Stellar Core Collapse and Exotic Matter

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In the process of a stellar core collapse leading a black hole formation, a central core becomes enough hot and dense for hyperons and quarks to appear. In order to compute the stellar core collapse and black hole formation, we use the numerical code of general relativistic ν-radiation hydrodynamics which solves the Boltzmann equation for neutrinos together with Lagrangian hydrodynamics under spherical symmetry. As an initial condition, the stellar model with 40 solar mass and solar metallicity from the evolutionary calculation [1] is adopted. To examine the effects of hyperons, we utilize the tables of EOS in Ref. [2], which are based on an $SU_f(3)$ extended relativistic mean field model and constructed as an extension of the EOS in Ref. [3]. Since whether the Σ-N interaction is attractive or repulsive is undetermined, we adopt the both of EOS sets with the potential depths $(U_\Lambda, U_\Sigma, U_\Xi) = (-30$ MeV, $+30$ MeV, -15 MeV) for the repulsive case and (-30 MeV, -30 MeV, -15 MeV) for the attractive case. As for the quark effects, we investigate the MIT bag model with the EOS in Ref. [3] as in Ref. [4]. In this model, the ambiguities of the interaction are encapsulated in one parameter called bag constant, B, and we examine $B = 90$, 150 and 250 MeV/fm^3.

In Figure 1, we show the time profiles of the central baryon mass density. The core is bounced once and then recollapses to a black hole. We can recognize that the time interval between the bounce and black hole formation gets shorter as we put additional degrees of freedom, hyperons or quarks. As for the hyperonic models, the black hole is formed earlier for the attractive case because Σ hyperons appear more easily and soften the EOS. On the other hand, for the quark models, the time interval of the lower bag constant case is shorter because the phase transition occurs lower density and trigger the black hole formation. Note that the density at the bounce of the model with $B = 90$ MeV/fm^3 differs from those of other models because the transition occurs already at the bounce. Since the duration of neutrino emission corresponds to the time interval between the bounce and black hole formation, we may be able to probe observationally the effects of hyperons and quarks using the difference of the time interval in future. Further details of this study can also be found in our recent paper [5].

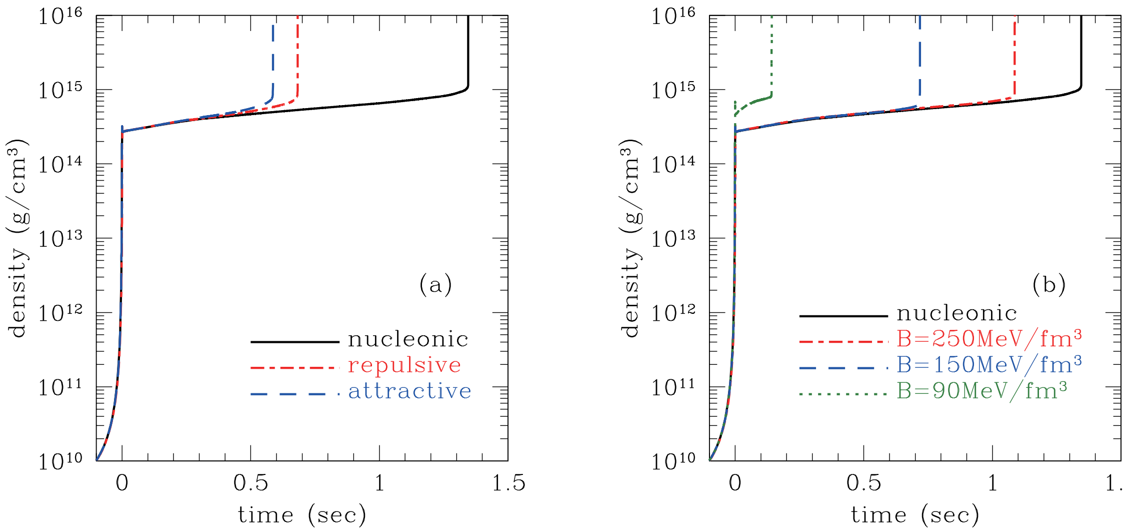

Figure 1: Time evolutions of the central baryon mass density for the collapse of models with *(a)* hyperons and *(b)* quarks. In both panels, the solid lines show the result for the model without hyperons and quarks.

References

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