Complementary Elements for the DOE Supernova DE Program

Saul Perlmutter

University of California, Berkeley
Lawrence Berkeley National Laboratory

Cosmic Visions: Dark Energy
SLAC
November 2015

1 *WFIRST update*


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

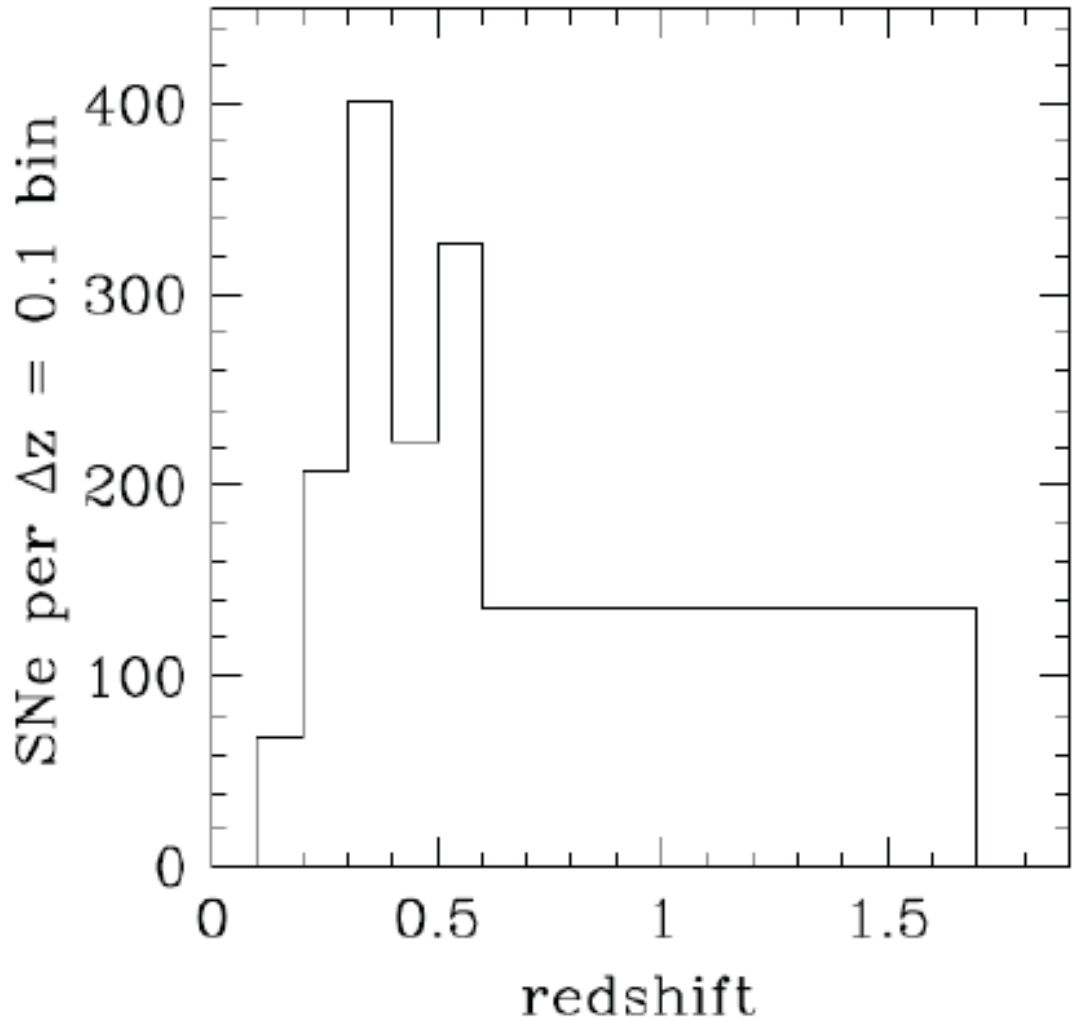
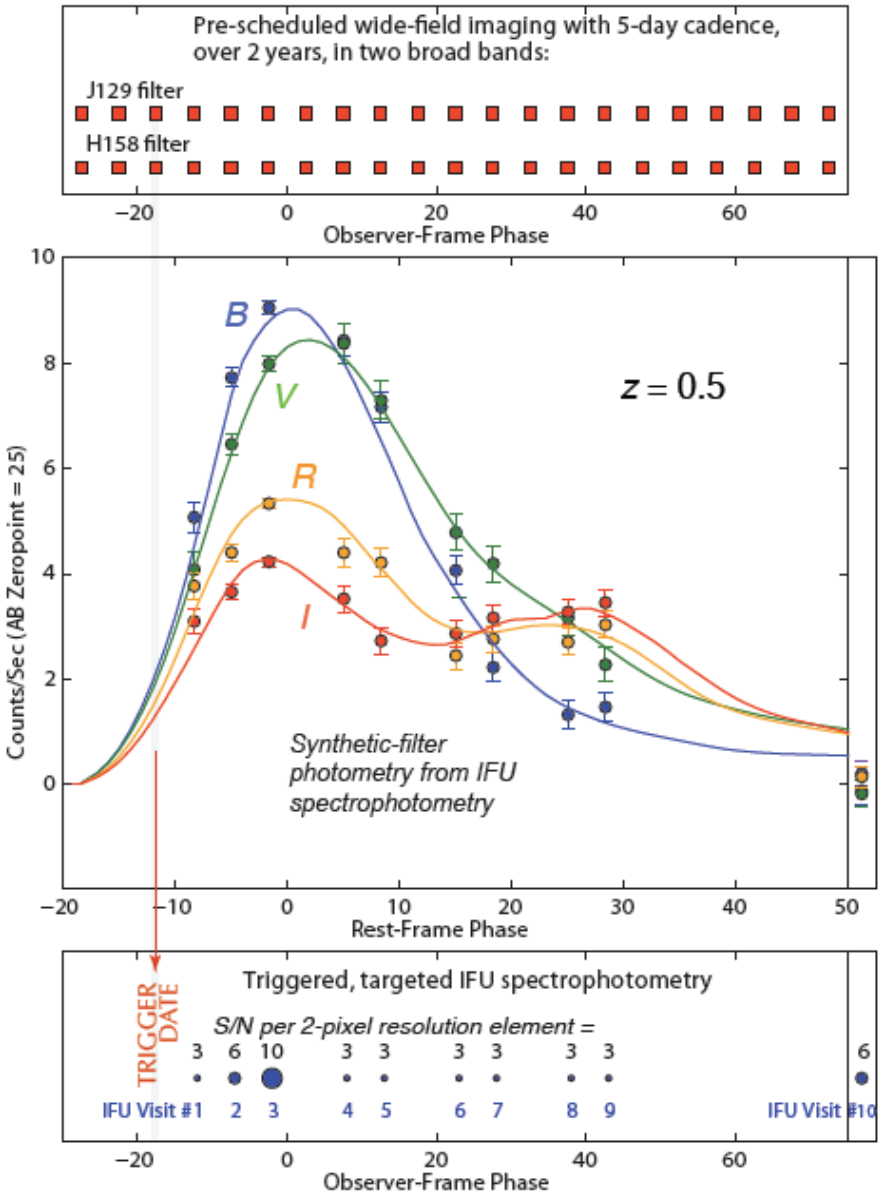
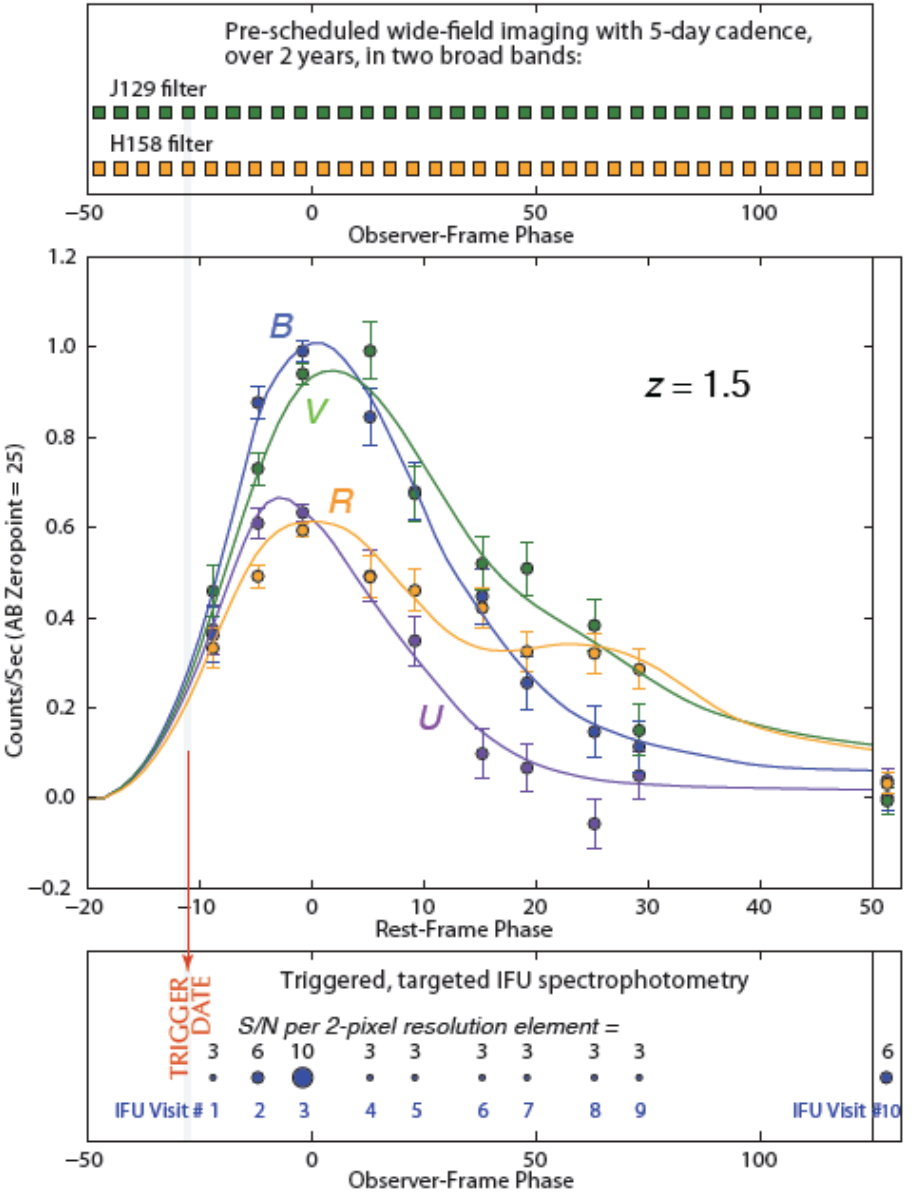


Figure 2-6: Expected number of Type Ia SNe to be followed in each Δz = 0.1 redshift bin. For z > 0.6 there are, by design, 136 SNe followed up with spectroscopic observations in each bin (from a larger number detected). The total number of SNe is 2725.


Pre-scheduled wide-field imaging with 5-day cadence,
over 2 years, in two broad bands:
J129 filter
H158 filter
Observer-Frame Phase
B
V
R
I
z = 0.5
Counts/Sec (AB Zeropoint = 25)
Synthetic-filter
photometry from IFU
spectrophotometry
Rest-Frame Phase
Triggered, targeted IFU spectrophotometry
TRIGGER DATE
S/N per 2-pixel resolution element =
3 6 10 3 3 3 3 3 3 6
IFU Visit #1 2 3 4 5 6 7 8 9 IFU Visit #10
Observer-Frame Phase


Pre-scheduled wide-field imaging with 5-day cadence,
over 2 years, in two broad bands:
J129 filter
H158 filter
Observer-Frame Phase
B
V
R
U
z = 1.5
Counts/Sec (AB Zeropoint = 25)
Rest-Frame Phase
Triggered, targeted IFU spectrophotometry
TRIGGER DATE
S/N per 2-pixel resolution element =
3 6 10 3 3 3 3 3 3 6
IFU Visit # 1 2 3 4 5 6 7 8 9 IFU Visit #10
Observer-Frame Phase

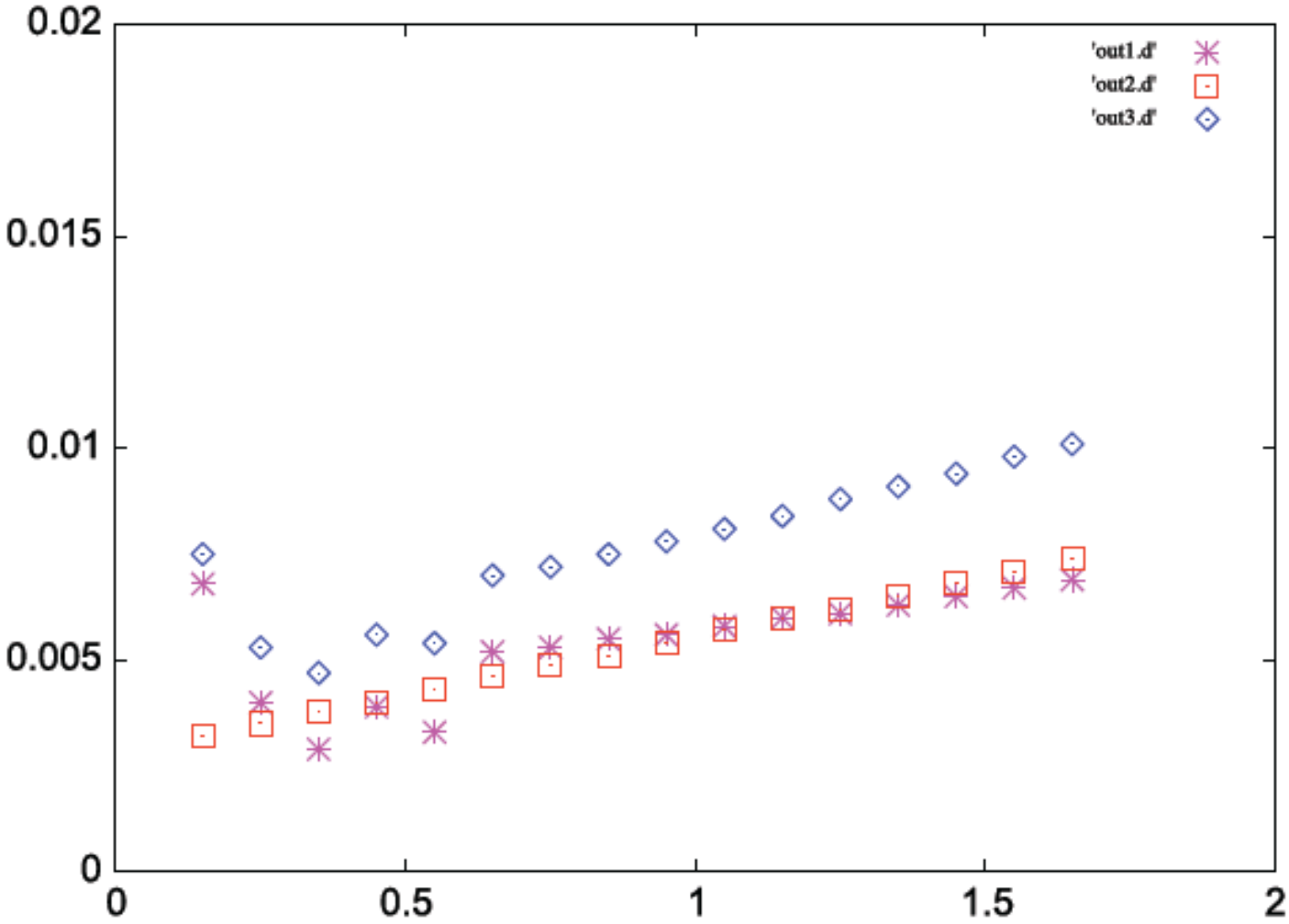


Figure 2-7: Fractional errors in distance per Δz = 0.1 bin. Squares and crosses show the statistical and systematic contributions, respectively, and diamonds show the total error.

The Latest News

2 *Advance in the SN technique: Twins*

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)

ABSTRACT

We introduce a method for identifying "twin" Type Ia supernovae, and using them to improve distance measurements. This novel approach to Type Ia supernova stan-

[1] Physics Division, Lawrence Berkeley National Laboratory, 1 Cyclotron Road, Berkeley, CA, 94720

[2] Department of Physics, University of California Berkeley, 366 LeConte Hall MC 7300, Berkeley, CA, 94720-7300

[3] Laboratoire de Physique Nucléaire et des Hautes Énergies, Université Pierre et Marie Curie Paris 6, Université Paris Diderot Paris 7, CNRS-IN2P3, 4 place Jussieu, 75252 Paris Cedex 05, France

[4] Department of Physics, Yale University, New Haven, CT, 06250-8121

[5] Tsinghua Center for Astrophysics, Tsinghua University, Beijing 100084, China

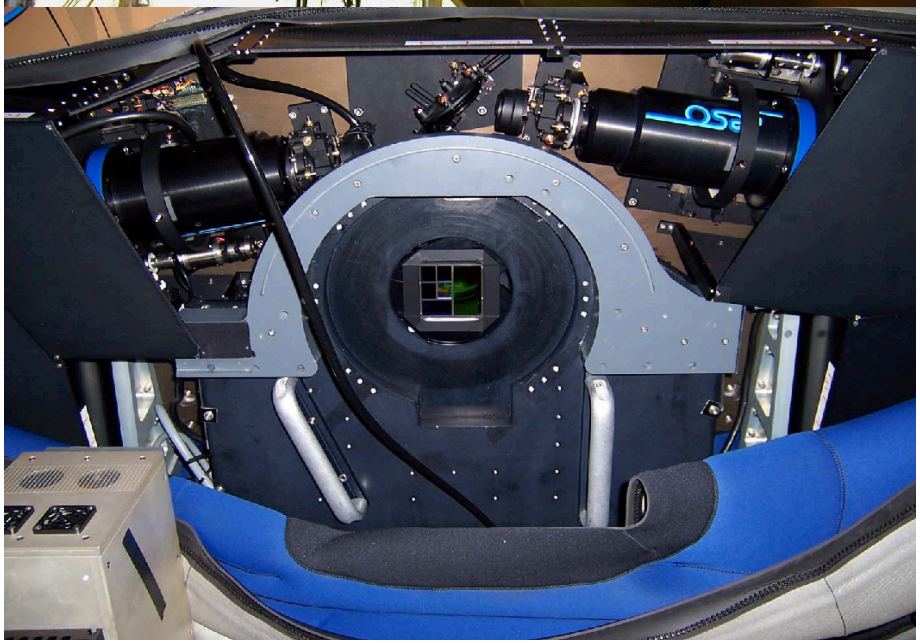
[6] Université de Lyon, F-69622, Lyon, France ; Université de Lyon 1, Villeurbanne ; CNRS/IN2P3, Institut de Physique Nucléaire de Lyon.

[7] Research School of Astronomy and Astrophysics, Australian National University, Canberra, ACT 2611, Australia

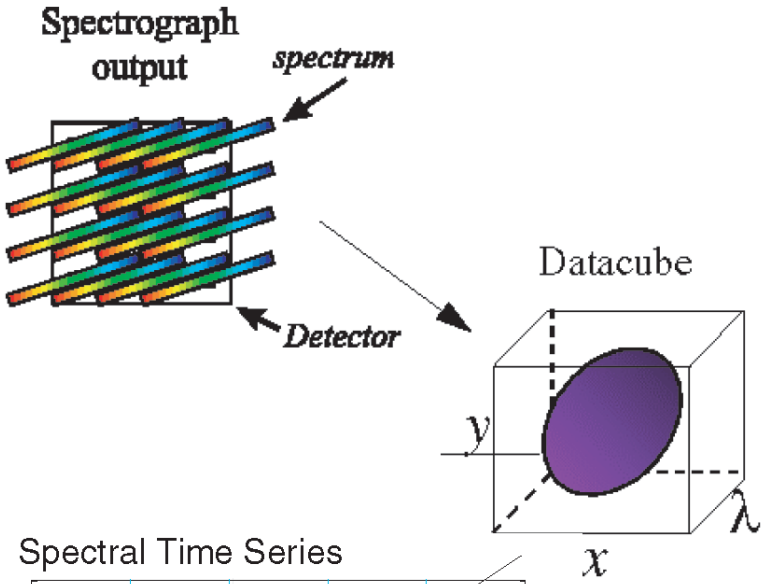
[8] Institut fur Physik, Humboldt-Universitat zu Berlin, Newtonstr. 15, 12489 Berlin

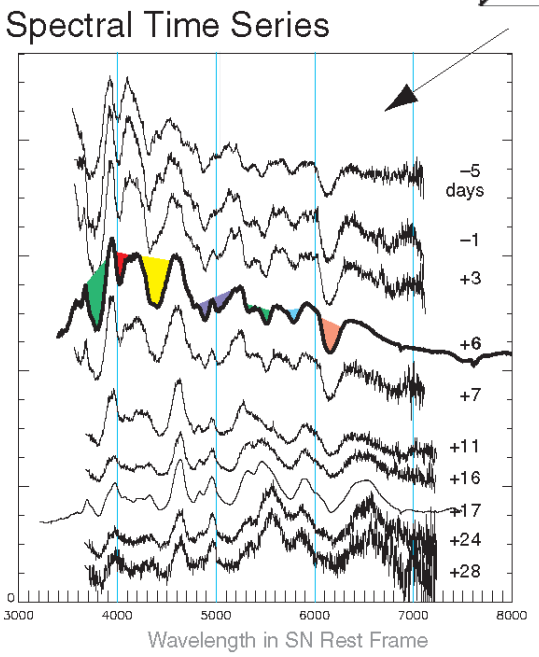
[9] Centre de Physique des Particules de Marseille, Aix-Marseille Université , CNRS/IN2P3, 163 avenue de Luminy - Case 902 - 13288 Marseille Cedex 09, France

SNIFS on the UH 2.2m

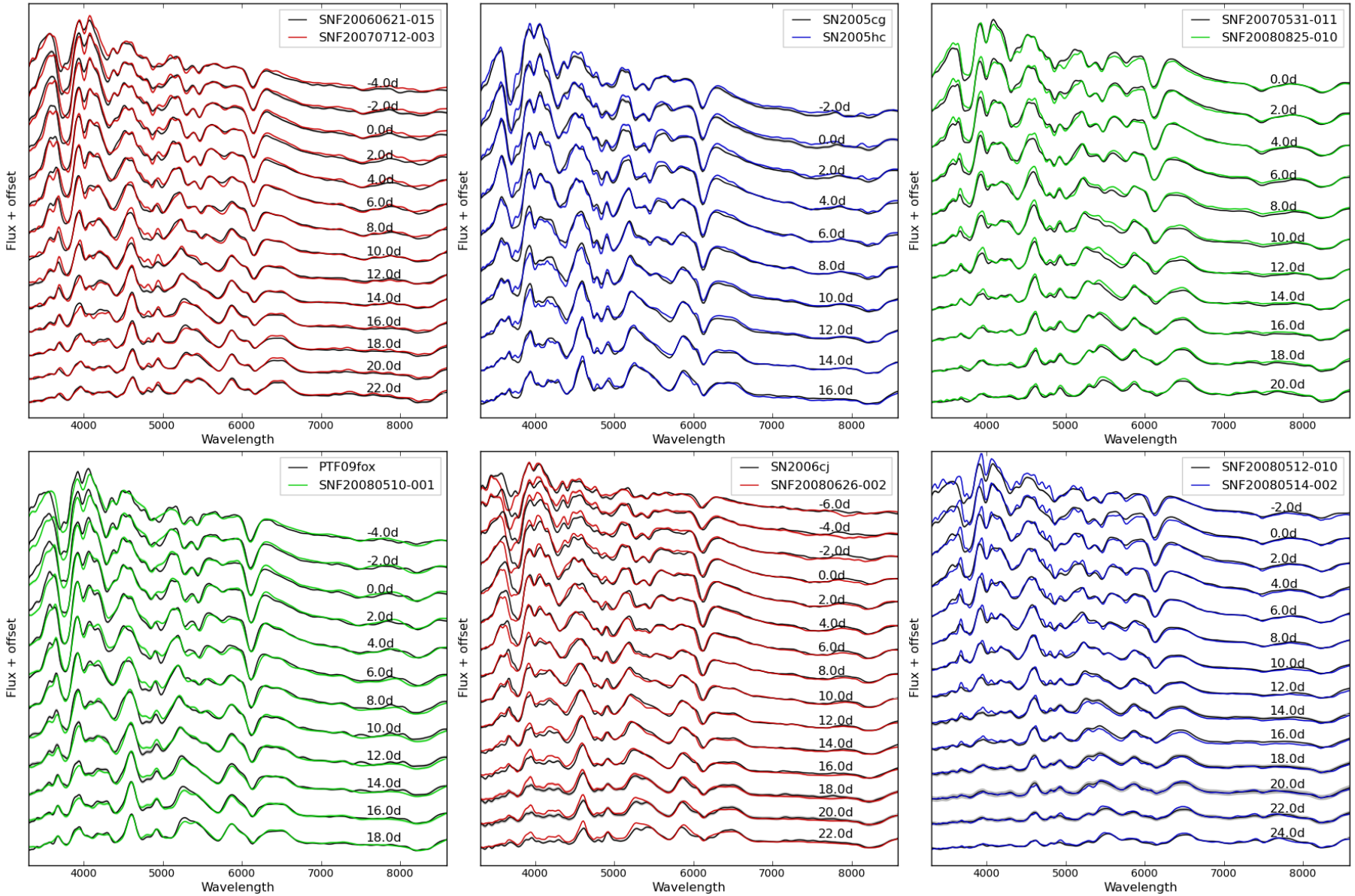


IFU = "Integral Field Unit"





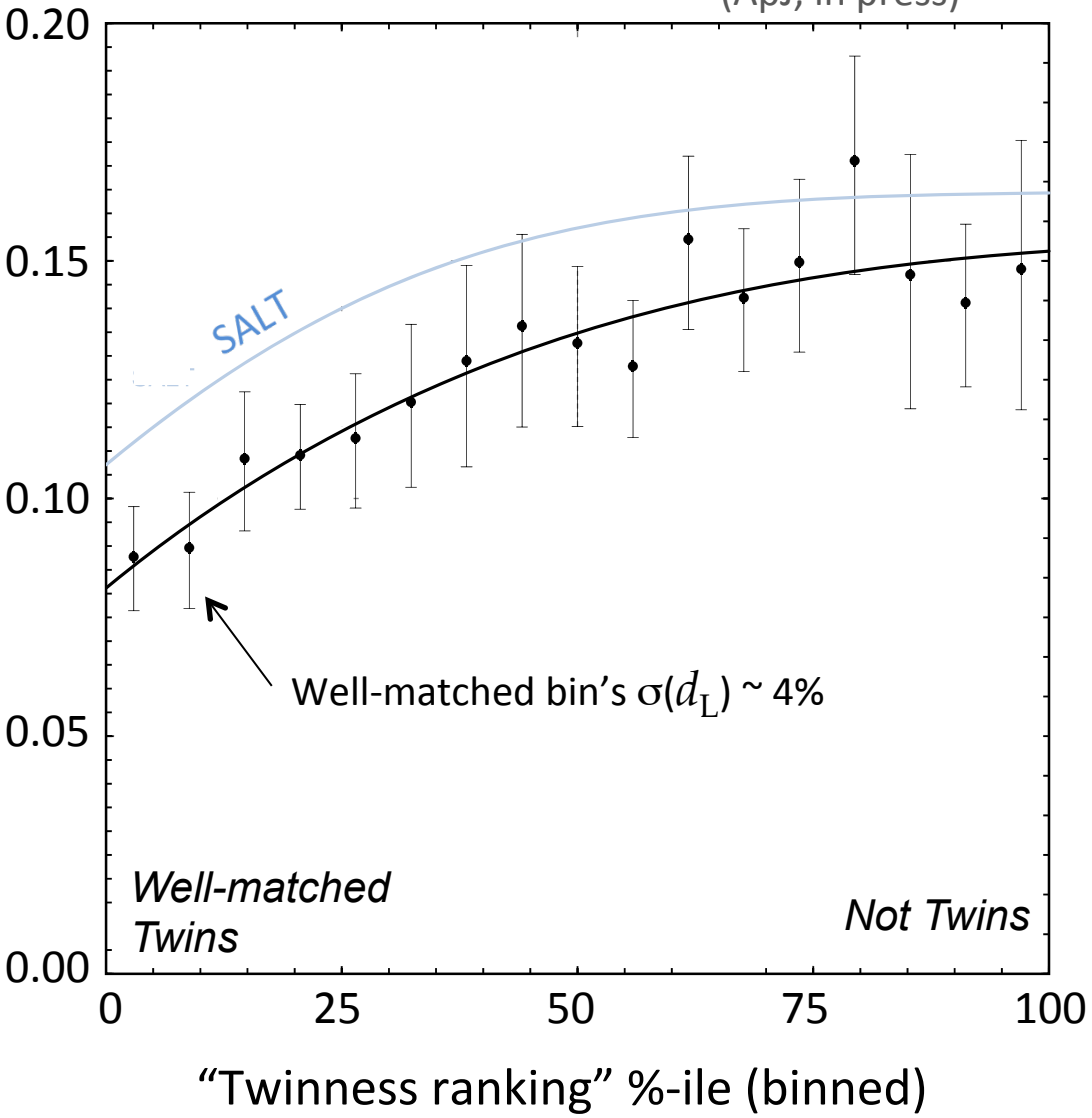
SN Factory spectral time-series



SN Factory: H. Fakhouri thesis

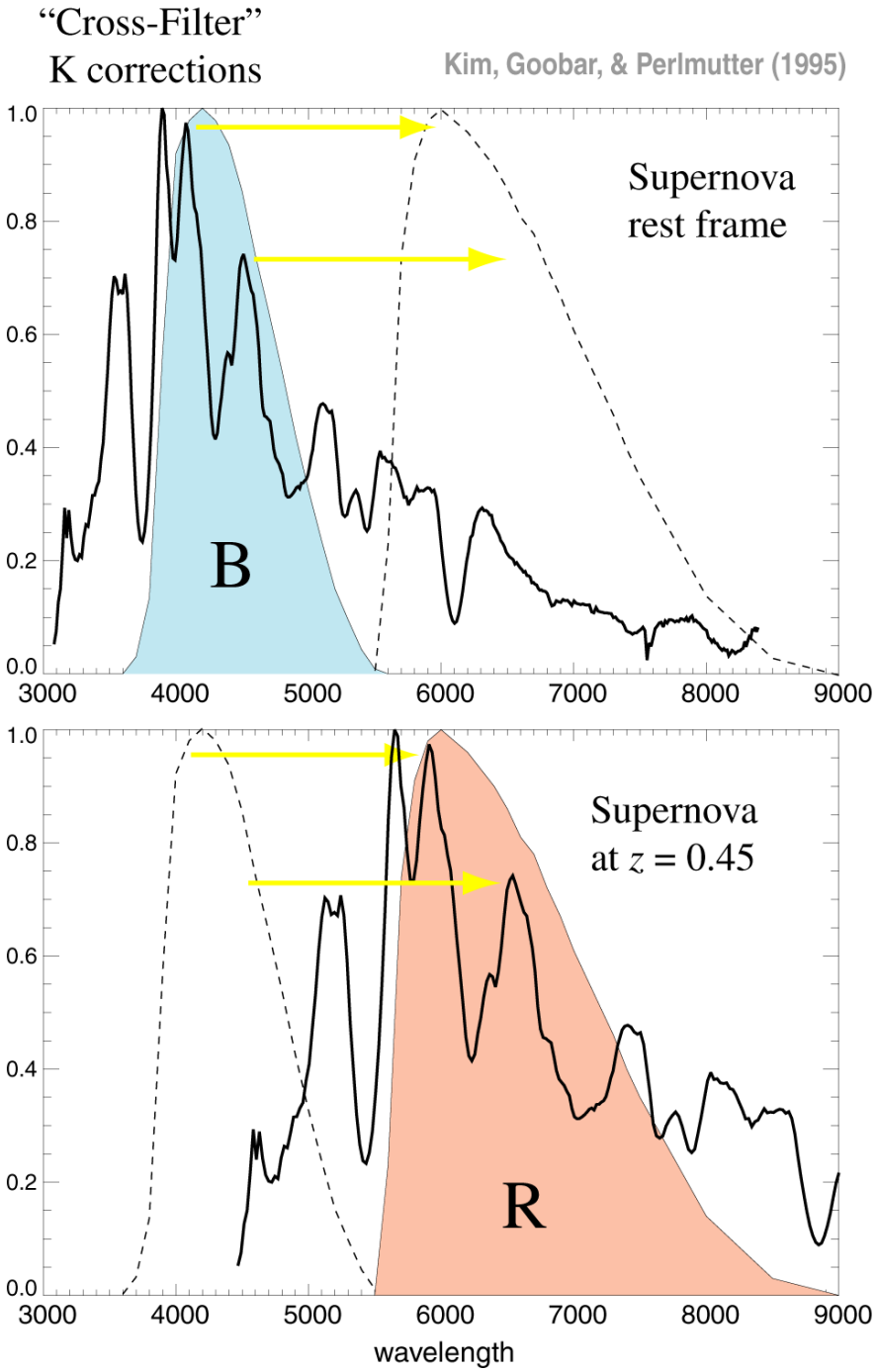
Twin SNe

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



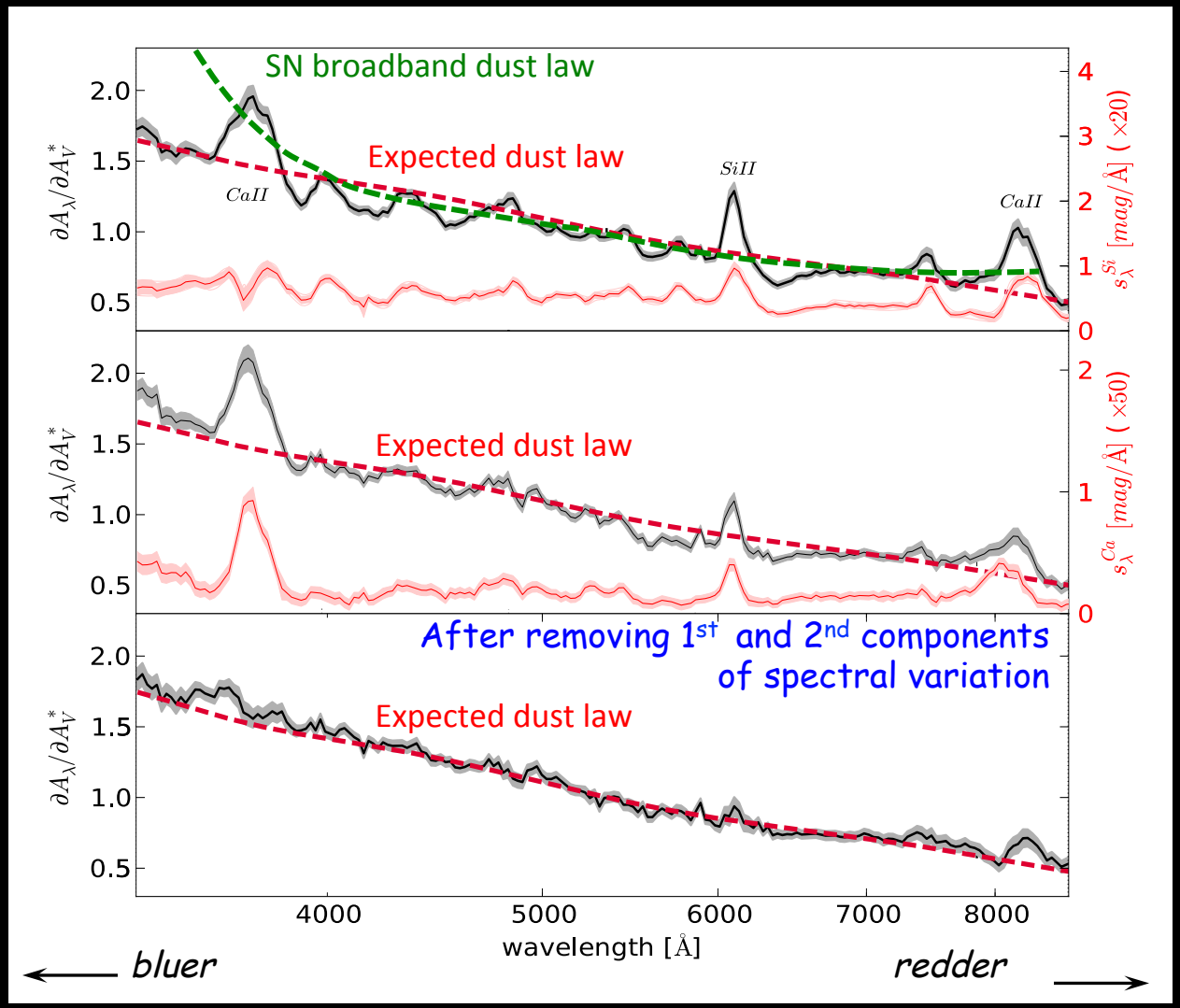
for SN pairs in the %-ile bin

NB: Blind analysis methods used.

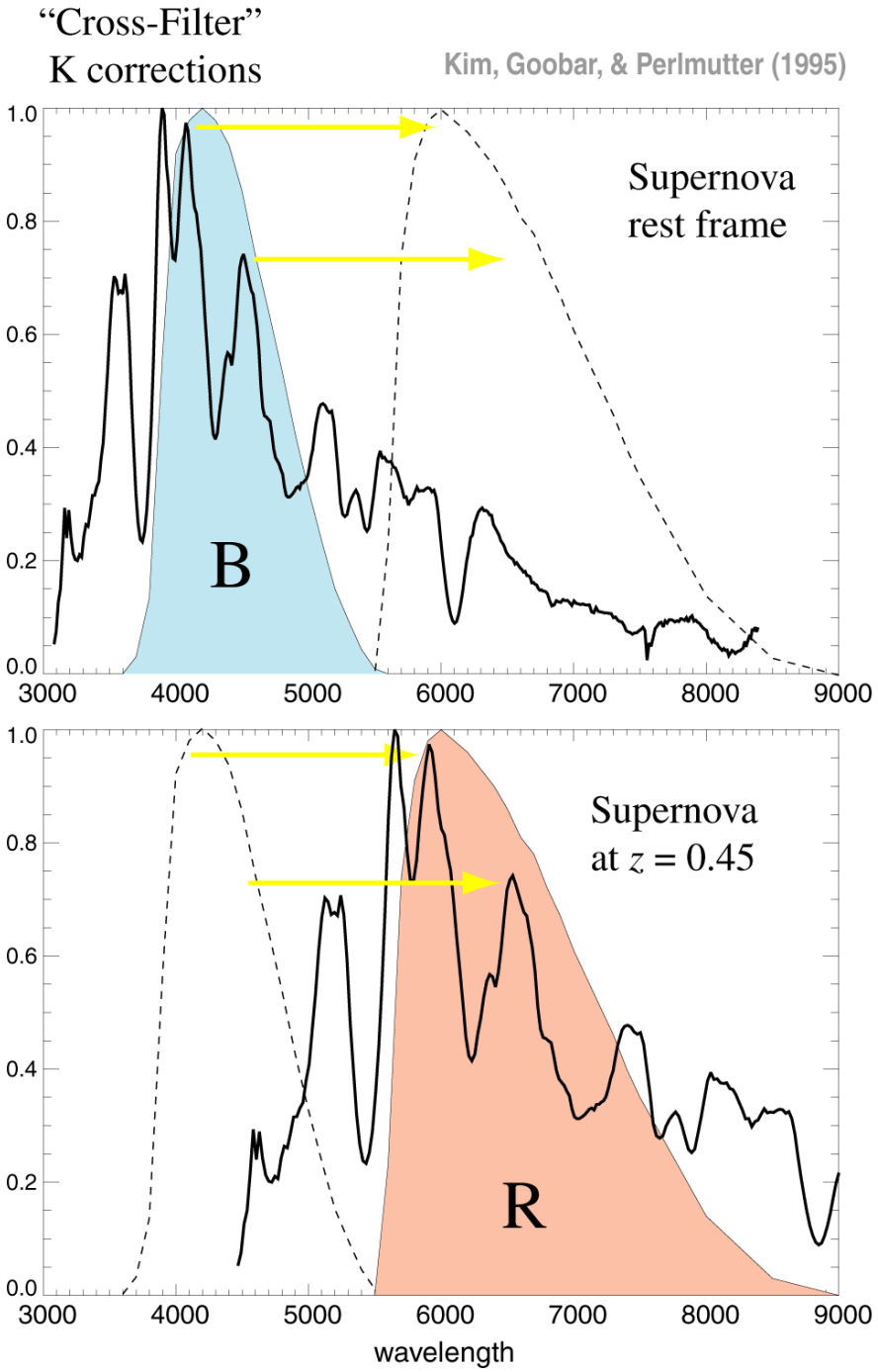


But when the filters don't match perfectly across redshift, this approach is accurate only to the extent that the spectral template family captures the distribution of SN Ia behavior – at both low and high redshift.

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



Chotard et al 2011 (SNfactory)

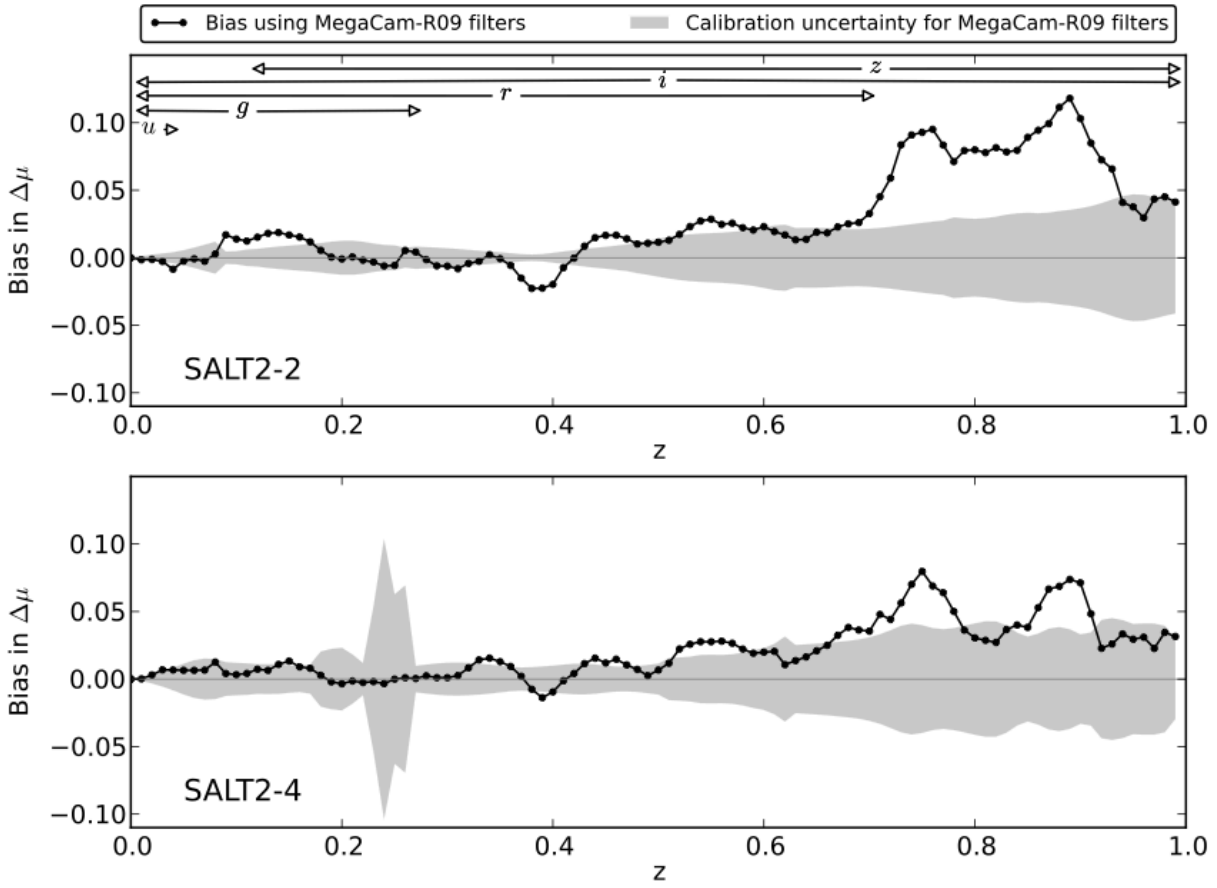


But when the filters don't match perfectly across redshift, this approach is accurate only to the extent that the spectral template family captures the distribution of SN Ia behavior – at both low and high redshift.

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

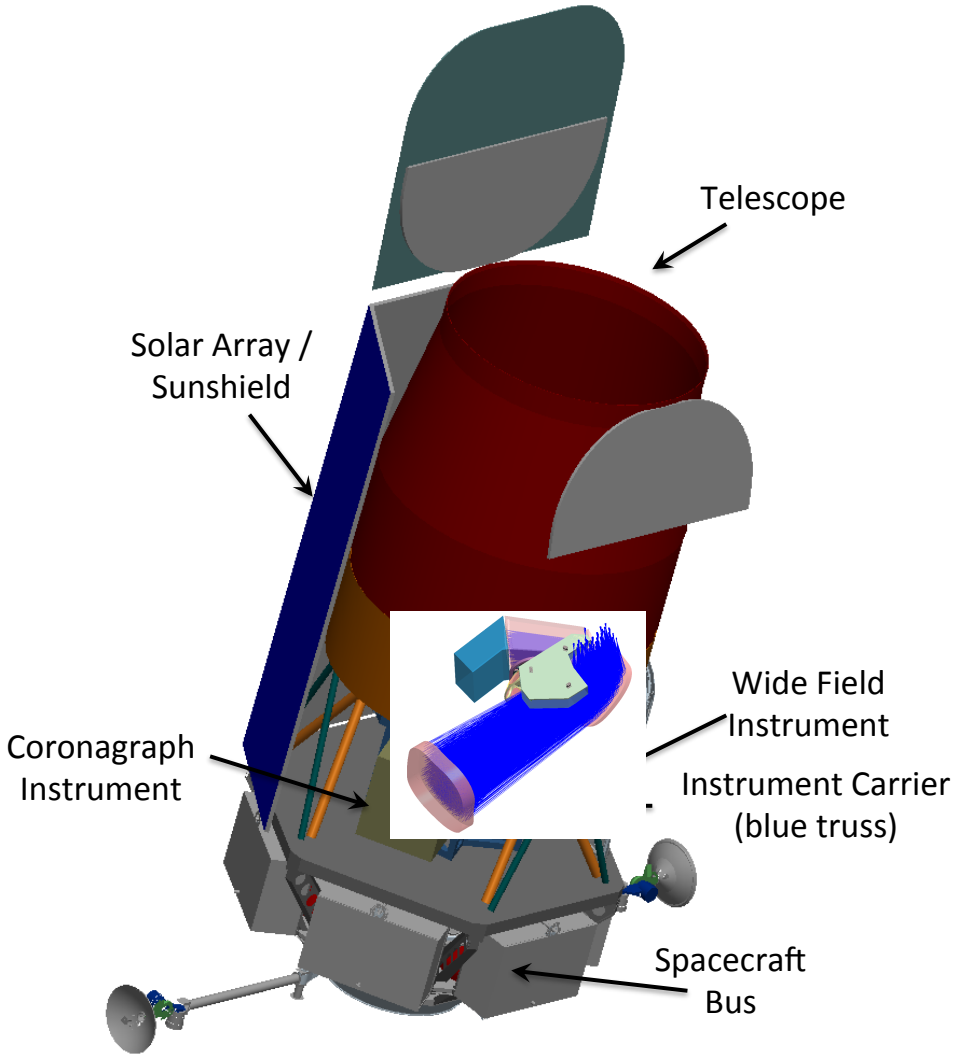


Saunders+ (ApJ 2015)

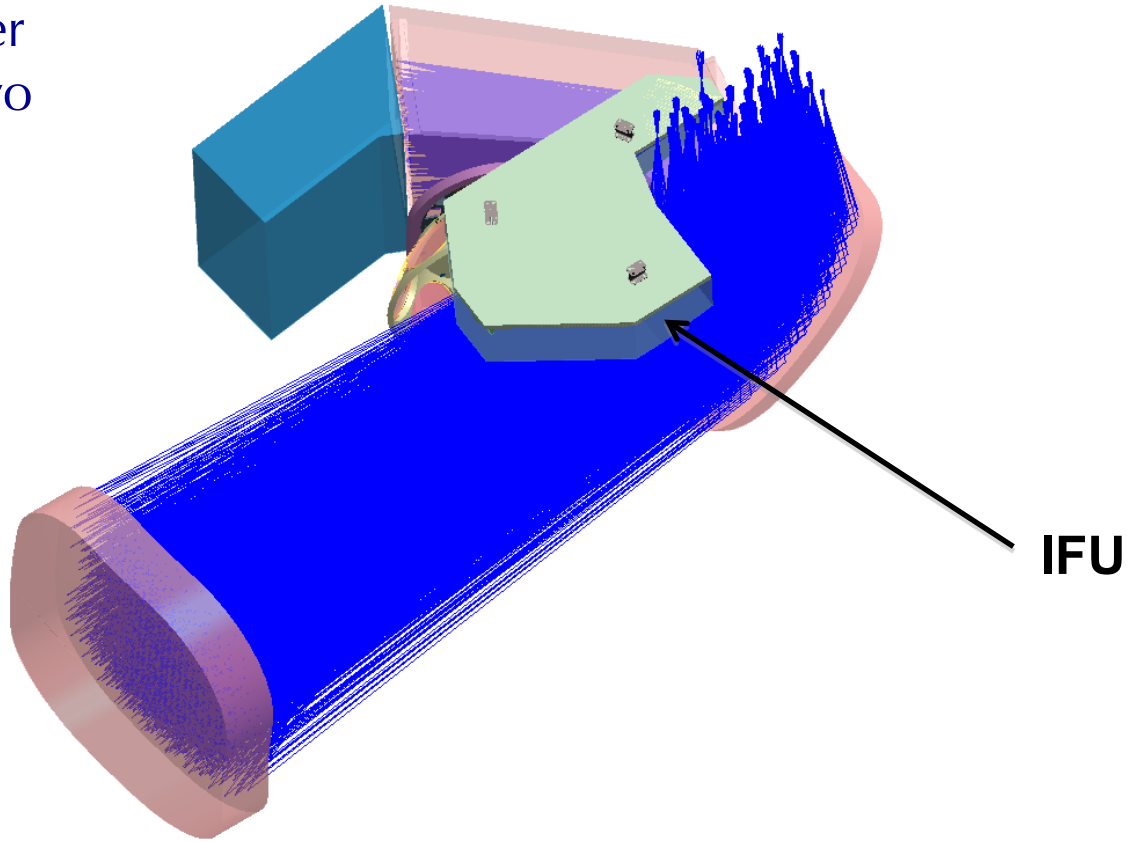
Nearby SN Factory

3

Using this advanced SN technique in the era of LSST and WFIRST

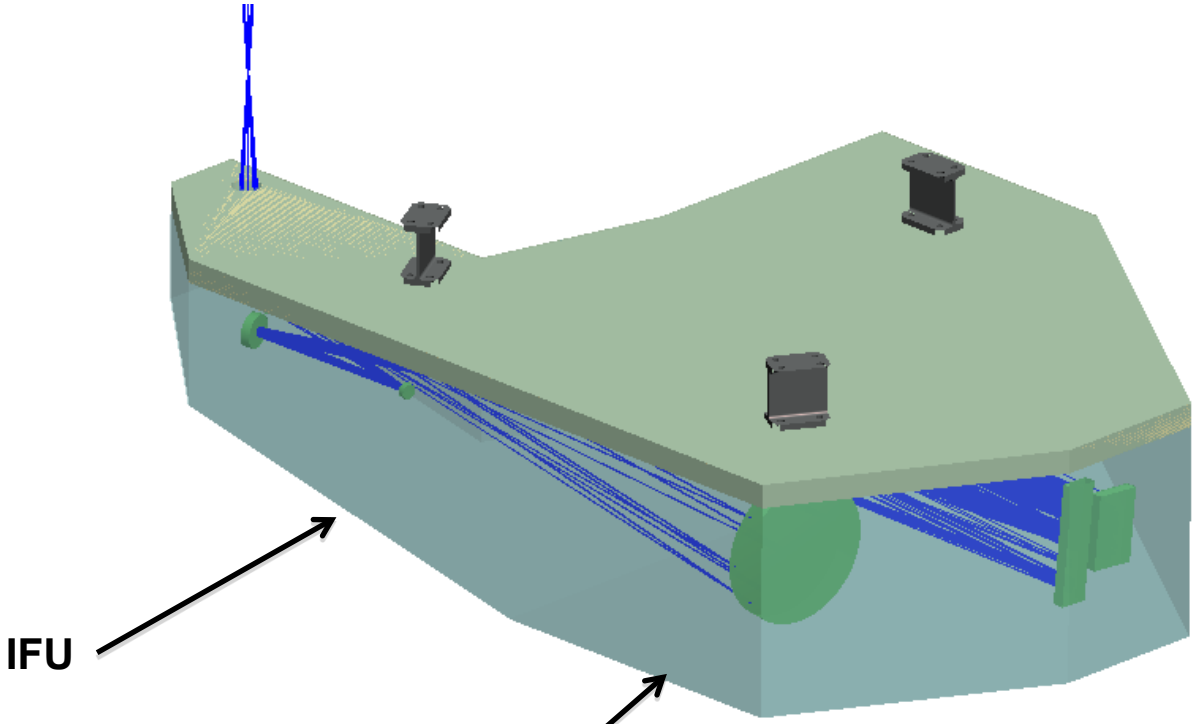

Telescope
Solar Array /
Sunshield
Wide Field
Instrument
Coronagraph
Instrument
Instrument Carrier
(blue truss)
Spacecraft
Bus

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

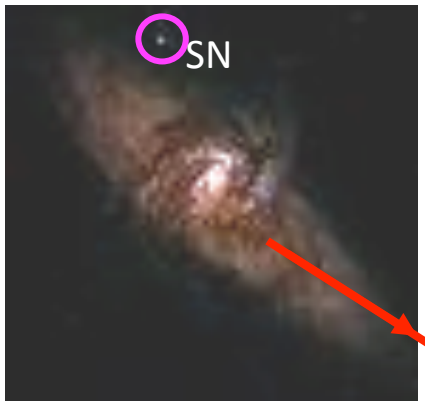


Small, compact assembly:

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



Integral Field Spectroscopy Concept



Telescope Focal Plane

Telescope

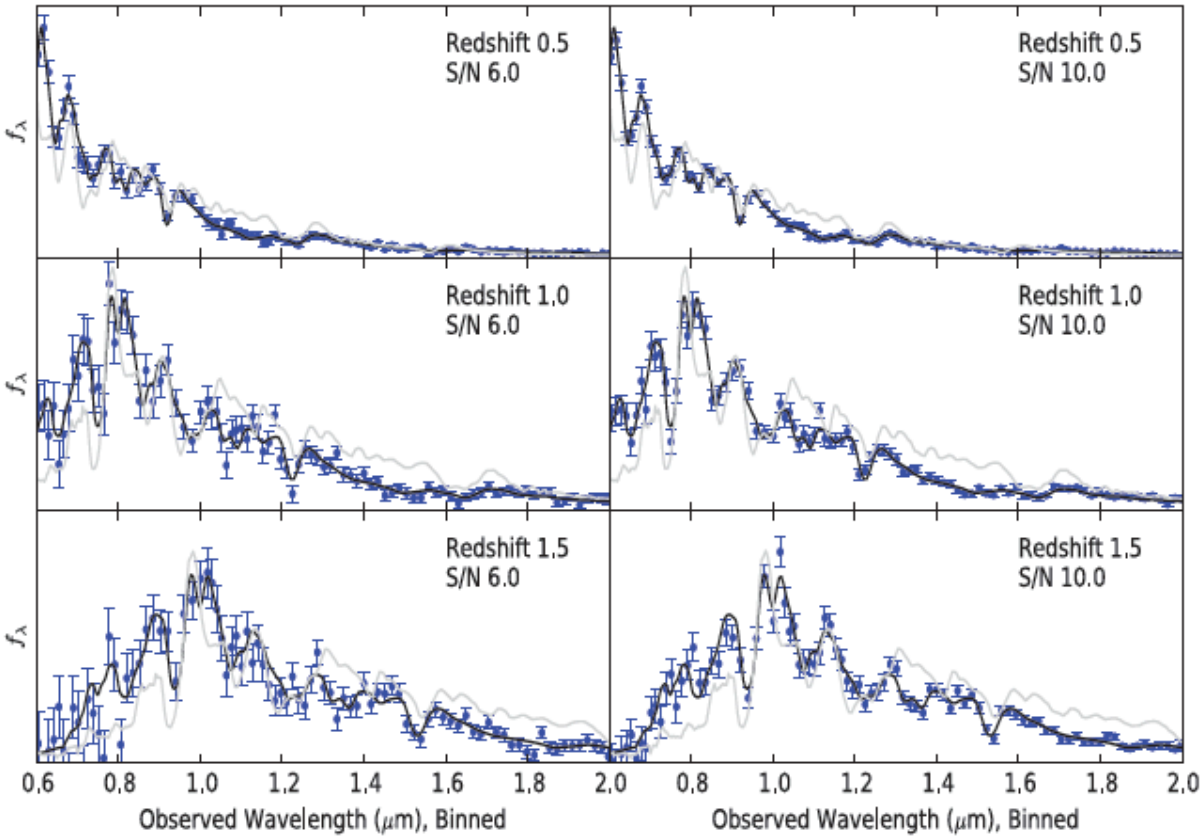
Slicer Mirror Array

Row of Pupil Mirrors

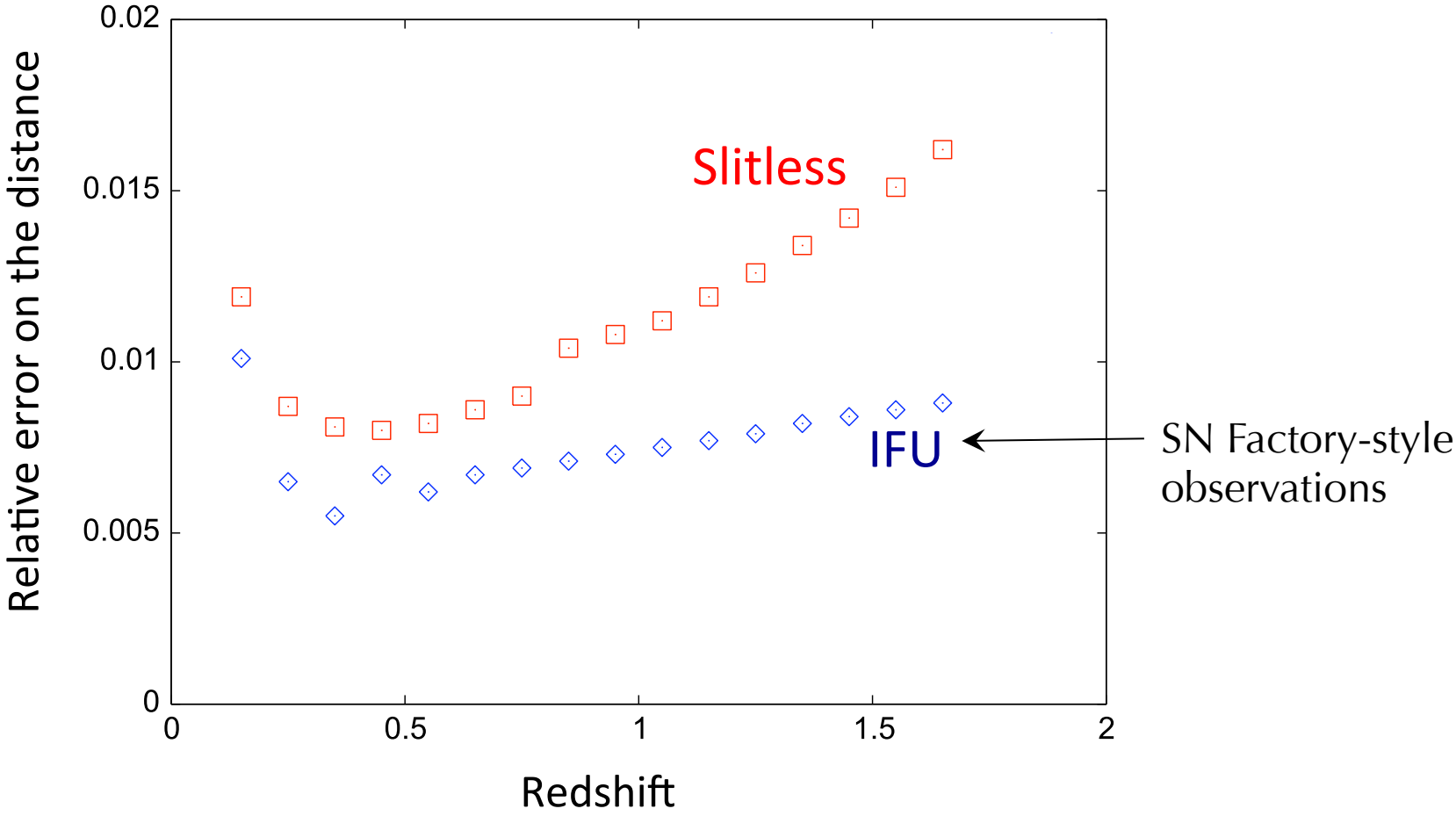
Row of Slit Mirrors

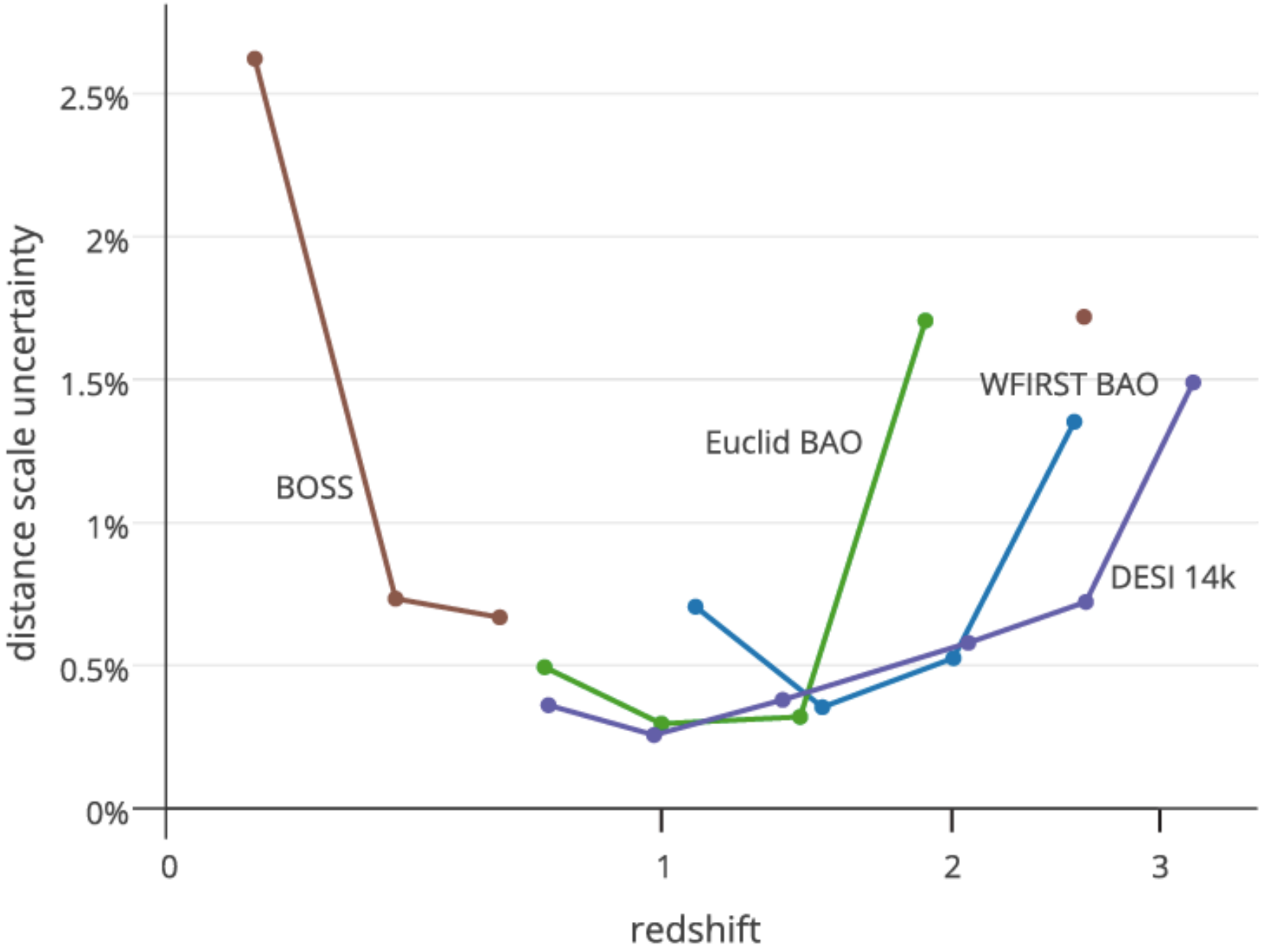
λ

Baseline:
3" x 3" with 0.15" slits
0.6 – 2.0 μm wavelengths
R = ~ 75—100


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
Observed Wavelength (μm), Binned

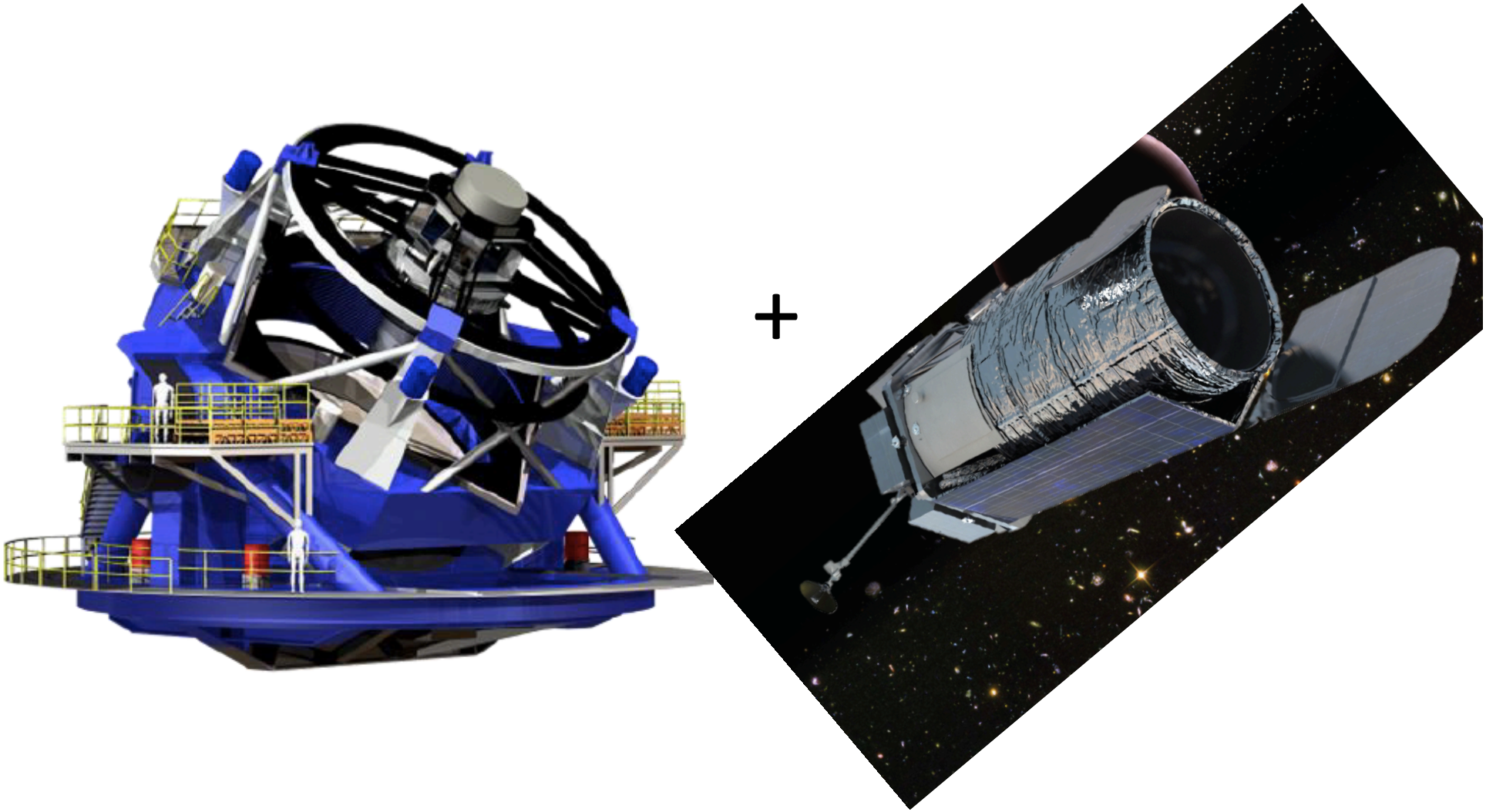
WFIRST with 2.4m telescope:
Relative Error on the Distance Measurement




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

LSST's SN program is photometry-based

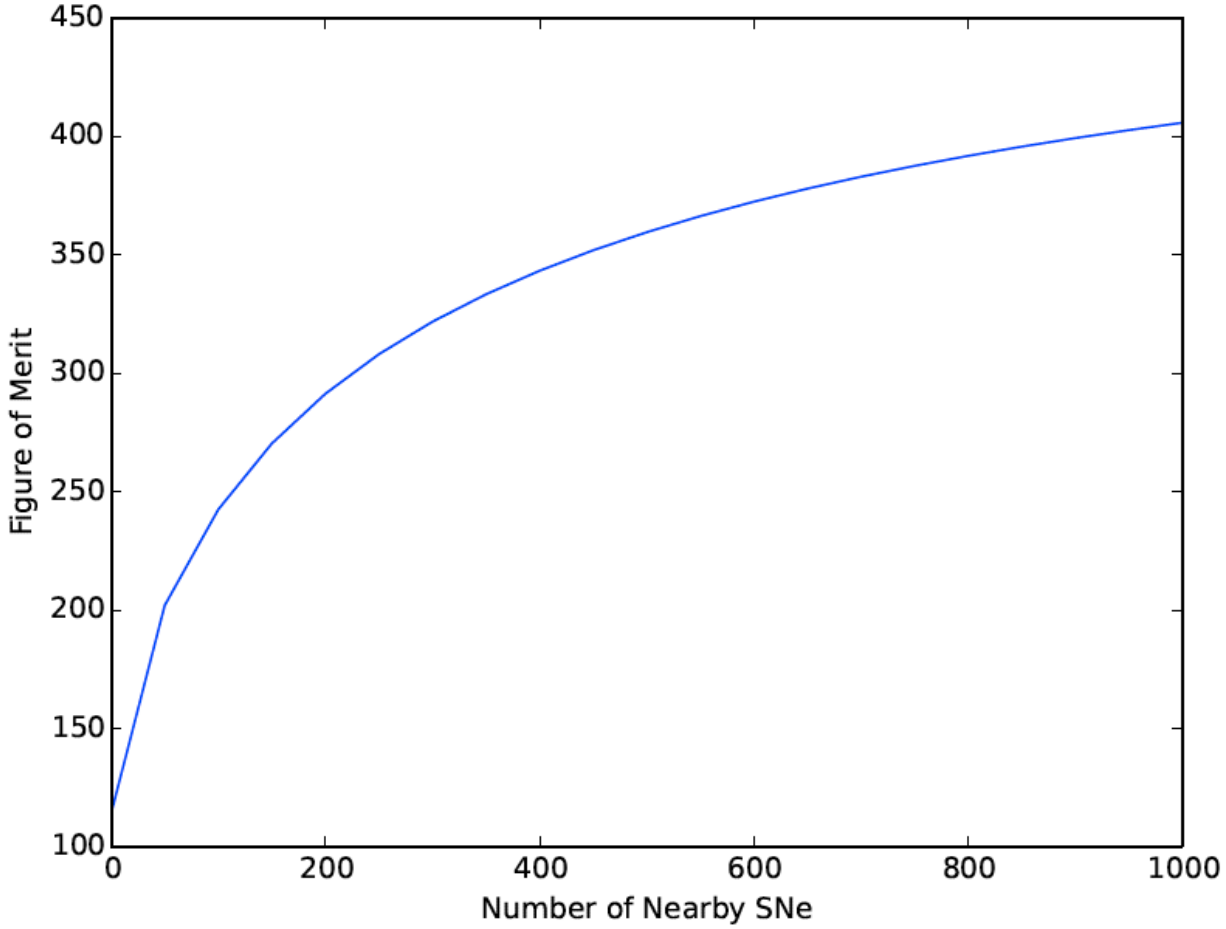
Add a complementary WFIRST follow-up program



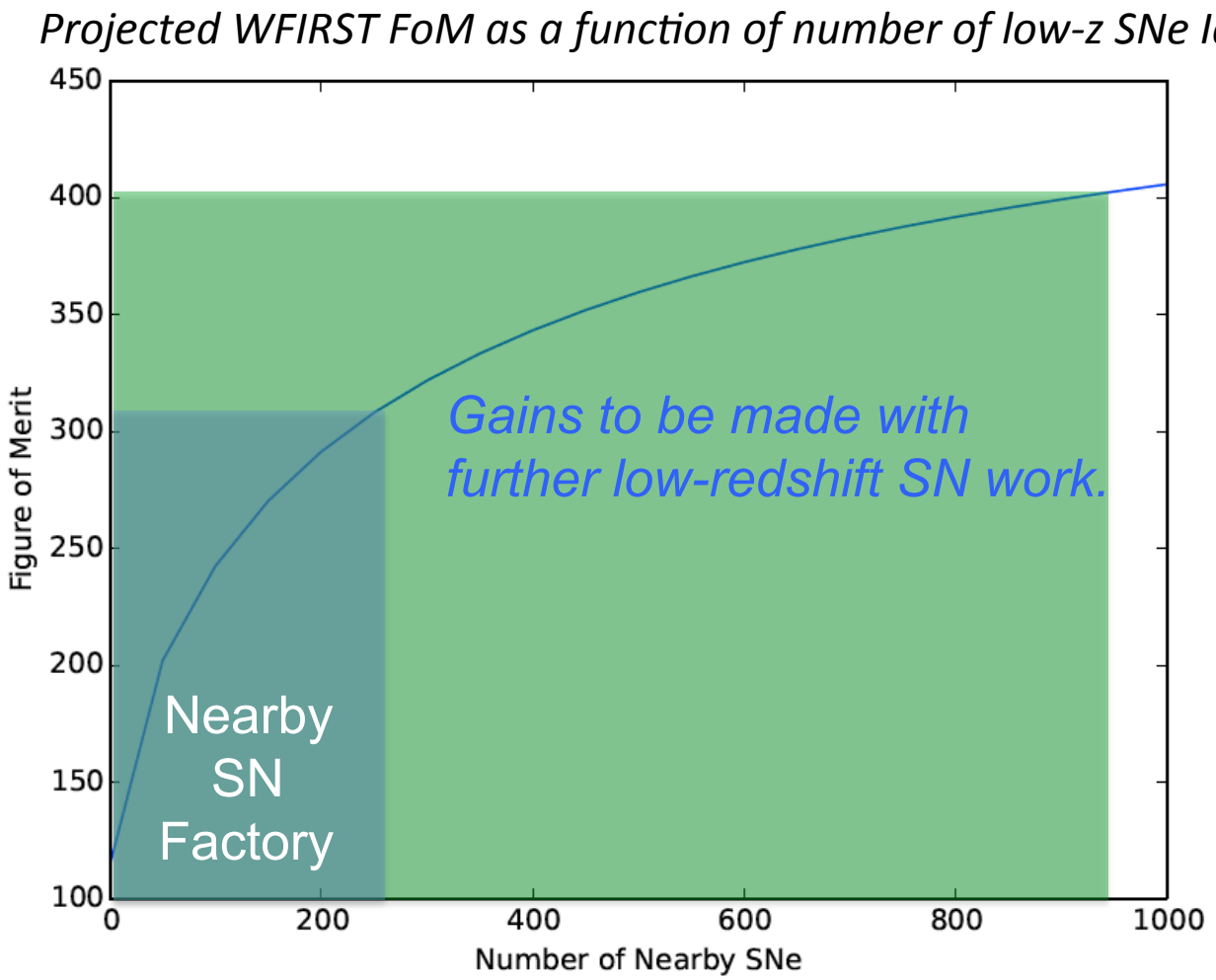
4 *An easier, but still needed, complementary element: more spectrophotometric low-z SNe*

Distance measurements improve as the number of nearby ($z < 0.1$) SNe is made comparable to the number of distant SNe

Projected WFIRST FoM as a function of number of low-z SNe Ia



Distance measurements improve as the number of nearby ($z < 0.1$) SNe is made comparable to the number of distant SNe



The z< 0.1 SNe could come from ZTF before LSST is commissioned, or from LSST after.

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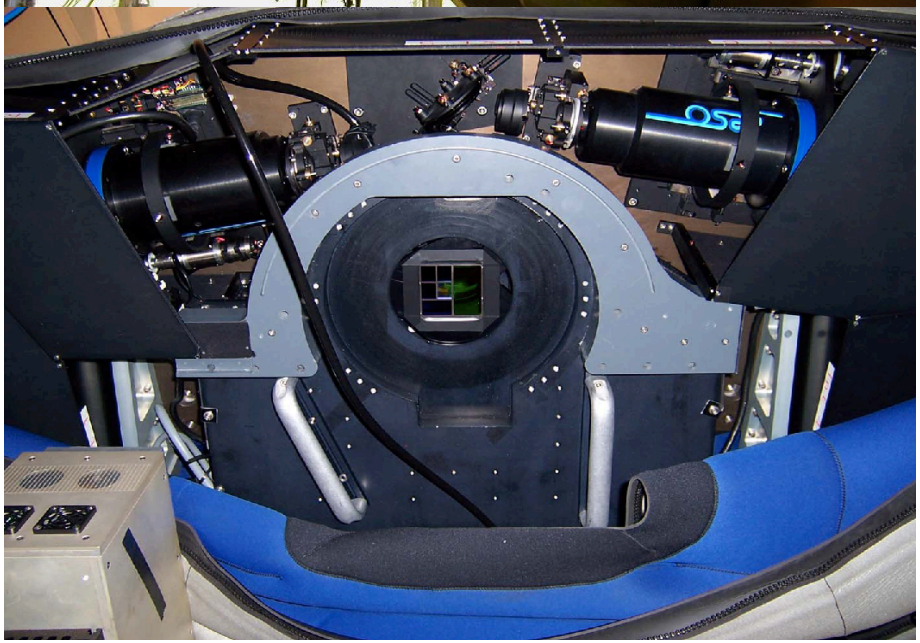

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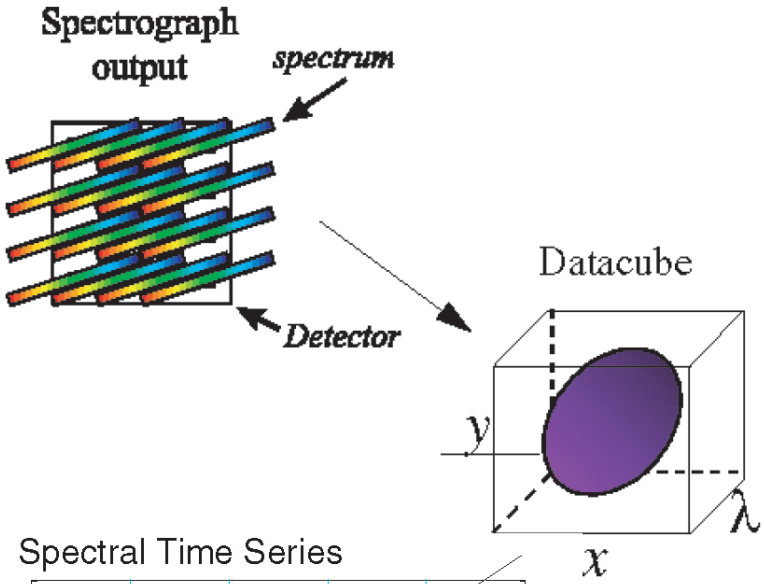

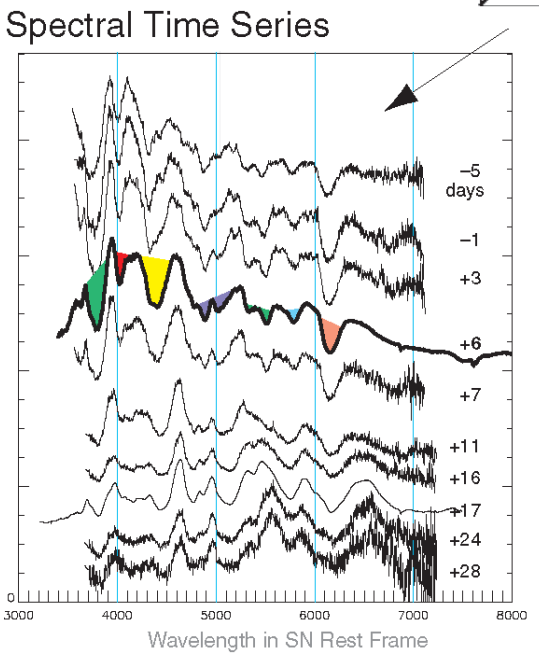

5 *Two complementary DOE programs can be transformative for the SN DE measurements.*