Type Iax SNe 2010ae and 2012Z: from the faint and fast to the bright and slow

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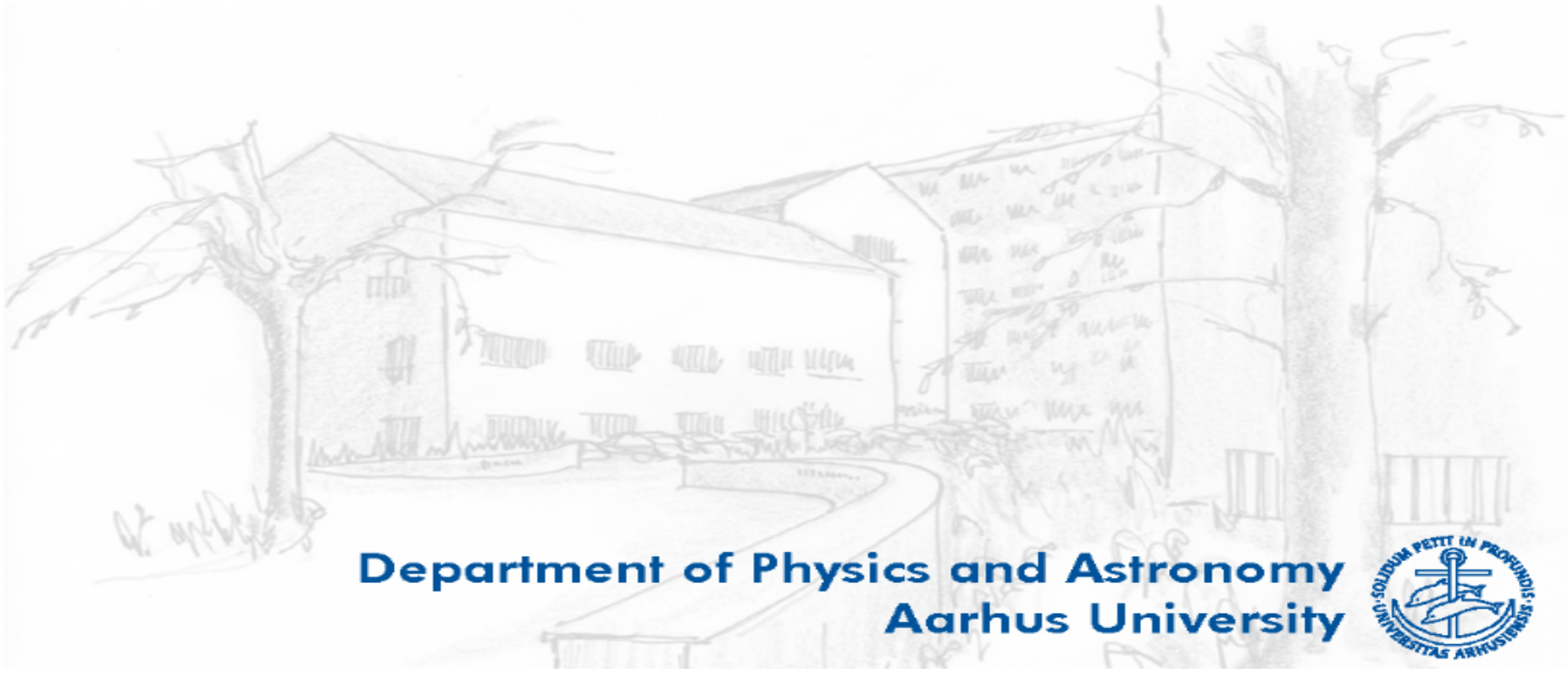
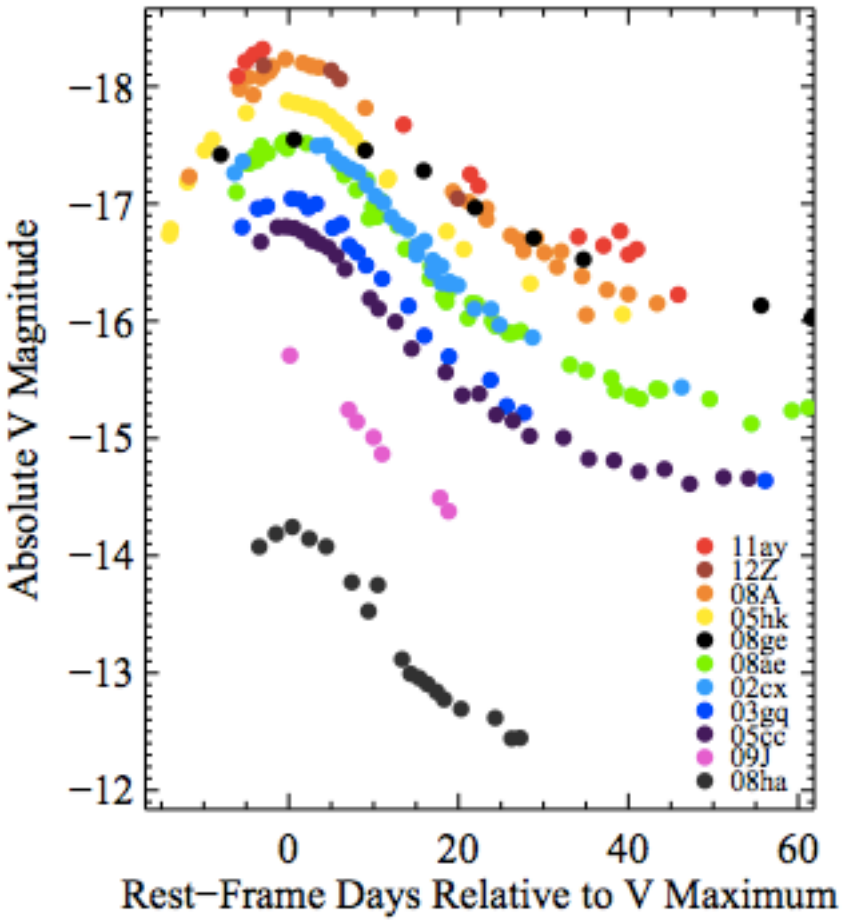
Stritzinger et al. 2014, A&A, 561, 146
Stritzinger et al. 2014, A&A, submitted

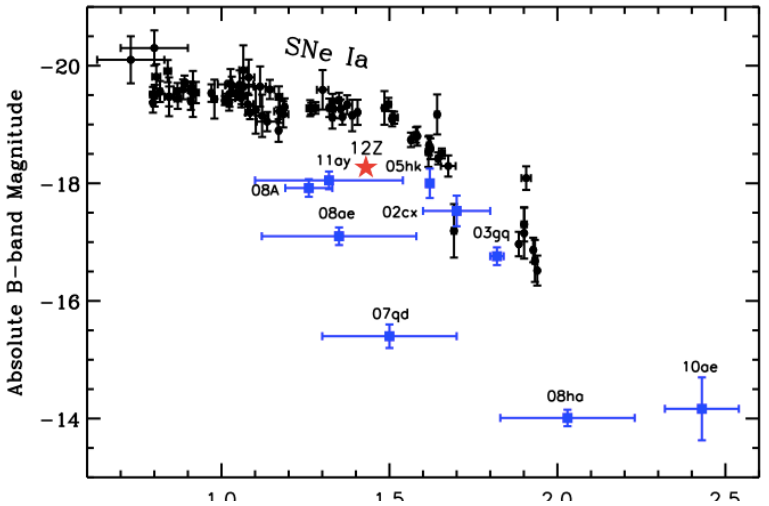


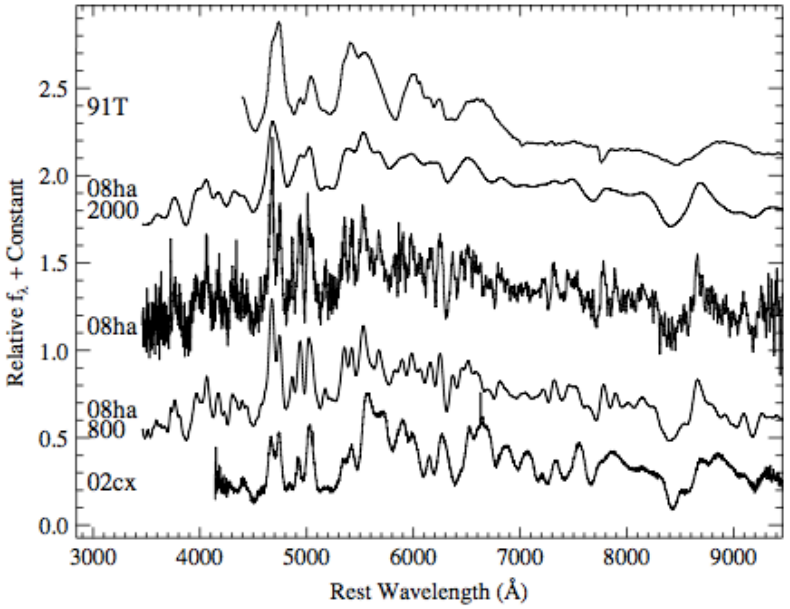
Overview

- Brief overview of the 2002cx or Type "Iax" class
- Observations of the low luminosity SN 2010ae
- Observations of the bright SN 2012Z
- Viable progenitor scenarios

Properties of the Iax class







Foley et al. (2013)

Foley et al. (2009)
Valenti et al. (2009)

Summary of SNe Iax (2002cx-like)

Bizarre & Coarsely similar to normal SNe Ia

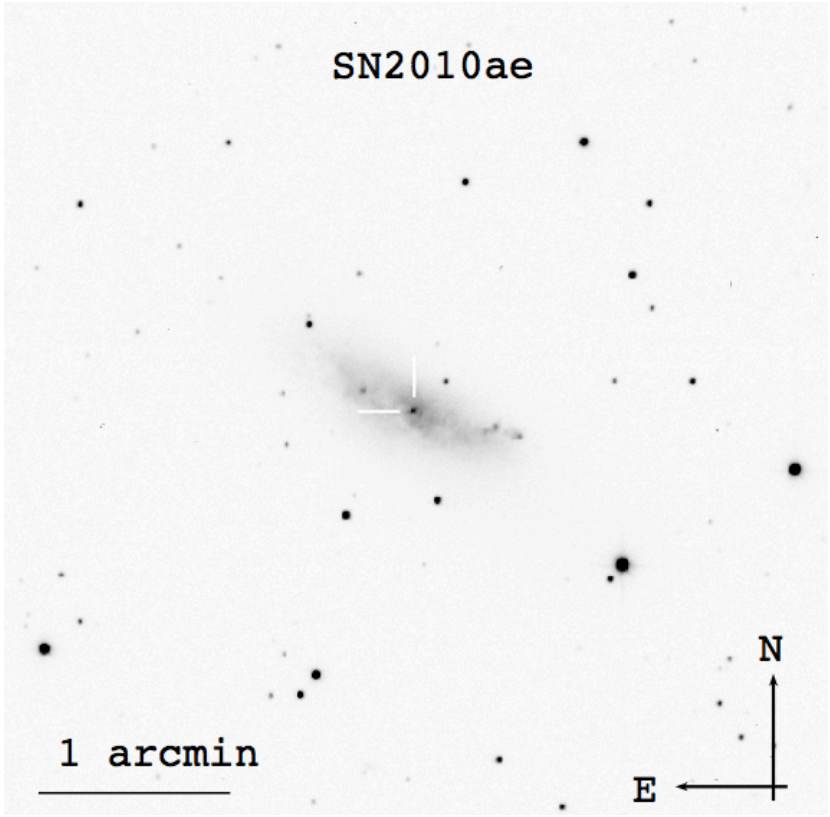
- Significant range in luminosity (-18.5 < M < -14 mag)
  → small ^{56}Ni content, and do not *really* obey a LWR
- NIR bands peak well after optical bands
- No secondary maximum in the NIR
- Hot spectra with low velocities (narrow lines)
- Late phase spectra are just odd, not truly nebular!

- Tend to occur in late-time galaxies, low metallicity?
- 5-30% of the overall SNe Ia rate

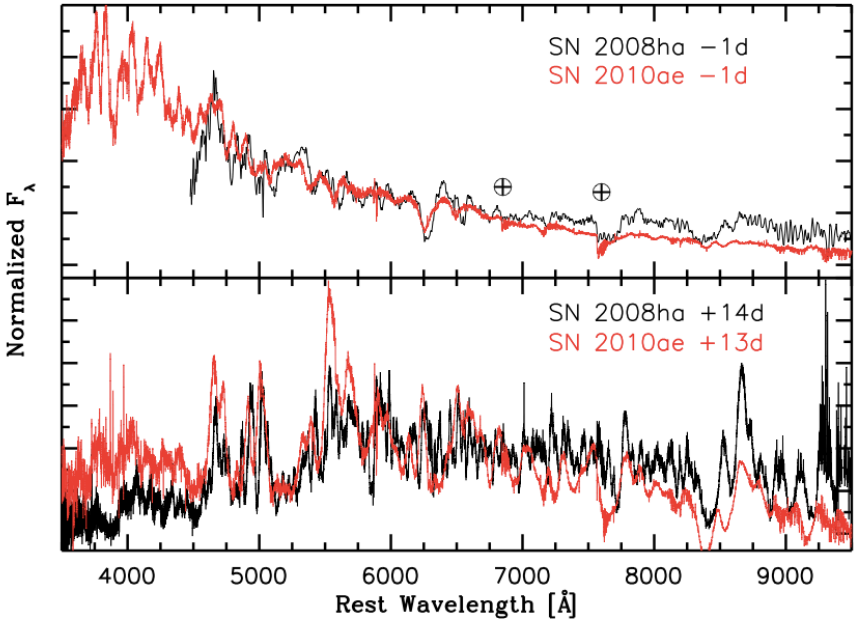
Supernova 2010ae

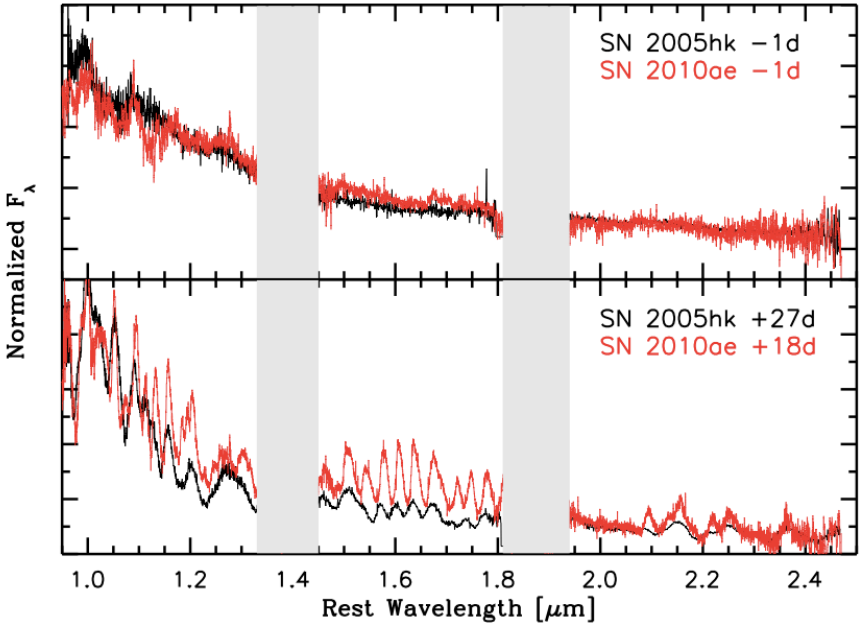
- Discovered by CHASE within a week of explosion (Pignata et al. 2010)

- Classified as a bright SN, but soon after realized it to be a low-luminosity 2002cx-like

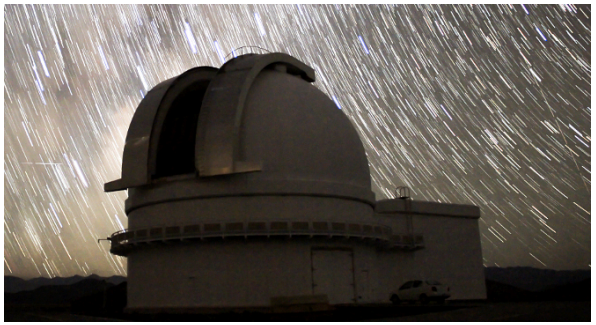


Spectral comparison to SN 2008ha

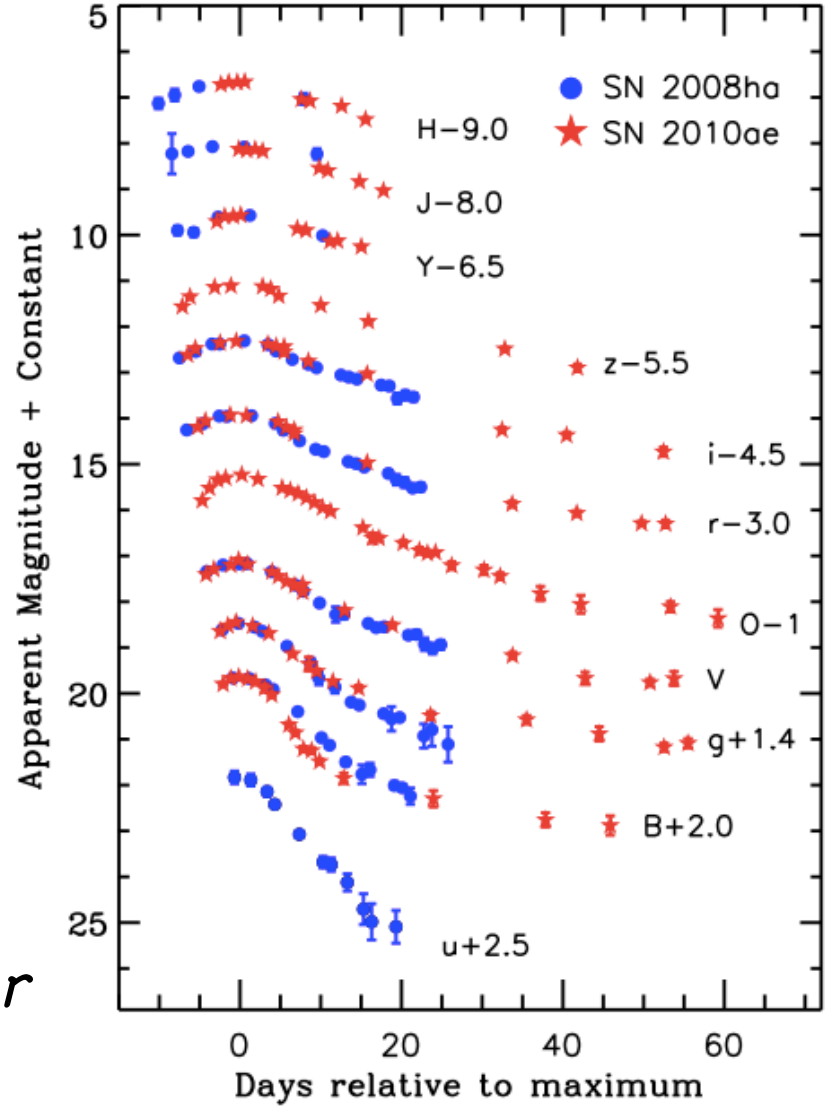




Optical and Near-IR Light Curves

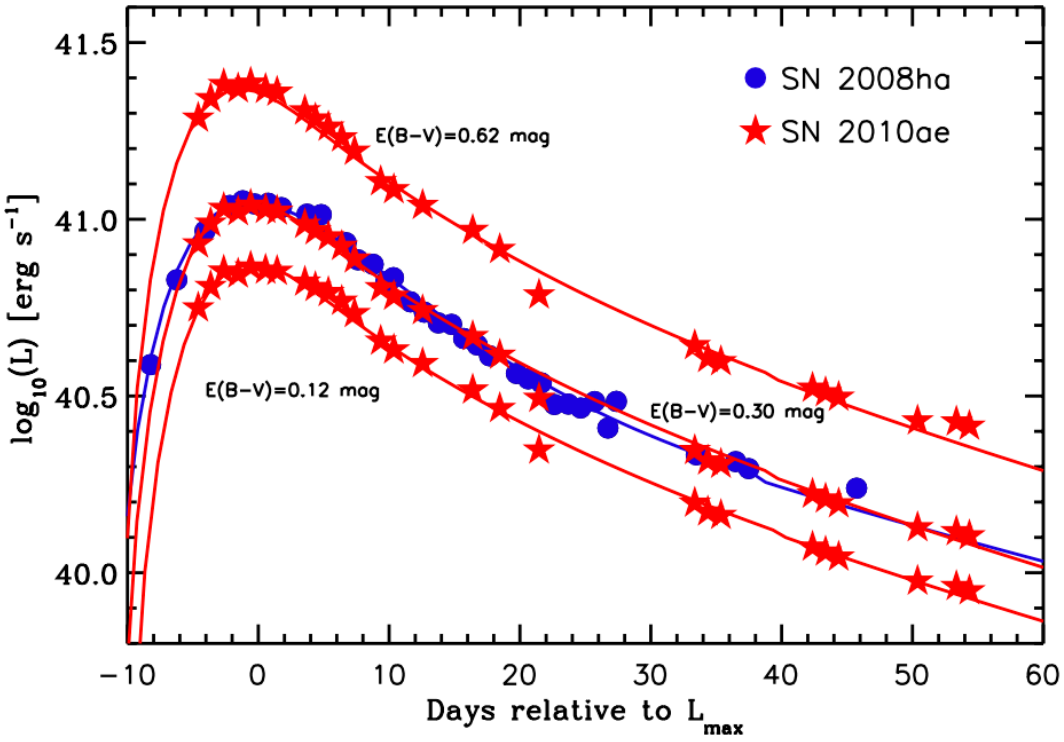


- Light curve shape is fast and suggestive of a small M_{ej}
- NIR bands peak ≈ 7 days *after* the optical

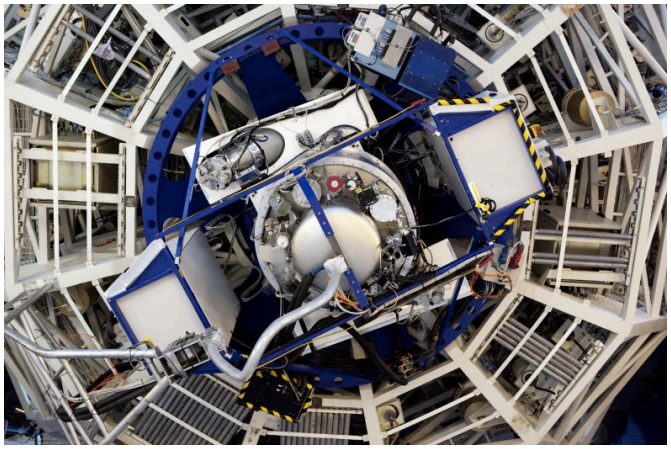


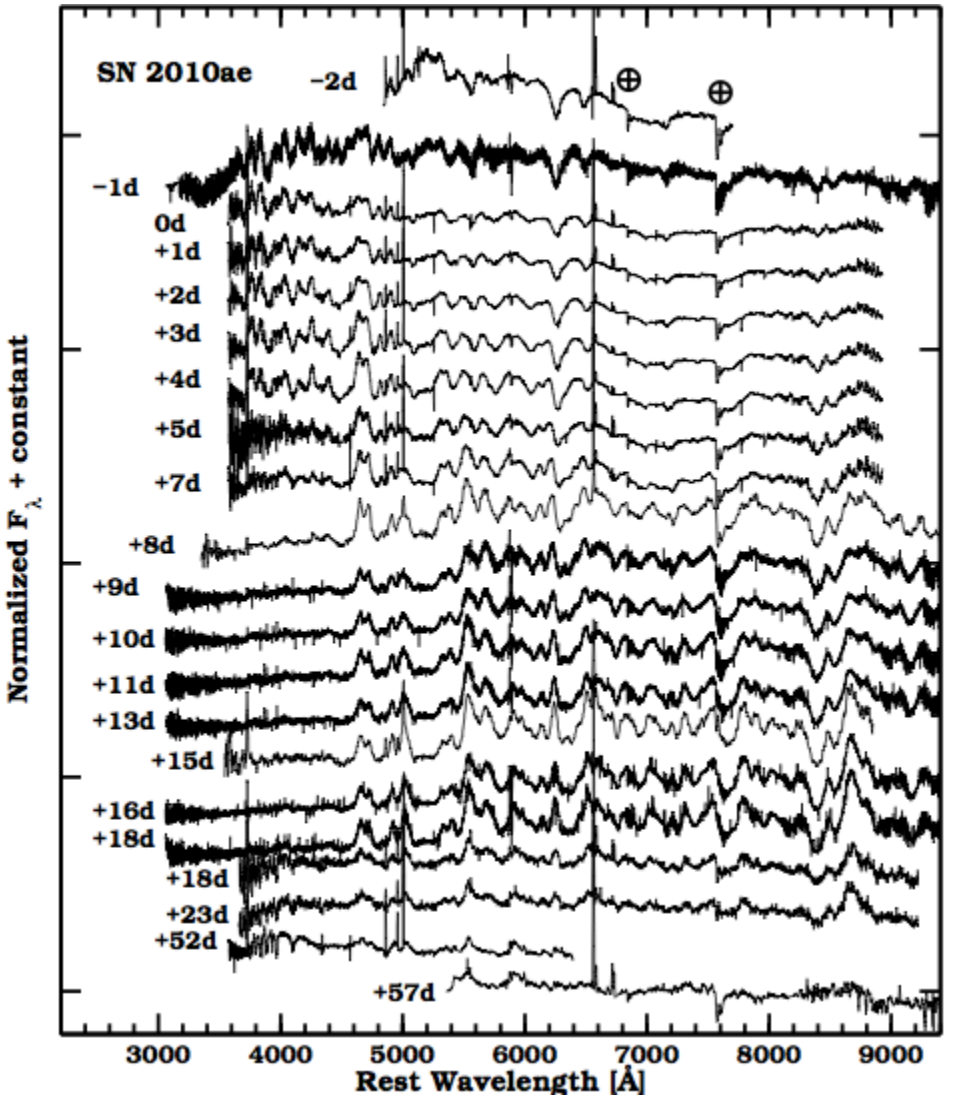
UVOIR Light Curves

- Peak brightness implies $^{56}Ni \approx 0.003\ M_{\odot}$
- LCs suggest $M_{ej} \approx 0.5\ M_{\odot}$
- Low Kinetic energy $\approx 10^{49}$ erg

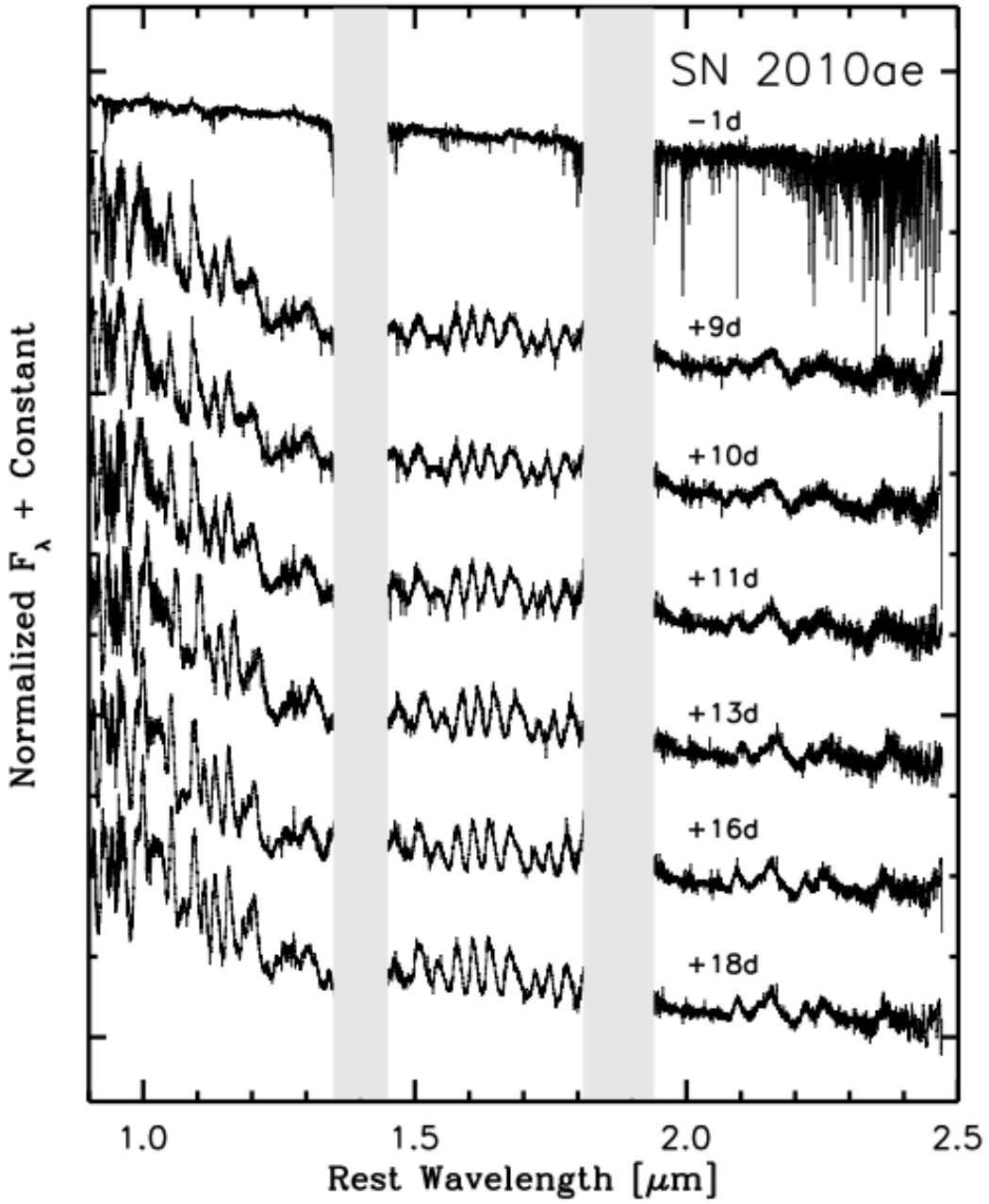


Optical Spectroscopy

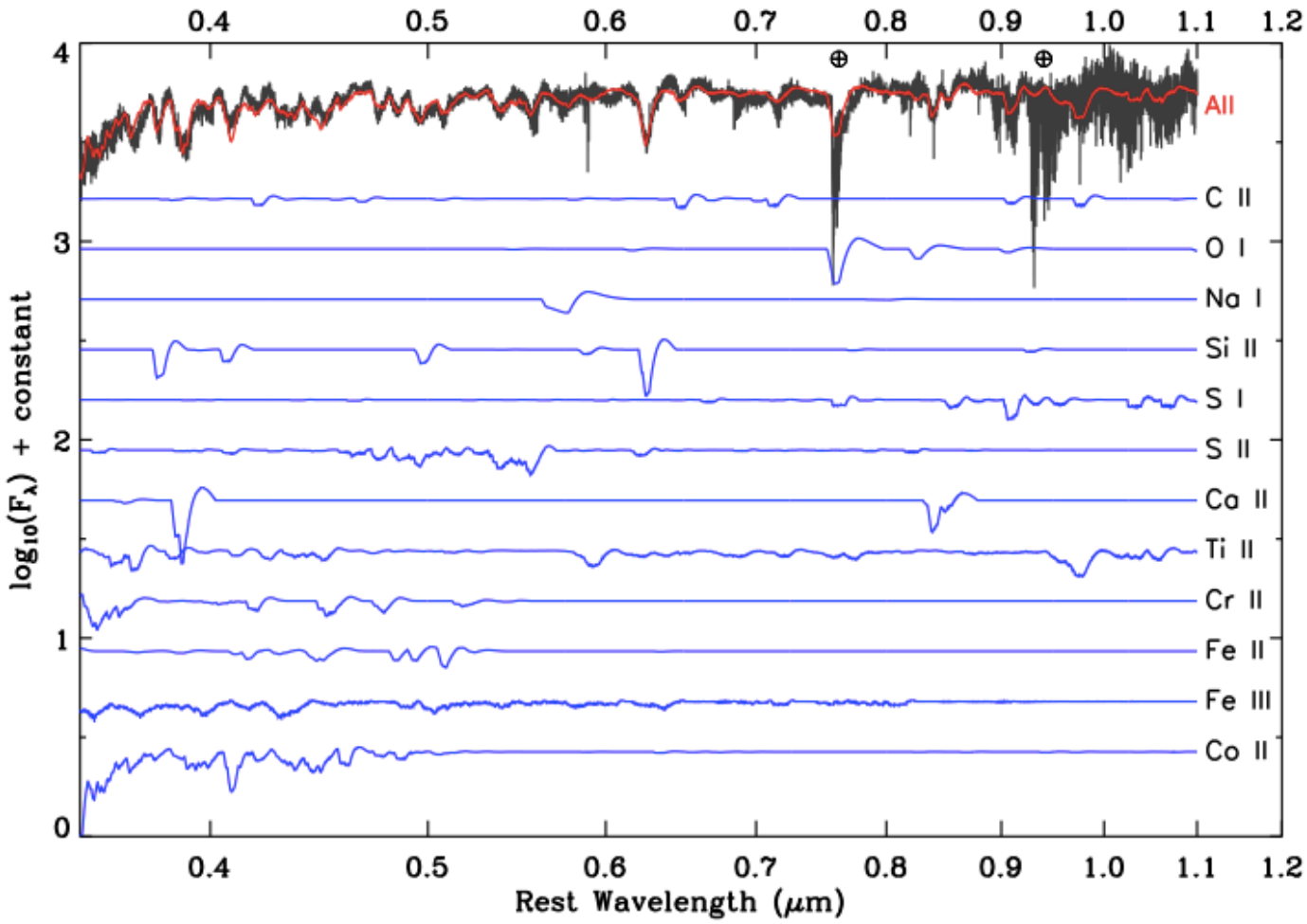




NIR Spectra

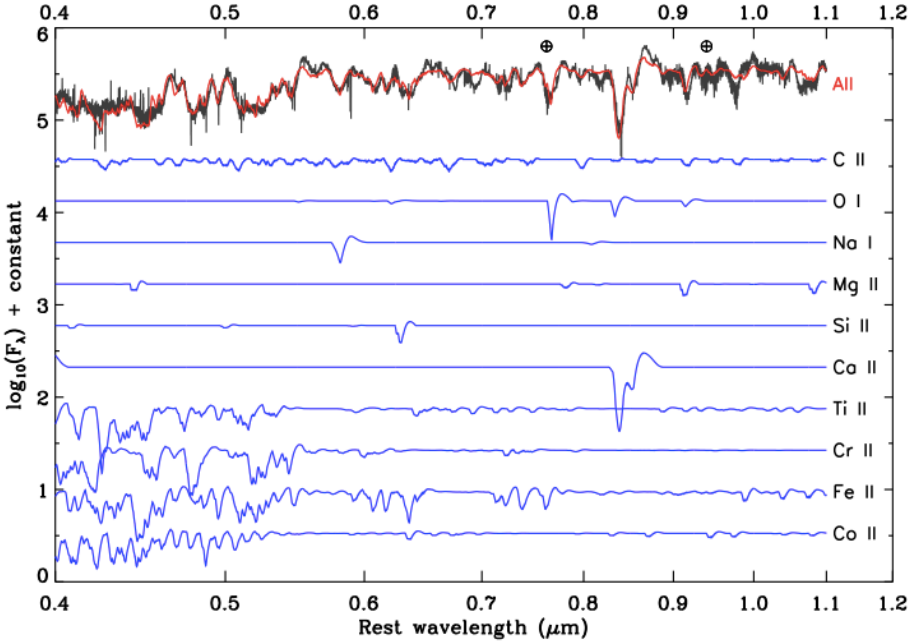

SN 2010ae
−1d
+9d
+10d
+11d
+13d
+16d
+18d
Normalized F_λ + Constant
1.0
1.5
2.0
2.5
Rest Wavelength [μm]

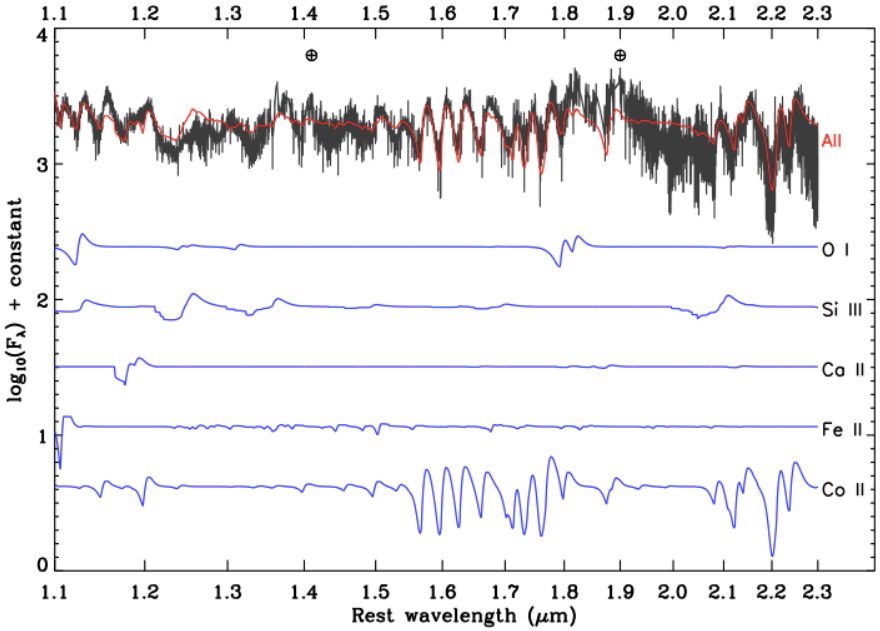
ID of spectral features I.



via SYNAPPS

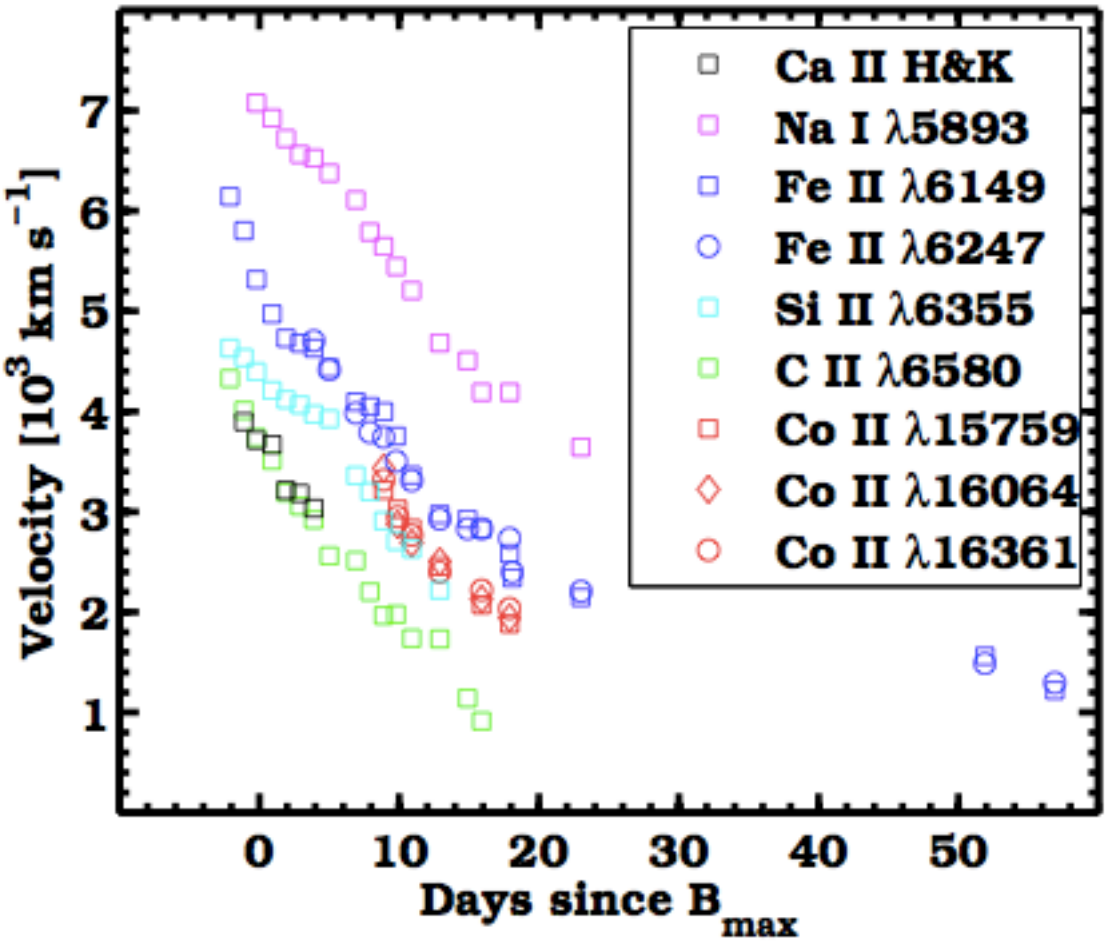
ID of spectral features II.



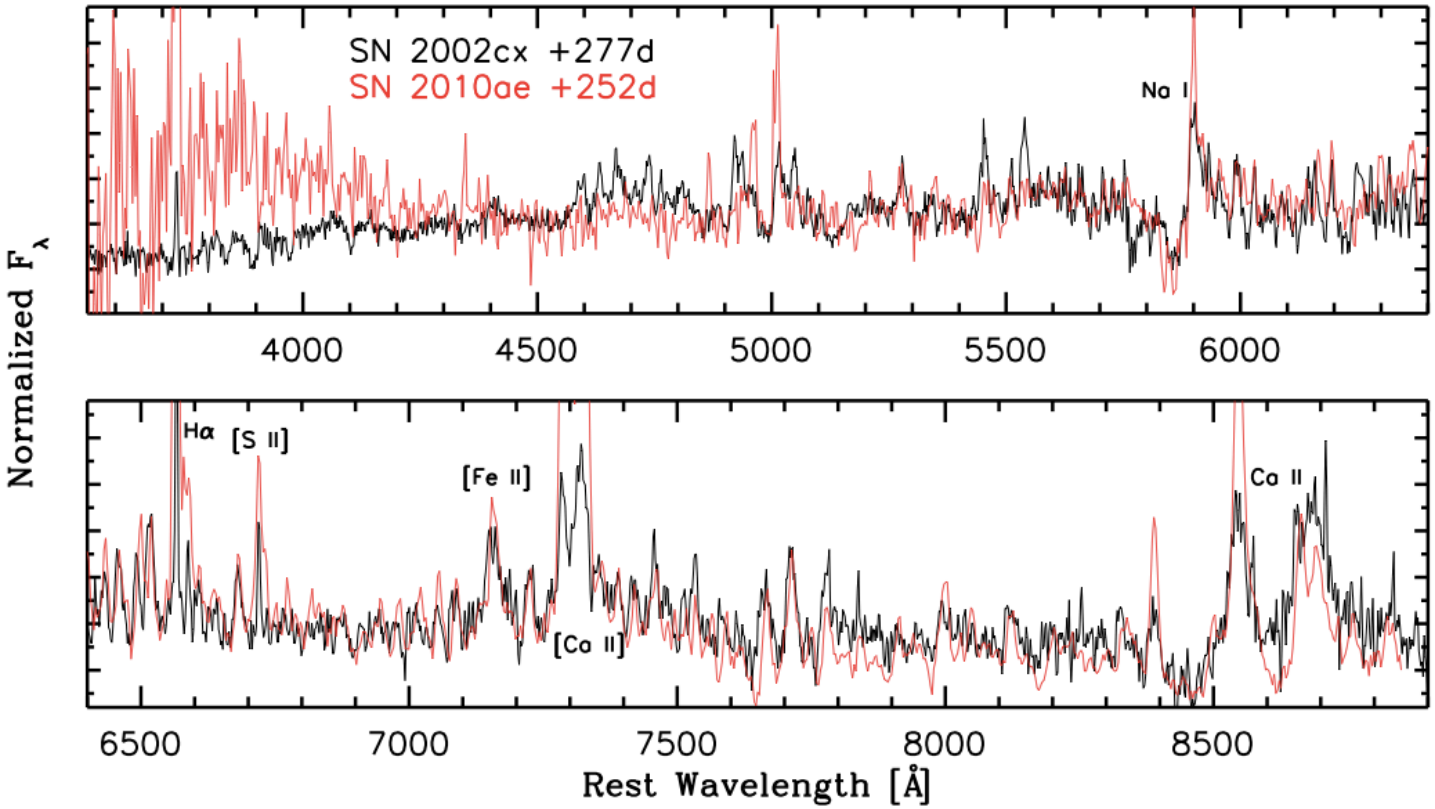


via SYNAPPS

Optical and NIR Line Velocities



Late phase VLT spectrum



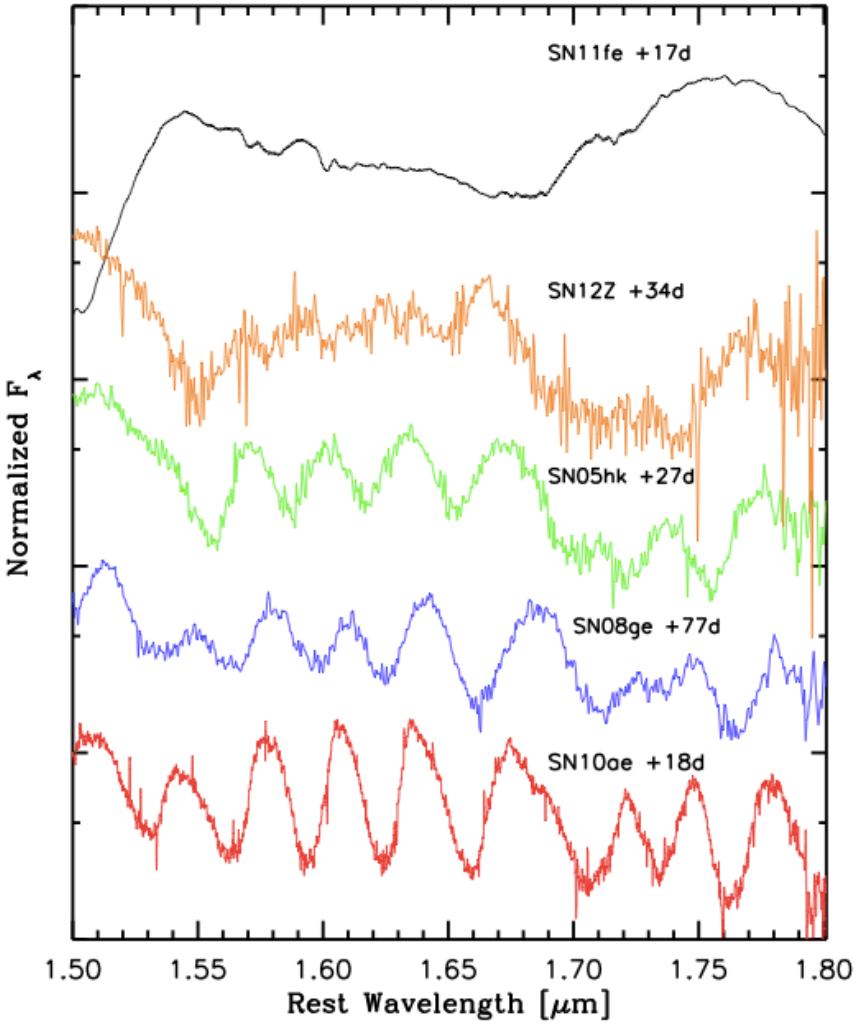
- No Fe III/Fe II
- No Oxygen
- Prevalent Ca lines
- Like 2002cx, *but not exactly*

New Insight from NIR spectroscopy

- Co II features are ubiquitous to SN Iax
- Smaller velocities

→less blending
→more prevalent features!

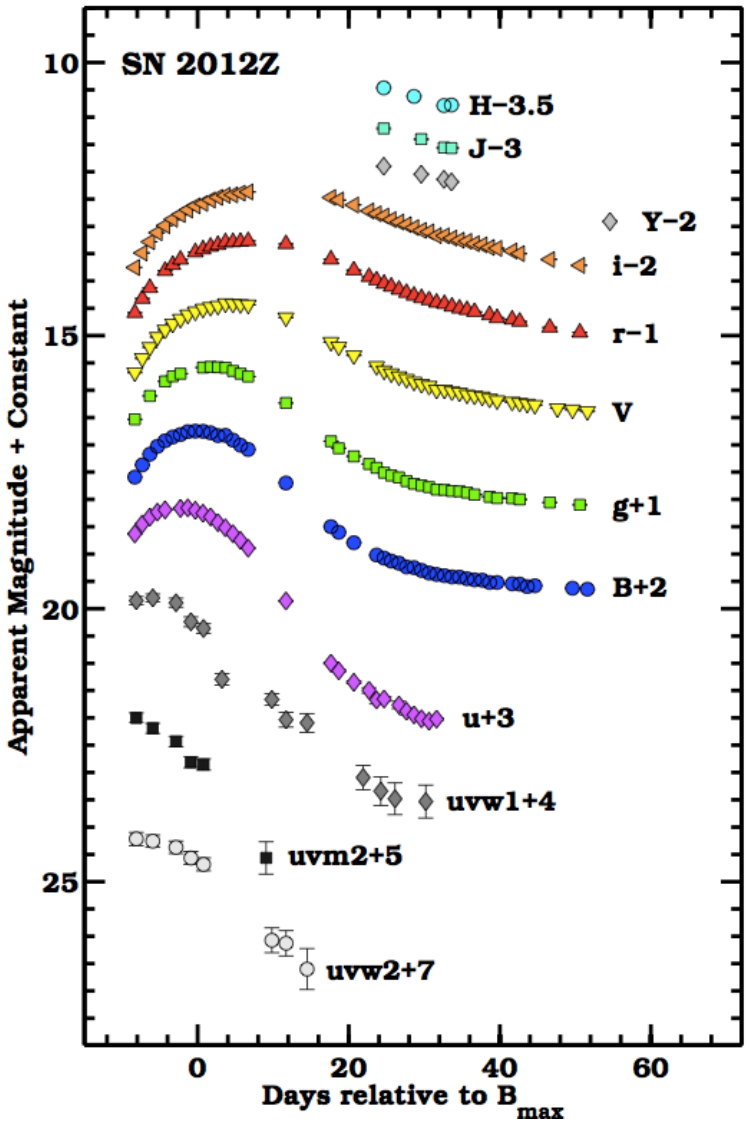
- Faint and fast objects are linked to the brighter end of the SN Iax distribution

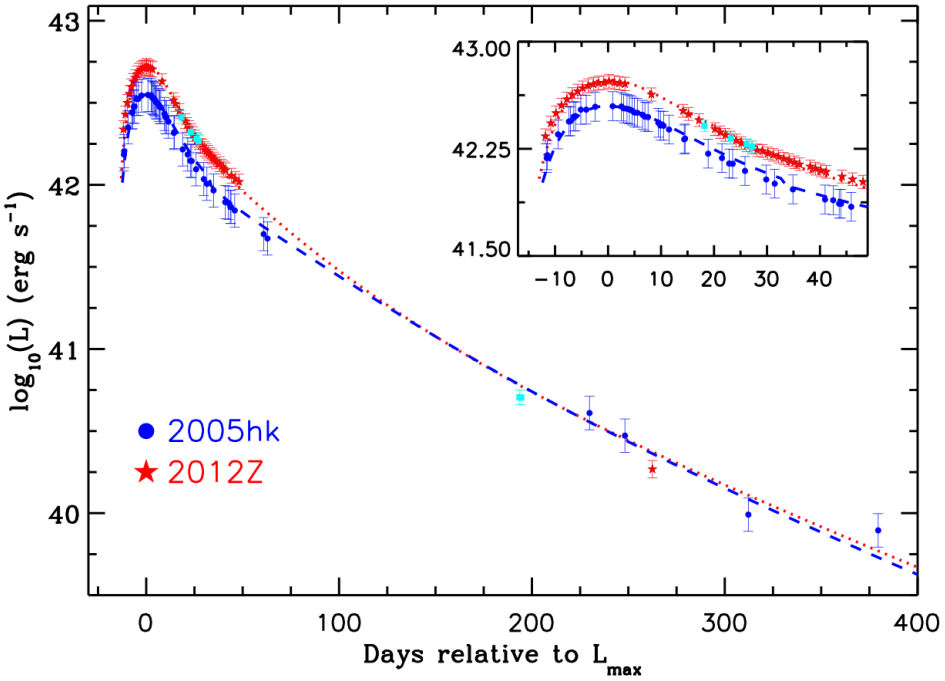


SN 2012Z

Observed as part of CSP II

Swift & CSP LCs

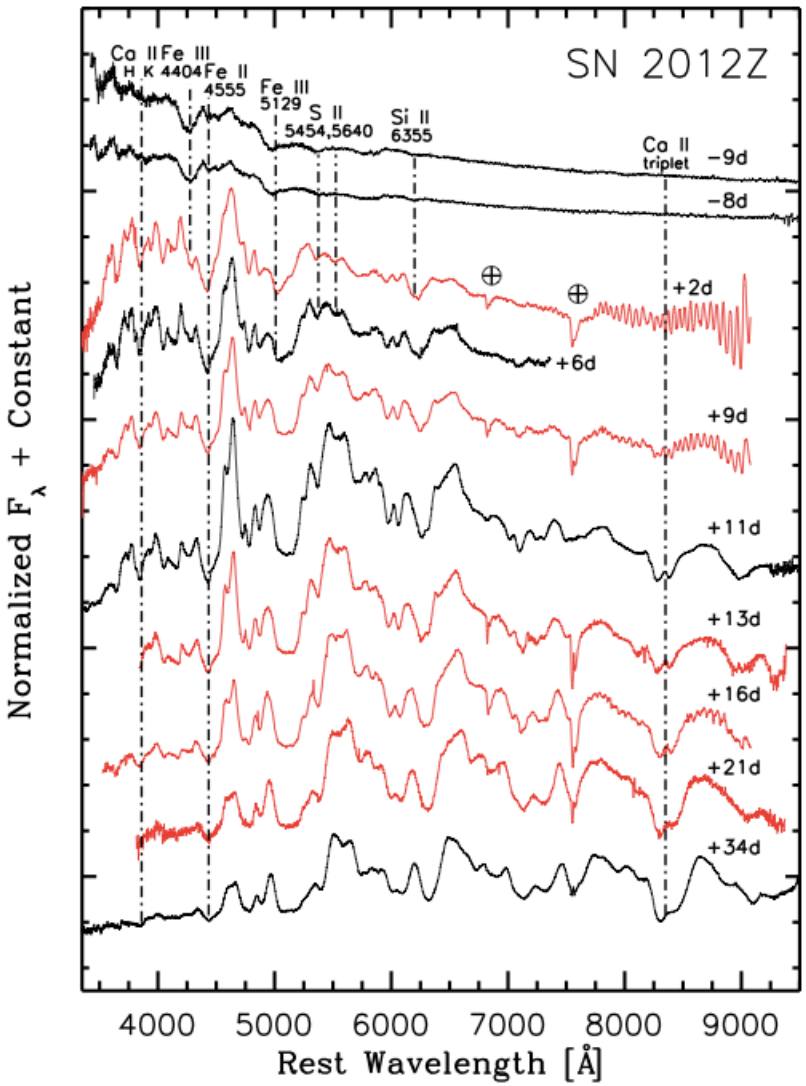


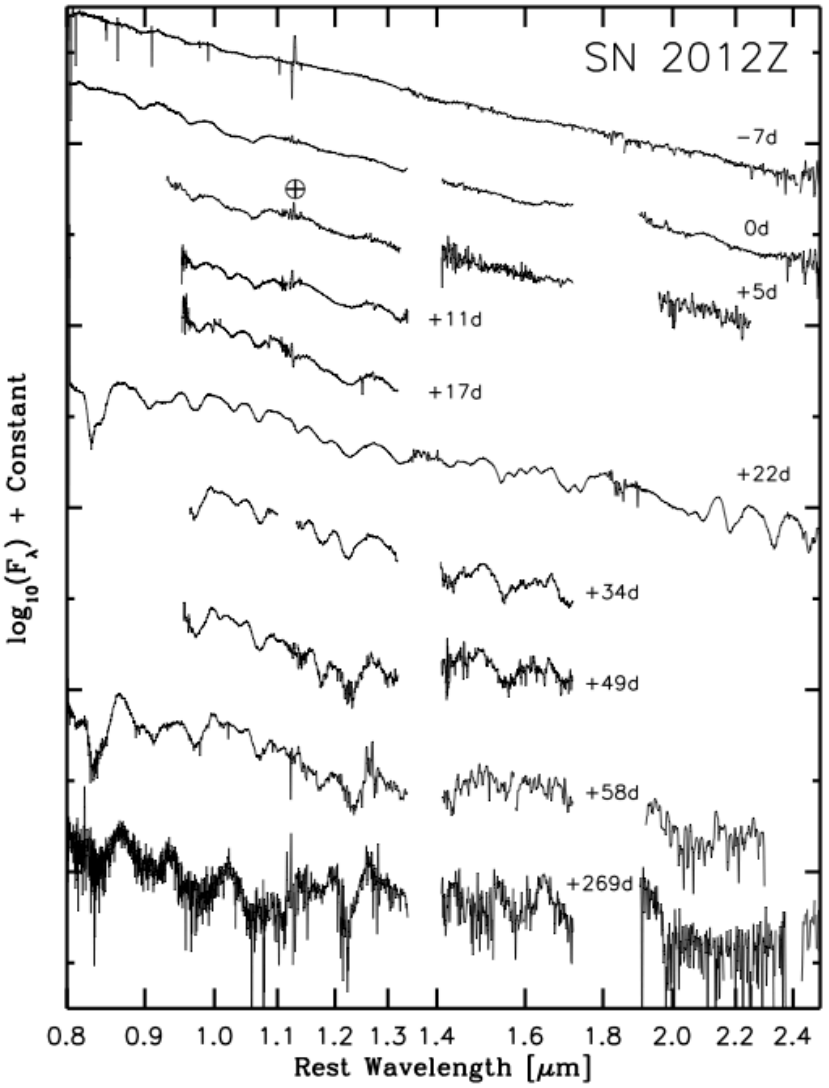


Toy Model Fits Indicate:

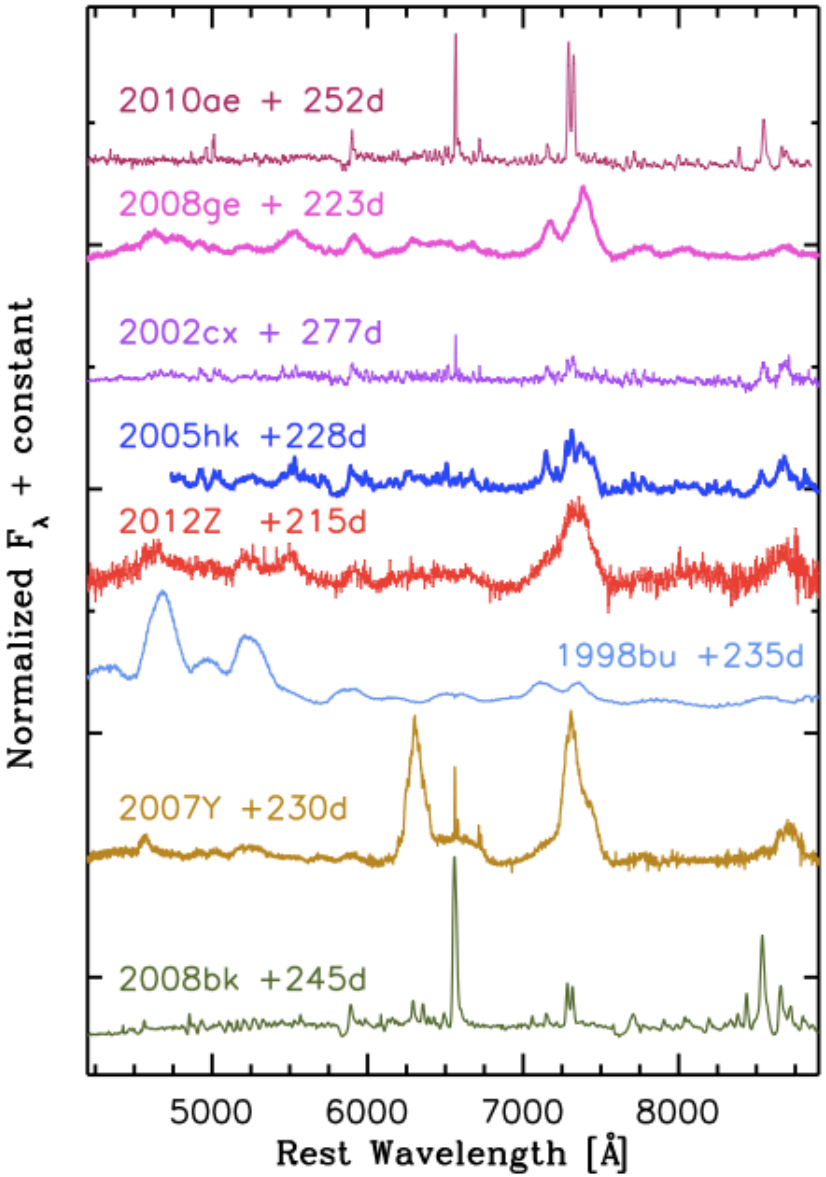
- 0.15-0.20 $M_\odot$ of ^{56}Ni
- $M_{ej} = M_{CH}$
- KE = 10^{51} erg

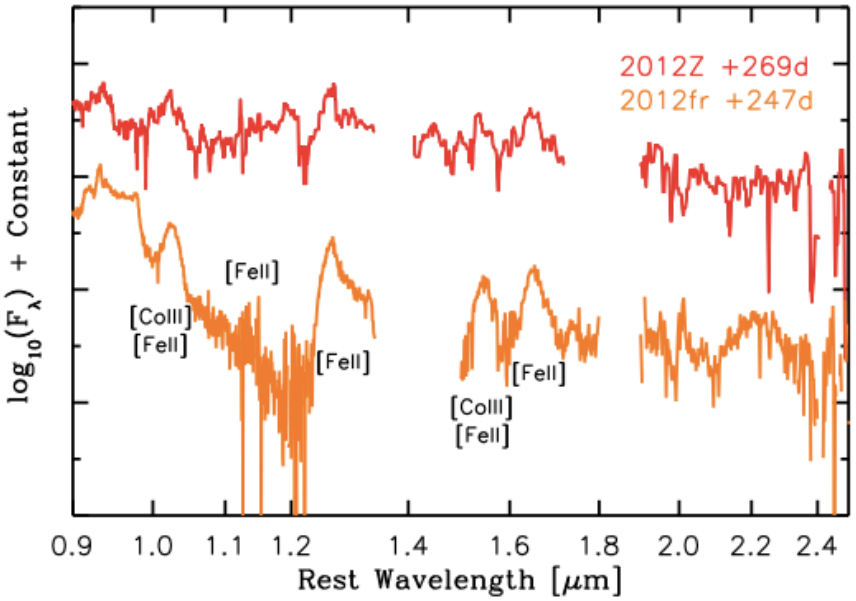
Spectra

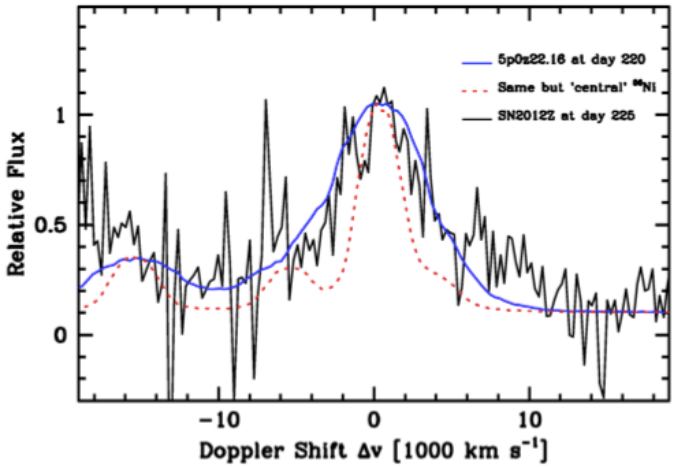

SN 2012Z
Ca II H K
Fe III 4404
Fe II 4555
Fe III 5129
S II 5454,5640
Si II 6355
Ca II triplet
−9d
−8d
+2d
+6d
+9d
+11d
+13d
+16d
+21d
+34d
Normalized F_λ + Constant
4000 5000 6000 7000 8000 9000
Rest Wavelength [Å]


SN 2012Z
−7d
0d
+5d
+11d
+17d
+22d
+34d
+49d
+58d
+269d
$\log_{10}(F_\lambda)$ + Constant
0.8 0.9 1.0 1.1 1.2 1.3 1.4 1.6 1.8 2.0 2.2 2.4
Rest Wavelength [μm]

Late Phase Spectroscopy of SNe Iax

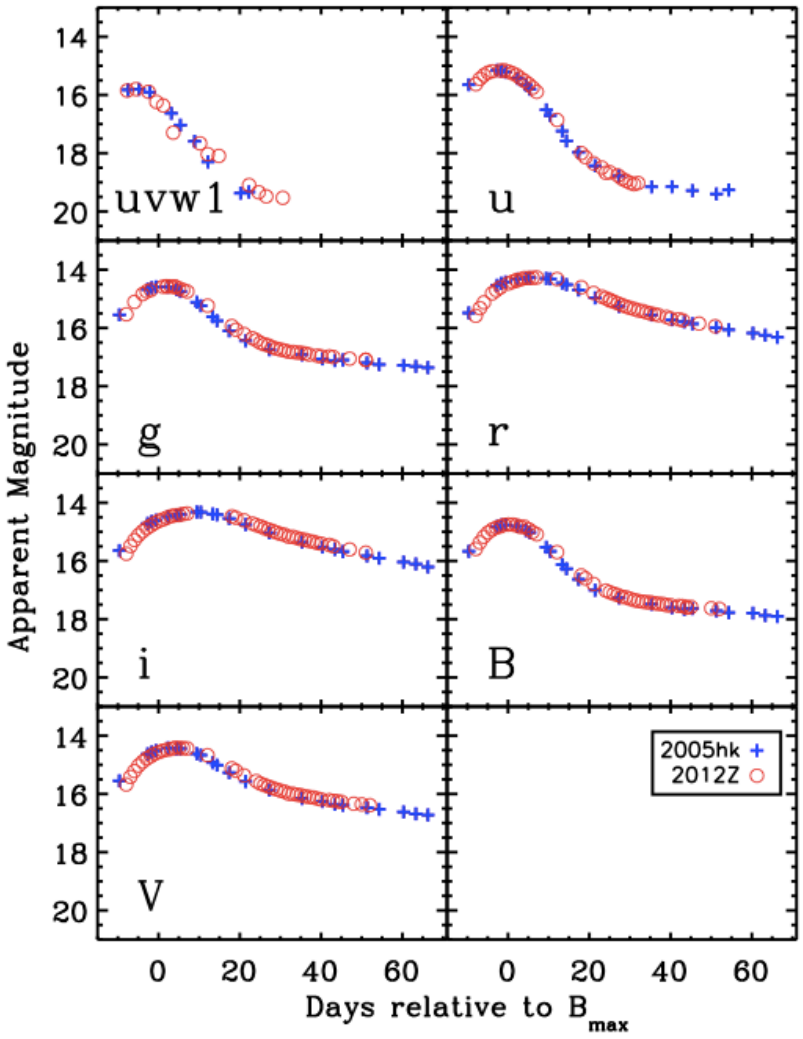


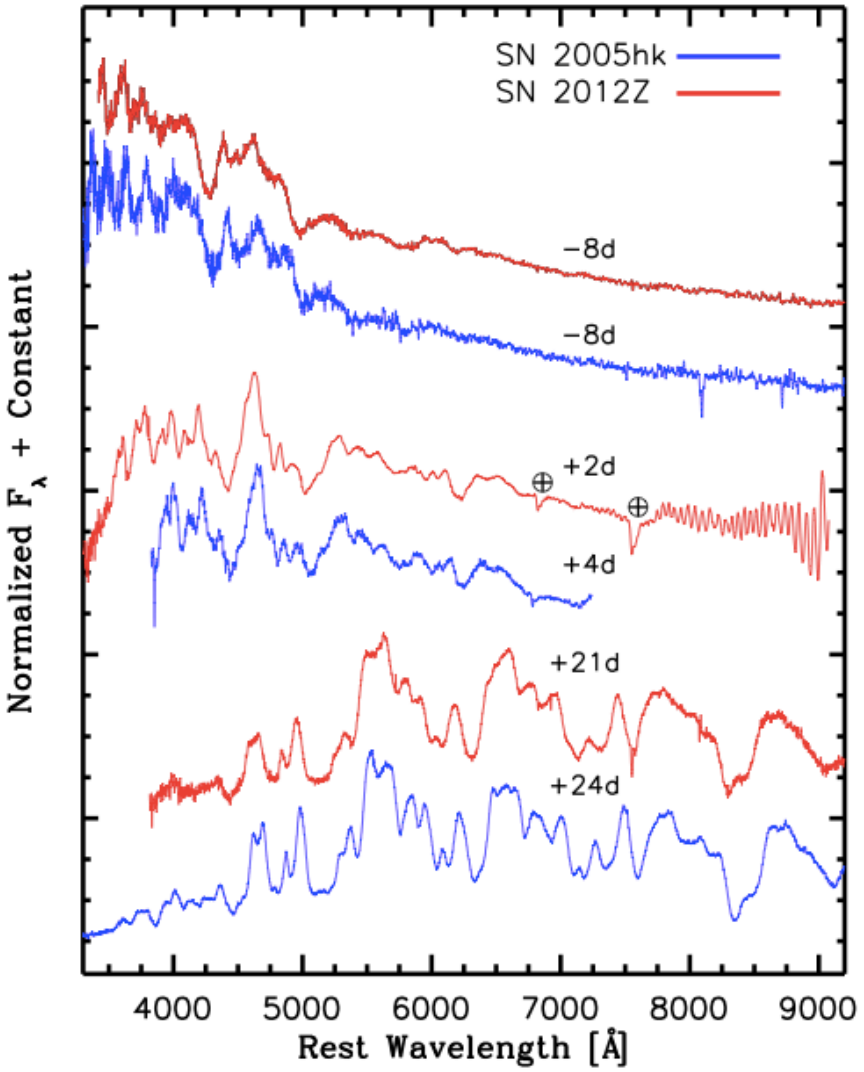




→ ^{56}Ni hole in the center

Comparison to SN 2005hk

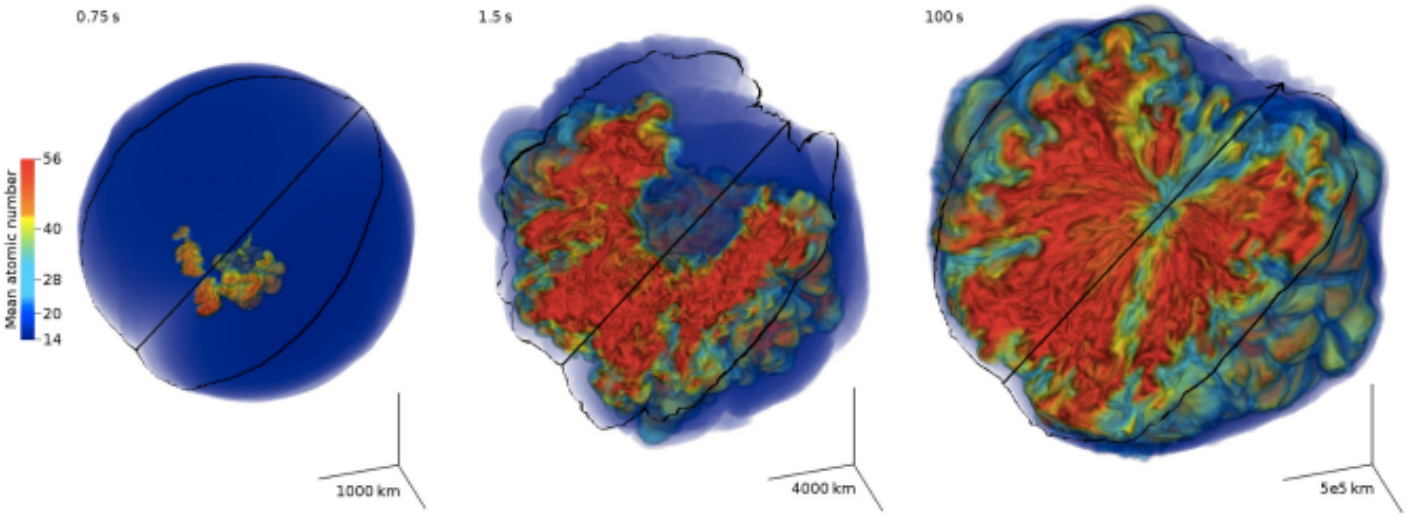




Summary of Main Findings

- Consistent with a M_{ch} white dwarf
- Spectra reveal a layered chemical structure
- Late NIR line profile suggests high density burning
- Very similar to SN 2005hk

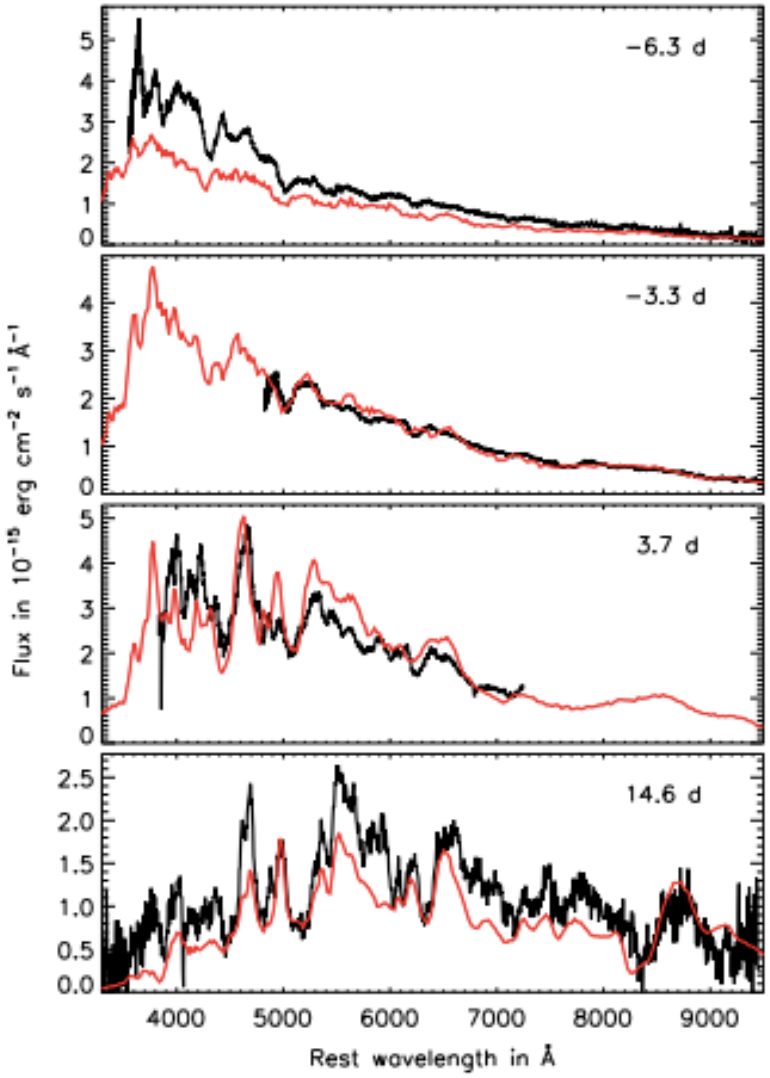
Progenitor: Bound Remnants

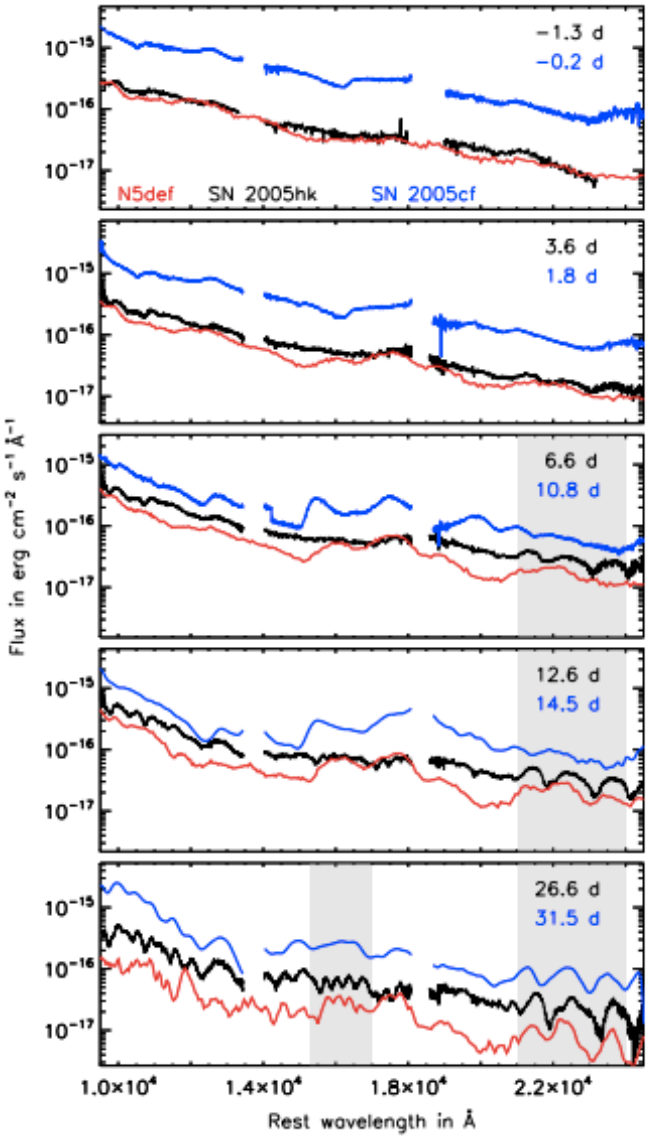


- Early phase emission powered by ejected ^{56}Ni
- Late phase emission powered by bound remnant

Kromer et al. 2013

Bound Remnants: Model Spectra of SN 2005hk





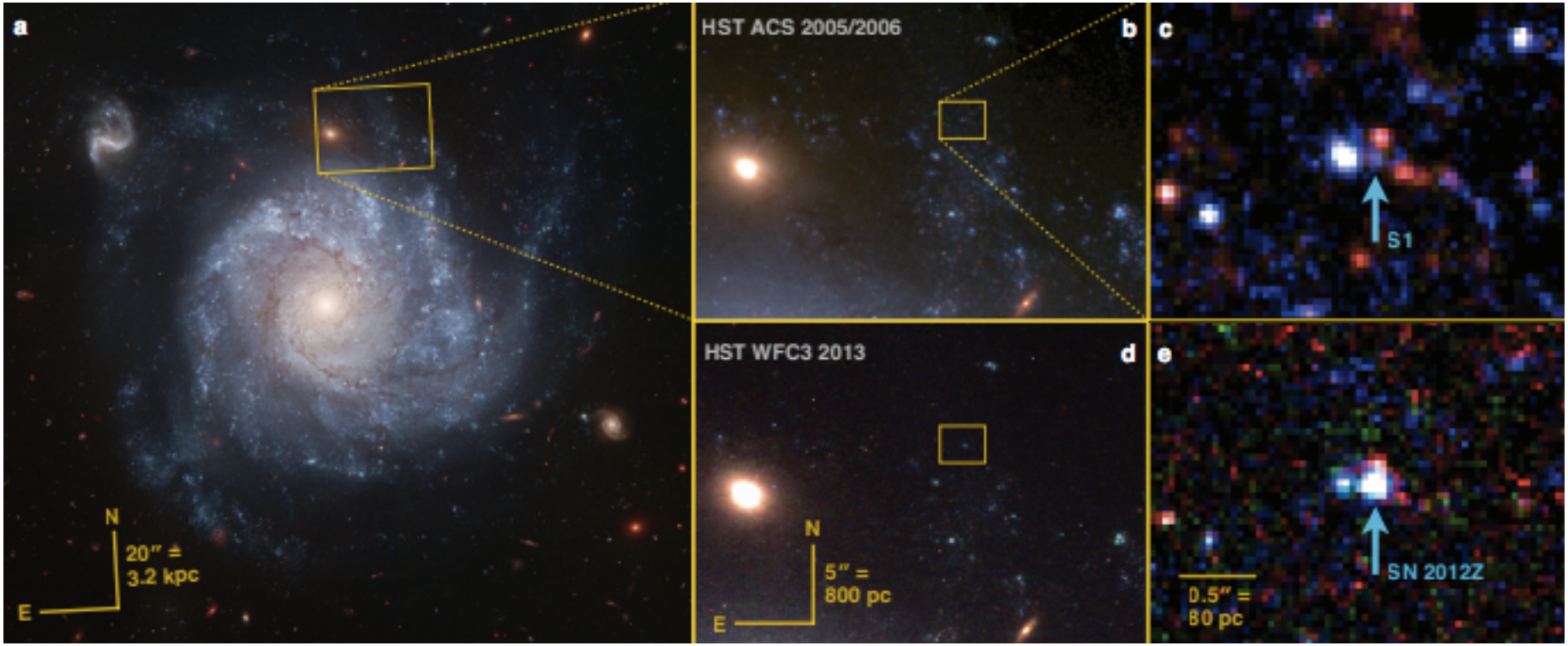
Alternative Model: PDD

- Start with a deflagration at high density, producing Fe-group elements (opposite of SNe Ia)
- Expansion followed by shell fall back
- Detonation is ignited (little to no ^{56}Ni is produced here)

→

- Produces low velocities
- Gives layered structure, but with ^{56}Ni in outer layers (This explains the early blue colors and hot spectra)
- Flat top late phase NIR profiles
- Little unburned C/O
- Low velocities of ejecta explains lack of forbidden Fe at late phases
- Range of possible ^{56}Ni mass from near 0 to 0.8 M_{sun}

Detection of the Progenitor?



Luminosity, color, and environment of S1 are all similar to the Galactic helium nova V455 Puppis

McCully et al. 2014, in press

Saludos from Las Campanas