Abstract

Neutron stars, produced as remnants of supernova explosions, can be viewed as ideal astrophysical laboratories in the view of theoretical studies of matter in extreme conditions. They are highly compact stars with mass as high as the sun's but with radii around ~ 10 km. Consequently, the interior of these compact object systems proves to be the only laboratory to study matter at high-density regimes. Hence, the astrophysical observations of neutron stars directly or indirectly related to the dense matter properties and composition come to the aid of dense matter study.

The recent observations of massive neutron stars ($\sim 2\ M_{\odot}$) along with the mass–radii measurements by Neutron star Interior Composition ExplorER (NICER) space mission, gravitational-wave observables (tidal response) have put sturdy bounds on the equation of state at high matter densities. In addition, they provide vital information regarding the inclusion of exotic particle species into neutron star matter. The discovery of these massive compact stars opens up the possibility of exotic matter appearance in their respective interiors.

This thesis considers the inter-particle interactions in the dense matter within the phenomenological relativistic mean-field model framework. We present the study implementing the coupling parameters of non-linear Walecka type and density-dependent schemes. This work explores the new aspects of the possibility of exotic matter (viz. heavier strange, non-strange baryons, meson condensations) with a focus on explaining the matter in $\geq 2\ M_{\odot}$ neutron stars. We find that (anti)kaon condensation (through first and second-order phase transition) is, in fact, possible in massive compact stars for an allowed range of (anti)kaon optical potentials. The effect of (anti)kaon condensation on the properties of massive stars that develop hypernuclear cores with an admixture of Δ-resonances is also studied. We report that larger values of (anti)kaon and Δ potentials in symmetric nuclear matter lead to an extinction of $\Xi^{-,0}$ particles. Additionally, the inclusion of heavier baryons and (anti)kaons in dense matter lead to narrow bounds on the (anti)kaon optical potential range. The constraints from gravitational-wave observations demand the dense matter to be highly compact (or softer equation of state). We find that the inclusion of Δ-baryons proves to be a viable option in explaining this matter behaviour. Nuclear symmetry energy has a crucial role in describing asymmetric dense matter interior to compact object systems. Based on our study, we also report that lower $L_{\mathrm{sym}}(n_0)$ favours the early appearance of Δ-resonances in comparison to hyperons leading to the latter's threshold at higher matter densities. Dense matter comportment in the presence of intense magnetic fields is also explored in this thesis, and it was perceived that the alterations are observed to be in a number of microscopic properties, which can be traced back to the occupation pattern of Landau levels.