

Near-infrared spectroscopy of type Ia supernovae

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CSP I

- 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

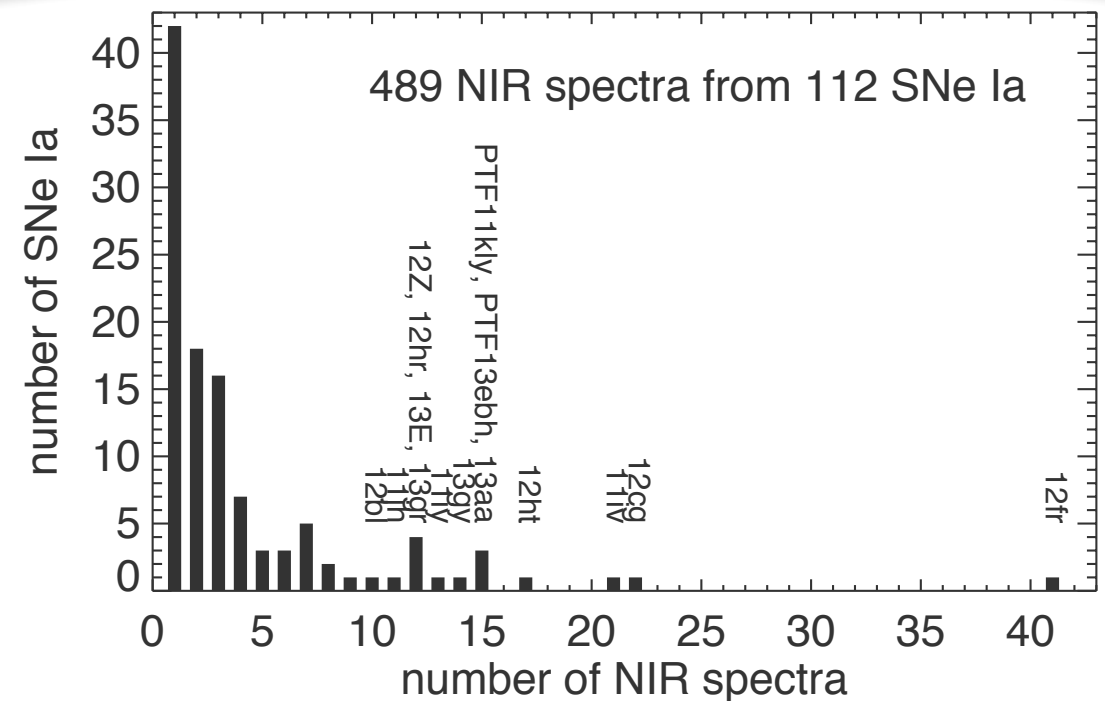
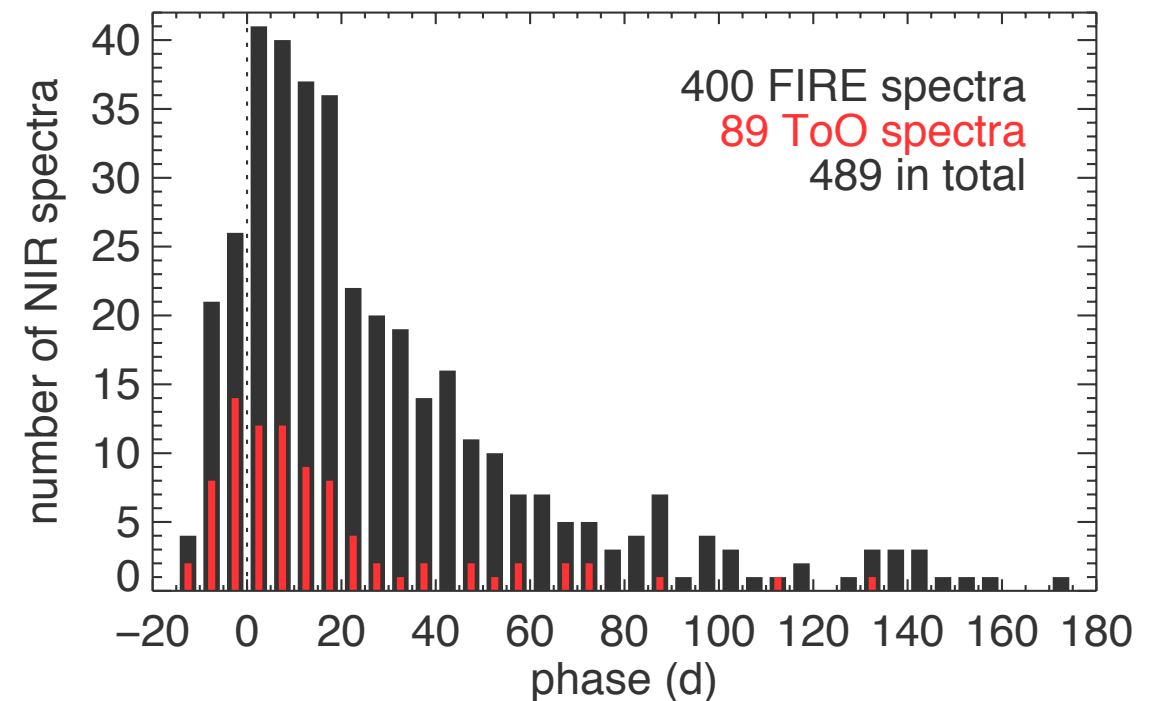
10^2

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

CSP2

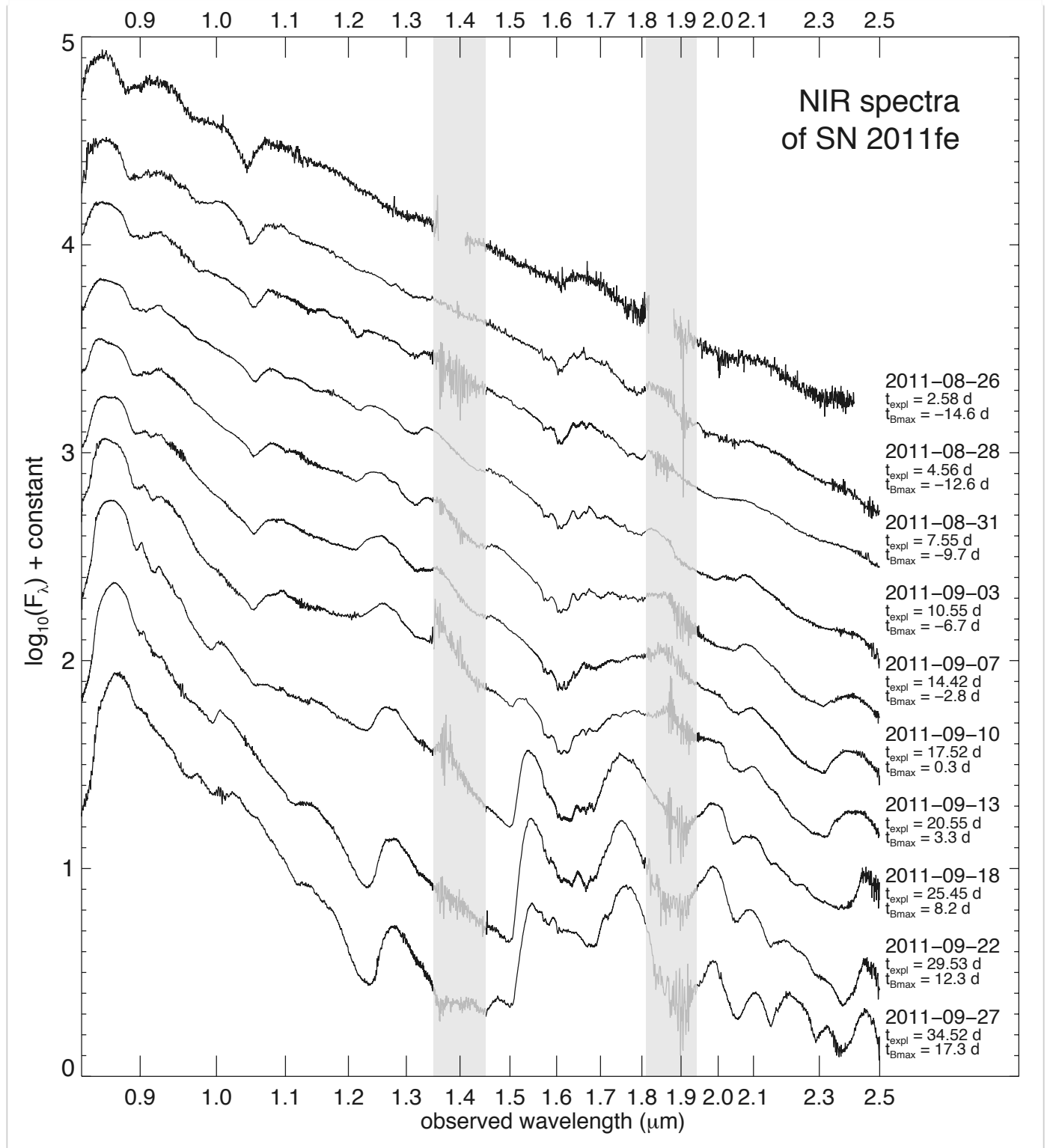
NIR Spectroscopy

- 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



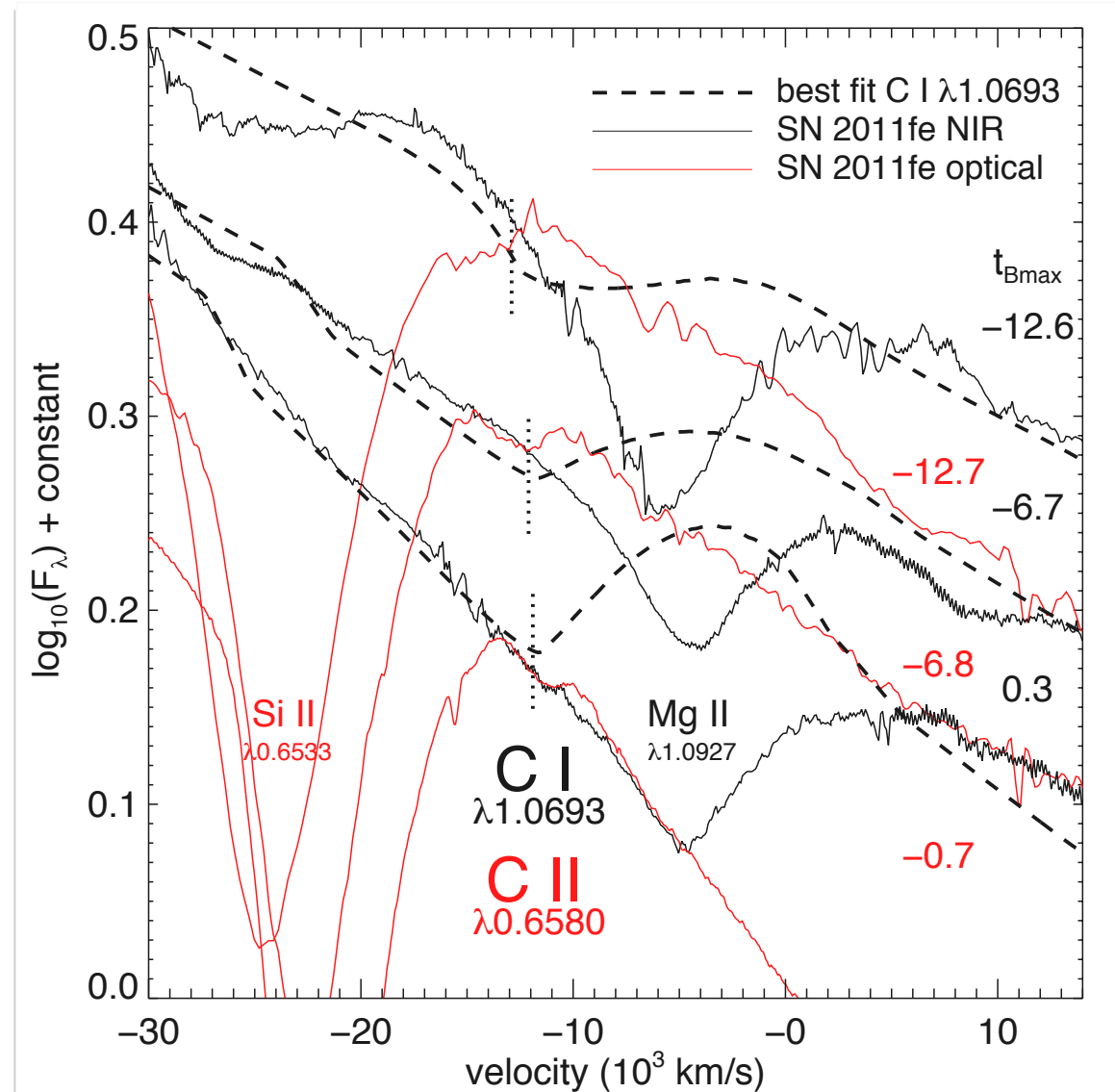
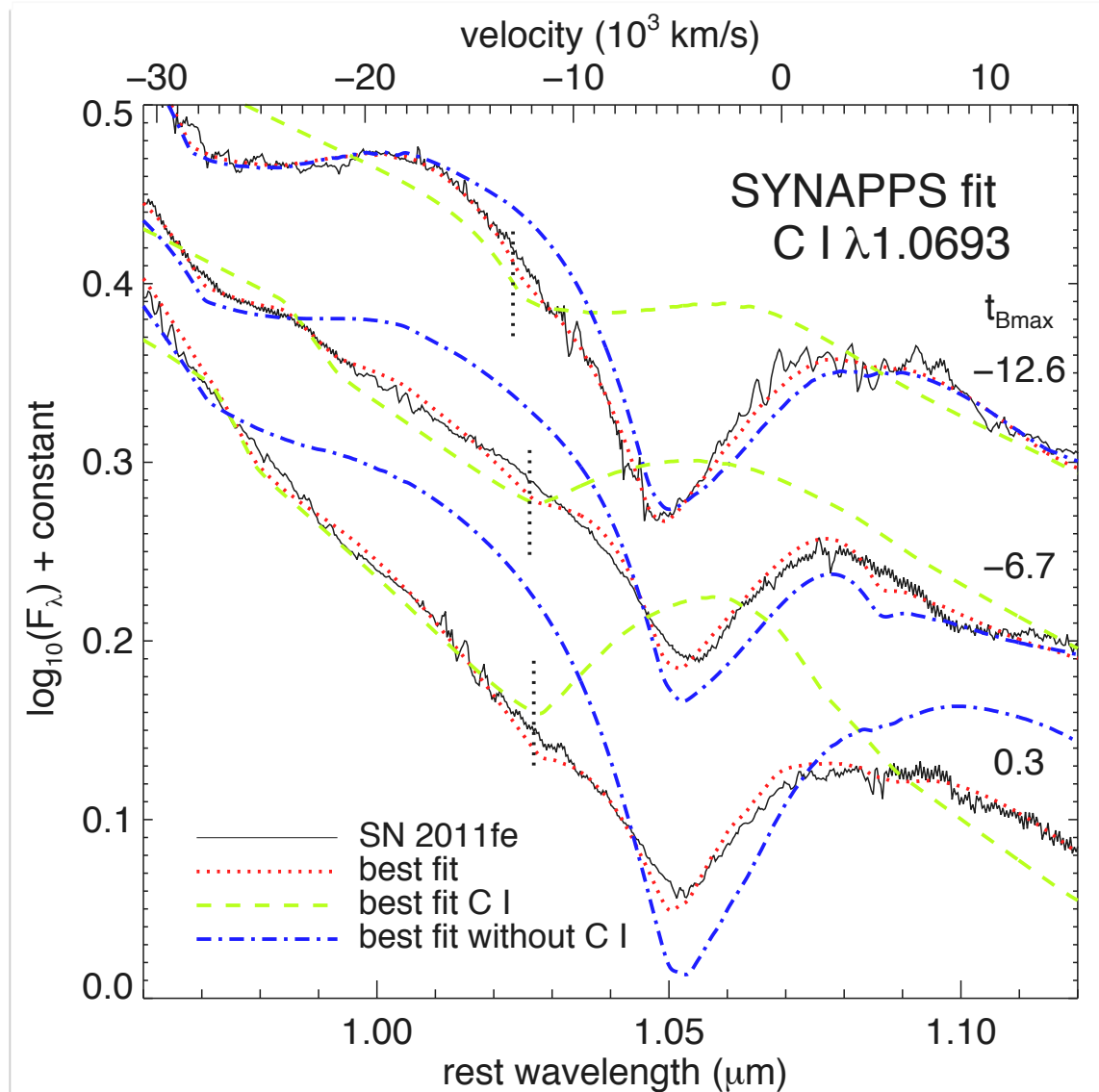
SN2011fe

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



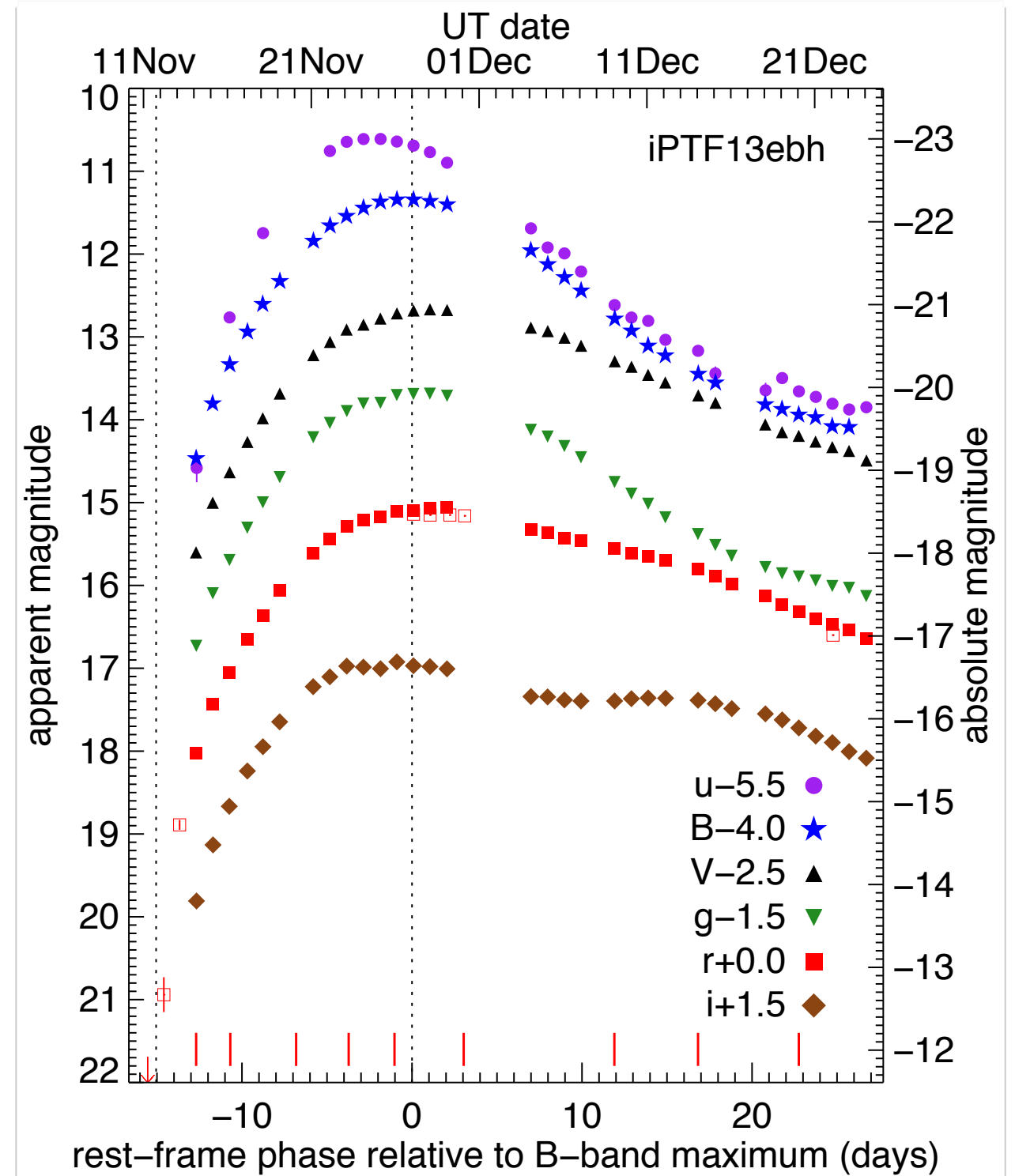
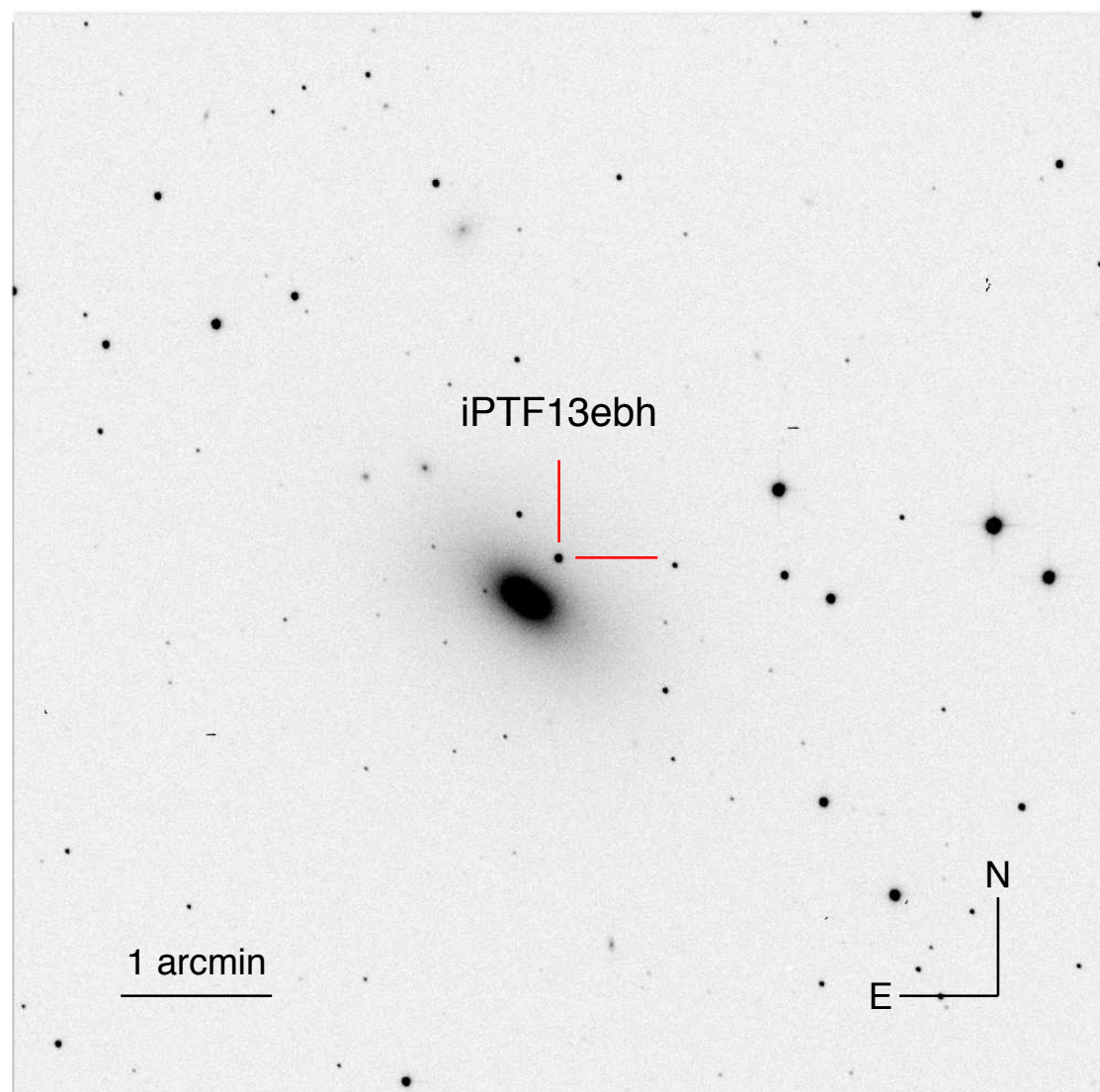
Hsiao et al. (2013)

SN2011fe NIR carbon



Hsiao et al. (2013)

iPTF 13ebh



Hsiao et al. (2014) in prep

“Transitional” objects

91bg-like

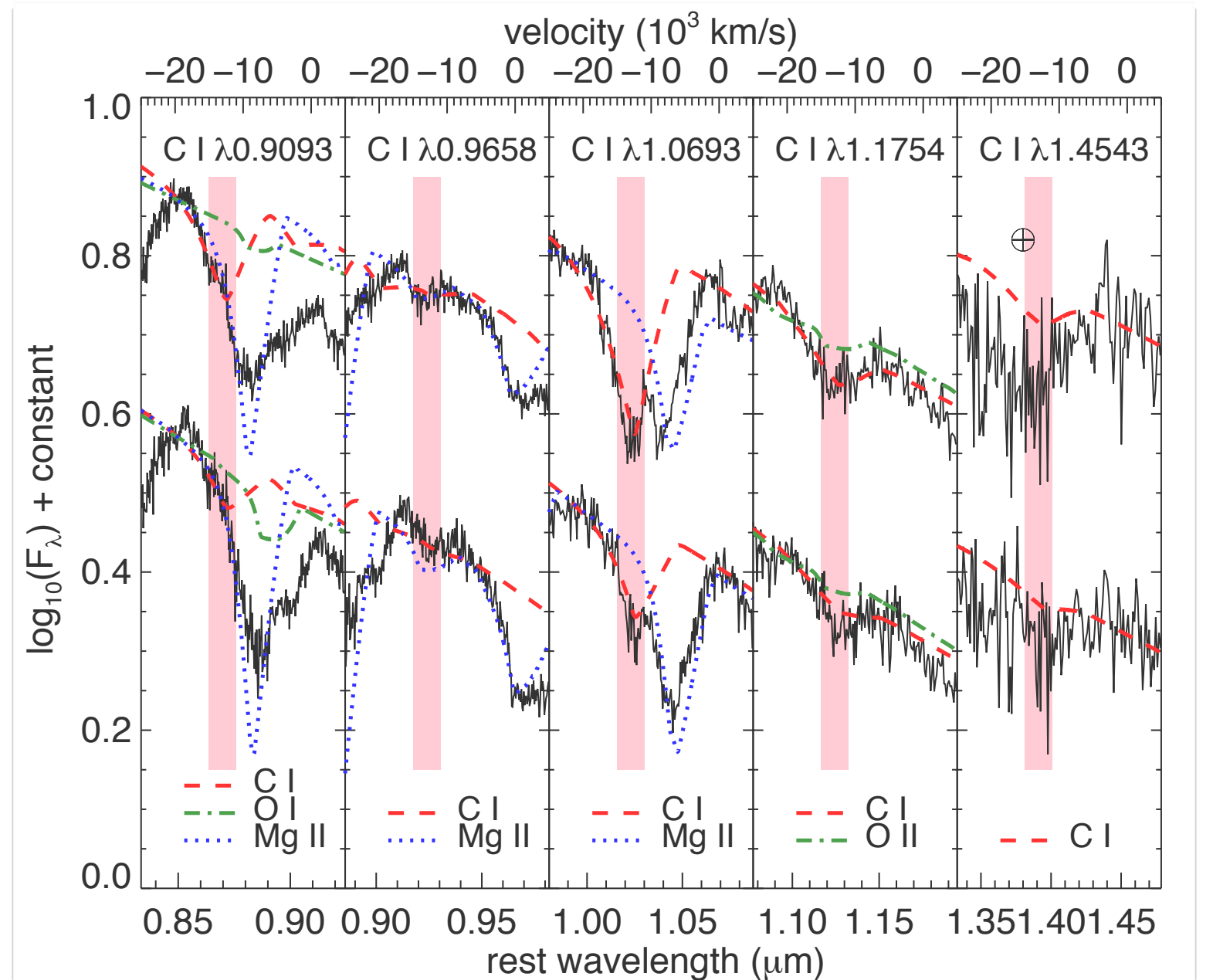
	Δm_{15}		Δm_{15}
SN2004eo	1.45 ± 0.04	SN1991bg	1.87 ± 0.08
SN2009an	1.51 ± 0.03	SN1999by	1.98 ± 0.08
SN2011iv	1.69 ± 0.05		
iPTF13ebh	1.79 ± 0.01		

sub-luminous/fast decliner
without Ti II

iPTF 13ebh

NIR Carbon

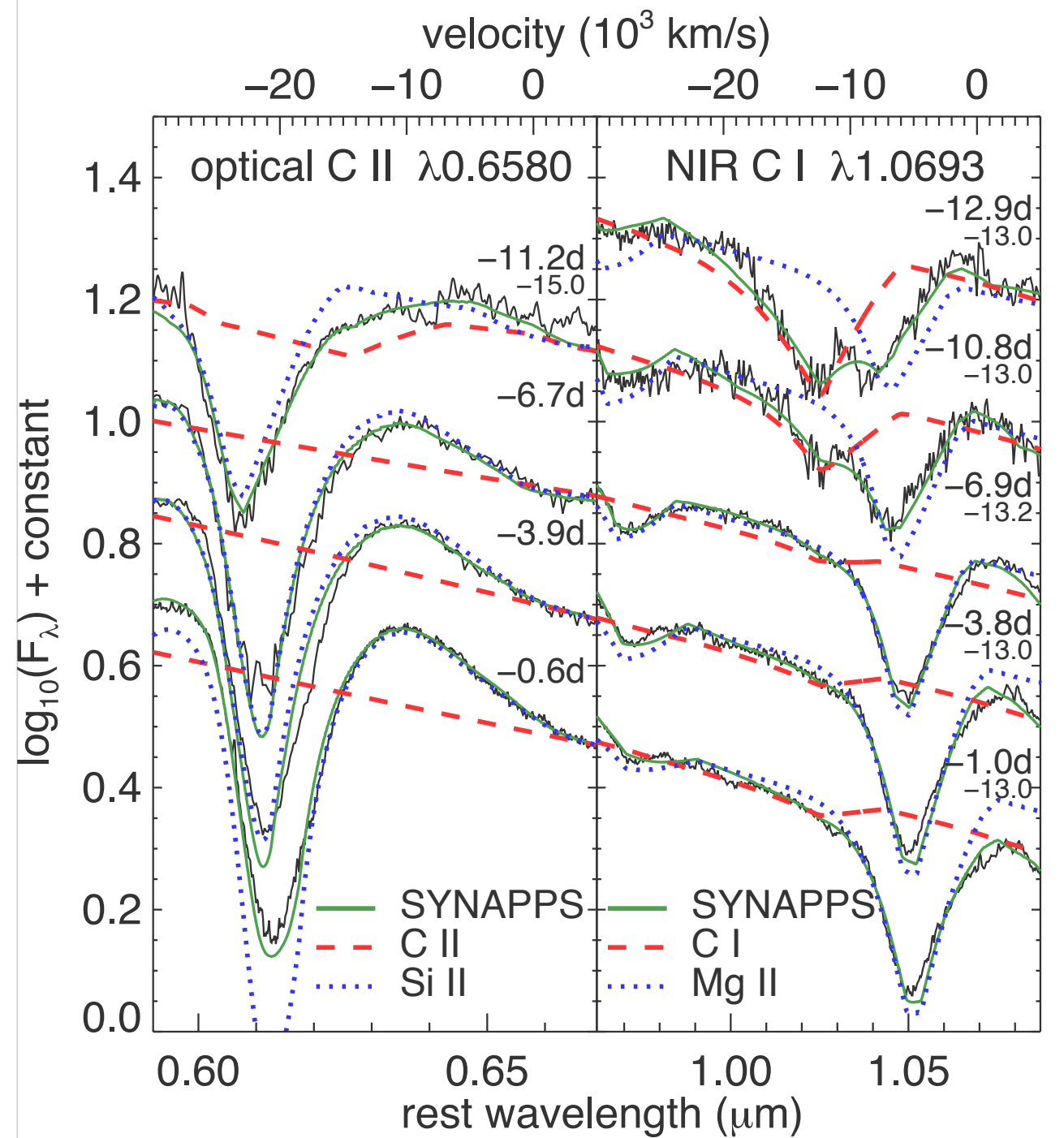
- definitive C I detections
- C I 10693, best feature for tracing carbon



iPTF 13ebh

optical C II vs NIR C I

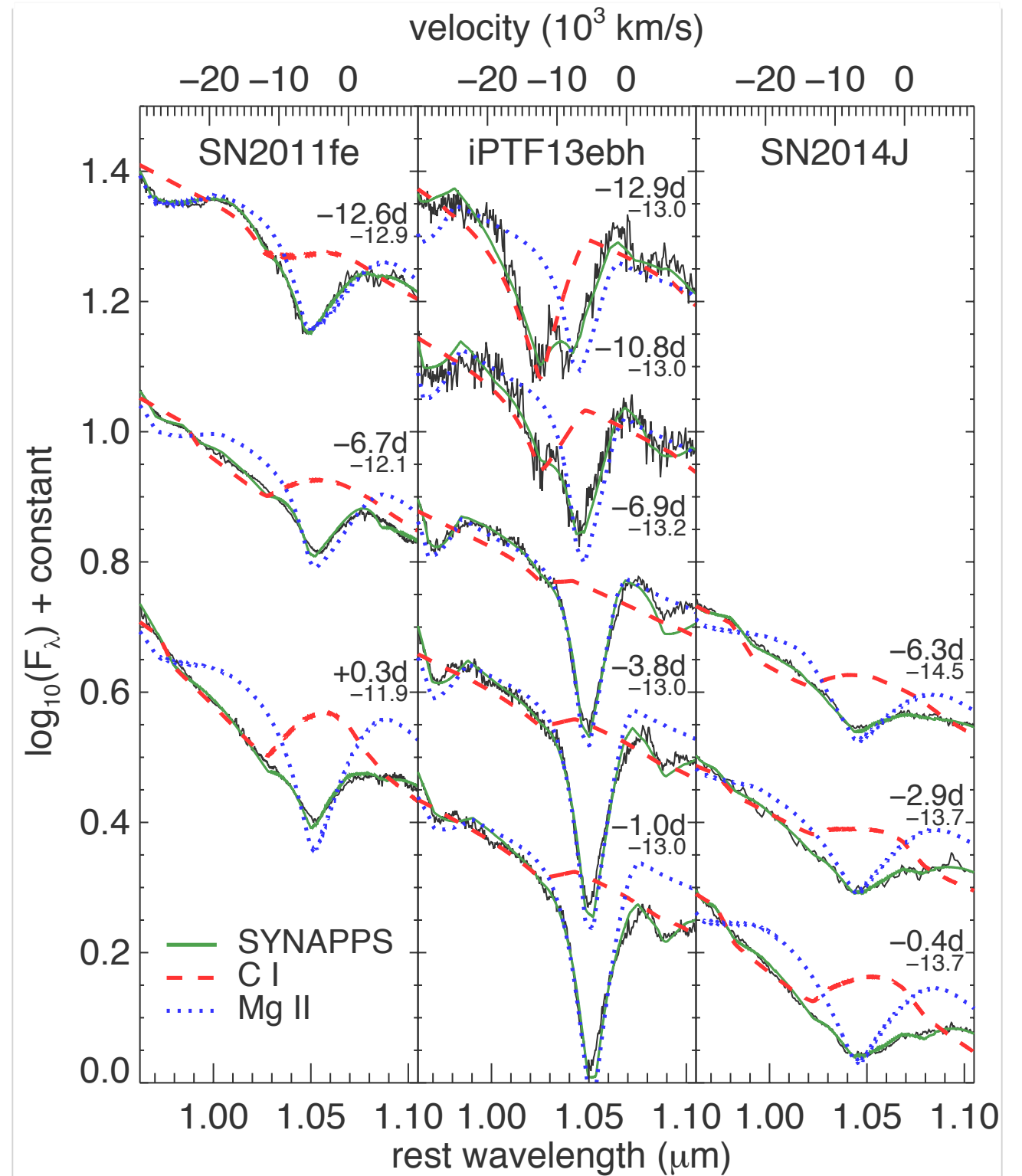
- In terms of line strength
C II 0.6570 $\sim 10^2 \times$ C I 1.0693
- But NIR C I much stronger than optical C II
- Also true in SN2011fe and SN2014J



iPTF13ebh

NIR C I of other SNe

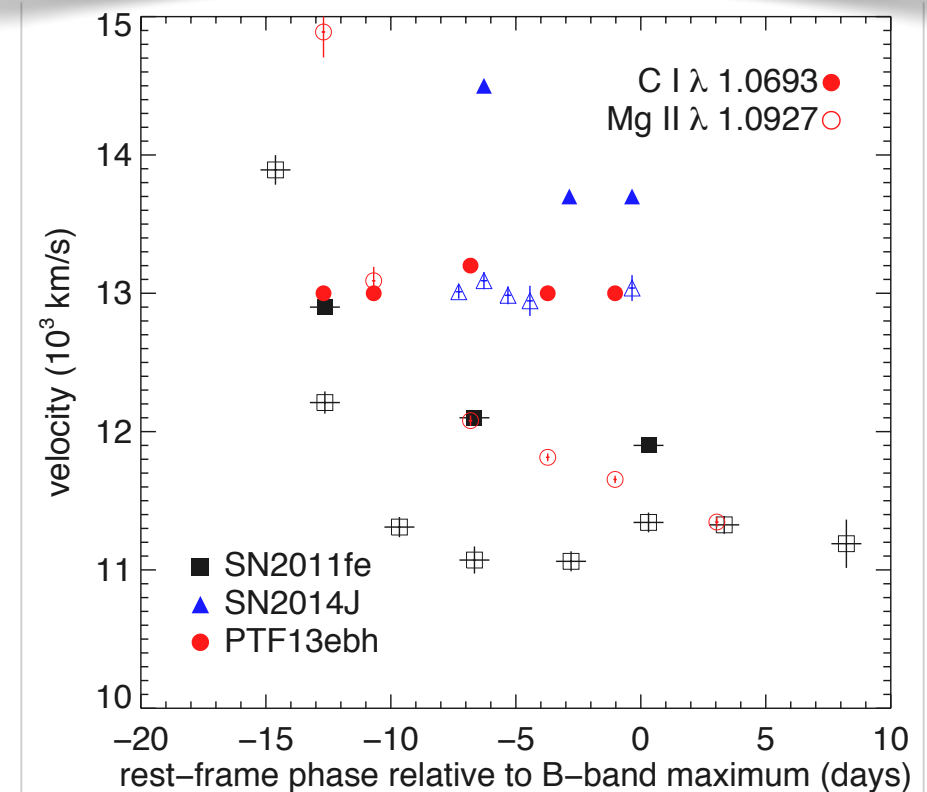
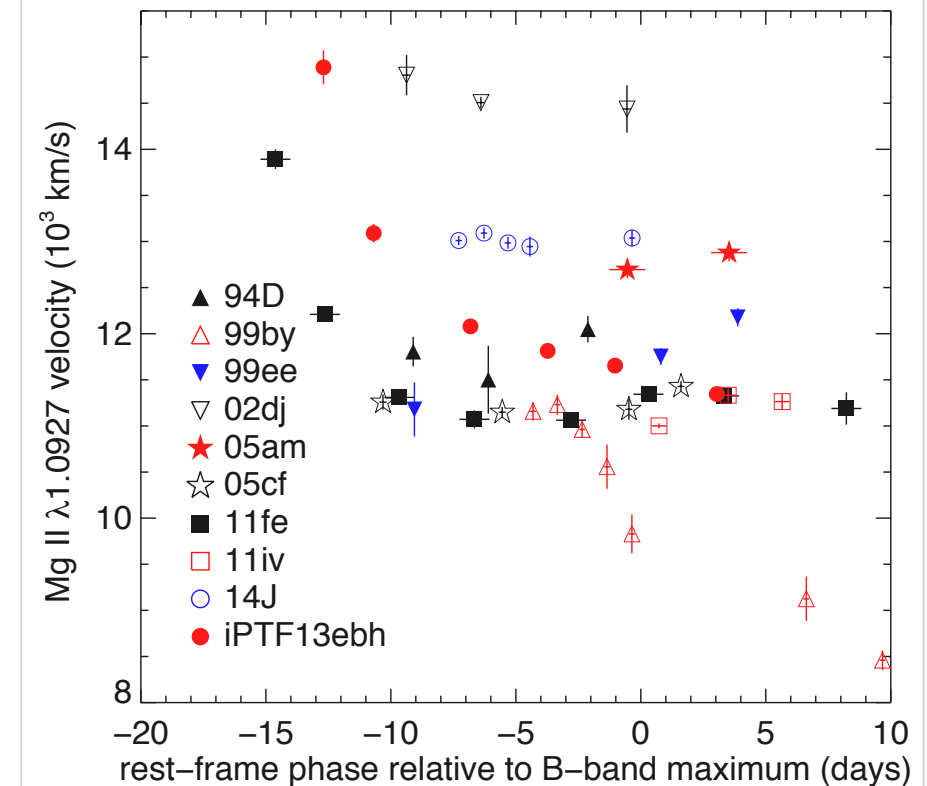
- SN2011fe, SN2014J both show increasing C I strength, C II to C I
- iPTF13ebh shows C I strong and early, faster cooling



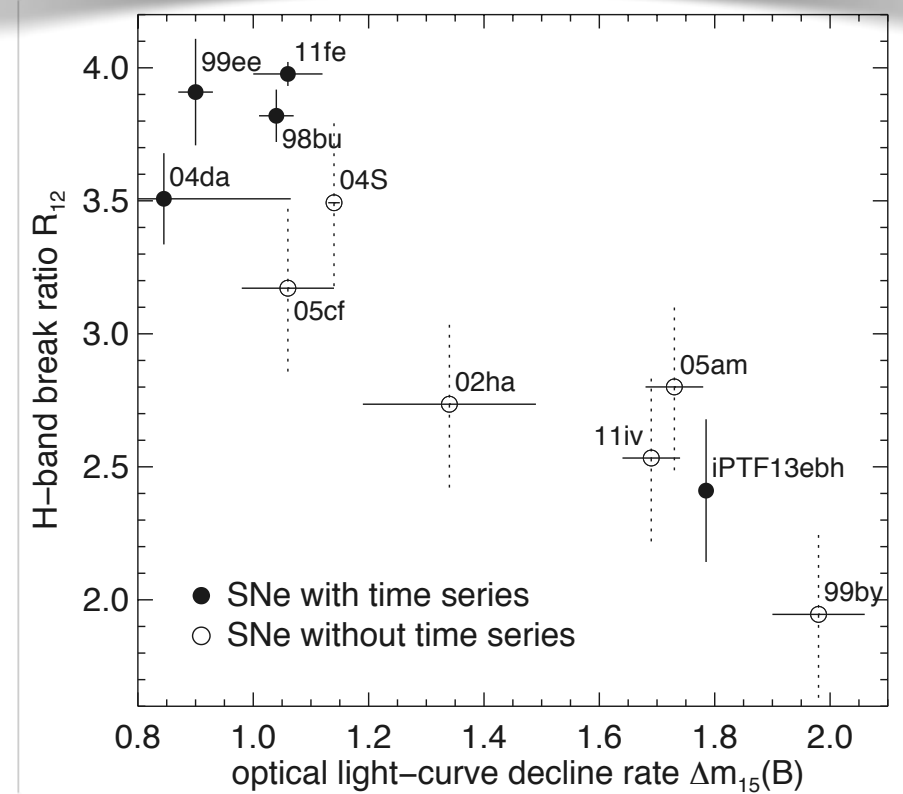
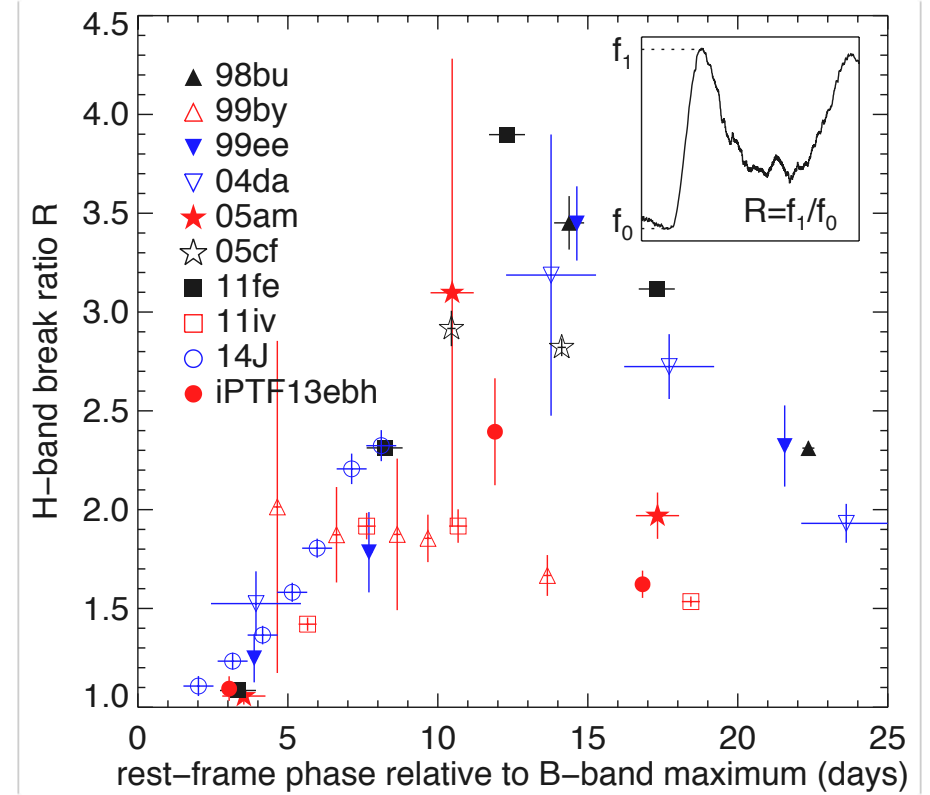
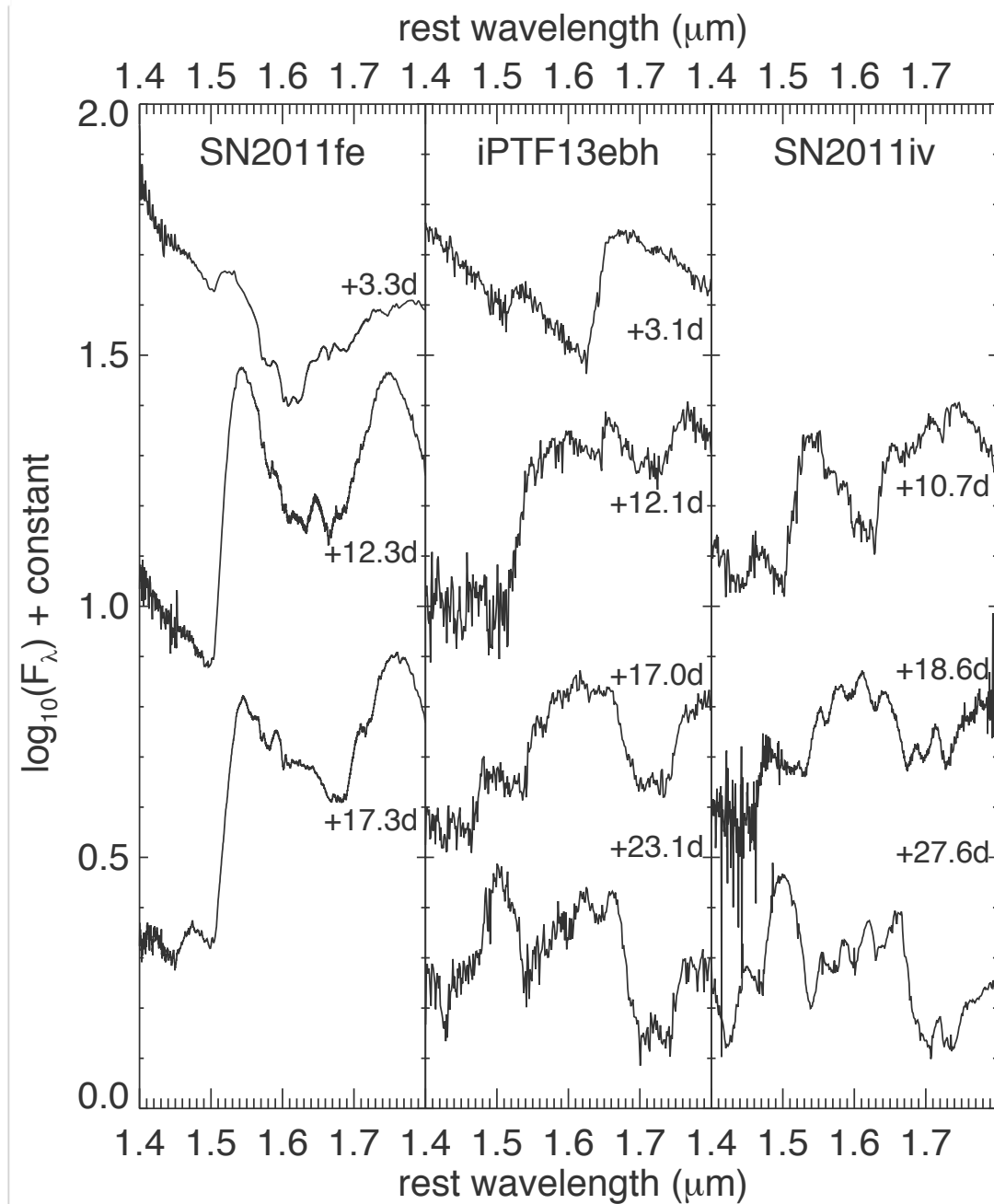
iPTF I 3ebh

Mg II and C I velocities

- Isolated Mg II $\lambda 10927$ line probes carbon burning layer
- Flat velocity evolution for normal Ia
- iPTF I 3ebh shows decreasing velocity like SN I 999by



iPTF13ebh H-band break



Summary

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