Characterizing Surviving Companions After Type Ia Supernova explosions

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Abstract

Type Ia supernovae are crucial for cosmological research, but the nature of its progenitor system is still elusive. In the single-degenerate scenario(SDS), the companion star can be survived after the supernova impact and is detectable in nearby supernova remnants. We use the stellar evolution code MESA to construct several main sequence (MS) companions within the SDS, and then perform 2D hydrodynamics simulation with the FLASH code to characterize the response of binary companion on supernova impact. We applied this method to a wide range of possible companion configurations to characterize the companion response systematically. Furthermore, we perform post-impact evolutions of surviving companions within MESA to predict possible observables.

Introduction: Single-degenerate scenario (SDS)

In the single-degenerate scenario (SDS), the explosion of the carbon-oxygen white dwarf (WD) is triggered by accretion from a non-degenerate companion star, such as a main-sequence (MS) star, red giant, or helium star, through Roche lobe overflow or winds. In this scenario, the non-degenerate companion has a high chance to be survived after a supernova explosion and therefore could be detectable in nearby supernova remnants. Identifying these surviving companions could shed light on the nature of Type Ia supernova progenitor.

Simulation

We use MESA to construct 4 zero-age main-sequence stars (MS) with masses equal to 0.8, 1.0, 1.5, and 2 solar mass and with solar metallicity. We then interpolate these companion models in 2D cylindrical grids using FLASH. Since the MESA model is created from the 1D Lagrangian grid, we relax the companion model in the 2D grids by damping their kinetic energy for several dynamical time scales (~10^4 sec). A W7-like supernova explosion (Nomoto et al. 1984) is then imposed at a binary separation a= 2~6R*, where R* is the companion radius. Then we use MESA to perform post-impact evolution. Figure 1 shows the density slice of the 2 solar mass companion with a binary separation at a = 3R* at different times after a supernova explosion. Figure 4 is the HR diagram for post-impact evolution.

Results

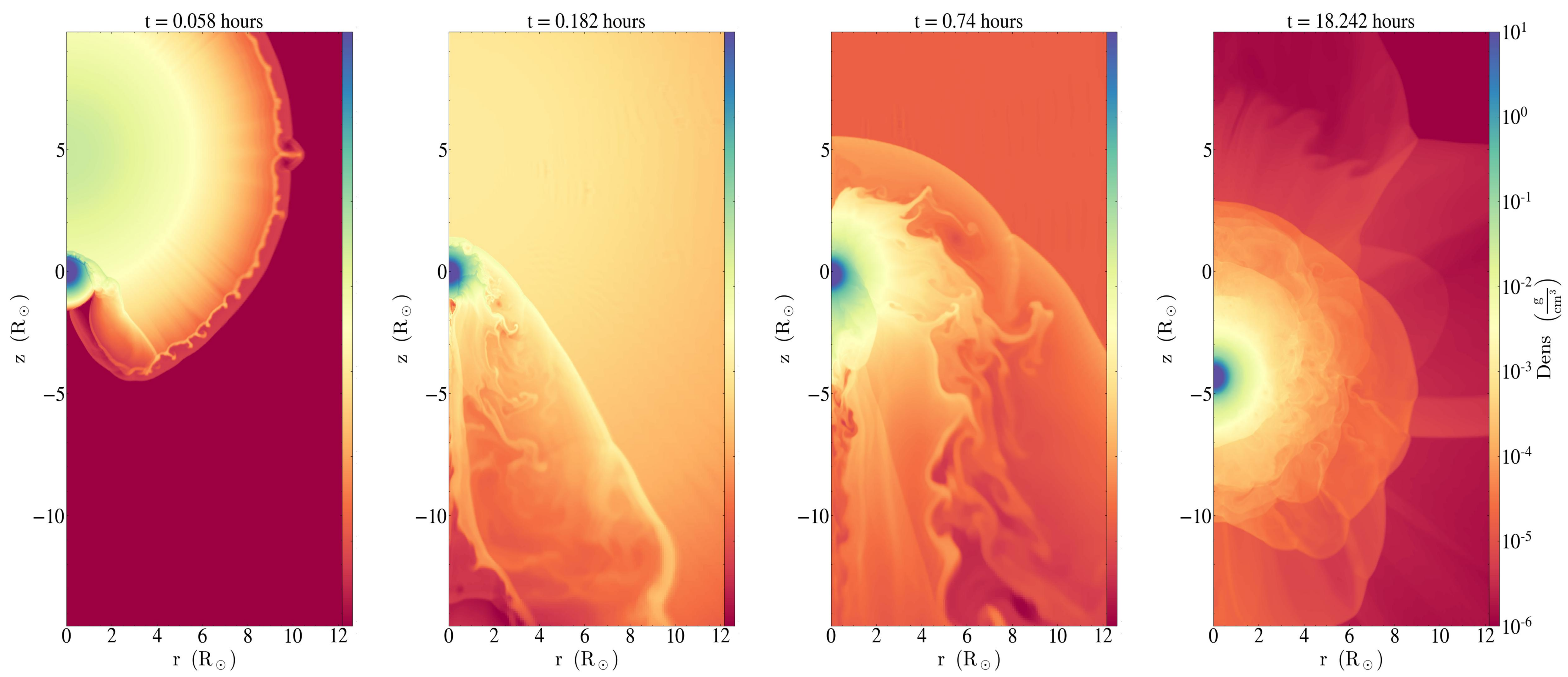

Fig. 1 Density slice (2 solar mass, a = 3R*) at different time after a supernova explosion.

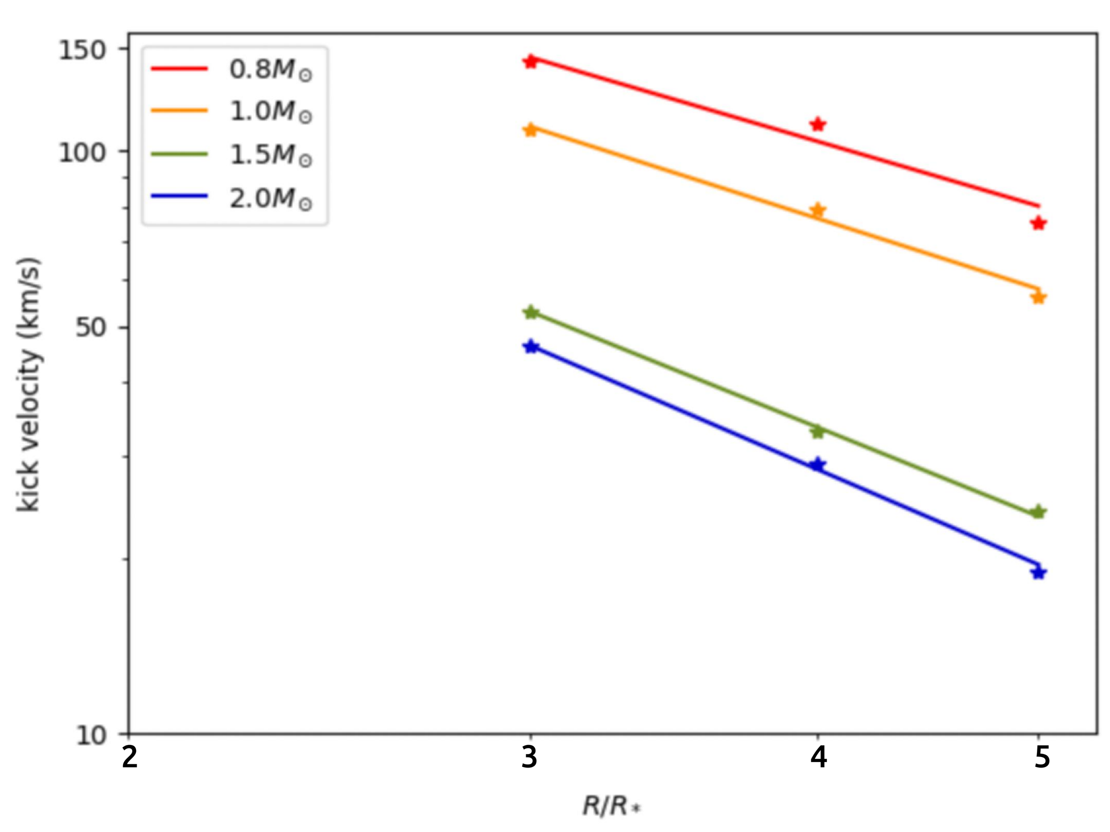

Fig 2. Kick velocity as function of radius for different companion mass.

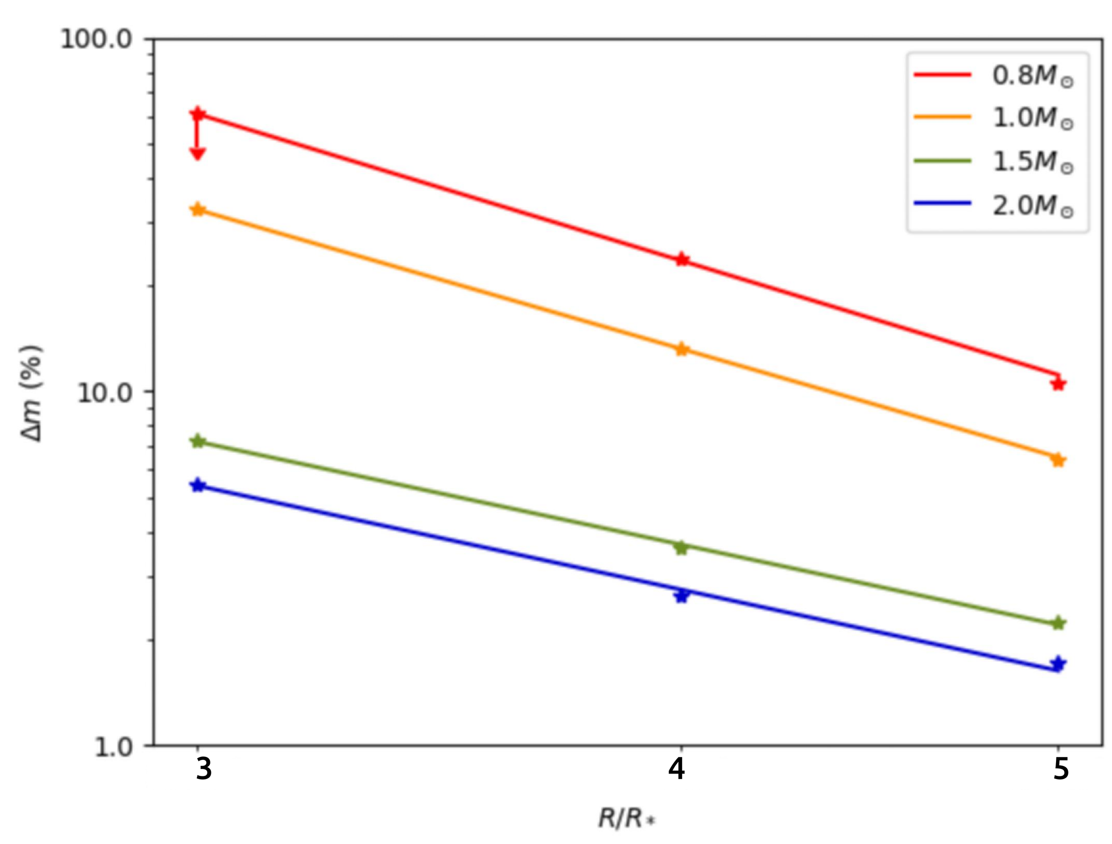

Fig 3. Mass loss as function of radius for different companion mass.

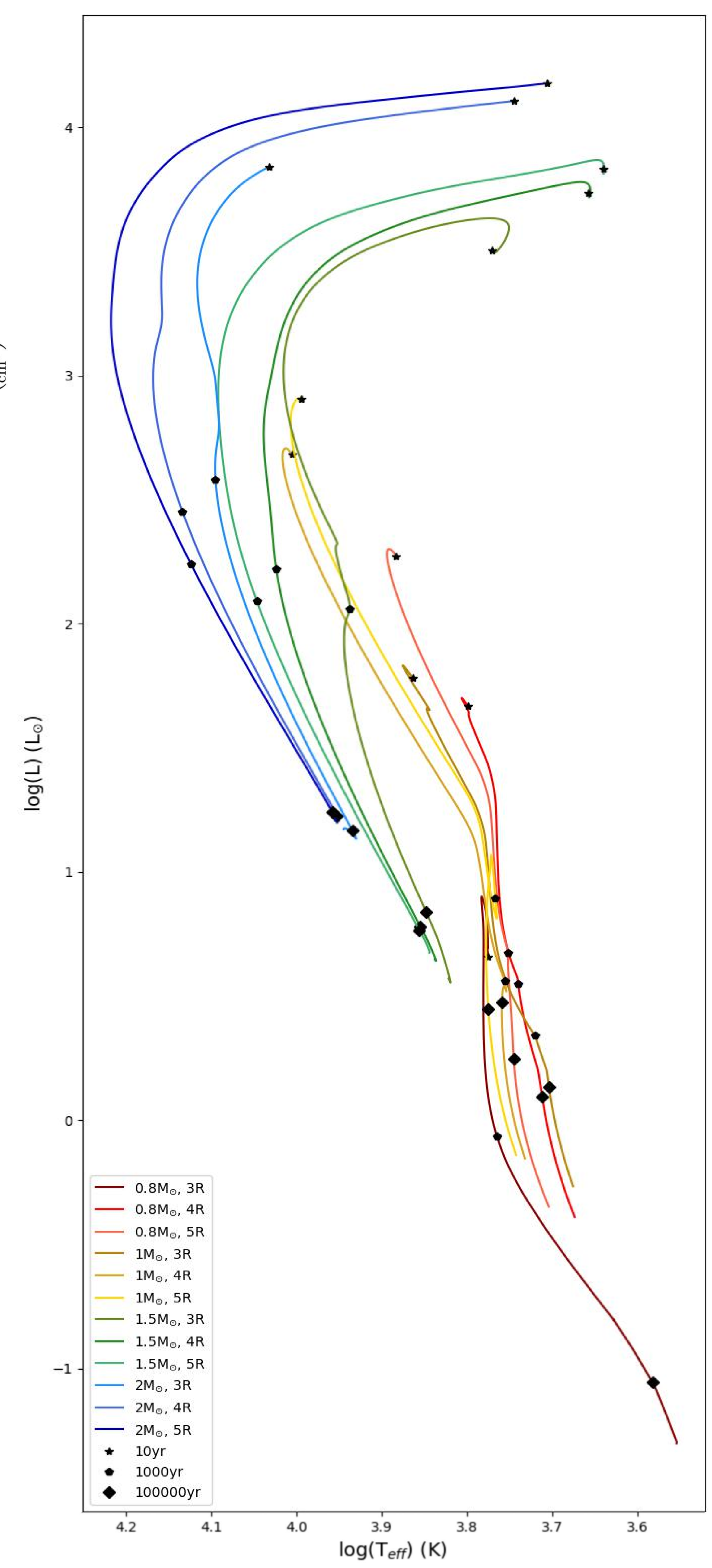

Fig 4. HR diagram.

Conclusions and Future Work

In this work, we have investigated a wide range of progenitor systems of type Ia supernovae explosion with a main-sequence star companion. It is found that the dependence of final mass lost after the supernova explosion on the binary separation can be fitted by a power-law relation. By characterizing the entropy changes during the supernova explosion in the 2D FLASH code, we then adopt the same entropy changes in the 1D MESA stellar evolution code to perform post-impact evolutions.

References

1. Nomoto, K., Thielemann, F.-K., & Yokoi, K. 1984, ApJ, 286, 644
2. Pan, K.C., Ricker, P.M., & Taam, R.E. 2012, ApJ, 750, 151

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