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UNIVERSITY
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Wrocław
University of
Science and
Technology



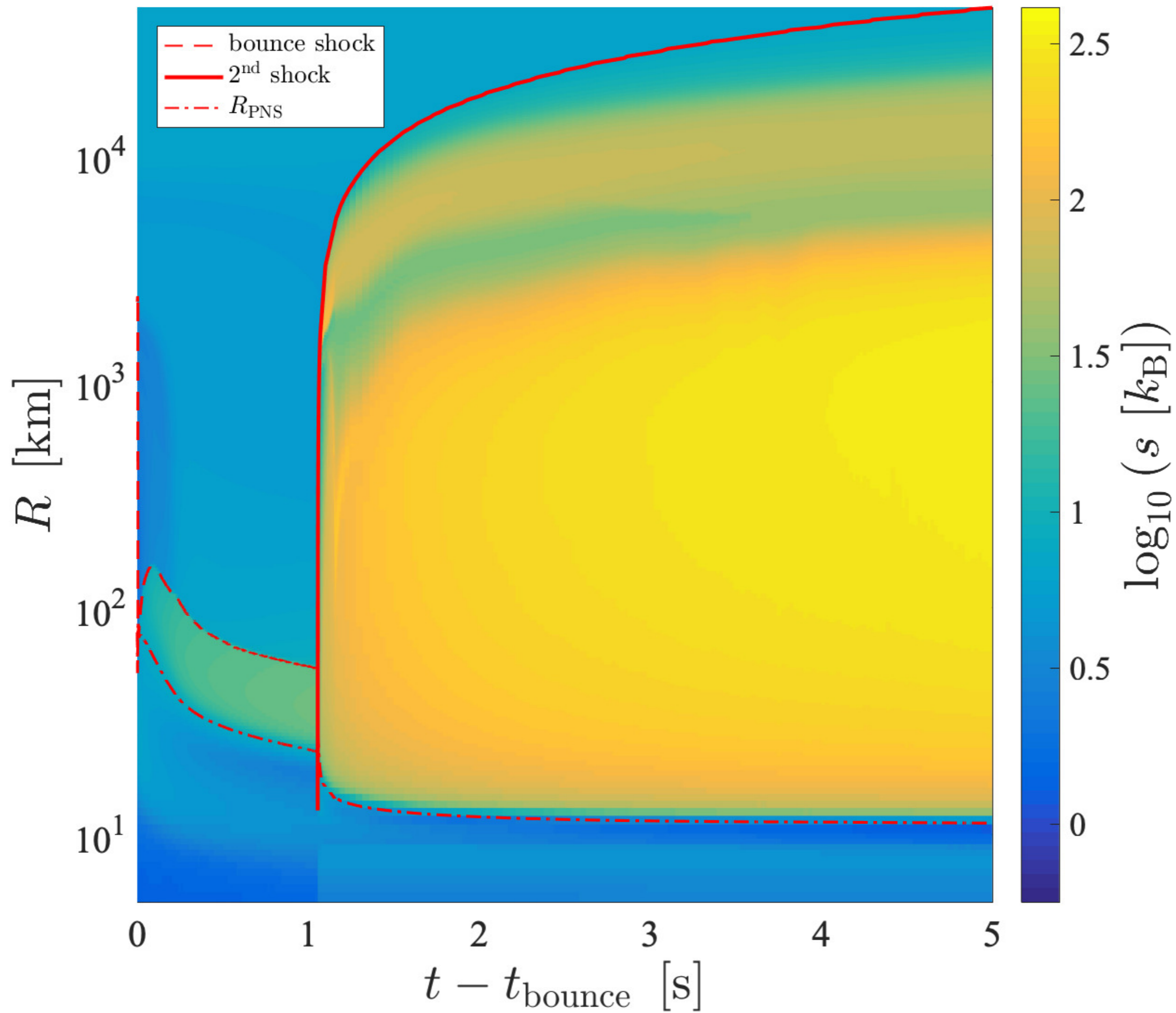
Narodowe
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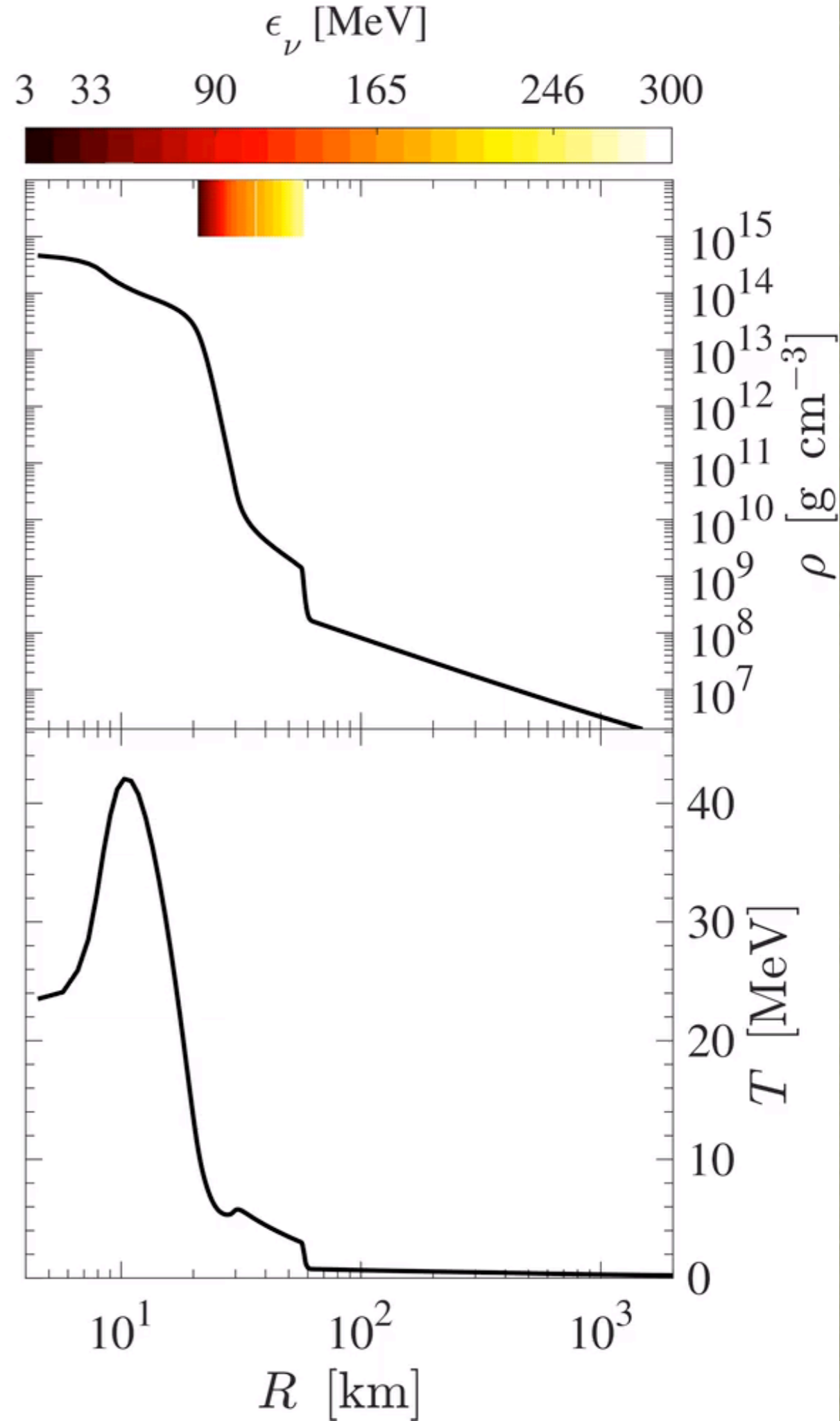
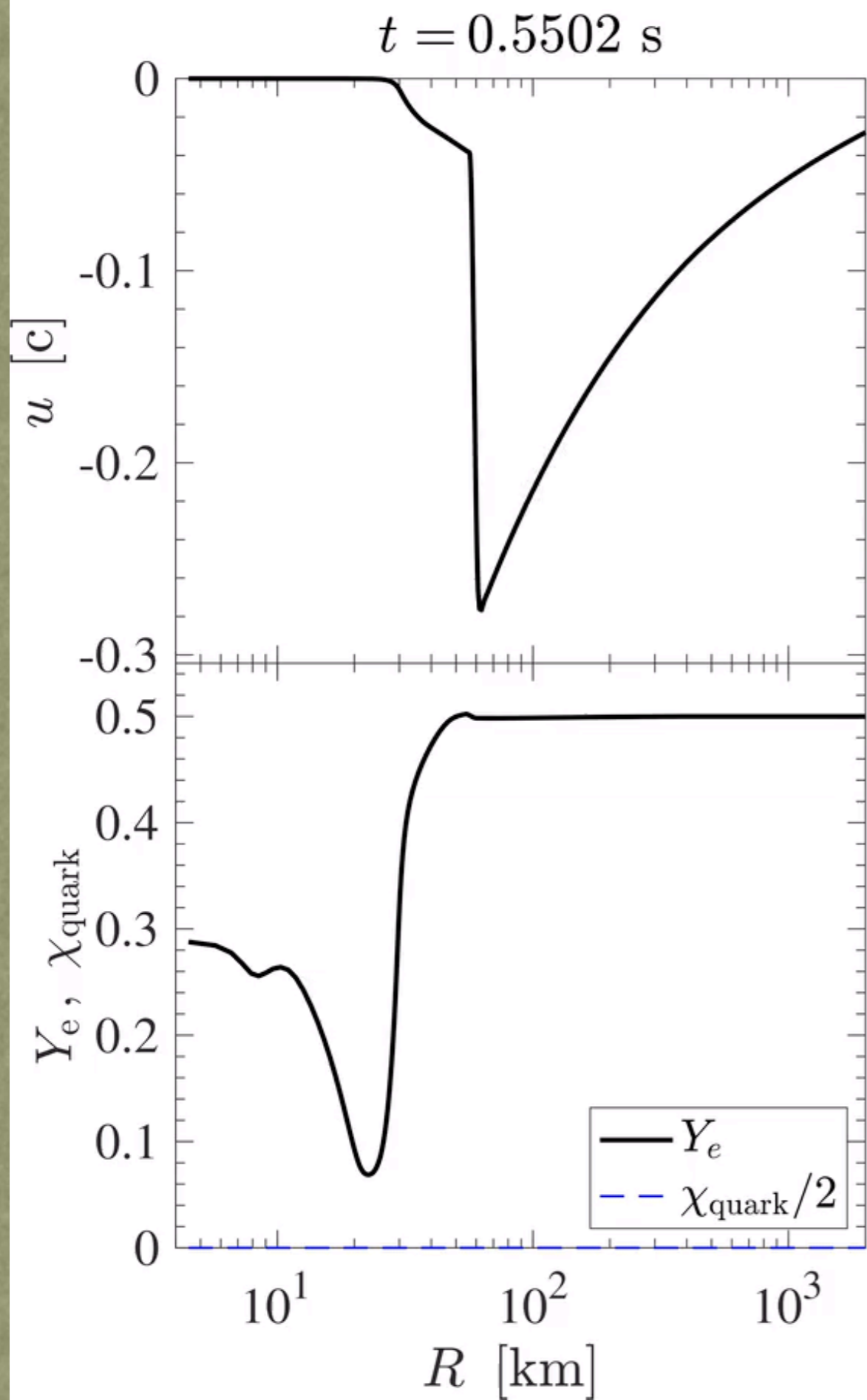


Noshad Khosravi Largani
Collective Neutrino Oscillation in Supernovae and
Neutron Star Mergers
Academia Sinica, 27 March 2026

In collaboration with

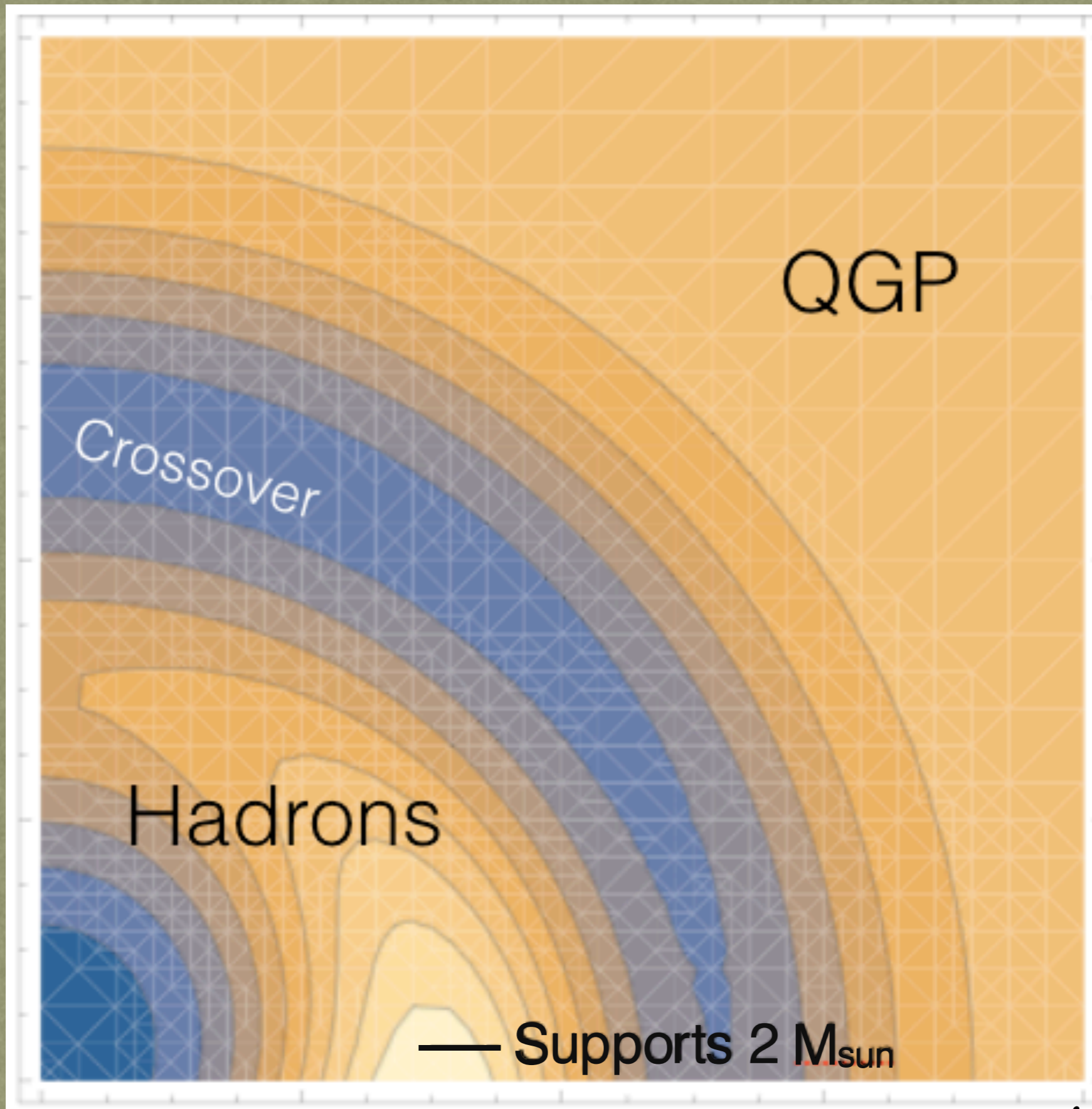
**Tobias Fischer,
Kei Kotake,
Takami Kuroda,
Zewei Xiong,
Meng-Ru Wu,
Anil Kumar**





PSR J0348+0432: $2.01 \pm 0.04 M_{\odot}$

T



c_s^2

QGP

Crossover

Hadrons

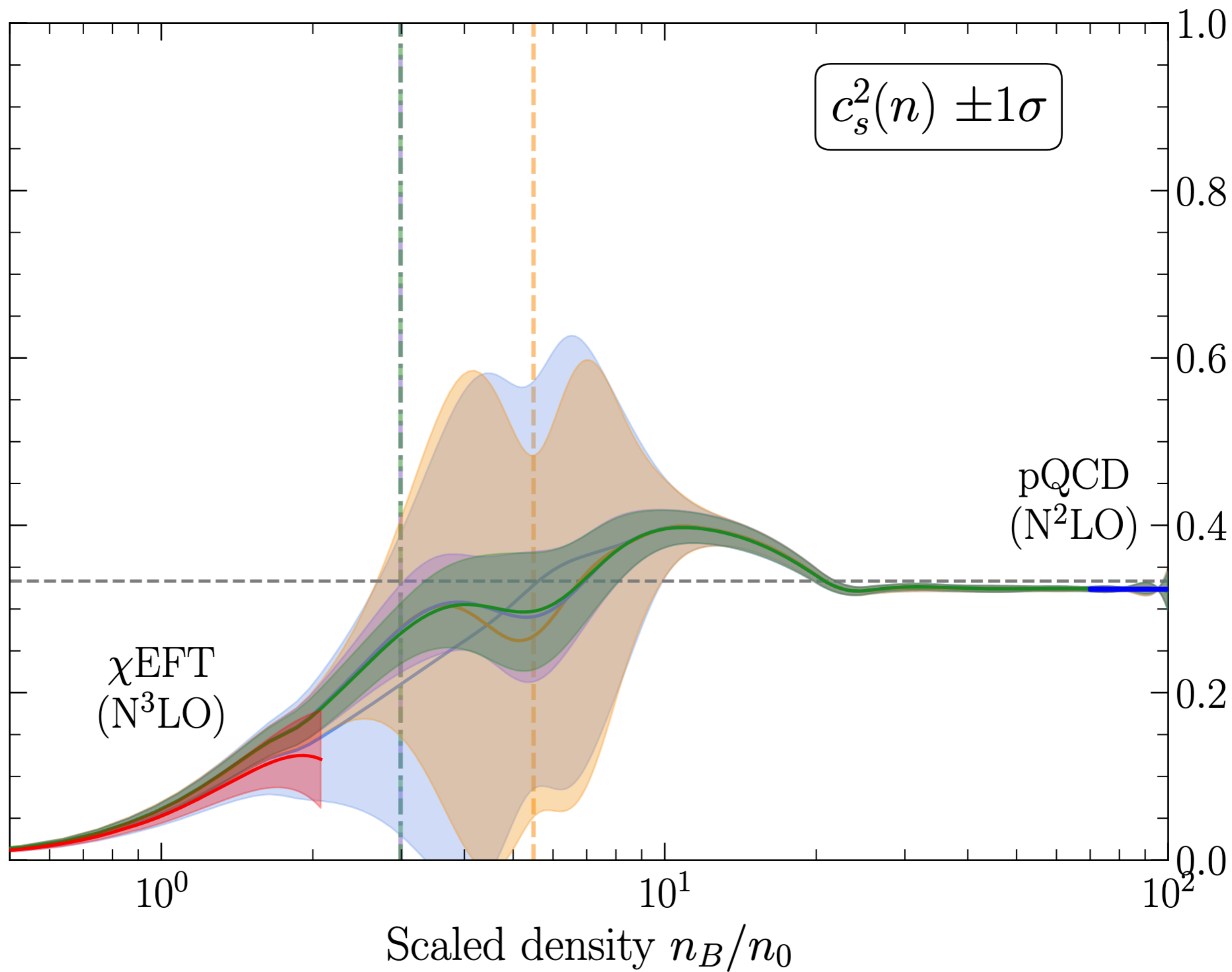
— Supports $2 M_{\text{sun}}$

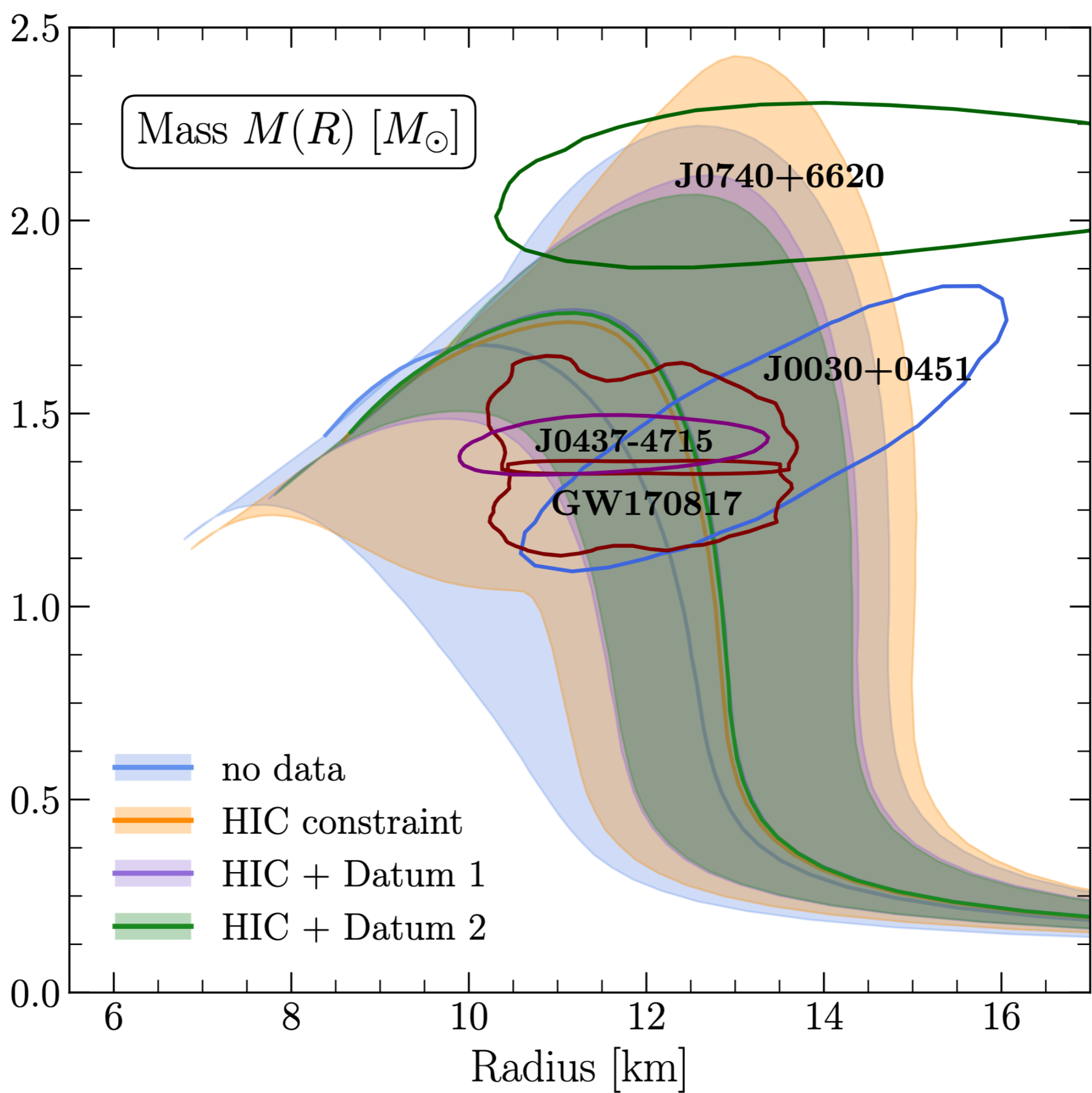
$> \frac{1}{3}$

$\frac{1}{3}$

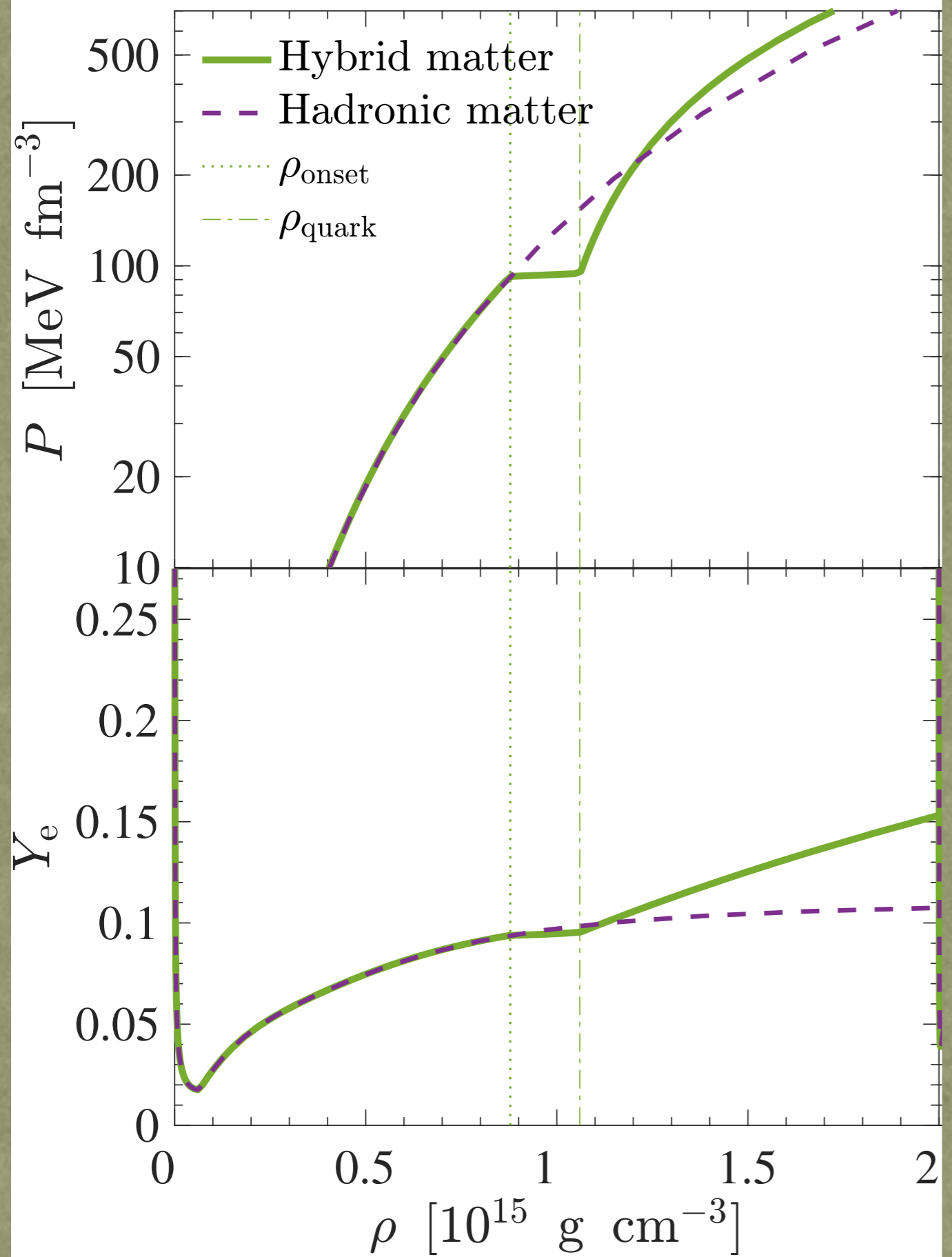
$< \frac{1}{3}$

μ



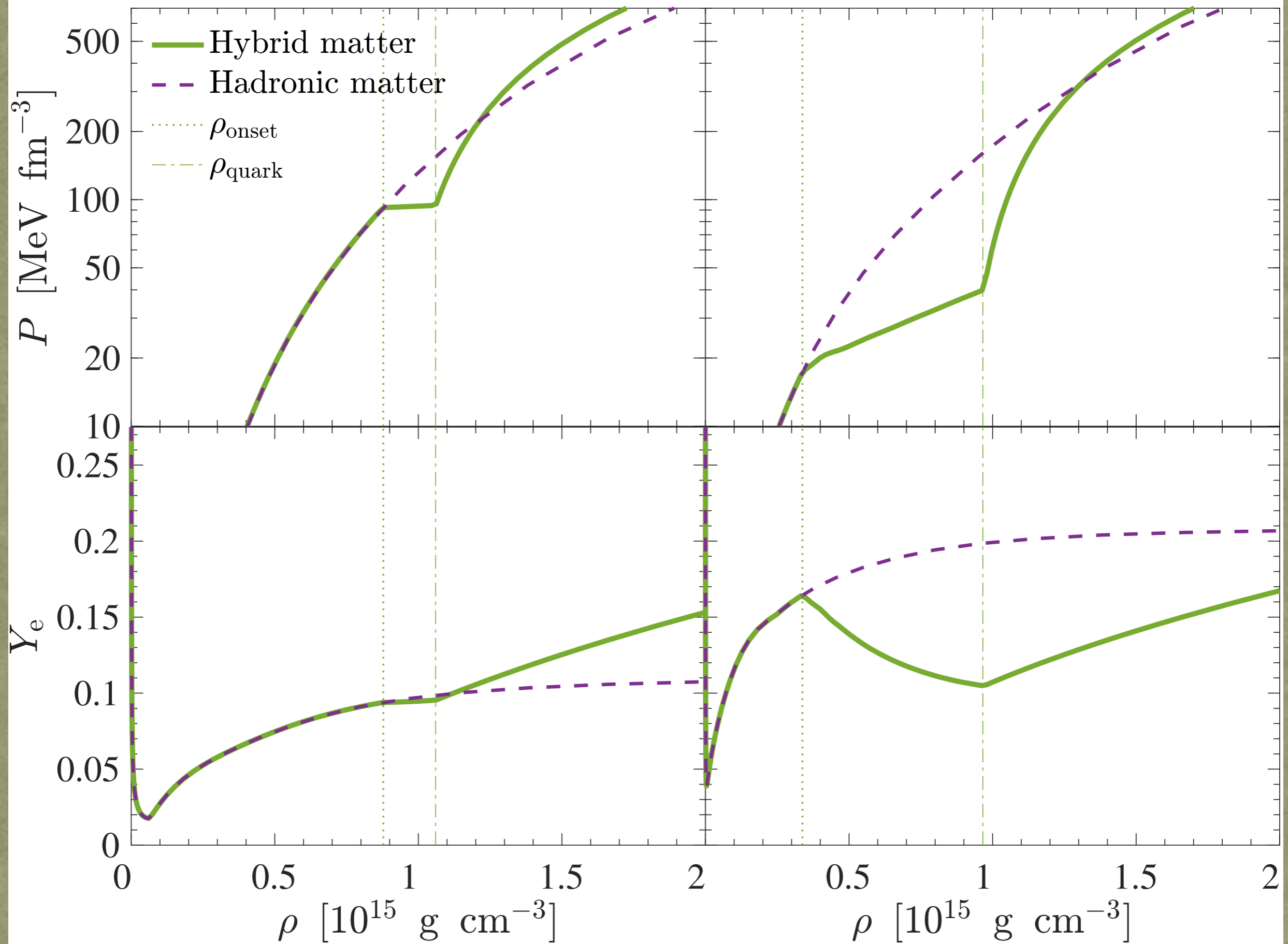


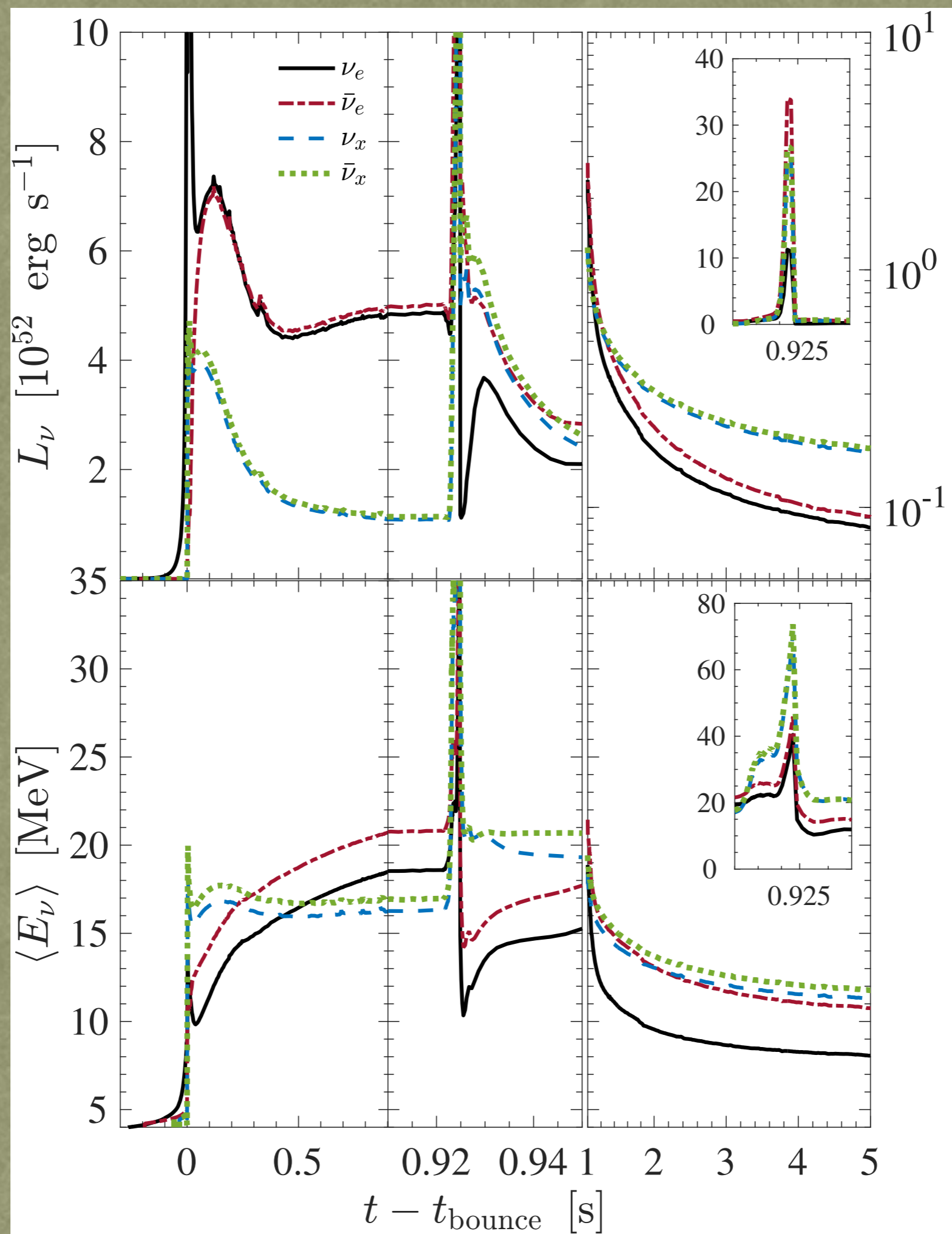
$(T = 0)$

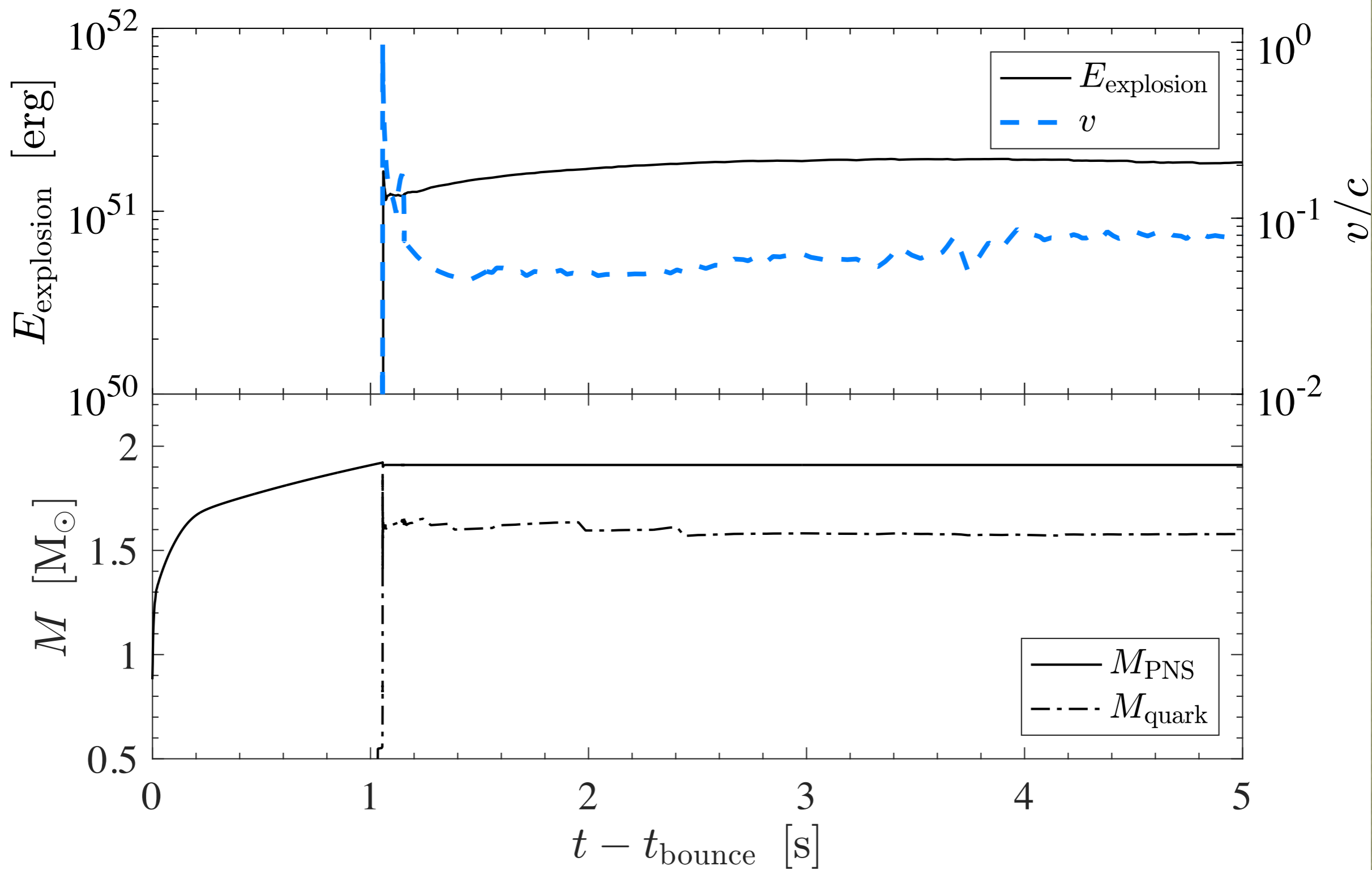


$(T = 0)$

$(s = 3 k_B) \quad Y_L = 0.3$



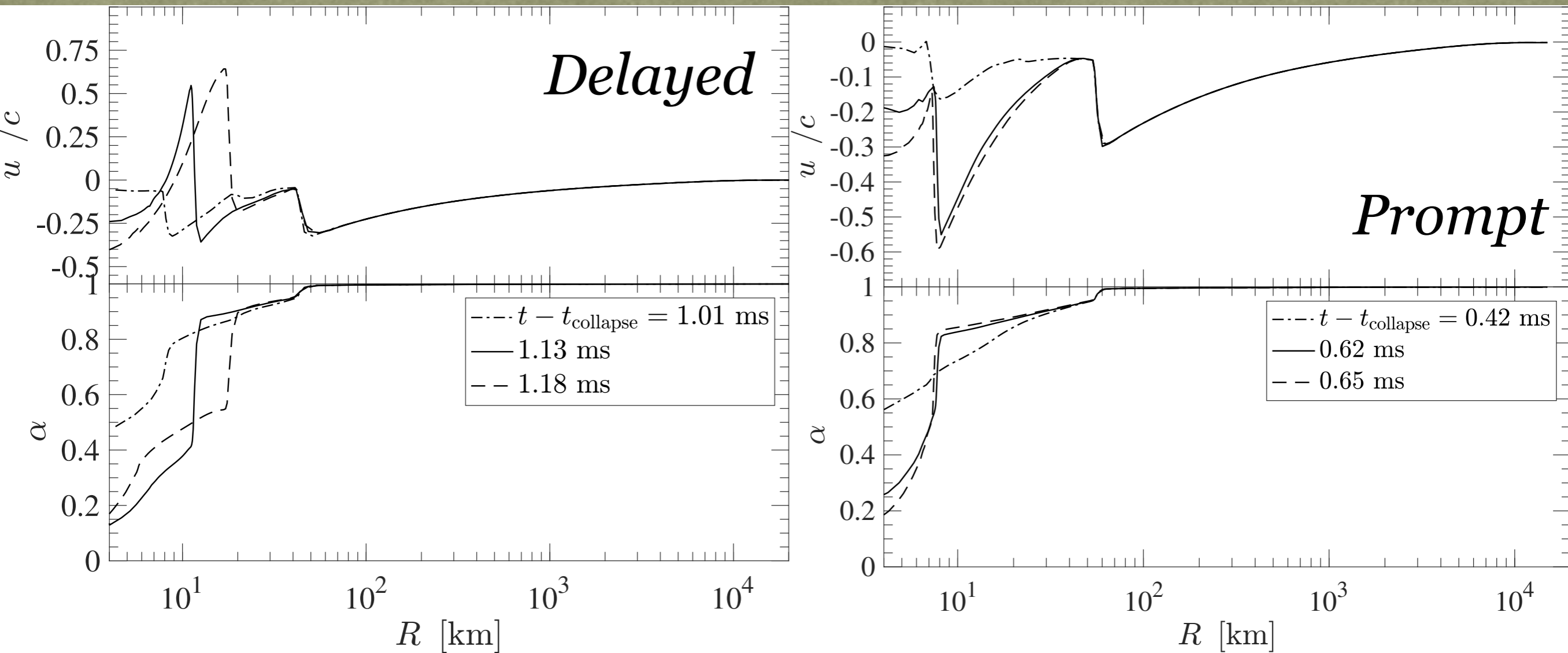




$$E_{\text{expl}} = 3 \times 10^{51} \text{ erg}$$
$$M_{\text{NS}} \simeq 2 M_{\odot}$$

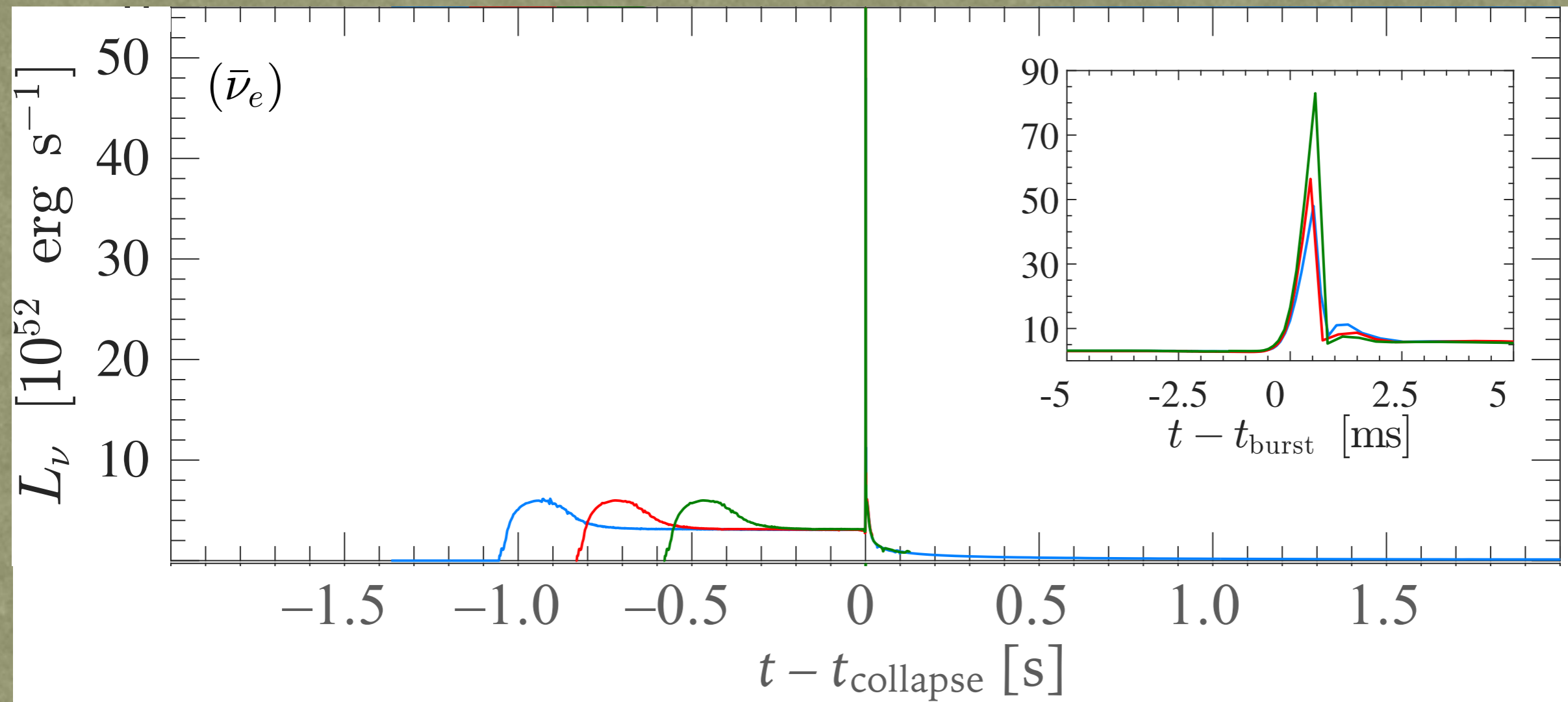


Black-hole formation: **Two distinct scenarios**



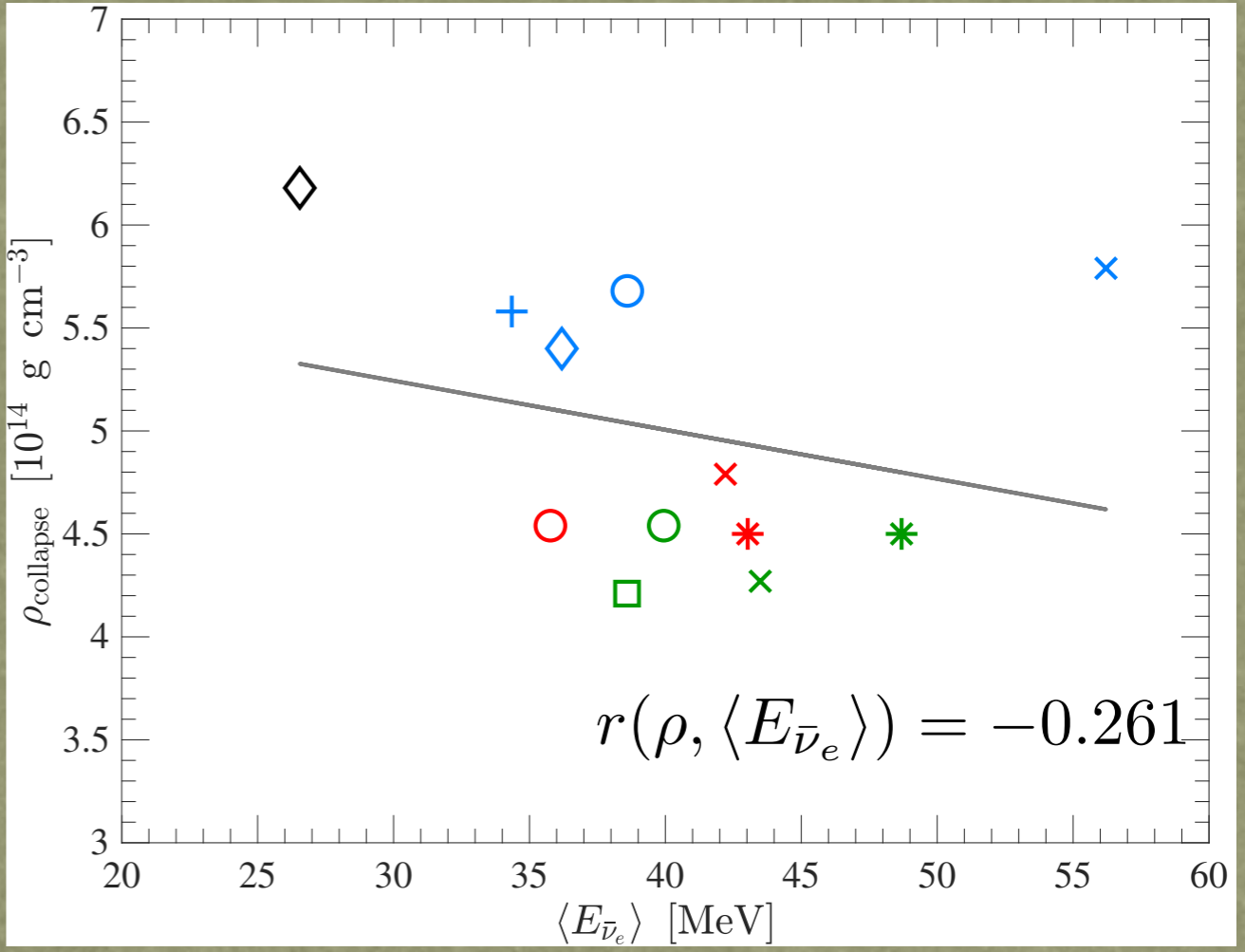
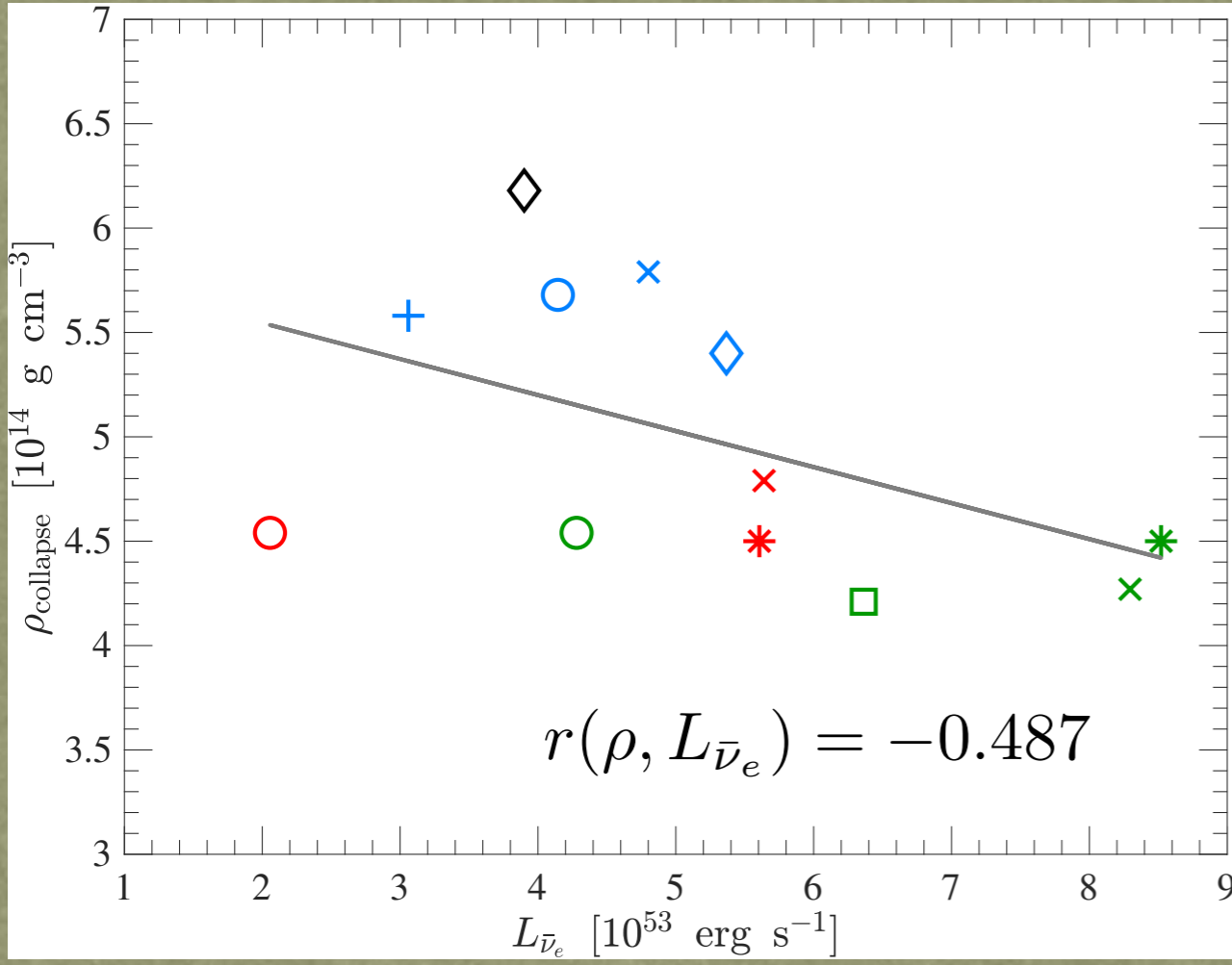
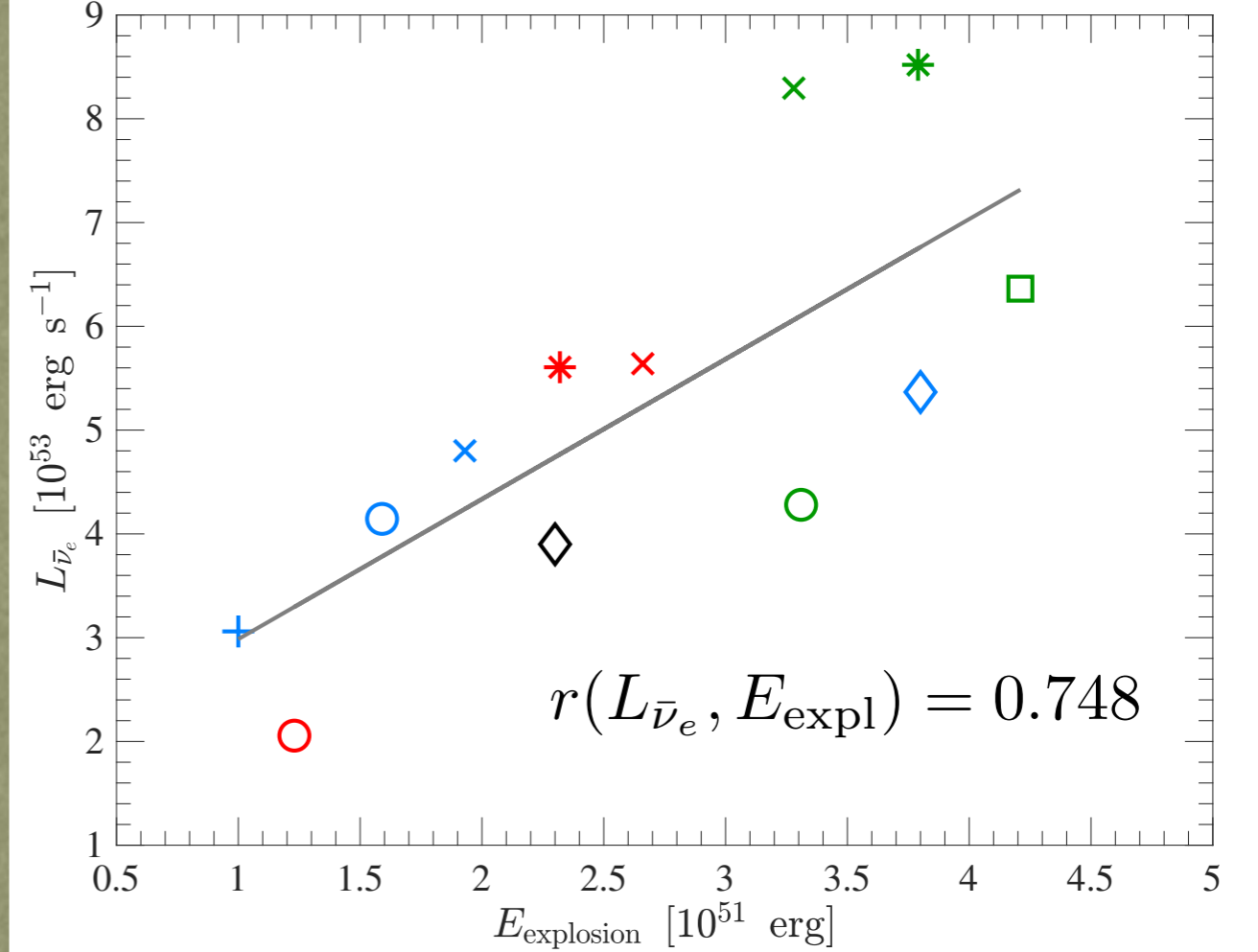
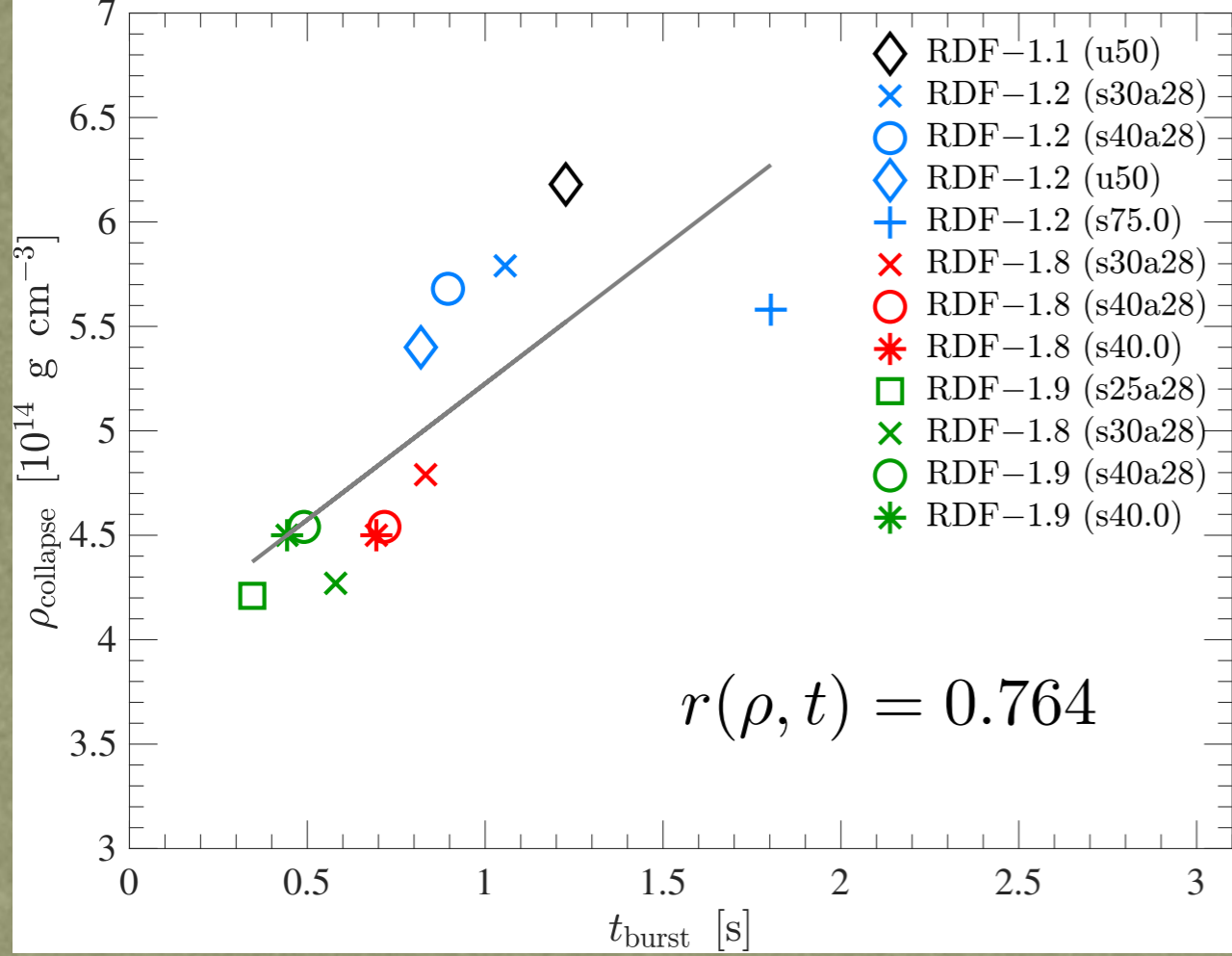
Jakobus et al., MNRAS, 516, 2554 (2022)

Khosravi Largani et al., ApJ 946, 143 (2024)

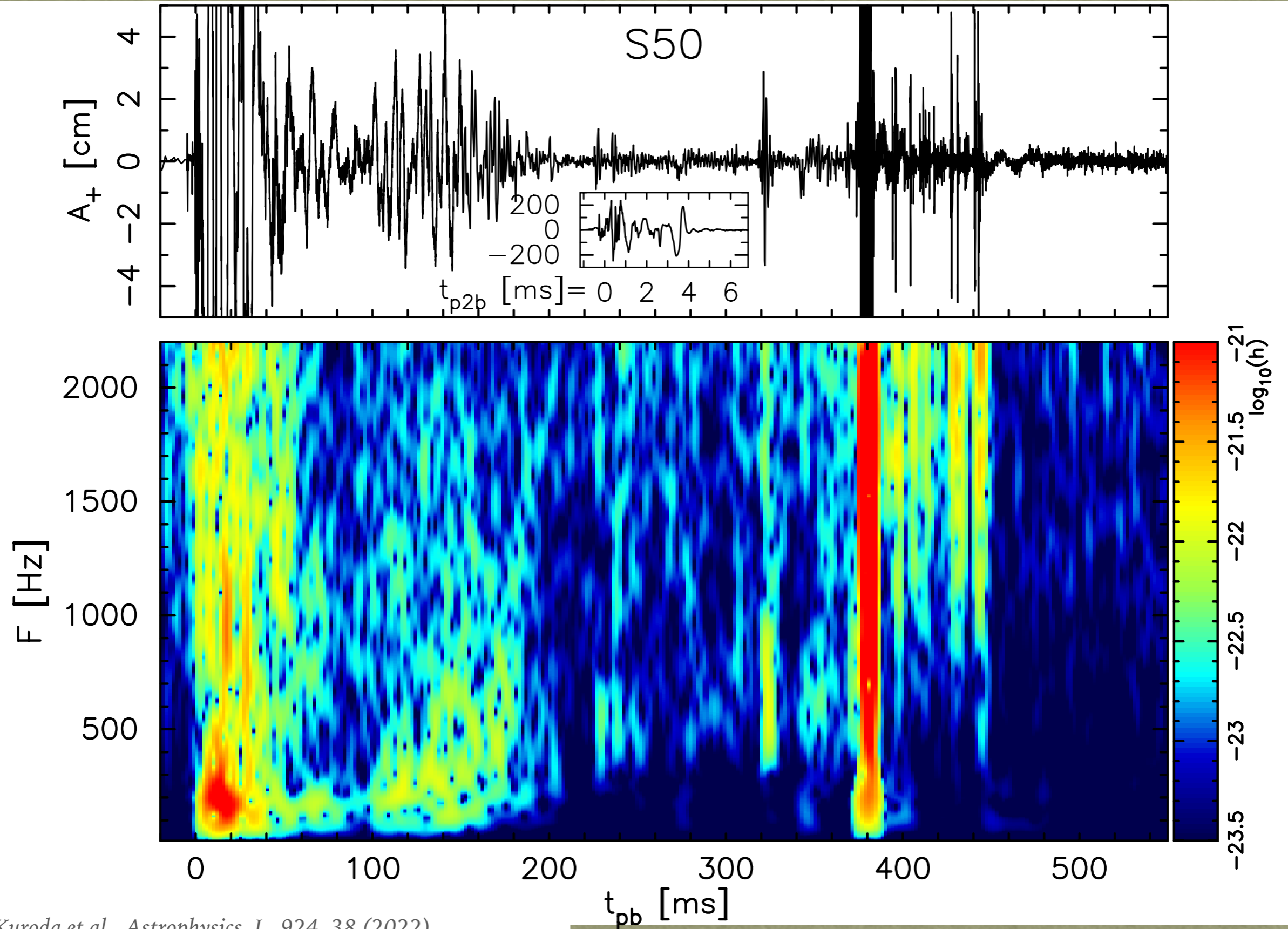




Progenitor	EOS RDF	t_{burst} [s]	$L_{\bar{\nu}_e, \text{peak}}$ [10^{53} erg s $^{-1}$]	$\langle E_{\bar{\nu}_e} \rangle$ [MeV]	E_{expl} [10^{51} erg]
s25a28	1.9	0.345	6.36	38.59	4.21
s30a28	1.2	1.056	4.80	56.21	1.93
s30a28	1.8	0.833	5.64	42.21	2.66
s30a28	1.9	0.580	8.30	43.49	3.28
s40a28	1.2	0.895	4.15	38.60	1.59
s40a28	1.8	0.717	2.06	35.77	1.23
s40a28	1.9	0.491	4.28	39.94	3.31
s40.0	1.8	0.694	5.61	43.03	2.32
s40.0	1.9	0.443	8.52	48.69	3.79
u50	1.1	1.227	3.90	26.55	2.3
u50	1.2	0.819	5.37	36.19	3.8
s75.0	1.2	1.803	3.06	34.35	1.0

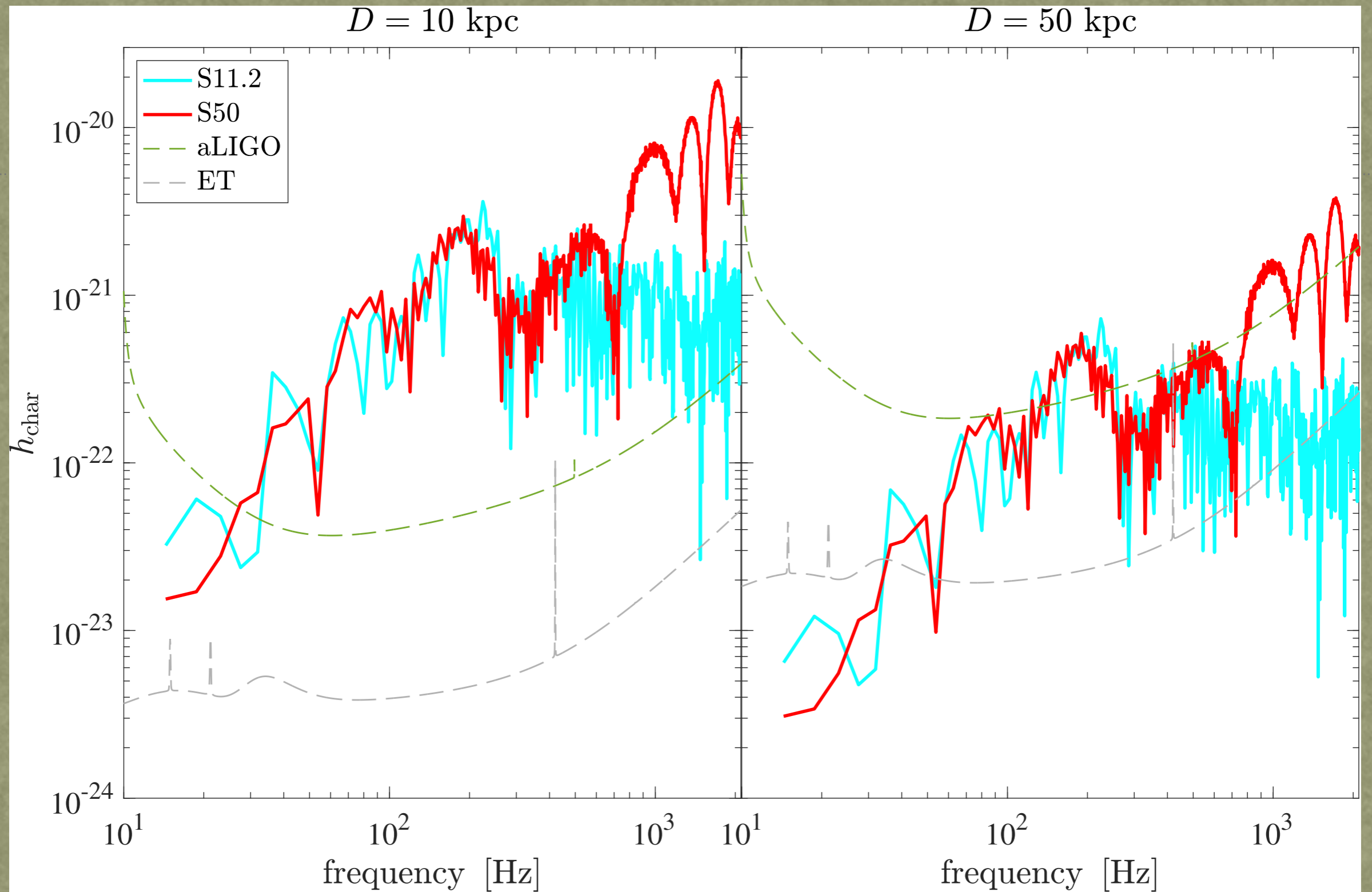


GRAVITATIONAL WAVES

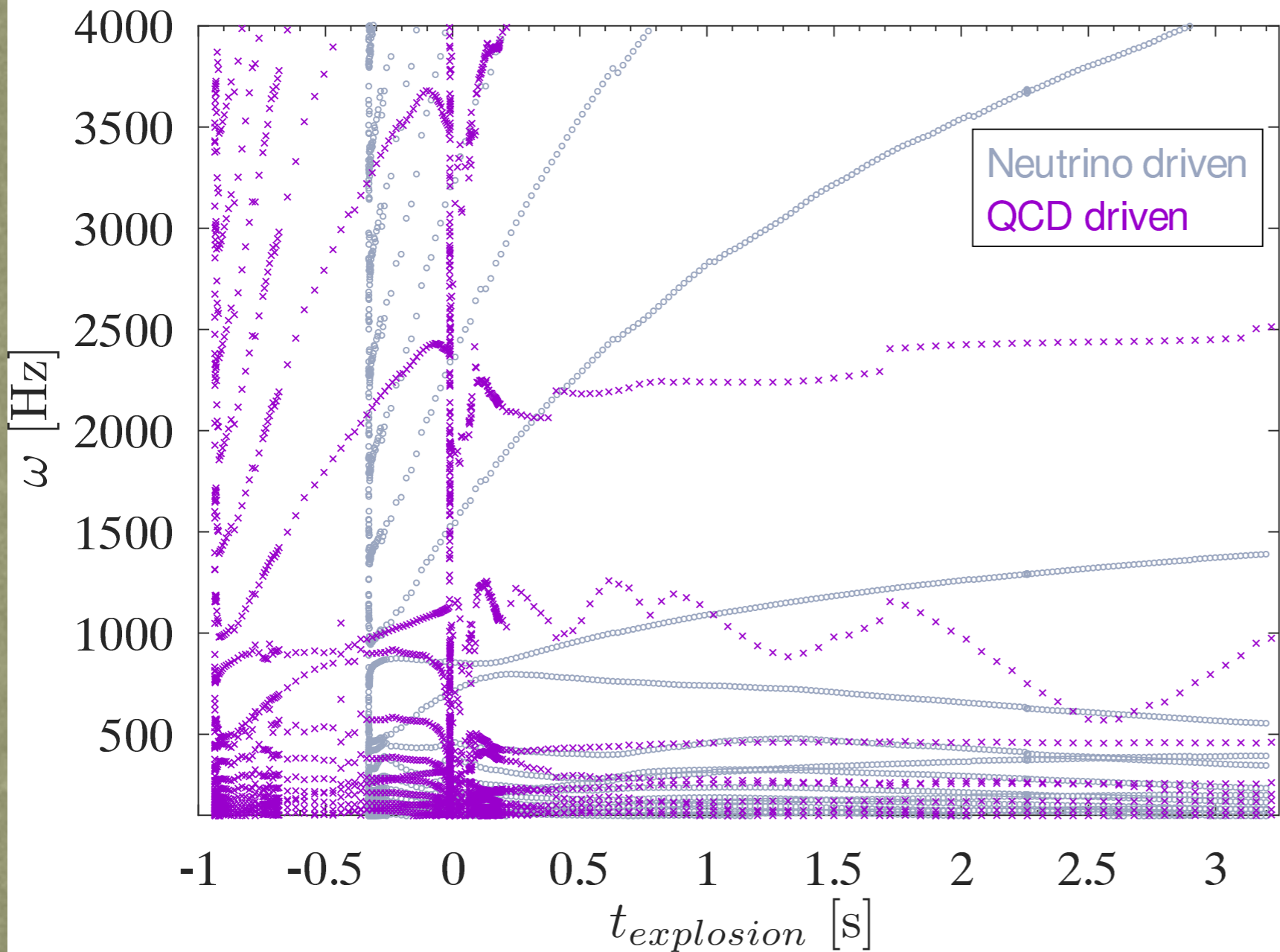


Kuroda et al., *Astrophysics. J.*, 924, 38 (2022)

Zha et al., *Phys. Rev. L.*, 125, 051102 (2020)



MODE ANALYSIS



$$\Delta\rho = \delta\rho + \xi^i \partial_i \rho$$

$$\delta P = \delta \hat{P} Y_{lm} e^{-i\sigma t},$$

$$\xi^r = \eta_r Y_{lm} e^{-i\sigma t},$$

$$\xi^\theta = \eta_\perp \frac{1}{r^2} \partial_\theta Y_{lm} e^{-i\sigma t},$$

$$\xi^\varphi = \eta_\perp \frac{1}{r^2 \sin^2 \theta} \partial_\varphi Y_{lm} e^{-i\sigma t}$$

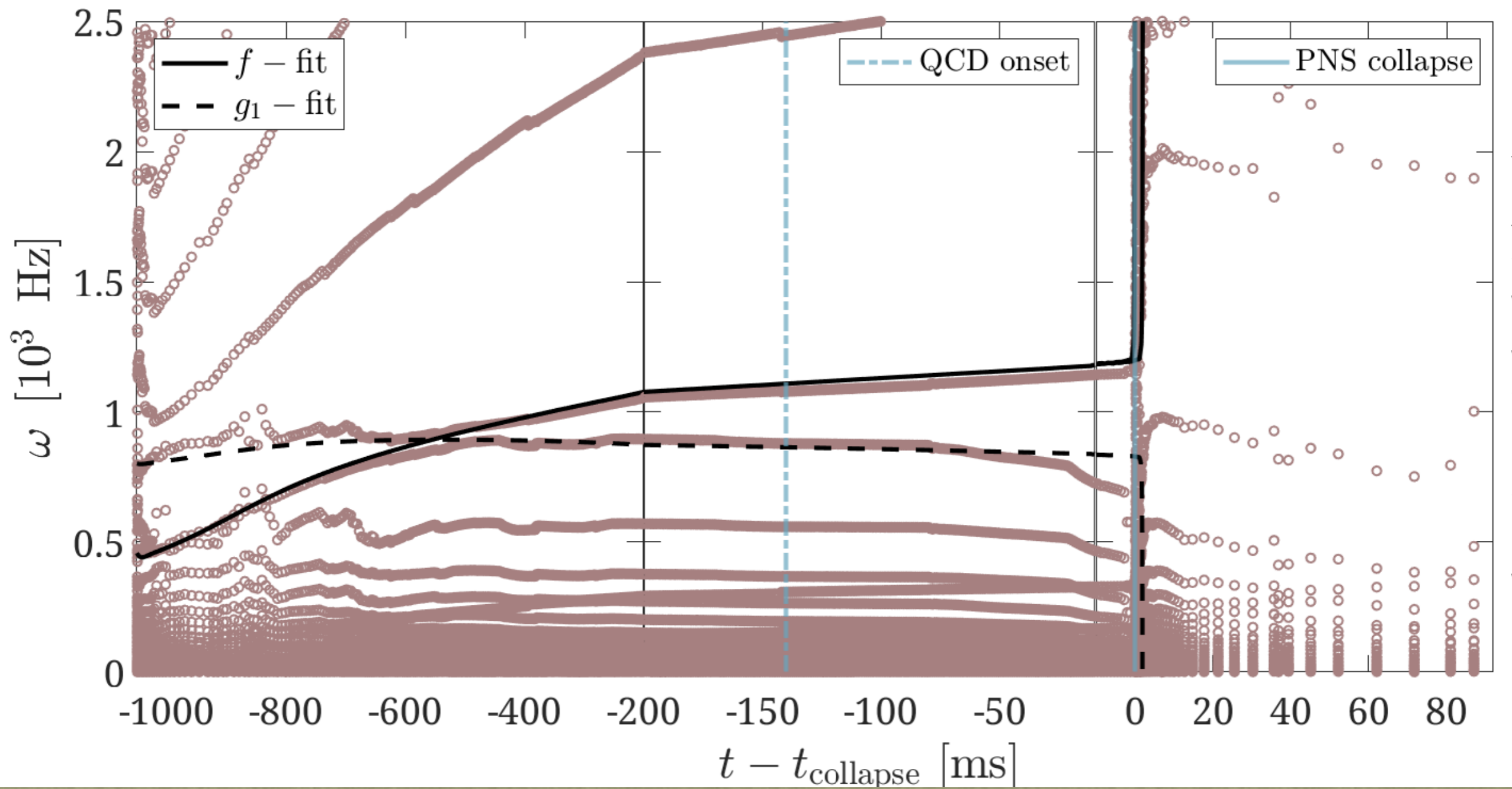
Torres-Forne et al. (2019), Mon. Not. Roy. Astron. Soc.

Torres-Forne et al. (2018), Mon. Not. Roy. Astron. Soc.

$$f \quad x = \sqrt{M_{\text{PNS}}/R_{\text{PNS}}^3}$$

$$g_1 \quad x = M_{\text{PNS}}/R_{\text{PNS}}^2$$

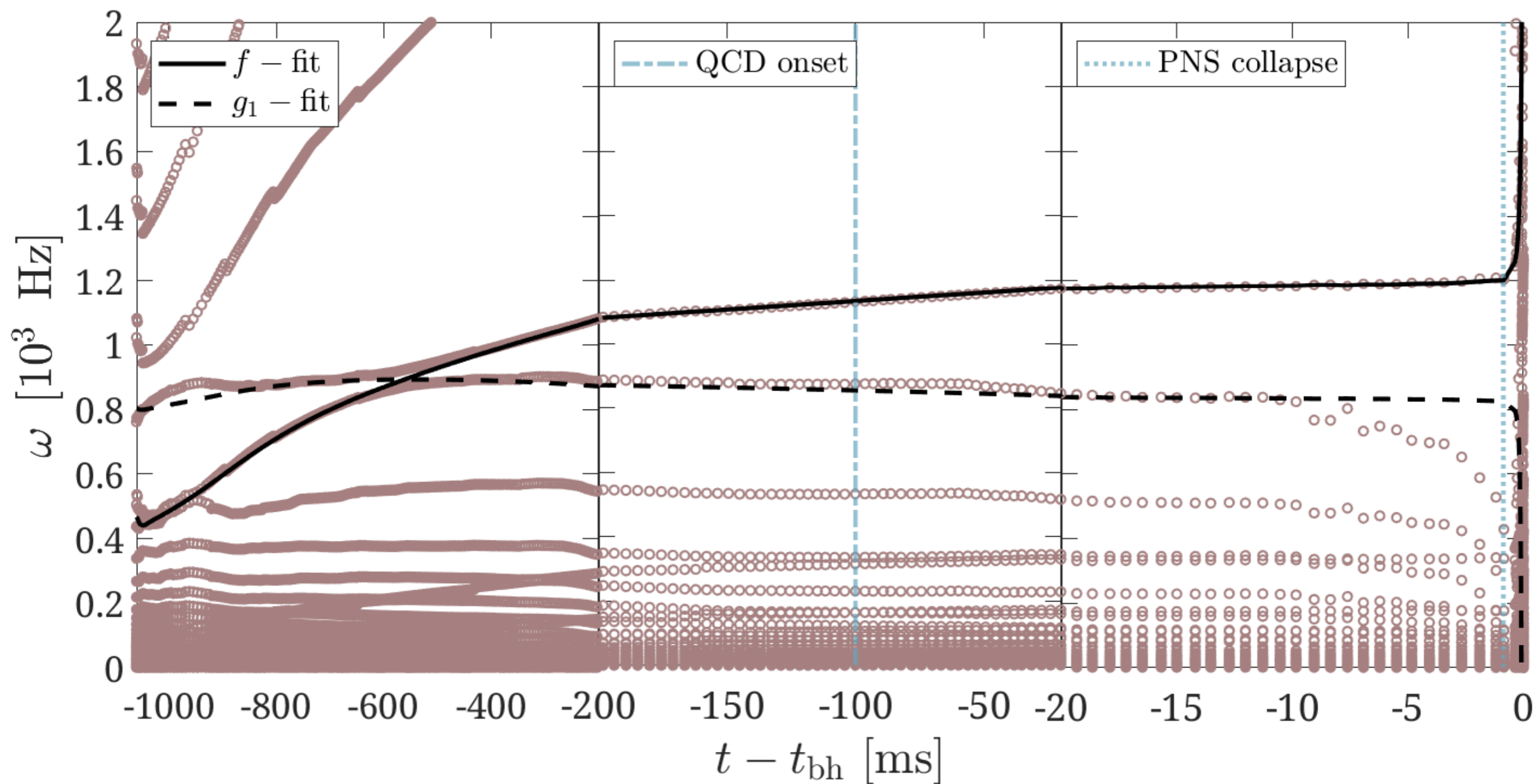
$$\omega_{\text{fit}}(x) = a_0 + a_1 x + a_2 x^2 + a_3 x^3$$



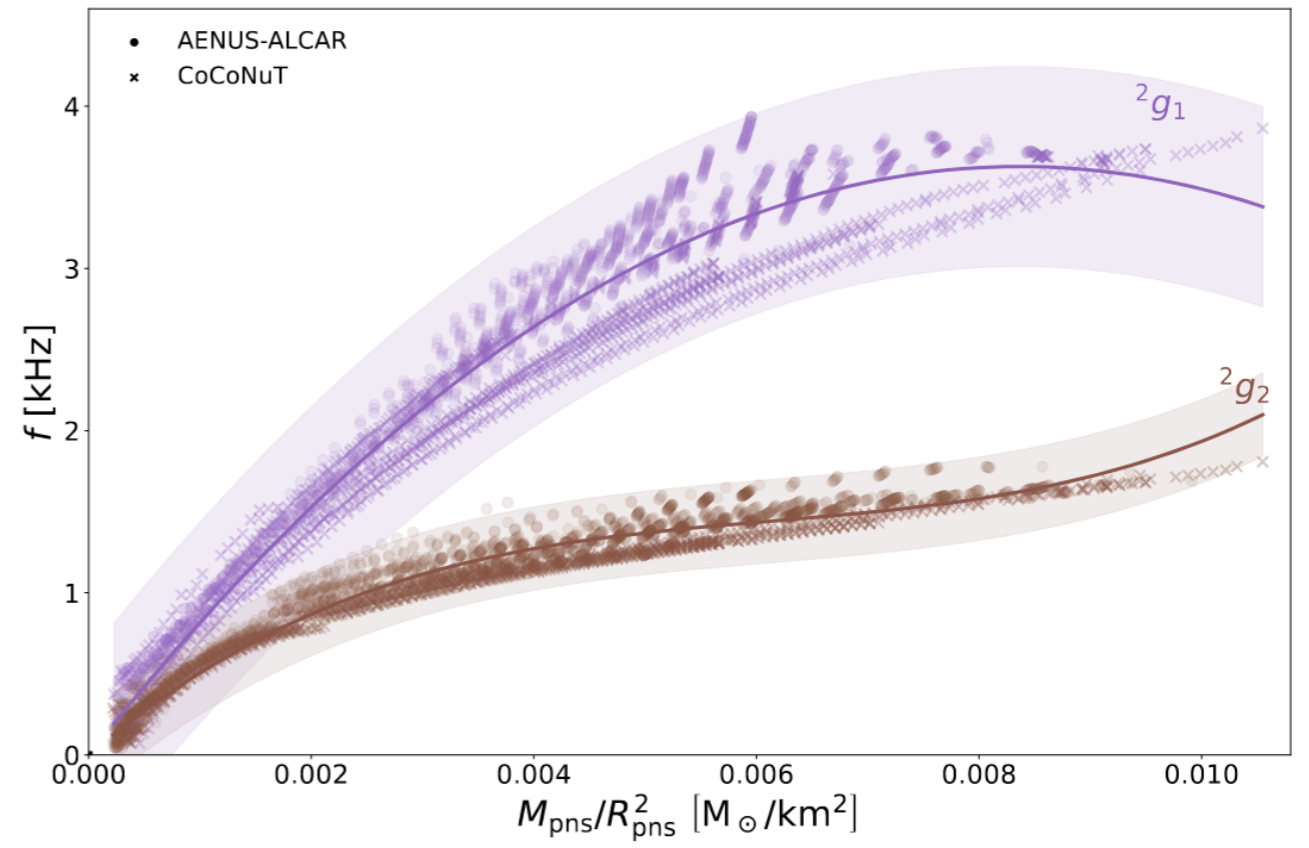
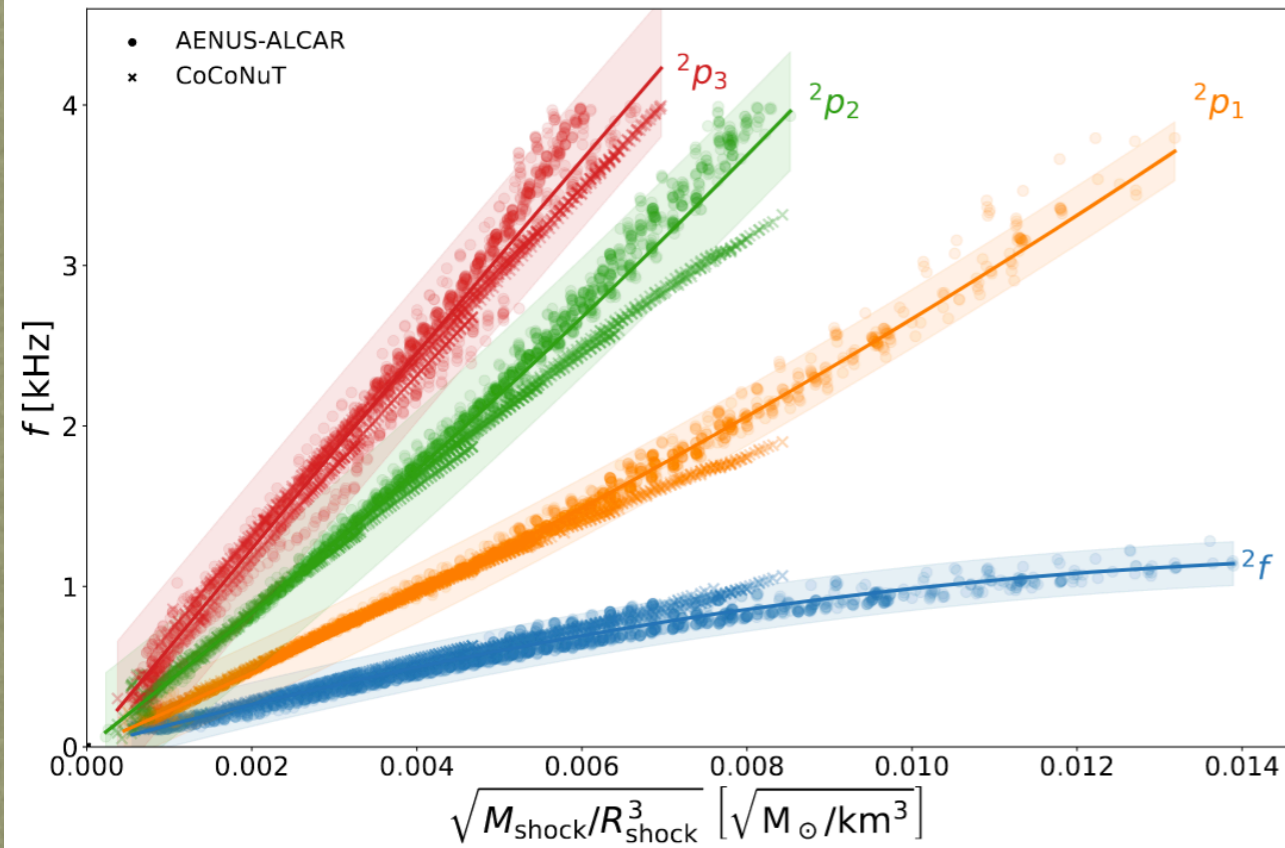
$$f \quad x = \sqrt{M_{\text{PNS}}/R_{\text{PNS}}^3}$$

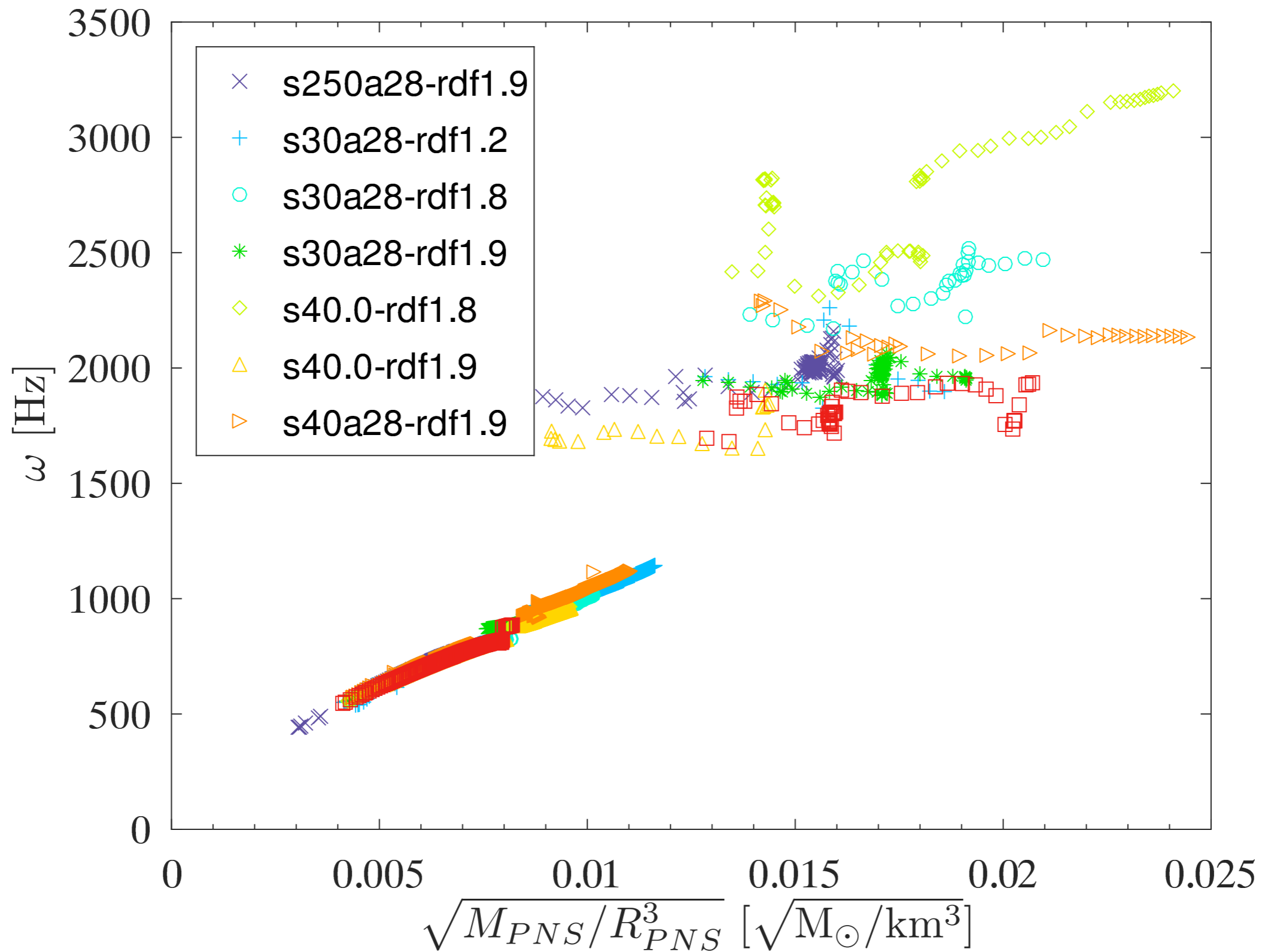
$$g_1 \quad x = M_{\text{PNS}}/R_{\text{PNS}}^2$$

$$\omega_{\text{fit}}(x) = a_0 + a_1 x + a_2 x^2 + a_3 x^3$$

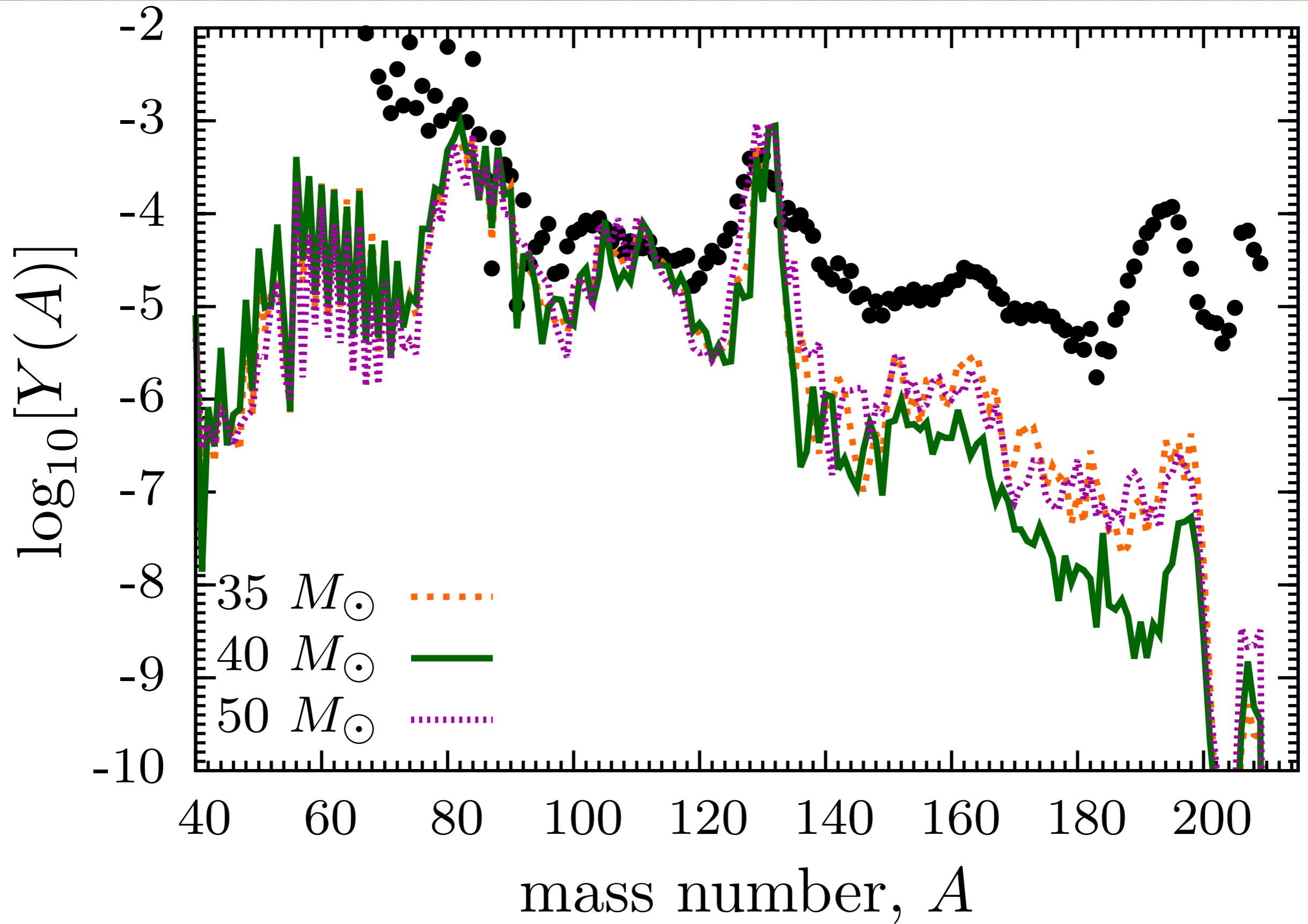


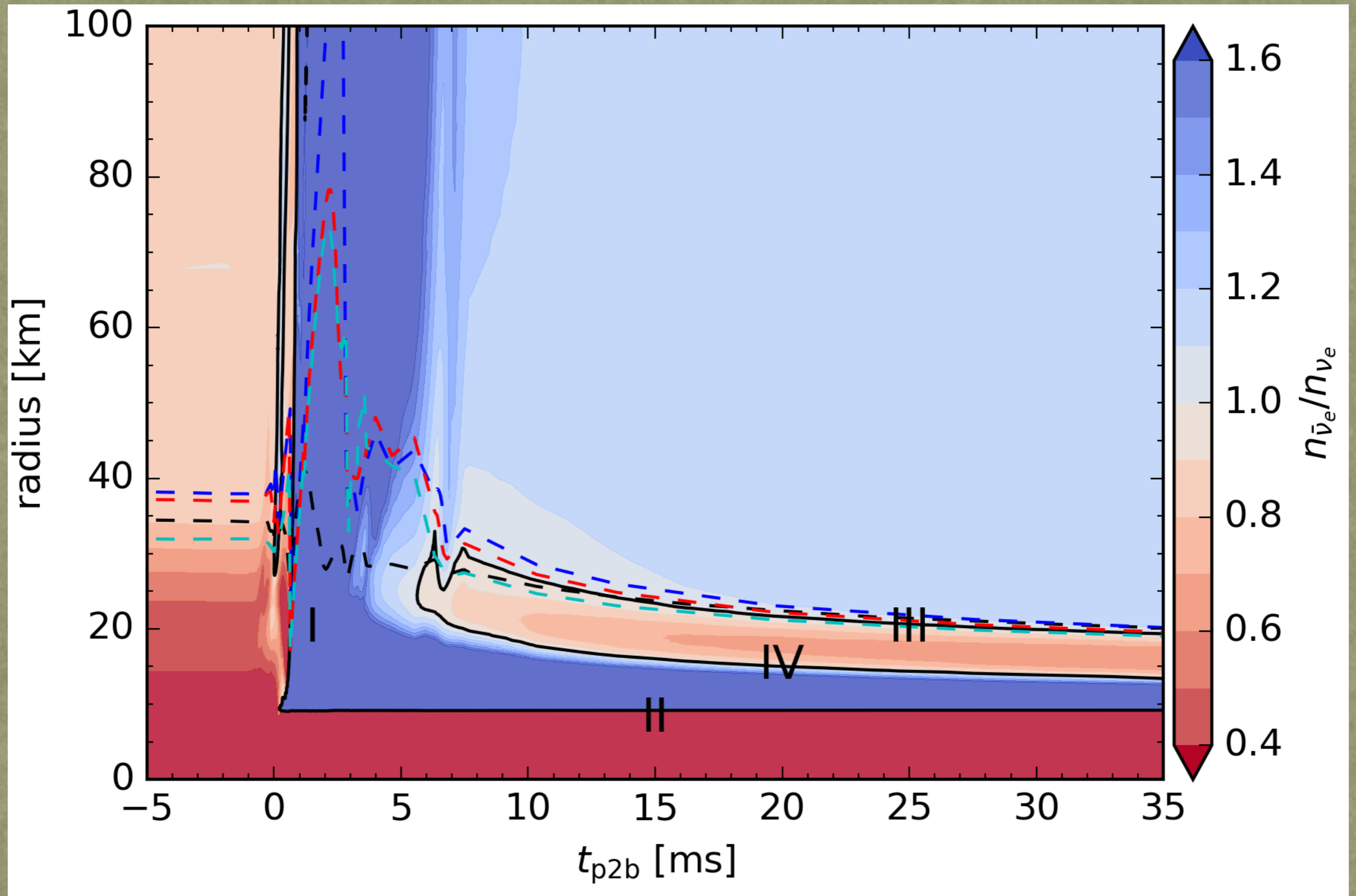
UNIVERSAL RELATIONS

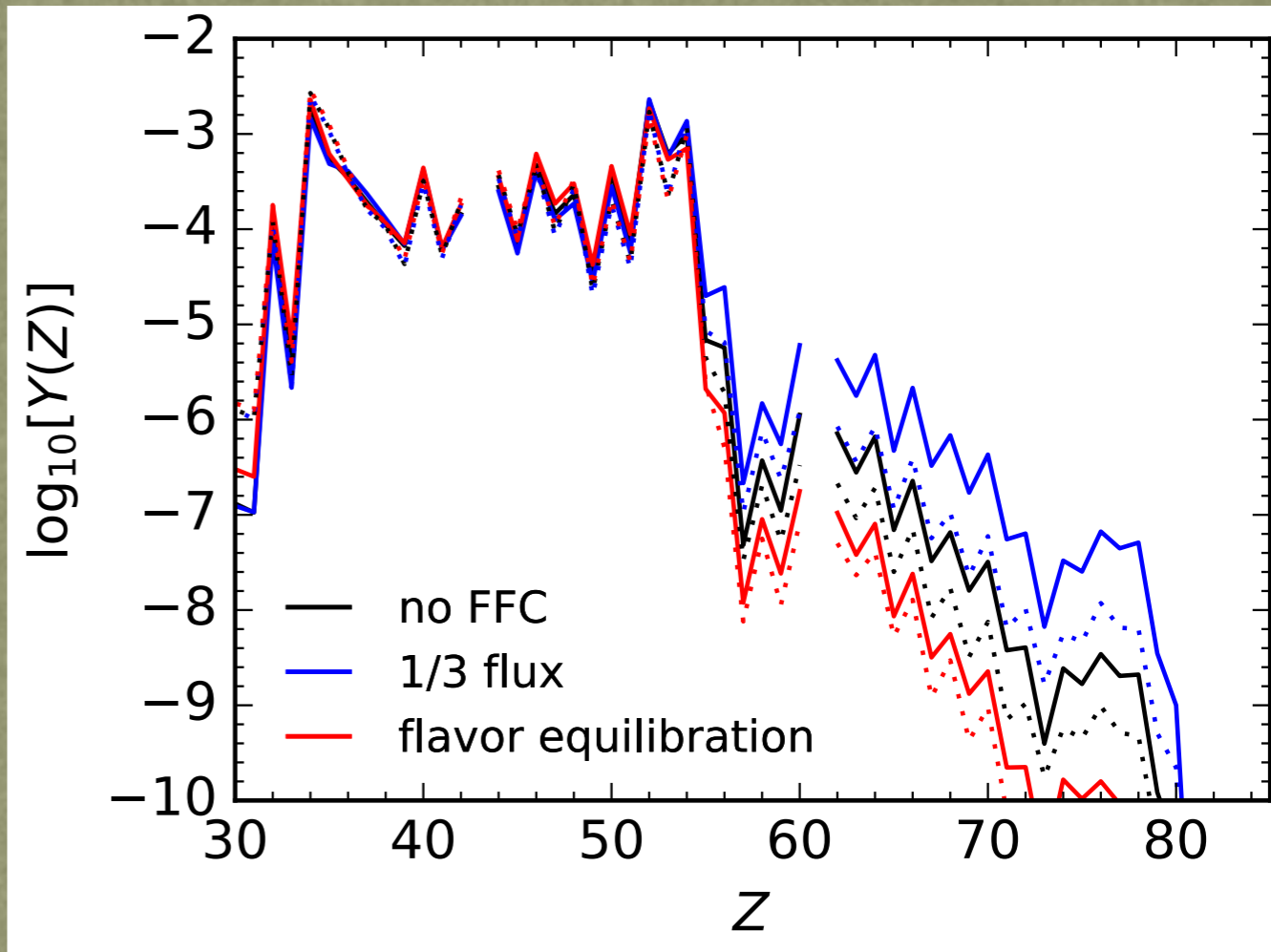
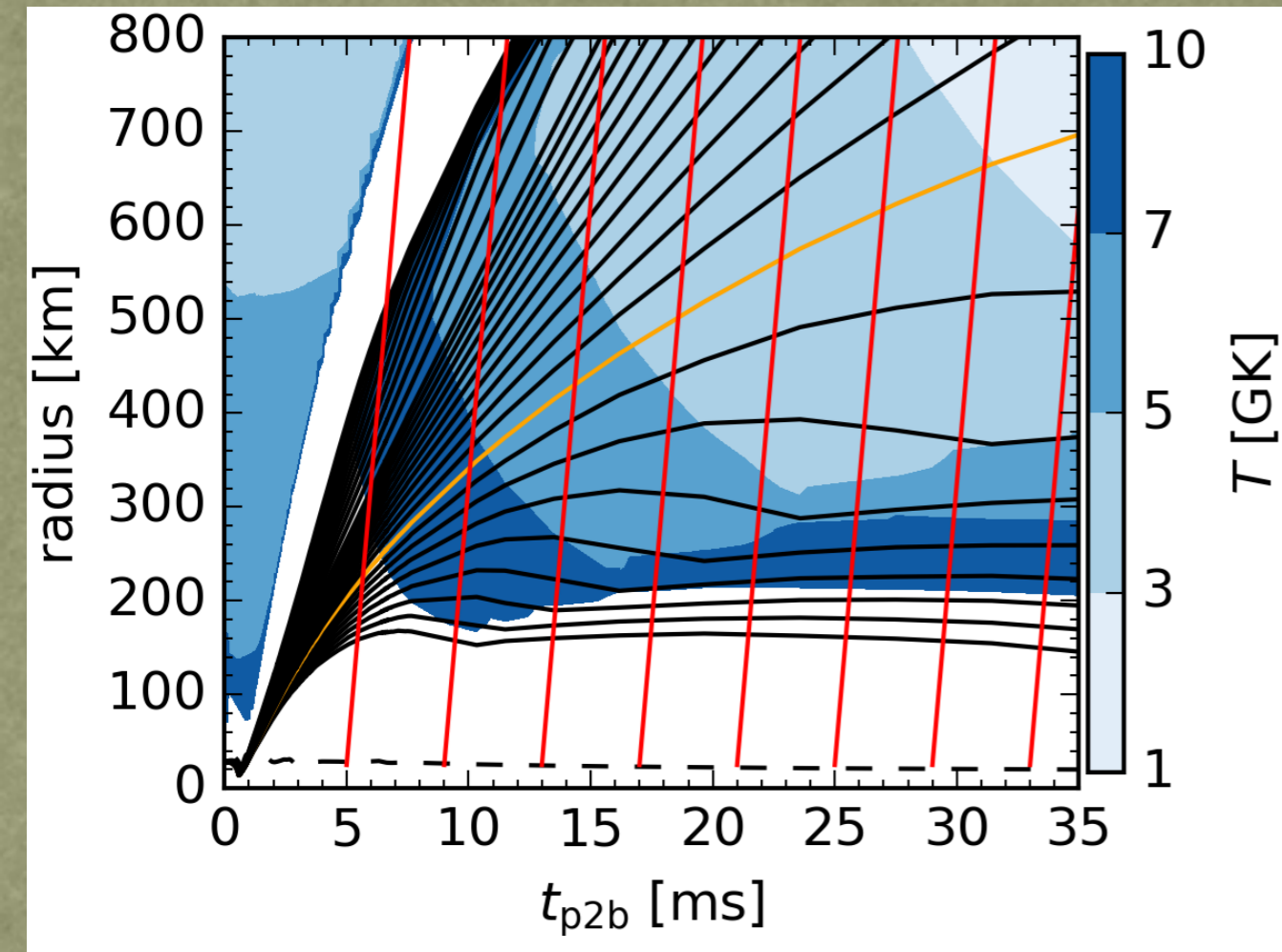




NUCLEOSYNTHESIS



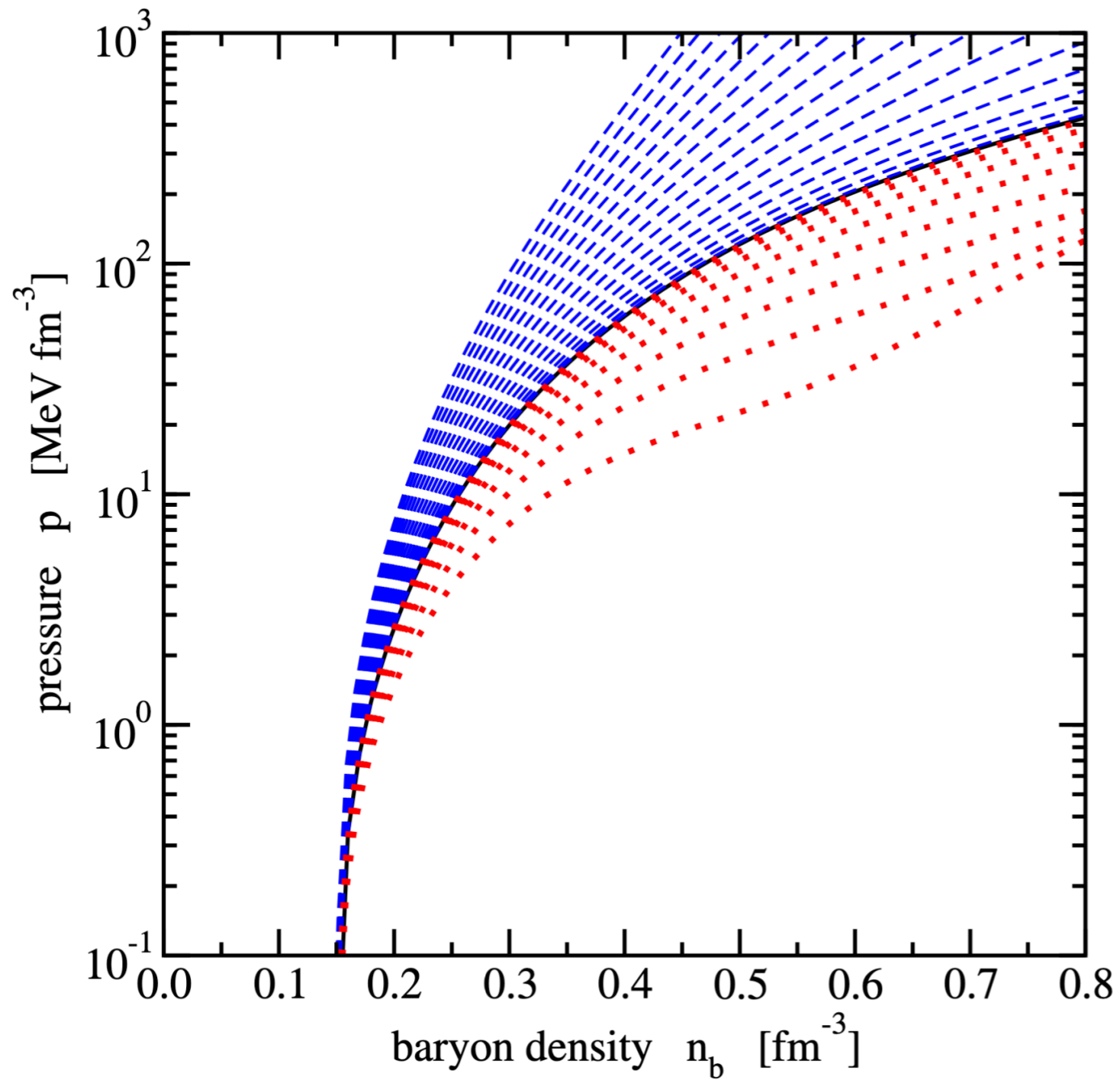




Two scenarios for FFC:

- Fluxes in electron flavor reduced by a factor of 3
 - Y_e decreases by ~ 0.01
 - enhance the produced abundance for $Z \gtrsim 55$ within one order of magnitude
- Assuming flavor equilibration between electron and heavy-lepton flavors
 - enhancement on neutrino mean energy & change the equilibrium Y_e
 - Y_e increases by ~ 0.01
 - reduce the produced abundance

BEYOND A MAXWELL CONSTRUCTION PHASE TRANSITION



$$g_N \longrightarrow g_{\text{eff}}(T, n_B) = g_N \Phi_N(T, n_B)$$

$$\text{with : } \Phi_N(T, x) \propto 1 + \Theta(x) \exp\left(-\frac{1}{2x^2}\right)$$

$$\{x = v(n_B - n_{\text{cut}})\}$$

S. Typel (2016) European Physical Journal A 52, p. 16

Typel & Blaschke (2018) Universe 4, id. 32

Table 1: Excluded volume parametrisation.

v (fm)	n_{cut} (fm $^{-3}$)	ρ_{onset}^a (fm $^{-3}$)	ρ_{end}^b (fm $^{-3}$)
2	0.149 ^d	0.268	0.412

^a onset density for the phase transition at $T = 1$ MeV and $Y_p = 0.3$

^b end density for phase transition at $T = 1$ MeV and $Y_p = 0.3$

$$(s = 3 k_B)$$

