Using SNANA to do SNIa [and non-SNIa] analyses

Dan Scolnic and Rick Kessler
University of Pittsburgh, Nov. 17 2016

Mysterious 'Dark Energy' May Not Exist, Study Claims

By Mike Wall, Space.com Senior Writer | October 25, 2016 05:52pm ET

Marginal evidence for cosmic acceleration from Type Ia supernovae
J. T. Nielsen, A. Guffanti & S. Sarkar

This Swift UVOT image shows galaxy M82 before the explosion and combines data acquired between 2007 and 2013. Mid-ultraviolet light is shown in blue, near-UV light in green and visible light in red. The image is 17 arcminutes across, or slightly more than half the apparent diameter of a full moon. (Credit: NASA/Swift/P. Brown, TAMU)

Accelerating Universe: Not As Fast?

A UA-led team of astronomers found that the type of supernovae commonly used to measure distances in the universe fall into distinct populations not recognized before. The findings have implications for our understanding of how fast the universe has been expanding since the Big Bang.

The Changing Fractions of Type Ia Supernovae Optical Subclasses with Redshift
Milne et al. 2015

Have a new interesting idea with big implications?

With SNANA!

Don't want to bother with SNANA? At least try it on some premade simulated results:

http://kicp.uchicago.edu/~dscolnic/SNSIMSFORYOU.tar

Mysterious 'Dark Energy' May Not Exist, Study Claims

By Mike Wall, Space.com Senior Writer | October 25, 2016 05:52pm ET

Marginal evidence for cosmic acceleration from Type Ia supernovae
J. T. Nielsen, A. Guffanti & S. Sarkar

Technical Rebuttal: Rubin+Hayden, Arxiv
Not Very Technical Rebuttal: Scolnic+Riess, Scientific American

Big technical issue is they assume a single distribution of color and stretch for the full JLA sample

That's a big no-no, and earlier this year Scolnic+Kessler showed why

MEASURING TYPE IA SUPERNOVA POPULATIONS OF STRETCH AND COLOR AND PREDICTING DISTANCE BIASES

D. Scolnic[1] & R. Kessler[1]

May 11, 2016

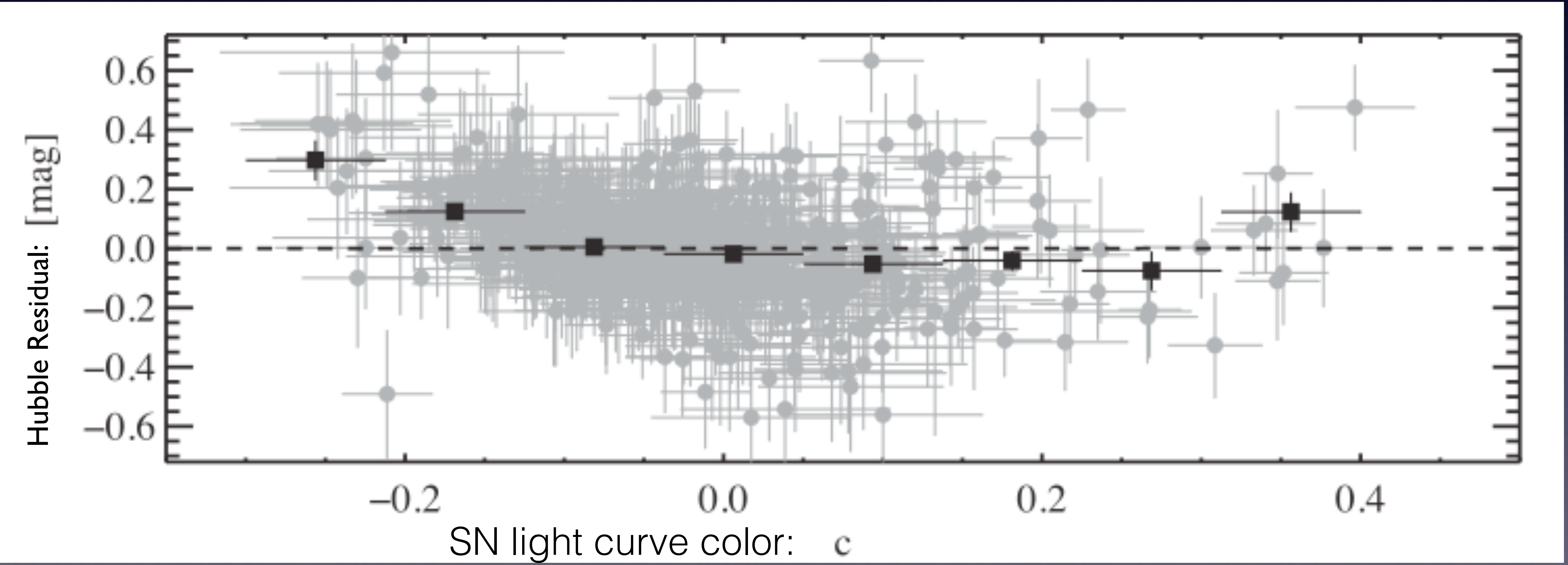
ABSTRACT

Simulations of Type Ia Supernovae (SN Ia) surveys are a critical tool for correcting biases in the analysis of SN Ia to infer cosmological parameters. Large scale Monte Carlo simulations include a thorough treatment of observation history, measurement noise, intrinsic scatter models and selection effects. In this paper, we improve simulations with a robust technique to evaluate the underlying populations of SN Ia color and stretch that correlate with luminosity. In typical analyses, the standardized SNIa brightness is determined from linear 'Tripp' relations between the light curve color and luminosity and between stretch and luminosity. However, this solution produces Hubble residual biases because intrinsic scatter and measurement noise result in measured color and stretch values that do not follow the Tripp relation. We find a 10σ bias (up to 0.3 mag) in Hubble residuals versus color and 5σ bias (up to 0.2 mag) in Hubble residuals versus stretch in a joint sample of 920 spectroscopically confirmed SN Ia from PS1, SNLS, SDSS and several low-z surveys. After we determine the underlying color and stretch distributions, we use simulations to predict and correct the biases in the data. We show that removing these biases has a small impact on the low-z sample, but reduces the intrinsic scatter σ_{int} from 0.101 to 0.083 in the combined PS1, SNLS and SDSS sample. Past estimates of the underlying populations were too broad, leading to a small bias in the equation-of-state of dark energy w of $\Delta w = 0.005$.

arxiv: 1603.01559

There is an ongoing effort to better standardize the SNIa.

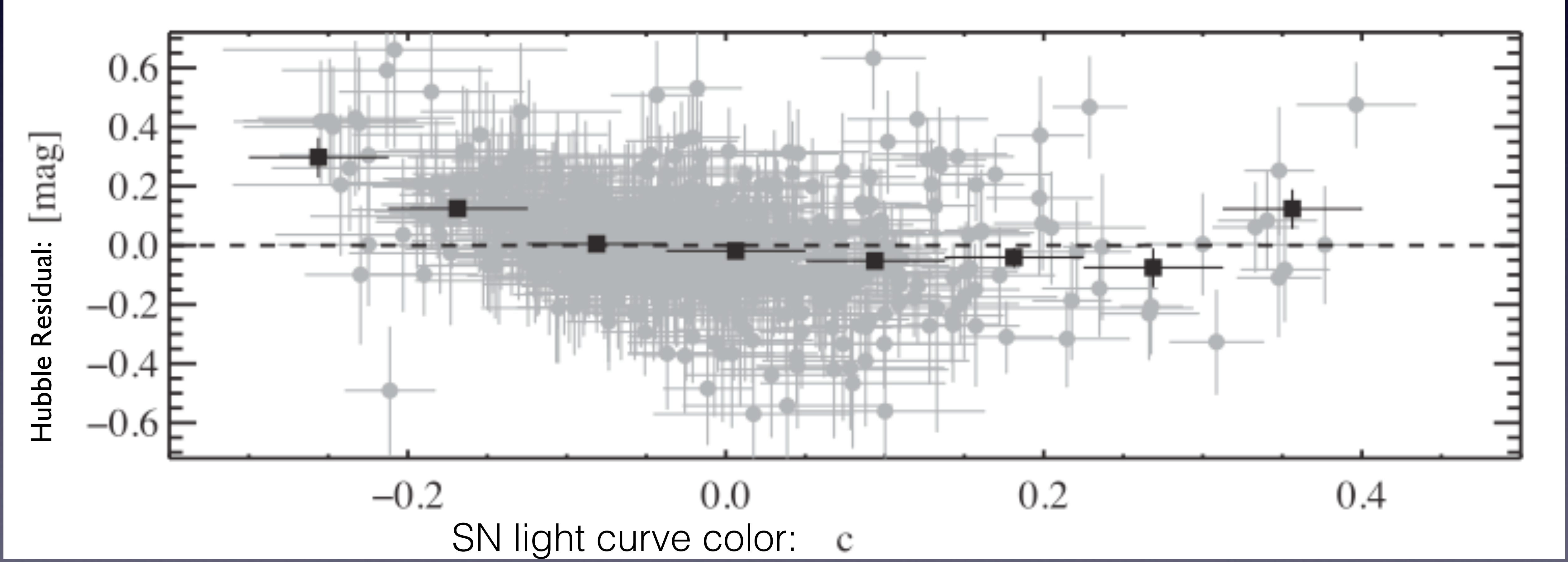
In past, we fit the correlation between luminosity and SN color, but afterwards, we will be left with something like this:



Ganeshalingam,13

The physics behind the color of SNe light curves is not well understood

In past, we fit the correlation between luminosity and SN color, but afterwards, we will be left with something like this:

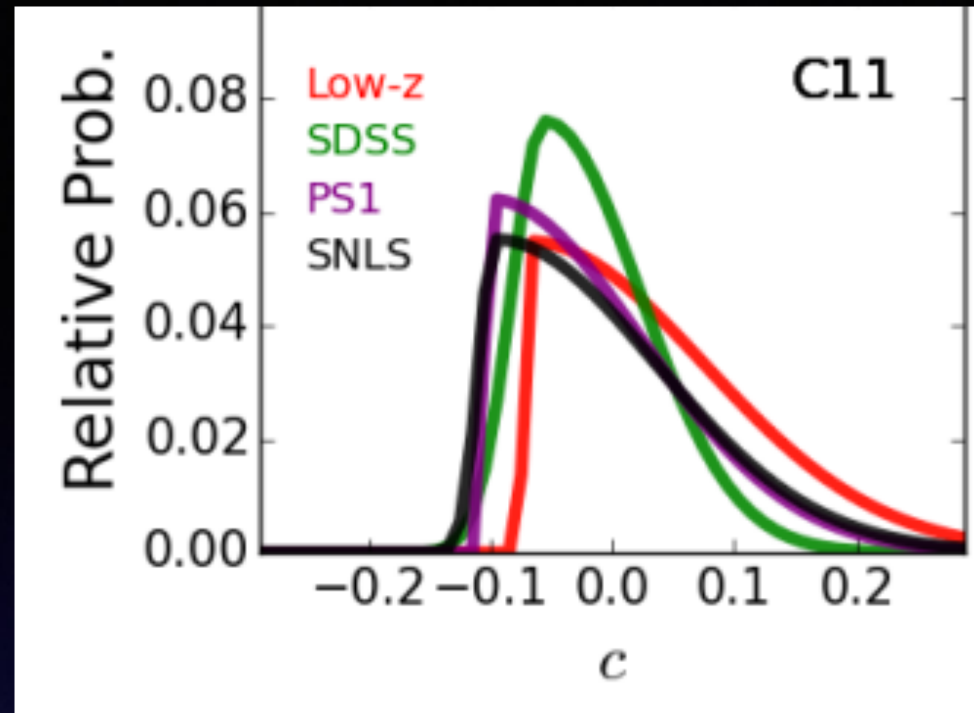


Ganeshalingam, 13

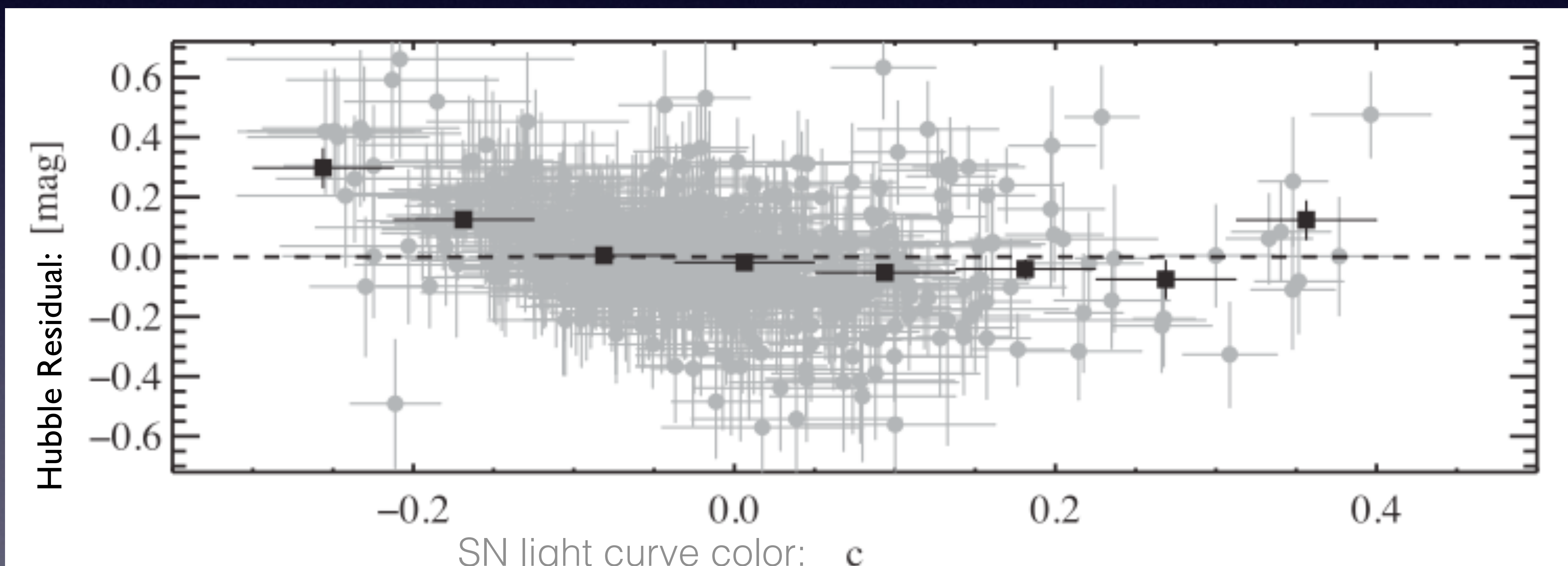
The observed color distribution is:

underlying distribution + physical scatter + measurement error

Underlying population of color that correlates with luminosity:



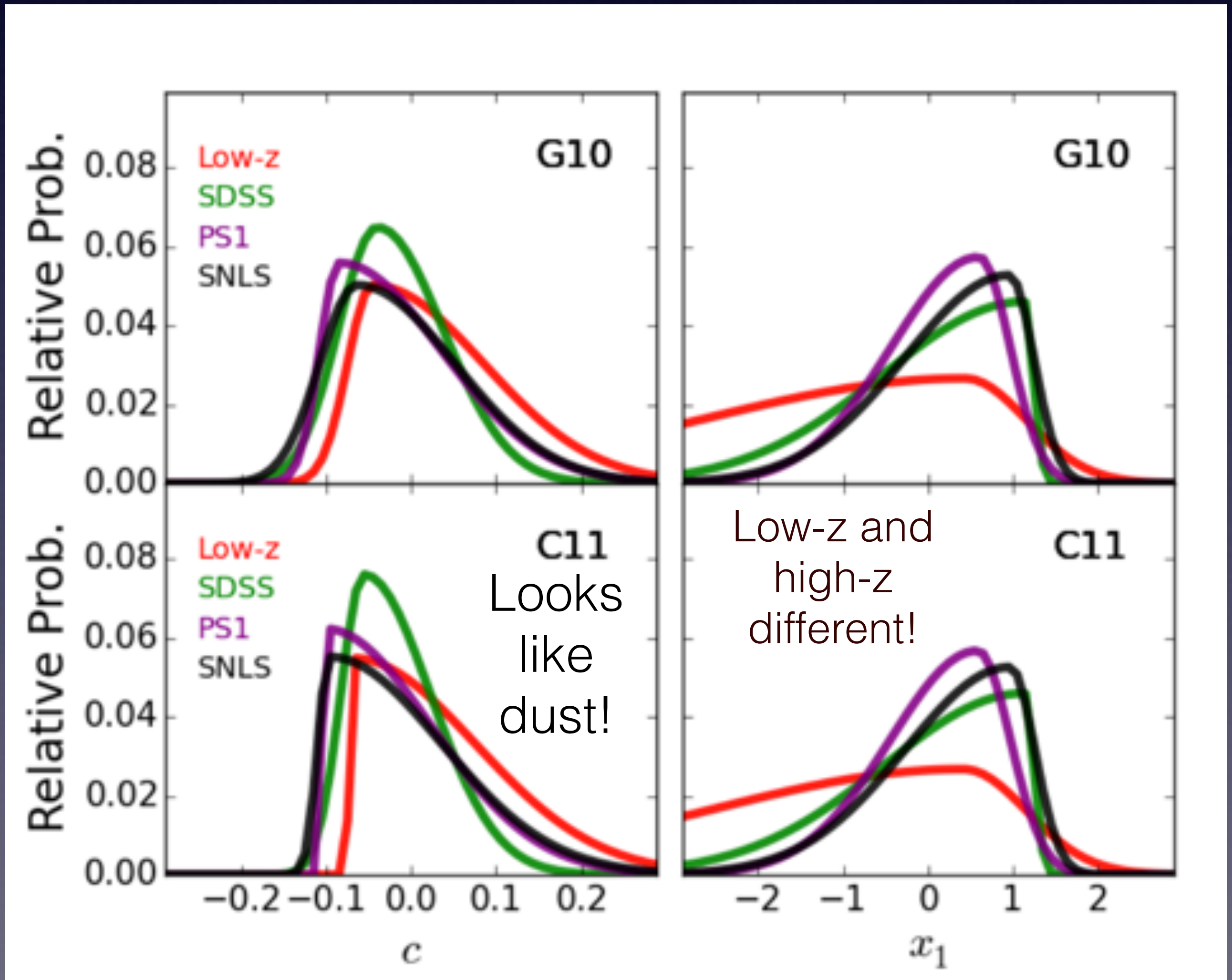
With almost 1000 SNe, now have statistics to forward model this



The observed color distribution is:
underlying distribution + physical scatter + measurement er

Used SNANA to measure how color (stretch) gets smeared. Know the final color (stretch) data distribution. Invert smearing matrix and multiply by observed vector to find underlying population.

Initial Populations

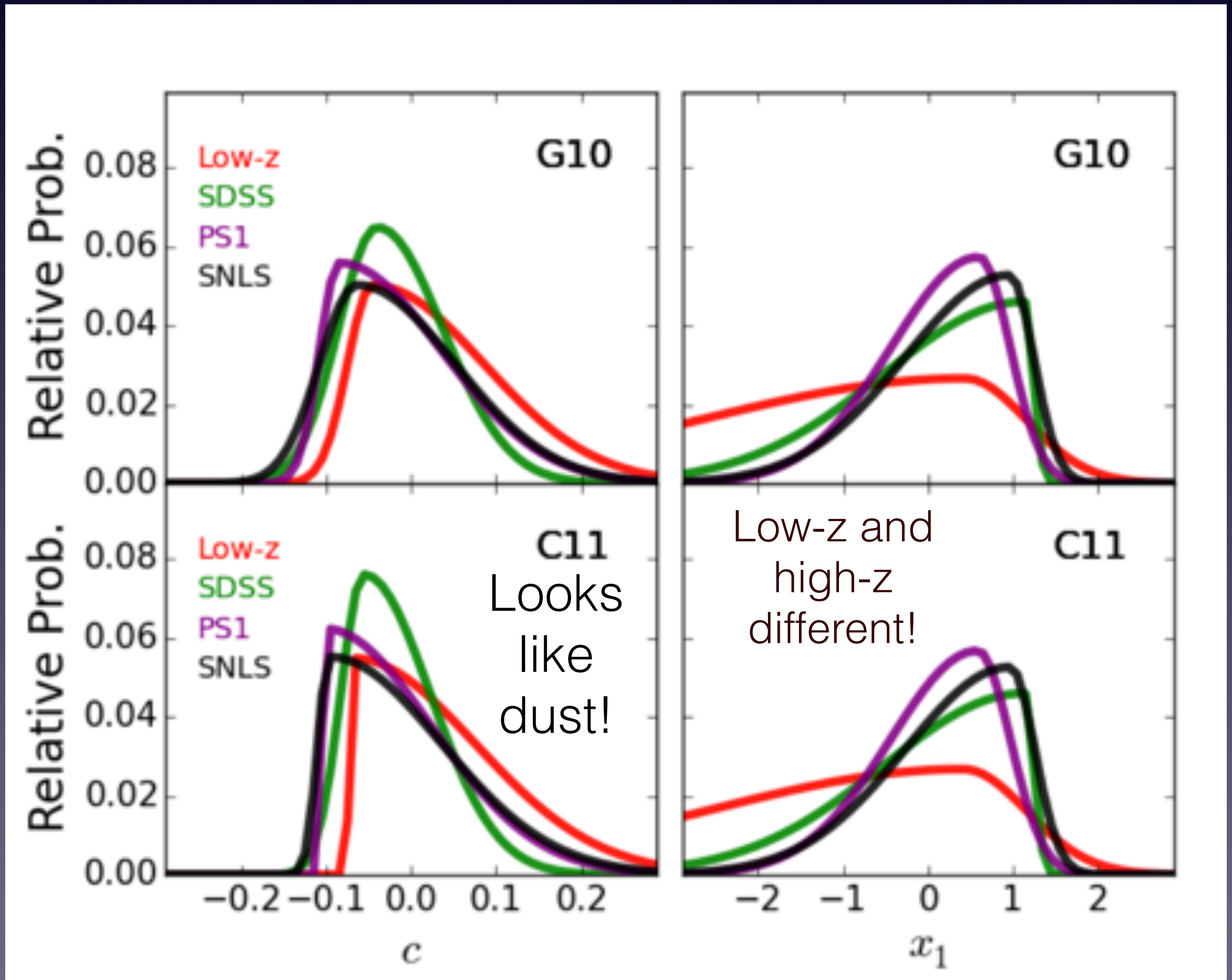


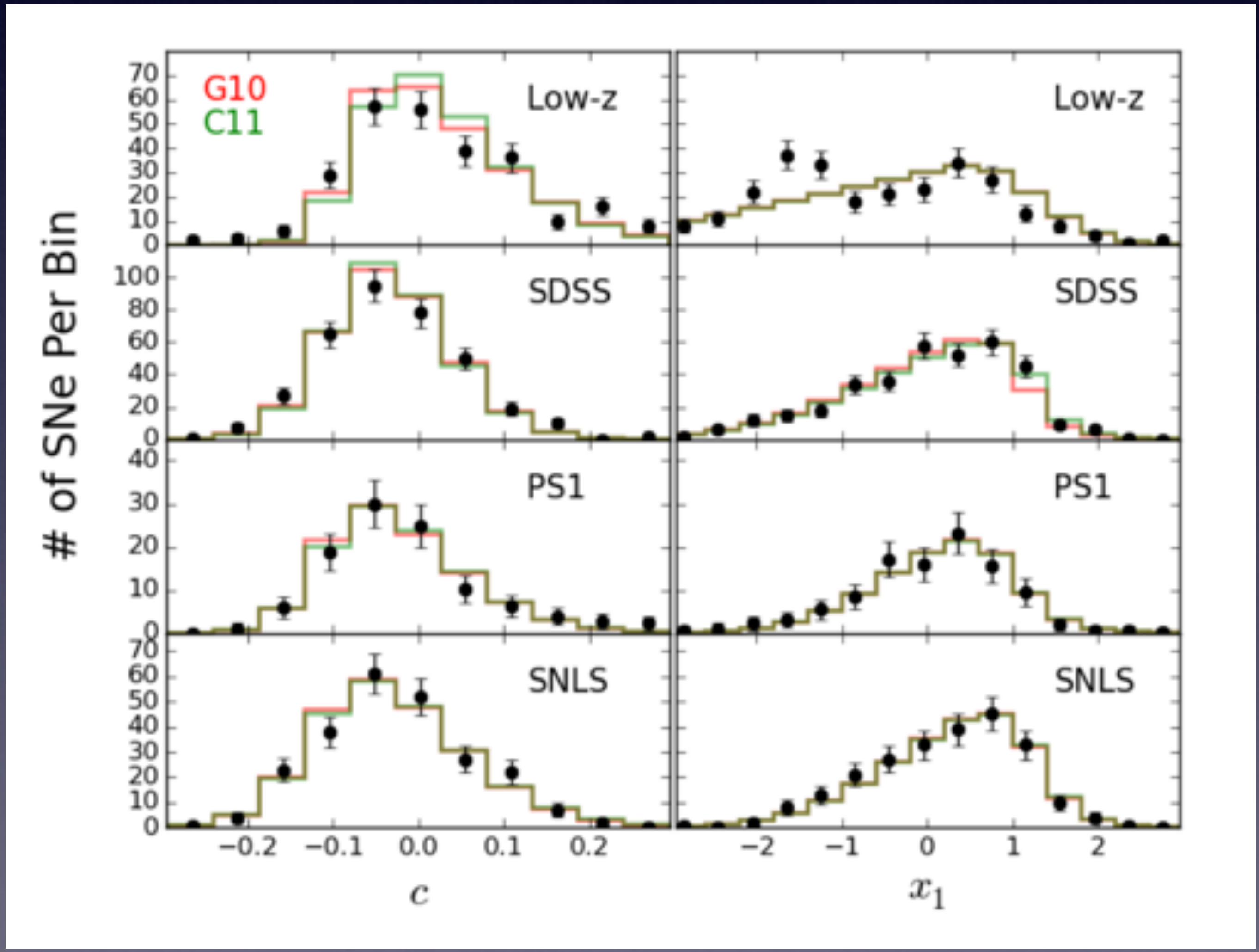
Do this for each sample, for two different intrinsic scatter models

Used SNANA to measure how color (stretch) gets smeared. Know the final color (stretch) data distribution. Invert smearing matrix and multiply by observed vector to find underlying population.

Initial Populations

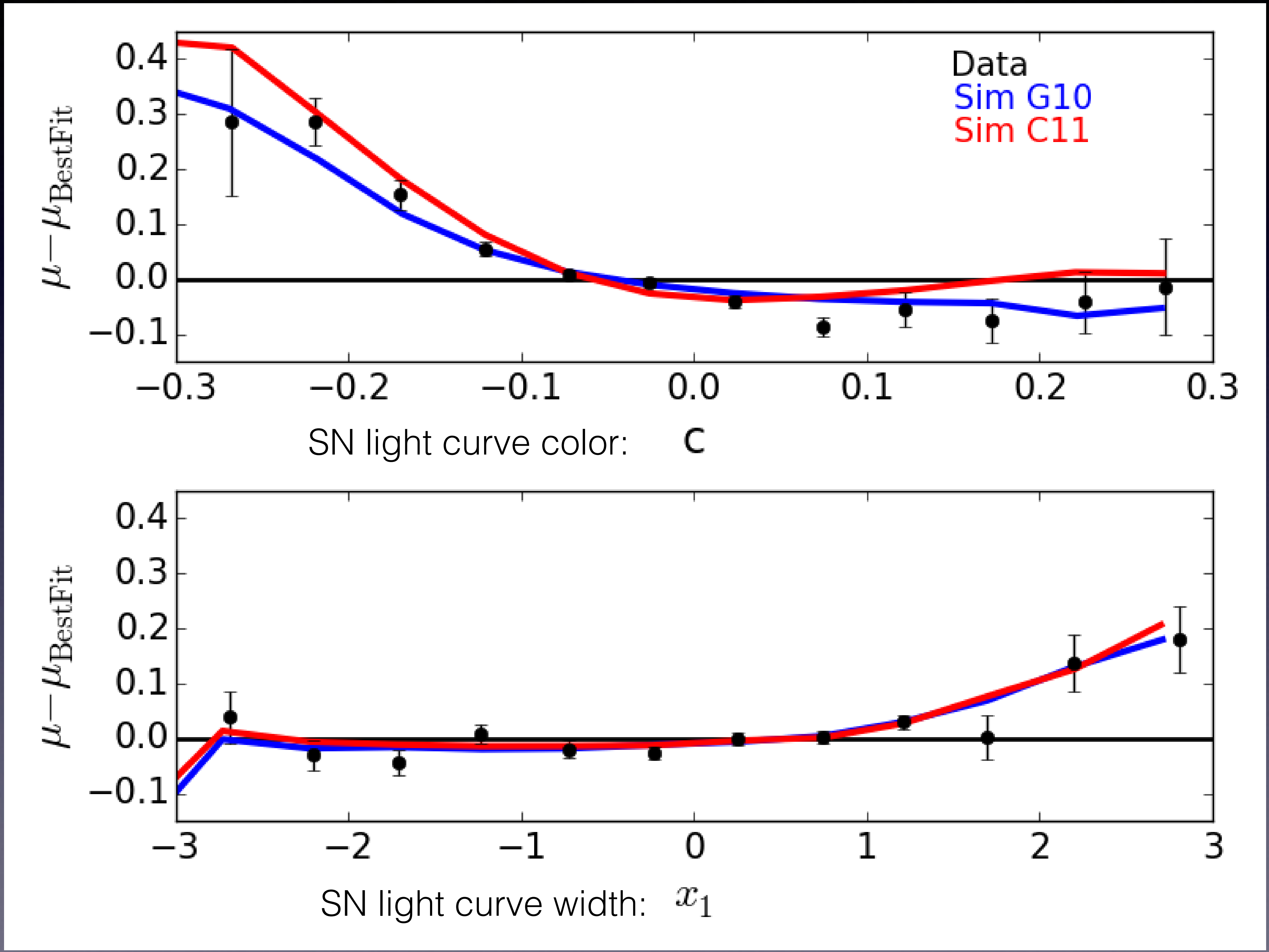
Final Populations





Do this for each sample, for two different intrinsic scatter models

Scolnic & Kessler 2016 can use fully realized simulations to forward model distance biases and compare against data.



Very high significance match and with corrections, int. scat goes from 0.1 to 0.08

The sequel: How to do these bias corrections, and at the same time, deal with photometric classification.

CORRECTING TYPE IA SUPERNOVA DISTANCES FOR SELECTION BIASES AND CONTAMINATION IN PHOTOMETRICALLY IDENTIFIED SAMPLES

R. KESSLER[1,2], D. SCOLNIC[1,3]

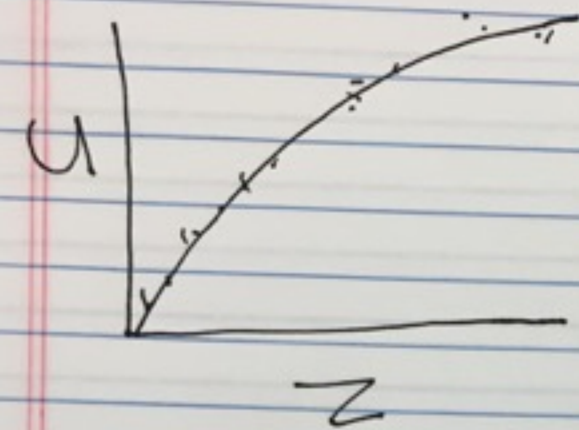
submitted.arxiv: 1610.04677

October 18, 2016

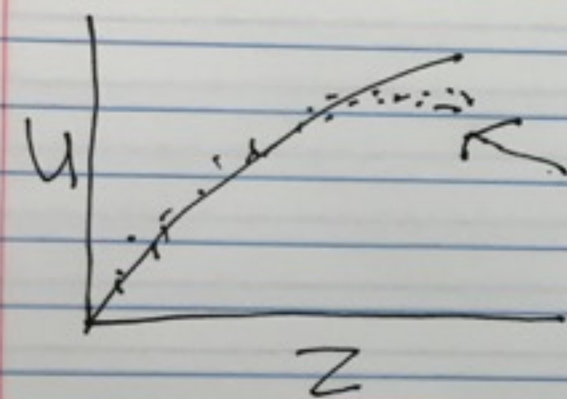
ABSTRACT

We present a new technique to create a bin-averaged Hubble Diagram (HD) from photometrically identified SN Ia data. The resulting HD is corrected for selection biases and contamination from core collapse (CC) SNe, and can be used to infer cosmological parameters. This method, called "Bias Corrected Distances" (BCD), includes two fitting stages. The first BCD fitting stage combines a Bayesian likelihood with a Monte Carlo simulation to bias-correct the fitted SALT-II parameters, and also incorporates CC probabilities determined from a machine learning technique. The BCD fit determines 1) a bin-averaged HD (average distance vs. redshift), and 2) the nuisance parameters α and β, which multiply the stretch and color (respectively) to standardize the SN brightness. In the second stage, the bin-averaged HD is fit to a cosmological model where priors can be imposed. We perform high precision tests of the BCD method by simulating large (150,000 event) data samples corresponding to the Dark Energy Survey Supernova Program (DES-SN). Our tests include three models of intrinsic scatter, each with two different CC rates. In the BCD fit, the SALT-II nuisance parameters α and β are recovered to within 1% of their true values. In the cosmology fit, we determine the dark energy equation of state parameter w using a fixed value of Ω_M as a prior: averaging over all six tests based on $6 \times 150,000 = 900,000$ SNe, there is a small w-bias of 0.006 ± 0.002. There is an additional w-uncertainty due to the assumed cosmology in the simulations; after iterating, this uncertainty is roughly equal to $\sigma_w/7$ where σ_w is the uncertainty of the data. For spectroscopically confirmed SN Ia samples, we compare the BCD method to other HD fitting methods, and we explain a long-standing paradox in which highly biased results are obtained if the Gaussian normalization term, $-2\ln(\sigma_\mu)$, is included in the HD chi-squared likelihood: the solution is that bias corrections are needed to obtain unbiased results. Finally, the BCD fitting code is publicly available in the SNANA package.

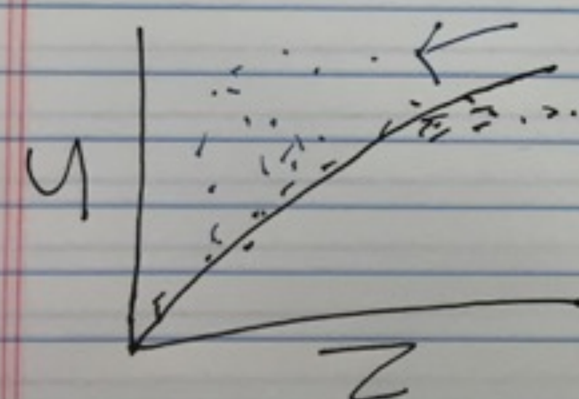
Subject headings: techniques: cosmology, supernovae



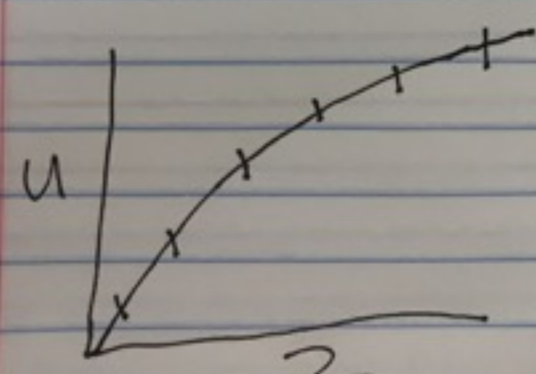
Just SN Ia
No Selection Effects



Just SN Ia
With Selection Effects

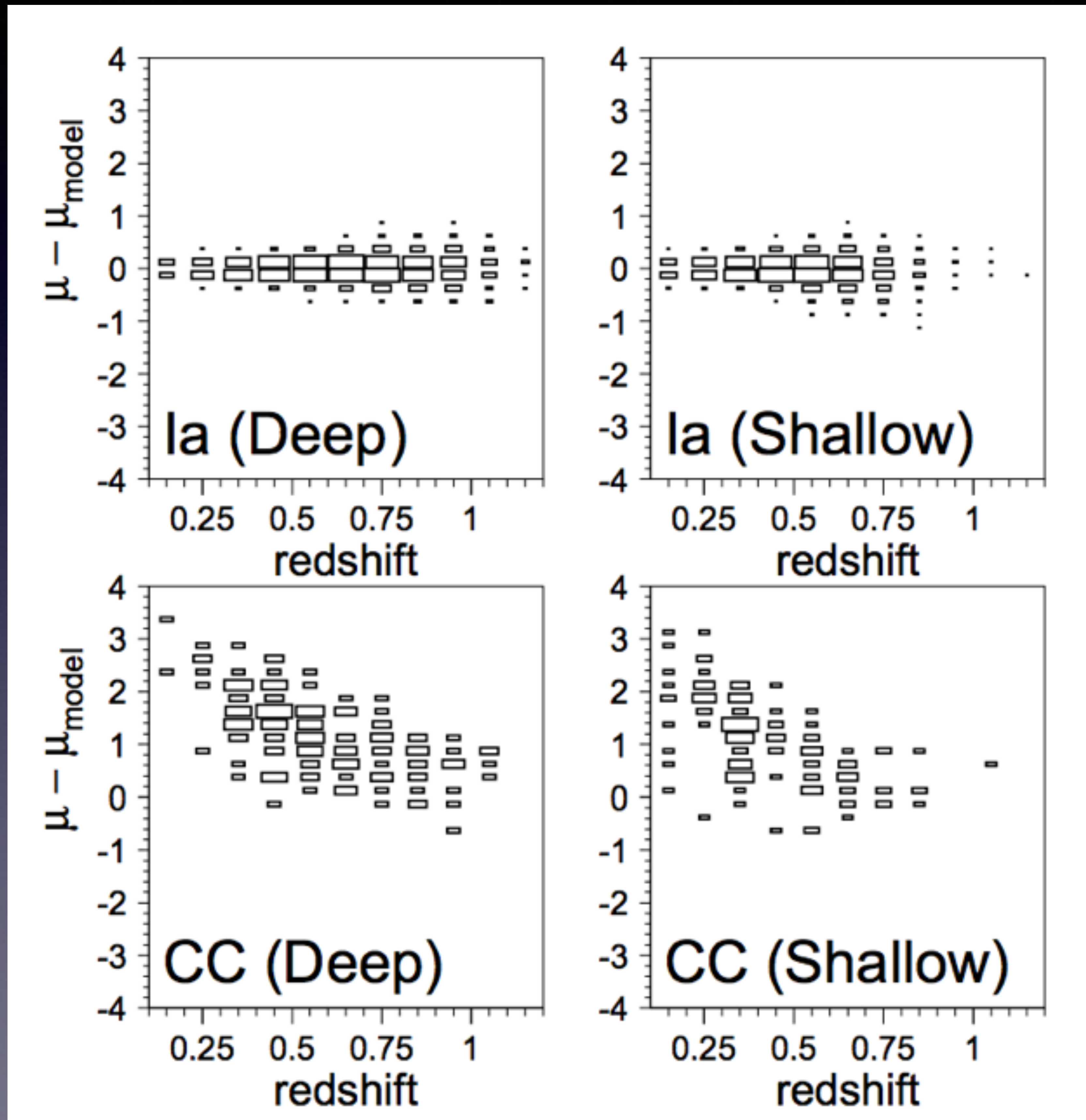


SN Ia + CC SNe
With Selection Effects

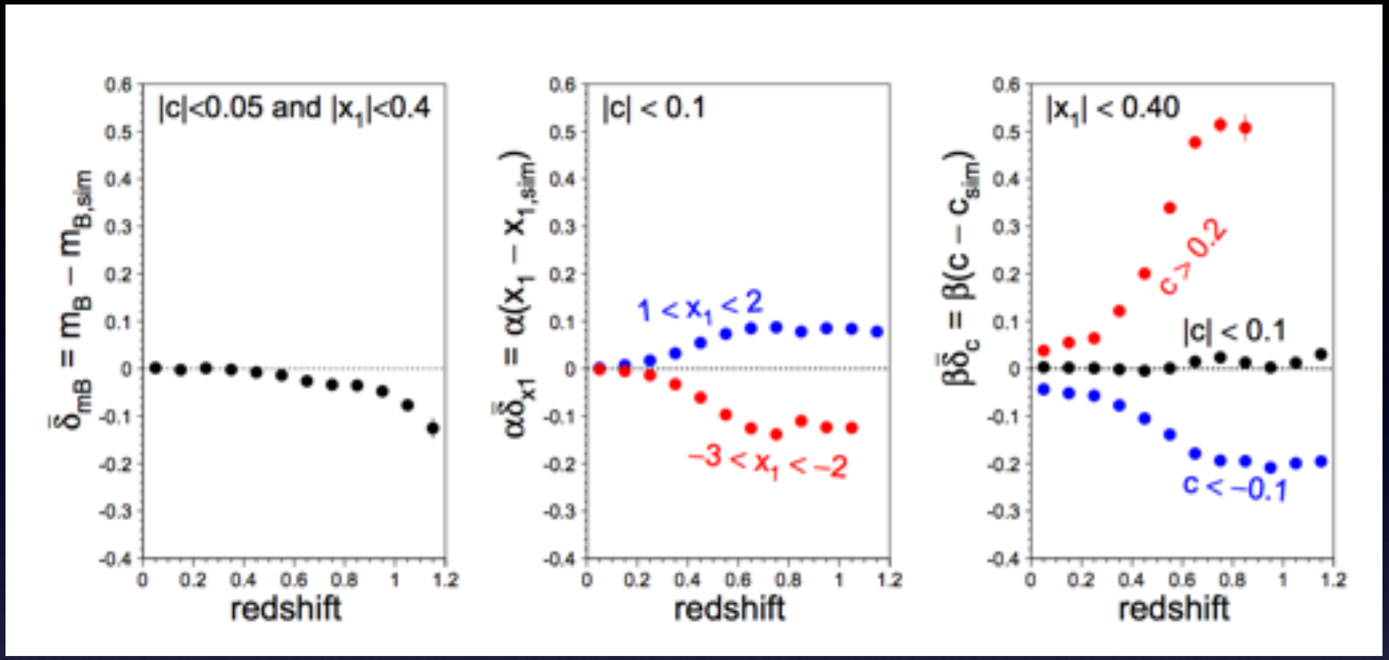


After BCD
Binned Huble
Diagram

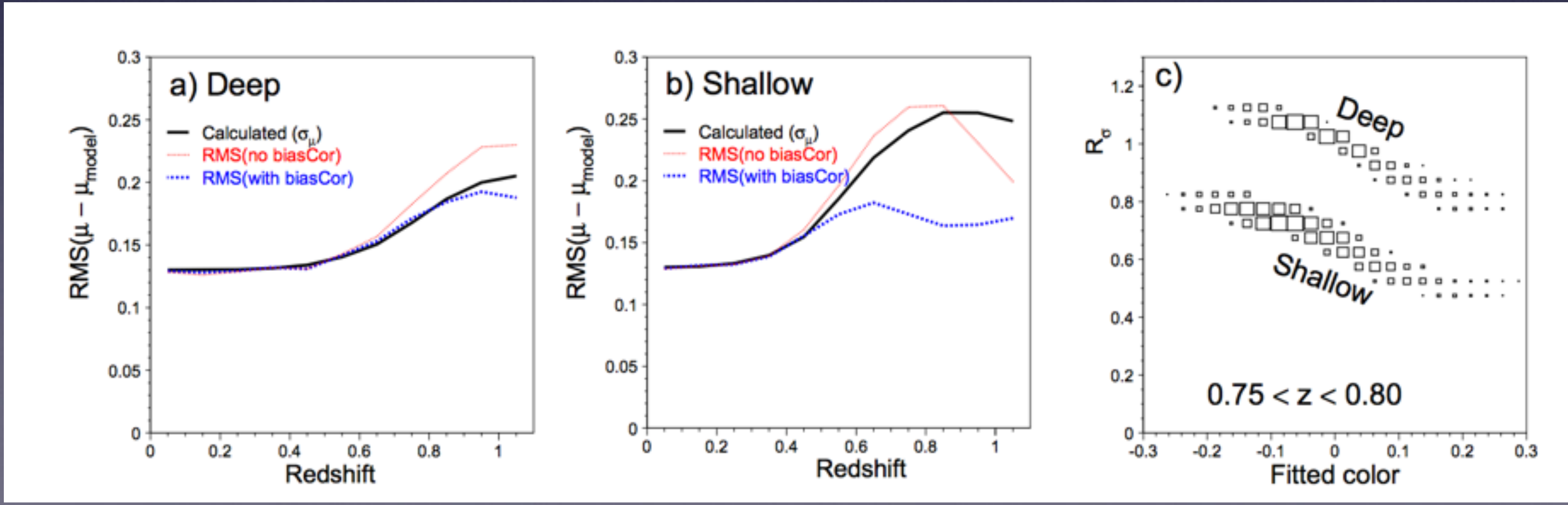
Methodology relies on BEAMS (Kunz et al.2007, Hlozek et al. 2012), but maps out parameter space of SNIa and CC using simulations



Corrects distance biases - which are huge



And error biases - which are also large



Finds small biases in recovered values of alpha, beta, w

Intrinsic scatter model	R_{CC}	True CC fraction[c]	α/α_{SIM}	χ^2_{red}	β/β_{SIM}	χ^2_{red}	σ_{int}	S_{CC}	χ^2_{red}	w-bias	χ^2_{red}
COH	1	0.009	1.010(3)	1.0	0.997(2)	1.3	0.108	1.03(4)	1.8	0.015(4)	1.3
G10	1	0.010	1.002(4)	1.3	0.999(2)	1.1	0.075	1.02(4)	2.0	0.011(4)	1.0
C11	1	0.010	1.013(3)	1.3	0.997(2)	1.4	0.103	1.09(4)	1.4	0.000(3)	1.1
COH	3	0.023	1.001(3)	0.9	1.003(2)	2.7	0.103	1.00(2)	1.0	0.003(4)	1.6
G10	3	0.025	1.008(3)	0.5	1.005(2)	1.9	0.069	1.02(2)	0.9	0.002(3)	0.7
C11	3	0.026	1.016(3)	0.9	1.007(2)	2.1	0.096	1.04(2)	1.2	0.006(3)	0.8

and a bunch of other interesting stuff like the 2ln(sigma) problem

To close the loop

This Swift UVOT image shows galaxy M82 before the explosion and combines data acquired between 2007 and 2013. Mid-ultraviolet light is shown in blue, near-UV light in green and visible light in red. The image is 17 arcminutes across, or slightly more than half the apparent diameter of a full moon. (Credit: NASA/Swift/P. Brown, TAMU)

Accelerating Universe: Not As Fast?

A UA-led team of astronomers found that the type of supernovae commonly used to measure distances in the universe fall into distinct populations not recognized before. The findings have implications for our understanding of how fast the universe has been expanding since the Big Bang.

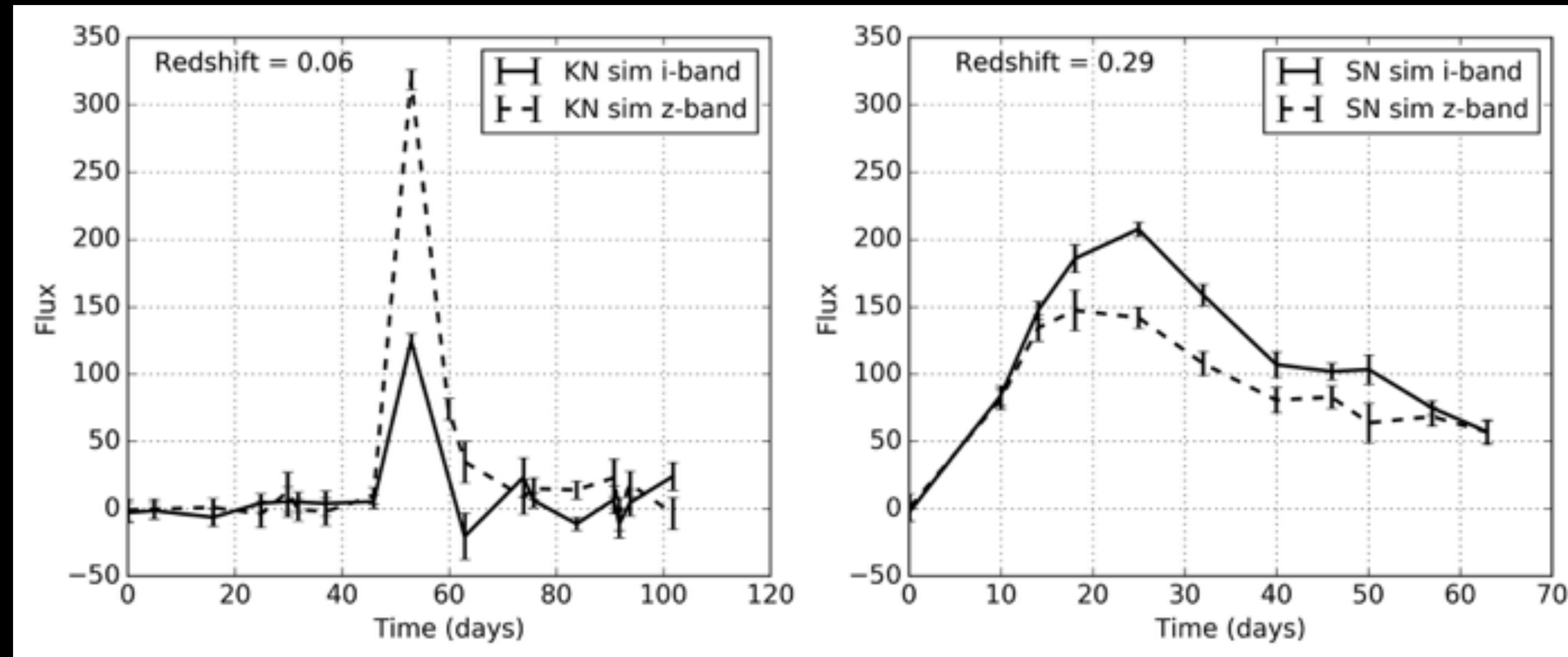
The Changing Fractions of Type Ia Supernovae Optical Subclasses with Redshift
Milne et al. 2015

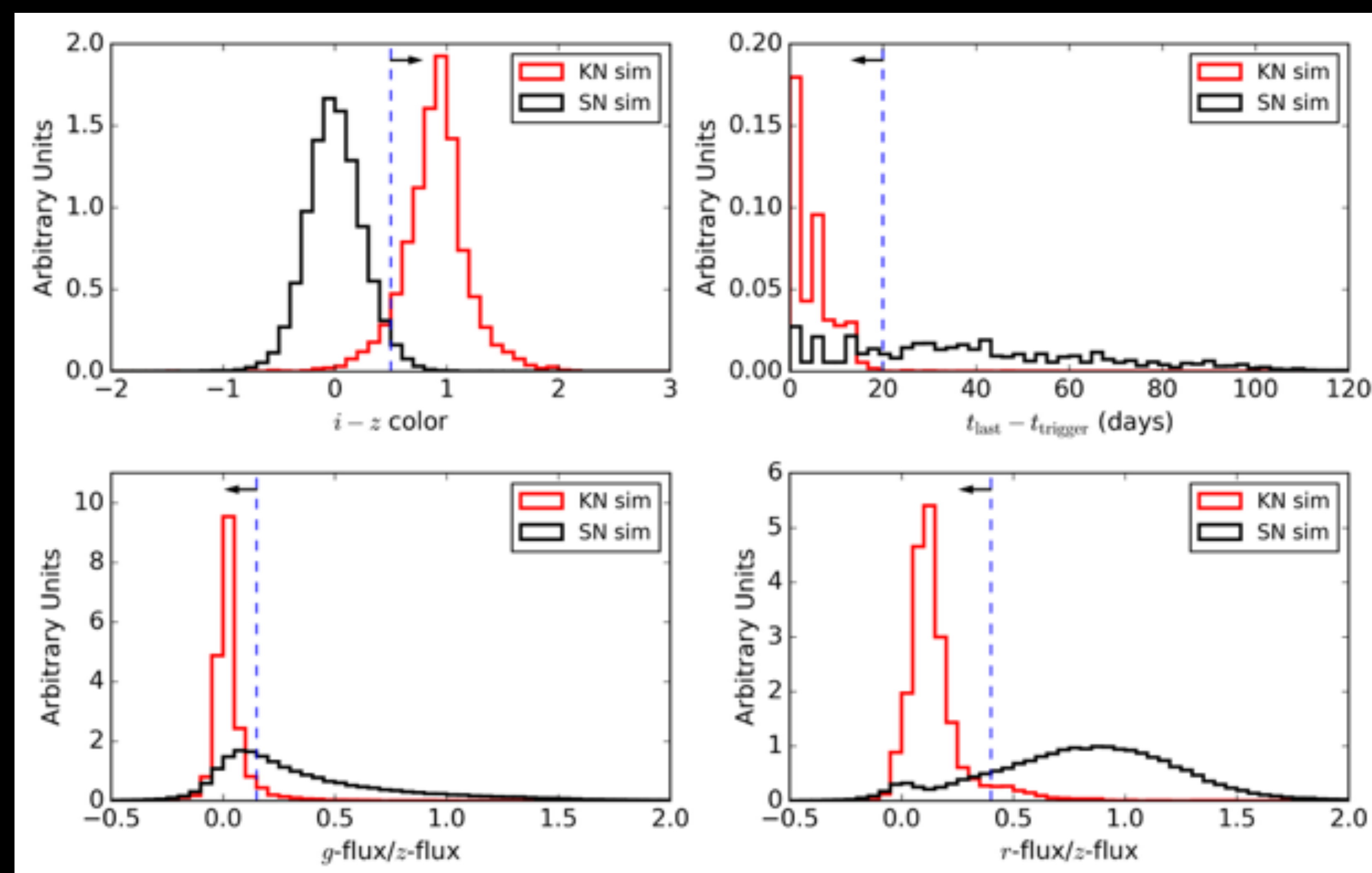
Search for Type Ia Supernova NUV-Optical Subclasses
Cinabro, Scolnic, Kessler et al. 2016

SNANA tutorial on LC fitting

Search for Kilonova in Dark Energy Survey

[Doctor et al. 2016]





1. Specify library of observations (SIMLIB)

2. Supply SEDs

3. Include different noise components

4. Output is detected light curves, can be post-processed with favorite selection requirements.

5. Great for studying the efficiency of finding certain types of transients given a cadence structure.

Some facts and some opinions by me [Dan]

1. SNANA is an amazing tool that allows the user to do a state-of-the-art SN analysis.

2. All code is public.

3. The number of features is huge. Anything I want to do for a SN analysis can be done in SNANA.

4. The manual is here: http://snana.uchicago.edu/doc/snana_manual.pdf . It seems scary, but it helps for someone to show the basics and then use manual for reference.

-People (including myself) have struggled in the past with installation of SNANA (mostly due to CERNLIB, which is gone). SNANA is designed to be software run on a cluster for multiple users. It can be run on your laptop, but that's like buying a Ferrari and never going on the highway. On a cluster, only one person needs to maintain it.

-SNANA is designed to be run on multiple cores of your cluster. No more launching some simple simulations or fits and waiting a day for it to finish. Also, if you know how to launch a job on your cluster, SNANA will do all the parallelization for you - you don't have to think about it.

-Your own processing scripts can be used in between certain steps of SNANA. Often I would write scripts analyzing different parts of the SNANA analysis. SNANA keeps getting bigger, doing more and more of my side scripts.

-A lot of work has gone into getting data into SNANA's format, or making simulations for different past surveys. These are all available. This would be a HUGE pain to redo for every analysis. And here it's free.

-SN surveys are complicated. For accurate analyses and modeling selection effects or intrinsic scatter or spectral models or whatever, the analysis package to do this will also be complicated. But SNANA is very well documented, and almost every piece of the analysis gets its own knob for the user to play with.

SNANA has everything ready to analyze:

JLA (SDSS+SNLS), PS1, Low-z (>10 subsamples), HST surveys, DES, LSST, WFIRST and many more.

Simulation generates ~50 LC per/sec, and SALT2 fitter 5/sec — which is extremely important for over 100 systematics we have in recent analyses.

Can also do fake monitoring for analyzing surveys in real time.

You+SNANA

(after just a little handholding by blackbelt SNANA user)

Three important steps for today:

- Simulation (snlc_sim.exe, sim_SNmix.pl)
- Fitting (snlc_fit.exe, split_and_fit.pl)
- Bias-correction (salt2mu.exe, salt2mu_fit.pl)

- Chris discussed PSNID. There is also full NN neighbor pipeline, can integrate Lochner’s code..