Universal 3-body force as a candidate to solve the "hyperon crisis"problem

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The hyperon(Y) mixing in neutron stars(NSs) dramatically softens the equation of state (EOS) and the NS maximum mass($M_{\max}$) goes down, e.g., from $1.88M_{\odot}$(without Y) to $1.10M_{\odot}$(with Y) ,contradicting even the "minimal mass"$1.44M_{\odot}$ observed for PSR1913+16, as has been discussed in [1]. Recent discoveries of a 2-solar-mass NS [2,3] make definitive the inconsistency between theory and observation ("hyperon crisis "), strongly suggesting that something is missing in the theory of dense matter relevant to NSs.

In our earlier works[1] ,we have made an approach to use a 3-body force universally to baryon(B) matter composed of N and Y($NNN \to BBB$; universal 3-body force) from a view that the 3-body force whose necessity is well recognized for nuclear systems should not be restricted to nucleons, and found that the softening of EOS due to Y-mixing turns out to be moderate, not dramatic, and $M_{\max}$ can be recovered almost to that without Y($M_{\max} \to 1.83M_{\odot}$). Our universal 3-body force, however, is introduced quite phenomenologically, following the type of three nucleon interaction by Friedman-Pandharipande [4].

In this paper, we aim to discuss the problem by using the 3-body force ($U_{3\mathrm{B}}$) based on the microscopic descriptions.. We use $U_{3\mathrm{B}}$ consisting of two parts ,$U(2\pi\Delta)$ and U(SJM).[5] Here U($2\pi\Delta$) is the extended version of the 3-body force from 2π-exchange via isobar Δ excitation (so-called Fujita-Miyazawa type) to be applied to $(N+Y)$ system and mainly works in the long and intermediate distances. U(SJM) is the 3-body force from a string-junction quark model(SJM) of baryons proposed recently by R.Tamagaki [6] and predominantly works in the short distance. It should be noted that U(SJM) is independent of quark flavor and hence satisfies the required universal nature of 3-body force. We stress that the Y-mixed NS-EOS with this $U_{3\mathrm{B}}$ can generate NSs with the mass greater than $2M_{\odot}$, compatible with recent observations of so massive NSs. We investigate how the composition depends on the nuclear symmetry energy under current interests and also the finite-temperature effects on Y-mixed NSs. Our main conclusion is that the universal 3-body force is a promising candidate to explain the existence of massive NSs with $2M_{\odot}$.

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