基于无量纲TOV方程研究压力各向异性对于限制大质量中子星高密物态方程的影响

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华南理工大学物理与光电学院

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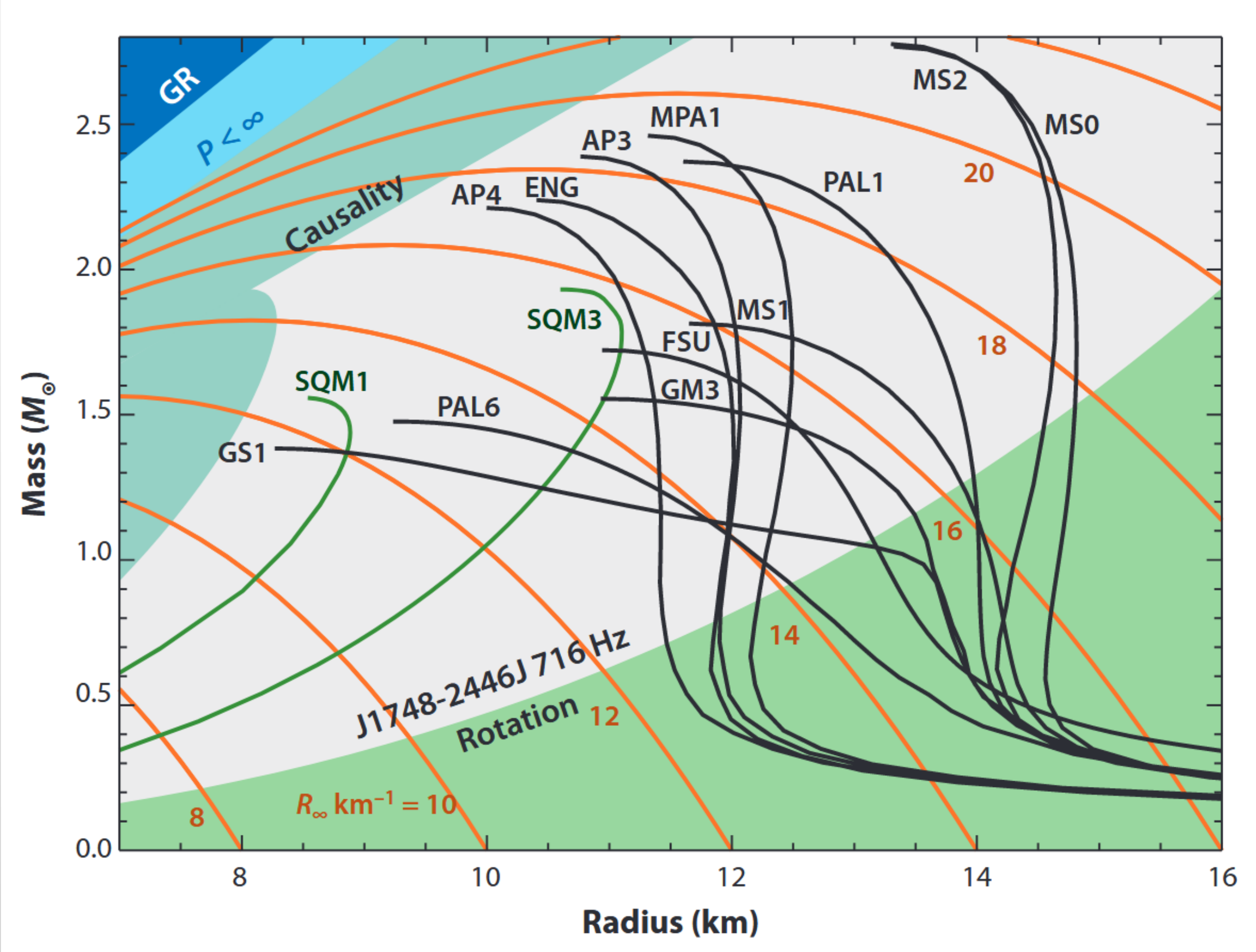
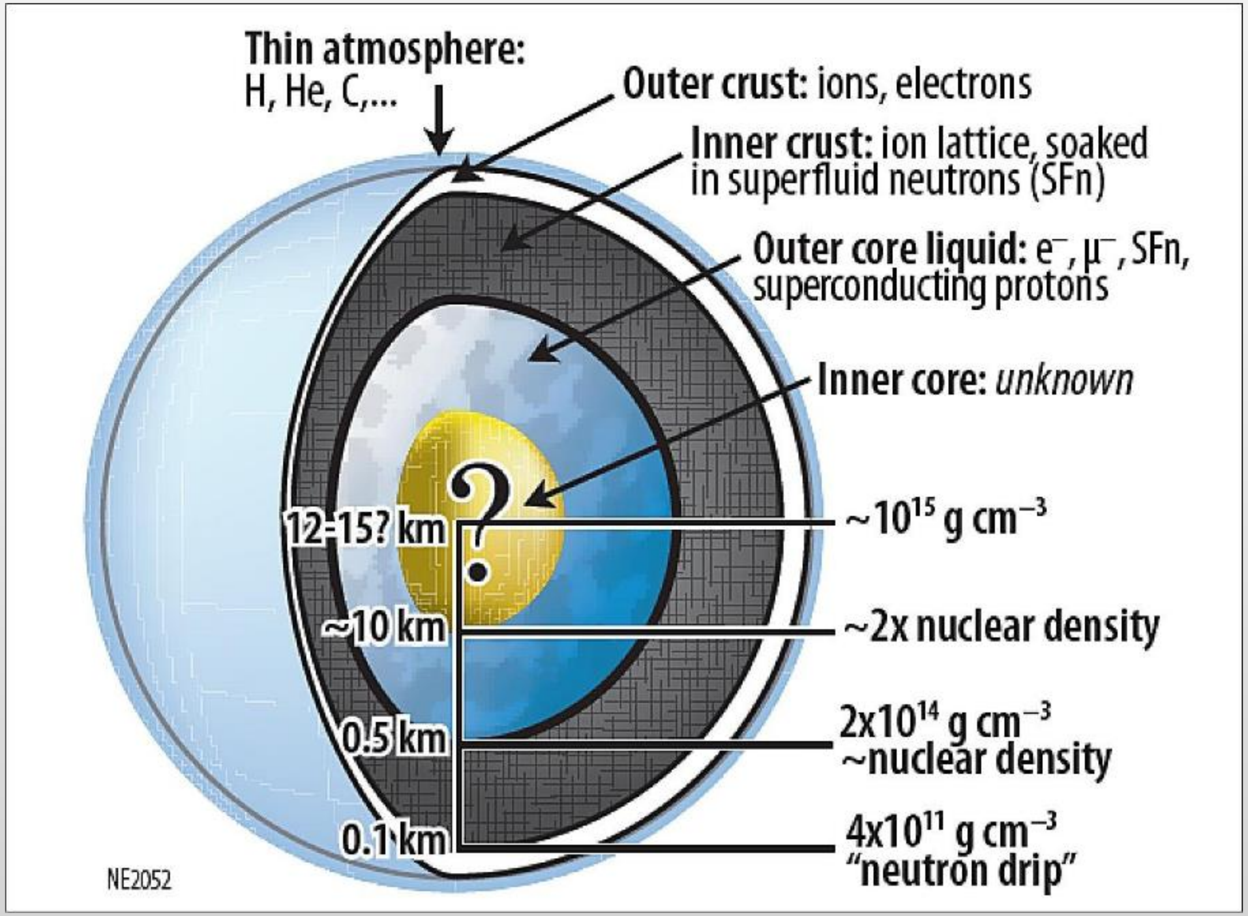
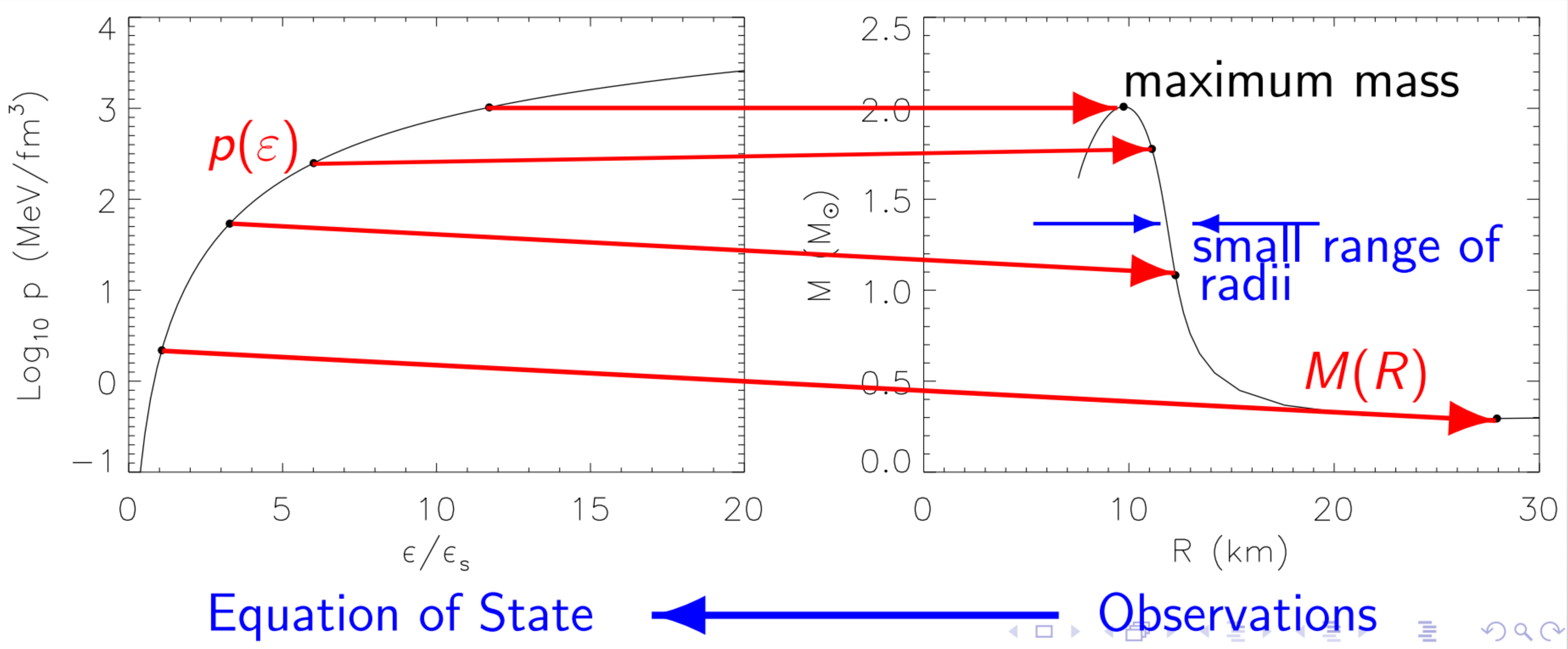


Phys. Rep. 442, 109 (2007)



Nat. Rev. Phys. 4, 237 (2022)



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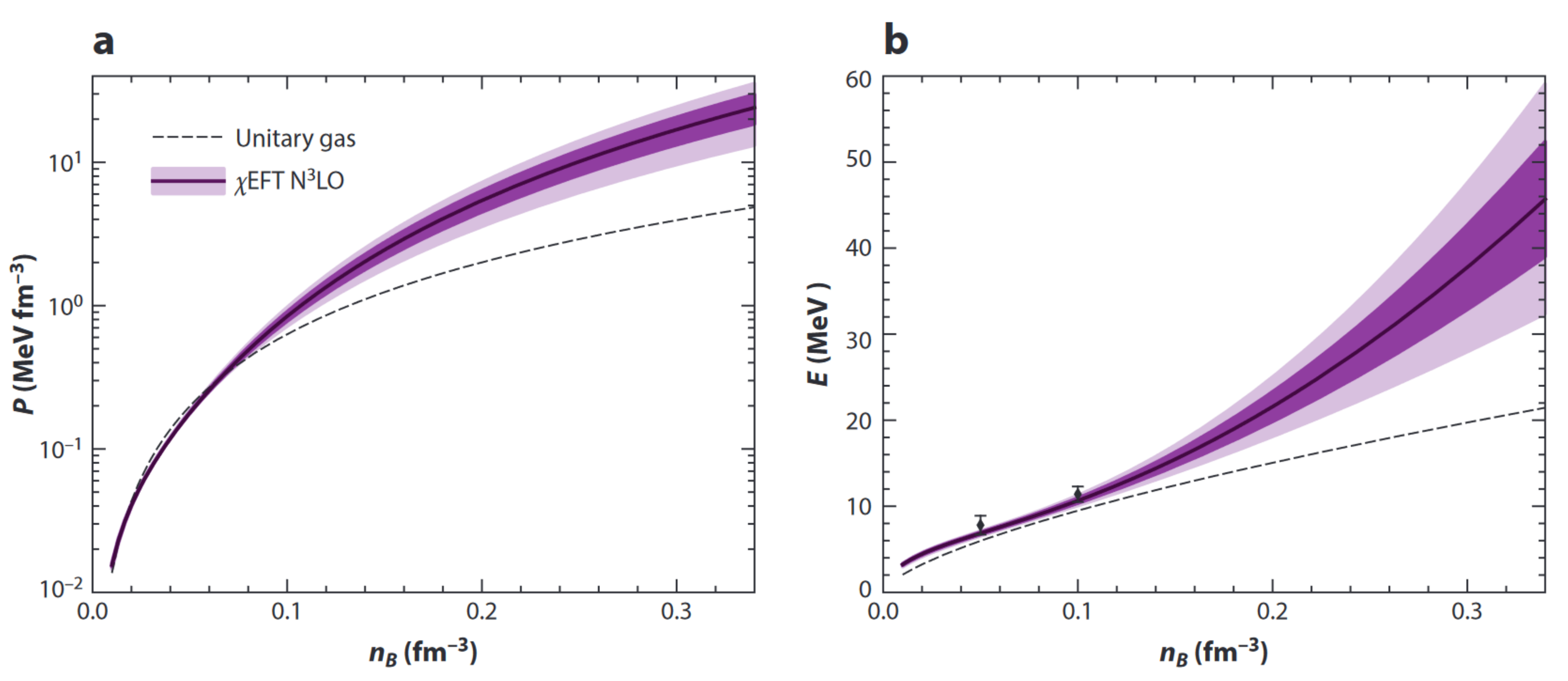
(2024)



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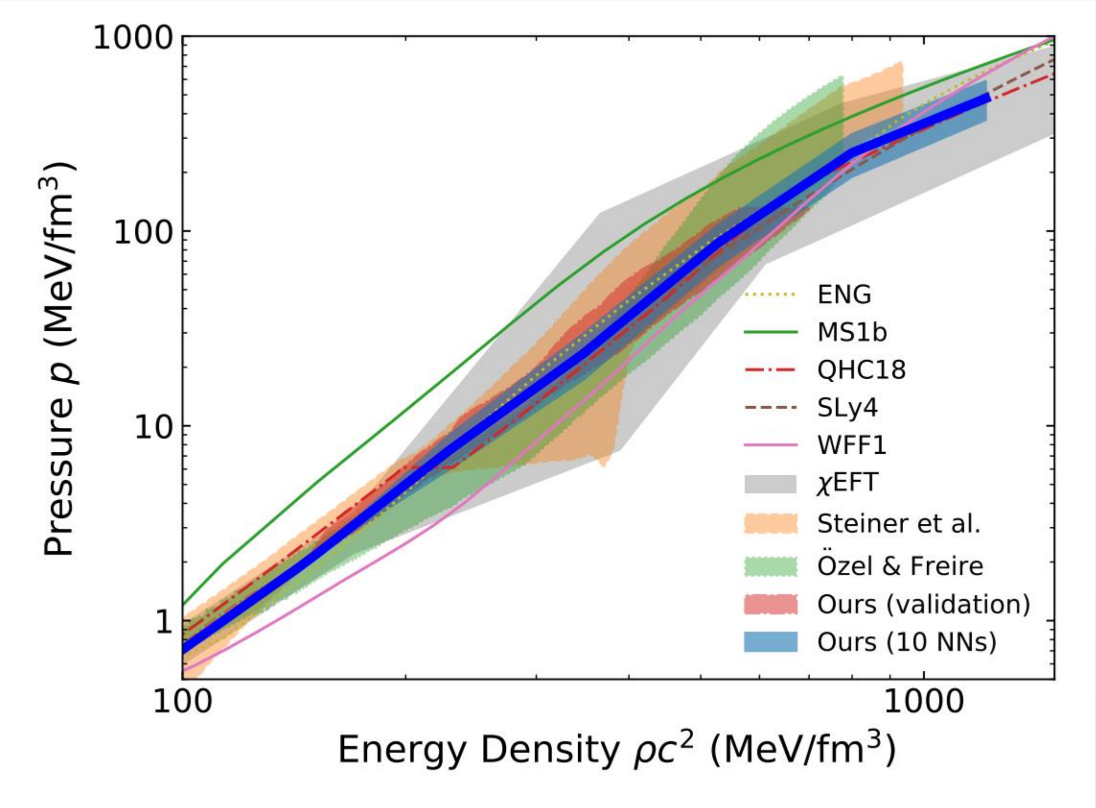
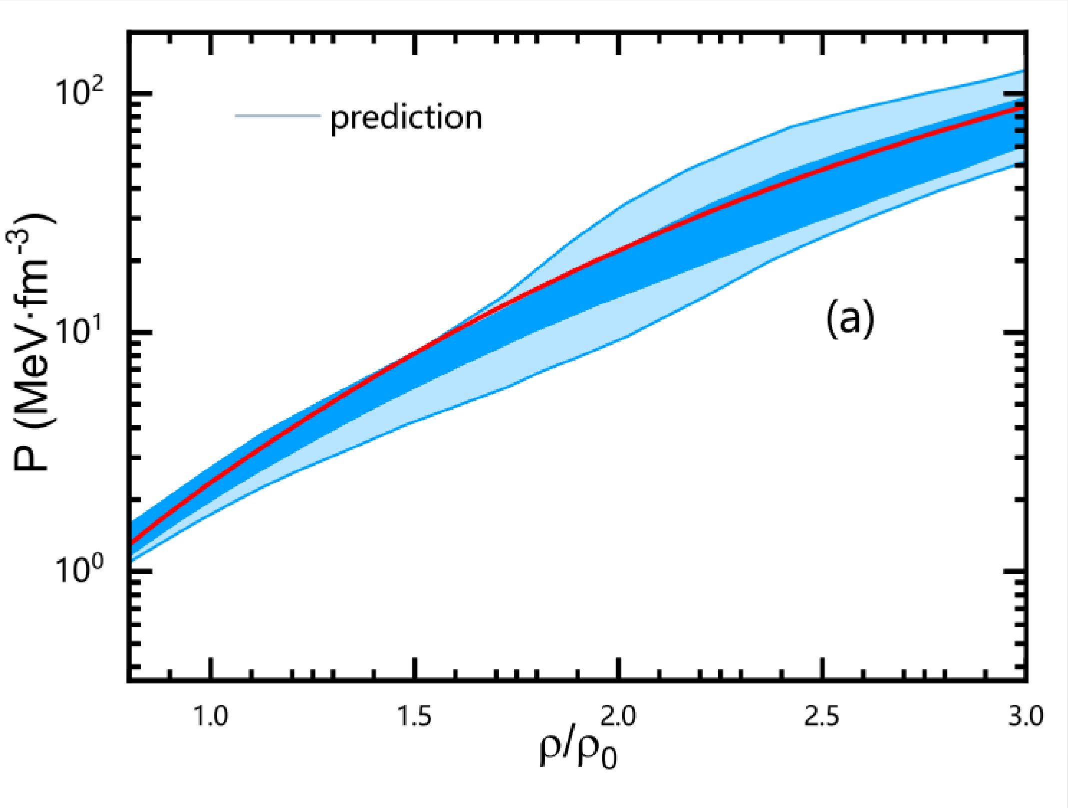
机器学习



Phys. Rev. D 98, 023019 (2018)



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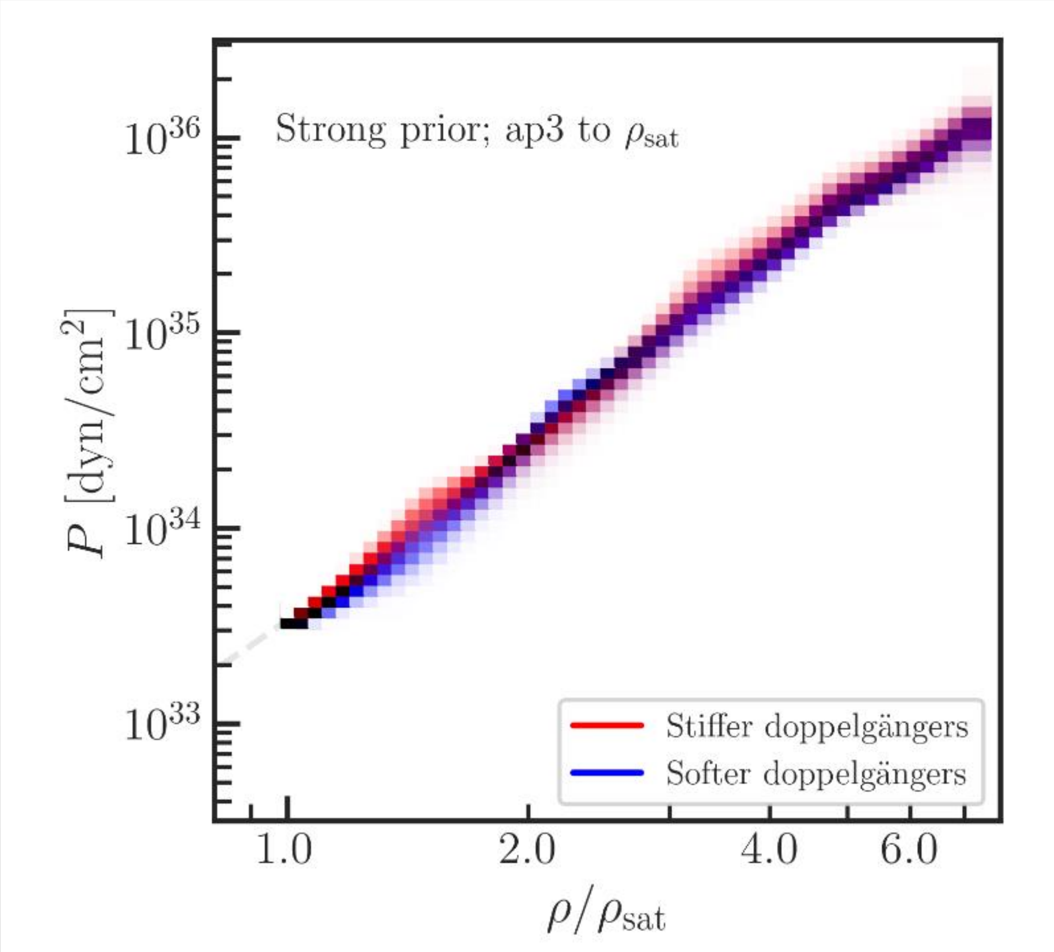

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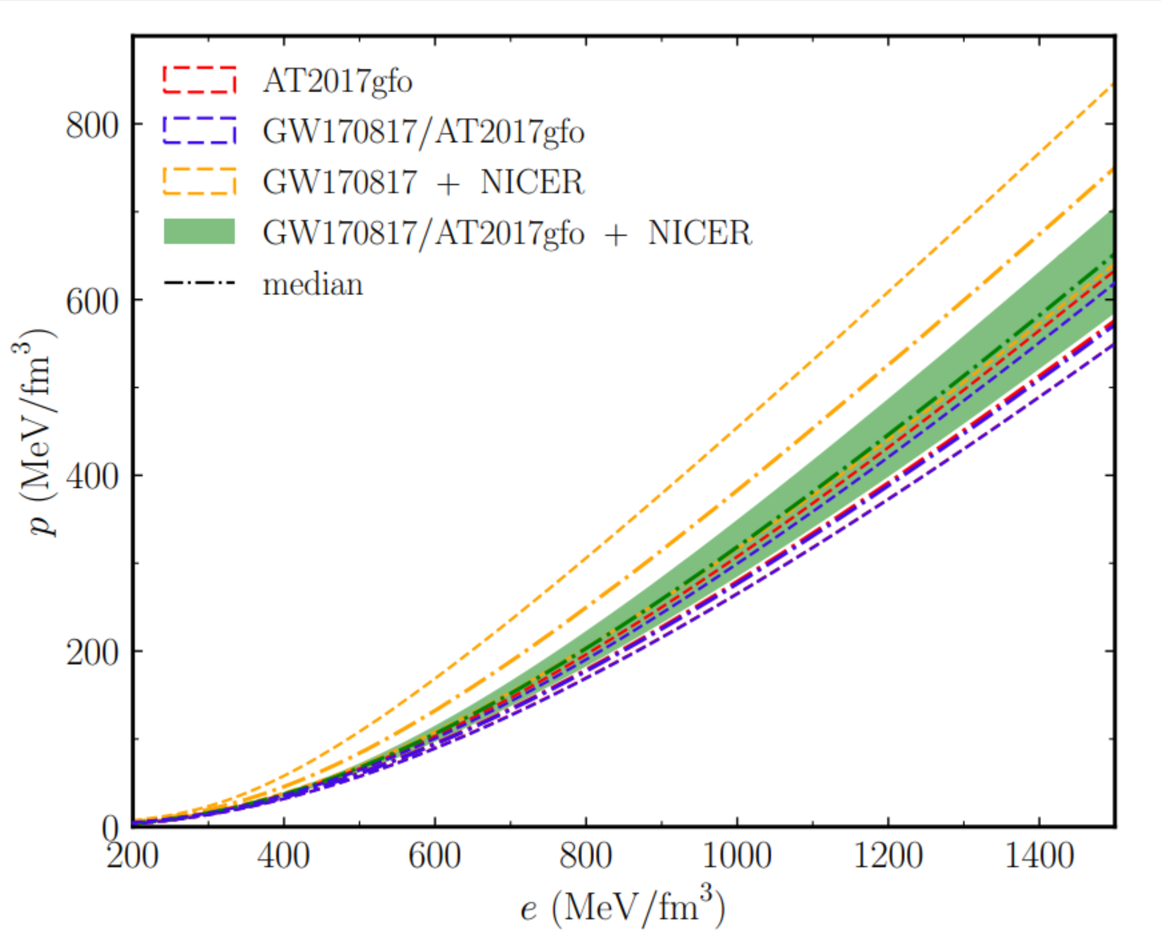
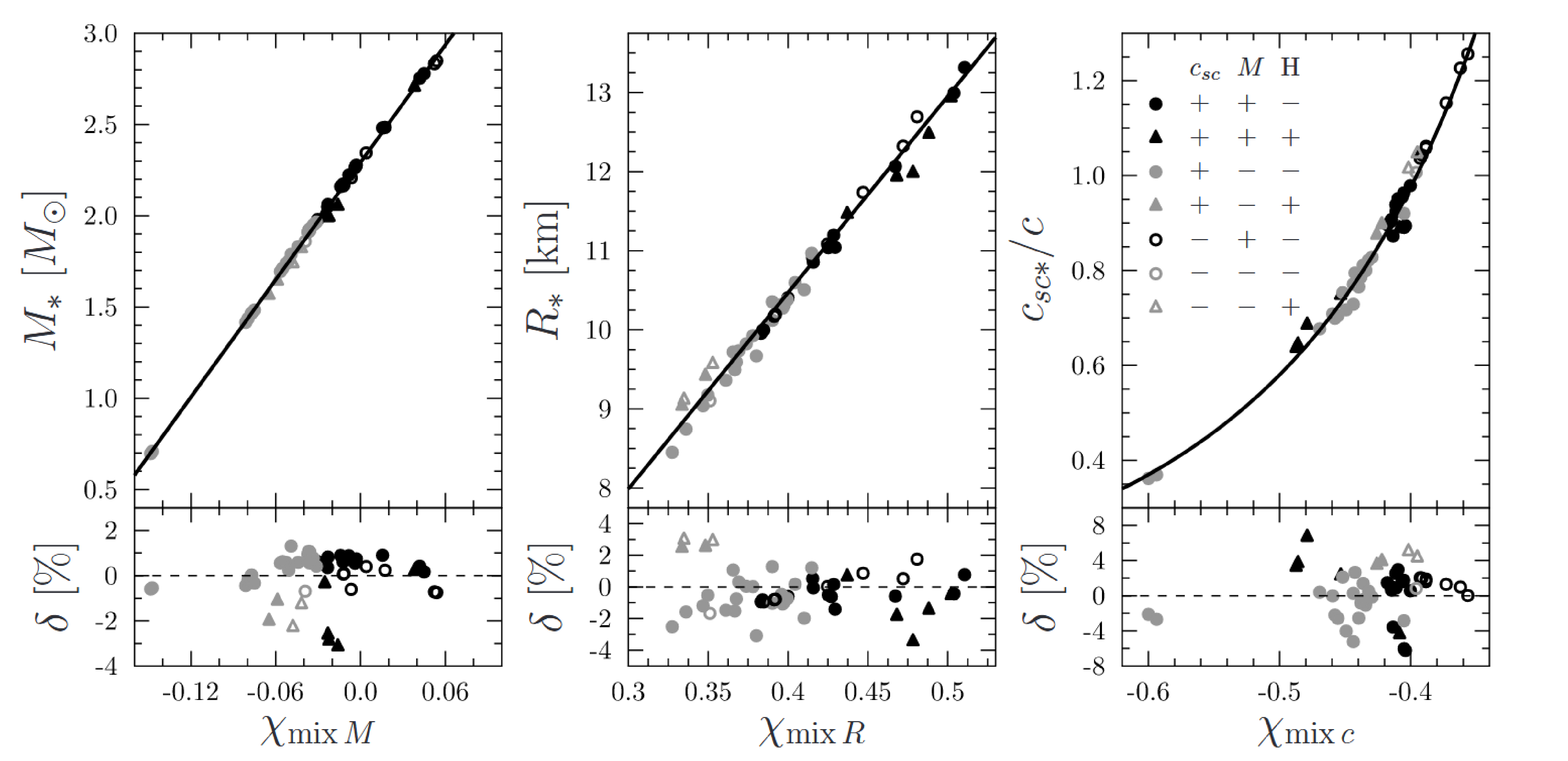


Astrophys. J. 943, 163 (2023)

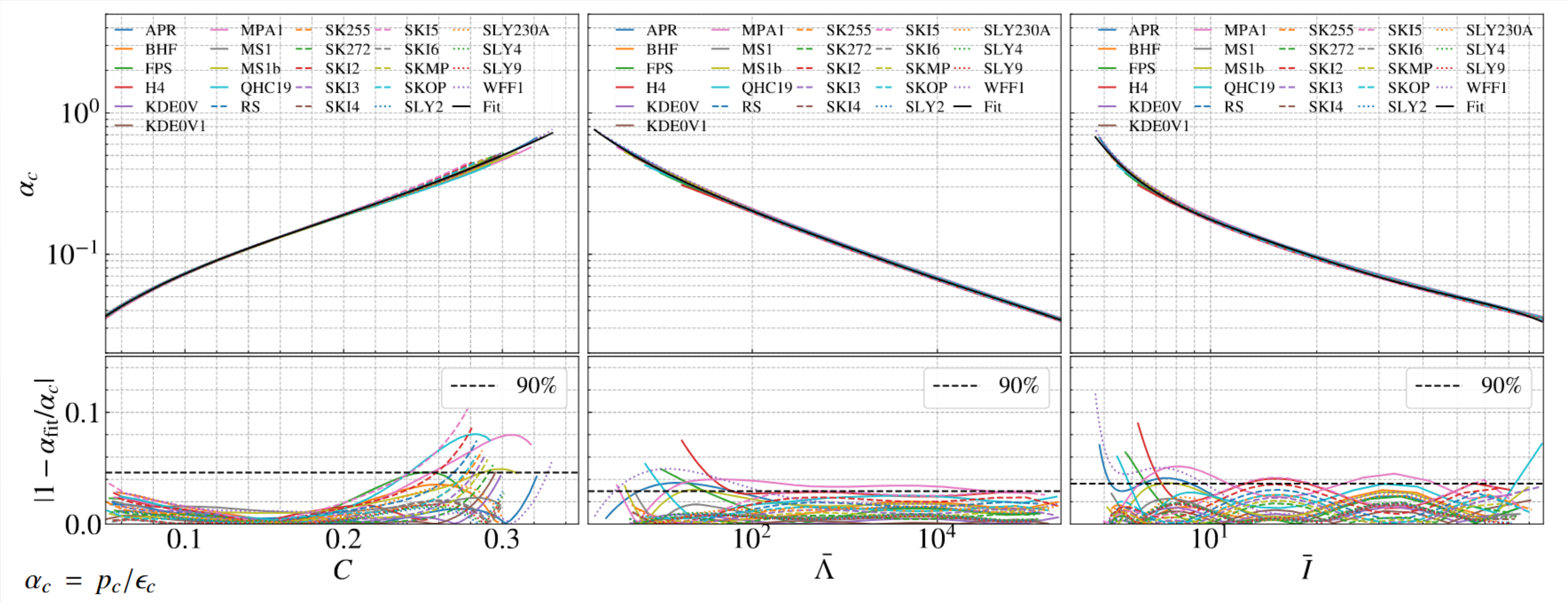
普适性关系



$$\chi_{\mathrm{mix}\,y} = (\rho_0/\rho_{c*})^{1/1.72} \cos \Phi_y + (\rho_0 c^2/P_{c*})^{1/5.32} \sin \Phi_y$$

Phys. Rev. D 101, 103029 (2020)

普适性关系



Phys. Rev. D 106, 043027 (2022)

PSR J0952-0607: The Fastest and Heaviest Known Galactic Neutron Star

Roger W. Romani,[1] D. Kandel,[1] Alexei V. Filippenko,[2] Thomas G. Brink,[2] and WeiKang Zheng[2]

[1] *Department of Physics, Stanford University, Stanford, CA 94305, USA*
[2] *Department of Astronomy, University of California, Berkeley, CA 94720-3411, USA*

$2.35^{+0.17}_{-0.17}\ M_\odot$

(Accepted July 4, 2022)

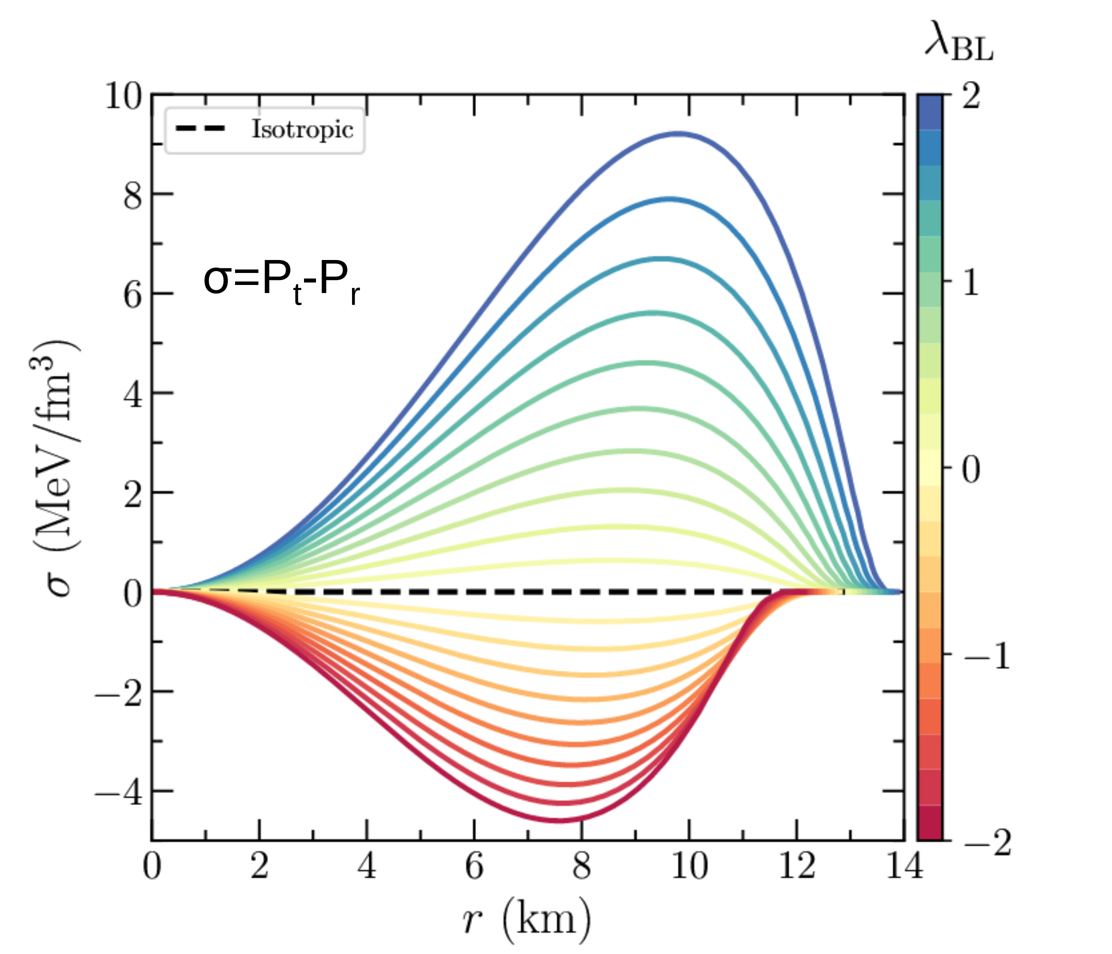
Astrophys. J. Lett. 934, L17 (2022)

GW190814: Gravitational Waves from the Coalescence of a 23 $M_\odot$ Black Hole with a 2.6 $M_\odot$ Compact Object

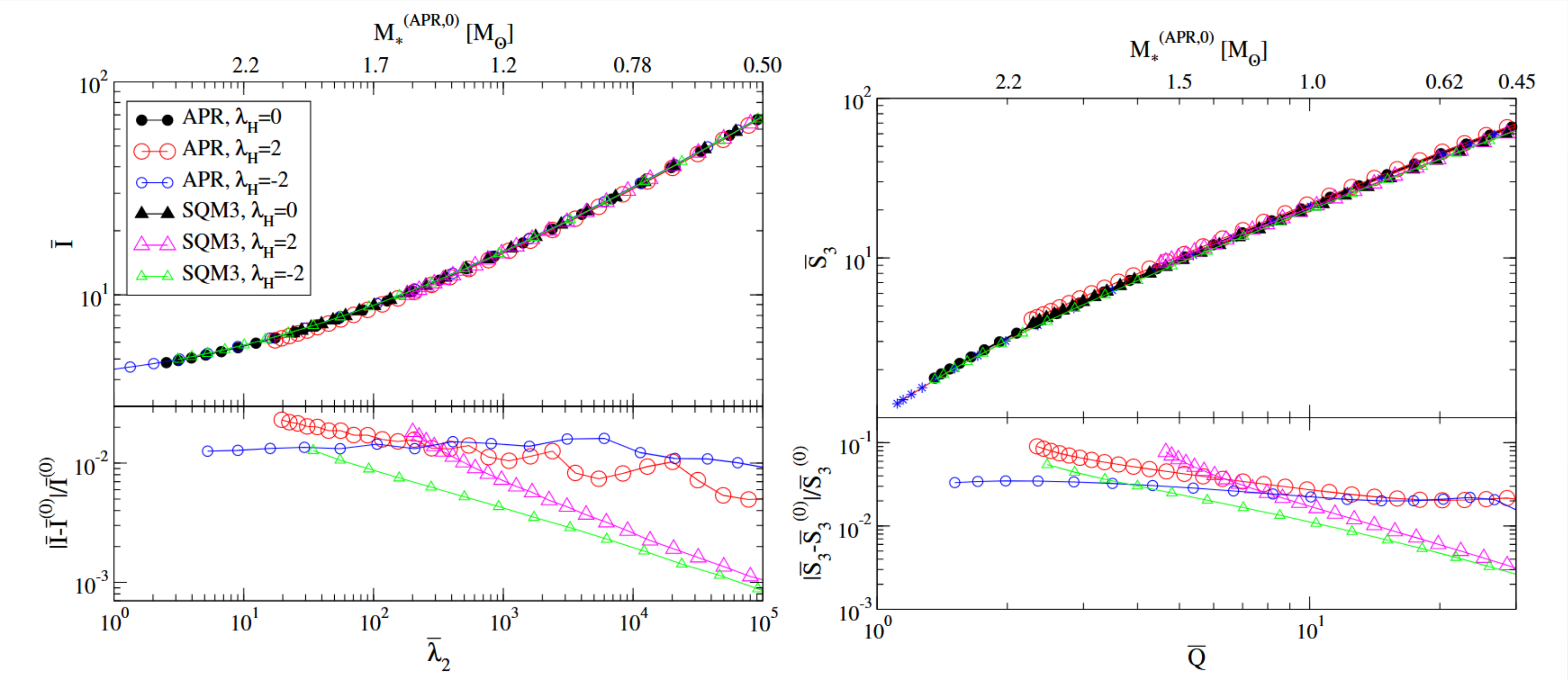
LIGO Scientific Collaboration and Virgo Collaboration

$2.59^{+0.08}_{-0.09}\ M_\odot$

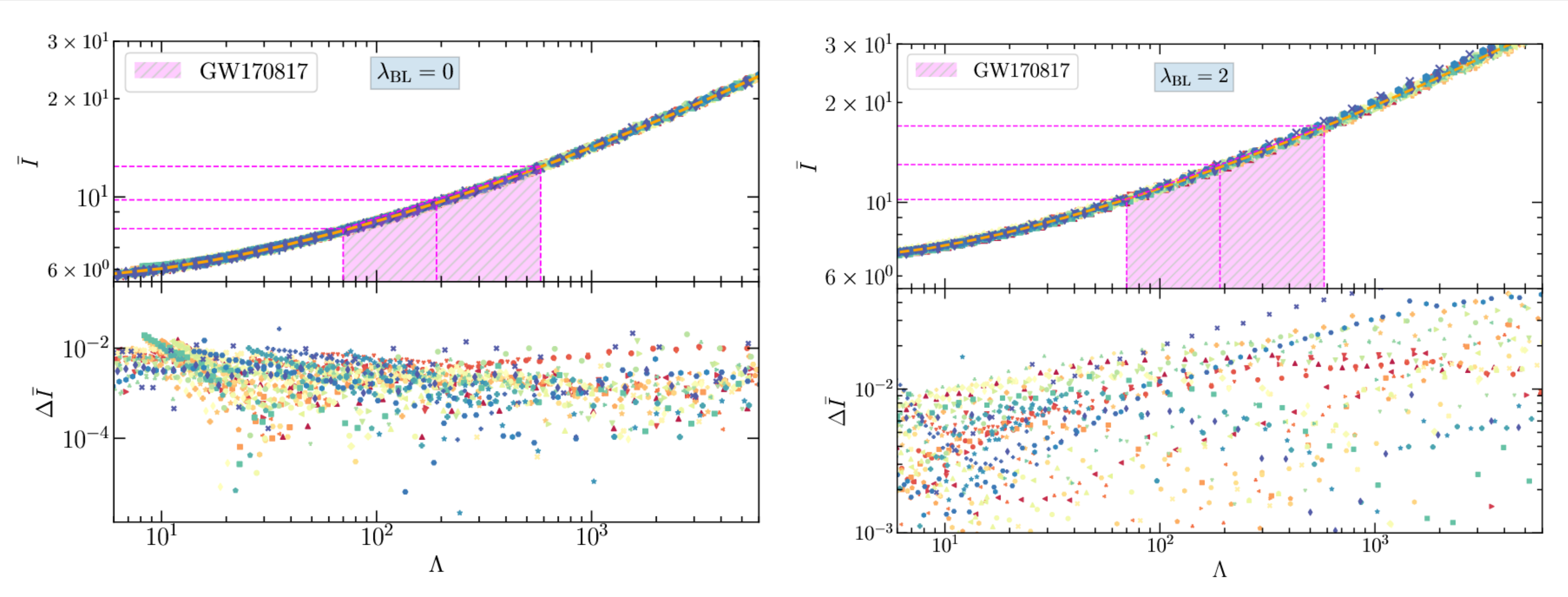
Astrophys. J. Lett. 896, L44 (2020)



Phys. Rev. D 106, 103518 (2023)



Phys. Rev. D 91, 123008 (2015)



Phys. Rev. D 106, 103518 (2023)

无量纲TOV方程研究压力各向异性对于限制中子星高密物态影响

Unit：G=c=1 $A=(4\pi\varepsilon_c)^{-\frac{1}{2}}$ $\hat{m}=\frac{m}{A}$ $\hat{r}=\frac{r}{A}$ $\widehat{p_r}=\frac{p_r}{\varepsilon_c}$ $\widehat{p_t}=\frac{p_t}{\varepsilon_c}$ $\hat{\varepsilon}=\frac{\varepsilon}{\varepsilon_c}$

各向同性TOV

$$\frac{dp}{dr}=\frac{-(\varepsilon+p)(m+4\pi r^3 p)}{r^2(1-\frac{2m}{r})}$$

$$\frac{dm}{dr}=4\pi\varepsilon r^2$$

Phys. Rev. 55, 364 (1939).

Phys. Rev. 55, 374 (1939).

各向异性TOV

$$\frac{dp_r}{dr}=\frac{-(\varepsilon+p_r)(m+4\pi r^3 p_r)}{r^2(1-\frac{2m}{r})}+2\frac{p_t-p_r}{r}$$

$$\frac{dm}{dr}=4\pi\varepsilon r^2$$

$$BL:\ p_t=p_r+\frac{\lambda_{BL}}{3}\frac{(\varepsilon+3p_r)(\varepsilon+p_r)}{(1-\frac{2m}{r})}r^2$$

Astrophys. J. 188, 657 (1974).

无量纲各向异性TOV

$$\frac{d\widehat{p_r}}{d\hat{r}}=\frac{-(\hat{\varepsilon}+\widehat{p_r})(\hat{m}+\hat{r}^3\widehat{p_r})}{\hat{r}^2(1-\frac{2\hat{m}}{\hat{r}})}+2\frac{\widehat{p_t}-\widehat{p_r}}{\hat{r}}$$

$$\frac{d\hat{m}}{d\hat{r}}=\hat{\varepsilon}\hat{r}^2$$

$$BL:\ \widehat{p_t}=\widehat{p_r}+\frac{\lambda_{BL}}{12\pi}\frac{(\hat{\varepsilon}+3\widehat{p_r})(\hat{\varepsilon}+\widehat{p_r})}{1-\frac{2\hat{m}}{\hat{r}}}\hat{r}^2$$

$$\hat{\varepsilon} = 1 + a_1\hat{r} + a_2\hat{r}^2 + a_3\hat{r}^3 + \cdots \ldots \qquad \widehat{p_r} = \widehat{p_{rc}} + b_1\hat{r} + b_2\hat{r}^2 + b_3\hat{r}^3 + \cdots \ldots$$

$$\widehat{p_t} = \widehat{p_{tc}} + c_1\hat{r} + c_2\hat{r}^2 + c_3\hat{r}^3 + \cdots \ldots \qquad \hat{m} = 0 + d_1\hat{r} + d_2\hat{r}^2 + d_3\hat{r}^3 + \cdots \ldots$$

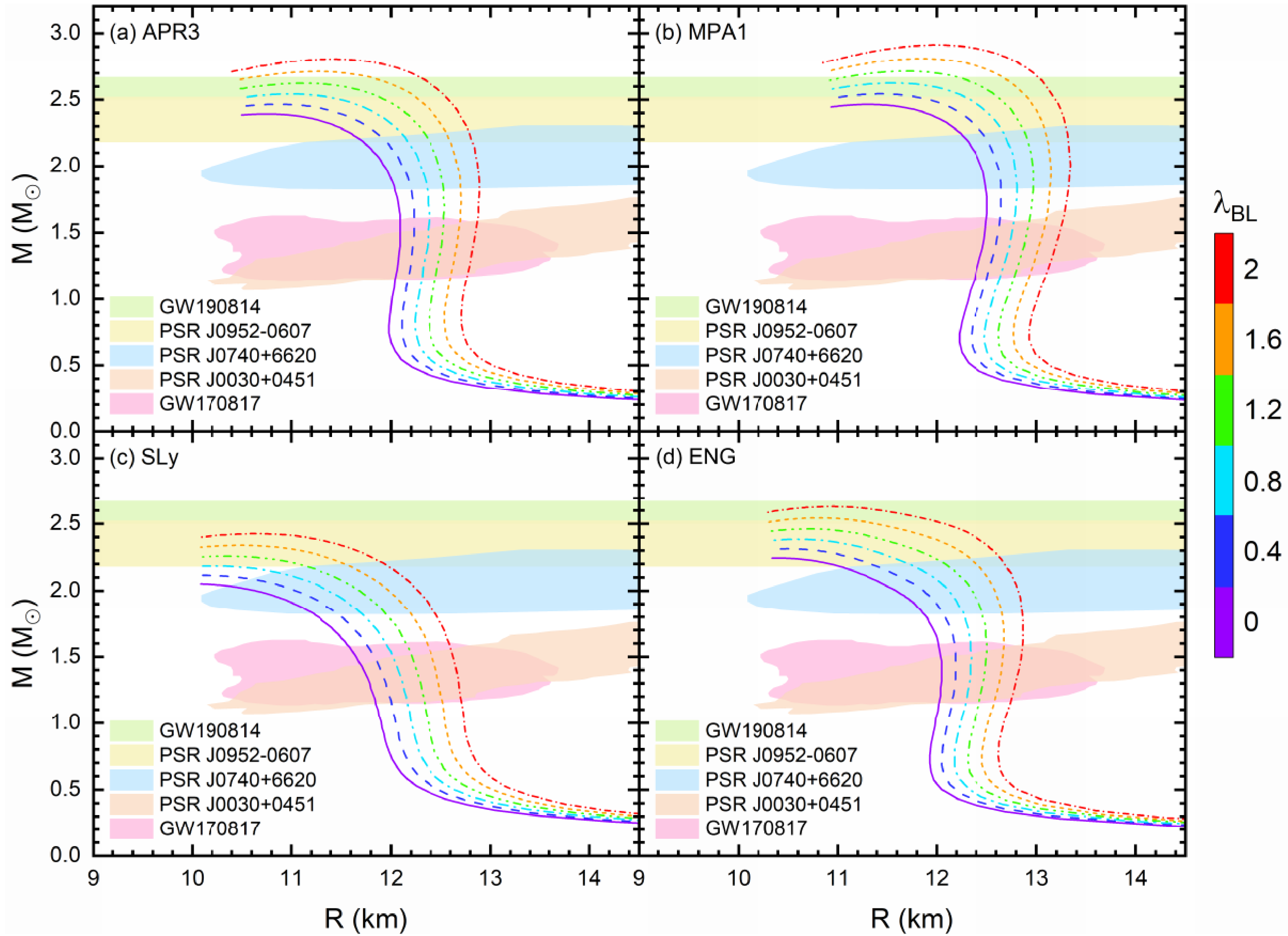
$$b_1 = c_1 = 0, d_1 = d_2 = 0, d_3 = \frac{1}{3}; \qquad b_2 = \frac{1}{2}(\frac{\lambda_{BL}}{2\pi} - 1)(\widehat{p_{rc}} + 1)(\widehat{p_{rc}} + \frac{1}{3}); \qquad c_2 = \frac{1}{2}(\frac{2\lambda_{BL}}{2\pi} - 1)(\widehat{p_{rc}} + 1)(\widehat{p_{rc}} + \frac{1}{3})$$

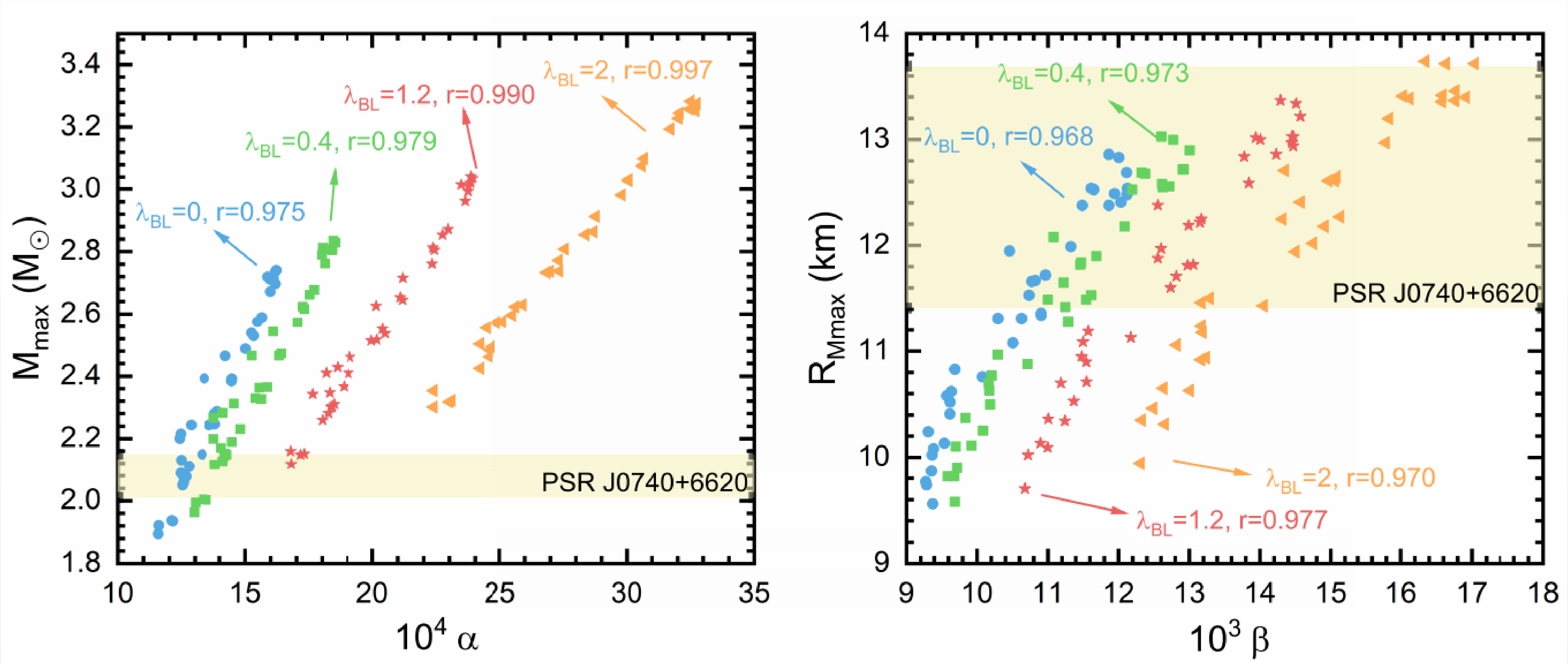
BL:

$$M \propto \alpha_c \equiv \frac{1}{\sqrt{\varepsilon_c}}[\frac{\widehat{p_{rc}}}{(1 - \frac{\lambda_{BL}}{2\pi})(\widehat{p_{rc}} + 1)(3\widehat{p_{rc}} + 1)}]^{\frac{3}{2}}$$

$$R \propto \beta_c \equiv \frac{1}{\sqrt{\varepsilon_c}}[\frac{\widehat{p_{rc}}}{(1 - \frac{\lambda_{BL}}{2\pi})(\widehat{p_{rc}} + 1)(3\widehat{p_{rc}} + 1)}]^{\frac{1}{2}}$$

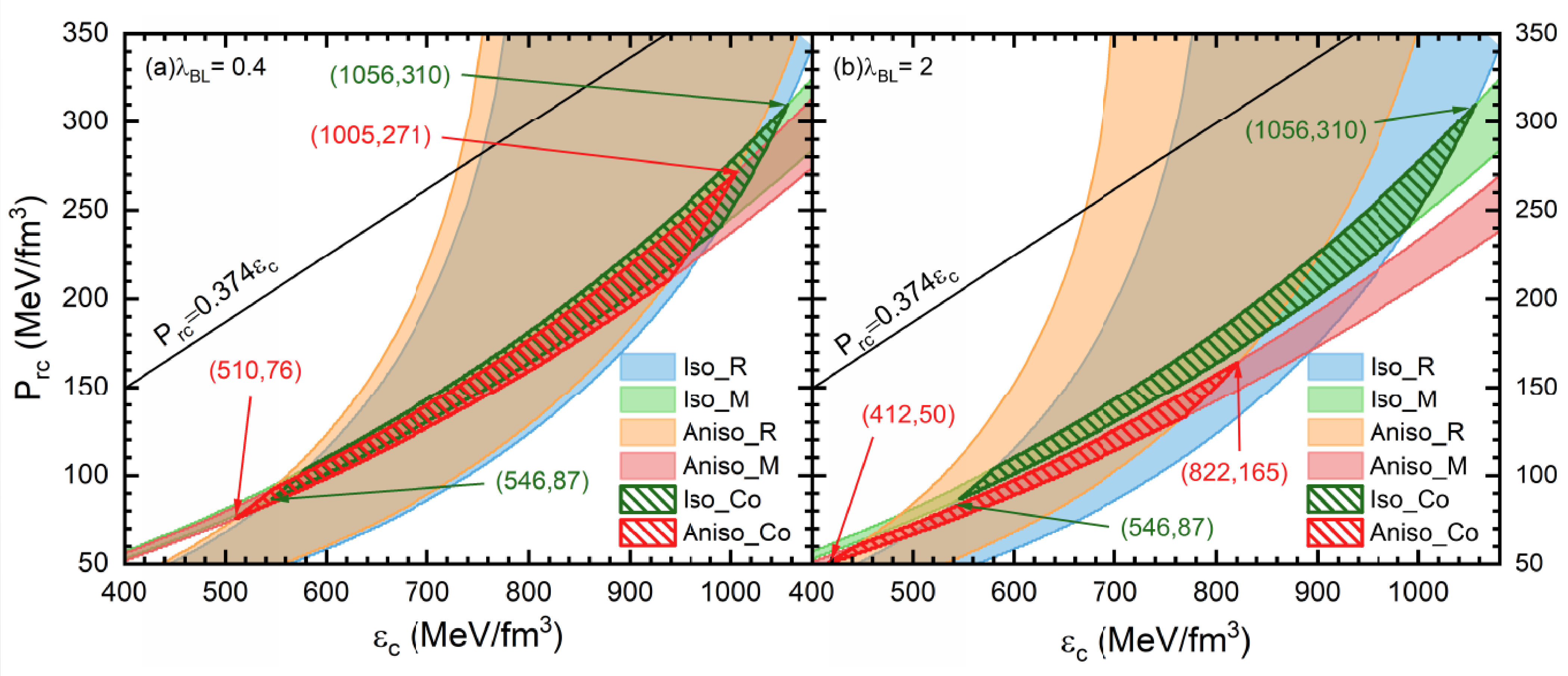
$$c_s^2 = \frac{dp_{rc}}{d\varepsilon_c} = \widehat{p_{rc}}(\frac{1}{3}\frac{(\widehat{p_{rc}} + 1)(3\widehat{p_{rc}} + 1)}{1 - 3\widehat{p_{rc}}^2} + 1)$$


(a) APR3
(b) MPA1
(c) SLy
(d) ENG
GW190814
PSR J0952-0607
PSR J0740+6620
PSR J0030+0451
GW170817
M (M☉)
R (km)
λBL
2
1.6
1.2
0.8
0.4
0



PSR J0740+6620： $2.01<M/M_\odot<2.15$ $12.41<R/\mathrm{km}<13.69$

$$M \propto \alpha_c \equiv \frac{1}{\sqrt{\varepsilon_c}}\left[\frac{\widehat{p_{rc}}}{(1-\frac{\lambda_{BL}}{2\pi})(\widehat{p_{rc}}+1)(3\widehat{p_{rc}}+1)}\right]^{\frac{3}{2}} \qquad R \propto \beta_c \equiv \frac{1}{\sqrt{\varepsilon_c}}\left[\frac{\widehat{p_{rc}}}{(1-\frac{\lambda_{BL}}{2\pi})(\widehat{p_{rc}}+1)(3\widehat{p_{rc}}+1)}\right]^{\frac{1}{2}}$$



PSR J0740+6620： 2.01<M/M$_\odot$<2.15 12.41<R/km<13.69

$$M_{max}^{\lambda_{BL}=0} = 0.172_{-0.007}^{+0.007} \times 10^4\alpha - 0.062_{-0.094}^{+0.094}$$

$$R_{Mmax}^{\lambda_{BL}=0} = 0.969_{-0.043}^{+0.043} \times 10^3\beta + 1.052_{-0.462}^{+0.462}$$

$$M_{max}^{\lambda_{BL}=0.4} = 0.151_{-0.005}^{+0.005} \times 10^4\alpha + 0.040_{-0.084}^{+0.084}$$

$$R_{Mmax}^{\lambda_{BL}=0.4} = 0.903_{-0.037}^{+0.037} \times 10^3\beta + 1.323_{-0.414}^{+0.414}$$

$$M_{max}^{\lambda_{BL}=2.0} = 0.096_{-0.001}^{+0.001} \times 10^4\alpha + 0.158_{-0.038}^{+0.038}$$

$$R_{Mmax}^{\lambda_{BL}=2.0} = 0.730_{-0.031}^{+0.031} \times 10^3\beta + 1.463_{-0.458}^{+0.458}$$

总结及展望

总结：

1.考虑压力各向异性的存在有望解决大质量致密天体观测与微观相互作用理论不兼容的情况；

2.在不同程度的各向异性下，中子星质量半径与内部压强和能量密度均存在着线性关系；

3.压力各向异性的存在将会影响我们对于中子星内部高密核物质的认识。

展望：

1.未来利用天文观测，基于可观测效应区分各向异性中子星与各向同性中子星；

2.更多天文观测对于为约束中子星高密物态提供先验条件。

感谢您的观看

THANK YOU FOR WATCH

2024年11月17日