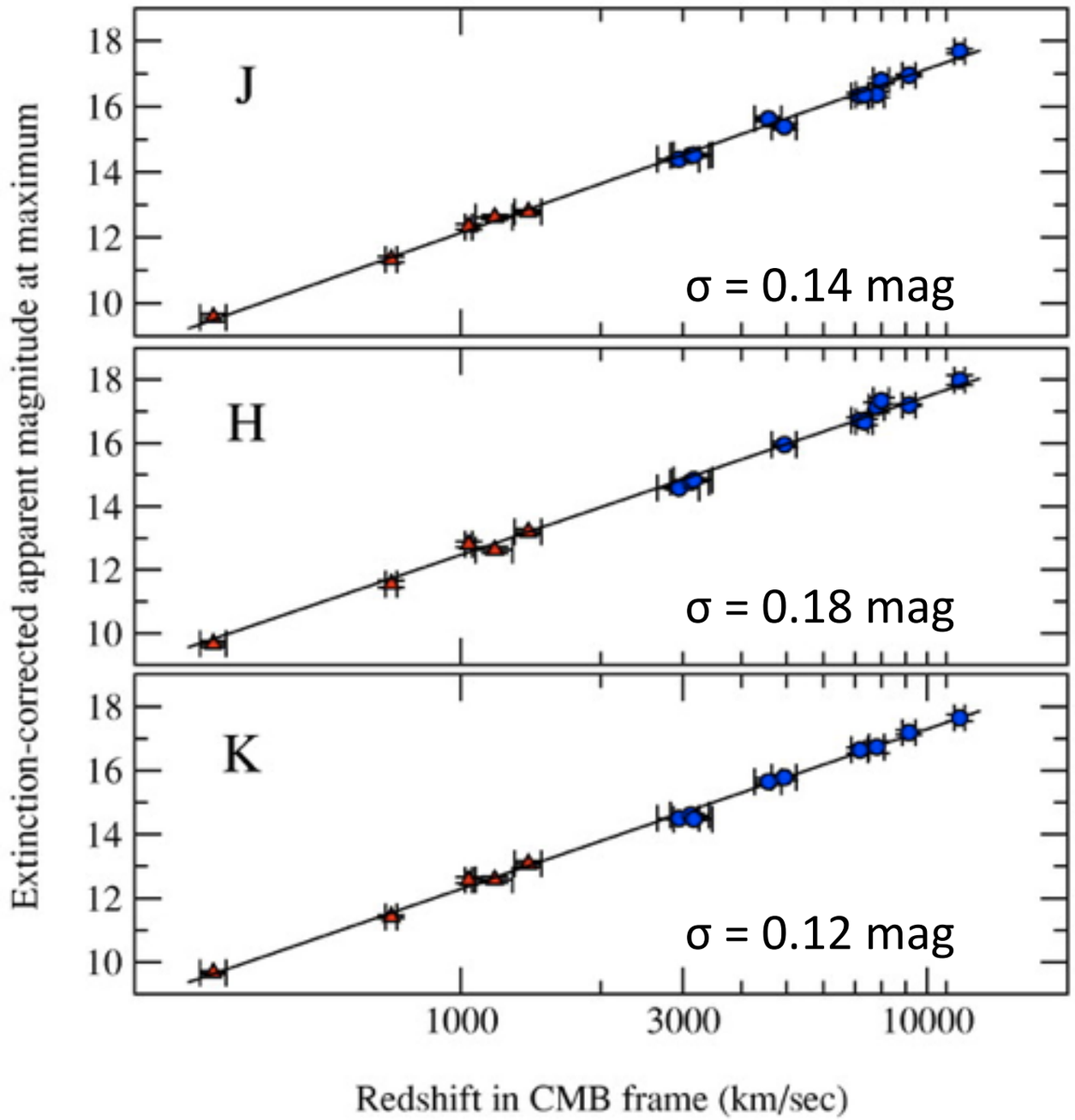
Overview of the CSP-I and CSP-II Surveys

Mark M. Phillips
Carnegie Observatories

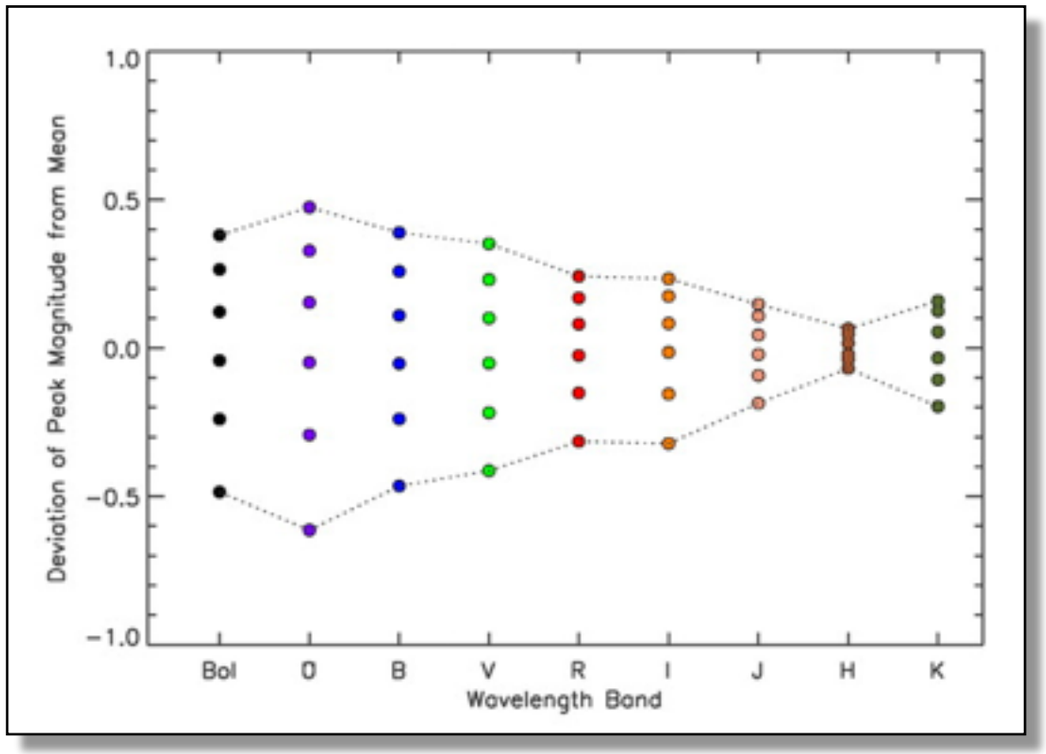
New Advances in NIR Type Ia Supernova Science, Pittsburgh, 2018 April 11-13

SNe Ia are Excellent Standard Candles in the NIR



Krisciunas, Phillips, & Suntzeff (2004)

- Extinction from dust is much less in the NIR
- SNe Ia are intrinsically much better standard candles in the NIR

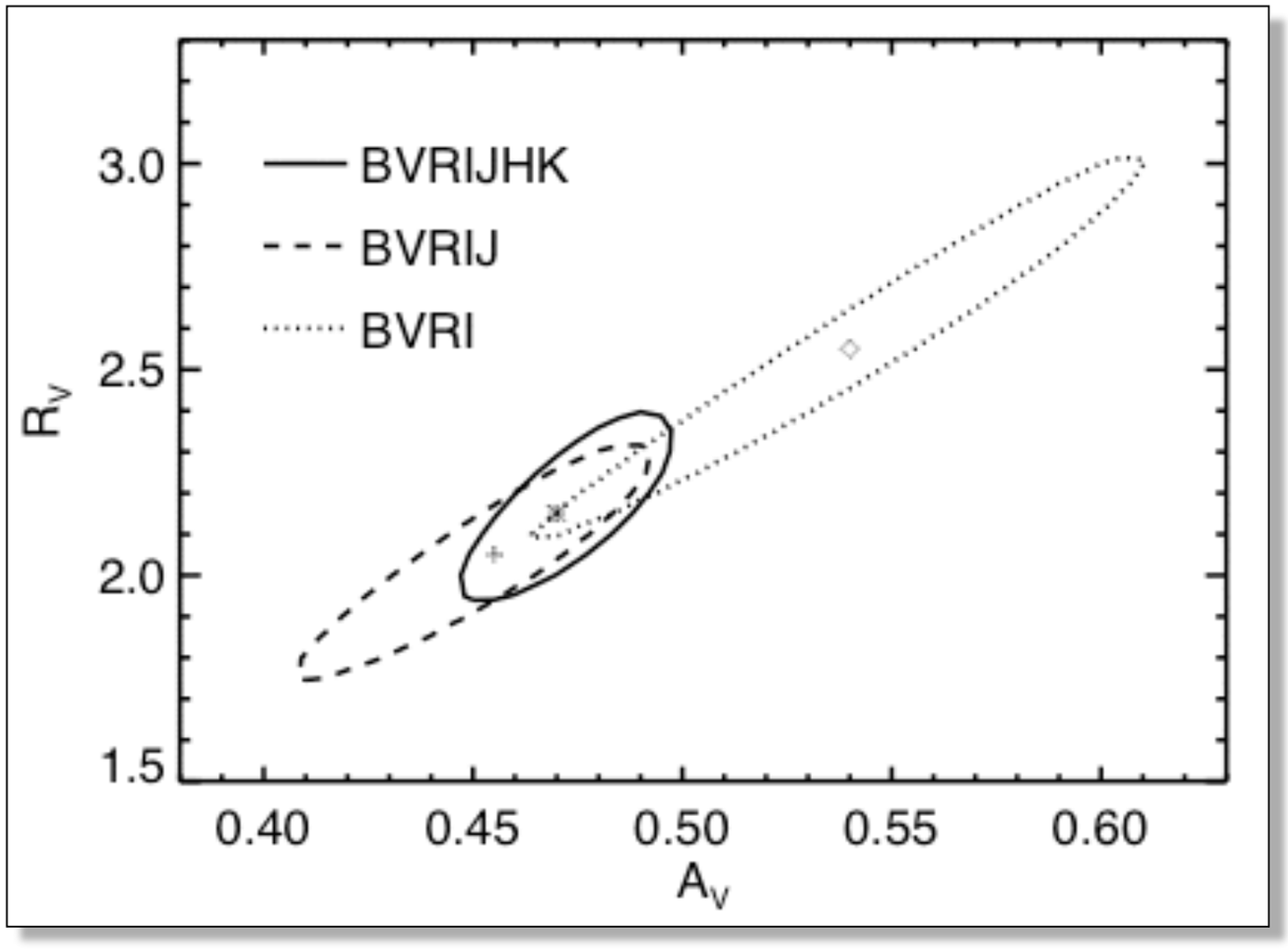


Kasen 2006

Constraining the Reddening Law

- The combination of optical + near-IR photometry is essential for constraining the reddening law

- The near-IR allows both A_V and R_V to be precisely determined
  - $E(V\text{-}H) = A_V - A_H \sim A_V$
  - $R_V = A_V / E(B\text{-}V)$



Krisciunas et al. 2007

The Carnegie Supernova Project I (CSP-I)

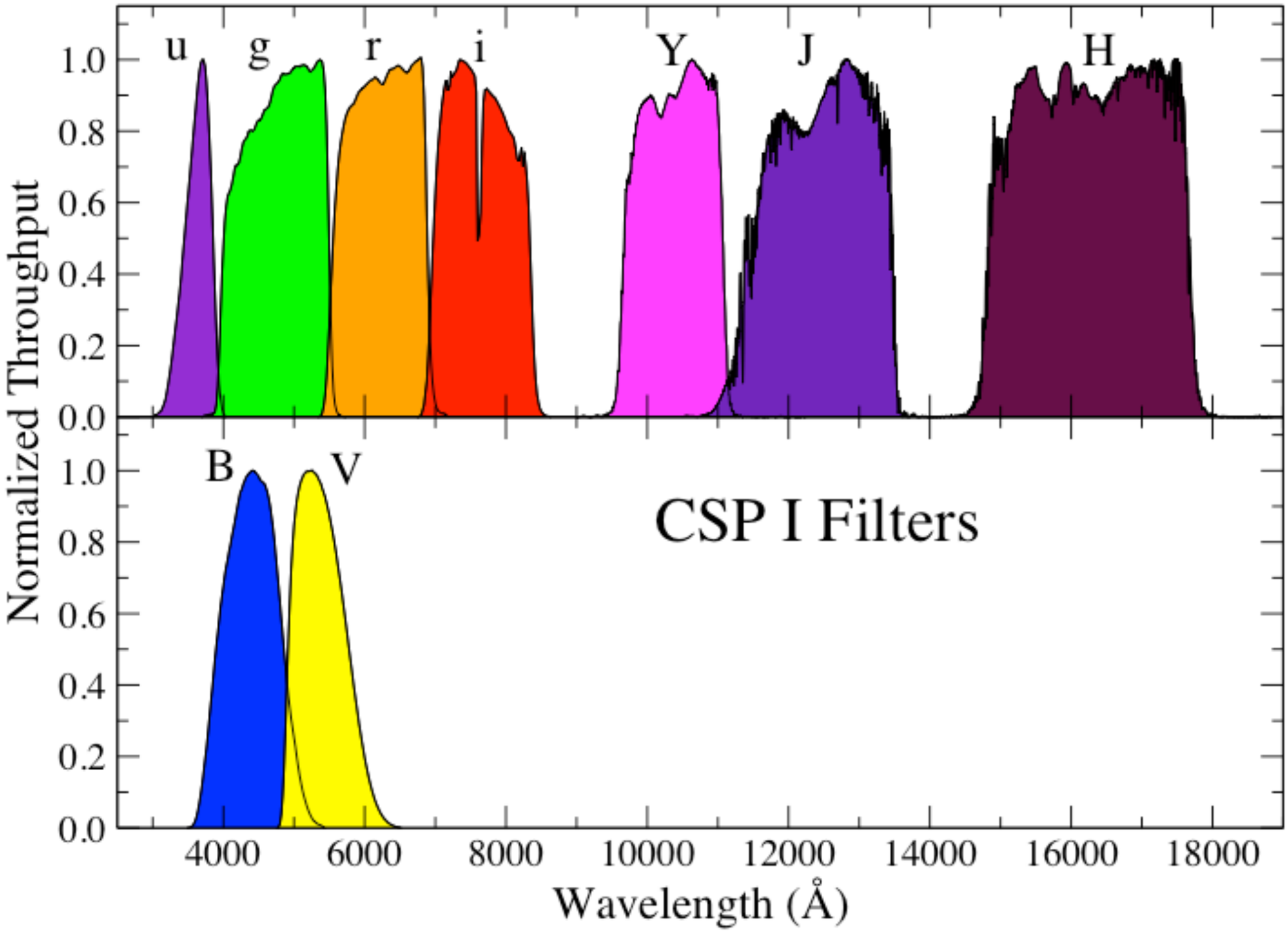
- Five campaigns between 2004-2009
- Follow-up optical (*ugriBV*) light curves obtained of
    - 123 SNe Ia (z_{median} = 0.025)
    - 5 SNe Iax, 2 Ia-csm, 2 06bt-like, 2 "super-Chandra"
    - 34 Stripped Core-Collapse SNe
    - 83 SNe II
- NIR (YJH) photometry obtained for the majority
- Extensive optical spectroscopy also obtained

Swope 1-m

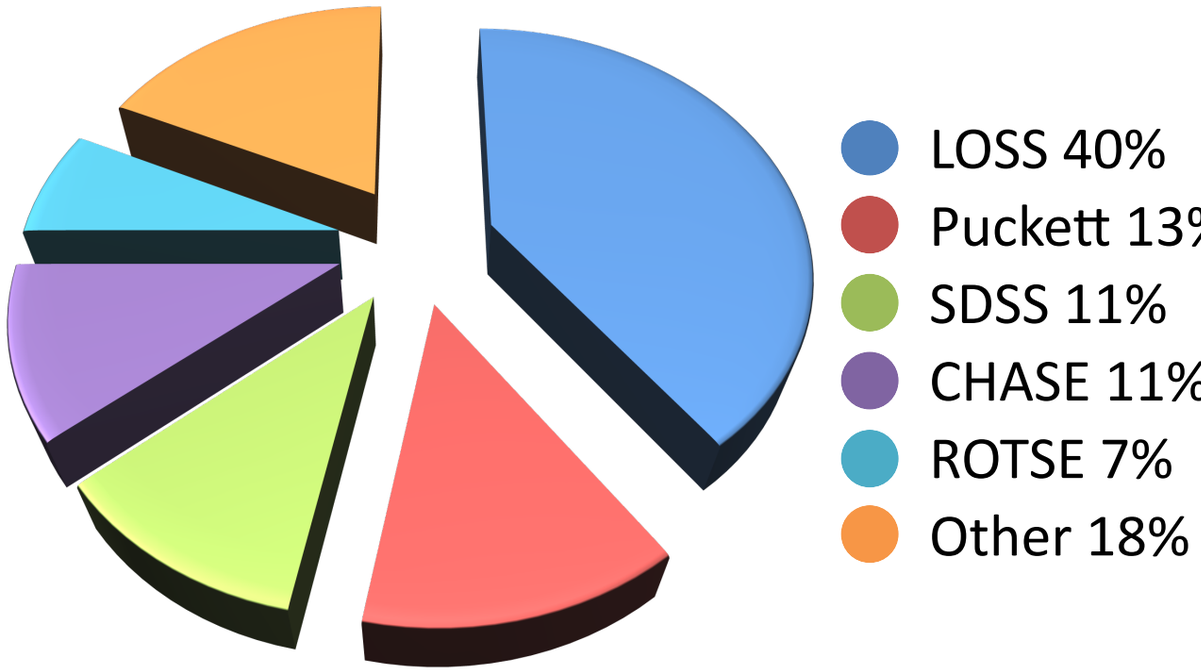
Du Pont 2.5-m

Magellan 6.5-m

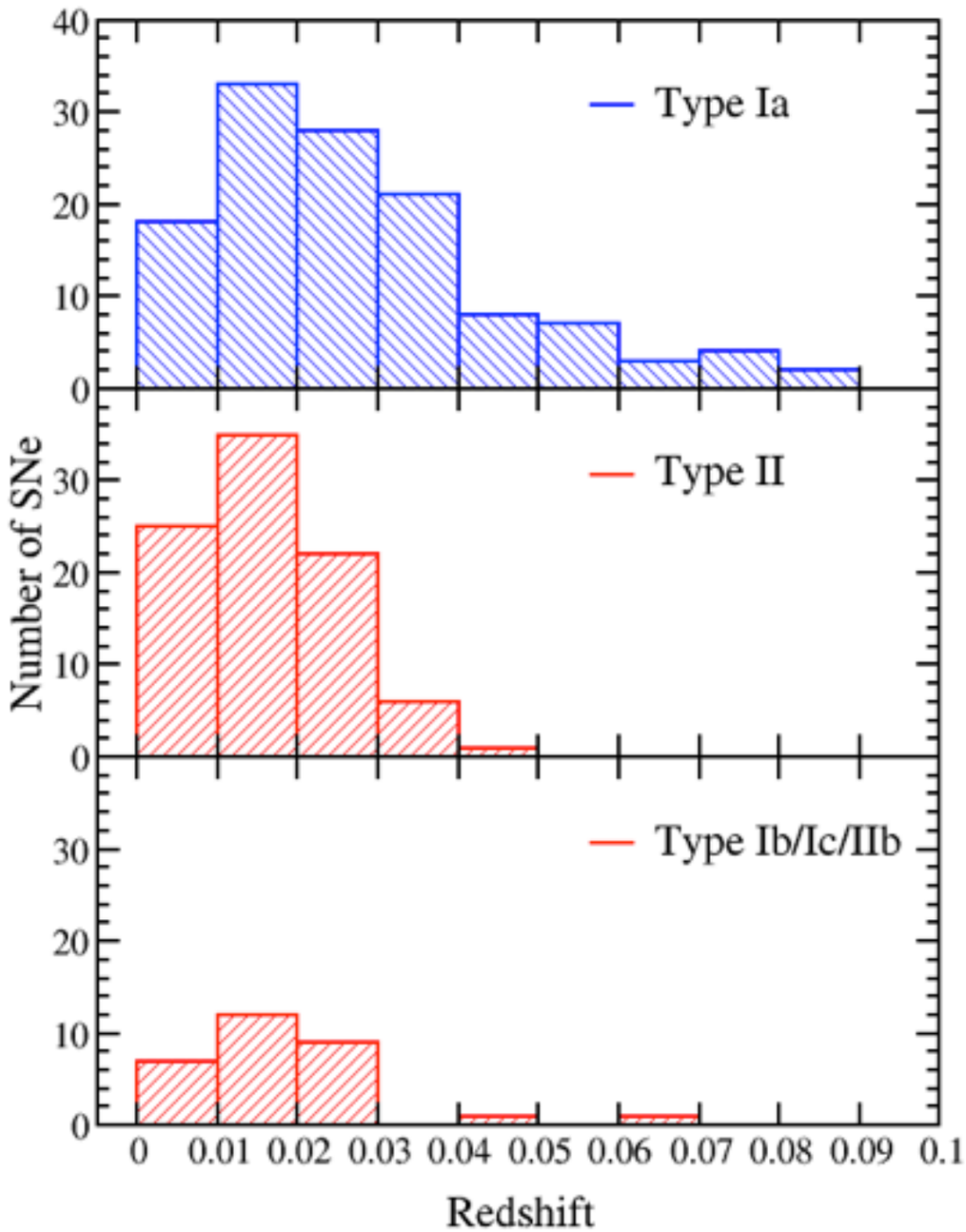
CSP-I: *uBgVriYJH* filters



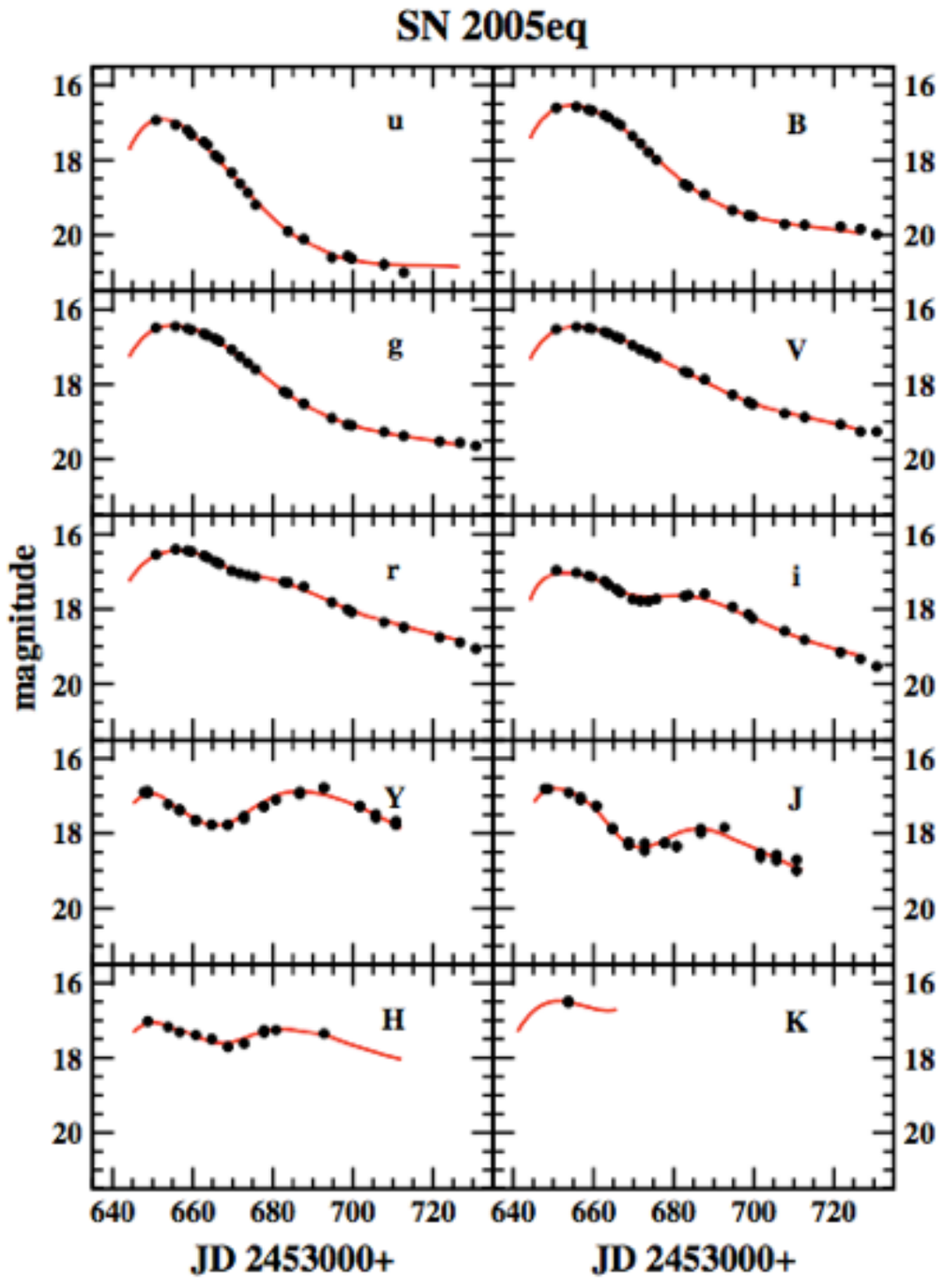
CSP-I Sample Summary

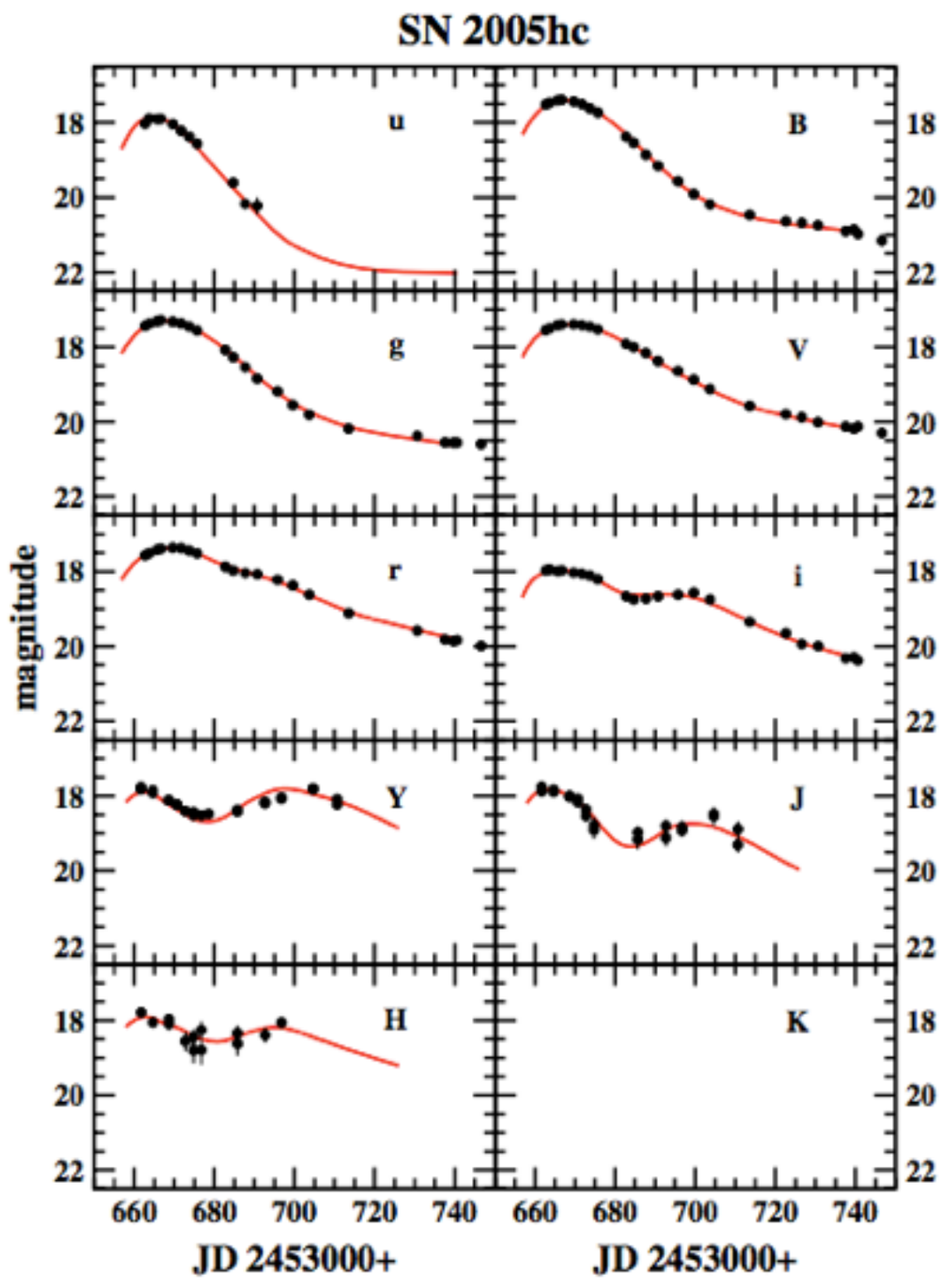


z_{median} of SNe Ia ~ 0.024



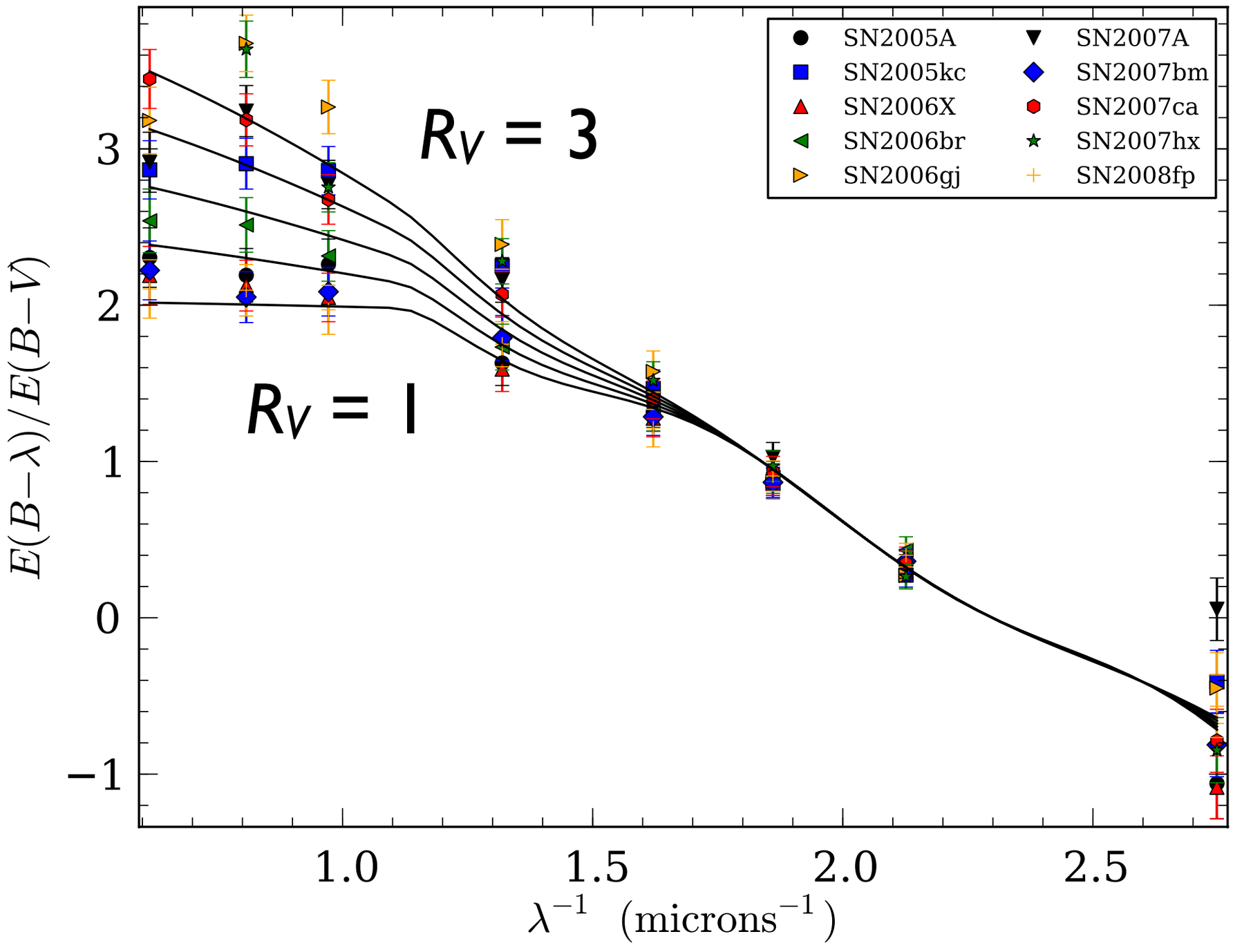
Optical and NIR Light Curves of SNe Ia from the CSP-I





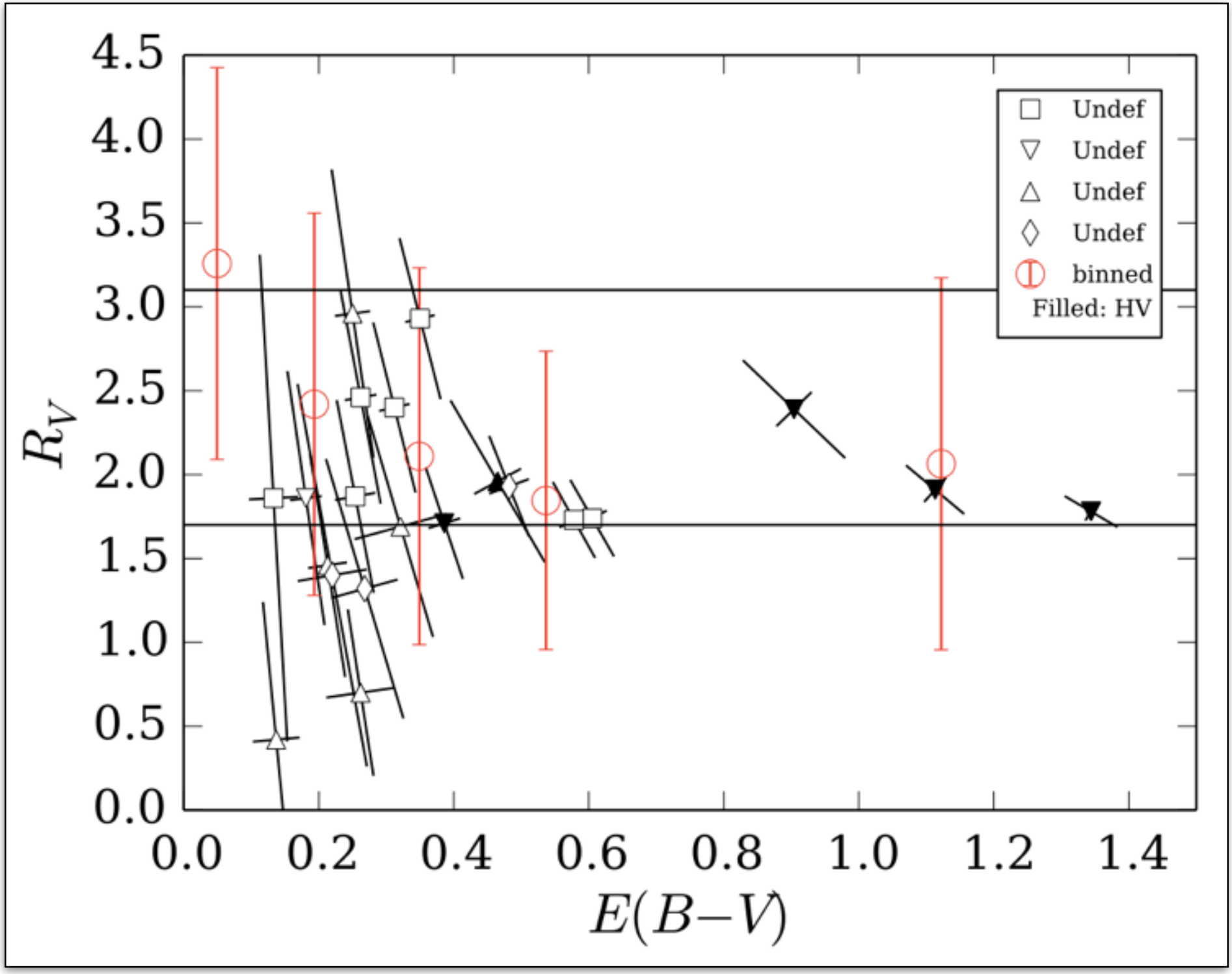
Contreras et al. 2010

The NIR Pins Down R_V



Burns et al. 2013

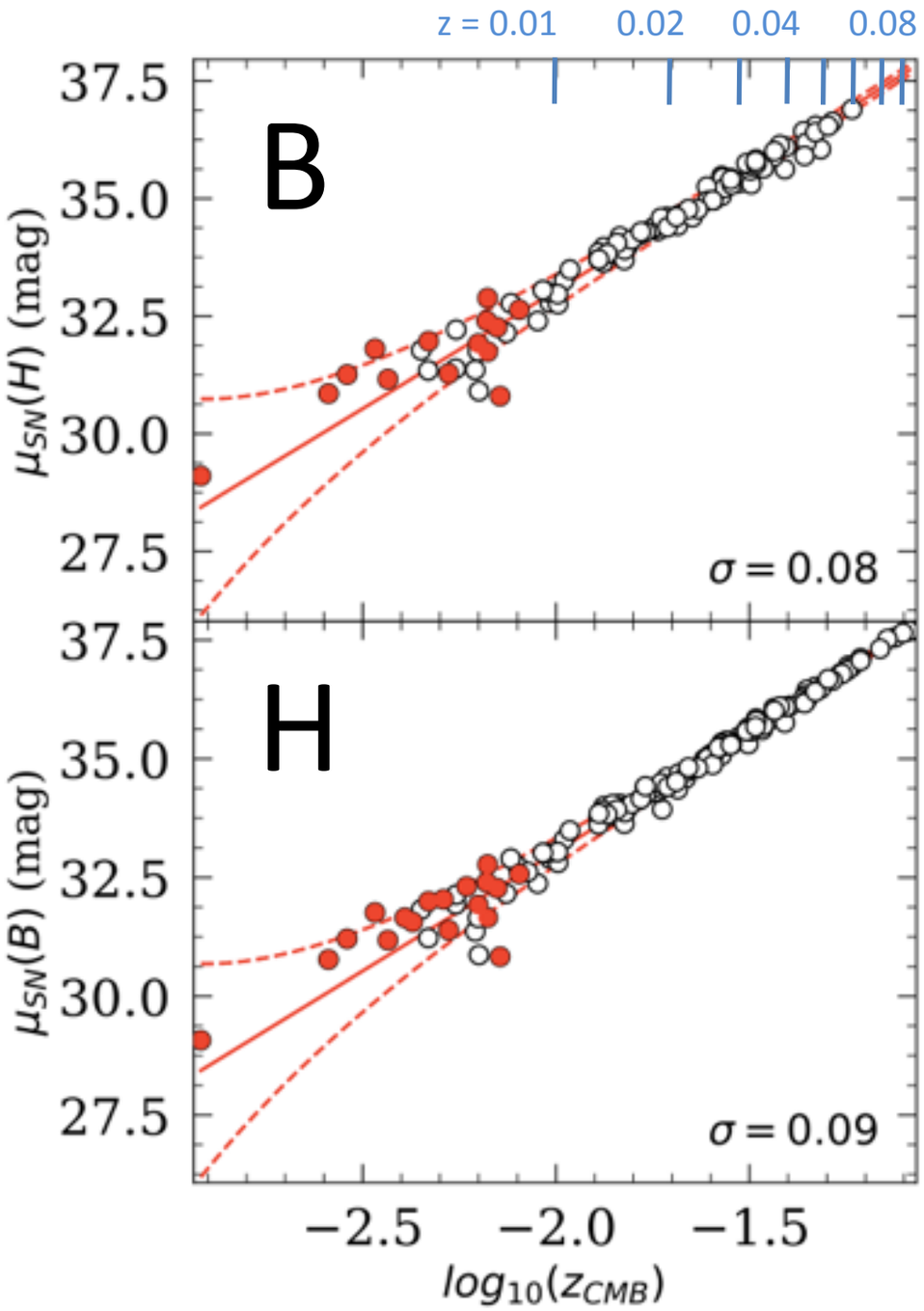
The Value of R_V Is Not Constant



Burns et al. 2013

CSP-I Hubble Diagrams

Correcting for decline rate and determining the dust extinction for each SN gives σ = 0.08-0.09



CSP-I DR3

Cepheid calibrators

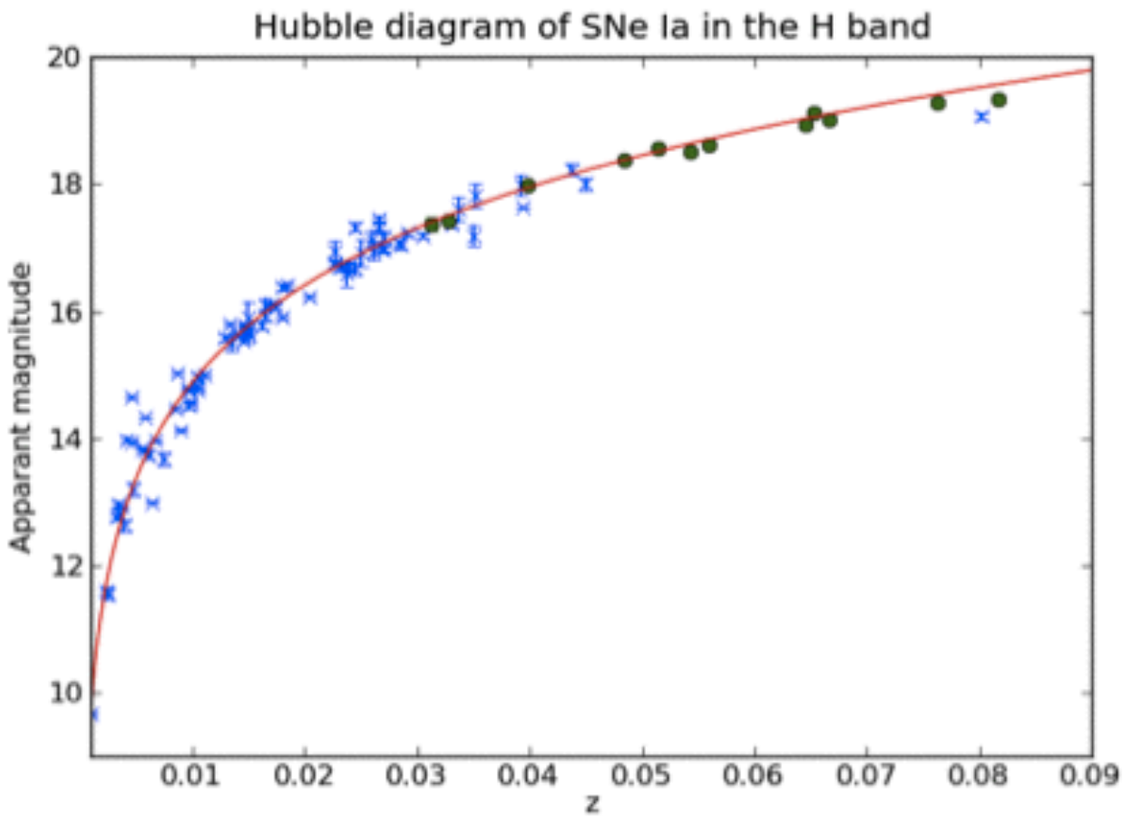
Burns et al., in preparation

CSP-I: Status

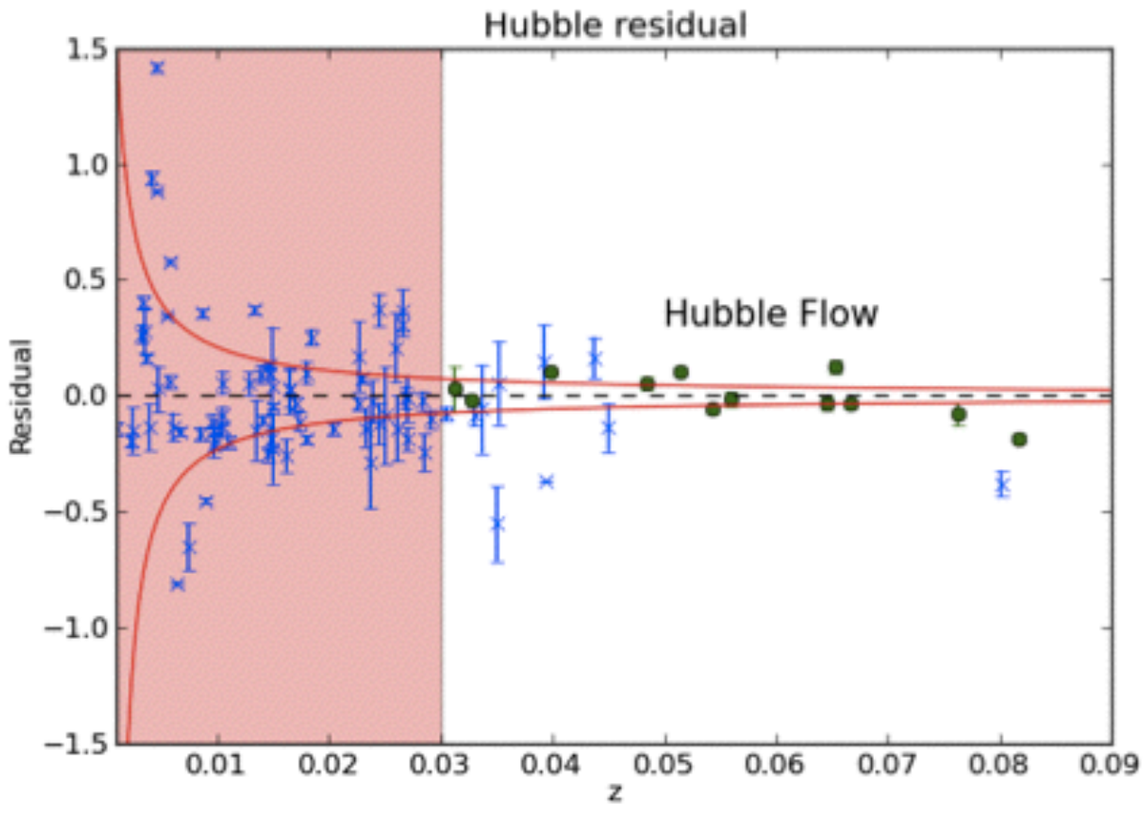
- Data Taking & Reductions — Done
- Papers Published in 2017-2018
  - SCCSNe photometry DR (Stritzinger et al. 2018)
  - SCCSNe host reddening (Stritzinger et al. 2018)
  - SCCSNe photometry analysis (Taddia et al. 2018)
  - SN II spectral diversity - I & II (Gutierrez et al. 2017)
  - SN II Hubble diagram (de Jaeger et al. 2017)
  - SN Ia photometry DR3 (Krisciunas et al. 2017)
  - SN Ia light & color curve properties (Hoeflich et al. 2017)
- Papers That Should Be Published in 2018
  - Spectroscopy of SCCSNe (Holmbo et al.)
  - SN II photometry DR (Contreras et al.)
  - SN Ia absolute calibration & Hubble constant (Burns et al.)
  - SN Ia optical spectroscopy (Morrell et al.)

Pushing Further into the Hubble Flow

- Peculiar velocities account for ±0.11 mag of the observed Hubble diagram dispersion at the median redshift ($z \sim 0.02$) of the CSP-I sample of SNe Ia
- To better determine the true precision of SNe Ia in the NIR, we need to observe further into the Hubble flow ($z \sim 0.03 – 0.09$)



Barone-Nugent et al. (2012)
12 PTF SNe Ia



At $0.03 < z < 0.09$, $\sigma_J = 0.12$ mag
and $\sigma_H = 0.09$ mag

The Carnegie Supernova Project II (CSP-II)

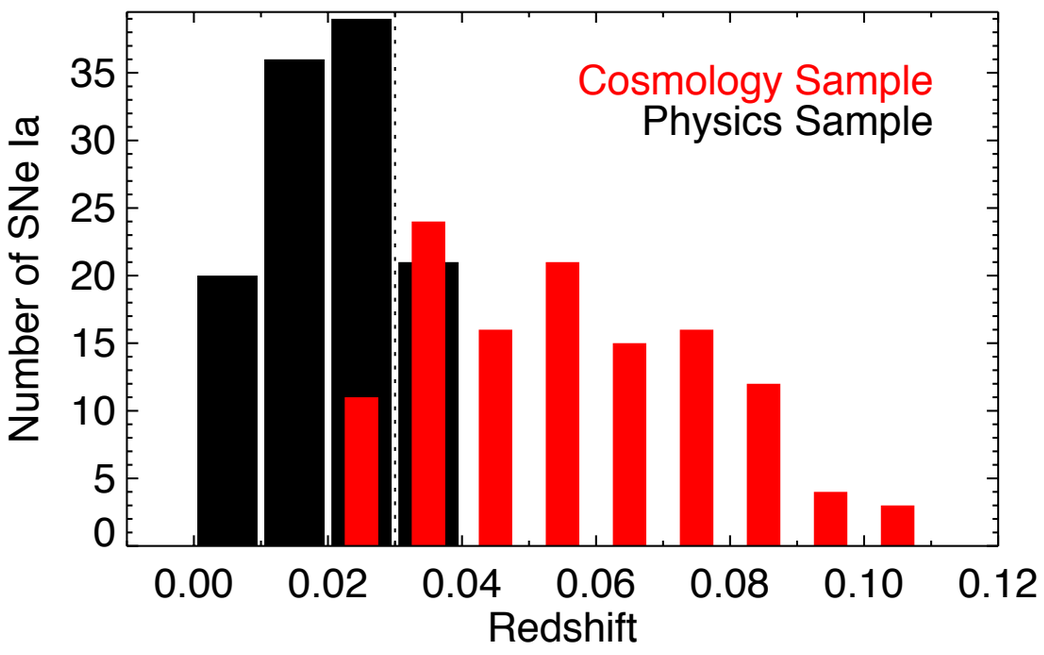
- In Nov 2011, we began a second stage of the CSP to obtain *BVriYJH* light curves of a sample of ~100 SNe Ia at $0.03 < z < 0.10$ using the du Pont 2.5 m and Swope 1.0 m telescopes

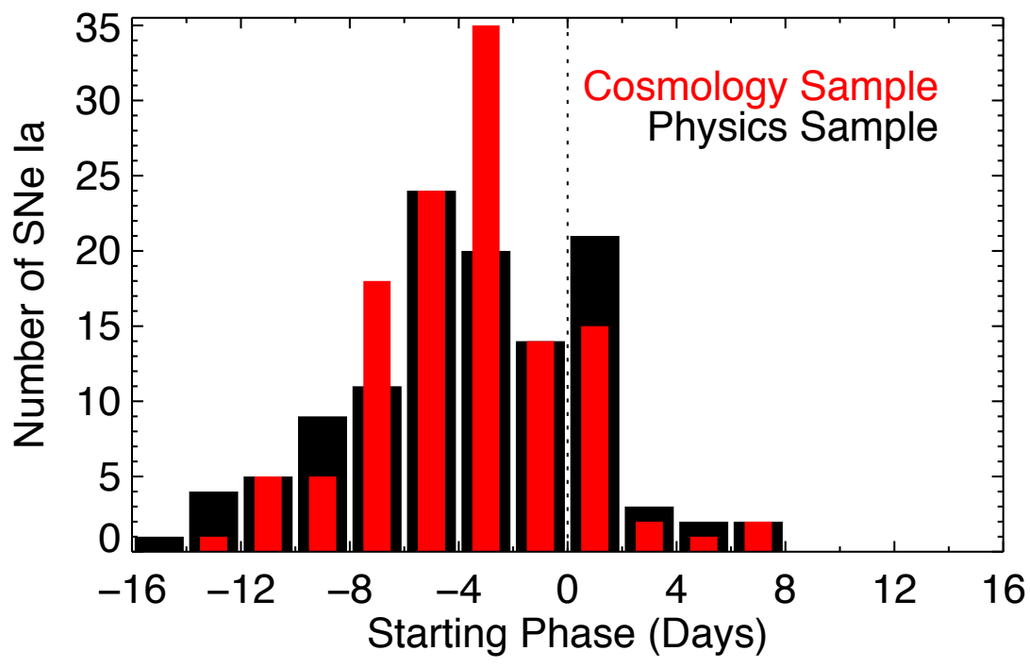
- The SNe were drawn from blind searches to minimize bias

- In a parallel effort, we also obtained NIR spectroscopy of as many SNe Ia as possible; such data are crucial for minimizing errors due to K-corrections, and are also invaluable for insight into the explosion physics

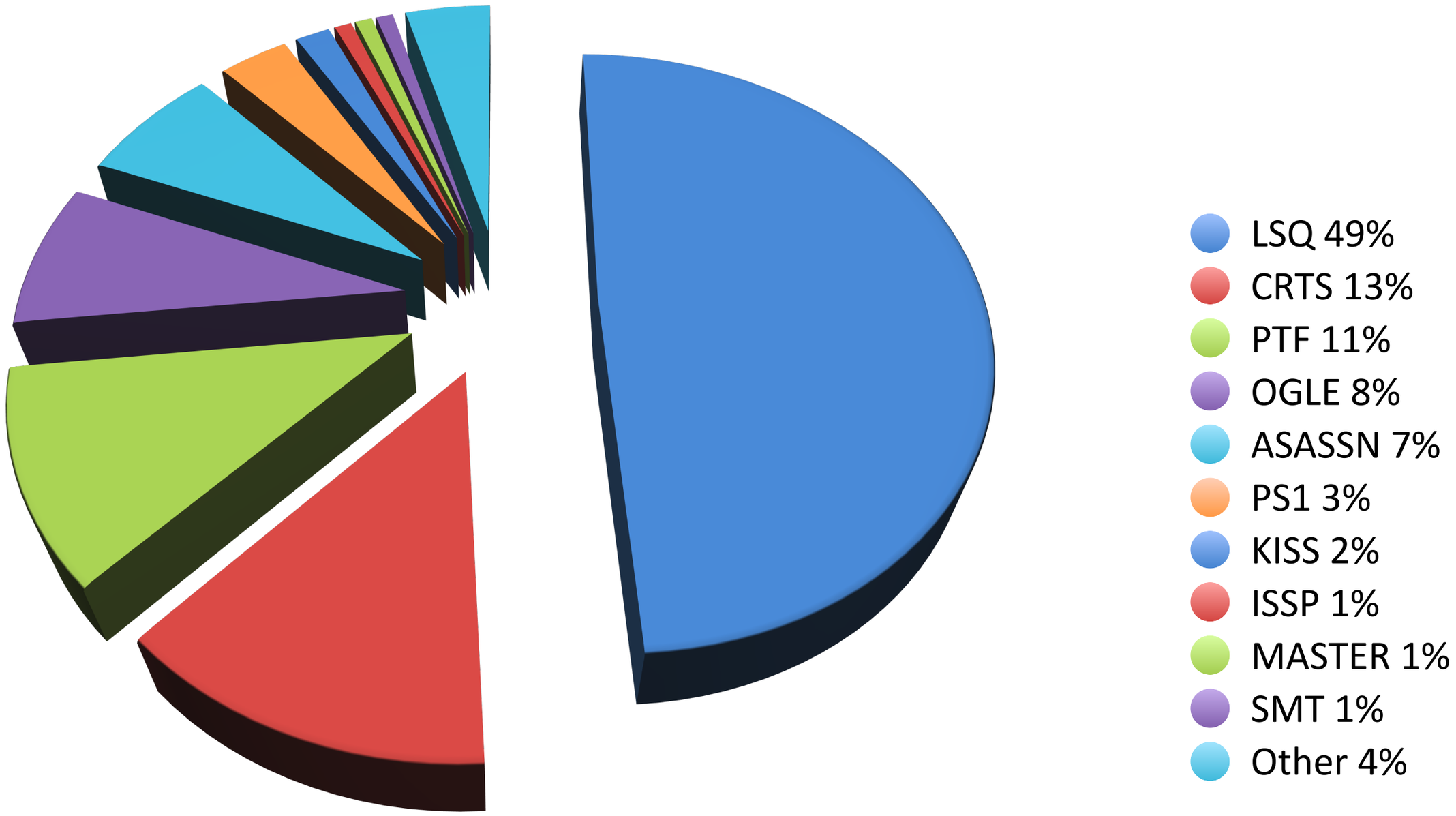
The Carnegie Supernova Project II (CSP-II)

- Four 9-month campaigns between 2011-2015
- Follow-up optical (*ugriBV*) light curves obtained of
  - 120 SNe Ia (z_{median} = 0.056) — "Cosmology Sample" } 30 in common
  - 113 SNe Ia (z < 0.04) — "Physics Sample" } 30 in common
  - ~60 SNe Ibc/II/IIn/SLSN
- NIR (YJH) photometry obtained of SNe Ia near maximum
- Extensive NIR spectroscopy obtained for SNe Ia in Physics Sample





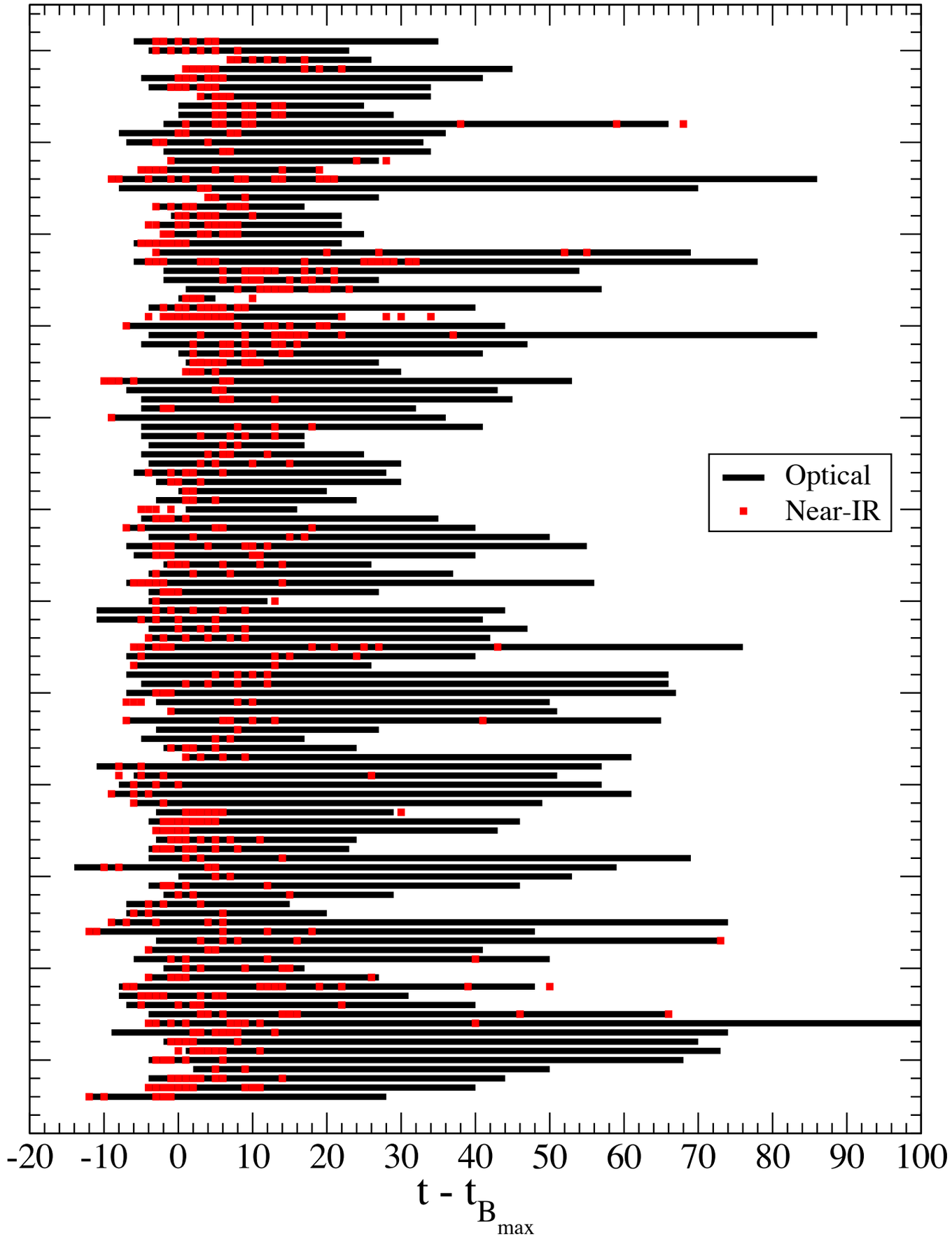
The CSP-II: Sample Summary



96% from “blind” searches

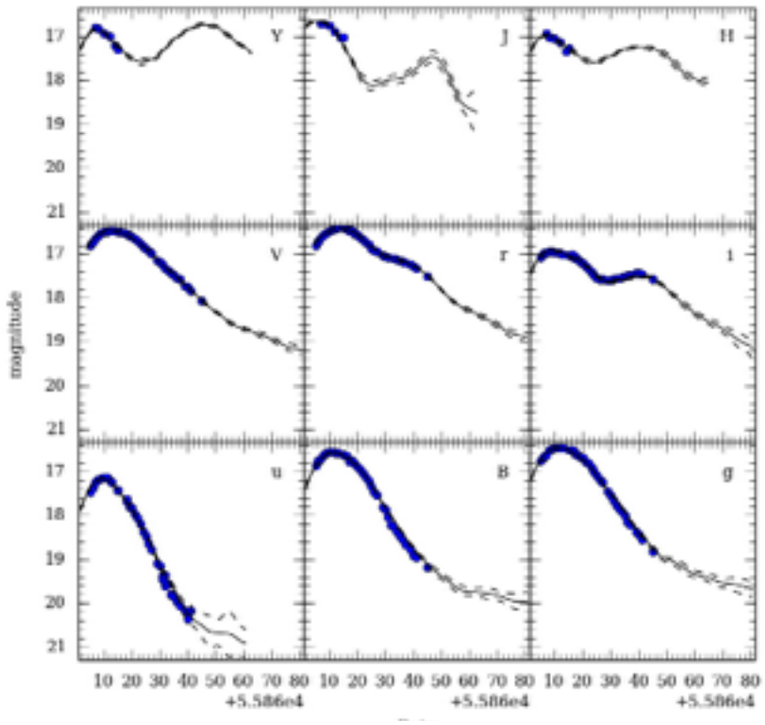
“Cosmology” Sample: Optical and Near-IR Coverage

	Median
Optical Coverage	***-4 to +41***
Near-IR Coverage	***-2 to +10***

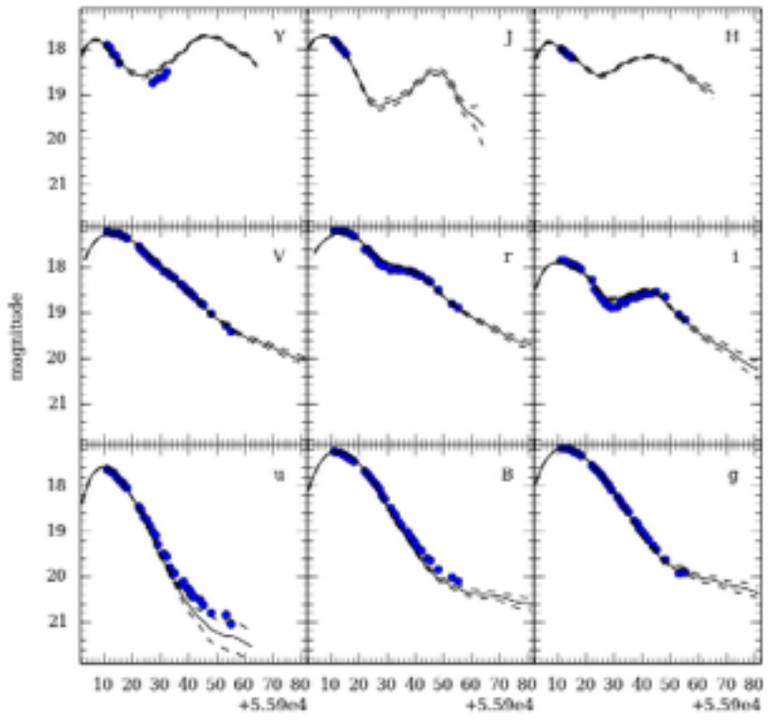


CSP-II: Sample Light Curves

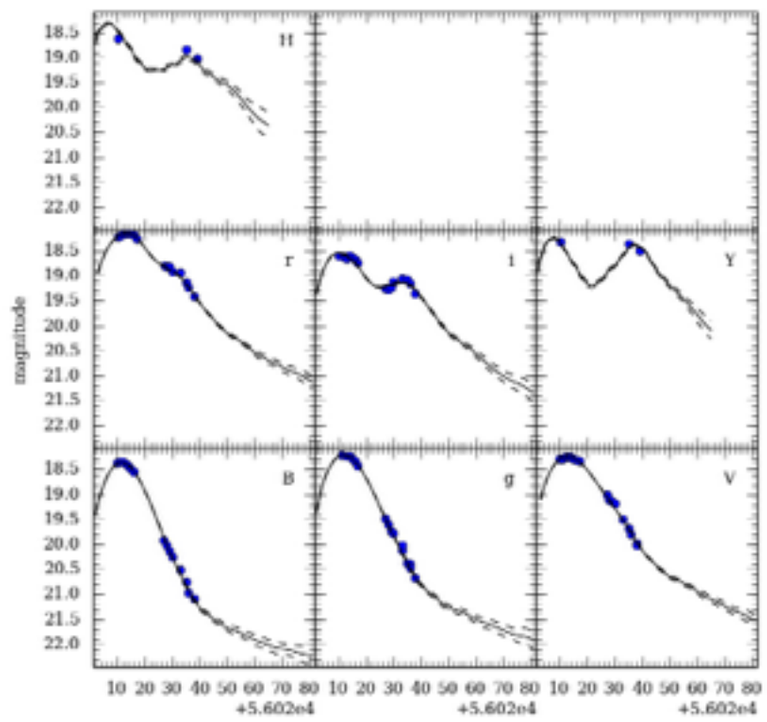
PTF11pbp (z = 0.028)



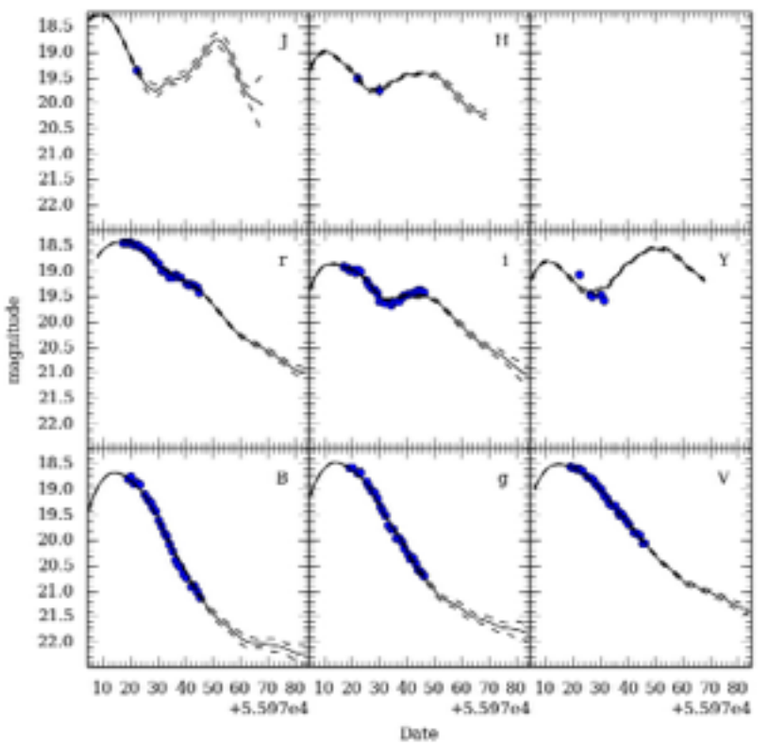
LSQ11bk (z = 0.040)



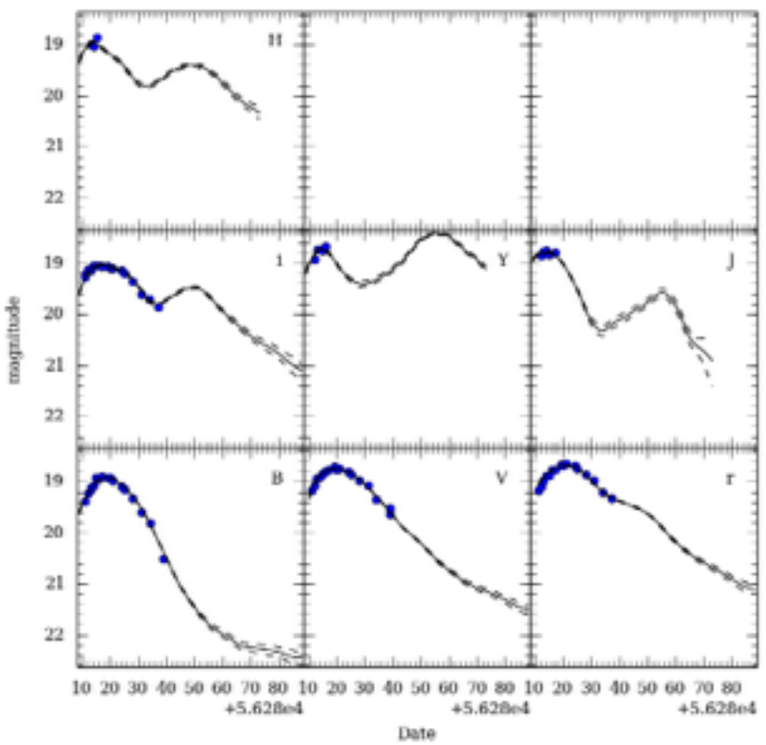
LSQ12btn (z = 0.055)



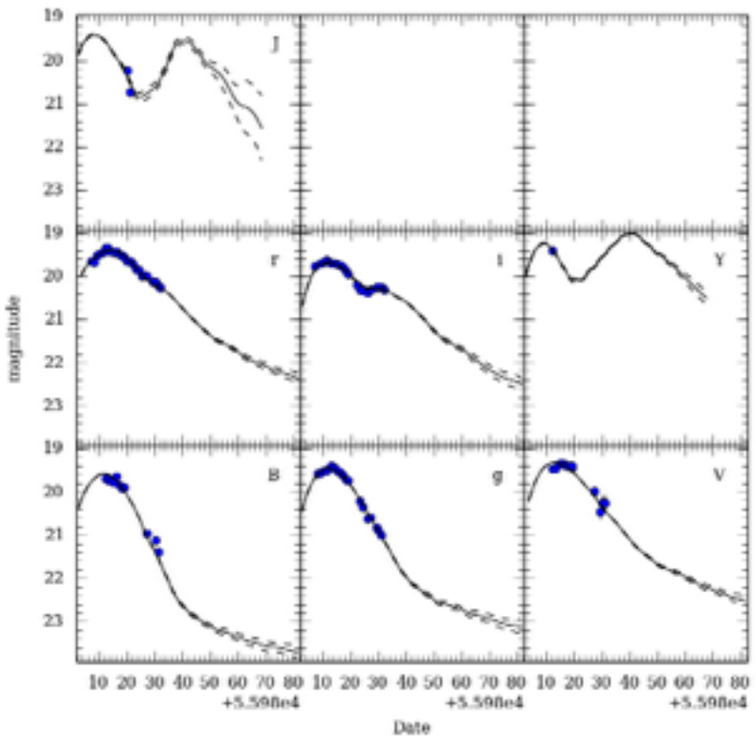
LSQ12agq (z = 0.065)



LSQ12hzs (z = 0.072)

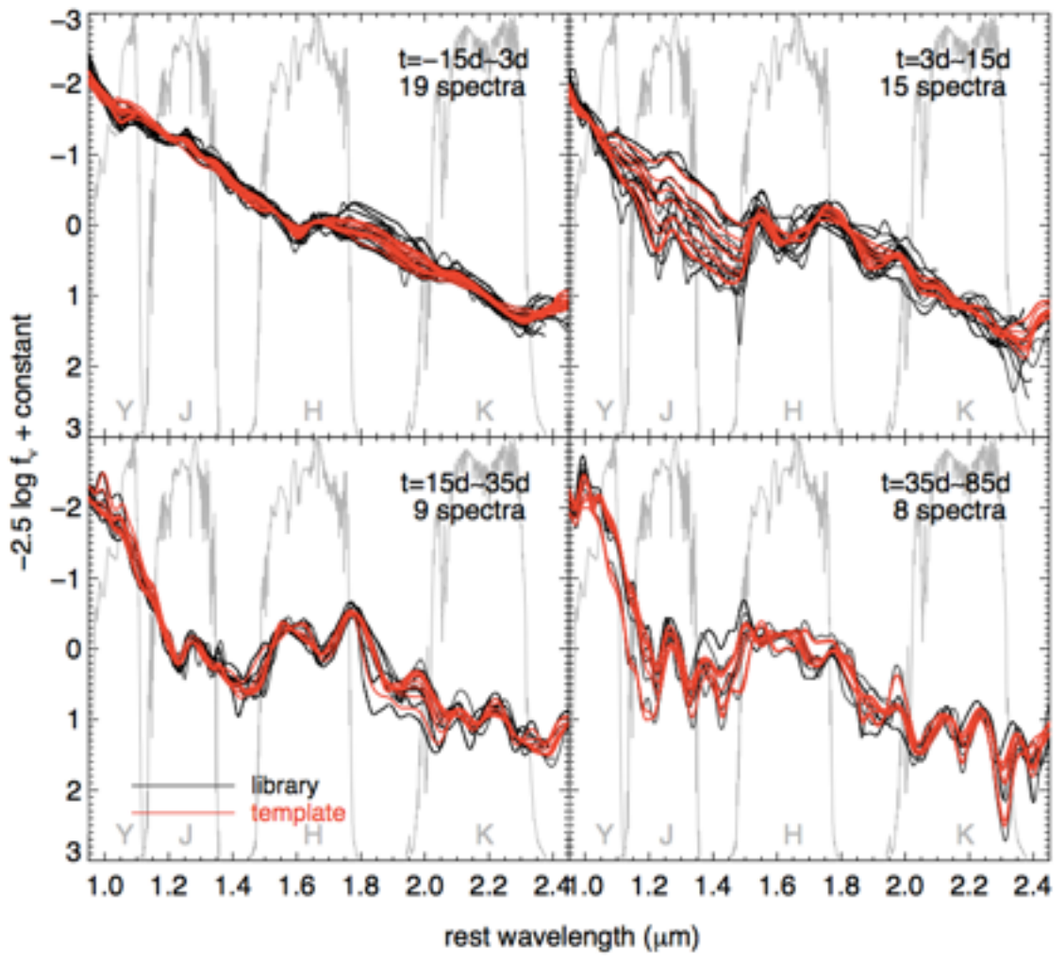


LSQ12aor (z = 0.095)

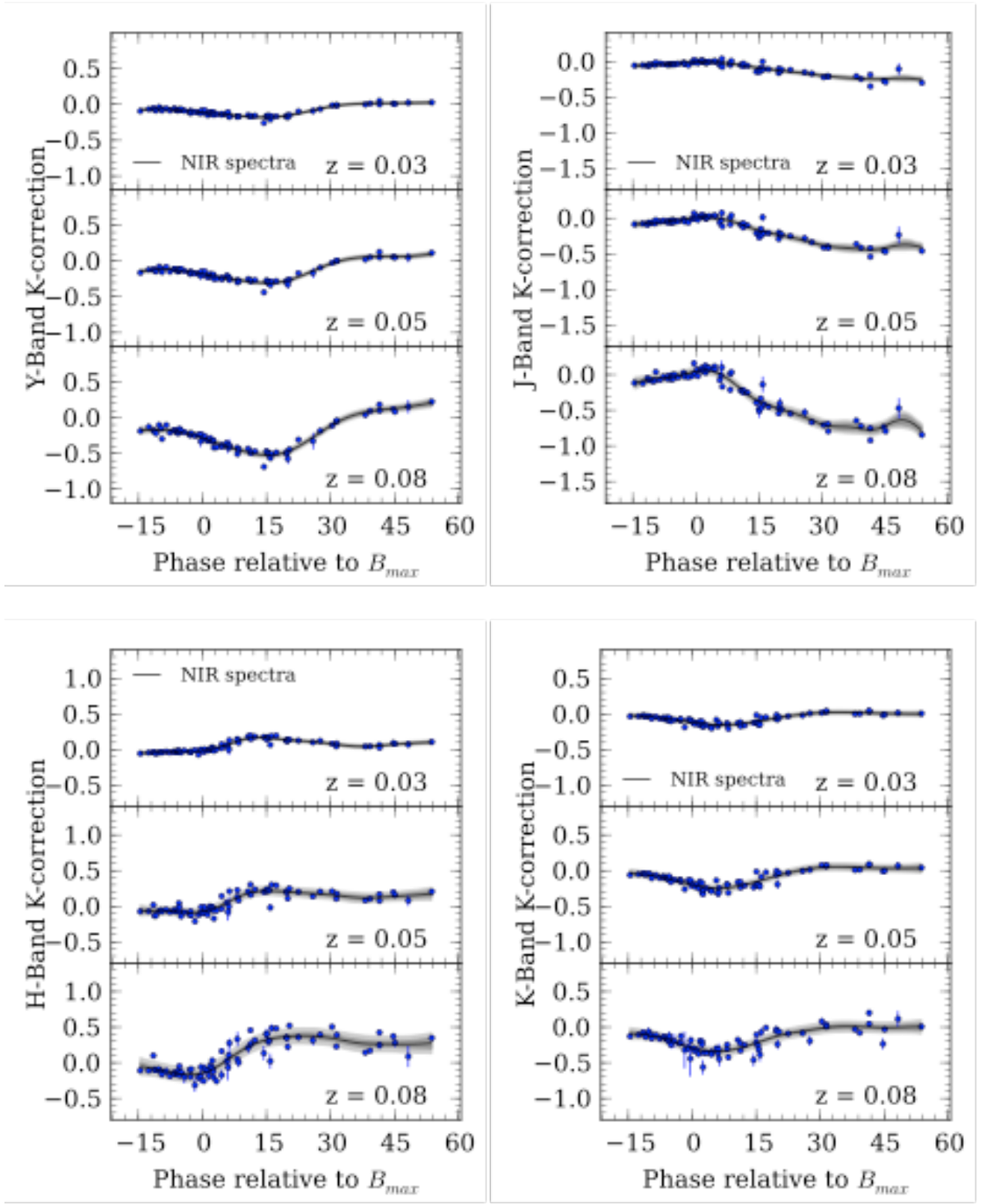


NIR Spectroscopy: K Corrections

- Near-IR spectral characteristics of SNe Ia are still relatively unexplored
- K corrections can be large!

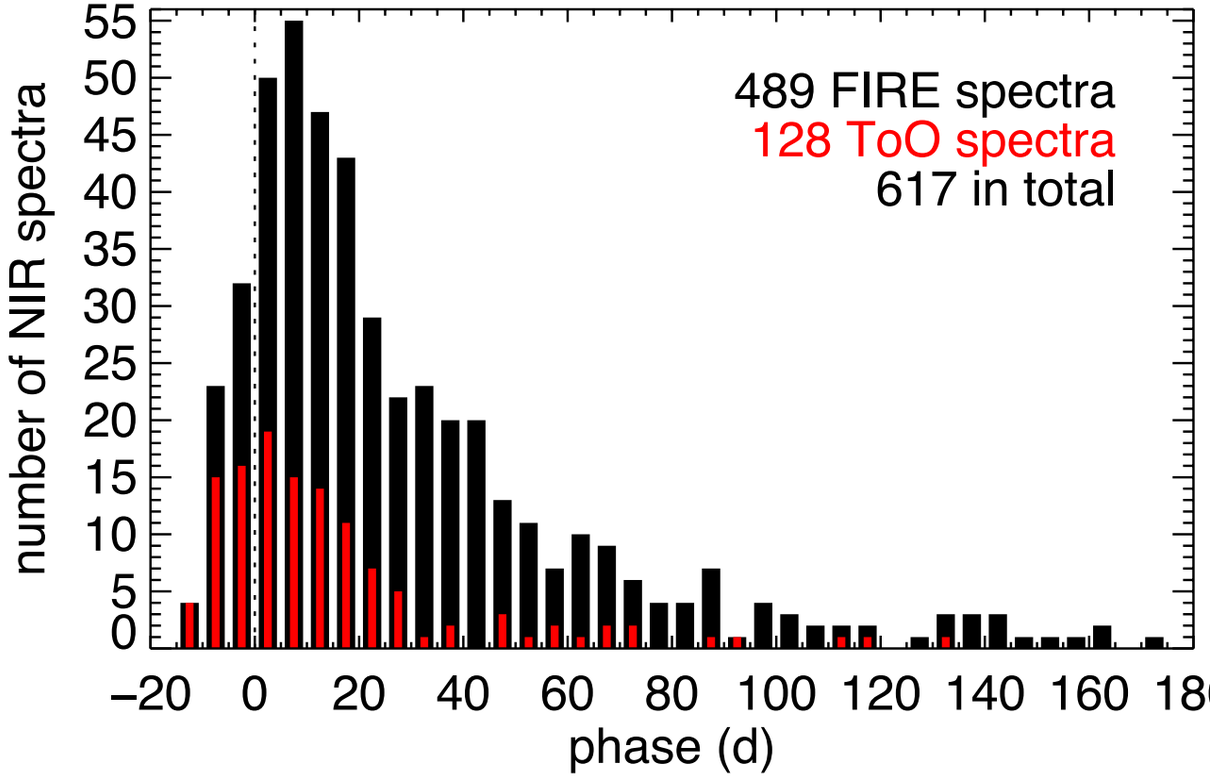


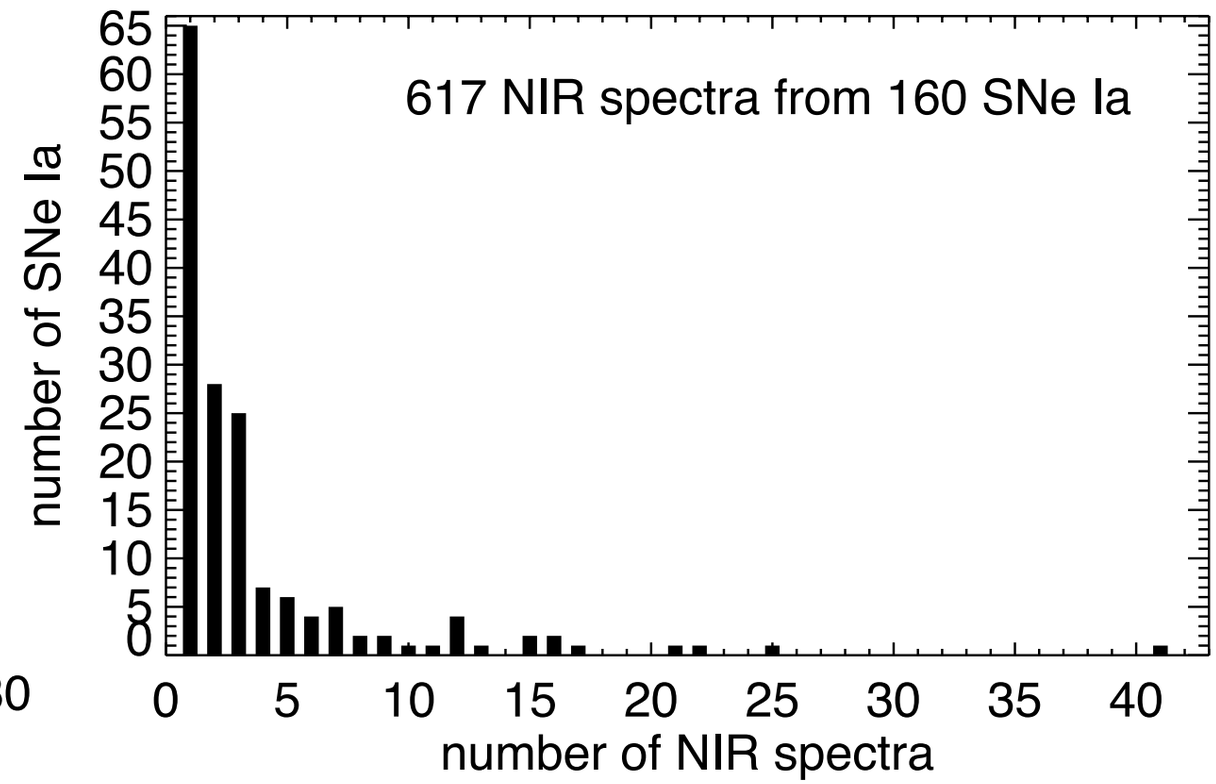
Hsiao (thesis, 2009)



Boldt et al. (2014)

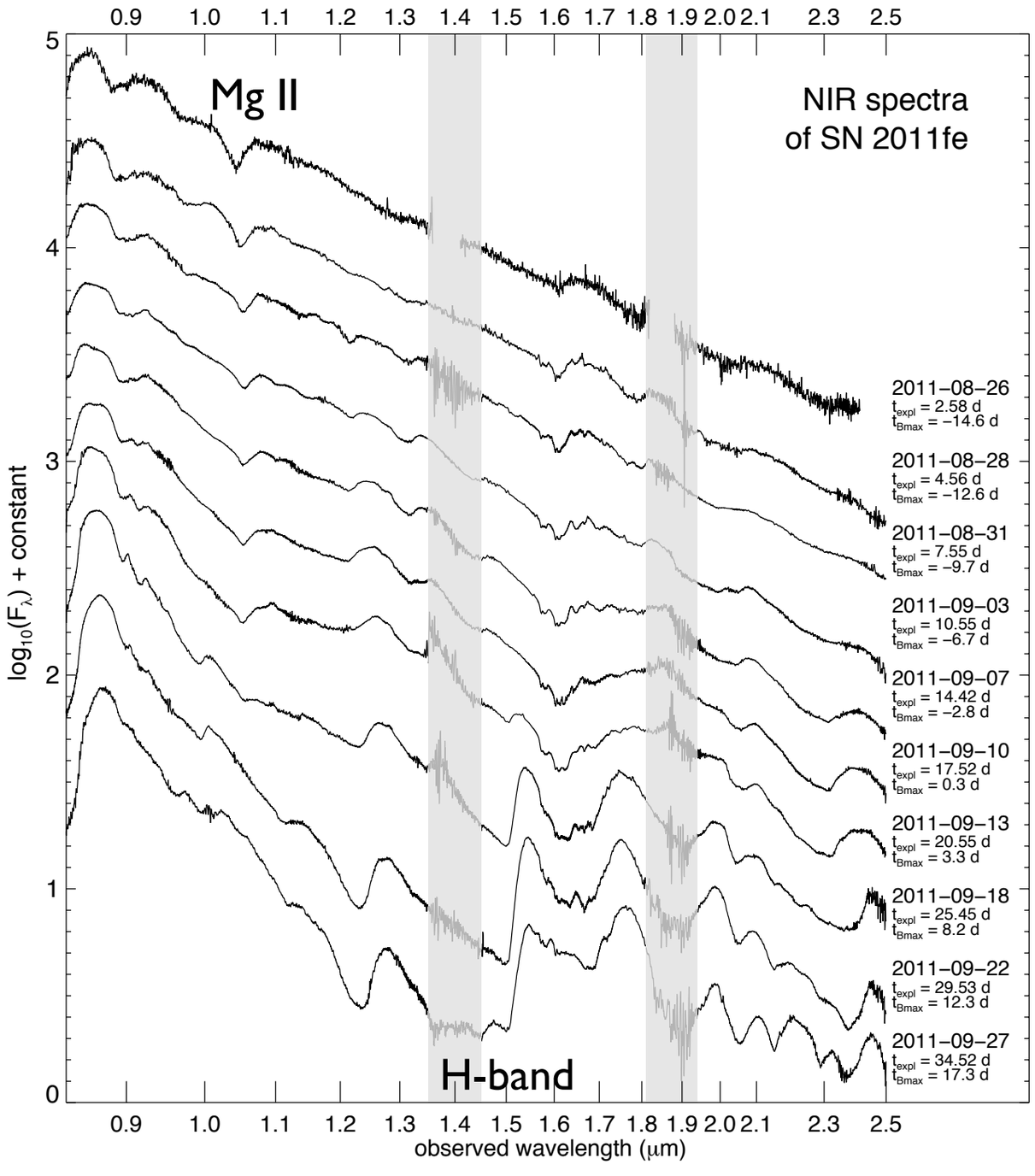
CSP-II: NIR Spectroscopy



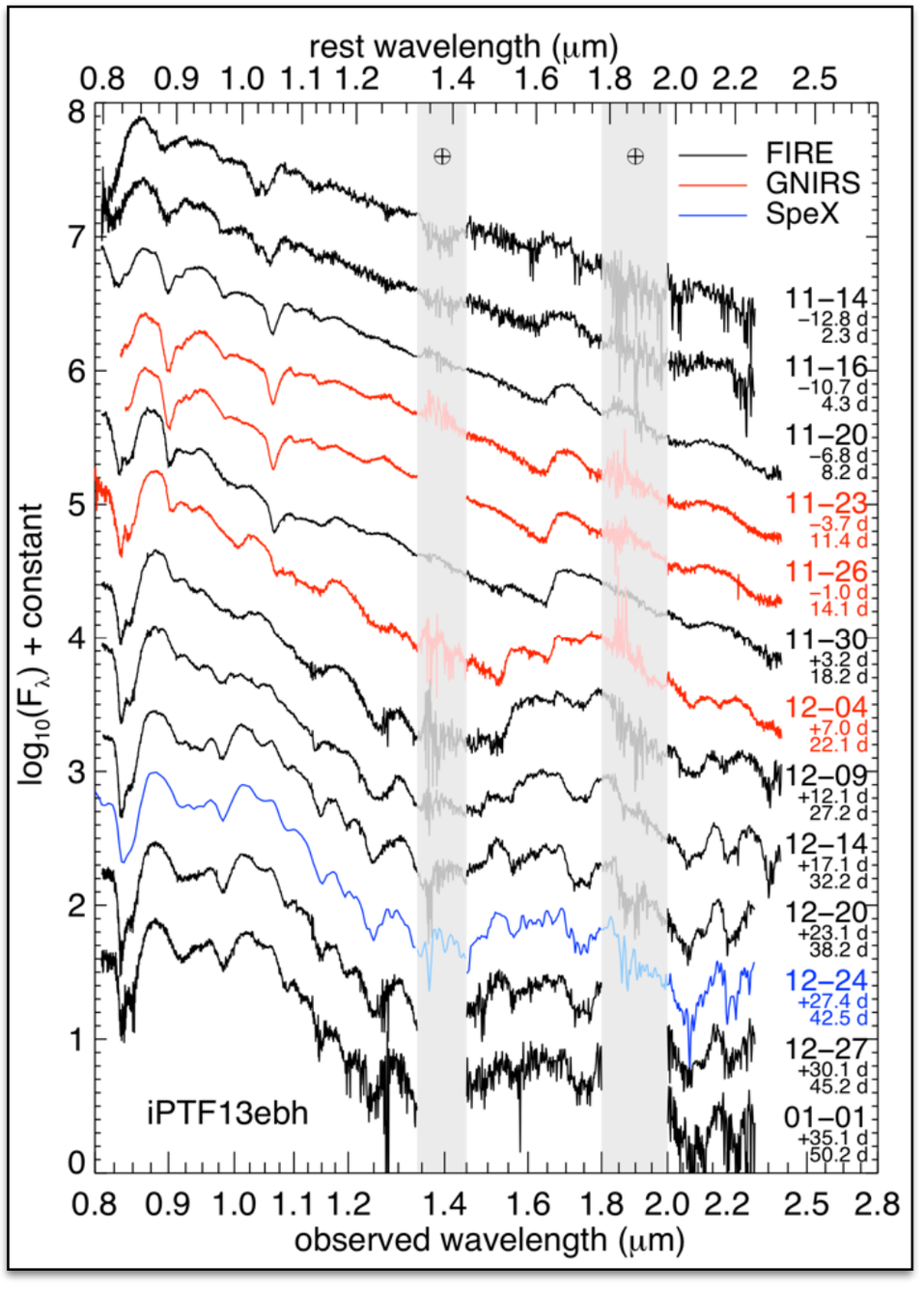


- In collaboration with CfA group (Marion, Kirshner) and Dave Sand
- FIRE is the workhorse instrument, but ToO spectra obtained with IRTF and Gemini-N helped to improve the statistics at maximum and pre-maximum
- Sample is 15 times larger than the previous largest sample from Marion et al. (2009)

CSP-II: NIR Spectroscopy: Studying the Physics of SNe Ia



Hsiao et al. 2013

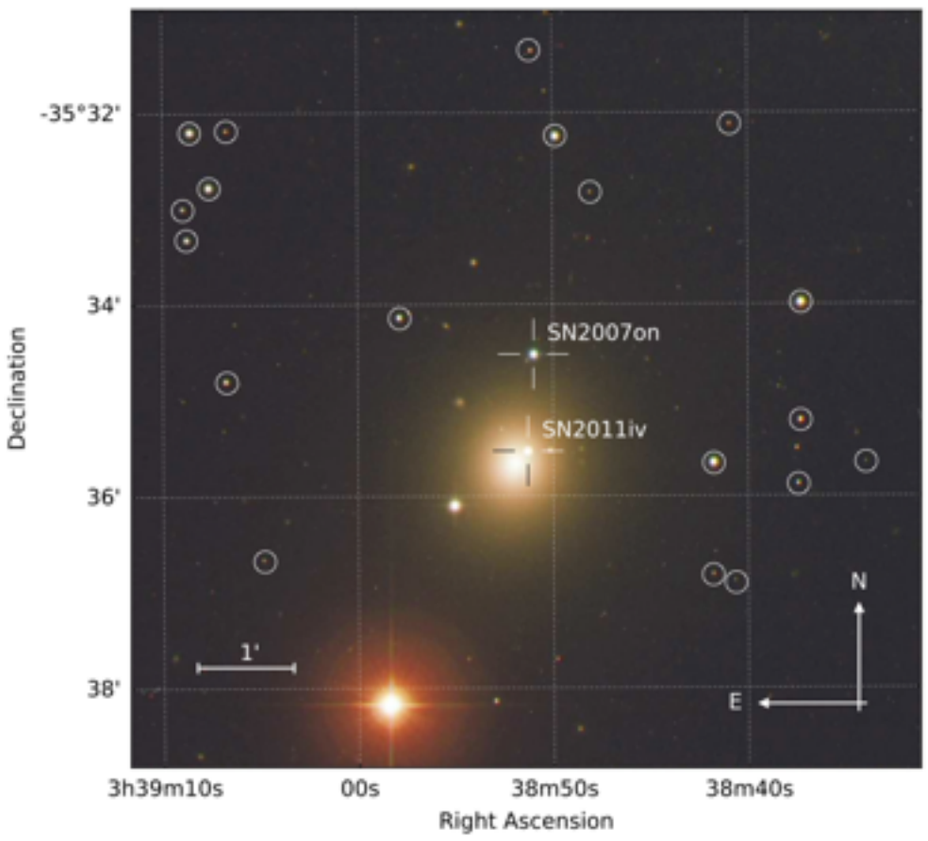


Hsiao et al. 2015

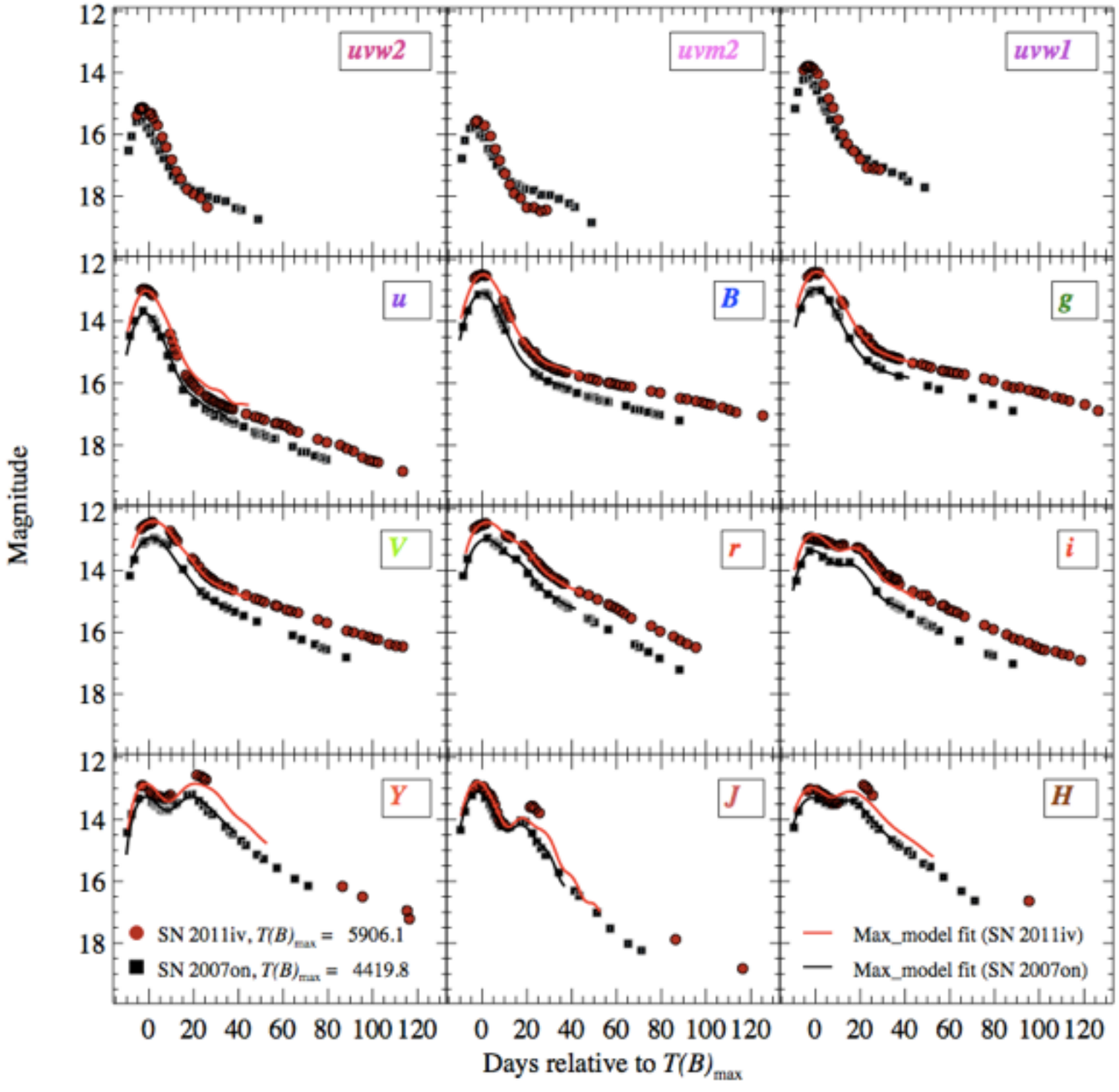
CSP II: Status of Data

- Data Taking
  - Optical photometric calibration: Done
  - IR photometric calibration: A handful of SNe still to be calibrated.
  - Optical host galaxy templates: Done
  - NIR host galaxy templates: Essentially done
  - Host Redshifts: Only 9 host galaxy redshifts left to measure out of original total of ~50.
- Data Reductions
  - Optical light curves: Final
  - NIR light curves: Mostly final
  - Optical spectra: Reduced
  - NIR spectra: Final reductions in progress

SNe 2007on & 2011iv in NGC 1404

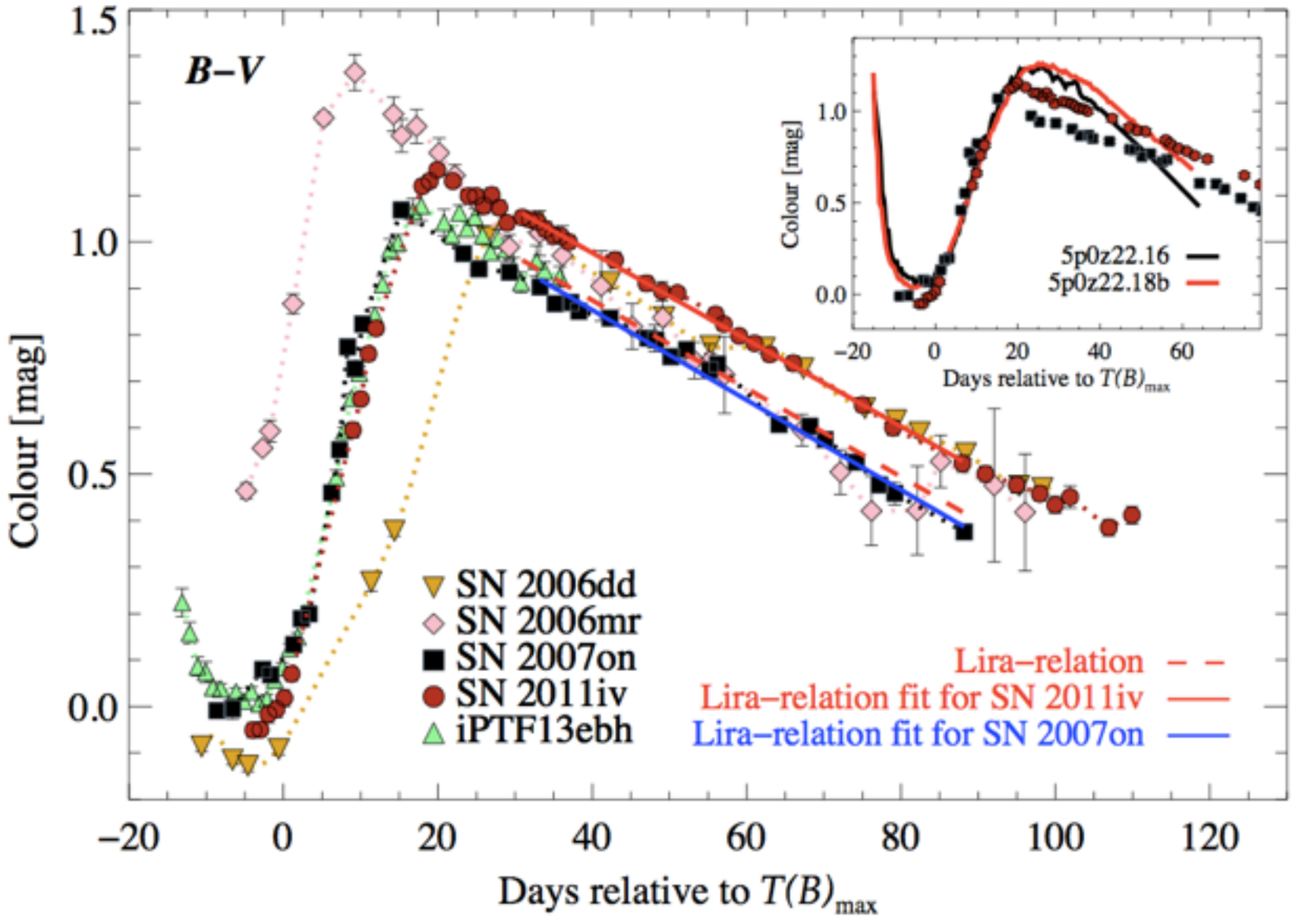


Two “transitional” SNe Ia hosted by the Fornax cluster member, NGC 1404, and observed by the CSP-I and II.



Gall et al. 2018

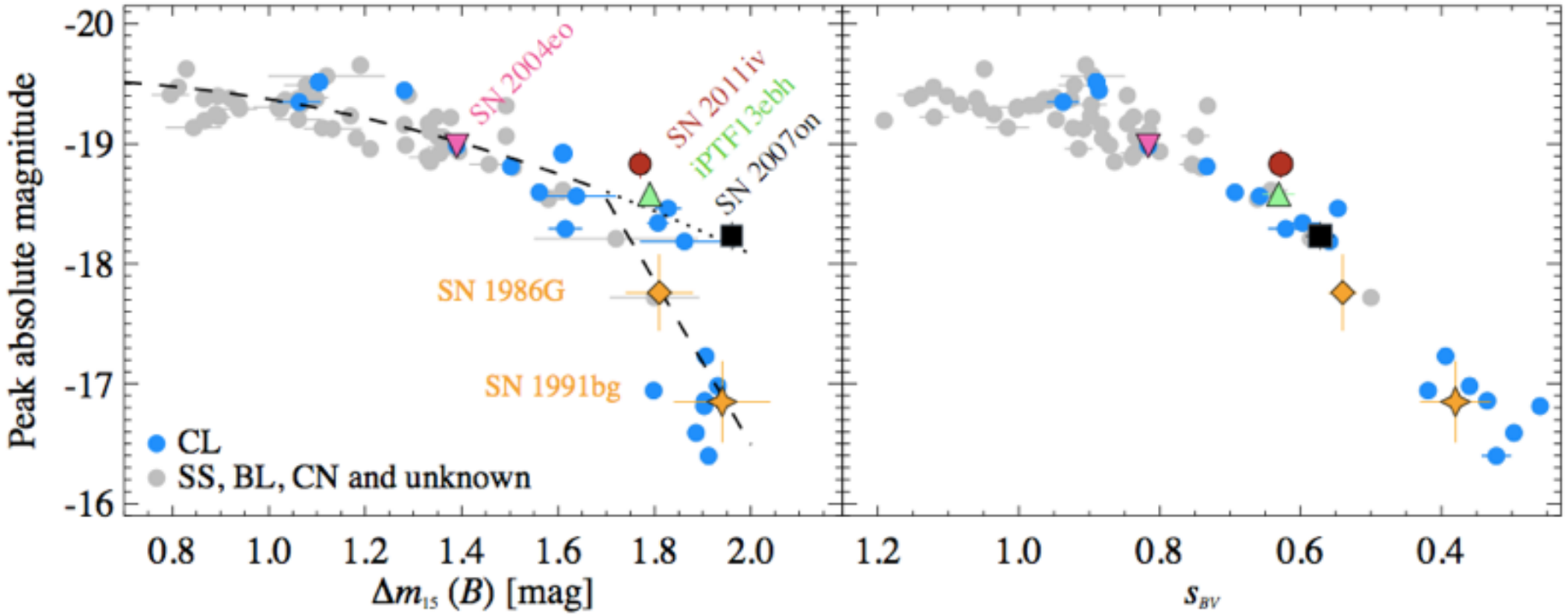
SNe 2007on & 2011iv in NGC 1404

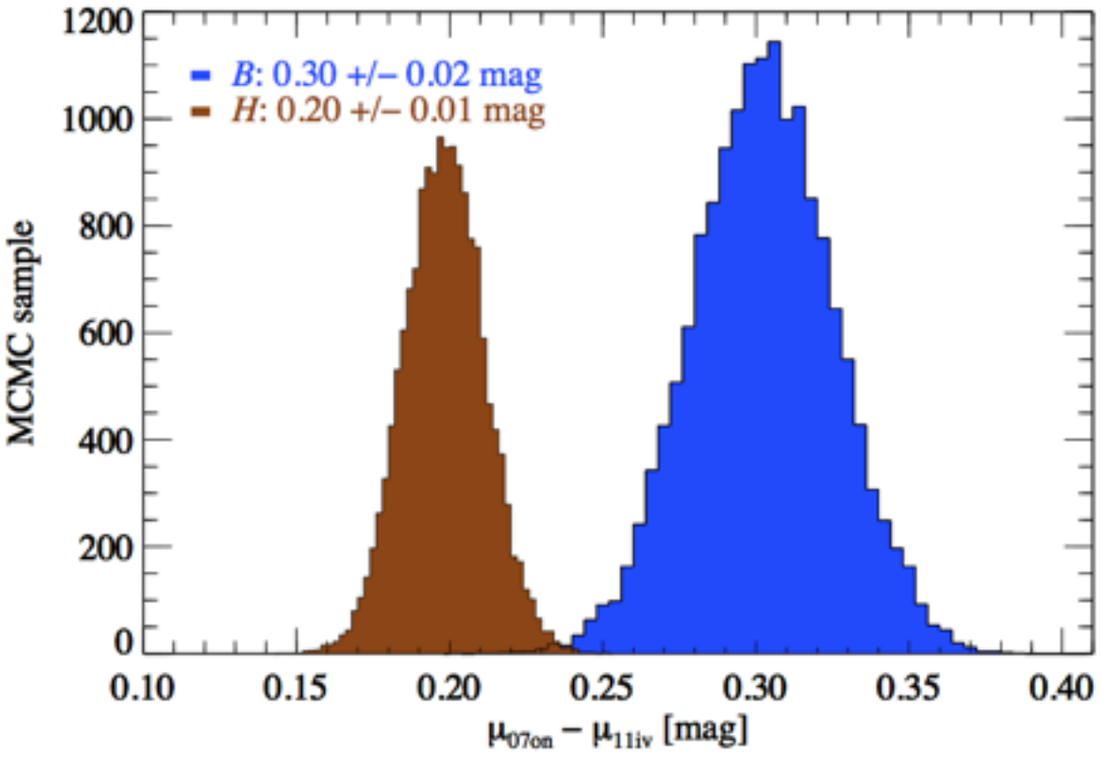


Gall et al. 2018

To first order, the transition density drives the luminosity–width relation, while the central density is an important second-order parameter. Within this context, the differences in the (*B*–*V*) color evolution along the Lira regime suggests the progenitor of SN 2011iv had a higher central density than SN 2007on.

SNe 2007on & 2011iv in NGC 1404





These findings serve as a cautionary tale for the use of transitional SNe Ia located in early-type hosts in the quest to measure cosmological parameters.

Gall et al. 2018

Where Do We Go From Here?

- The CSP-II has concluded. We're working to get the light curves and spectra published, and are also discussing where to go from here.
  - What are the most important ground-based observations to carry out in the future?
  - Early time? Late time? Light curves? Spectra? Wavelengths coverage?

Thanks

Nidiafest

- "Massive Stars and Supernovae"
- November 5-9, 2018
- Bariloche, Argentina
- http://nidiafest.fcaglp.unlp.edu.ar/