Studies of WFIRST Supernovae Program for Dark Energy Measurements

WFIRST Preparatory Study
Perlmutter, Rubin, Baltay

WFIRST WPS Meeting
Pasadena
March 2016

WFIRST Science Investigation Team Members

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IFU SIT WG Co-Chairs: Andrew Fruchter & Greg Aldering
Plan and Sim Co-Chairs: Masao Sako & Mark Phillips

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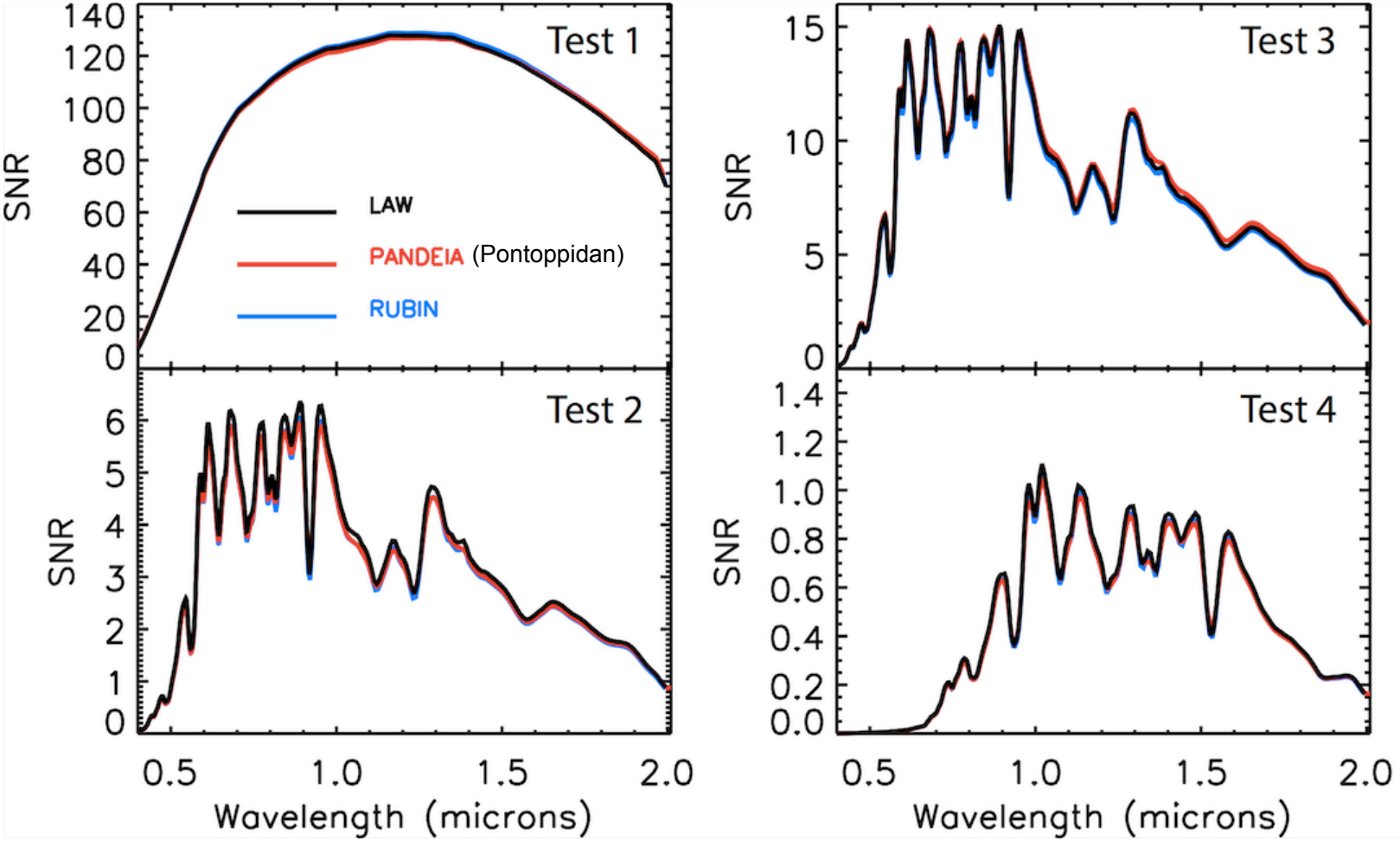
Michael Wood-Vasey
Andrew Connolly
Mario Juric
Andy Howell
Lifan Wang

Eric Hsiao
Christopher Burns
J. Craig Wheeler
Michael McElwain
Jeffrey Newman
Alex Kim
Kyle Barbary

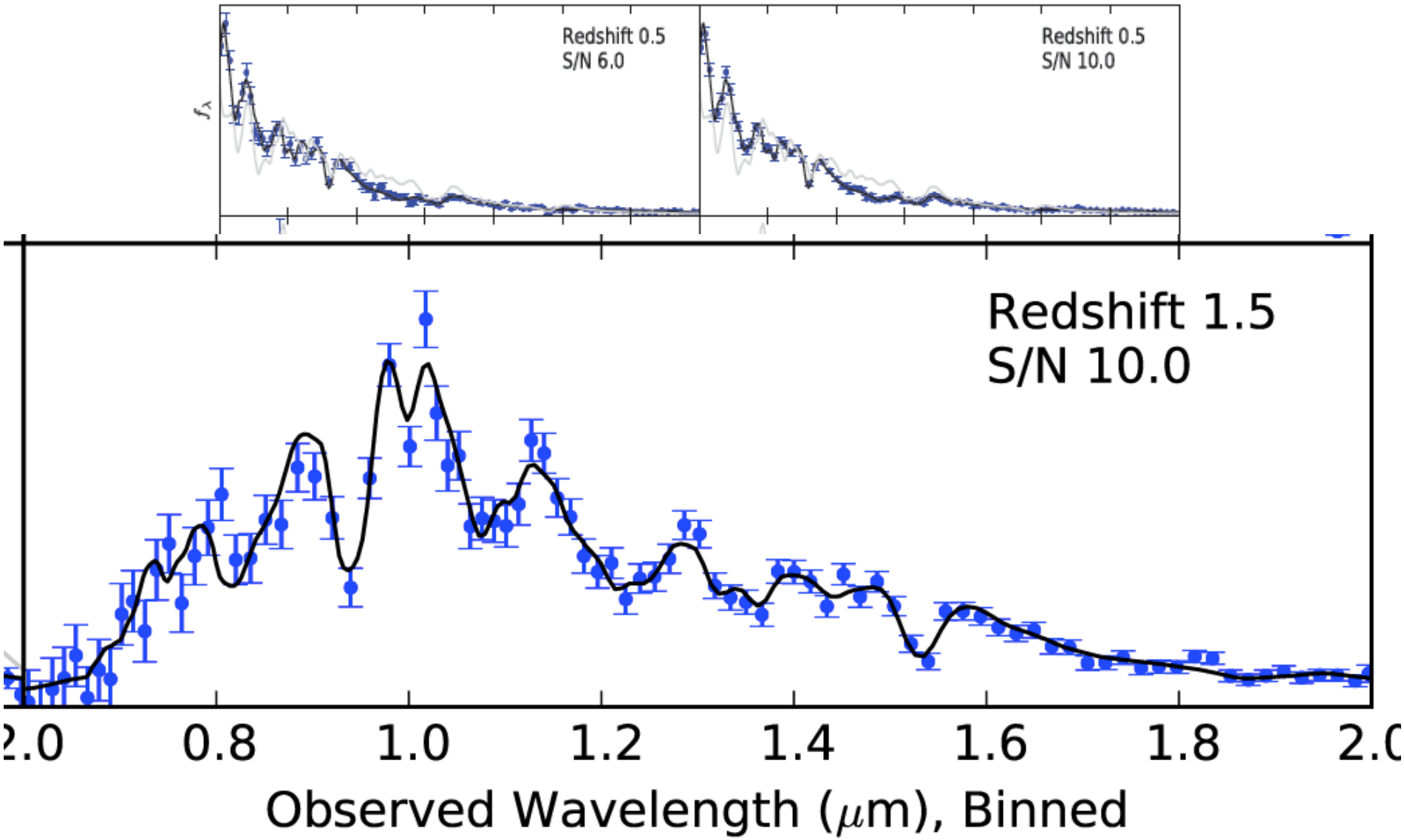
David Law
Klaus Pontoppidan
David Rabinowitz
Schuyler Van Dyk
Rollin Thomas
Peter Nugent

IFU Exposure Time Calculator (ETC)

Three separate ETCs agree:



Useful spectra:



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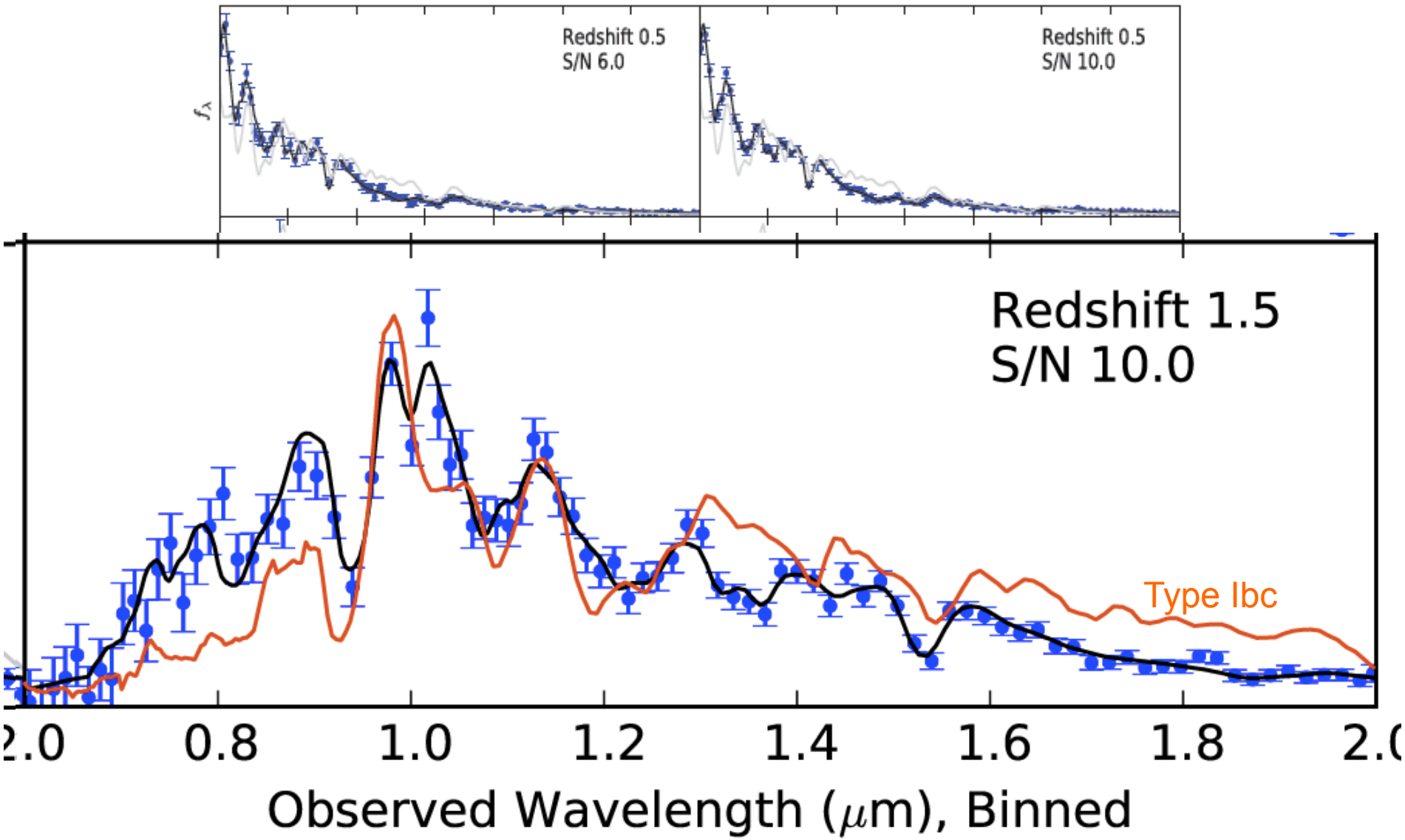
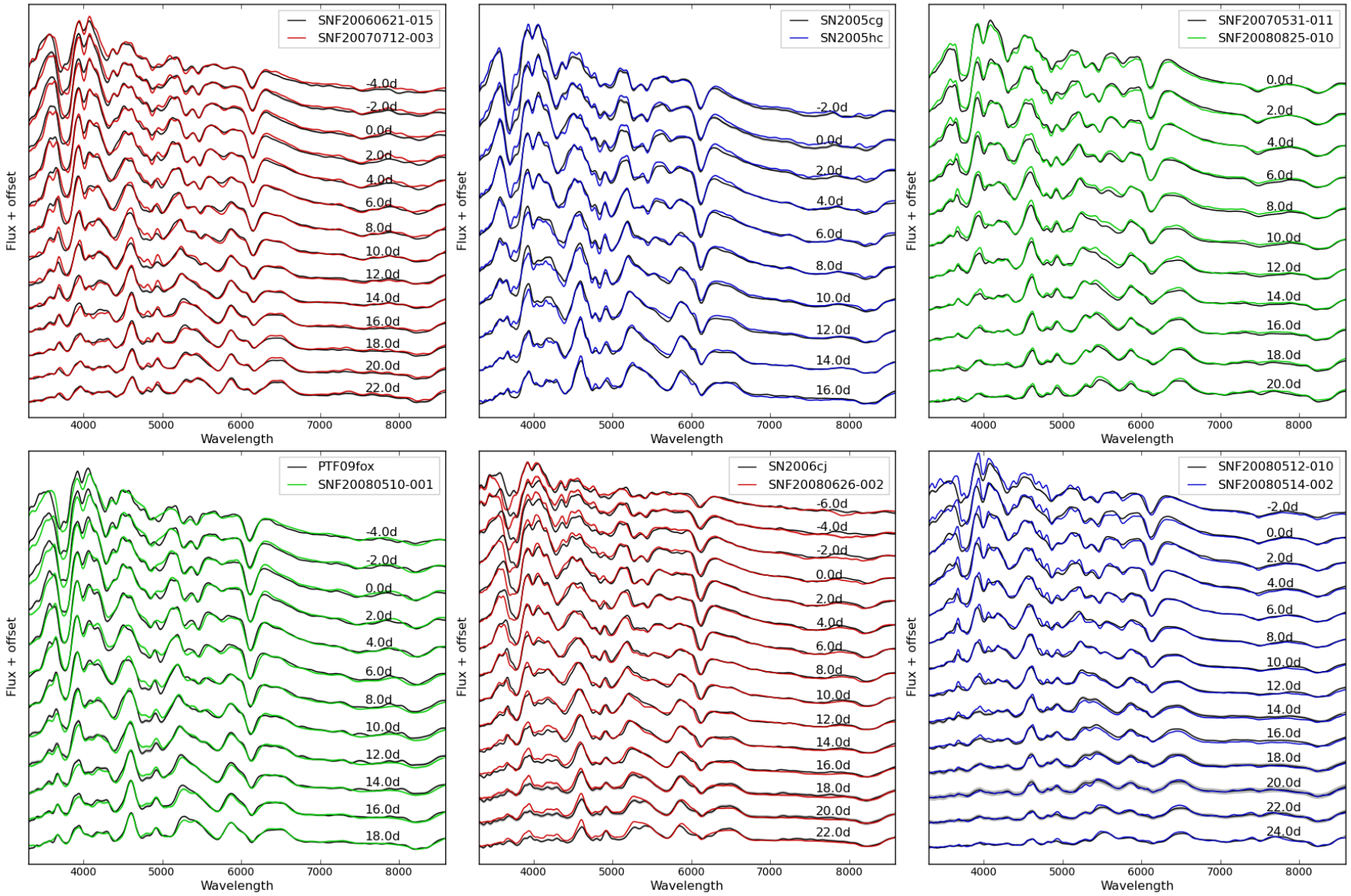


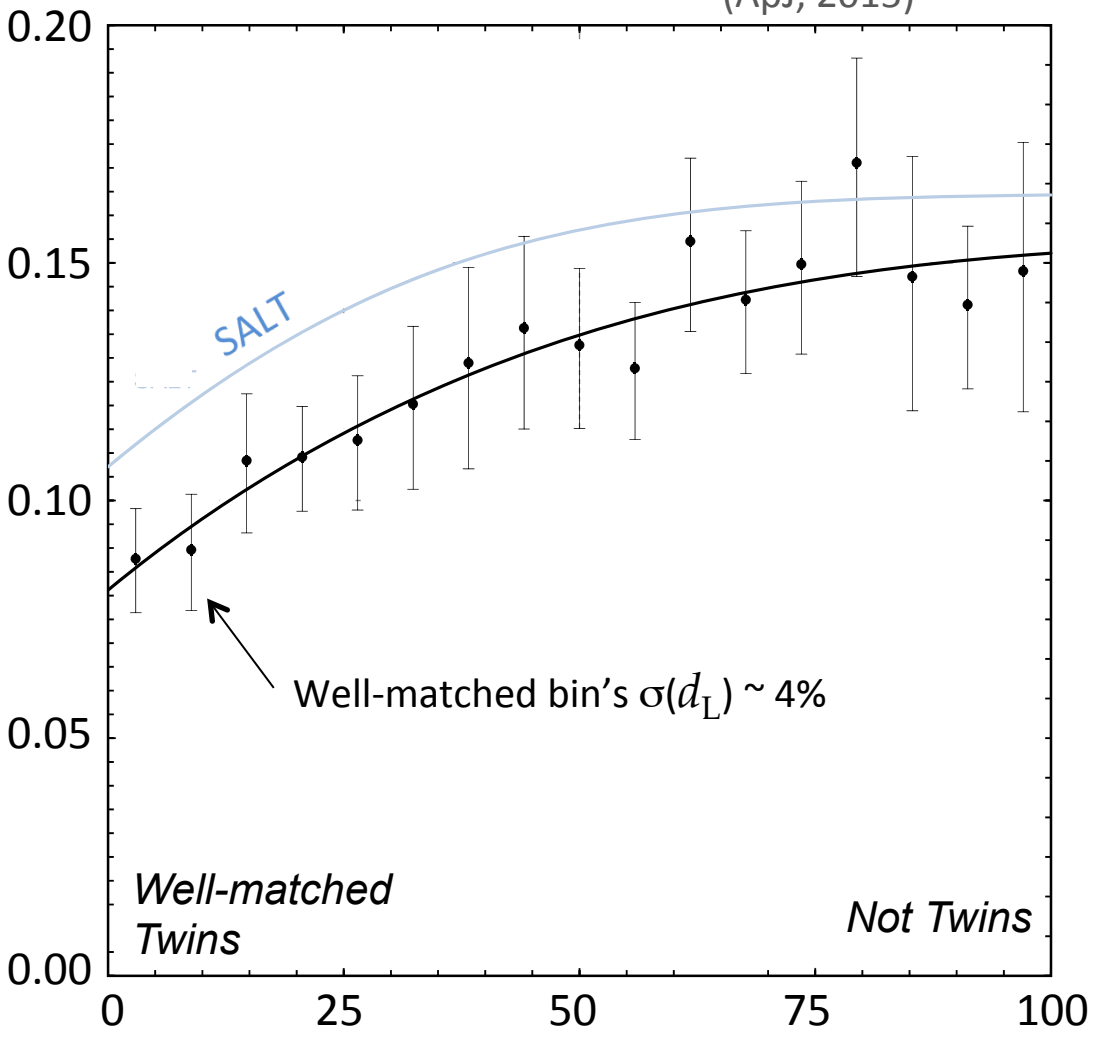
Twins study from SN Factory spectral time-series



SN Factory: Fakhouri+ ApJ 2015

Twin SNe

Nearby SN Factory
Fakhouri, Boone, et al.
(ApJ, 2015)



for SN pairs in the %-ile bin

NB: Blind analysis methods used.

Checking Limiting Magnitudes

"What Every Astronomer Should Know" appears to have overestimated open-shutter exposure times.

132 visits	WFIRST-2.4: What Every Astronomer Should Know	David Rubin's pixel-level ETC
Wide (13s per filter)	Y = 27.1 J = 27.5	Y = 25.0 J = 25.0
Medium (67s per filter)	J = 27.6 H = 28.1	J = 27.5 H = 27.5
Deep (265s per filter)	J = 29.3 H = 29.4	J = 29.2 H = 29.1

SN Program Simulation Capabilities

Simulated Observations:

- Multiple SED Population Models
- Non-Ia Contamination

- Electron Counts from Effective Area
- WebbPSF PSFs
- IFU: Sliced Image
- IFU: Monochromatic PSFs Mapped to Detector Pixels
- WFI: Monochromatic PSFs Stacked
- Convolution with Square Detector Pixel + Inter-Pixel Capacitance
- Other Noise:
  - OTA Thermal
  - Dark Current/ Instrumental Thermal
  - Read-Noise/Readout Implementations
  - Zodiacal
  - Galaxy Background (Currently Spatially Uniform)

Survey:

- Multi-Tiered Space/Ground
- IFU + WFI

Cosmological Analysis:

- Simultaneous fit of SN flux, SED, systematics and cosmology
- Host-Galaxy Extinction (redshift)
- Intergalactic Extinction (redshift)
- Milky-Way Extinction
- Gravitational Lensing Dispersion (redshift)
- Peculiar Velocity Dispersion (redshift)
- Population Drift: Distribution of SED (redshift)
- “Intrinsic” Dispersion
- “Fundamental” Energy Calibration
- Count-Rate Nonlinearity
- Selection Effects (“Malmquist Bias”)
- Host-Galaxy Environment
- Non-Ia Contamination

Systematics

Examples from current lists of systematic uncertainties included in studies. Constraints (priors) on systematics are constantly being refined

Fundamental calibration

Instrument calibrations

Count-rate nonlinearity

Milky Way extinction zero point

Milky Way extinction Rv

Intergalactic extinction

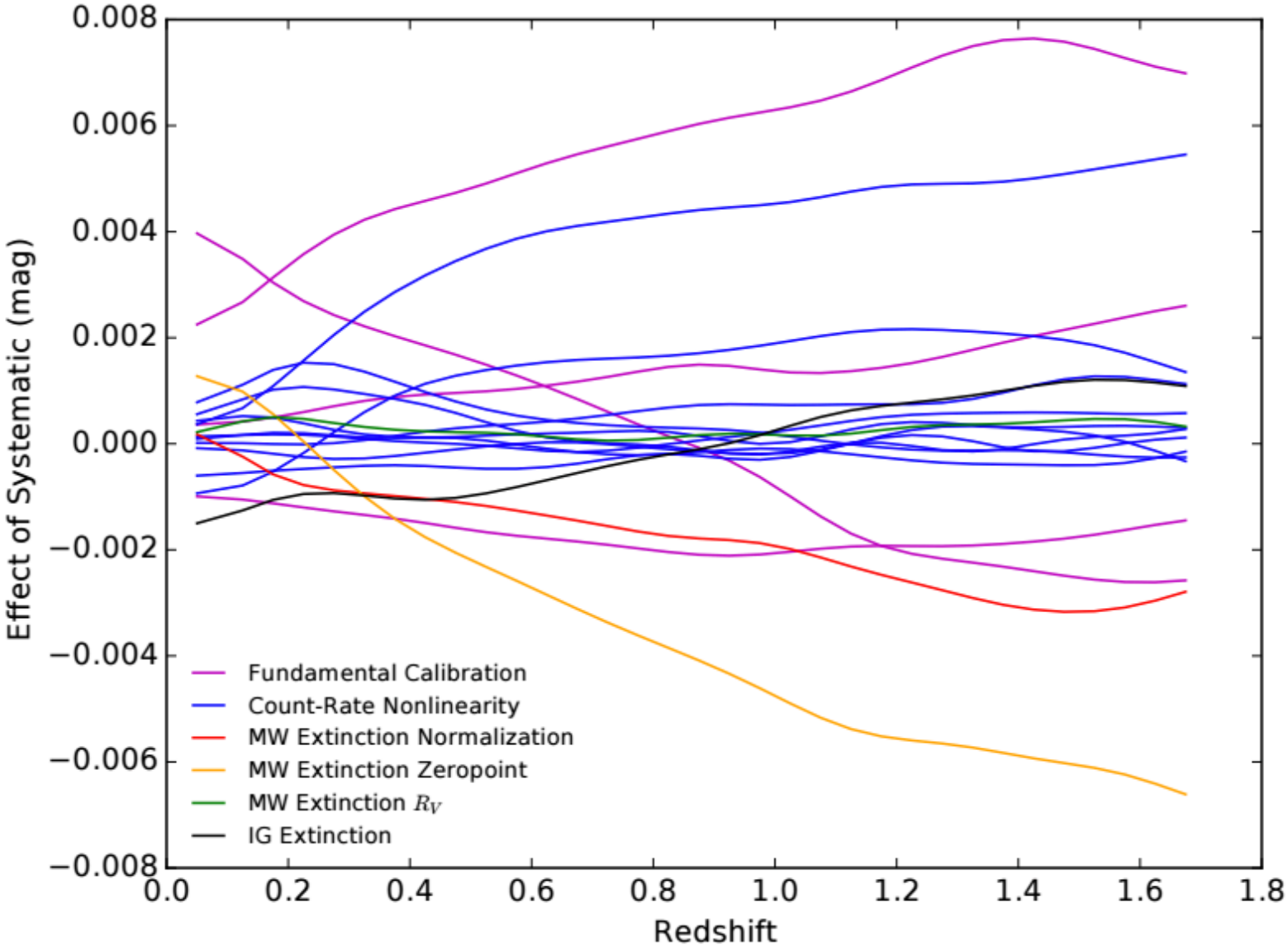
Malmquist bias

Evolutionary drift in Rv (even 10% change in Rv)

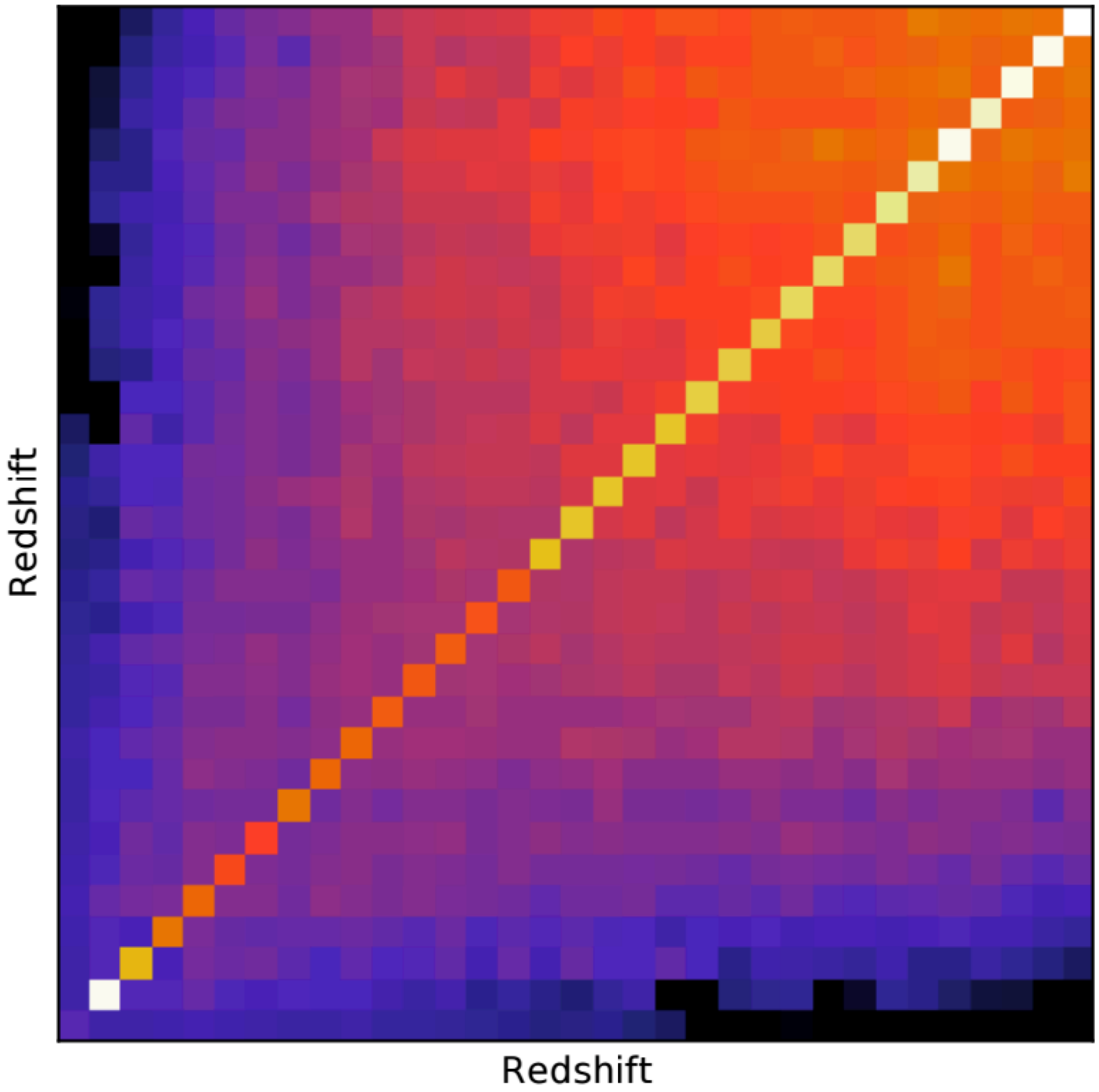
Evolutionary population drift within known range of SNe Ia (~1σ)

Non-SN Ia contamination

Systematics models



Correlation matrix (with redshift)



Current work on SN program concept

with and without ground-based discoveries

Updates:

- Higher S/N follow-up
- More time for high-z SNe, less time for low-z SNe
- Optimize choice of filters. Low-z tier: ZY rather than YJ

Program Concept	**Number of SNe**			**FoM** (±~10)	
z =	0.1--0.4	0.4--0.8	0.8--1.7	*Without Rv drift syst.*	*With the systematics*
2-band **WFIRST imaging discovery** and lightcurves. Spectrophotometric time series.	420	912	606	350	300
Ground imaging discovery and lightcurves. WFIRST spectrophotometric time series.	2,239	6,101	0	375	210
Ground & WFIRST imaging discovery and lightcurves. Spectrophotometric time series.	591	1,712	909	460	360

Select ~70% of confirmed SN Ia to follow to be picky about SN and host- galaxy types. Reject 91T, 91bg
Spectroscopic screening for twice as many as are chosen for follow-up

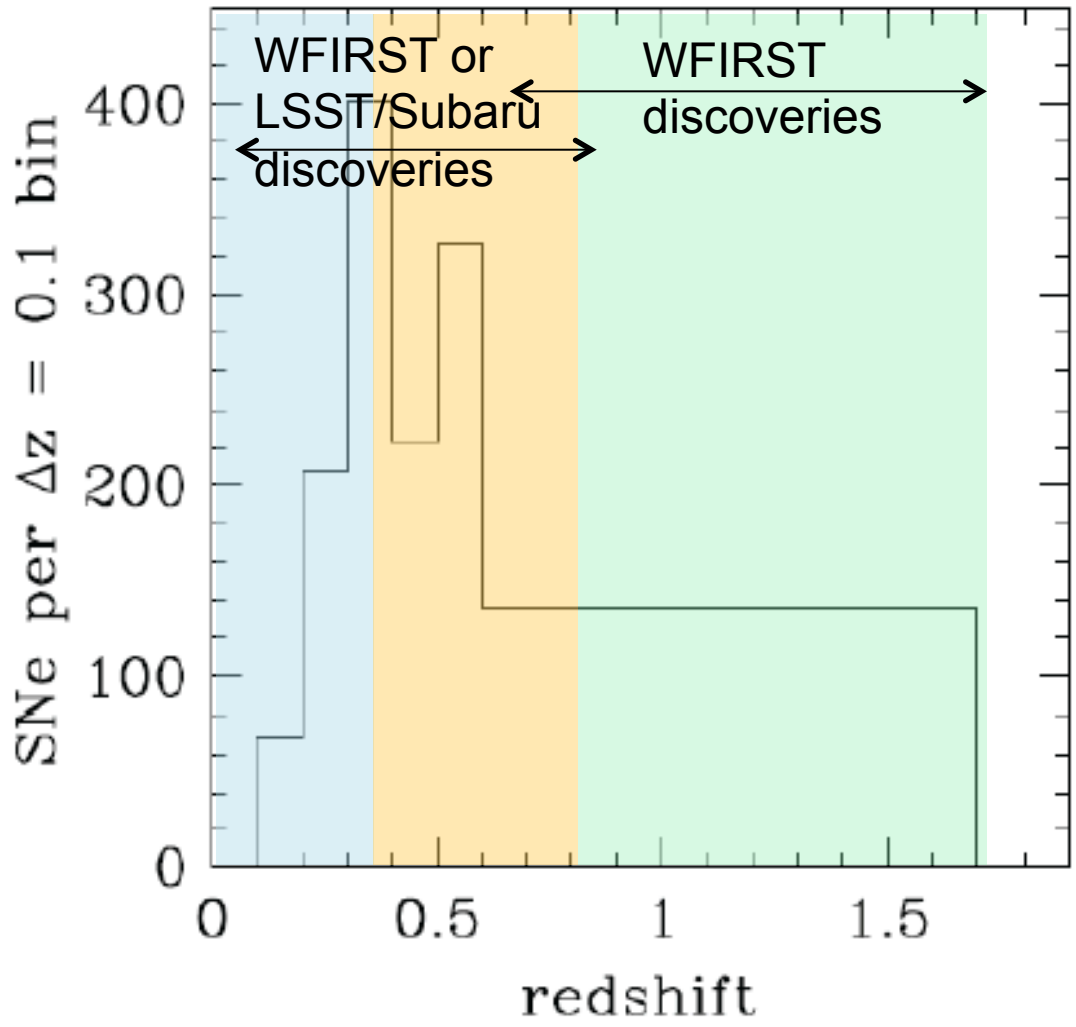


Figure 2-6: Expected number of Type Ia SNe to be followed in each Δz = 0.1 redshift bin. For z > 0.6 there are, by design, 136 SNe followed up with spectroscopic observations in each bin (from a larger number detected). The total number of SNe is 2725.

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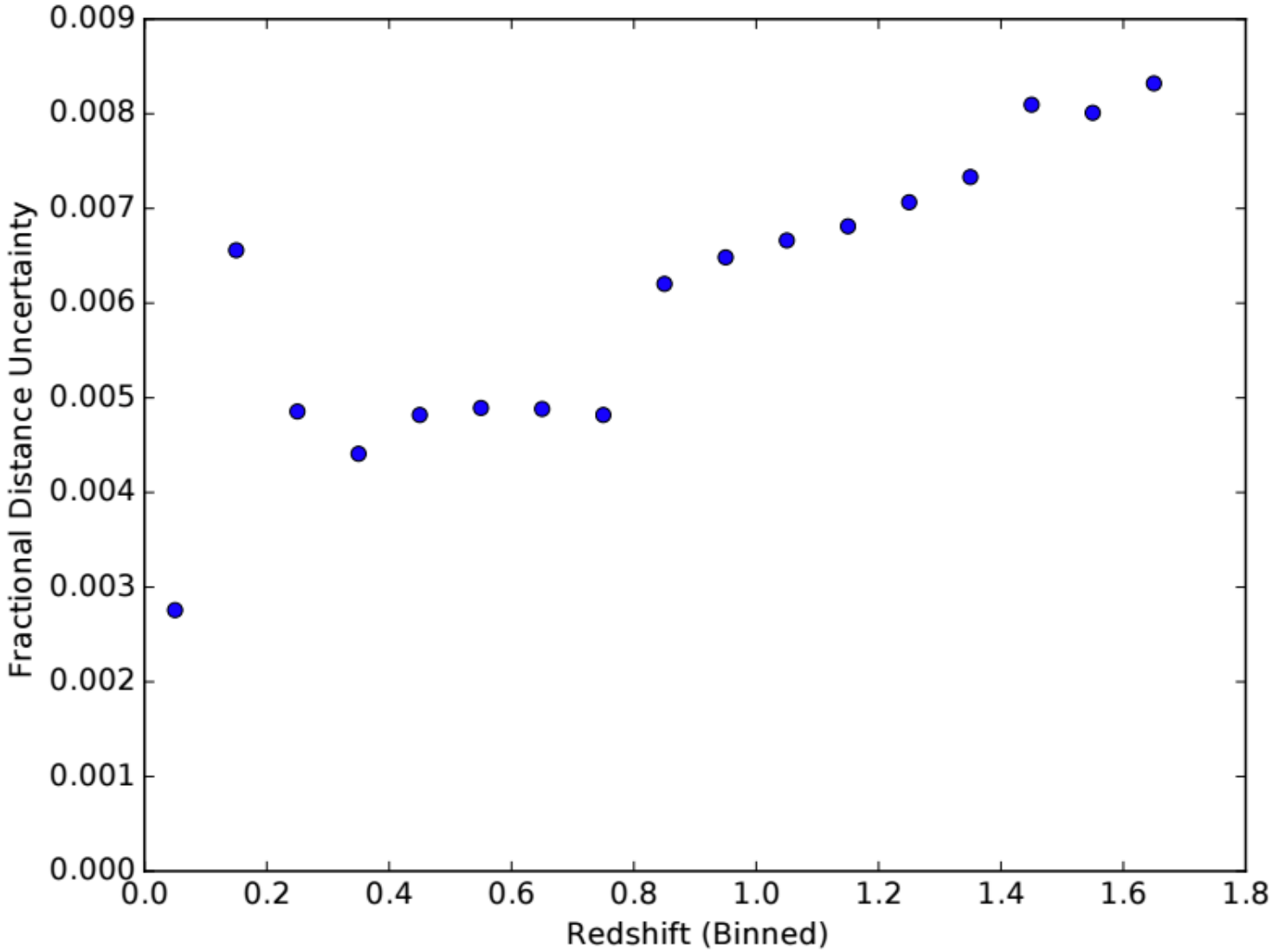
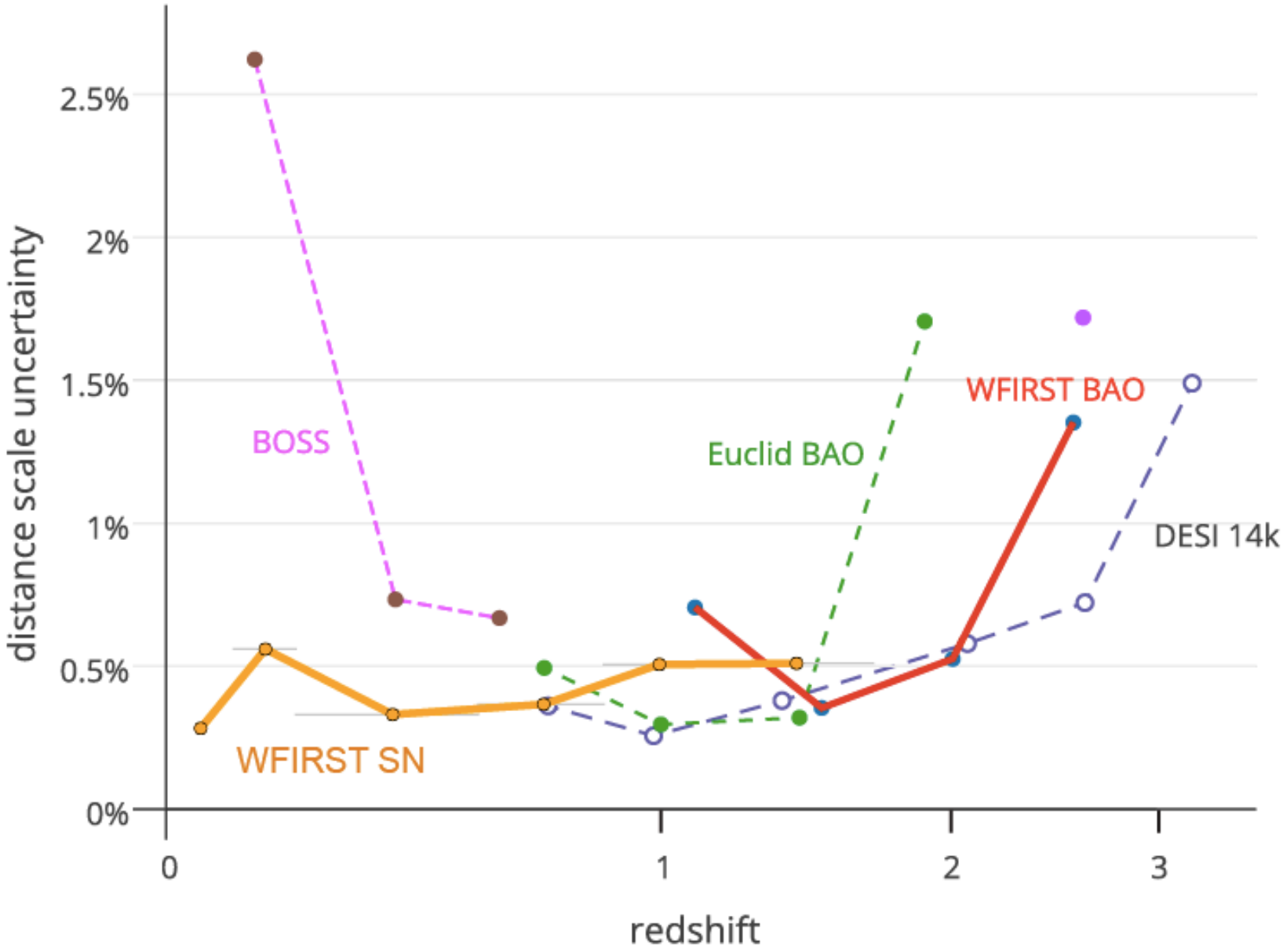
Now running: Simultaneous fit of SN fluxes, SN SED, systematics, and cosmology					

Results: distance uncertainty vs z




2.5%
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distance scale uncertainty
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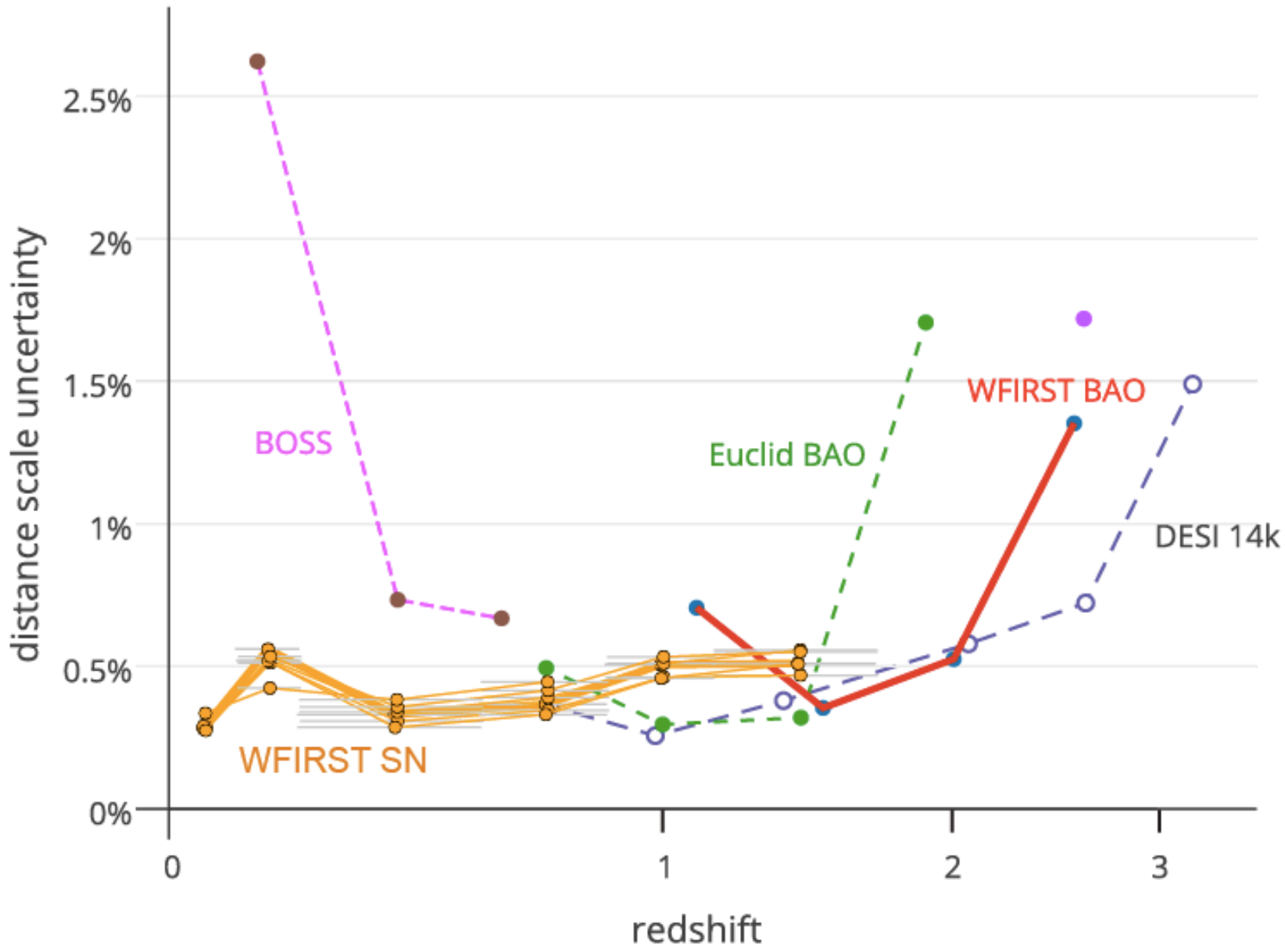
3
redshift
BOSS
Euclid BAO
WFIRST BAO
DESI 14k
WFIRST SN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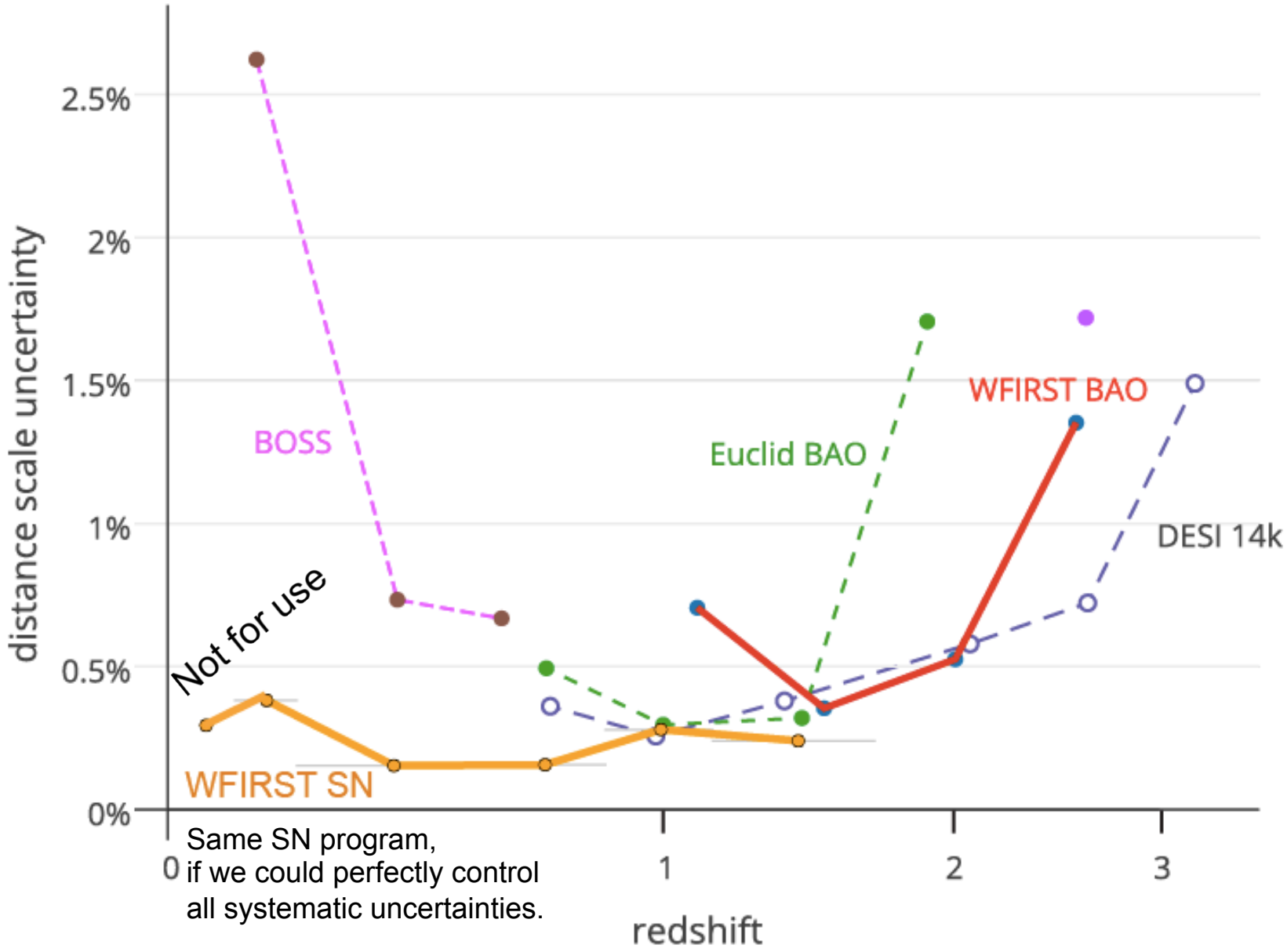
distance scale uncertainty
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2%
1.5%
1%
0.5%
0%
0
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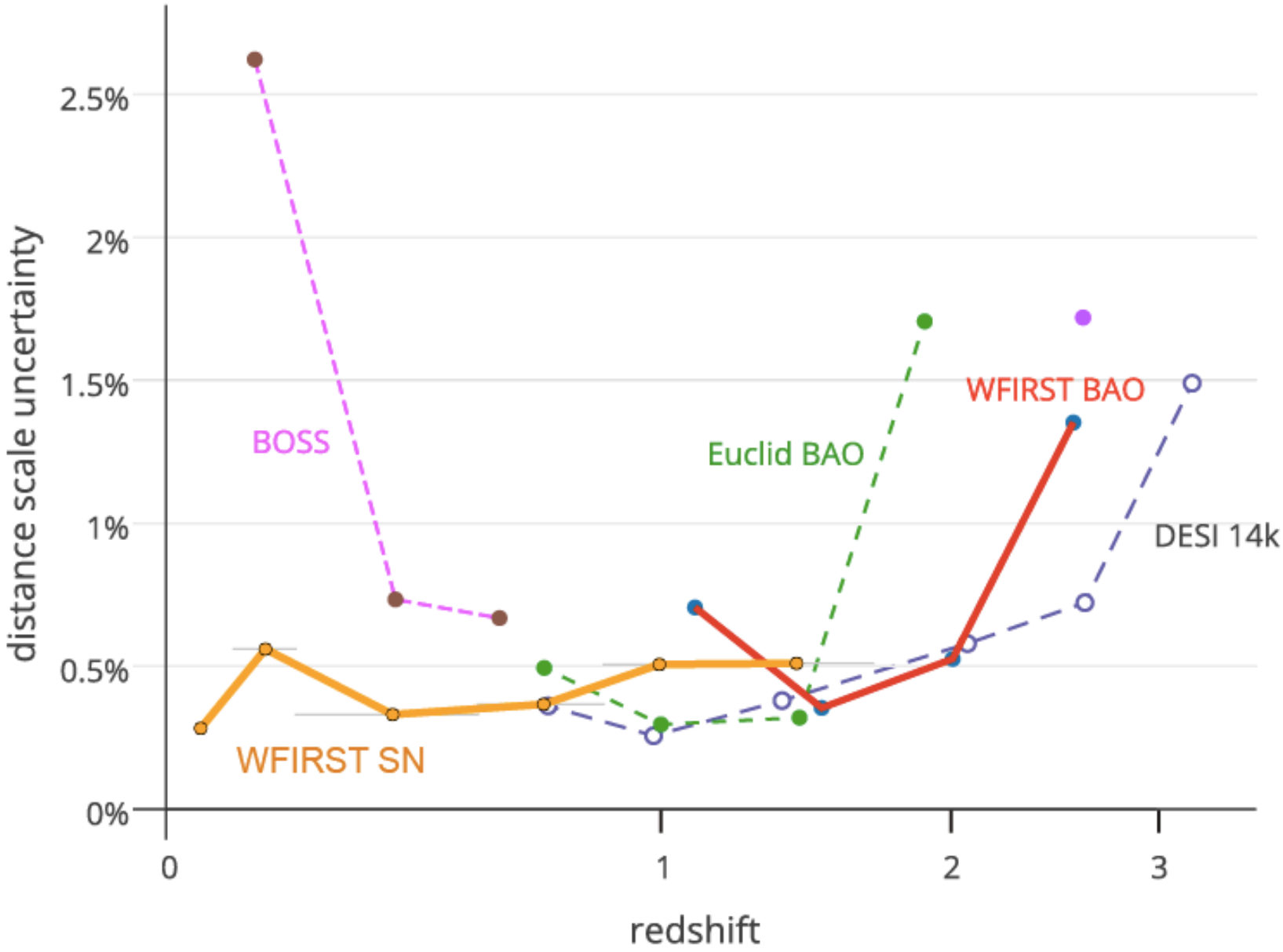
2
3
redshift
BOSS
Euclid BAO
WFIRST BAO
DESI 14k
Not for use
WFIRST SN
Same SN program,
if we could perfectly control
all systematic uncertainties.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