Isospin- and momentum-dependent effective interactions for the baryon octet and the properties of hybrid stars

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We have extended the momentum-dependent interaction (MDI) for the nucleon-nucleon effective interaction in nuclear medium [1] to include the nucleon-hyperon and hyperon-hyperon interactions by assuming that they have the same density and momentum dependence as that for the nucleon-nucleon interaction [2]. The parameters in this extended MDI interaction (MDI-Hyp) were determined by fitting the empirical hyperon single-particle potentials in symmetric nuclear matter at its saturation density. As an example for the application of the extended MDI interaction, we have investigated the properties of hybrid stars that include not only the hyperon degrees of freedom but also those of quarks by taking into account the phase transition between the hadron and quark phases. Our results indicate that the extended MDI interaction can give a reasonable description of the properties of hypernuclear matter. We have also found that the equation of state (EOS) of hypernuclear matter is much softer than that of pure nuclear matter and that it becomes even softer if the hadron-quark phase transition is included. The masses and

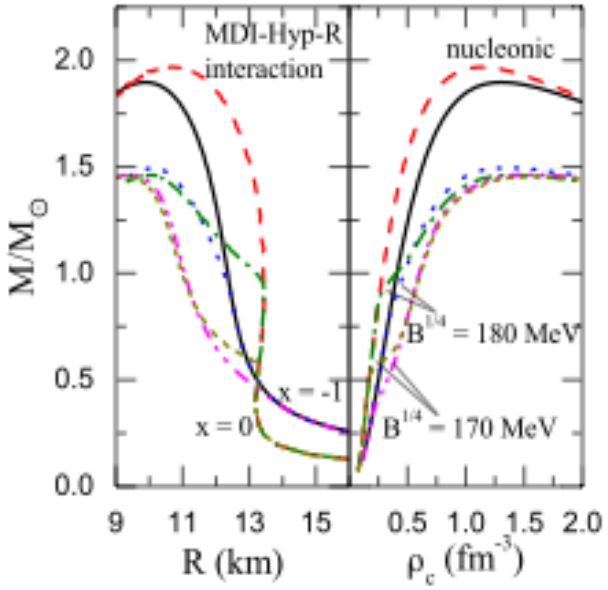

FIG. 1. The hybrid star mass as a function of radius (left panel) and central density (right panel) in the presence of the hadron-quark phase transition. Results from the MDI-Hyp-R interaction for the hadron phase with x=0 and x=-1 and the MIT bag model for the quark phase with $B^{1/4}$=180 MeV and 170 MeV are shown for comparison. Results from a pure nucleonic approach are also displayed.

radii of hybrid stars have also been studied with these EOSs, and they were found to remain reasonable after including hyperons and the hadron-quark phase transition as shown in Fig. 1 for a repulsive ΣN interaction (MDI-Hyp-R) and for both a soft (x=0) or a stiff (x=-1) nuclear symmetry energies as well as for different values for the bag constant B. We have further studied the effects of using attractive and repulsive ΣN interactions and different symmetry energies on the hybrid star properties. The results show that the appearance of the Σ hyperon in hybrid stars depends sensitively on the sign of the ΣN interaction with a repulsive ΣN interaction giving a higher critical density for the appearance of Σ hyperons. In addition, a stiffer symmetry energy usually leads to a larger fraction of hyperons in the hypernuclear matter. We have further found that both the low-density boundary of the hadron-quark phase transition and the EOS at high densities in hybrid stars are more sensitive to the bag constant than to the stiffness of the nuclear symmetry energy at high densities. This extended MDI interaction will also be very useful in transport models that simulate heavy-ion reactions in future radioactive beam facilities, particularly at the FAIR/GSI energies.

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[2] J. Xu, L.W. Chen, C.M. Ko, and B.A. Li, arXiv:1001.2239 [nucl-th].