

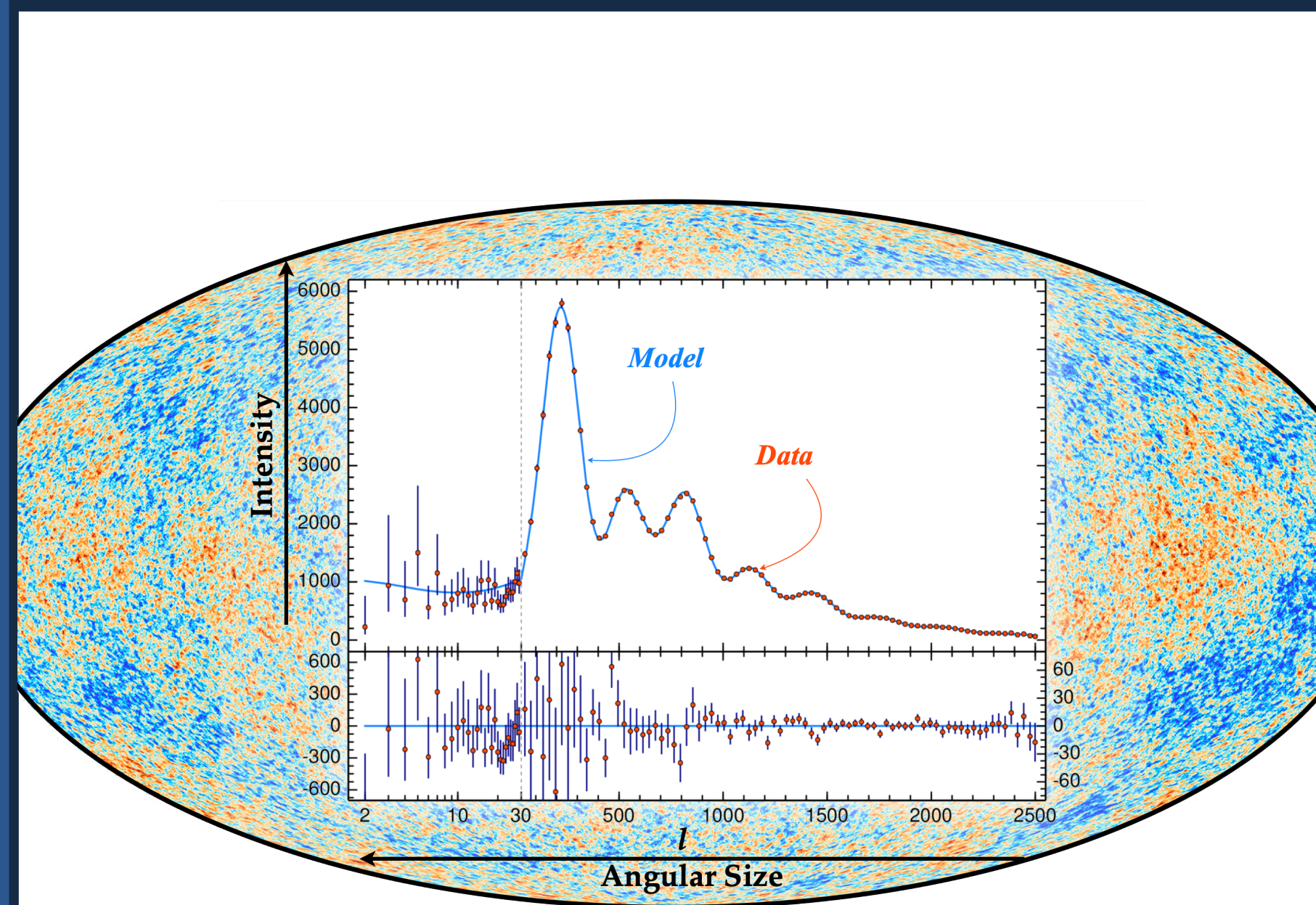
Tension in Cosmology

The role of Type Ia Supernovae

Context of Research | Λ CDM Works

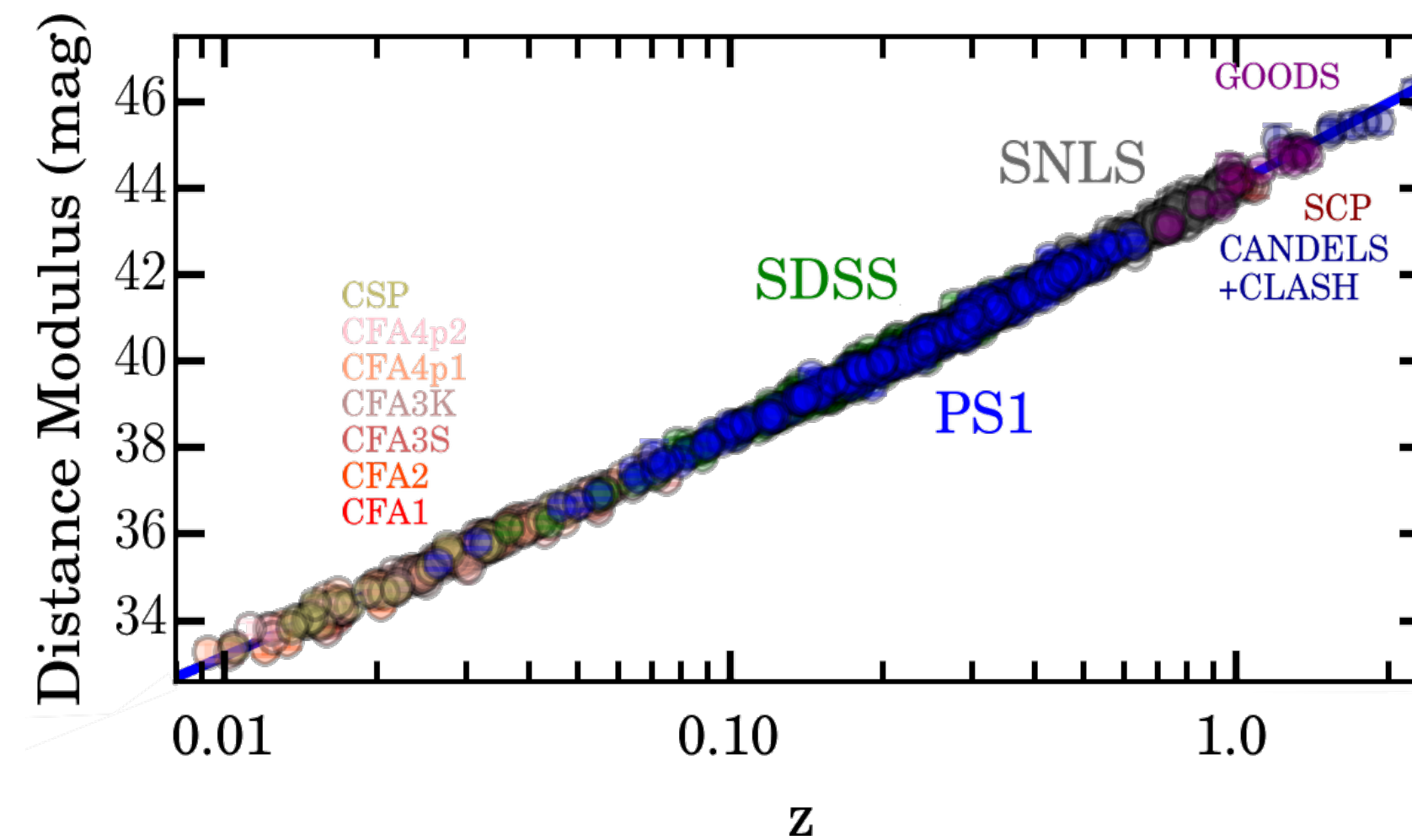
Only 6 free parameters

Cosmic MicroWave Data



$z \sim 1100$

Type Ia Supernovae



$z < 1$

Baryon Acoustic Oscillation

Clusters

Weak Lensing

Baryon Nucleosynthesis

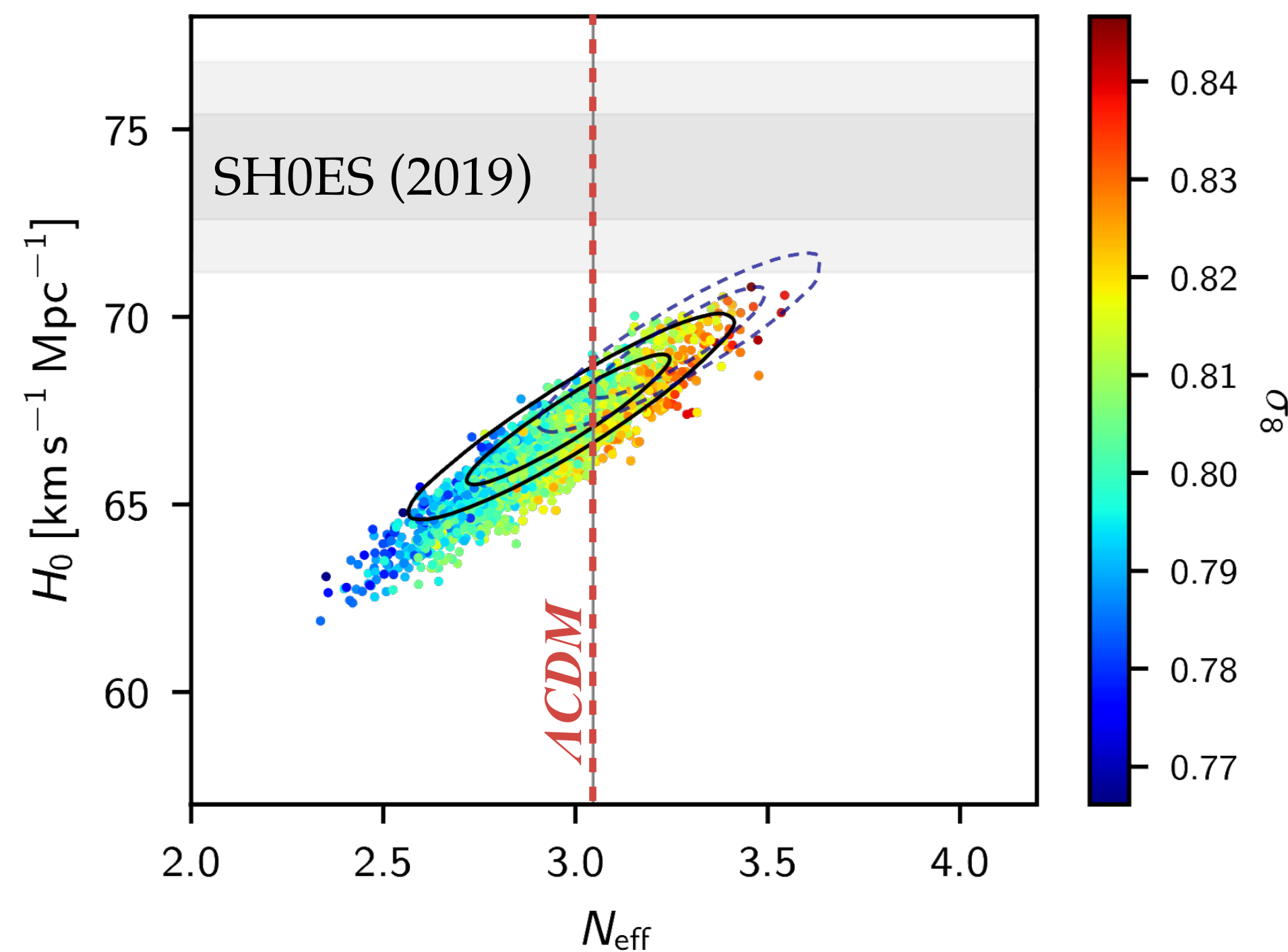
...

Context of Research | Λ CDM Works, *except when it doesn't* !

Only 6 free parameters | *but “ Λ ” and “CDM”*

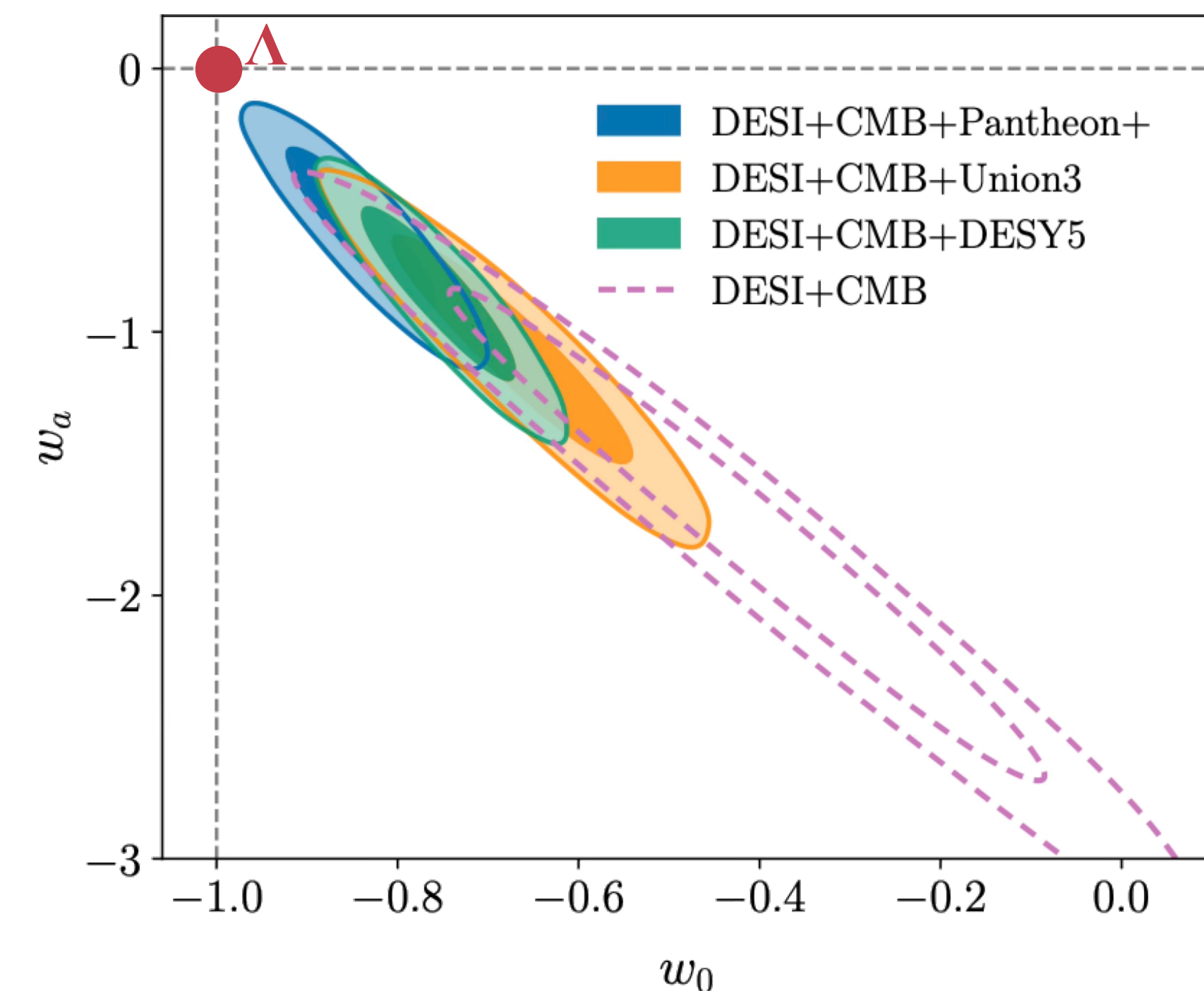
H_0 Tension | 5σ

Universe's expansion is too fast



Λ Tension | 4σ

Dark energy equation of state is evolving



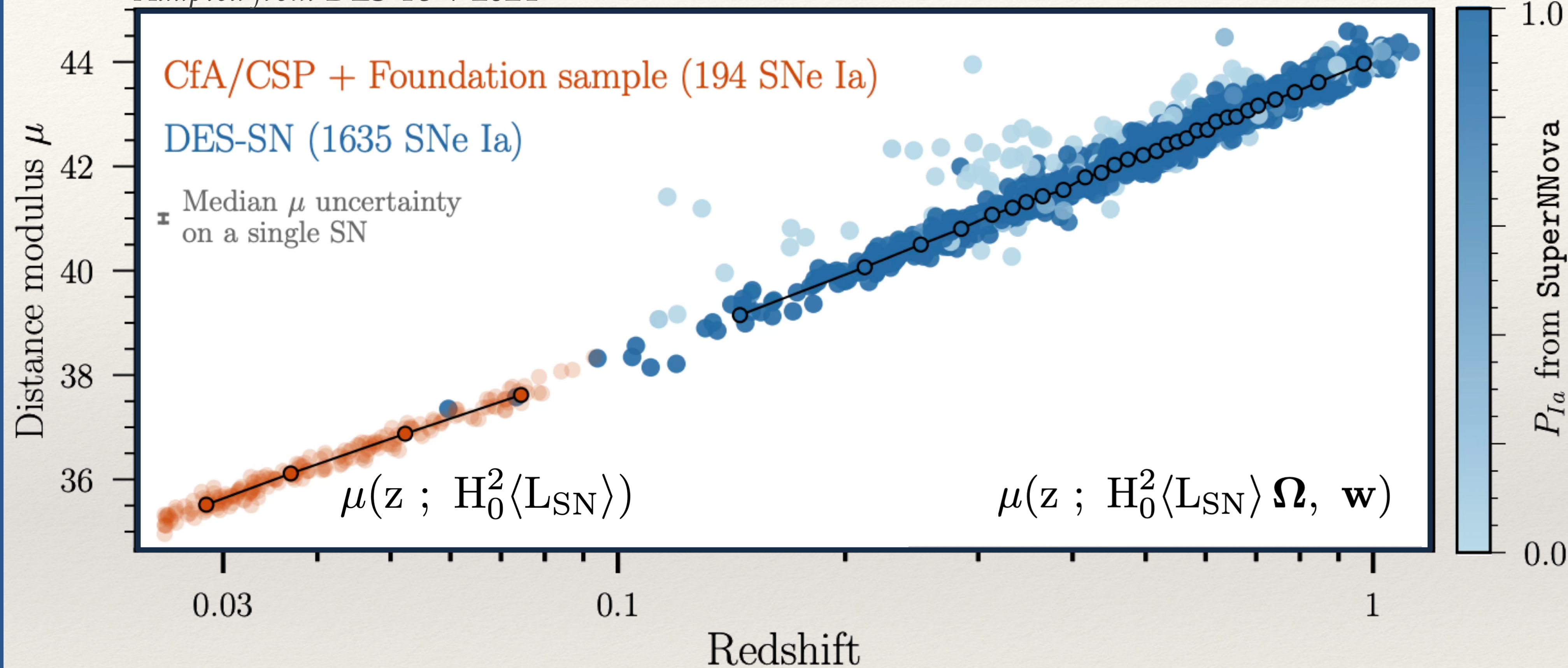
SN Ia

Concept

Relative flux
 $\Rightarrow w, \Omega_m$

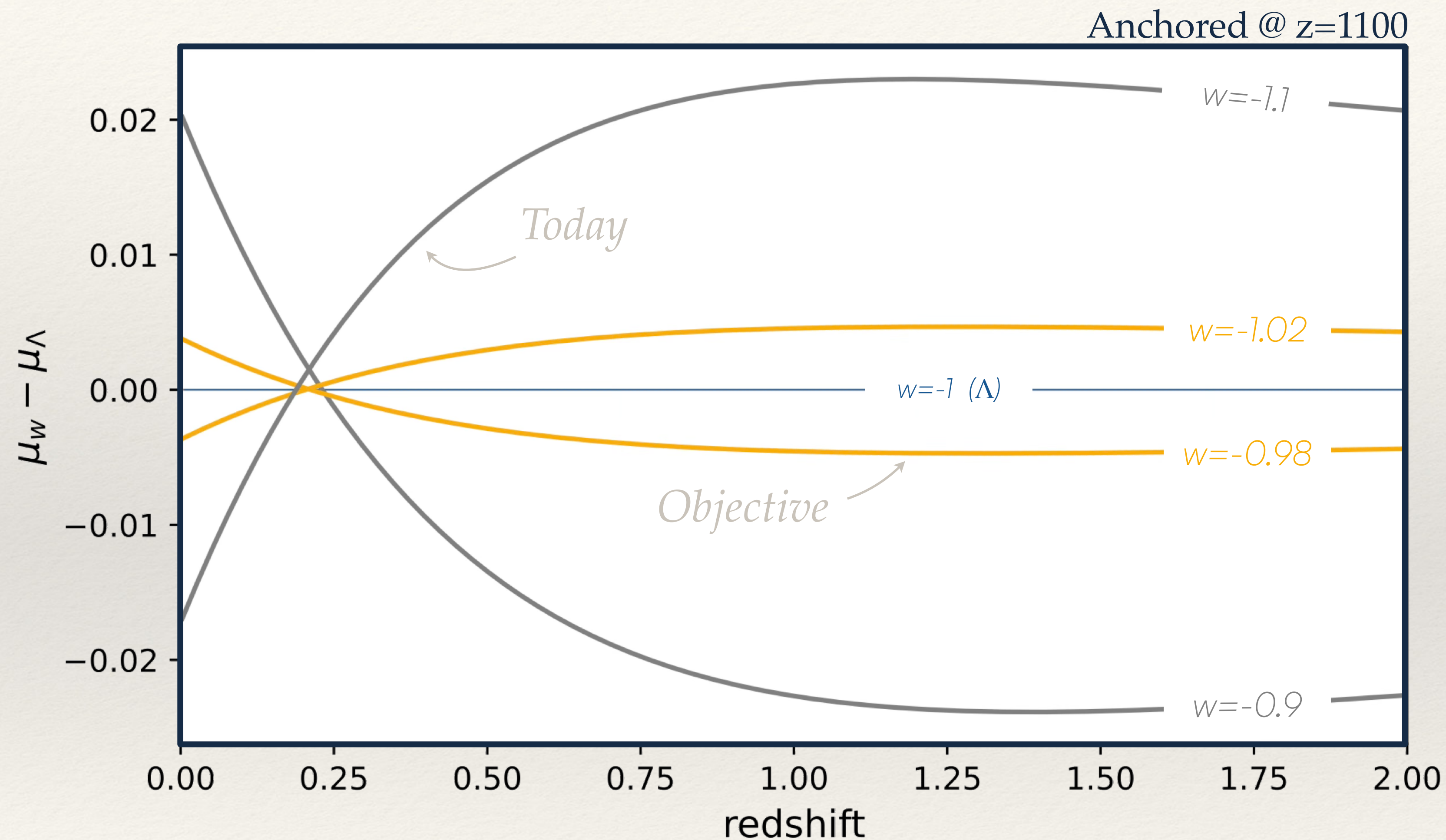
Cosmology

Adapted from DES Y5 | 2024



Type Ia Supernova Cosmology | w

Relative flux



SNe Ia

$\rightarrow \Delta \text{mag} = 15\%$

O(5000) SNe Ia

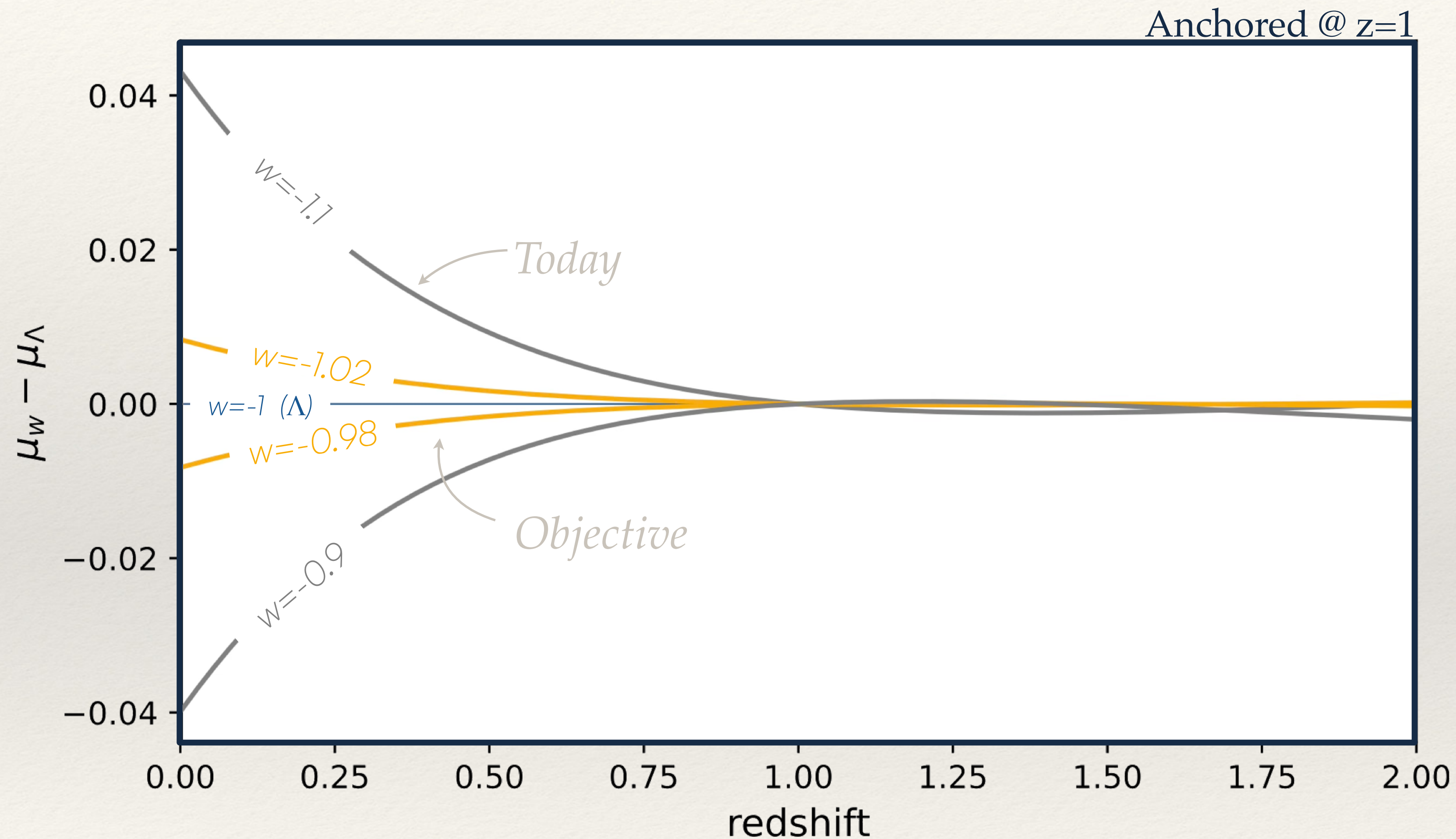
$\rightarrow \Delta \text{mag} = 0.2\%$

Photometric Accuracy

$\rightarrow \Delta \text{mag} = 0.1\%$

Type Ia Supernova Cosmology | w

Relative flux



SNe Ia

$\rightarrow \Delta\text{mag}=15\%$

O(5000) SNe Ia

$\rightarrow \Delta\text{mag}=0.2\%$

Photometric Accuracy

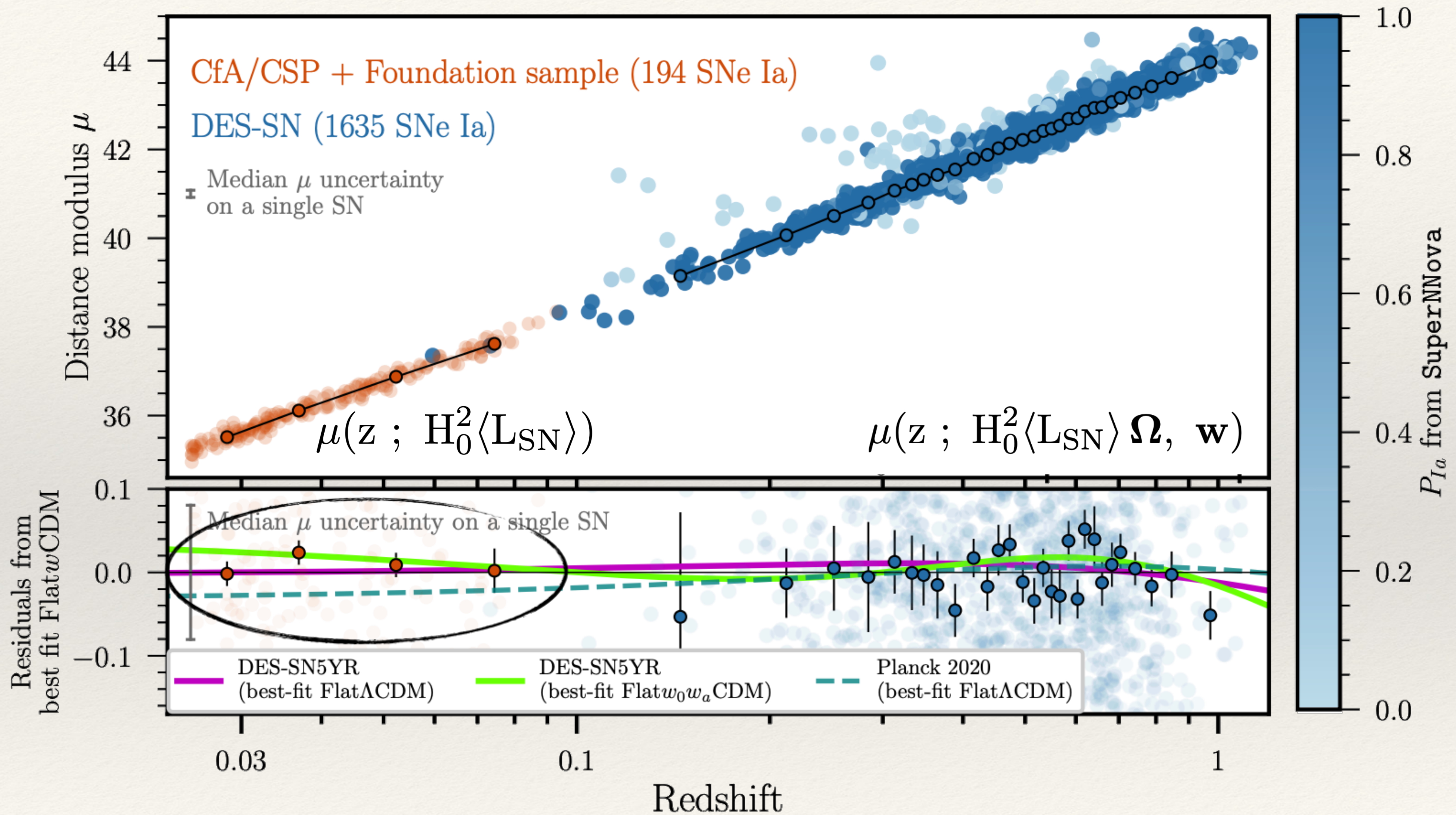
$\rightarrow \Delta\text{mag}=0.1\%$

SN Ia

Concept

Relative flux
 $\Rightarrow w, \Omega_m$

Cosmology



SN Ia

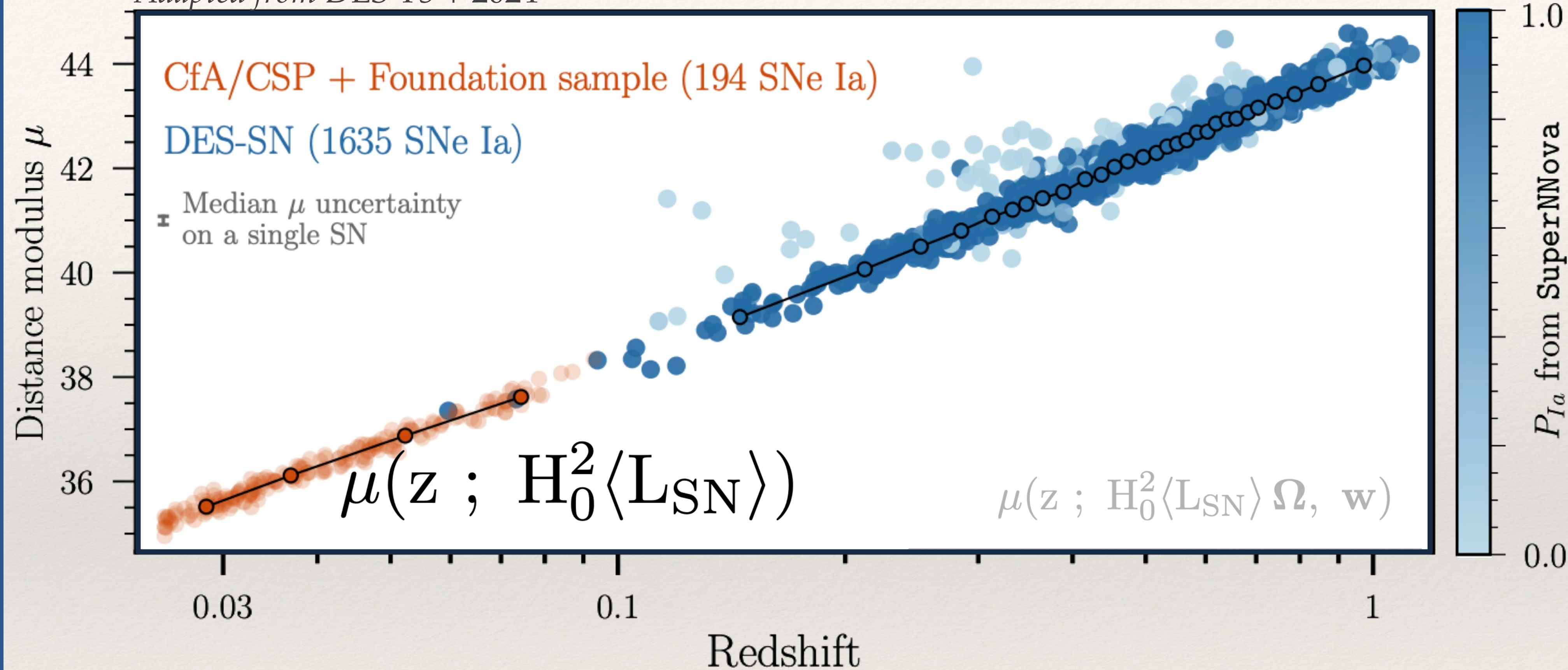
Concept

Relative flux
 $\Rightarrow w, \Omega_m$

Absolute flux
 $\Rightarrow H_0$

Cosmology

Adapted from DES Y5 | 2024



To get H_0 : Independent distance measurements for some SNeIa

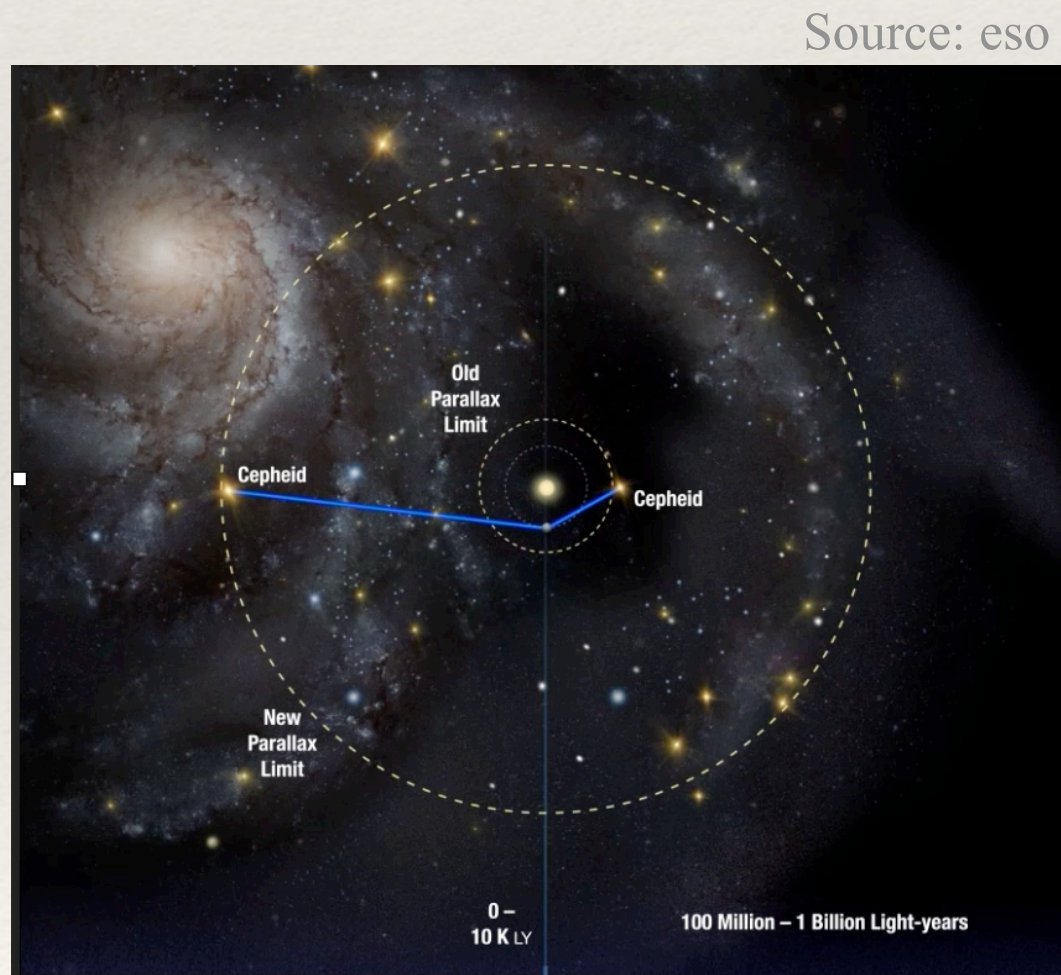
Direct Distance Ladder | *SH0ES*

Get independent distances for SNe Ia



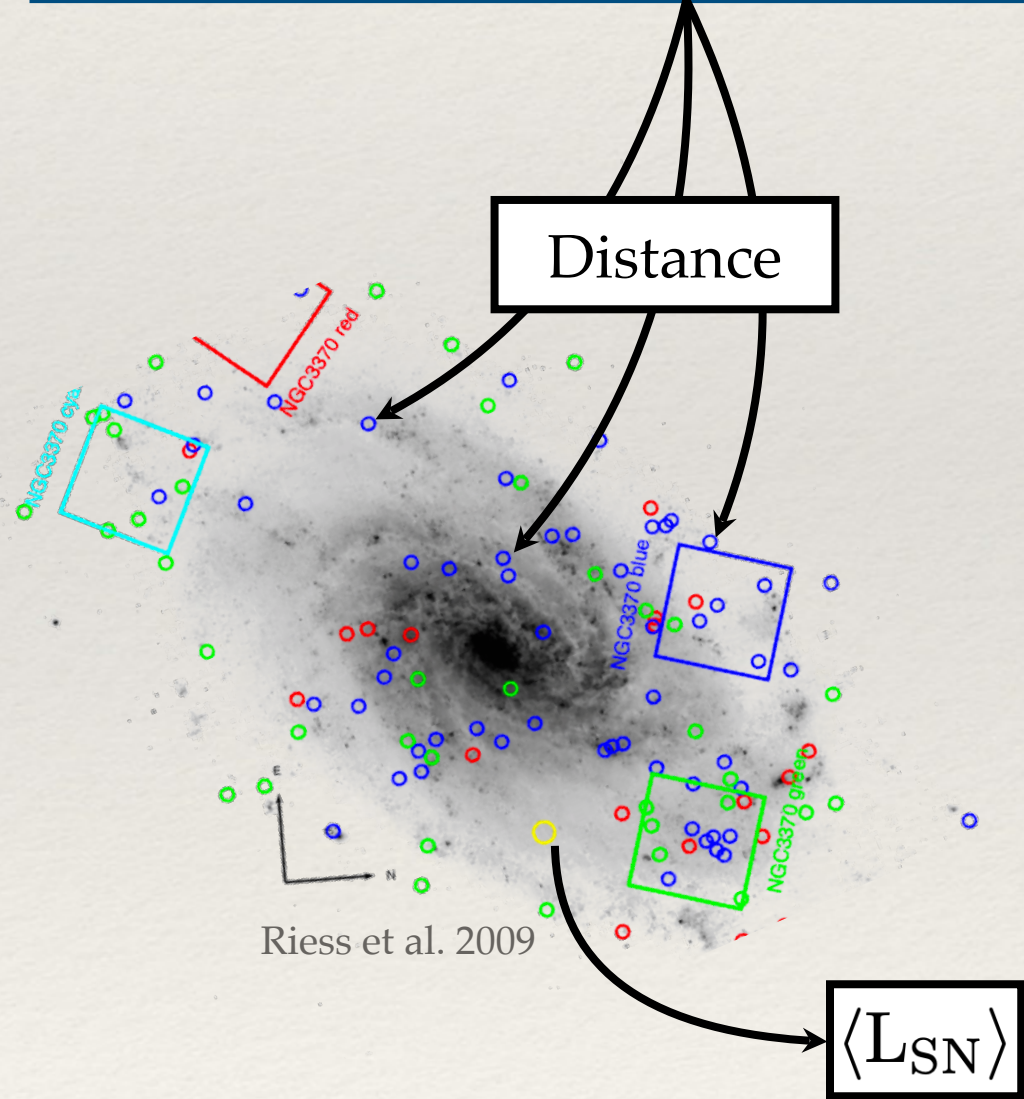
“Geometry”

Parallaxes | D.E.B. | Maser

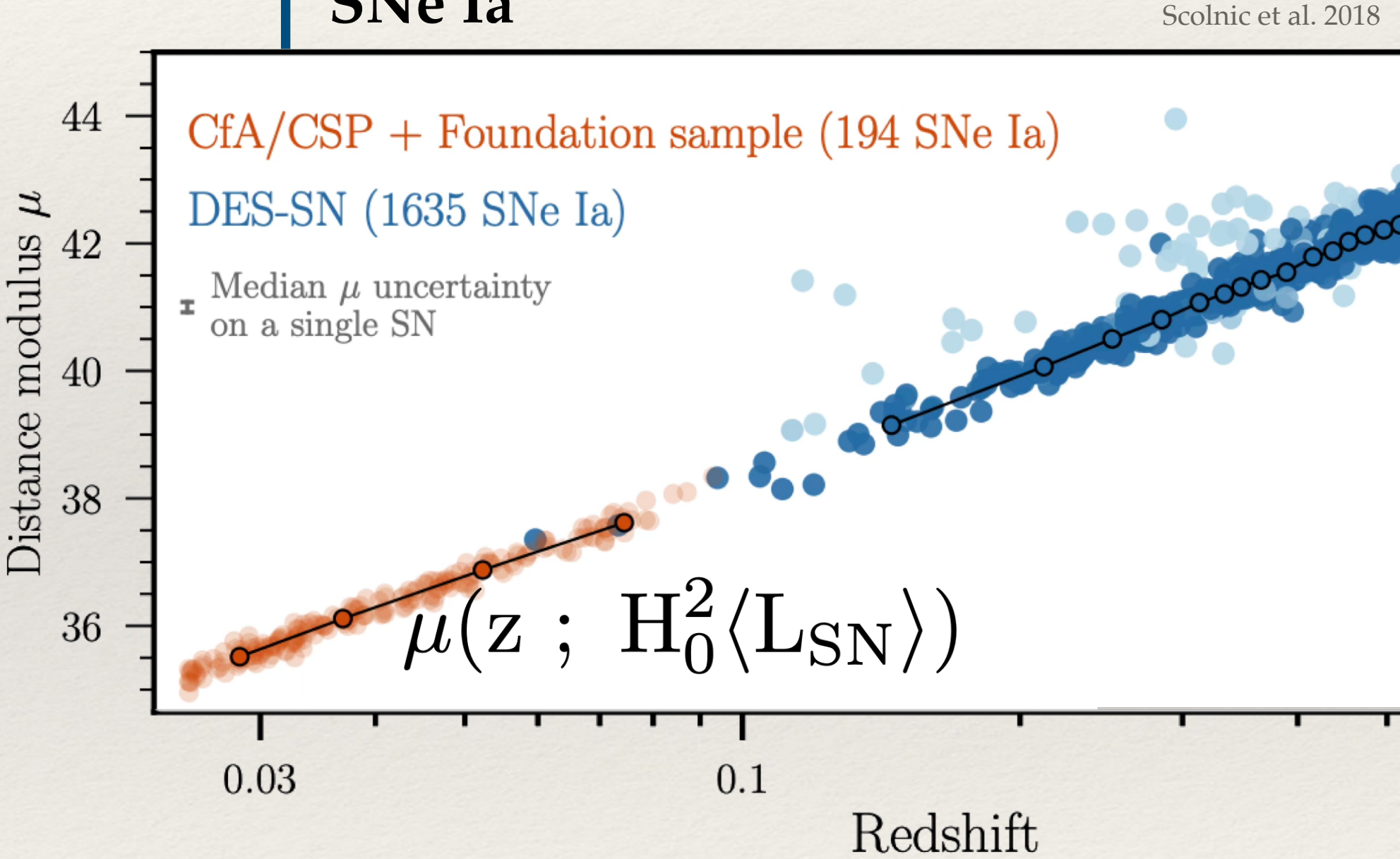


“Calibrators”

Cepheids



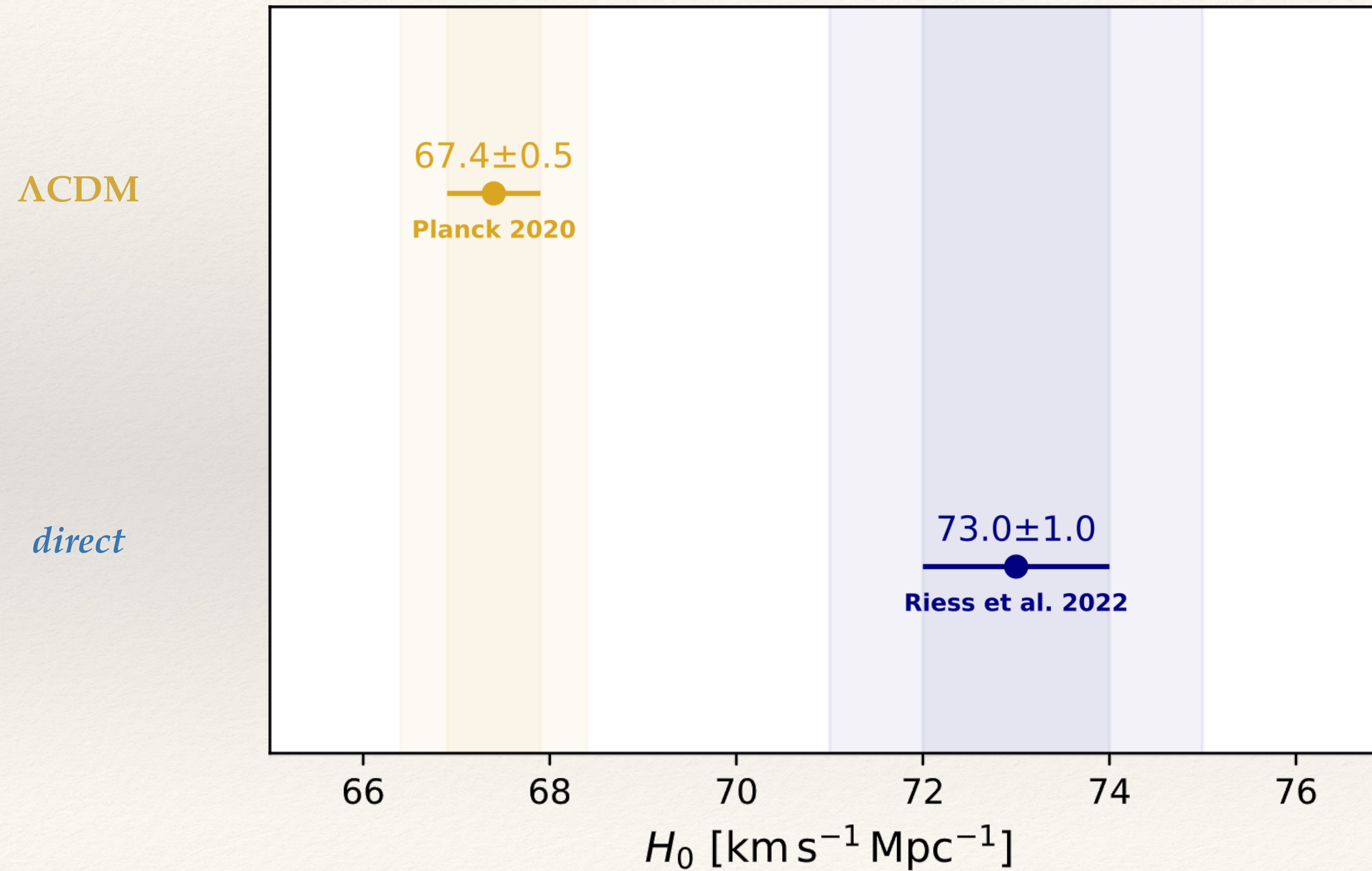
“SNe Ia”



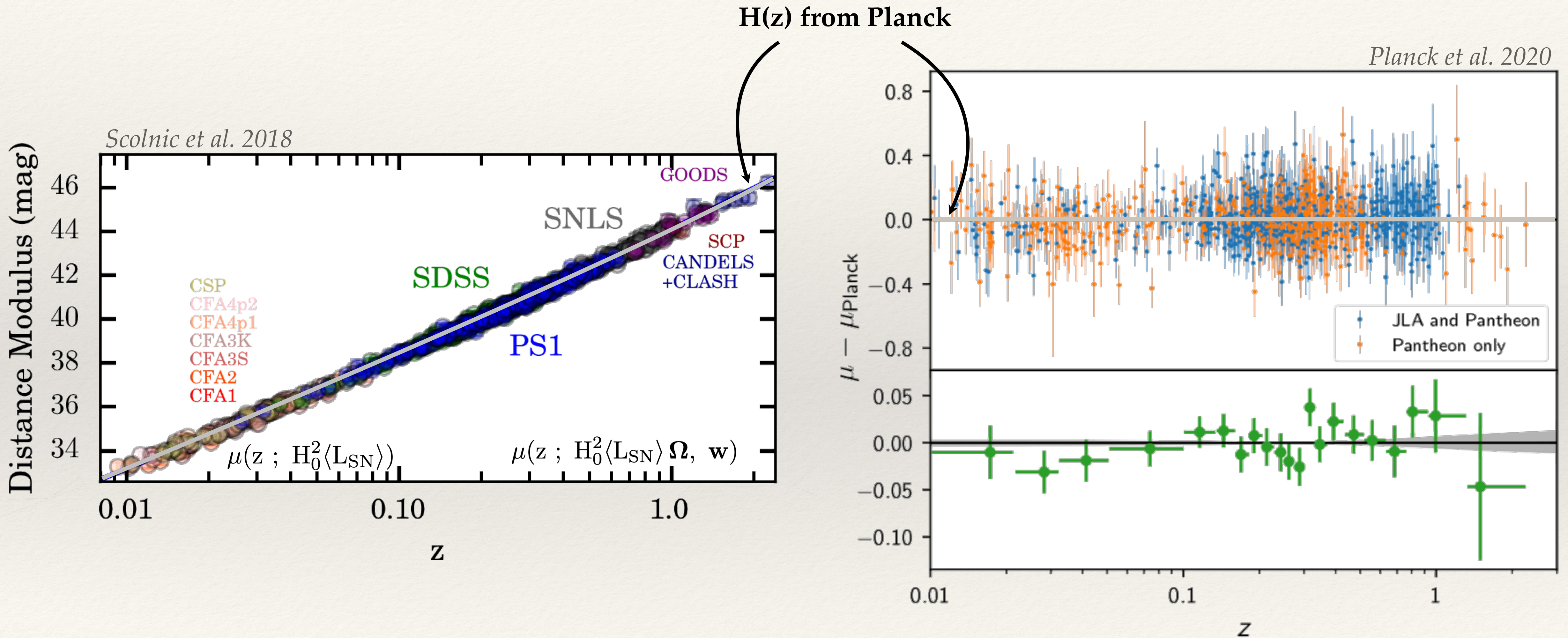
Breuval, Riess et al. 2024

$$H_0 = 73.17 \pm .86 \text{ km s}^{-1} \text{ Mpc}^{-1}$$

H_0 Tension | *SH0ES* vs. *Planck*



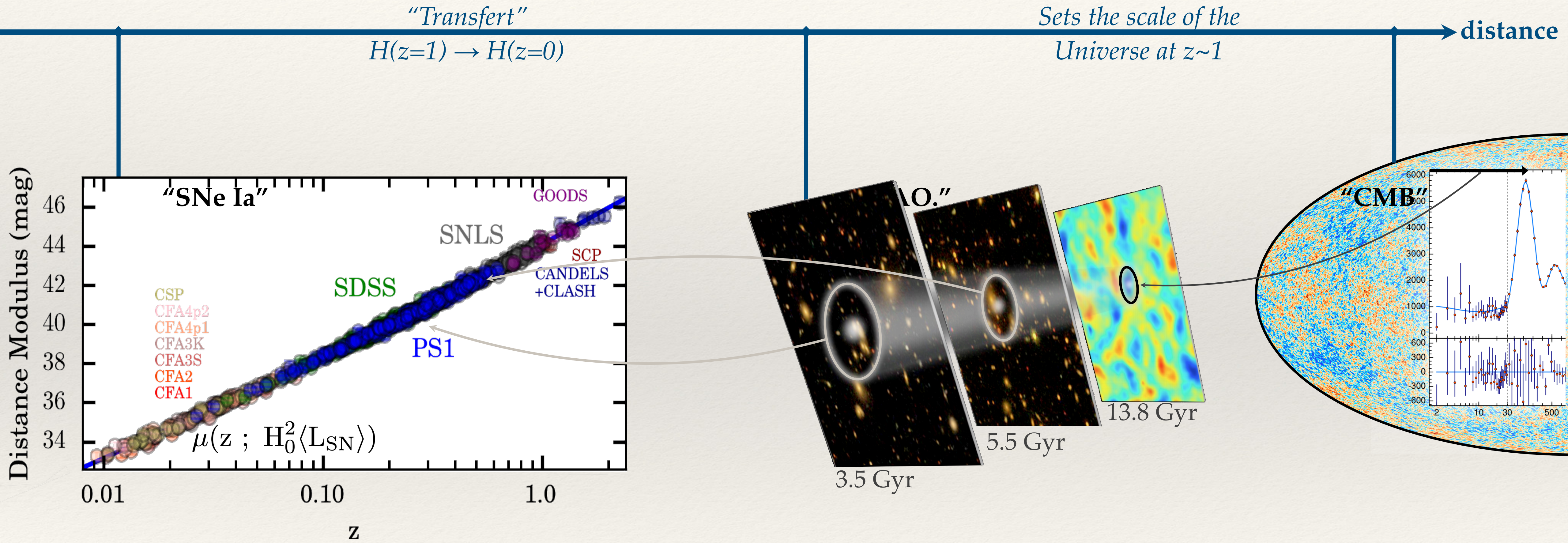
Are Supernovae & CMB in tension ? *No!*



Inverse Distance Ladder

See also e.g.:
Aubourg et al. 2015 • Macaulay et al. 2018

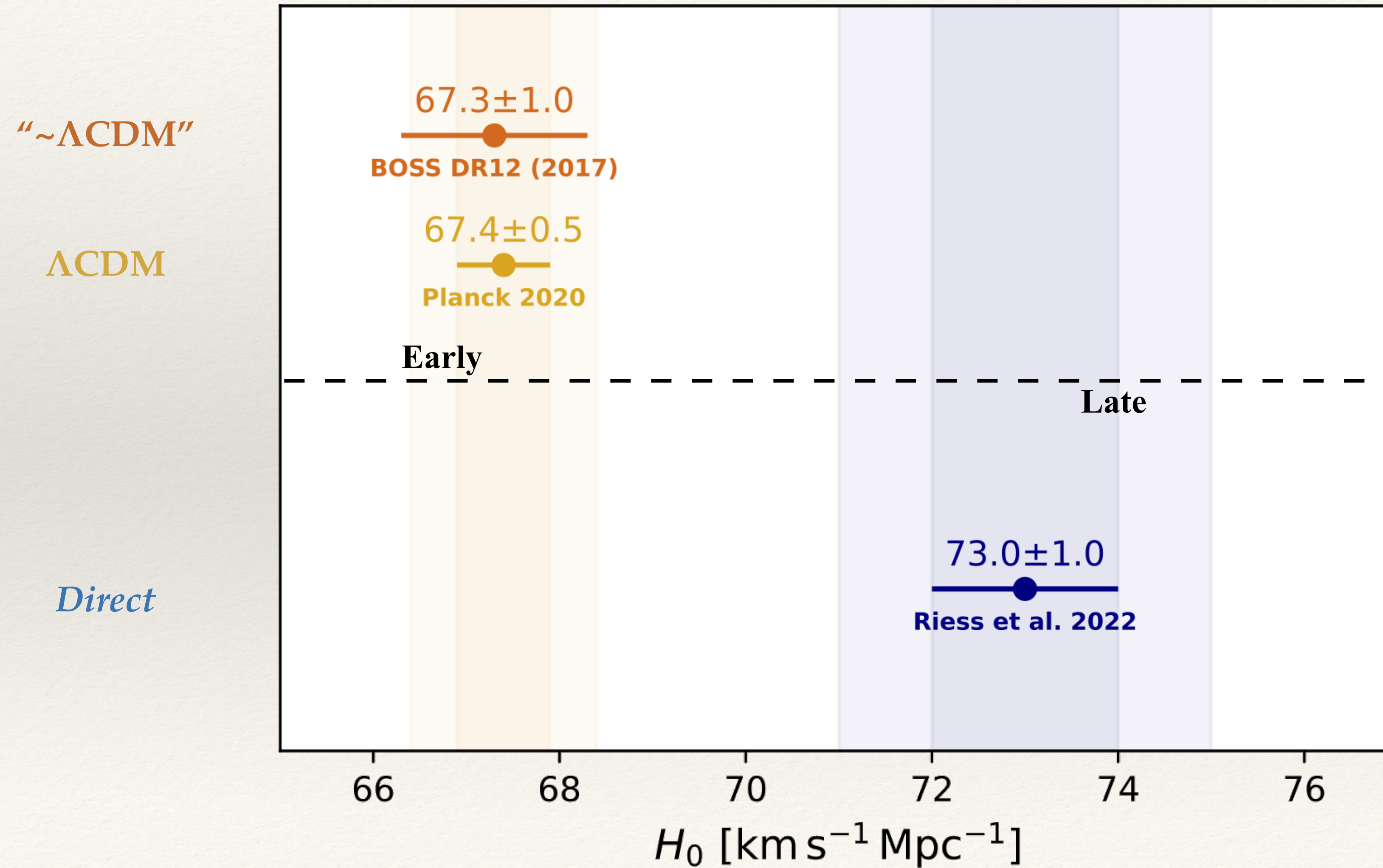
Get independent distances for SNe Ia



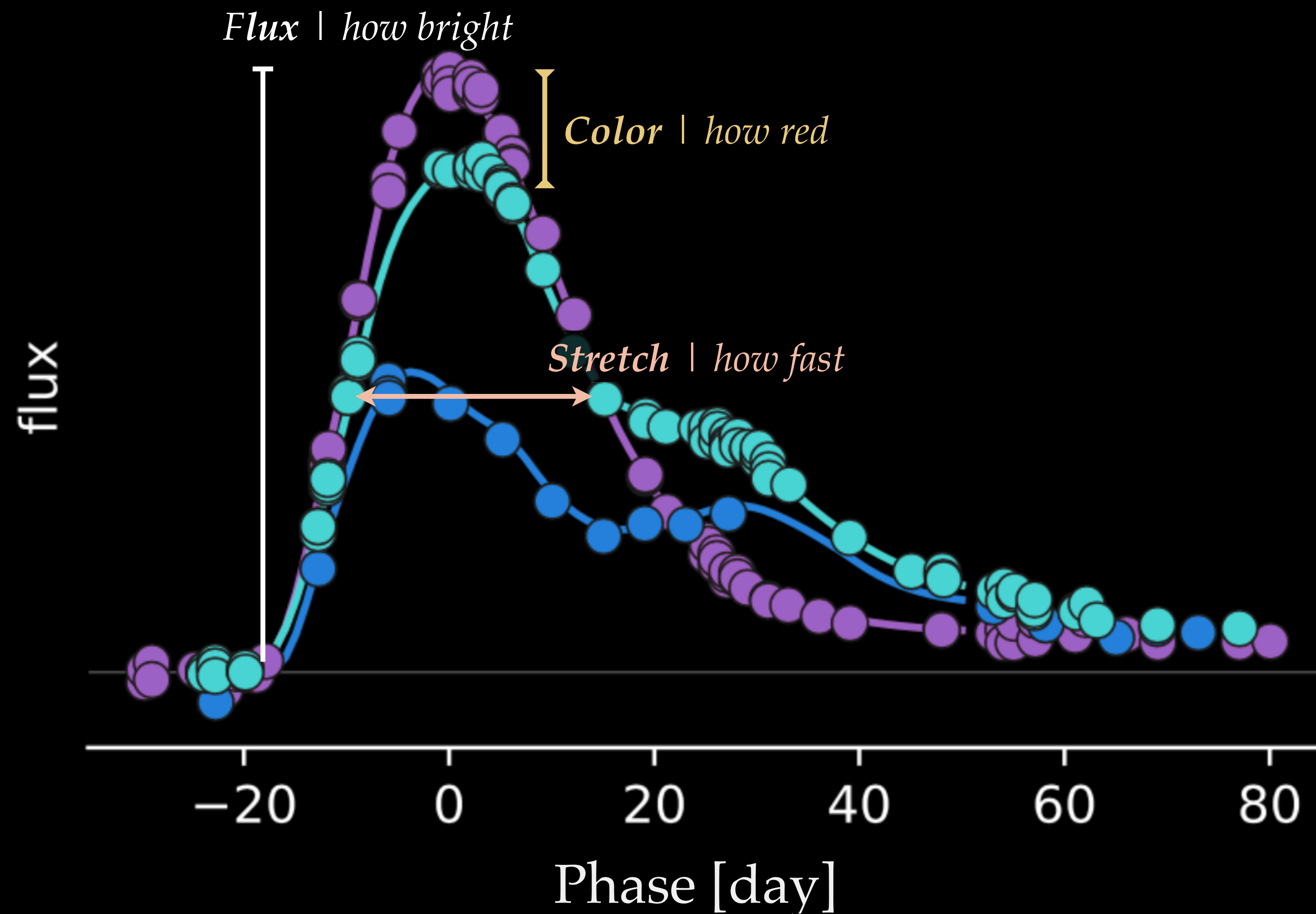
BOSS DR12 | Alam et al. 2017

$$H_0 = 67.3 \pm 1.0 \text{ km s}^{-1} \text{ Mpc}^{-1}$$

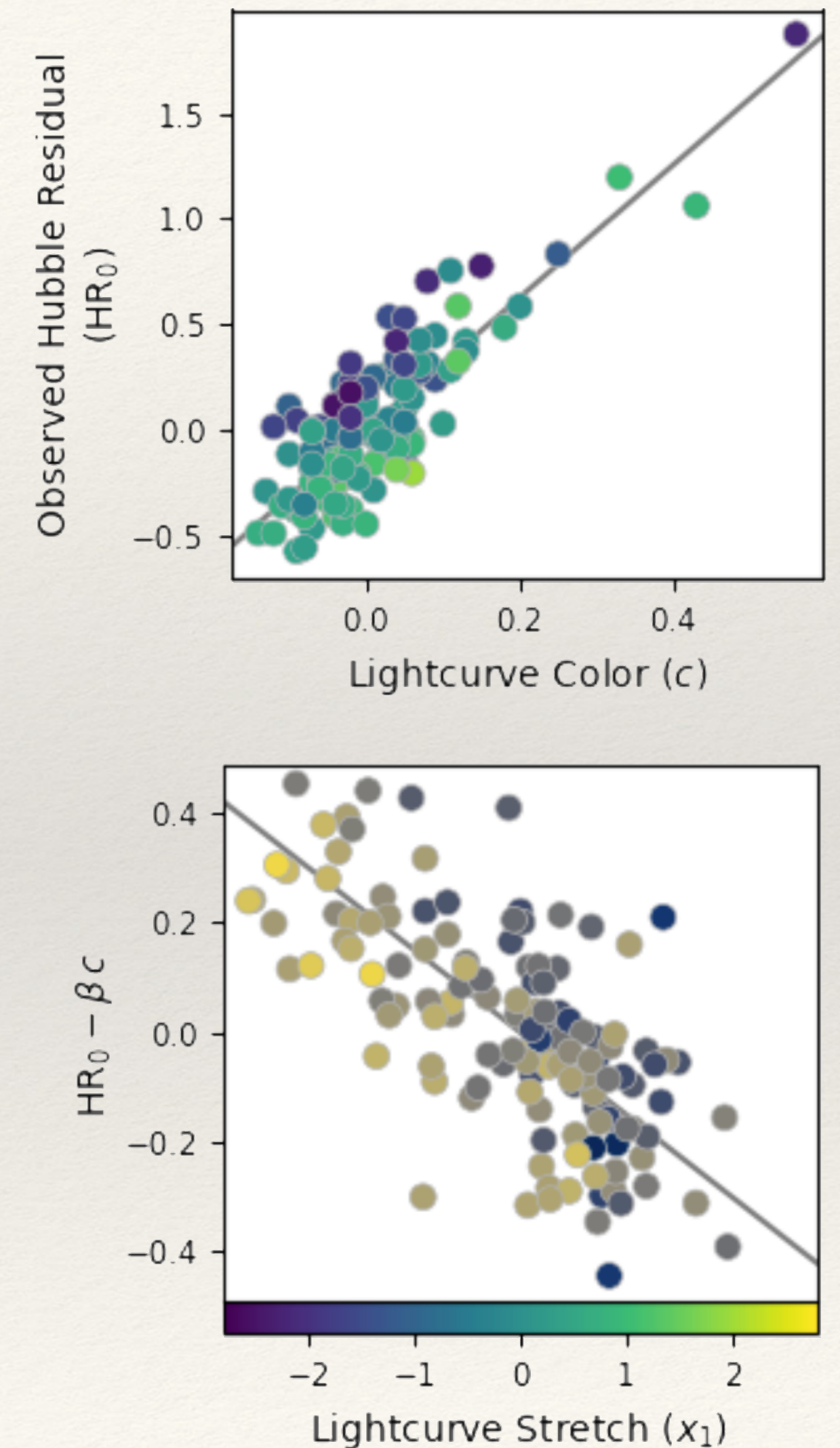
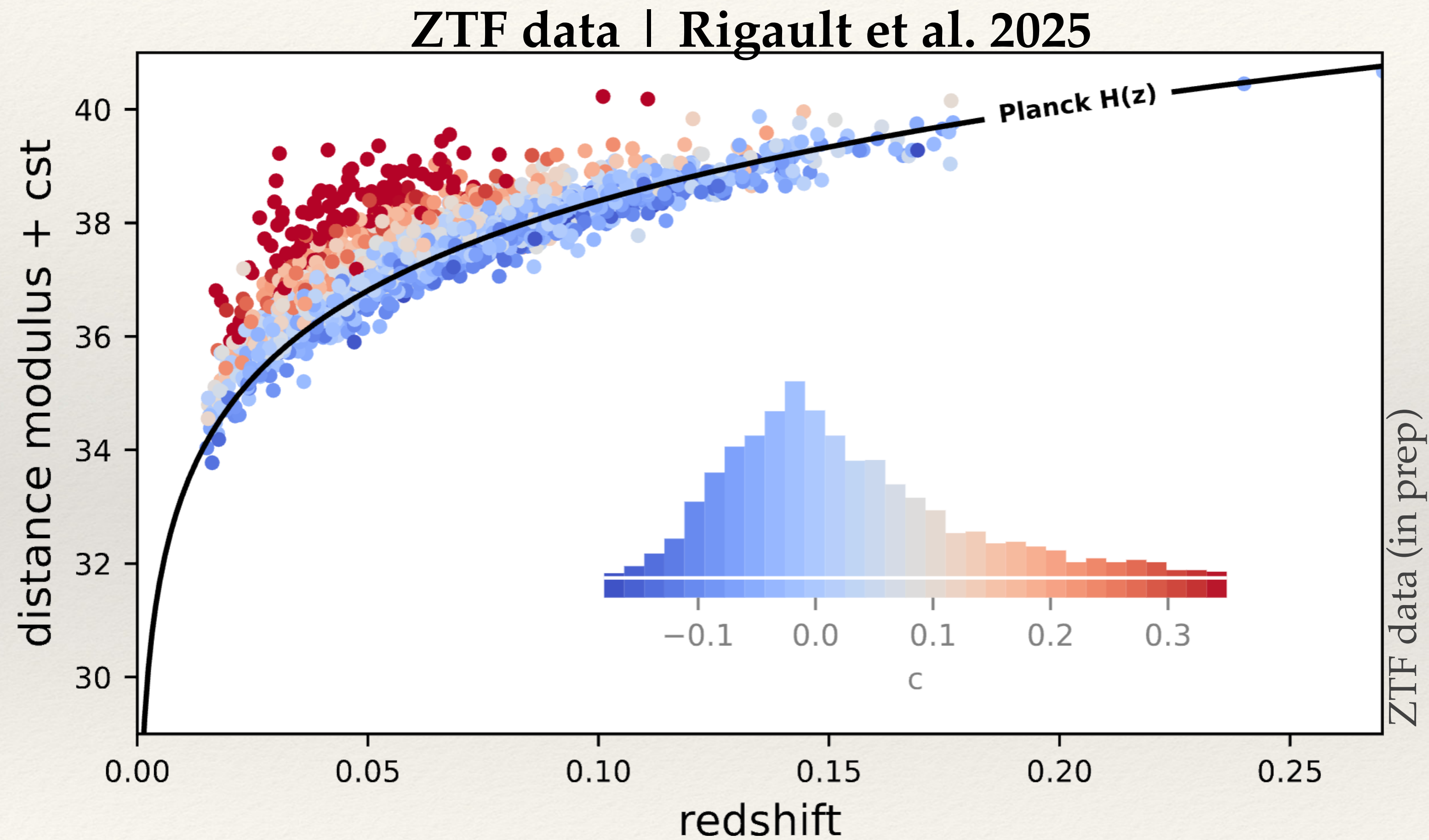
H_0 Tension | *Early vs. Late*



Flux, stretch & color

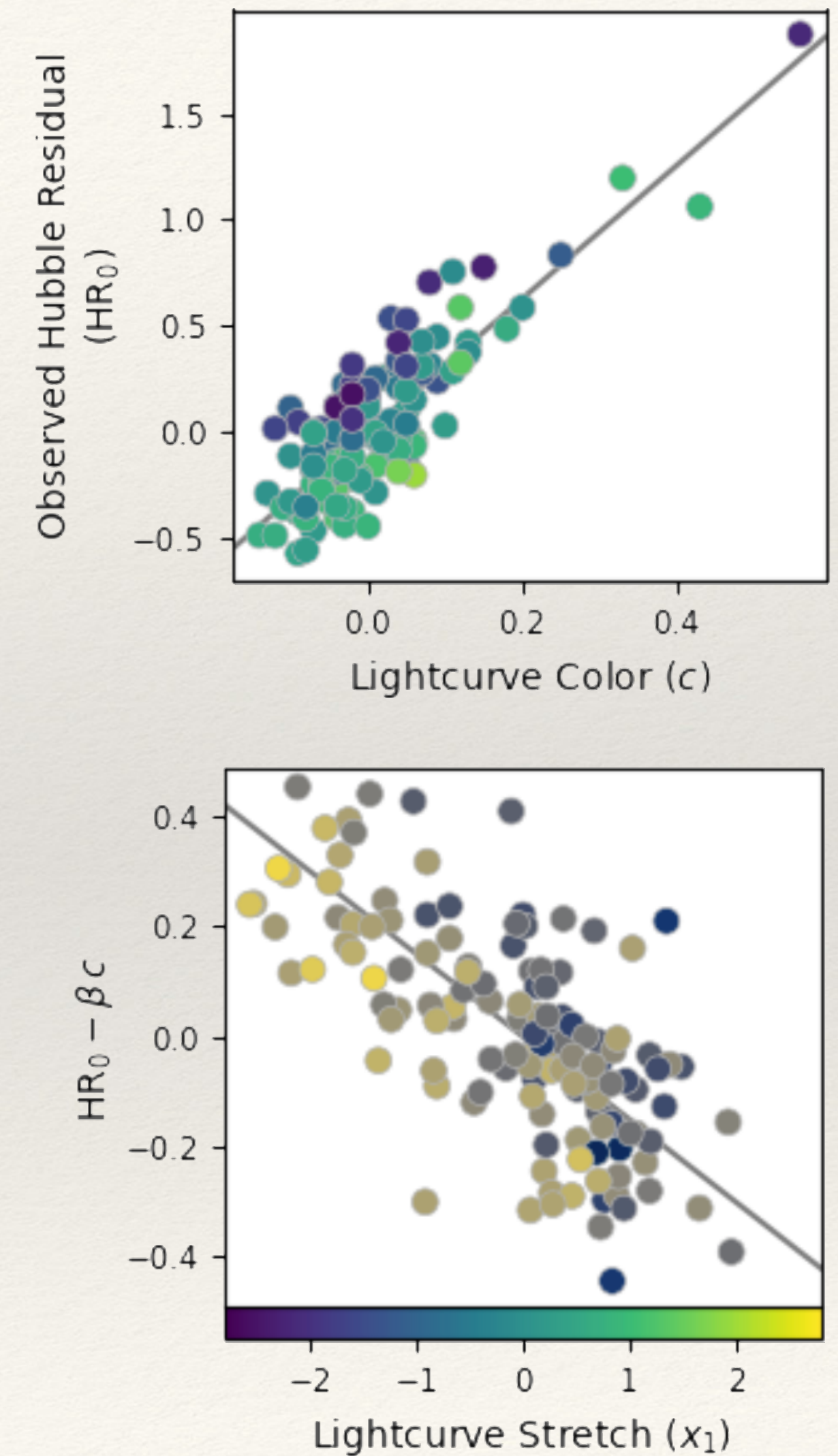
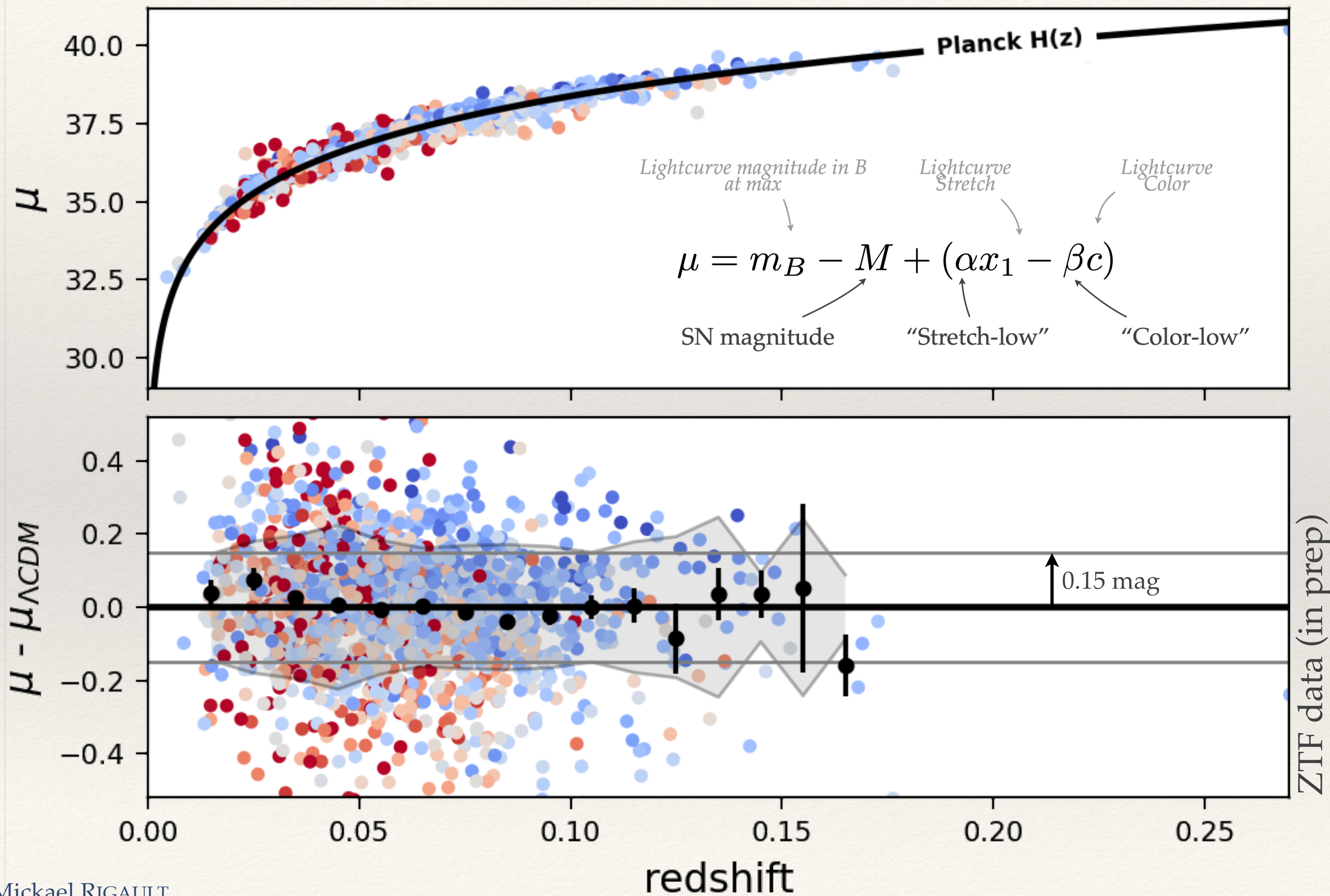


Type Ia Supernovae | *Standardizable Candles*

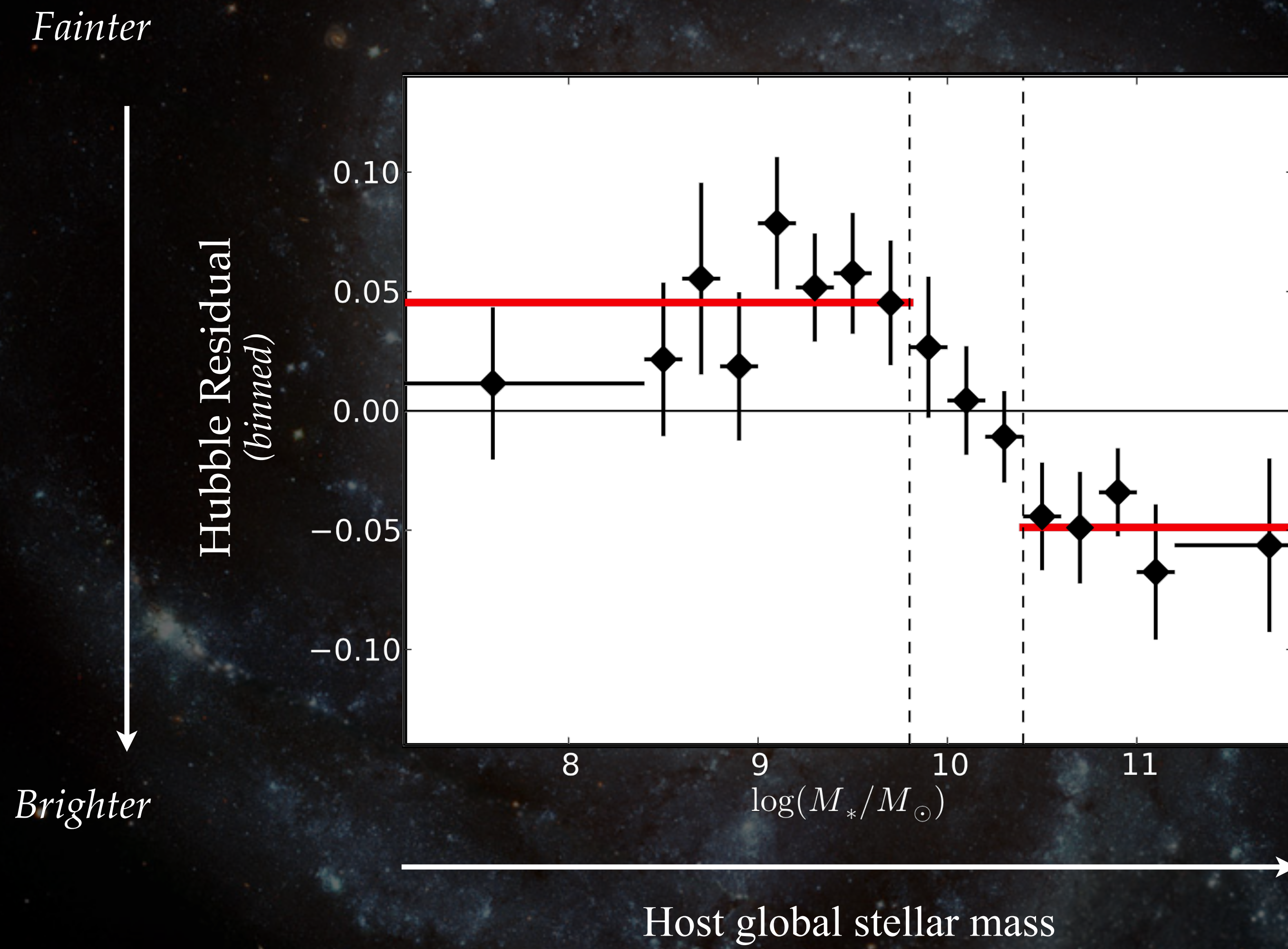


SNfactory data | Rigault et al. 2020

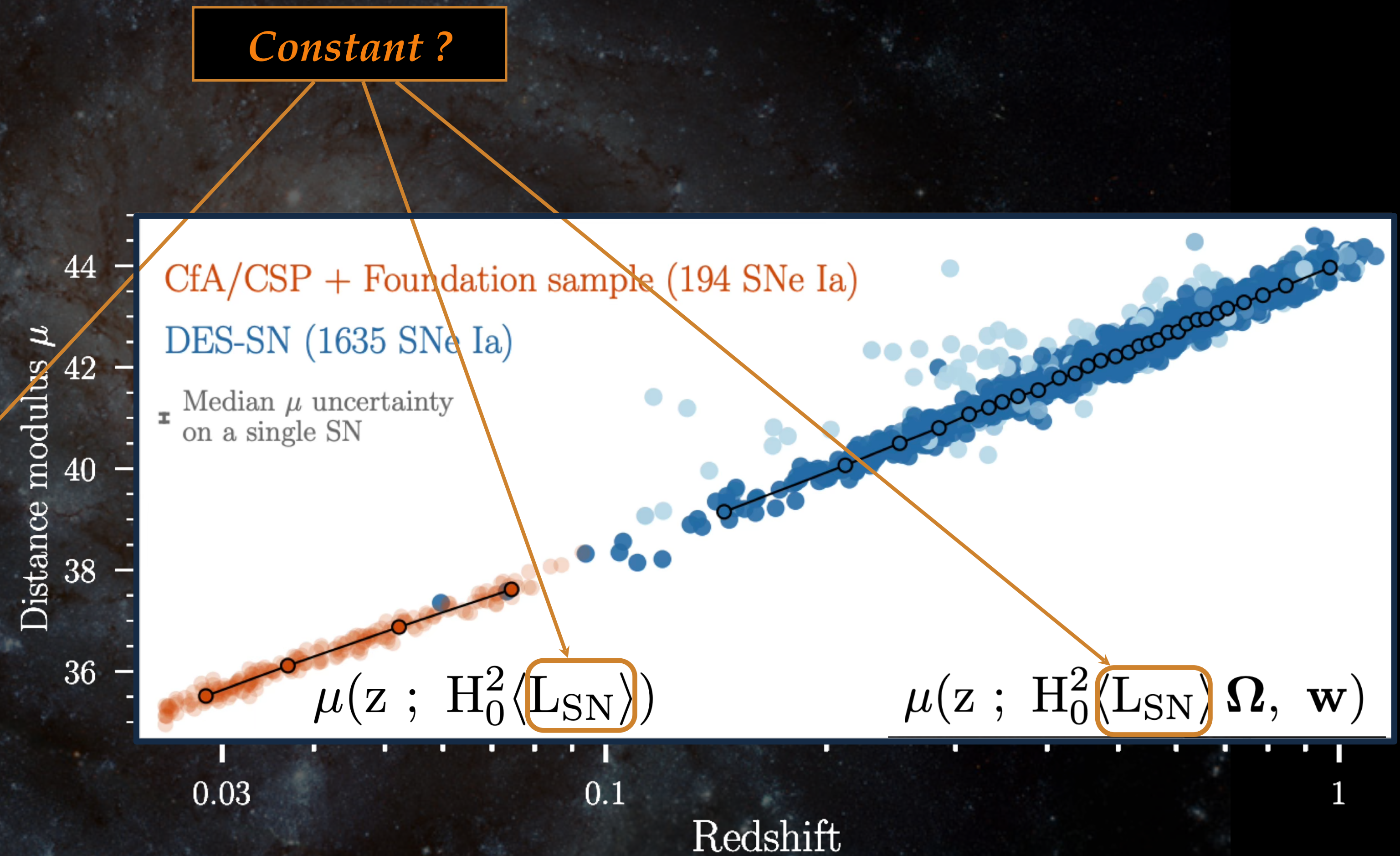
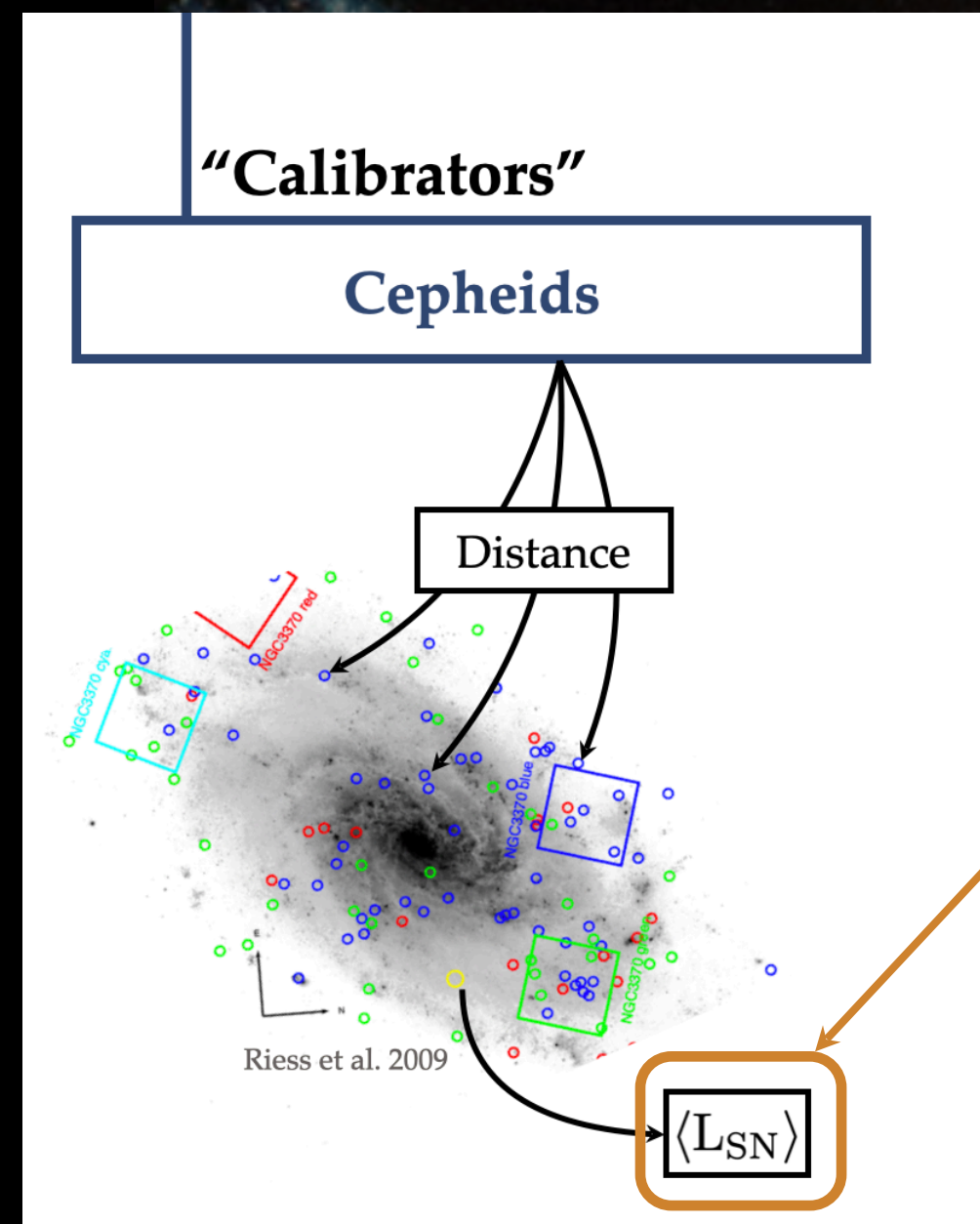
Type Ia Supernovae | *Standardizable Candles*



SNfactory data | Rigault et al. 2020



The Progenitor issue | *Astrophysical biases*



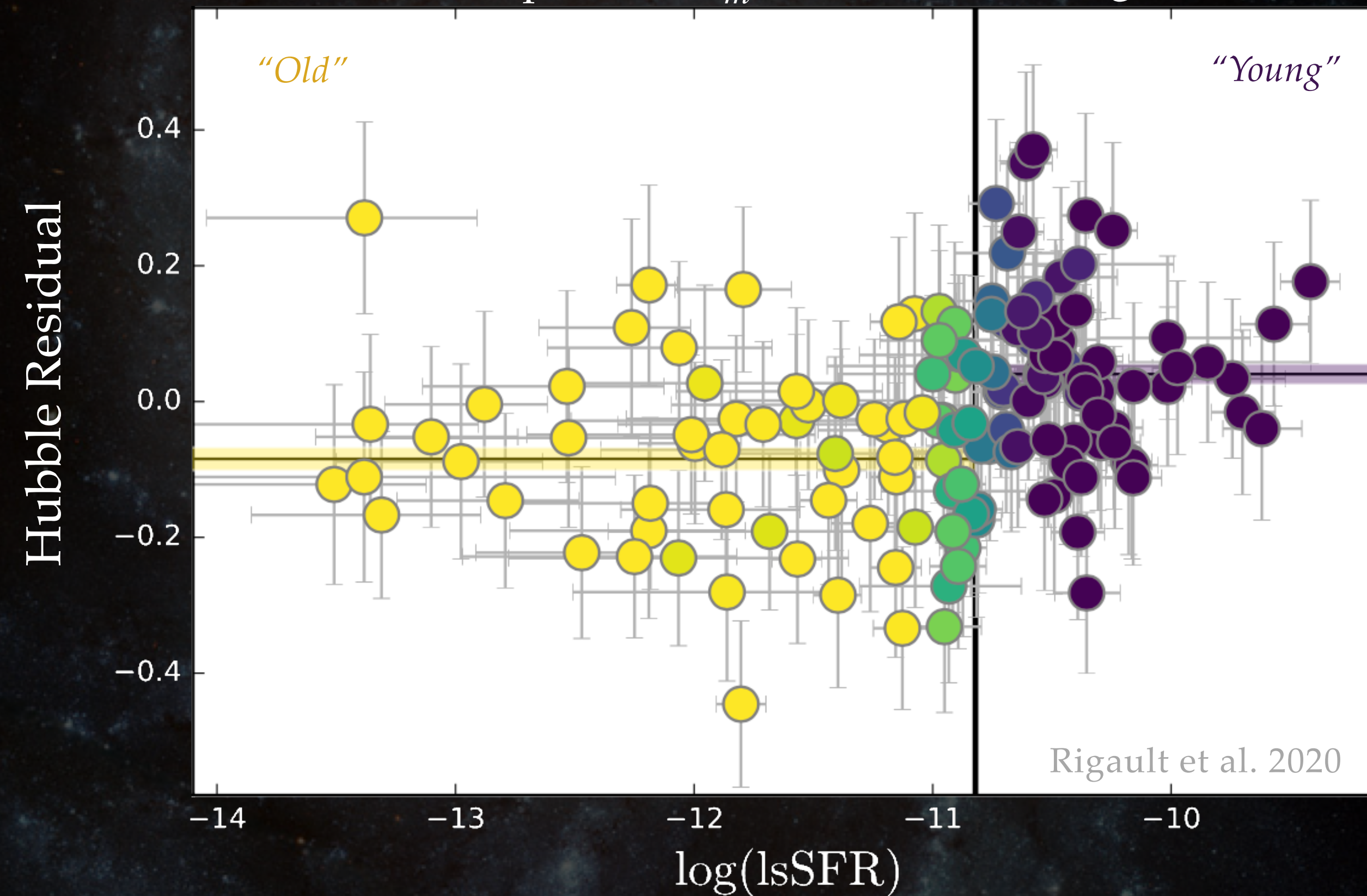
SN2011fe →

“No”
young stars

High fraction of
young stars

Fainter

Amplitude: $\Delta_m = 0.16 \pm 0.03$ mag



Brighter

Bias on w :

Rigault et al. 2013, 2020

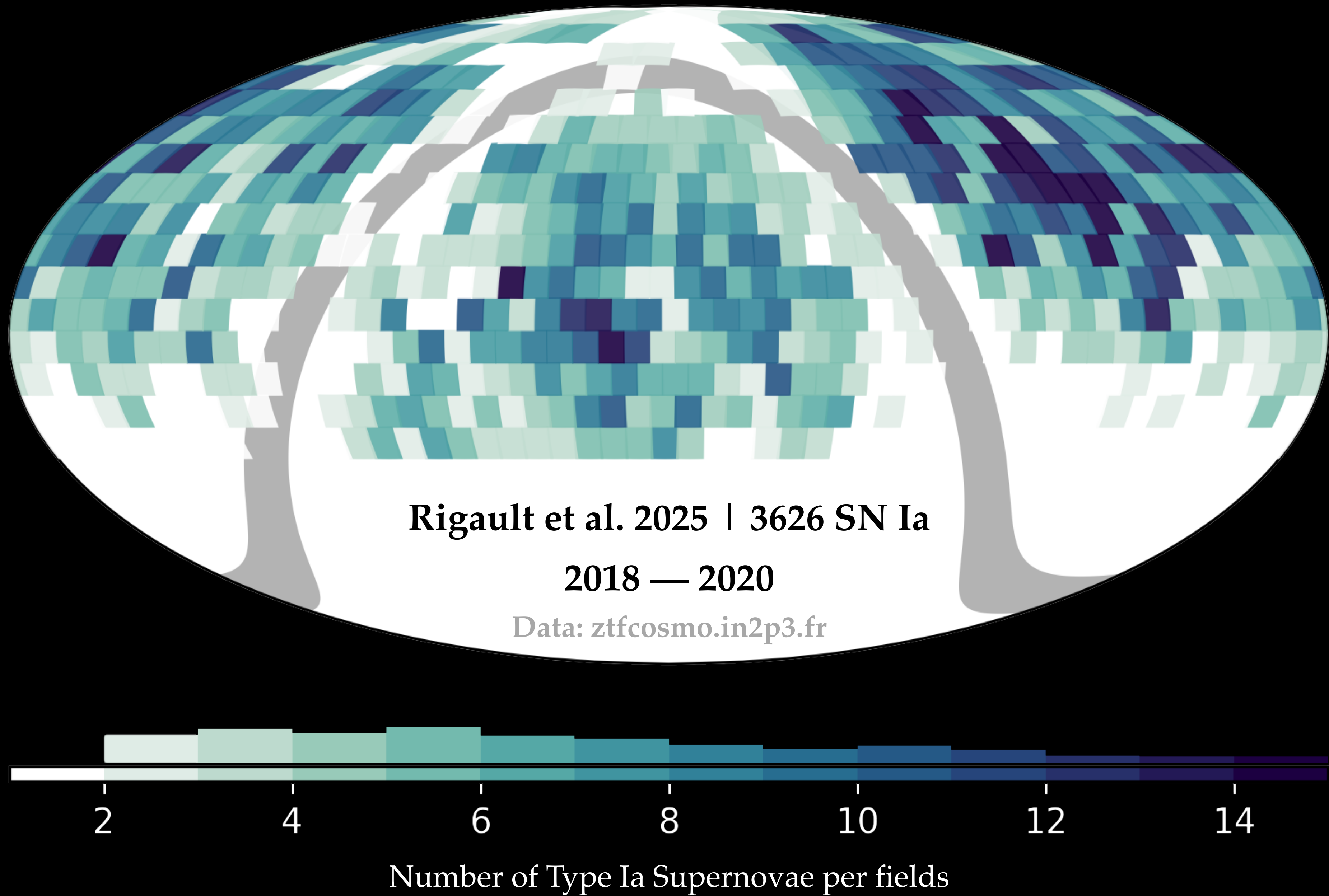
Bias on H_0 :

Rigault et al. 2015

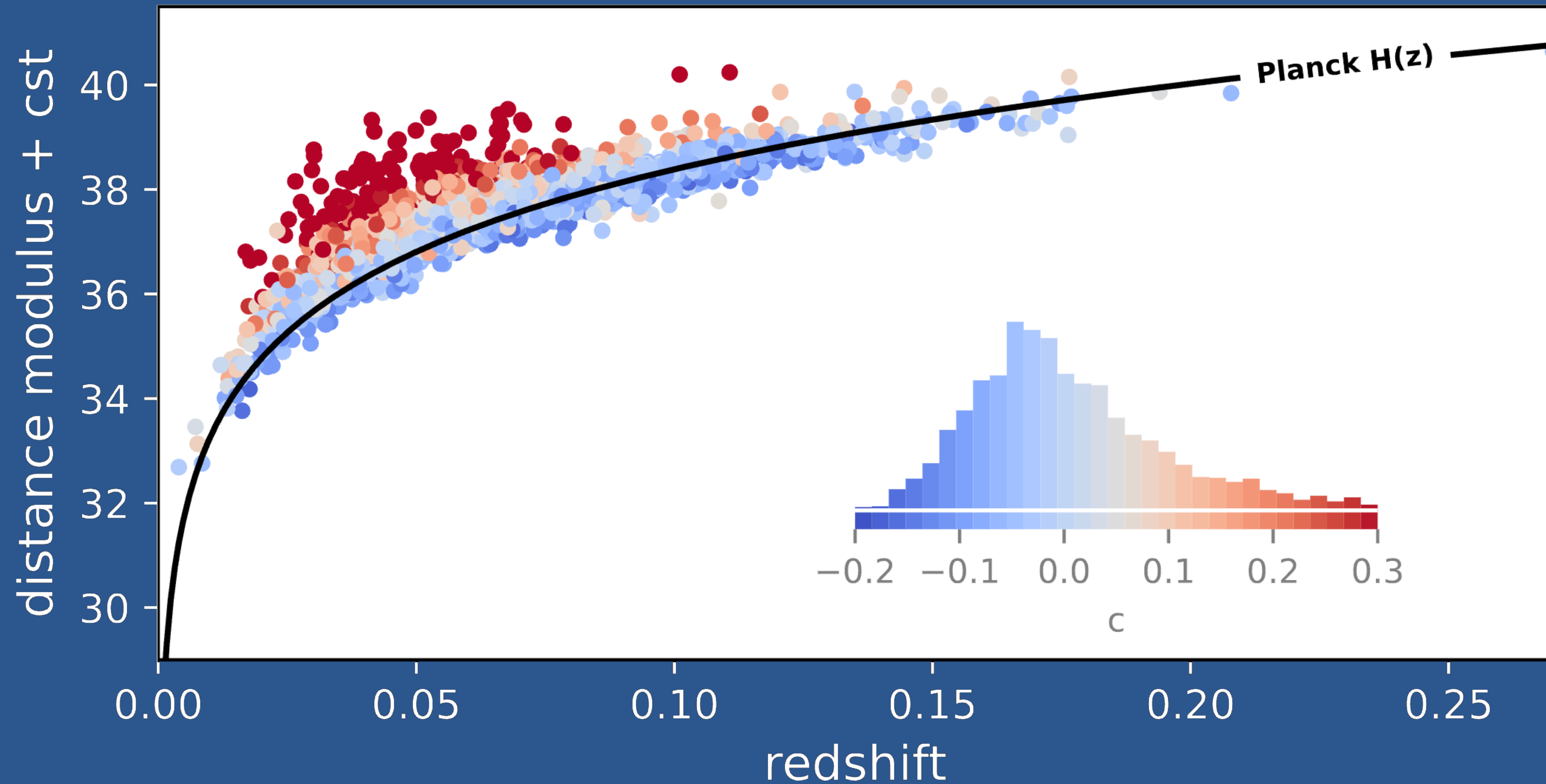
$$\text{lsSFR} \propto \frac{\# \text{ Young Stars}}{\# \text{ Old Stars}}$$



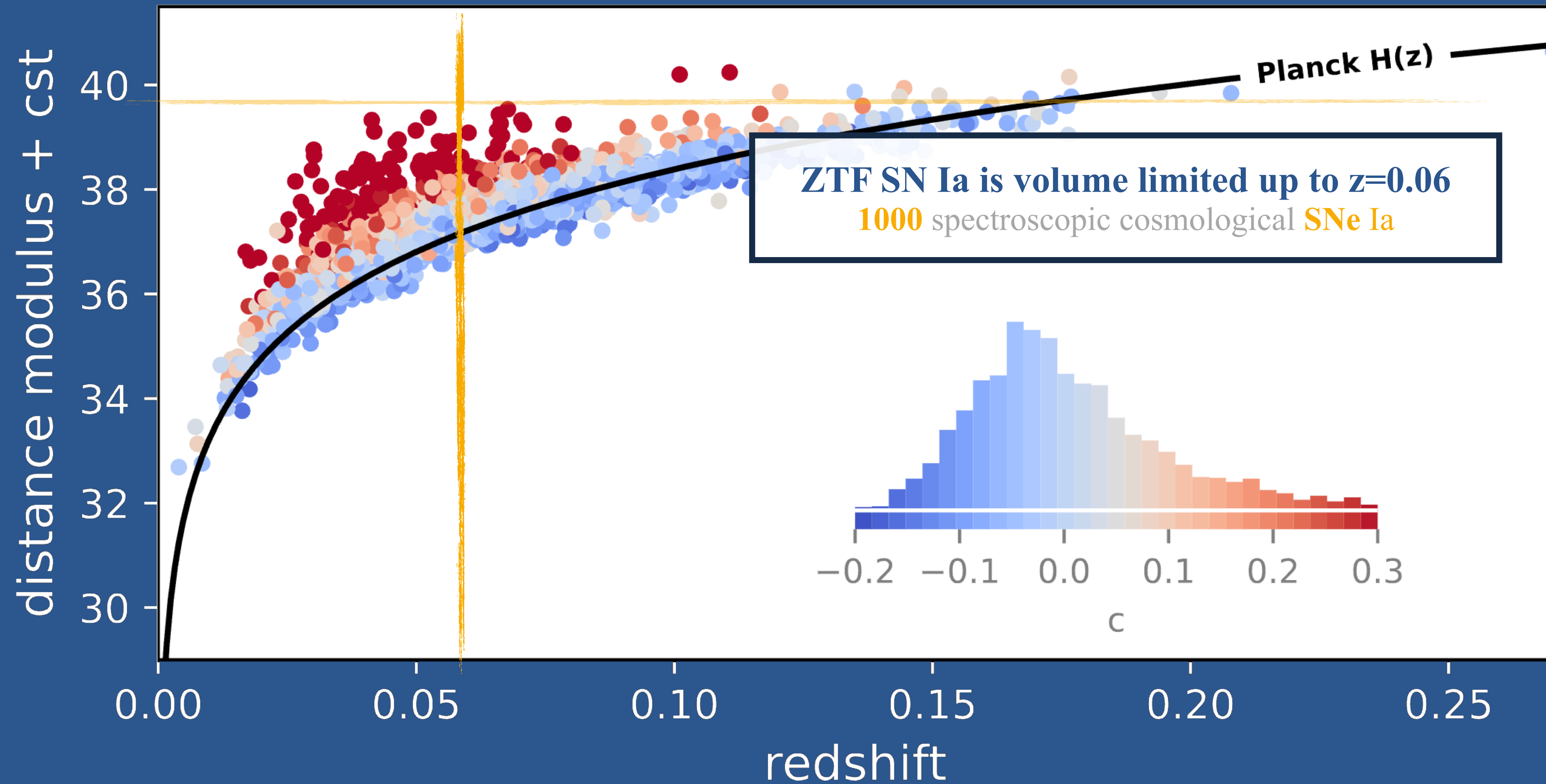
ZTF



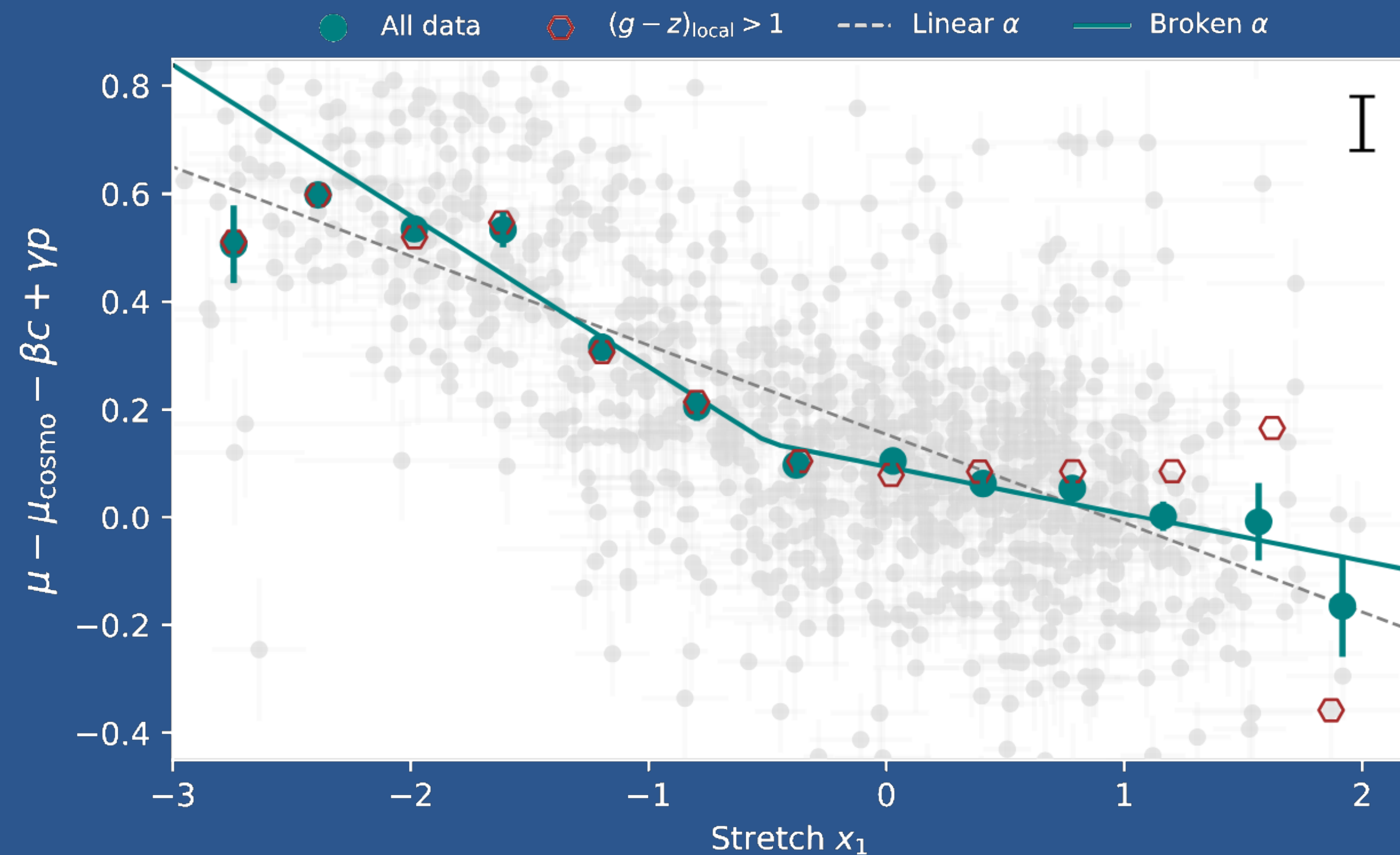
“Non-standardised” Hubble Diagram



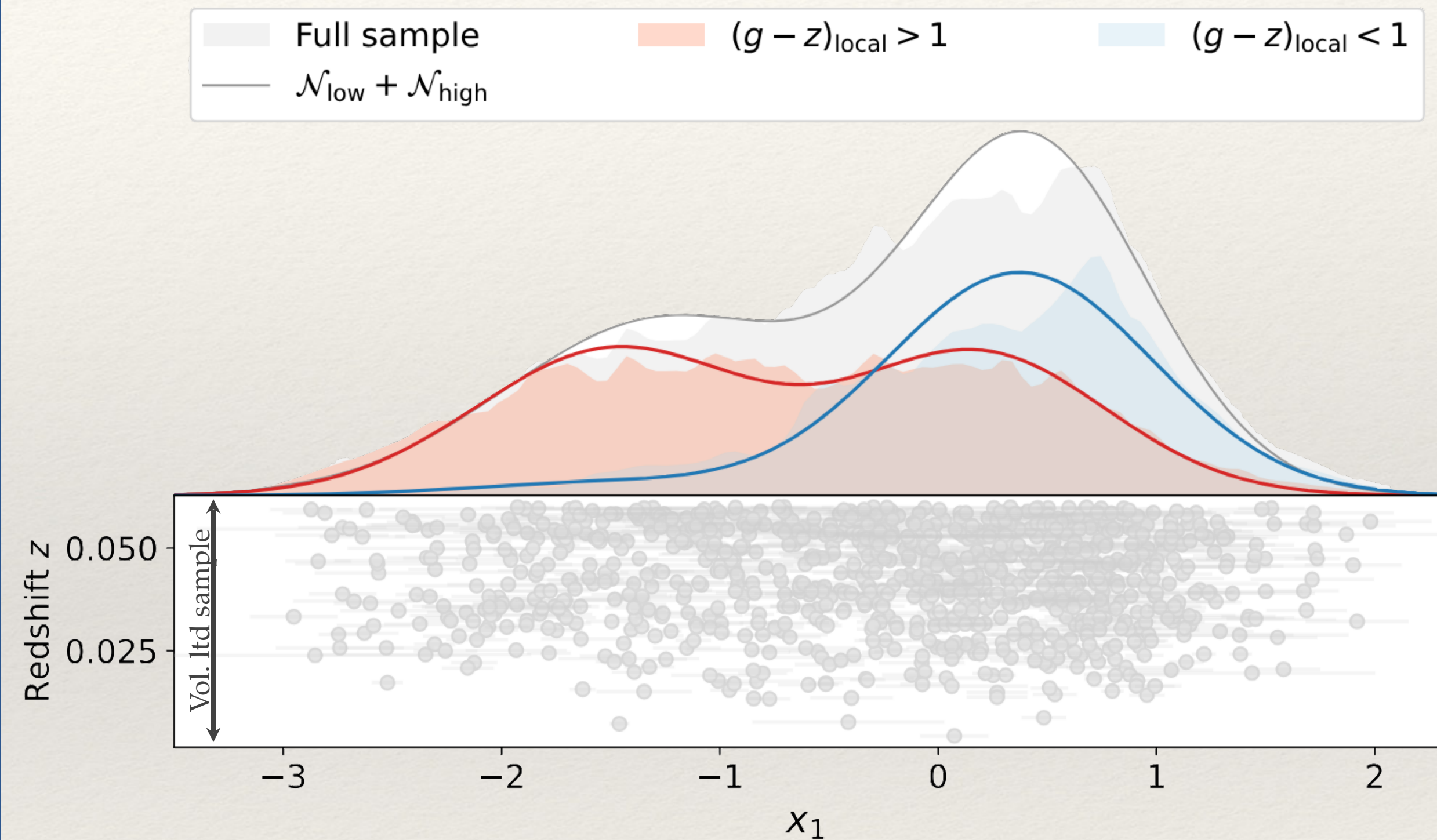
“Non-standardised” Hubble Diagram



Stretch Standardisation

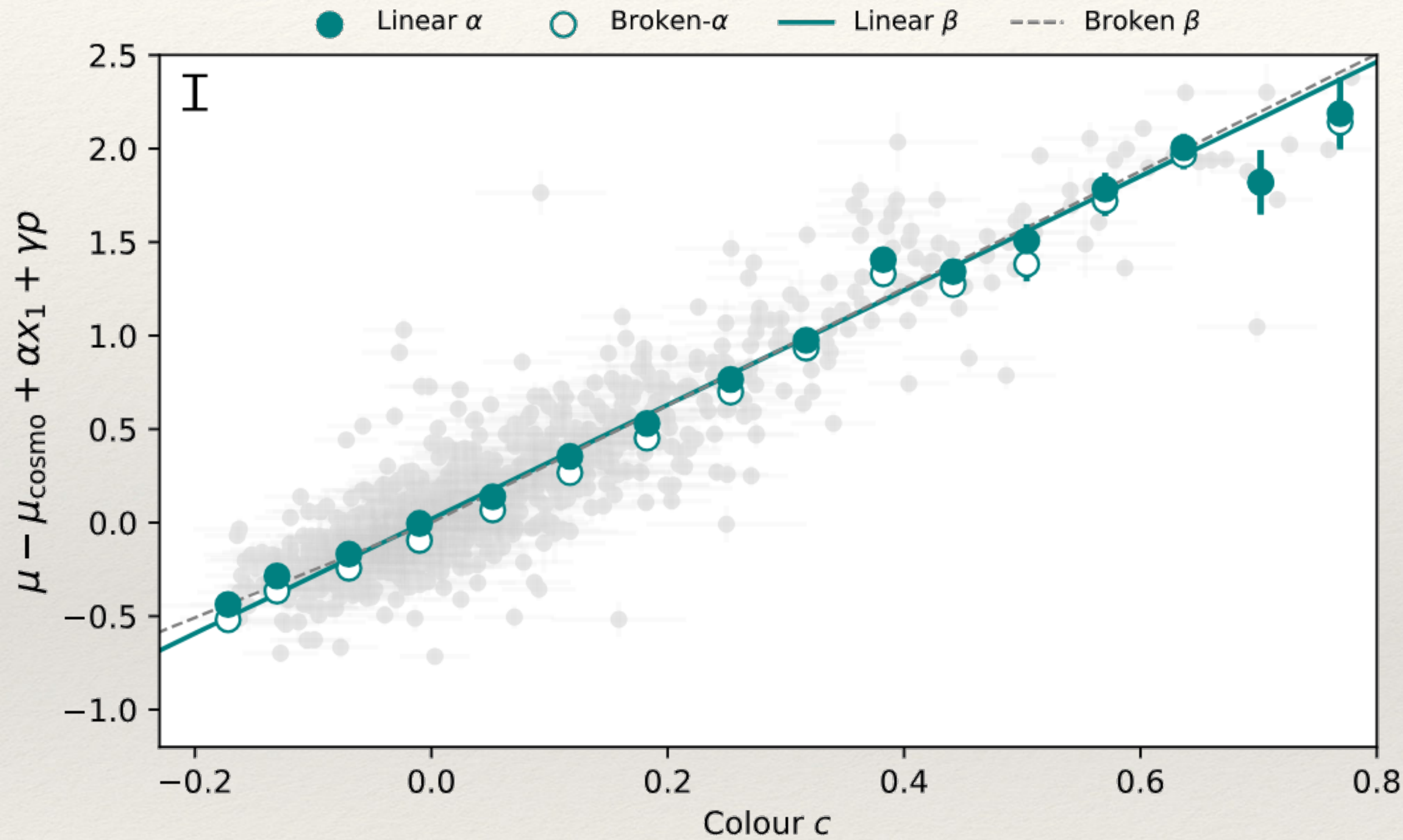


The “**brighter-slower**”
stretch-magnitude
relation **is non-linear**



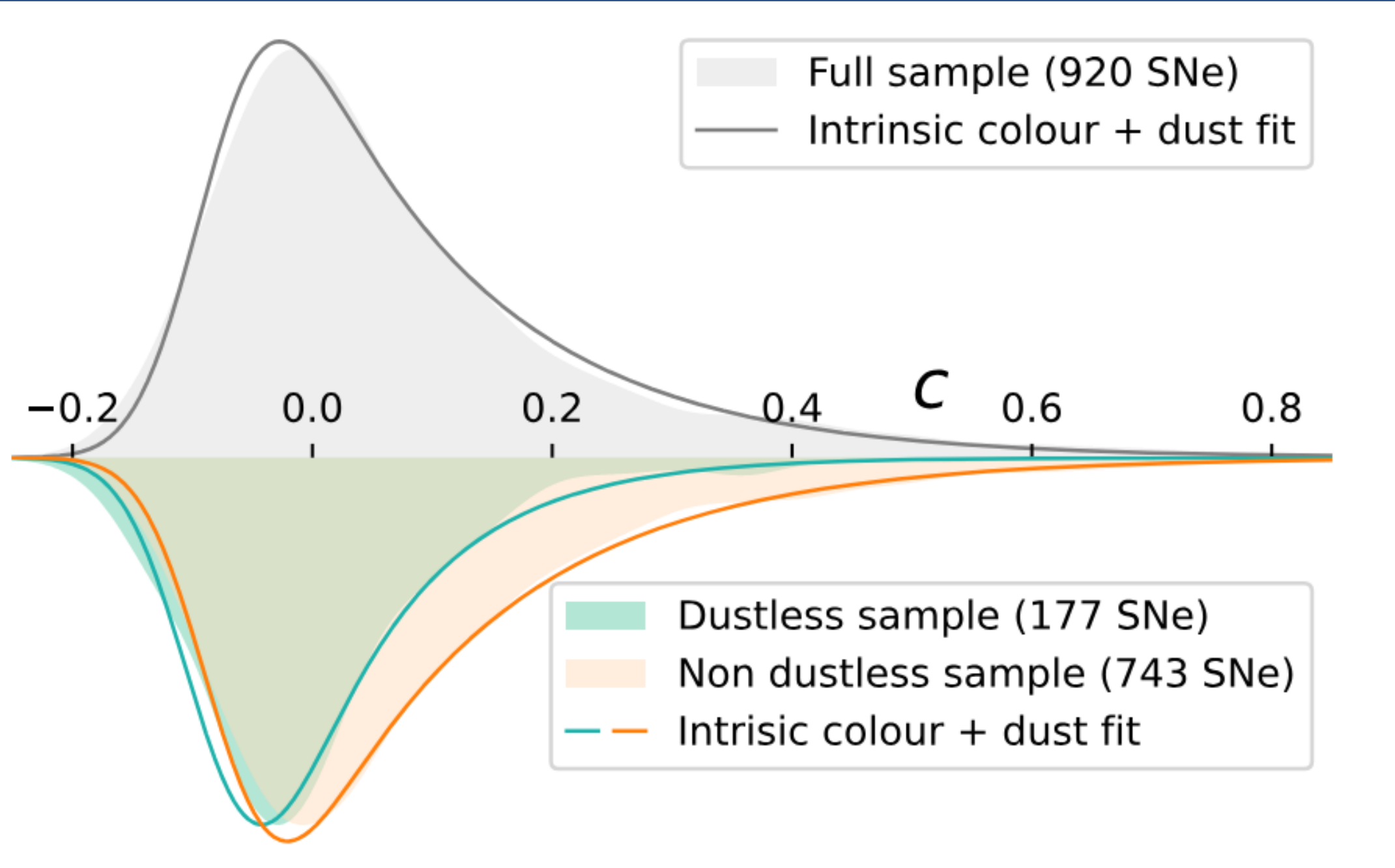
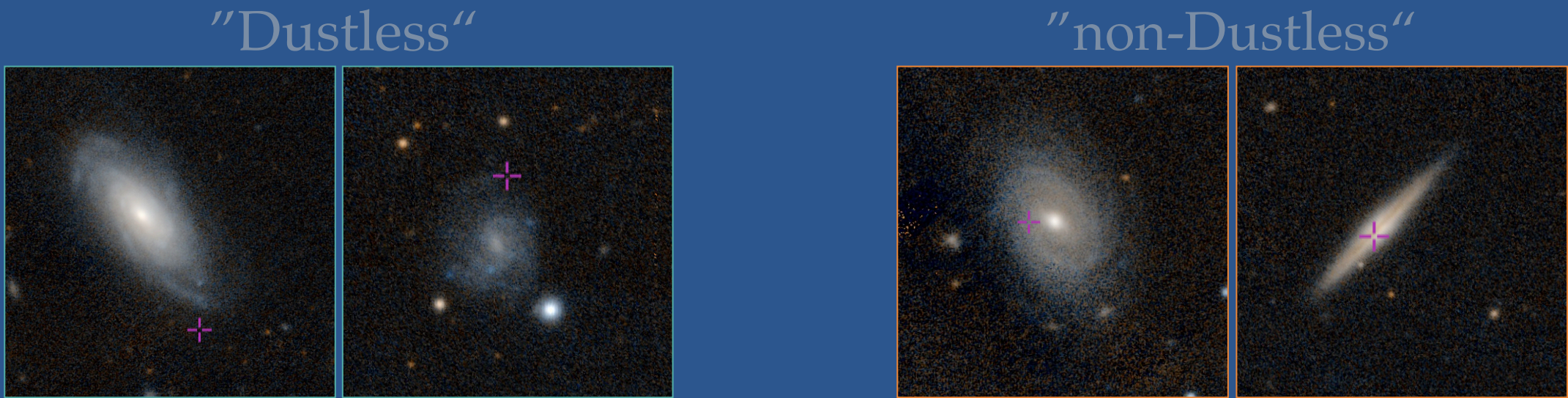
Bimodal | confirming
progenitor age origin

Color Standardisation

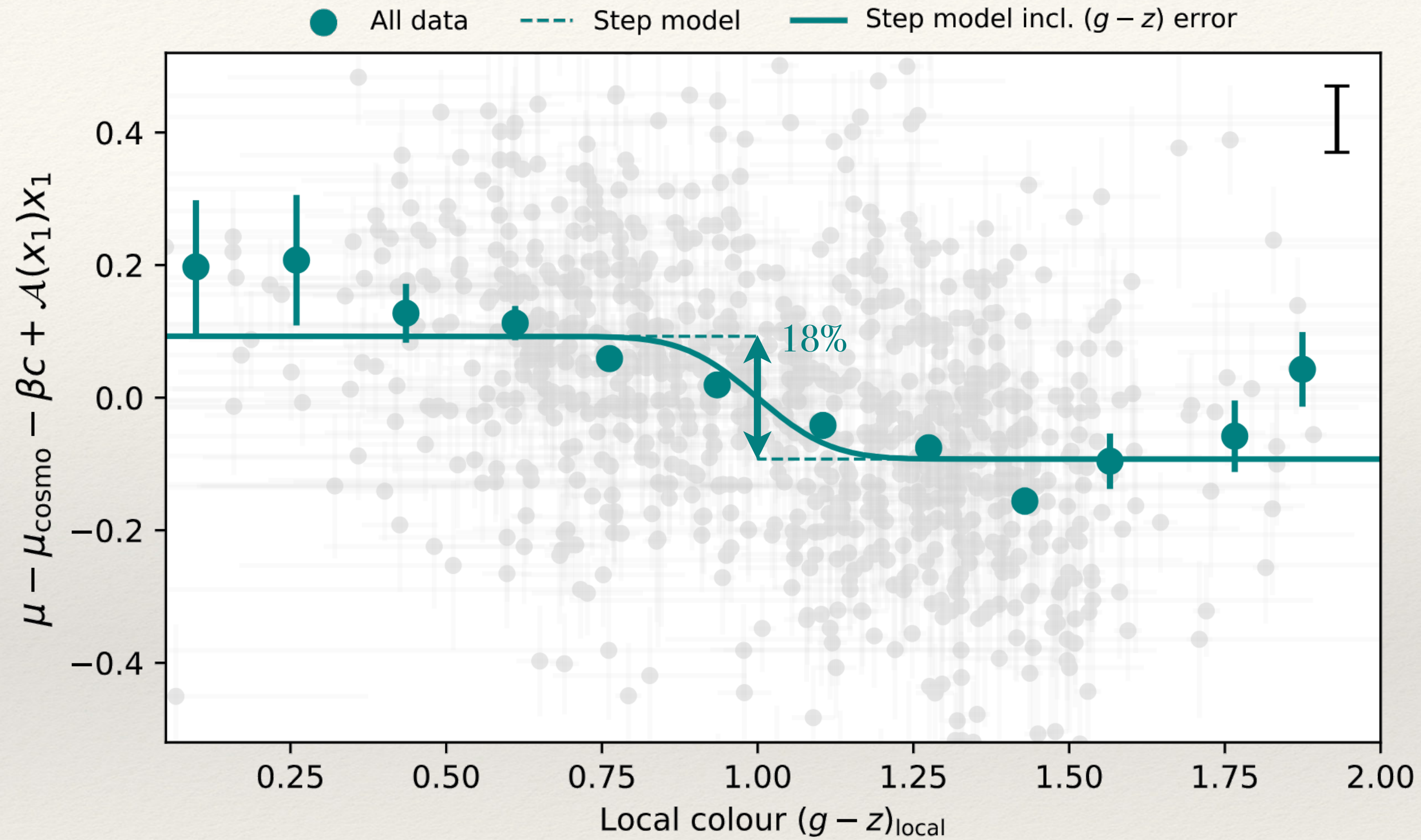


The redder-fainter relation *is linear*

[Ginolin et al. 2025 \(b\)](#)

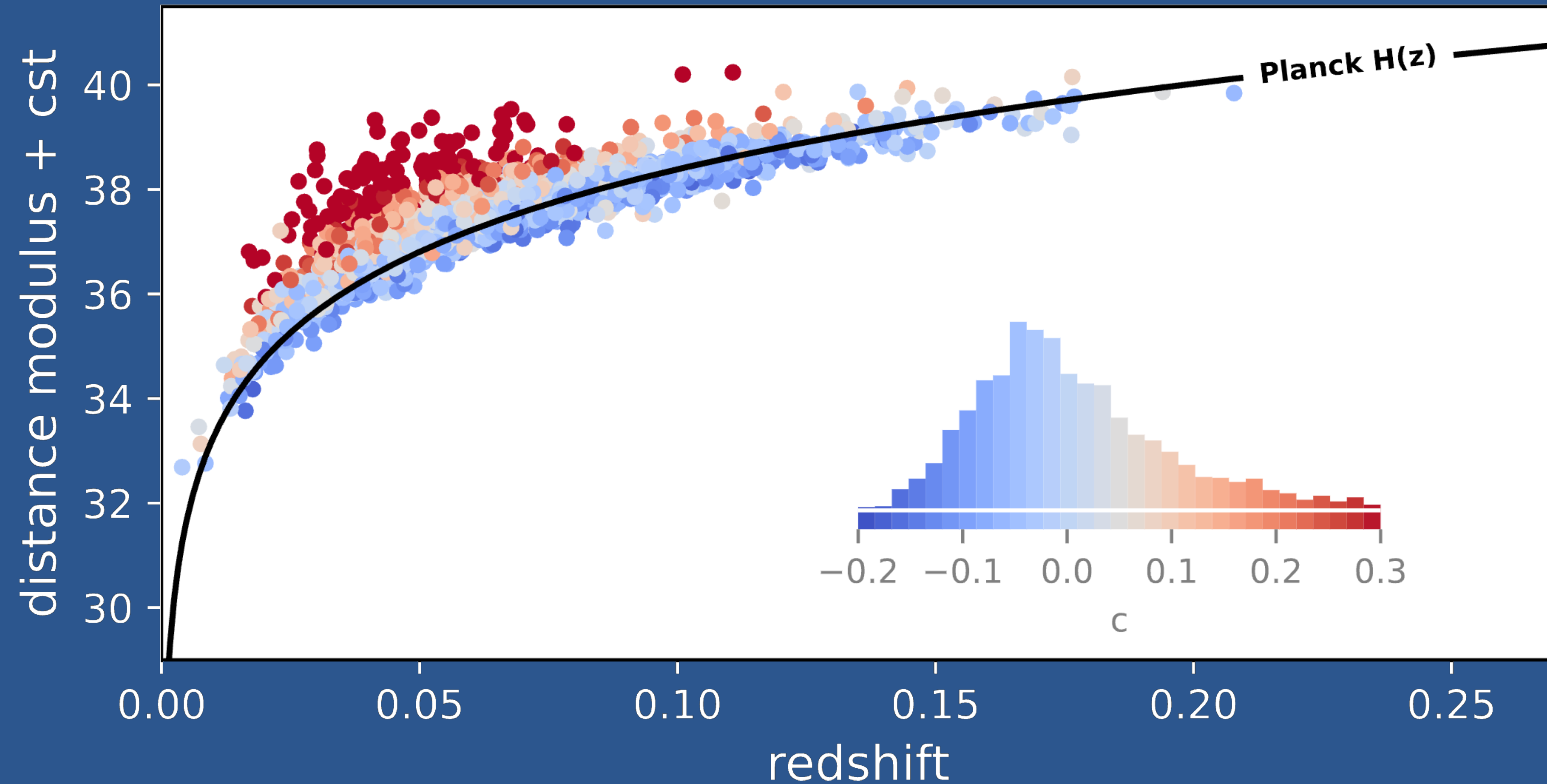


SNe Ia in **non-dusty** environments **don't show a red tail.**

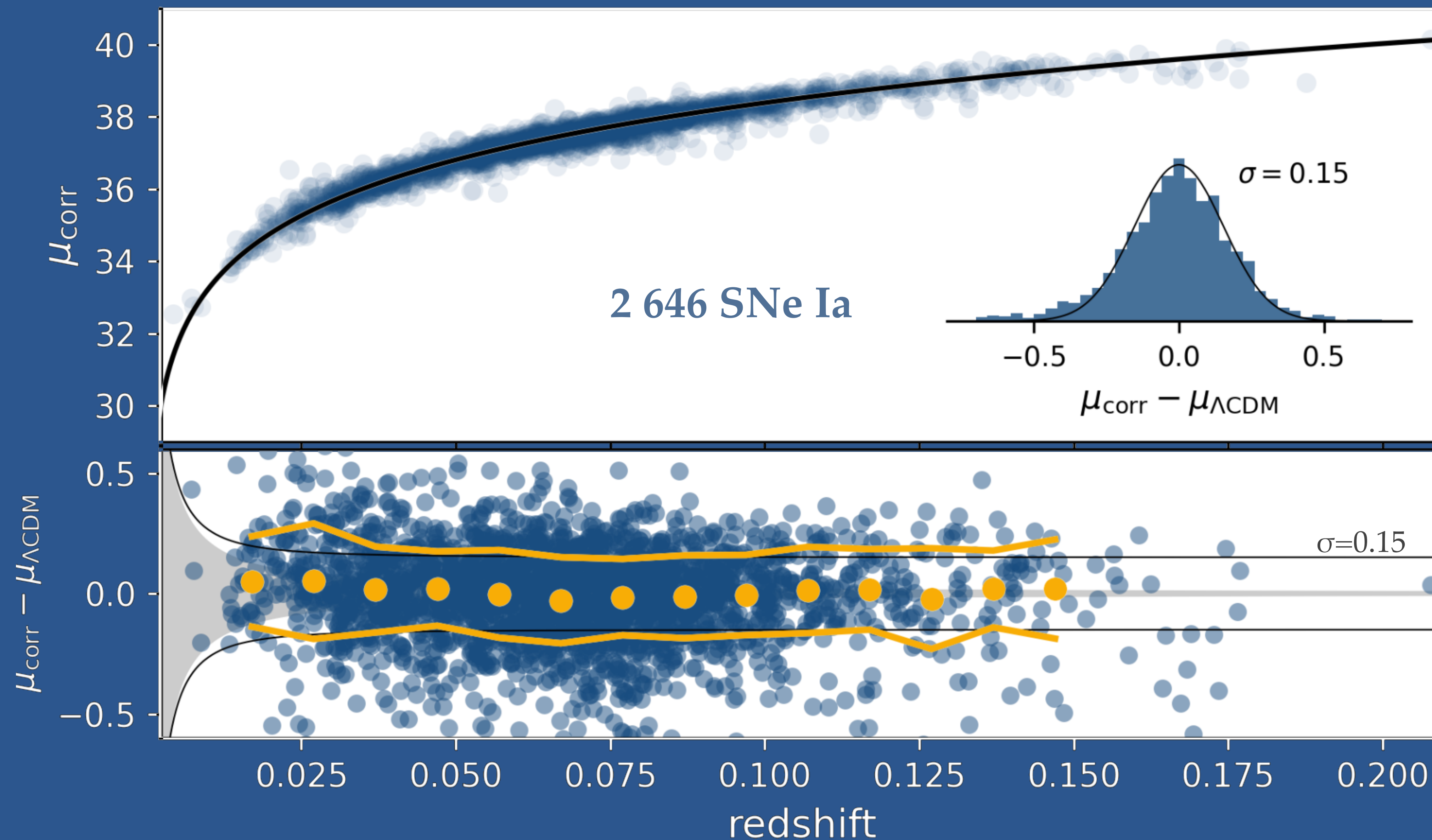


Environmental biases **are larger**
 than expected ~ 0.18 mag
x2 larger than most literature

“Non-standardised” Hubble Diagram



Standardised Hubble Diagram



LEMAITRE

Next step

⇒ DR2 +
New light-curves

*Pocket effect & new flats
& ubercal*

Filter throughput

CBP Campaign this Fall

+ SNLS & Subaru

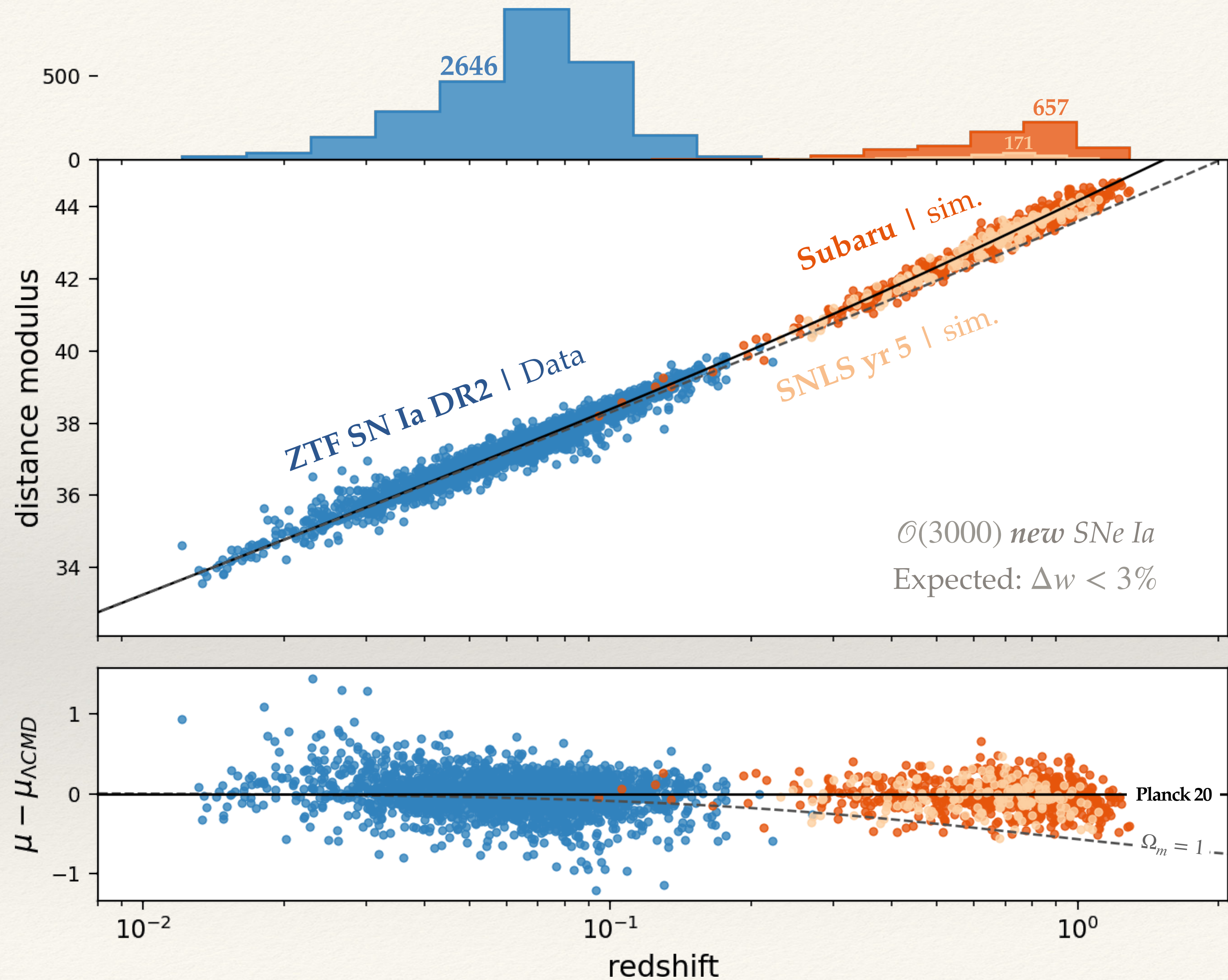
Unique Framework

New Inference

EDRIS | No more BBC

New Simulations

Skysurvey



ZTF H_0

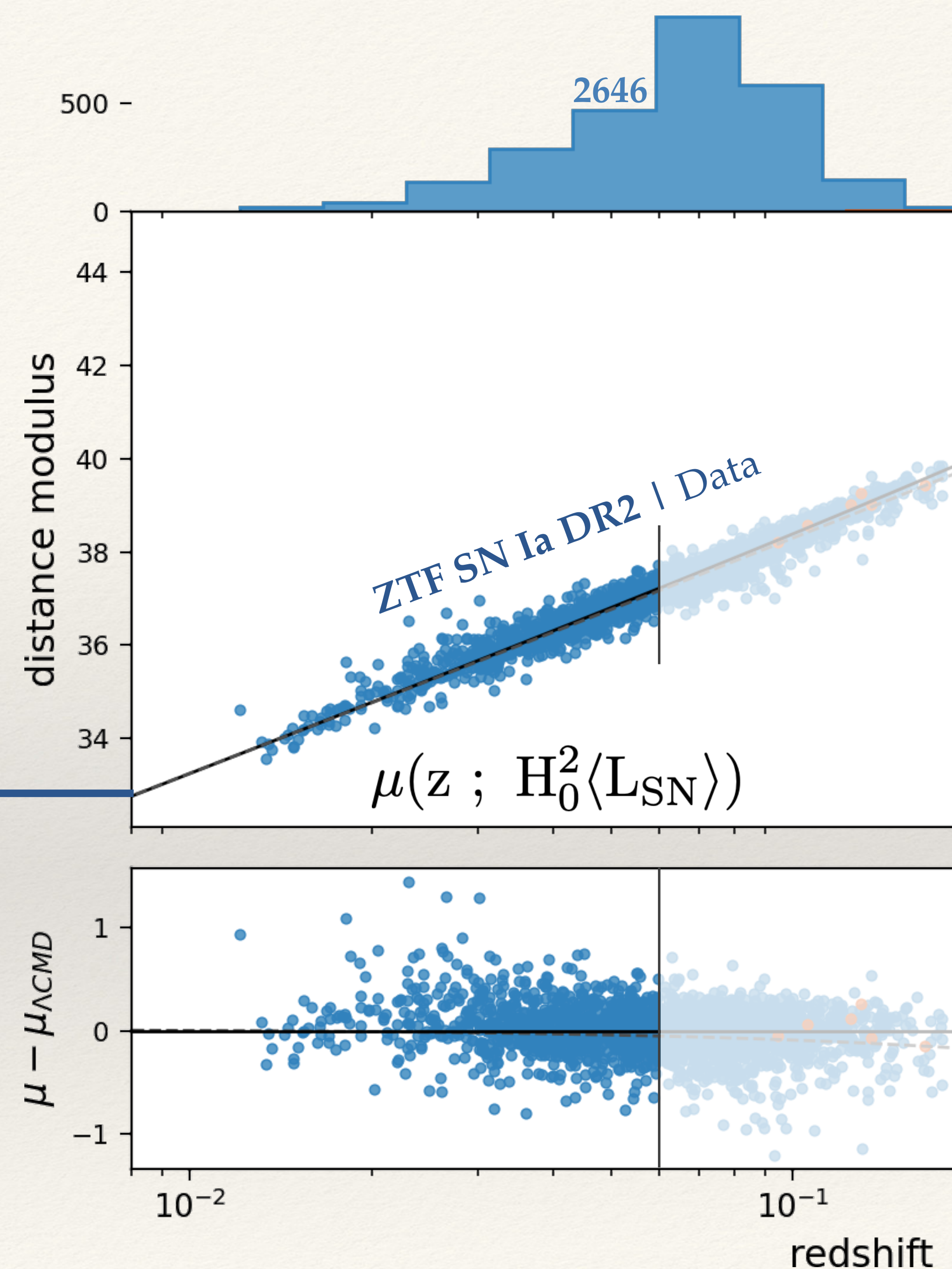
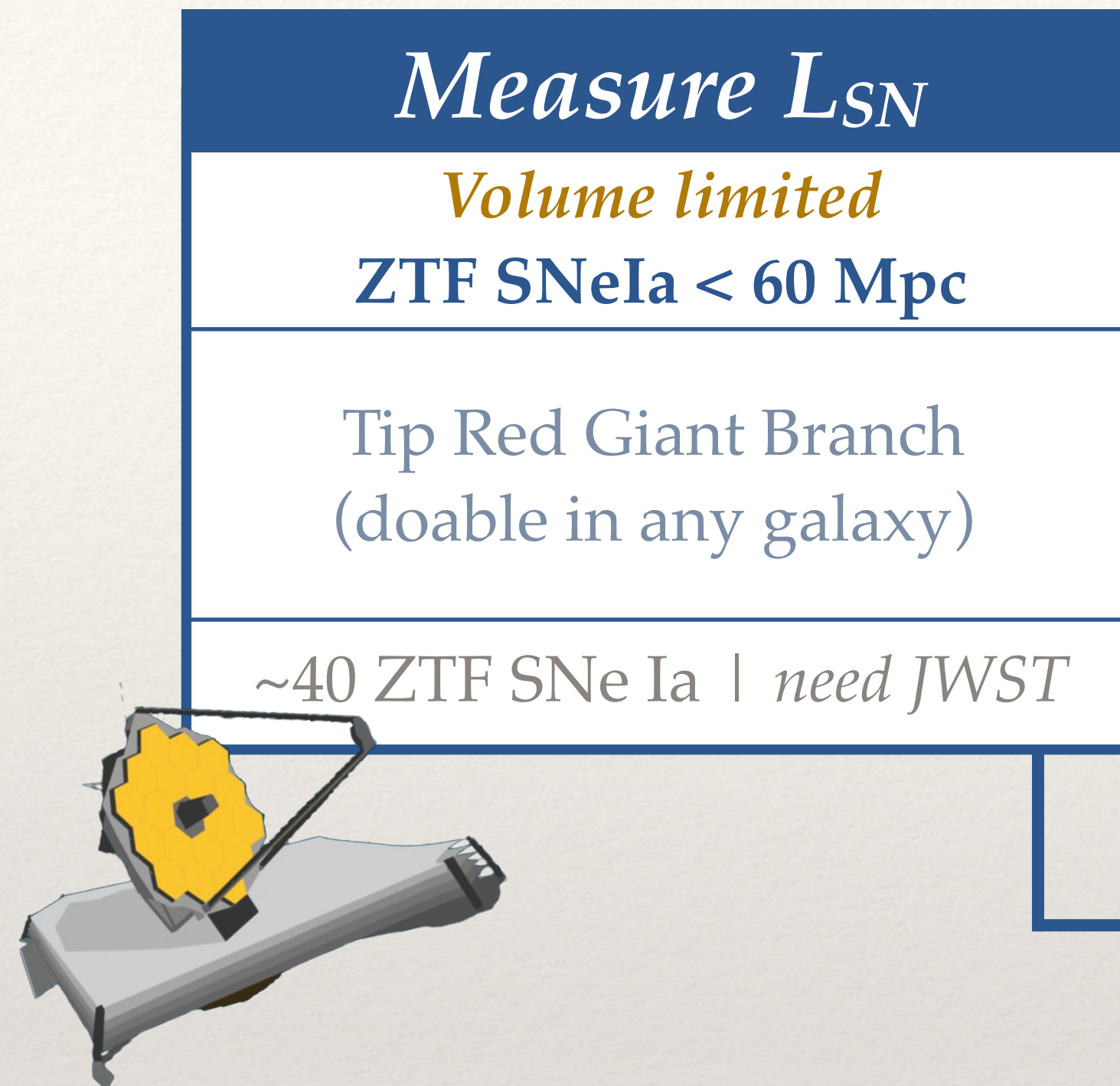
Pure ZTF

Pure Volume limited

Get an
independent
measurement of
 L_{SN}

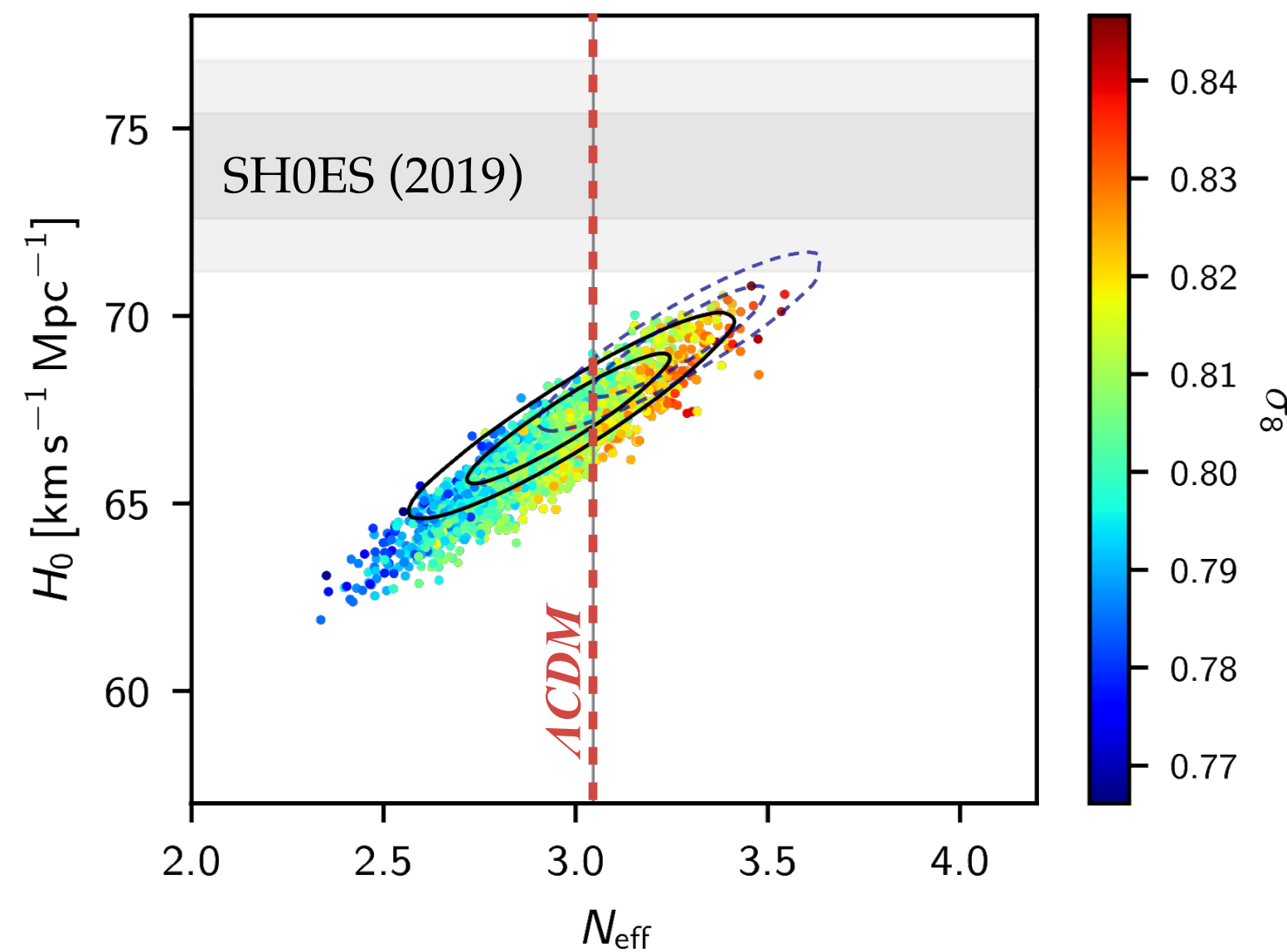
No selection
effect

Self-consistent
calibration



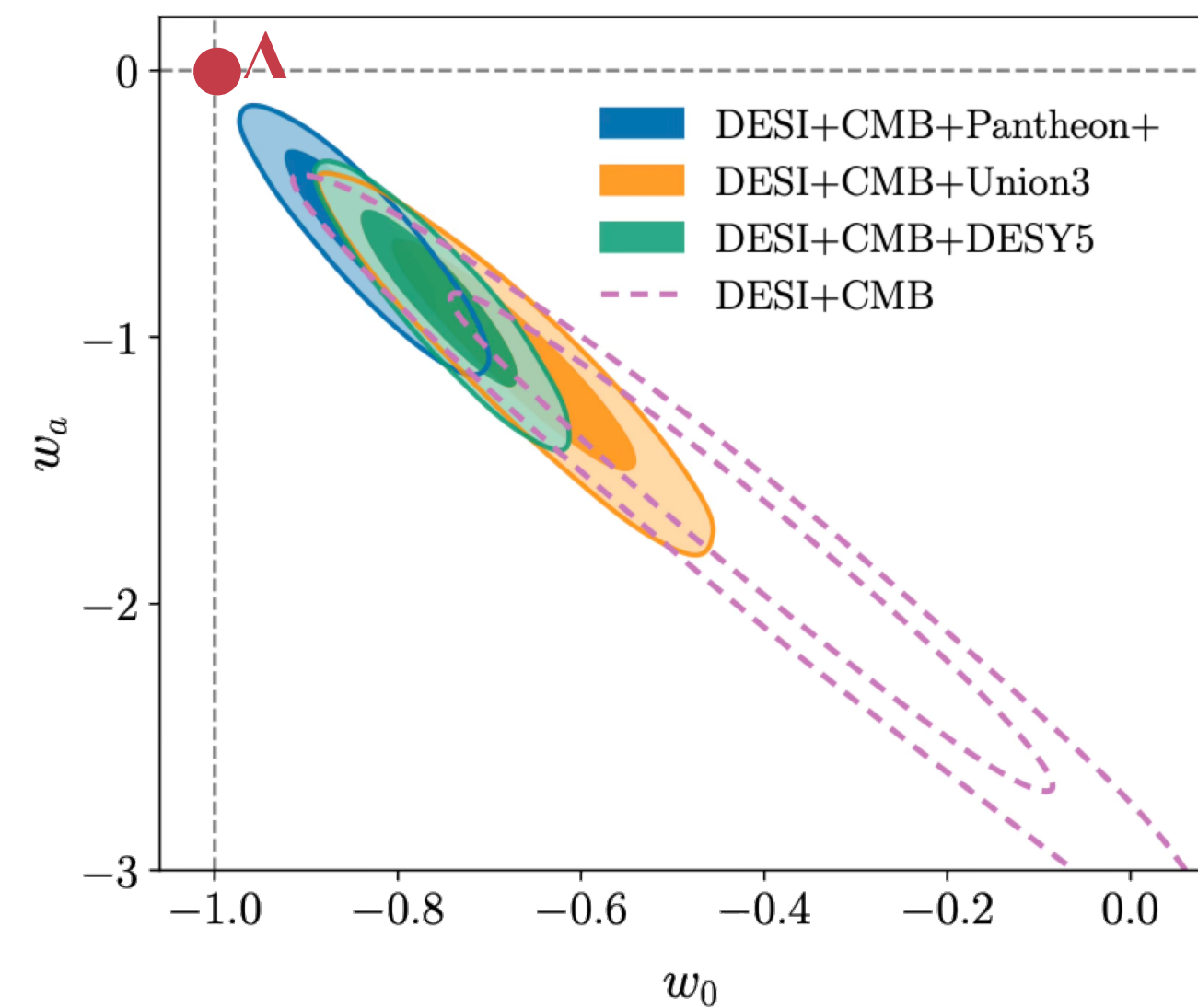
Tension in Cosmology | *the central role of Type Ia Supernovae*

H_0 | Hubble Constant



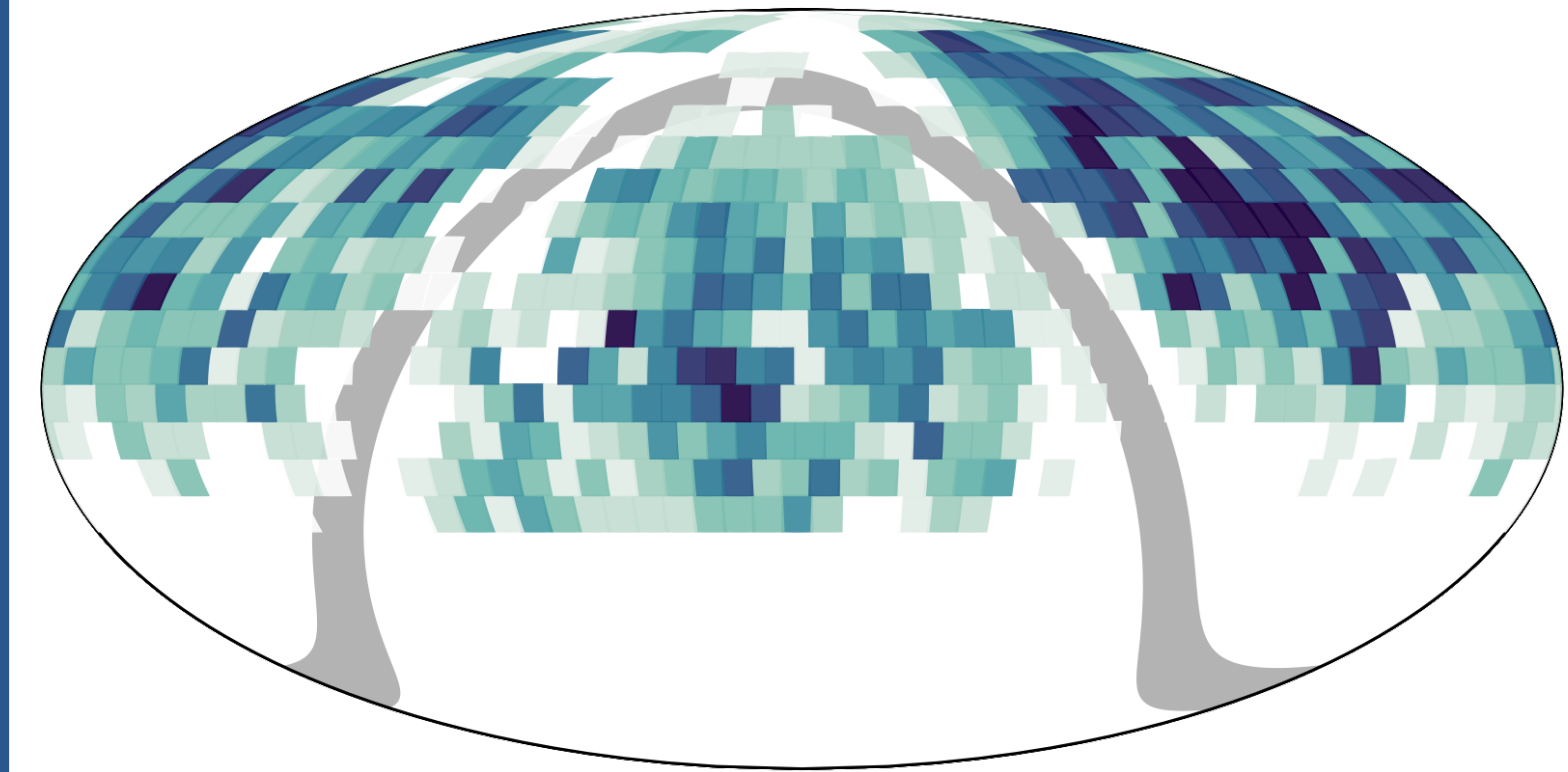
ZTF could be signe sample & volume limited

Λ | Evolving dark energy



ZTF to provide fully independent results

ZTF SN Ia DR2



Rigault et al. 2025 | 3626 SN Ia

Current data : ztfcosmo.in2p3.fr