1103/PhysRevC.67.029801 PACS number(s): 21.60.−n, 24.30.Cz

In a recent article [1], the phonon damping model (PDM) has been applied for a description of the giant dipole resonance (GDR) and pygmy dipole resonance (PDR) in oxygen and calcium isotope chains, from double-magic to exotic isotopes. It has been argued that it provides much better agreement with the GDR photoabsorption cross sections (PCS's) than more advanced, microscopic, approaches. The main purpose of the present Comment is to understand why it is so.

The PDM is a model in which the mode under discussion, the phonon Q (with the excitation energy ω) and its coupling to N uncorrelated $1p1h$ states are described phenomenologically. The $1p1h$ spectrum is calculated microscopically. Let us start with the PDM application to double-magic nuclei.

A key starting point of almost all PDM calculations is an approximation that the phonon and any $1p1h$ state interact with an equal strength f_1, a model parameter. From a microscopic point of view, this assumption is very far from reality.

The general features of the Q fragmentation due its interaction with some other states $|\alpha\rangle$ may be found in textbooks (see, e.g., Appendix 2D in Ref. [2]). Then, the second moment for the phonon distribution in the PDM has a simple analytical form:

$$W_2=(f_1)^2 \;\; N. \tag{1}$$

Equation (1) is exact and independent of the details of the spectrum E_α. However, the shape of the distribution does depend on it, having the Breit-Wigner (BW) form if the energies E_α are equidistant [2]. Again, the nature of $|\alpha\rangle$ (whether they are $1p1h$ or $npnh$ states) is not essential. It is only important that the energy scales of ω, f_1, and E_α are of the same order.

This means that the BW form for the GDR within the PDM is a direct consequence of the assumption that the coupling matrix element is the same for all $1p1h$ states. When a realistic $1p1h$ spectrum is used in the PDM calculations, the BW shape is disturbed. To check how strong this disturbance is in general, the PDM calculations with random values of E_α from 0 to 50 MeV have been performed. The purpose of these calculations is to reproduce the Lorentz line for the GDR PCS in some hypothetical nucleus with $E_0=15.0$ MeV and $\Gamma=4.3$ MeV by fitting the PDM parameters f_1 and ω. The results of calculations with an additional smearing parameter $\varepsilon=0.5$ MeV (as in Ref. [1] for the oxygen chain) are represented in Fig. 1 by thick lines. Cross sections are plotted in arbitrary units. For the amplitude adjustment, a free parameter c_1 is available in the PDM.

The calculations show that the PDM results for the GDR PCS converge rather fast to the Lorentz line as N increases, even for a random E_α spectrum. To exclude any accidental coincidence, the calculations have been repeated with several different random spectra. Qualitatively, the results are similar. So, any traces of the PDM "microscopy" vanish if N is not small.

Adopting the Lorentz shape for the GDR PCS as the model input, it is not surprising that the PDM "describes" the photoabsorption data better than microscopic models in which such physical observable as the GDR width is calculated. But, to understand whether there is any physical content behind the PDM fits, one needs to analyze the physical meaning of the PDM parameters and/or check how it describes some independent data.

In microscopic perturbative approaches, the matrix element of the interaction between $1p1h$ configurations and a phonon tends to increase when a larger basis of $1p1h$ states is employed. This is due to the increase of the phonon's collectivity. However, in the PDM, the collectivity of Q does not depend on the $1p1h$ basis, and the strength parameter f_1 decreases with increasing N. Roughly, it goes as $f_1\sim 1/\sqrt{N}$, since W_2 in Eq. (1) is more or less fixed by the data to which f_1 is adjusted. Since f_1 is determined not according to its

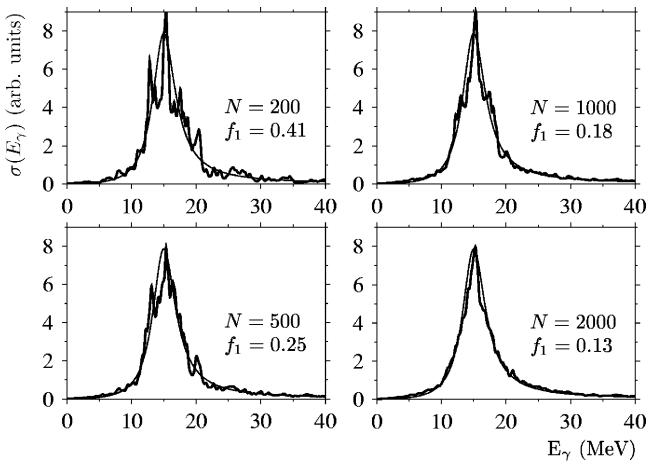

FIG. 1. The PDM calculations of the GDR PCS with a random spectrum E_α (thick line) in comparison with the Lorentz distribution (thin line). See text for details.

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physical meaning, but only to fit the data, this procedure leads Dang *et al.* into a contradiction in principle with rather general arguments on the properties of the system under consideration. Indeed, the strength of the interaction between any configuration $|\alpha_0\rangle$ and Q is determined not by their physical properties but only by the number of other configurations $|\alpha\rangle$. The authors define it as ''microscopic description of damping.''

Another misleading statement in Ref. [1] is that the coupling to higher-order graphs are included effectively in the strength parameter f_1 of the lowest-order graphs. This is not true because these are two different physical processes.

Let us briefly consider the PDM results in Ref. [1]. The physics of the essential difference of the GDR width in ^{40}Ca and ^{48}Ca is still an open question. Dang *et al.* report an agreement with the data in both nuclei. The agreement for ^{48}Ca is obtained by renormalizing f_1 by 34% (note that f_1 is fitted up to four digits). But it is difficult to learn anything from this agreement when the true physical meaning of f_1 in the PDM model is ignored.

The extention of the PDM to open-shell nuclei in Ref. [1] by including pairing for the $1p1h$ states only stresses the internal PDM problems. The lack of the PCS data for these nuclei, except for ^{18}O, allows Dang *et al.* to keep f_1 fixed from ^{18}O to ^{24}O, from ^{42}Ca to ^{46}Ca, and from ^{50}Ca to ^{60}Ca as an assumption. But the data available for ^{16}O and ^{18}O already forces the authors to reduce f_1 by $\sim 25\%$ from ^{18}O to ^{16}O to achieve an agreement in both (see Ref. [3]). They claim that the renormalization is to compensate for the enlargement of the configuration space in ^{18}O due to the pairing. But a smaller configuration space should lead to a larger f_1 and not vice versa [see Eq. (1)]. Again, considering the physical meaning of f_1, there are no physical grounds for such renormalization.

The properties of the PDR are considered as independent data for the PDM calculations. Although Dang *et al.* conclude a ''consistent and quantitative description'' of this resonance, it is difficult to find any agreement of the calculation with the fine structure of the PCS at low energies presented in Fig. 4 of Ref. [1], especially for ^{18}O. For both ^{40}Ca and ^{48}Ca, high-resolution data below 10 MeV are available [4]. The PDM results are compared to these data in Ref. [1] for ^{48}Ca, but not for ^{40}Ca. Such selective comparison may mislead the reader. The PDM predictions for ^{40}Ca were published before the data in Ref. [5]. We find that the PDR exhausts 0.3% of the energy weighted sum rule in this nucleus. The same value obtained experimentally in ^{40}Ca equals about 0.007% after the two-phonon candidate $[2_1^+ \times 3_1^-]_{1^-}$ at 6.950 MeV, which is outside the PDM space, is excluded from consideration. The difference by a factor of 40 cannot be defined as quantitative agreement.

The failure to describe the PDR by the GDR spreading to lower energies, as the PDM does, has been sufficiently discussed in the literature (see, e.g., Refs. [4,6] as latest references). In microscopic models, the PDR is associated with the excitation of the lowest $1p1h$ 1^- configurations [6–10]. These configurations are included in the PDM model space but their $B(E1)$ values are set to zero to avoid an obvious PDM problem with double counting.

To conclude, it is not clear what Dang *et al.* mean by the ''consistent and quantitative'' description of the GDR within the PDM in Ref. [1]. The possibility to fit the PCS by a Breit-Wigner shape, as a phenomenological *ad hoc* model input, is not under question. For those nuclei for which the data is available and presented, the PDM needs different sets of the model parameters that are fitted to the described physical observables (three parameters for three observables). Taken together with the above analysis of the physical meaning of the strength parameter, this makes the physical content of the PDM calculations very doubtful. The predictive power of this model is also doubtful and it makes little sense to use it for such purpose. The nature of the PDR in the PDM contradicts the microscopic understanding of this resonance, and the conclusion that this model describes the PDR properties at a quantitative level is not justified.

It is not possible to agree that the PDM fits confirm ''the authentic damping mechanism of giant resonances'' as ''the result of coupling between collective phonon and noncollective p-h configurations'' (with equal matrix elements) see also Ref. [11].

The author thanks Professor J. Weil for a careful reading of the manuscript.

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