

Impact of Si/O interface on core-collapse supernova explosions

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Core-collapse supernovae (CCSN) : why do they explode?

1. Massive stars form onion-like shells through successive burning stages.
2. When the iron core becomes too massive, it starts collapsing until central density reaches nuclear saturation density.

Infalling matter bounces back and **creates a shock propagating outwards**.

3. The resulting shock loses its energy while travelling and stalls. It stays in dynamical equilibrium between :

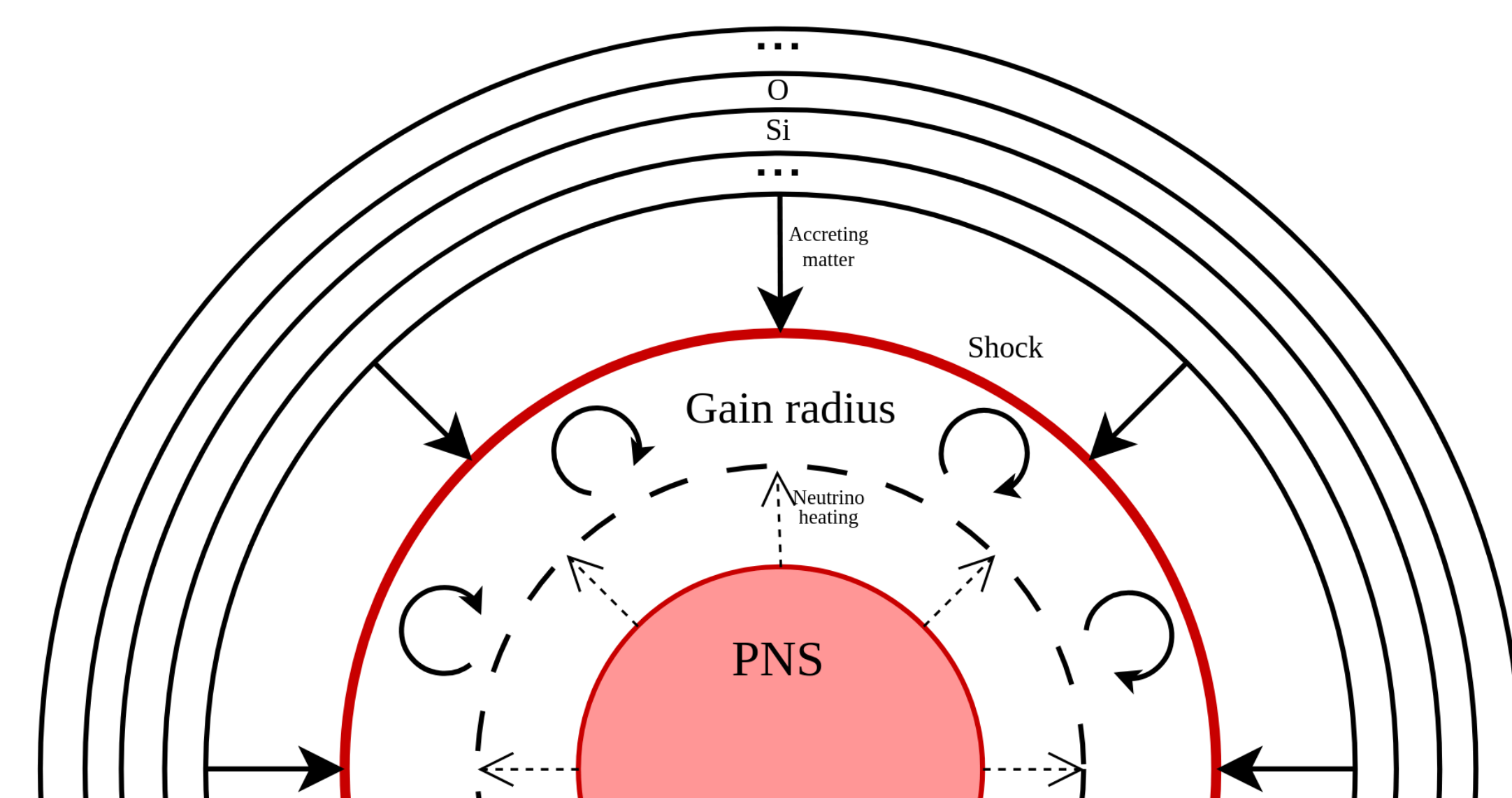
- **Ram pressure** from the accreting material
- **Neutrino heating** of material behind the shock

As the shock accretes stellar layers with different densities, the **progenitor structure strongly affects the explosion outcome**.

Key questions:

How does the progenitor density structure affect shock revival and explodability?

Can we predict the outcome without relying on expensive simulations?

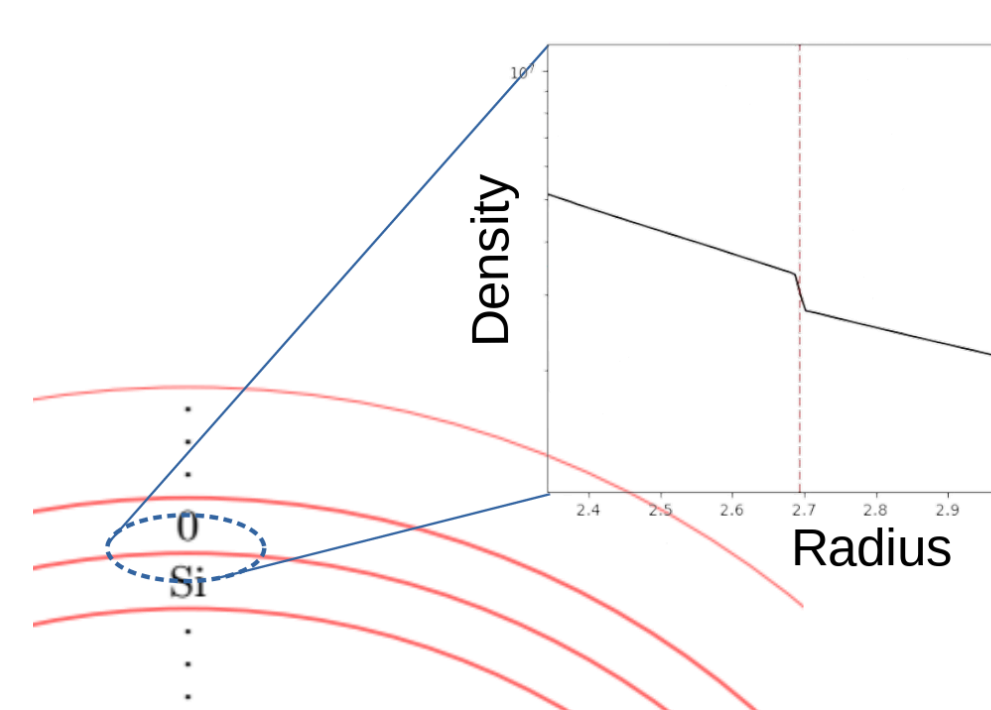


Schematic view of CCSN structure during the stalled shock phase.

Progenitor structure: impact of the Si/O interface

When the **density drop** at the Si/O interface is accreted, the ram pressure drops sharply and may **enable the explosion**. [1]

To test the impact of this parameter, we **modify the density jump** at the interface, while keeping other parameters the same and **measure the effects on the shock dynamics**.

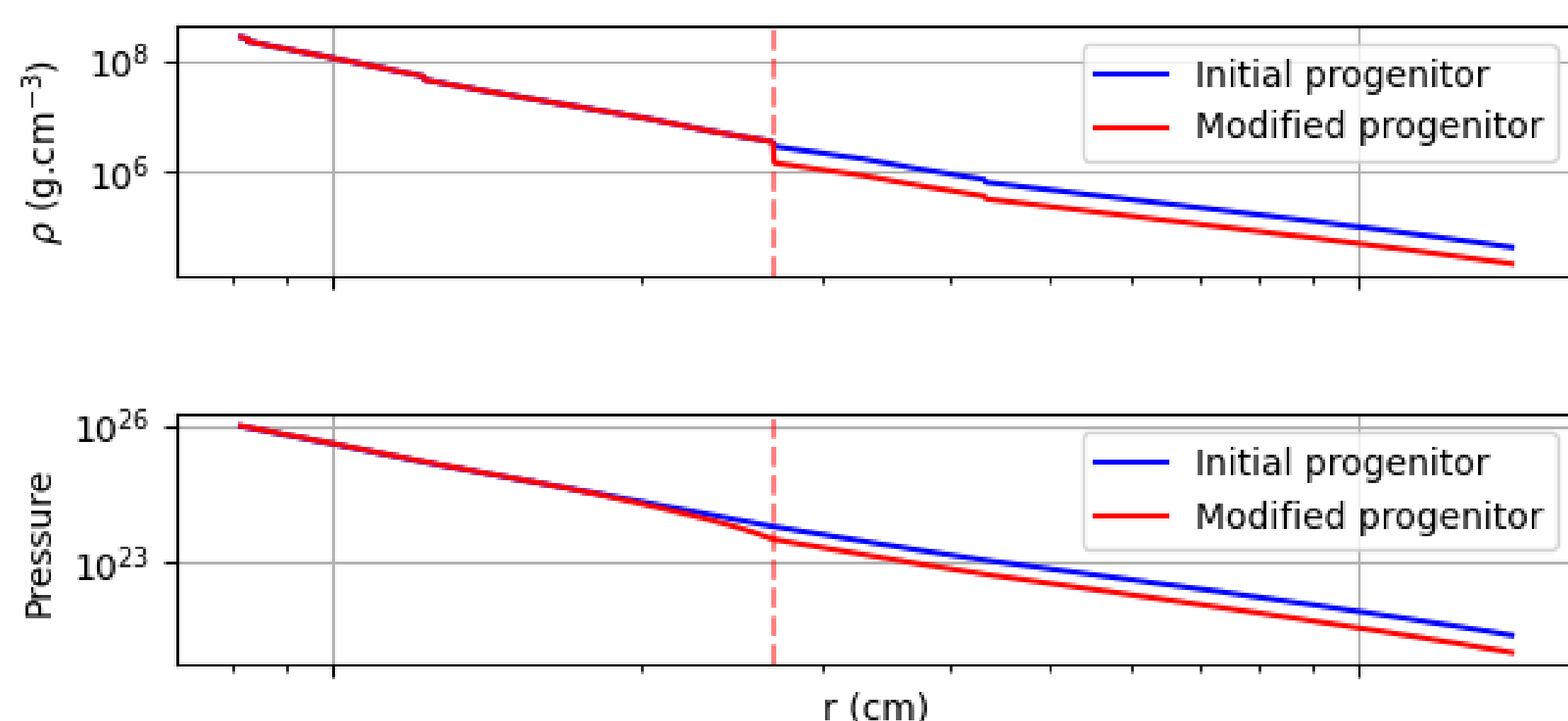


Controlled variation of Si/O density jump

The baseline progenitor models are taken from [2], then :

- Density profiles are changed to **raise or lower the density jump**
- Pressure is changed to restore **hydrostatic equilibrium**
- **Tabulated EOS** is used to recompute the temperature

Composition and global structure are kept unchanged.



Simulation setup

Simulations are run using the **CoCoNuT** code [3] :

- **General relativity** in the CFC approximation with LORENE (spectral methods) [4]
- (GR) **Hydrodynamics** : Eulerian High resolution shock capturing schemes
- **Neutrino transport** : M1 scheme

Modified progenitors are used as initial conditions and evolved in 1D up to core bounce then in 2D (350 × 128 grid). 16 neutrino energy bins from 2 to 350 MeV are evolved for all 3 neutrino species.

Bibliography

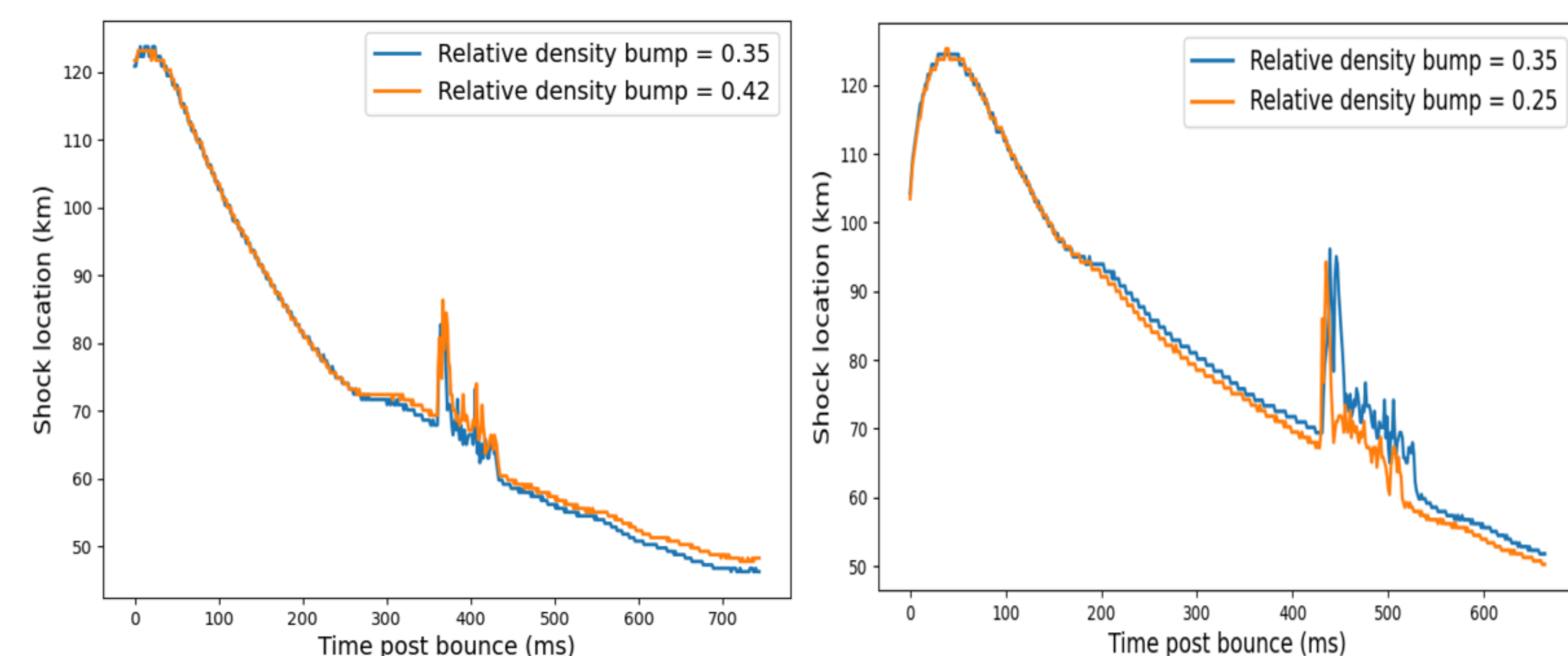
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Explodability in 1D

Explosions are **inherently multidimensional** and do not occur in 1D simulations.

However, **1D runs can probe the impact of the Si/O interface** on the shock dynamics. The shock radius is used as a proxy : larger expansion suggests **more favorable conditions** for explosion in 2D.

For each progenitor, we quantify the density jump by the **relative density bump** $\frac{\Delta\rho}{\rho}$ at the interface.

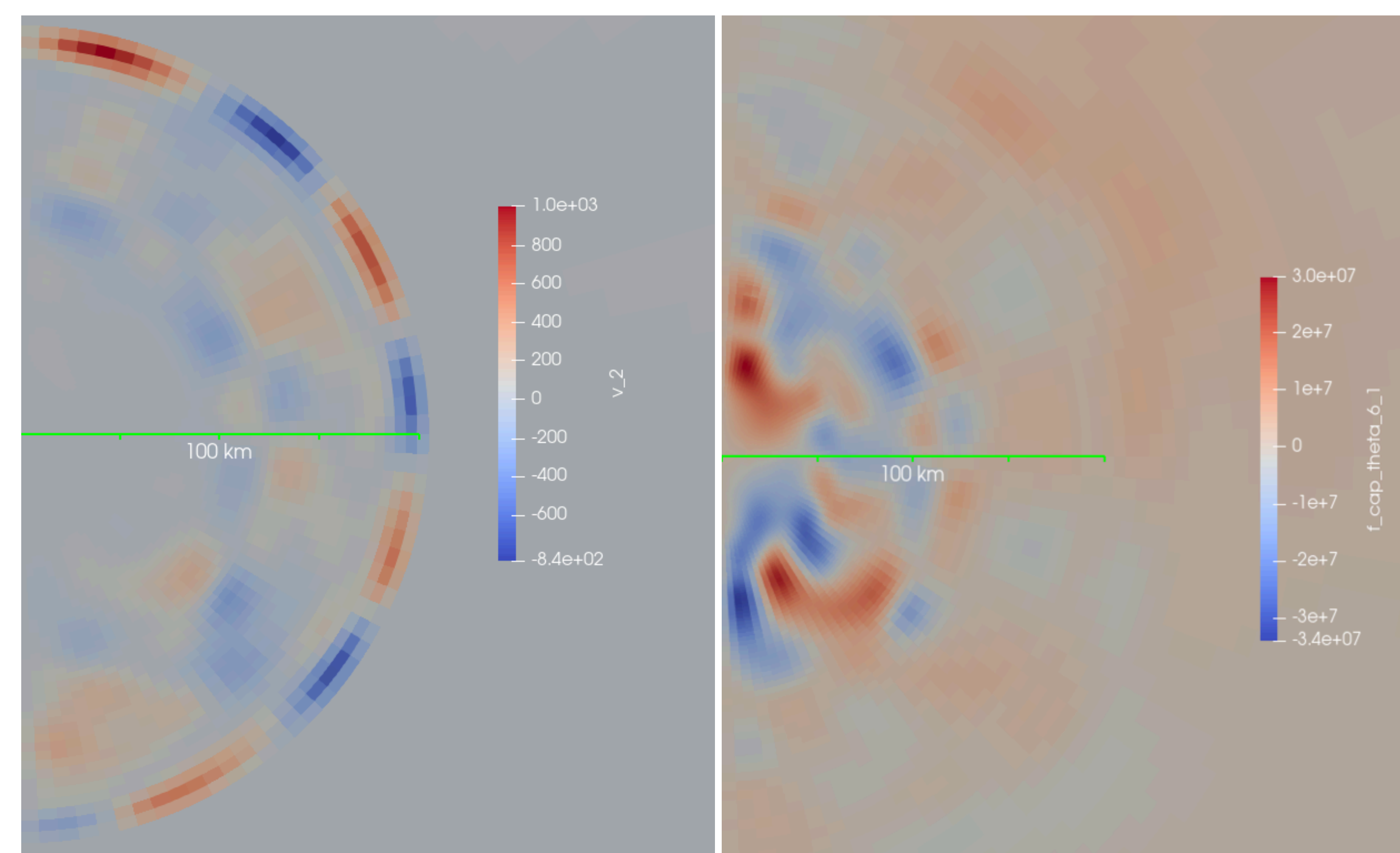


Shock location versus time for 15 M_{\odot} (left) and 16 M_{\odot} (right) progenitors, with different density jumps.

Models with a larger density jump show a **more extended shock**, indicating that the interface can **promote the explodability**.

2D simulations and perspectives

2D simulations are needed to be able to test the impact of the interface when all the physical ingredients are present. The 2D simulations are still in progress.



Angular velocity and angular neutrino flux for a 15 M_{\odot} progenitor, a few ms after bounce.