Microscopic description of low-lying vibrations and giant resonances

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Nuclei can take all sorts of shapes: spheres, rugby ball, discus, pear, banana... They can also oscillate between these shapes, leading to nuclear vibrations. The description of these vibrations is a fundamental test of quantum many-body models. In addition, vibrations strongly affect nuclear reactions such as fusion and fission. It is then crucial to have a proper description of these vibrations in order to get a deep insight into such reaction mechanisms.

Our basic tool is the time-dependent Hartree-Fock (TDHF) theory) [1] and its extensions including pairing correlations [2]. The TDHF approach describes the time-dependent motion of each nucleon wave-function, assuming that each nucleon moves freely in a mean-field generated by all the other nucleons. In its linearised version, it is fully equivalent to the RPA which is a standard tool to study nuclear vibrations.

Several modern TDHF codes using realistic Skyrme interactions are now available. In order to study nuclear vibrations, these codes are used to compute the time evolution of various multipole moments after a small excitation of the nucleus. The linear response theory is then used to extract the energies and transition strengths of the first phonon of these vibrations. This approach allows to study both low-lying collective states as well as giant resonances, including their direct decay via nucleon emission [3]. It is also possible to investigate the origin of non-linearities in nuclear vibrations from the coupling between various types of vibrations [4,5].

We will present an overview of recent applications to low-lying octupole, quadrupole, and pairing vibrations as well as direct decay and non-linearities in giant resonance. The impact of these vibrations on fusion [6] and fission [7] processes will be also discussed.

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