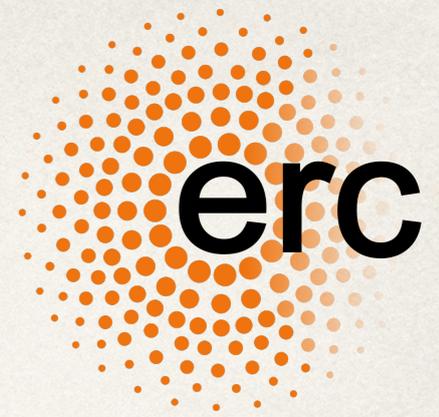




**IN2P3**

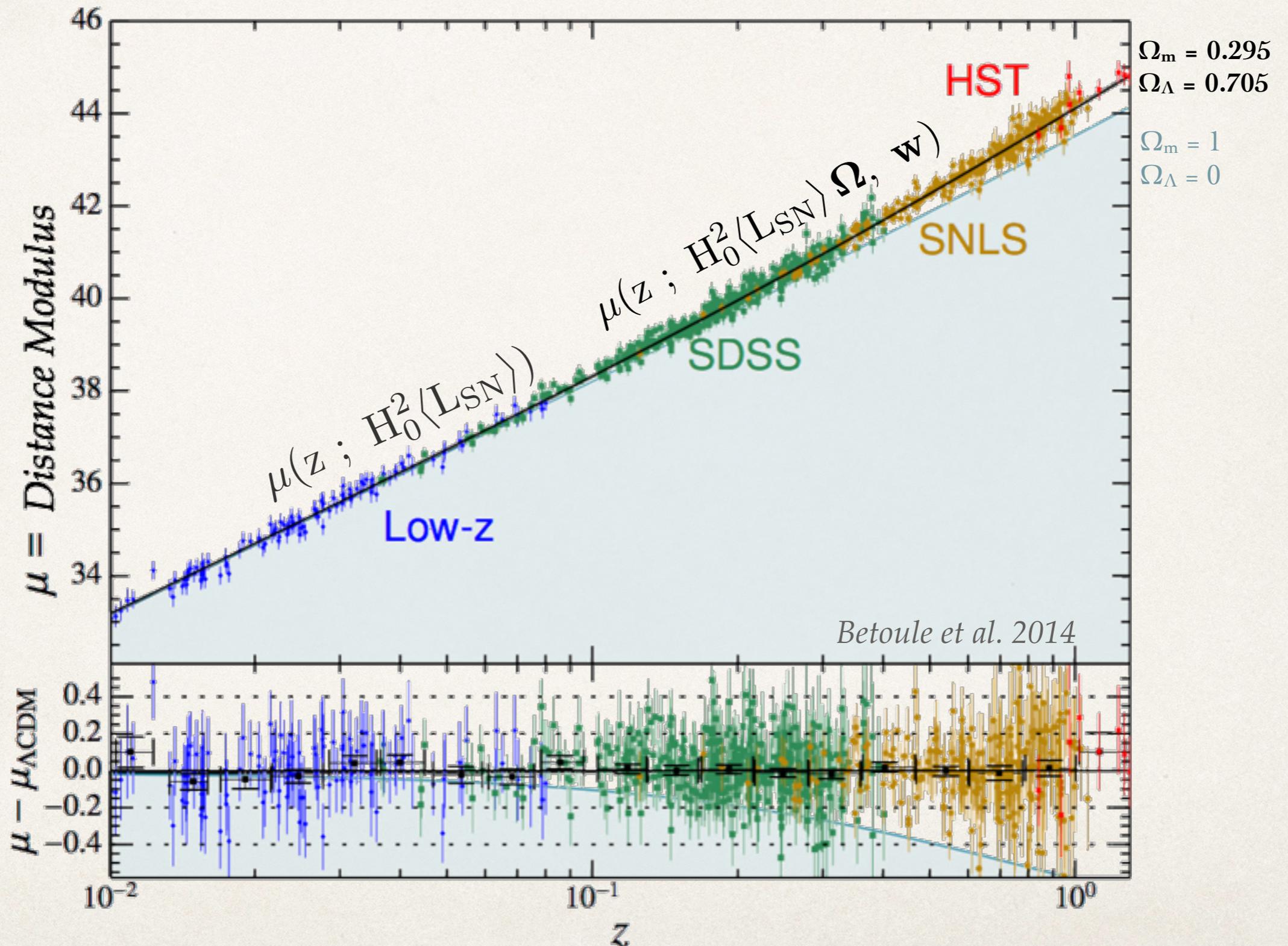
Institut national de **physique nucléaire**  
et de **physique des particules**



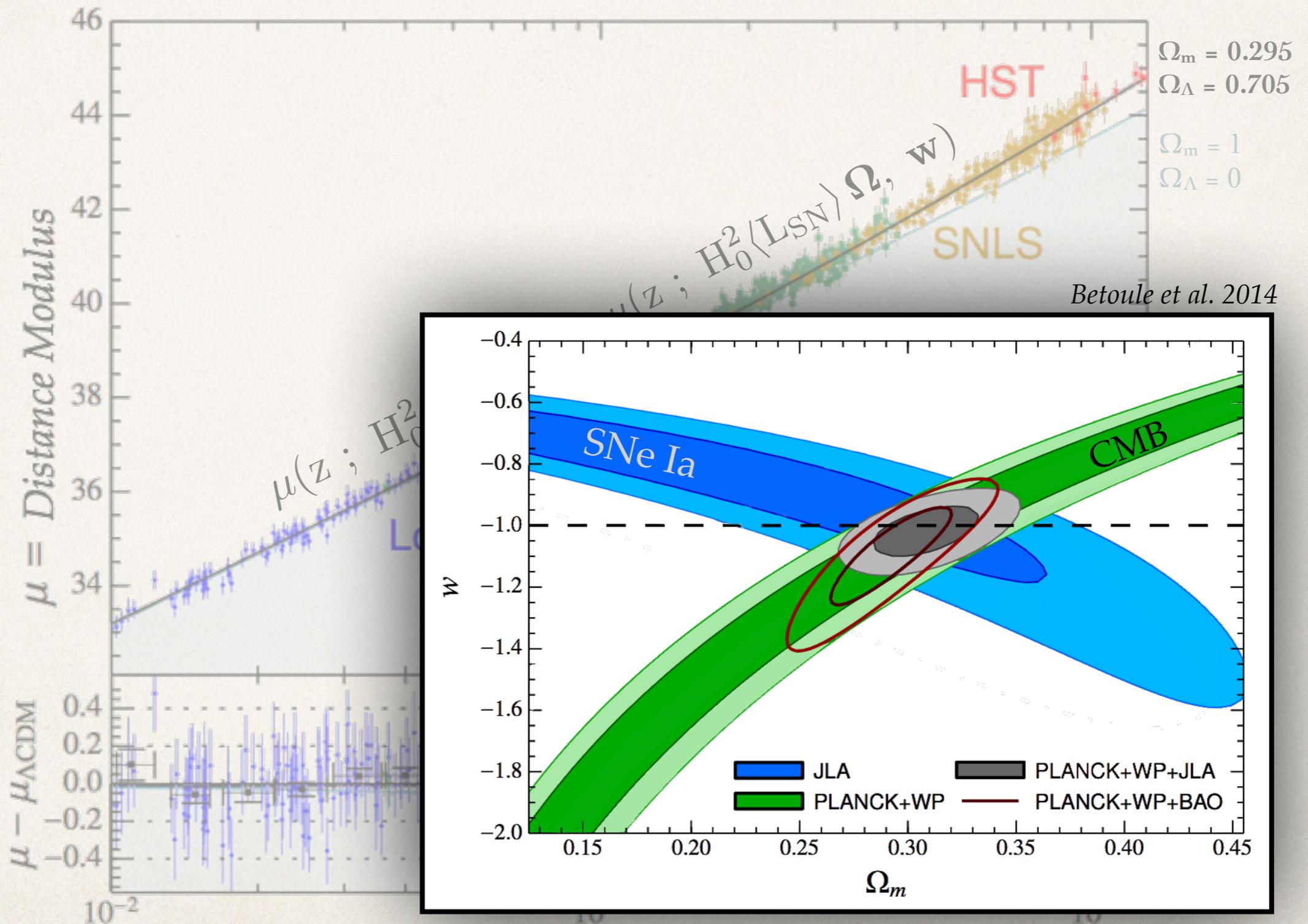
# NEARBY SUPERNOVA COSMOLOGY

Mickael RIGAULT

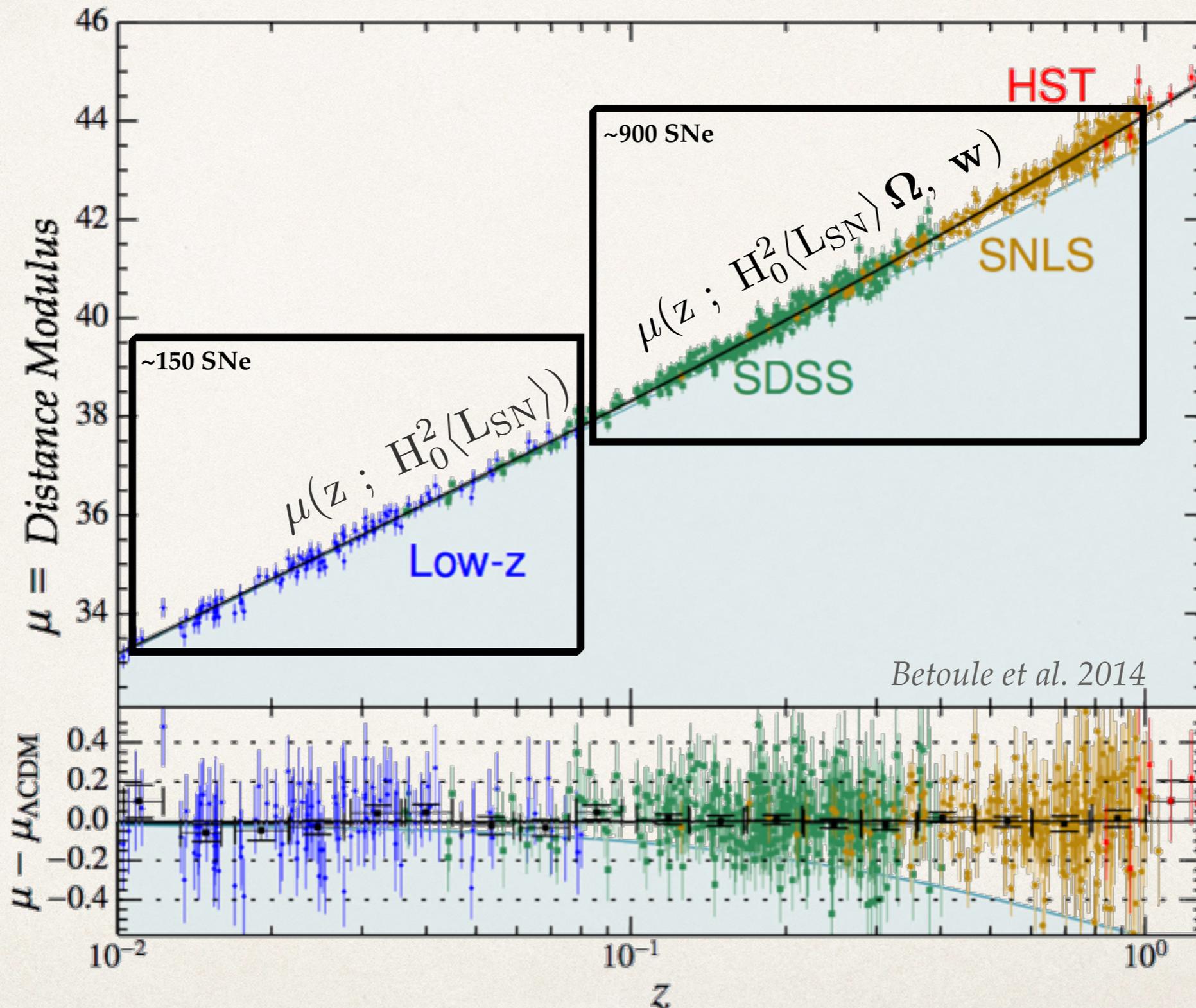
# Type Ia Supernova Cosmology | $w$ & $H_0$



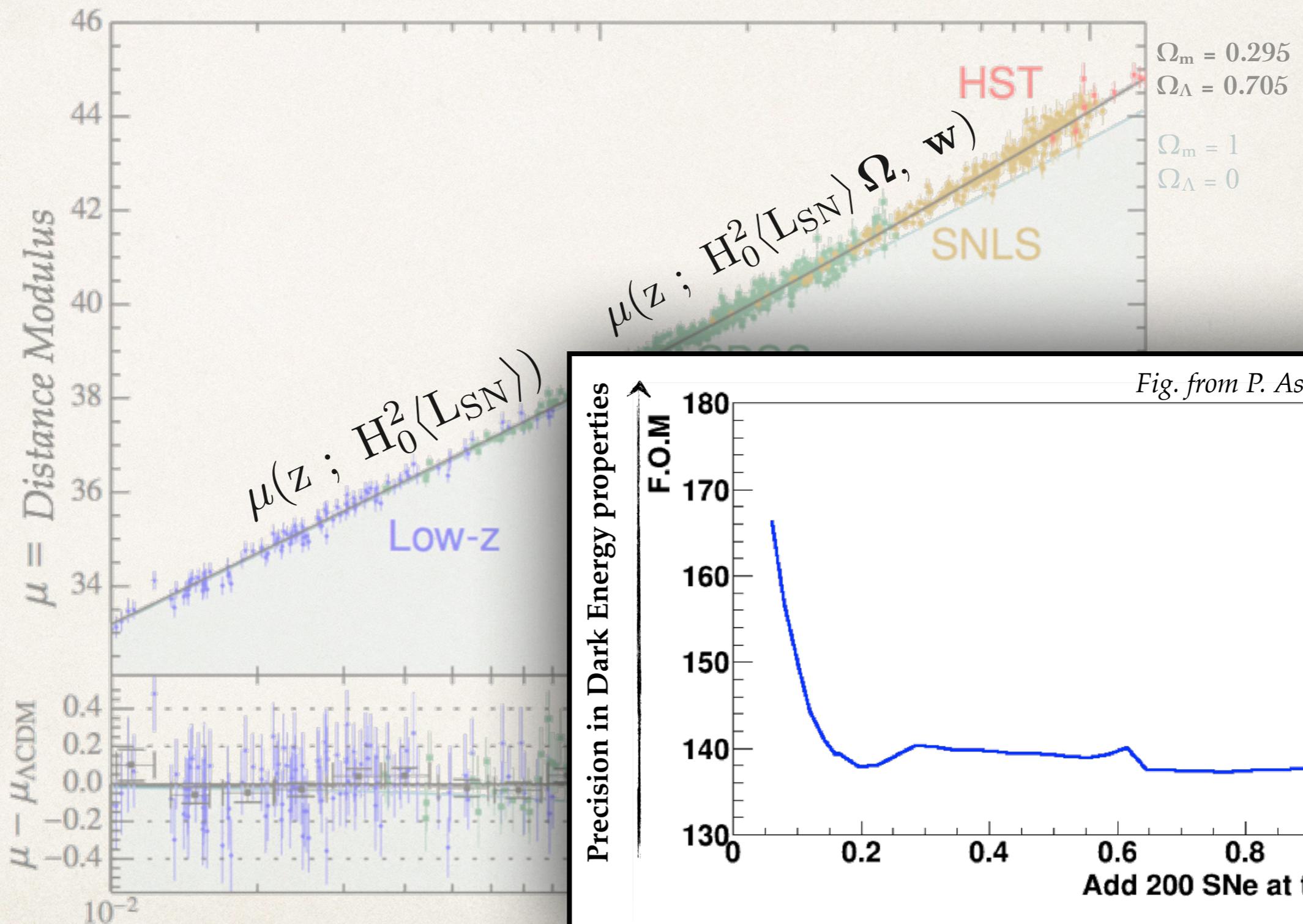
# Type Ia Supernova Cosmology | $w$ & $H_0$



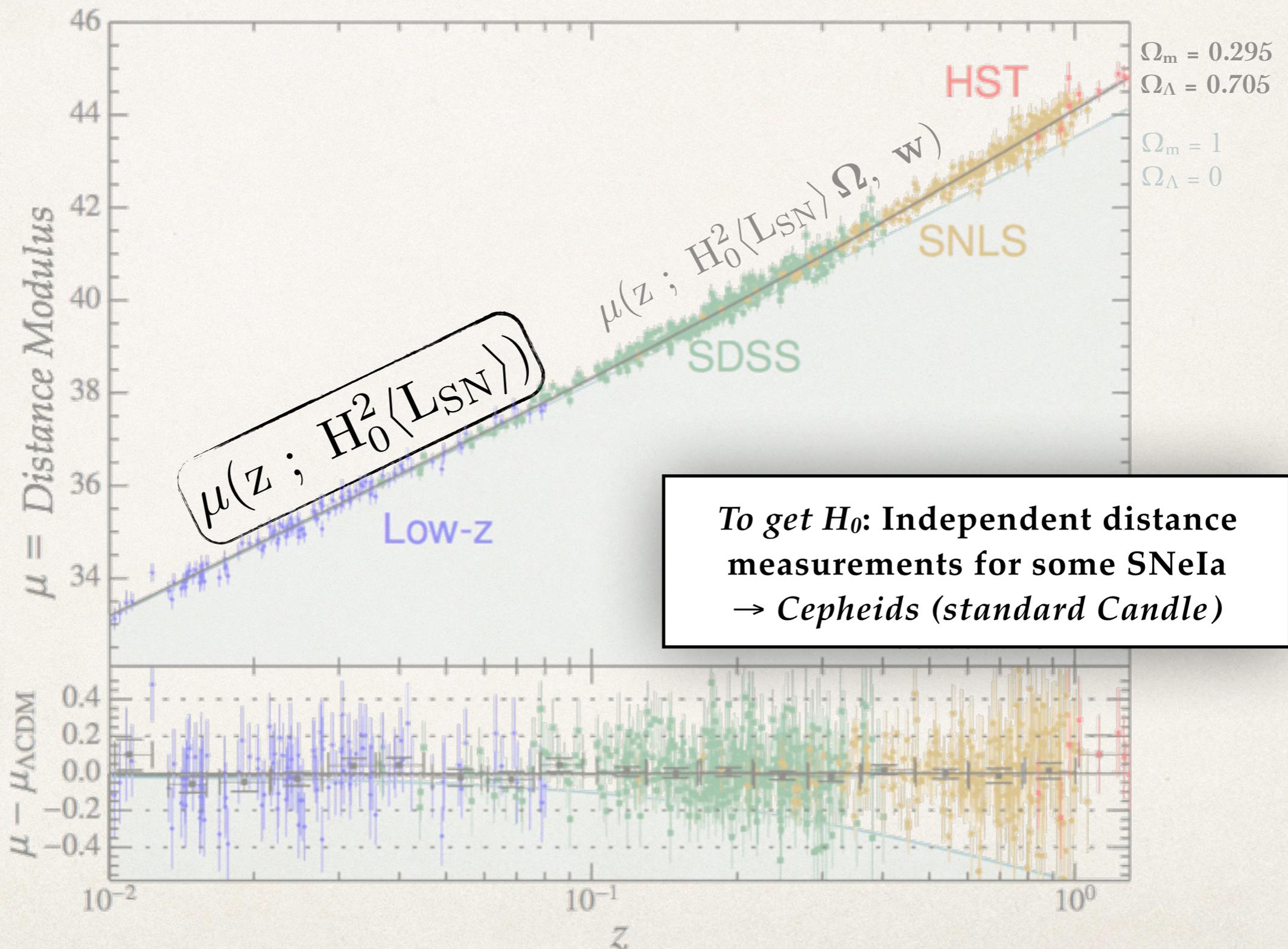
# Type Ia Supernova Cosmology | $w$ & $H_0$



# Type Ia Supernova Cosmology | $w$ & $H_0$

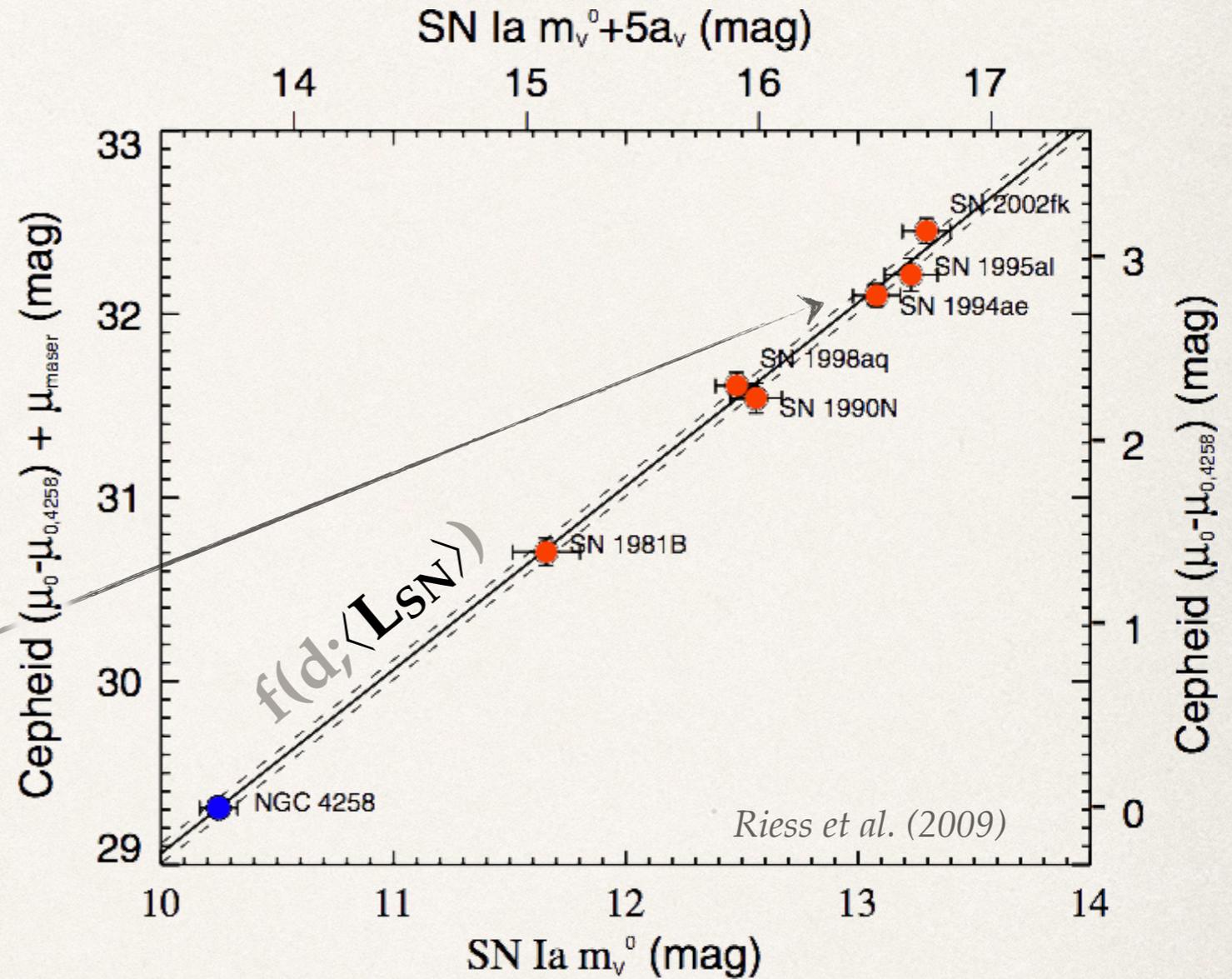
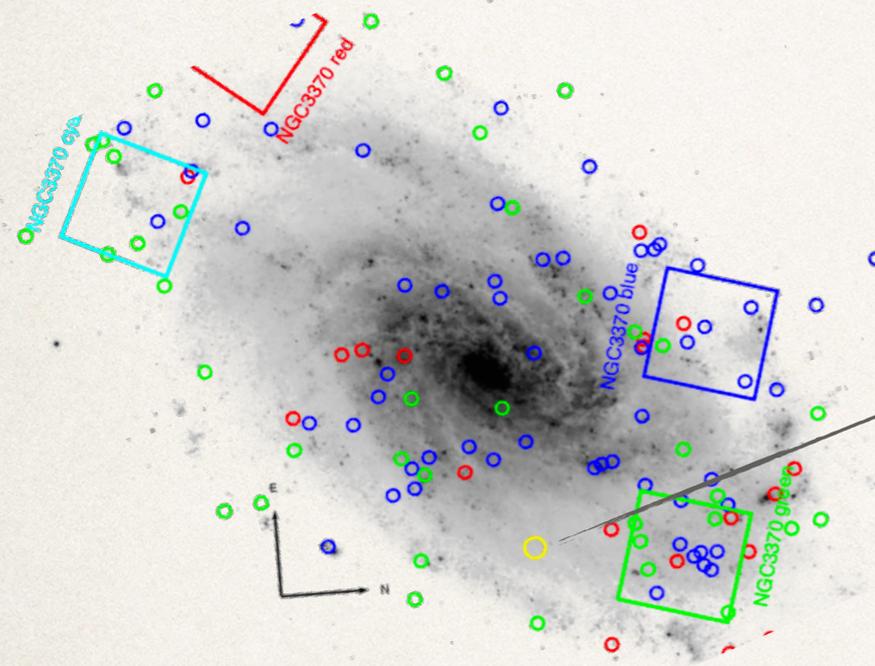


# Type Ia Supernova Cosmology | $w$ & $H_0$



# Disentangle $H_0$ from $L_{SN}$

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

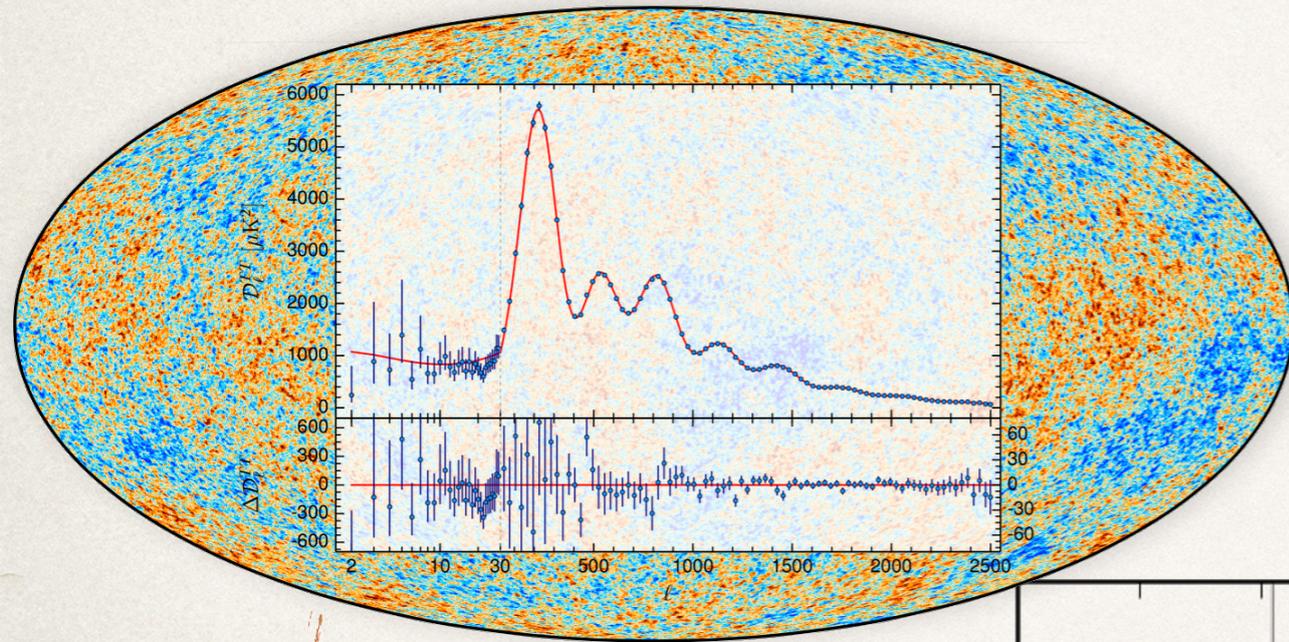


$$H_0 = 73.2 \pm 1.8 \text{ km s}^{-1} \text{ Mpc}^{-1}$$

(2.4% ; Riess et al 2016)

# The Hubble Constant

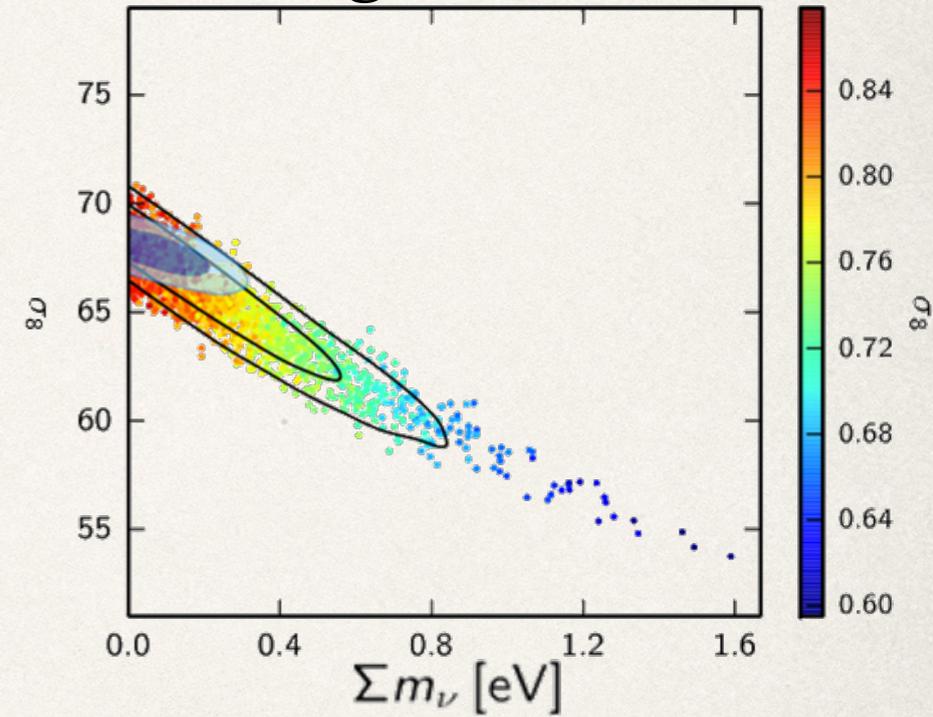
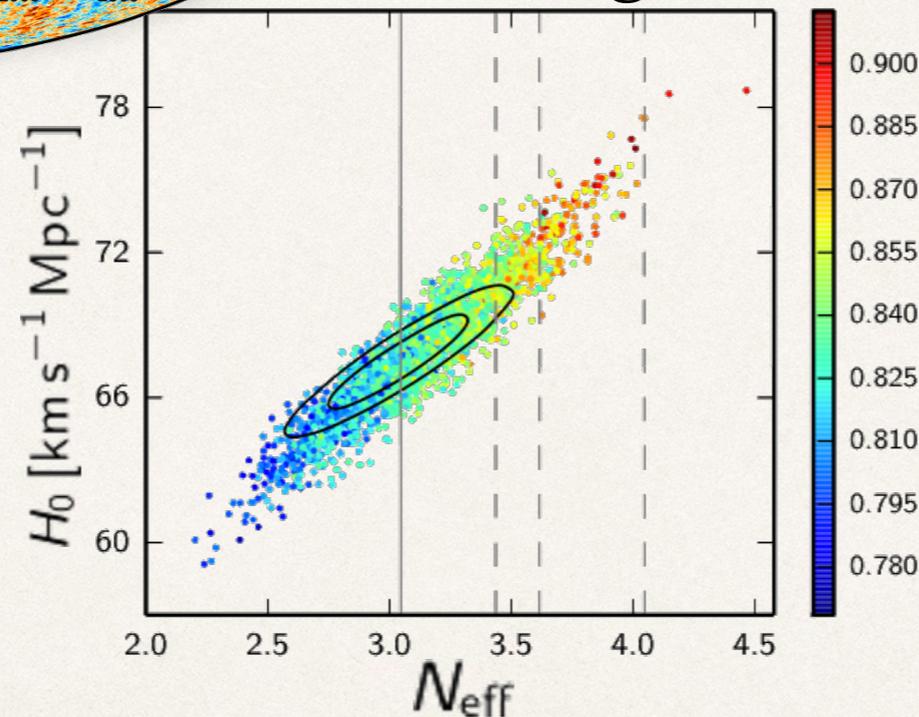
Planck 2015 — Résultats Cosmologiques



*Test the concordance  
model  $\Lambda$ CDM*

*Change the model, change  $H_0$*

**THE MODEL  
CONSTRAINS  $H_0$**



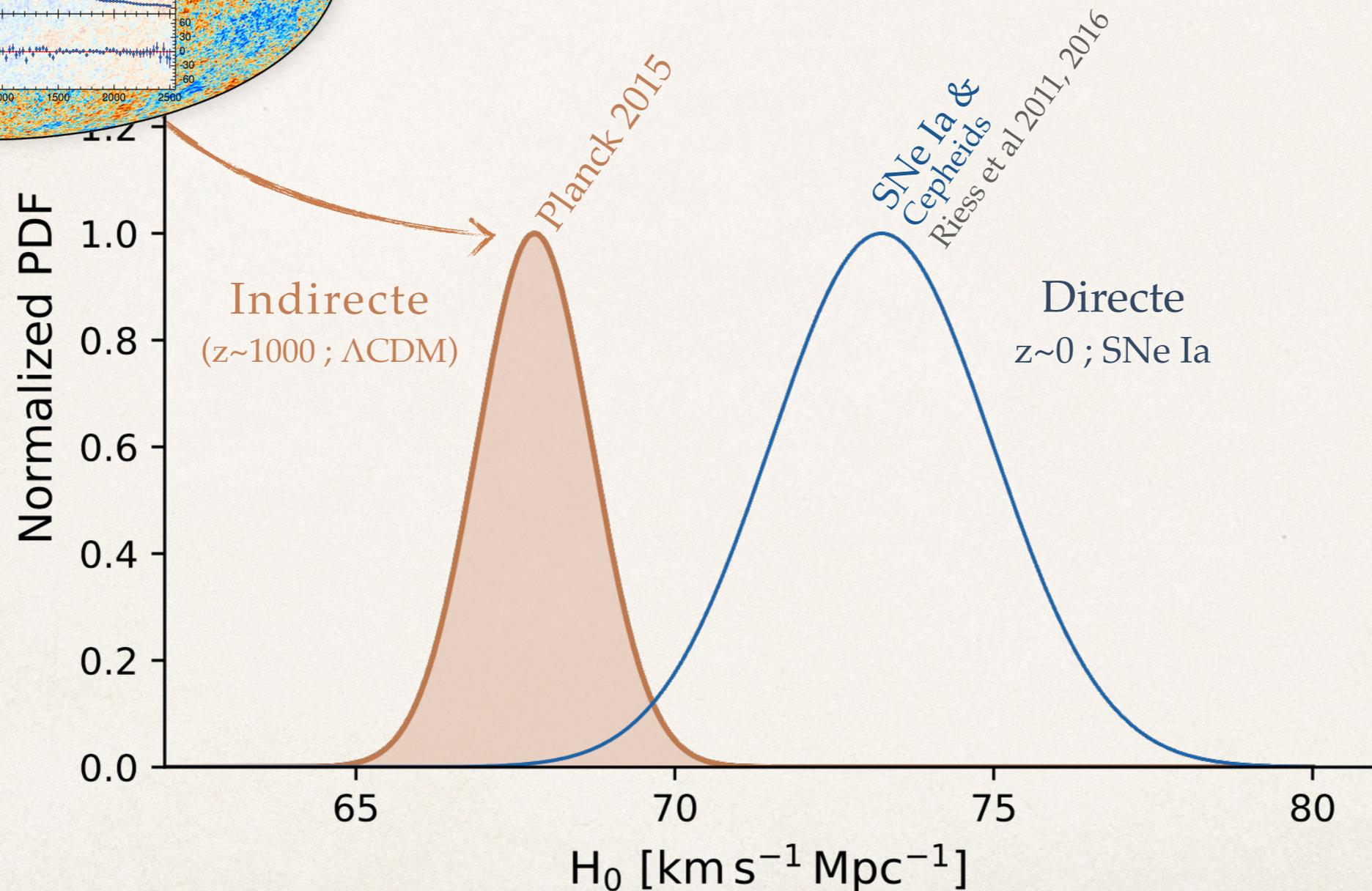
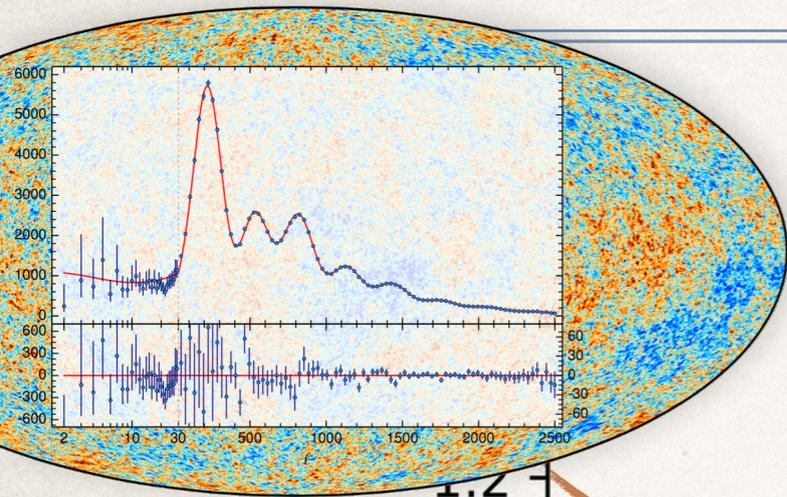
$z \sim 0$

**$H_0 = 67.8 \pm 0.9 \text{ km s}^{-1} \text{Mpc}^{-1}$   
— based on  $\Lambda$ CDM —**

# Tension in the concordance model?

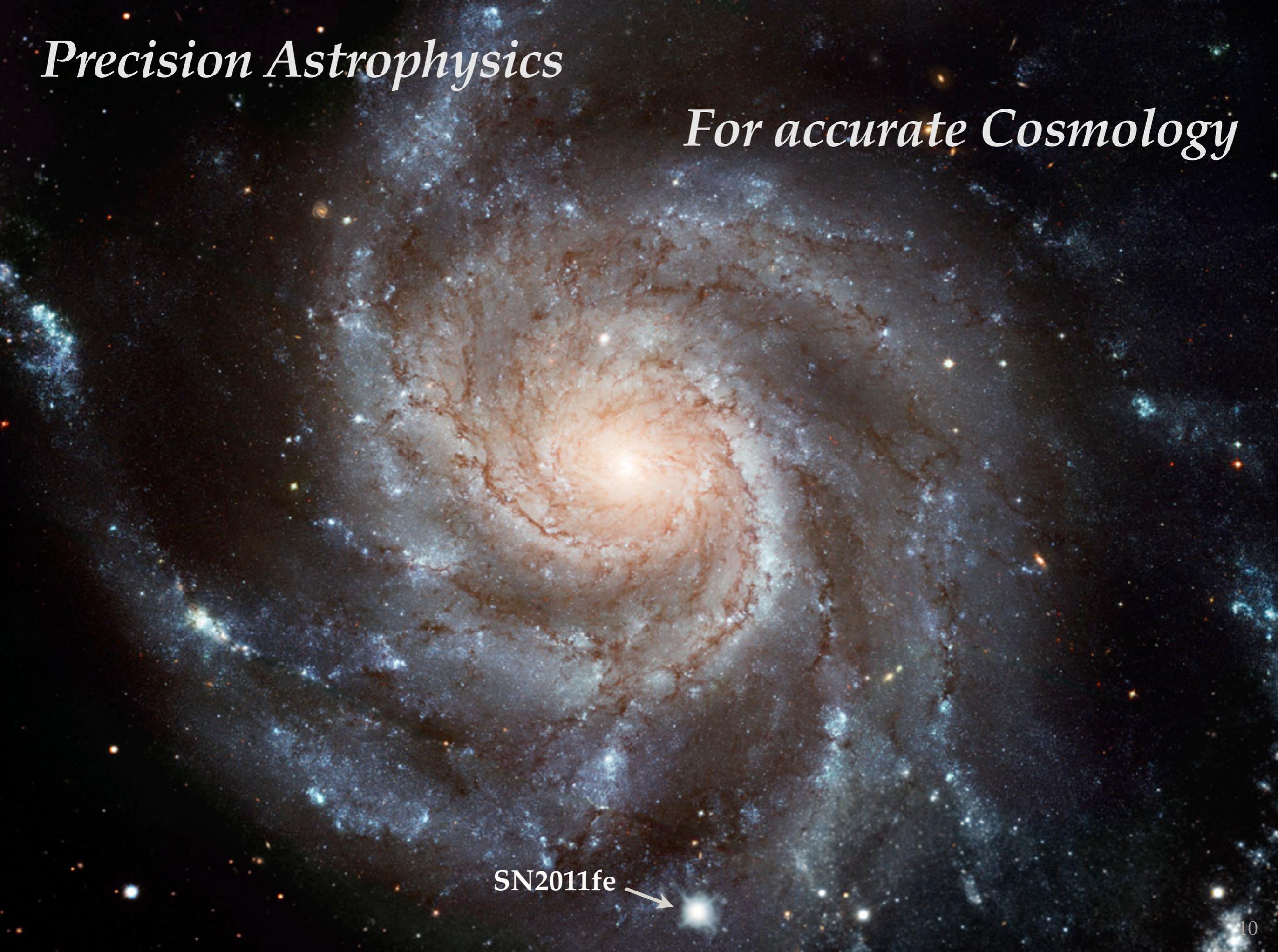
$\sim 3\sigma$

*New physics or a systematic error ?*



*Precision Astrophysics*

*For accurate Cosmology*



SN2011fe →

# *Precision Astrophysics*

*For accurate Cosmology*

*Rigault et al. 2013, 2015, 2017 & Roman et al. 2017:*

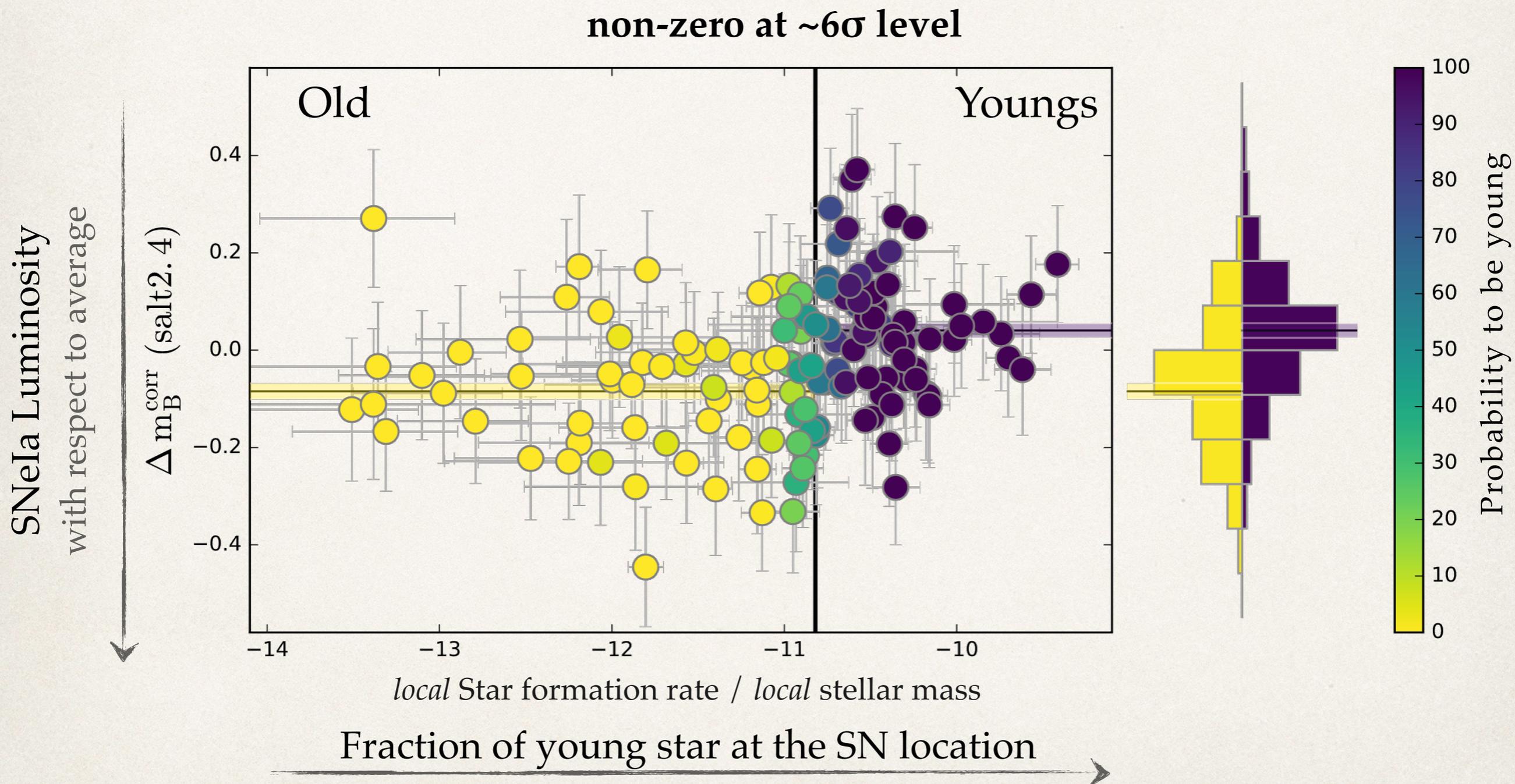
**Young progenitors lead to Fainter SNeIa ( $6\sigma$ )**

SN2011fe →

# Physics of the probe

Rigault et al. 2013, 2015

Rigault et al. 2017



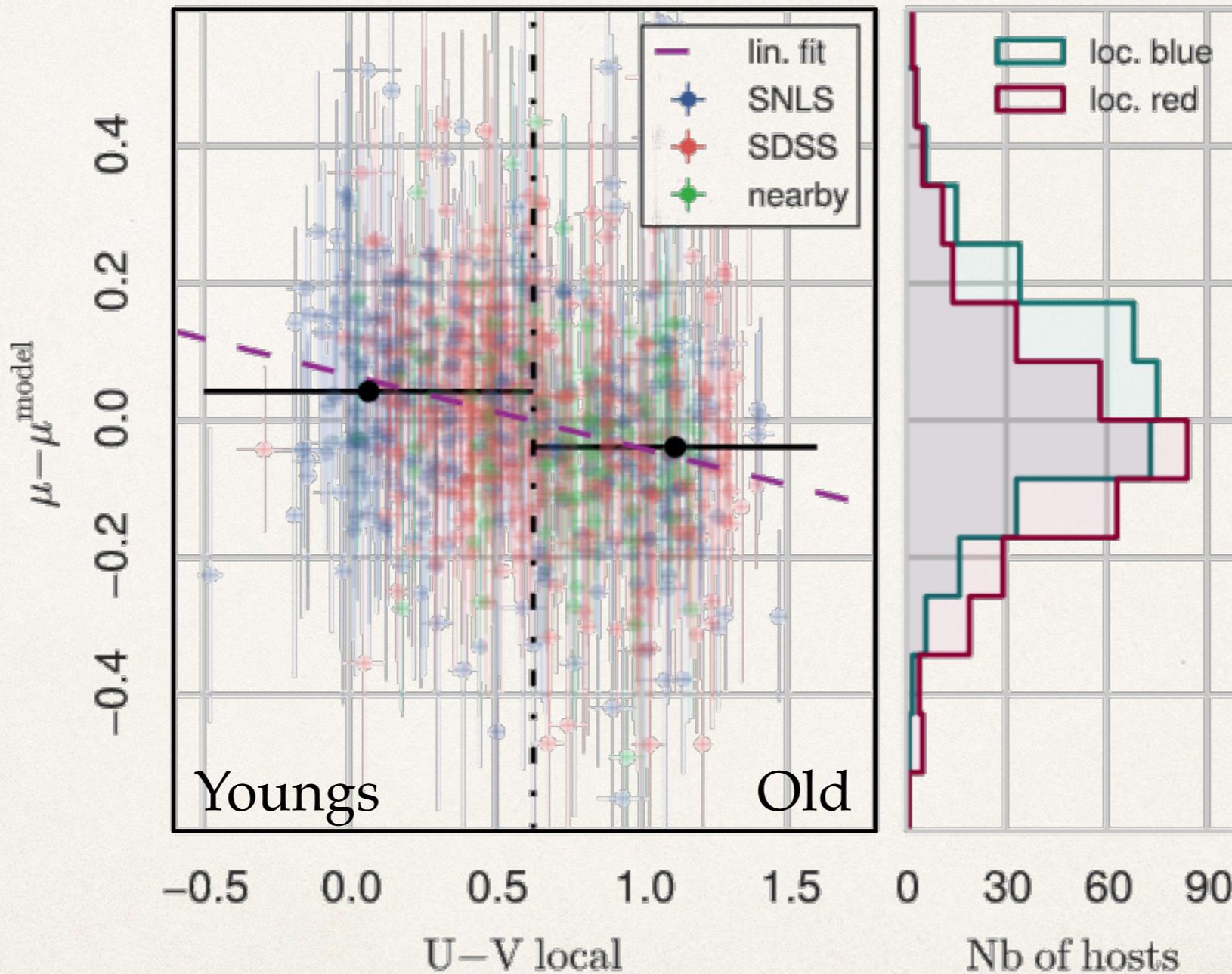
# Physics of the probe

Confirmed @ high-z

Roman et al. 2017

non-zero at  $\sim 7\sigma$  level

SNeIa Luminosity  
with respect to average



Fraction of young star at the SN location

# Impact on Cosmology – $H_0$

Rigault et al. 2015 | 2015ApJ...802...20R

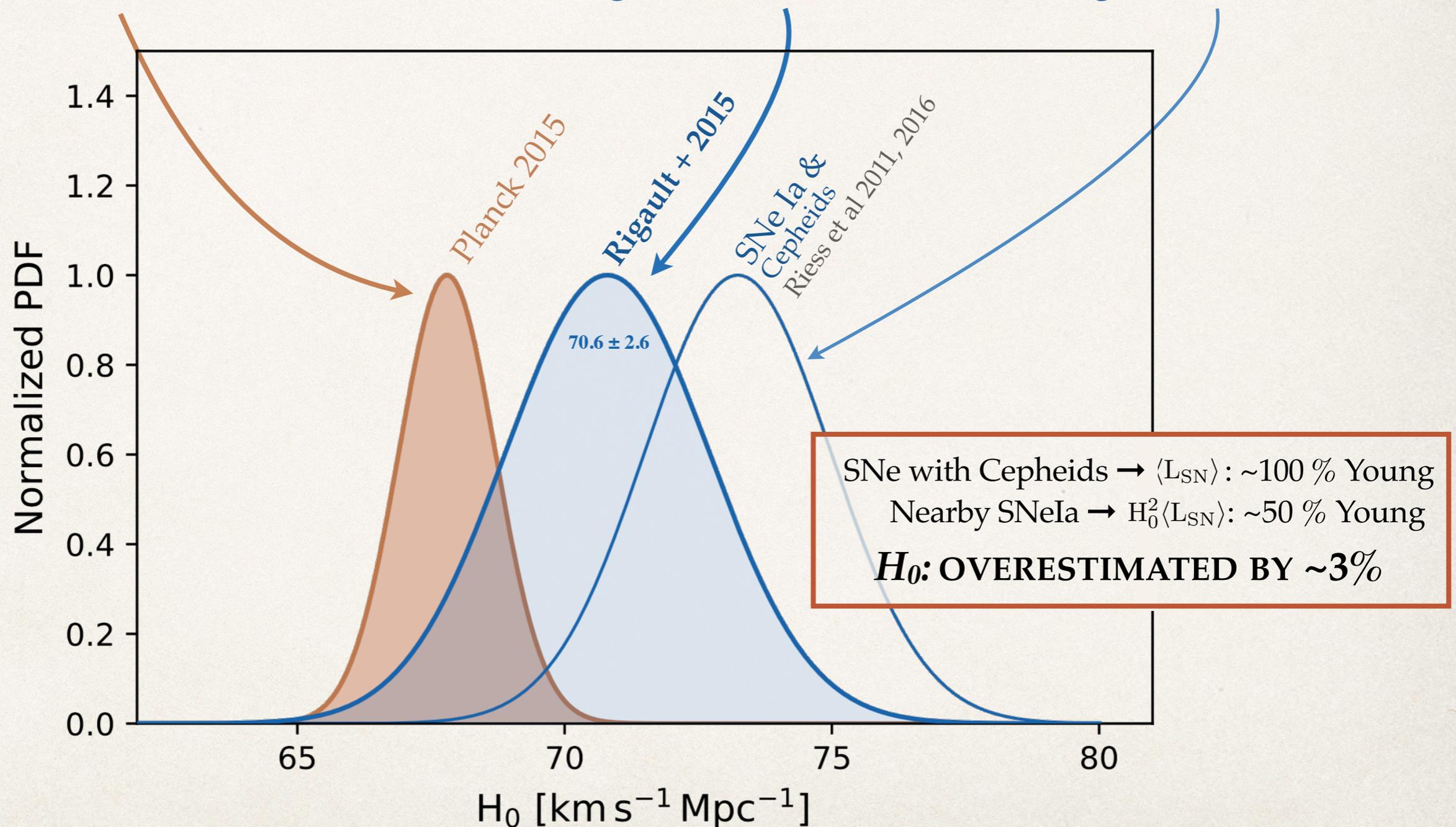
## $\Lambda$ CDM PREDICTION

— Planck 2015 —

## DIRECT MEASUREMENTS (SNeIA)

age-bias correction

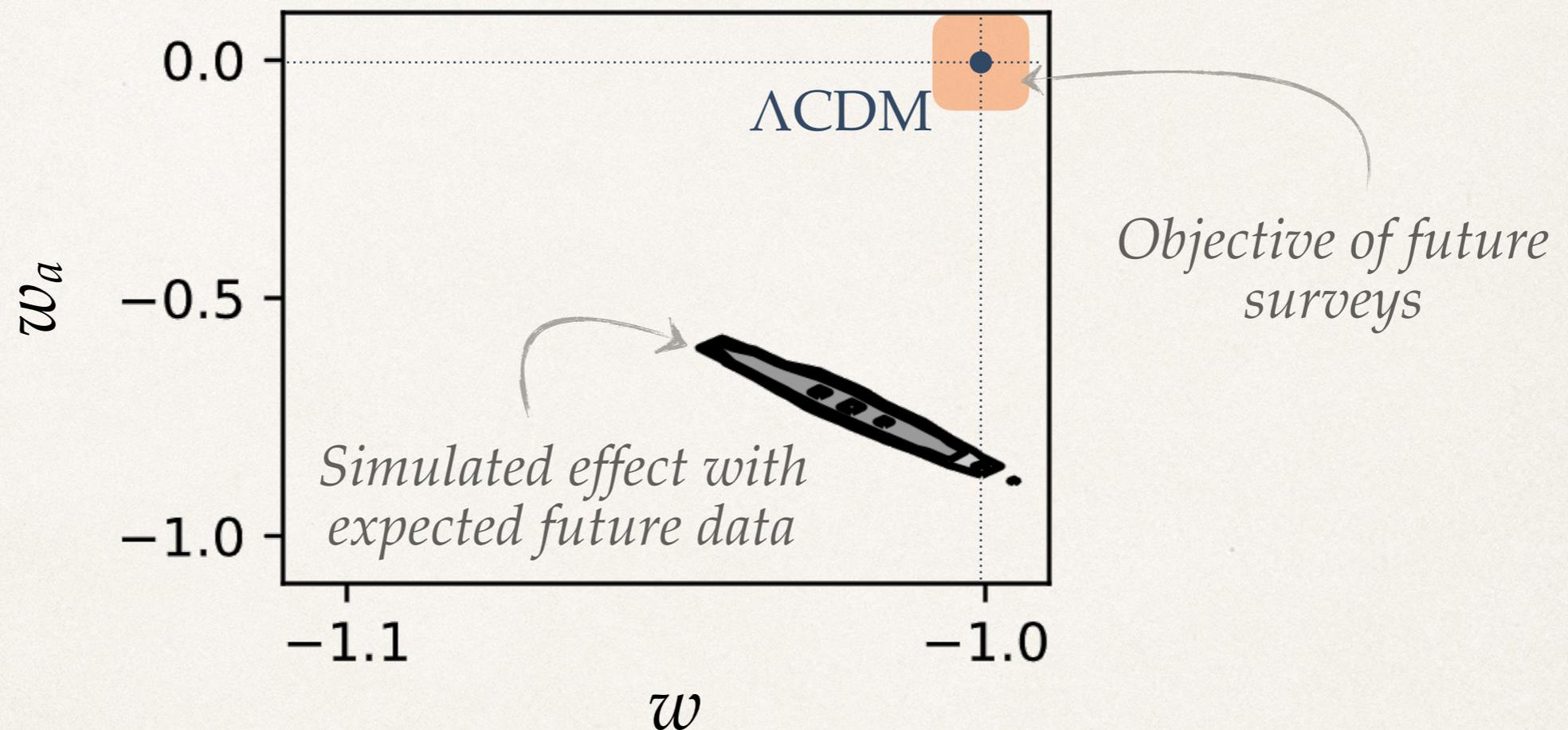
no age-bias correction



# Impact on Cosmology – *Dark Energy*

Rigault et al. 2017

Galaxies are more star-forming at higher redshift



*Progenitor variabilities strongly bias the measurement of Dark Energy properties*

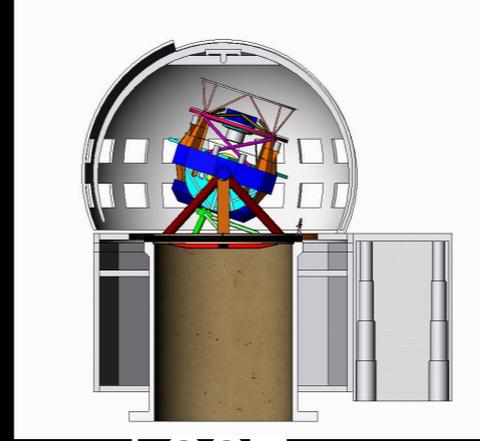
from Pierre Antilogus



Hubble

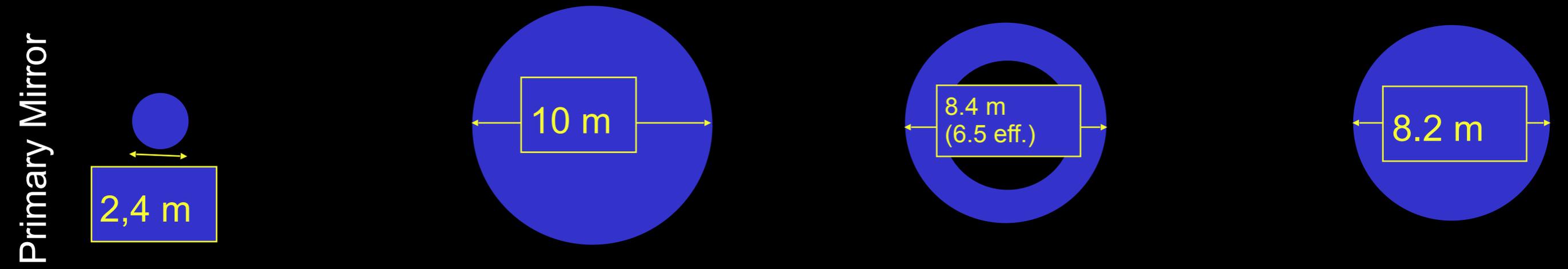
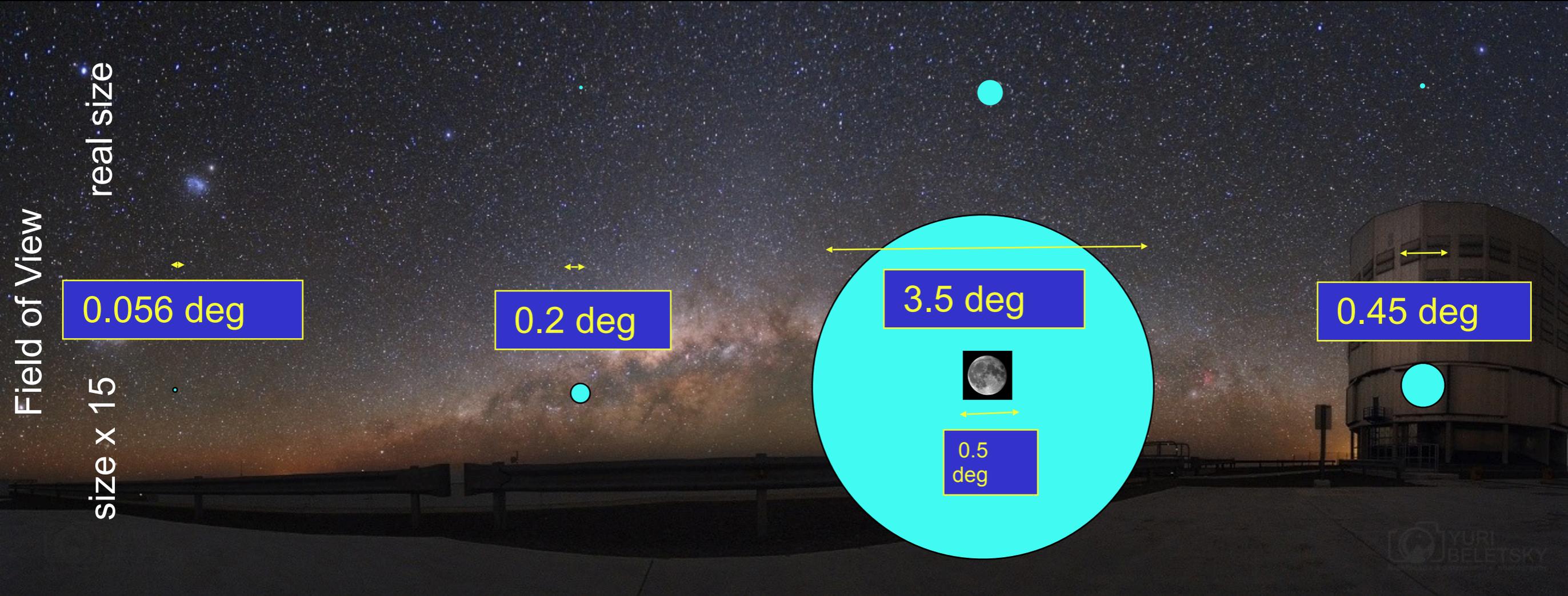


Keck



LSST

VLT



# ZTF | The First New Generation Survey



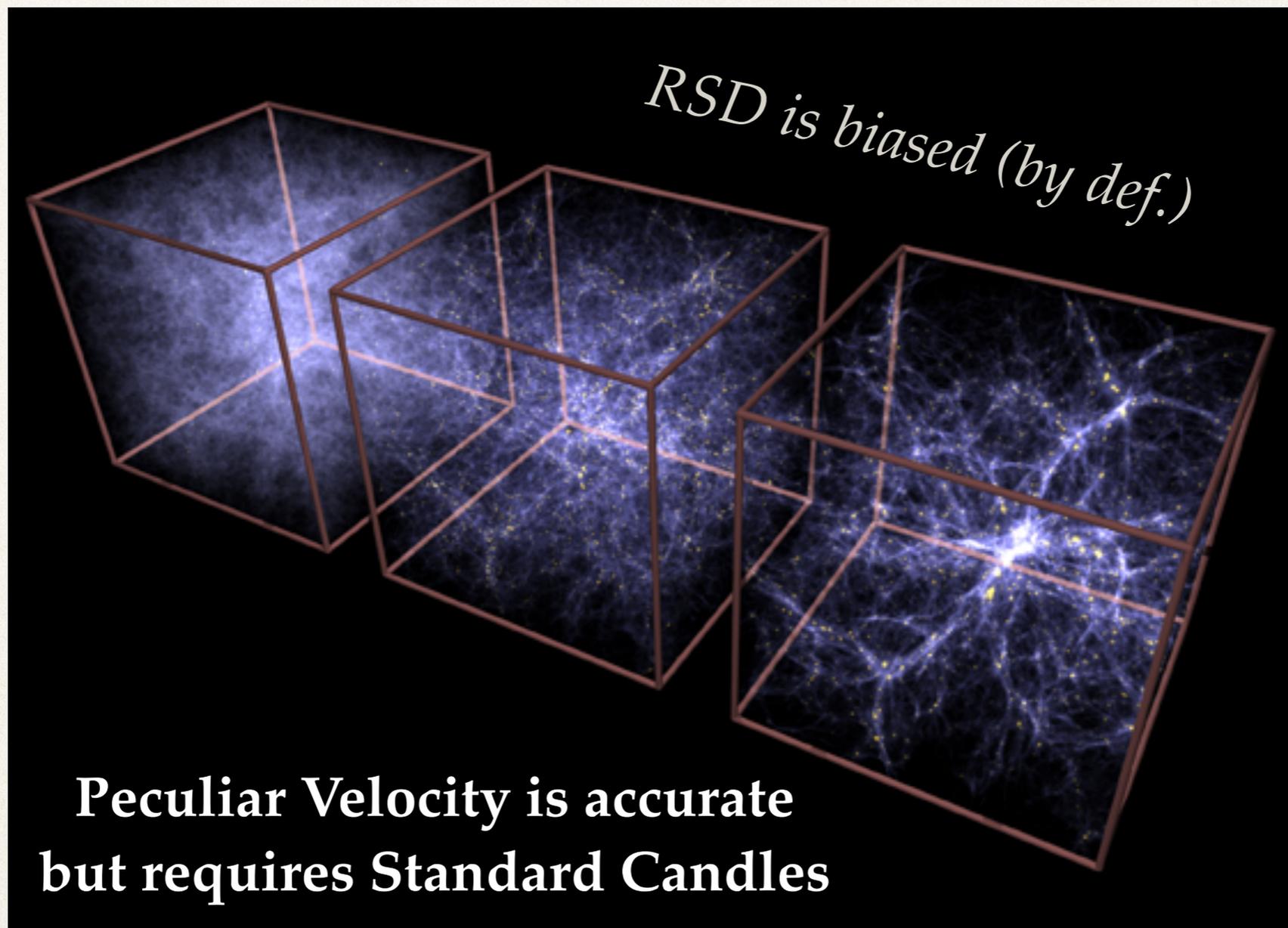
~800 SNeIa per year in *all* astrophysical conditions nature provides ( $z < 0.1$ )

*ZTF @  $z \sim 0.05$  = LSST @  $z \sim 0.5$  | Use ZTF to prepare LSST*

# Nearby Supernova Cosmology | $w$ , $H_0$ & $\sigma_8$

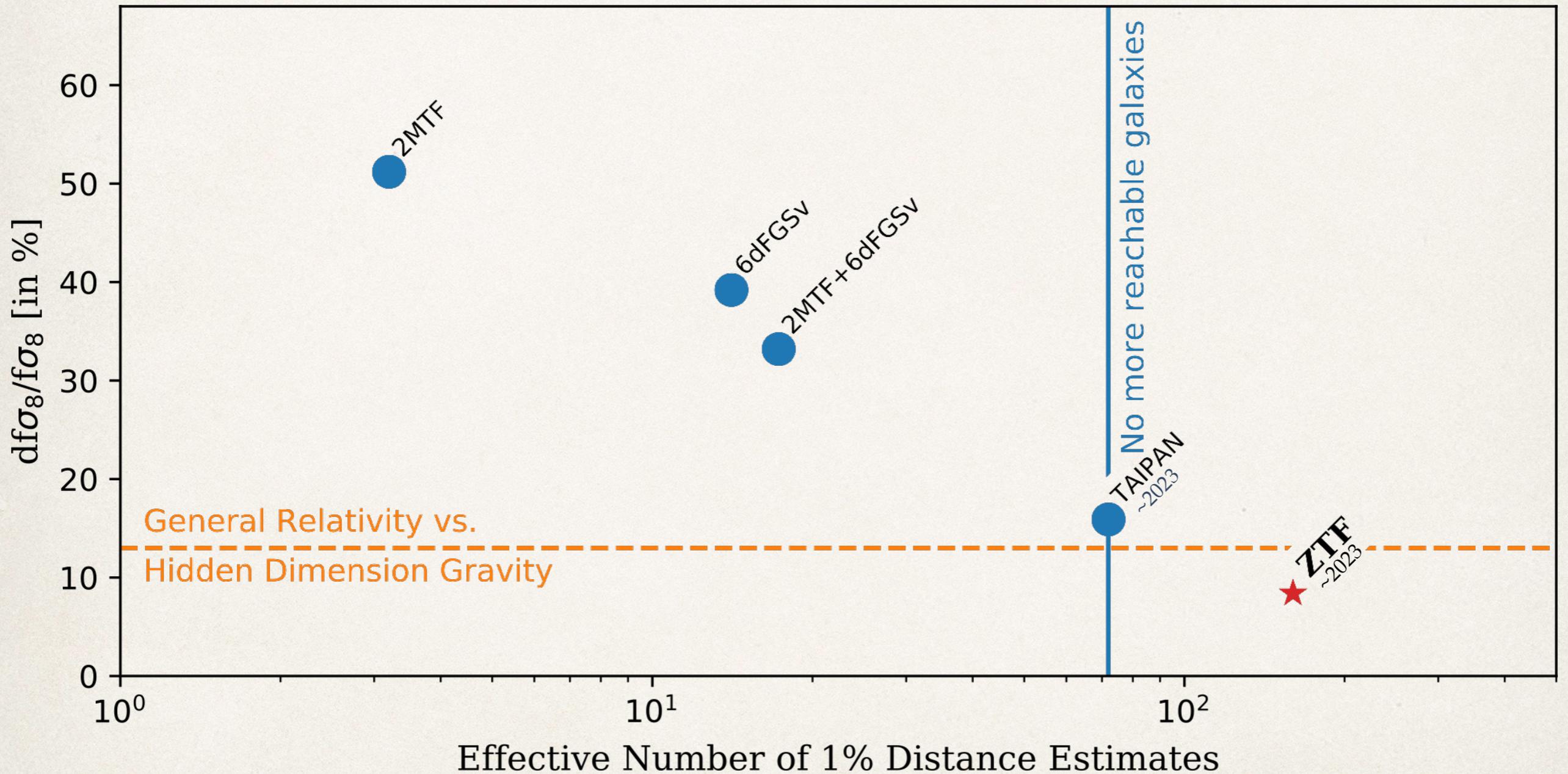
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How fast the Structures Grow ?  
*gravity vs. dark energy*



# Nearby Supernova Cosmology | $w, H_0$ & $\sigma_8$

*SNeIa can once again change our understanding of the Universe*



# Nearby Supernova Cosmology | $w$ , $H_0$ & $\sigma_8$

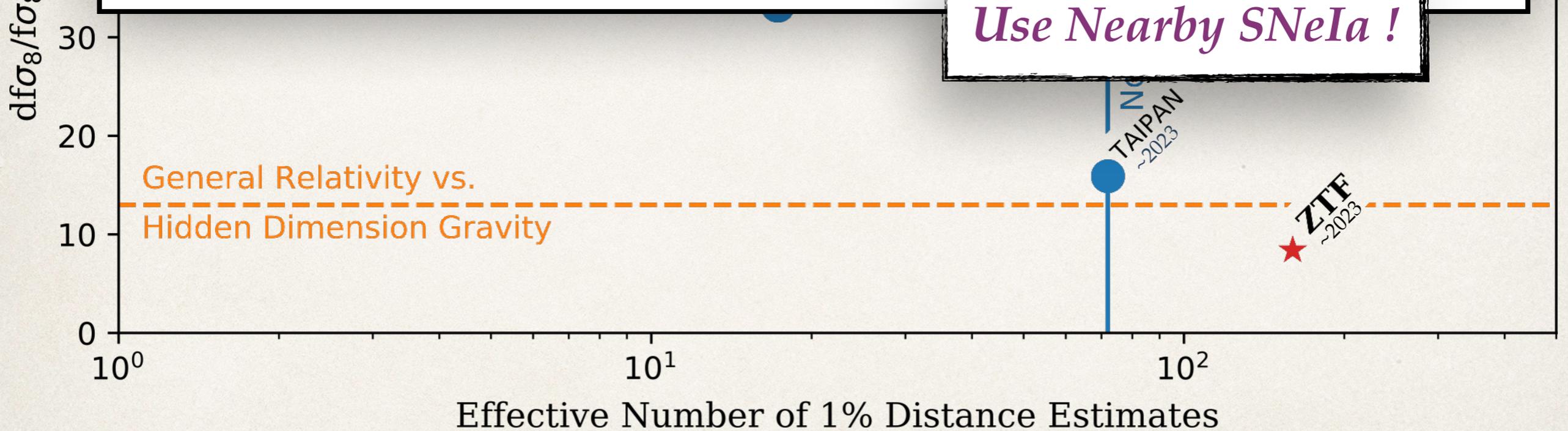
*SNeIa can once again change our understanding of the Universe*

## les secteurs sombres des secteurs sombres

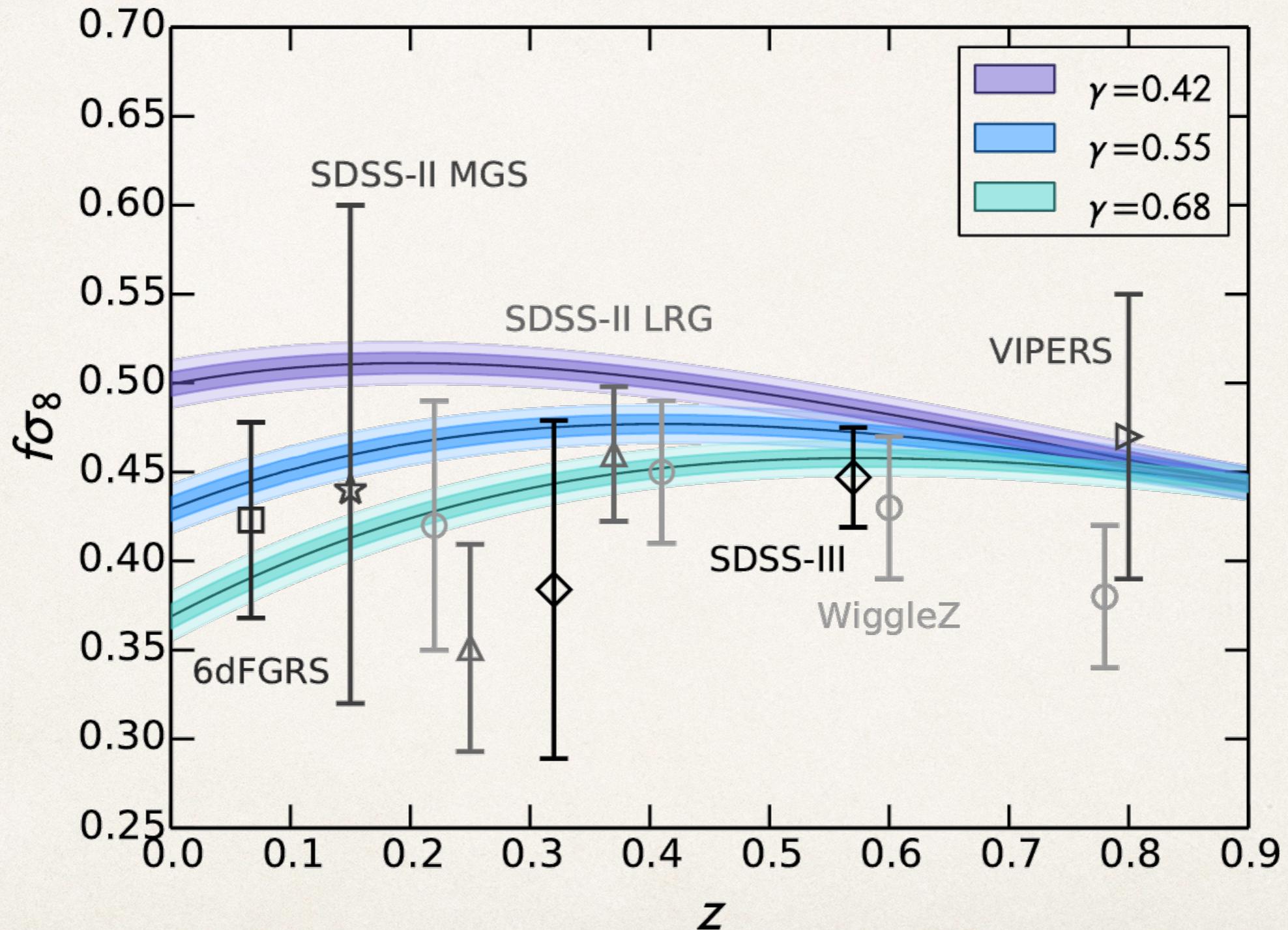
*cf. Martin Kunz*

- dark energy still looks compatible with flat  $\Lambda$ CDM  
(but keep eye on  $\sigma_8$ ,  $H_0$ , large-scale anomalies, ... and keep an open mind for other possibilities!)

*Use Nearby SNeIa !*

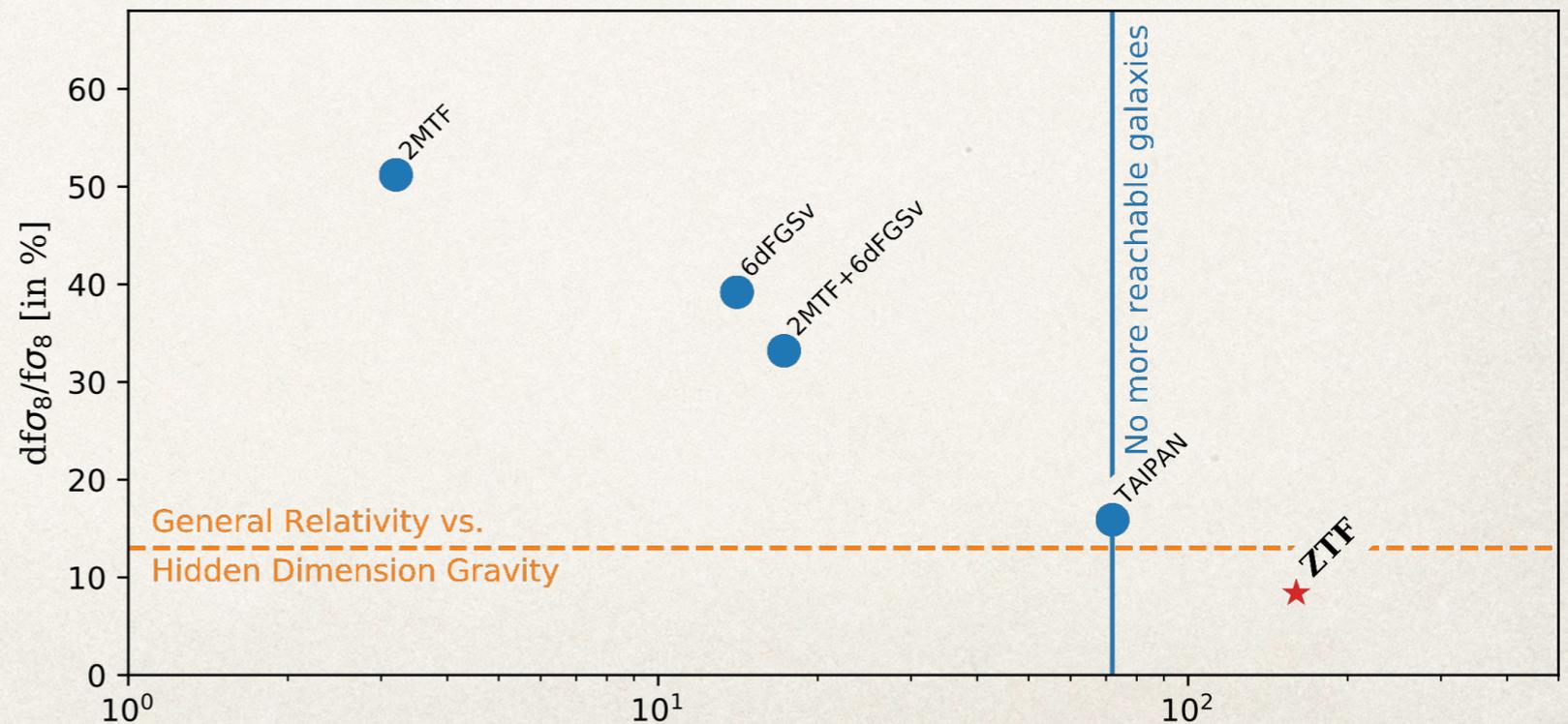
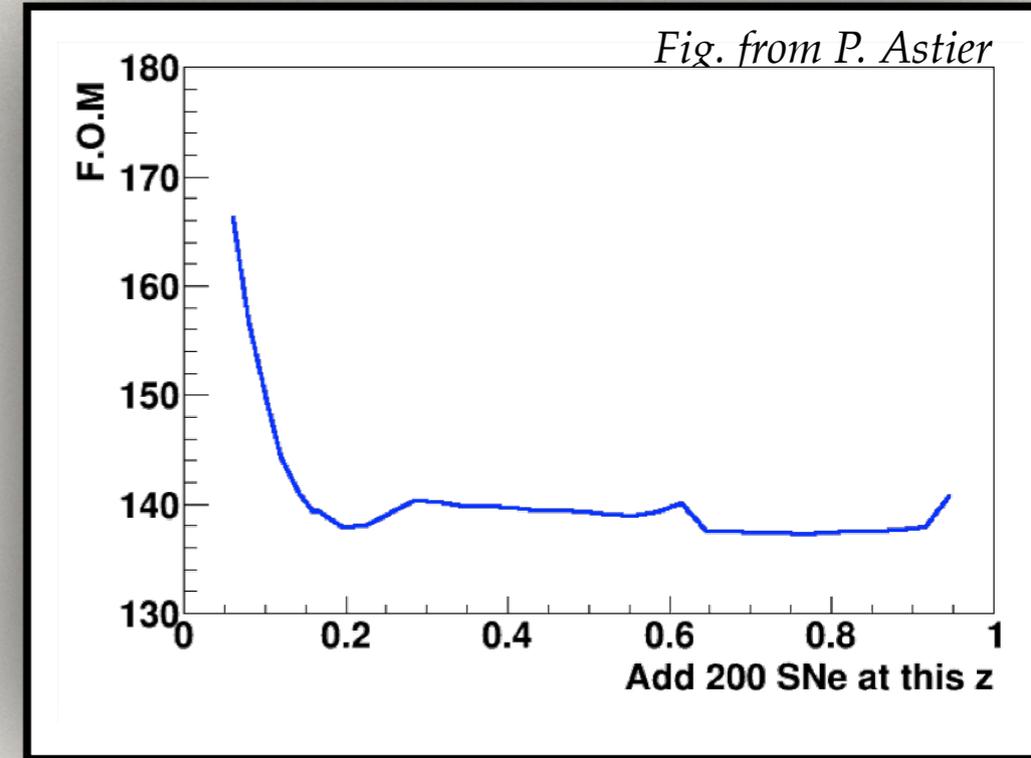
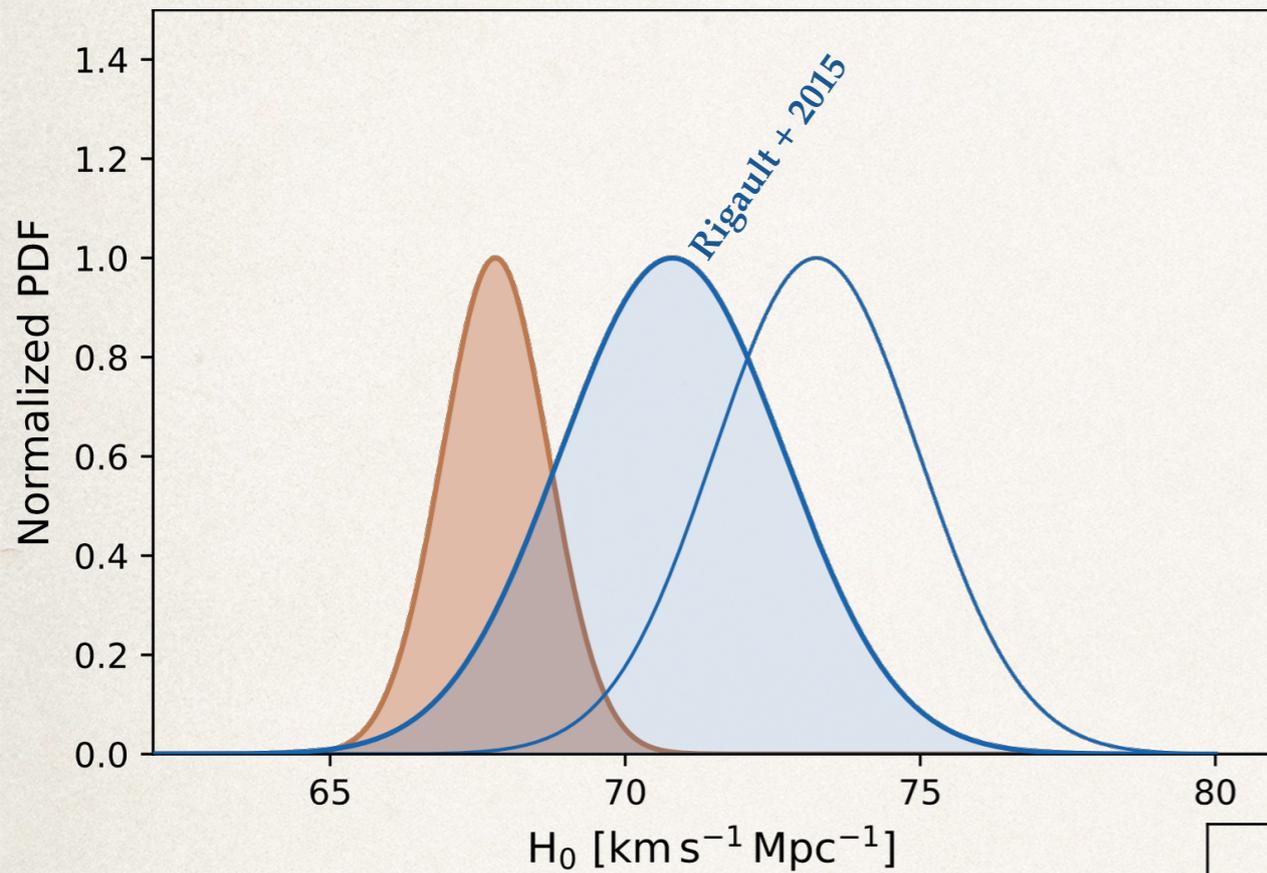


# Probing modified gravity



# Nearby SN Cosmology

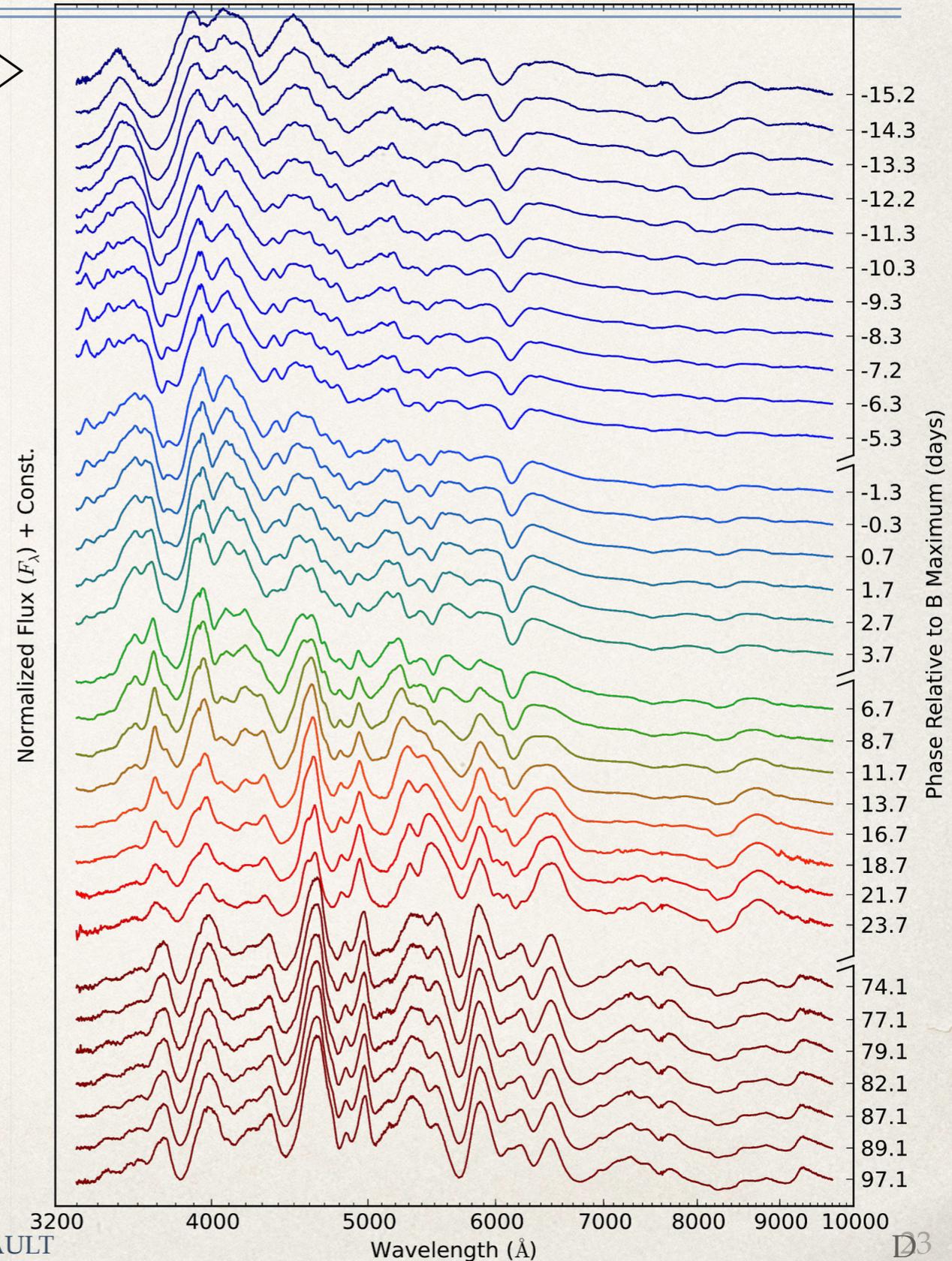
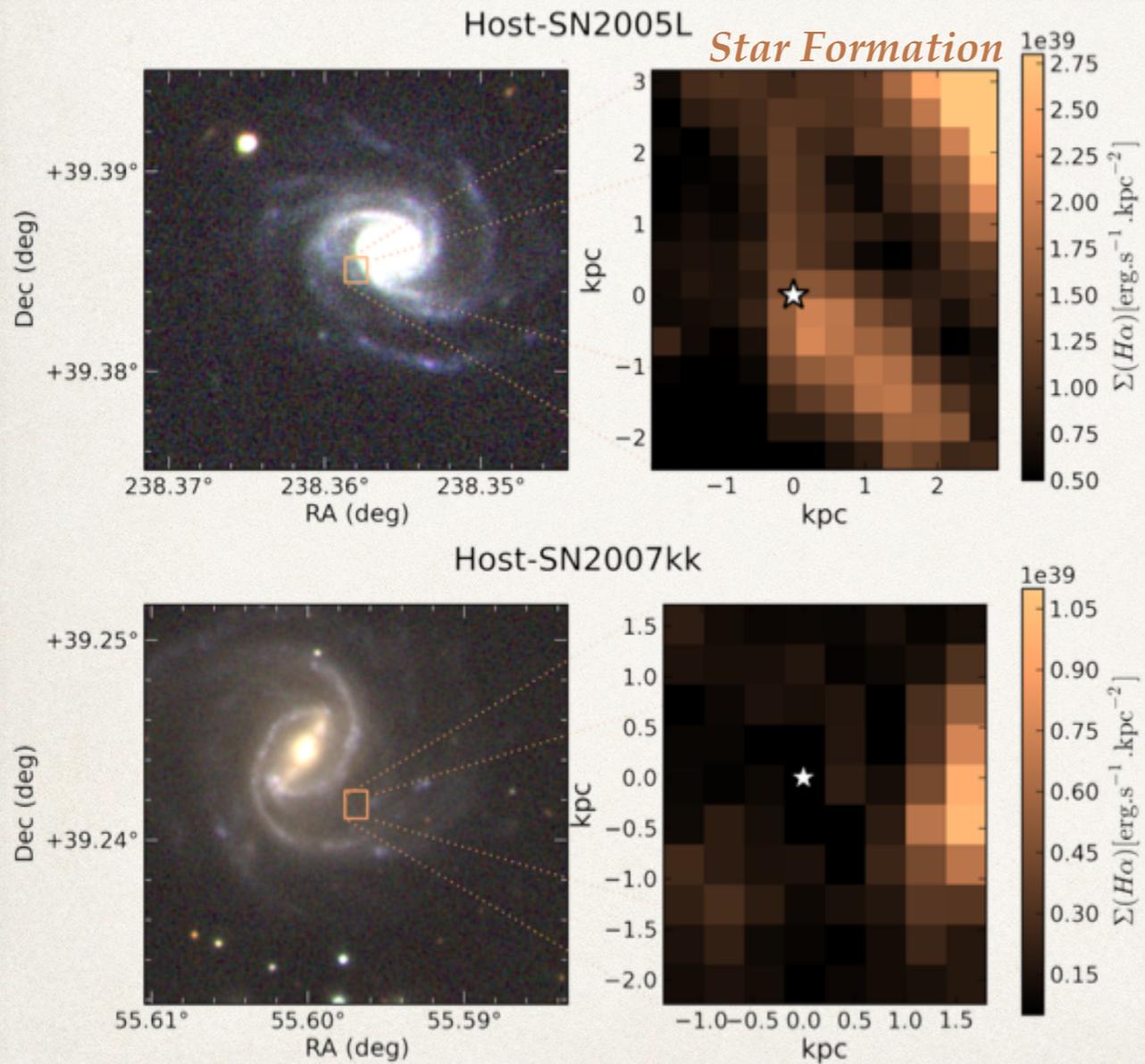
## $w, H_0$ & $\sigma_8$



# SNfactory | The Spectrophotometric SN dataset

SN's spectra ▷

SN's environment ▽

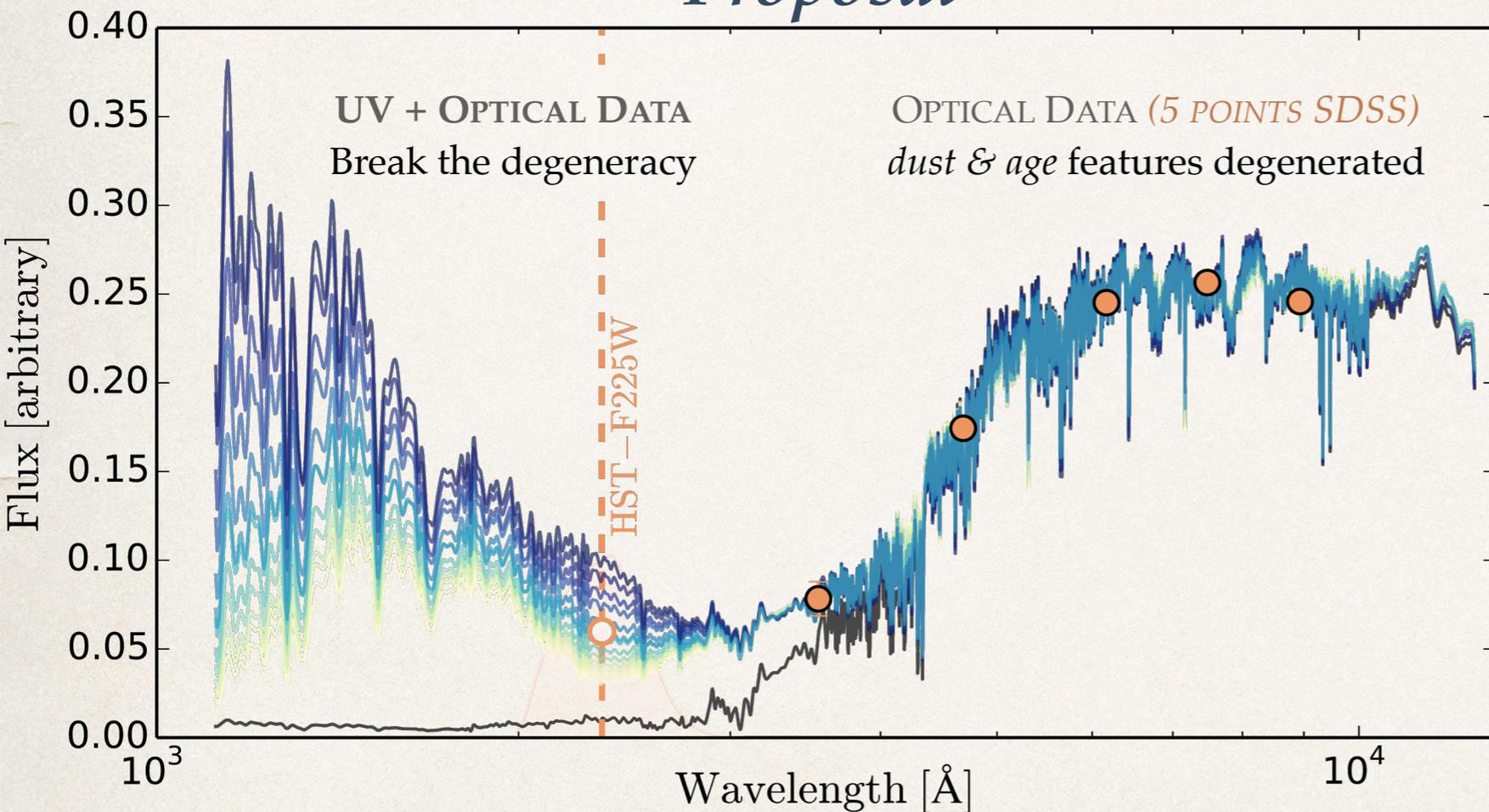


# HST & Optical | Measure the host dust

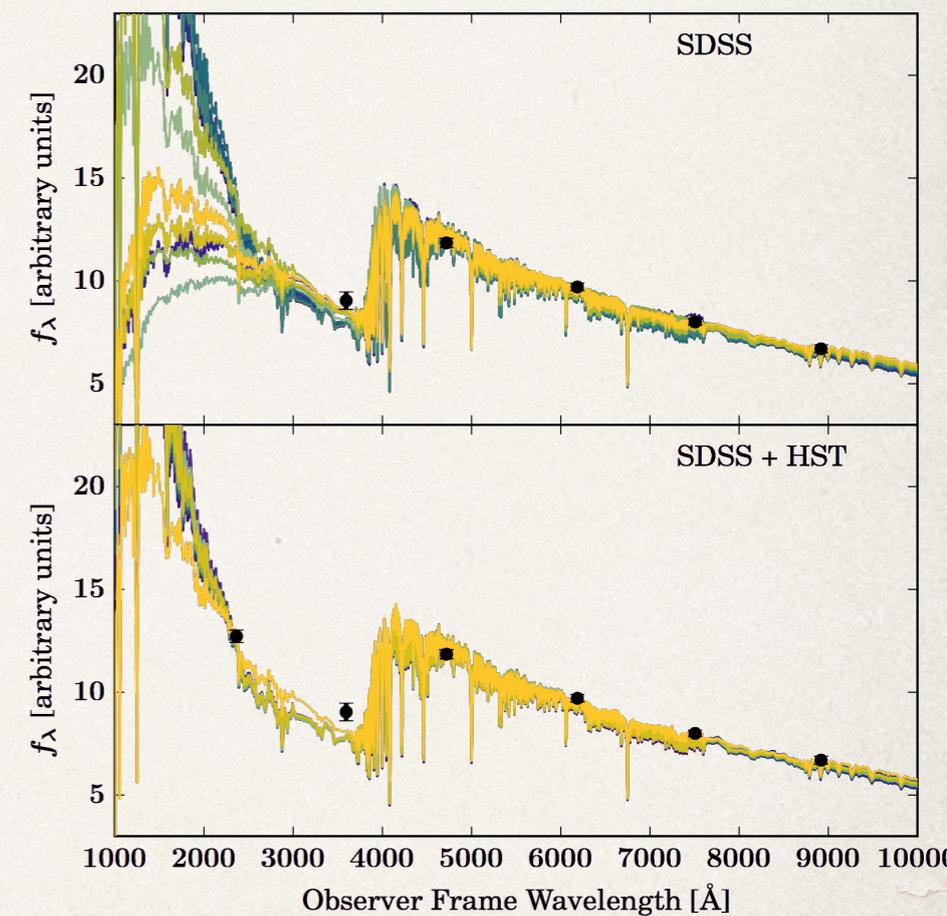
PI: Rigault ; GO14163

70 HST orbits for 70 UV images of host galaxies

*Proposal*

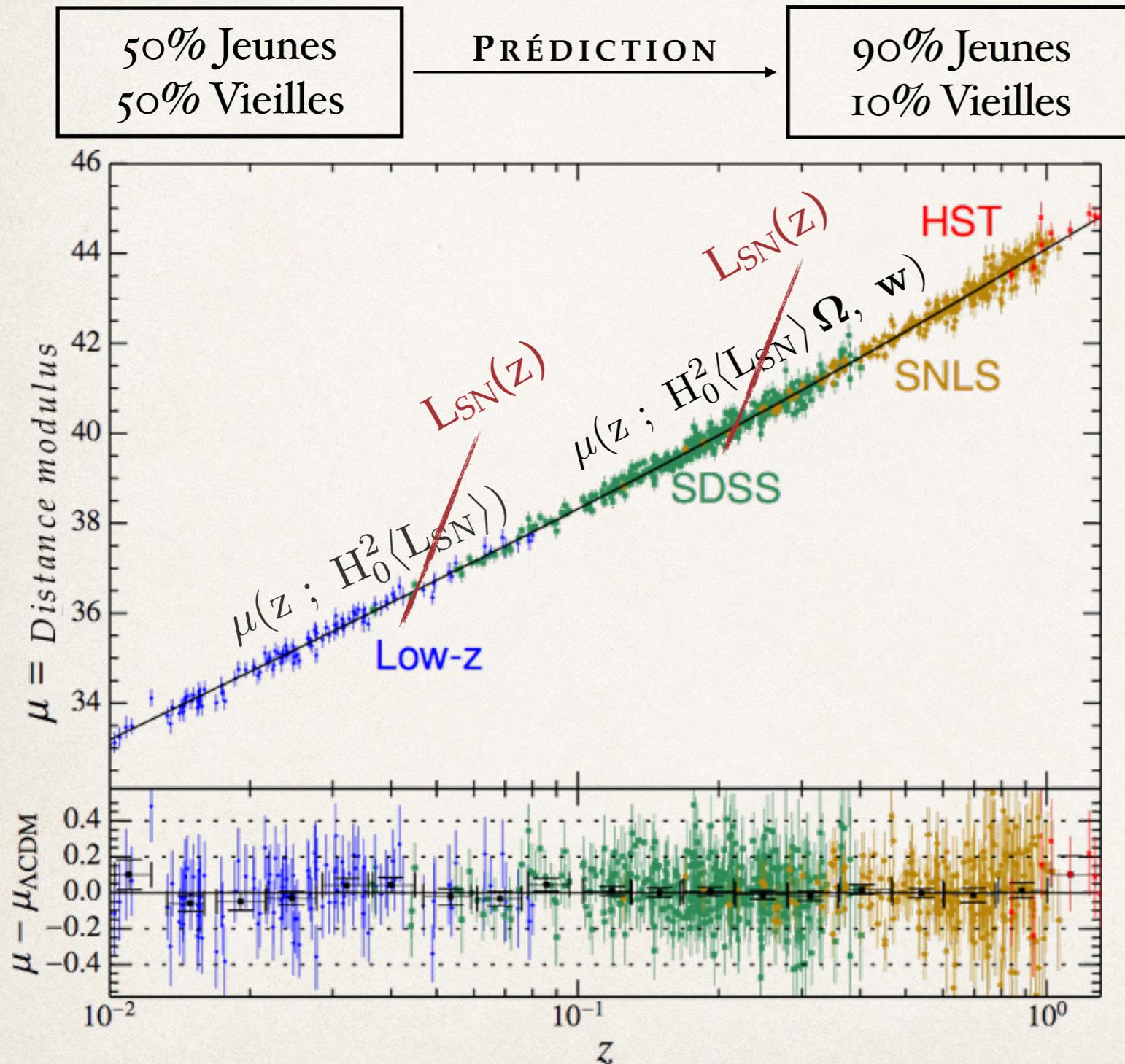


*Data*



# Impact sur les mesures cosmologiques — $w$

Rigault et al. 2013, 2017

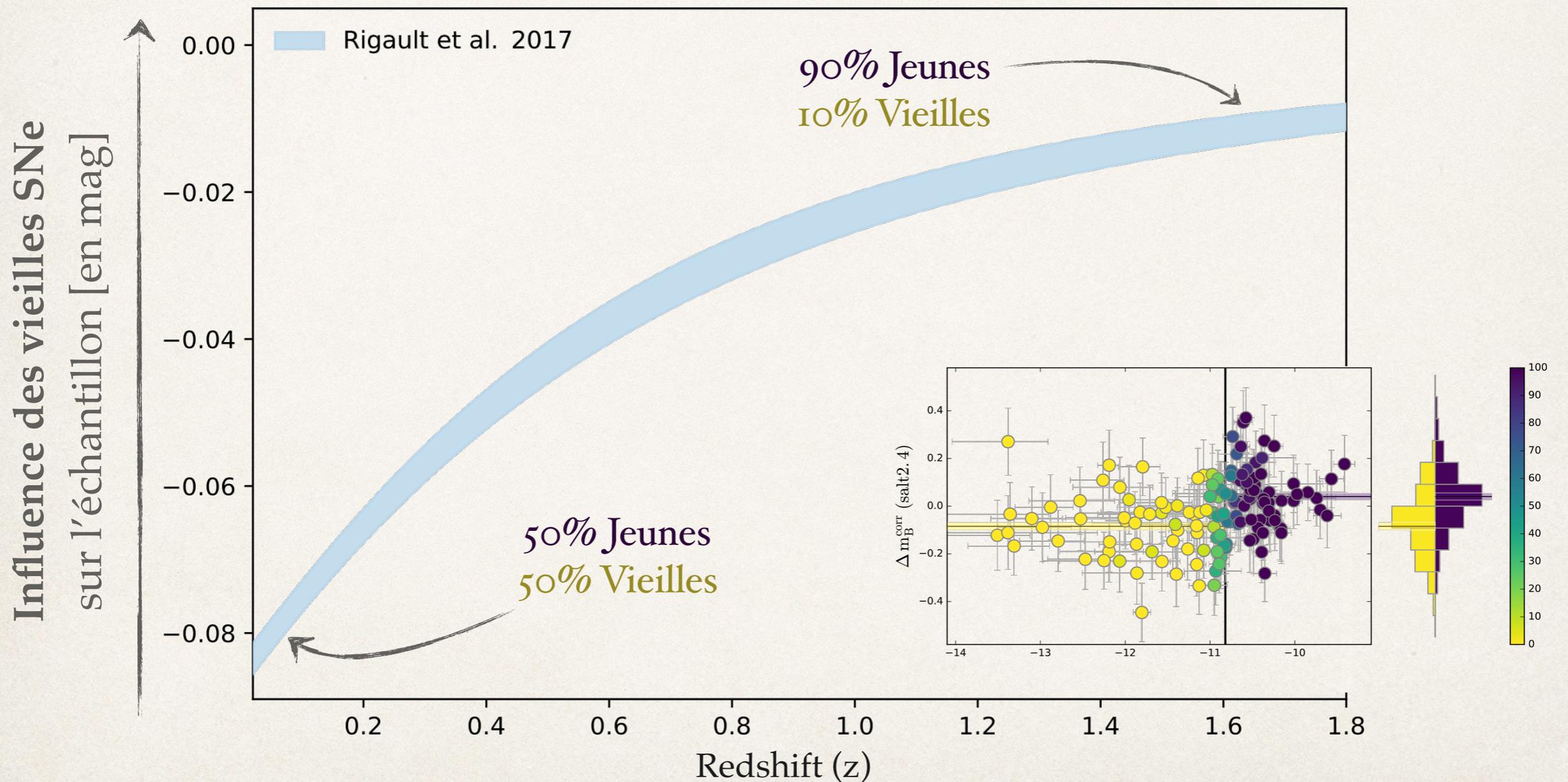


*Les galaxies forment plus d'étoiles à grand redshift*

# Impact sur les mesures cosmologiques — $w$

*Évolution astrophysique ou énergie noire exotique?*

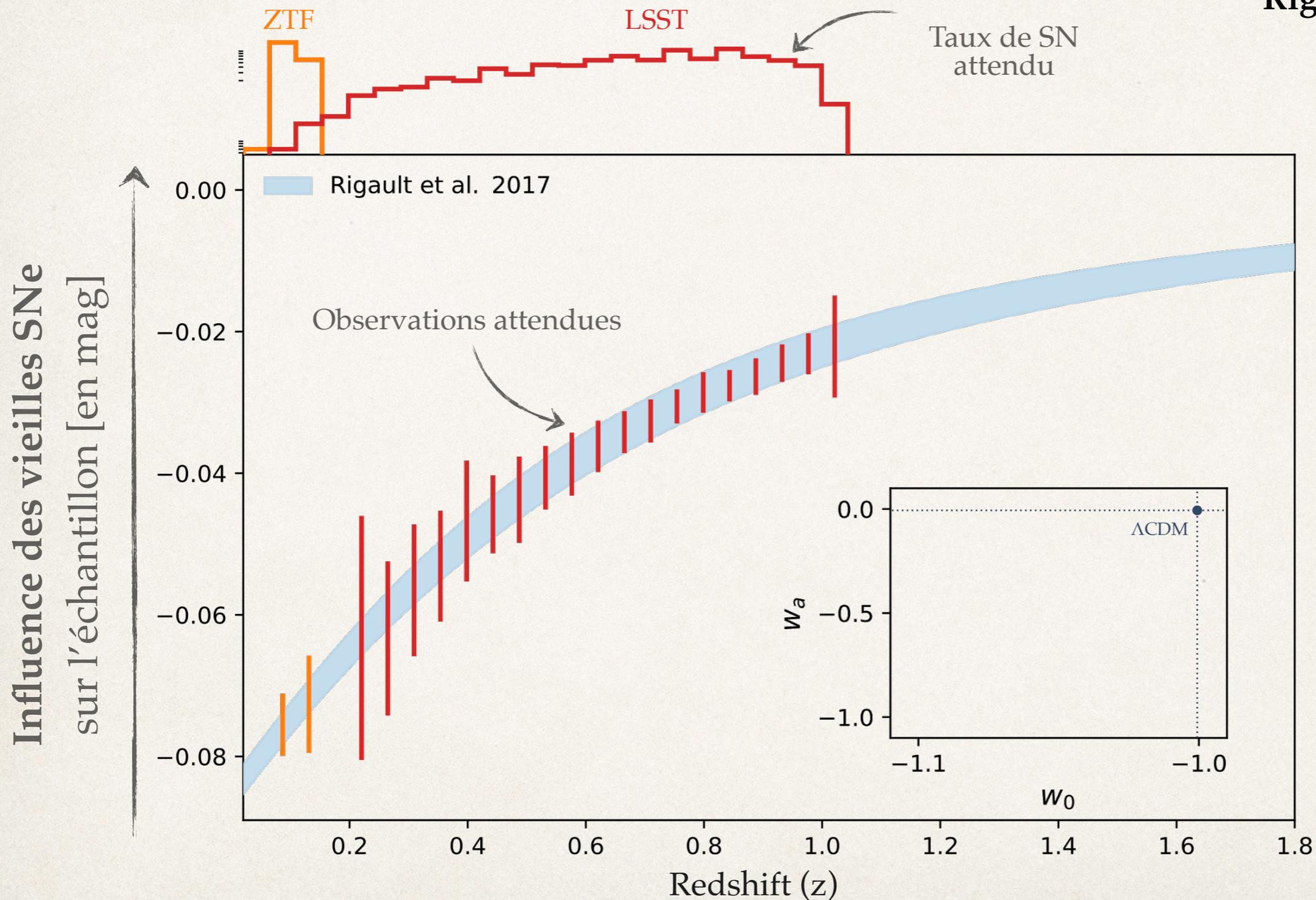
Rigault et al. 2017



# Impact sur les mesures cosmologiques — $w$

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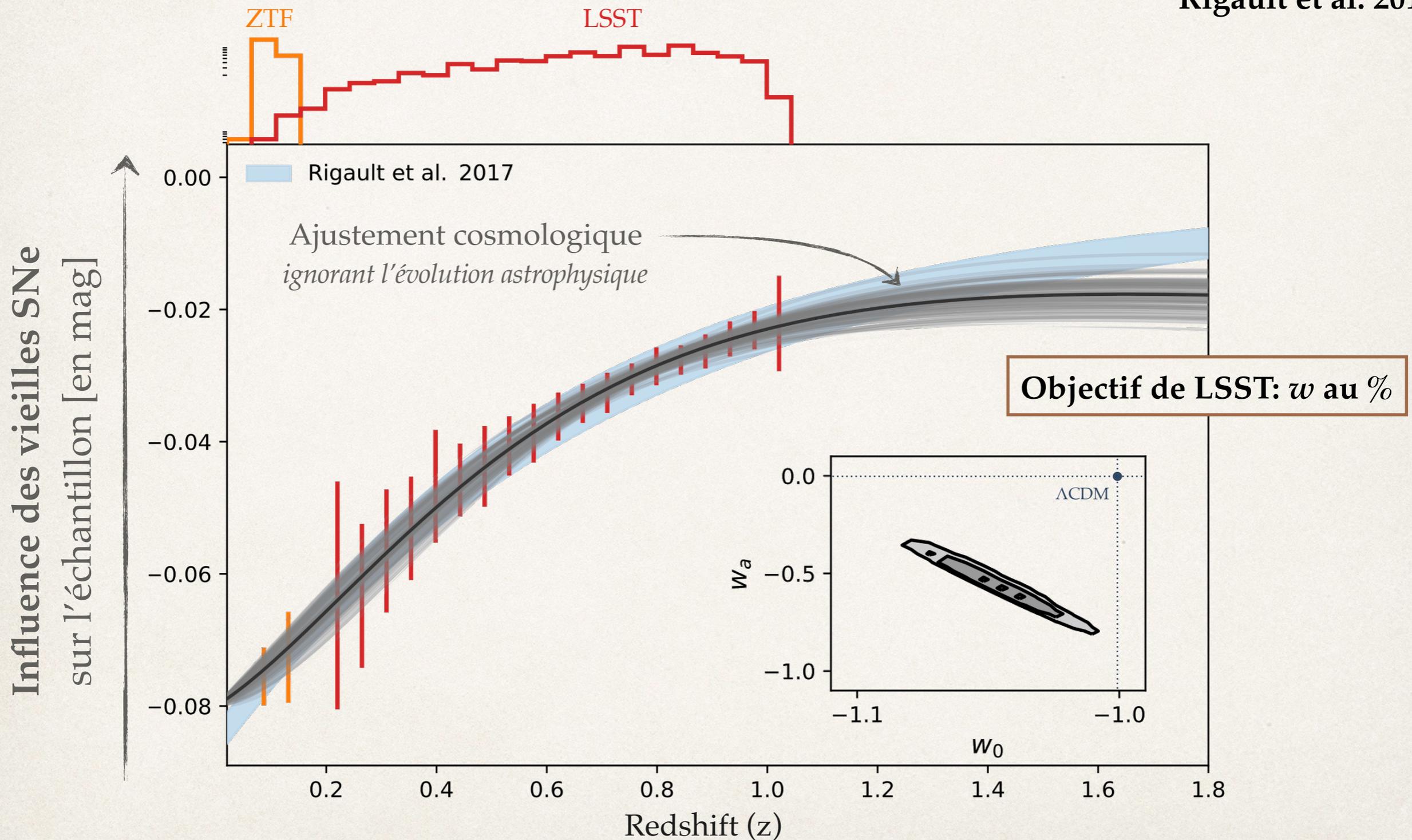
Rigault et al. 2017



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*Évolution astrophysique ou énergie noire exotique?*

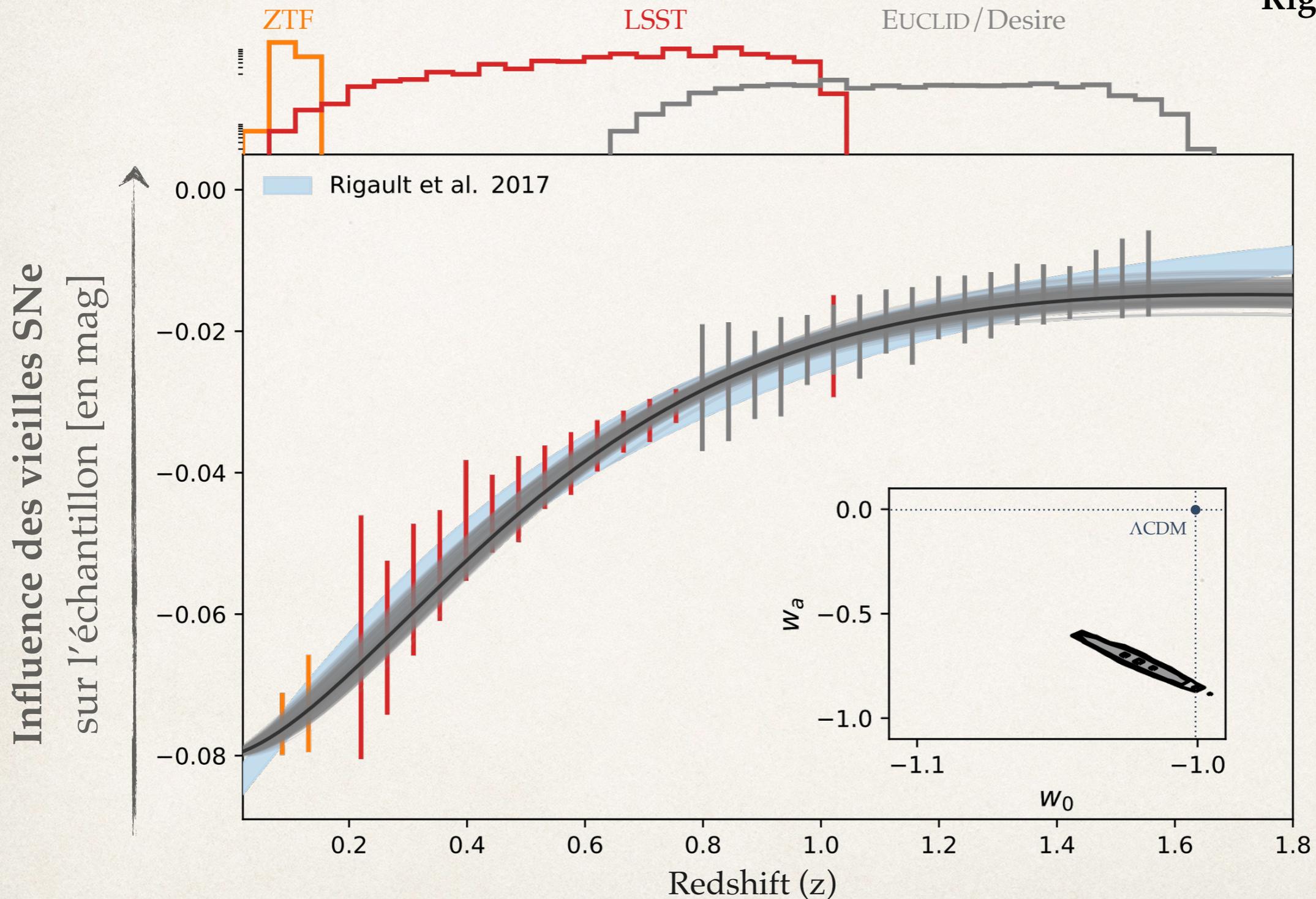
Rigault et al. 2017



# Impact sur les mesures cosmologiques — $w$

*Évolution astrophysique ou énergie noire exotique?*

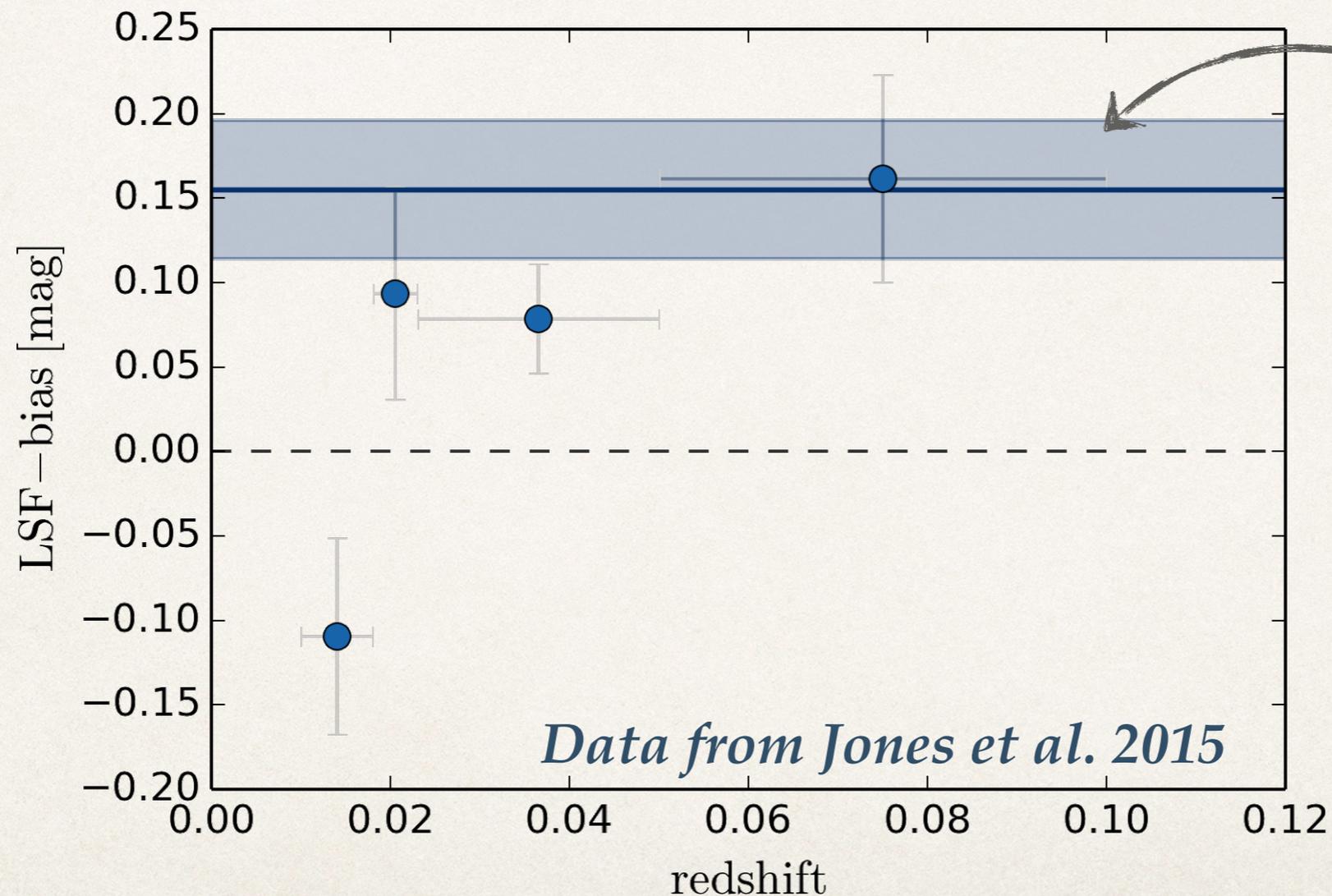
Rigault et al. 2017



# Jones, Riess and Scolnic 2015

*They claim to see no environmental effect*

*They reproduce my result (at  $7\sigma$ !) using the same SNeIa (from Riess11)  
increase the sample and claim not to see anything ( $0\sigma$ ) ...*



Rigault et al. 2015