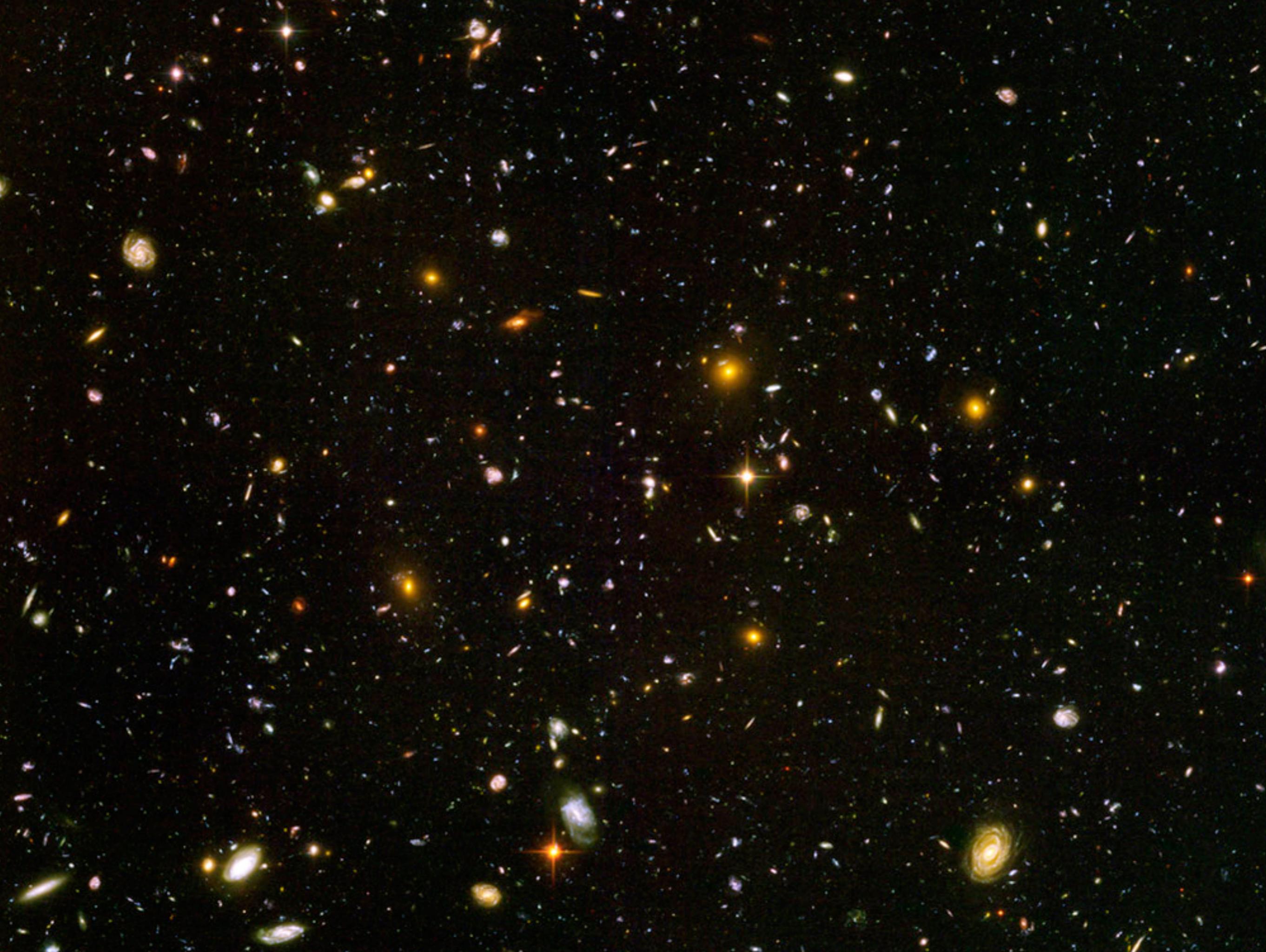




Modern Cosmology: Astrophysical analyses of SNeIa and future surveys

LPC Clermont – Mickael RIGAULT



The Universe is Expanding !

Edwin HUBBLE, 1929

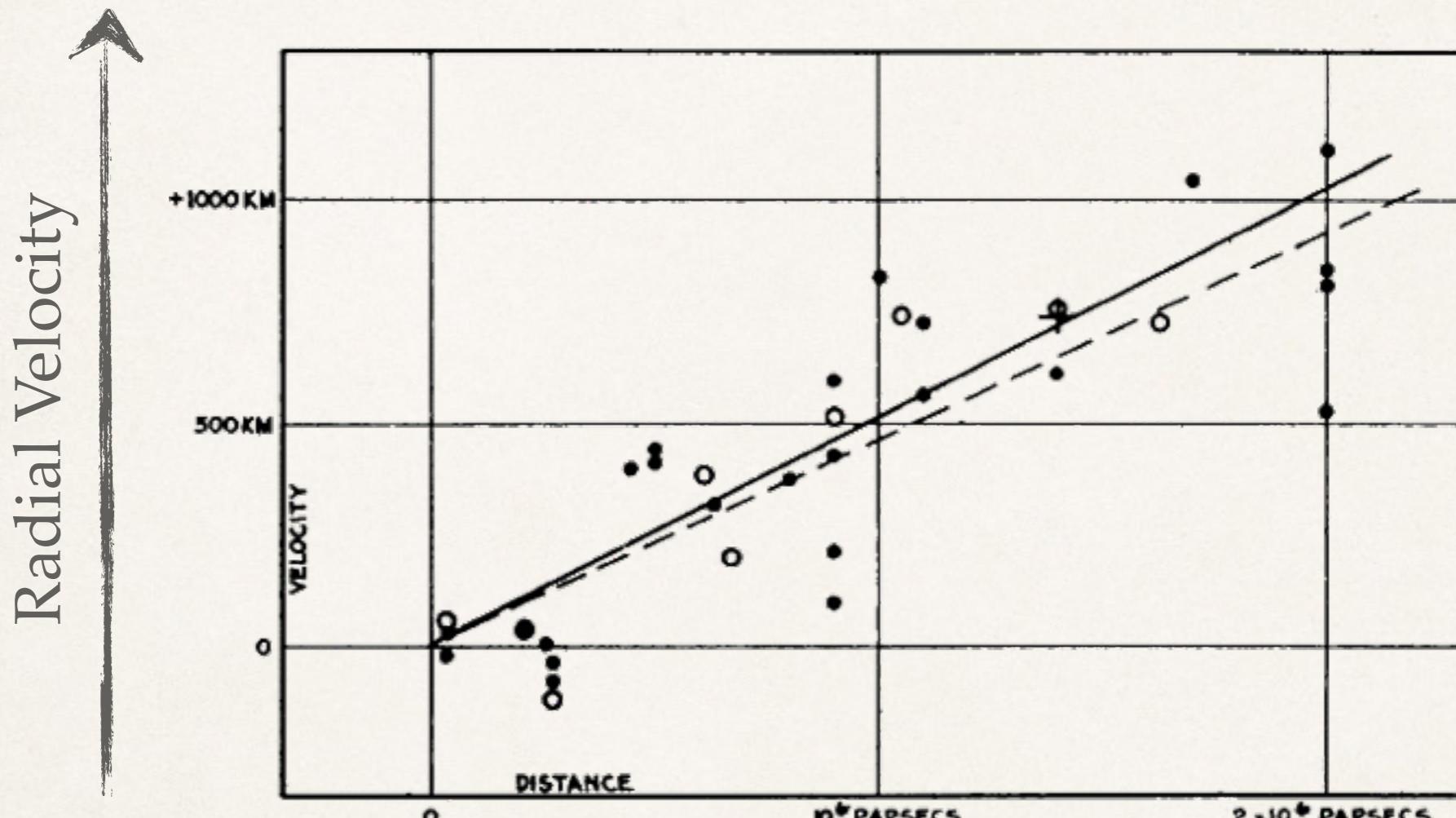
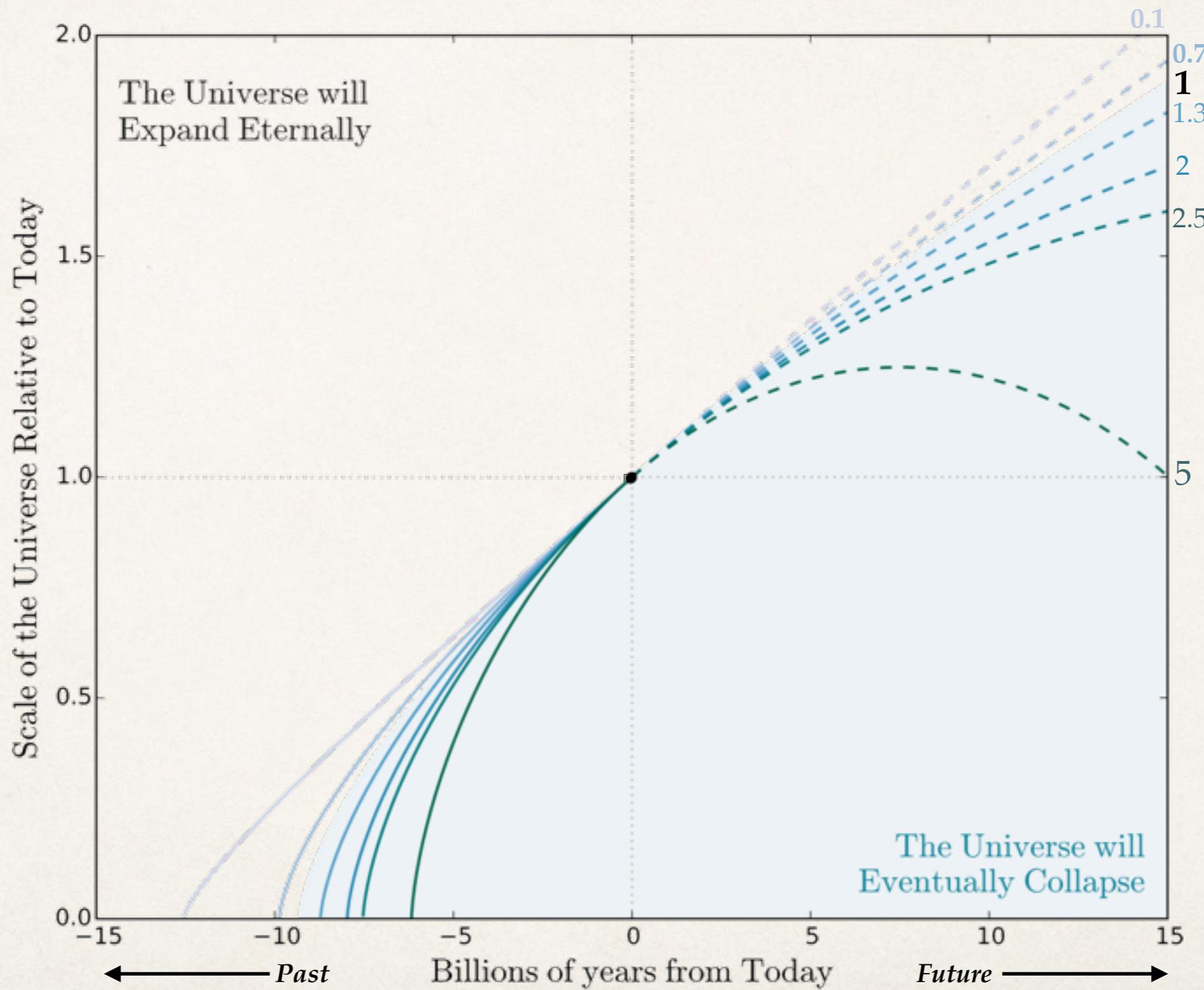


FIGURE 1

Distance from us

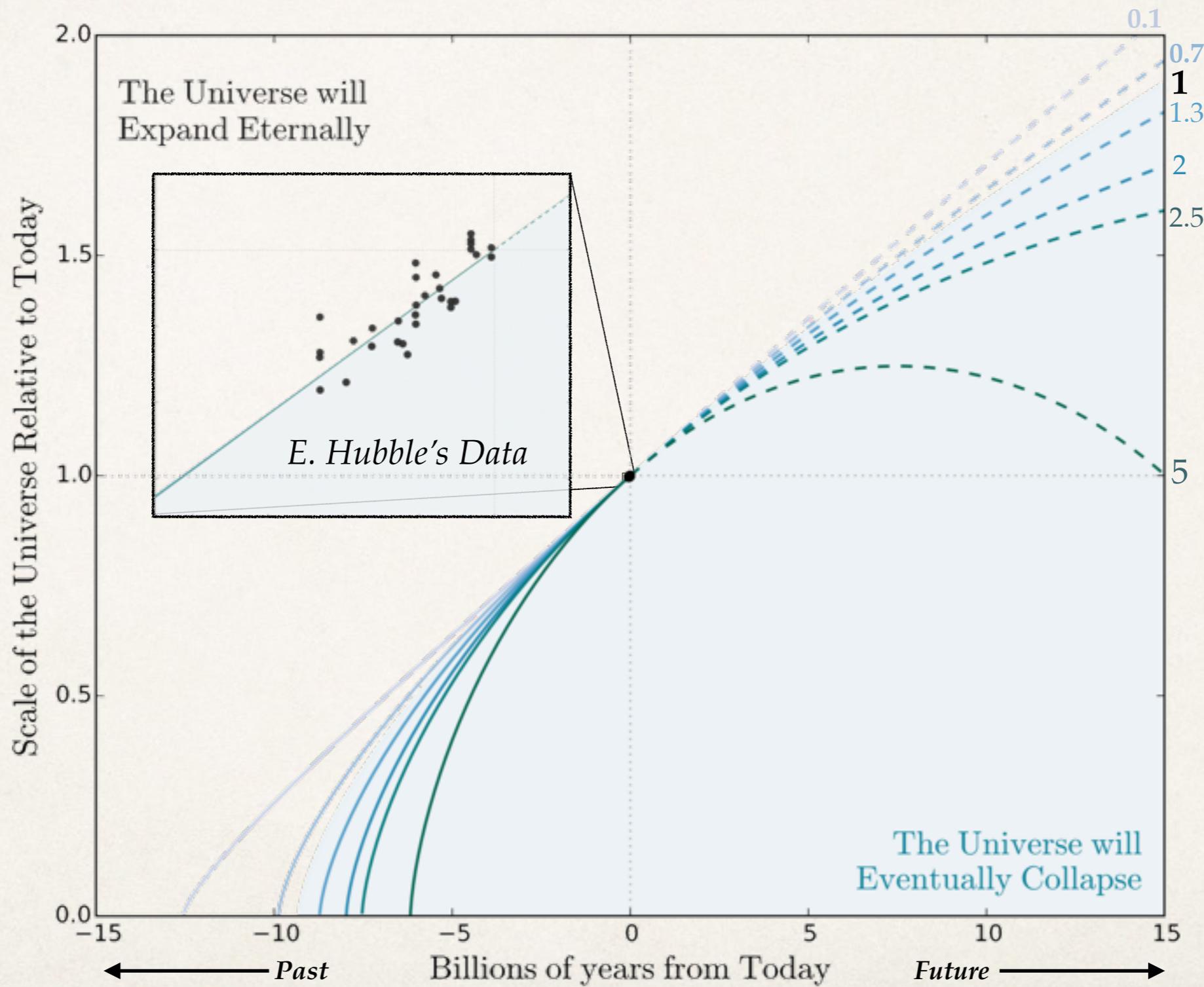
Measuring the Fate of the Universe

Density of the Universe
in « Critical Density »

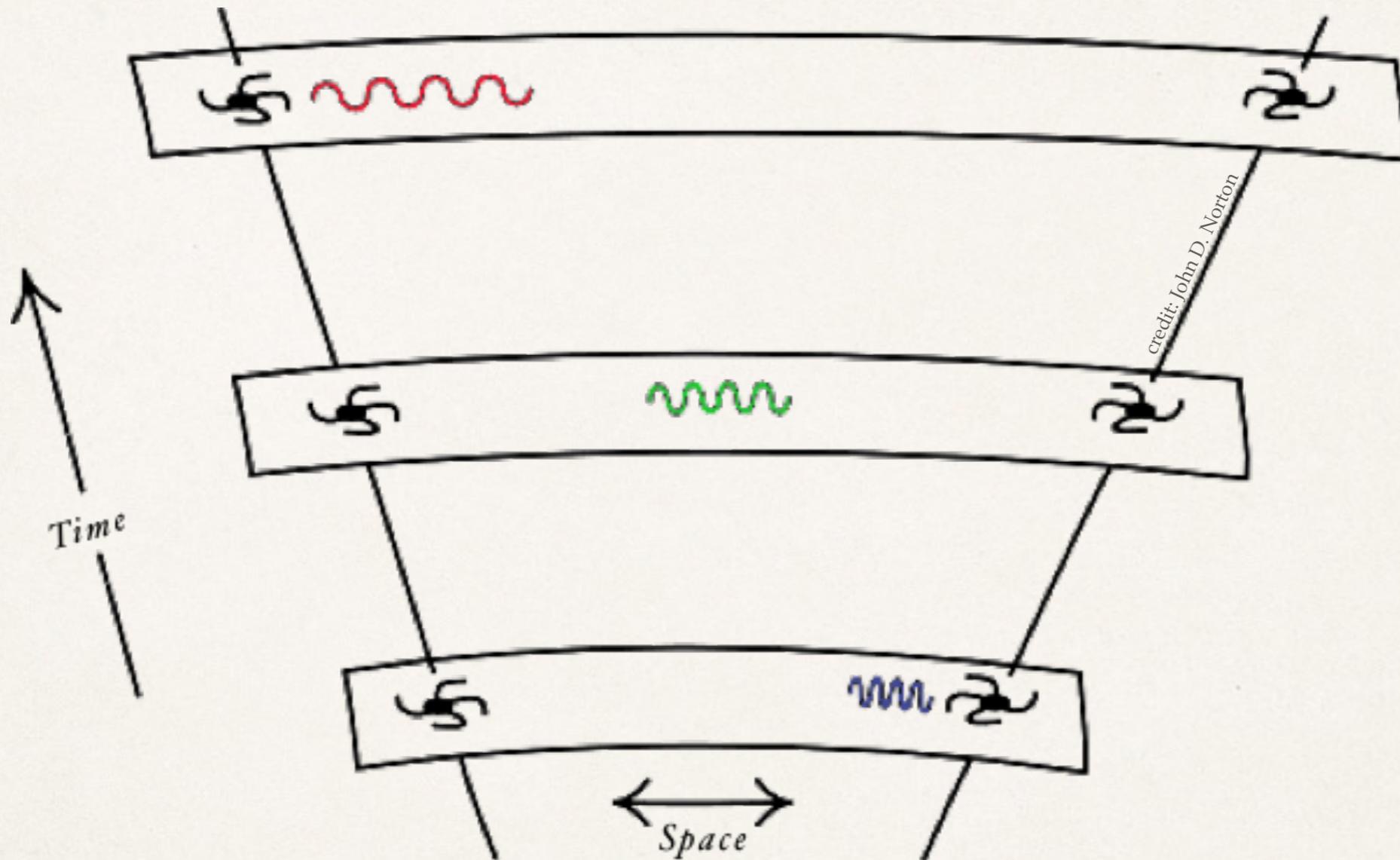


Measuring the Fate of the Universe

Density of the Universe
in « Critical Density »



The Redshift as an Expansion Tracer



The expansion of the Universe stretches the photon's wavelength

Type Ia Supernovae: Standard Candles

Flux \Leftrightarrow Distance



As bright as a galaxy for few days

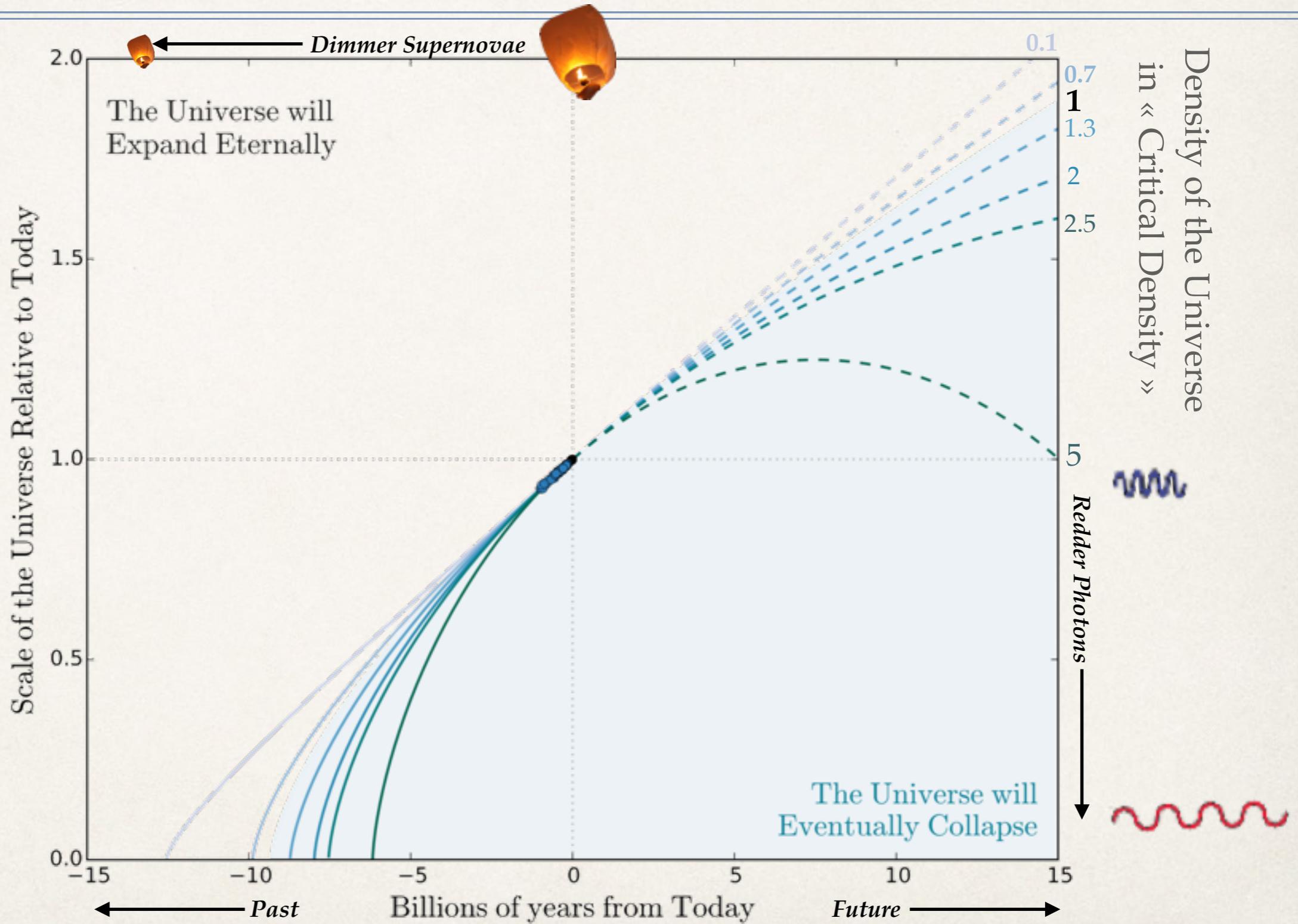


Artist's Concept

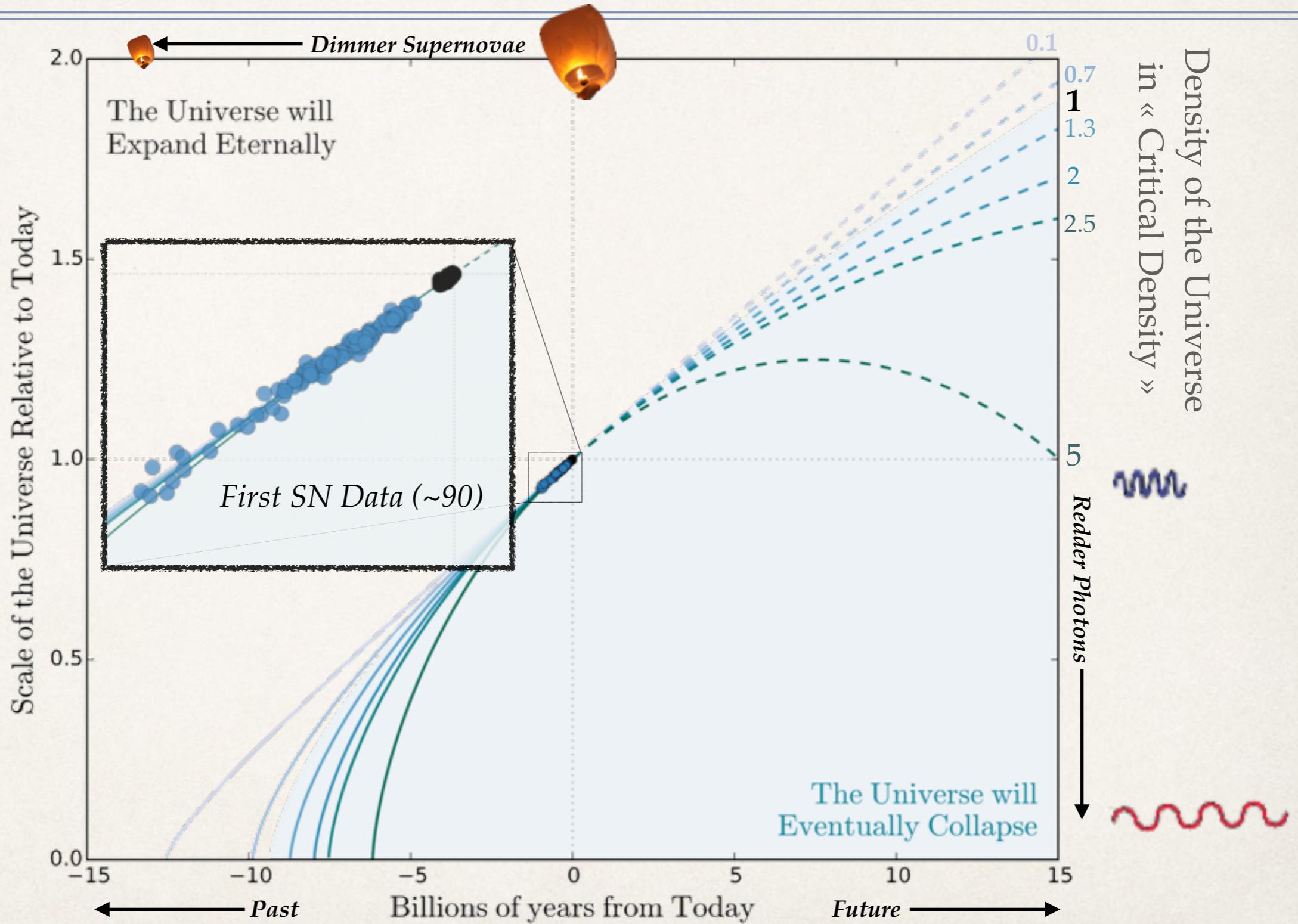


Artist's Concept

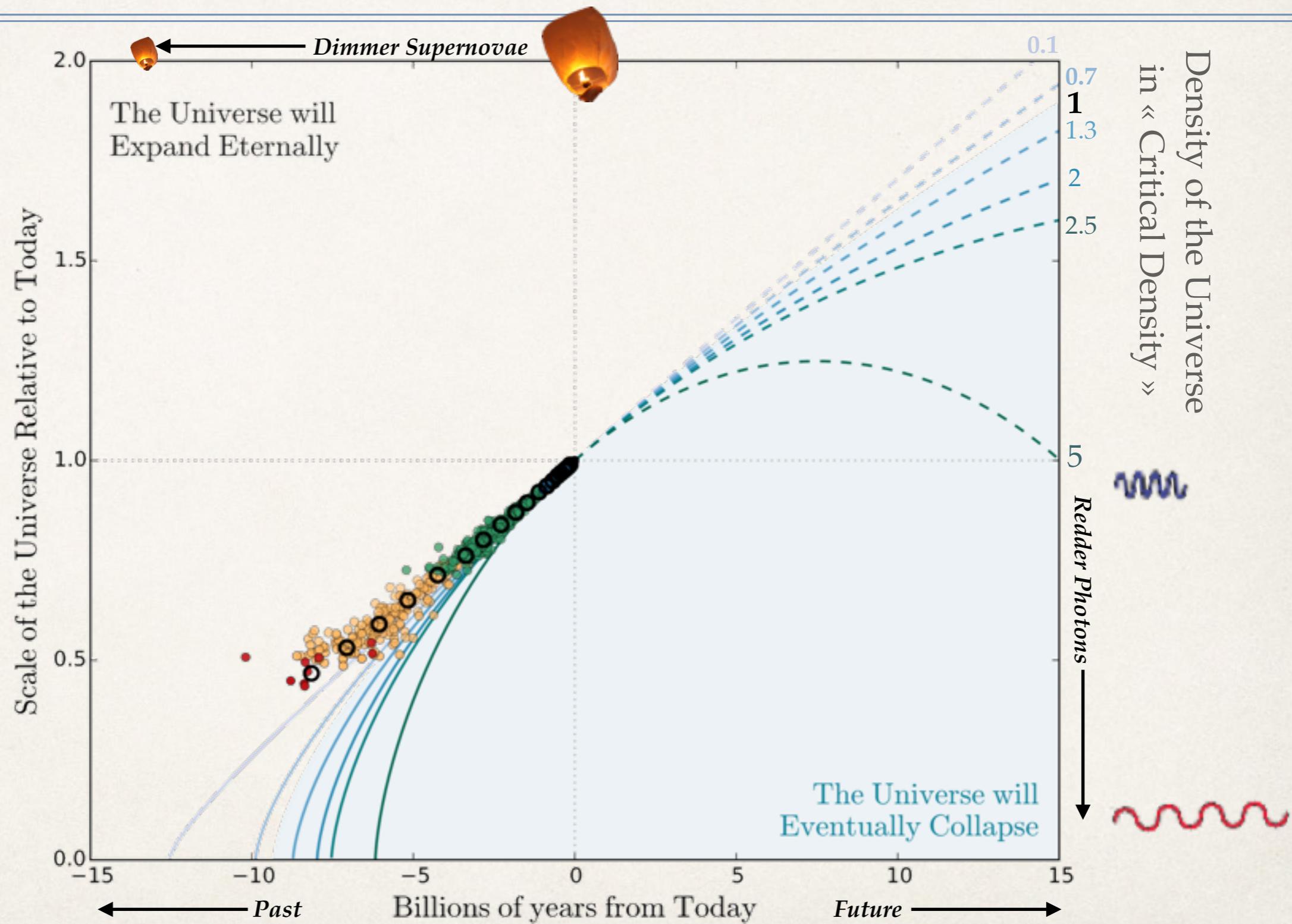
Measuring the Fate of the Universe



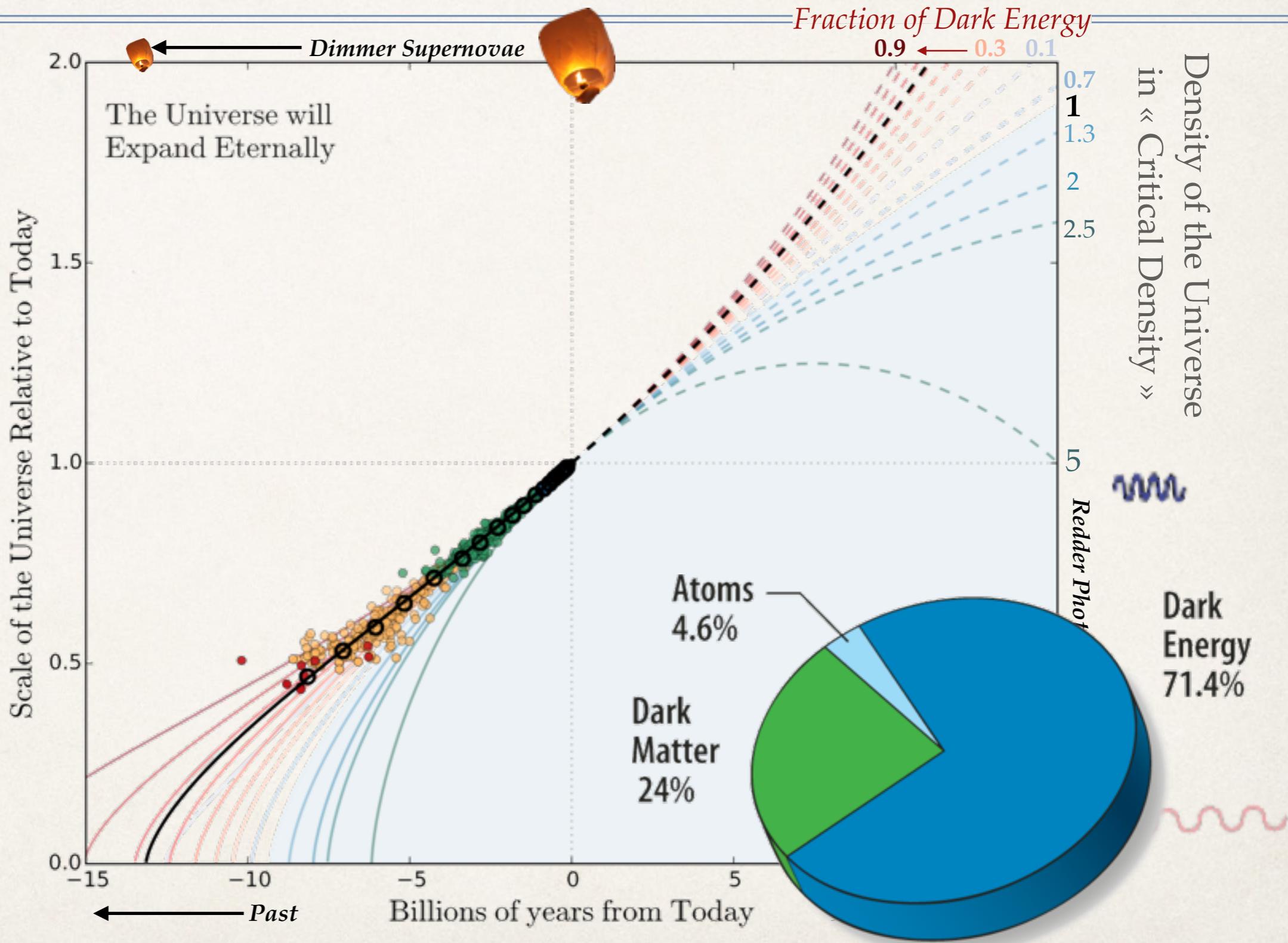
Measuring the Fate of the Universe



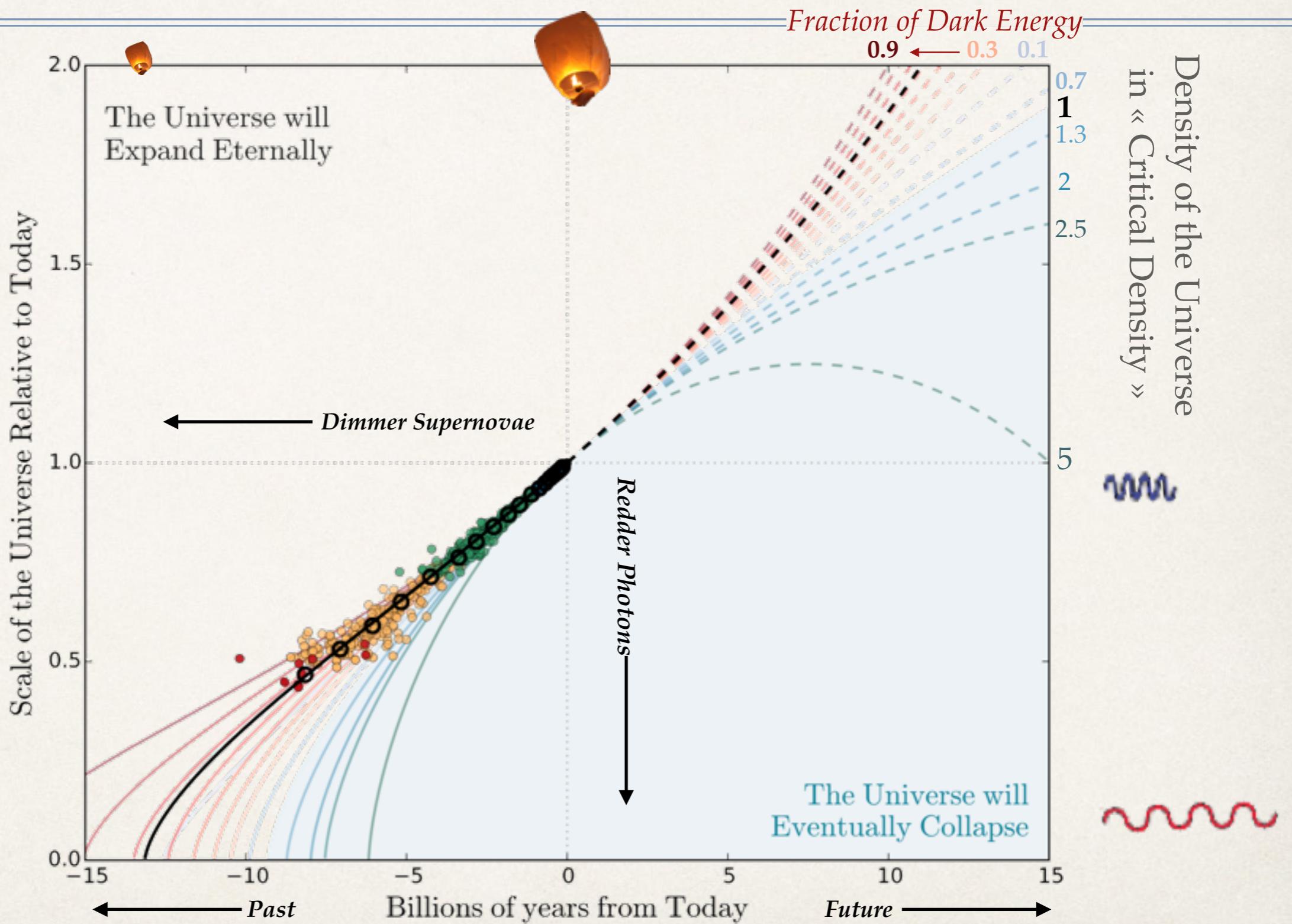
The Data do not match the Predictions



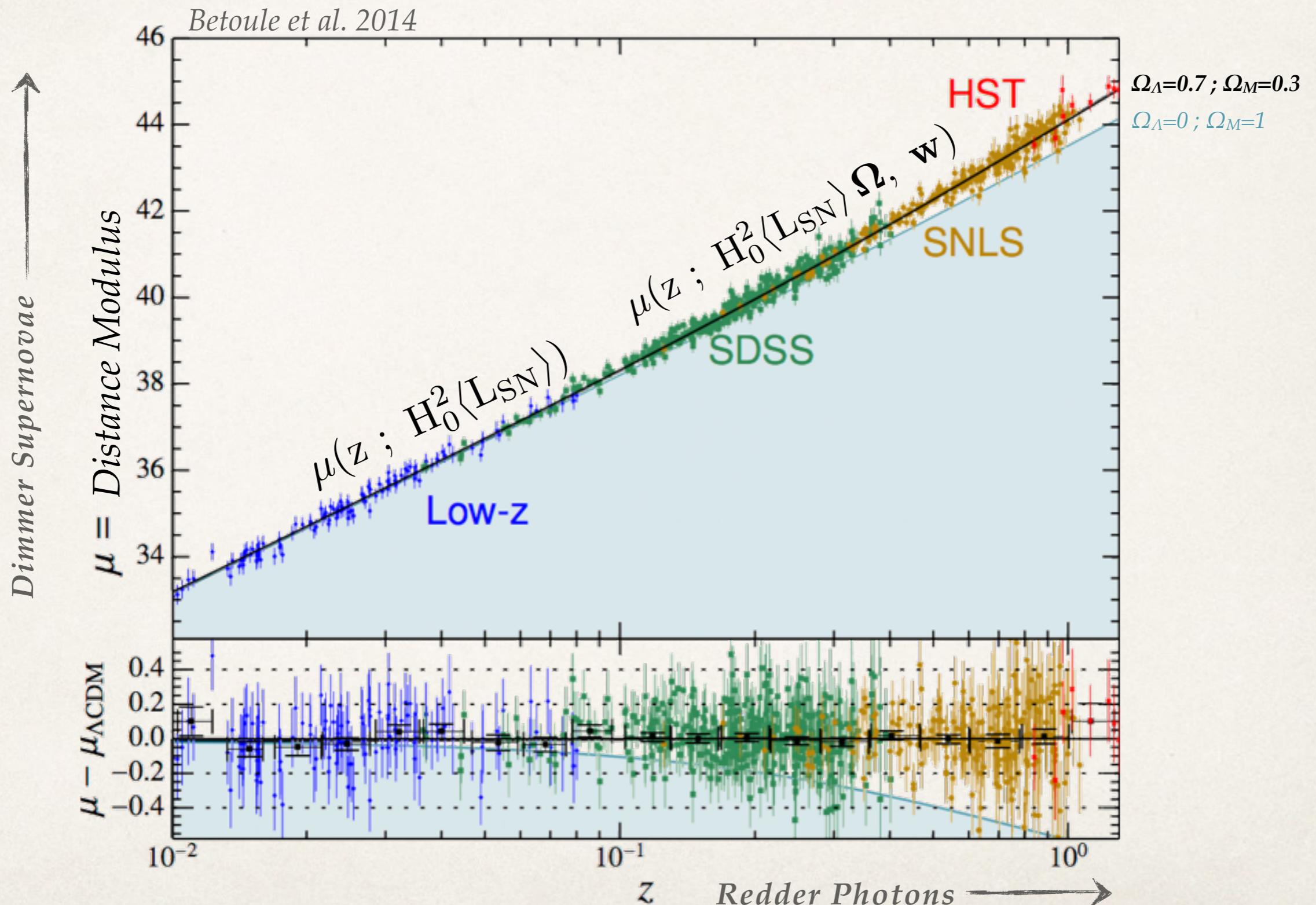
The Universe's Expansion is Accelerating !



Study the Acceleration

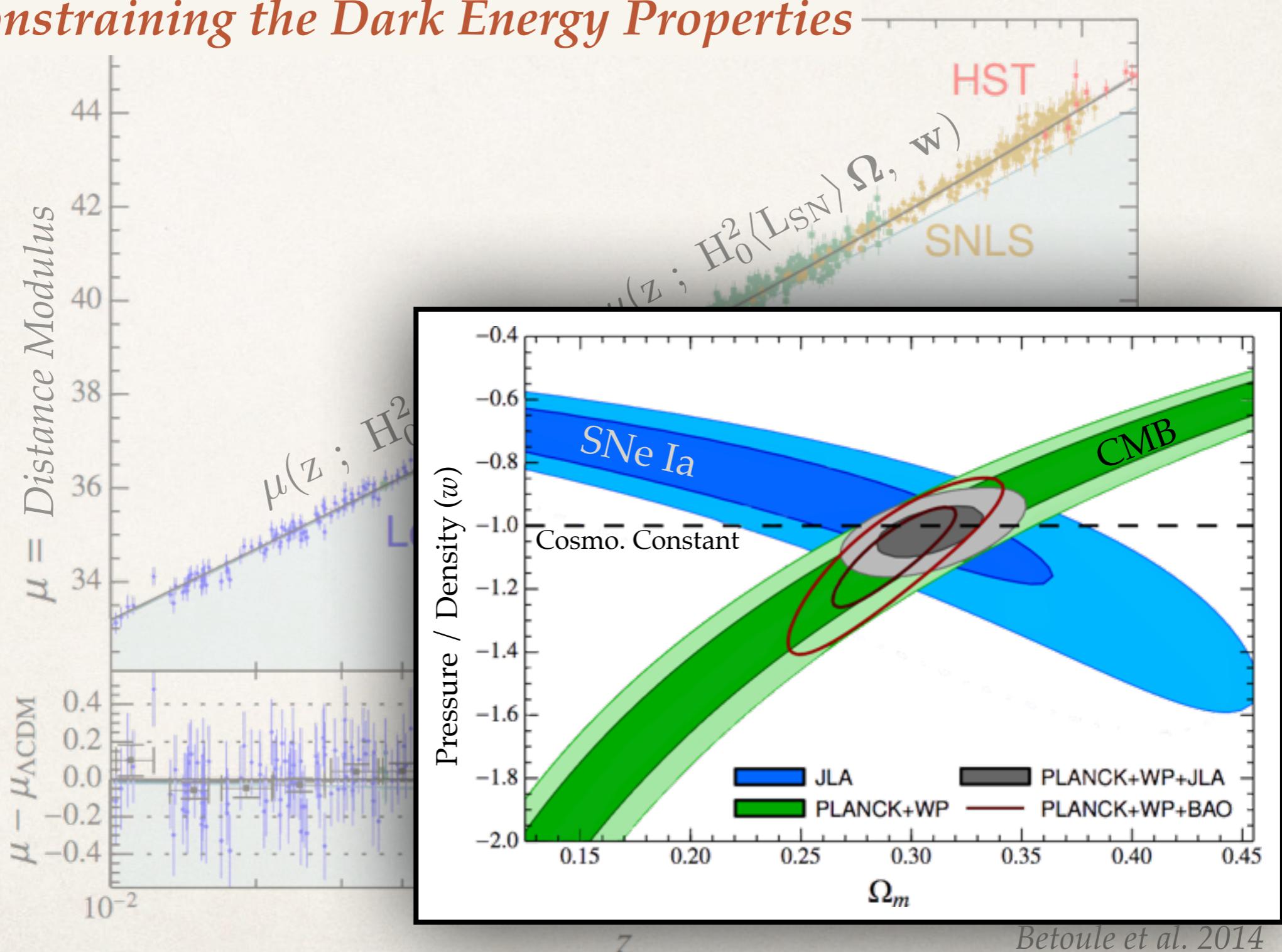


Cosmology using Type Ia Supernovae



Cosmology using Type Ia Supernovae

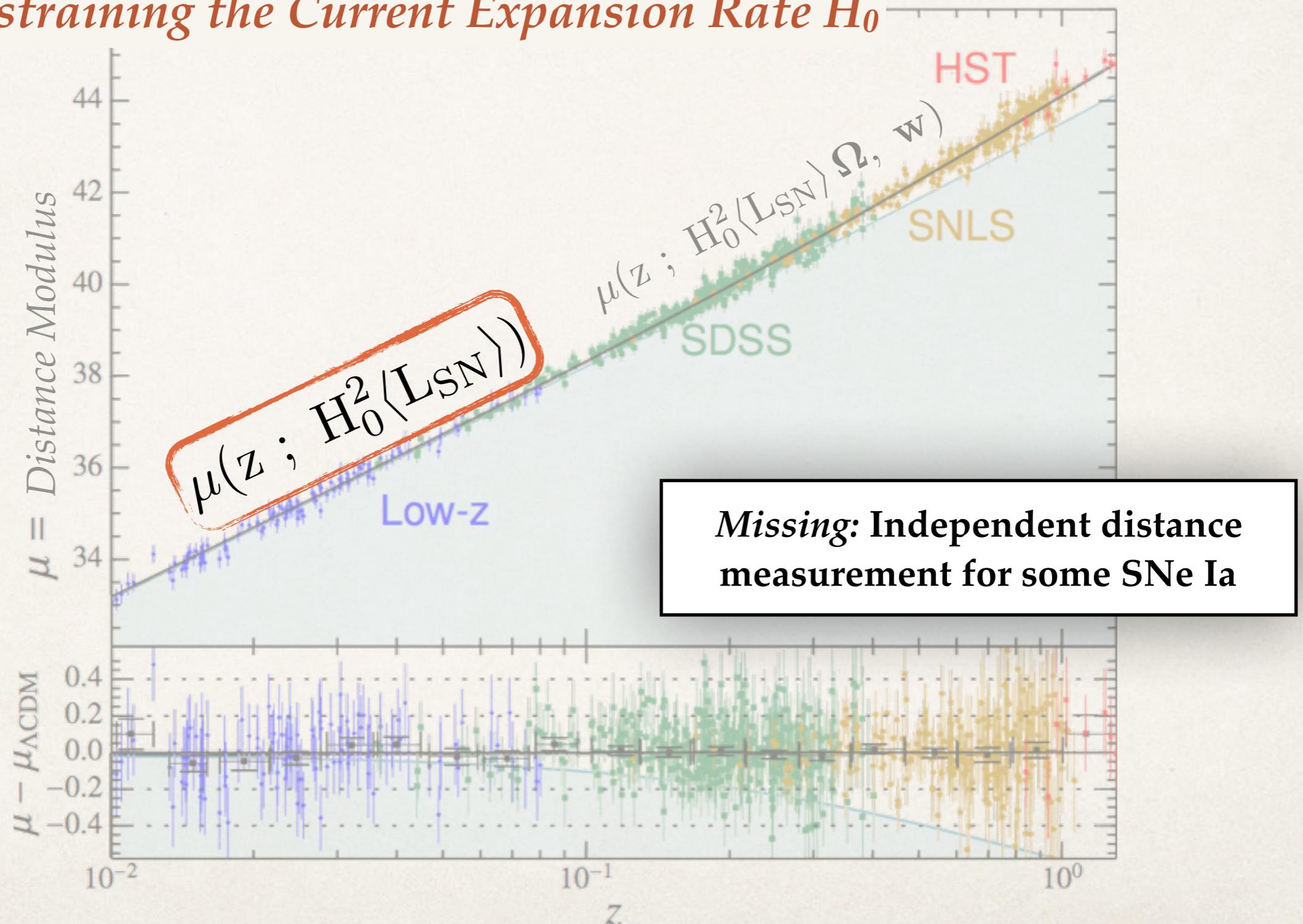
Constraining the Dark Energy Properties



Betoule et al. 2014

Cosmology using Type Ia Supernovae

Constraining the Current Expansion Rate H_0

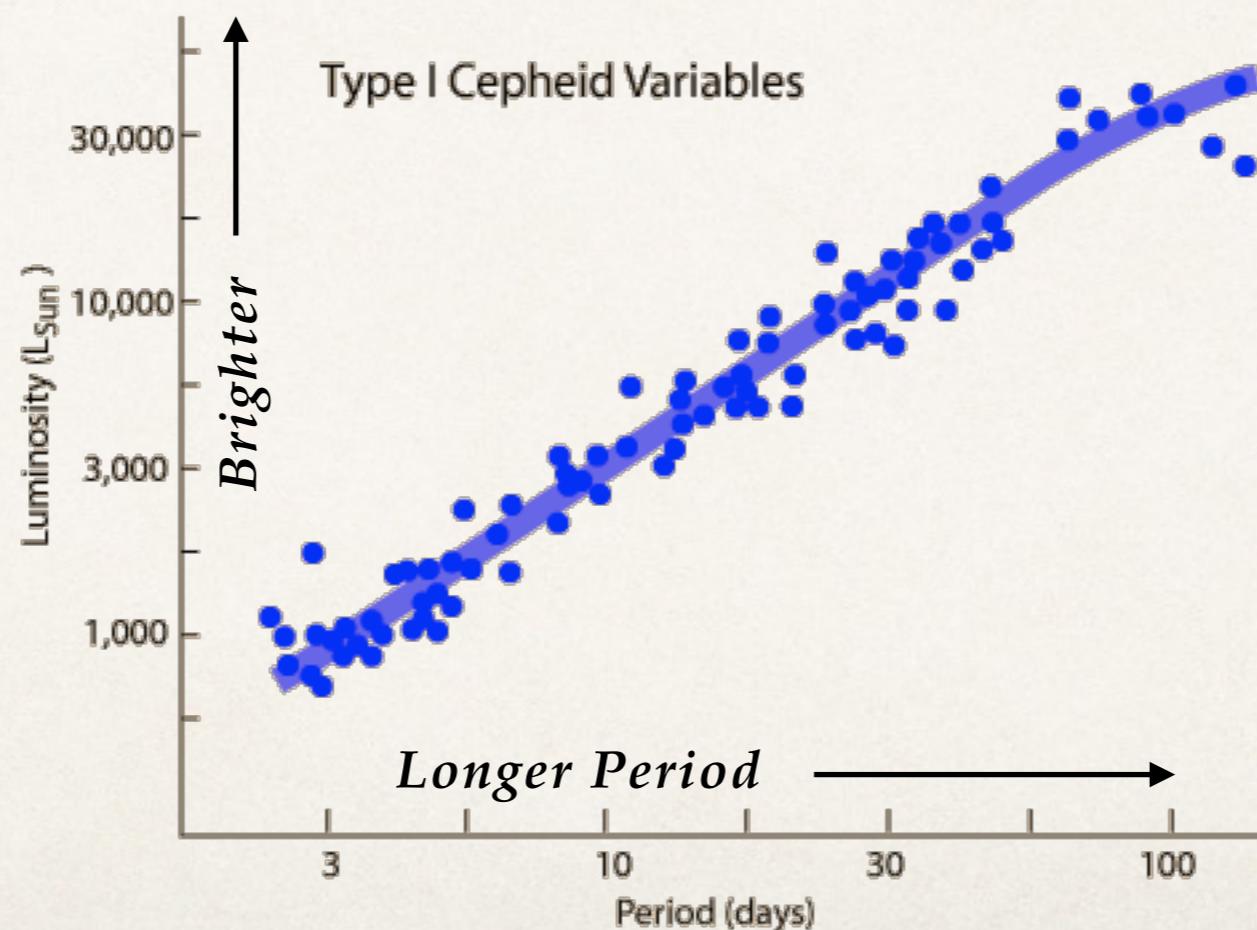


Disentangle H_0 and the SN luminosity

Independent distance measurement for some SNe Ia

Best case: Cepheids

Cepheids: Bright Young Stars with a *Pulsation – Luminosity relation*

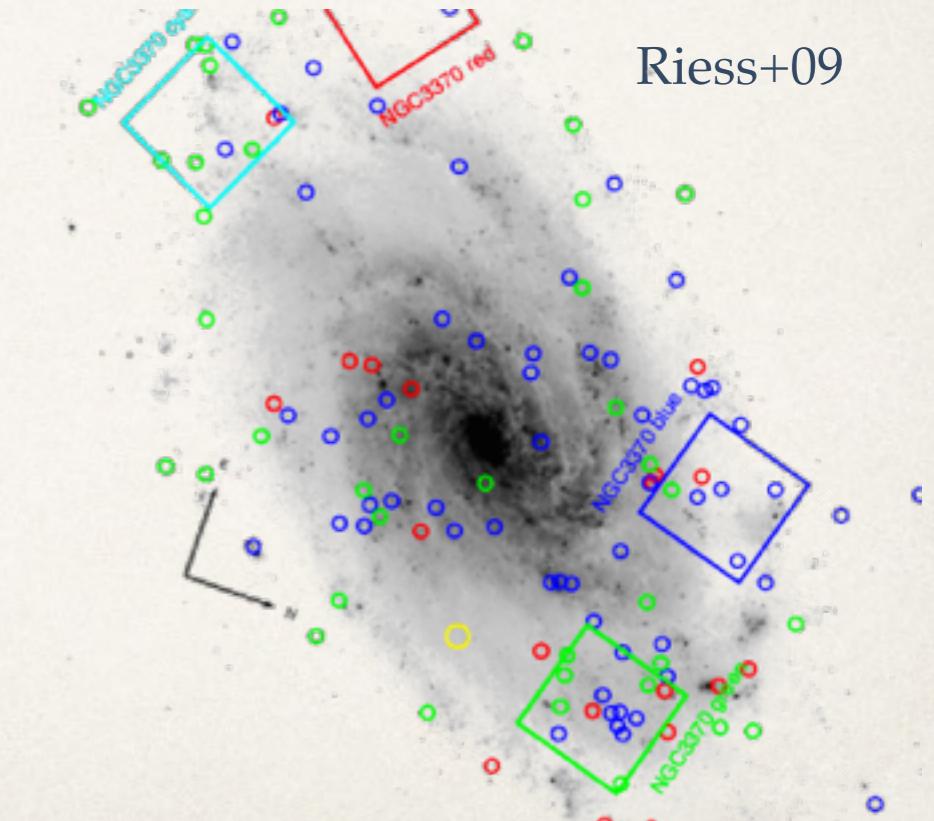
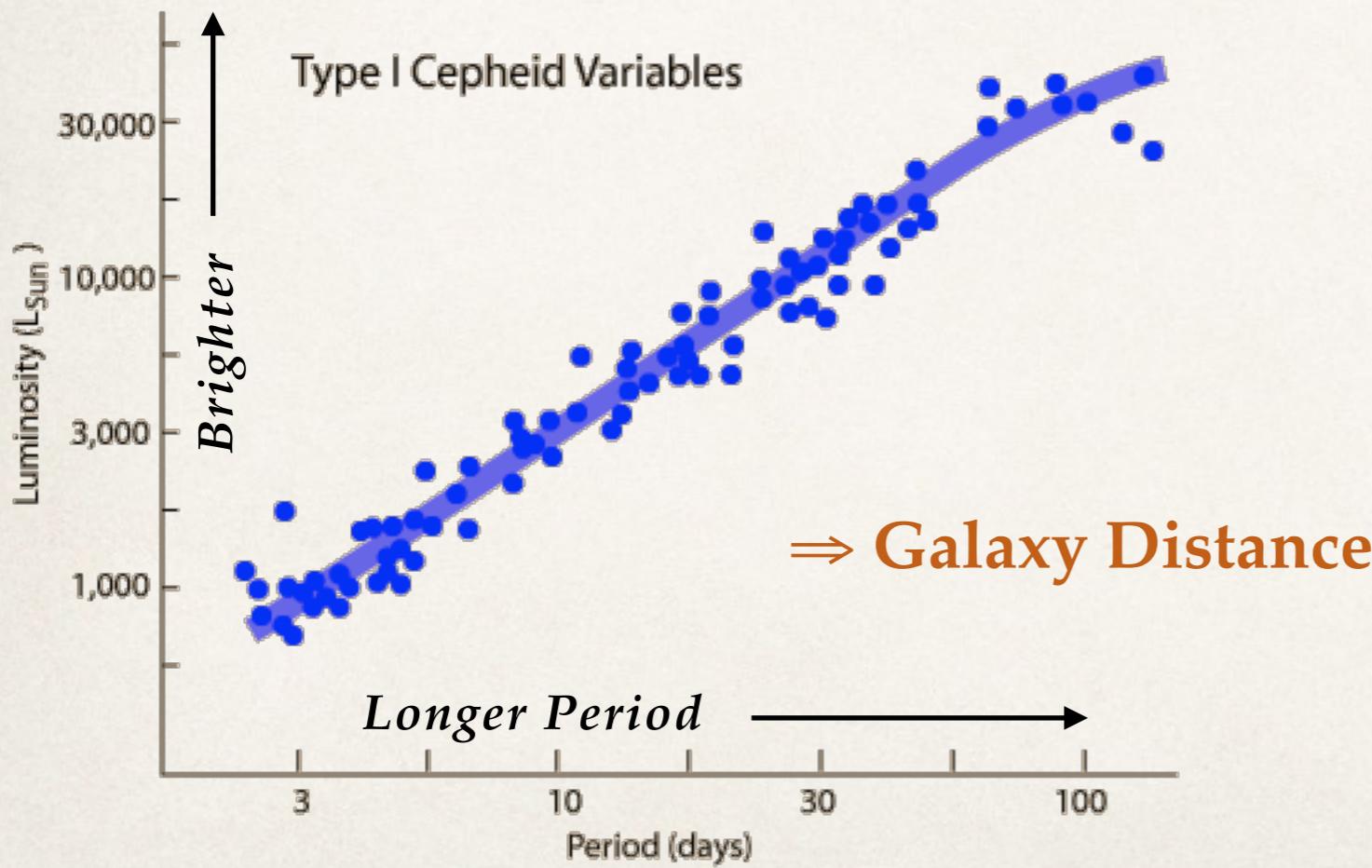


Disentangle H_0 and the SN luminosity

Independent distance measurement for some SNe Ia

Best case: Cepheids

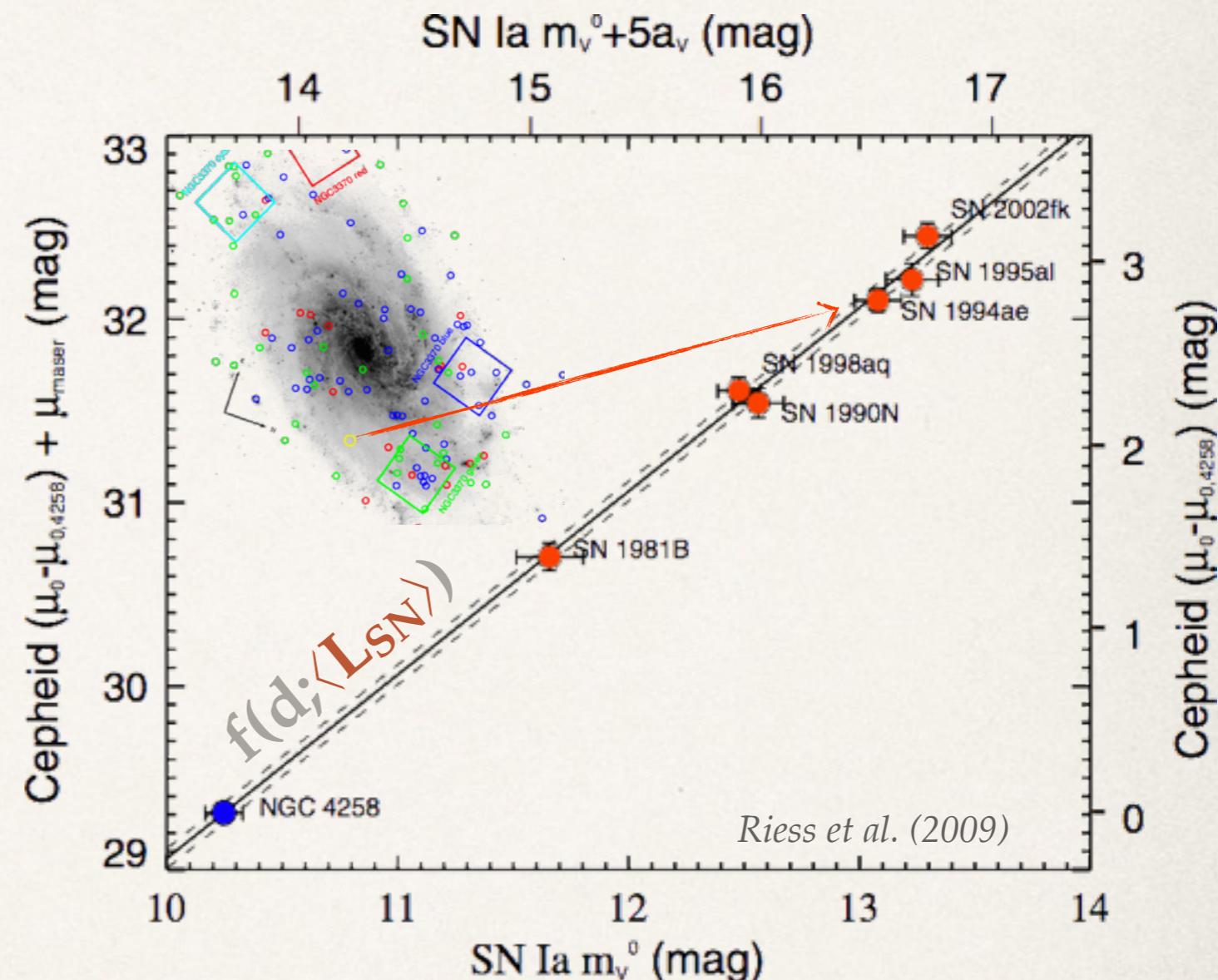
Cepheids: Bright Young Stars with a Pulsation–Luminosity relation



Disentangle H_0 and the SN luminosity

Independent Distance Measurement
— Distance & Flux \Rightarrow Luminosity —

*Cepheids: Bright young stars
with a pulsation-luminosity
relation*

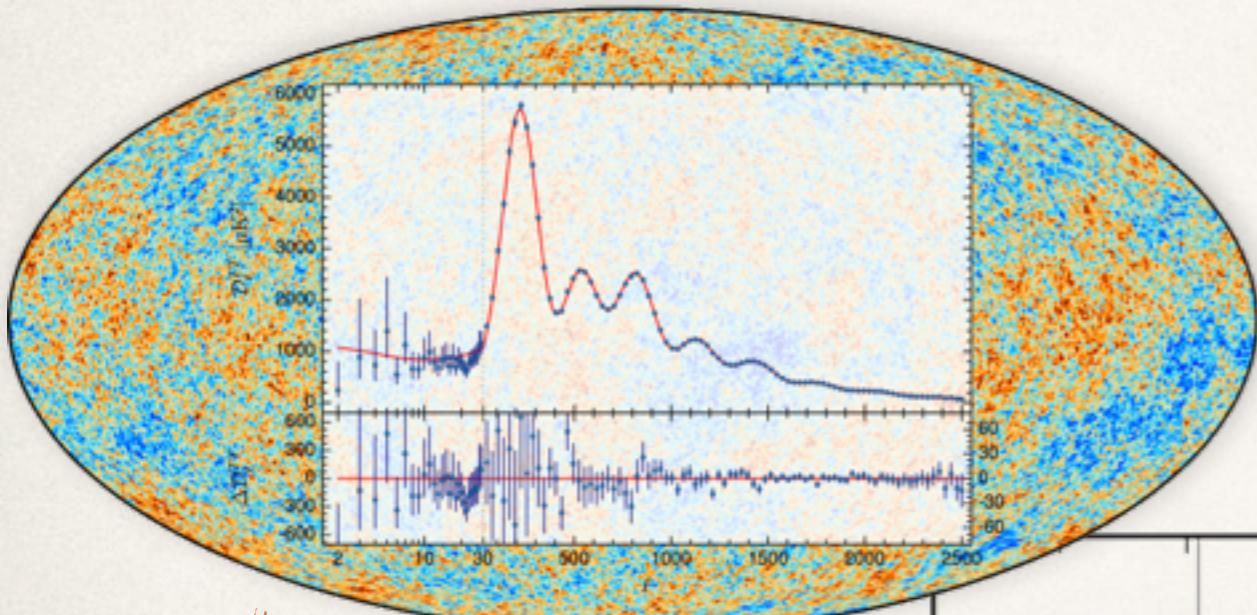


$$H_0 = 73.2 \pm 1.8 \text{ km s}^{-1} \text{ Mpc}^{-1}$$

(2.5% ; Riess et al 2016)

The Hubble Constant

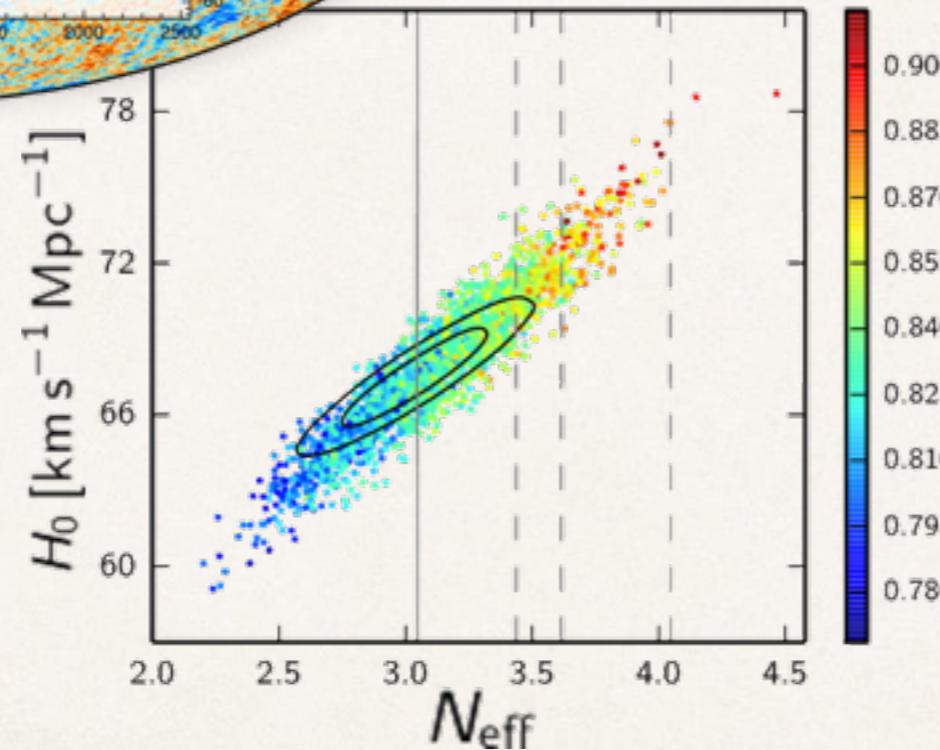
Planck 2015 – Cosmological Results



$z \sim 1000$

**THE MODEL
CONSTRAINS H_0**

$z \sim 0$

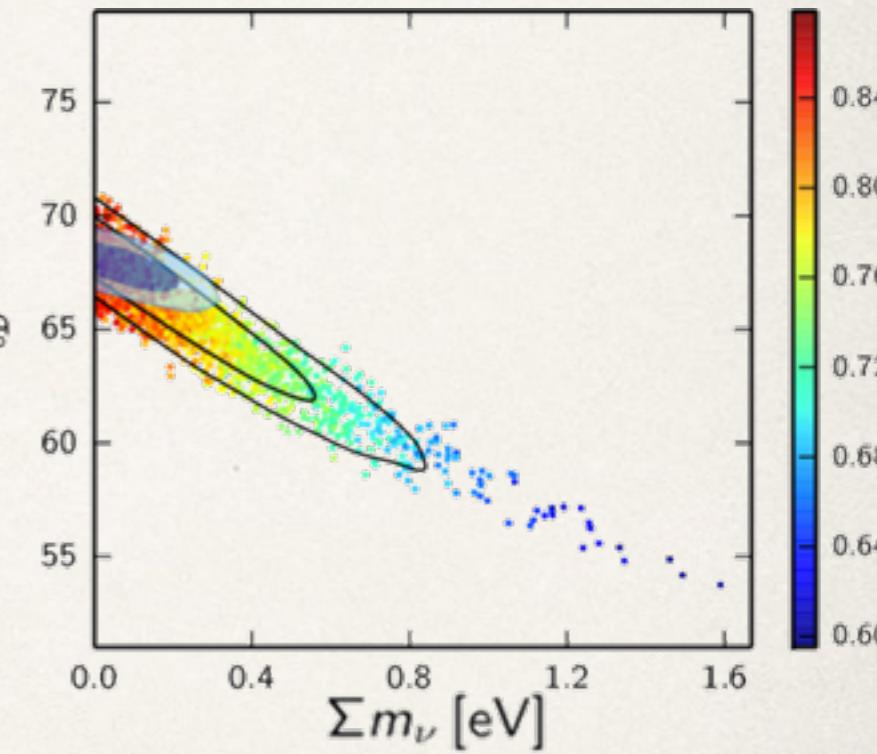


$$H_0 = 67.8 \pm 0.9 \text{ km s}^{-1} \text{ Mpc}^{-1}$$

— Derived —

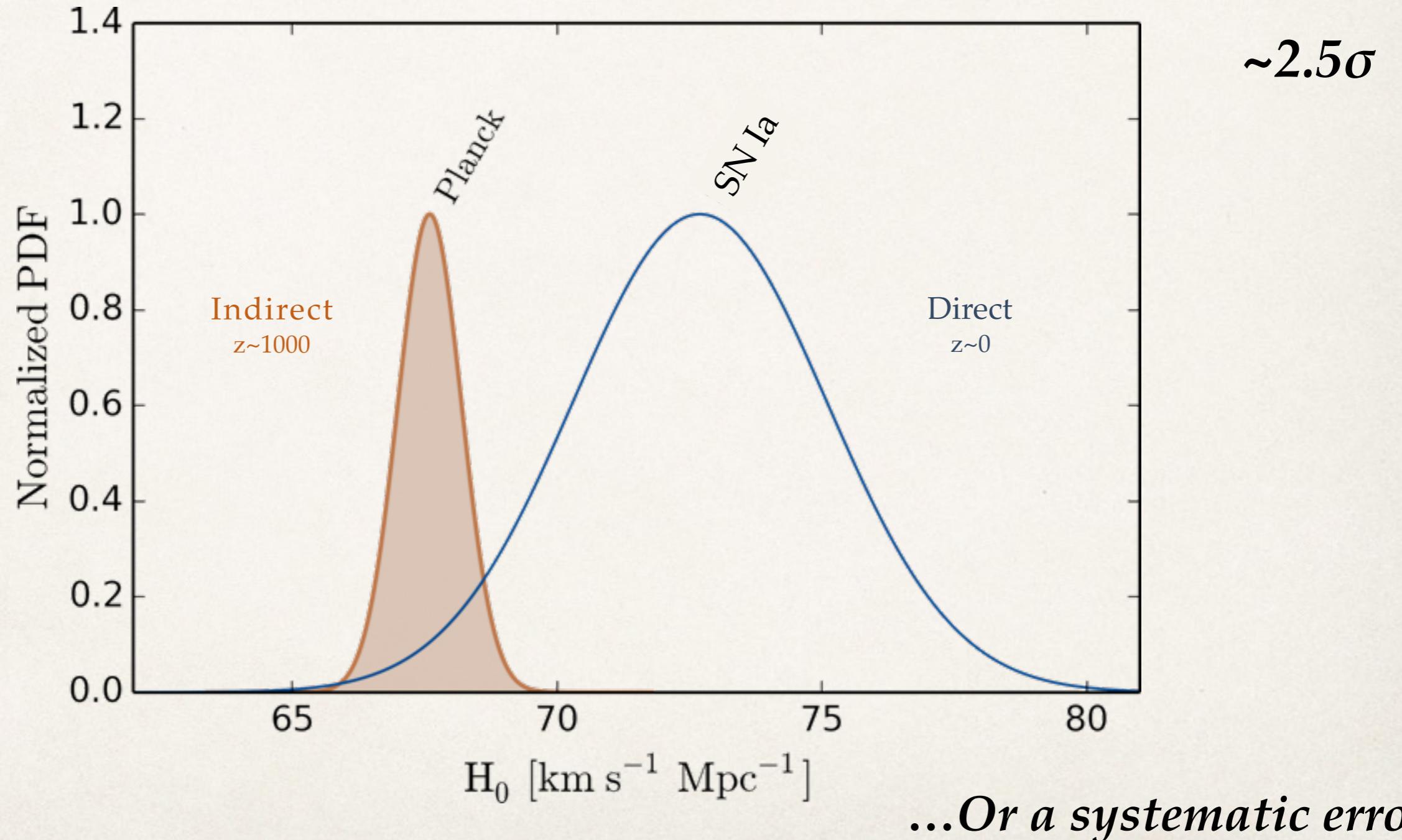
*Test the Standard Model
of Cosmology*

Change the model, change H_0



Tension in the Standard Model of Cosmology

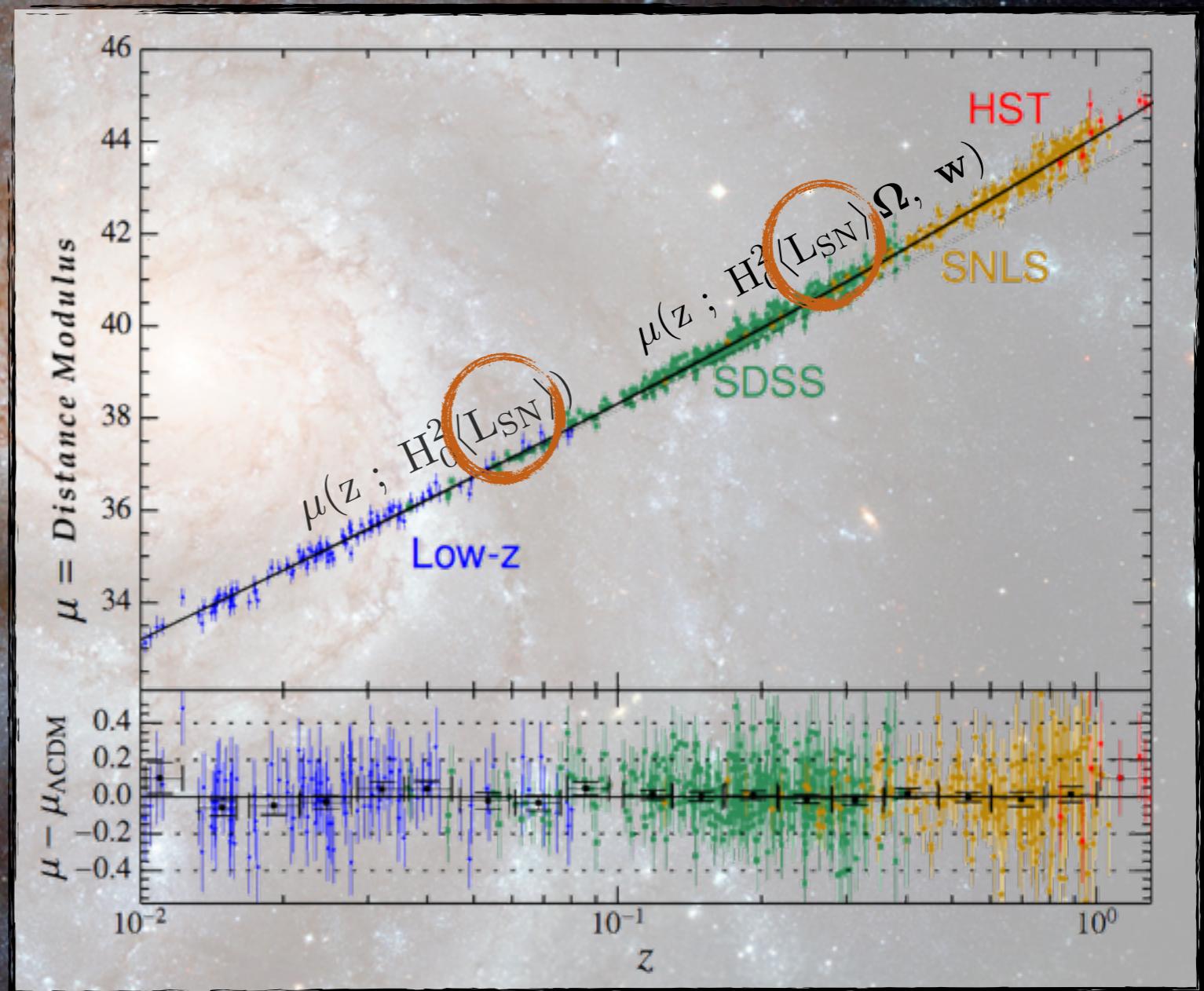
Could it be an indication for a new (massless) particle ?



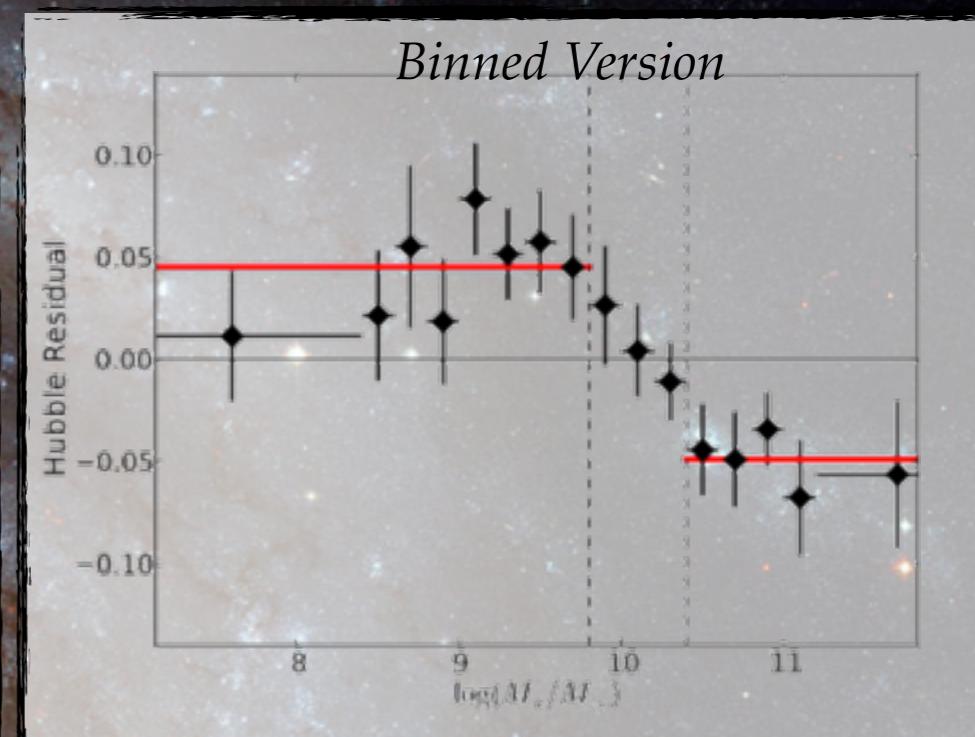
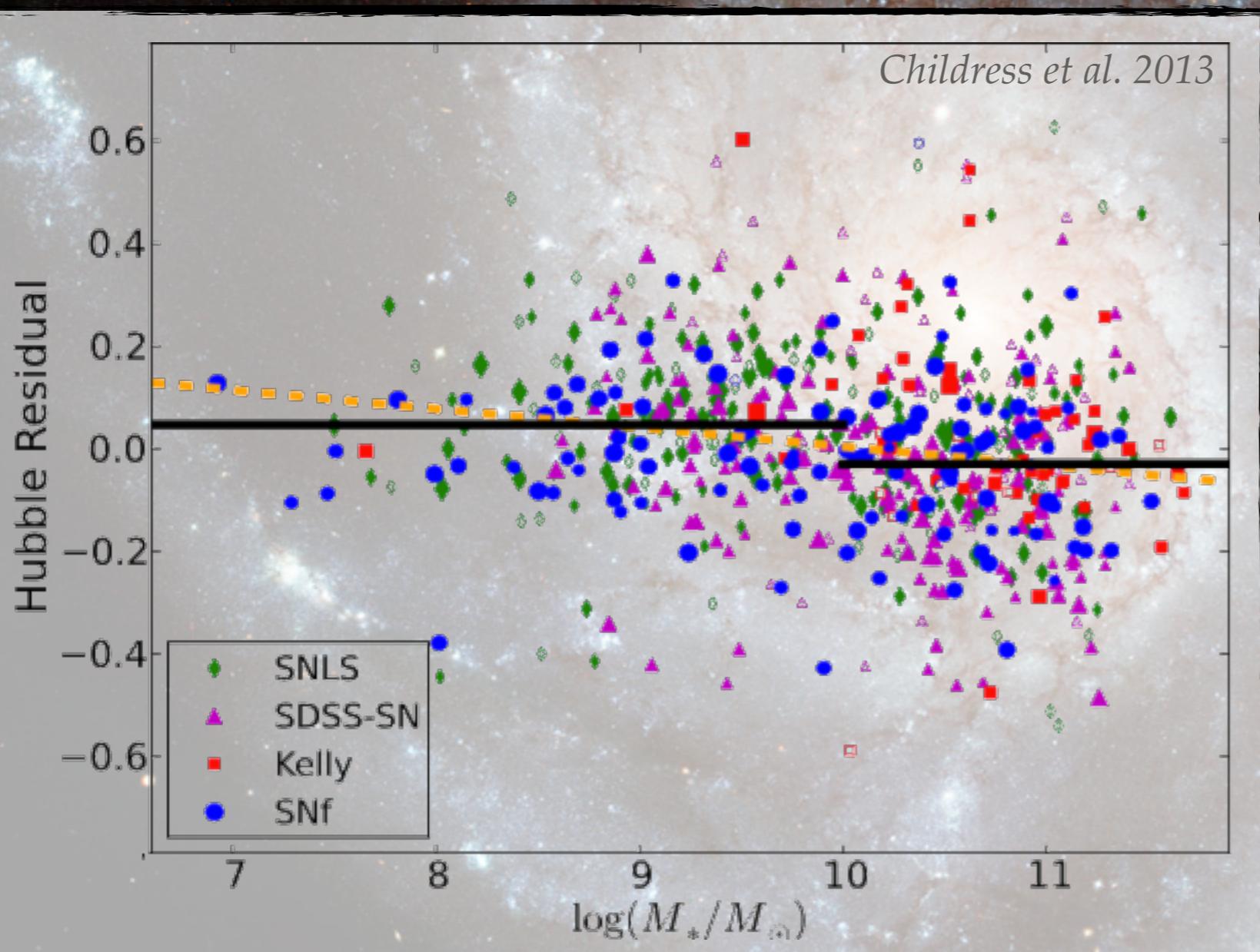
Precise Astrophysics for Accurate Cosmology



Potential Astrophysical Biases of SNe Ia



The first observed effect: The Mass Step



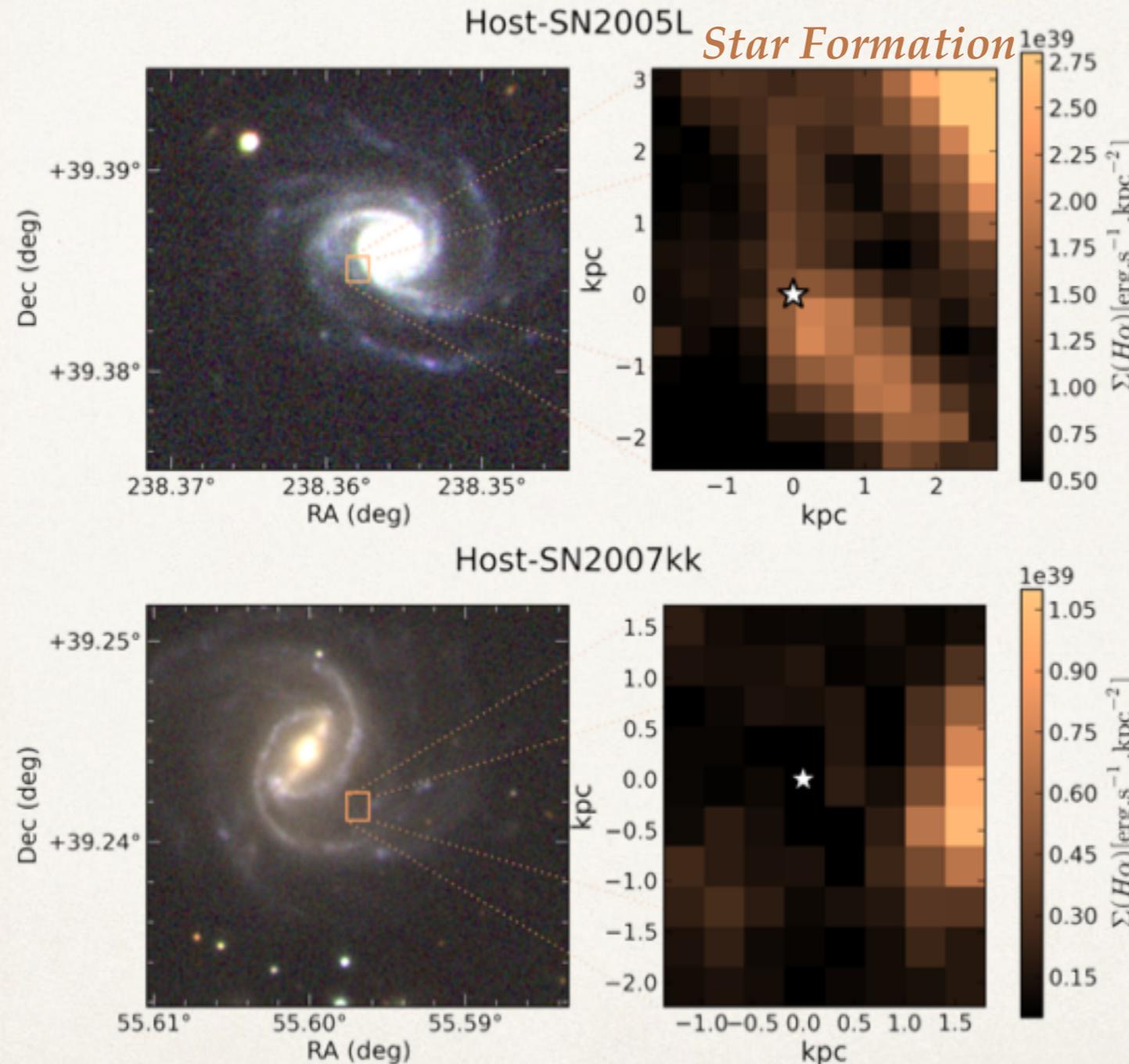


The Local Perspective

Rigault et al. 2013

GLOBAL

Spiral, Star Forming,
host galaxies



LOCAL

Star Formation

Young Stars

No Star Formation

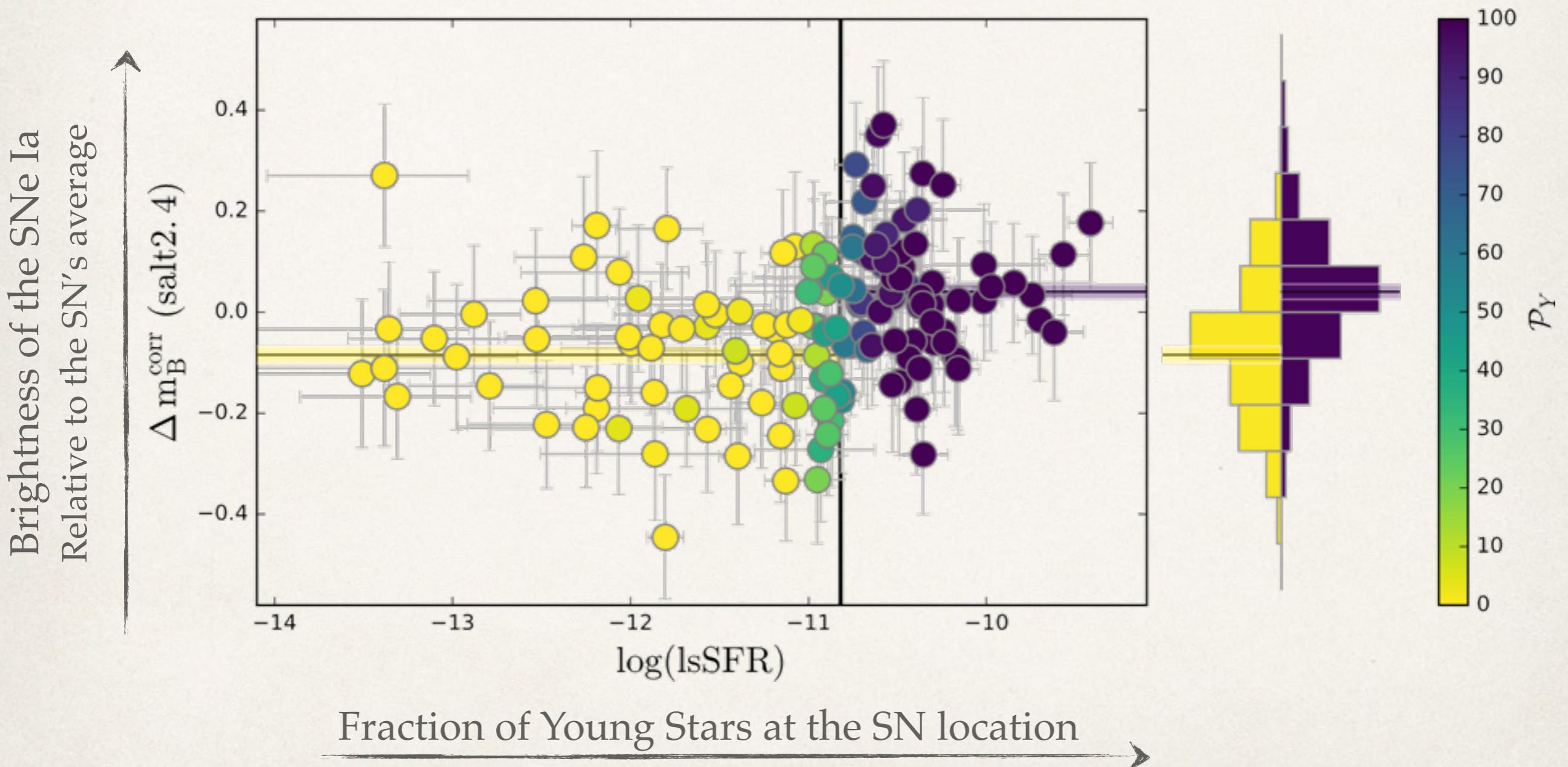
Older Stars

A Star Formation Bias

Rigault et al. 2013, 2015

Rigault et al. 2017

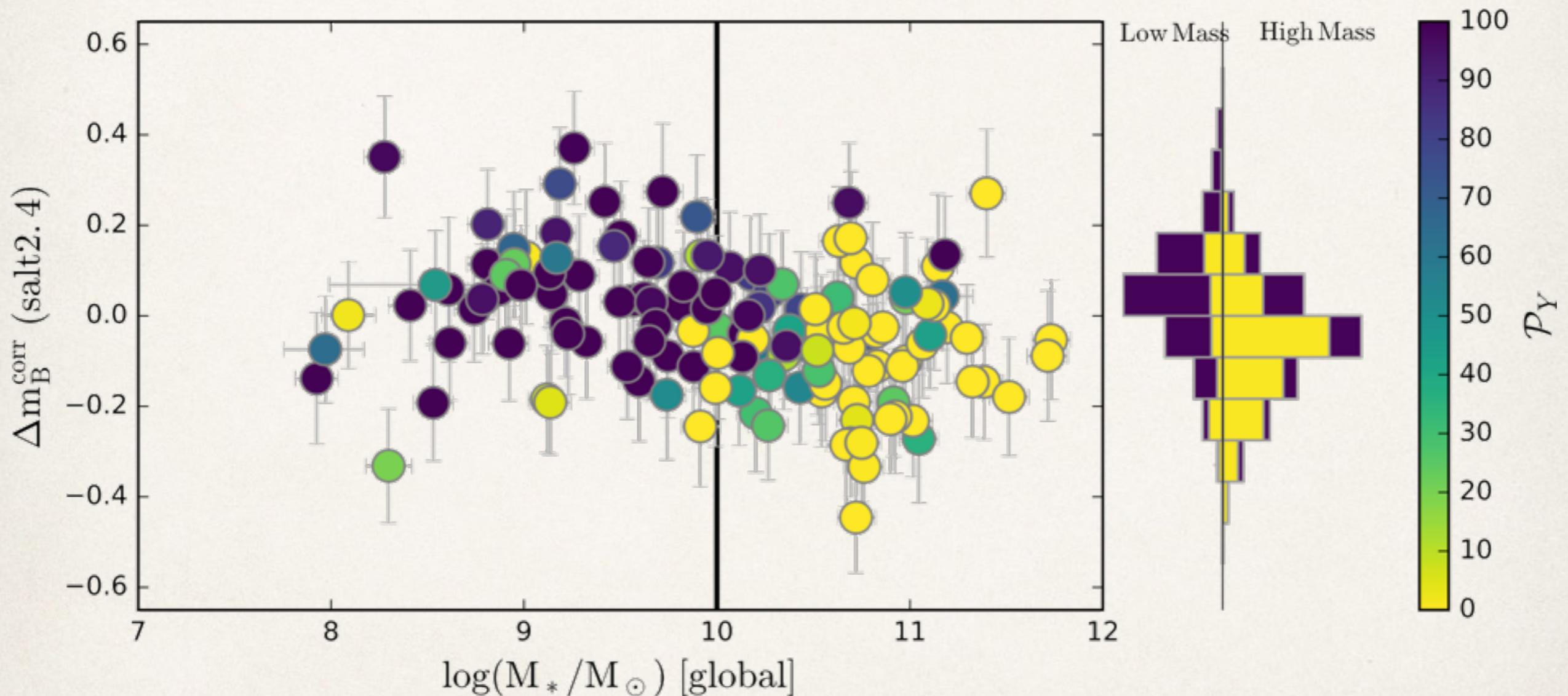
~ 6σ detection level



Explaining the Mass Step

Rigault et al. 2017

More massive galaxies have a lower fraction of young stars



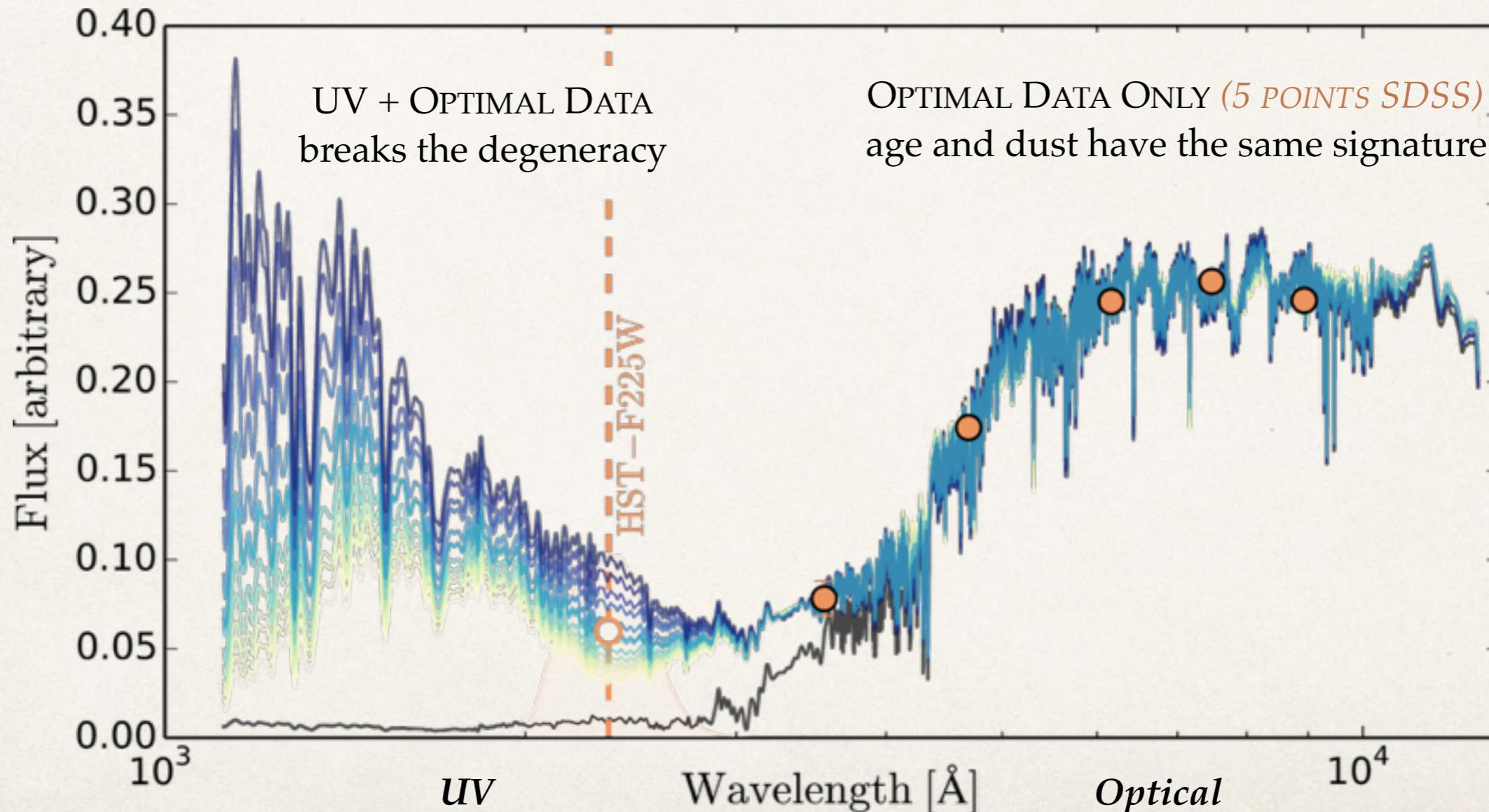
The Next Step

Understand the physical origin of the effects

PI: Rigault ; GO14163

Projet HST GO14163 (PI: Rigault) enables:

- to get the dust extinction along the line of sight
- to get the expected age of the progenitor

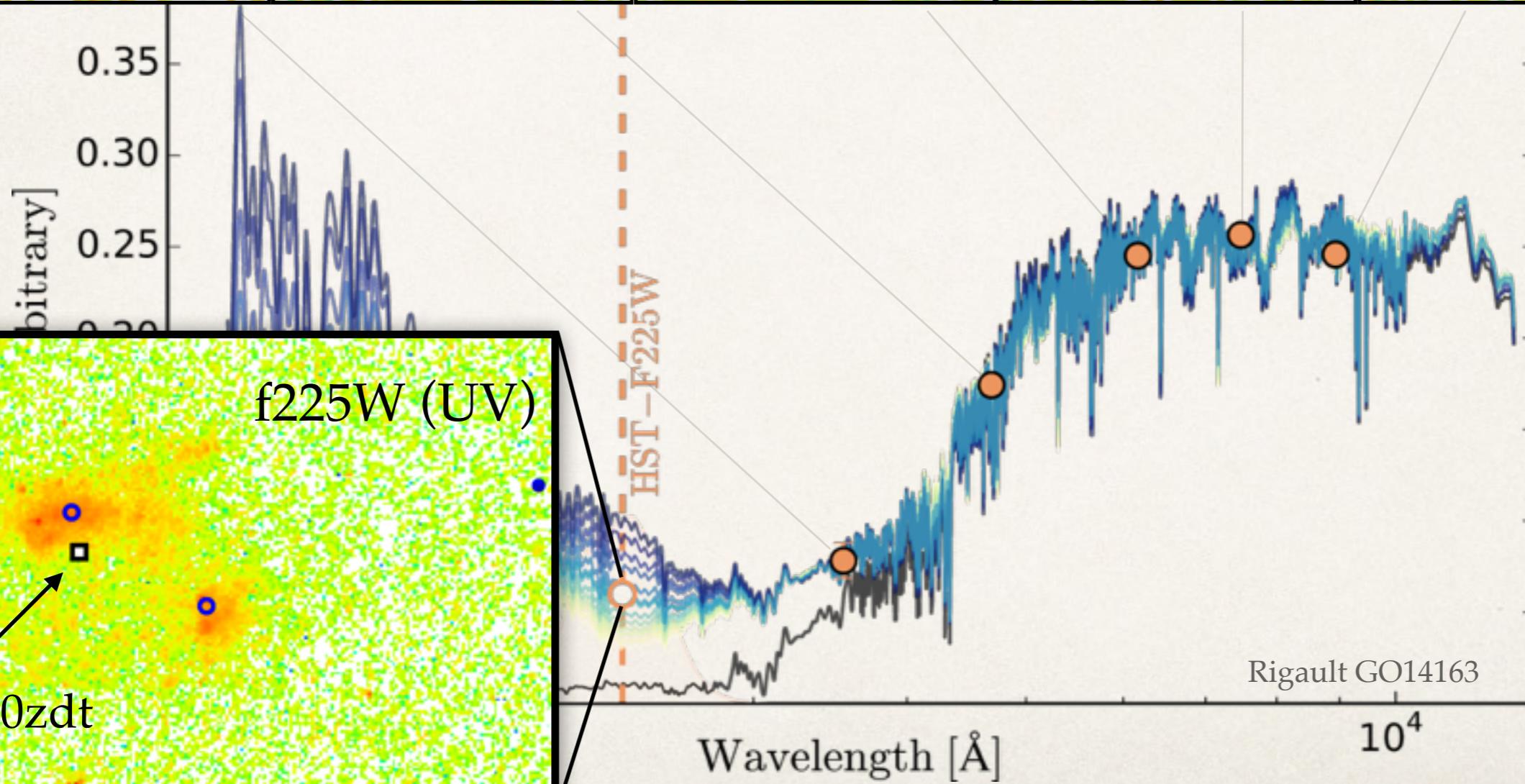
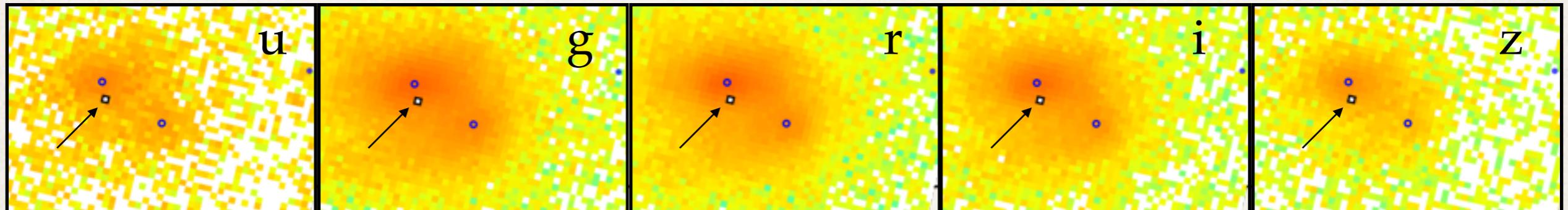


The Next Step

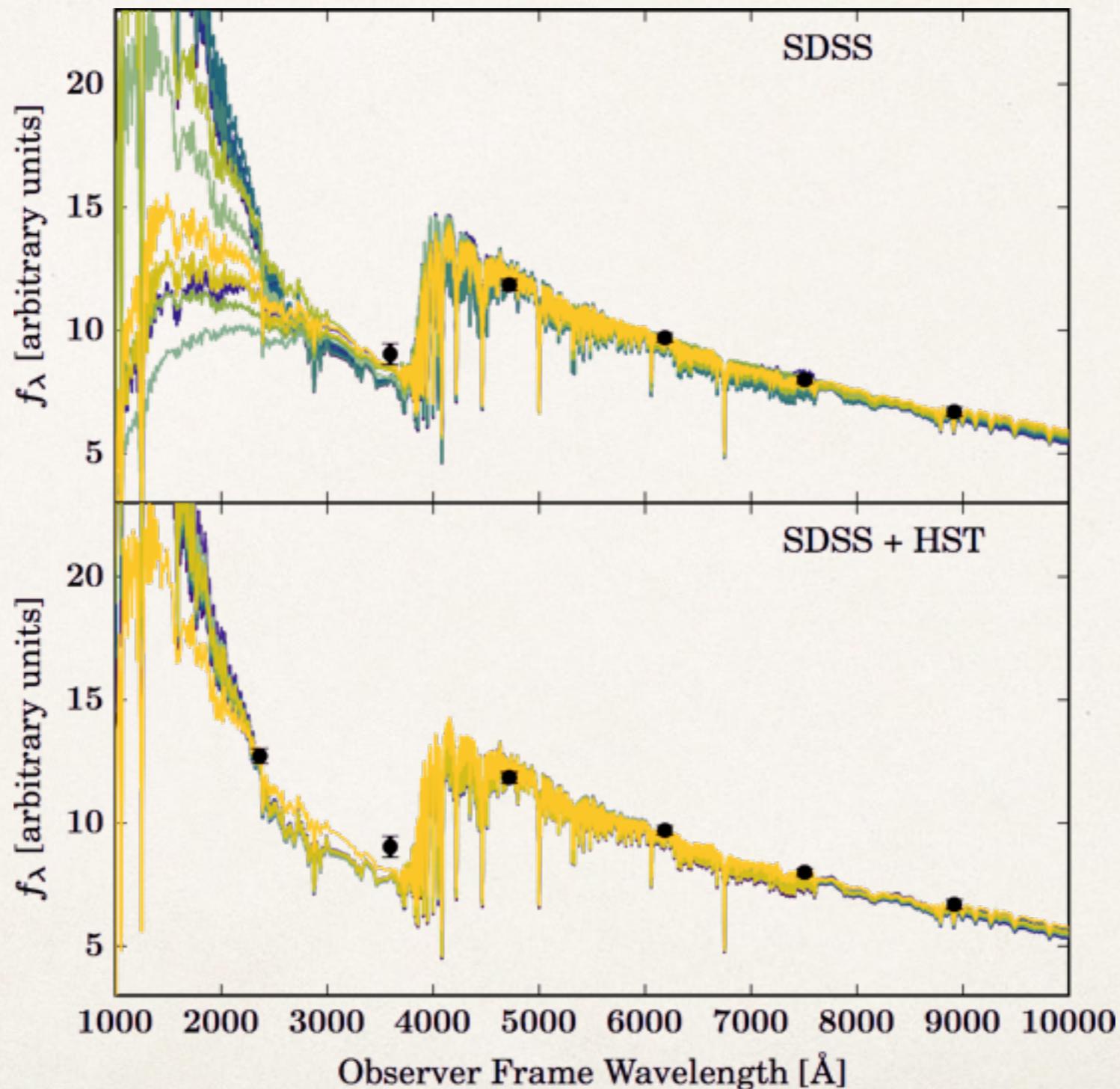
>60 SNeIa

Understand the physical origin of the effects

PI: Rigault ; GO14163



Data reduced and photometry extracted

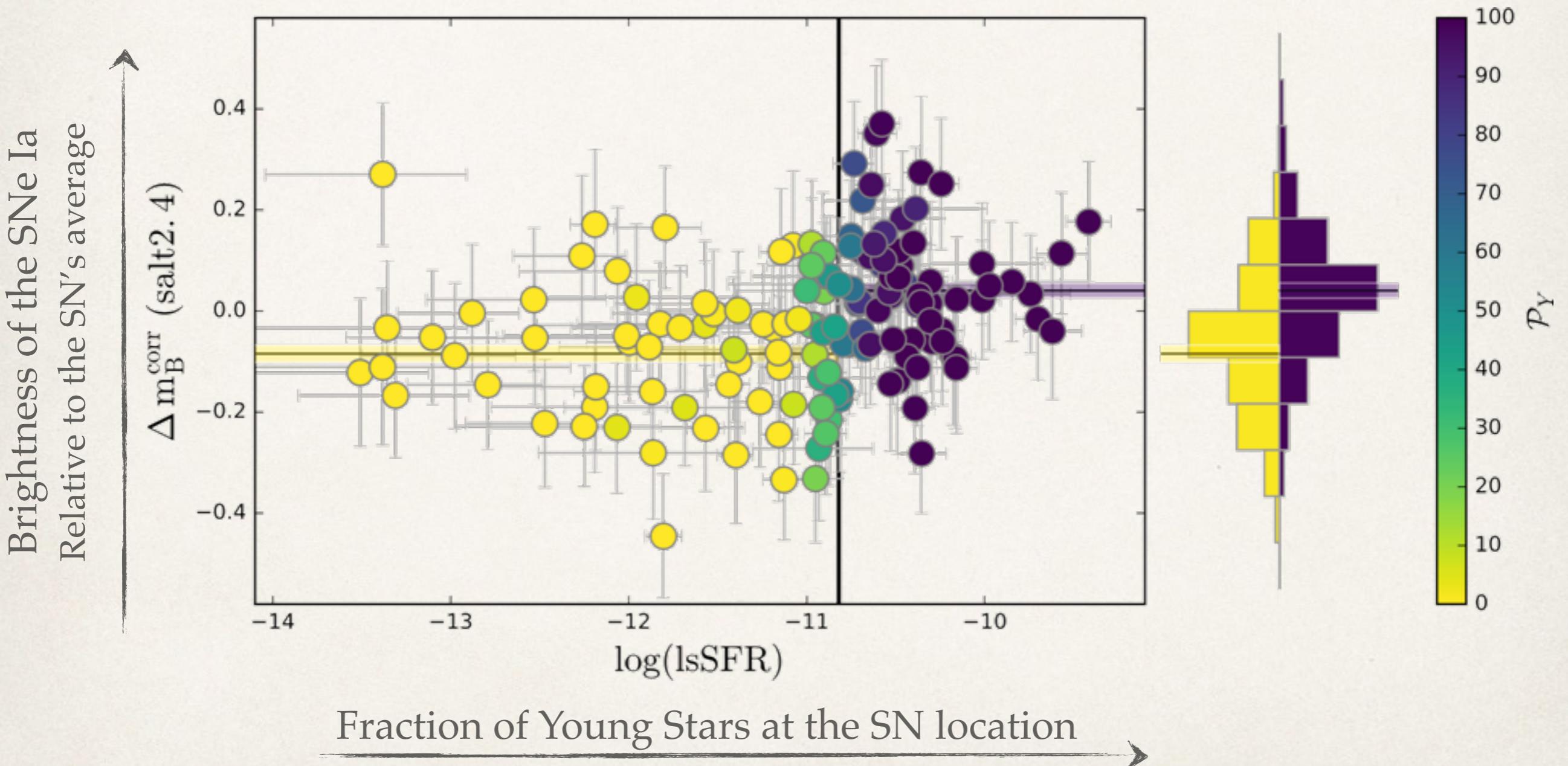


A Star Formation Bias

Rigault et al. 2013, 2015

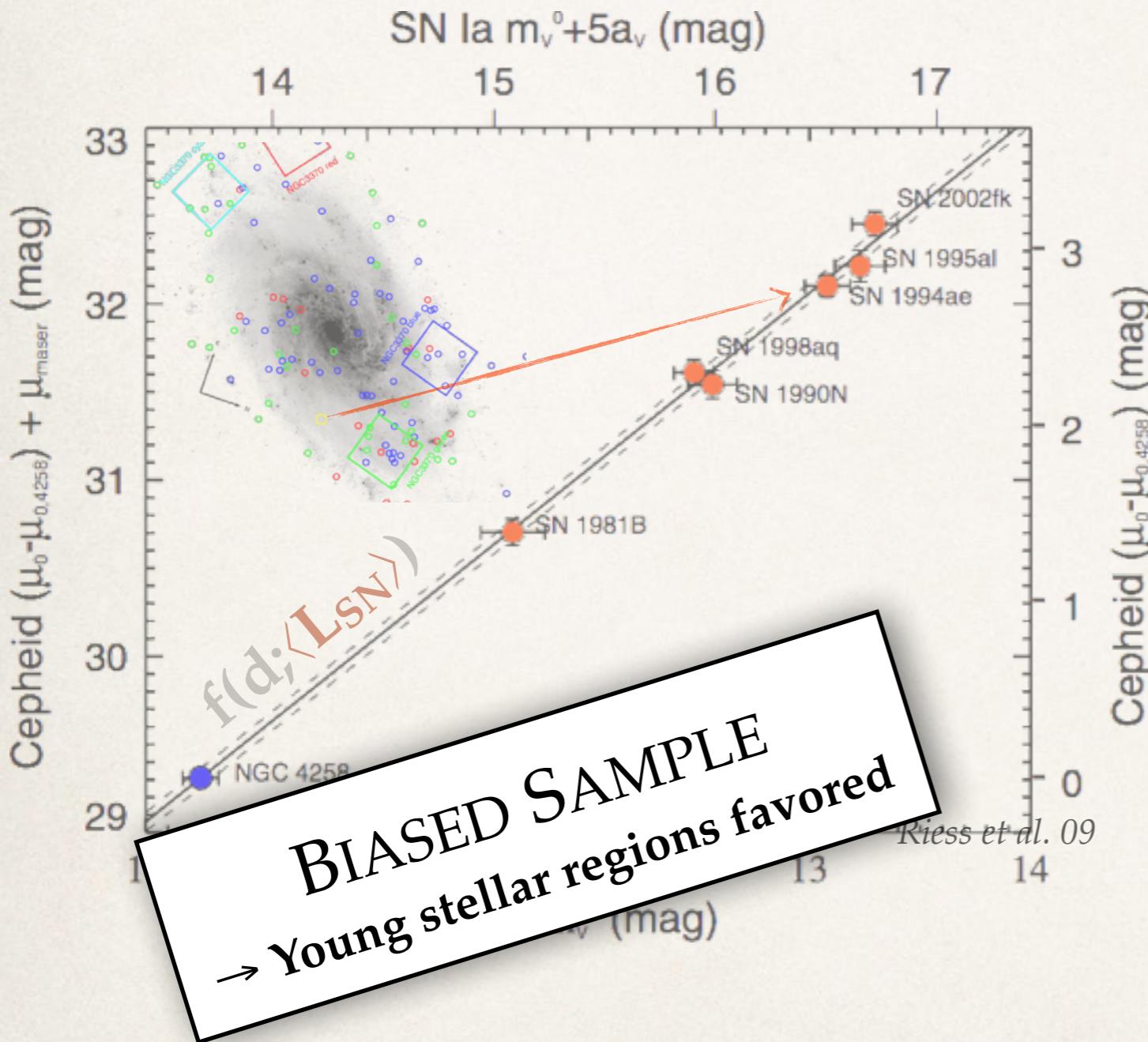
Rigault et al. 2017

~ 6σ detection level



Disentangle H_0 and the SN luminosity

Sample Selection – Impact on H_0



Cepheids: Bright young stars with a pulsation-luminosity relation

MEASURES

SN w Cepheids : ~100 % Young
SN in Hubble Flow : ~50 % Young

H_0 : OVERESTIMATED BY ~3%

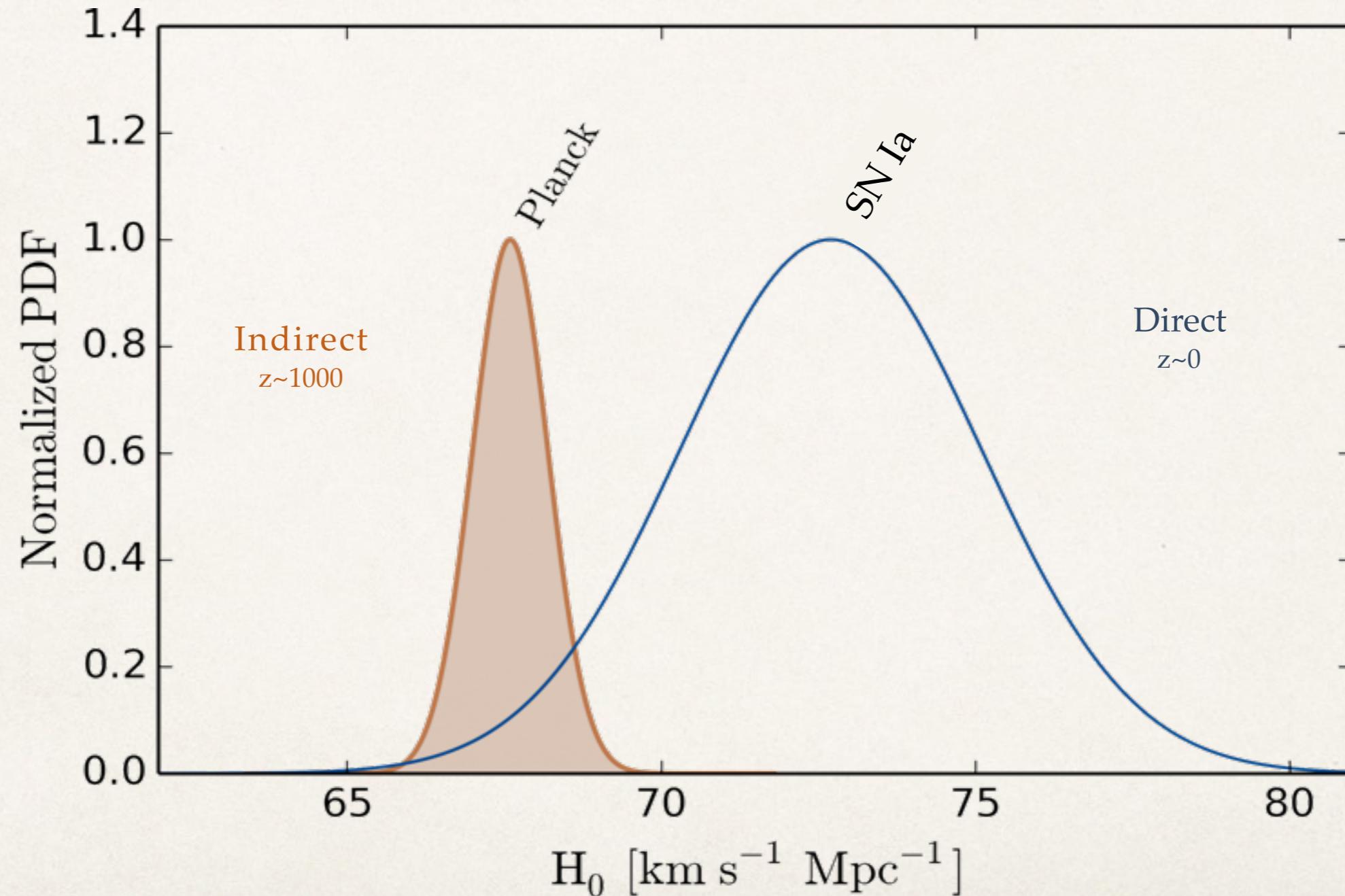
Rigault et al. 2015

~~$H_0 = 73.2 \pm 1.8 \text{ km s}^{-1} \text{ Mpc}^{-1}$~~

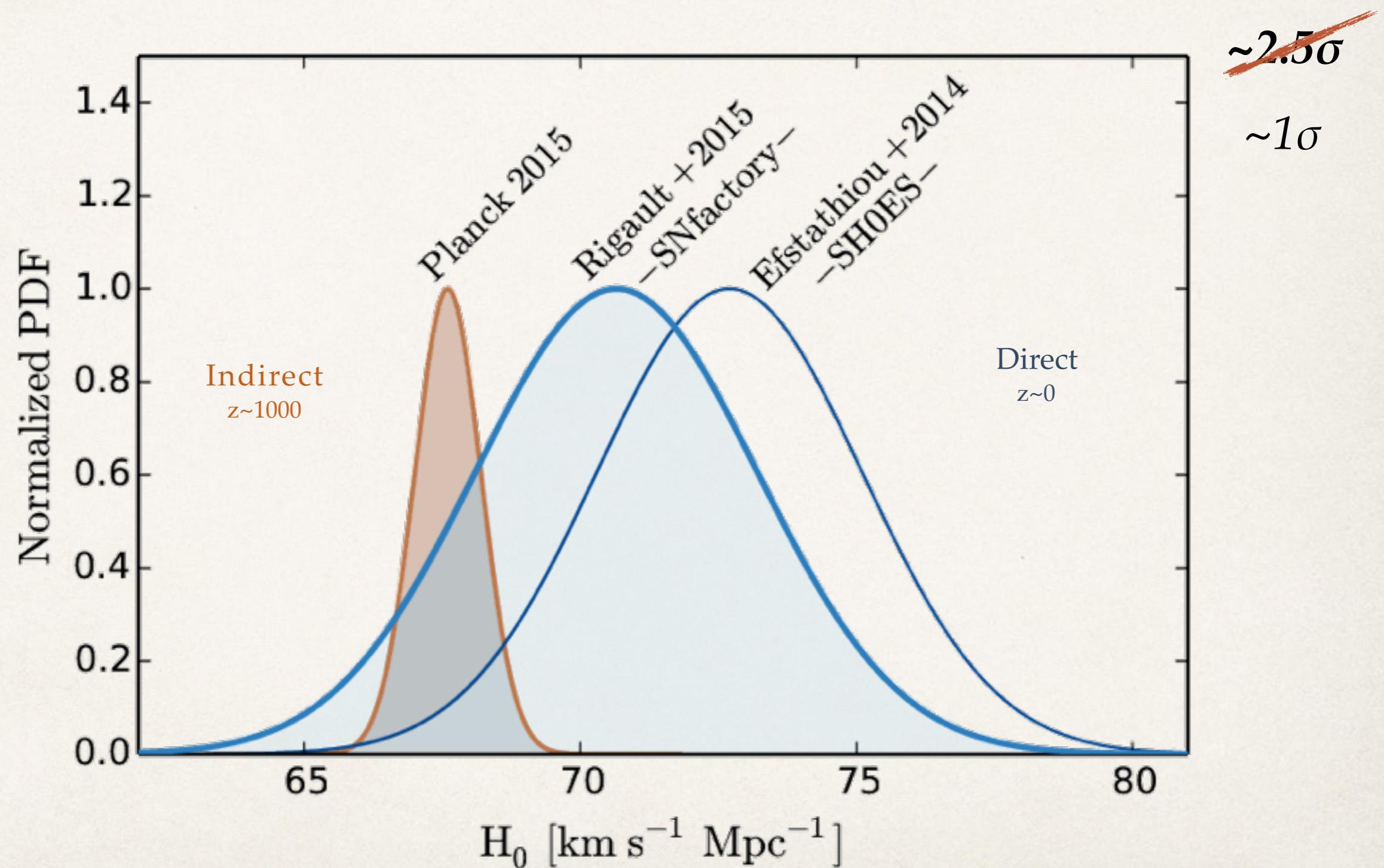
(2.5% ; Riess et al 2016)

Tension in the Standard model of Cosmology

$\sim 2.5\sigma$



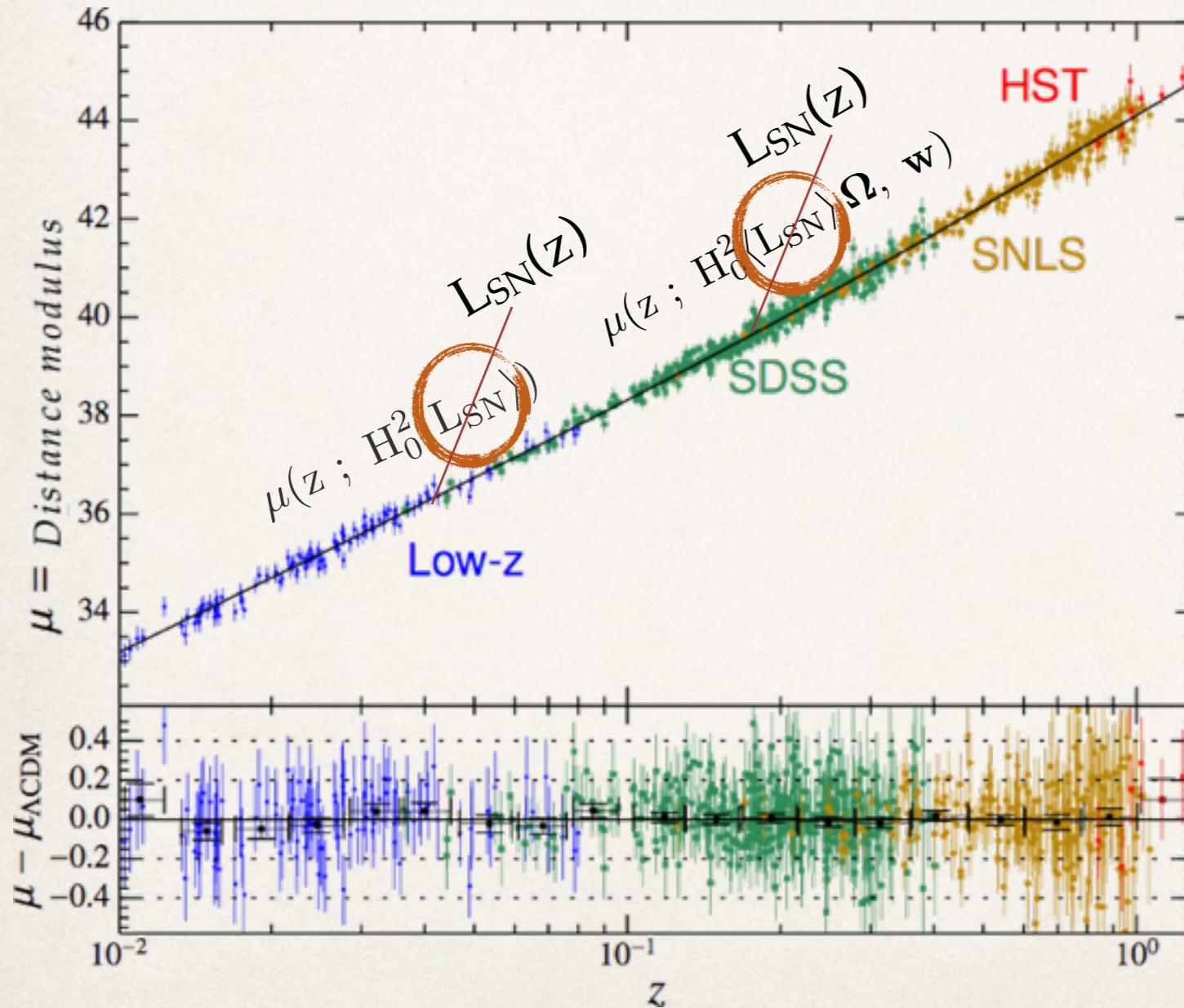
Tension in the Standard model of Cosmology



Consequence on the Cosmology — w

Rigault et al. 2013, 2017

Redshift evolution — Impact on w

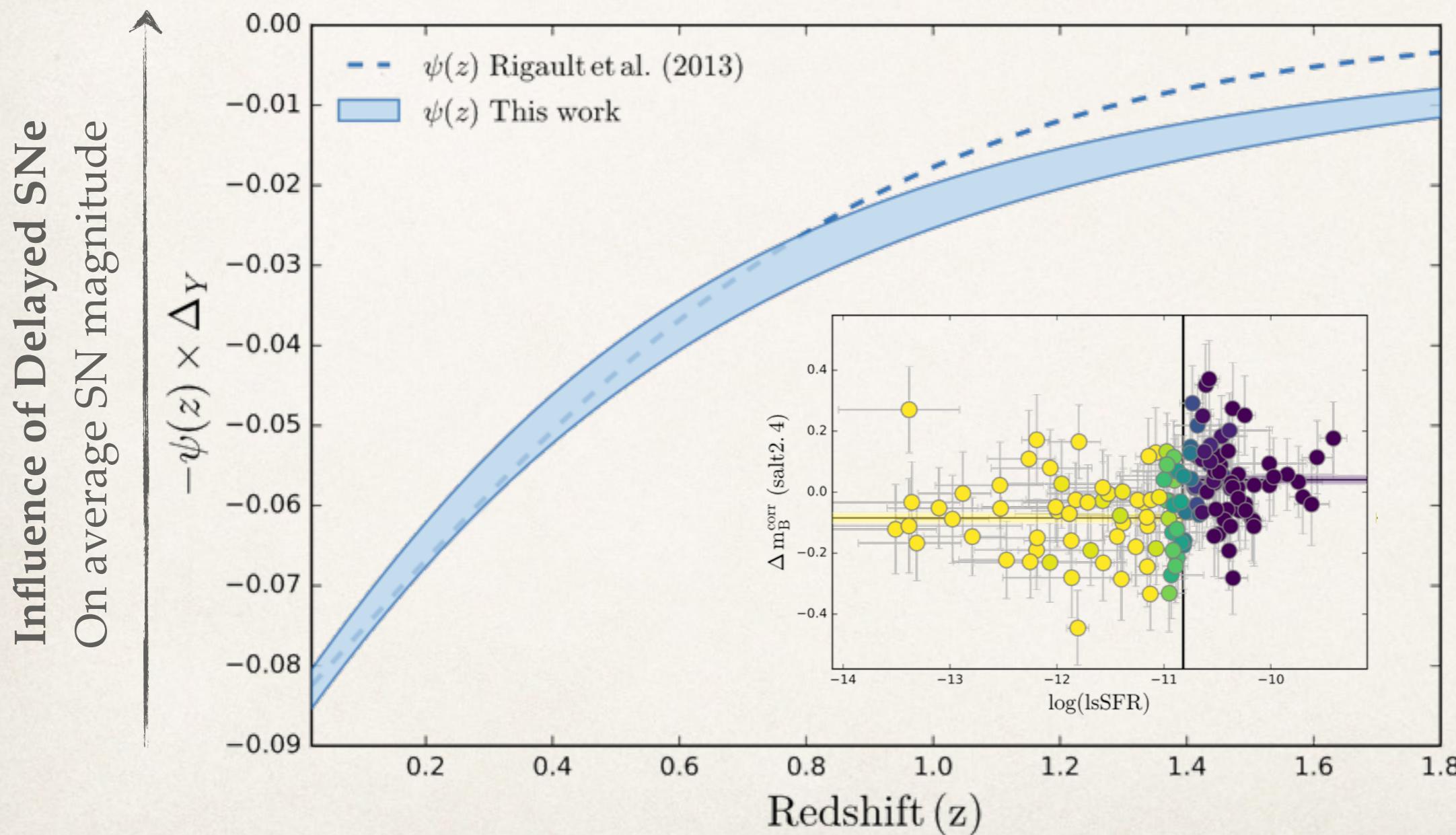


GALAXIES ARE MORE STAR FORMING AT HIGHER REDSHIFT

Could impact w by few percents
Goal of modern Cosmology: 1%

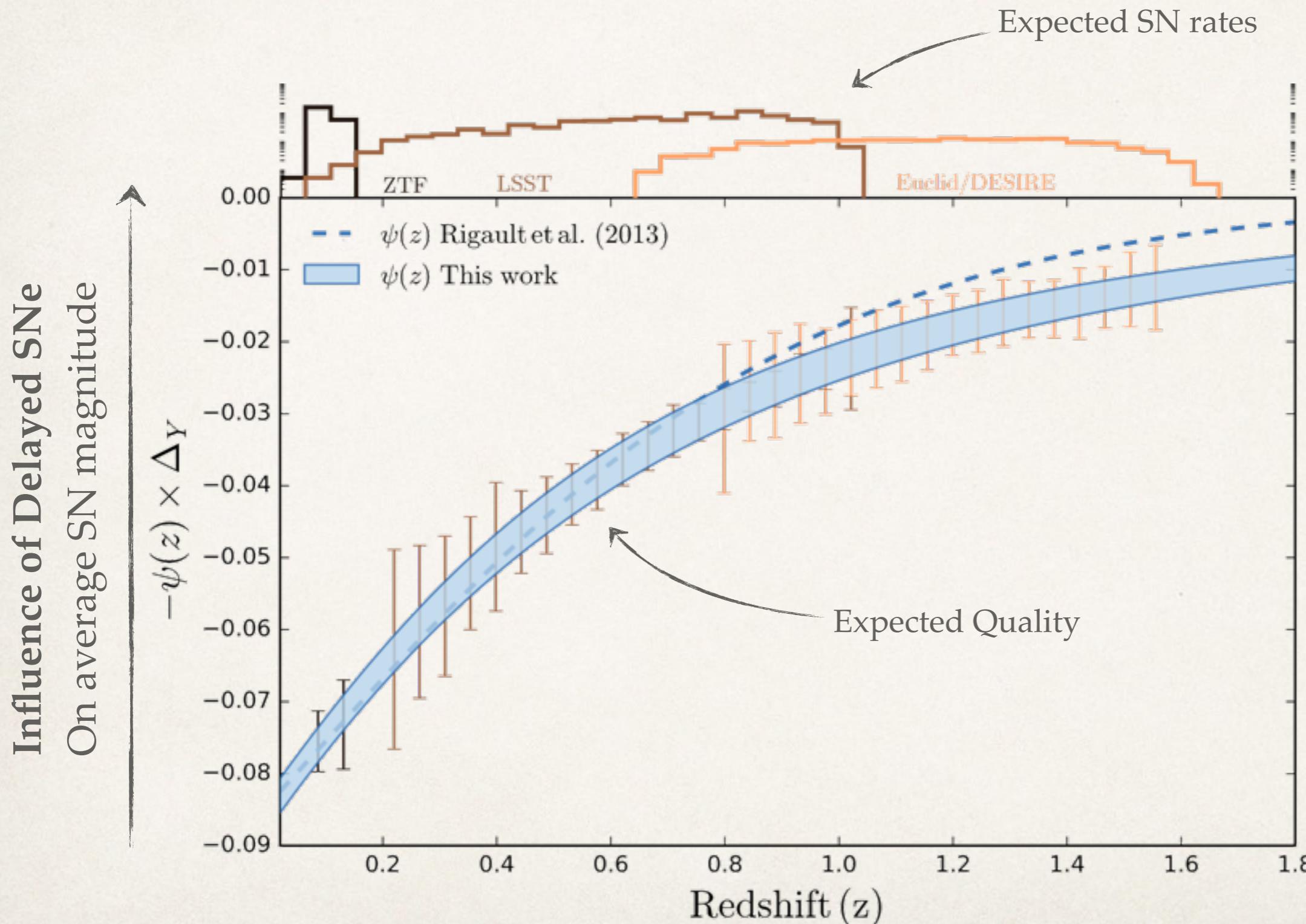
Astrophysical evolution or exotic dark energy?

Rigault et al. 2017



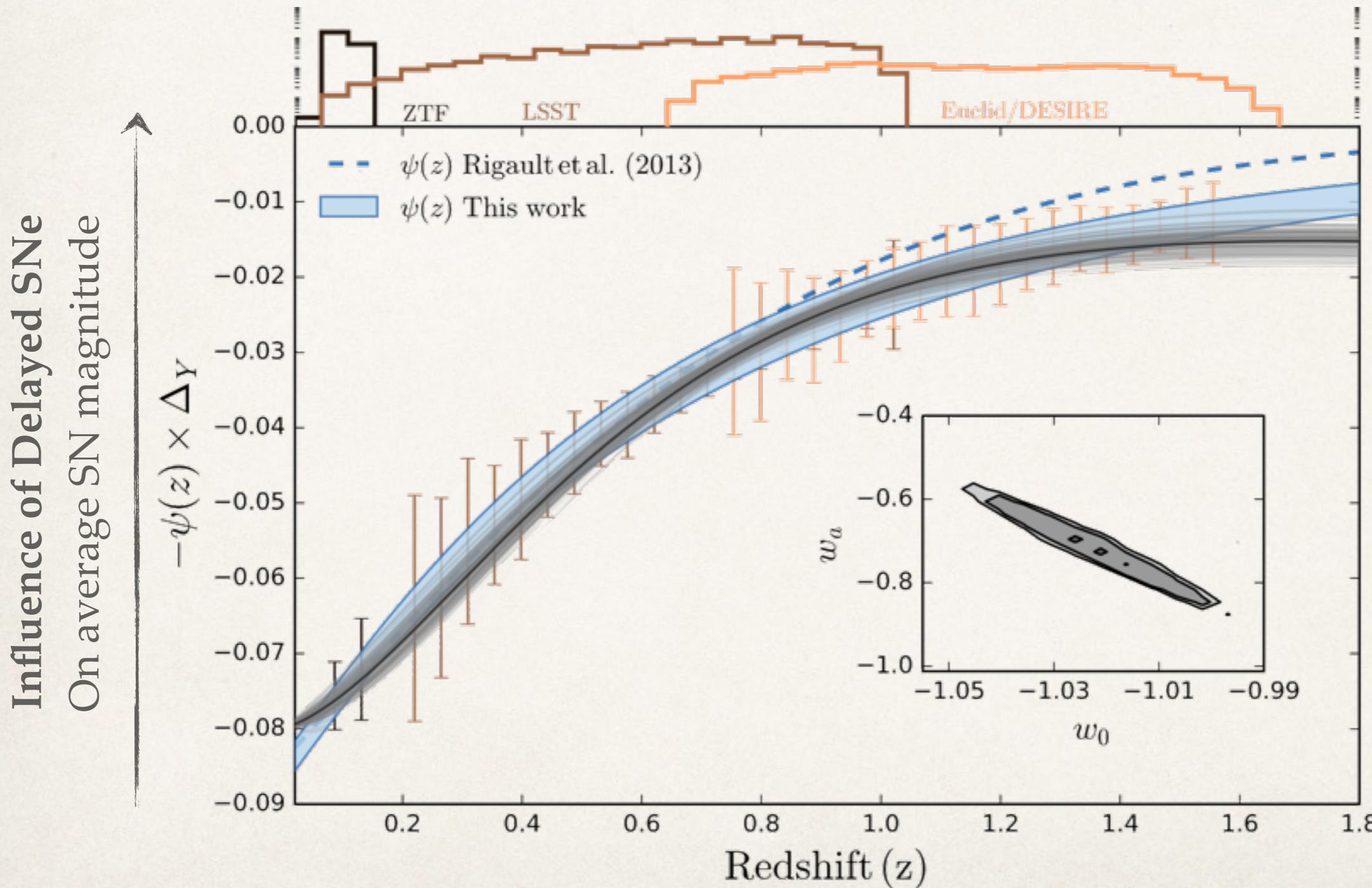
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Astrophysical evolution or exotic dark energy?

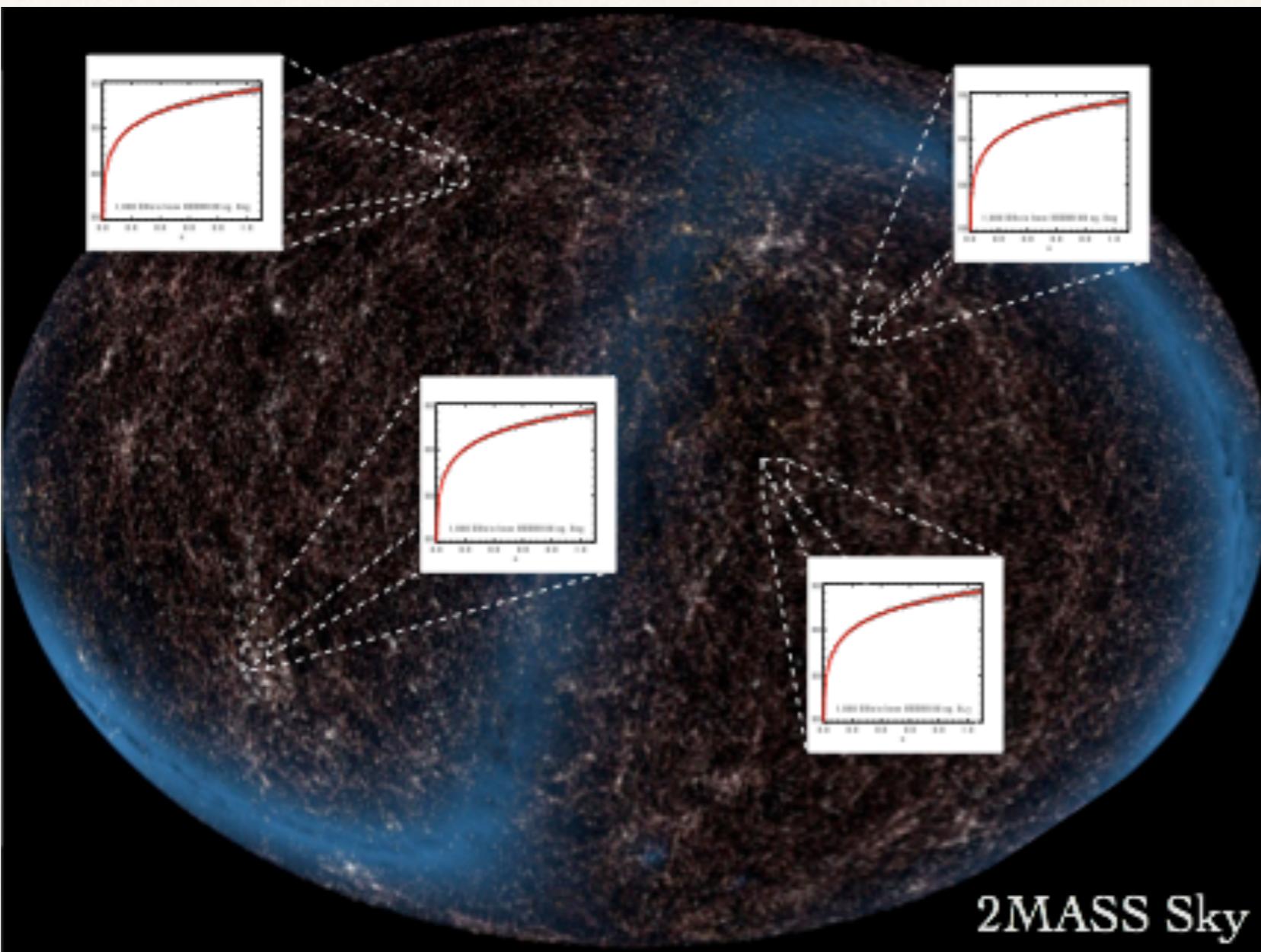
Rigault et al. 2017



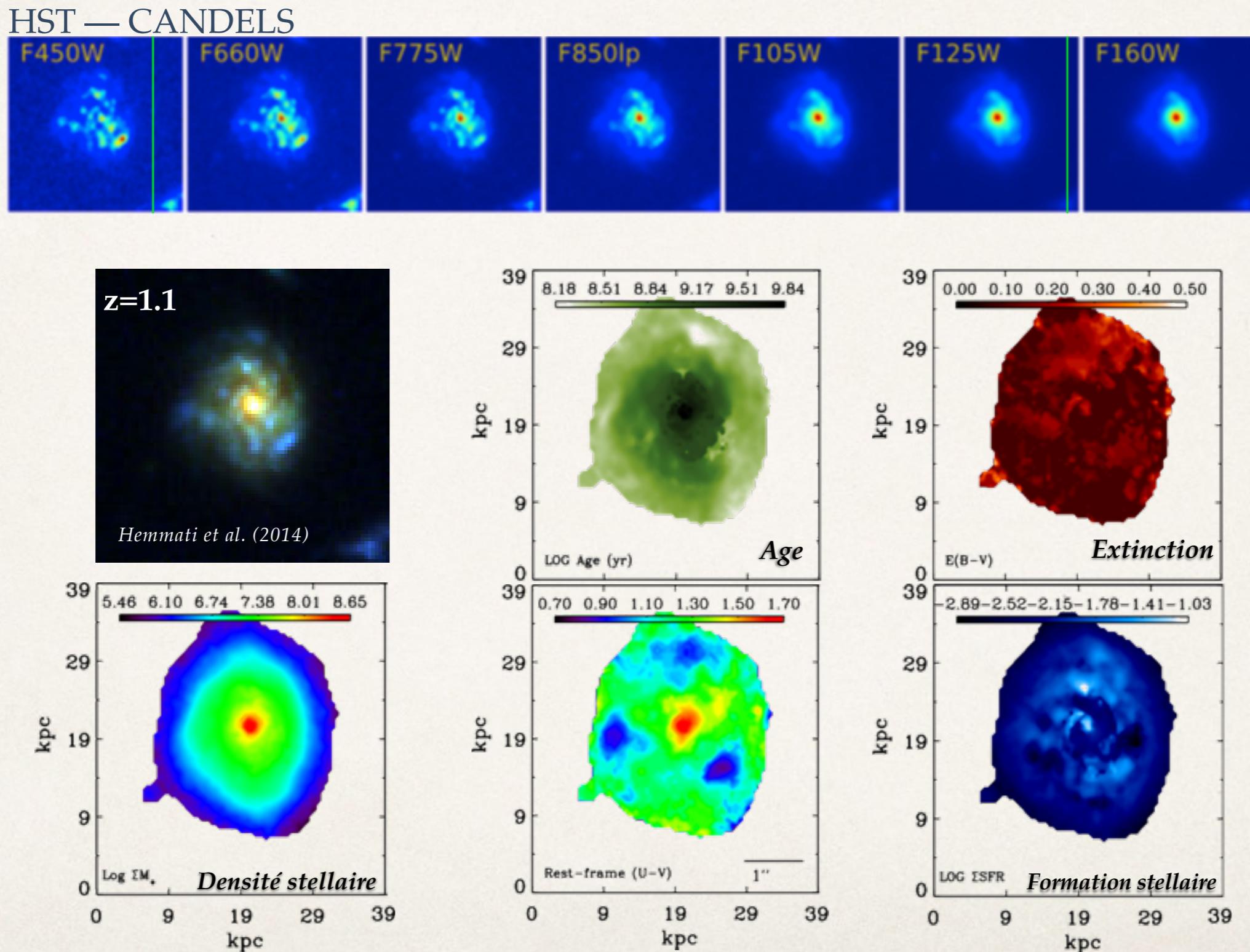


LSST

$\sim 10^6$ SNeIa!
+ other probes: Weak lensing, BAO, Clusters



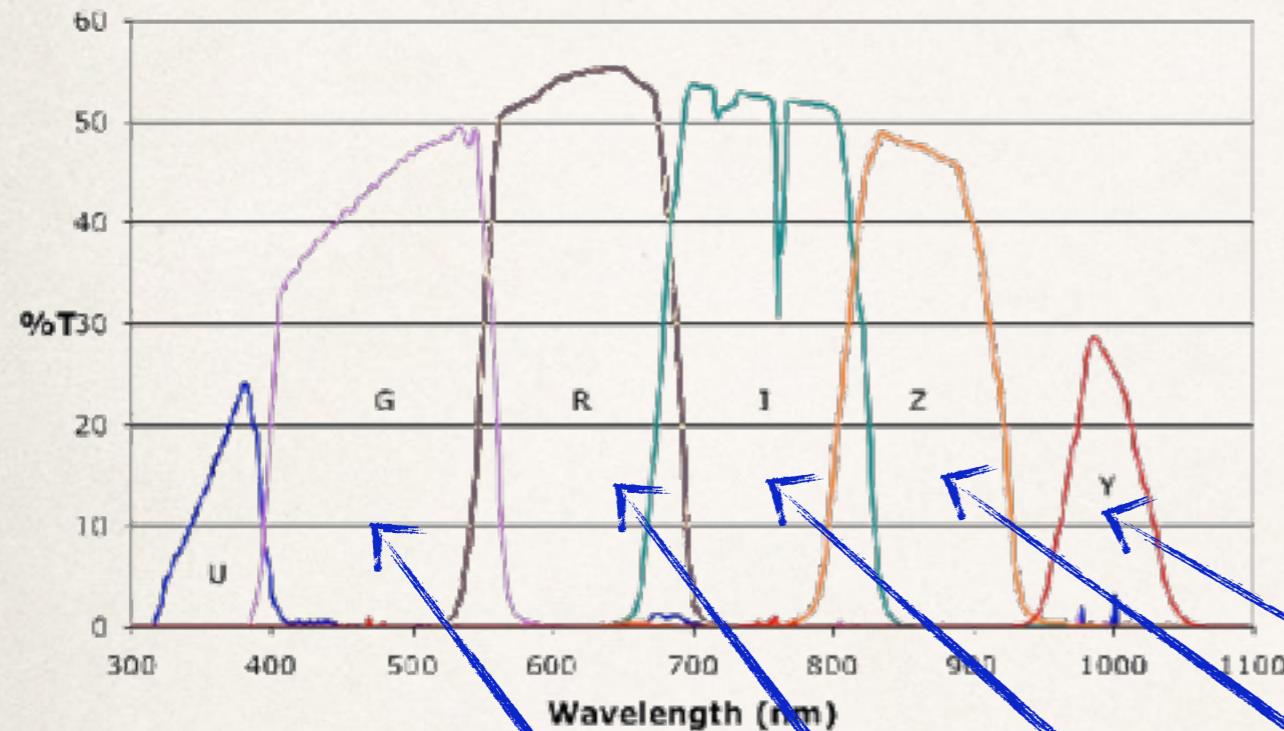
Local Analyses at high-redshift



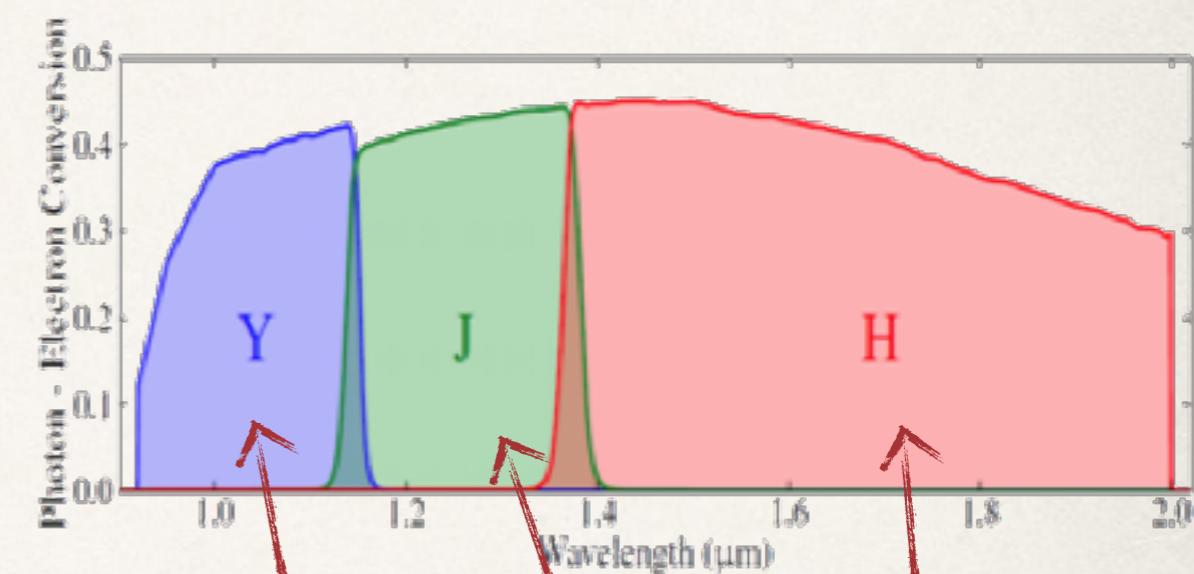
LSST & EUCLID

Getting the local environments of SNeIa

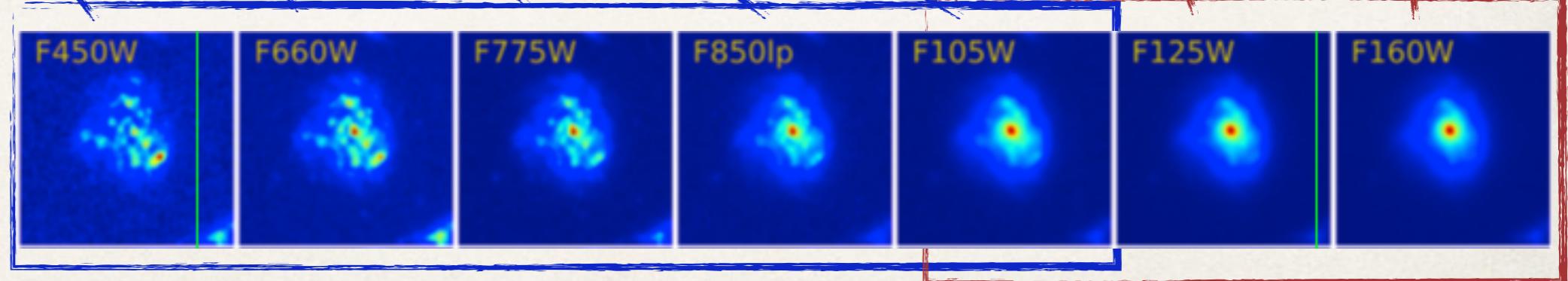
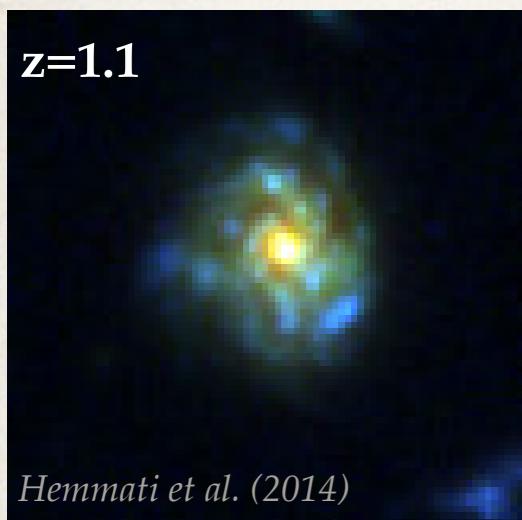
LSST ugrizY Filter Set



EUCLID Y, J, H



$z=1.1$



Hemmati et al. (2014)

New Surveys and Time Domain Astronomy



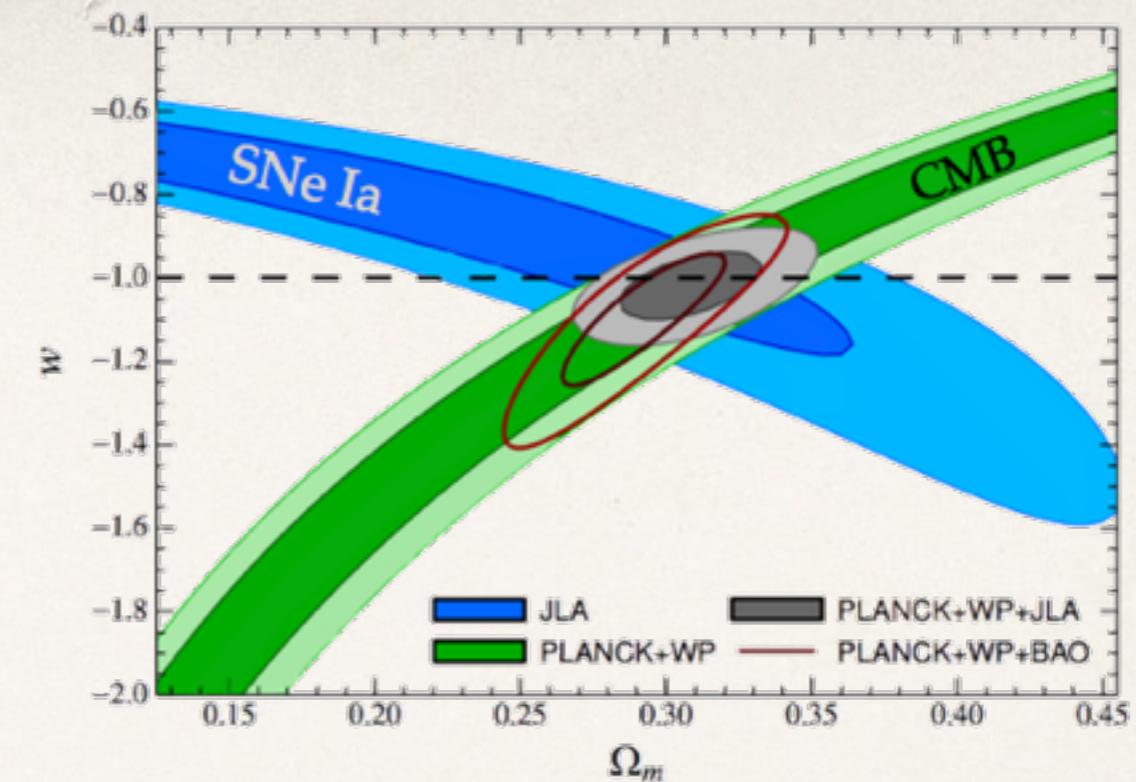
Discovery of Dark Energy

Looks like a Cosmological Constant

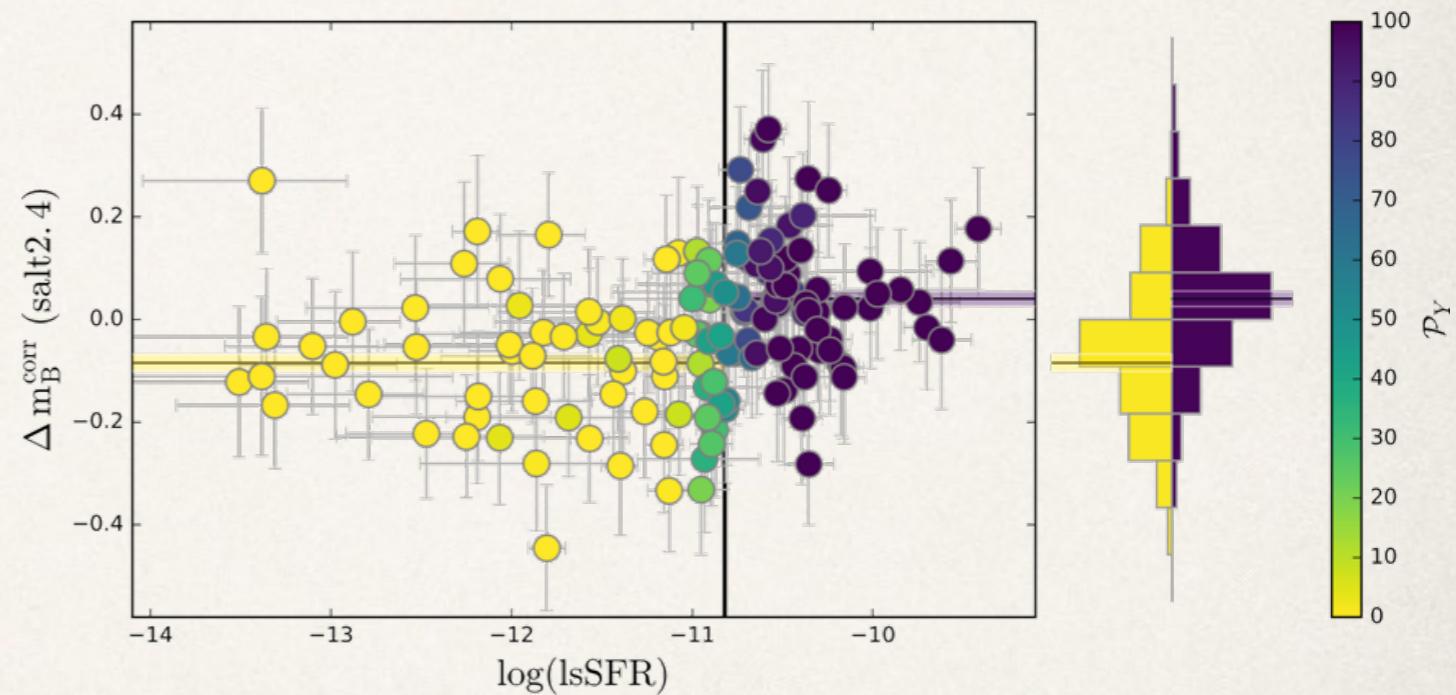
Is it really ?

Conclusion

Type Ia Supernova are key to understand dark energy



Astrophysical effects have to be taken into account



We (will) have all the data we need to do so!