Intrinsic Scatter, and Why We Don't Need to Use All the SNe in our samples

Dan Scolnic, Assistant Professor at Duke University in collaboration with
Dillon Brout on new color dependancies
Dave Jones, Adam Riess on improved H0 robustness

#SCAM2019

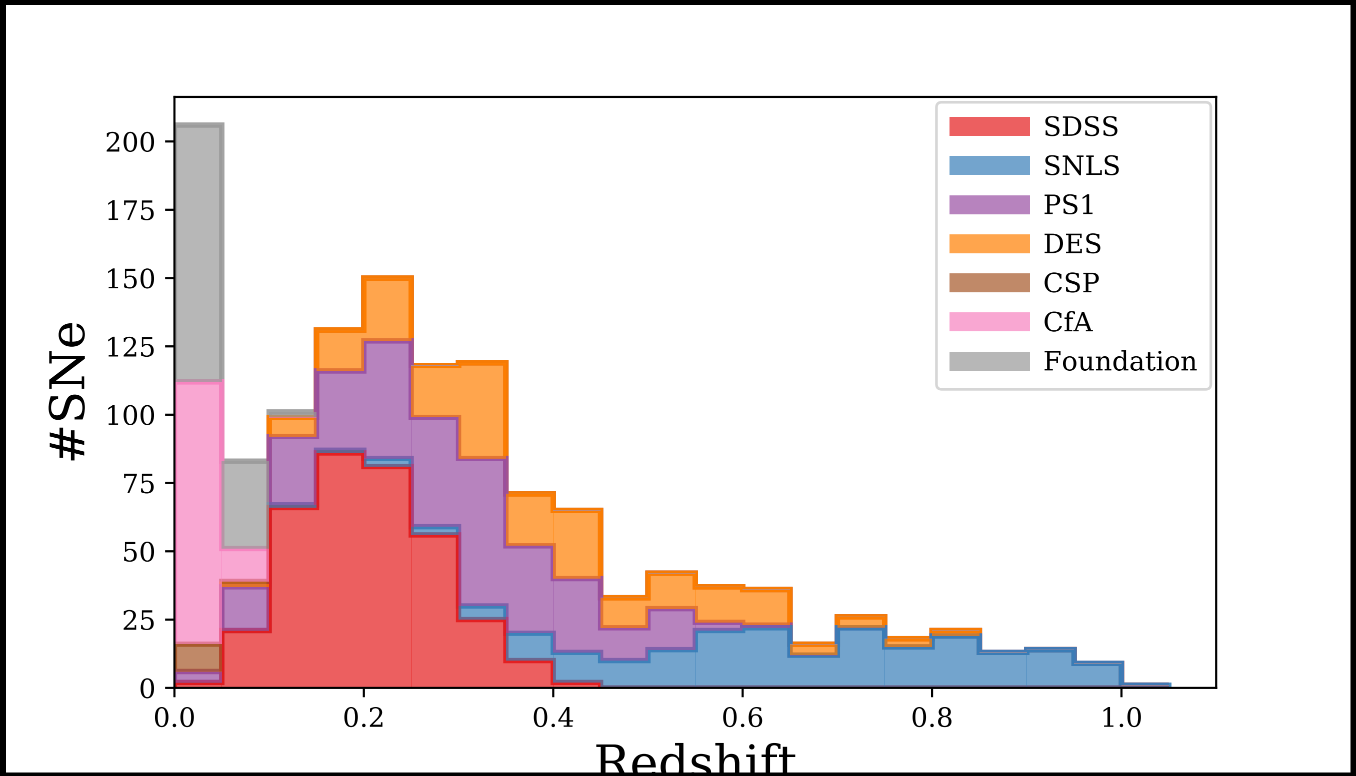
My thesis: Let’s think about how much of the samples we want.

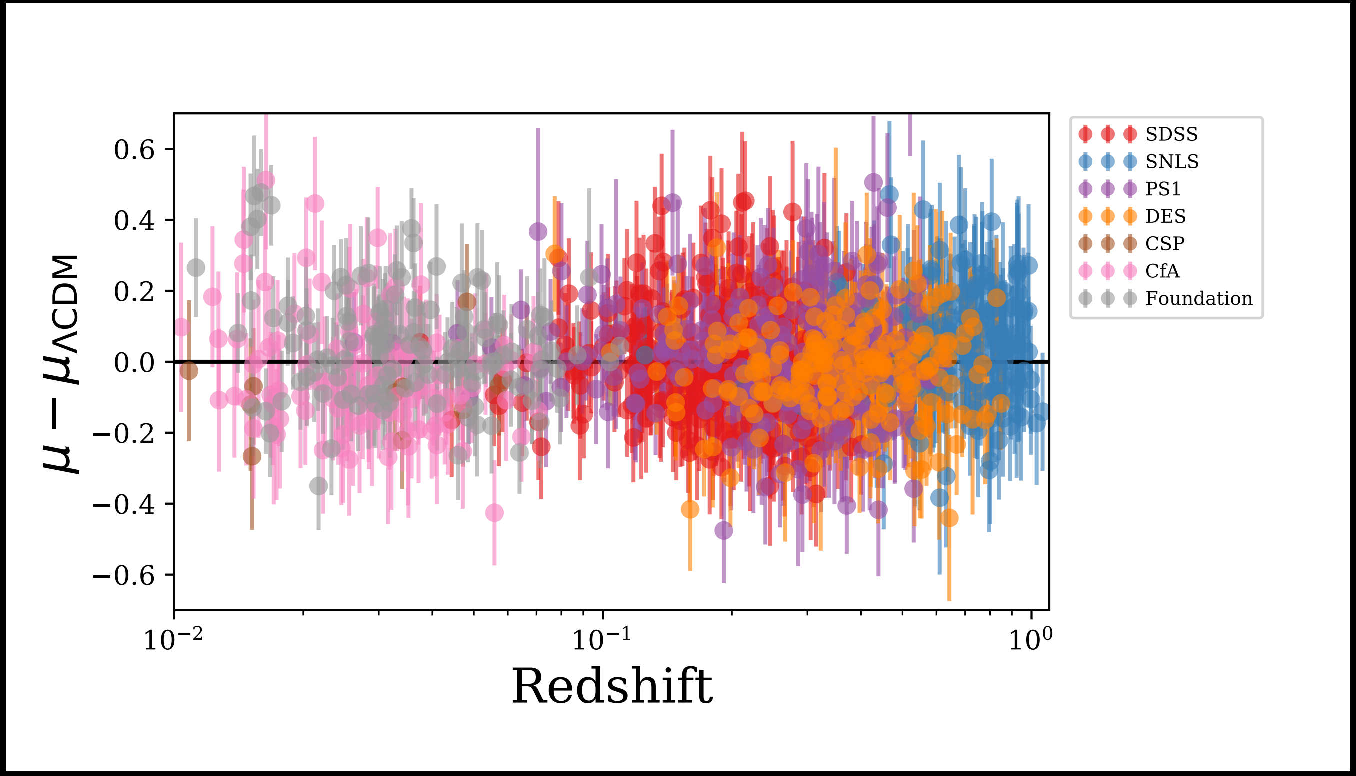
- There are still a number of questions and obstacles for next generation of SNIa cosmology analyses: What is deal with host relations? What is intrinsic scatter due to? How well can we do with calibration?

- SN surveys typically aren’t ‘complete’. We always have selection effects; cut our sample down with light curve quality cuts, and push even more with new photometric analyses.

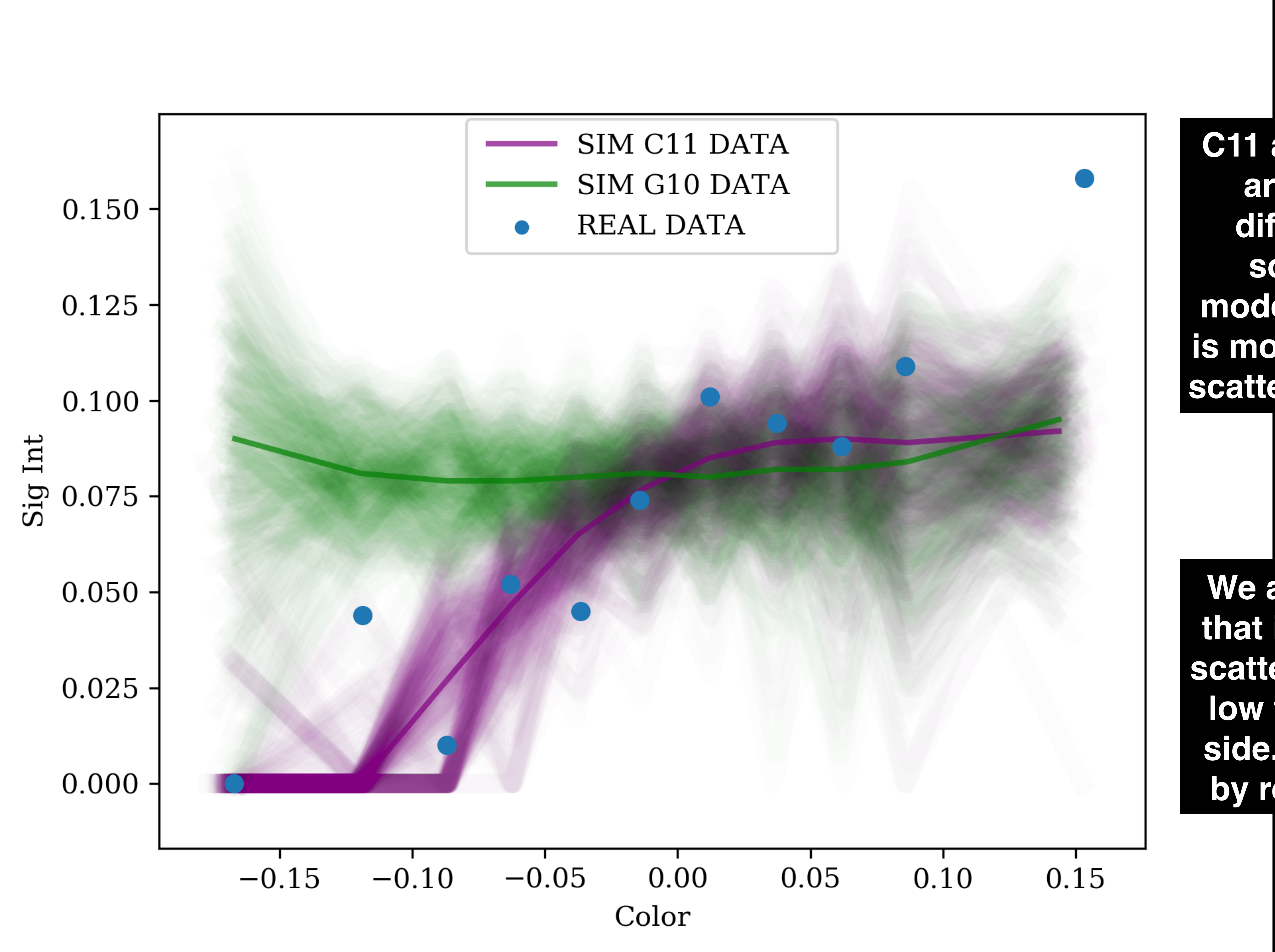
- As we push on systematic floor, it’s time to figure out the optimal sample for doing SNIa cosmology, rather than stretching for more statistics.

Work from Brout+Scolnic 2020 in prep. (But 97% done by Dillon)





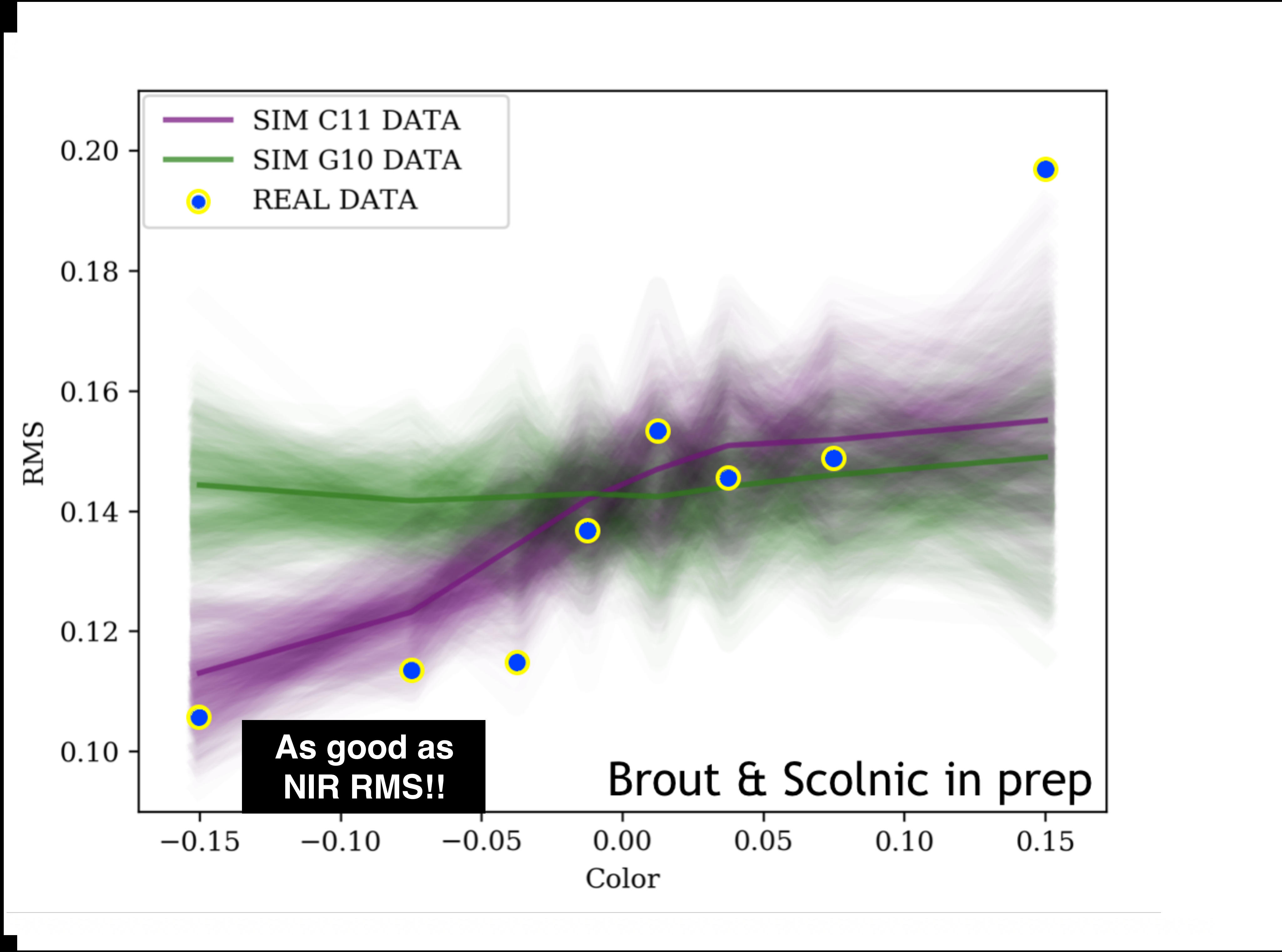
Here we plot the intrinsic scatter versus color. It's very not flat.



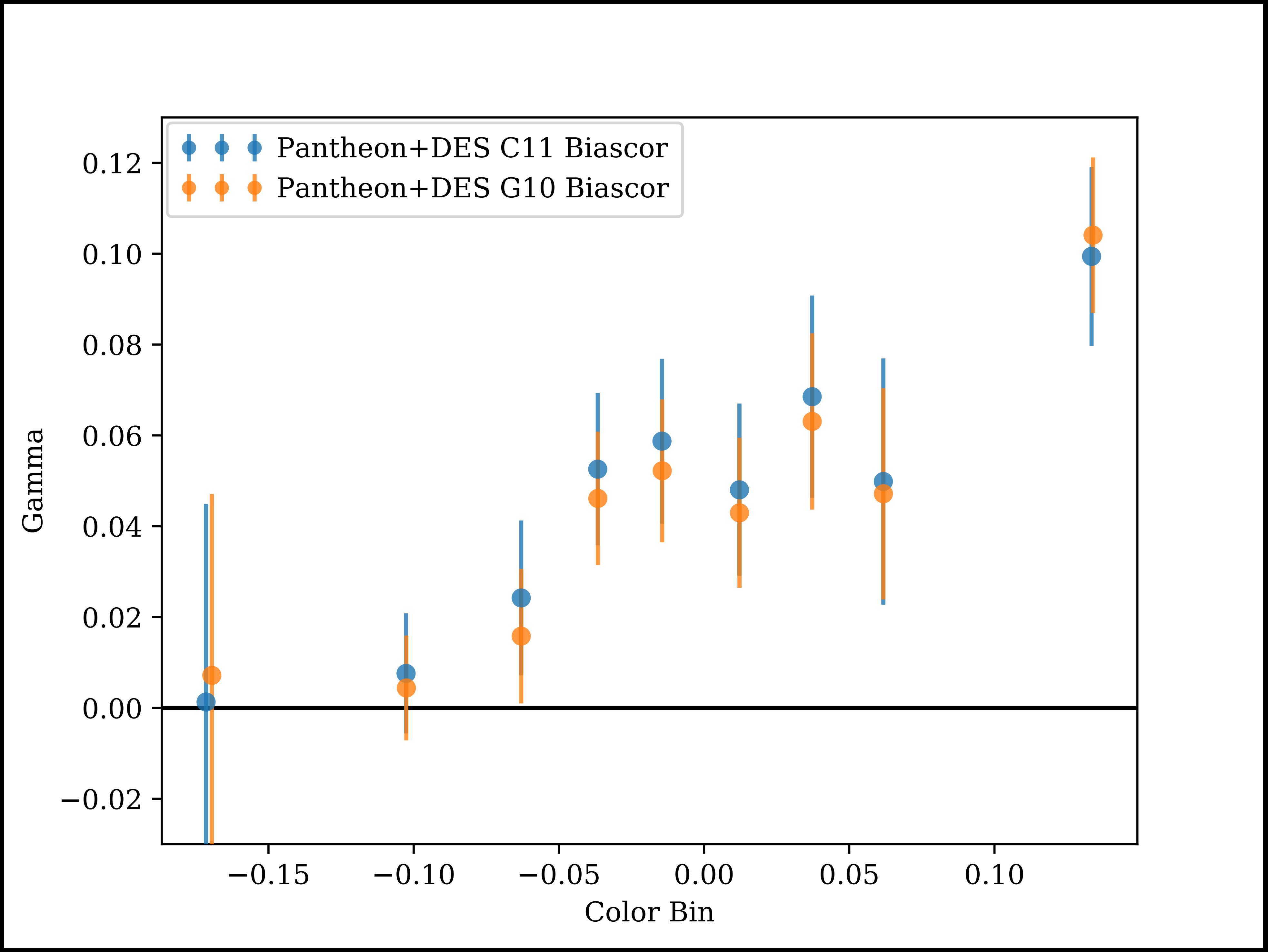
C11 and G10 are two different scatter models. C11 is more color-scatter driven.

We also see that intrinsic scatter is very low for blue side. Driven by red side.

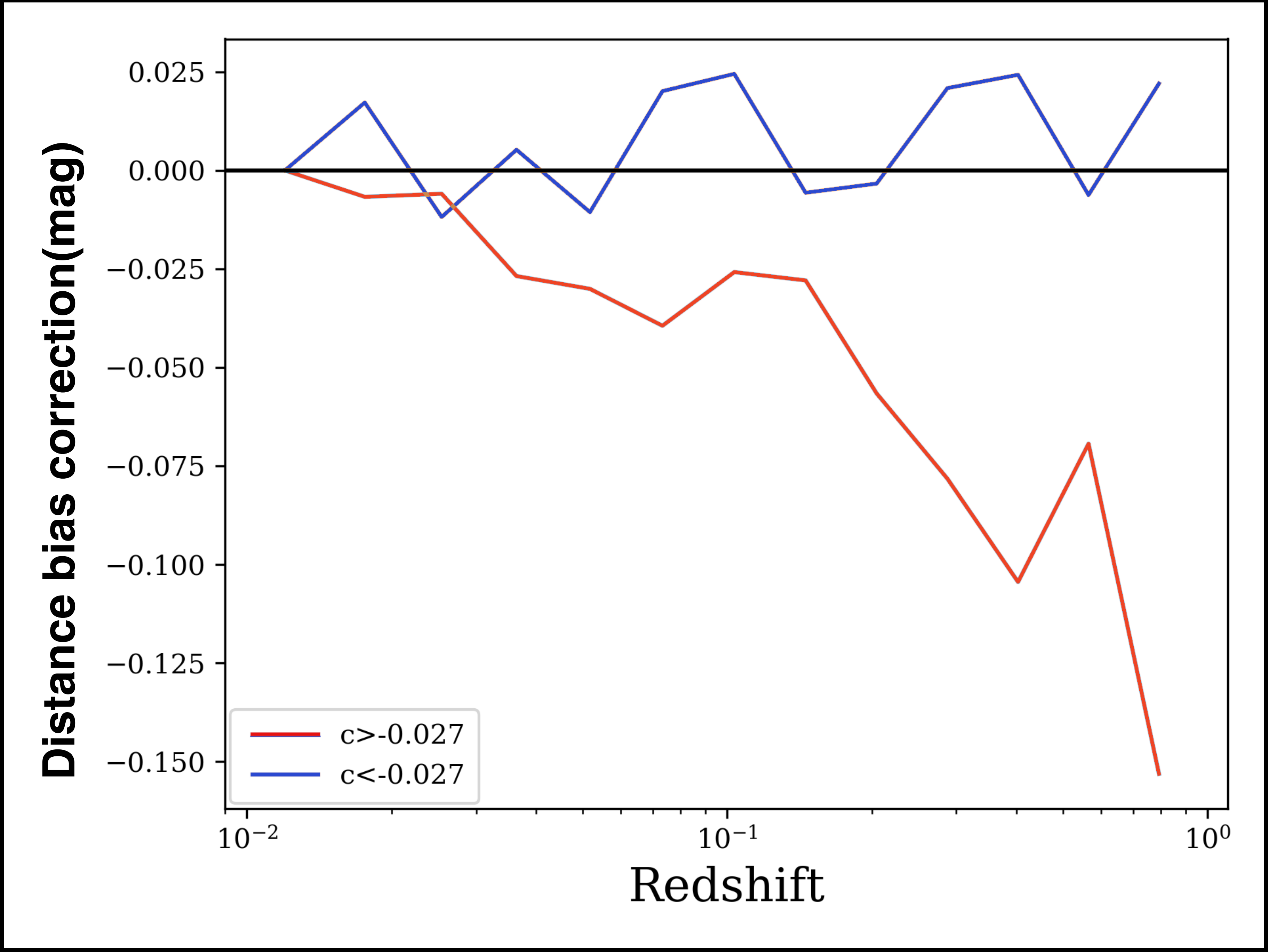
Same for dispersion.



The mass step also seems to be driven by the redder SNe.



For DES, one thing no one feels great about is size of distance bias correction. However, it is way worse for red SNe than brighter, blue ones.

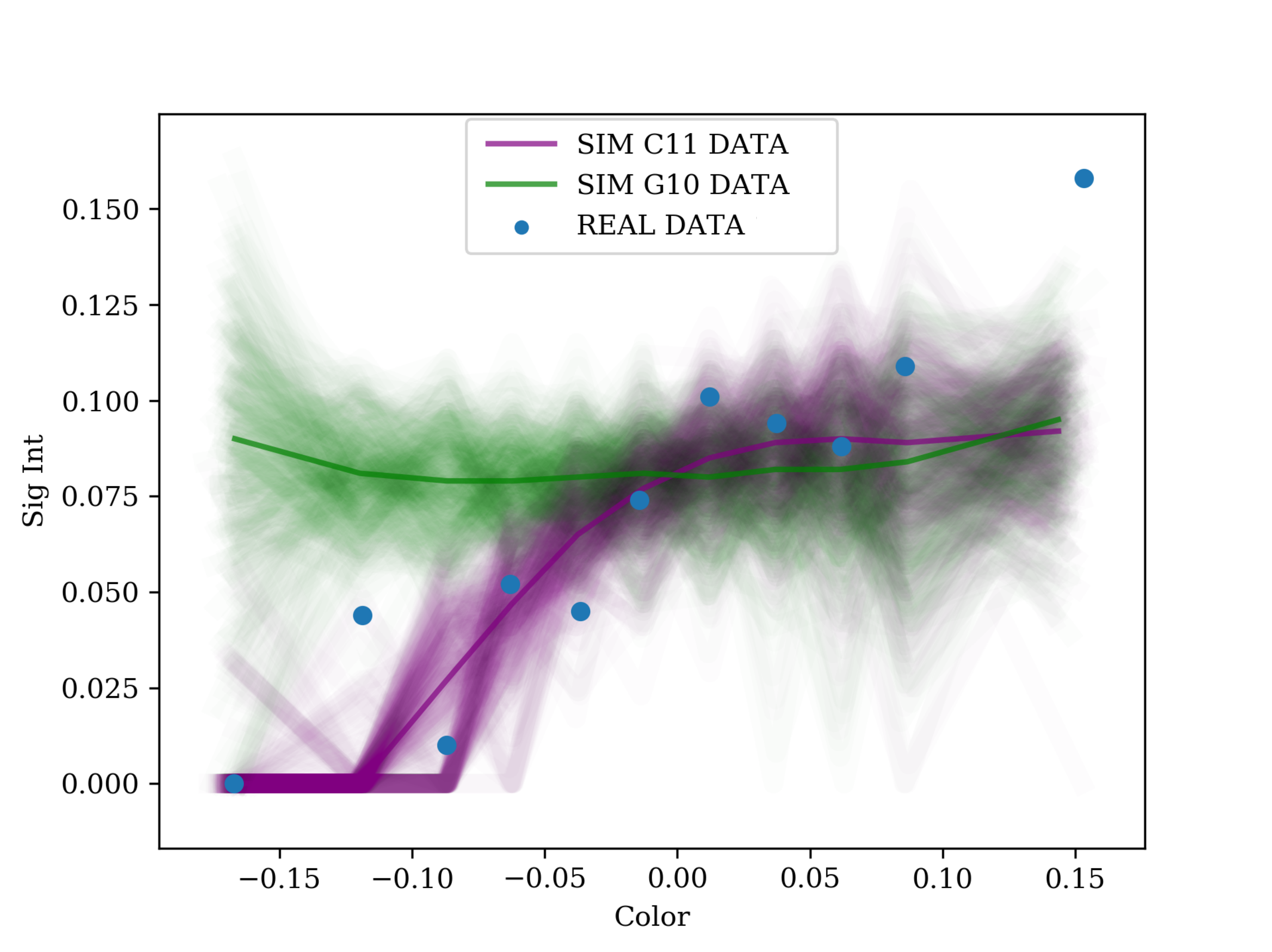


So bluer SNe compared to redder SNe have:

- Lower intrinsic scatter
- Lower mass steps
- Lower distance bias corrections
- So why are we using red SNe?

- But let’s keep pushing….

We are solving for *one* intrinsic scatter value, but clearly this is color dependent. This is bad weighting!

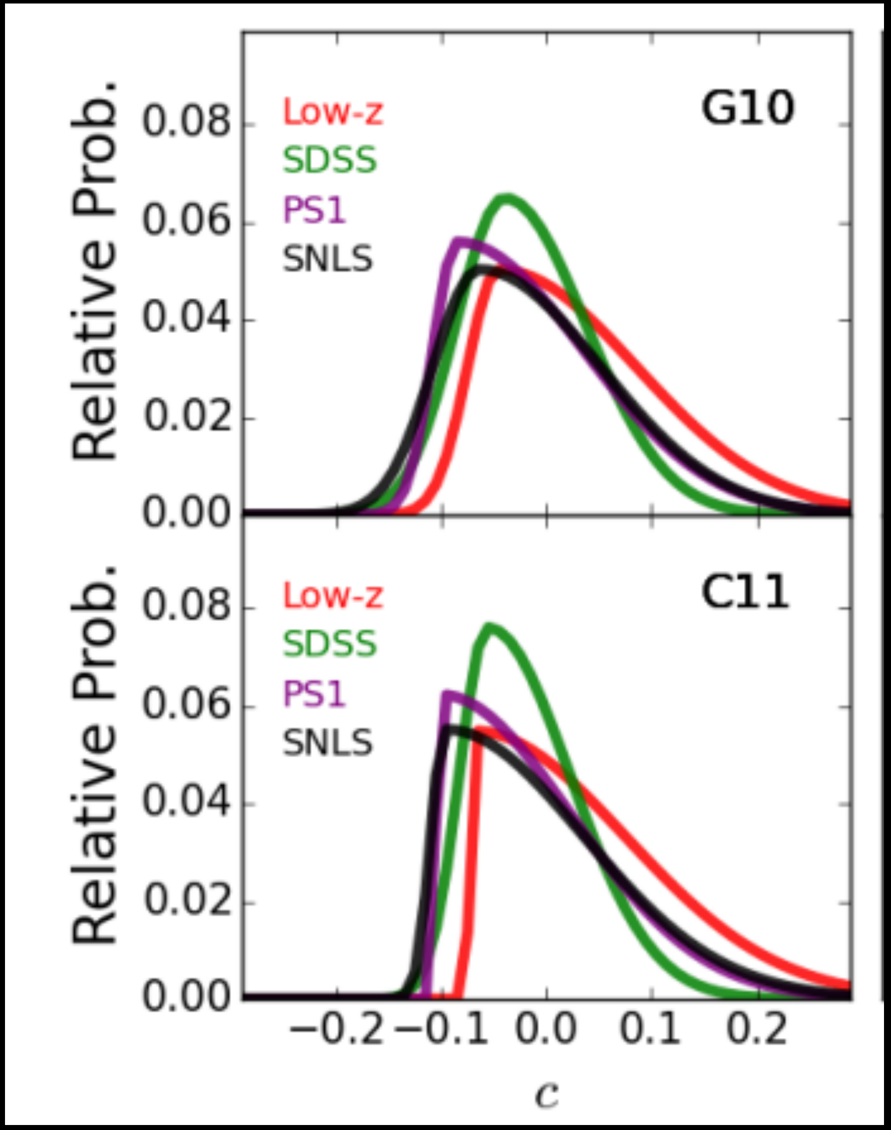


So what would happen if we cut $c<0.1$, and don't have redder colors??

- Uncertainty on w goes from 0.036 to 0.029 - with a simple cut!!!
- Don't necessarily need to cut, but this means we are not doing something right.
- But let's go further….

What dominates our systematic uncertainties.

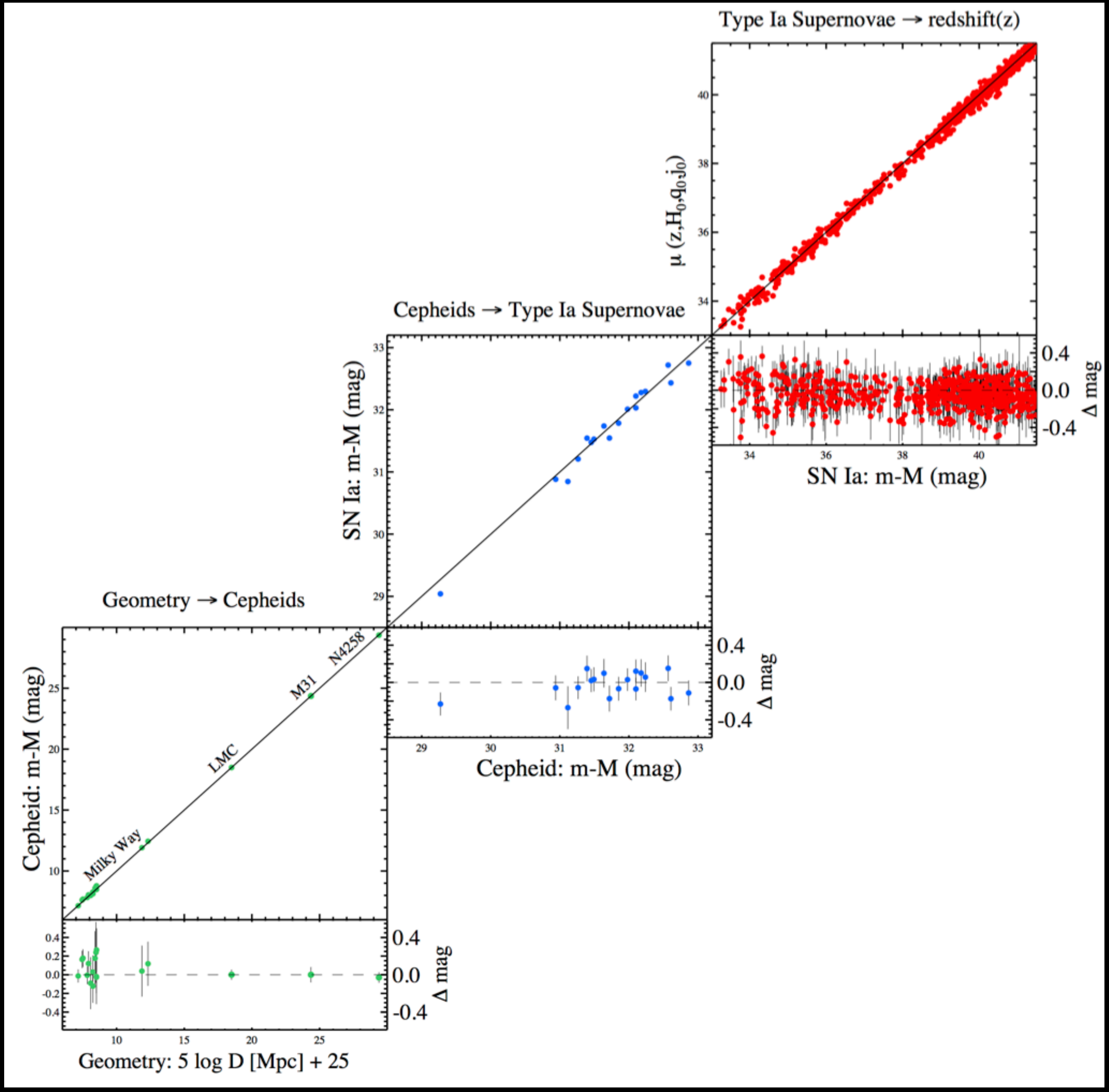
- Tripp equation is mu=mb+0.14x1-3.1c —> that 3.1c dominates.
- But if we just take the blue side (basically the not dusty part), we don't need to standardize with color…
- Setting beta to 0, c<-0.027… dispersion is same as with beta..and…



Full sample: sig_w=0.029 (stat), 0.037 (sys)
Color cut, beta=0: sig_w=0.032 (stat), 0.034 (sys)

Can do better with half the sample!!!!

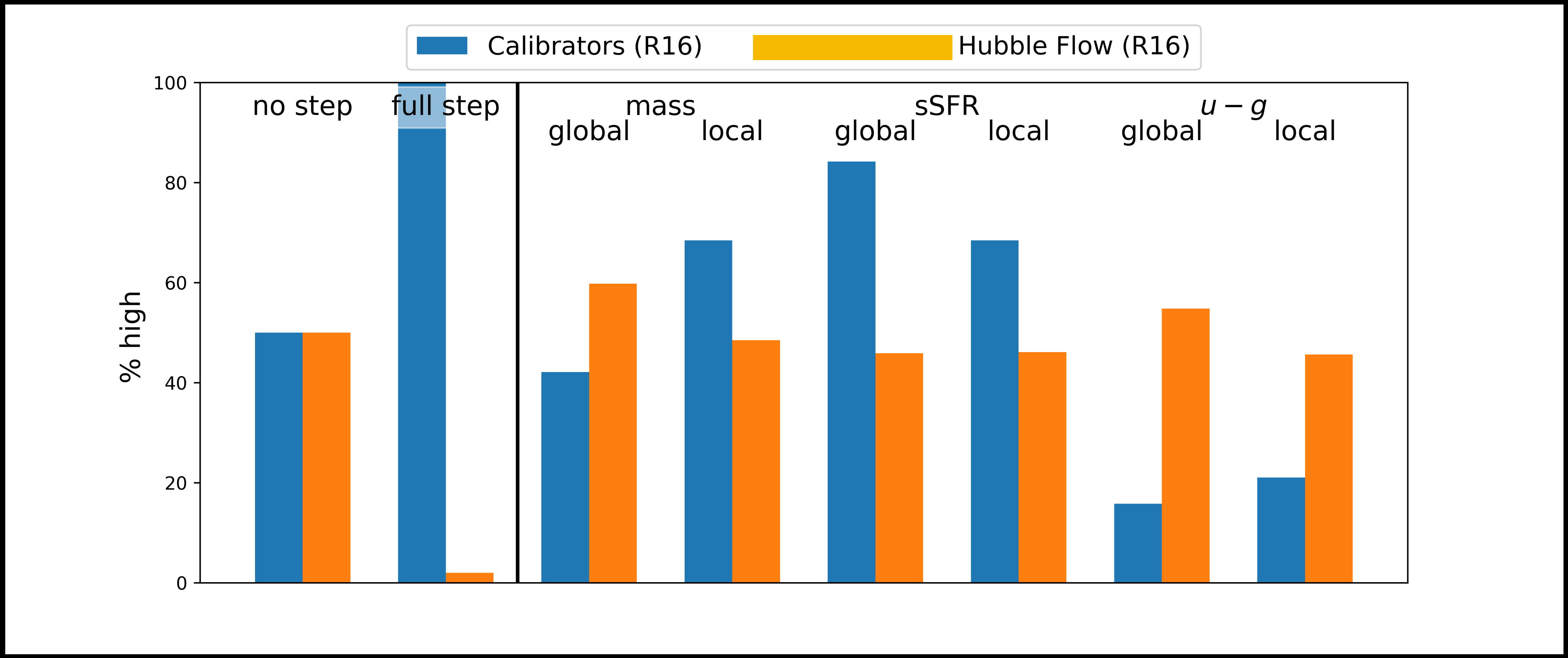
Now switching to H0, how can we do better here?



Key is to make second and third rung as similar as possible. Need to address:

- Our calibrator set does not go as red as our full sample
- Second, can model the intrinsic scatter better
- Third, want to be more insensitive to host galaxy correlations, so how? Want host galaxy demographics for calibrators and Hubble flow to be the same.
- Fourth, want to keep calibrator and Hubble Flow (HF) samples as similar as possible.

Bias on H0 measurement due to host relation is the relative percentage difference between the Calibrators and Hubble Flow set *times* the size of the step



Typical step of 0.06 mag x typical percentage difference of 0.25 means 0.015 mag bias, ~0.8% in H0.

If already correcting for mass step, step size goes down, bias in H0 goes down.

Jones et al. 2018 doubles low-redshift sample with what we will use in next H0 analysis (including all SNe in R16). And is similar to R16 as shows *after mass correction*. Overall, impact is small.

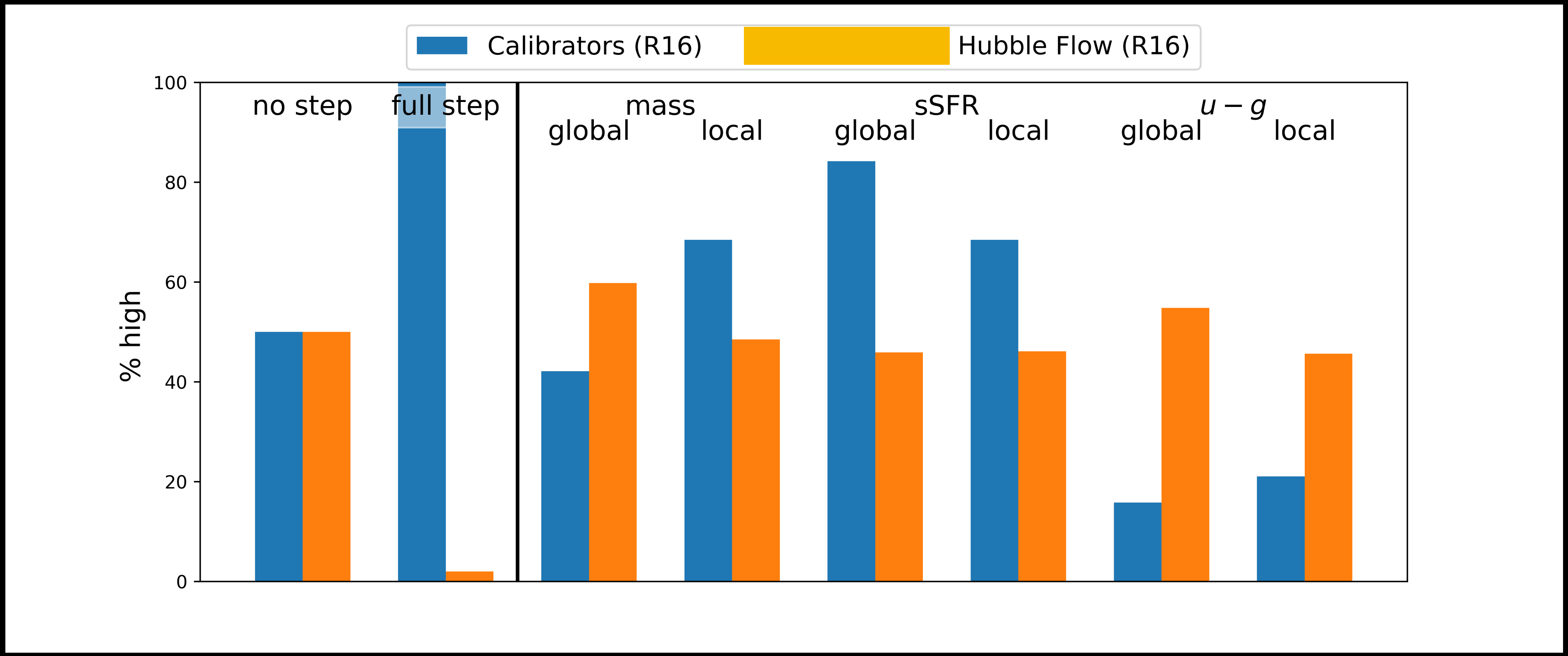
Late-type, star forming only,19 CC

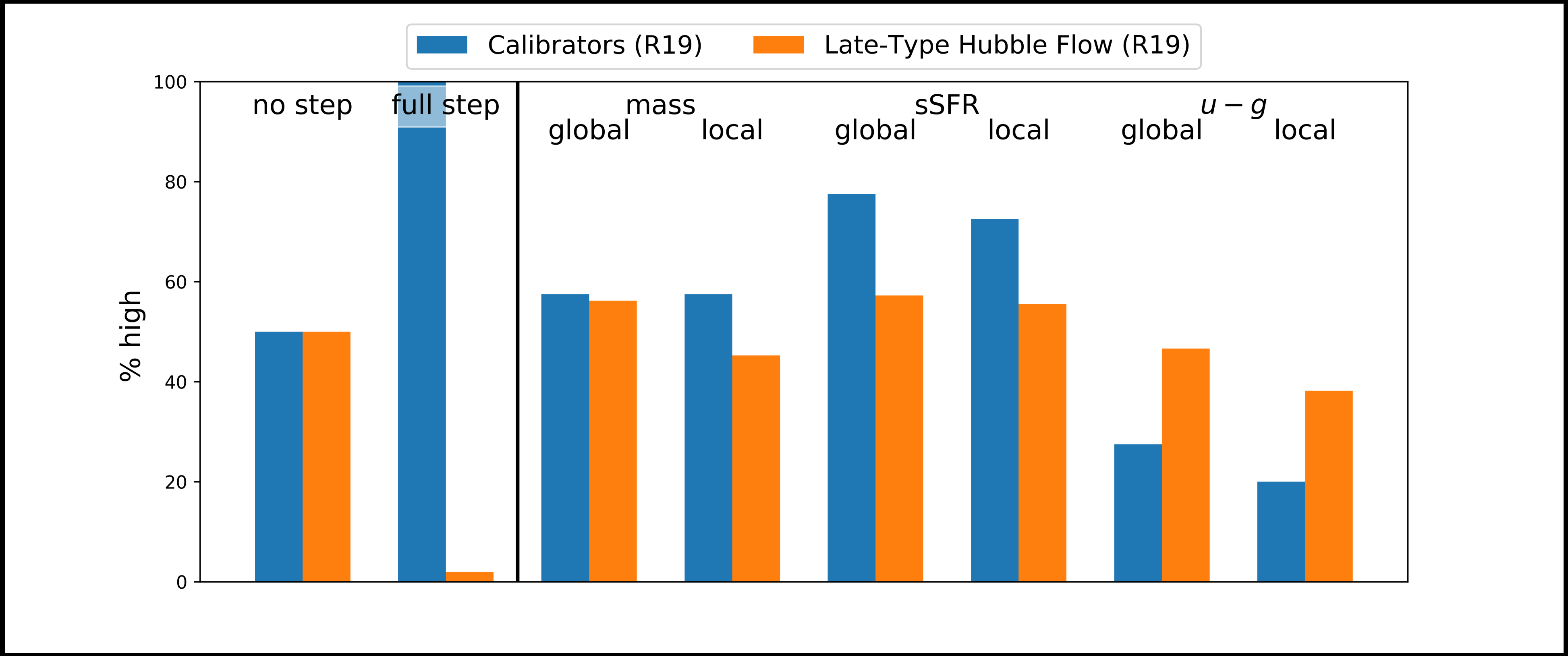
SN Host Property in R16 (Pantheon z<0.15) sample	Step Size	Step Significance	% HF-CC R16	Delta H_0 R16 (km/s/Mpc)
Local mass > 8.3 dex	0.055 +/- 0.17	3.2	15.3%	-0.28
Global mass > 10 dex	-0.002 +/- 0.018	0.1	22.6%	0.02
Local u-g > 1.3	0.033 +/- 0.020	1.7	39.5%	-0.44
Global u-g>1.3	0.035 +/- 0.020	1.8	20.2%	-0.24
Local sSFR < -10.6	0.035 +/- 0.021	1.7	30.9%	-0.37
Global sSFR < -10.6	0.029 +/- 0.020	1.4	21.1%	-0.21

Mean=24.9% -0.31
Max=39.5% -0.44
Only Sig=15.3% -0.28

All these differences are >10x smaller than tension with CMB H0!!!

But if we cut to late-type hosts, and cut color range to match, demographics become more similar.





But how even better?

Late-type, star forming only,38 CC

With next data release -> doubling of the CC sample, and cutting to late-type hosts, cut out red SNe, we will reduce sensitivity HF-CC differences to 0.2 dex in H0

SN Host Property in R16 (Pantheon z<0.15) sample	Step Size	Step Significance	% HF-CC R16	Delta H_0 R16 (km/s/Mpc)	% HF-CC R20 in prep	Delta H_0 R20 in prep (km/s/Mpc)
Local mass > 8.3 dex	0.055 +/- 0.17	3.2	15.3%	-0.28	-15.2%	+0.28
Global mass > 10 dex	-0.002 +/- 0.018	0.1	22.6%	0.02	-8.7%	0.00
Local u-g > 1.3	0.033 +/- 0.020	1.7	39.5%	-0.44	18.7%	-0.21
Global u-g>1.3	0.035 +/- 0.020	1.8	20.2%	-0.24	17.3%	-0.21
Local sSFR < -10.6	0.035 +/- 0.021	1.7	30.9%	-0.37	15.1%	-0.18
Global sSFR < -10.6	0.029 +/- 0.020	1.4	21.1%	-0.21	19.3%	-0.19

We can cut possible bias on H0 down to 0.1!

Mean=24.9%	-0.31	Mean=11.0%	$\boxed{-0.10}$
Max=39.5%	-0.44	Max=19.3%	$\boxed{-0.21}$
Only Sig=15.3%	-0.28	Only Sig=-15.2%	$\boxed{+0.28}$

Conclusions

- If goal is SNIa cosmology, not every SNIa is created equal.
- Need to think about right places to either cut, or add the right level of complexity, to make best measurements possible.
- Goal should be to make comparison samples that are as similar as possible.
- Hiring a postdoc (singular)