WFIRST Supernovae for Dark Energy Measurements

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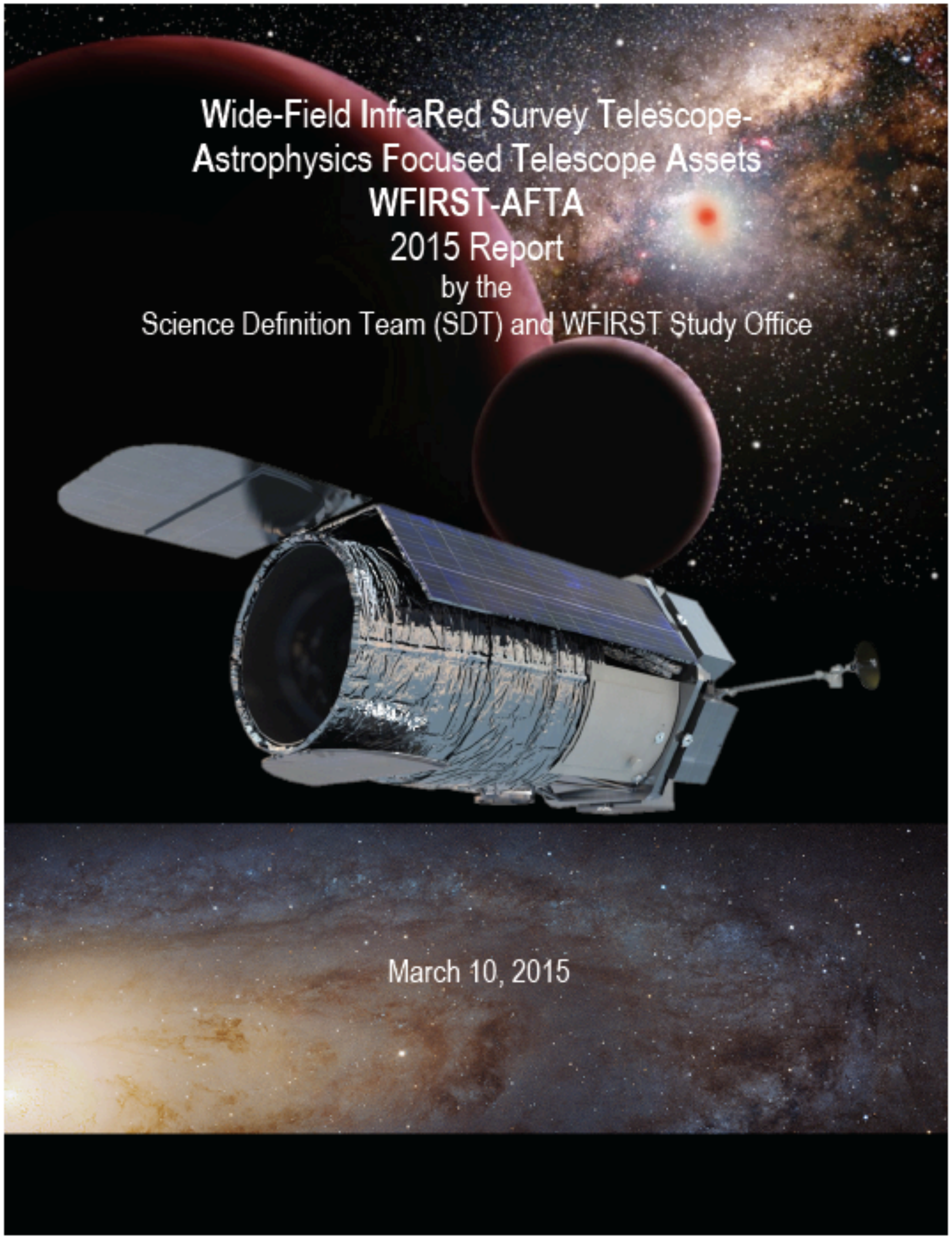
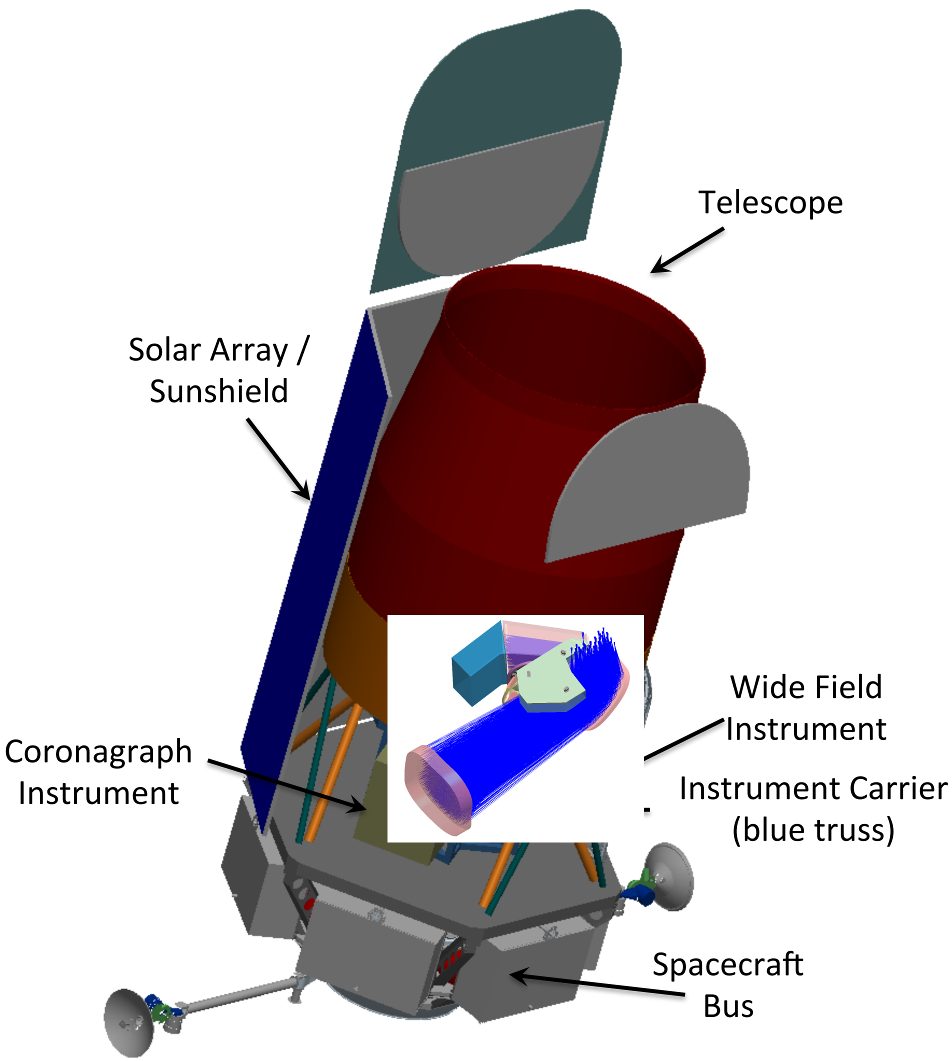
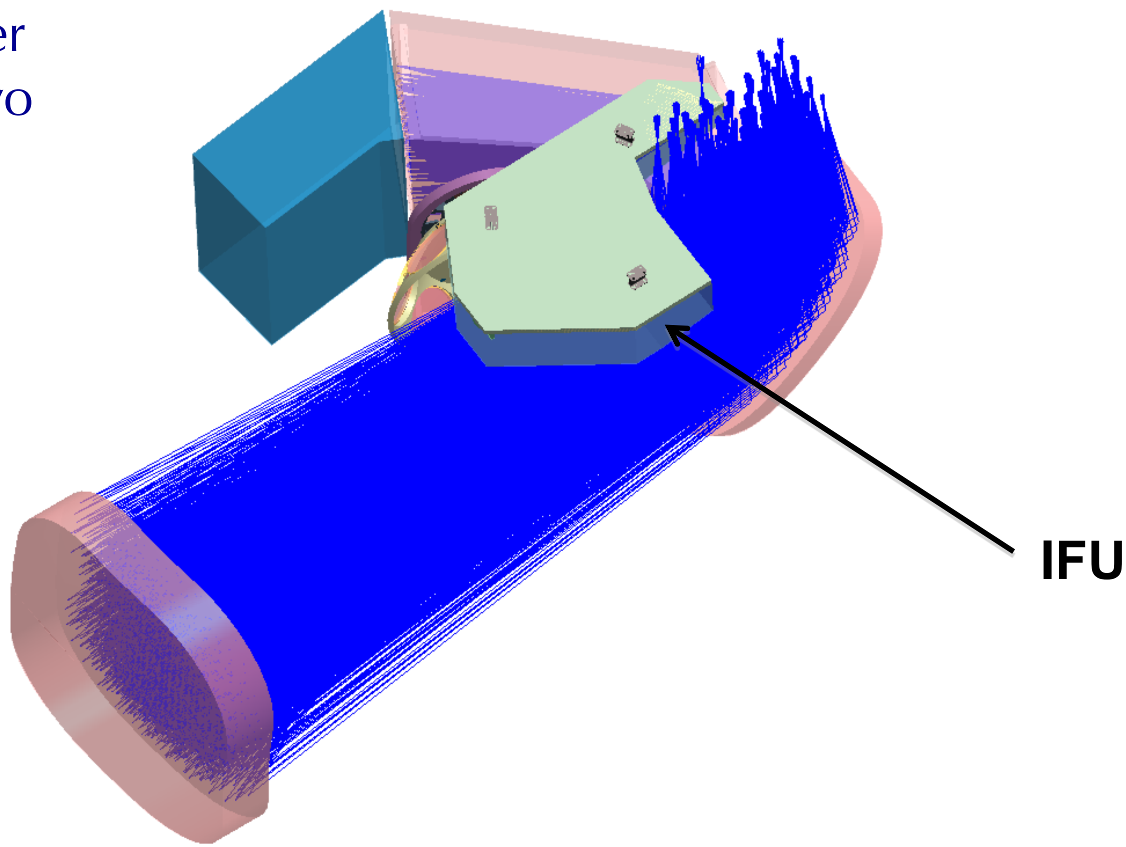

Wide-Field InfraRed Survey Telescope-
Astrophysics Focused Telescope Assets
WFIRST-AFTA
2015 Report
by the
Science Definition Team (SDT) and WFIRST Study Office
March 10, 2015



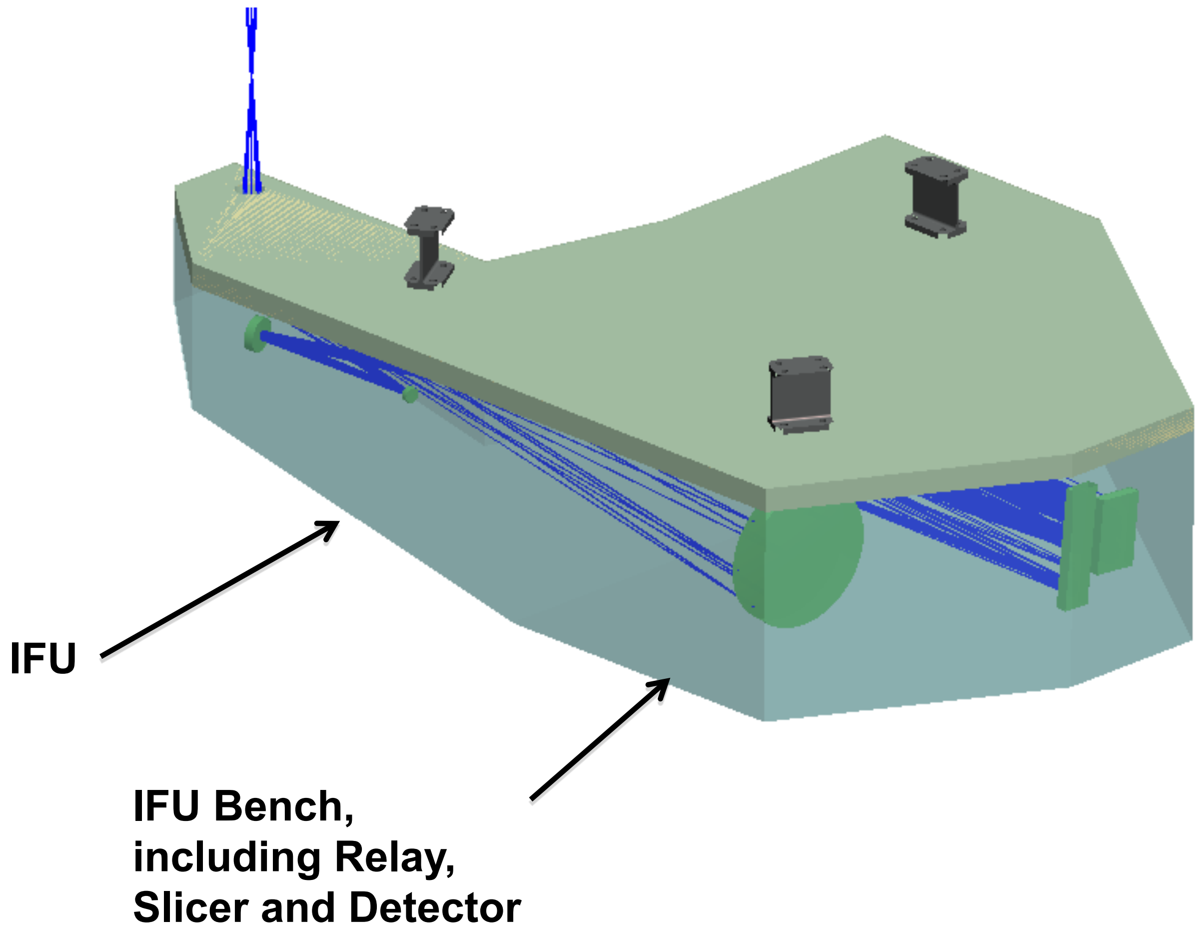
Telescope
Solar Array /
Sunshield
Wide Field
Instrument
Instrument Carrier
(blue truss)
Coronagraph
Instrument
Spacecraft
Bus

Use the 0.28 sq degree Wide Field Imager (with 0.11″ pixels) to discover supernovae in two filter bands.

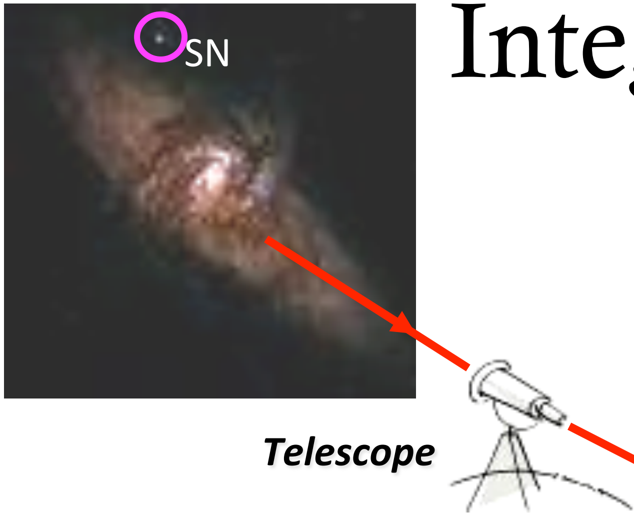


Small, compact assembly:

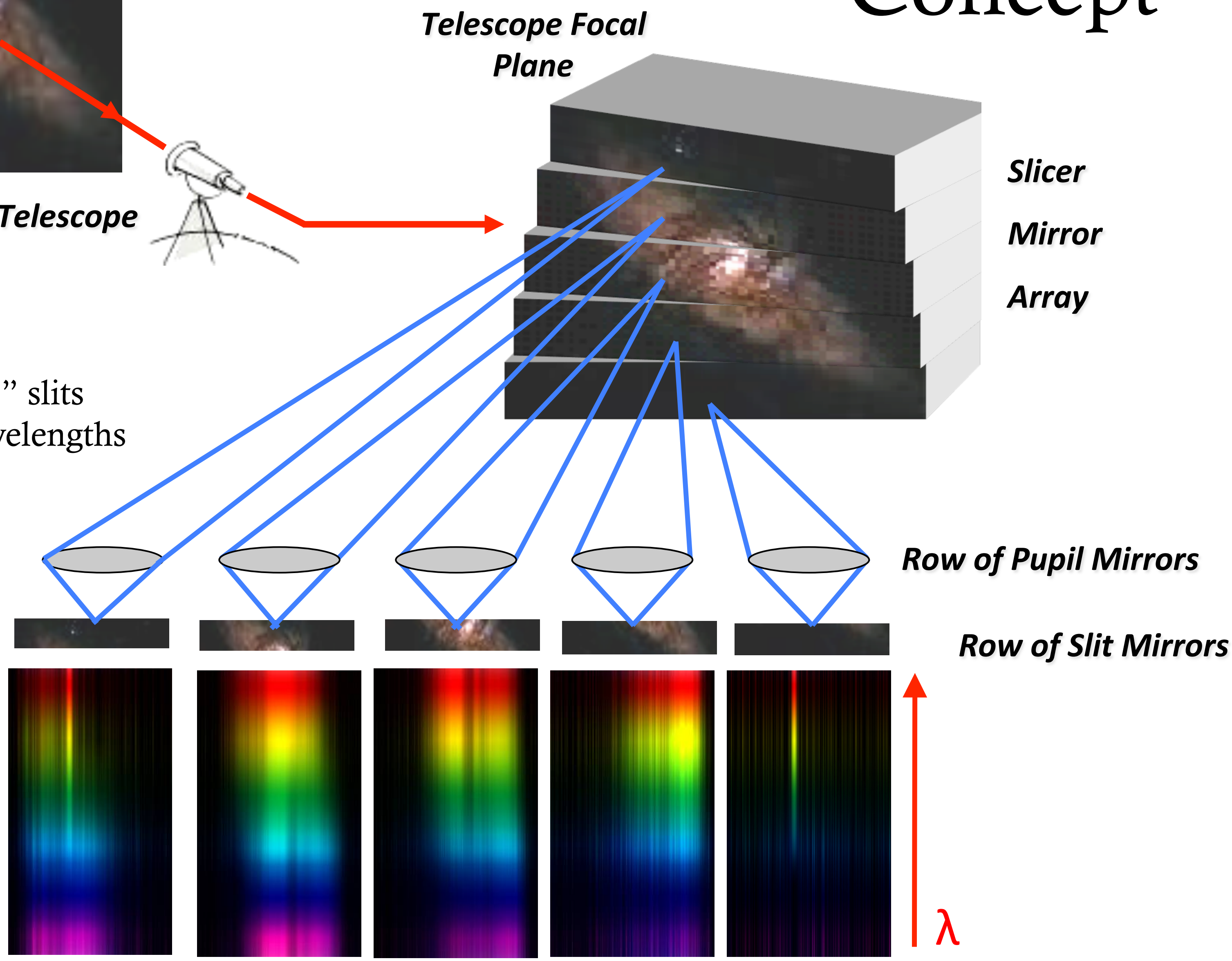
- ~ 6 to 7 kg
- 30 x 50 x 12.5 cm



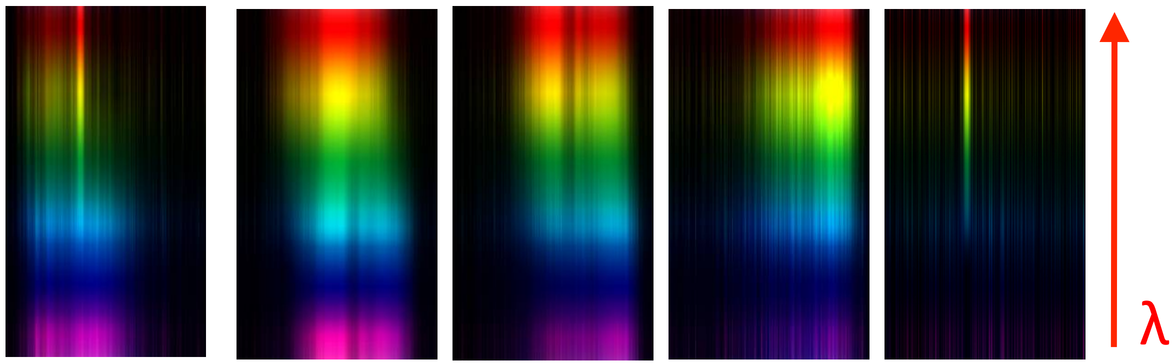
Integral Field Spectroscopy Concept

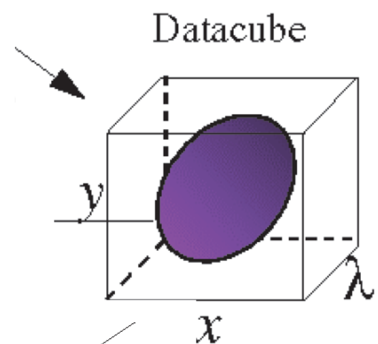


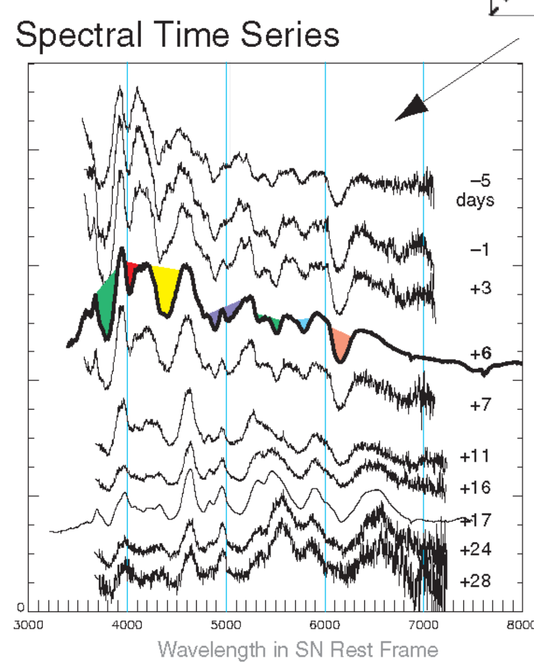
<u>Baseline</u>:
3" x 3" with 0.15” slits
0.6 – 2.0 μm wavelengths
R = ~ 75—100



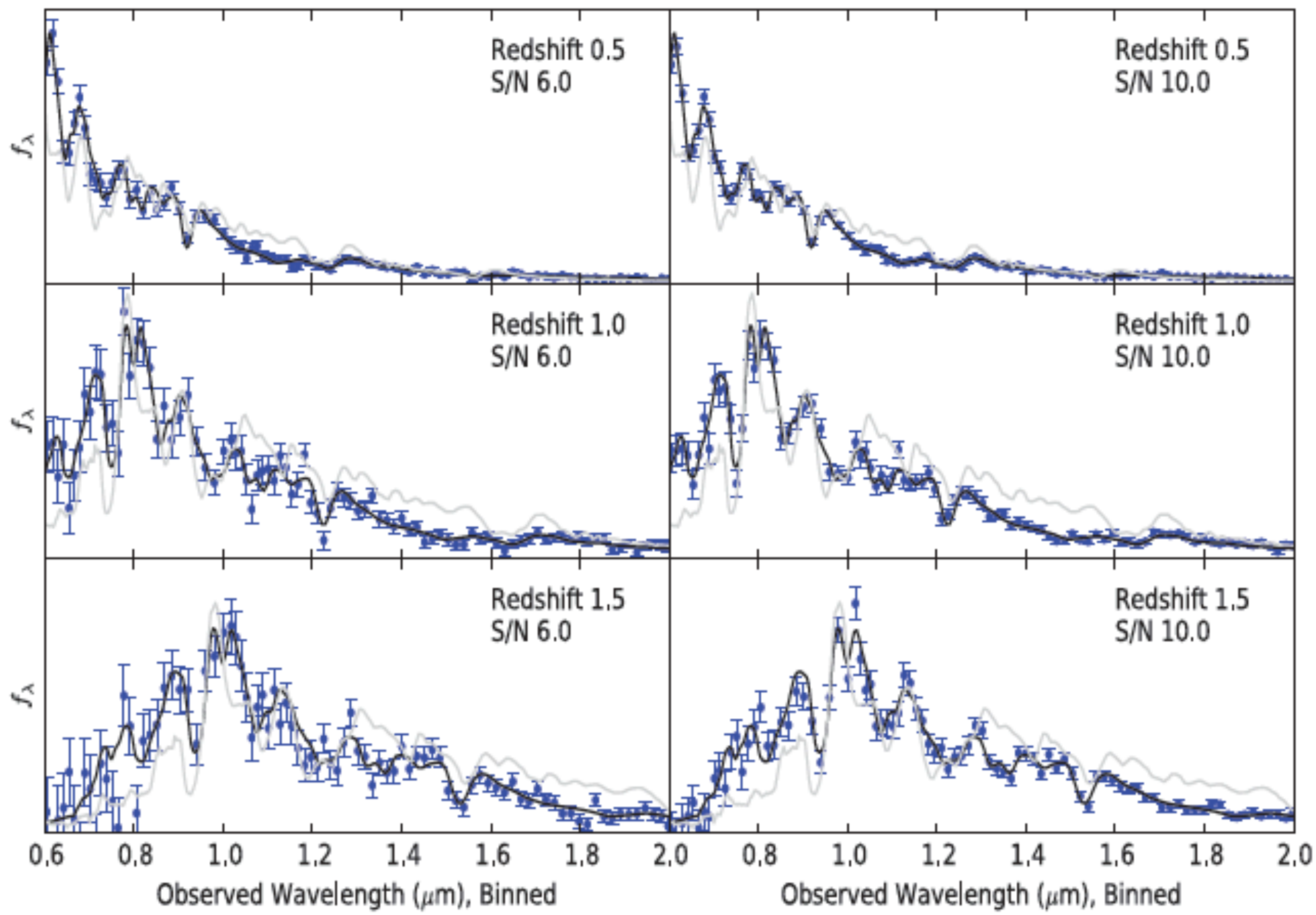
IFU = “Integral Field Unit”







WFIRST-AFTA


Redshift 0.5
S/N 6.0
Redshift 0.5
S/N 10.0
Redshift 1.0
S/N 6.0
Redshift 1.0
S/N 10.0
Redshift 1.5
S/N 6.0
Redshift 1.5
S/N 10.0
f_λ
0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0
Observed Wavelength (μm), Binned

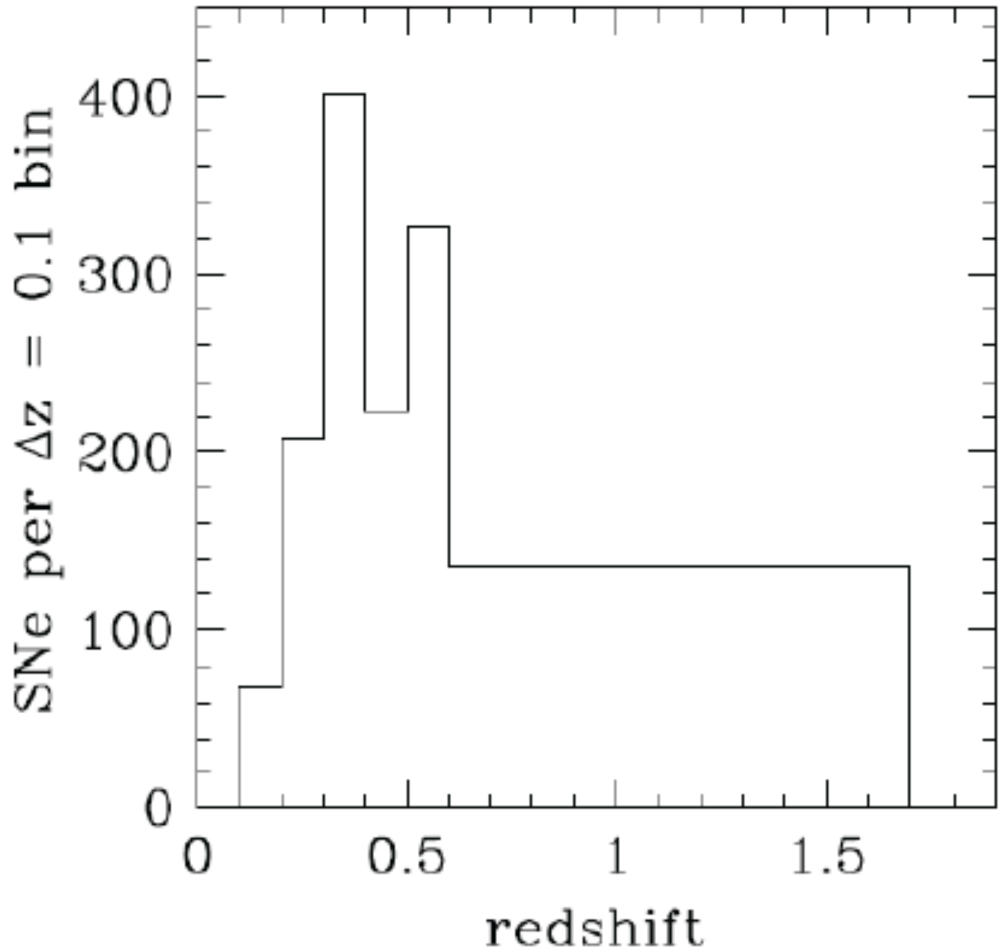
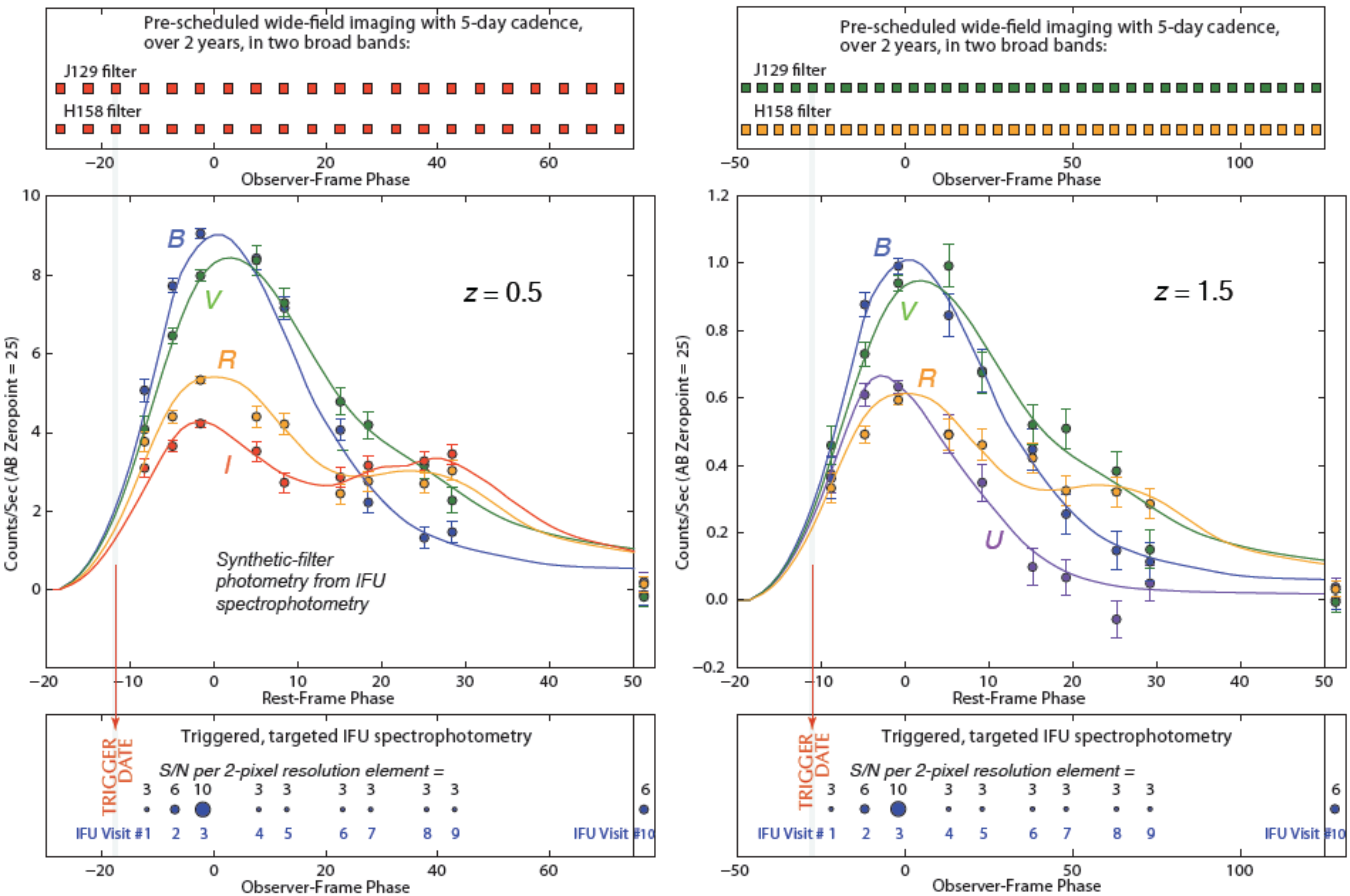
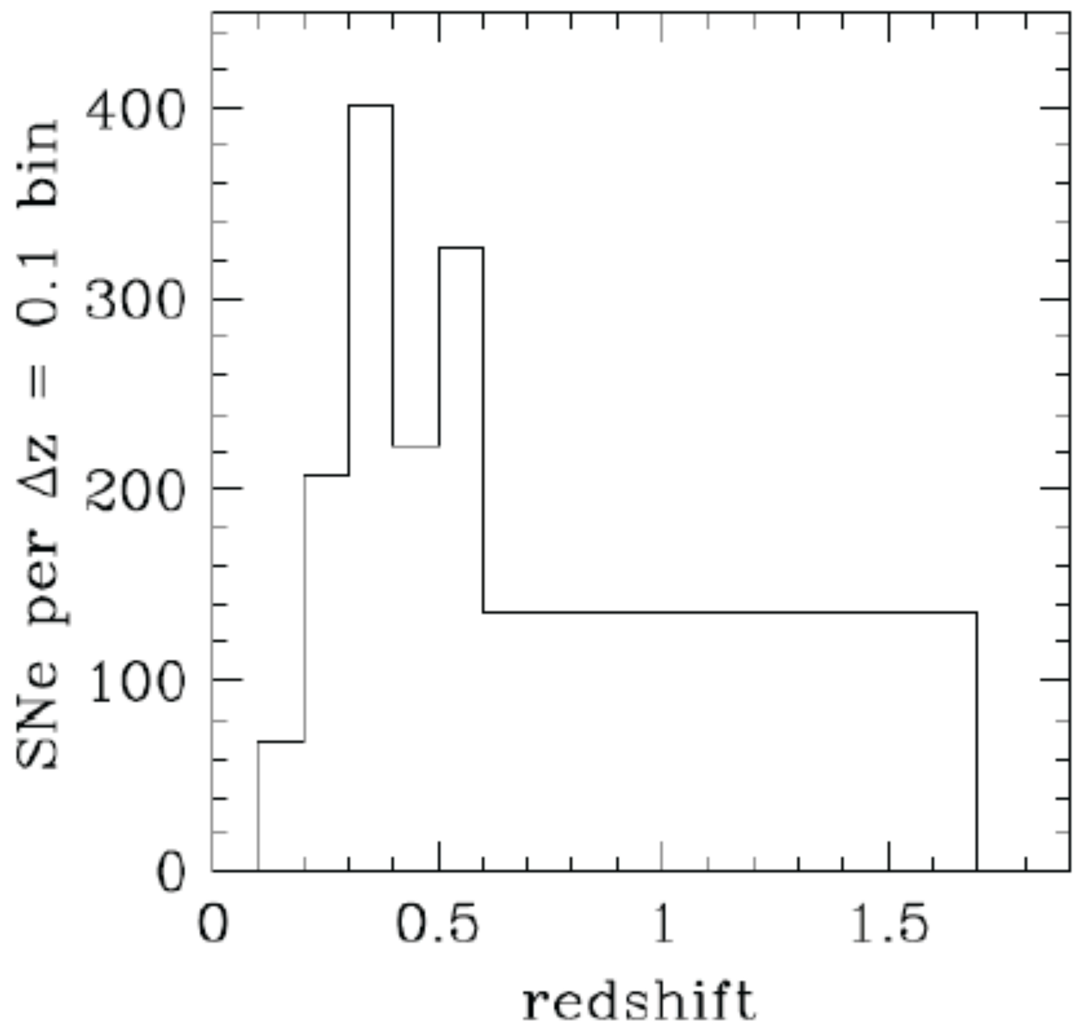


Figure 2-6: Expected number of Type Ia SNe to be followed in each Δz = 0.1 redshift bin. For z > 0.6 there are, by design, 136 SNe followed up with spectroscopic observations in each bin (from a larger number detected). The total number of SNe is 2725.



Pre-scheduled wide-field imaging with 5-day cadence, over 2 years, in two broad bands:
J129 filter
H158 filter
Observer-Frame Phase
Counts/Sec (AB Zeropoint = 25)
B
V
R
I
z = 0.5
Synthetic-filter photometry from IFU spectrophotometry
Rest-Frame Phase
TRIGGER DATE
Triggered, targeted IFU spectrophotometry
S/N per 2-pixel resolution element =
IFU Visit #1
IFU Visit #10
Pre-scheduled wide-field imaging with 5-day cadence, over 2 years, in two broad bands:
J129 filter
H158 filter
Observer-Frame Phase
Counts/Sec (AB Zeropoint = 25)
B
V
R
U
z = 1.5
Rest-Frame Phase
TRIGGER DATE
Triggered, targeted IFU spectrophotometry
S/N per 2-pixel resolution element =
IFU Visit # 1
IFU Visit #10

What does this spectrophotometry make possible?



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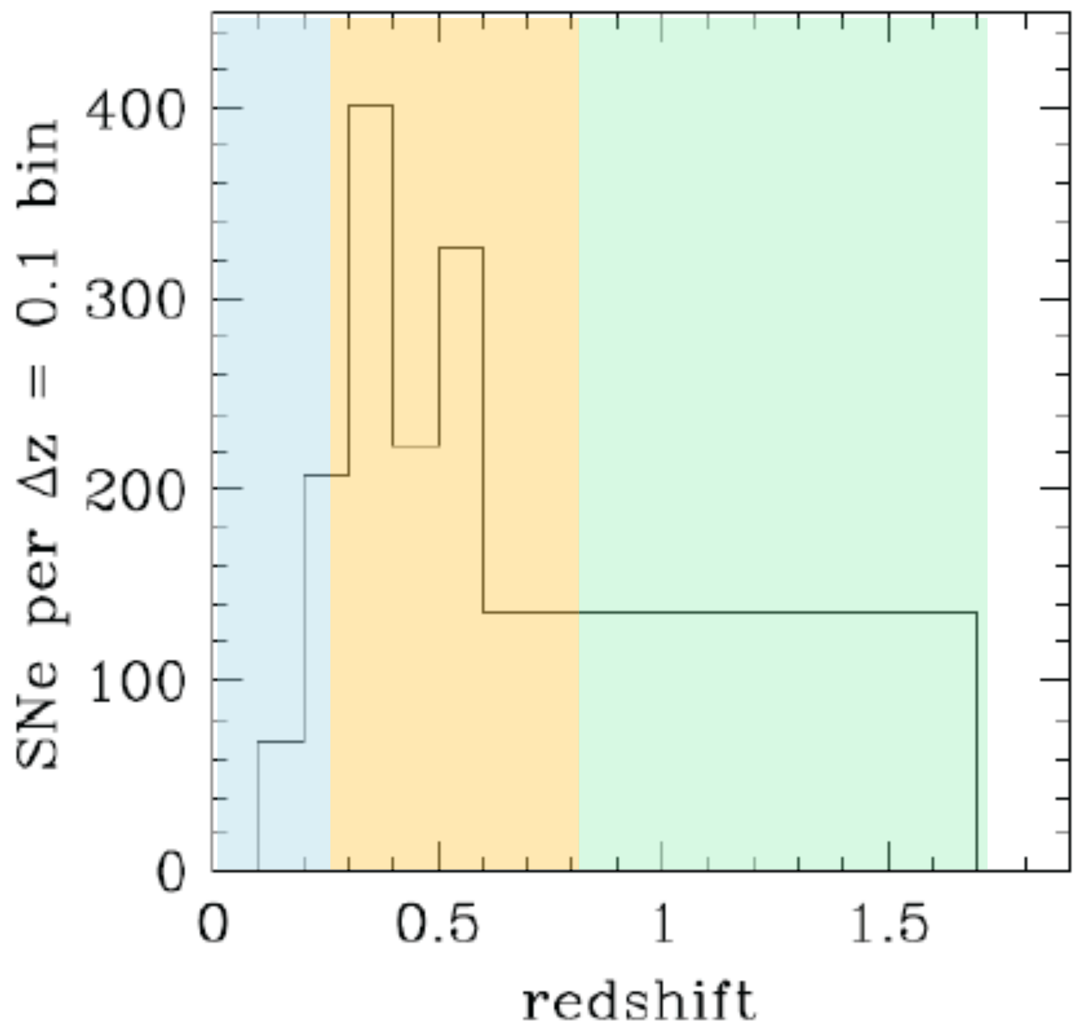

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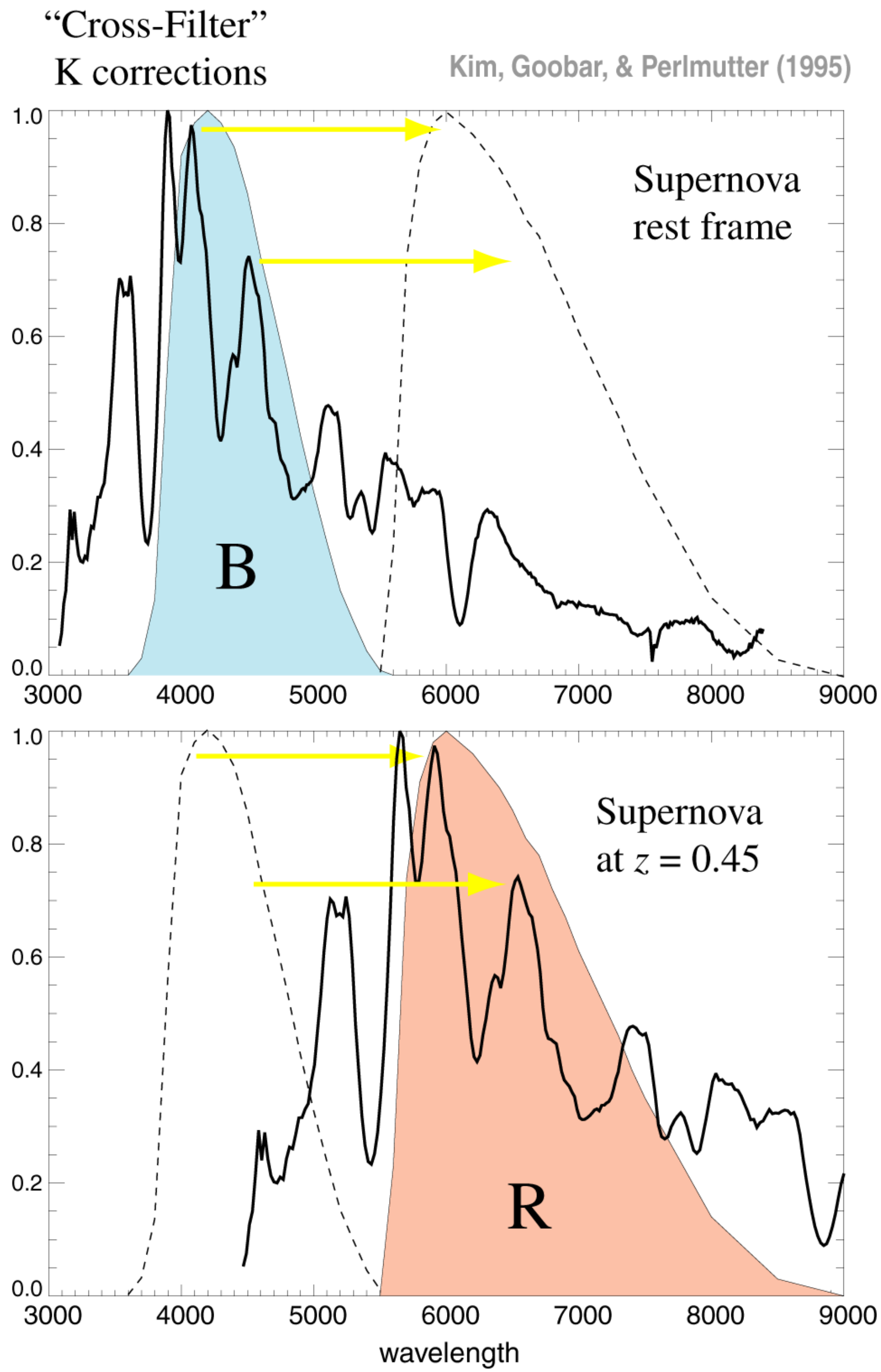
What does this spectrophotometry make possible?

At all redshifts:

- Removes K-correction systematics
- Provides photometry at the reddest available wavelengths for a given redshift.
- Identifies Type Ia SNe

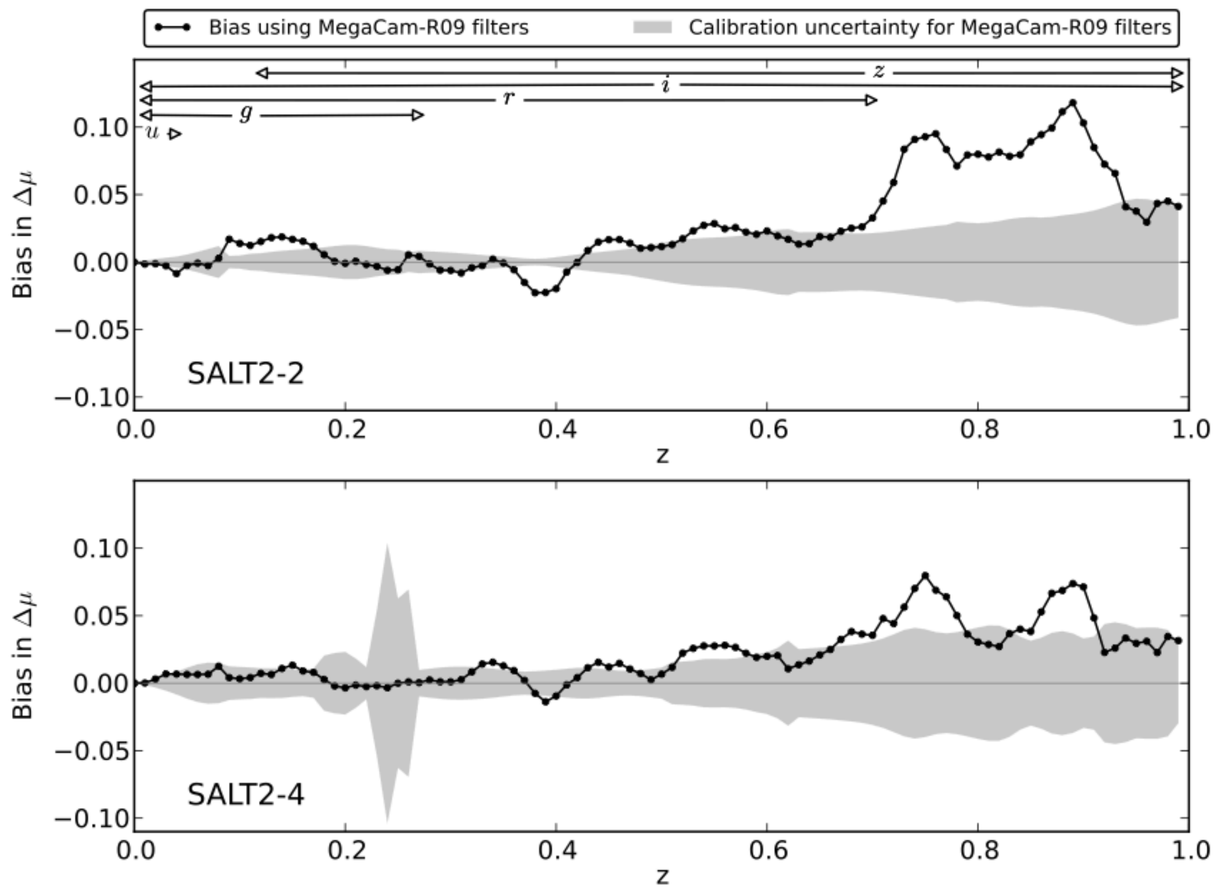


But when the filters don't match perfectly across redshift, this approach is accurate only to the extent that the spectral template family captures the distribution of SN Ia behavior – at both low and high redshift.

Average K-correction bias from a single-parameter spectral time series

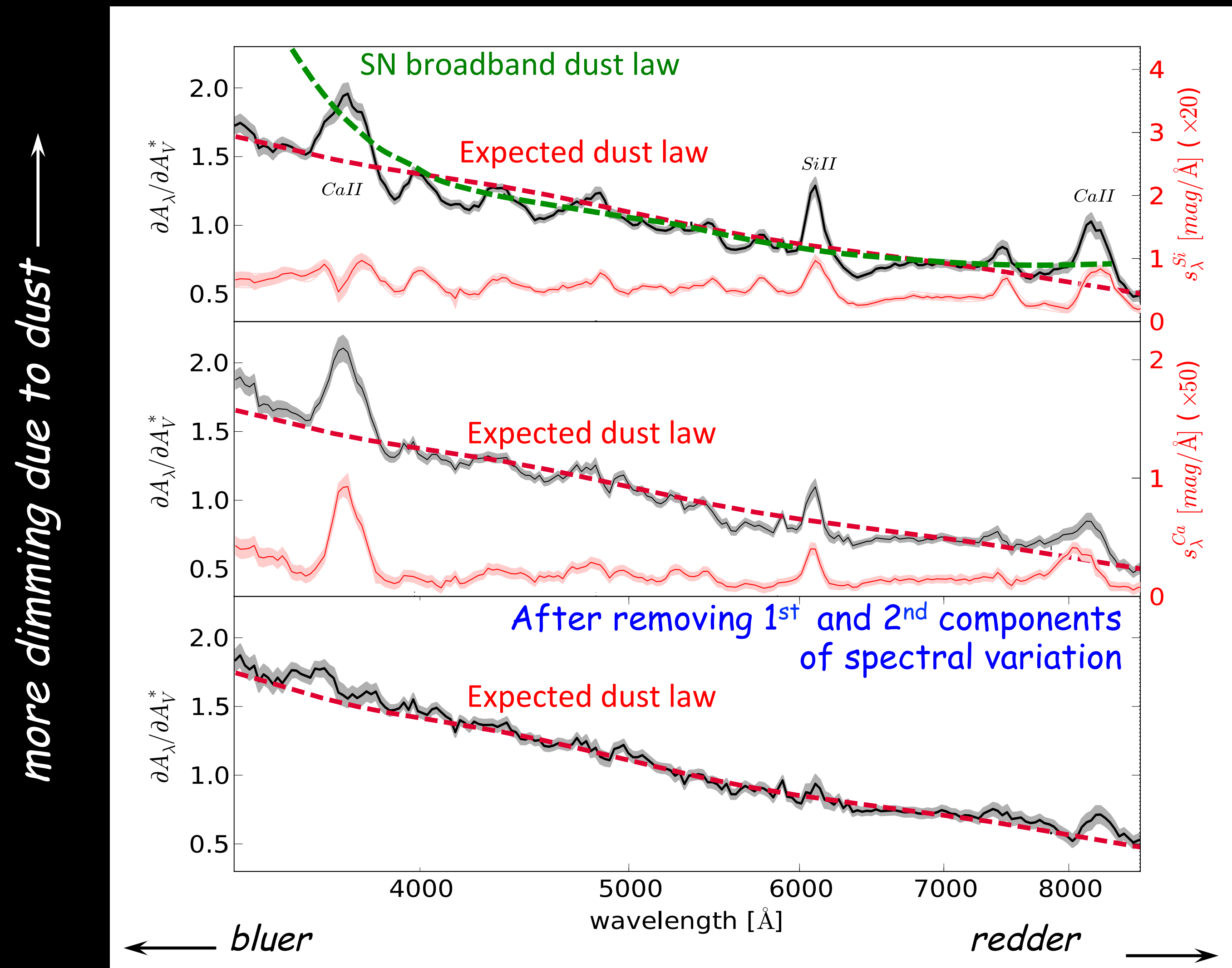
Implied bias on current estimates of *w* is 0.03. This compares with overall error of 0.06

Bias on *w* in the range 0.03 – 0.06 if there is population drift, even if full spectral diversity is sampled with nearby SNe



Saunders+ (ApJ 2015)
Nearby SN Factory

Dust Systematic: Spectral indicator distinguishes dust reddening from intrinsic SN color



Chotard et al 2011 (SNfactory)

THE ASTROPHYSICAL JOURNAL

IMPROVING COSMOLOGICAL DISTANCE MEASUREMENTS USING TWIN TYPE IA SUPERNOVAE

H. K. Fakhouri[1,2], K. Boone[1,2], G. Aldering[1], P. Antilogus[3], C. Aragon[1], S. Bailey[1], C. Baltay[4], K. Barbary[2], D. Baugh[5], S. Bongard[3], C. Buton[6], J. Chen[5], M. Childress[7], N. Chotard[6], Y. Copin[6], P. Fagrelius[1,2], U. Feindt[8], M. Fleury[3], D. Fouchez[9], E. Gangler[10], B. Hayden[1], A. G. Kim[1], M. Kowalski[8,11], P.-F. Leget[10], S. Lombardo[8], J. Nordin[1,8], R. Pain[3], E. Pecontal[12], R. Pereira[6], S. Perlmutter[1,2], D. Rabinowitz[4], J. Ren[1,2], M. Rigault[8], D. Rubin[1,13], K. Runge[1], C. Saunders[1,2], R. Scalzo[7], G. Smadja[6], C. Sofiatti[1,2], M. Strovink[1,2], N. Suzuki[1], C. Tao[5,9], R. C. Thomas[14], B. A. Weaver[15] (The Nearby Supernova Factory)

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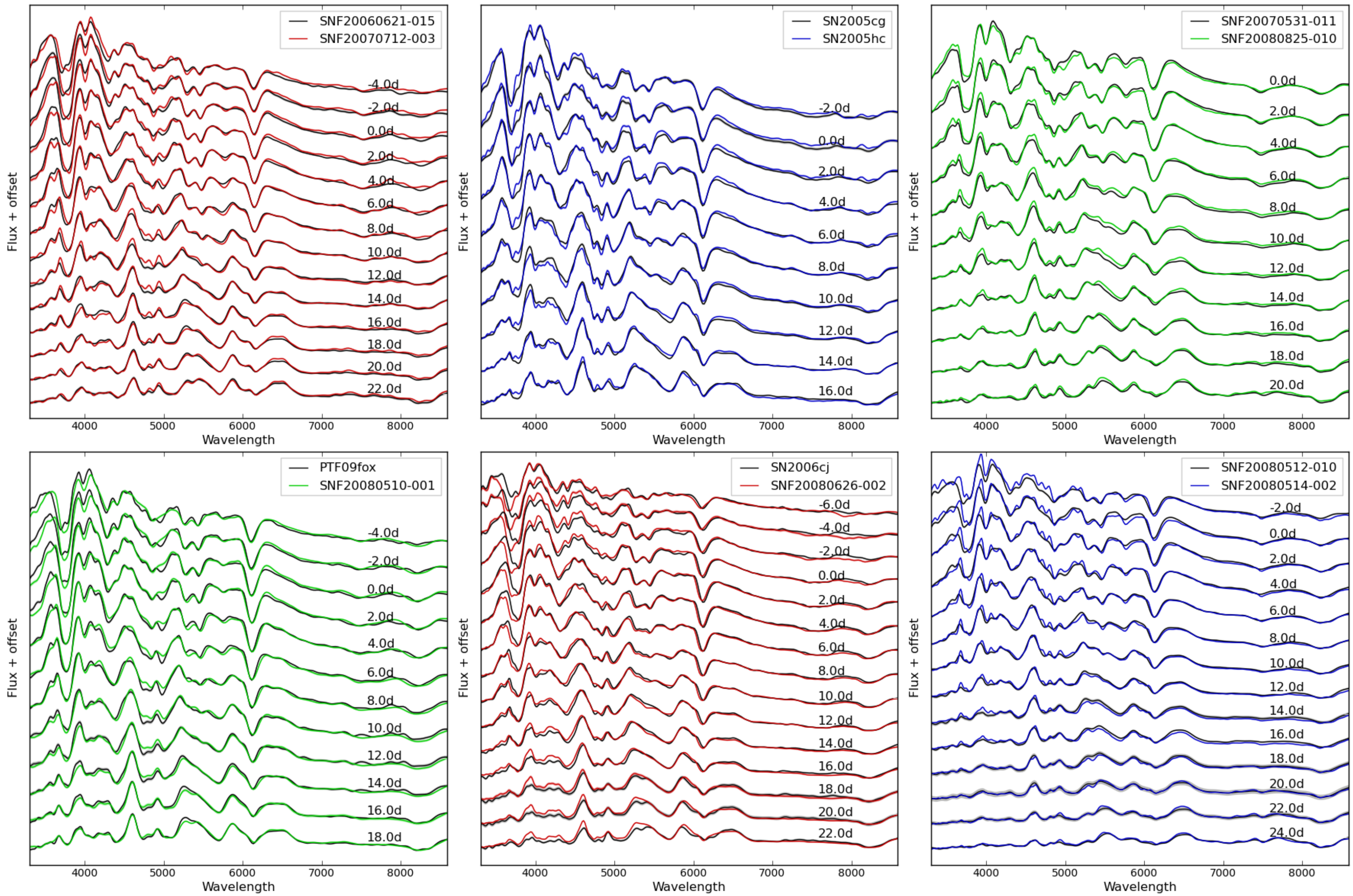
+ Article information

Abstract

We introduce a method for identifying "twin" Type Ia supernovae (SNe Ia) and using them to improve distance measurements. This novel approach to SN Ia standardization is made possible by spectrophotometric time series observations from the Nearby Supernova Factory (SNfactory). We begin with a well-measured set of SNe, find pairs whose spectra match well across the entire optical window, and then test whether this leads to a smaller dispersion in their absolute brightnesses. This analysis is completed in a blinded fashion, ensuring that decisions made in implementing the method do not inadvertently bias the result. We find that pairs of SNe with more closely matched spectra indeed have reduced brightness dispersion. We are able to

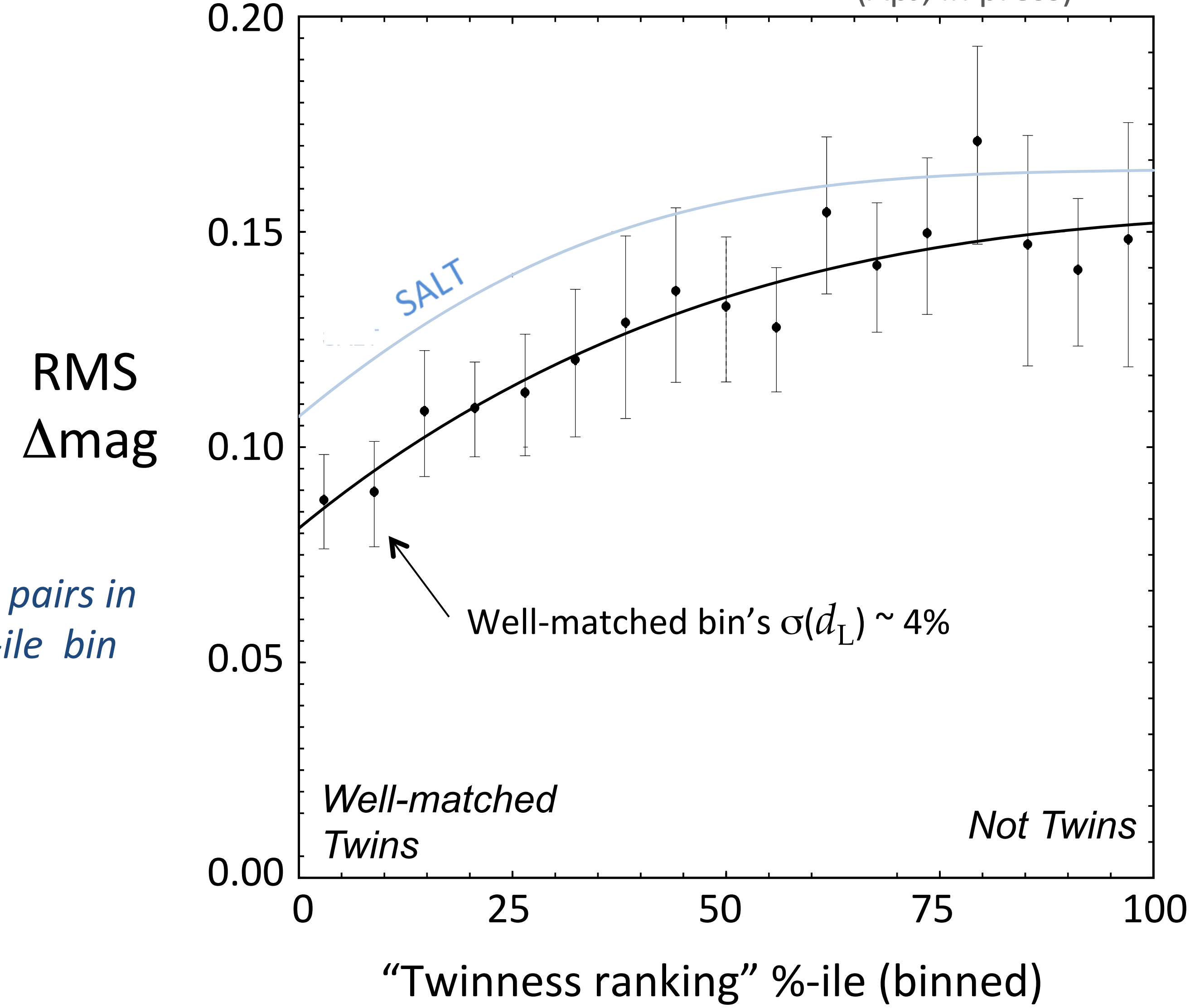
SN Factory spectral time-series



SN Factory: H. Fakhouri thesis

Twin SNe

Nearby SN Factory
Fakhouri et al.
(ApJ, in press)



NB: Blind analysis methods used.

for SN pairs in the %-ile bin

What does this spectrophotometry make possible?

Precision expansion history measurements

Foundational dark energy constraints

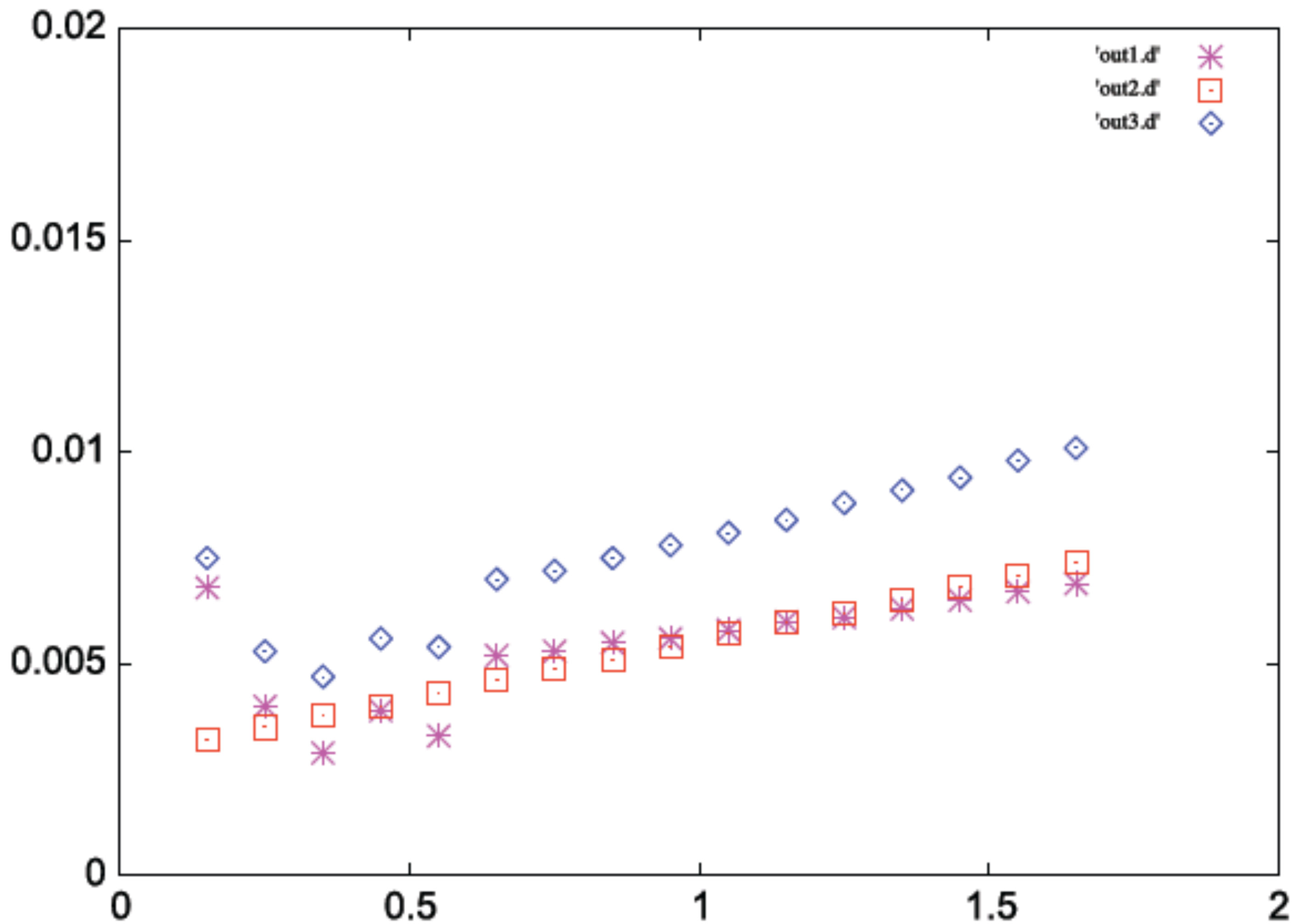
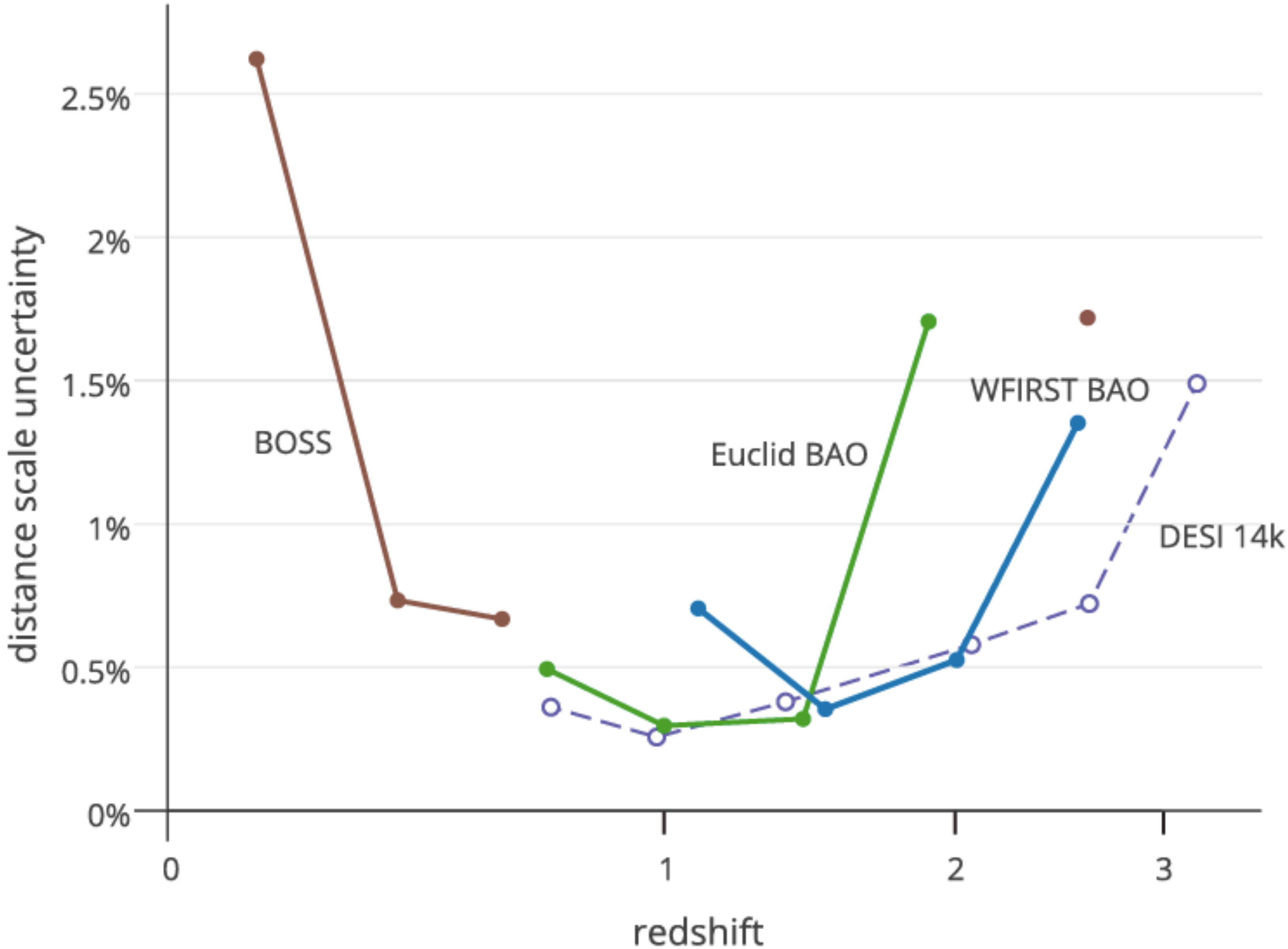
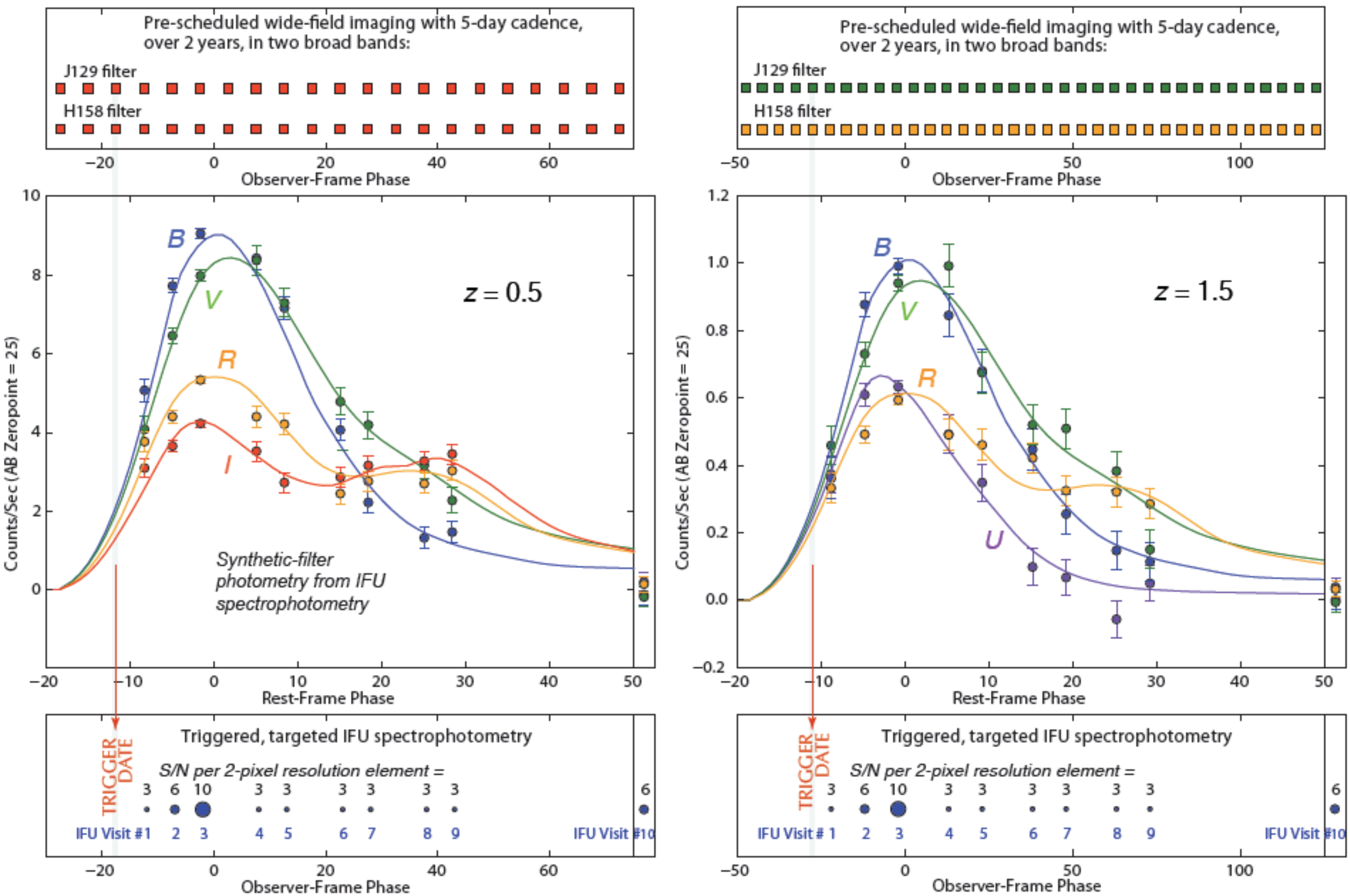


Figure 2-7: Fractional errors in distance per $\Delta z = 0.1$ bin. Squares and crosses show the statistical and systematic contributions, respectively, and diamonds show the total error.



2.5%
2%
1.5%
1%
0.5%
0%
distance scale uncertainty
0
1
2
3
redshift
BOSS
Euclid BAO
WFIRST BAO
DESI 14k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