Uniwersytet Wrocławski

Narodowe Centrum Nauki

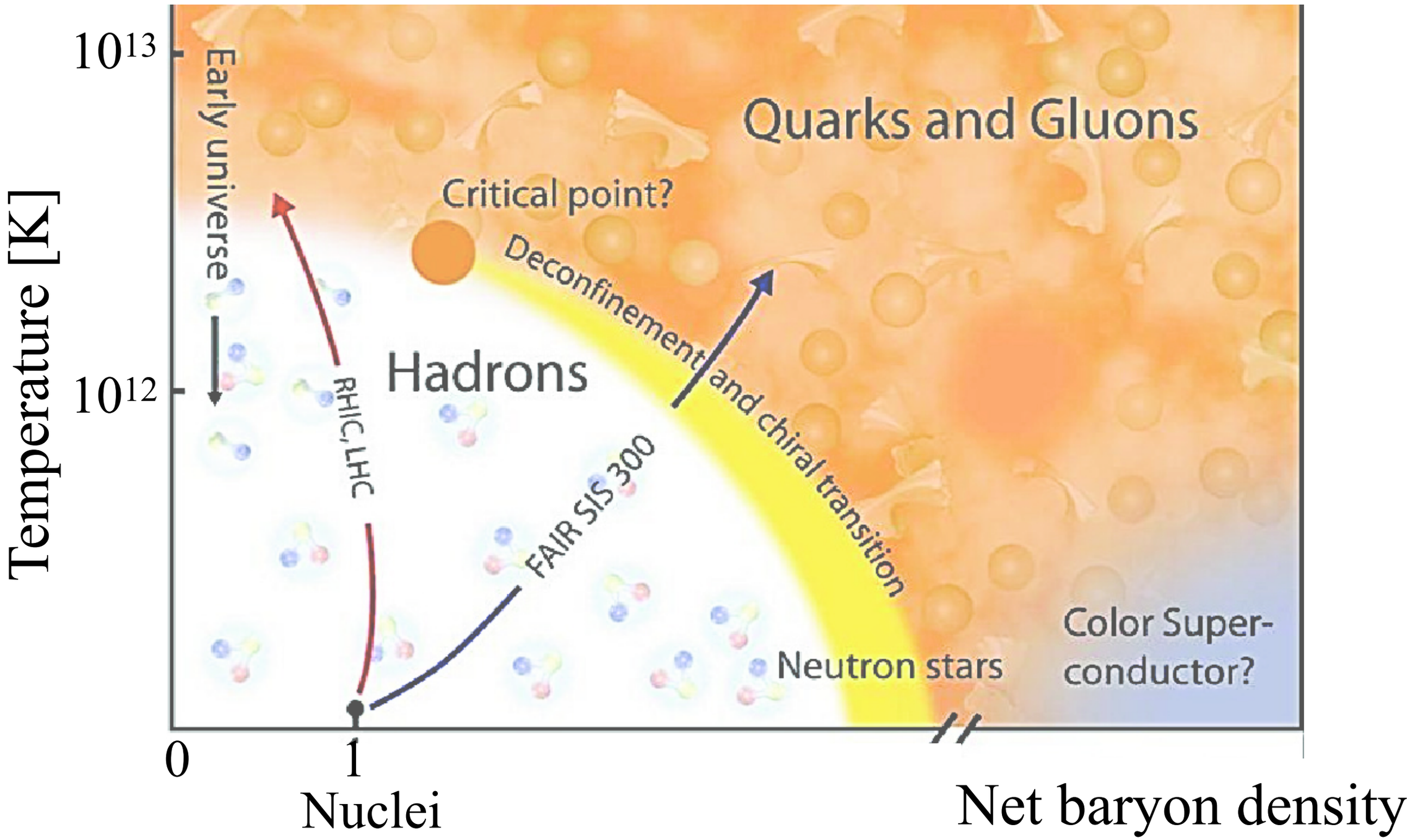
Simulations of Core Collapse Supernovae with QCD phase transition

Noshad Khosravi Largani

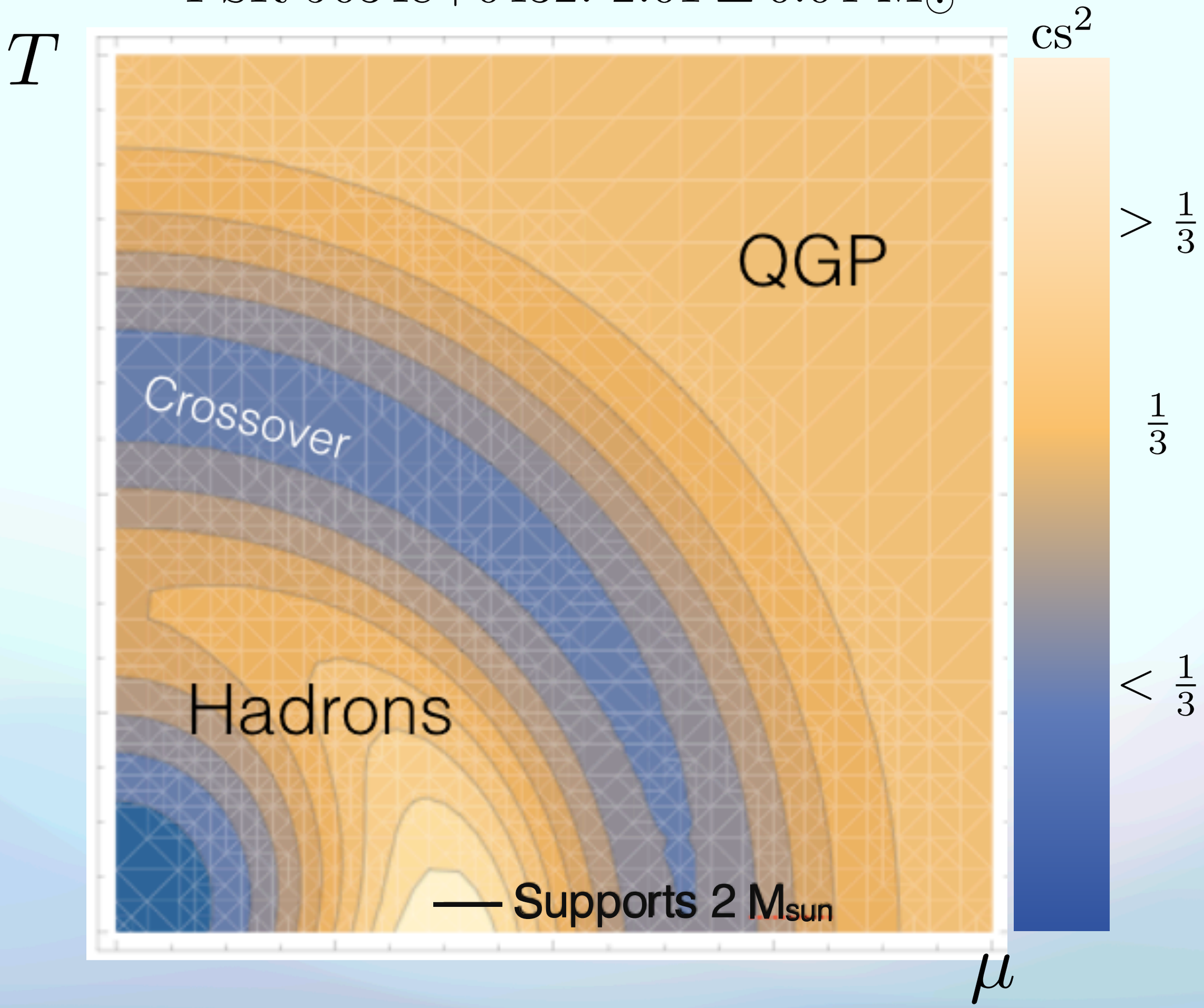
First GWSN symposium

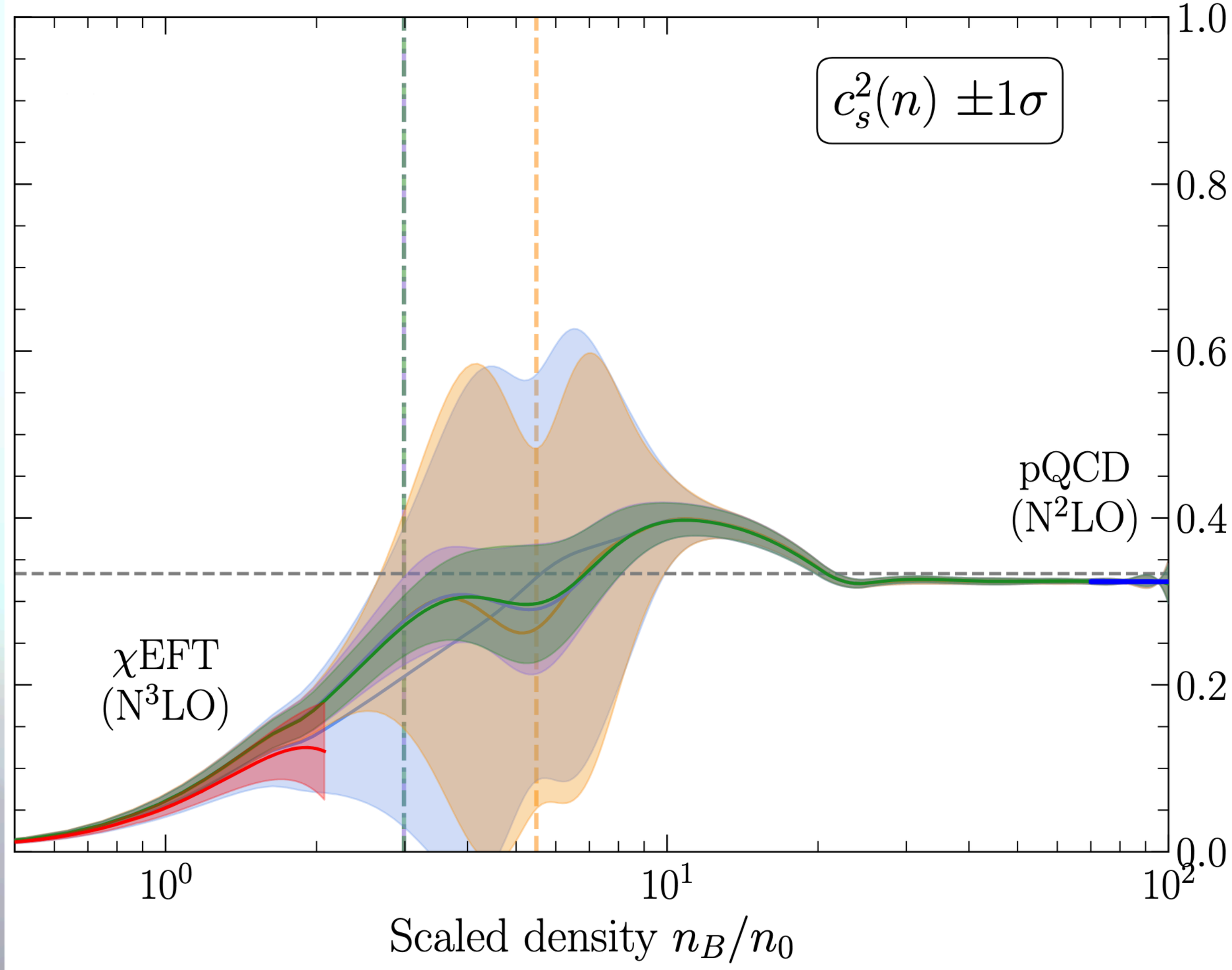
University of Warsaw, 25 July 2025

Tobias Fischer, Shota Shibagaki, Pablo Cerda-Duran, Alejandro Torres-Forne

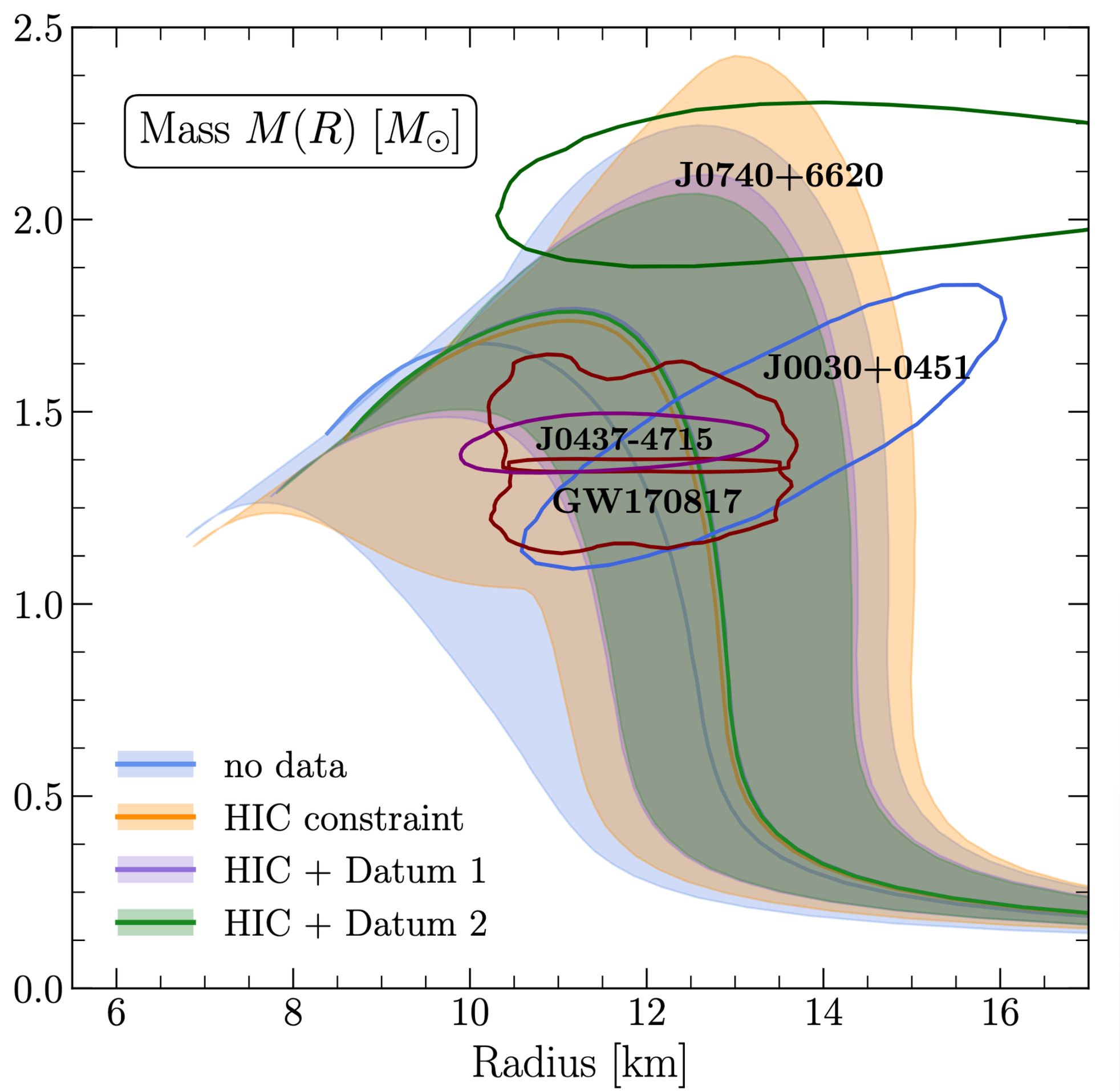

Temperature [K]
10^{13}
10^{12}
Early universe
RHIC, LHC
FAIR SIS 300
Quarks and Gluons
Critical point?
Deconfinement and chiral transition
Hadrons
Neutron stars
Color Super-conductor?
0
1
Nuclei
Net baryon density

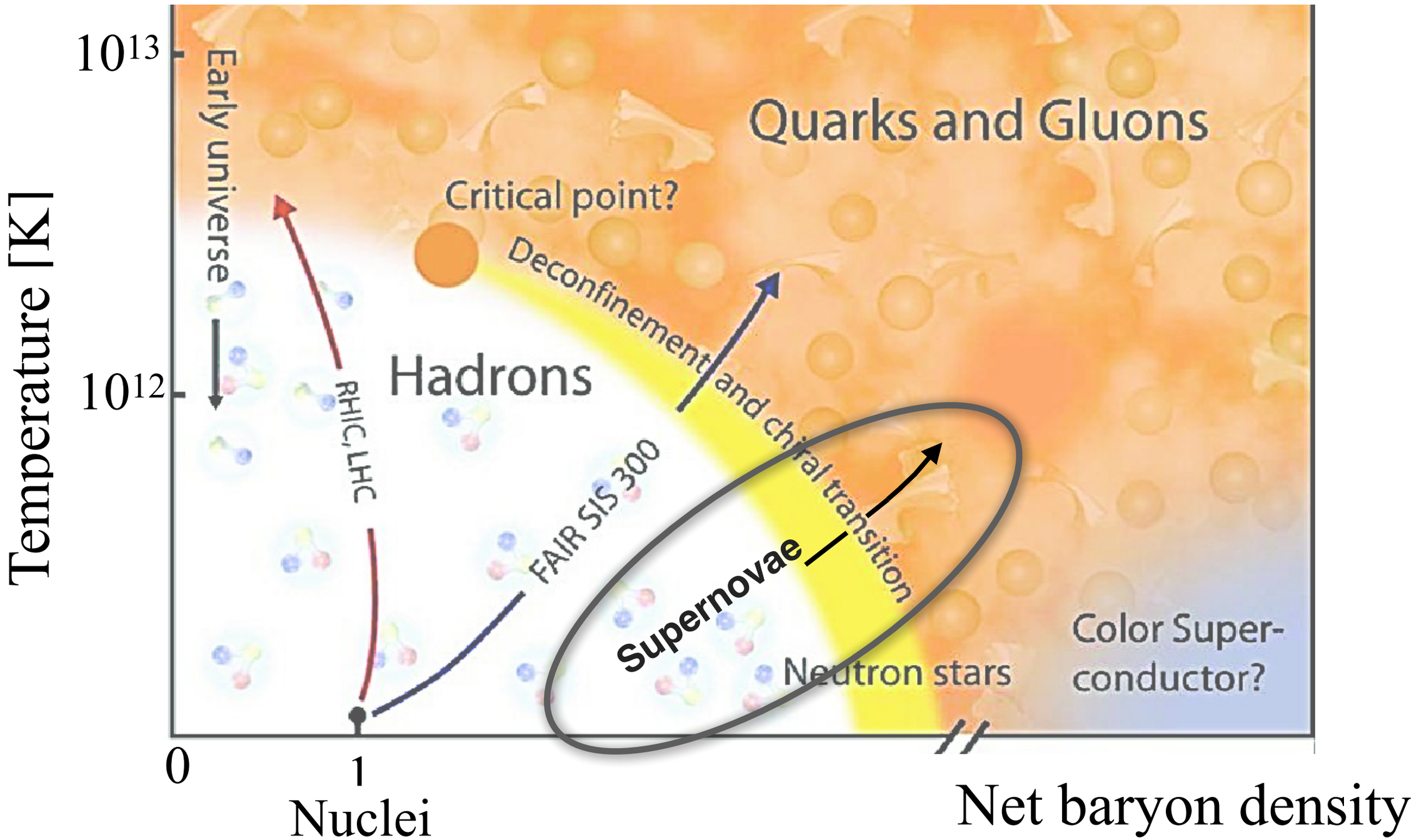
PSR J0348+0432: 2.01 ± 0.04 $M_\odot$





A. C. Semposki et al., arXiv:2505.18921




Temperature [K]
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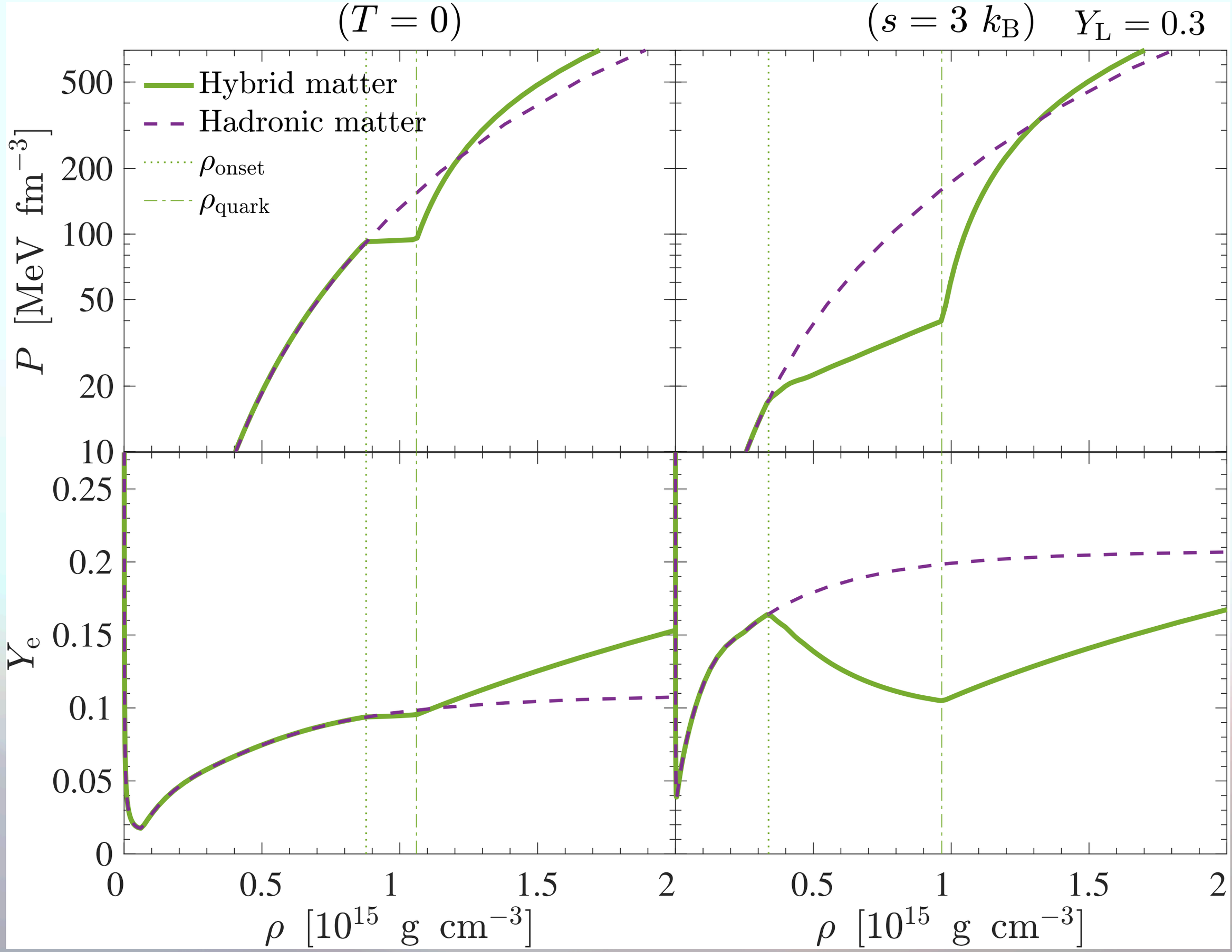


Bastian, Phys. Rev. D, 103, 023001 (2021)

$t = 0.5502$ s

u [c]

Y_e , $\chi_{\rm quark}$

Y_e

$\chi_{\rm quark}/2$

R [km]

ϵ_ν [MeV]

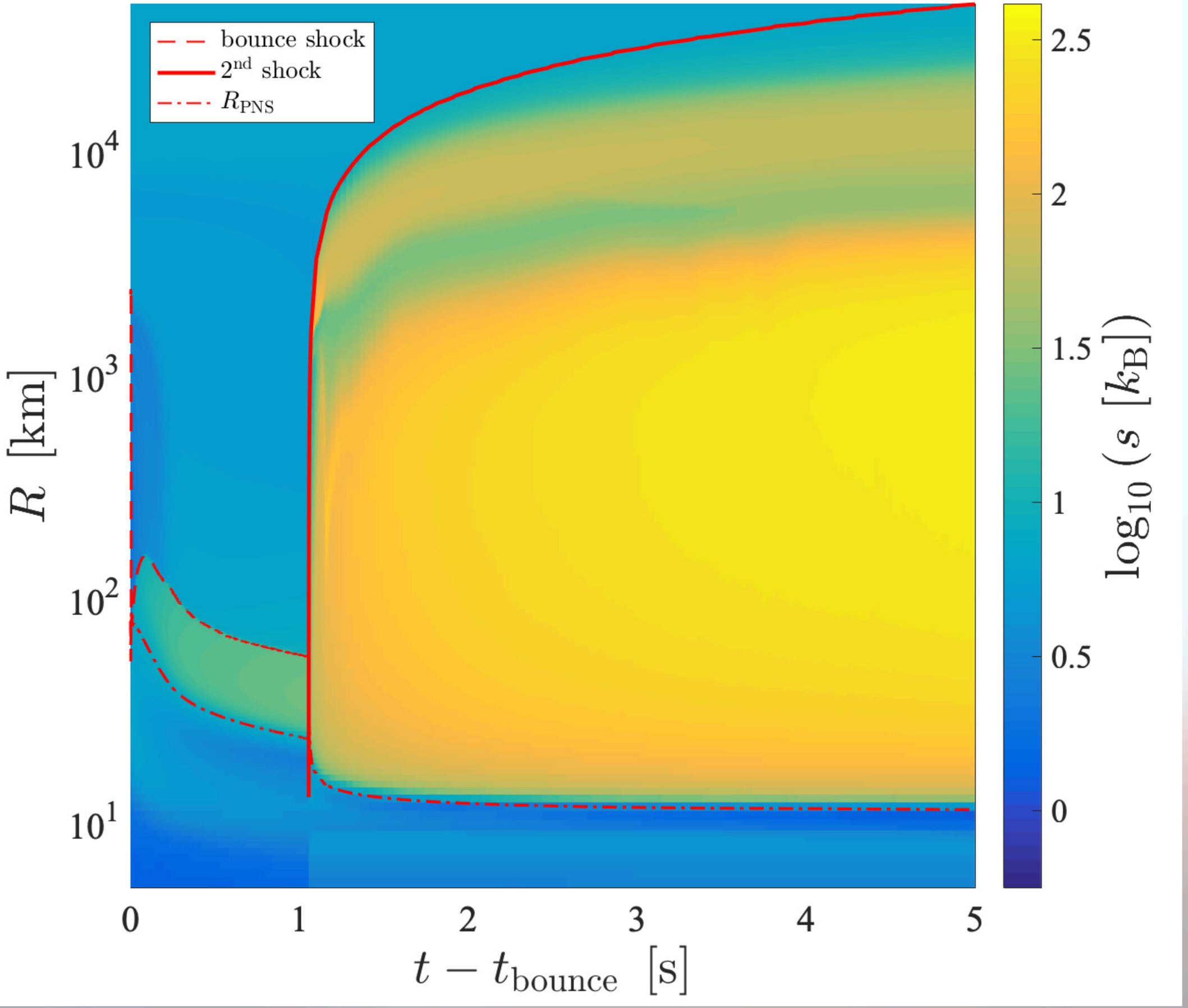
3 33 90 165 246 300

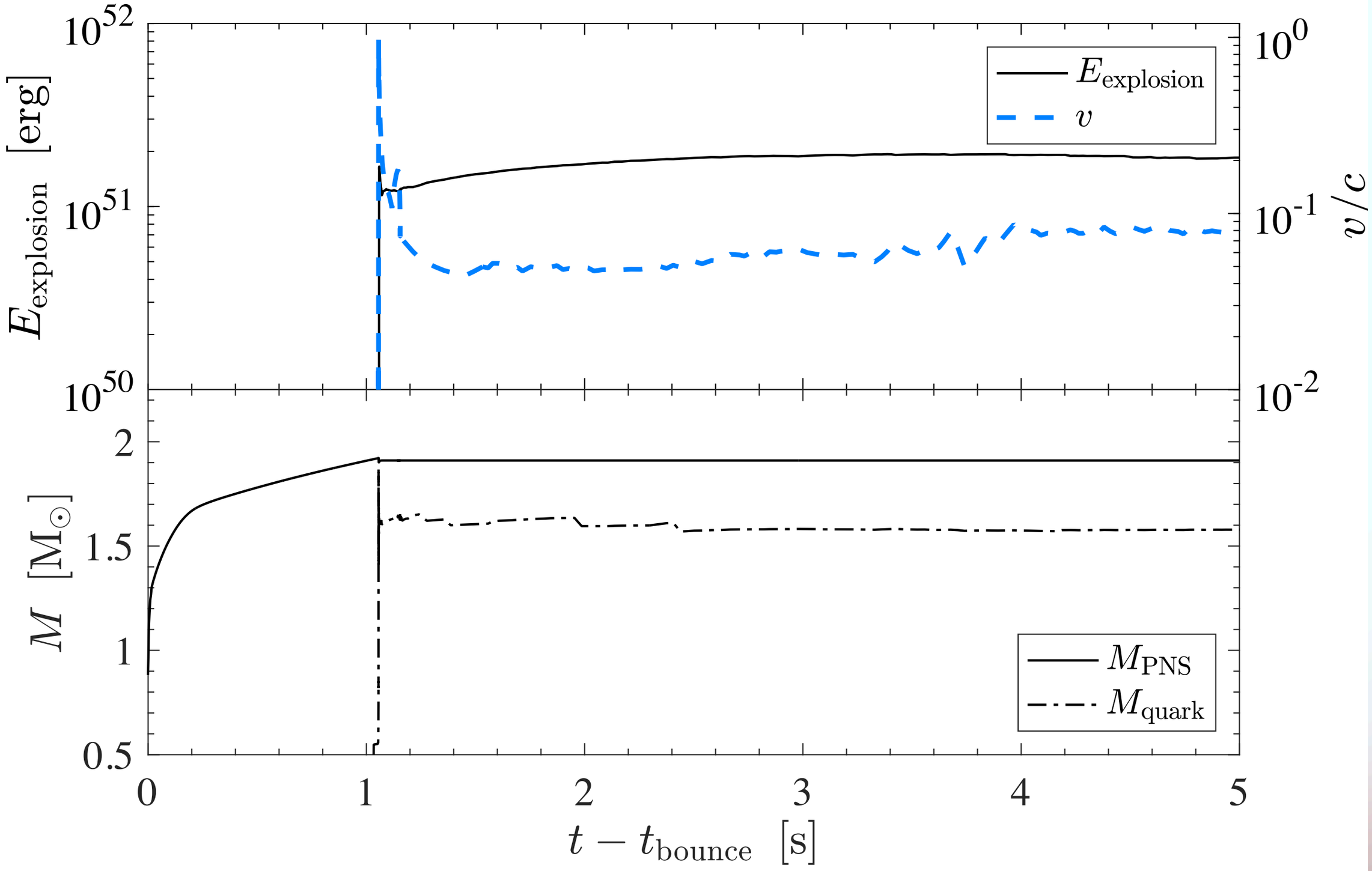
ρ [g cm^{-3}]

T [MeV]

R [km]

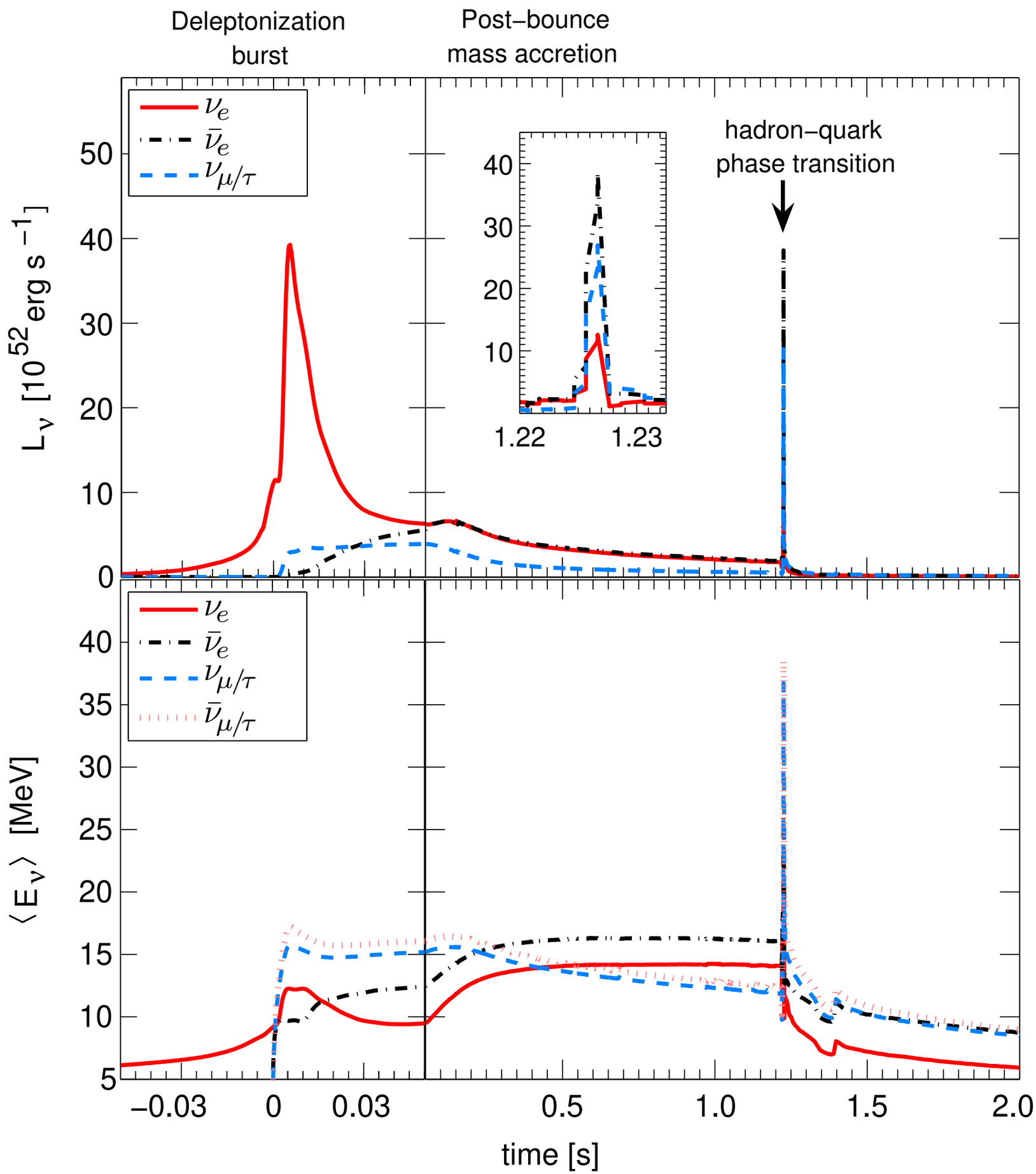
Khosravi Largani et al., Astrophys. J, 946, 143 (2024)





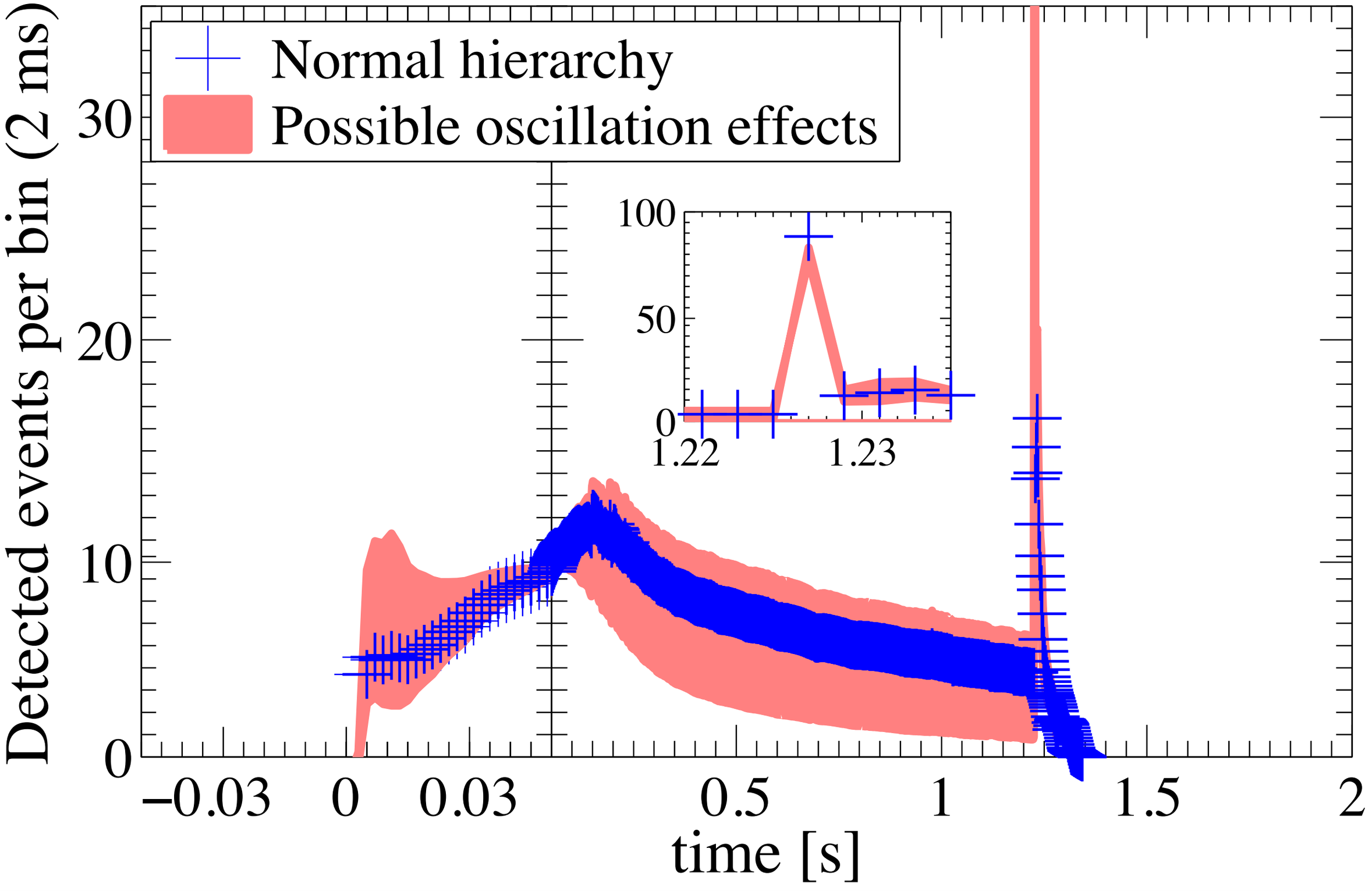
$$\begin{aligned} \mathrm{E_{expl}} &= 3 \times 10^{51}\ \mathrm{erg} \\ \mathrm{M_{NS}} &\simeq 2\ \mathrm{M_\odot} \end{aligned}$$

Khosravi Largani et al., Astrophys. J, 946, 143 (2024)



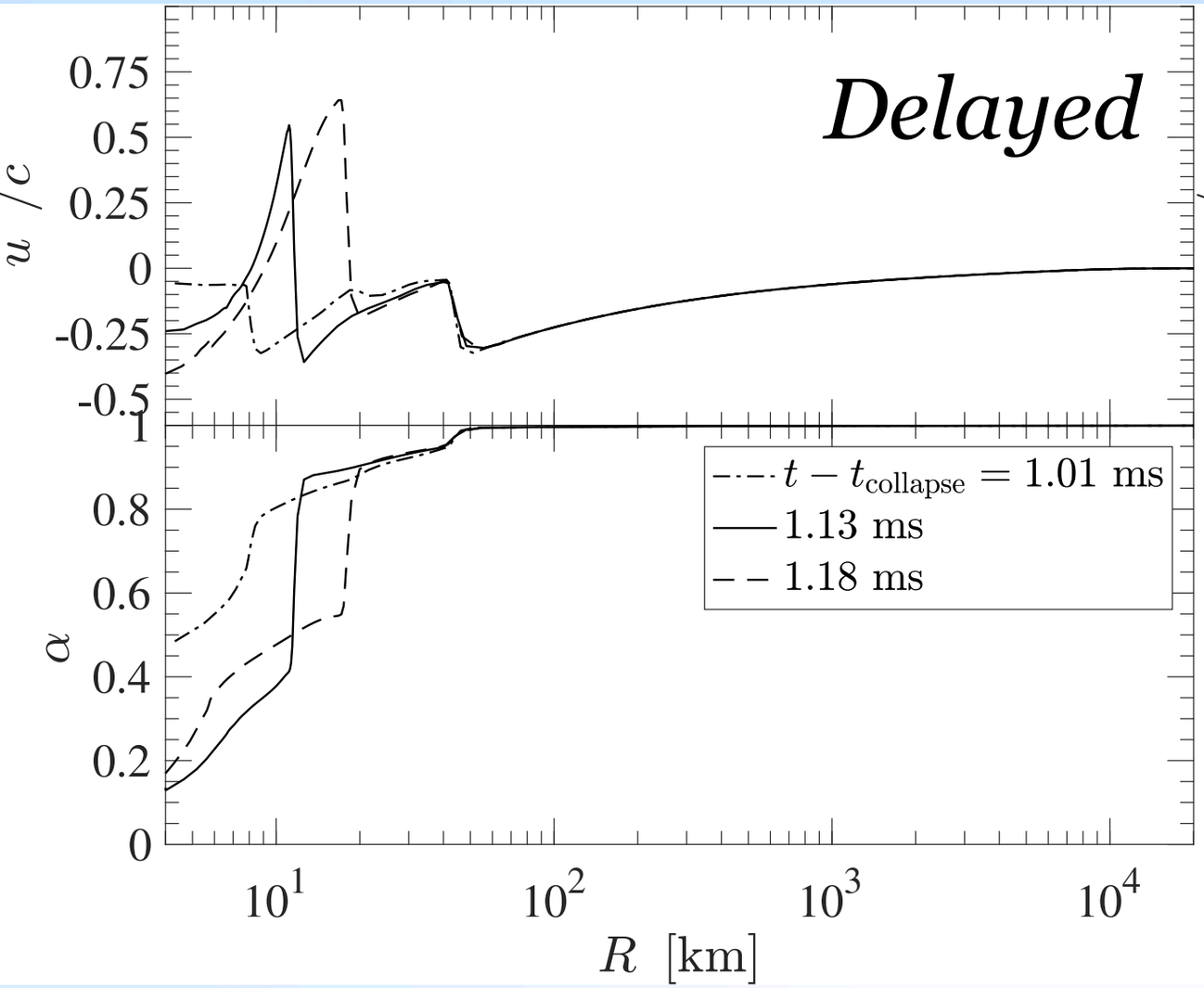
Fischer et al., Nat. Astron. 2, 980 (2018)

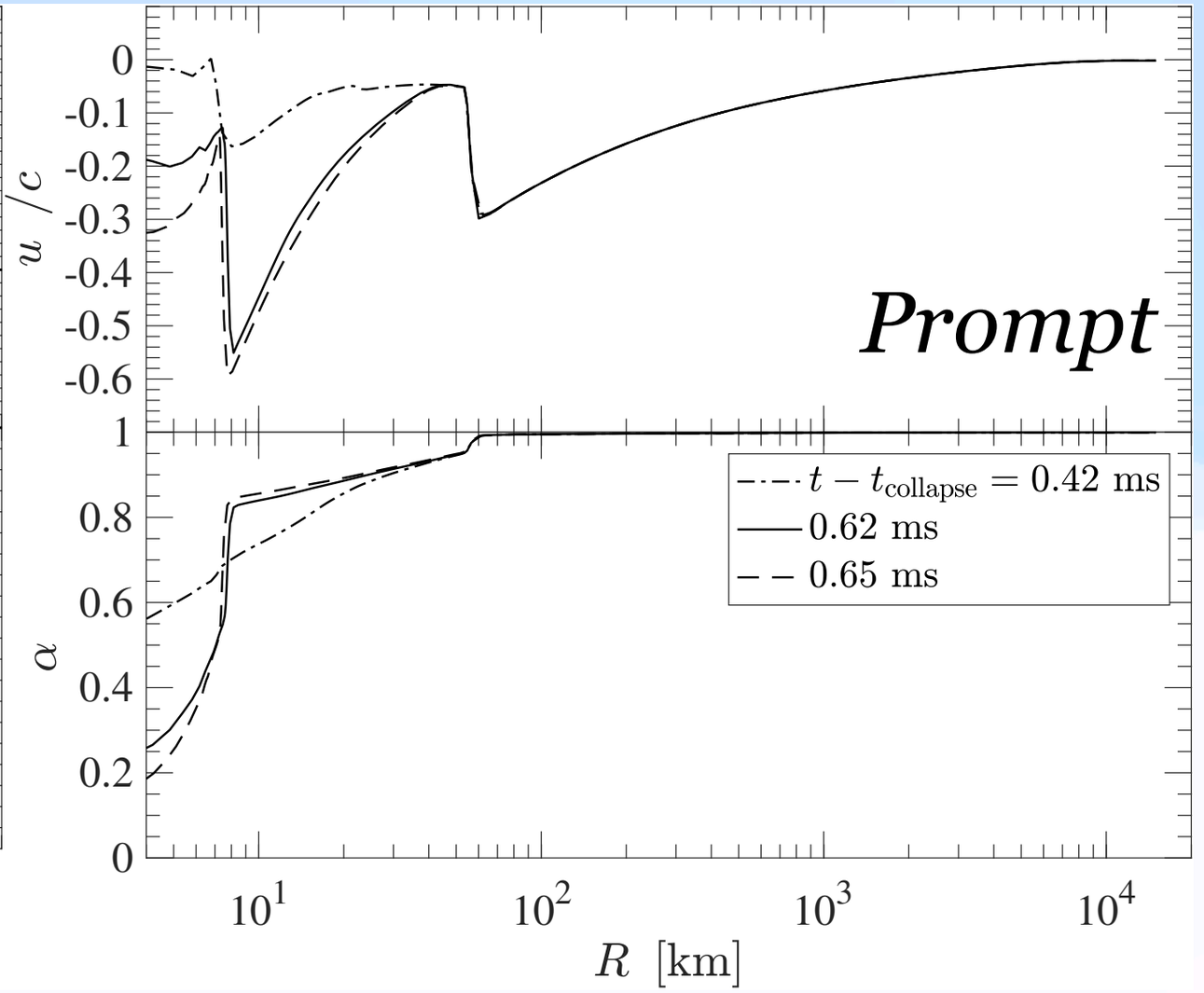
ν – signal @ Super-Kamiokande (d ~ 10 kpc)



Fischer et al., Nat. Astron. 2, 980 (2018)

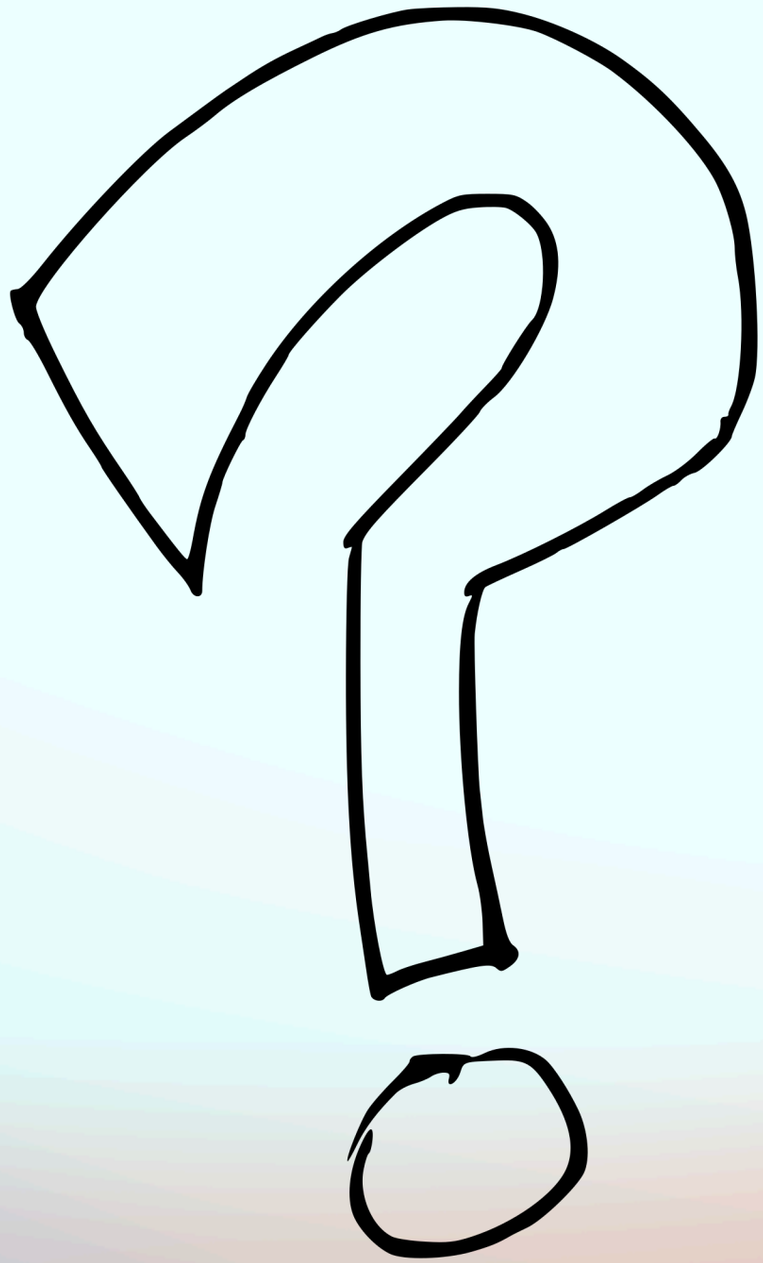
Black-hole formation: **Two distinct scenarios**

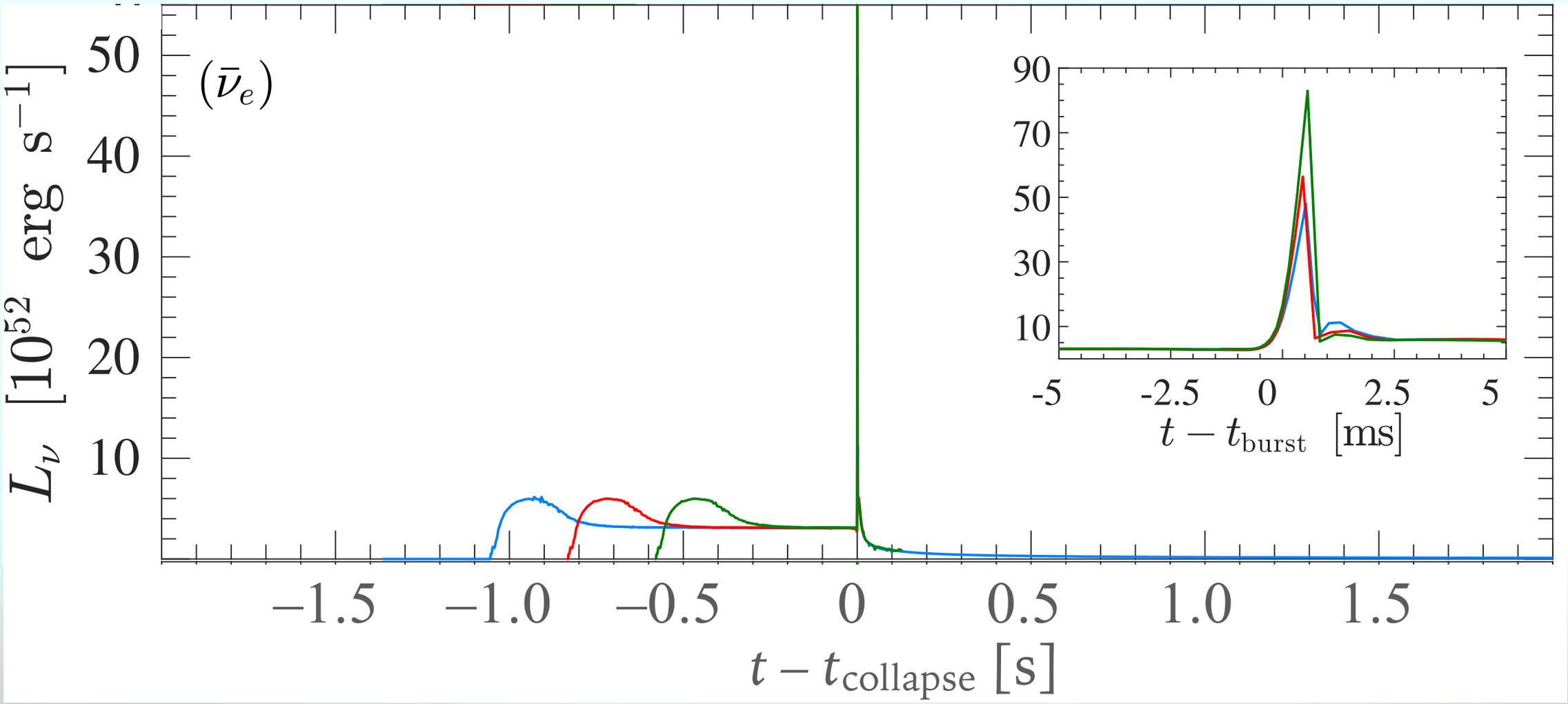




Jakobus et al., MNRAS, 516, 2554 (2022)

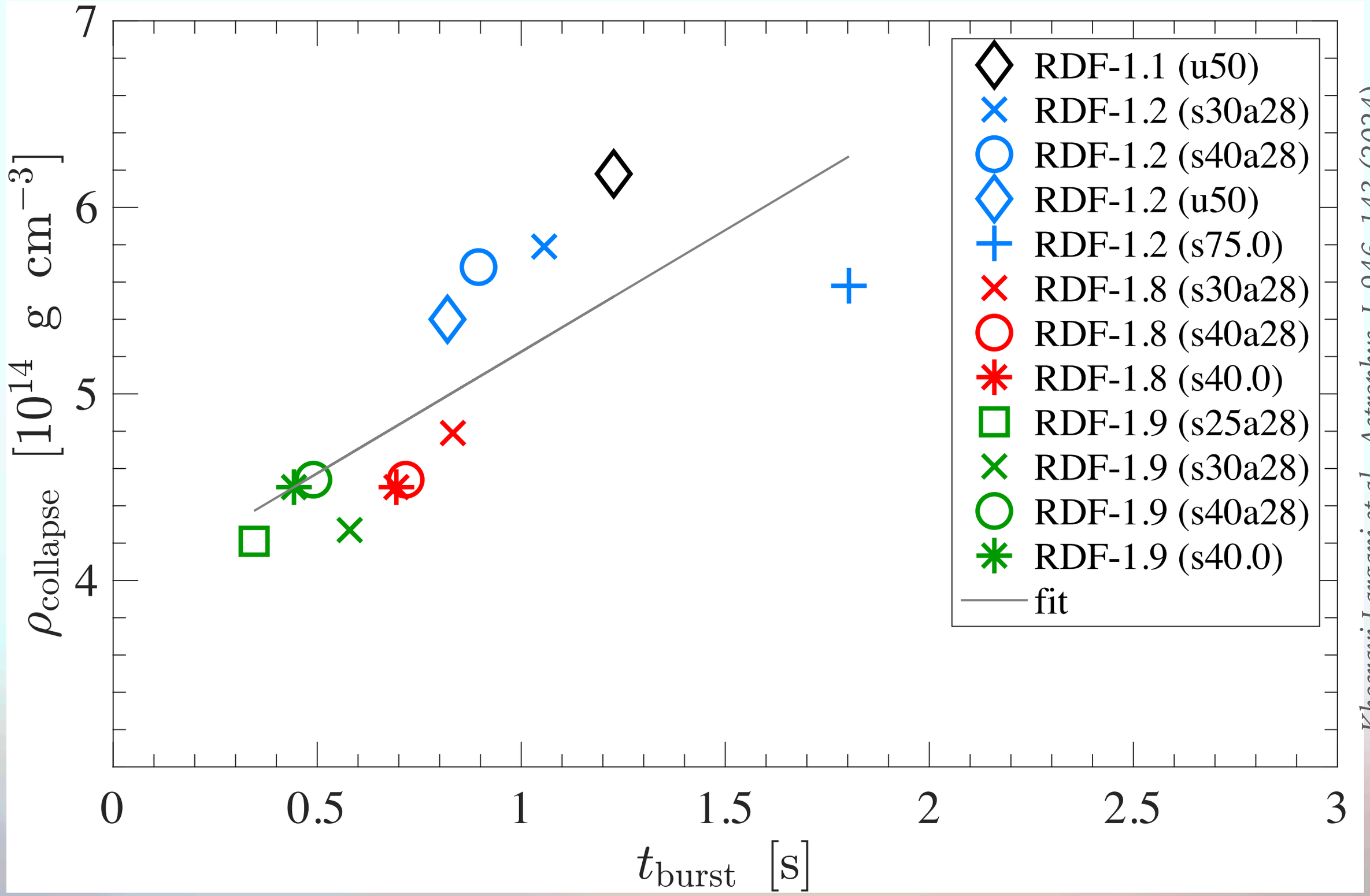
Khosravi Largani et al., ApJ 946, 143 (2024)



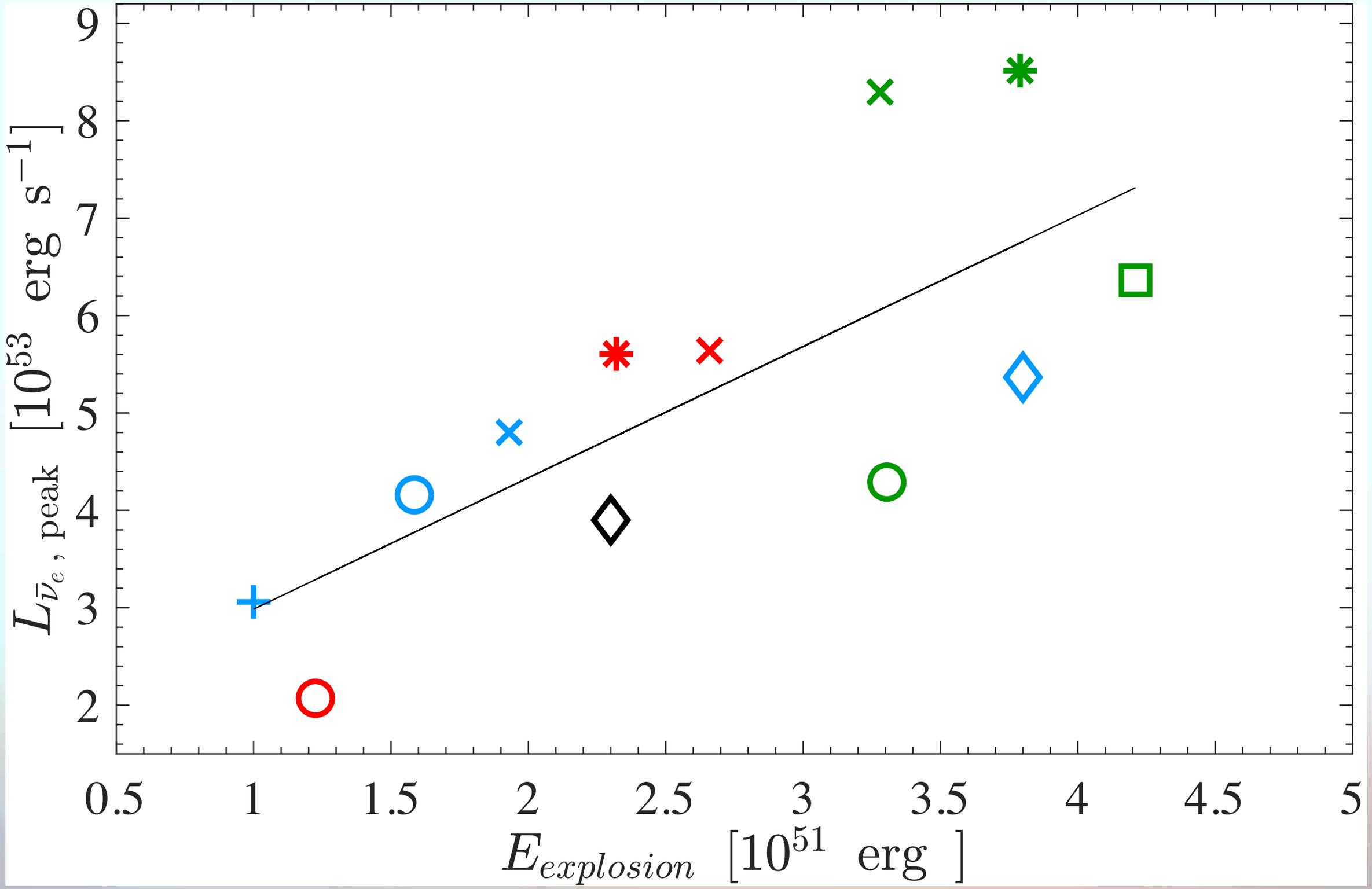


Khosravi Largani et al., Astrophys. J, 946, 143 (2024)

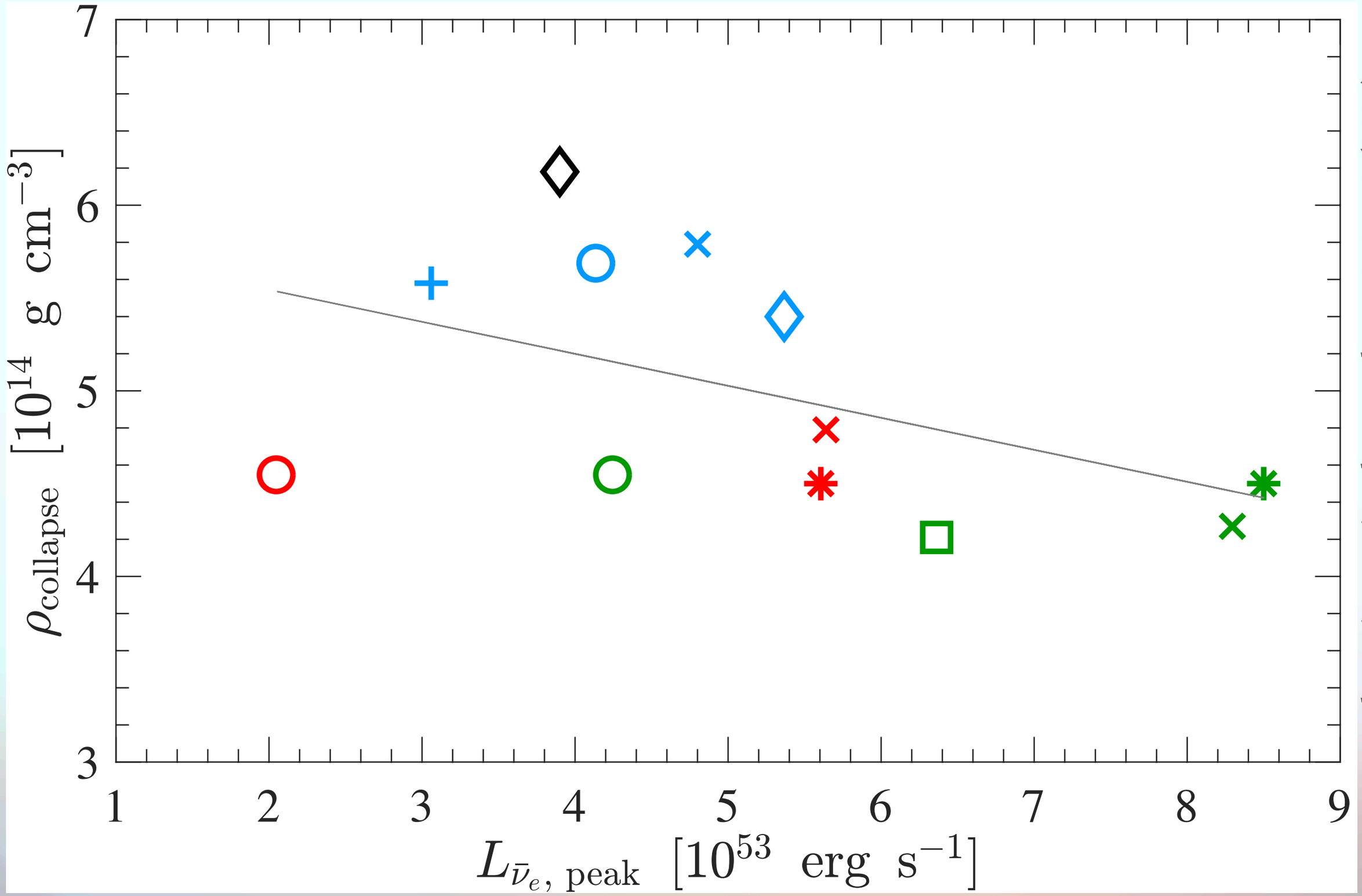
Progenitor	EOS RDF	$t_{\rm burst}$ [s]	$L_{\bar{\nu}_e,\rm peak}$ [10^{53} erg s^{-1}]	$\langle E_{\bar{\nu}_e}\rangle$ [MeV]	$E_{\rm expl}$ [10^{51} erg]
s25a28	1.9	0.345	6.36	38.59	4.21
s30a28	1.2	1.056	4.80	56.21	1.93
s30a28	1.8	0.833	5.64	42.21	2.66
s30a28	1.9	0.580	8.30	43.49	3.28
s40a28	1.2	0.895	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



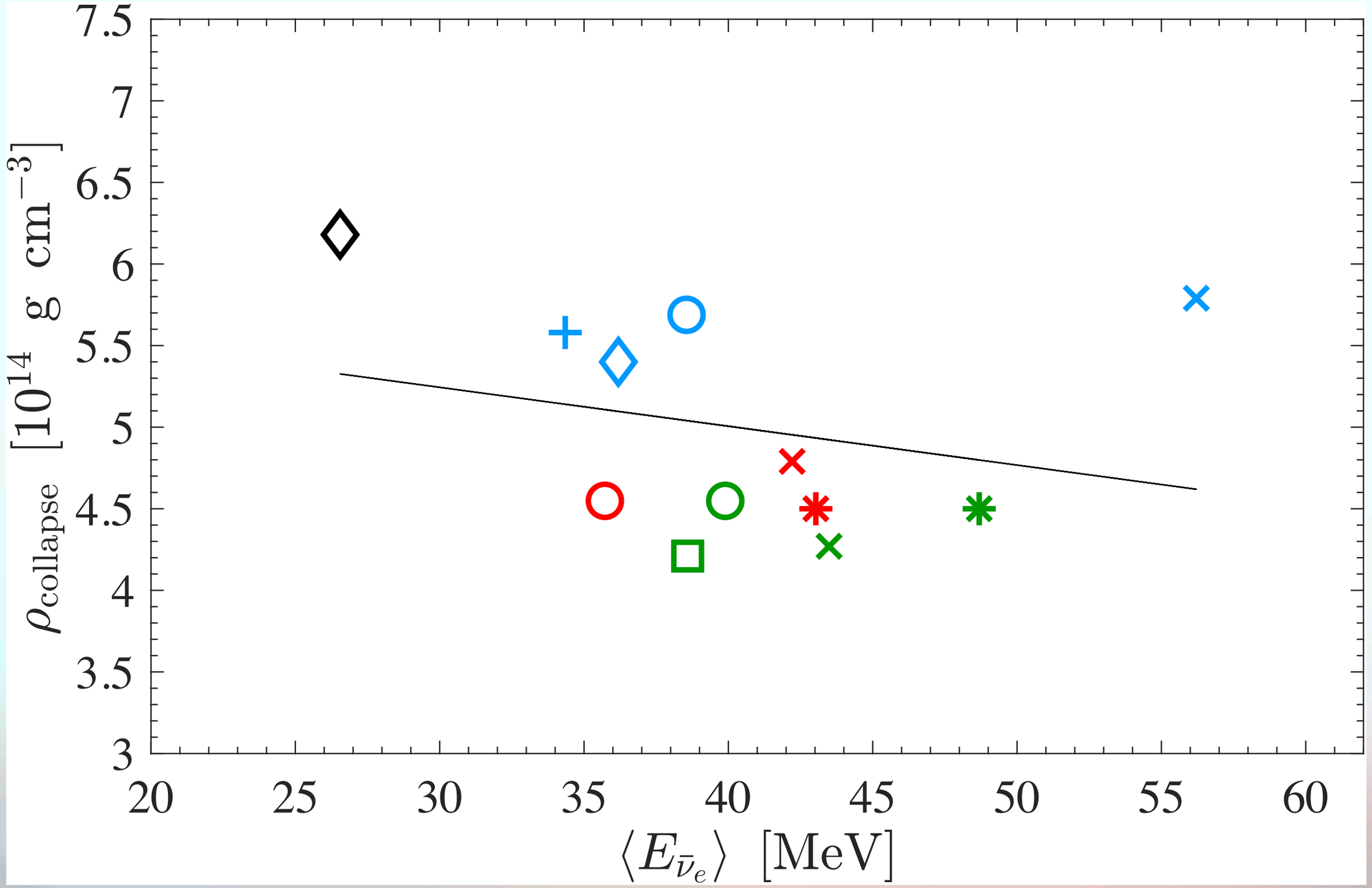
Khosravi Largani et al., Astrophys. J, 946, 143 (2024)



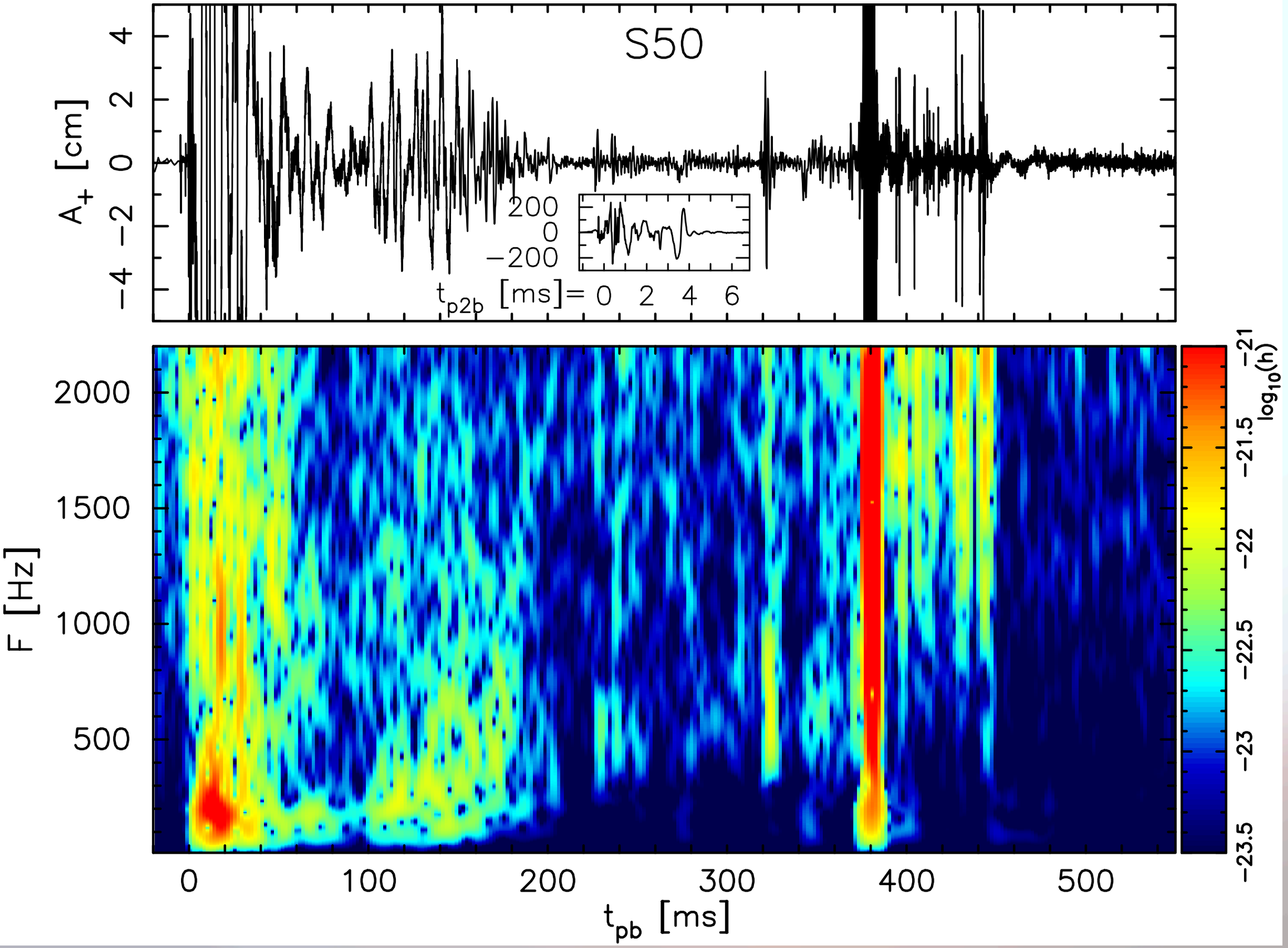
Khosravi Largani et al., Astrophys. J, 946, 143 (2024)



Khosravi Largani et al., Astrophys. J, 946, 143 (2024)

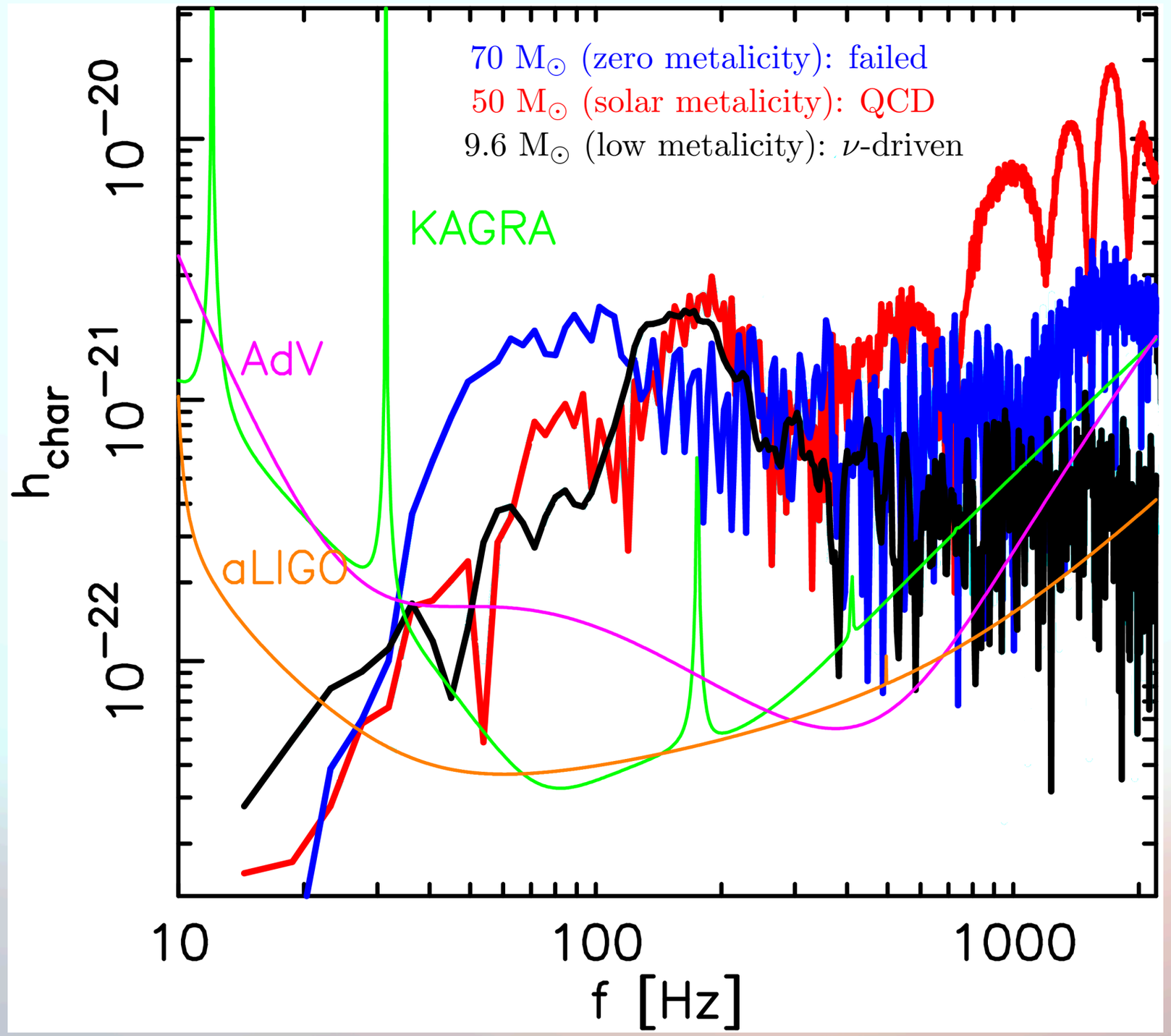


Khosravi Largani et al., Astrophys. J, 946, 143 (2024)

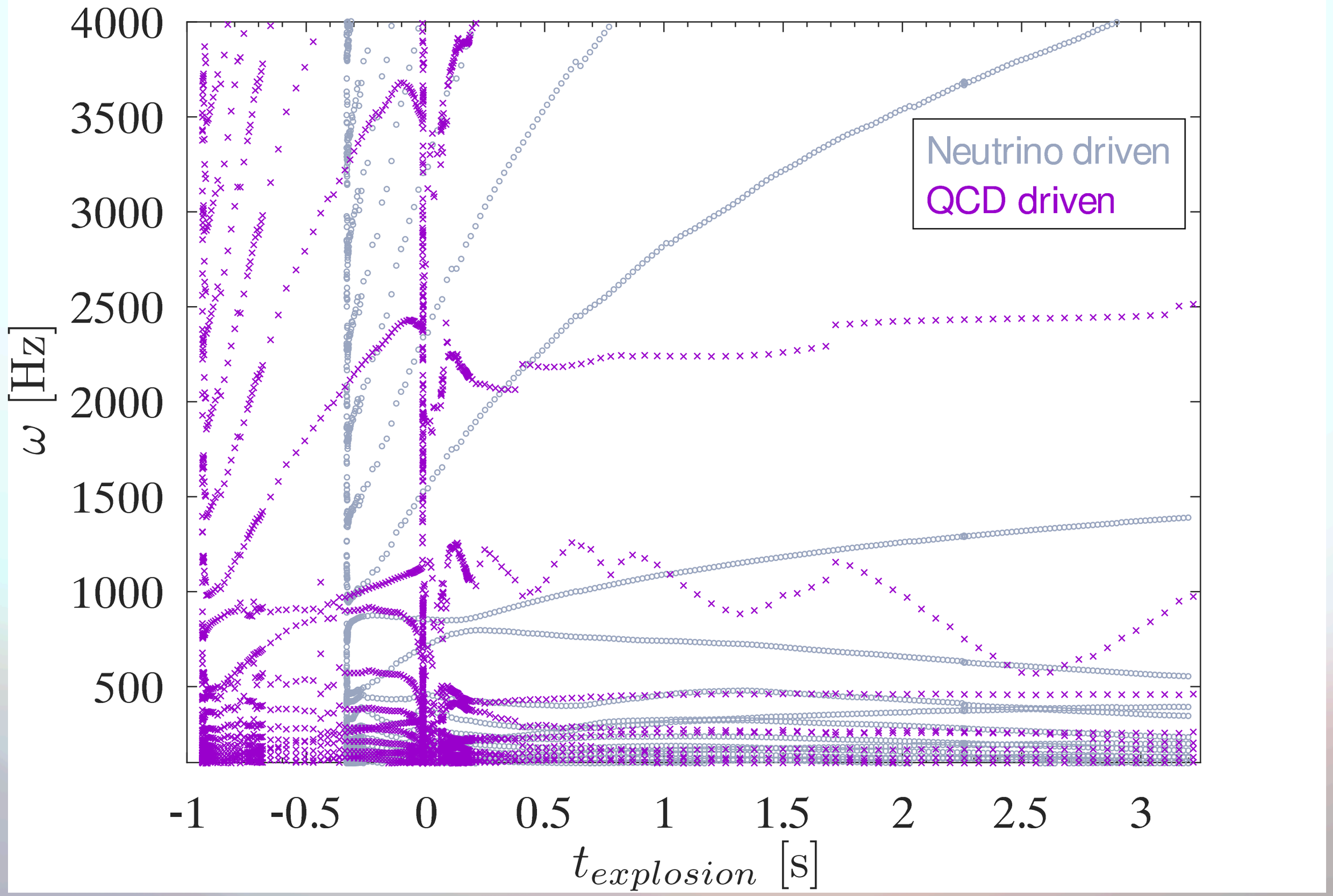


Kuroda et al., Astrophysics. J., 924, 38 (2022)

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



Kuroda et al., Astrophys. J, 924, 38 (2022)

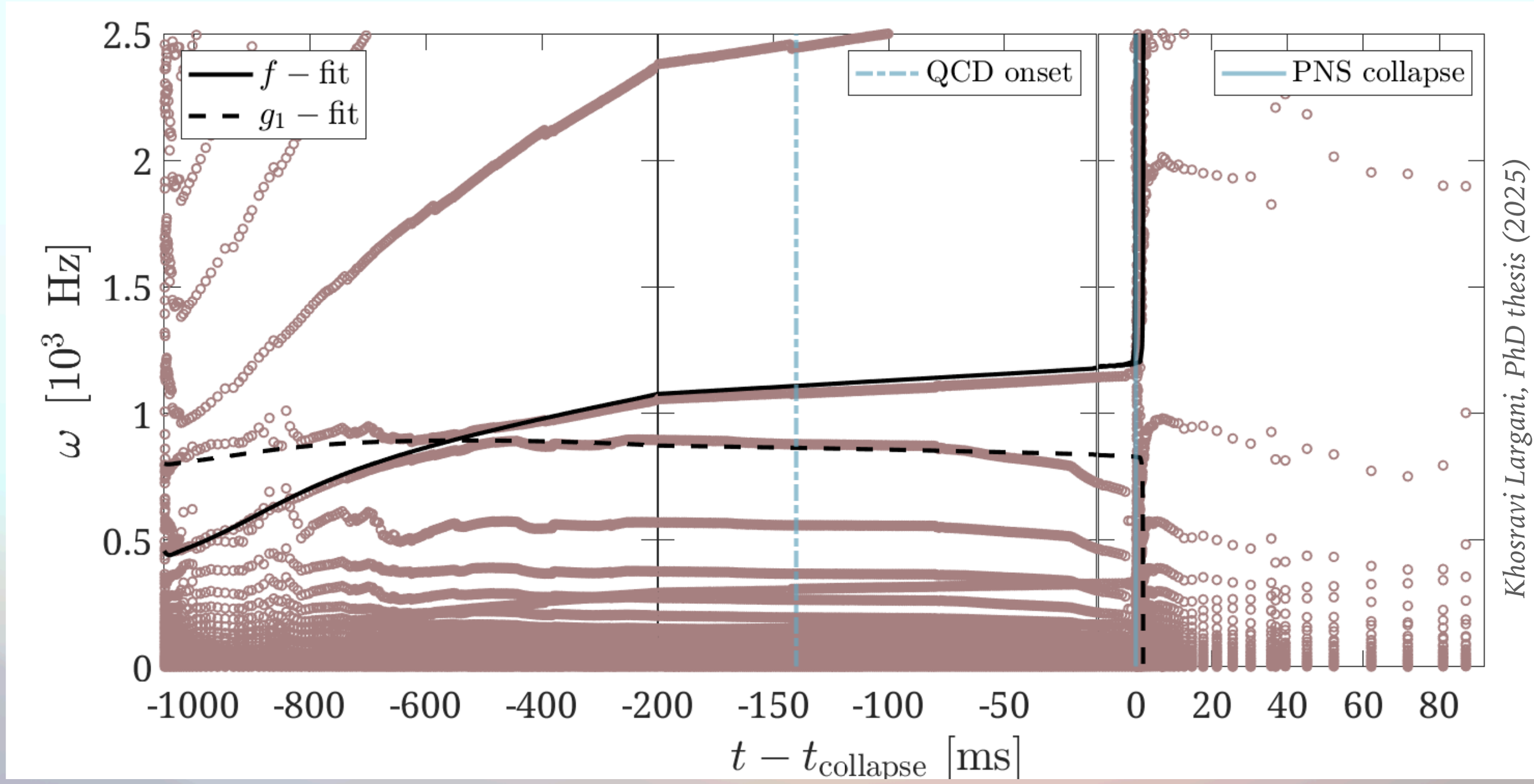

4000
3500
3000
2500
2000
1500
1000
500
ω [Hz]
Neutrino driven
QCD driven
-1
-0.5
0
0.5
1
1.5
2
2.5
3
$t_{explosion}$ [s]

$$f \qquad x = \sqrt{M_{\rm PNS}/R^3_{\rm PNS}}$$

$$g_1 \qquad x = M_{\rm PNS}/R^2_{\rm PNS}$$

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

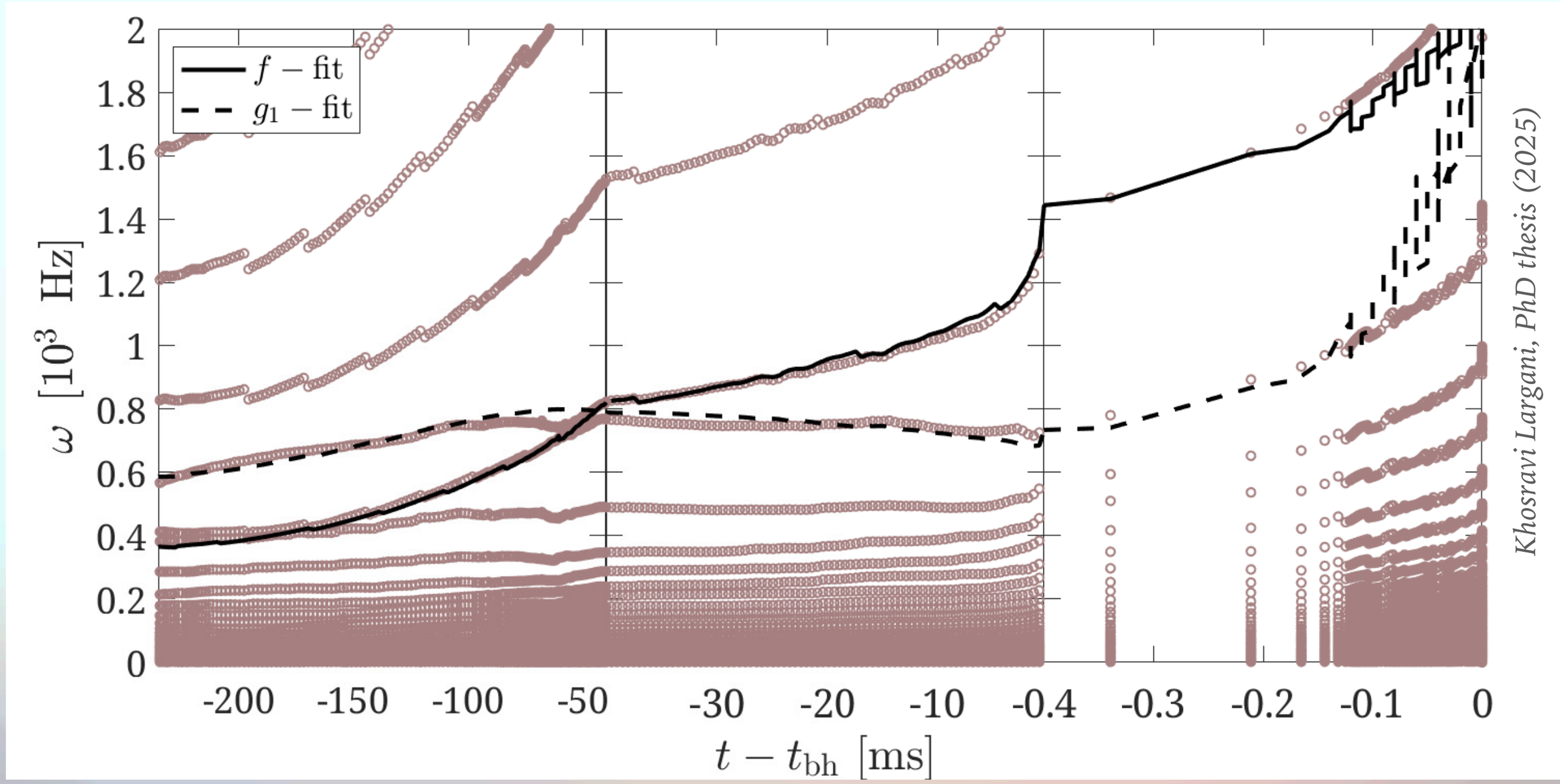
Torres Forne et al., Phys. Rev. Lett. 123, 051102 (2019)



f $\quad x = \sqrt{M_{\rm PNS}/R^3_{\rm PNS}}$

g_1 $\quad x = M_{\rm PNS}/R^2_{\rm PNS}$

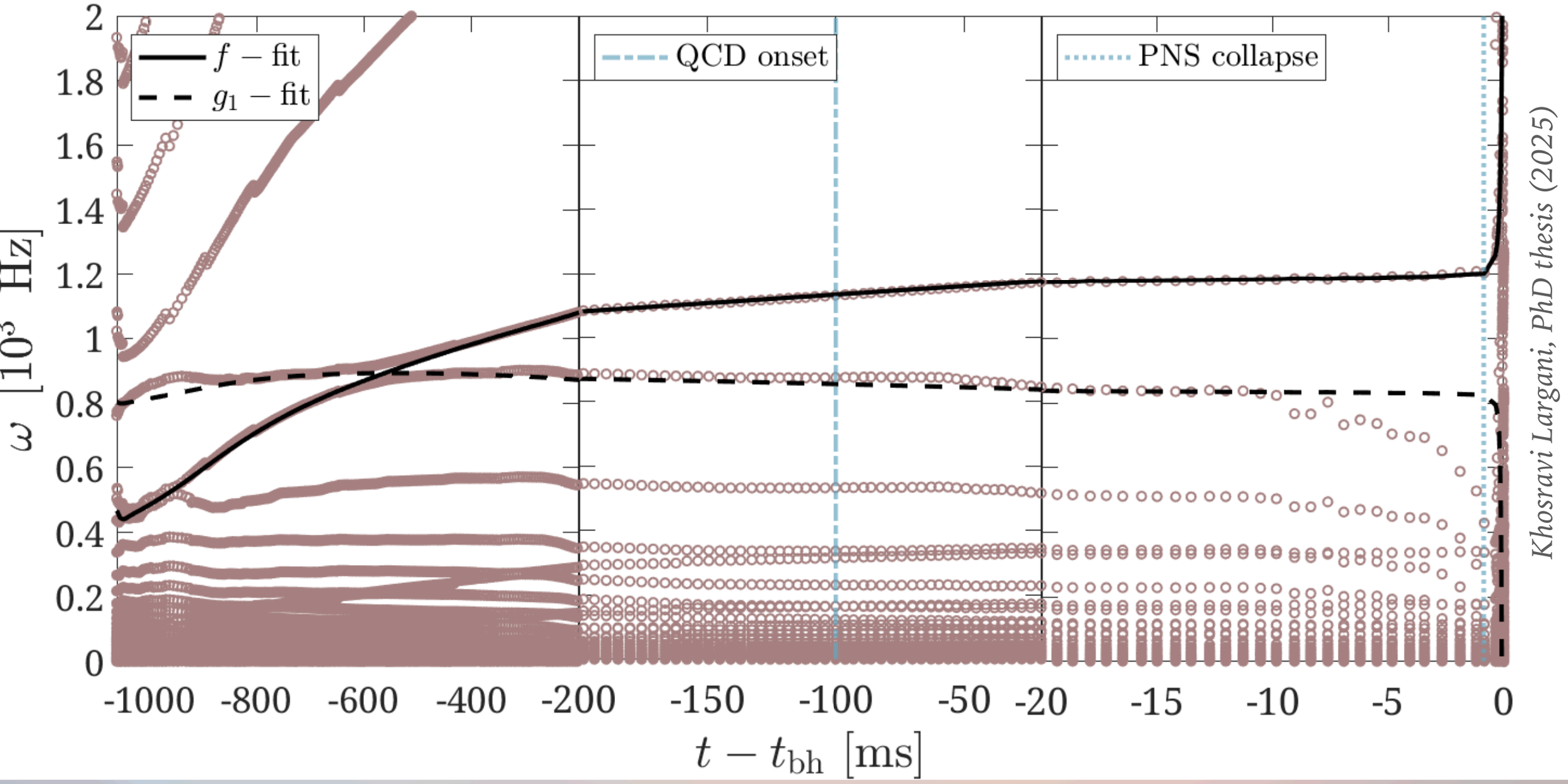
$$\omega_{\rm fit}(x) = a_0 + a_1\, x + a_2\, x^2 + a_3\, x^3$$



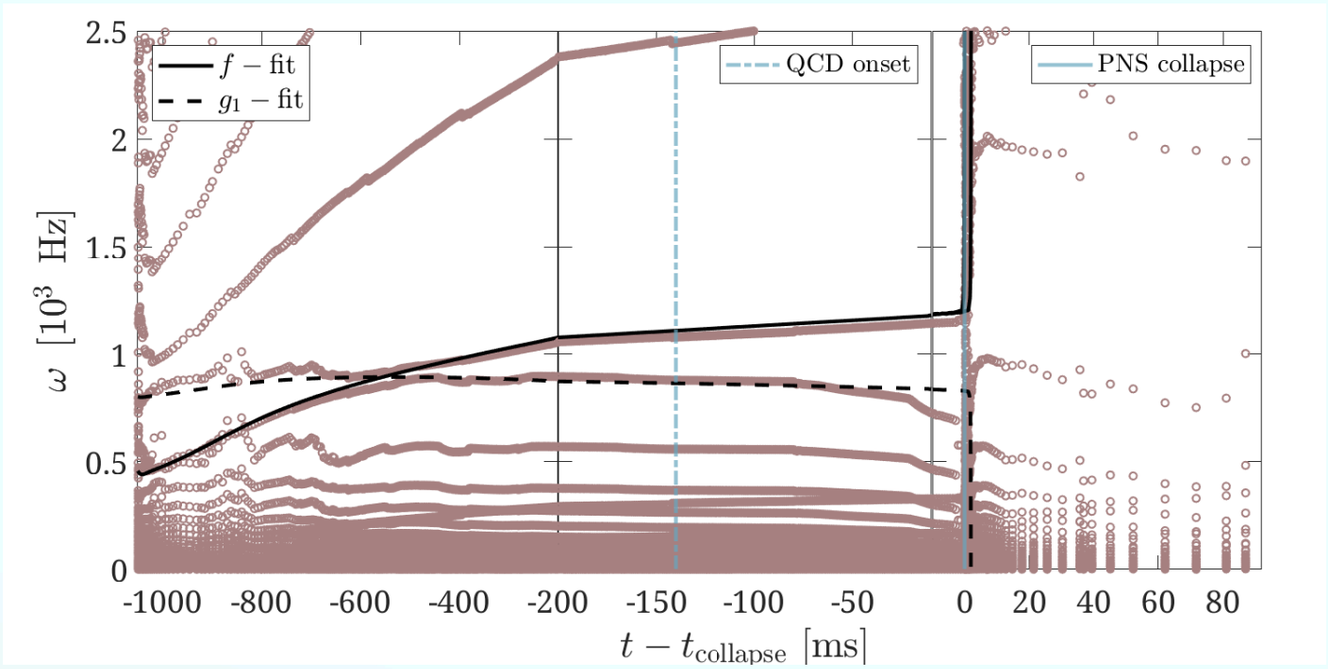
$$f \qquad x = \sqrt{M_{\rm PNS}/R^3_{\rm PNS}}$$

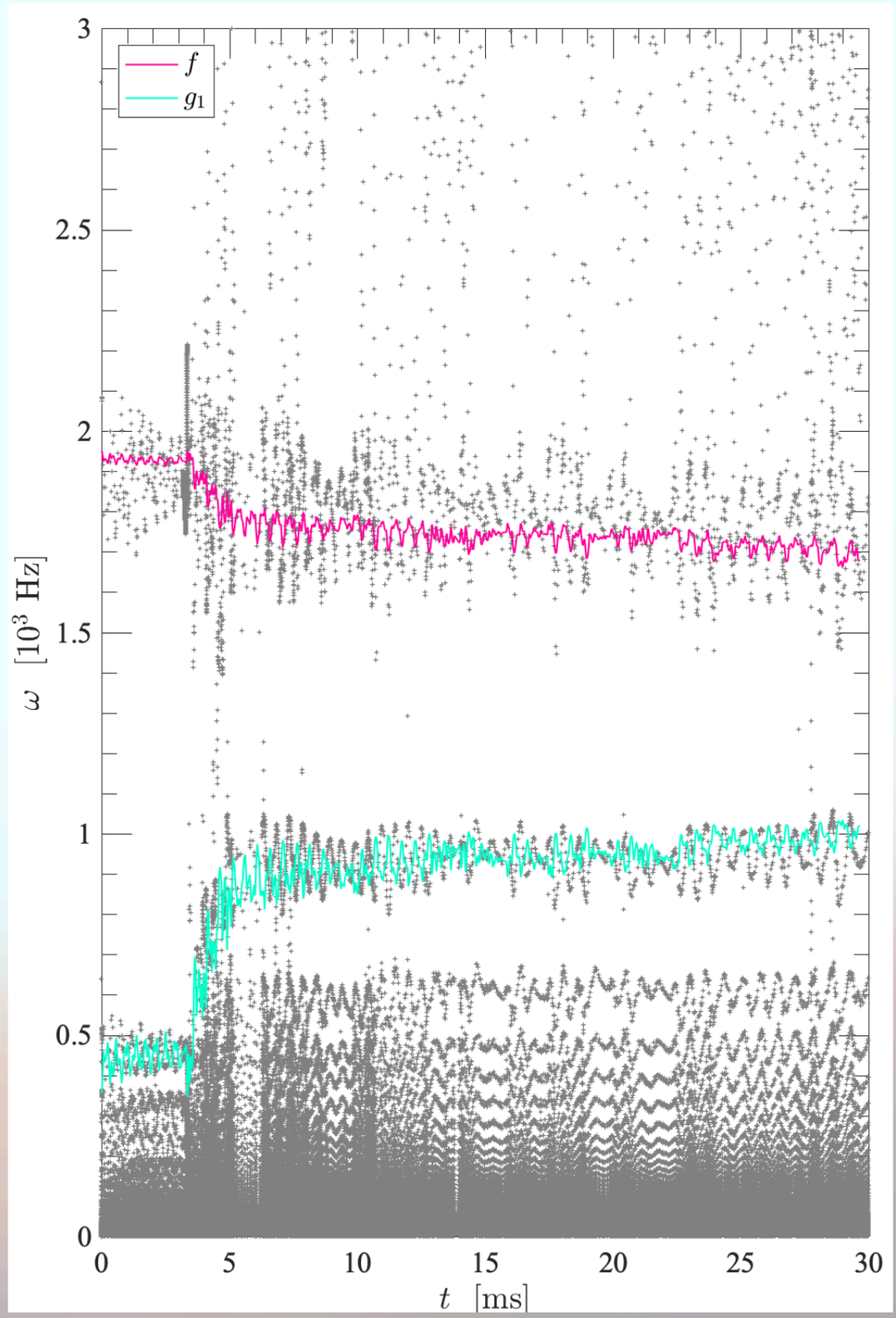
$$g_1 \qquad x = M_{\rm PNS}/R^2_{\rm PNS}$$

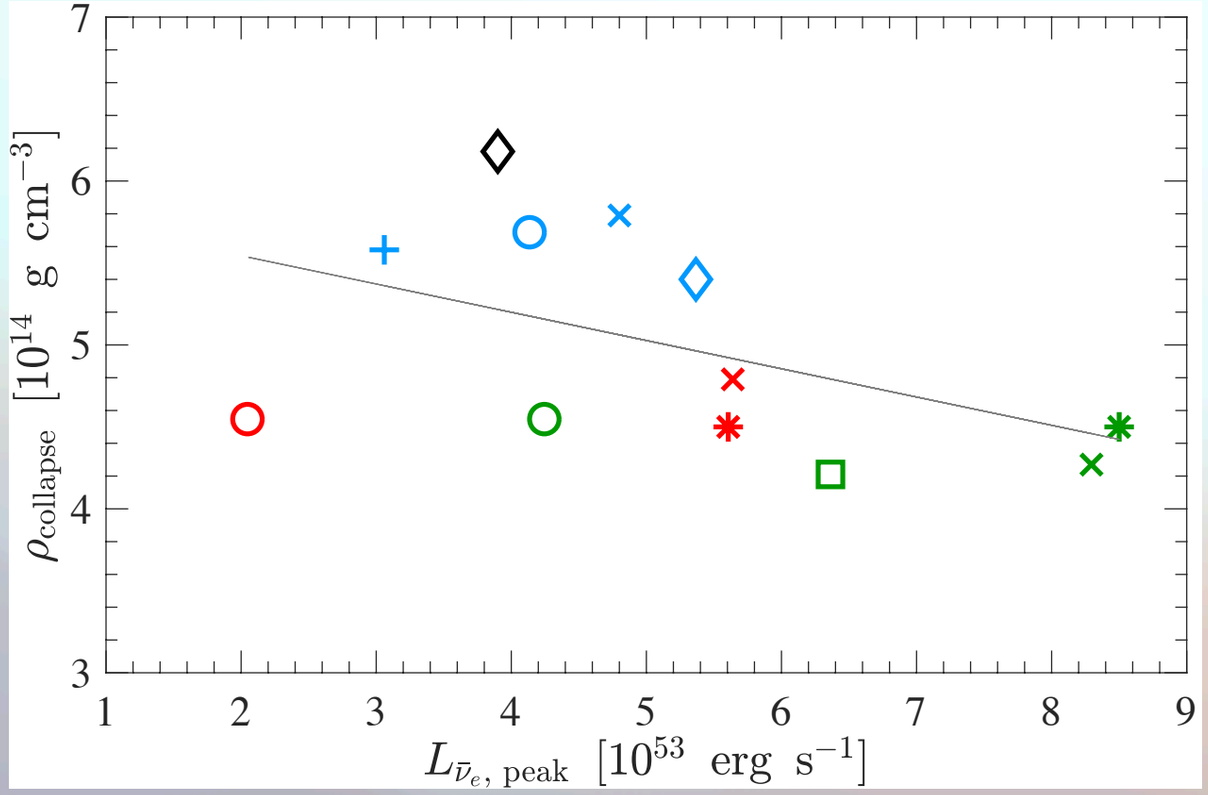
$$\omega_{\rm fit}(x) = a_0 + a_1\, x + a_2\, x^2 + a_3\, x^3$$



Summary







Khosravi Largani et al., Astron. Astrophys., 687, A245, 15 (2024)

Thank You
Multumesc
Matondo
Terima Kasih
Obrigado
Dankon
Arigatô
Diolch
Спасибо
ありがとう
Danke
Kiitos
Thank You
감사합니다
Teşekkür ederim
Shukran
Merci
Danke
Thank You
Obrigado
Merci
Maake
Asante
Salamat
Xièxiè
Welalin
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Kiitos
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Thank You
Xièxiè