

Numerical Study of Thermonuclear Explosion of White Dwarfs Induced by Tidal Disruption Events

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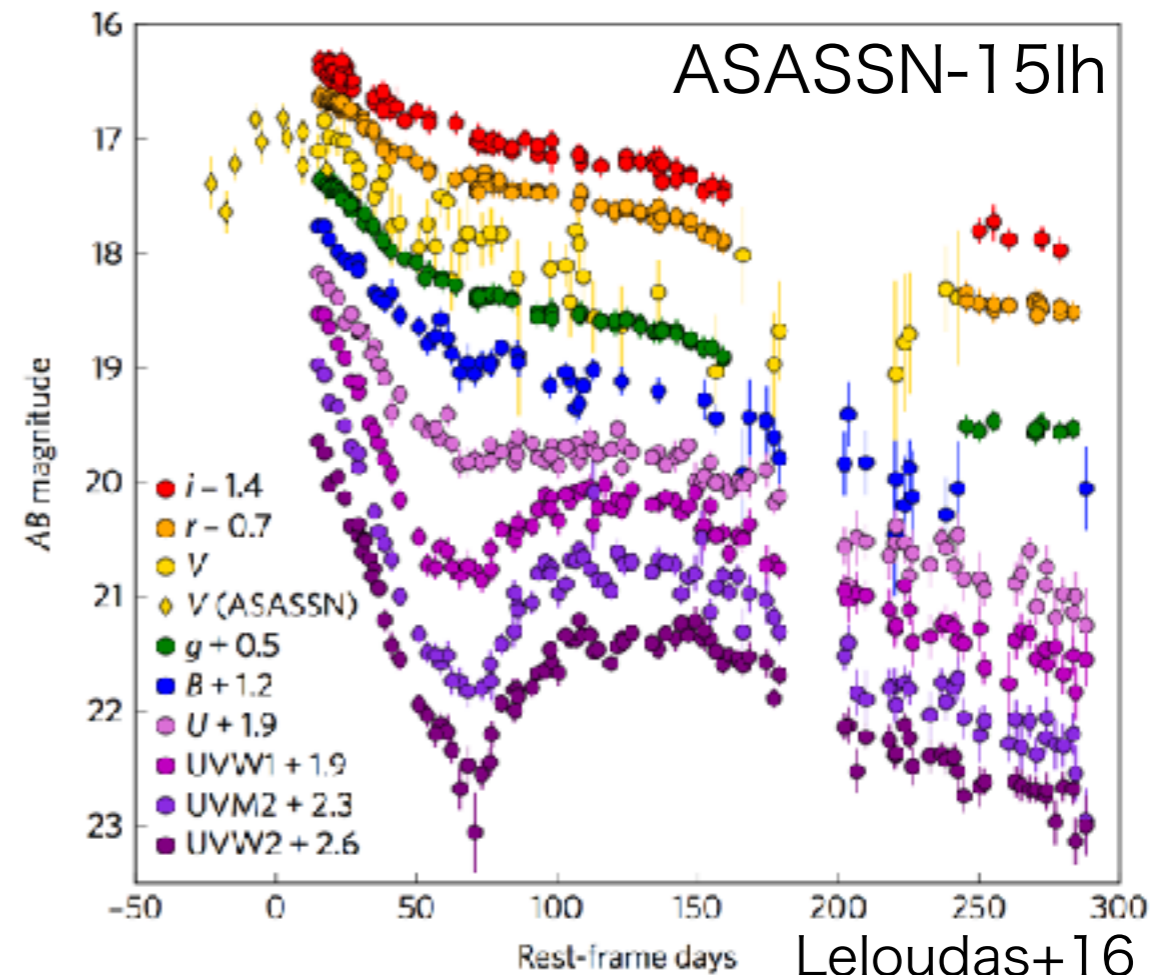
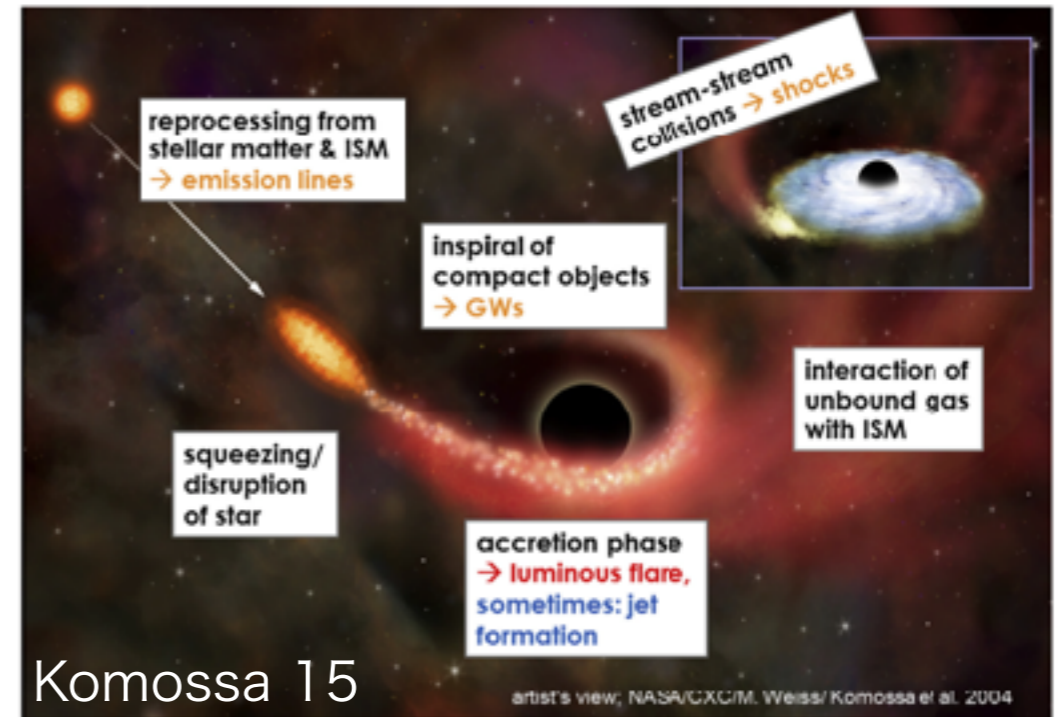
The BN4 SN Ia and WD session of the MG15

University of Rome “La Sapienza”

Rome, July 6th, 2018

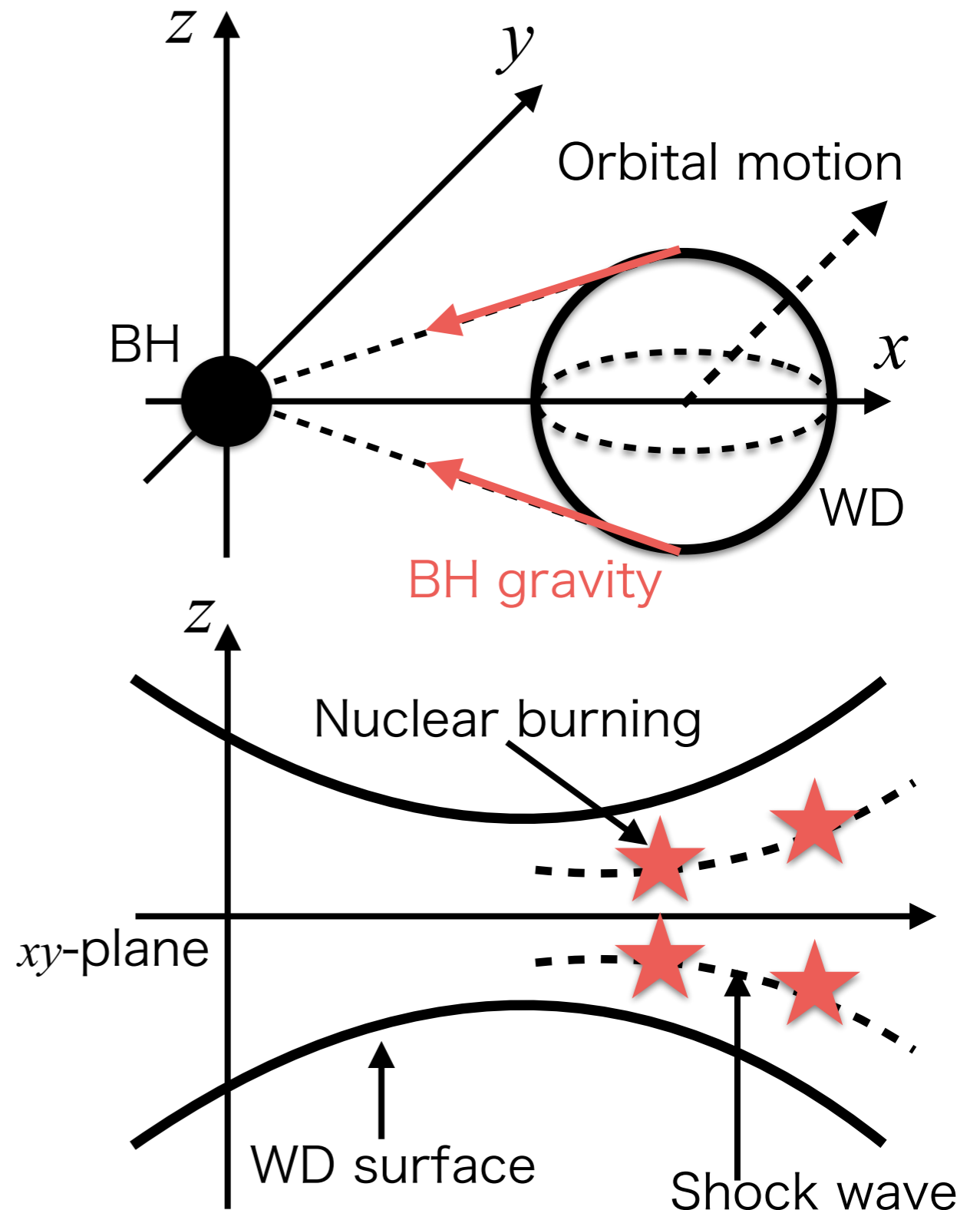
Tidal Disruption Event

- 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



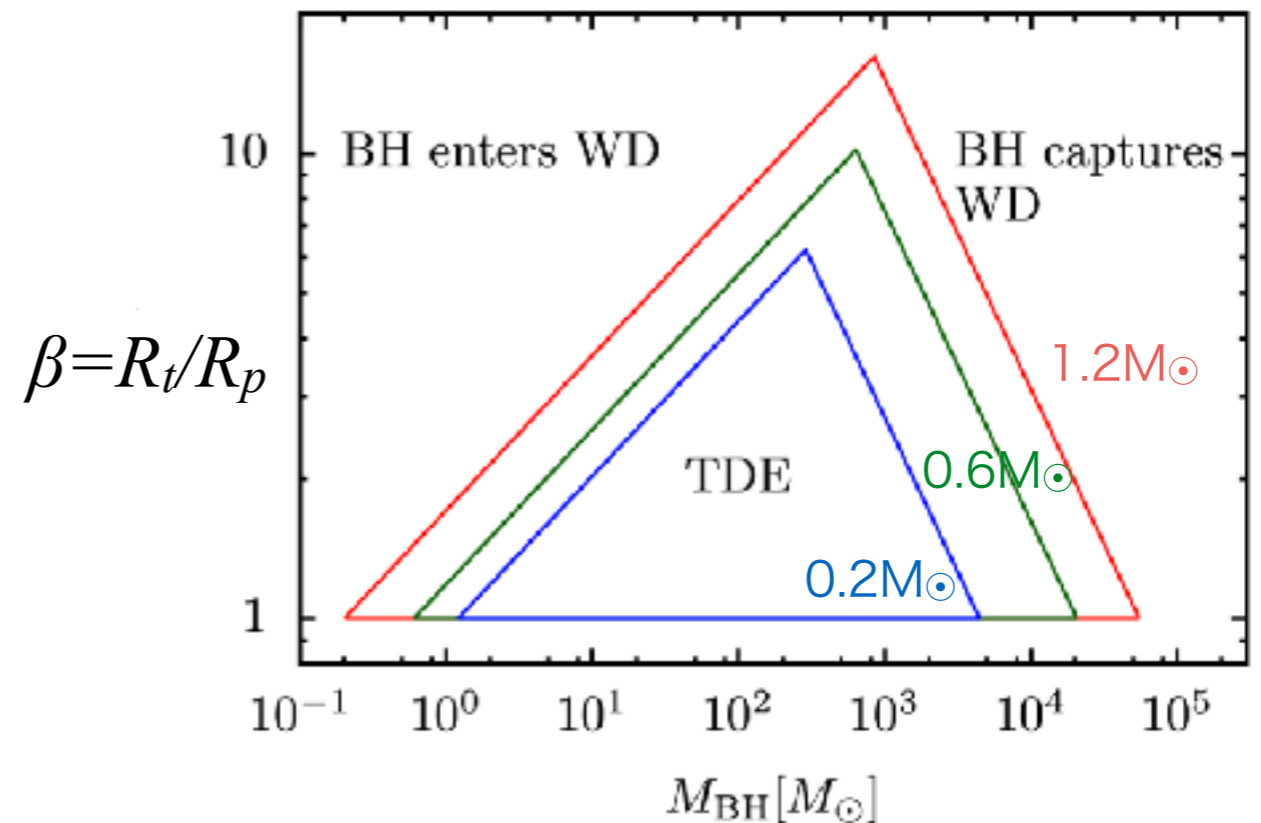
Tidal detonation

- 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 ^{56}Ni , similarly to SNe Ia.



Probe to search for Intermediate mass black hole

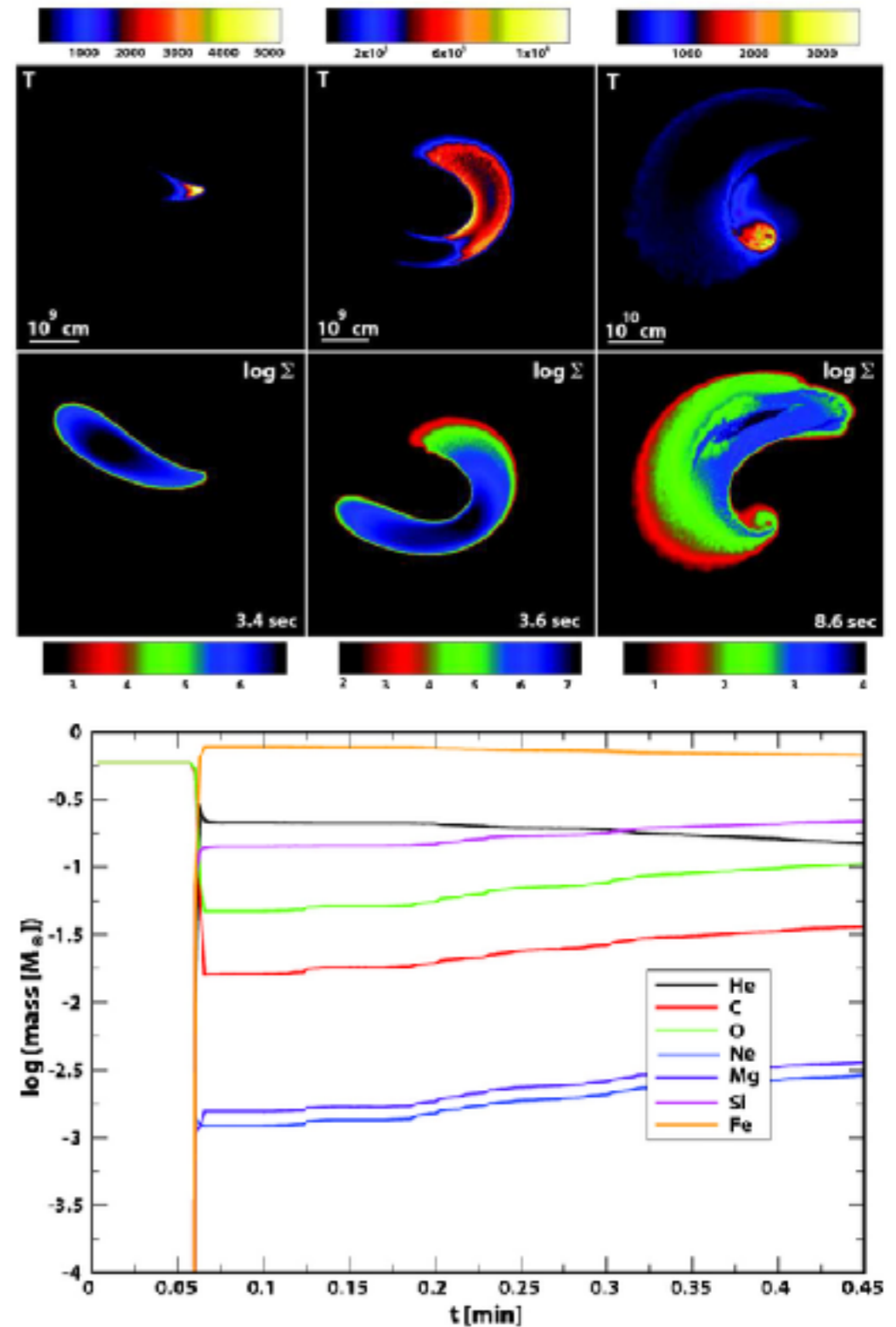
- Tidal detonation requires a WD TDE.
- A WD can be tidally disrupted only by an IMBH.
 - swallowing a stellar-mass BH.
 - swallowed by a massive BH.
- WD TDEs can illuminate only IMBHs.
- **WD TDEs can be probes to search for IMBHs.**



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

Previous and our studies

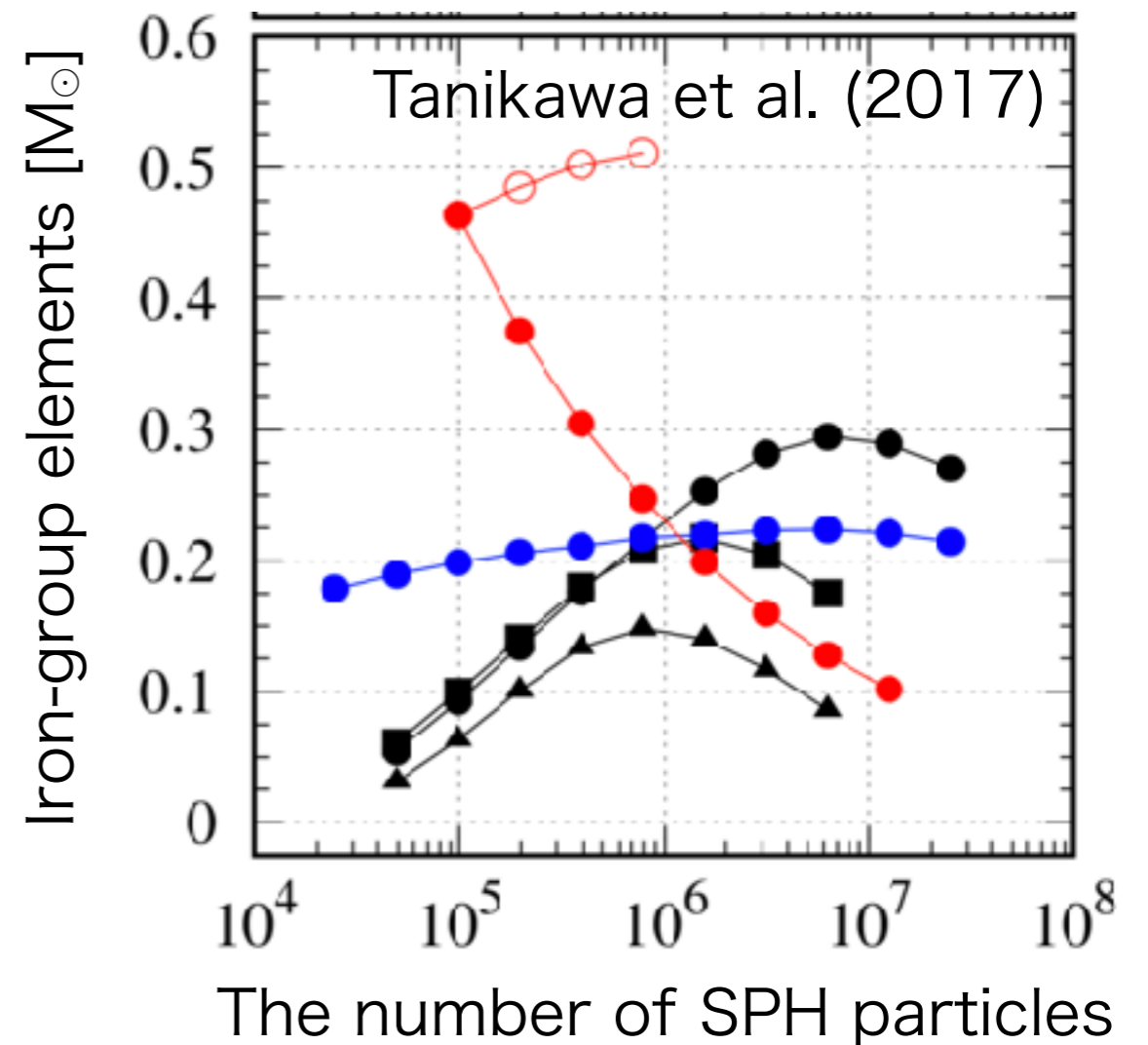
- Previous studies
 - Demonstration of large amounts of ^{56}Ni yielded
 - No convergence check about mass resolution
 - No demonstration of shock generation
- Our studies
 - Convergence check
 - Demonstration of shock generation



Rosswog et al. (2008; 2009)

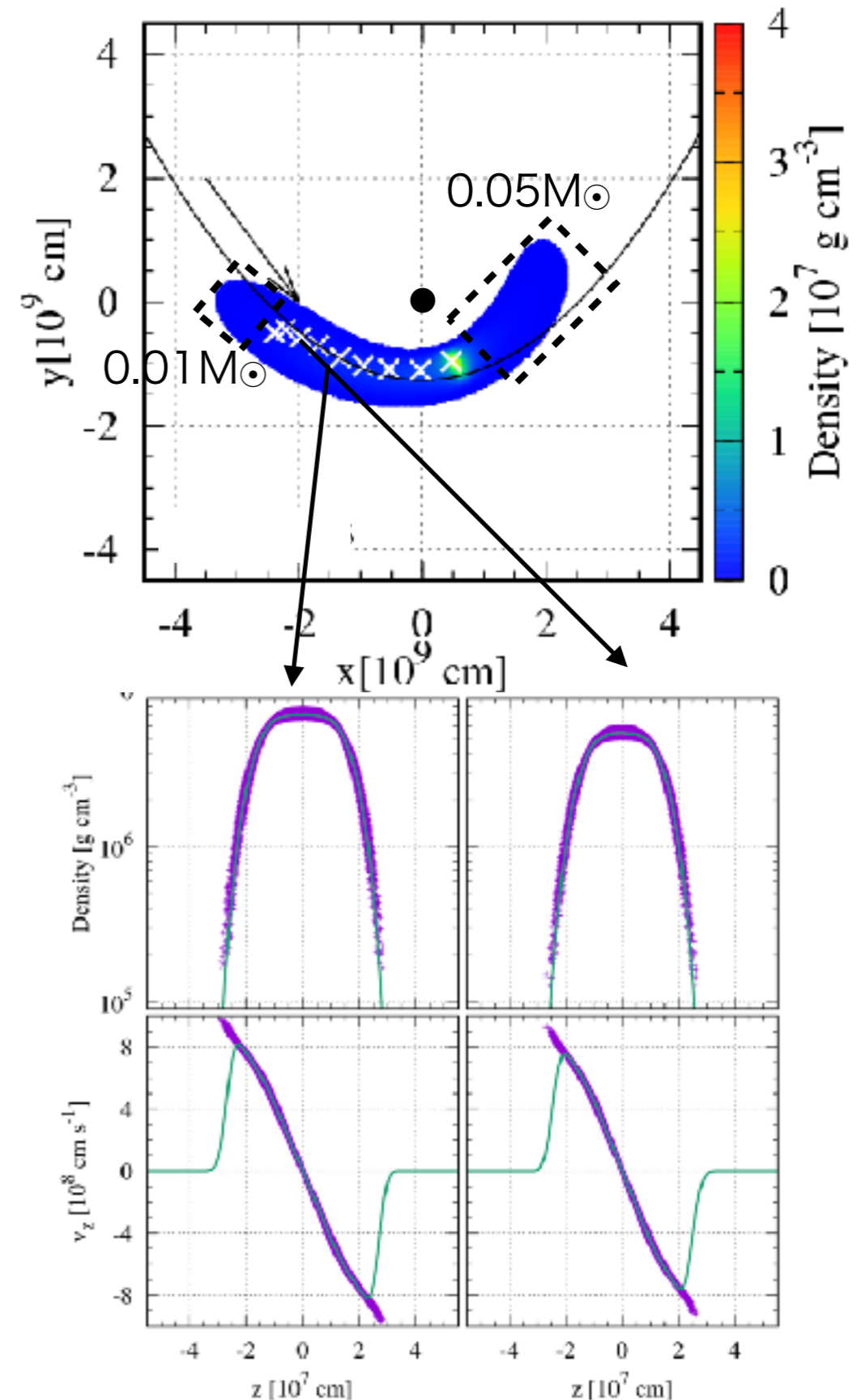
SPH simulation

- SPH simulation in the same way as in previous studies, but with higher-mass resolution
- Massively-parallel 3D SPH simulation code
- Helmholtz EoS
- Aprox 13 nuclear reaction networks
- $N > \sim 10^7$
- Ni yielded by spurious heating due to low resolution, not by a shock wave

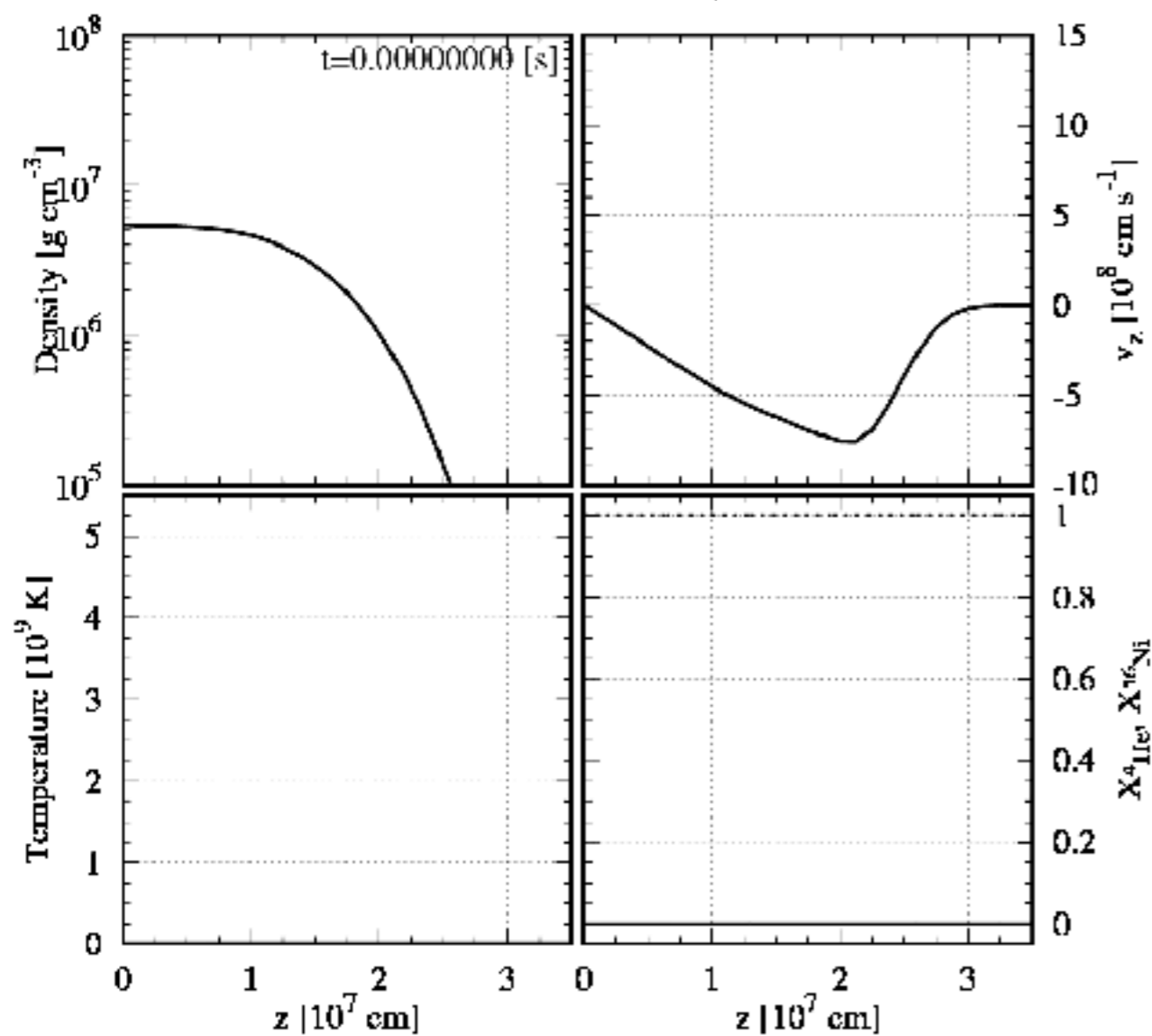
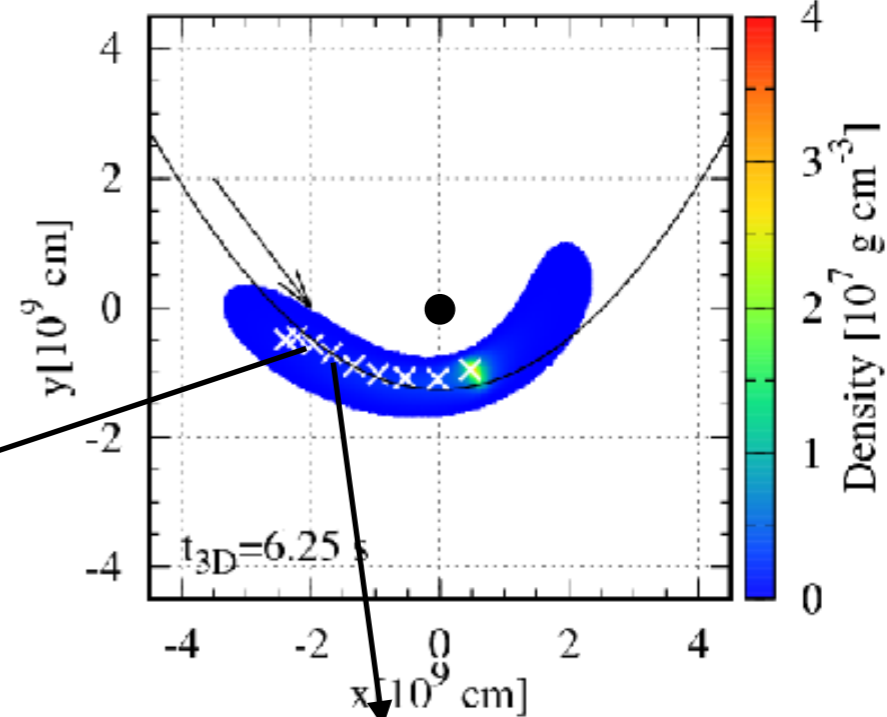


Switch 3D to 1D

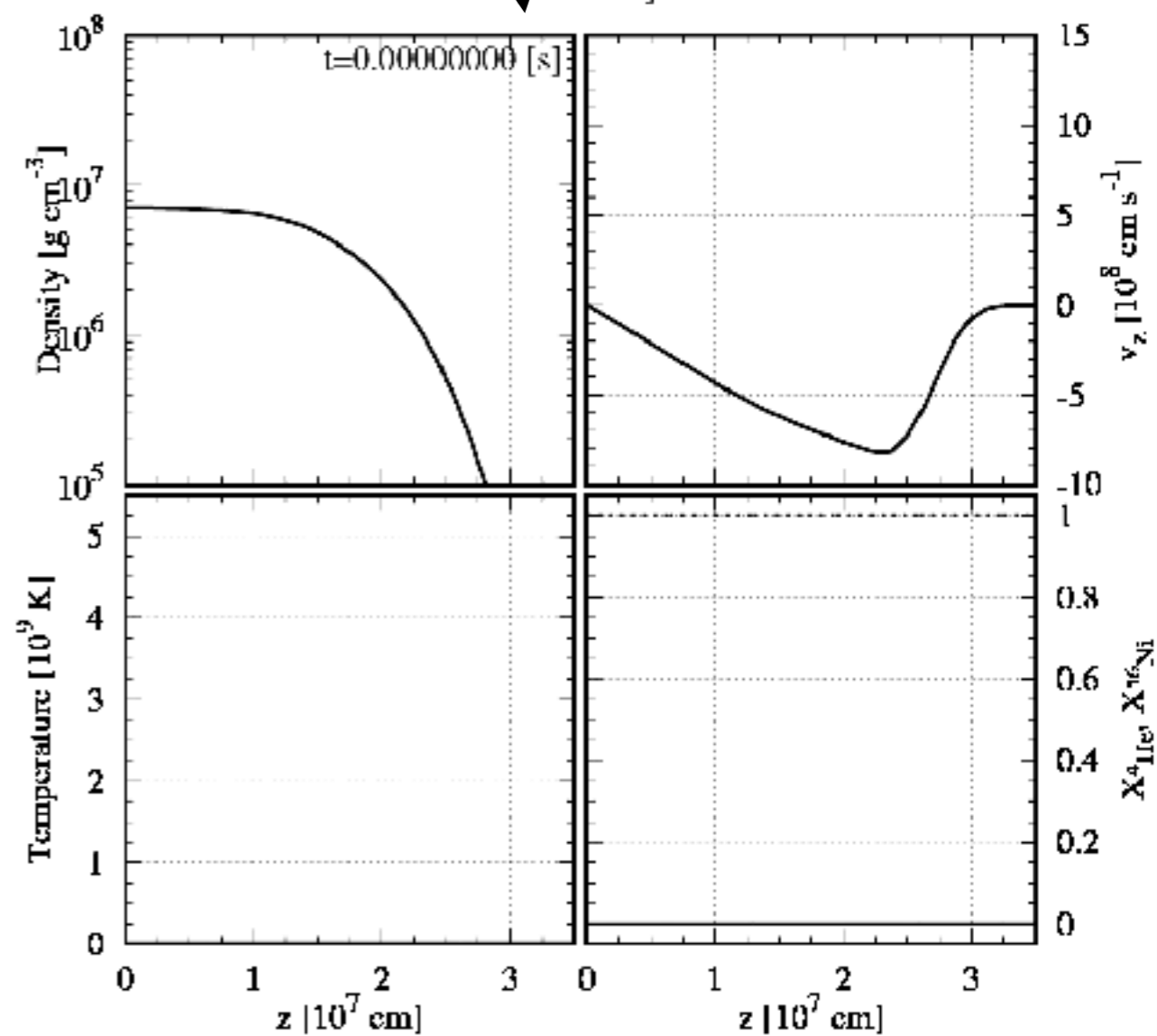
- 3D SPH simulation
 - $0.45M_{\odot}$ HeWD disrupted by $300M_{\odot}$ IMBH
 - $N \sim 3 \times 10^8$ for the He WD
 - without nuclear reactions
- Extracting z-columns indicated by white crosses
- 1D mesh simulation
 - z-columns
 - with nuclear reactions



Movies

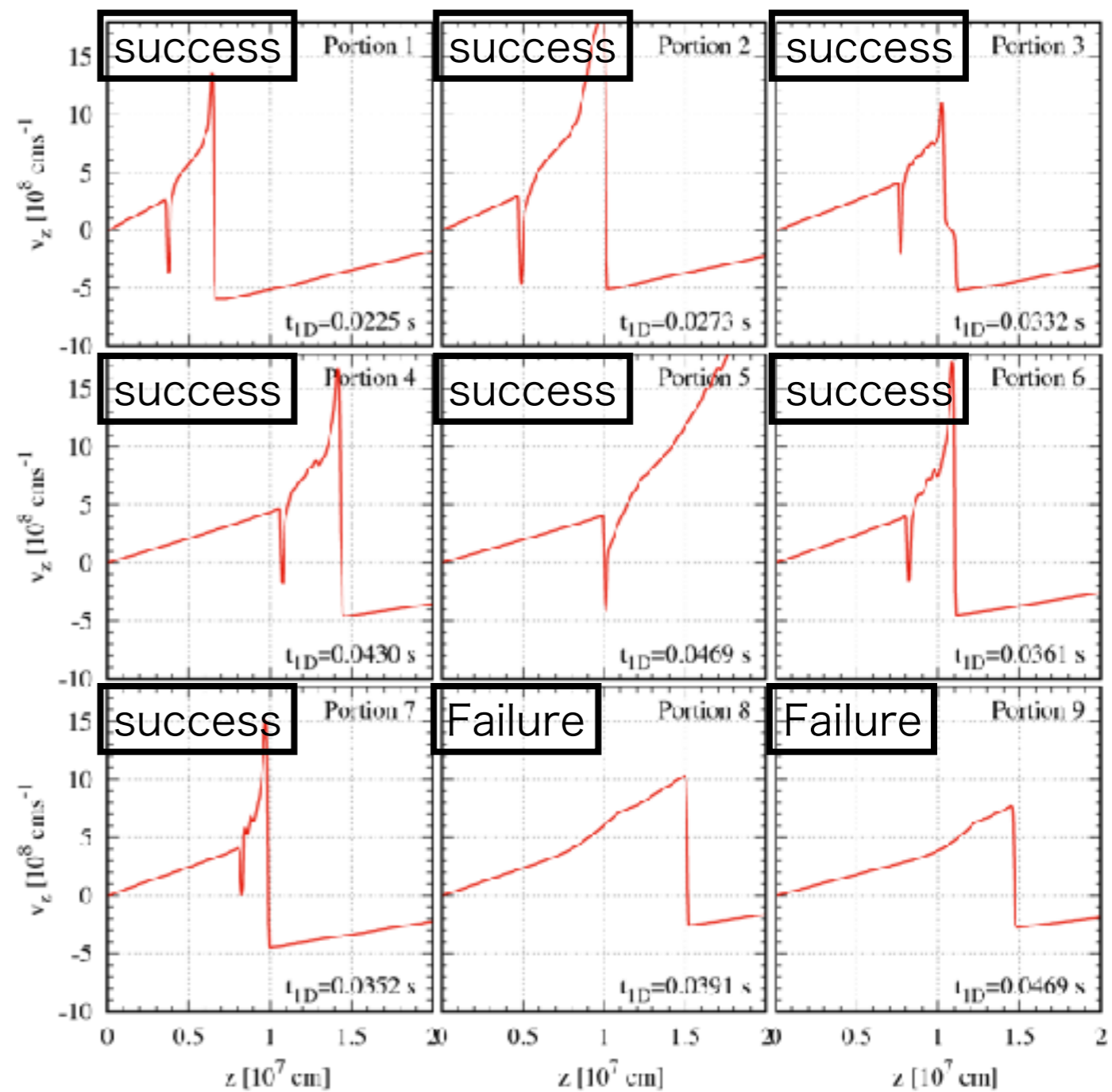
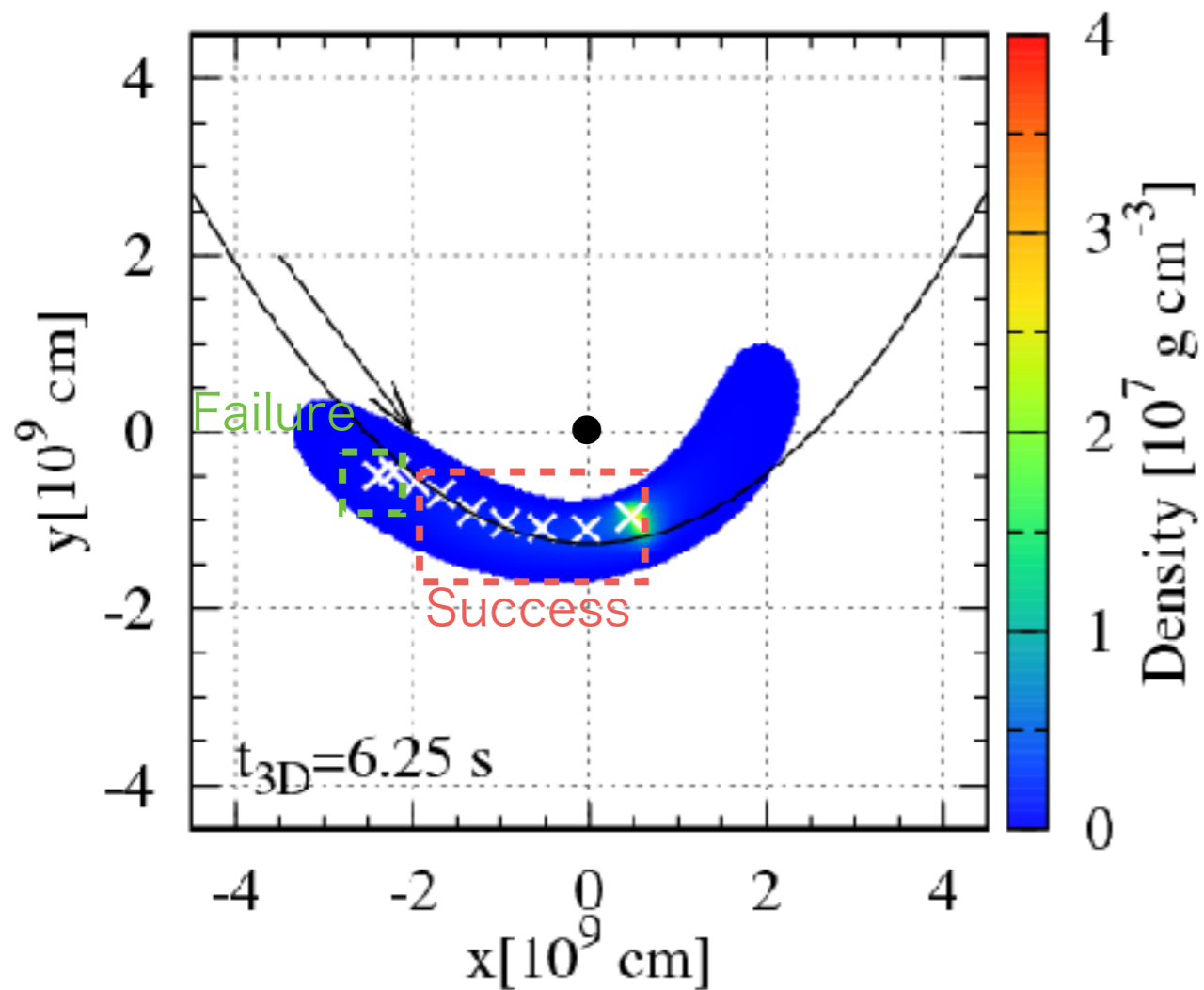


Failure case

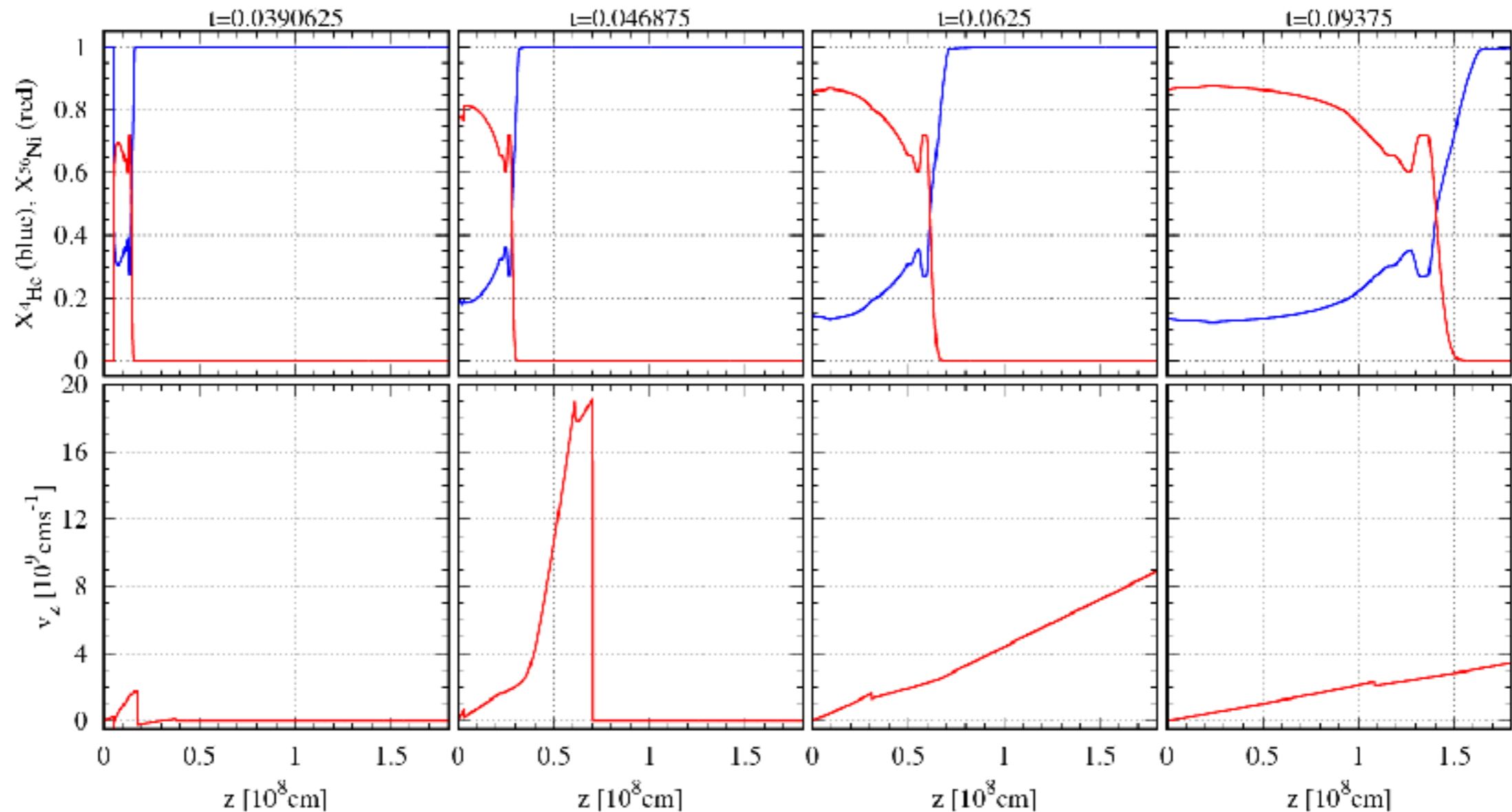


Success case

Results



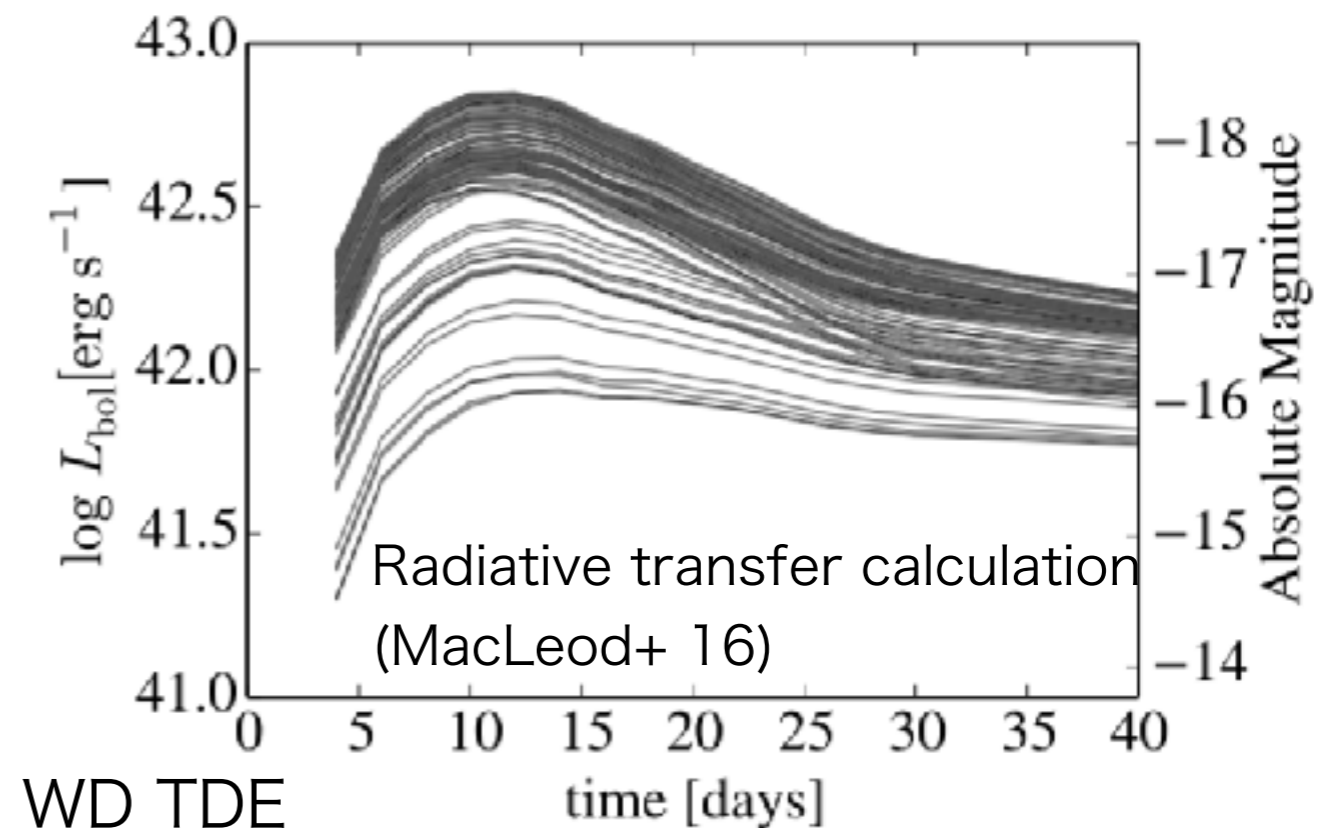
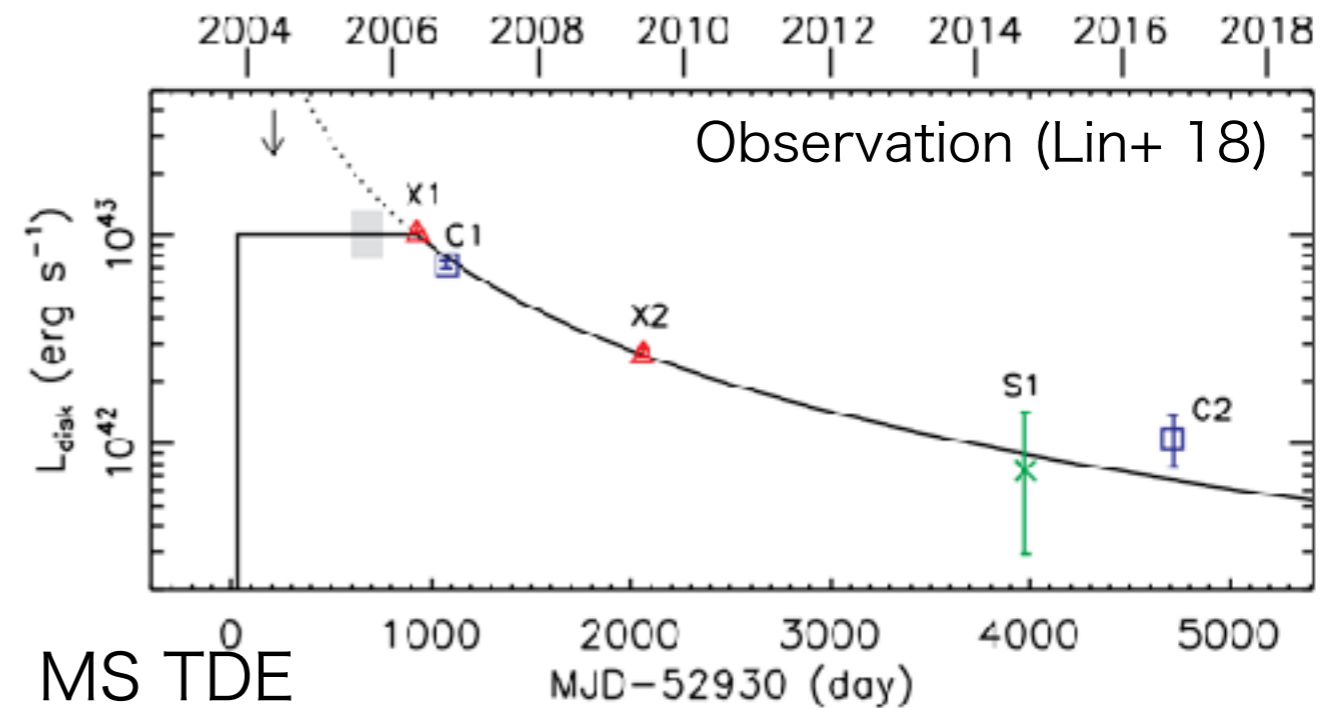
Nucleosynthesis



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

Comparison with MS TDEs

- MS TDEs can be a clue to search for IMBHs.
 - But, timescale to identify transients as MS TDEs is long (~10yrs).
- For WD TDEs, the timescale is ~100 days, ~ timescale of SNe Ia.
- Difference from SNe Ia
 - Rapid light-curve evolution (~10 days) due to small ejecta mass (~ 0.6 M_{\odot})
 - Large velocity shift due to orbital motion around IMBHs (~ 10⁴ km/s)



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.**