(Pulsational) Pair Instability SN

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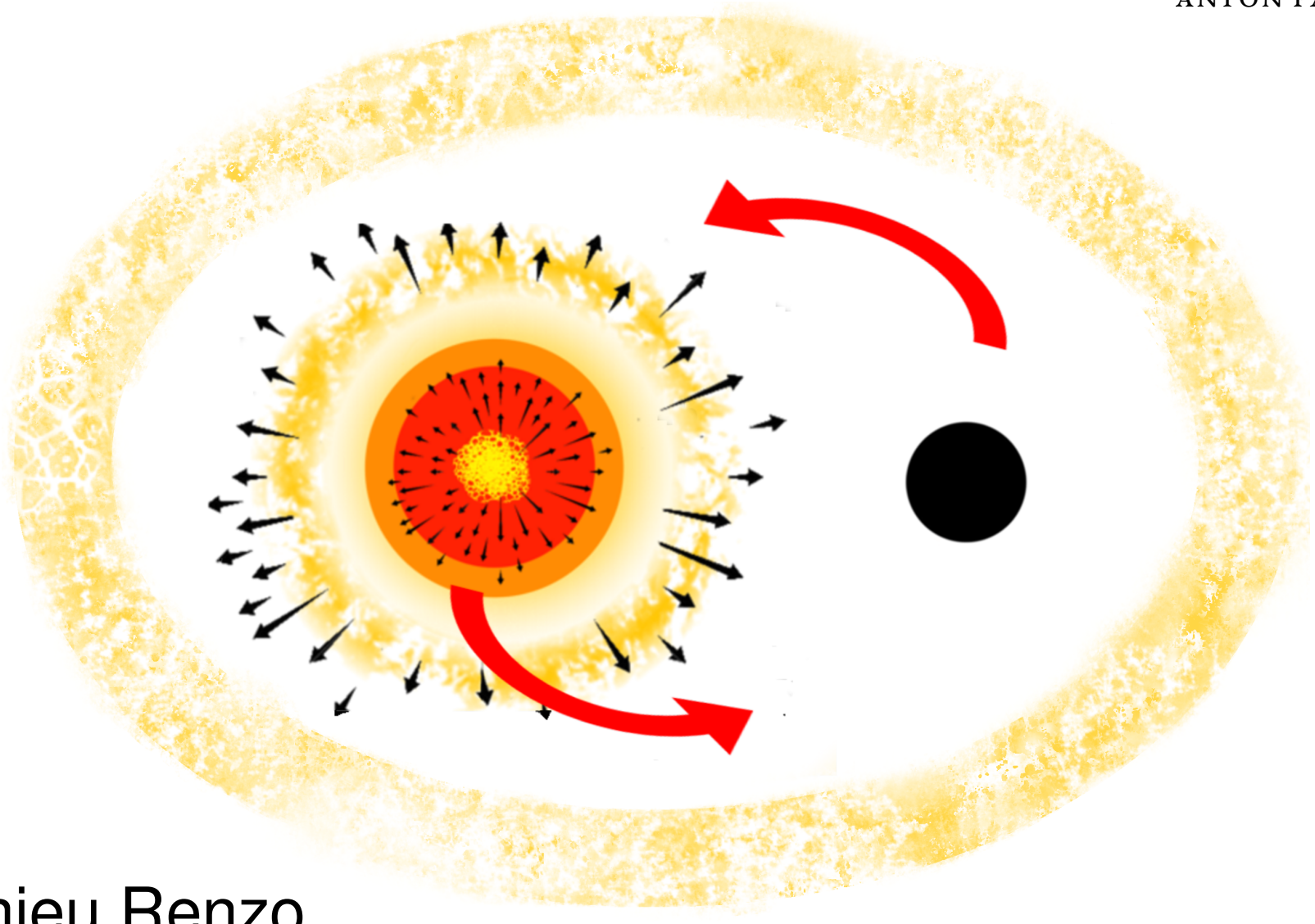

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Bin Cosmos

Late mass loss

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BBH-merger EM counterpart $\Rightarrow$ mass loss needs to be close to 2$^{\text{nd}}$ core-collapse

Observational evidence

- Flash spectroscopy of SNe
  - e.g., Khazov *et al.* 2016
- narrow-lined SNe (Ibn & IIn)
  - e.g., Filippenko 1997,
    Smith 2016
- CSM-powered SLSNe
  - e.g., Chevalier & Fransson 1994,
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- SN-impostors
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- ...

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Theoretical ideas

- Wave driven mass loss
  - e.g., Shiode & Quataert 2014,
    Fuller *et al.* 2017
- Pulsational pair instability + Core collapse
  - e.g., Barkat *et al.* 1967,
    Chatzopoulos & Wheeler 2012,
    Woosley 2017
- ...

Different behaviors with $M_{\rm ZAMS}$ and/or $M_{\rm He}$

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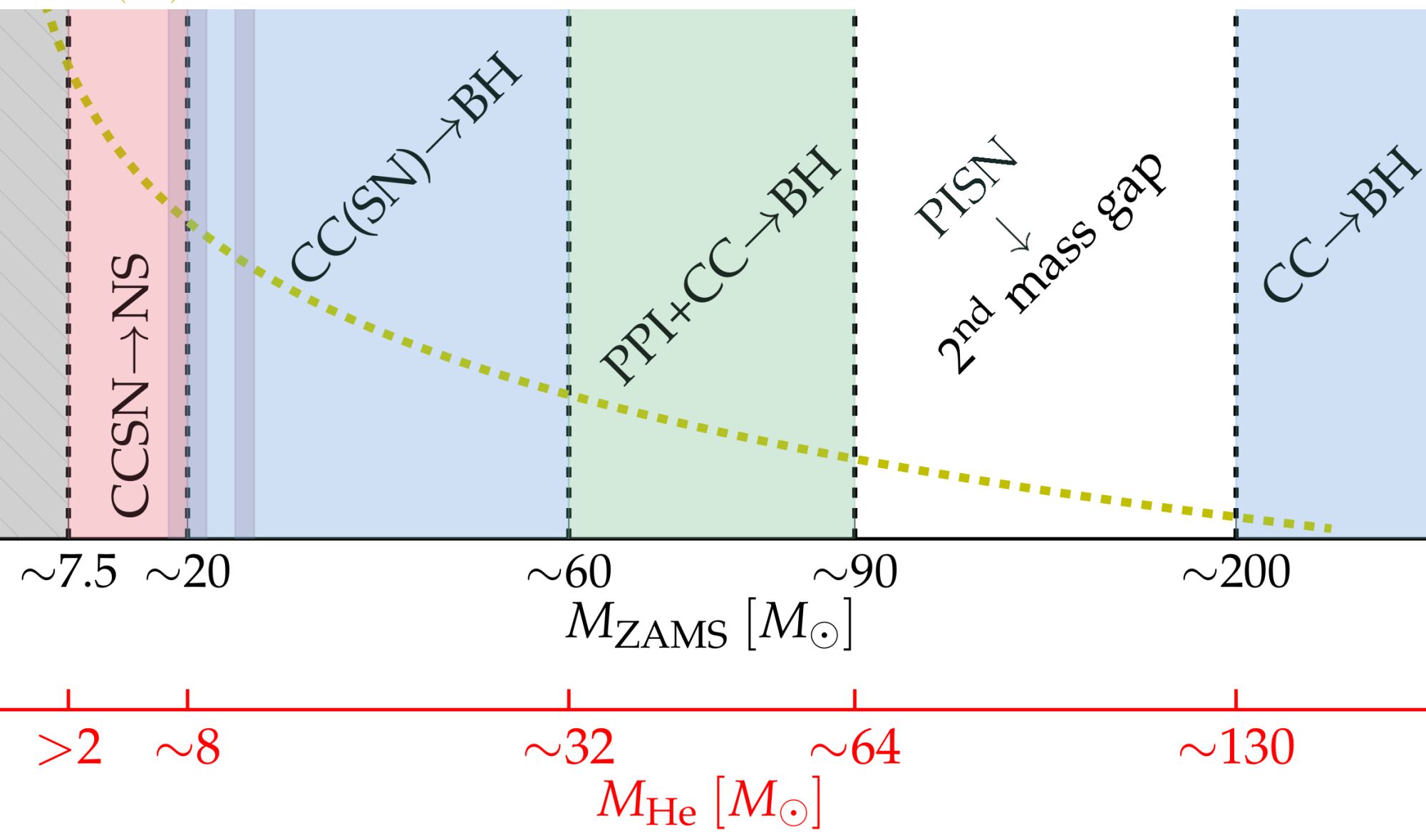


cf. Woosley 2017

$M_{\rm He}$ governs the fate, determines $M_{\rm BH}$

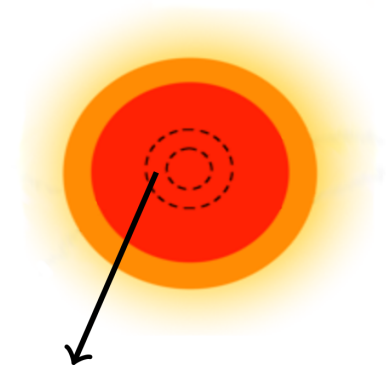
Evolution during (P)PISN

Radiation dominated:

$$P_{\rm tot} \simeq P_{\rm rad}$$

$$M_{\rm He} \gtrsim 32\, M_{\odot}$$

(Woosley 2017)



1. Pair production
$\gamma\gamma \rightarrow e^+e^-$

$M_{\rm He} = 46\,M_\odot$, $Z = 0.001$

non rel. $e^\pm$ pressure support

$\Gamma_1 < 4/3$

$\langle E_\gamma \rangle < 2m_e c^2$

$\langle E_\gamma \rangle < E^{e^\pm}_{\rm Fermi}$

T [K]

10^9

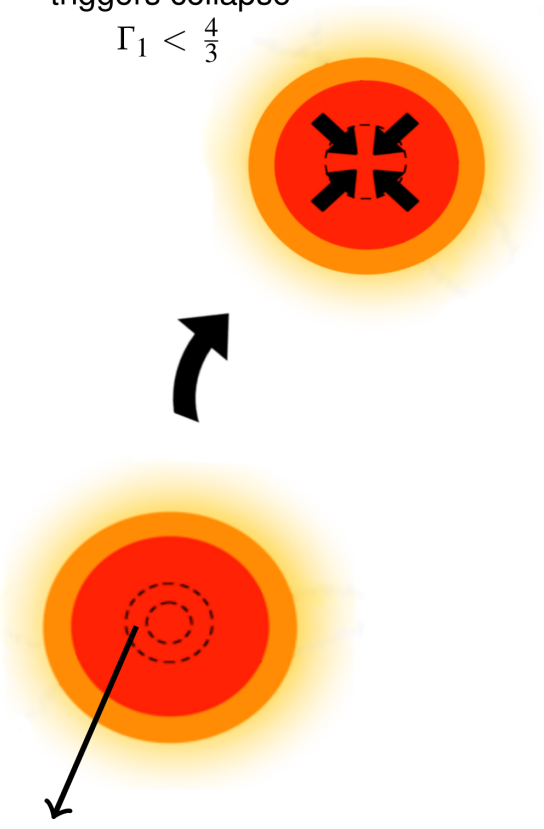
10^8

10^3 10^4 10^5 10^6

ρ [g cm^{-3}]

Preliminary calculations with MESA

2. Softening of EOS
triggers collapse
$\Gamma_1 < \frac{4}{3}$



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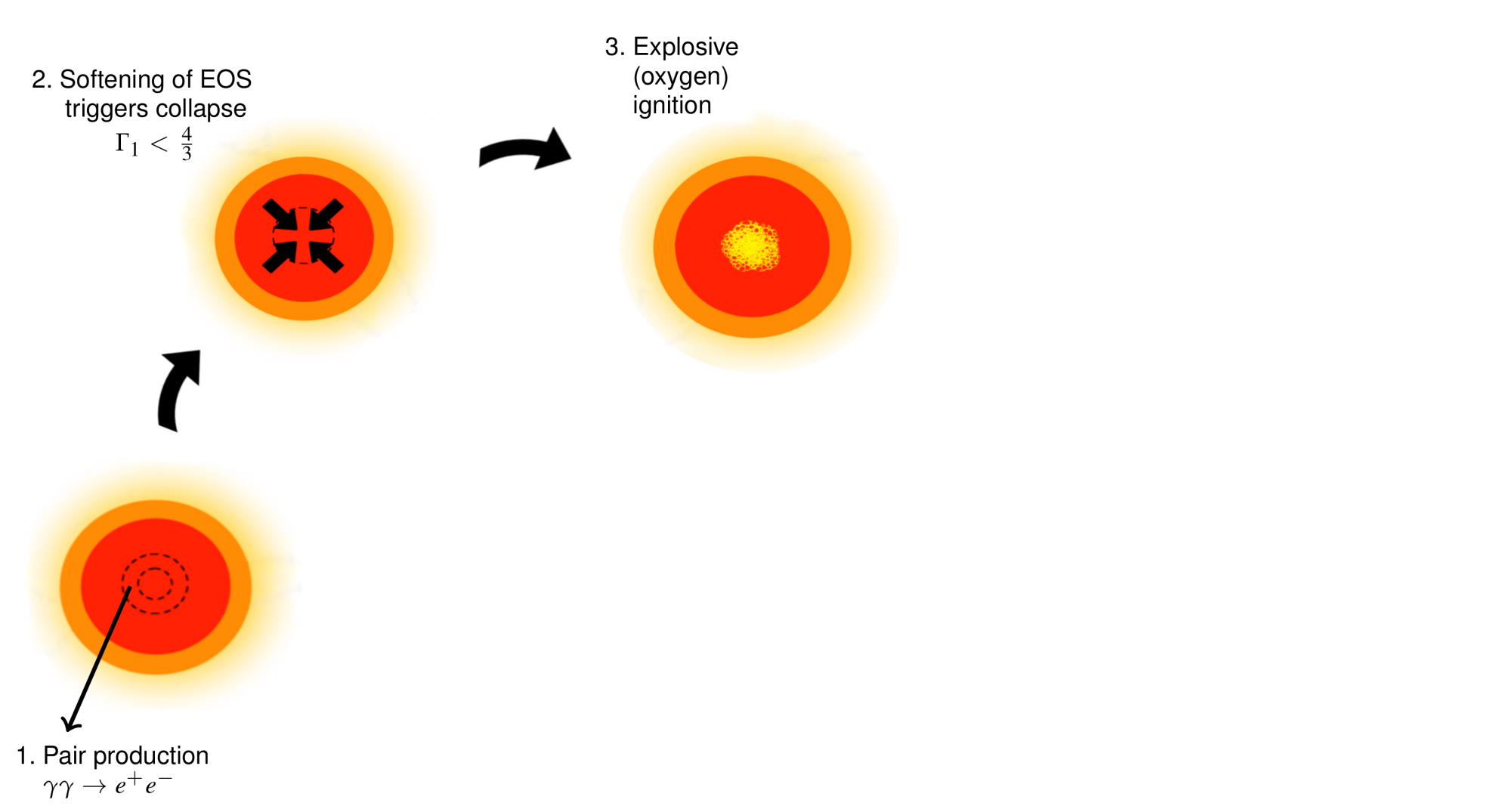
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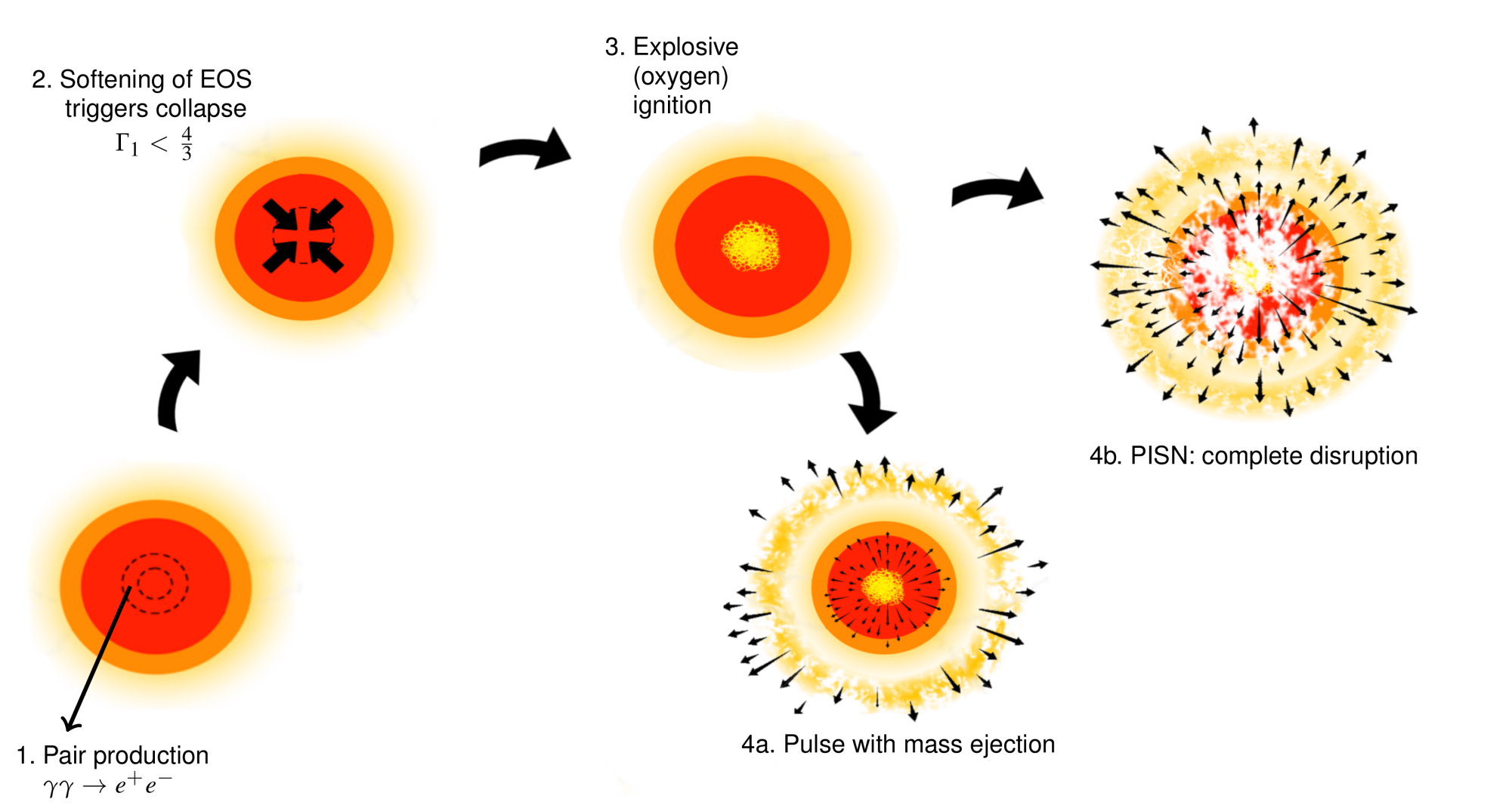
$\Gamma_1 < \frac{4}{3}$
3. Explosive
(oxygen)
ignition
1. Pair production
$\gamma\gamma \rightarrow e^+e^-$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4b. PISN: complete disruption
4a. Pulse with mass ejection
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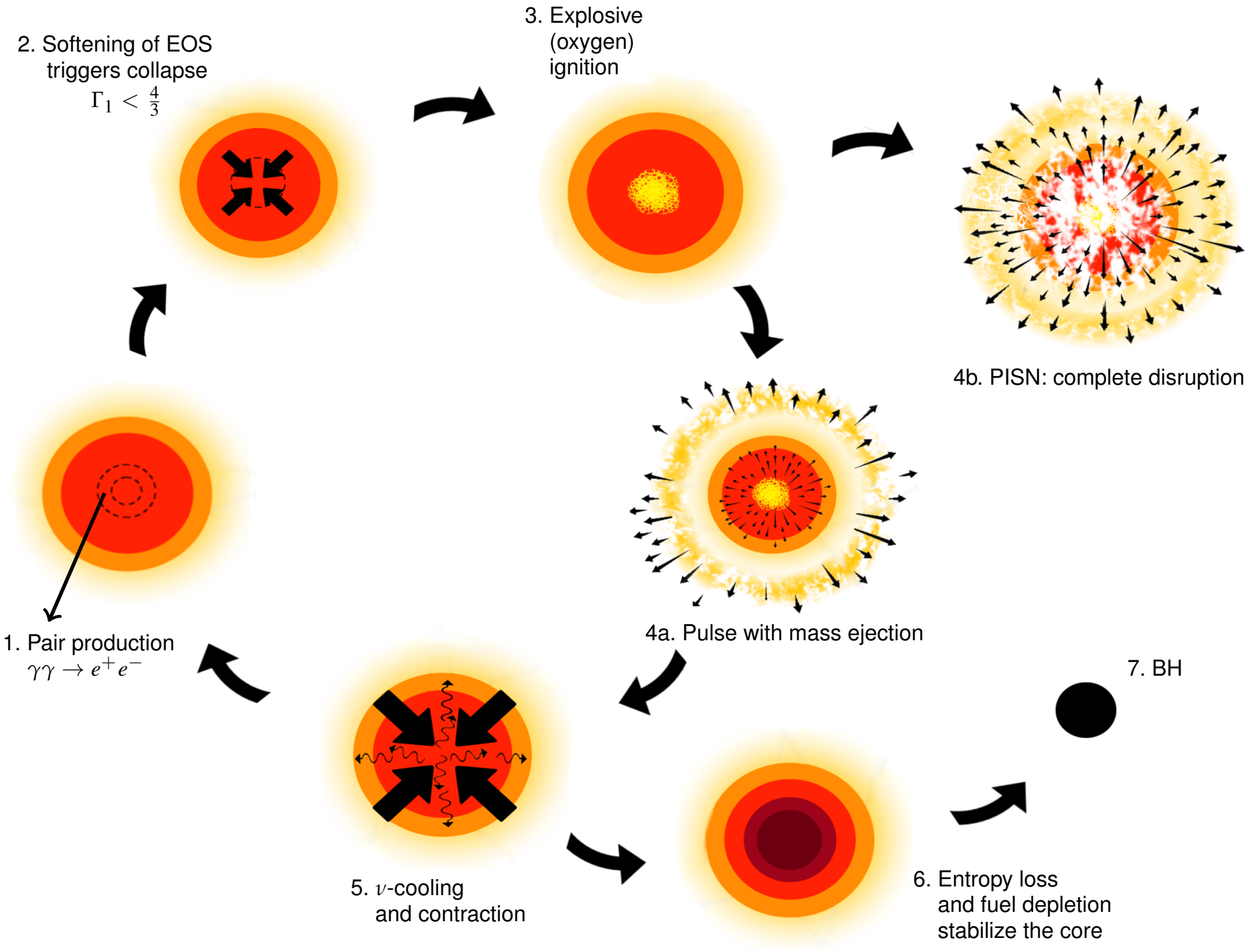
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1. Pair production
$\gamma\gamma \rightarrow e^+e^-$
5. ν-cooling
and contraction
6. Entropy loss
and fuel depletion
stabilize the core
7. BH

PPISN mass loss history

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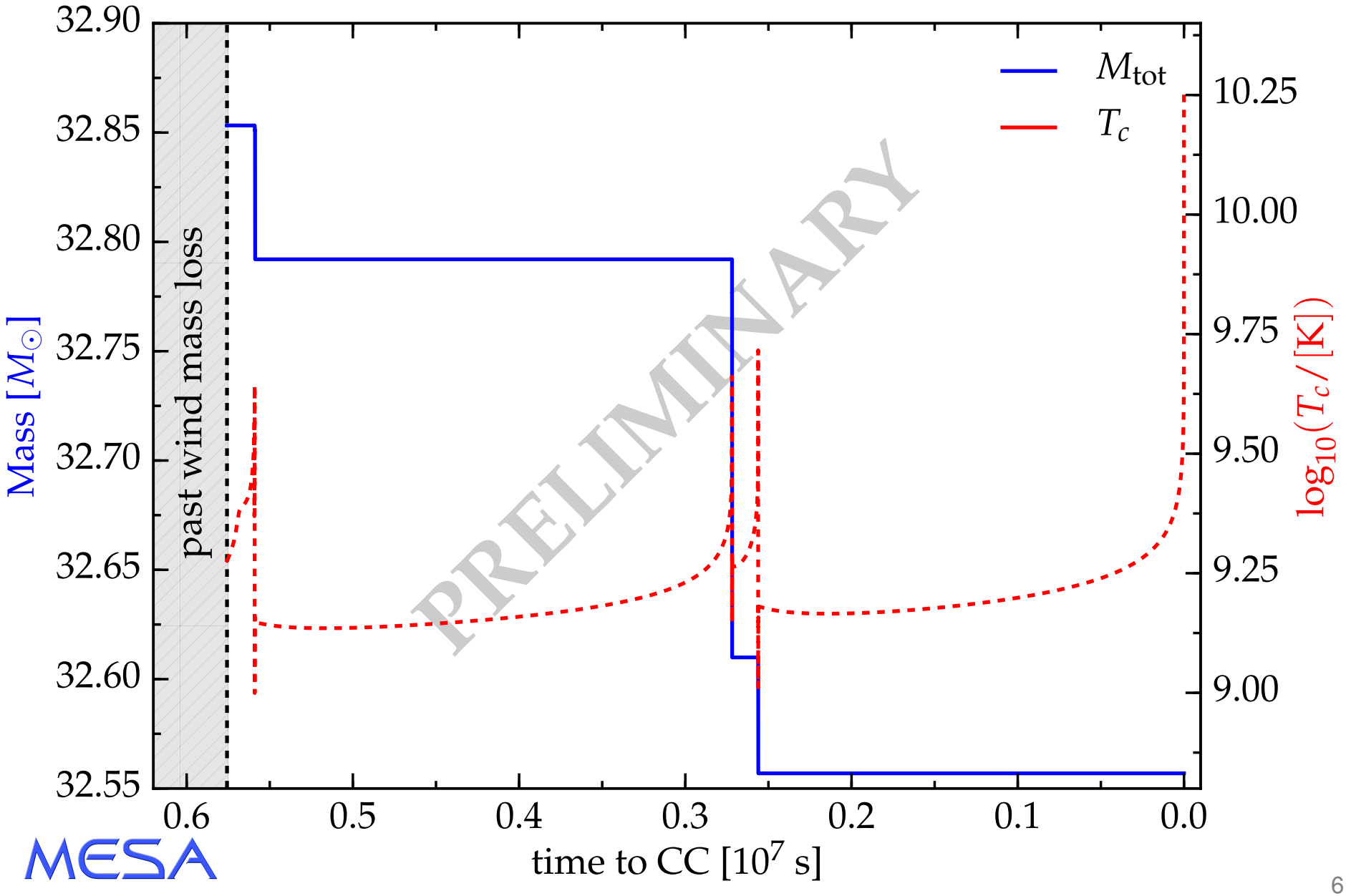
Example: $M_{\rm He} = 46\,M_\odot$, $Z = 0.001$, no envelope



MESA

Discussion

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Can PPISN provide the mass aroung the BBH?

Pros

- ✓ Timed shortly before BH formation
- ✓ Sufficient amount of mass;
- ✓ Can increase eccentricity $\Rightarrow$ decrease $\tau_{\rm GW}$;
- ✓ ...

Cons

- ✗ Can possibly unbind the binary;
- ✗ $v_{\rm ejecta} \gtrsim 10^3 - 10^4\,{\rm km\ s^{-1}}$;
- ✗ Still have to survive $\tau_{\rm GW}$.
- ✗ ...

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Bonus:

- Naturally produces BHs of $\sim 30\,M_\odot$
- Can modify the BH mass function (2$^{\rm nd}$ mass gap)

Correlation between $M_{\rm BH}$ and EM signal?