

Stony Brook University The Graduate School

Doctoral Defense Announcement

Abstract

Thermal Effects in Supernova Matter

By

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A crucial ingredient in simulations of core collapse supernova (SN) explosions is the equation of state (EOS) of nucleonic matter for densities extending from 10^{-7} fm^{-3} to 1 fm^{-3} , temperatures up to 50 MeV, and proton-to-baryon fraction in the range 0 to 1/2. SN explosions release 99% of the progenitor star's gravitational potential energy in the form of neutrinos and, additionally, they are responsible for populating the universe with elements heavier than ^{56}Fe . Therefore, the importance of understanding this phenomenon cannot be overstated as it could shed light onto the underlying nuclear and neutrino physics.

A realistic EOS of SN matter must incorporate the nucleon-nucleon interaction in a many-body environment. We treat this problem with a non-relativistic potential model as well as relativistic mean-field theoretical one. In the former approach, we employ the Skyrme-like Hamiltonian density constructed by Akmal, Pandharipande, and Ravenhall which takes into account the long scattering lengths of nucleons that determine the low density characteristics. In the latter, we use a Walecka-like Lagrangian density supplemented by non-linear interactions involving scalar, vector, and isovector meson exchanges, calibrated so that known properties of nuclear matter are reproduced. We focus on the bulk homogeneous phase and calculate its thermodynamic properties as functions of baryon density, temperature, and proton-to-baryon ratio. The exact numerical results are then compared to those in the degenerate and non-degenerate limits for which analytical formulae have been derived.

The importance of the correct momentum dependence in the single particle potential that fits optical potentials of nucleon-nucleus scattering was highlighted in the context of intermediate energy heavy-ion collisions. To this end, we explore the thermal properties of dense isospin-symmetric nucleonic matter using the schematic model constructed by Welke et al. in which the appropriate momentum dependence that fits optical potential data is built through finite-range exchange forces of the Yukawa type.

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