"爆発的質量放出を伴った超新星の前兆現象の理解"

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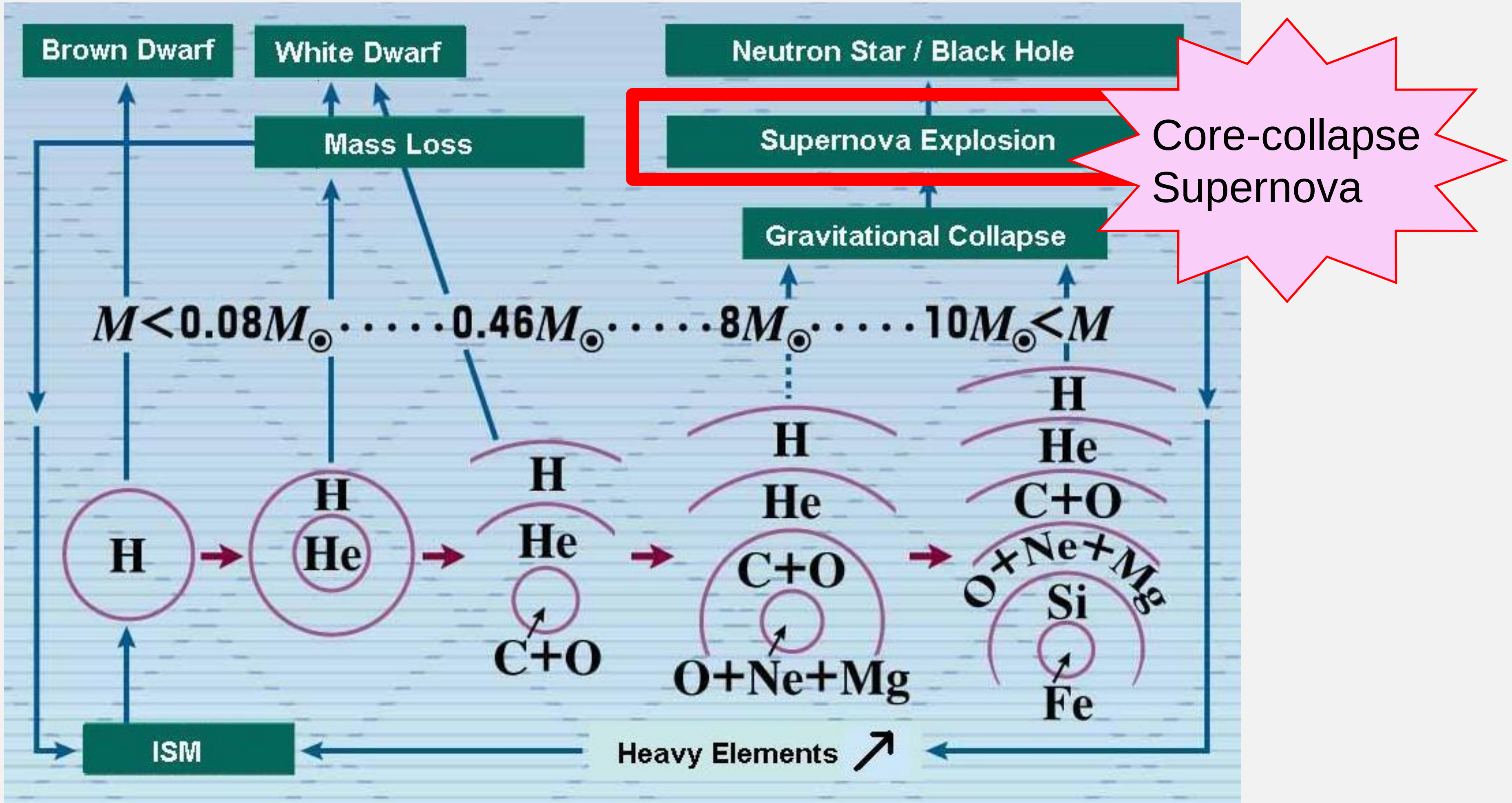
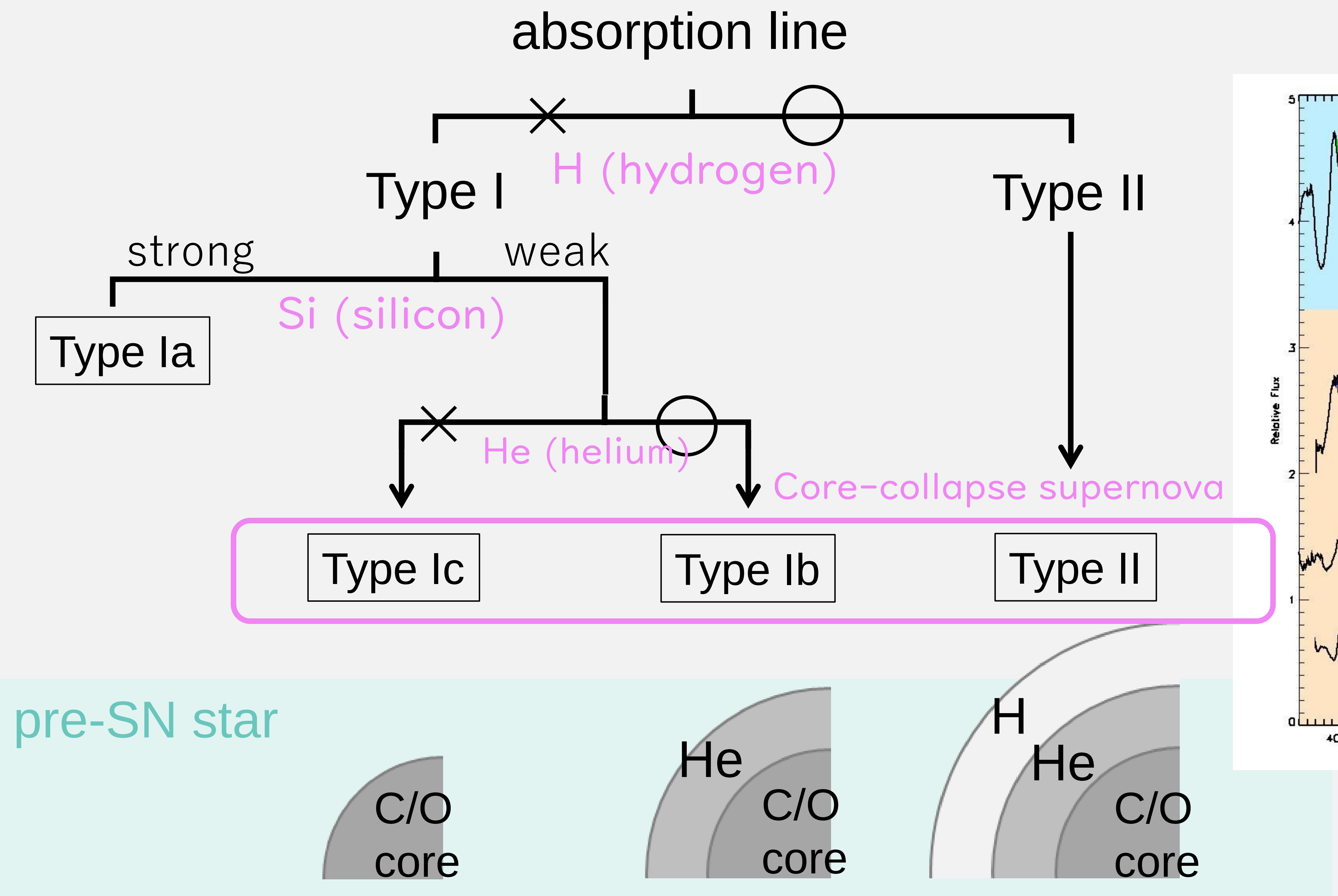
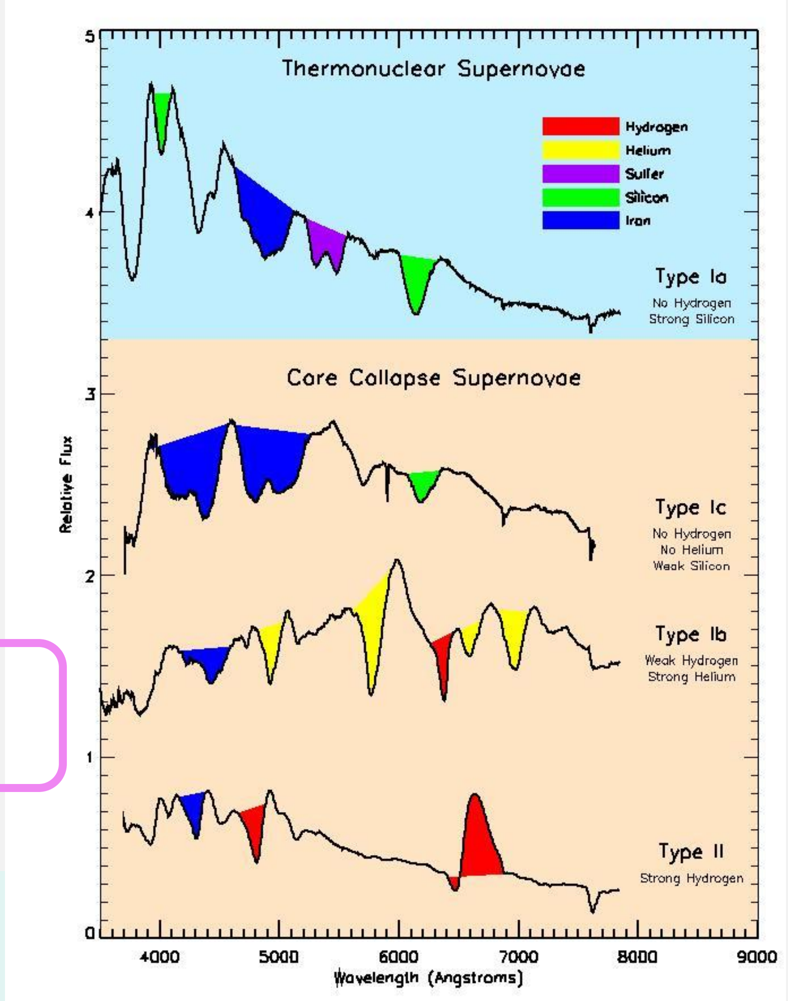
What is the core-collapse supernova ?

Core-collapse supernovae (CCSNe)
occur at the end of the lives of massive stars ($M_{\mathrm{ZAMS}} > 8M_{\odot}$).



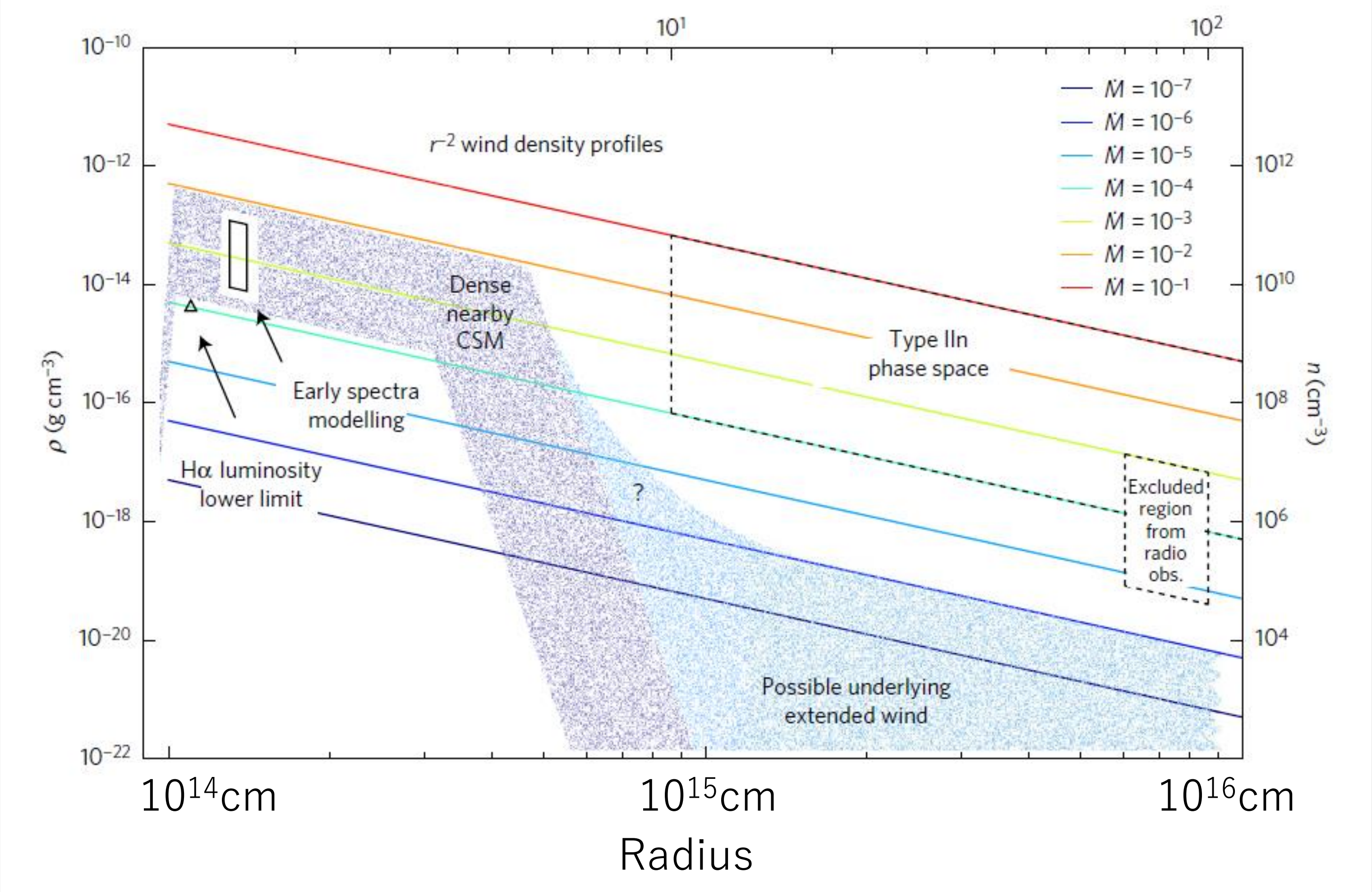
What is the core-collapse supernova ?





Dense-Circumstellar Material surrounding a regular type II Supernova

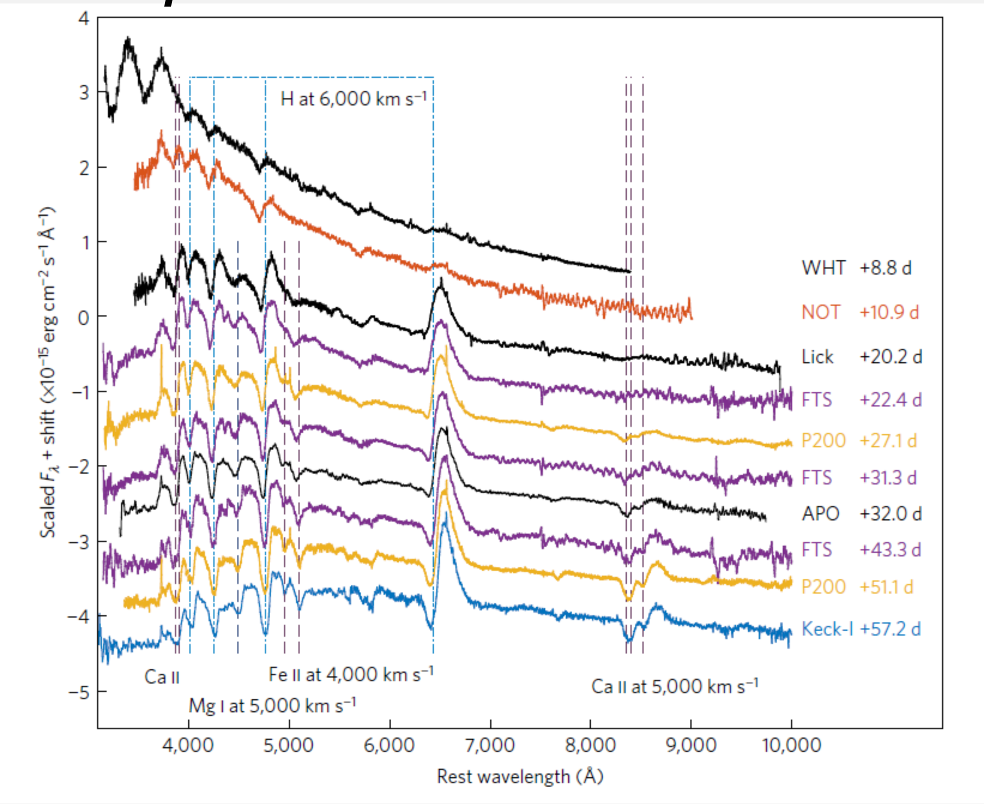
Yaron et al. (2017), Nature



$$\dot{M} = 4\pi\rho v_{\mathrm{esc}} r^2 = \mathrm{const.}$$

$$(v_{\mathrm{esc}} = GM_*/R_*)$$

$$\Rightarrow \rho \propto r^{-2}$$



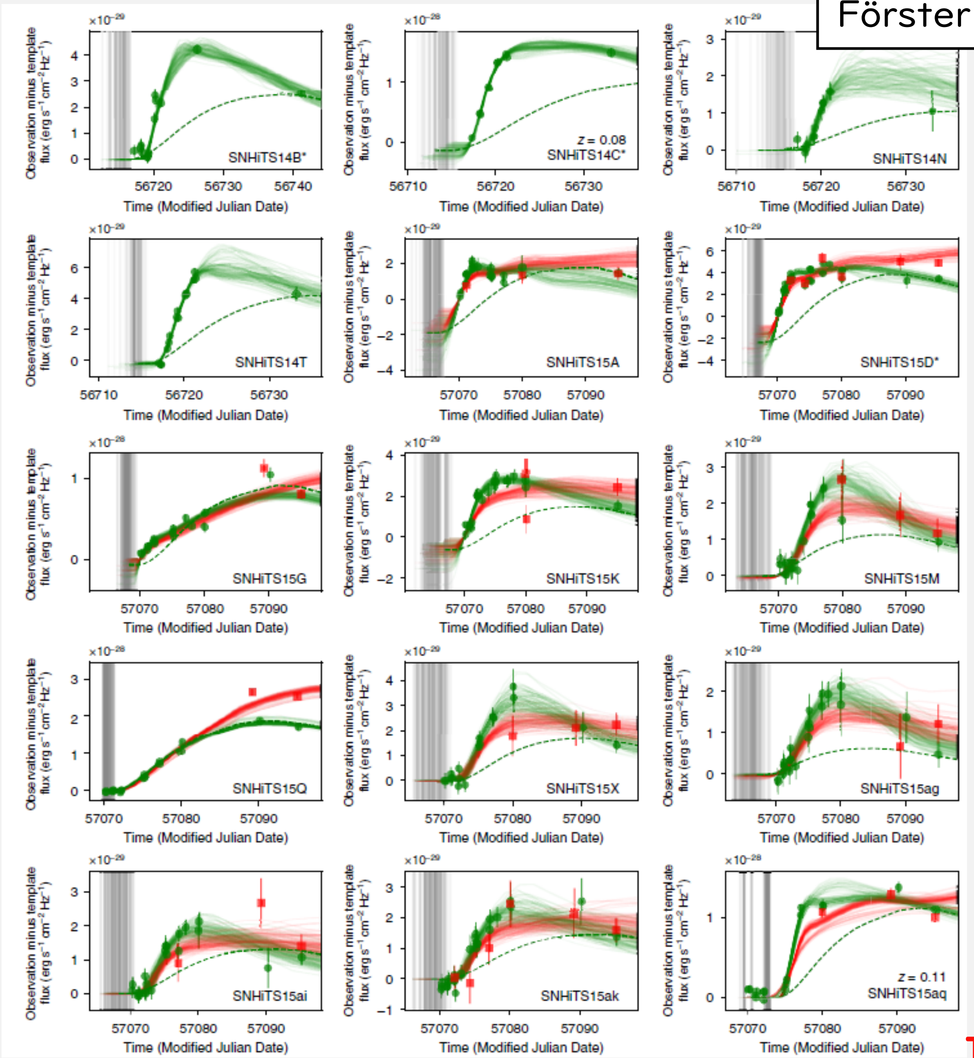
…significant enhancement of the mass-loss before the SN explosion??

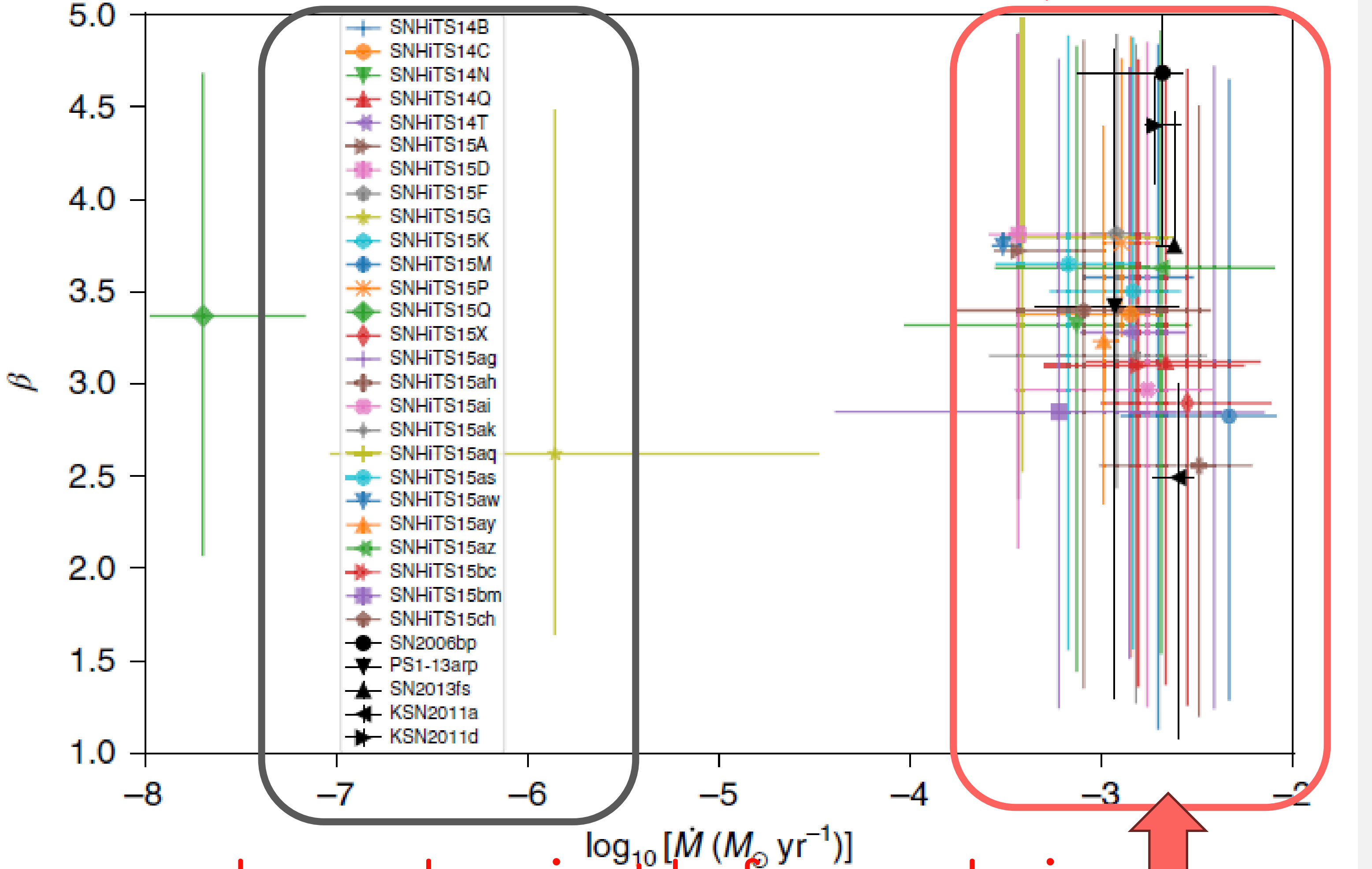
Dense CSM around the progenitor of a supernova?

Förster et al. (2018)

Steady wind of
red super giant star

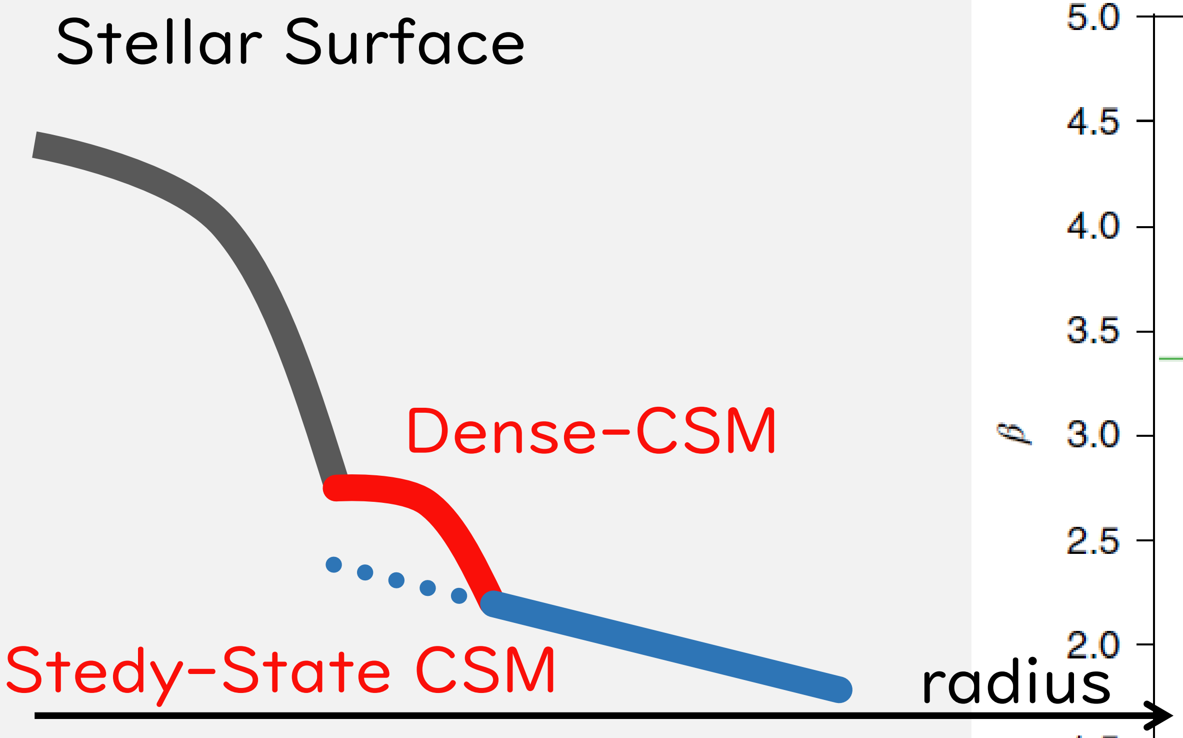
Observation
Implications

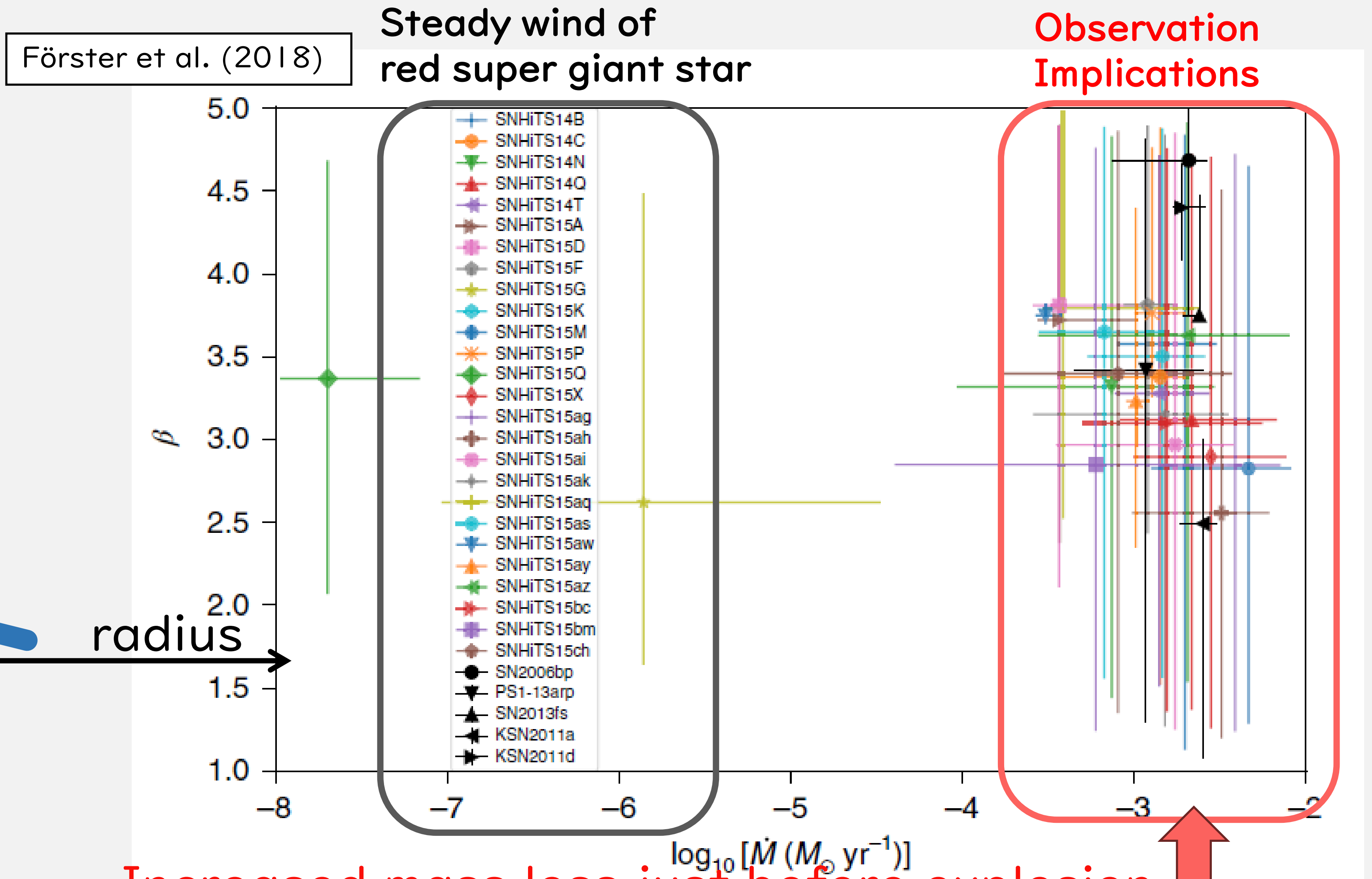




Increased mass loss just before explosion
is not specific, but a universal phenomenon?

Dense CSM around the progenitor of a supernova?

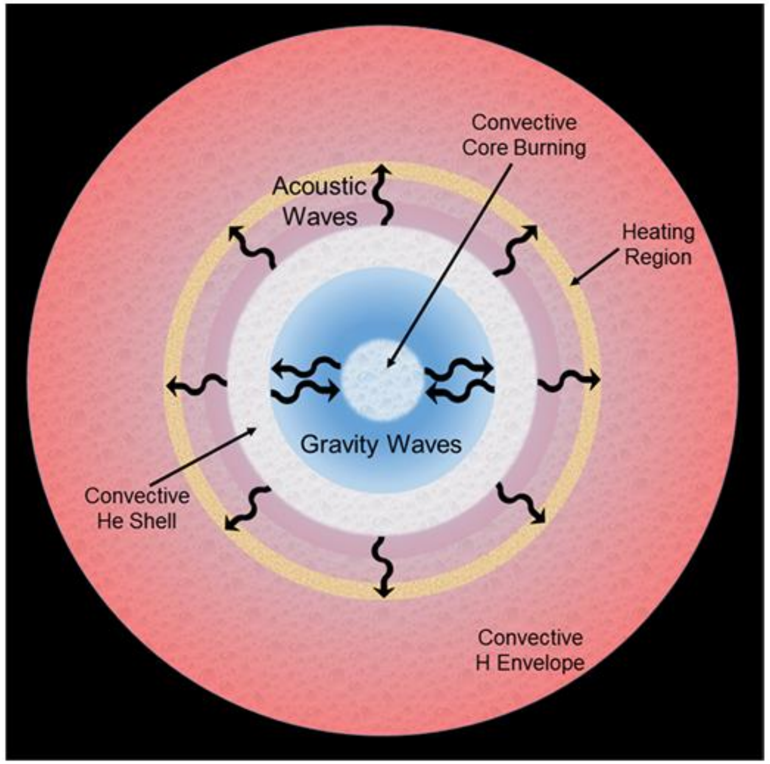




Increased mass loss just before explosion
<u>is not specific, but a universal phenomenon?</u>

Where dose this dense-CSM comes from?

Canonical stellar evolution theories do not expect it



- **Single star origin?**
  - Core Convection
    from Core Burning? Shell Burning?
    (e.g.,gravity wave; Fuller 2017)
  - Phenomenological modeling
    (e.g.,energy injection& LC model)

- **Binary stars origin?**

->How about in a binary stellar evolution process??

Setup of binary stellar evolution

motivation → Can we create this dense-CSM by the binary stellar evolution?

our work

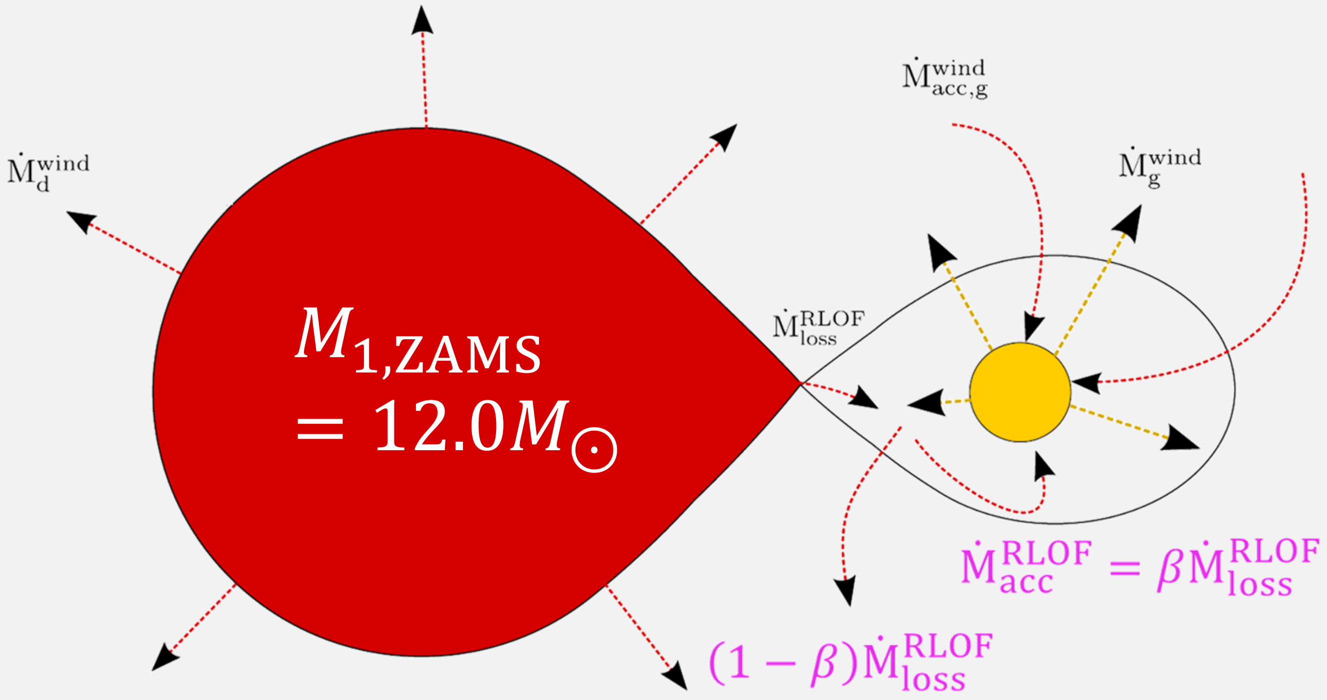
1D stellar simulation by MESA-r15140

- $M_{1,\mathrm{ZAMS}} = 12.0 M_\odot$
- $M_{2,\mathrm{ZAMS}} = 10.8 M_\odot (q = 0.9)$
- initial period

$$P = 1100, 1300, 1500, 1700 [\mathrm{days}]$$

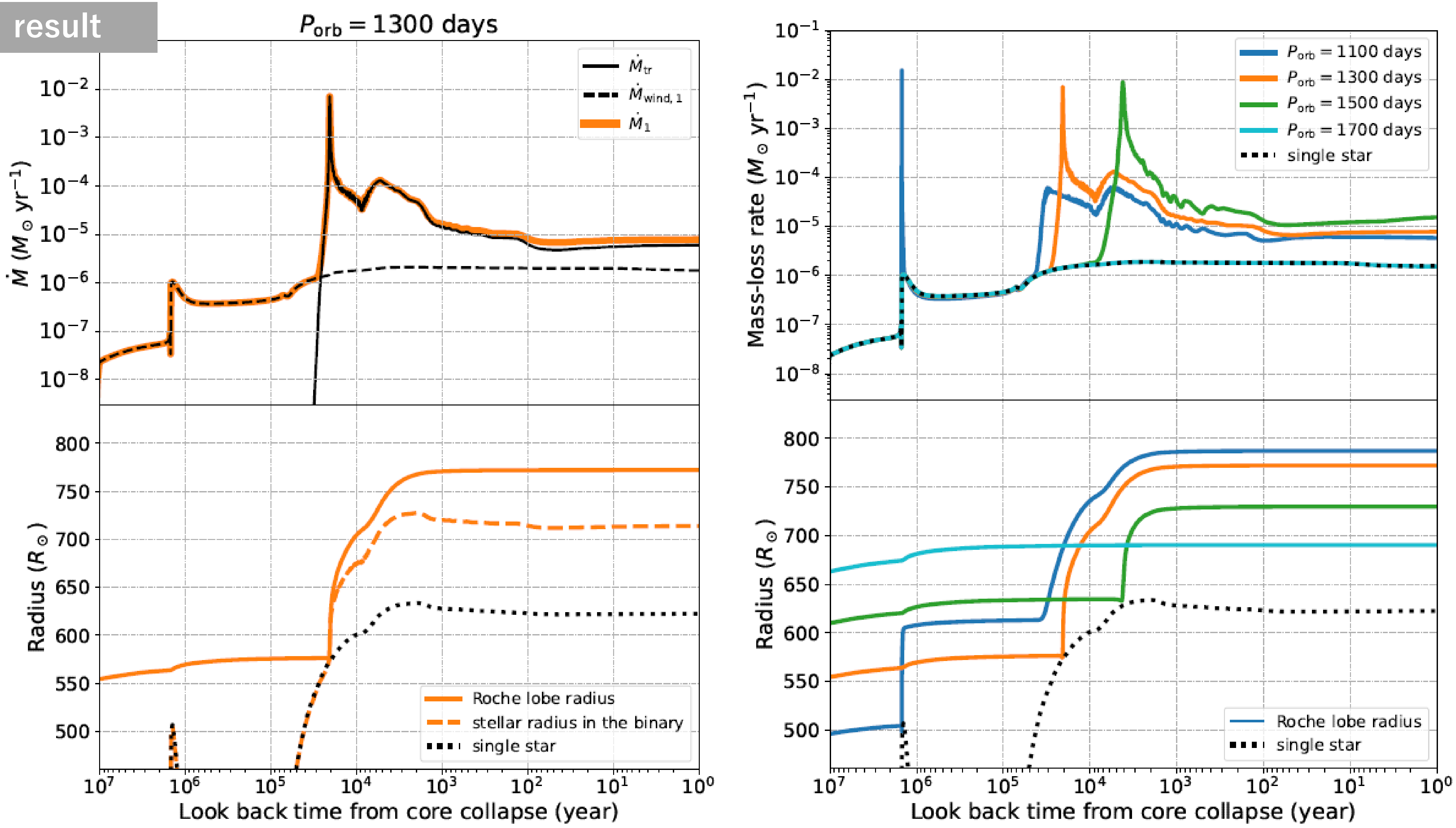
- consider only non-conservative mass transfer

$$\begin{cases} \dot{M}_1 = \dot{M}_{\mathrm{wind},1} + \dot{M}_{\mathrm{loss}}^{\mathrm{RLOF}}, \\ \dot{M}_{\mathrm{CSM}} = \dot{M}_{\mathrm{wind},1} + (1-\beta)\dot{M}_{\mathrm{loss}}^{\mathrm{RLOF}}, \ (\beta = 0.5) \end{cases}$$



mass transfer rate in binary stellar evolution

result



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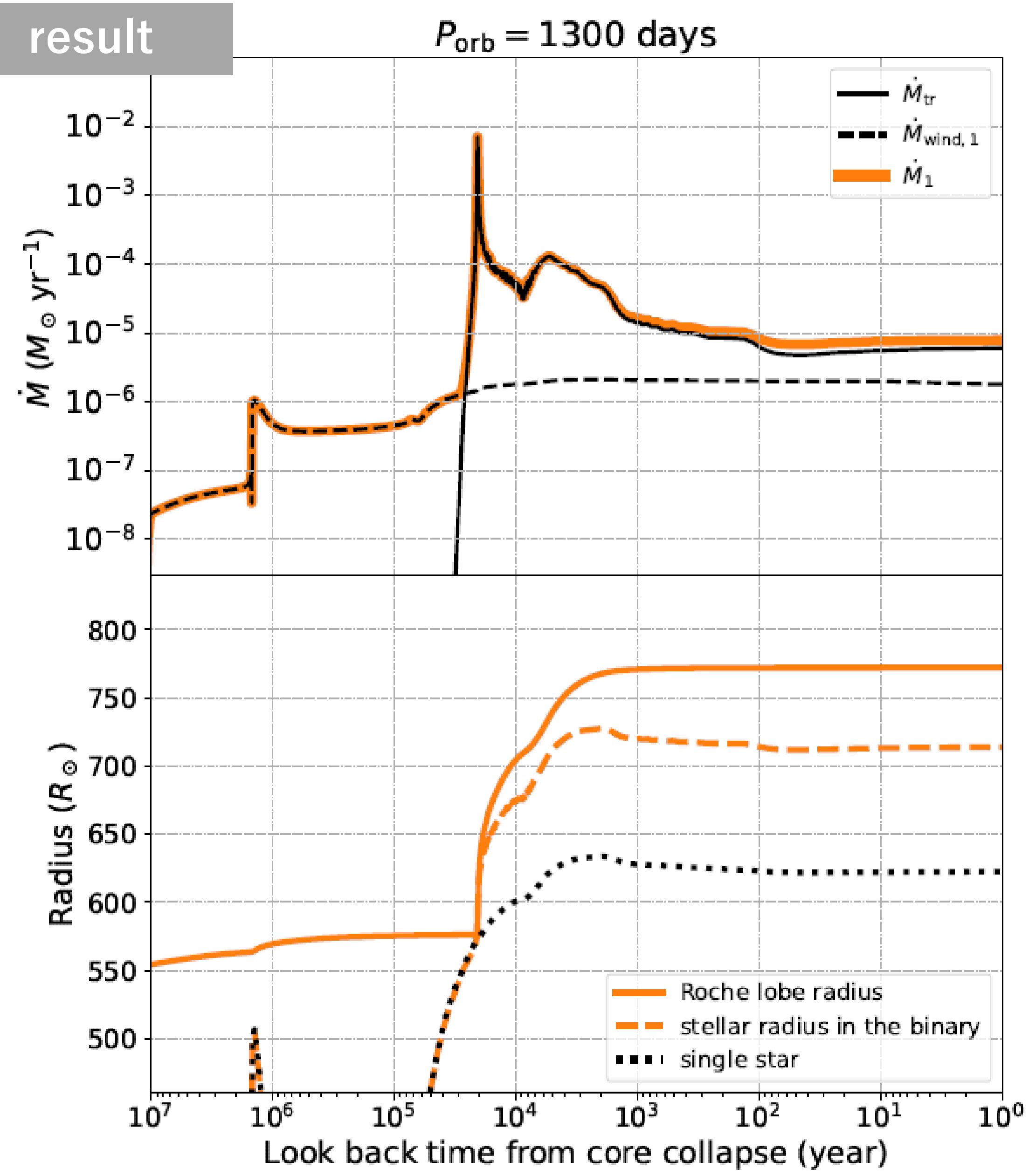

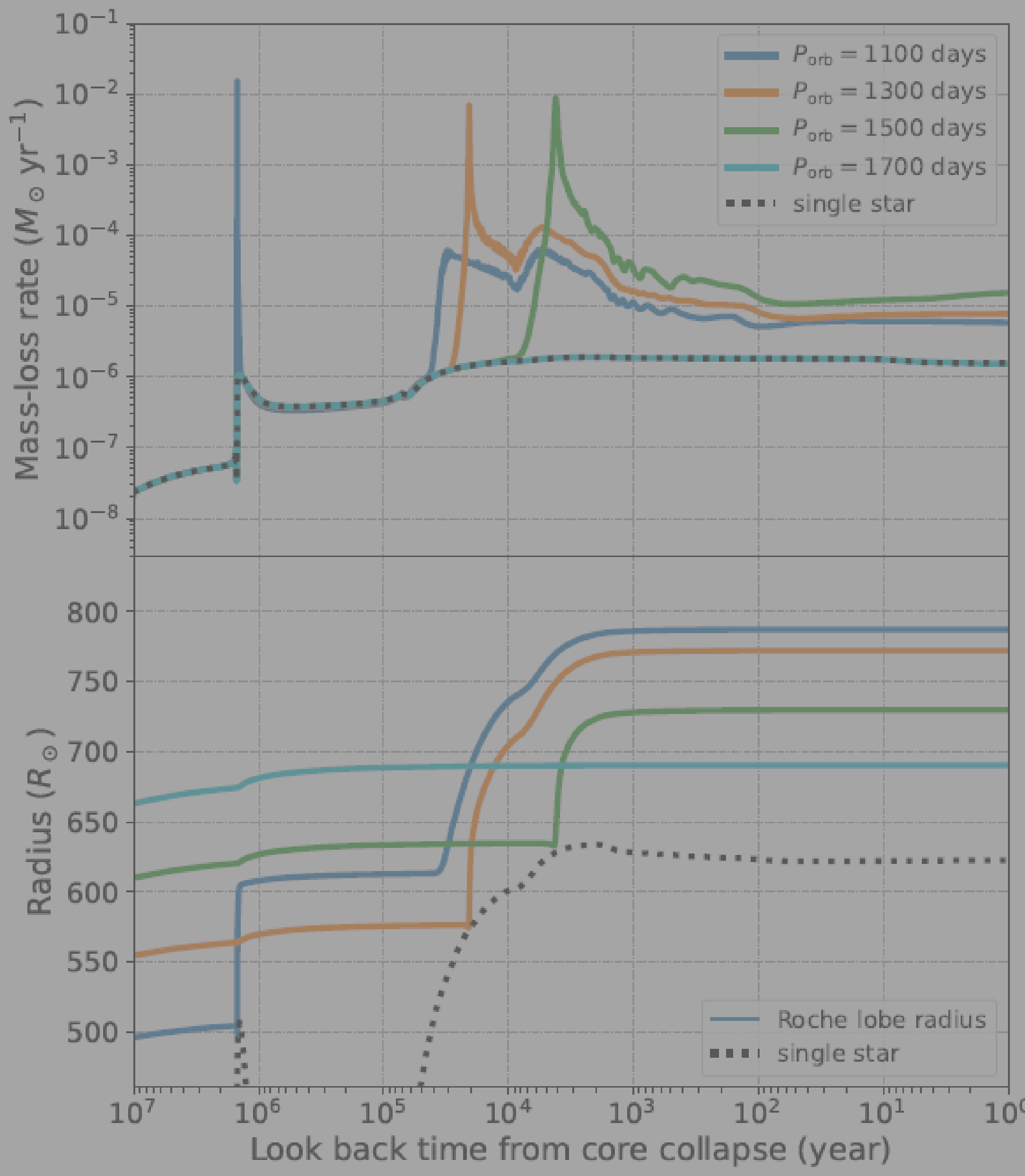

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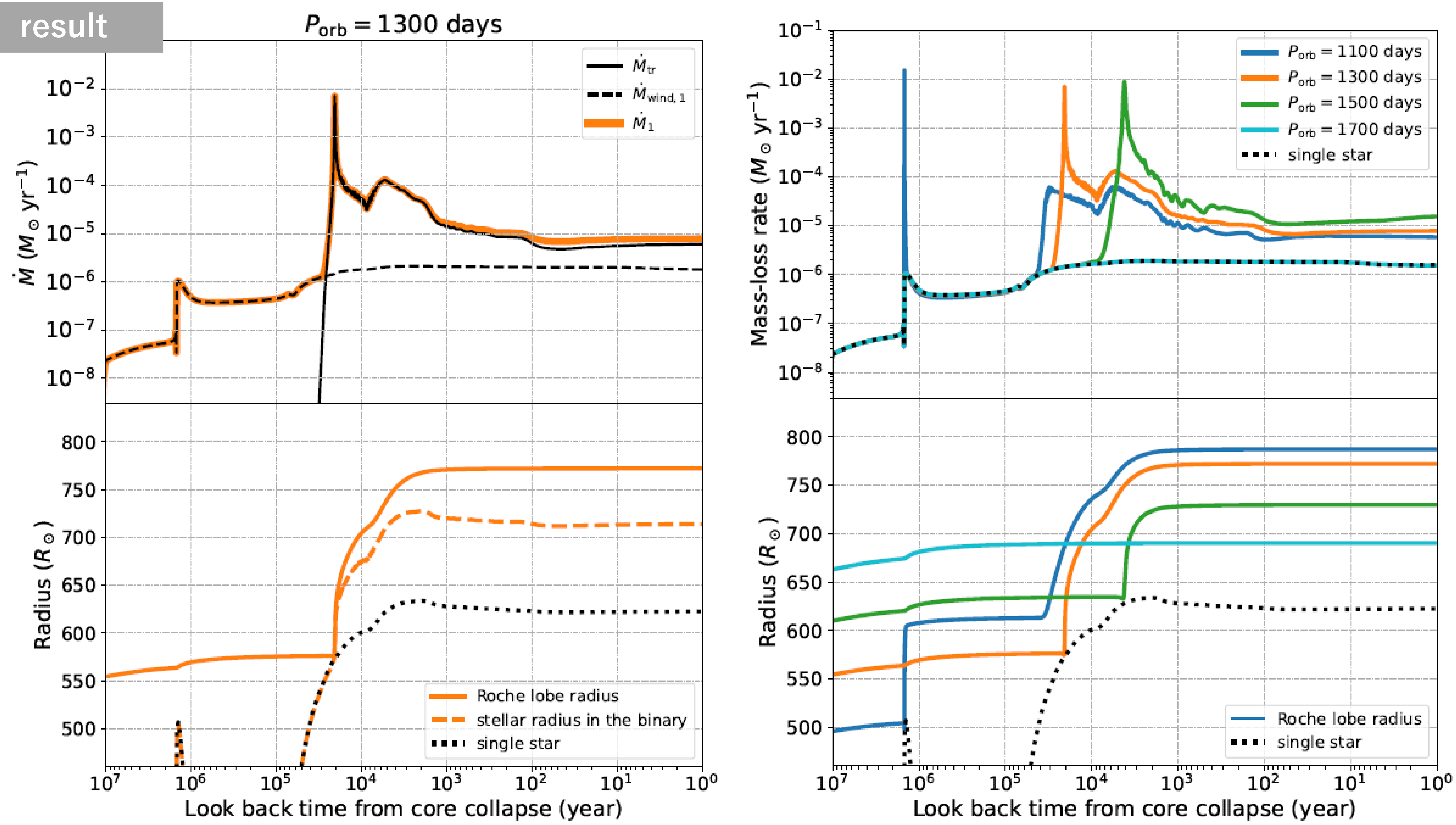


CSM in binary stellar evolution

our work

Next, 1D hydrodynamical simulation

by PLUTO

- **initial profile**:

  isothermal-uniform density ISM

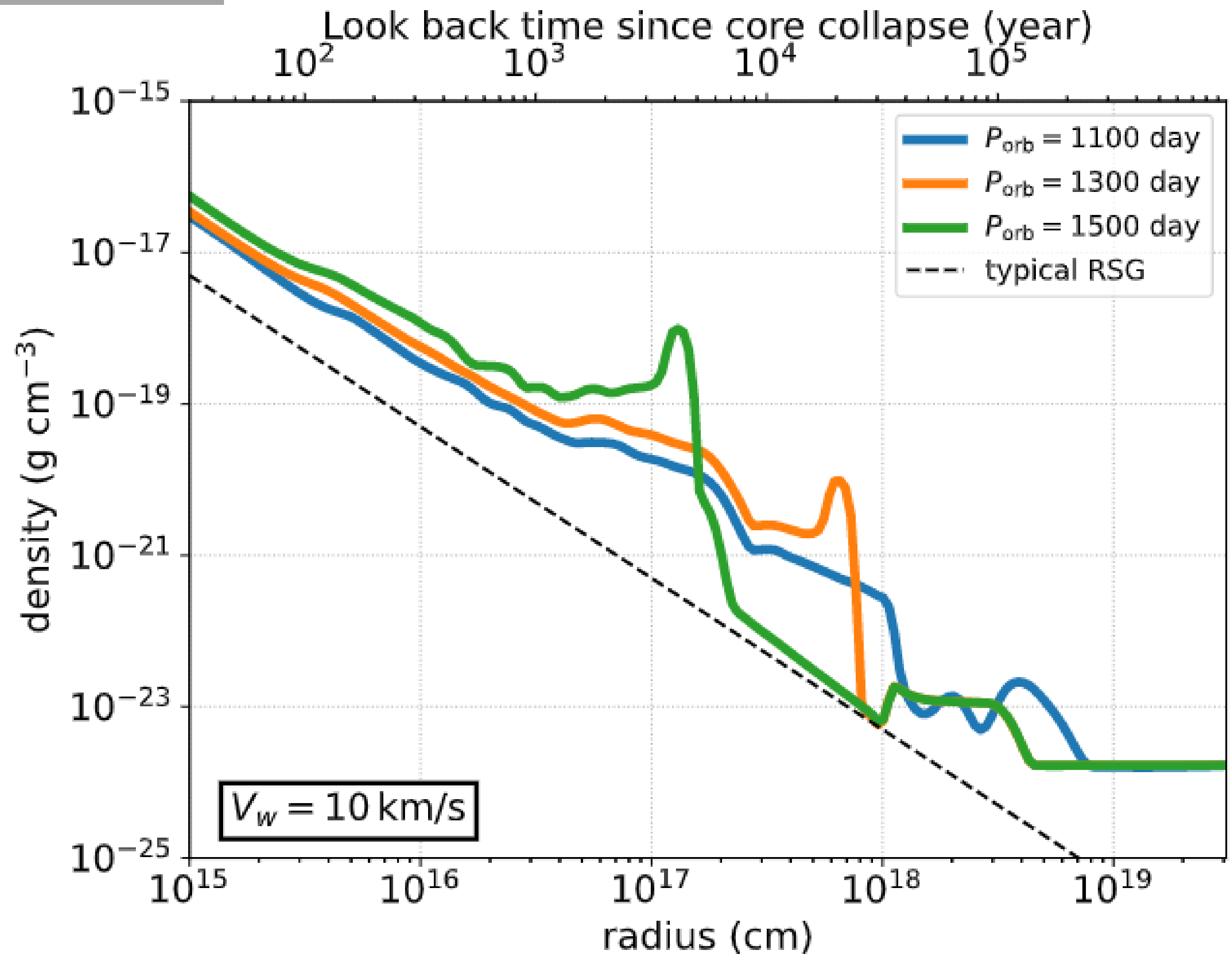
  $\rho = 1.6 \times 10^{-24}$ g cm^{-3}, $T = 10^4$ K

- **inject:** the $\dot{M}_{\rm loss}$ from inner boundary

$$\rho_{\rm inj} = \frac{\dot{M}_1}{4\pi r_{\rm in}^2 v_w},$$

(parametrizing $v_w = 10, 100, 1000$ km/s)

result



CSM in binary stellar evolution

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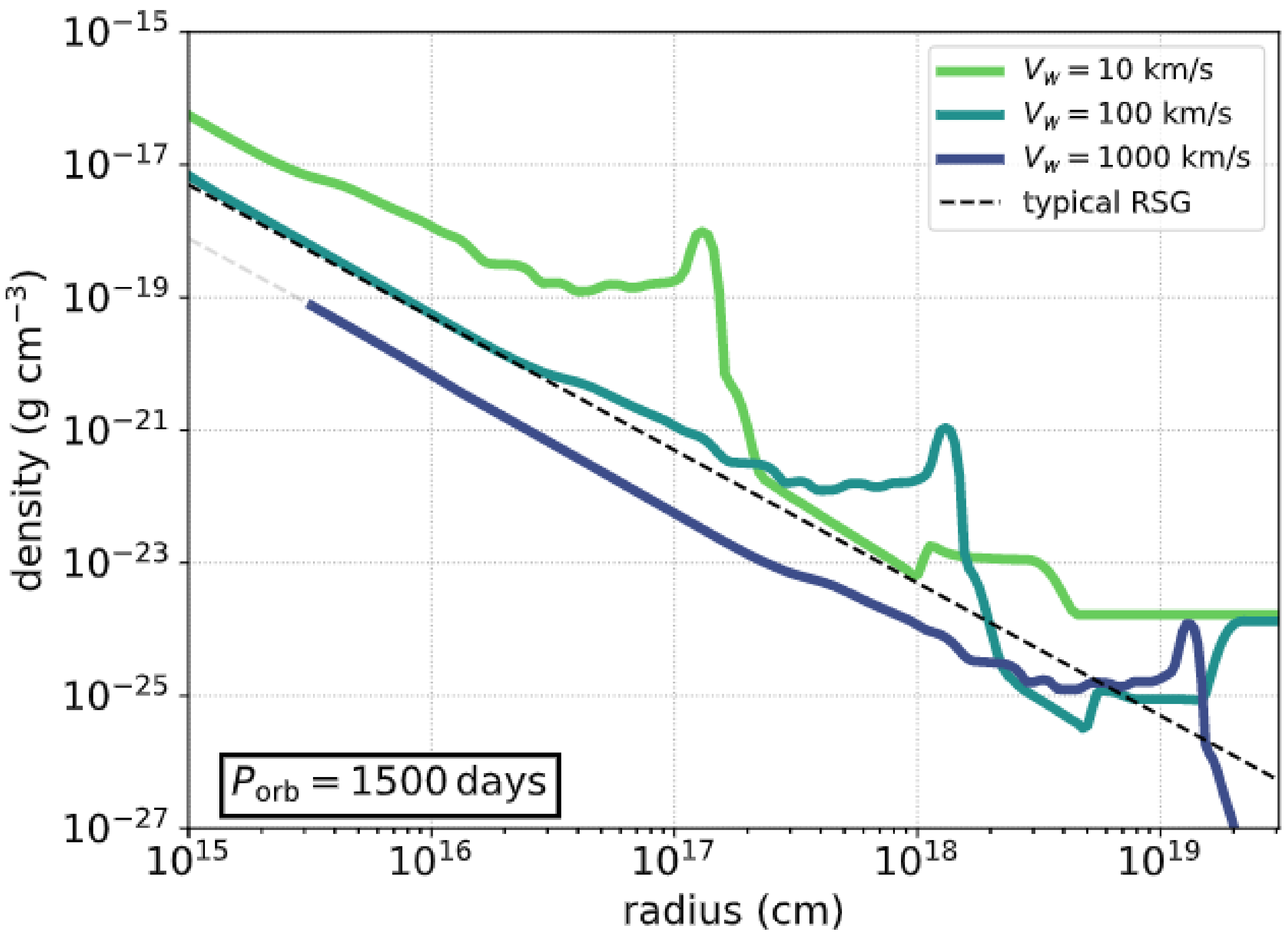

CSM in binary stellar evolution

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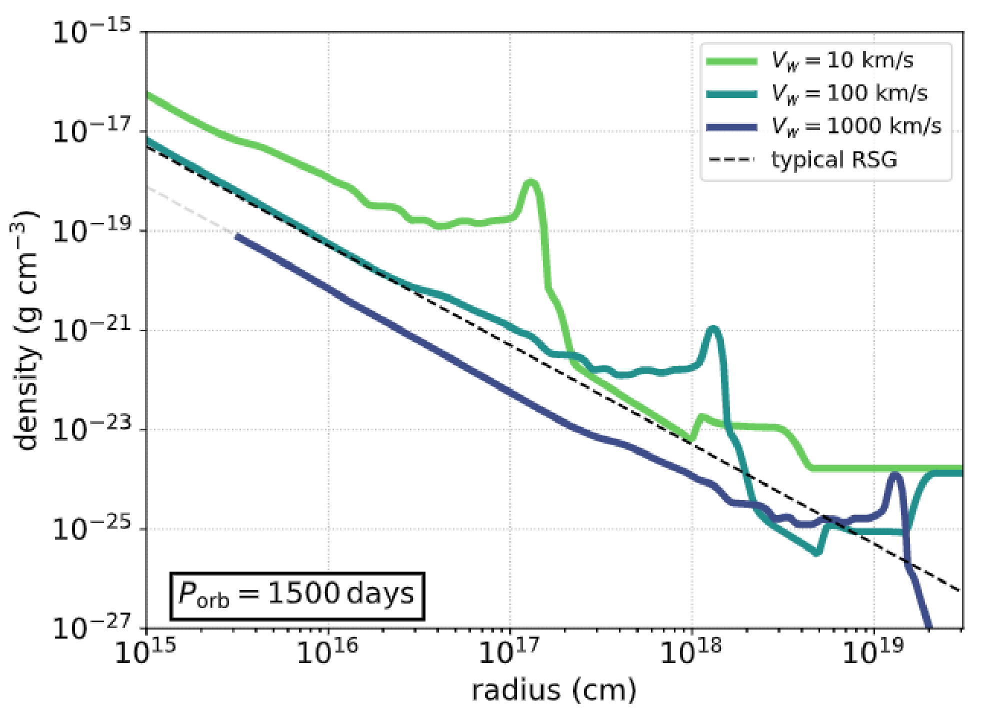
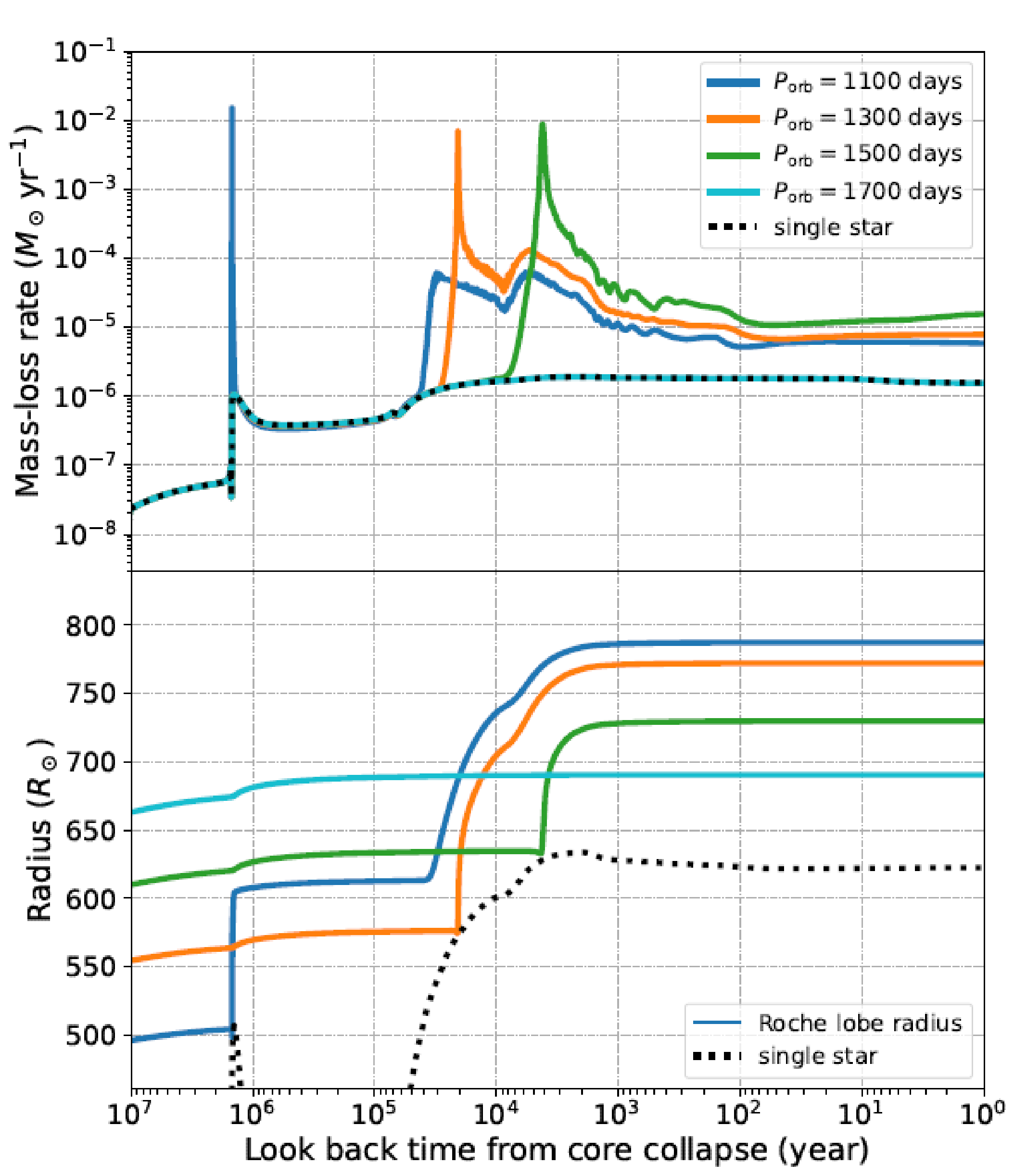




Diagnosis of the origin of enhanced Circumstellar Media around Type Ibc Supernova using multiple MeV/TeV-Neutrinos

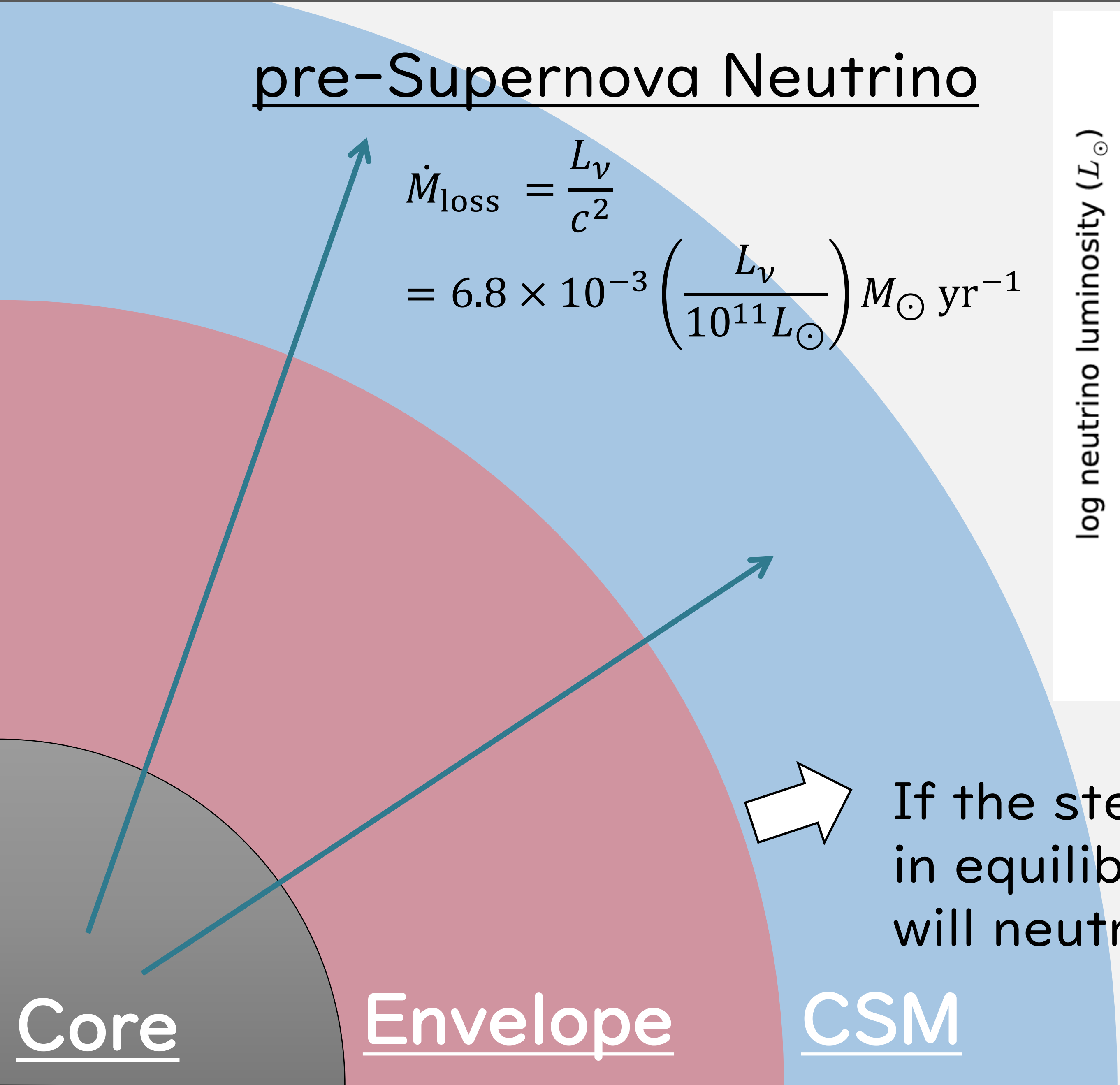
- Ryo Sawada (ICRR, The University of Tokyo)
- Yosuke Ashida (University of Utah)

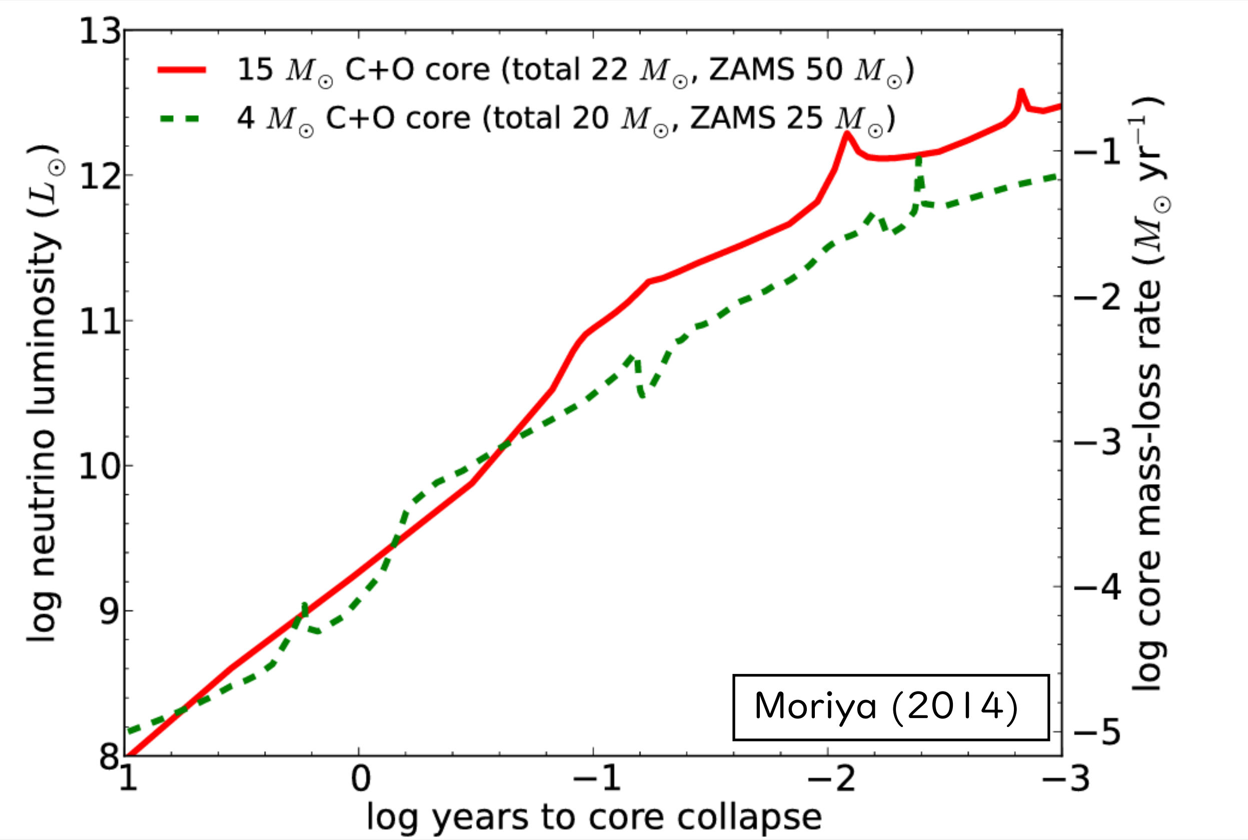
core mass loss due to pre-Supernova Neutrino affected?

pre-Supernova Neutrino

$$\dot{M}_{\rm loss} = \frac{L_\nu}{c^2}$$

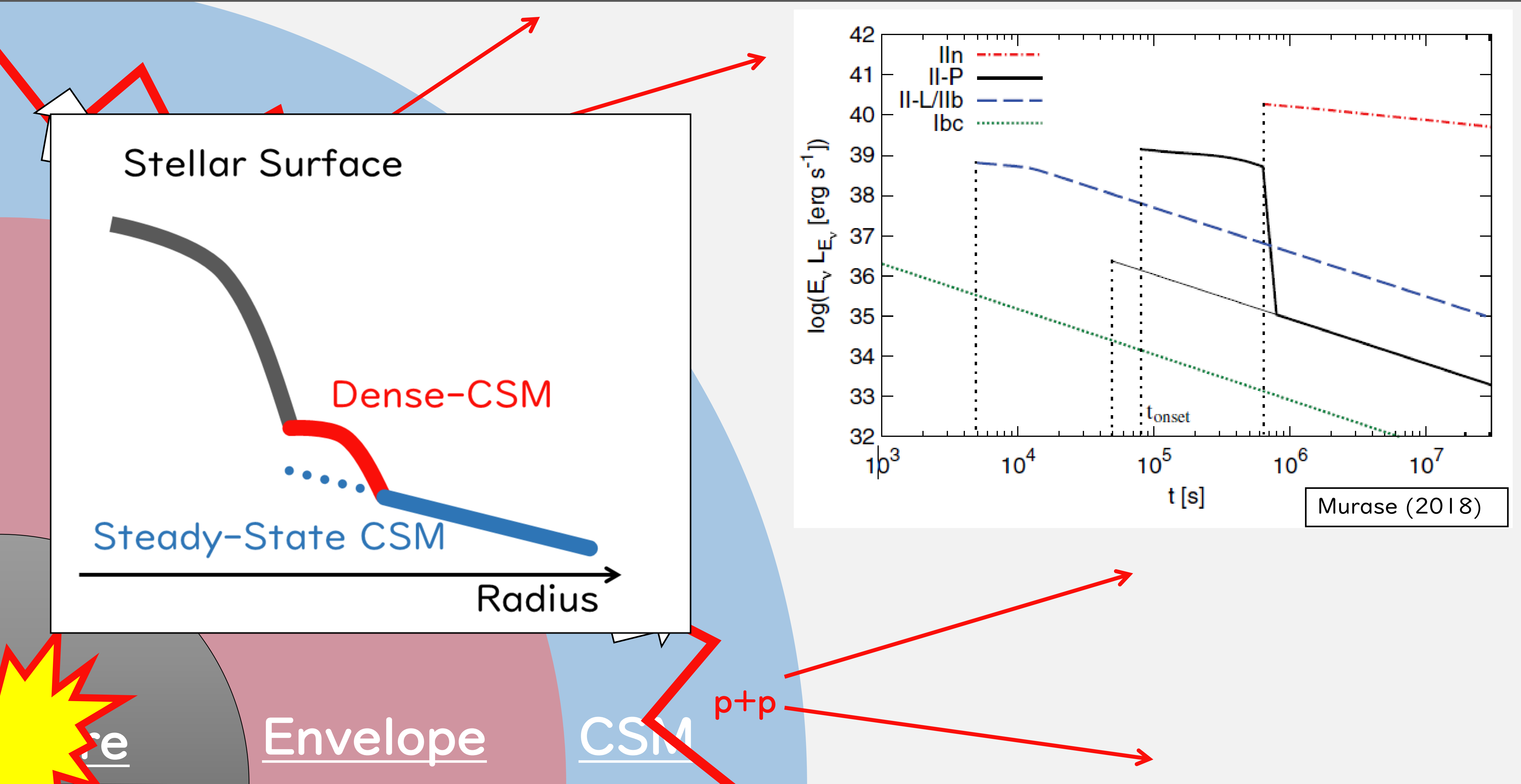
$$= 6.8 \times 10^{-3} \left(\frac{L_\nu}{10^{11} L_\odot} \right) M_\odot \ {\rm yr}^{-1}$$





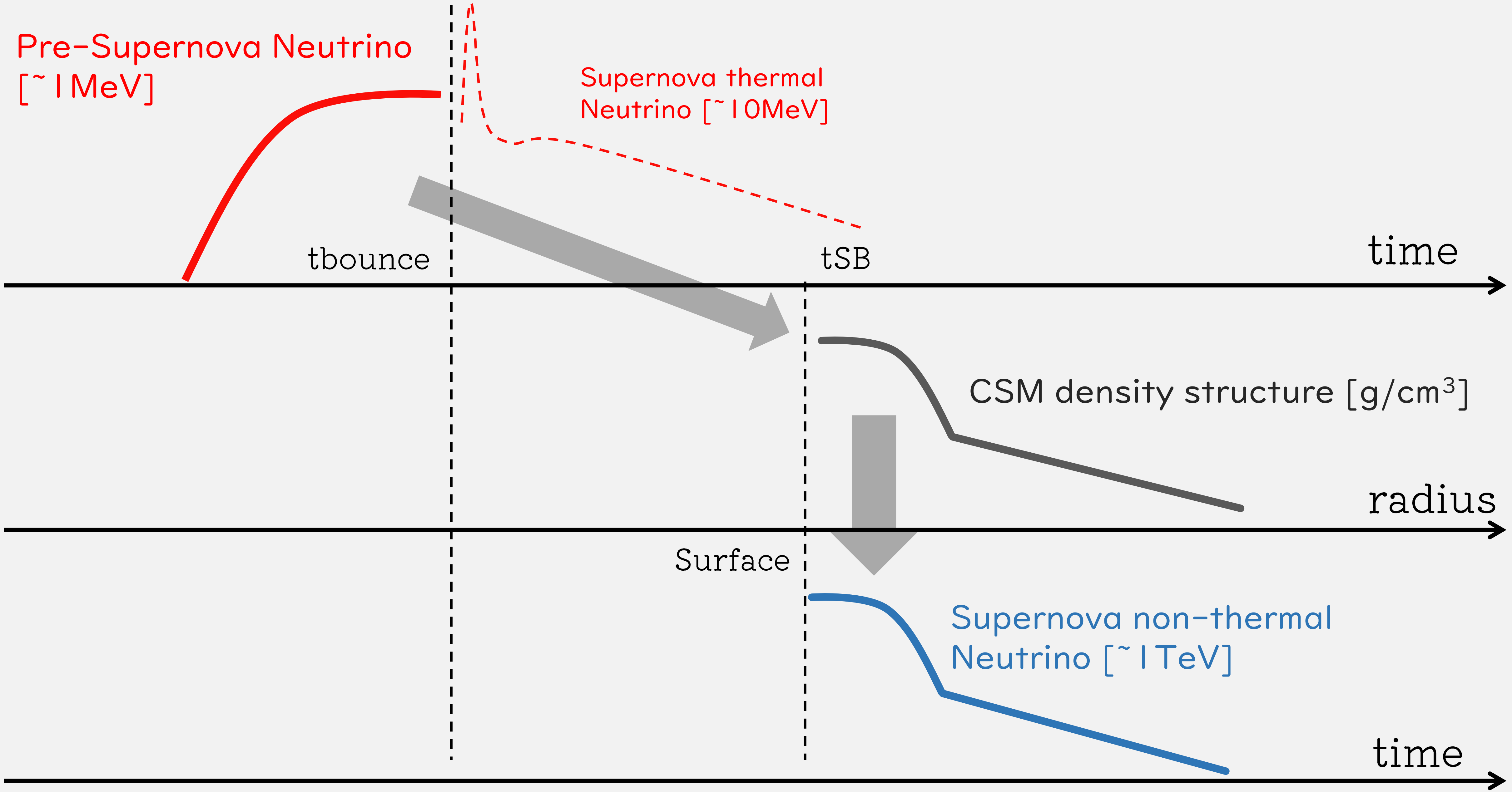
If the stellar surface is
in equilibrium with the Eddington luminosity,
will neutrino radiation create a dense CSM?

Neutrino emission due to SN shock and CSM collisions?



Murase (2018)

Strategy of Diagnosis of CSM with Neutrinos



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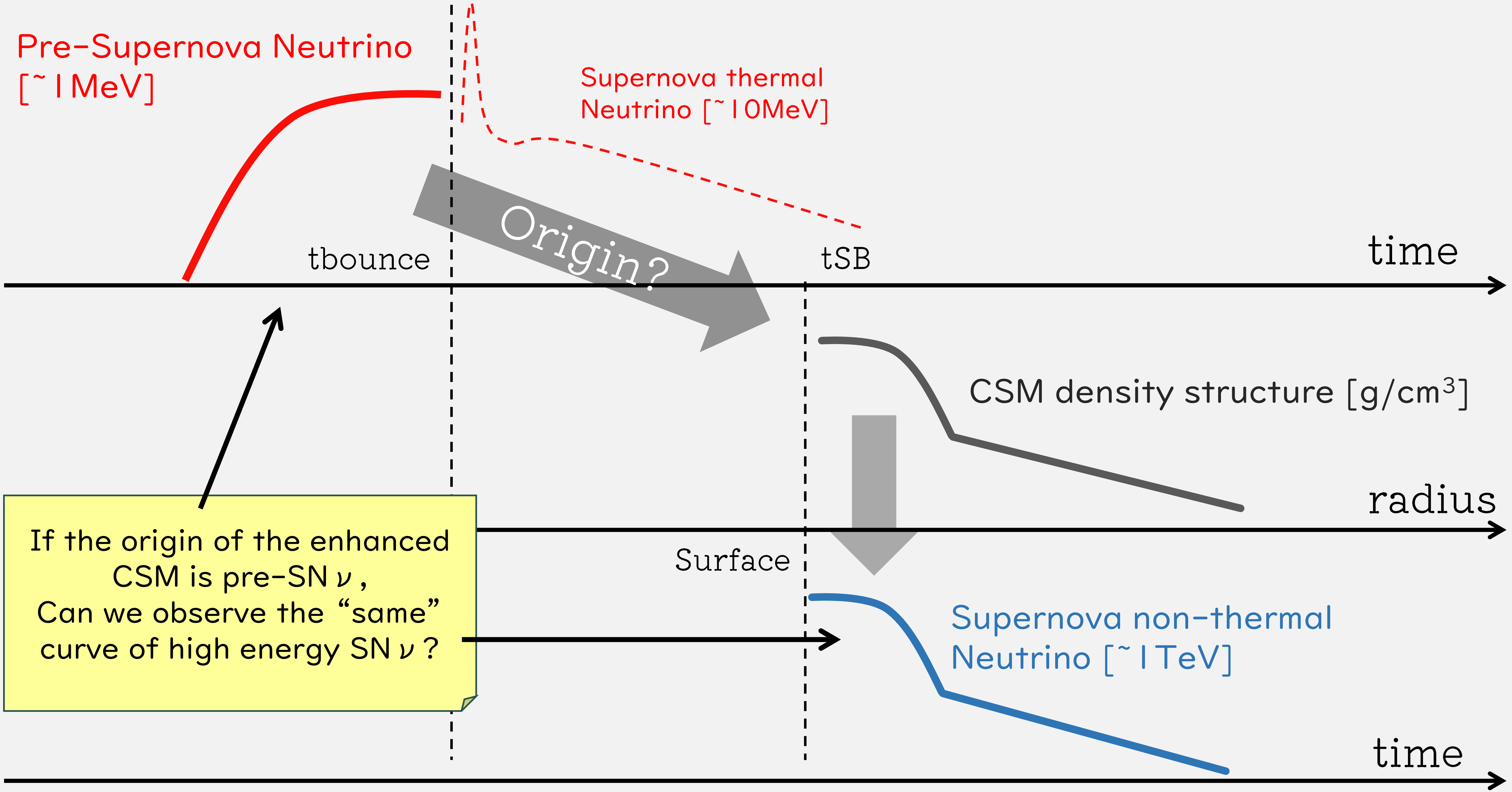


Setup of CSM re-construction & Neutrino emission

Theoretical Model

- Pre-Supernova Neutrino model;
  use Odrzywolek & Heger (2010)

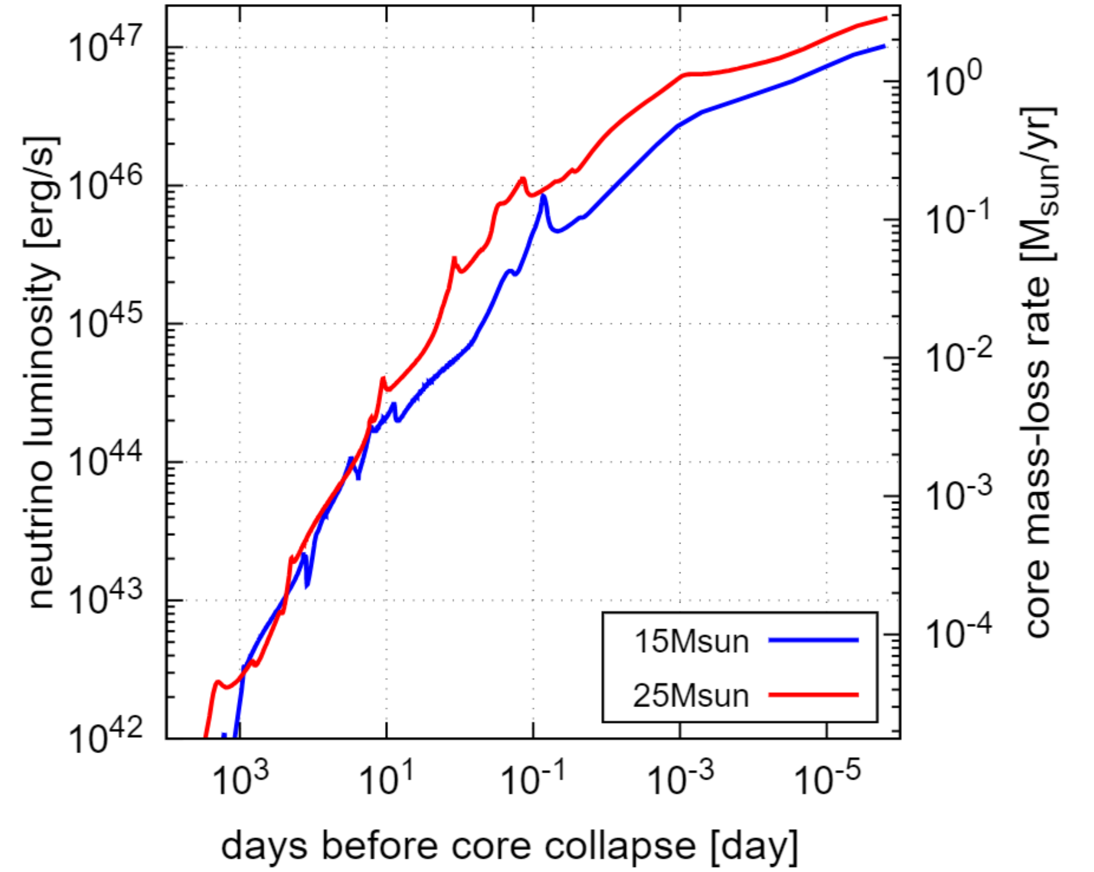
- CSM density structure

$$\dot{M}_w(t) \approx \dot{M}_{w,ss}(t) + L_{\mathrm{pre}-\nu}(t)/c^2$$

$$v_w \sim v_{\mathrm{esc}} = \sqrt{GM_*/R_*}$$

$$\rho_{\mathrm{CSM}}(r,t) \approx \frac{\dot{M}_{w,ss}\left(t - \frac{r - r_{\mathrm{surf}}}{v_w}\right)}{4\pi v_w r^2}$$

- Post High-Energy Neutrino model;
  calculated based on Murase (2018)



Observation Model

- Pre-SN neutrino ; JUNO
- Post-SN neutrino ; HK, IceCube