The Carnegie Supernova Project II (CSP II)

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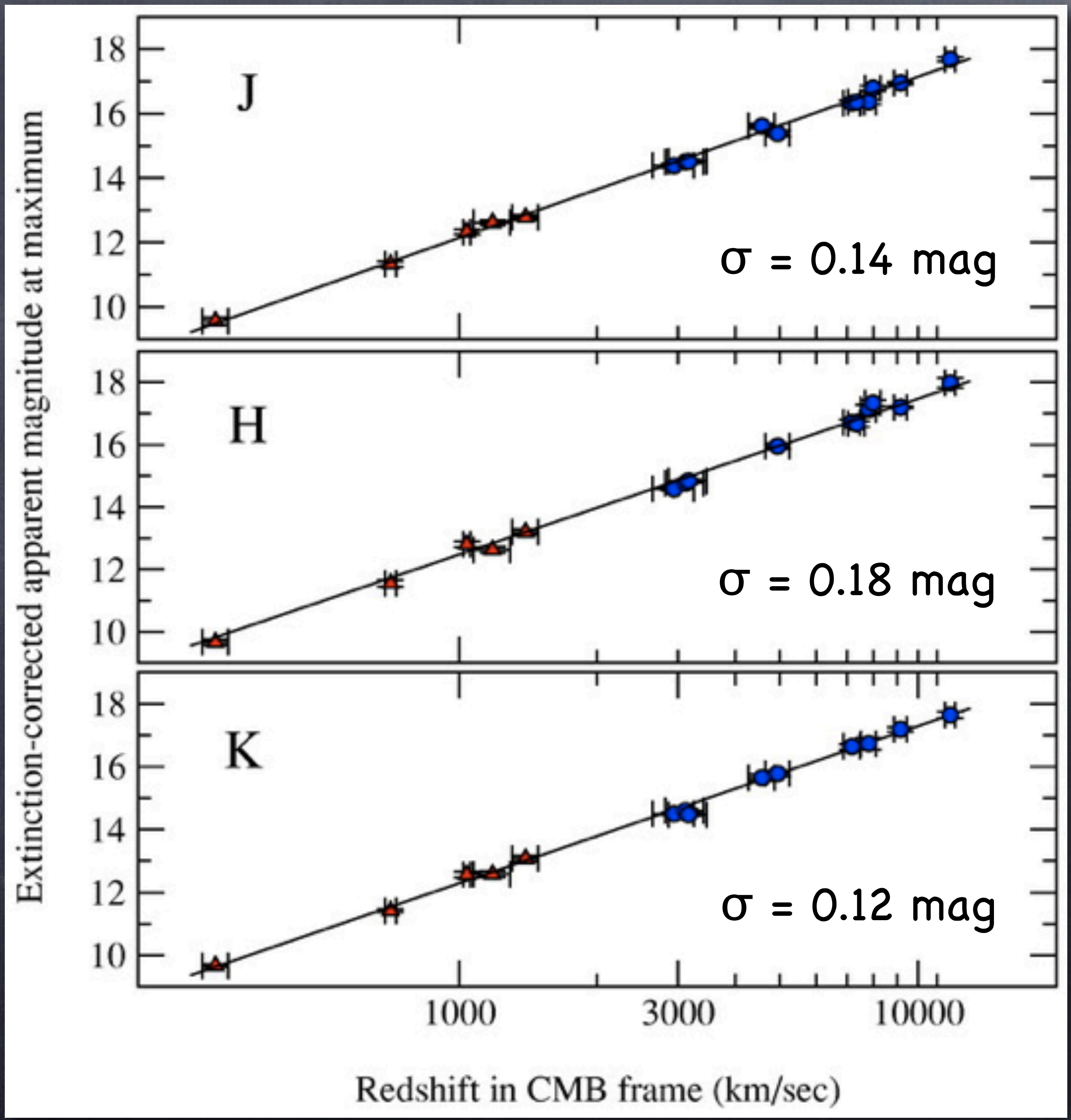
Carnegie Observatories

CARNEGIE INSTITUTION FOR SCIENCE

NSF

SNe Ia are Excellent Standard Candles in the Near-IR



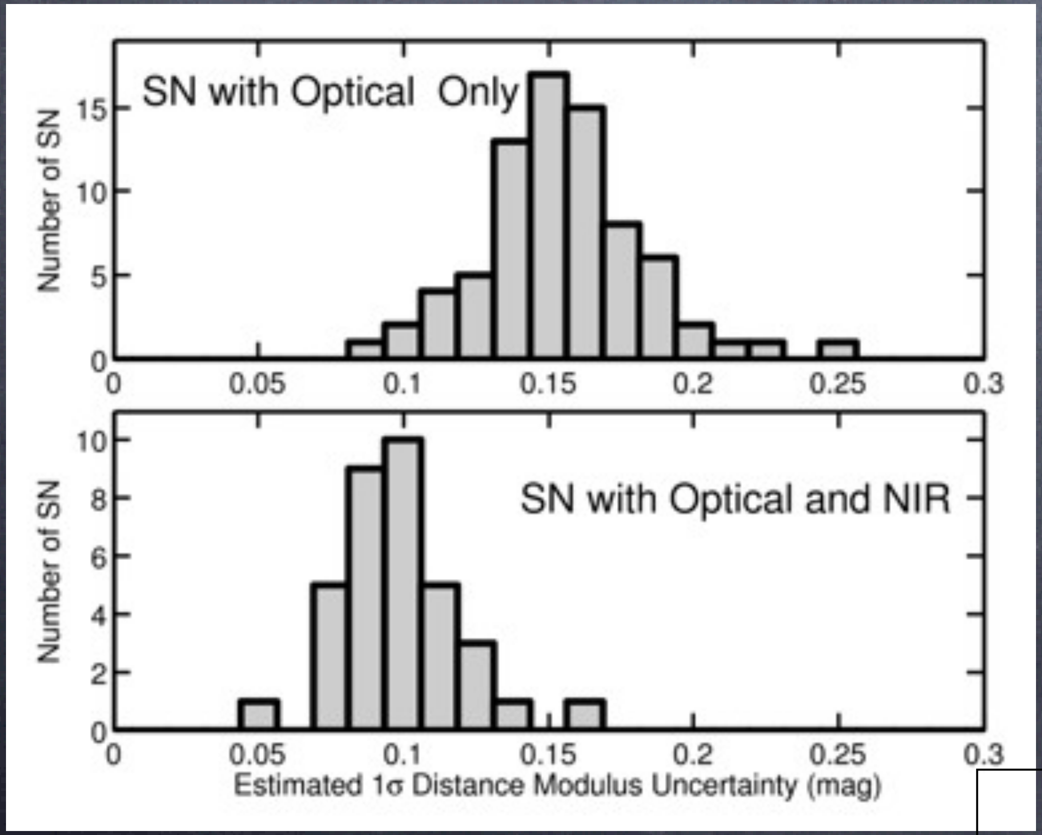
Krisciunas, Phillips, & Suntzeff 2004

- 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

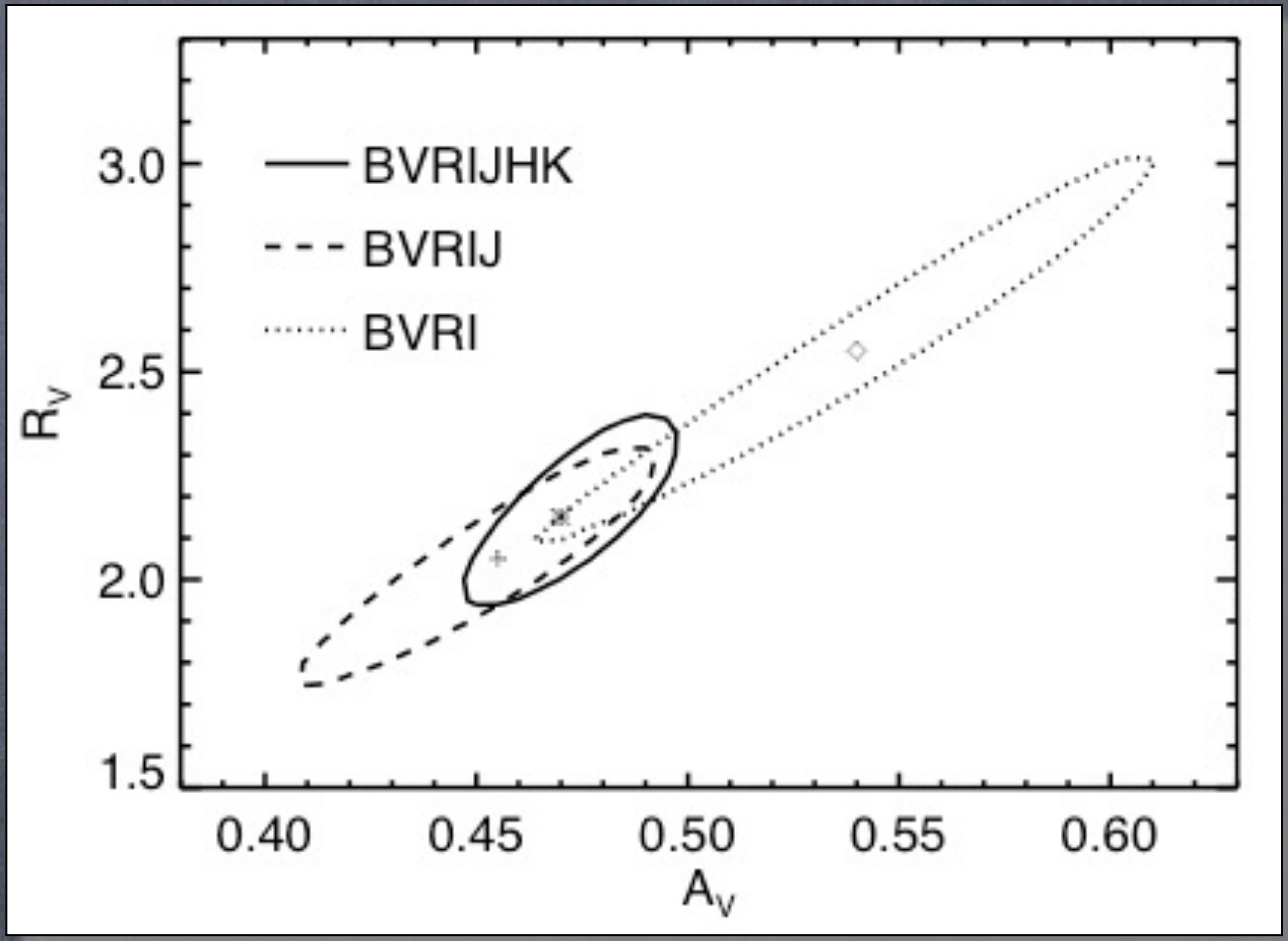
Constraining the Reddening Law

- 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 2012



Krisciunas et al. 2007

The Carnegie Supernova Project I (CSP I)

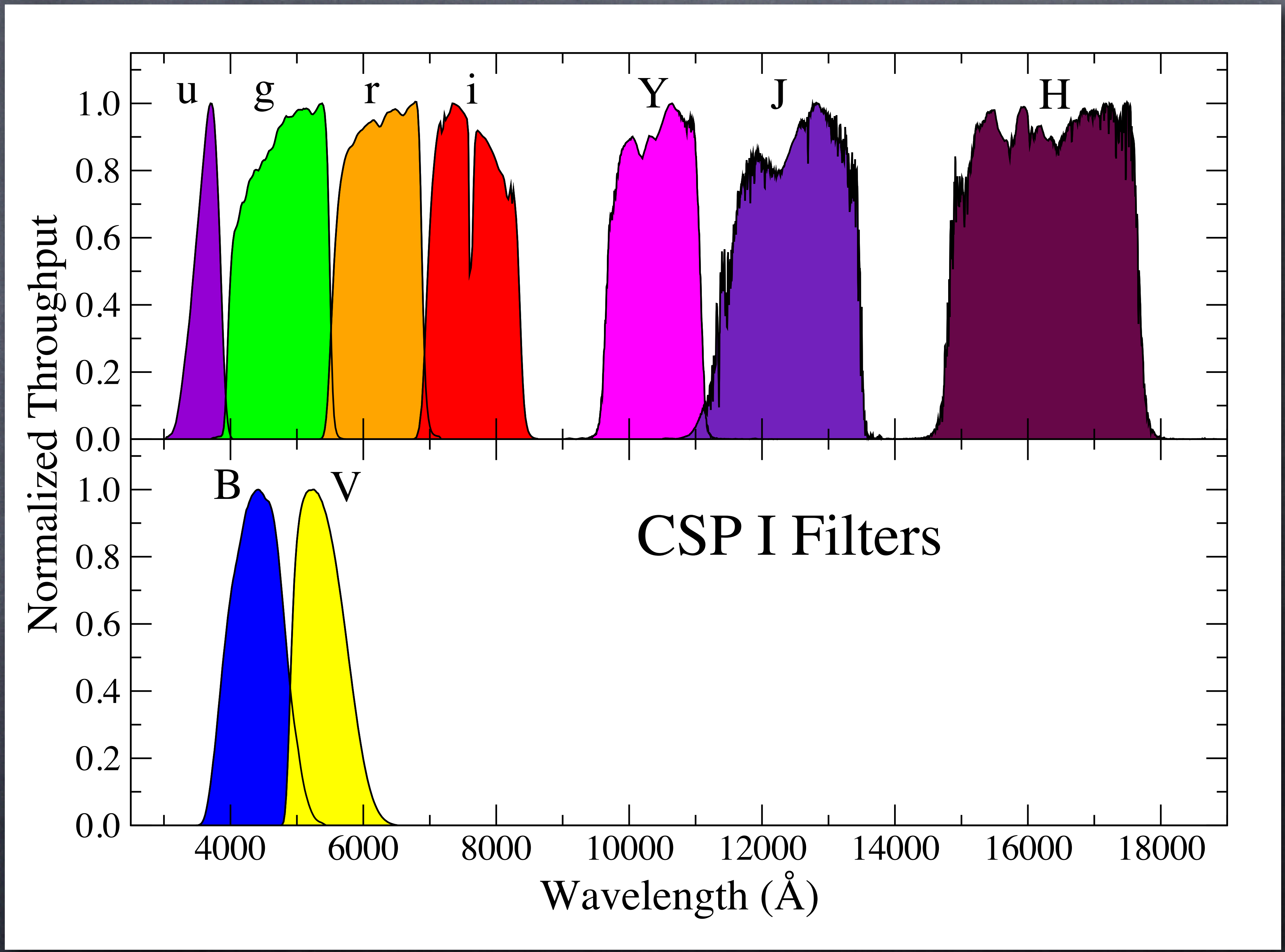
- Five 9-month campaigns between 2004-2009
- Follow-up optical (ugriBV) light curves obtained of 130 SNe Ia
- Near-IR (YJH) photometry obtained of 113 (87%) of these
- Light curves of 85 SNe Ia published to date (remaining 45 will be published late this year)

Swope 1-m

Du Pont 2.5-m

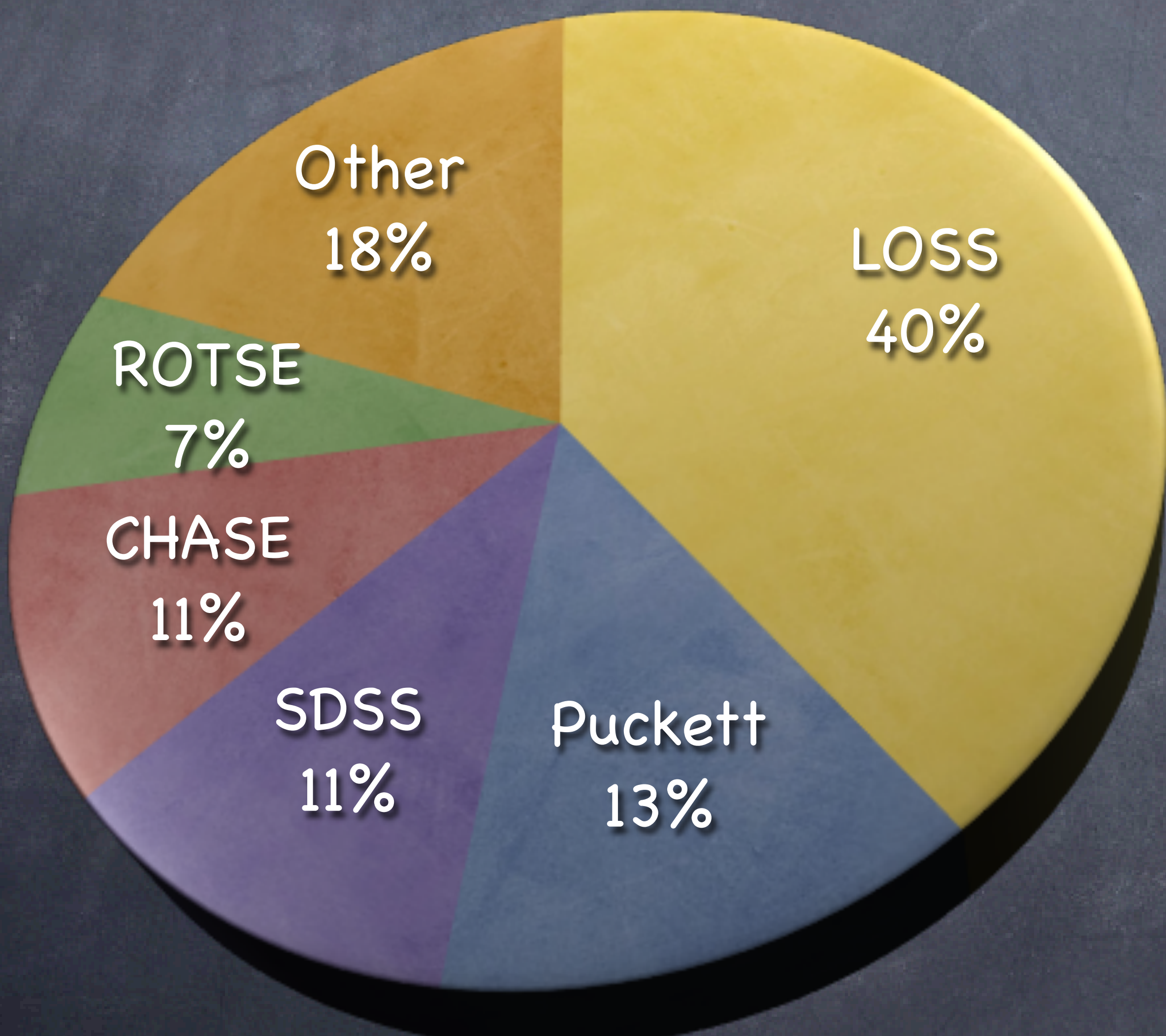
Magellan 6.5-m

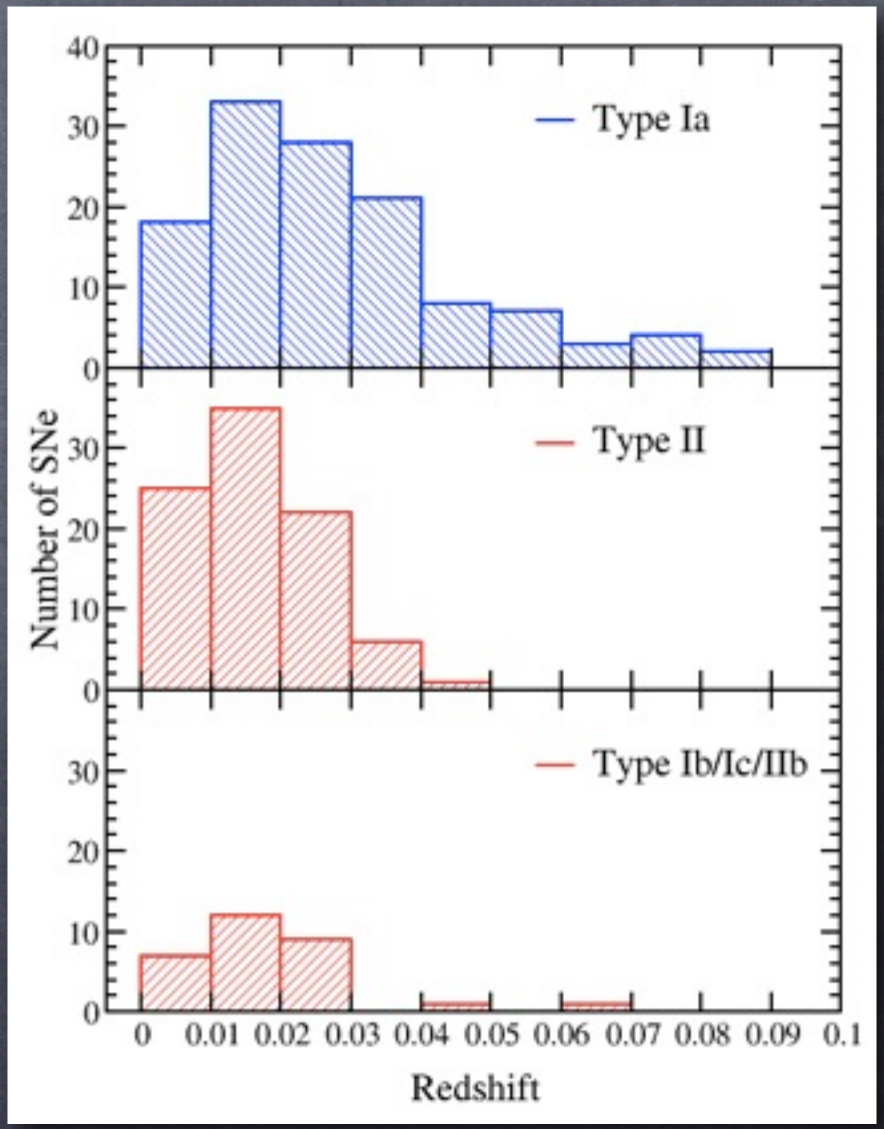
CSP I: ugriBVYJH Filters



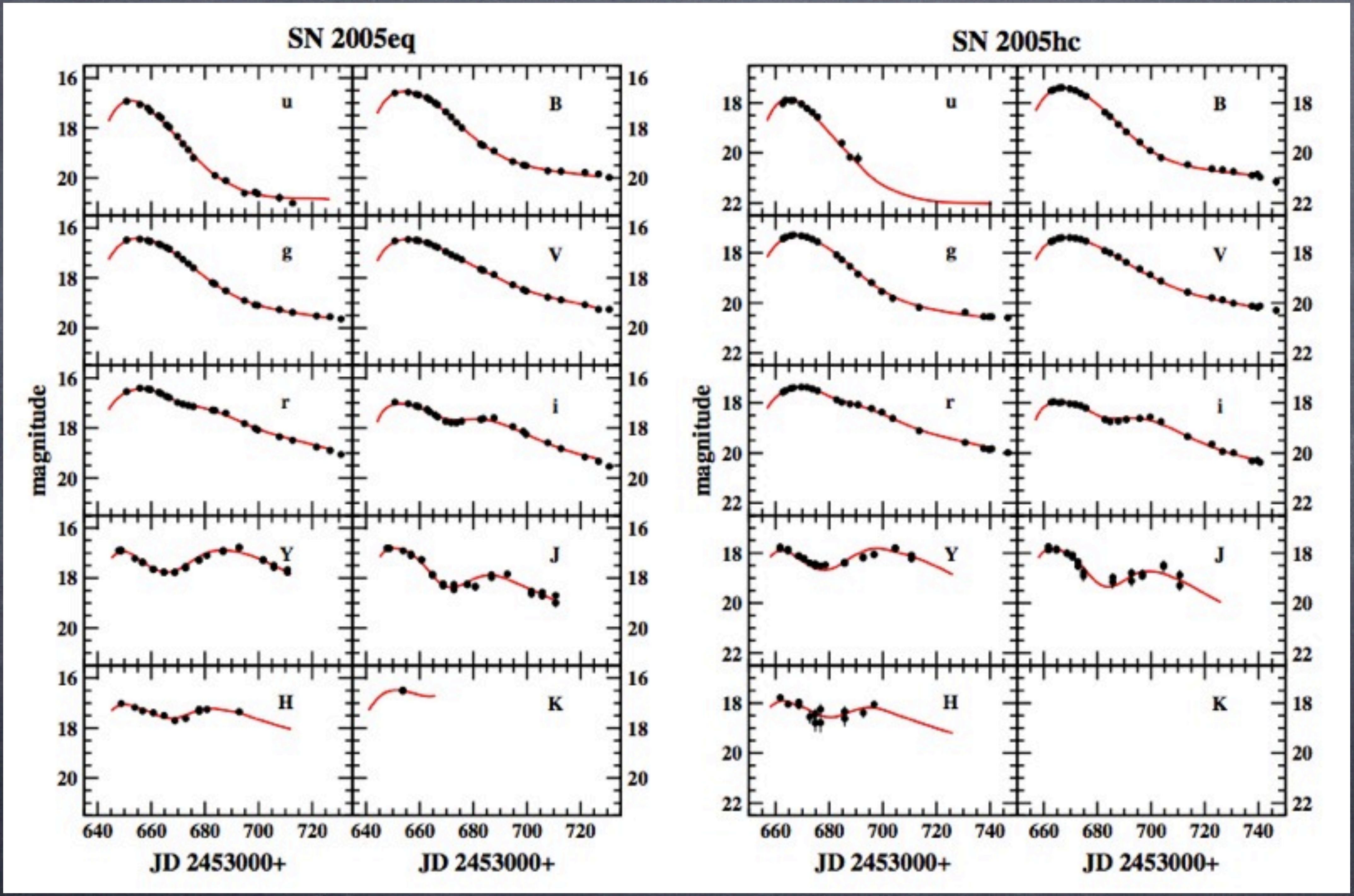
CSP I: Summary

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





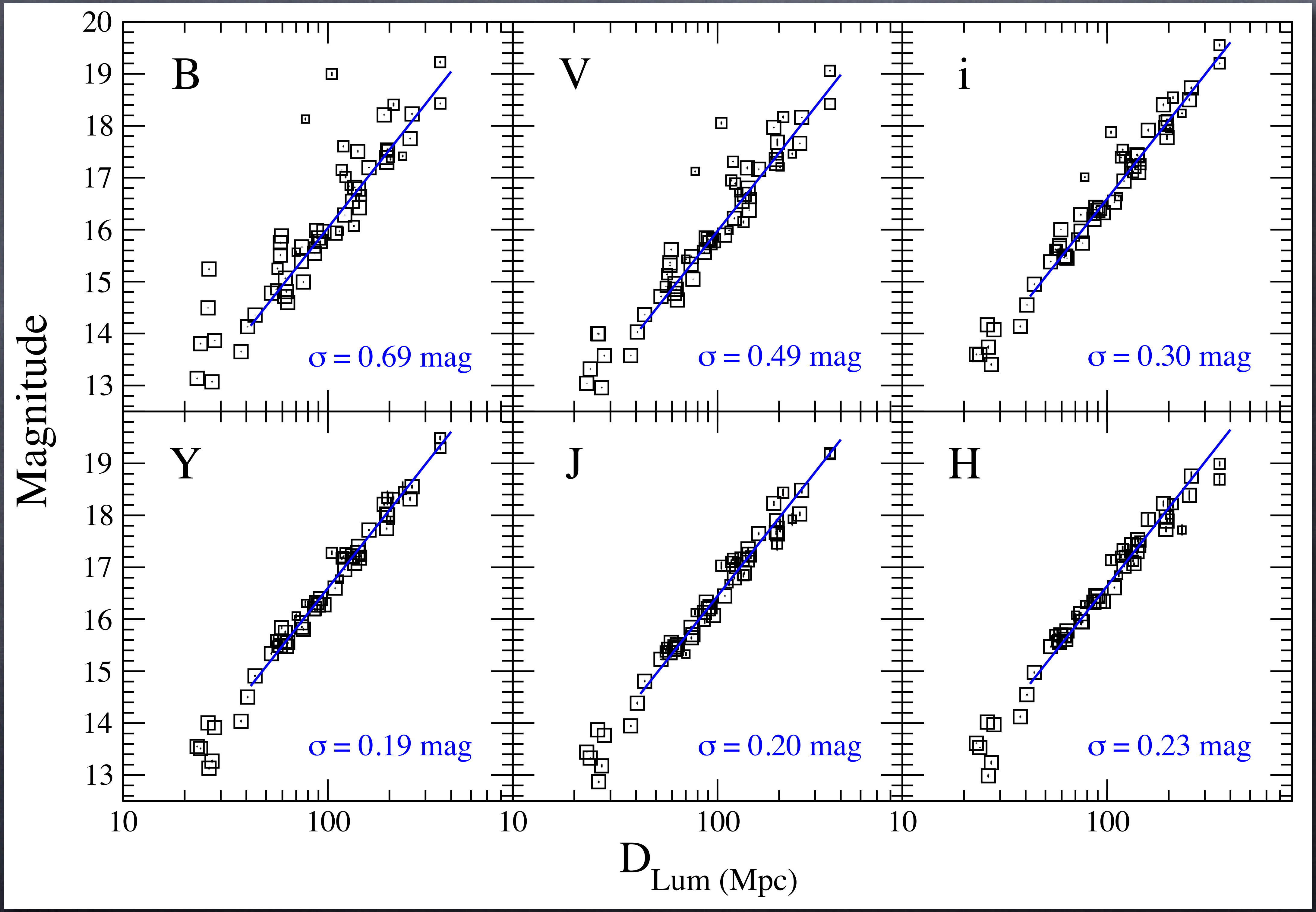
Optical and Near-IR Light Curves of SNe Ia from the CSP I



Contreras et al. 2010

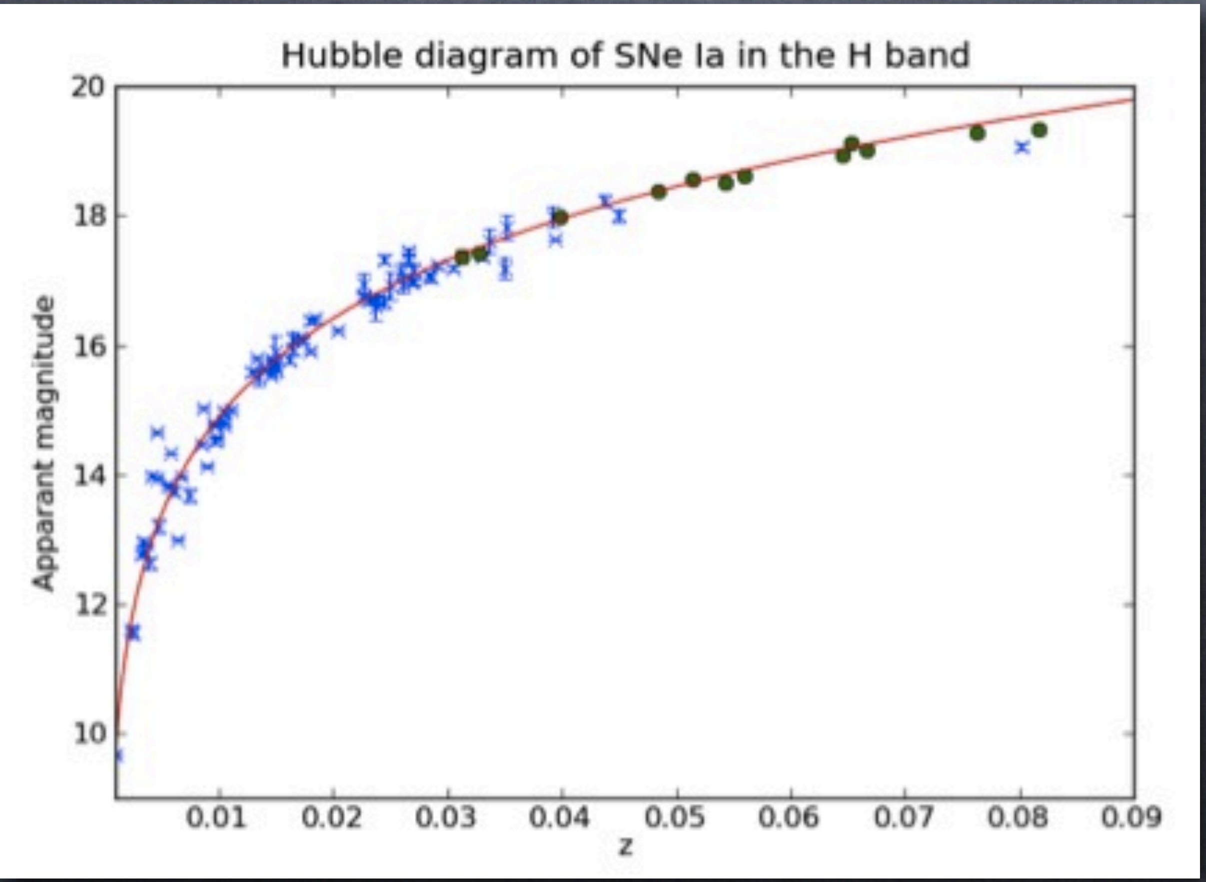
CSP I Hubble Diagrams

No corrections for either decline rate or host extinction!

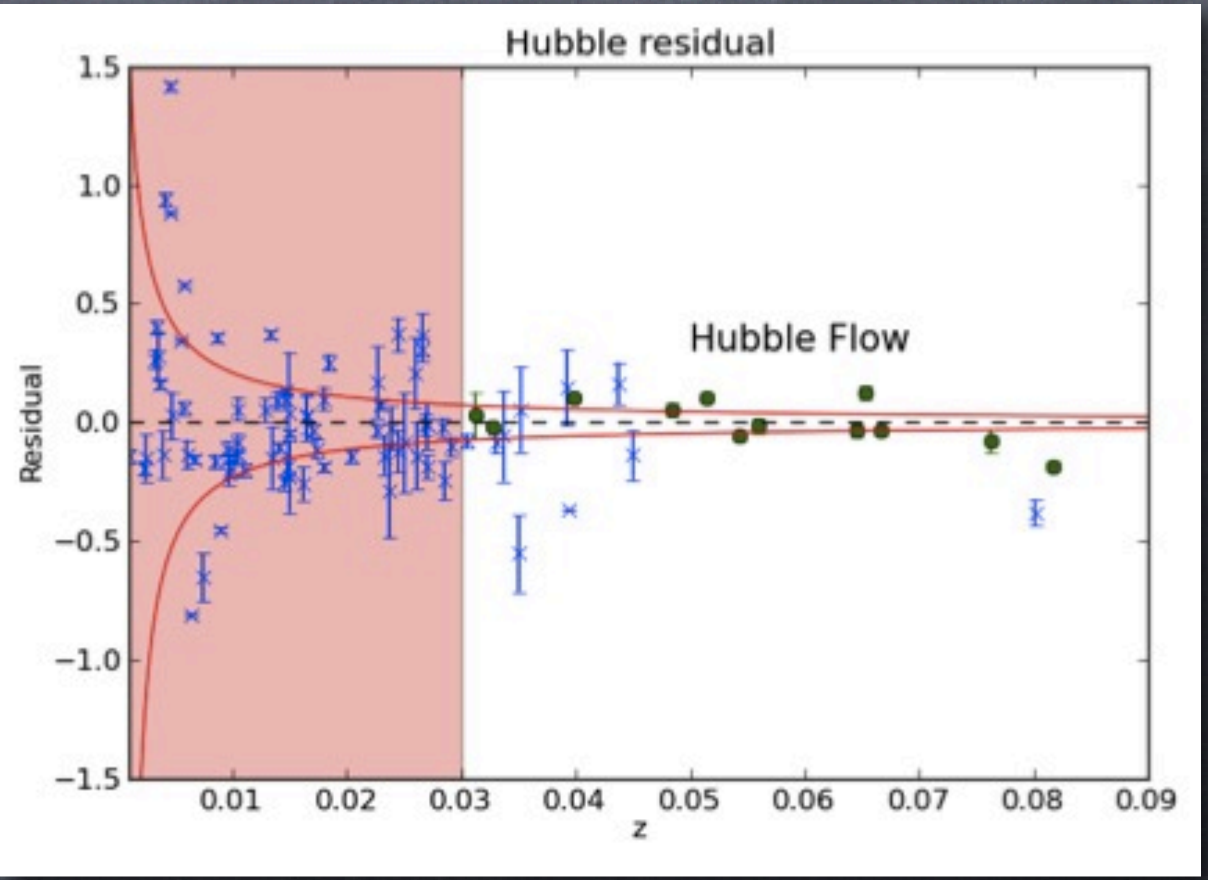


Pushing Further into the Hubble Flow

- 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
12 PTF SNe Ia

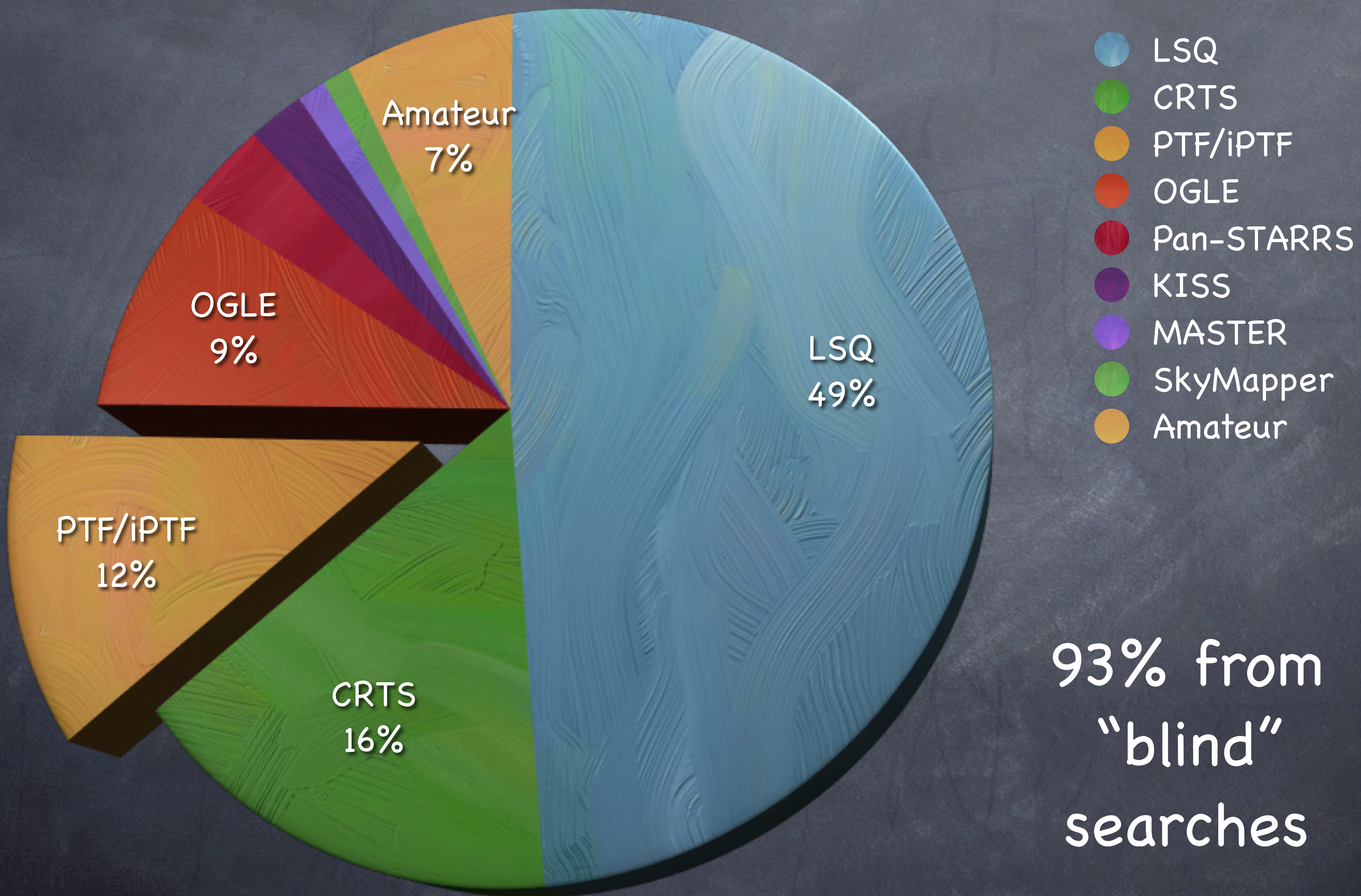


At $0.03 < z < 0.09$, $\sigma_J = 0.12$ mag and $\sigma_H = 0.09$ mag

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

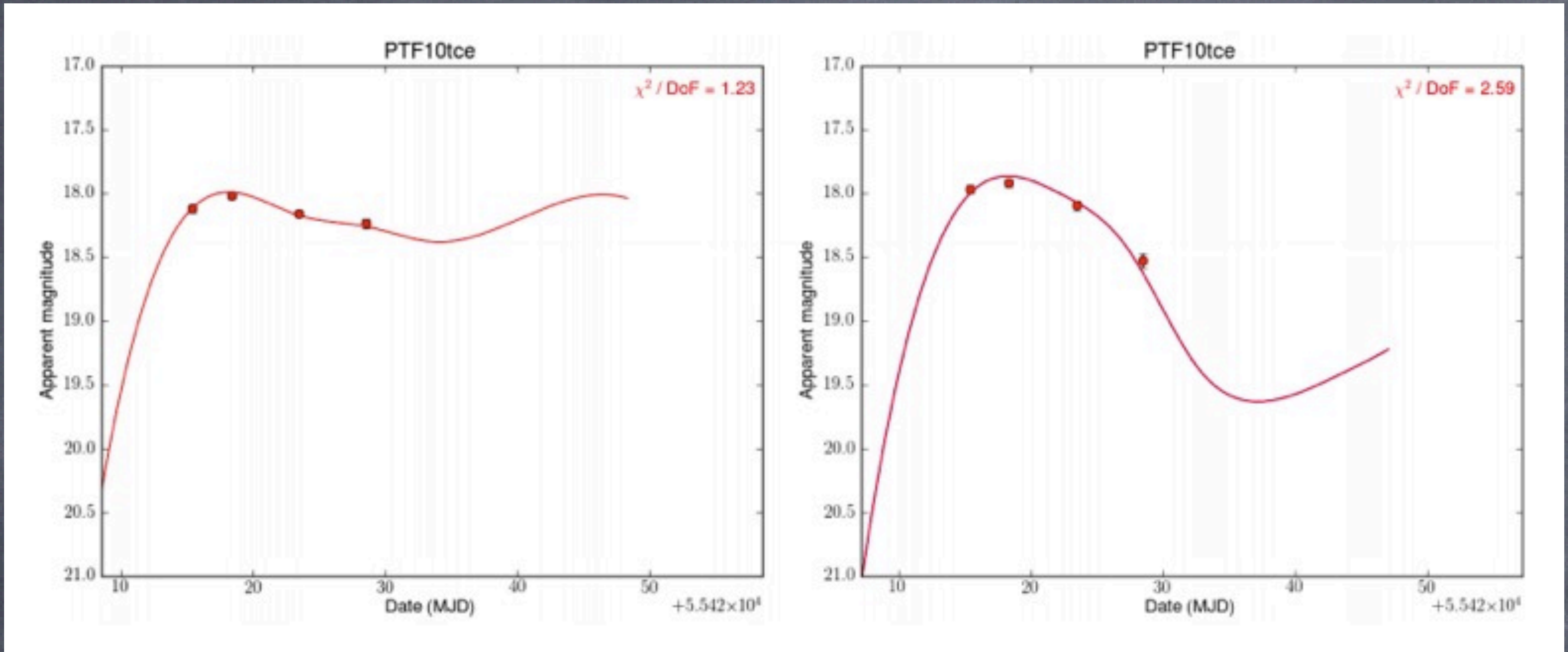


93% from "blind" searches

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



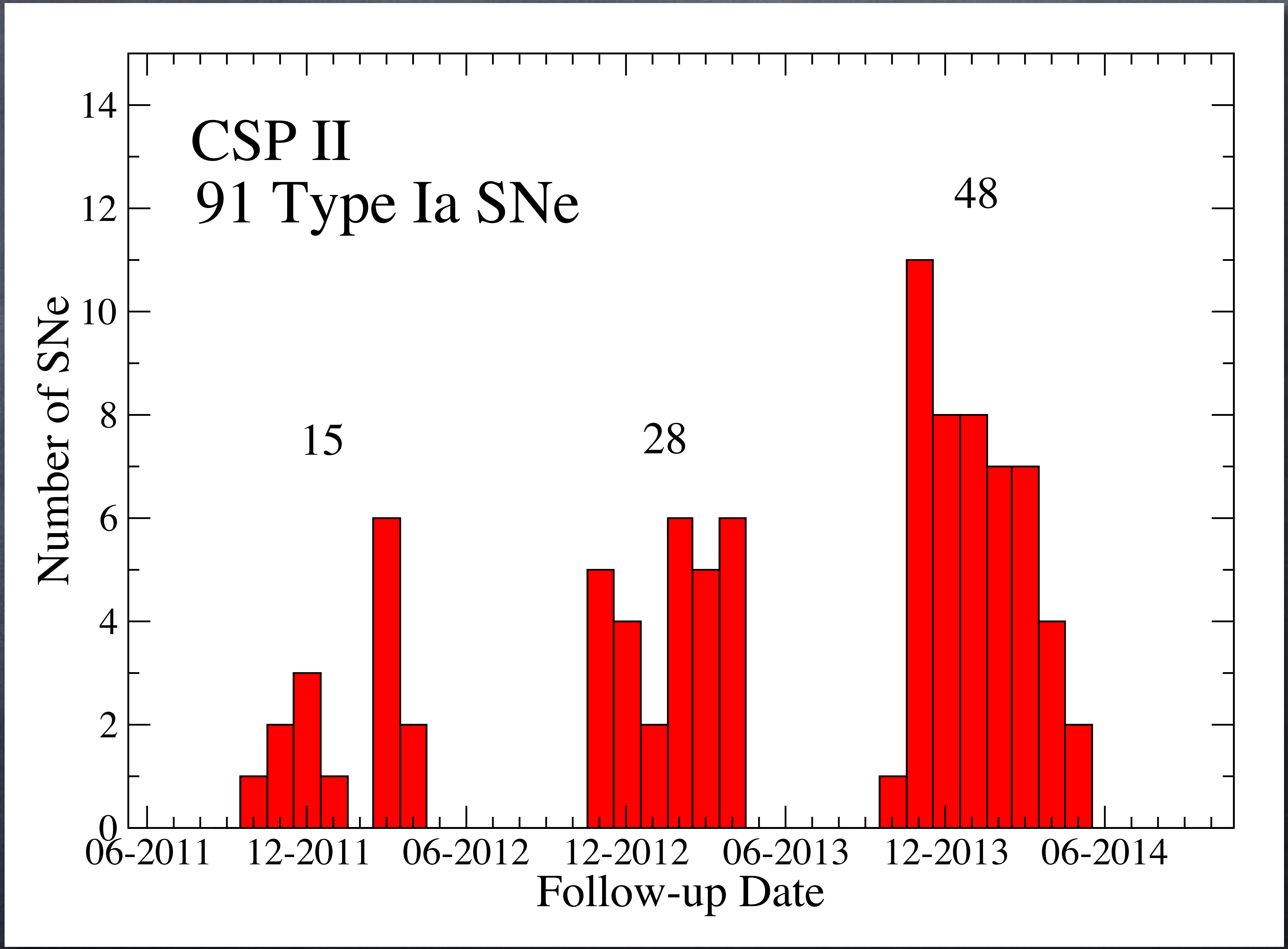
Sample	σ_J	SEM_J	σ_H	SEM_H
12 SNe x 1 obs	0.15 mag	0.04 mag	0.12 mag	0.03 mag
6 SNe x 2 obs	0.13 mag	0.05 mag	0.10 mag	0.04 mag
4 SNe x 3 obs	0.12 mag	0.06 mag	0.09 mag	0.05 mag
3 SNe x 4 obs	0.12 mag	0.07 mag	0.09 mag	0.05 mag

NIR obtained at -10 to +15 days

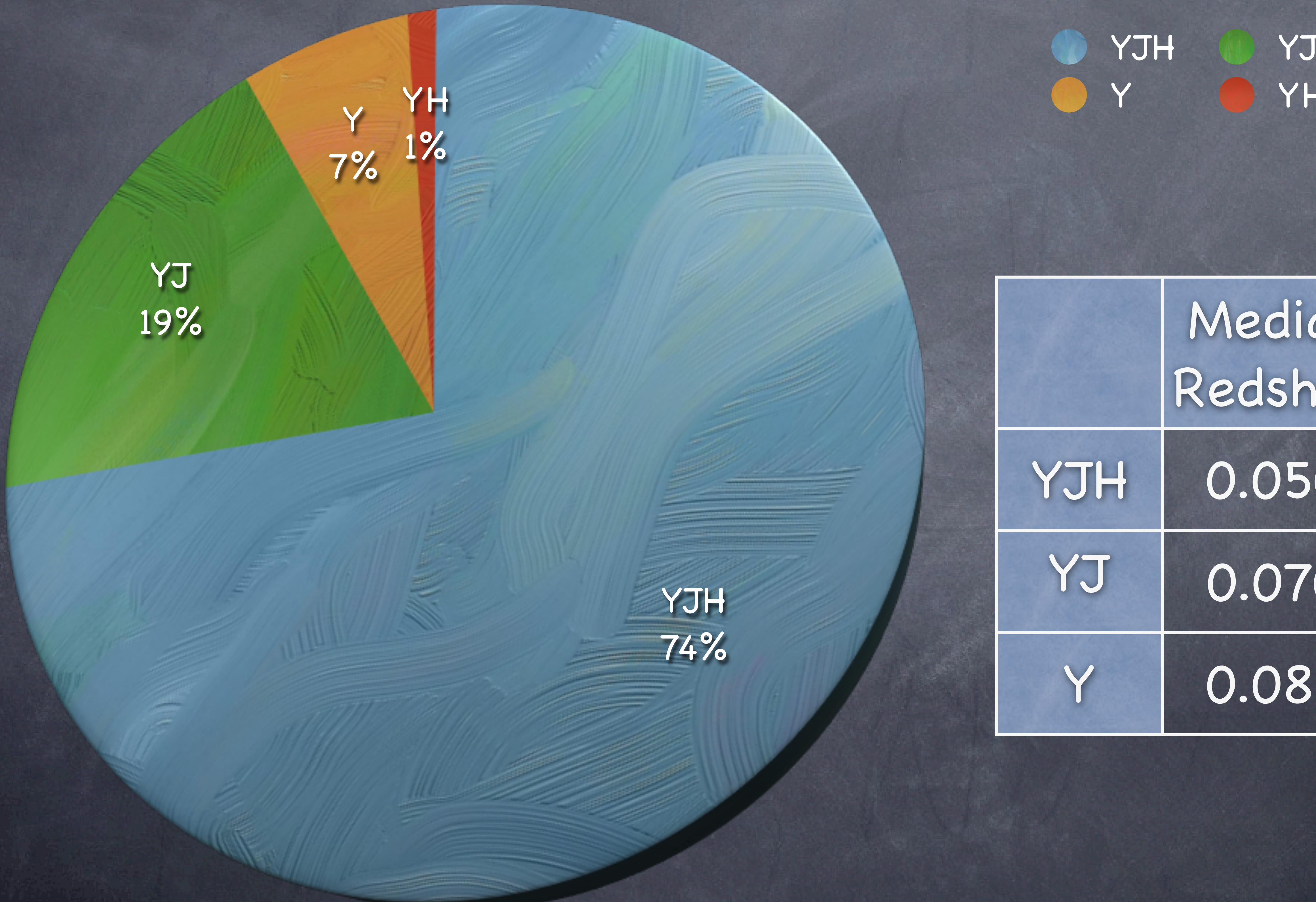
$SEM = \sigma / \sqrt{n}$

Barone-Nugent et al. 2012

Progress Through 3 Campaigns

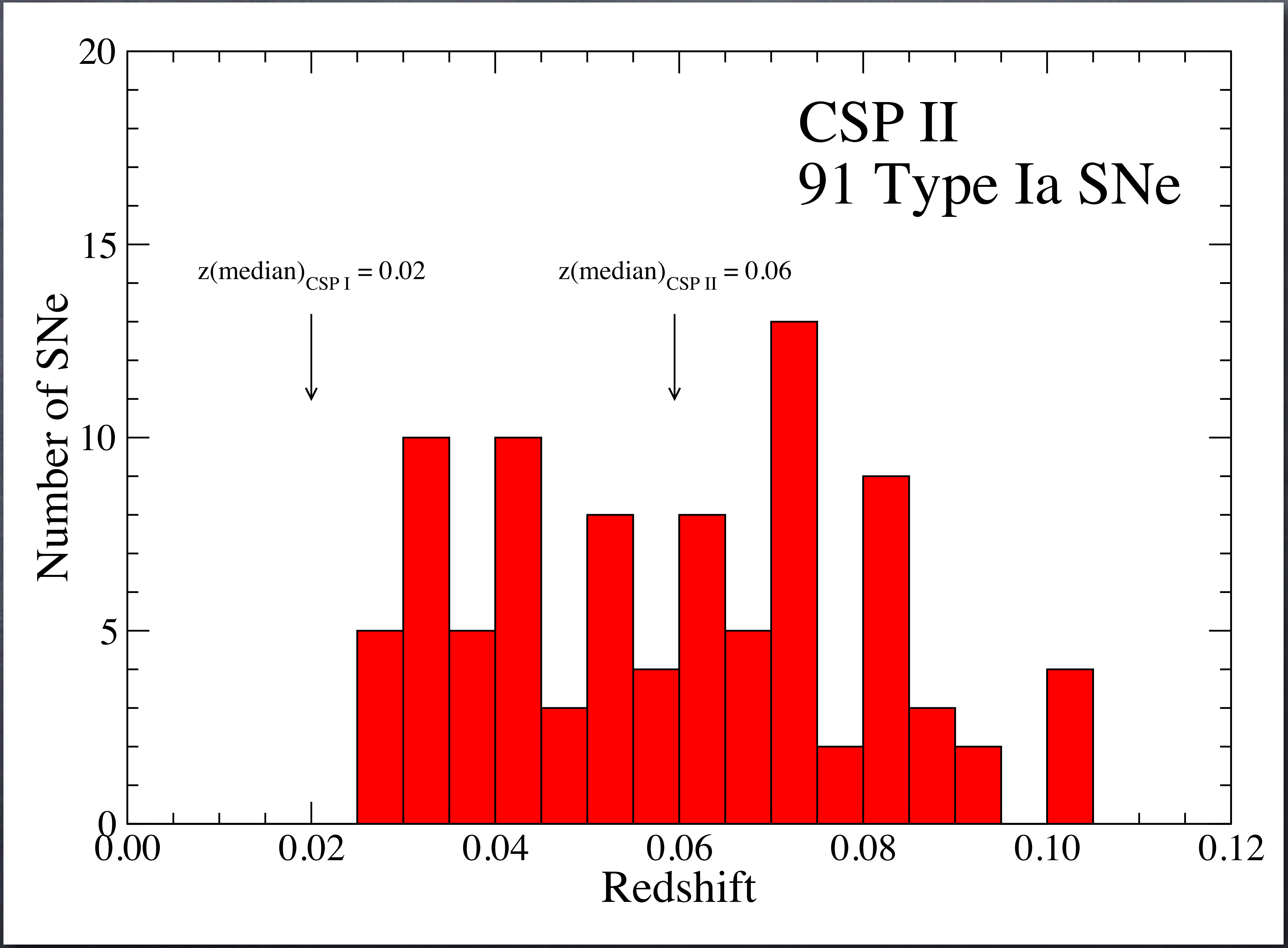


CSP II: Near-IR Filters

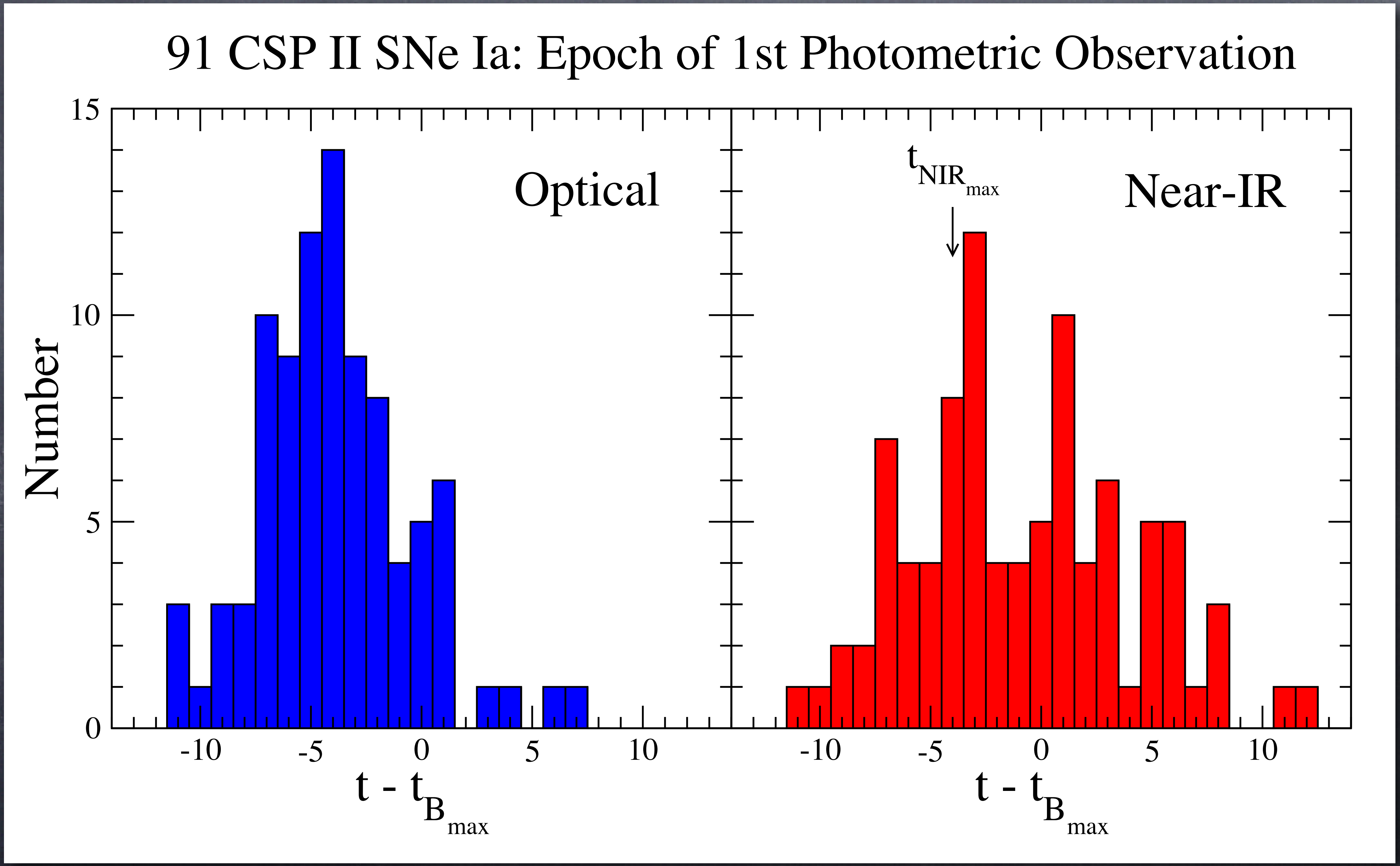


	Median Redshift
YJH	0.050
YJ	0.070
Y	0.085

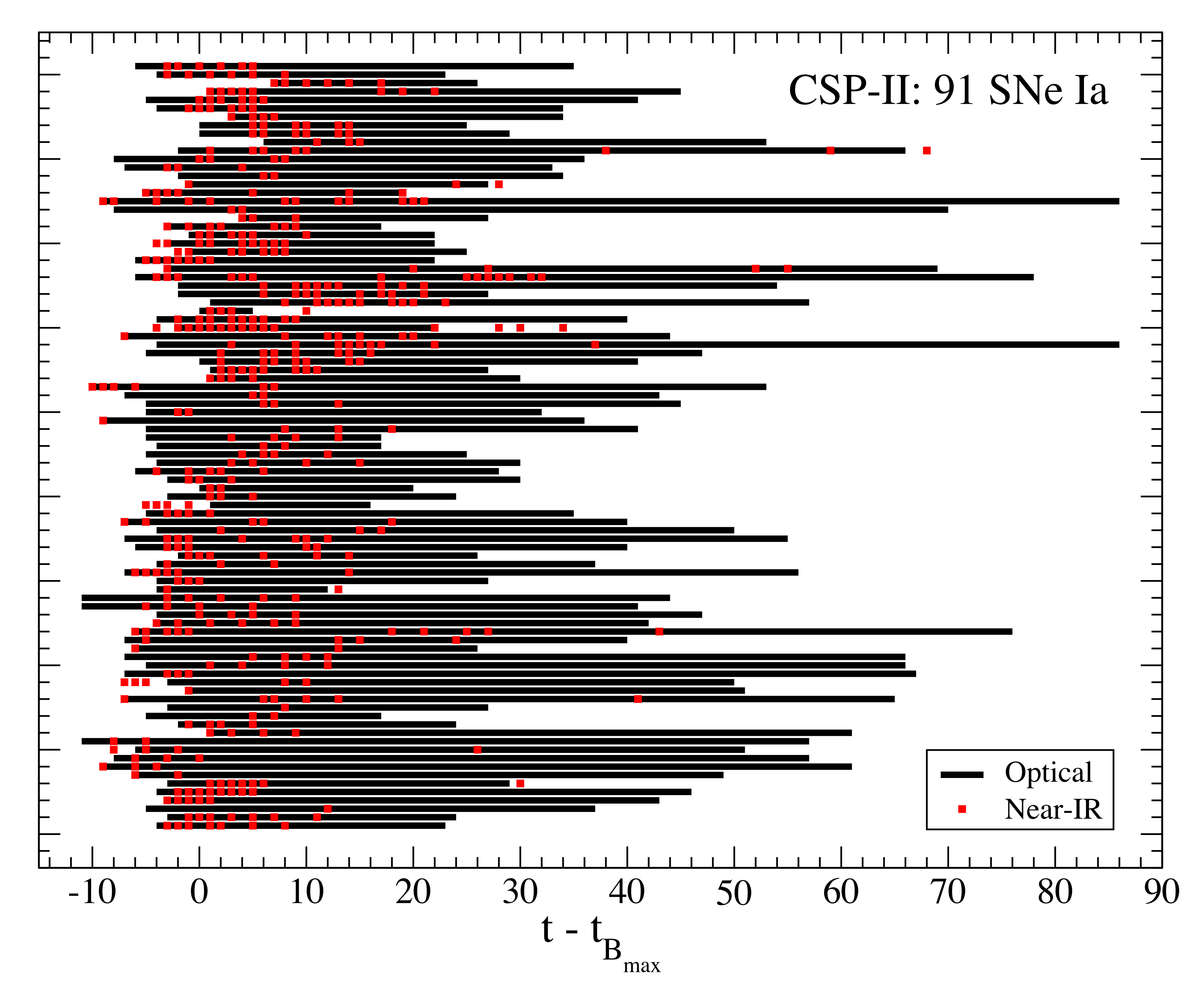
Redshift Distribution



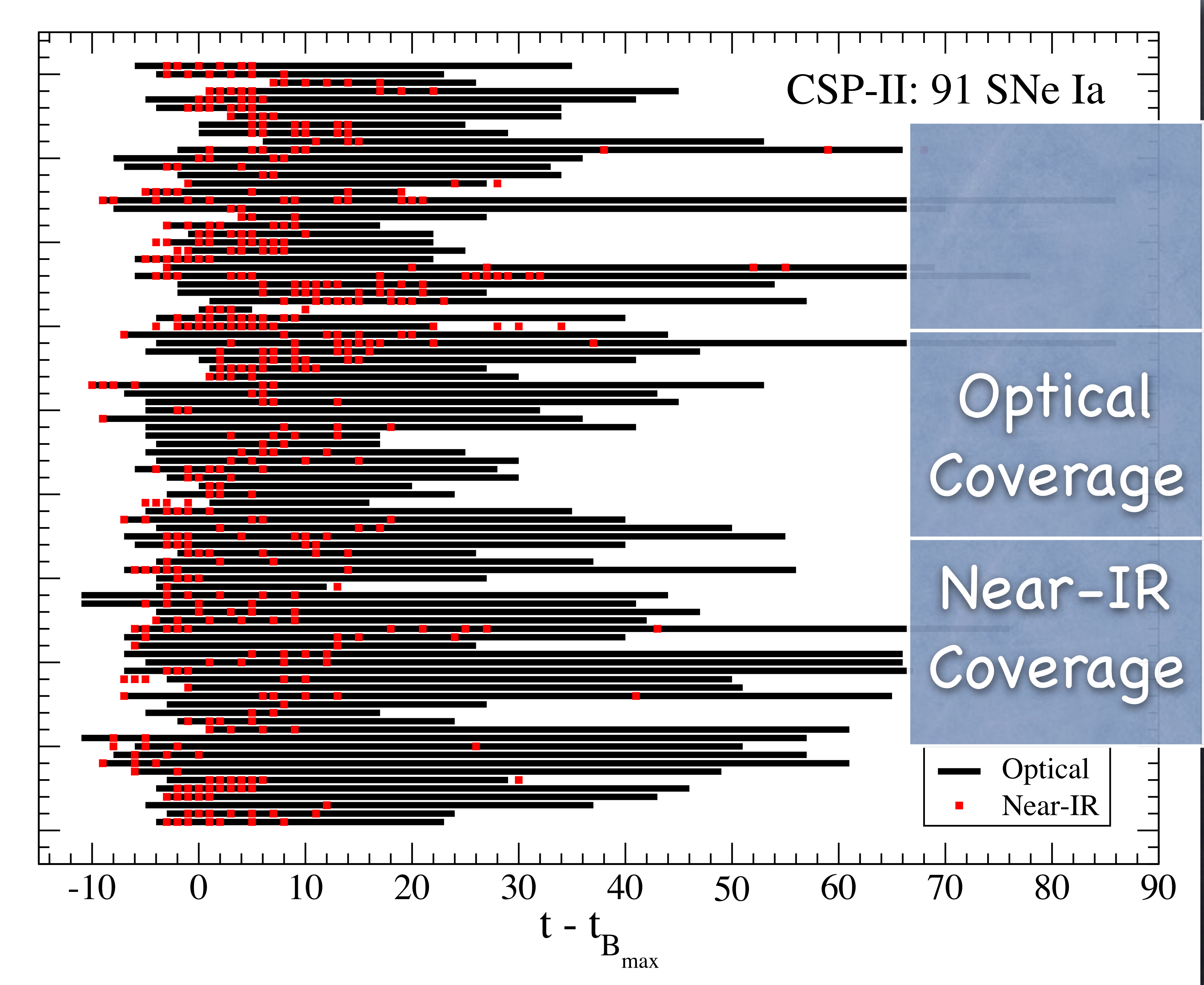
Epoch of First Observation



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



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



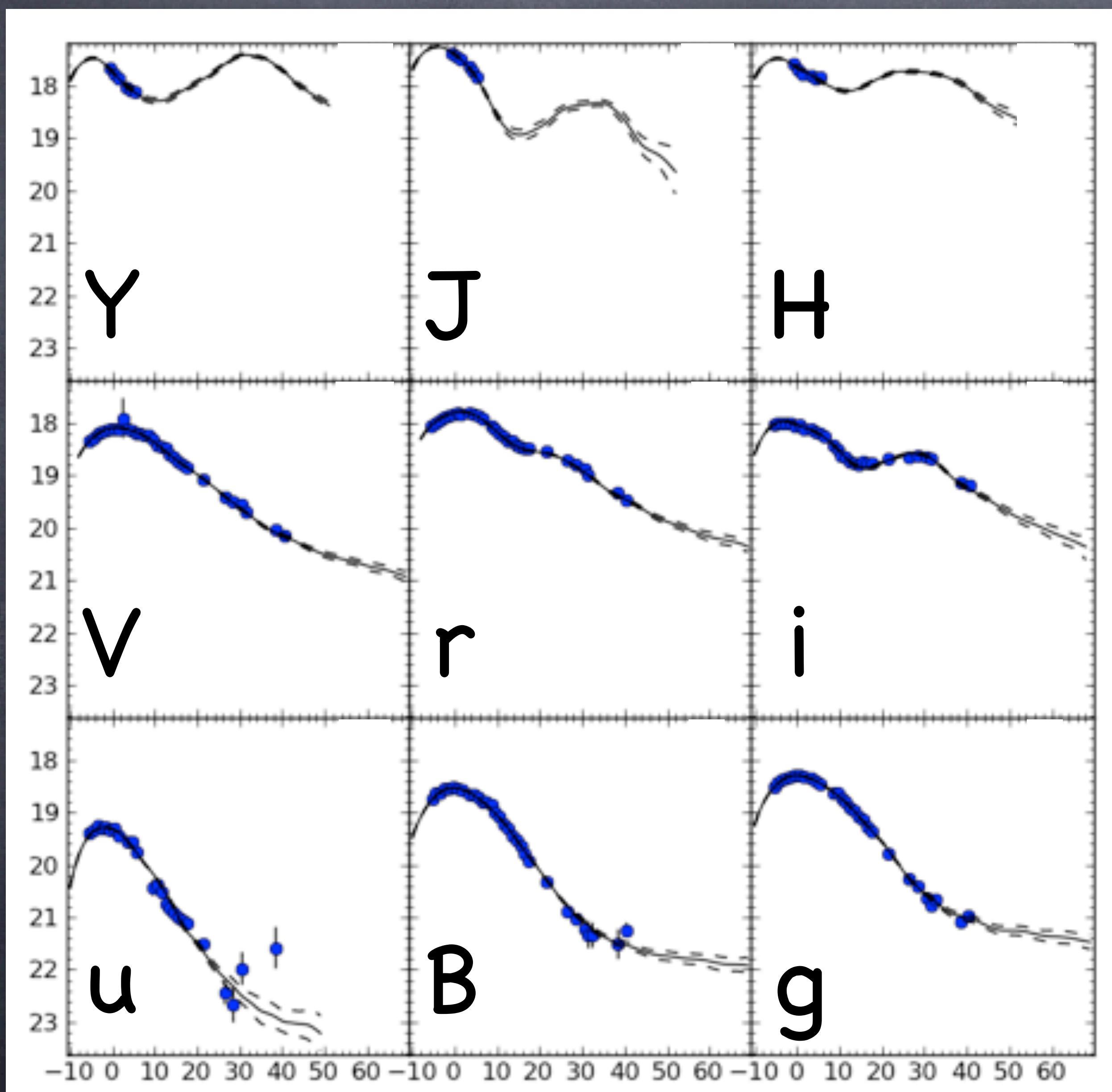
	Median
Optical Coverage	-4 to +36
Near-IR Coverage	-1 to +10

Sample Light Curves

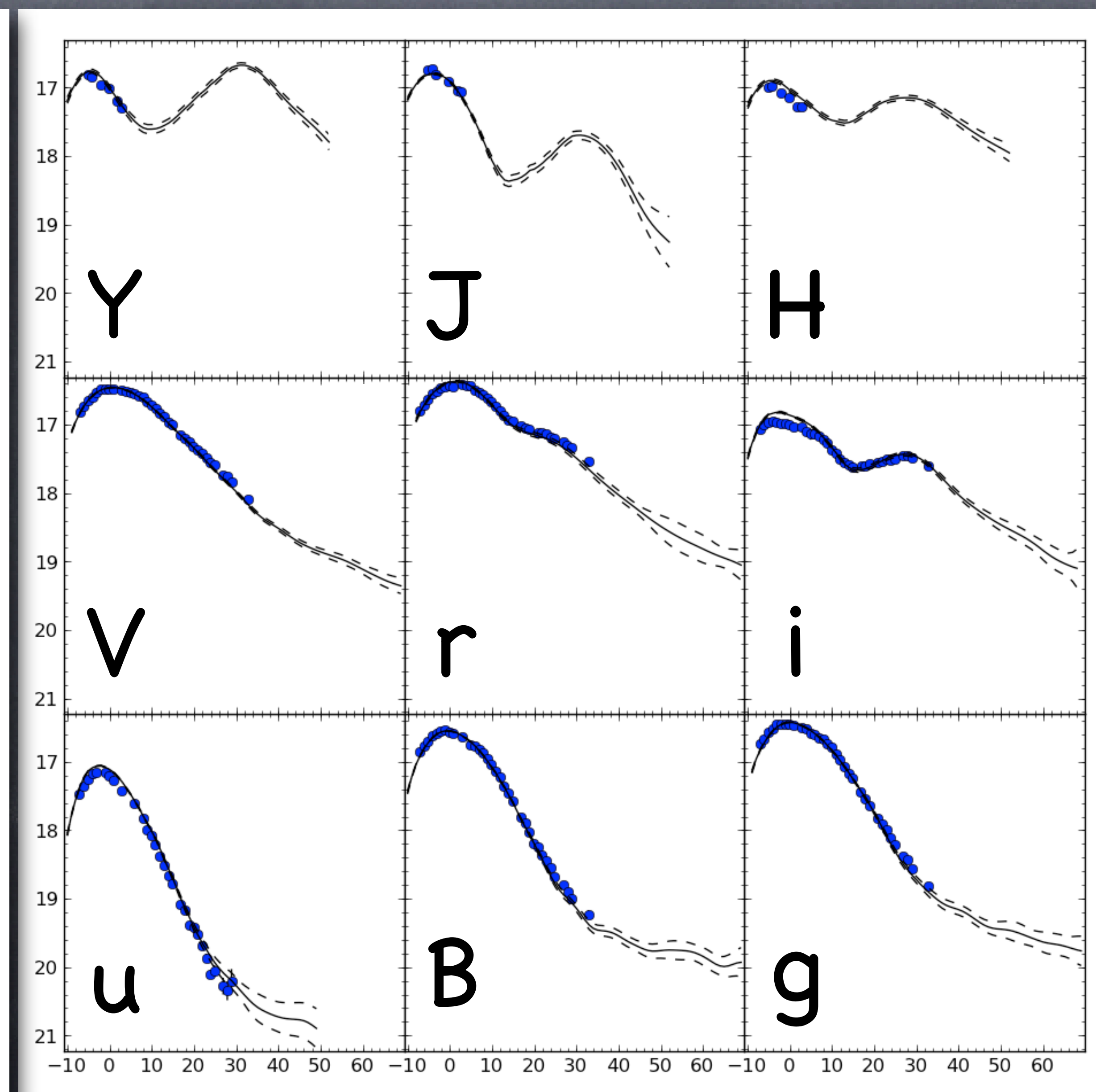
LSQ11ot (z = 0.03)

PTF11pbp (z = 0.03)

magnitude



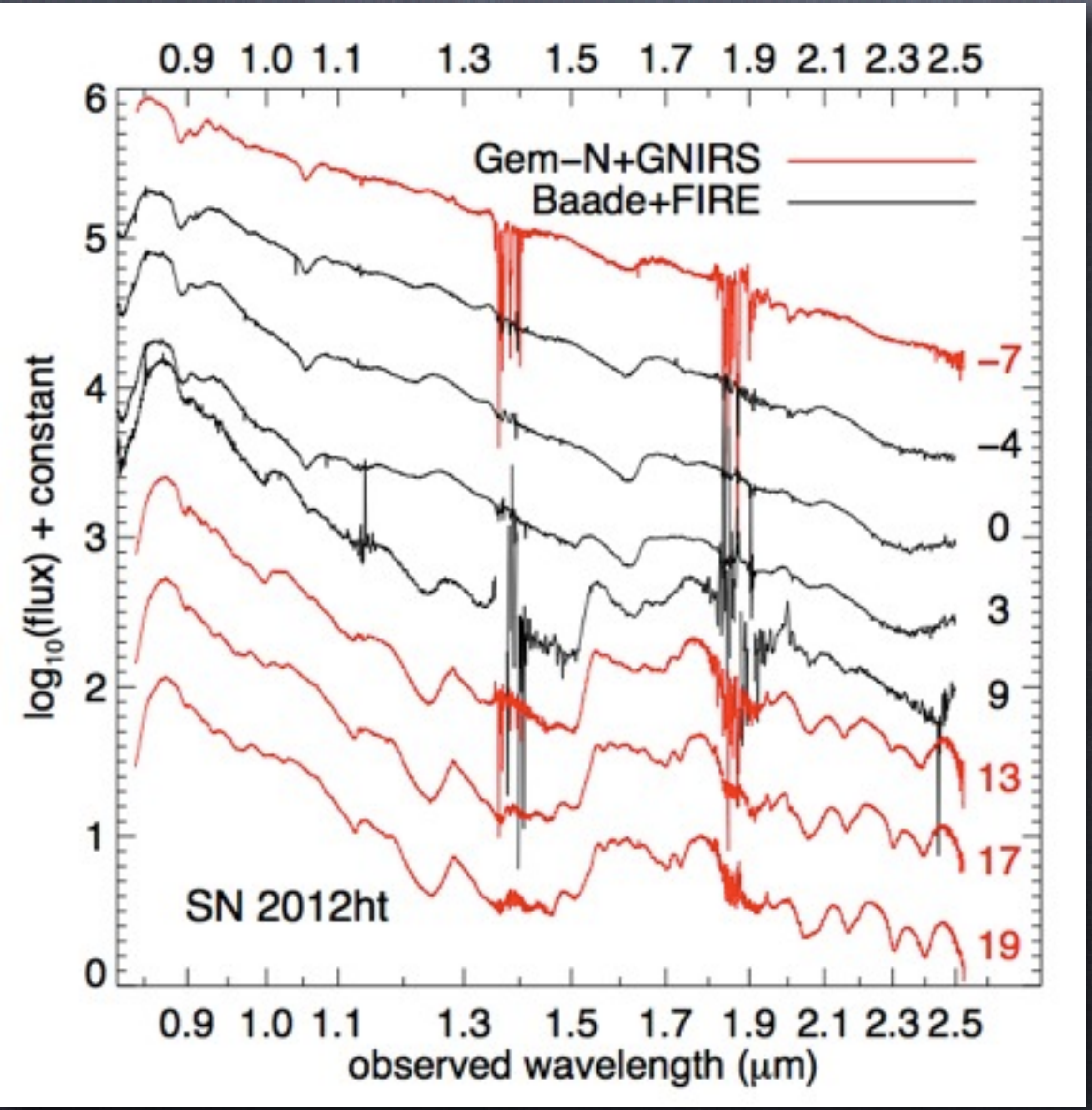
t − t_{Bmax}

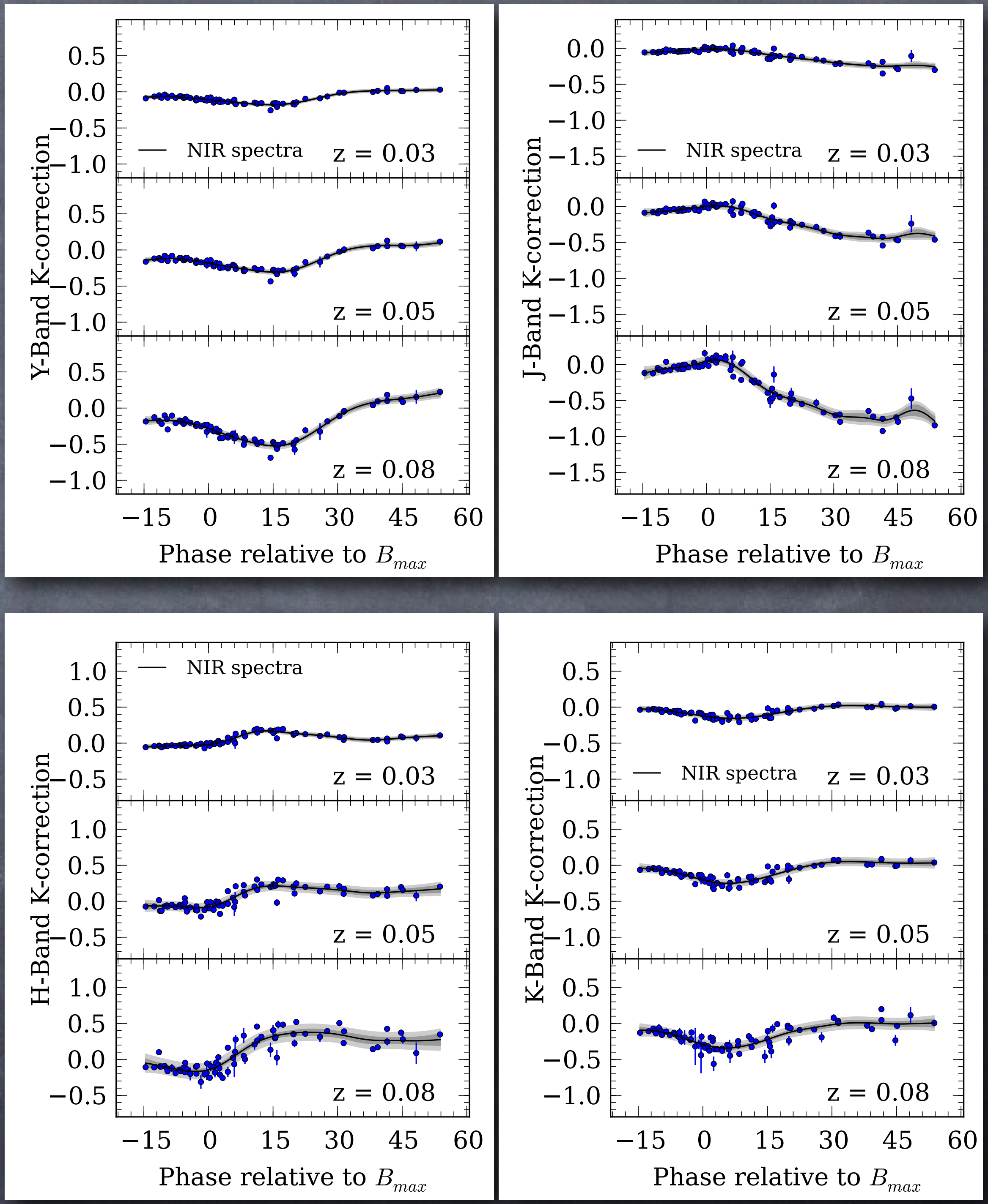


t − t_{Bmax}

Near-IR Spectroscopy

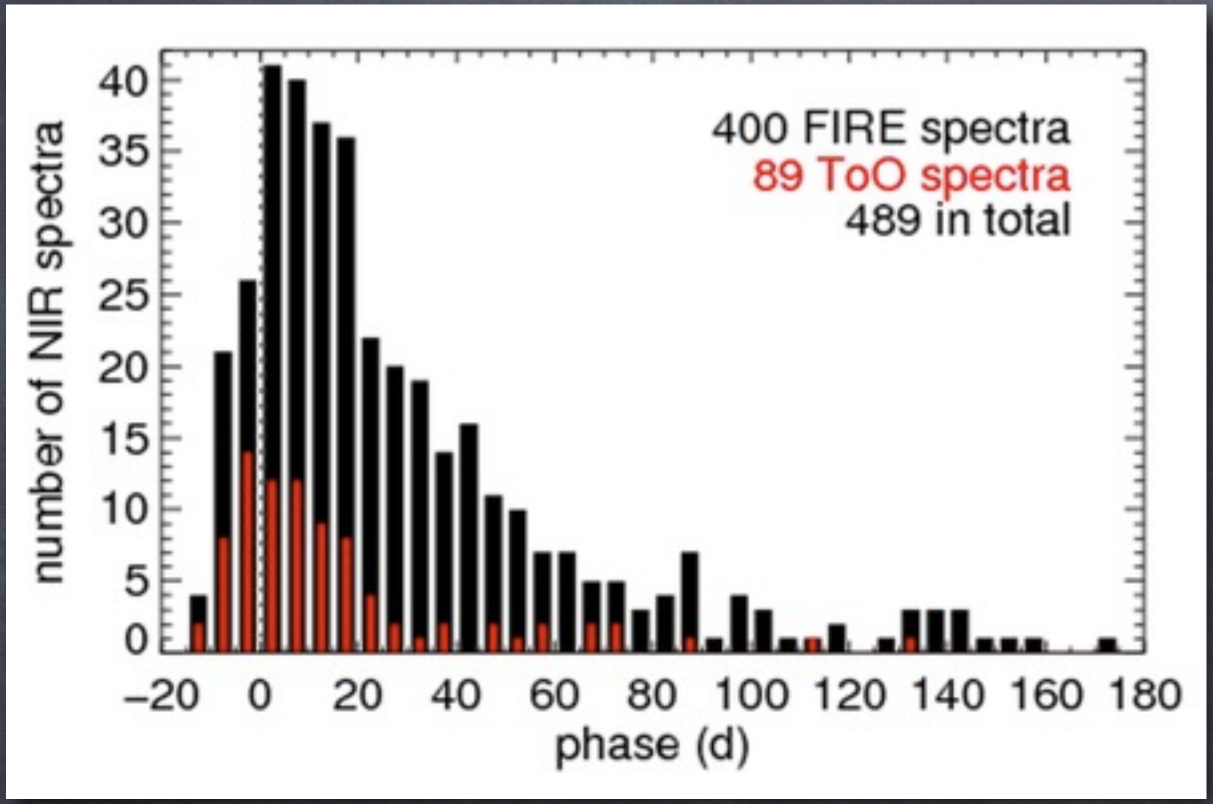
- Near-IR spectral characteristics of SNe Ia are still relatively unexplored
- K-corrections can be large!

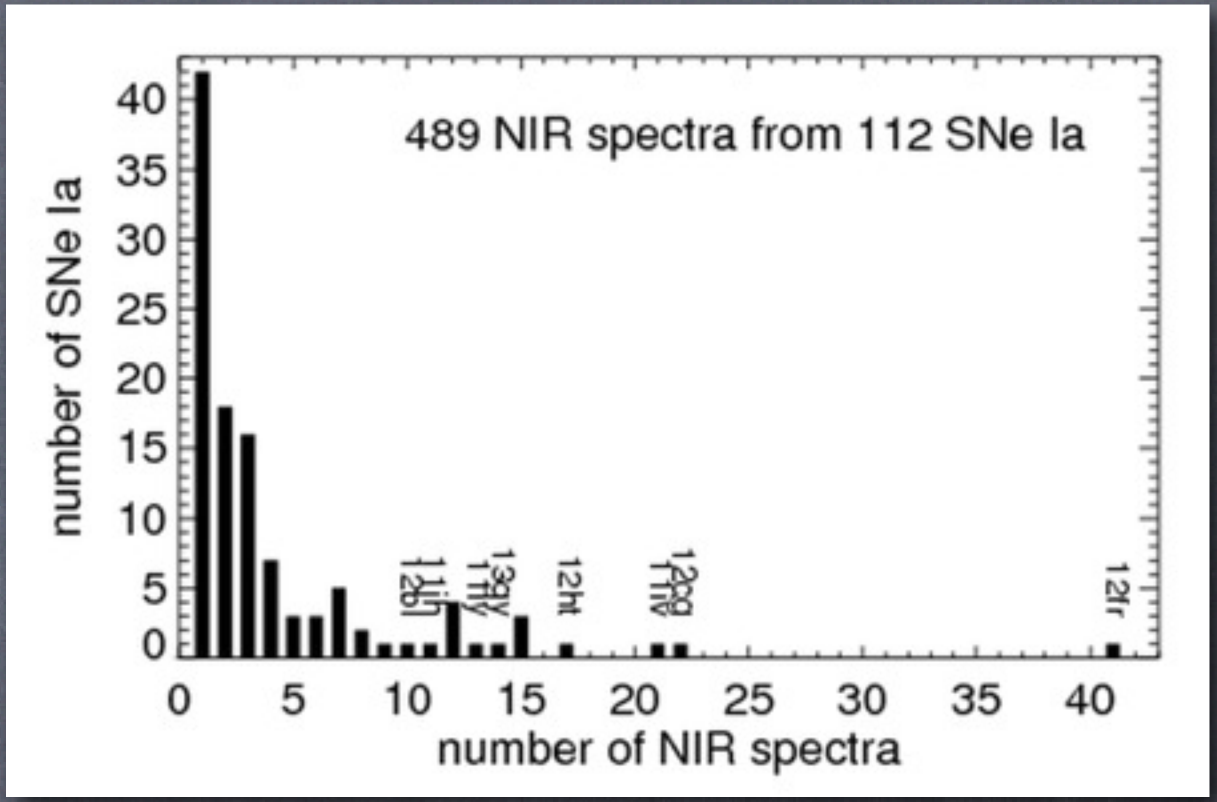




Boldt et al. 2014

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!

Photo by Yuri Beletsky

CSP Papers Published or Submitted to Date

1. Hamuy, M., et al., "The Carnegie Supernova Project: The Low-Redshift Survey", 2006, PASP, 118, 2 [119]
2. Folatelli, G., et al., "SN 2005bf: A Possible Transition Event between Type Ib/c Supernovae and Gamma-Ray Bursts", 2006, ApJ, 641, 1039 [57]
3. Phillips, M.M., et al., "The Peculiar SN 2005hk: Do Some Type Ia Supernovae Explode as Deflagrations?", 2007, PASP, 119, 360 [103]
4. Hsiao, E., et al., "K-Corrections and Spectral Templates of Type Ia Supernovae", 2007, ApJ, 663, 1187 [109]
5. Taubenberger, S., et al., "The Underluminous Type Ia Supernova 2005bl and the Class of Objects Similar to SN 1991bg", 2008, MNRAS, 385, 75 [62]
6. Schweizer, F., et al., "A New Distance to the Antennae Galaxies (NGC 4038/39) Based on the Type Ia Supernova 2007sr", 2008, AJ, 136, 1482 [46]
7. Stritzinger, M. et al., "The He-rich Core-Collapse Supernova 2007Y: Observations from X-ray to Radio Wavelengths", 2009, ApJ, 696, 713 [42]
8. Freedman, W. et al., "The Carnegie Supernova Project: First Near-Infrared Hubble Diagram to z ~ 0.7", 2009, ApJ, 704, 1036 [59]
9. Contreras, C. et al., "The Carnegie Supernova Project: First Photometry Data Release of Type Ia Supernovae", 2010, AJ, 139, 519 [82]
10. Folatelli, G. et al., "The Carnegie Supernova Project: Analysis of the First Sample of Low-Redshift Type Ia Supernovae", 2010, AJ, 139, 120 [121]
11. Höflich, P. et al., "Secondary Parameters of Type Ia Supernova Light Curves", 2010, ApJ, 710, 444 [36]
12. Foley, R. J., et al., "On the Progenitor and Supernova of the SN 2002cx-like SN 2008ge, 2010, AJ, 140, 1321 [16]
13. Stritzinger, M., et al., "The Distance to NGC 1316 (Fornax A) From Observations of Four Type Ia Supernovae", 2010, AJ, 140, 2036 [32]
14. Pignata, G., et al., "SN 2009bb: A Peculiar Broad-Lined Type Ic Supernova", ApJ, 2011, 728, 14 [22]
15. Burns, C., et al., "The Carnegie Supernova Project: Light Curve Fitting with SNooPy", AJ, 2011, 141, 19 [42]

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CSP Papers Published or Submitted to Date (cont.)

16. Stritzinger, M., et al., "The Carnegie Supernova Project: Second Photometry Data Release of Low-Redshift Type Ia Supernovae", AJ, 2011, 142, 156 [44]
17. Folatelli, et al., "Unburned Material in the Ejecta of Type Ia Supernovae", 2012, ApJ, 745, 74 [28]
18. Taddia, et al., "The Type II Supernovae 2006V and 2006au: Two SN 1987A-Like Events", A&A, 537, 140 [9]
19. Phillips, M. M., "Near-Infrared Properties of Type Ia Supernovae", 2012, PASA, 29, 434 [13]
20. Kattner, S. et al., "The Standardizability of Type Ia Supernovae in the Near-Infrared: Evidence for a Luminosity-Decline Rate Relation in the Near-Infrared", 2012, PASP, 124, 114 [20]
21. Mosher, J., et al., "A Precision Photometric Comparison between SDSS-II and CSP Type Ia Supernova Data", 2012, AJ, 144, 17 [8]
22. Taddia, F., et al., "Supernova 2008J: Early Time Observations of a Heavily Reddened SN 2002ic-like Transient", 2012, A&A, 545, L7 [13]
23. Stritzinger, M., et al., "Multi-wavelength Observations of the Enduring Type IIn Supernovae 2005ip and 2006jd", 2012, ApJ, 756, 173 [18]
24. Hsiao, E. Y., et al., "The Earliest Near-infrared Time-series Spectroscopy of a Type Ia Supernova", 2013, ApJ, 766, 72 [16]
25. Foley, R. J., et al., "Type Iax Supernovae: A New Class of Stellar Explosion", 2013, ApJ, 767, 57 [37]
26. Childress, M. J., "Spectroscopic Observations of SN 2012fr: A Luminous, Normal Type Ia Supernova with Early High-velocity Features and a Late Velocity Plateau", 2013, ApJ, 770, 29 [13]
27. Milisavljevic, D., et al., "SN 2012au: A Golden Link between Superluminous Supernovae and Their Lower-luminosity Counterparts", 2013, ApJ, 770, L38 [9]
28. Taddia, F., et al. "Carnegie Supernova Project: Observations of Type IIn Supernovae", 2013, A&A, 555, 10 [14]
29. Folatelli, G., et al. "Spectroscopy of Type Ia Supernovae by the Carnegie Supernova Project", 2013, ApJ, 773, 53 [11]
30. Phillips, M. M., et al., "On the Source of the Dust Extinction in Type Ia Supernovae and the Discovery of Anomalously Strong Na I Absorption", ApJ, 779, 38 [13]

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CSP Papers Published or Submitted to Date (cont.)

31. Stritzinger, M., et al., "Optical and Near-IR Observations of the Faint and Fast 2008ha-like Supernova 2010ae", 2014, A&A, 561, 146 [1]
32. Margutti, R., et al., "A Panchromatic View of the Restless SN 2009ip Reveals the Explosive Ejection of a Massive Star Envelope", 2014, ApJ, 780, 21 [30]
33. Takáts, K., et al., "SN 2009N: Linking Normal and Subluminous Type II-P SNe", 2014, MNRAS, 438, 368 [4]
34. Bufano, F., et al., "SN 2011hs: a Fast and Faint Type IIb Supernova from a Supergiant Progenitor", 2014, MNRAS, 439, 1807 [2]
35. Anderson, J. P., et al., "Characterizing the V-band Light-curves of Hydrogen-rich Type II Supernovae", 2014, ApJ, 786, 67 [4]
36. Gutierrez, C. P., et al., "Hα Spectral Diversity of Type II Supernovae: Correlations with Photometric Properties", 2014, ApJ, 787, L15 [0]
37. Dessart, L., et al., "Type II Plateau supernovae as metallicity probes of the Universe", 2014, MNRAS, 440, 1856 [1]
38. Anderson, J. P., et al., "Analysis of Blueshifted Emission Peaks in Type II Supernovae", 2014, MNRAS, 441, 671 [1]
39. Burns, C. R., et al., "The Carnegie Supernova Project: Intrinsic Colors of Type Ia Supernovae", 2014, ApJ, 789, 32 [0]
40. Scalzo, R. A., et al., "Early Ultraviolet Emission in the Type Ia Supernova LSQ12gdj: No Evidence for Ongoing Shock Interaction", 2014, MNRAS, submitted (arXiv:1404.1002) [0]
31. Stritzinger, M., et al., "Comprehensive Observations of the Bright and Energetic Type Iax SN 2012Z: Interpretation as a Chandrasekhar Mass White Dwarf Explosion", 2014, A&A, submitted [0]
41. Prieto, J.L., et al., "A Study of the Type Ia/IIn Supernova 2005gj from X-ray to the Infrared: Paper I", ApJ, submitted (arXiv:0706.4088) [61]

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