# Nuclear Symmetry Energy and its Effect on Neutron Stars

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The nuclear symmetry energy $a_{sym}$ plays an important role to determine the composition of nuclear matter. Without the symmetry energy, pure neutron matter would be the most stable configuration. On the other hand, if the symmetry energy is present, symmetric nuclear matter is the most stable one. The composition of neutron stars is also affected by the symmetry enegy especially at higher nuclear matter density. The larger symmetry energy yields the stronger proton mixing and reduces the neutron density.

The symmetry energy is a sum of a kinetic energy term and a potential energy term. The latter contribution to $a_{sym}$ depends on two-nucleon potentials and yields a characteristic density-dependence of $a_{sym}$, which is very important to determine the composition of neutron stars. The proton mixing ratio $y_p$ estimated with results of the G-matrix calculation is several % depending on the potential and the density [1]. The difference in $y_p$ estimated with different potentials becomes large as the density increases and originates from the density-dependence in the triplet even channel. The weaker tensor force results in larger attractive contribution of the triplet even channel to the potential energy at high density than the stronger tensor force.

Since the neutron density in the core region of neutron stars exceeds several times the standard nuclear matter density, neutrons could be replaced by hyperons as $\Lambda$ and $\Sigma^-$ [2]. The mixing ratios of hyperons, $y_\Lambda$ and $y_{\Sigma^-}$, are determined by the chemical equilibrium relations and the charge neutrality under the baryon number conservation. With the effective interactions in Refs. [1] and [2], the mixing ratios $y_\Lambda$, $y_{\Sigma^-}$ and $y_p$ are about 20%. If we increase the force strength of the two-nucleon effective interaction in the triplet odd channel, the symmetry energy increases more steeply as the density increses. Then hyperons start to appear at lower baryon density and the mixing ratios $y_\Lambda$, $y_{\Sigma^-}$ and $y_p$ at high density increase slightly. Some properties of neutron stars with the maximum mass such as the radius, the central density and the baryon number do not change so much in contrast to the hyperon distributions in neutron stars.

The nuclear symmetry energy at high density is one of the most important factor to understand properties of neutron stars. Therefore we need obtain the clear information about the density dependece of the symmetry energy.

[1] S. Nishizaki, T. Takatsuka, N. Yahagi and J. Hiura, Prog. Theor. Phys. **86**(1991), 853.

[2] S. Nishizaki, Y. Yamamoto and T. Takatsuka, Prog. Theor. Phys. **108**(2002), 703.