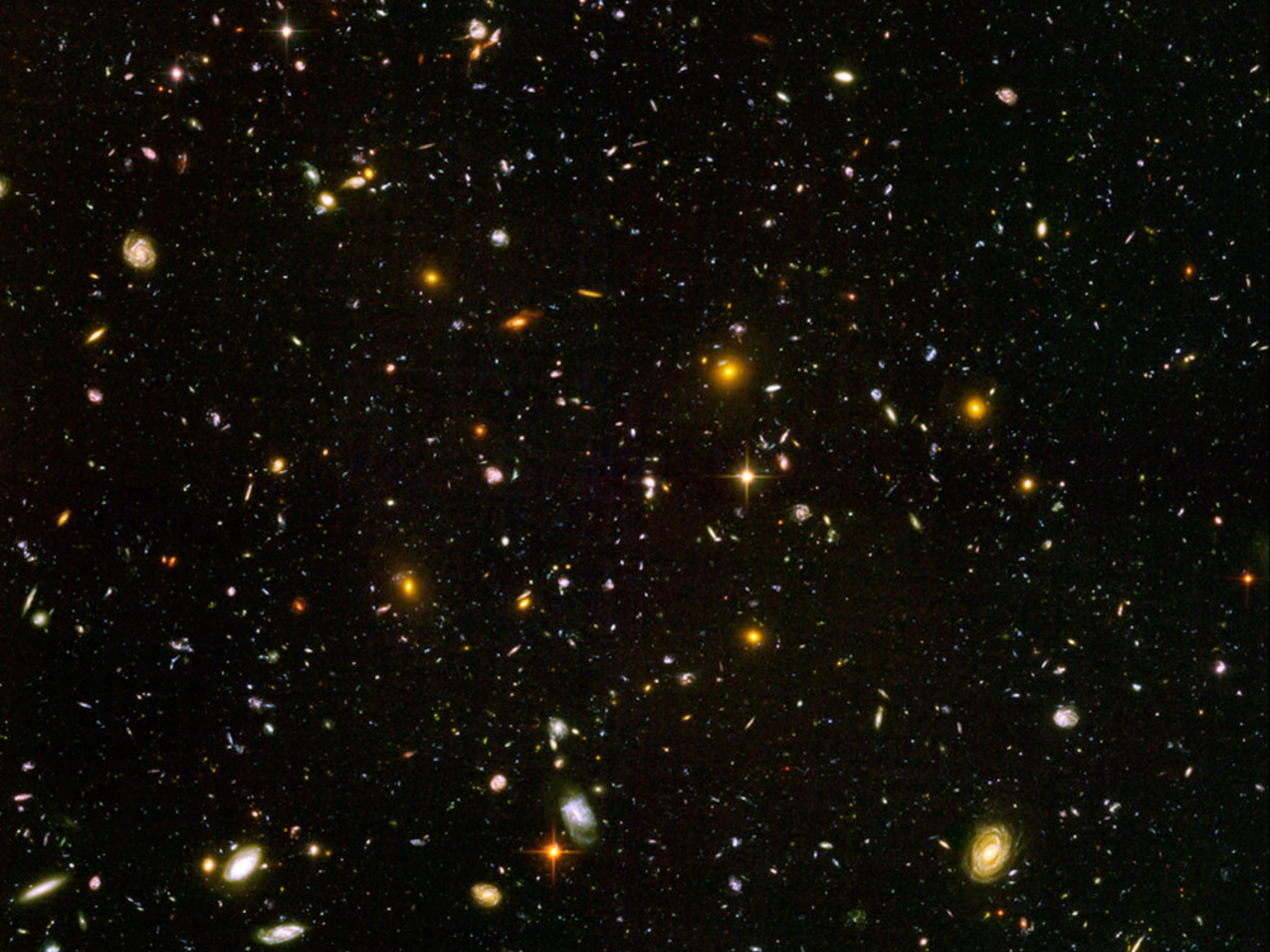
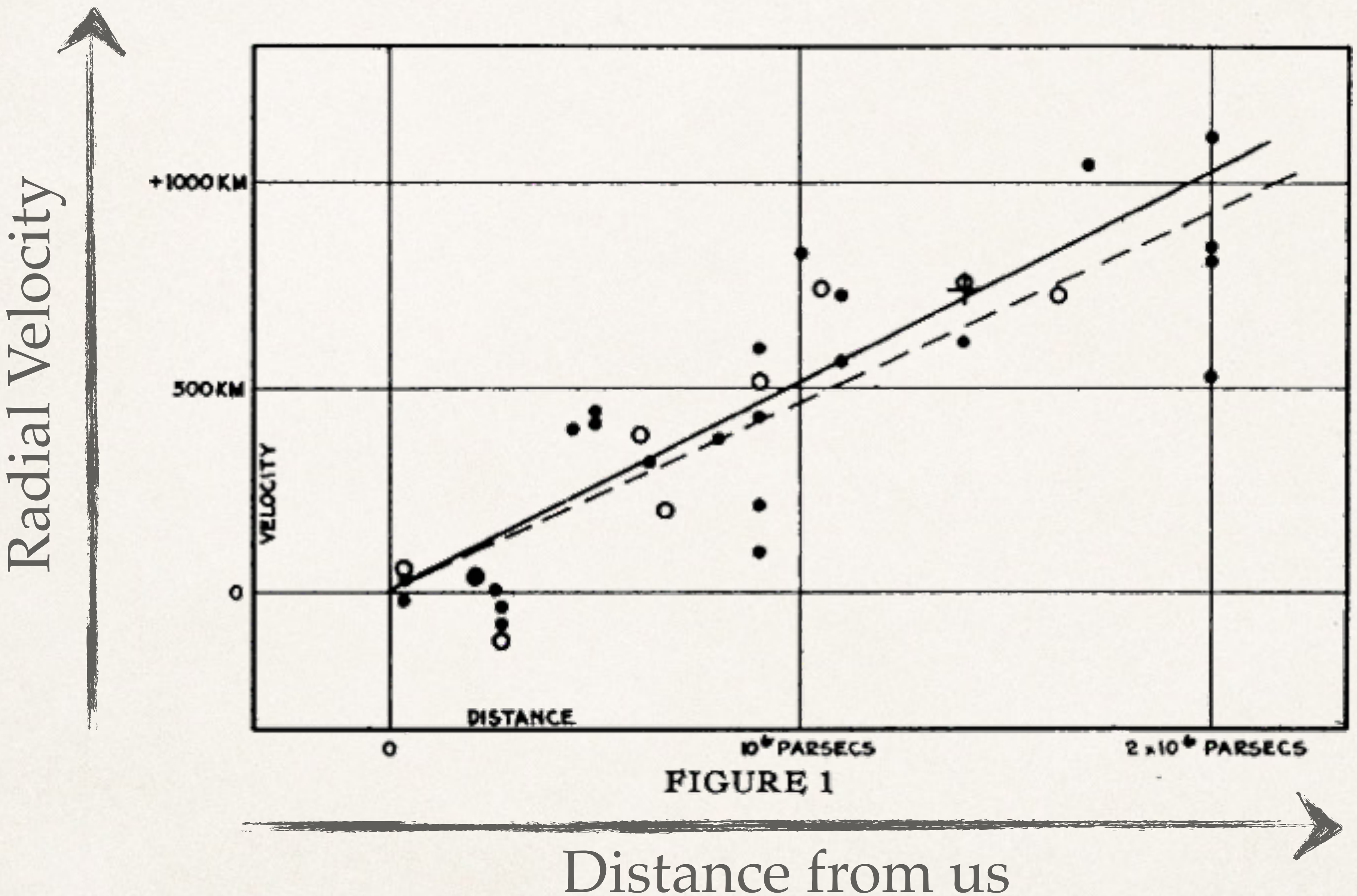
Modern Cosmology: Astrophysical analyses of SNeIa and future surveys

IPHC – Mickael RIGAULT

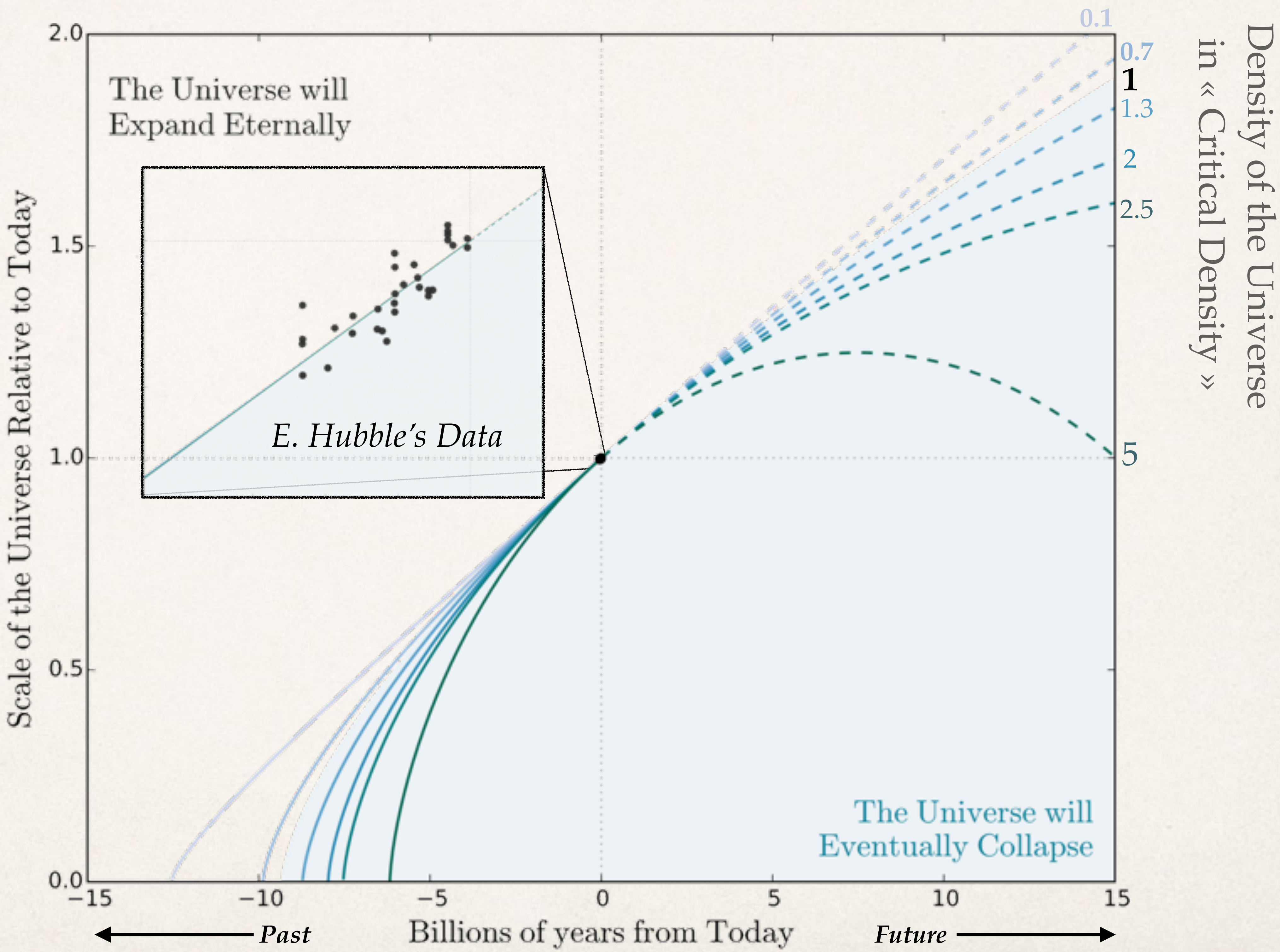


The Universe is Expanding !

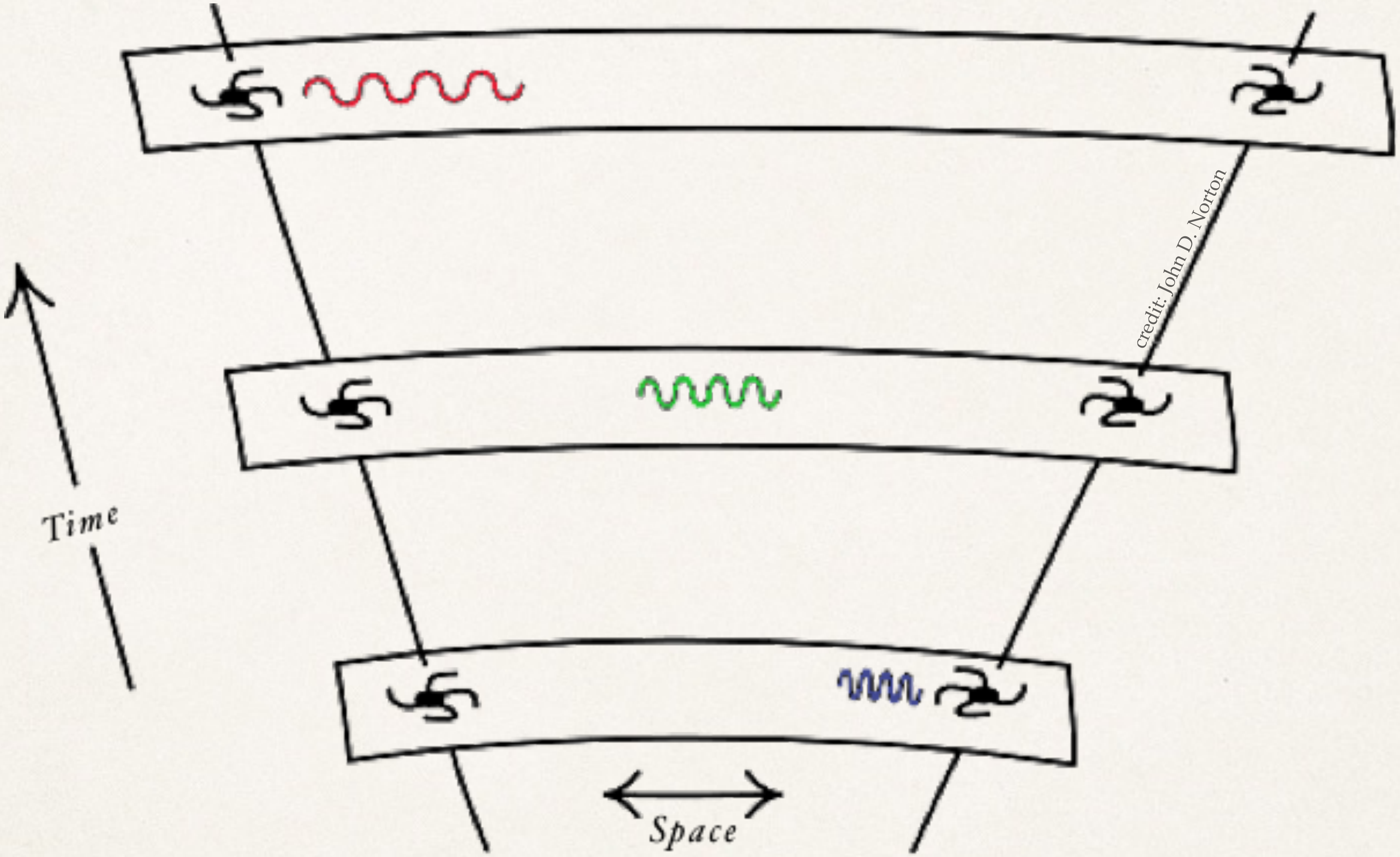
Edwin HUBBLE, 1929



Measuring the Fate of the Universe



The Redshift as an Expansion Tracer



The expansion of the Universe stretchs the photon's wavelength

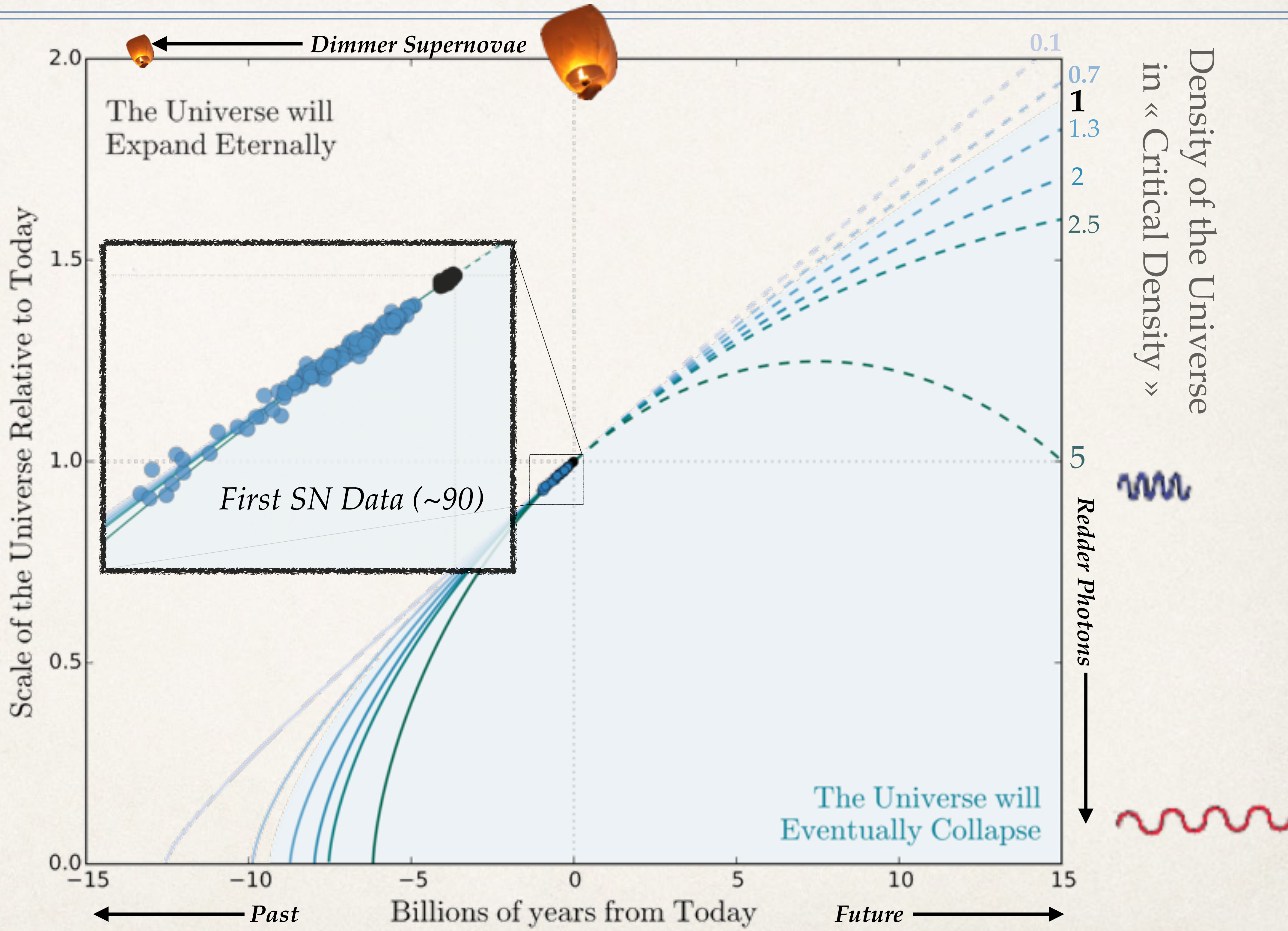
Type Ia Supernovae: Standard Candles

Flux ⇔ Distance

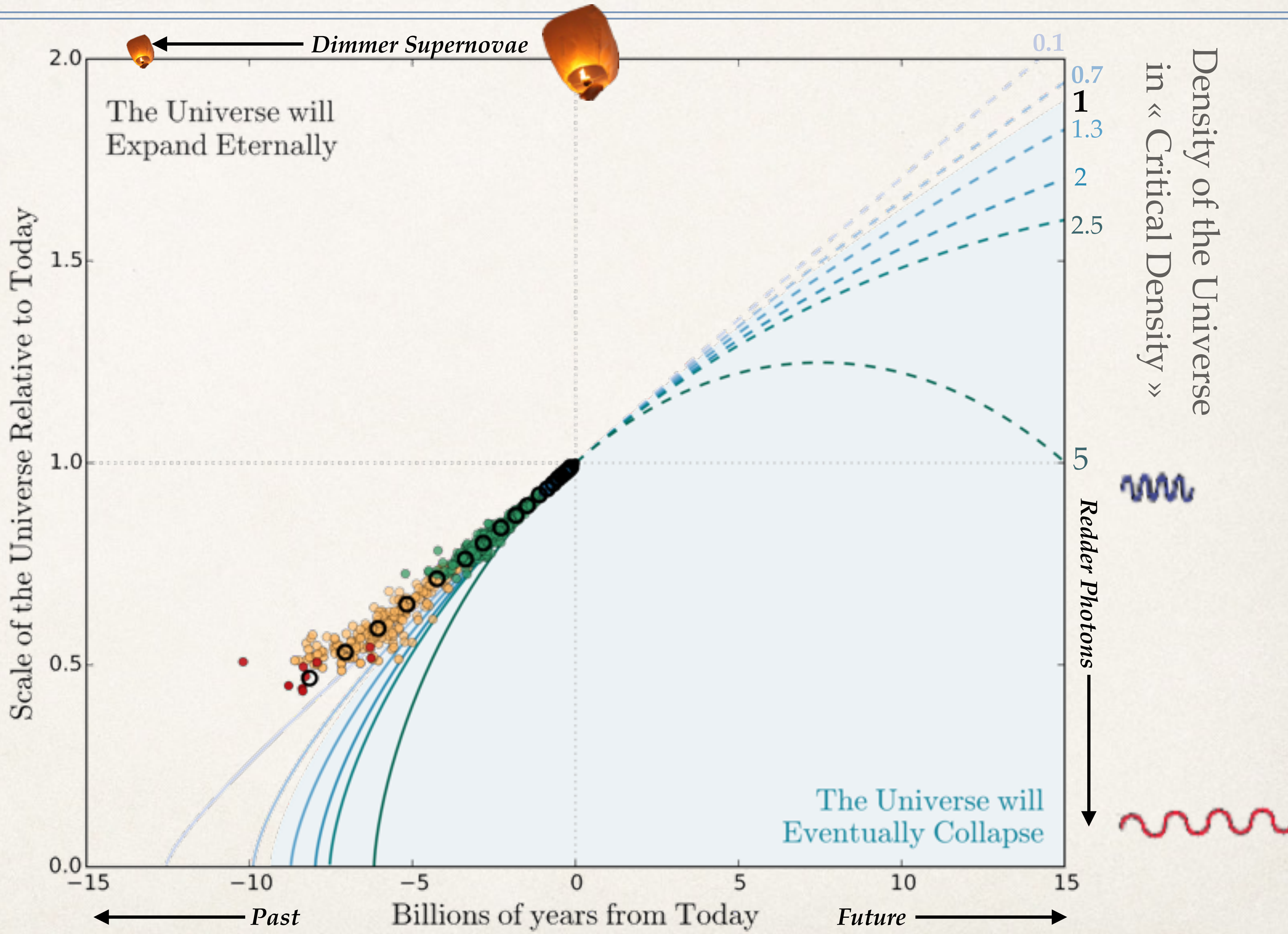
As bright as a galaxy for few days


Artist's Concept

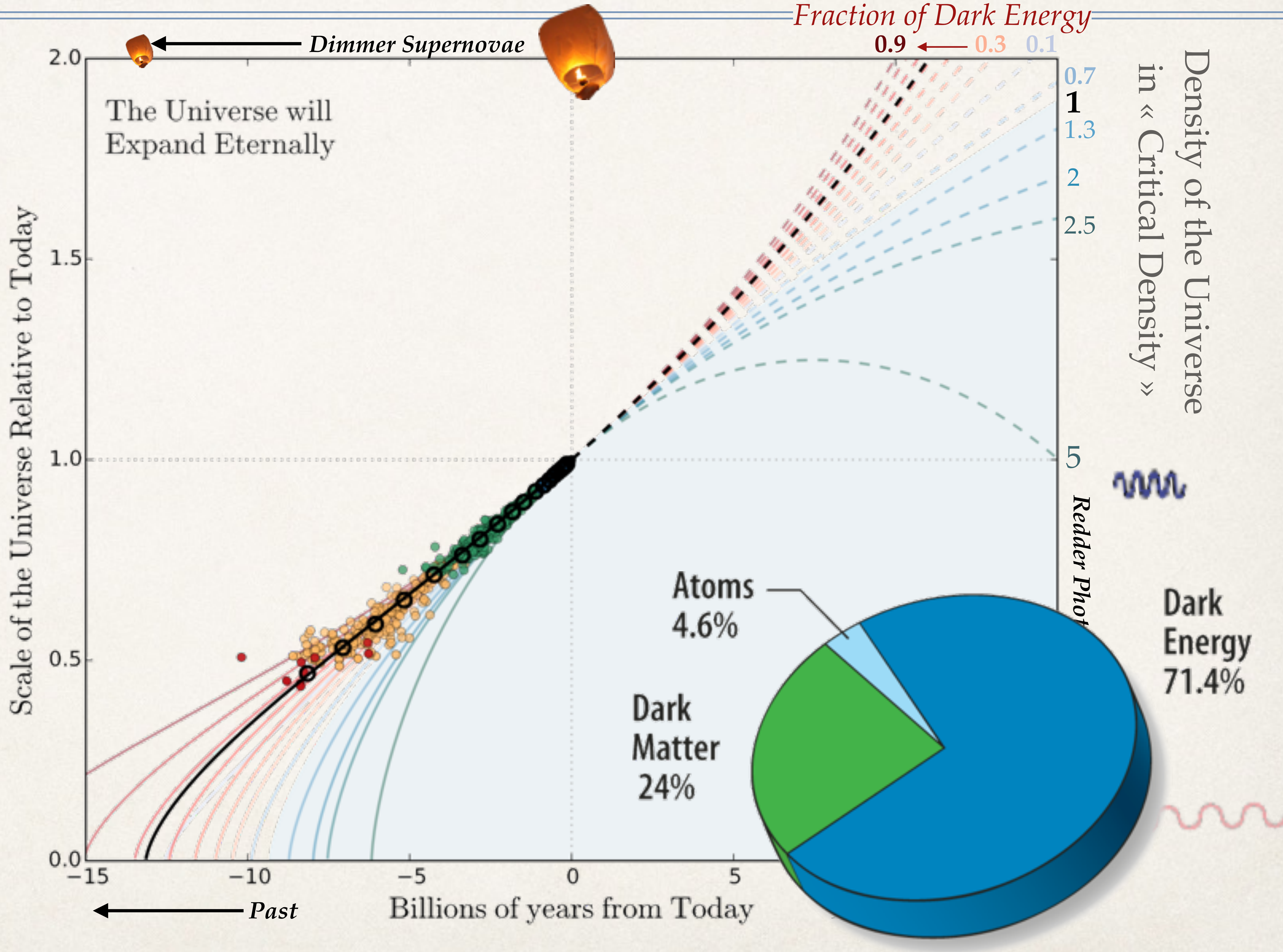
Measuring the Fate of the Universe



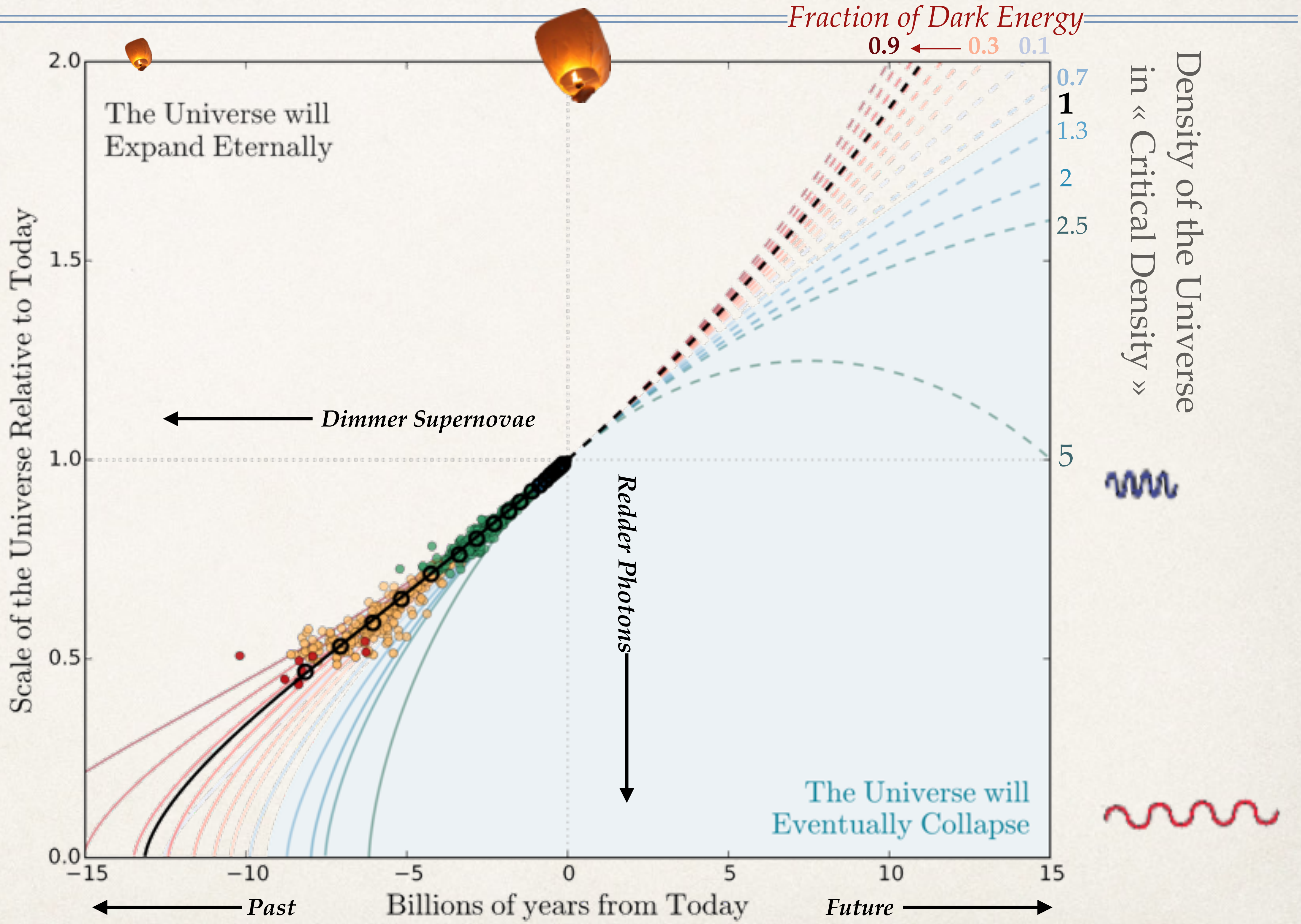
The Data do not match the Predictions



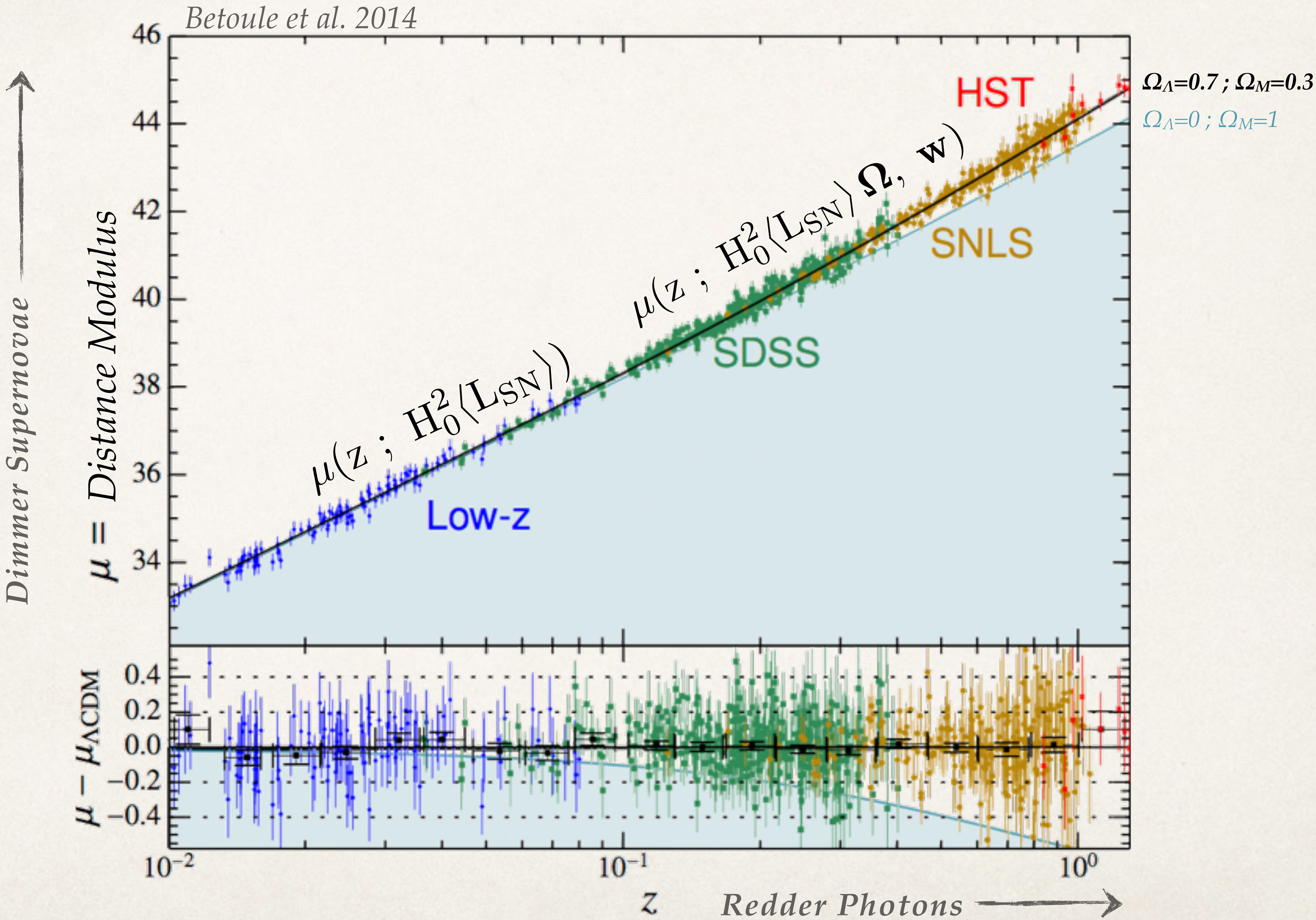
The Universe's Expansion is Accelerating !



Study the Acceleration

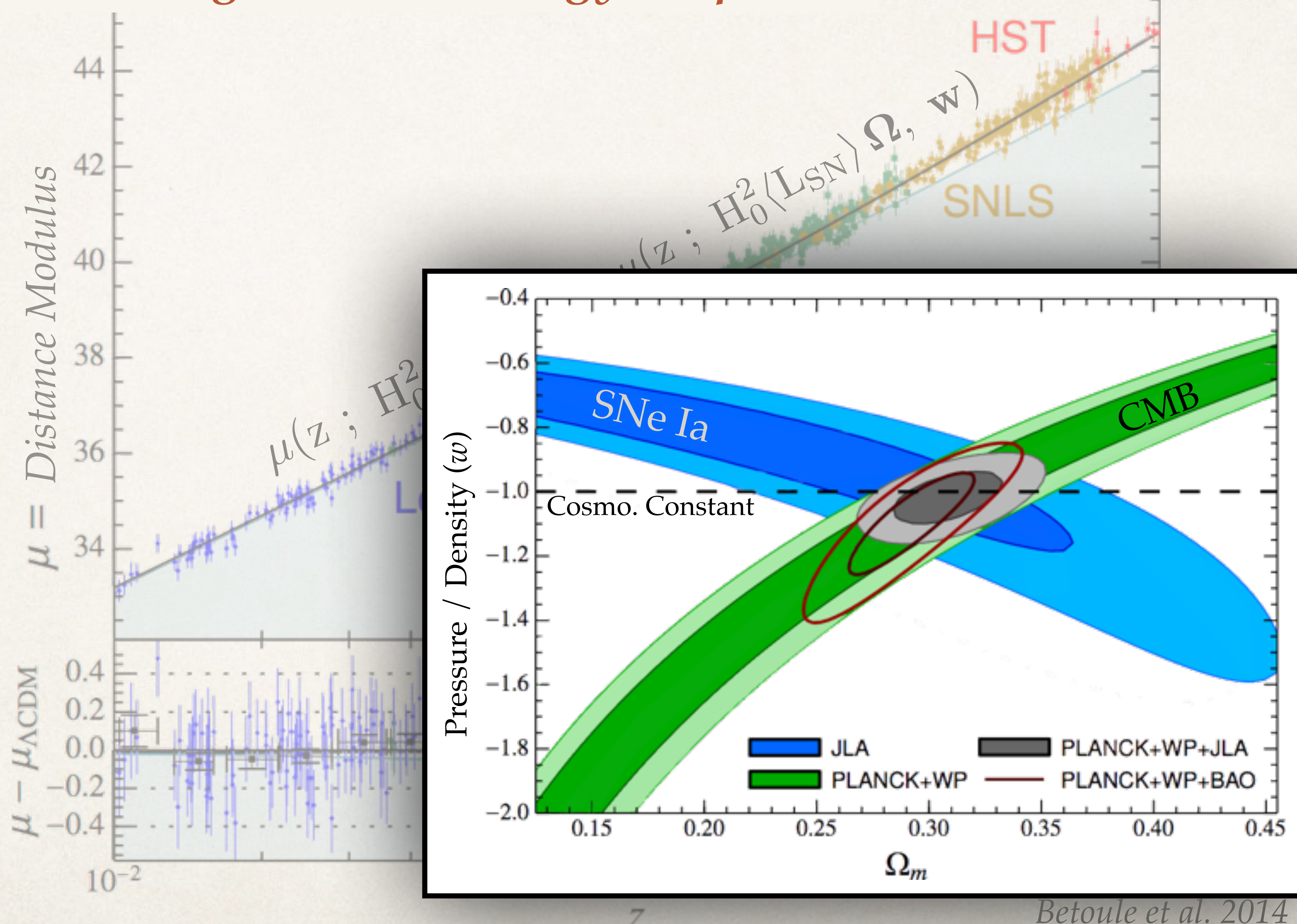


Cosmology using Type Ia Supernovae



Cosmology using Type Ia Supernovae

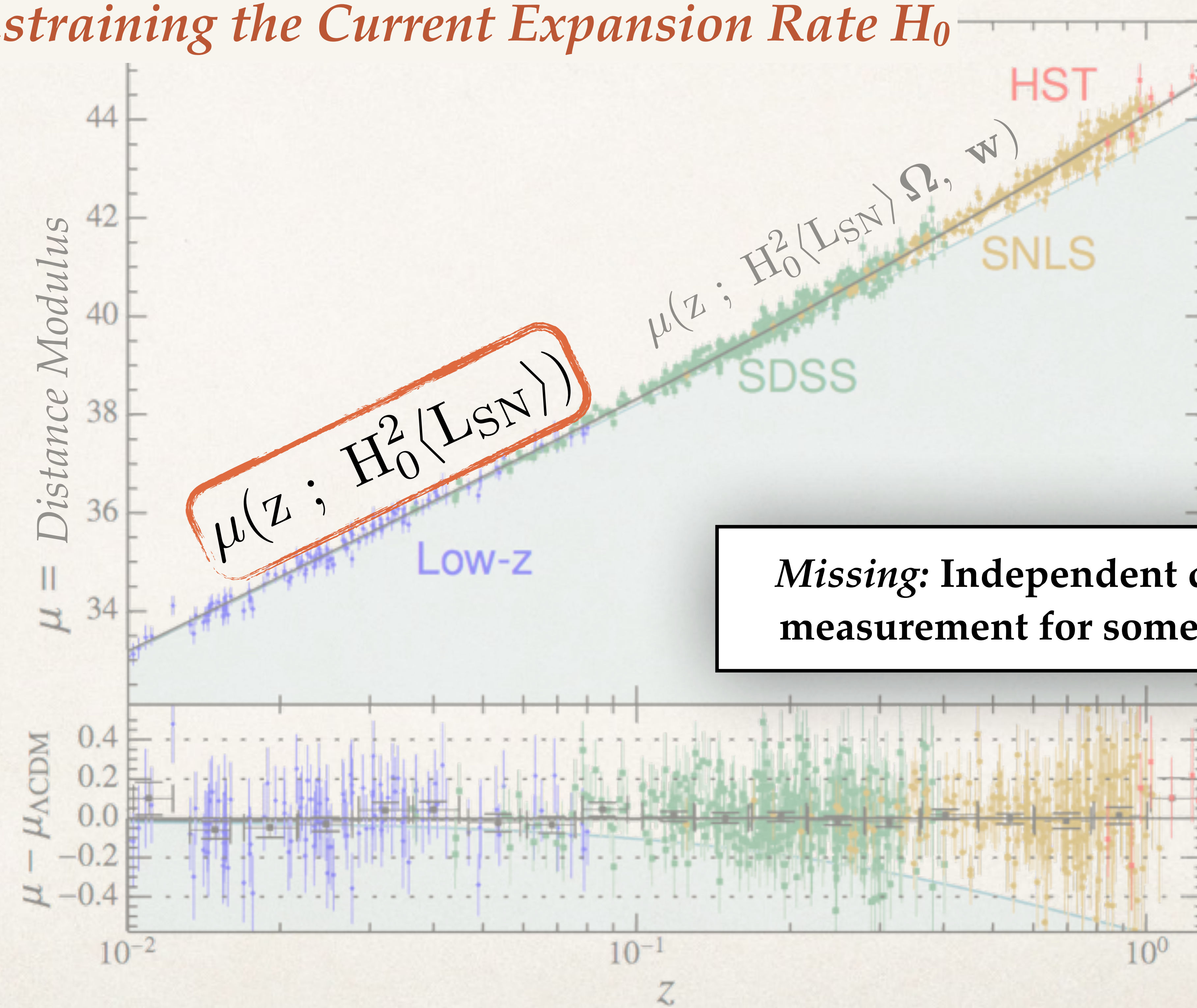
Constraining the Dark Energy Properties



Betoule et al. 2014

Cosmology using Type Ia Supernovae

Constraining the Current Expansion Rate H_0



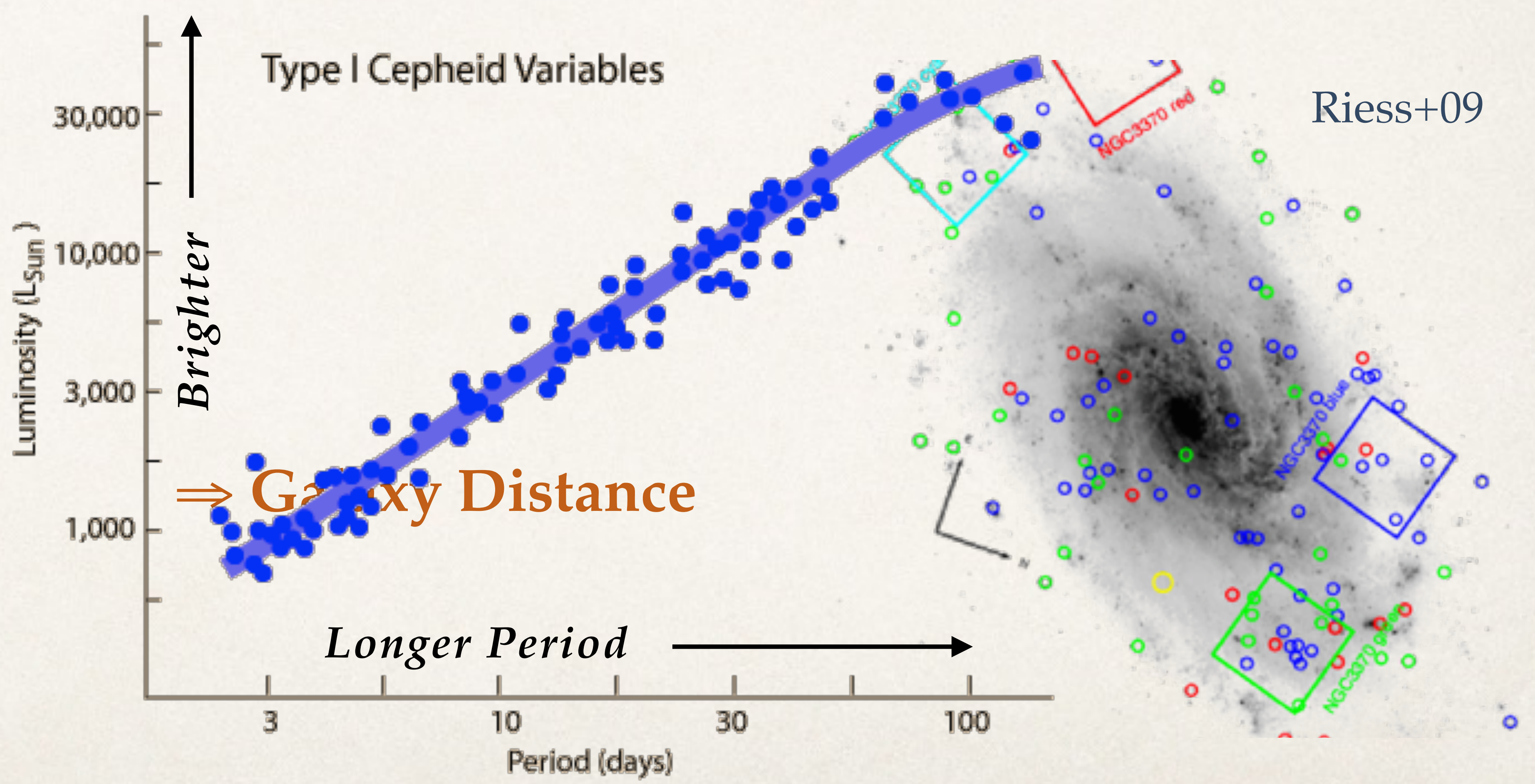
Missing: **Independent distance measurement for some SNe Ia**

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*

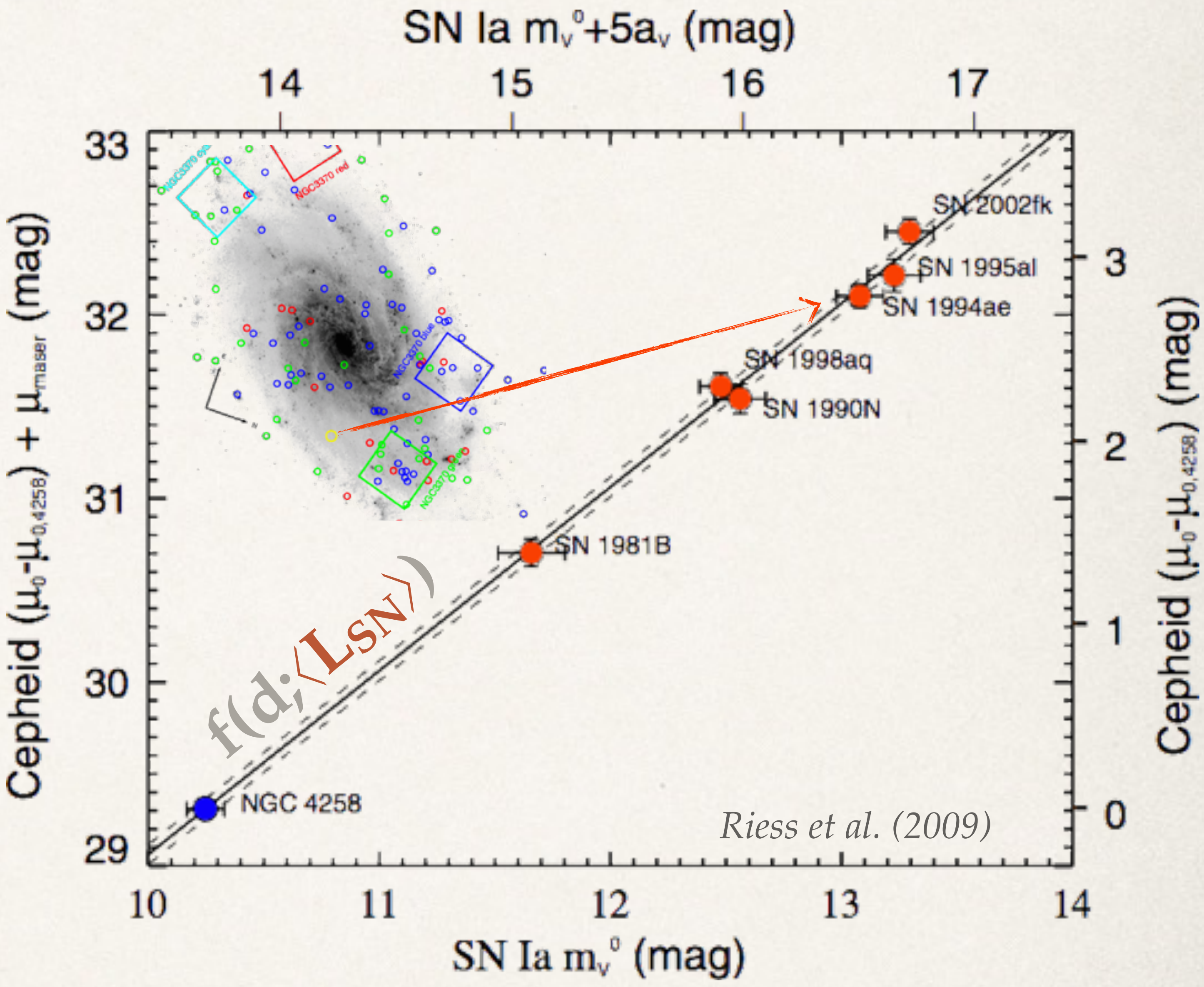


Riess+09

Disentangle H_0 and the SN luminosity

Independent Distance Measurement
— Distance & Flux ⇒ Luminosity —

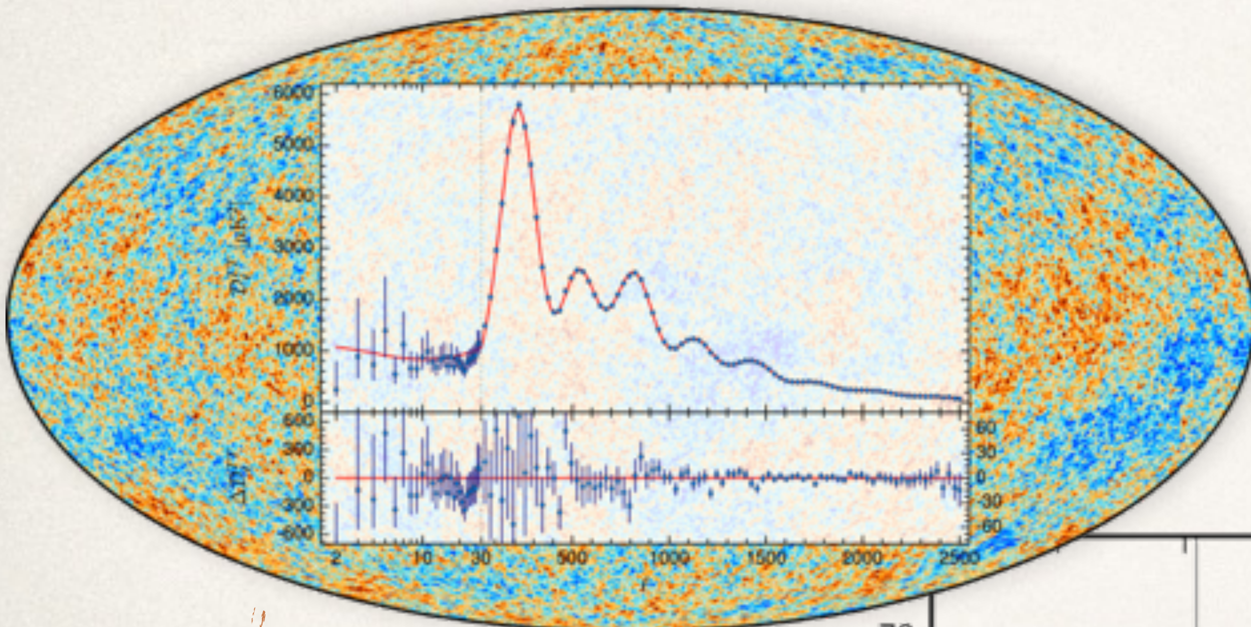
***Cepheids**: Bright young stars with a **pulsation-luminosity** relation*



H_0 = 73.2 ± 1.8 km s^{-1} Mpc^{-1}
(2.5% ; Riess et al 2016)

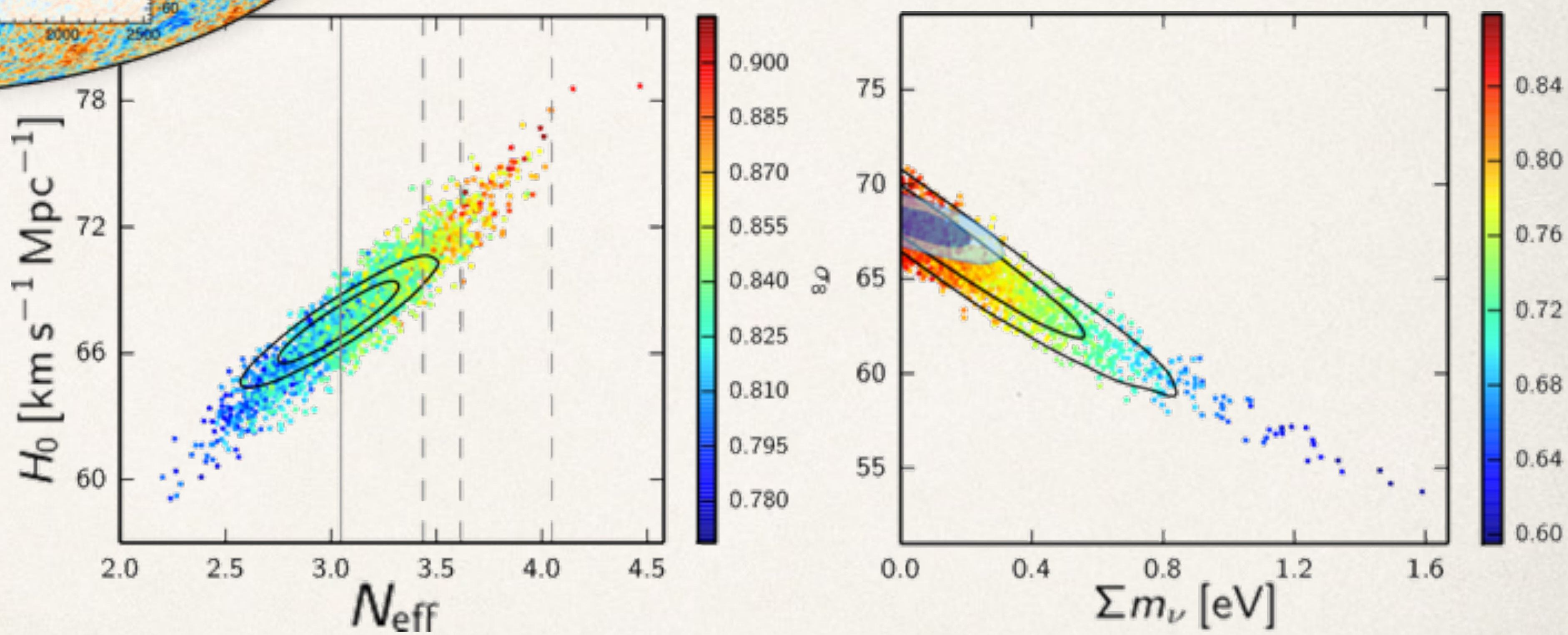
The Hubble Constant

Planck 2015 — Cosmological Results



Test the Standard Model of Cosmology

Change the model, change H_0



z~1000

THE MODEL CONSTRAINS H_0

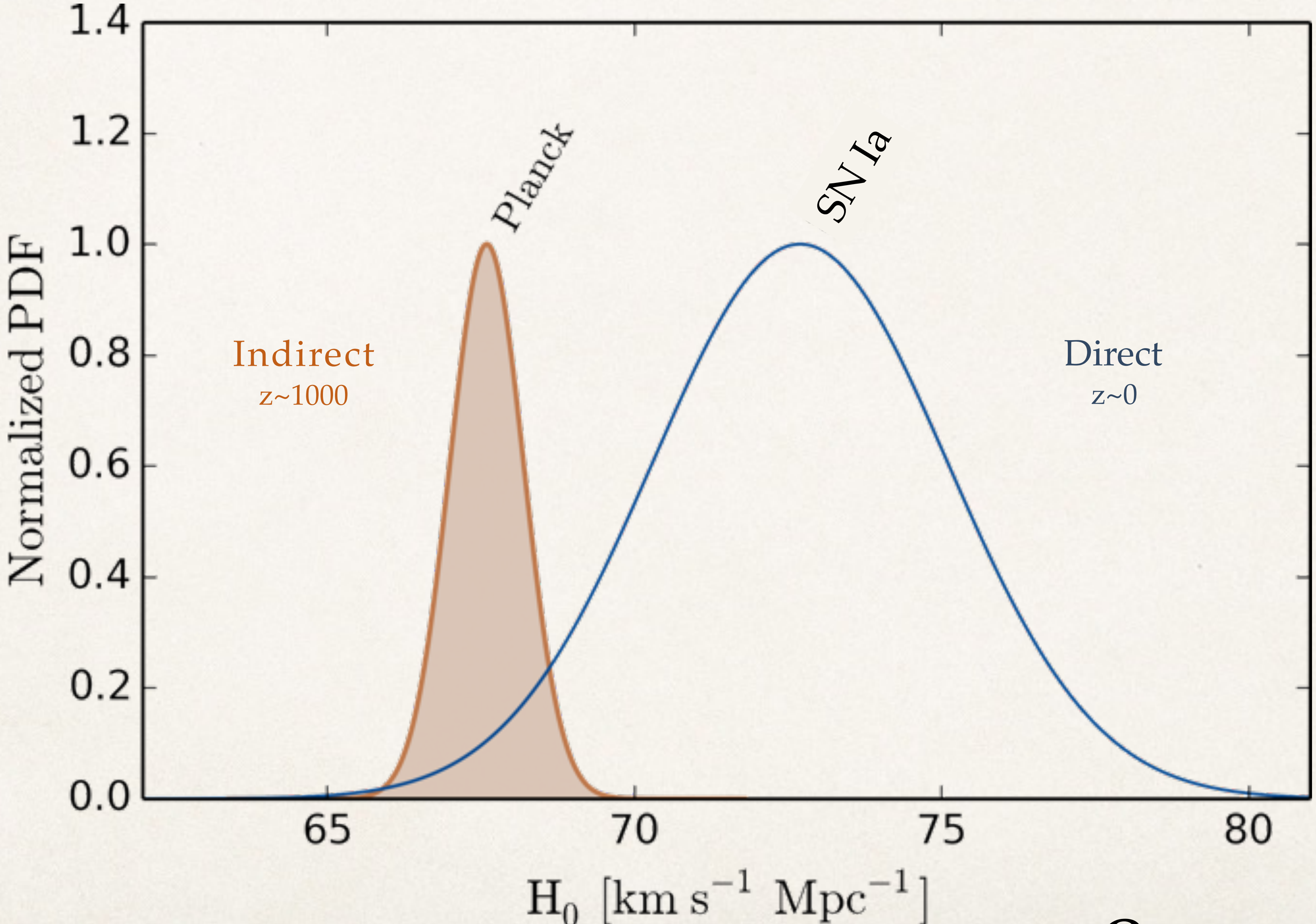
z~0

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

— Derived —

Tension in the Standard Model of Cosmology

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

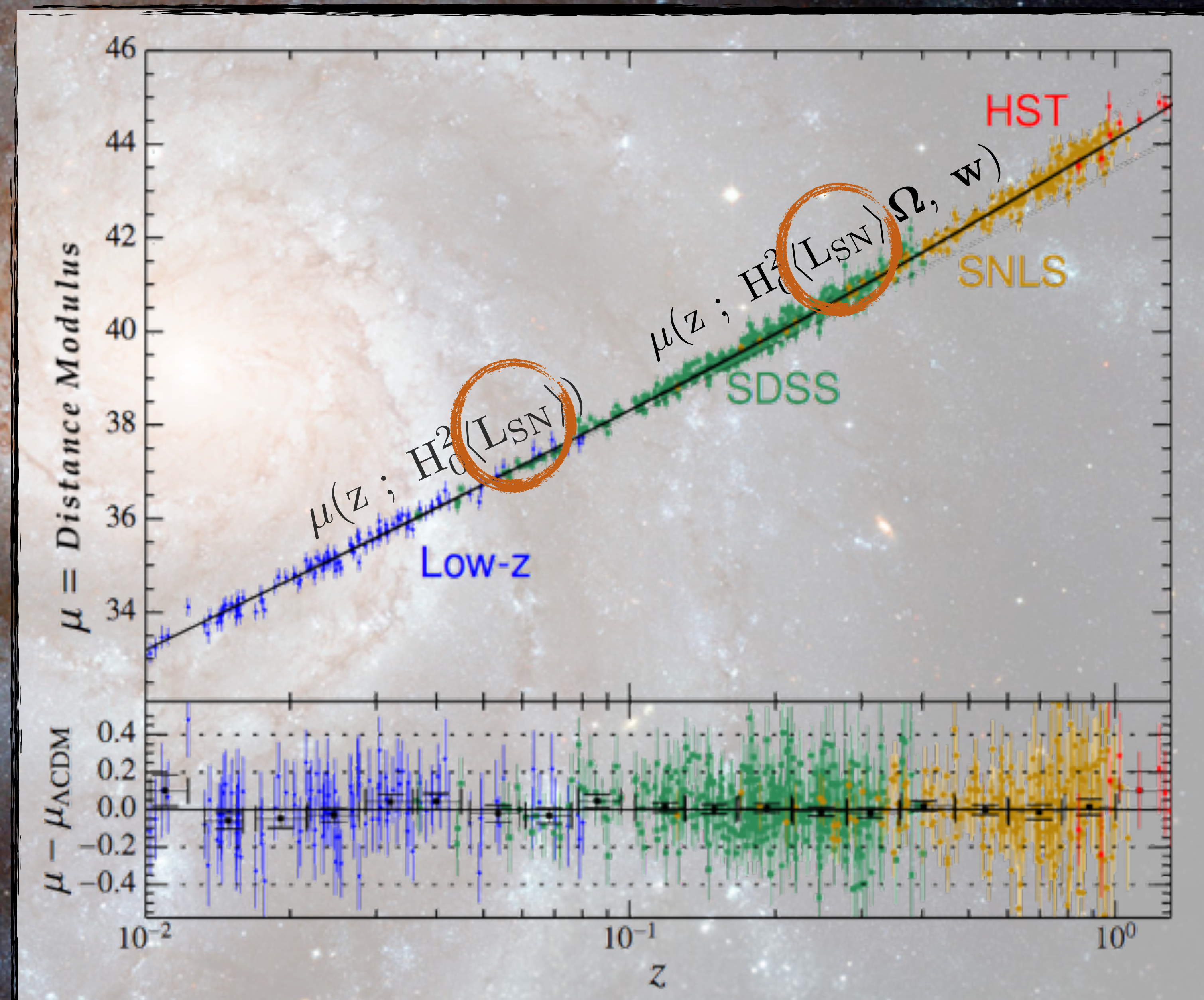


~2.5σ

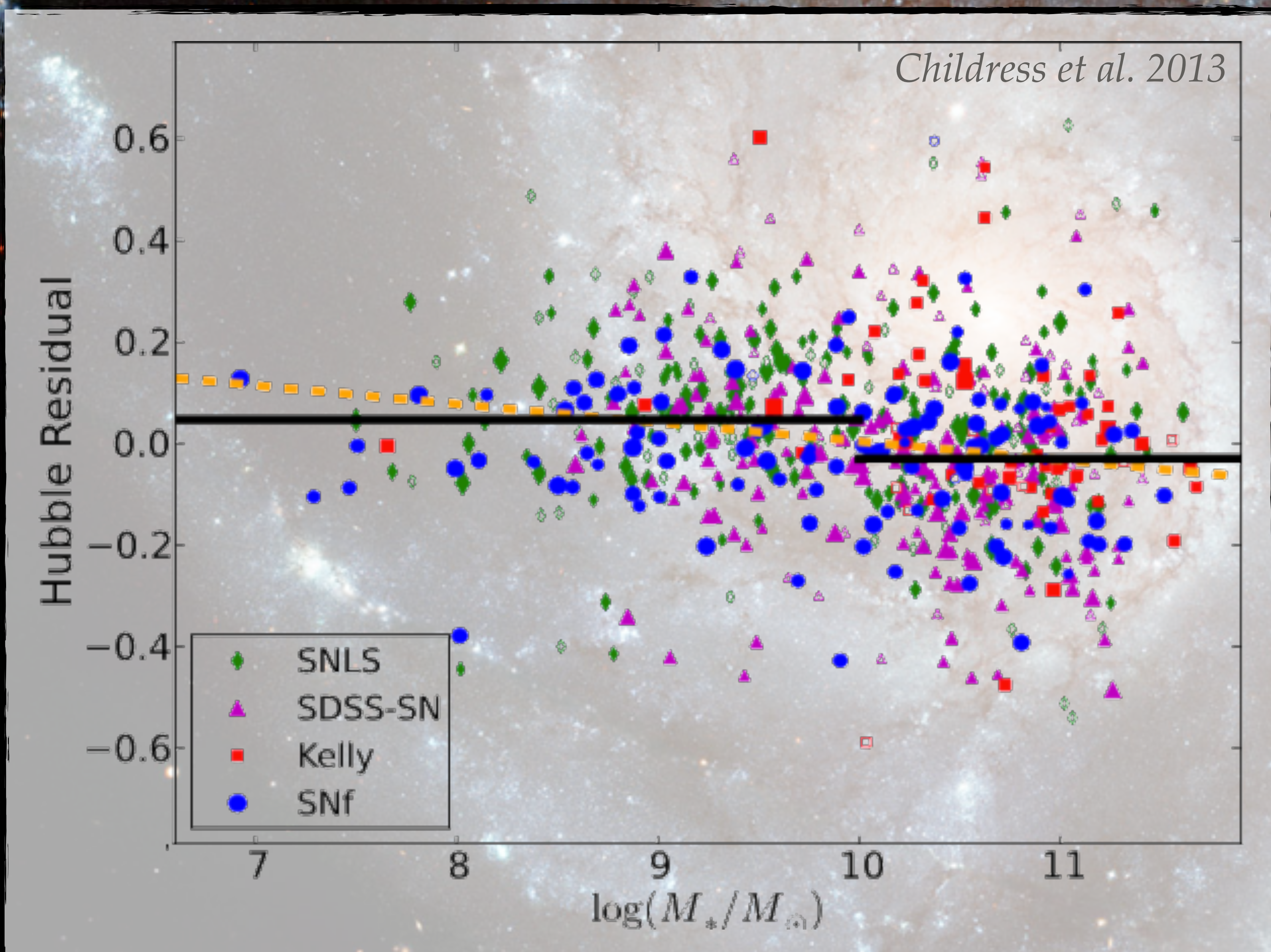
…Or a systematic error

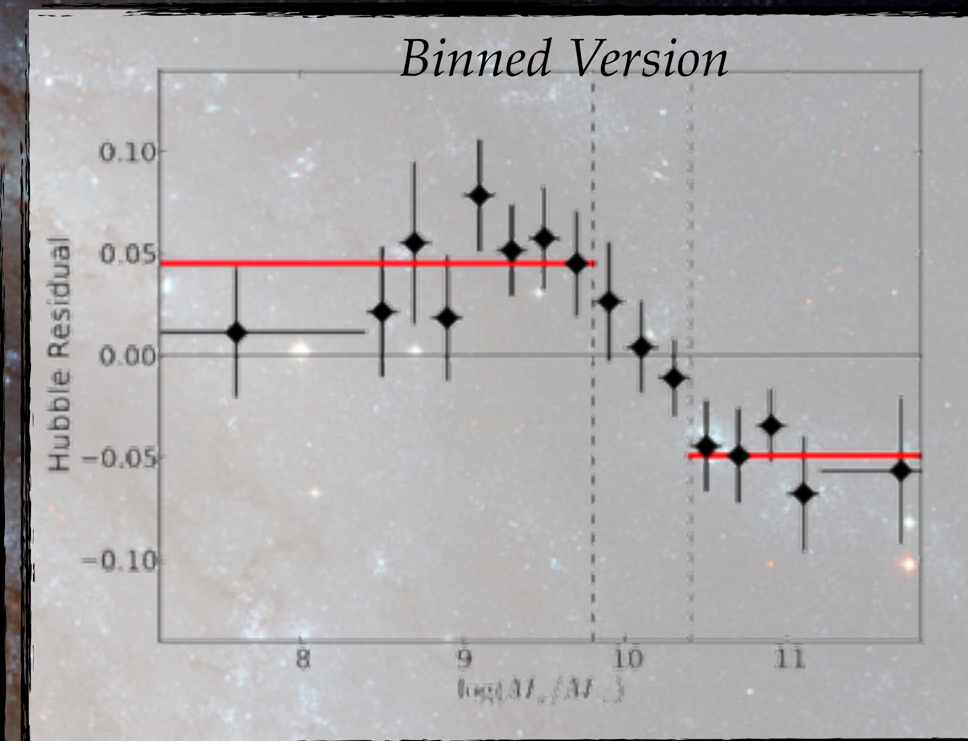
Precise Astrophysics …
… for Accurate Cosmology

Potential Astrophysical Biases of SNe Ia



The first observed effect: The Mass Step



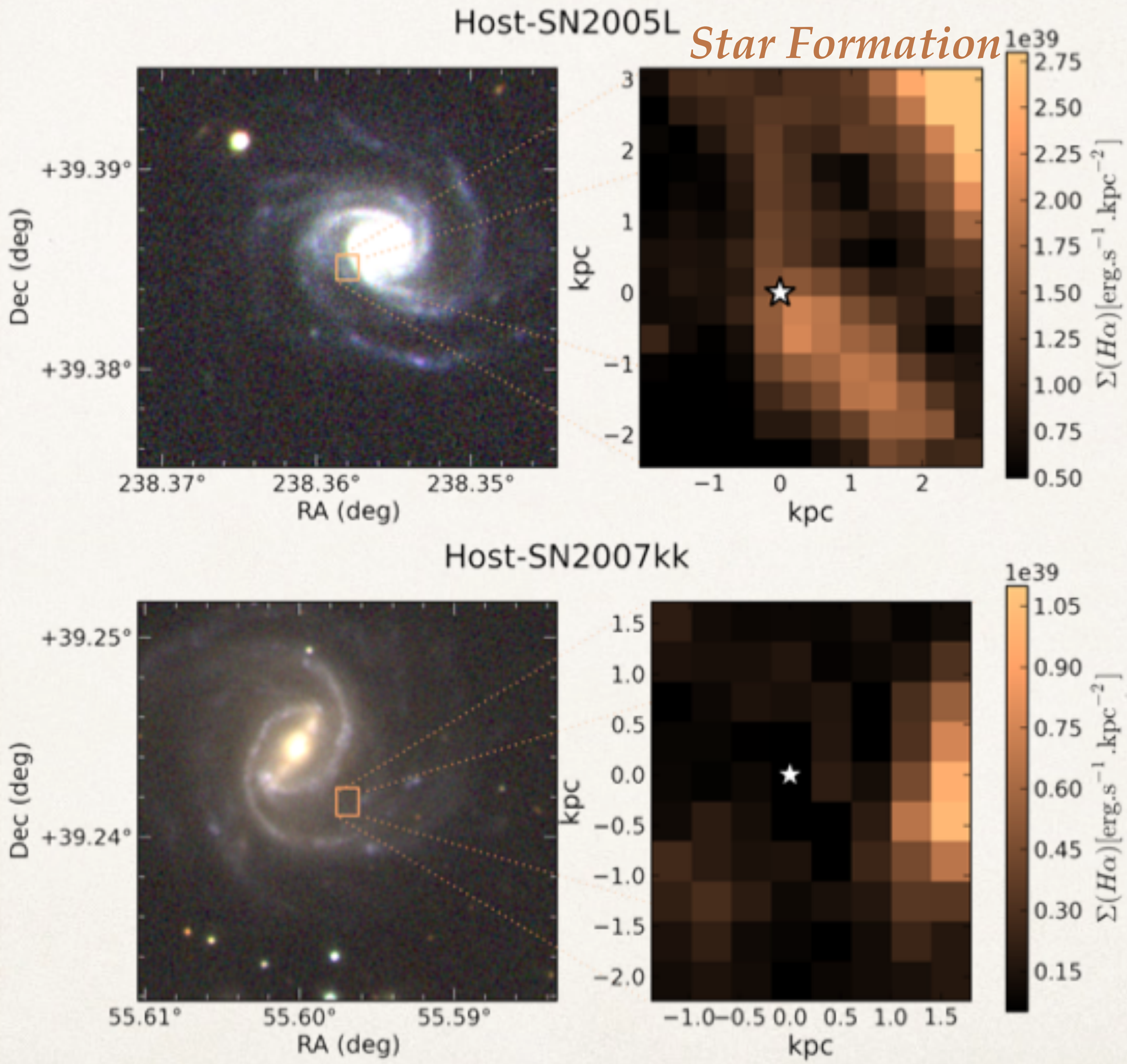


The Local Perspective

Rigault et al. 2013

Global

Spiral, Star Forming,
host galaxies



Local

Star Formation

—

Young Stars

No Star Formation

—

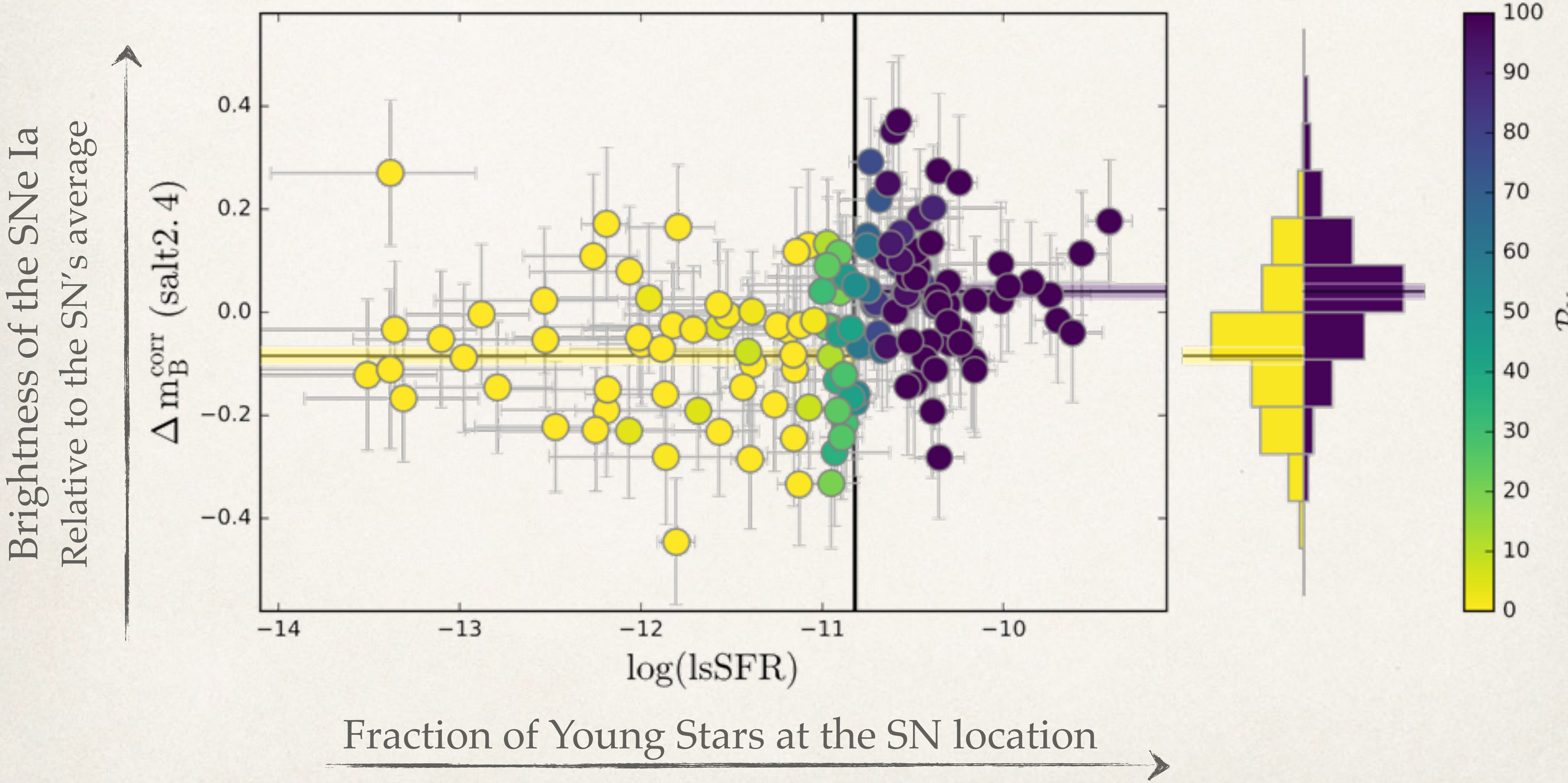
Older Stars

A Star Formation Bias

Rigault et al. 2013, 2015

Rigault et al. 2017*

~6σ detection level

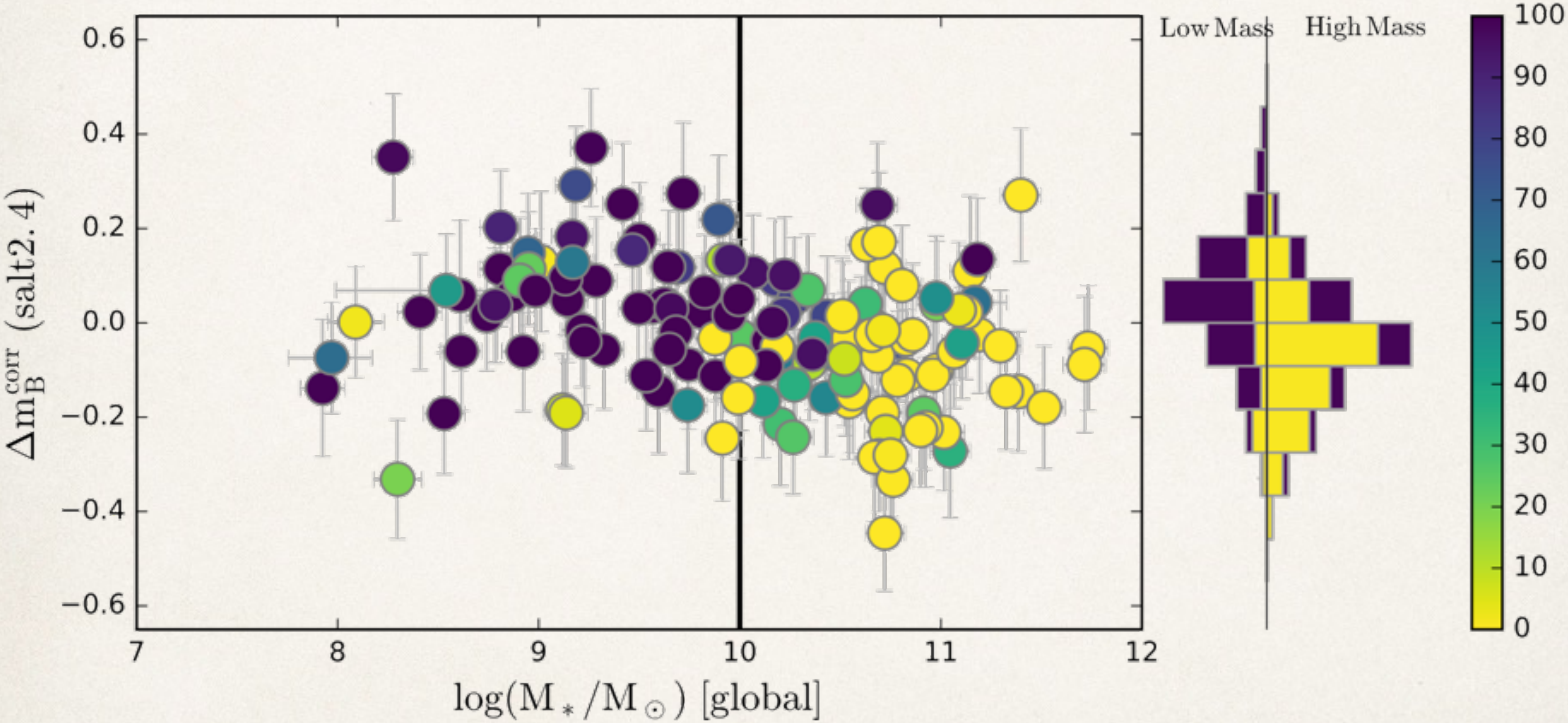


**Rigault et al 2017 is submitted*

Explaining the Mass Step

*Rigault et al. 2017**

More massive galaxies have a lower fraction of young stars



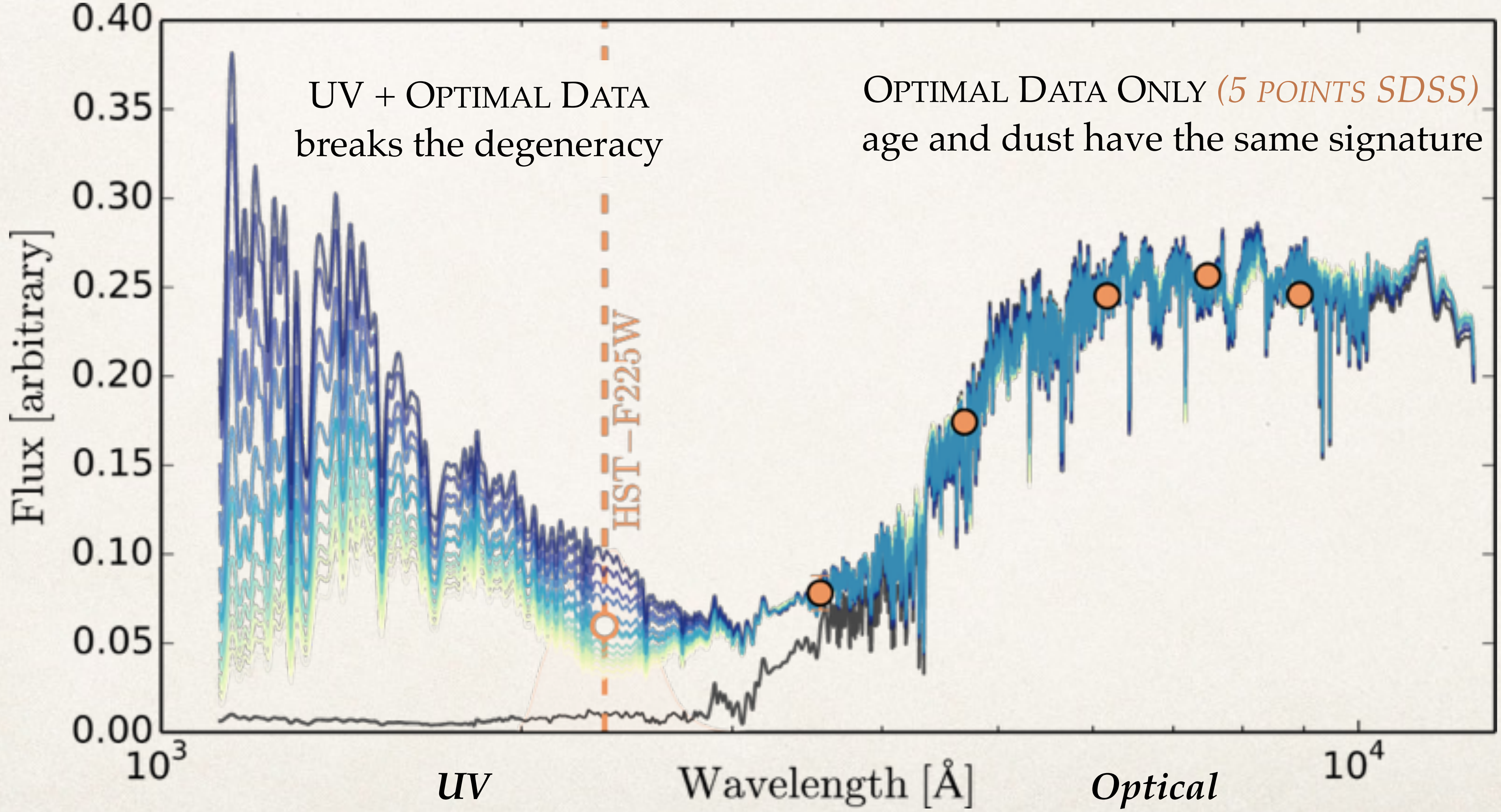
The Next Step

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

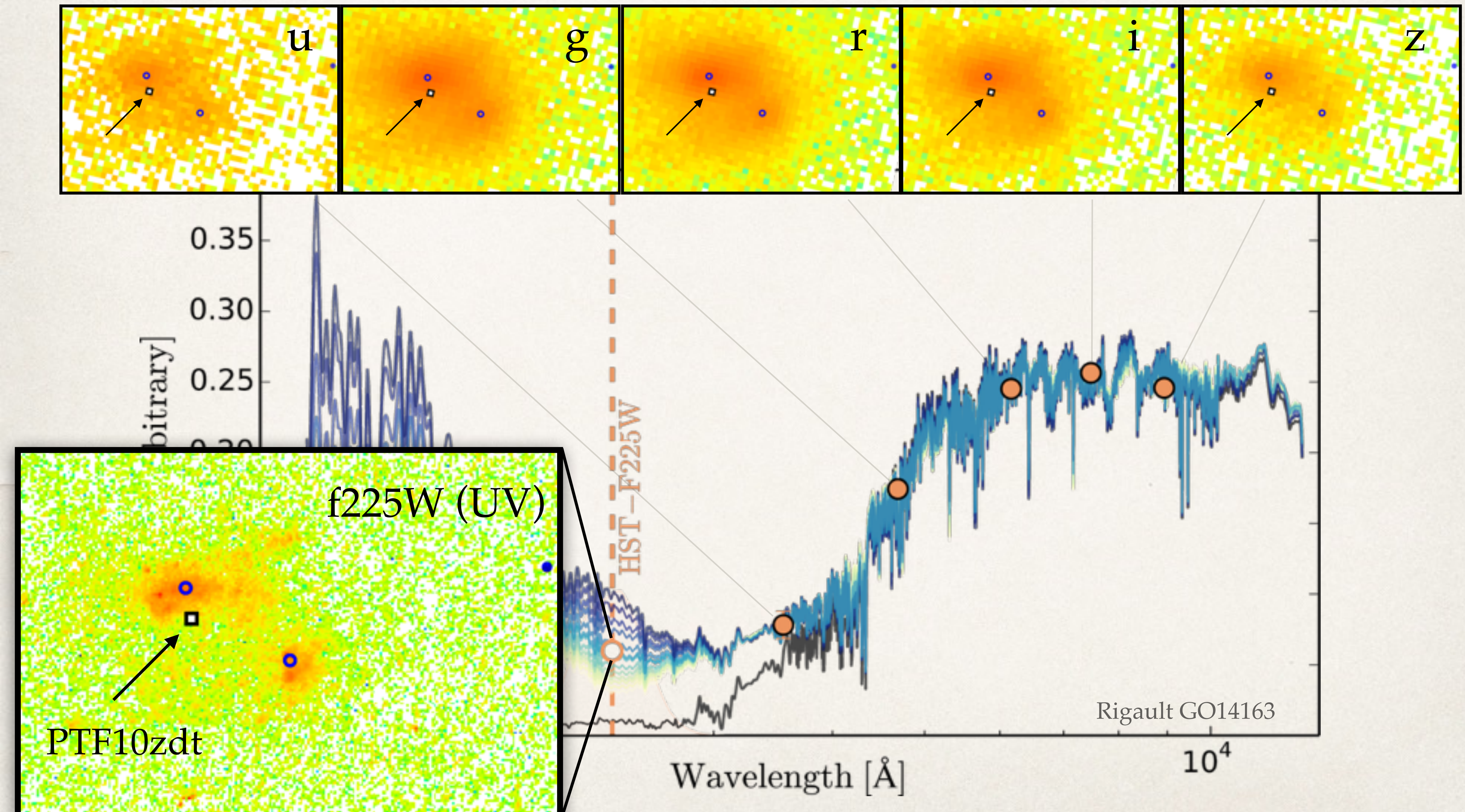


The Next Step

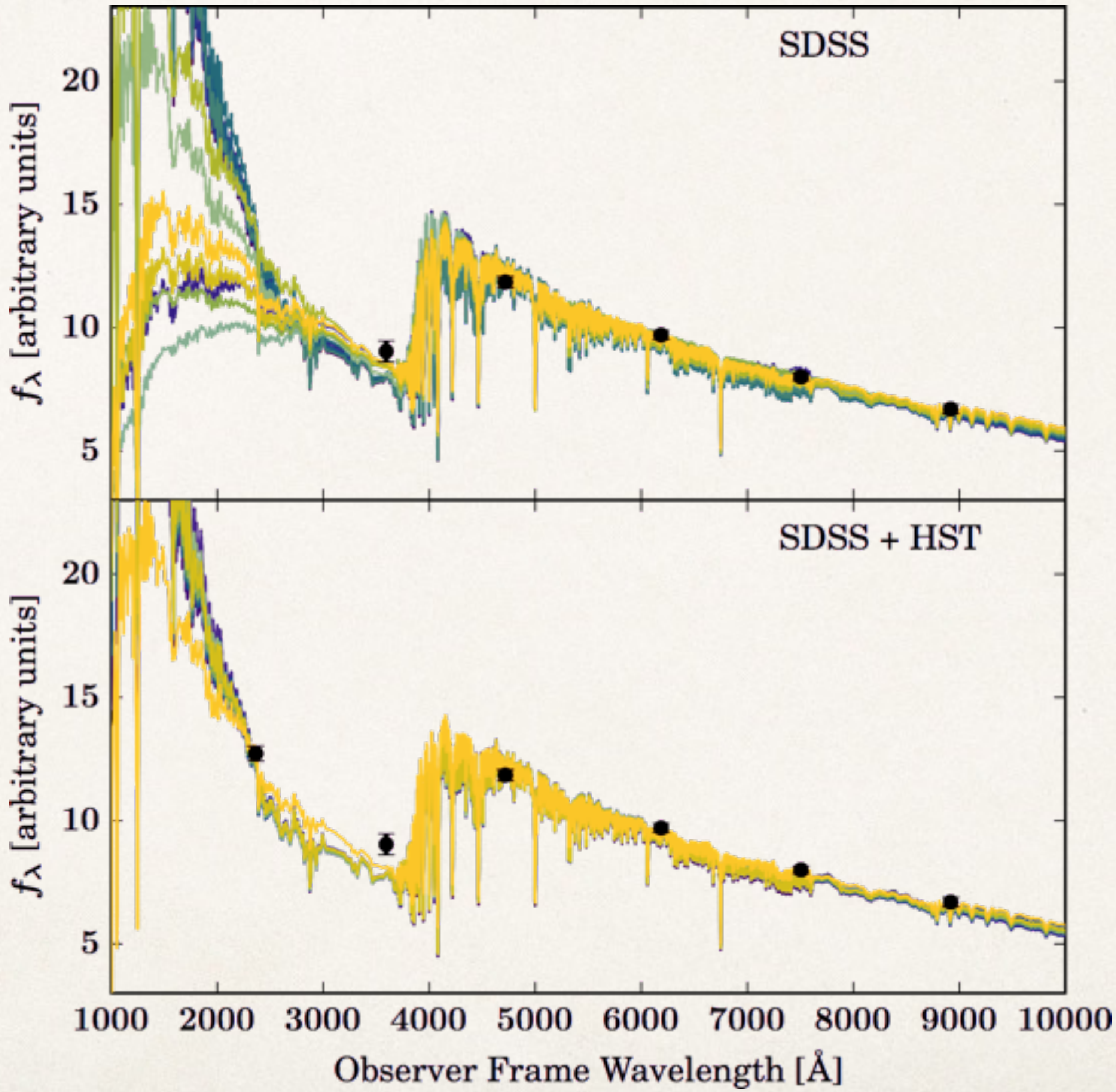
>60 SNeIa

Understand the physical origin of the effects

PI: Rigault ; GO14163



Data reduced and photometry extracted

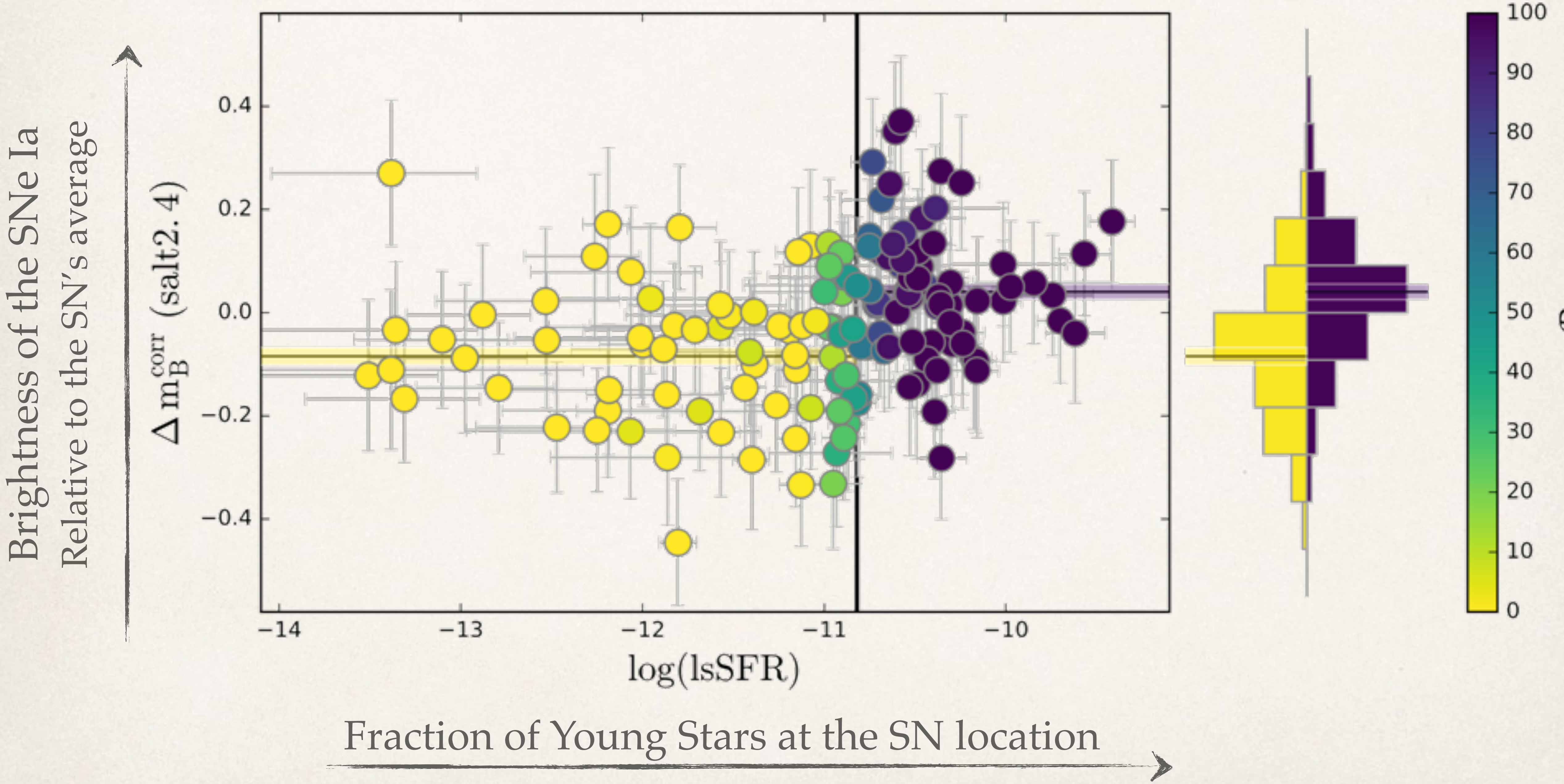


A Star Formation Bias

Rigault et al. 2013, 2015

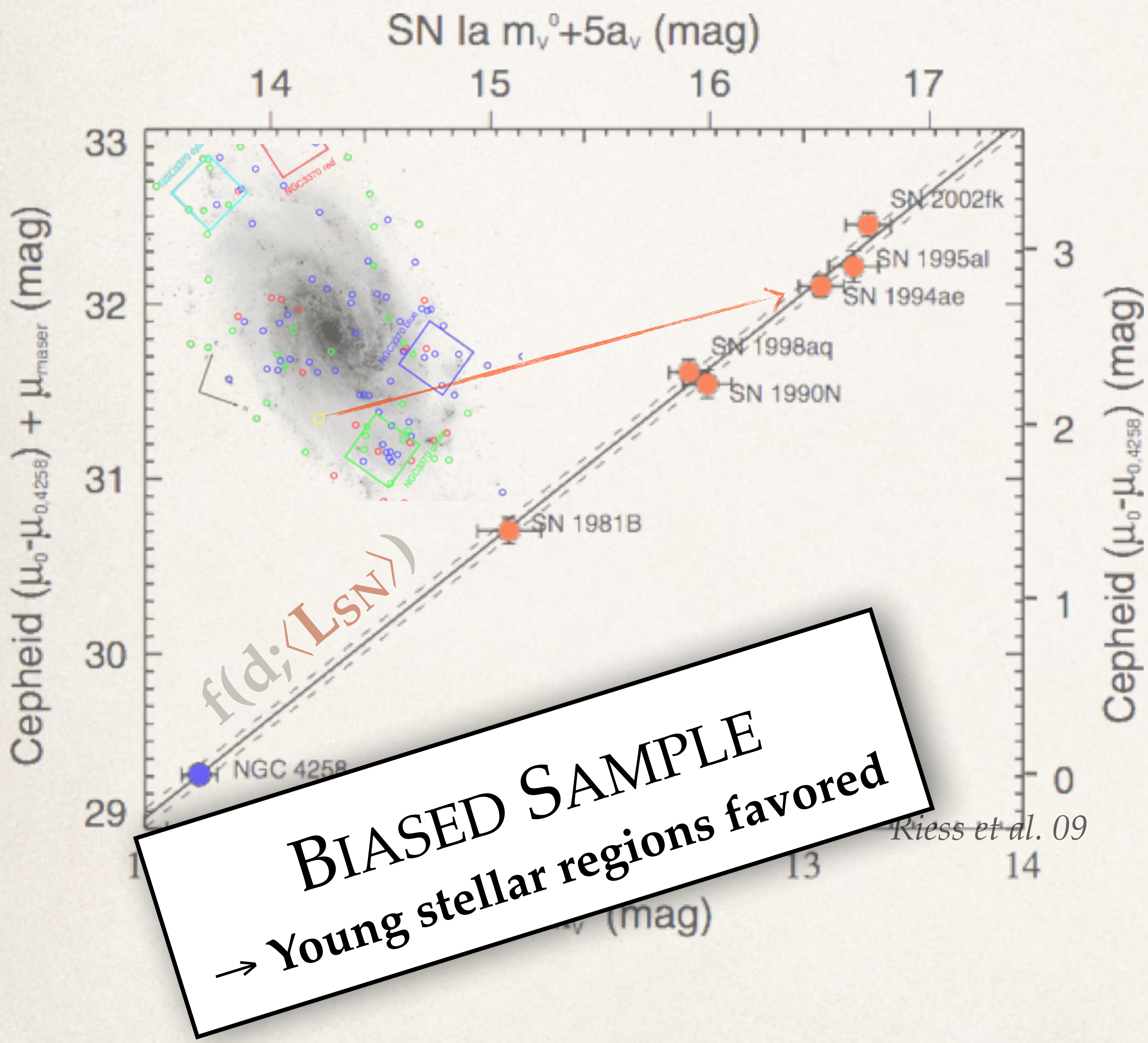
Rigault et al. 2017*

~6σ detection level



Disentangle H_0 and the SN luminosity

*Sample Selection — **Impact on H_0***



BIASED SAMPLE
→ Young stellar regions favored

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

MAESURES

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

***H_0*: OVERESTIMATED BY ~3%**

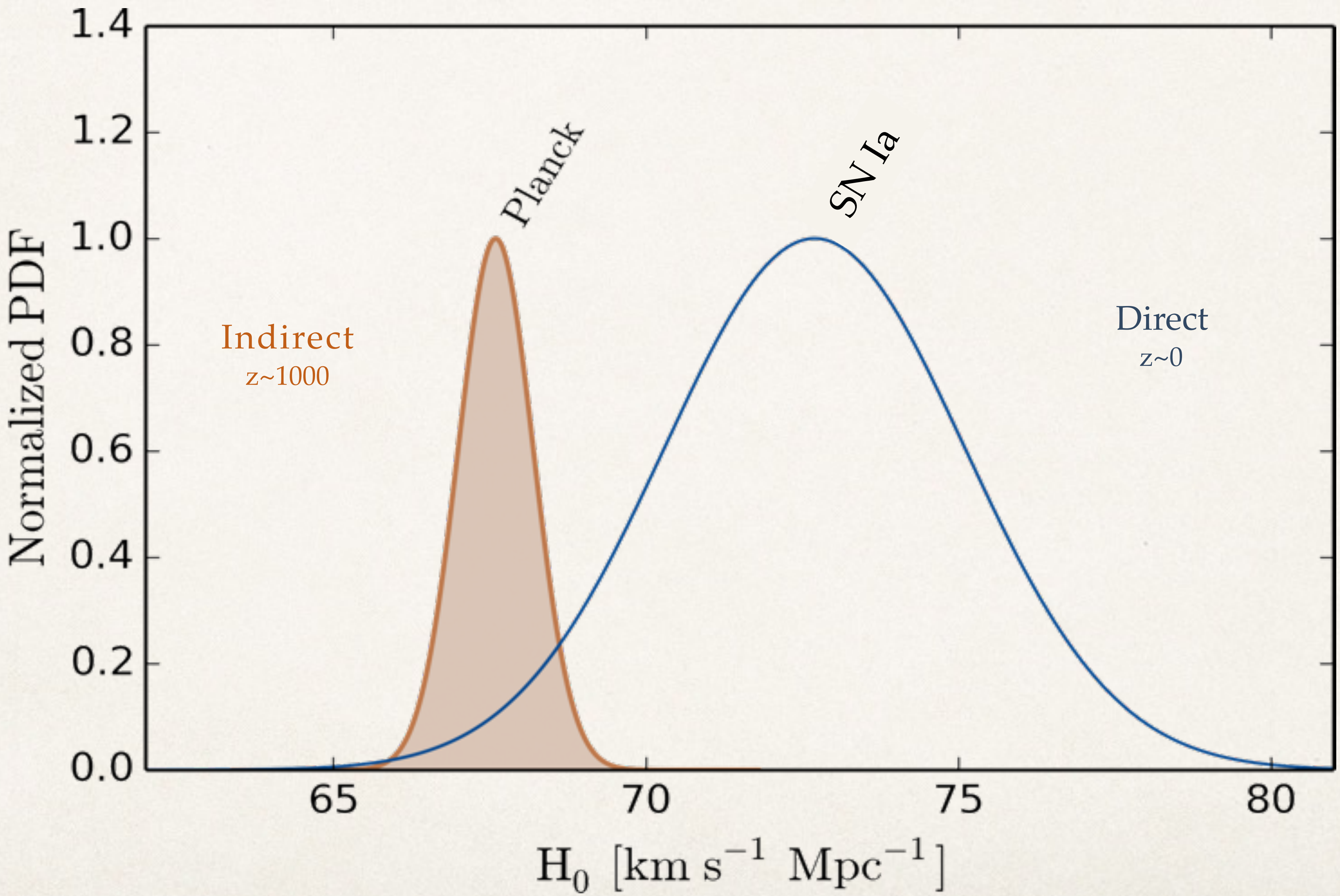
Rigault et al. 2015

H_0 = ~~73.2~~ ± 1.8 km s^{-1} Mpc^{-1}

(2.5% ; Riess et al 2016)

Tension in the Standard model of Cosmology

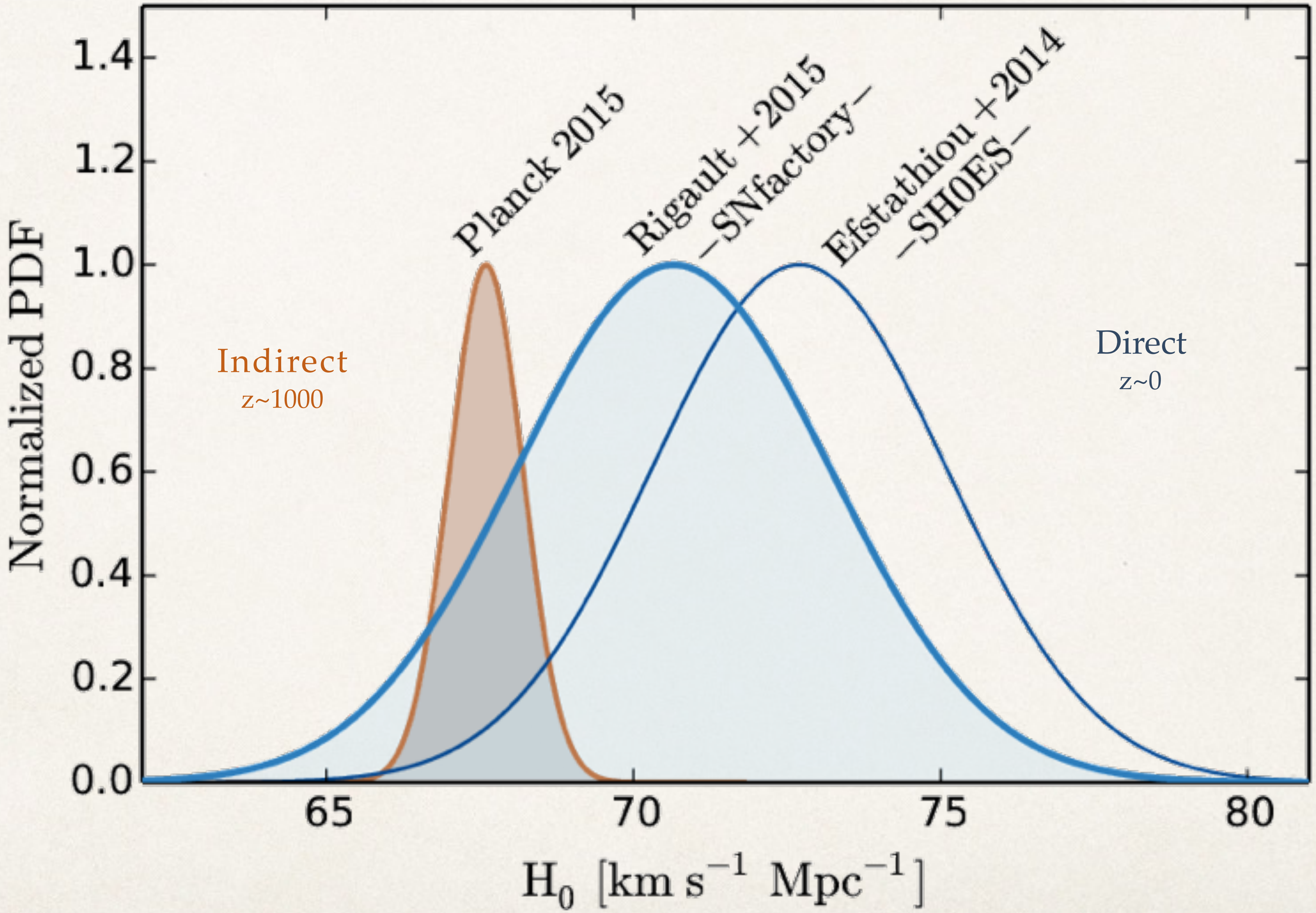
~2.5σ



Tension in the Standard model of Cosmology

~2.5σ

~1σ

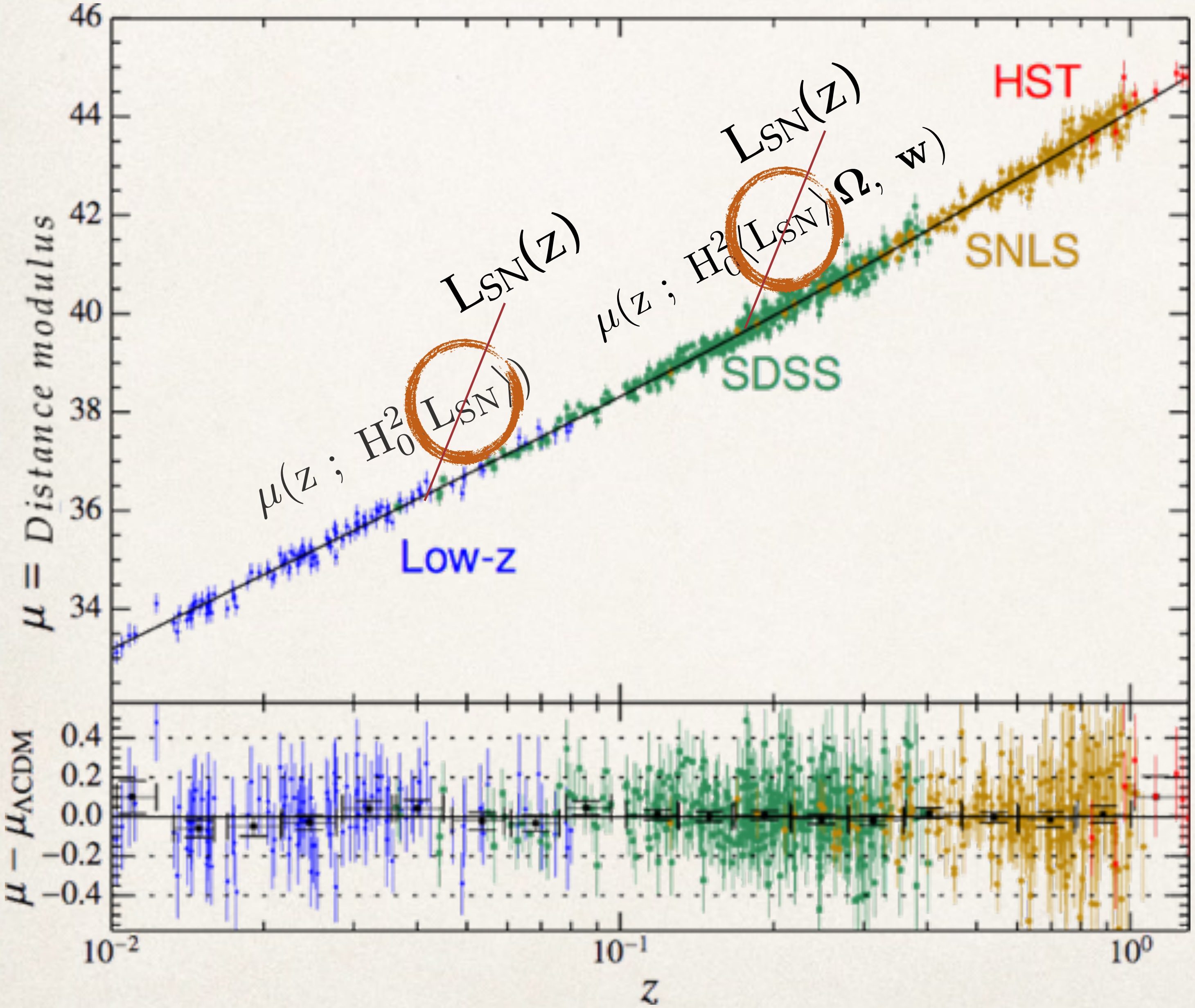


Consequence on the Cosmology — w

Rigault et al. 2013, 2017

*Redshift evolution — **Impact on w***

50% S-F 50% Passives	PREDICTION →	90% S-F 10% Passives



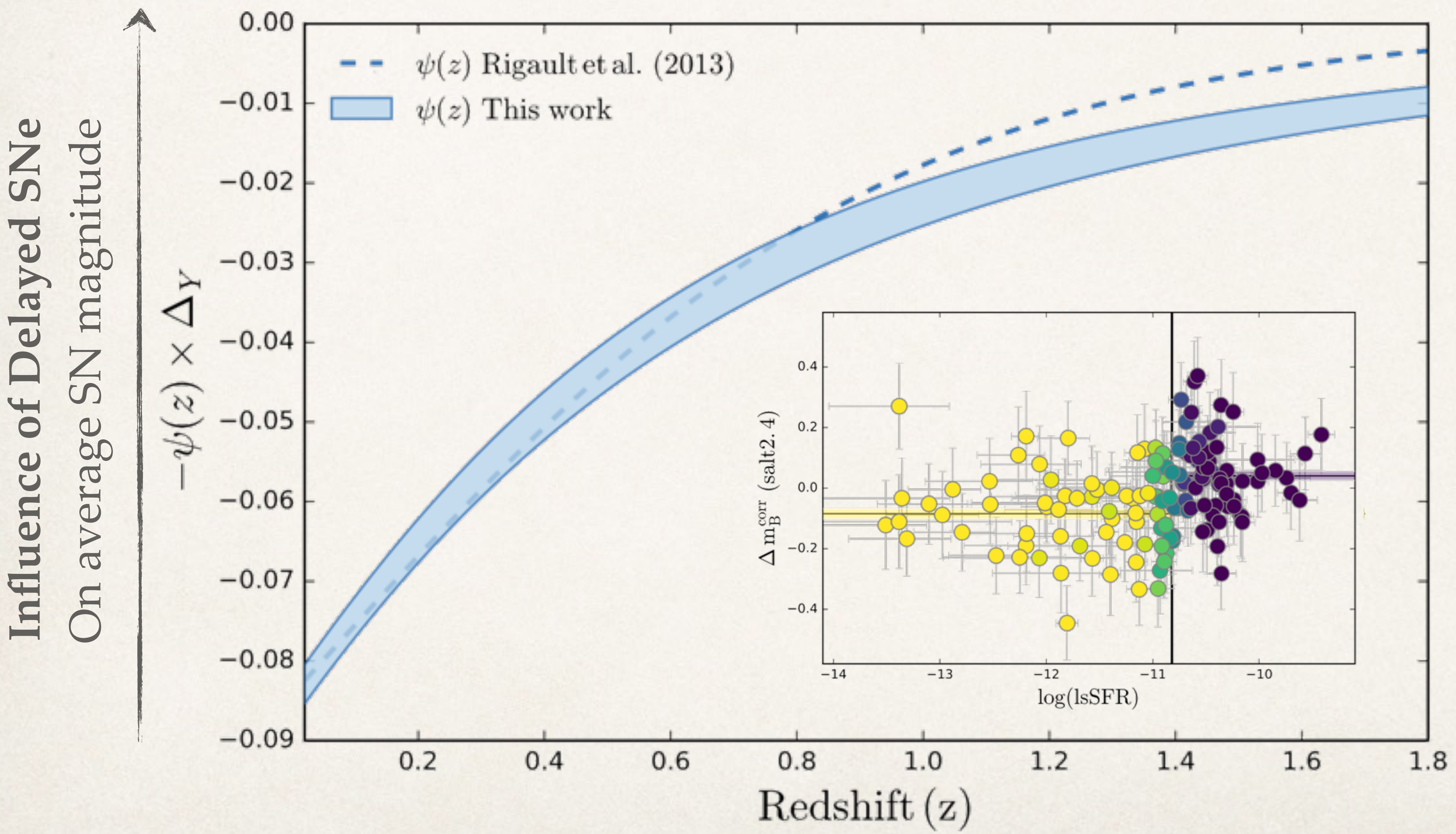
GALAXIES ARE MORE STAR FORMING AT HIGHER REDSHIFT

Could impact w by few percents

Goal of modern Cosmology: 1%

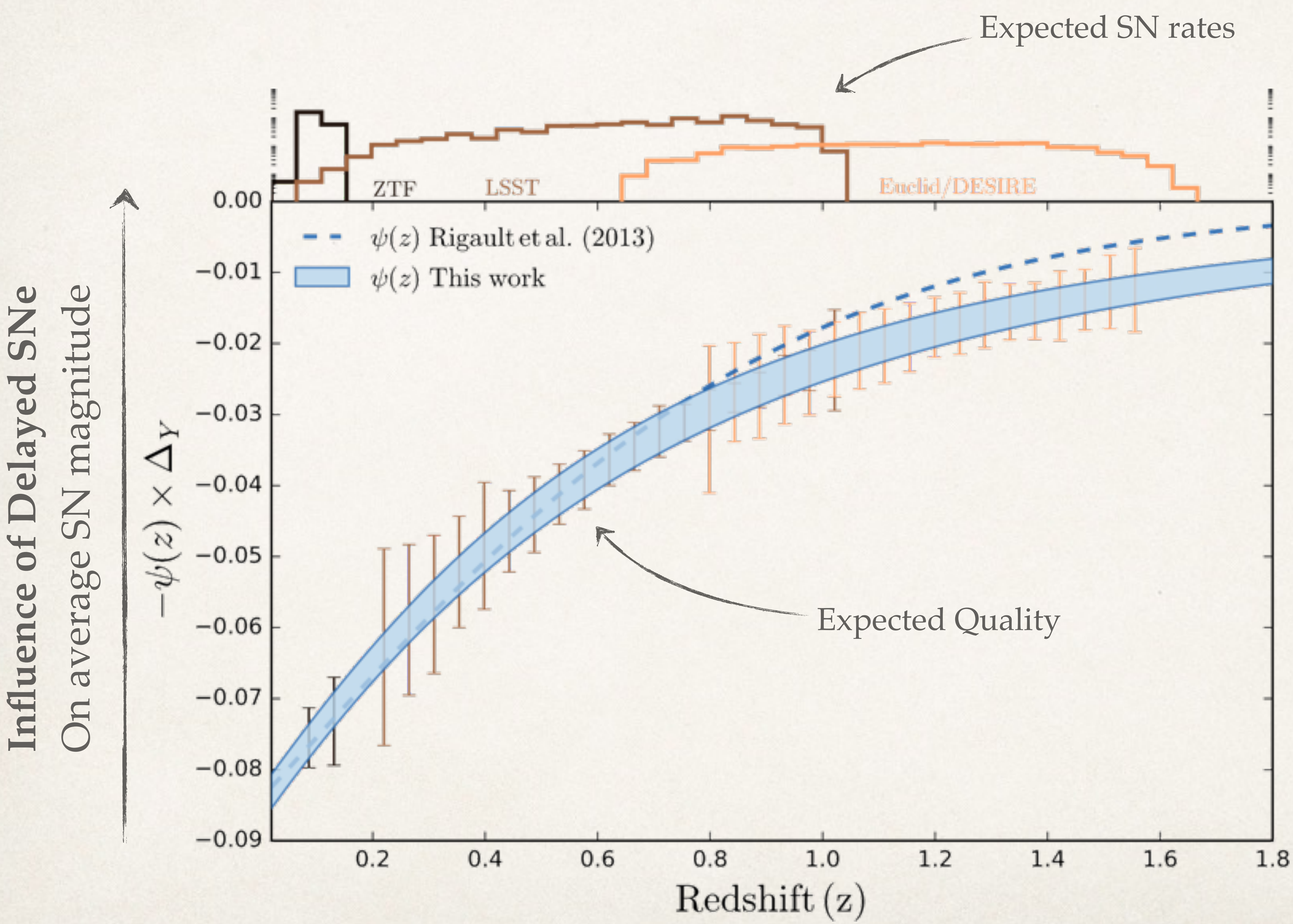
Astrophysical evolution or exotic dark energy?

*Rigault et al. 2017**



Astrophysical evolution or exotic dark energy?

Rigault et al. 2017



Astrophysical evolution or exotic dark energy?

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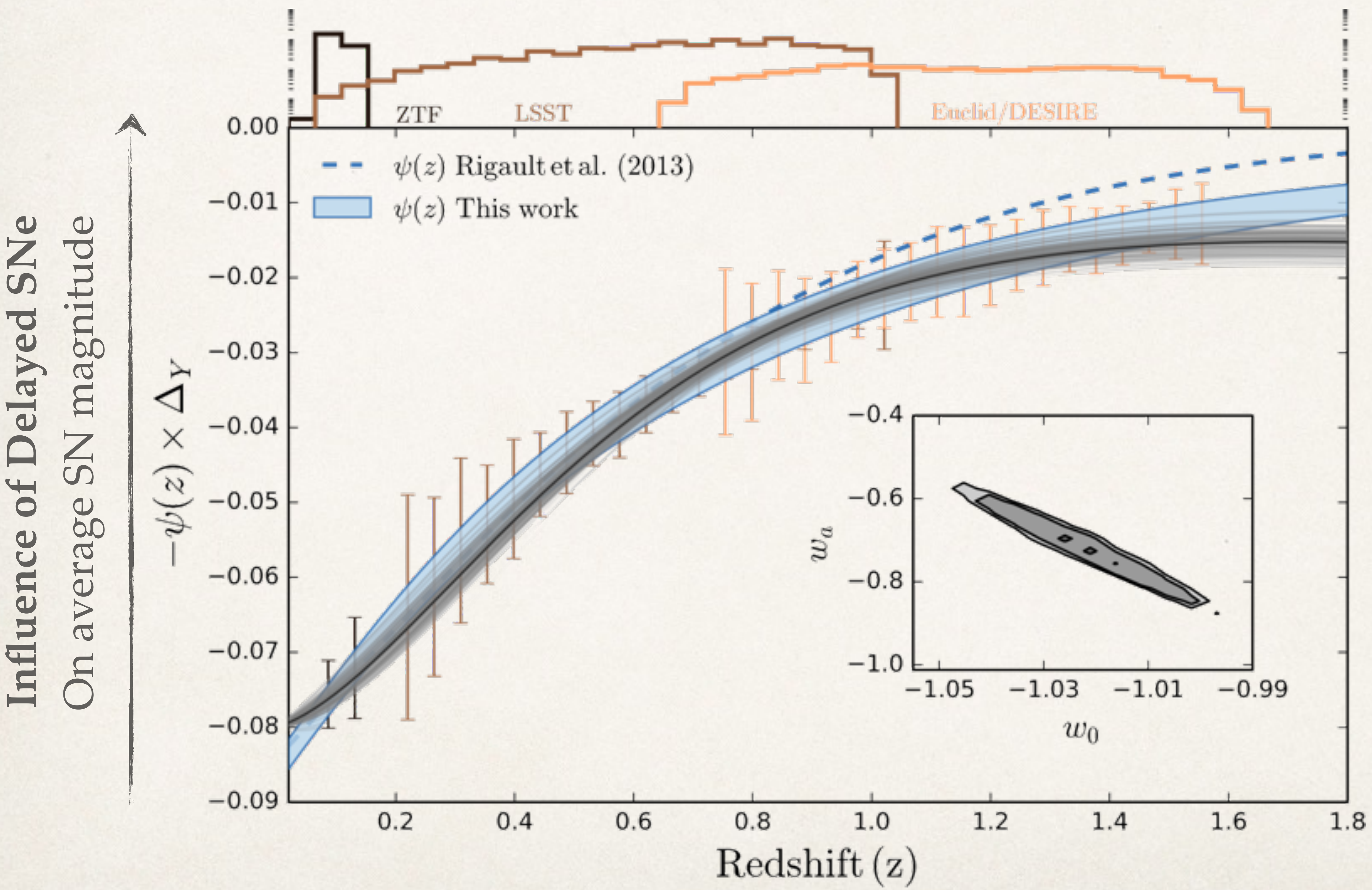
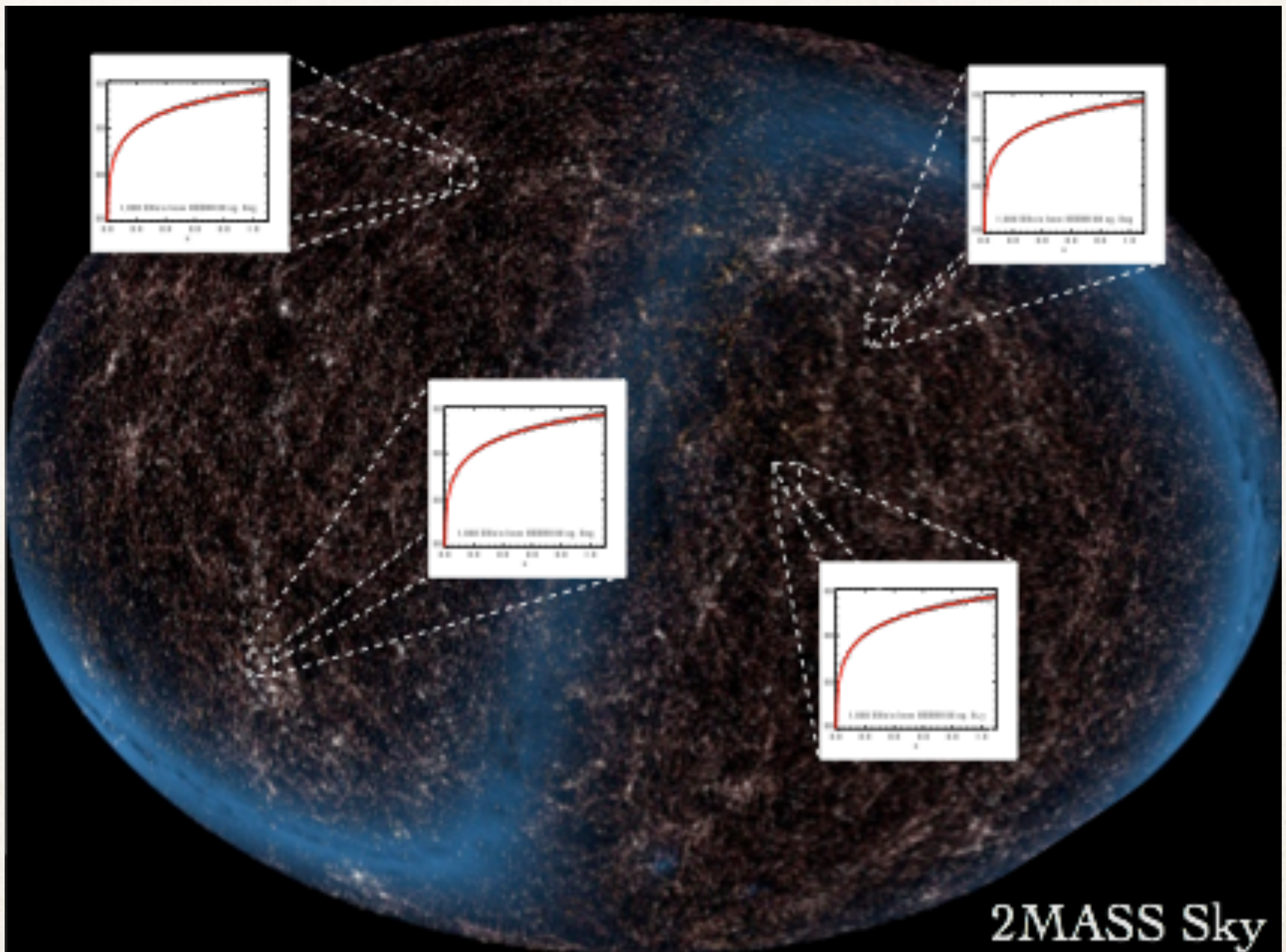


LSST

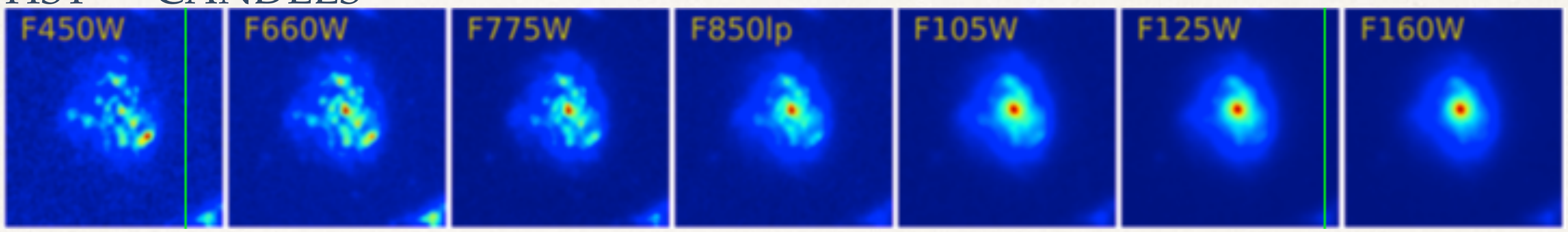
~10^6 SNeIa!

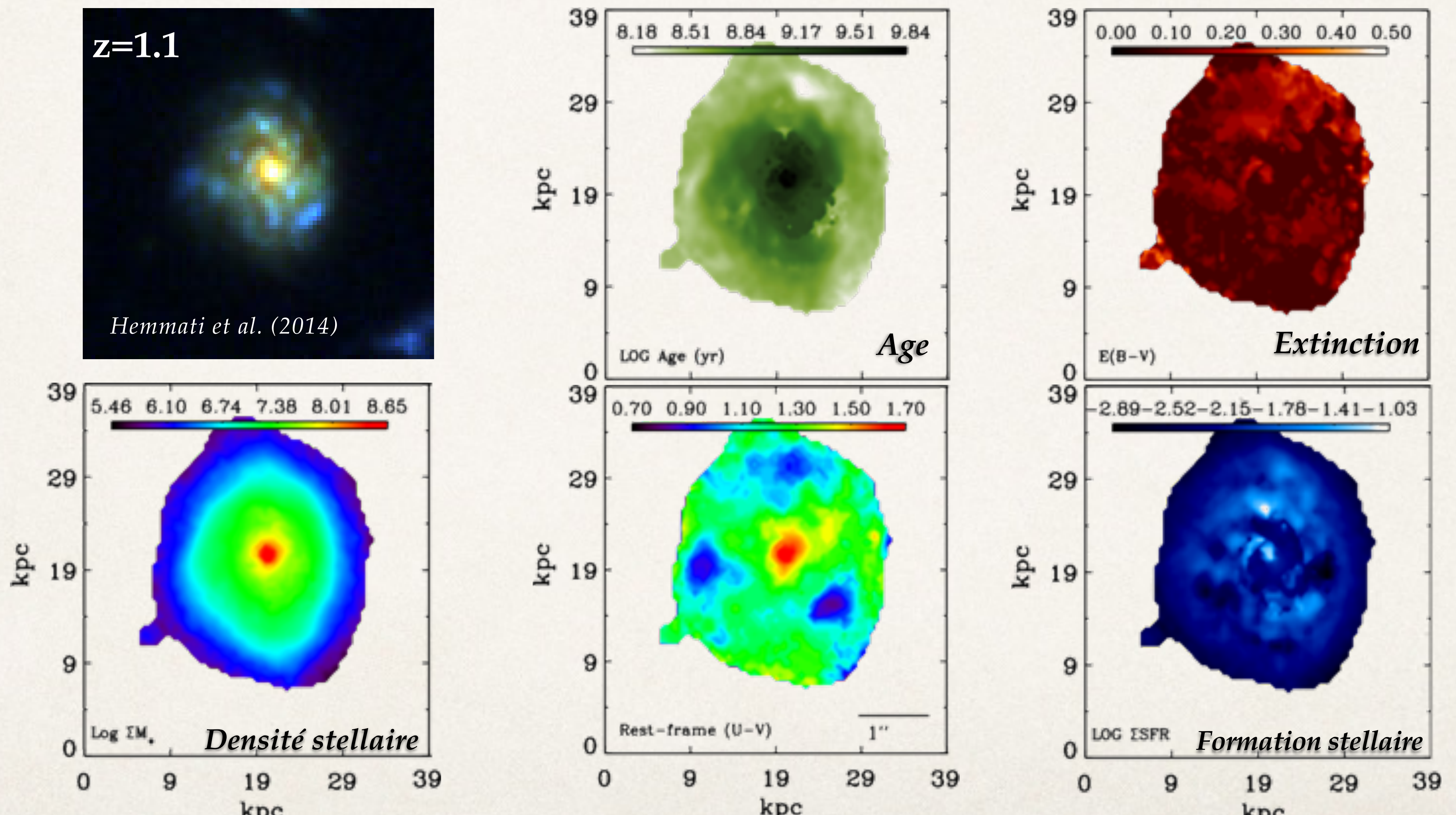
+ other probes: Weak lensing, BAO, Clusters



Local Analyses at high-redshift

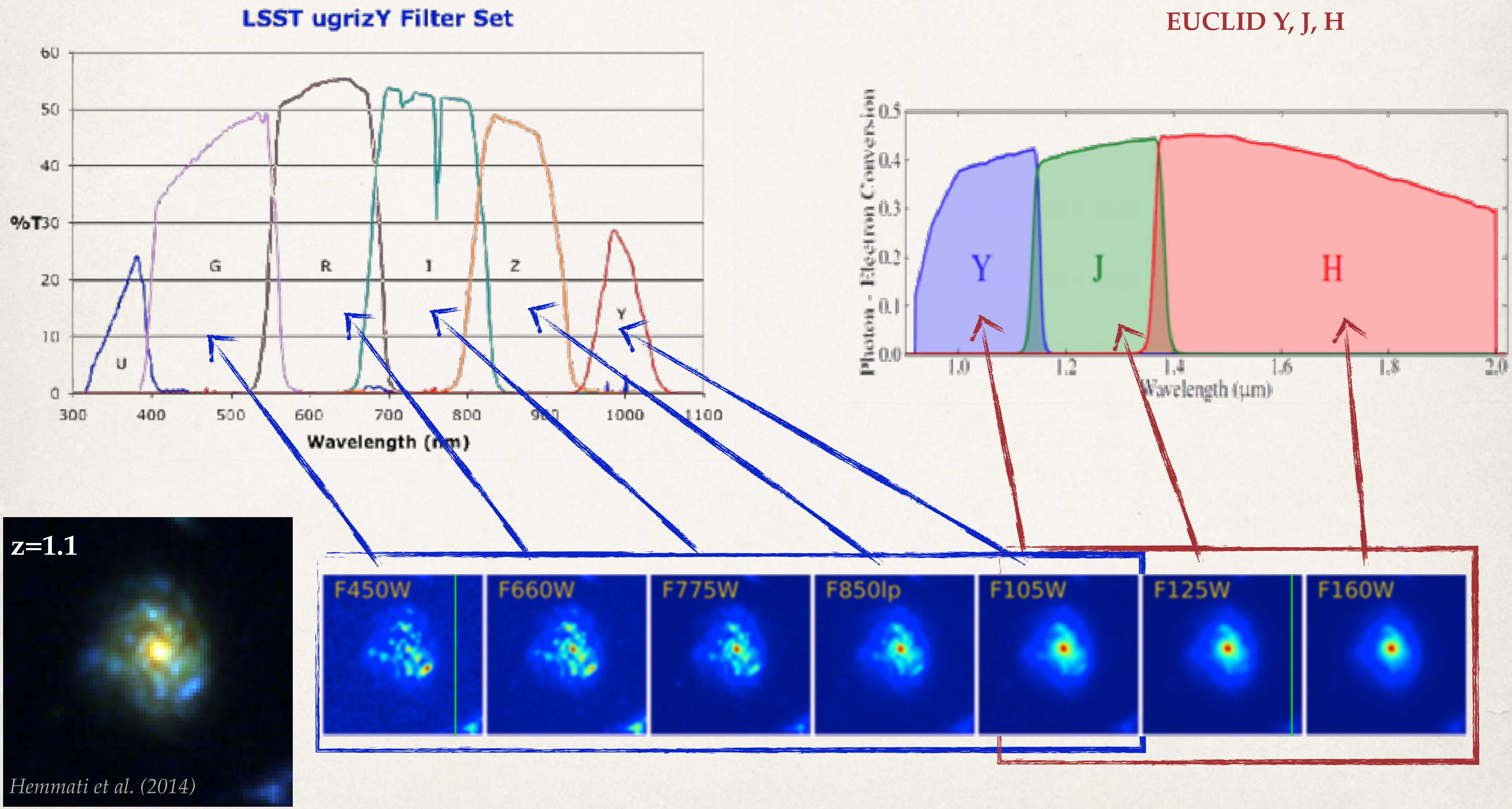
HST — CANDELS





LSST & EUCLID

Getting the local environments of SNeIa



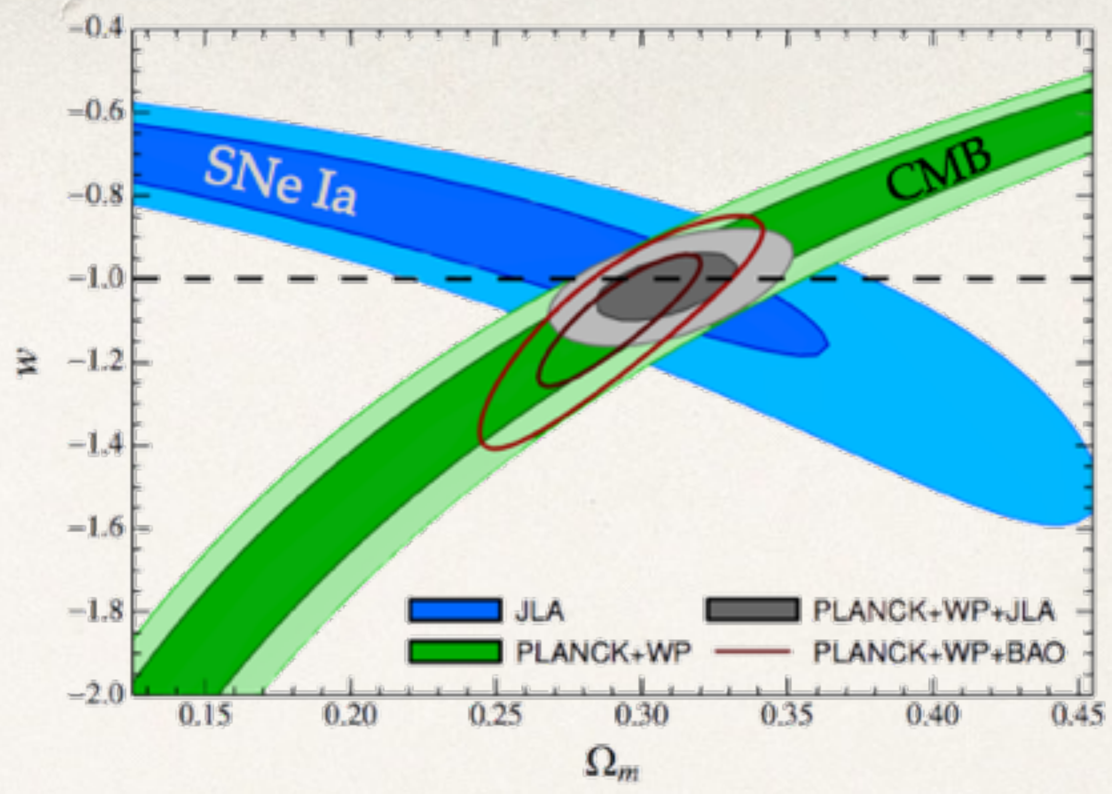
Hemmati et al. (2014)

New Surveys and Time Domain Astronomy

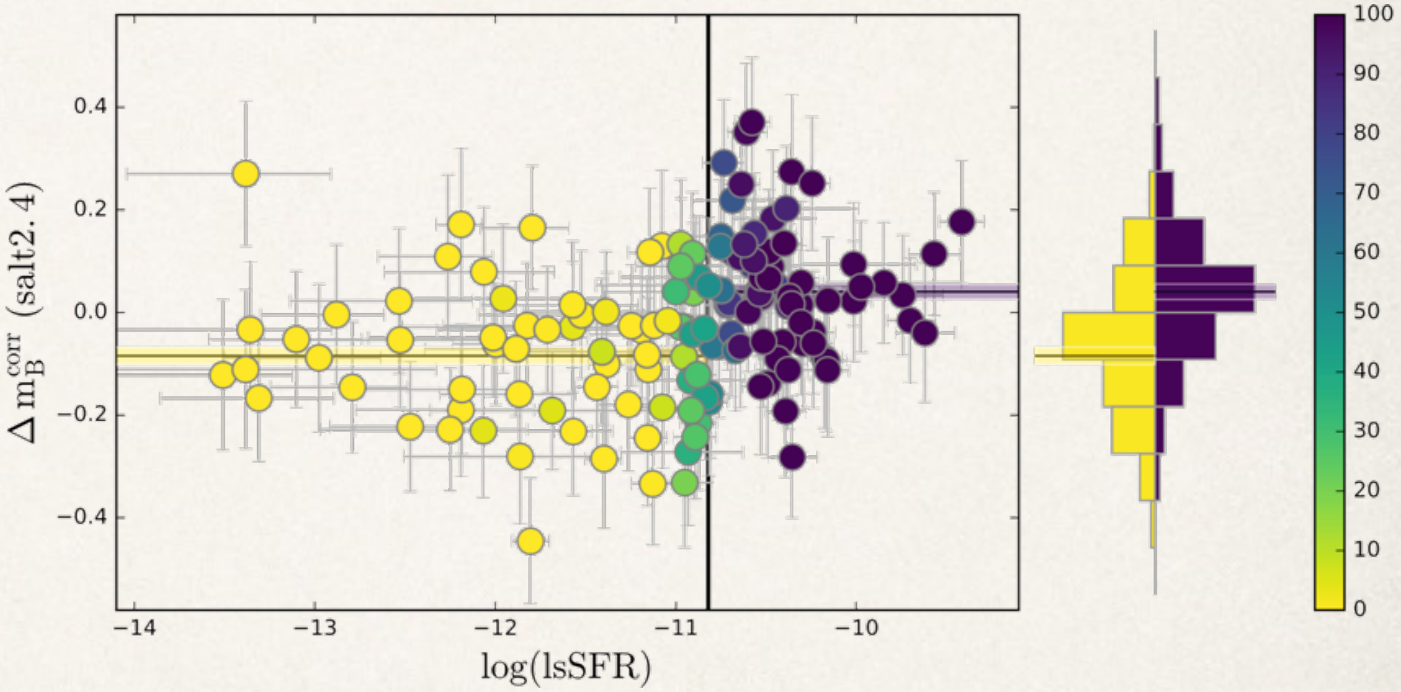
1990 → 2000 ~ 100 SNe Ia | 2000 → 2015 ~ 10^3 SNe Ia | 2017 → 2030 ~ 10^6 SNe Ia

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!