Characterizing the surviving companion after a Type Ia supernova explosion

Shiau-Jie Rau (Department of Physics, National Tsing Hua University, Taiwan)
Kuo-Chuan Pan (Institute of Astronomy, National Tsing Hua University, Taiwan)

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 generate a $2M_\odot$ companion within the SDS and then perform a 2D hydrodynamics simulation with the FLASH code to characterize the response of binary companion on supernova impact. This method can be applied to a wide range of possible companion configurations to systematically characterize the companion response.

Introduction: Single-degenerate scenario (SDS)

In the 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.

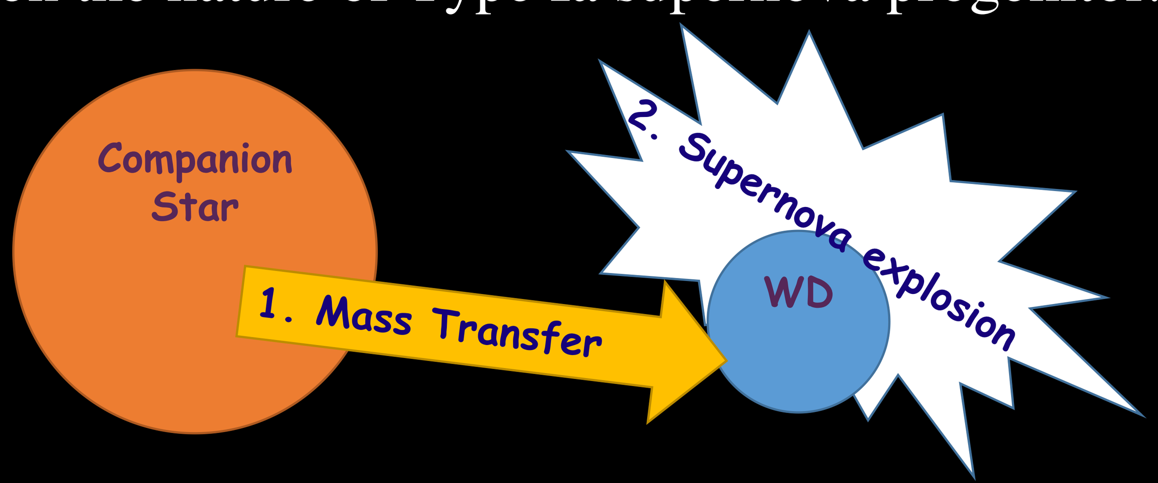

Fig 1. Cartoon of SDS

Simulation

We use MESA to generate a $2M_\odot$ zero-age main sequence star (MS) and then interpolate the companion model in 2D cylindrical grids in FLASH. Since the MESA model is created from the 1D Lagrangian grid, we relax the companion model in the 2D grids by damping its kinetic energy for several dynamical time scales (~10^4 sec). A W7-like supernova explosion (Nomoto et al. 1984) is then imposed at binary separation a= $3R_*$, where R_* is the companion radius. This separation is a typical value for a companion start filling its Roche lobe radius.

Results

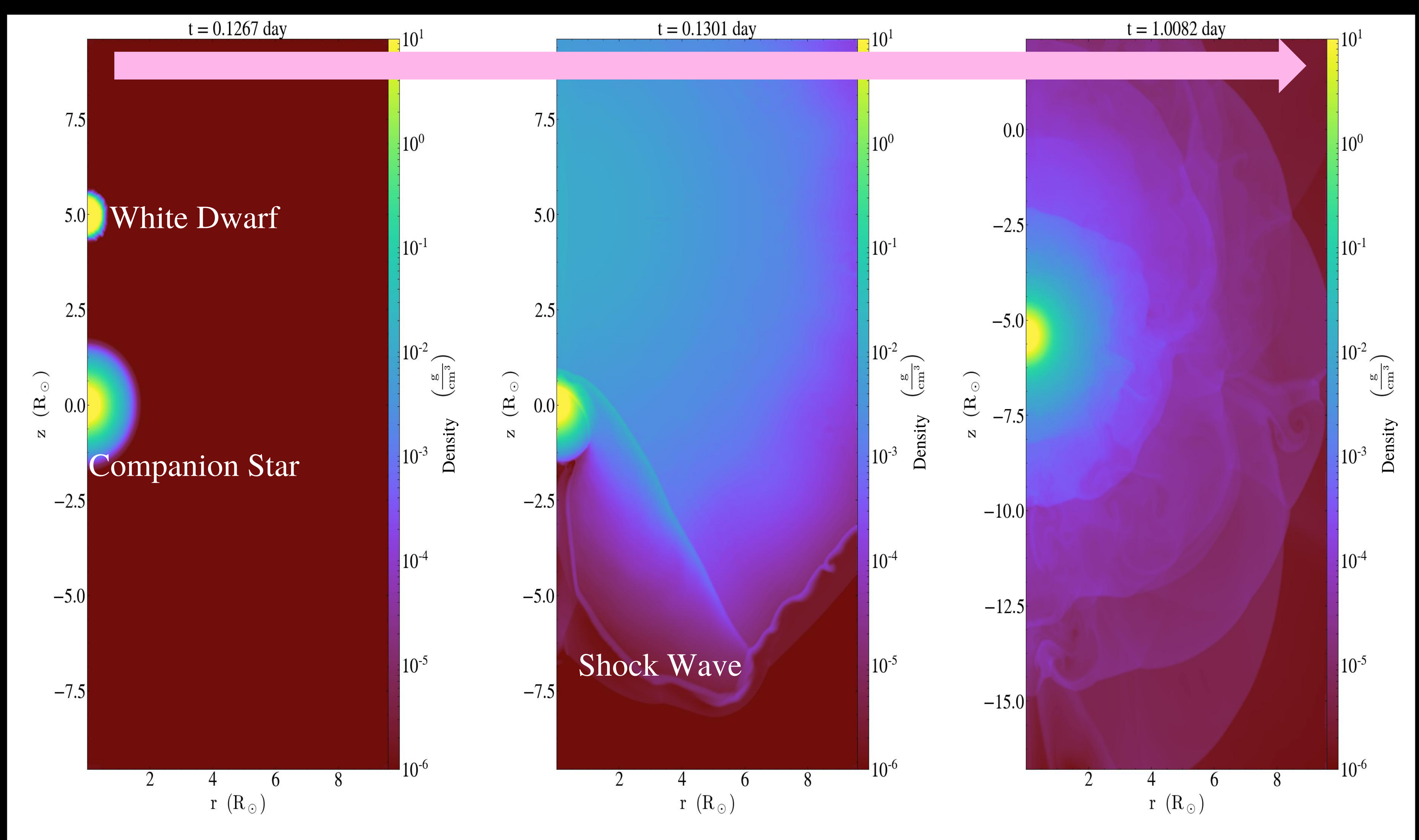

Fig 2. Density slice plots at different time after a Type Ia supernova explosion.

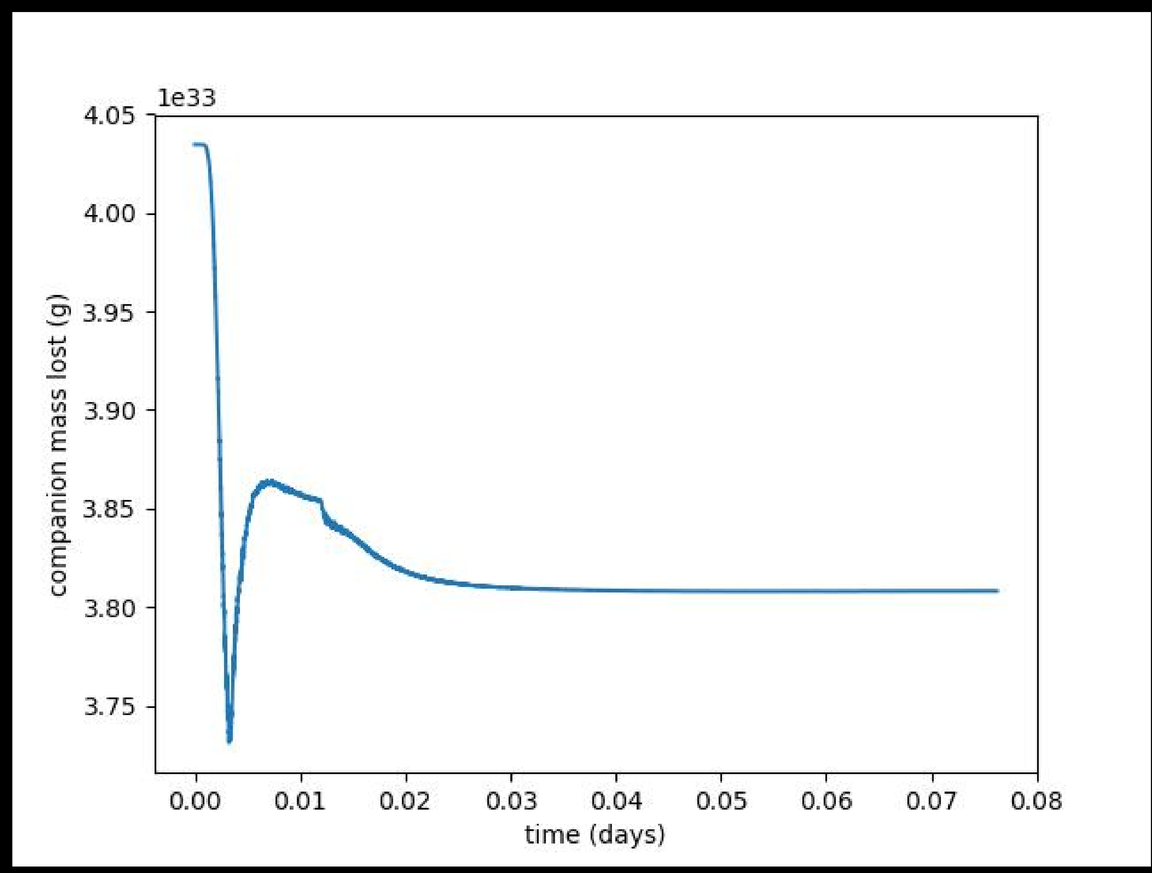

Fig 3. Time evolution of the companion mass. When the shock wave passes through the companion star, SN ejecta will strip and ablate the companion envelope. For this $2M_\odot$ companion, ~4% of its mass is stripped after the explosion.

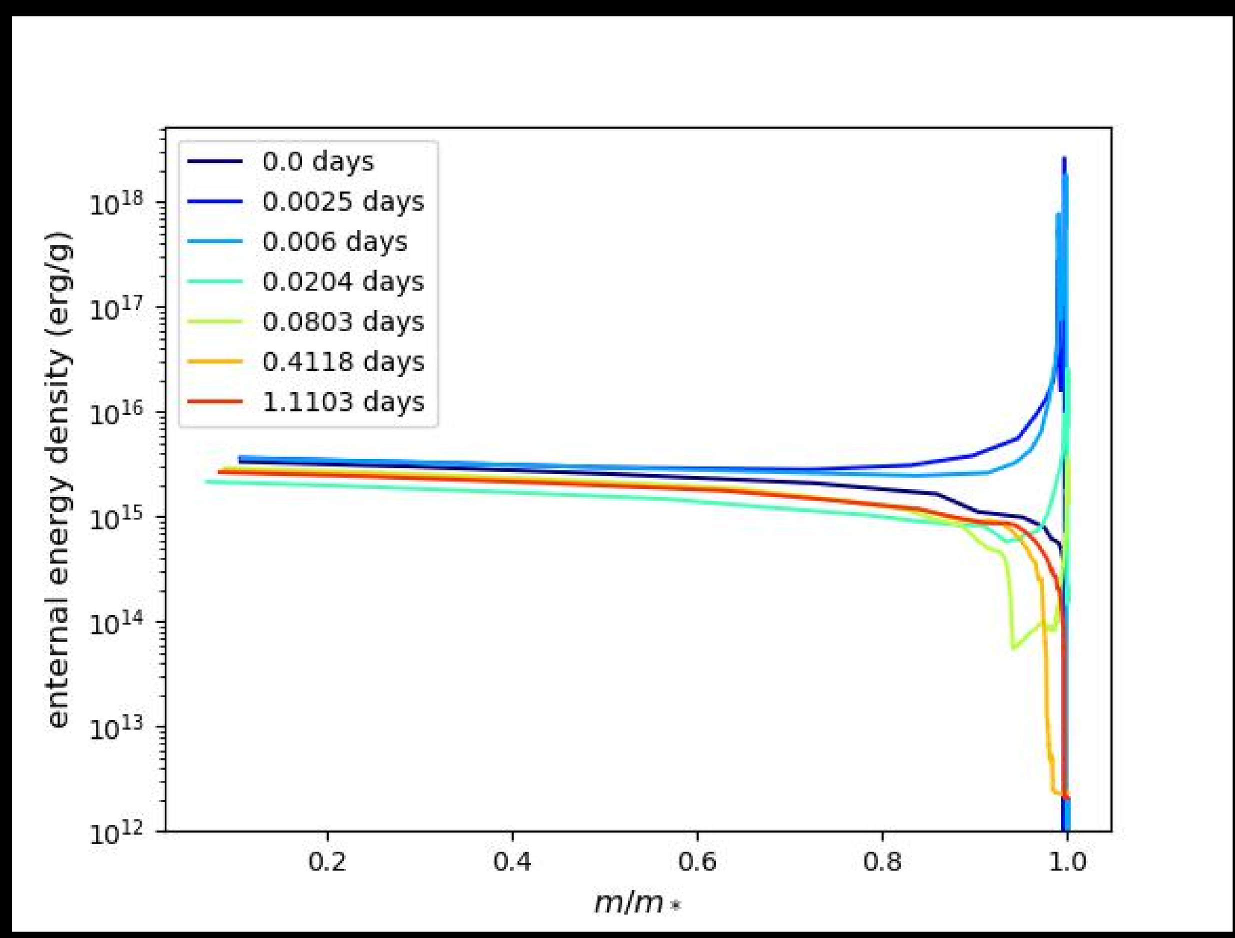

Fig 4. Evolution of radial averaged specific internal energy in the mass coordinate. Different color represents the averaged specific internal energy at a different time since the explosion. The internal energy in the stellar enveolope is increasing due to heat from the explosion.

Conclusions and Future Work

- The companion lost 4% of its mass after the explosion. This mass loss is much less than the previous studies with a 1 solar mass MS companion (i.e., Pan et al. 2012), suggesting the post-impact surviving companion could be less luminous than the previous thought.
- The numerical tools we have developed can be applied to a wide range of parameter space (i.e., companion mass, types, binary separation, and explosion energies) for a systematically study.

References

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