Explosions from Double Neutron Star Mergers

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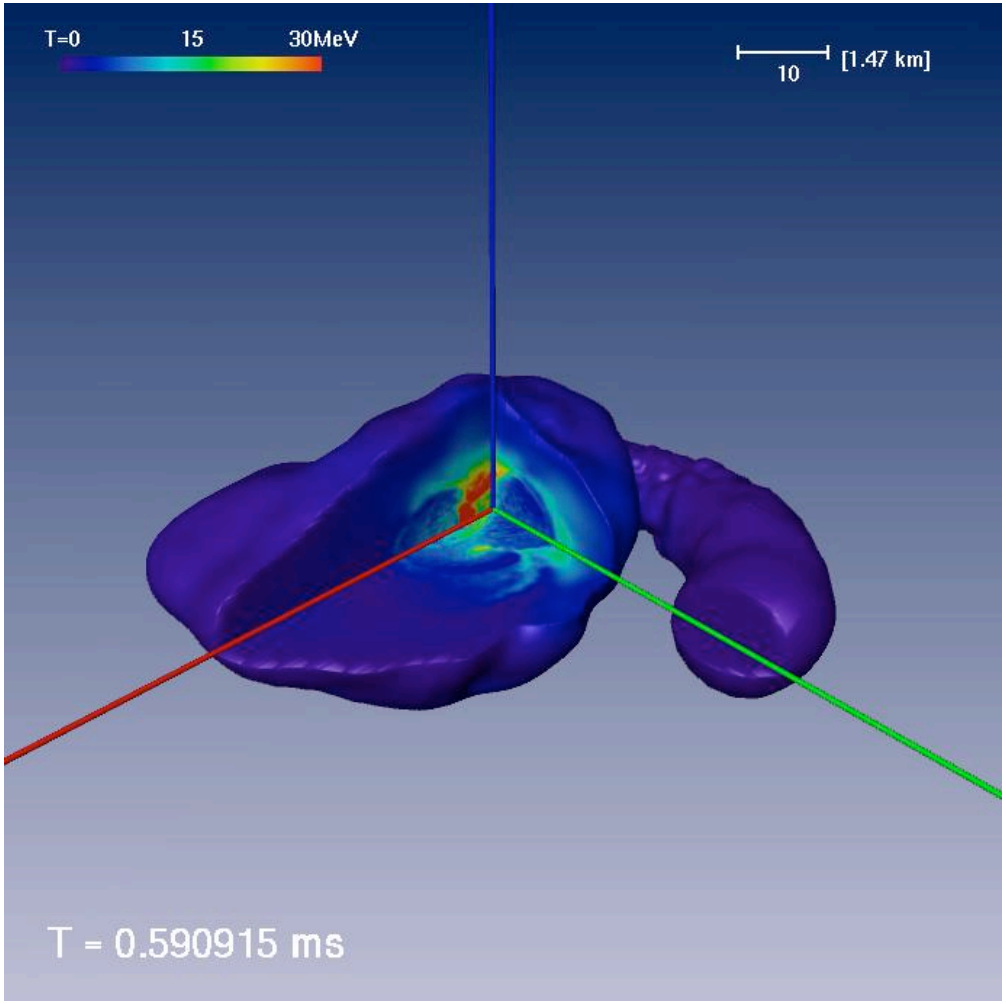
- Population Synthesis Studies: Rates, Delays, Locations and Problems
- Merger: Comparison between DNS and stellar collapse
- Nucleosynthesis



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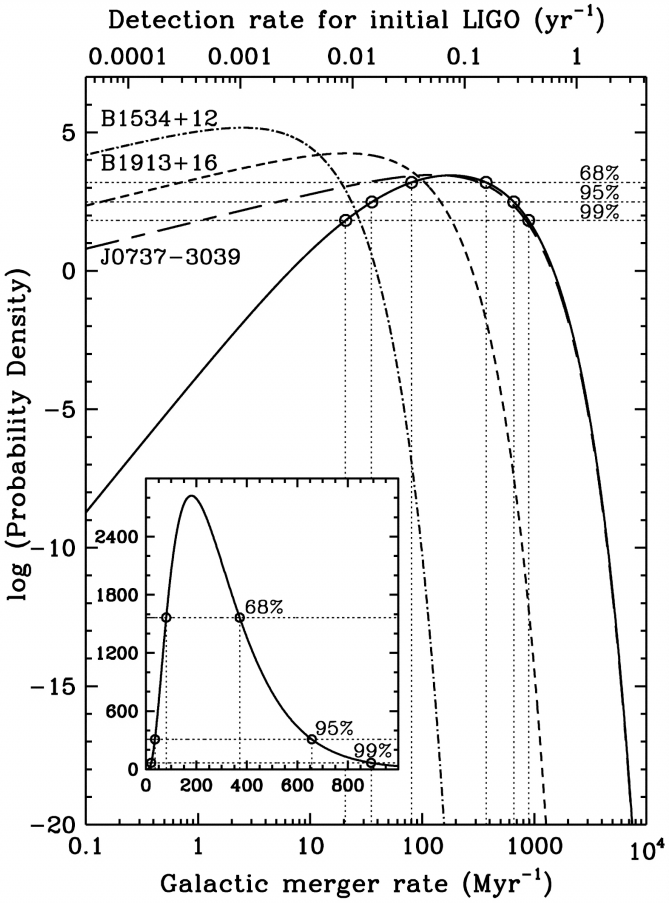
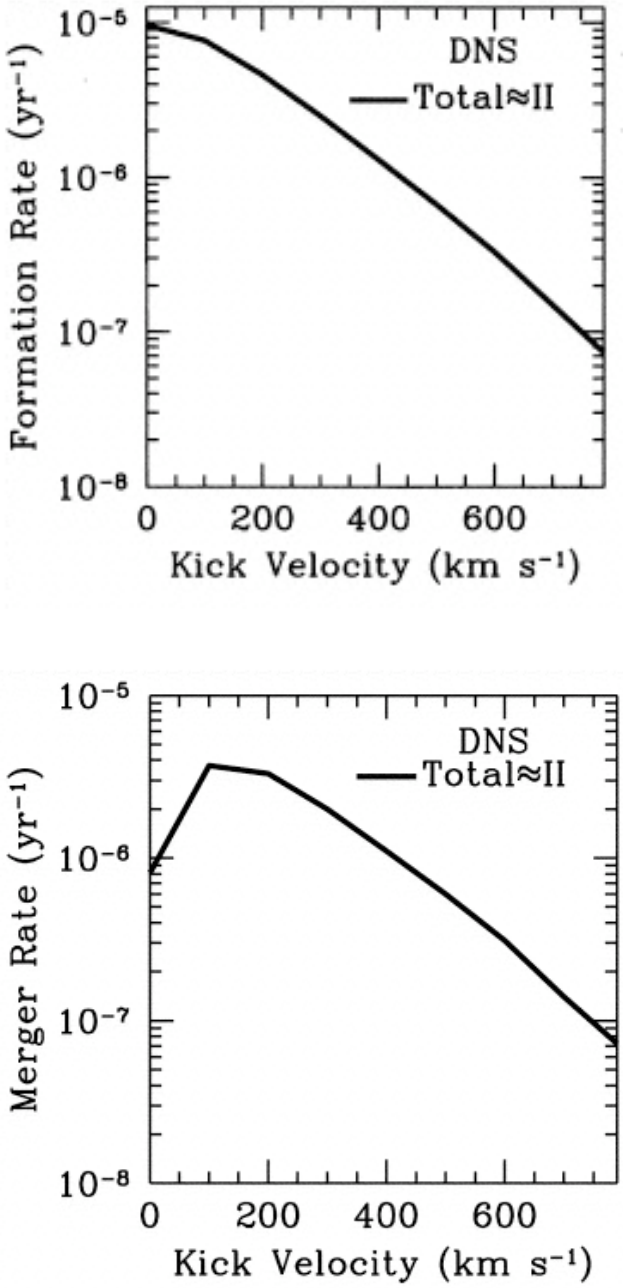
Progenitors: Merger Rates



Kalogera et al. 2004

- Theoretical estimates of merger rates are plagued by uncertainties: we are slowly making progress on these uncertainties.
- Observational predictions are plagued by small number statistics.



Fryer, Woosley & Hartmann 1999

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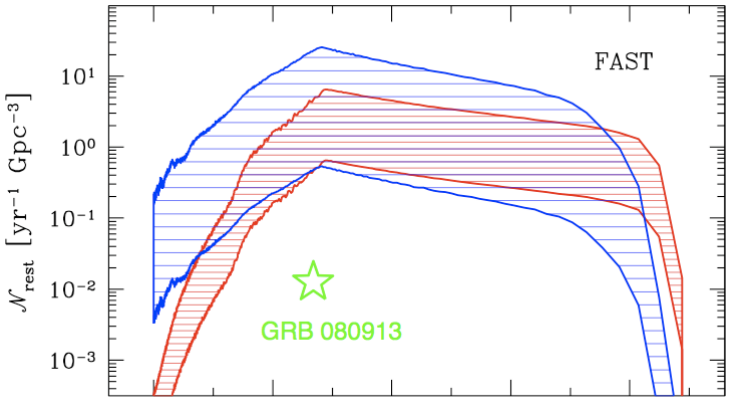
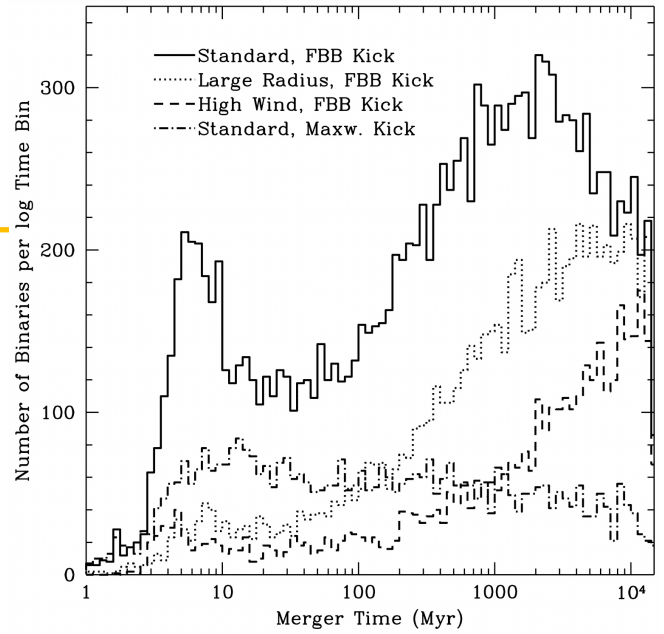
New Formation Scenario Changes Distribution of Merger Times

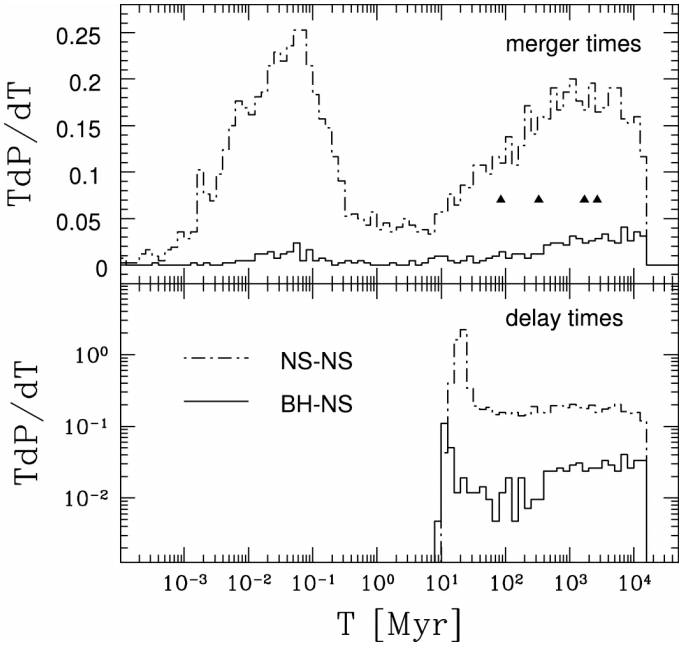
- Lots of population studies: Belcyznski, Kalogera and collaborators; Lee, Park, Brown and collaborators; Tutukov, Yungelson and collaborators; Bloom et al., Tout et al., Portegies Zwart, van den Heuvel…
- Belczynski & Kalogera (2001) argue for He-giant formation scenario. By 2004, they argue that this scenario contributes half of their DNS rate.



Belczynski et al. 2009



Fryer et al. 1999



Belczynski et al. 2004

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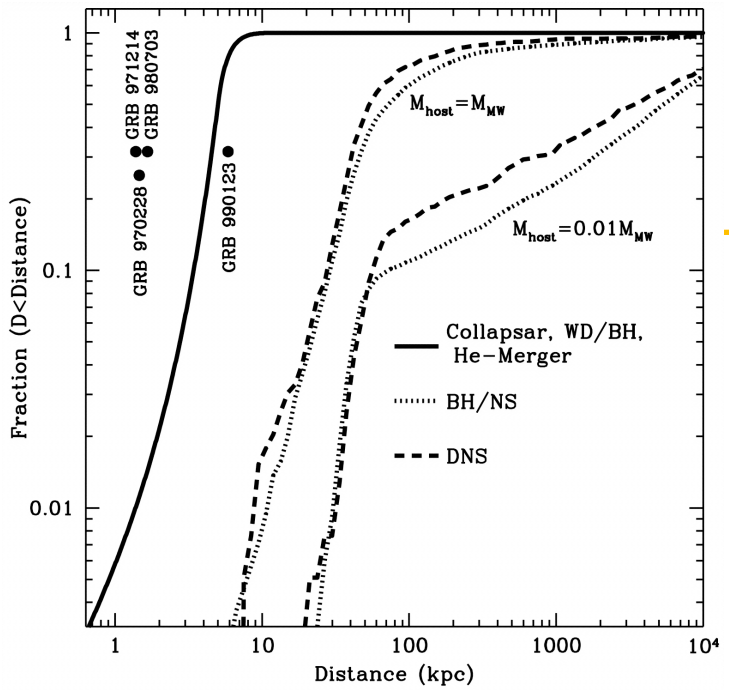
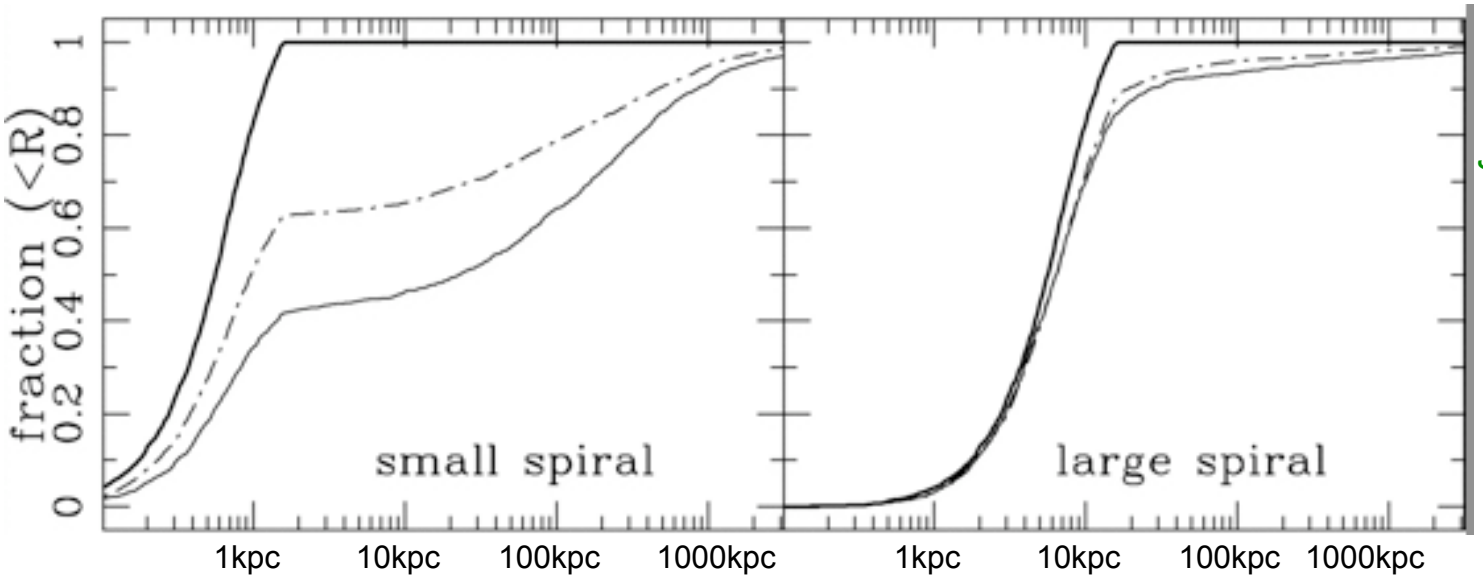
Distribution of Short GRBs: Assuming DNS mergers make GRBs



FWH99

- many short GRBs in close proximity to small galaxies argue for the He-giant scenario (or for alternate short GRB scenario).
- many short GRBs outside of large galaxies argues against the He-merger scenario.

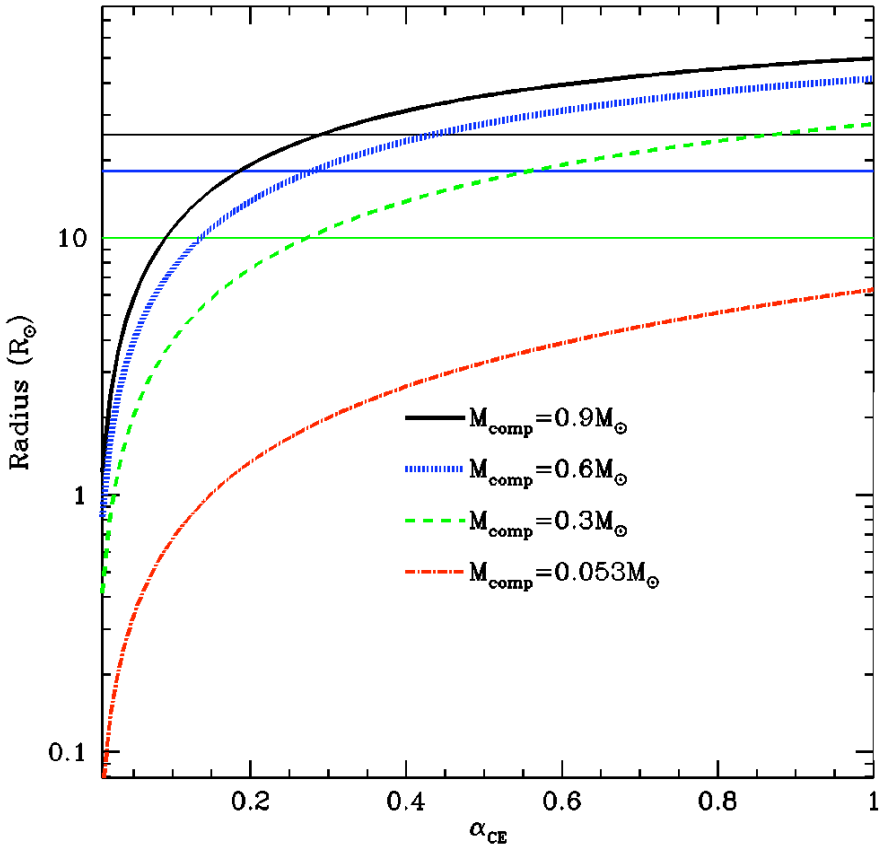


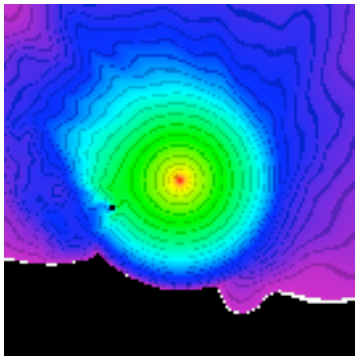
Belczynski et al. 2004

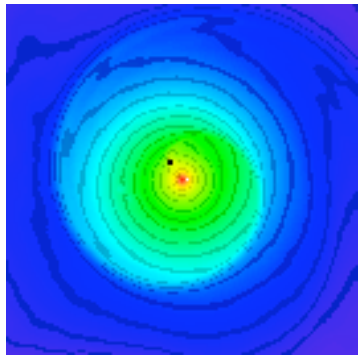
Progenitors: Outstanding Problems

- Stellar Radii
- Stellar Structure
- Winds
- Binary Mass Transfer
- Common Envelope Evolution
- Neutron Star Kicks
- NS and BH distribution functions (see stellar structure)

Diehl et al. 2009







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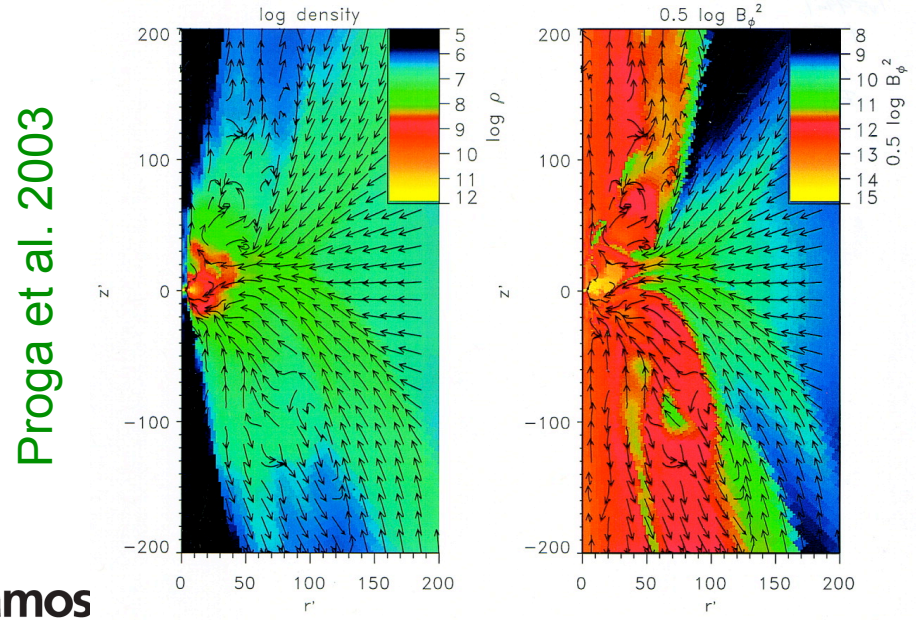
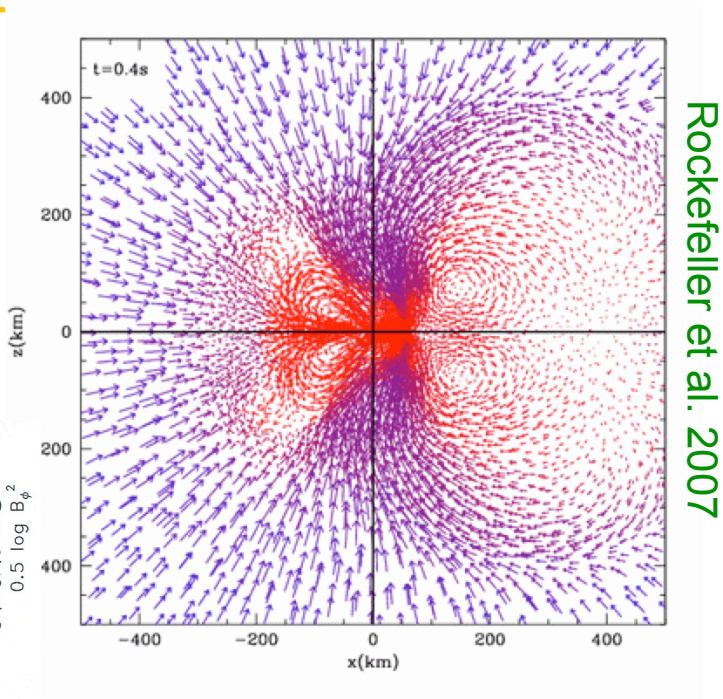
DNS as GRB engines: First, let's review the collapsar engine

- In 2-dimensions, the angular momentum piles up material in a disk, producing a narrow funnel along the rotation axis.
- Need source of angular momentum
- Must invoke magnetic fields



Proga et al. 2003



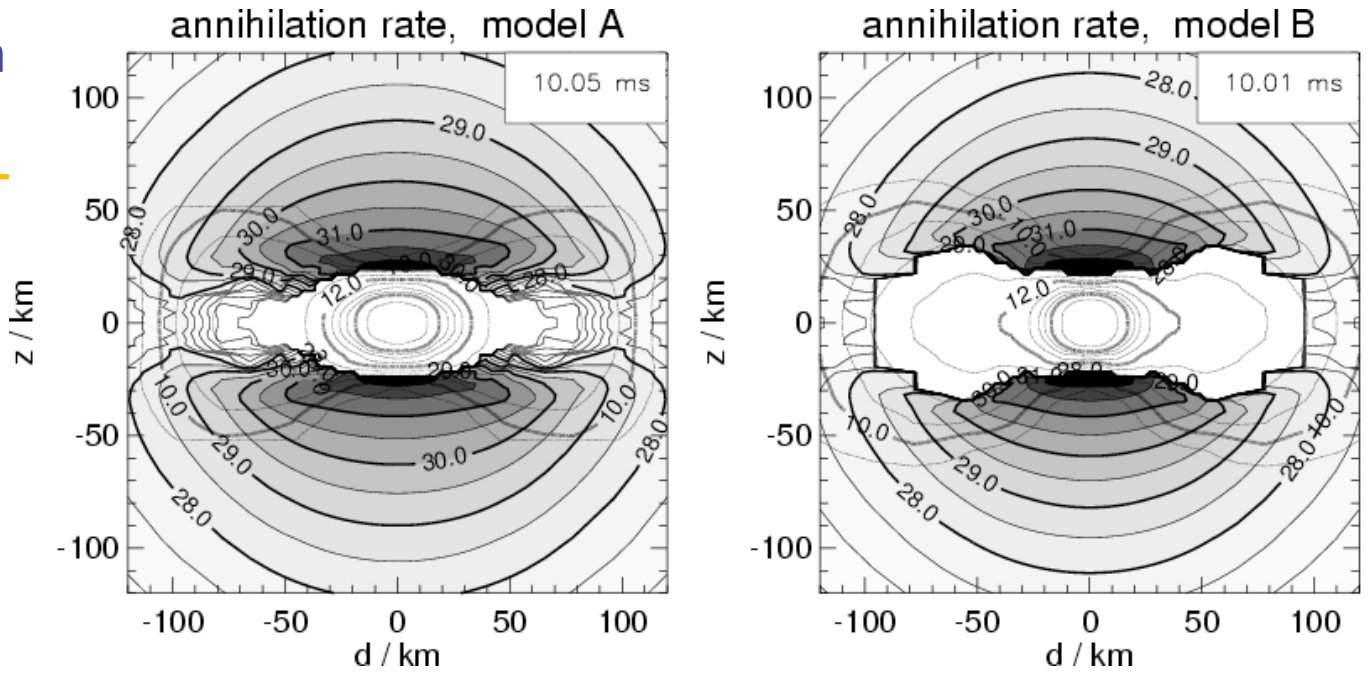
Rockefeller et al. 2007

The collapsar gets messier in 3-dimensions, with low-entropy flows near the axis.

DNS mergers as GRBs: Comparison to Collapsar

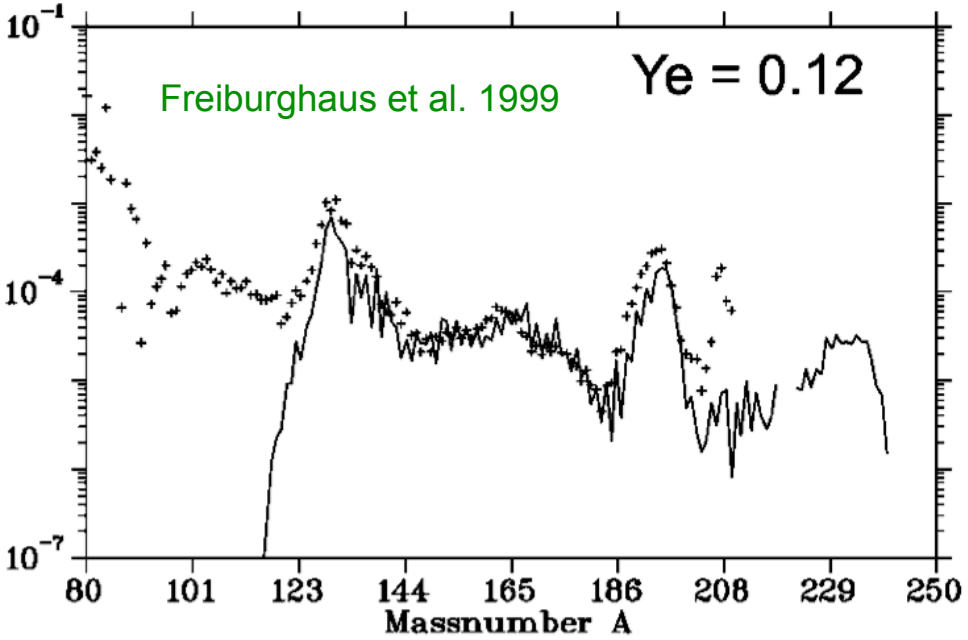
- Long history of 3-dimensional simulations (Rasio et al. 1992, Davies et al. 1992)

Ruffert et al. 2001

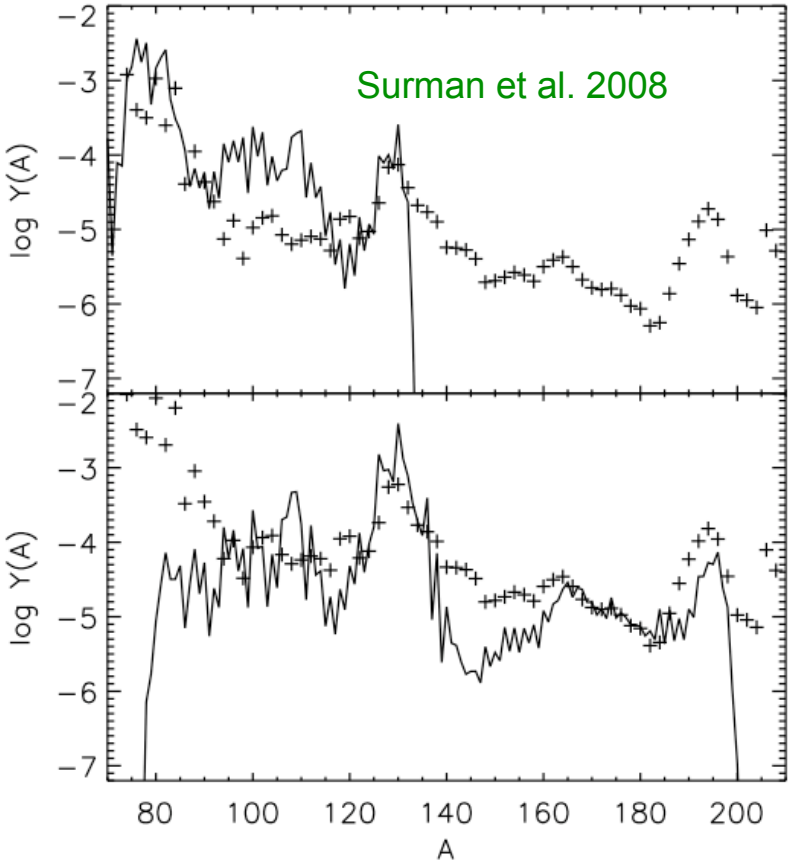


- Merger provides angular momentum
- Accretion rates higher, shorter, and more disruptive. The energy requirements for short bursts are less extreme. Hence, mergers can produce GRBs through neutrino annihilation.
- Merger outbursts should be less beamed than Can magnetic fields produce a narrow jet?
- Fallback can produce late-time accretion (Rosswog 2007 – although see Metzger et al. 2009)

DNS mergers may also produce r-process



The ejecta from DNS merger is neutron rich and may form r-process elements (both peaks).



Accretion disk winds may also form r-process (this model from BH/NS merger).

Lots of nice work here, see also Arnould et al. 2007; Metzger et al. 2008

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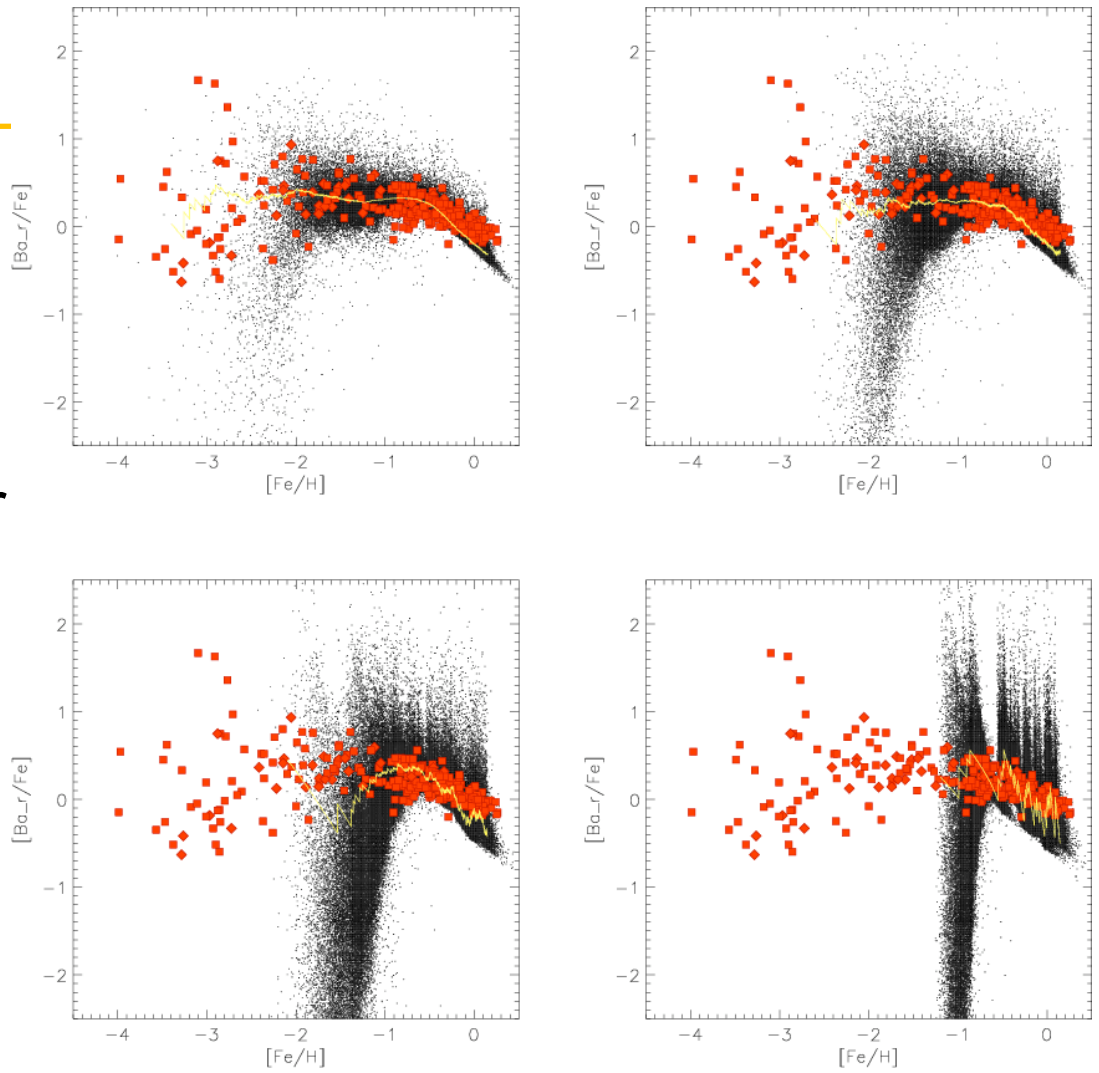
DNS and r-Process Nucleosynthesis

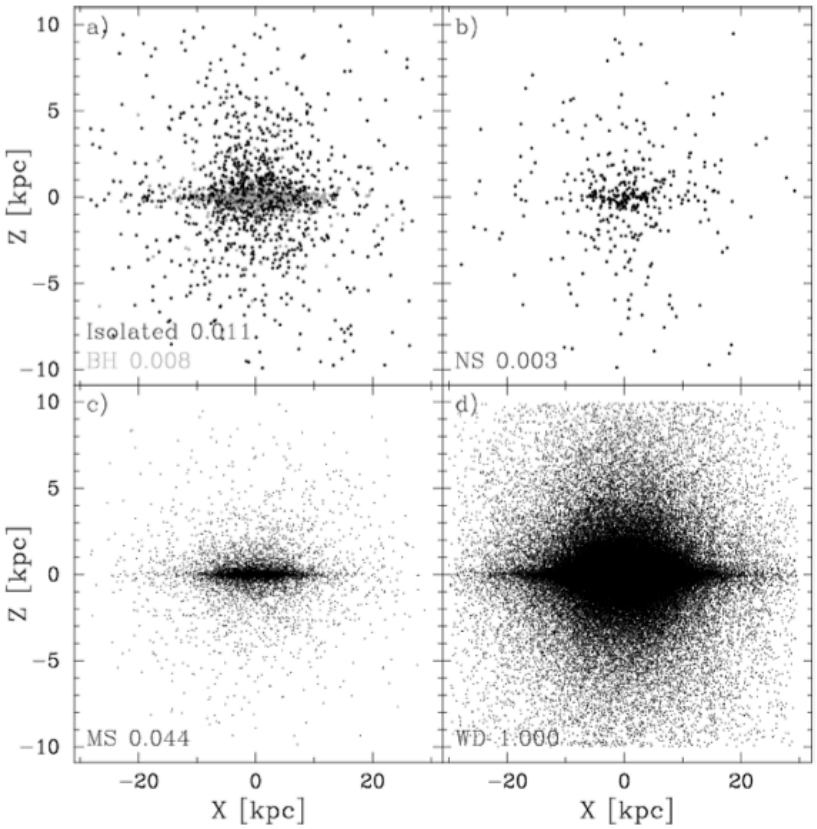
Although DNS mergers may produce r-process elements, they have a distribution problem:

- r-process yields appear along with iron and other explosive yields.
- If deposited at the star formation site, the DNS rate would need to be nearly as fast as the supernova rate.

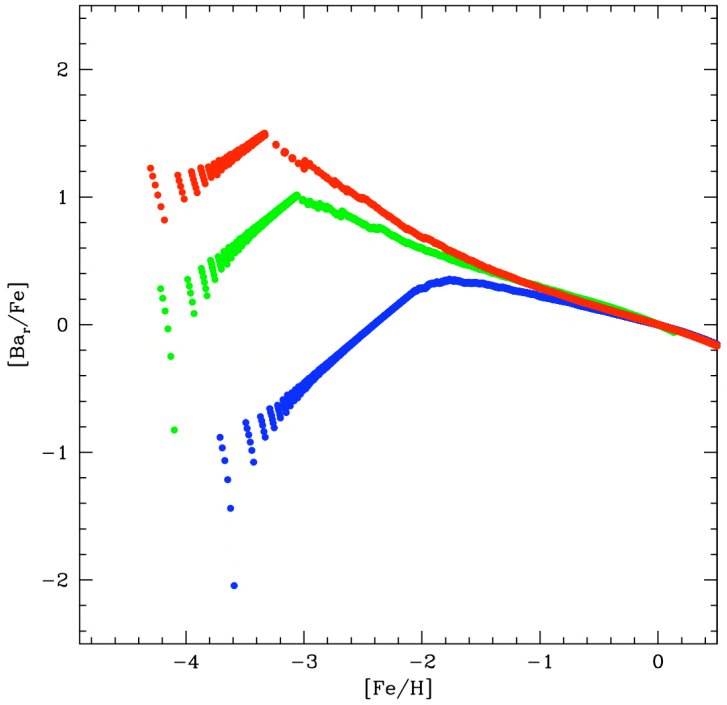


Argast et al. 2004

r-Process from NS Mergers – may not be completely ruled out



Kiel & Hurley 2009



Snyder et al. in preparation

- Many DNS mergers occur in the halo. Hence, the yields can be mixed more simply.
- A 1-zone model including these yields through infall can be made to match the observations.

Summary

- Population studies plagued by uncertainties in stellar evolution and binary effects. The rates are uncertain to at least 1 order of magnitude. Although these mergers should be more distributed than stellar collapse, the fraction of mergers far from the disk depends upon population synthesis calculations.
- Advanced LIGO should place strong constraints both on the rates and on the neutron star equation of state.
- DNS mergers may still produce r-process yields.