Progenitor-explosion Connection and Remnant Birth Masses for Neutrino-driven Supernovae

Spherically Symmetric Models

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Fifty-One Erg - Raleigh (NC) - May 13th, 2013
Motivation

- What is the link between the properties of supernovae and their progenitors?
- Why different explosion energy and nickel?
- What is the birth mass function of neutron stars and black holes?
- What are the products of explosive nucleosynthesis?
- Artificially initiated explosions: piston (Woosley), thermal bomb (Nomoto), kinetic energy bomb (Chieffi)...
- Drawbacks: uncertainties, ad-hoc assumptions, lack of physics.
- New approach: neutrino-driven explosions.
Numerical Methods

- Progenitors: 101 solar metallicity stars (Woosley et al. 2002).
- Collapse: VERTEX (A. Marek, L. Hüdepohl).
- Gravity: Newtonian with GR corrections (Marek et al. 2006).
- Neutrino transport: gray scheme (Scheck et al. 2006; Arcones et al. 2007; Wongwathanarat et al. 2010).
- Nucleosynthesis: $\alpha$-network.
Neutrino Treatment

- Inner core (1.1 $M_\odot$) of the PNS replaced by a shrinking Lagrangian boundary.

- Neutrino fluxes imposed at the inner boundary according to a simple, analytic two zones cooling model.

- Neutrino parameters calibrated in order to reproduce SN1987A observables for a “suitable” progenitor (19.8 $M_\odot$ model).

- Calculations performed until shock breakout from star surface.
Results

Explosion Energy

- Vertical ticks mark non-exploding cases.
- Green bar marks calibration case.
- Large variations between 0.4 and 2 B.
- “Islands” of non-exploding models around 15 and 23 M☉.
Nickel Ejected

- Vertical ticks mark non-exploding cases.
- Green bar marks calibration case.
- Orange bars mark neutron-rich tracer.
- Large variations between 0.01 and 0.15 $M_\odot$. 
Baryonic Remnant Mass

- Gray bars mark black holes.
- Green bar marks calibration case.
- Blue bars mark fallback.
- Fallback is more massive in low-mass progenitors (reverse shock).
- Only one fallback-supernova.
Neutron Stars and Black Holes Birth Function

- Remnant mass distribution folded with Salpeter IMF.
- Two distinct peaks for NS and BH.
- Zoom on NS: peak around 1.6 $M_\odot$.
- Few low-mass black holes.
Conclusions and Outlook

- Systematic study of a range of progenitors exploded with neutrino heating.
- Significant variations in explosion energy and Nickel mass ejected.
- No clear threshold between NS and BH formation.
- Fallback supernovae rare for solar-metallicity stars.
- Strong dependance on the progenitor structure. Multi-parameter problem.
- No hypernovae.
- Next (i): detailed nucleosynthesis calculations.
- Next (ii): more progenitors, multi-D, more physics...

Thanks for your attention!