Carnegie Supernova Project II

Eric Y. Hsiao

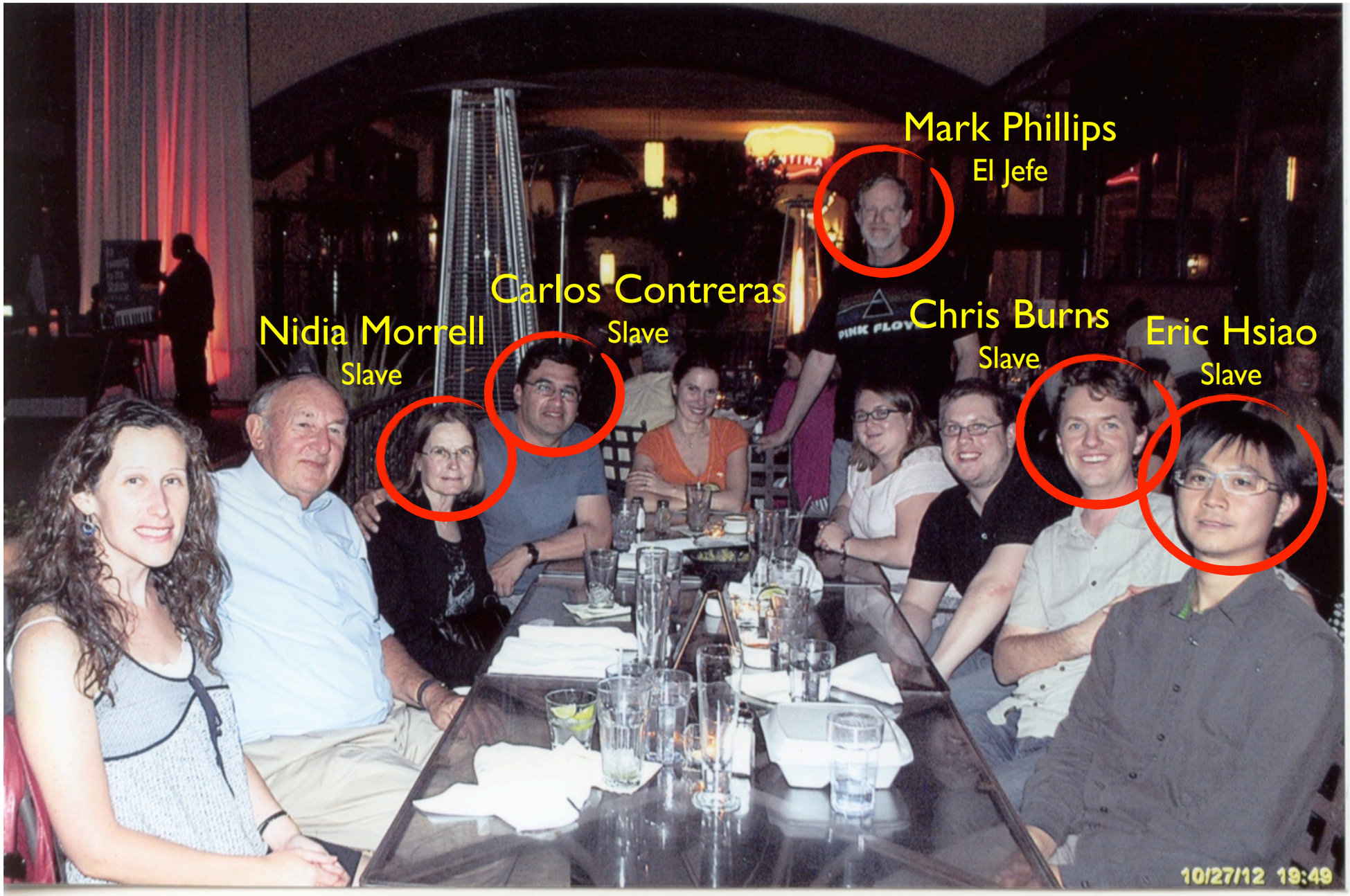
CSP2

- We propose to carry out a second stage of the CSP with the goal of producing optical and NIR light curves of 100-200 SNe Ia in the redshift range $0.03 < z < 0.08$, thereby reducing the rms error due to peculiar motions to ±2% in distance.

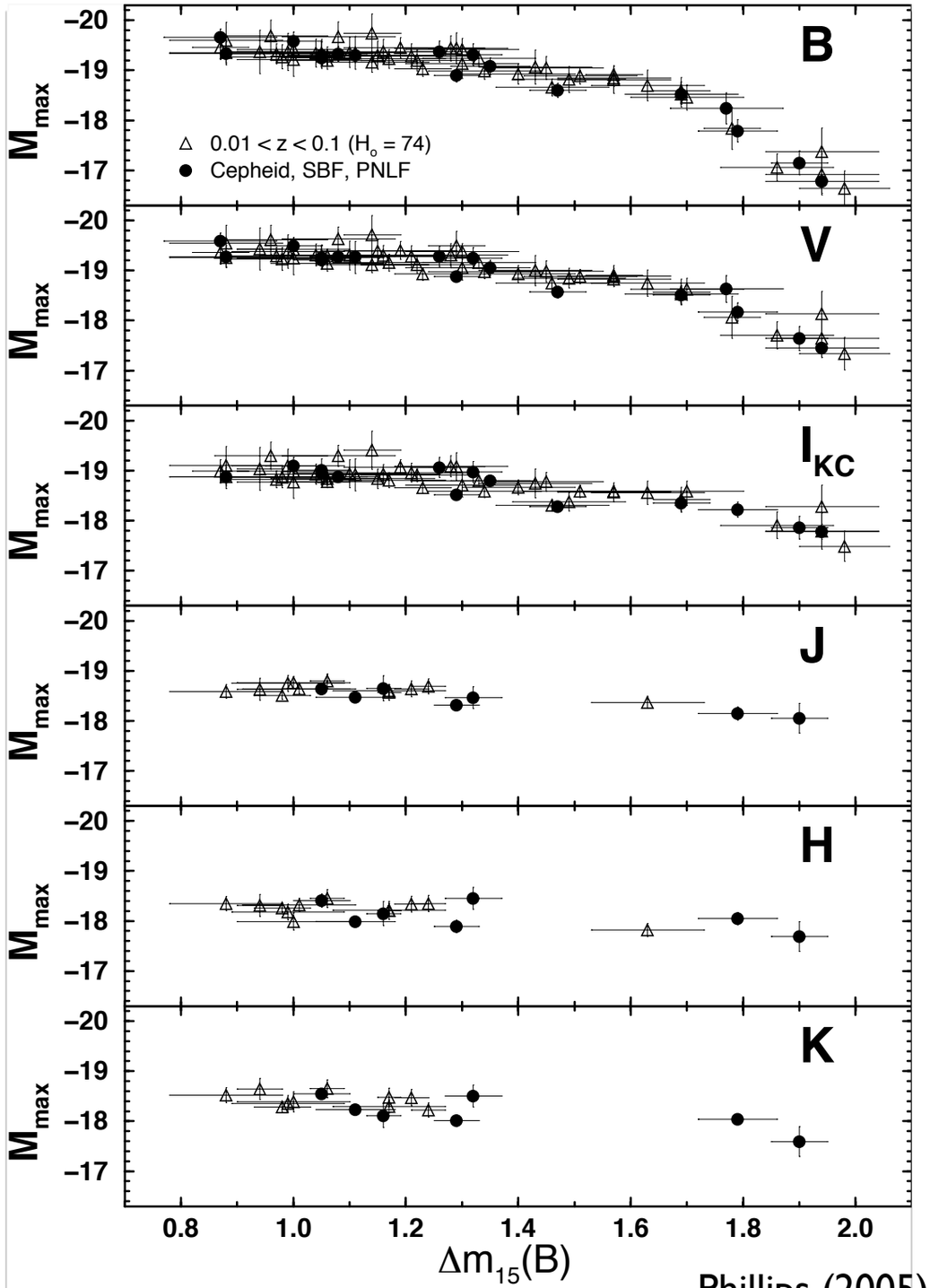
- NSF-funded for 5 years, started in Nov 2011

Organization chart

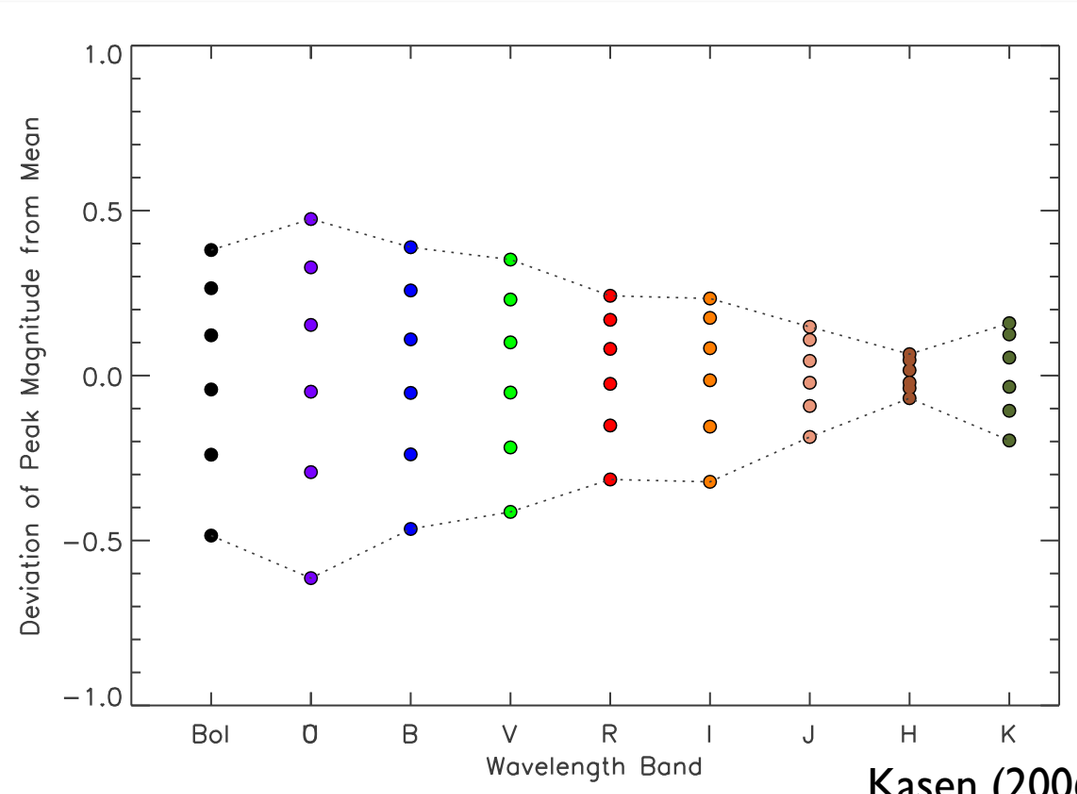
Organization chart



Why NIR?

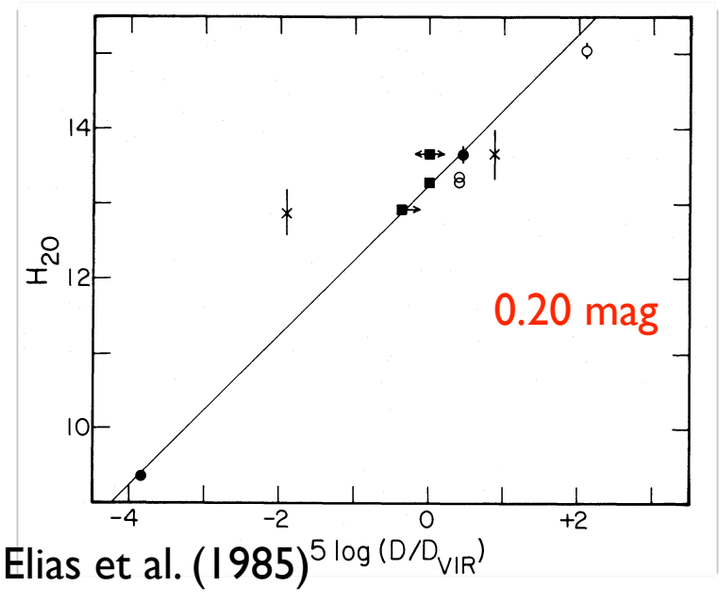


Phillips (2005)

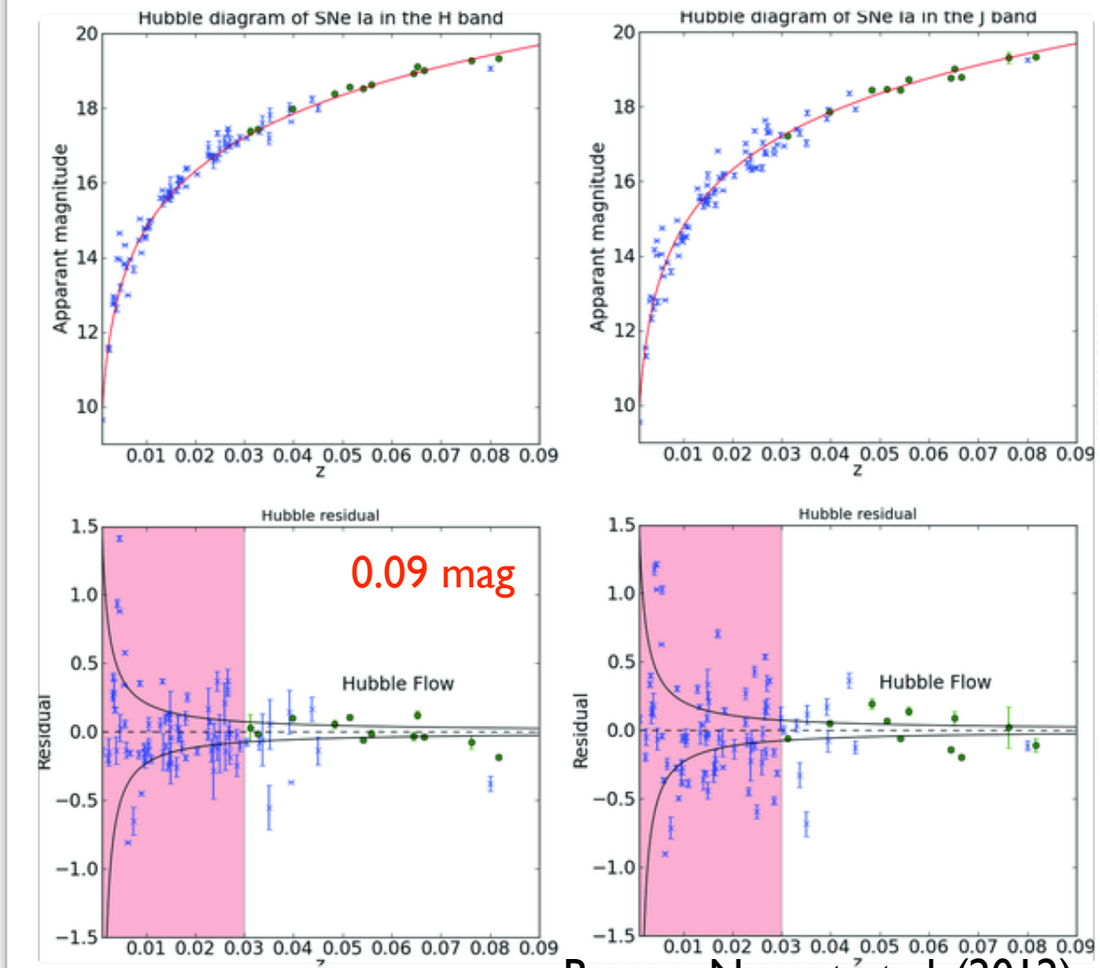


Kasen (2006)

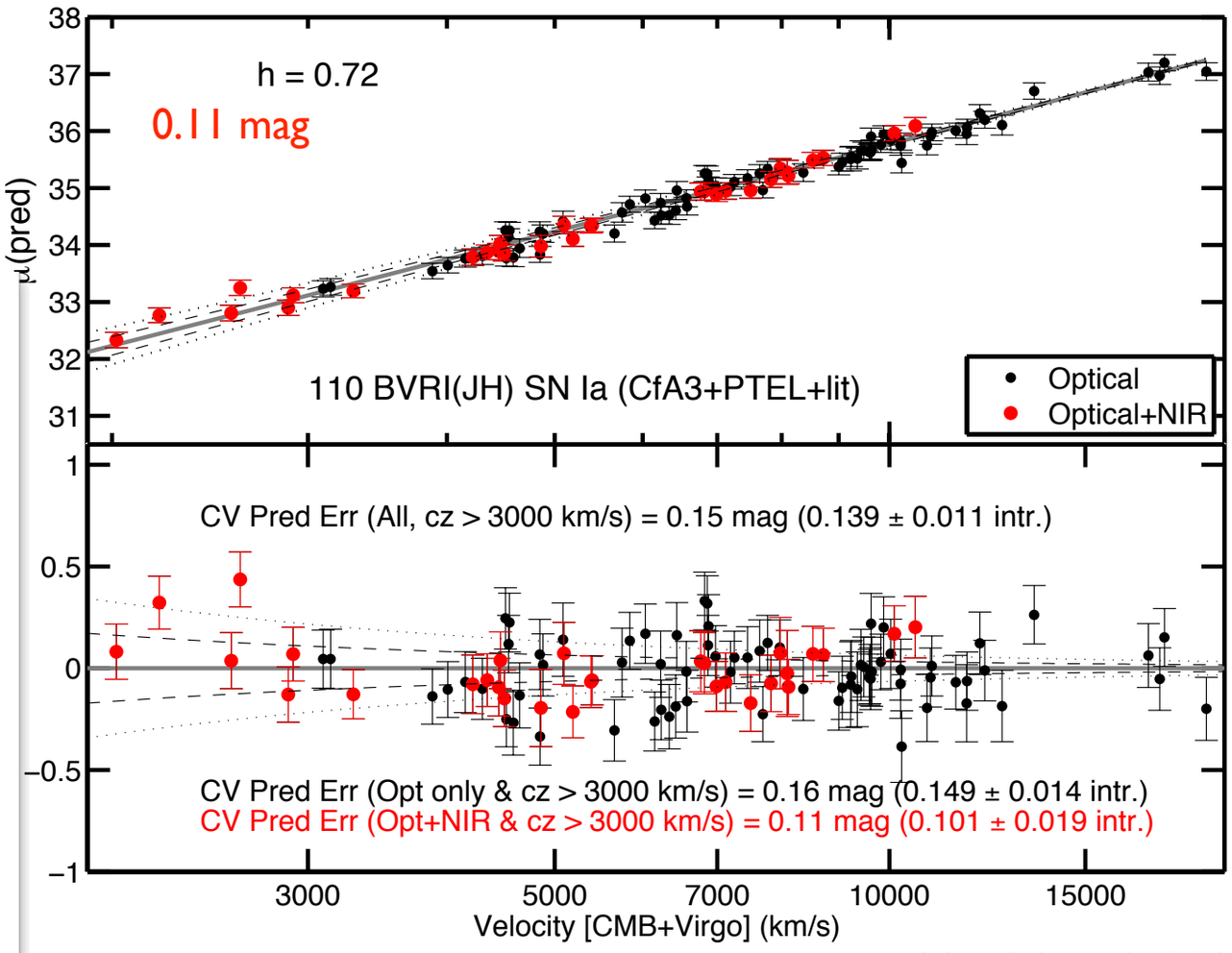
Why NIR?



Elias et al. (1985)



Barone-Nugent et al. (2012)



Mandel et al. (2011)

Improvements over CSP1

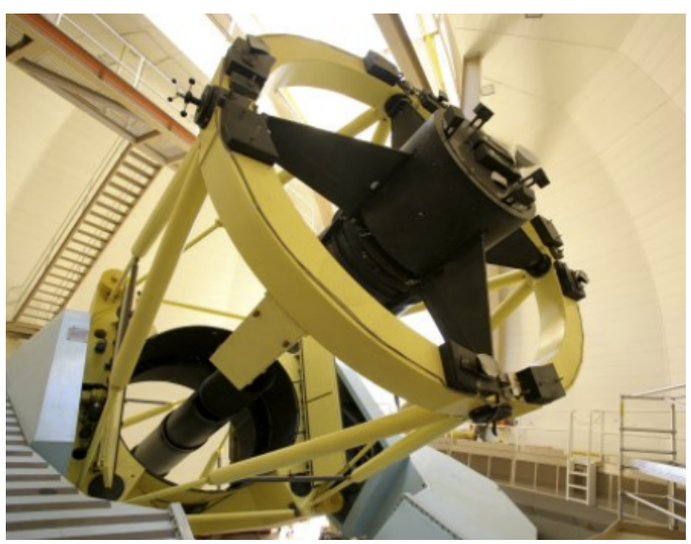
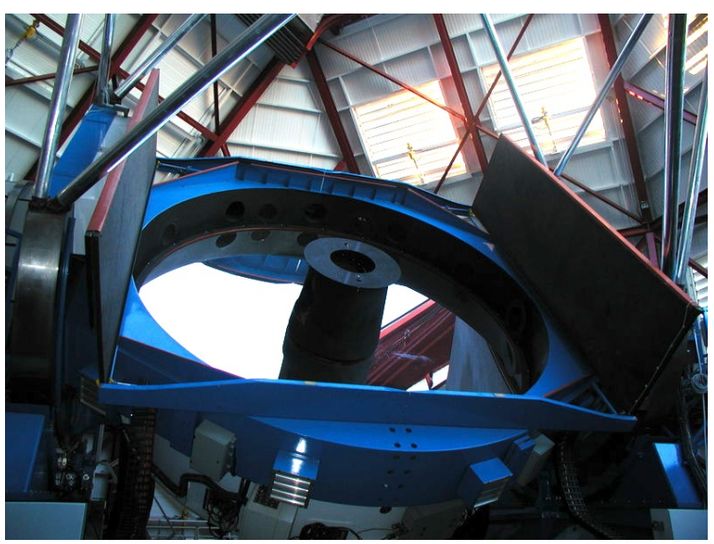
- SNe from blind searches: LSQ, PTF, SkyMapper
- routinely catch NIR primary maximum
- lower peculiar velocity error
- improve NIR K-correction
- examine host properties

Improvements over CSP1

- Hardware improvements
  - Relocate RetroCam from 1-m Swope to 2.5-m du Pont: done.
  - New e2v CCD on 1-m Swope: soon-ish.
  - Roboticize 1-m Swope: I don't know.

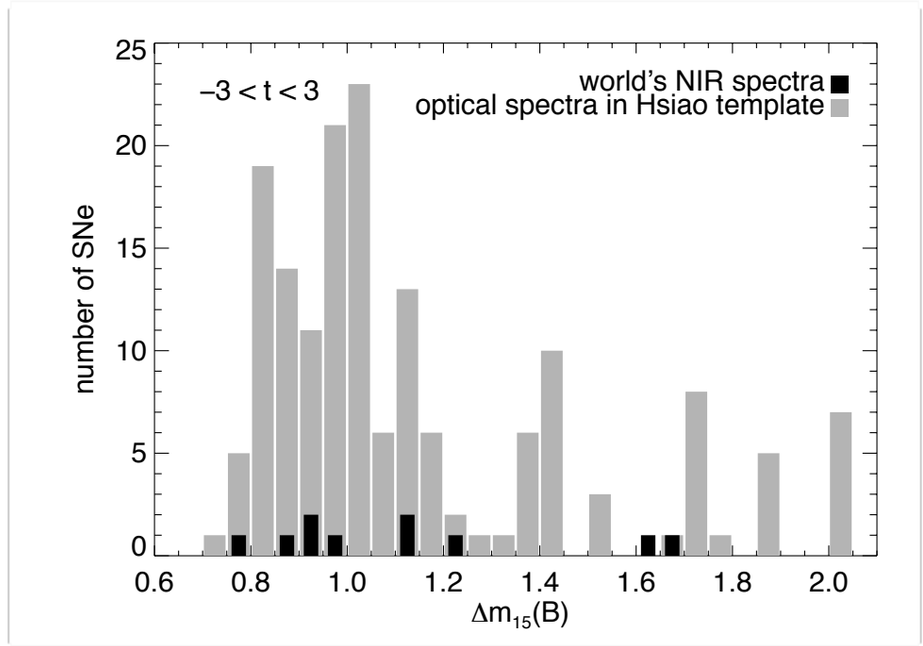
Observing strategy

- 5 years, ~150 SNe Ia in total, 5 SNe/month
- each year: 6 months centered on summer
  (75% photometric nights)
  - 1 nights of spec screening
  - 6 nights YJH imaging: 2.5-m du Pont+RetroCam
  - nightly uBVgri imaging: 1-m Swope+e2v CCD
  - 3+ nights NIR spectroscopy/imaging (FIRE/FourStar)

Why NIR spectroscopy?

- cosmological utility
  - k-correction errors
    need to be minimized/understood



- physical diagnostics
  - probe of primordial material
  - accurate measure of boundary between C/O burning layers
    transition between sub/supersonic burning front
  - conditions of synthesized material in core

- NIR provides independent information
  not available in the optical

NIR spectroscopy

- 6.5-m Baade + FIRE
  3+ nights/month
  CSP, CfA(Kirshner, Marion),
  Australia (Lidman), Chile (Förster)

- 8.1-m Gem-N + GNIRS
  3 hours/month
  GNIRS is kaput...

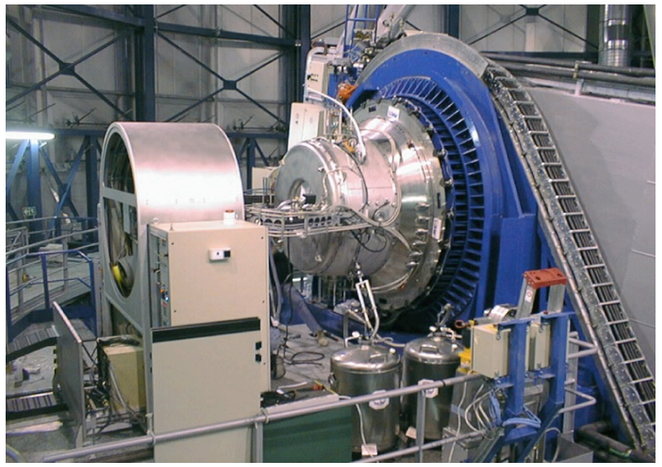
- 8.1-m Gem-S + FLAMINGOS-2
  FLAMINGOS-2 is kaput...

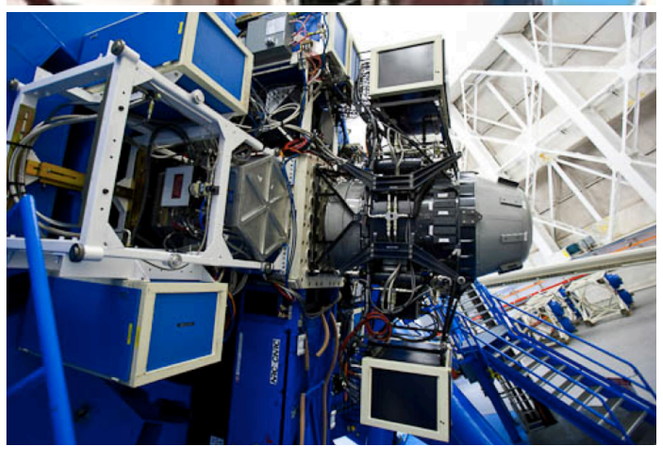
- 8.2-m VLT + ISAAC
  3 hours/month
  through Stritzinger, not continued

- 3.6-m NTT + SofI
  through PESSTO

- 3.0-m IRTF + SpeX
  through Marion et al., 2013A?

- 8.2-m Subaru + IRCS
  nebular phase, through Maeda et al.

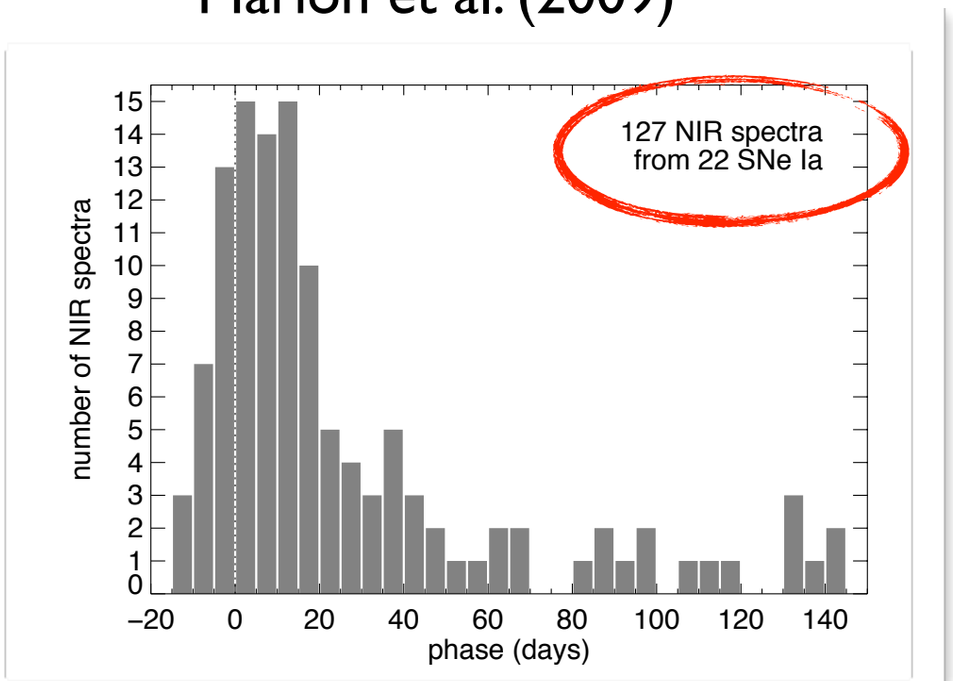


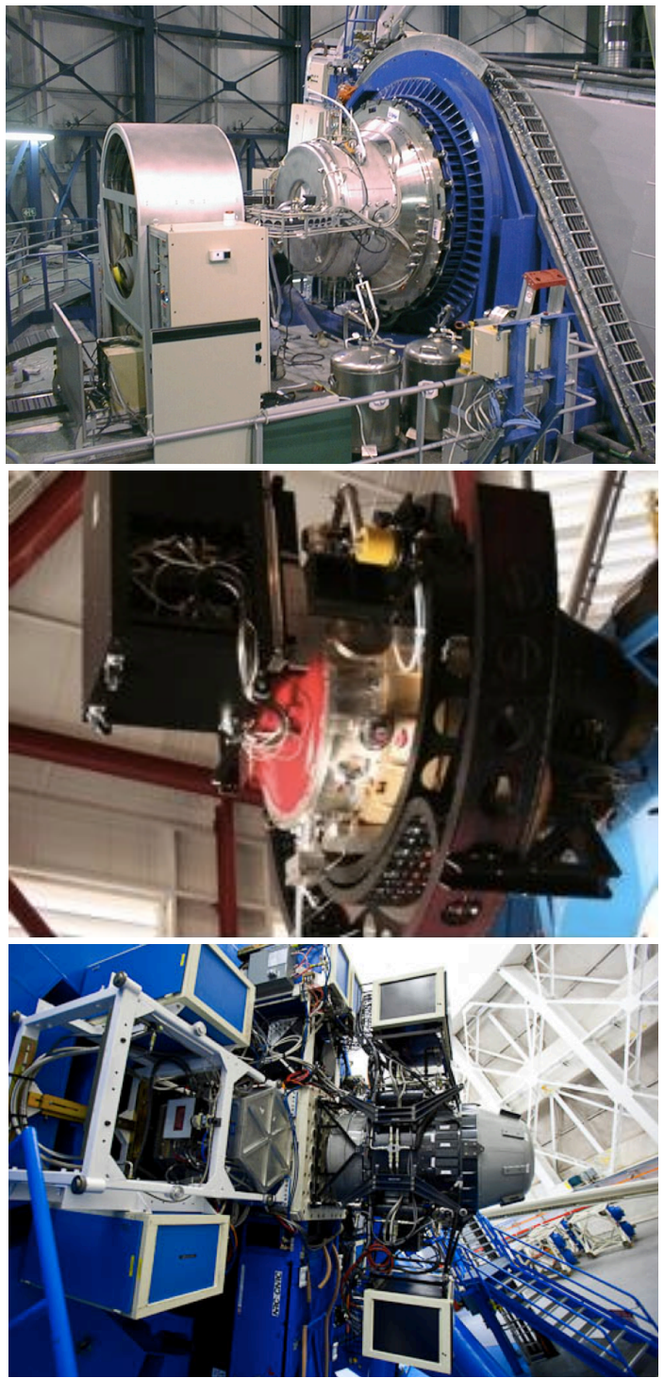


NIR spectroscopy

- time series
- accompanying opt/NIR LCs
- simultaneous optical spectra
- Hubble flow/blind-search objects

Year 1 already tripled
Marion et al. (2009)



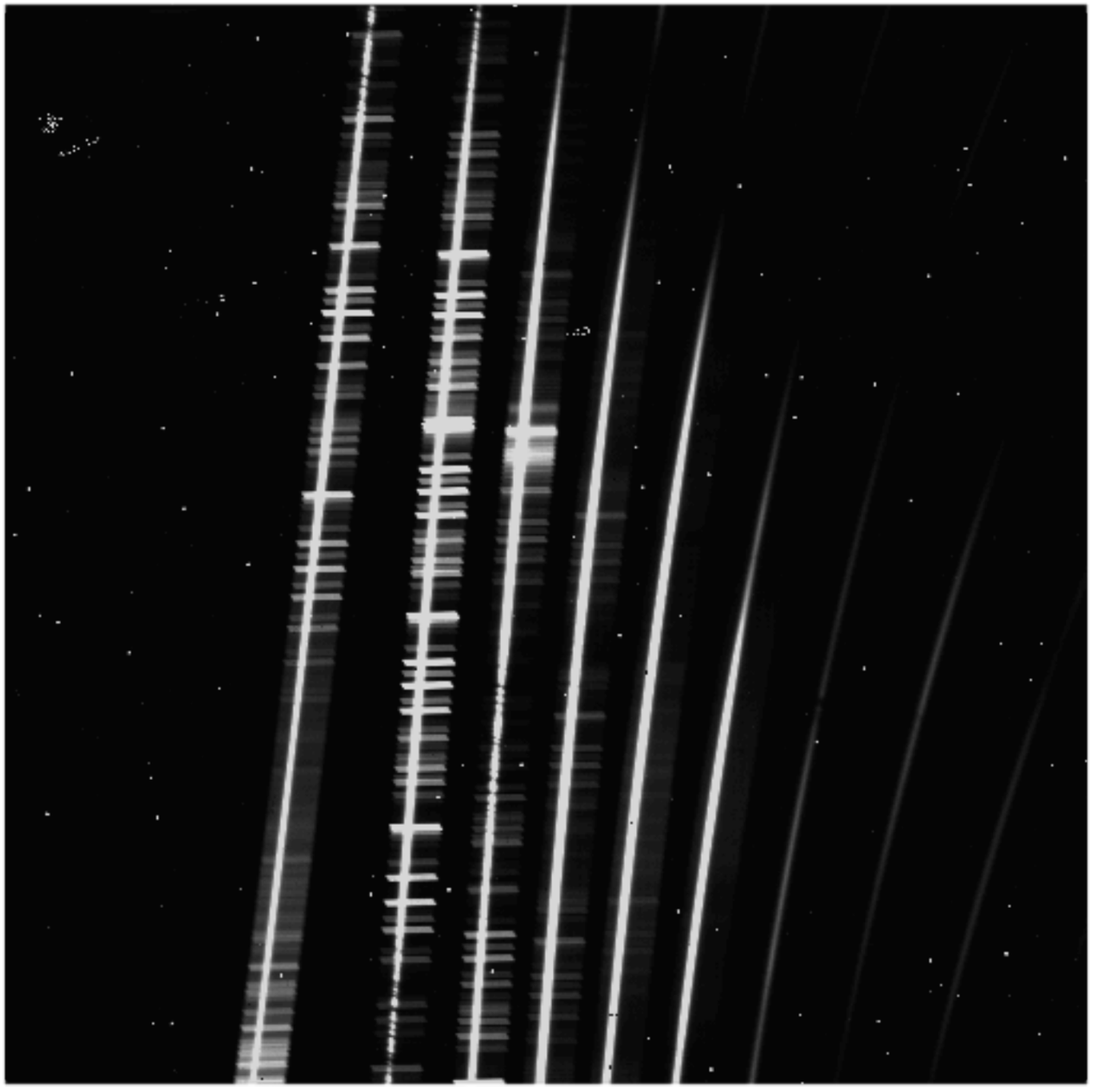


NIR time-series spectroscopy of SN 2011fe

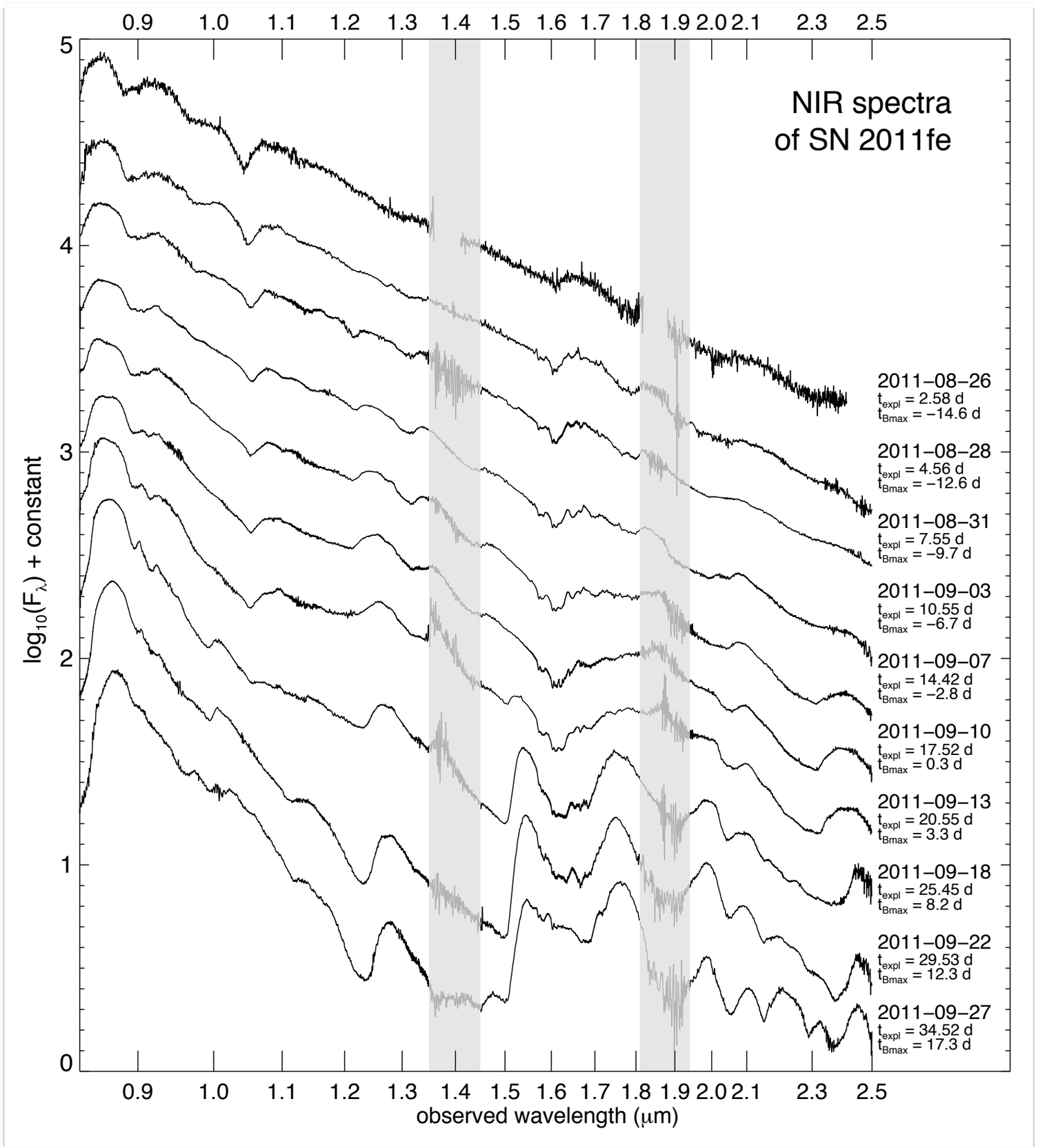
THE EARLIEST NEAR-INFRARED TIME-SERIES SPECTROSCOPY OF A TYPE Ia SUPERNOVA

E. Y. Hsiao[1], G. H. Marion[2], M. M. Phillips[1], C. R. Burns[3], C. Winge[4], N. Morrell[1], C. Contreras[1], W. L. Freedman[3], M. Kromer[5], E. E. E. Gall[5,6], C. L. Gerardy[7], P. Höflich[7], M. Im[8], Y. Jeon[8], R. P. Kirshner[2], P. E. Nugent[9,10], S. E. Persson[3], G. Pignata[11], M. Roth[1], V. Stanishev[12], M. Stritzinger[13], N. B. Suntzeff[14]

GNIRS observations of SN2011fe



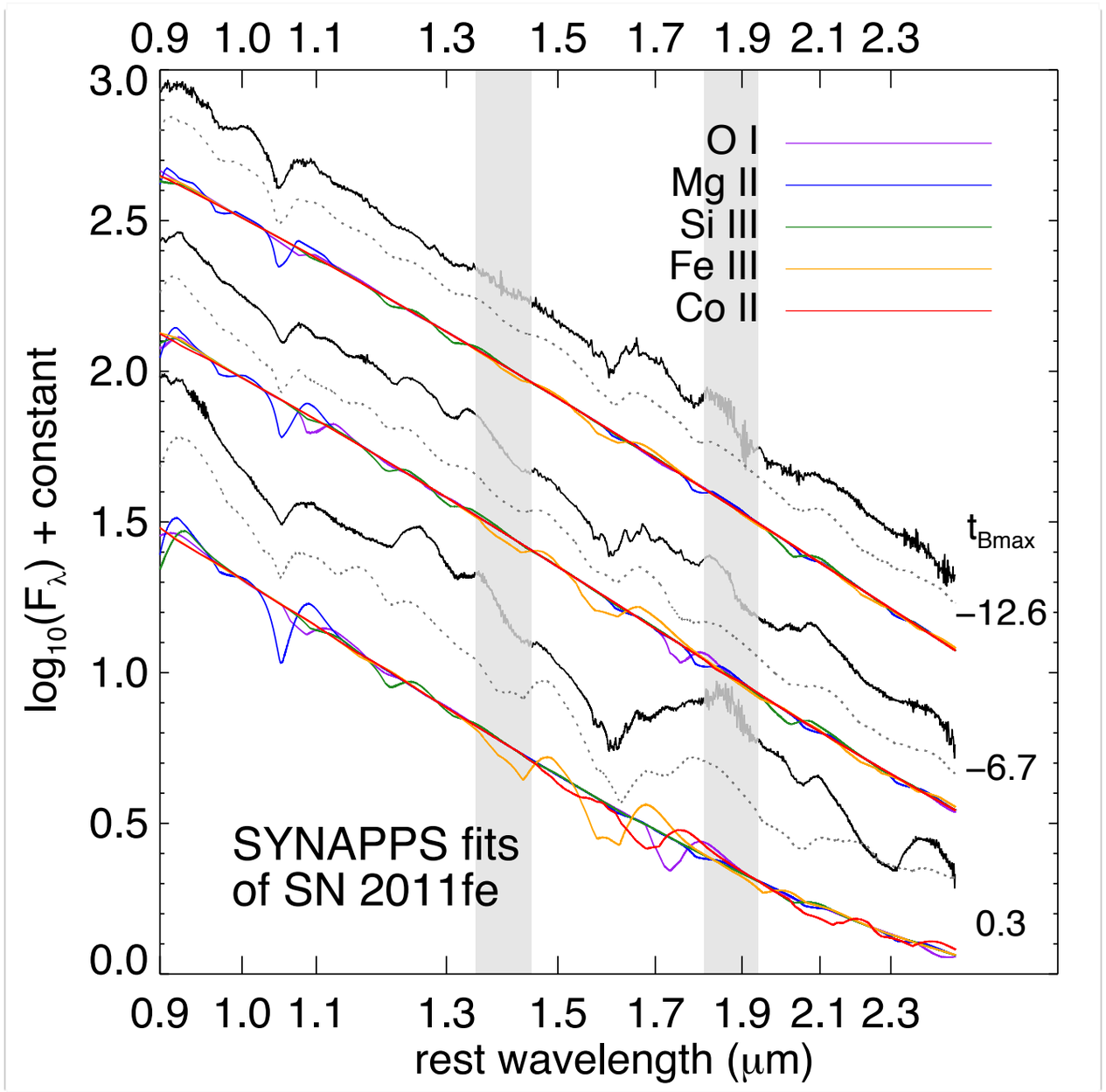
- short blue camera 0.15”/pixel
- cross-dispersing prism
- 32 l/mm grating
- 6 orders
- simultaneous 0.9-2.5 μm coverage
- R~1700



- 1 SpeX (Marion)
  +
  9 GNIRS
  NIR spectra

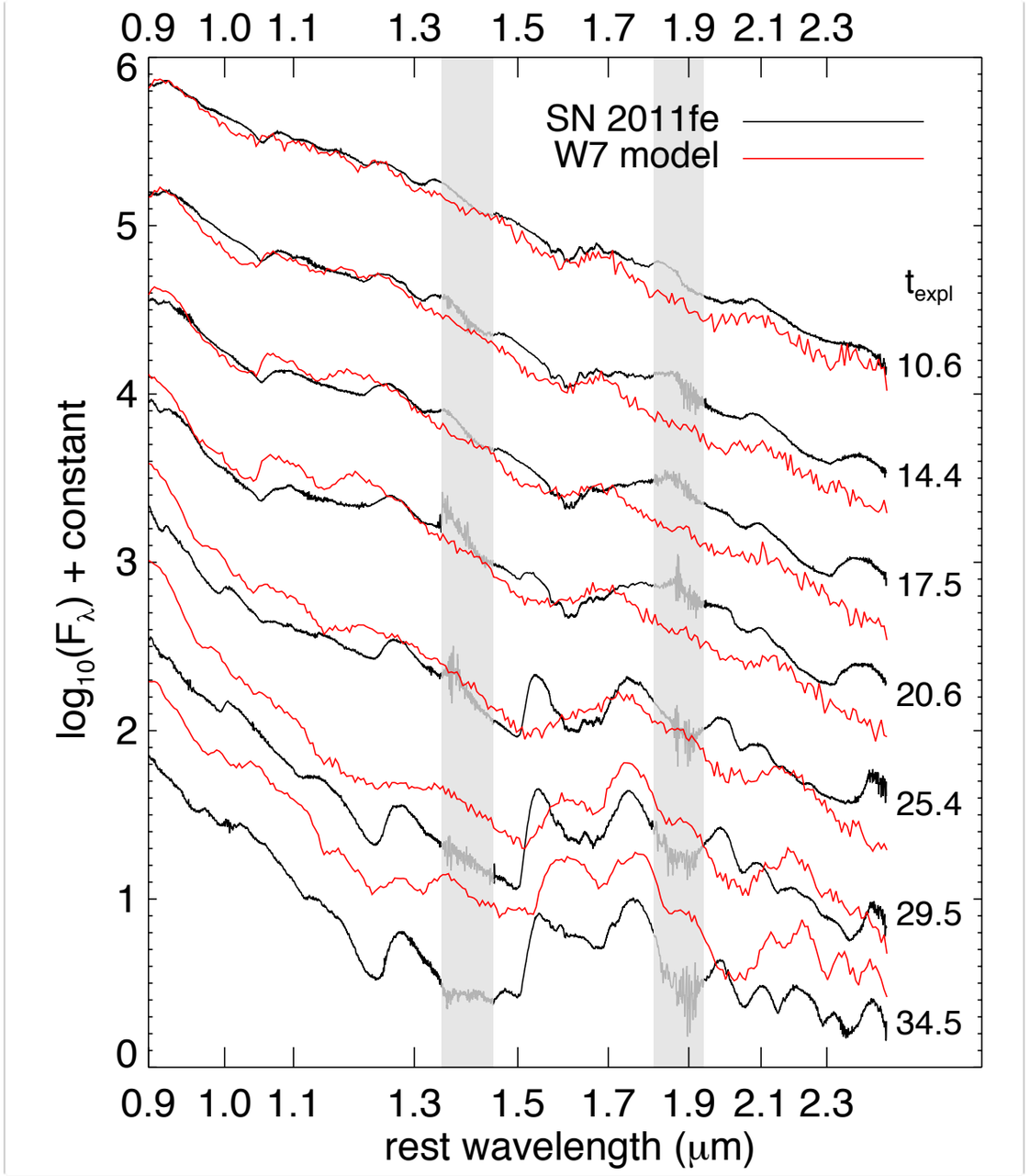
- earliest time series
- high S/N
- medium res
- 3-day cadence around max

SYNAPPS fits of early spectra



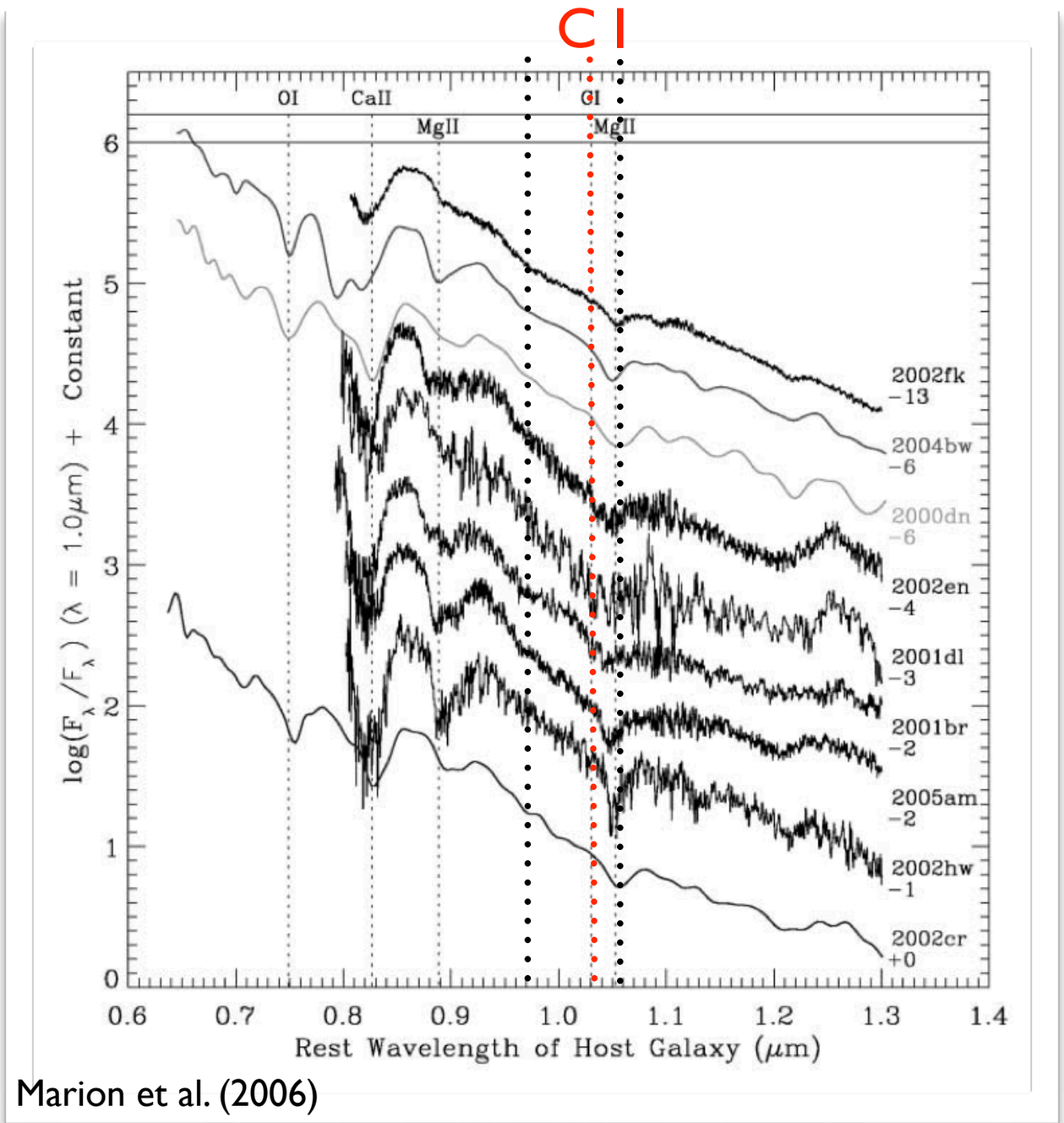
- dominated by IME
- presence of Fe III (previously identified as Si III)
- presence of increasing Co II
- absence of Ni

W7 model + ARTIS RT



- ARTIS radiative transfer (Kromer & Sim 09)
- Monte Carlo code
- time-dependent spectral synthesis
- no free parameters
- low opacity in NIR
- features formed by fluorescence

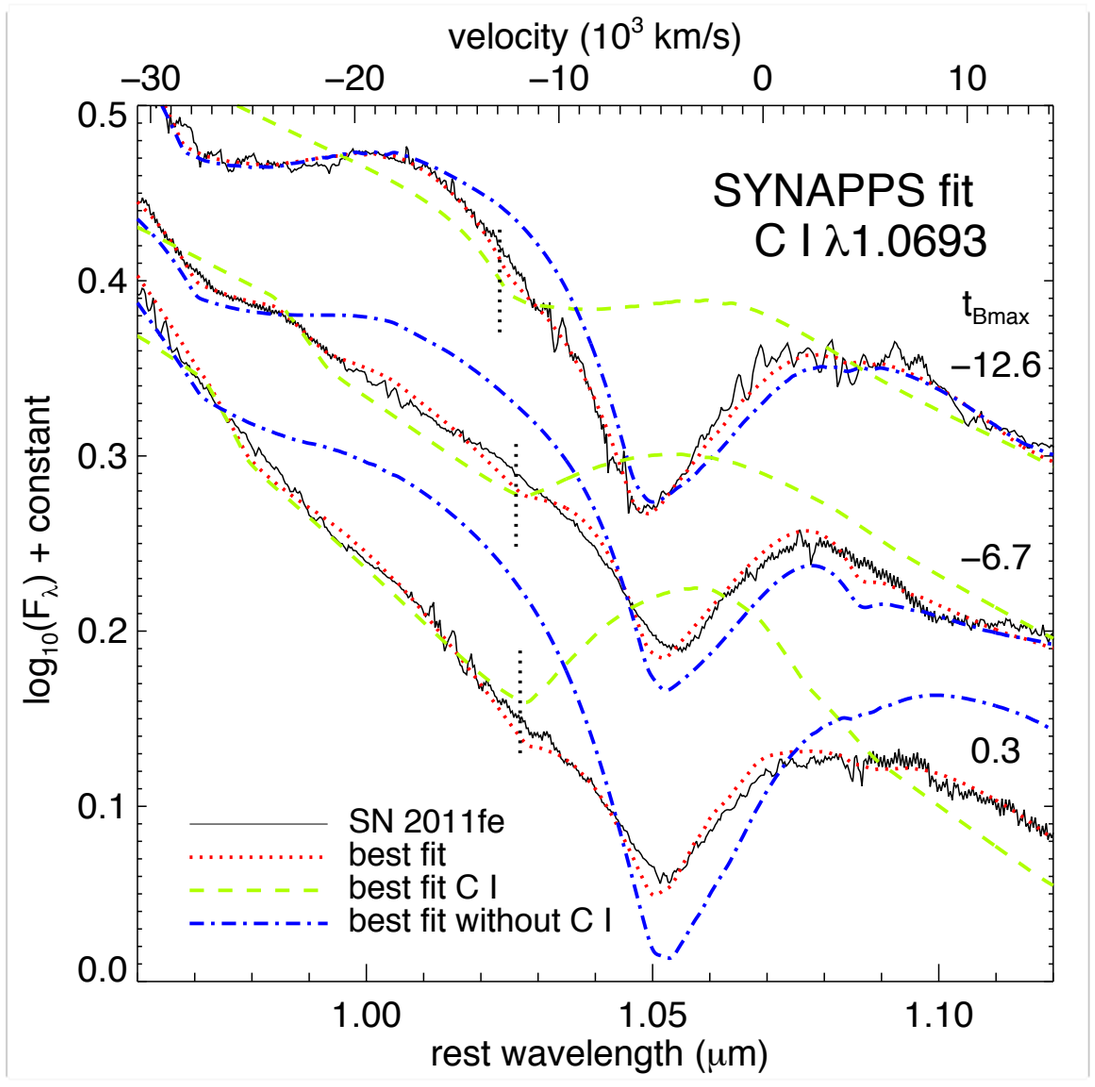
unburnt carbon

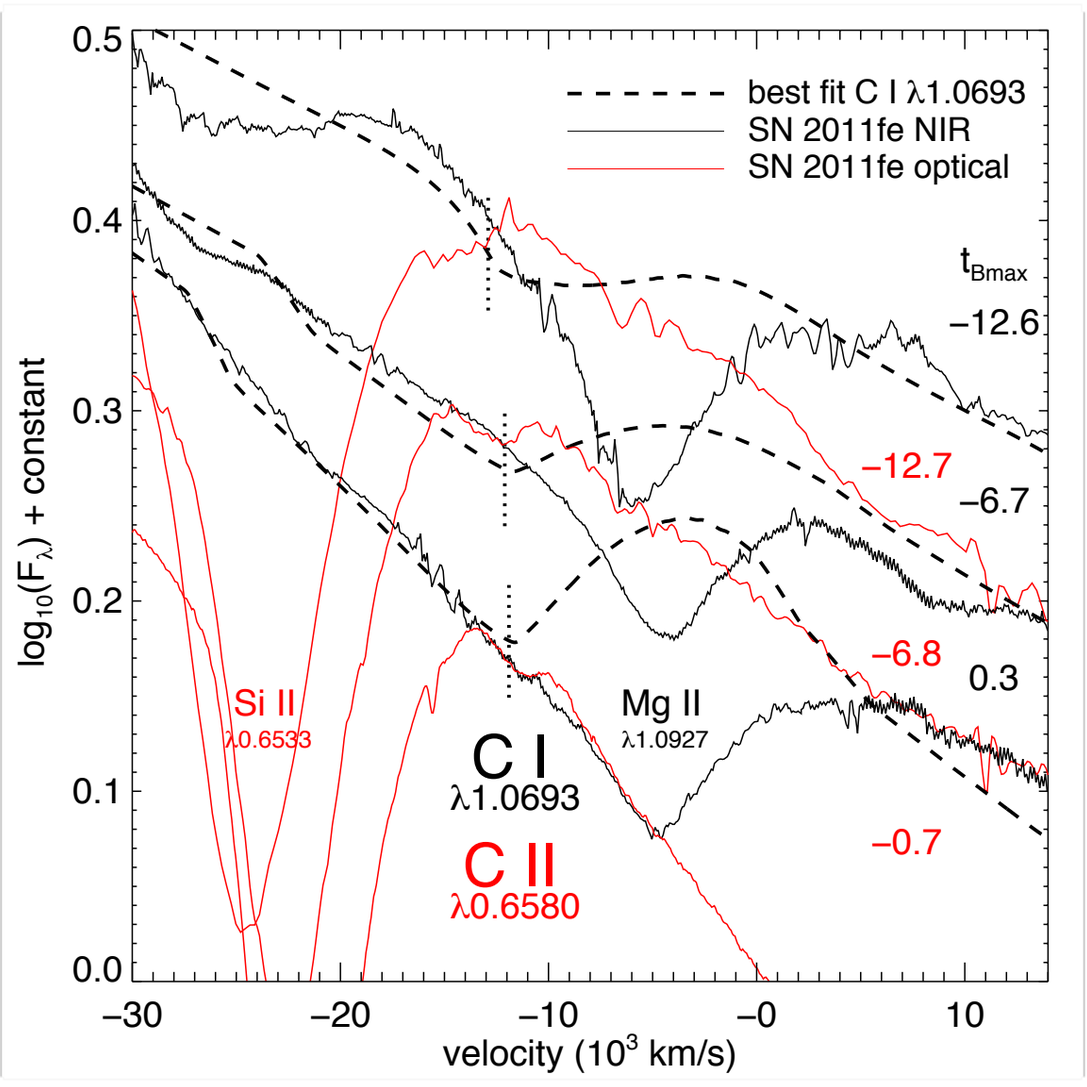


Marion et al. (2006)

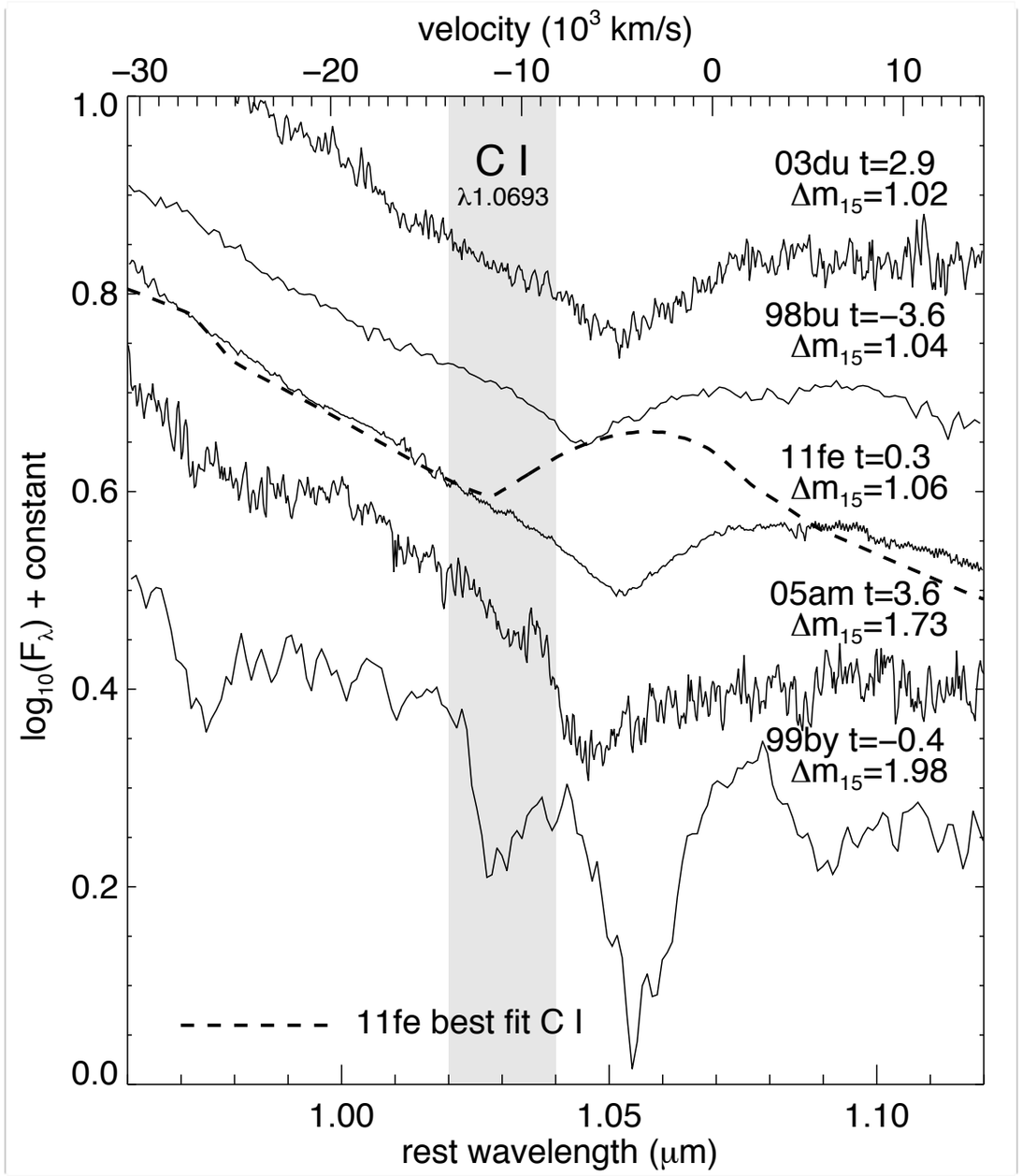
- strongest NIR line C I 10693
- between 2 Mg II features
- unblended at high velocities
- non-detections by Marion et al. (2006)

unburnt carbon



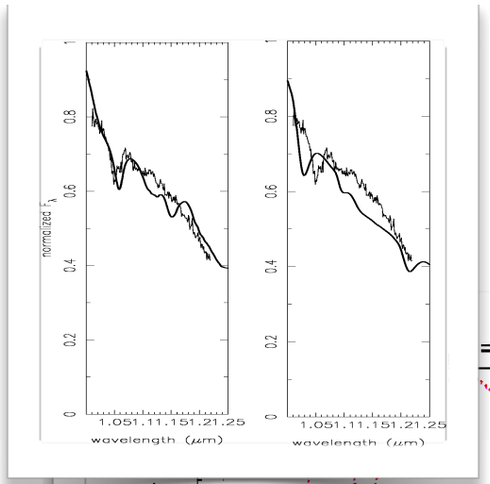


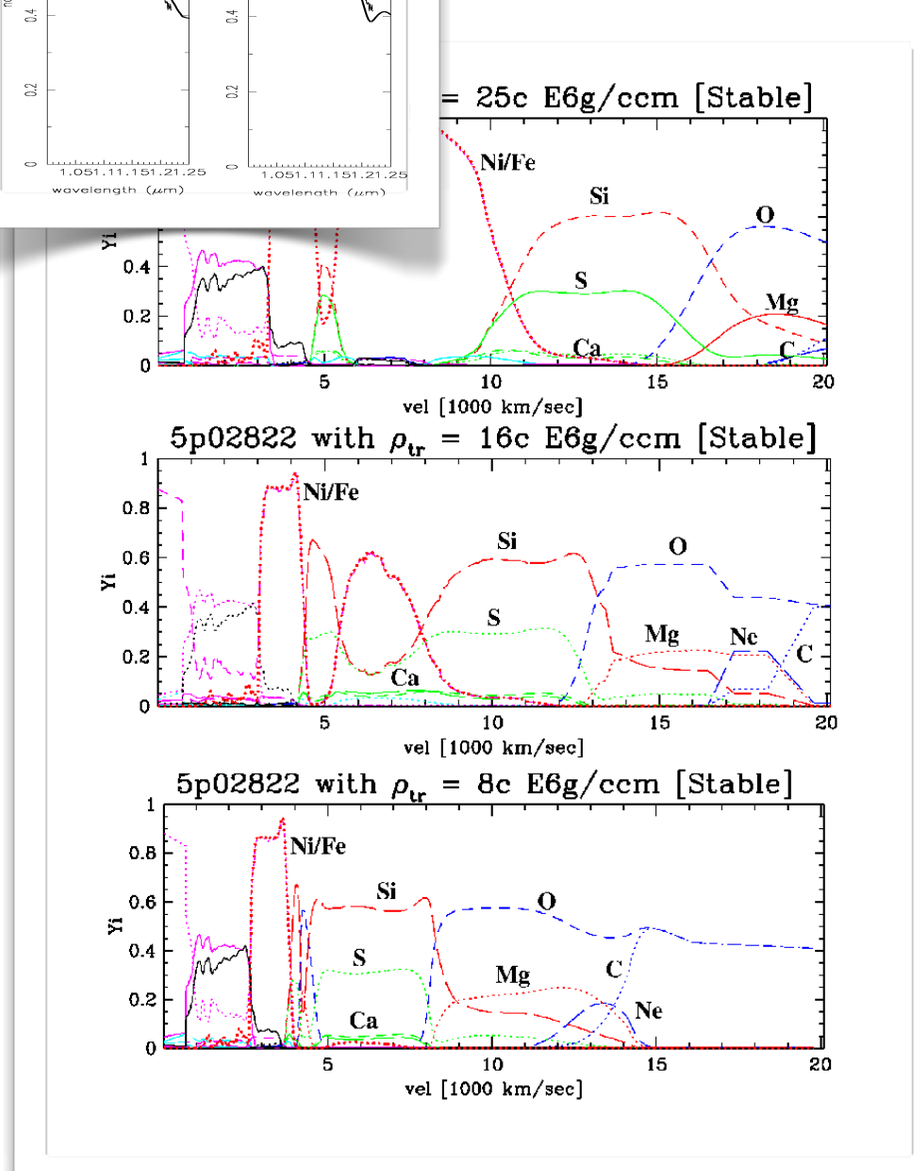
unburnt carbon



- C I 10693 suppresses the emission wing of Mg II 10092 P Cygni
- While optical C II decreases in strength with time, NIR C I strongest near max
- matches photospheric velocity
- NIR C I and optical C II have same velocity
- C II to C I recombination?
- optical studies yielded 20-30%
  Thomas et al. 2011; Parrent et al. 2011; Folatelli et al. 2012; Silverman & Filippenko 2012
- "flattened" feature is common carbon ubiquitous in SNe Ia?

Mg II 10927 velocity

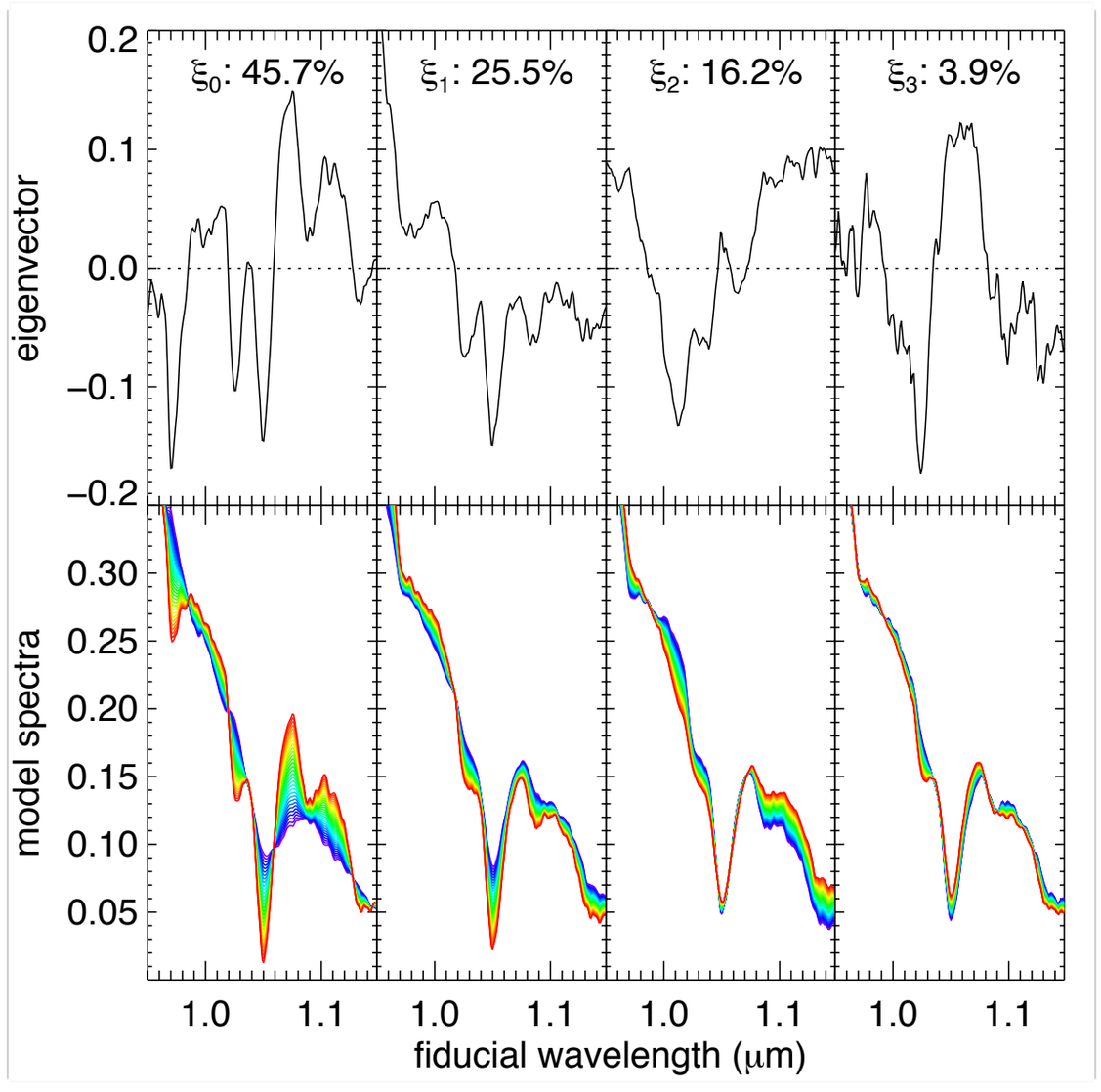




- photosphere recedes below inner edge of Mg distribution
  - constant velocity
- accurate measure of the inner edge of C burning
- probing deflagration to detonation transition density
- transition density sets amount of expansion during deflagration, sets amount of 56Ni

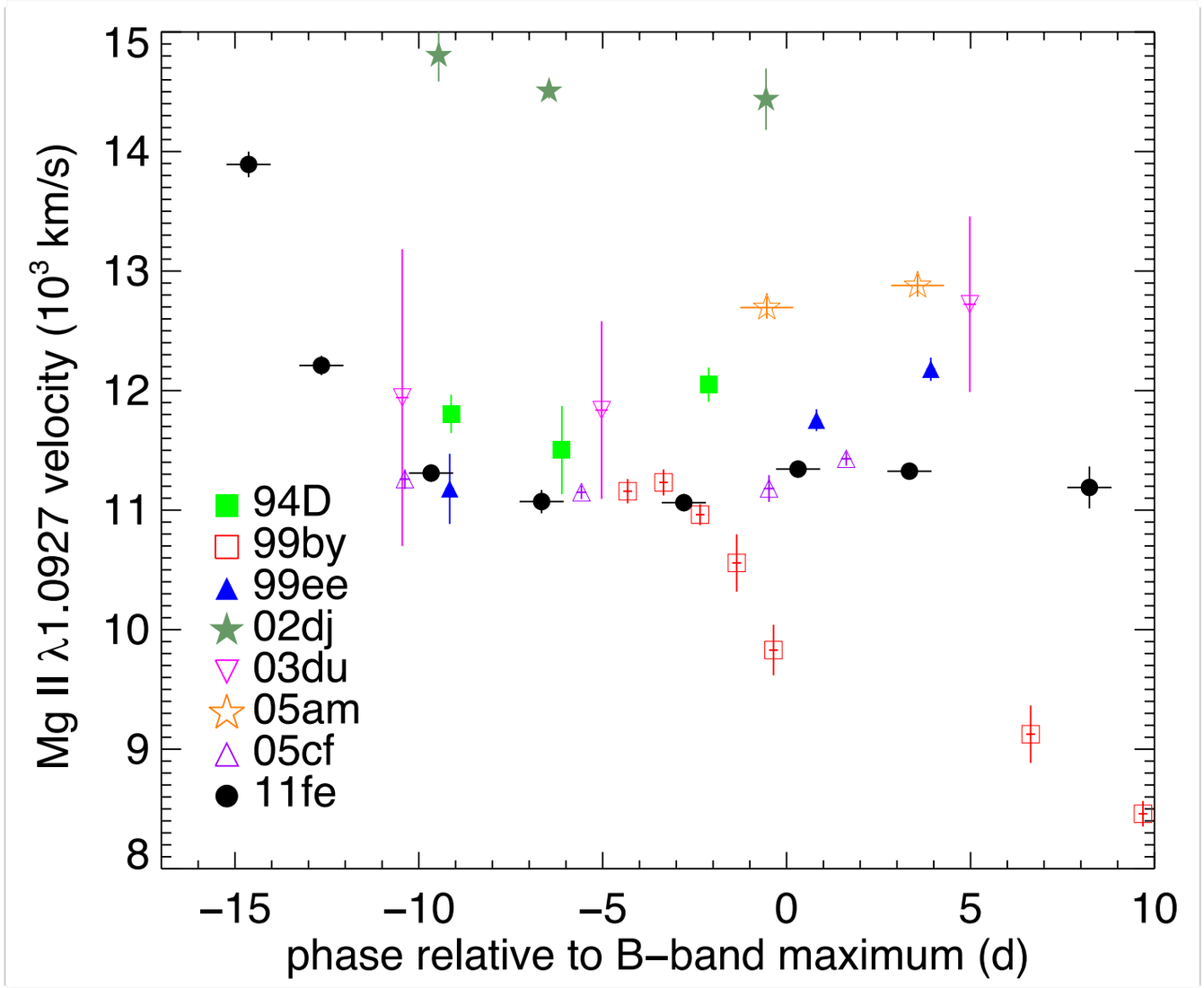
Wheeler et al. (1998)
Marion (2001)
Höflich et al. (2002)

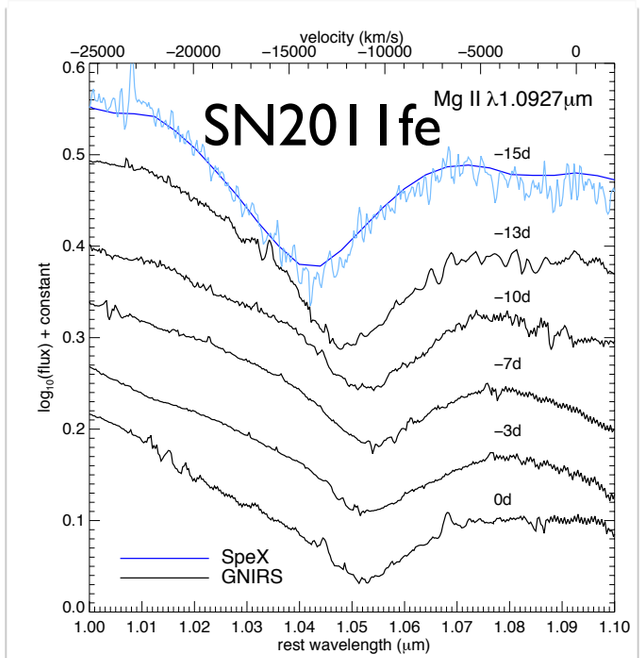
Mg II 10927 velocity



- line profiles not Gaussian
- use observed line profiles to build PCA model
- least-squares fit with PCA projections and velocity as fit arameters

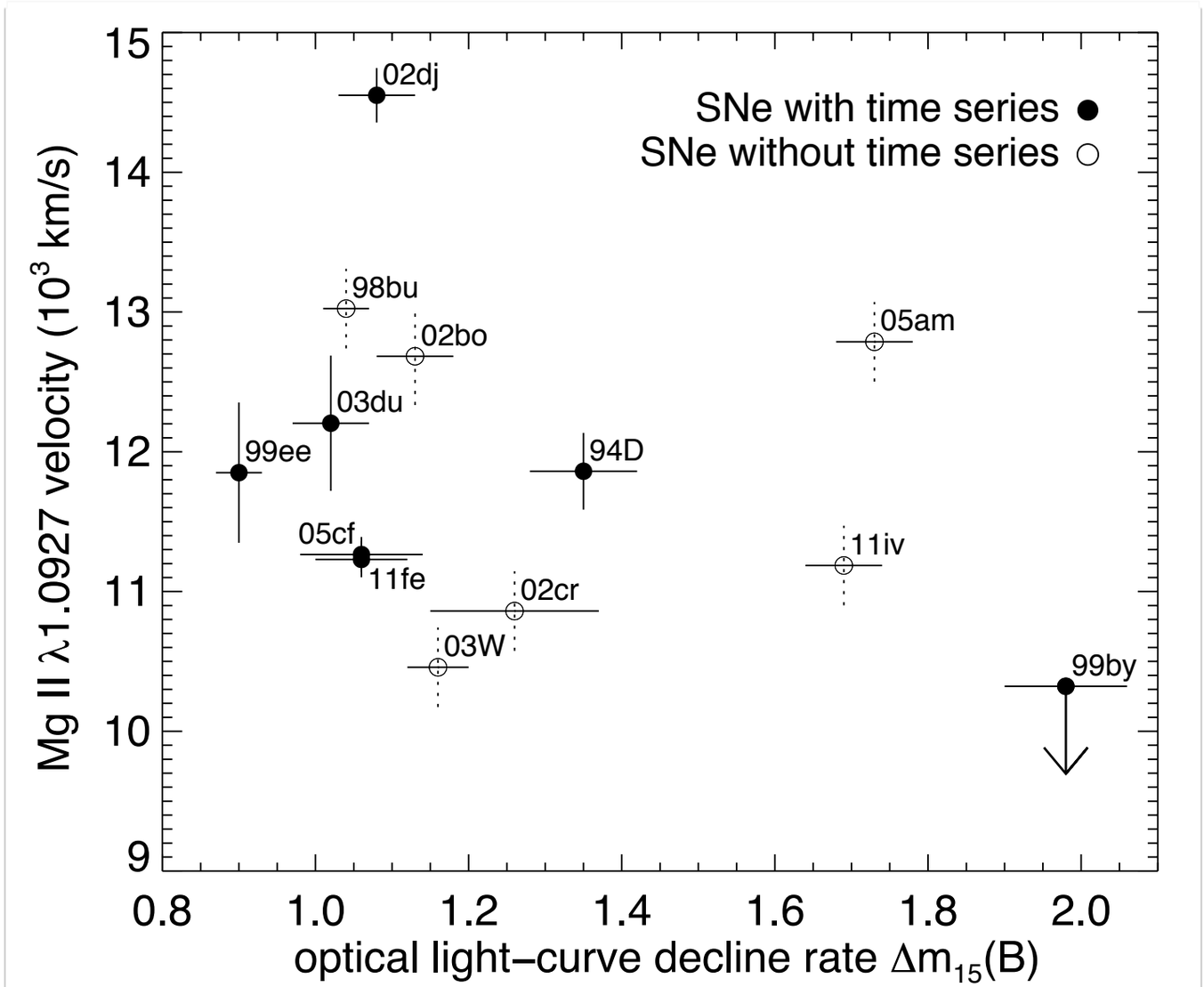
Mg II 10927 velocity





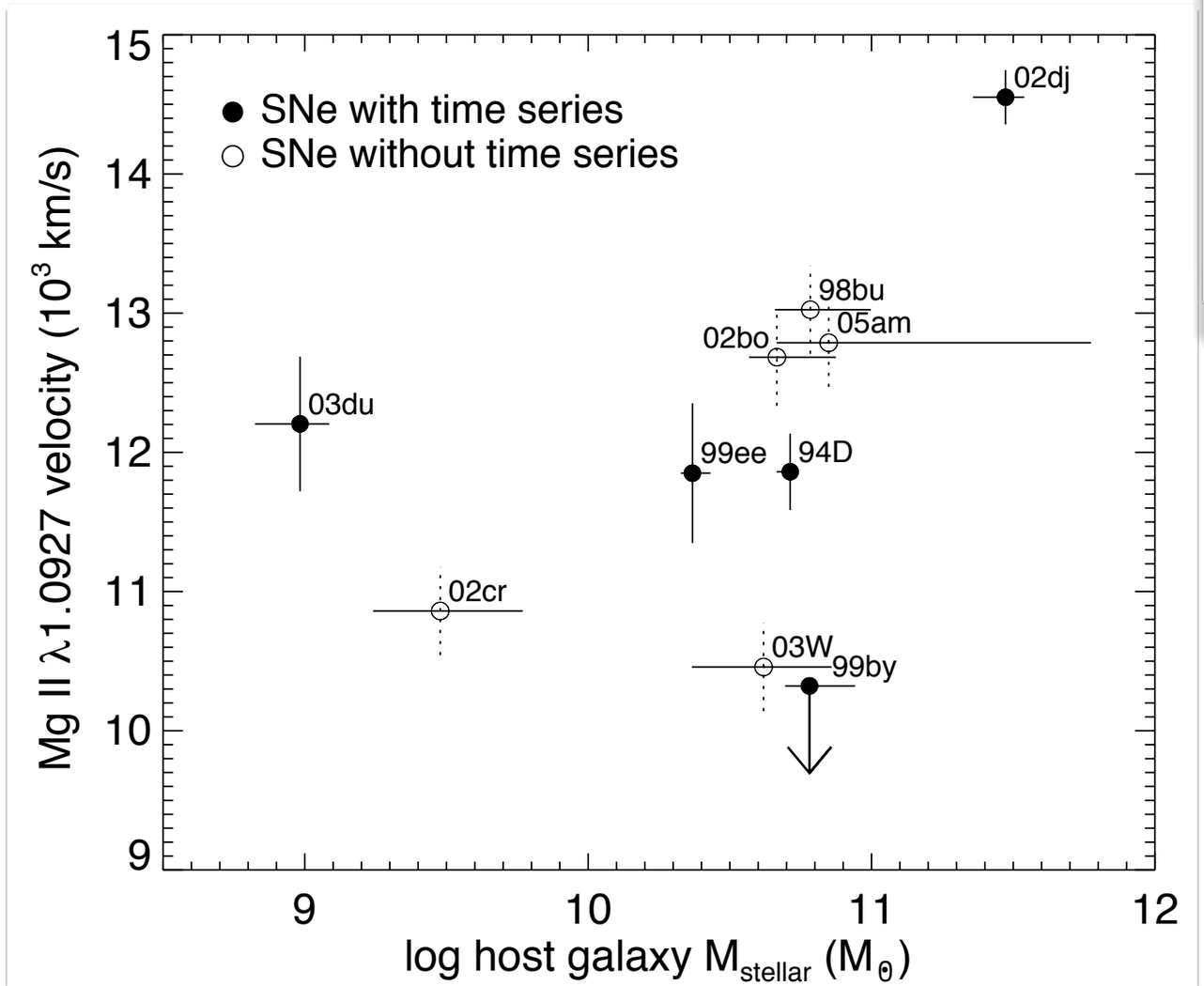
- velocity remarkably constant from -10 to 10 d until line disappears

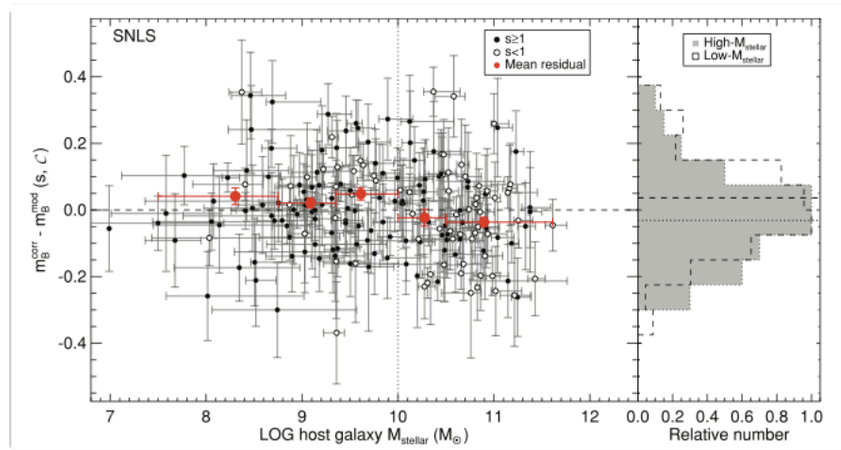
Mg II 10927 velocity



- Is DDT transition density the main driver for SN Ia luminosity variation?
- secondary effect?

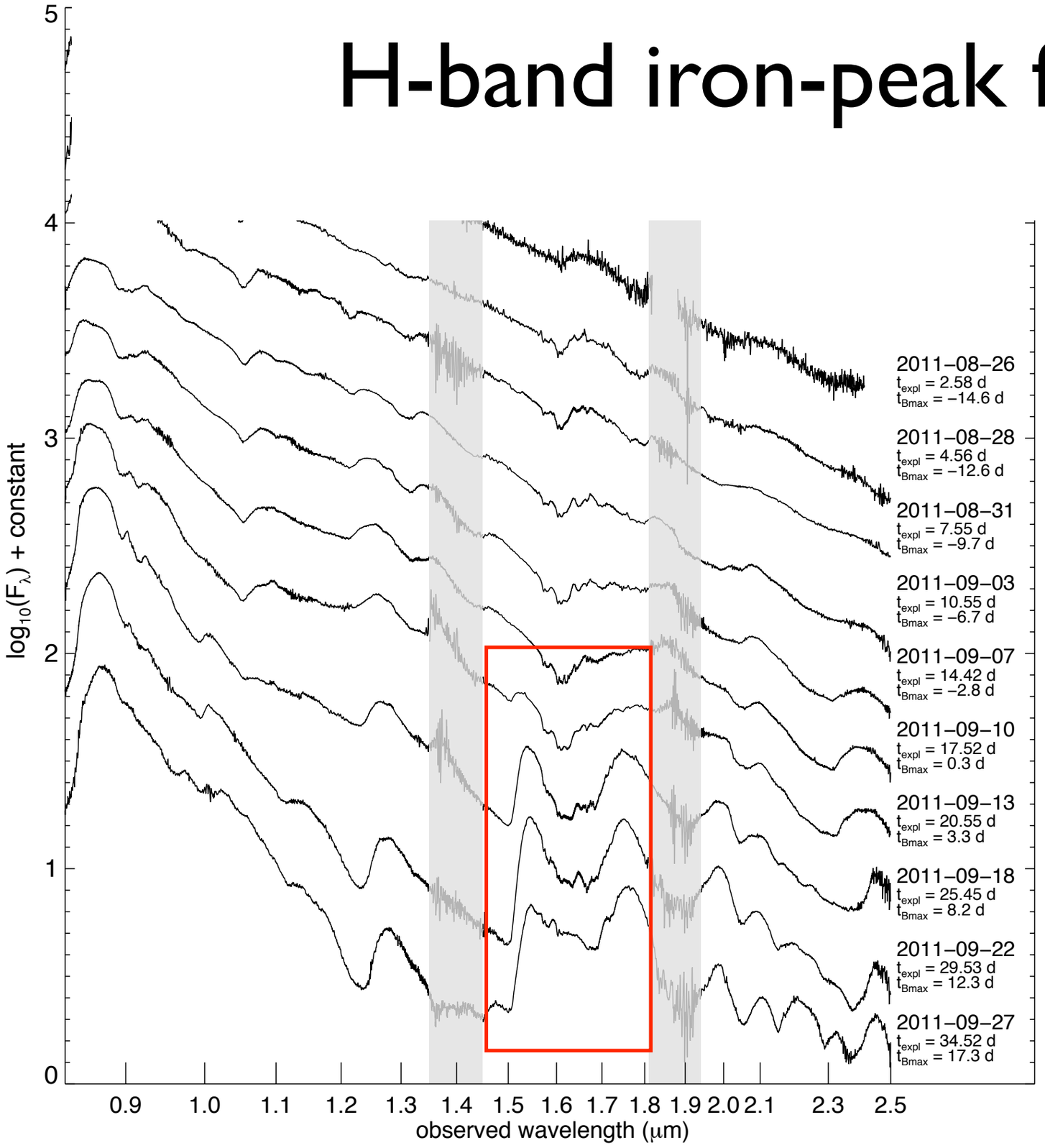
Mg II 10927 velocity



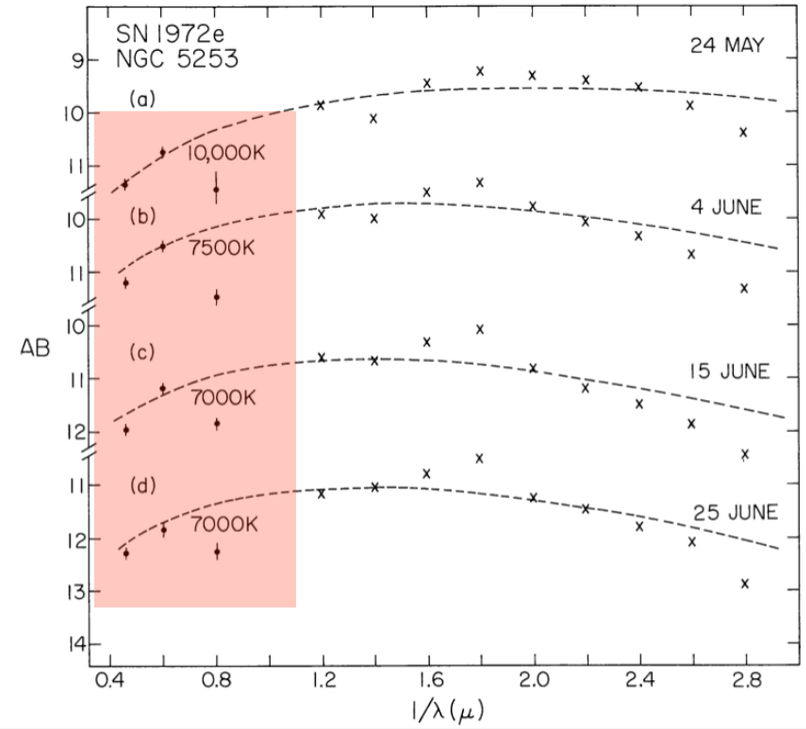


- Sullivan et al. (2010): dependence of SN Ia luminosity on host galaxy mass, in addition to LC shape, color dependence
- Jackson et al. (2010): metallicity affects transition density
- Mg II velocity more direct probe of this secondary effect?

H-band iron-peak feature



Kirshner et al. (1973)

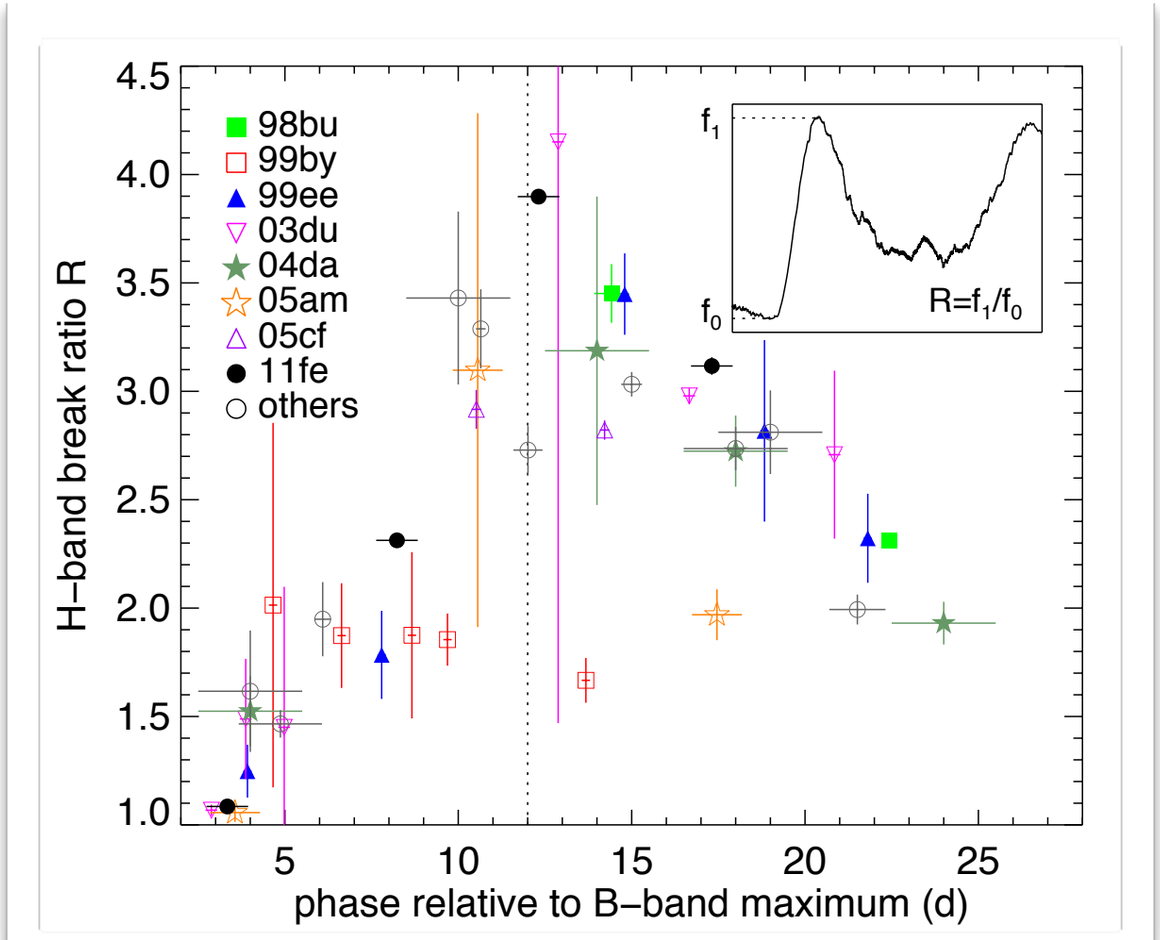


- contrasting opacity

  - OR -

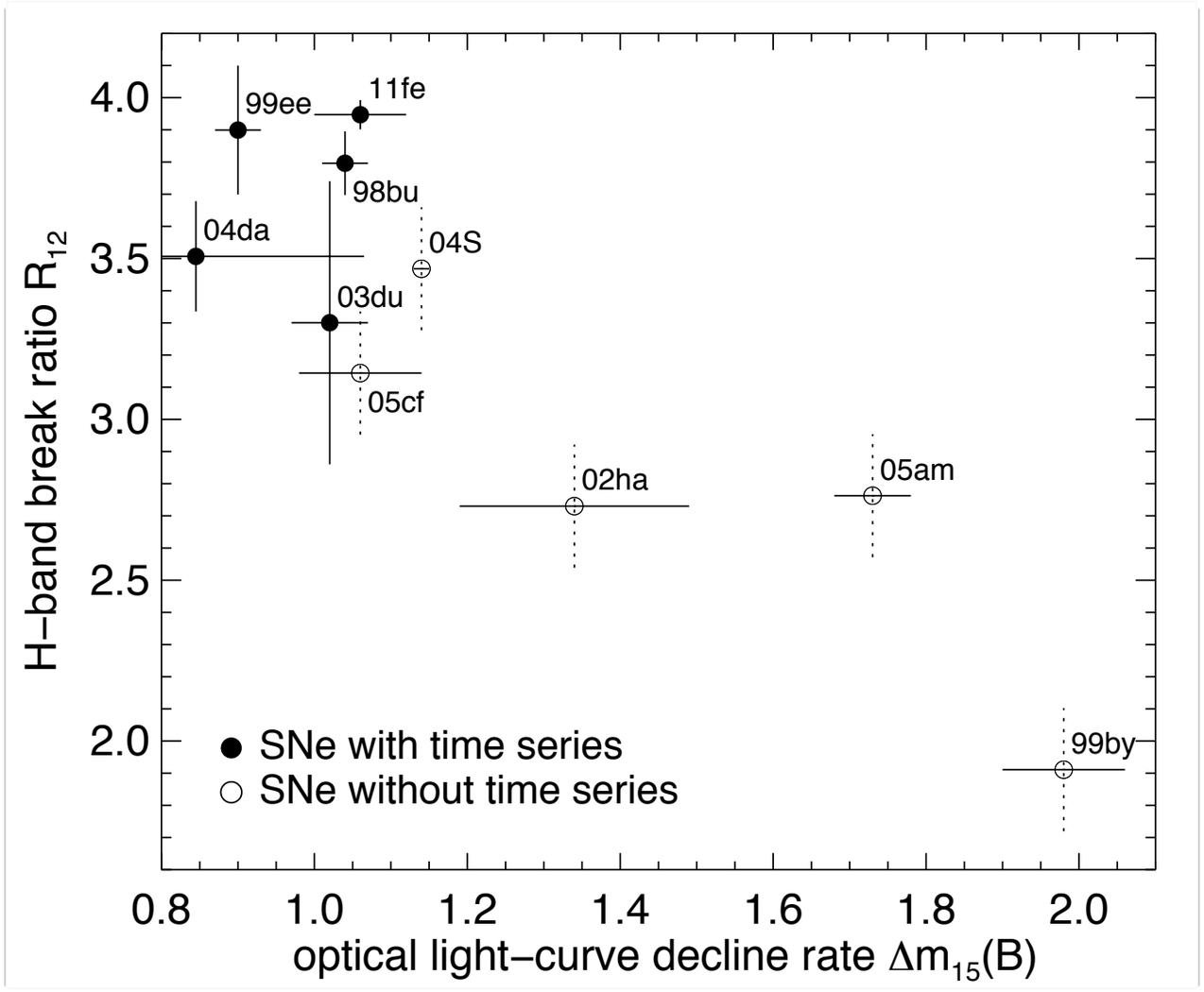
- fluorescence

H-band iron-peak feature



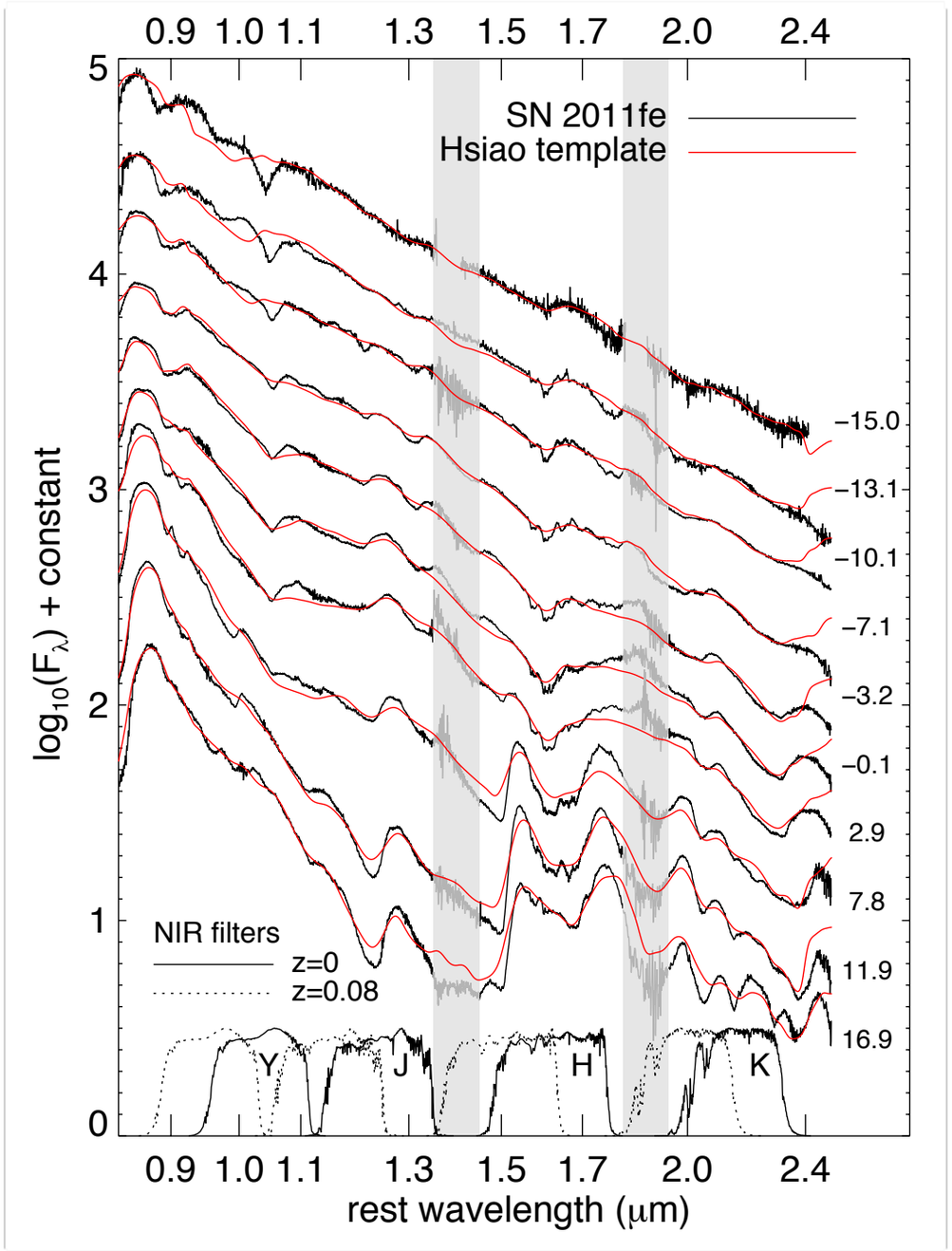
- ratio has uniform evolution
  - begins at 3 d
  - peaks at 12 d at various strengths
    - uniform linear decline
- at 12 d, the iron-peak structure is completely exposed
- decline reflects temperature decline

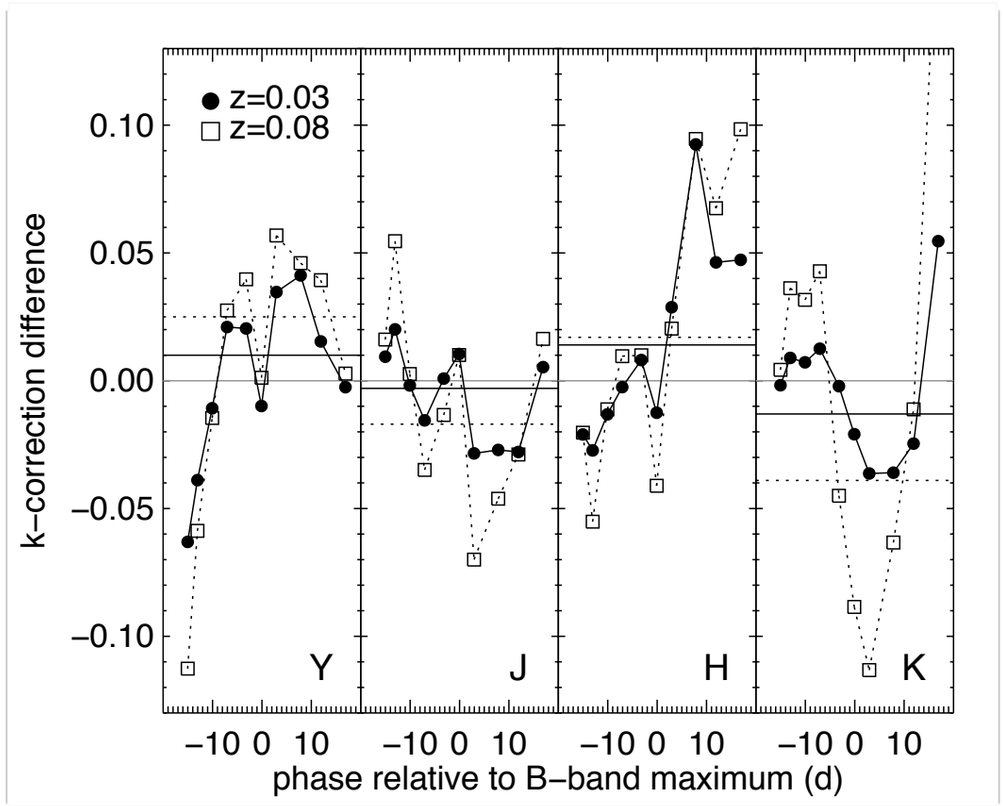
H-band iron-peak feature



- ratio strengths at their peak correlates with Δm_{15}
- more time-series data is needed
- first step toward improved k-corrections

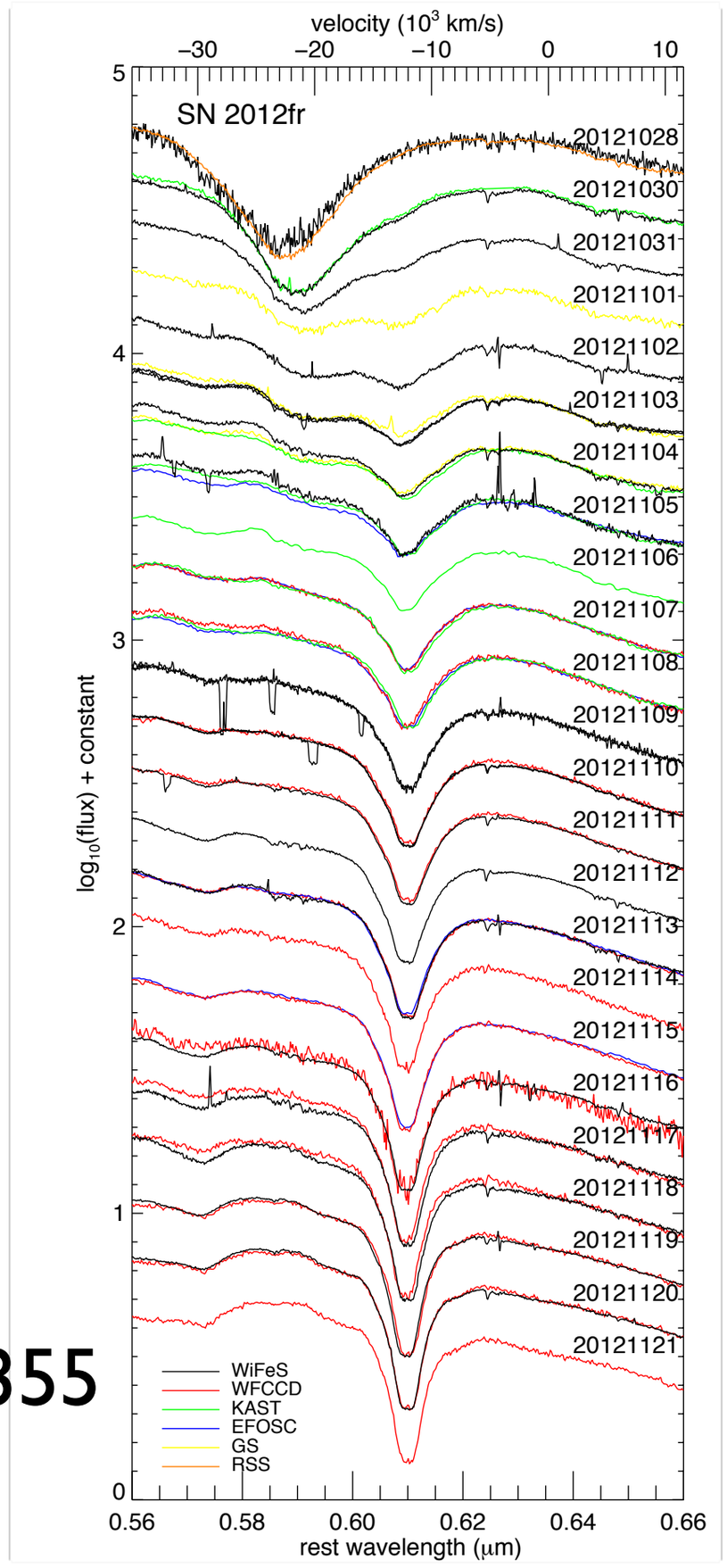
NIR k-correction



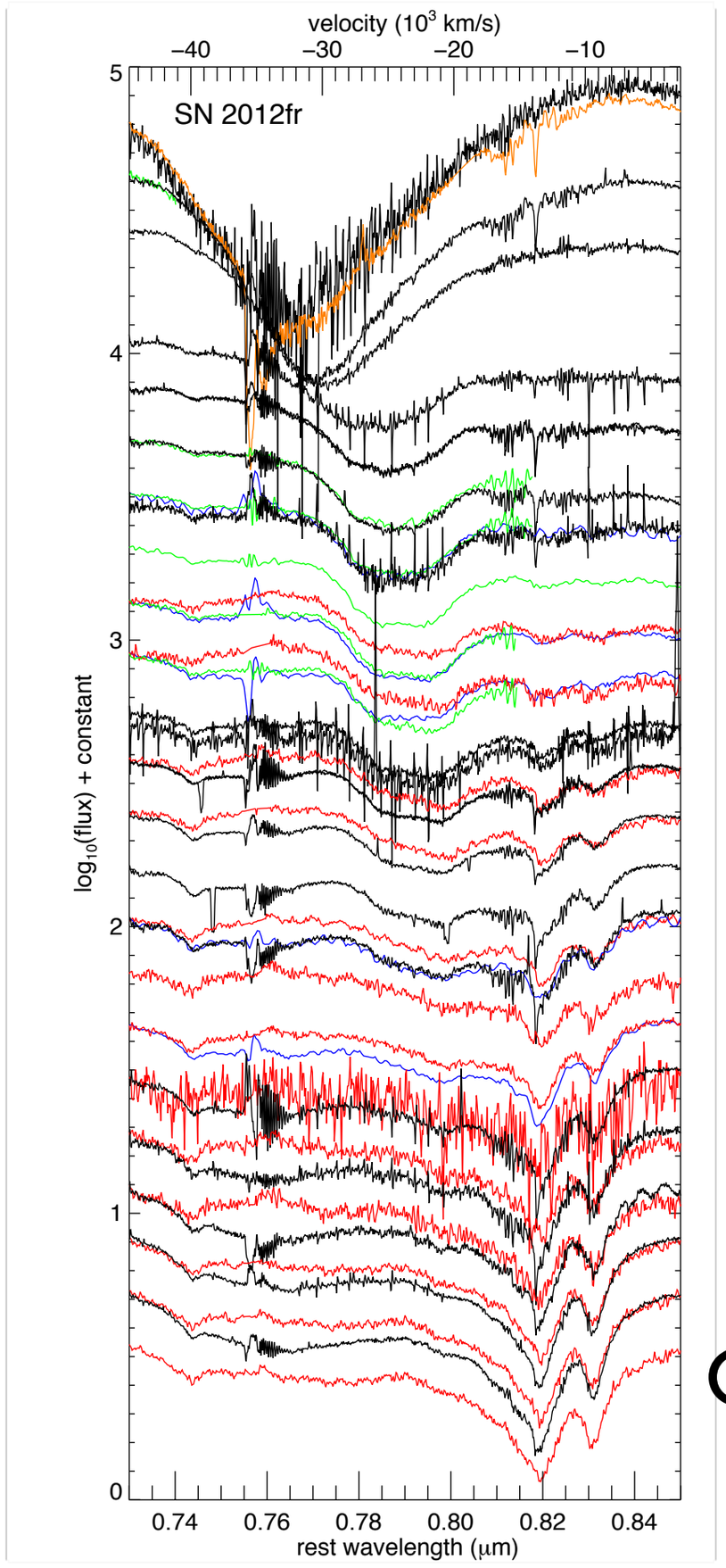


summary

- primordial carbon from WD
  - NIR C I 10693 detected at the same velocity as optical C II 6580
  - The relative isolation and delayed onset of NIR C I 10693 make it a better probe of unburnt carbon than optical C II 6580
  - Unburnt carbon ubiquitous in SNe Ia?
- Mg II velocity as probe of boundary between C/O burning
  - Rapid decline, then stays constant for an extended time
  - Does not correlate with Δm_{15}
  - Affects SN luminosity on a secondary level?
- ratio across H-band iron-peak break
  - Uniform evolution
  - Correlates with Δm_{15}
  - First step toward improving k-corrections



Si II 6355



Ca II triplet