Carnegie Supernova Project II

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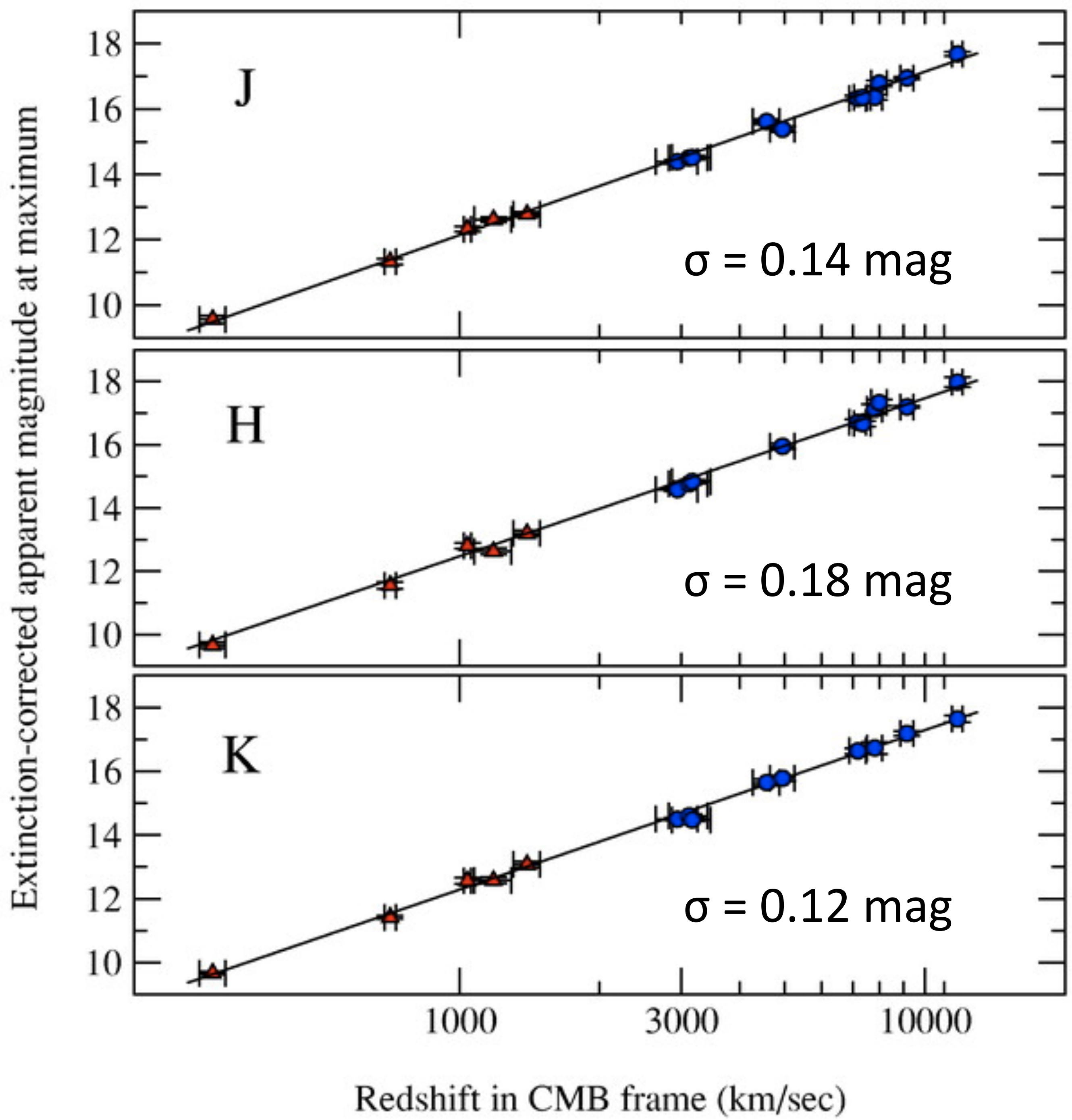
Carnegie Observatories

CARNEGIE INSTITUTION FOR SCIENCE

National Science Foundation
WHERE DISCOVERIES BEGIN

Carnegie SN Ia Progenitor Workshop, August 2015

SNe Ia are Excellent Standard Candles in the Near-IR

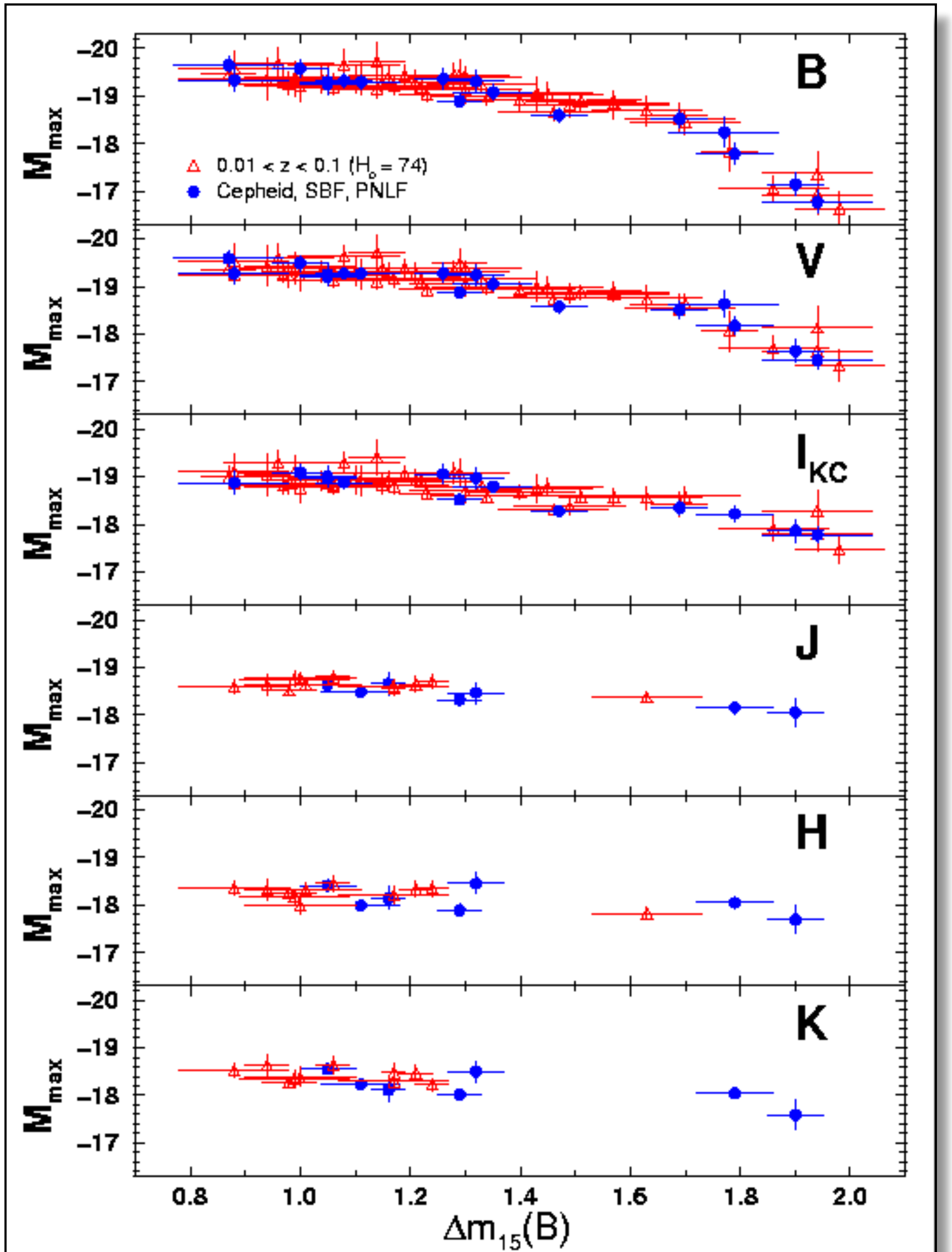


- Extinction from dust is much less in the near-IR
- SNe Ia are intrinsically much better standard candles in the near-IR

Krisciunas, Phillips, & Suntzeff (2004)

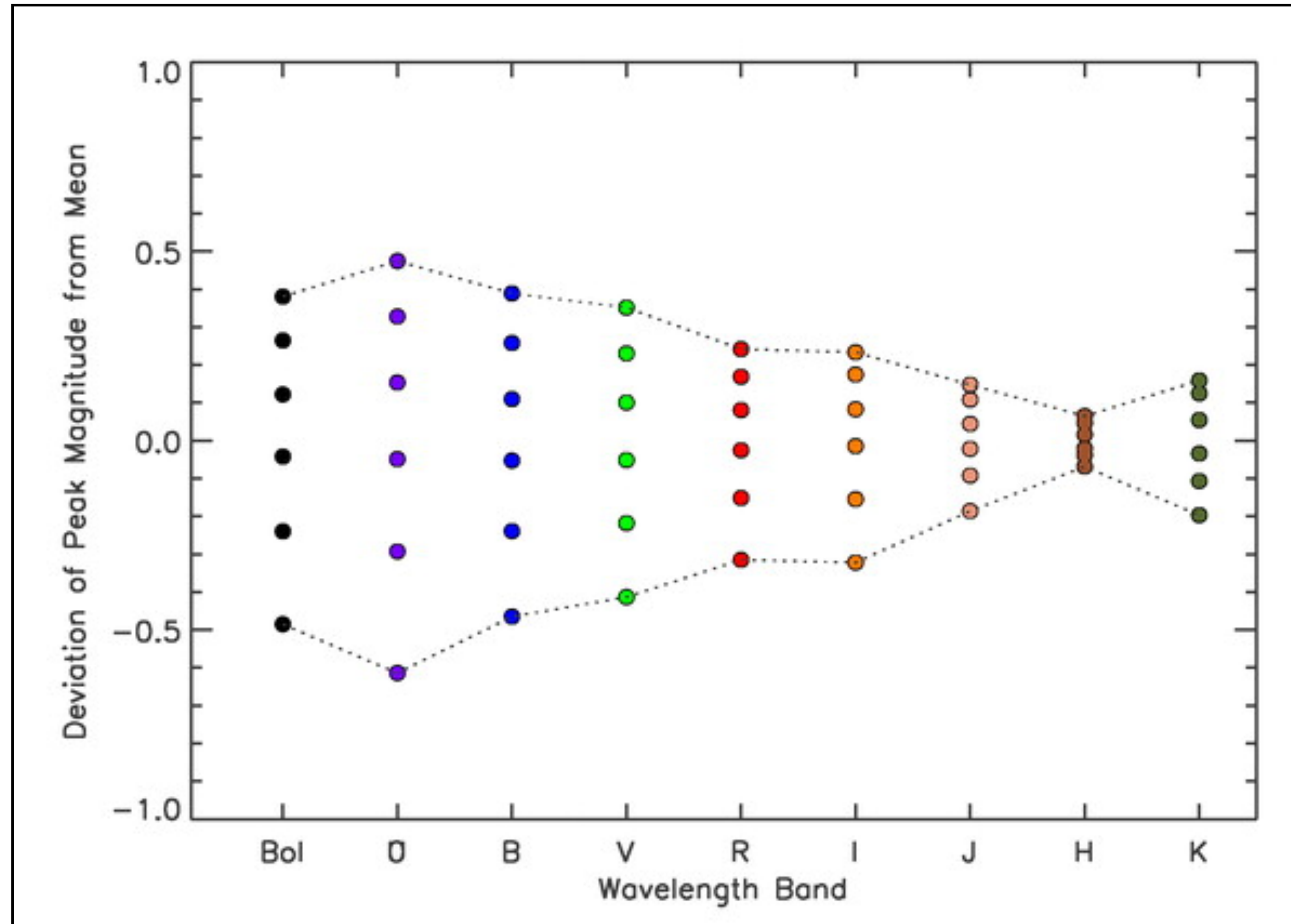
The Luminosity-Decline Rate Relation

Observations



Phillips 2005

Theory



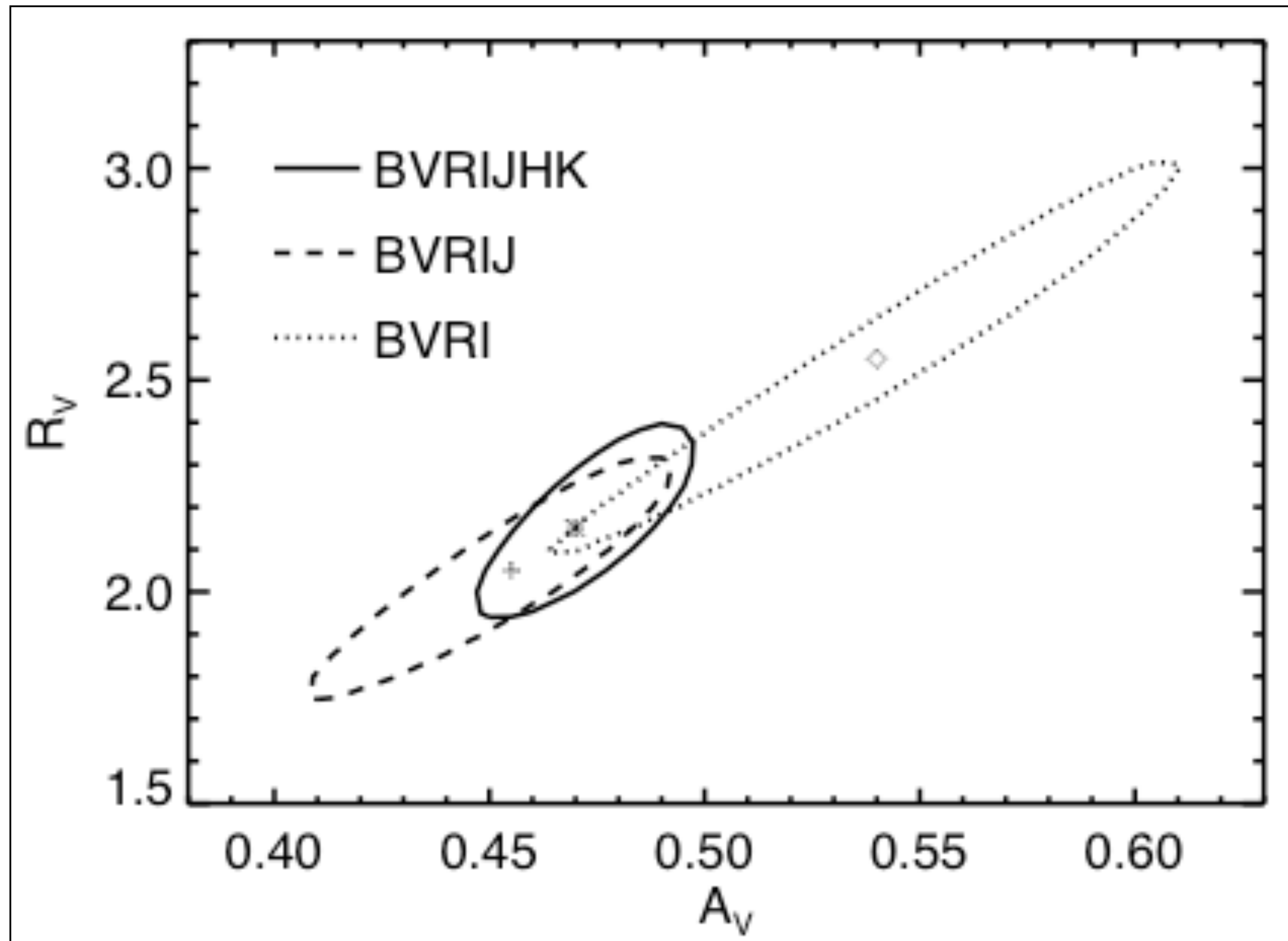
Kasen 2006

Both observations and theory confirm that the dispersion in peak luminosities is smallest in the NIR

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
- $E(V-H) = A_V - A_H \sim A_V$
- $R_V = A_V / E(B-V)$



Krisciunas et al. 2007

The Carnegie Supernova Project I (CSP I)

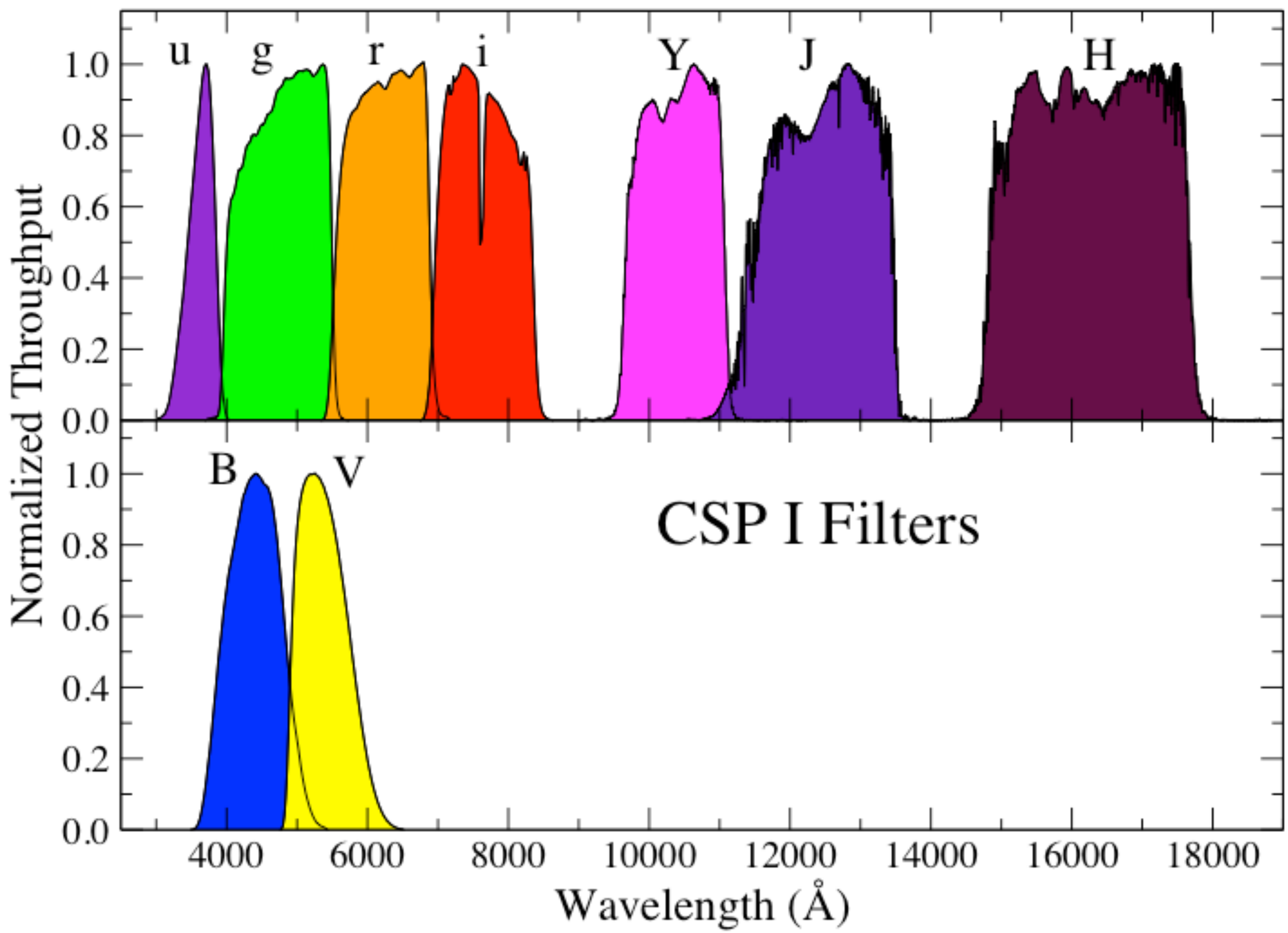
- Five 9-month campaigns between 2004-2009
- Follow-up optical (*ugriBV*) light curves obtained of 130 SNe Ia
- Near-IR (*YJH*) photometry obtained of 113 (87%) of these
- Light curves of 85 SNe Ia published to date
- Light curves of remaining 45 SNe Ia to be submitted for publication by end of 2015


Swope 1-m


Du Pont 2.5-m

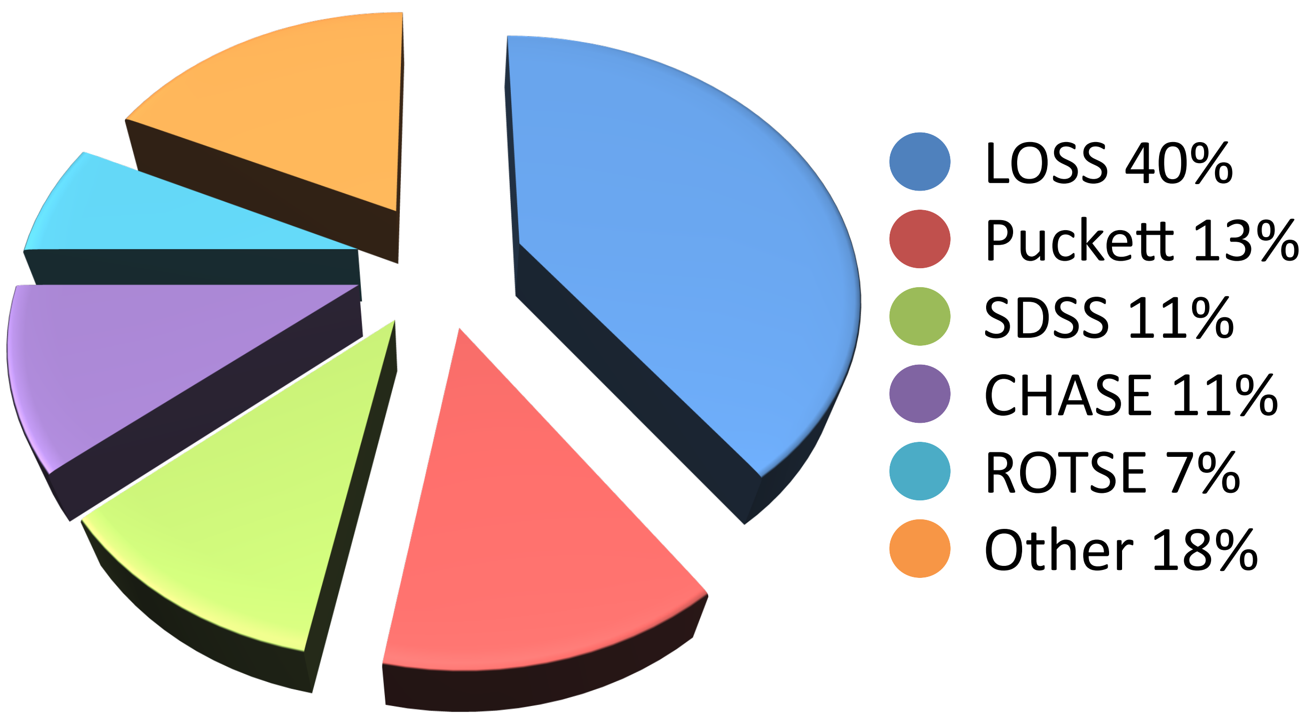

Magellan 6.5-m

CSP-I: uBgVriYJH filters

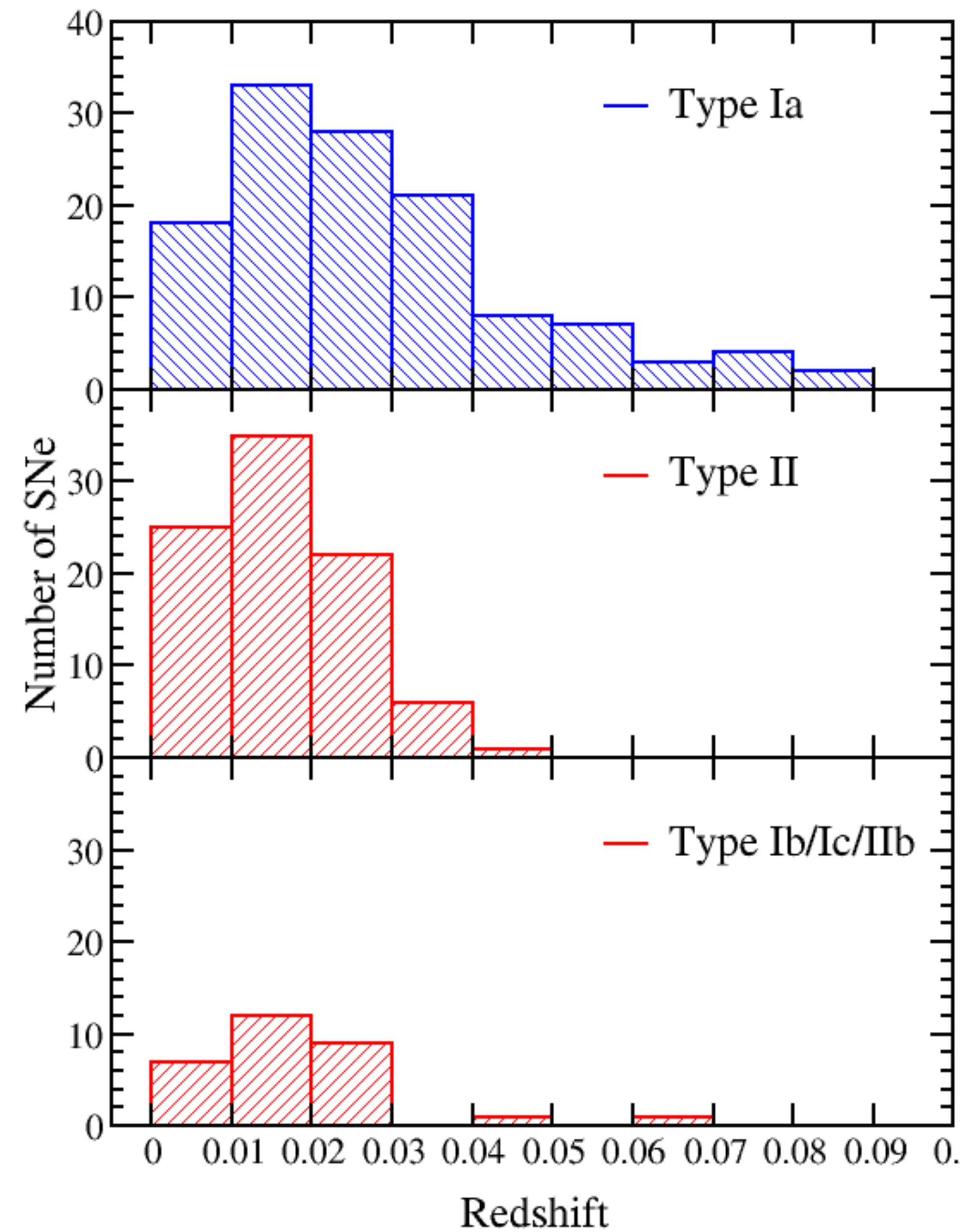


CSP I Summary

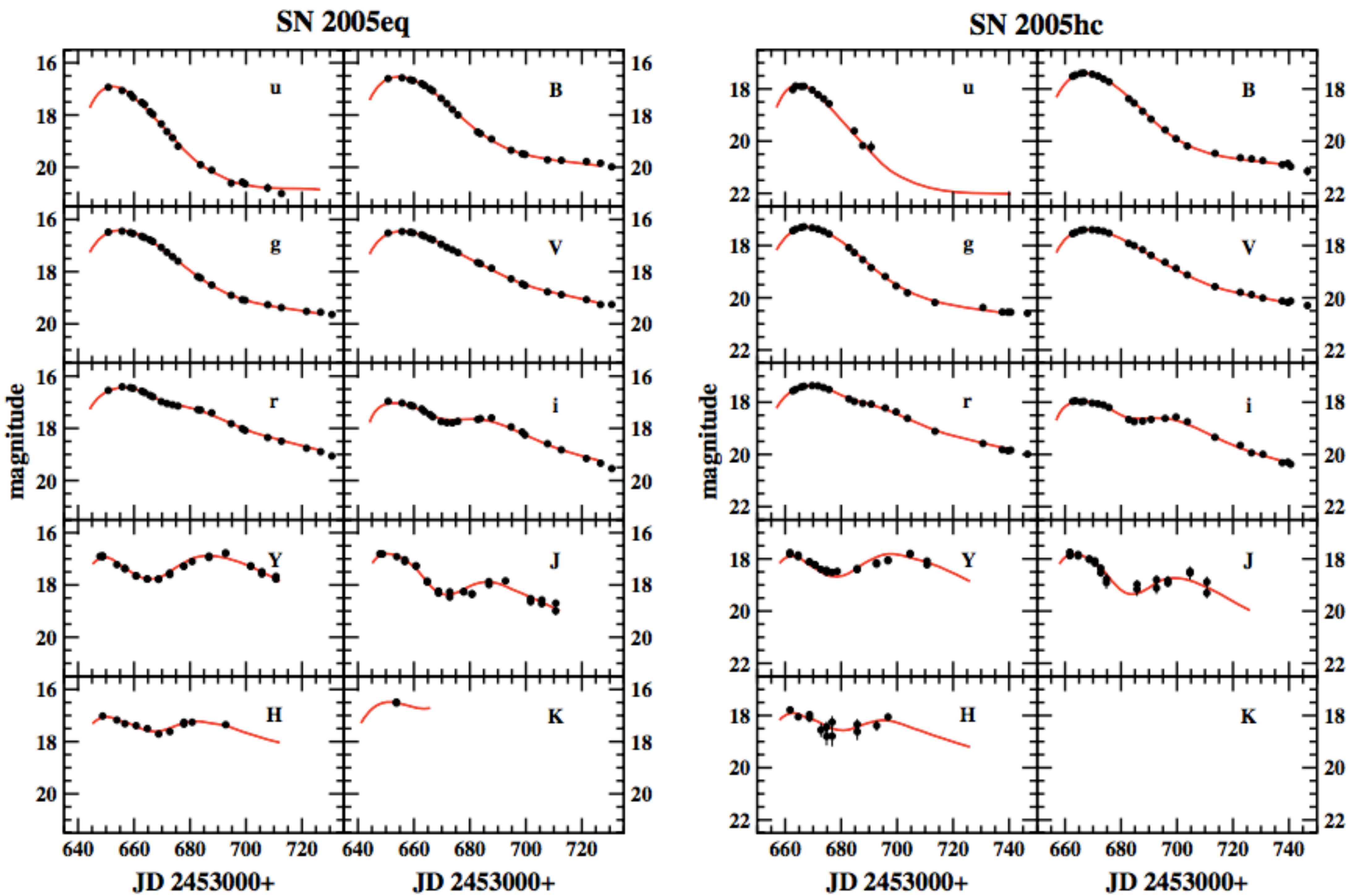
	Ia	II	Ib/Ic/IIb	Total
# Observed	***130***	***93***	***31***	***254***



z_{median} of SNe Ia ~ 0.023

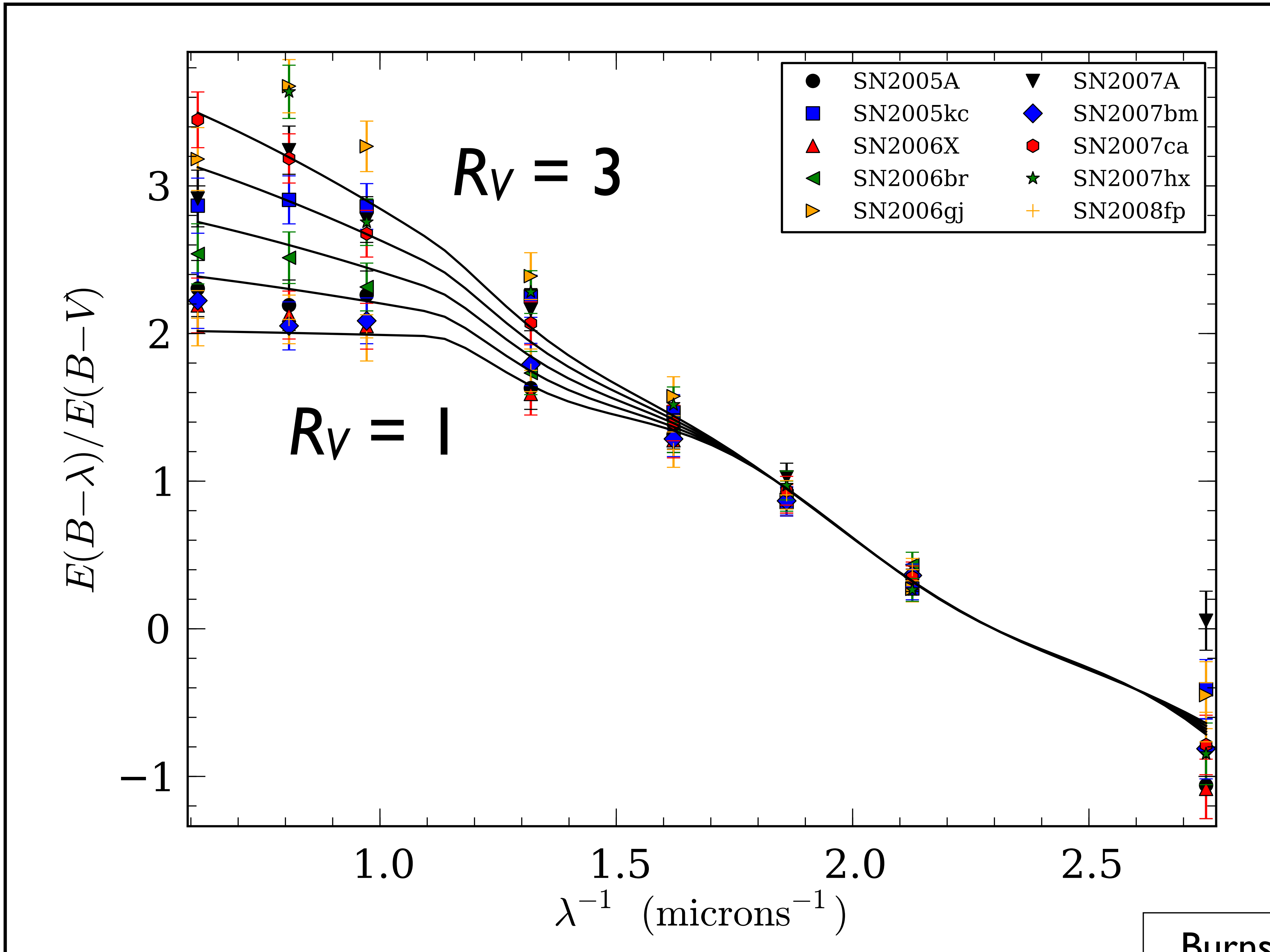


Optical and Near-IR Light Curves of SNe Ia from the CSP-I



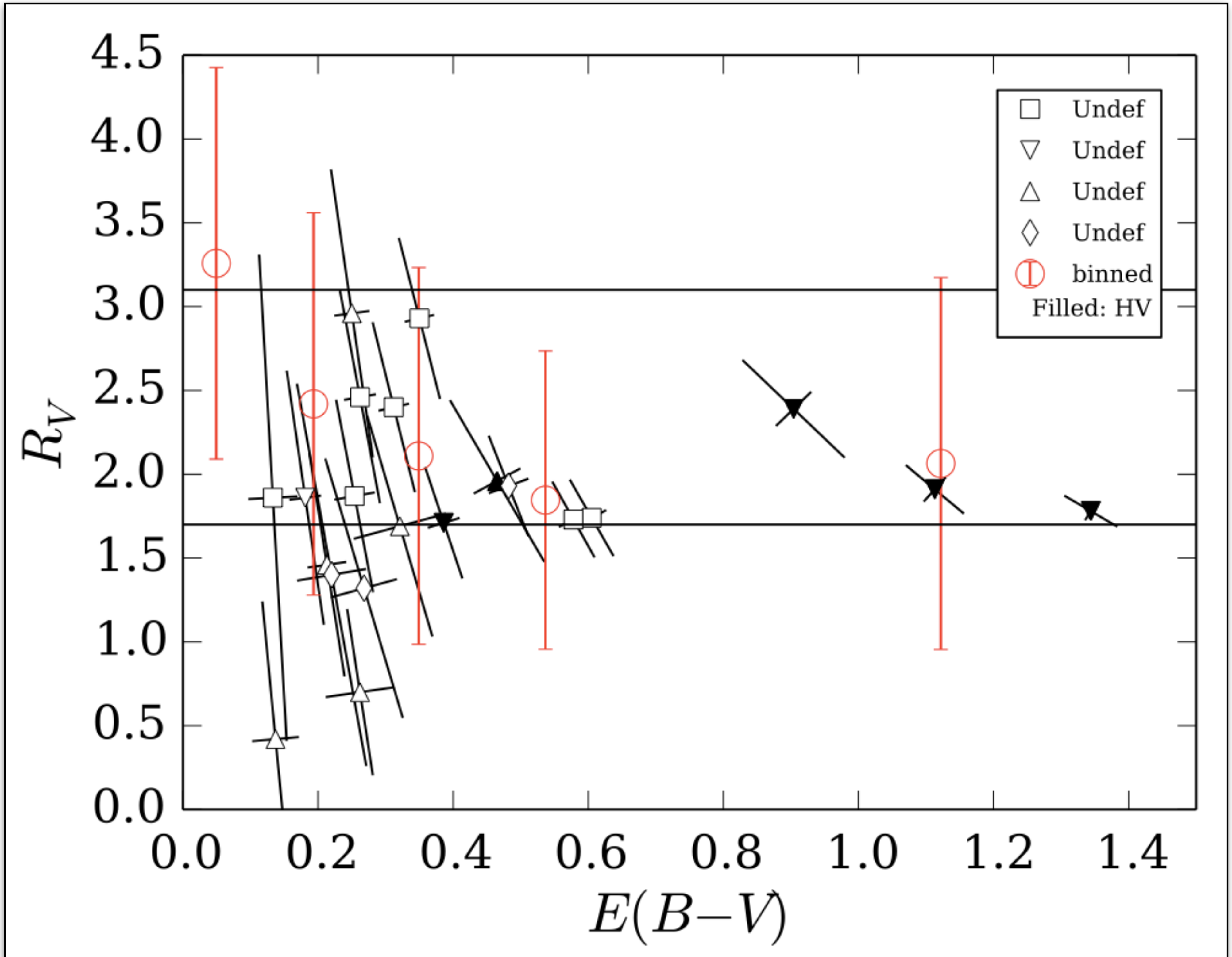
Contreras et al. 2010

The Near-IR Pins Down R_V



Burns et al. 2013

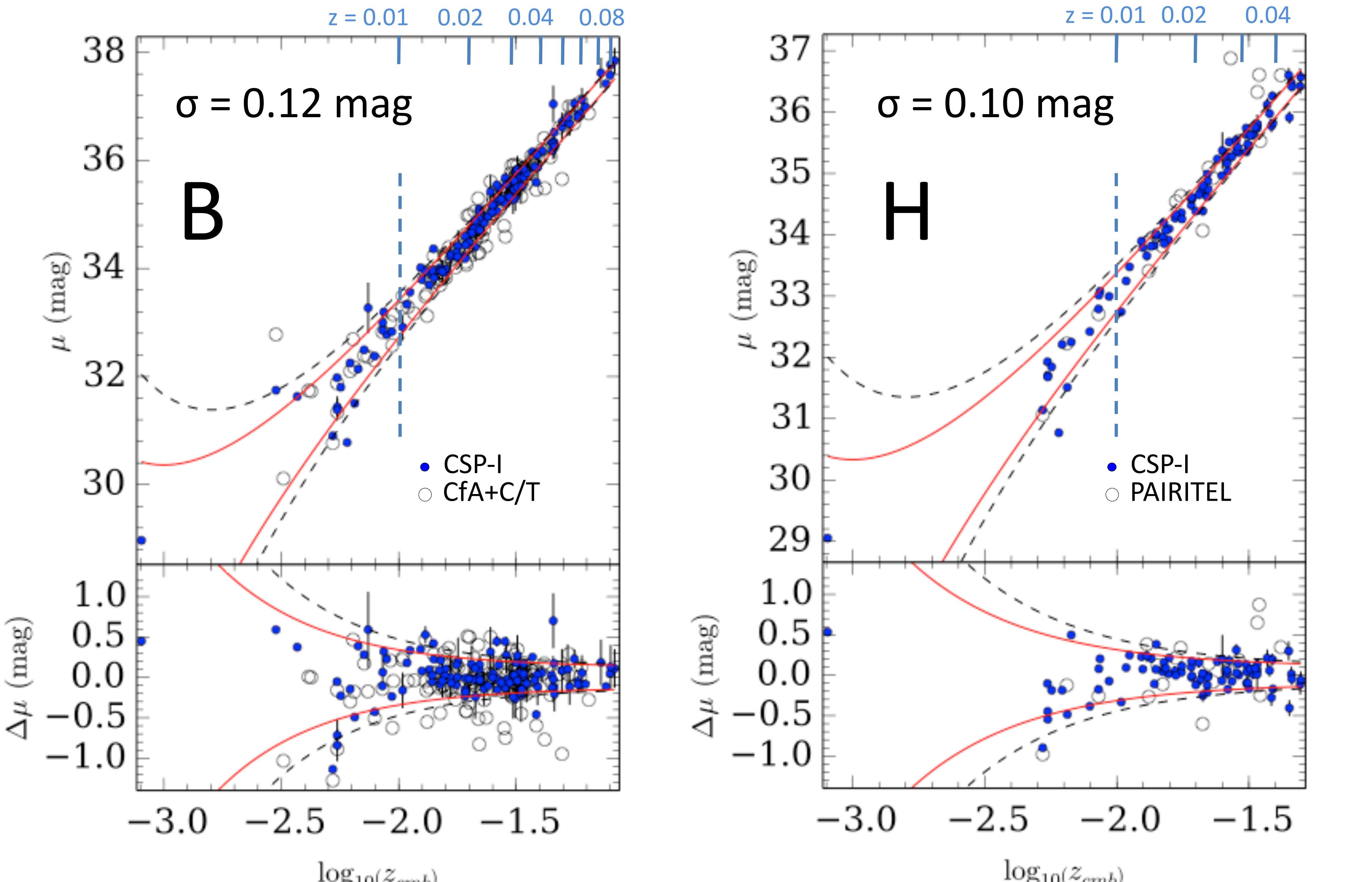
The Value of RV Is Not Constant



Burns et al. 2013

CSP I Hubble Diagrams

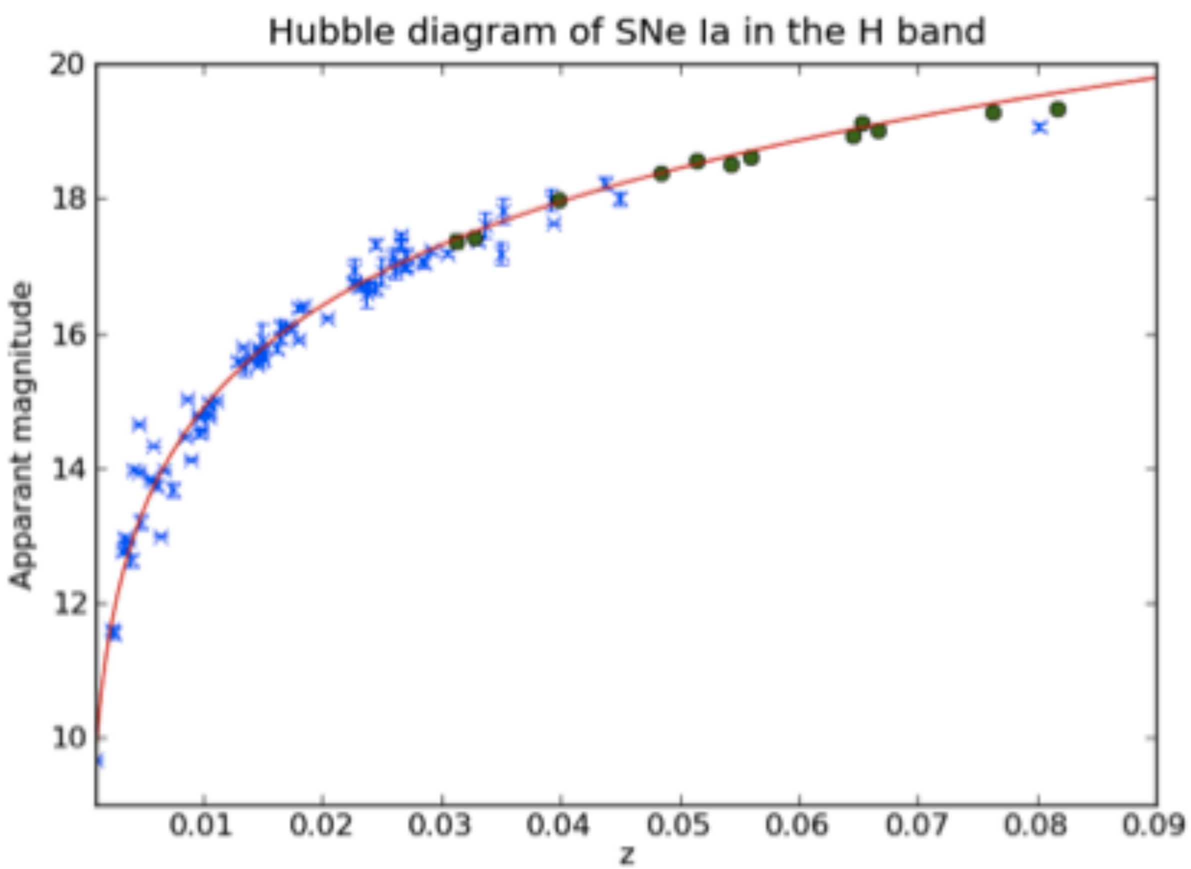
Correcting for decline rate and determining the dust extinction for each SN gives σ = 0.10-0.12 assuming V_{pec} = 300 km s^{-1}



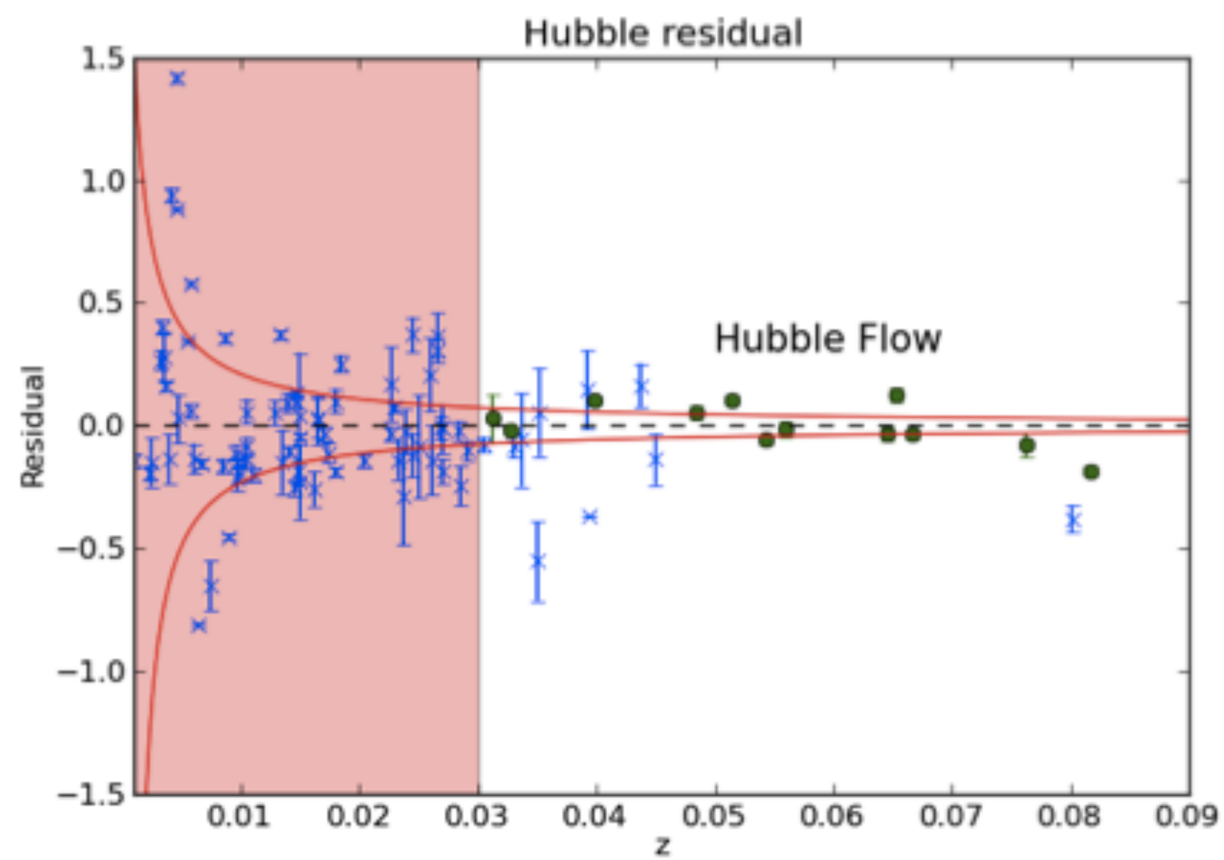
Parent, Burns et al., in preparation

Pushing Further into the Hubble Flow

- Peculiar velocities account for ±0.11 mag of the observed Hubble diagram dispersion at the median redshift (z ~ 0.02) of the CSP-I sample of SNe Ia
- To determine the true precision of Sne Ia in the near-IR, we need to observe further into the Hubble flow (z ~ 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

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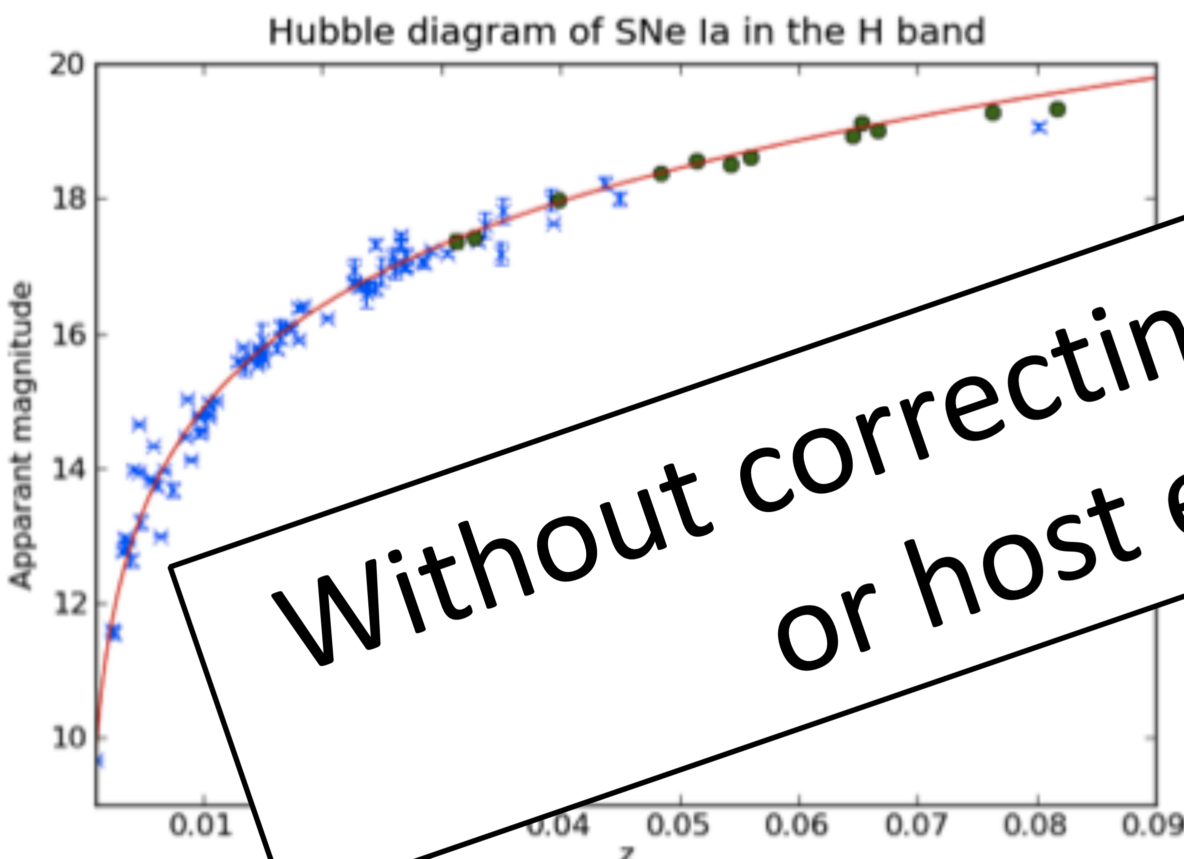

Barone-Nugent et al. (2012)
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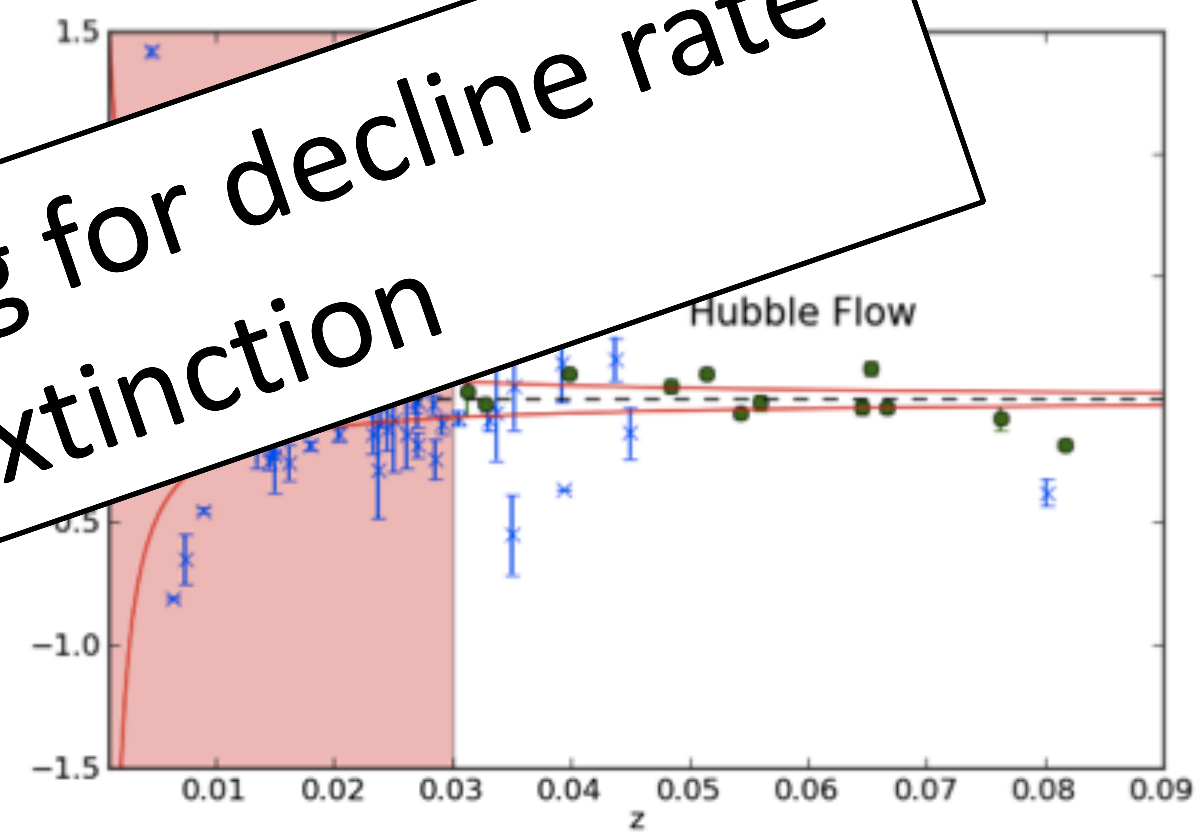


At 0.03 < z < 0.09, σ_J = 0.12 mag and σ_H = 0.09 mag

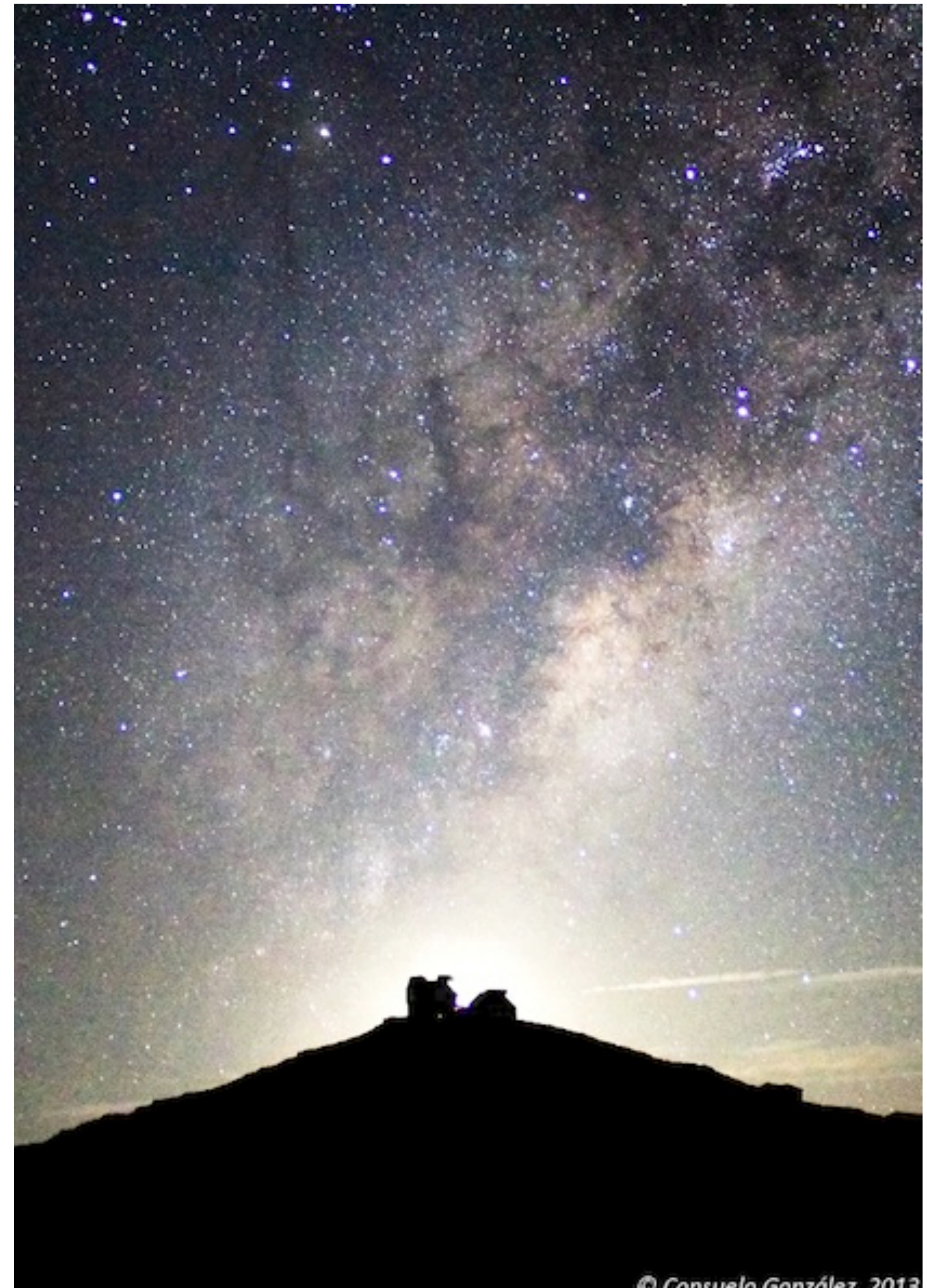
Without correcting for decline rate or host extinction

The Carnegie Supernova Project II (CSP II)

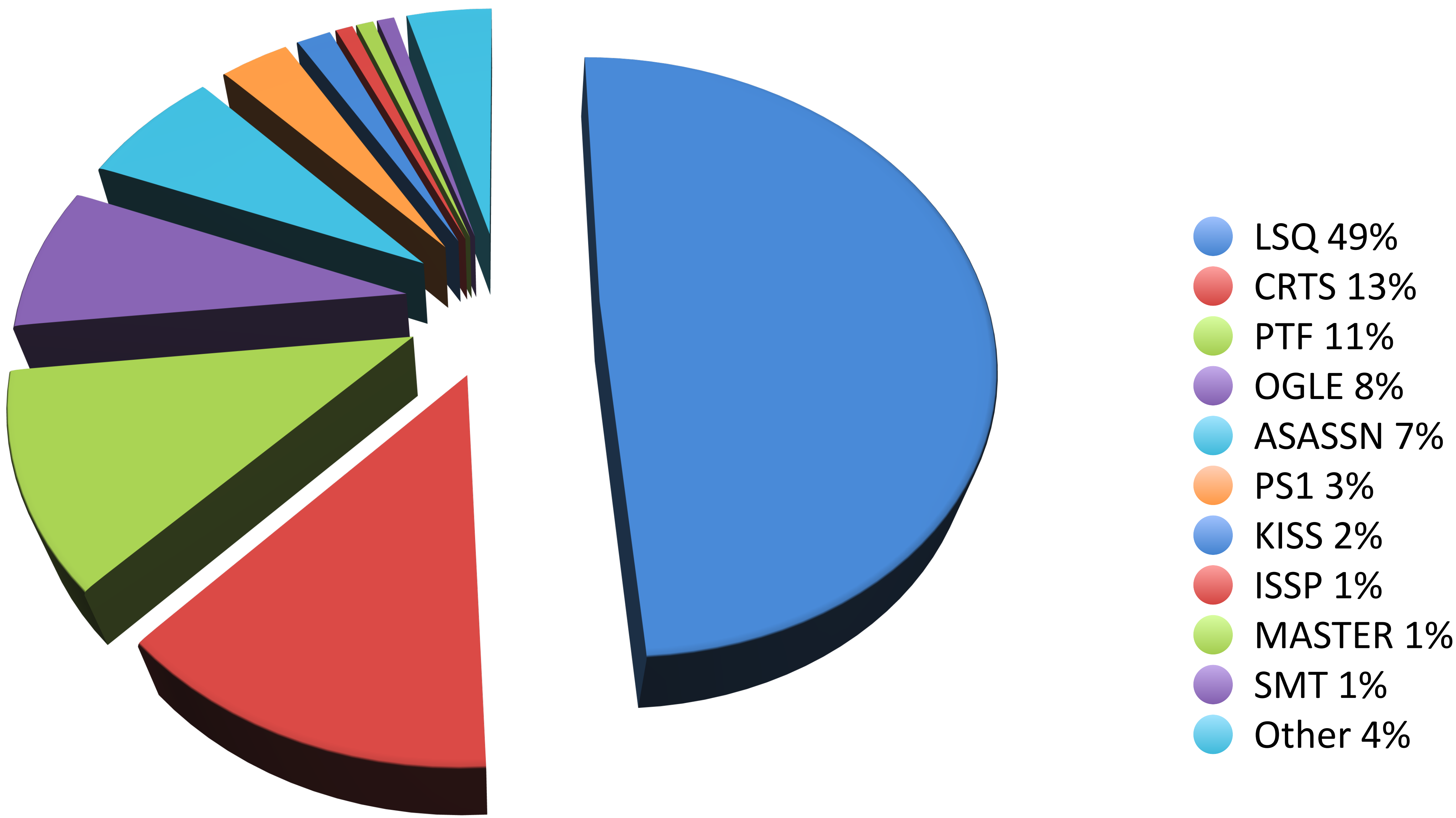
- In Nov 2011, we began a second stage of the CSP to obtain BV*riYJH* light curves of a sample of ~100 SNe Ia at $0.03 < z < 0.10$ using the du Pont 2.5 m and Swope 1.0 m telescopes

- The SNe were drawn from blind searches to minimize bias

- In a parallel effort, we also obtained near-IR 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

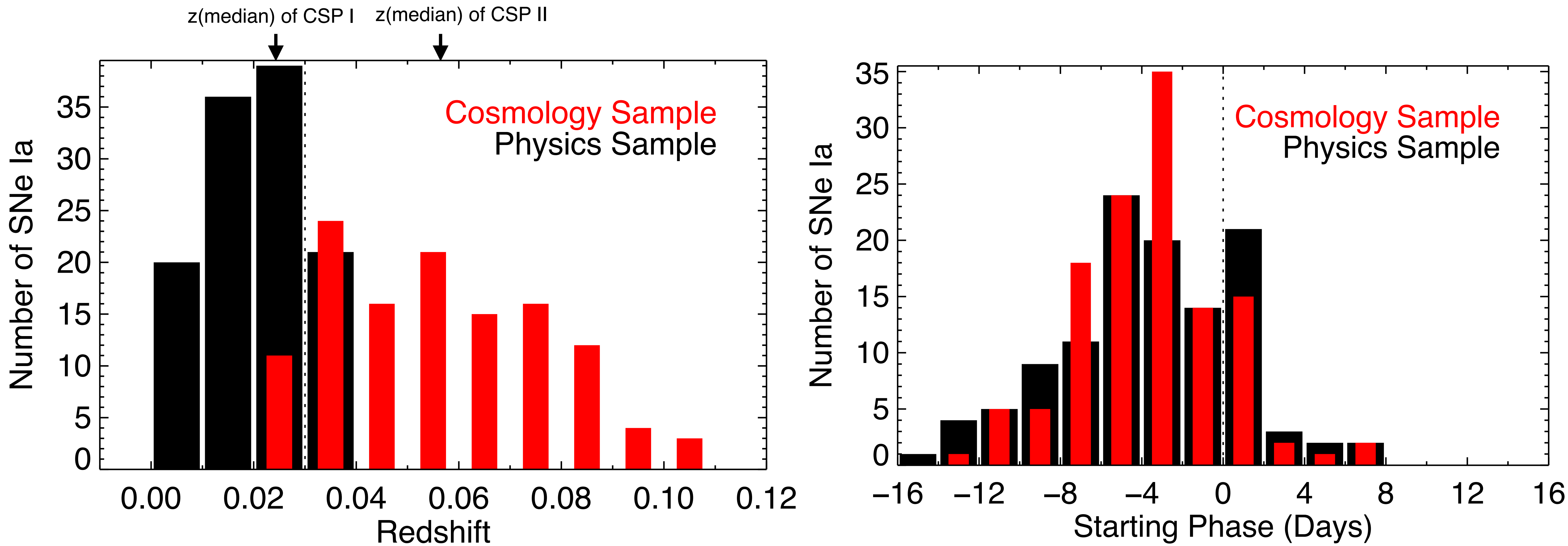


The CSP II: SN Sources



96% from "blind" searches

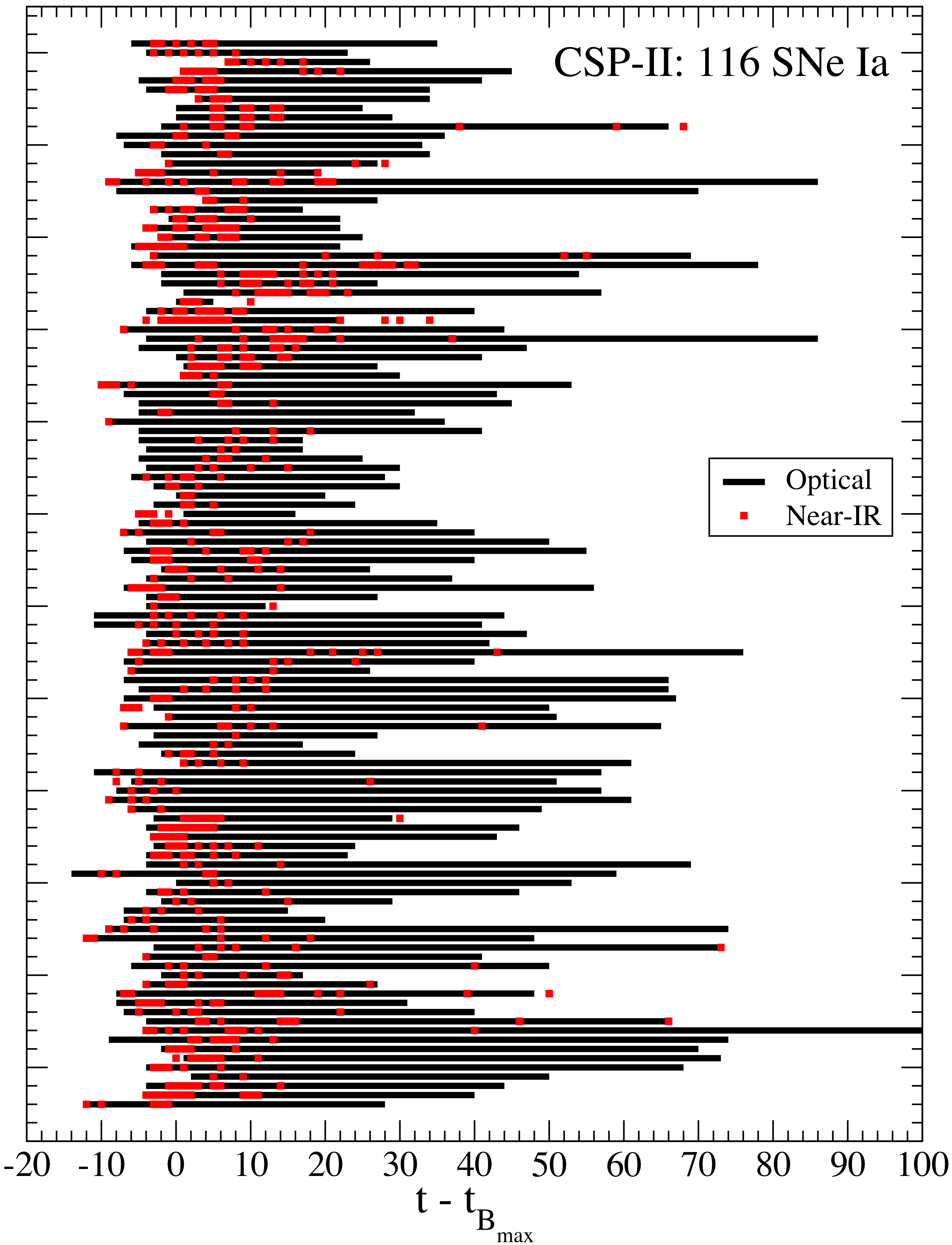
The CSP II: "Cosmology" and "Physics Samples



- "Cosmology" sample consists of 116 young SN Ia in the desired redshift range of $0.03 < z < 0.10$
- z(median) = 0.056 for "Cosmology" sample → Peculiar velocities are 1-2% of recession velocity
- "Physics" sample composed of 111 nearby SNe Ia at $z \leq 0.04$ for detailed NIR spectroscopic time-series observations

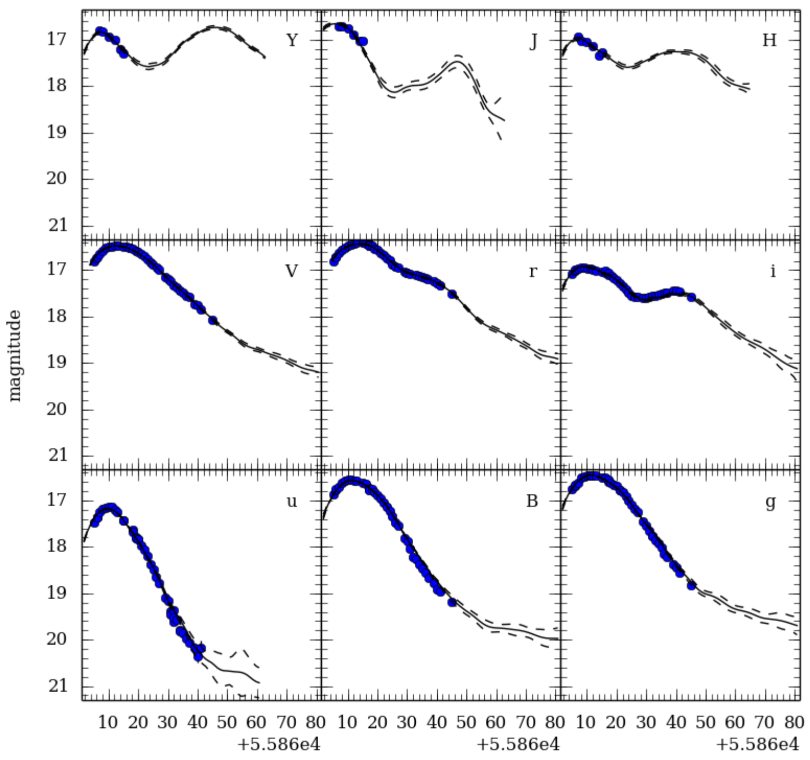
"Cosmology" Sample: Optical and Near-IR Coverage

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

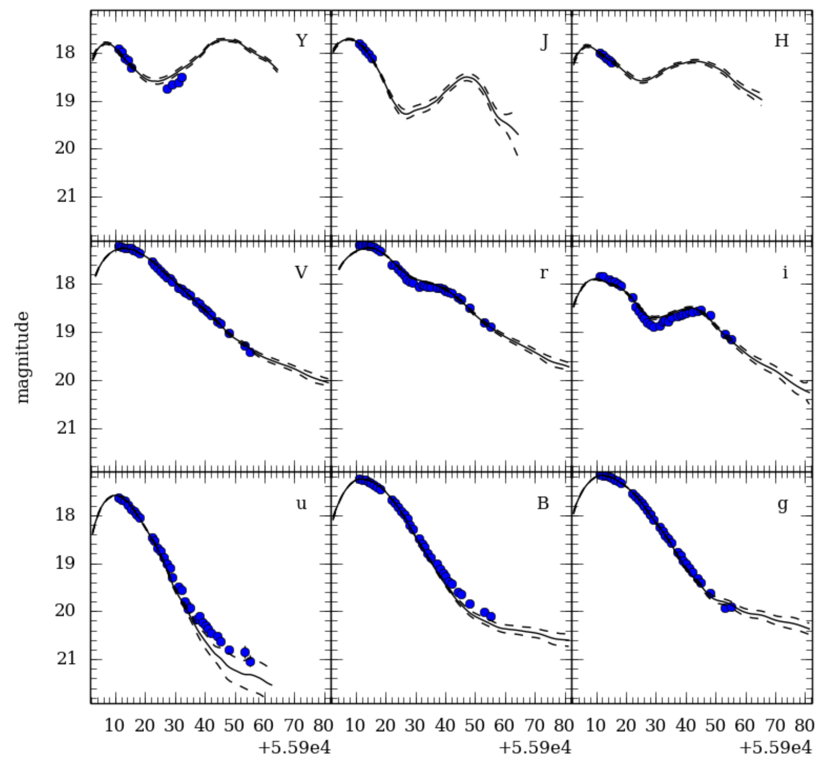


CSP II: Sample Light Curves

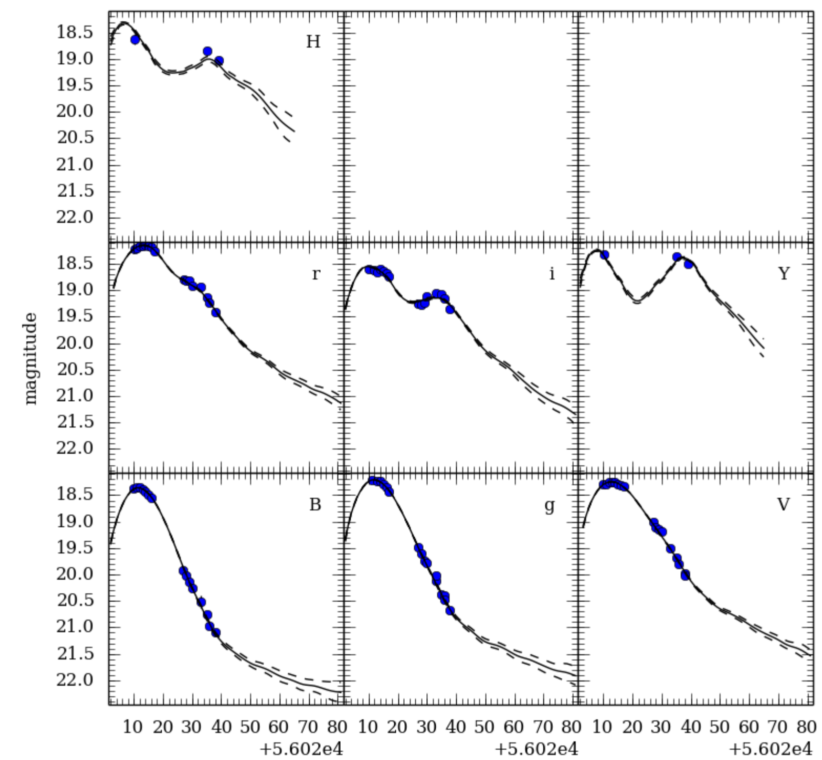
PTF11pbp (z = 0.028)



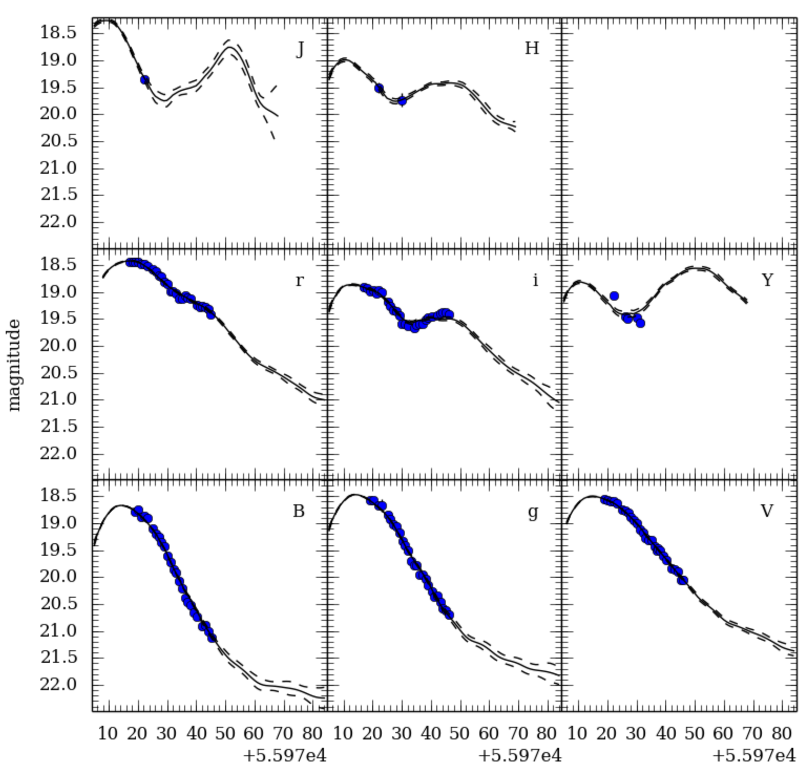
LSQ11bk (z = 0.040)



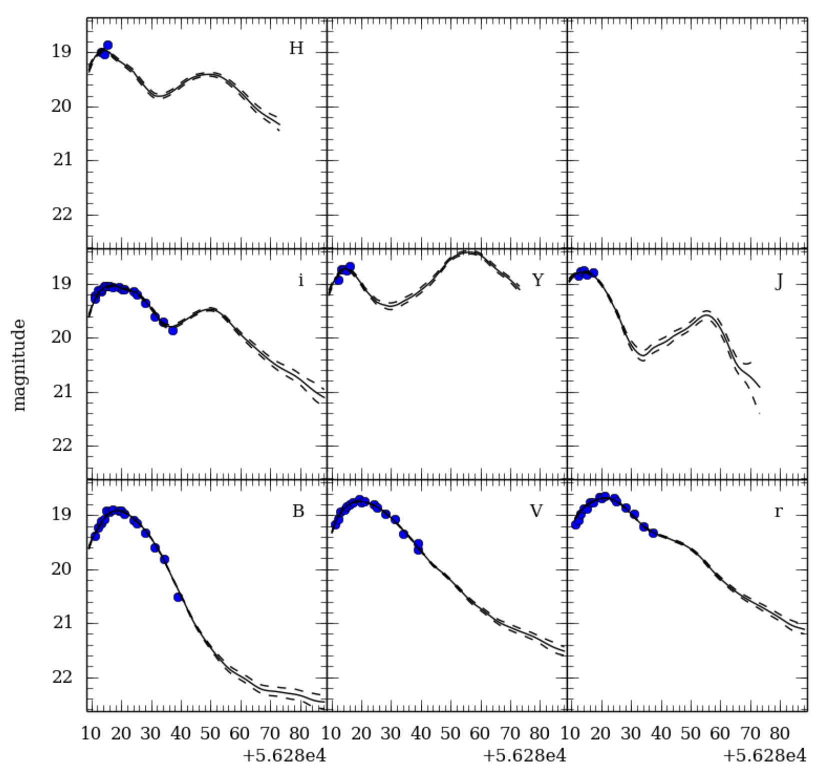
LSQ12btn (z = 0.055)



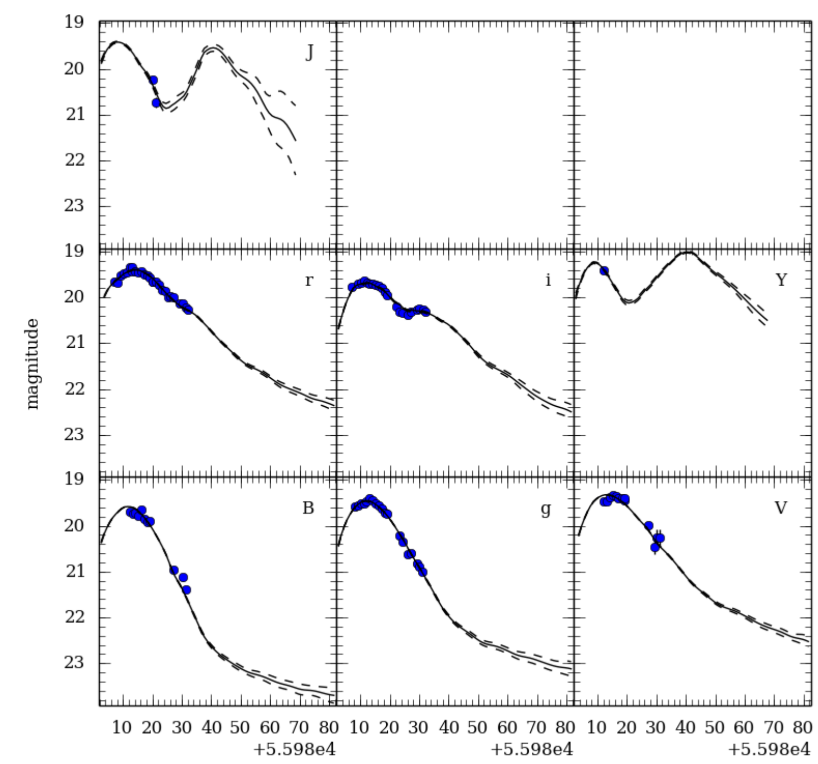
LSQ12agq (z = 0.065)



LSQ12hzs (z = 0.072)

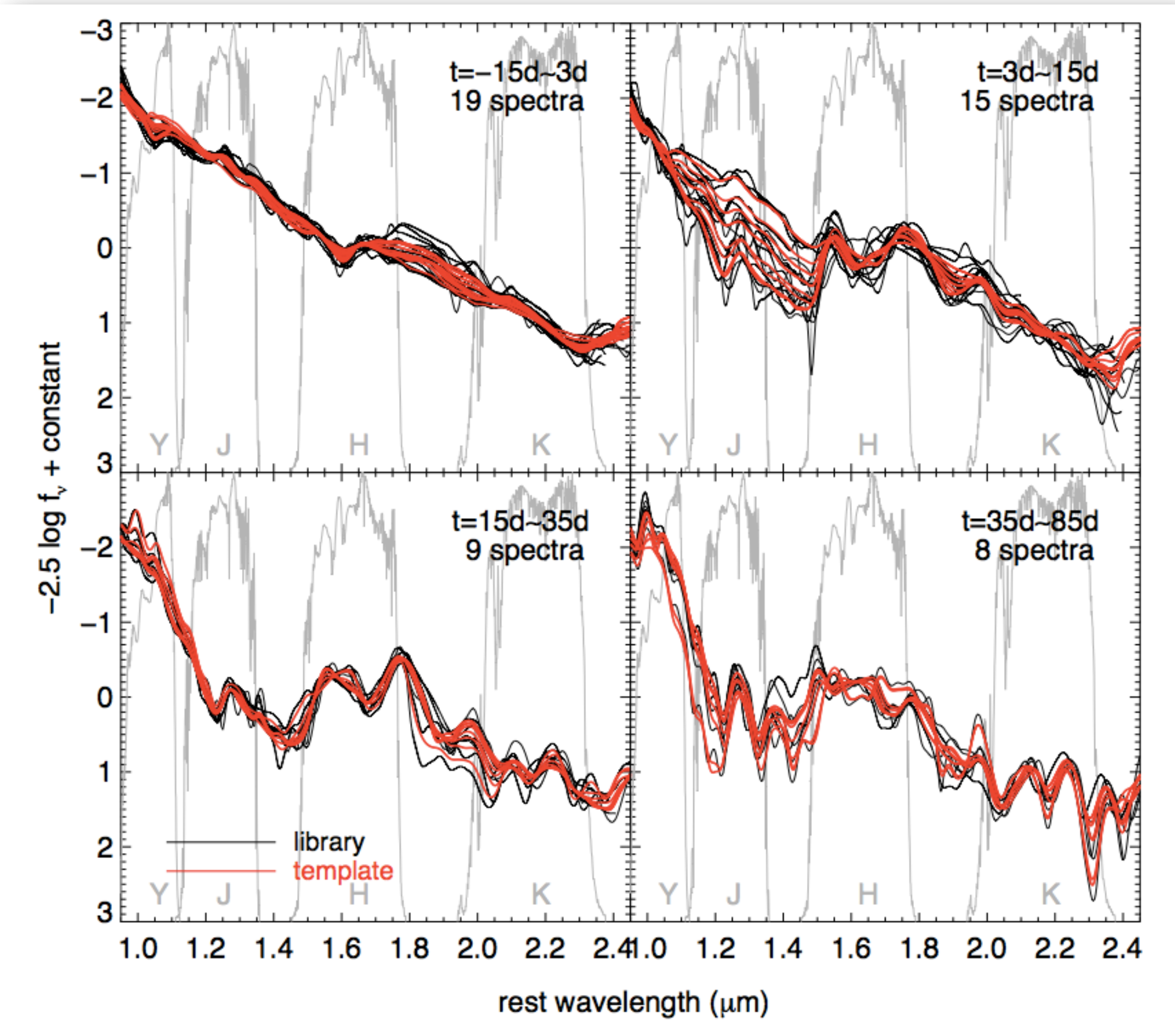


LSQ12aor (z = 0.095)

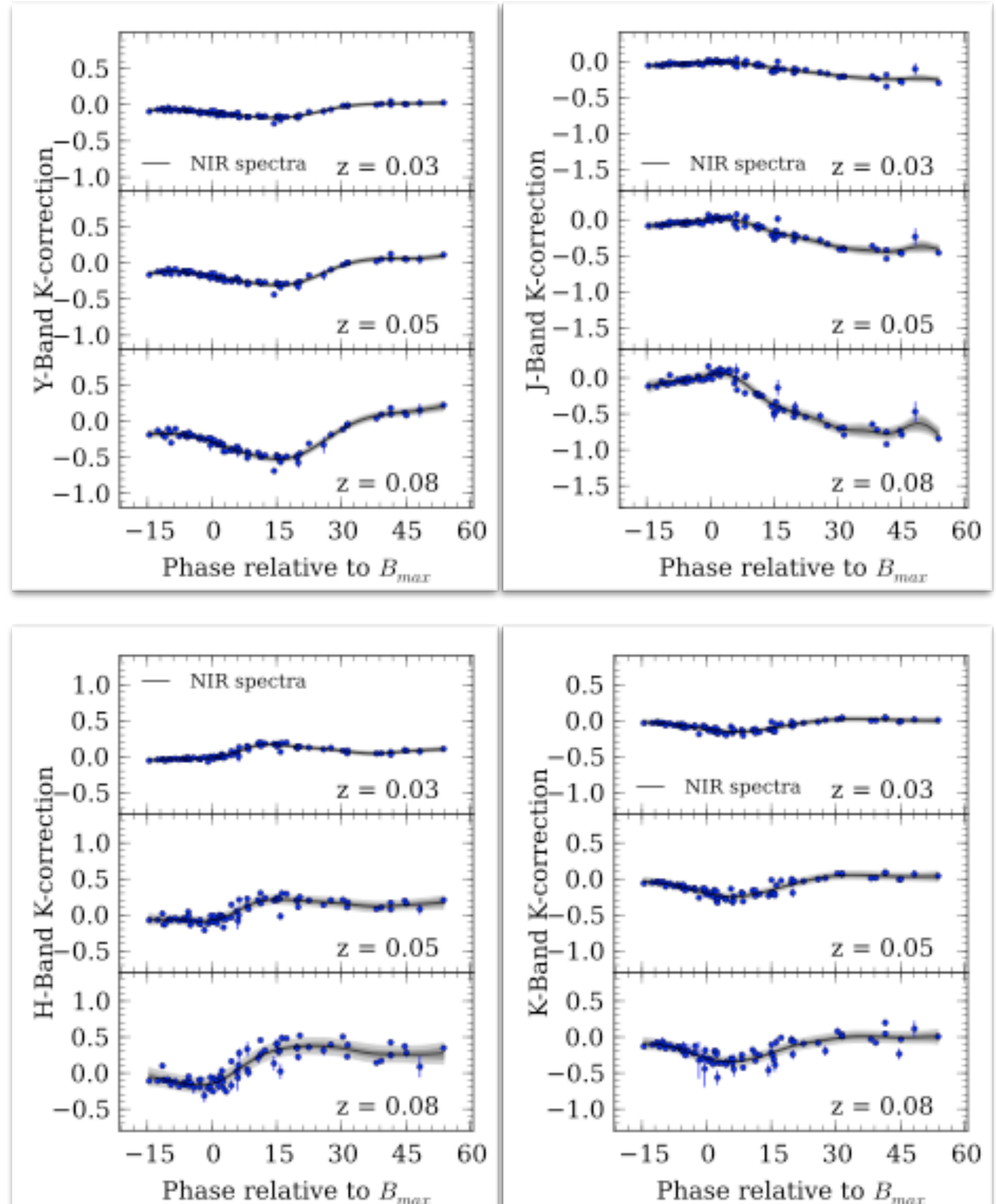


Near-IR Spectroscopy: K Corrections

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

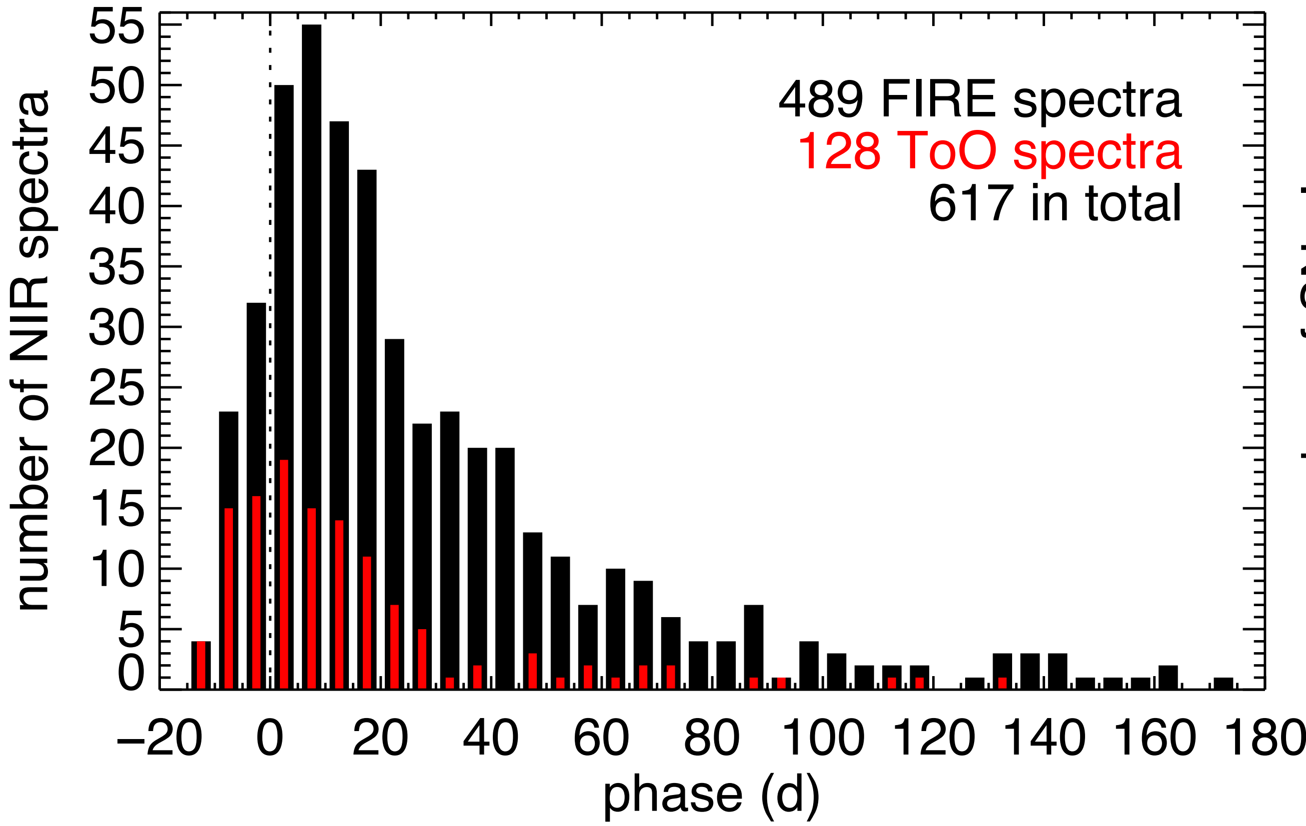


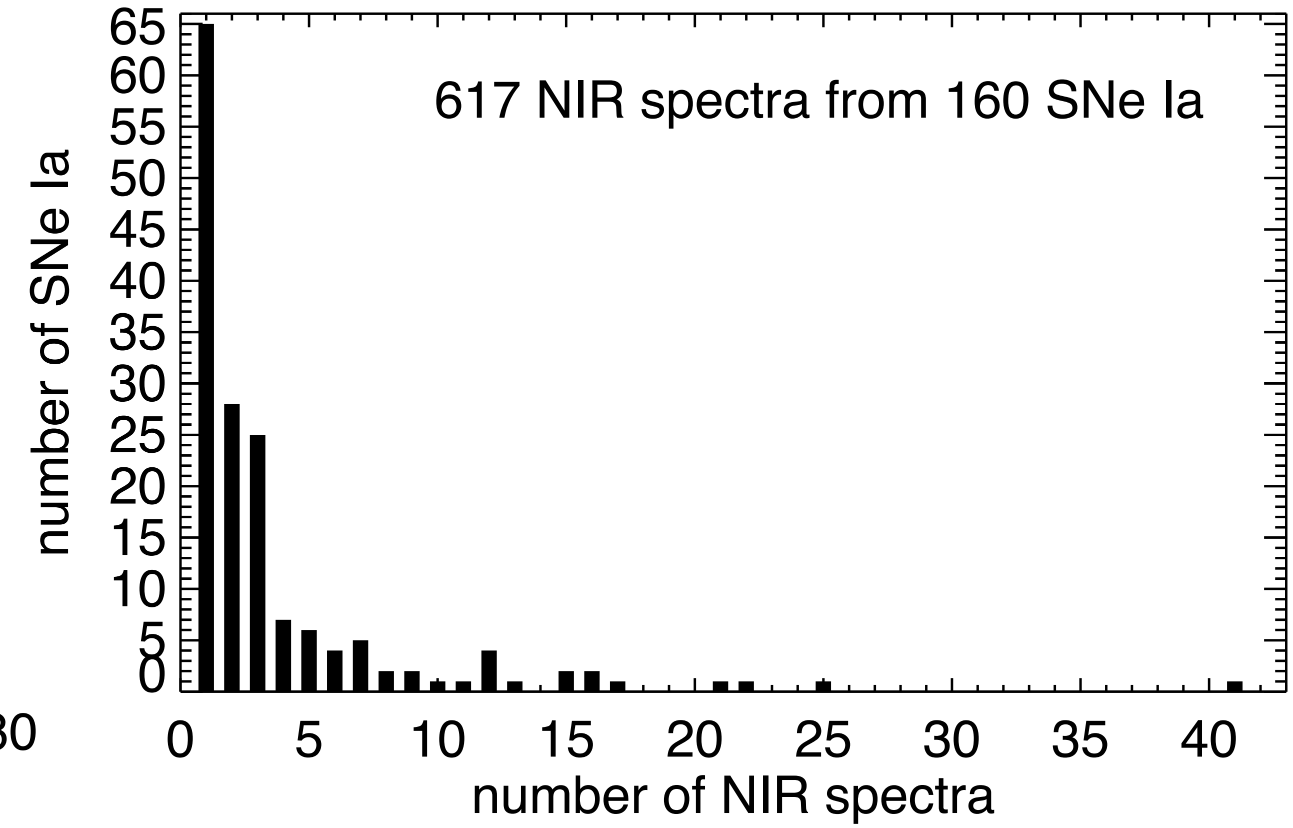
Hsiao (thesis)



Boldt et al. (2014)

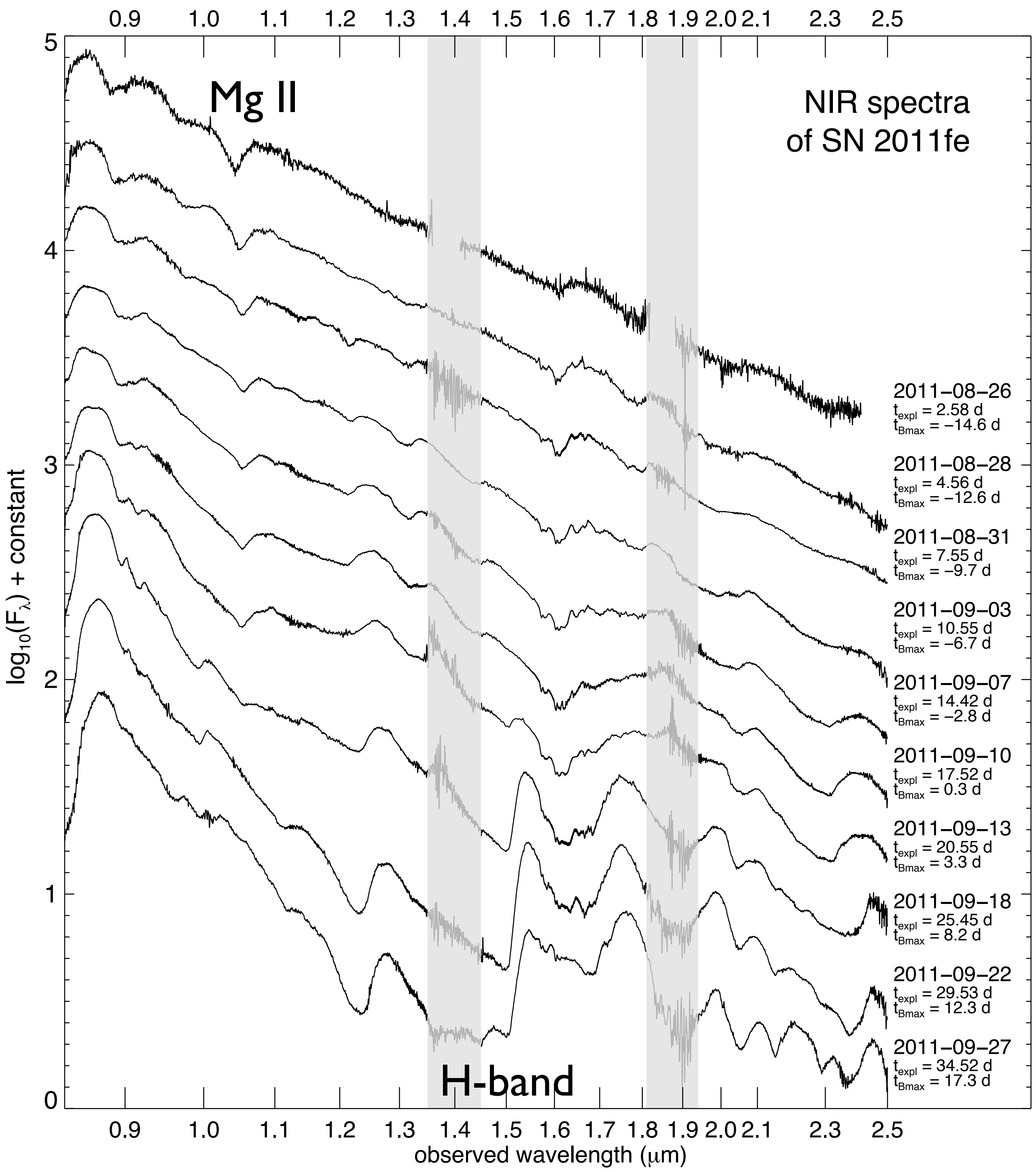
Near-IR Spectroscopy

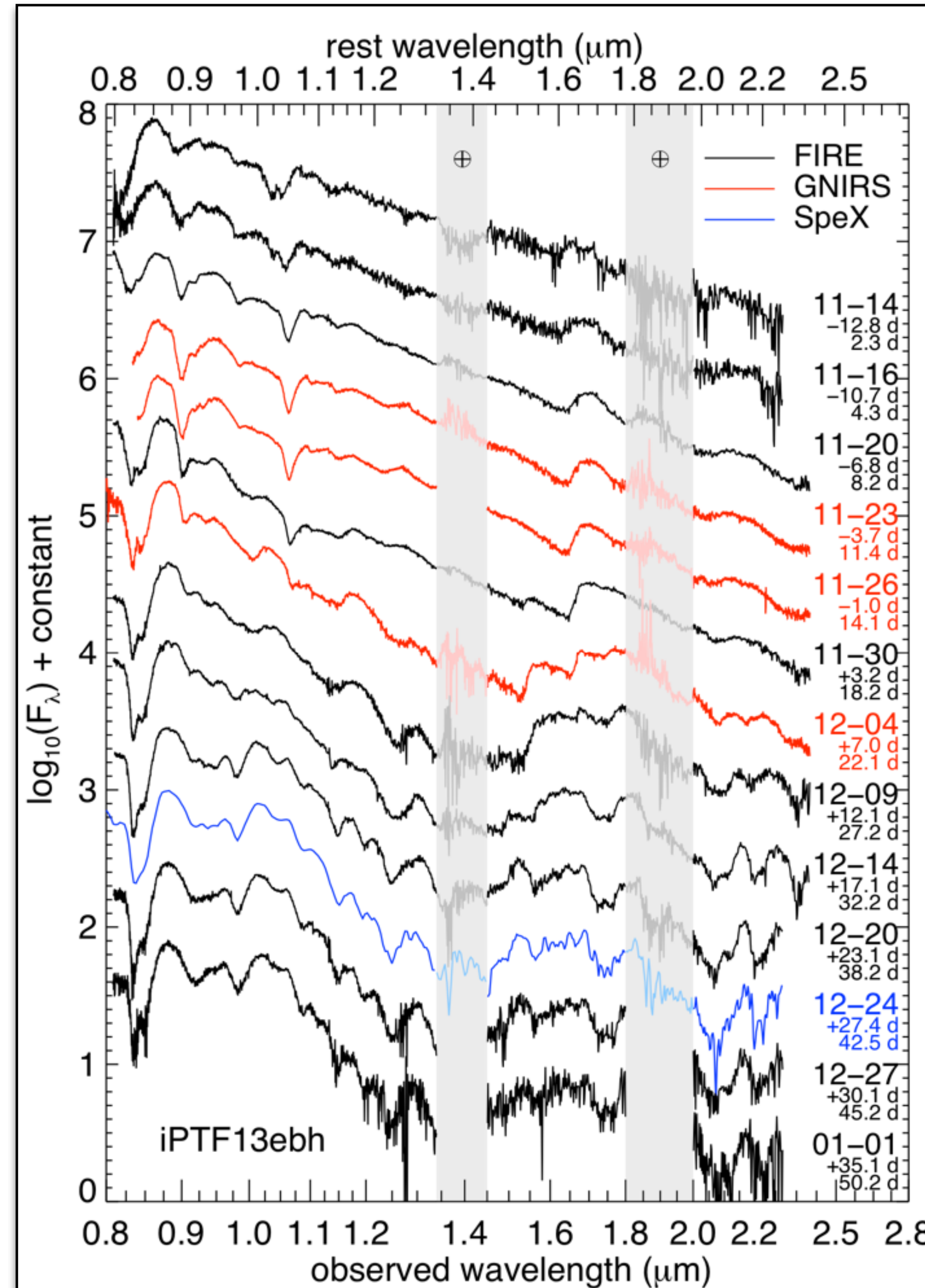




- In collaboration with CfA group (Marion, Kirshner) and Dave Sand
- FIRE is the workhorse instrument, but ToO spectra obtained with IRTF and Gemini-N have helped to improve the statistics at maximum and pre-maximum
- Sample is 15 times larger than the previous largest sample from Marion et al. (2009)

Near-IR Spectroscopy: Studying the Physics of SNe Ia





Hsiao et al. 2013

Hsiao et al. 2015

Questions

- The CSP II has concluded. We are 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