Nuclear Mass Model School

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Compact Star Structure

Different models for Neutron Star Structure

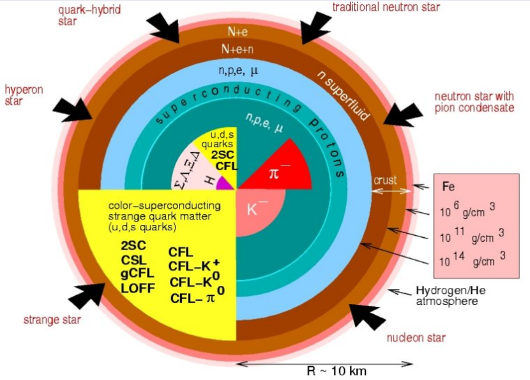

IMAGE CREDIT: Dr. Fridolin Weber.

- There are several models competing to describe the structure of a compact star.
- In this work we assume that the Neutron Star is composed of absolute stable strange matter (More stable than atomic nuclei).

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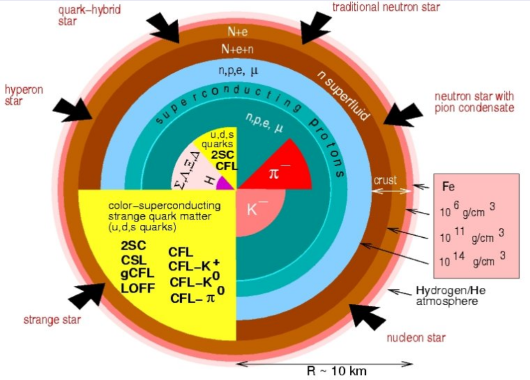

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Strange Star Structure

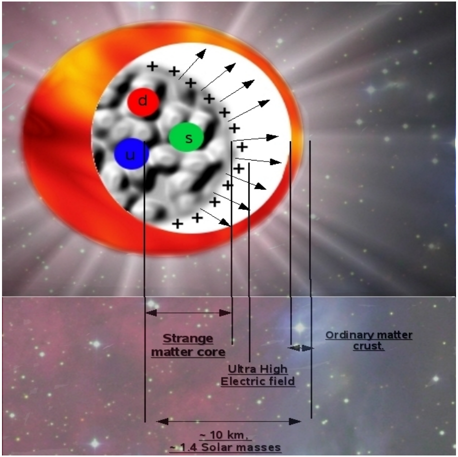

IMAGE CREDIT: Rodrigo P. Negreiros

- The theory of Strange Matter predicts an accumulation of charge at the surface of the strange core.
- This charge generates an ultra-high electric field, which supports an ordinary matter crust.
- Our objective is to model this charge distribution and investigate the effects of this ultra high electric field on the bulk properties of the star.

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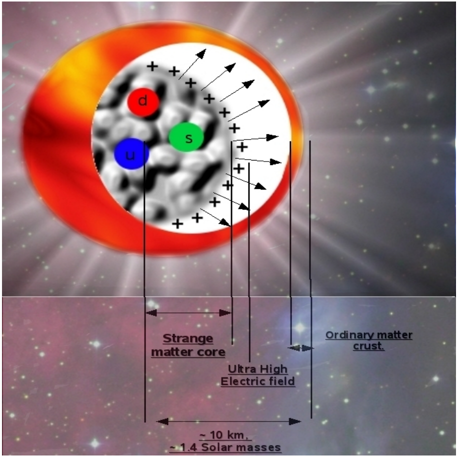

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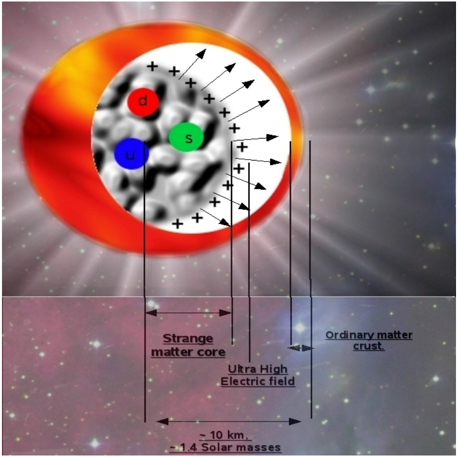

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The Energy-Momentum tensor

Since we are dealing with a spherically symmetric problem, the obvious choice for the metric is

$$ds^2 = e^{\nu(r)}c^2dt^2 - e^{\lambda(r)}dr^2 - r^2(d\theta^2 + sen^2\theta d\phi^2). \quad (1)$$

The Energy-Momentum tensor of the star is

$$T^{\mu}_{\nu} = (p + \rho c^2)u_{\nu}u^{\mu} + p\delta_{\nu\mu} + \frac{1}{4\pi}\left[F^{\mu l}F_{\nu l} + \frac{1}{4\pi}\delta^{\mu}_{\nu}F_{kl}F^{kl}\right], \quad (2)$$

where we have the usual perfect fluid Energy-Momentum tensor and a new contribution coming from the electromagnetic field.
The components $F^{\nu\mu}$ satisfy the Maxwell equations in its covariant formulation. Assuming spherical symmetry we can work out these equations finding the following expression for the Energy-Momentum tensor:

$$T^{\mu}_{\nu} = \begin{pmatrix} -\left(\epsilon + \frac{Q^2(r)}{8\pi r^4}\right) & 0 & 0 & 0 \\ 0 & p - \frac{Q^2(r)}{8\pi r^4} & 0 & 0 \\ 0 & 0 & p + \frac{Q^2(r)}{8\pi r^4} & 0 \\ 0 & 0 & 0 & p + \frac{Q^2(r)}{8\pi r^4} \end{pmatrix}. \quad (3)$$

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The structure equations

Here we summarize all structure equations we have for a charged relativistic star .

$$\frac{d\lambda}{dr} = \frac{8\pi G}{c^4}\left(\epsilon + \frac{Q^2(r)}{8\pi r^4}\right) r e^{\lambda} - \left(\frac{e^{-\lambda}-1}{r}\right), \quad (4)$$

$$\frac{dm}{dr} = \frac{4\pi r^2}{c^2}\epsilon + \frac{Q(r)}{c^2 r}\frac{dQ(r)}{dr}, \quad (5)$$

$$\frac{dQ}{dr} = 4\pi r^2 j^0 e^{-(\nu+\lambda)/2}. \quad (6)$$

$$\frac{dp}{dr} = -\frac{2G\left[m(r) + \frac{4\pi r^3}{c^2}\left(p - \frac{Q^2(r)}{4\pi r^4 c^2}\right)\right]}{c^2 r^2\left(1 - \frac{2Gm(r)}{c^2 r} + \frac{GQ^2(r)}{r^2 c^4}\right)}(p+\epsilon) + \frac{Q(r)}{4\pi r^4}\frac{dQ(r)}{dr}. \quad (7)$$

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$$P = \frac{\epsilon - 4B}{3} \quad (9)$$

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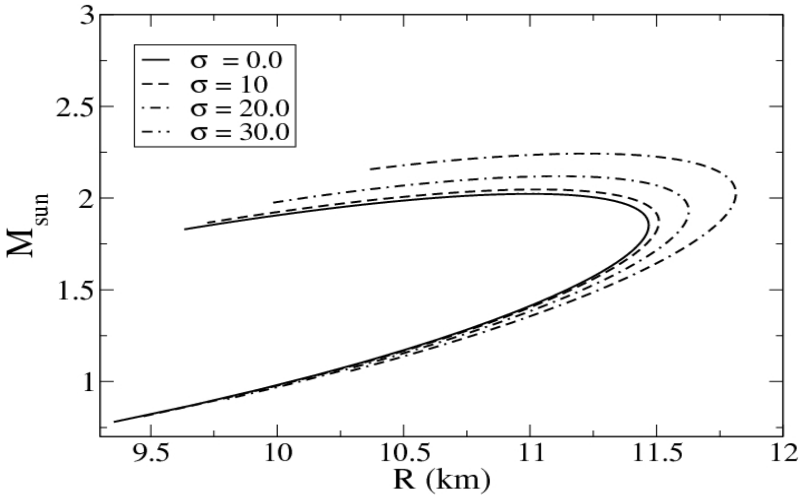
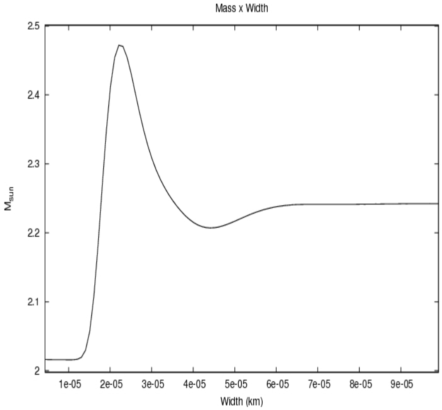
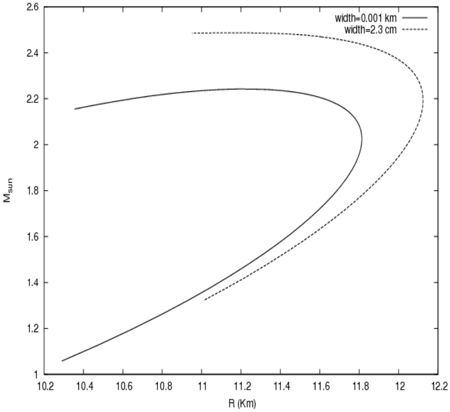
Mass-Radius Diagram



Mass x Width


Mass x Width
2.5
2.4
2.3
2.2
2.1
2
M_sun
1e-05
2e-05
3e-05
4e-05
5e-05
6e-05
7e-05
8e-05
9e-05
Width (km)


width=0.001 km
width=2.3 cm
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
M_sun
10.2
10.4
10.6
10.8
11
11.2
11.4
11.6
11.8
12
12.2
R (Km)

RMF

$$m_\omega^2 \omega_0 = \sum_B g_{\omega B} n_B \tag{10}$$

$$\rho_{03} = \frac{g_\rho}{m_\rho^2} \sum_B I_3 n_B \tag{11}$$

$$m_\sigma^2 \sigma_0 + g_3 \sigma_0^2 + g_4 \sigma_0^3 = \sum_B g_{\sigma B} S(m_{eff,B}, k_{F,B}) \tag{12}$$

$$S(m_{meff,B}, k_{F,B}) = \frac{2J_B + 1}{2\pi^2} \int_0^{k_{F,B}} \frac{m_{eff,B}}{\sqrt{k^2 + m_{eff,B}^2}} k^2 dk \tag{13}$$

Compossition