Mass and Radius of rotating Protoneutron Star with in extended relativistic mean field model and their corelation with frequency

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Introduction

Protoneutron star is a result of the gravitational collapse of a massive stellar core. Initially, it can have large radius of about 100 km and a temperature of 50-100 MeV. The Protoneutron star may be born with a large rotational kinetic energy and initially it will be differentially rotating. Due to the violent nature of the gravitational collapse, the PNS pulsates heavily, emitting significant amounts of gravitational radiation. After a few hundred pulsational periods, bulk viscosity will damp the pulsations significantly. Rapid cooling due to deleptonization transforms the PNS, shortly after its formation, into a hot compact star of T $\sim$ 10 MeV [1]. This work is in continuation to previous work [2]. We verified the corelation of cold compact stars to the Protoneutron star at various temperature. In the present work we have employed BSR15 parameterization of the Extended Relativistic Mean Field Model [3, 4], generated by choosing the ω meson self-coupling ζ as 0.06 and neutron skin thickness Δr for the ^{208}Pb nucleus as 0.16. Further, the hyperon-meson coupling parameters are expressed in terms of the nucleon-meson coupling using the SU(6) model [3]. This parameterization is selected for this study as this parameterization produces a canonical mass ($1.4M_{\odot}$) at rest when composition is assumed to possess hyperon.

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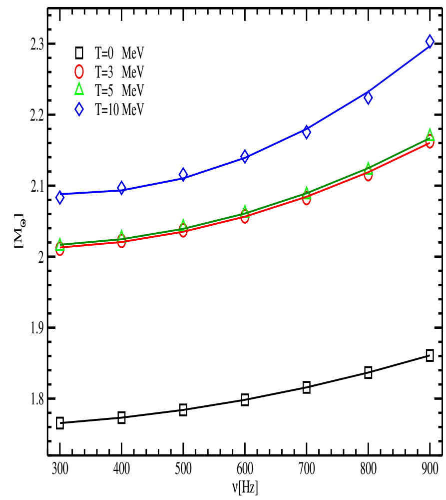

FIG. 1: The variation of compact star mass with frequency is plotted as black square, red circles, green triangles and blue diamonds at a temperature of 0,3,5 and 10 MeV. The best fit line for each case is plotted as solid line of respective colour.

Result & Discussion

In Fig.1 we plotted mass as a function of frequency for BSR15 parameterization at different temperatures. The black squares are the values of cold star mass at different frequencies, whereas red circles, green triangles and blue diamonds are the star masses at a temperature of 3,5 and 10 MeV. The solid line represent the best fit line. BSR15 parameterization yield a rest mass of 1.76 $M_{\odot}$ and a radius of 11.28 Km whereas mass becomes 1.99$M_{\odot}$, 2.0 $M_{\odot}$ and 2.07 $M_{\odot}$ and radius of 12.69 Km, 12.74 Km and 13.61 Km at a temperature of 3 MeV, 5 MeV and 10 MeV re-

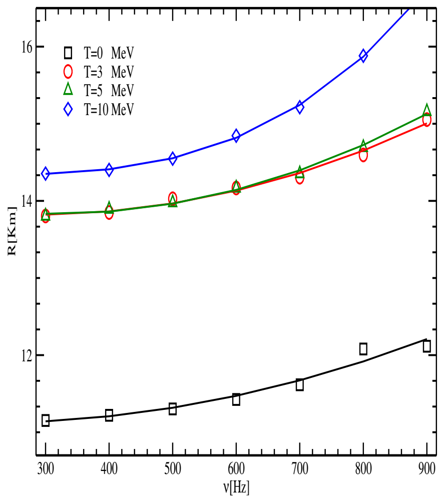

FIG. 2: The variation of compact star radius with frequency is plotted as black square, red circles, green triangles and blue diamonds at a temperature of 0,3,5 and 10 MeV. The best fit line for each case is plotted as solid line of respective colour.

spectively. It is found that best fit line follow the same relation irrespective of temperature

$$M_\nu = a1 * \nu^2 - a2 * \nu + a3 * M_{static} \quad (1)$$

where respective parameters for the Protoneutron stars at different temperatures is

TABLE I: The parameters a1,a2 and a3 of eq. 1 at different temperatures

Parameter	Temperature			
	0 MeV	3 MeV	5 MeV	10 MeV
a1(x10^{-7})	1.66	3.35	3.45	5.89
a2(x10^{-4})	4.03	1.57	1.64	3.60
a3	1.00	1.02	1.02	1.04

In Fig.2 we plotted radius as a function of frequency for BSR15 parameterization at different temperatures with best fit solid line. It is found that best fit line for radius also follow the same relation irrespective of temperature

$$R_\nu = a1 * \nu^2 - a2 * \nu + a3 * R_{static} \quad (2)$$

where respective parameters for the Protoneutron stars at different temperatures is

TABLE II: The parameters a1,a2 and a3 of eq. 2 at different temperatures

Parameter	Temperature			
	0 MeV	3 MeV	5 MeV	10 MeV
a1(x10^{-6})	2.24	3.18	3.75	8.05
a2(x10^{-4})	9.21	17.70	23.23	58.16
a3	0.99	1.11	1.12	1.13

From the tables of parameters we find that parameters for Protoneutron star at different temperature remains almost same for mass but vary slightly for radius. Hence we conclude that above corelation hold good irrespective of temperature. So if the mass and radius of static star is known we can estimate either frequency from known mass or mass and radius from frequency considerations.

References

[1] M. Marques, M. Oertal, M. Hempel, and J. Novak, Phys. Rev. C **96**, 045806 (2017).
[2] A. Sharma, S. K. Dhiman, and G. Mahajan, Proceedings of the DAE Symp. on Nucl.Phys. **62**, 722 (2017).
[3] S. K. Dhiman, R. Kumar, and B. K. Agrawal, Phys. Rev. C **76**, 045801 (2007).
[4] B. K. Agrawal, Phys. Rev. C **81**, 034323 (2010).