Thesis abstract Mingya Duan

« Response functions of neutron-star and supernova matter»

Neutron stars are dense objects that are produced in core collapse supernova explosions. For the modeling of the supernova and of the subsequent cooling of the neutron star, neutrino absorption, emission, and scattering rates play a crucial role. In a large part of these astrophysical systems, nuclei are completely dissolved. Then the neutrino rates can be directly related to the response functions of nuclear matter, computed at the relevant density, asymmetry, and temperature.

This thesis develops first the random-phase approximation (RPA) model for the response functions with Skyrme effective interactions in asymmetric nuclear matter and finite energy transfer, and relates the neutrino scattering rate to the response functions. Then, the energy and angle dependence of neutrino scattering rates in proto-neutron star and supernova matter within Skyrme RPA are studied.

Many previous Skyrme interactions predict that neutron Fermi velocity exceeds the speed of light at densities that neutron stars can reach. To solve this problem and continue the computation of neutrino rates for astrophysical simulations at high densities using Skyrme functional theory, we then explore the construction of the new Skyrme-like functionals. Sky1 and Sky2 are obtained by including constraints from microscopic calculations of the effective mass in addition to binding energies and charge radii of finite nuclei and different microscopic equations of state of pure neutron matter. To test whether they are suitable for describing finite nuclei and neutron star matter, we compute properties of finite nuclei and infinite nuclear matter, including neutron star matter, and present them in this thesis.

Also, we consider the Skyrme interaction as a density-functional rather than a density-dependent two-body force to explore the determination of the spin-dependent terms of the new Skyrme-like functionals. The parameters of the spin-dependent terms are determined by fitting the Landau parameters G_0 and G'_0 in neutron matter and symmetric nuclear matter to the results of the microscopic Brueckner-Hartree-Fock theory.

Finally, we develop the improved fitting protocol for the new Skyrme-like forces by adding other constraints, such as the equation of state of symmetric nuclear matter at high density, the onset of the spurious instability in the spin-0 channel, the splitting between the spin up and down nucleon effective masses in the polarized matter, obtaining better new functionals, Sky3s and Sky4s. The response functions and neutrino scattering rates of neutron-star matter can be computed with the new functionals having realistic effective masses and Landau parameters.