Supernova explosions of massive blue-supergiant stars triggered by the QCD phase transition

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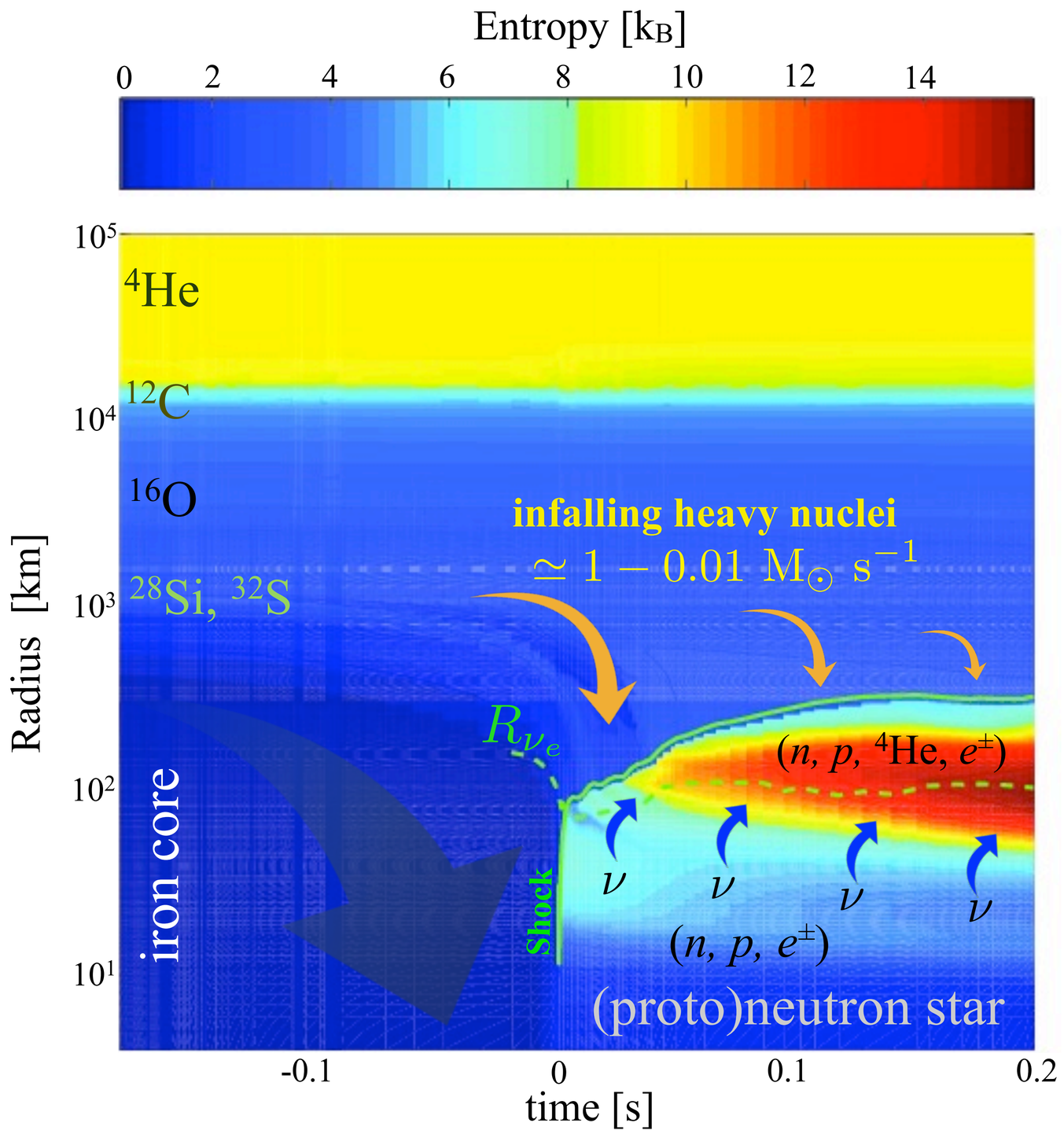
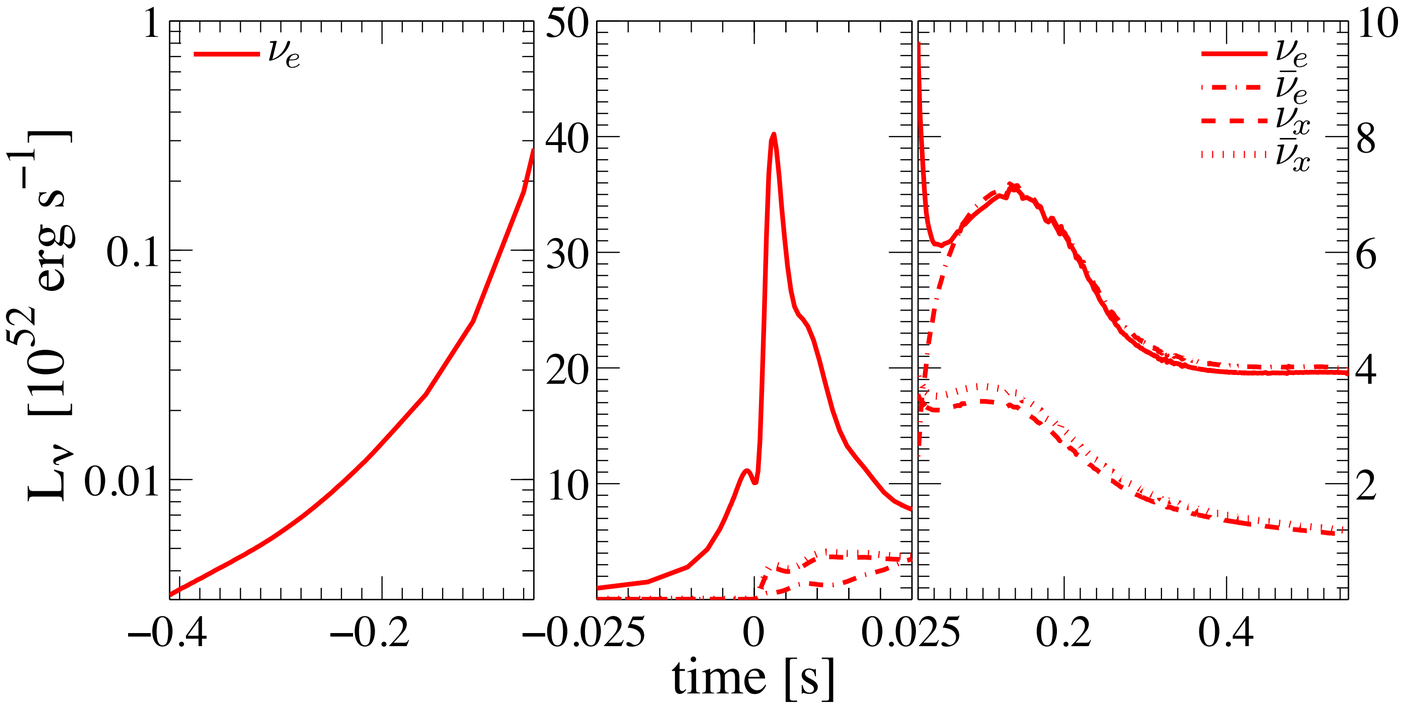
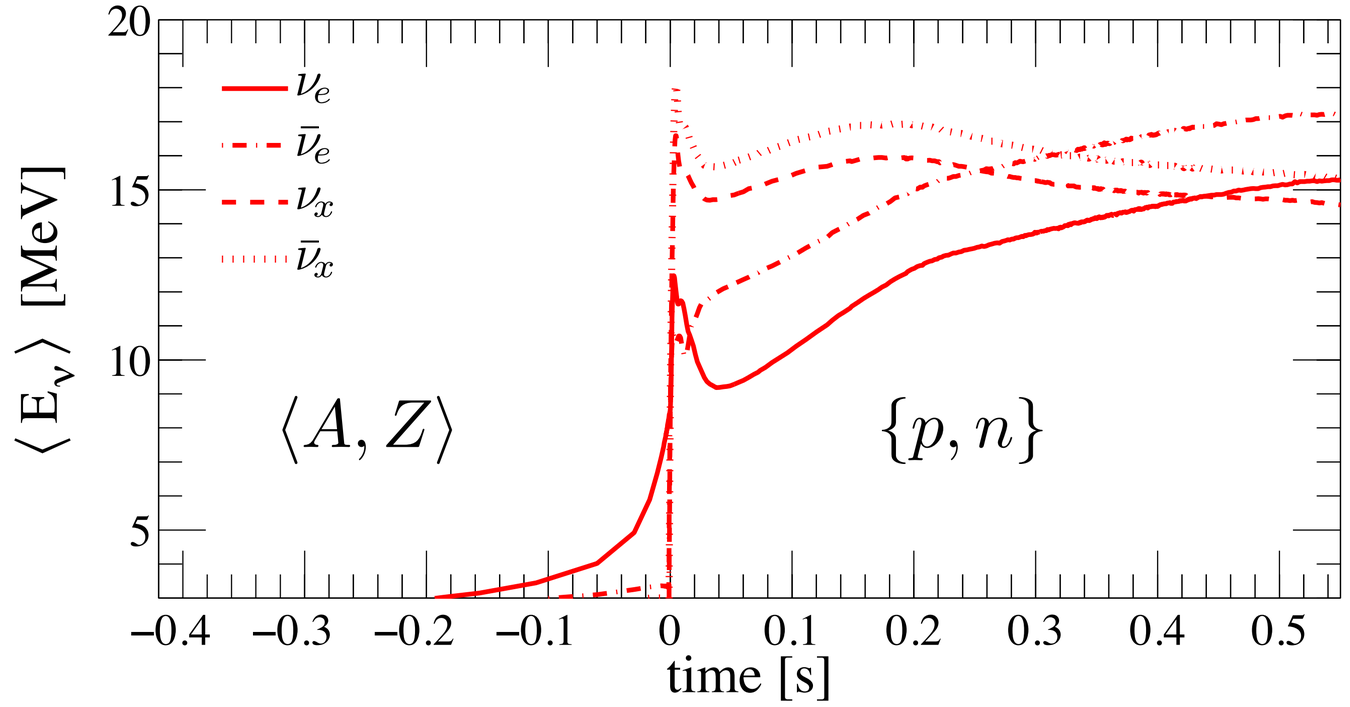
Origin of massive neutron stars ?

and

***r* process**


Entropy [k_B]
0
2
4
6
8
10
12
14
10^5
10^4
10^3
10^2
10^1
Radius [km]
^{4}He
^{12}C
^{16}O
^{28}Si, ^{32}S
infalling heavy nuclei
$\simeq 1 - 0.01\ M_\odot\ s^{-1}$
R_{ν_e}
iron core
Shock
ν
ν
ν
ν
(n, p, ^{4}He, $e^\pm$)
(n, p, $e^\pm$)
(proto)neutron star
-0.1
0
0.1
0.2
time [s]





$$e^- \, p \leftrightarrows n \, \nu_e$$
$$e^+ \, n \leftrightarrows p \, \bar{\nu}_e$$

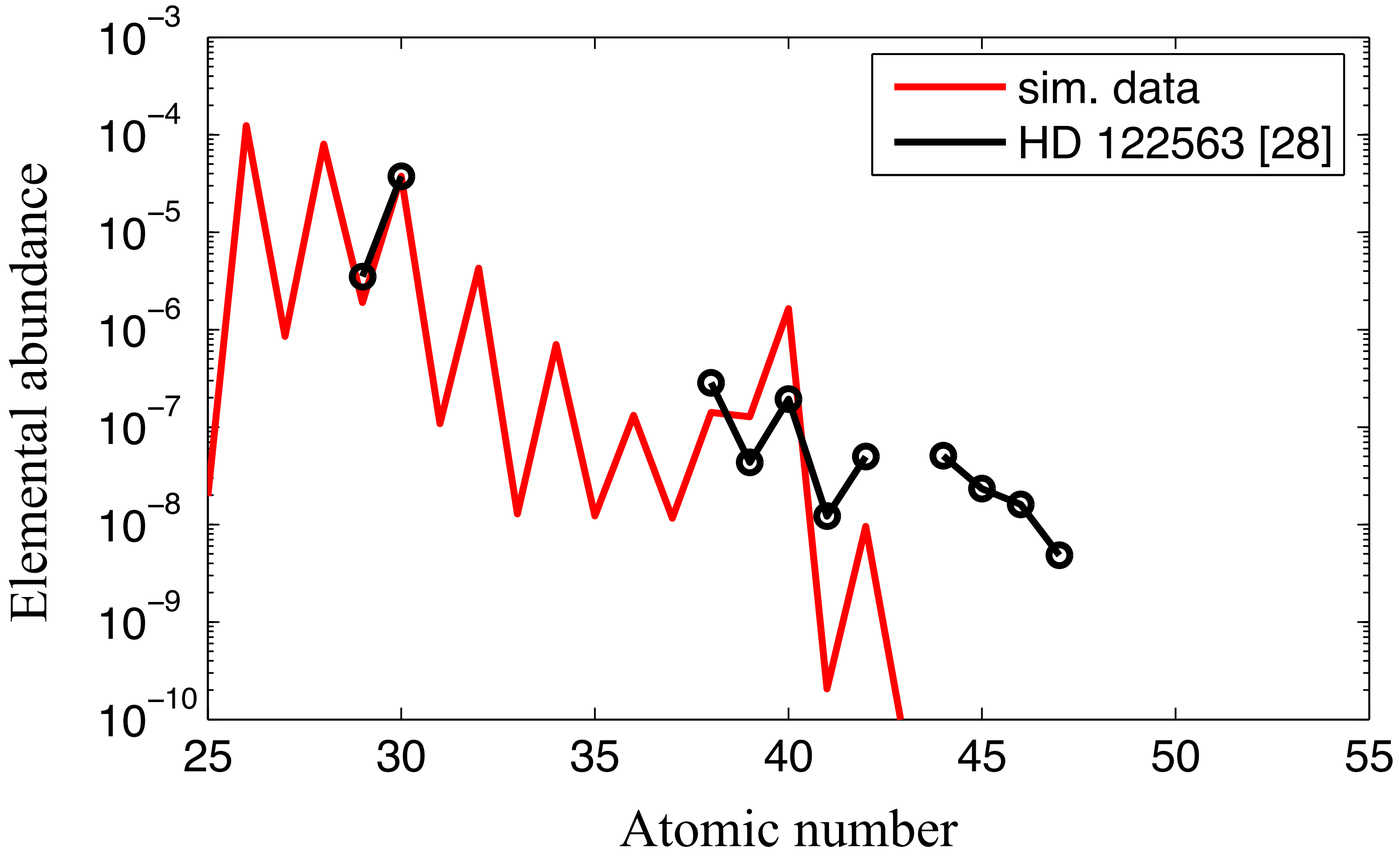
$$\nu_\alpha \, N \leftrightarrows N \, \nu'_\alpha$$

$$\nu_\alpha \, e^\pm \leftrightarrows e^\pm \, \nu'_\alpha$$

$$e^- e^+ \leftrightarrows \nu_\alpha \bar{\nu}_\alpha$$

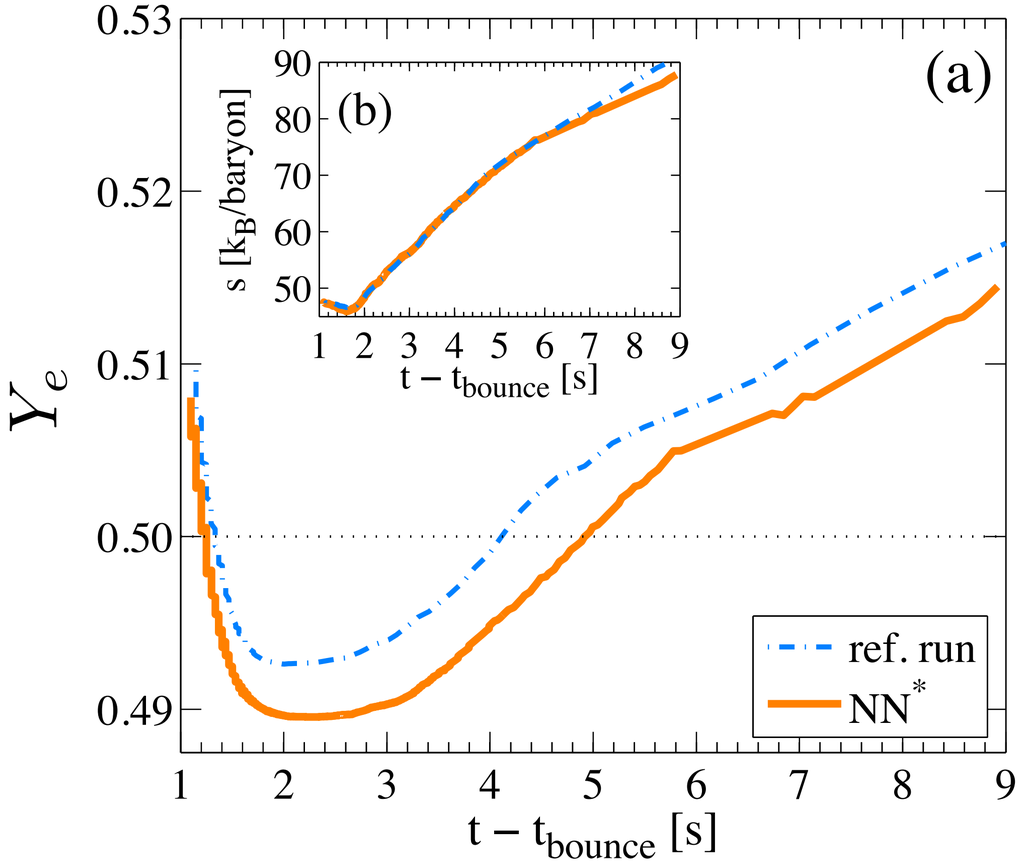
$$NN \leftrightarrows NN + \nu_\alpha \bar{\nu}_\alpha$$

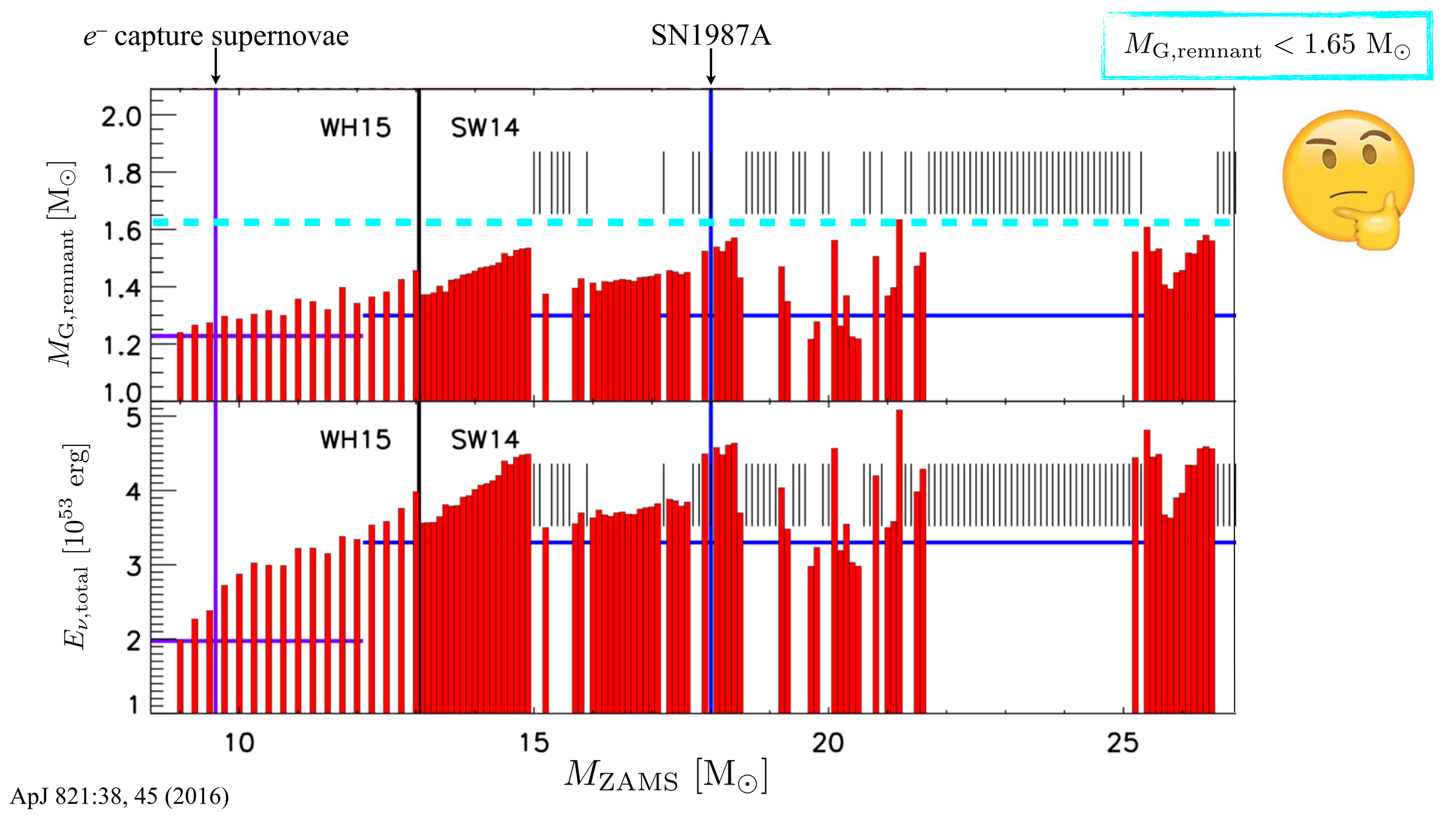
$$\nu_\alpha \bar{\nu}_\alpha \leftrightarrows \nu_\beta \bar{\nu}_\beta$$



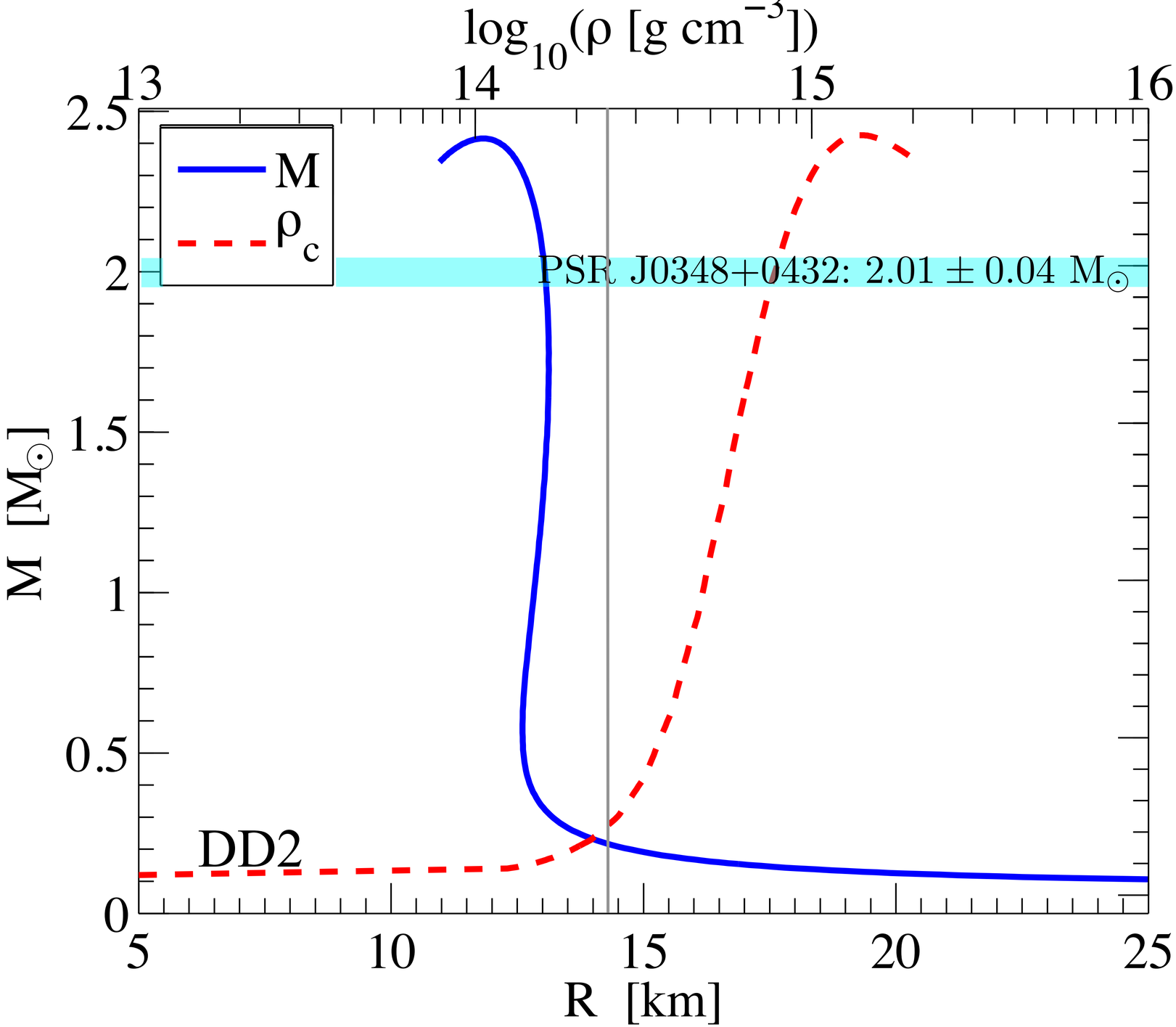
no *r* process associated with supernova explosions

(neutrino driven wind)

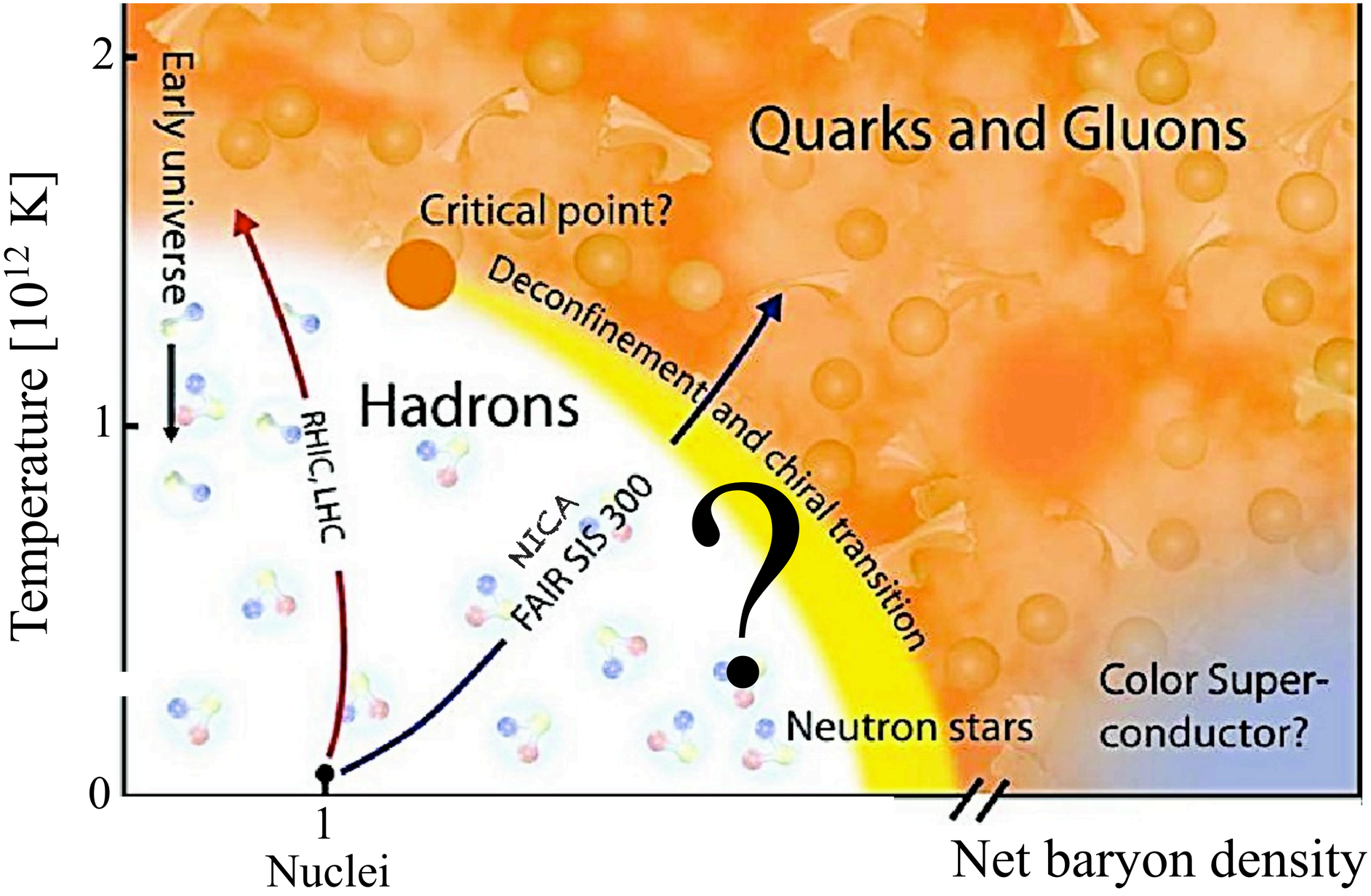




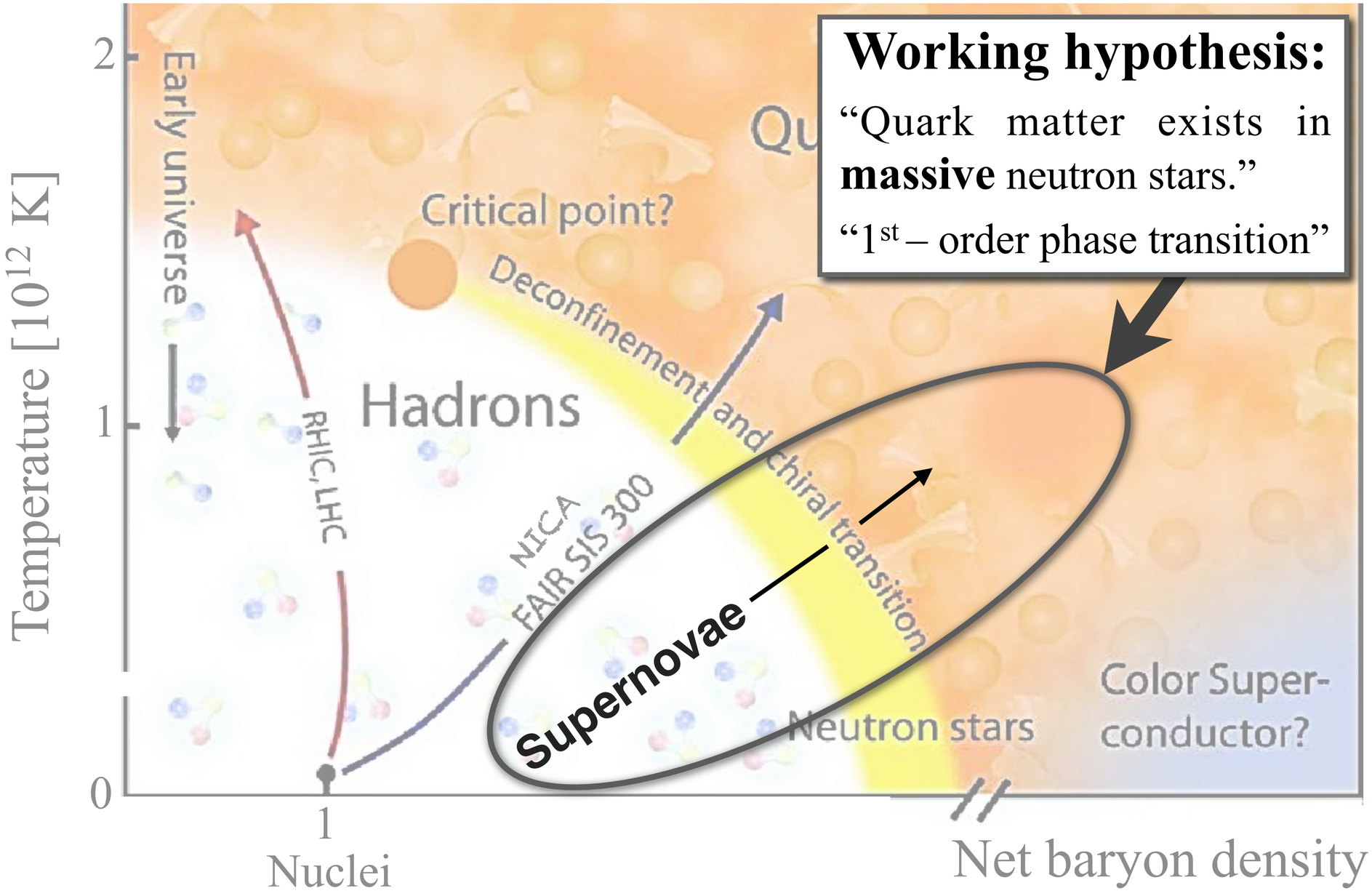
ApJ 821:38, 45 (2016)

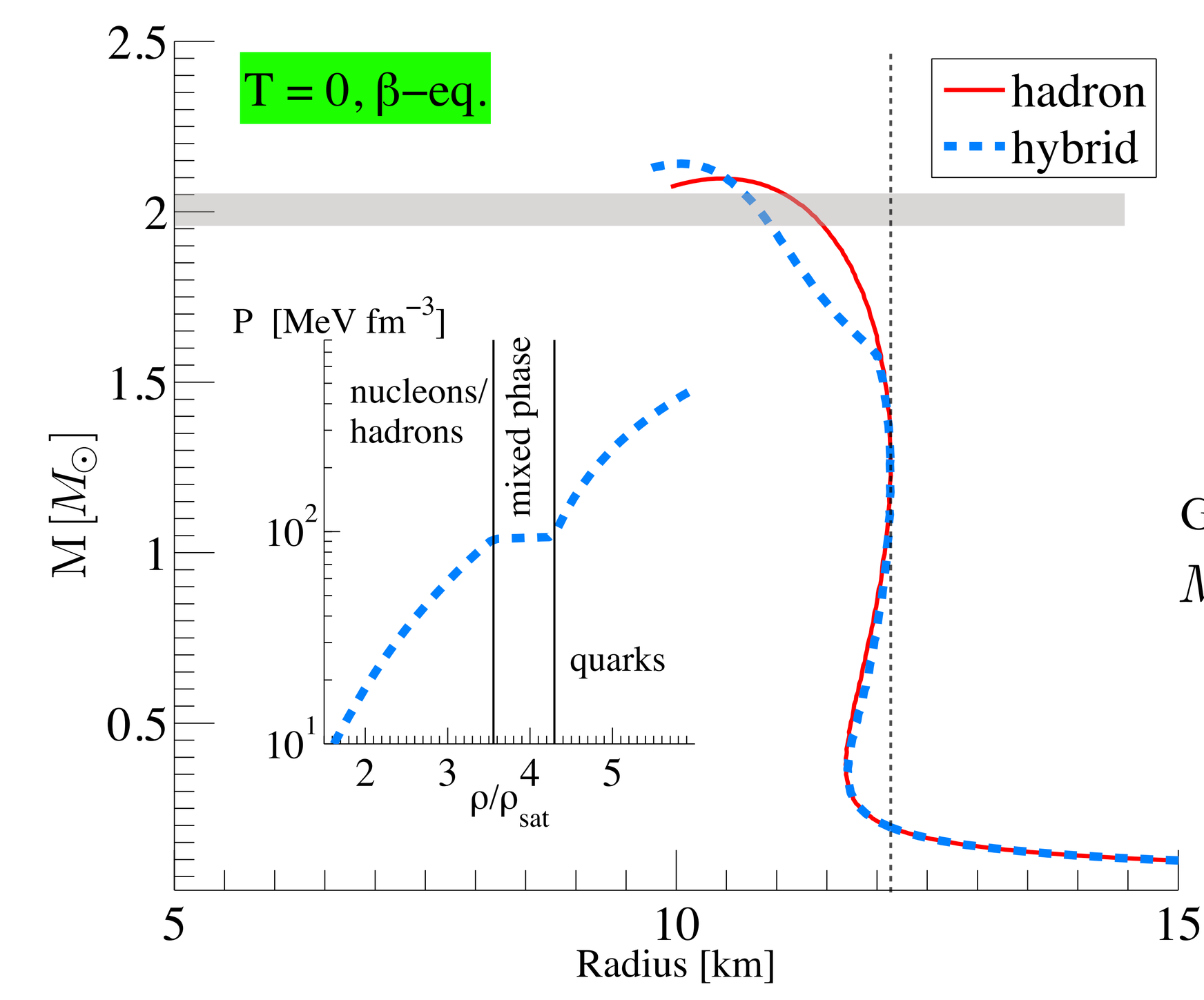

log10(ρ [g cm−3])
13
14
15
16
2.5
2
1.5
1
0.5
0
M
ρc
PSR J0348+0432: 2.01 ± 0.04 M⊙
DD2
M [M⊙]
5
10
15
20
25
R [km]

Hot and dense phases of matter ?



Hot and dense phases of matter ?





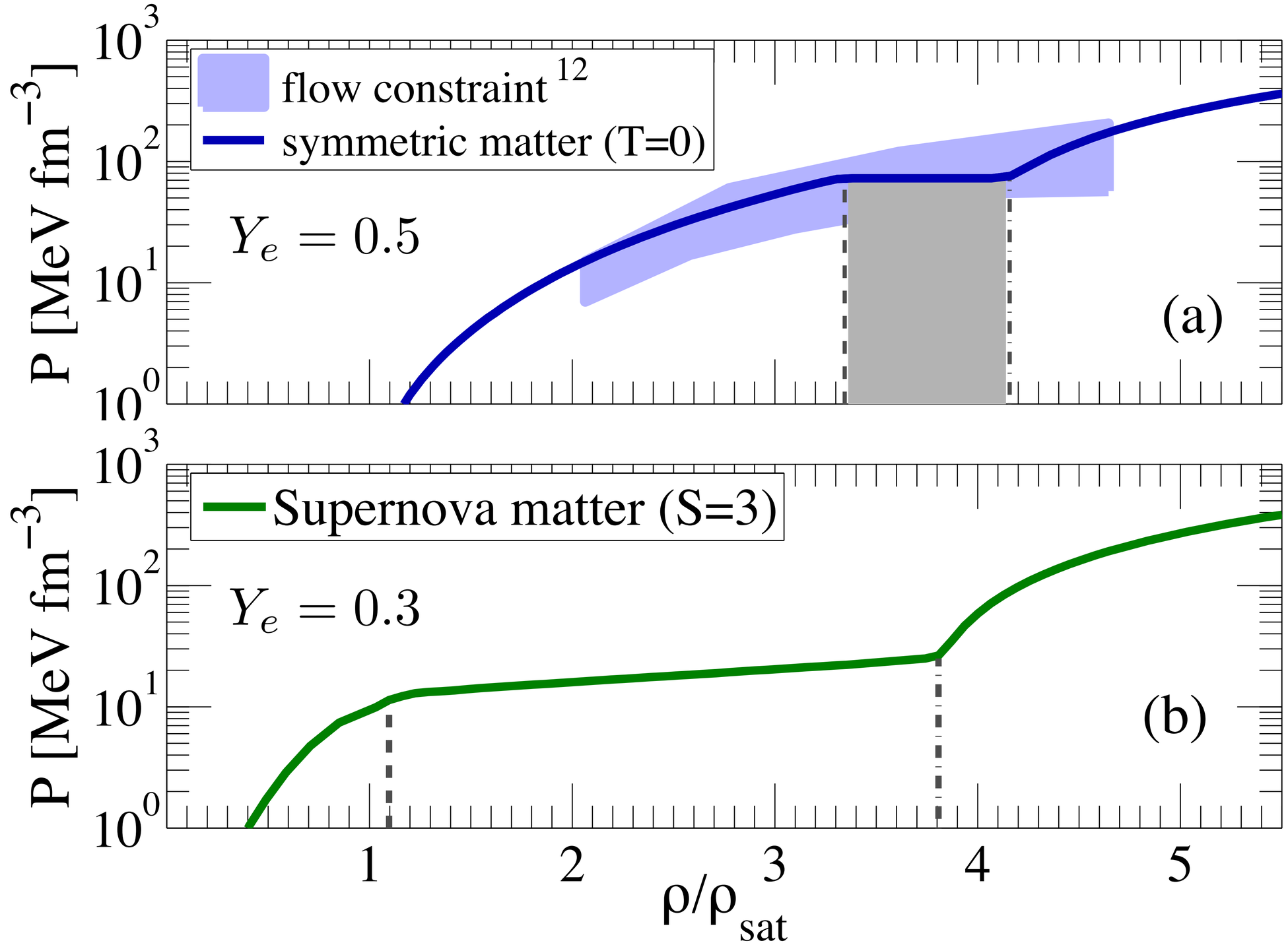
$$R_{1.5\,\mathrm{M}_\odot} = 12.2\ \mathrm{km}$$

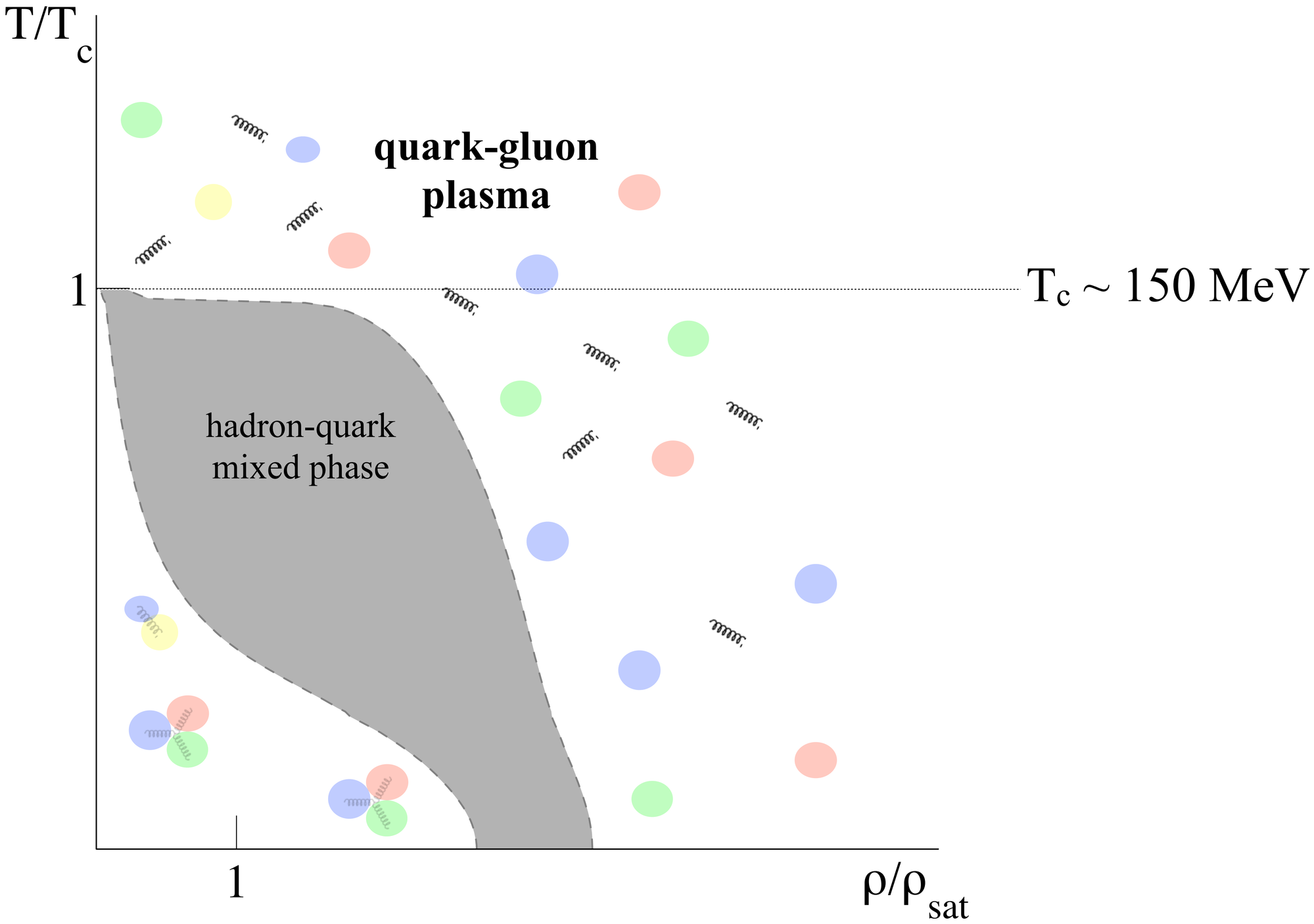
$$M_{\mathrm{NS}} = 2.15\ \mathrm{M}_\odot$$

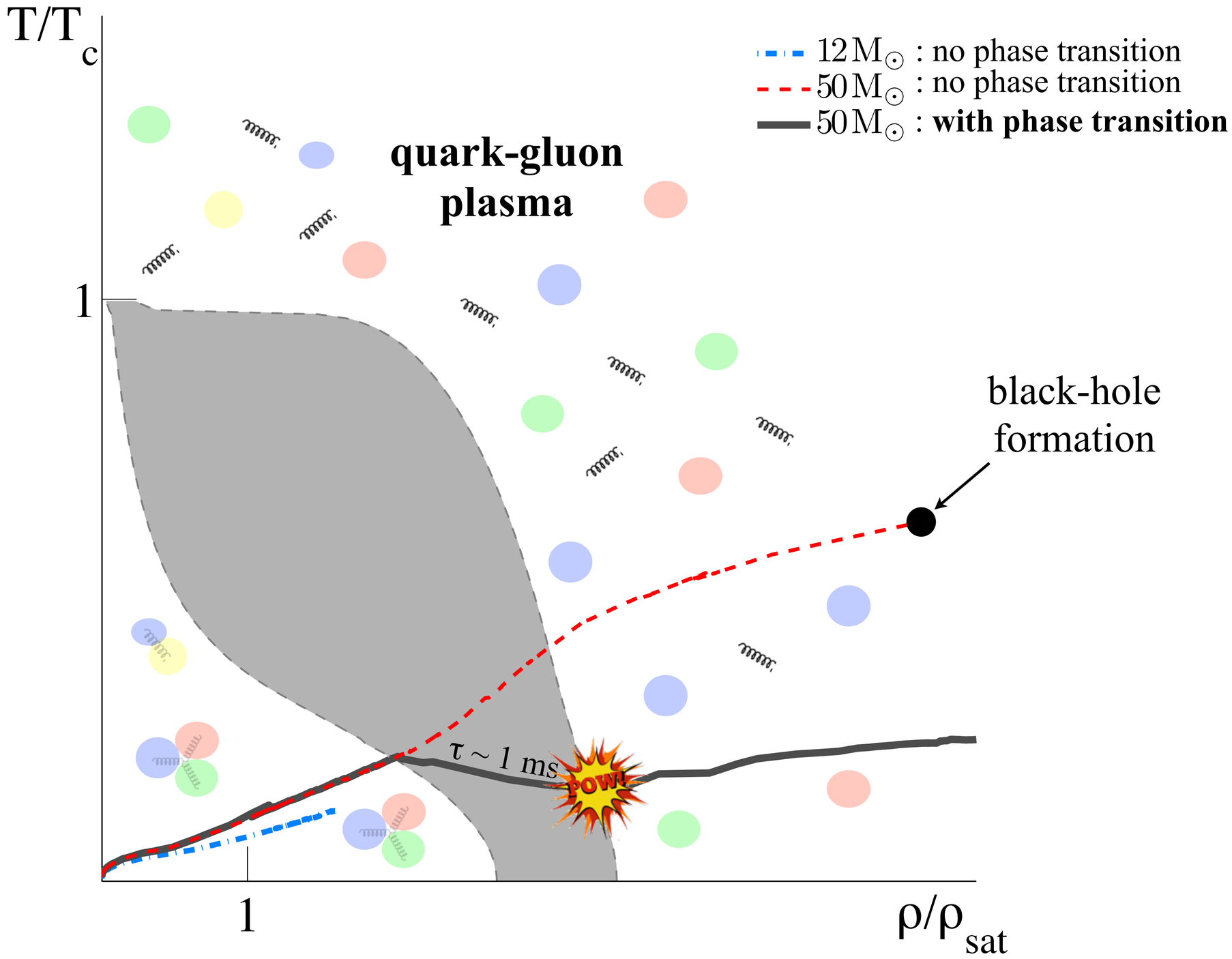
GW170817:

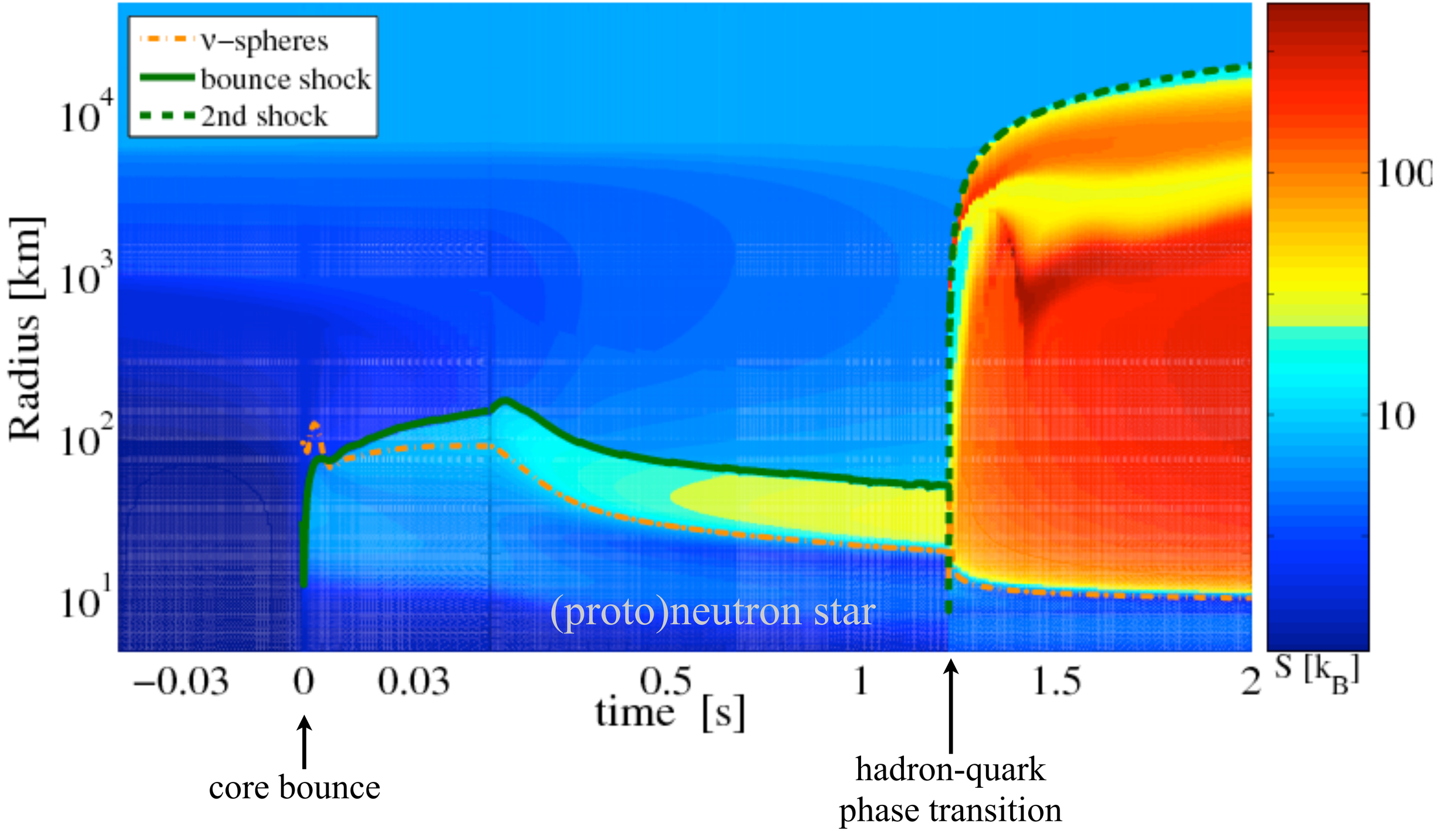
$$M_{\mathrm{NS,max}} = 2.0 - 2.3\ \mathrm{M}_\odot$$

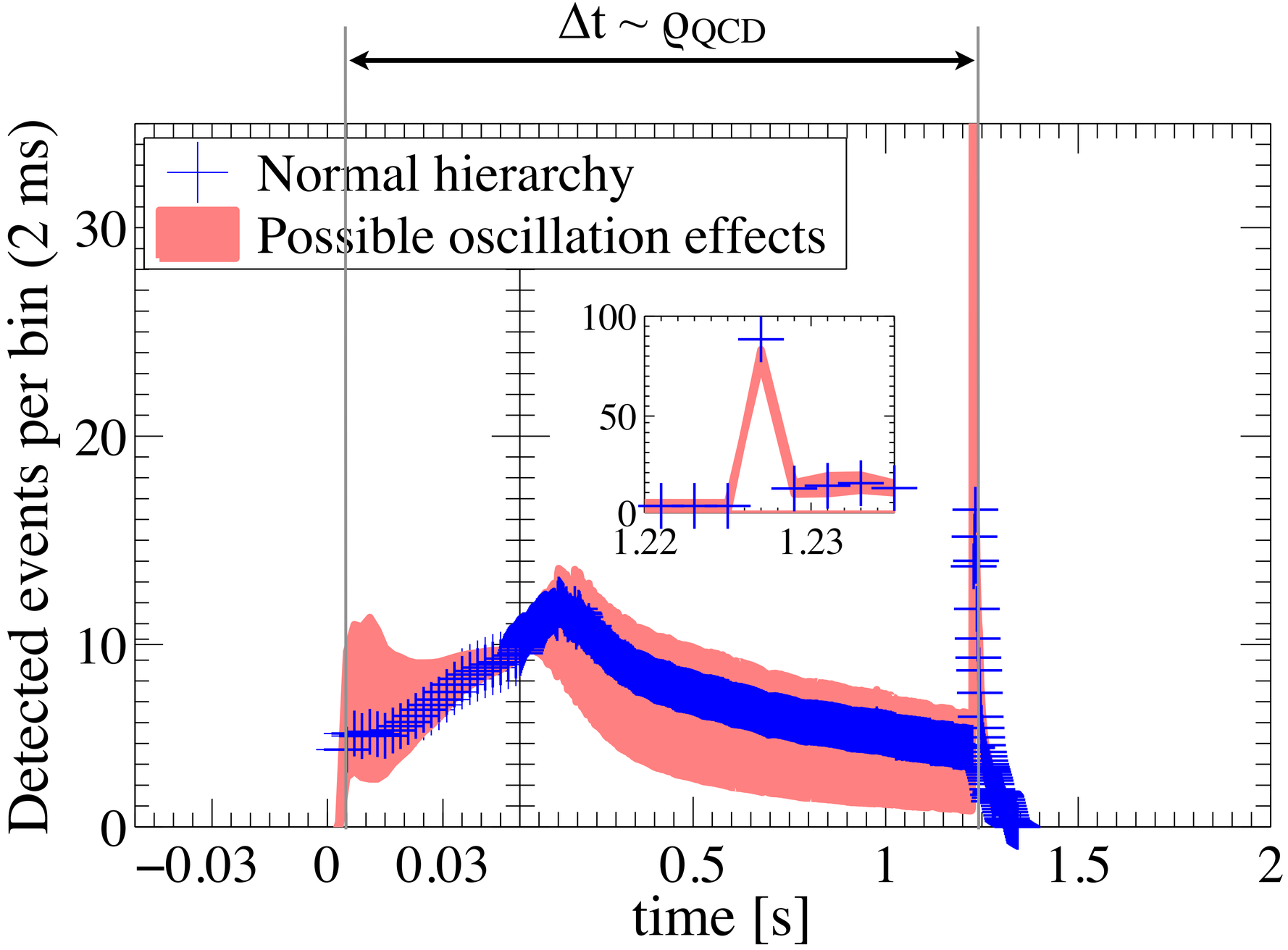
Margalit & Metzger (2017) ApJ 850, L19
Shibata et al., (2017) PRD 96, 123012
Rezzolla et al., (2018) ApJ 852, L25
Ruiz et al., (2018) PRD 97


flow constraint [12]
symmetric matter (T=0)
$Y_e = 0.5$
(a)
Supernova matter (S=3)
$Y_e = 0.3$
(b)
P [MeV fm^{-3}]
10^0
10^1
10^2
10^3
1
2
3
4
5
ρ/ρ_{sat}


T/T c
quark-gluon
plasma
1
T c ~ 150 MeV
hadron-quark
mixed phase
1
ρ/ρ sat

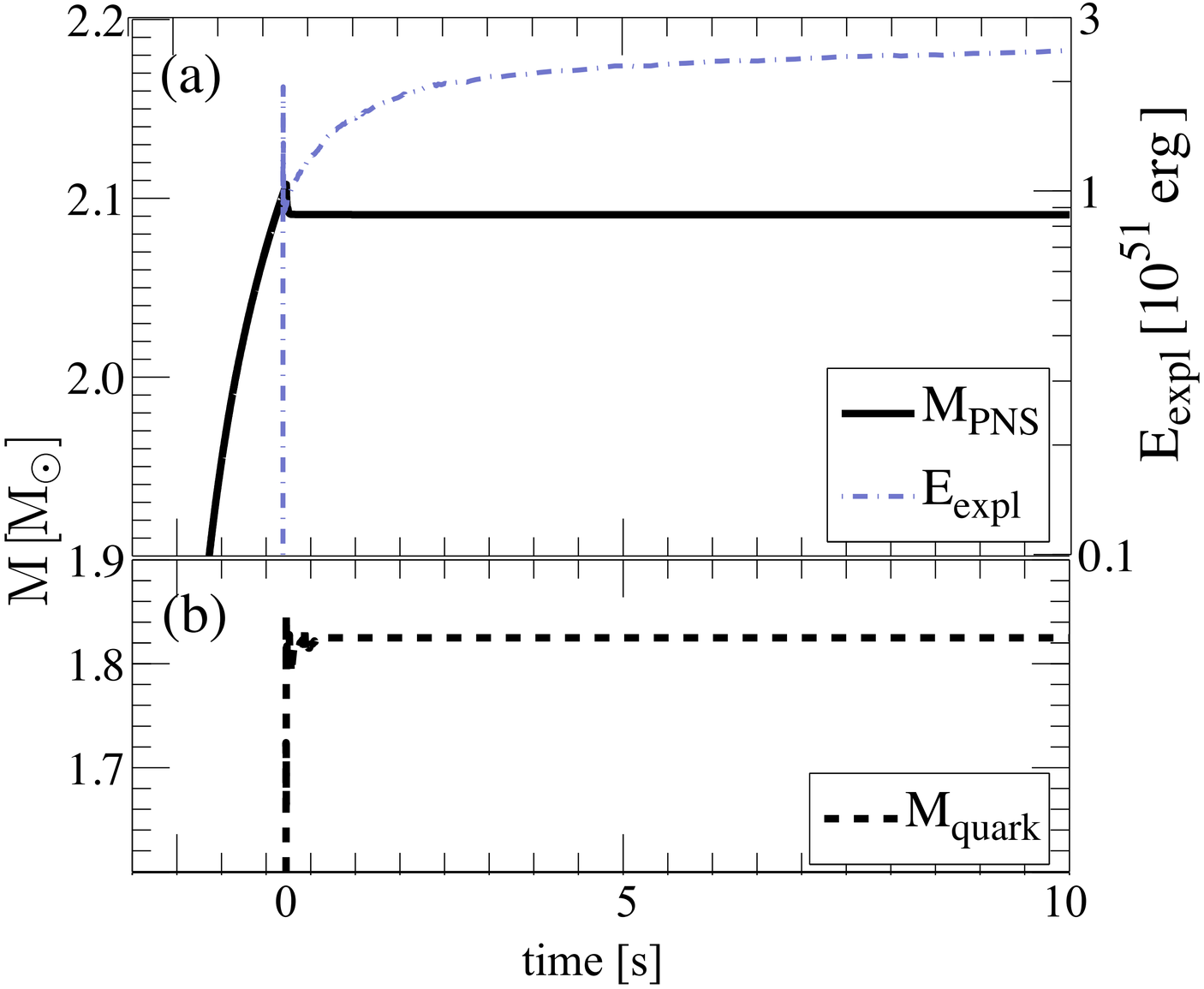

T/T c
1
1
ρ/ρ sat
quark-gluon plasma
12 M⊙ : no phase transition
50 M⊙ : no phase transition
50 M⊙ : with phase transition
black-hole formation
τ ~ 1 ms
POW!


ν–spheres
bounce shock
2nd shock
Radius [km]
10^4
10^3
10^2
10^1
(proto)neutron star
–0.03
0
0.03
0.5
1
1.5
2
time [s]
core bounce
hadron-quark
phase transition
S [k_B]
100
10

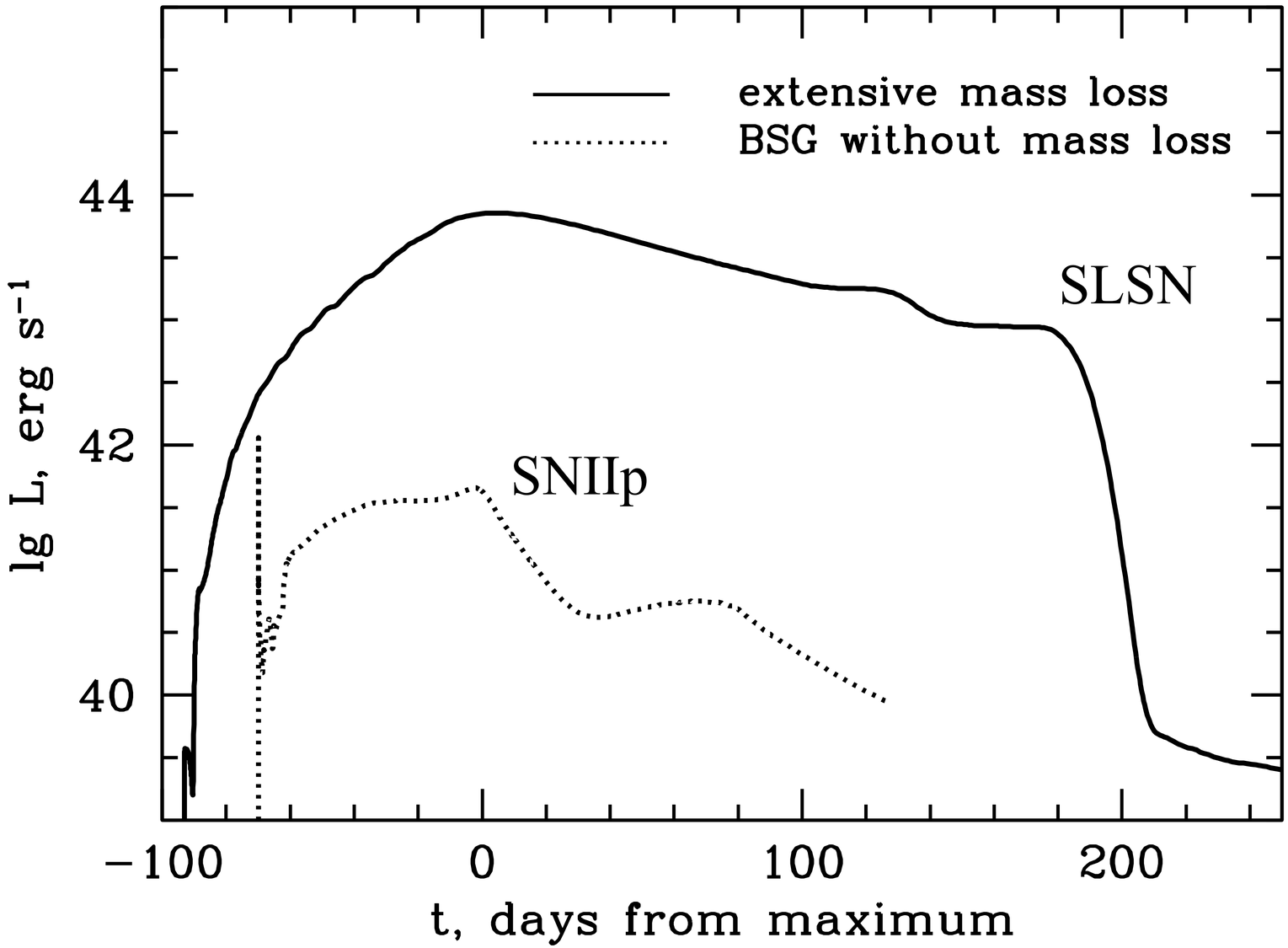


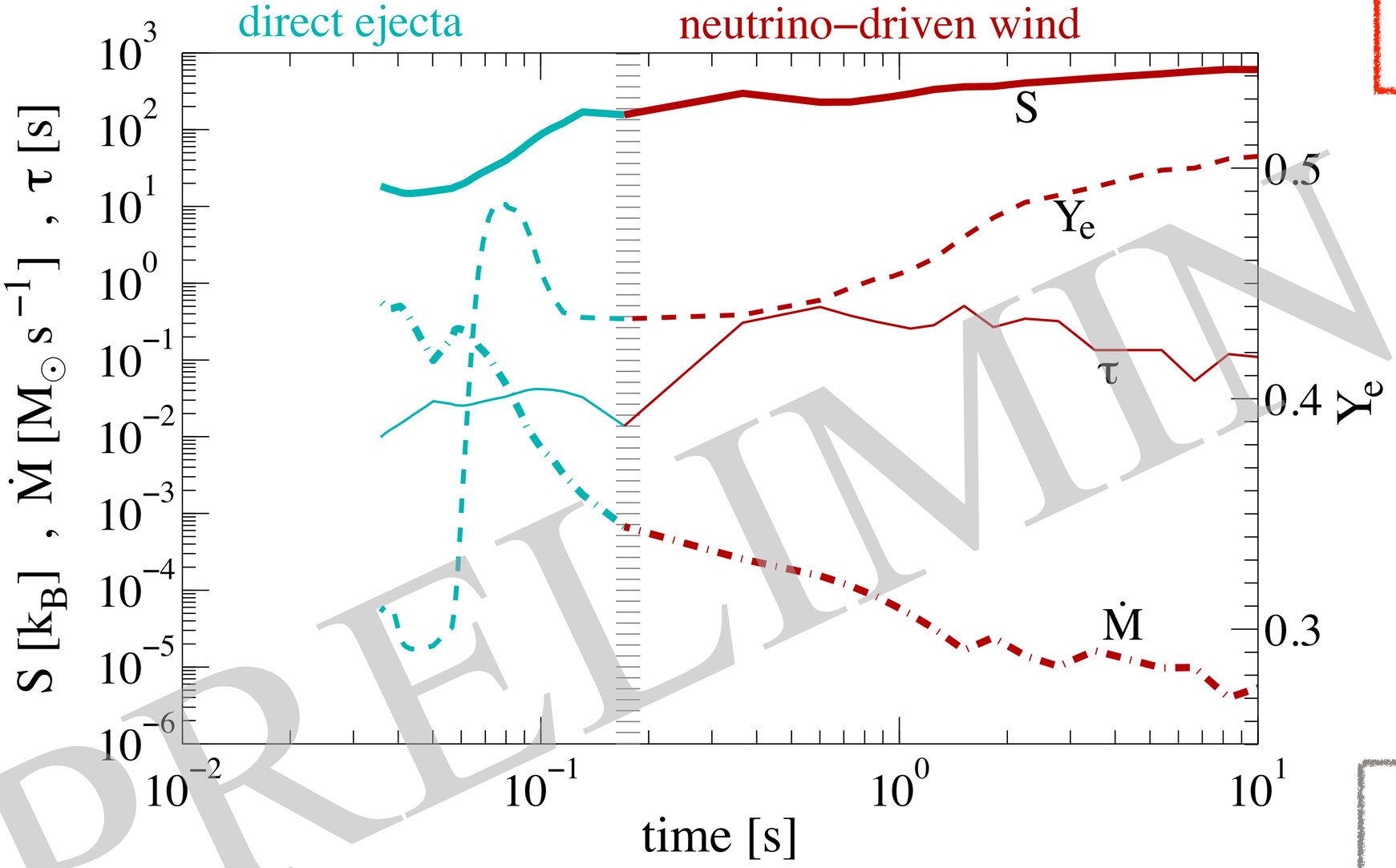
ArXiv astro-ph.HE/1712.08778

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



$$M_{Ni} \simeq 0.024\ M_{\odot}$$





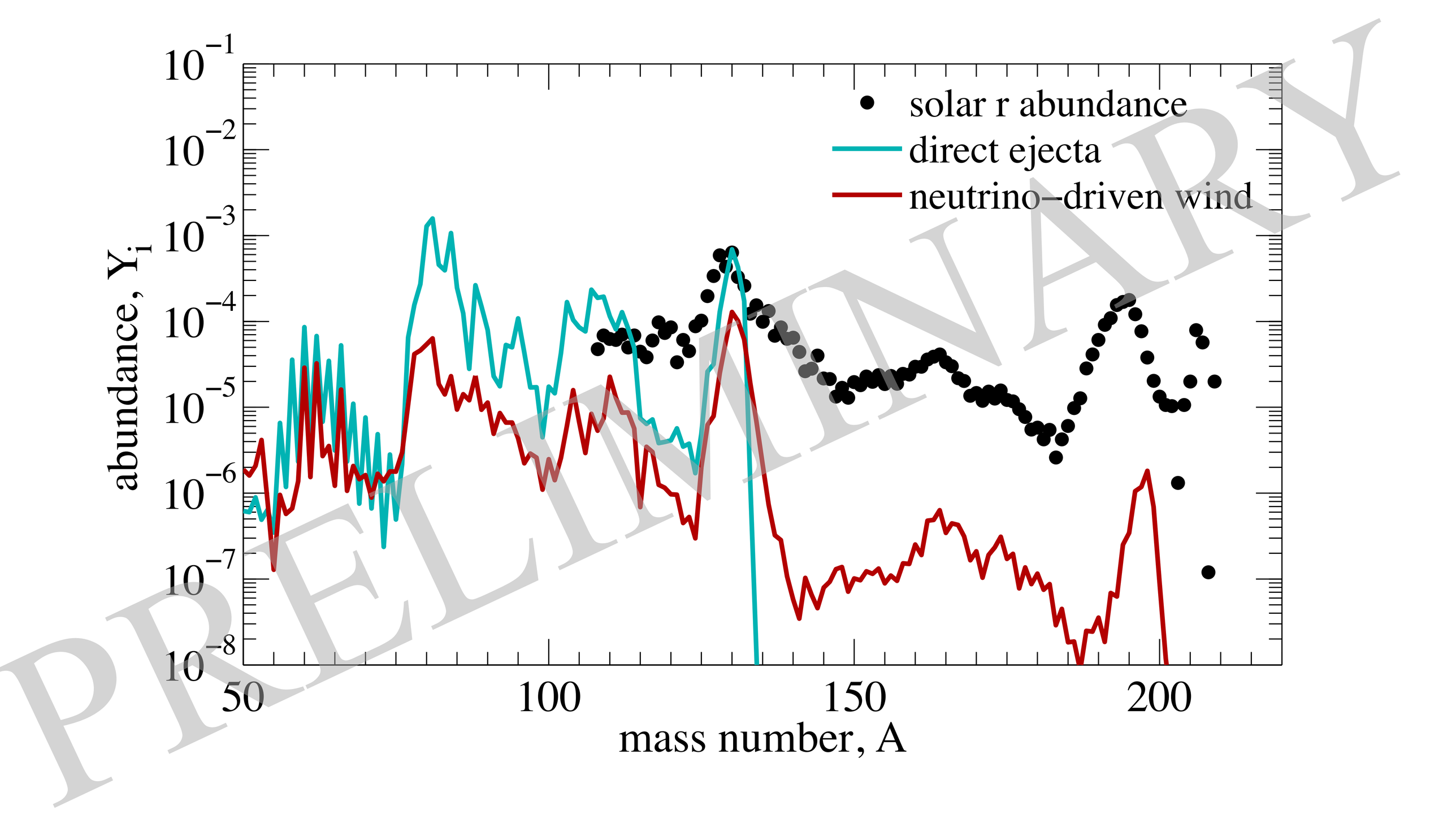
$S \simeq 100 - 300\ k_B$

$Y_e \simeq 0.3 - 0.5$

'normal' *ν*-driven wind

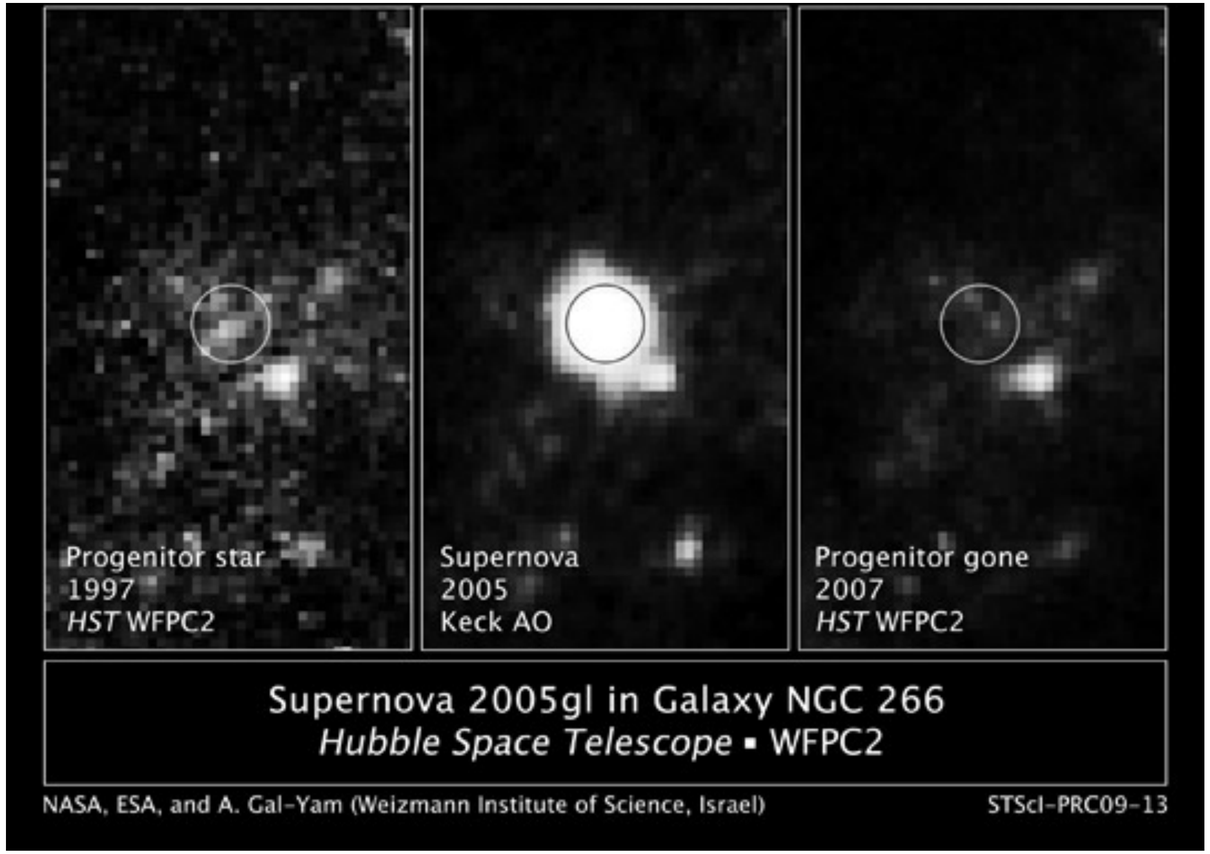
$S \simeq 50\ k_B$

$Y_e \simeq 0.49 - 0.55$



Novel road to explosions of very massive stars $\sim 50\ M_\odot$

"The progenitor was so bright that it probably belonged to a class of stars called Luminous Blue Variables (LBVs)"



<u>remnants</u>: massive neutron stars $\sim 2\ M_\odot$

***r*–process nucleosynthesis $A \sim 195$**

Wroclaw Supernova Project

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