連星白色矮星におけるDouble Detonationの３次元シミュレーション

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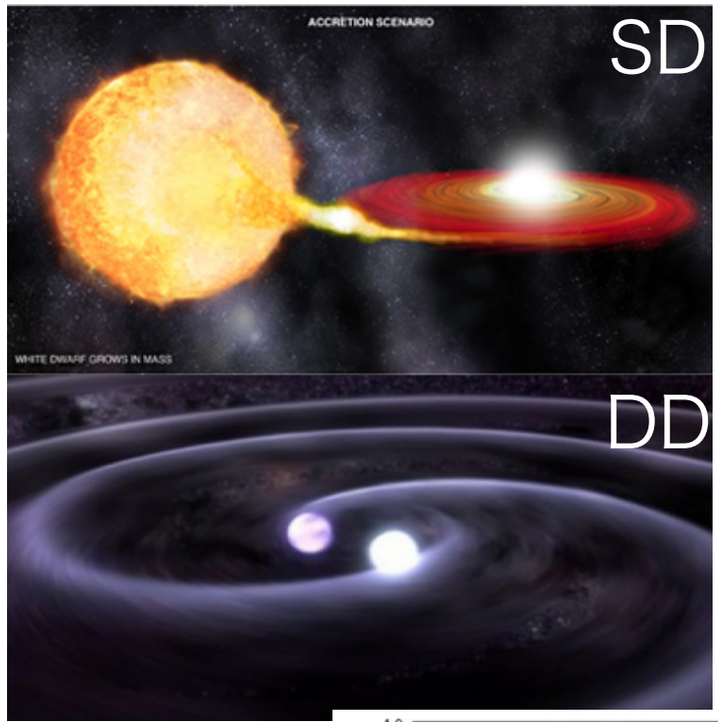
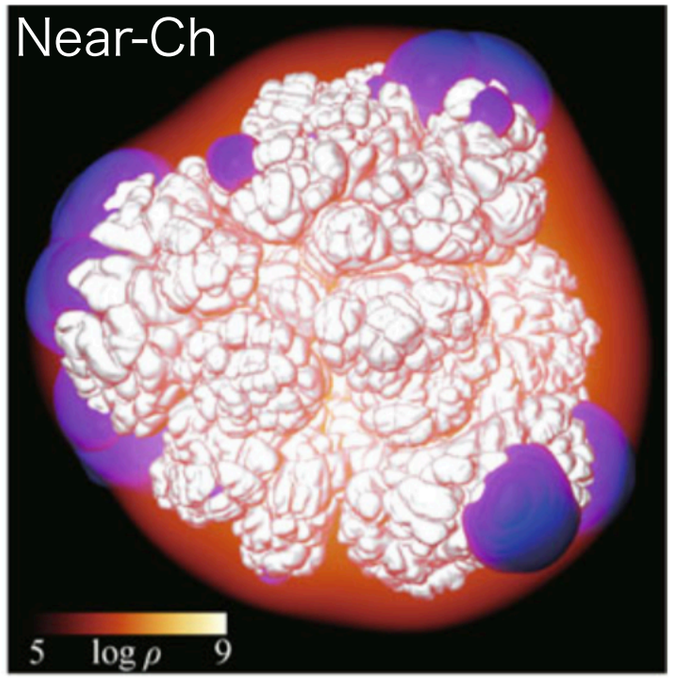
Tanikawa, Nomoto, Nakasato (2018, ApJ, 868, 90)

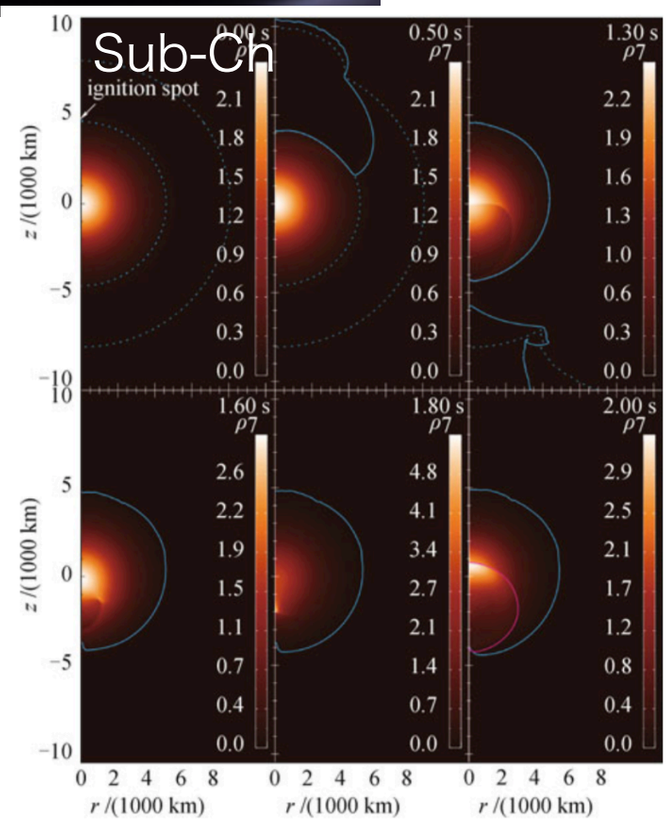
Type Ia supernovae

- One of the brightest and most common objects in the universe
- A cosmic distance indicator
- The origin of iron peak elements
- Thermonuclear explosions of white dwarfs (WDs)
- Unknown progenitor
  - Single Degenerate (SD) or Double Degenerate (DD)
  - Near-Chandrasekhar mass (Near-Ch) or sub-Chandrasekhar (sub-Ch) mass





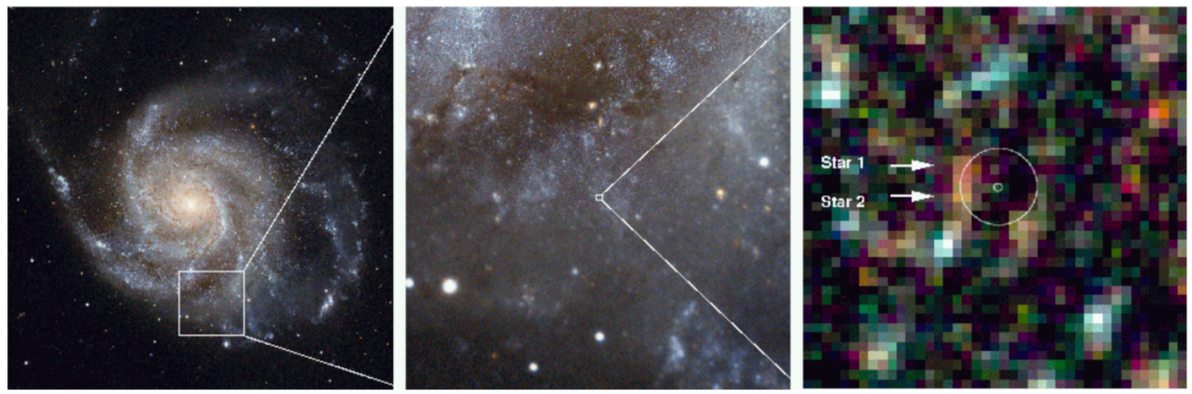
Seitenzahl et al. (2013)



Fink et al. (2010)

Constraints on the progenitor

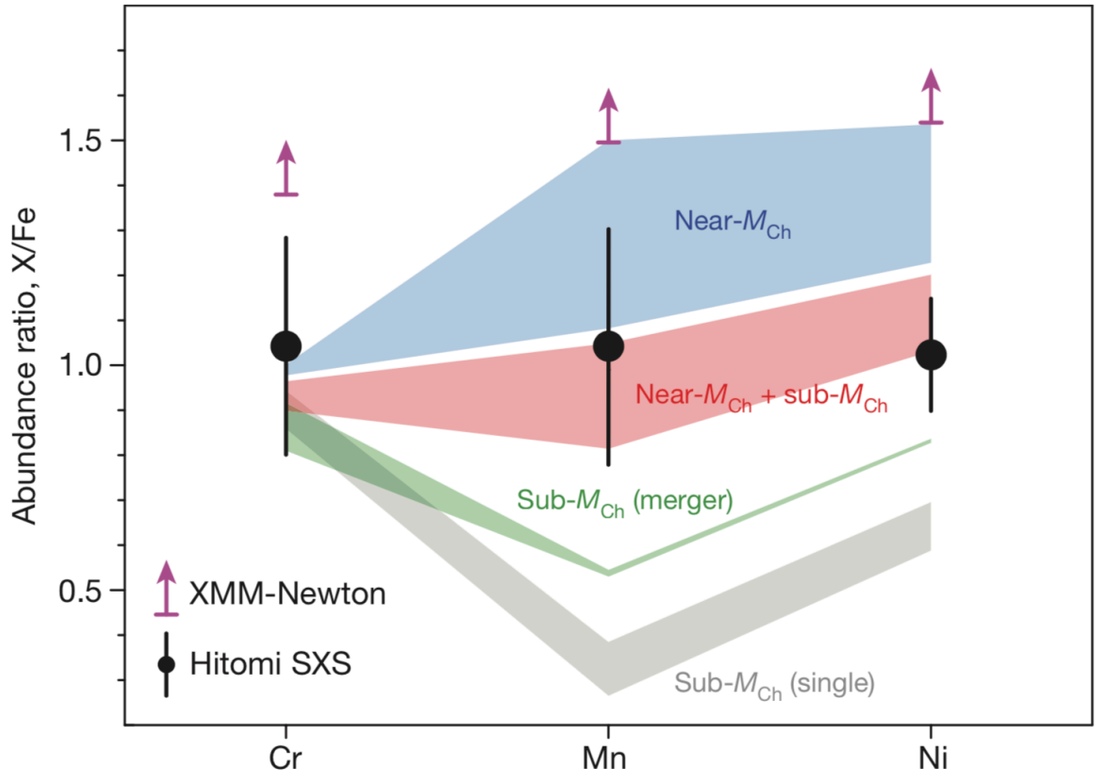
- SD or DD
  - Non detection of RG in the pre-explosion image of SN2011fe (e.g. Li et al. 2011)



Li et al. (2011)

- Non detection of MS in LMC SNR 0509-67.5 (e.g. Schaefer, Pagnotta 2012)

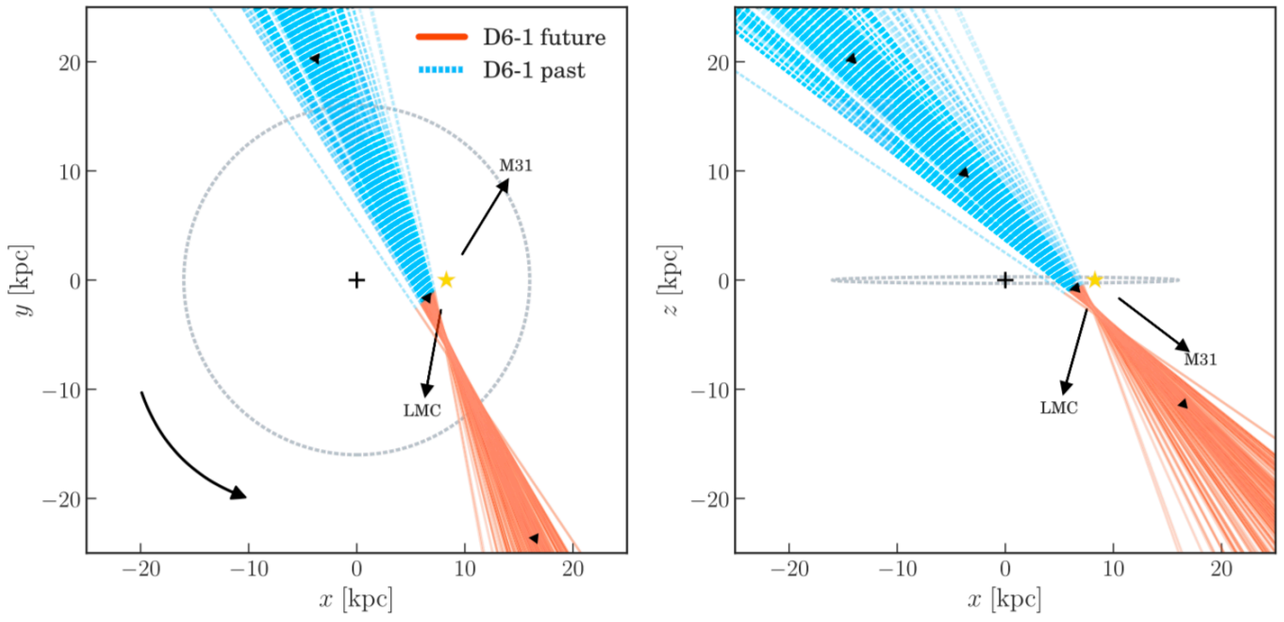
- Near-Ch or sub-ch
  - Both required (Hitomi Collaboration 2017)

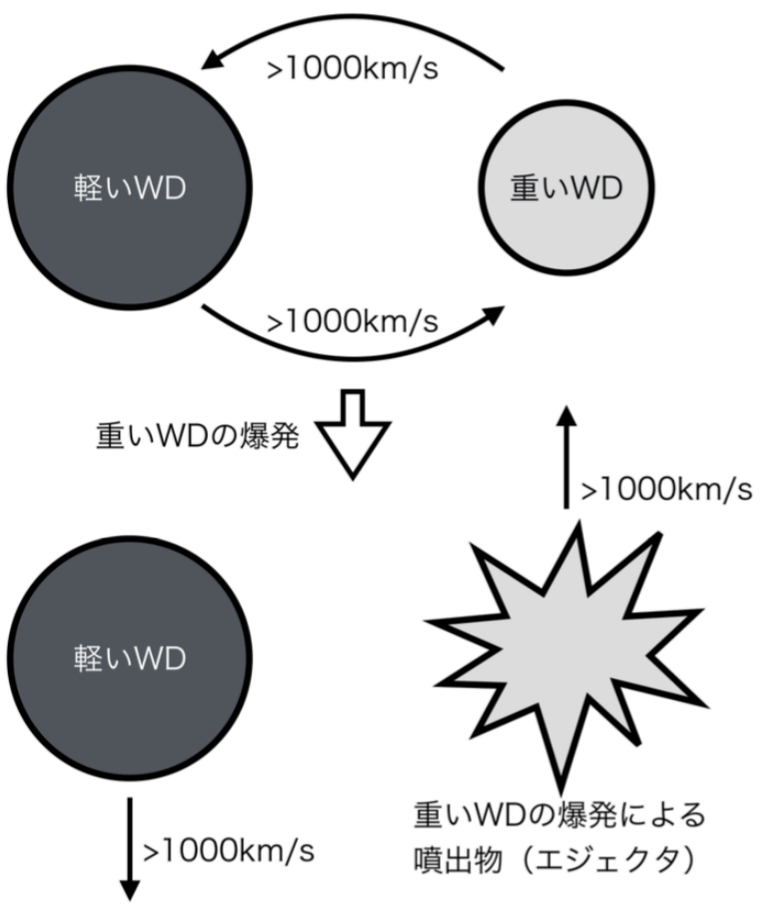


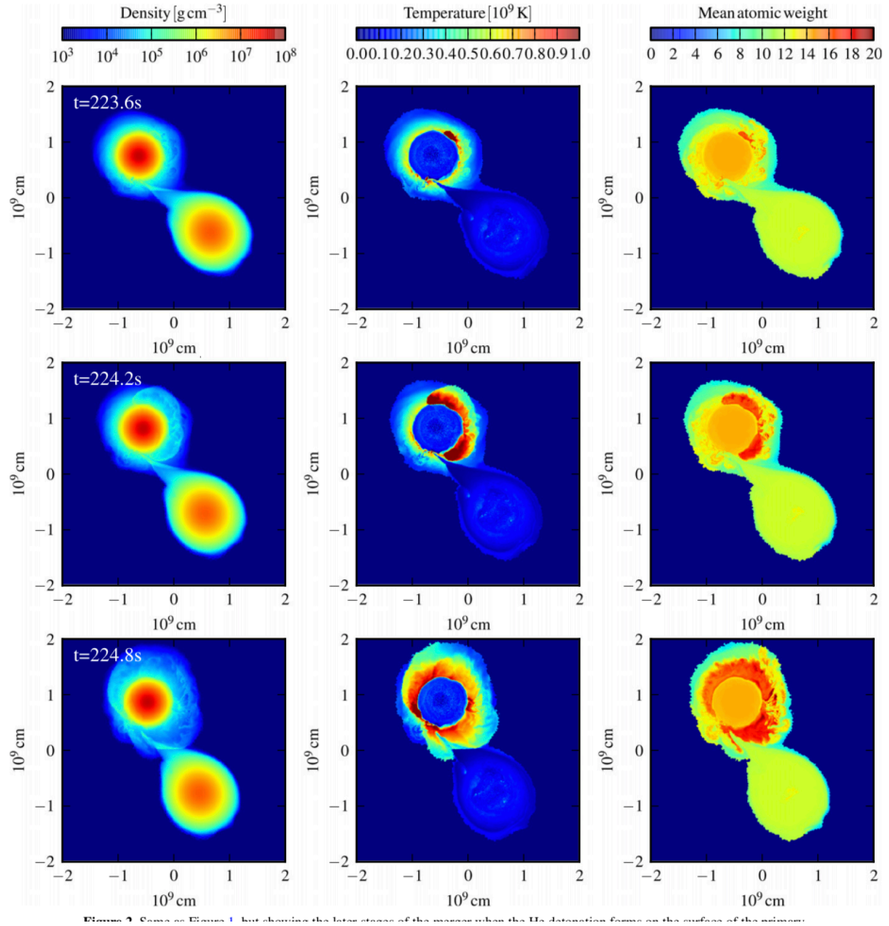
Hitomi Collaboration (2017)

Hypervelocity WDs

- The discovery of hypervelocity (~1000km/s) WDs (Shen et al. 2018)
- Double detonations in a DD system (Guillochon et al. 2010; Pakmor et al. 2013)







This study

- We perform a SPH simulation of double detonations in a DD system.

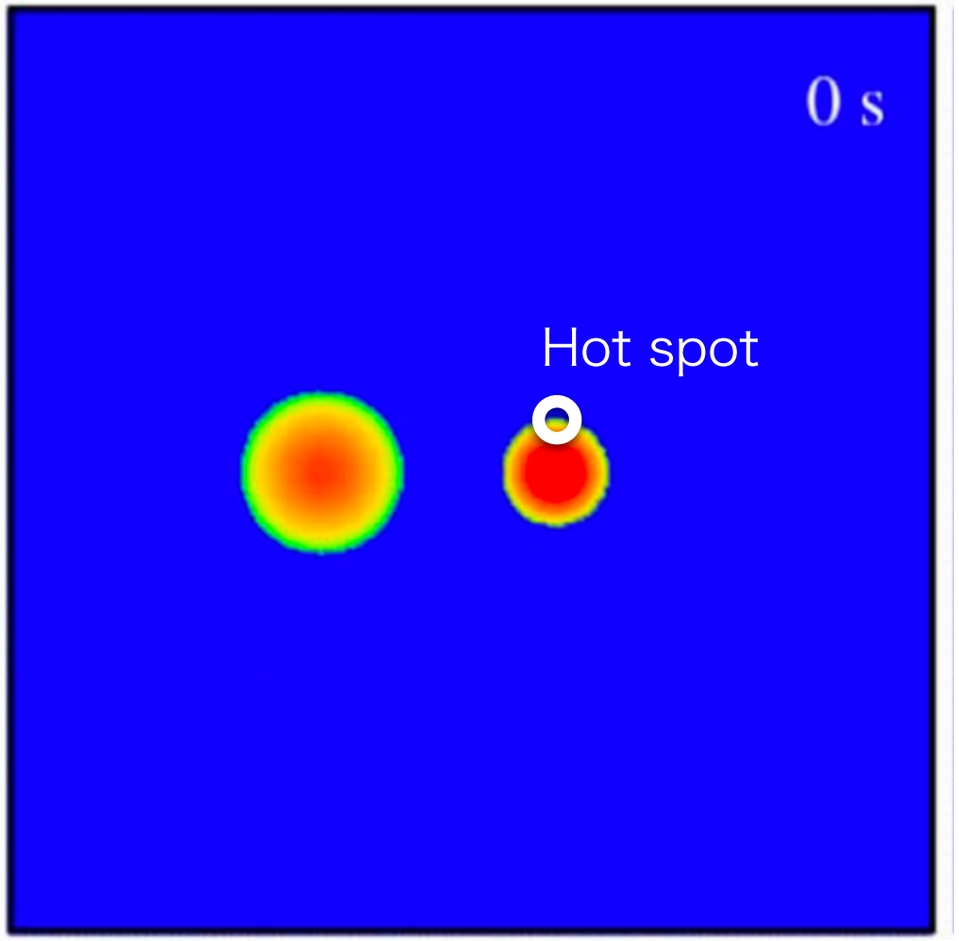
- We explore signals of the progenitor model.

Method

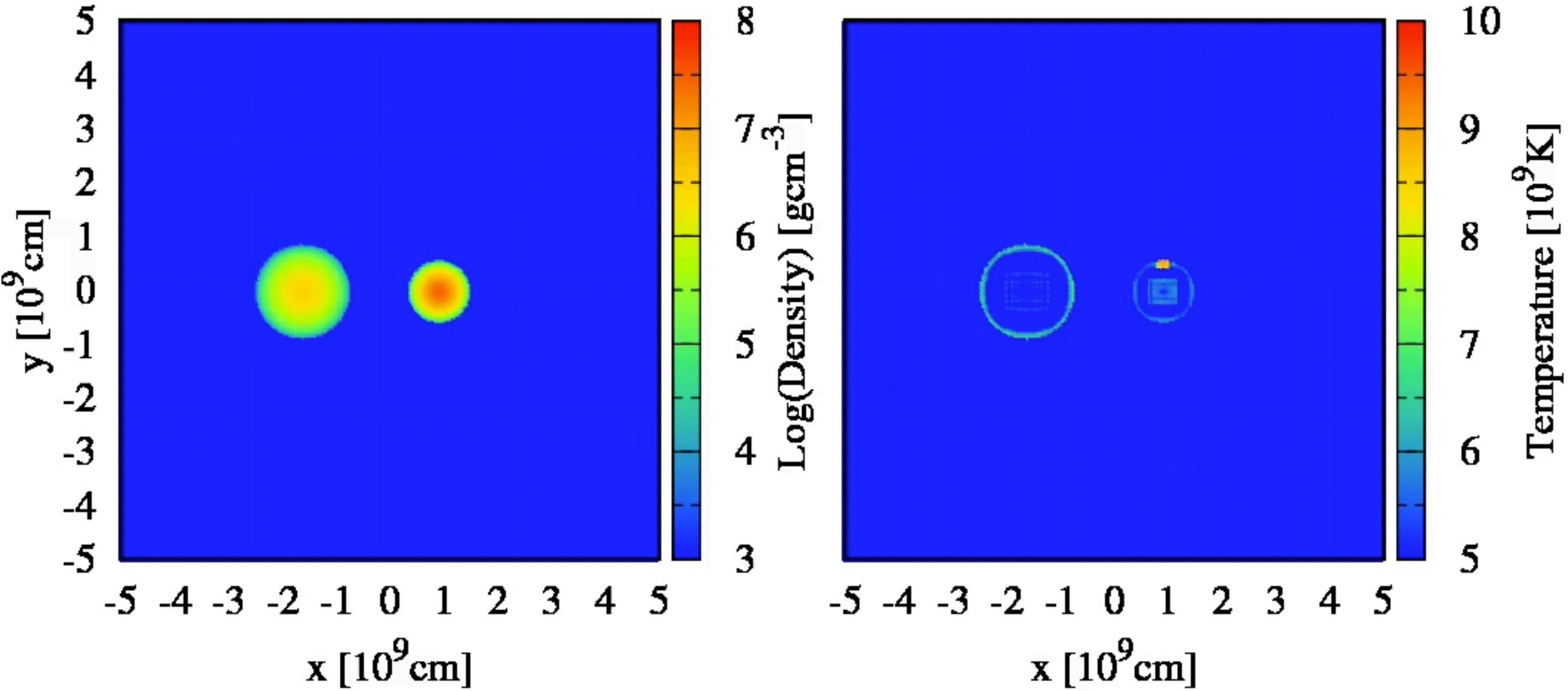
- SPH method
  - Parallelized by FDPS (Iwasawa, AT+ 2016)
  - Vectorized by SIMD (e.g. AT+ 2012; 2013)
  - Helmholtz EoS (Timmes, Swesty 2000)
  - Approx13 nuclear reaction networks (Timmes et al. 2000)

Initial condition

- 1.0Msun WD + 0.6Msun WD
- 1.0Msun WD
  - 0.95Msun CO core
  - 0.05Msun He outer shell
- 0.6Msun CO WD
- Separation: 1.6x10^4 km
- N=83,886,080
  (1.2x10^-8Msun per prt)
- Hot spot in the He outer shell

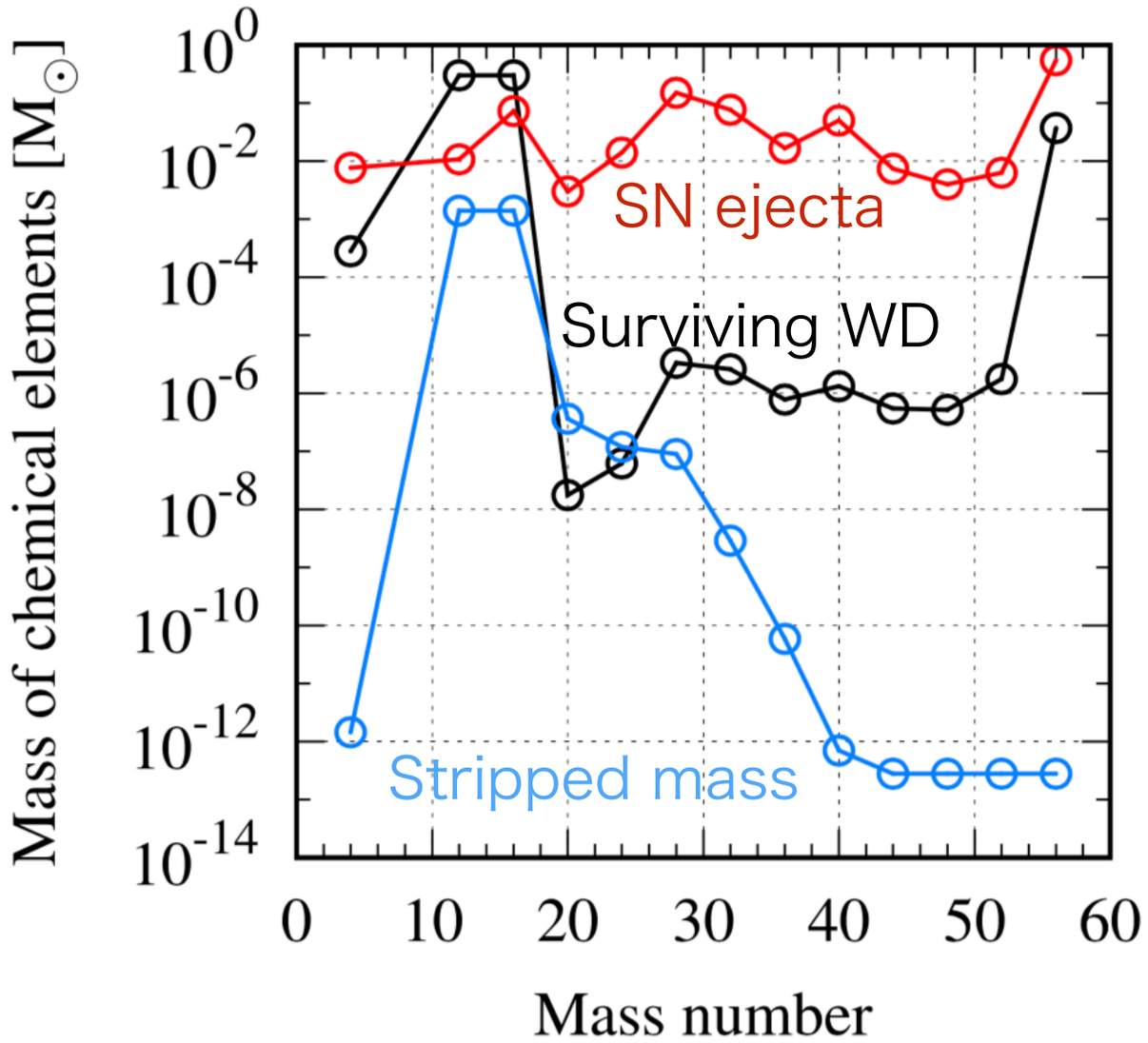


Animation

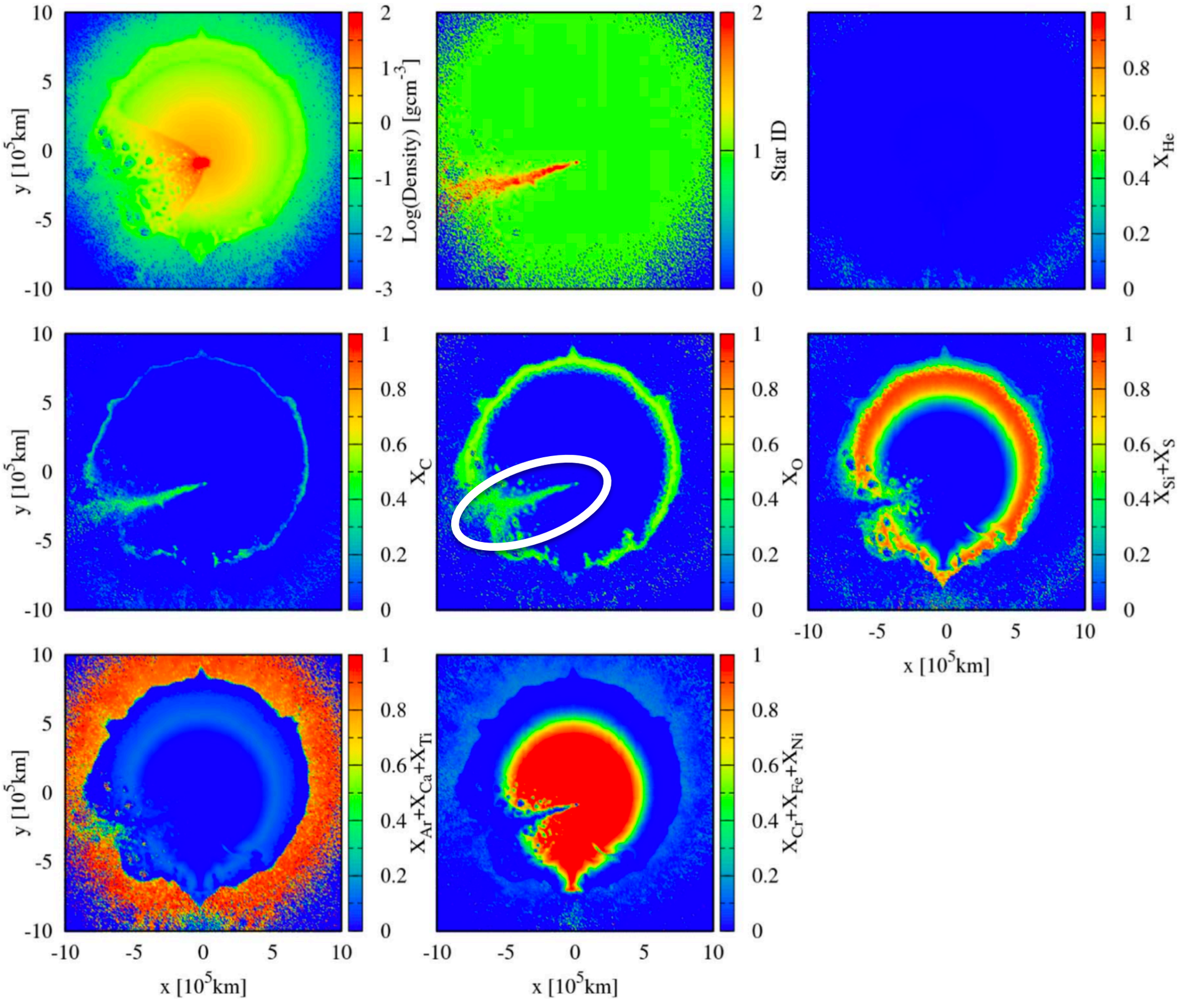


Chemical elements

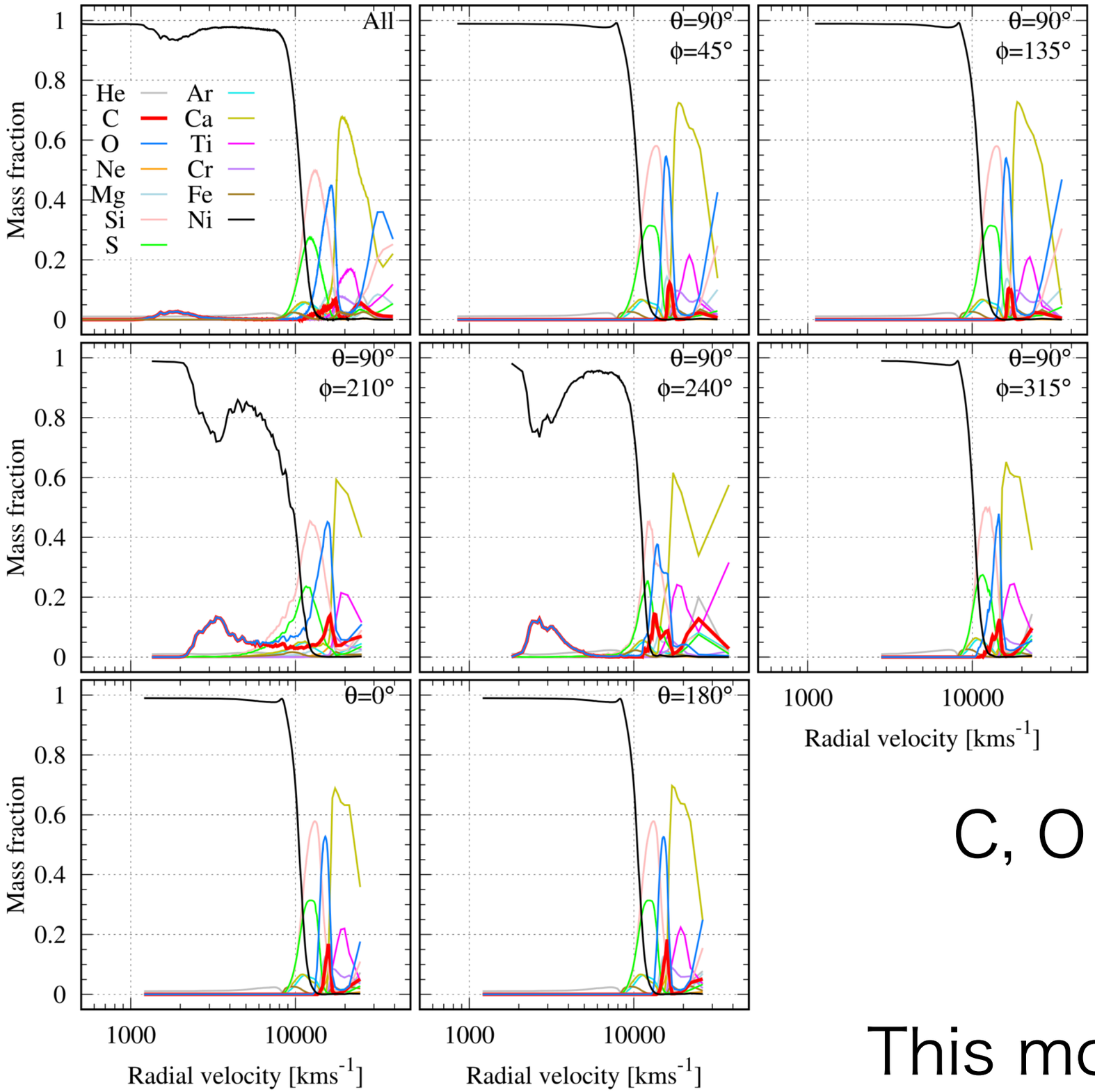
- Nuclear energy:
  1.35x10^51 erg
- 56Ni: ~0.6Msun
- Stripped mass from the secondary WD:
  ~0.003Msun
- Captured mass by the secondary WD: ~0.03Msun



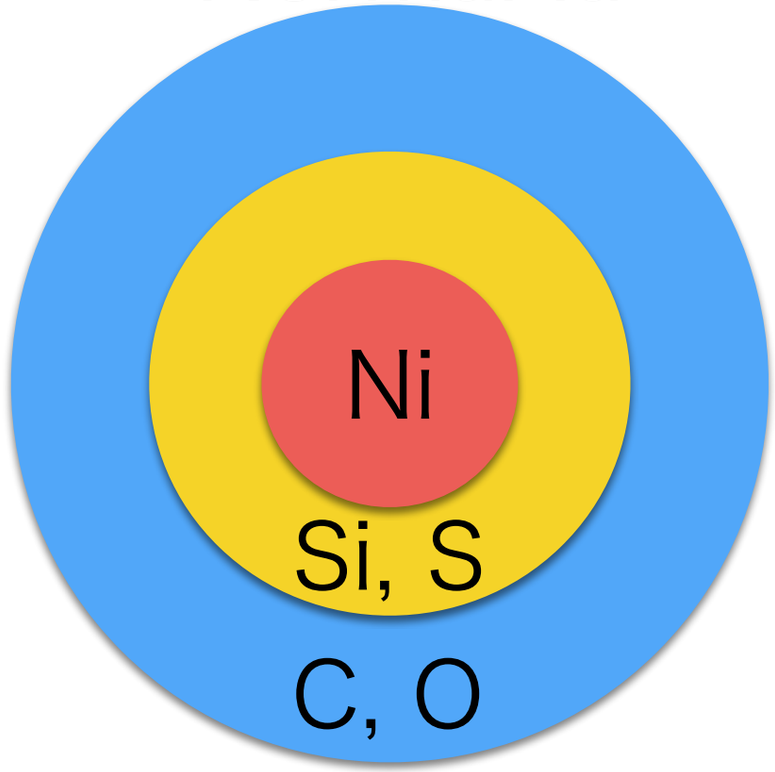
SN ejecta

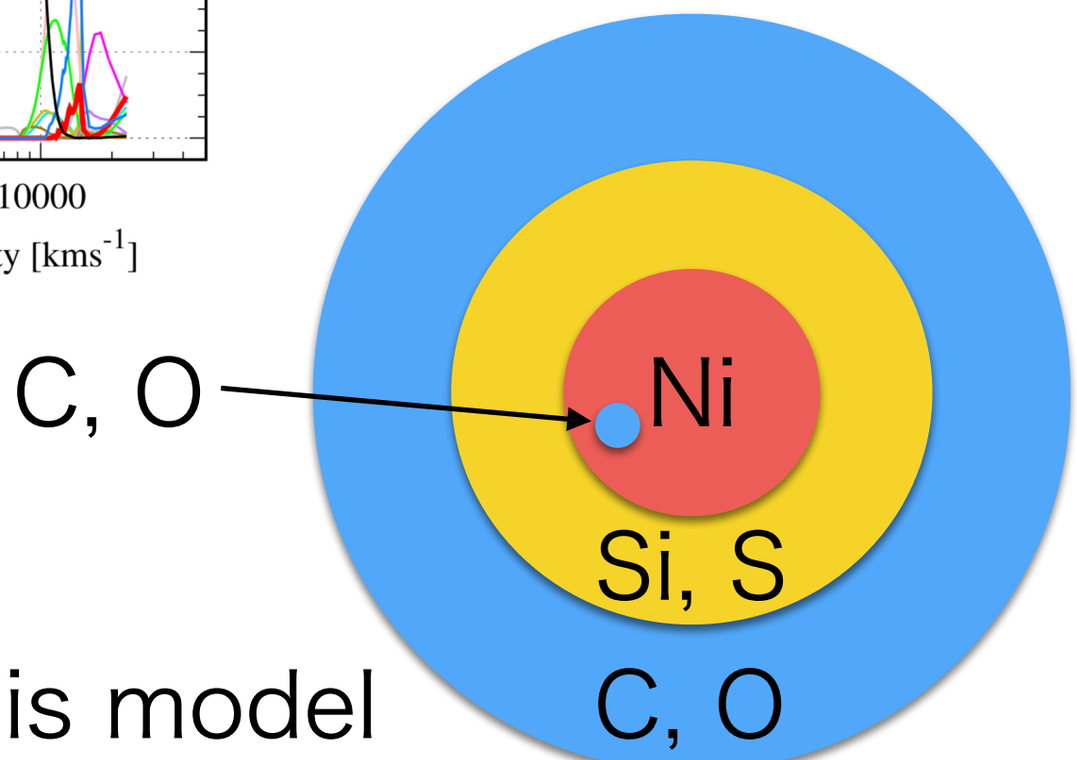

y [10^5km]
x [10^5km]
Log(Density) [gcm^-3]
Star ID
X_He
X_C
X_O
X_Si+X_S
X_Ar+X_Ca+X_Ti
X_Cr+X_Fe+X_Ni

Velocity distribution



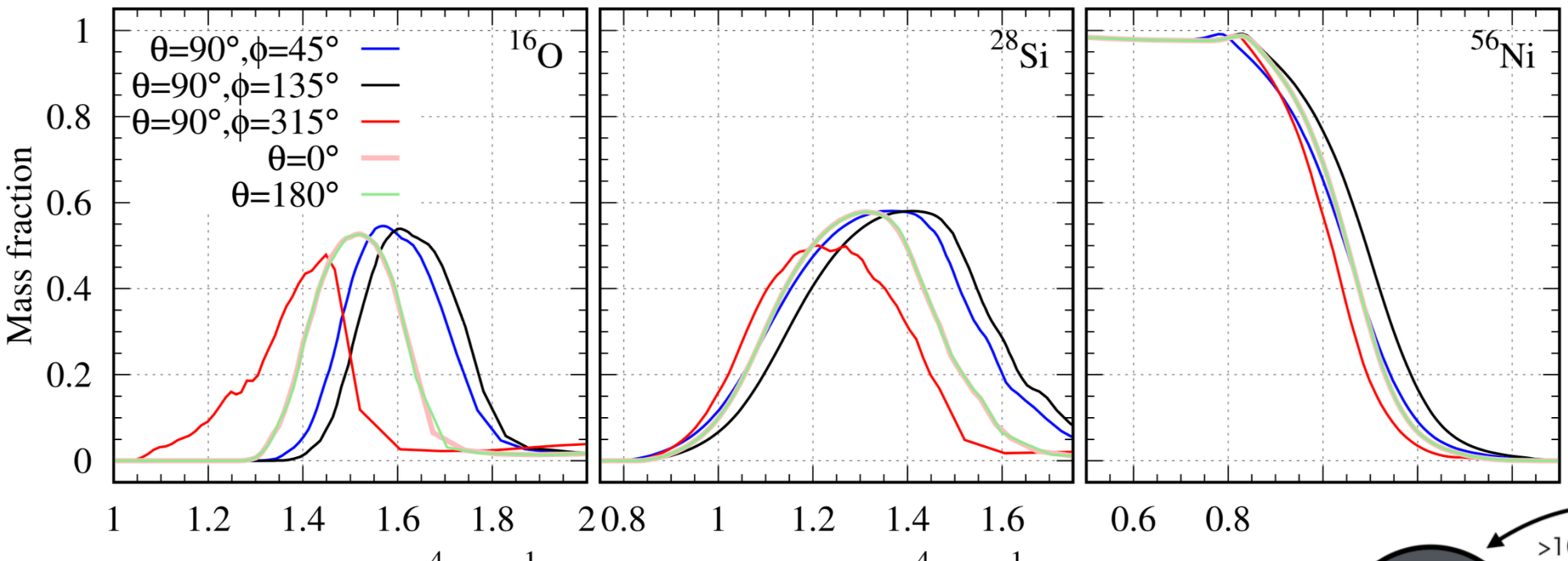
Normal Ia

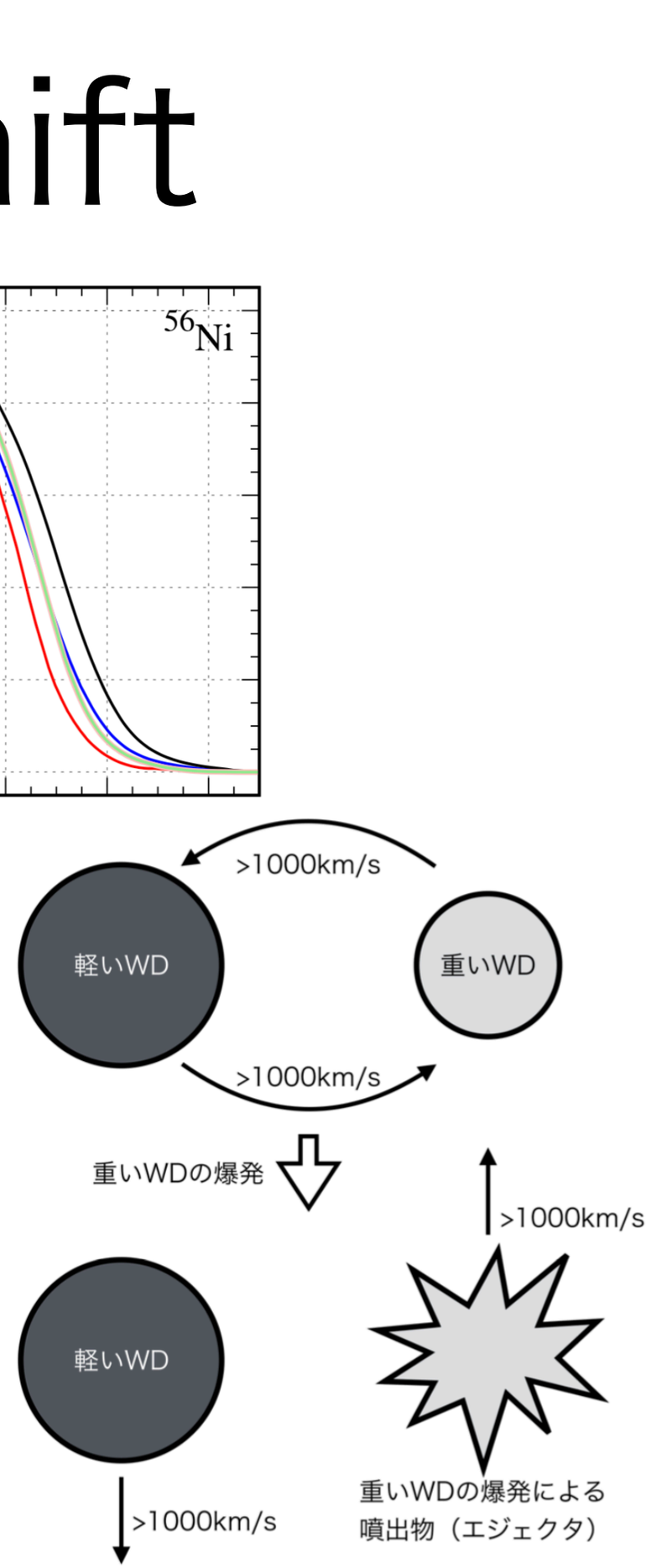




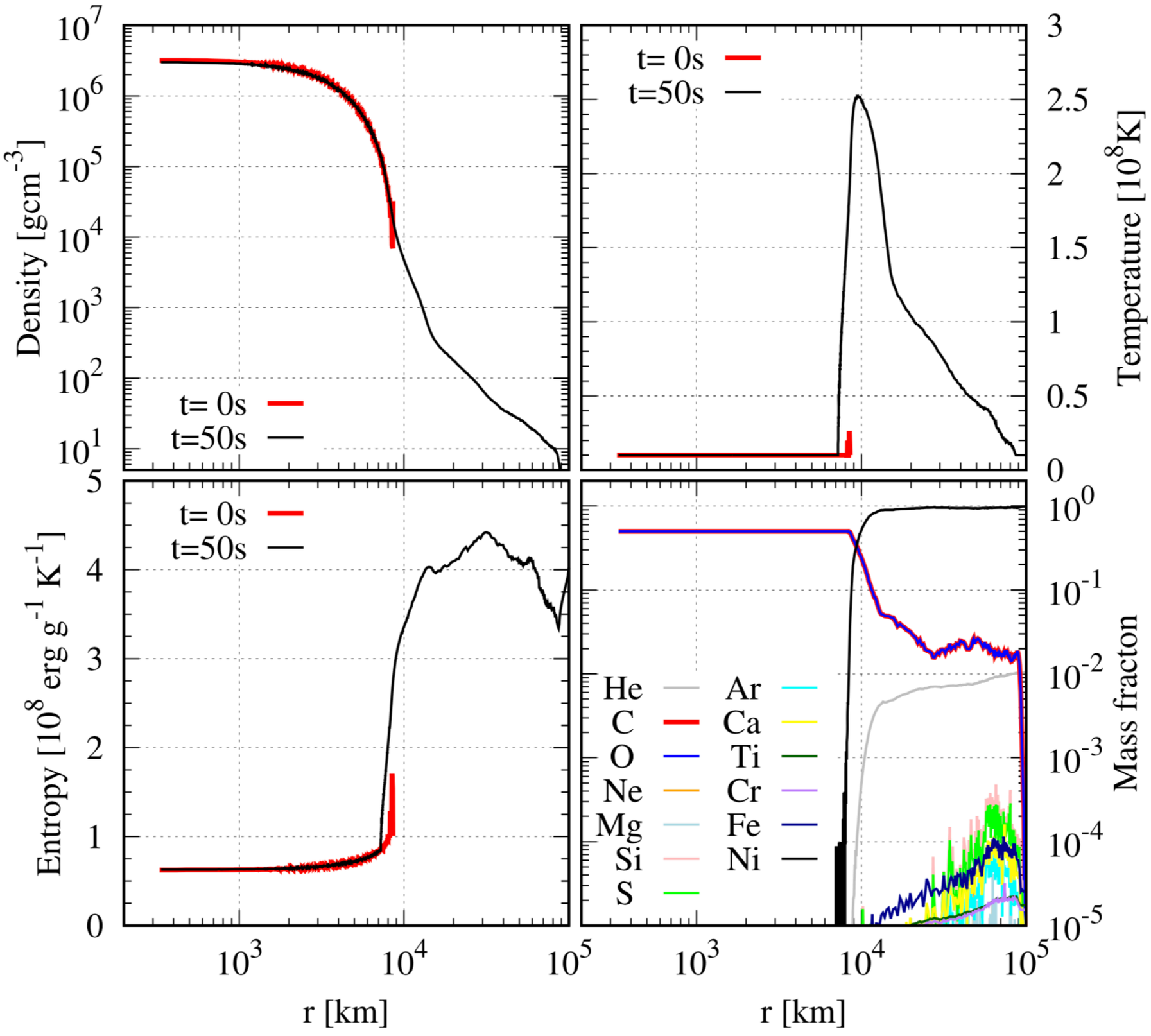
This model

Velocity shift



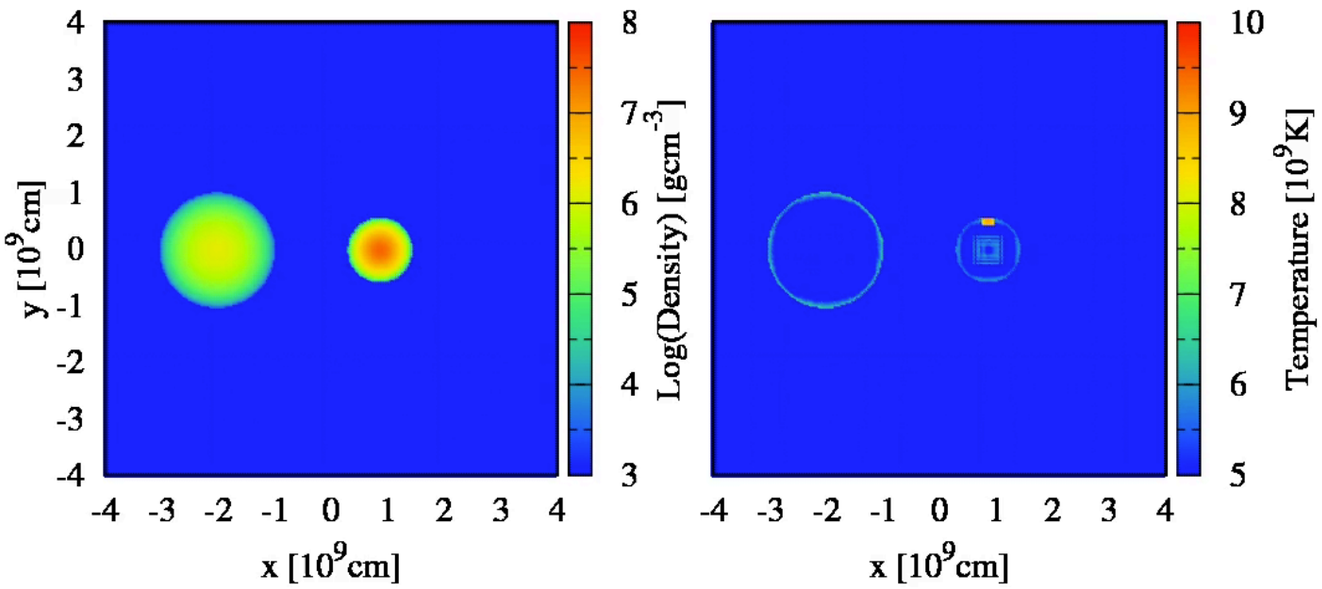


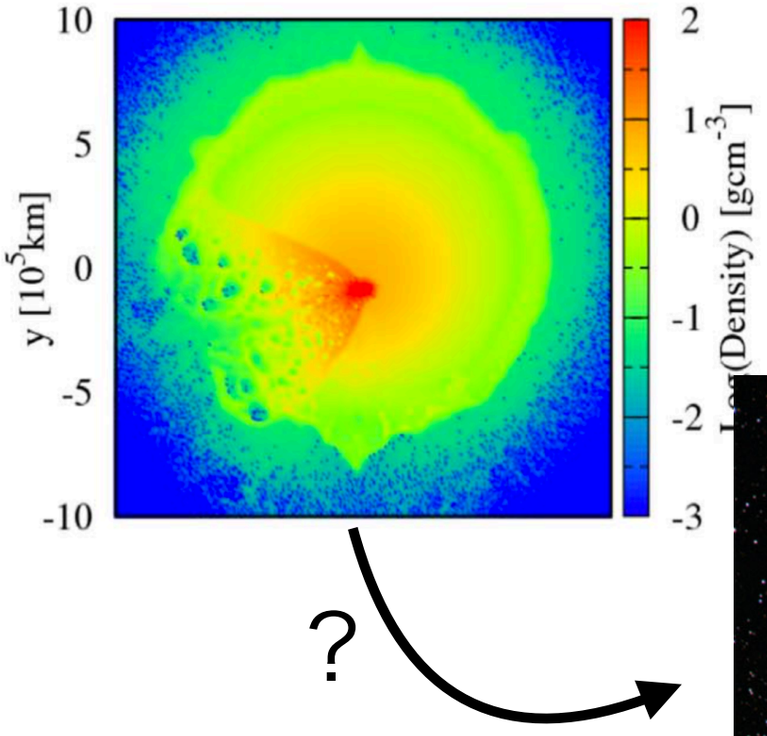
Surviving WD



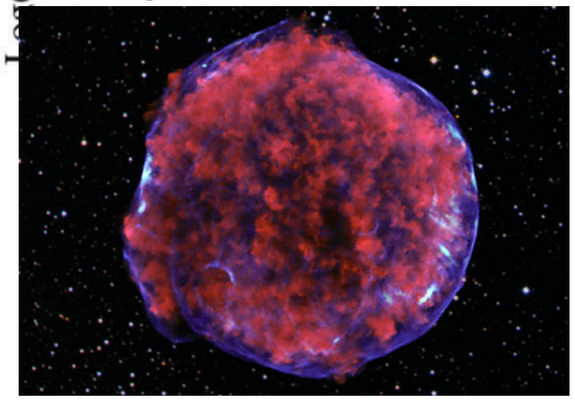
Future work

- Various combinations of WD masses
- Supernova remnants of D6 models
- Long-term evolution of surviving WDs





Tycho SNR



Summary

- We have performed a 3D simulation of the D6 model for type Ia supernova.
- CO materials are stripped by the SN ejecta, and compose low-velocity components.
- The SN ejecta have a velocity shift (~1000km/s) due to the binary motion of the progenitor system.
- The surviving WD captures a fraction of the SN ejecta, and may have atmosphere polluted by Fe peak elements.