Pressure Anisotropy Effects on Surface Curvature of the Neutron Star

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Plan of the Talk

- Introduction
- Motivation
- Formalism
- Results and Discussions
- Summary

Introduction

- It is the most common assumption is that the pressure inside the neutron star (NS) is isotropic in nature. However, the pressure is locally anisotropic in nature which is a more realistic case.

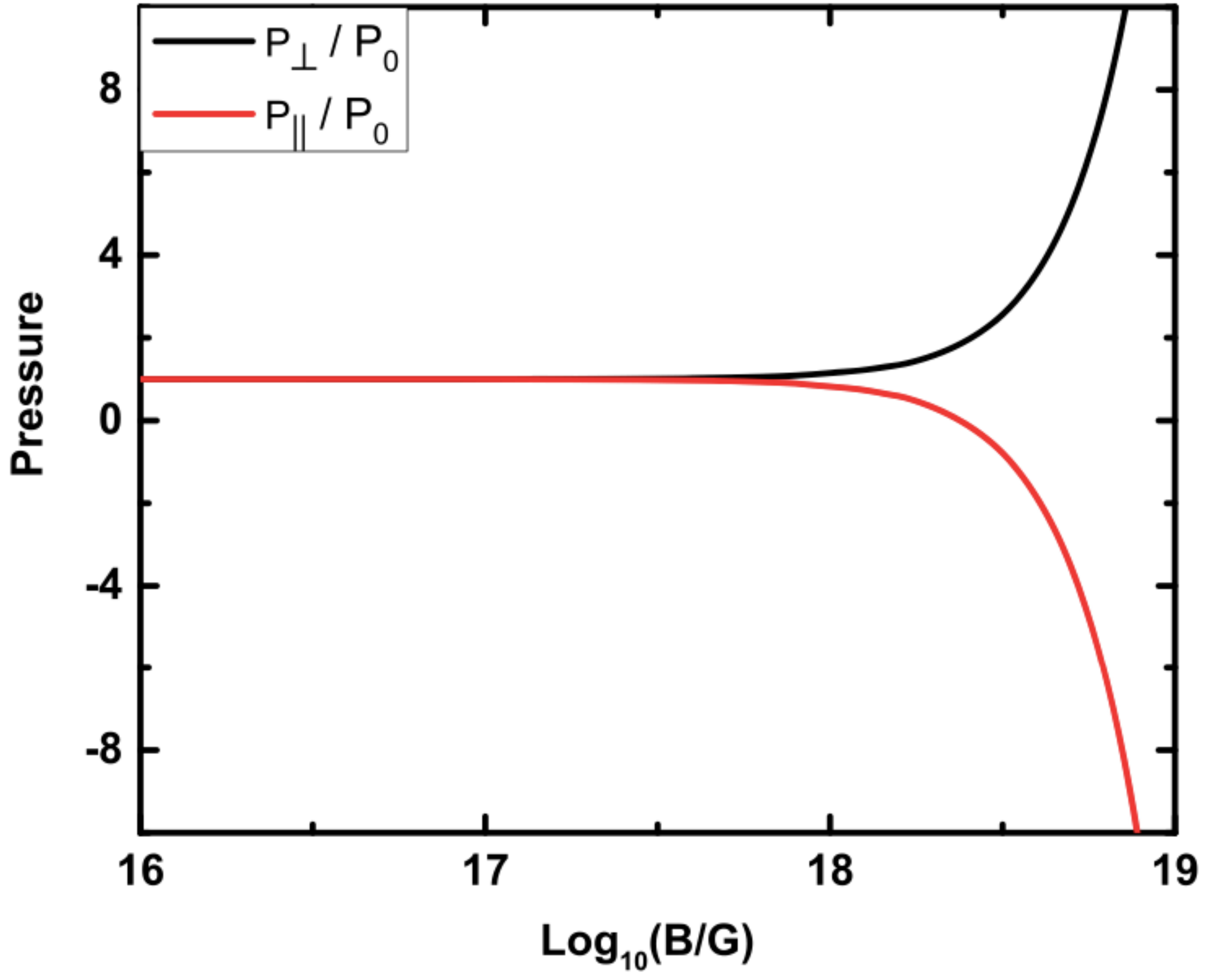
- Due to various exotic processes inside the NS, such as strong magnetic field, pion condensation, phase transitions, superfluid core, etc., are the main sources of the anisotropy.

- The difference between the magnitude of radial and tangential pressure produces pressure anisotropy, and it is purely model-dependent.

- The magnitude of various properties such as mass, radius, and surface curvature are changed due to pressure anisotropy.

H. C. Das, Phys. Rev. D 106, 103518 (2022)

Z. Roupas, Astrophys. Space Sci. 366, 9 (2021)



P_0 is the pressure without magnetic field.

Patra et al. Astrophysical Journal, 900, 49 (2020)

Motivation

- The GW190814 event opens a possibility that the secondary component might be a anisotropic NS.

- Due to pressure anisotropy, the system needs more/less gravitational forces to maintain the hydrostatic equilibrium based on the degree of anisotropy.

- Various macroscopic magnitudes increase/decreases due to anisotropy.

- One can constrain the amount of anisotropy inside the NS using various observational data.

Z. Roupas, Astrophys. Space Sci. 366, 9 (2021)

Formalism

- The Maxwell stress-energy tensor for a perfect fluid is defined as

$$T_{\mu\nu} = (\mathscr{E} + P_r)u_\mu u_\nu + P_r g_{\mu\nu}\,,$$

where u_μ and $g_{\mu\nu}$ are the four-velocity of the fluid and metric respectively.

- Due to pressure anisotropy, the stress energy tensor modified as

$$T_{\mu\nu} = (\mathscr{E} + P_t)u_\mu u_\nu + (P_r - P_t)k_\mu k_\nu + P_t g_{\mu\nu}\,,$$

where k_μ is the unit radial vector $(k_\mu k^\mu = 1)$ with $u_\mu k^\mu = 0$.

Formalism

- To calculate mass and radius of the anisotropic NS, we solve the modified Tolmann-Oppenheimer-Volkoff equations

$$\frac{dP_r}{dr} = -\frac{\left(\mathscr{E} + P_r\right)\left(m + 4\pi r^3 P_r\right)}{r\,(r-2m)} + \frac{2}{r}(P_t - P_r)\,, \frac{dm}{dr} = 4\pi r^2 \mathscr{E}$$

with boundary conditions $r = 0,\ P = P_c,\ \text{and}\ r = R,\ P = 0.$

- For the P_r and $\mathscr{E}$, we take the IOPB-I equation of state (EOS).

- For P_t , we take the BL model given as $P_t = P_r + \frac{\lambda_{\rm BL}}{3}\frac{(\mathscr{E} + 3P_r)(\mathscr{E} + P_r)r^2}{1 - 2m/r}$

where $\lambda_{\rm BL}$ is the degree of anisotropy.

H. C. Das, Phys. Rev. D 106, 103518 (2022)

Bower, and Liang, Astro. Phys. Jour. 188, 657 (1974)

Results and Discussions

1. Pressure-radius, Mass-Radius relations

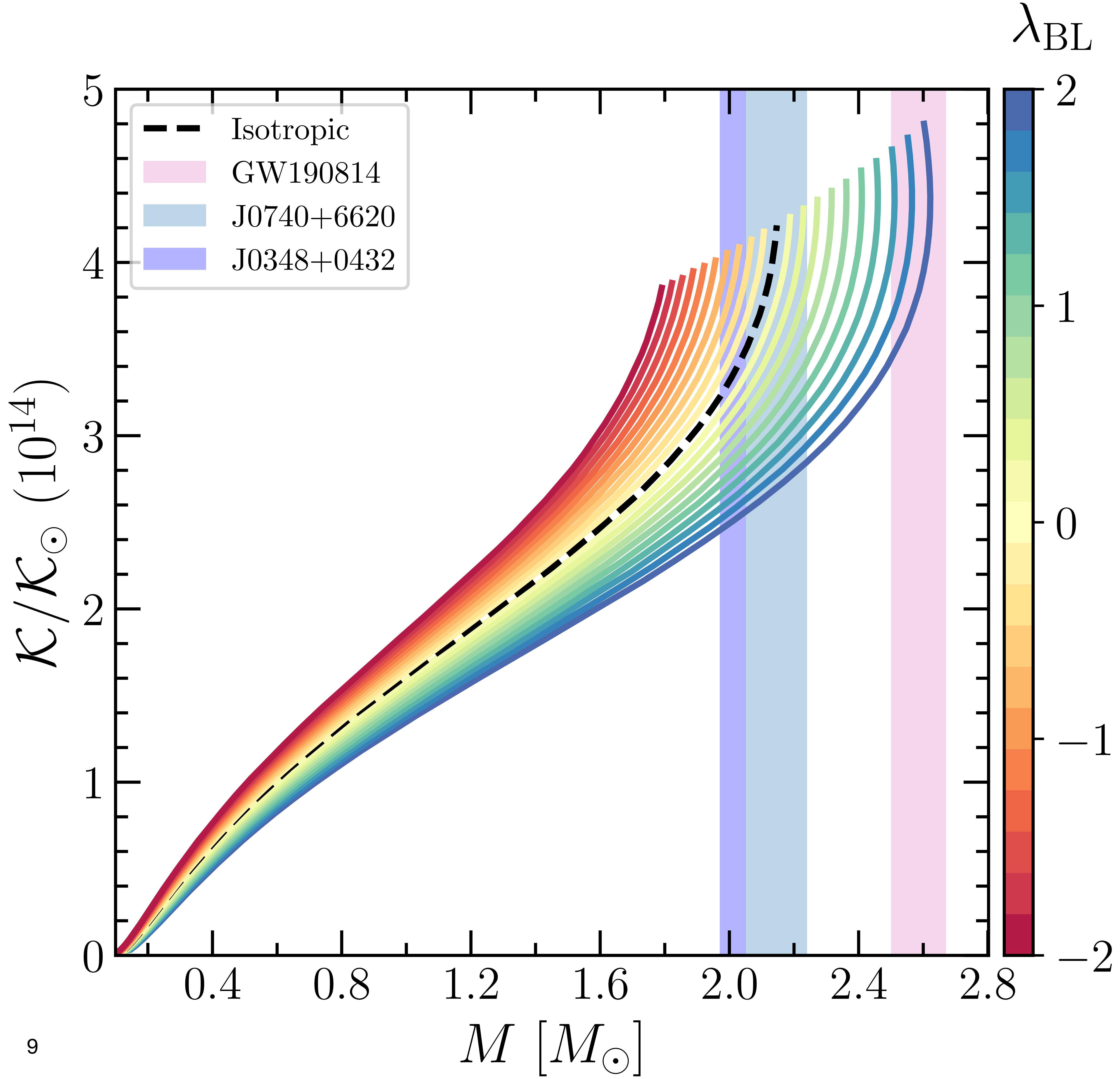
H. C. Das, Phys. Rev. D 106, 103518 (2022)

Results and Discussions

2. Surface Curvature

- Surface Curvature (SC) of the star defined as $\mathscr{K} = M/R^3$, where M and R are the mass and radius of the star.

- The dimensionless surface curvature is defined as $\mathscr{K}/\mathscr{K}_\odot$ which is order of 10^{14}.



Summary

- We use BL model to calculate the magnitude of tangential pressure inside the neutron star.
- The relativistic mean-field EOS (IOPB-I) is taken to solve the TOV equations, which provide the mass-radius profiles of the star.
- We observe that with an increase in the degree of anisotropy, the magnitude of mass, radius, and surface curvature increases.
- From various observational data, one can constrain the degree of anisotropy inside the NS.

THANK YOU