The Long-Term Outcomes of Double White Dwarf Mergers

with L. Bildsten, E. Quataert, K. Shen, & others

Josiah Schwab

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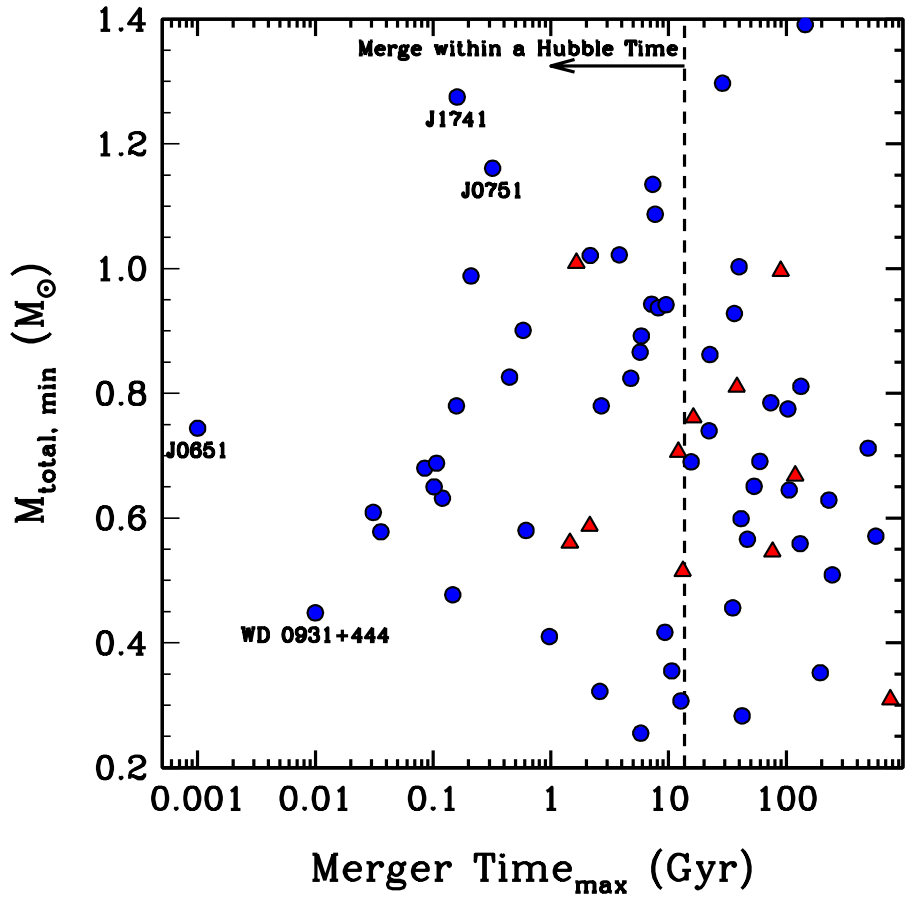
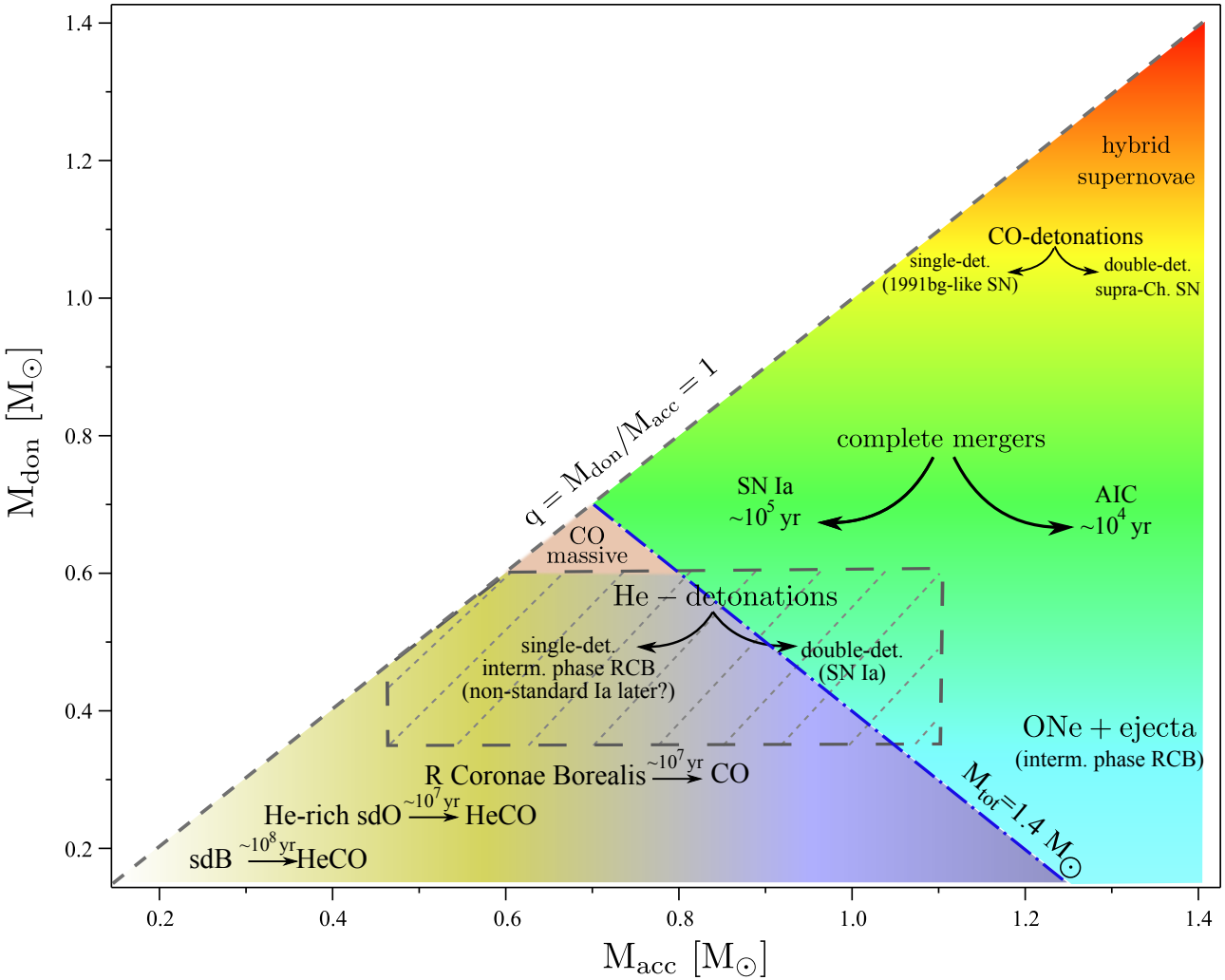
There are WD+WD binaries that will merge;
the rate in the Milky Way is ~1 per century.



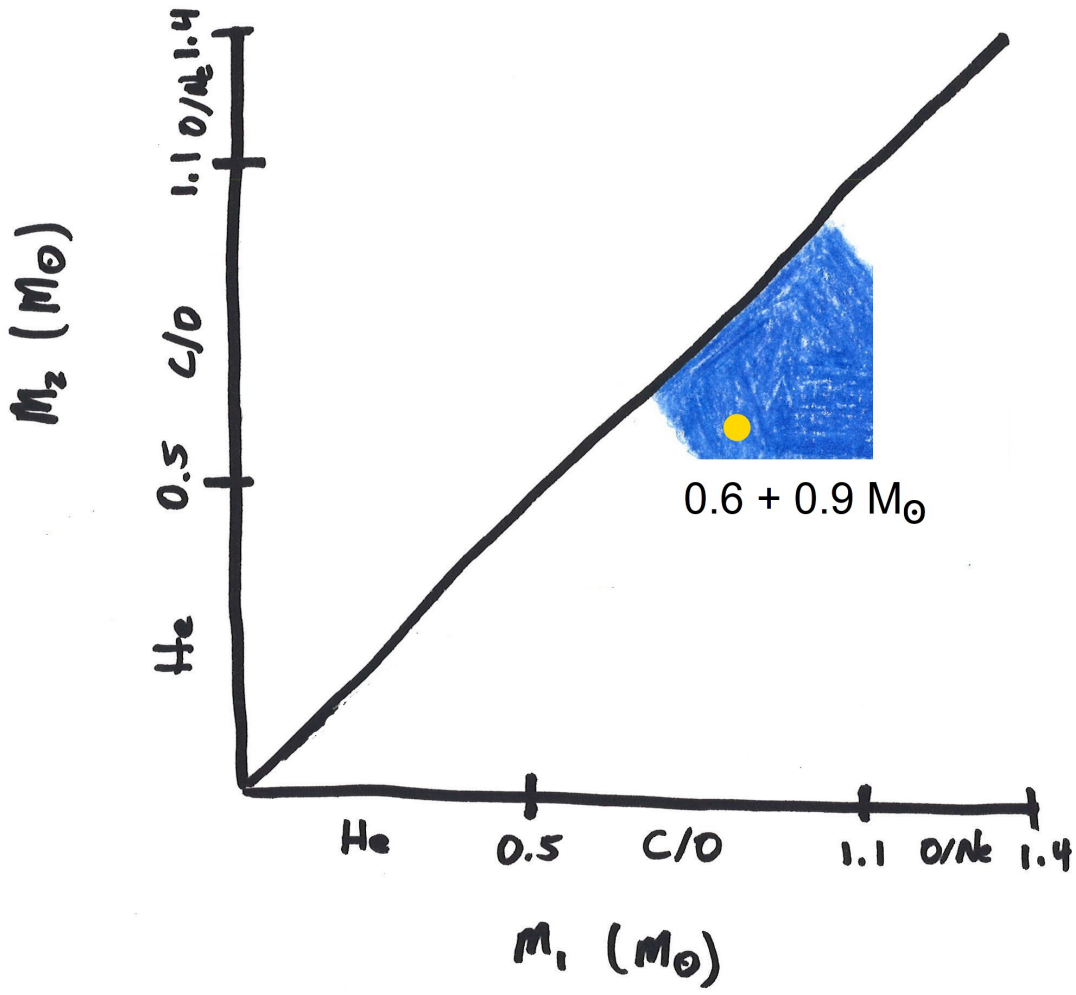
Badenes & Maoz (2012); ELM: Gianninas et al. (2015)

There are a wide variety of post-merger outcomes.



e.g., Webbink (1984), ... ; Fig. from Dan et al. (2014)

Today, I will focus on the merger of two CO WDs, with a total mass above the Chandrasekhar mass.



The primary WD remains relatively undisturbed;

The secondary WD is disrupted, forming a disk.

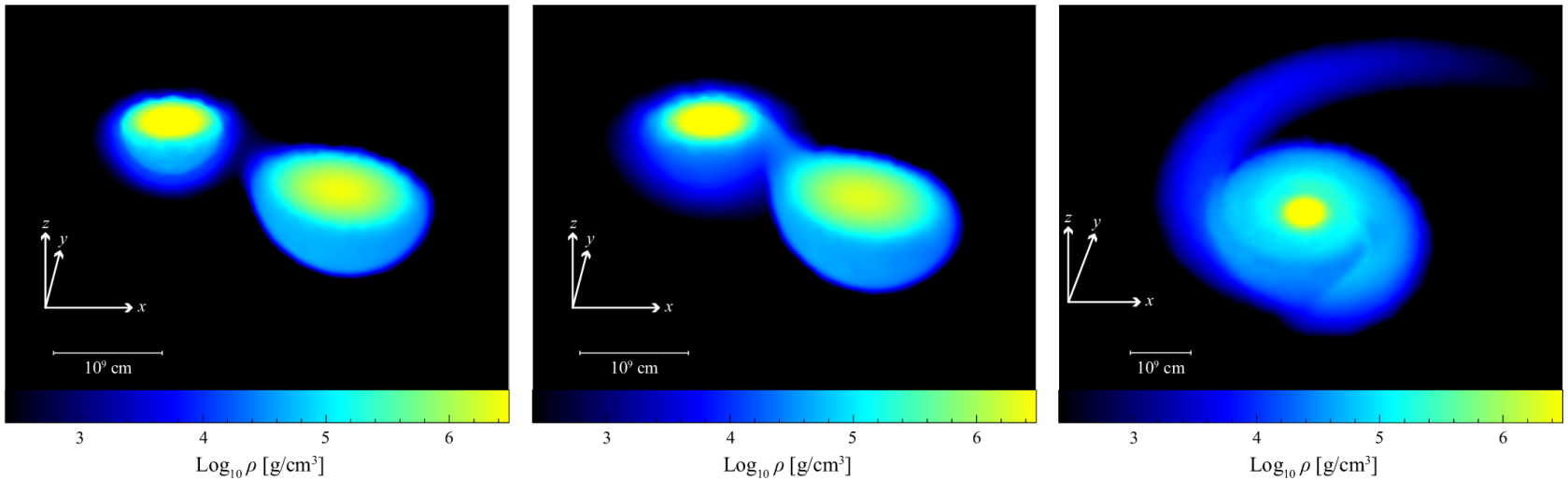


Fig. from Dan et al. (2011)

The evolution can be divided into three phases with well-separated timescales.

Dynamical Time (min)

Completion of merger

Viscous Time (hr)

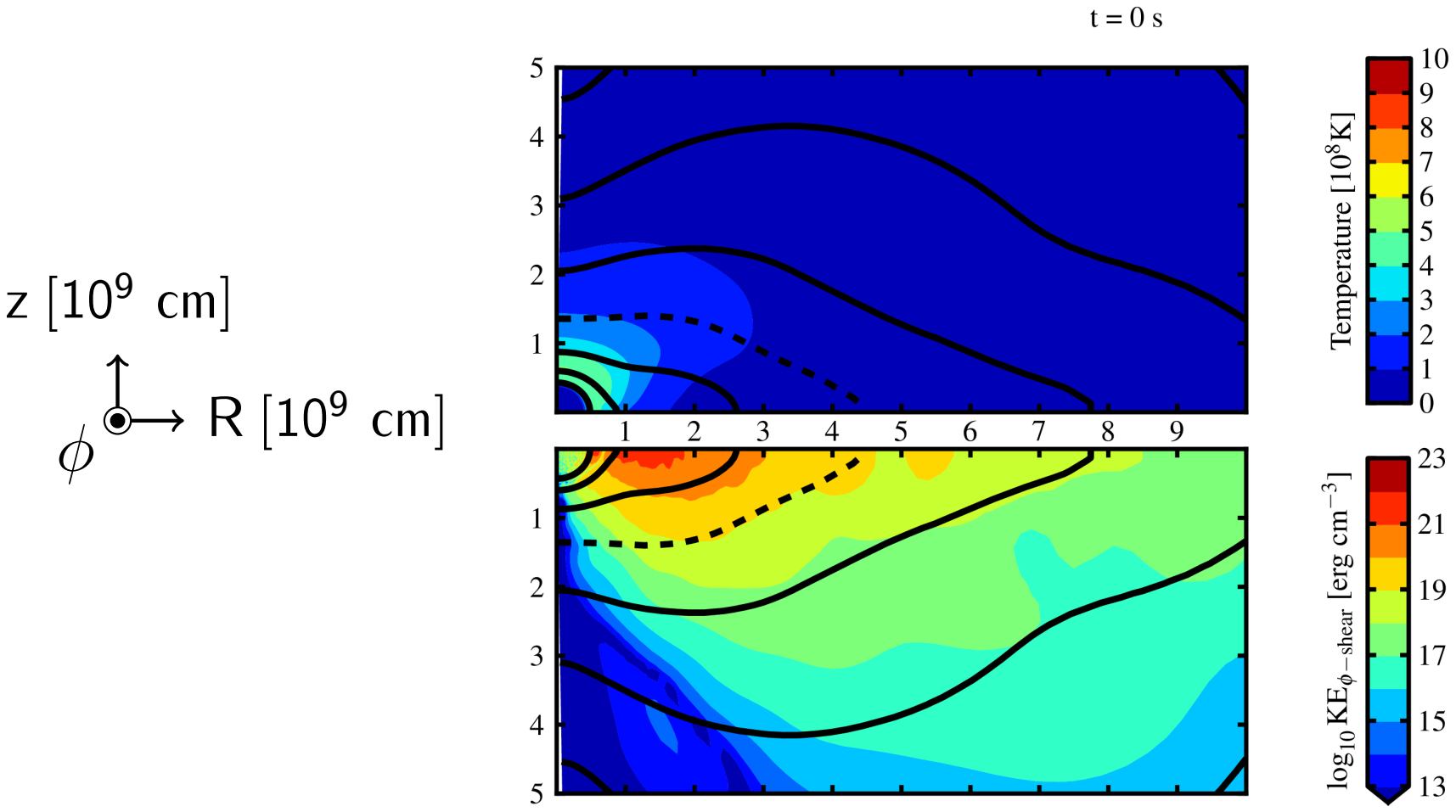
Redistribute ang. mom.

Thermal Time (kyr)

Radiate away energy

Shen et al. (2012); Schwab et al. (2012)

The remnant is unstable to the MRI and evolves viscously before cooling significantly.



Schwab et al. (2012)

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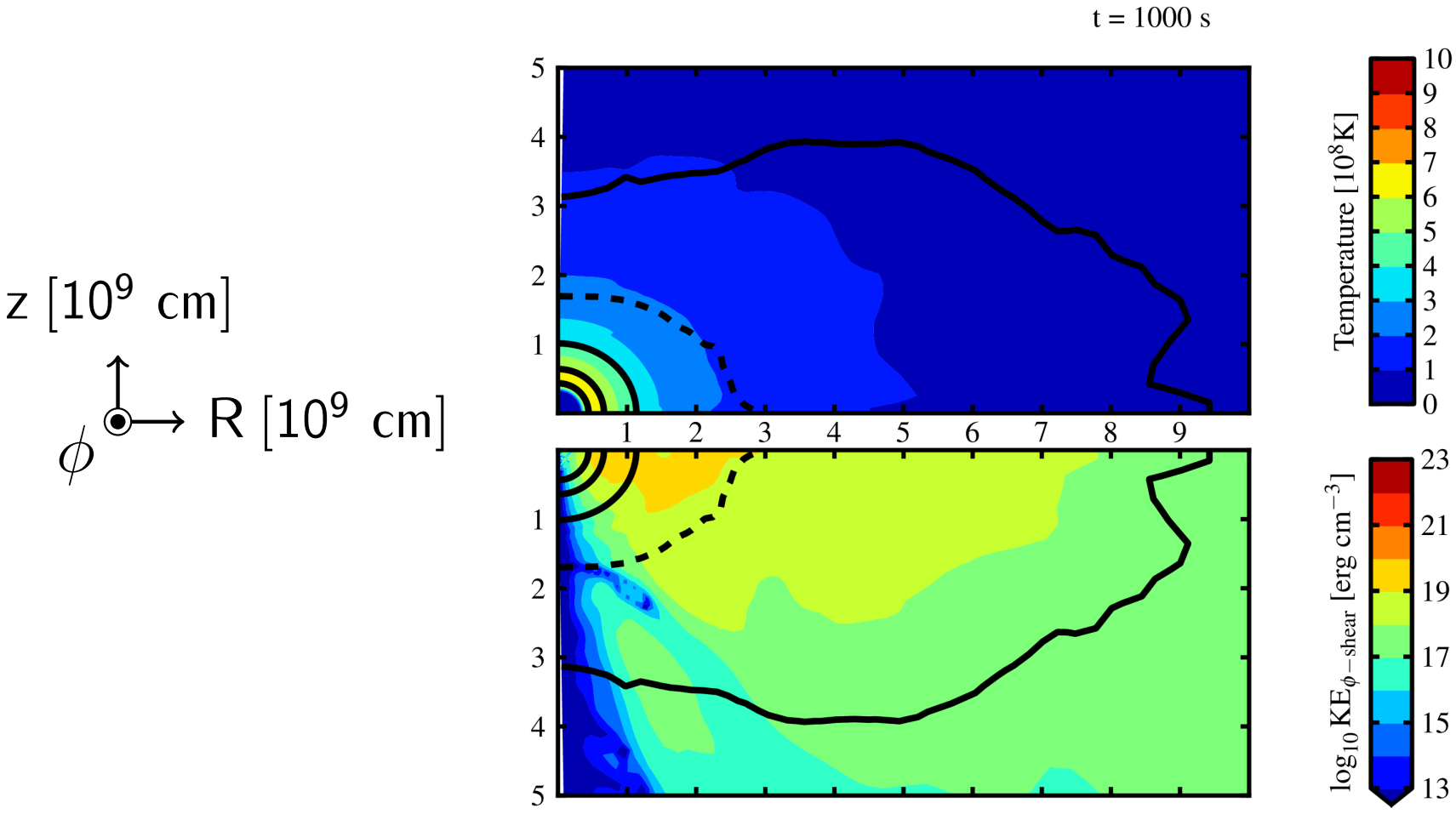

Schwab et al. (2012)

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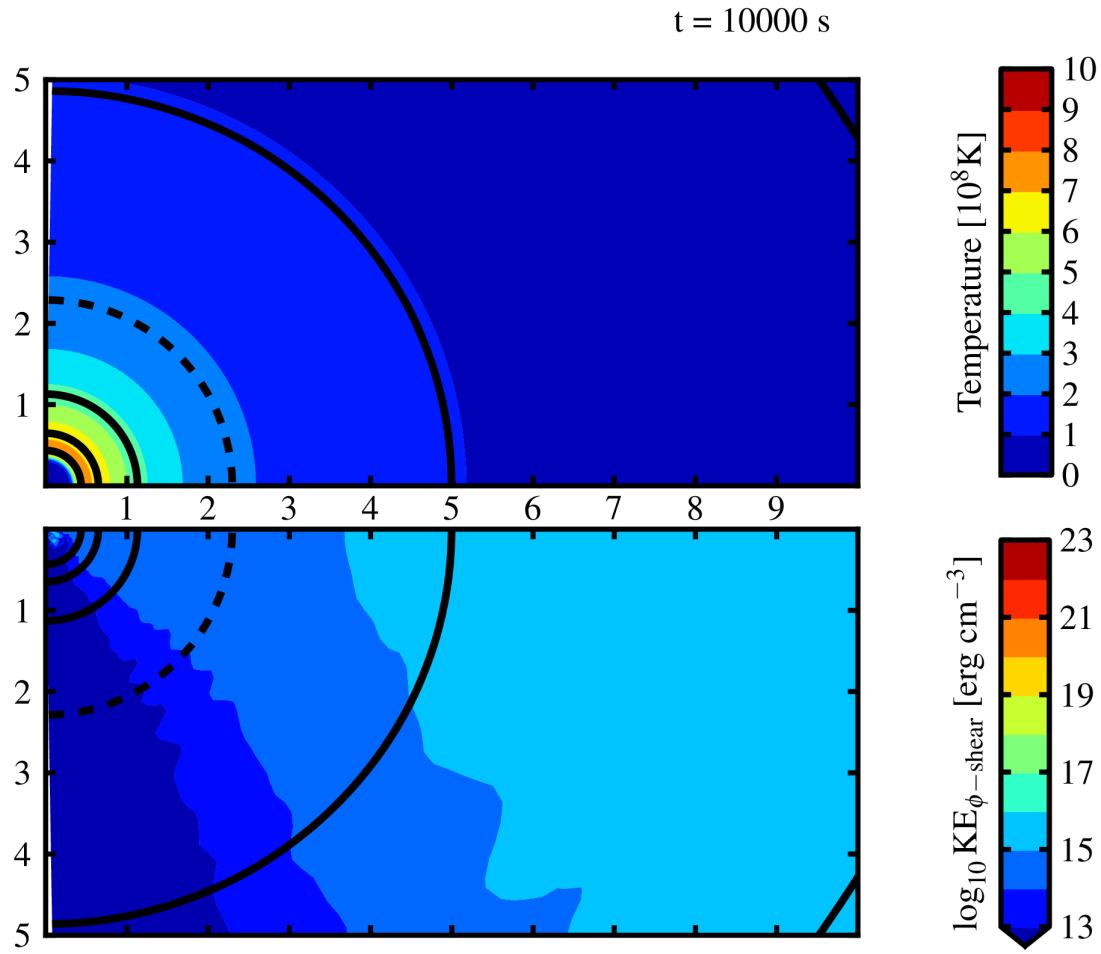
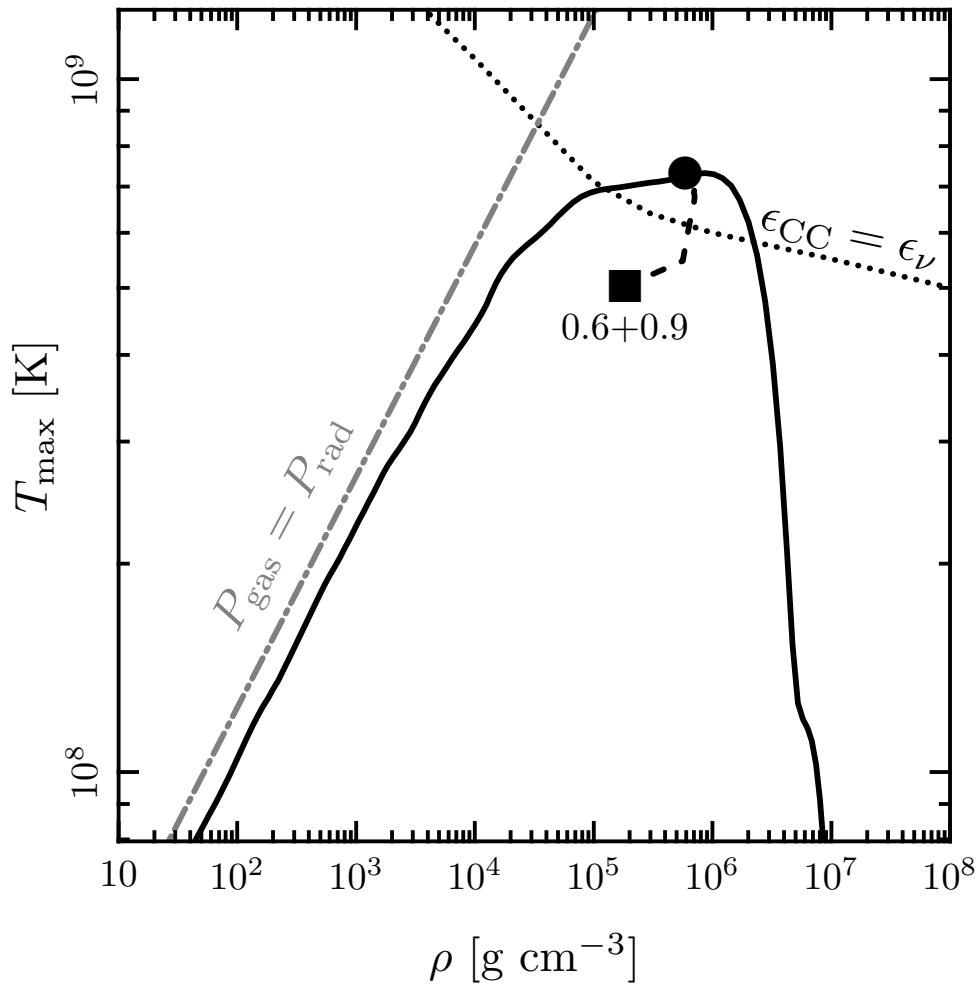
z [10^9 cm]

ϕ ⊙⟶ R [10^9 cm]



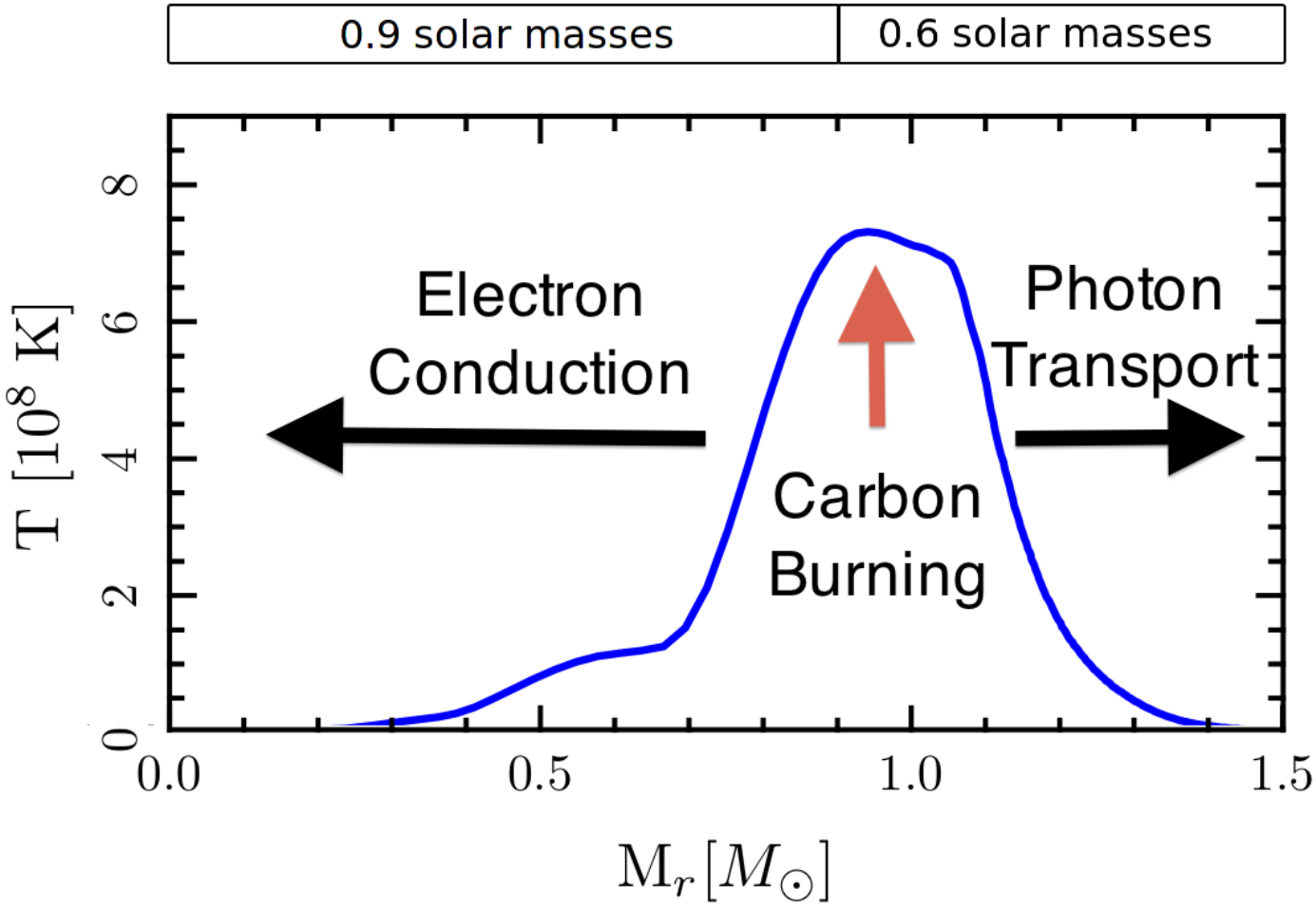
Schwab et al. (2012)

The viscous heating ignites carbon fusion off-center in the remnant.



Schwab et al. (2012)

Energy generation and heat transport will drive the next phase of evolution.



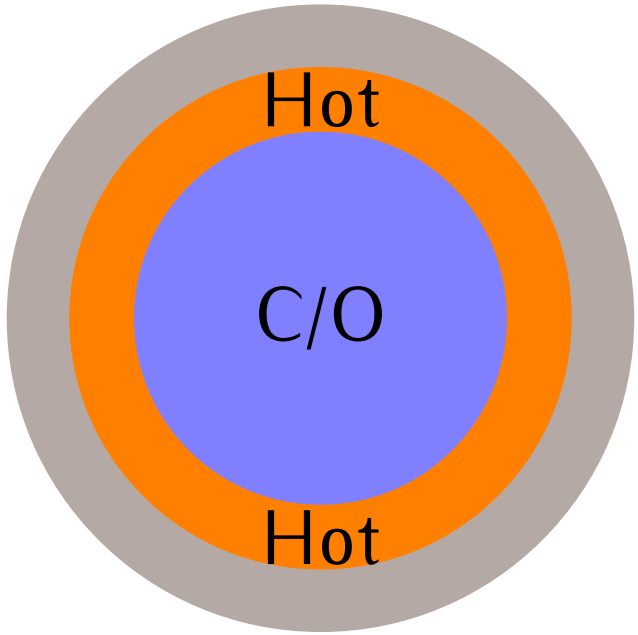
Introduction to WD+WD Mergers

The Viscous Evolution of WD Merger Remnants

The Thermal Evolution of WD Merger Remnants

Summary and Conclusions

This doesn't make a Type Ia supernova.



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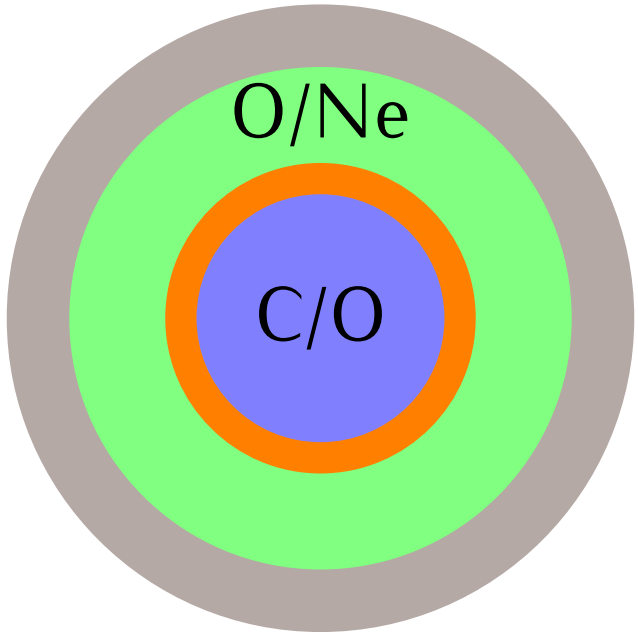

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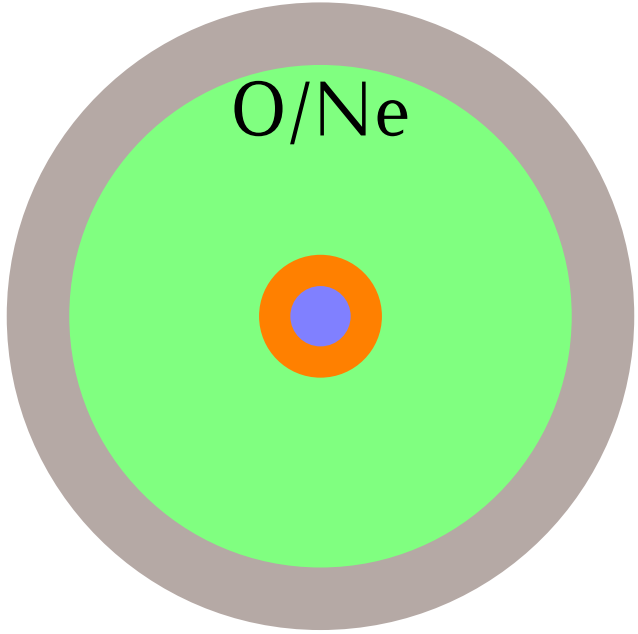

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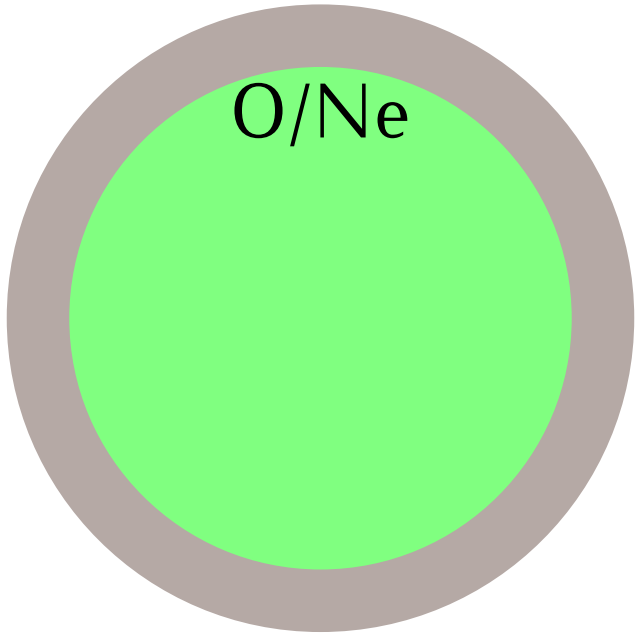
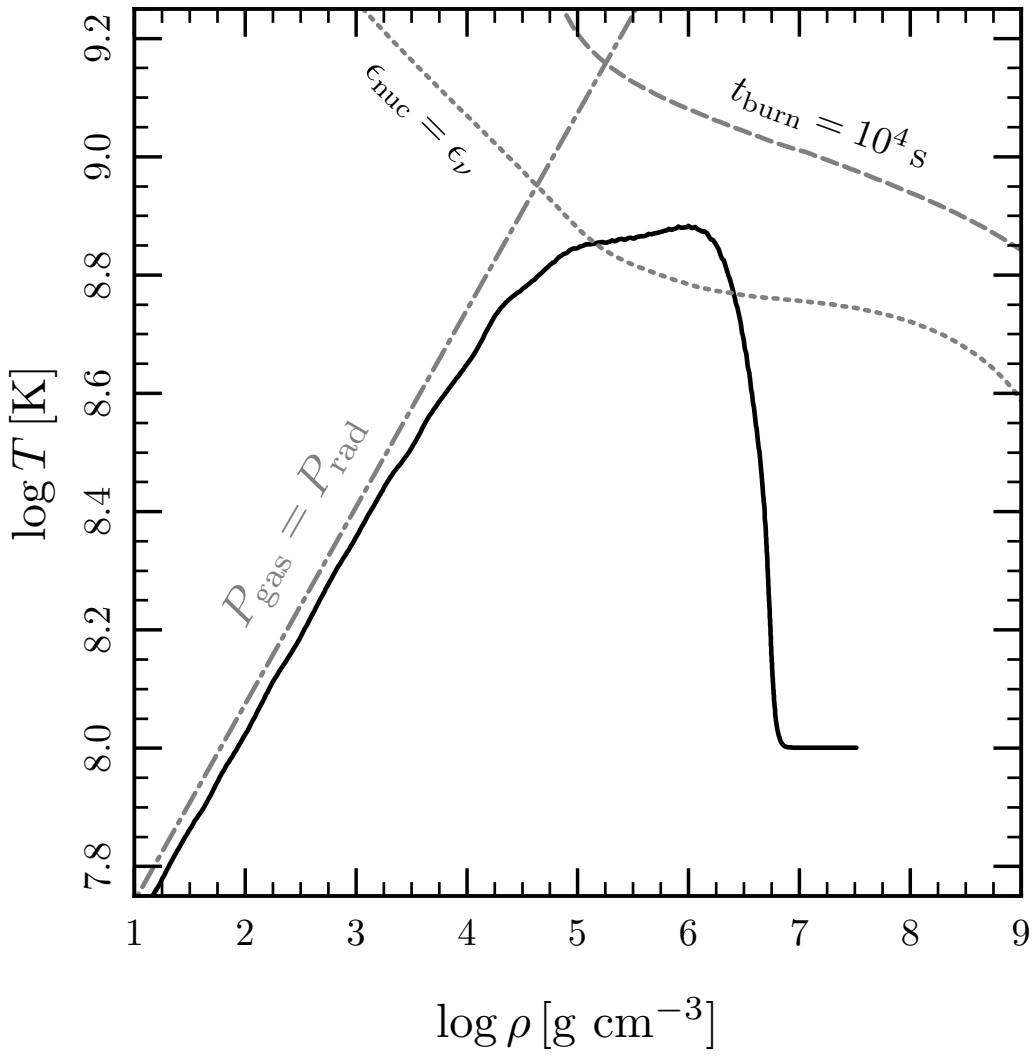
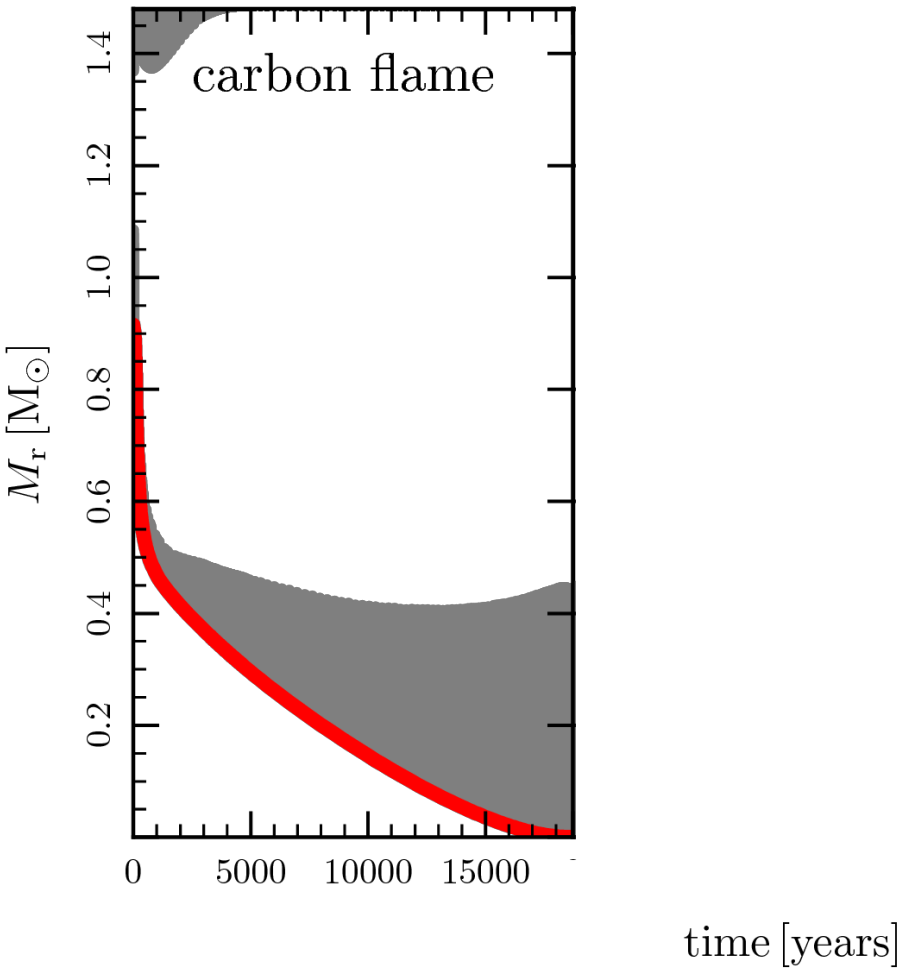


I map the output of the hydro simulations into the MESA stellar evolution code.

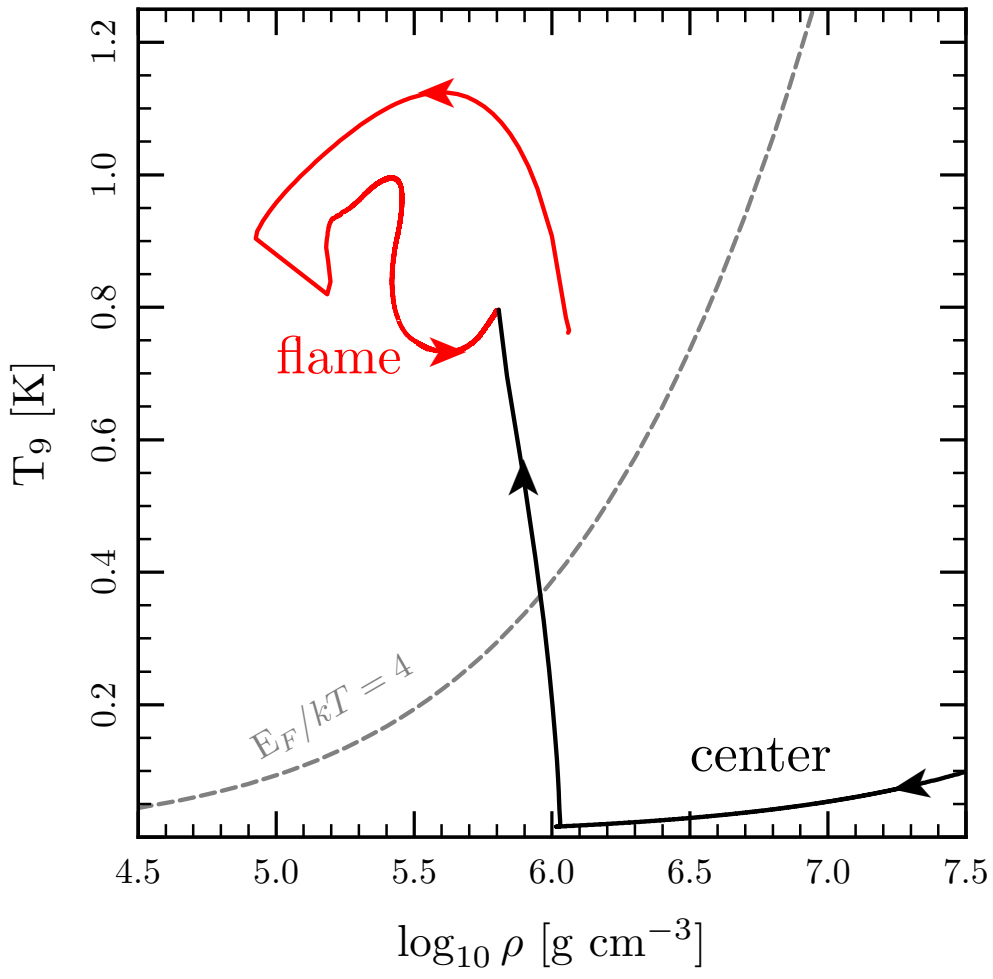


A convectively-bounded carbon deflagration forms and propagates inward.

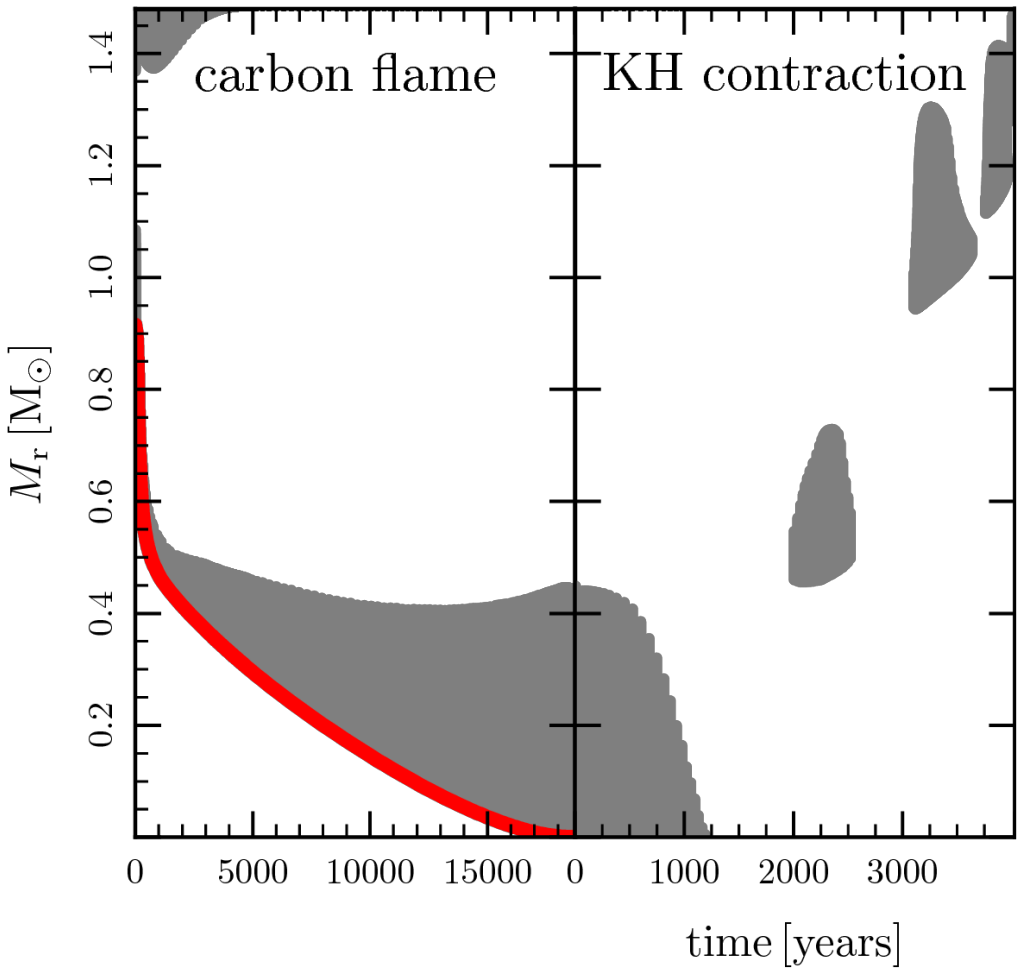


The flame reaches the center;

the material is oxygen-neon and non-degenerate.



Then the remnant undergoes a phase of Kelvin-Helmholtz contraction.



The KH contraction is neutrino-cooled and leads to off-center neon ignition.

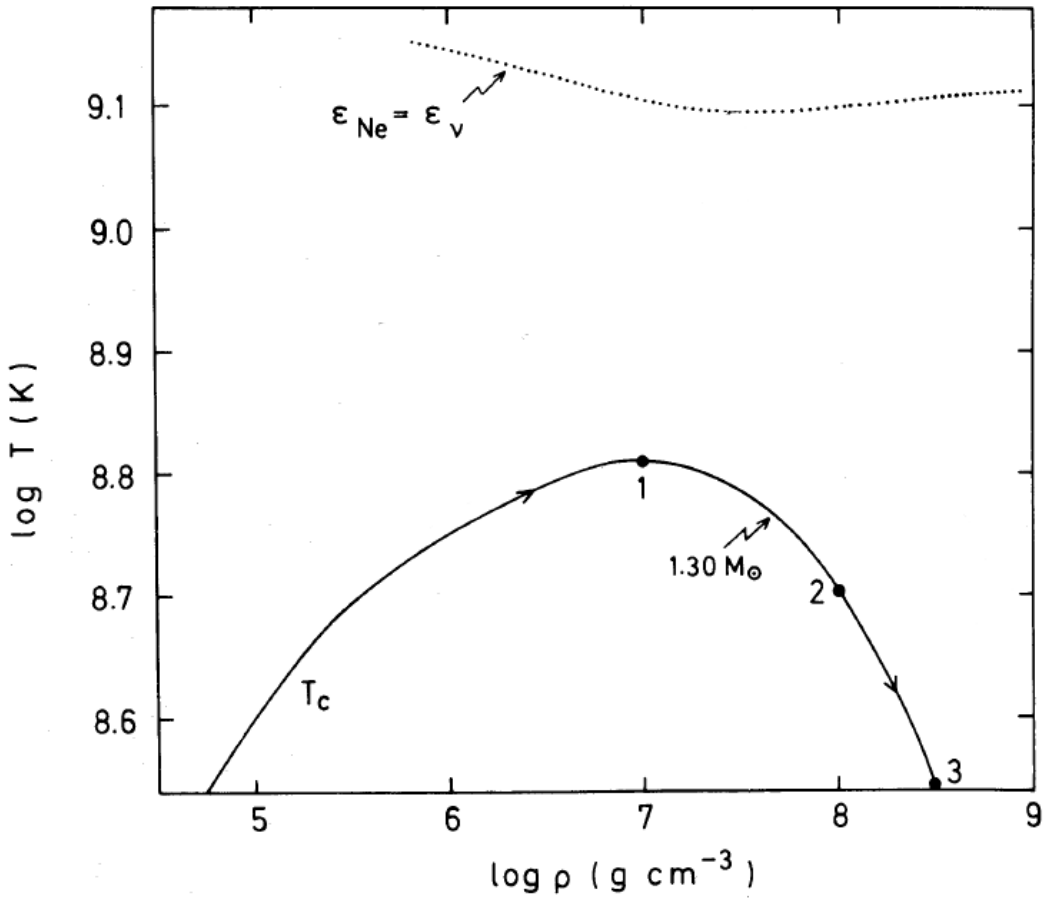


Fig. adapted from Nomoto (1984)

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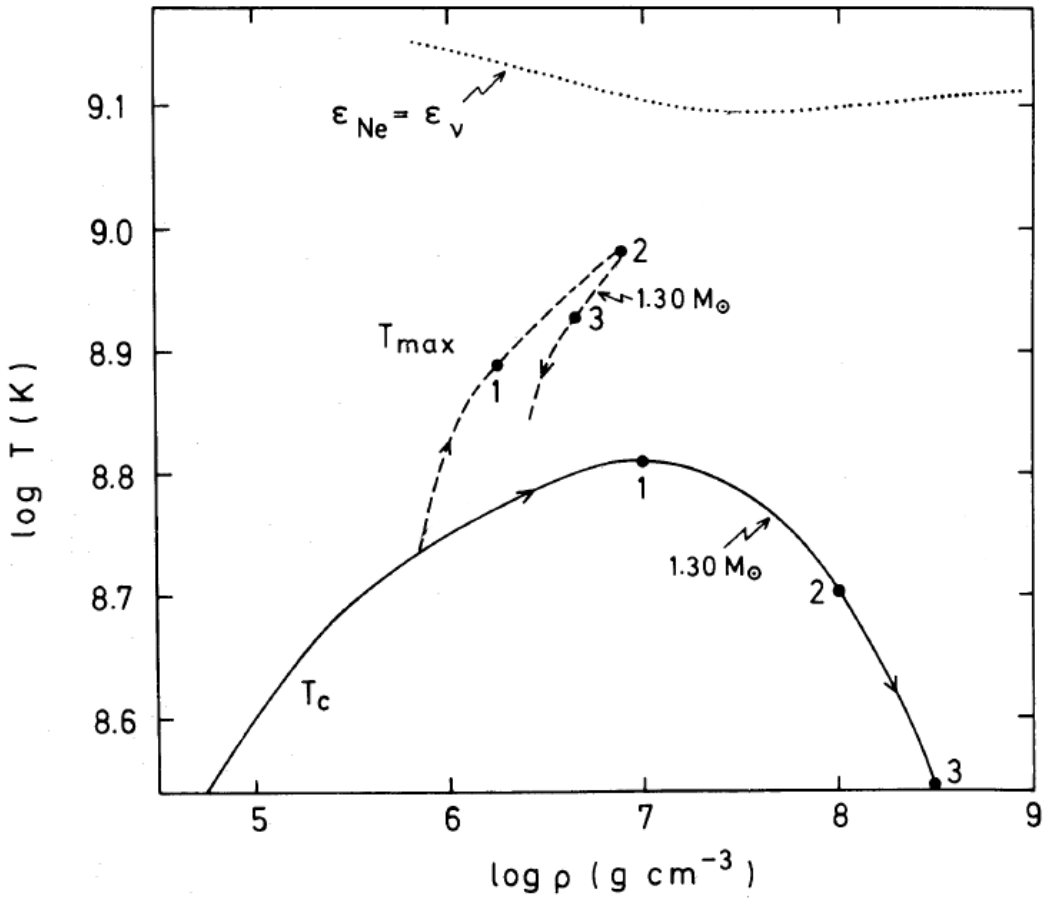

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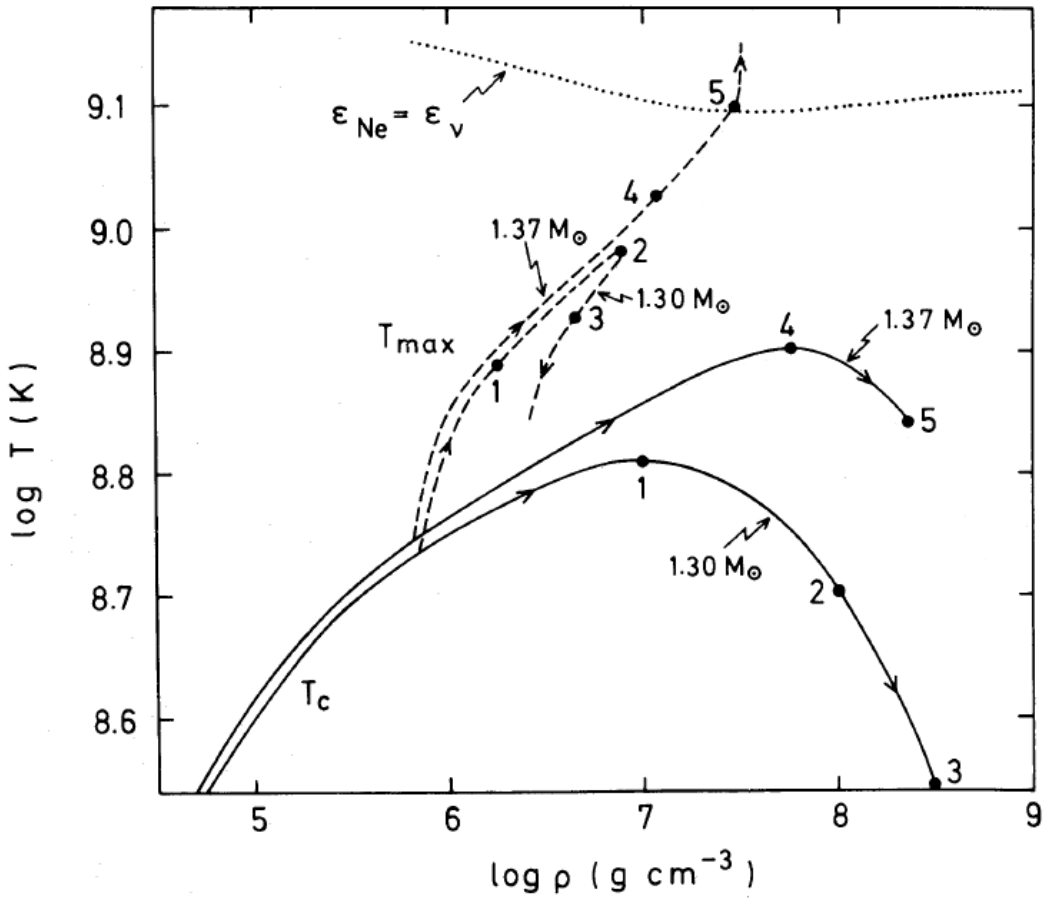

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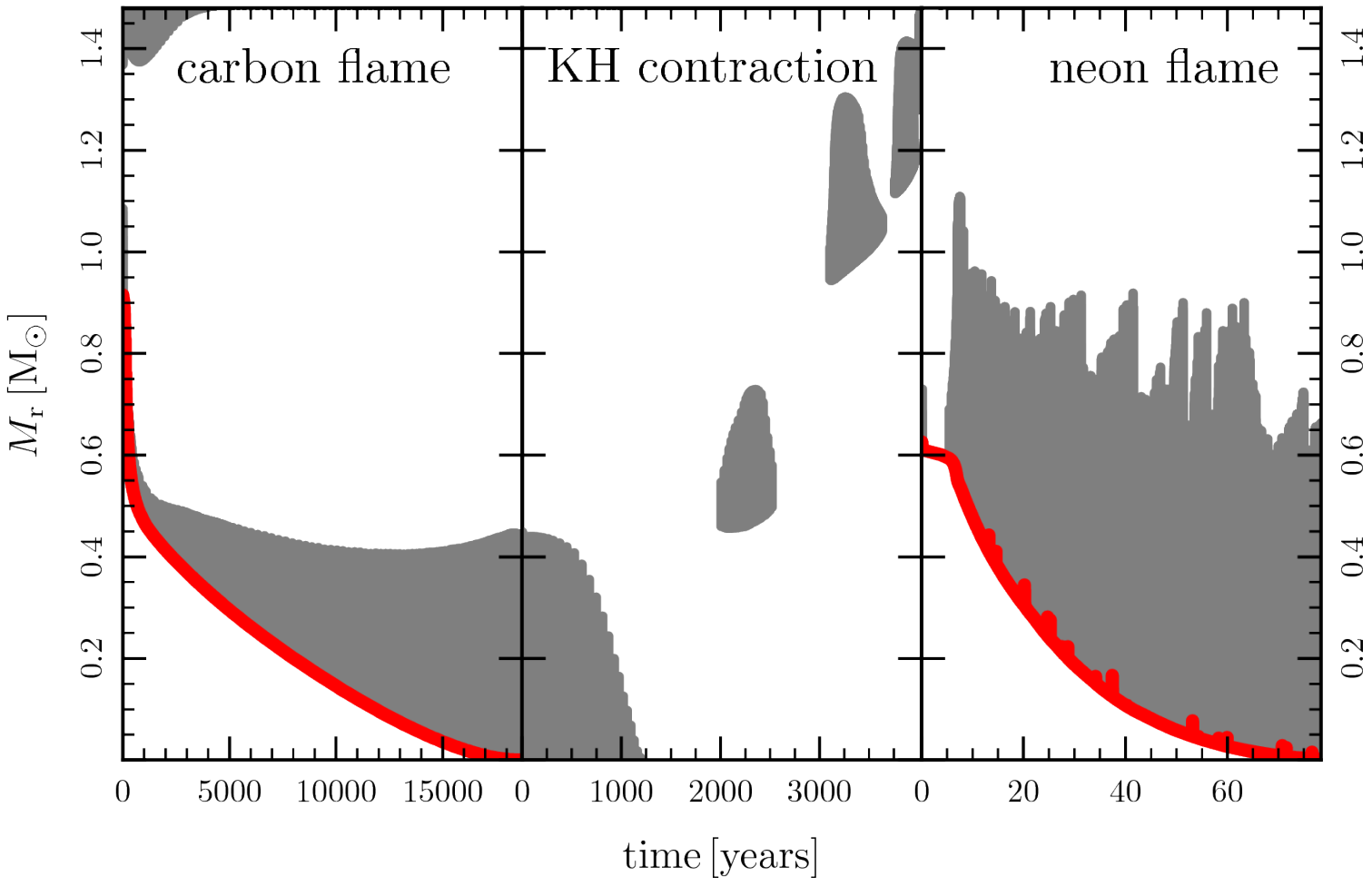
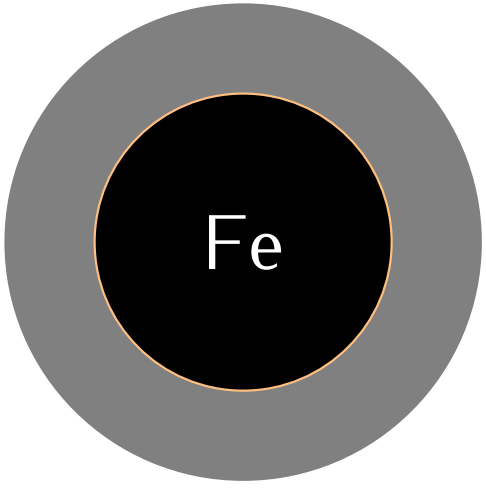


The outcome depends on the central composition; does the off-center burning reach the center?

Core-collapse



Schwab+ (in prep)

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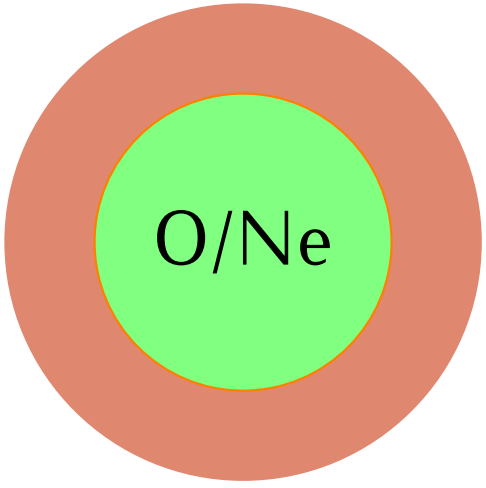
Electron-capture



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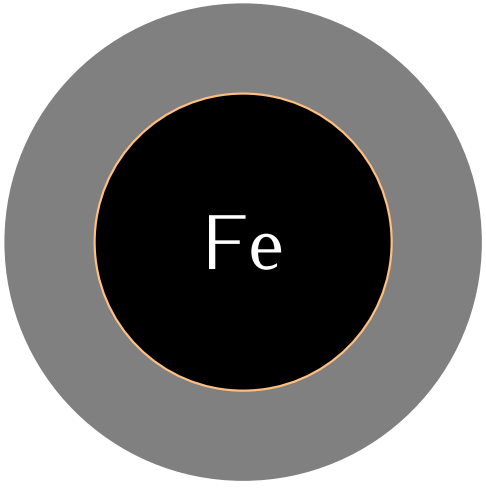

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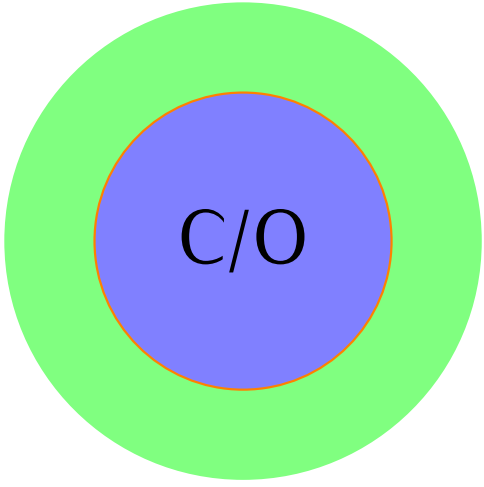
Hybrid Ia



Denissenkov+ (2013)

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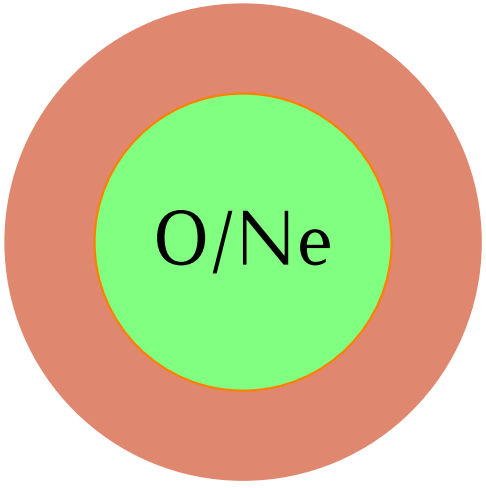

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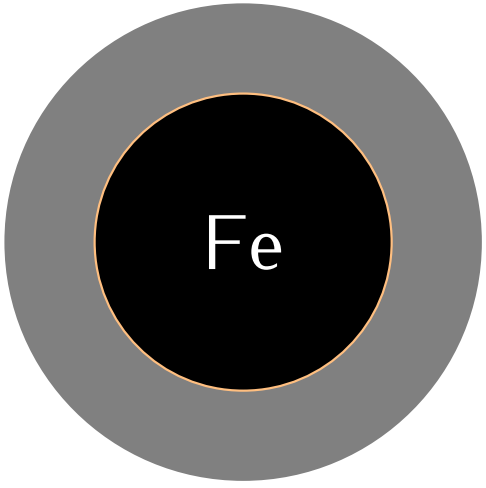

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- Connecting simulations of each phase enables studies of the long-term evolution.
- For super-Chandrasekhar WD mergers, the likely fate is collapse to a neutron star; the evolution towards collapse appears to be more complicated than previously understood.