New Measurements of the Hubble Constant

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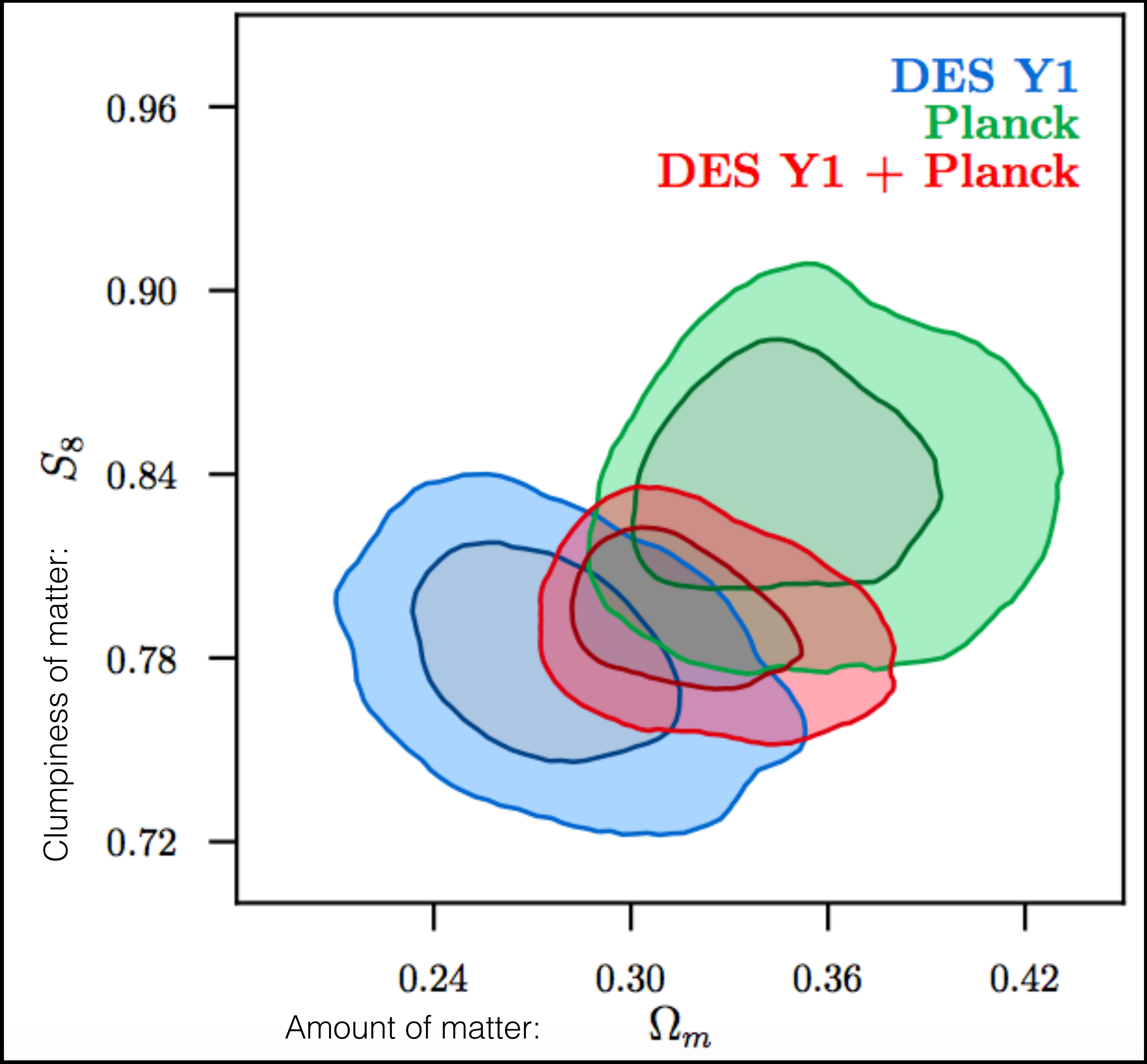
The National Science Foundation
The University of Chicago
The Kavli Foundation

Over next few years, story of cosmology will have a lot of plots like this:



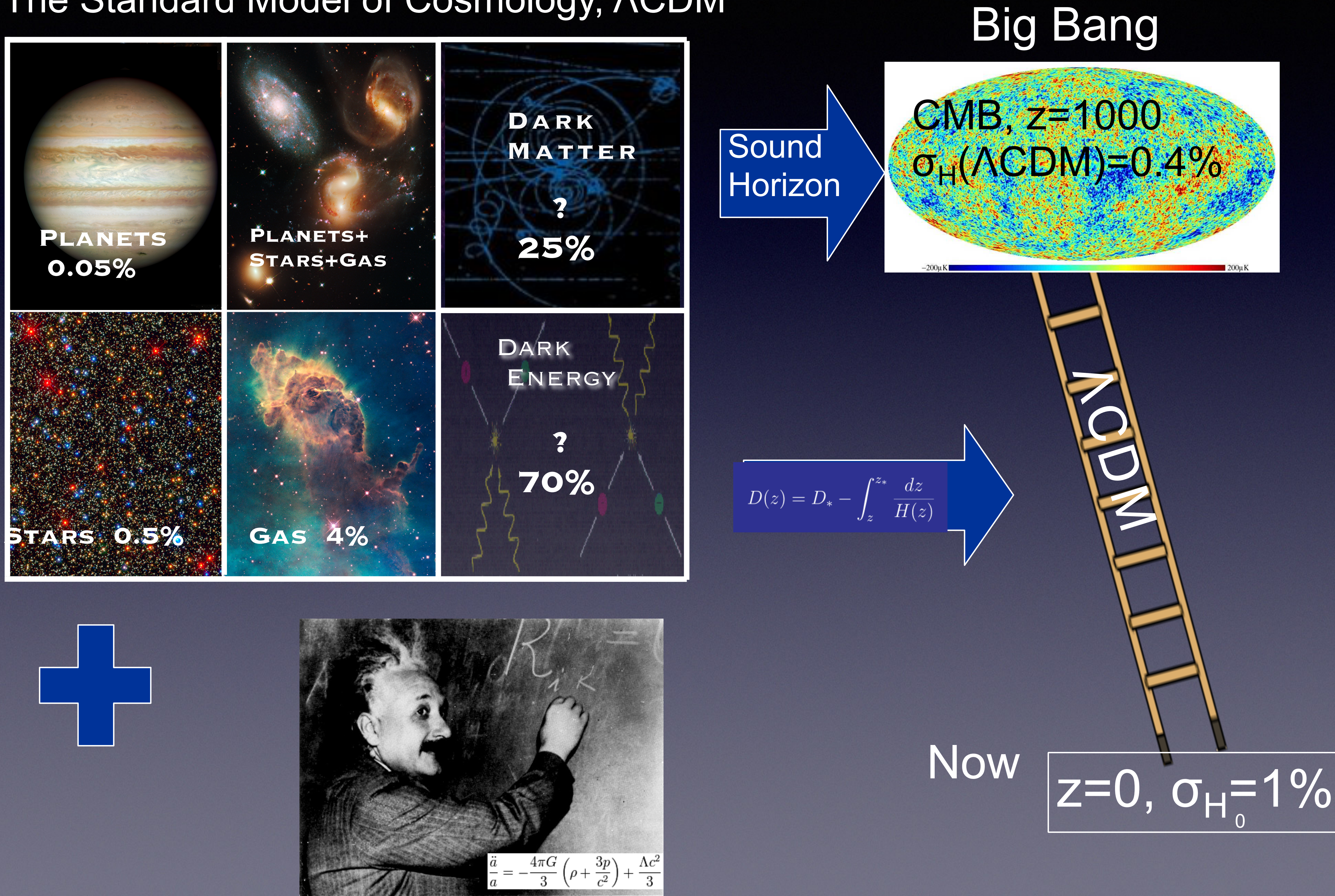
DES 2017

Game of Tension: Results are Coming.

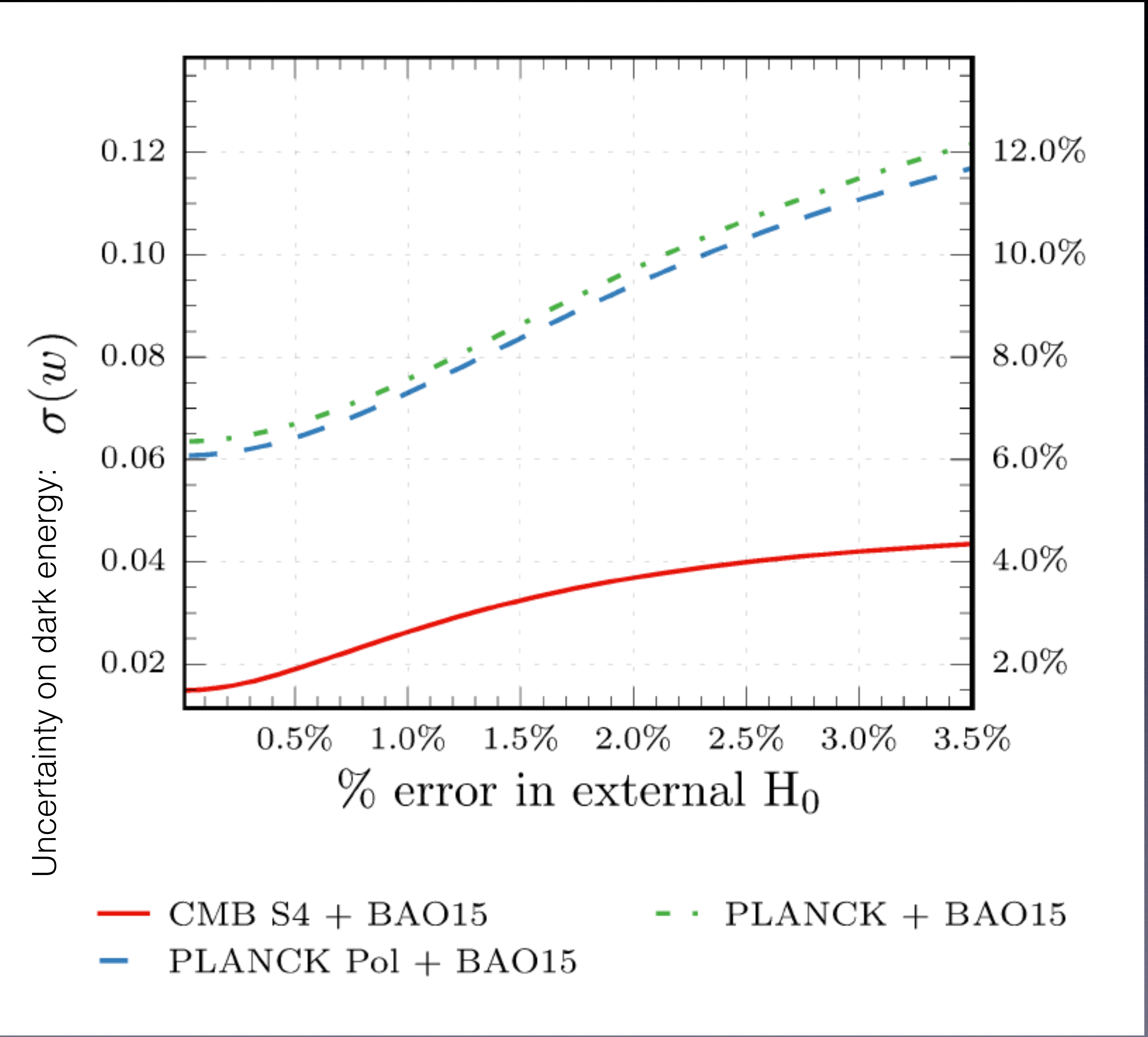
CMB | BAO | Supernova | Weak Lensing | Cepheids/SN | Strong Lensing

Ultimate "End-to-end" test for ΛCDM: Predict and Measure H_0

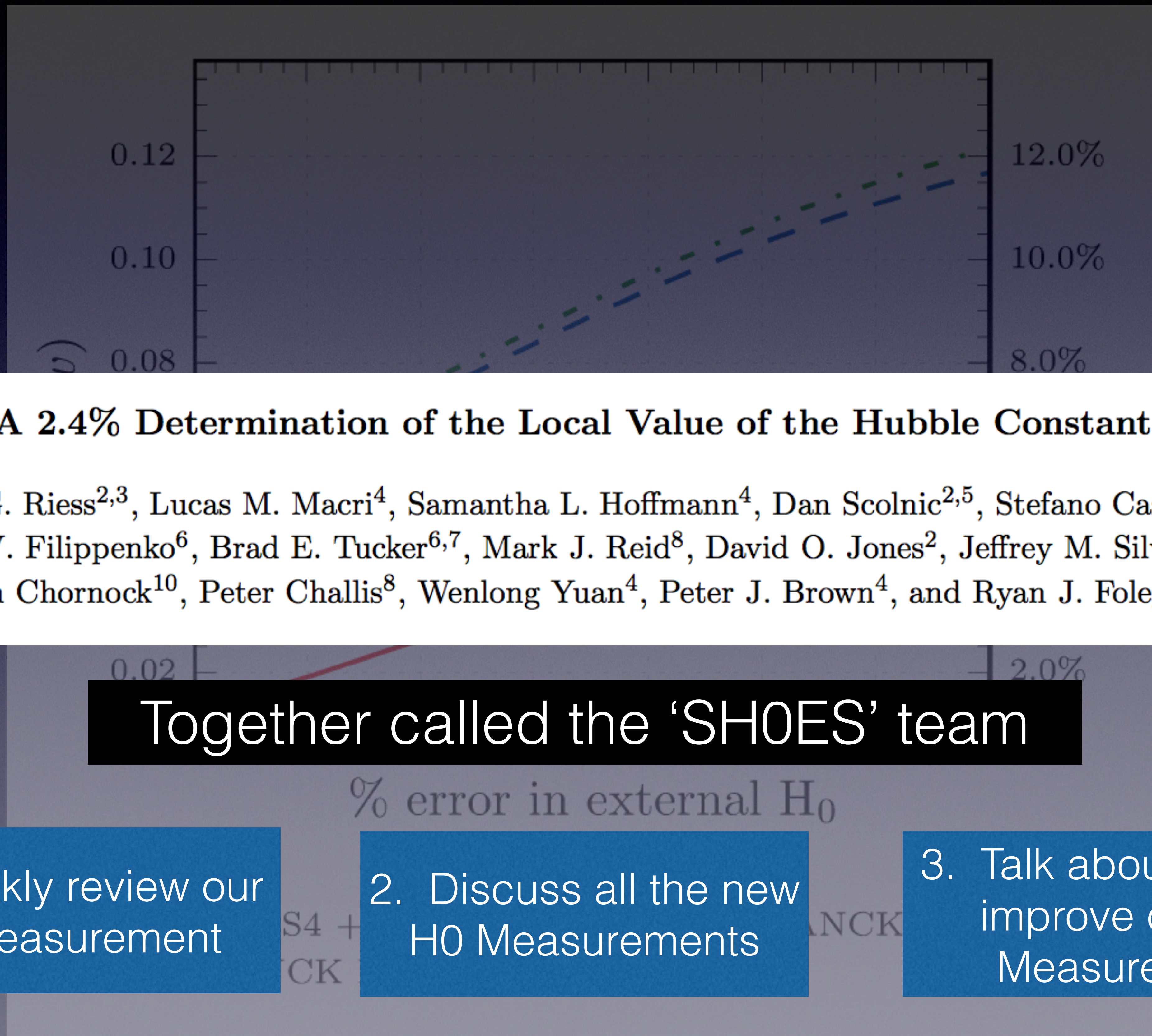
The Standard Model of Cosmology, ΛCDM



Put another way, combining local and CMB-inferred values of H0 constrains dark energy (w)



Based on Manzotti, Dodelson, Park 2016

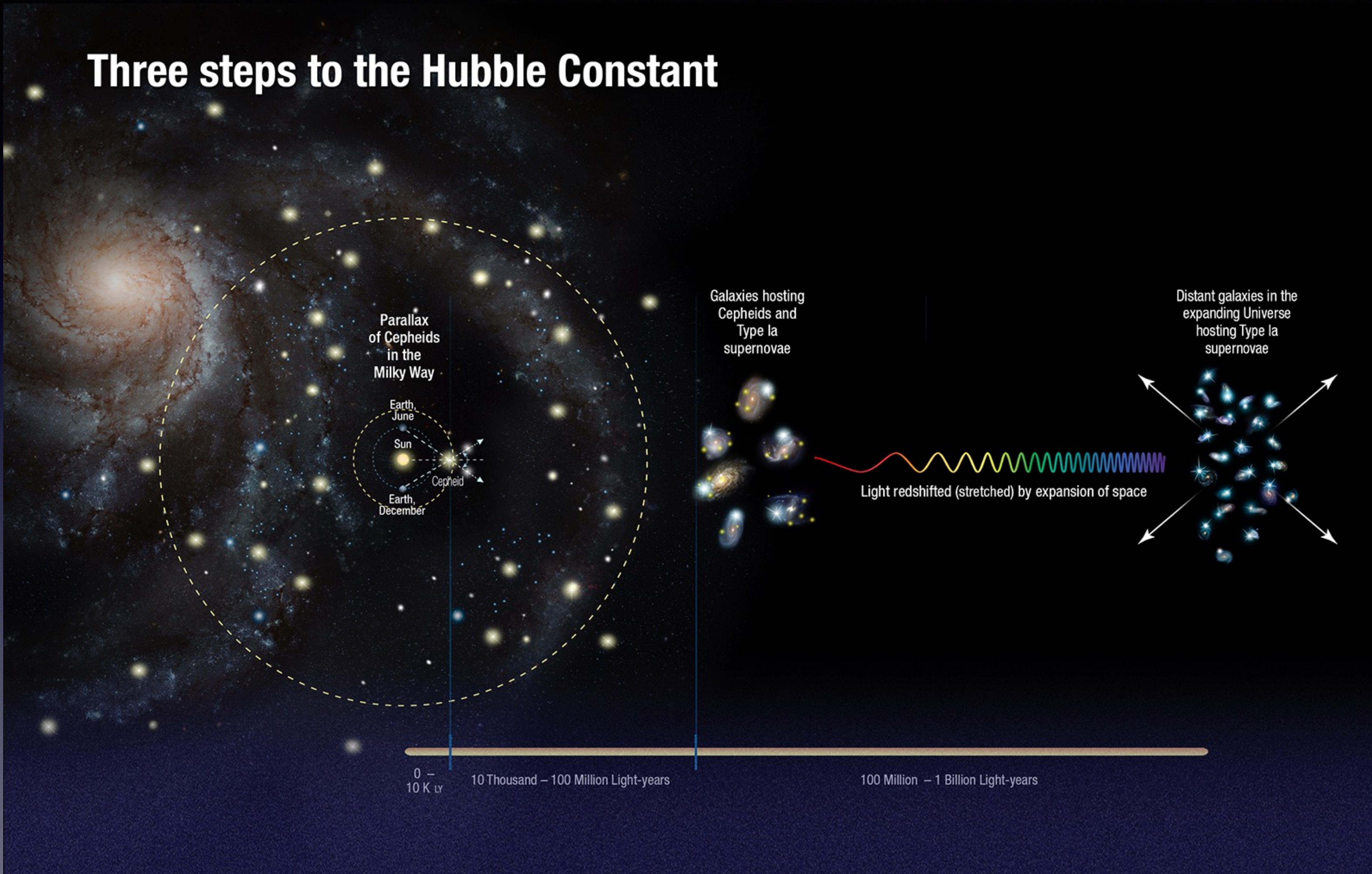


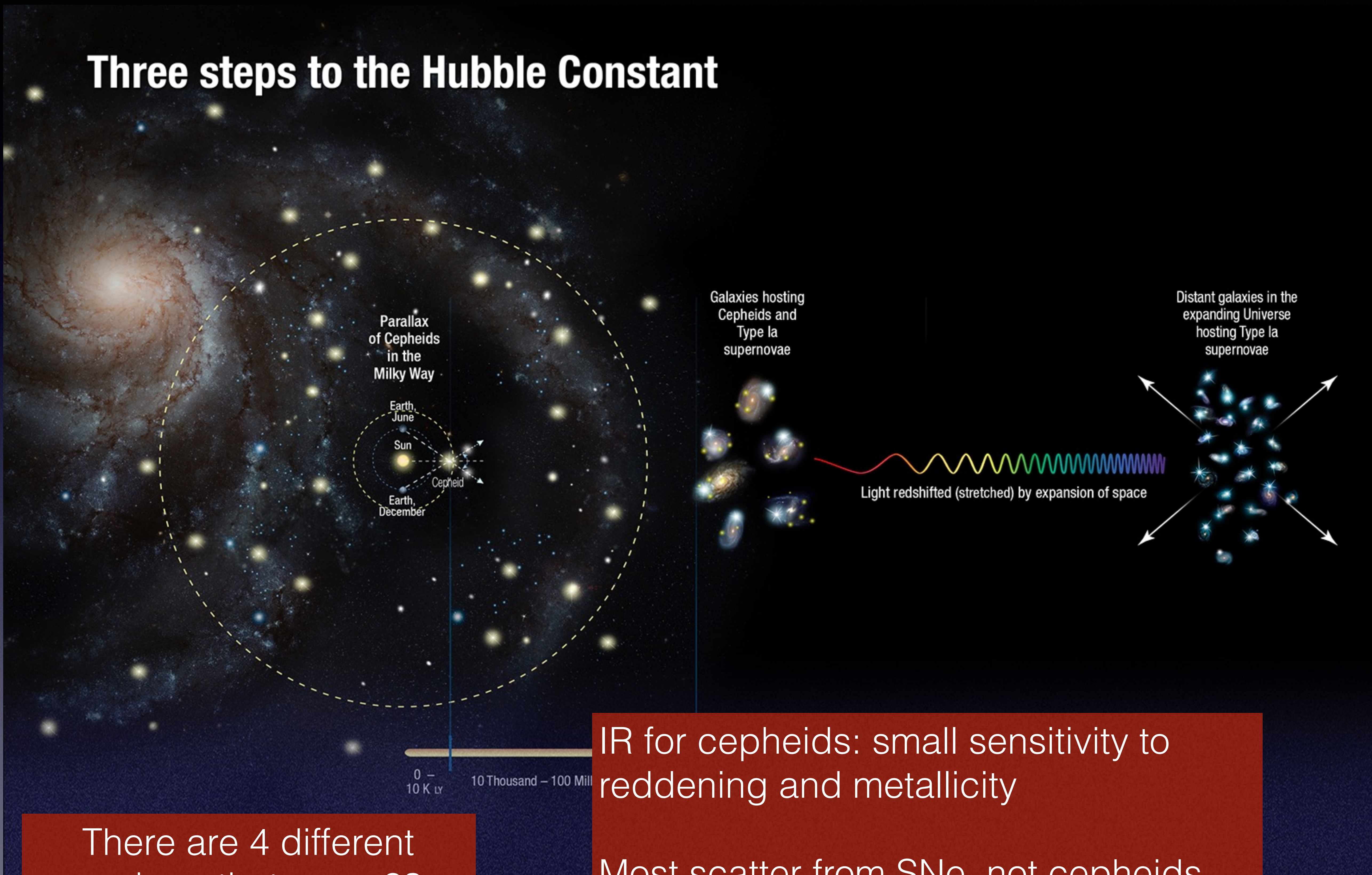
A 2.4% Determination of the Local Value of the Hubble Constant[1]

Adam G. Riess[2,3], Lucas M. Macri[4], Samantha L. Hoffmann[4], Dan Scolnic[2,5], Stefano Casertano[3], Alexei V. Filippenko[6], Brad E. Tucker[6,7], Mark J. Reid[8], David O. Jones[2], Jeffrey M. Silverman[9], Ryan Chornock[10], Peter Challis[8], Wenlong Yuan[4], Peter J. Brown[4], and Ryan J. Foley[11,12]

Together called the ‘SH0ES’ team

1. Quickly review our H0 Measurement
2. Discuss all the new H0 Measurements
3. Talk about how we improve our H0 Measurement


Three steps to the Hubble Constant
Parallax of Cepheids in the Milky Way
Earth, June
Sun
Cepheid
Earth, December
Galaxies hosting Cepheids and Type Ia supernovae
Distant galaxies in the expanding Universe hosting Type Ia supernovae
Light redshifted (stretched) by expansion of space
0 – 10 K LY
10 Thousand – 100 Million Light-years
100 Million – 1 Billion Light-years

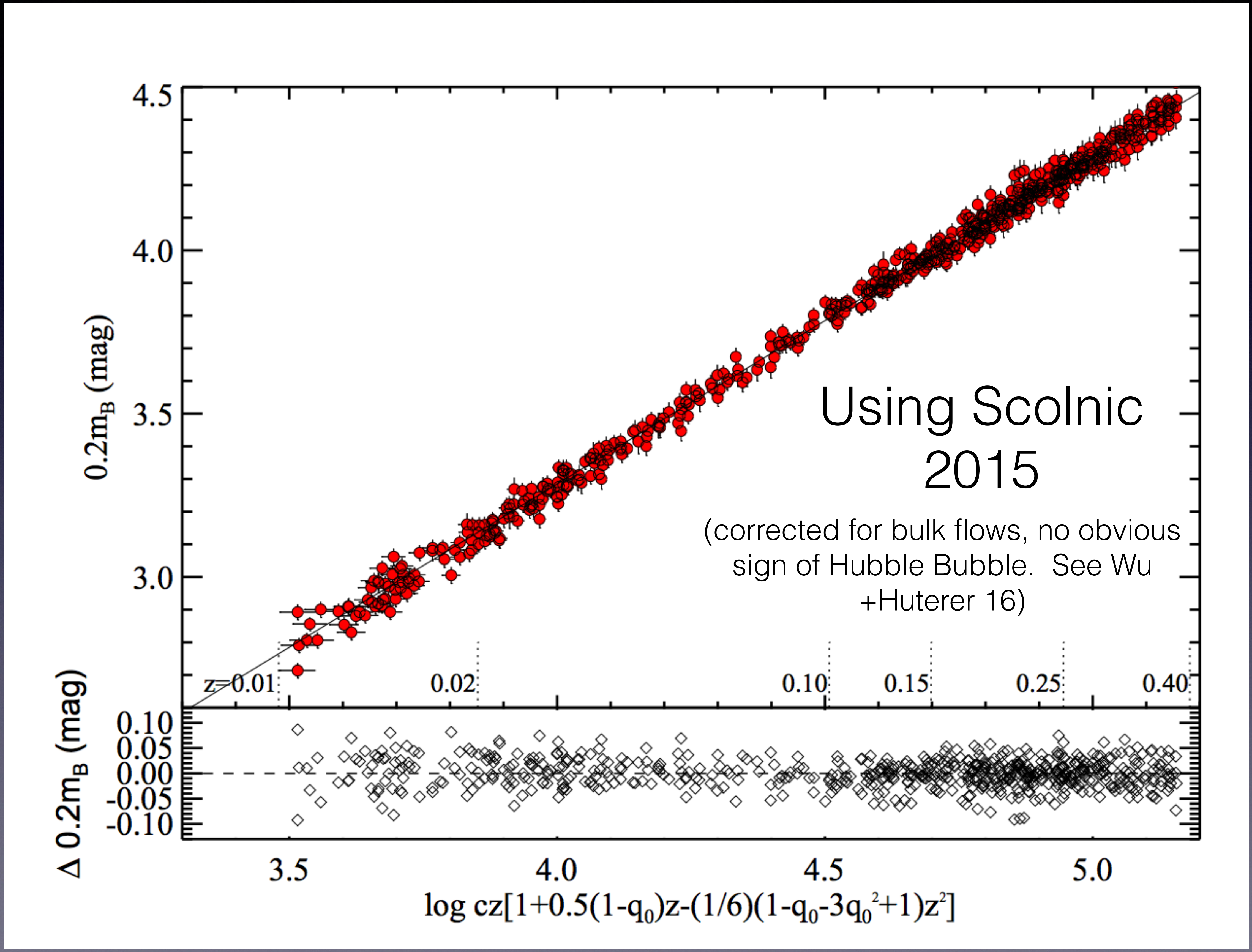


IR for cepheids: small sensitivity to reddening and metallicity

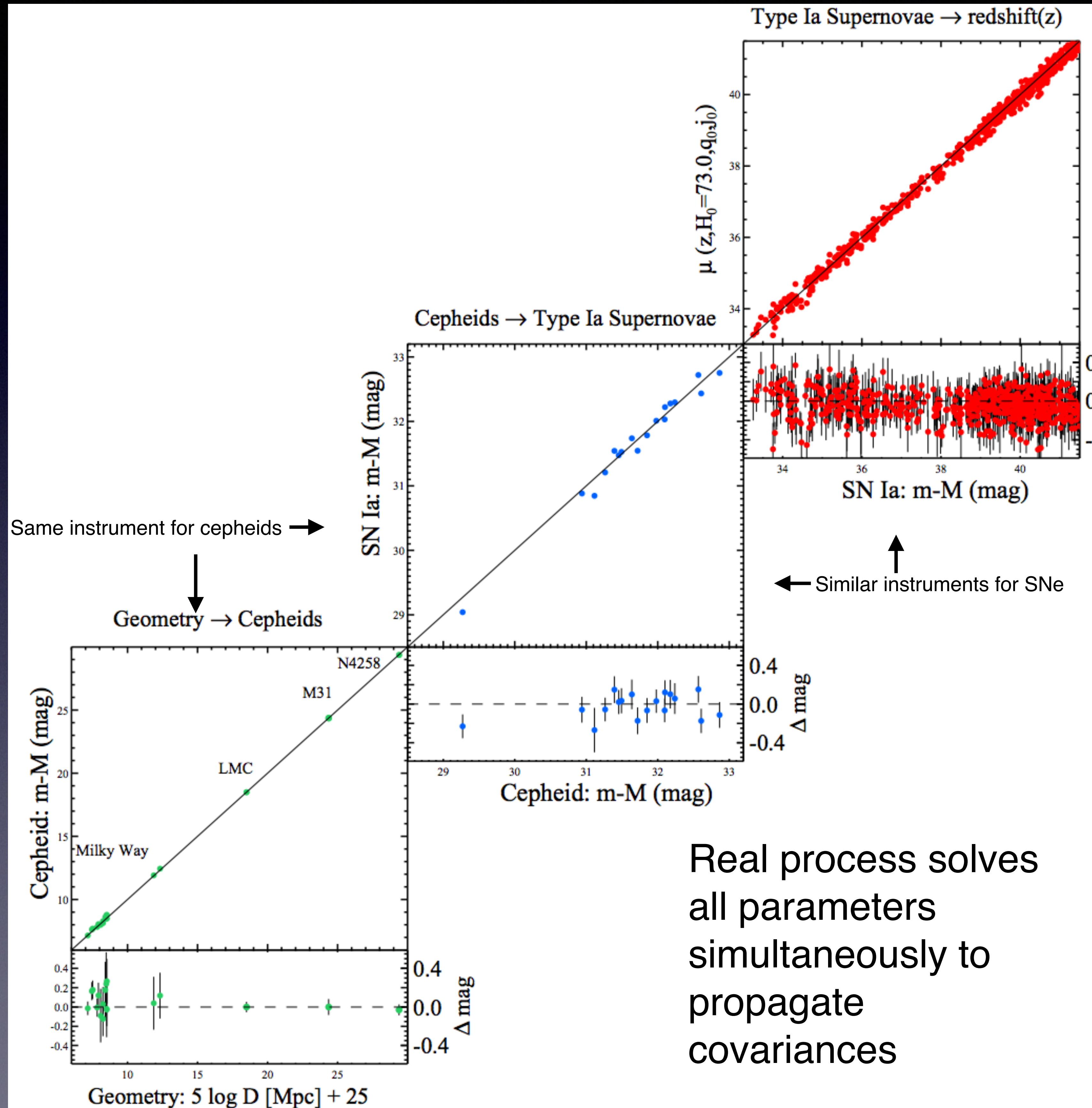
Most scatter from SNe, not cepheids [Need better understanding of SN physics - e.g. LOX project by R. Miller]

There are 4 different anchors that span 23 mags with <2% error!

For last step, we have >200 low-z SNe so intercept is well constructed



Ultimately, we produce the distance ladder.



Real process solves all parameters simultaneously to propagate covariances

Four geometric distance calibrations of Cepheids:

	H_0 (km/s/Mpc)
(i) megamasers in NGC 4258:	72.25±2.51
(ii) 8 DEBs in the LMC:	72.04±2.67
(iii) 15 MW Cepheids with parallaxes:	76.18±2.37
(iv) 2 DEBs in M31:	74.50±3.27

Best estimate of H0: 73.24±1.74

This value is 3.4σ higher than Planck 66.9 ± 0.6 km/s/Mpc for ΛCDM with 3 neutrino flavors having a mass of 0.06 eV and the Planck data

(2.0σ relative to the prediction of 69.3 ± 0.7 km/s/Mpc from WMAP+SPT+ACT+BAO)

There have been a number of re-analyses of SH0ES paper in last year, nothing too different

Our best estimate of H0: 73.24±1.74 km/s/Mpc

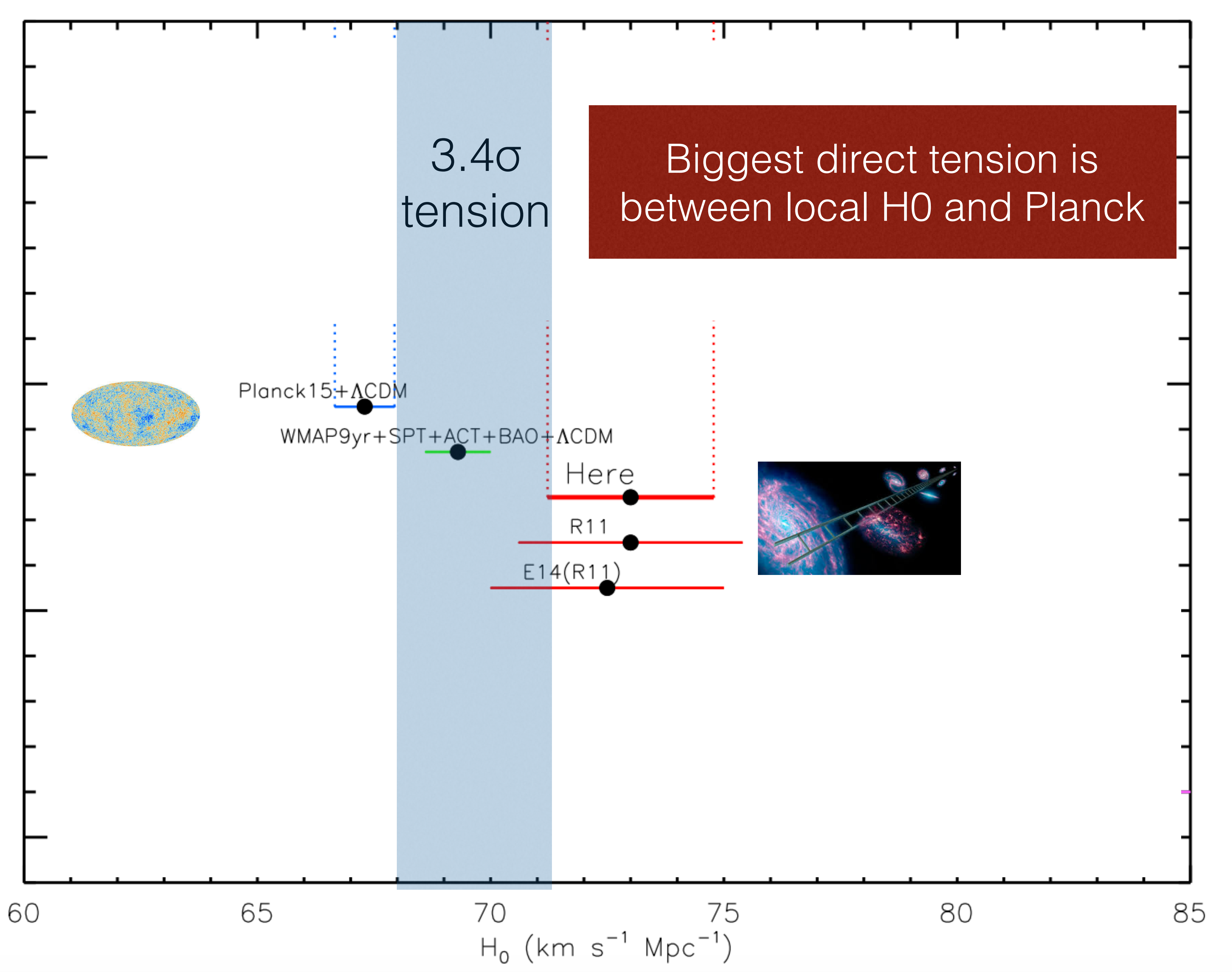
– Follin & Knox 2017 (arXiv:1707.01175) (modelling of cepheid systematics/photometry. H0=73.3 ± 1.7 (stat) km/s/Mpc)

– Cardona et al. 2017 (arxiv:1611.06088): Bayesian hyper-parameters for outlier rejection H0 = 73.75 ± 2.11 km/s/Mpc

– Feeney et al. 2017 (arXiv:1707.00007): Bayesian hierarchical model, impact of non-gaussian likelihoods. H0 = 72.72 ± 1.67 km/s/Mpc

– Zhang et al. 2017 (arXiv:1706.07573v1): Blinded reanalysis R11 [my take: technical error of not treating systematics simultaneously] finds. H0 = 72.5 ± 3.1(stat) ± 0.77(sys) km/s/Mpc

“If a persuasive case can be made that a direct measurement of H0 conflicts with these estimates, then this will be strong evidence for additional physics beyond the base LCDM model”. [Planck 2015]



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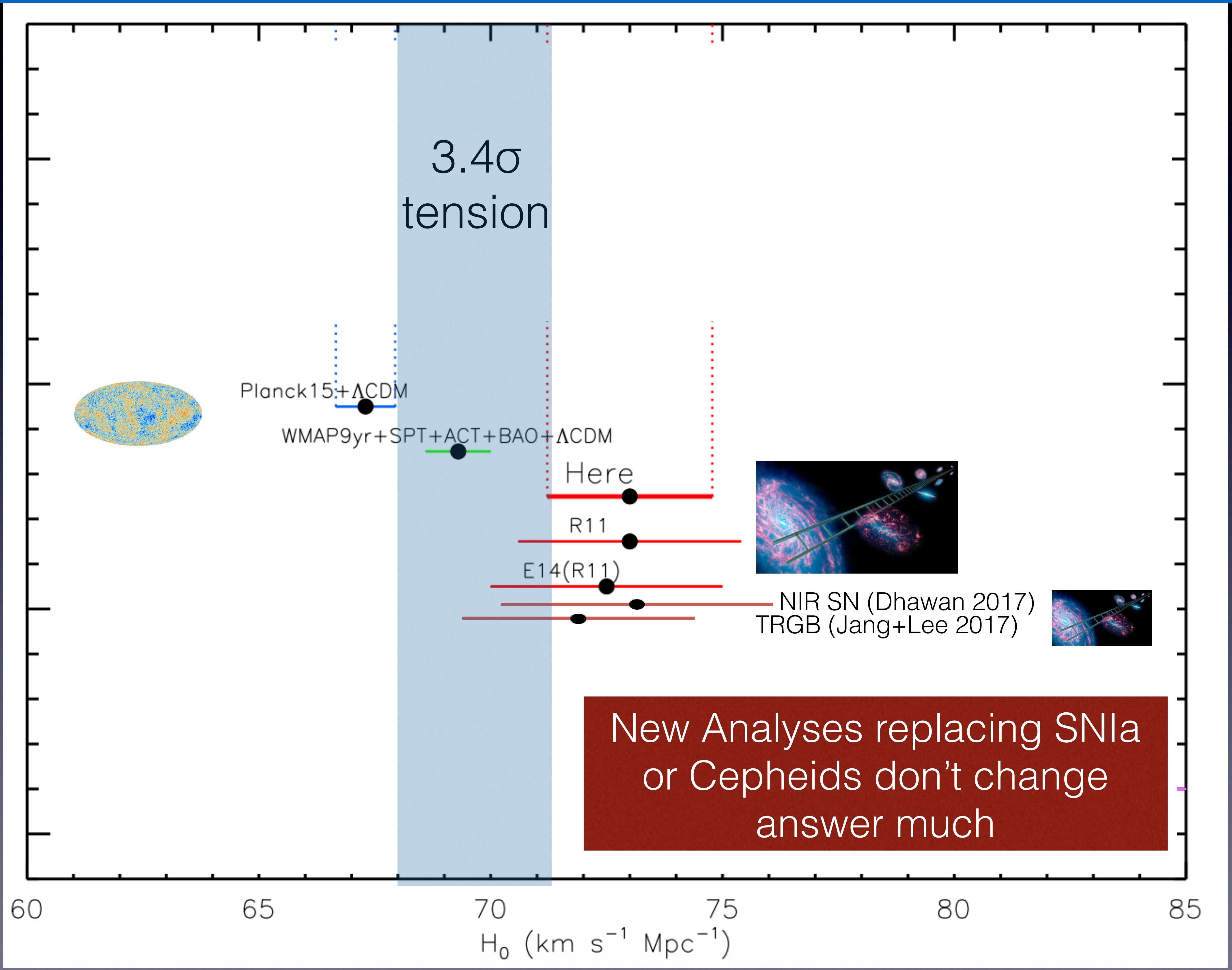

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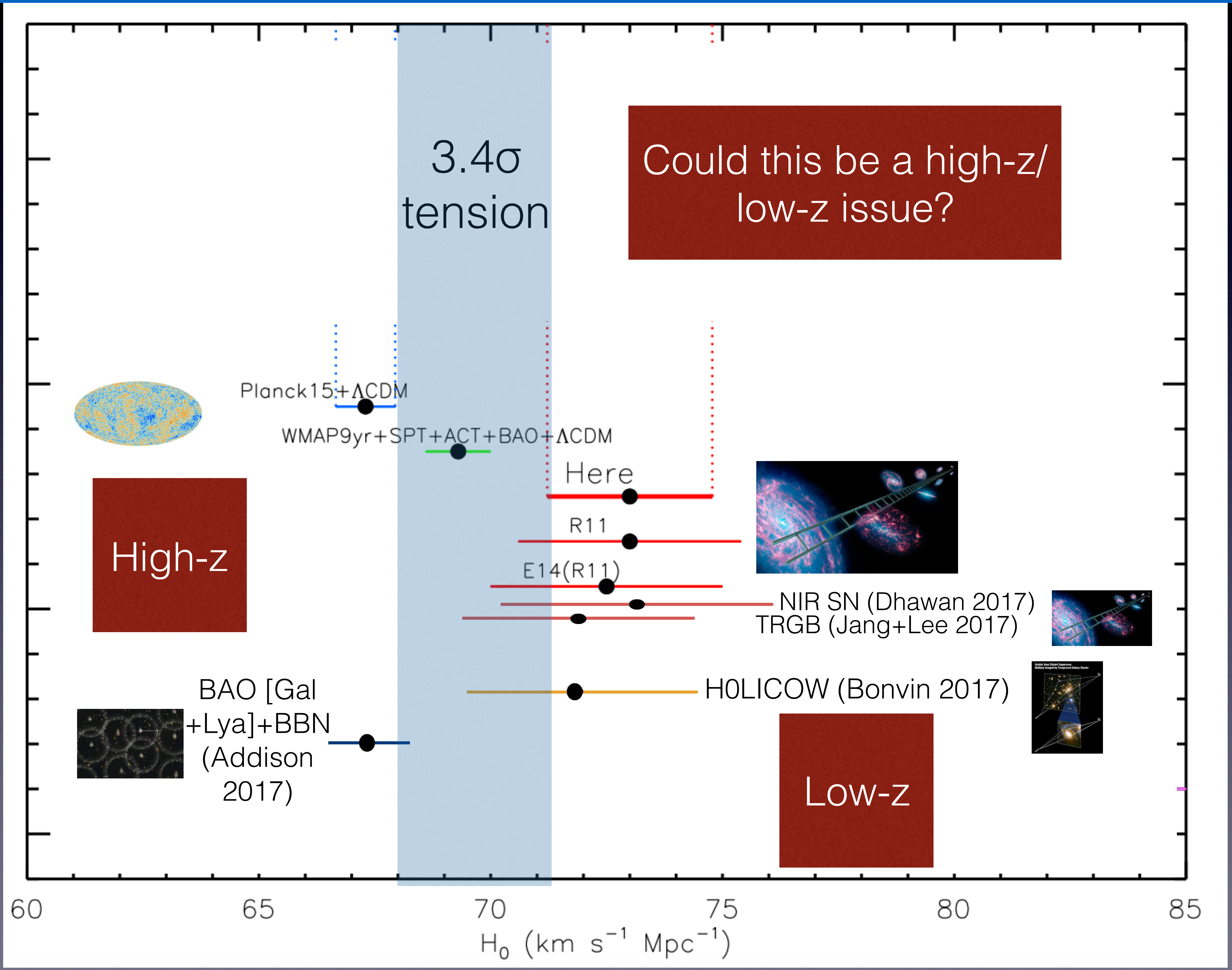

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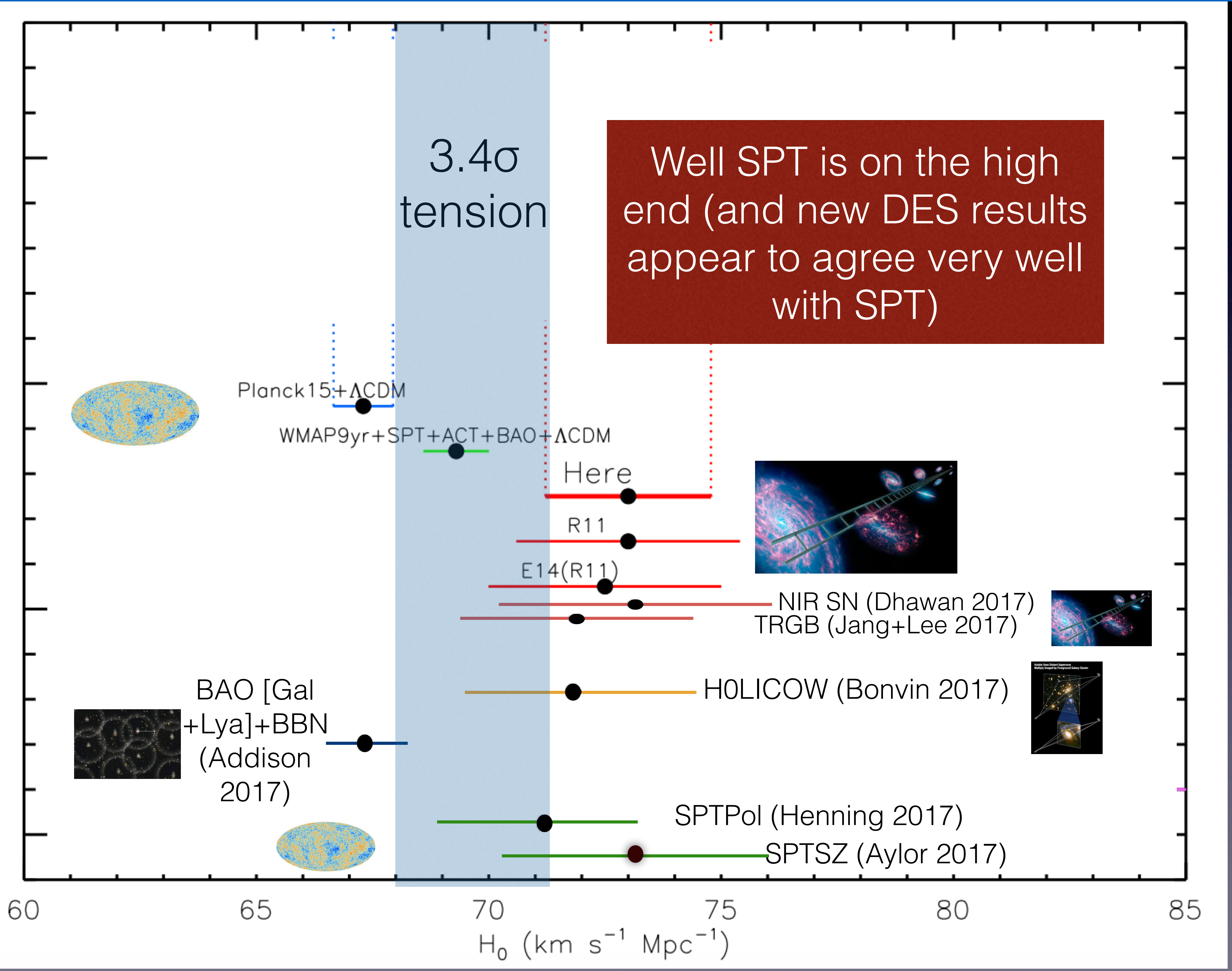

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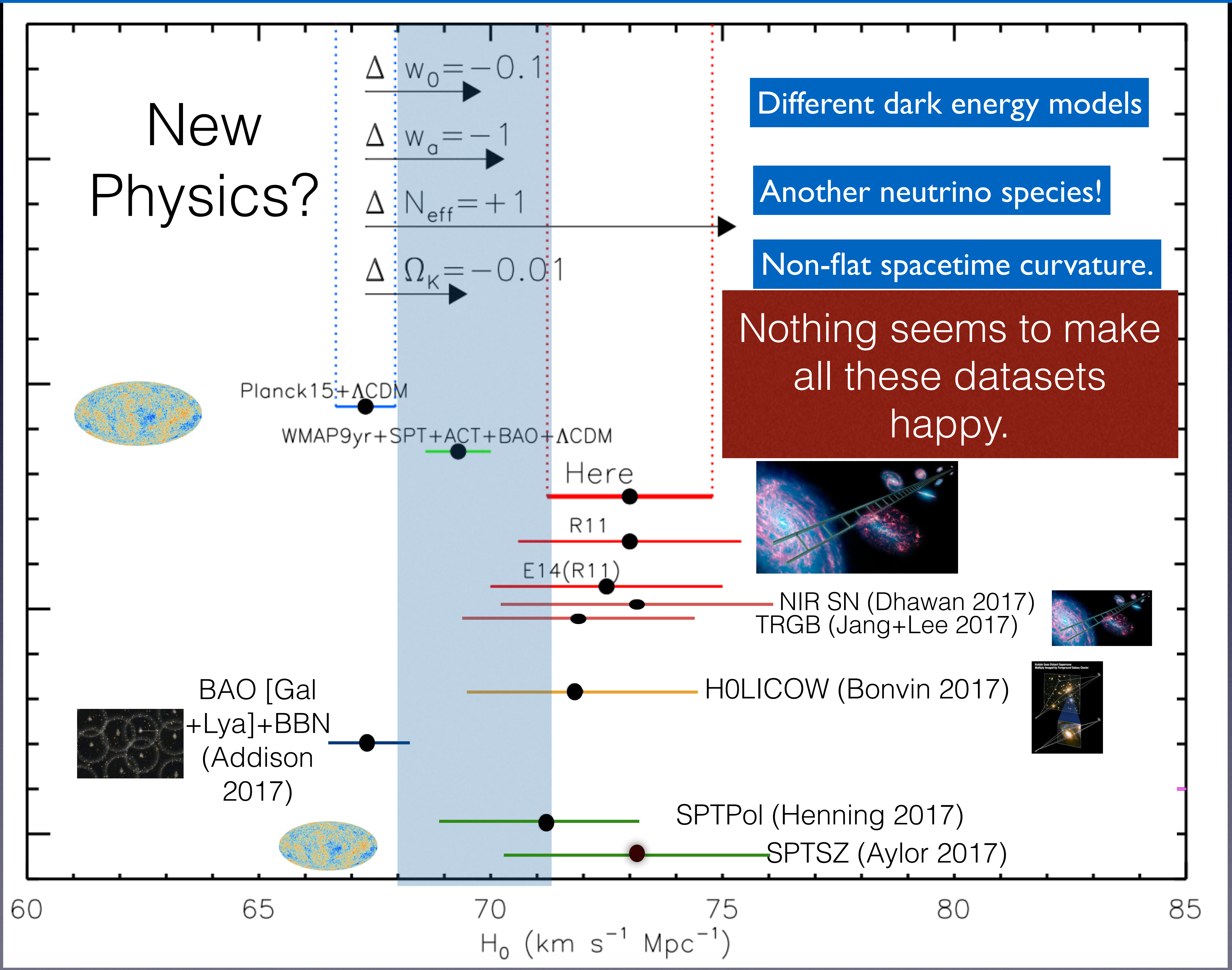

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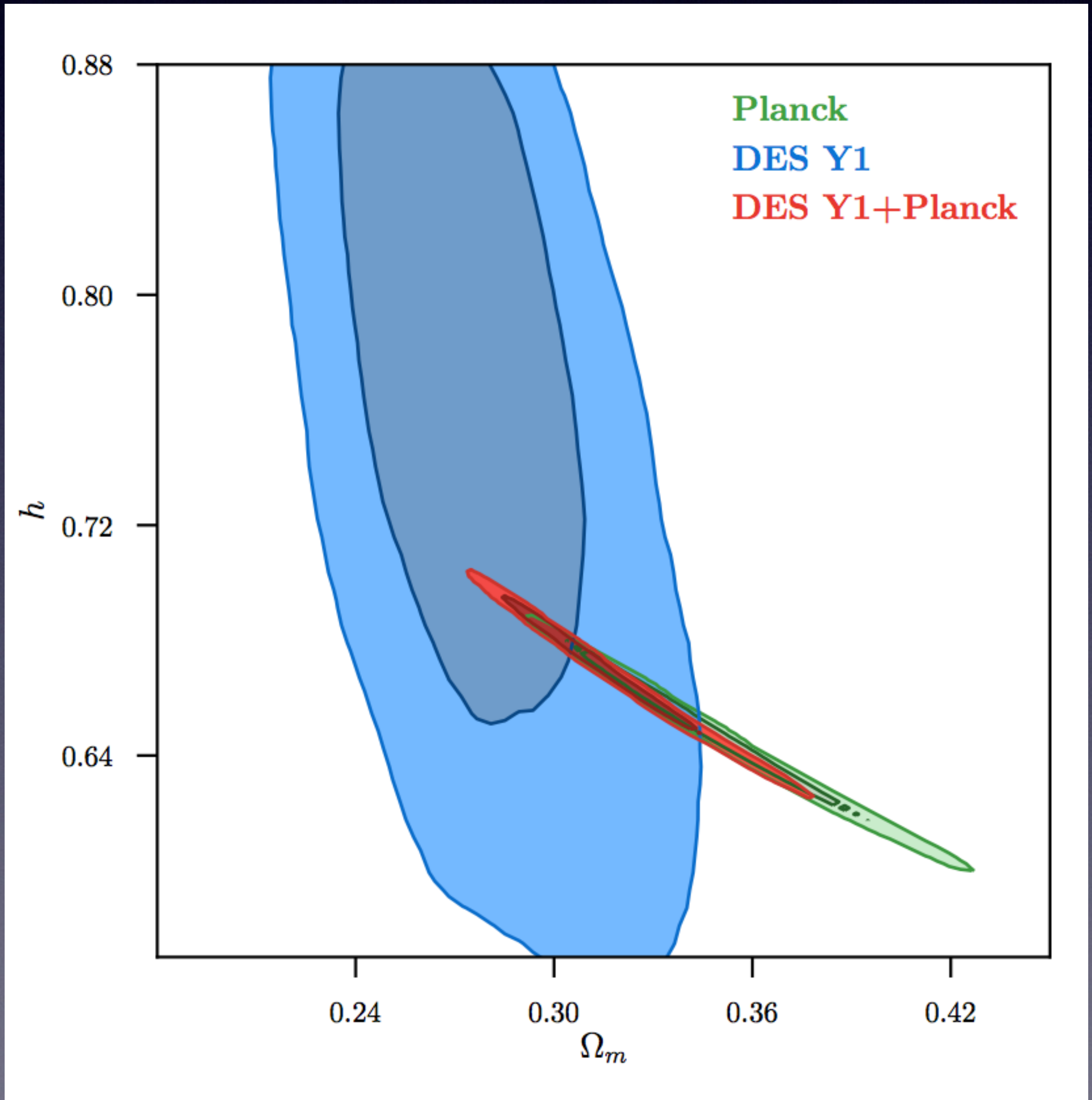
DES pulls OmegaM lower



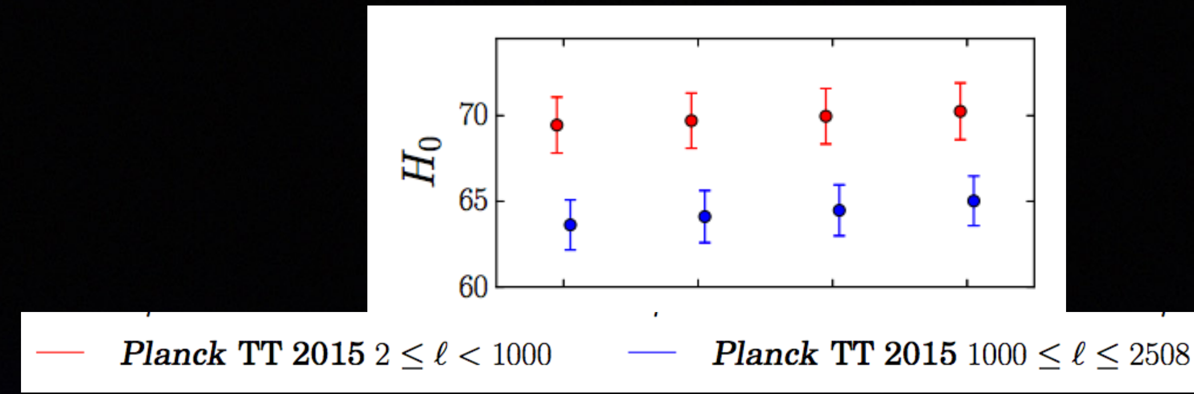
DES 2017

SPT favors a lower OmegaM, higher H0

Parameter	Dataset SPTPOL	PLANCKTT
Free		
$100\Omega_b h^2$	2.295 ± 0.048	2.222 ± 0.023
$\Omega_c h^2$	0.1099 ± 0.0048	0.1198 ± 0.0022
$100\theta_{MC}$	1.0398 ± 0.0014	1.0408 ± 0.0005
n_s	0.9969 ± 0.0238	0.9655 ± 0.0062
$10^9 A_s e^{-2\tau}$	1.7706 ± 0.0414	1.8805 ± 0.0138
Derived		
Ω_Λ	0.736 ± 0.025	0.685 ± 0.013
σ_8	0.769 ± 0.023	0.830 ± 0.014
H_0	71.23 ± 2.12	67.30 ± 0.96

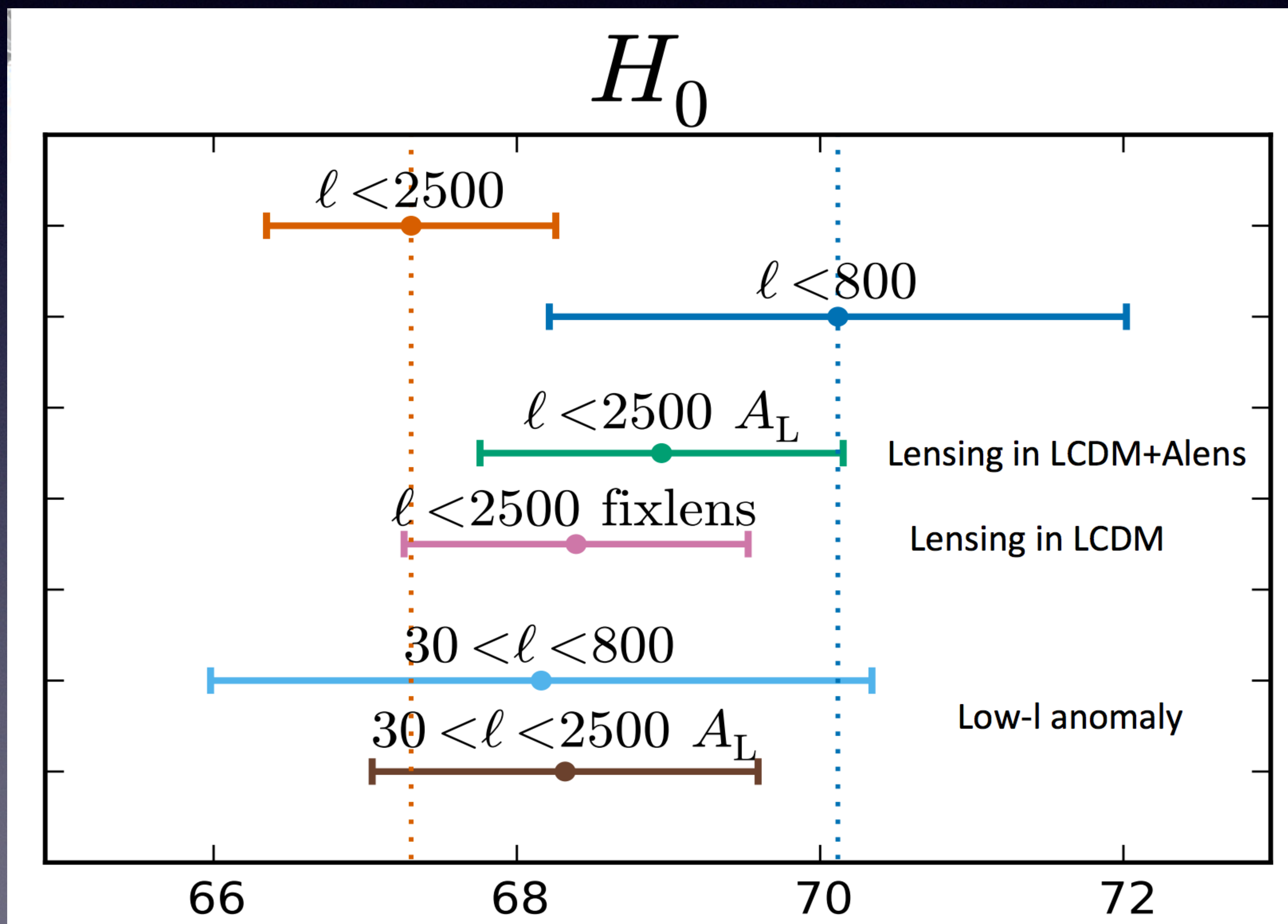
Henning 2017

There is slight tension within CMB measurements, so this may be a part of the story.



Addison 2016

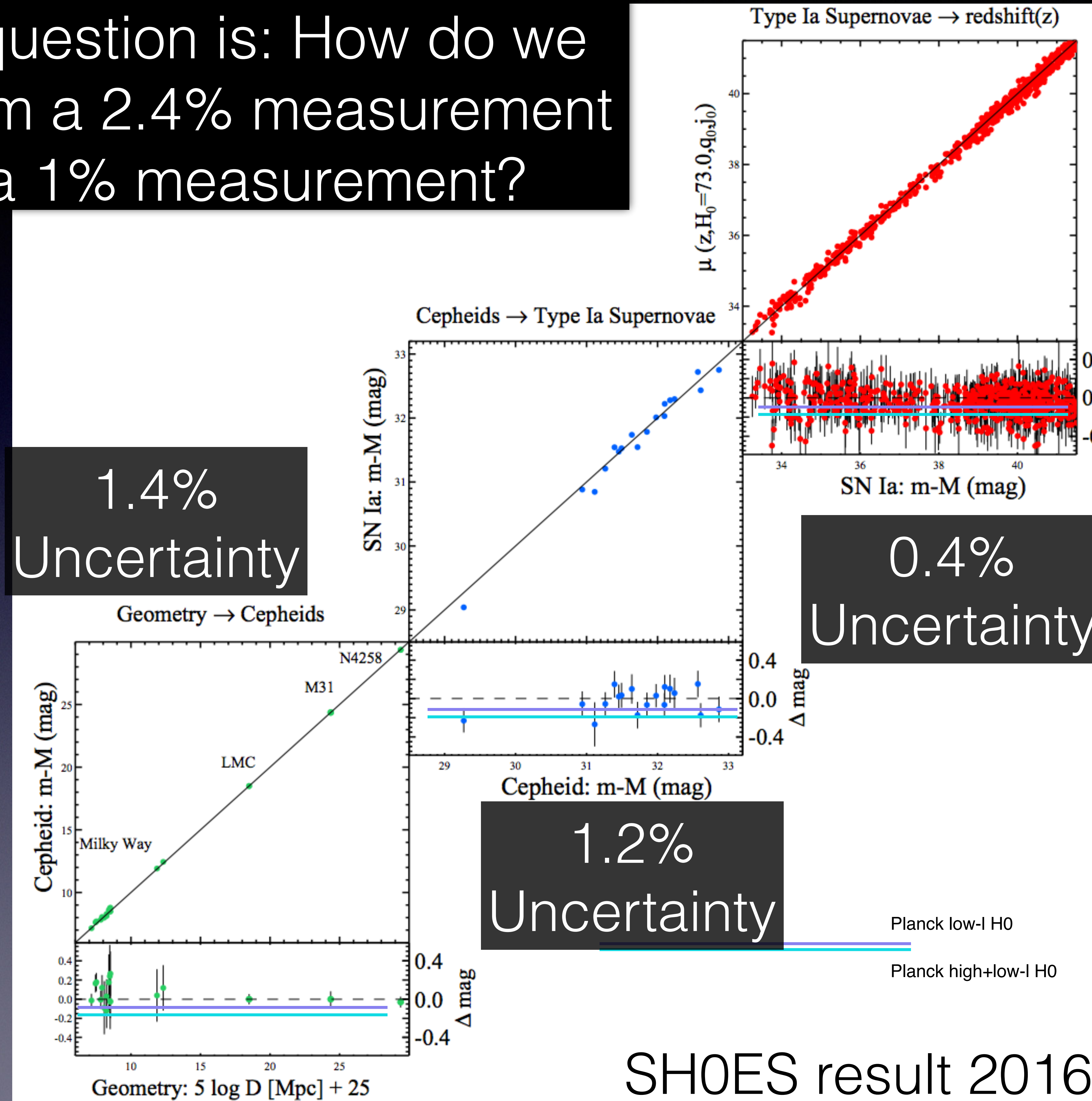
Planck Data



Work by Galli et al.

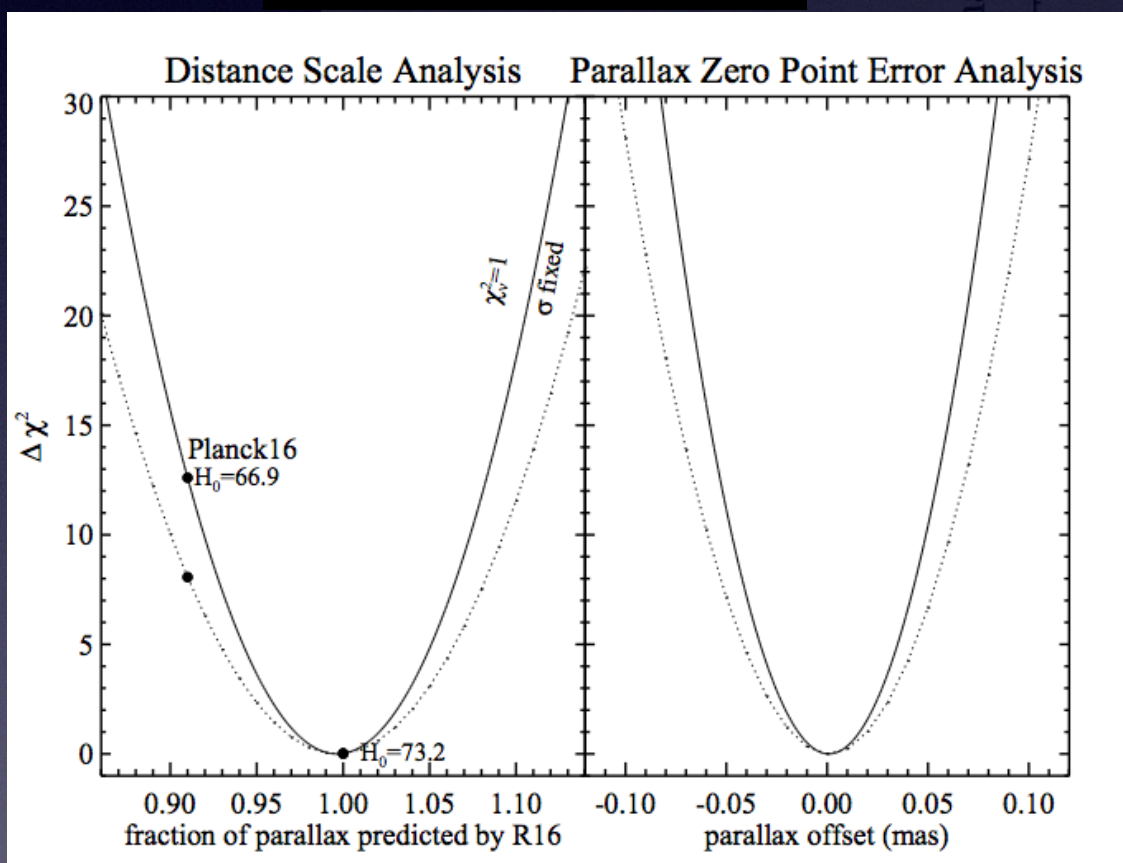
http://cosmo-nordita.fysik.su.se/talks/w3/d2/Galli_nordita.pdf

The question is: How do we go from a 2.4% measurement to a 1% measurement?



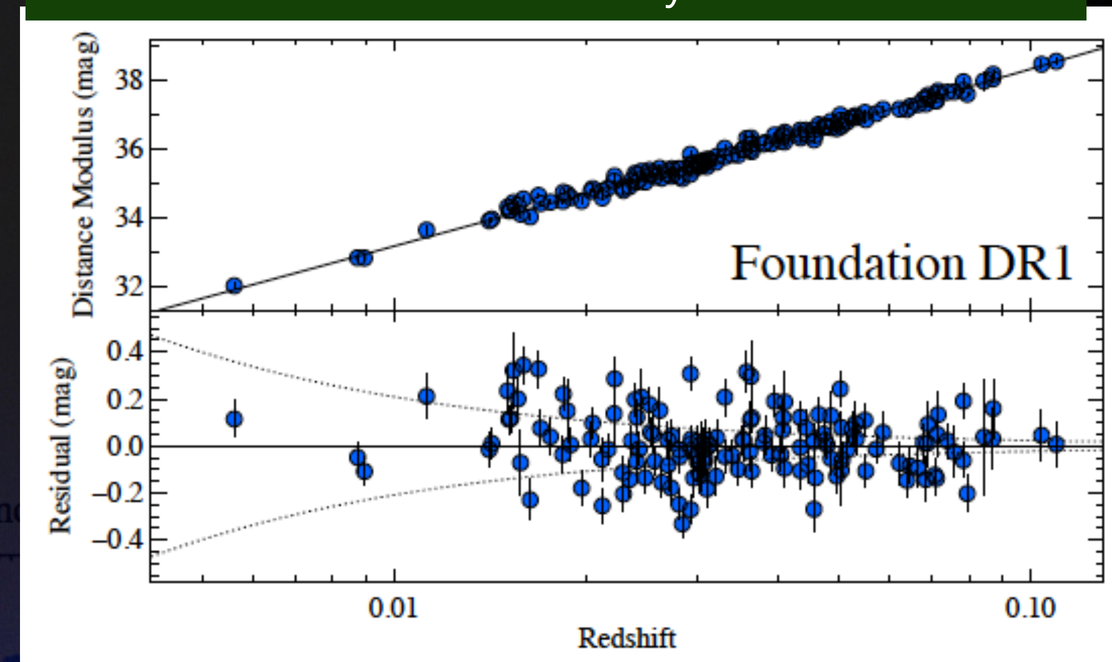
Gaia will squash:

1.4% Uncertainty



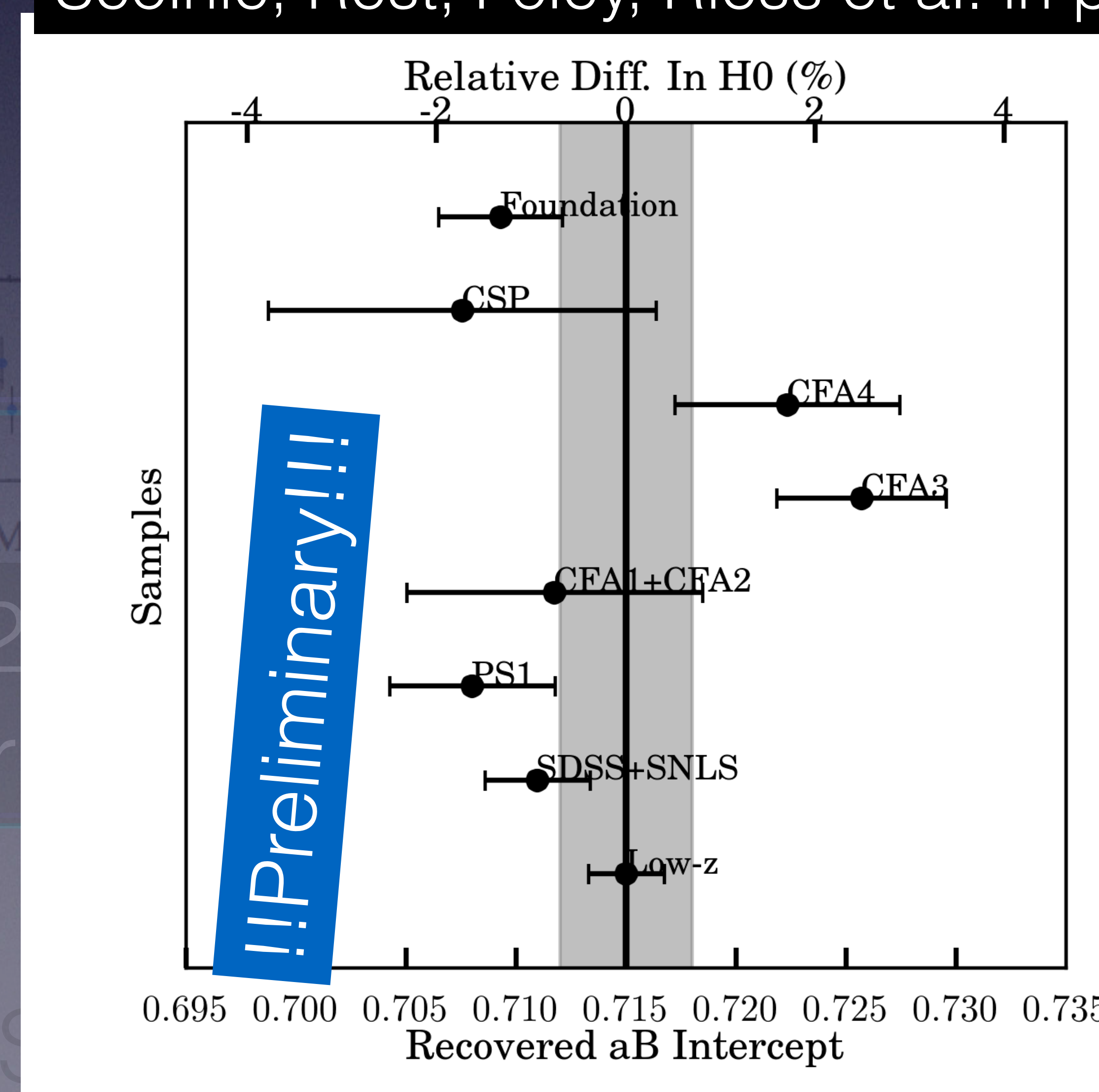
from Casertano,Riess et al. 2016

New Foundation SN Survey will check 0.4%



Foley, Scolnic, Rest et al. in prep

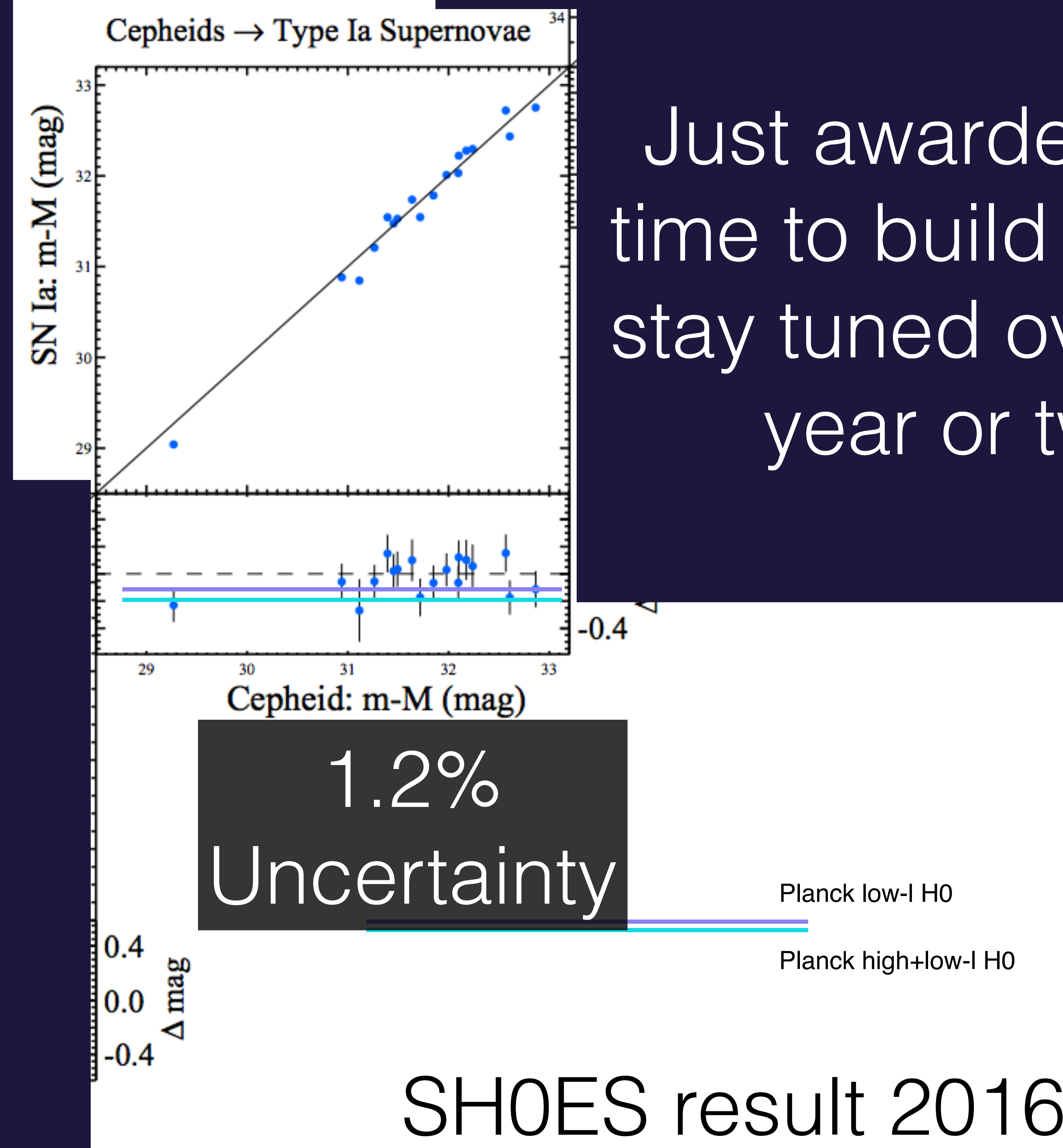
Scolnic, Rest, Foley, Riess et al. in prep



The question is: How do we go from a 2.4% measurement to a 1% measurement?

The answer is: Right now we have 19 calibrators, want to get to 50.

Just awarded HST time to build this up, stay tuned over next year or two.



1.2% Uncertainty

SH0ES result 2016

“If a persuasive case can be ma… …ent of H0 conflicts with these estimates, then this will be stro… …hysi… …CDM

Game of Tension:

No Spoilers!