Cosmology with Type Ia Supernovae and the ZTF survey

Supervisor: Mickaël Rigault - COSMOS team

Madeleine GINOLIN - 18th April 2024

Outline

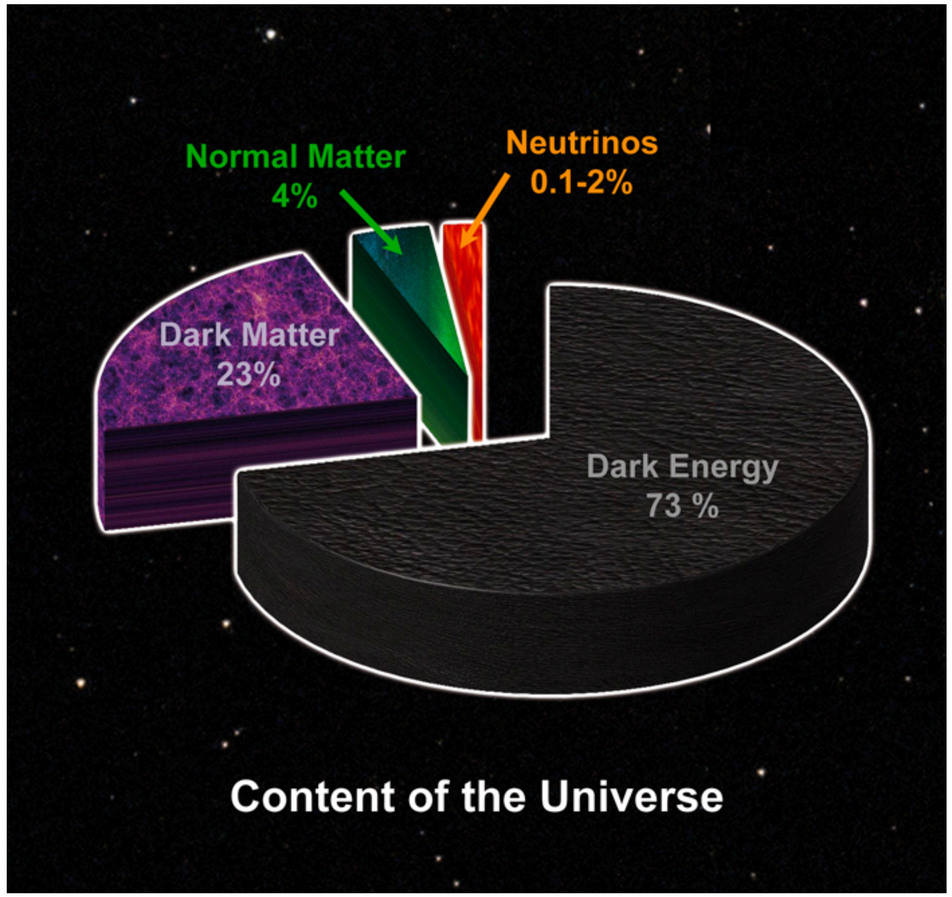
I. Cosmology

II. ZTF

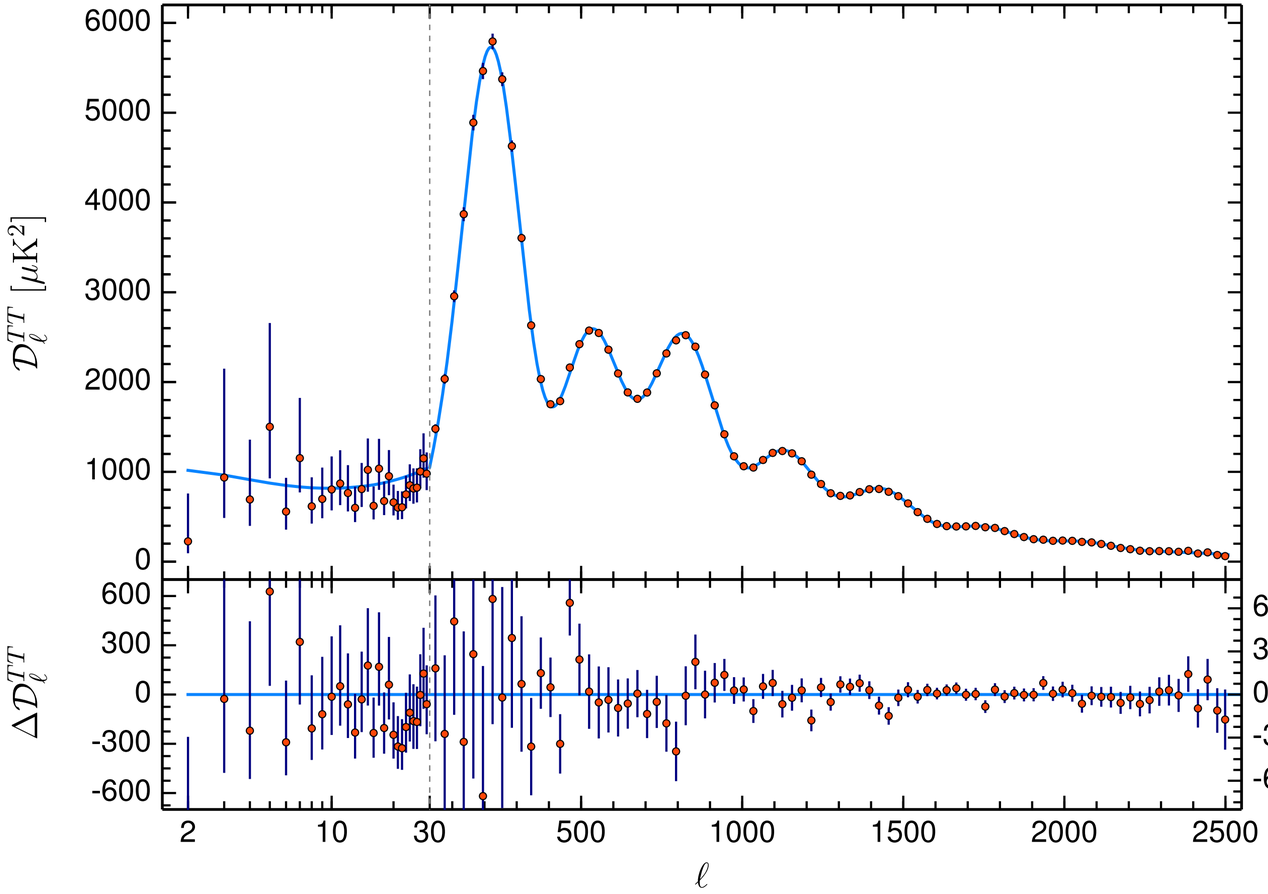
III. What I do in ZTF

Cosmology

ΛCDM model



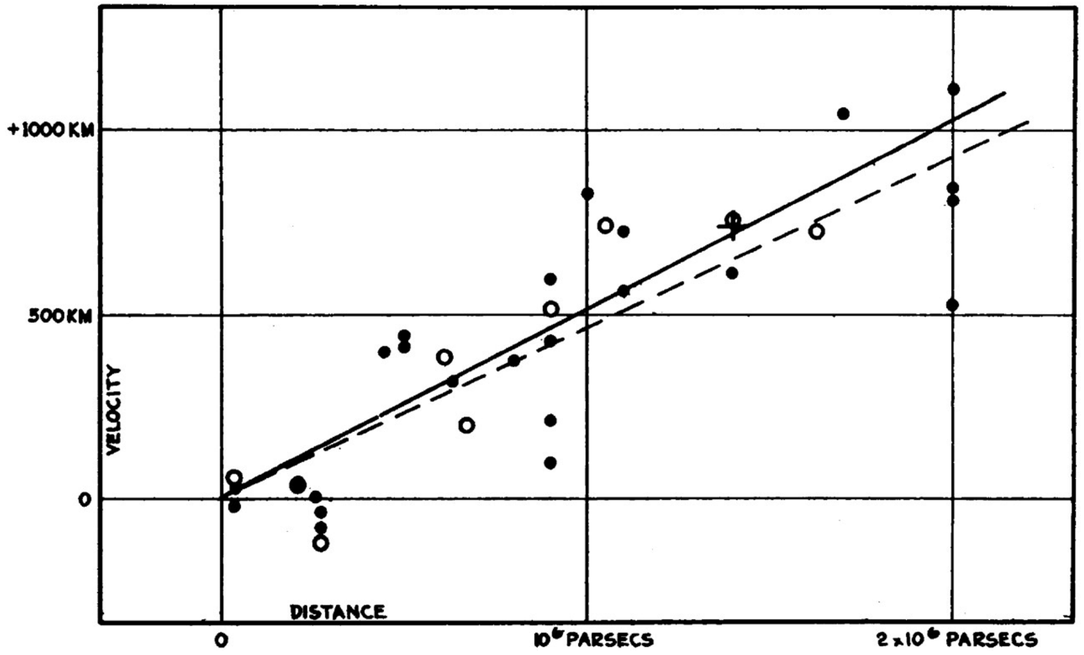
Credits: HAP / A. Chantelauze



Planck 2018

Cosmology

Hubble-Lemaître constant

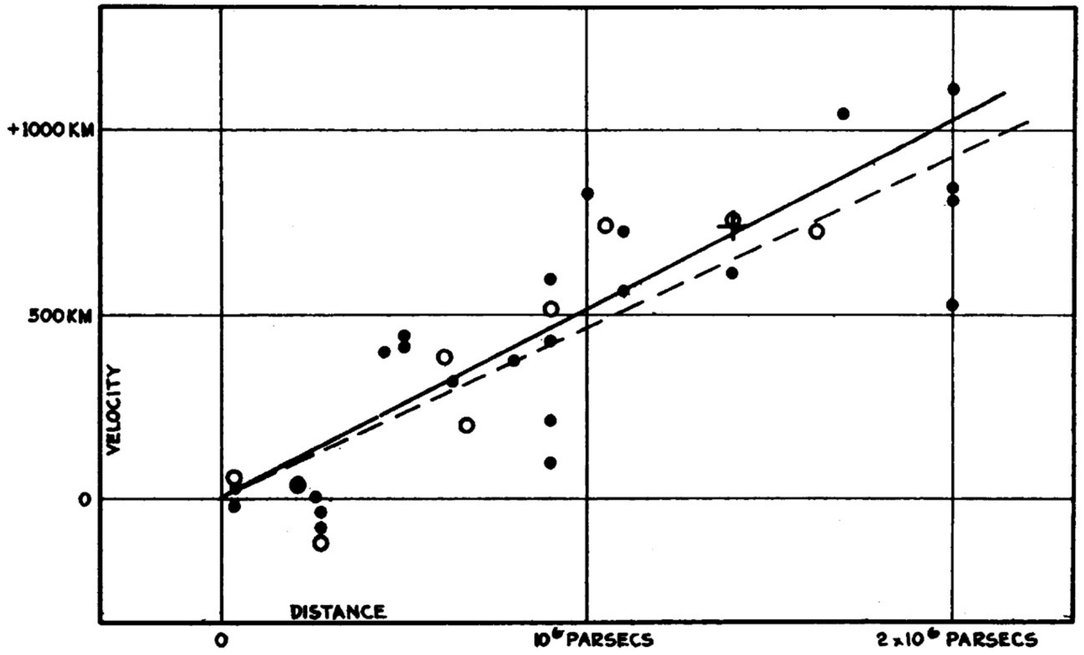


Hubble (1929)

Cosmology

Hubble-Lemaître constant

$$v = H_0 D \approx cz$$



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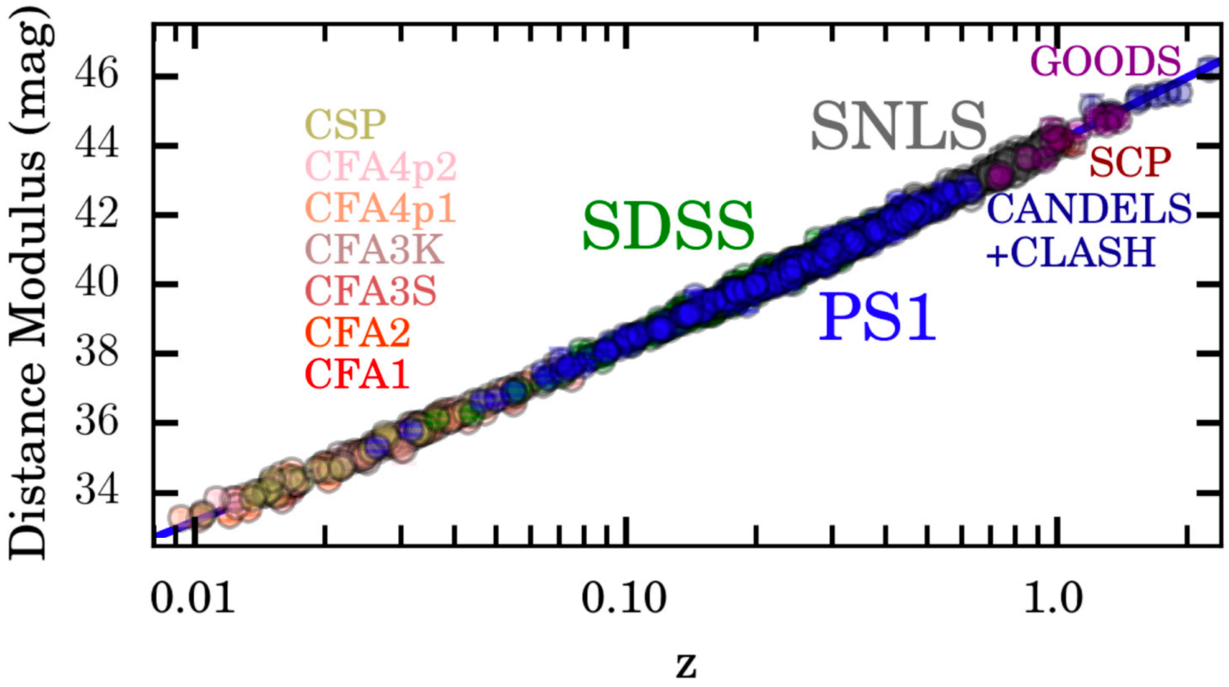


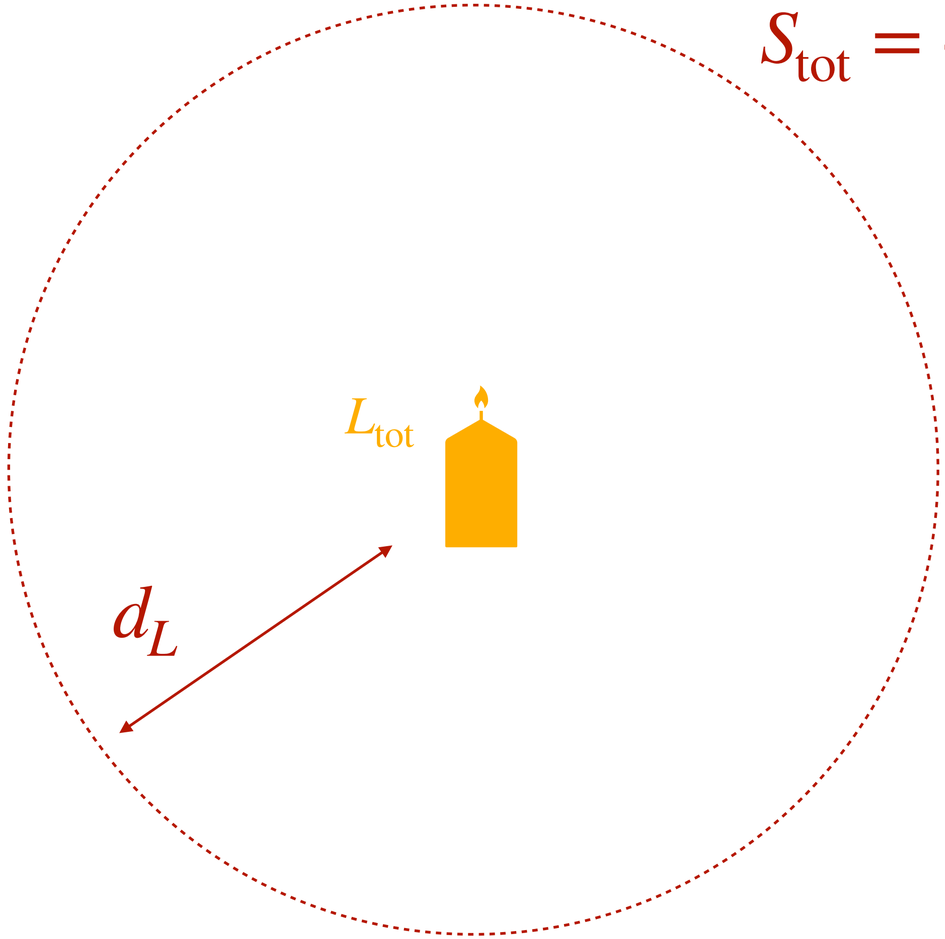
Scolnic et al (2018)

Cosmology
Standard candle

Cosmology

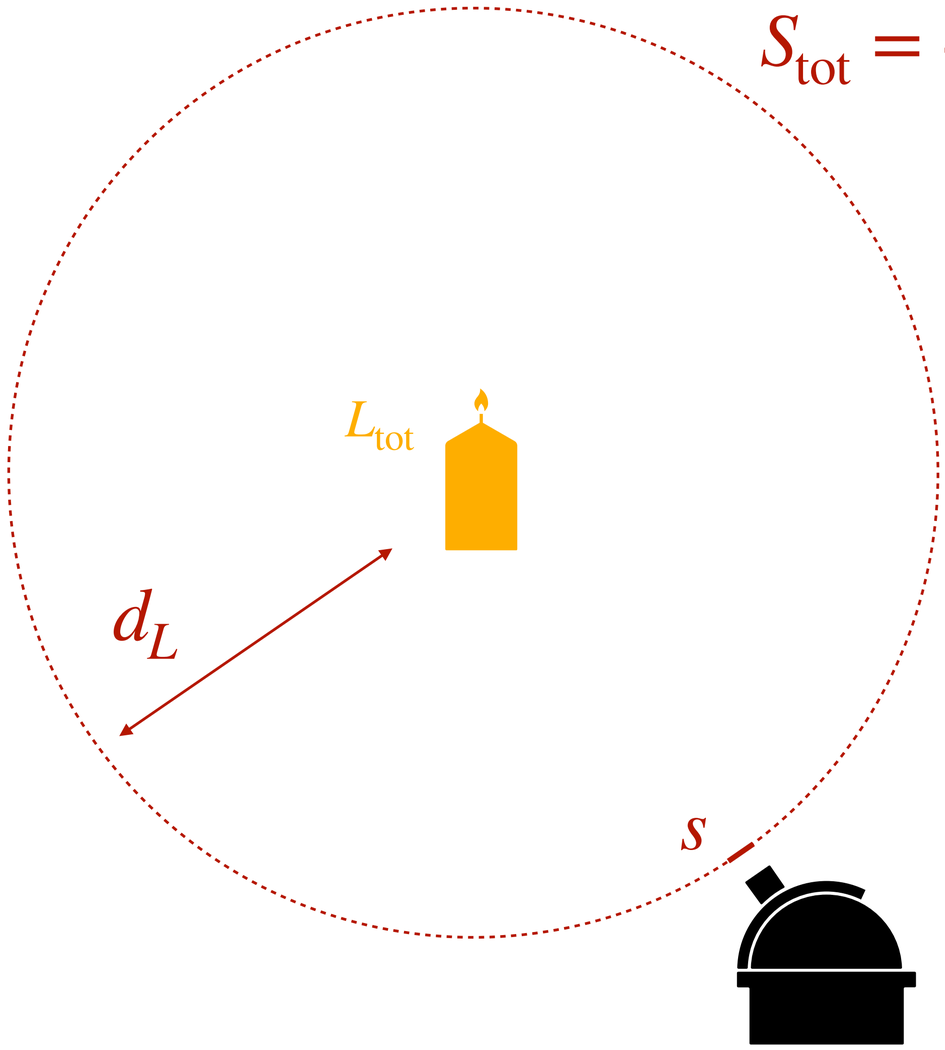
Standard candle

$$S_{\text{tot}} = 4\pi d_L^2$$



Cosmology

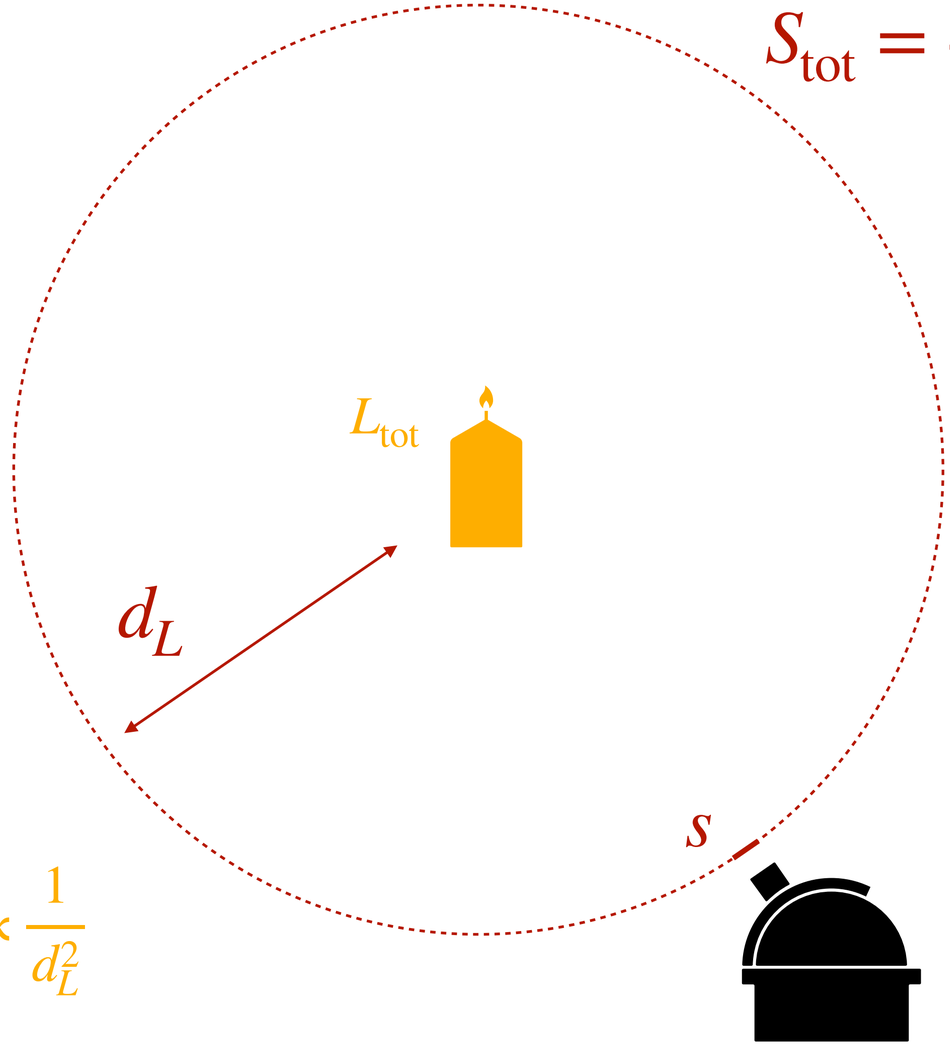
Standard candle



Cosmology

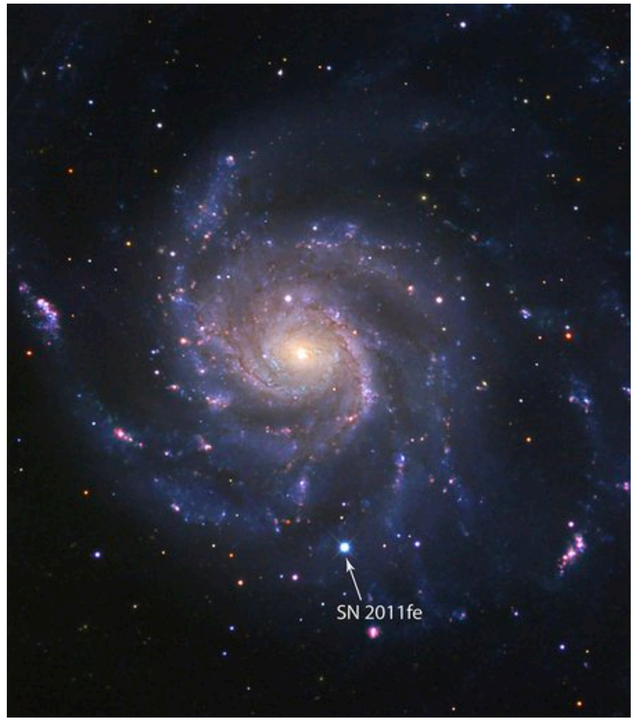
Standard candle

$$S_{\text{tot}} = 4\pi d_L^2$$

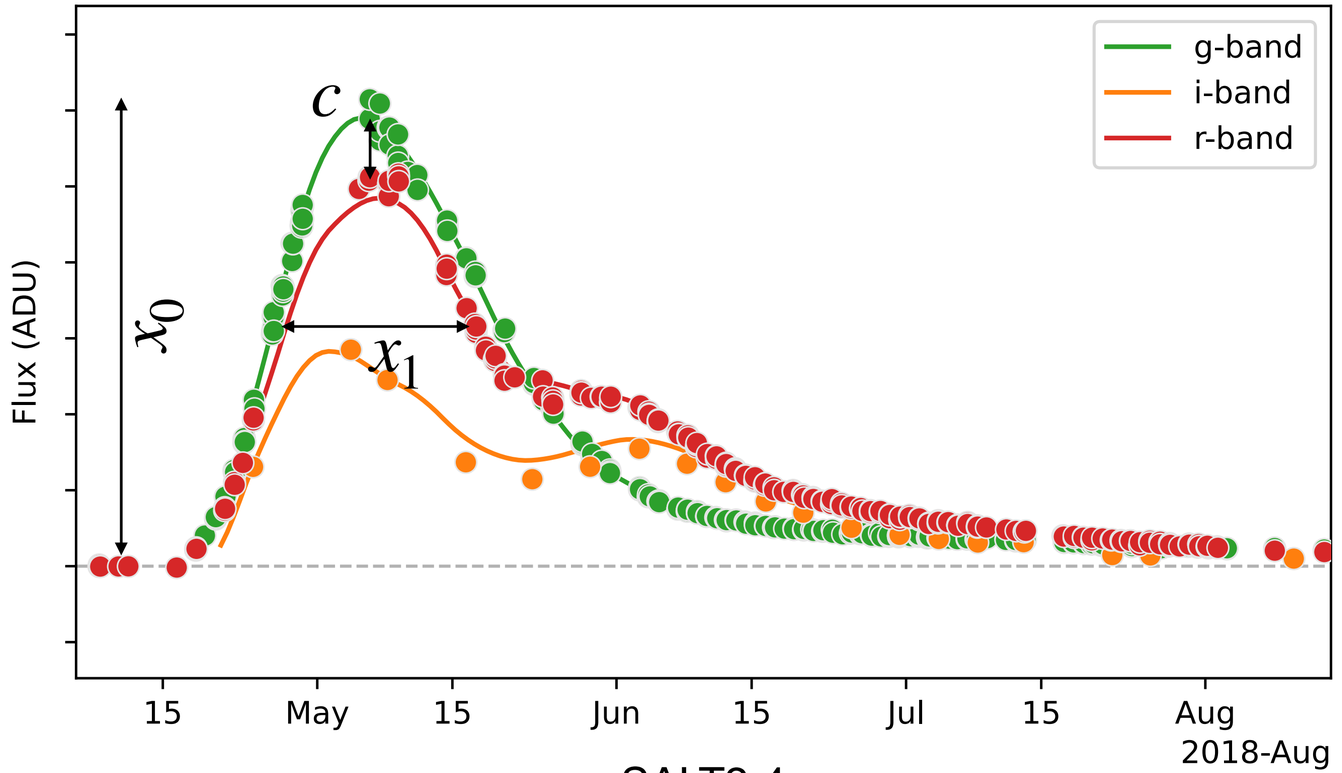


$$L_{\text{measured}} = L_{\text{tot}} \frac{s}{S_{\text{tot}}} \propto \frac{1}{d_L^2}$$

Supernovae



Credits: B.J. Fulton/
LCOGT/Caltech



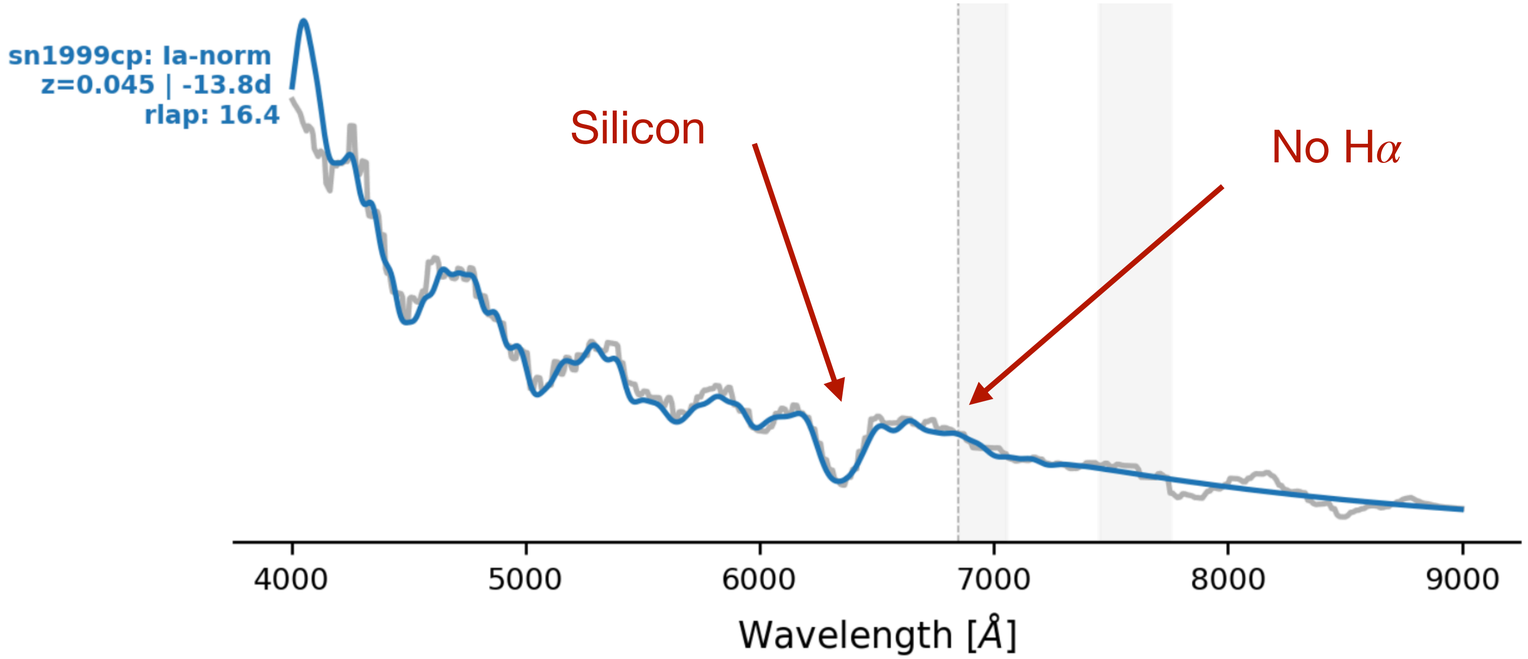
SALT2.4
(Guy et al 2007)

x_0

x_1

c

Type Ia Supernovae



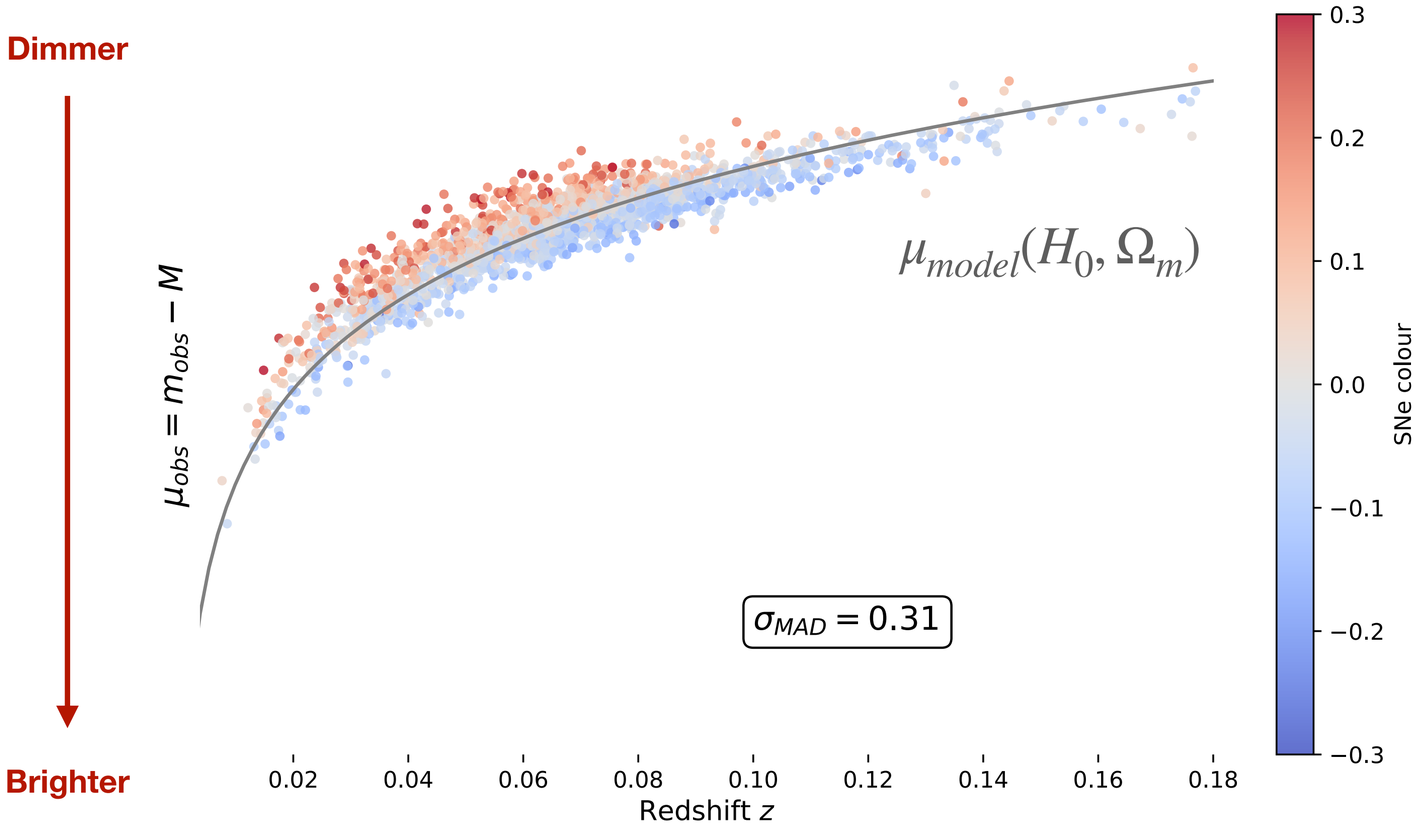
Typing

z

SNID
(Blondin & Tonry 2007)

Cosmology with SNe

Supernovae standardisation



Cosmology with SNe

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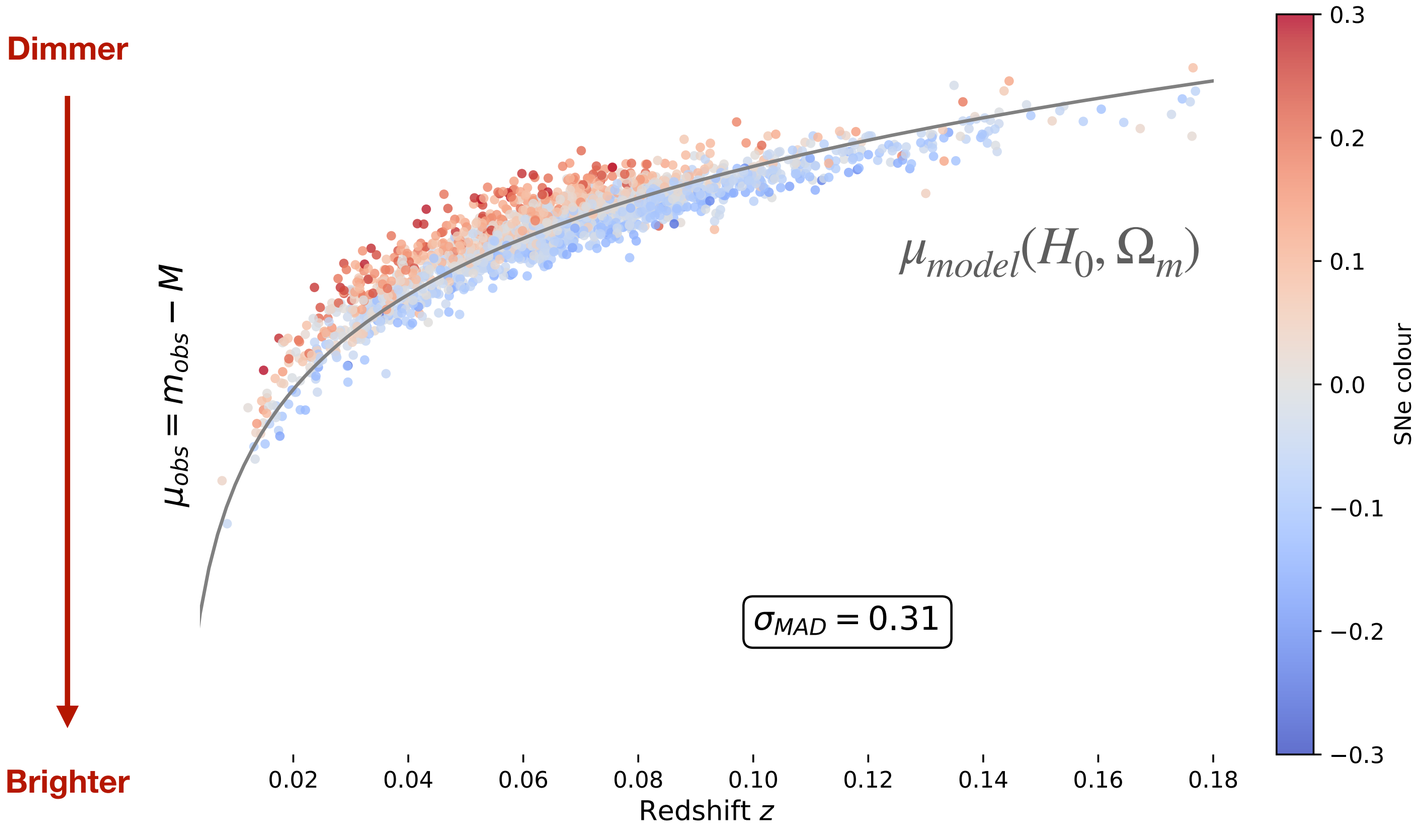

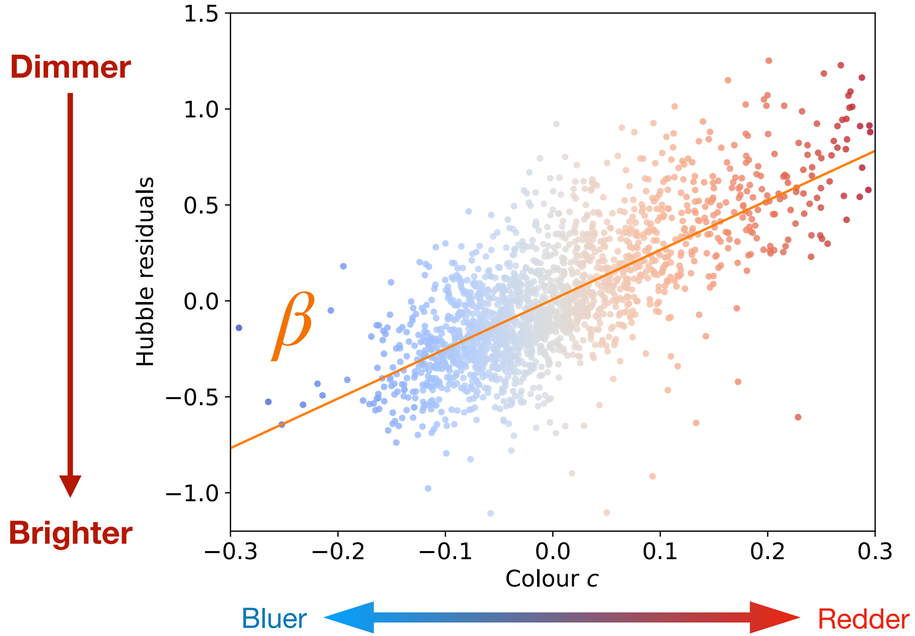

Cosmology with SNe

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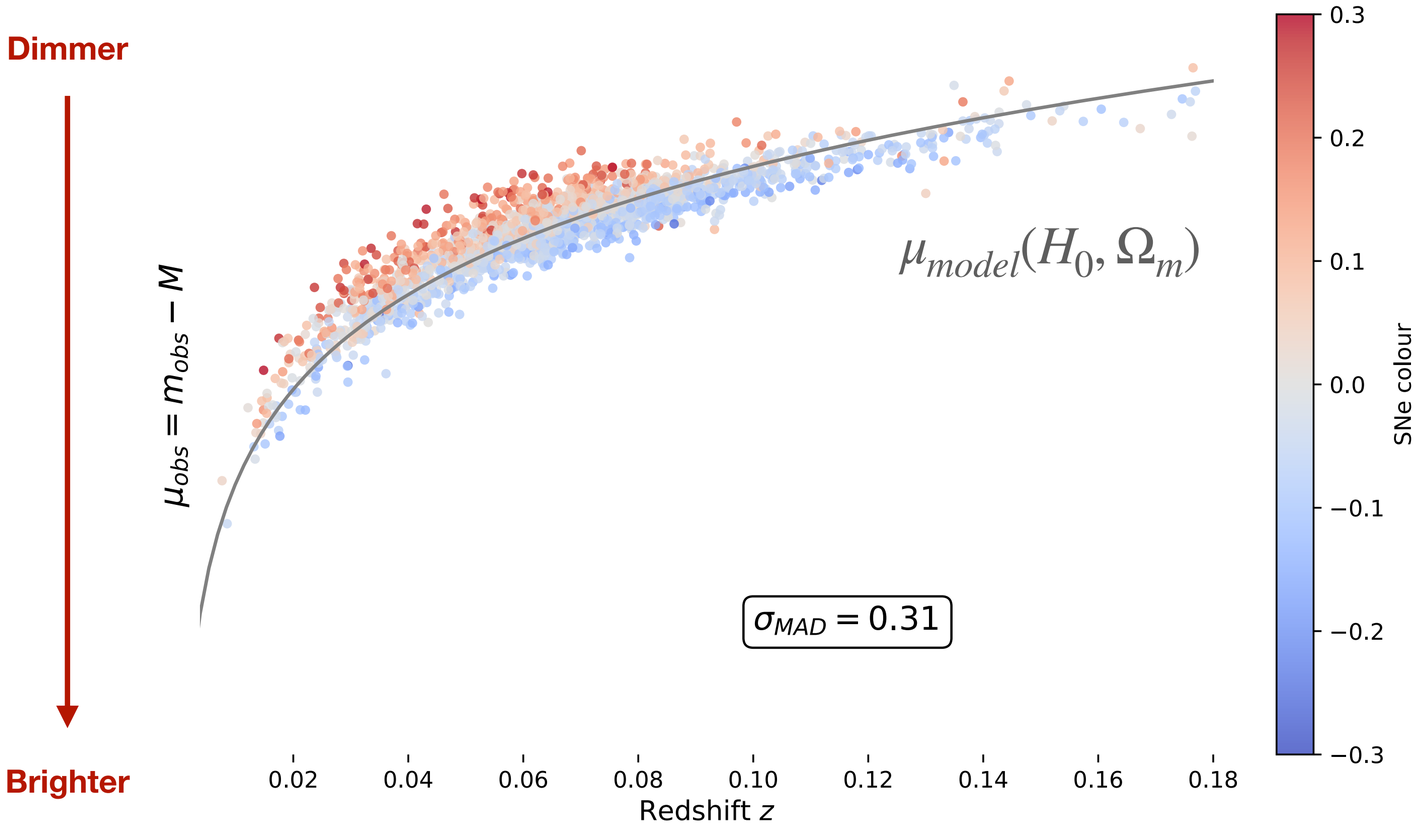
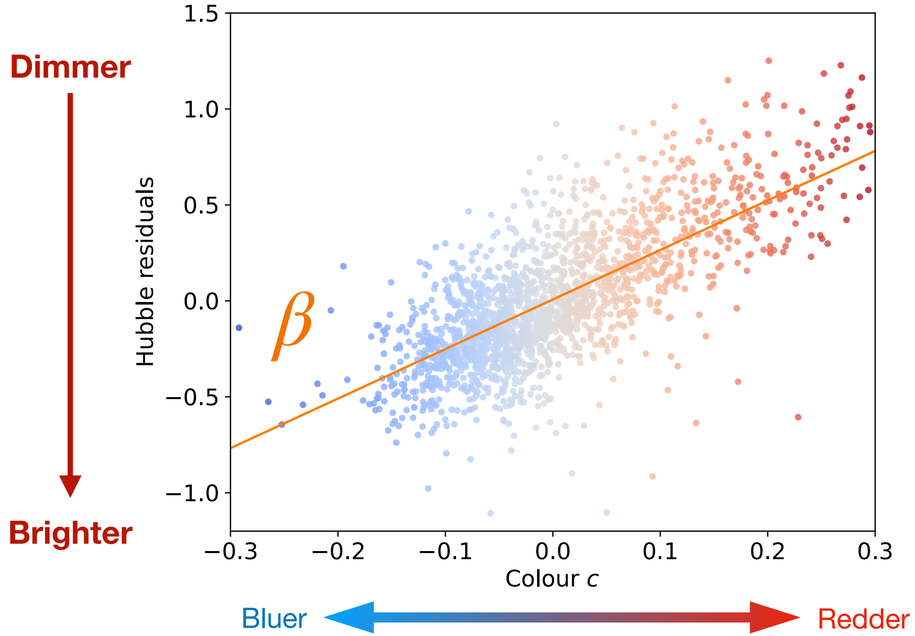
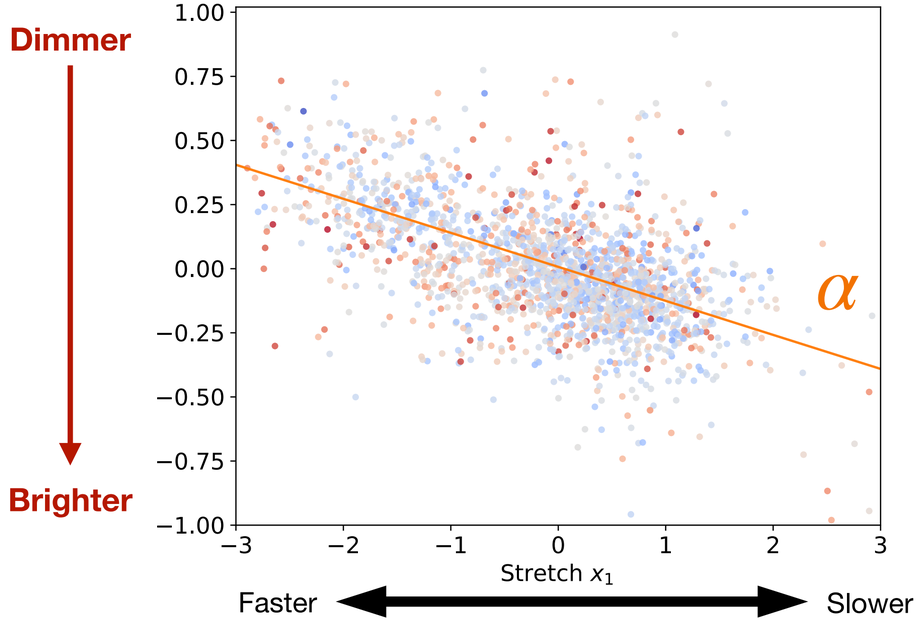


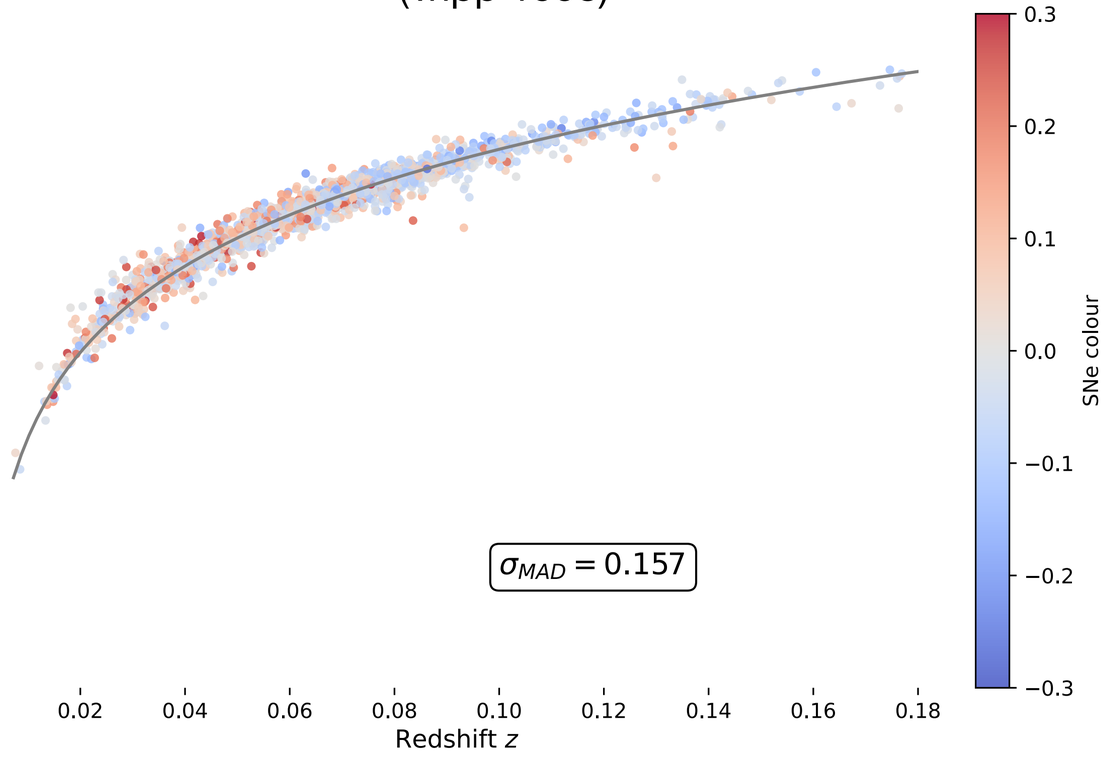




Cosmology with SNe

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

(Tripp 1998)



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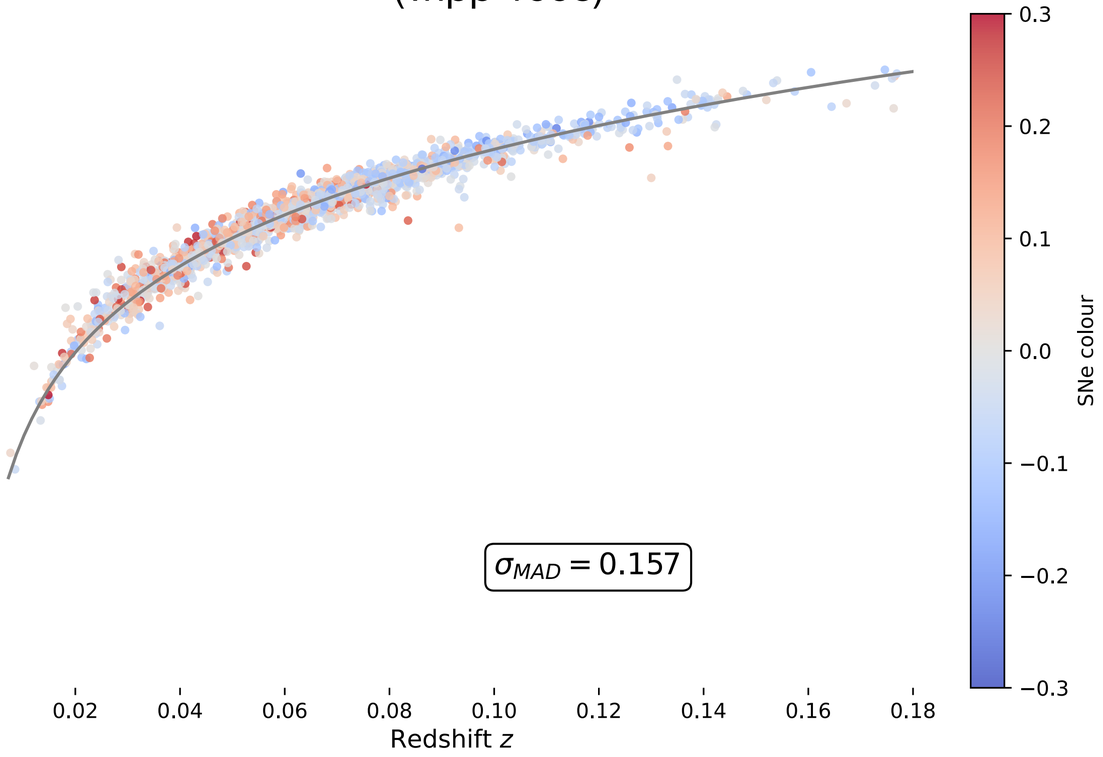
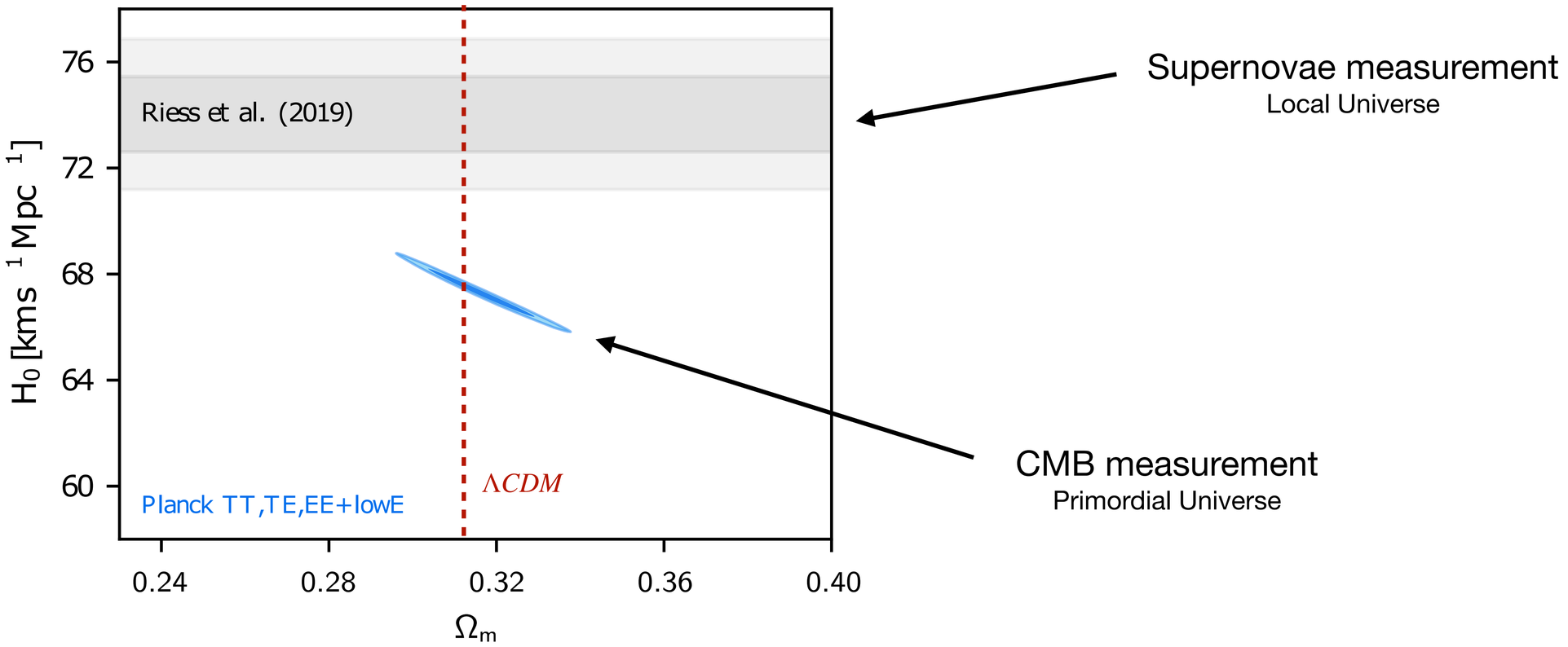


+

Anchoring to Cepheids

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

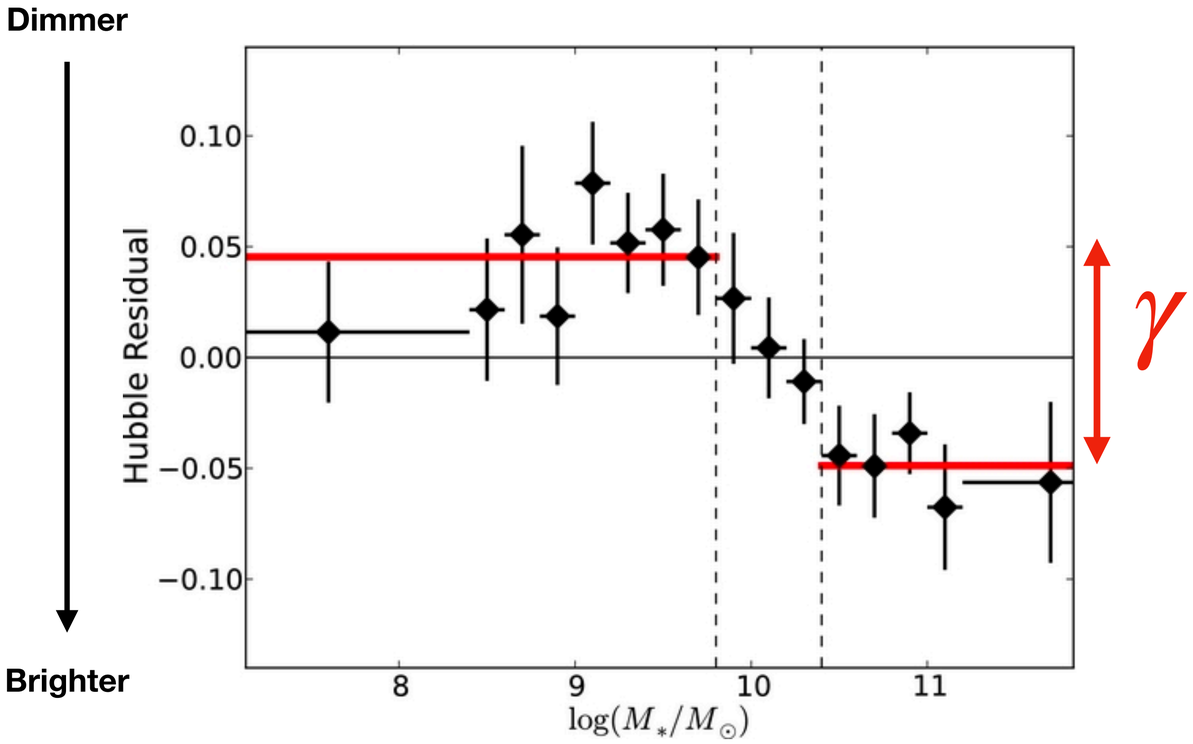
Hubble tension



Adapted from Planck collaboration (2020)

Astrophysical biases

Mass step γ



Childress et al (2013)

Astrophysical biases

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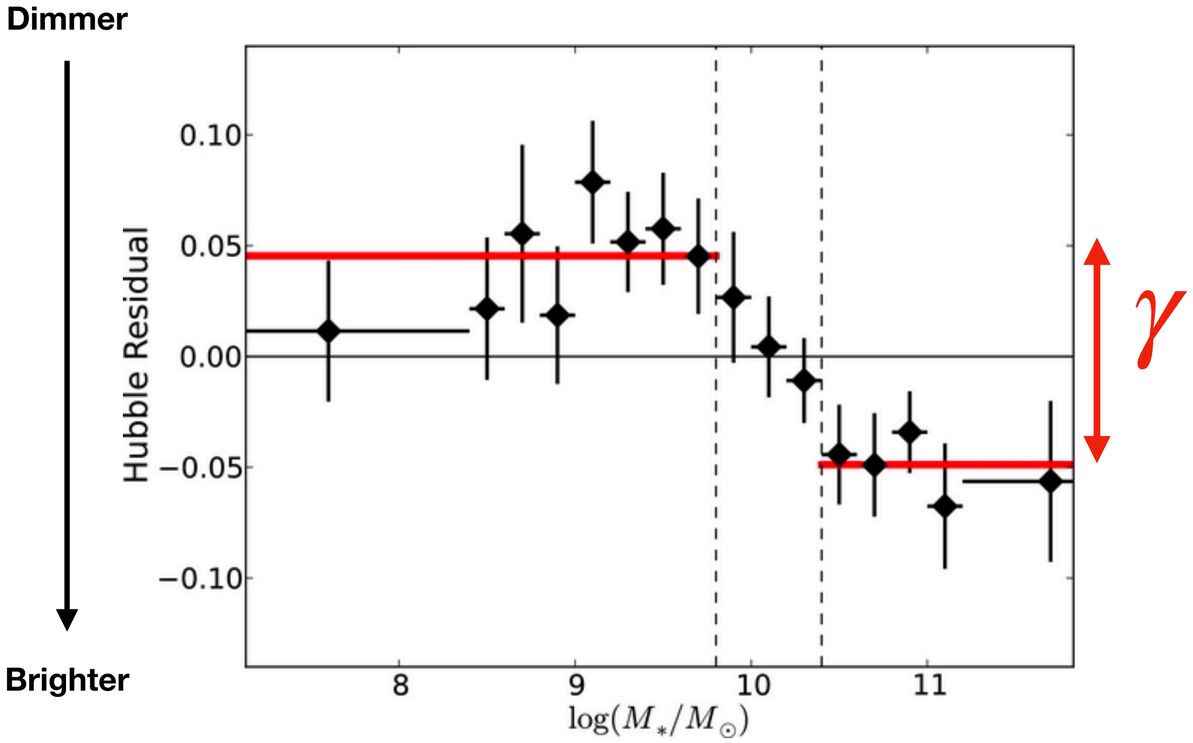
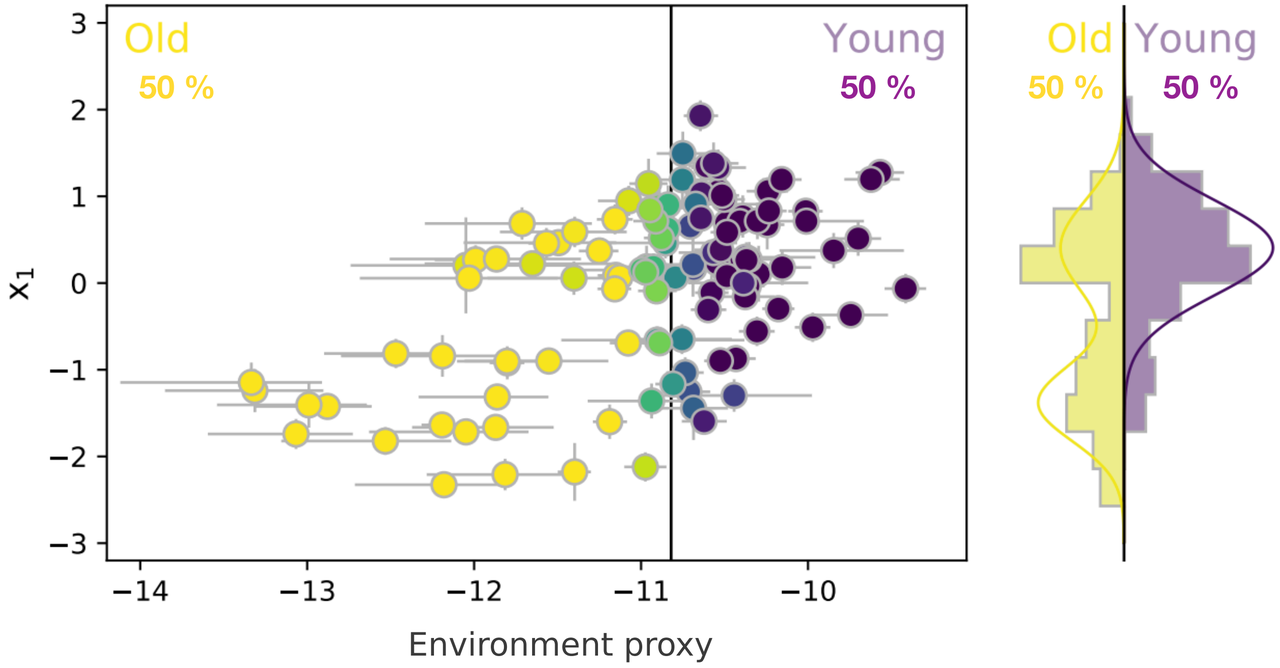


Childress et al (2013)

Two population model



Nicolas et al (2021)

PhD goal

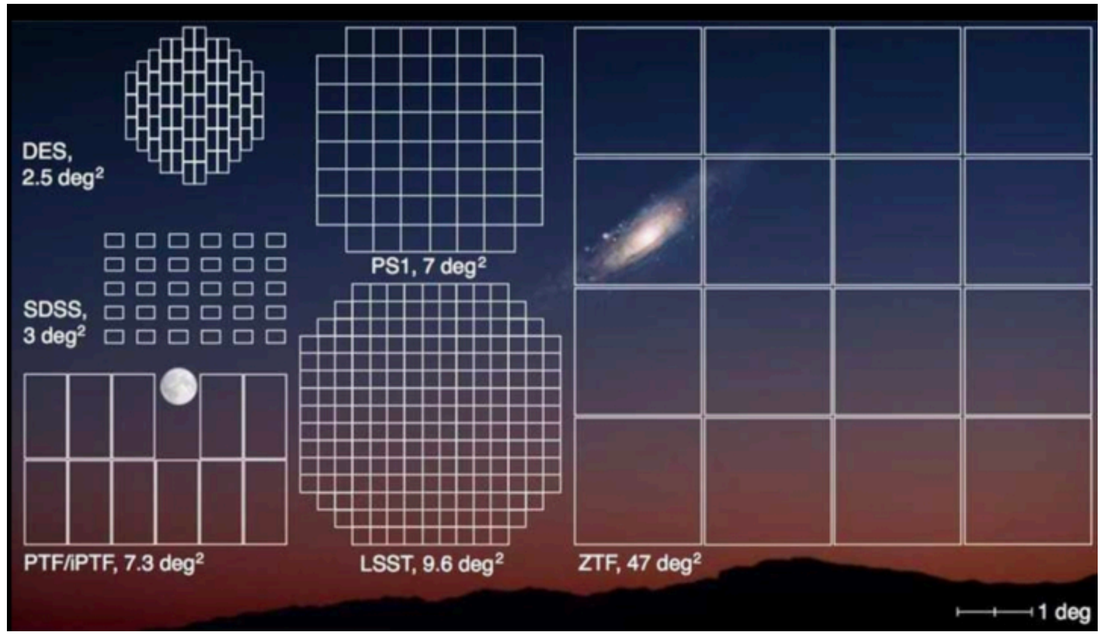
$$\mu + M = m_{obs} - \beta c + \alpha x_1 + p\gamma$$

ZTF

Zwicky Transient Facility

ZTF

Zwicky Transient Facility

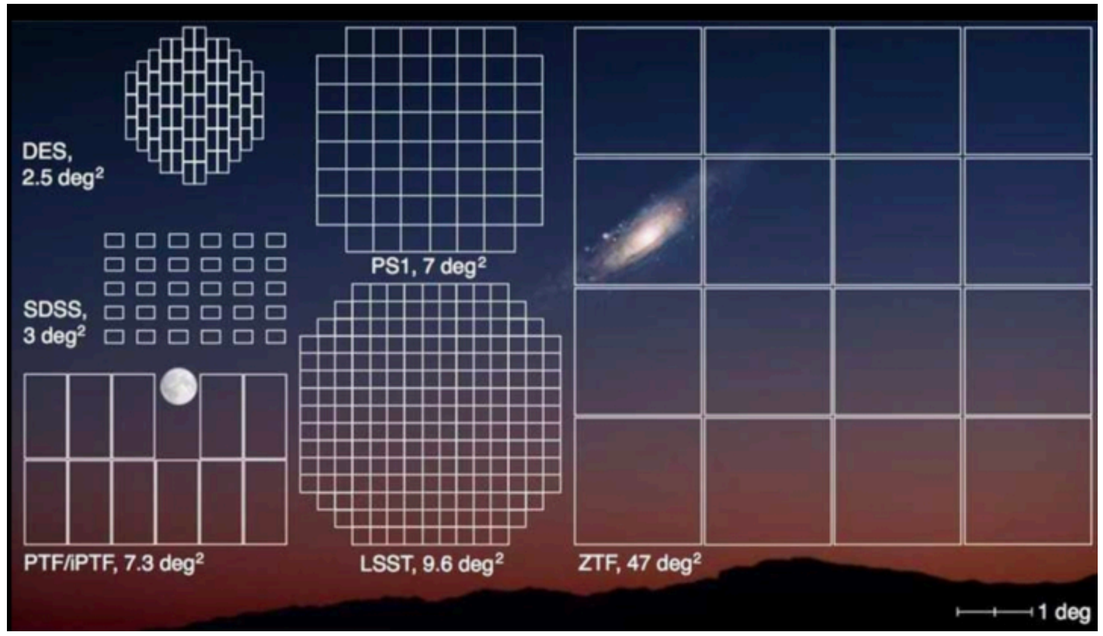


Zwicky Transient Facility (P48)

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

ZTF

Zwicky Transient Facility



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 mag

ZTF Cosmo-DR2

Numbers

3628 SNe

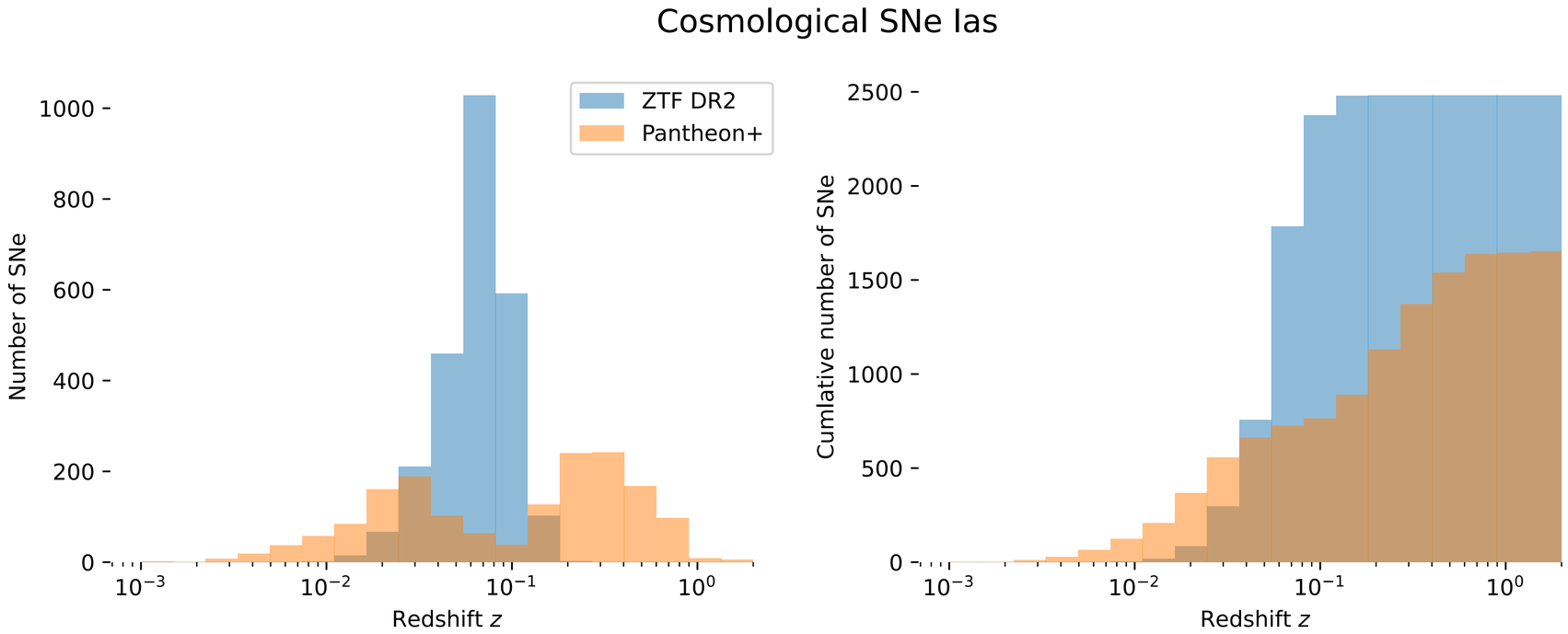
Confirmed SNe Ia

2959 SNe

with well-sampled lightcurves

2626 SNe

usable for cosmology

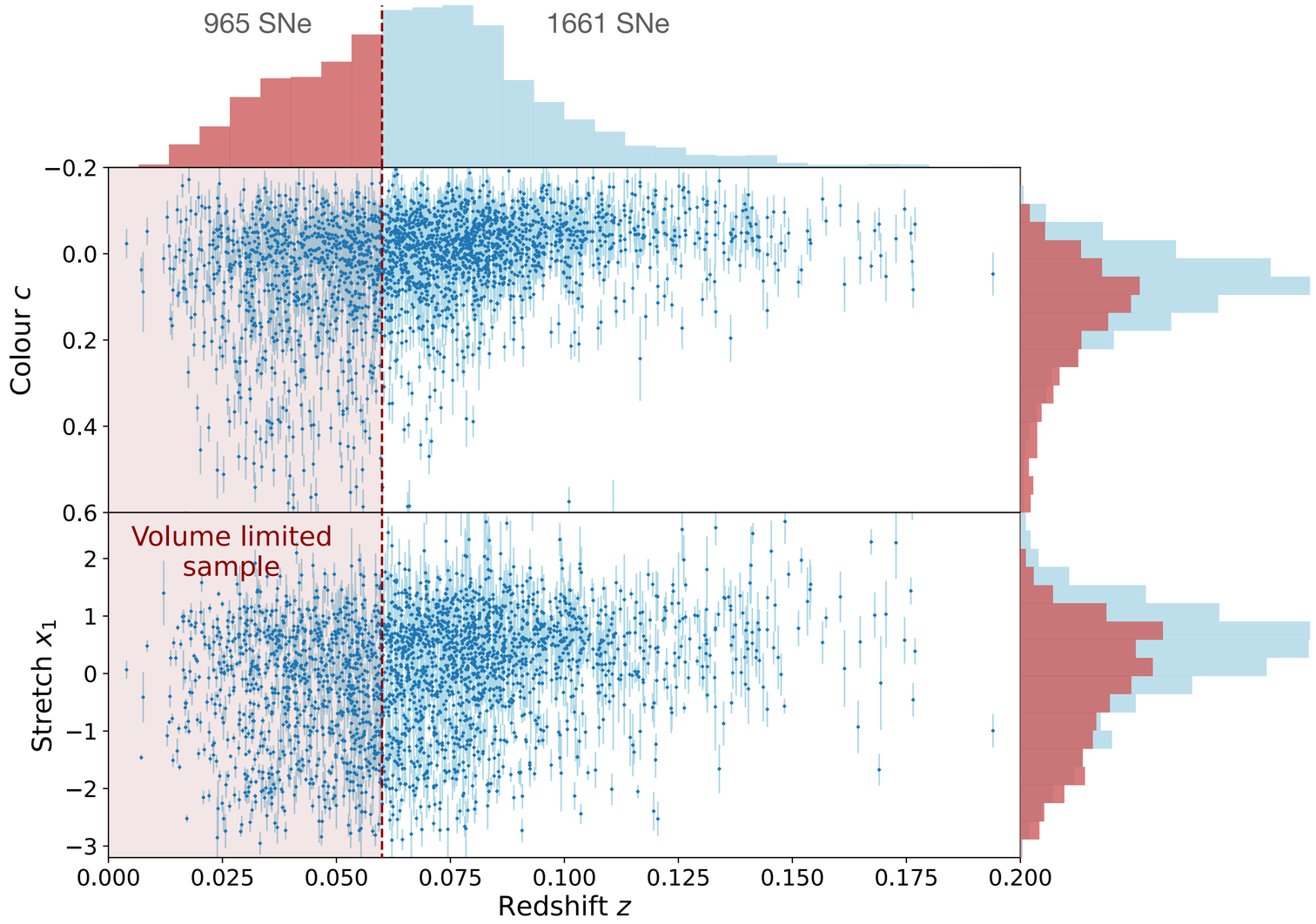


ZTF Cosmo-DR2

Volume limited sample

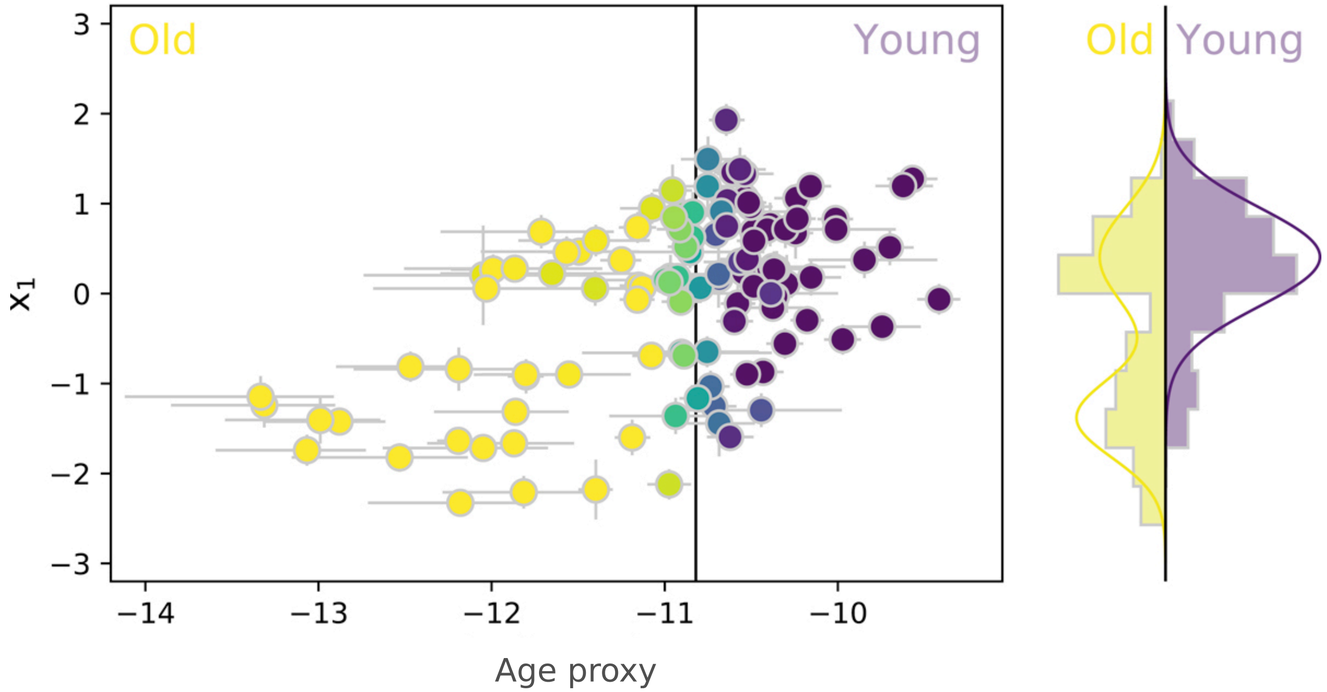
- $z < 0.06$
- Additional quality cuts:
  - $(x_1, x_1^{\mathrm{err}})$
  - (c, c^{err})
  - t_0^{err}
  - SN Ia type
  - SALT fit probability χ^2_{SALT}

862 SNe in the final sample



Standardisation

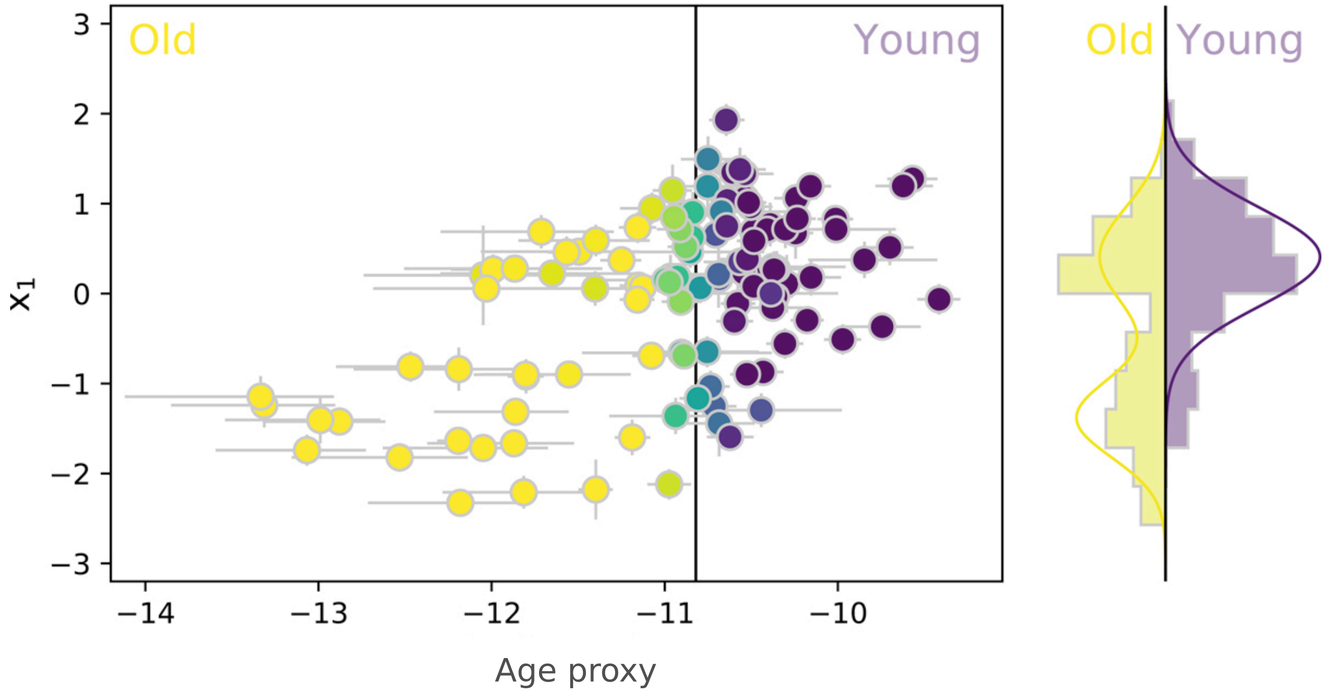
Stretch distribution



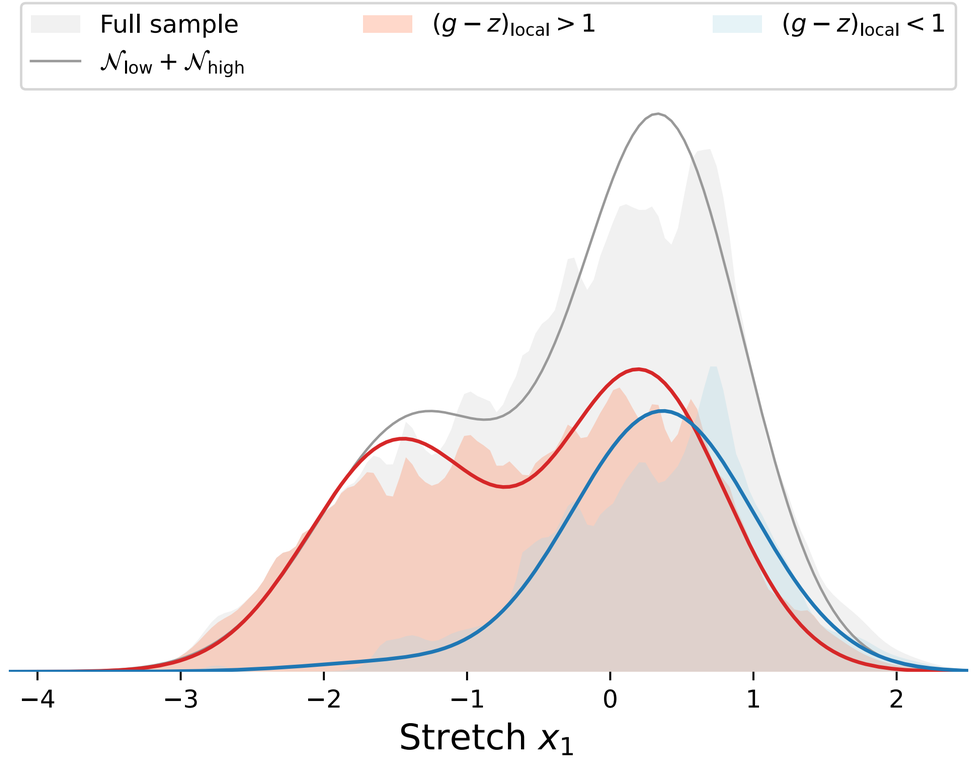
Nicolas et al (2021)
SNFactory - 114 SNe

Standardisation

Stretch distribution



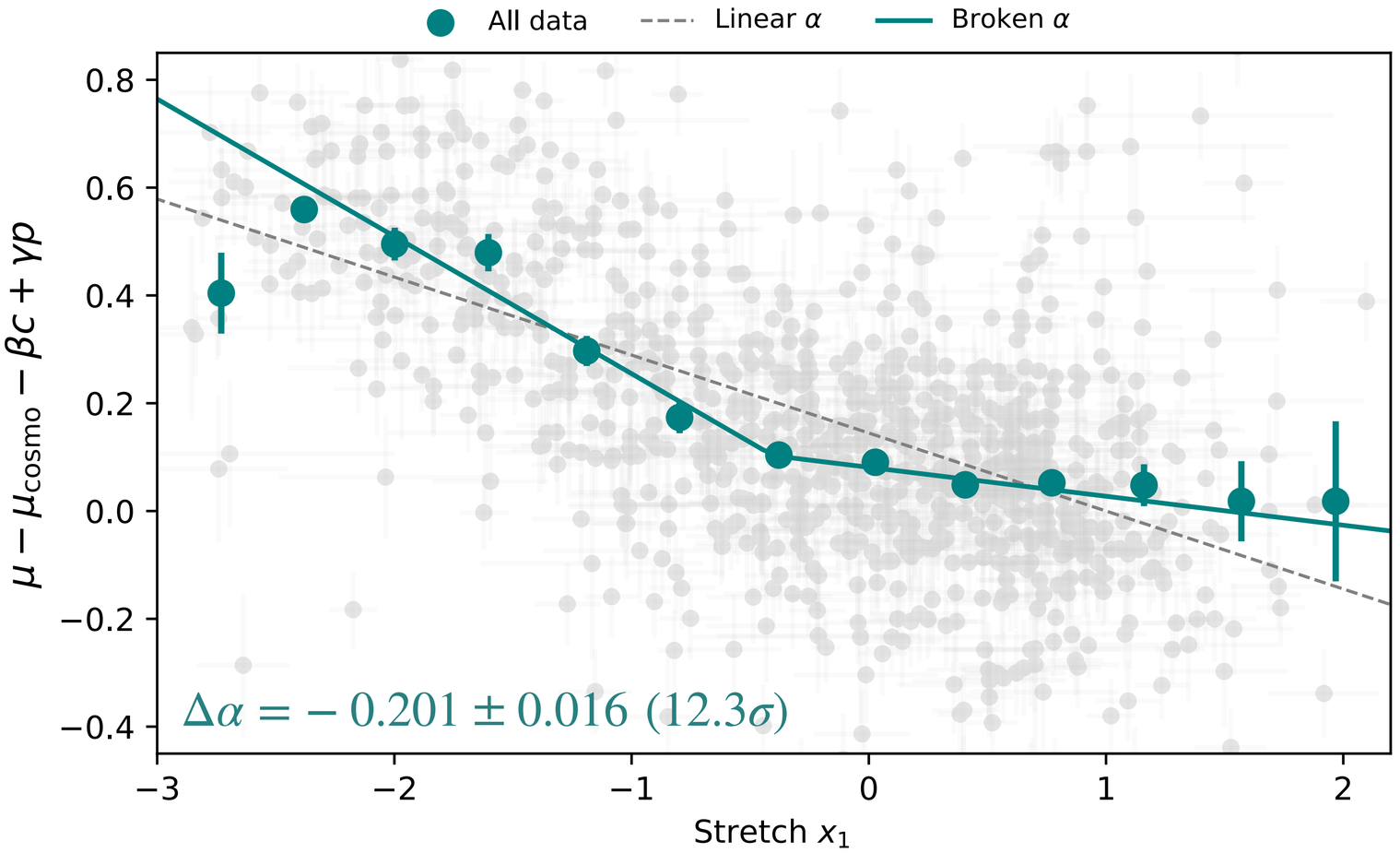
Nicolas et al (2021)
SNFactory - 114 SNe



Ginolin et al (2024a, in prep)

Standardisation

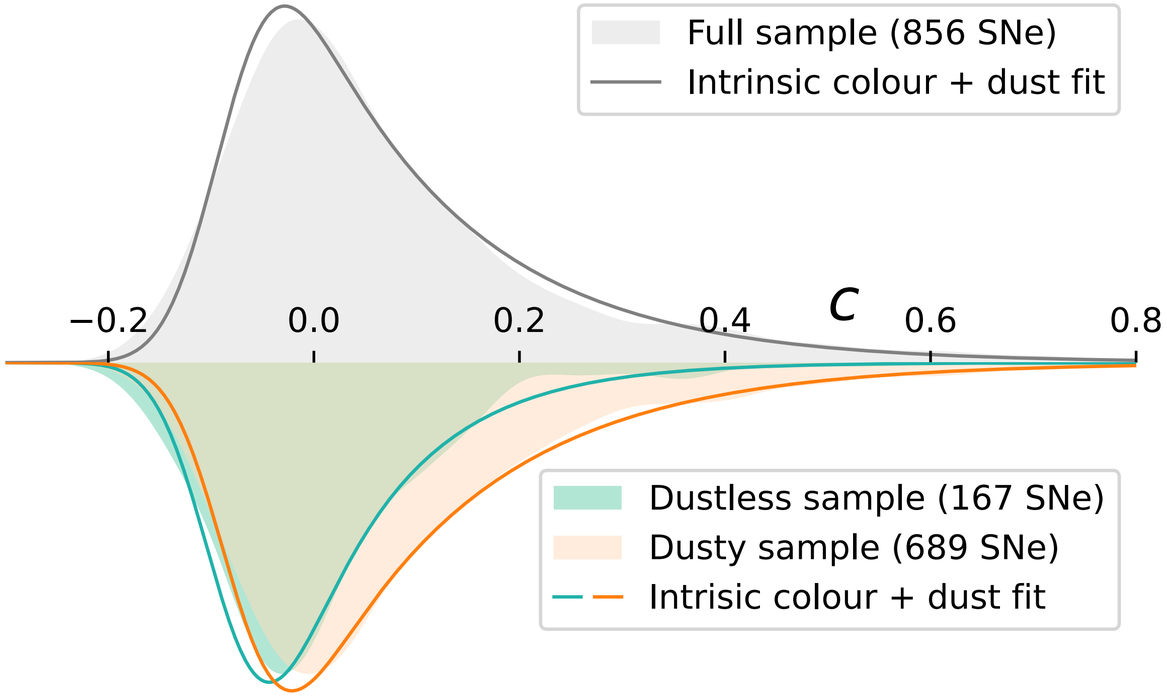
Non linearity of the stretch-residuals relation



Ginolin et al (2024a, in prep)

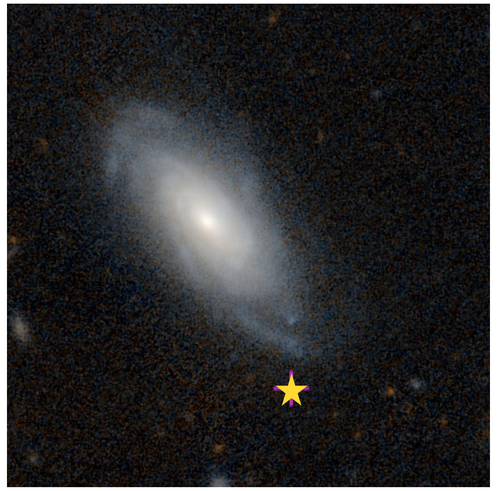
Standardisation

Colour distribution



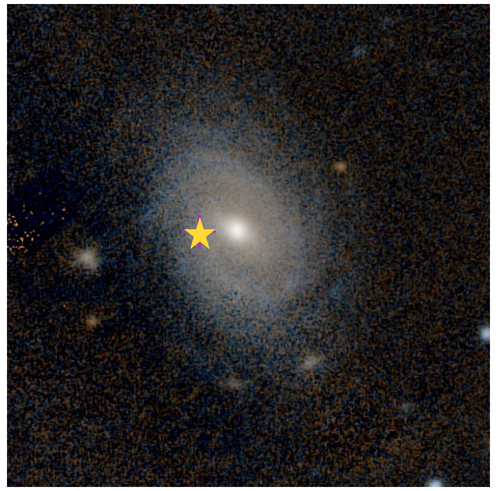
Ginolin et al (2024b, in prep)

« Dustless » example



ZTF18aahfzea

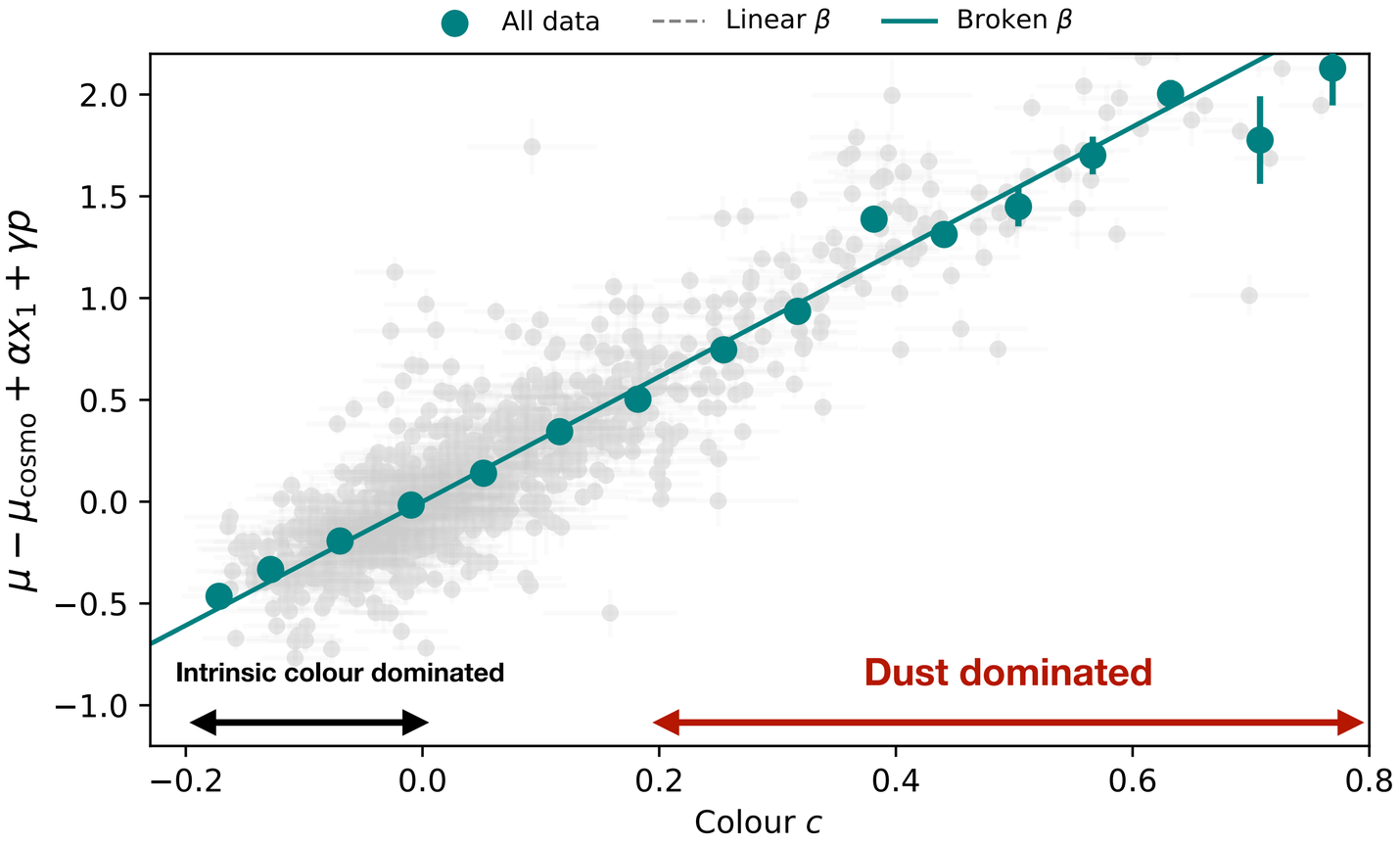
« Dusty » example



ZTF18aaqfziz

Standardisation

Linearity of the colour-residuals relation



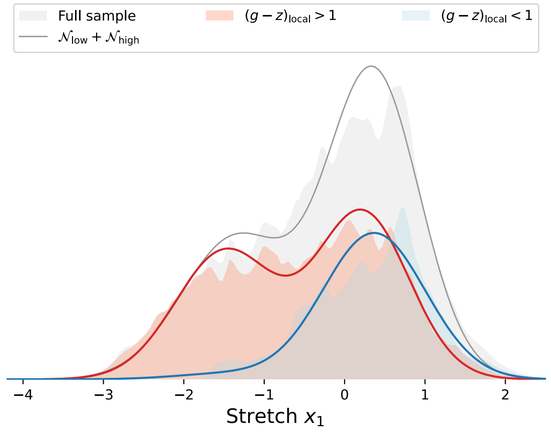
Ginolin et al (2024b, in prep)

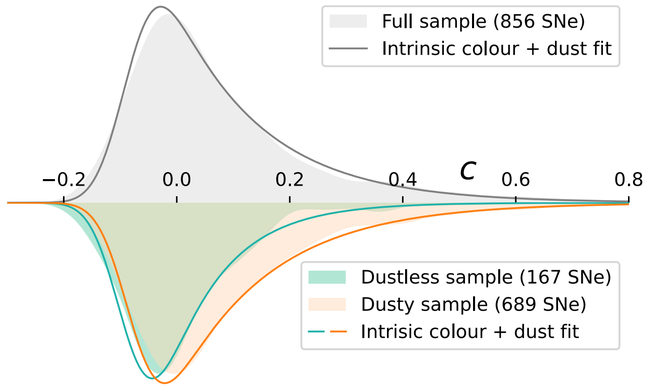
Conclusion

ZTF DR2

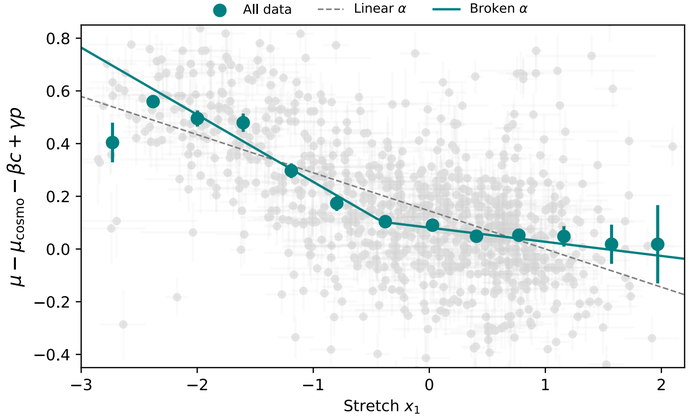
2626 cosmological Ia
Highest low-z Ia sample
Homogenous
High cadence + high quality

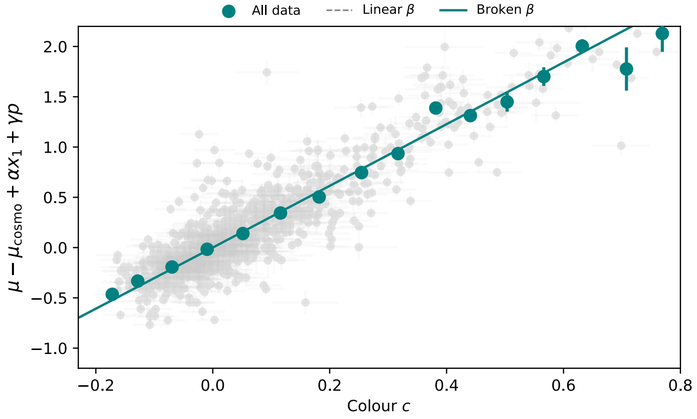
Supernovae physical properties





Standardisation dependency on environment





What’s next

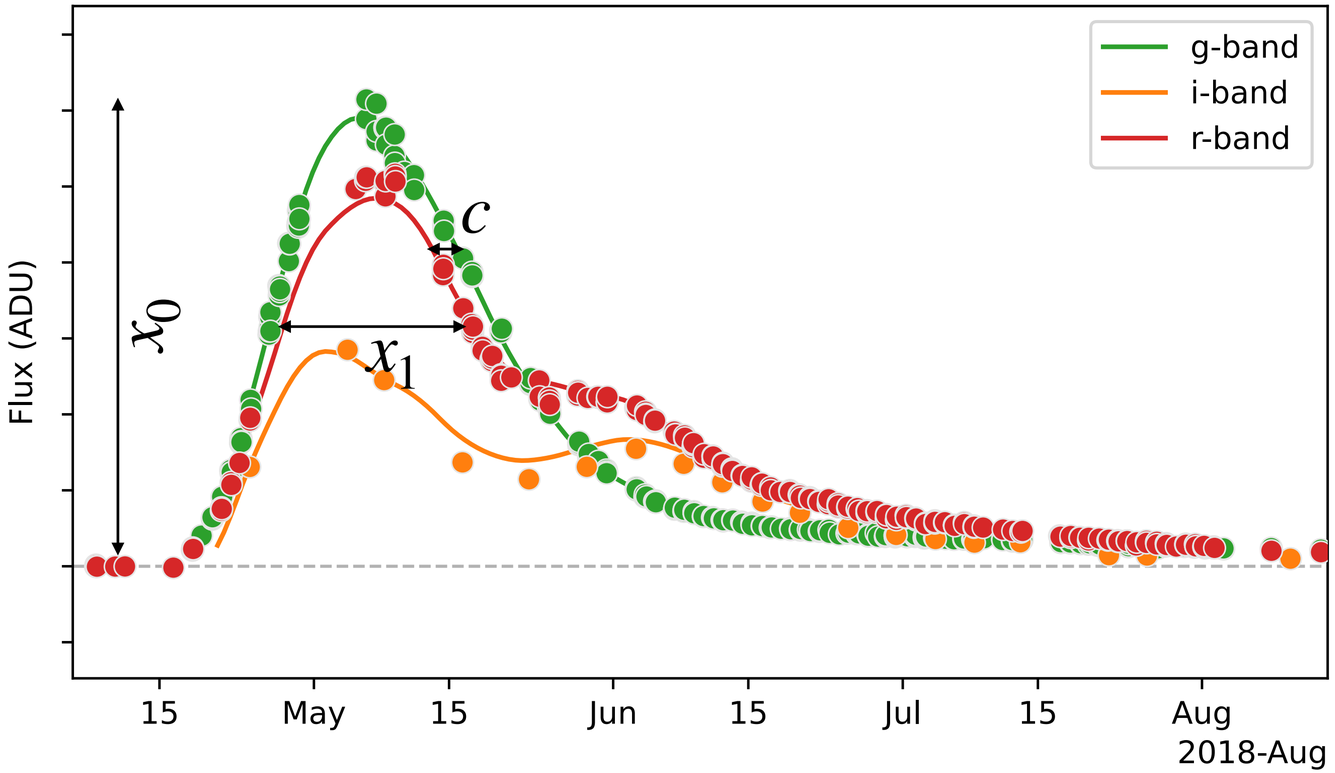
- Publishing the papers (submitted)

- Simulating the impact on cosmology of all the effects we see

Backup

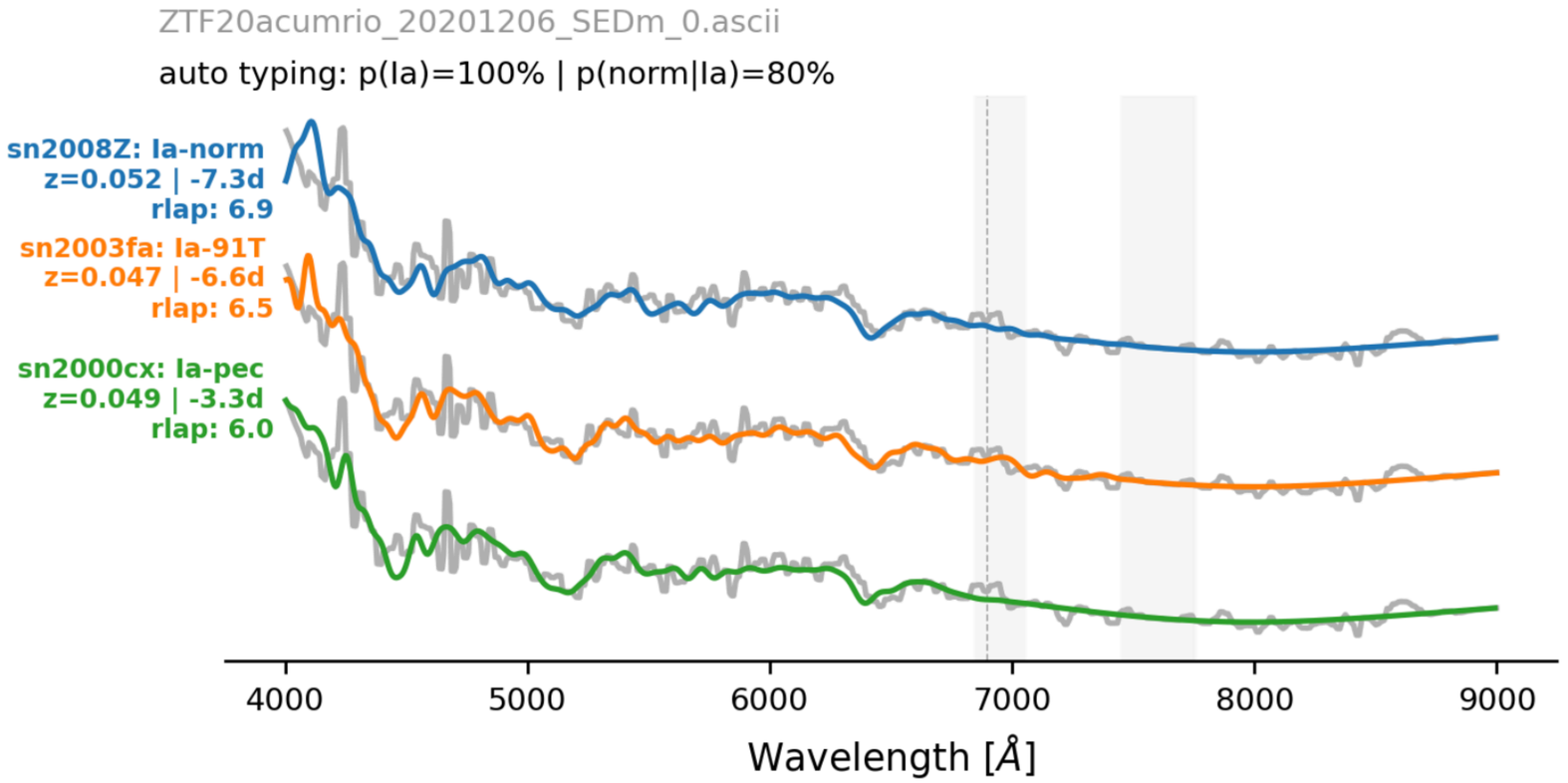
SALT2.4

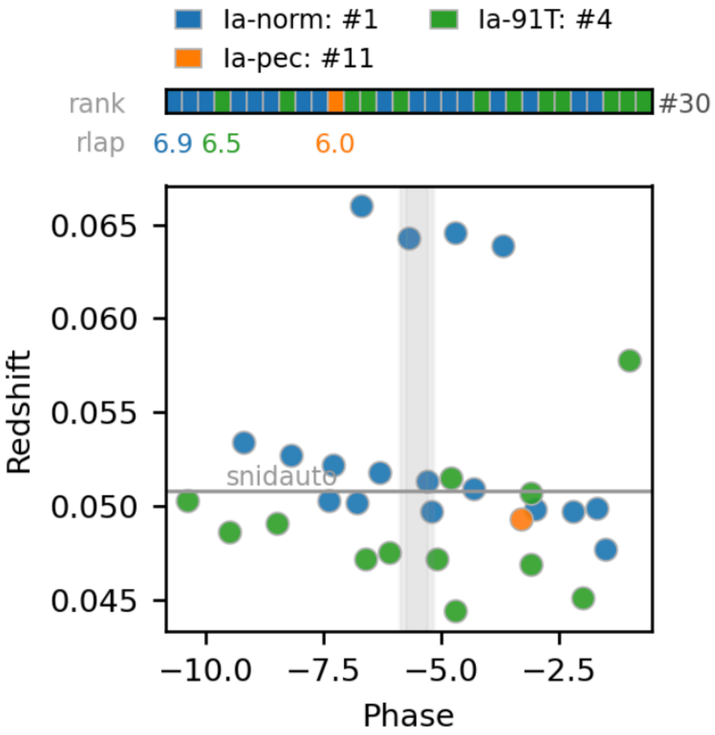
Functional form describing the flux: $F(SN, p, \lambda) = x_0 \left[M_0(p, \lambda) + x_1 M_1(p, \lambda)\right] \exp(cCL(\lambda))$



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

SNID (Blondin & Tonry 2007)





Credits: Typing App