Imperical relationship in the properties of static and rotating protoneutron star

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I. INTRODUCTION

Recently, the efforts have been made to establish the empirical relationship between observable properties of static star with keplerian angular velocity of uniformally rotating star [1]. The similar empirical relationship for the keplerian angular velocity employed to make prediction in case of protoneutron star (PNS) as; $\Omega_K[S^{-1}] = a_o + a_1 \left(\frac{M_{max}}{M_\odot}\right)^{1/2} \left(\frac{10km}{R_{max}}\right)^{3/2}$, where M_{max} and R_{max} are the gravitational maximum mass and radius of the static PNS. In the present work we have employed the extended relativistic mean field (ERMF) model and its perametrizations BSR1 - BSR21 [2, 3]. The Lagrangian density, Lagrangian terms and the Euler-Lagrangian equations for ground state expectation values of the meson fields are same as in [2]. At finitetemperatures the baryon vector density, scalar density and charge density are as defined in [4]. The keplerian configurations of rapidly rotating protoneutron stars have been computed in framework of general relativity by solving the Einstein field equations for stationary axisymmetric space time (e.g. see Ref.[5] and references therein). The numerical calculations have been performed by employing the Rotating Neutron Star (RNS) code [6]. The perametrizations have been generated by varying the ω meson self-coupling ζ and neutron skin thickness Δr for the ^{208}Pb nucleus. These parametrizations have been obtained so as to reproduce the nuclear structure properties in finite nuclei and bulk properties of nuclear matter at nuclear saturation density [2]. The parametrization sets BSR1-BSR7 correspond to the value of ω meson self-coupling $\zeta = 0.0$, sets BSR8-BSR14 correspond to $\zeta = 0.03$, and sets BSR15-BSR21 correspond to $\zeta = 0.06$, and for each parametrization set the value of neutron skin thickness of ^{208}Pb varies from 0.16 to 0.28 fm in intervals of 0.02 fm. Further, the hyperon-meson coupling parameters are expressed in terms of the nucleon-meson coupling using the SU(6) model [2].

II. RESULT AND DISCUSSIONS

In figs.1 and 2, the correlation between keplerian angular velocity calculated within relativistic framework assuming uniform rotation using different parametrizations of ERMF model with nonrotating mass-radius relationship $(M_{max}/M_\odot)^{1/2}(10km/R_{max})^{3/2}$ is presented. These calculations are performed assuming nuclear dense matter EOS without and with inclusion of hyperons. The black, blue and red colors represent the keplerian frequencies for EOSs at 0 MeV, 5 MeV and 10 MeV. The solid black line is calculated by employing the approximate empirical relation for keplerian angular velocity with nonrotating maximum gravitational mass and radius of compact star. It can be observed from Fig.1 that keplerian angular velocity for almost all the EOSs (except BSR1, BSR3 and BSR4) of PNS are close to the best fit line. The maximum deviation is $\sim 5\%$ for the cold matter EOSs without hyperons. The same phenomenon is observed for the EOSs having hyperons in their nuclear matter composition from Fig.2. Although the deviation for EOSs without hyperons from best fit line is more as compared to EOSs with hyperons. The values of best fit

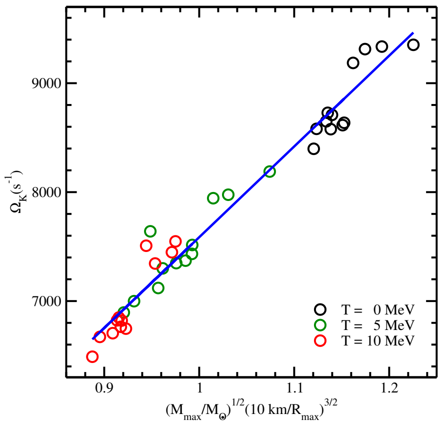

FIG. 1: The correlation between keplerian angular velocity of PNS calculated within relativistic framework assuming uniform rotation using different parametrizations of ERMF model with nonrotating mass-radius relationship $(M_{max}/M_\odot)^{1/2}(10km/R_{max})^{3/2}$. These calculations are done assuming nuclear dense matter without any hyperons. The black, green and red colors represent the keplerian frequencies for EOSs at 0 MeV,5 MeV and 10 MeV. The solid black line is the best fit of the data.

parameters in Fig. 1 for EOS without hyperons are calculated as; $a_0 = -0.745 \times 10^3 s^{-1}$ and $a_1 = 8.331 \times 10^3 s^{-1}$. These results are almost same as compared to calculations of Ref.[1]. Whereas these values are slightly different for EOS with hyperons in Fig. 2 and are; $a_0 = -0.062 \times 10^3 s^{-1}$ and $a_1 = 7.258 \times 10^3 s^{-1}$.

References

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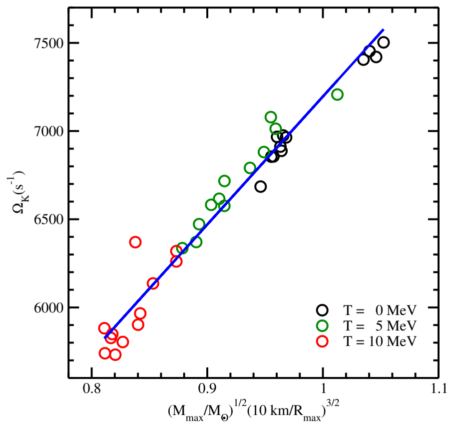

FIG. 2: Same as Fig.1 but with inclusion of hyperons in calculation.

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