



# Cosmology with Type Ia Supernovae and the ZTF survey

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Madeleine GINOLIN - 24<sup>th</sup> October 2023



PHAST  
PHYSIQUE  
ET ASTROPHYSIQUE  
UNIVERSITÉ DE LYON

# Outline

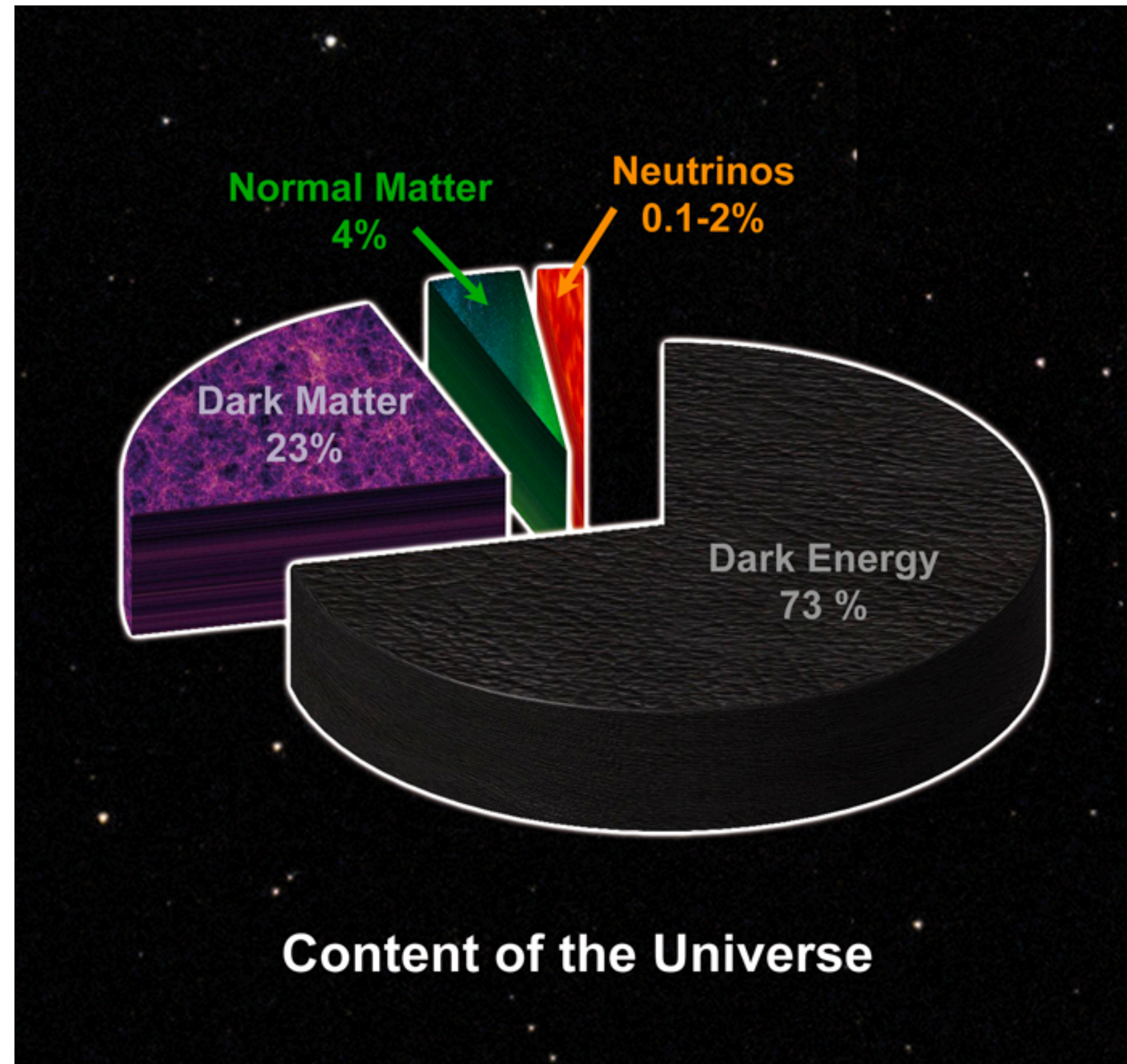
I. Cosmology

II. ZTF

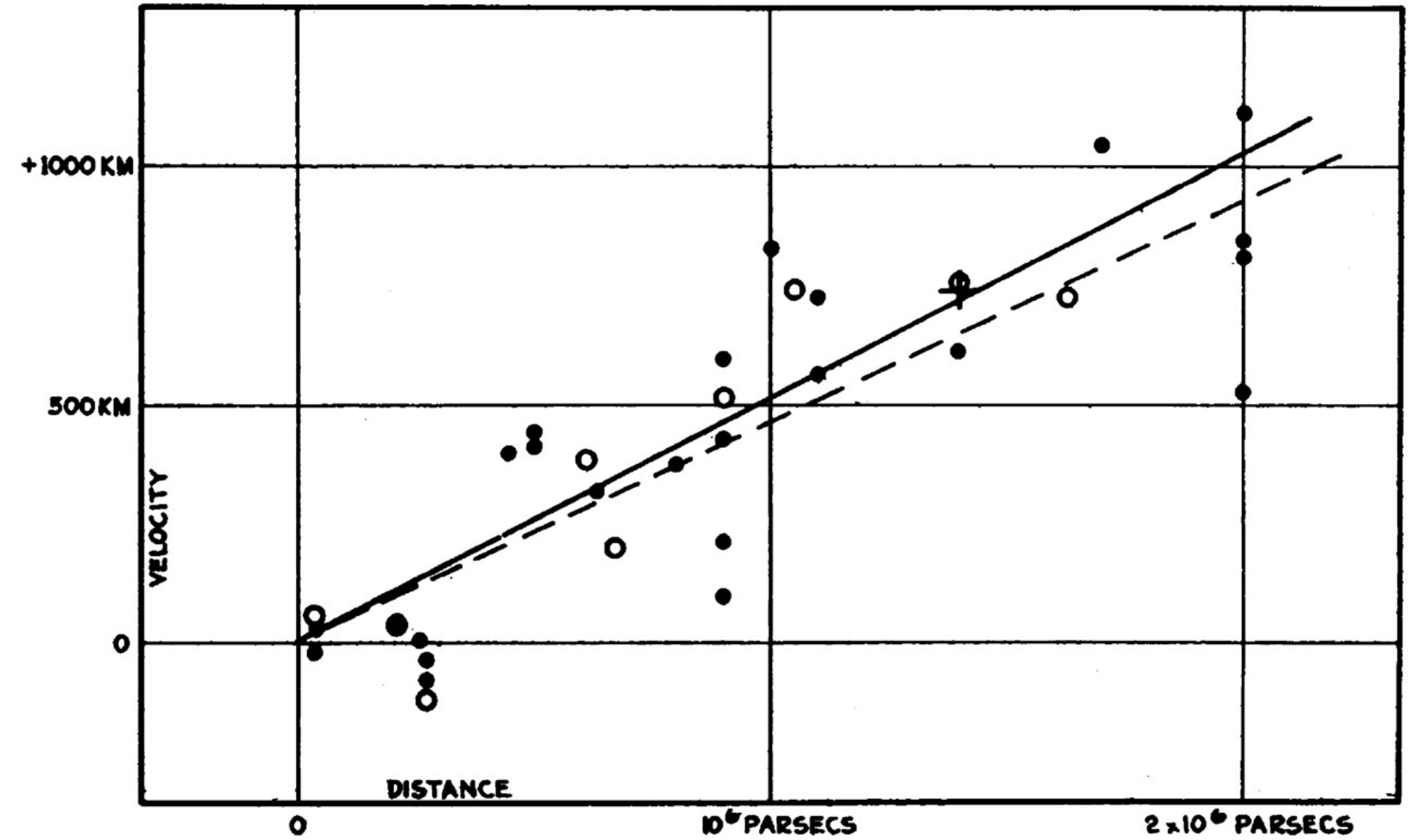
III. What I do in ZTF

# Cosmology

## $\Lambda$ CDM model



Credits: HAP / A. Chantelauze

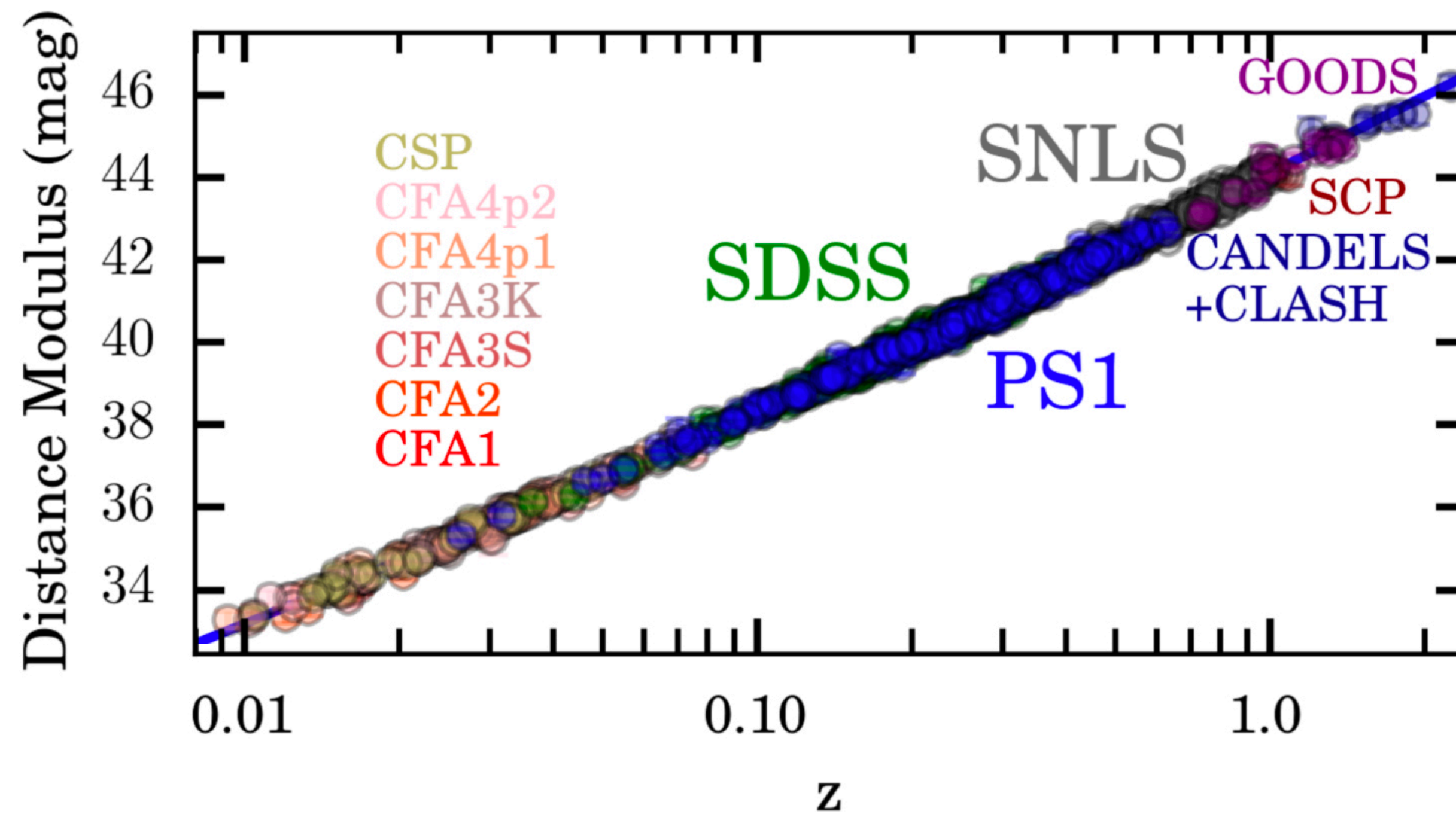


Hubble (1929)

# Cosmology

## Hubble-Lemaître law

$$v = H_0 D = cz$$

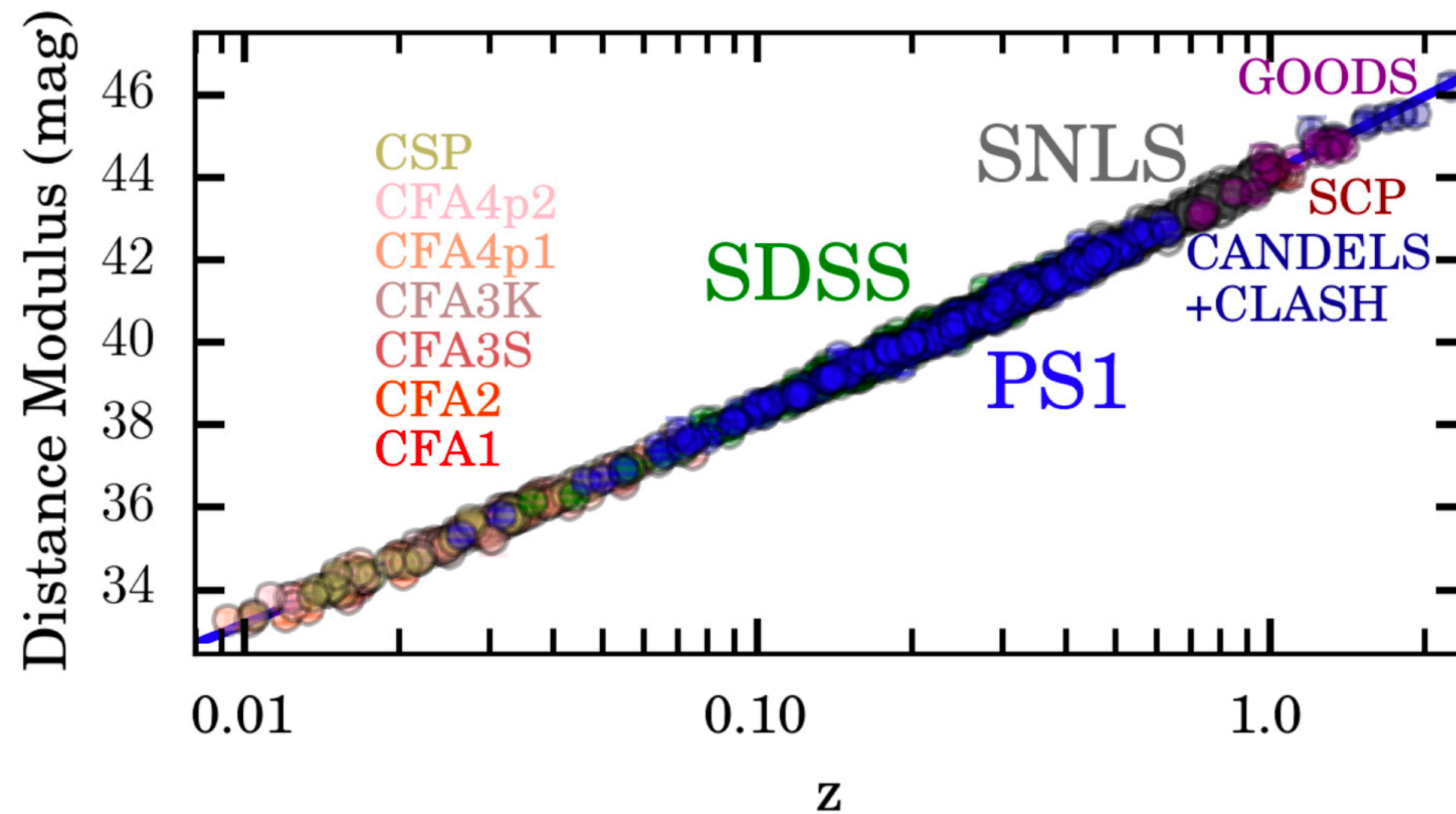


Scolnic et al (2018)

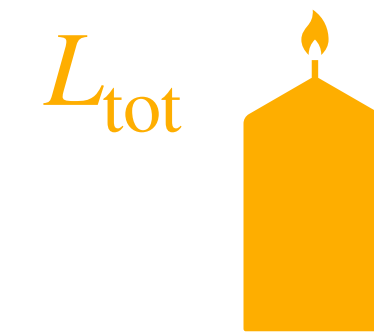
# Cosmology

## Hubble-Lemaître law

$$v = H_0 D = cz$$



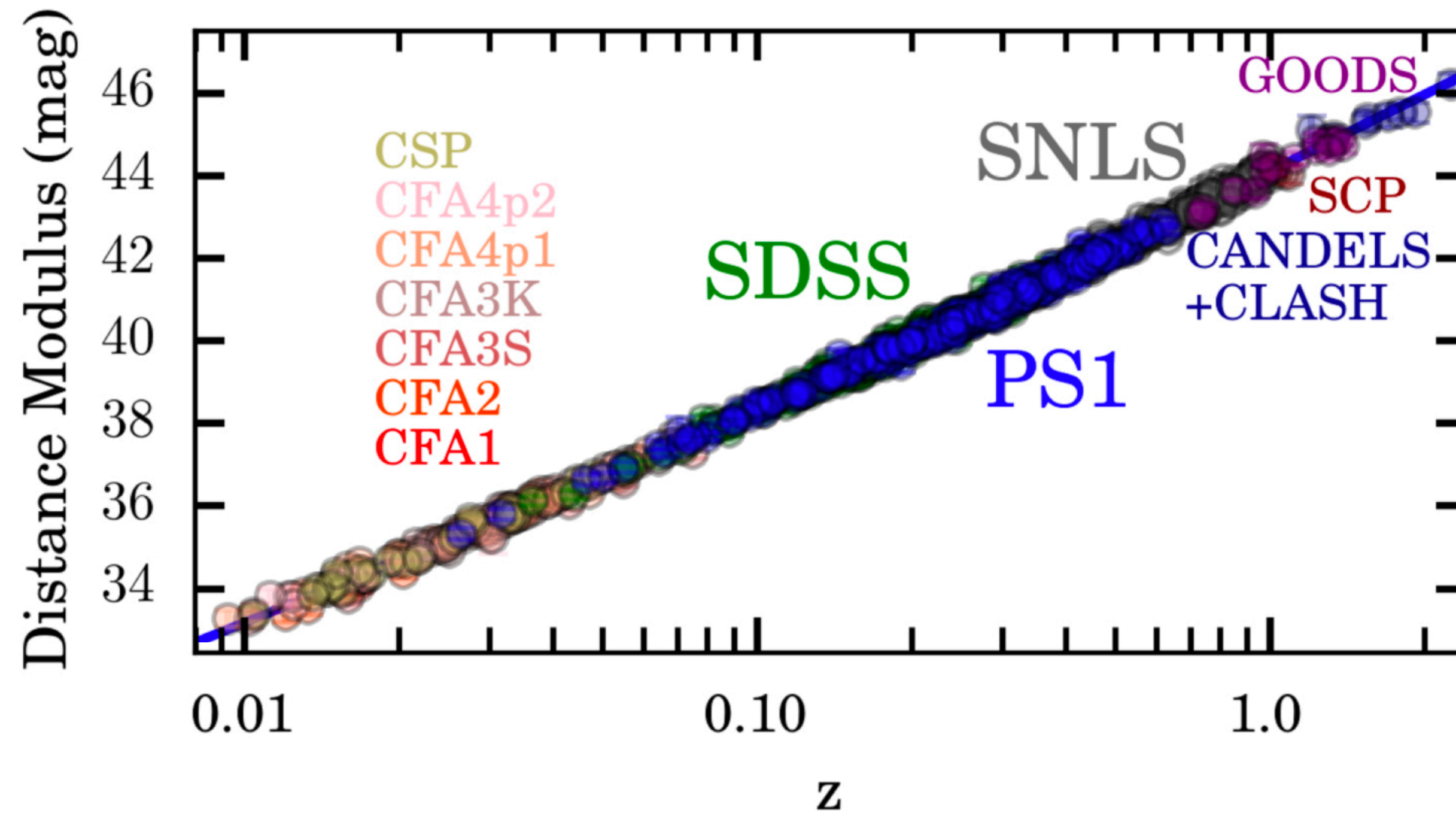
Scolnic et al (2018)



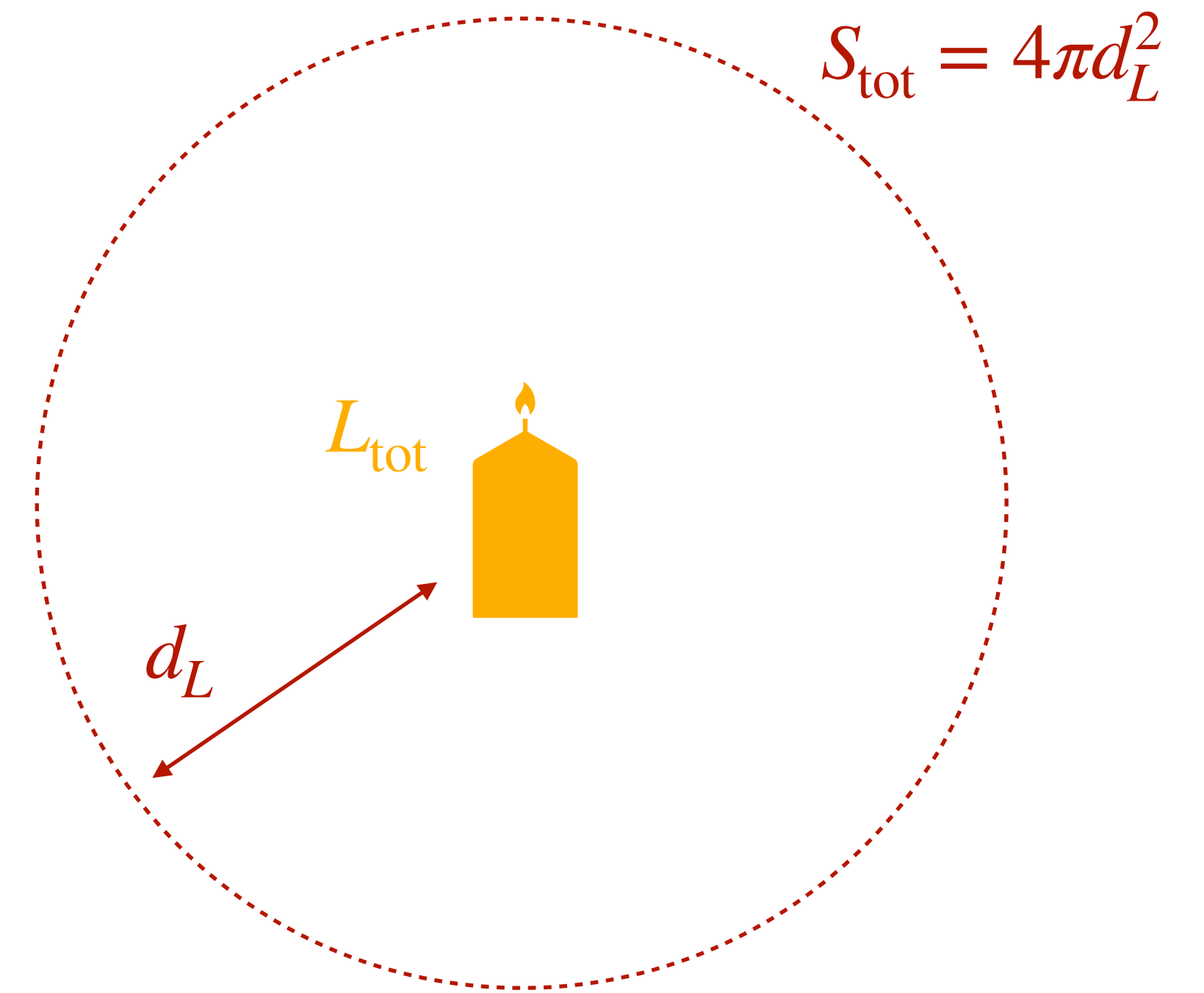
# Cosmology

## Hubble-Lemaître law

$$v = H_0 D = cz$$



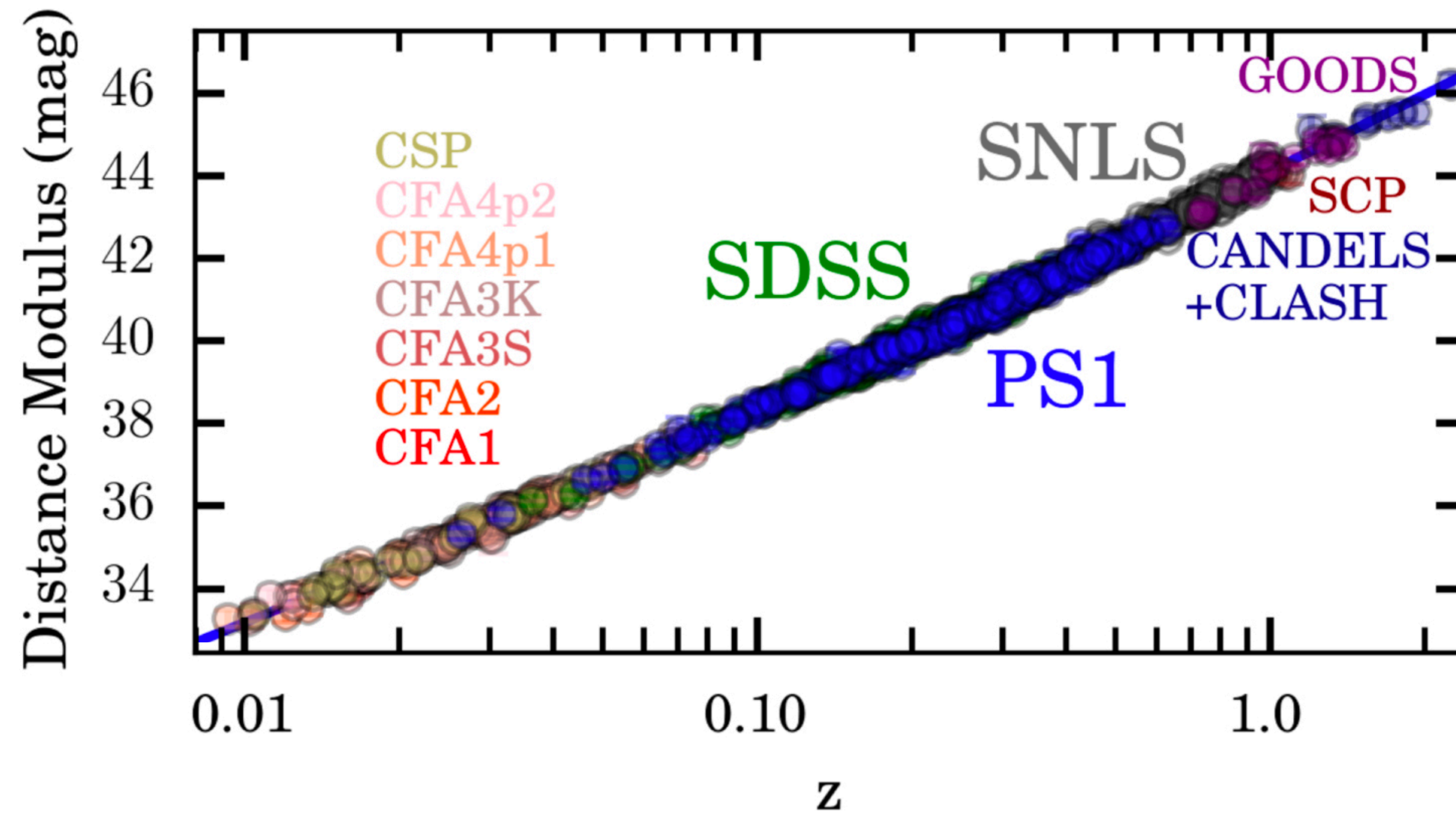
Scolnic et al (2018)



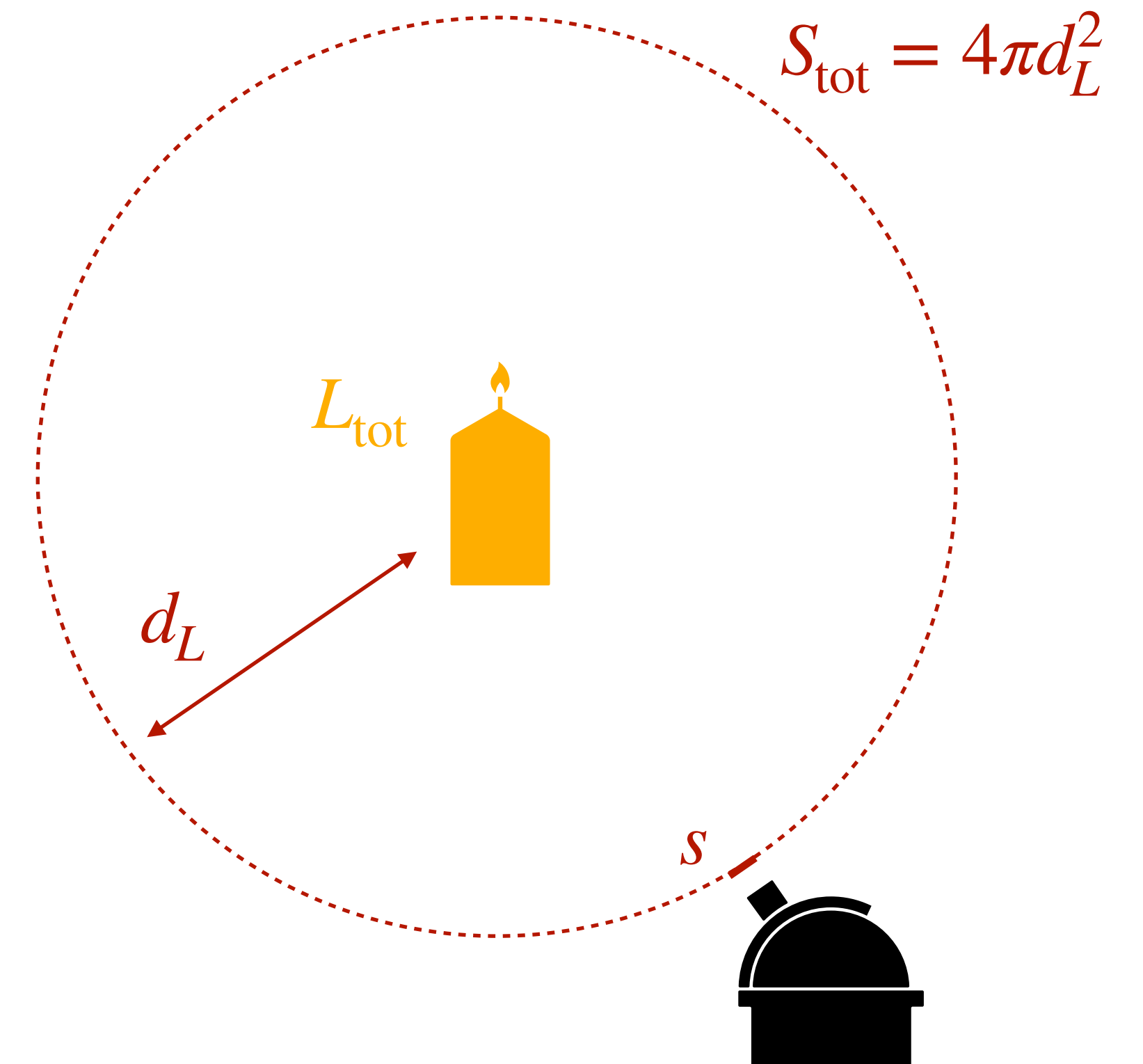
# Cosmology

## Hubble-Lemaître law

$$v = H_0 D = cz$$



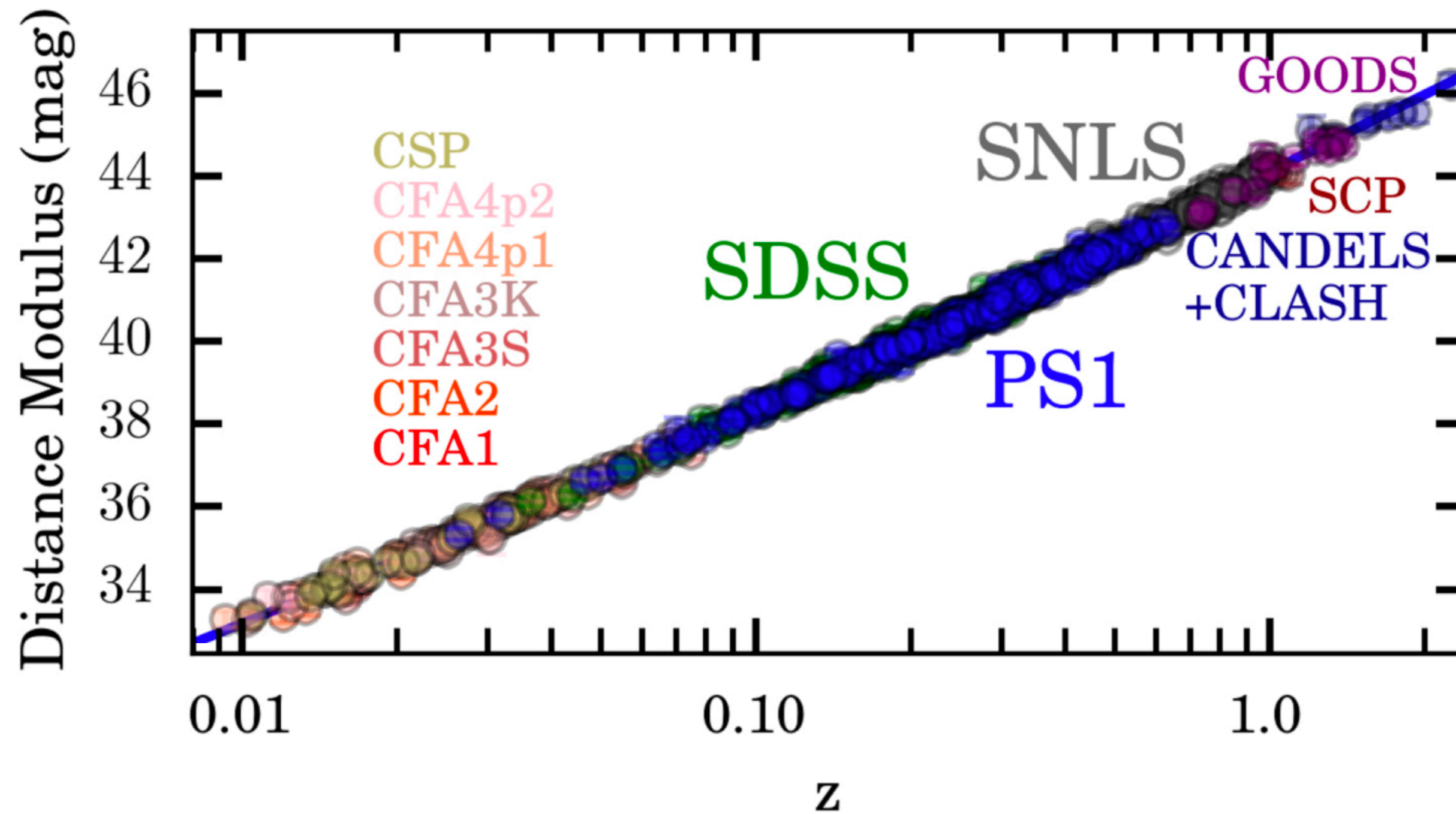
Scolnic et al (2018)



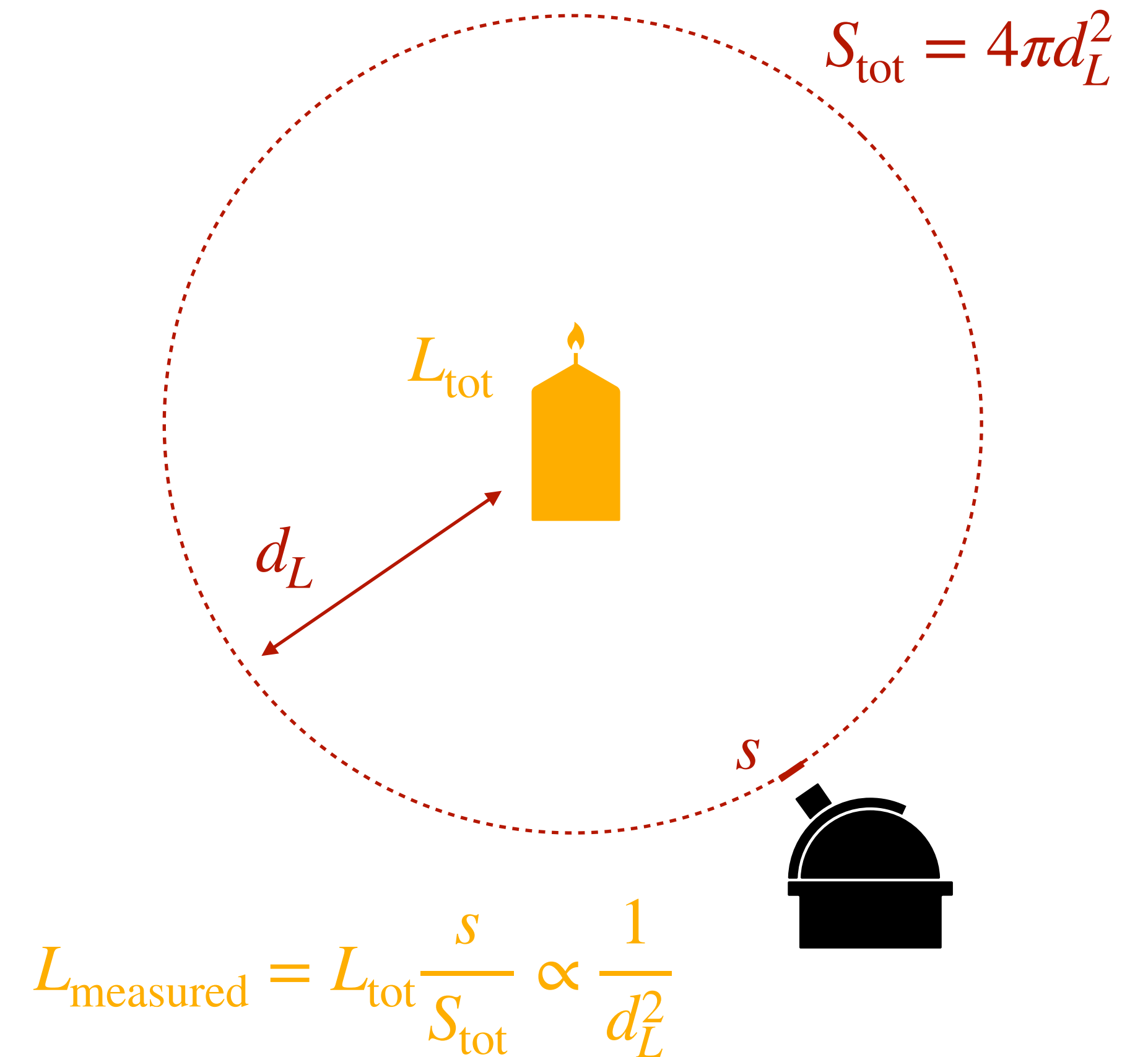
# Cosmology

## Hubble-Lemaître law

$$v = H_0 D = cz$$



Scolnic et al (2018)

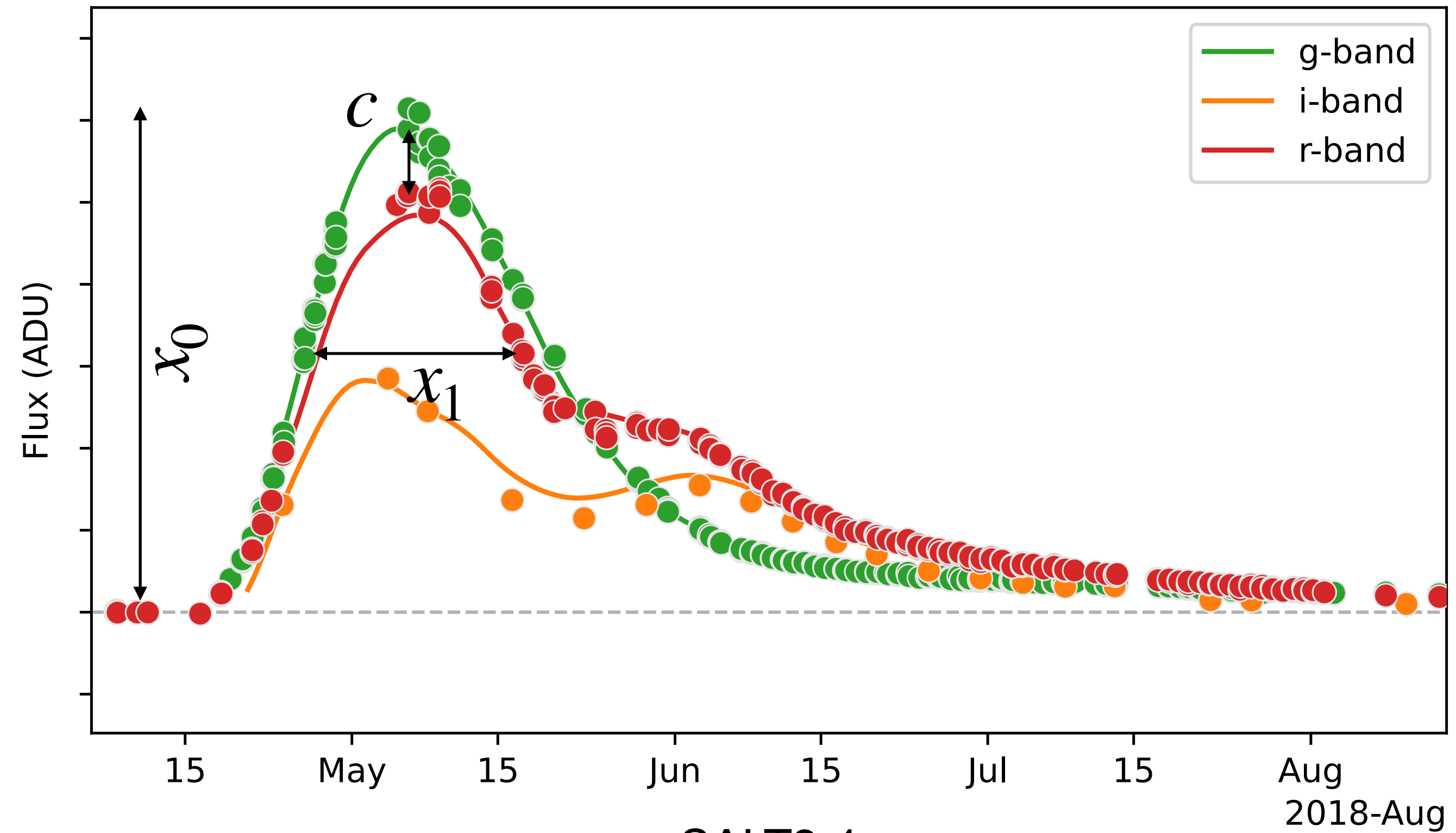




# Supernovae



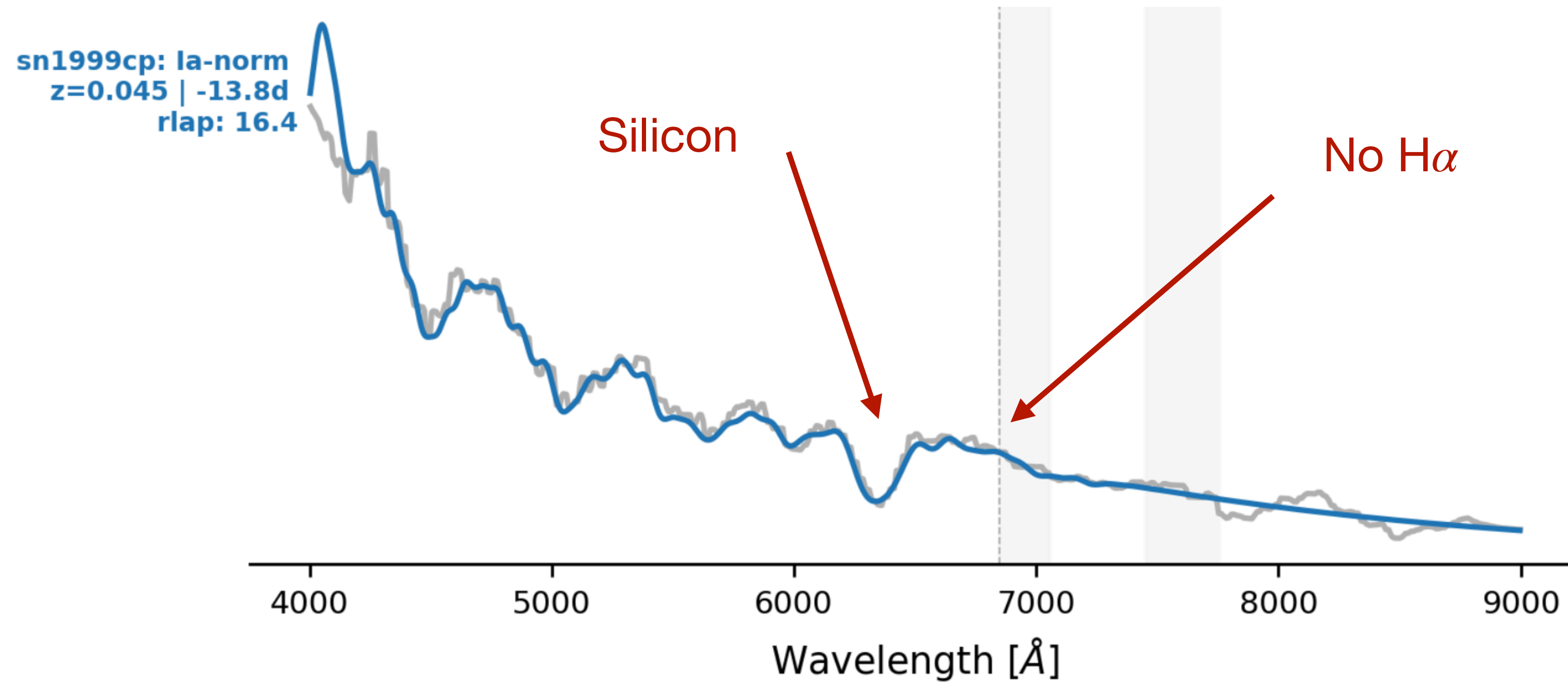
Credits: B.J. Fulton/  
LCOGT/Caltech



$x_0$   
 $x_1$   
 $c$

SALT2.4  
(Guy et al 2007)

# Type Ia Supernovae



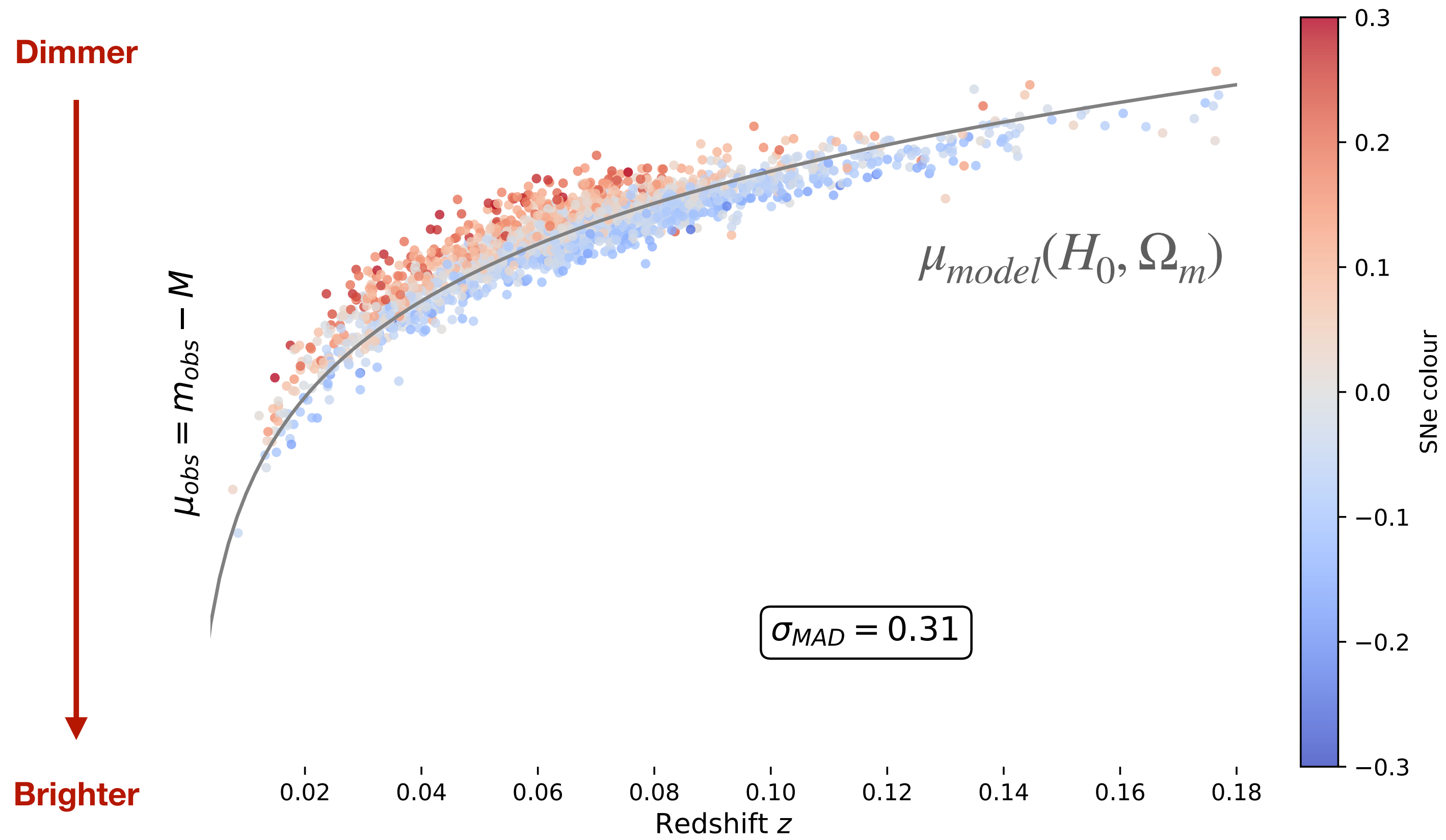
Typing

$z$

SNID  
(Blondin & Tonry 2007)

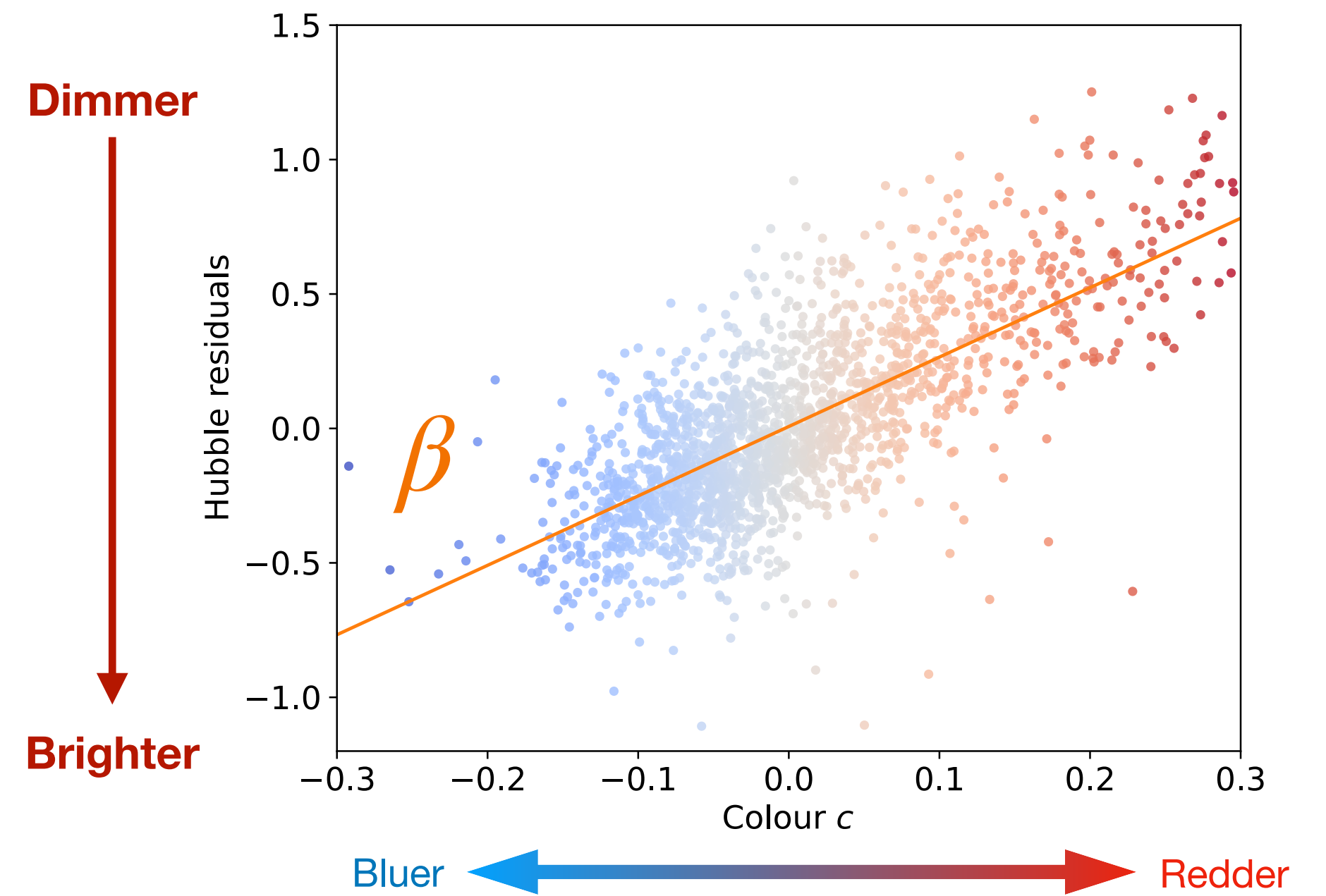
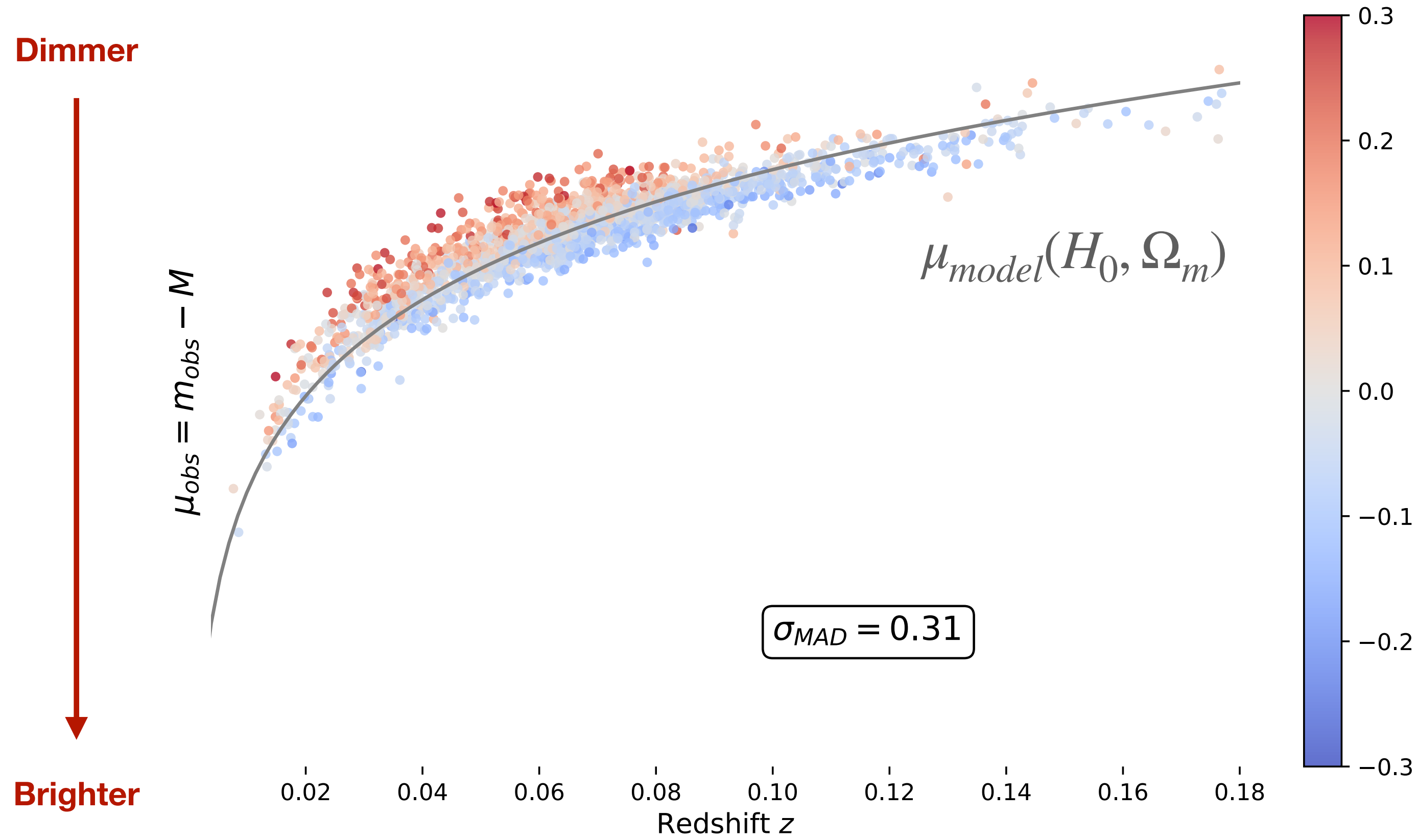
# Cosmology with SNe

## Supernovae standardisation



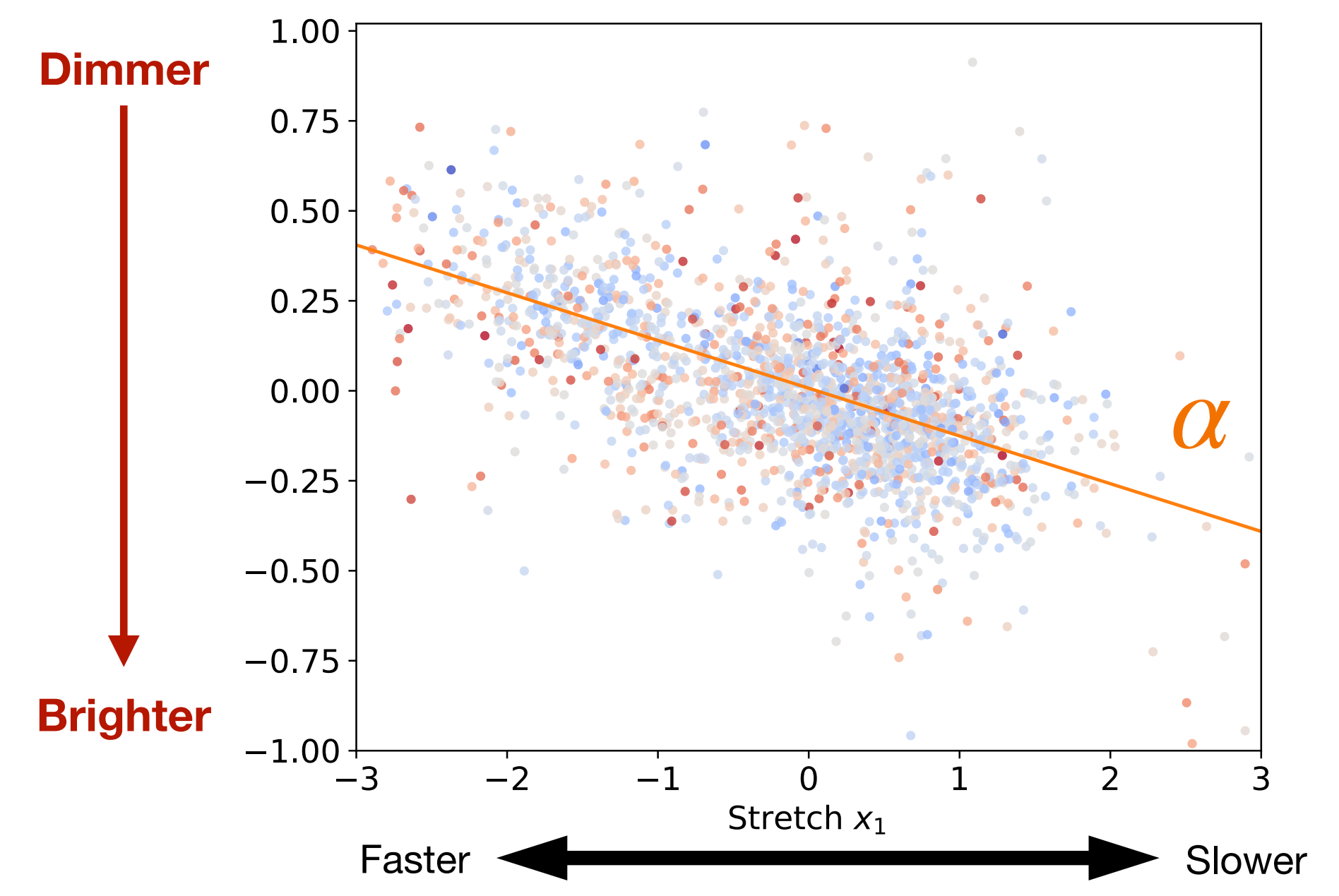
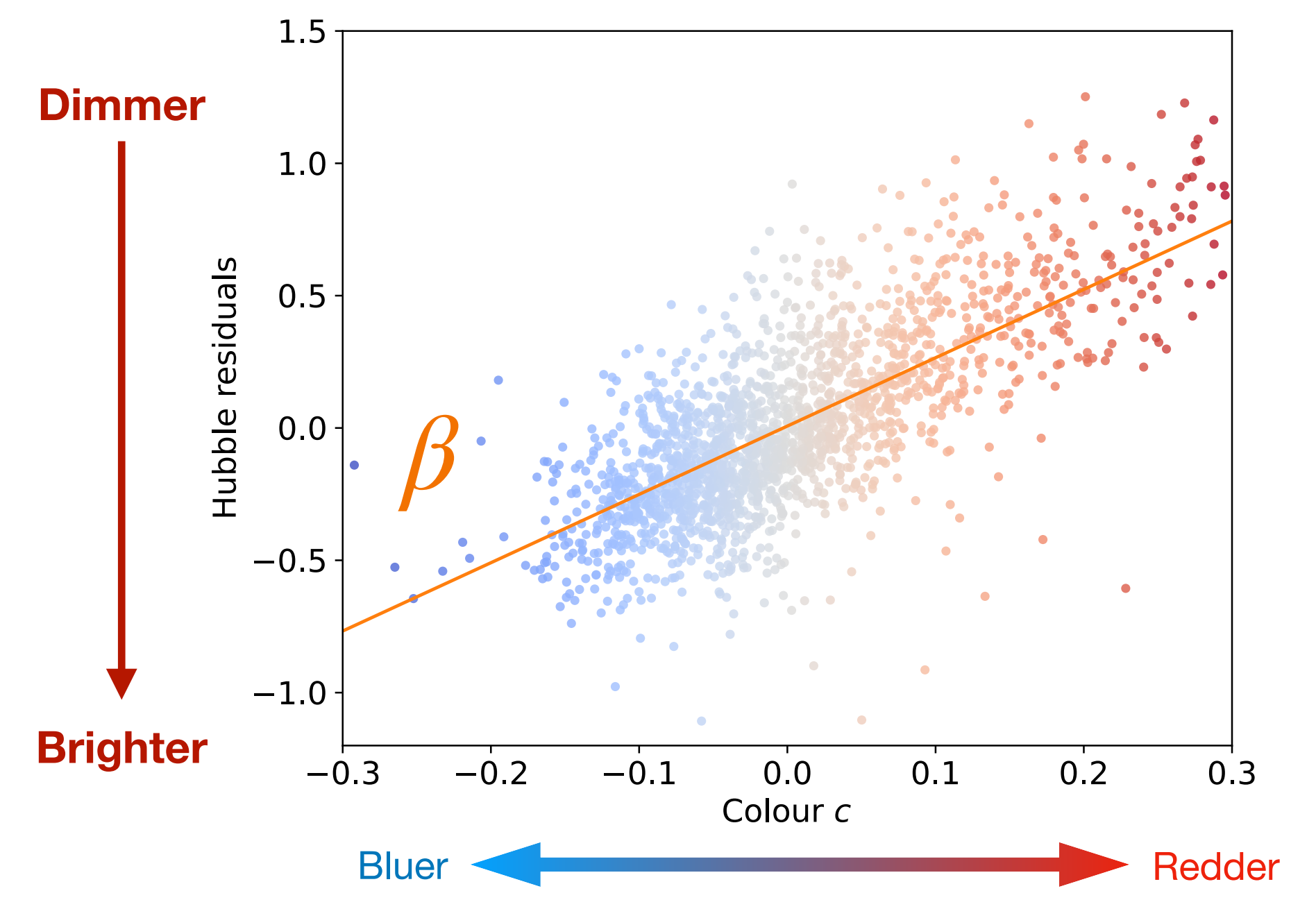
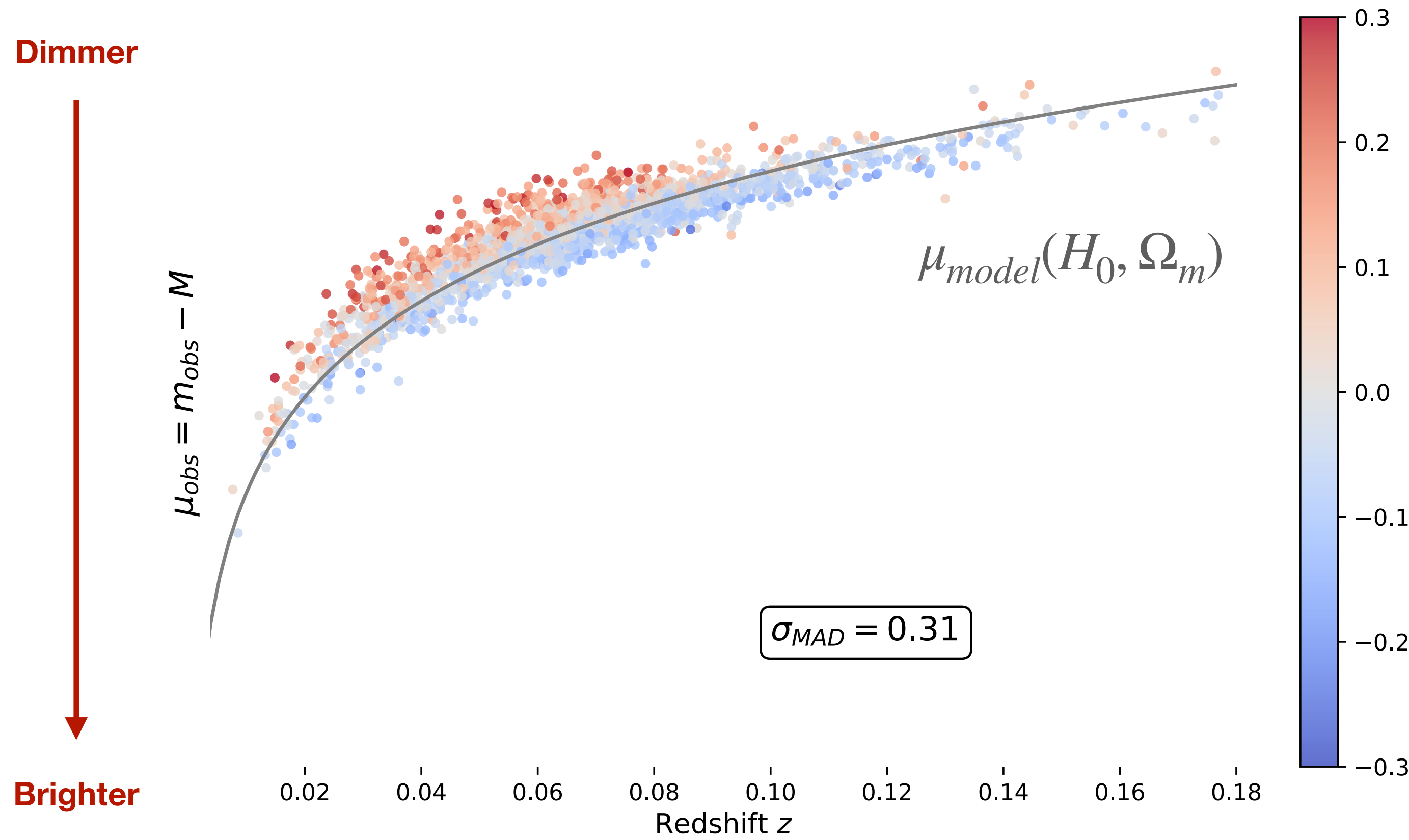
# Cosmology with SNe

## Supernovae standardisation



# Cosmology with SNe

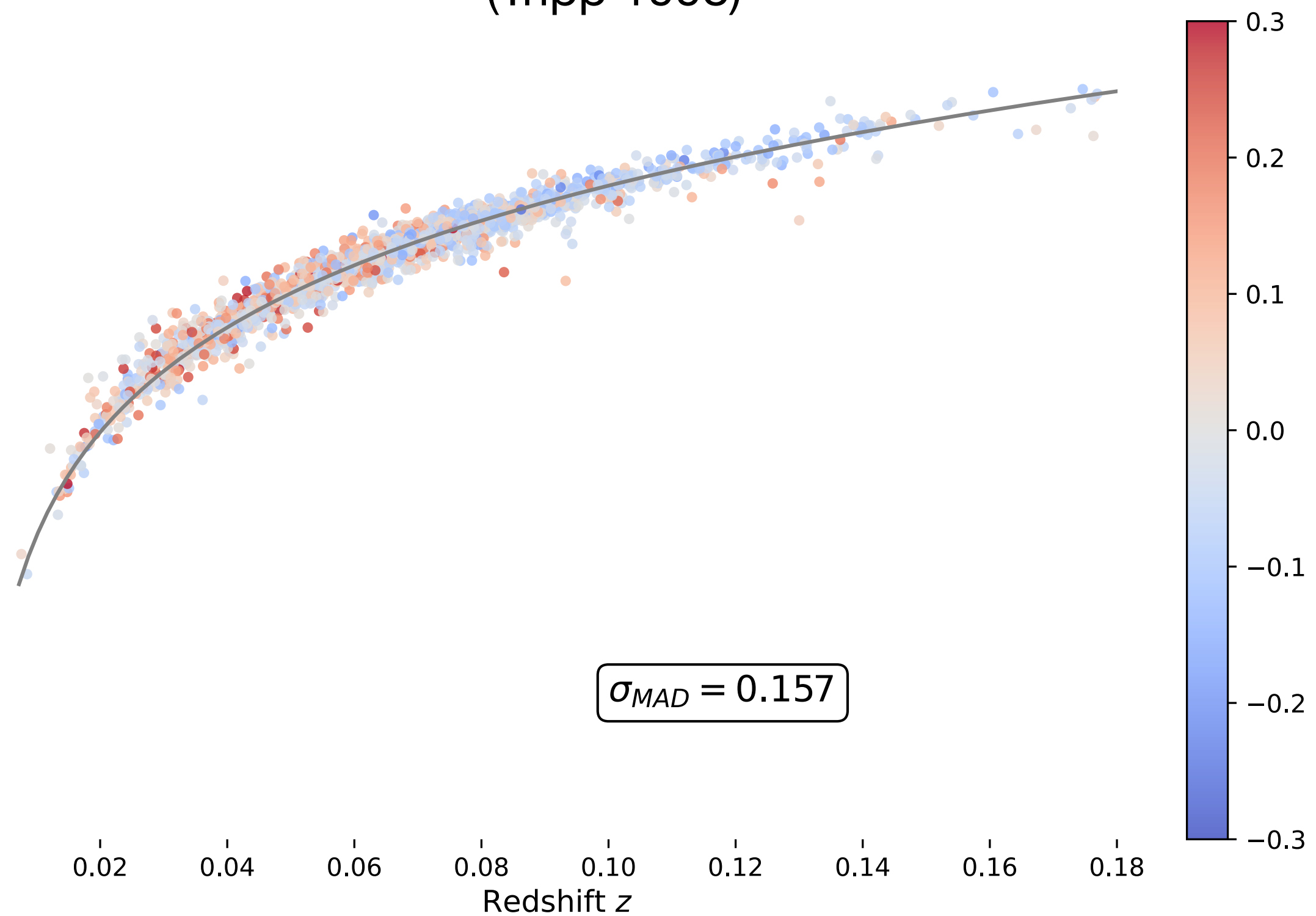
## Supernovae standardisation



# Cosmology with SNe

$$\mu + M = m_{obs} - \beta c + \alpha x_1$$

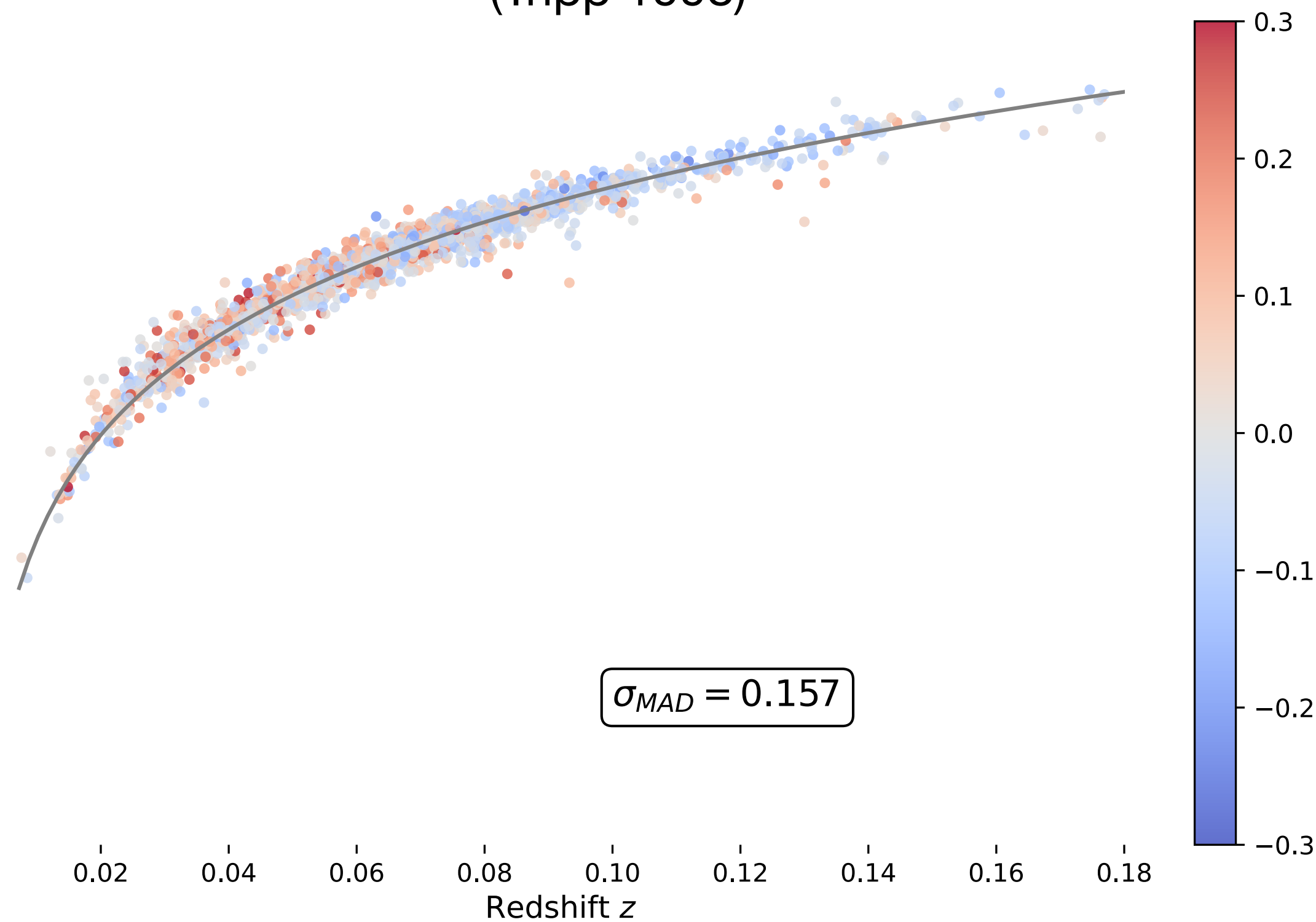
(Tripp 1998)



# Cosmology with SNe

$$\mu + M = m_{obs} - \beta c + \alpha x_1$$

(Tripp 1998)

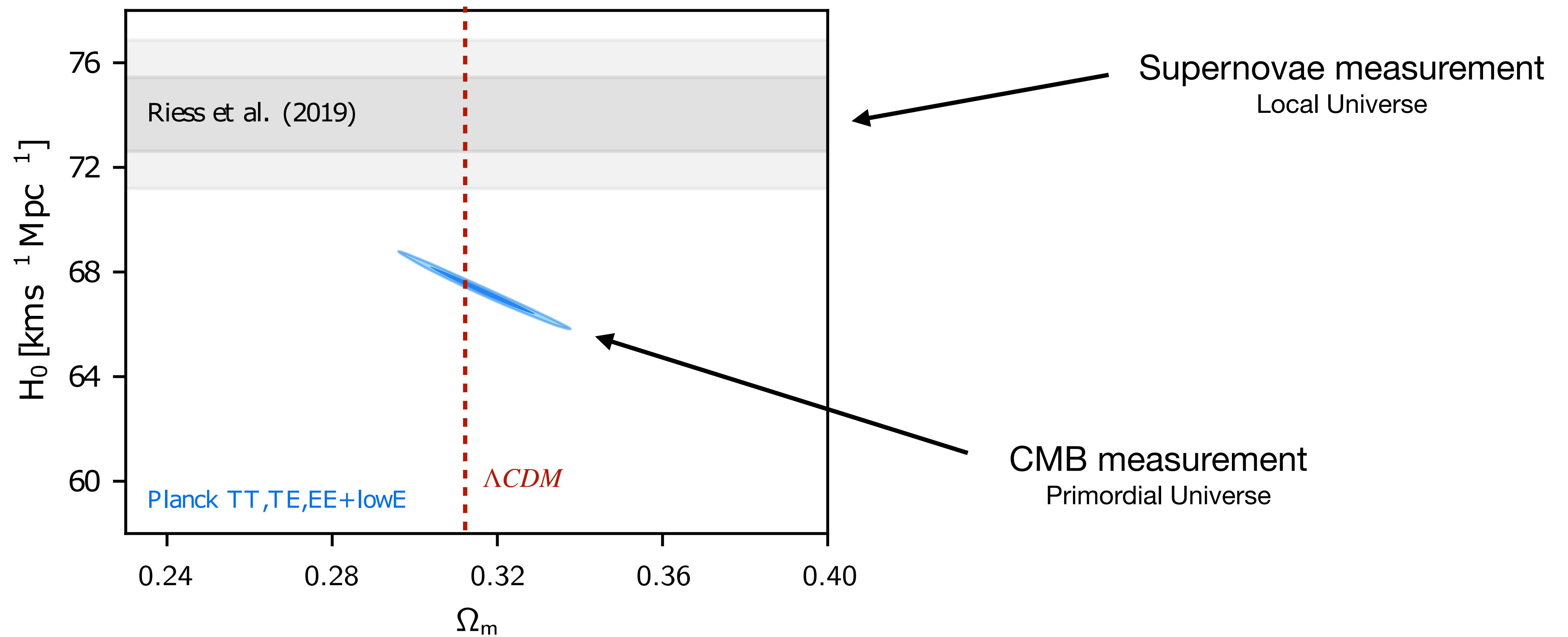


+

Anchoring to the Cepheids

$$\mu + M = m_{obs} - \beta c + \alpha x_1$$

# Hubble tension

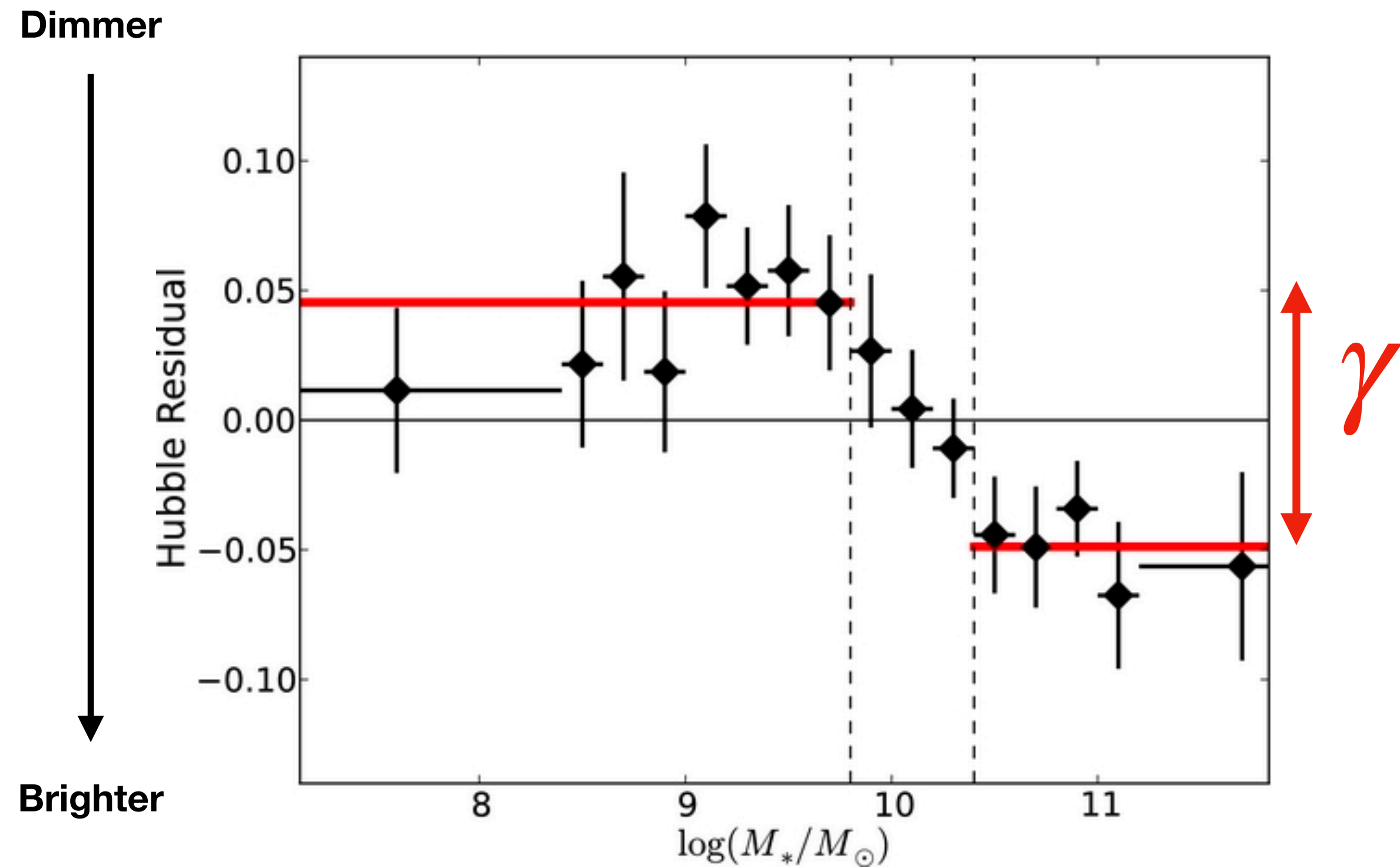


Adapted from Planck collaboration (2020)



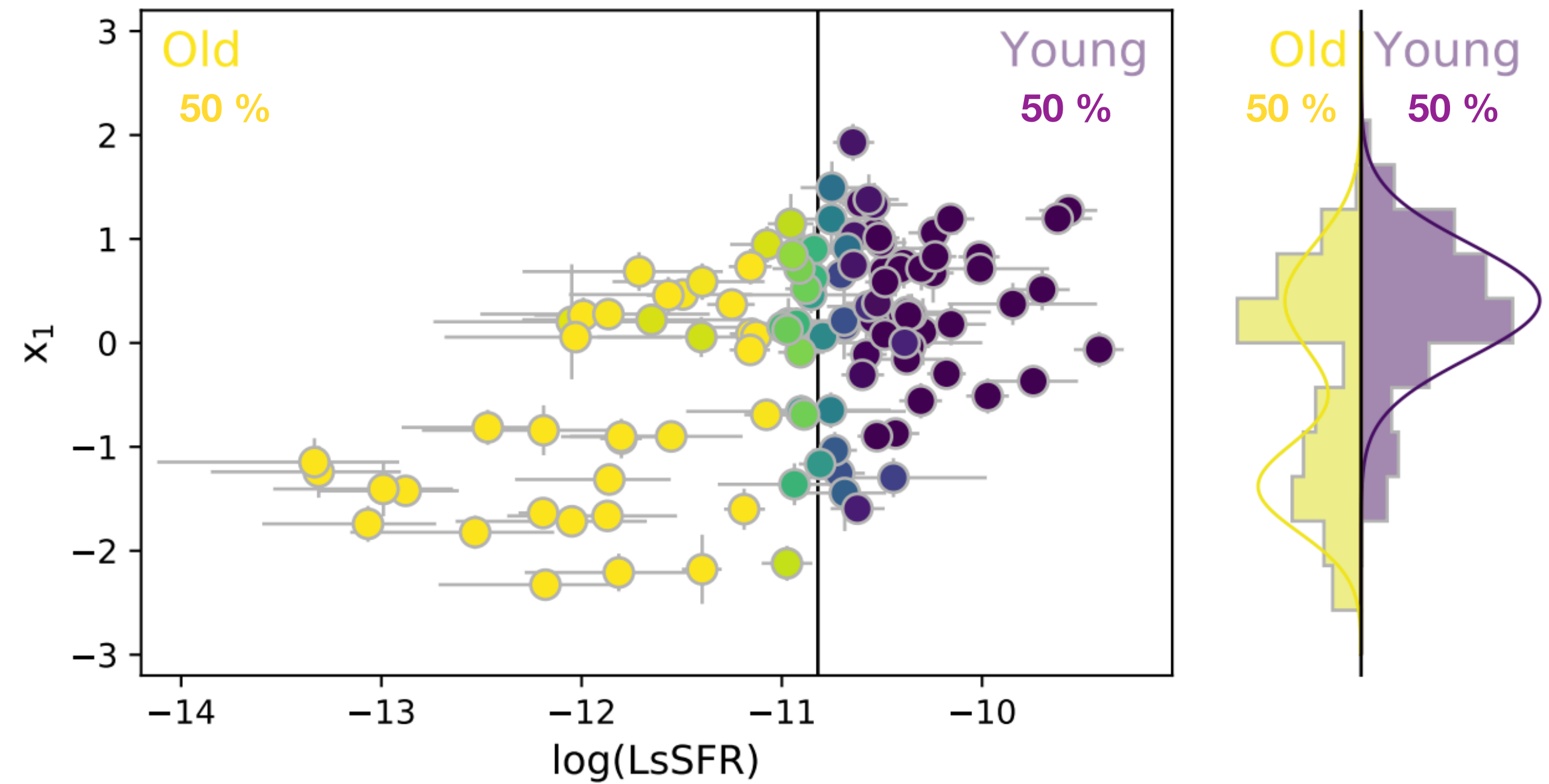
# Astrophysical biases

### Mass step $\gamma$



Childress et al (2013)

### Two population model



Nicolas et al (2021)

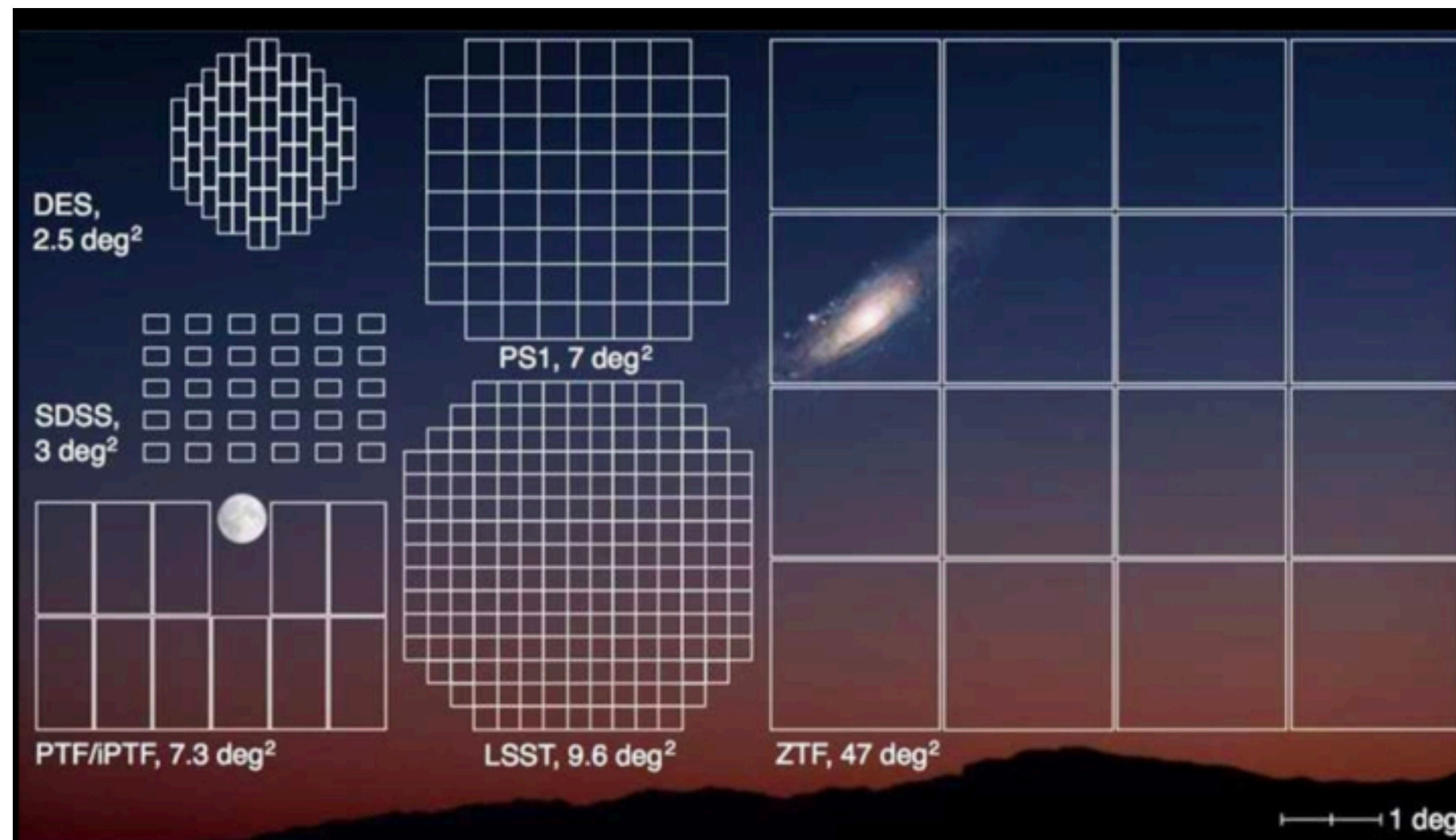
# PhD goal

$$\mu + M = m_{obs} - \beta c + \alpha x_1 + p\gamma$$

# ZTF



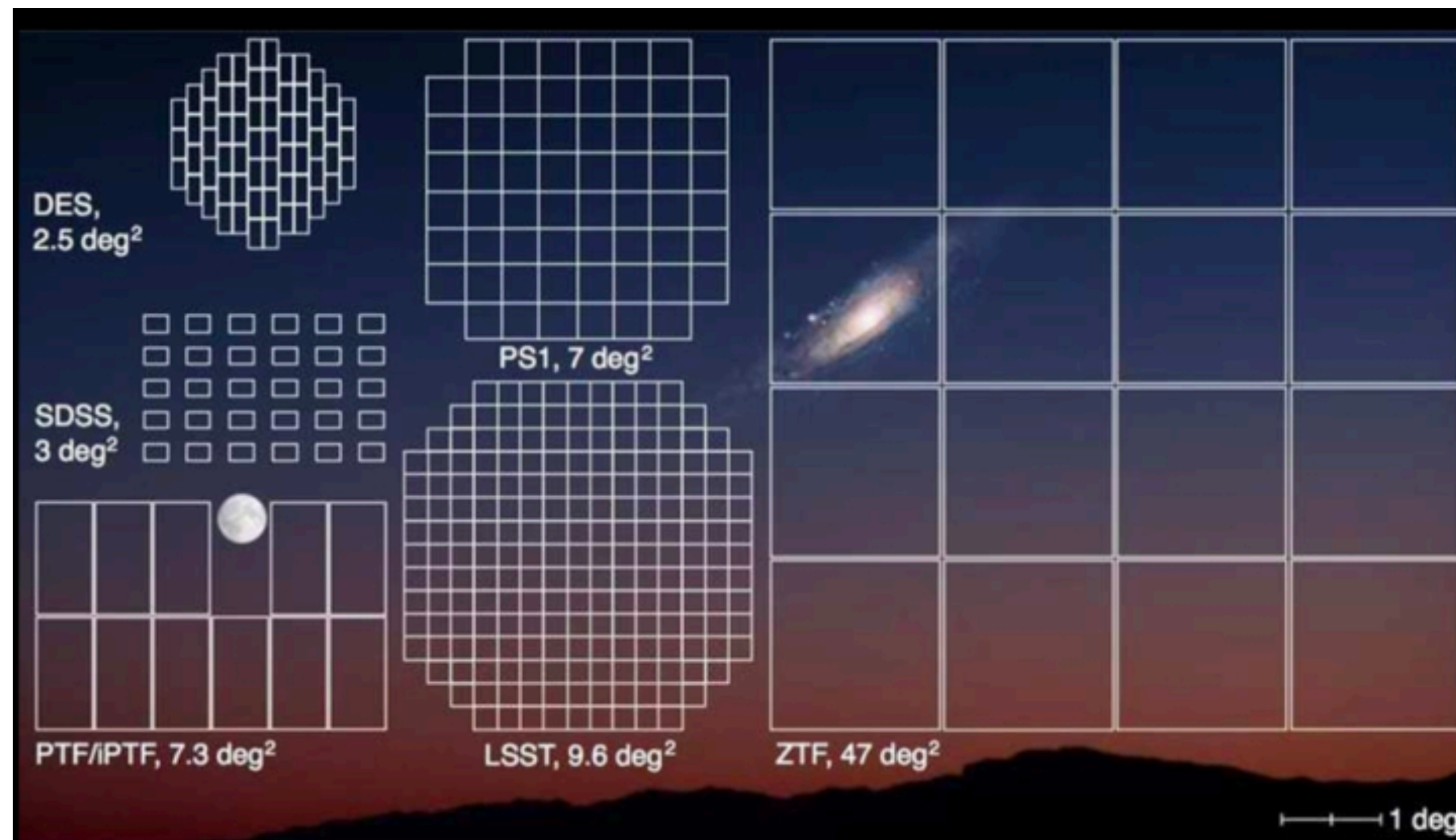
# ZTF



## Zwicky Transient Facility (P48)

- High FoV
- Short (30s) exposures
- 3 bands (g, r, i)
- Median depth in r band at  $\sim 20.4$  mag ( $z=0.1$ )

# ZTF



## Zwicky Transient Facility (P48)

- High FoV
- Short (30s) exposures
- 3 bands (g, r, i)
- Median depth in r band at ~ 20.4 mag (z=0.1)

## SEDmachine (P60)

- Low resolution ( $\frac{\lambda}{\Delta\lambda} \sim 100$ )
- ~ 1h exposure
- Limiting magnitude at ~ 19.5 mag

# ZTF DR2

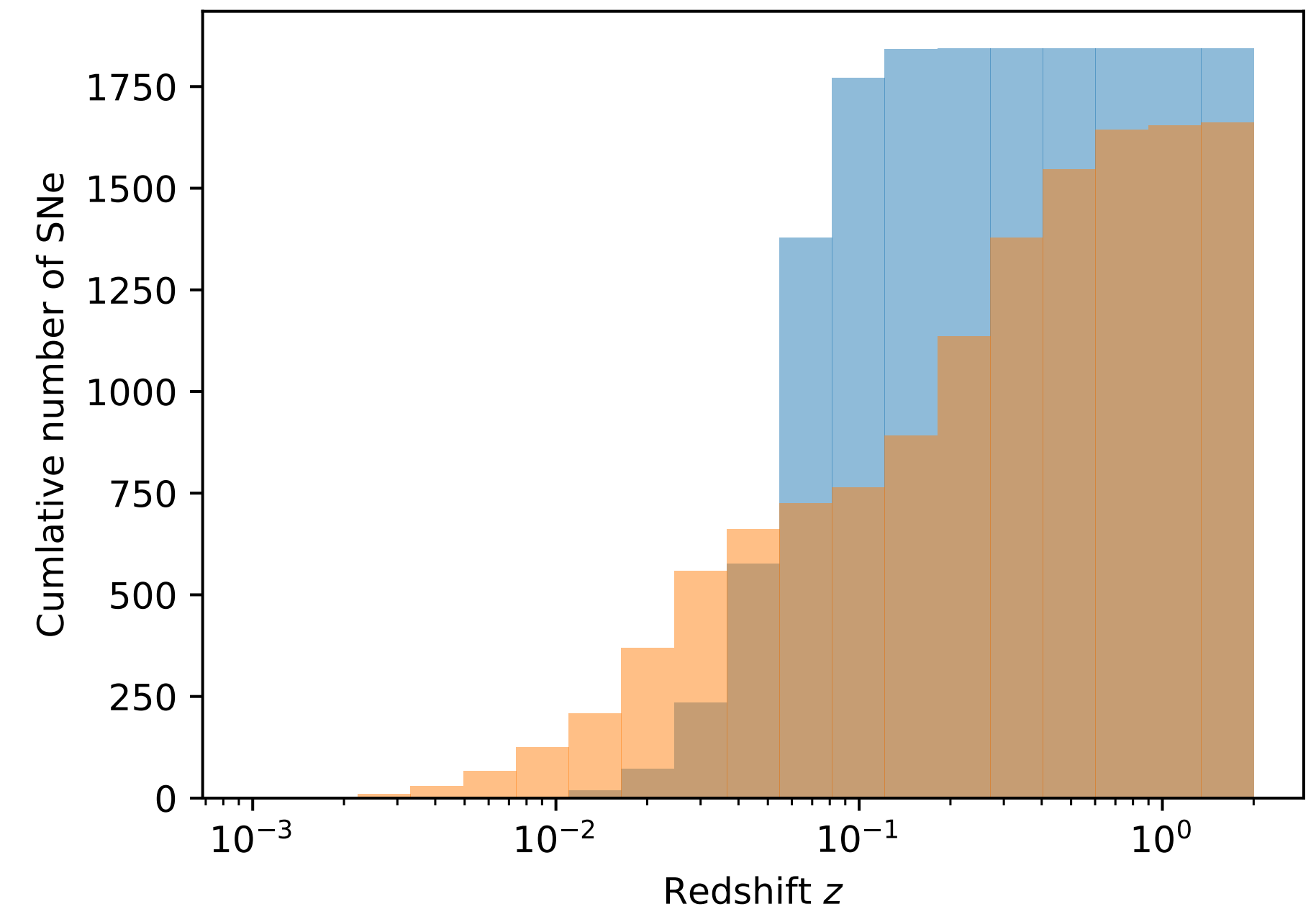
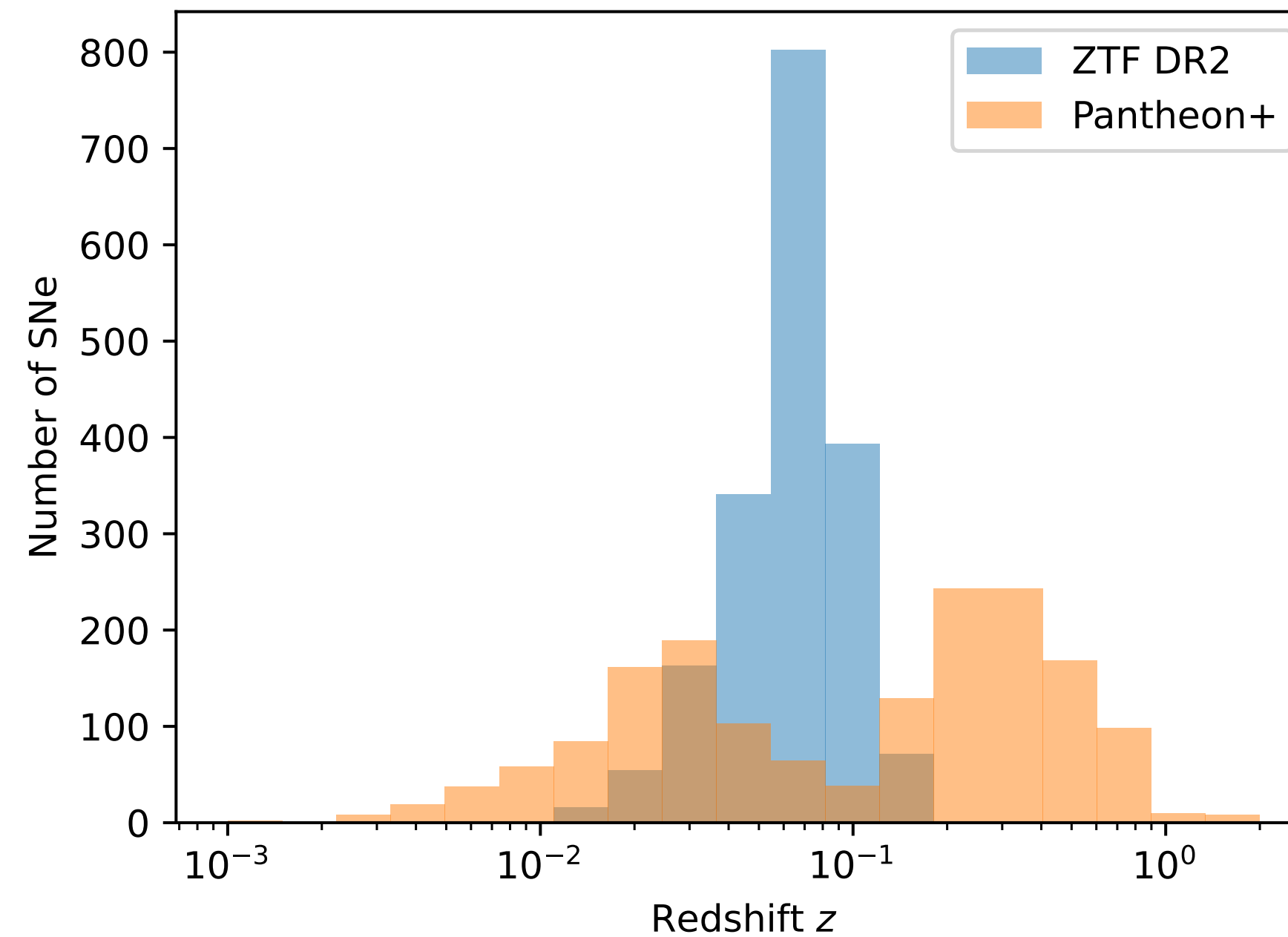
## Numbers

➔ 3627 spectroscopically confirmed SNe Ia

➔ 2930 with a good light curve

➔ 1843 cosmological Ias

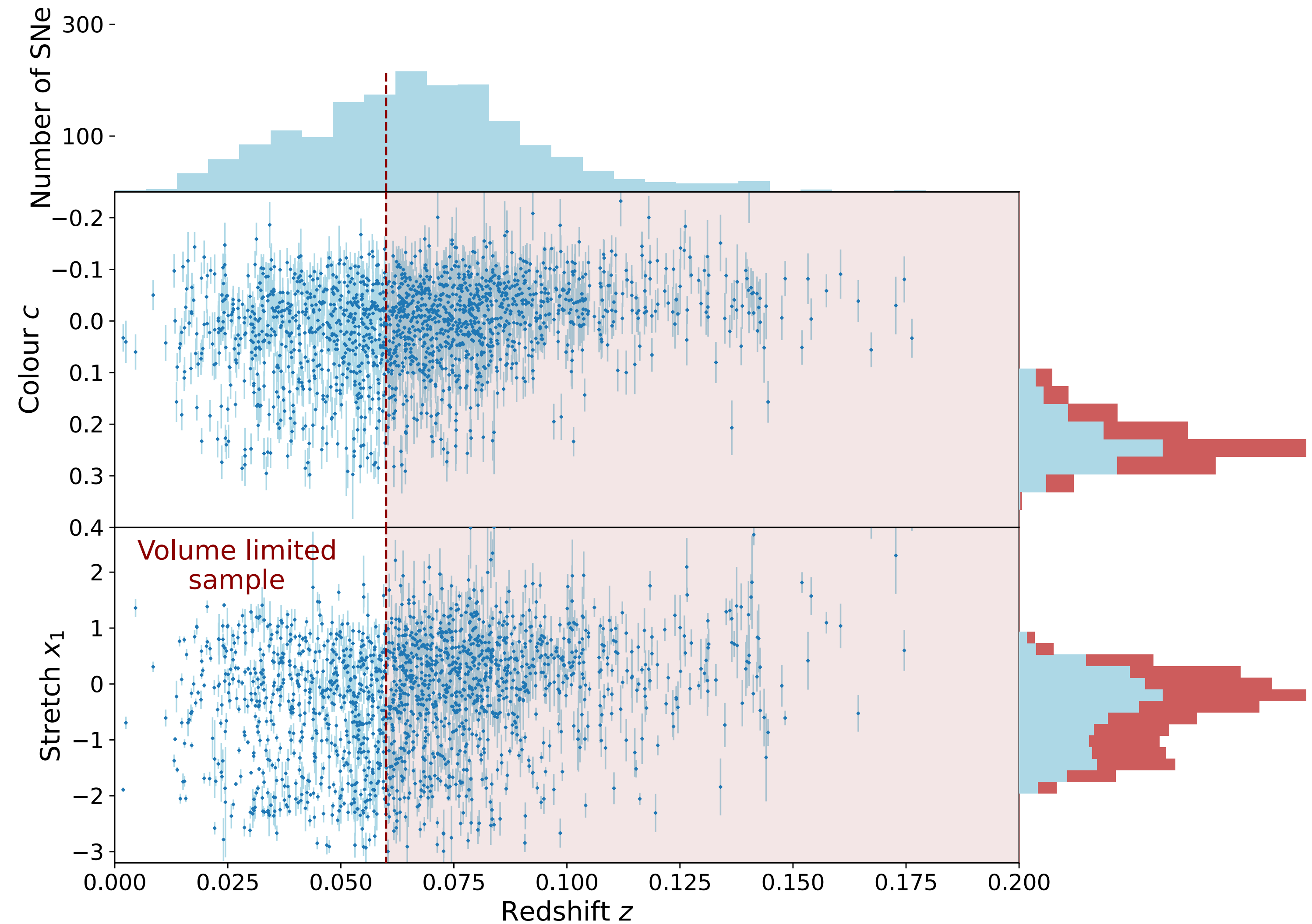
Cosmological SNe Ias



# ZTF DR2

## Volume limited sample

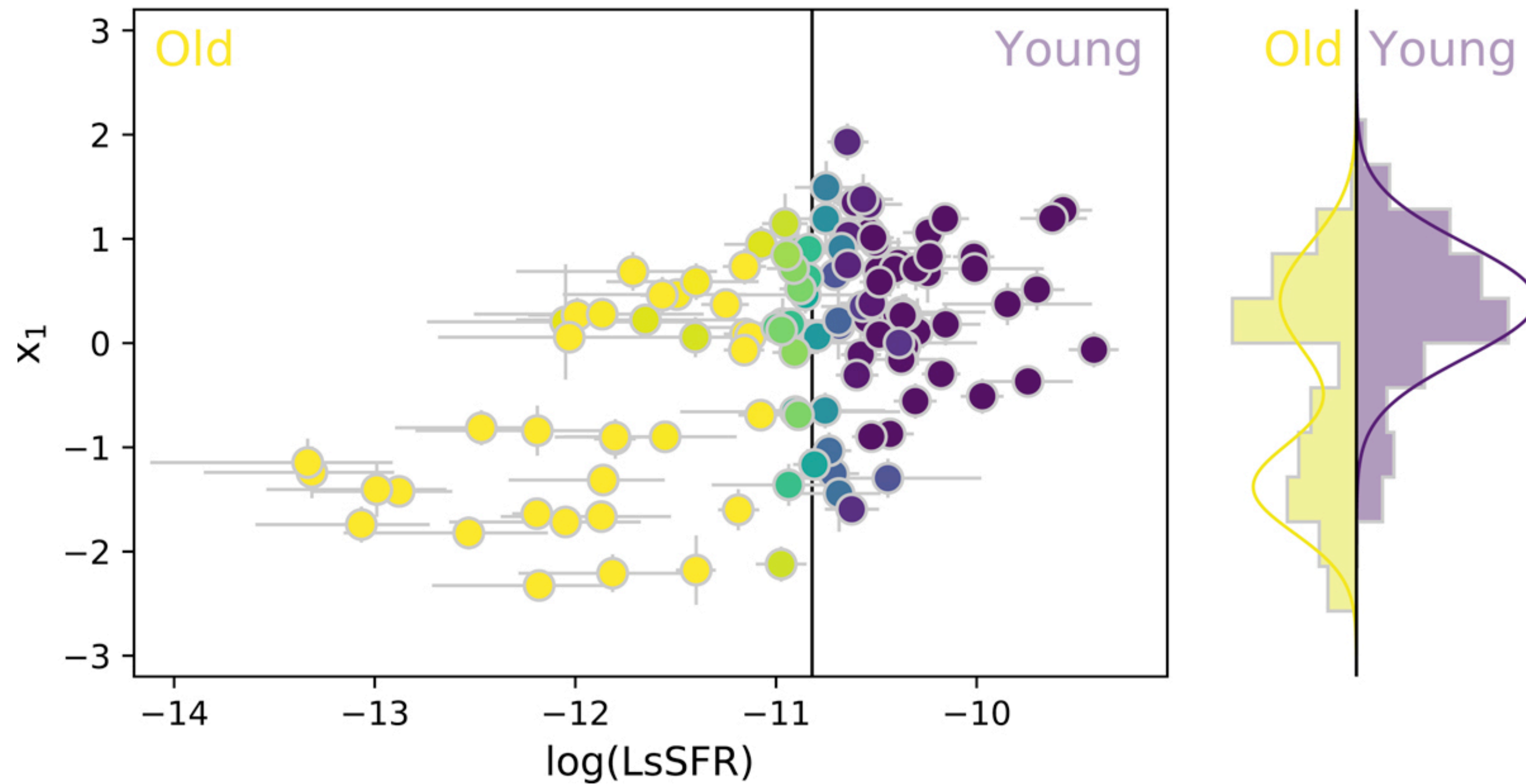
- Redshift cut: no selection effects (see Dylan's talk)
- Additional cuts:
  - $(x_1, x_1^{\text{err}})$
  - $(c, c^{\text{err}})$
  - $t_0^{\text{err}}$
  - Normal SNe Ias
  - SALT fit probability  $\chi_{\text{SALT}}^2$



➔ **889 SNe** in the final sample

# Standardisation

## Stretch distribution

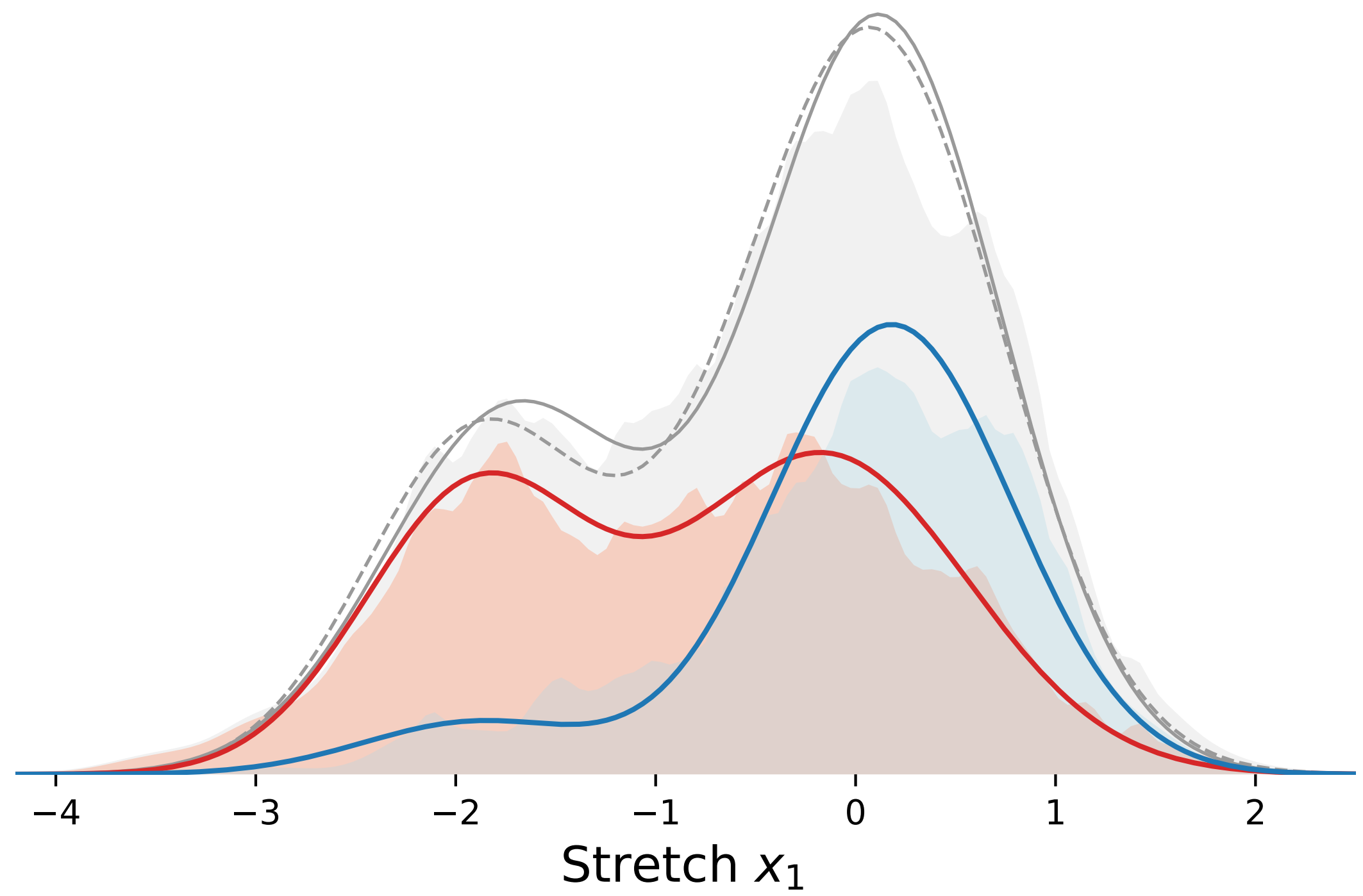
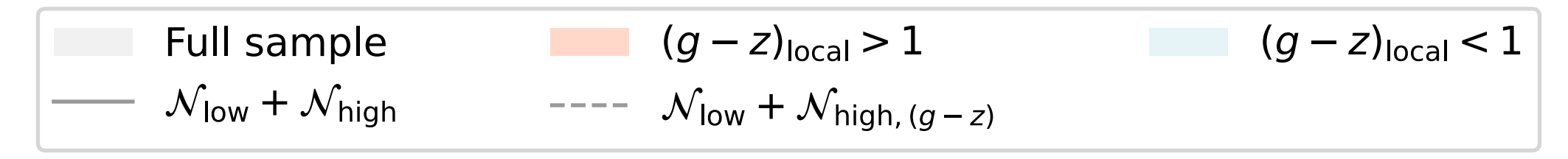
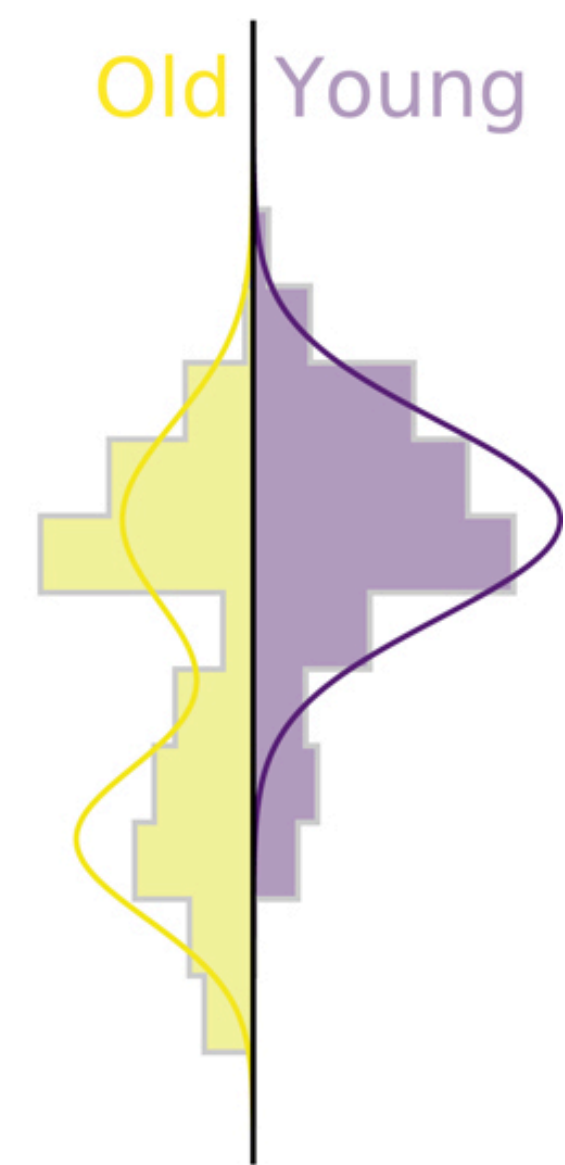
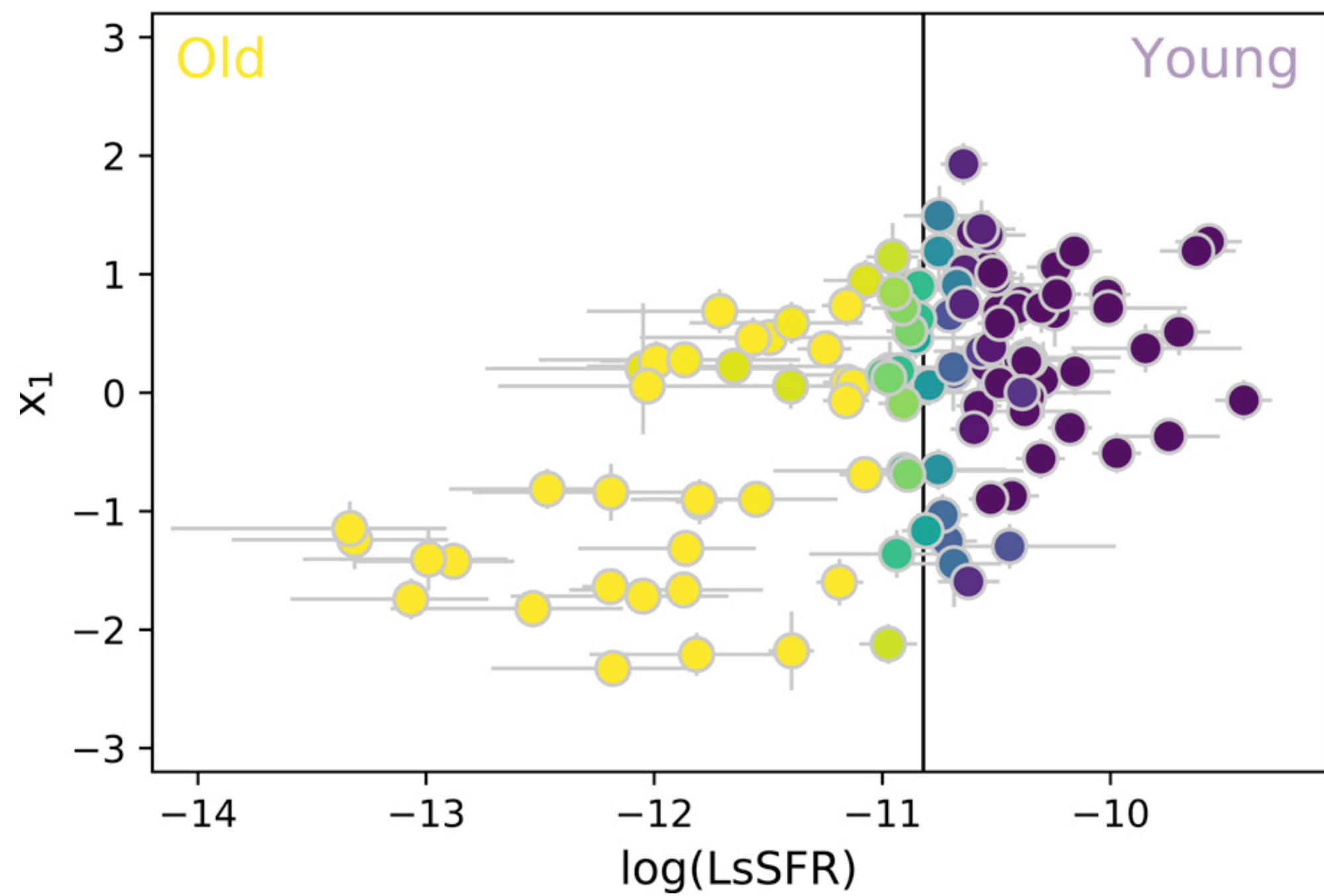


Nicolas et al (2021)  
SNF - 114 SNe



# Standardisation

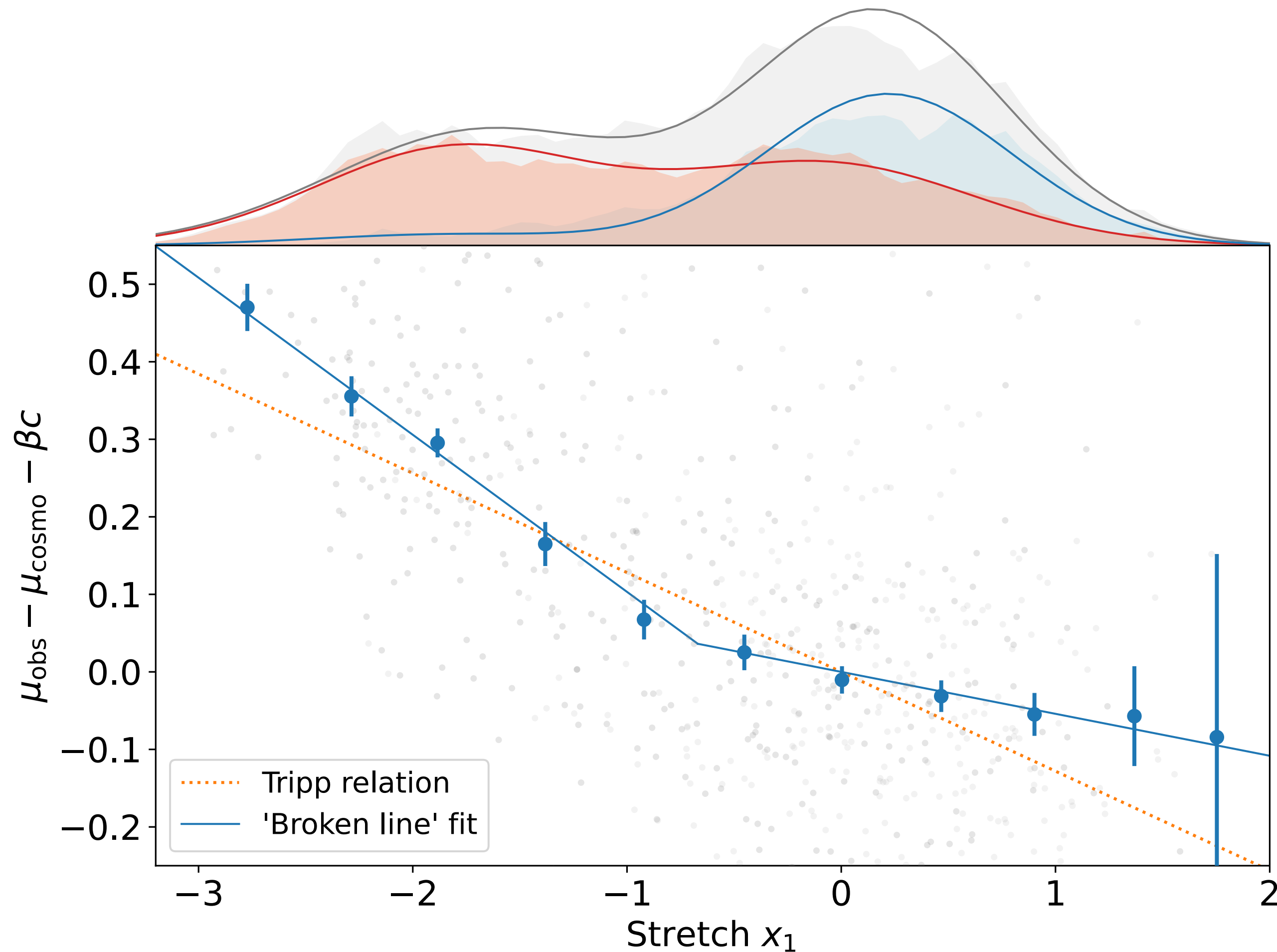
## Stretch distribution



Nicolas et al (2021)  
SNF - 114 SNe

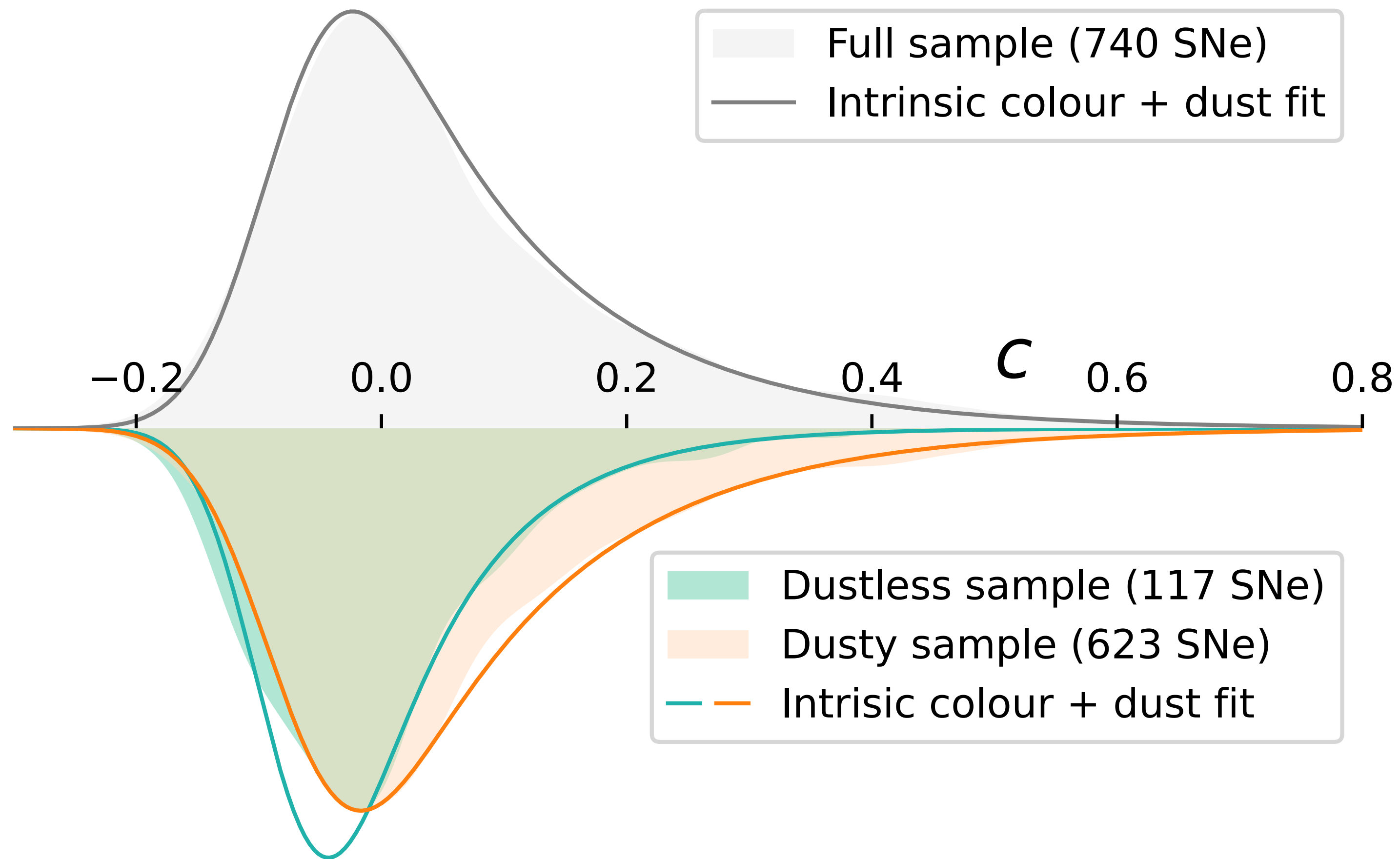
# Standardisation

## Non linearity of the stretch-residuals relation

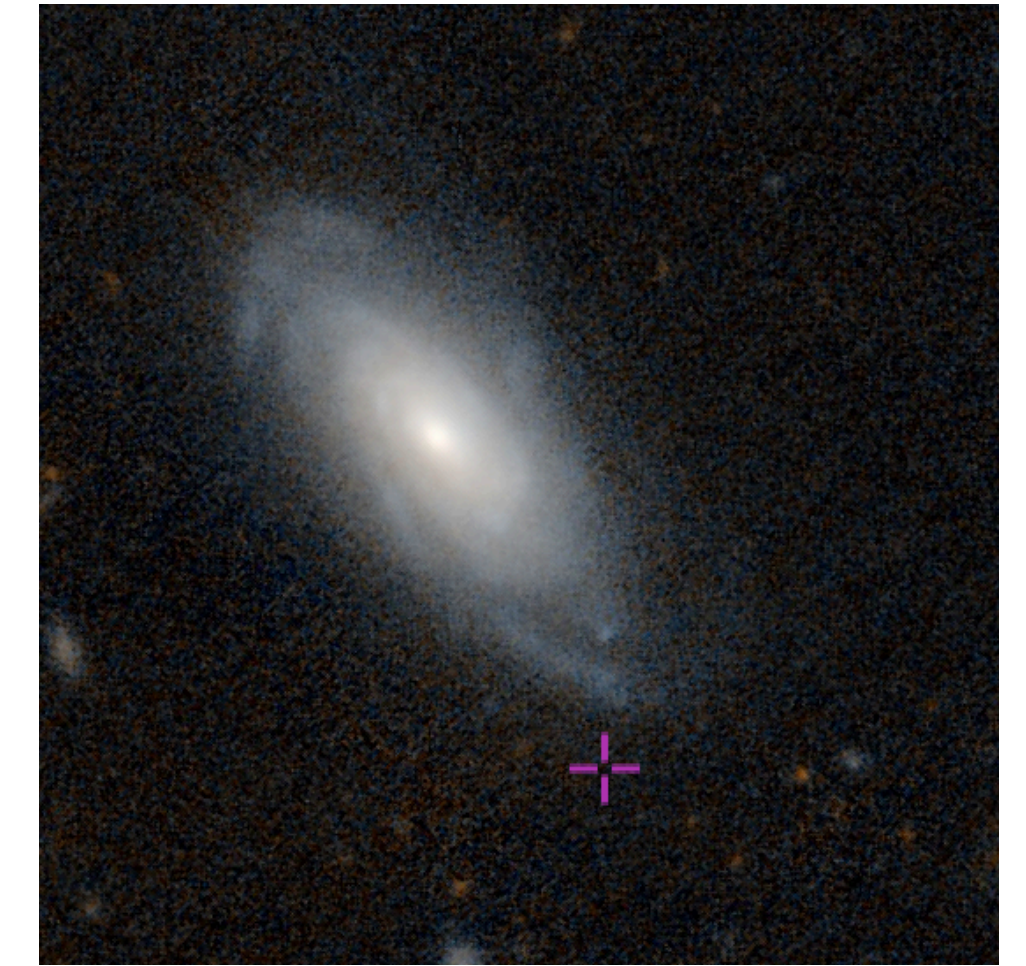


# Standardisation

## Colour distribution

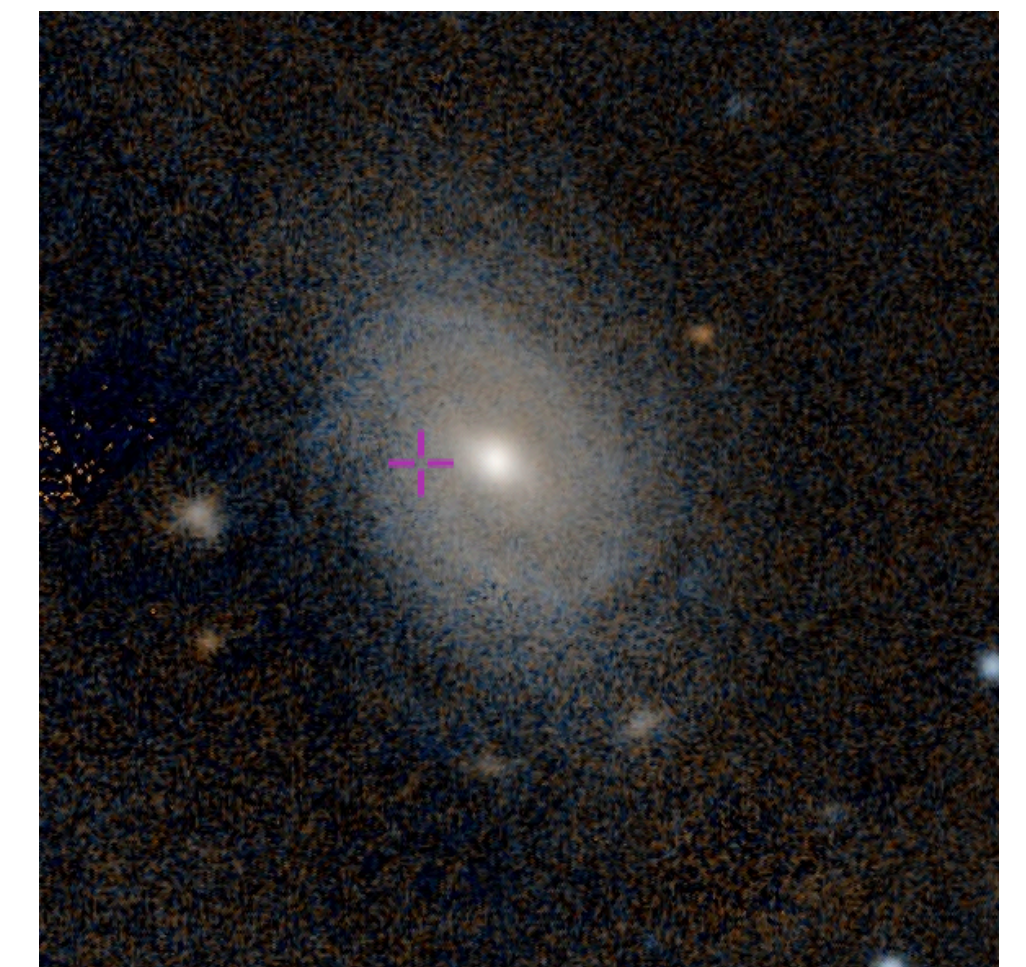


« Dustless » example



ZTF18aahfze

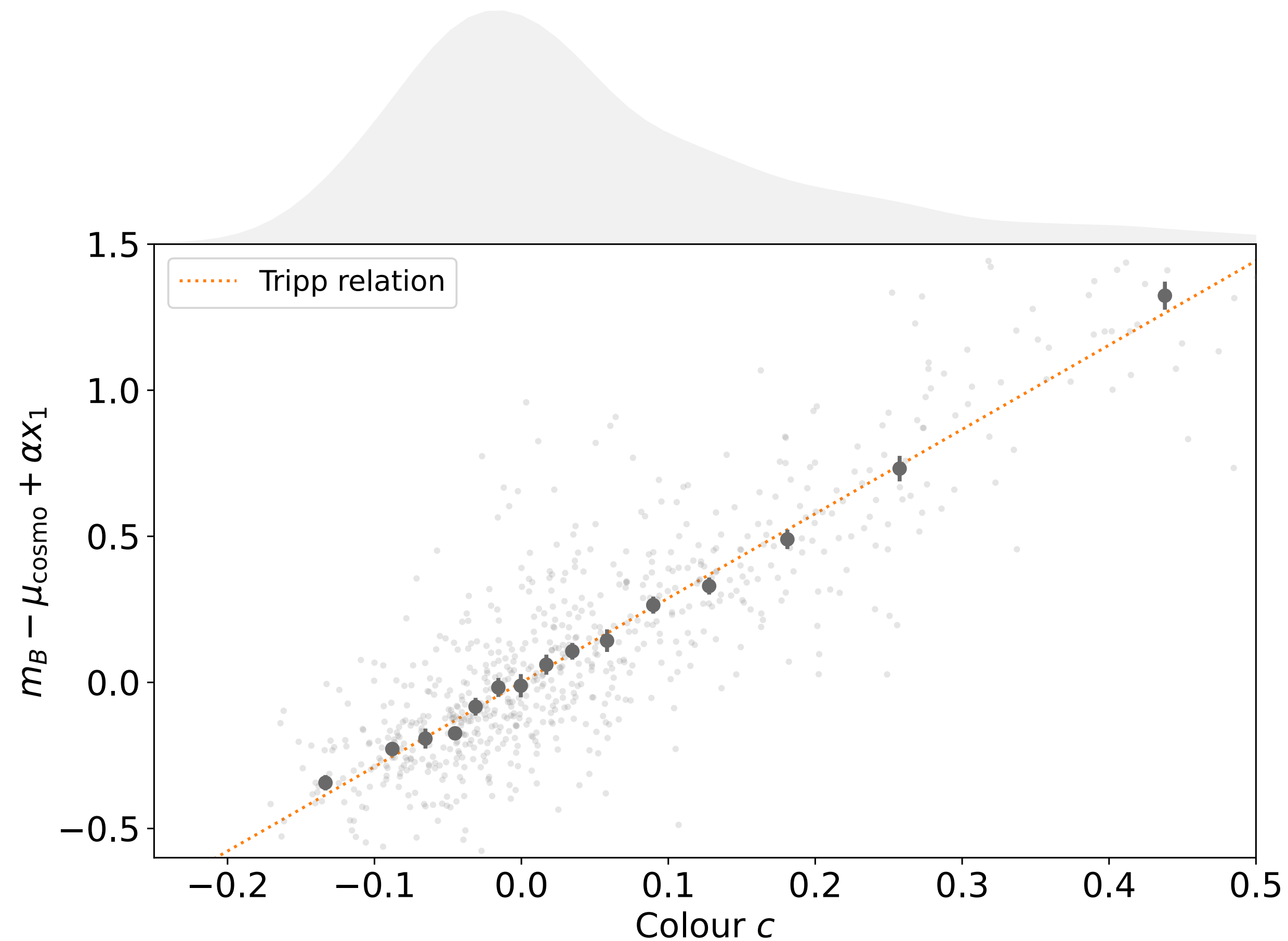
« Dusty » example



ZTF18aaqfziz

# Standardisation

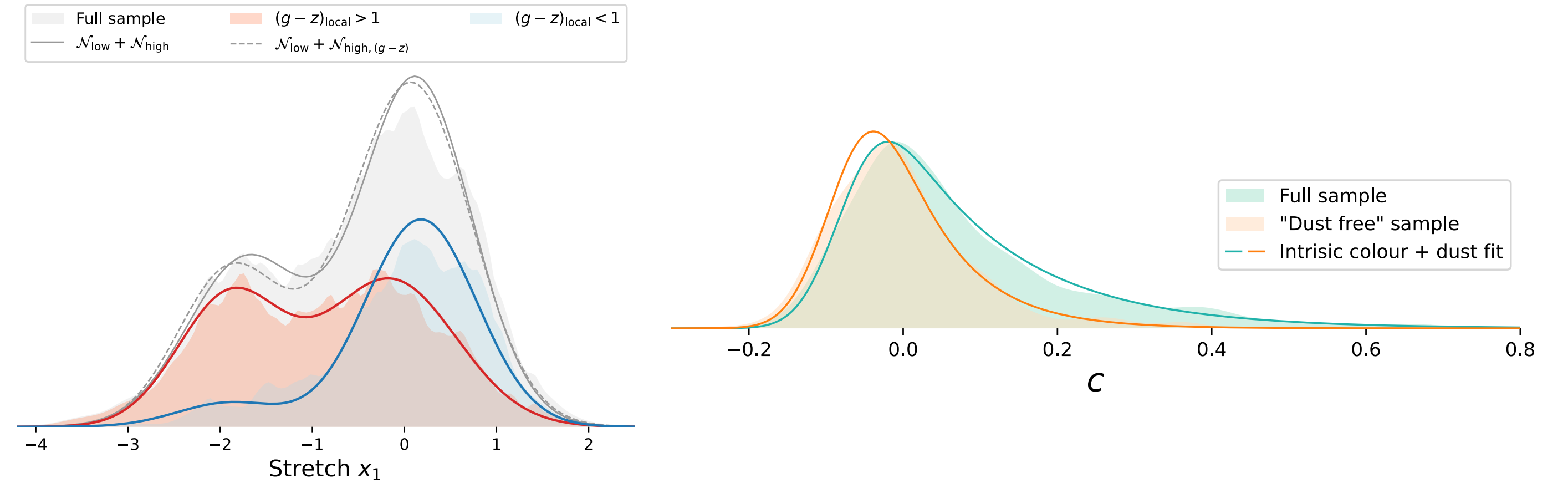
## Linearity of the colour-residuals relation



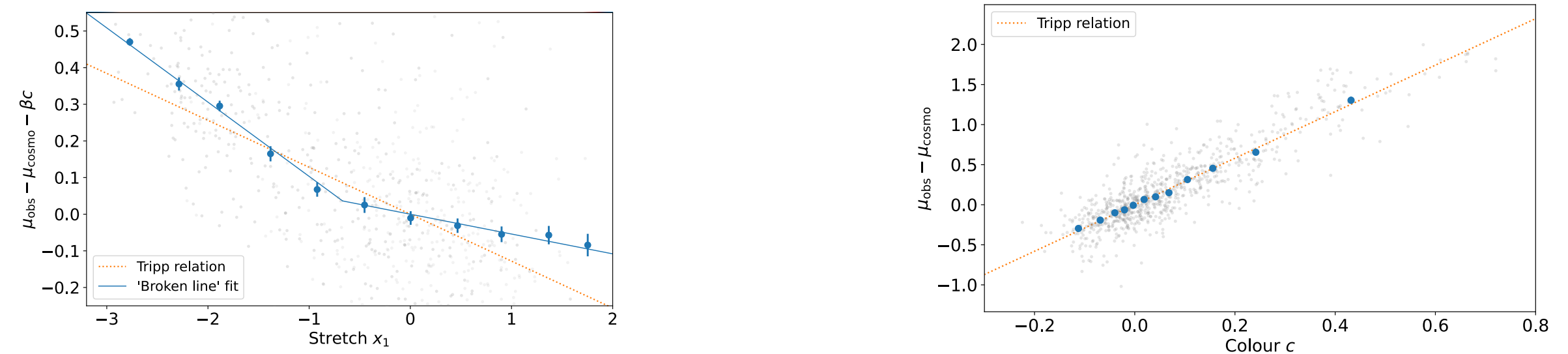
# Conclusion

ZTF DR2

## Supernovae physical properties



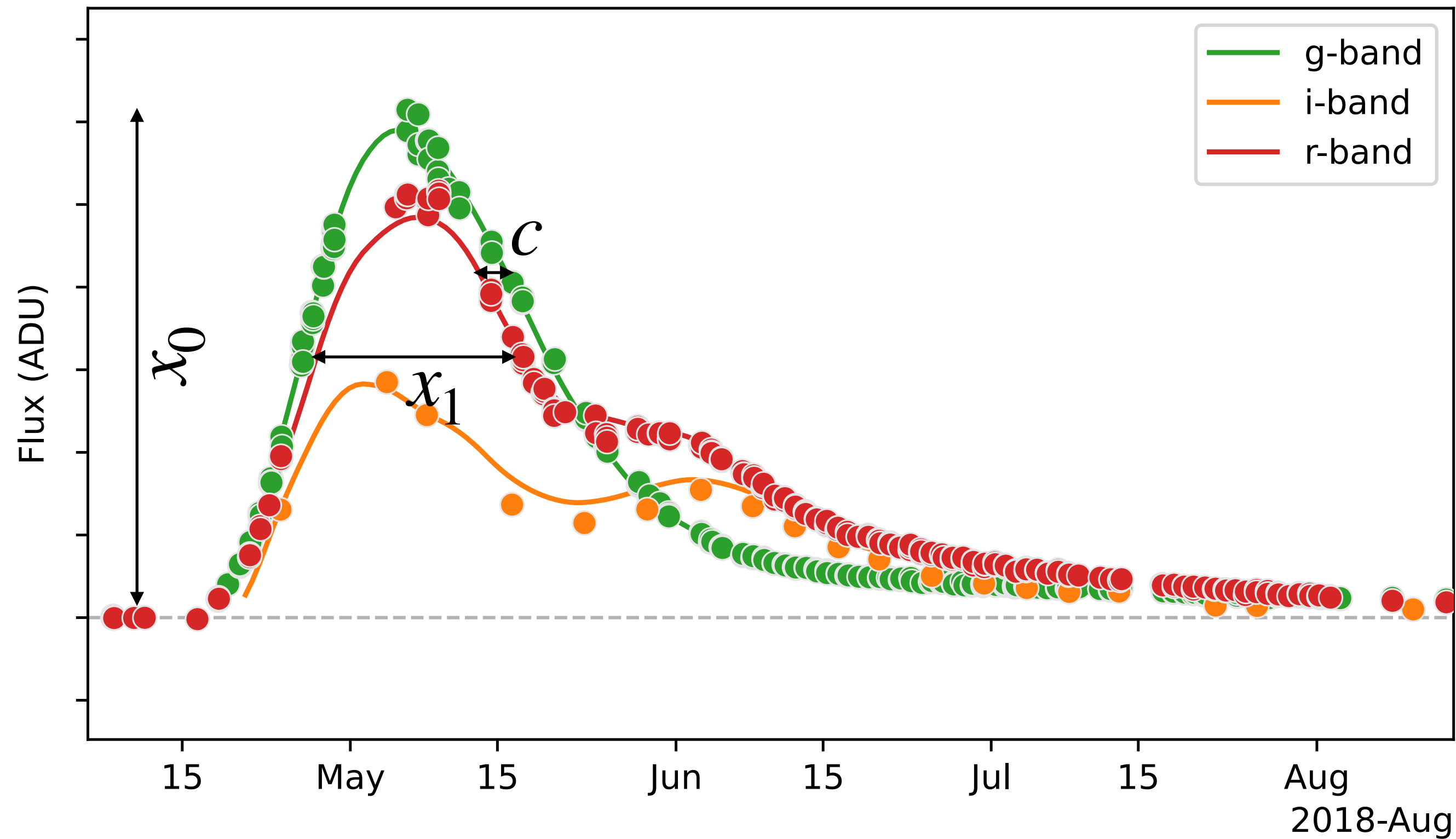
## Standardisation dependency on environment



# Backup

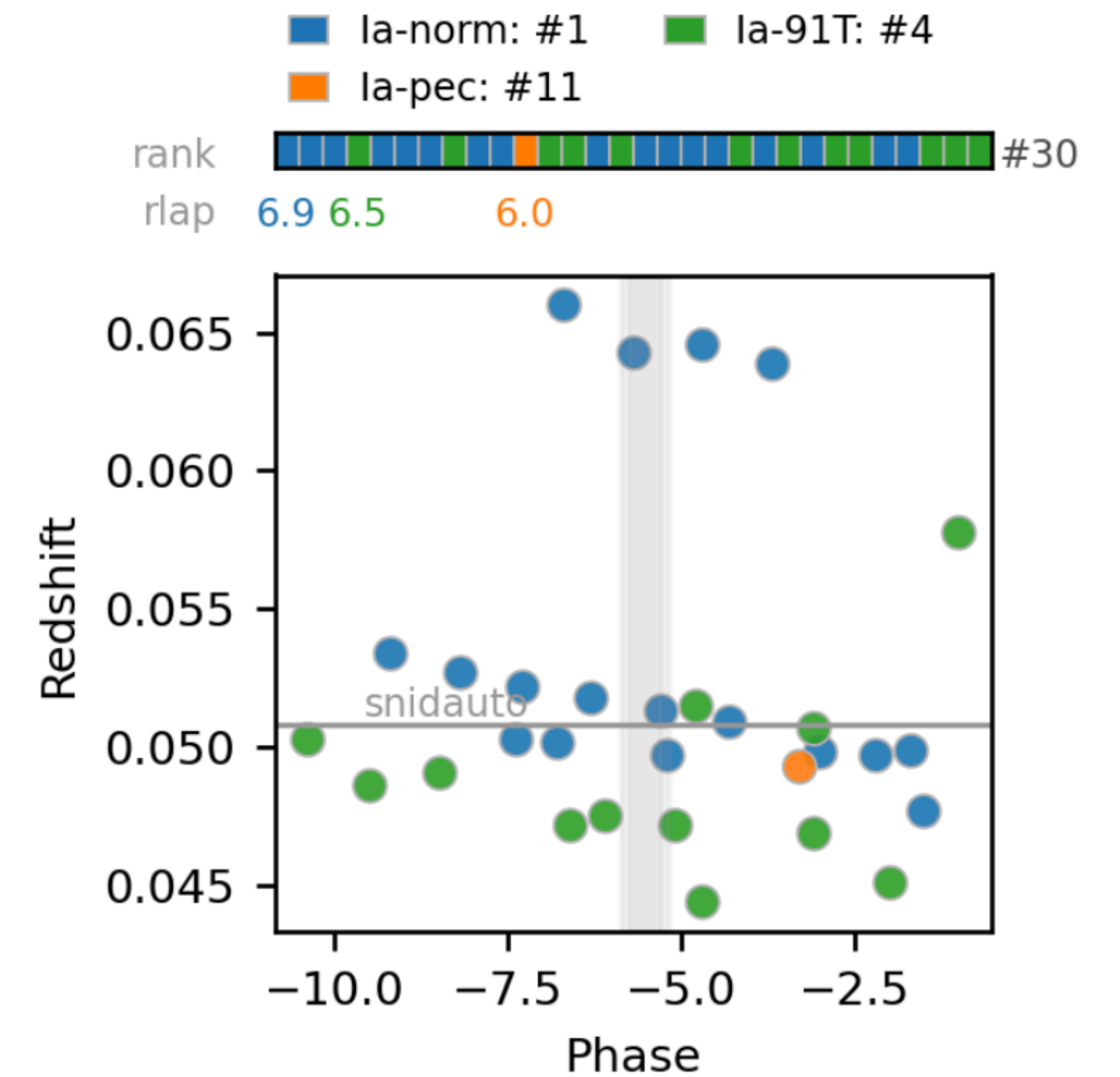
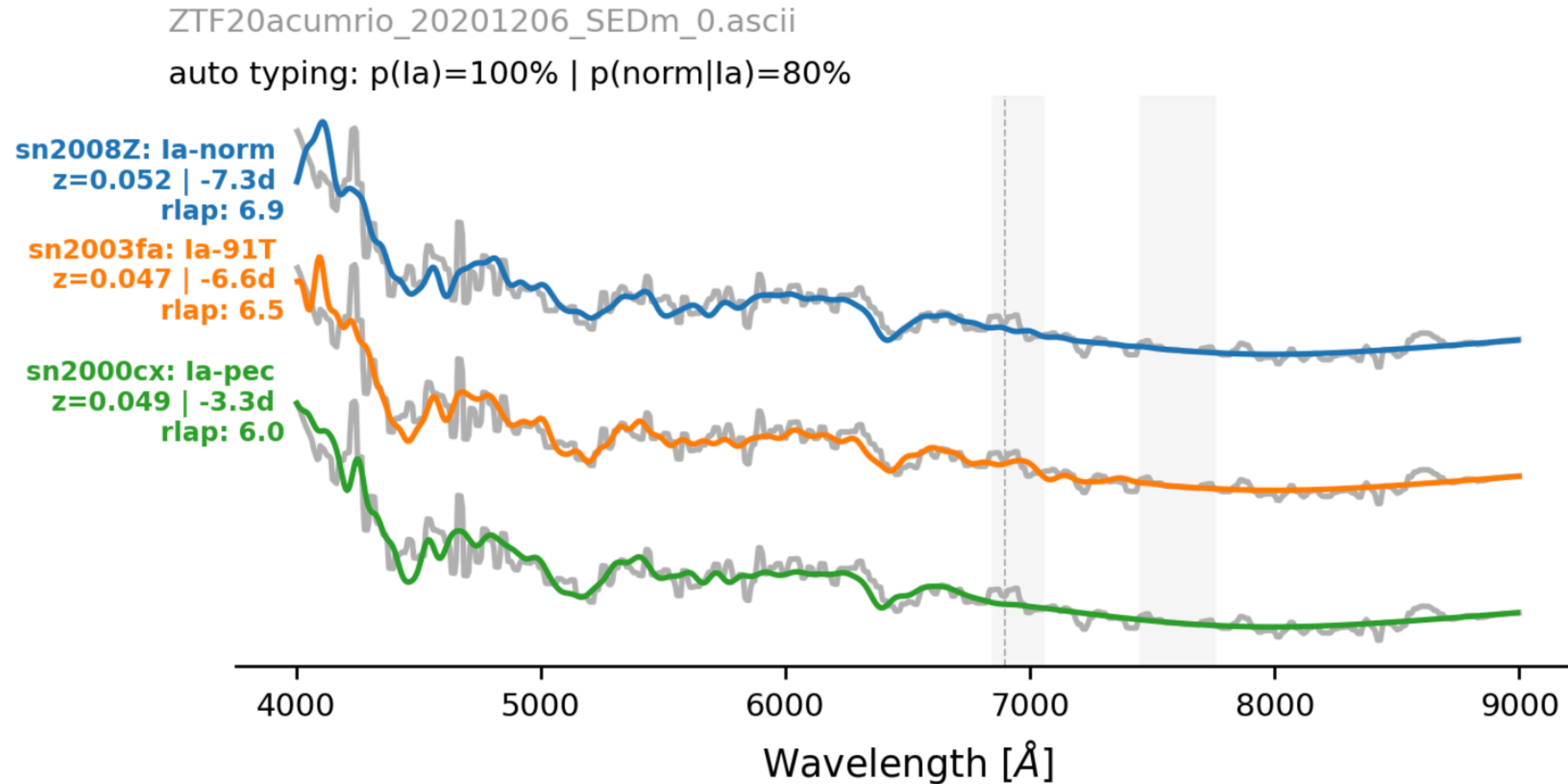
# SALT2 (Guy et al 2007)

Functional form describing the flux:  $F(SN, p, \lambda) = x_0 [M_0(p, \lambda) + x_1 M_1(p, \lambda)] \exp(c CL(\lambda))$



- Parameters relative to the SN
- Parameters relative to the observation

# SNID (Blondin & Tonry 2007)



Credits: Typing App