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Gravitational and Structural Modifications of Compact Objects due to Quadrupole Moments in General Relativity

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This study investigates the gravitational behavior of compact astrophysical objects, specifically white dwarfs and neutron stars, within Einstein's General Relativity framework. We incorporate the quadrupole moment in a first-order approximation to analyze how deviations from spherical symmetry influence their internal structure.

The Einstein field equations for a perfect fluid are given by:
$R_{\mu\nu} - \frac{1}{2} R g_{\mu\nu} = 8\pi[(\rho + p)U_\mu U_\nu - p g_{\mu\nu}]$

where ρ and p represent the density and pressure, respectively. The interior metric includes quadrupole corrections [1]:
$ds^2 = e^{2\nu}(1 + qa)dt^2 -$
$dfrac(1 + qc + qb)1 - dfrac2mrdr^2 - (1 + qa + qb)r^2 d\theta^2 - (1 - qa)r^2 \sin^2\theta d\varphi^2$

Here, $\nu = \nu(r)$, $a = a(r)$, $c = c(r)$, $b = b(r, \theta)$, and q is the quadrupole parameter.

We compare two fundamental equations of state (EoS), the Chandrasekhar and Salpeter EoS, to examine their impact on mass distributions and pressure gradients. The Chandrasekhar EOS is given by [2,3]:
$p_{\mathrm{Ch}} =$
$dfrac43 \left(dfracm_e m_n\right)^4 K_n \left[y(2y^2 - 3)\sqrt{1 + y^2} + 3\ln(y + \sqrt{1 + y^2})\right]$

while the Salpeter EoS includes electrostatic corrections:
$p_{\mathrm{Sal}} = p_{\mathrm{Ch}} + p_C + p_{TF}$

Numerical solutions of the Einstein equations reveal that quadrupole-induced modifications significantly alter the gravitational field and structural properties of these stars.

References:
[1] Abishev M., Beissen N., Belissarova F., Boshkayev K., Mansurova A., Muratkhan A., Quevedo H., Toktarbay S. Int. J. Mod. Phys. D, 2021, Vol. 30, No. 13, p. 2150096.
[2]Chandrasekhar, S. The Maximum Mass of Ideal White Dwarfs. Astrophys. J. 1931, Vol 74, No. 81.
[3] Rotondo M., Rueda J. A., Ruffini R., Xue S. S. Phys. Rev. D, 2011, Vol. 84, No. 8, p. 084007.

Secondary track

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