Hyperon mixing and universal many-body repulsion in neutron stars

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Neutron stars with large masses $\sim 2M_\odot$ require the hard stiffness of equation of state (EoS) of neutron-star matter. On the other hand, hyperon mixing brings about remarkable softening of EoS. In order to solve this "Hyperon puzzle in neutron stars", a multi-pomeron exchange potential (MPP) is introduced as a model for the universal many-body repulsion in baryonic systems on the basis of the Extended Soft Core (ESC) baryon-baryon interaction. The strength of MPP is determined by analyzing the nucleus-nucleus scattering with the G-matrix folding model. The interactions in ΛN, ΣN and ΞN channels are shown to be consistent with experimental indications. The EoS in neutron-star matter with hyperon mixing is obtained from ESC in addition of MPP, and mass-radius relations of neutron stars are derived. The maximum mass is shown to reach $2M_\odot$ even in the case of including hyperon mixing by model-parameters determined by terrestrial experiments.

KEYWORDS: neutron star, EOS, hyperon mixing, hypernuclei . . .

1. Introduction

The observed masses of neutron stars J1614-2230 [1] and J0348+0432 [2] are given as $(1.97 \pm 0.04)M_\odot$ and $(2.01 \pm 0.04)M_\odot$, respectively. These large masses give a severe condition for the stiffness of equation of state (EoS) of neutron-star matter. It is well known that the stiff EoS giving the maximum mass of $2M_\odot$ can be derived from the existence of strong three-nucleon repulsion (TNR) in the high-density region. However, the hyperon (Y) mixing in neutron-star matter brings about remarkable softening of the EoS, which cancels the TNR effect for the maximum mass [3]. One of ideas to avoid this "Hyperon puzzle in neutron stars" is to assume that the TNR-like repulsions work universally for YNN, YYN YYY as well as for NNN [3]. In our previous works [4], we introduced the multi-pomeron exchange potential (MPP) as a model of universal repulsions among three and four baryons on the basis of the Extended Soft Core (ESC) baryon-baryon interaction model developed by two of authors (T.R. and Y.Y.) and M.M. Nagels [5, 6].

Our approach is based on the Brueckner-Hartree-Fock (BHF) theory. Strength parameters of MPP are determined with no ad hoc parameter for the stiffness by using the result that the TNR effect appeared in the experimental angular distributions of $^{16}O+^{16}O$ elastic scattering (E/A=70 MeV) [9, 10]: Here, they analyzed successfully with the complex G-matrix folding potentials derived from ESC including MPP contributions, strengths of which were adjusted so as to reproduce the experimental data. Additionally to MPP, the three-nucleon attraction (TNA) is introduced phenomenologically so as to reproduce the nuclear saturation property. Our interaction model composed of ESC, MPP and