Effect of hyperon interaction on properties of proto neutron star PSR J0740+6620

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Abstract The effect of the interaction between hyperons on the properties of proto neutron star (PNS) PSR J0740+6620 is examined with relativistic mean field theory in consideration of a baryon octet. The nucleon coupling constant GM1 is used and the temperature of the PNS is chosen as the equation of state (EoS) of the NS [8]. Yang et al. investigated the effects of non-Newtonian gravity on the properties of strange quark stars (QSs). They found that the existence of QSs without the inclusion of non-Newtonian gravity effects is ruled out by the observations [9]. Zhou et al. found that the symmetry energy Esym(n) cannot be super-soft so that it becomes negative at supersaturation densities in NSs and thus may make the NS have a pure neutron matter core [10].

NSs are created by supernova explosions. Proto neutron stars (PNSs) are formed first, and can be as hot as 30 MeV. Later, the PNS becomes a NS, cooled by neutrino radiation giving off energy [11]. The large mass of the PNS must also limit its properties and research in this area is important for understanding the evolution of NSs.

In NS matter, the interactions between nucleons need to be considered and can be described by the mesons σ, ω and ρ [12]. Moreover, the interaction between hyperons can not be ignored, they will also affect the properties of NS matter. The interaction between hyperons can be determined by the mesons f0(975) (σ* for short) and φ(1020) (φ for short) [13].

In this paper, effect of interaction between hyperons on the properties of PNS PSR J0740+6620 is examined with the relativistic mean field (RMF) theory in consideration of a baryon octet.

1 Introduction

Neutron star (NS) is a high density star whose mass has a great restriction on the properties of NS [1–3]. Therefore, the discovery of massive NSs is of great benefit for studying the properties of nuclear matter at high density. In 2010, massive NS PSR J1614-2230 was discovered, and its mass was eventually identified as \( M = 1.93 \pm 0.07 \, M_\odot \) [4, 5]. In 2013, massive NS PSR J0348+0432 was discovered, with a mass of \( M = 2.01 \pm 0.04 \, M_\odot \) [6]. In 2020 the massive NS PSR J0740+6620 was discovered whose mass is \( M = 2.14^{+0.10}_{-0.09} \, M_\odot \) [7]). It is the most massive NS ever discovered.

The large mass of the NS PSR J0740+6620 will impose a constraint on the equation of state (EoS) of the NS [8]. The Lagrangian density of the PNS matter can be written as

\[
L = \frac{1}{2} \left( \partial \phi \right)^2 - \frac{1}{4} g_{\sigma \sigma} \left( \phi^2 - \langle \phi \rangle^2 \right)^2 - \frac{1}{4} g_{\omega \omega} \left( \omega^2 - \langle \omega \rangle^2 \right)^2 - \frac{1}{4} g_{\rho \rho} \left( \rho^2 - \langle \rho \rangle^2 \right)^2
\]

\[
+ \frac{1}{2} \left( \partial \sigma \right)^2 - \frac{1}{4} g_{\sigma \sigma} \langle \sigma \rangle^2 - \frac{1}{4} g_{\omega \omega} \langle \omega \rangle^2 - \frac{1}{4} g_{\rho \rho} \langle \rho \rangle^2 - \frac{1}{4} \lambda \langle \phi \rangle^4 - \frac{1}{4} \lambda \langle \sigma \rangle^4 - \frac{1}{4} \lambda \langle \omega \rangle^4 - \frac{1}{4} \lambda \langle \rho \rangle^4
\]

\[
+ f \left( \frac{1}{2} \frac{\partial^2 \phi}{\partial x^2} - \frac{1}{2} \frac{\partial \phi}{\partial x} \right)^2 + \text{terms containing } f_0(975), \phi(1020)
\]

\[
\]
The baryon partition function of the PNS matter considering the neutrino binding is

\[
\ln Z_B = \frac{V}{T} \langle \mathcal{L} \rangle + \sum_B \frac{2J_B + 1}{2\pi^2} \times \int_0^\infty k^2 dk \left[ \ln \left[ 1 + e^{-\left(\varepsilon_B(k) - \mu_B\right)/T} \right] \right].
\]

From above the total baryon number density [15,16] is obtained,

\[
\rho_B = \sum_B \frac{2J_B + 1}{2\pi^2} \int_0^\infty k^2 n_B(k) dk.
\]

The energy density and the pressure [15,16] respectively are

\[
\varepsilon = \frac{1}{2} m_\sigma^2 \sigma^2 + \frac{1}{2} m_\omega^2 \omega^2 + \frac{1}{3} g_2 \sigma^3 + \frac{1}{4} g_3 \sigma^4 + \frac{1}{2} m_\rho^2 \rho^2 + \frac{1}{2} m_\omega^2 \omega^2 + \frac{1}{2} m_\rho^2 \rho^2
\]

\[
+ \sum_B \frac{2J_B + 1}{2\pi^2} \int_0^\infty k^2 n_B(k) dk \sqrt{k^2 + m_B^2},
\]

\[
p = \frac{1}{2} m_\sigma^2 \sigma^2 + \frac{1}{2} m_\omega^2 \omega^2 + \frac{1}{3} g_2 \sigma^3 + \frac{1}{4} g_3 \sigma^4 + \frac{1}{2} m_\rho^2 \rho^2 + \frac{1}{2} m_\omega^2 \omega^2 + \frac{1}{2} m_\rho^2 \rho^2
\]

\[
+ \sum_B \frac{2J_B + 1}{2\pi^2} \int_0^\infty k^2 n_B(k) dk \sqrt{k^2 + m_B^2}.
\]

Here, \( n_B(k) \) is the Fermi–Dirac partition function of baryon

\[
n_B(k) = \frac{1}{1 + \exp \left[ (\varepsilon_B(k) - \mu_B)/T \right]}. \tag{6}
\]

If the interactions of leptons at finite temperature are ignored, their partition function is written as

\[
\ln Z_L = \frac{V}{T} \sum_i \frac{\mu_i^4}{24\pi^2} \left[ 1 + 2 \left( \frac{\pi T}{\mu_i} \right)^2 + \frac{7}{15} \left( \frac{\pi T}{\mu_i} \right)^4 \right]
\]

\[
+ V \sum_\lambda \frac{1}{\pi^2} \int_0^\infty k^2 dk \left[ \ln \left[ 1 + e^{-(\varepsilon_L(k) - \mu_L)/T} \right] \right]. \tag{7}
\]

the first line represents the contribution of massless neutrinos and the second line the contribution of electrons and \( \mu \).

The lepton number density is

\[
\rho_1 = \frac{1}{\pi^2} \int_0^\infty k^2 n_1(k) dk, \tag{8}
\]

\[
\rho_\nu = \frac{\pi^2 T^2 \mu_\nu + \mu_\nu^3}{6\pi^2}. \tag{9}
\]

The contribution of leptons to the energy density and the pressure are

\[
\varepsilon = \sum_\nu \frac{1}{\pi^2} \int_0^\infty k^2 n_\nu(k) dk \sqrt{k^2 + m_\nu^2} + \sum_\nu \left( \frac{7\pi^2 T^4}{120} + \frac{T^2 \mu_\nu^2}{4} + \frac{\mu_\nu^4}{8\pi^2} \right), \tag{10}
\]

\[
p = \frac{1}{3} \sum_\nu \frac{1}{\pi^2} \int_0^\infty \frac{k^4}{\sqrt{k^2 + m_\nu^2}} n_\nu(k) dk + \sum_\nu \frac{1}{360} \left( 7\pi^2 T^4 + 30T^2 \mu_\nu^2 + \frac{15\mu_\nu^4}{\pi^2} \right). \tag{11}
\]

The chemical potentials of baryons are

\[
\mu_i = \mu_\pi - q_i (\mu_e - \mu_\nu e). \tag{12}
\]

We take the following 8 sets of nucleon coupling parameters to calculate the PNS: DD-MEI [19], GL85 [12], GL97 [14], TW99 [19], GM1 [20], FSUGold [21], FSU2R [22] and FSU2H [22].

### 3 Parameters

We take the following 8 sets of nucleon coupling parameters to calculate the PNS: DD-MEI [19], GL85 [12], GL97 [14], TW99 [19], GM1 [20], FSUGold [21], FSU2R [22] and FSU2H [22].

In PNSs, temperature \( T \) can be thought of as a function of energy density \( \varepsilon \) and pressure \( p \). However, the PNS matter can be treated as infinite nuclear matter. If the temperature is set to a constant value, the energy density \( \varepsilon \) and pressure \( p \) will vary with the change of the nucleon coupling constants [15,16], which depend on the properties of saturated nuclear matter, such as the effective mass of baryons [14]. In this work, we take the temperature of the PNS PSR J0740+6620 as \( T=20 \) MeV [11].

We define the ratios of hyperon coupling constant to nucleon coupling constant as \( x_{\sigma h} = \frac{g_{\sigma h}}{g_\pi} = x_\sigma, x_{\omega h} = \frac{g_{\omega h}}{g_\pi} = x_\omega, x_{\rho h} = \frac{g_{\rho h}}{g_\pi} = x_\rho, x_{\mu h} = \frac{g_{\mu h}}{g_\pi} = x_\mu \) (\( h \) denoting hyperons \( \Lambda, \Sigma \) and \( \Xi \)), which are in the range of \( \sim 1/3 \) to \( 1 \) [20]. \( x_{\sigma h}, x_{\omega h}, x_{\rho h}, x_{\mu h} \) are selected according to quark SU(6) symmetry [23,24]. The calculation results show
that the PNS’s mass increases with the increase of the $x_{\sigma h}$ and $x_{\omega h}$ [25]. In order to obtain a larger PNS mass, we must select a larger hyperon coupling parameter $x_{\omega h}$. Therefore, we choose $x_{\omega h} = 0.9$ while $x_{\sigma h}$ is obtained by the following formula [14]

$$U_0^{(N)} = m_N \left( \frac{m^*_N}{m_N} - 1 \right) x_{\sigma h} + \left( \frac{g_\omega}{m_\omega} \right)^2 \rho_0 x_{\omega h}. \quad (15)$$

Here, the hyperon-potentials are chosen as $U_\alpha = -30$ MeV [24,26,27], $U_\Sigma^{(N)} = 30$ MeV [24,26–28] and $U_\Sigma^{(N)} = -14$ MeV [29], respectively.

The interaction between hyperons is described by the coupling parameters between mesons $\sigma^*$ and $\phi$ and hyperons [13]

$$g_{\phi \Sigma} = 2g_{\phi \Lambda} = g_{\phi \Sigma} = -2\sqrt{2}g_{\omega}/3, \quad (16)$$

$$g_{\sigma^* \Lambda}/g_{\sigma} = g_{\sigma^* \Sigma}/g_{\sigma} = 0.69, \quad (17)$$

$$g_{\sigma^* \Sigma}/g_{\sigma} = 1.25. \quad (18)$$

Figure 1 shows the relationship between the mass and radius of the PNS calculated by 8 groups of nucleon coupling parameters. It can be seen that only DD-MEI, TW99 and GM1 can give the mass of the PNS PSR J0740+6620. We know that Riley et al. and Miller et al. respectively accurately calculated the mass and radius of the NS PSR J0030+0451. This can be used as the basis for judging the choice of the above three groups of coupling parameters. The results of Riley et al are $M = 1.34^{+0.15}_{-0.16} M_\odot$ and $R = 12.71^{+1.14}_{-1.19}$ km [30], and the results of Miller et al are $M = 1.44^{+0.15}_{-0.14} M_\odot$ and $R = 13.02^{+1.24}_{-1.06}$ km [31]. Our previous calculations show that the radius of the PNS is larger than that of its corresponding NS [32]. When the NS’s mass is $M = 1.34 M_\odot$ and $M = 1.44 M_\odot$ respectively, the radius of the PNS with corresponding mass given by DD-MEI, TW99 and GM1 is smaller than those given by Riley et al. and Miller et al. (see Fig. 1). However, the radius given by GM1 is the smallest, which is closer to that given by Riley et al. and Miller et al. Therefore, GM1 is selected to describe the PNS PSR J0740+6620.

4 The radius and the central baryon density of the PNS PSR J0740+6620

Influence of hyperon interaction on the radius of PNS PSR J0740+6620 is shown in Fig. 2. Mesons $\sigma^*$ and $\phi$ describe the interaction between hyperons. The temperature of the PNS is chosen as $T = 20$ MeV and nucleon coupling constant GM1 is used. The PNS PSR J0740+6620 has mass $M = 2.14 M_\odot$ and has a radius of 14.262 km without considering the interaction between hyperons (see Table 1). When the interaction of mesons $\sigma^*$ and $\phi$ is taken into account, the radius of the PNS PSR J0740+6620 is reduced to 14.243 km, a reduction of 0.13%.

The interaction between hyperons also has an effect on baryon density $\rho$. The central baryon density of the PNS PSR J0740+6620 increases from $\rho_c = 0.571$ fm$^{-3}$ to $\rho_c = 0.578$ fm$^{-3}$, by 1.23%, taking into account the interaction between the hyperons (see Table 1).

5 The effective masses of baryons and the chemical potentials of neutron and electron

The effective masses of nucleons N and hyperons $\Lambda$, $\Sigma$ and $\Xi$ as a function of baryon density are shown in Fig. 3. The thick solid red curves represent the case where the hyperon...
The effective mass. As can be seen from Fig. 3, the effective mass increases. The interaction between hyperons has an effect on hyperons $\Lambda$, $\Sigma$, and $\Xi$, respectively. $\mu_n$ and $\mu_e$ are the chemical potentials of neutron $n$ and electron $e$, respectively. $e_\varepsilon$ and $\rho_c$ are the central energy density and the central pressure, respectively.

| Parameter | Unit | No $\sigma^*$ and $\phi$ | With $\sigma^*$ and $\phi$ |
|-----------|------|--------------------------|--------------------------|
| $R$       | km   | 14.262                   | 14.243                   |
| $\rho_c$  | fm$^{-3}$ | 0.571                  | 0.578                   |
| $m_{N,c}$ | MeV | 873.464                  | 872.996                  |
| $m_{\Lambda,c}$ | MeV | 602.228                  | 571.297                  |
| $m_{\Sigma,c}$ | MeV | 816.690                  | 786.755                  |
| $m_{\Xi,c}$ | MeV | 840.885                  | 788.139                  |
| $\mu_n$   | fm$^{-1}$ | 6.868                  | 6.884                   |
| $\mu_e$   | fm$^{-1}$ | 1.001                  | 0.987                   |
| $e_\varepsilon$ | g cm$^{-3}$ | 1.117 $\times$ 10$^{15}$ | 1.133 $\times$ 10$^{15}$ |
| $p_c$     | dyne cm$^{-2}$ | 2.529 $\times$ 10$^{35}$ | 2.561 $\times$ 10$^{35}$ |

The chemical potentials of neutrons and electrons as a function of baryon density $\rho$ are given in Fig. 4. The thick solid red curves represent the case where the hyperon interaction is not considered, while the green virtual curves represent the case where the hyperon interaction is considered.

Fig. 3 The effective masses of nucleons $N$ and hyperons $\Lambda$, $\Sigma$, and $\Xi$ as a function of baryon density. The thick solid red curves represent the case where the hyperon interaction is not considered, while the green virtual curves represent the case where the hyperon interaction is considered.

Fig. 4 The chemical potentials of neutrons and electrons as a function of baryon density $\rho$. The thick solid red curves represent the case where the hyperon interaction is not considered, while the green virtual curves represent the case where the hyperon interaction is considered.

The chemical potentials of neutrons and electrons as a function of baryon density $\rho$ are given in Fig. 4. The thick solid red curves represent the case where the hyperon interaction is not considered, while the green virtual curves represent the case where the hyperon interaction is considered. The chemical potentials of neutrons and electrons increase with the increase of baryon density $\rho$. Taking into account the interaction between hyperons, the chemical potential of neutrons will decrease by less. For example, when the baryon density $\rho = 0.56$ fm$^{-3}$, the chemical potential of neutrons decreases from $\mu_n = 6.807$ fm$^{-1}$ to $\mu_n = 6.789$ fm$^{-1}$, by 0.26%, taking into account the interaction between hyperons. But the chemical potential of the electron goes from $\mu_e = 0.999$ fm$^{-1}$ to $\mu_e = 0.987$ fm$^{-1}$, by 1.20%. However, due to the constraint of the mass $M = 2.14 M_\odot$ of the PNS PSR J0740+6620, the central chemical potential of the neutron increases by 0.23% from $\mu_n.c = 6.868$ fm$^{-1}$ to $\mu_n.c = 6.884$ fm$^{-1}$, taking into account the interaction between the hyperons. And the central chemical potential of the electron decreases from $\mu_e.c = 1.001$ fm$^{-1}$ to $\mu_e.c = 0.987$ fm$^{-1}$, by 1.4%.

6 Energy density and pressure of PNS PSR J0740+6620

The pressure $p$ of the PNS as a function of the energy density $\varepsilon$ is shown in Fig. 5. The thick solid red curves represent the
The case where the hyperon interaction is not considered, while the green virtual curves represent the case where the hyperon interaction is considered.

We see that the pressure $p$ of the PNS increases as the energy density $\varepsilon$ increases. Given the interaction between hyperons, the pressure relative to the same energy density will decrease. For example, for $\varepsilon = 7.84 \times 10^{14}$ g cm$^{-3}$, $p = 1.256 \times 10^{35}$ dyne cm$^{-2}$. Taking into account the interaction between hyperons, the pressure will be reduced to $p = 1.254 \times 10^{35}$ dyne cm$^{-2}$. Of course, the reduction is small.

However, under the constraint of the mass $M = 2.14 M_\odot$ of the PNS PSR J0740+6620, taking into account the interaction between hyperons, the central energy density increases from $\varepsilon_c = 1.117 \times 10^{15}$ g cm$^{-3}$ to $\varepsilon_c = 1.133 \times 10^{15}$ g cm$^{-3}$ by 1.4% and the central pressure increases from $p_c = 2.529 \times 10^{35}$ dyne cm$^{-2}$ to $p_c = 2.561 \times 10^{35}$ dyne cm$^{-2}$ by 1.3%.

### 7 The relative density of baryons in PNS PSR J0740+6620

Figure 6 gives the relative density of baryons in PNS as a function of the baryon density $\rho$. The thick solid red curves represent the case where the hyperon interaction is not considered, while the green virtual curves represent the case where the hyperon interaction is considered. According to Table 1, when the interaction between hyperons is not considered, the central baryon density is $\rho_c = 0.571$ fm$^3$. When the interaction between hyperons is considered, the central baryon density is $\rho_c = 0.578$ fm$^3$. This is due to the mass $M = 2.14 M_\odot$ constraint of the PNS PSR J0740+6620. As can be seen from Fig. 6, n, p, $\Lambda$, $\Sigma^+$, $\Sigma^0$, $\Sigma^-$, $\Xi^0$ and $\Xi^-$ all will be generated in PNS PSR J0740+6620 regardless of whether the interaction between hyperons is considered. However, the interaction between hyperons does affect the relative density of each baryon.

As can be seen from Fig. 6, in PNS PSR J0740+6620 ($\rho_c < 0.571$ fm$^{-3}$, without $\sigma^*$ and $\phi$; $\rho_c < 0.578$ fm$^{-3}$, with $\sigma^*$ and $\phi$), considering the interaction between hyperons, the relative density of $n$ decreases, while the relative density of $p$, $\Lambda$, $\Sigma^+$, $\Sigma^0$, $\Sigma^-$, $\Xi^0$ and $\Xi^-$ increases, indicating that more $n$ are converted into $p$ and hyperons such as $\Lambda$, $\Sigma^+$, $\Sigma^0$, $\Sigma^-$, $\Xi^0$ and $\Xi^-$ in the PNS. It is considered that the interaction between hyperons is beneficial to the generation of hyperons in PNSs.

In the center of the PNS PSR J0740+6620, the interaction between hyperons has the greatest influence on the relative density of baryons. For example, the hyperon $\Sigma^-$ has a center relative density $\rho_{\Sigma^-}/\rho = 30\%$. Taking into account the interaction between hyperons, the center relative density increases to $\rho_{\Sigma^-}/\rho = 37\%$ (see Table 2), an increase of about 23%.

### 8 Summary

We study the effect of the interaction between hyperons on the properties of PNS PSR J0740+6620 with RMF theory in consideration of a baryon octet. The nucleon coupling constant GM1 is used and the temperature of the PNS is chosen as $T = 20$ MeV.

Corresponding to the mass of the PNS PSR J0740+6620 $M = 2.14 M_\odot$, the PNS’s radius decreases from $R = 14.262$ km to $R = 14.243$ km, a reduction of 0.13%. The central baryon density of the PNS PSR J0740+6620 increases from $\rho_c = 0.571$ fm$^{-3}$ to $\rho_c = 0.578$ fm$^{-3}$, by 1.23%, taking into account the interaction between the hyperons.
Table 2  The baryon center relative density of PNS J0740+6620 calculated in this work. The mass of PNS J0740+6620 is $M = 2.14 \, M_\odot$. $\rho_{n,e}/\rho$, $\rho_{p,e}/\rho$, $\rho_{\Lambda,e}/\rho$, $\rho_{\Sigma^+,e}/\rho$, $\rho_{\Sigma^0,e}/\rho$, $\rho_{\Sigma^-,e}/\rho$, $\rho_{\Xi^0,e}/\rho$, $\rho_{\Xi^+,e}/\rho$, $\rho_{\Xi^-,e}/\rho$ and $\mu_{\mu,e}/\rho$ are center relative density of $n$, $p$, $\Lambda$, $\Sigma^+$, $\Sigma^0$, $\Sigma^-$, $\Xi^0$, $\Xi^+$, $\Xi^-$ and $\mu$, respectively.

| Parameter | Unit | No $\sigma^*$ and $\phi$ | With $\sigma^*$ and $\phi$ |
|-----------|------|--------------------------|--------------------------|
| $\rho_{n,e}/\rho$ | % | 73.9 | 71.7 |
| $\rho_{p,e}/\rho$ | % | 12.9 | 12.9 |
| $\rho_{\Lambda,e}/\rho$ | % | 11.1 | 12.5 |
| $\rho_{\Sigma^+,e}/\rho$ | % | $3 \times 10^{-6}$ | $4 \times 10^{-6}$ |
| $\rho_{\Sigma^0,e}/\rho$ | % | $9 \times 10^{-4}$ | 0.001 |
| $\rho_{\Sigma^-,e}/\rho$ | % | 0.30 | 0.37 |
| $\rho_{\Xi^0,e}/\rho$ | % | $8 \times 10^{-4}$ | 0.001 |
| $\rho_{\Xi^+,e}/\rho$ | % | 1.85 | 2.23 |
| $\rho_{\Xi^-,e}/\rho$ | % | 6.53 | 6.21 |
| $\mu_{\mu,e}/\rho$ | % | 4.17 | 3.92 |

The effective masses of both nucleons and hyperons $\Lambda$, $\Sigma$ and $\Xi$ increase as the baryon density increases. The interaction between hyperons has an effect on the effective mass and the effect is greatest at the centers of PNSs. Taking into account the interaction between hyperons, the chemical potential of both neutrons and electrons will decrease relative to the same baryon density $\rho$. Under the constraint of the mass $M = 2.14 \, M_\odot$ of the PNS PSR J0740+6620, the central chemical potential of the neutron increases by 0.23% from $\mu_{n,e} = 6.868 \text{ fm}^{-1}$ to $\mu_{n,e} = 6.884 \text{ fm}^{-1}$ and that of the electron decreases by 1.4% from $\mu_{e,c} = 1.001 \text{ fm}^{-1}$ to $\mu_{e,c} = 0.987 \text{ fm}^{-1}$, taking into account the interaction between the hyperons.

As the interaction between hyperons is considered, the pressure relative to the same energy density will decrease. Under the constraint of the mass $M = 2.14 \, M_\odot$ of the PNS PSR J0740+6620, taking into account the interaction between hyperons, the central energy density increases from $\varepsilon_c = 1.117 \times 10^{15} \text{ g cm}^{-3}$ to $\varepsilon_c = 1.133 \times 10^{15} \text{ g cm}^{-3}$ by 1.4% and the central pressure increases from $p_c = 2.529 \times 10^{15} \text{ dyne cm}^{-2}$ to $p_c = 2.561 \times 10^{15} \text{ dyne cm}^{-2}$ by 1.3%.

Baryons $n$, $p$, $\Lambda$, $\Sigma^+$, $\Sigma^0$, $\Sigma^-$, $\Xi^0$ and $\Xi^-$ all will be generated in PNS PSR J0740+6620 regardless of whether the interaction between hyperons is considered. Considering the interaction between hyperons, the relative density of $n$ decreases, while the relative density of $p$, $\Lambda$, $\Sigma^+$, $\Sigma^0$, $\Sigma^-$ and $\Xi^0$ and $\Xi^-$ increases, indicating that more $n$ are converted into $p$ and hyperons such as $\Lambda$, $\Sigma^+$, $\Sigma^0$, $\Sigma^-$, $\Xi^0$ and $\Xi^-$ in the PNS. The interaction between hyperons is beneficial to the generation of hyperons in PNSs. In the center of the PNS PSR J0740+6620, the interaction between hyperons has the greatest influence on the relative density of baryons.

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