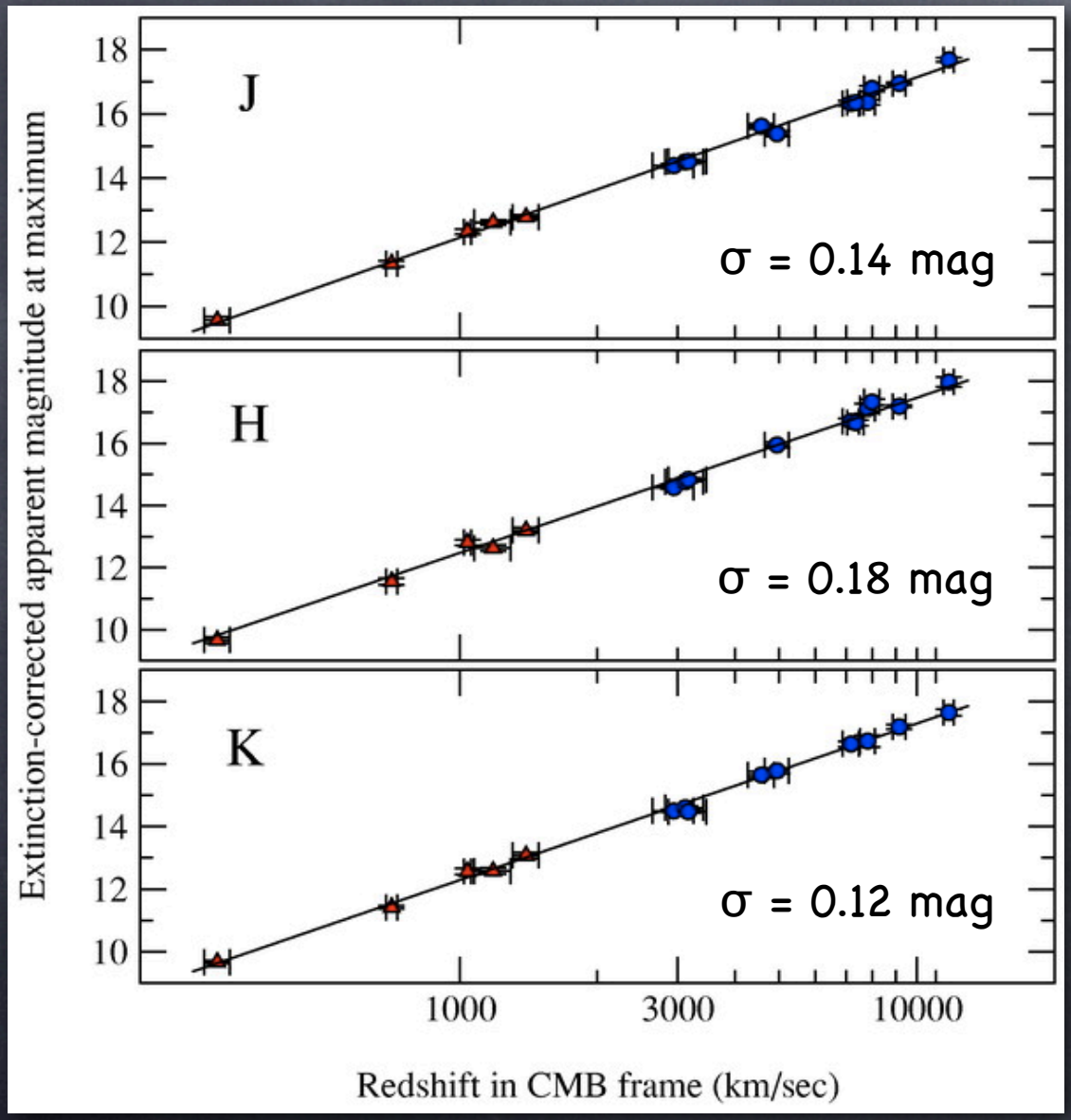
The Carnegie Supernova Project II (CSP II)

M. M. Phillips
Carnegie Observatories

SNe Ia are Excellent Standard Candles in the Near-IR

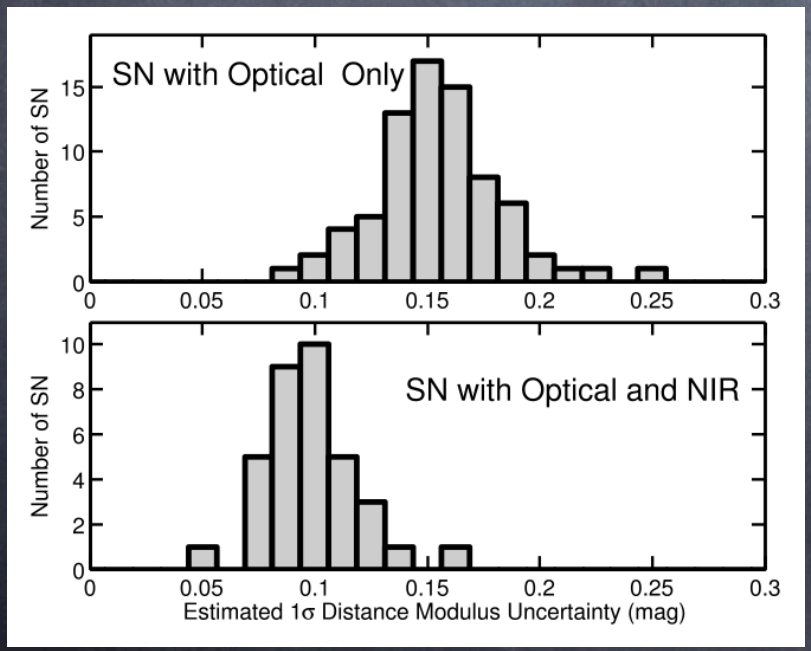


Krisciunas, Phillips, & Suntzeff 2004

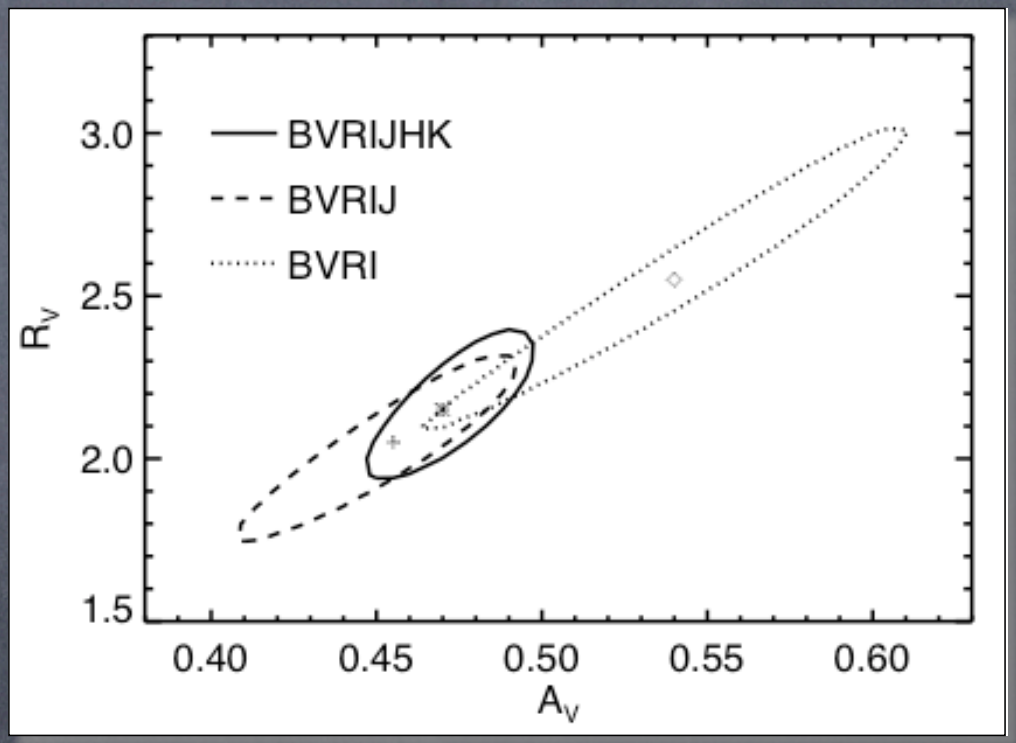
- Extinction from dust is much less in the near-IR
- SNe Ia are intrinsically much better standard candles in the near-IR
- Systematic errors due to a color offset are a factor of ~4 lower in the near-IR

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



Mandel 2013



Krisciunas et al. 2007

The Carnegie Supernova Project I (CSP I)

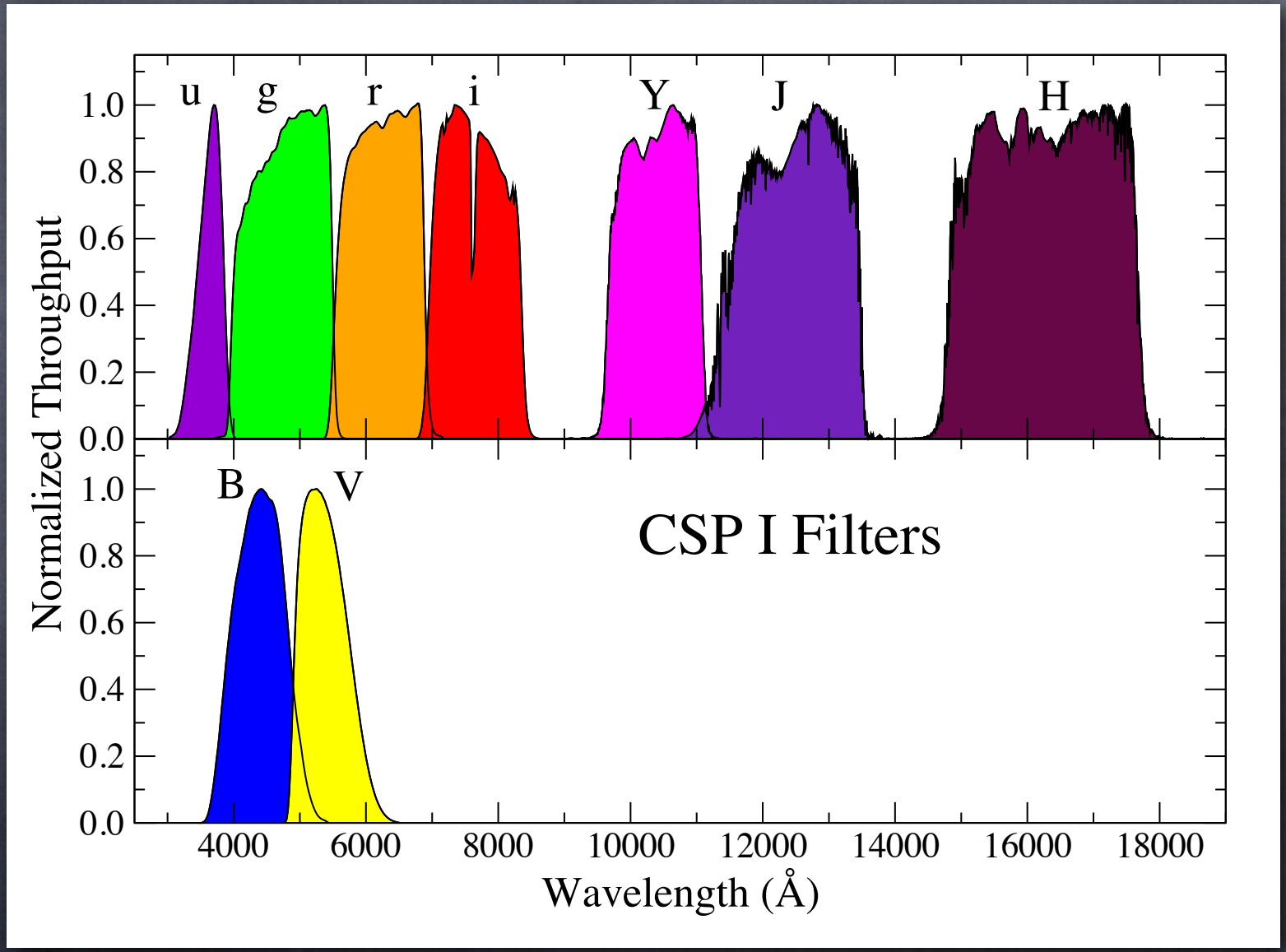
- Five 9-month campaigns between 2004-2009
- Follow-up optical (ugriBV) light curves obtained of 130 SNe Ia
- Near-IR (YJH) photometry obtained of 113 (87%) of these
- Light curves of 85 SNe Ia published to date (remaining 45 will be published later this year)

Swope 1-m

Du Pont 2.5-m

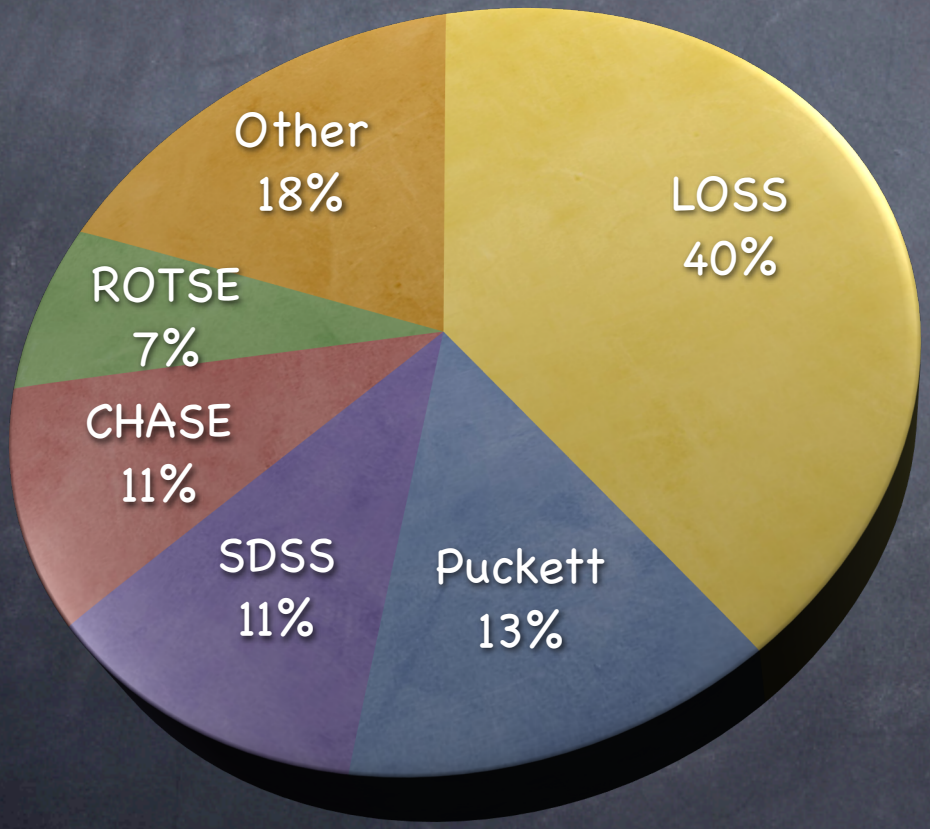
Magellan 6.5-m

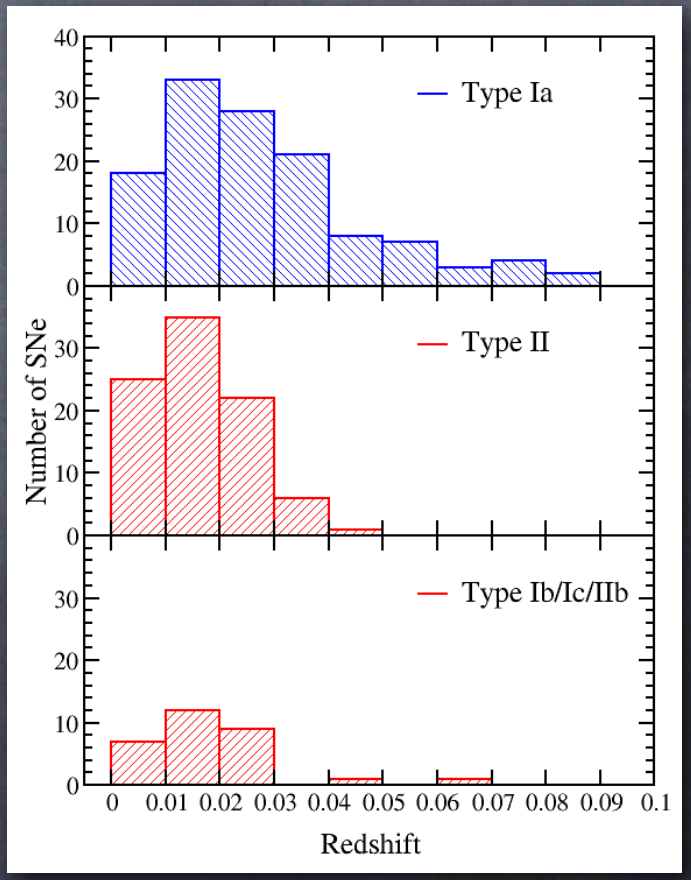
CSP I: ugriBVYJH Filters



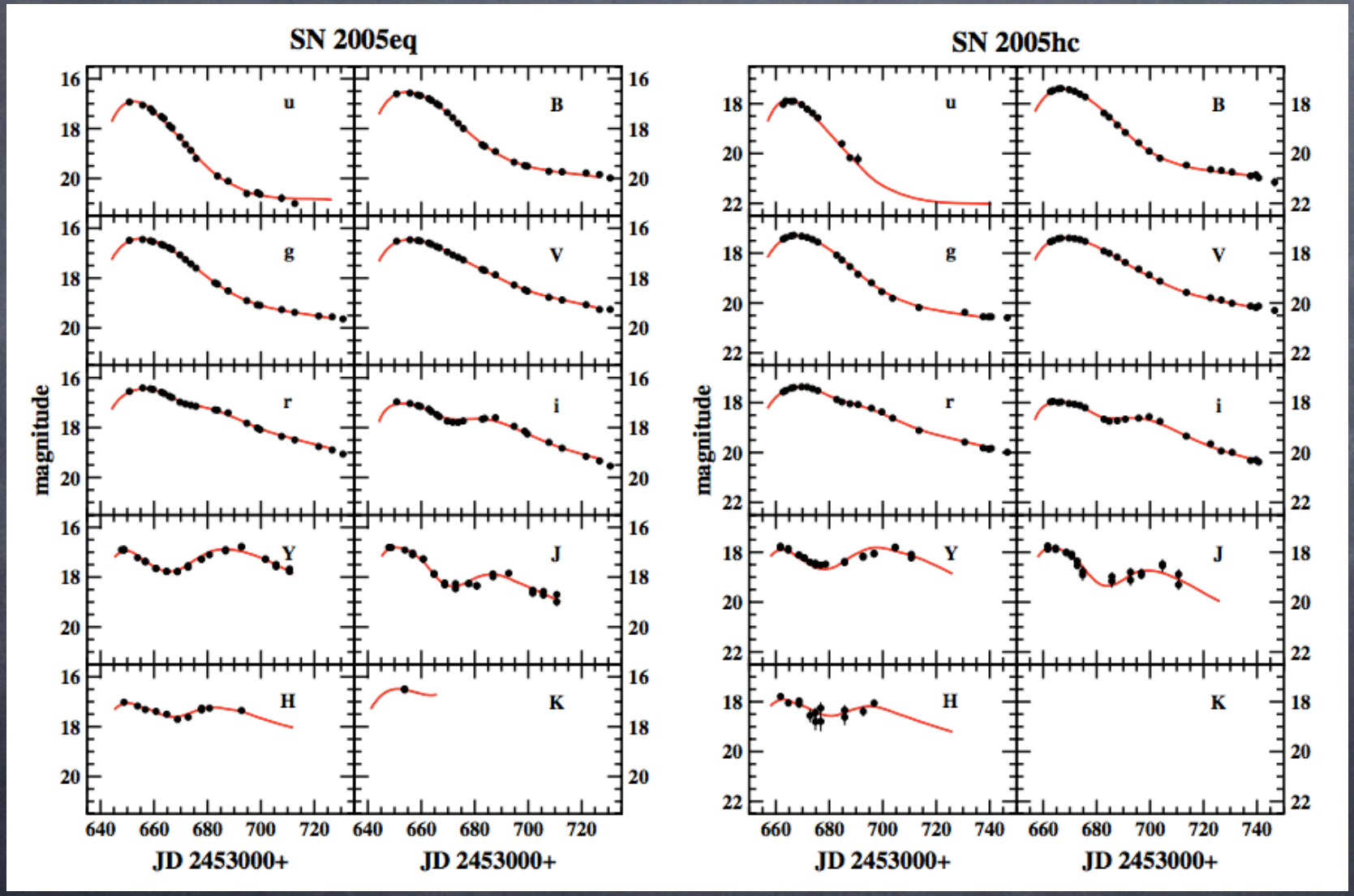
CSP I: Summary

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





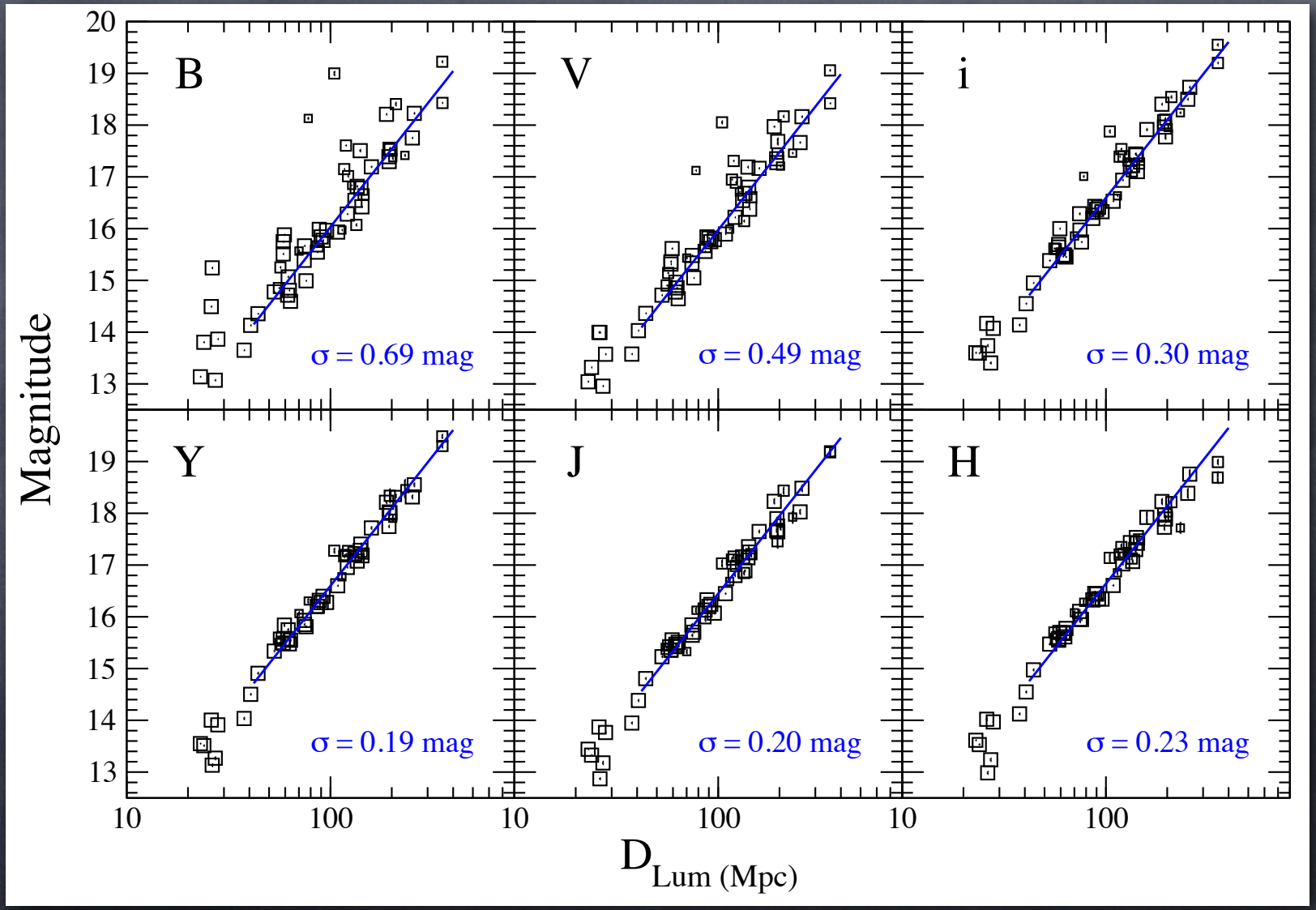
Optical and Near-IR Light Curves of SNe Ia from the CSP I



Contreras et al. 2010

CSP I Hubble Diagrams

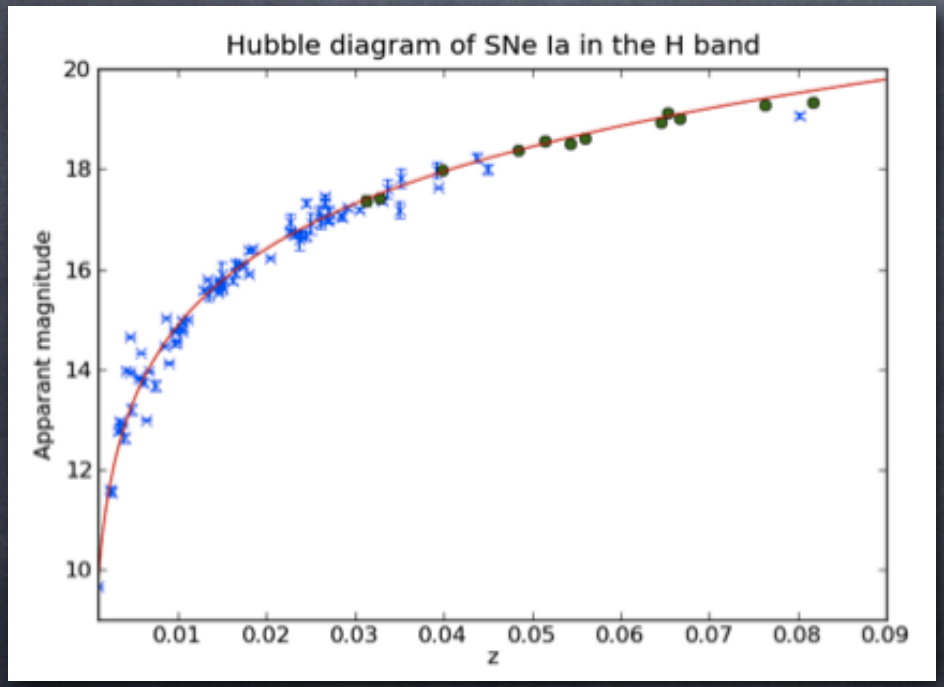
No corrections for either decline rate or host extinction!



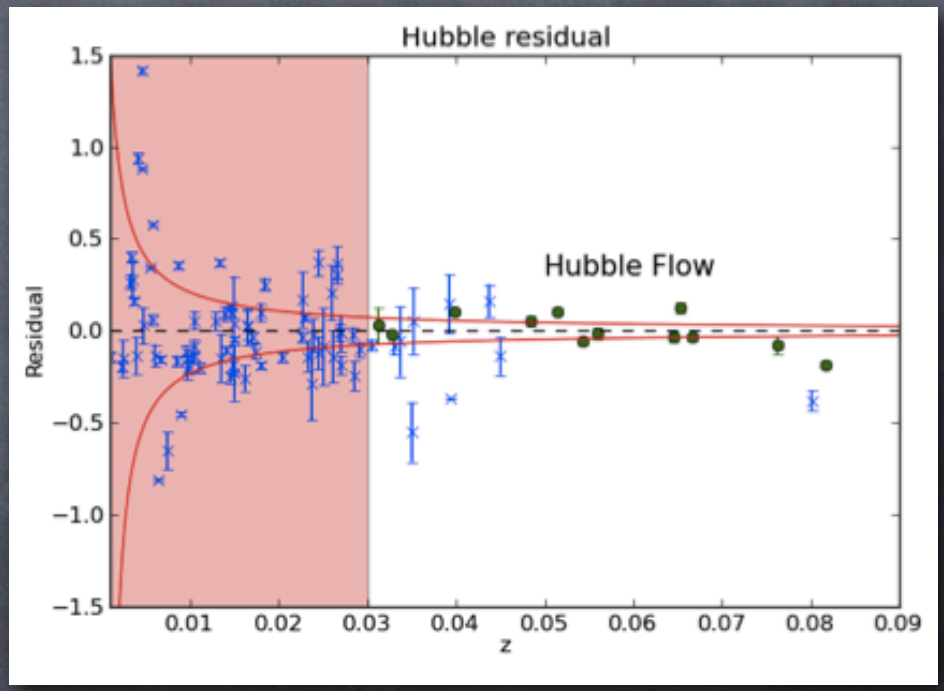
Phillips 2012

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 = 0.03-0.08)**



Barone-Nugent et al. 2012



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

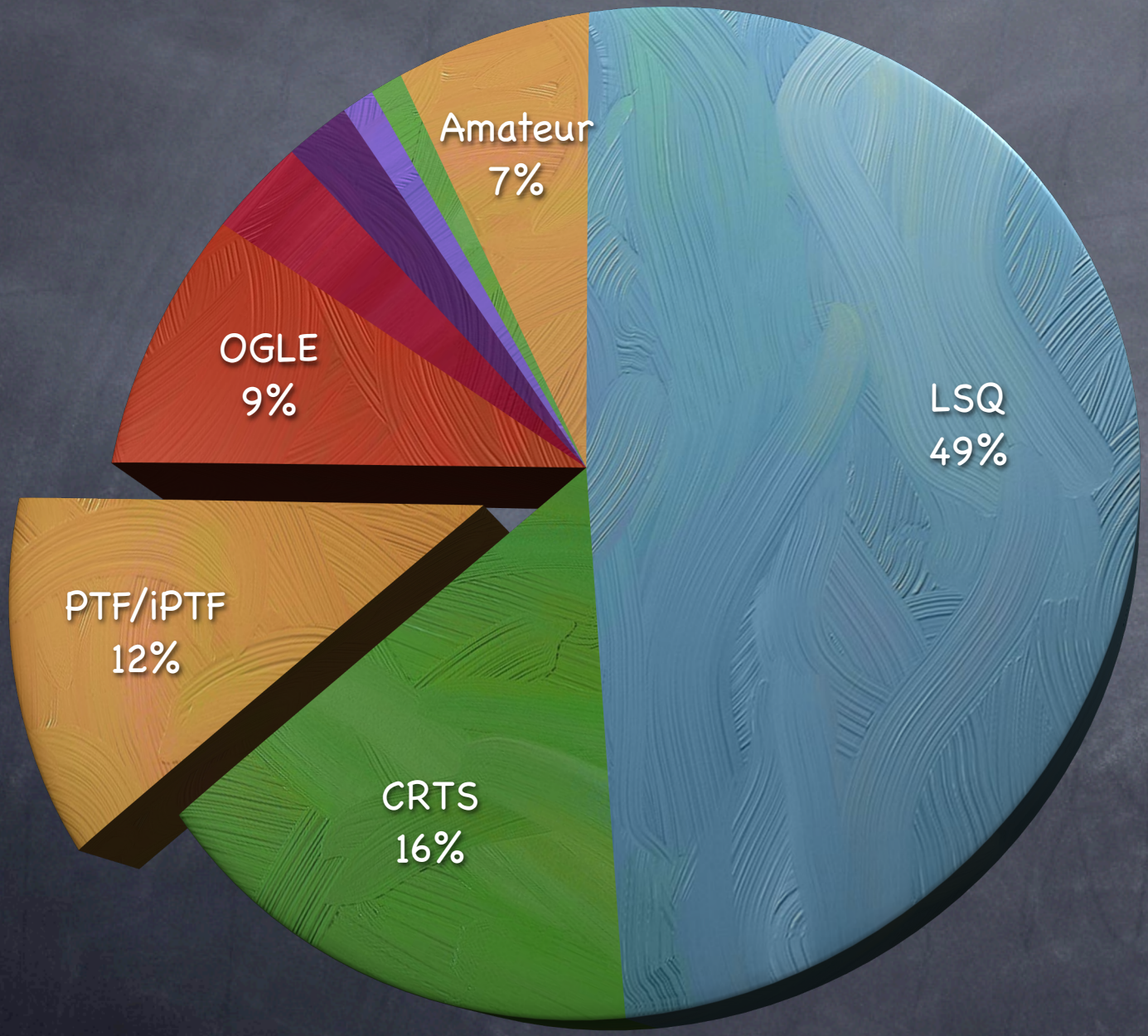
Carnegie Supernova Project II

- In Nov 2011, we began a second stage of the CSP to obtain optical & NIR light curves of a sample of 100-150 SNe Ia at $0.03 < z < 0.08$ using the du Pont 2.5 m and Swope 1.0 m telescopes

- The SNe are being drawn from blind searches to minimize bias

- In a parallel effort, we are also obtaining 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

CSP II: Sources of Supernovae



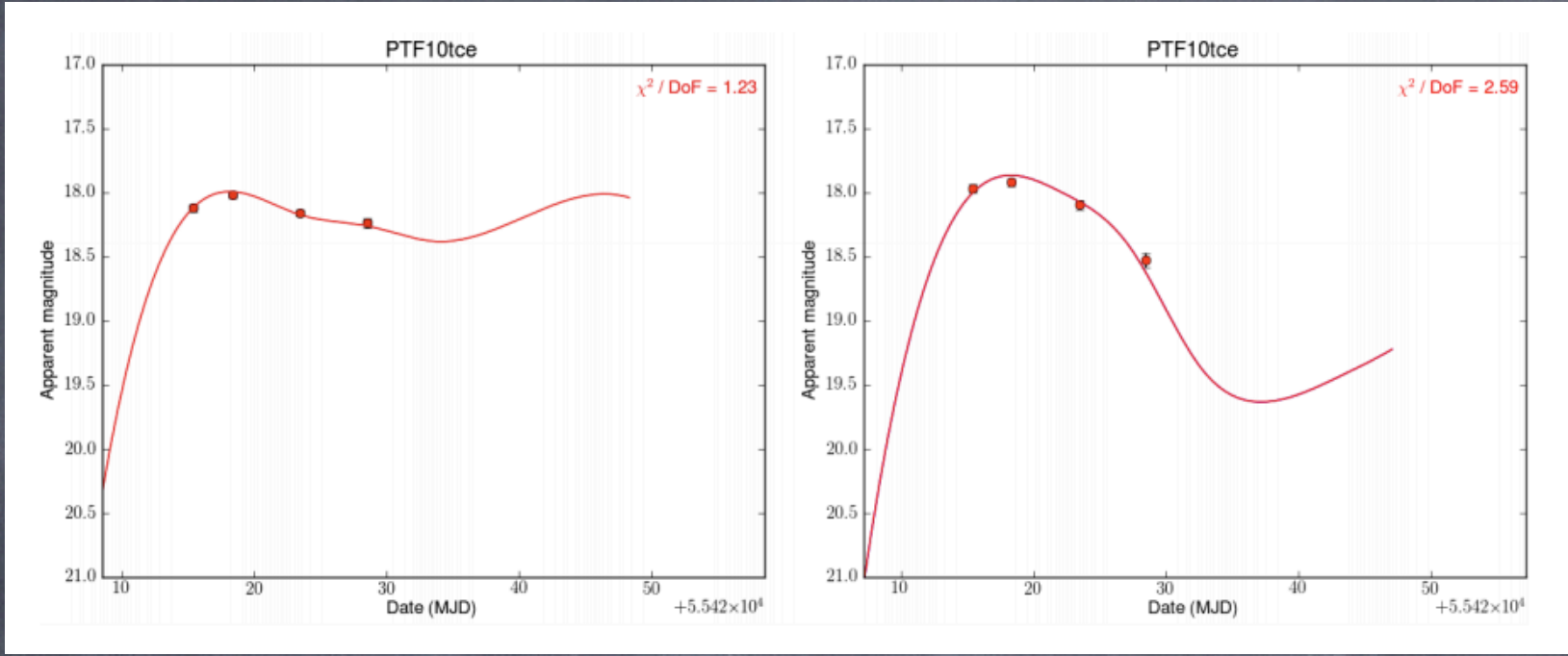
- LSQ
- CRTS
- PTF/iPTF
- OGLE
- Pan-STARRS
- KISS
- MASTER
- SkyMapper
- Amateur

93% from "blind" searches

Observing Strategy

- SN candidates are screened via optical spectroscopy to determine the type, phase, and redshift (NOT, LCO, PESSTO, etc.)
- BVgri photometry is started using the LCO 1 m Swope telescope (often before spectroscopic screening)
- YJH imaging covering ~3-5 epochs as close as possible to NIR maximum is obtained of each confirmed SN Ia with the 2.5 m du Pont telescope

Observing Strategy



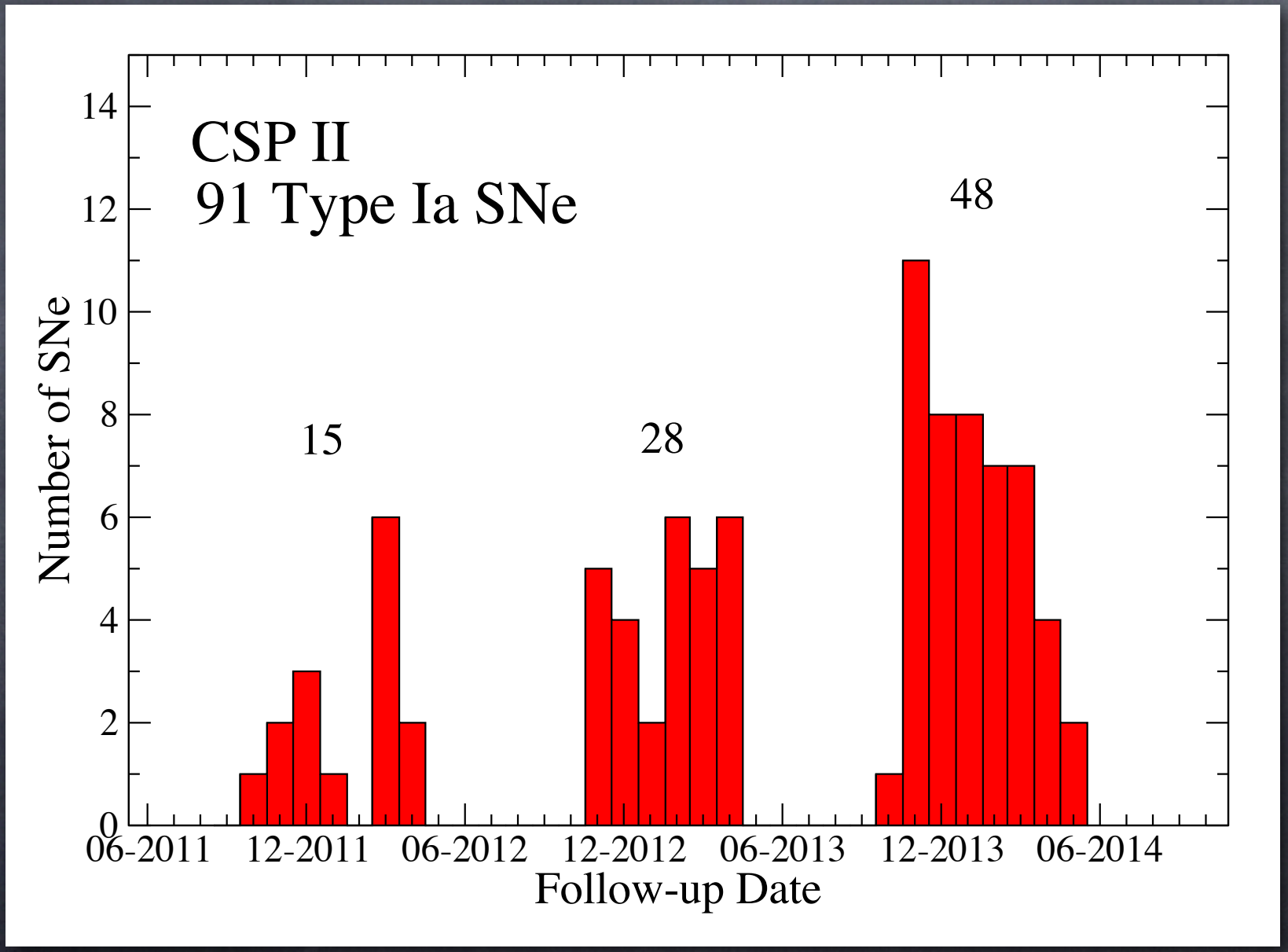
Sample	σ_J	SEM_J	σ_H	SEM_H
12 SNe x 1 obs	0.15 mag	0.04 mag	0.12 mag	0.03 mag
6 SNe x 2 obs	0.13 mag	0.05 mag	0.10 mag	0.04 mag
4 SNe x 3 obs	0.12 mag	0.06 mag	0.09 mag	0.05 mag
3 SNe x 4 obs	0.12 mag	0.07 mag	0.09 mag	0.05 mag

Monte Carlo Simulations
NIR obtained at -10 days
to +15 days

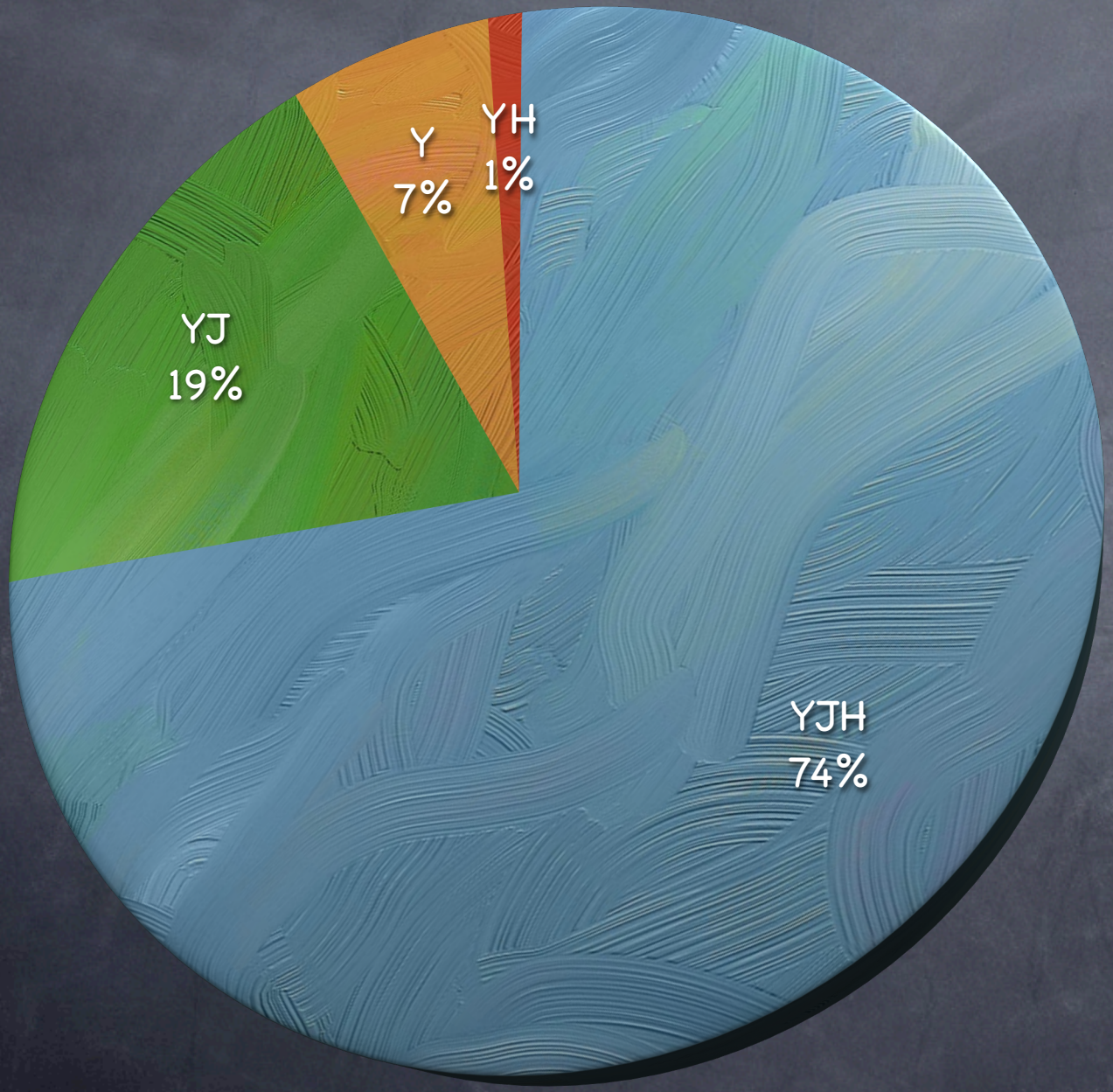
$SEM = \sigma / \sqrt{n}$

Barone-Nugent et al. (2012)

Progress Through 3 Campaigns

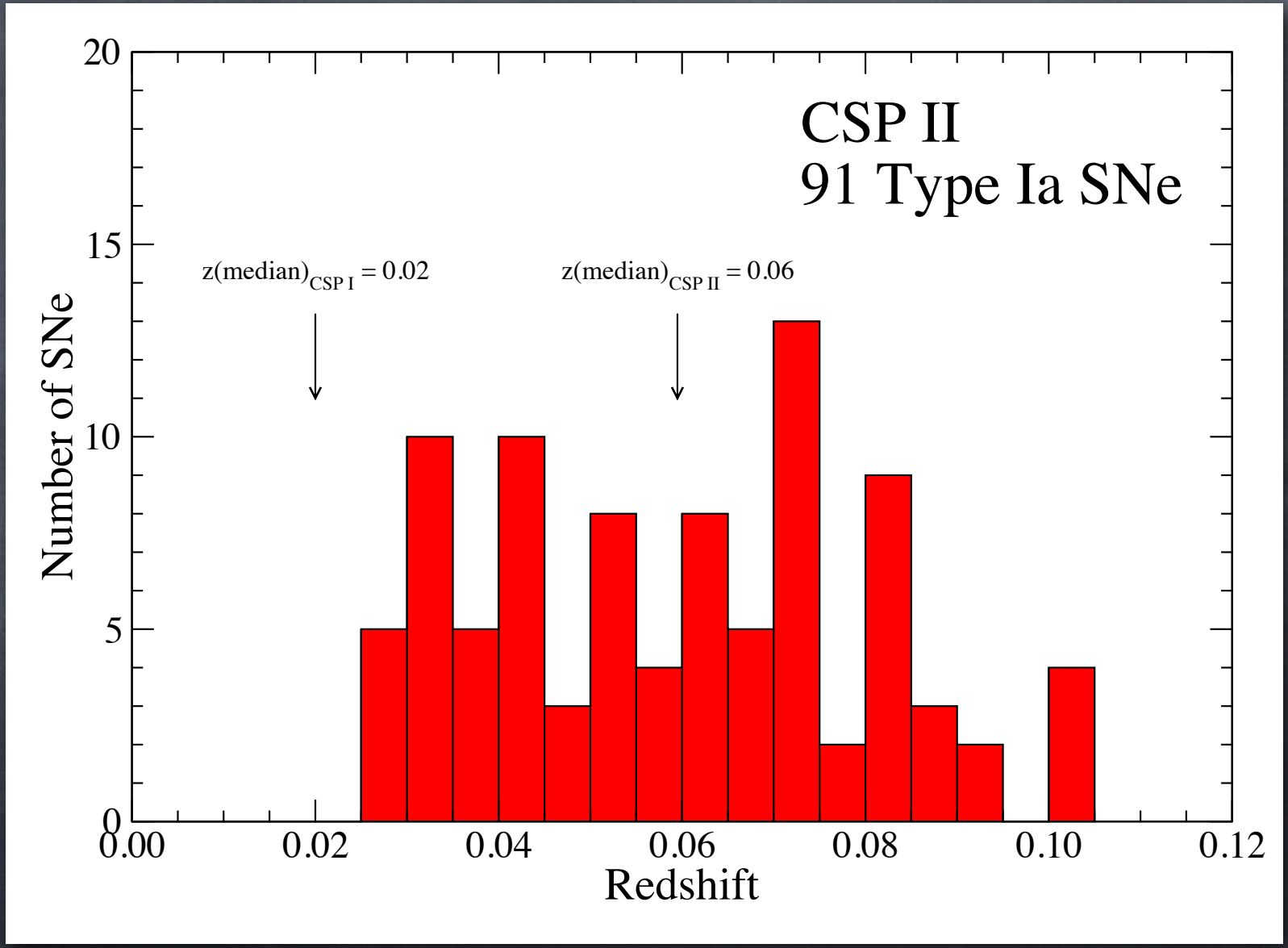


CSP II: Near-IR Filters

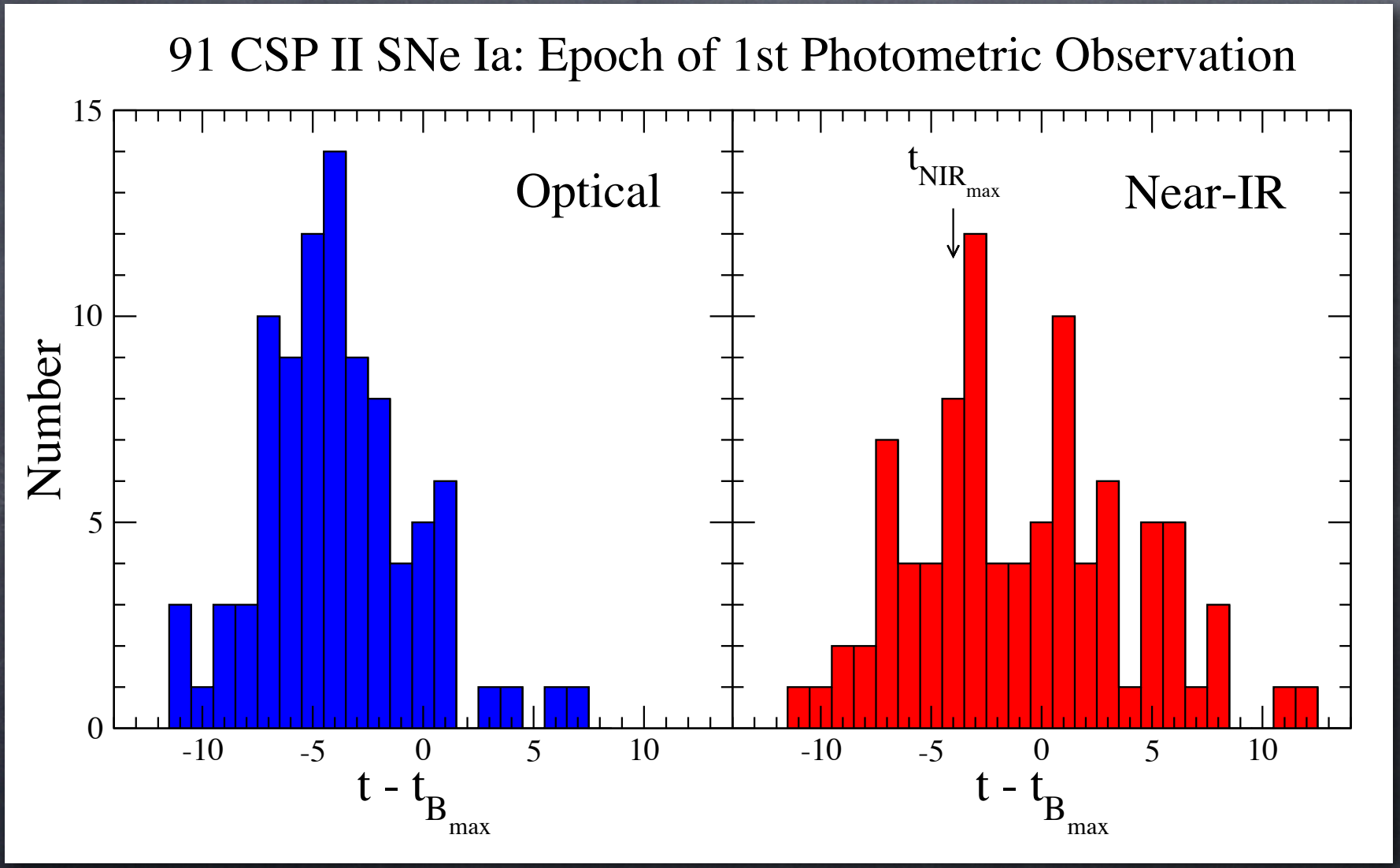


	Median Redshift
YJH	0.050
YJ	0.070
Y	0.085

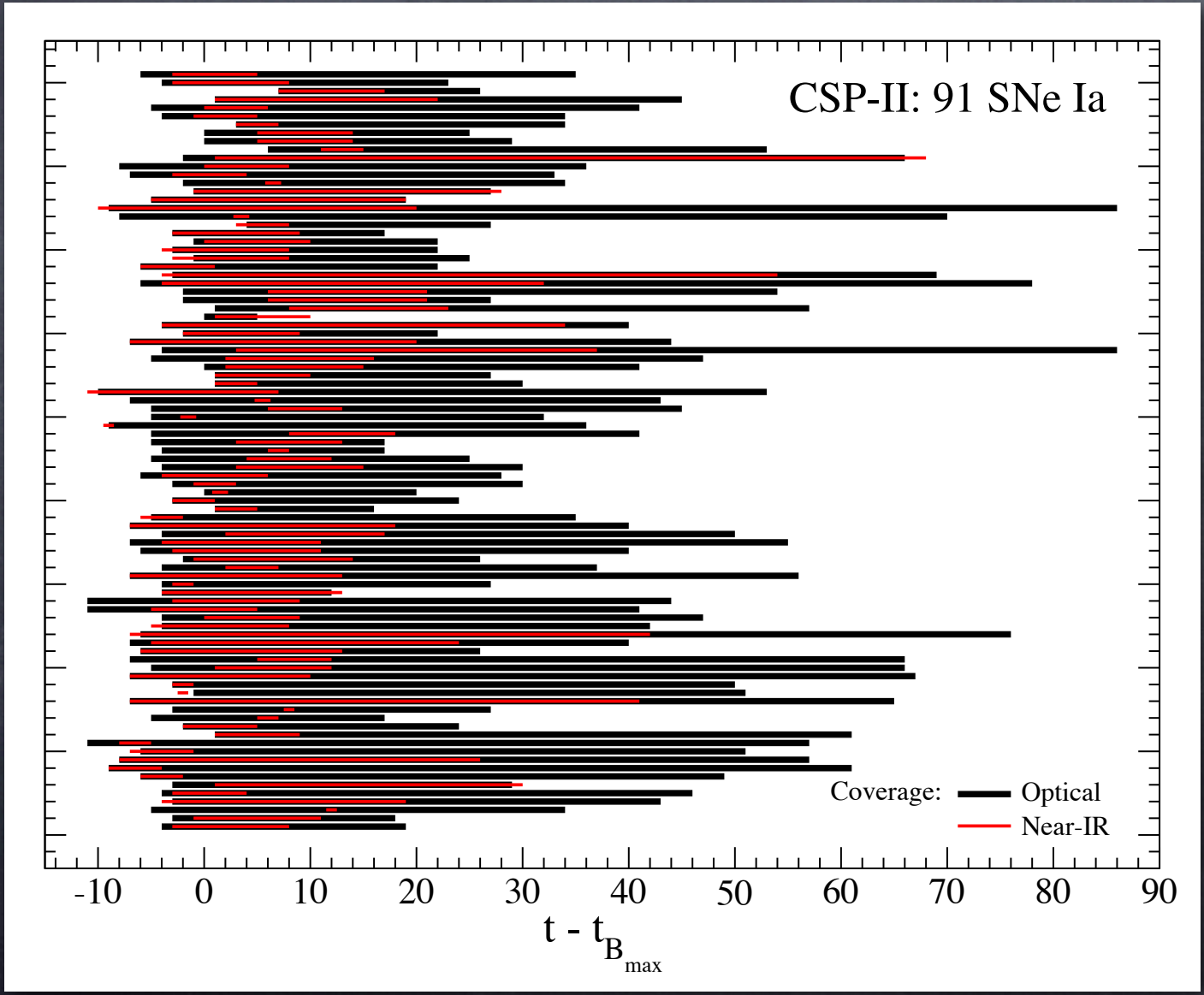
Redshift Distribution



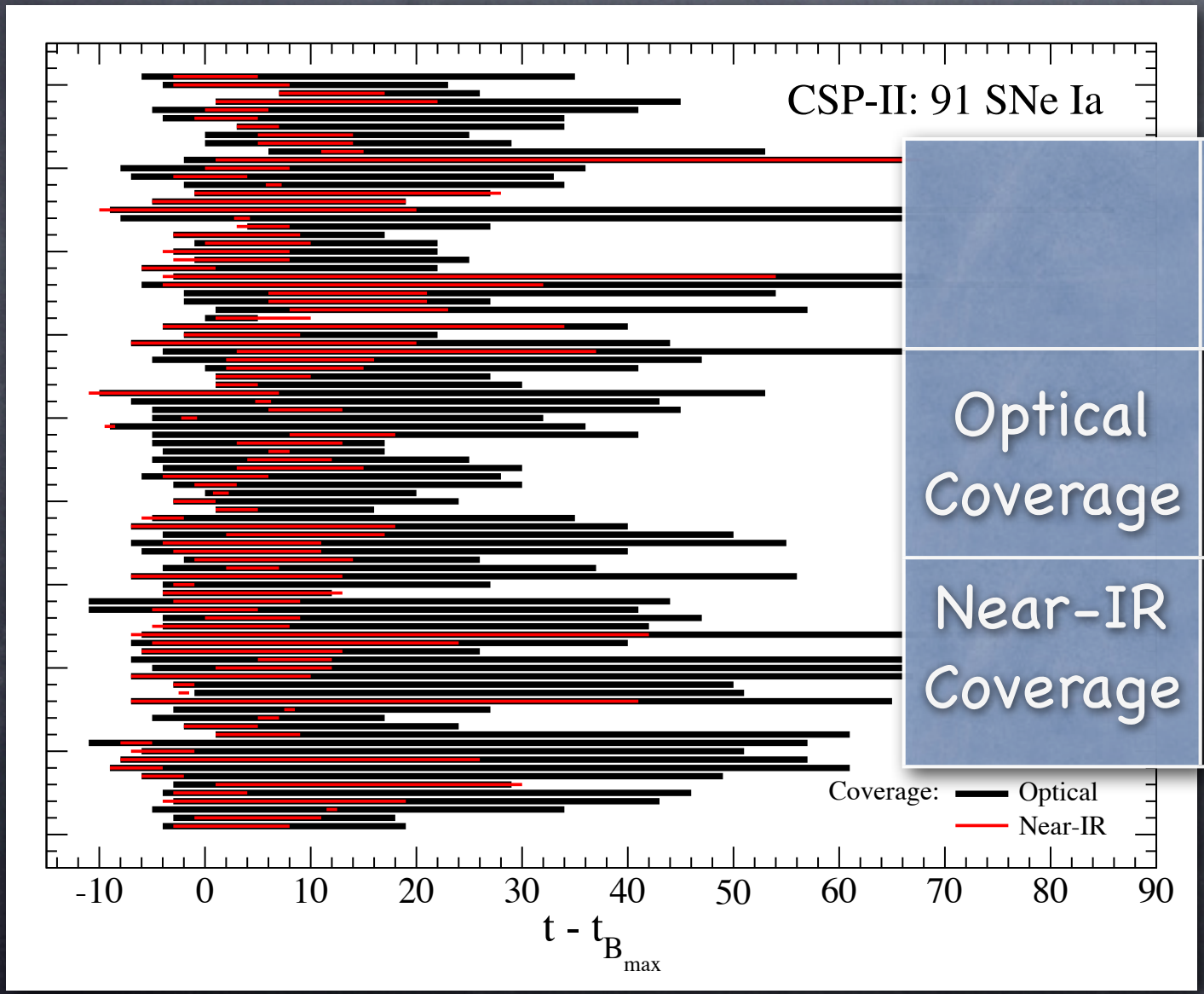
Epoch of First Observation



91 CSP II SNe Ia: Optical and Near-IR Coverage



91 CSP II SNe Ia: Optical and Near-IR Coverage

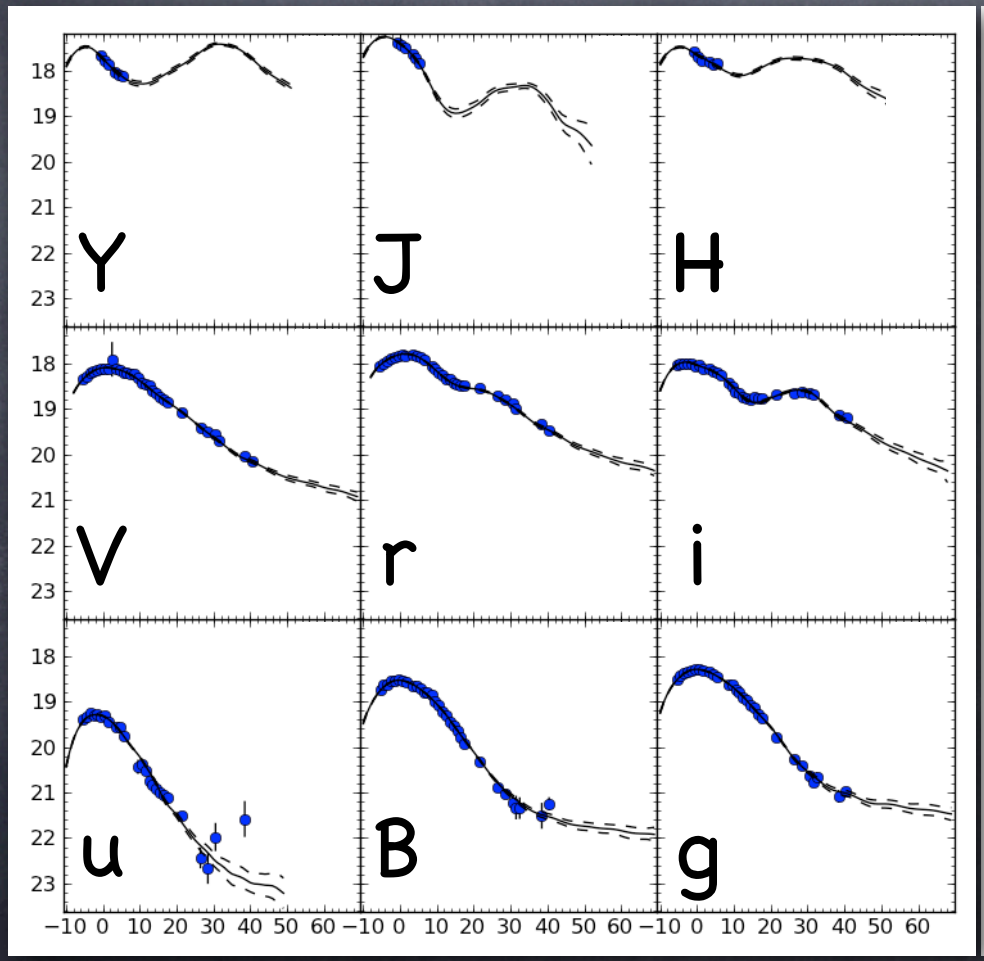


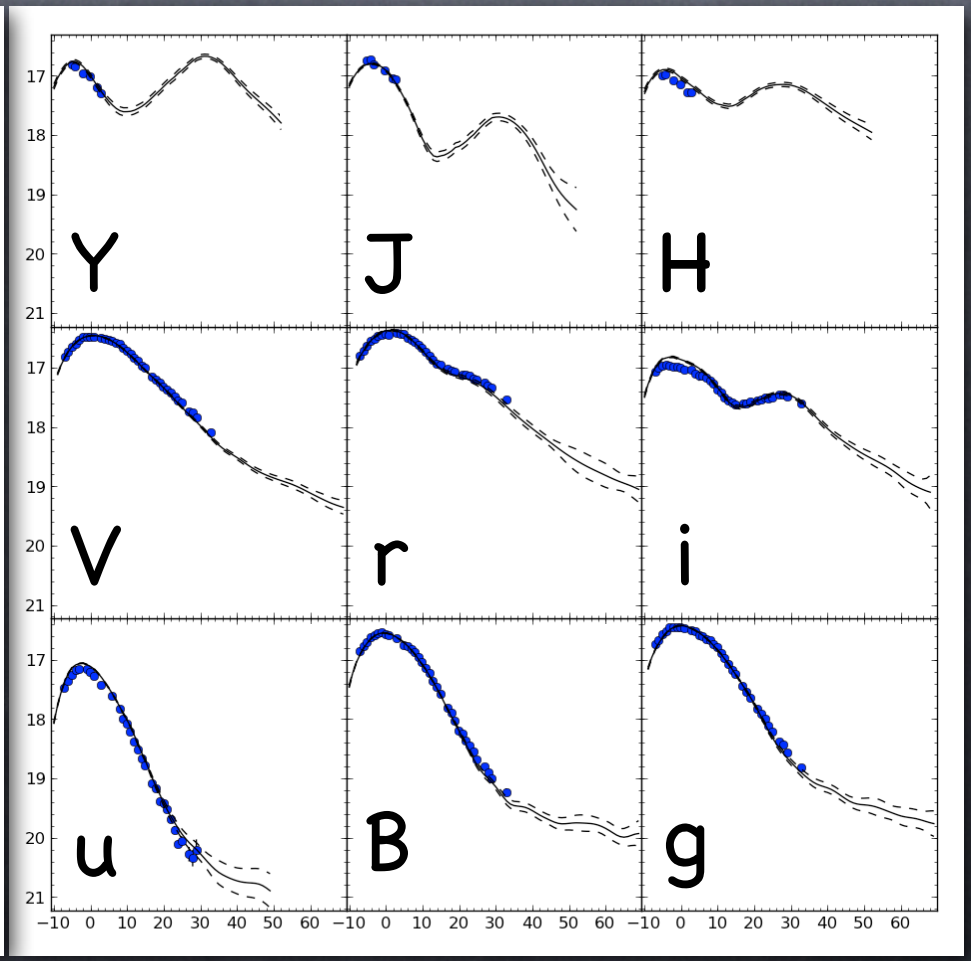
	Median
Optical Coverage	-4 to +36
Near-IR Coverage	-1 to +10

Sample Light Curves

LSQ11ot (z = 0.03)

PTF11pbp (z = 0.03)





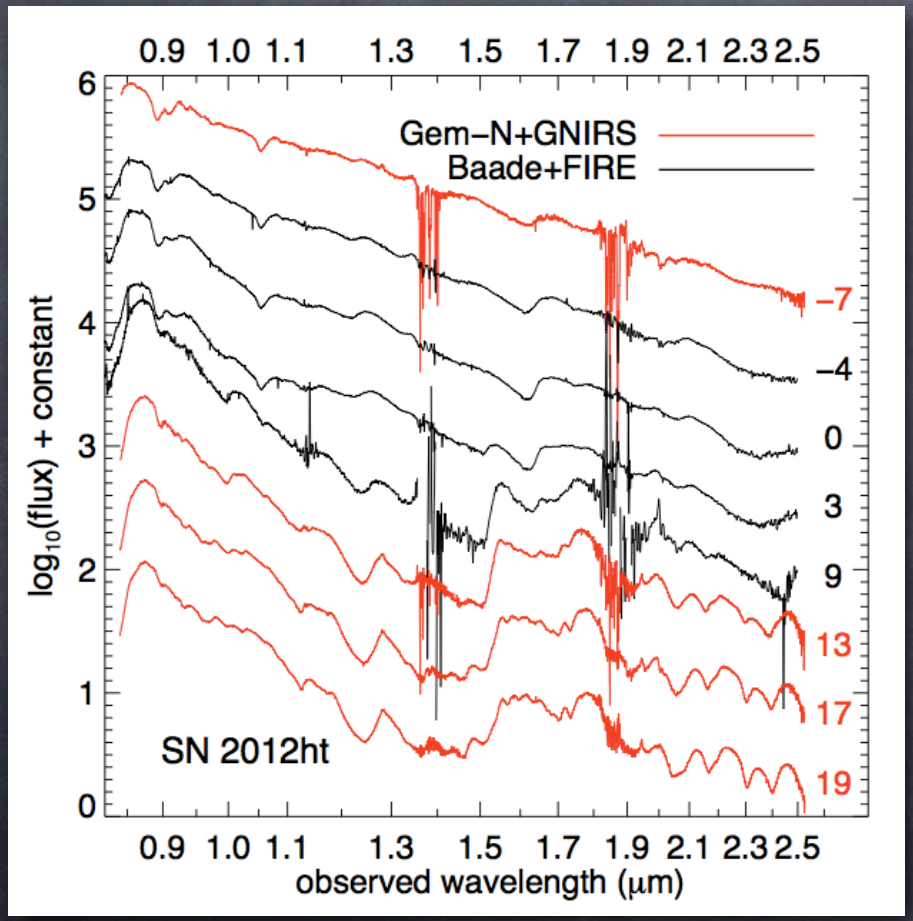
magnitude

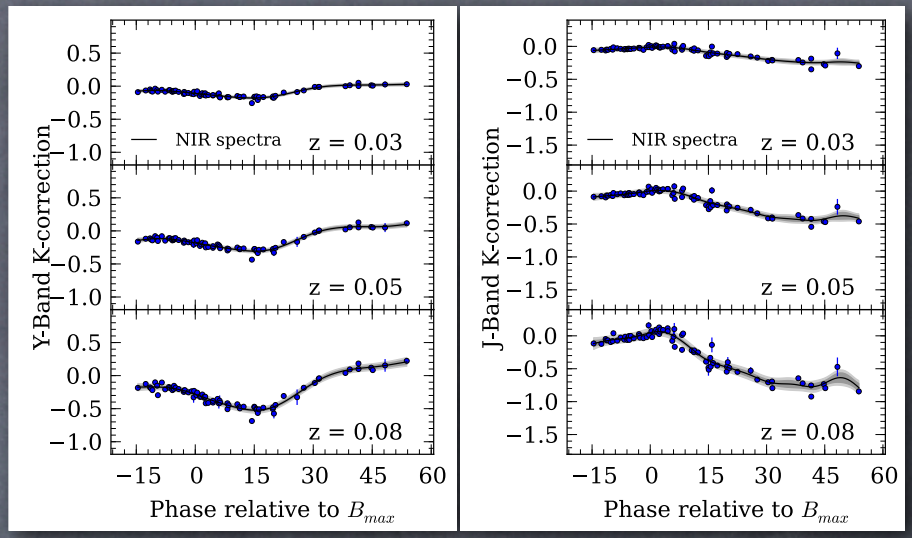
$t - t_{Bmax}$

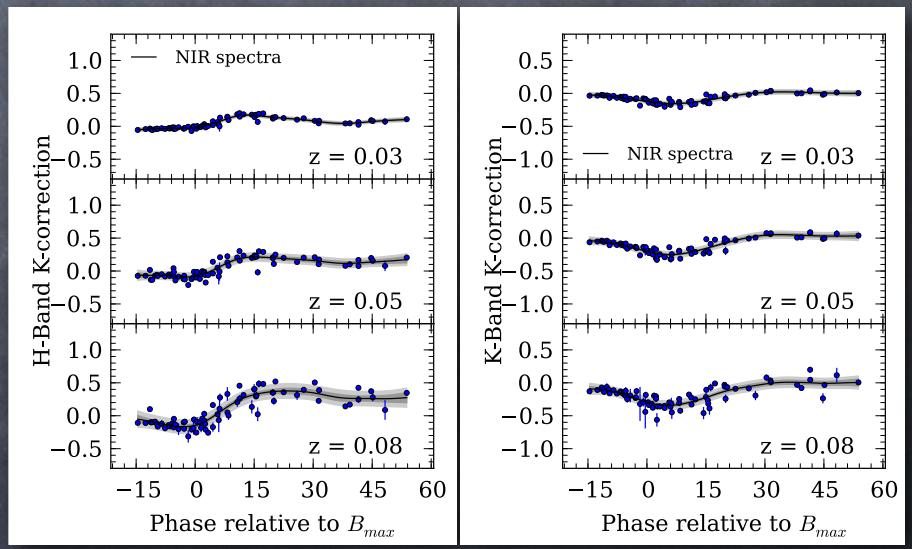
$t - t_{Bmax}$

Near-IR Spectroscopy

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

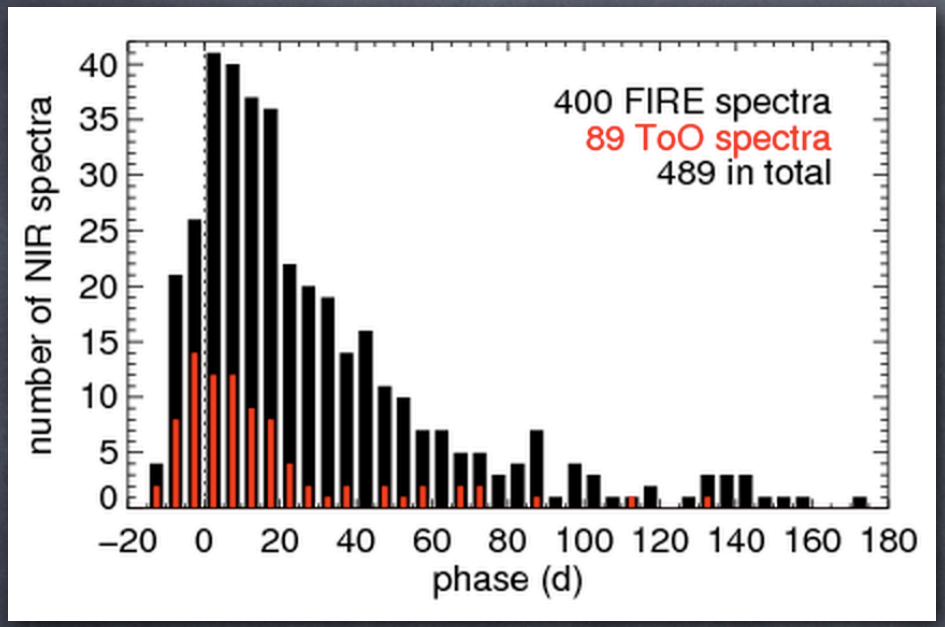


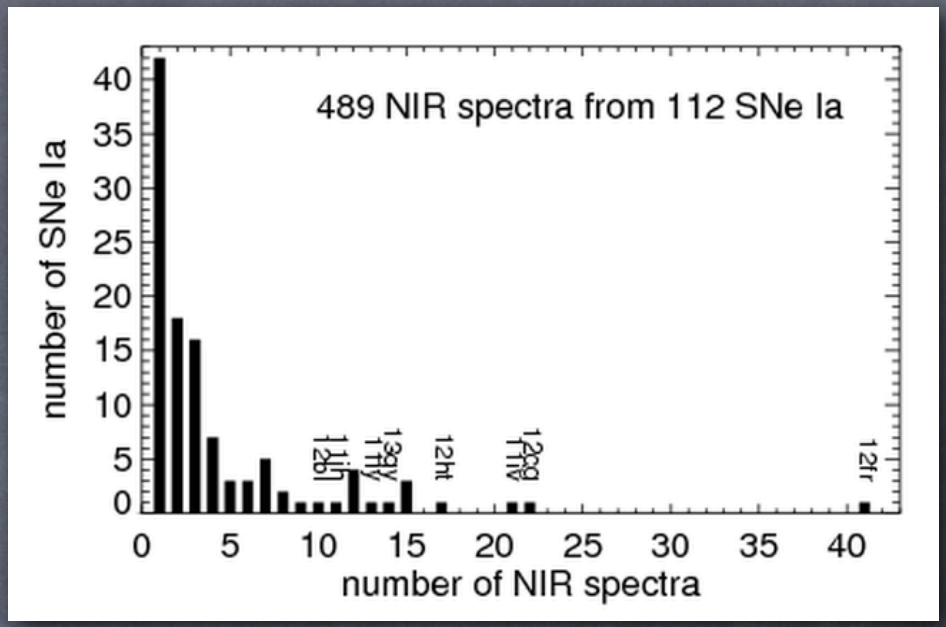




Boldt et al. 2014

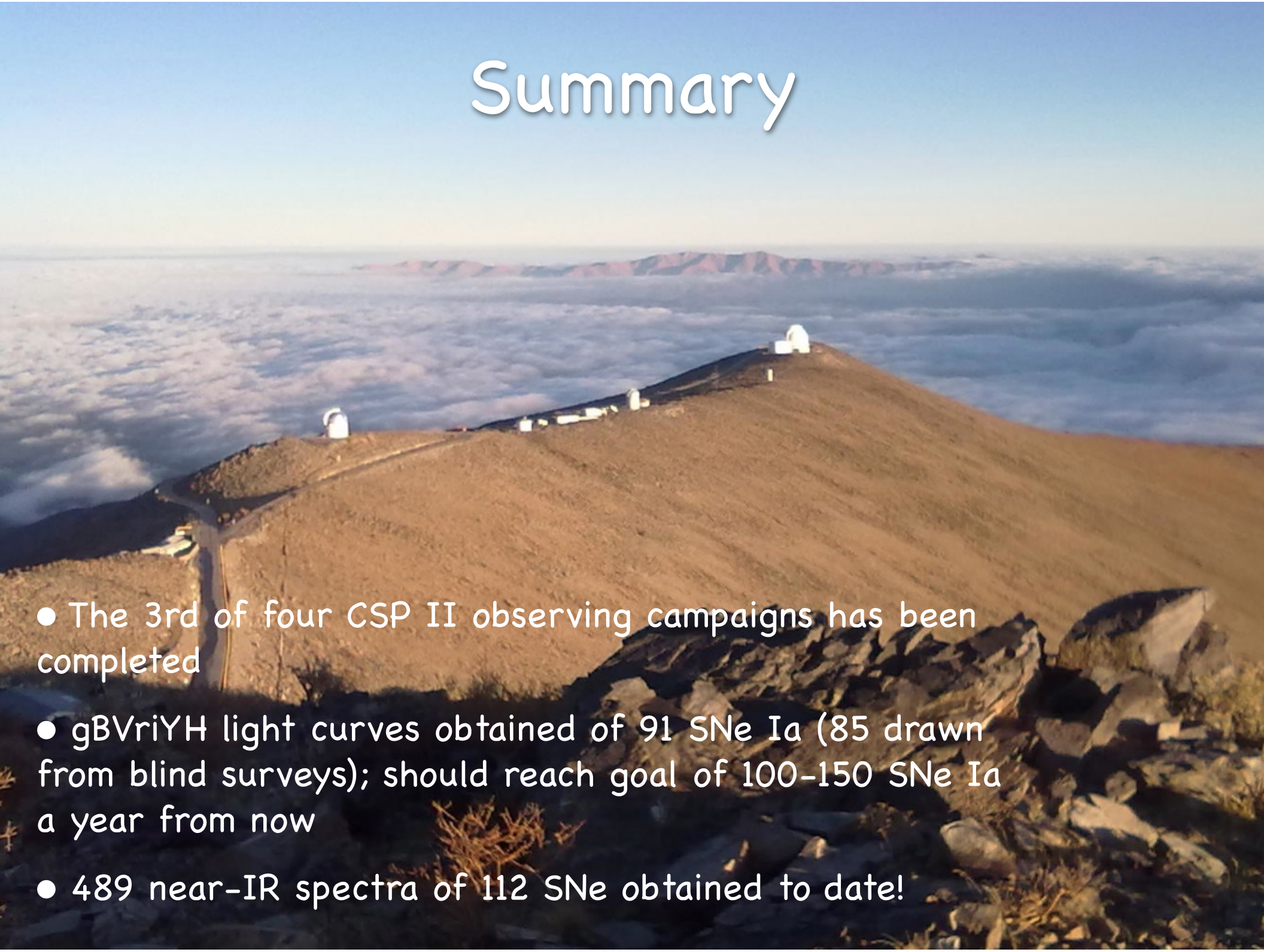
Near-IR Spectroscopy Stats to Date





- In collaboration with Marion, Kirshner, et al.
- FIRE is the workhorse instrument, but ToO spectra obtained with IRTF and Gemini-N have helped to improve the statistics around maximum light

Summary



- The 3rd of four CSP II observing campaigns has been completed
- gBVriYH light curves obtained of 91 SNe Ia (85 drawn from blind surveys); should reach goal of 100-150 SNe Ia a year from now
- 489 near-IR spectra of 112 SNe obtained to date!


Thank you!
Photo by Yuri Beletsky