Hyperon Mixing in Neutron Star Cores

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In this paper we discuss the problem of Y-mixing in neutron star cores, particularly paying attention to the recent information of YN and YY interactions extracted from hypernuclear data. We approach to the problem by constructing the G-matrix-based effective NN, YN and YY interactions and making an extended use of them to the high-density regime of neutron star matter.
In the following we point out some interesting aspects [1-3]:
(1) The threshold density $\rho_t(Y)$ for the appearance of hyperons and the fraction $y_Y(\equiv \rho_Y/\rho)$ versus ρ depend interestingly on the properties of interaction associated. First, $\rho_t(\Lambda)$ (determined by the chemical equilibrium condition $\mu_n = \mu_\Lambda$) depends not only on the YN interaction but also on the NN interaction, i.e., Λ begins to appear at lower ρ when the NN interaction is more repulsive (namely stiffer nucleon-part EOS), as well as for the stronger YN attraction. For instance $\rho_t(\Lambda)$ gets lower as $(2.94 \to 2.40)\rho_0$ (ρ_0 being the nuclear density) for the nucleon-part EOS with the nuclear incompressibility $\kappa = (250 \to 300)$ MeV. Second, $\rho_t(\Sigma^-)$ is controlled also by the nuclear symmetry energy $E_{\rm sym}$, in addition to the NN repulsion and YN attraction. This is because Σ^- can substitute the negative charge of electrons and so $\rho_t(\Sigma^-)$ is determined by the condition $\mu_{\Sigma^-} = \mu_n + \mu_e$. Charge neutrality means that larger μ_e is generated by higher proton concentration, the latter being associated with larger $E_{\rm sym}$. Therefore the combined effects from the YN attraction, the NN repulsion and the magnitude of $E_{\rm sym}$ determine which is the first to appear between Λ and Σ^-.
(2) The transition to the Y-mixed phase causes a dramatic softening of the equation of state (EOS), leading to a crucial problem that the maximum mass $M_{\rm max}$ of Y-mixed neutron stars cannot exceed the observed mass $M_{\rm obs} = 1.44$ $M_\odot$ for PSR1913+16. Of course such a problem is encounterd also for the pion- and the kaon-condensed neutron stars. But in these cases, $M_{\rm max} > M_{\rm obs}$ can be assured by choosing a stiffer nucleon-part EOS within the present uncertainties in the NN short-range repulsion. In the Y-mixed case, however, this problem cannot be solved by such a choice and hence serious. We stress that this problem $M_{\rm max} < M_{\rm obs}$ is an interesting problem suggesting the necessity of some extra repulsion in hypernuclear systems.

References

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