# Rotating Hadron Stars Under Strong Magnetic fields

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## Introduction

Nevertheless, all pulsars have relatively strong magnetic fields and due to this reason, a complete analysis of pulsar should include magnetic field effects. Compact stars gives us the opportunity to study the strongly interacting dense nuclear matter under the extreme condition in their interior. Theoretically, it is discussed that the composition of compact stars is ranging from the mixture of hadrons, leptons to various phases of superconducting quark matter under beta equilibrium. Since rotation is a general property of all stellar bodies. Many recent observations of gravitational maximum masses and extraction radius of the pulsars have imposed restriction on their composition, to as a plausible set of equations of state (EOS) must support the limits of observed maximum gravitational masses of compact stars. In the present work, we study the effect of strong magentic fields on the structure properties of rotating neutron star. We have constructed a set of equations of state with composition of neutron, proton, hyperons and lepton in beta equilibrium under the strong magnetic field varying upto eB = $1.2\times10^{-2}GeV^2$. To study the influence of magnetic field in the steller interior, we consider altogether two decay modes of a density-dependent magnetic field, a fast decay($\gamma$=3.00, $\beta$=0.02), a slow decay($\gamma$=2.00, $\beta$=0.05).

## Theoretical Framework

The total energy density and total pressure of dense nuclear matter in the framework of Field Theoretial Based Relativisitic Mean Field (FTRMF) can be written as,

$$\mathcal{E}^H = \mathcal{E}_m + \mathcal{E}_l + \frac{[B(\frac{\rho}{\rho_0})]^2}{2}, \qquad (1)$$

$$P^H = P_m + P_l + \frac{[B(\frac{\rho}{\rho_0})]^2}{2}, \qquad (2)$$

where $\mathcal{E}_m$ and $\mathcal{E}_l$ corresponds to energy densities of baryons and leptons, respectively. The $P_m$ and $P_l$, corresponds to pressures of baryons and leptons, respectively. The B($\rho/\rho_0$) is representing density-dependent magnetic field [1].

The matter inside the star is approximated by a perfect fluid and the energy-momentum tensor is given by

$$T^{\mu\nu} = (\mathcal{E} + P)u^\mu u^\nu - Pg^{\mu\nu} \qquad (3)$$

where $\mathcal{E}$, P and u$^\mu$ are the energy density, pressure, and four-velocity, respectively. In order to solve Einstein's field equation for the potentials $\gamma$, $\rho$, $\beta$ and $\omega$, we adopt the KEH method [3] and use the public RNS code [4] for calculating the properties of a roating star.

## Results and Discussions

In present theoretical calculatiom, we have employed BSR10 parametrisation [2] for computing the energy density and pressure of EOSs in fast and slow decay modes.

The Interaction strength couplings of hyperons with the meson fields and hyperons with strange meson field are employed as suggested in [2]. For charged particles, the effect of Landau quantization appears as $\sqrt{m_b^{*2} + 2\nu eB}$ in the energy spectra from field equation. Here, $\nu$, representing the Landau level, varying in integer as, $\nu = 0, 1, 2, ., ., ., ..$ In Figure(1), we present the variation of energy density $\mathcal{E}^H$ and pressure $P^H$ in units of MeVfm$^{-3}$ with increasing magnetic fields

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TABLE I: The structural properties of rotating compact stars, the maximum gravitational mass $M_{max}(M_\odot)$ and its corresponding equatorial radius $R_{max}$(km), central energy density $\mathcal{E}_c(\times 10^{15} g/cm^{-3})$, baryon density $\rho(fm^{-3})$, the maximum Keplerian frequency $f_K$(Hz).

| | | Fast Decay | | | Slow Decay | |
|---|---|---|---|---|---|---|
| | | **B=0** | $\mathbf{B_{core} = 10^{16}G}$ | $\mathbf{B_{core} = 2 \times 10^{18}G}$ | $\mathbf{B_{core} = 10^{16}G}$ | $\mathbf{B_{core} = 2 \times 10^{18}}$ |
| **Static** | $M_{max}/M_\odot$ | 1.74 | 1.90 | 2.10 | 1.90 | 2.03 |
| | $R_{eq}$(km) | 11.62 | 12.50 | 12.58 | 12.50 | 12.84 |
| | $\mathcal{E}_c(\times 10^{15} g/cm^{-3})$ | 2.11 | 1.80 | 1.78 | 1.80 | 1.65 |
| | $\rho(fm^{-3})$ | 1.00 | 0.85 | 0.82 | 0.85 | 0.78 |
| **Keplerian** | $M_{max}/M_\odot$ | 2.08 | 2.28 | 2.52 | 2.28 | 2.46 |
| | $R_{max}$(km) | 16.46 | 17.46 | 17.25 | 17.56 | 17.77 |
| | $\mathcal{E}_c(\times 10^{15} g/cm^{-3})$ | 1.69 | 1.52 | 1.53 | 1.47 | 1.42 |
| | $\rho(fm^{-3})$ | 0.83 | 0.74 | 0.73 | 0.72 | 0.69 |
| | $f_K$(Hz) | 1241 | 1189 | 1266 | 1179 | 1200 |

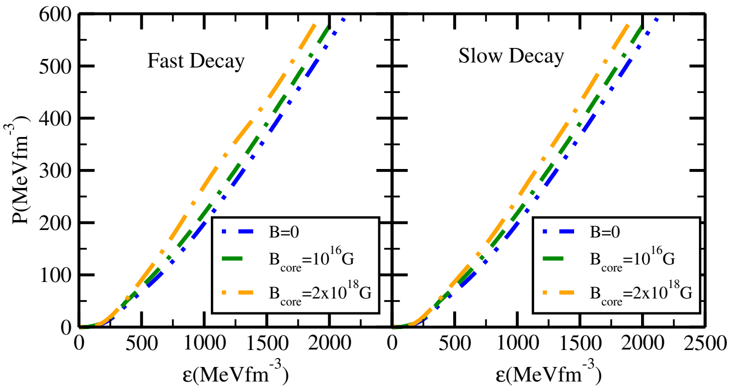


FIG. 1: Pressure versus energy density for fast decays as well as slow decays.

from eB = 0 - 1.2× $10^{-2} GeV^2$ for BSR10 model parametrisation. It is observed that EOS get stiffened as the magnetic fields increased for both case of decays. In Table (I), we present the structural properties of rotating compact stars, the maximum gravitational mass $M_{max}(M_\odot)$ and its corresponding equatorial radius $R_{max}$(km), central energy density $\mathcal{E}_c(\times 10^{15} g/cm^{-3})$, baryon density $\rho(fm^{-3})$, the maximum Keplerian frequency $f_K$(Hz). It is observed that the gravitational mass is increased by 0.16 $M_\odot$as magnetic field increased from 0G to $10^{16}$G and, thereafter there is a variation in mass of compact star to the order of 0.2$M_\odot$. The gravitational radius increased by a magnitude of 0.88km and then it remains almost constant as the variation in the radius of compact star is 0.1km from magnetic field $10^{16}G$ to $2 \times 10^{18}G$. For the Keplerian configurations, it is observed that the maximum gravitational mass is increased from that of non-rotating configurations. But, corresponding number density is reduced in keplerian sequences.

## References


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