Correlation in the Properties of Static and Rotating Compact Star within Extended Relativistic Mean Field Model

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Introduction

The efforts have been made to establish the empirical relationship between observable properties of static star with uniformly rotating star [1]. Many correlations have been calculated which correlate the static properties with the keplerian properties of star. In present work we tried to correlate the static mass with the mass of star rotating with some frequency ν.

Formalism

The different parametrizations of Extended Relativistic Mean Field 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]. In the present work we have employed BSR15 parametrisations of the Extended Relativistic Mean Field Model [2, 3], 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 [2]. 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.

Result and Discussion

In Fig.1 we present the variation of mass with frequency. The blue circle present the mass calculated corresponding to respective frequency with including Hyperons in the calculations for BSR15 parametrization. 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 solid black line represent the best fit line given by the equation given by

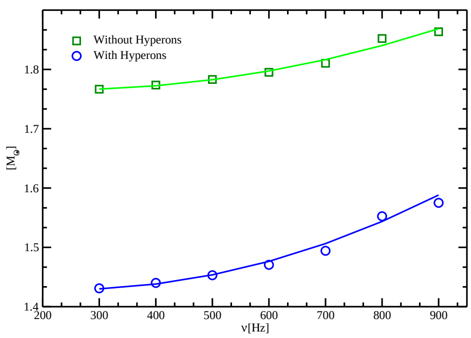

FIG. 1: The variation of compact star mass with frequency is plotted as blue circles(calculation with Hyperons) and green squares (calculation without hyperons). The best fit line for each case is plotted as solid black line.

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

where M_ν and M_{static} are mass of rotating compact star with frequency ν and static mass (ν=0) respectively. The values of a1, a2 and a3 are calculated from best fit line are 3.64x10^{-7},1.73x$10^{-4}$and 1.02 respectively This relation not only gives static mass but mass at all frequency upto keplers frequency.

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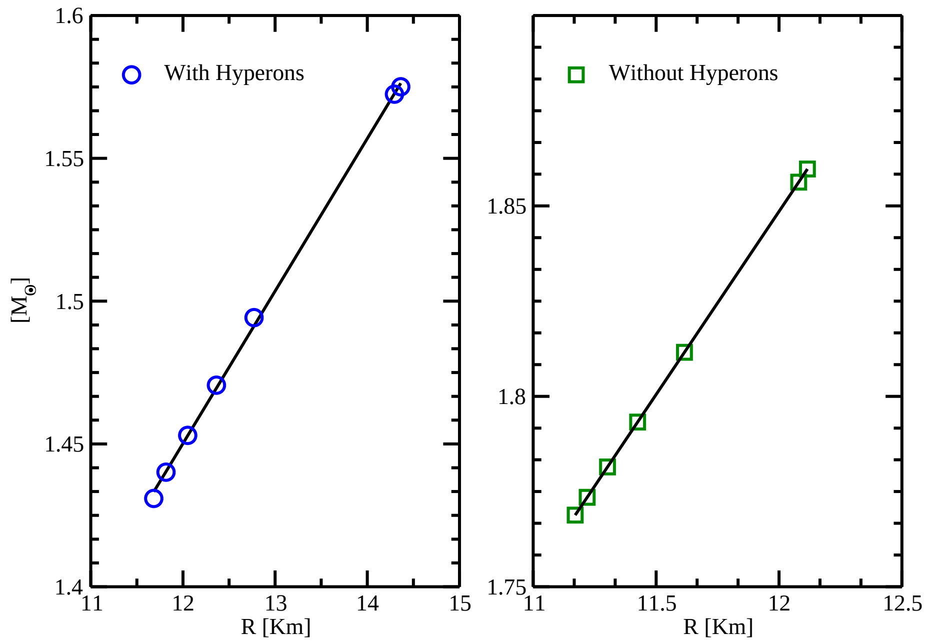

FIG. 2: The mass as a function of radius at different frequencies is plotted. The blue circles are masses calculated when hyperons included in calculation and green squares when heperons are not included. The best fit line in each case is represented by solid black line.

The green squares present the mass at different frequency without including Hyperons in calculation The BSR15 parametrisation yield a mass of $1.73M_\odot$ and radius of 10.92 Km at rest (ν=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. The Solid black line represent the best fit line given by the same relation (1) but with a1, a2 and a3 as $2.26\text{x}10^{-7}$,$1.02\text{x}10^{-4}$and 1.04 respectively.

In Fig.2 we present the mass as a function of radius at different frequencies. The blue circles are mass calculated when hyperons included in calculation and green squares when heperons are not included. The best fit line is also plotted.The best fit line in each case is represented by solid black line.

The imperical relation between mass and radius is calculated to be

$$M_\nu = a1 * R + a2 \quad (2)$$

The values of a1 and a2 are found to be 0.054 and 0.81 for calculation with hypenons and 0.096 and 0.69 without hyperons respectively. Hence if static mass of a star is known then we can calculate the mass at any frequency using equation (1) and also respective radius using equation (2).

References

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