Observables of spheroidal magnetized Strange Stars

Workshop on Heavy Ions Physics and Compact Stars

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December 1-4, 2020

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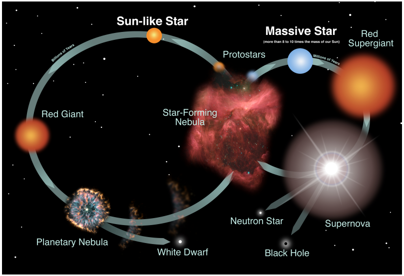
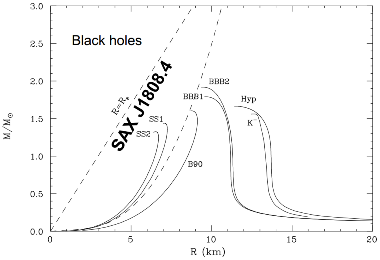
Motivation

Compact Objects



- Final stage in the evolution of ordinary stars.
- Formed when thermonuclear fusion cannot compensate the gravitational collapse.

Strange Stars



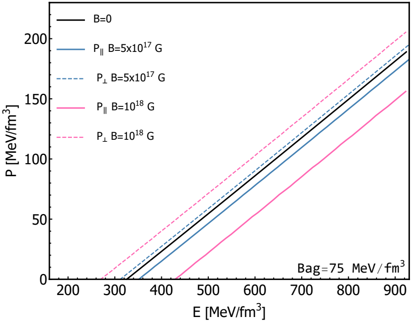
- Hypothetical class of Compact Object.
- Could be composed entirely by SQM (Strange Stars), or have a core of quark matter surrounded by a layer of hadrons (Hybrid Stars).
- M$\sim 1.5 - 2 M_{\odot}$, R$\sim 4 - 8$ km.

Motivation

Constant magnetic field effects on a fermion gas:

- Anisotropic energy-momentum tensor: $T_{\mu\nu} = \mathrm{diag}(-E, P_{\|}, P_{\|}, P_{\perp})$
- Anisotropic equation of state for magnetized Strange Stars

$$
\begin{aligned}
E(B,\mu,0) &= \sum_{\mathbf{f}}\left[\Omega_f(B,\mu,0) + \mu_f N_f(B,\mu,0)\right] + \mathrm{B_{bag}} + B^2/8\pi, \\
P_{\|}(B,\mu,0) &= -\sum_{\mathbf{f}}\Omega_f(B,\mu,0) - \mathrm{B_{bag}} - B^2/8\pi, \\
P_{\perp}(B,\mu,0) &= -\sum_{\mathbf{f}}\left[\Omega_f(B,\mu,0) + B\mathcal{M}_f(B,\mu,0)\right] - \mathrm{B_{bag}} + B^2/8\pi,
\end{aligned}
$$



γ-Metric Structure Equations

- γ Metric in spherical coordinates

$$ds^2 = -\left(1 - \frac{2M(r)}{r}\right)^{\gamma} dt^2 + \left(1 - \frac{2M(r)}{r}\right)^{-\gamma} dr^2 + r^2 \sin\theta d\phi^2 + r^2 d\theta^2$$

- Ansatz: $\gamma = \frac{P_{\parallel 0}}{P_{\perp 0}} = \frac{z}{r} \approx 1$
- Structure equations:

$$\frac{dM}{dr} = r^2 E\gamma$$

$$\frac{dP_{\parallel}}{dr} = -\frac{(E + P_{\parallel})[\frac{r}{2} + r^3 P_{\parallel} - \frac{r}{2}(1 - \frac{2M}{r})^{\gamma}]}{r^2(1 - \frac{2M}{r})^{\gamma}}$$

$$\frac{dP_{\perp}}{dz} = \frac{1}{\gamma}\frac{dP_{\perp}}{dr} = -\frac{(E + P_{\perp})[\frac{r}{2} + r^3 P_{\perp} - \frac{r}{2}(1 - \frac{2M}{r})^{\gamma}]}{\gamma r^2(1 - \frac{2M}{r})^{\gamma}}$$

Reduces to TOV equations at $P_{\parallel} \equiv P_{\perp}$ ($B = 0$ case)

Solutions for magnetized Strange Stars

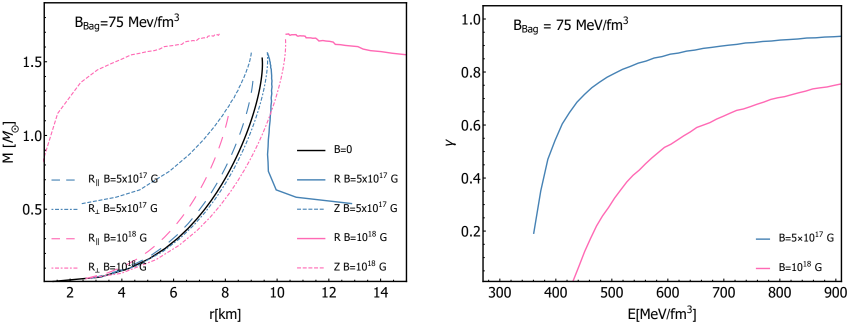


Figure: Solutions for spheroidal configurations in comparison with the non-magnetized configuration at $B = 5 \times 10^{17}$ G and $B = 10^{18}$ G for $\mathrm{B_{bag}} = 75$ MeV/fm^3, where r represents both radii R and Z.

Comparison with Strange Stars candidates

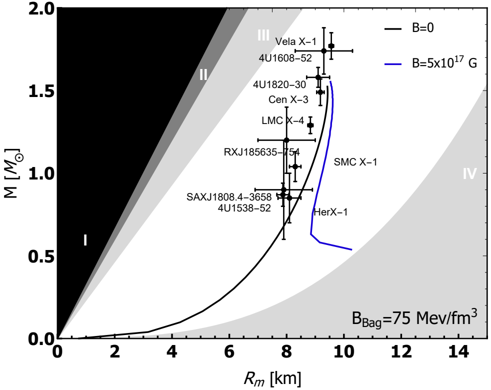
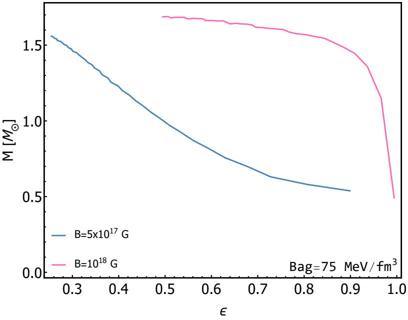


Figure: Comparion of observational data for candidates of SSs with the stars obtained from TOV and γ equations. The shaded regions correspond to theoretical constraints. Gravitational collapse (I). Requirement of finite pressure inside the star (II). Casualty (III). Rotational stability (IV).

$$A = 2\pi R \left[R + \frac{Z}{\epsilon} \arcsin \epsilon \right]$$

Eccentricity and Gravitational Redshift



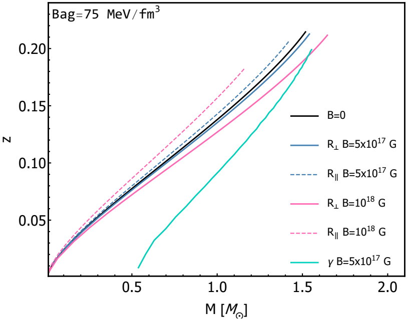
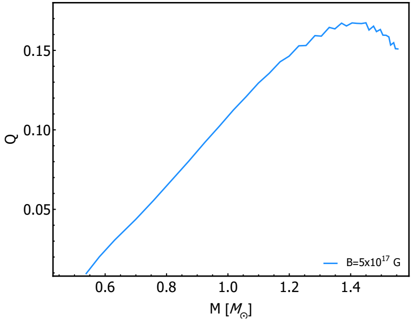


Figure: Eccentricity (ϵ) and Gravitational Redshift (z) as a function of the mass.

$$\epsilon = \sqrt{1-\gamma}, \qquad z = \frac{1}{(1-\frac{2M}{R})^{\gamma/2}} - 1$$

Mass Quadrupole Moment and Moment of Inertia



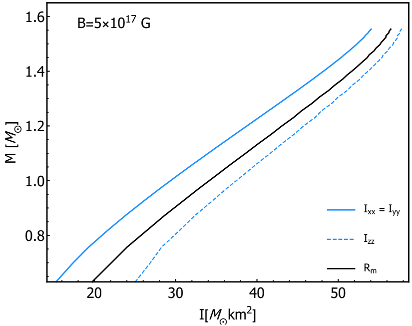


Figure: Mass quadrupole moment and moment of inertia as a function of the mass.

$$Q = \frac{\gamma^3}{3} M^3 (1 - \gamma^2)$$

10.1051/0004-6361:20021241

$$\begin{aligned} I_{xx} &= I_{yy} = \frac{1}{5} M(R^2 + Z^2), \\ I_{zz} &= \frac{2}{5} MR^2, \\ I &= a_{ss}(x) MR_m^2, \quad a_{ss} = \frac{2}{5}\left(1 + \frac{M \cdot km}{M_\odot \cdot R_m}\right), \end{aligned}$$

Conclusions

- This work is an step forward in our studies about magnetized SSs.
- To compute the star's observables the EoS have been restricted to the stability region (energies below 930 MeV).
- The macroscopic properties of the SSs were calculated using the equations for spheroidal COs.
- The mass-radius curves of the stable configurations obtained are consistent with the observed properties of SSs candidates and comply with the theoretical constraints, this result supports the plausibility of our model.
- In our model, less massive stars suffer bigger deformations in contrast with the results from TOV solutions for the perpendicular and the parallel pressure independently.
- Augmenting both, $\mathrm{B_{Bag}}$ or B, increases the deformation.
- The curve of the gravitational redshift of SSs has remarkable differences with respect to the ones of the spherical case.
- The maximum values of the mass quadrupole moment occur for the stars with intermediate values of masses and deformation.
- The moment of inertia in the transverse direction is smaller than along the magnetic field direction. While the one corresponding to the mean radius, lays between the polar and equatorial components.

Future work perspectives

- Consider $\mathtt{Bag}(\mathbf{B})$ and $\mathtt{Bag}(\mathbf{n_B})$.
- Keep searching for structure equations that allow to describe magnetized Compact Objects without the restriction of small deformations.
- Include the effects of rotation and temperature in the modeling of magnetized Strange Stars.
- Study the effects of magnetic deformation in the emission of Gravitational Waves.
- Include General Relativity and rotation in the computation of the moment of inertia.