Properties of rotating compact star within Extended Relativistic Mean Field Model

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Introduction

It is now a well known fact that rotation increases the mass of of the compact stars. Nearly ∼ 2500 pulsar have been observed, the frequency data indicate that the most of pulsar have frequency ranging from 0 to 100 Hz. Few pulsar have high frequencies also. Pulsar J1748-2446ad is assumed to have frequency of 716 Hz Ref.[1]. The bulk properties of rotating relativistic star constrain the proposed equations of state in the high density region. Accreted matter in their gravitational fields undergoes high frequency oscillations that could become a sensitive probe for general relativistic effects. The configurations of rapidly rotating compact stars have been computed in framework of general relativity by solving the Einstein field equations for stationary axisymmetric space time (e.g. see Ref.[2] and references therein). The numerical calculations have been performed by employing the Rotating Neutron Star (RNS) code [3].

Formalism

In the present work we have employed BSR15 parametrisations of the Extended Relativistic Mean Field Model [4, 5], 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. This parametrization is selected for this study as this parametrization produces a canonical mass ($1.4M_{\odot}$) at rest when composition is assumed to possess hyperons.

The structural properties such as central energy density (ϵ_c), maximum gravitational mass (M_{max}), radius (R_{max}), moment of inertia (I), ratio of rotational kinetic energy to gravitational kinetic energy (T/$|W|$), ratio of equatorial radius at pole to the equatorial radius at the equator (r_{pole}/r_{eq}) of rotating protoneutron star, rotating with different frequency are presented in Table I. In Table. I we present the results of rotating compact star. The uppper panel contains EOS without hyperons, whereas the lower panel contain EOS having hyperons in its composition.

Result and Discussion

The BSR15 parametrisation yield a mass of $1.73M_{\odot}$ and radius of 10.92 Km at rest (ω=0)and a mass of $2.09M_{\odot}$ and radius of 15.3455 when rotating with keplers frequency, which terns out to be 1374 Hz when no hyperons are included in the calculation. On including hyperons into the calculation the mass and radius becomes $1.41M_{\odot}$ and 11.52 Km respectively at rest and it becomes $1.71M_{\odot}$ and 16.71 Km when rotating with keplers frequency, which is calculated to be 1108.39 Hz. The calculation indicates that if hyperons are included in the calculation the keplers frequency decreases significantly, but the frequency is still greater than the highest observed frequency of 716 Hz.

Further from table I it is clear that corresponding mass and radius increases with increase in the rotation frequency ω. Since the value of r_{pole}/r_{eq} decreases with the frequency indicating that the star flattens and mass scatters from axis of rotation because of which the moment of inertia also increases. Similarly there is increase in the value of T/$|W|$ because of increase in rotational kinetic energy. From calculations it is clear that when we move from static to keplerian sequence the mass increases ∼20% for calculations done with out hyperons and this increase is slightly greater ∼ 22%

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TABLE I: The properties of rotating compact star, rotating with different frequencies. The uppper panel contains EOS without hyperons, whereas the lower panel contain EOS having hyperons in its composition. The values of central energy density (ϵ_c), maximum gravitational mass (M_{max}), radius (R_{max}), moment of inertia (I), ratio of rotational kinetic energy to gravitational kinetic energy (T/$|W|$), ratio of equatorial radius at pole to the equatorial radius at the equator (r_{pole}/r_{eq}) is presented for BSR15 of Extended Relative Mean Filed model.

ω Hz	ϵ_c ($10^{15} gmcm^{-3}$)	M_{max} ($M_\odot$)	R_{max} (Km)	I ($10^{45} gmcm^{-2}$)	T/$\|W\|$	r_{pole}/r_{eq}
Without hyperons						
300	2.362	1.767	11.171	1.661	0.0036	0.986
400	2.339	1.774	11.220	1.686	0.0065	0.976
500	2.315	1.783	11.302	1.716	0.0103	0.962
600	2.269	1.795	11.425	1.761	0.0151	0.944
700	2.180	1.810	11.615	1.827	0.0214	0.923
800	2.032	1.852	12.079	1.995	0.0378	0.865
900	2.012	1.853	12.116	2.006	0.0386	0.863
1000	1.913	1.884	12.489	2.141	0.0504	0.8224
With hyperons						
300	1.992	1.431	11.683	1.289	0.0048	0.981
400	1.952	1.440	11.816	1.324	0.0087	0.964
500	1.857	1.453	12.052	1.387	0.0145	0.942
600	1.748	1.471	12.363	1.473	0.0221	0.913
700	1.628	1.494	12.771	1.587	0.0324	0.875
800	1.294	1.572	14.295	2.011	0.0668	0.753
900	1.281	1.575	14.363	2.029	0.0681	0.749
1000	1.069	1.654	16.732	2.553	0.0826	0.608

when hyperons are included. These calculations are in good agreement with the various other calculations done [6–8] The discovery of the massive neutron star PSR J1614-2230 [9]and PSR J0348+0432[8] indicate a large mass of $1.97 \pm 0.04 M_\odot$. From calculations we can see that if we include hyperons in the calculations despite of keplerian frequency the mass obtained is much smaller.But if we assume some finite temperature of star of order of 3 MeV the mass at rest becomes 1.97 $M_\odot$,indicating that those binaries may possesses some temperature and are in a stage of getting cooled.

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