Near-infrared spectroscopy of type Ia supernovae

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Carnegie Supernova Project II

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CSP1

- emphasis on NIR
- SNe from targeted searches
- old-school NIR k-corrections
- NIR imager on 1-m Swope
- 6.5-m Magellan time was dedicated to the high-z project

CSP2

- emphasis on NIR
- SNe from blind searches
- improved NIR k-corrections
- NIR imager on 2.5-m du Pont
- addition of FIRE/FourStar on 6.5-m Magellan

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no. of SN Ia
optical spectra

10^4

no. of SN Ia
NIR spectra

10^2

41 from Marion et al. (2009)
+ from individual SNe
91T, 94D, 98bu, 99by, 99ee,
02bo, 02dj, 03du, 05cf, 11fe, 14J, etc

CSP2
NIR Spectroscopy

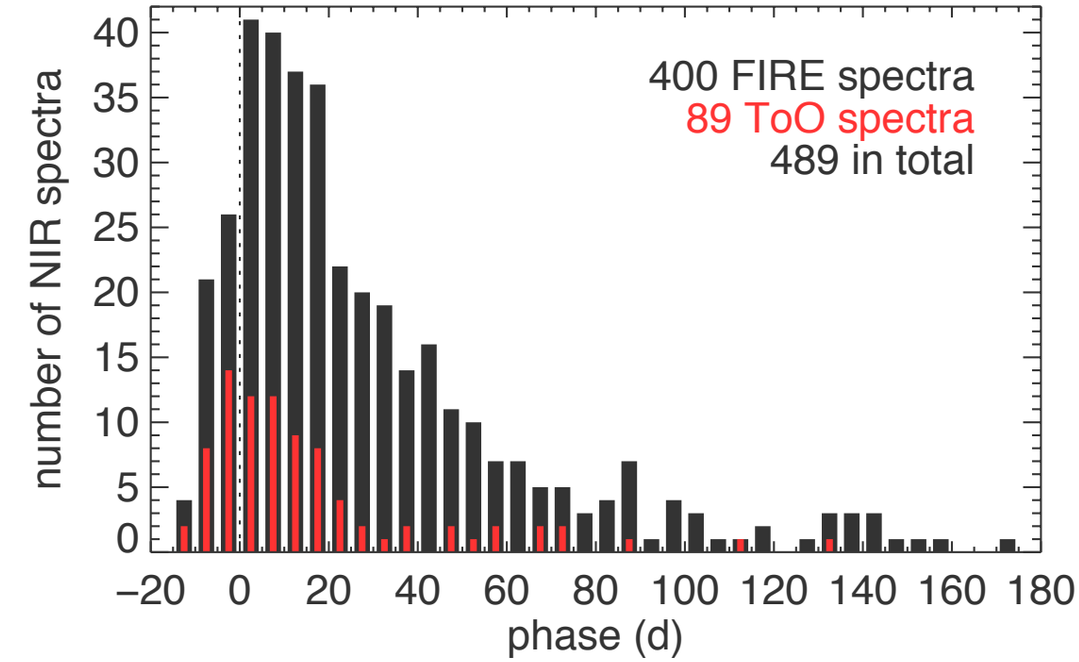
- larger sample
  ~500 Ia spectra in 3 years
  ~700 in total

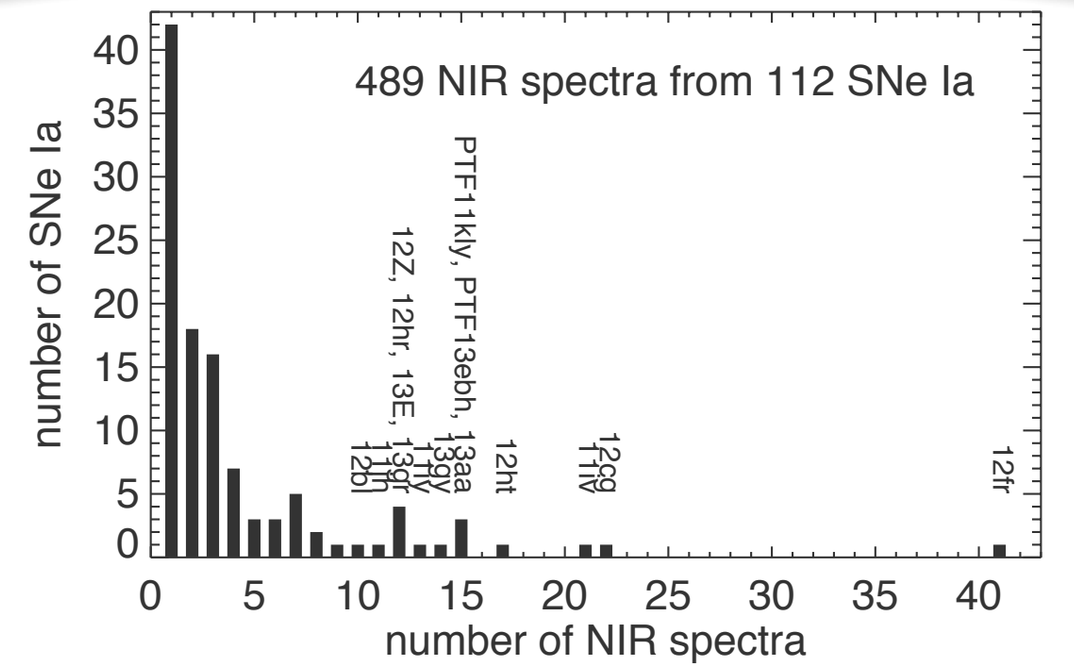
- better S/N
  Magellan+FIRE, Gemini-N+GNIRS

- time series
  scheduled FIRE nights
  + ToO GNIRS time

- accompanying optical+NIR LCs

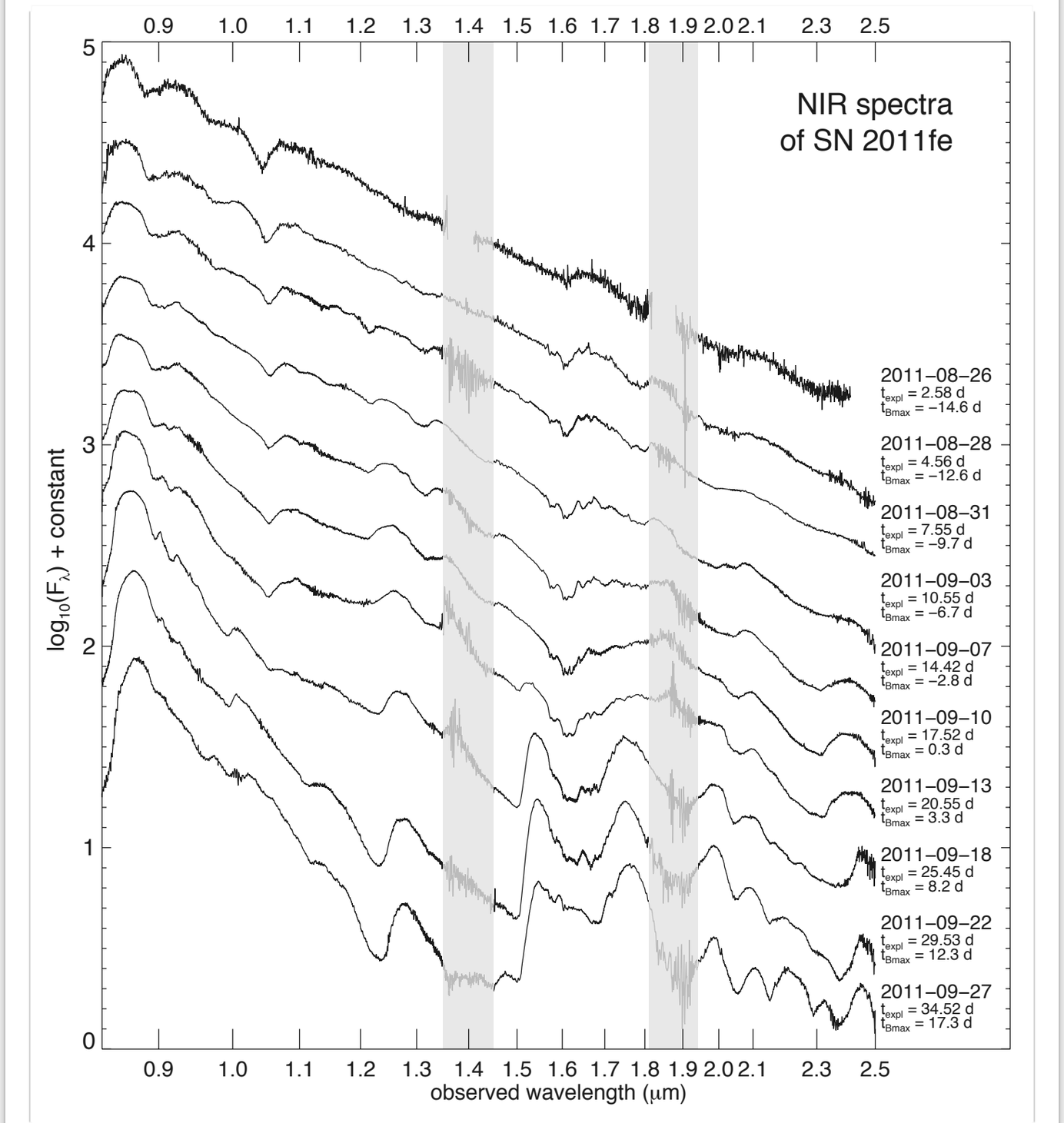
- simultaneous optical spectra





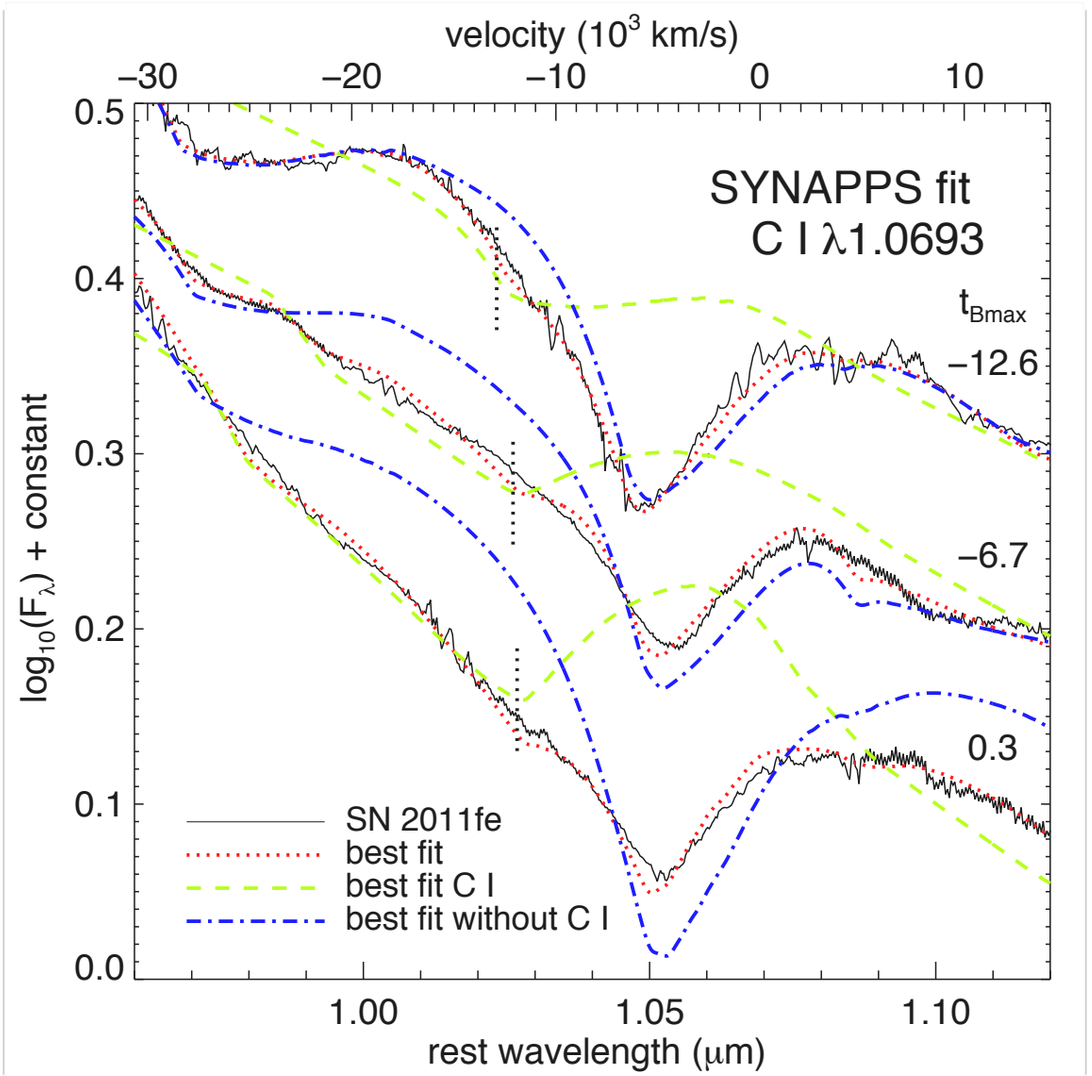
SN2011fe

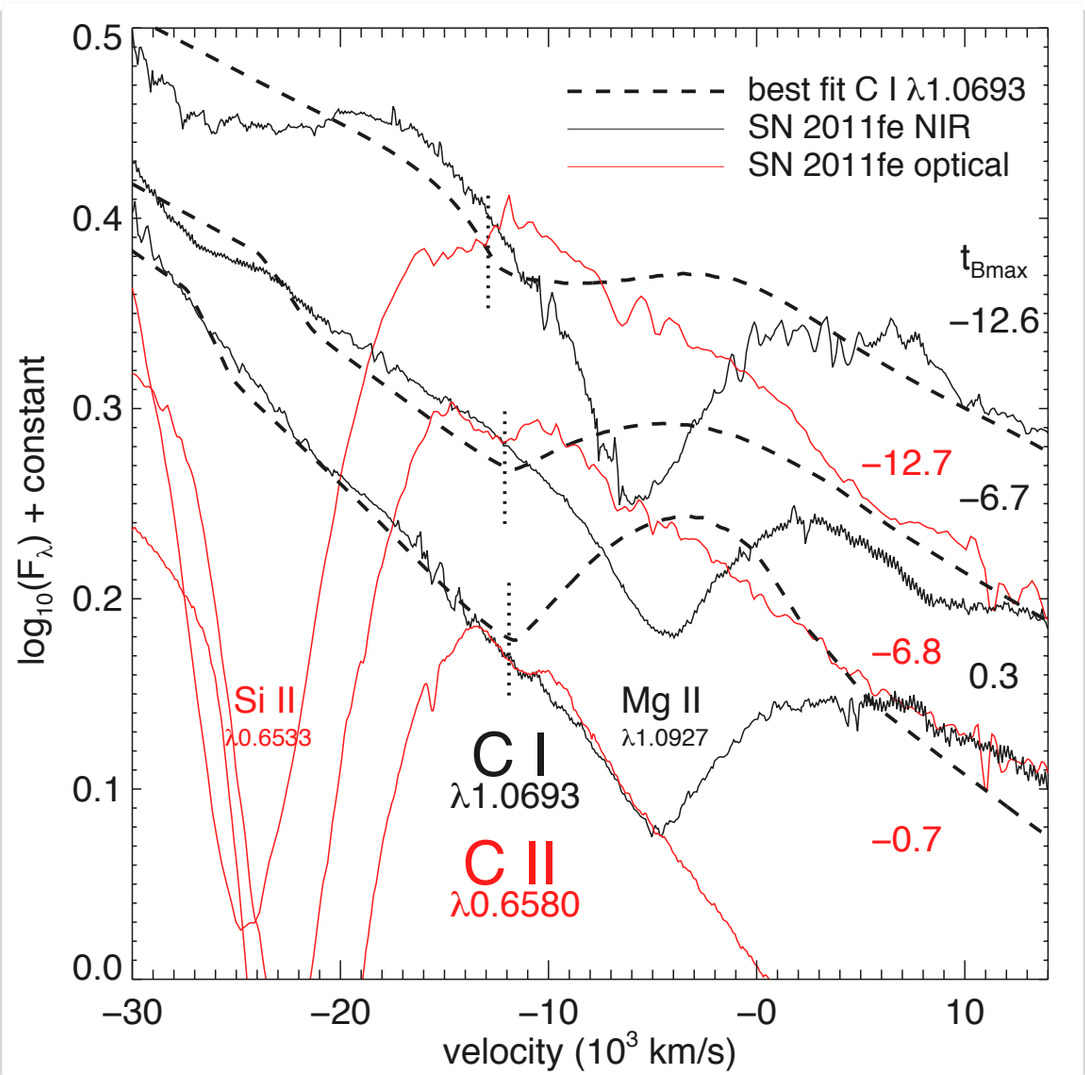
- NIR C I is present and increases in strength
- Mg II velocity is flat
- H-band break correlates with decline rate Δm_{15}



Hsiao et al. (2013)

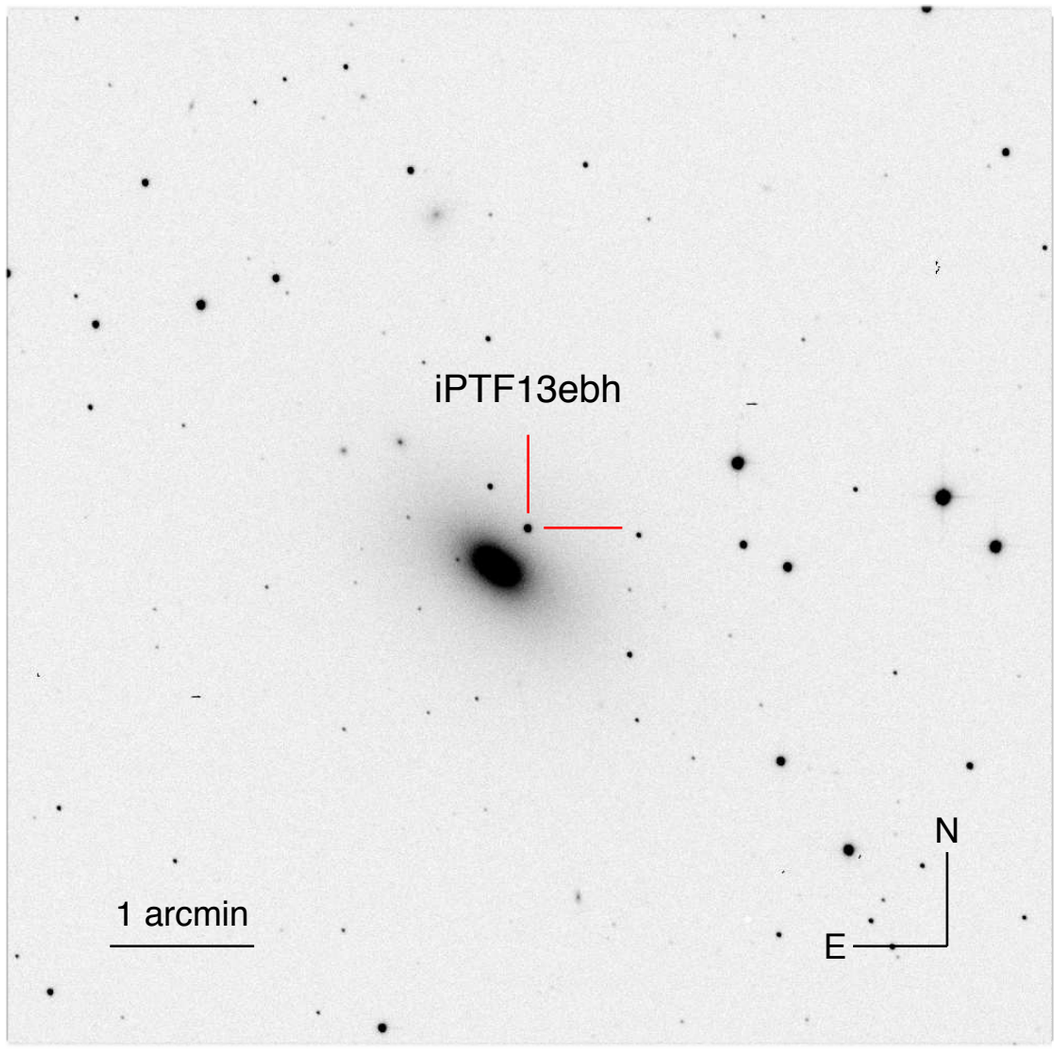
SN2011fe NIR carbon

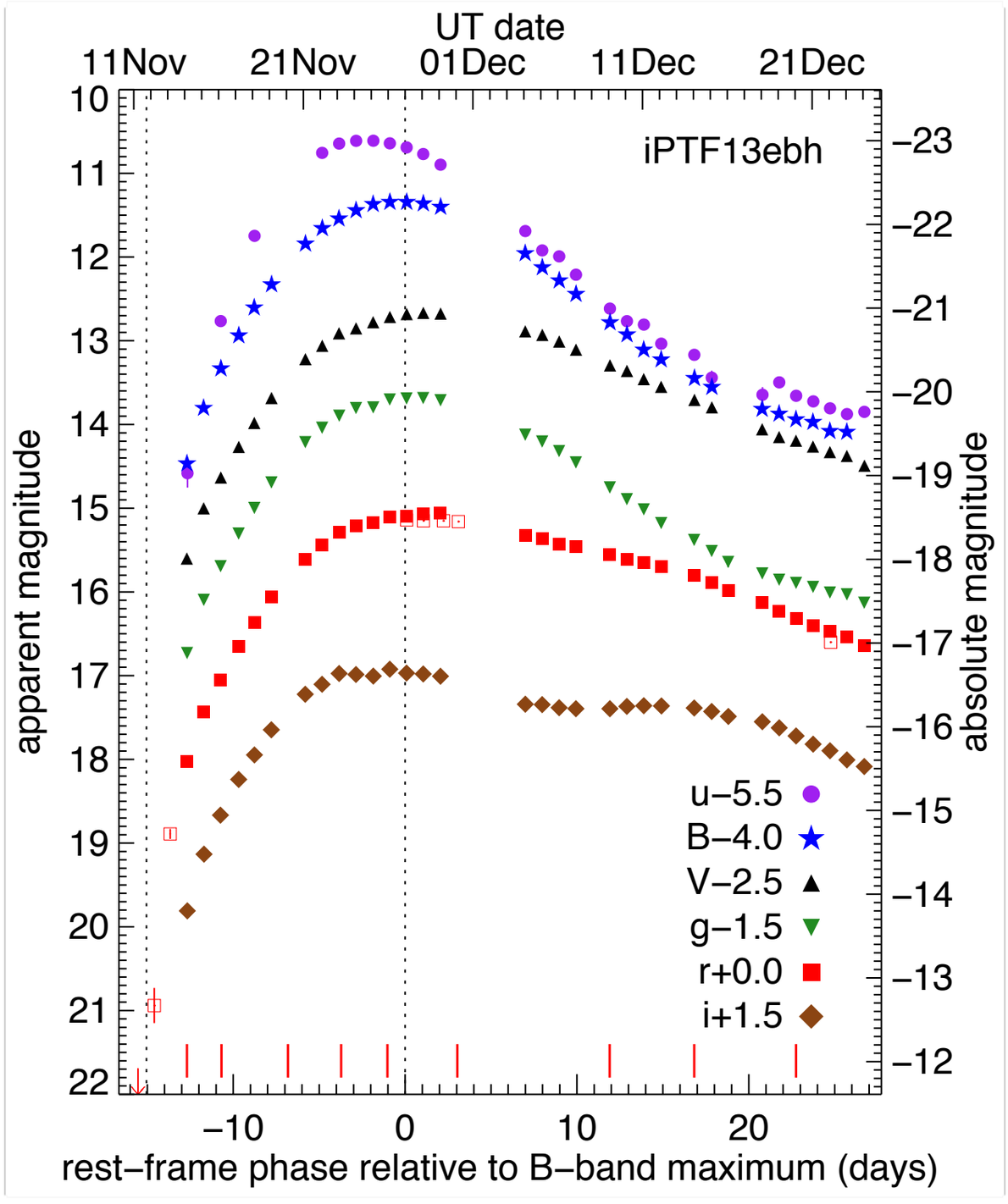




Hsiao et al. (2013)

iPTF13ebh





Hsiao et al. (2014) in prep

"Transitional" objects

	Δm_{15}
SN2004eo	1.45±0.04
SN2009an	1.51±0.03
SN2011iv	1.69±0.05
iPTF13ebh	1.79±0.01

sub-luminous/fast decliner
without Ti II

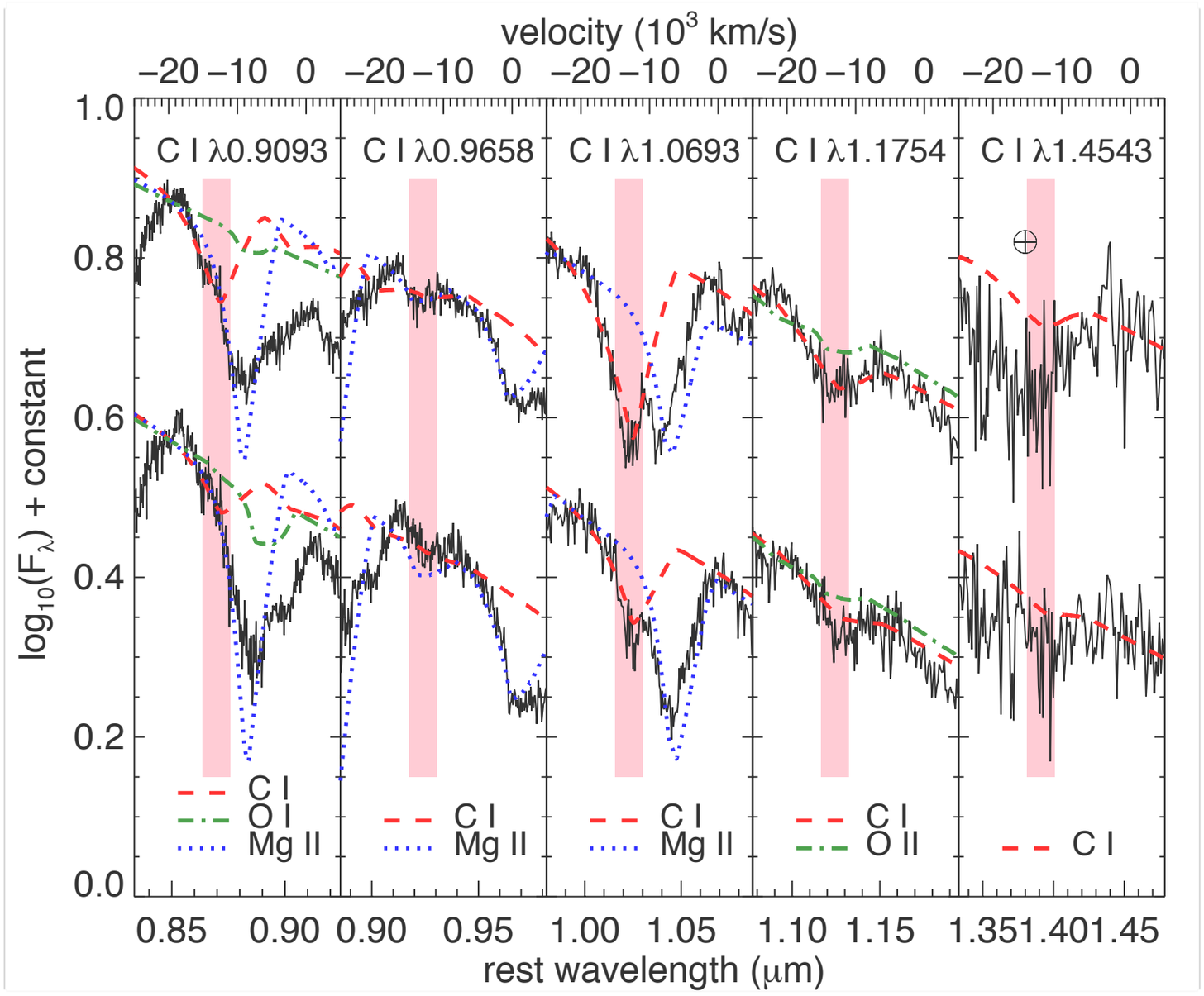
91bg-like

	Δm_{15}
SN1991bg	1.87±0.08
SN1999by	1.98±0.08

iPTF13ebh

NIR Carbon

- definitive C I detections
- C I 10693, best feature for tracing carbon



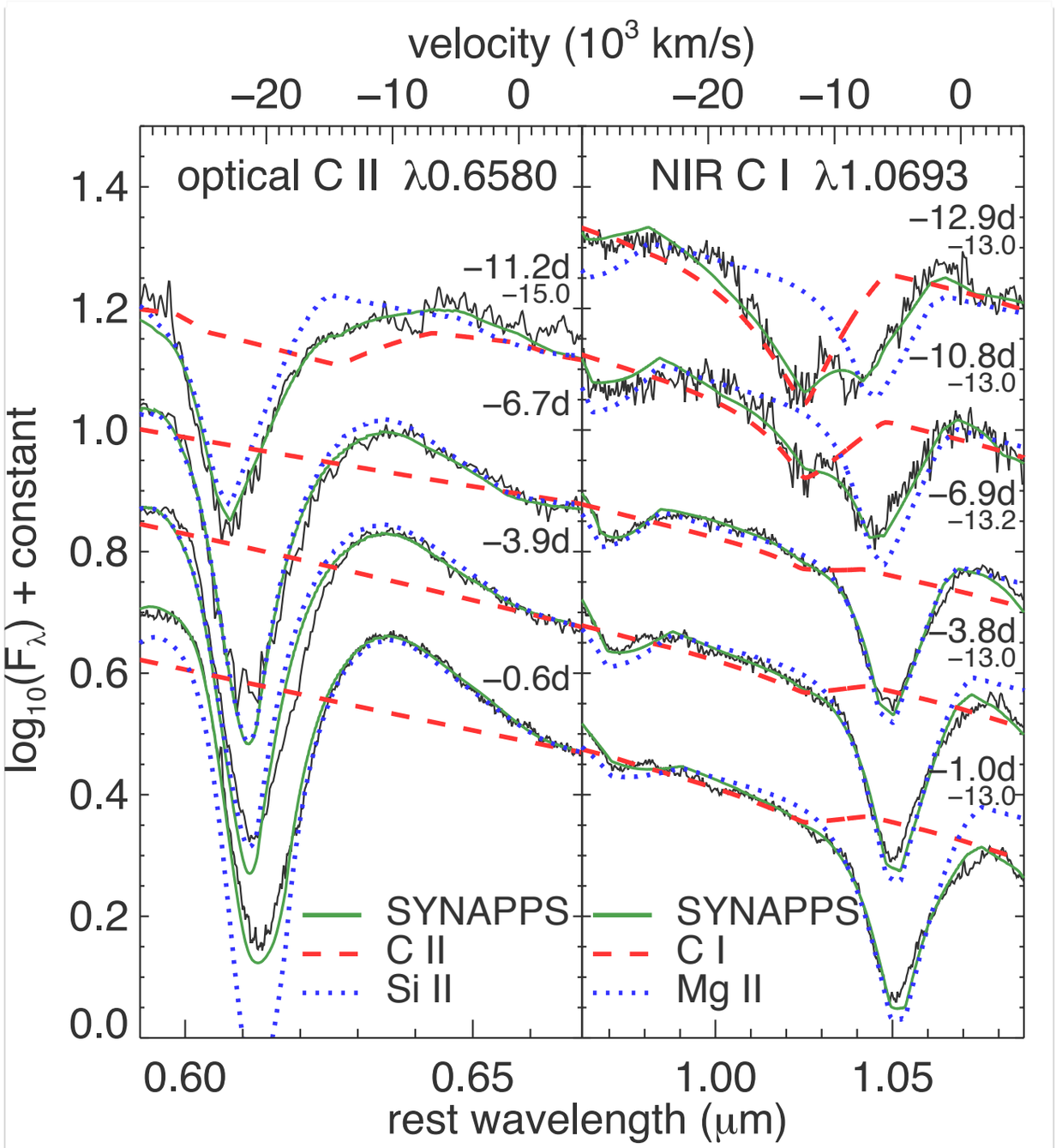
iPTF13ebh

optical C II vs NIR C I

- In terms of line strength
  C II 0.6570 ~10^2x C I 1.0693

- But NIR C I much stronger than optical C II

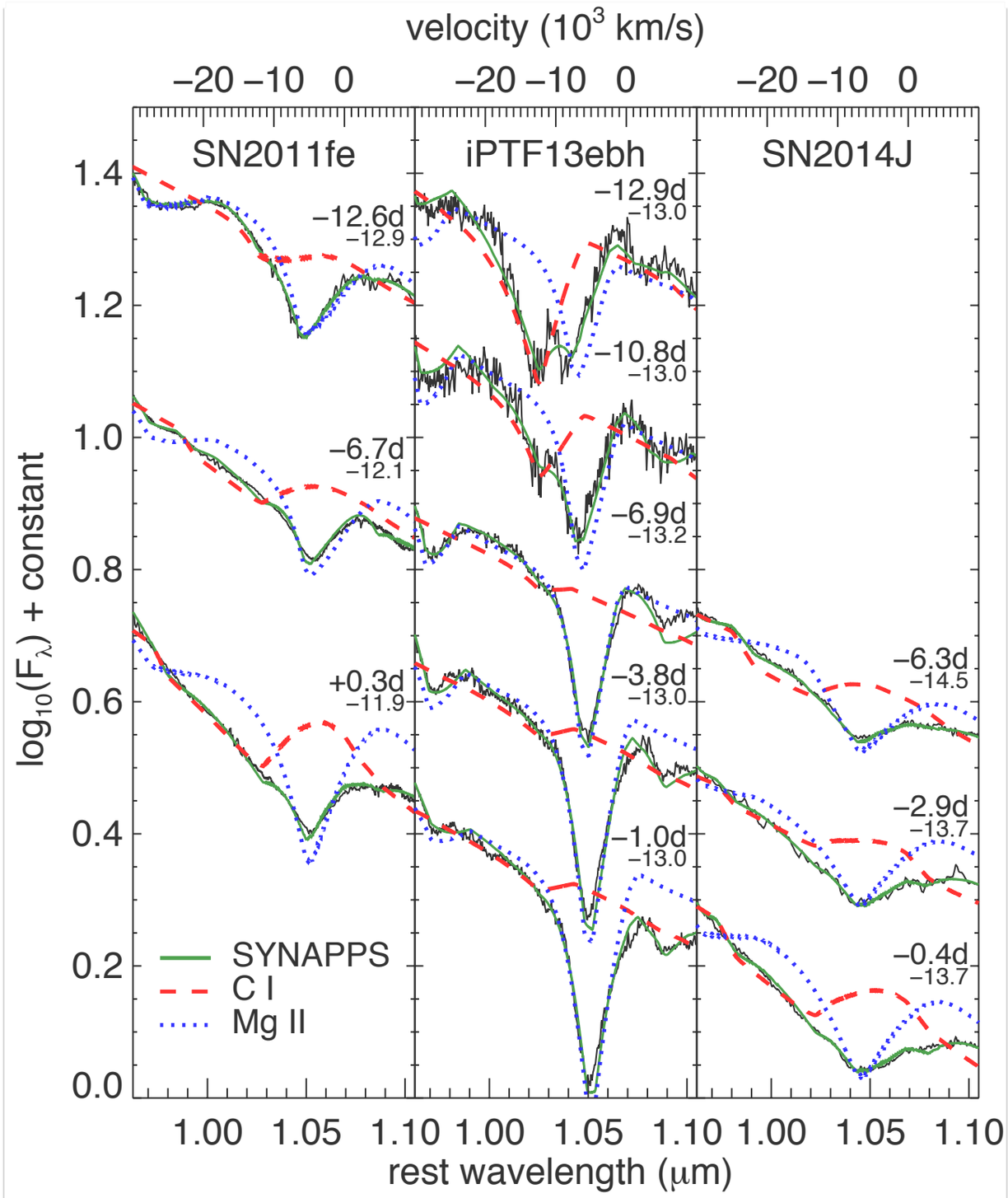
- Also true in
  SN2011fe and SN2014J



iPTF13ebh

NIR C I of other SNe

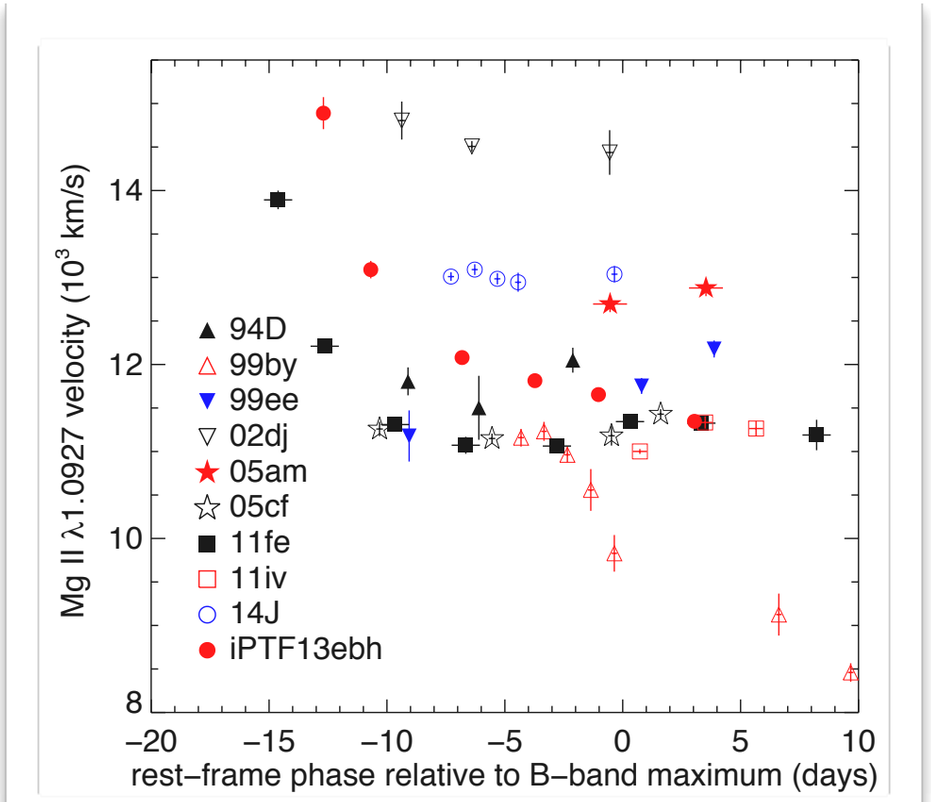
- SN2011fe, SN2014J both show increasing C I strength, C II to C I
- iPTF13ebh shows C I strong and early, faster cooling

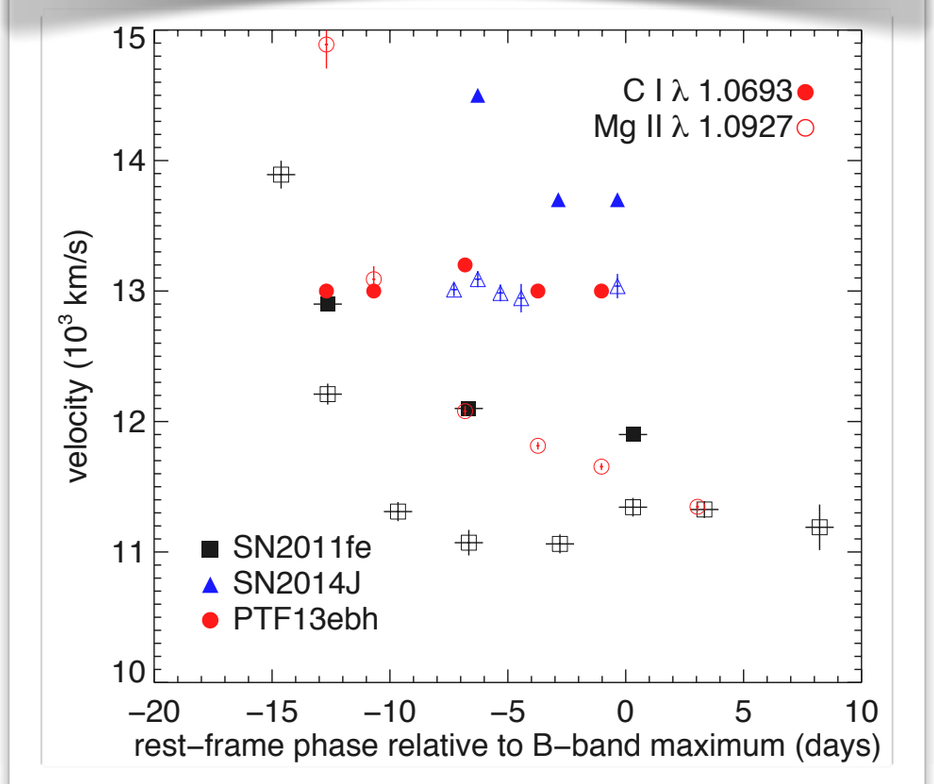


iPTF13ebh

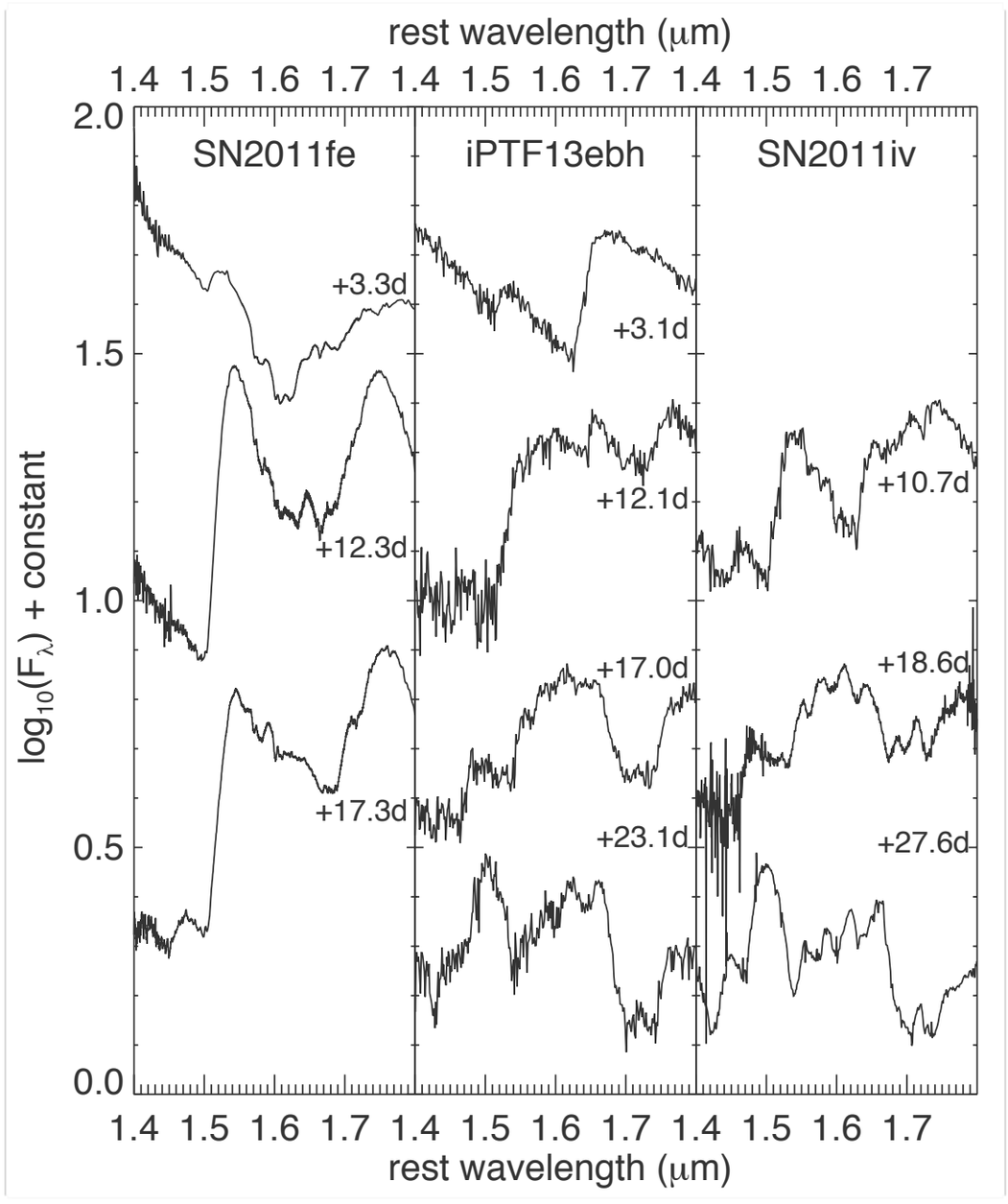
Mg II velocities

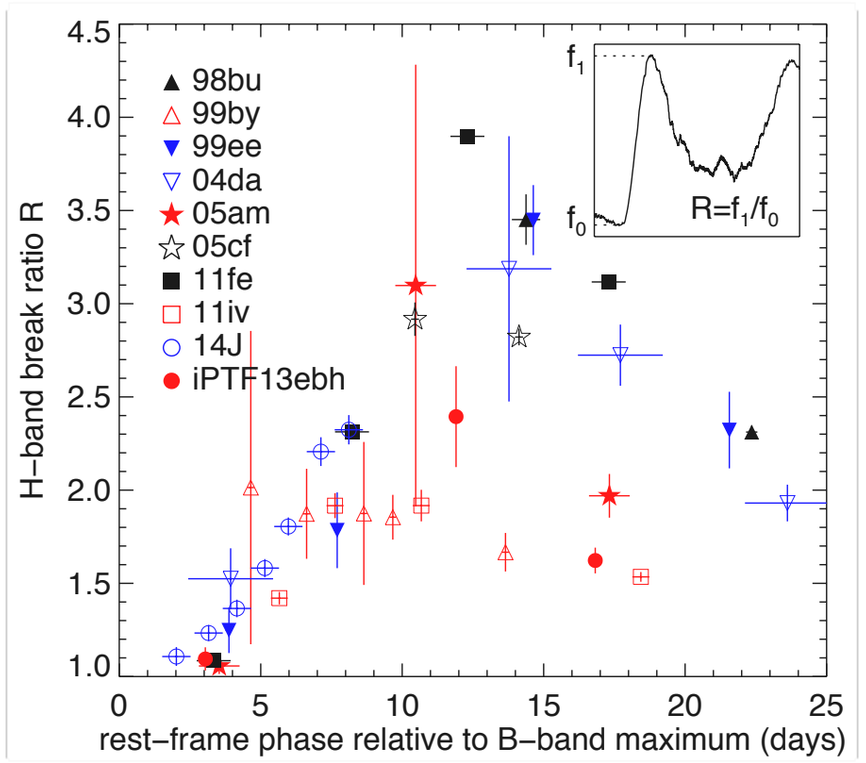
- Isolated Mg II 10927 line probes carbon burning layer
- Flat velocity evolution for normal Ia
- iPTF13ebh shows decreasing velocity like SN1999by

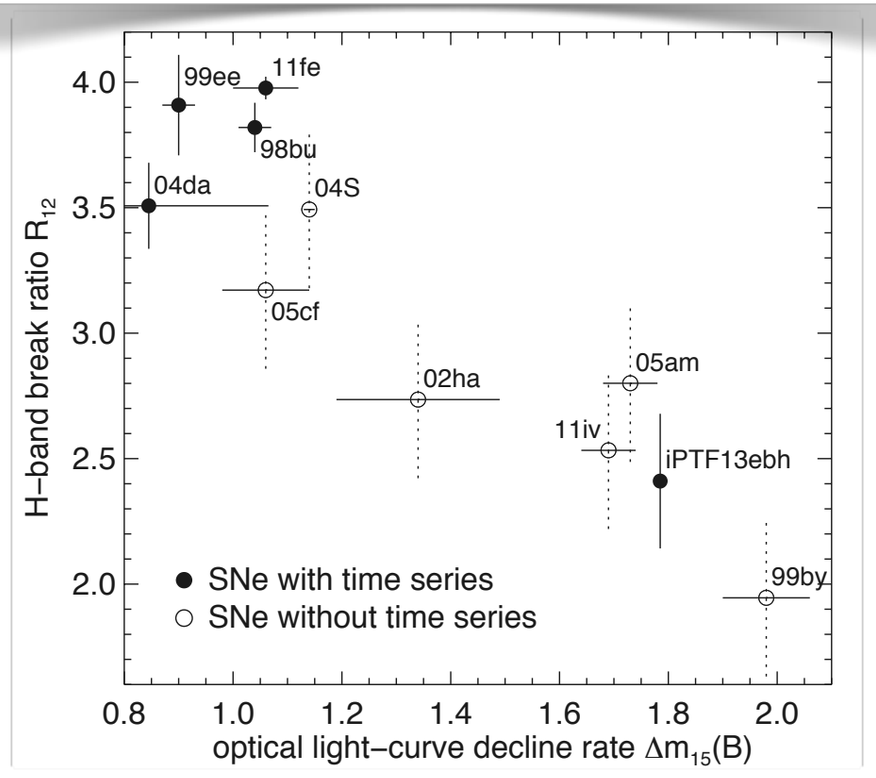




iPTF13ebh H-band break







Summary

- NIR spec differences between "transitional" and normal SNe Ia
  - strong C I early, faster cooling
  - non-flat Mg II velocity deeper carbon burning
- C I 1.0693 is the best probe of pristine WD material
  - Is unburned carbon ubiquitous in SNe Ia?