Nuclear giant resonances

The phenomenology of nuclear giant resonances, in which the reaction cross section is strongly peaked at a specific energy, has been crucial to understanding nucleons of exotic, neutron-rich nuclei will be necessary to better constrain the values of these properties. The behavior of the symmetry energy at high density and neutron asymmetry is particularly relevant to the interior of neutron stars, and gives the large-scale structure of stellar evolution and properties of compact objects.

Hartree-Fock theory

Hartree-Fock theory addresses the complexity of the nucleus by assuming that nucleons interact via a mean-field potential $V$ caused by the nuclear density, $\rho$, as follows:

$$\rho = \int \rho(x) dx$$

where $\rho$ is the spin and isospin quantum numbers, respectively. The Hartree-Fock equation can be written as:

$$\frac{\partial^2 \psi}{\partial r^2} + \left( E - V(r) \right) \psi = 0$$

where $E$ is the energy, and $V(r)$ is the potential energy. The Hartree-Fock equation is then used to calculate the single-particle wavefunctions, $\psi(x)$, which are then used to calculate the single-particle energy levels, $E_n$, and the single-particle wavefunctions, $\psi_n(x)$.

Calculations and results

All calculations were carried out using the self-consistent Hartree-Fock multipole approximation [8,19]. Energy density at saturation $E_{\text{sym}}$ and the charge density $\rho^c$ at saturation $\rho^c_s$ were also calculated. The Skyrme interaction used is a phenomenological parameterization and is consistent with the calculated values of these properties. The behavior of the symmetry energy at high density and neutron asymmetry is particularly relevant to the interior of neutron stars, and gives the large-scale structure of stellar evolution and properties of compact objects.

Random-phase approximation

Random-phase approximation (RPA) is a method for calculating the properties of many-body systems. In this approximation, the Hamiltonian is divided into a mean-field part and a fluctuation part, and the single-particle wavefunctions are calculated from the mean-field potential. This is then used to calculate the single-particle energy levels and the single-particle wavefunctions.

Conclusions and outlook

The PES09 energy $E_{\text{sym}}(\rho)$ of the double-magic, neutron-rich nucleus $^{132}\text{Sn}$ has been calculated using the Hartree-Fock-random-phase approximation theory, for a variety of commonly used Skyrme interactions. All calculations were carried out using a method similar to the nucleon-nucleon interactions. The calculations were carried out using the self-consistent Hartree-Fock multipole approximation [8]. The Skyrme interaction used is a phenomenological parameterization and is consistent with the calculated values of these properties. The behavior of the symmetry energy at high density and neutron asymmetry is particularly relevant to the interior of neutron stars, and gives the large-scale structure of stellar evolution and properties of compact objects.

References


Acknowledgements

The support of the Texas A&M Cyclotron Institute, in particular Prof. Yonathan and the other coordinators of the REU program, is gratefully acknowledged. B.R. would also like to thank M. Anders for providing data on the Skyrme interactions and nuclear matter properties. This research was supported by the National Science Foundation, Grant 1205329.