Two Dimensional Simulations of Pair-Instability Supernovae

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Abstract. We present preliminary results from two dimensional numerical studies of pair instability supernova (PSN). We study nuclear burning, hydrodynamic instabilities and explosion of very massive stars. Use a new radiation-hydrodynamics code, `CASTRO`.

Keywords: Stellar evolution, Massive star, Pair instability supernovae
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INTRODUCTION

The first stars that formed after the big bang may have a characteristic mass scale about hundred times heavier than present stars [1, 2]. Stars with initial mass between $140\,M_\odot$ and $260\,M_\odot$ end their lives in a very powerful explosion, called pair-instability supernovae (PSN) [3, 4]. Such supernovae could play an important role in the synthesis of the first heavy elements [5]. The energy output into their surroundings can affect the structure and evolution of the early universe. Current theoretical models for PSN are mostly based on one-dimensional calculations [5]. Until now, multidimensional simulations have been scarce However, here we present 2D simulations that aim to study how fluid instabilities affect the nucleosynthesis and energetics of PSN.

NUMERICAL APPROACH

We start our simulations using one-dimensional models obtained from the `KEPLER` code [6], a implicit spherically symmetric Lagrangian hydrodynamics code. We follow the stellar evolution until 10 sec before maximum compression. Then we map the resulting 1D profiles into 2D using a conservative mapping procedure [7] to serve as the initial conditions for a new Eulerian AMR code, `CASTRO` [8]. We then follow the contraction, burning and onset of explosion for about one hundred seconds. During this period, thermonuclear burning releases almost all of the explosion energy.

RESULTS AND DISCUSSION

The results presented here are from a $150\,M_\odot$ star for which we simulate one hemisphere using cylindrical symmetry. Figure 1 shows the oxygen mass fraction in the inner

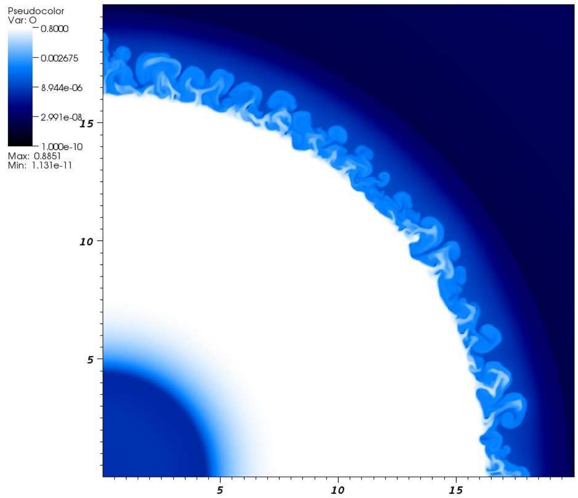

FIGURE 1. Oxygen mass fraction; *x* and *z* coordinate is in the unit of 1×10^9 cm

$\left(2\times10^{10}\,\mathrm{cm}\right)^2$ domain at about 60 secs after maximum compression. We find Rayleigh-Taylor (RT) instabilities develop at the outer edge of the oxygen-burning shell. The RT instabilities at 1.8×10^{10} cm are generated by helium shell burning. Later, we expect that these instabilities grow further after passing of the reverse shock. They could lead to large-scale mixing and affect the observable PSN light curve. Anisotropic ejection of material of different compositions may affect the chemical evolution of its surrounding.

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