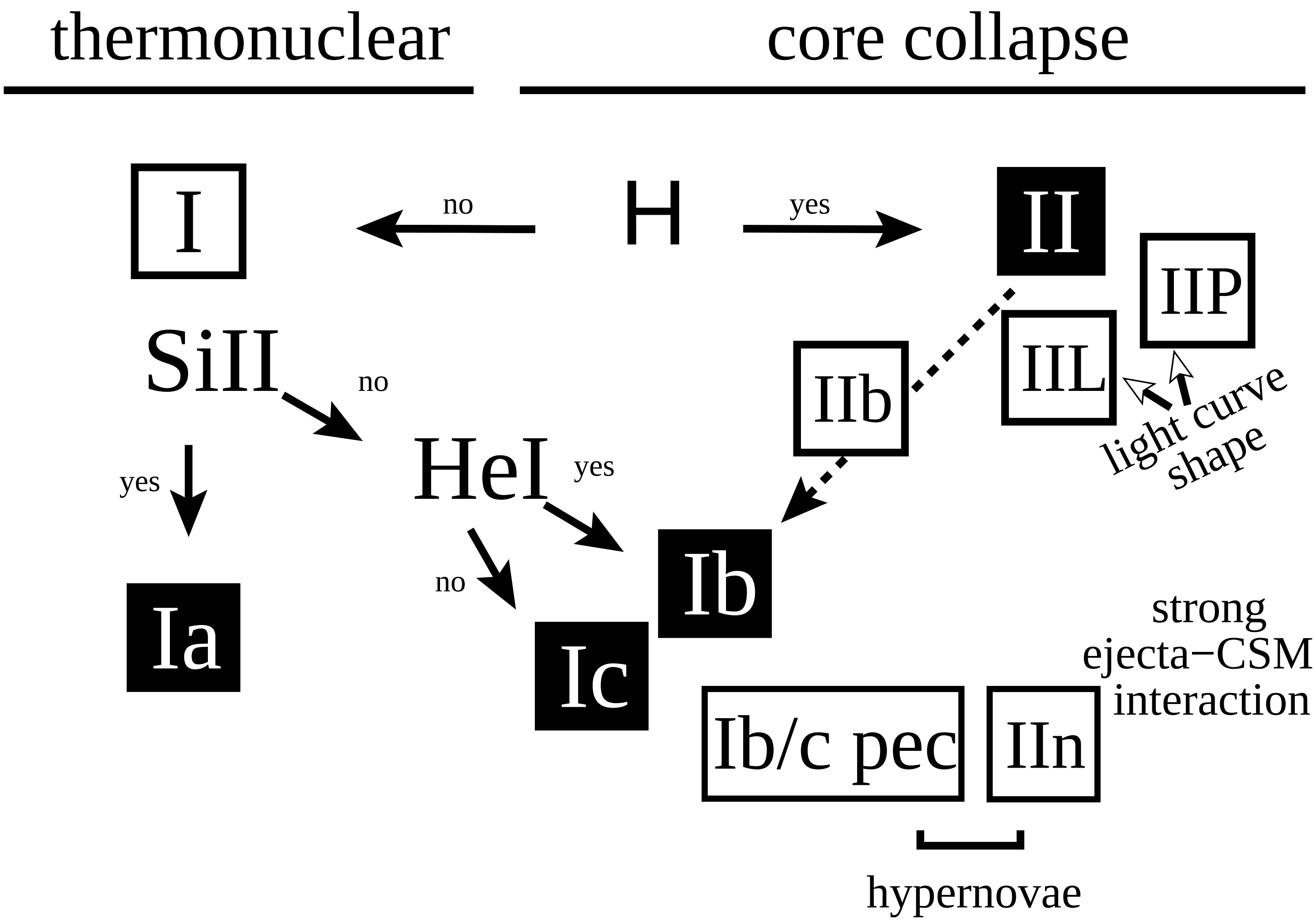
SN Explosions inside C-O Circumstellar Shells

Elena Sorokina[1], *Sergei Blinnikov*[2]

[1]*Sternberg Astronomical Institute, Moscow*

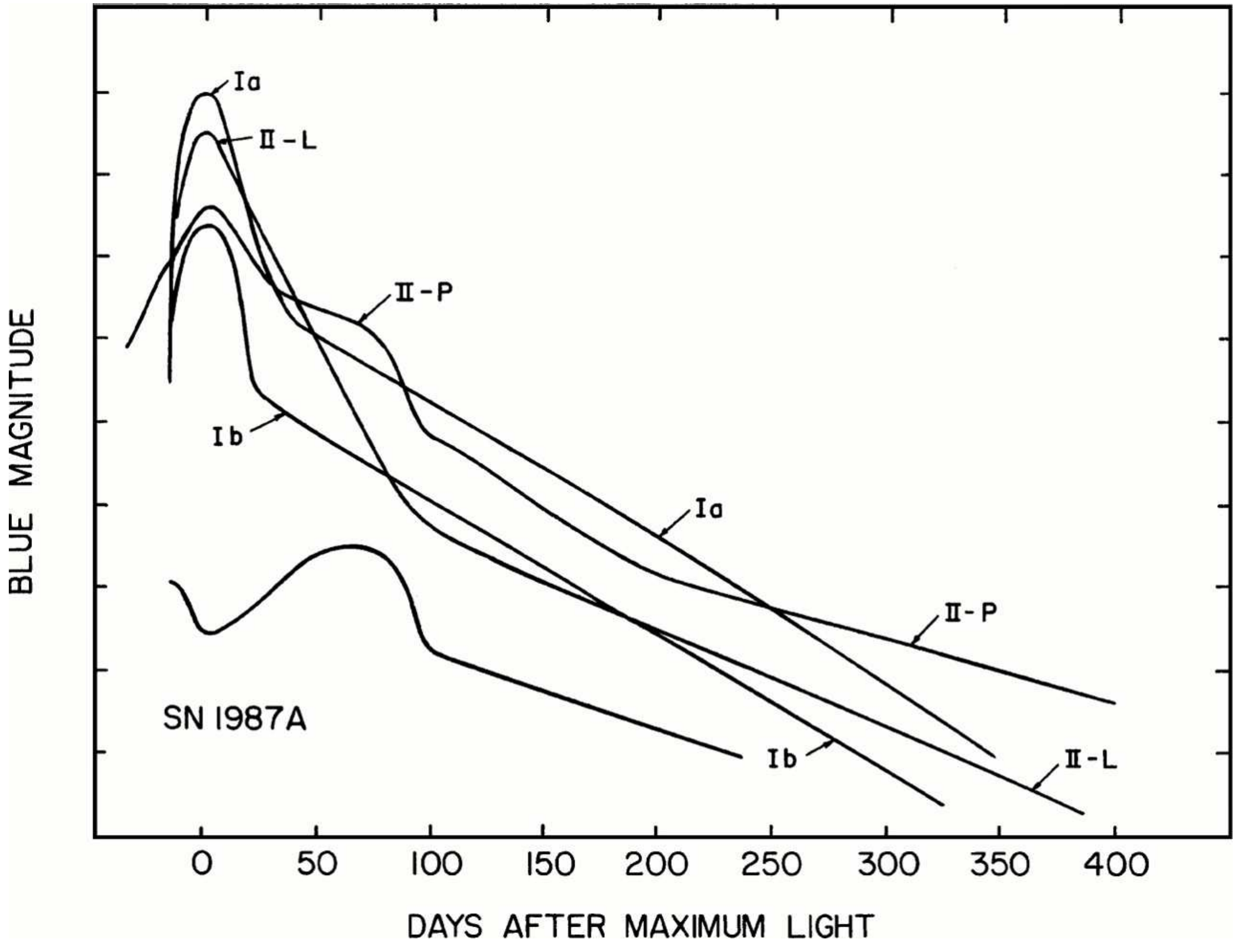
[2]*Institute for Theoretical and Experimental Physics, Moscow*

SN classification



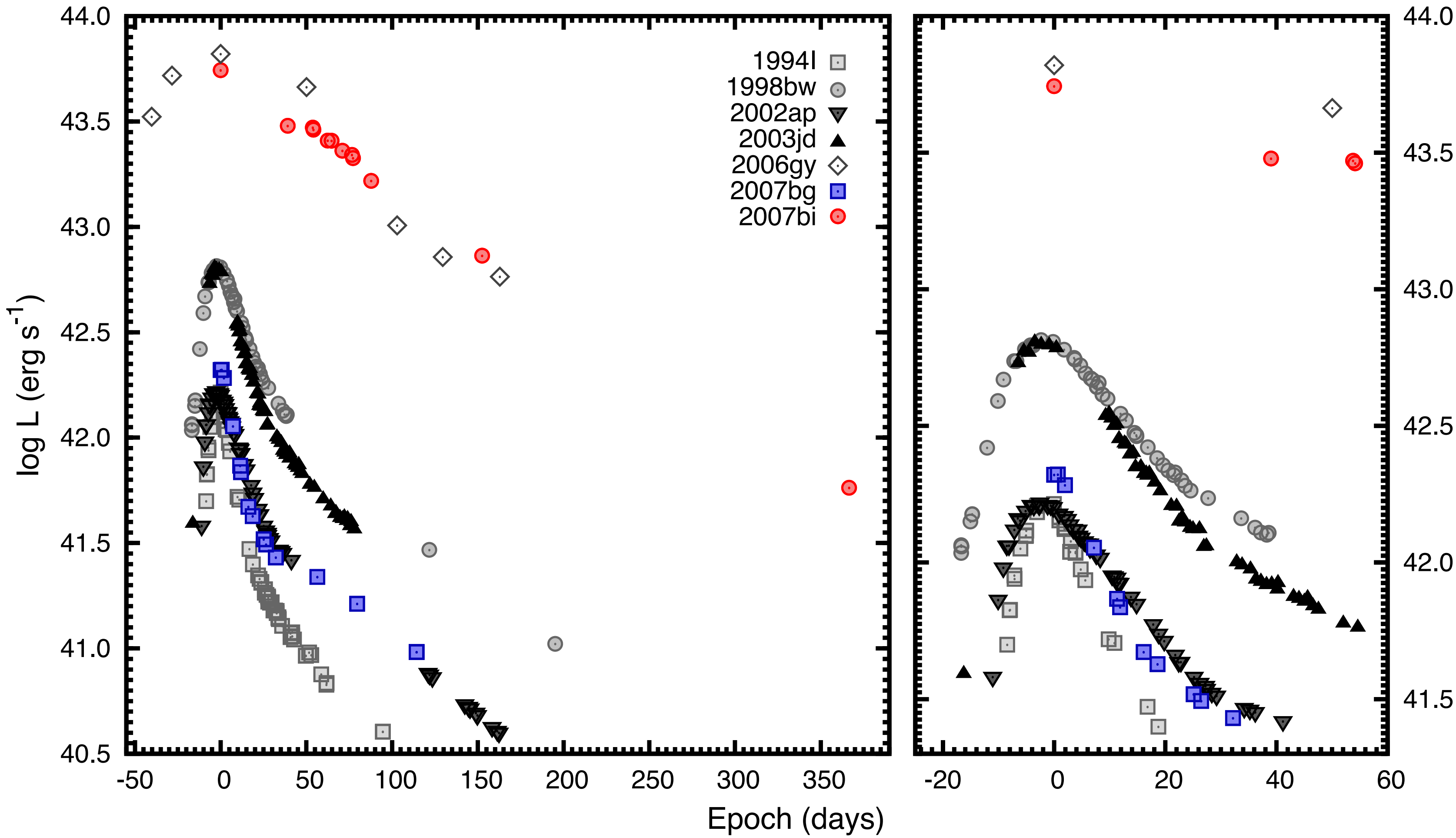
Turrato 2003

SN Light Curves



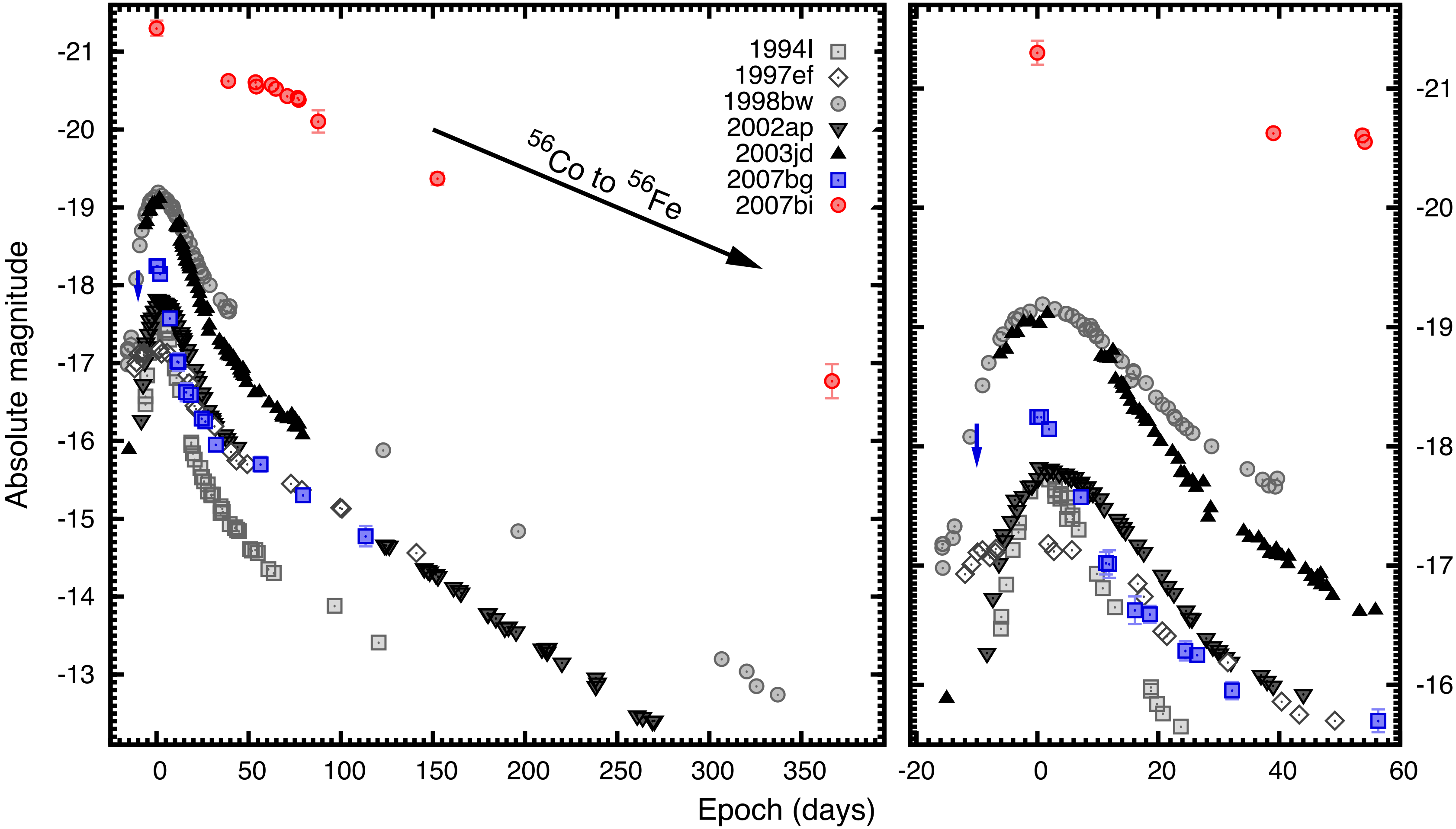
Extremely bright Type Ic SNe

Quasi-bolometric light curves (Young et al. 2010)

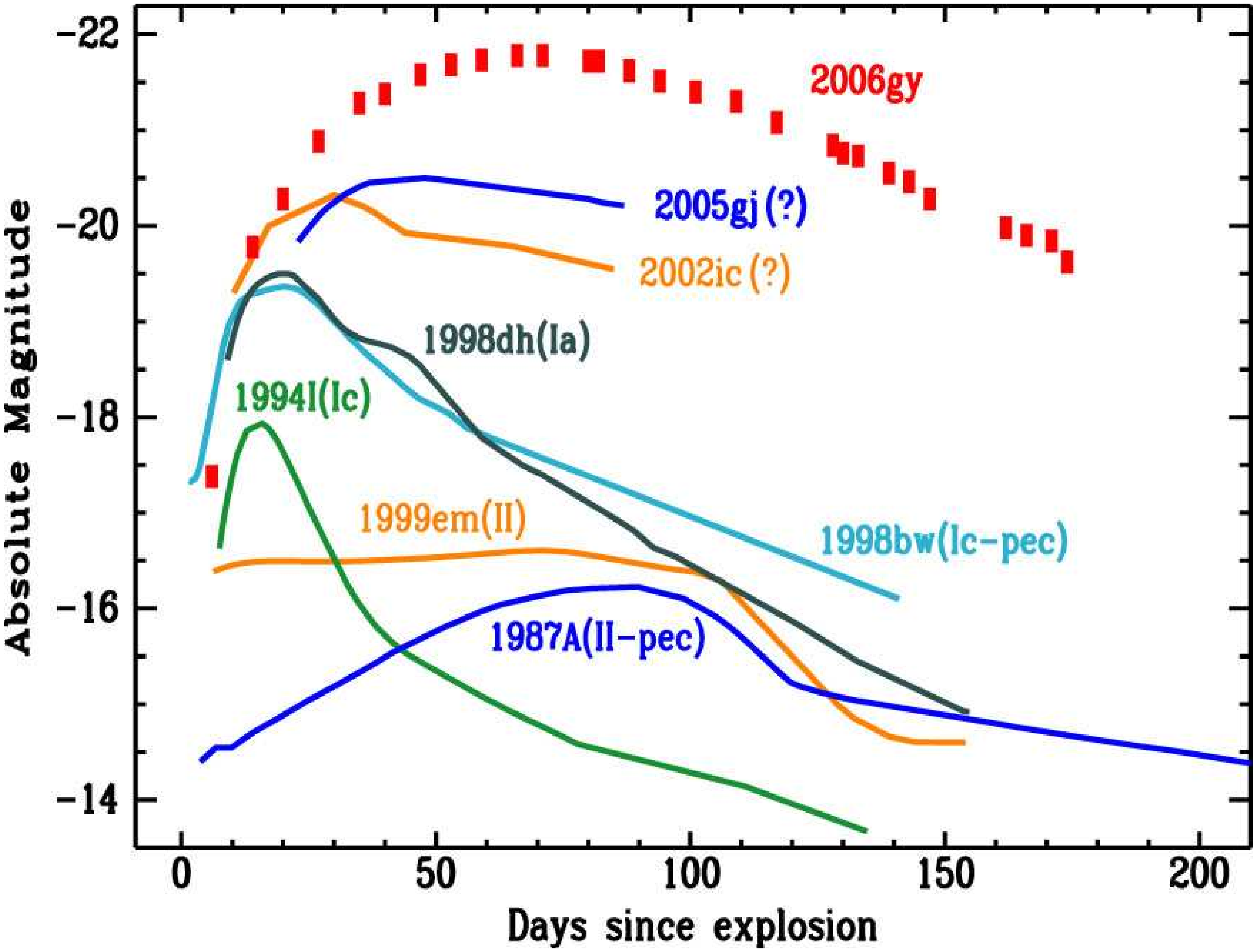


Extremely bright Type Ic SNe

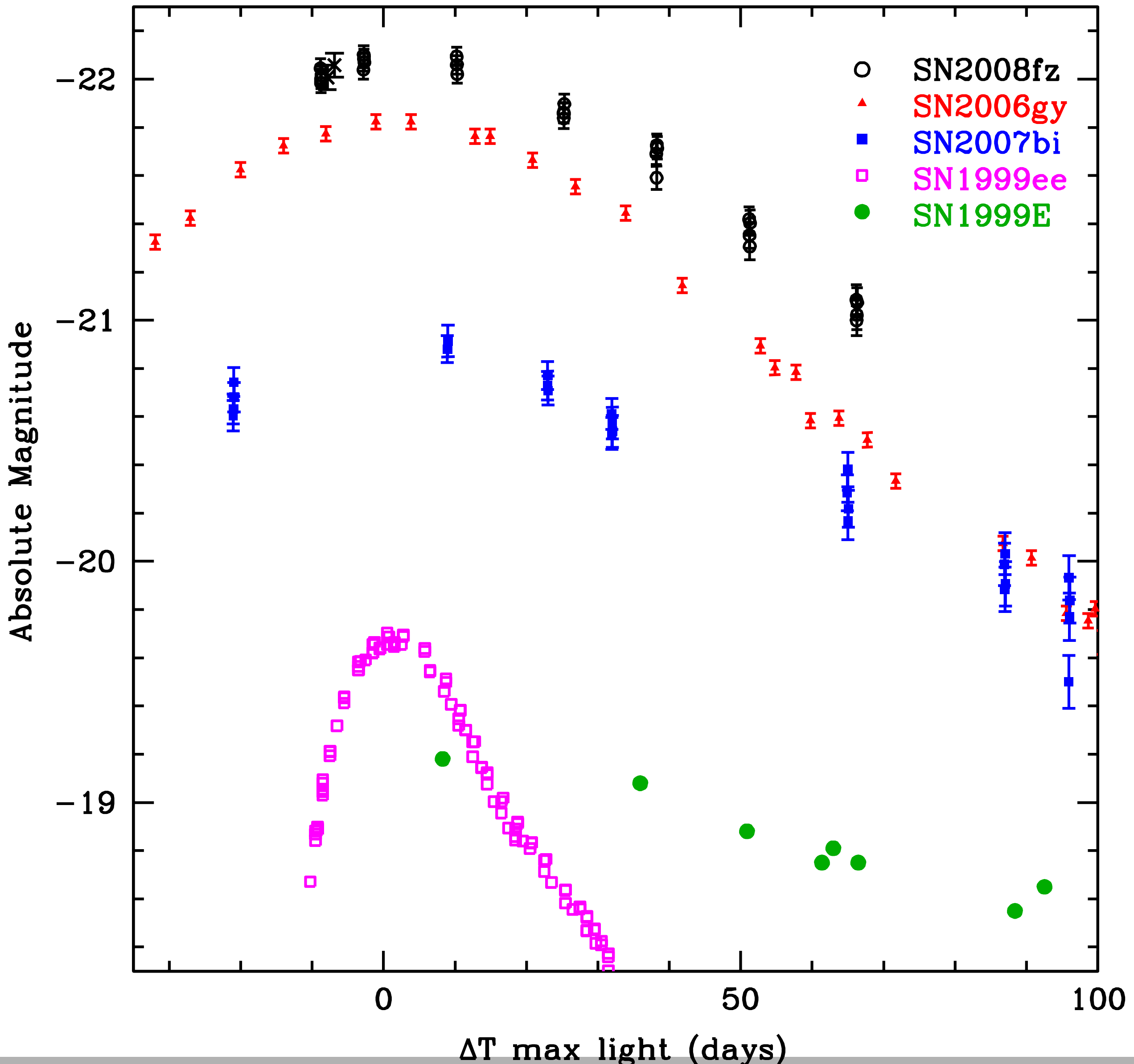
R-band light curves (Young et al. 2010)



Extremely bright Type IIn SNe

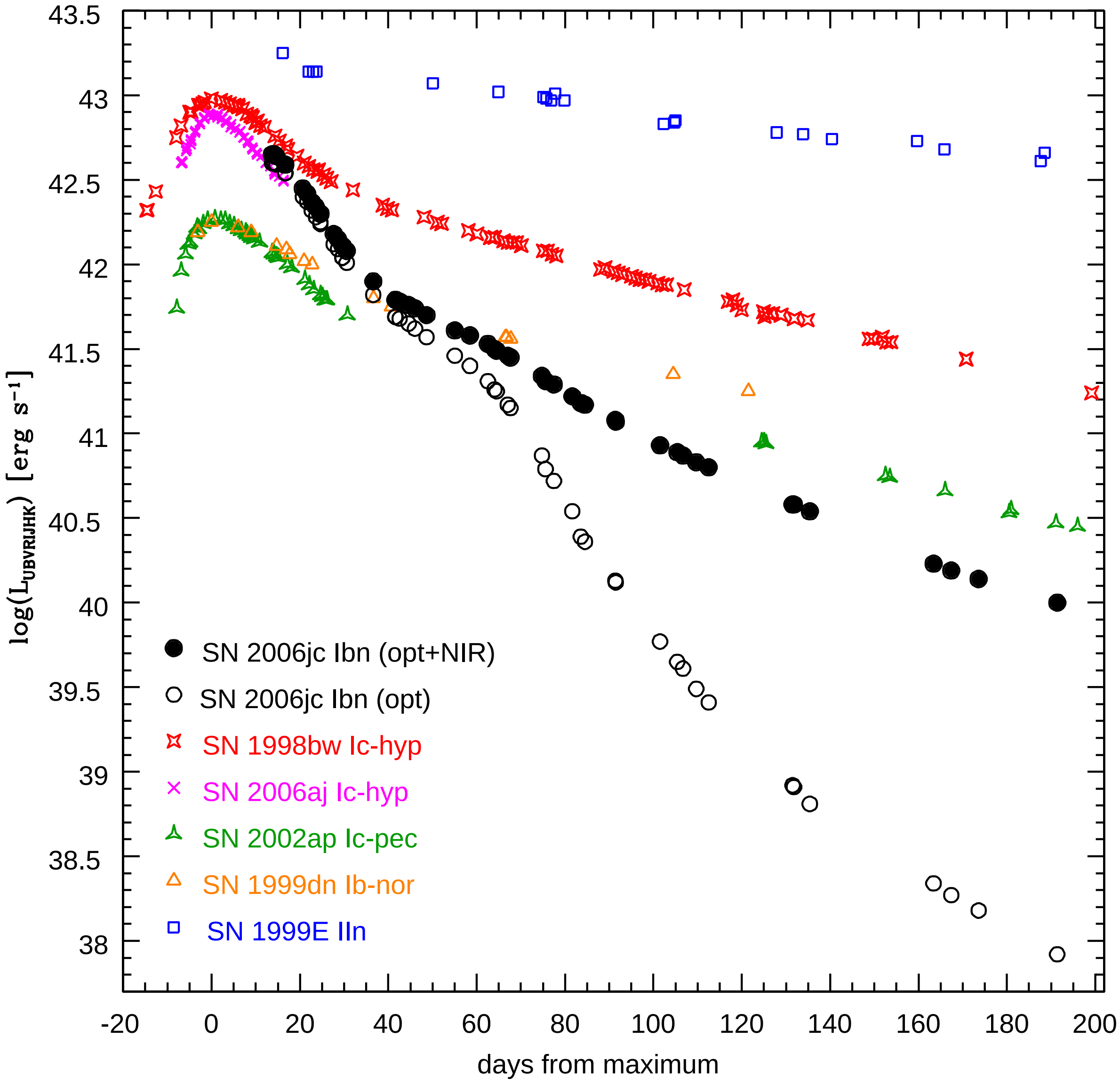


Extremely bright Type IIn SNe



V-band
(Drake et al. 2010)

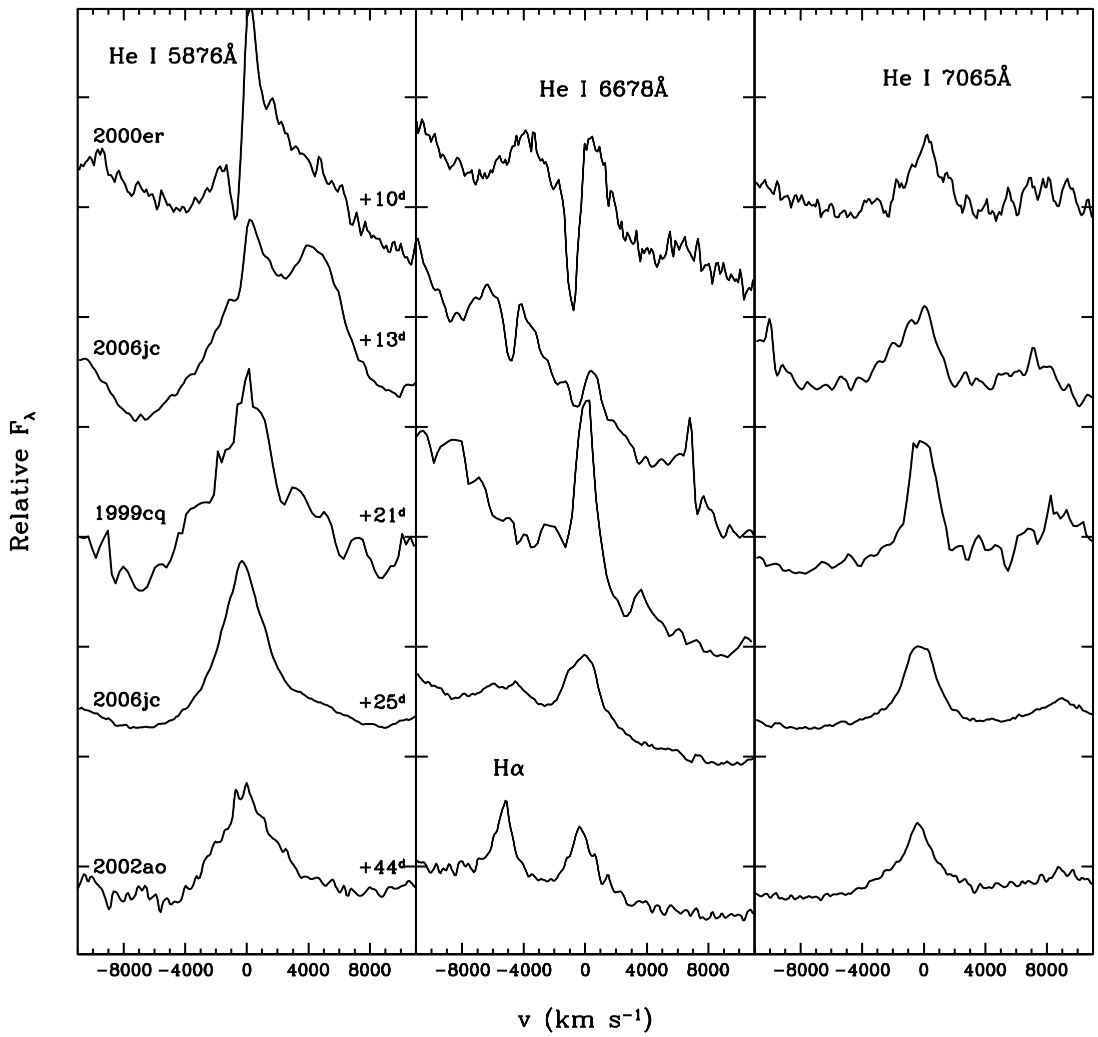
Very bright Type Ib SNe with narrow lines



Type Ibn

Quasi-bolometric (optical+NIR) (Pastorello et al. 2008)

Very bright Type Ib SNe with narrow lines



Pastorello et al. 2008

Windy models for type Ic SNe

Ejecta: politropic mass distribution;
Wind: $\rho \sim r^{-p}$

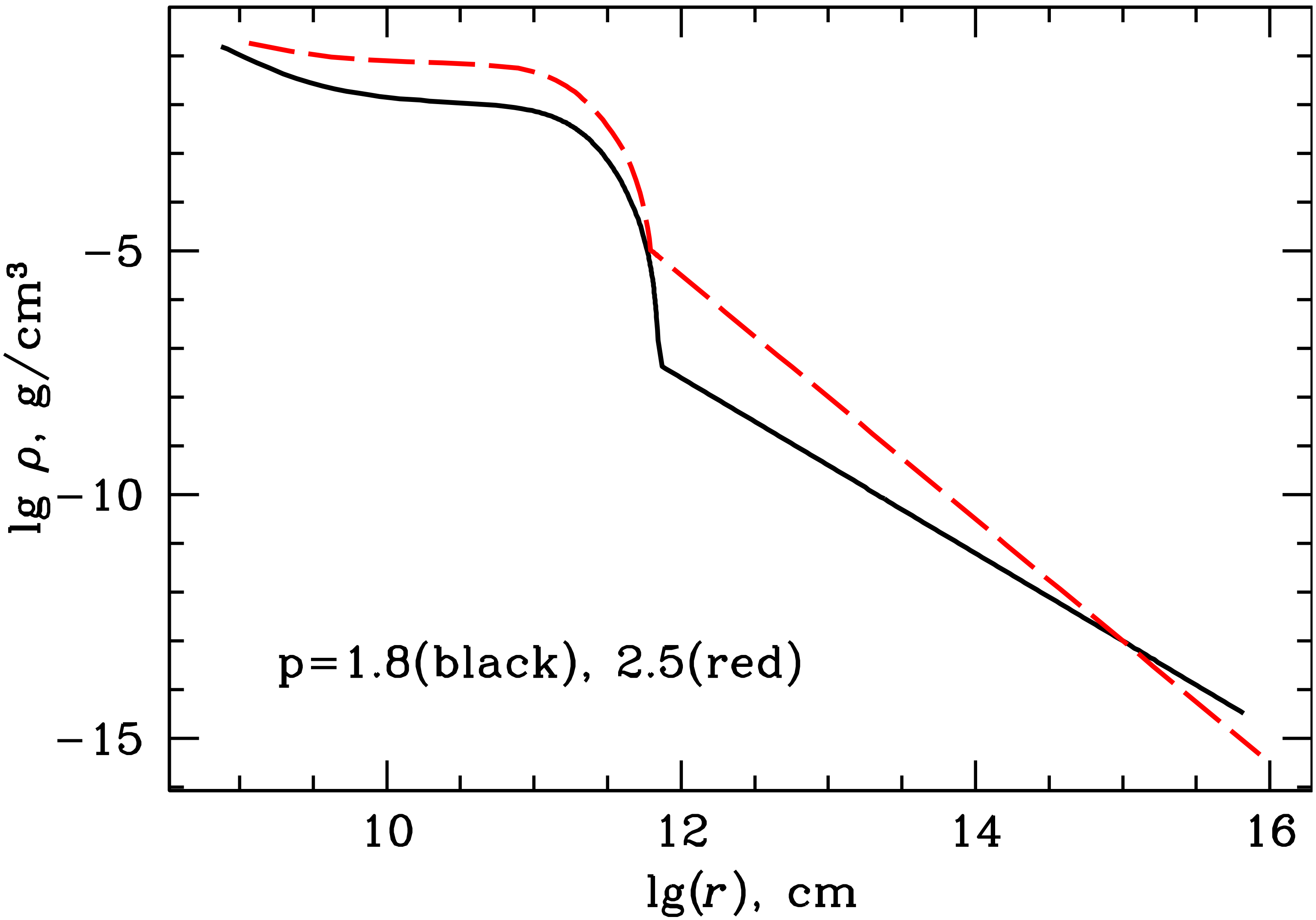
Models (all masses M and radii R are in solar units)

Model	$M_{\rm ej}$	$R_{\rm ej}$	$M_{\rm Ni}$	p	$M_{\rm w}$	$R_{\rm w}$	E, foe
`shallowIb`	1	10	0	2.5	2.9	10^5	3
`standardIb`	0.2	10	0	2	3.5	$8 \cdot 10^4$	3
`brightIb`	0.2	10	0	1.8	4.8	$9 \cdot 10^4$	1, 2, 4

Composition: uniform;
0.5 C + 0.5 O + 1% heavier elements of Solar abundance;
no ^{56}Ni – to check the influence of the pure shock

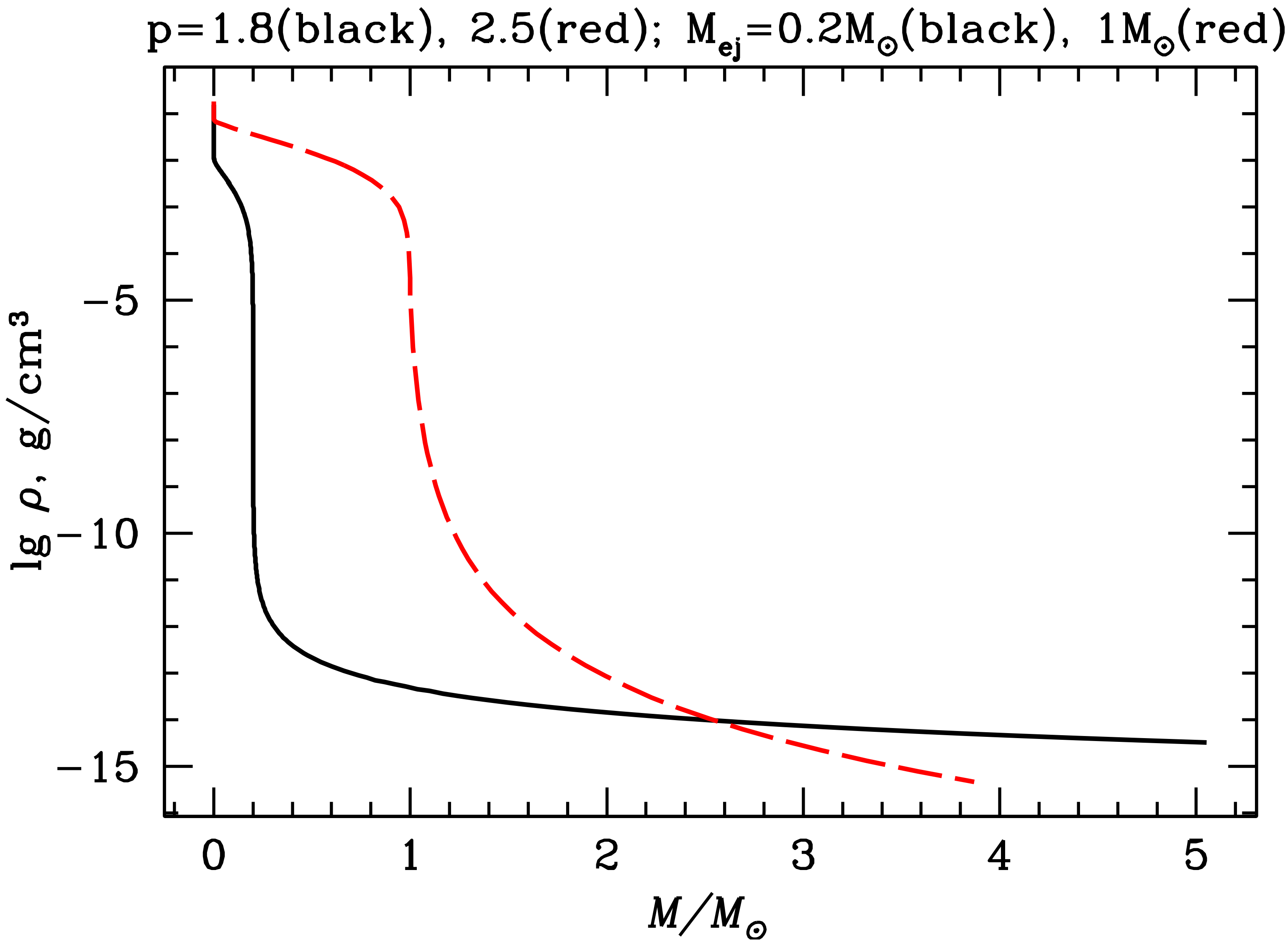
Initial models

Samples of the density distribution

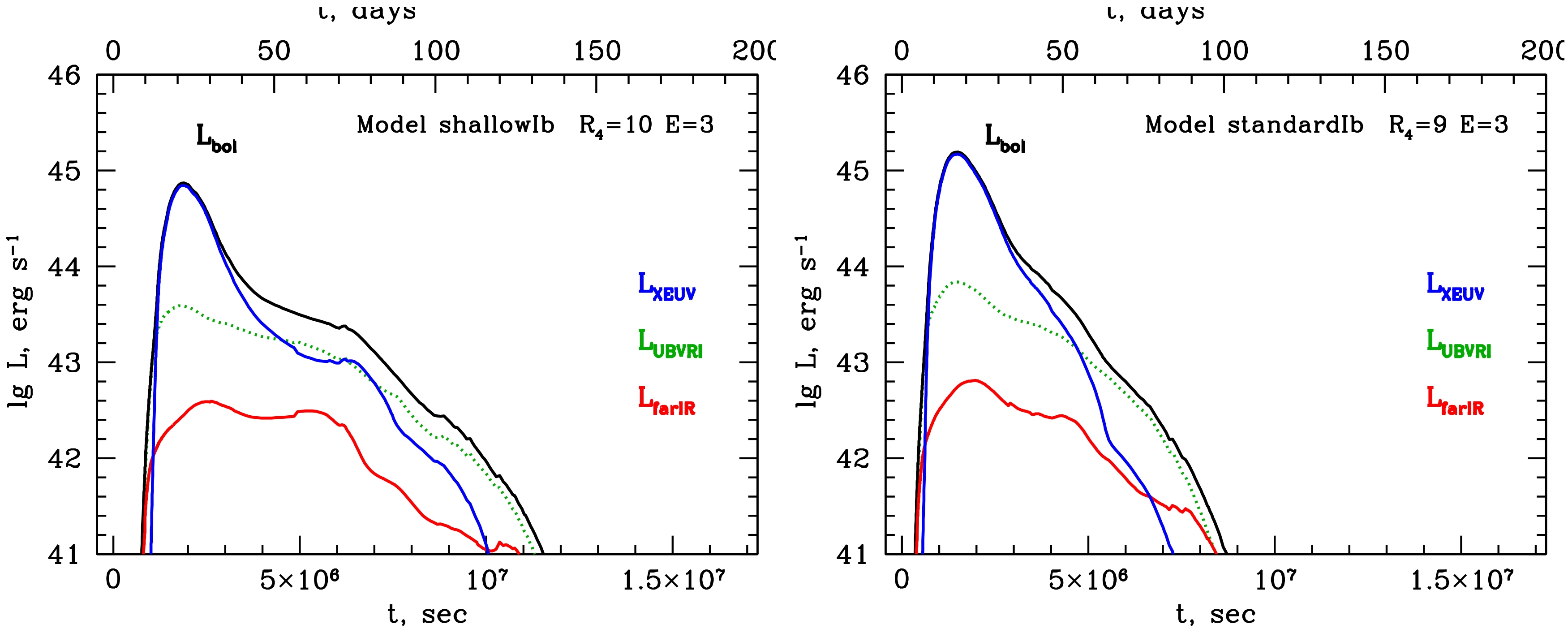


Initial models

Samples of the density distribution

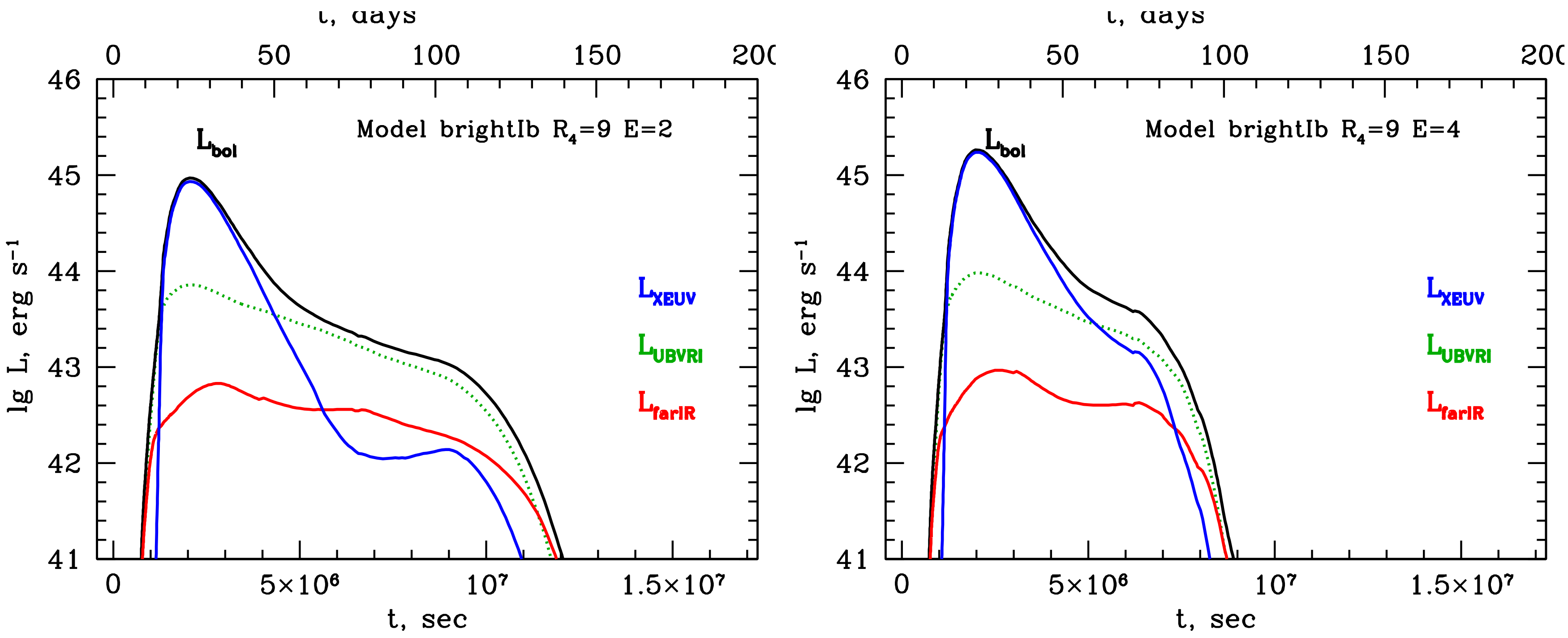


Light curves for different wind structure



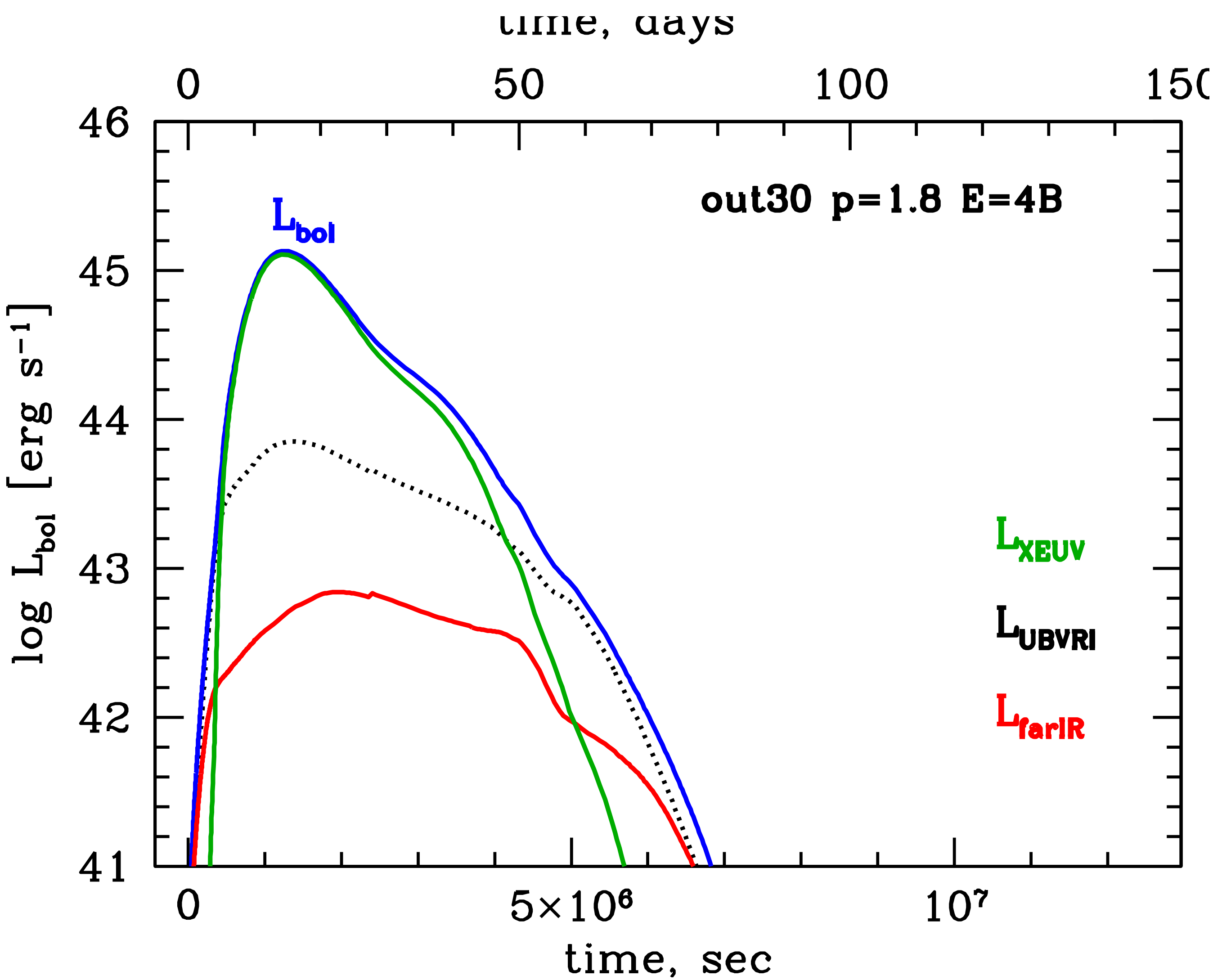
$p = 2.5, M_w = 2.9 M_\odot$ $p = 2, M_w = 3.5 M_\odot$

Light curves for different explosion energies



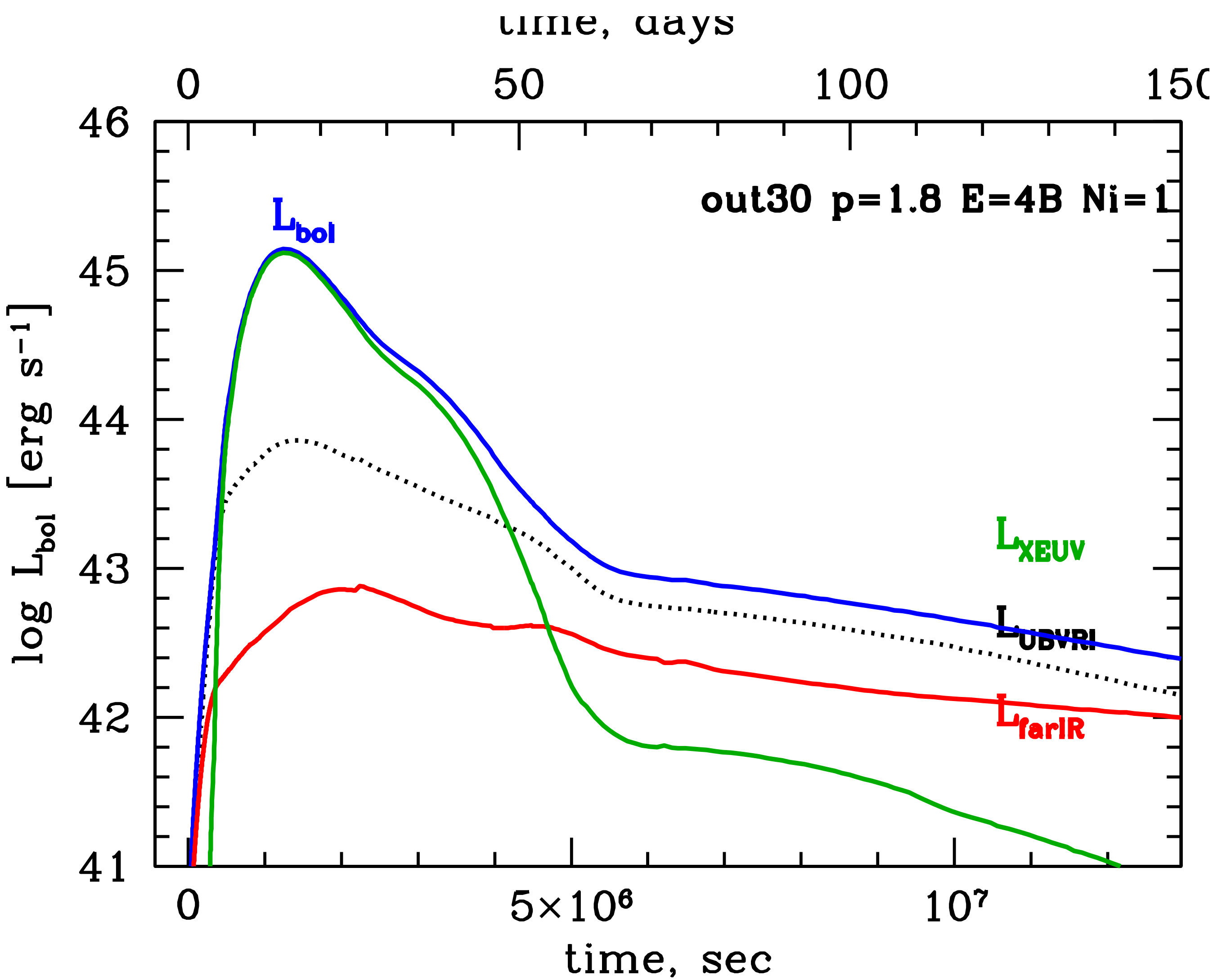
$$p = 1.8, M_w = 4.8M_\odot$$

^{56}Ni vs. Shock wave heating



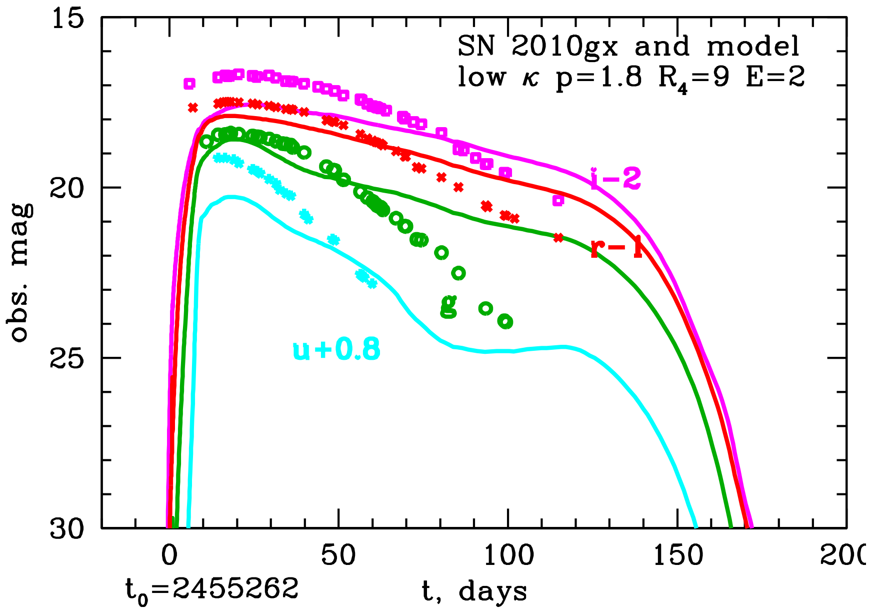
no ^{56}Ni

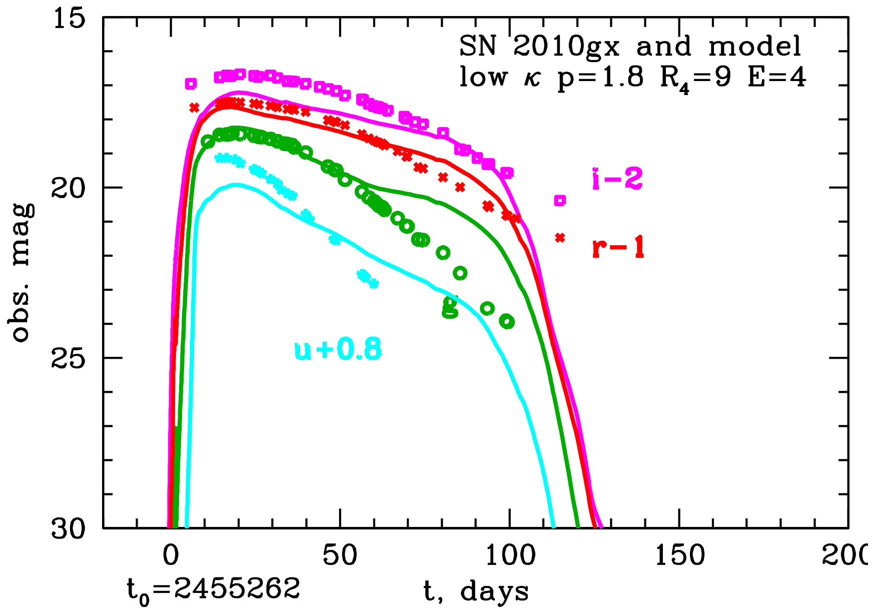
^{56}Ni vs. Shock wave heating



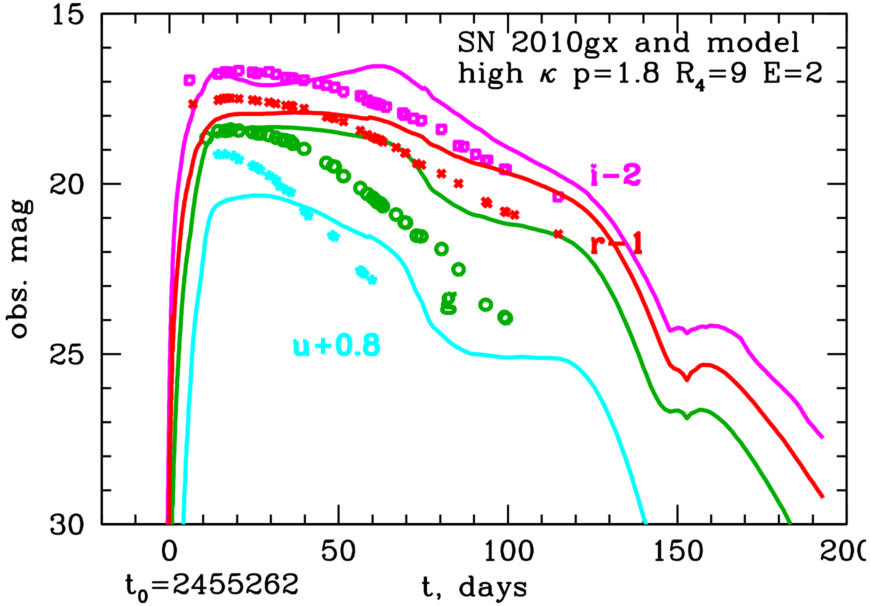
$M(^{56}\text{Ni}) = 1M_{\odot}$ in the ejecta

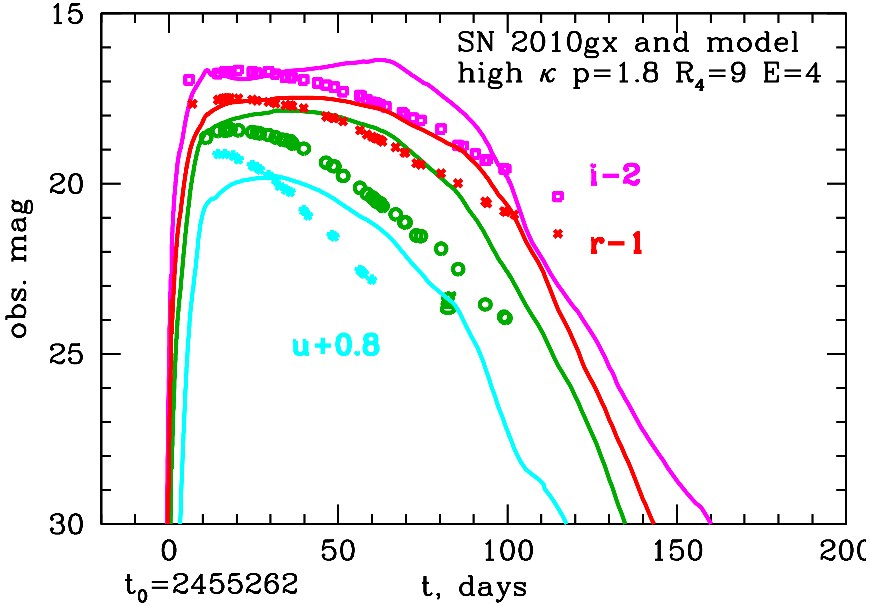
Best models for SN 2010gx





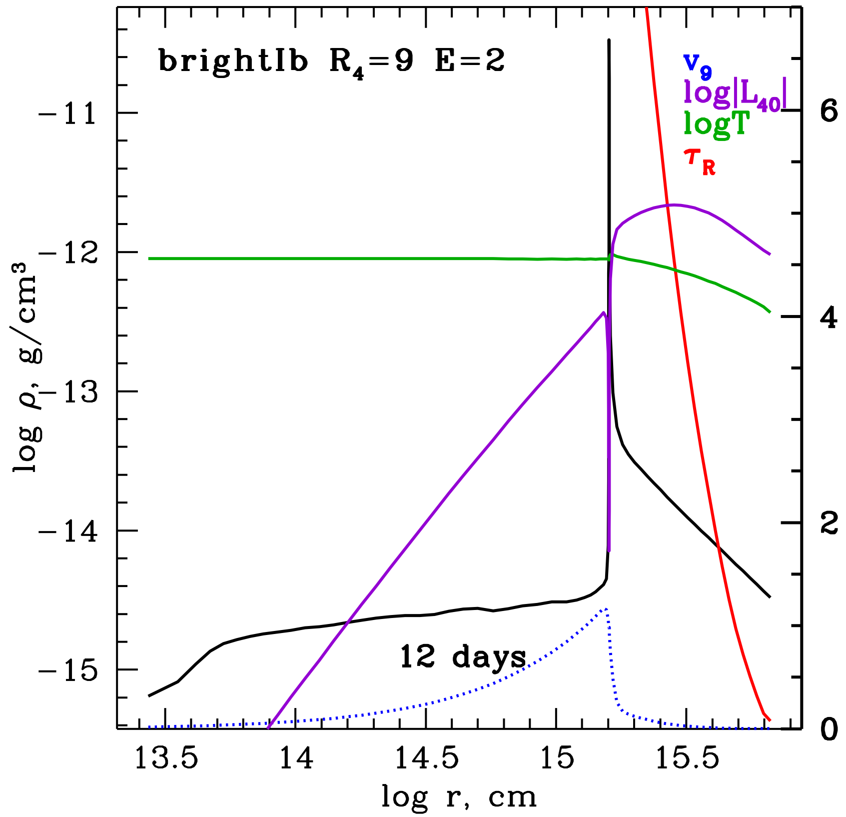
Expansion opacity enhanced

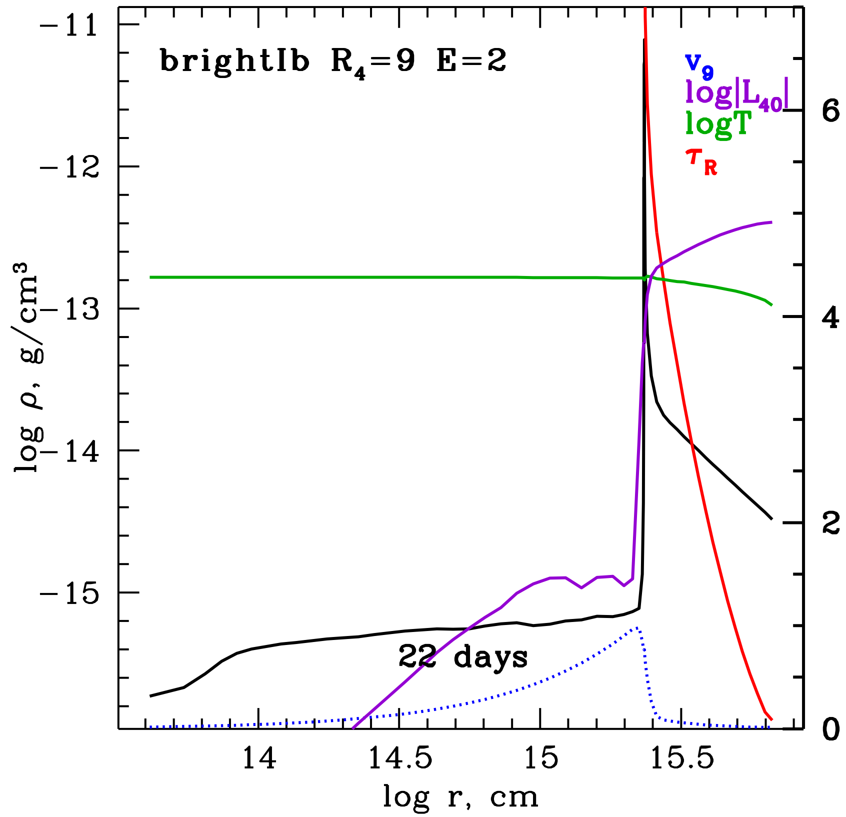




Opacity is taken as for $dv/dr = 1/t = 1/1$day

Evolution of model structure





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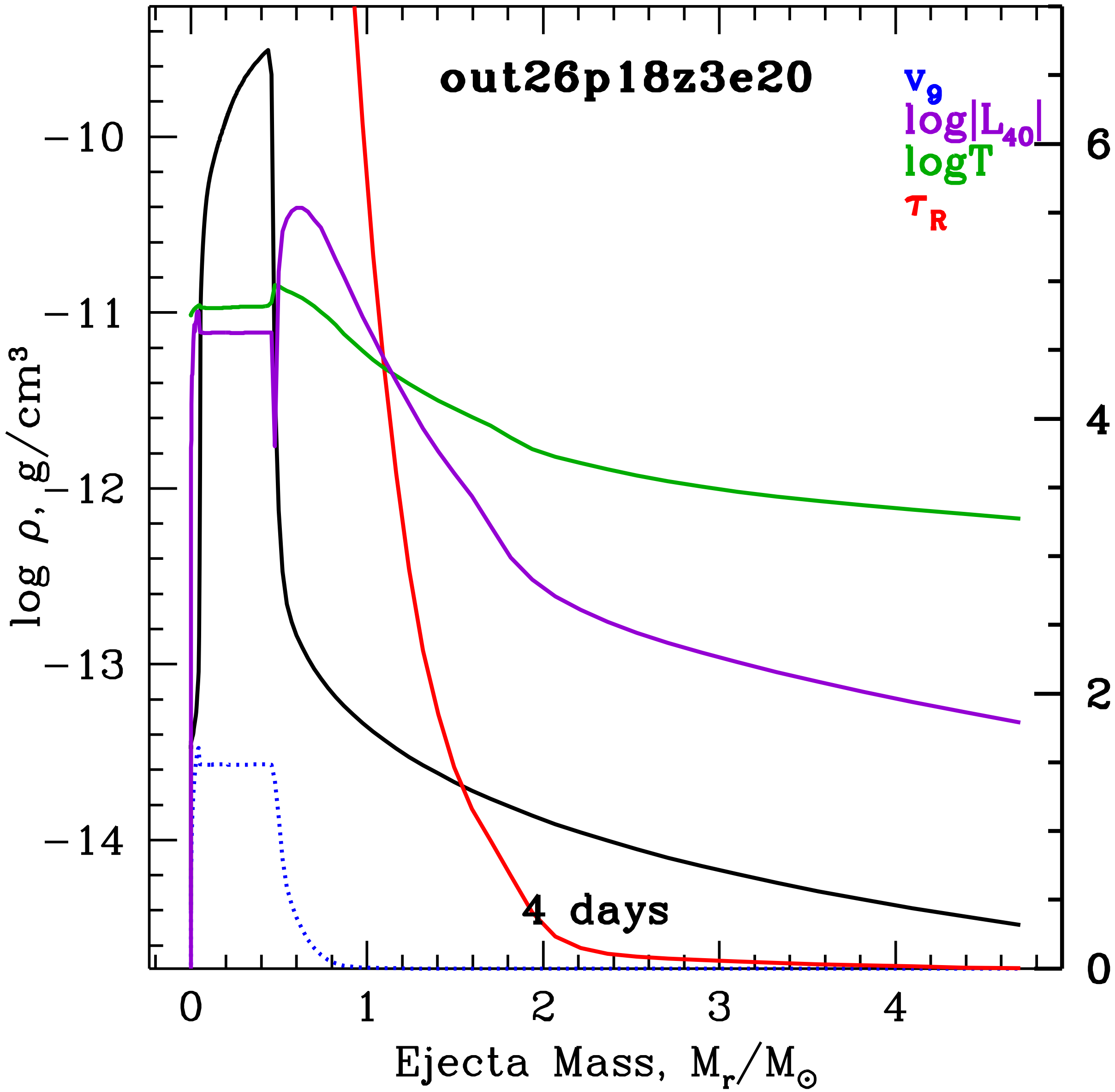

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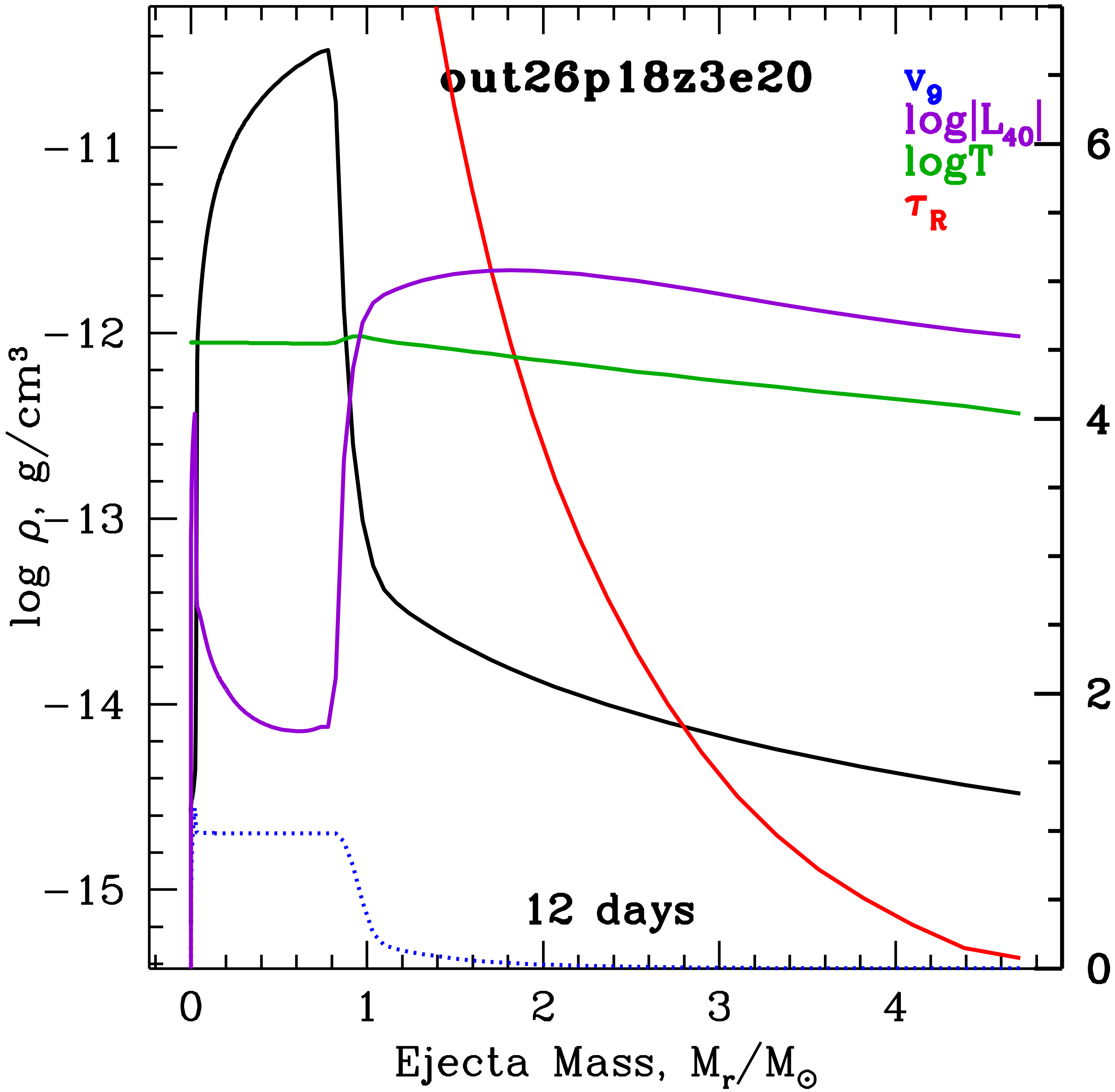

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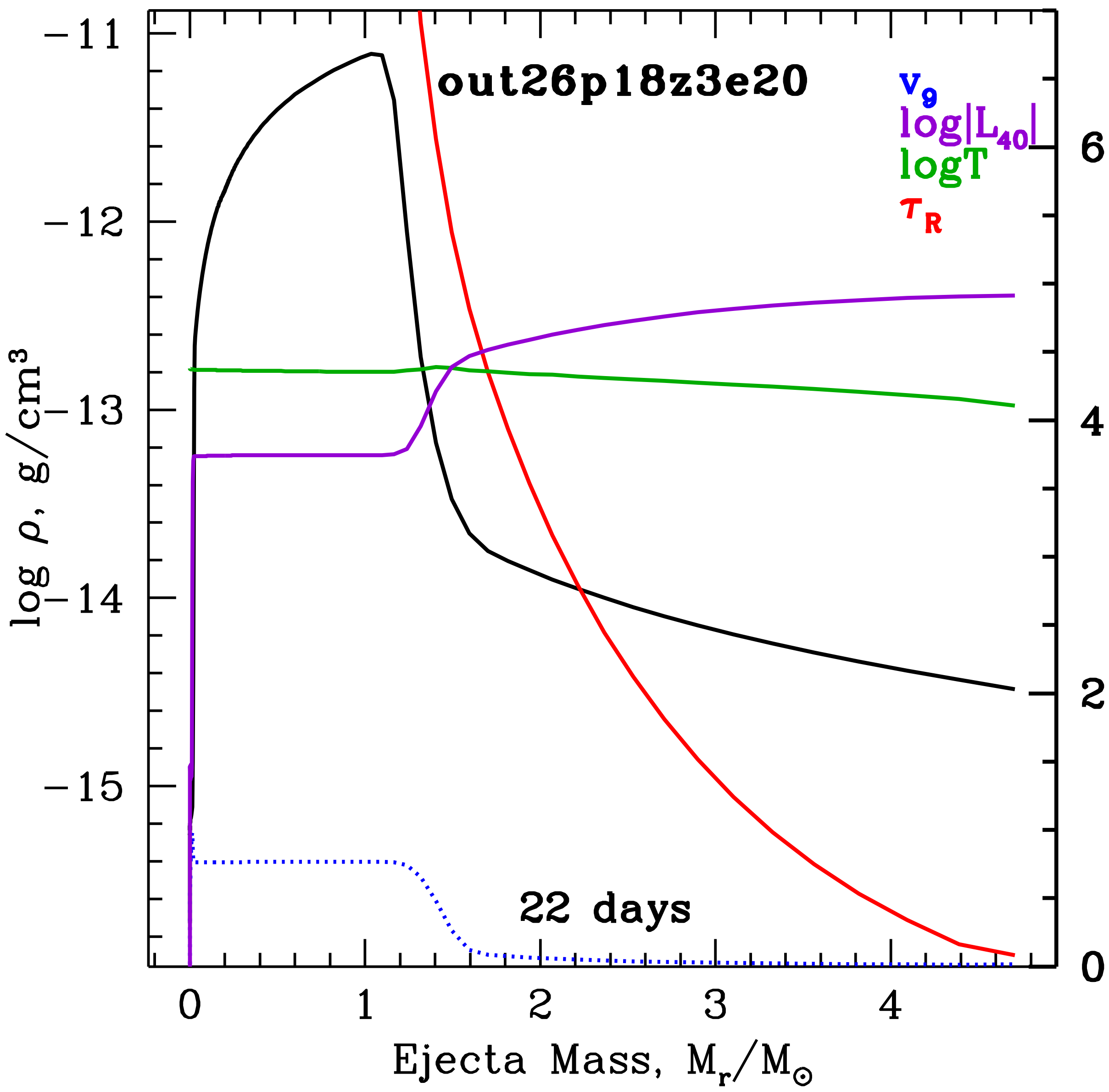

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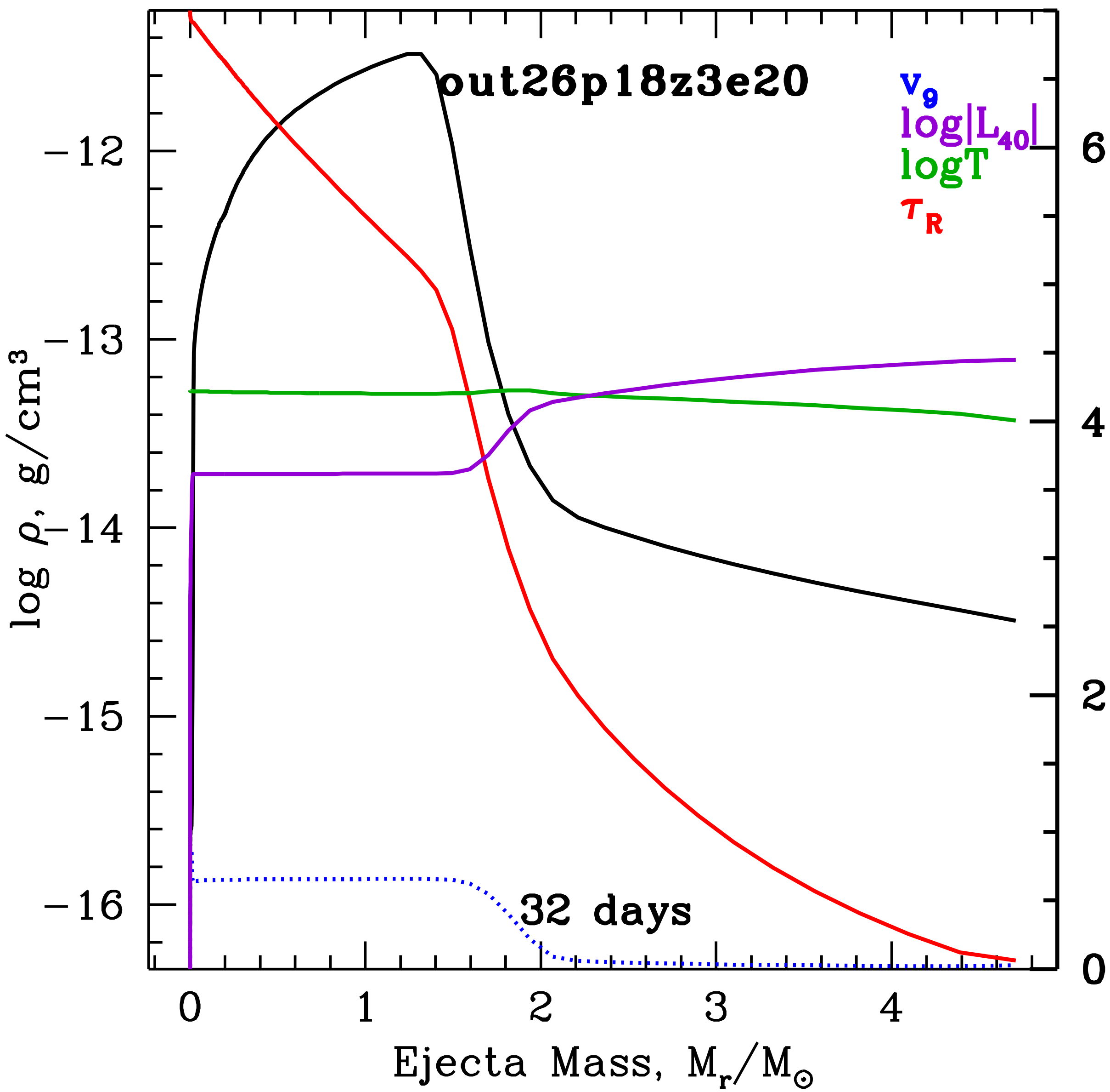

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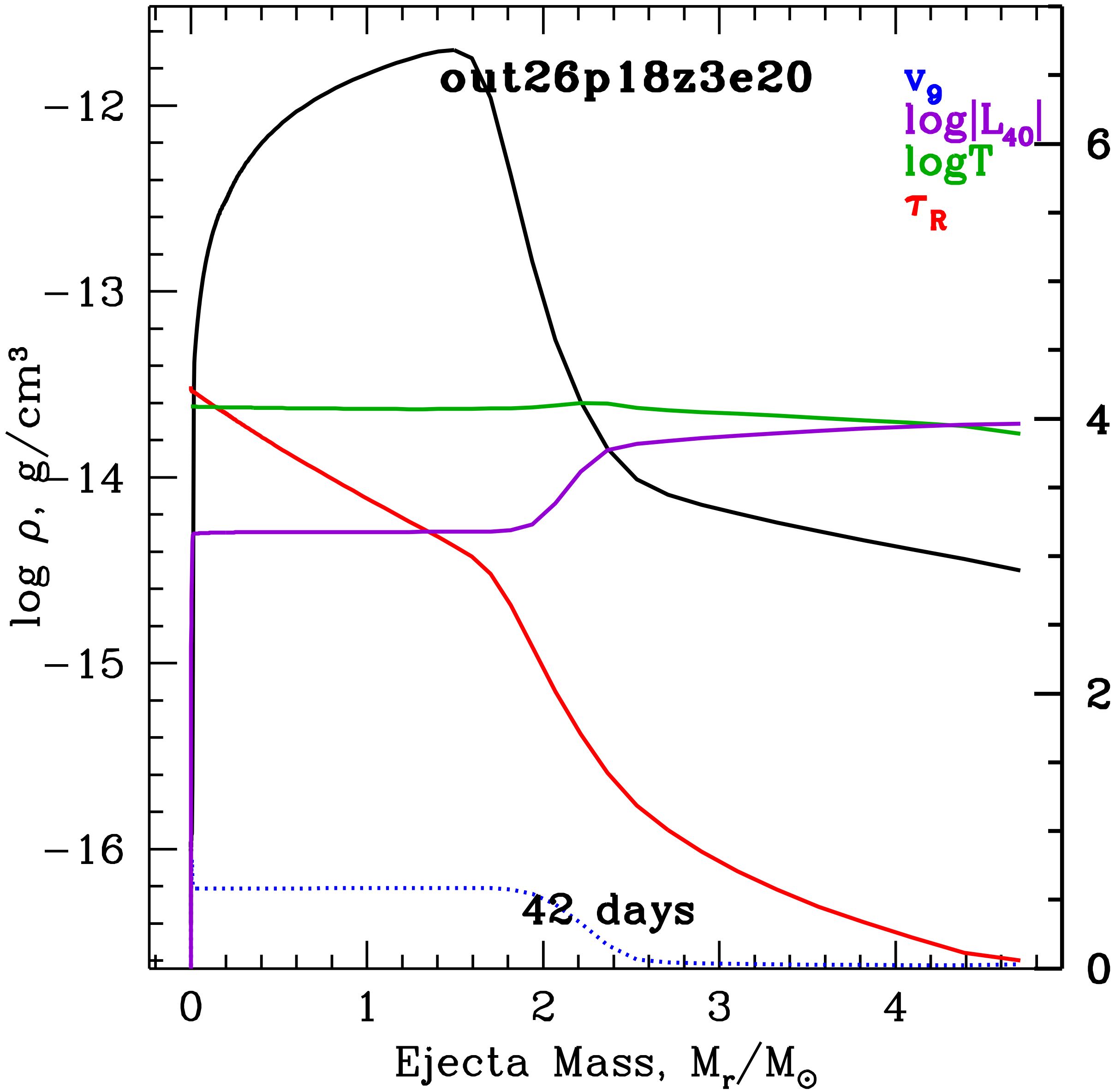

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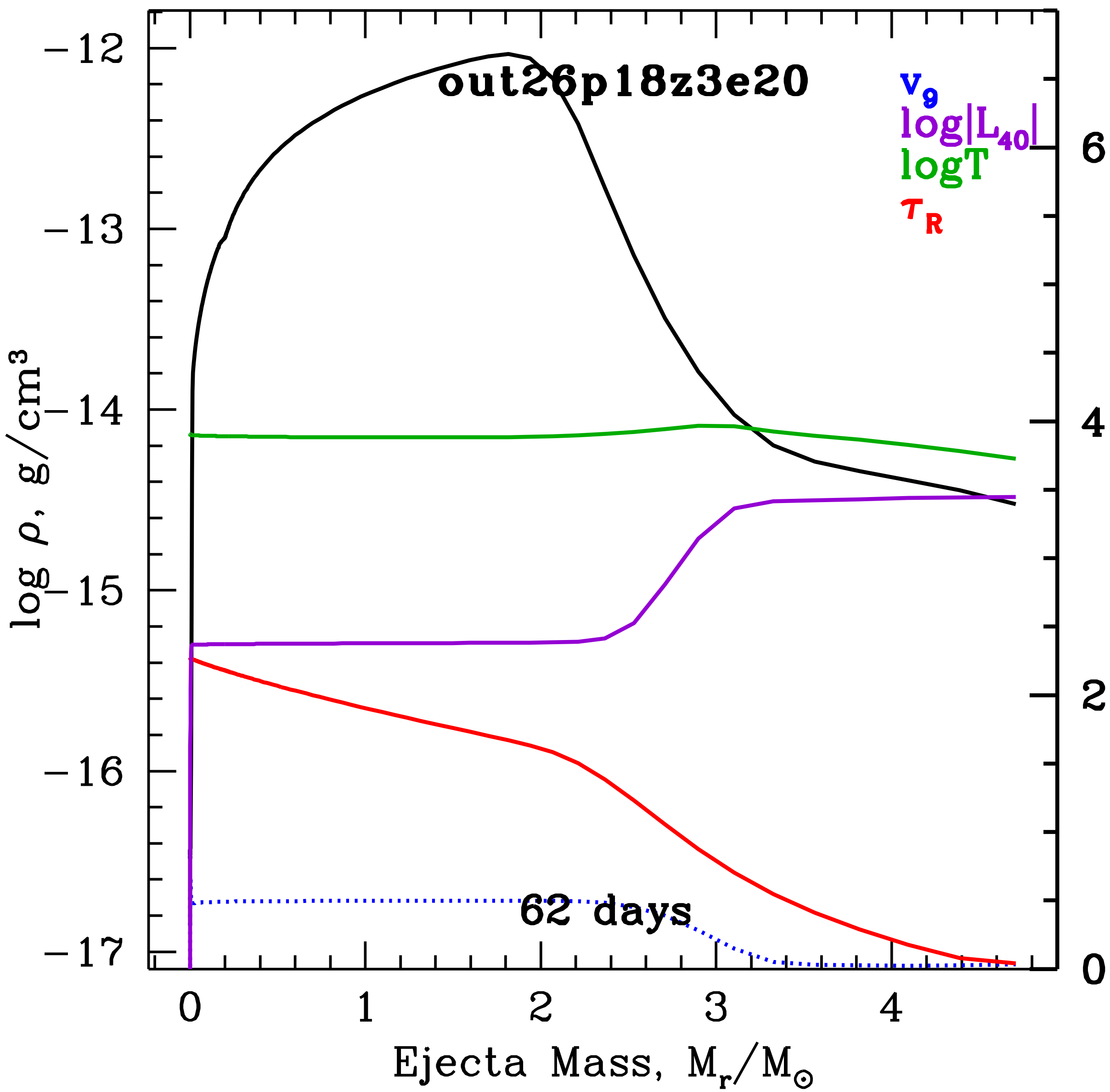

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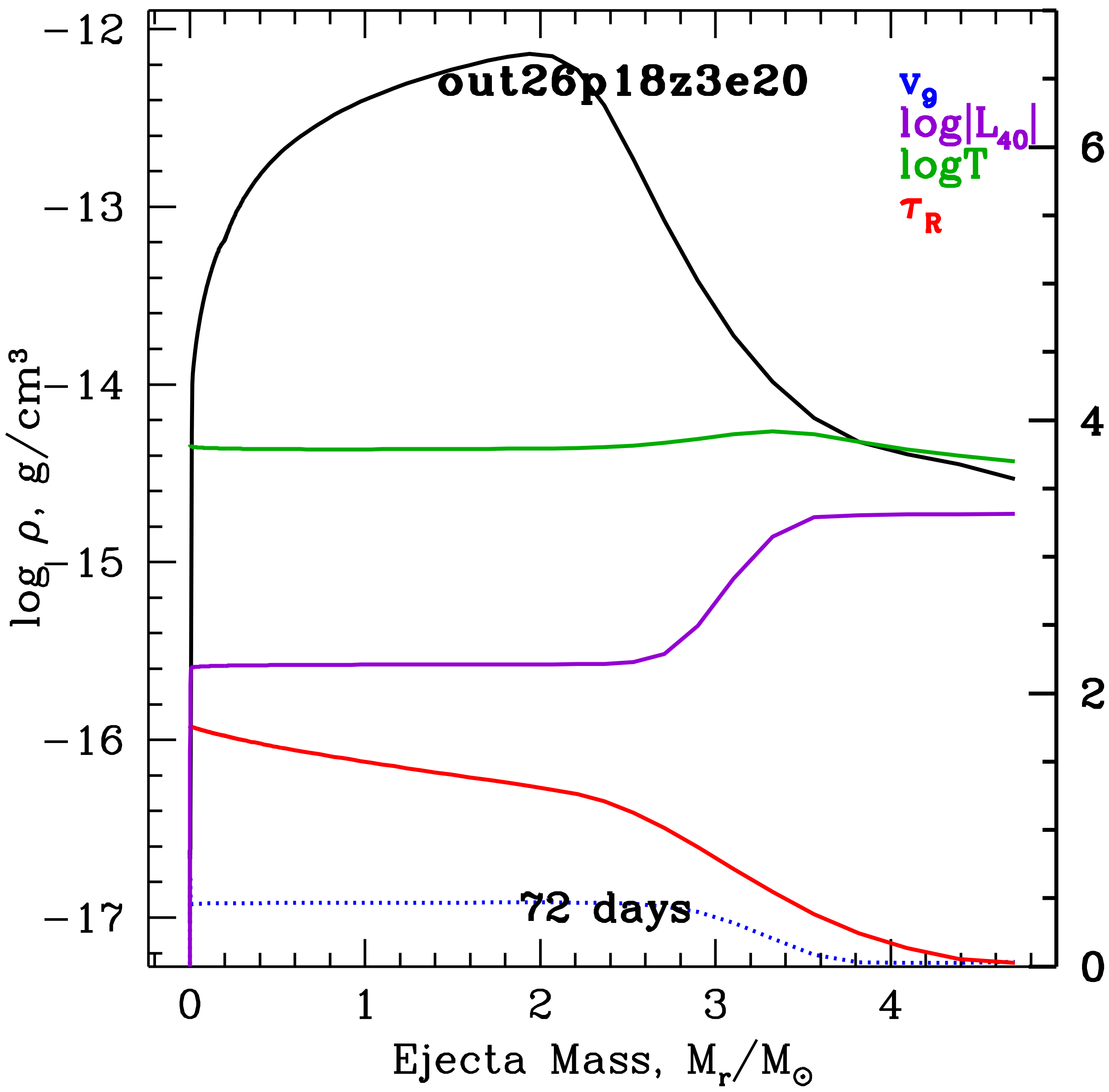

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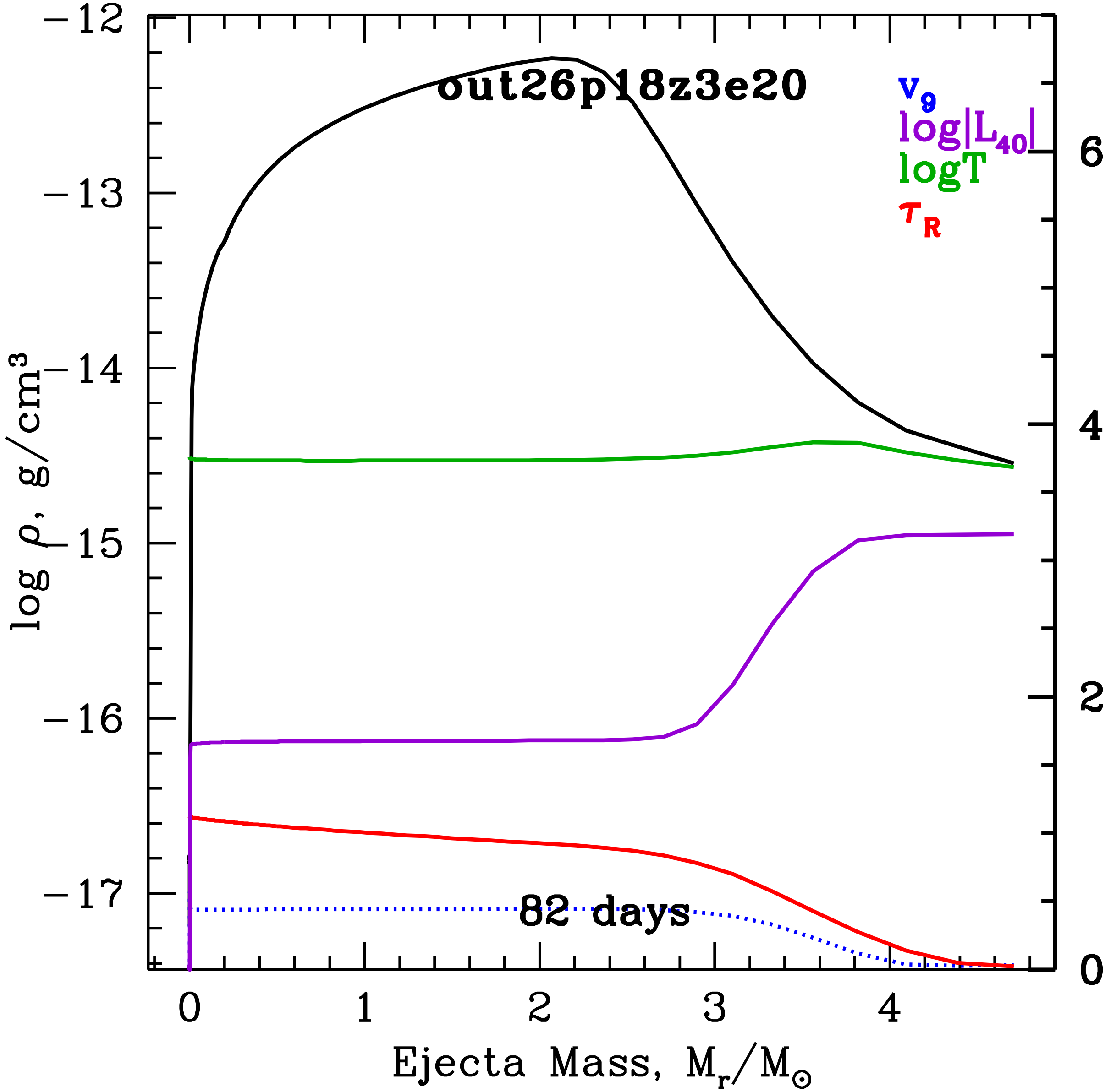

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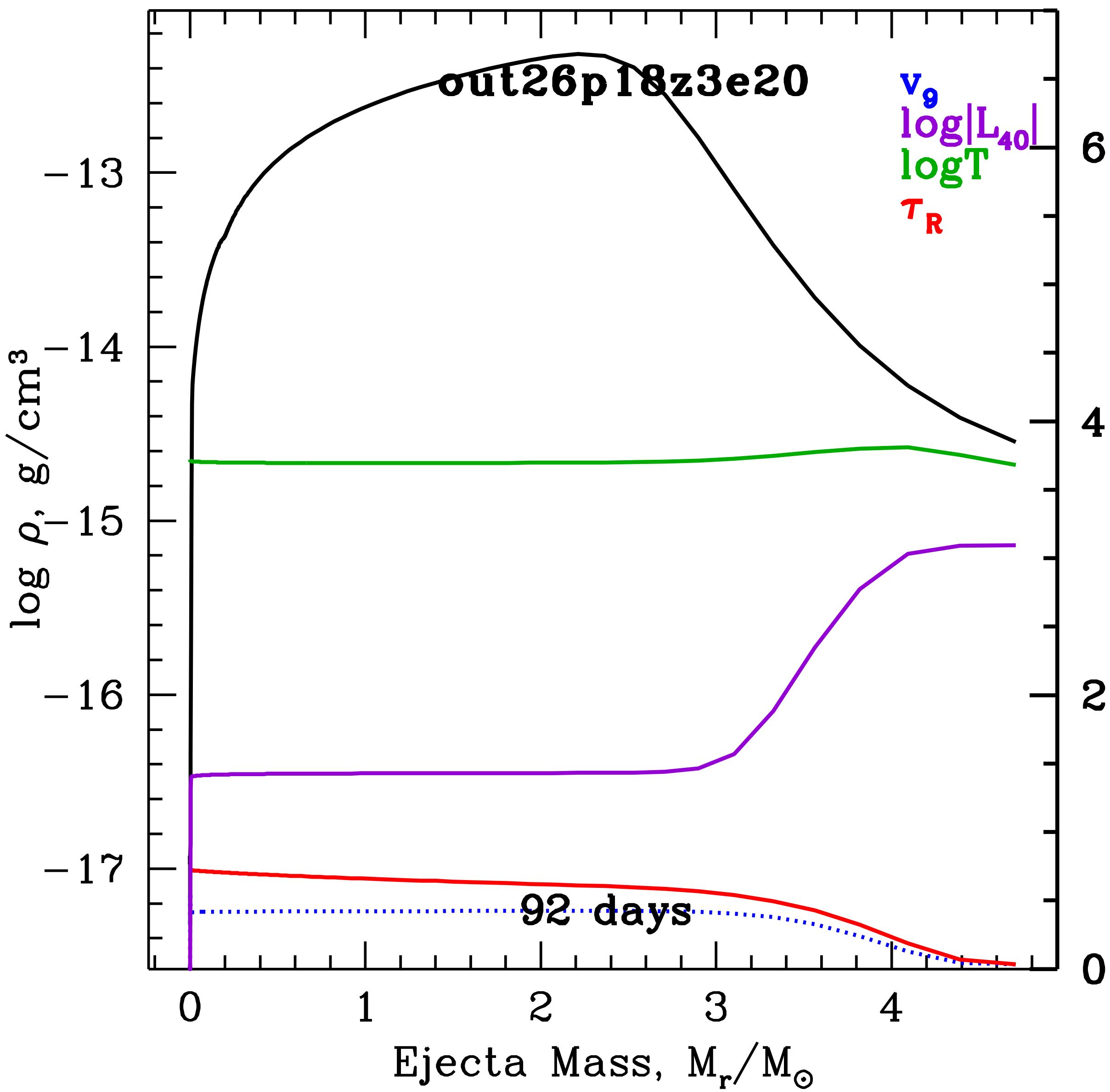

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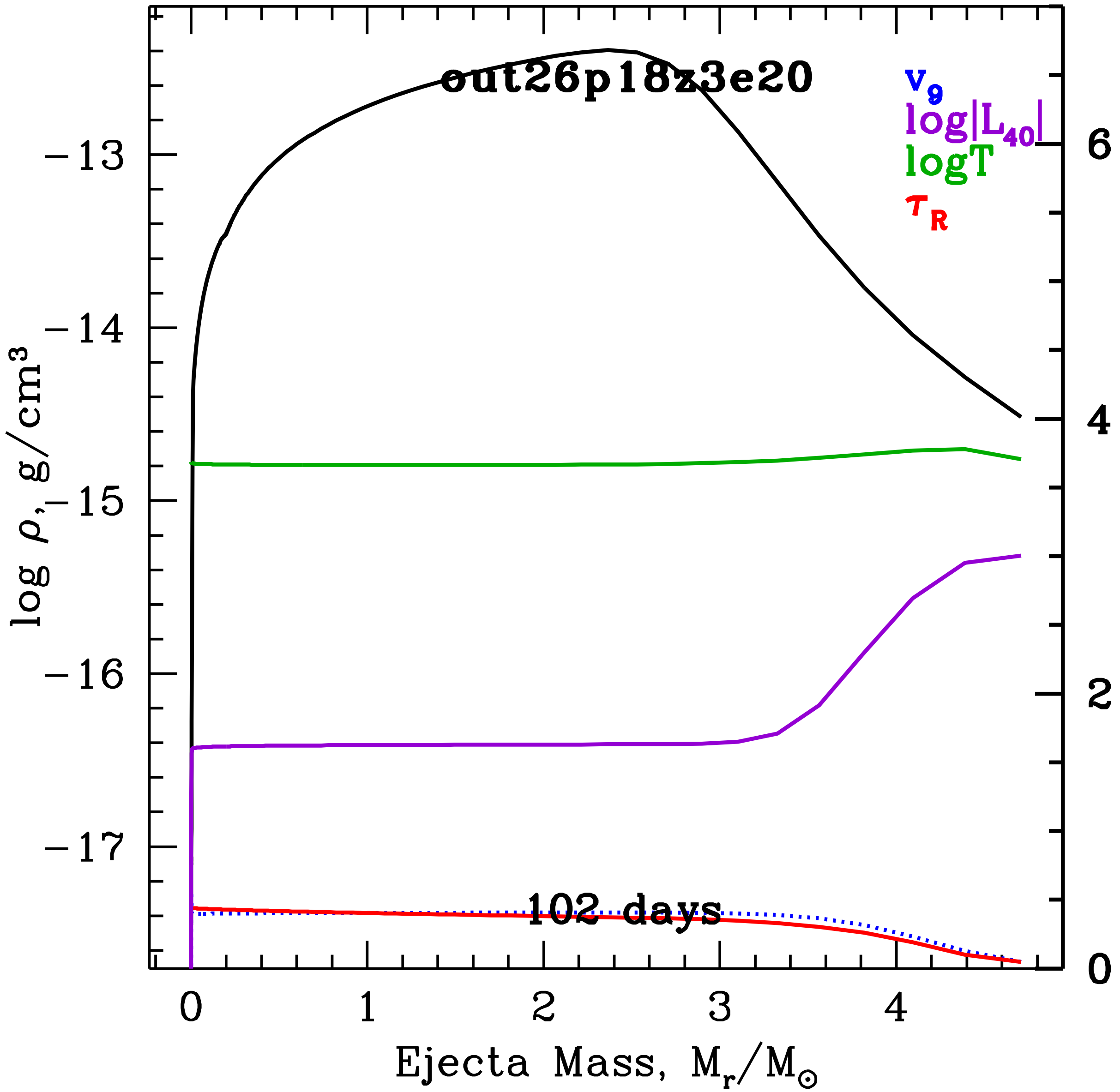

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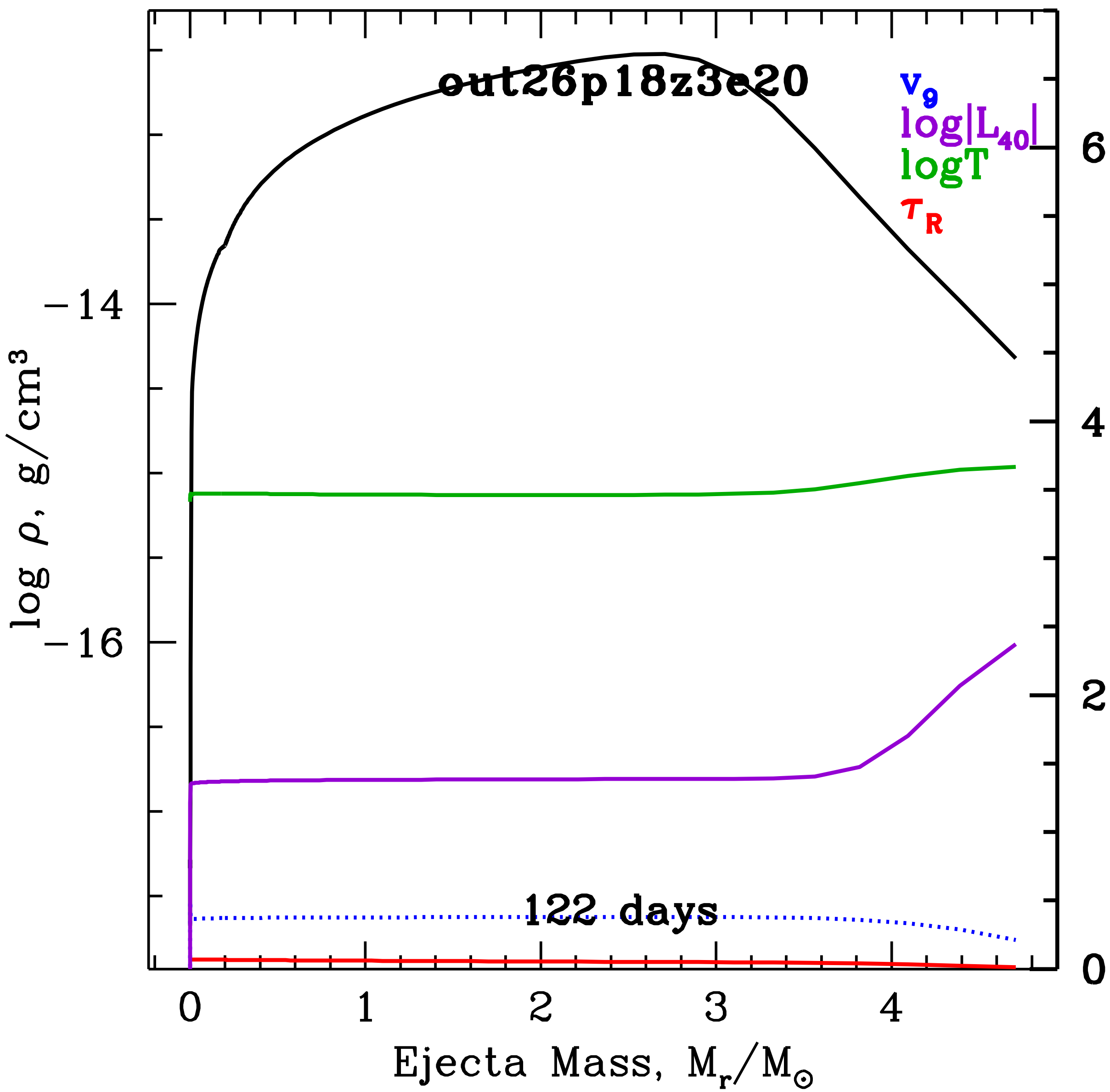
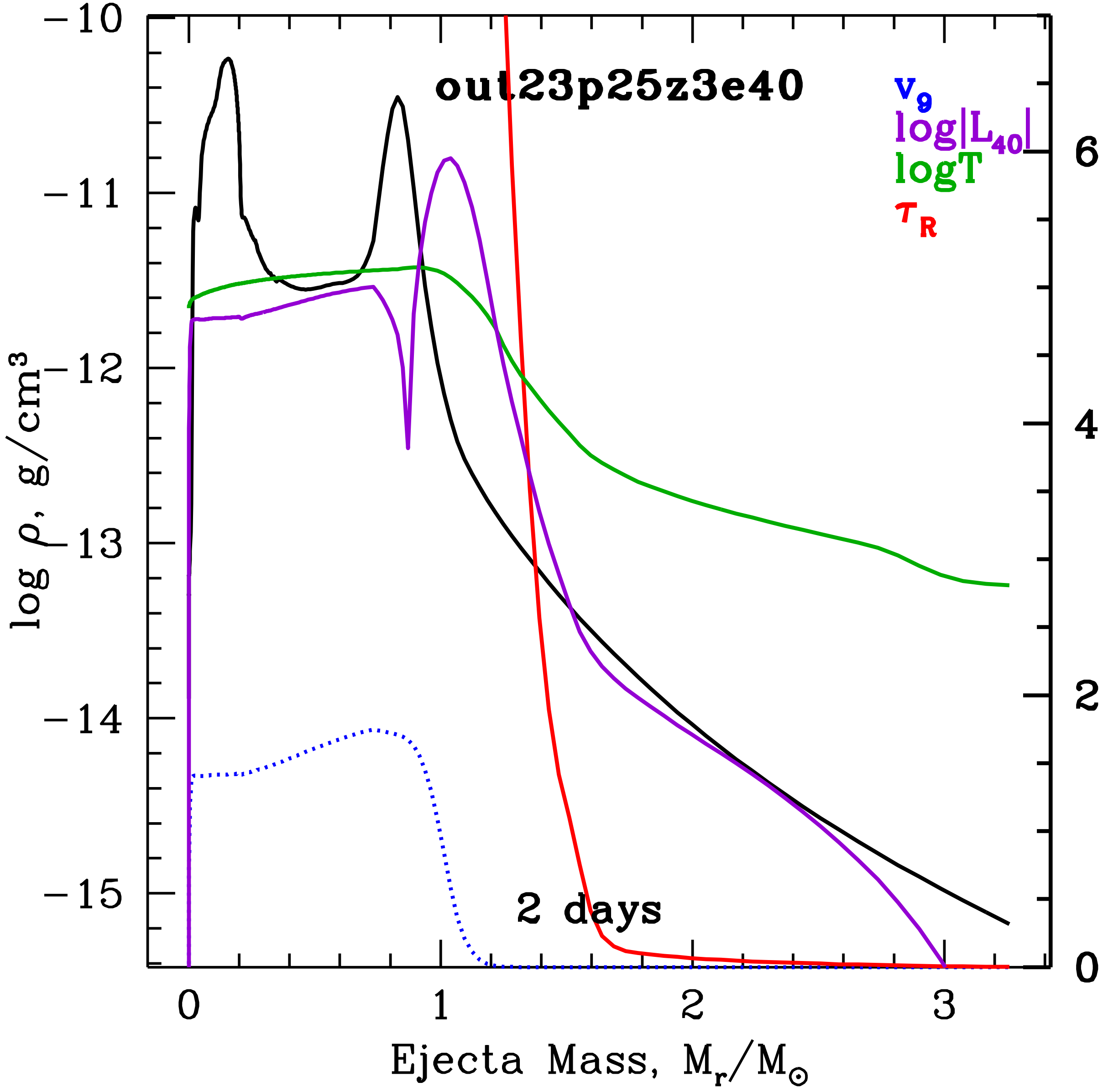


Evolution of another model structure



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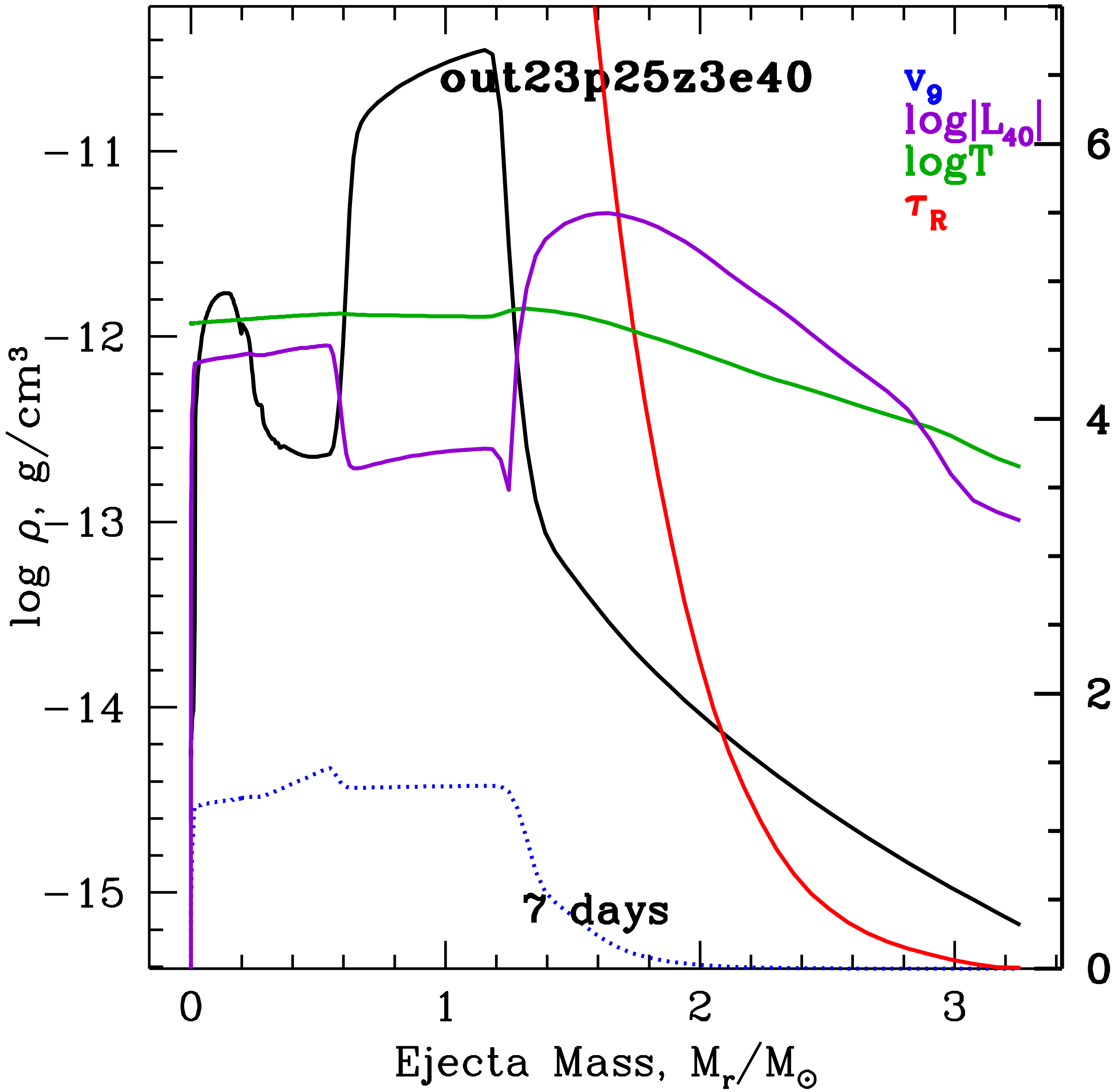

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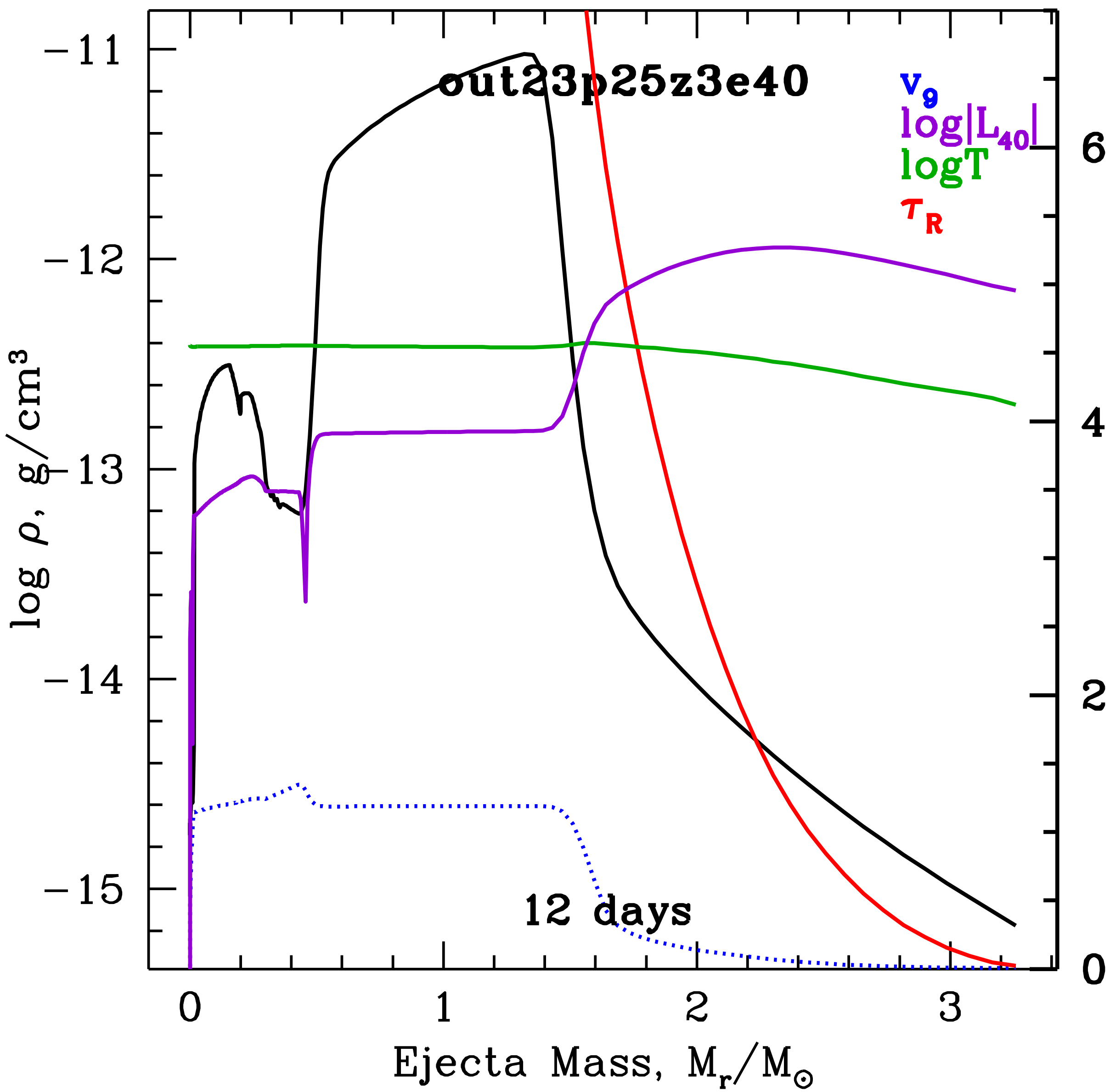

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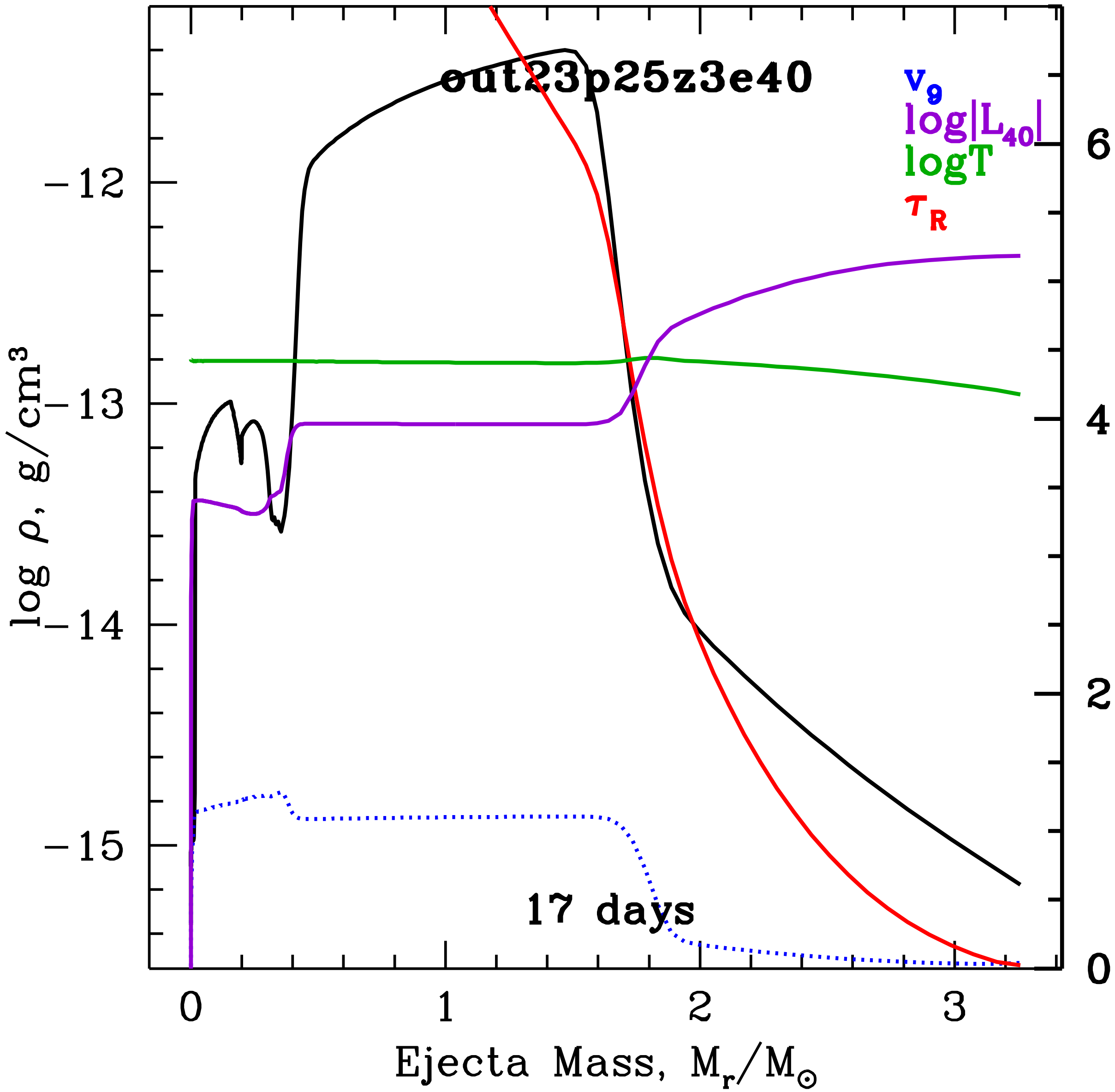

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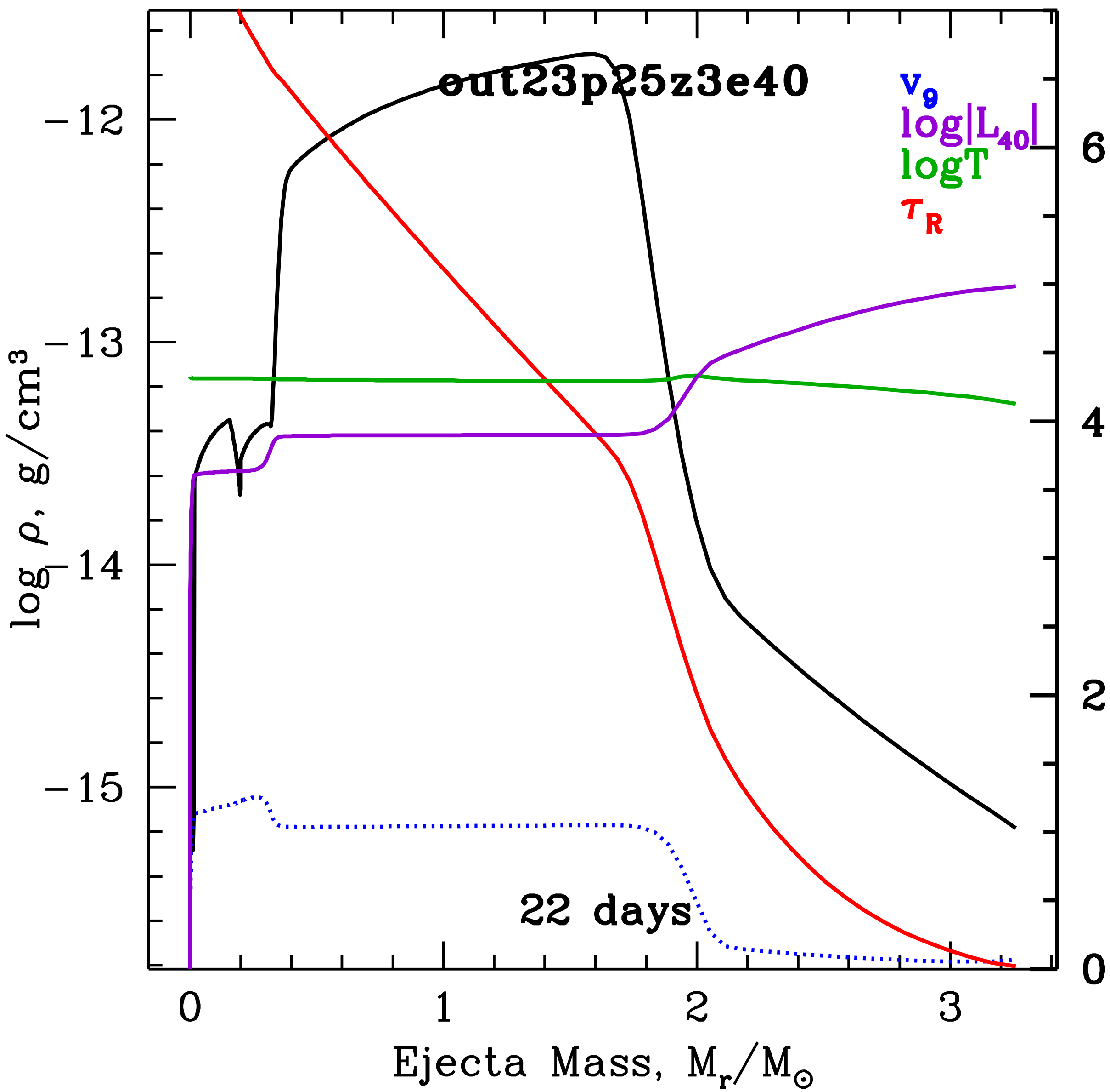

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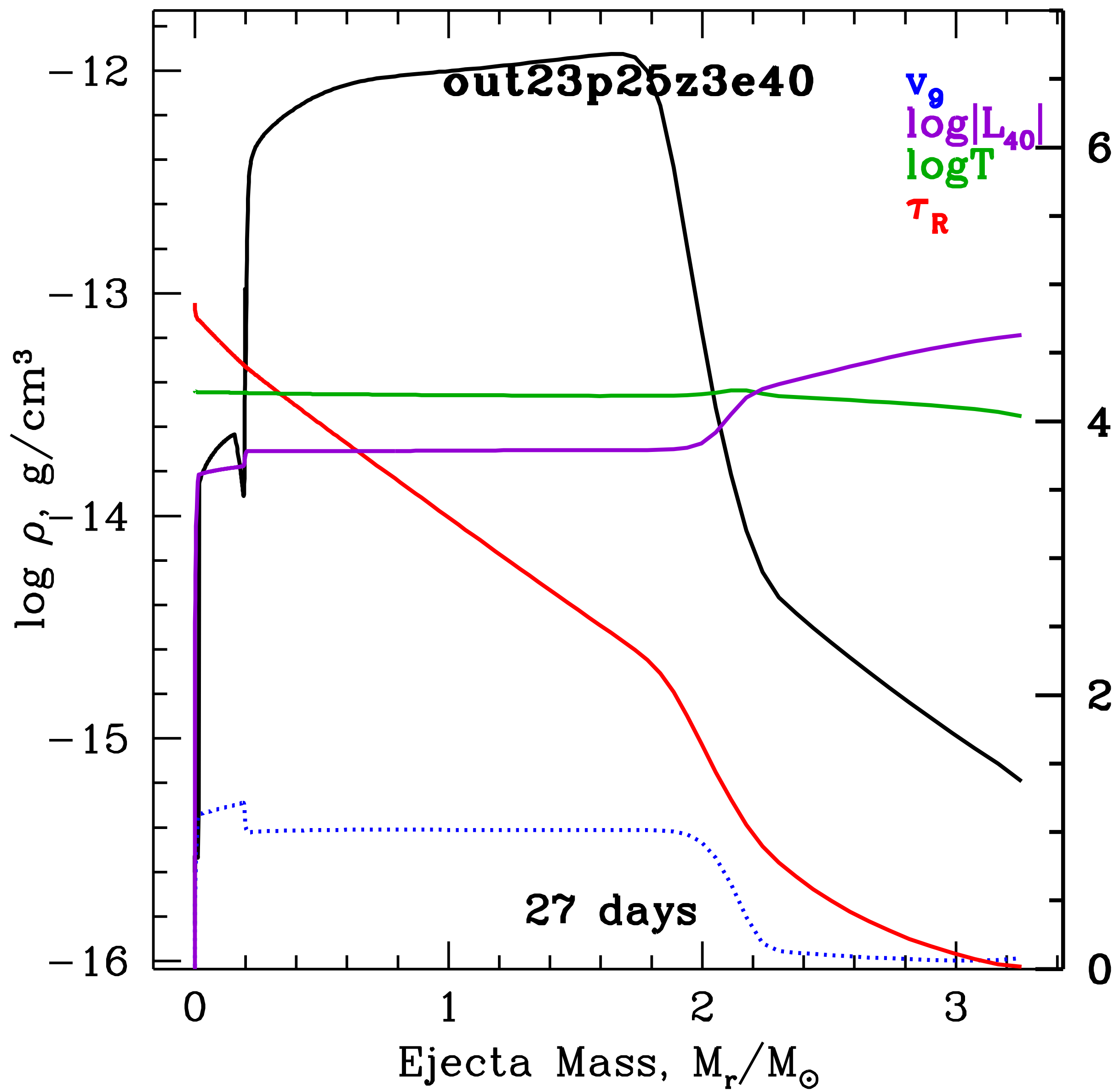

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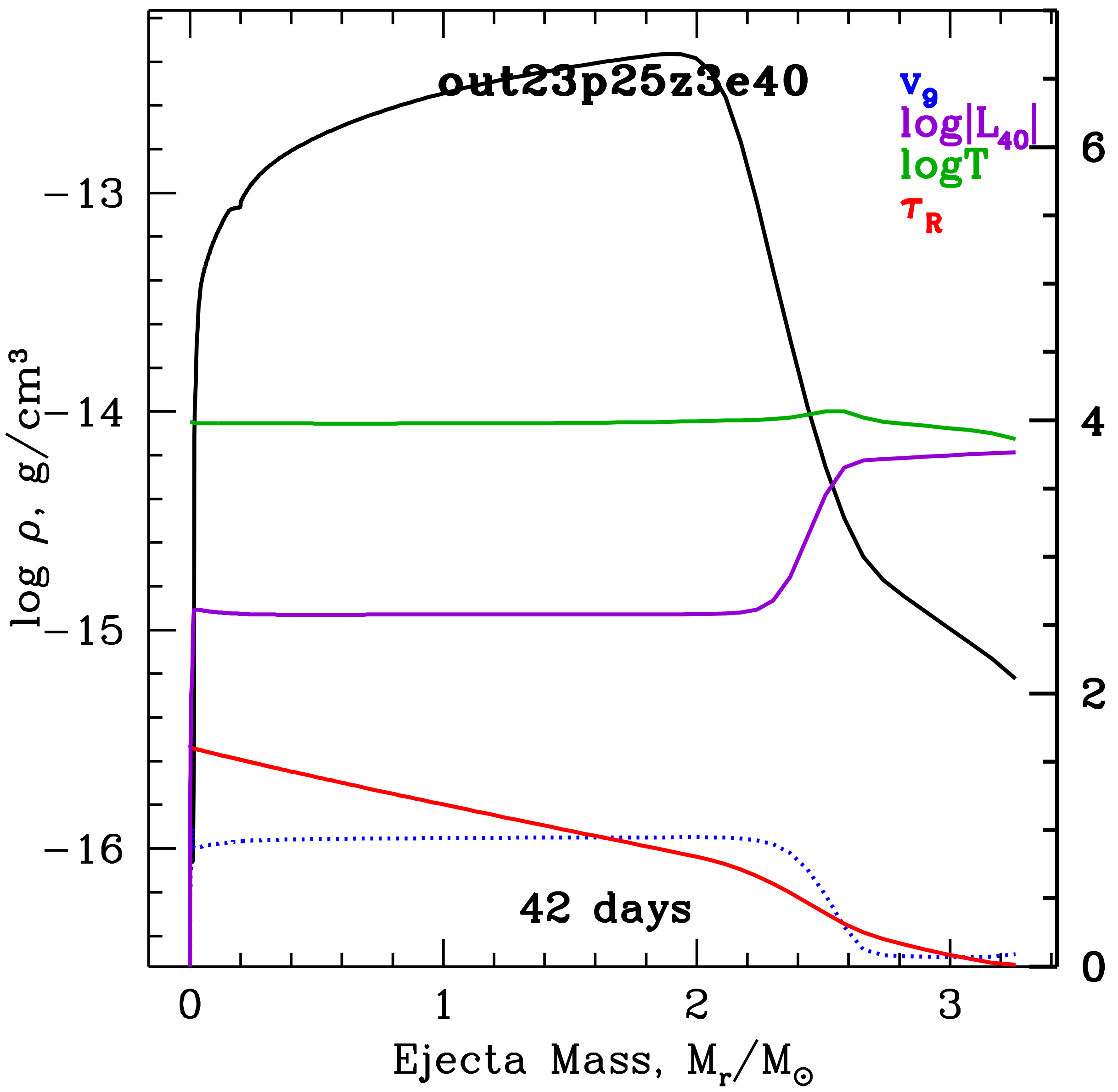

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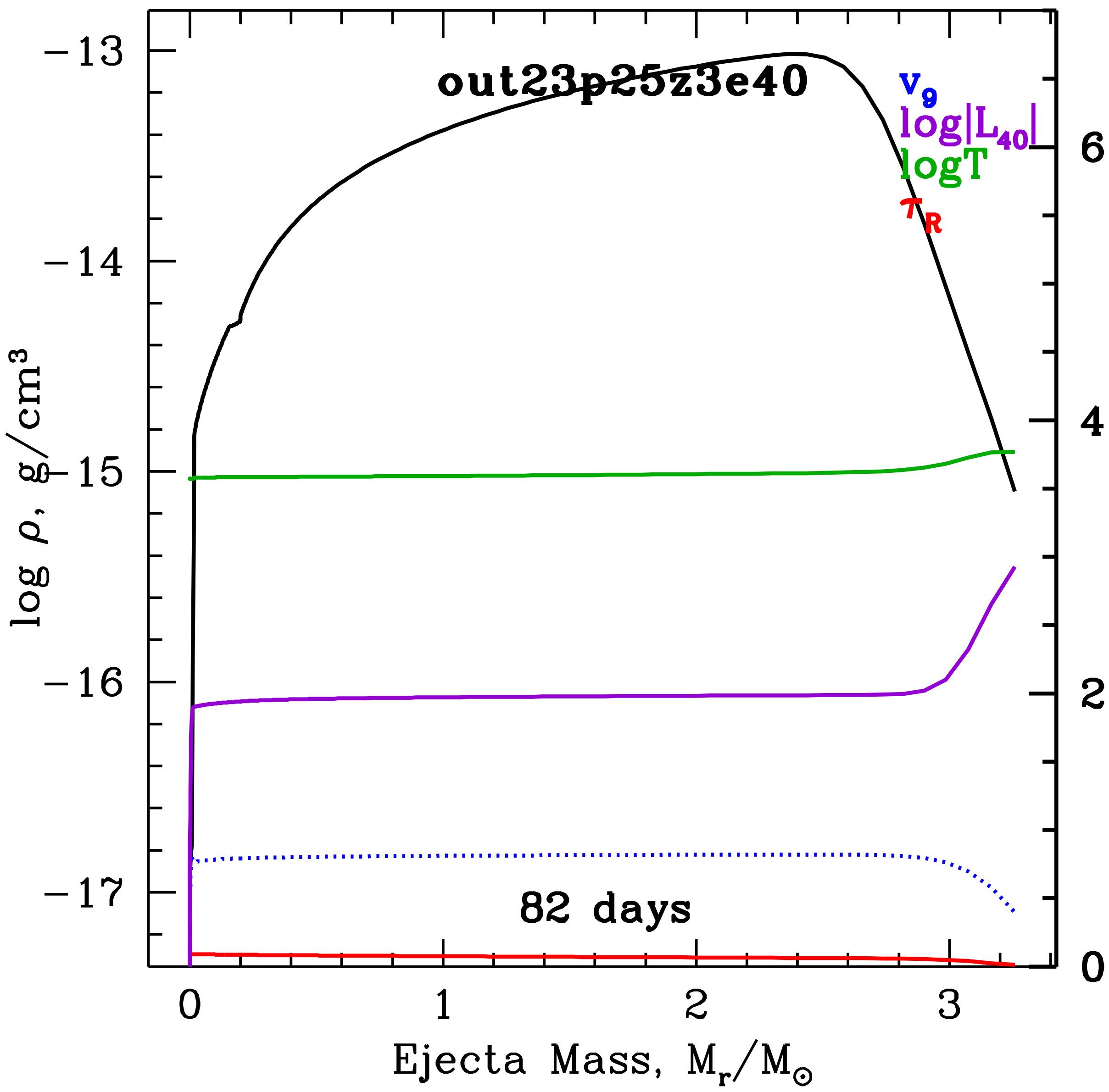
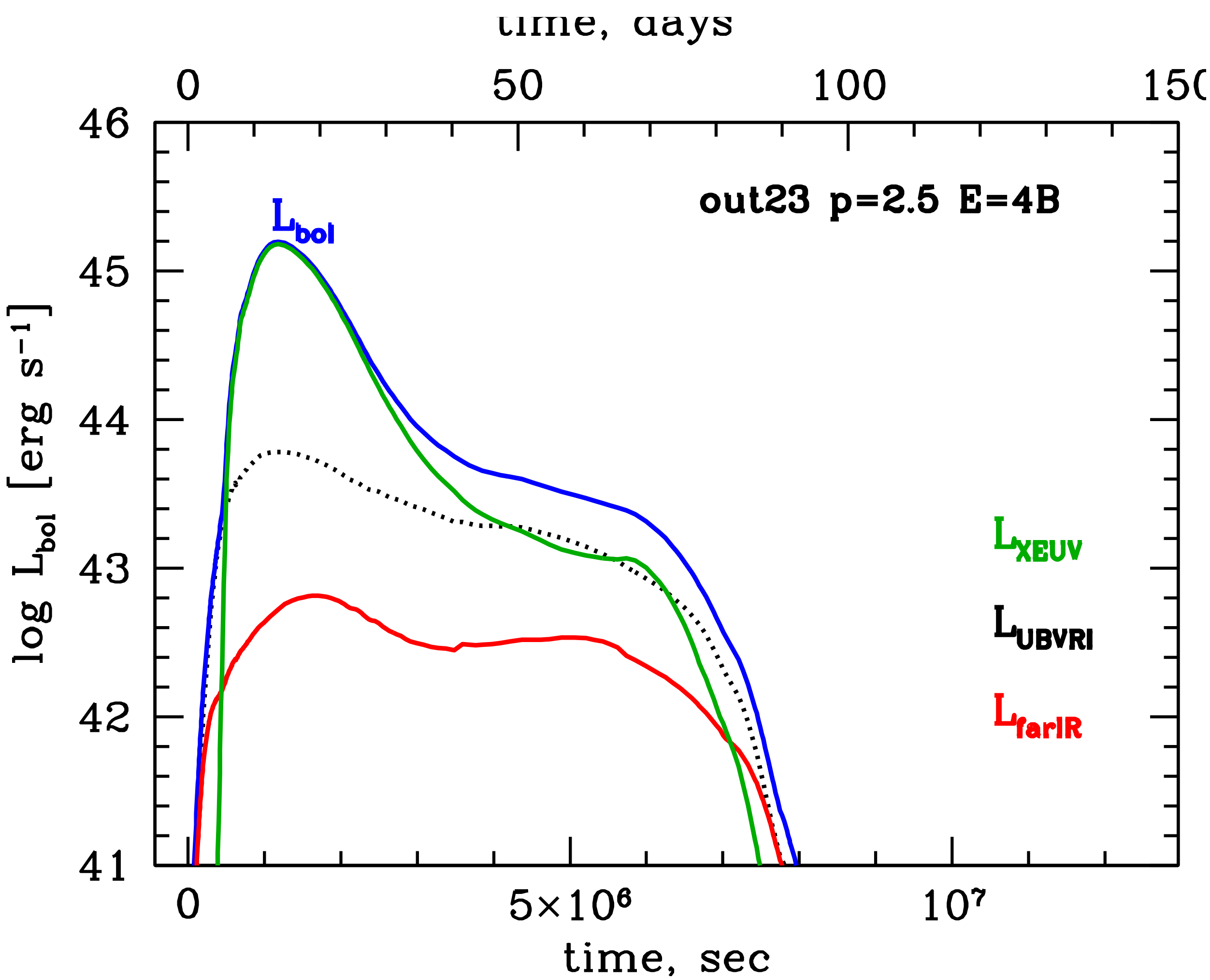


The light curve for the last model



Conclusions

- The shock wave which runs through rather dense matter surrounding an exploding star can produce enough light to explain very luminous SN events. No ^{56}Ni is needed in this case to explain the light curve near maximum light (some amount is of course needed to explain light curve tails).
  We need the explosion energy of only 2-3 Bethe for the shell with $M = 3 - 5M_\odot$ and $R < 10^{16}$cm.
  The brightness and the duration of the light curve maximum strongly depends on the mass and structure of the envelope.

Conclusions

- Questions on the latest phases of star evolution arise:
  - Is it possible to form so big and dense envelopes? And how?
  - Time scale for such a formation
  - How far can the envelope extend?
  - Density and temperature profiles inside the envelope right before the explosion
- Question to observetions: try to find traces of such shells for bright explosions.
  (There are spectral evidence of circumstellar shells for type IIn and Ibn SNe. Is it possible to find C–O envelopes as well?)

Conclusions

- Many technical problems in light curve calculations:
  - line opacities;
  - dimensionality: 3D is preferable, since the envelope can most probably be clumpy;
  - NLTE spectra