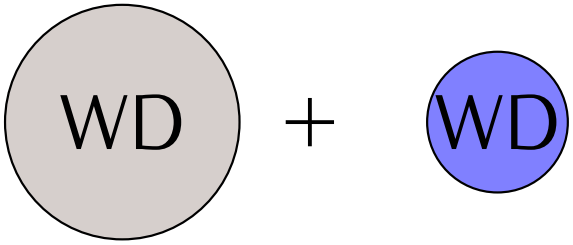
The evolution and fate of super-Chandrasekhar mass white dwarf merger remnants

with E. Quataert, D. Kasen & others

Josiah Schwab

25 July 2016

Double white dwarf mergers evolve towards a thermally-supported, spherical state.



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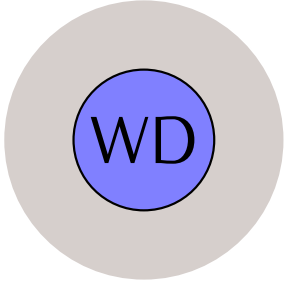
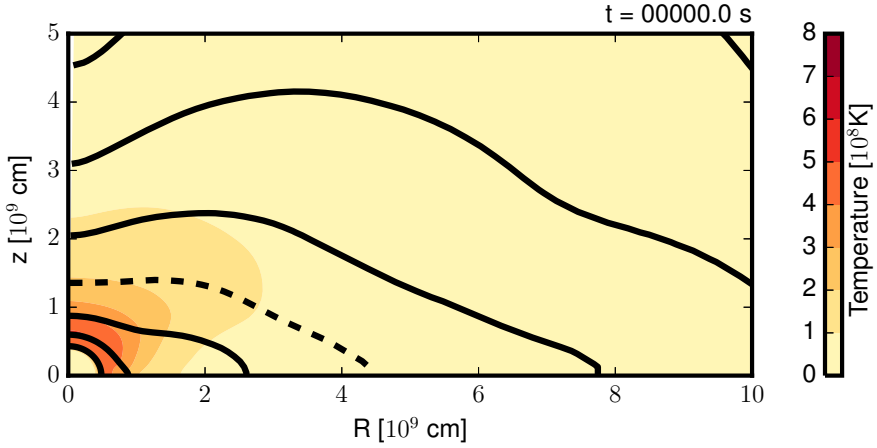
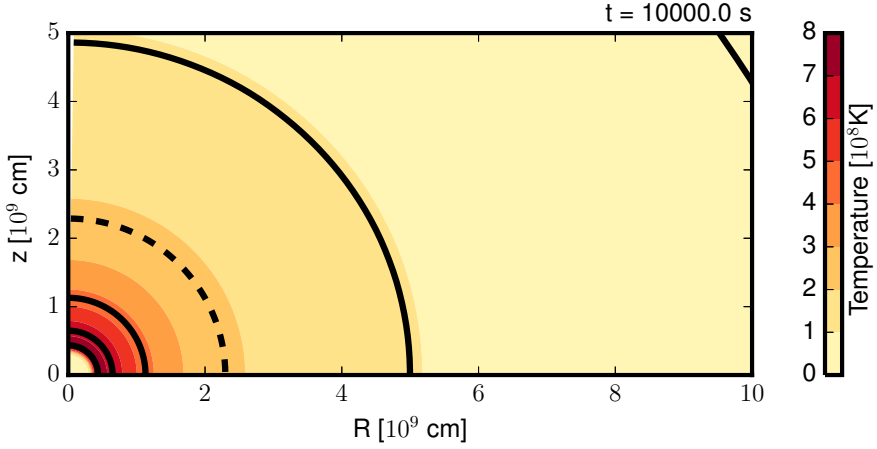
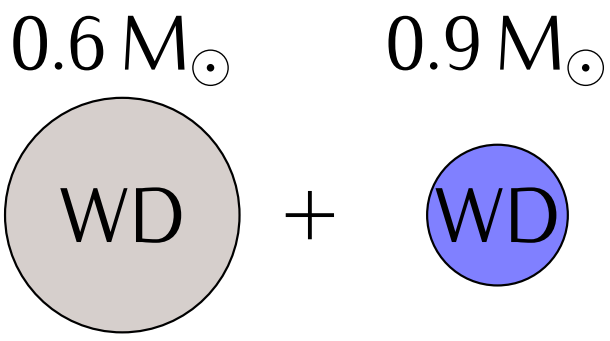






see Shen et al. (2012); Schwab et al. (2012)

Double white dwarf mergers evolve towards a thermally-supported, spherical state.



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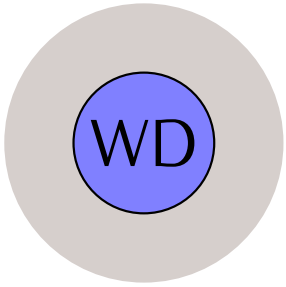

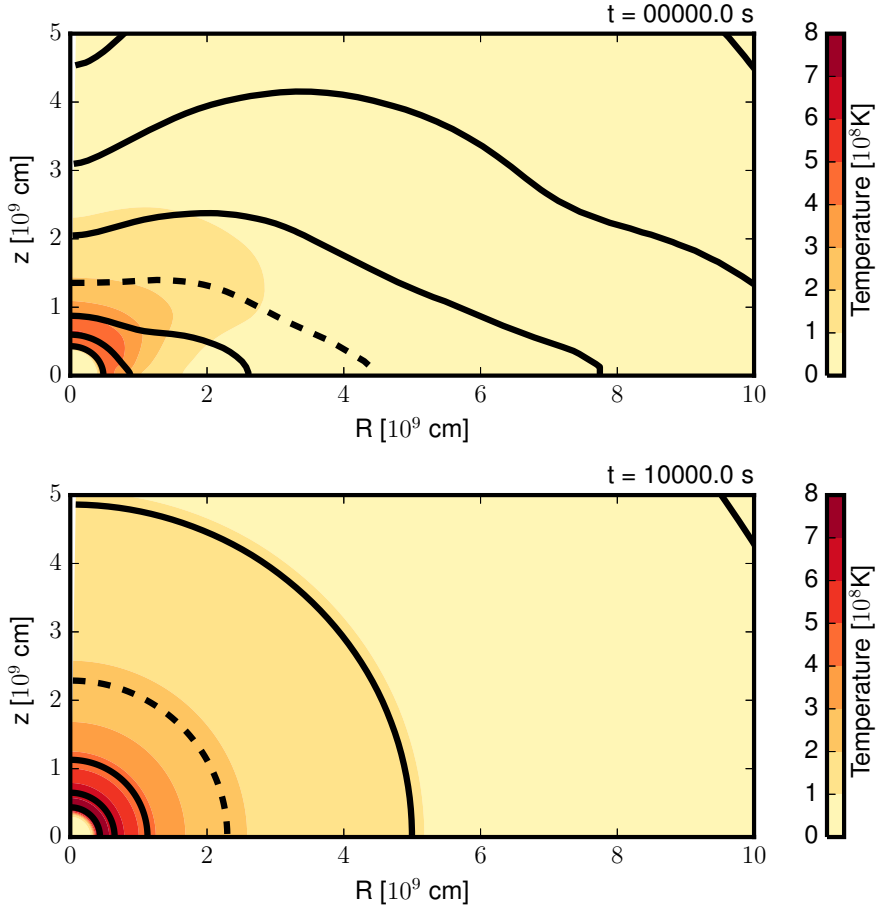

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Previous work has taken several approaches.

Model merger as accretion on cold WD

Nomoto & Iben (1985); Saio & Nomoto (1985)
Finds off-center carbon ignition before core ignition (so no Ia; instead massive ONe core $\rightarrow$ NS).

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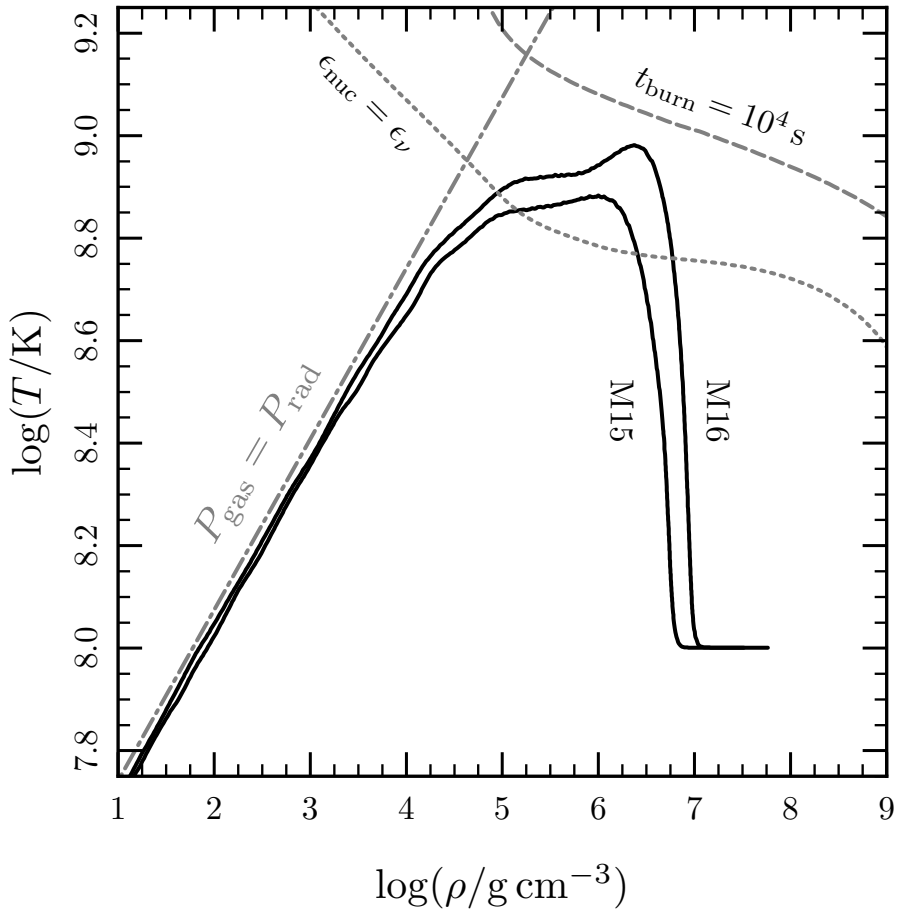
Use initial conditions from SPH merger sims

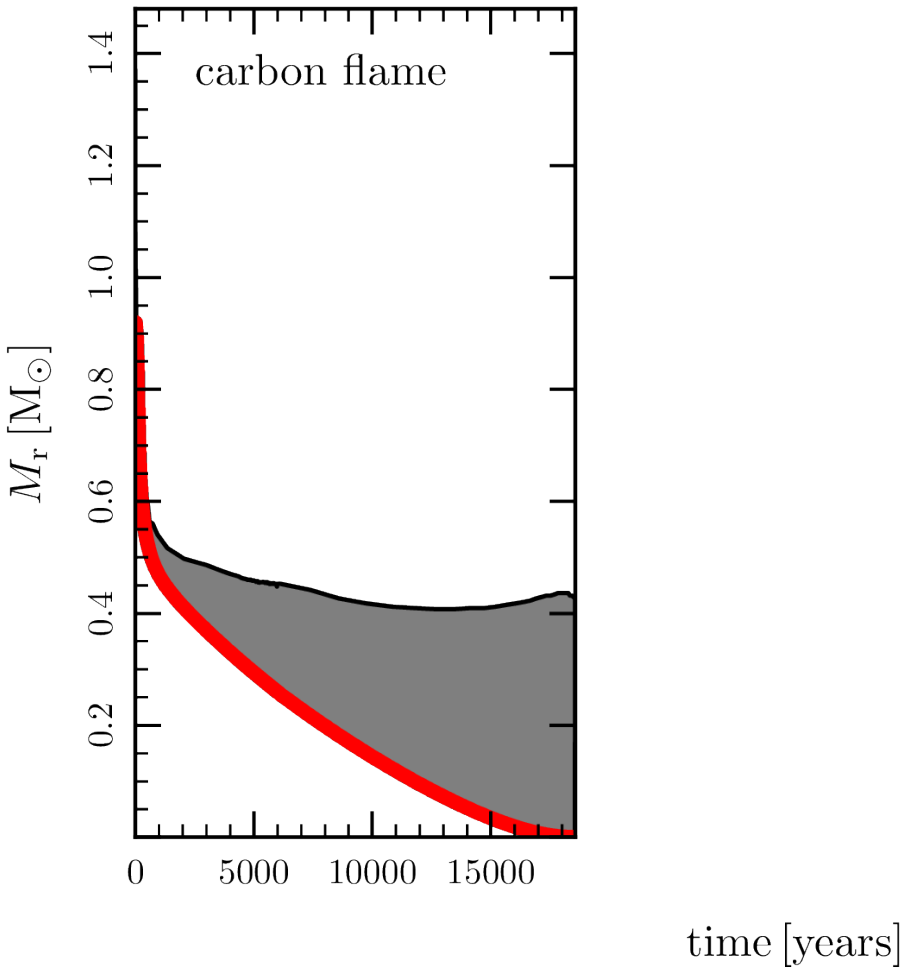
Yoon et al. (2007)
Can avoid off-center carbon ignition if angular momentum transport slow compared to neutrino cooling. (This seems unlikely to me, given MRI.)

I map the output of my previous work into the MESA stellar evolution code.

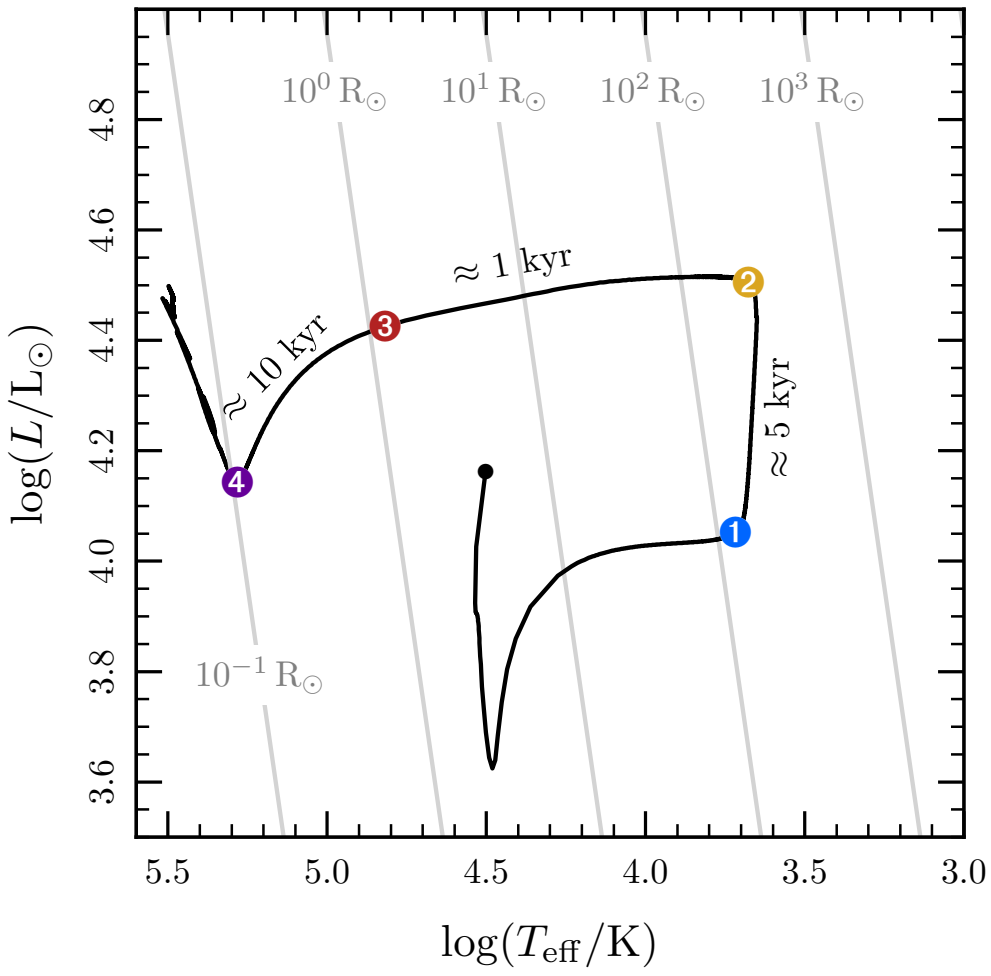


see Shen et al. (2012); Schwab et al. (2012)

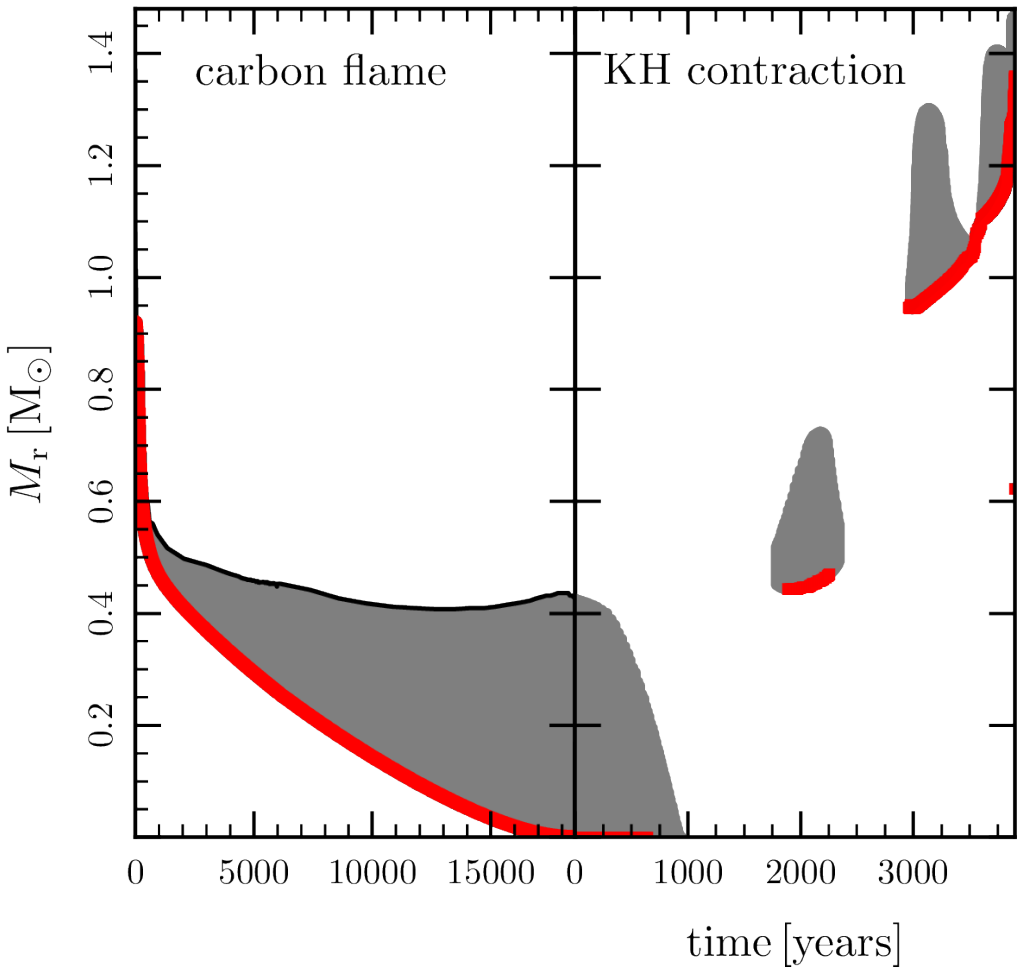
A convectively-bounded carbon deflagration forms and propagates inward, reaching the center.



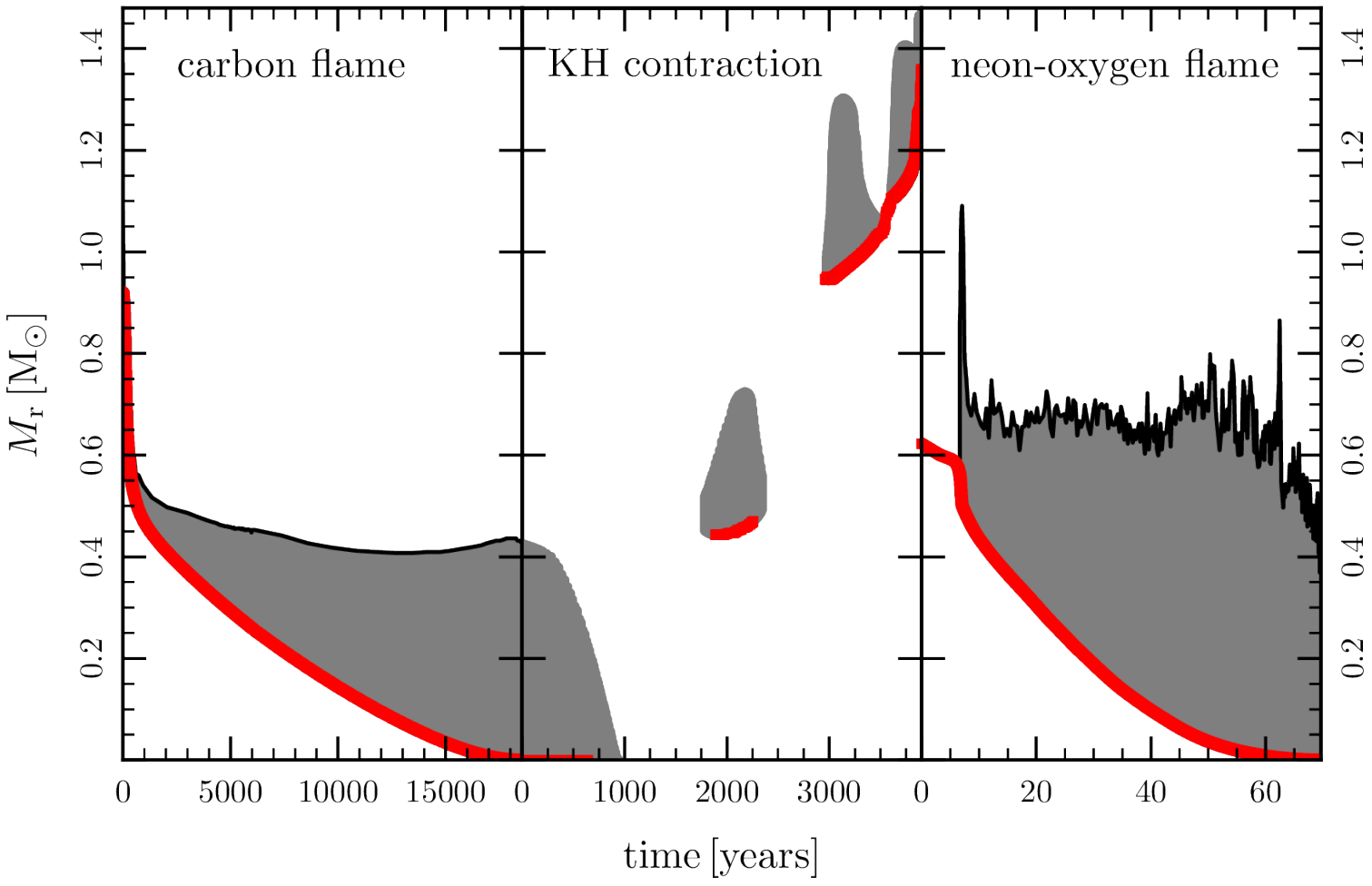
The post-merger there is a cool, giant phase, but the carbon-burning is too deep to sustain it.



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



A neon-oxygen deflagration forms and propagates inward, burning to Si-group.



A key uncertainty in our calculations

is the amount of mass loss during the evolution.

Effect on final fate

- If mass loss causes the remnant to become sub-Chandrasekhar, then the end product may be a massive WD (and not a NS).

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Effects on observational manifestation

- The material shed would be primarily carbon/oxygen and which could cause the remnant to be obscured by a dusty wind.

- We've evolved double degenerate systems from soon after the merger (nearly) up to the collapse to a NS.

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- We've outlined the observational signatures of the merger remnants during these phases. ($L \sim 3 \times 10^4 \mathrm{L}_\odot$, lifetime $\sim 10^4$yr, dusty?)

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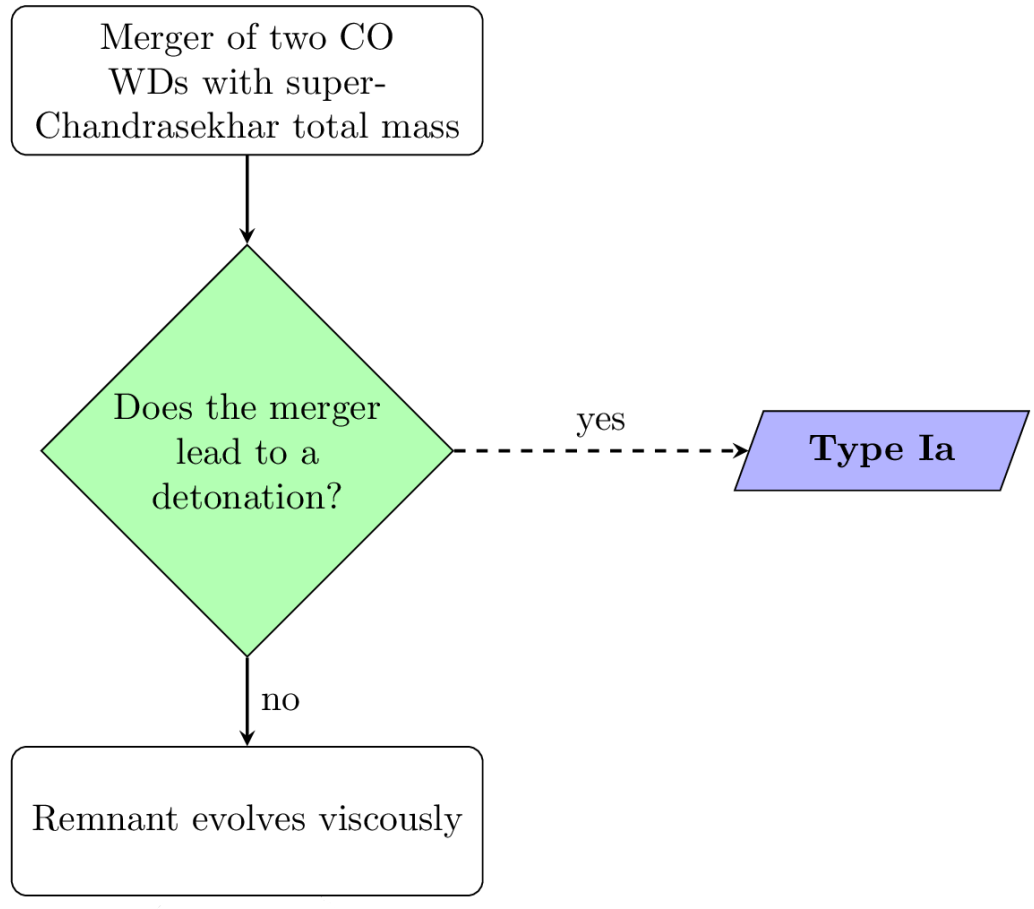
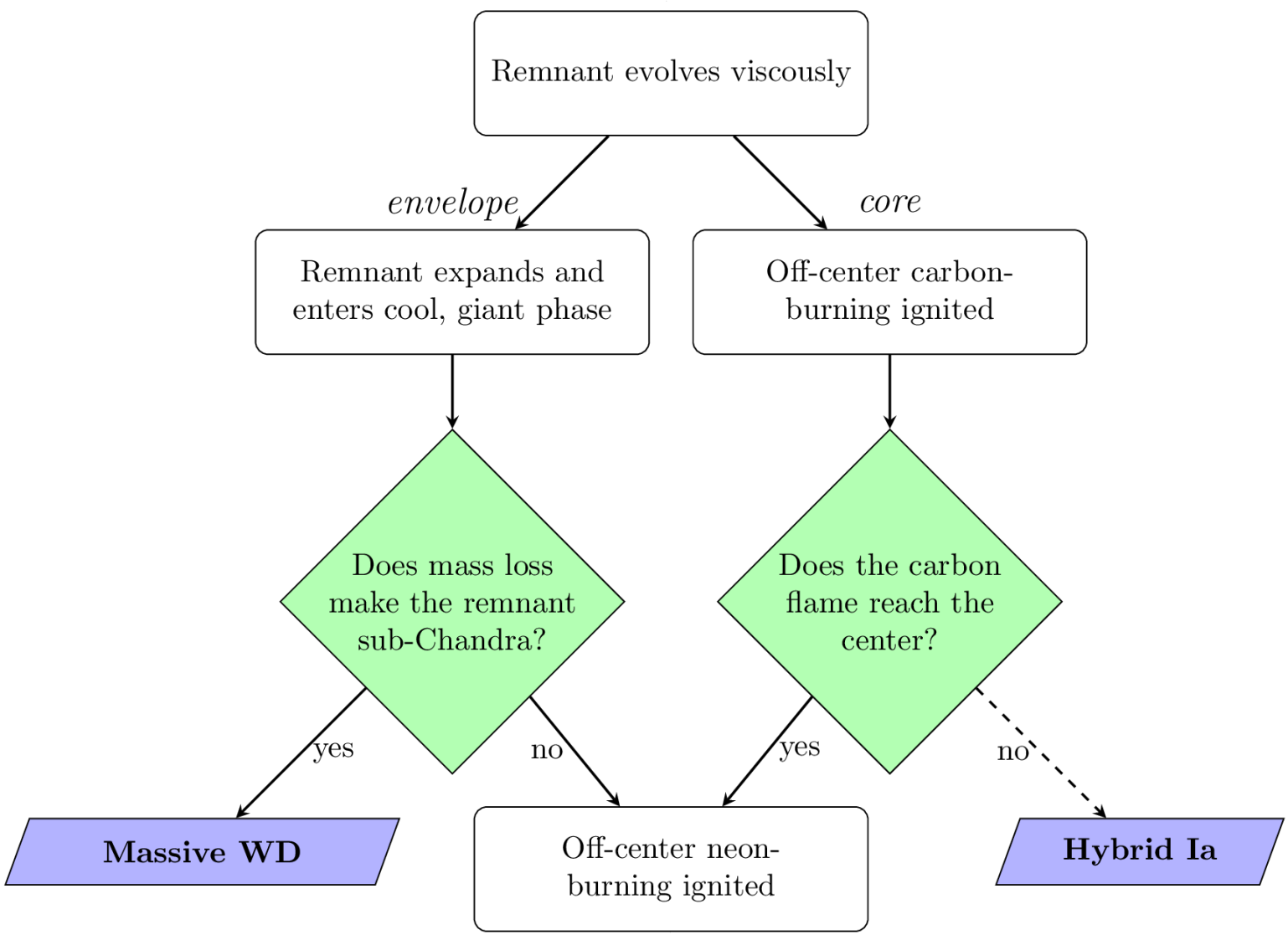
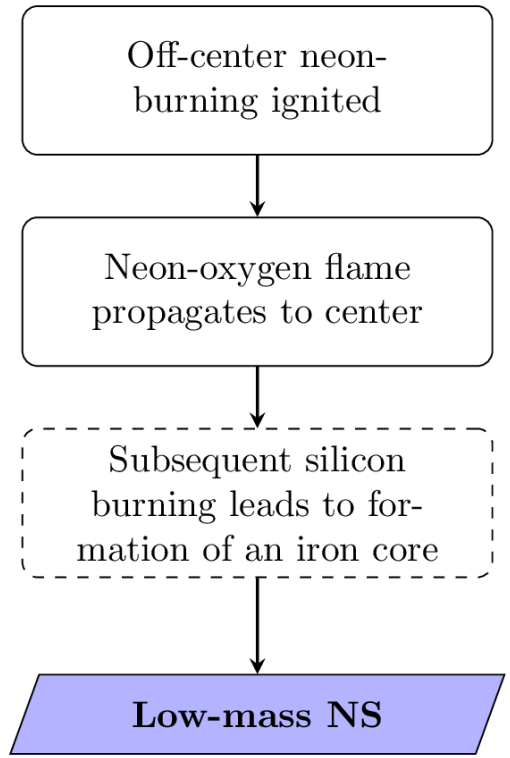
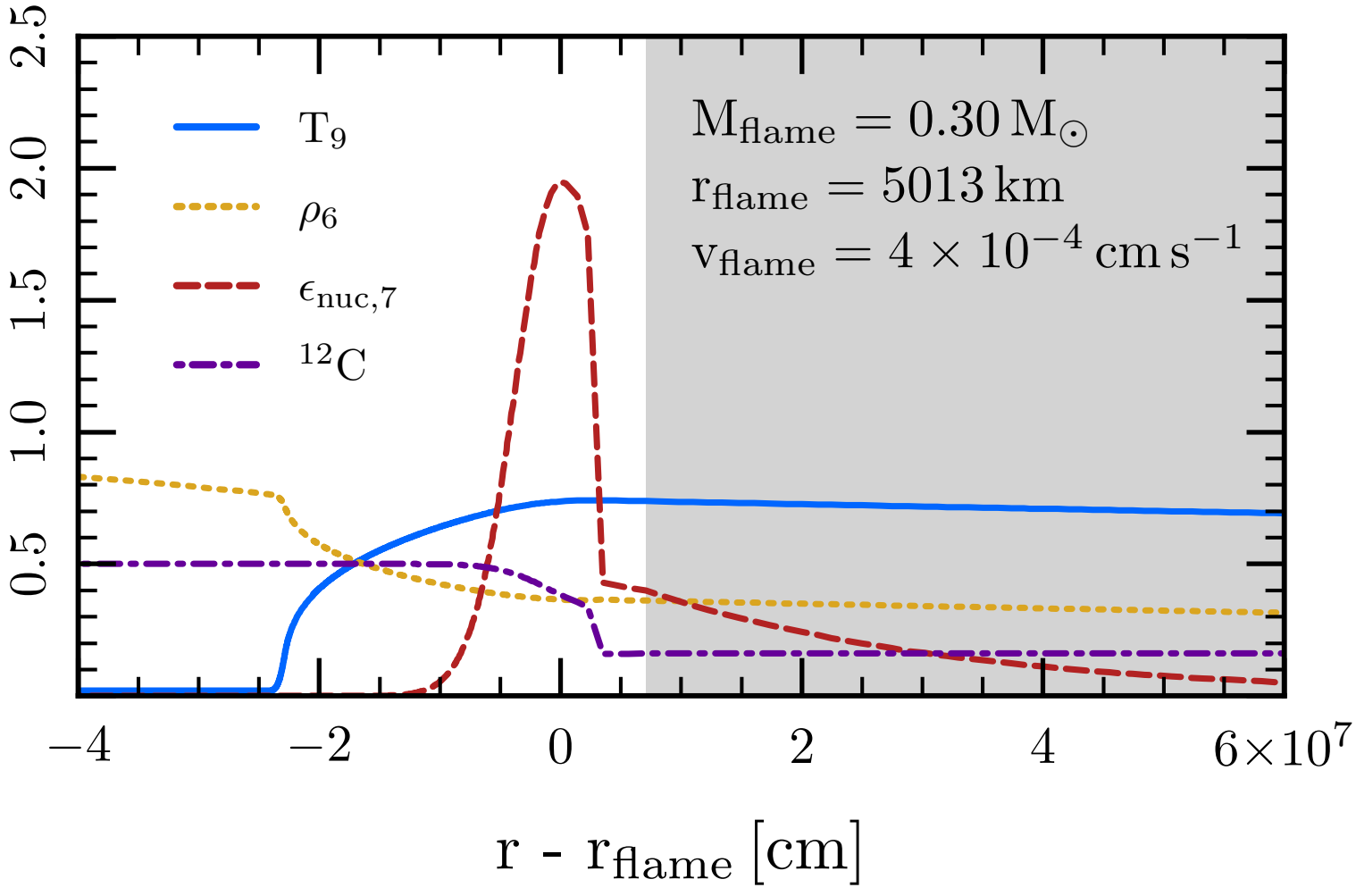
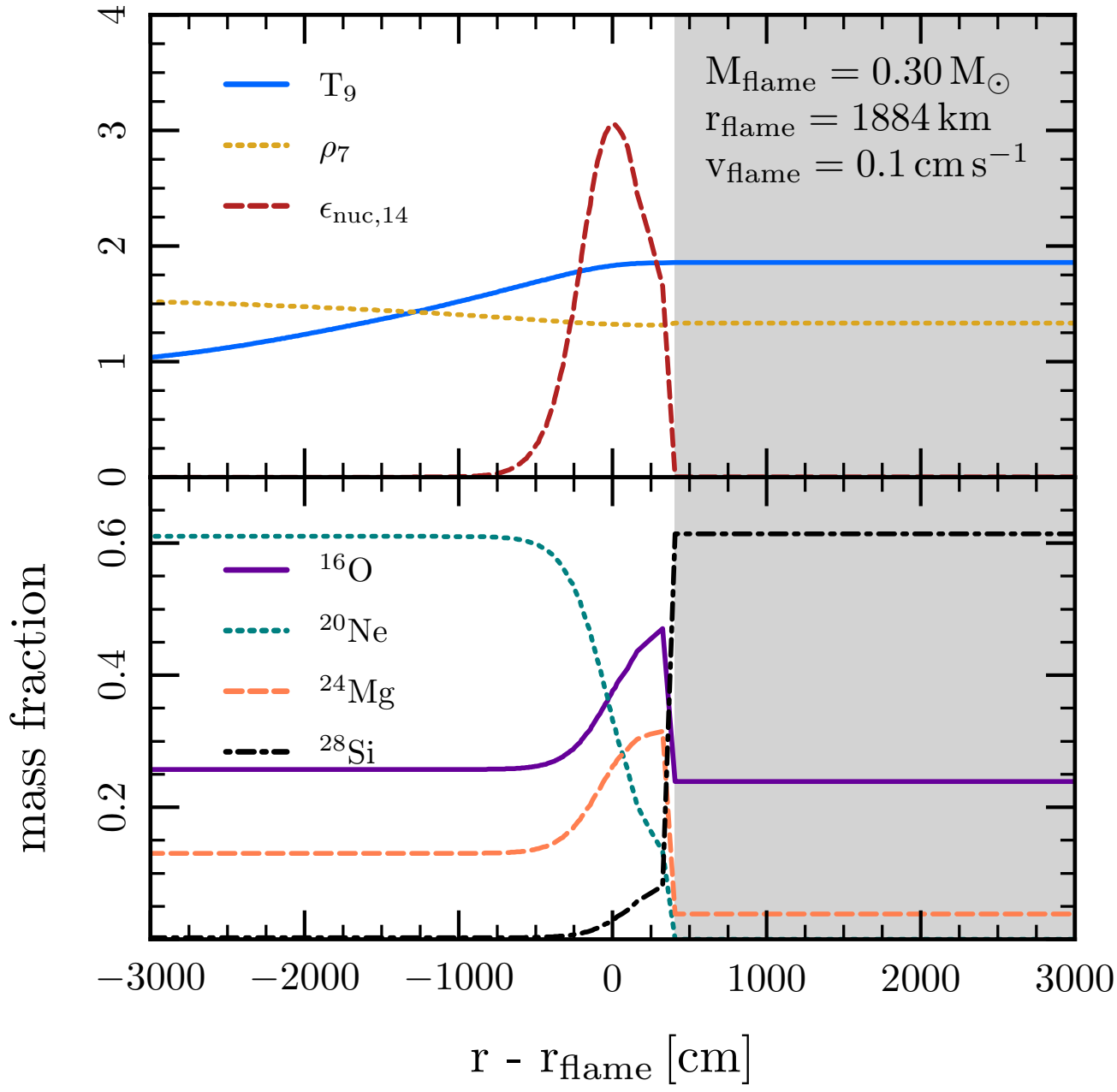
- We've outlined the observational signatures of the merger remnants during these phases. ($L \sim 3 \times 10^4 L_\odot$, lifetime $\sim 10^4$yr, dusty?)
- For super-Chandrasekhar WD mergers, the likely fate is collapse to a neutron star, though the collapse may not occur via an O/Ne core.


Merger of two CO WDs with super-Chandrasekhar total mass
Does the merger lead to a detonation?
yes
Type Ia
no
Remnant evolves viscously


Remnant evolves viscously
envelope
core
Remnant expands and enters cool, giant phase
Off-center carbon-burning ignited
Does mass loss make the remnant sub-Chandra?
Does the carbon flame reach the center?
yes
no
yes
no
Massive WD
Off-center neon-burning ignited
Hybrid Ia


Off-center neon-burning ignited
Neon-oxygen flame propagates to center
Subsequent silicon burning leads to formation of an iron core
Low-mass NS


T_9
ρ_6
$\epsilon_{nuc,7}$
^{12}C
$M_{flame} = 0.30\,M_\odot$
$r_{flame} = 5013\,km$
$v_{flame} = 4 \times 10^{-4}\,cm\,s^{-1}$
0.5
1.0
1.5
2.0
2.5
−4
−2
0
2
4
6×10^7
r - r_flame [cm]


T_9
ρ_7
$\epsilon_{nuc,14}$
$M_{flame} = 0.30\,M_\odot$
$r_{flame} = 1884\,km$
$v_{flame} = 0.1\,cm\,s^{-1}$
^{16}O
^{20}Ne
^{24}Mg
^{28}Si
mass fraction
$r - r_{flame}$ [cm]