Effect of hyperon meson coupling parameter on keplerian frequency of compact star

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Introduction

A protoneutron star (PNS) is a result of gravitational collapse of a massive stellar core. Initially it has large radius($\sim$ 100 Km) and also large temperature which may vary from 50-100 MeV. The process of deleptonization transforms it, into a hot compact star (CS) of T $\sim$ 10 MeV [1–4]. It is now a well known fact that rotation and temperature of a star increases the equatorial radius and also its mass that can be sustained at a given central energy density [5–7]. The mass shedding limit of a rotating star will be different than cold CS because of increased radius. The properties of the compact stars are mainly determined by the equation of state(EOS) of nuclear dense matter, which is charge neutral matter in β-equilibrium [8]. The discovery of the massive neutron star PSR J1614-2230 (M= 1.97 $\pm 0.04 M_\odot$) [9], J0740+6620 (M= $1.14^{+0.20}_{-0.18} M_\odot$) [10], J0348+0432 (M=2.01 $\pm 0.04 M_\odot$) [11] etc has questioned the existing models as no relativistic model assuming hyperons in its core predicts mass nearing this. [12–15]. Some of the models produces stars with maximum masses larger than $2M_\odot$ assuming strong hyperon vector repulsion [7, 15–21]. In present work we have investigated the role of hyperon vector repulsion on the keplerian frequency of the star. The Lagrangian density for the extended relativistic mean field(ERMF) model describes the interactions from self and mixed terms for the scalar-isoscalar (σ), vector-isoscalar (ω), and vector-isovector (ρ) mesons are expalined in reference Further, the hyperon-meson coupling parameters are expressed in terms of the nucleon-meson coupling using the SU(6) model. The coupling parameters of σ-meson-hyperon and ω-meson-hyperon are very sensitive to structural properties of compact stars, so these parameters have been fitted to the hyperon-nucleon potential depth the same as in Ref. [17], and its value $X_{\omega y}$ varies from 0.5 to 0.7, where $X_{\omega y}$ is defined as,

$$X_{\omega Y} = \begin{cases} \left(\frac{g_{\omega Y}}{g_{\omega N}}\right) & for \quad \Lambda \quad and \ \Sigma \ hyperons \\ 2\left(\frac{g_{\omega Y}}{g_{\omega N}}\right) & for \quad \Xi \quad hyperons, \end{cases} \tag{1}$$

where $g_{\omega Y}$ and $g_{\omega N}$ are the ω- meson-hyperon and ω-meson-nucleon coupling parameters. [17, 22]. We have used the RNS code for calculating the keplerian frequency of different EOS.

Result and discussion

We calculated the keplerian frequency value for different EOS of ERMF model generated by varying the ω meson self-coupling ζ and neutron skin thickness Δr for the ^{208}Pb nucleus [17] by putting the value of $X_{\omega y}$ as 50, 60 and 70 at various temperatures. We found that the keplerian frequency for cold matter EOS increases as we increase the value of $X_{\omega y}$ from 50 to 70. Further for cold matter EOS the keplerian frequency decreases as we increase the neutron skin thickness Δr from 0.16 to 0.28. The difference Δf_k of keplerian frequency f_k at Δr = 0.16 and Δr = 0.28 increases on increasing the hyperon-meson coupling parameters $X_{\omega y}$. It is further observed that if we fix the value of $X_{\omega y}$ the value of Δf_k increases on increase of ζ peramenter.
It is further found that these results reverses for the EOS at finite temperature. We verified these results at a temperature of 5 MeV and 10

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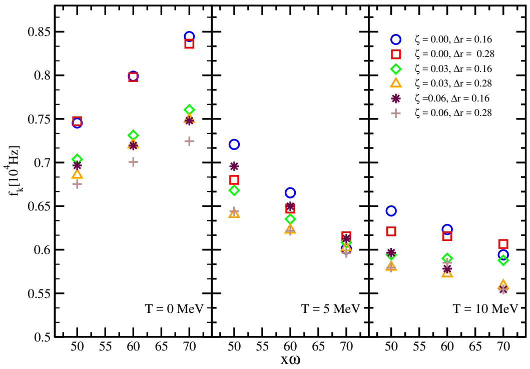

FIG. 1: The figure presents the variation of keplerian frequency f_k with hyperon-meson coupling parameters $X_{\omega y}$ at various values of ω meson self-coupling and neutron skin thickness Δr for the ^{208}Pb nucleus

MeV. At finite temperature as we increase the value of $X_{\omega y}$ from 50 to 70 the value of kepler frequency decreases. We also varified that the value of Δf_k approaches towards zero on incereasing the ζ peramenter to 0.06 from 0.03. At 10 MeV temperature the Δf_k just becomes zero for the 0.06 value of ζ peramenter. So we conclude that the keplerian frequency depends upon the hyperon meson coupling parameter $X_{\omega y}$ and the ω meson self-coupling parameter ζ but is almost independent of neutron skin thickness Δr.

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