On the Nature of the Pygmy Dipole Resonance

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In the last years the properties of collective states in neutron-rich nuclei have been studied with special attention to the presence of dipole strength at low excitation energy. This strength has been often associated to the possible existence of a new collective mode of new nature: Pygmy Dipole Resonance (PDR).

From a theoretical point of view the presence of this low-lying strength is predicted by almost all microscopic models, ranging from Hartree-Fock plus RPA with Skyrme interactions to relativistic Hartree-Bogoliubov plus relativistic quasiparticle RPA. All these approaches predict similar amounts of strength, but often disagree on the collective (or not) nature of these states, on their fragmentation and on their isoscalar/isovector contents.

We will use the results obtained in the simplest discrete non-relativistic RPA approach with Skyrme interactions, consistently used both at the level of mean-field Hartree-Fock and of RPA. We have performed calculations for several Sn isotopes.

One important question is how much collective are these dipole states. One measure of the collectivity is the number of particle-hole components entering in the RPA wave-function with an appreciable weight. Such criterion does not take into account the other fundamental concept that underlies collectivity that is coherence. Both aspects have to taken into account in order to establish whether the state under study is collective or not. From our novel analysis, it emerges that the low lying structures are related to the co-operative, although not coherent, effect of several p-h excitations.

More precise information on the specific nature of the states is contained in their transition densities. For the PDR state the neutron and proton components oscillate in phase in the interior region, while in the external region only the neutrons give a contribution to both isoscalar and isovector transition densities which have the same magnitude. Such behaviour, which has been found also in all the other microscopic approaches, can be taken as a sort of definition of PDR.

This brings in the question of the interpretation of this state, macroscopically described as the oscillation of the neutron skin with respect to the proton-neutron cores. Calculations done along these lines show that, although some similarities are present, a full interpretation of the state in the above macroscopic terms is not obvious. It should be noted that the macroscopic picture should also involve a collective nature of the state, which was not found to be fulfilled at least in our calculations.

From an experimental point of view the evidence for these states has come from Coulomb excitation processes. As known, these can only provide values of the multipole B(Eλ) transition rates. Much more information, like wave function and transition densities, can be obtained by resorting to reactions where the nuclear part of the interaction is involved. This can be done because of the strong isoscalar component of the PDR state. By tuning the projectile mass, charge, bombarding energy and scattering angle one can alter the relative role of the nuclear and Coulomb components, as well as of the isoscalar and isovector contributions.

Our calculations show that valuable information on the nature of the PDR can be obtained by excitation processes involving the nuclear part of the interaction. The use of different bombarding energies, of different combinations of colliding nuclei involving different mixture of isoscalar/isovector components, together with the mandatory use of microscopically constructed form-factors, can provide the clue to reveal the characteristic features of these states.