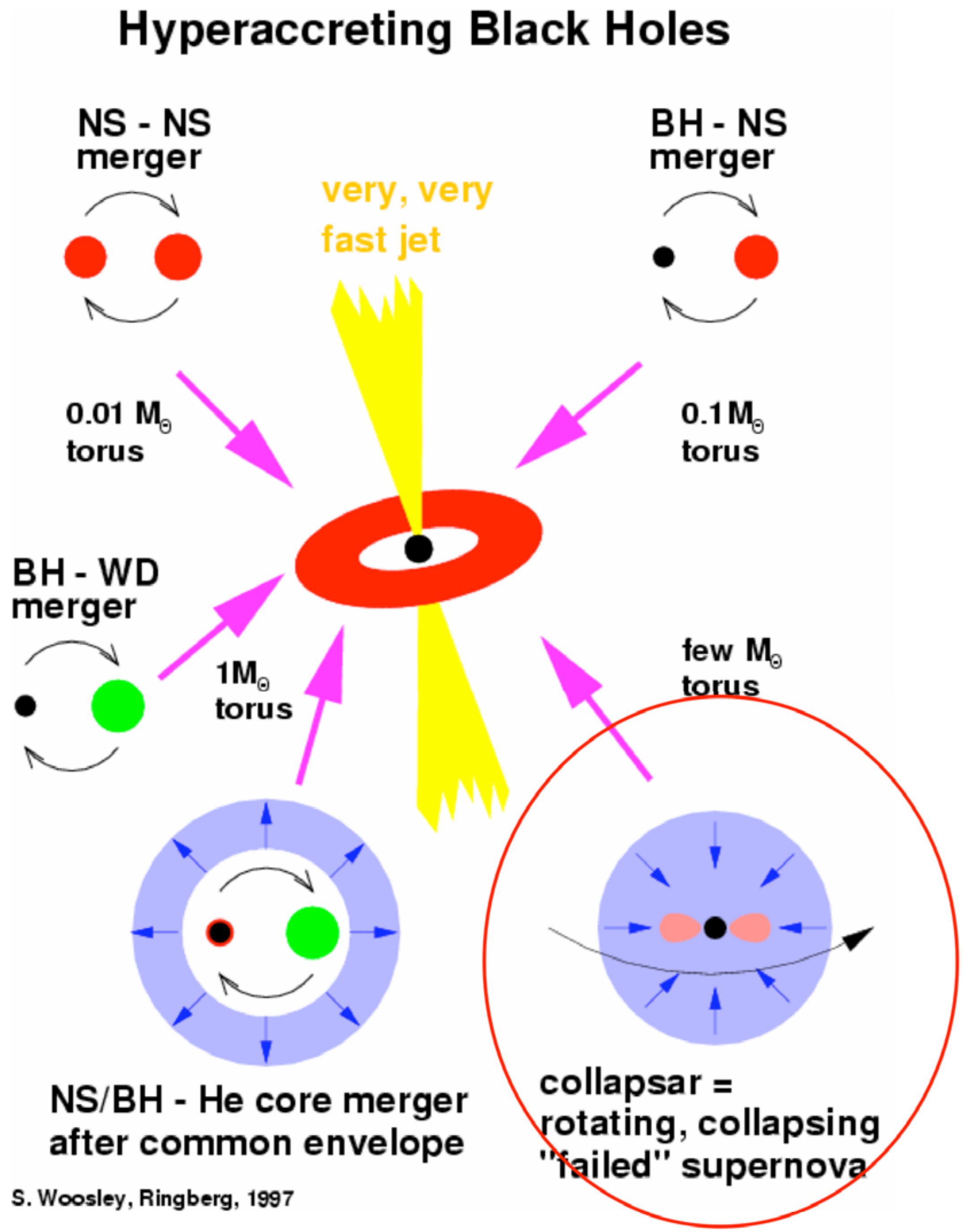
GRBs with Dim Supernovae

Aimee Hungerford and Chris Fryer w/ Patrick Young and Frank Timmes(LANL)

- A little bit on Collapsars
- Nucleosynthesis in Collapsars
- Calculating Light Curves

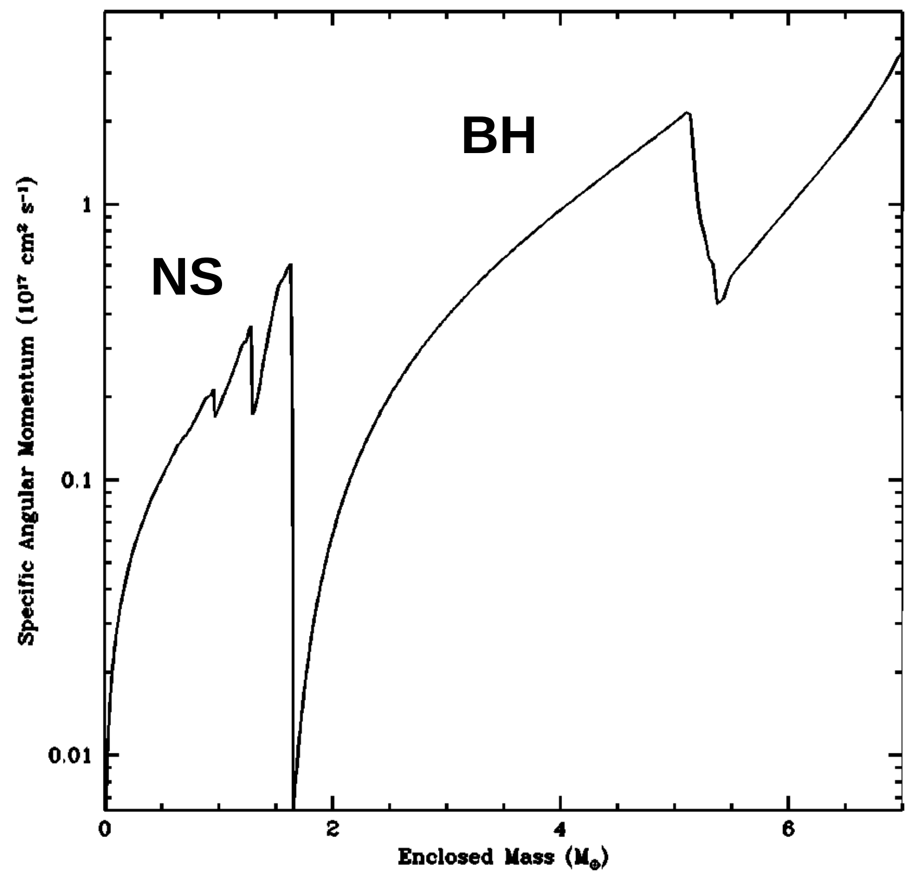
Gamma-Ray Burst Engines

The Black Hole Accretion Disk systems are the leading models for GRBs with collapsars (the collapse of a massive star) the favored model for long-duration bursts and neutron star mergers the favored model for short duration bursts.

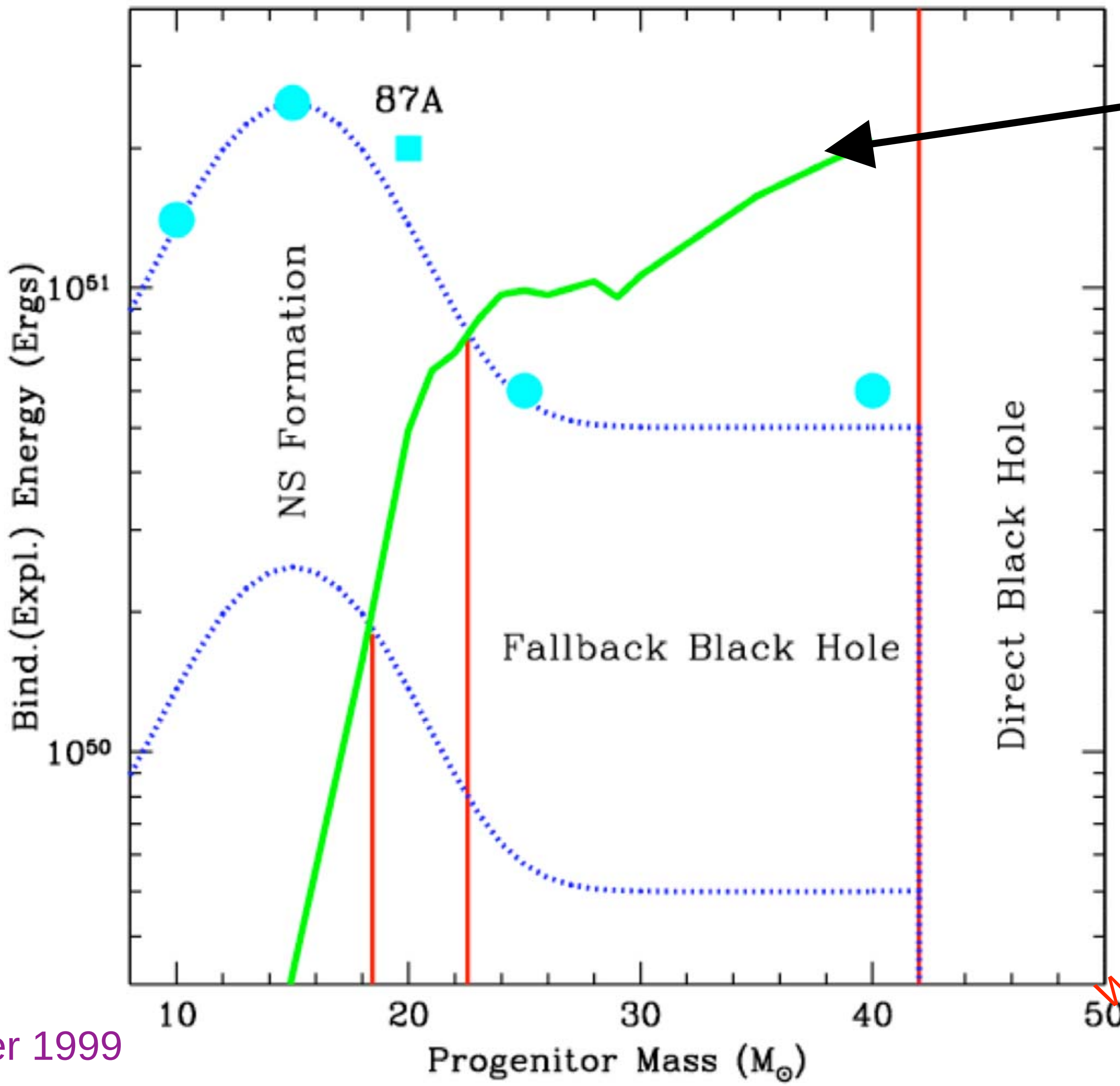


Why does BH formation open up a new type of explosion?

- Angular Momentum can move from a supporting role (possibly producing asymmetries) to the lead role (energy source) in the explosion. But this does not preclude NS accretion disks as an explosion mechanism - we just don't understand rotation enough to say one way or the other.



Two Types of Collapsar: Direct Collapse (I) and Fallback (II)

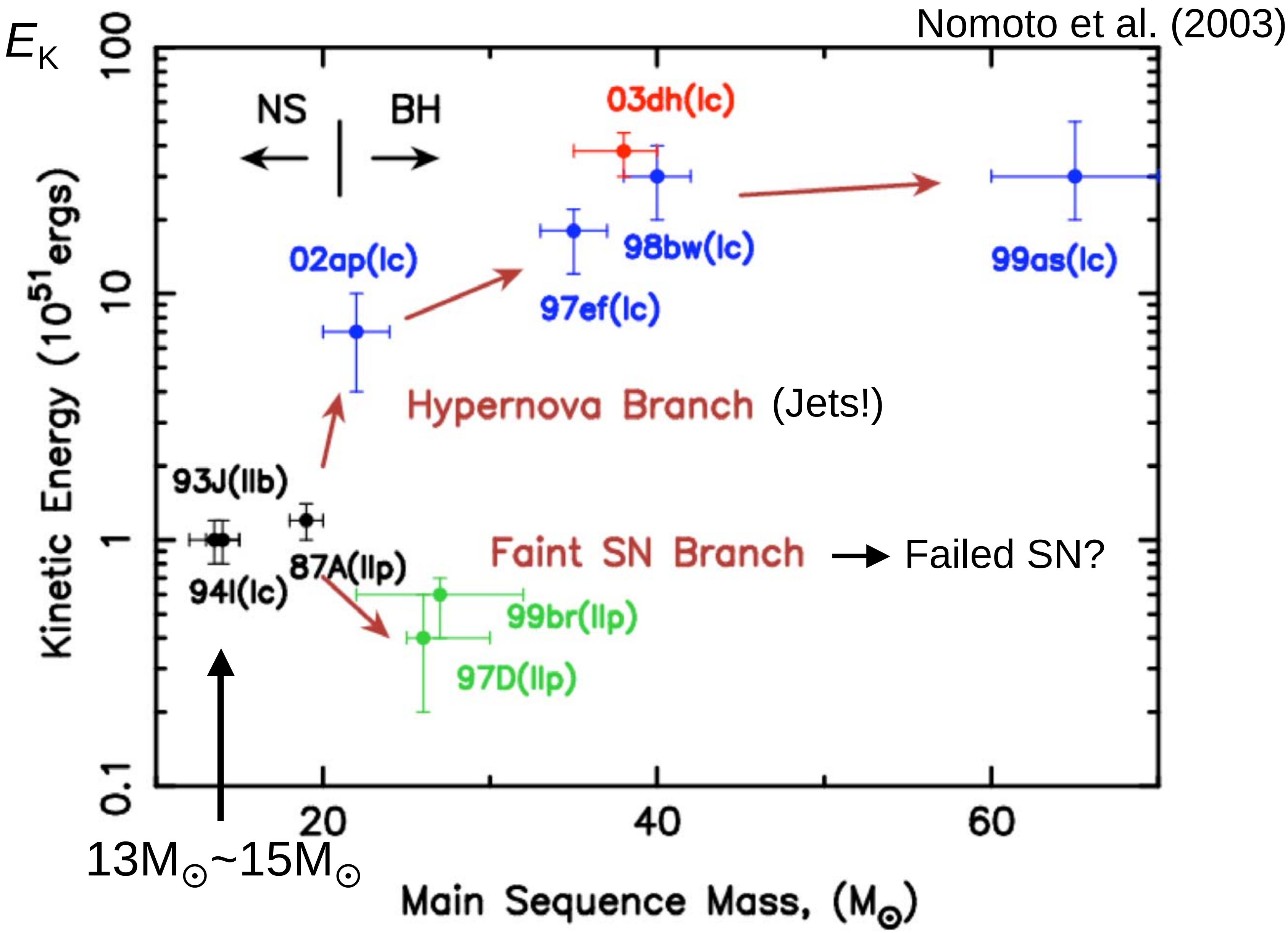


Binding Energy Of the Outer Layers Of the Star (M_{star} -3 solar Masses)

Warning! Assumes no mass loss

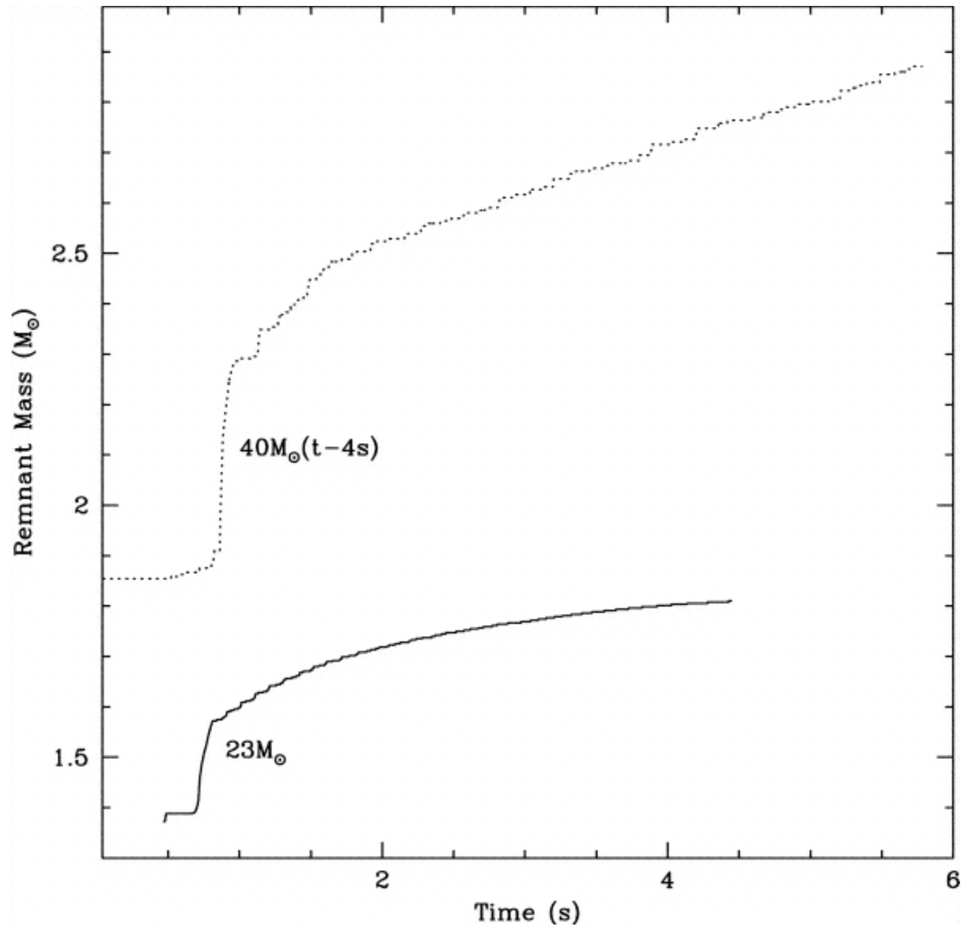
Fryer 1999

Prediction - SN vs. Hypernovae



Can we differentiate the two different GRB scenarios?

- Fallback BHs are likely to be more common, but
- Accretion rates on Fallback Black Holes are lower and such BHs may not produce strong GRBs
- Fallback BHs are formed after a weak supernova is launched - as we shall see, this can mean a different nucleosynthetic yield!



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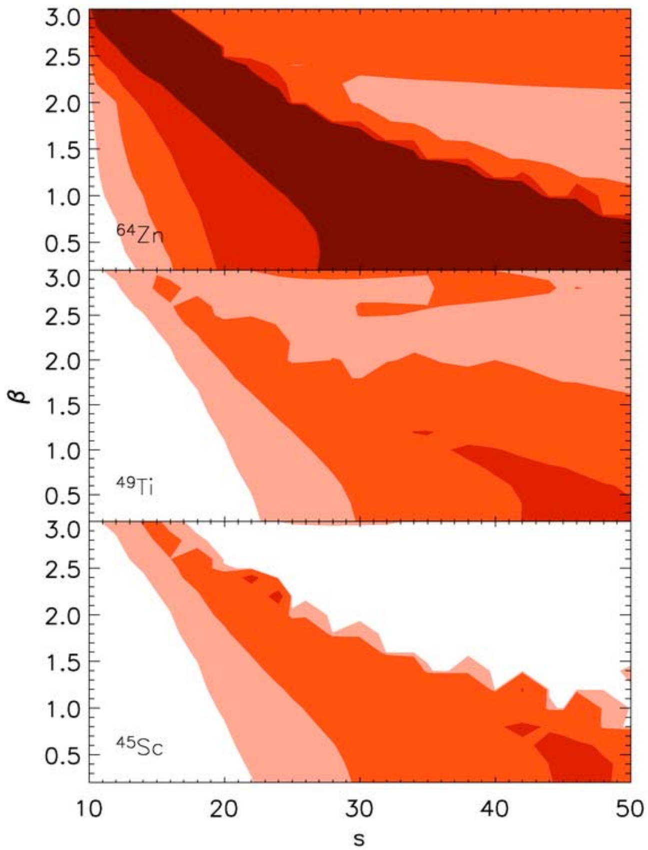
GRBs produce heavy elements in 2 ways.

I. In the accretion disk itself, ejected in a wind (e.g. Surman and collaborators; Pruet and collaborators)

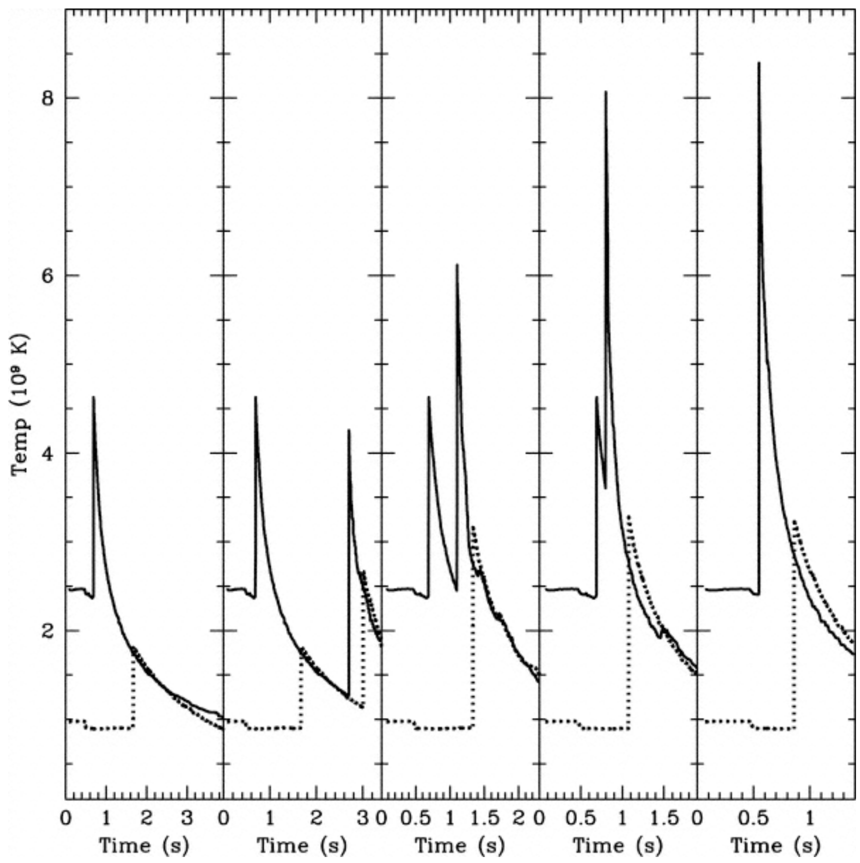
II. “Explosive Nucleosynthesis” in the strong shock (Nomoto and collaborators)



Surman, Mclaughlin & Hix 2006

Nucleosynthesis with a Fallback BH

- The weak supernova pushes material outward. If the delay is long, the temperatures and densities from the shock will be lower than predicted by a single strong explosion.
- The longer the delay, the more fallback and less material ejected.



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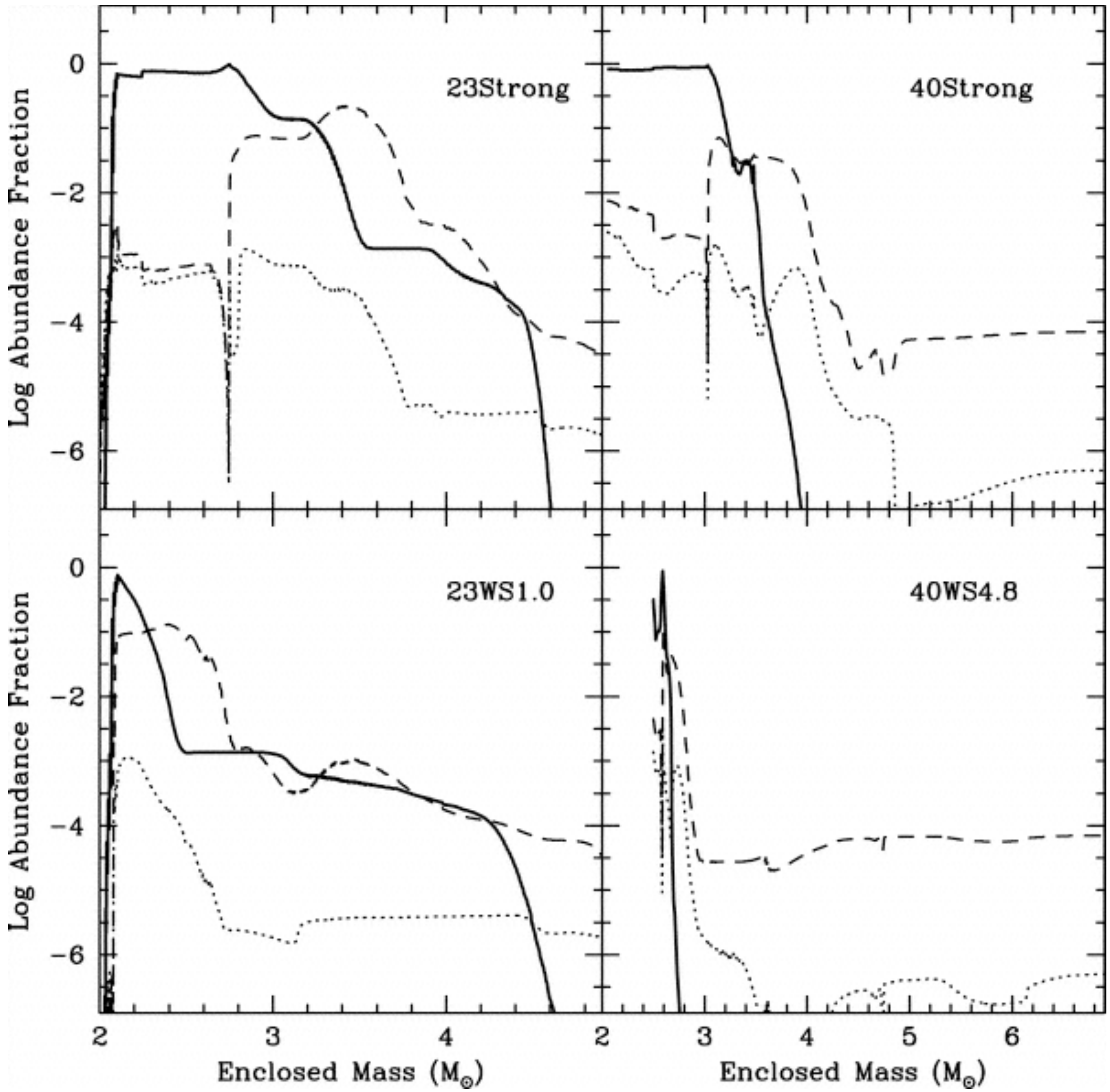
Explosive Nucleosynthesis Yields from Fallback GRBs (long delays produce little ^{56}Ni):

^{56}Fe - solid line

Titanium - dotted line

Calcium - dashed line



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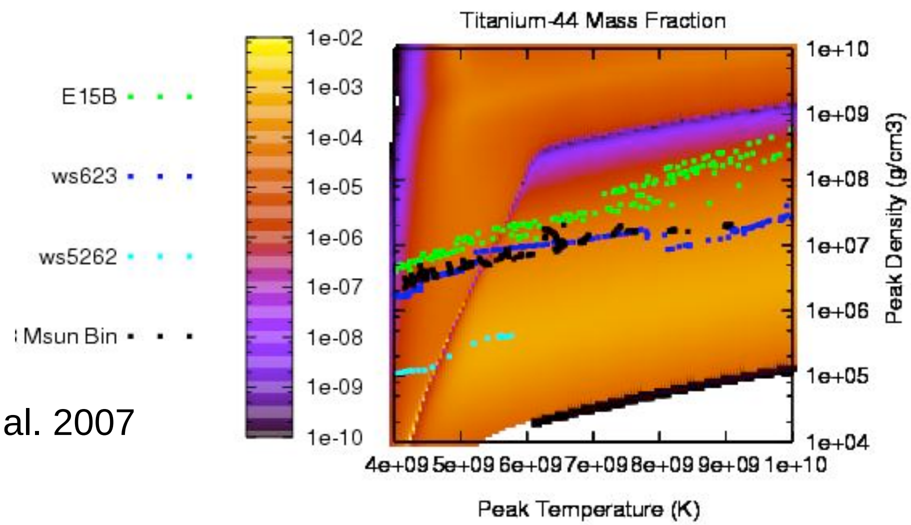
Understanding Yields

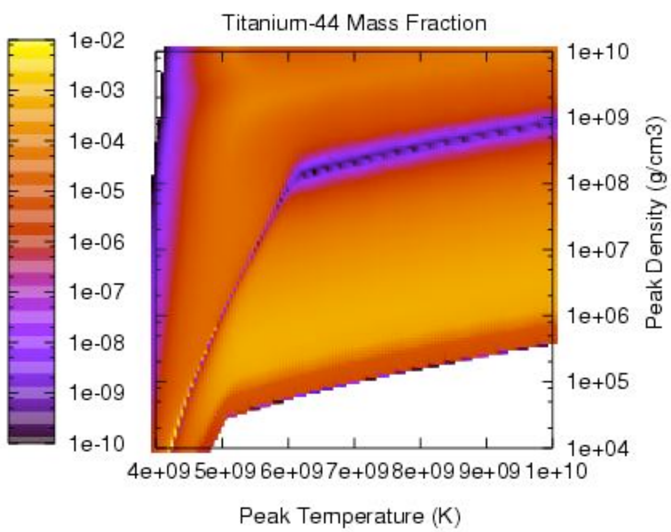
We can not simply state that higher entropy means we will produce more of something and less of something else. Instead, we are trying the Brad Meyer approach of understanding the results over a grid.

Ye=0.5

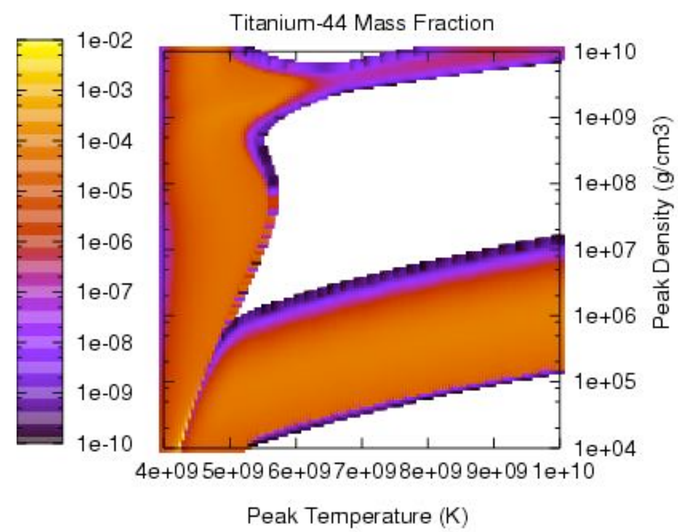


AH, Timmes et al. 2007

Ye=0.498

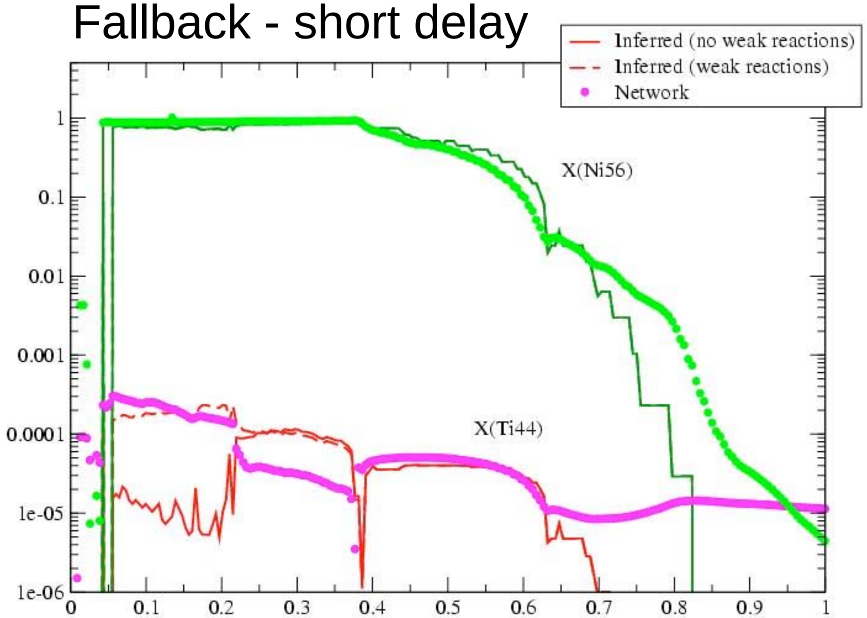


Ye=0.502

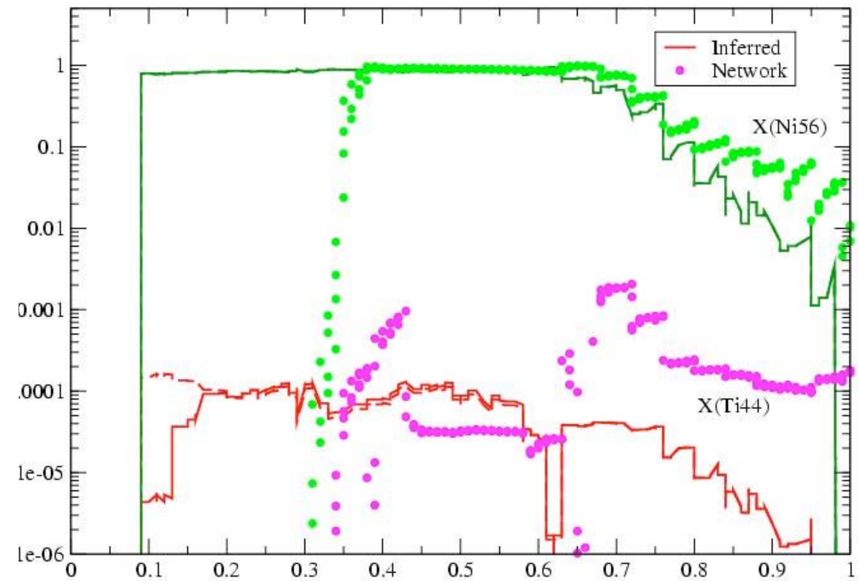


Understanding Yields - sometimes it works, sometimes it doesn't

Fallback - short delay



Normal Supernova



Enclosed Mass

AH, Timmes et al. 2007

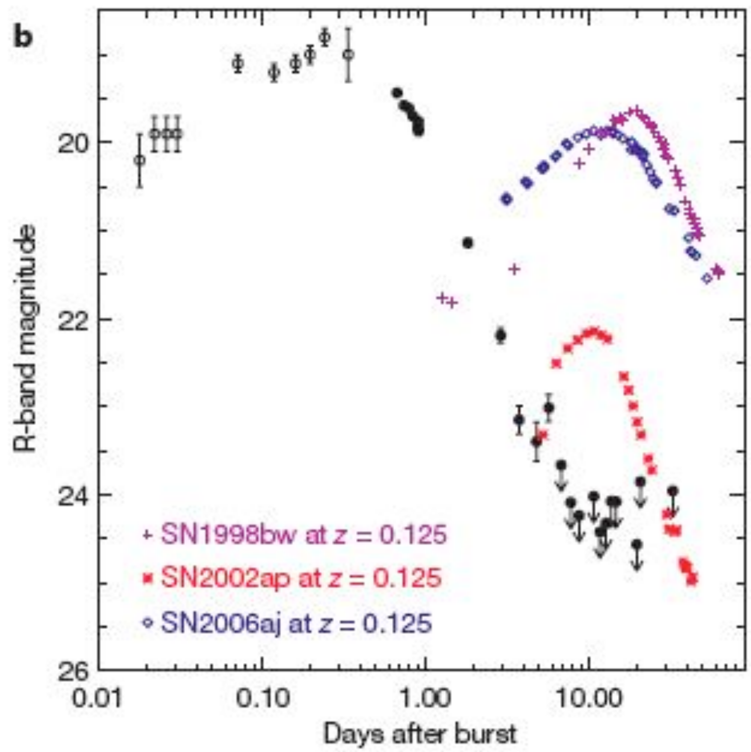
Enclosed Mass

T_{peak},ρ_{peak} studies alone can roughly estimate the yields, but not exactly.

Low Nickel Yields Imply Low Supernova Luminosities

Long-Duration (?) GRBs have been observed with no associated supernovae.

- Are these fallback black holes?
- Can the dim supernovae place limits on the nickel yields?

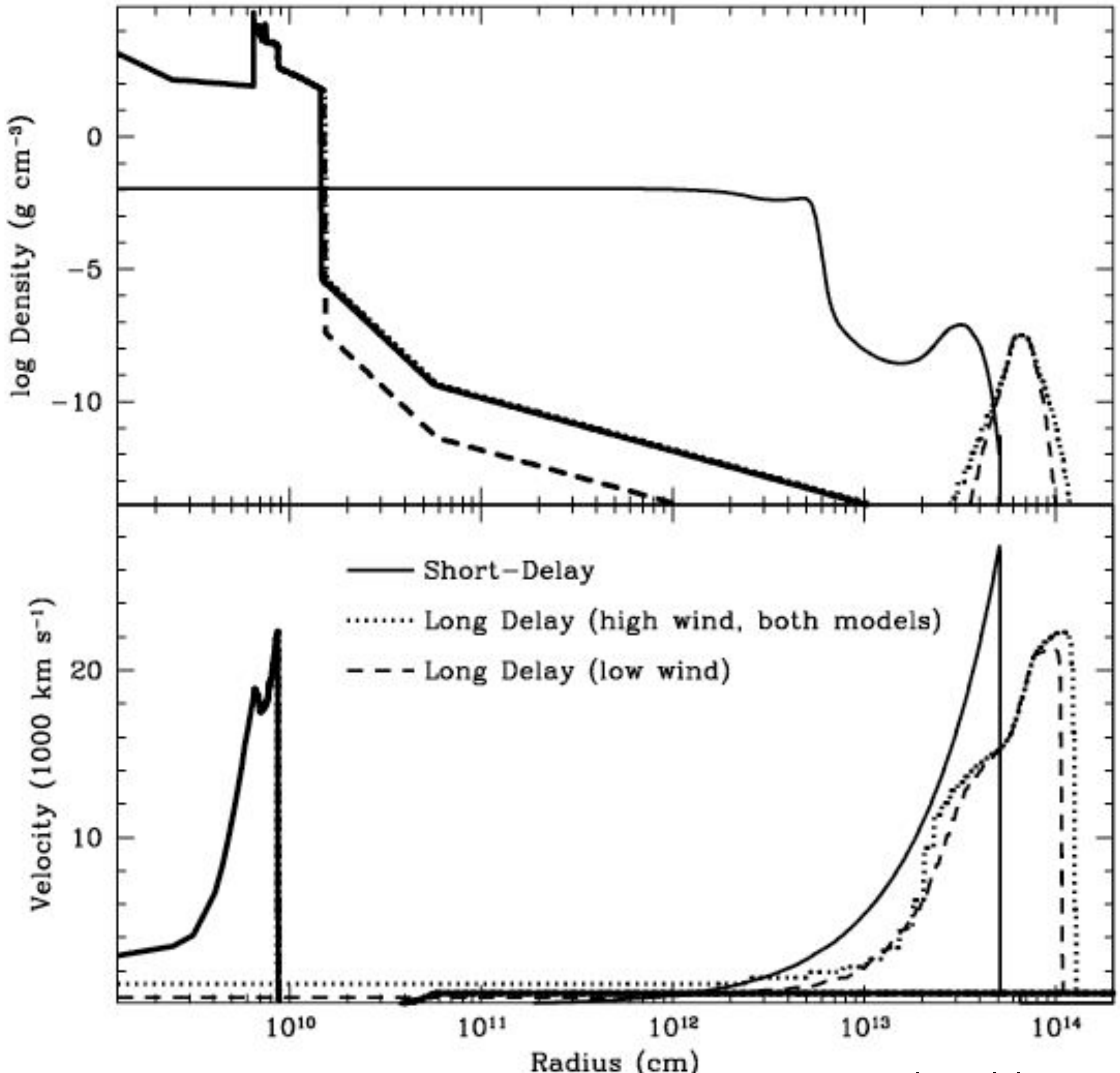


Fynbo et al. 2006

We can calculate these light-curves using RAGE

- RAGE - Radiation Adaptive Grid Eulerian
- Adaptive Mesh Refinement Scheme (more primitive hydro solver than FLASH)
- Multi-group flux-limited diffusion scheme (we show gray simulations here)
- Connected with LANL opacities and equations of state
- 1,2, and 3 dimensions (we show 1D spherical results here)

We ran a series of models, focusing on our long-delay 23 solar mass progenitor with its 2e-5 solar mass per year mass-loss rate.



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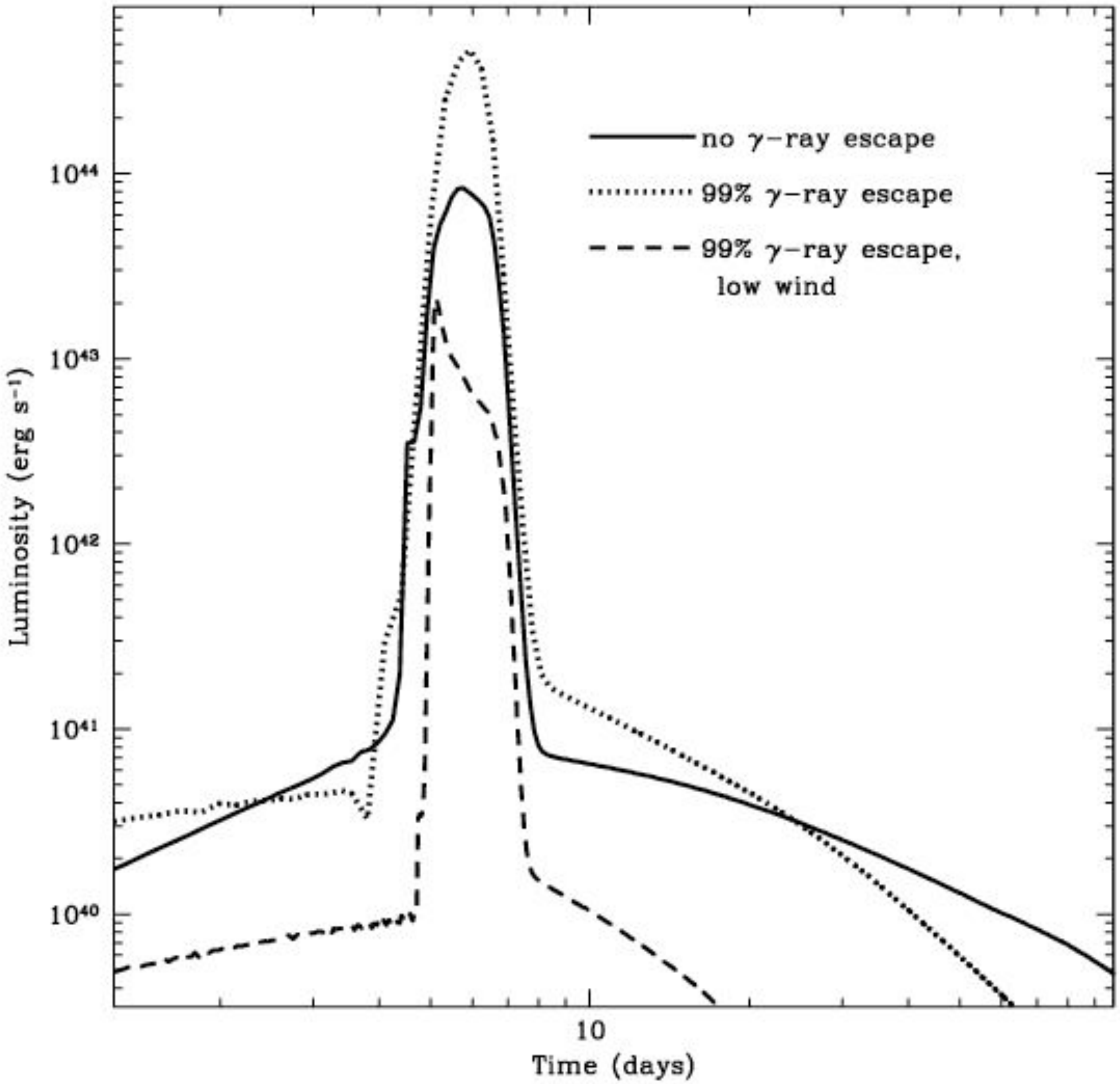
With our fast (10^{52} erg) explosions and low nickel yields, the light curve peaks early and drops suddenly (dominated by thermal energy and not ^{56}Ni decay). The strength of the wind plays the dominant role in producing the emission. Light curve estimates measure winds, not ^{56}Ni.



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Conclusions

- Nucleosynthesis for Fallback BH GRBs will be different (less heavy element production), but the exact yields sensitive to a lot of effects.
- Fallback BH GRBs can produce dim supernovae
- Measuring Supernovae may be a better indicator of the mass-loss and not the nickel yield.