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# Si, O, Ne, and C shell burning

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**Abstract.** We simulate the reactive-hydrodynamic flow for a variety of convective shell burning epochs in supernova progenitor models. The neutrino-cooled stages of carbon, neon, oxygen, and silicon burning are simulated in two and three dimensions. Even in the absence of rotation significant symmetry breaking occurs (10% in rms variation in thermodynamic variables such as temperature and density). These distortions are caused by turbulent convection interacting with stably stratified boundaries. Strong interactions of multiple active shells is seen; it is mediated by waves generated by convection. Some implications for supernova progenitors are presented.

**Keywords.** Convection, nucleosynthesis, neutrinos, turbulence, waves, methods: numerical, stars: evolution, stars: supernovae

## 1. Introduction

The reactive-hydrodynamic flow for neutrino-cooled convective shell burning epochs in supernova progenitor models (see Arnett (1996)) is simulated with multi-fluid, compressible hydrodynamics. Initial conditions are calculated with the one-dimensional stellar evolution code, TYCHO. Silicon, Oxygen and Carbon burning are examined, including models with single as well as multiple simultaneously burning shells. Two and three-dimensional models are calculated. Nuclear reaction networks with as many as 50 isotopes are used to track compositional evolution and energy generation.

## 2. Results

The convective velocity scale is found to be exaggerated in two-dimensional simulations compared to those of three-dimensions by approximately an order of magnitude. The velocity scale in three-dimensions is found to be compatible with mixing length theory over most of the convectively unstable region simulated, but differ significantly near convective boundaries. Convective boundaries and adjacent stable layers are rife with interfacial and internal waves excited by convective motions. A large degree of mixing is driven by convective penetration, as well as shear instabilities and wave-breaking events. Asymmetries at convective boundaries induced by the impact of plumes are of low-order ($\ell < 4$) and large amplitude (rms deviations in thermodynamic variables exceed 10%). The enhanced mixing rates present in our simulations, if robust to the computational limitations (i.e., resolution, domain size, etc), will impart a large cumulative effect on supernova progenitors and ultimately on supernova explosion models. Core sizes, shell sizes, and entropy structure will probably be modified; these parameters are crucial for determining isotopic yields and the structure of presupernovae as they begin to collapse.

Similarly, large global asymmetries induced by internal wave modes excited by plumes may also play a central role in both the supernova explosion mechanism as well as material mixing in the ejecta. The interaction of active shell by waves is a new phenomena; it may well become more violent as collapse is approached. The symmetry breaking found here occurs even in the absence of rotation; the interaction of such convection with rotation becomes a key problem for presupernova evolution, and may have an impact on studies of explosion mechanisms for core-collapse supernovae.

More detail may be found in Meakin & Arnett (2006a), Meakin & Arnett (2006b), Meakin & Arnett (2006c), and subsequent papers in this series.

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