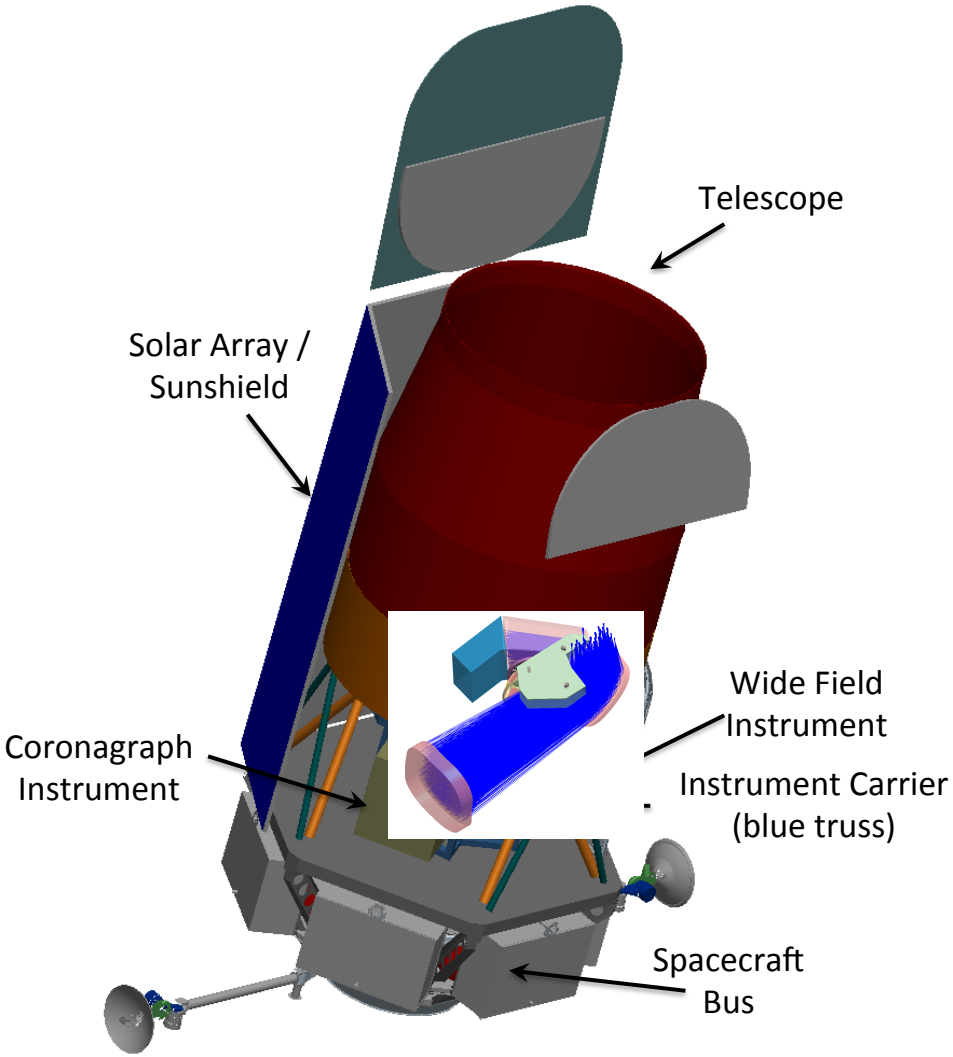
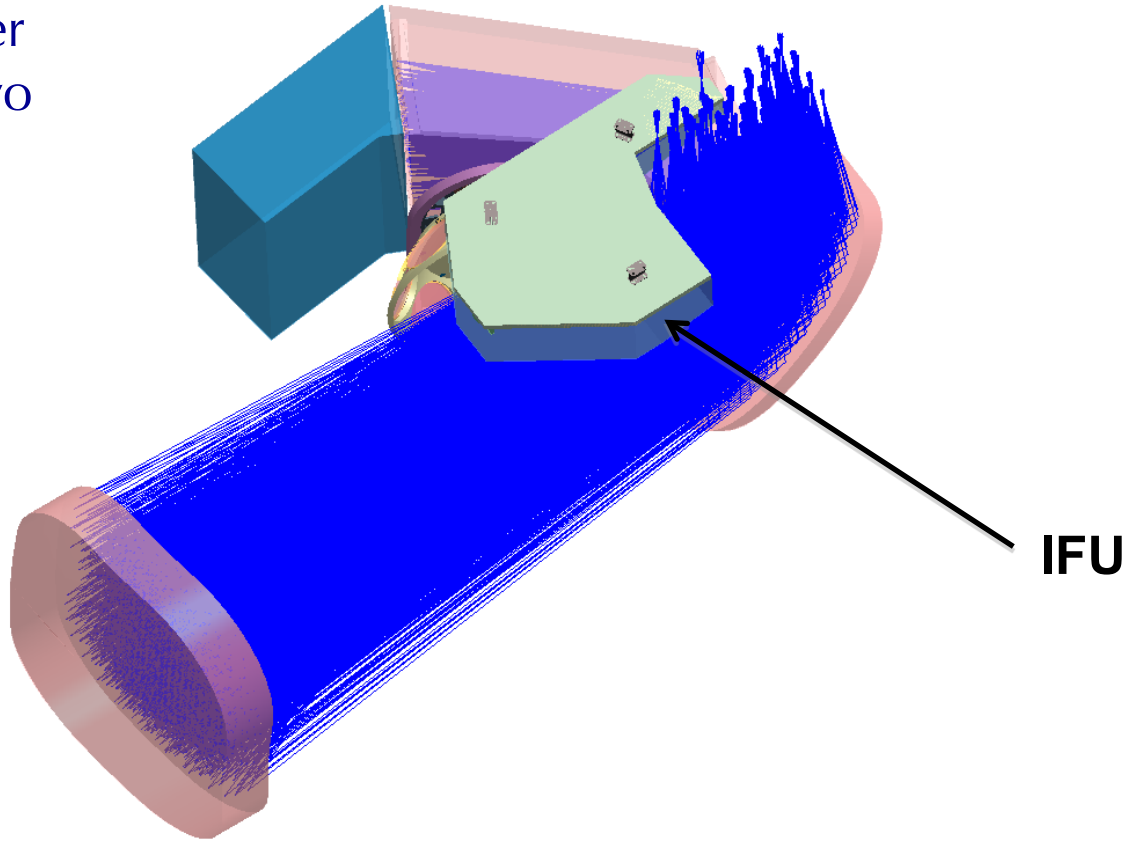
Supernovae and the 2.4-m WFIRST:

WFIRST Supernova Dark Energy Capabilities

Saul Perlmutter
for the WFIRST SDT

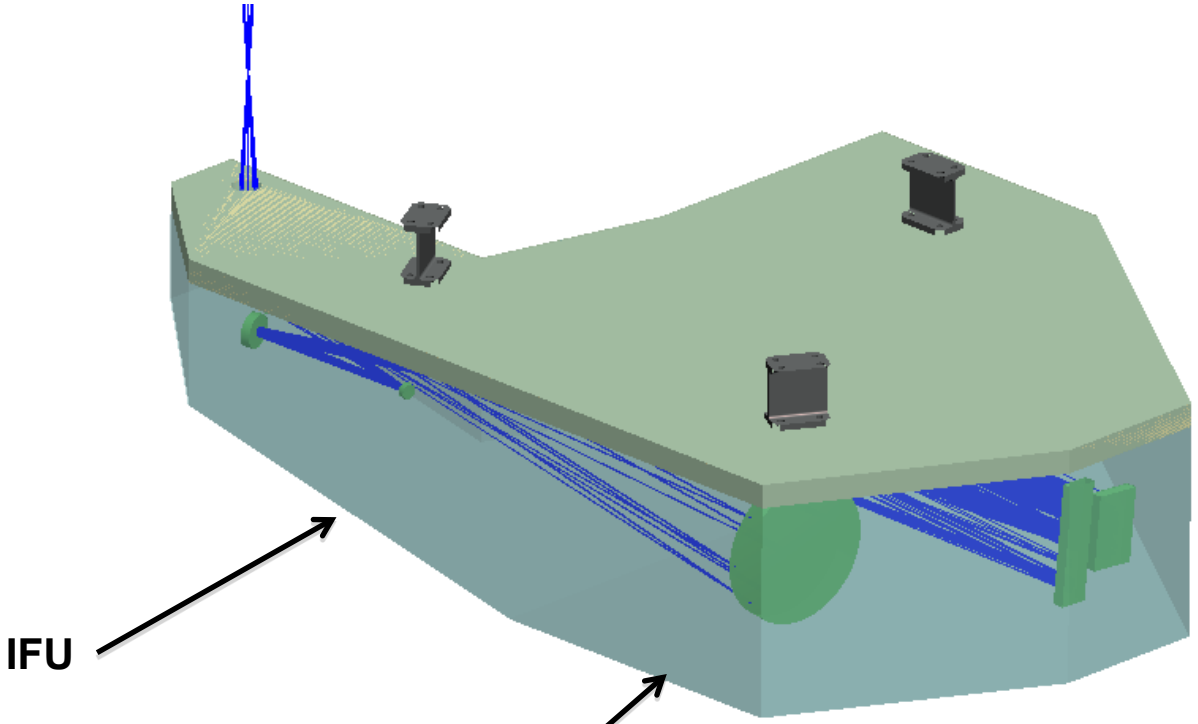

Telescope
Solar Array /
Sunshield
Wide Field
Instrument
Coronagraph
Instrument
Instrument Carrier
(blue truss)
Spacecraft
Bus

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

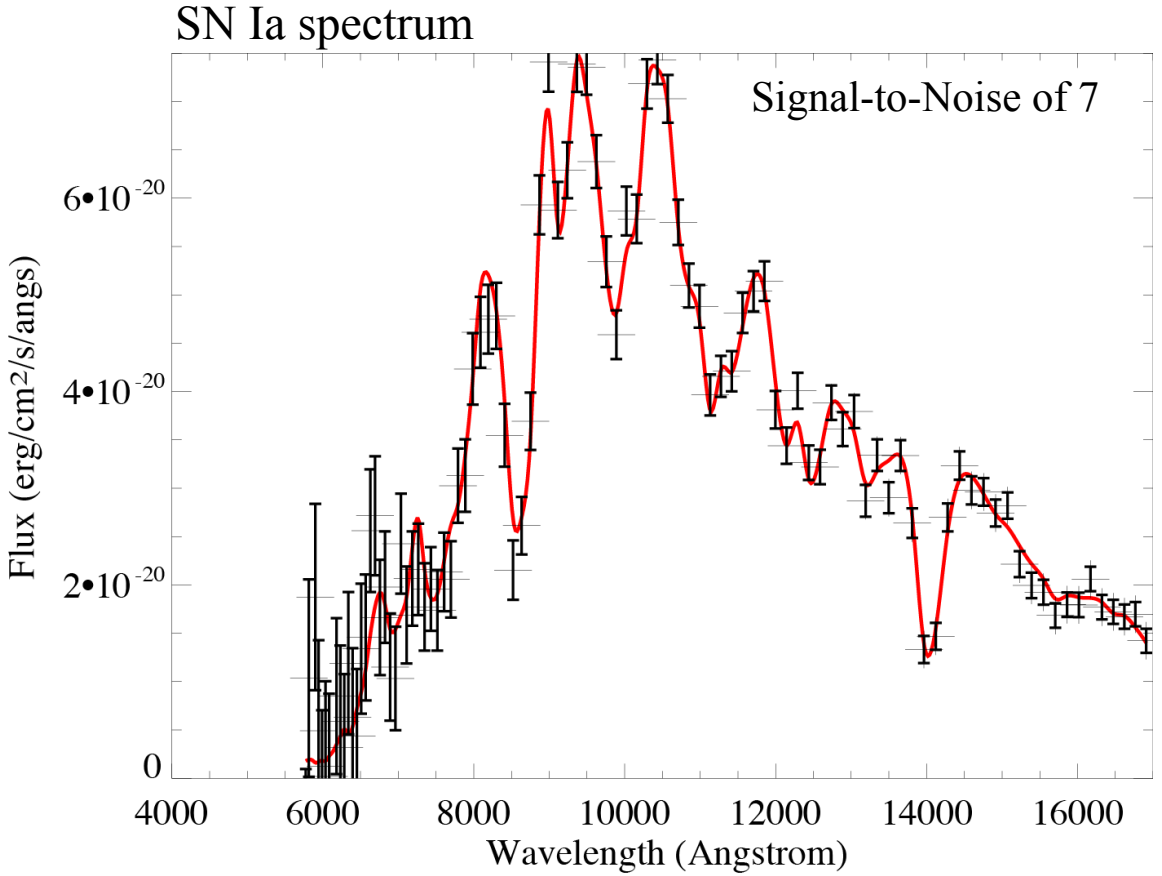
Use IFU spectra to get SN light curves with roughly a 5 day rest frame cadence.

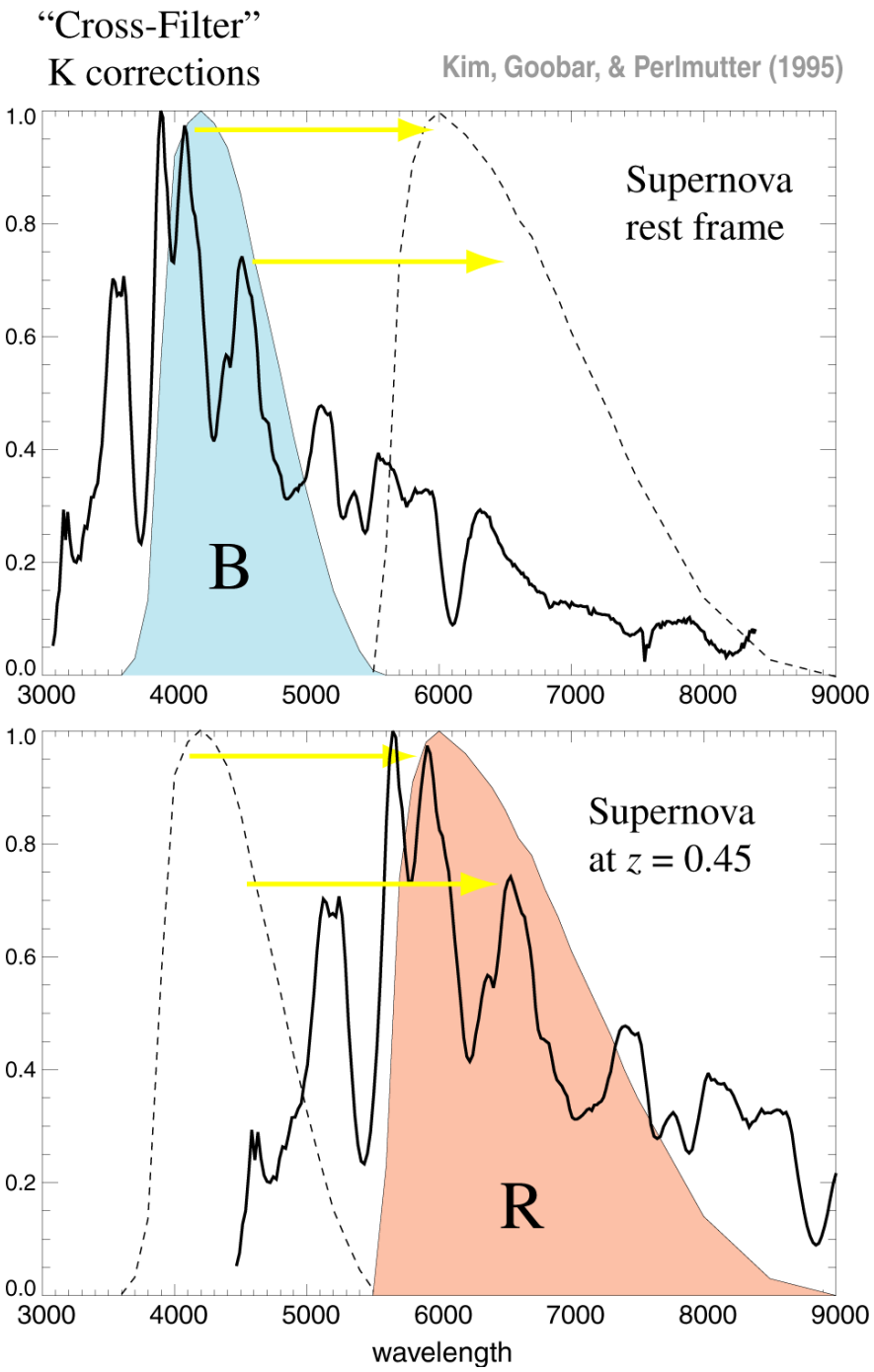
Example:

- 7 spectra on lightcurve from -10 rest frame days before peak to +25 rest frame days past peak, S/N = 3 per pixel (S/N = 15 per synthetic filter band)

- 1 reference spectrum after supernova has faded, for **galaxy subtraction** with S/N = 6 per pixel

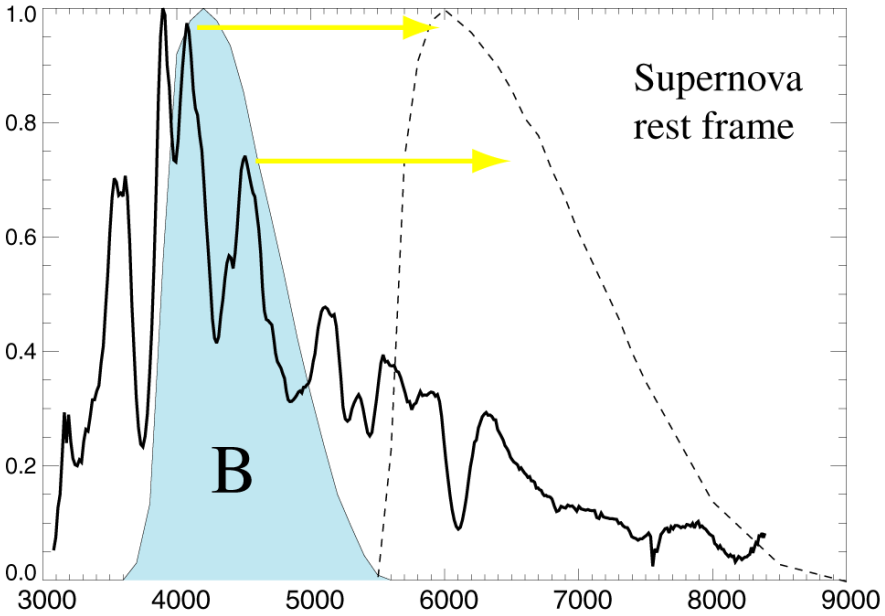
- 1 deep spectrum near peak for subtyping, spectral feature ratios etc. with S/N = 10 per pixel



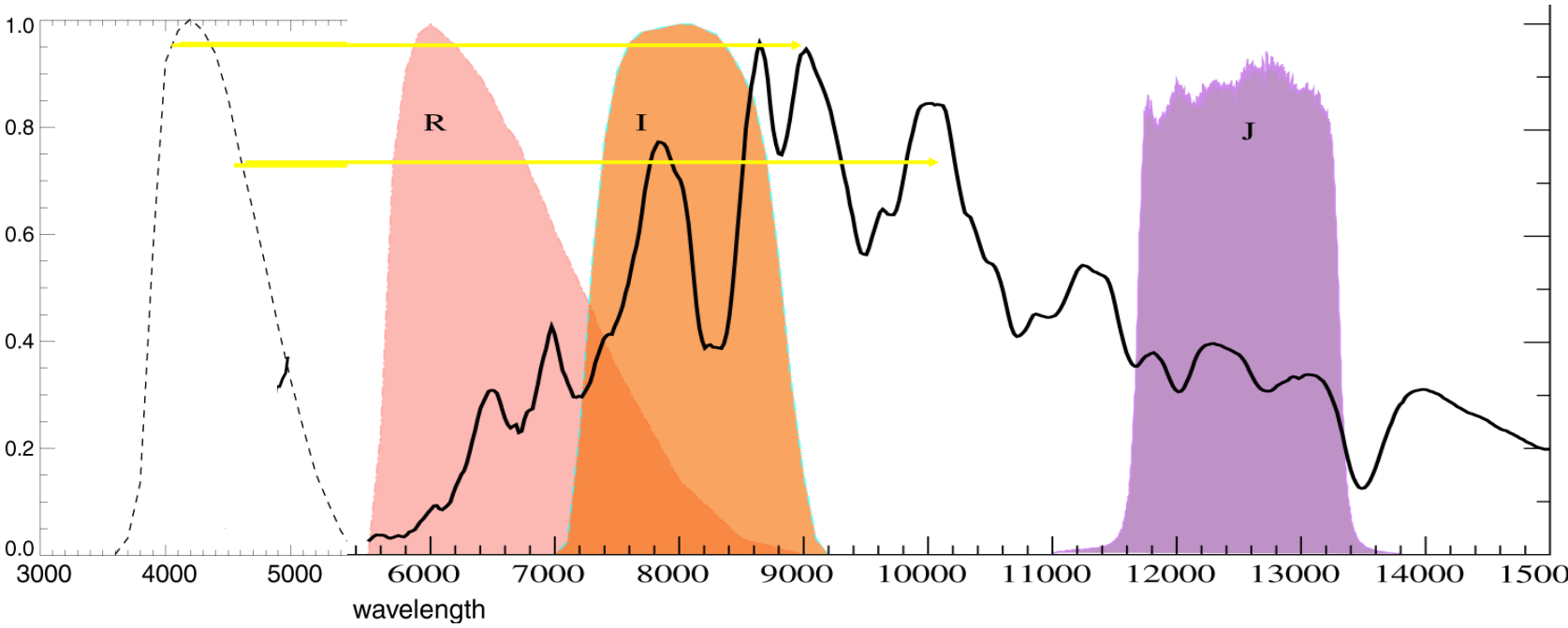

"Cross-Filter"
K corrections
Kim, Goobar, & Perlmutter (1995)
Supernova
rest frame
B
Supernova
at z = 0.45
R
1.0
0.8
0.6
0.4
0.2
0.0
3000
4000
5000
6000
7000
8000
9000
wavelength

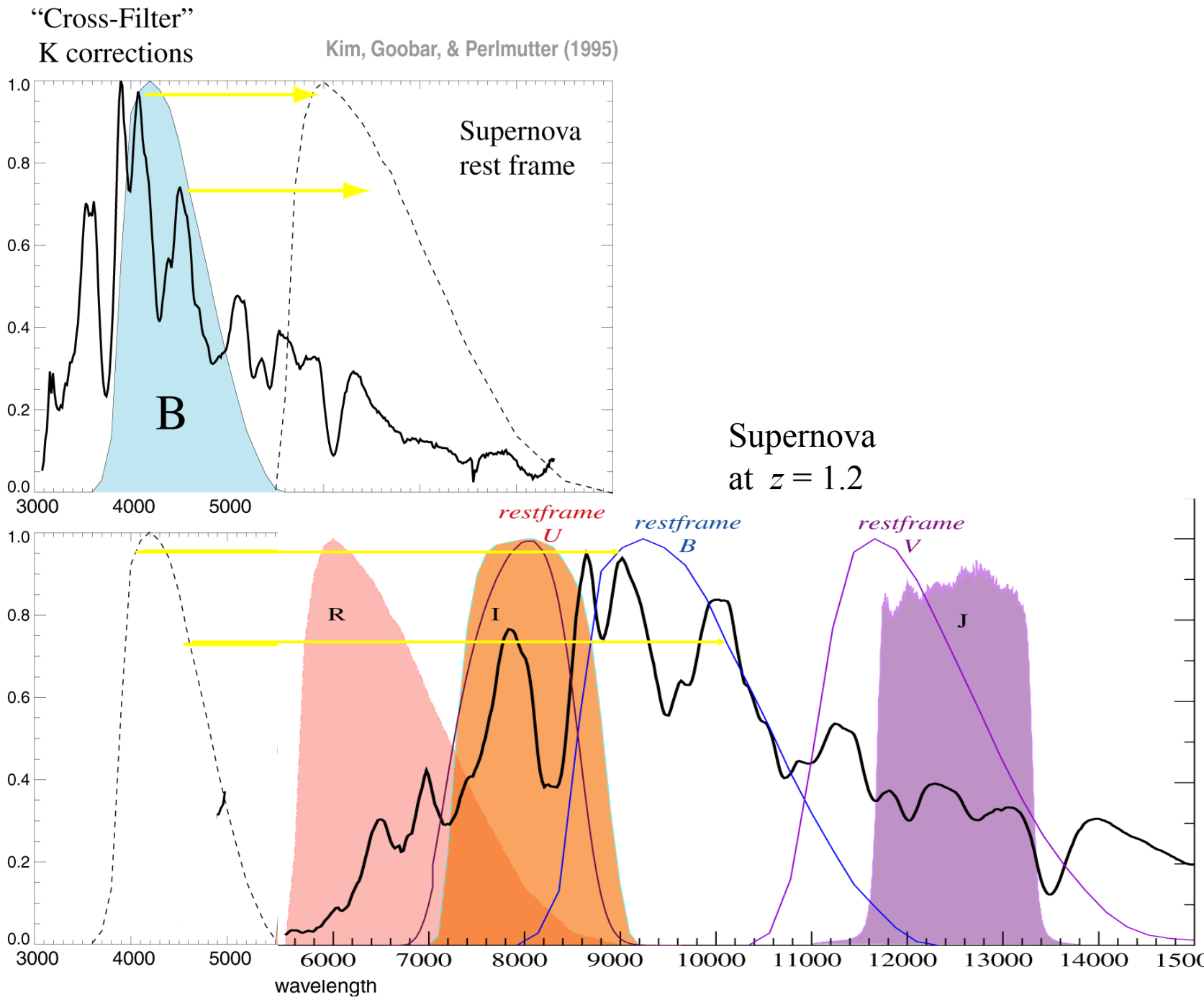
"Cross-Filter"
K corrections

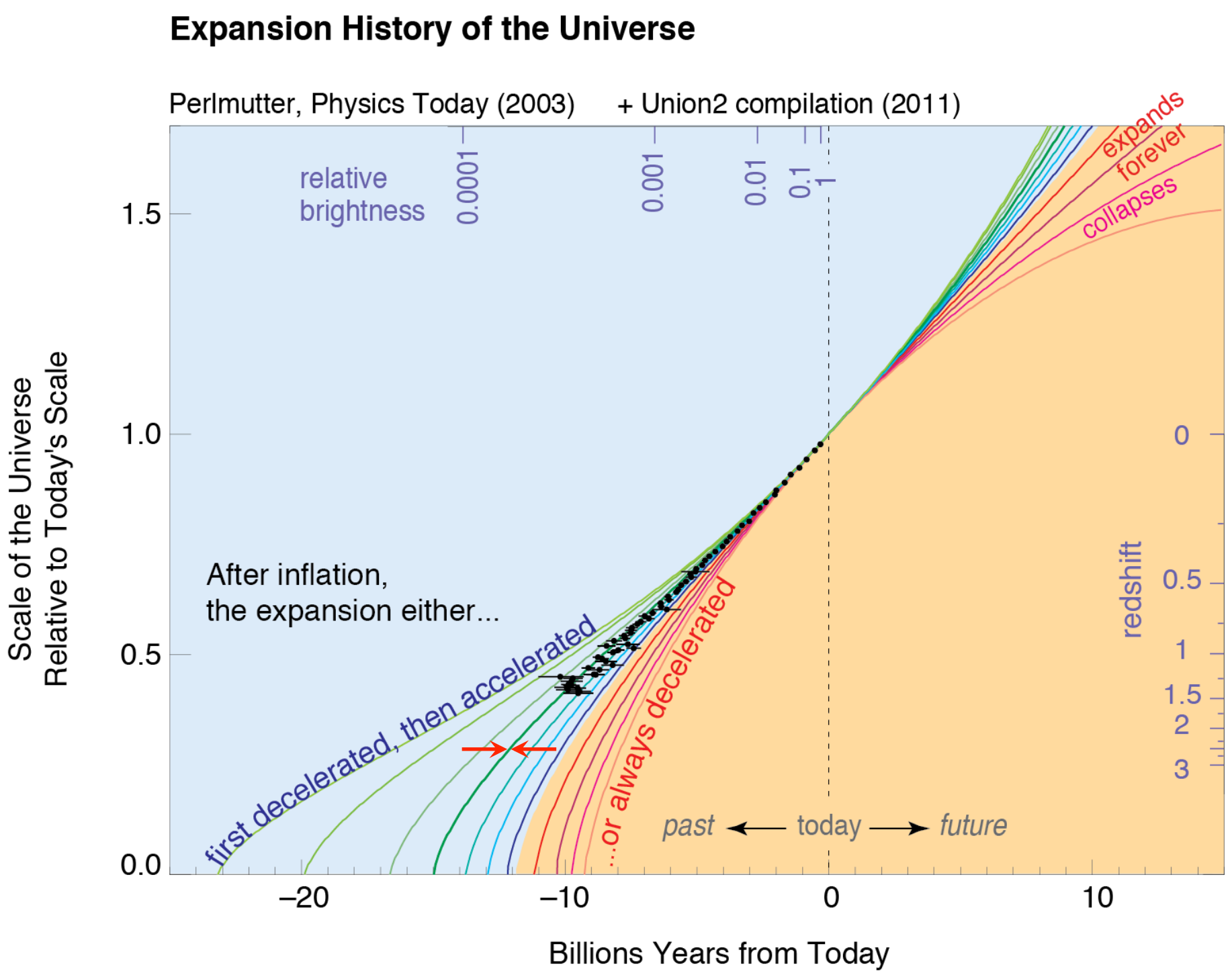
Kim, Goobar, & Perlmutter (1995)



Supernova
at $z = 1.2$



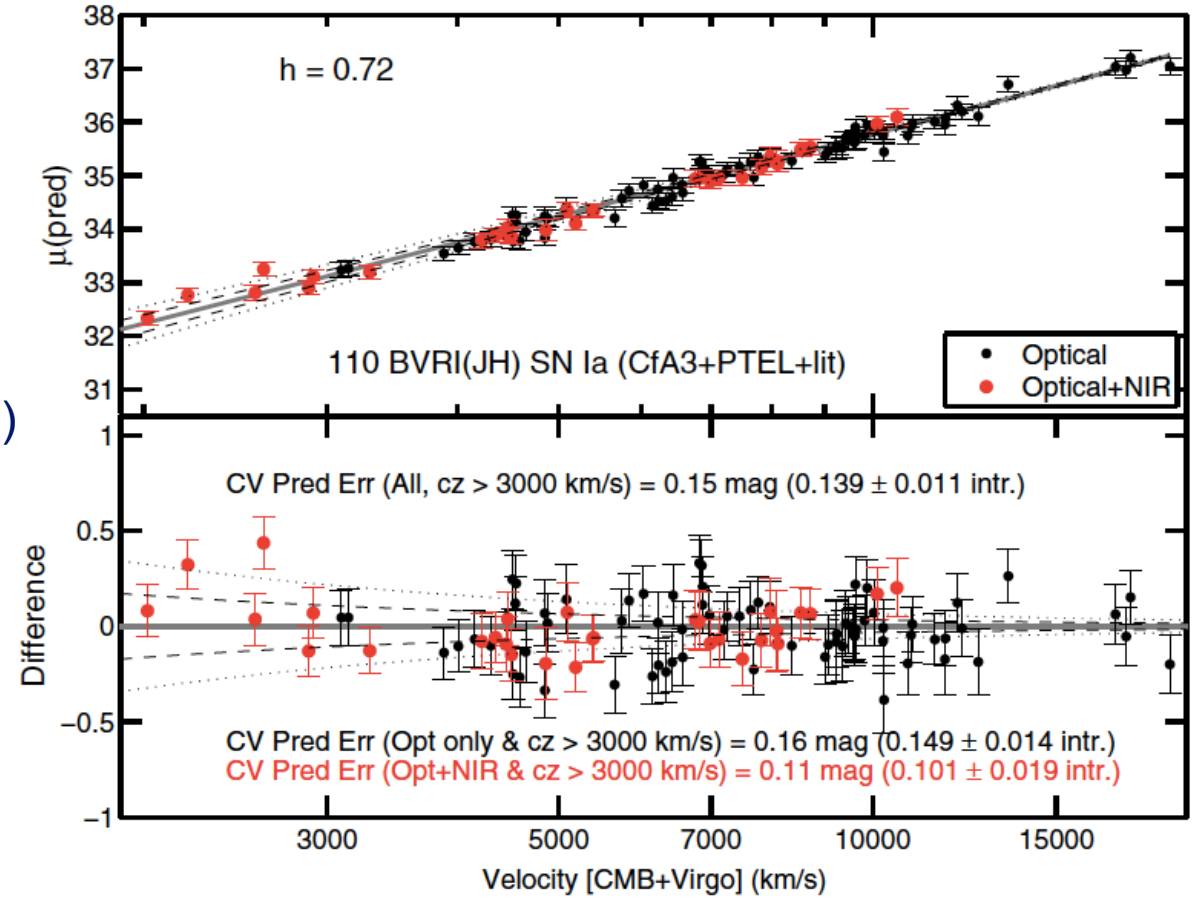

"Cross-Filter"
K corrections
Kim, Goobar, & Perlmutter (1995)
Supernova
rest frame
B
Supernova
at z = 1.2
restframe
U
restframe
B
restframe
V
R
I
J
wavelength


Expansion History of the Universe
Perlmutter, Physics Today (2003)
+ Union2 compilation (2011)
relative brightness
0.0001
0.001
0.01
0.1
1
expands forever
collapses
After inflation, the expansion either...
first decelerated, then accelerated
...or always decelerated
redshift
0
0.5
1
1.5
2
3
past
today
future
Scale of the Universe Relative to Today's Scale
0.0
0.5
1.0
1.5
–20
–10
0
10
Billions Years from Today

Lightcurve Standardization

A route to better standardization:
Add J and H band.

(But J band is not as big an improvement as H band.)

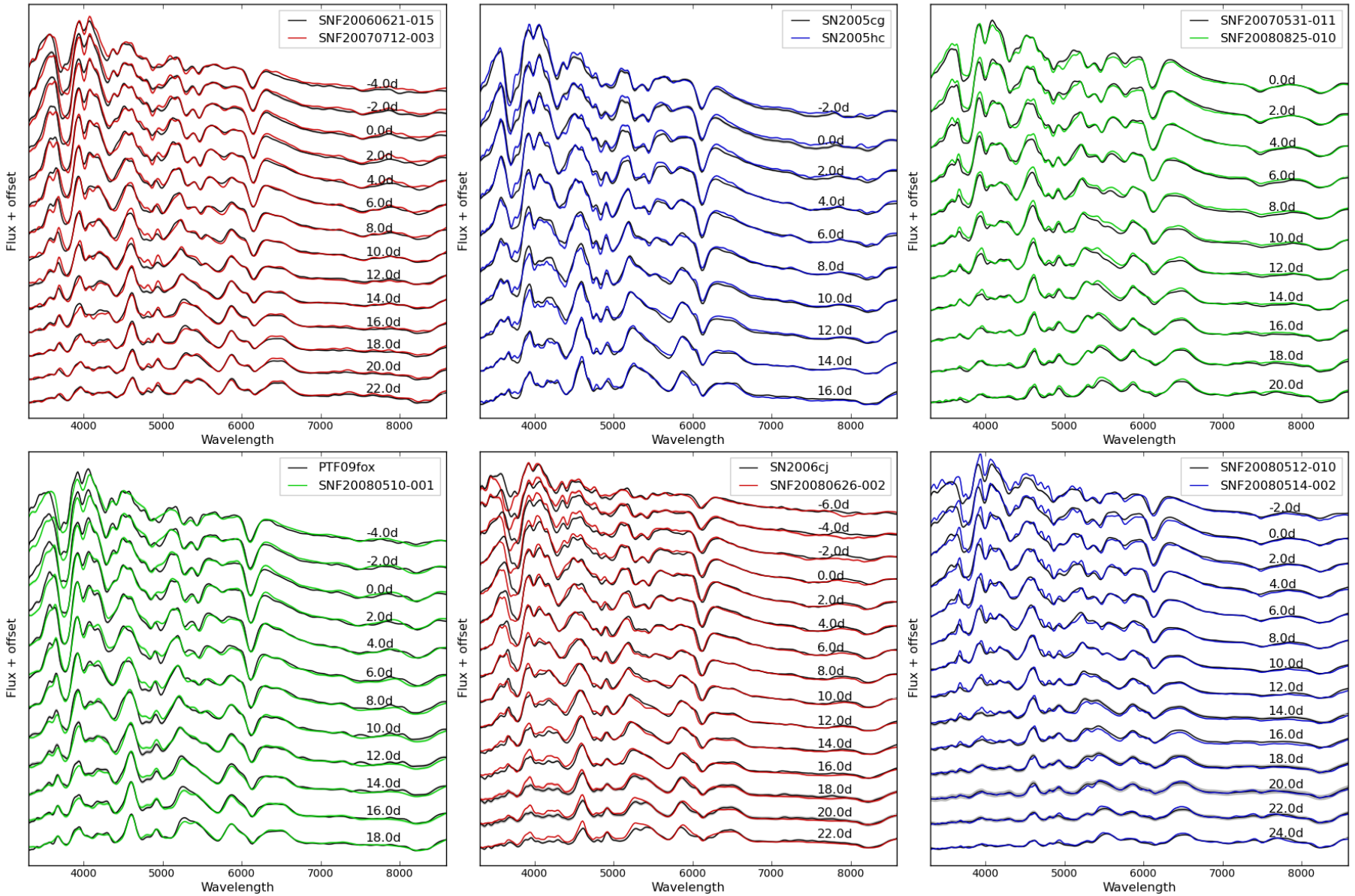


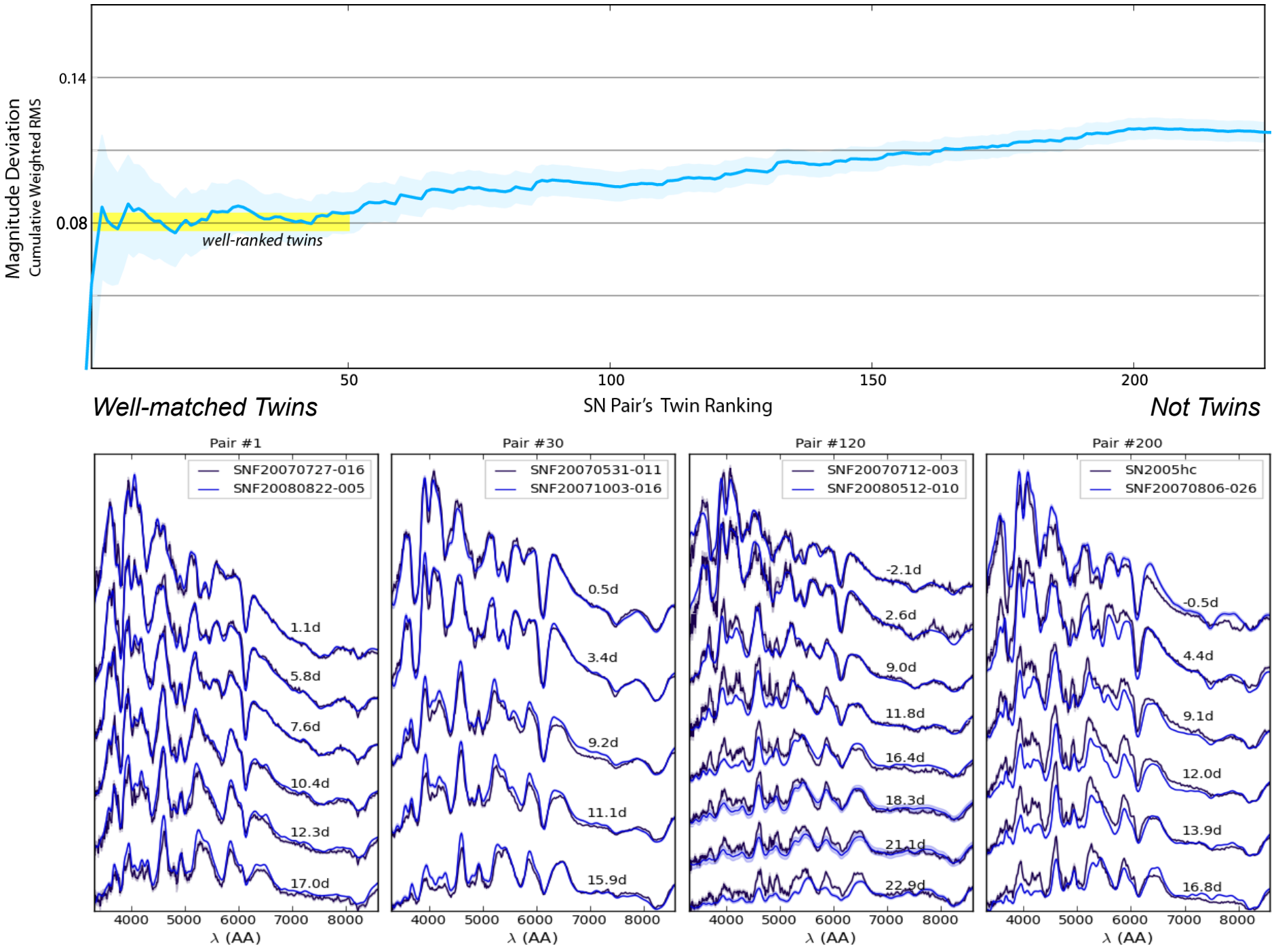
Mandel et al (2011)

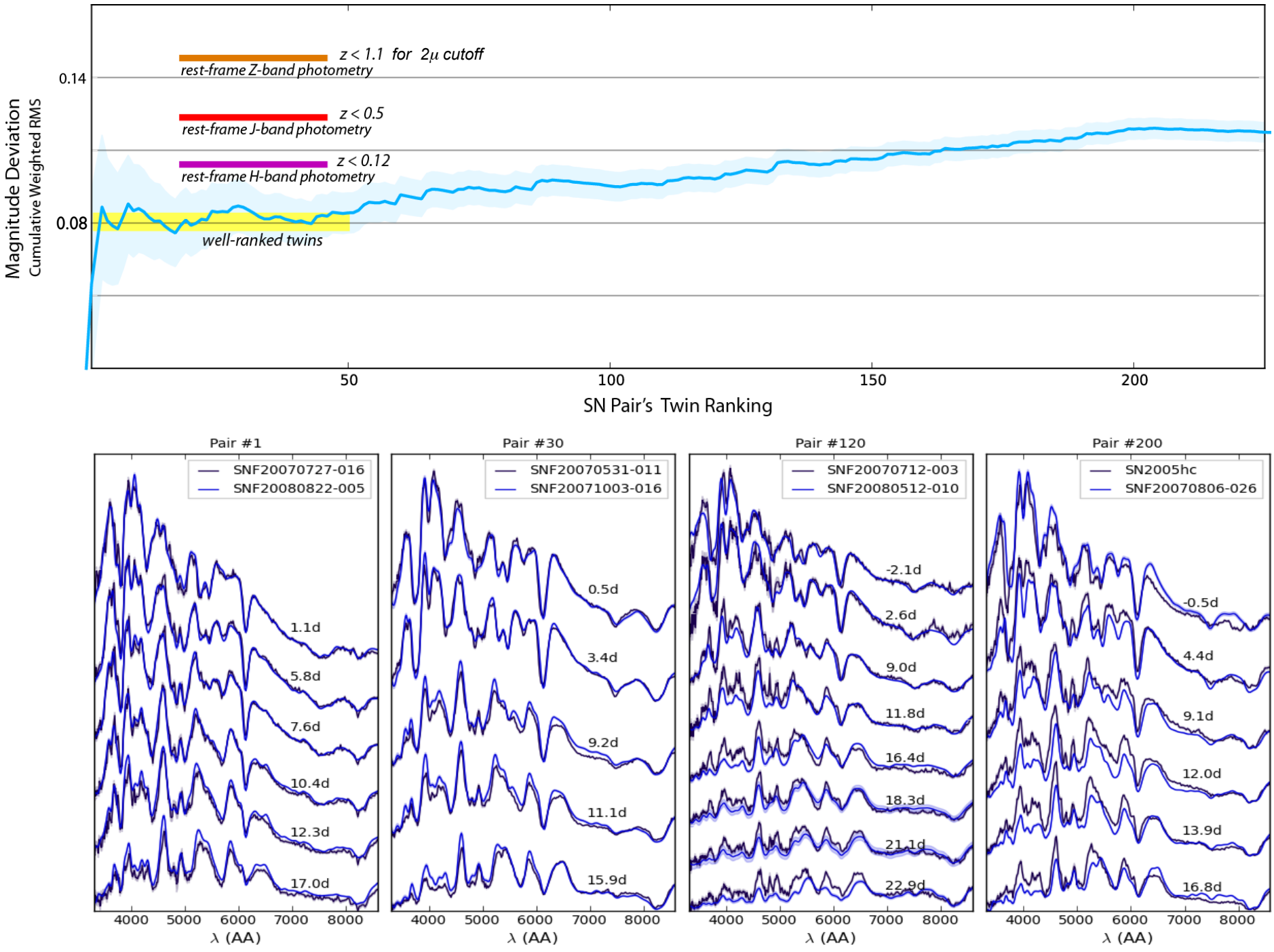
WFIRST can obtain H band out to z = 0.12 (with 2 micron cutoff) or z = 0.35 with (2.5 micron cutoff).

SN Twins

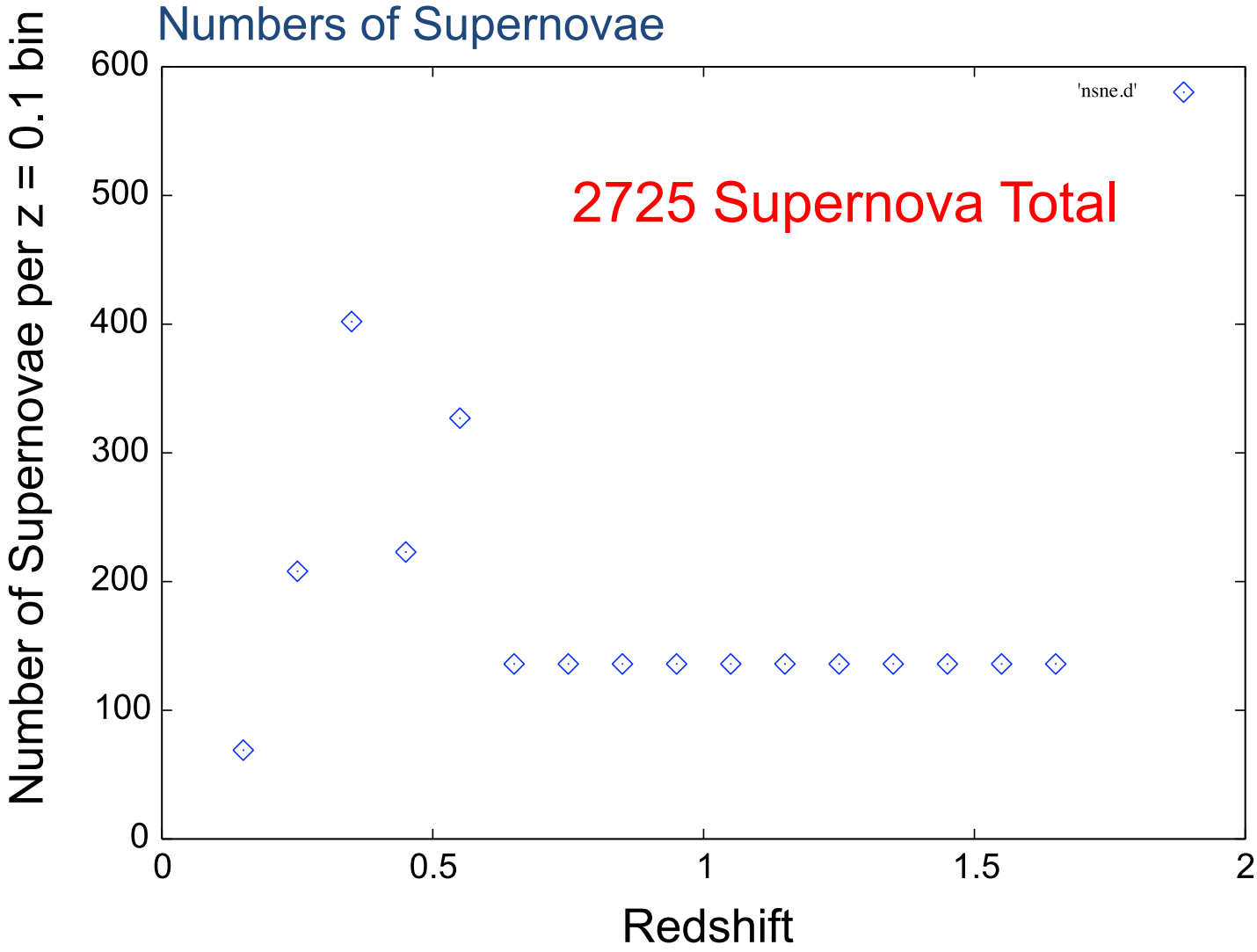
Nearby Supernova Factory



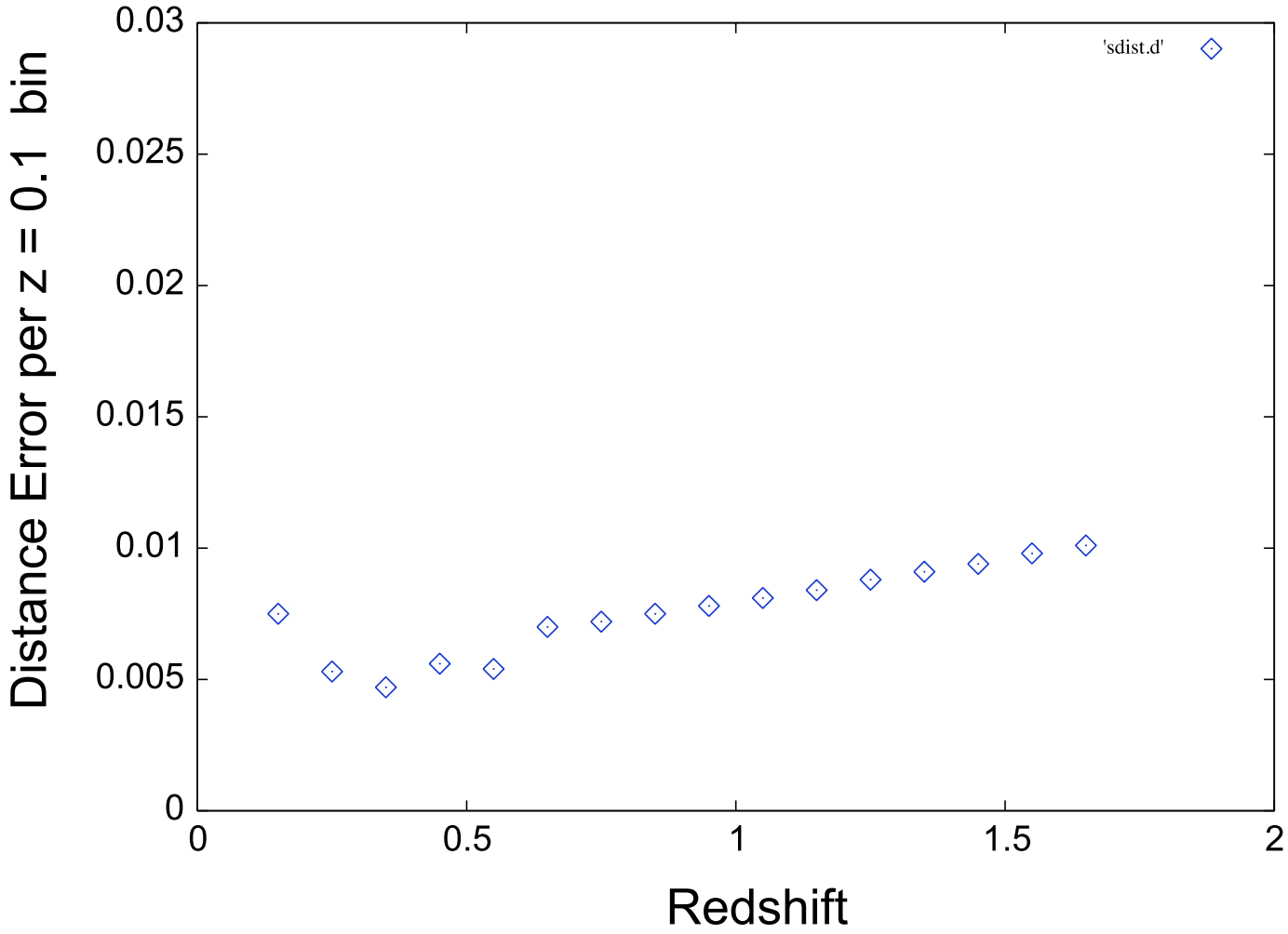

Magnitude Deviation
Cumulative Weighted RMS
0.14
0.08
well-ranked twins
50
100
150
200
Well-matched Twins
SN Pair's Twin Ranking
Not Twins
Pair #1
SNF20070727-016
SNF20080822-005
1.1d
5.8d
7.6d
10.4d
12.3d
17.0d
Pair #30
SNF20070531-011
SNF20071003-016
0.5d
3.4d
9.2d
11.1d
15.9d
Pair #120
SNF20070712-003
SNF20080512-010
-2.1d
2.6d
9.0d
11.8d
16.4d
18.3d
21.1d
22.9d
Pair #200
SN2005hc
SNF20070806-026
-0.5d
4.4d
9.1d
12.0d
13.9d
16.8d
4000
5000
6000
7000
8000
λ (AA)


Magnitude Deviation
Cumulative Weighted RMS
0.14
0.08
z < 1.1 for 2μ cutoff
rest-frame Z-band photometry
z < 0.5
rest-frame J-band photometry
z < 0.12
rest-frame H-band photometry
well-ranked twins
50
100
150
200
SN Pair's Twin Ranking
Pair #1
SNF20070727-016
SNF20080822-005
1.1d
5.8d
7.6d
10.4d
12.3d
17.0d
Pair #30
SNF20070531-011
SNF20071003-016
0.5d
3.4d
9.2d
11.1d
15.9d
Pair #120
SNF20070712-003
SNF20080512-010
-2.1d
2.6d
9.0d
11.8d
16.4d
18.3d
21.1d
22.9d
Pair #200
SN2005hc
SNF20070806-026
-0.5d
4.4d
9.1d
12.0d
13.9d
16.8d
4000
5000
6000
7000
8000
λ (AA)

For an example: 3 tier survey, scanning different areas of sky for different redshift ranges -- for 6 months spread over 2 years calendar time – yields

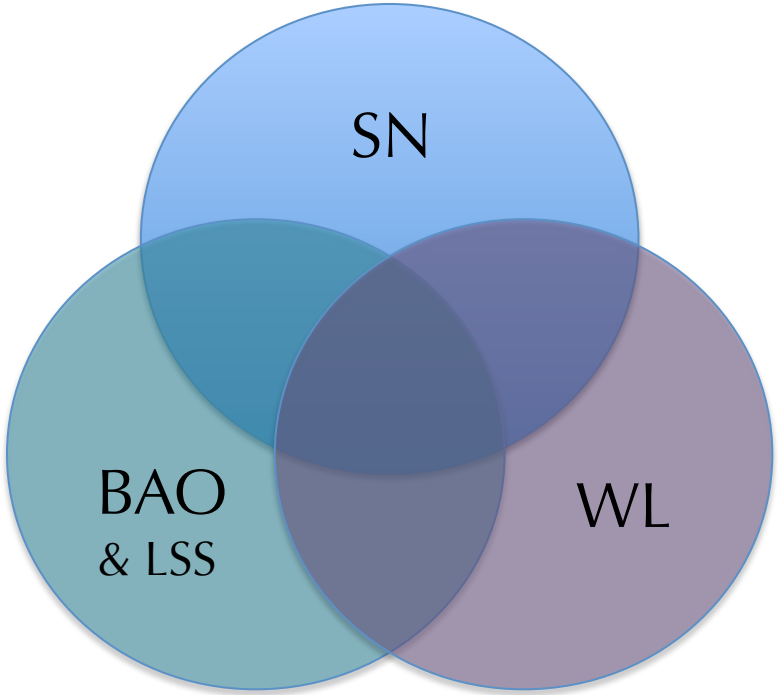


Error on Distance Measurement



Figures of Merit

- For the Supernova Survey only FoM = 312
- Supernova with Stage III prior FoM = 582



LSST & WFIRST Weak Lensing DETF FoM is >1.6x larger if can train at z>2 with IFU

A bigger issue for WFIRST WL: *H*-limited sample skews to higher z!

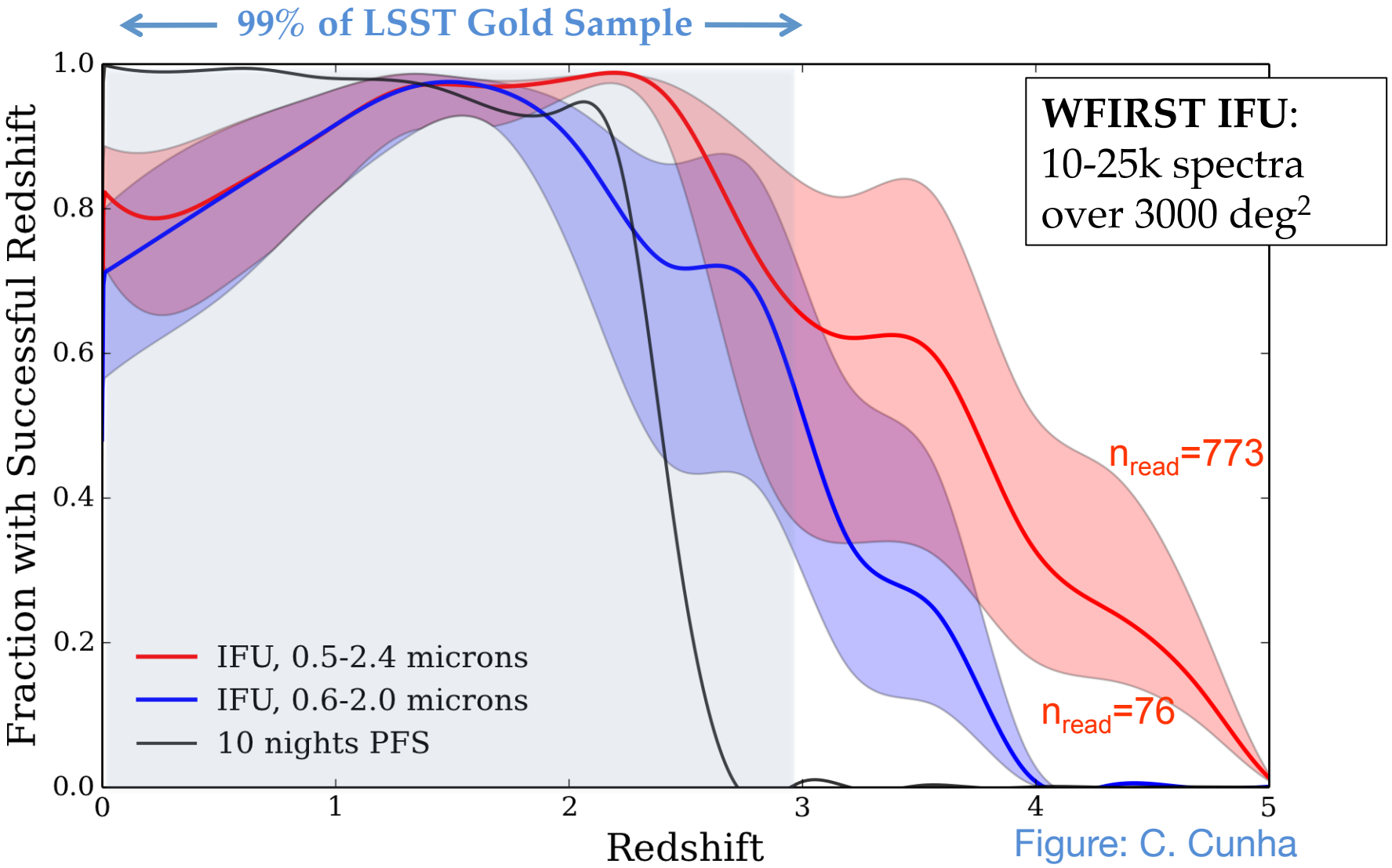


Figure: C. Cunha

The Dark Energy capabilities of the WIRST SN program are unmatched.

The 2.4m and IFU give spectral data cubes that make possible:

- SN spectra with host galaxy subtracted.
- SN lightcurves with no K-correction systematic errors, with as full a wavelength coverage as possible.
- Control of SN population-evolution systematics using matched spectra with high S/N.

The resulting distance-redshift measurements dramatically improve DE FoM's with or without the other techniques.

Chotard et al (A&A, 2011)

Nearby Supernova Factory