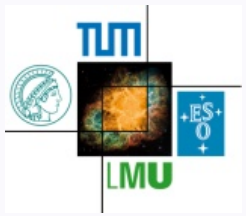
Observational Constraints

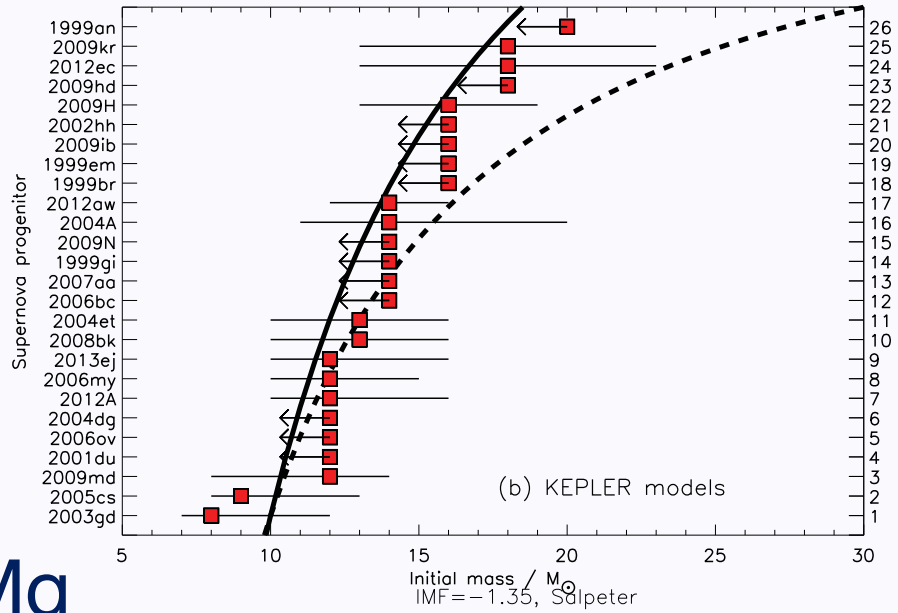
Bruno Leibundgut

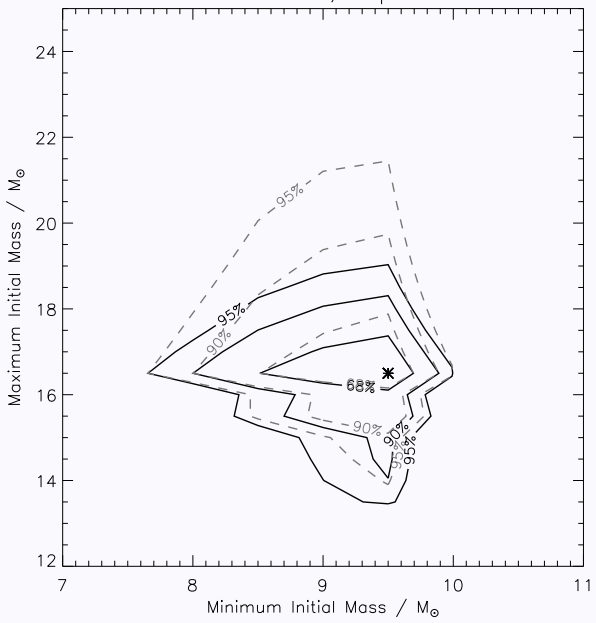


Progenitors

Core collapses

- missing high-mass progenitors
- distinction between C/O cores and ONeMg cores
- where is the exact lower mass limit?



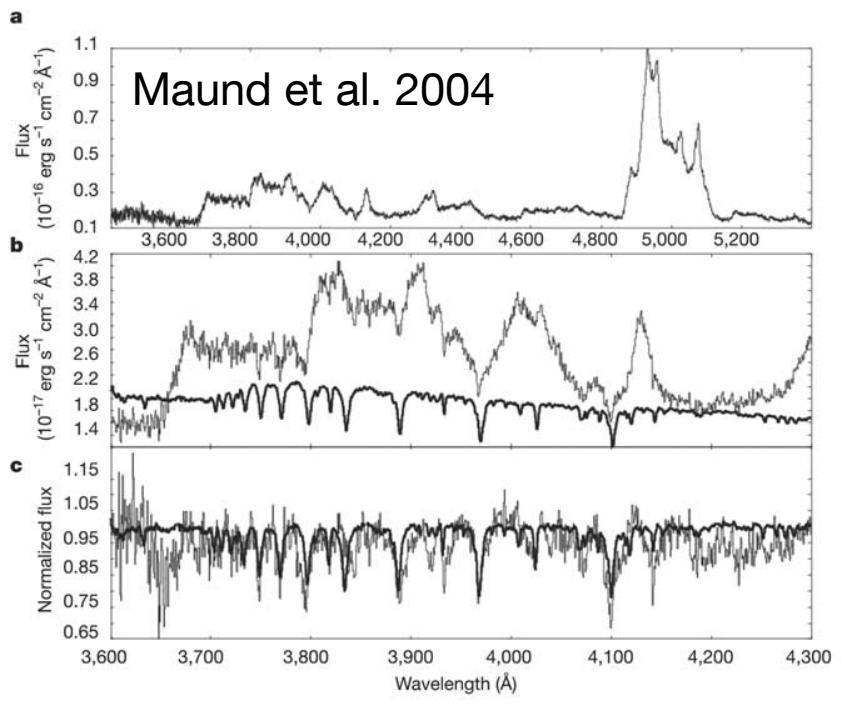


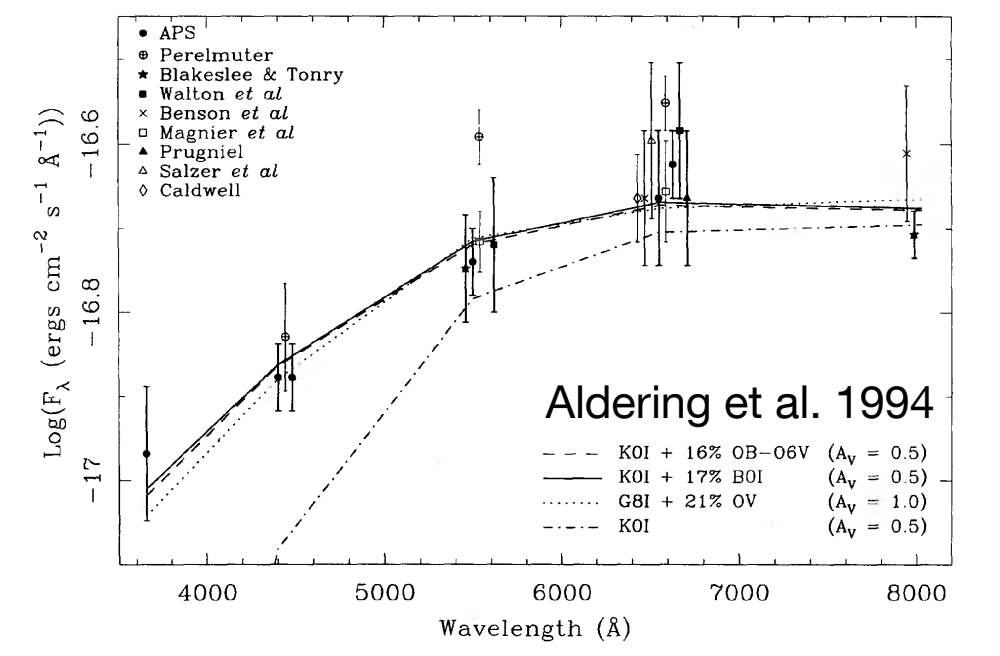
Smartt 2015

Progenitors

Core collapses

- Binary evolution → ‘free for all’
  - any meaningful constraints?
- very little information on companion stars
  - e.g. SN 1993J

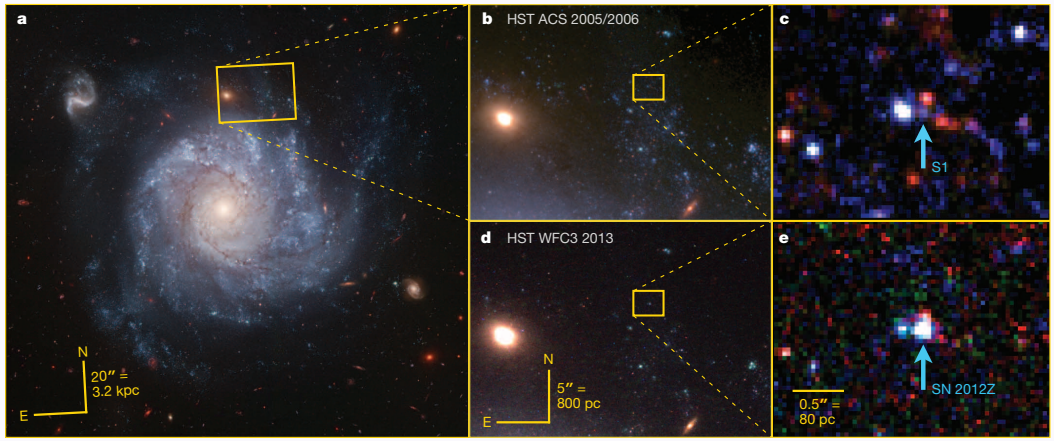




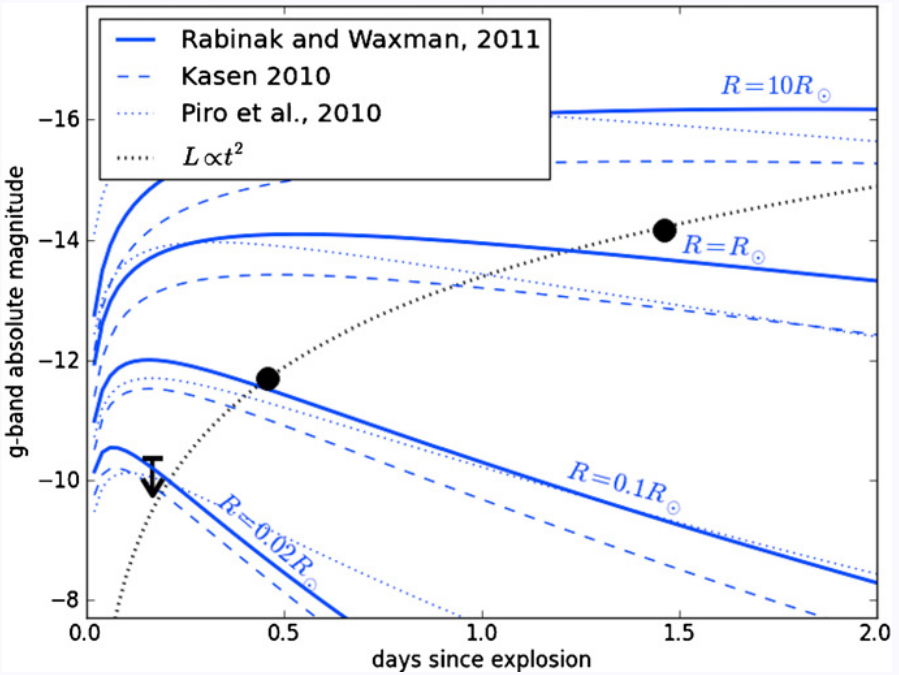
Progenitors

Thermonuclear

- white dwarfs about 30 magnitudes fainter than supernova → direct detection unlikely
- look for companions (binaries!)
- possible detection for a SN Iax



McCully et al. 2015



Bloom et al. 2012

Progenitors

Confusion!

Core collapses

- ‘wrong’ progenitors
  - where are the massive explosions?
  - how will η Car look as supernova?
- binary star evolution
  - combination with development of the core?

Thermonuclears

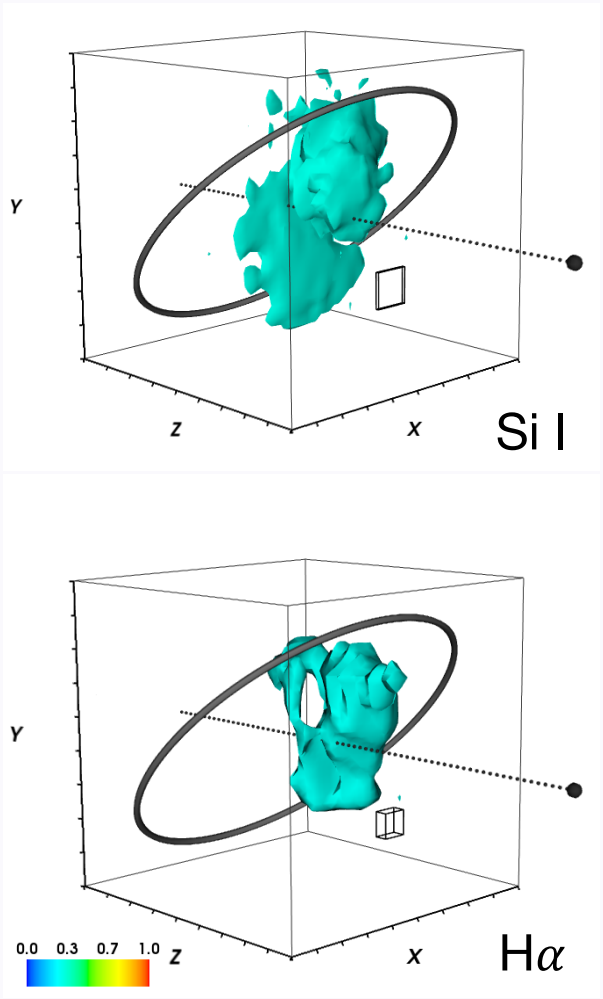
- several progenitors?
- how can they be separated?
- companion of SN 2012Z?

Explosions

Asymmetries

– directly observed

Fransson et al. 2015



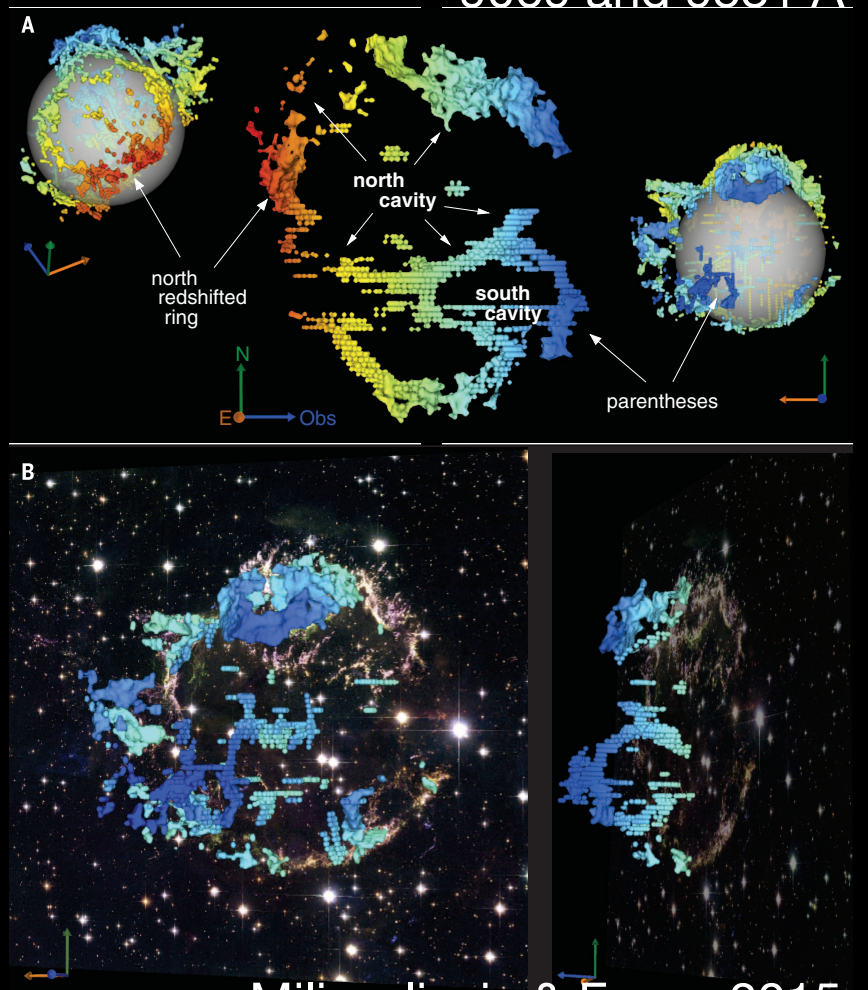
Larsson et al. 2016

Explosions

Asymmetries

– in remnants (Cas A)

[S III]
9069 and 9531 Å

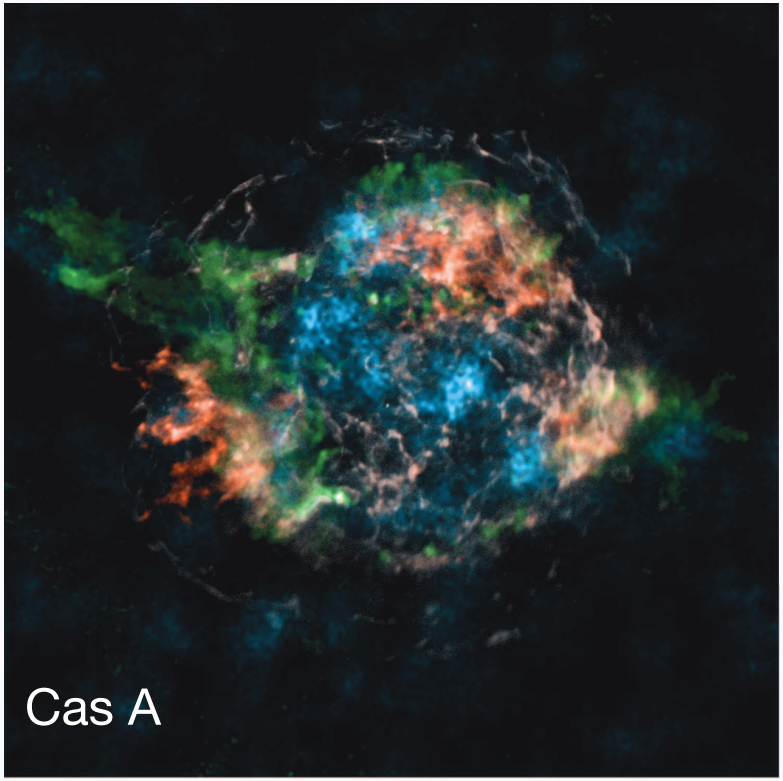


Milisavljevic & Fesen 2015

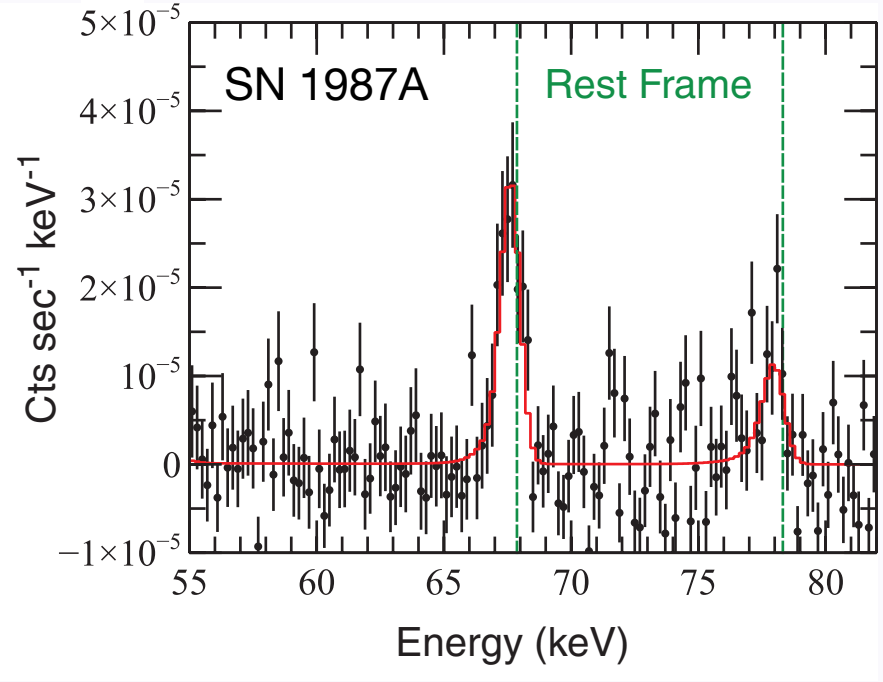
Explosions

Asymmetries

- Elemental distributions
  - Ti



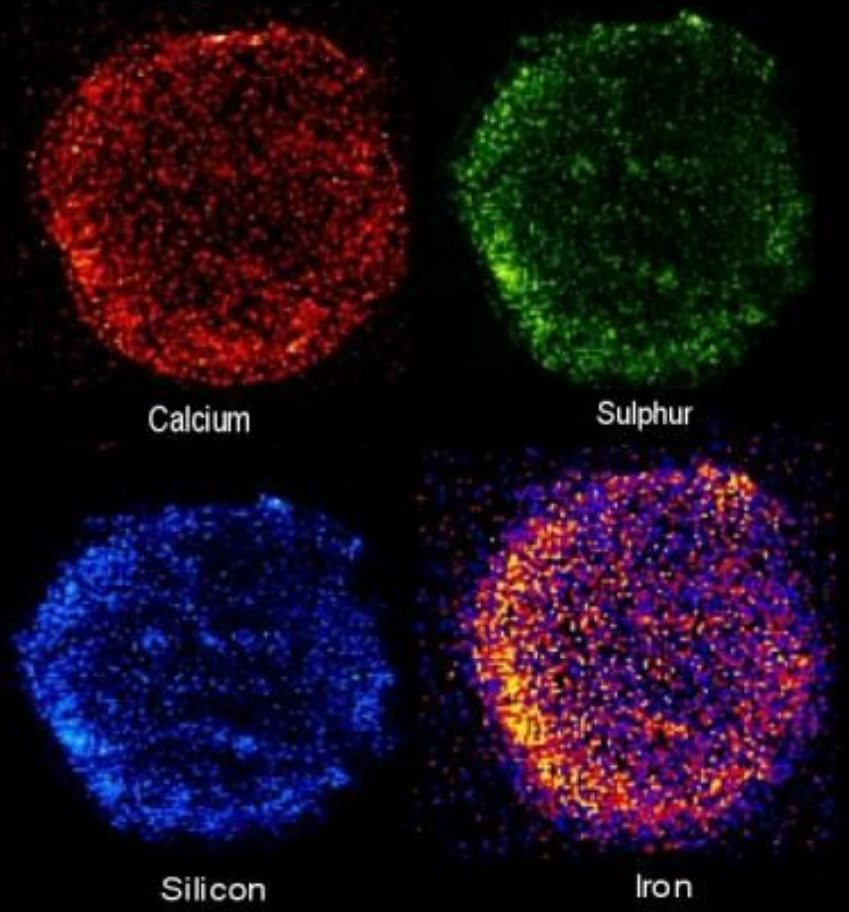
Boggs et al. 2015



Grevenstette et al. 2014

Explosions

No asymmetries for thermonuclears



Tycho (Chandra)

Explosions

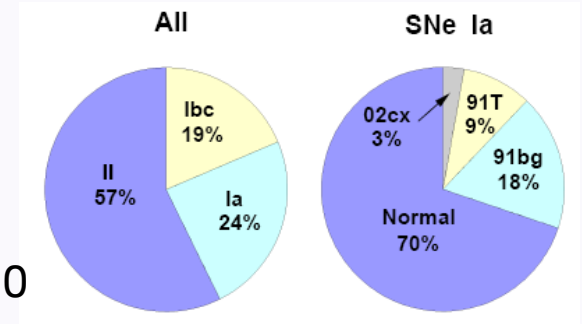
Separate physics from ‘weather’
(core evolution from stellar atmosphere)

- classification system not really helpful
  - sub-classes not necessarily distinct physics
- separate relevant topics
  - explosion mechanisms
    - compact remnants
  - influence of binaries
    - remaining H and He envelope → Ib/c
  - circumstellar interaction
    - depends on individual stellar evolution → IIn

Explosions

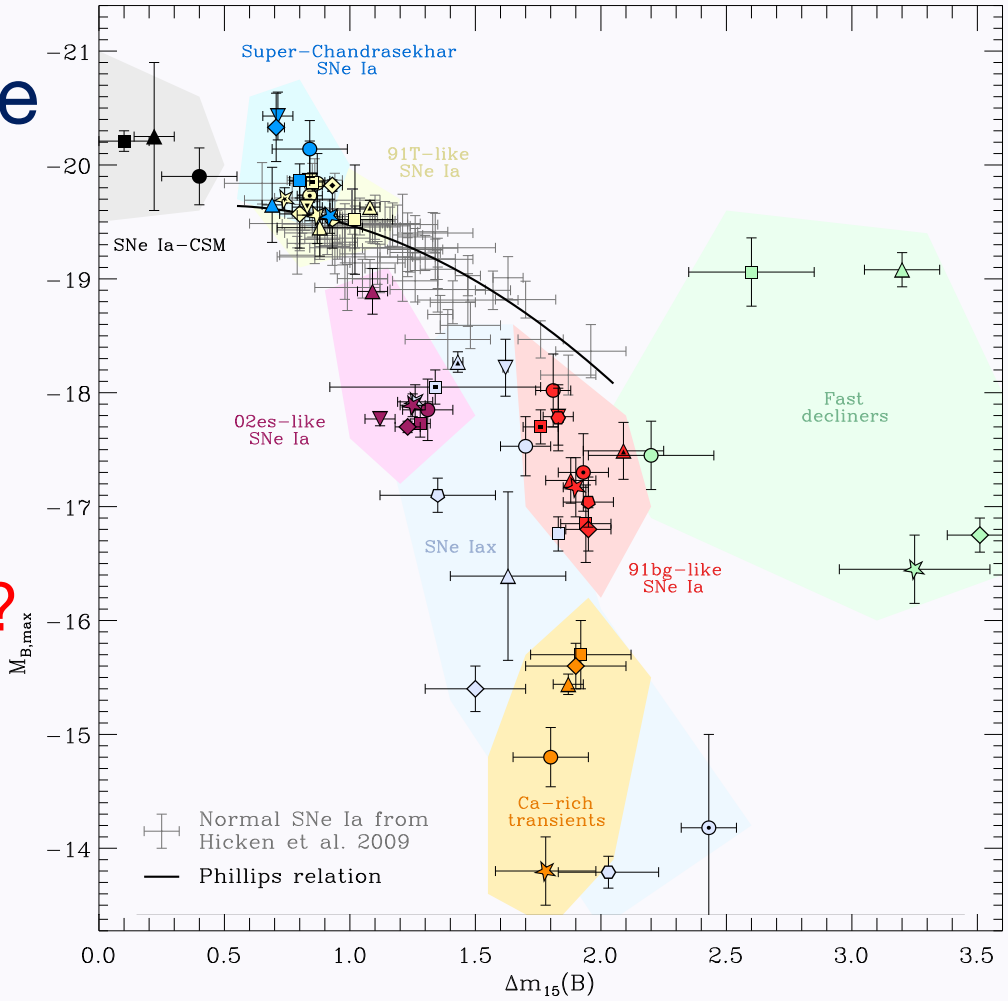
Thermonuclears

- variations on a theme
- critical parameters?
  - nickel mass
  - ejecta mass
  - explosion energy(?)
  - explosion mechanism?
  - progenitor evolution?



Li et al. 2010

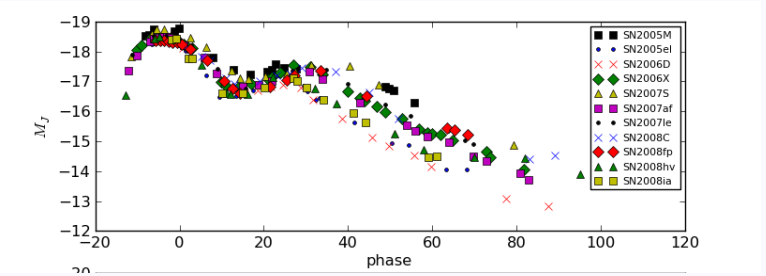
Taubenberger 2017



Explosions

Thermonuclears

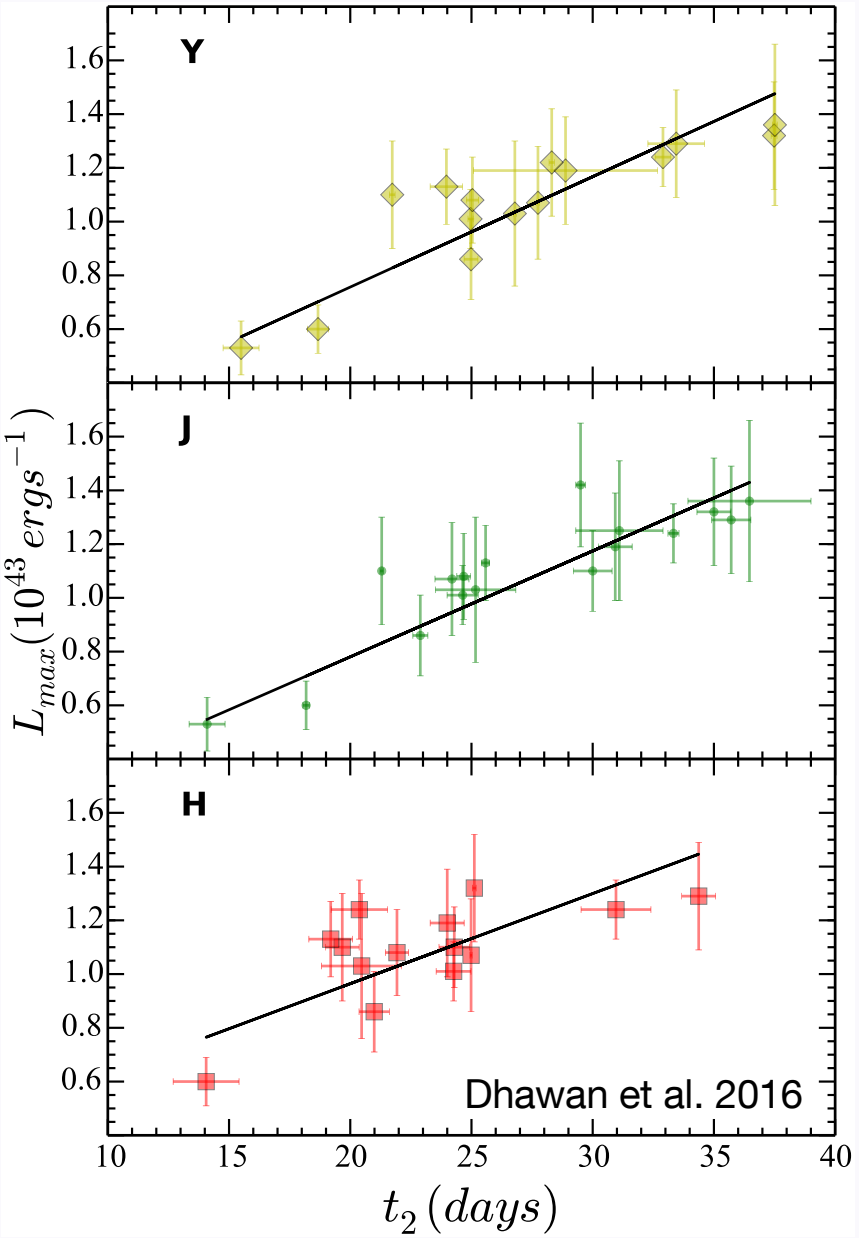
- Second peak in the near-IR is the result of the recombination of Fe^{++} to Fe^{+} (Kasen 2006)
- Uniform ejecta structure
  - late declines very similar



- higher luminosity indicates higher ^{56}Ni mass
- later secondary peak also indicates higher Fe/Ni mass
- Ni mass and (optical) light curve parameters correlate (Scalzo et al. 2014)

Luminosity function of SNe Ia

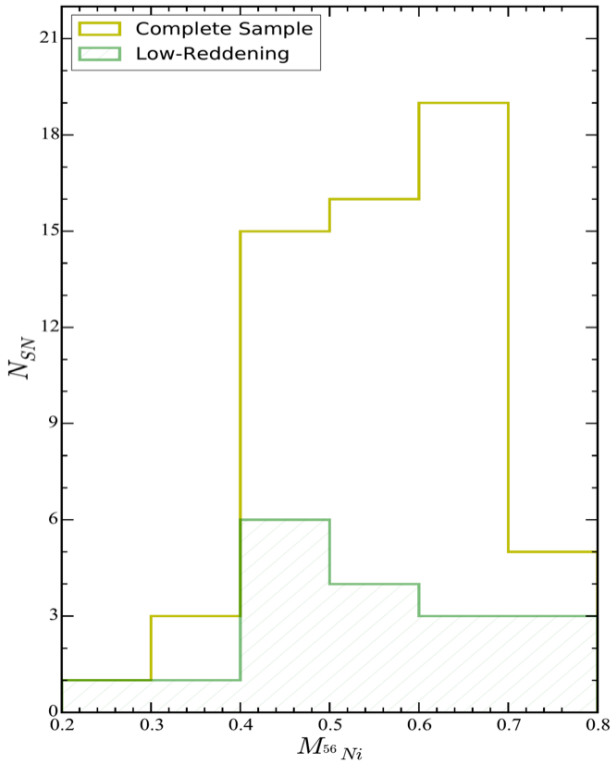
- Use the phase of the second maximum to derive the bolometric peak luminosity
  - calibrated on a sample of reddening-free SNe Ia
  - apply to reddened objects



Luminosity function of SNe Ia

$M_{\rm Ni}$ (inferred)	σ	Method	Reference
0.62	0.13	γ ray lines	Churazov et al. (2014)
0.56	0.10	γ ray lines	Diehl et al. (2015)
0.37	...	Bolometric light curve $A_V = 1.7$ mag	Churazov et al. (2014), Margutti et al. (2014)
0.77	...	Bolometric light curve $A_V = 2.5$ mag	Churazov et al. (2014), Goobar et al. (2014)
0.64	0.13	NIR second maximum	this work (combined fit)
0.60	0.10	NIR second maximum + measured rise	this work

- SN 2014J test passed
- Potential to determine the luminosity function and Ni distribution

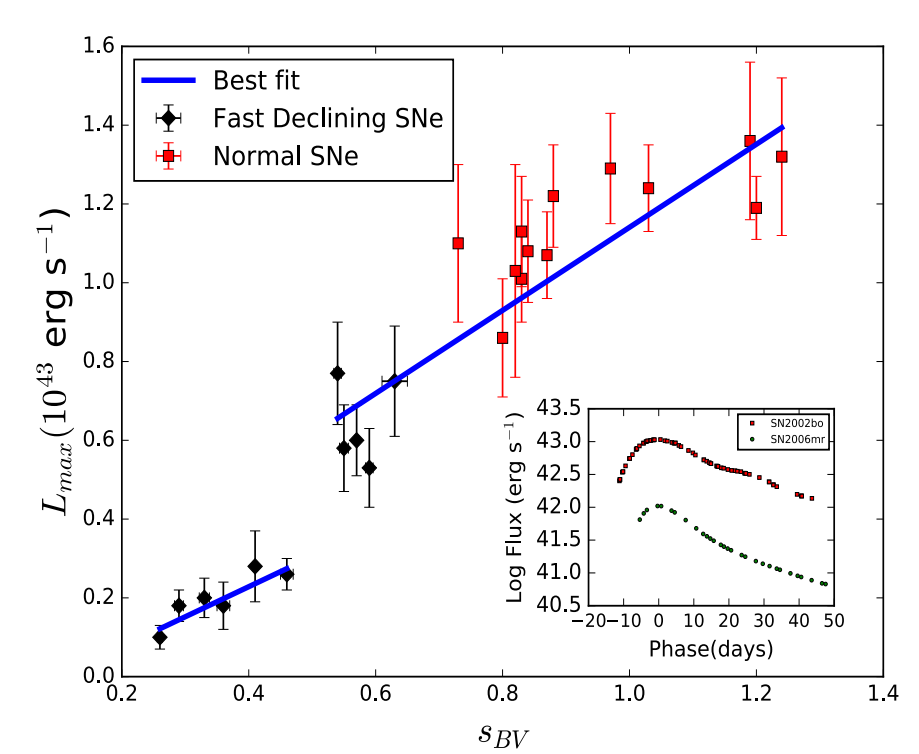


Dhawan et al. 2016

Fast-declining SNe Ia

- Two groups?
  - separation in
    - bolometric luminosity
    - phase of NIR first peak
    - luminosity of NIR first peak
    - lack of second second NIR maximum

Dhawan et al., in prep



Summary

- Core Collapses
  - no more spherical cows
  - missing important explosions
  - asymmetries point to explosion mechanism(s)
  - sub-classes of limited usefulness
- Thermonuclears
  - order in chaos? → how?
    - unclear what sub-classes tell us
    - diversity through progenitor evolution?
    - explosion mechanisms?
  - compact progenitors
  - nickel masses, ejecta masses