# Three Dimensional Dynamically Driven Double-Degenerate Double-Detonation Simulations for Type 1a Supernova

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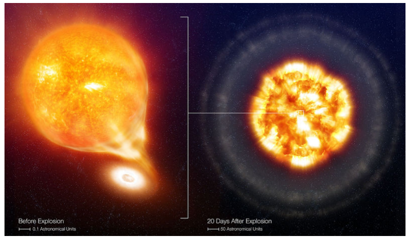
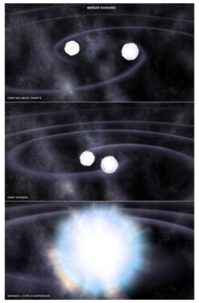
## Abstract

Type Ia supernovae are thermonuclear explosions of white dwarfs, characterized by the nuclear burning of carbon and oxygen and serve as standardizable candles for cosmology. However, the exact nature of the progenitors and mechanisms of explosions is still a mystery. In recent years, the dynamically driven double-degenerate double-detonation (D6) model is gaining popularity. A D6 model is a setup of double degenerate progenitors where the primary and the secondary have thin layers of He on their surface. The accretion of the He onto the primary can lead to a He detonation on the surface, which would eventually lead to the detonation of carbon, thus leading to a type Ia supernova. In this work, we present a three-dimensional simulation of a D6 scenario where we see a surface detonation on the primaries surface, which travels across the star and collides at the other end.



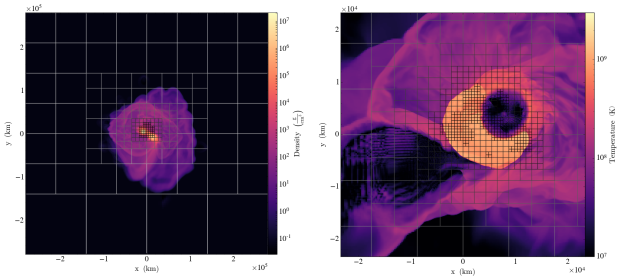
Single-Degenerate



Double-Degenerate

## Method

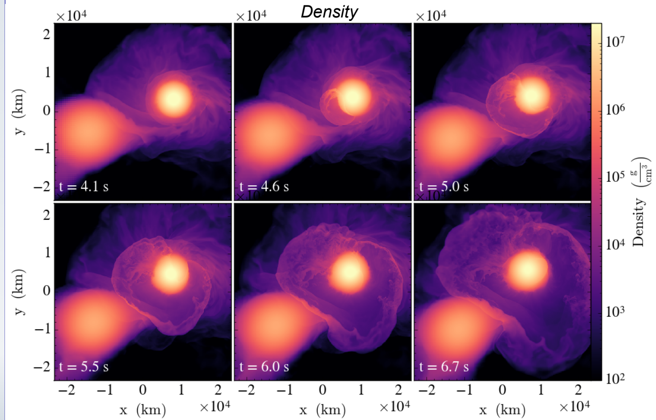
- We start with an SPH simulation of two white dwarfs with mass 1.0 + 0.6 solar masses, each with 0.01 solar mass He.
- The SPH simulation is mapped to an Eulerian grid in the FLASH code.
- The domain of the grid is 5.6 * 10^5 km along each side on the box.
- We make use of Adaptive Mesh Refinement (AMR) so that we only refine at the most "interesting" part and reduce the computational cost.
- Refinement is based on the mass and temperature of a block. Mass criteria select the central parts of the domain, while temperature criteria resolve the detonation front.
- We make use of a 19 isotope nuclear reaction network.
- A total of 4 simulations with min resolutions 136km, 68km, 34km, 17km.

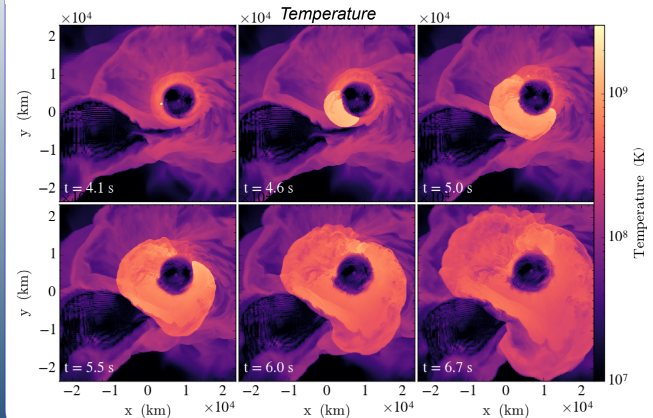


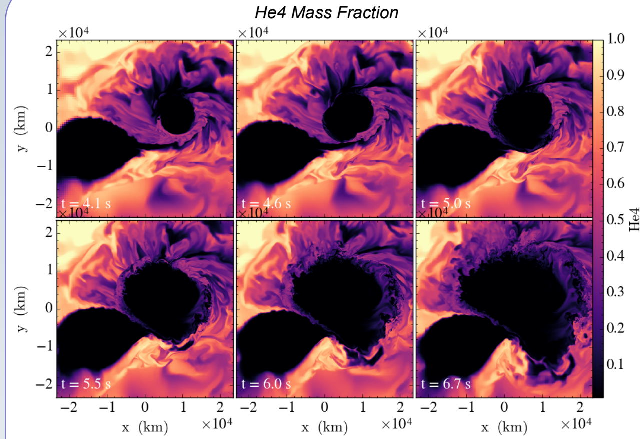
Adaptive Mesh Refinement

| Refinment Level | $\Delta x_{min}$ | Simulation Time (Secs) | Wall Clock Time(Days) | Max Blocks | Total Cores | Ignition Temp(1e9 K) | Shock Collison Temp (1e9 K) |
|---|---|---|---|---|---|---|---|
| 6 | 136 km | 35.65 | 2.34 | 1296 | 512 | 2.46 | 2.03 |
| 7 | 68 km | 23.79 | 1.60 | 2920 | 616 | 2.96 | 2.08 |
| 8 | 34 km | 9.02 | 2.22 | 2608 | 616 | 2.99 | 1.98 |
| 9 | 17 km | 3.92 | 5.28 | 17240 | 1600 | 3.03 | 2.29 |

- We observe a He detonation on the surface of the primary, which wraps around it and collides at the other end of the primary white dwarf.
- Maximum temperature and shock collision detonation go up when we increase the resolution.
- After the first detonation, the helium is depleted and is blow away, making it harder for a successful D6 model.




## Conclusion and Future Work

- None of our models show a second detonation of carbon on the primaries edge or the core.
- Going to a higher resolution increases the collision temperature. Thus running models with 8km or 4km runs might lead to a successful D6 model.
- Making use of a bigger nuclear reaction network will capture accurate energy release, which might lead to a successful carbon detonation.
- We will incorporate 231 nuclides nuclear reaction networks with xnet, with a collaboration with Oak Ridge National Laboratory, which makes using of GPUs for faster computations.

## Acknowledgement

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