Numerical Study of White Dwarf Thermonuclear Explosions induced by Tidal Disruption Events

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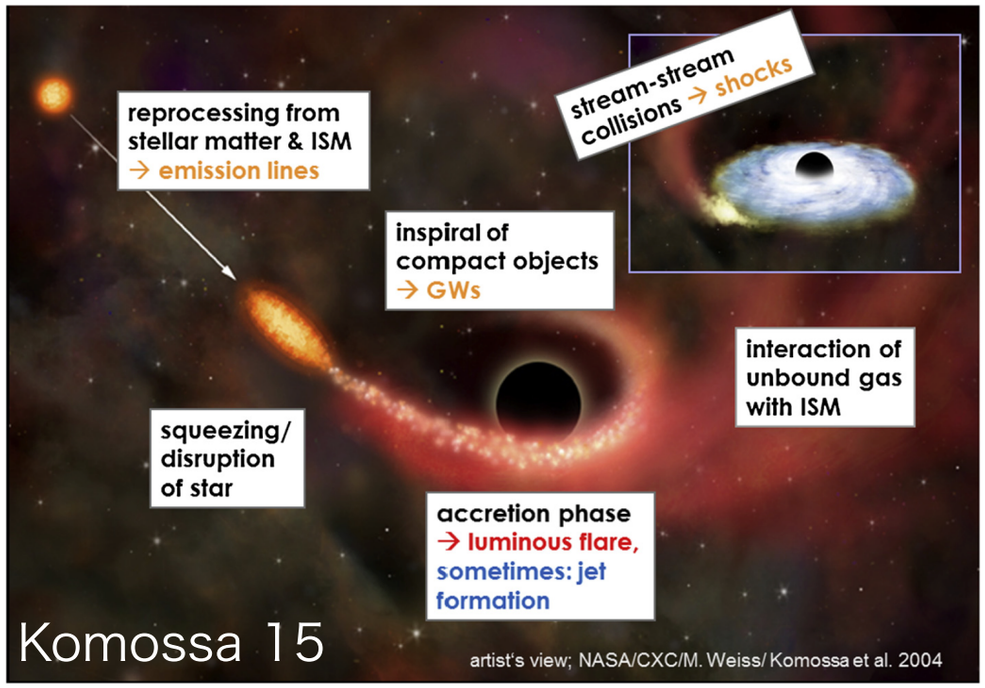
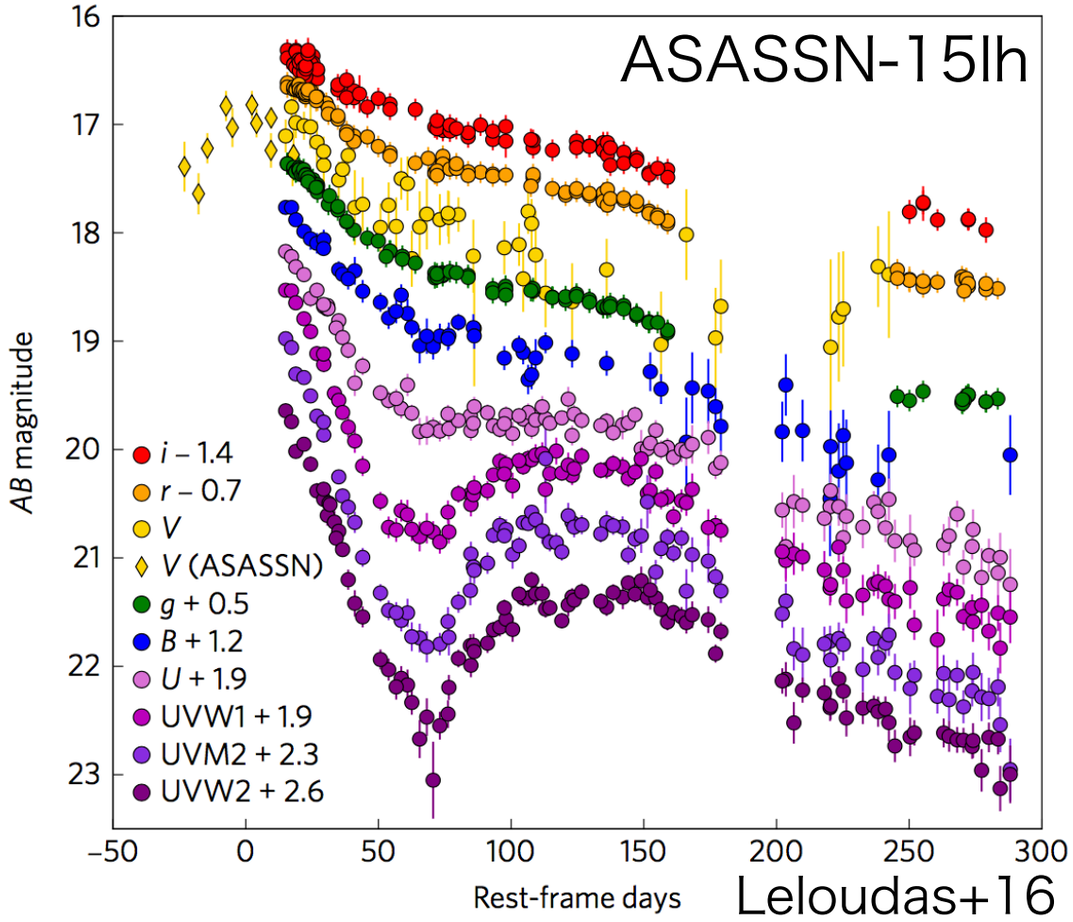
Tanikawa et al. (2017, ApJ, 839, 81)
Tanikawa (2018, ApJ, 858, 26)

Tidal Disruption Event

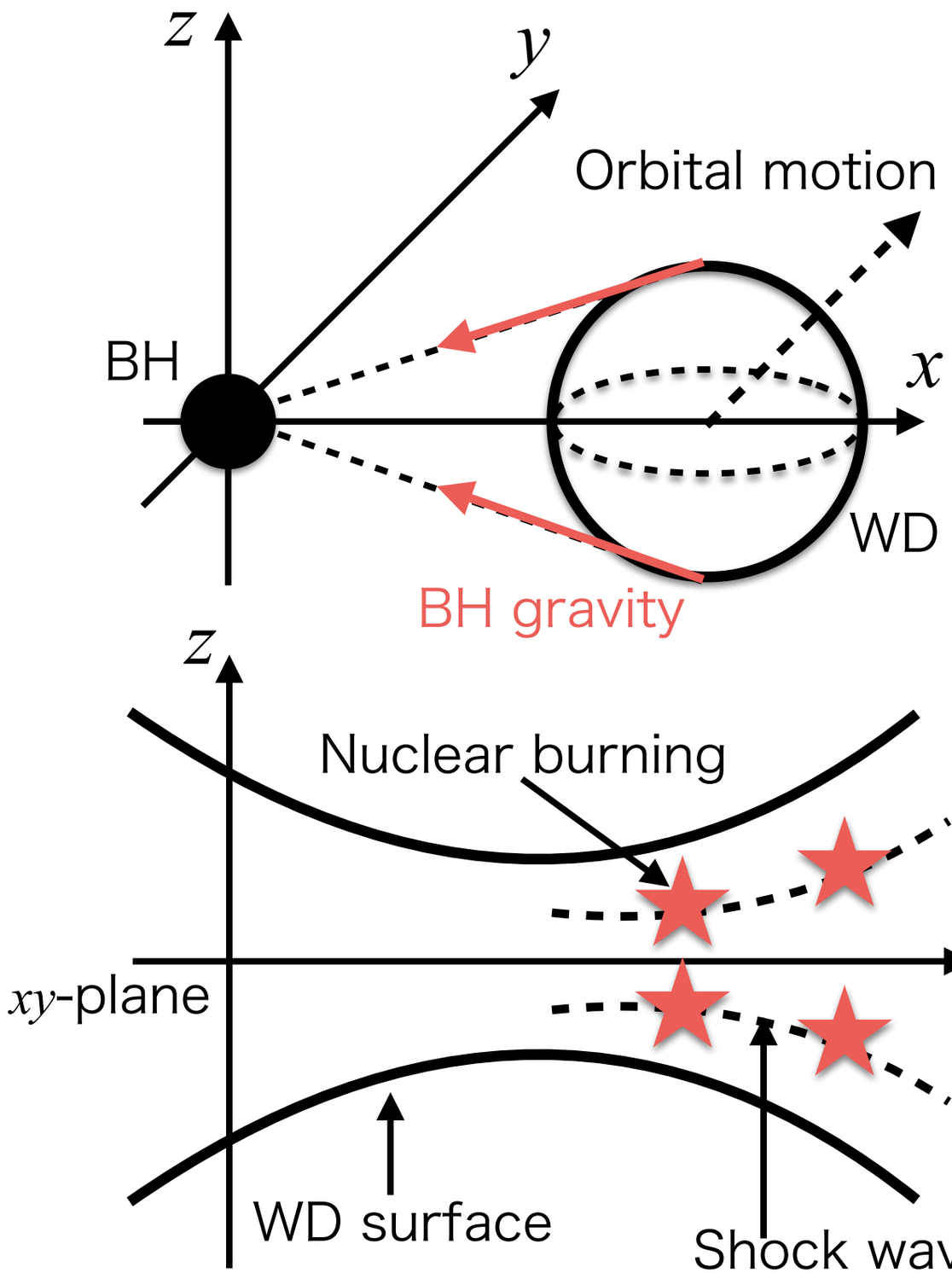
- Tidal disruption of a star (e.g. main sequence stars) by a BH
- Bright flare powered by accretion of the stellar debris
- Several ten candidates (Kommosa 2015)
  - TDEs of main sequence stars
  - No conformed WD TDEs





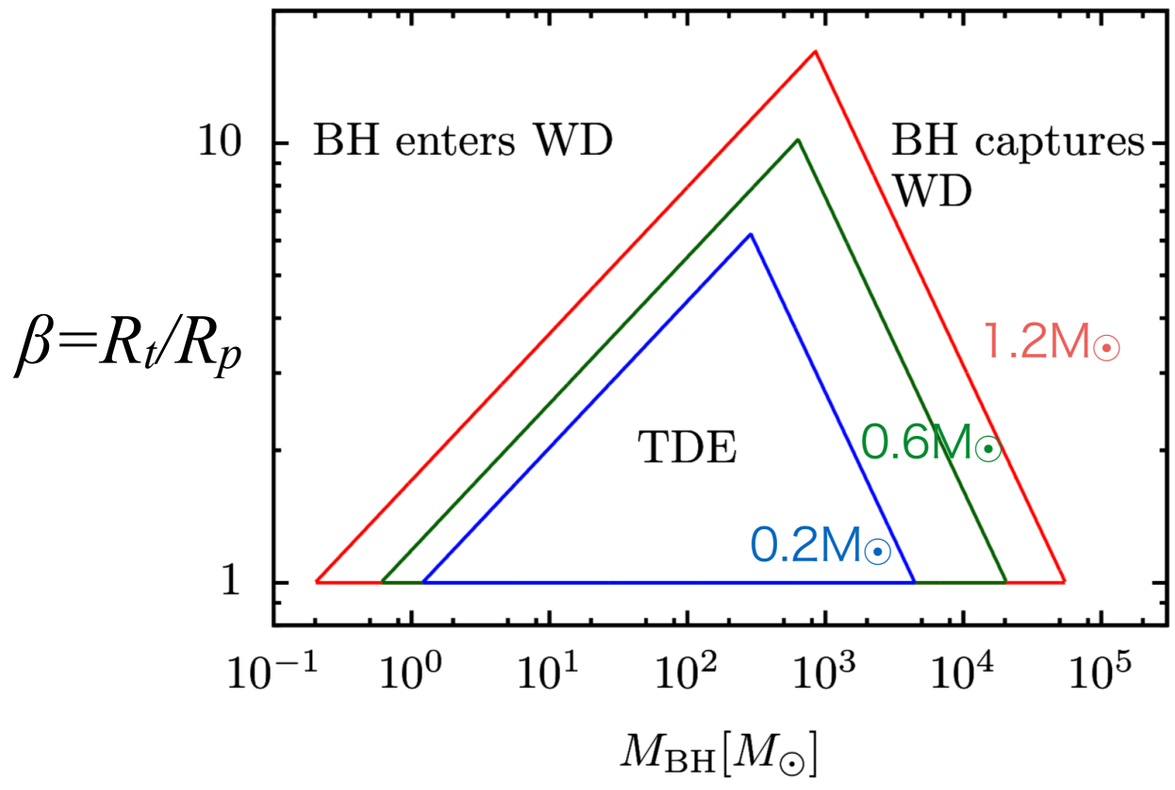
Tidal detonation

- Supersonic combustion induced by a tidal field of a BH
  - The WD is compressed in z-direction.
  - The compression induces a shock wave.
  - The shock wave triggers a detonation wave.
  - The detonation wave synthesizes large amounts of ^{56}Ni.
  - The WD TDE can be powered by radioactive decay ^{56}Ni, similarly to SNe Ia.



Probe to search for Intermediate mass black hole

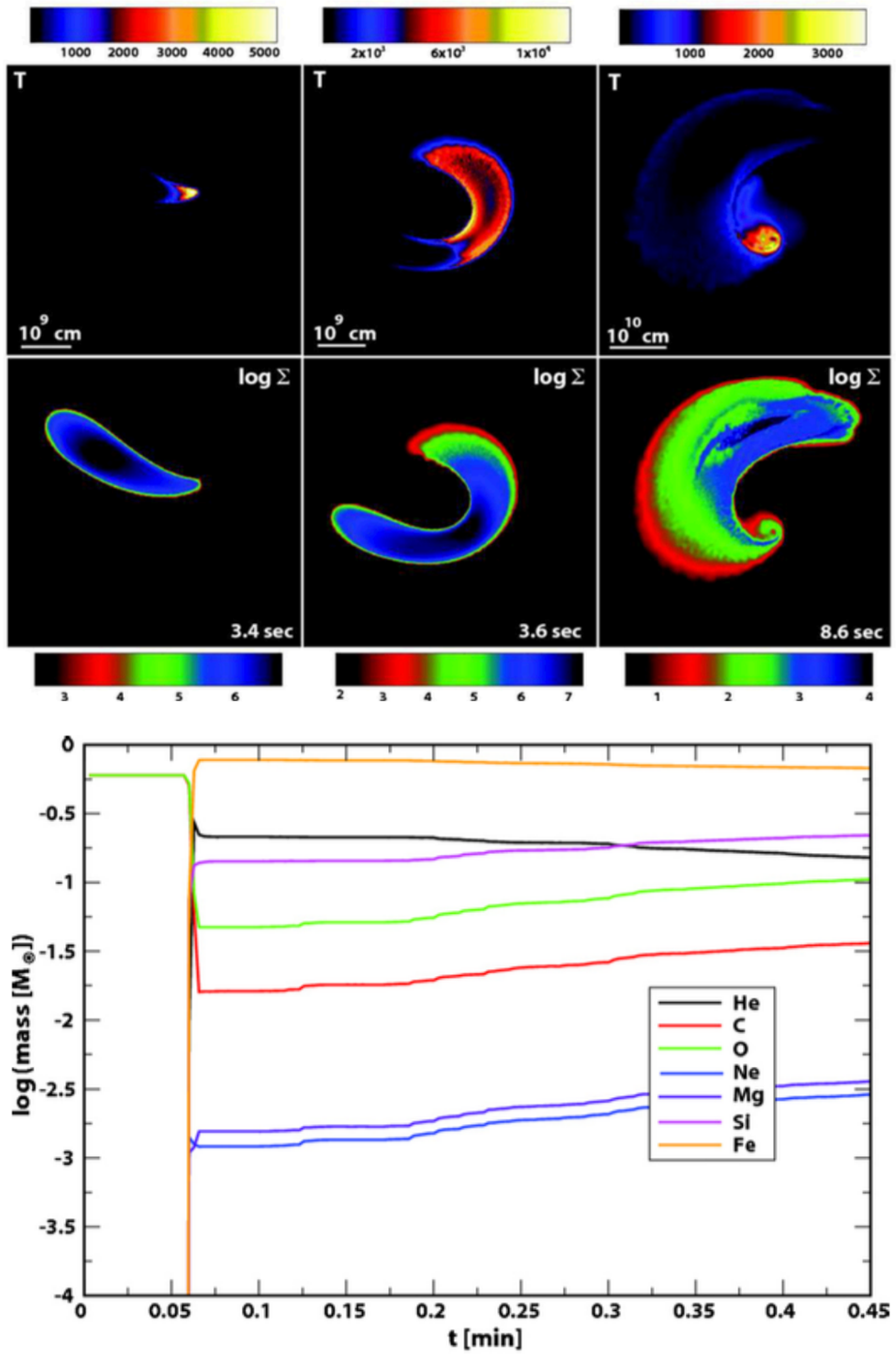
- Tidal detonation requires a WD TDE.
- A WD can be tidally disrupted only by an IMBH.
  - swallowing a stellar-mass BH.
  - swallowed by a massive BH.
- WD TDEs can illuminate only IMBHs.
- WD TDEs can be probes to search for IMBHs.



Kawana, AT+ 17 (see also Luminet, Pichon 1989 Rosswog et al. 2009; MacLeod et al. 2016)

Previous and our studies

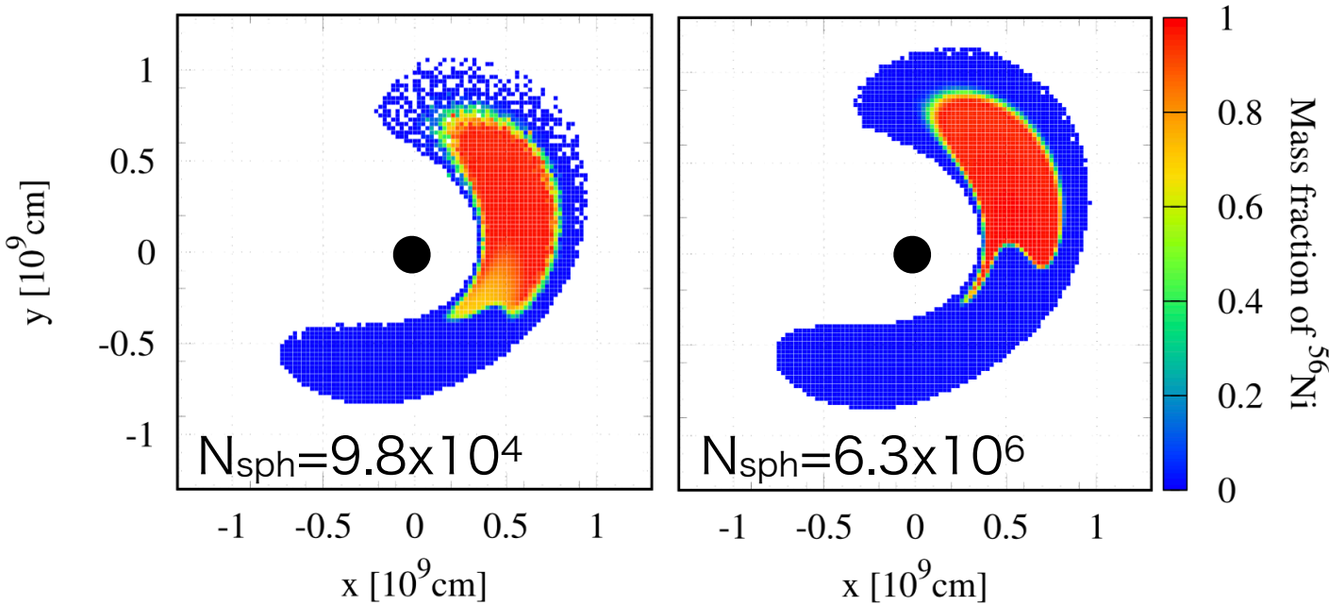
- Previous studies
  - Demonstration of large amounts of ^{56}Ni yielded
  - No convergence check about mass resolution
  - No demonstration of shock generation
- Our studies
  - Convergence check
  - Demonstration of shock generation

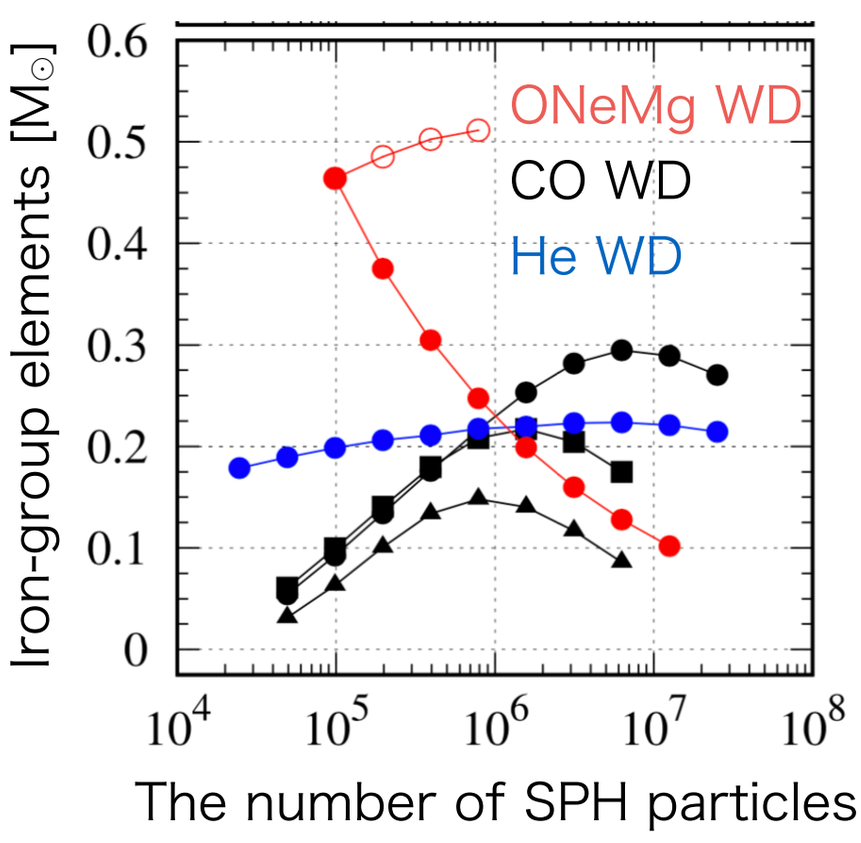


Rosswog et al. (2008; 2009)

SPH simulation

- We have performed SPH simulations in the same way as in previous studies, but with higher-mass resolution (N_{sph} ~ 10^7)
- The amounts of yielded ^{56}Ni are not converged with increasing N_{sph} in various WDs.

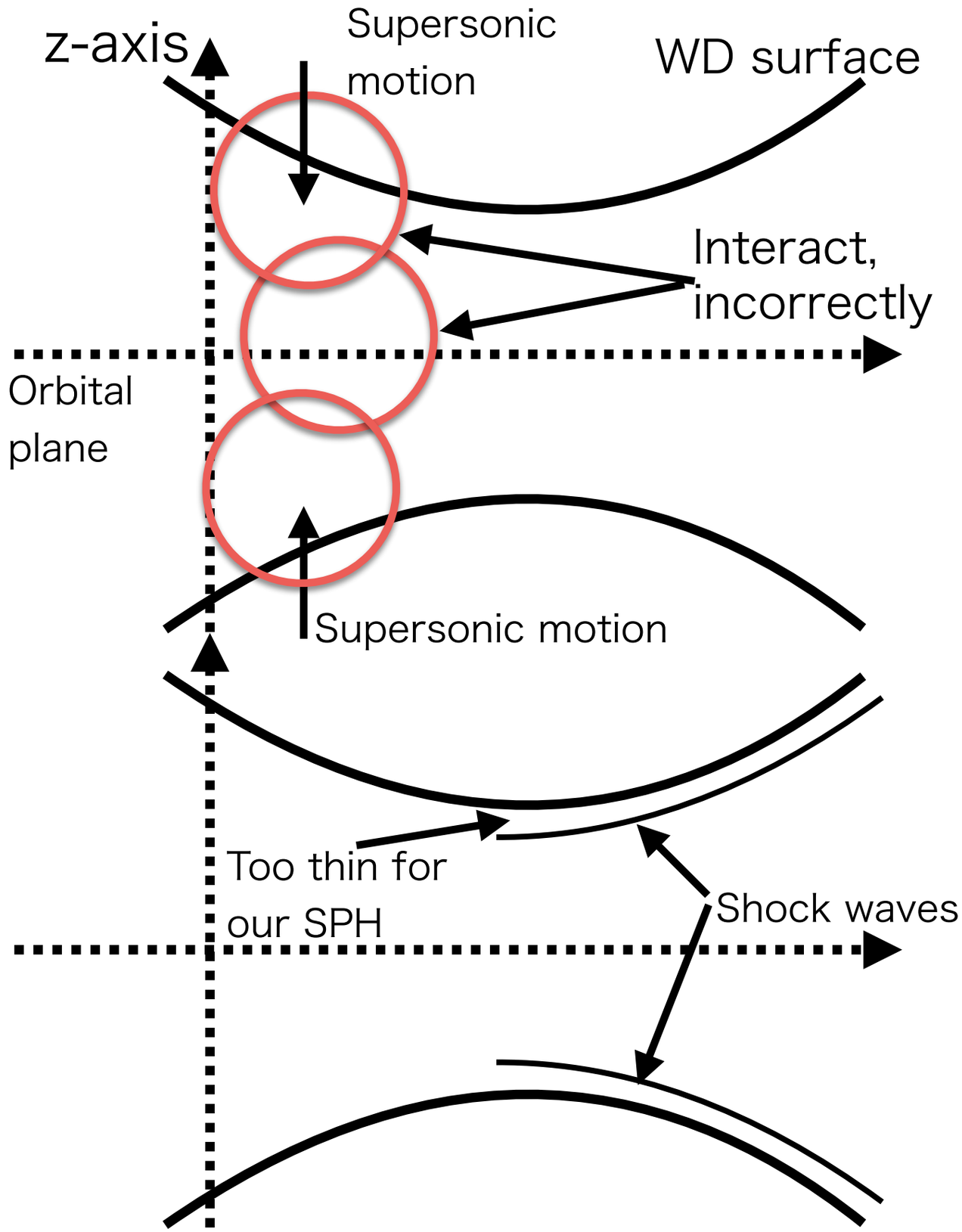




Tanikawa et al. (2017, ApJ, 839, 81)

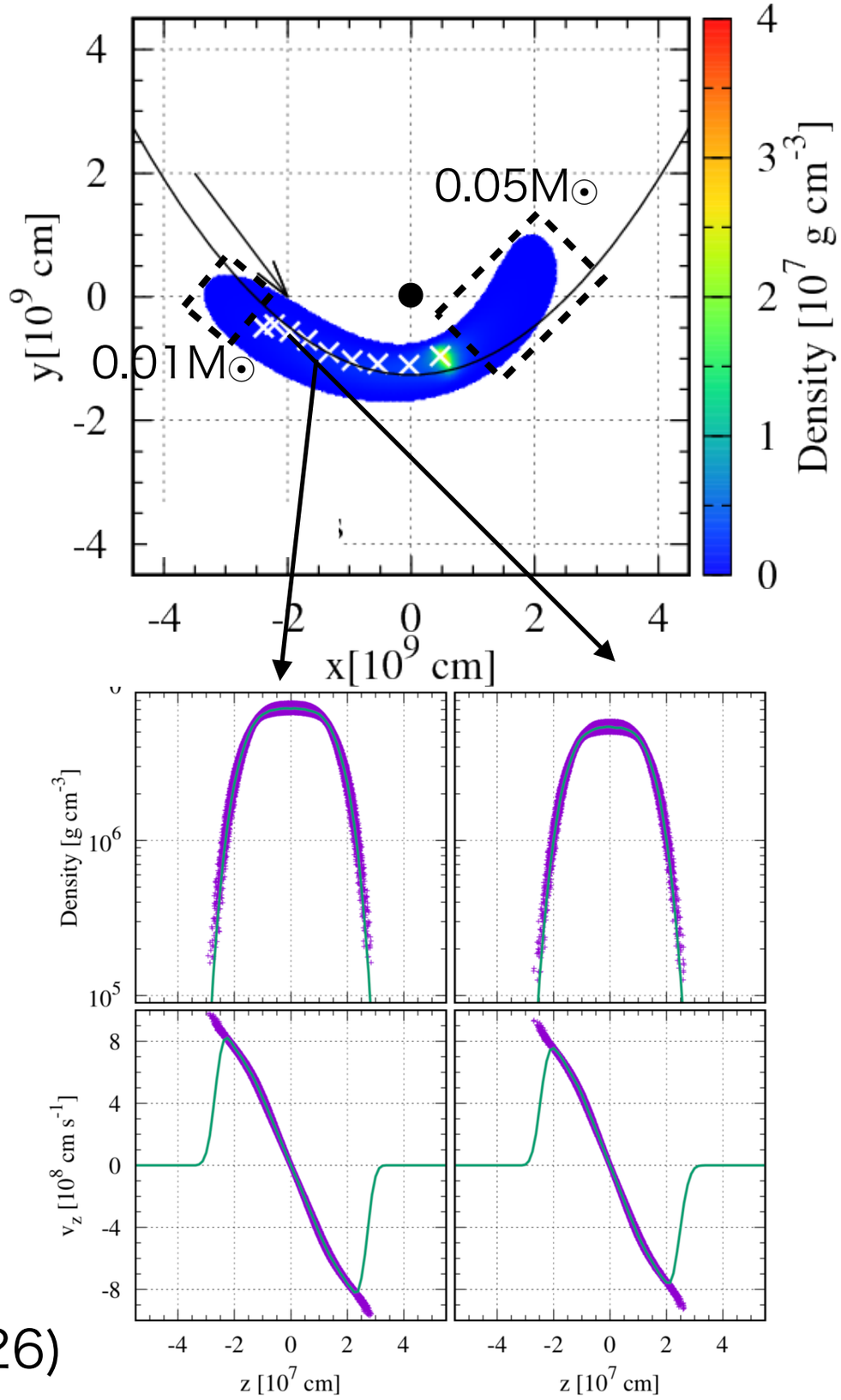
Interpretation

- The reason for active nucleosynthesis in low mass resolution
  - The number of SPH particles is too small in the direction normal to the orbital plane.
  - Distant particles interact incorrectly.
  - Artificial viscosity switches on falsely.
- The reason for inactive nucleosynthesis in high mass resolution
  - A shock wave should be generated in the outermost part of a WD.
  - Our SPH simulation cannot resolve such a thin structure even if $N_{sph} \sim 10^7$.
  - Note that SPH simulation does not work well in low-density regions.



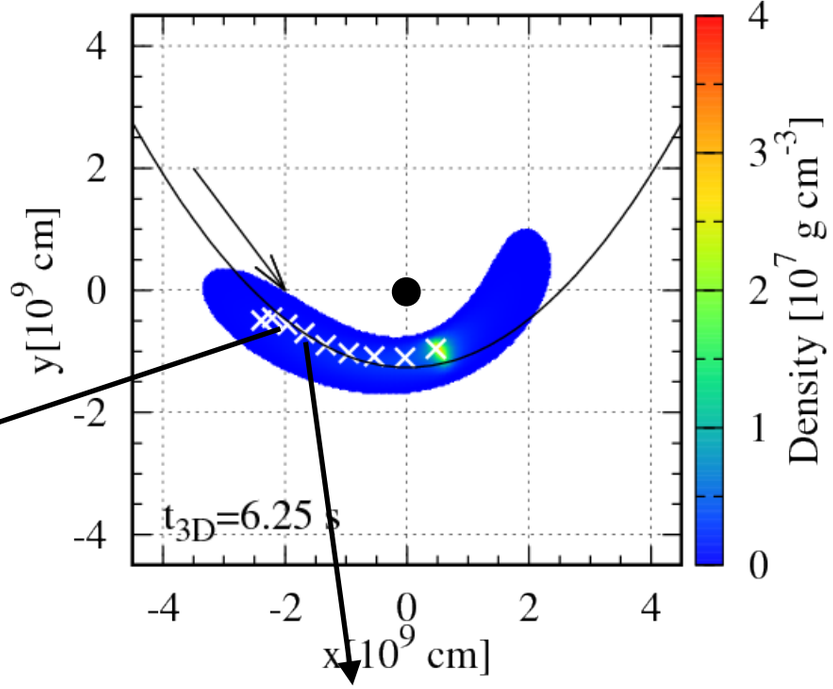
Switch 3D to 1D

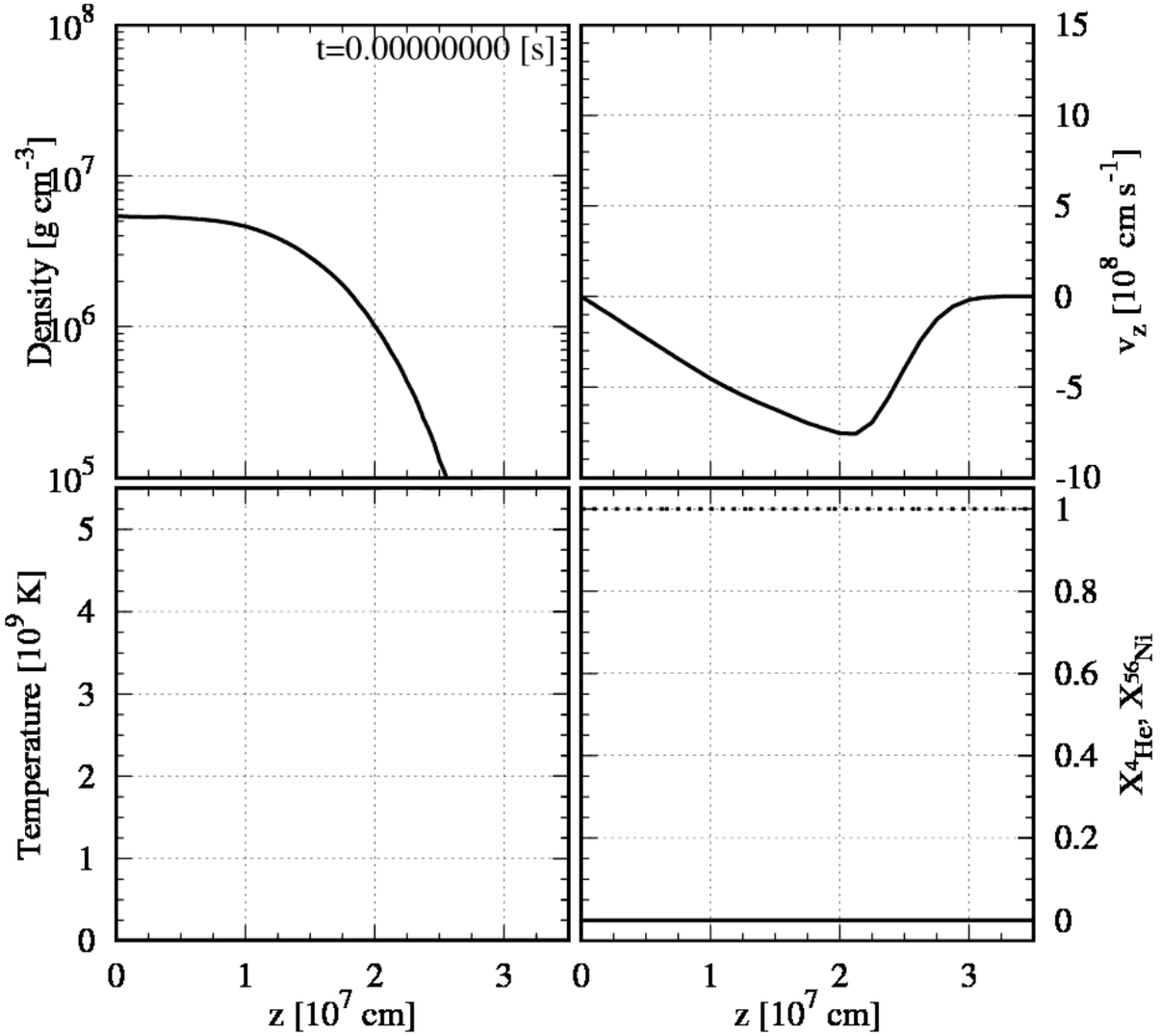
- 3D SPH simulation
  - 0.45M⊙ HeWD disrupted by 300M⊙ IMBH
    - N~3x10⁸ for the He WD
    - without nuclear reactions
- Extracting z-columns indicated by white crosses
- 1D mesh simulation
  - z-columns
  - with nuclear reactions



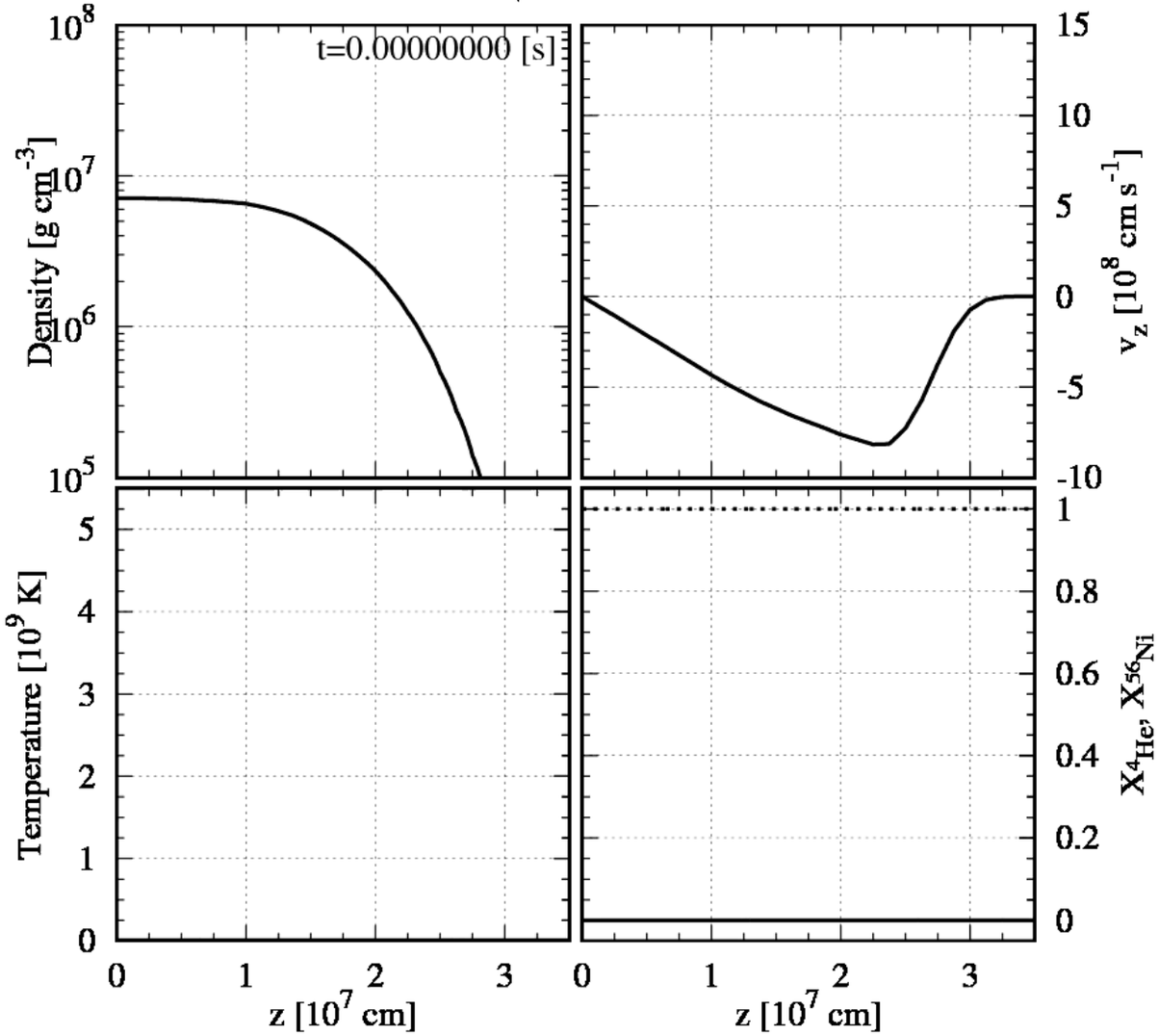
Tanikawa (2018, ApJ, 858, 26)

Movies



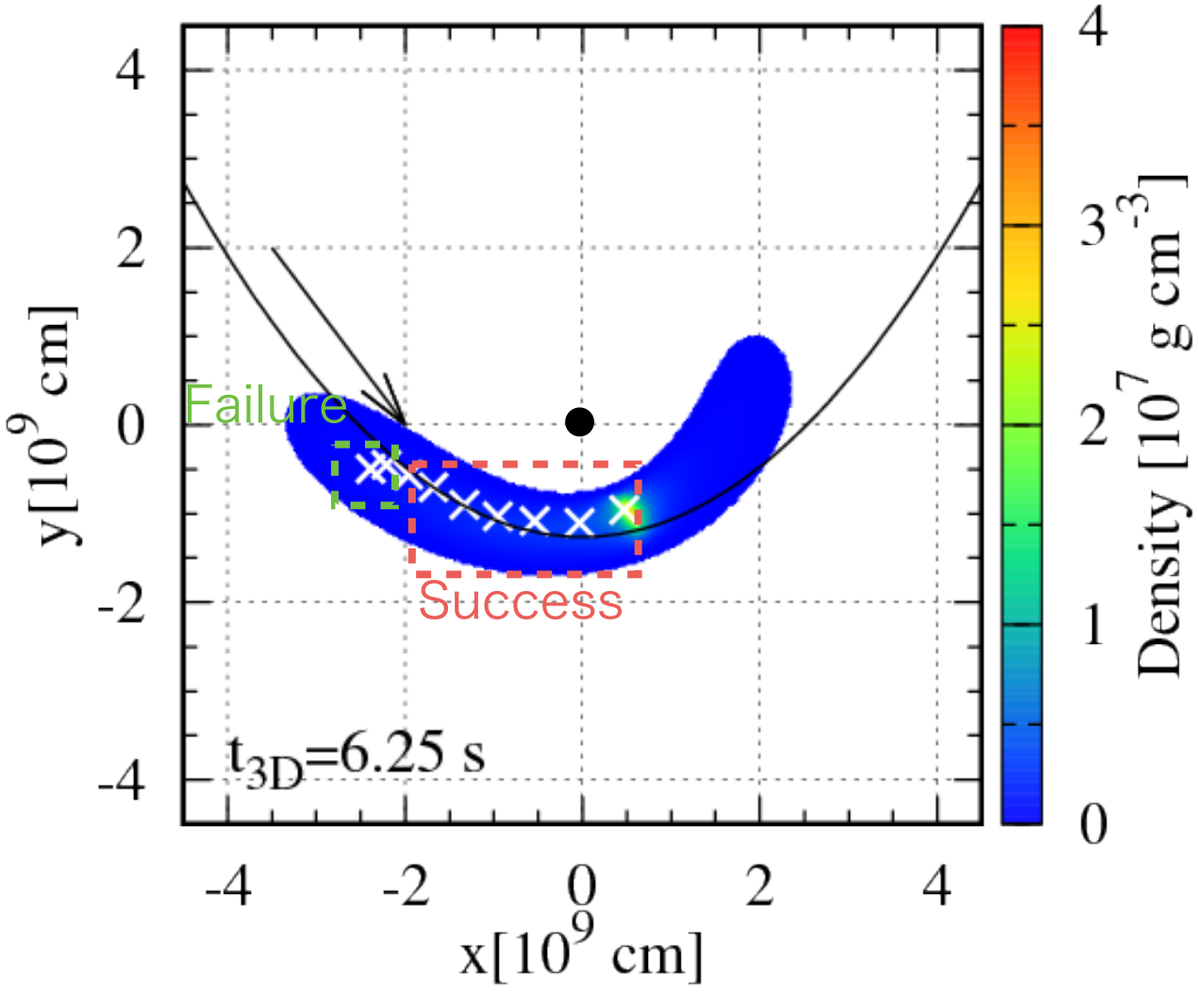


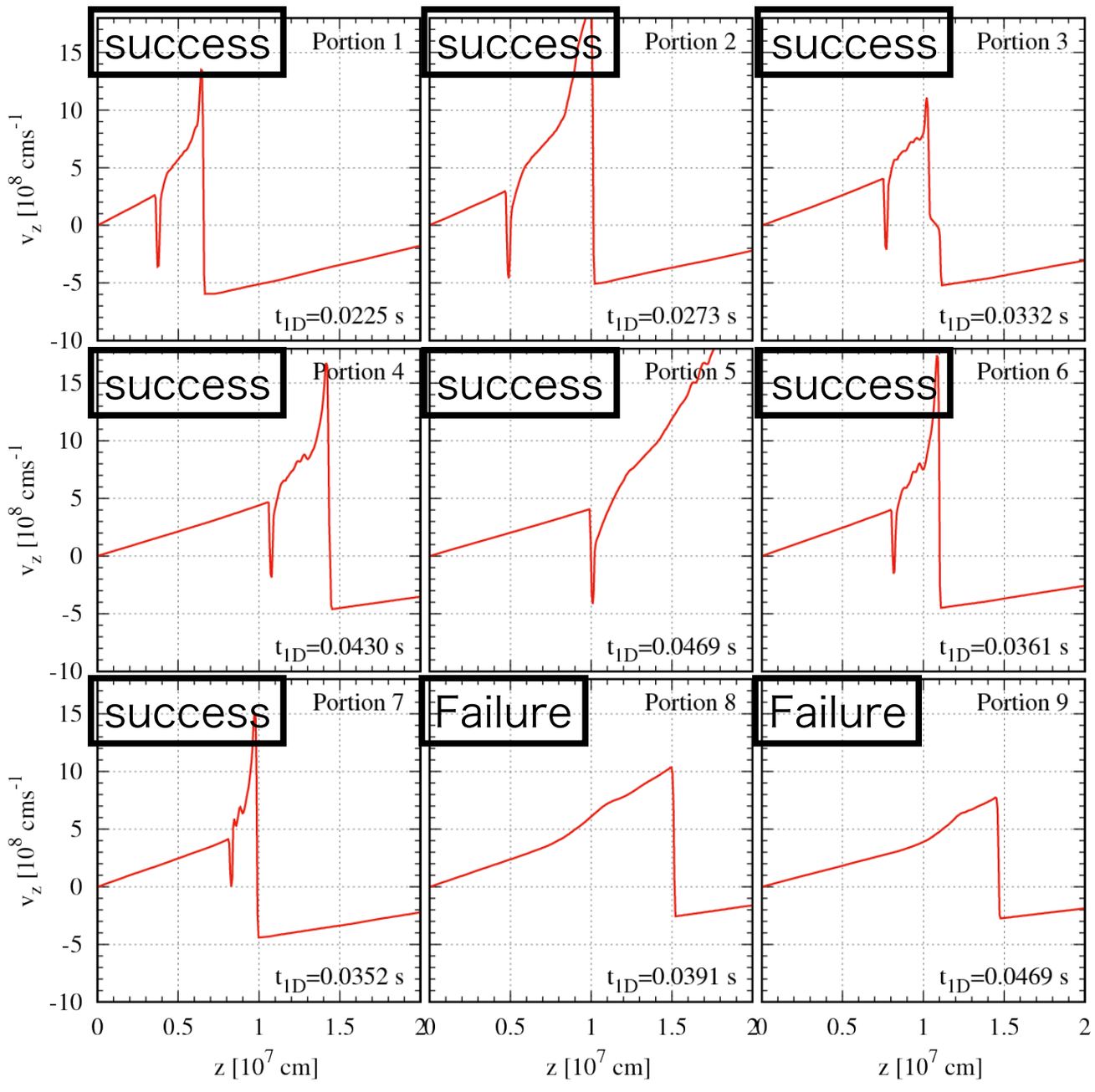
Failure case



Success case

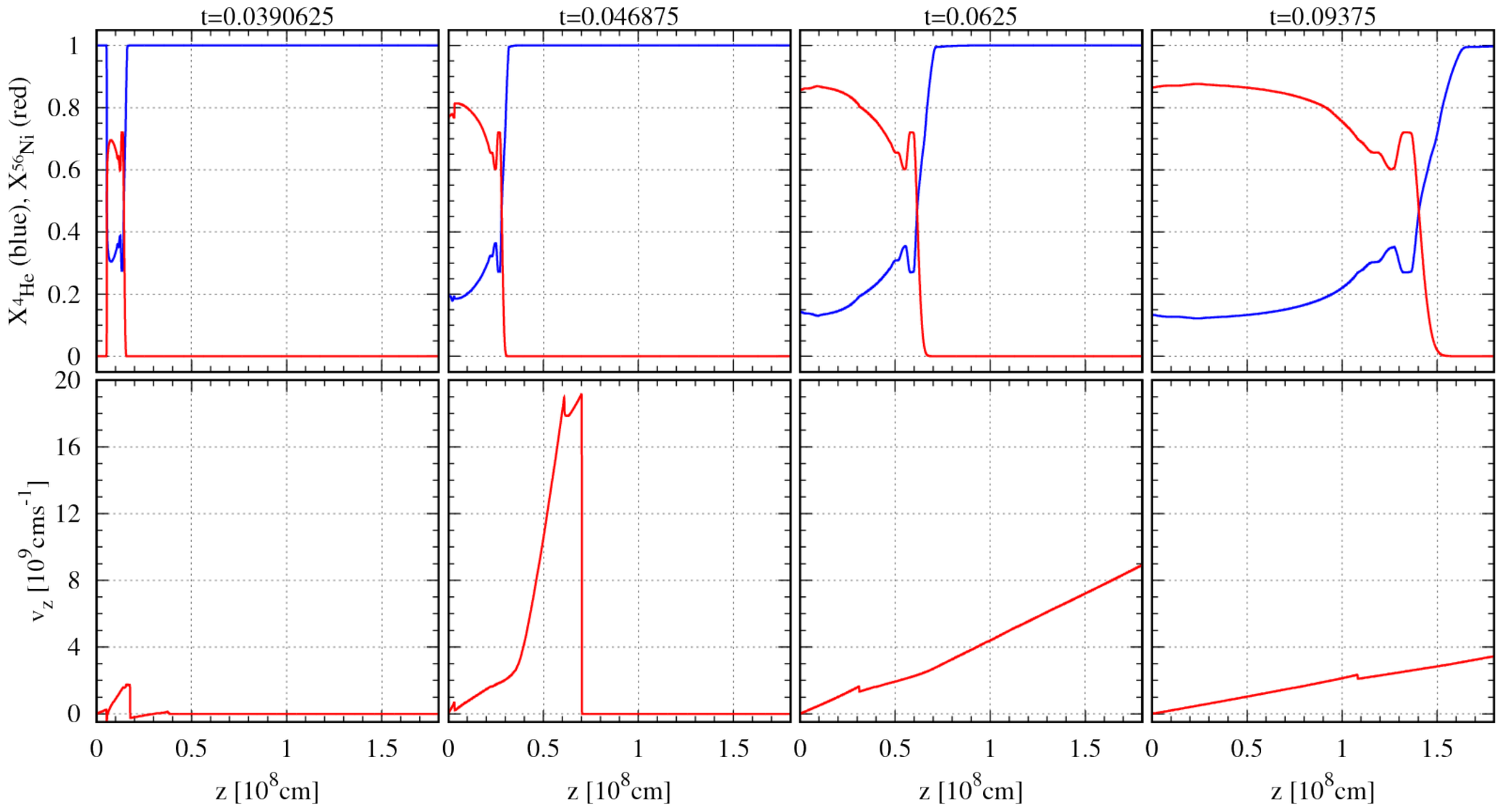
Results





More than 80% of this WD is detonated.

Nucleosynthesis



- The detonation wave leaves 20% ^{4}He and 80% ^{56}Ni.
  - The detonated region has high density (>10^6 gcm^{-3}).
- The total ^{56}Ni mass is about 0.3M$\odot$, comparable to SNela.

Summary

- We have studied tidal detonation of WDs.
- We should be careful of spurious heating in low-resolution SPH simulation (Tanikawa et al. 2017, ApJ, 839, 81).
- We have verified tidal detonation of WDs in the case of He WD with $0.45M_\odot$ in which large amount of ^{56}Ni ($\sim 0.3M_\odot$) is synthesized (Tanikawa 2018, ApJ, 858, 26).
- WD TDEs can be a clue to search for IMBHs.