The Interplay of SASI and Convection in Core-Collapse Supernovae

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Outline

• Overview of the SASI and Convection in CCSNe

• New results from 2D parametric CCSNe models on the transition to explosion
Stalled Shock

Region in between shock and neutrinosphere is subsonic

Unstable to:

1) Convection driven by neutrino heating

2) Global oscillation modes of the subsonic regions (SASI)
SASI = Standing/Spherical/Stationary Accretion Shock Instability


- Isolated in parametric setup by Blondin et al. (2003) without heating:

Blondin et al. (2003)
**SASI = Standing/Spherical/Stationary**

**Accretion Shock Instability**

Instability mechanism involves cycle of advected and acoustic perturbations

Foglizzo et al. (2007)

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Operates *in the absence of heating*, and saturates (with cooling)

Scheck et al. (2008)

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RF & C.Thompson (2009)
Convection with Advection

$\chi = \int_{\text{gain}} \frac{|\omega_{BV}| dr}{|v_r|}$

$\omega_{BV}^2 = g \left[ \frac{1}{\gamma} \frac{\partial \ln p}{\partial r} - \frac{\partial \ln \rho}{\partial r} \right]$,

$\chi_{\text{crit}} = 3$

(Foglizzo et al. 2006)
Recent Developments

1) First generation of 3D hydrodynamic models of CCSNe display lower amplitude shock oscillations than in 2D

   e.g., Iwakami et al. (2008), Nordhaus et al. (2010), Hanke et al. (2012), Dolence et al. (2013), Couch (2012)

2) Led to suggestion that SASI may not be a fundamental part of the explosion mechanism, and may even not arise in 3D

   Burrows et al. (2012), Burrows et al. (2013)

3) However, most models explore limited set of progenitors, and exclude effects that are favorable for SASI development

   Janka et al. (2012)

4) 2D GR-RHD models of 8.1 and 27 Msun progenitors by Müller et al. (2012) show the possibility of two different explosion paths from first principles

5) 3D models of 27 Msun progenitor see episodic strong SASI activity (Hanke et al. 2013) or very weak SASI amplitudes (Ott et al. 2012)
Open Issues / Questions

Q1: What are the fundamental differences between SASI- and Convection-dominated explosions?

Q2: Can initial perturbations change the explosion regime?

Q3: Are there good diagnostics to distinguish the instabilities in the non-linear regime?
Summary

- In 2D parametric models, interplay of SASI and convection is mediated by high-entropy bubbles.

- Regular sloshing of the shock requires efficient bubble destruction.

- Explosion involves the formation of a large-scale, long-lived high-entropy bubble (seeded by the SASI in SASI-dominated models).

- Initial perturbations do not (appear to) change the explosion regime, but can lead to significant differences in explosion times (in marginal models).

- Time-averaged flow in non-exploding models adjusts itself to be convectively sub-critical.

Will test in models of B. Müller et al. (2012)