Equation of state under the conditions of NSE and the properties of collapsing stellar cores

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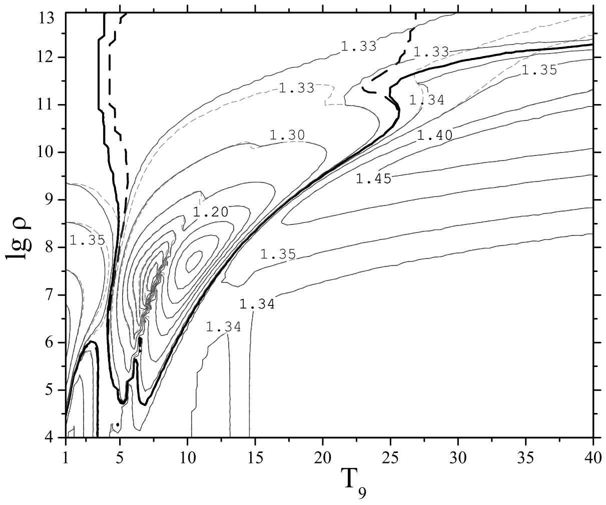

Figure 1: Levels of constant adiabatic index γ on the temperature-density plane for the neutron-to-proton ratio $\theta = 30/26$ (^{56}Fe) with (solid lines) and without (dashed lines) nuclear excitation [1].

We investigate the equation of state for stellar matter under the conditions of nuclear statistical equilibrium (NSE) in a wide range of thermodynamic parameters (temperature T, density ρ and neutron-to-proton ratio θ) specific for the gravitational collapse of massive stellar cores. First of all, we account for a variety of nuclei and try to adequately describe their properties especially such as a rapid increase of the number of nuclear excited states with temperature [1]. We suggest an algorithm that allows us to escape the overestimation of the nuclear partition functions at high temperatures and compare our results with other approaches available in literature. Figure 1 shows how the nuclear excited states modify the ravine of instability ($\gamma < 4/3$). The partition functions delay the nuclear dissociation during the collapse. At the same time, the rapid neutronization of stellar matter increases the neutron-to-proton ratio. Both effects shift the NSE composition to the state dominated by the neutron-rich nuclei whose properties are not well established yet. Moreover, we explore the non-ideal effects produced by the Coulomb interaction [2] and find that during the collapse stellar matter turns out to be in a state somewhere between weak and strong regimes of the Coulomb interaction. There exist domains in the space (T, ρ, θ) where nuclides with noticeably different charges may have comparable (and not negligible!) concentrations. The description of such a complicated multi-component and asymmetric system must be chosen with care to avoid nonphysical behavior of thermodynamic quantities. Our final goal is to explore how the aforecited effects influence the dynamics of the collapse and the parameters of resulting neutrino signal such as the temporal behavior of the neutrino spectra and luminosity.

References

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