Properties of rotating protoneutron star having keplerian frequency within the extended field theoretical model

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Introduction

The discovery of the massive neutron star PSR J1614-2230 has raised new challenges for the theories of dense matter beyond nuclear saturation density. Shapiro delay measurements from radio timing observations of the binary millisecond pulsar indicate a large mass of $1.97 \pm 0.04 M_{\odot}$ of the neutron star [1]. The core of a neutron star may contain hyperons but according to existing models of dense matter, the presence of hyperons considerably soften the equation of state (EOS), resulting in reduction of masses of star. Most relativistic models which assumes hyperons in the core of a star obtain maximum neutron star masses in the range $1.4 - 1.8 M_{\odot}$ which are in conflict with the large pulsar masses. There are few models in litrature which produces stars with maximum masses larger than $2M_{\odot}$ but those calculations are done assuming strong hyperon vector repulsion [2, 3]. It is now a well known fact that mass of the compact star is very sensitive to the ω-meson self coupling parameter (ζ) and the ratio of hyperon coupling constant to nucleon coupling constant [2, 3] which is reconfirmed in Ref. [4]. In this work we found the effect on the radius of the compact star with canonical mass by varing the neutron thickness (Δr) from 0.16 fm to 0.028 fm in steps of 0.04 fm and ω-meson self coupling parameter ζ with 0.00, 0.03 and 0.06 with in an extended relativistic mean field (ERMF)model [2, 3]. To study the effect of temperature on mass of uniformally rotating protoneutron stars (PNS), we used the BSR1(ζ =0.00, Δr = 0.16fm),BSR7(ζ =0.00, Δr = 0.28fm), BSR15(ζ =0.03, Δr = 0.16fm) and BSR21(ζ =0.03, Δr = 0.28fm) perametrization of ERMF model.

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1. Result

In Fig.1 the radius $R_{1.4}$, corresponding to the compact star having canonical mass and rotating with Keplerian frequency is plotted as a function of neutron skin thickness Δr in the ^{208}Pb nucleus for different parametrization of the extended FTRMF model. The black circles, triangles, and squares represent results for the parametrizations having ζ = 0.00, 0.03, and 0.06 respectively at $T = 0$ MeV. It is found that the radius corresponding to the canonical compact star increases on increasing the value of Δr. Also for a given Δr the value of radius decreases on increasing the ζ parameter. The radius has minimum value for the BSR15 parametrization (18.48 Km) and maximum value for the BSR7 parametrization(20.11 Km). It was interesting to note that the value of radius for the canonical compact star remains same when hyperons are included in the calculation. On increasing the temperature to 10 MeV, the value of radius increased by $\sim 23 - 26\%$ irrespective of parametrization used. In Fig.2 we present the mass shedding limit (Kepler) for EOS obtained using BSR1, BSR7, BSR15, and BSR21 parametrizations in terms of gravitational mass M as a function of central energy density ϵ_c. The bottom black, middle green and top blue solid/dashed lines are for a

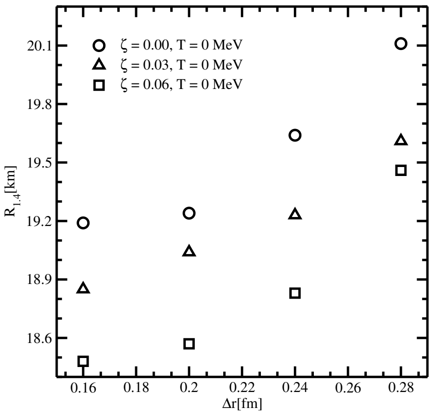

FIG. 1: The radius $R_{1.4}$ corresponding to the canonical compact star rotating with Keplerian frequency is plotted as a function of neutron skin thickness Δr in the ^{208}Pb nucleus for different parametrization of the extended FTRMF model. The black circles, triangles, and squares represent results for the parametrizations having $\zeta = 0.00$, 0.03, and 0.06 respectively at $T = 0$ MeV.

temperature of 0, 5, and 10 MeV respectively. The dashed lines represent EOS with hyperons having the hyperon meson coupling parameter $X_{\omega y} = 0.50$ and solid lines represent EOS without hyperons. Keplerian configurations terminate at the central energy density where equilibrium solutions are stable with respect to the small axisymmetric perturbations; the slanting dotted (red) line corresponds to the axisymmetric instability limit. In the Kepler limit sequences, the gravitational maximum mass of PNS increase with increase in temperature by $20 - 23\%$ and its corresponding equatorial radius increases by $25 - 46\%$, with respect to its non rotating gravitational maximum mass and radius, respectively. These observations are reasonably well within predictions provided in Ref. [5] and slightly higher in case of PNS with hyperons. It is also observed that the radius corresponding to gravitational maximum mass increases with increase in Δr but remains almost same with increase in the values of ζ parameter.

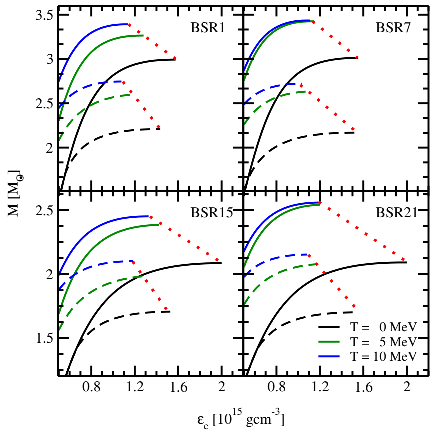

FIG. 2: (Color online)The mass shedding limit (Kepler) is plotted for EOS obtained using BSR1, BSR7, BSR15, and BSR21 parametrizations in terms of gravitational mass M as a function of central energy density ϵ_c. The bottom black, middle green and top blue solid/dashed lines are for a temperature of 0, 5, and 10 MeV respectively. The dashed lines represent EOS with hyperons having the hyperon meson coupling parameter $X_{\omega y}$ = 0.50 and solid lines represent EOS without hyperons. The slanting dotted red line corresponds to the axisymmetric instability limit.

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