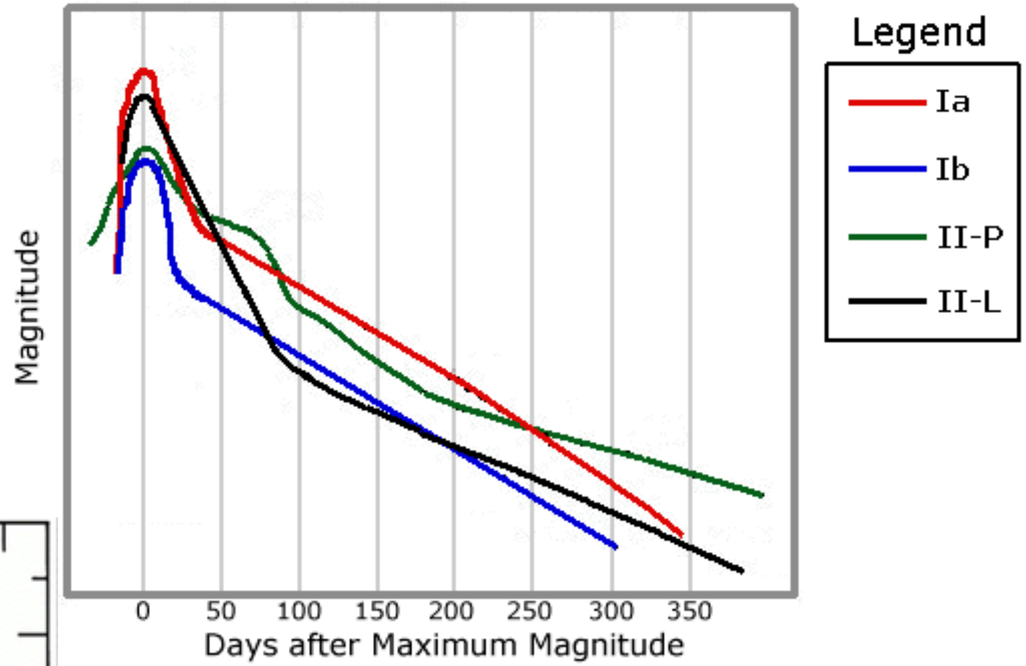
Progenitors of Gamma-Ray Bursts and Supernovae

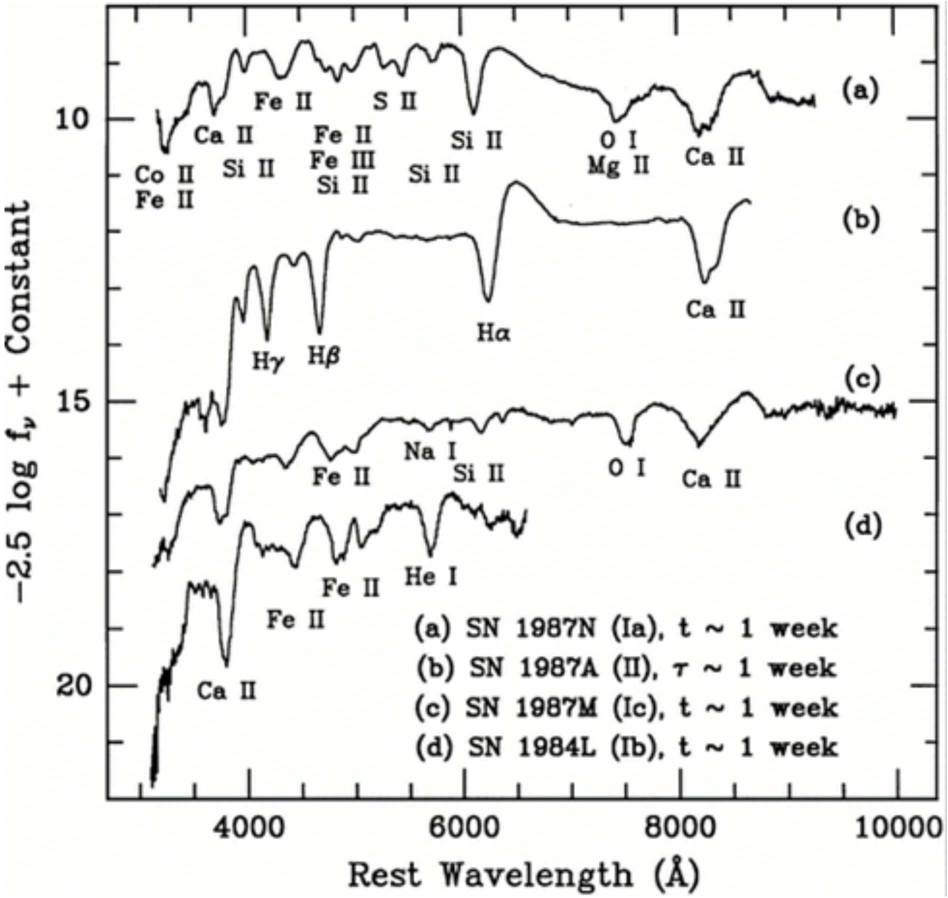
Chris Fryer (LANL)

- Types of supernova and GRBs
- Engines and their progenitor requirements
- Massive star progenitors and the circumstellar medium (single vs. binary)
- Specific examples – What have we learned?

Supernova Types

- Supernovae are distinguished by spectra and light curves.

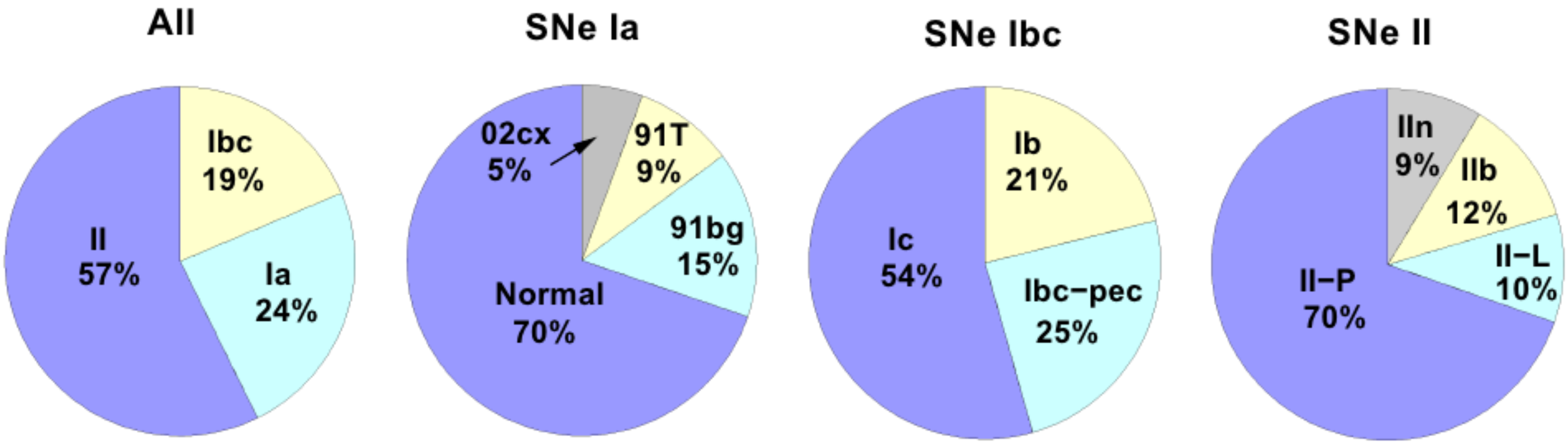




- Unfortunately, in core-collapse, the dividing lines are more like guidelines.
- There are many "stand-outs" among these supernovae (e.g. SN87A).

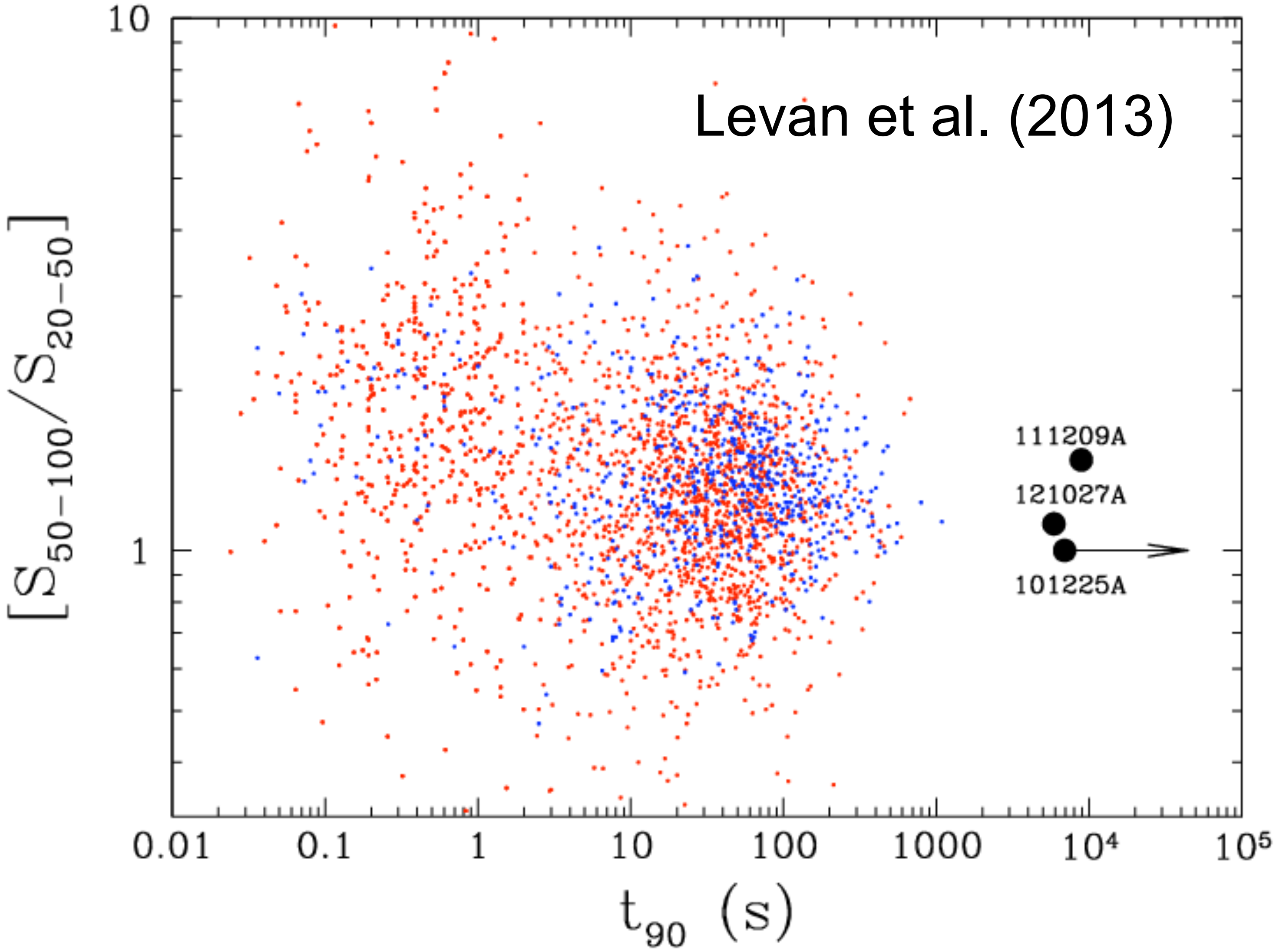
SN types - Rates

- Core-collapse (Ib/c, II) SNe make up 75% of all supernovae.
- Most Ib/c are Ic supernovae.
- Plateau SNe make up most of the type II class.
- New classes include Broad Line (tied to GRBs?) and Superluminous Supernova



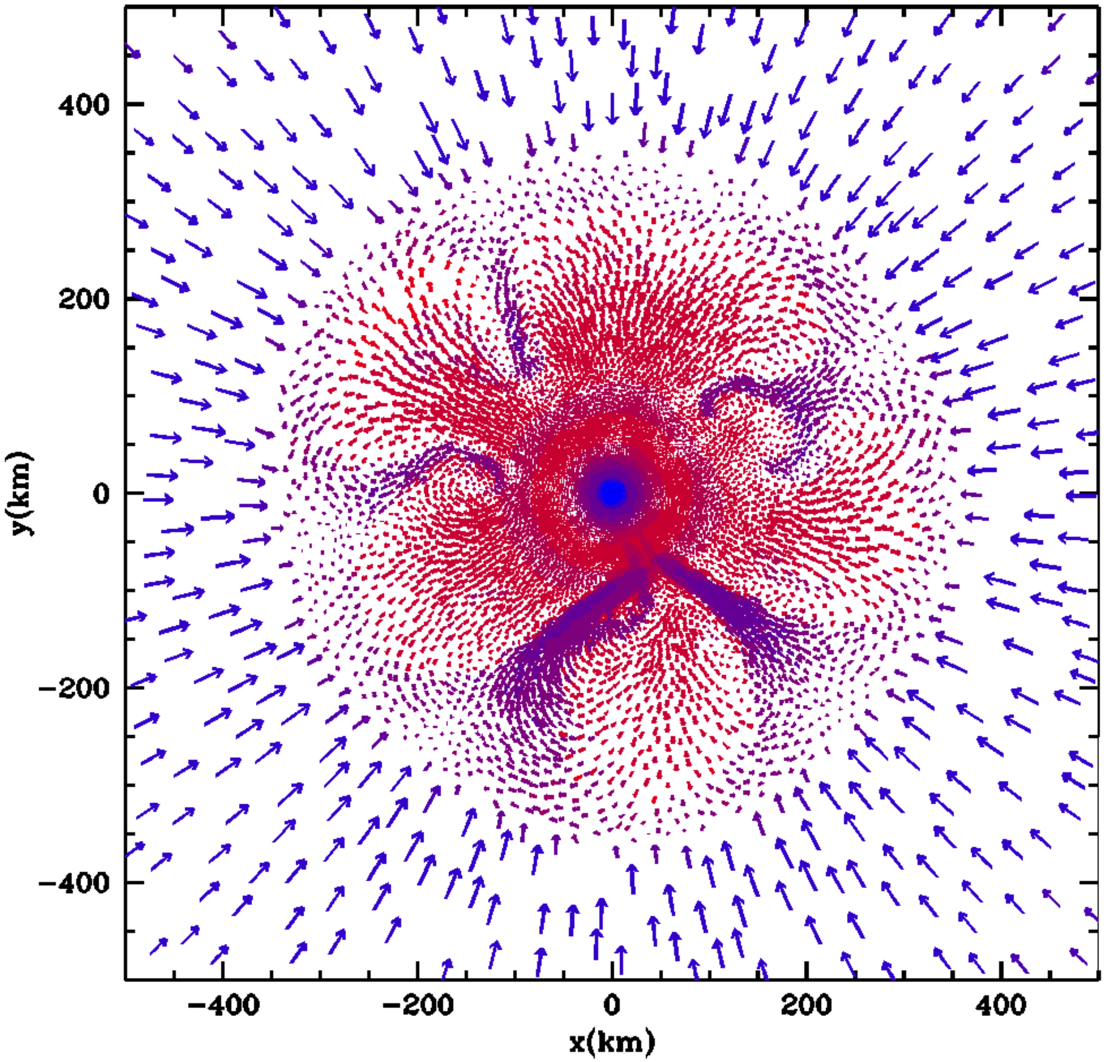
GRB Types

- GRBs have been roughly divided into short/hard and long/soft bursts.
- A new class of ultra-long bursts have been discovered.



SN Engines

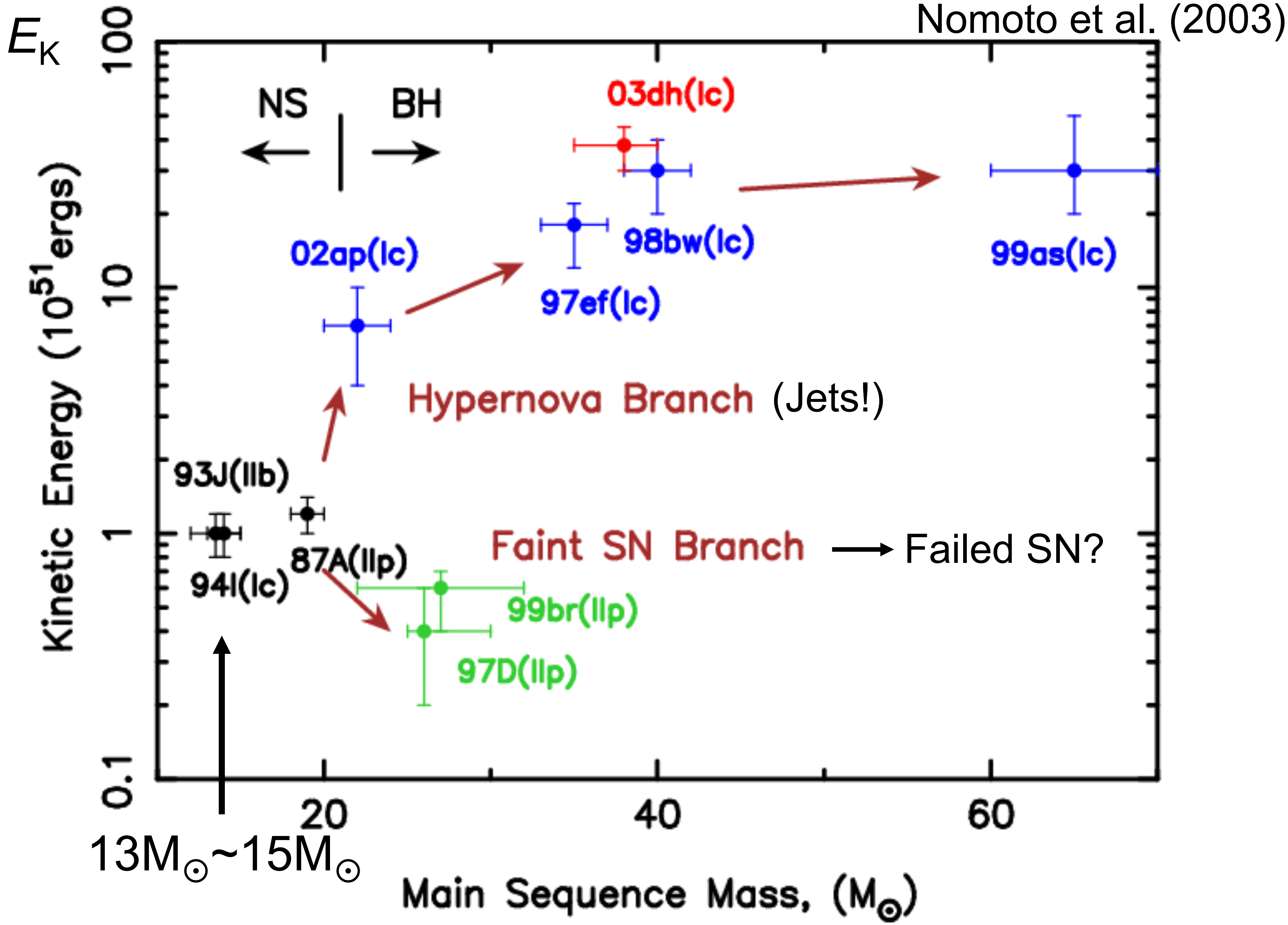
- ❑ Core-collapse Supernovae (Type II, Ib/c): Powered by the potential energy released in collapse
  - ➢ Source of convection (advective acoustic vs. Rayleigh Taylor), energy transport (neutrinos, pressure waves), role of magnetic fields.
  - ➢ Massive Star Progenitors (binaries vs. single stars)
- ❑ Thermonuclear Supernovae
  - ➢ Ignition site/sites
  - ➢ White dwarf (double Degenerate vs. single degenerate)



Possible Fates under the Convective Paradigm

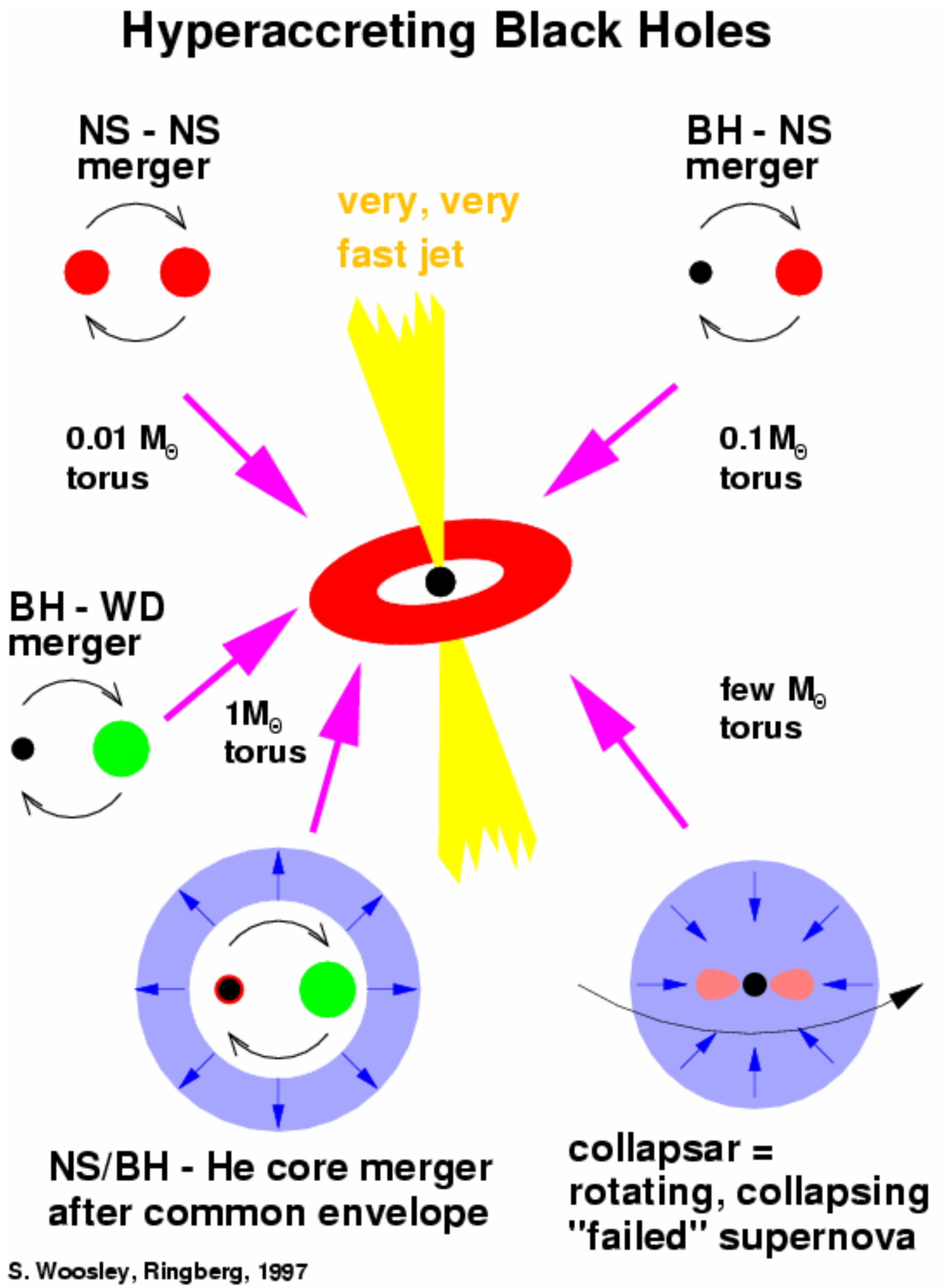
- Explosion within first ~200 ms, normal supernovae
- Explosion delayed, weak supernova, considerable fallback (BH formation – Collapsar type II for rotating systems)
- No explosion (BH Formation – Collapsar type I for rotating systems)

Supernovae/Hypernovae



BHAD GRB and Magnetar Engines

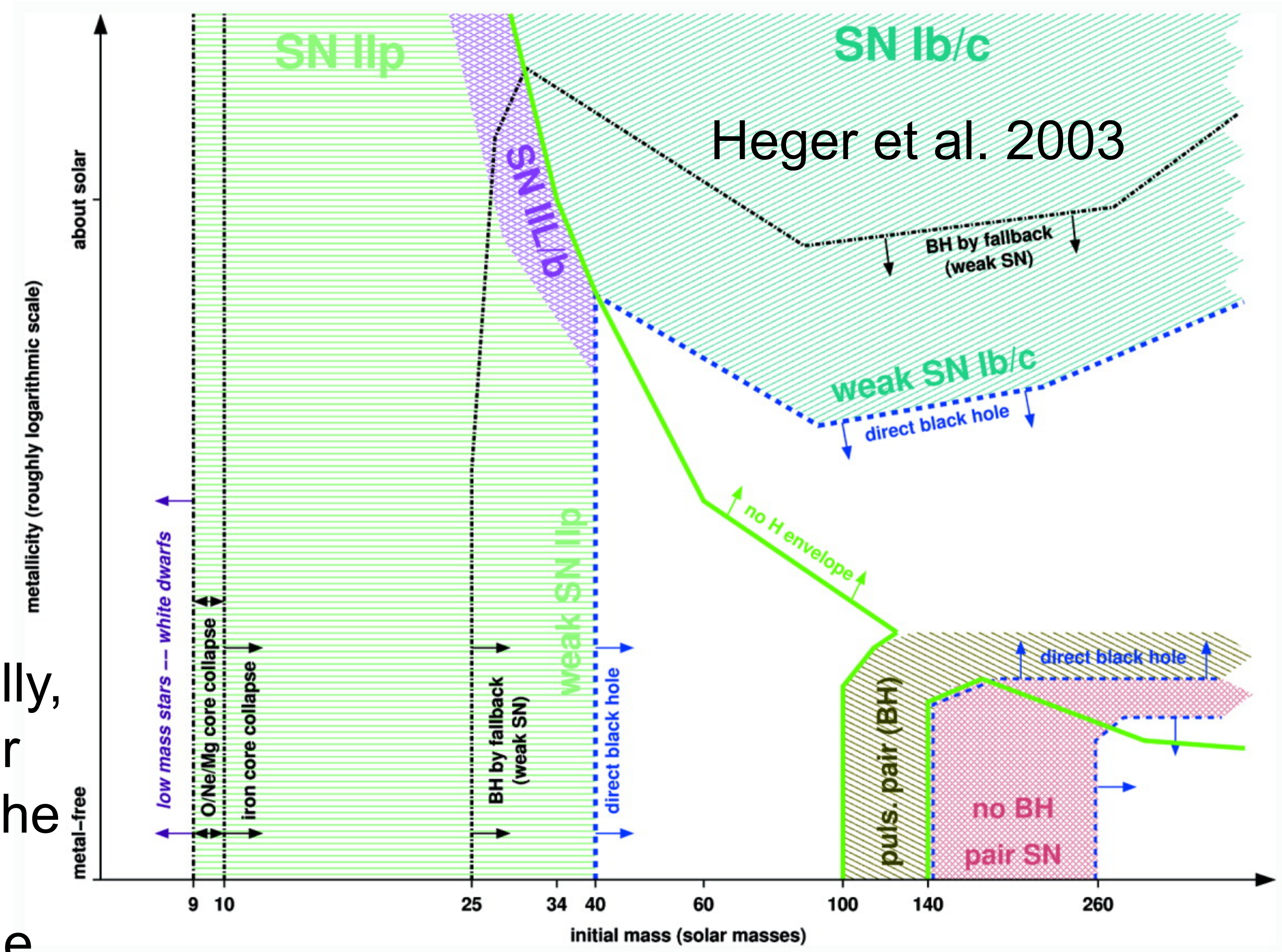
- ❑ Massive star Collapse (LGRB, very long GRB), only a very small fraction of massive stars (0.01-0.1% the supernova rate).
  - ➢ Single stars need considerable angular momentum
  - ➢ Binary scenarios have been developed to increase spin.
- ❑ Compact Merger (SGRB)
- ❑ Magnetar (neutron star) vs. BHAD (black hole)
- ❑ GRBs have Broad Lined Supernovae. Can this engine also produce Superluminous Supernovae?



Massive Star Progenitors

- SN and GRB progenitors are connected, leading to a number of questions:
  - SNe vs. GRB – which stars make which explosion?
  - Do we see similar CSM features (mass loss via winds, outbursts, binary effects) in both?
  - Do we see similar stellar structures?
  - What is the role of binaries?

Progenitors



Traditionally, the outer layers of the star determine the SN type.

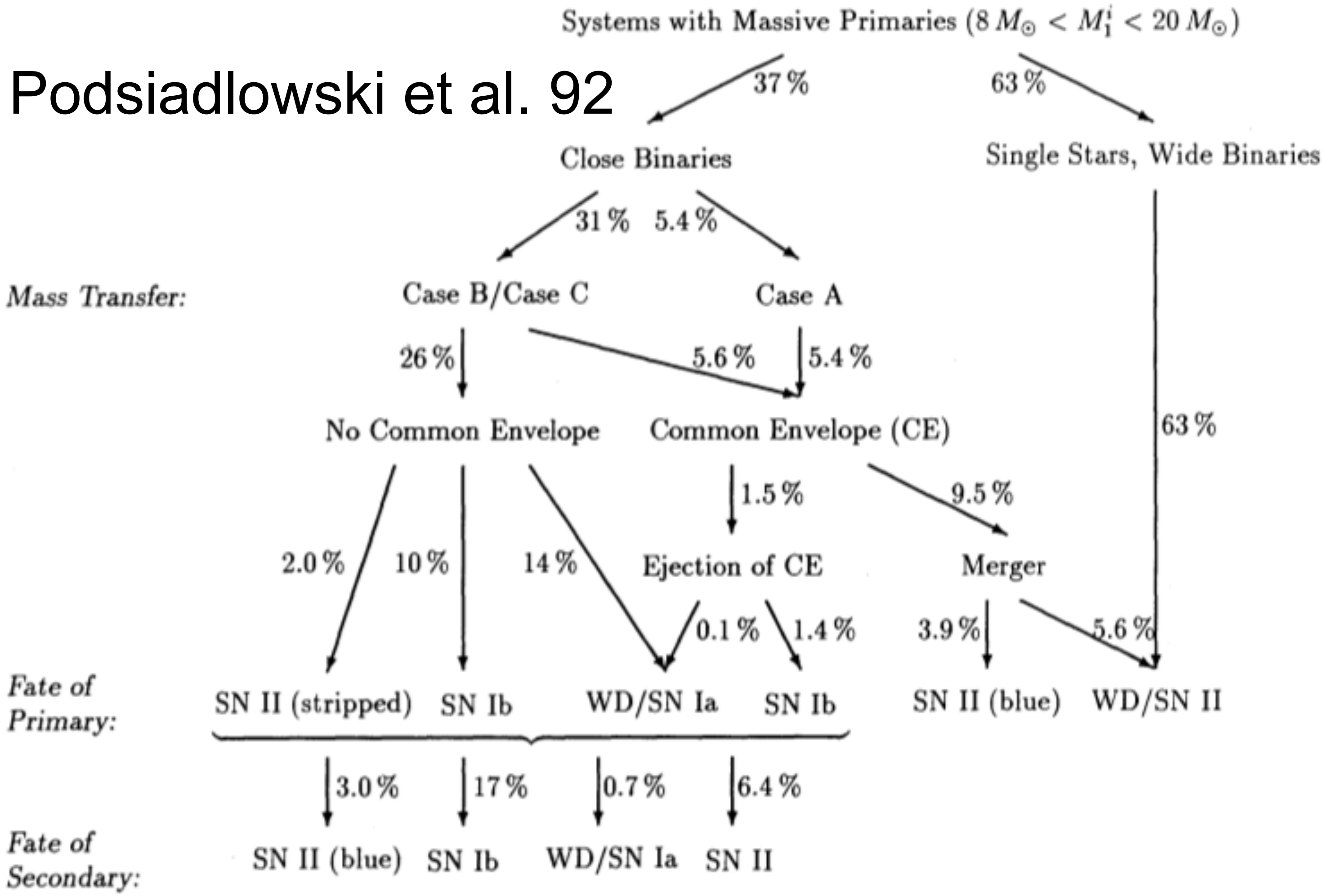
Now we know that the CSM (wind/binary interactions) are equally important.

Binaries are important

- 80-100% of massive stars in young clusters are in binaries, most of which are interacting (2/3 of total): e.g. Kobulnicky & Fryer 2007, Kiminki & Kobulniki 2012, Sana et al. 2012.
- Despite the fact that observations all agree on this, a large, but shrinking subset of stellar modelers insist on single star solutions.

Binary Progenitors

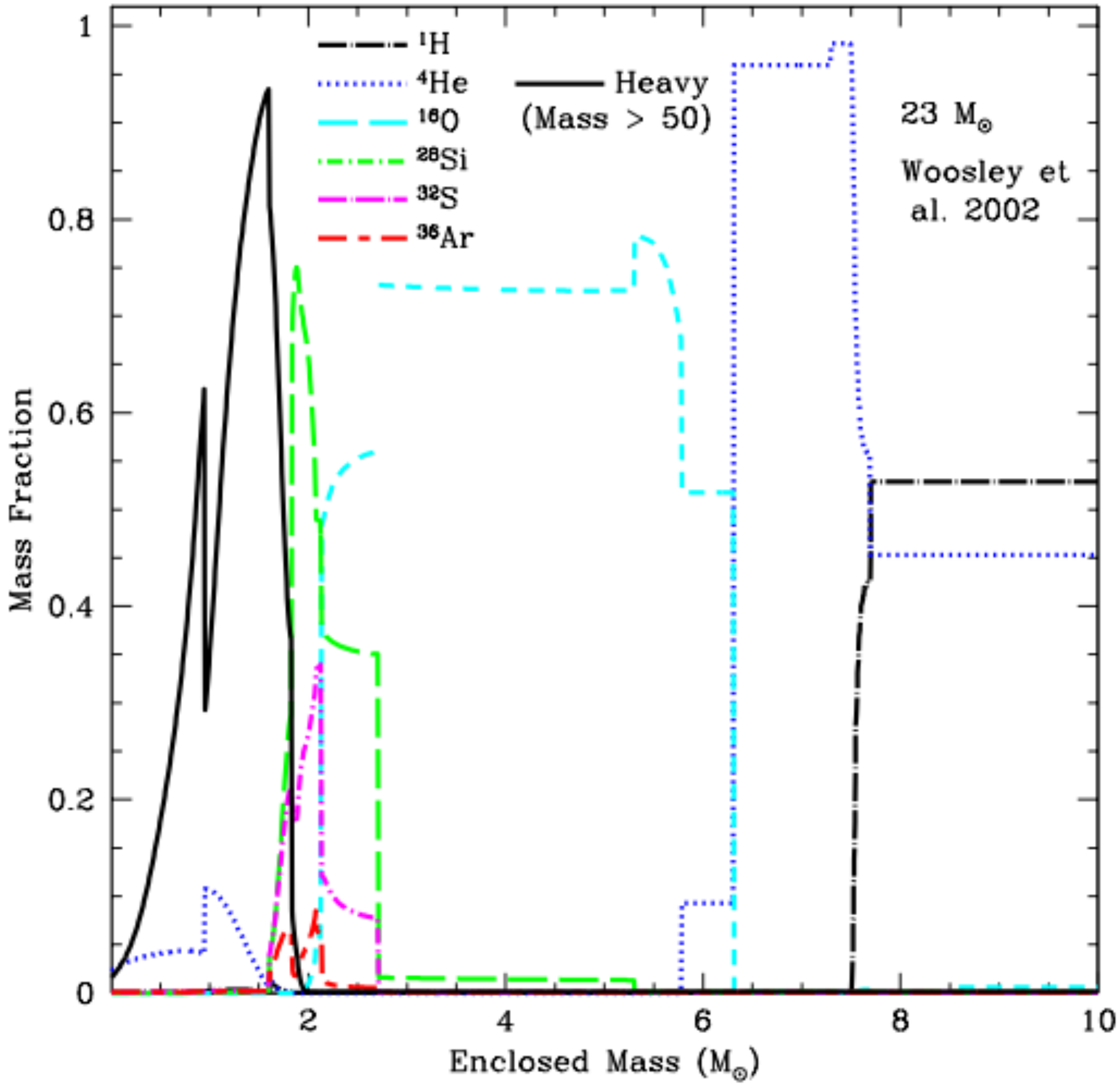
Podsiadlowski et al. 92



- Strong Winds: High-mass, high-metallicity stars can lose their hydrogen envelope.
- Binaries: Binary mass transfer can eject the hydrogen envelope (partial ejection is now the current model for SN 1987A)

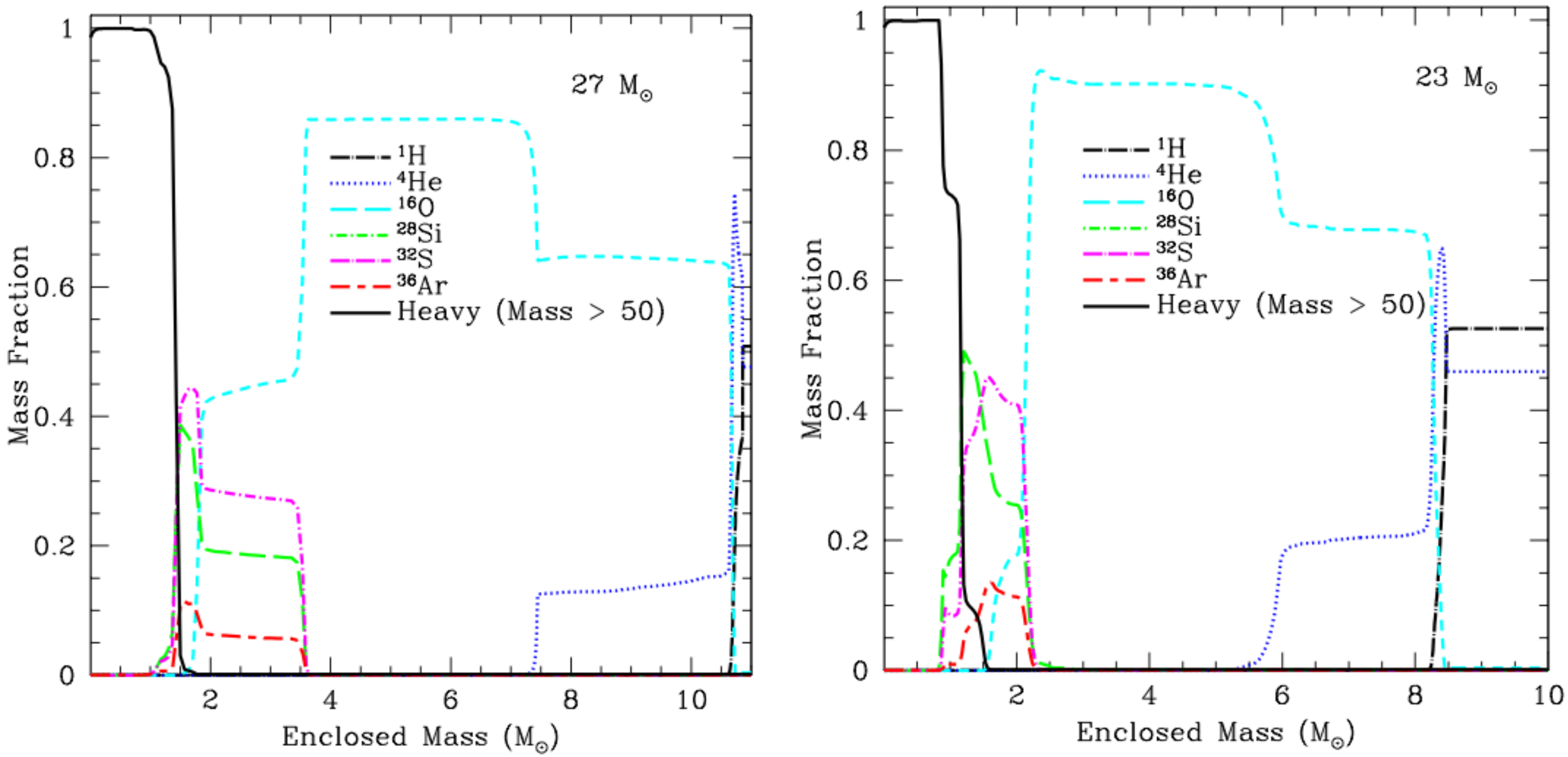
Ib vs. Ic Supernovae (the problem)

- Typical Stellar models predict hefty helium layers. Even if a wind blows off the hydrogen envelope, the star ends as a helium core.
- Most Ib/c SNe are Ic!
- SNe associated with GRBs are also Ic.



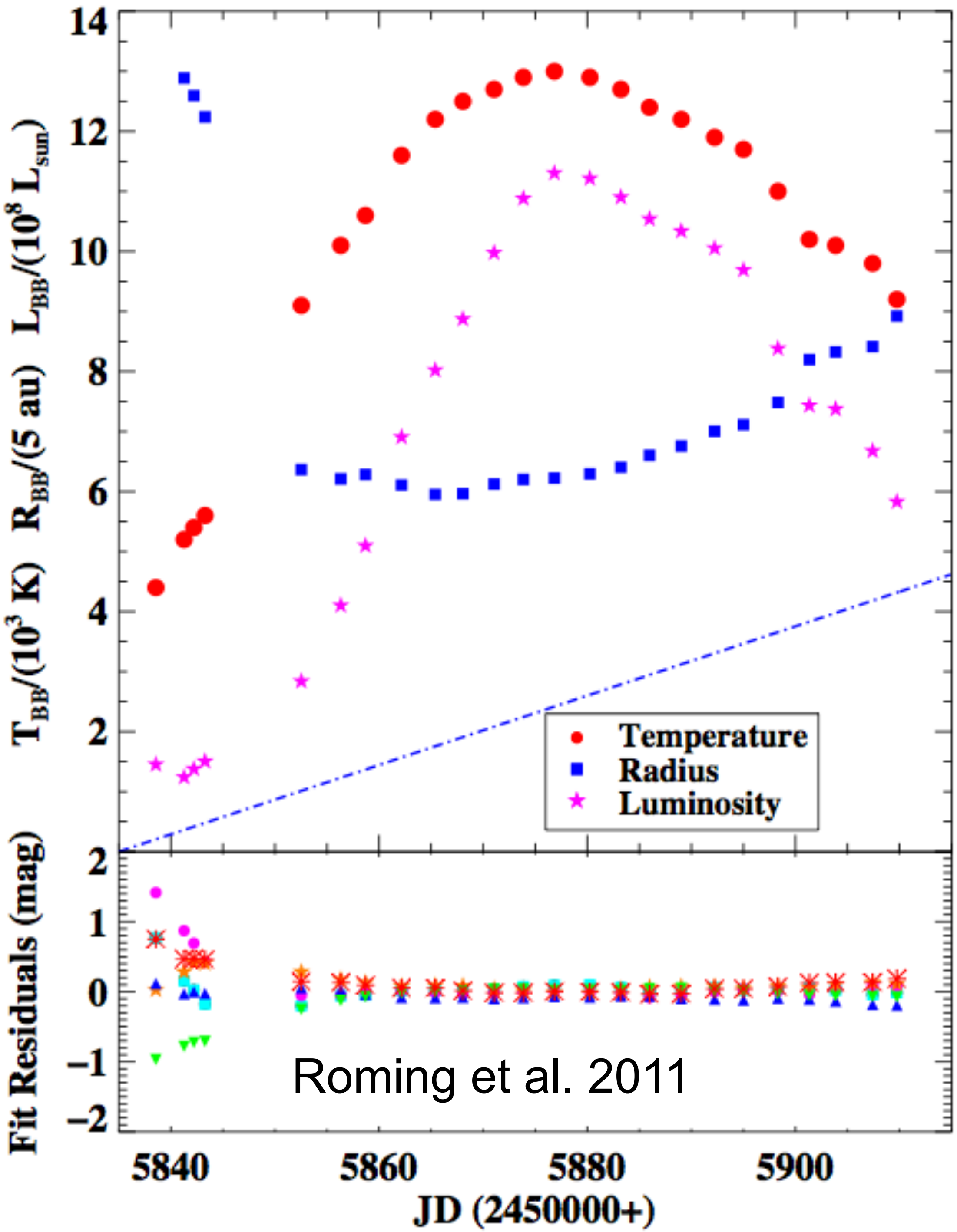
Ib vs. Ic Supernovae (solutions)

- Helium is hidden (Dessart et al. 2012, but see Hachinger et al. 2012)
- More realistic mixing suggests that the helium is mixed inward and burned (Frey et al. 2013). GRB and SN observations driving the progenitor evolution.



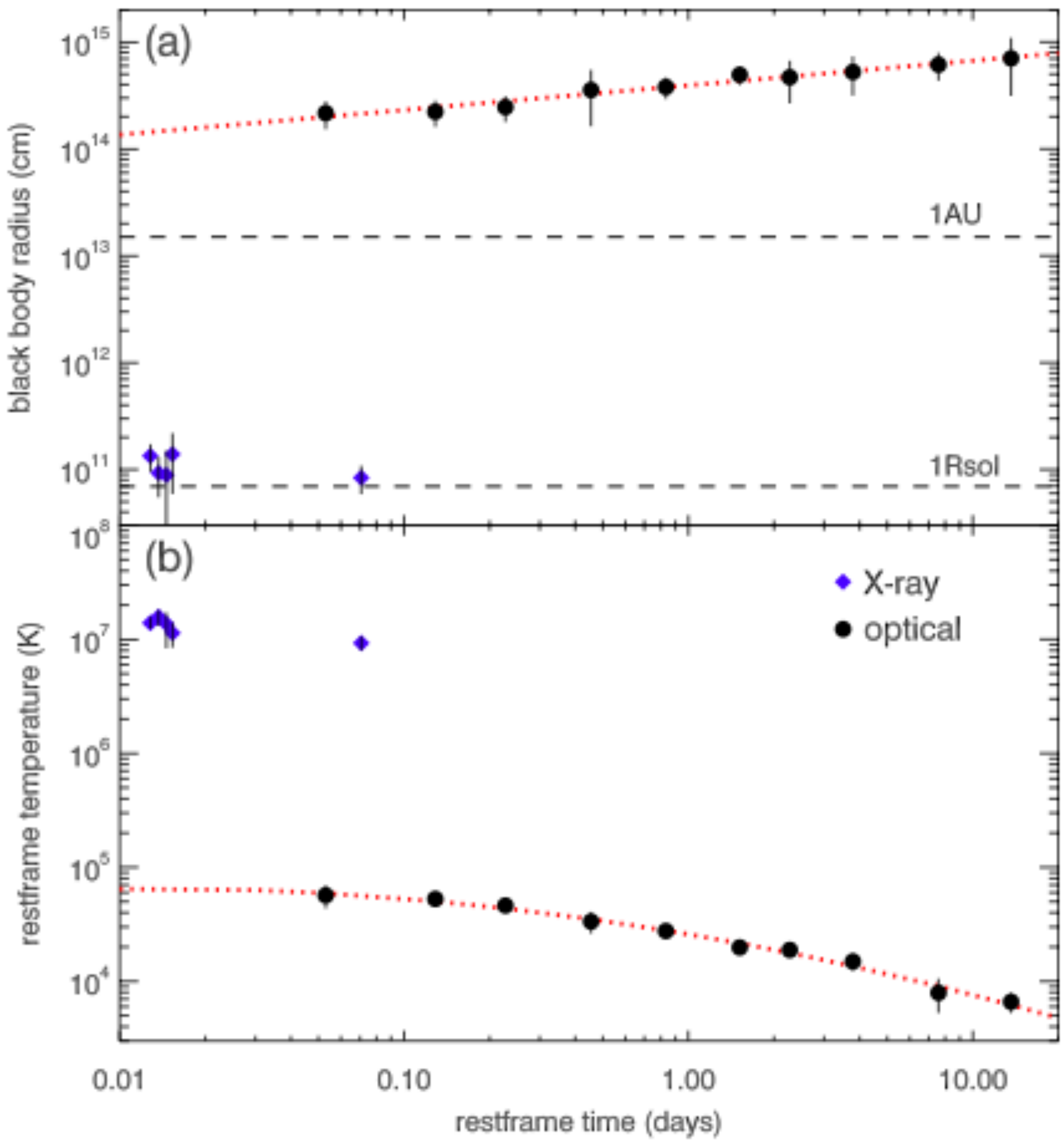
Outburst or Binary effects in type IIn SN: SN2011ht

- Initially classified as a supernova imposter (LBV outburst), later classified as a narrow-line type II supernovae.
- Initial blackbody radius indicates large radius, but it then shrinks by a factor of 2 before slowly rising (suggesting a shell).
- Narrow lines likely caused by shell as well.



Christmas Burst

- Scientists have proposed both binary and single-star progenitors for the Christmas burst (Thone et al. 2012, Woosley & Heger 2012)
- Again, a shell of ejecta makes it easier to explain all the data (recent outburst or CE phase)



Conclusions

- Massive star progenitors account for a wide range of SN (Type Ib/c, II) and GRB (LGRB, ULGRB).
- GRB and SN progenitors are intertwined… we can learn about the progenitors of one by studying the other:

➢ Helium shell and Ib/c supernovae

➢ Mass Loss

➢ Role of Binaries in SNe and GRBs