Isoscalar and isovector giant resonances in ^{40}Ca and ^{48}Ca

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The study of collective modes in nuclei has been the subject of extensive theoretical and experimental studies during several decades, since it contributes significantly to our understanding of bulk properties of nuclei, their non-equilibrium properties and properties of the nuclear force. Of particular interest is the equation of state (EOS), an important ingredient in the study of properties of nuclei at and away from stability, structure and evolution of compact astrophysical objects, such as neutron stars and core-collapse supernovae, and of heavy-ion collisions. To extend our knowledge of the EOS beyond the saturation point of the symmetric NM (SNM), an accurate value of the NM incompressibility coefficient K_{NM} is needed. An accurate value of the density dependence of the symmetry energy coefficient, J, is needed for the EOS of asymmetric NM. In this work we consider the high sensitivity of the strength function distributions of giant resonances to bulk properties of NM, such as K_{NM} and J. It is well known that the energies of the compression modes, the isoscalar giant monopole resonance (ISGMR) and isoscalar giant dipole resonance (ISGDR), are very sensitive to the value of K_{NM}. Also the energies of the isovector giant resonances, in particular, the isovector giant dipole resonance (IVGDR), are sensitive to the density dependence of J, commonly parameterized in terms of the quantities L and K_{sym}, which are directly related to the derivatives and the curvature of J at the saturation density. Furthermore, information on the density dependence of J can also be obtained by studying the isotopic dependence of strength functions, such as the difference between the strength functions of ^{40}Ca and ^{48}Ca. We note that the value of the neutron-proton asymmetry parameter $\delta = (N-Z)/A$ increases from ^{40}Ca to ^{48}Ca by a value of 0.167 which is significantly larger than the change of 0.087 between ^{112}Sn and ^{124}Sn.

In this work we adopt the microscopic approach of fully self consistent Hartree-Fock (HF) based random phase approximation (RPA), with specific interactions. It is important to note that ground state properties of nuclei can be well described by HF approximation, using an effective nucleon-nucleon interaction, such as the Skyrme type interaction, with parameters obtained by a fit to a selected set of experimental data on binding energies or radii of nuclei. It has also been demonstrated that HF-based RPA nicely reproduces the properties of low lying collective states as well as of giant resonances. We have carried out fully self-consistent Hartree-Fock (HF) based RPA calculations of the isoscalar ($T = 0$) giant monopole resonance (ISGMR), dipole (ISGDR), quadrupole (ISGQR), and the octopole (ISGOR) strength functions, and for the isovector ($T = 1$) giant monopole resonance (IVGMR), dipole (IVGDR), quadrupole (IVGQR) and octopole (IVGOR) strength functions, for ^{40}Ca and for ^{48}Ca, using a wide range of over 15 commonly employed Skyrme type interaction. These interactions, which were fitted to ground state properties of nuclei are associated with a wide range of nuclear matter properties such as incompressibility coefficient K_{NM} = 200 - 255 MeV, symmetry energy J = 27 - 37 MeV and effective mass m^* = 0.6 - 1.0. We compare the theoretical values to the available experimental data on the isoscalar and isovector giant resonances in ^{40}Ca and ^{48}Ca and discuss our results, considering, in particular, the issue of self consistency and the sensitivity of the giant resonances energies to various bulk properties of NM.

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