Near-infrared spectroscopy of Type Ia supernovae

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on behalf of the Carnegie Supernova Project and collaborations
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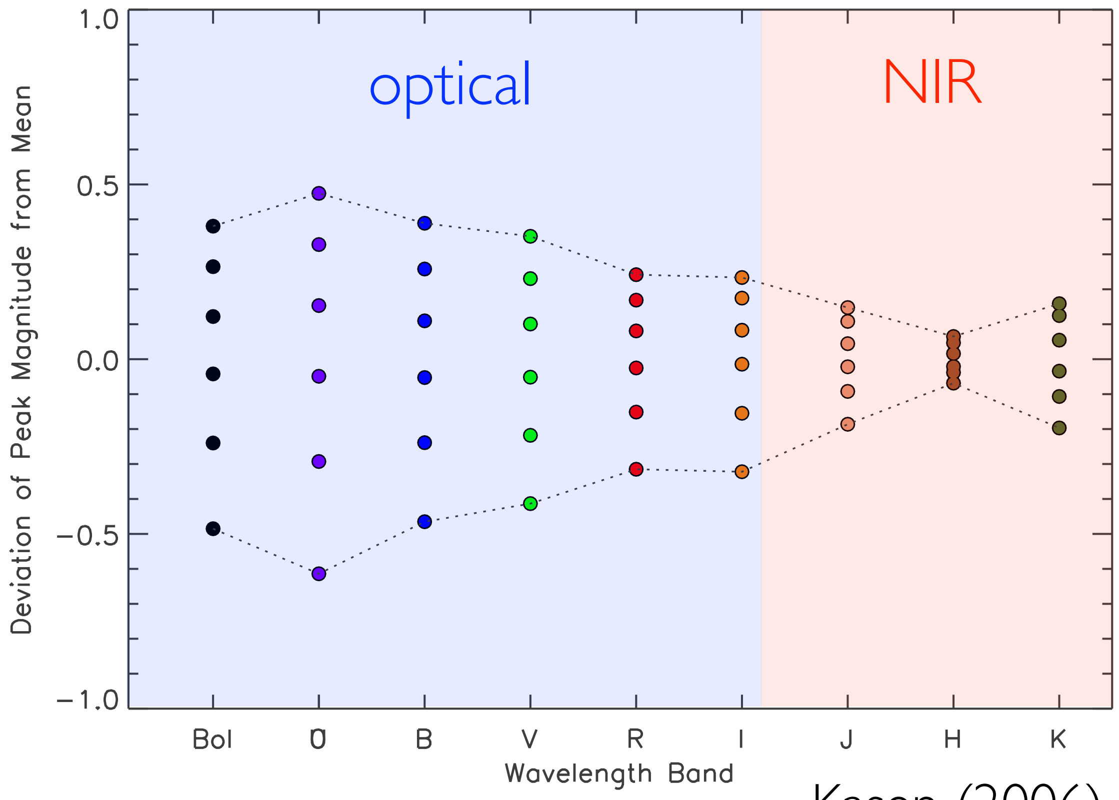
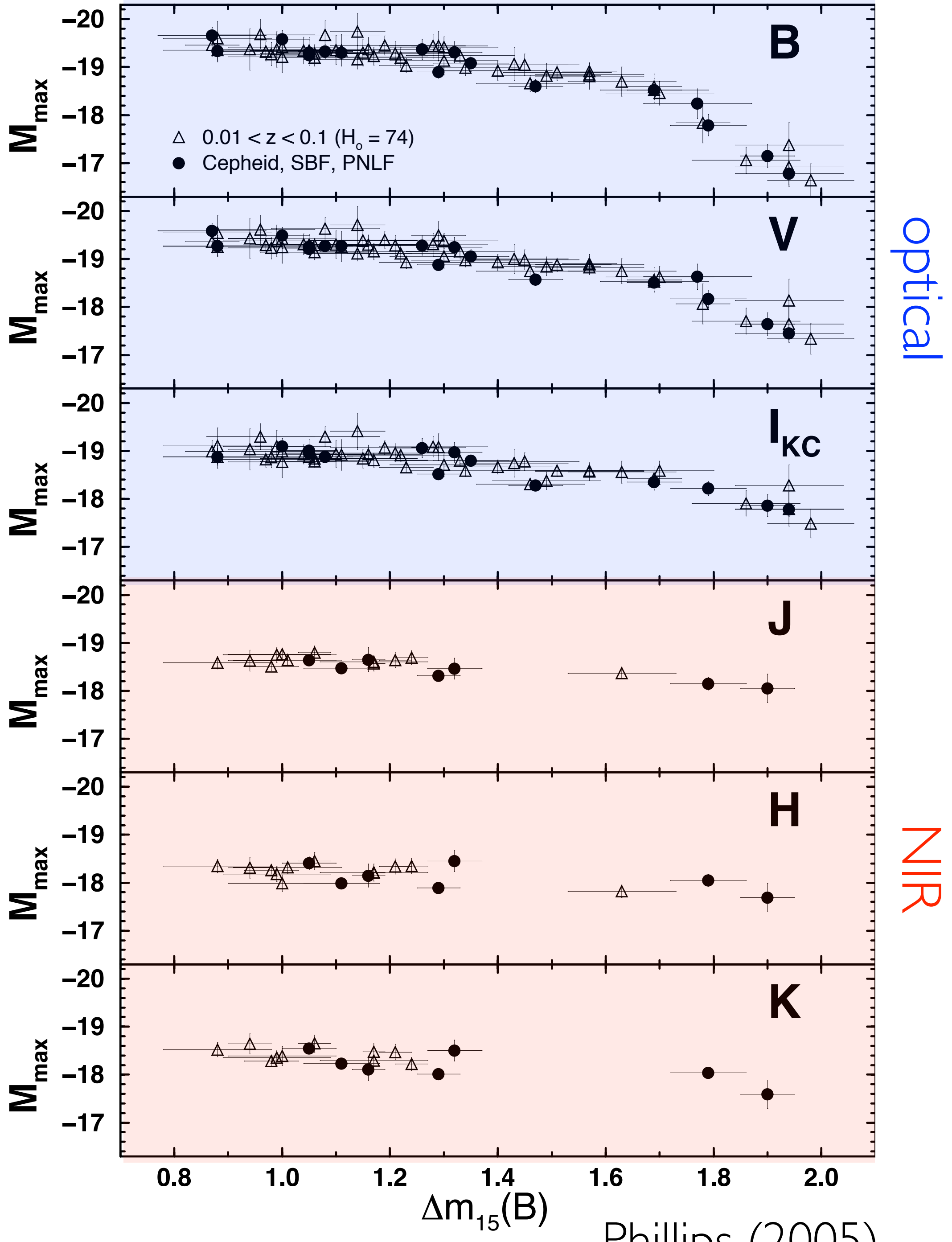
M. D. Stritzinger, C. Gall, et al.

Why NIR?



Kasen (2006)

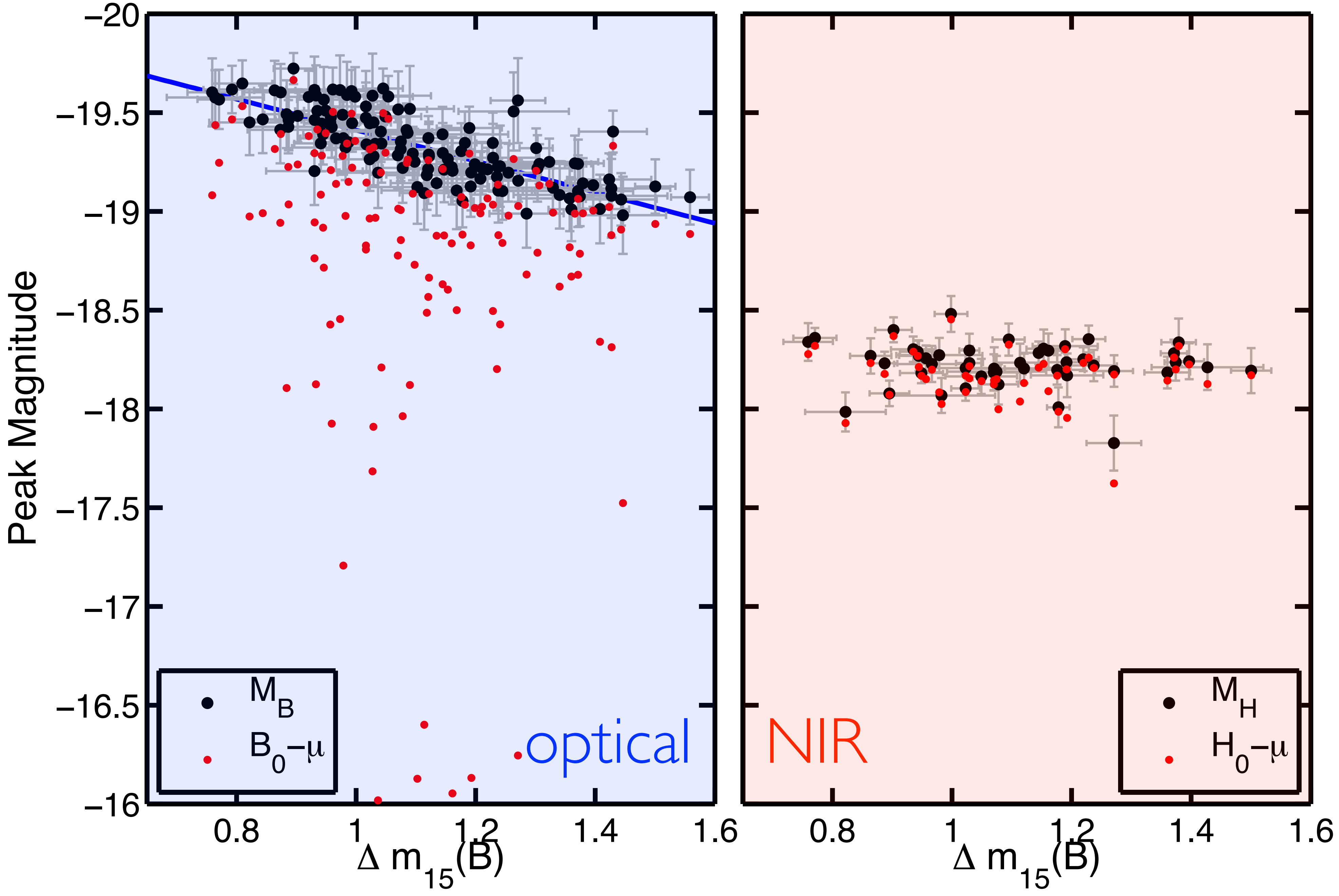


Phillips (2005)

Theory

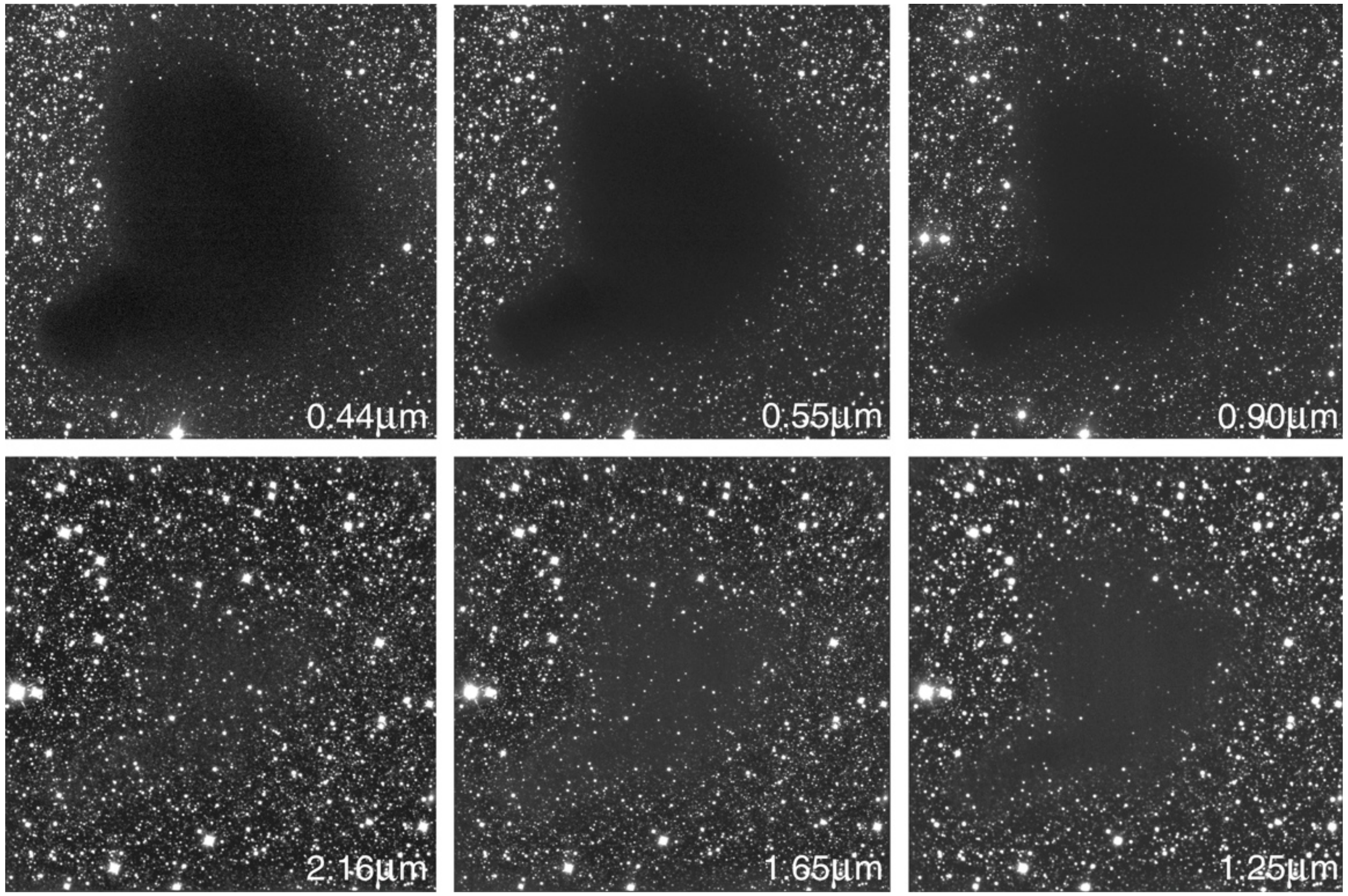
Observation

Why NIR?



Mandel et al. (2011)

Why NIR?

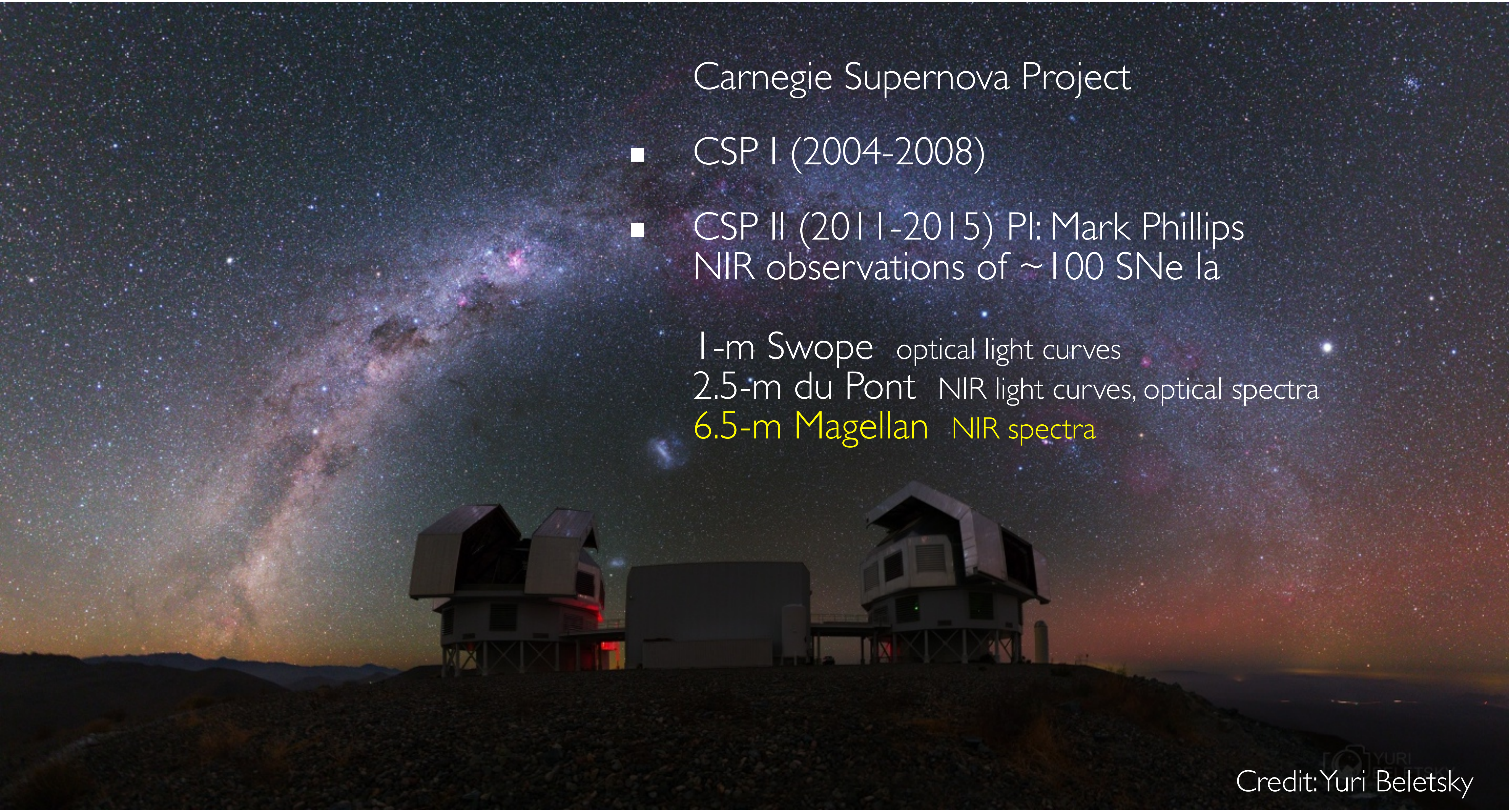


Credit: ESO

In the NIR, achieve higher precision through 2 routes:

- By avoiding things we do not understand (shortcut)
- By constraining the physics (more fun!)

CSP NIR spectroscopy



Carnegie Supernova Project

- CSP I (2004-2008)
- CSP II (2011-2015) PI: Mark Phillips
  NIR observations of ~100 SNe Ia

1-m Swope optical light curves
2.5-m du Pont NIR light curves, optical spectra
6.5-m Magellan NIR spectra

Credit: Yuri Beletsky

CSP NIR spectroscopy

of Ia
optical spectra

10^4

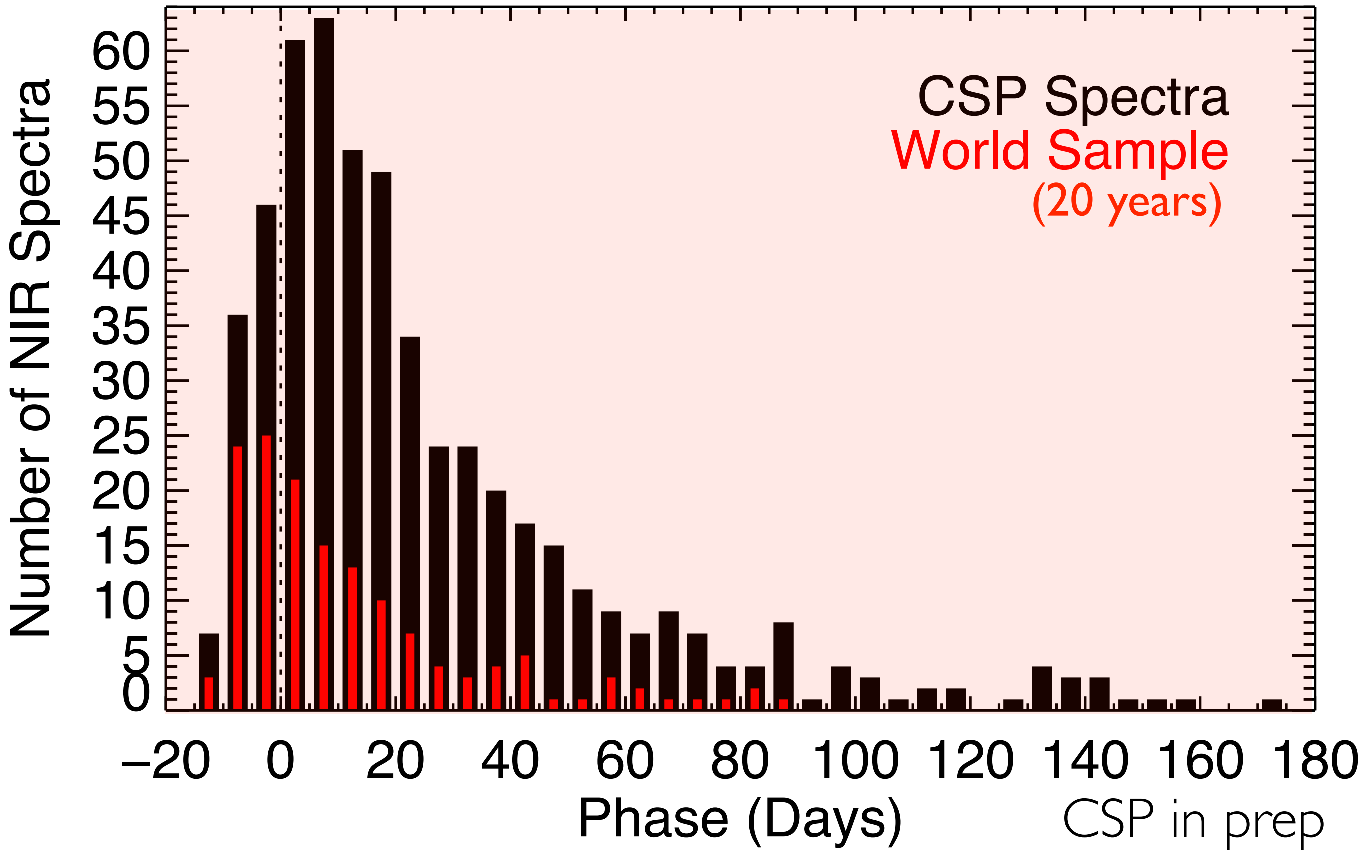
# of Ia
NIR spectra

10^2

41 from Marion et al. (2009)
+
91T, 94D, 98bu, 99by, 99ee, 02bo, 02dj,
03du, 05cf, 05df, 11fe, 13ebh,14J

CSP NIR spectroscopy

- FIRE on 6.5-m Magellan
  main workhorse
- In 4 years,
  600+ NIR spectra
  from 160 SNe Ia
- Large sample
  High S/N
  Time series
  Complementary optical
  and light-curve data

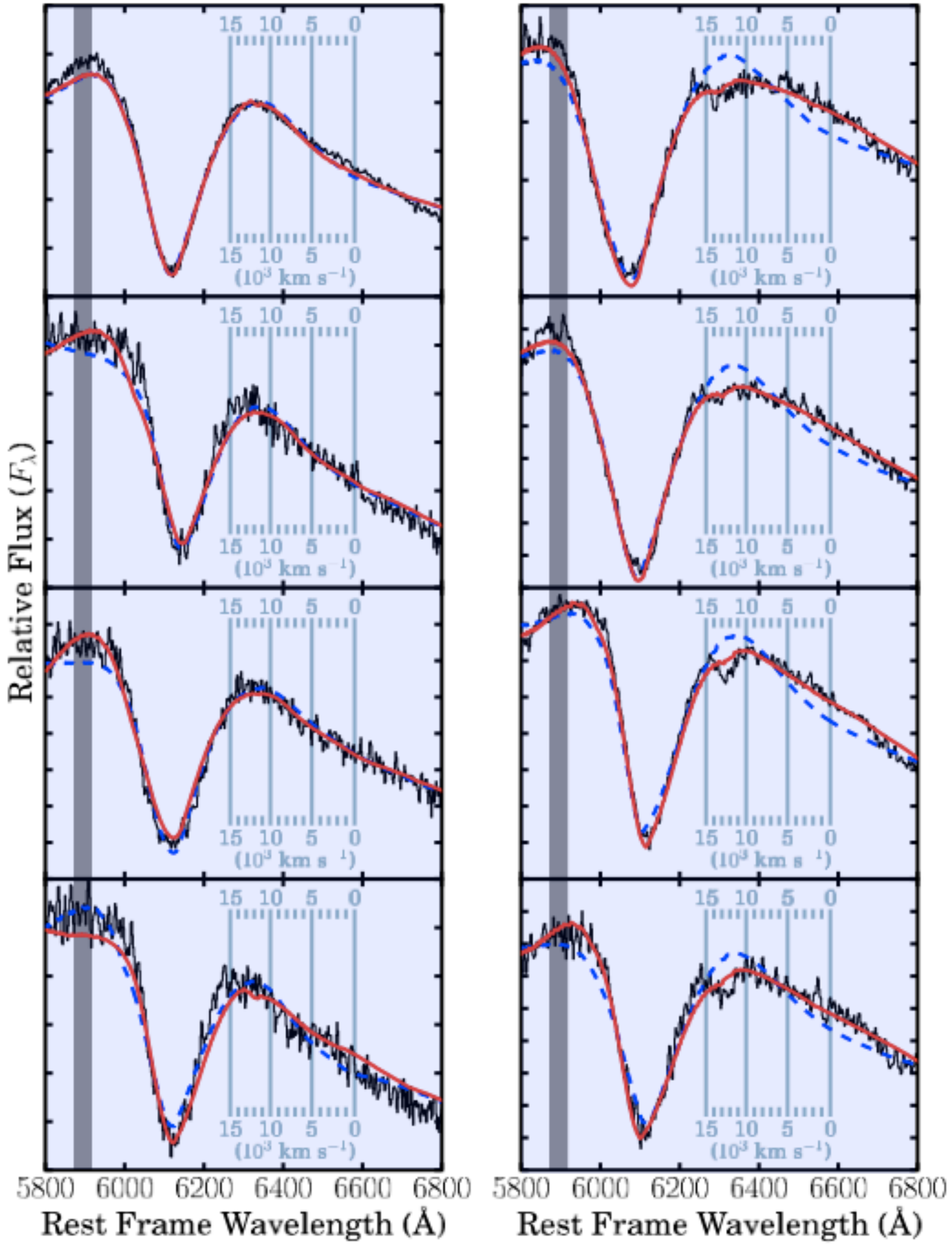


CSP in prep

Unburnt carbon

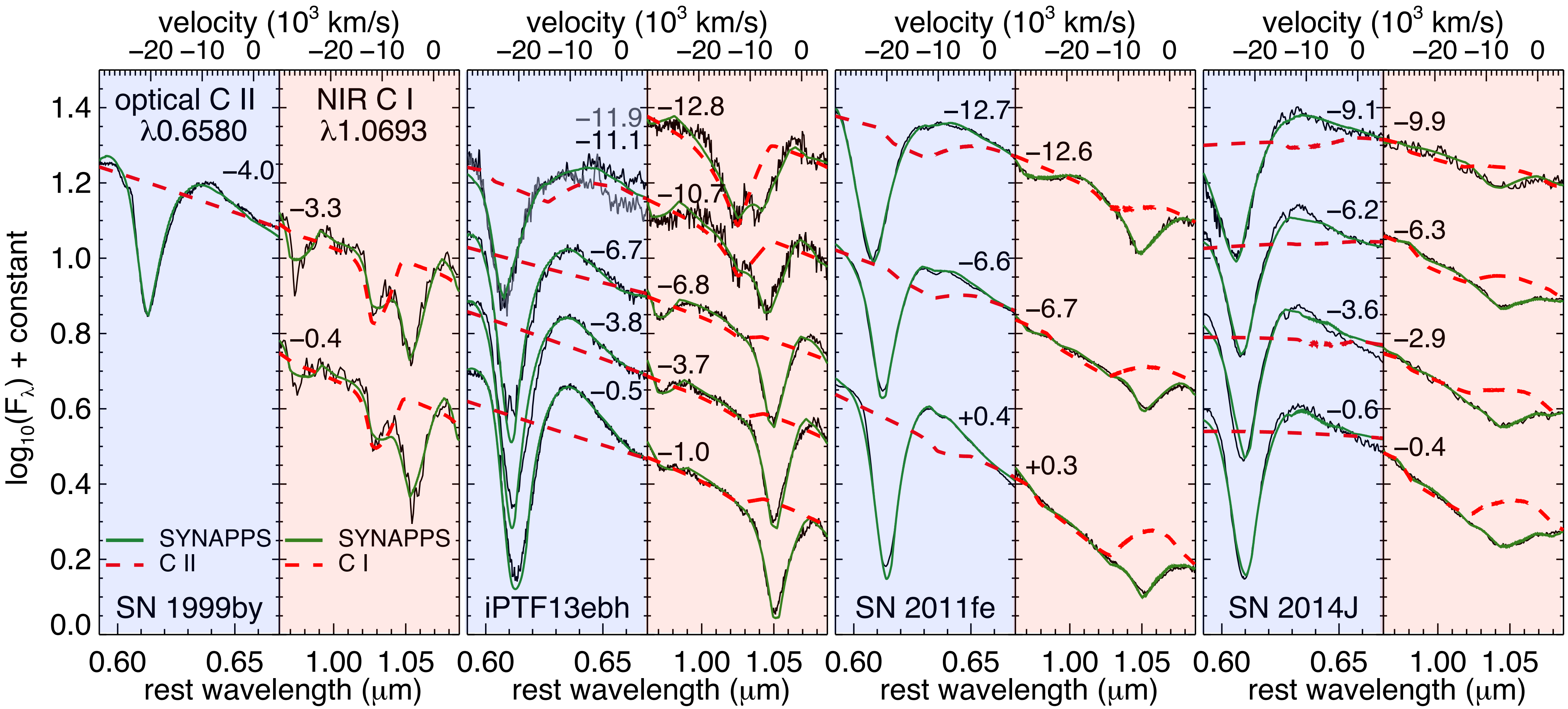
- Pristine material from the progenitor
- Incomplete burning: constraints for explosion models
- Optical C II 6580 detected in 20-30% of SNe Ia

Thomas et al. (2011)
Folatelli et al. (2012)
Silverman et al. (2012)



Thomas et al. (2011)

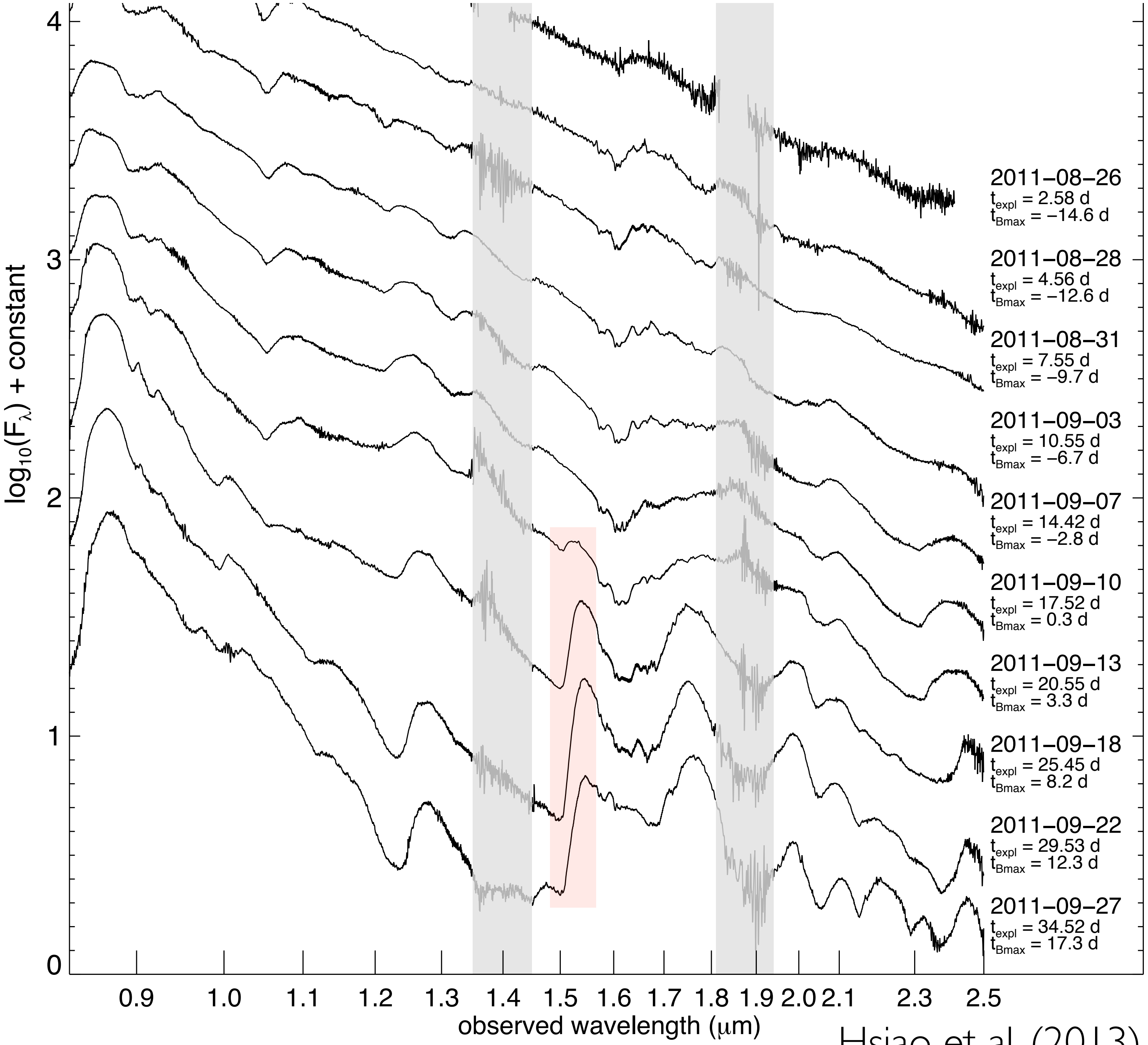
Unburnt carbon



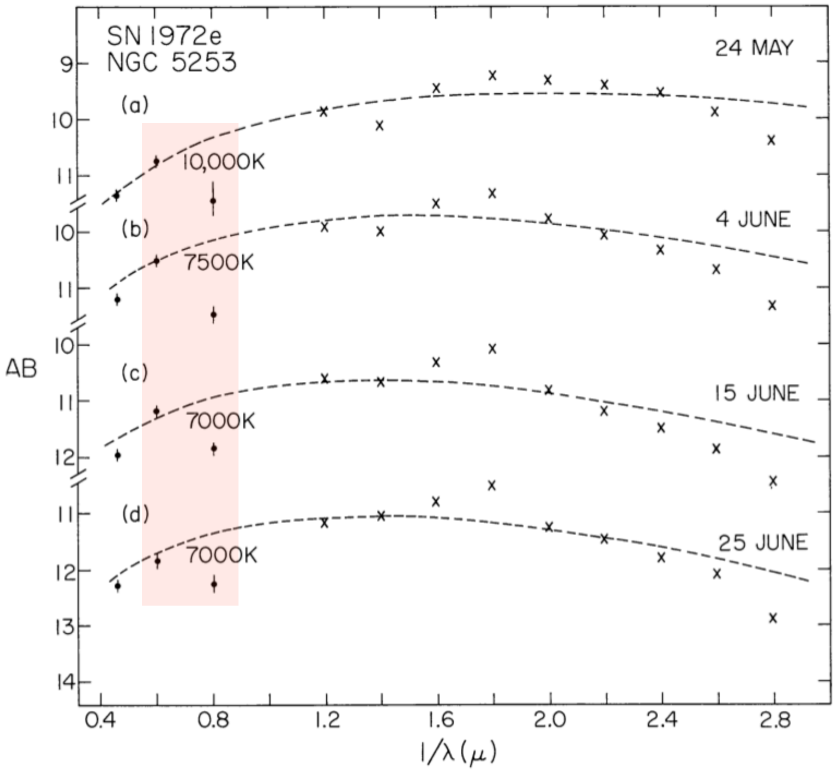
Hsiao et al. (2013, 2015)

- NIR provides a more complete census of carbon than the optical
- Is unburnt material present in all SNe Ia?

H-band break



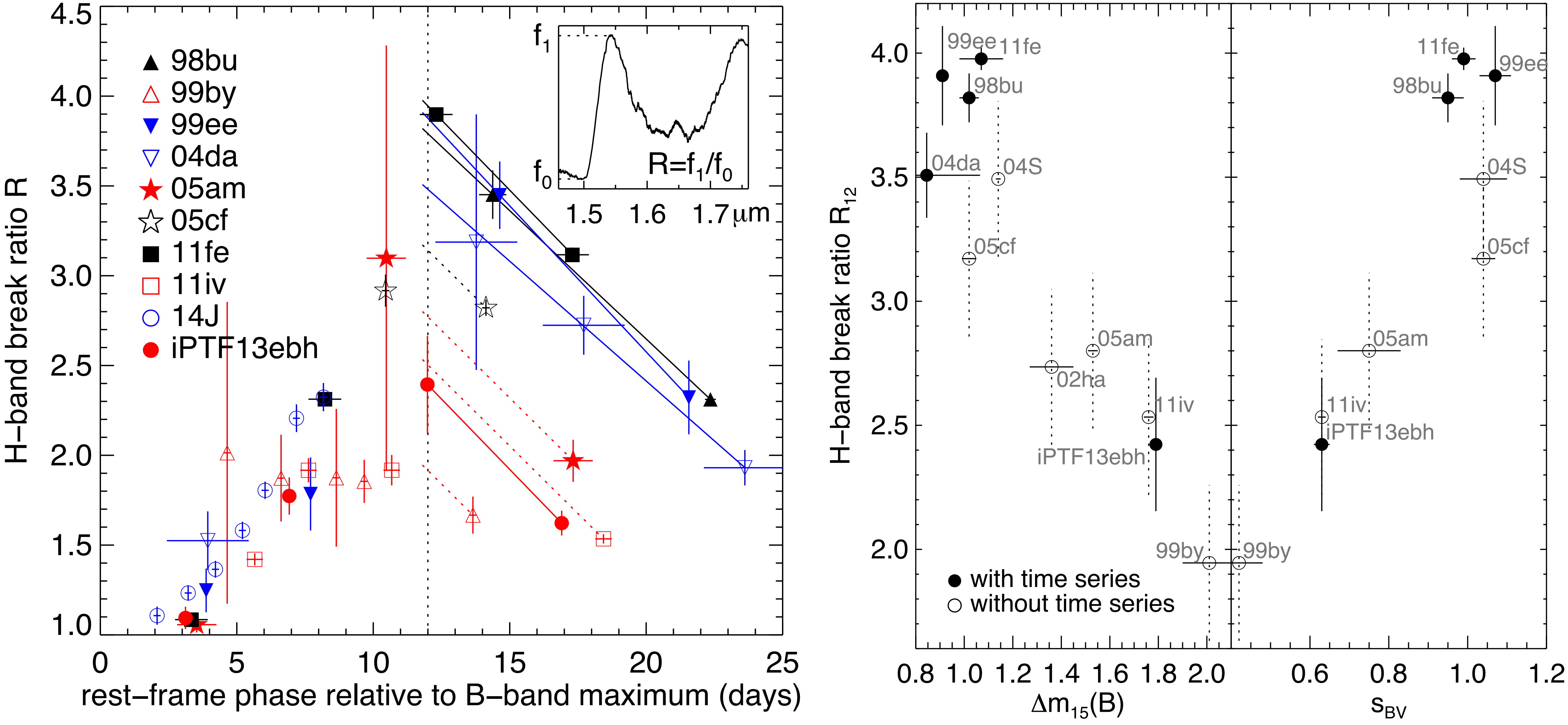
Hsiao et al. (2013)



Kirshner et al. (1973)

- H-band break: most prominent SN Ia NIR feature

H-band break

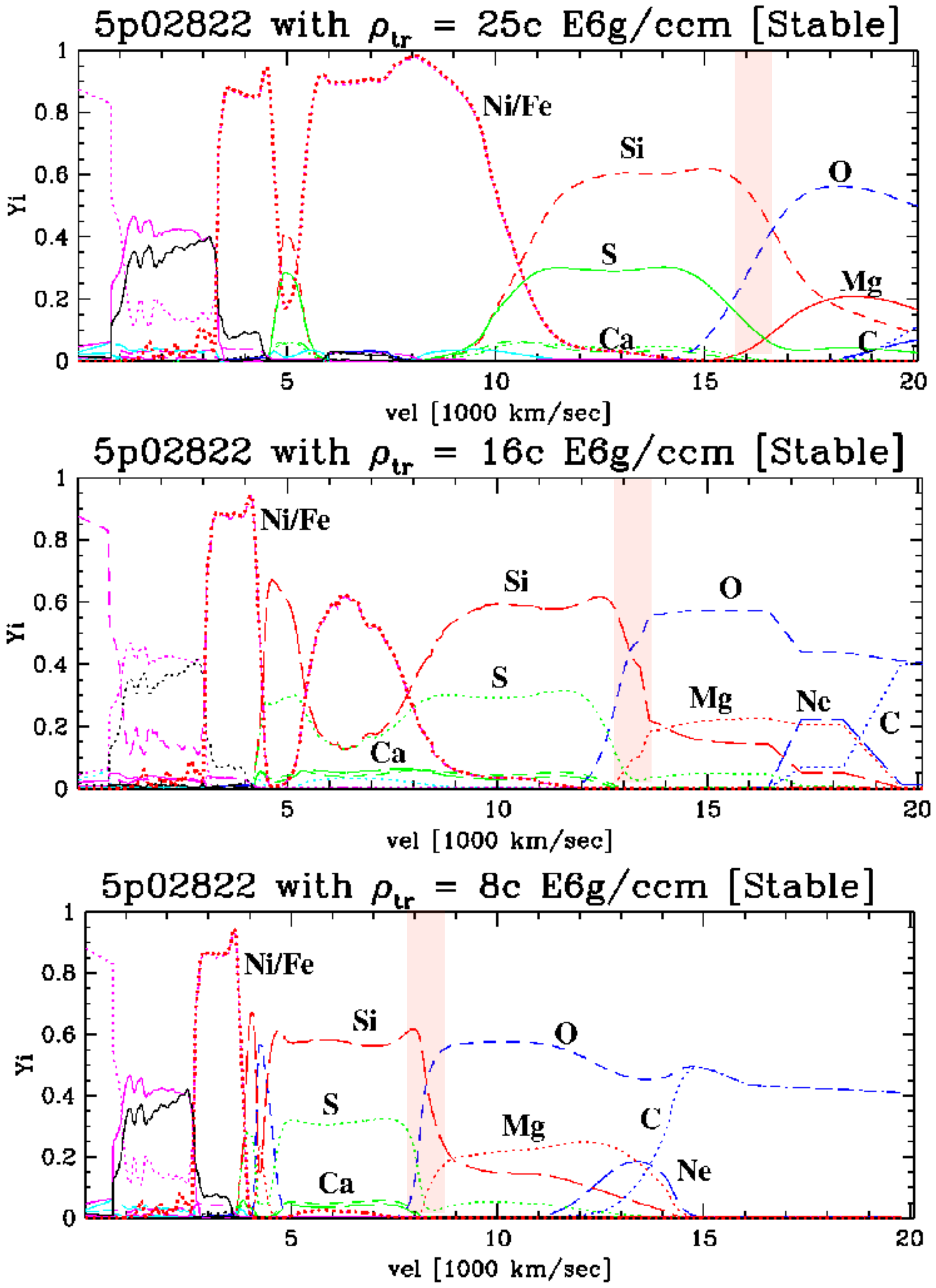


Hsiao et al. (2013, 2015)

- Strong correlation consistent with Chandrasekhar-mass delayed detonation
- Weak correlation expected for dynamical merger

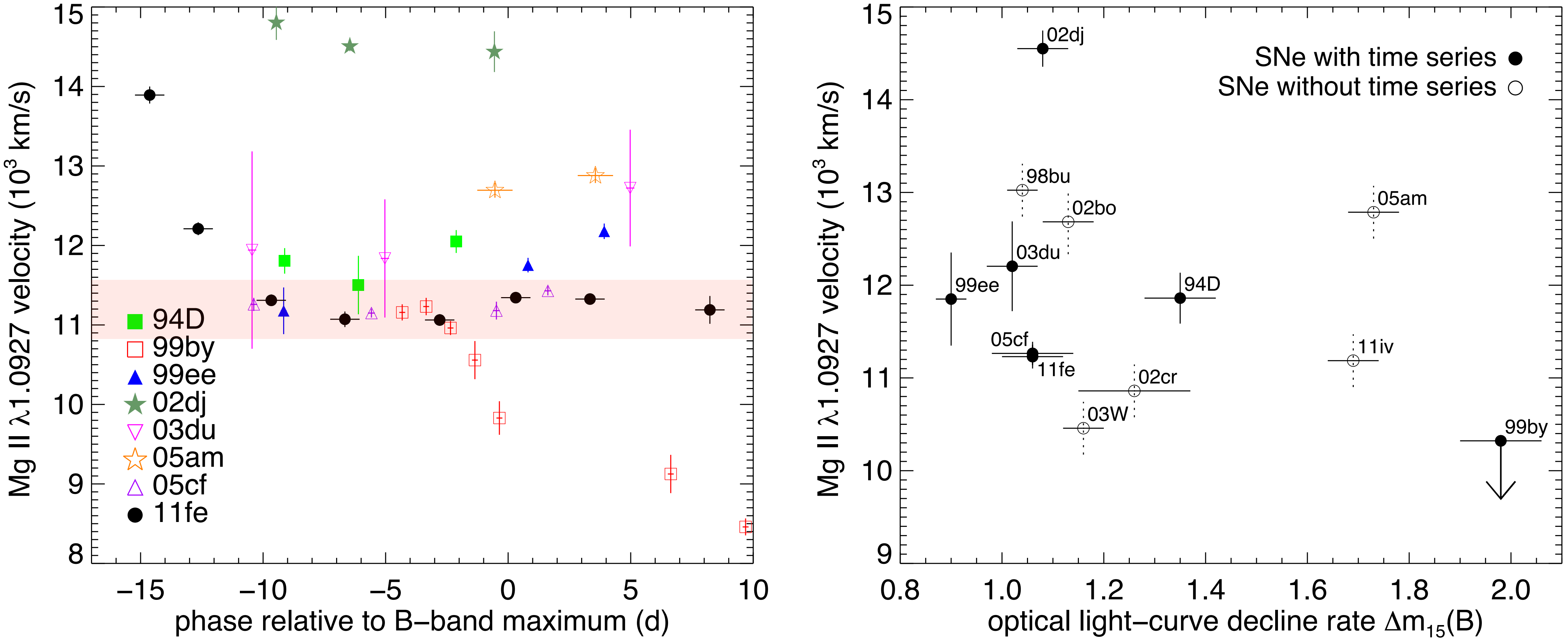
Magnesium velocity

- NIR Mg II 10927
  strong, isolated line
- Flat Mg velocity evolution:
  bottom of C burning layer
- Boundary between
  C/O burning
- Sensitive to transition density



Wheeler et al. (1998), Höflich et al. (2002)

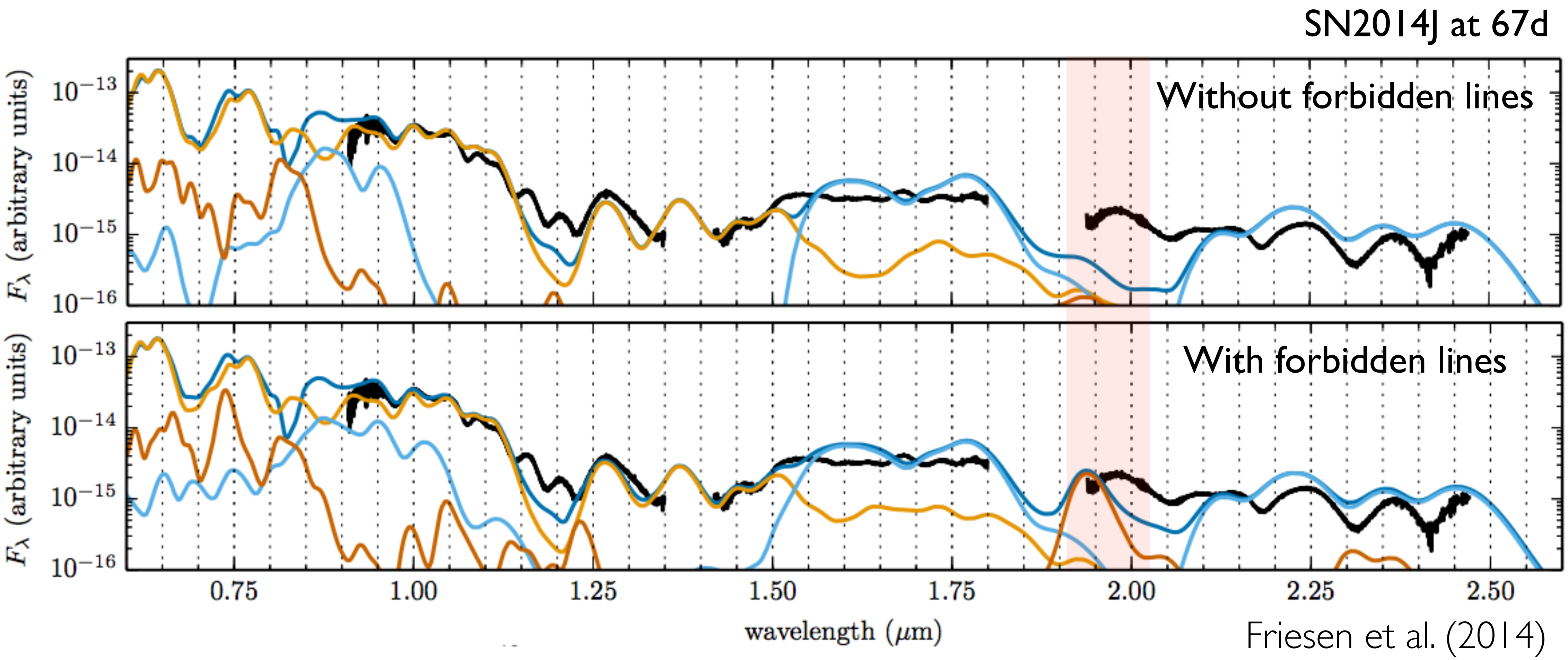
Magnesium velocity



Hsiao et al. (2013)

- No correlation with light-curve decline rate
- Transition density not the main driver of SN brightness?

Neutron content



Friesen et al. (2014)

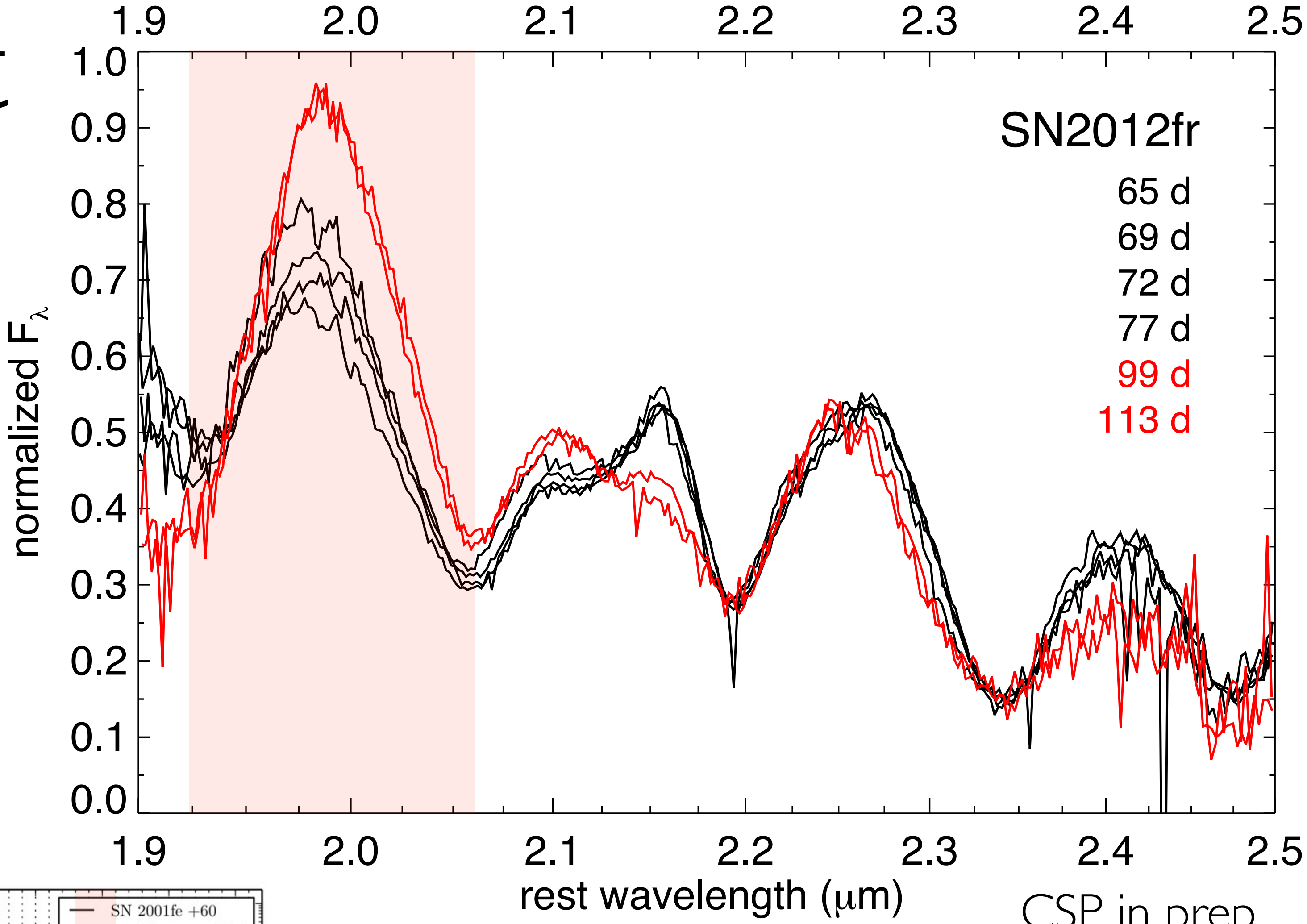
- Transitional phase NIR spectra ~50-100 d past explosion
- 1.98 micron feature possible [Ni II], stable nickel

Neutron content

Influenced by

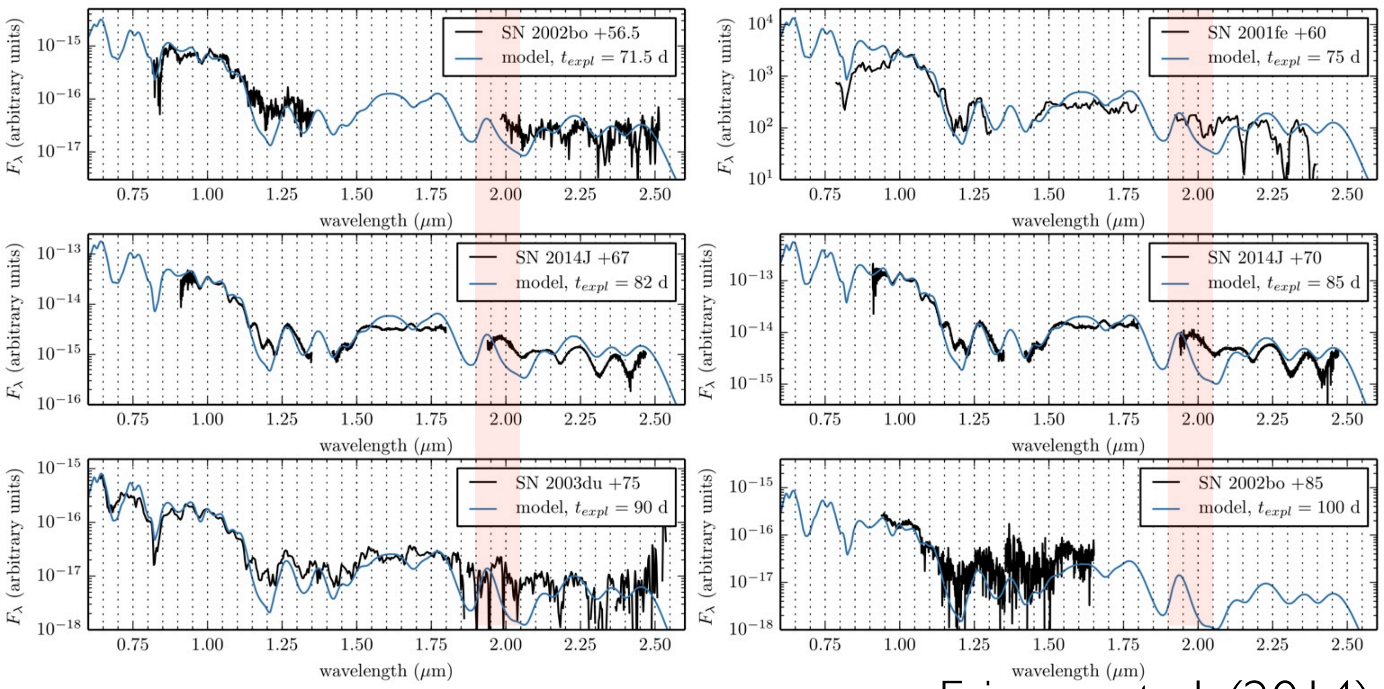
- Metallicity of progenitor
- Neutronization
  in simmering phase
- High density white dwarf

CSP data



CSP in prep

Archival data



Friesen et al. (2014)

Summary

Pre-maximum spectra

- Unburnt material (Marion et al. 2006, Hsiao et al. 2013, 2015)
- Boundary of C/O burning (Wheeler et al. 1998, Höflich et al. 2002, Hsiao et al. 2013)

Post-maximum spectra

- Distribution of ^{56}Ni (Höflich et al. 2002, Hsiao et al. 2013)
- Progenitor metallicity (Marion 2001)
- Companion signature (Maeda et al. 2014)

Transitional phase spectra

- Neutron content (Friesen et al. 2014)

Nebular phase spectra

- Mixing between ^{56}Ni and ^{58}Ni (Höflich et al. 2004)
- Asymmetric explosion (Motohara et al. 2006)
- Progenitor magnetic field (Penney & Höflich 2014)
- Initial central density (Diamond et al. 2014)