No stripped hydrogen in the nebular spectra of nearby Type Ia Supernova 2011fe

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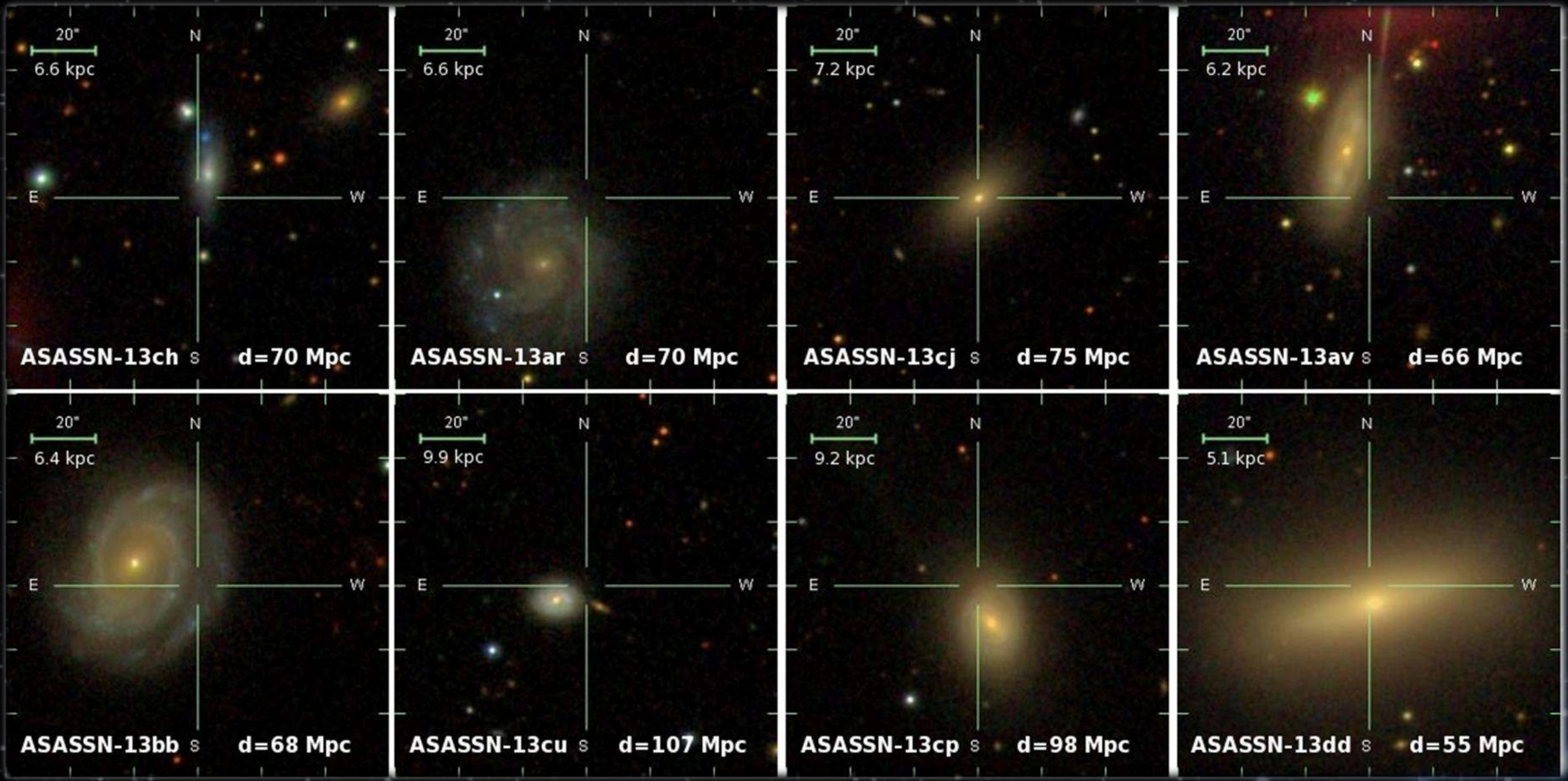
LBT Users Meeting

Mar 24, 2014

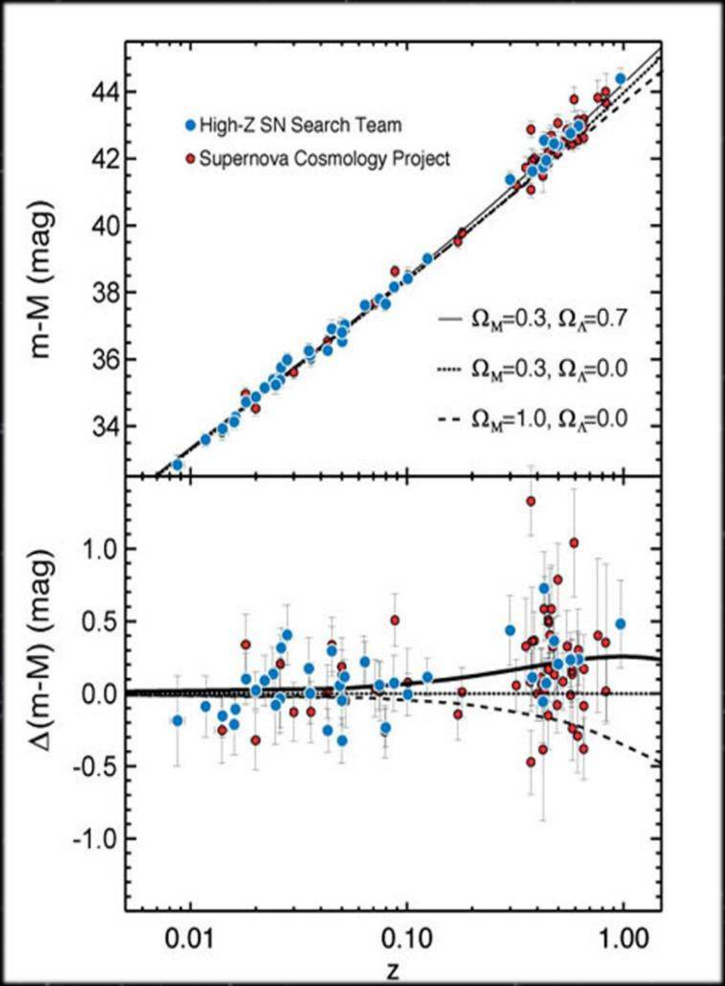
Supernovae

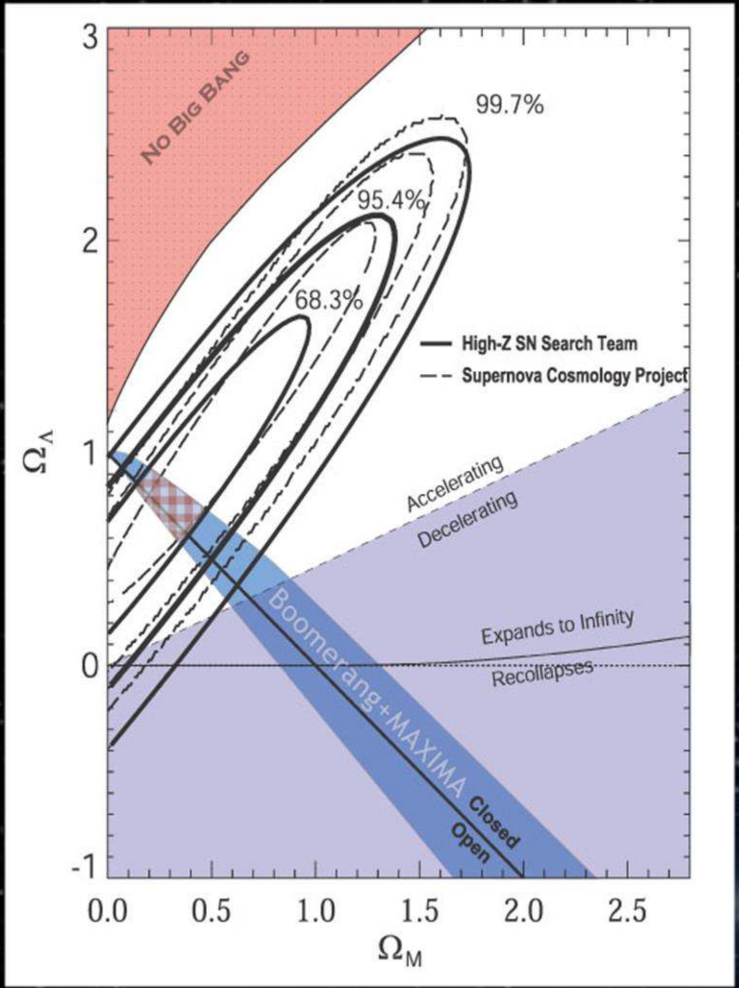


- Explode in a wide range of environments
- Affect the evolution of their host galaxies
- Creation and dispersal of metals

Shappee et al. 2014

Accelerating Universe

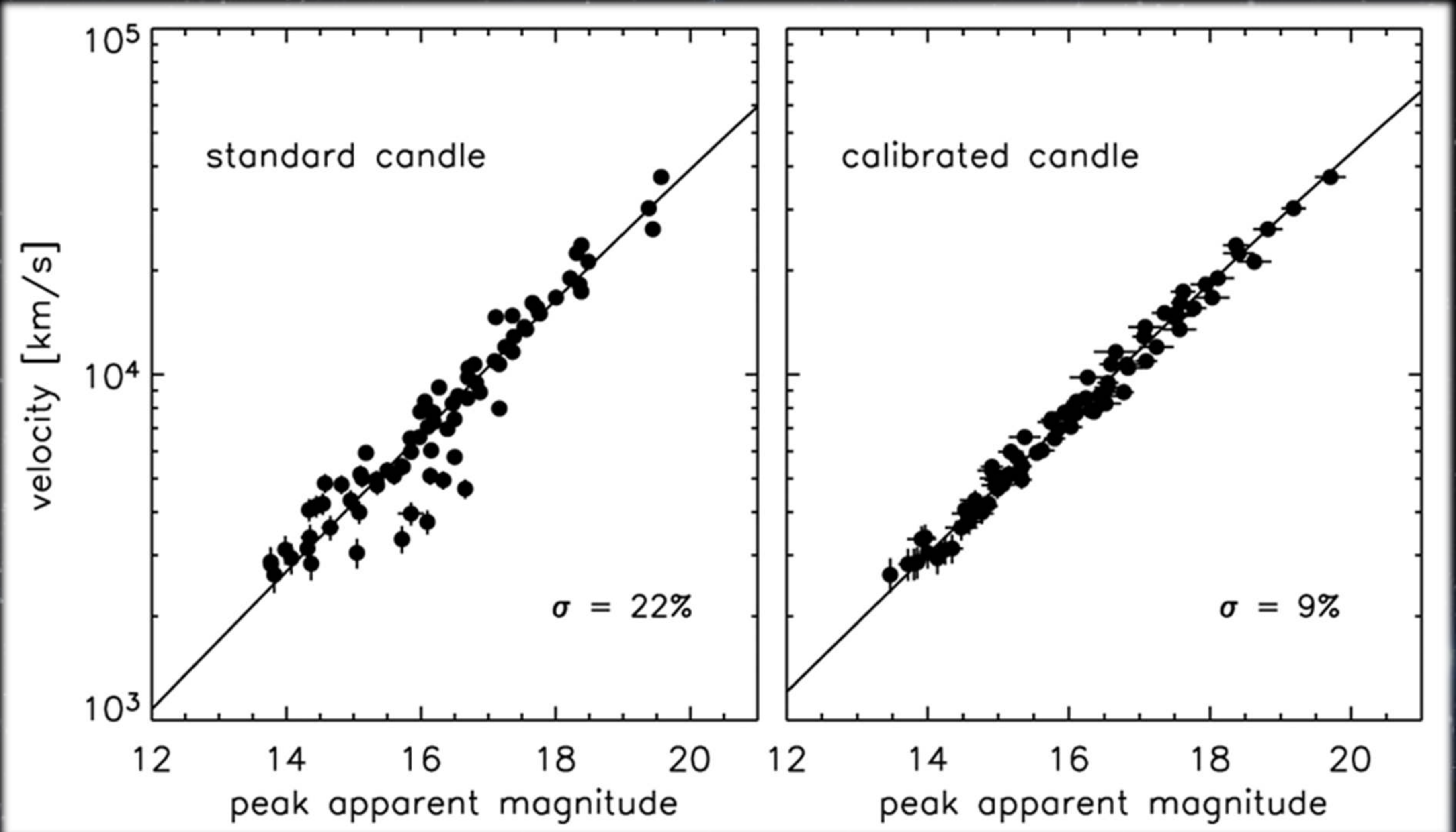




High-Z SN Search Team
Riess et al. (1998)

Supernova Cosmology Project
Perlmutter et al. (1999)

Standardizable Candles



Jha, Riess, & Kirshner (2007)

Double Degenerate Progenitor

- Collisions or merger of two WDs
- There are many variants, mergers due to:
  - Gravitational radiation (Tutukov & Tungelson 1979; Iben & Tutukov 1984; Webbink 1984)
  - Collision from three-body interactions (Thompson 2012; Katz & Dong 2013)
- Few observable consequences

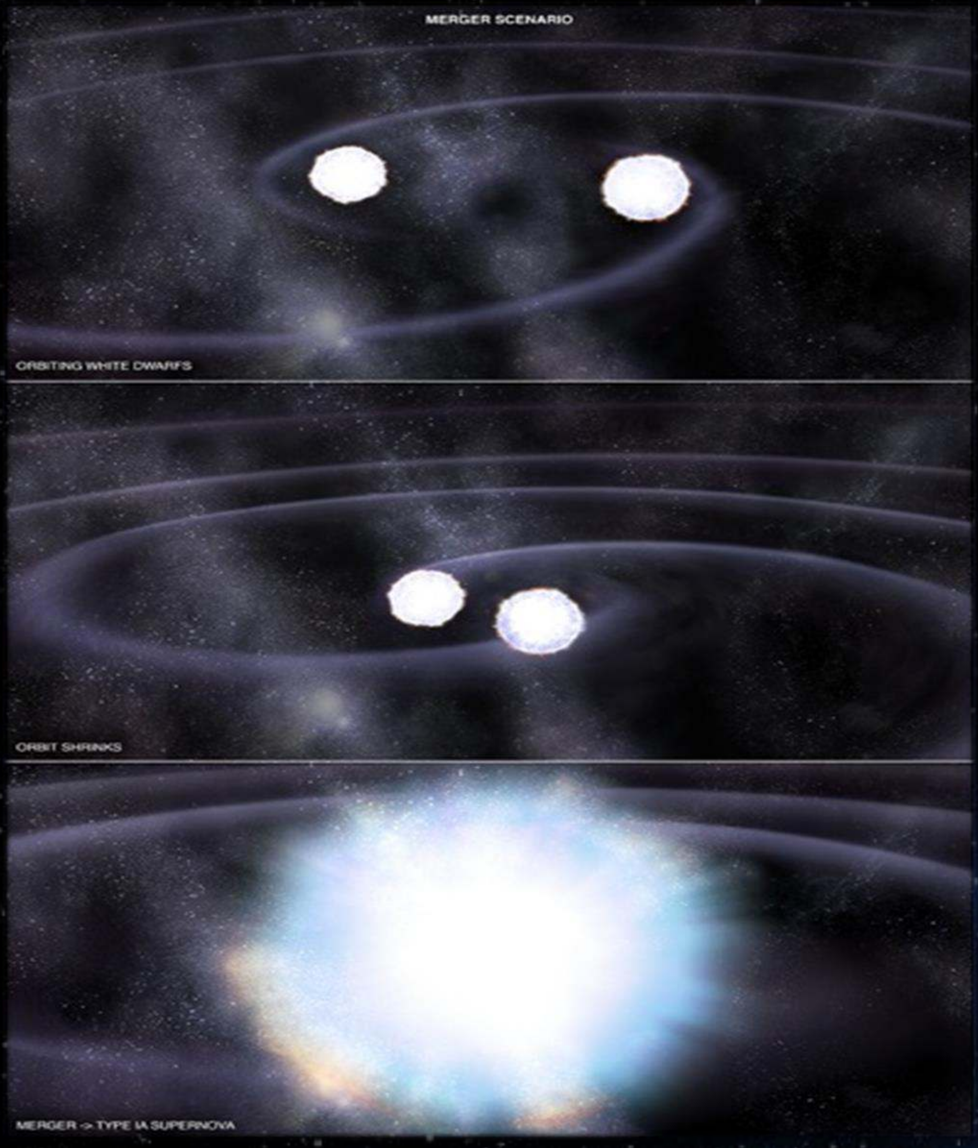


Image: NASA/CXC/M Weiss.

Single Degenerate Progenitor

- WD accretes material from a non-degenerate companion until exceeds the Chandrasekhar Mass (Whelan & Iben 1973; Nomoto 1982)
- Companion can be:
  - Main-sequence star
  - Sub-giant
  - Red giant
  - Helium star
- Many possible observable consequences

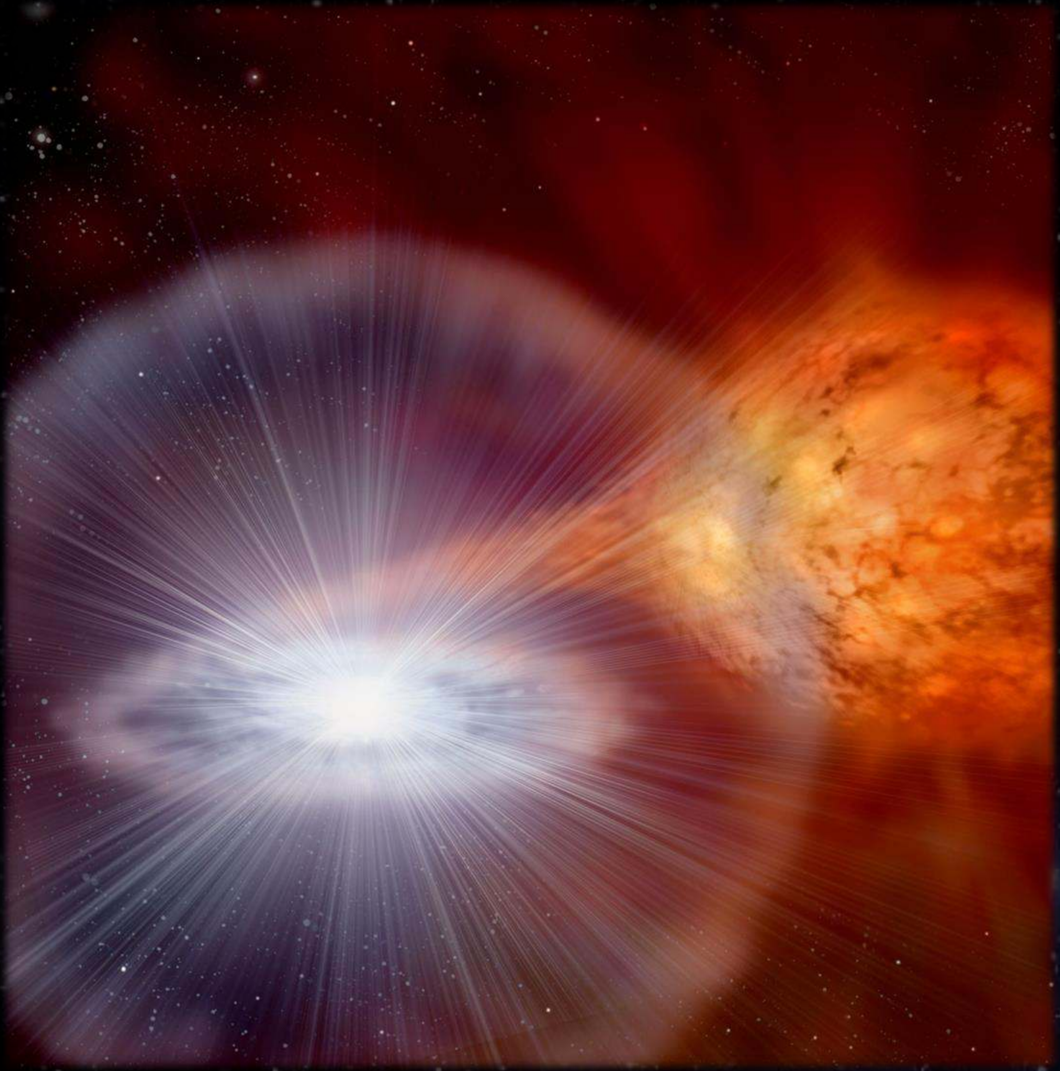
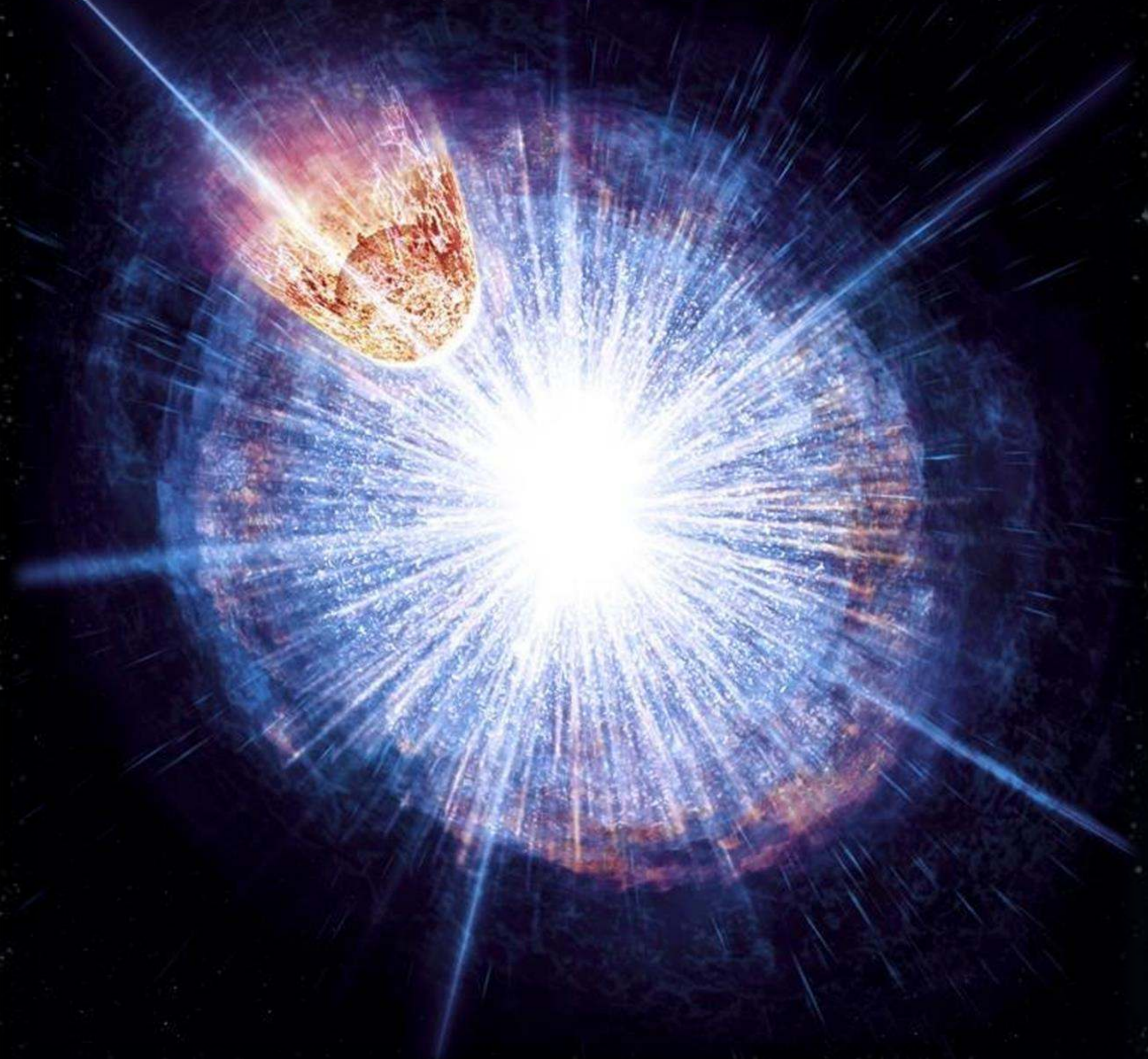


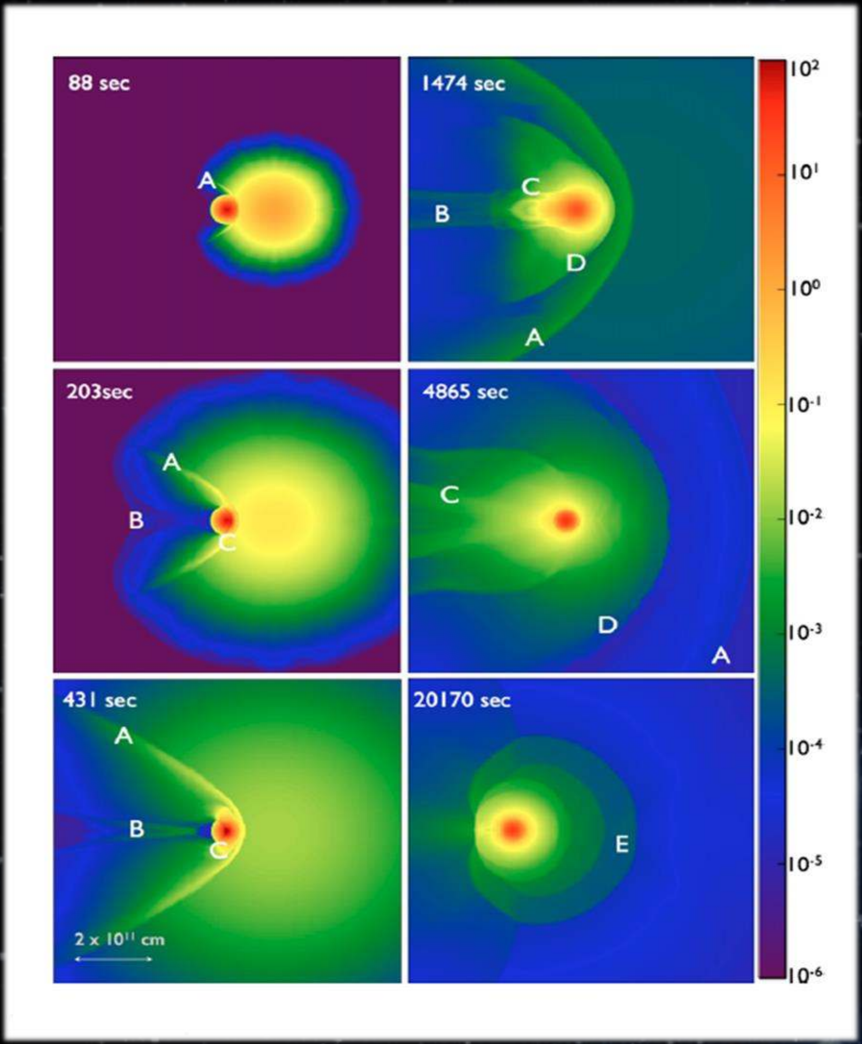
Image Dave A. Hardy.

SN Ejecta Impact on Companion



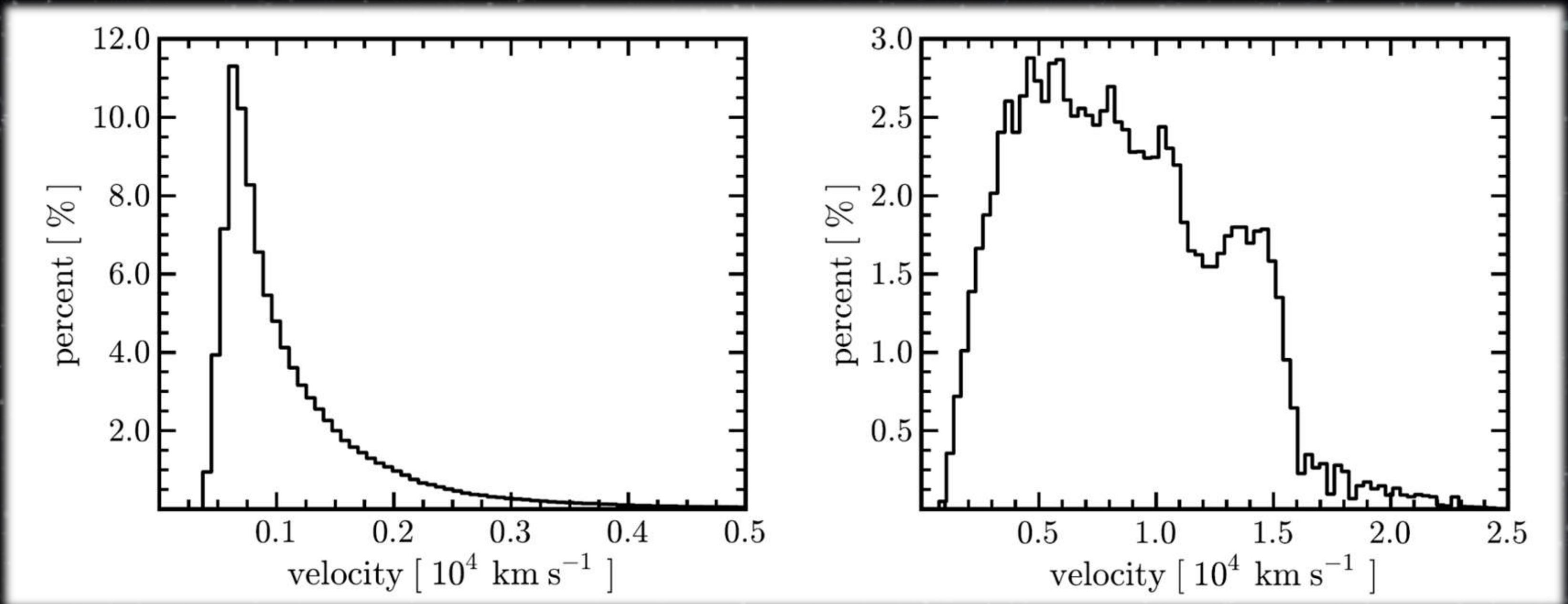
SN Ejecta Impact on Companion

- Material in the SN ejecta will remove material from companion (Wheeler et al. 1975)
- Hydrodynamic simulations show main sequence and sub-giant donors will lose ~ 15% of their mass (e.g., Pan et al. 2012, Liu et al. 2012)
- Star is left with a hot, extended, asymmetric envelope containing ~ 10% of the mass



Pan et al. (2012)

SN Ejecta Impact on Companion



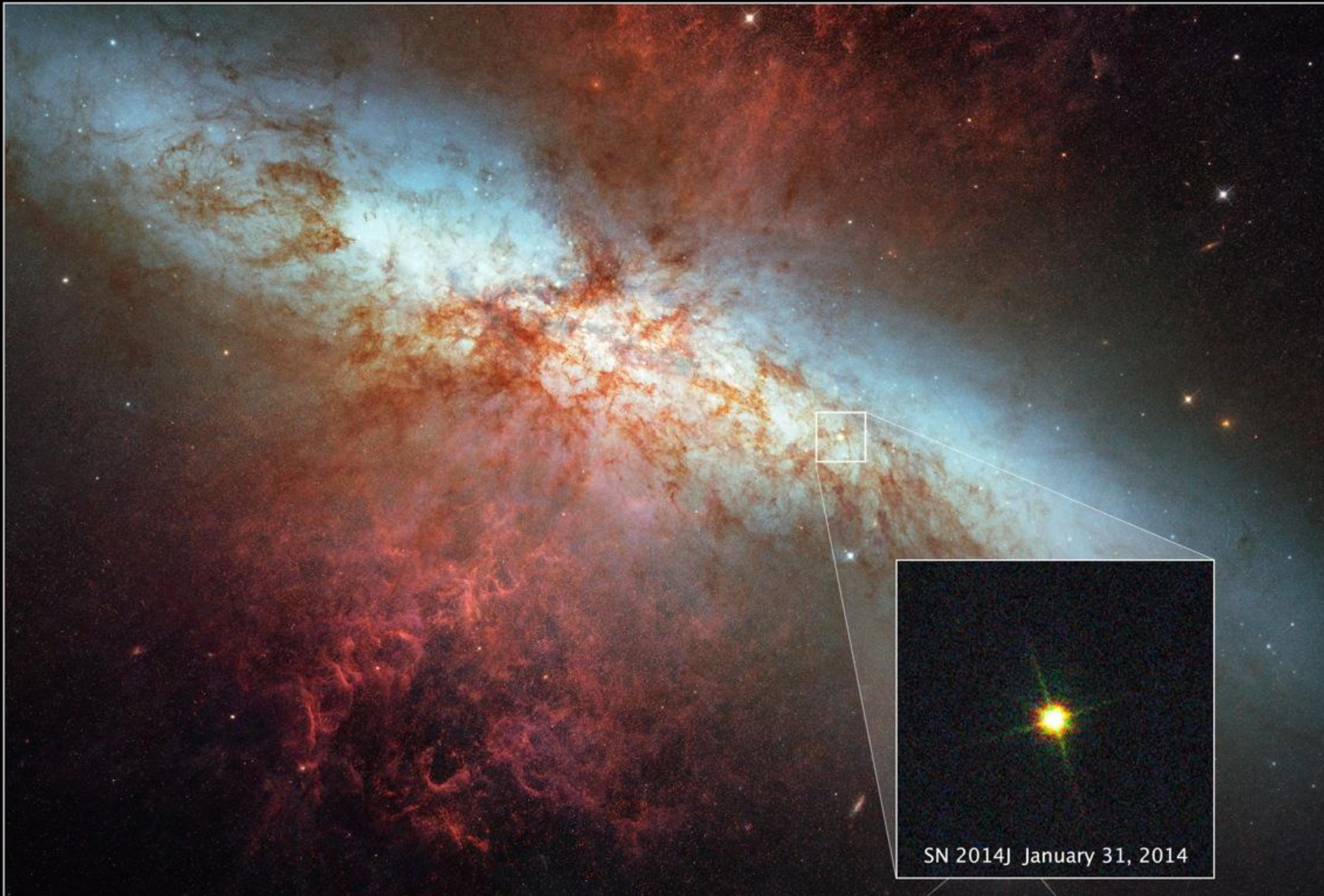
- Mass-loss mainly occurs due to ablation (shock-mediated heat transfer) and not stripping (momentum transfer) – Pan et al. (2012)
- Material is embedded in low-velocity SN ejecta with characteristic velocities of $\approx 1000\ km\ s^{-1}$
- Let's look for this material!

Liu et al. (2012)

SN 2011fe

- Brightest SN Ia since SN 1972E
- At only 6.4 Mpc (Shappee & Stanek 2011)
- Discovered less than 1 day after explosion by Palomar Transient Factory (Law et al. 2009)
- Extensive follow-up observations (from the radio to gamma rays)
- Normal "Plain Vanilla" Type Ia SN
- Only slightly reddened and in "clean" environment (Patat et al. 2011)

Image by B. J. Fulton, LCOGT



Supernova 2014J in Galaxy M82

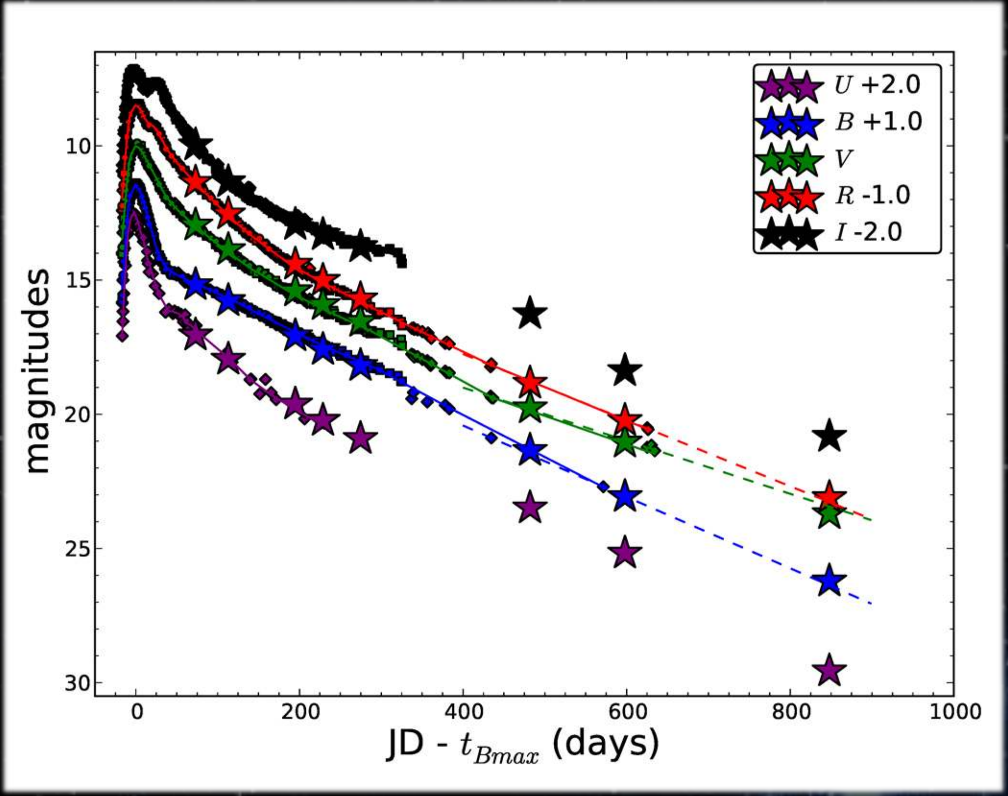
Hubble Space Telescope ▪ WFC3/UVIS ▪ ACS/WFC

NASA and ESA

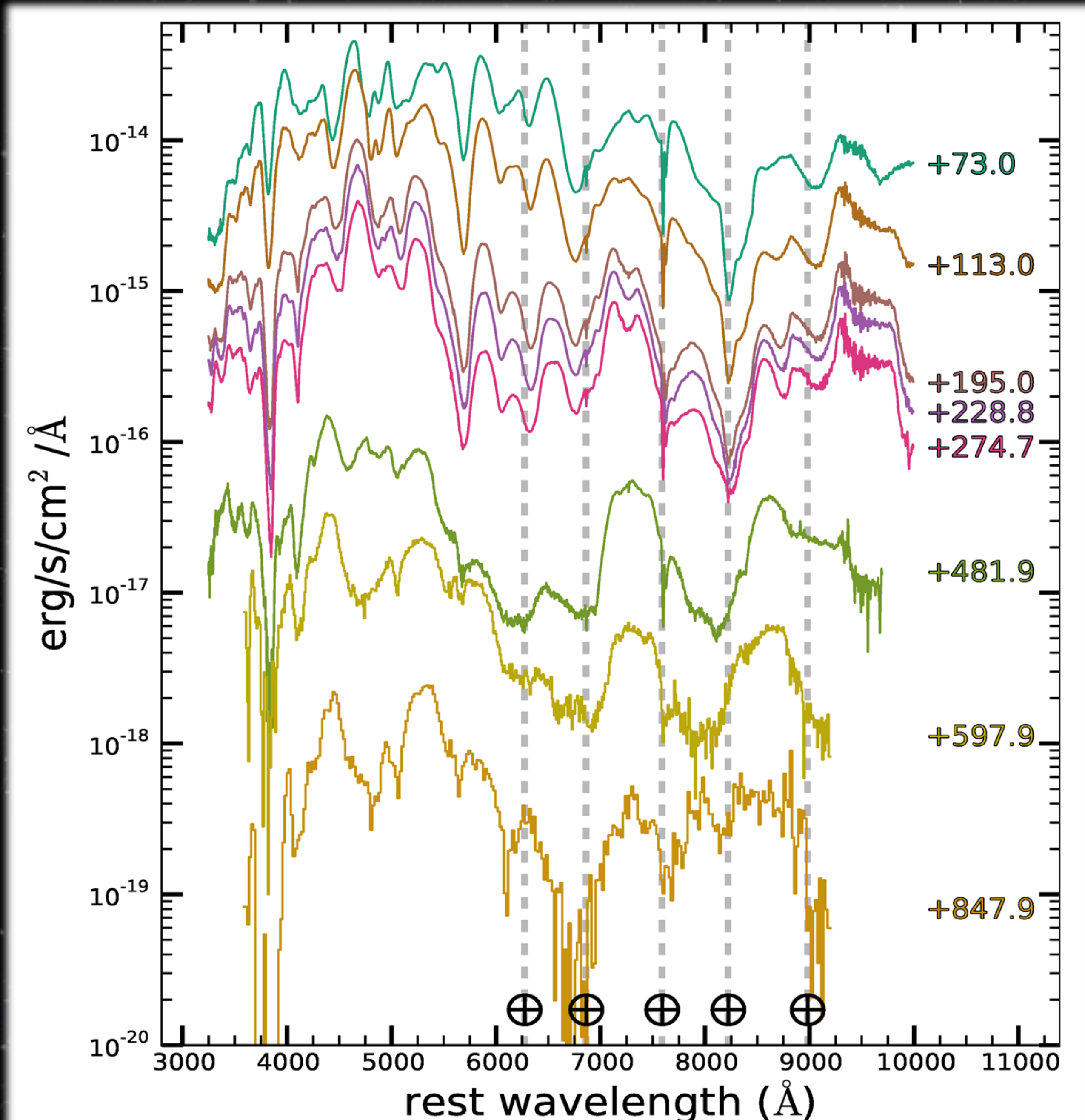
STScI-PRC14-13a

LBT and SN 2011fe

- 8 MODS spectra from 70 – 850 days are B-band maximum light
- LBC U,B,V,R-band observations
  - Before the SN and continuing
  - Part of the LBT monitor project (see Jill Gerke's talk… NEXT!!!)

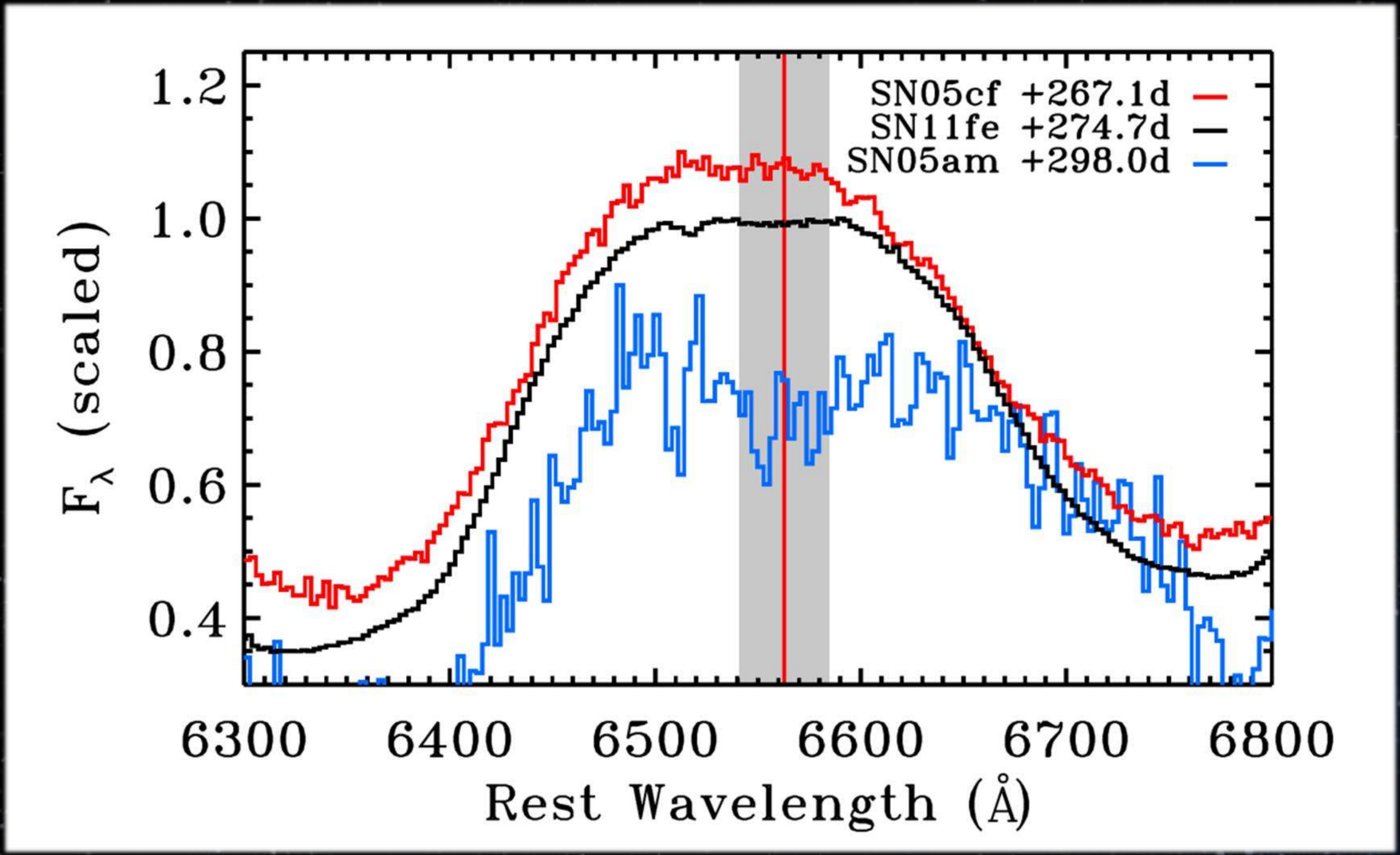


- Shappee et al. 2014 in prep.



- Shappee et al. 2014 in prep.

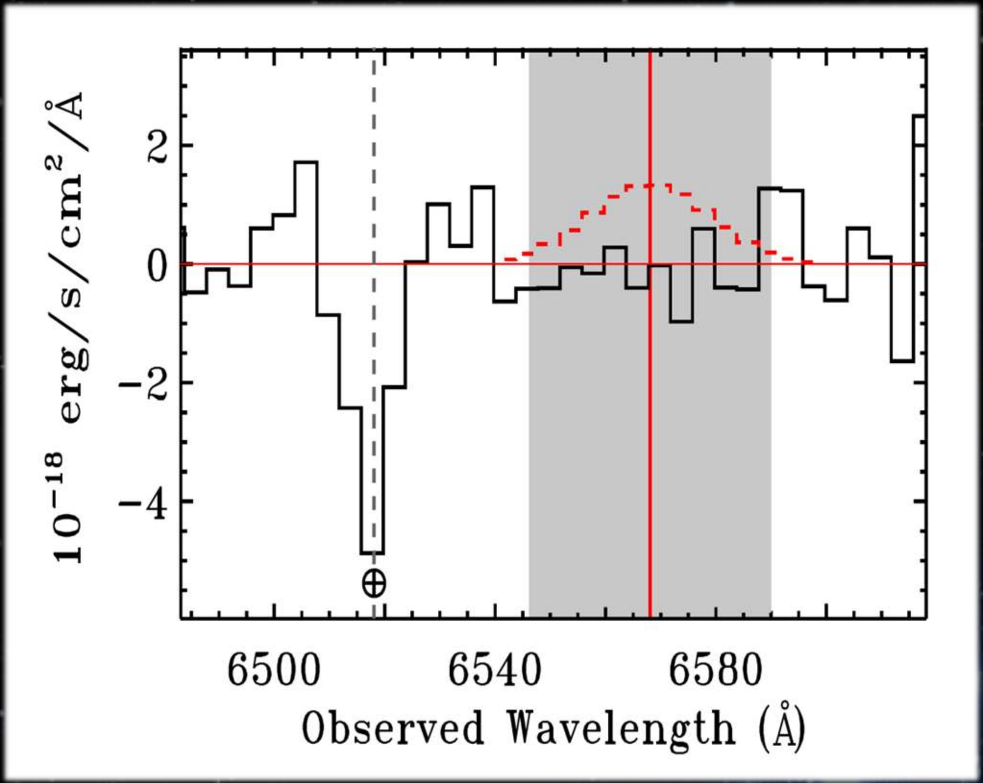
Nebular Phase Spectra Comparison



- Shappee et al. 2013

Nebular Phase Spectra

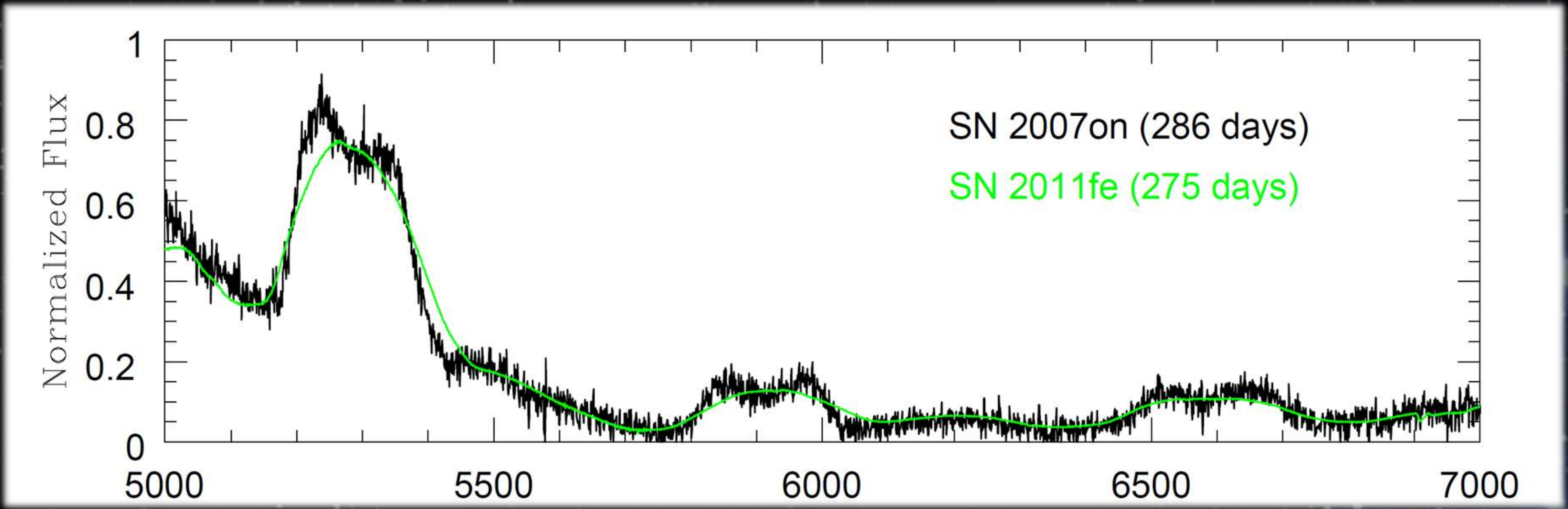
- Conservative limit on hydrogen flux of $< 3.14 \times 10^{-17} \mathrm{erg\ s^{-1} cm^{-2}}$
- Adopting the models of Mattila et al. (2005), these limits translate into a mass limit of $< 0.001\, M_{\odot}$
- This limit rules out non-degenerate hydrogen-rich companions



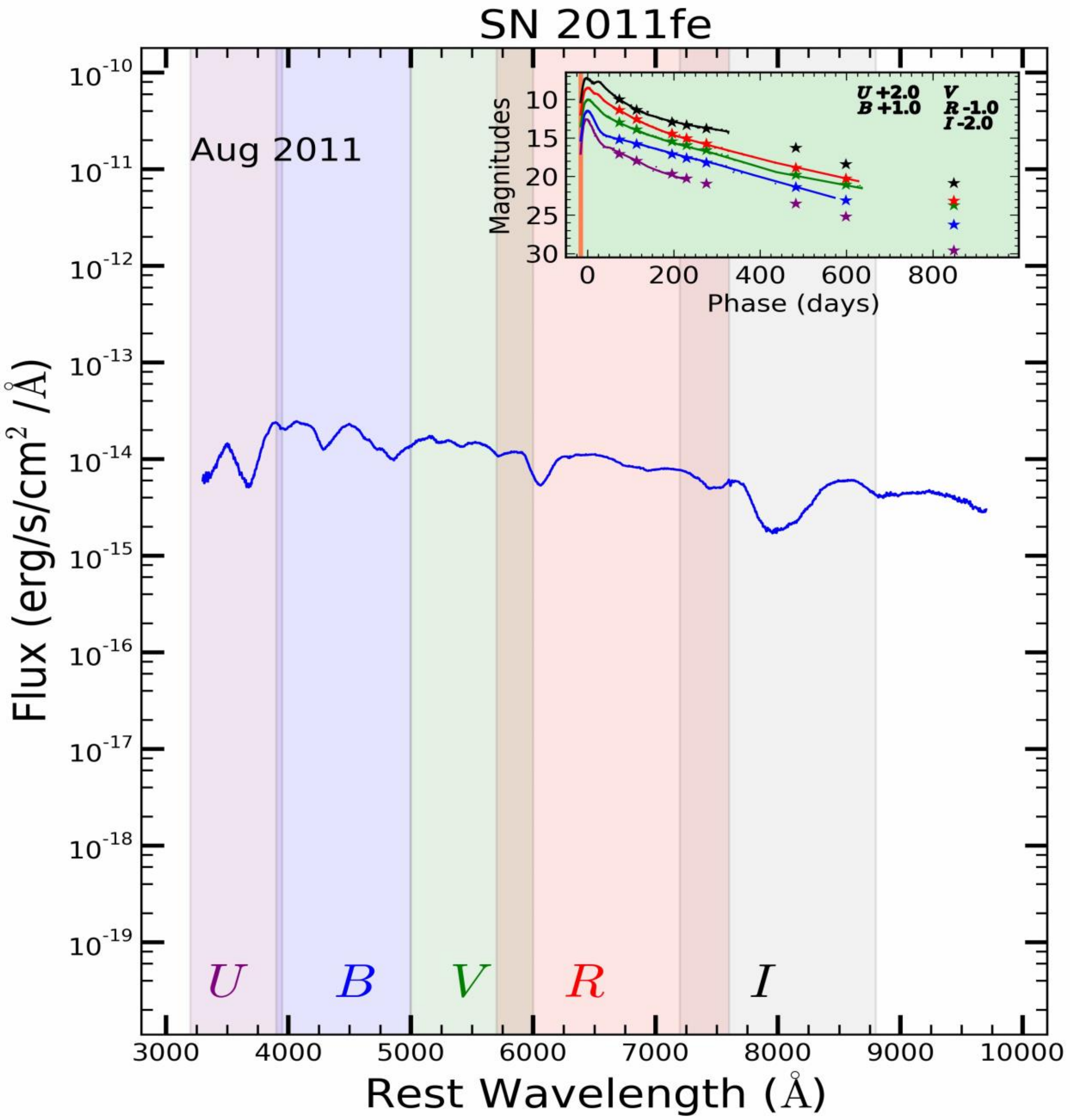
- Shappee et al. 2013

Golden Standard

The LBT late-time spectra of SN 2011fe are already being used as the standard comparison for SNe Ia.



- Dong et al. 2014



Shappee et al. (2014),
Spectra are from the Large Binocular telescope and The Nearby Supernova Factory
Inspired by http://snfactory.lbl.gov/snf/data/index.html