A Fully Realized Simulation of the WFIRST SN Survey

Dan Scolnic*, Ryan Foley
*KICP Fellow at UChicago

WFIRST meeting, Pasadena, Tuesday Nov. 18, 2014

WFIRST has the potential to improve upon current constraints of dark energy evolution by two orders of magnitude.

- It is also really expensive.

- Therefore, we need to make sure we optimize survey, and understand its potential, as best as possible.

Cosmology with Type Ia Supernovae are already nearly-systematics dominated.

In the WFIRST AFTA paper,one can see this:

fication, which we model as $\sigma_{lens} = 0.07 \times z$ mags. The overall statistical error in a $\Delta z = 0.1$ redshift bin is then

$$\sigma_{stat} = [(\sigma_{meas})^2 + (\sigma_{int})^2 + (\sigma_{lens})^2]^{1/2} / \sqrt{N_{SN}} ,$$

where N_{SN} is the number of SNe in the bin. We assume a systematic error per bin of

$$\sigma_{sys} = 0.01 (1+z) / 1.8 \text{ mag},$$

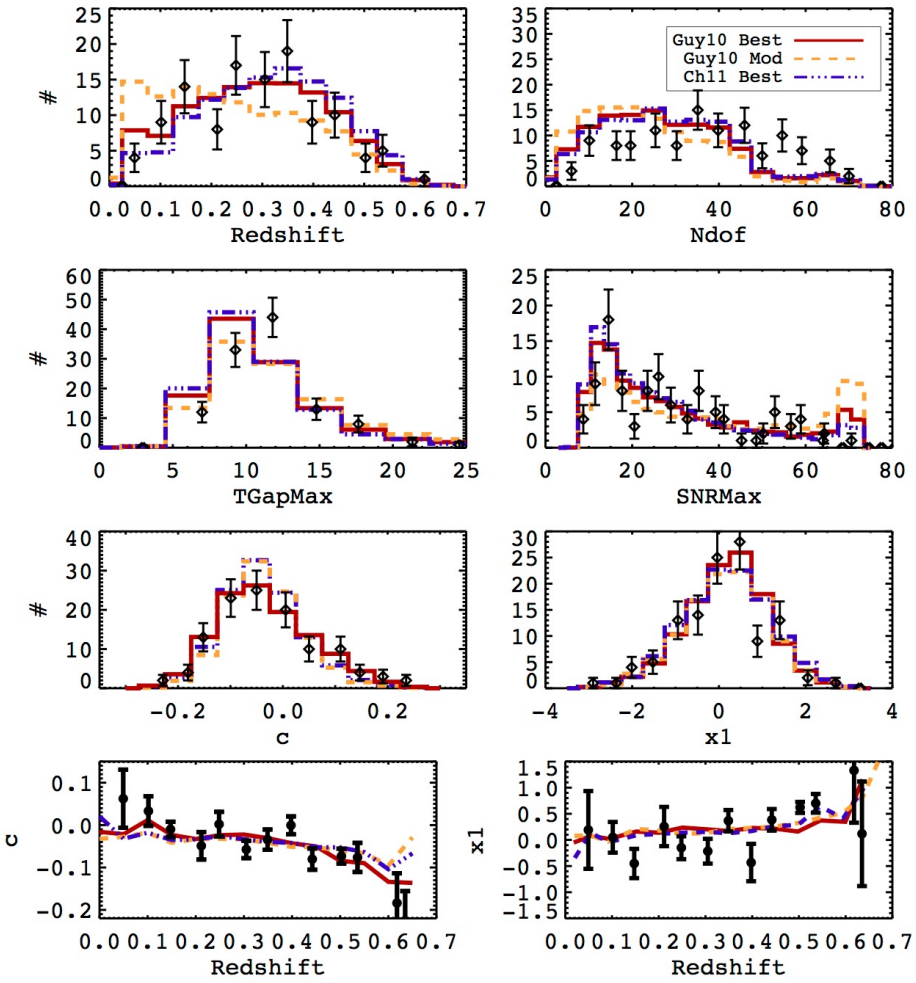
with no correlation of errors between redshift bins. This corresponds to the "optimistic" systematics case from the Green et al. report[1] because we expect the IFU spectrophotometry to minimize systematics associated with photometric calibration and K-corrections and to reduce evolutionary systematics.

We have to do a lot better than assuming systematic errors are just some fraction of statistical errors.

The good news is that we do this a lot.

- Pan-STARRs simulation for full survey to analyze selection biases, spectral models, various systematics.

Includes weather history, PSF information, SNR, cadence, follow-up..



Scolnic 2014b

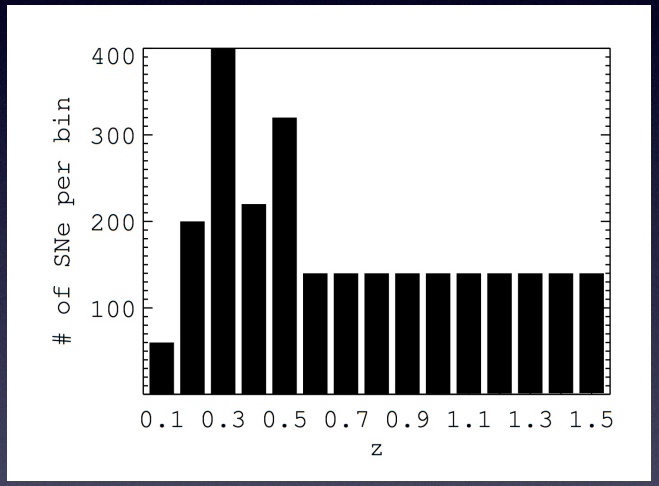
Is easier to do with WFIRST cause we won't have to deal with weather history, down time, processing failures

These are the WFIRST survey requirements.

We incorporated each one, and took each as literally as possible.

Supernova SN-Ia Survey

- >100 SNe-Ia per Δz=0.1 bin for all bins for 0.4 < z < 1.7, per dedicated 6 months
- Observational noise contribution to distance modulus error $\sigma_\mu \leq 0.02$ per Δz=0.1 bin up to z = 1.7
- Redshift error $\sigma \leq 0.005$ per supernova
- Relative instrumental bias ≤0.005 on photometric calibration across the wavelength range



From our simulation, matches survey prediction

Supernova Survey Data Set Rqts

- Minimum monitoring time-span for an individual field: ~2 years with a sampling cadence ≤5 days
- Cross filter color calibration ≤0.005
- Three filters, approximately Y, J, H for SN discovery
- IFU spectrometer, $\lambda/\Delta\lambda$ ~100, 2-pixel (S/N ≥ 10 per pixel bin) for redshift/typing
- IFU S/N ≥15 per synthetic fiber band for points near lightcurve maximum in each band at each redshift
- Dither with 30 mas accuracy
- Low Galactic extinction, E(B-V) ≤0.02

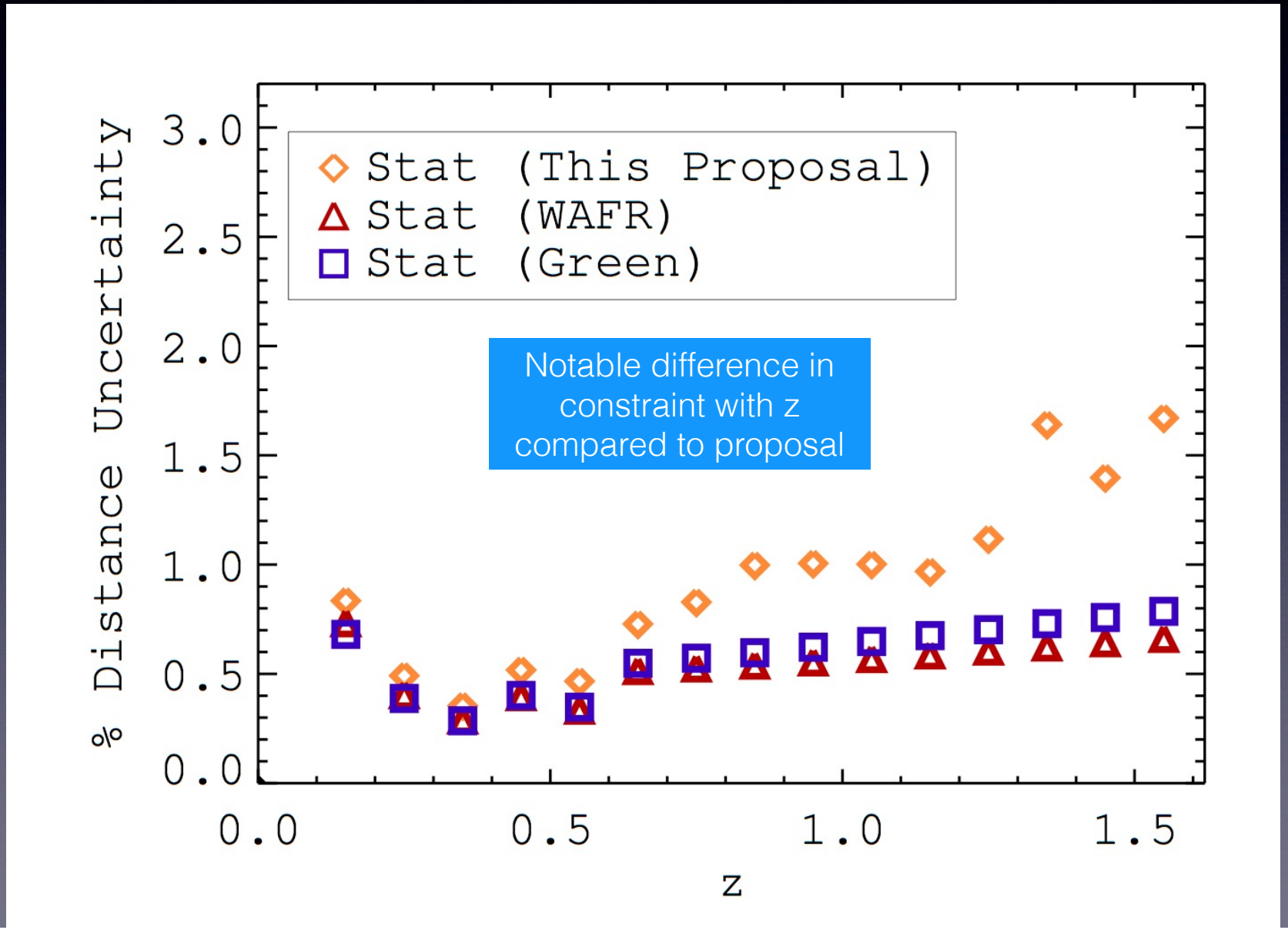
We have created 4 tools for publicly available software to do simulation, analysis and measuring cosmology

- WFIRST-specific simulation libraries for full simulation of SN survey*
- Light-curve fitting routines to incorporate best spectral models for Near-IR data*
- Conversion program between SNANA output and COSMOMC/ COSMOSIS input
- Routines to measure cosmological parameters specific to WFIRST, when combining with other probes^

*SNANA, Kessler et al.

^COSMOMC - Lewis et al.
^COSMOSIS - Zuntz et al.

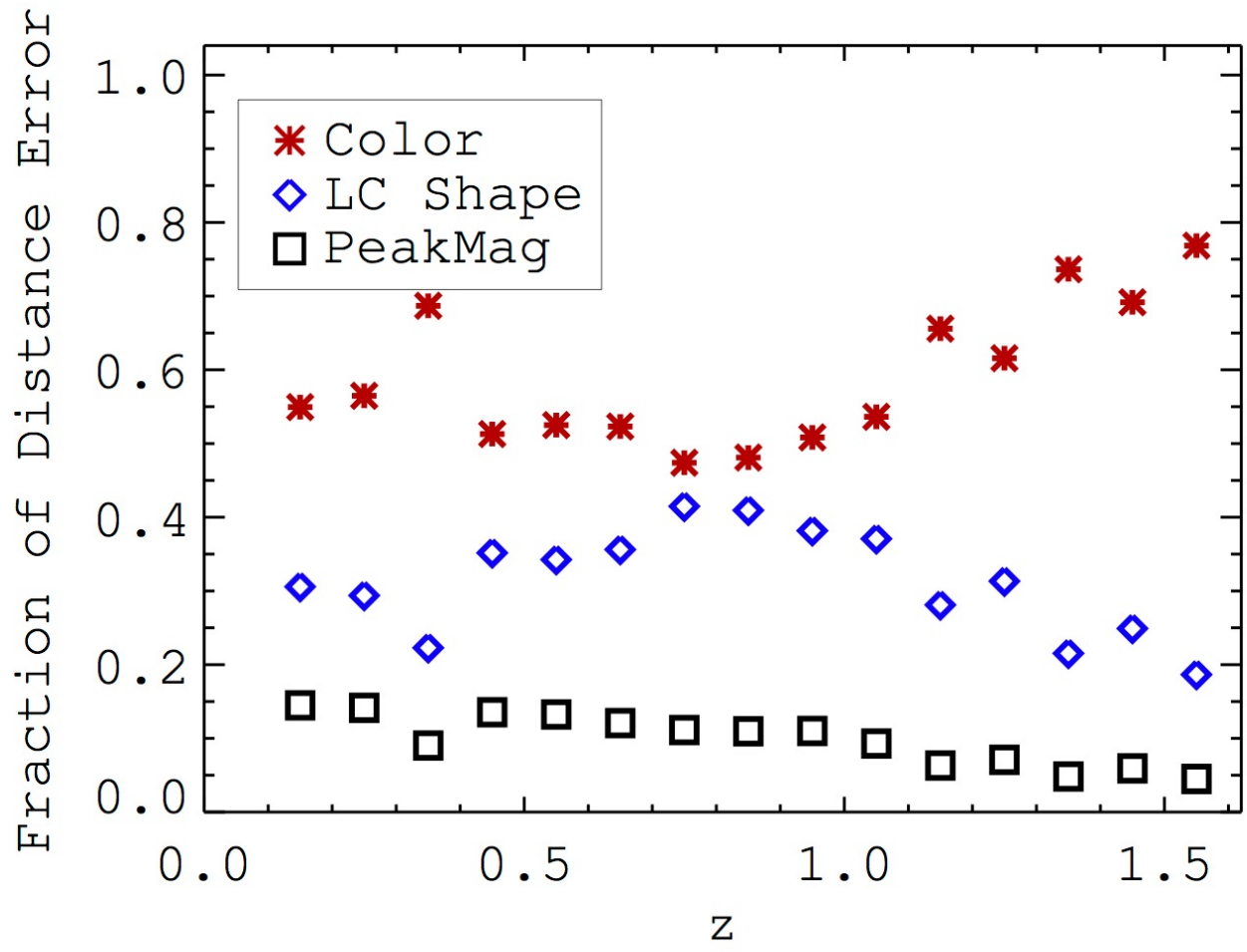
We do the entire WFIRST simulation, and fit all of the light curves, and we get this:



There's a quick way to understand precision of distance measurements with SNIa

SN distance =
peak brightness
-3 x color
+0.15 x stretch

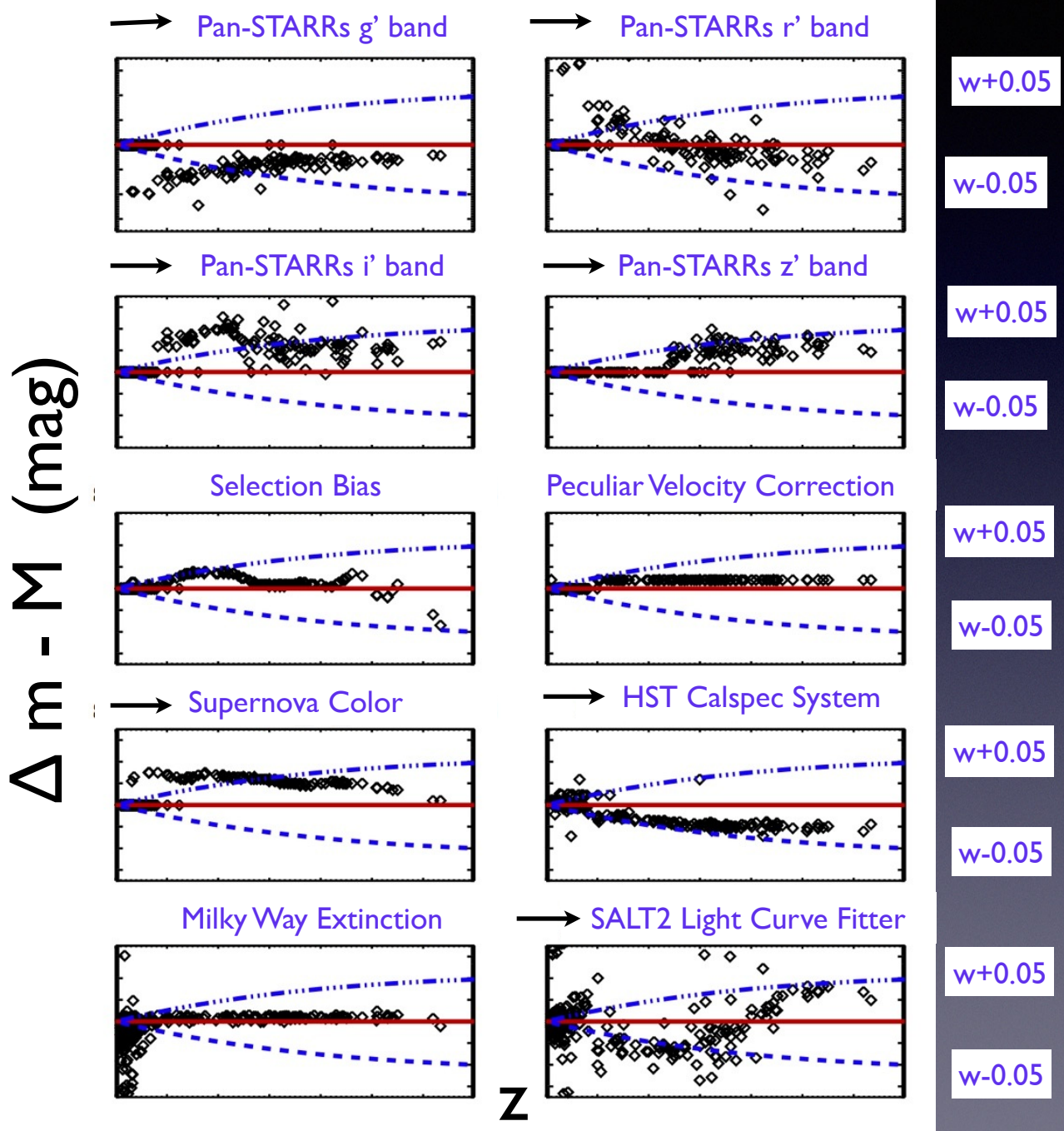
Typical errors on:
peak-b: 0.02 mag
color : 0.03 mag
stretch: 0.2 mag



Because of distance formula, color errors will dominate the statistical errors (and the systematic errors too!)

In Scolnic et al. 2014 PS1 Cosmology analysis, we showed how errors propagate to changes in w

Here we show Hubble diagram differences when we change our biggest systematics by 1σ



Systematic uncertainties are of similar size to statistical uncertainties. Propagate systematic uncertainties to covariance matrix.

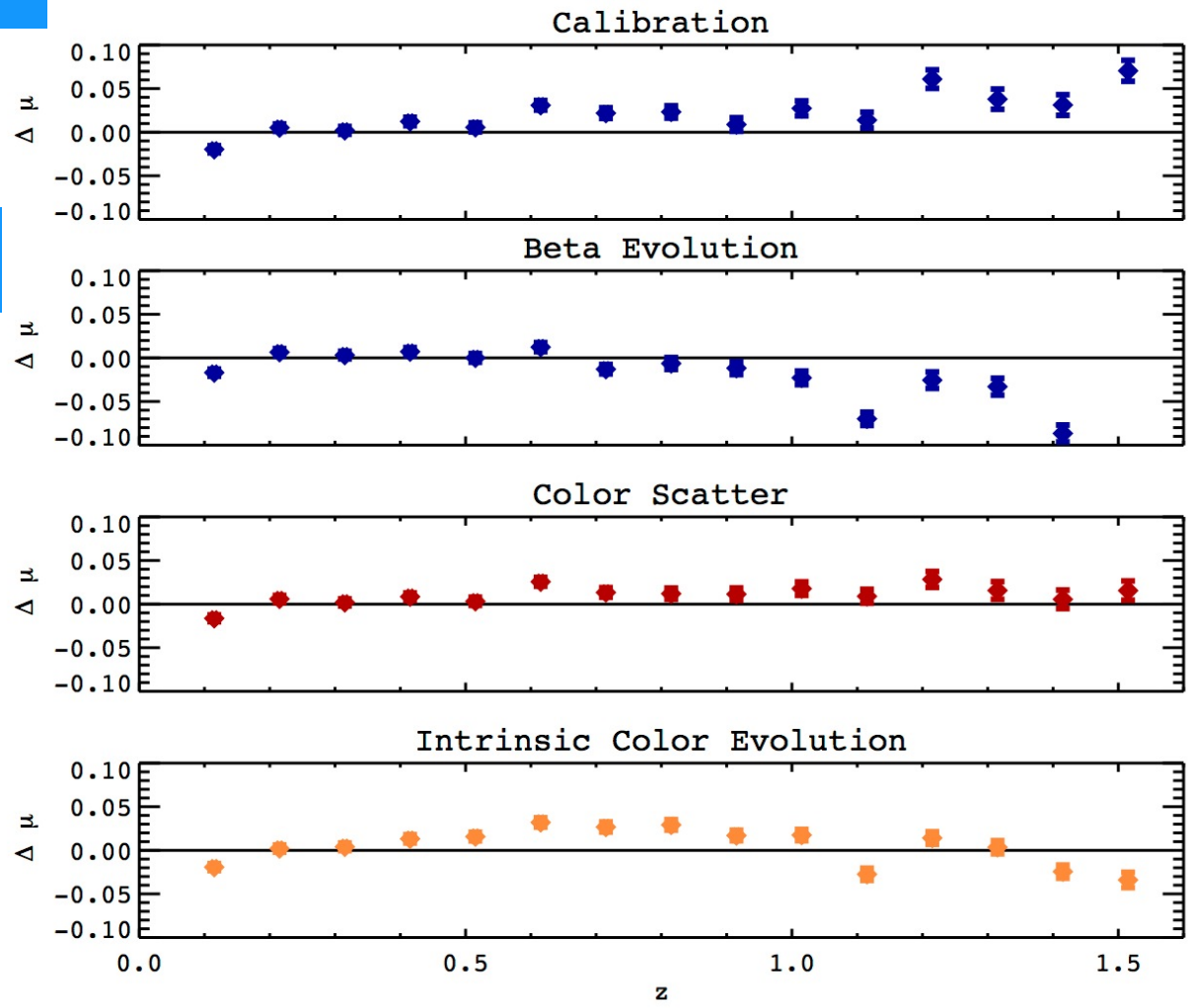
We took top systematics, all related to SN color and propagated them through our WFIRST analysis tools

As good as HST?

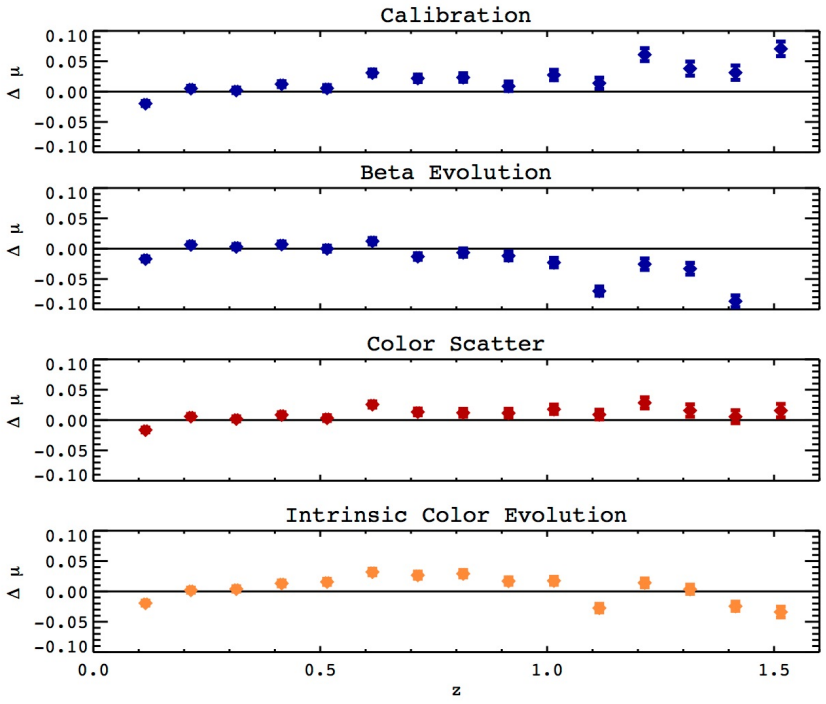
Does Reddening Law change with redshift?

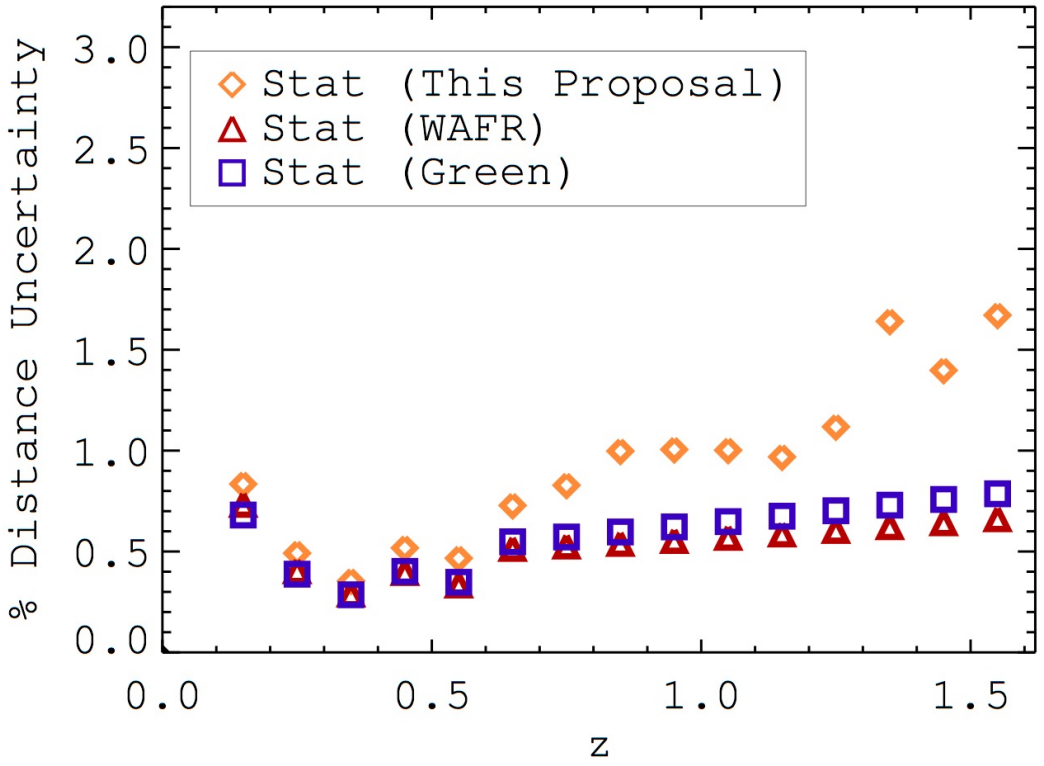
What is intrinsic scatter of SNeIa distances composed of?

How is intrinsic color changing with redshift?



We took top systematics, all related to SN color and propagated them through our WFIRST analysis tools



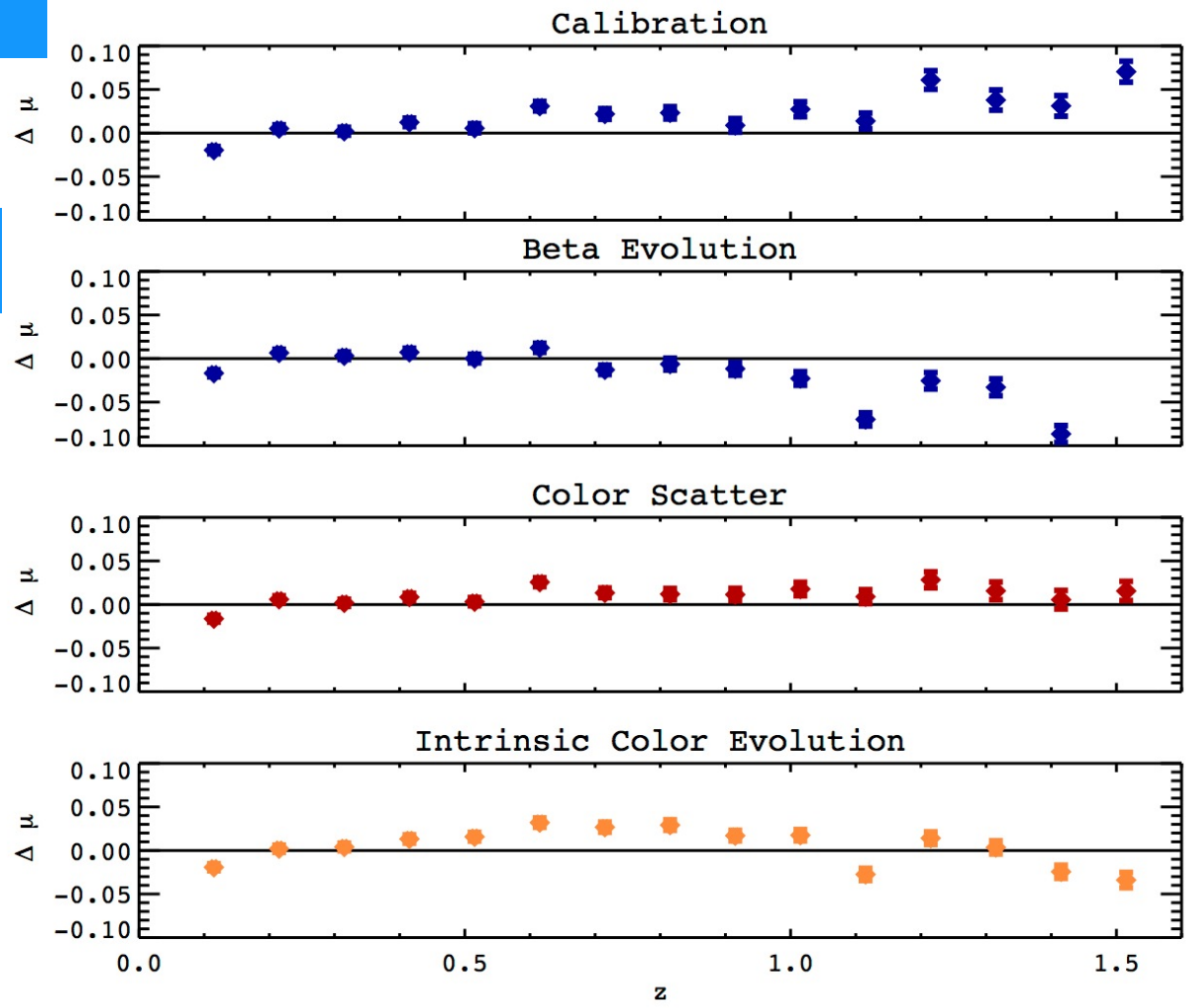


We can easily see how we will be systematics limited… by a lot

With serious analysis over the next few years, can see the way forward to reductions in some systematics by 2x

5mmag level in each bin

2x improvement reasonable



Does Reddening Law change with redshift?

Will improve with analysis of high-z datasets (DES)

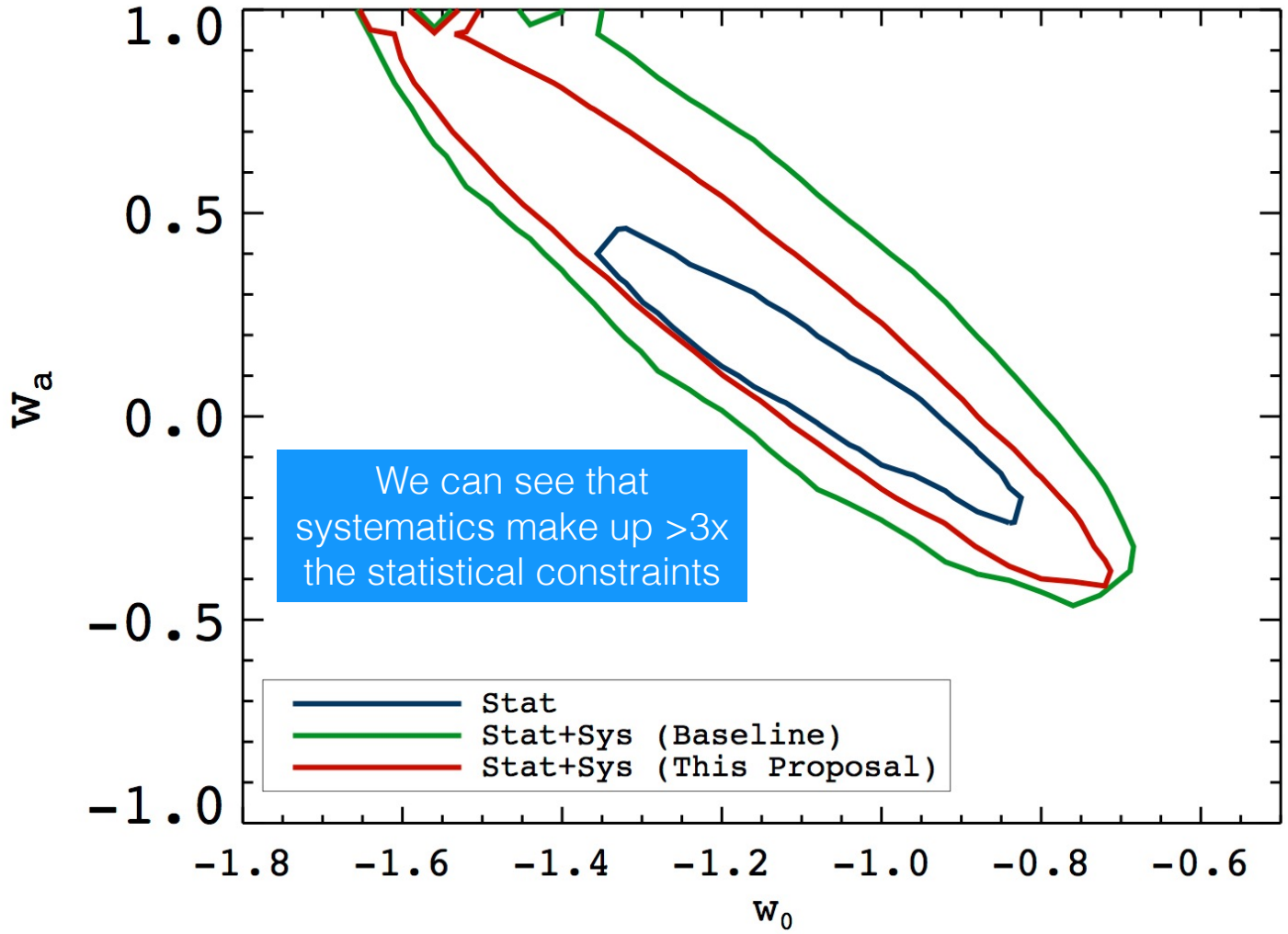
What is intrinsic scatter of SNeIa distances composed of?

More statistics, more blue SNeIa (Scolnic et al. 2014a)

How is intrinsic color changing with redshift?

Measurements of velocities (Mandel,Foley, Kirshner 2014)

We propagate uncertainties to constraints on w_a versus w_0



In conclusion:

- WFIRST isn't as far away as it seems
- We can rely heavily on simulations to determine what is best for SN survey
- See Ryan Foley's talk for a discussion of survey requirements for best constraints on dark energy with WFIRST