中間質量ブラックホールによる白色矮星の潮汐破壊と熱核爆発

WD TDE and explosion by IMBH

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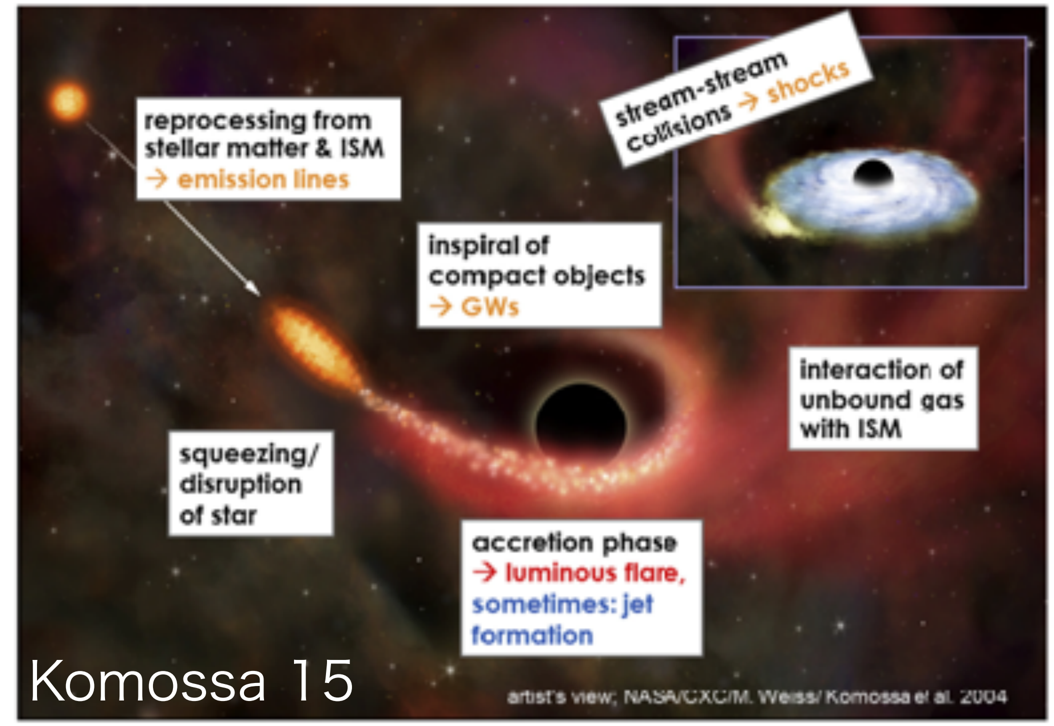
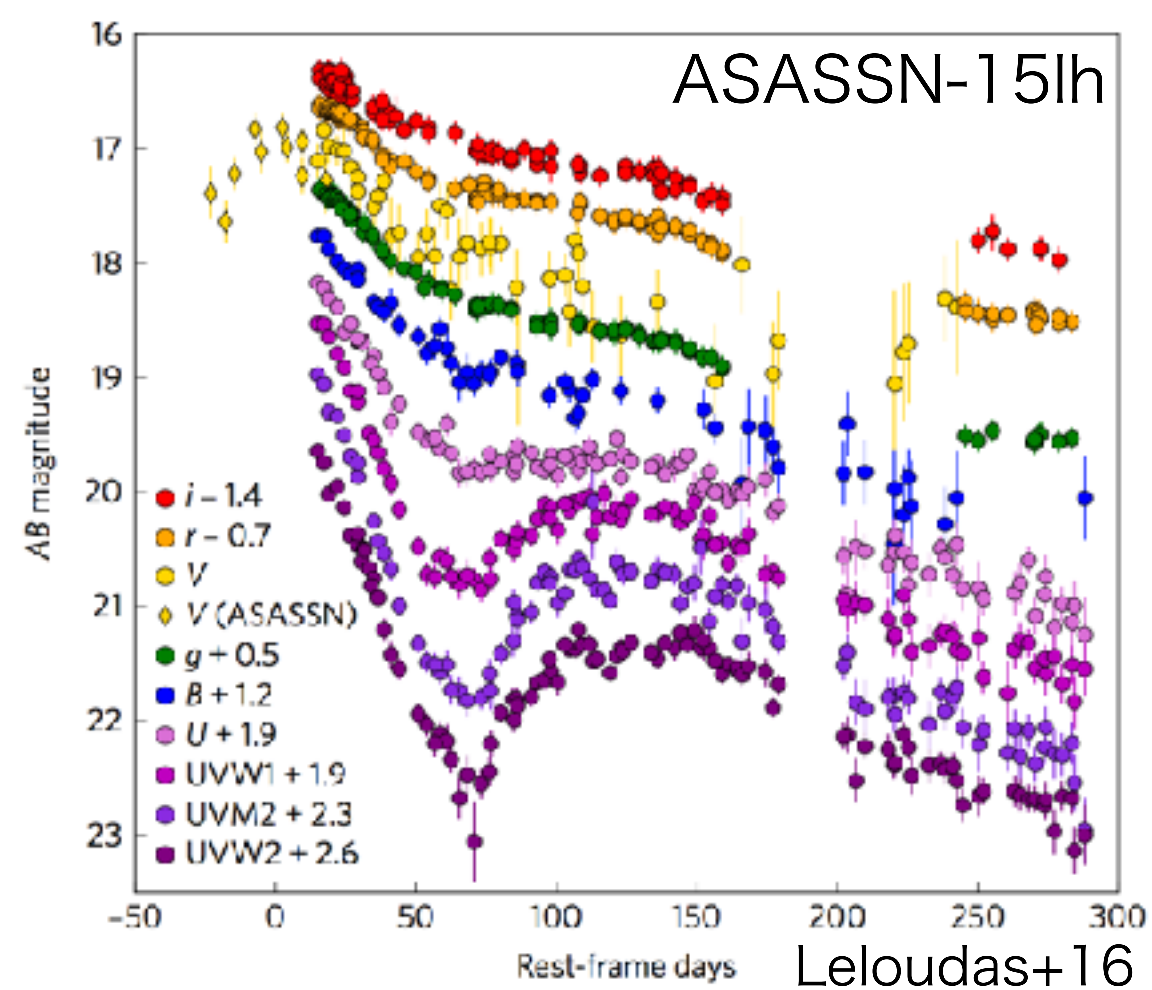
- Tanikawa et al. (2017, ApJ, 839, 81)
- Tanikawa (2018, ApJ, 858, 26)
- Tanikawa (2018, MNRAS, 475, L67)
- Kawana et al. (2018, MNRAS, 477, 3449)

Tidal Disruption Event

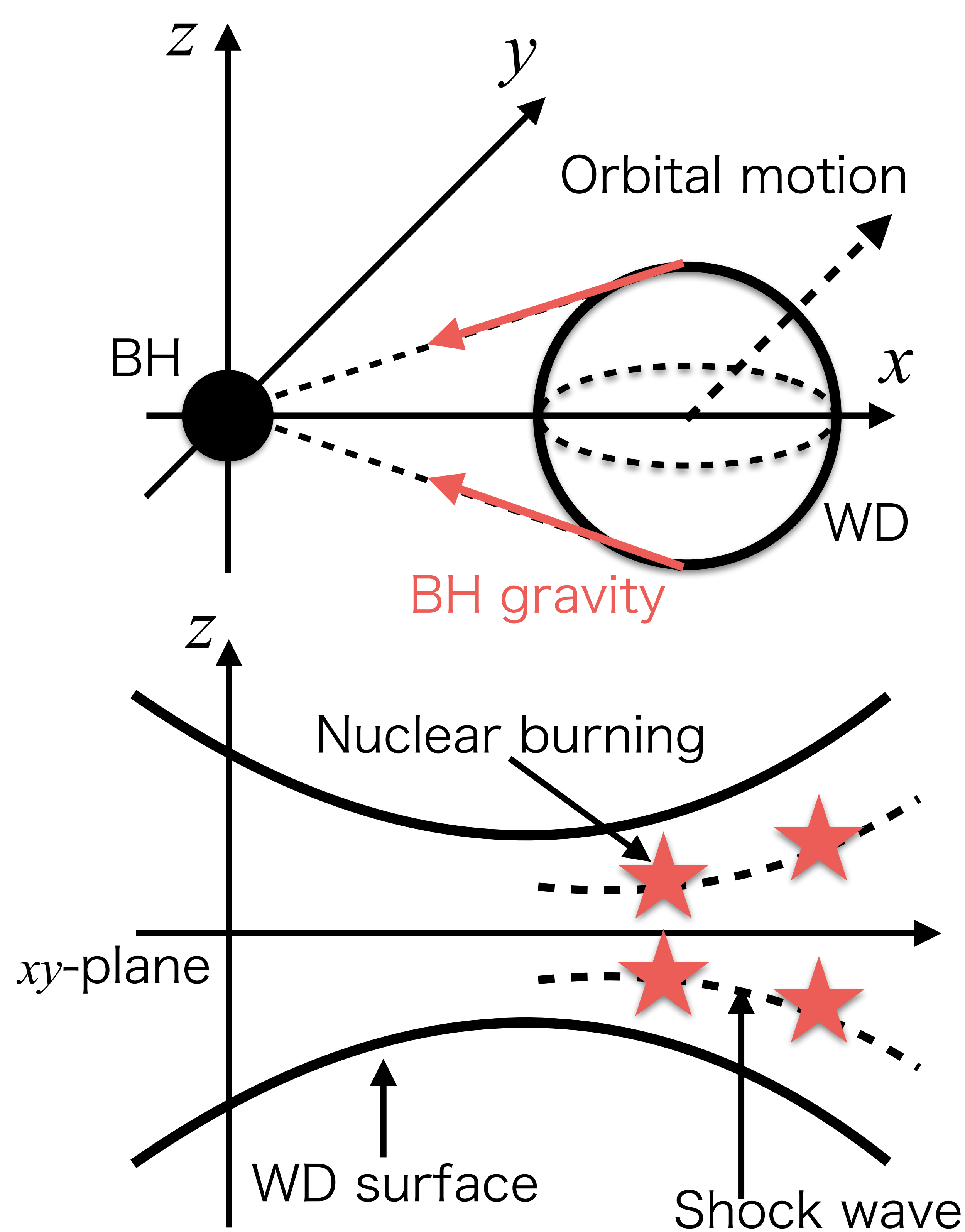
- Tidal disruption of a star (e.g. main sequence stars) by a BH
- Bright flare powered by accretion of the stellar debris
- Several ten candidates (Kommosa 2015)
    - TDEs of main sequence stars
    - Several candidates of WD TDEs (e.g. Ioka et al. 2016)





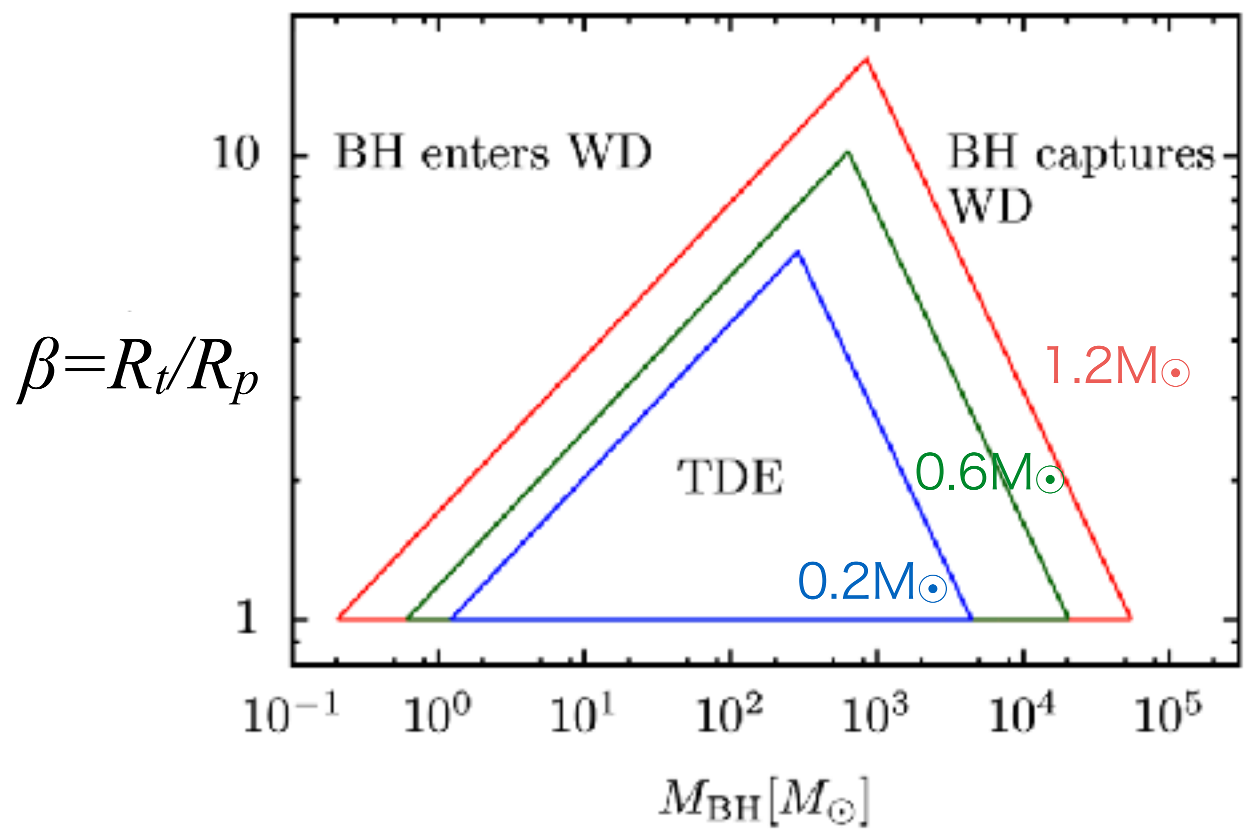
Tidal detonation

- Supersonic combustion induced by a tidal field of a BH
  - The WD is compressed in z-direction.
  - The compression induces a shock wave.
    - Bounce generates a pressure wave.
    - The pressure wave steepens into the 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 ^{56}Ni, similarly to SNe Ia.



Probe to search for Intermediate mass black hole

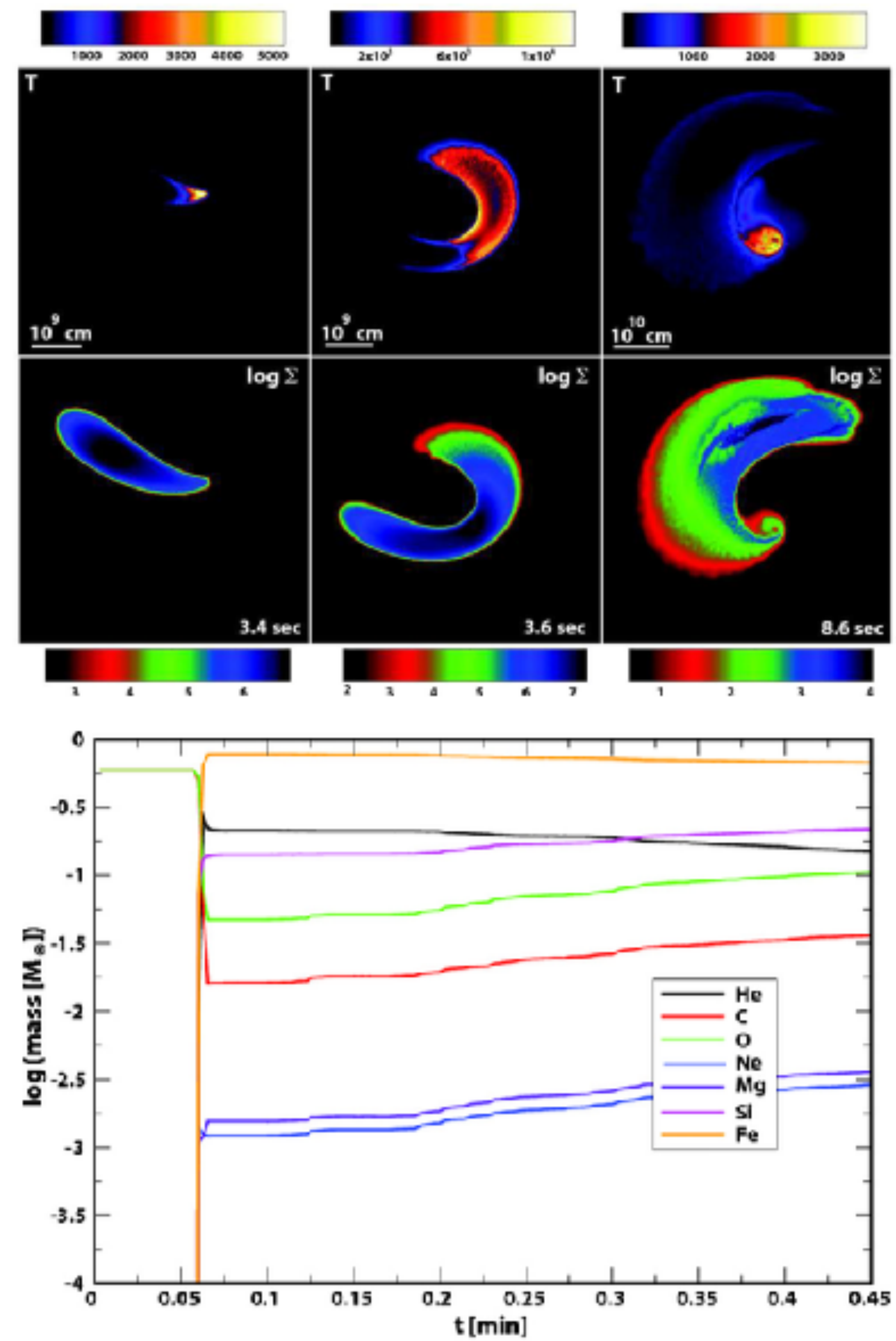
- Tidal detonation requires a WD TDE.
- A WD can be tidally disrupted only by an IMBH.
  - swallowing a stellar-mass BH.
  - swallowed by a massive BH.
- WD TDEs can illuminate only IMBHs.
- WD TDEs can be probes to search for IMBHs.



Kawana et al. 2017 (see also Luminet, Pichon 1989 Rosswog et al. 2009; MacLeod et al. 2016)

Previous and our studies

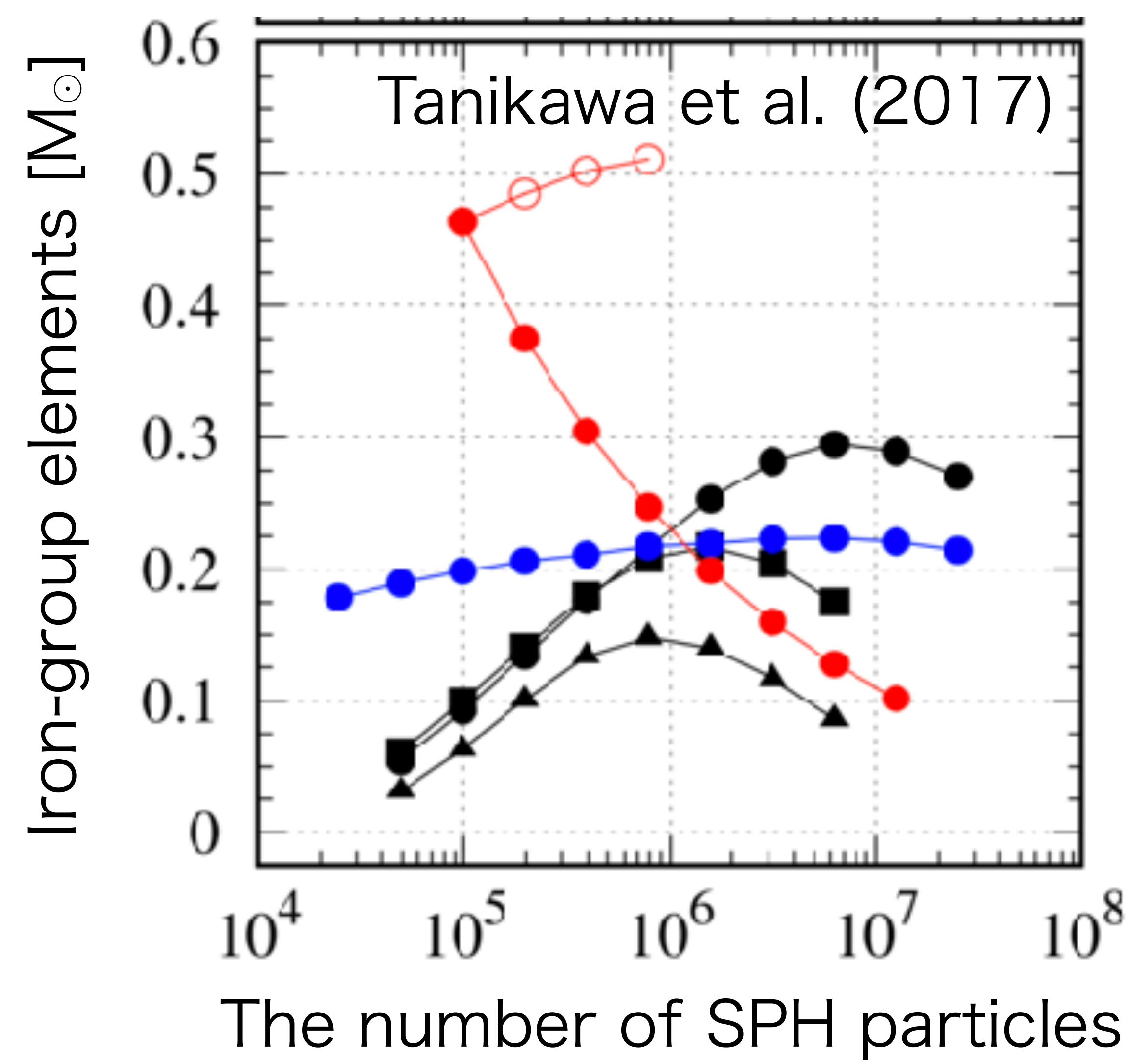
- Previous studies
  - Demonstration of large amounts of ^{56}Ni yielded
  - No convergence check about mass resolution
  - No demonstration of shock generation
- Our studies
  - Convergence check
  - Demonstration of shock generation



Rosswog et al. (2008; 2009)

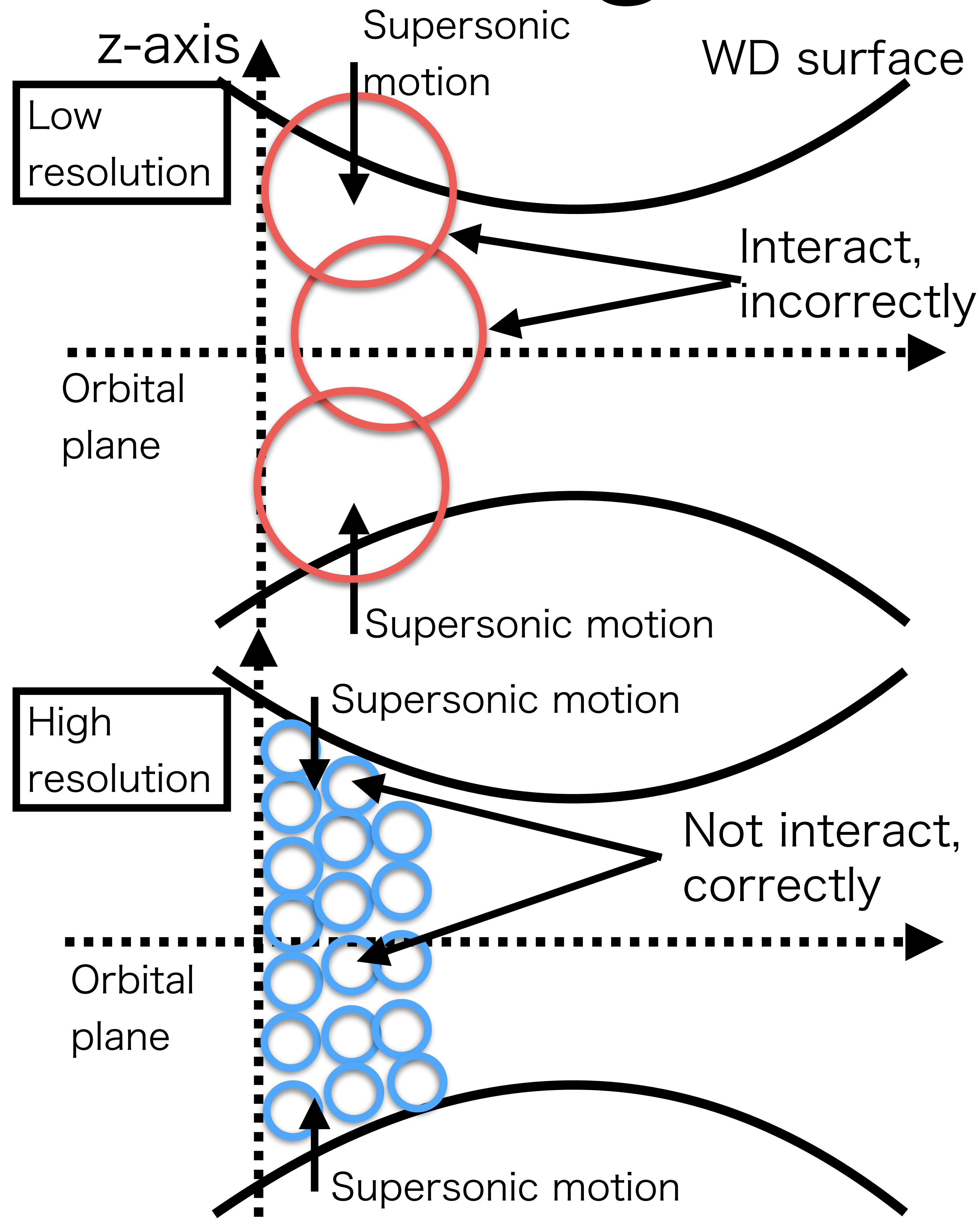
SPH simulation

- SPH simulation in the same way as in previous studies, but with higher-mass resolution
  - Massively-parallel 3D SPH simulation code
  - Helmholtz EoS
  - Aprox13 nuclear reaction networks
  - N >~ 10^7
- Ni yielded by spurious heating due to low resolution, not by a shock wave



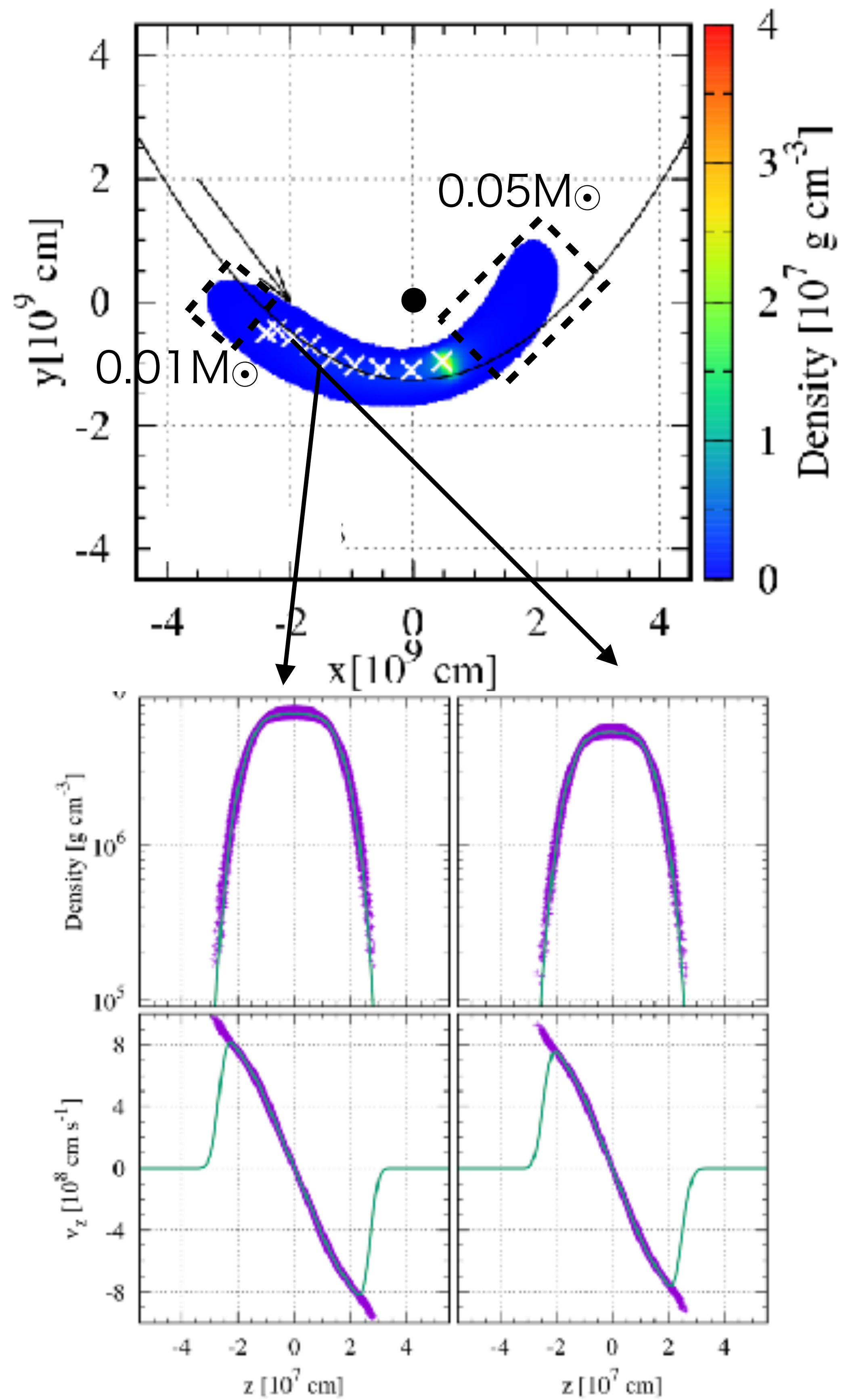
Spurious heating

- In small-N cases, the number of SPH particles is too few in z-direction.
- Distant particles interact incorrectly.
- Velocity gradient is overestimated.
- Overestimated velocity gradient falsely switches on artificial viscosity.
- The artificial viscosity raises spurious heating and false nuclear reactions.
- Note that artificial viscosity is correct, but velocity gradient is wrong.

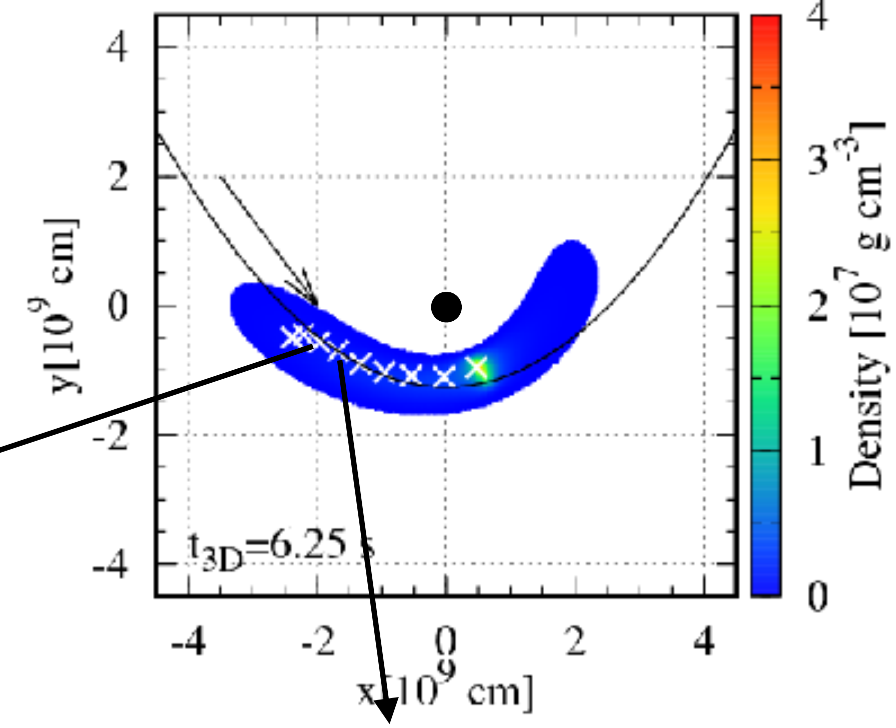


Switch 3D to 1D

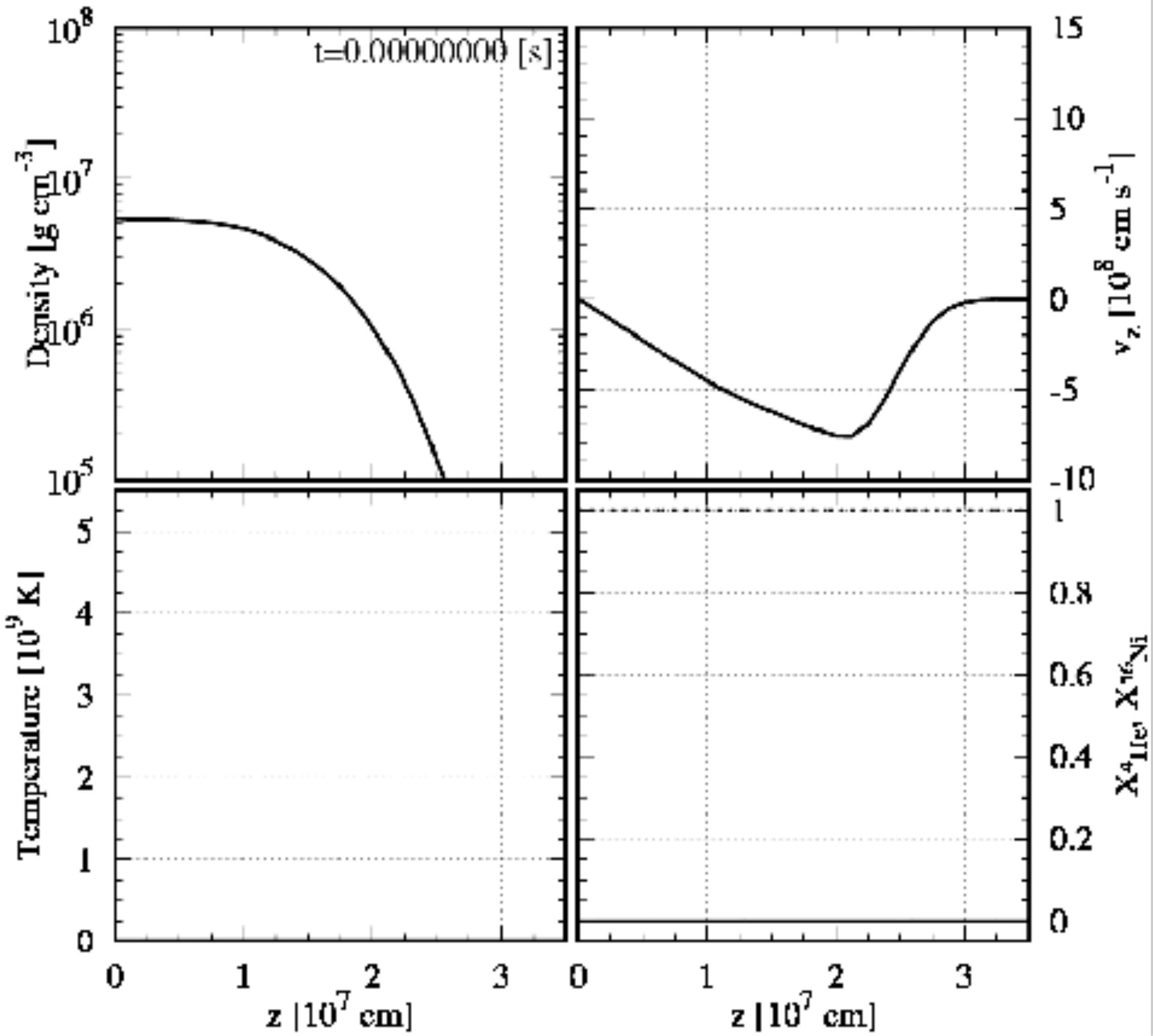
- 3D SPH simulation
  - 0.45M⊙ HeWD disrupted by 300M⊙ IMBH
    - N~3x10⁸ for the He WD
  - without nuclear reactions
- Extracting z-columns indicated by white crosses
- 1D mesh simulation
  - z-columns
  - with nuclear reactions



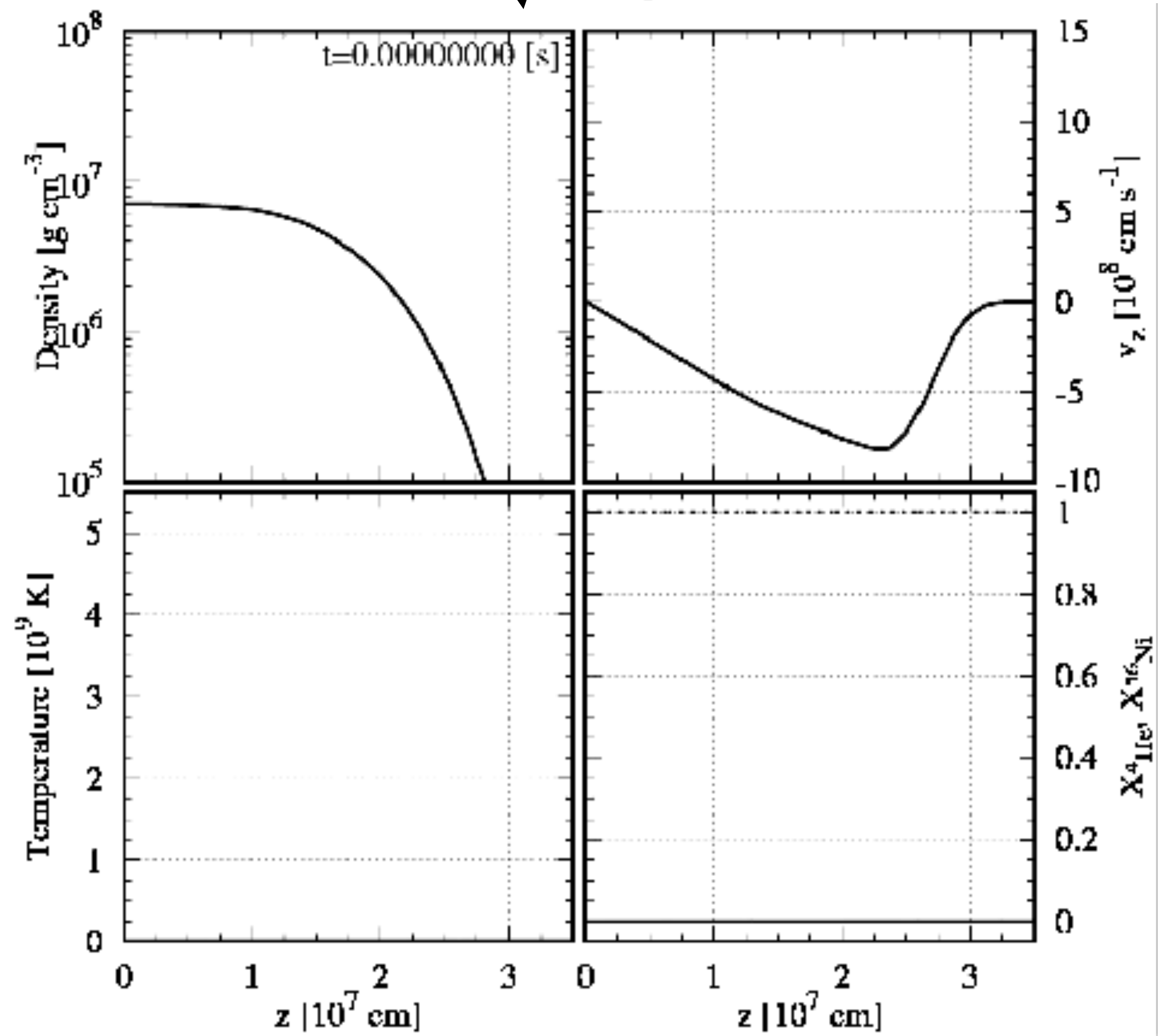
Movies



Tanikawa (2018, ApJ, 858, 81)

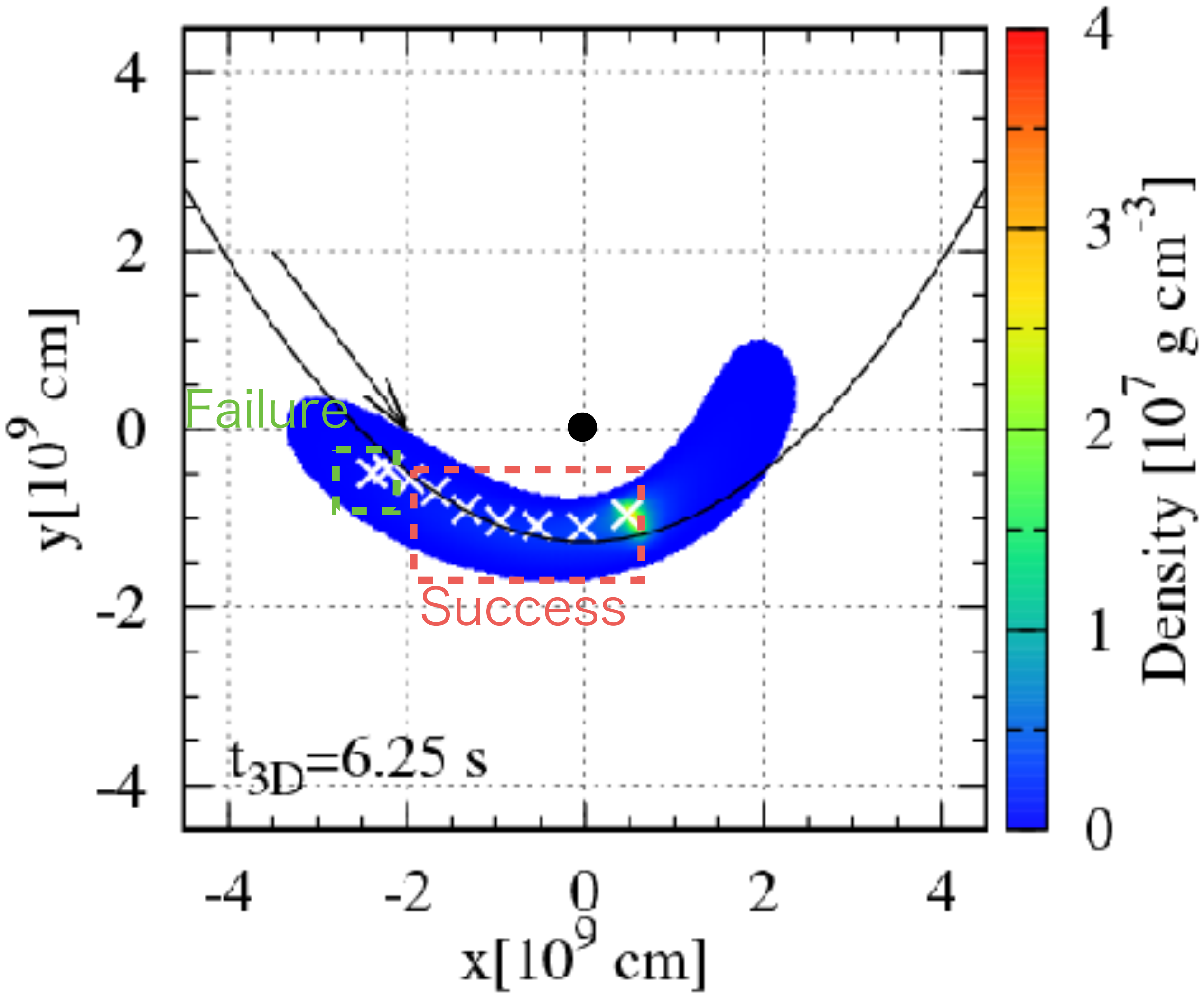


Failure case

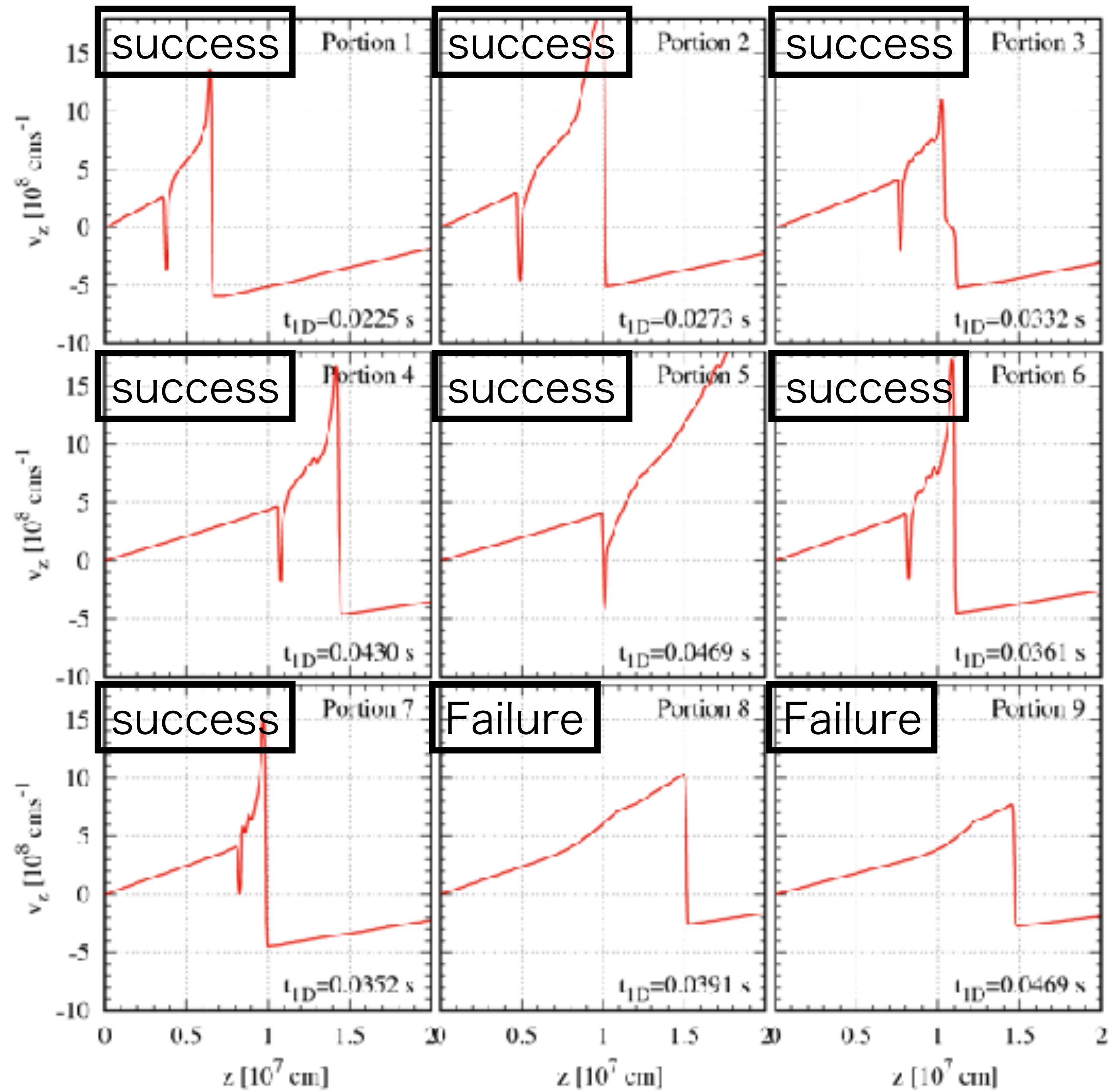


Success case

Results

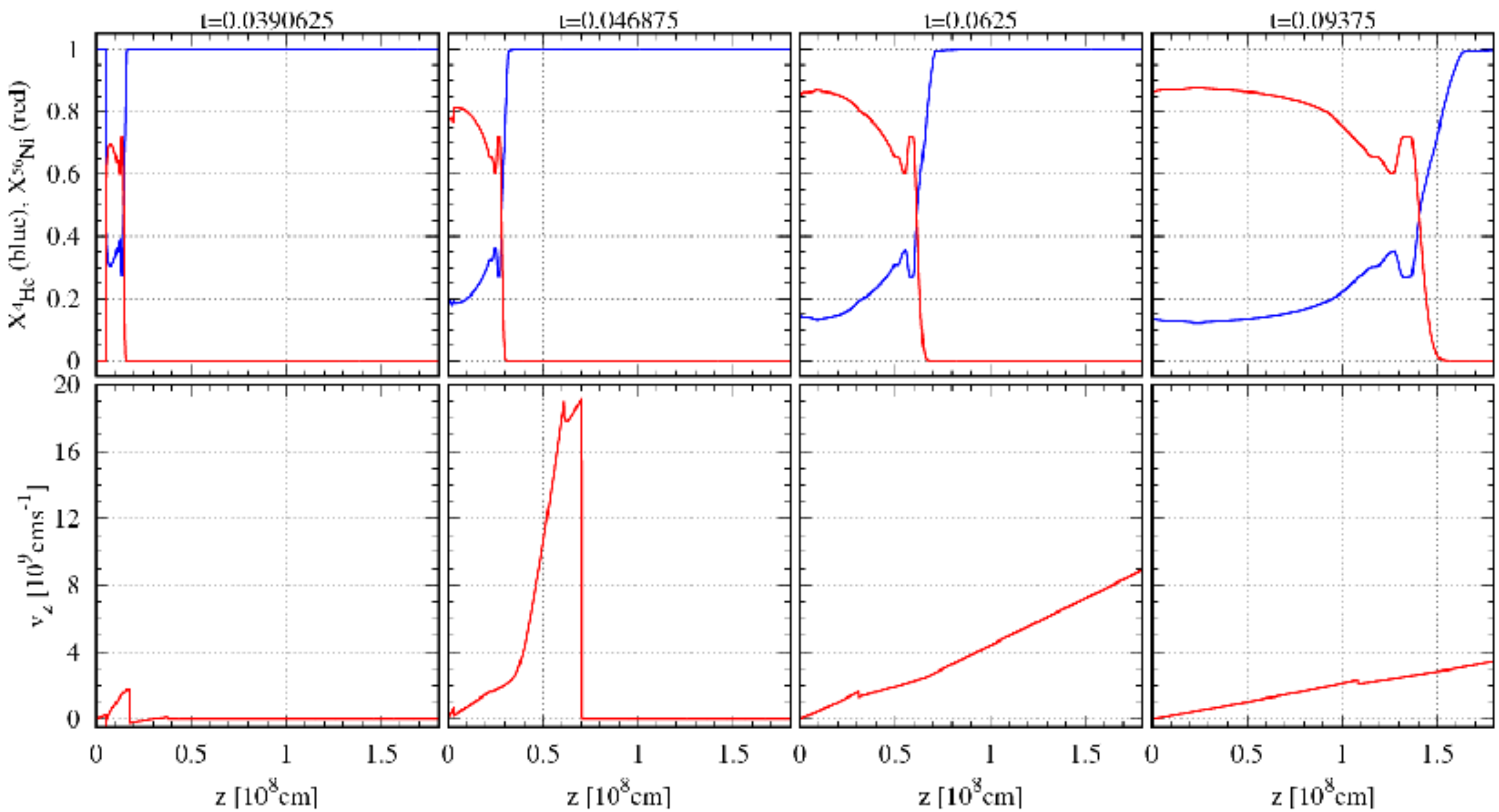


Failure
Success
t_{3D}=6.25 s
x[10^9 cm]
y[10^9 cm]
Density [10^7 g cm^{-3}]



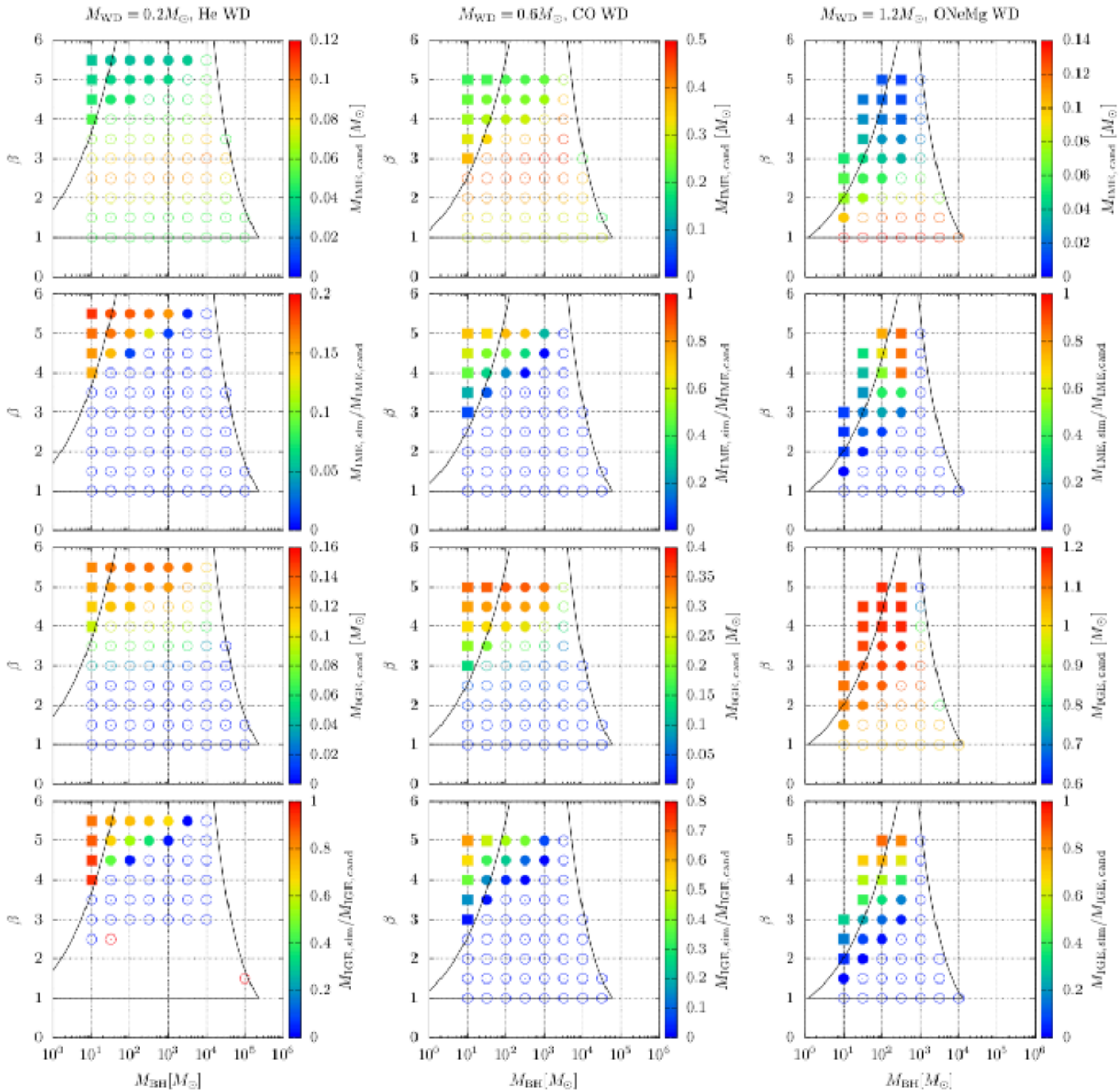
success
Portion 1
t_{1D}=0.0225 s
success
Portion 2
t_{1D}=0.0273 s
success
Portion 3
t_{1D}=0.0332 s
success
Portion 4
t_{1D}=0.0430 s
success
Portion 5
t_{1D}=0.0469 s
success
Portion 6
t_{1D}=0.0361 s
success
Portion 7
t_{1D}=0.0352 s
Failure
Portion 8
t_{1D}=0.0391 s
Failure
Portion 9
t_{1D}=0.0469 s
v_z [10^8 cm s^{-1}]
z [10^7 cm]

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 SNeIa.

Variety of tidal detonation



Kawana et al. (2018, MNRAS, 447, 3449)

Future work

- Estimate of the event rate
- Radiative transfer calculation of WD TDEs
- WD mass function of TDEs
  - The same as that of single WDs?
  - Top-heavy mass function due to dynamical effects?

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).
- Helium shell helps tidal detonation (Tanikawa et al. 2018, MNRAS, 475, L67).
- We have investigated various tidal detonation (Kawana et al. 2018 MNRAS, 477, 3449).
- WD TDEs can be a clue to search for IMBHs.