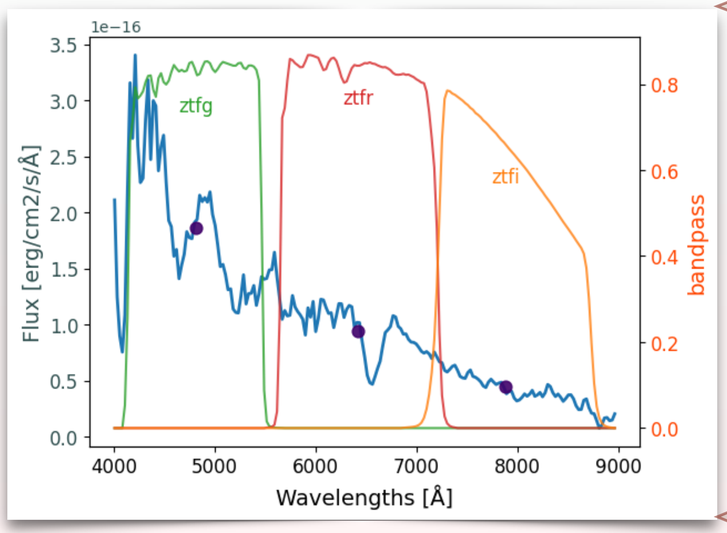
Twins Embedding spectrophotometric standardisation of the ZTF type Ia supernova sample

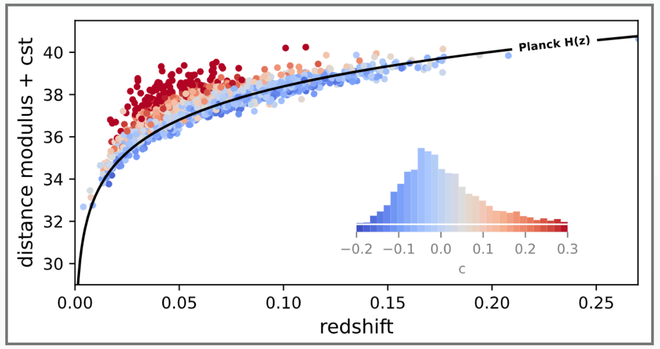
Constance Ganot, supervised by Yannick Copin and Mickael Rigault

- Spectrophotometric standardisation
- ZTF spectra sample, flux-calibration
- RBTL standardisation

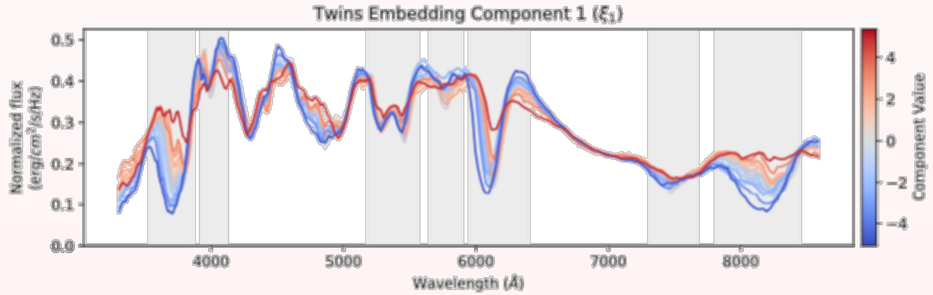
ADE meeting, Montpellier - 07/11/2025

Spectrophotometric standardisation





Hubble Diagram of ZTF "DR2" Data paper, Smith et al.



Twins Embedding - Boone et al. 2021

Before standardisation :

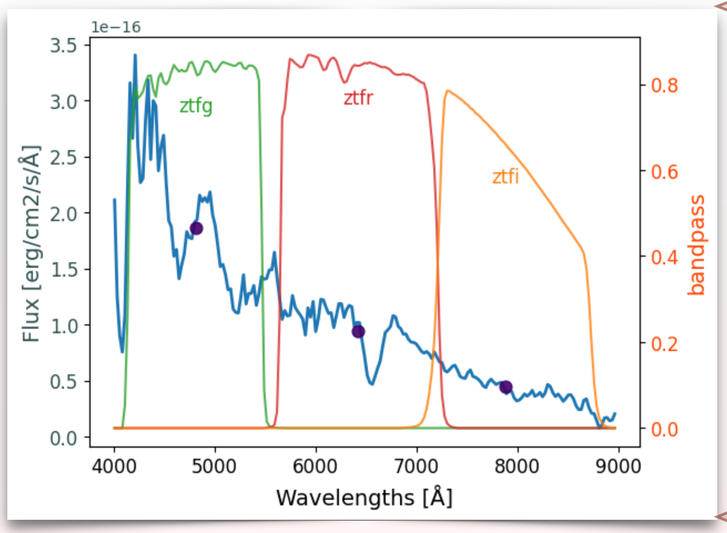
$$\sigma_{mag} = 0.40\text{mag}$$

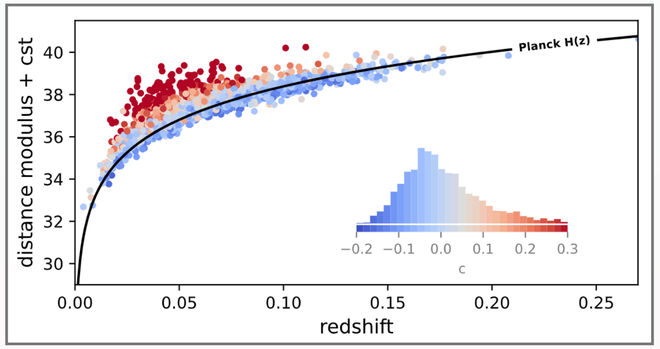
Photometry :

$$\sigma_{mag} = 0.15\text{mag}$$

★ New standardisation of SNe Ia, using spectral information

Spectrophotometric standardisation





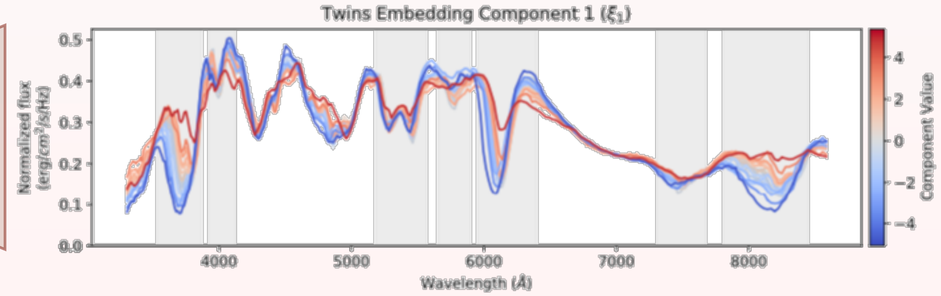
Hubble Diagram of ZTF "DR2" Data paper, Smith et al.

Before standardisation :

$\sigma_{mag} = 0.40\text{mag}$

Photometry :

$\sigma_{mag} = 0.15\text{mag}$



Twins Embedding - Boone et al. 2021

With SNFactory

Twins Embedding :

$\sigma_{mag} = 0.07\text{mag}$

- ★ New standardisation of SNe Ia, using spectral information

SNFactory : ~200 SNe

↓

ZTF : ~800 SNe

ZTF spectra flux-calibration

Purpose : typing

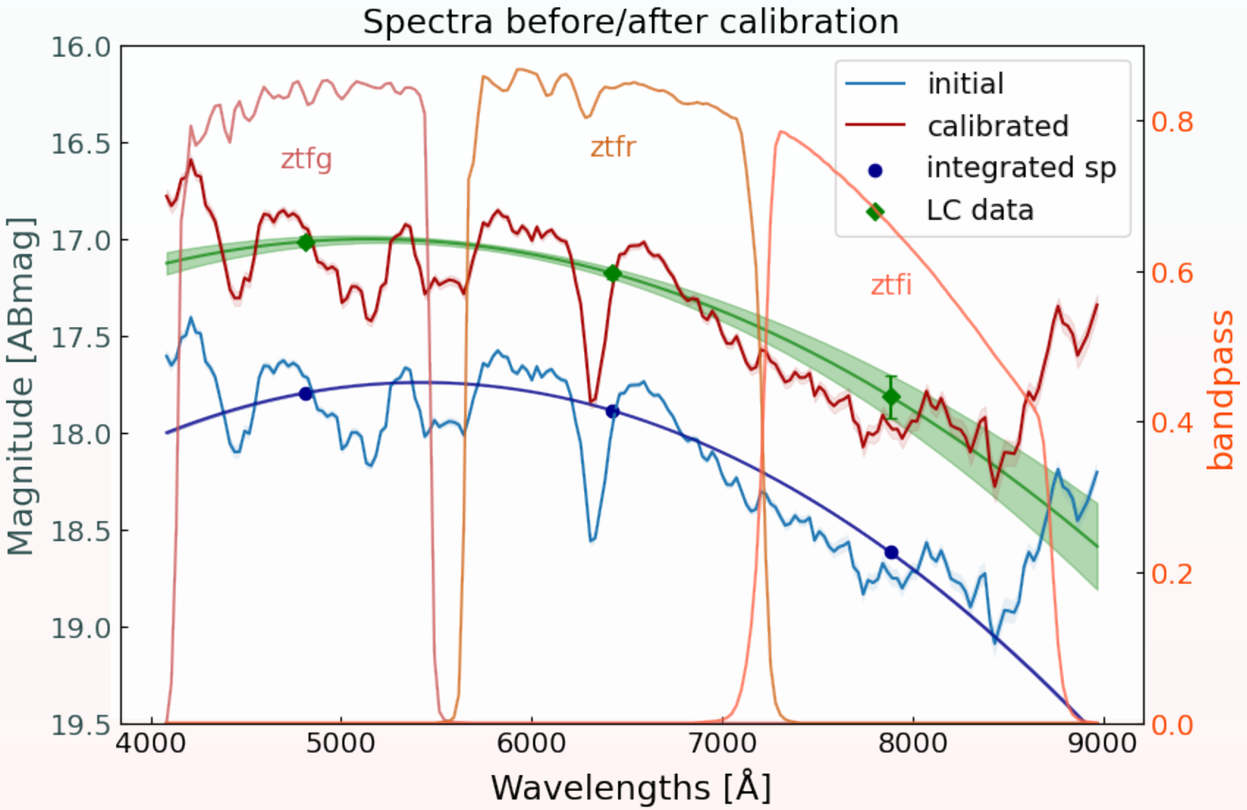
Low resolution : $R = \frac{\lambda}{\Delta\lambda} \sim 100$

✓ Spectral extraction by pysedm (Rigault 2019)

✓ Correction of host galaxy by Hypergal (Lezmy 2022)

60% SNe Ia spectra from the SEDm

SEDm (P60)
Integral field Spectrograph



—> 1607 flux-calibrated SNe Ia

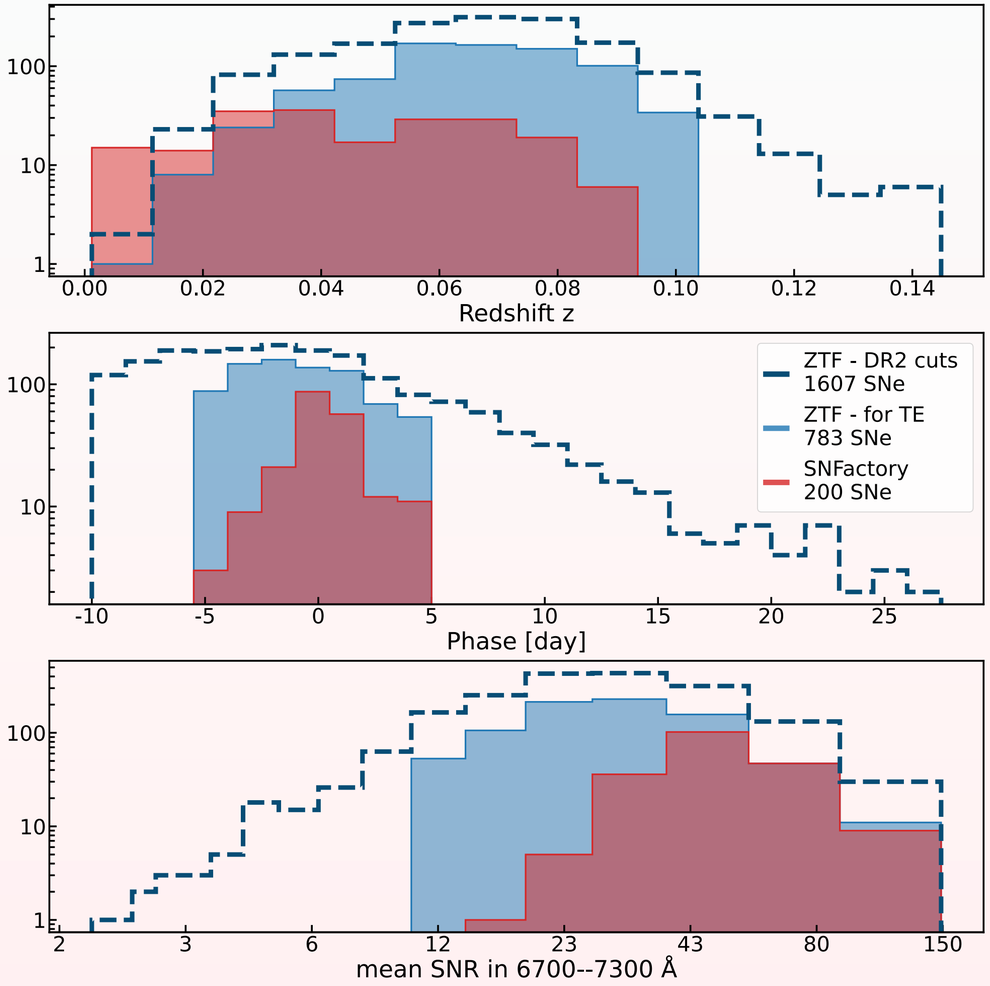
The flux-calibrated sample will be published in Ganot et al. (in prep)

ZTF spectra sample for TE

- ✓Flux calibration, precision of 0.07 mag
- ✓Milky Way dust correction
- ✓Shift spectra to z=0.05

Cut	Interval	Quantity removed
Calibration quality		around 7%
z	<0.1	around 5%
phase	[-5,+5] days	**around 40%**
cosmo		**around 7%**

—> 783 SNe Ia for TE application

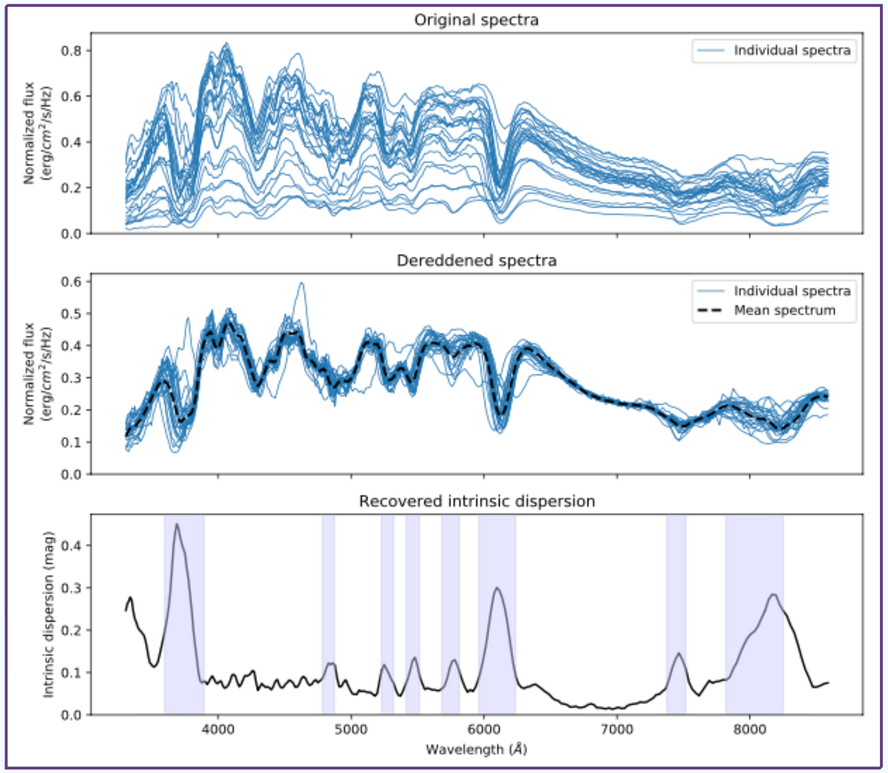


Twins Embedding - *Method*

3 steps

1. Shift spectra at phase=0

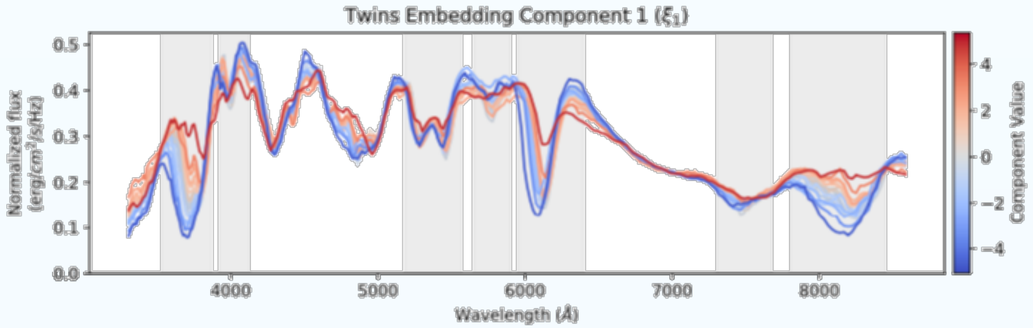
2. RBTL - fit one offset and a color outside the lines



SNFactory spectra before/after dereddening, and residuals intrinsic dispersion (std) *Credit : Boone et al. 2021*

only based on spectral data

3. Manifold Learning - parameters reduction



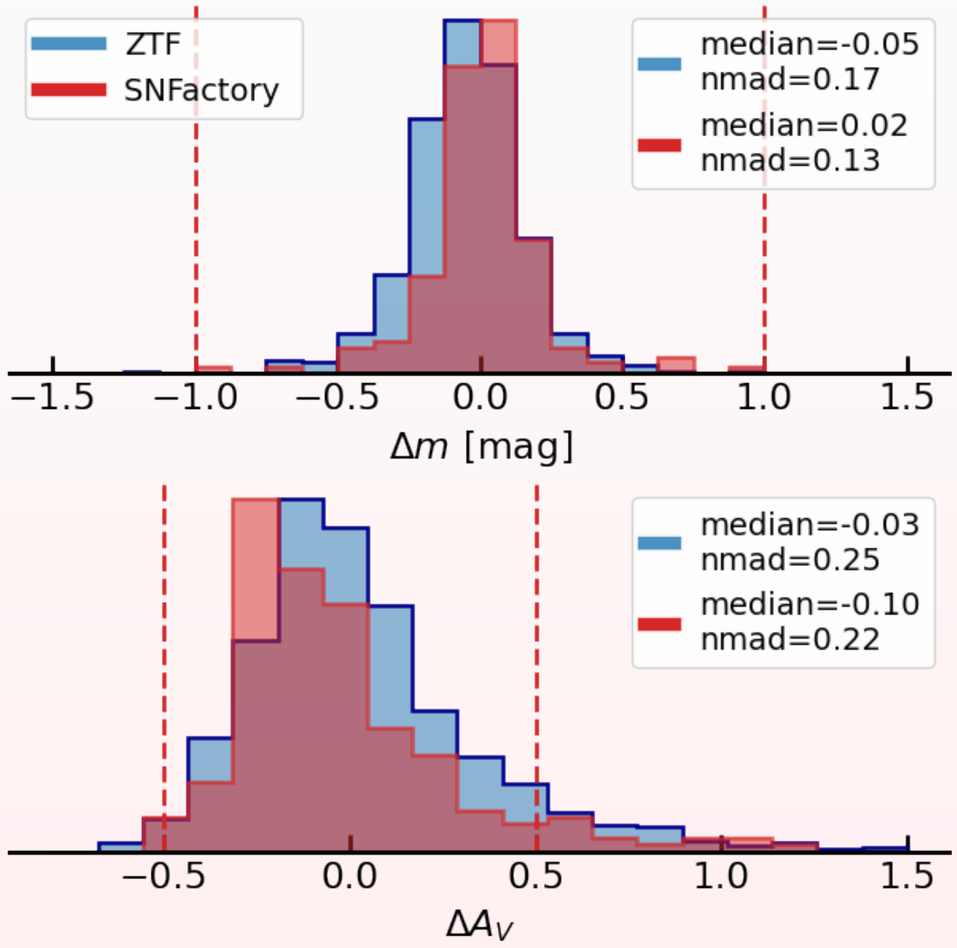
Twins Embedding components variation effects on spectra. *Credit : Boone et al. 2021*

87% of the remaining variance is explained with 3 components

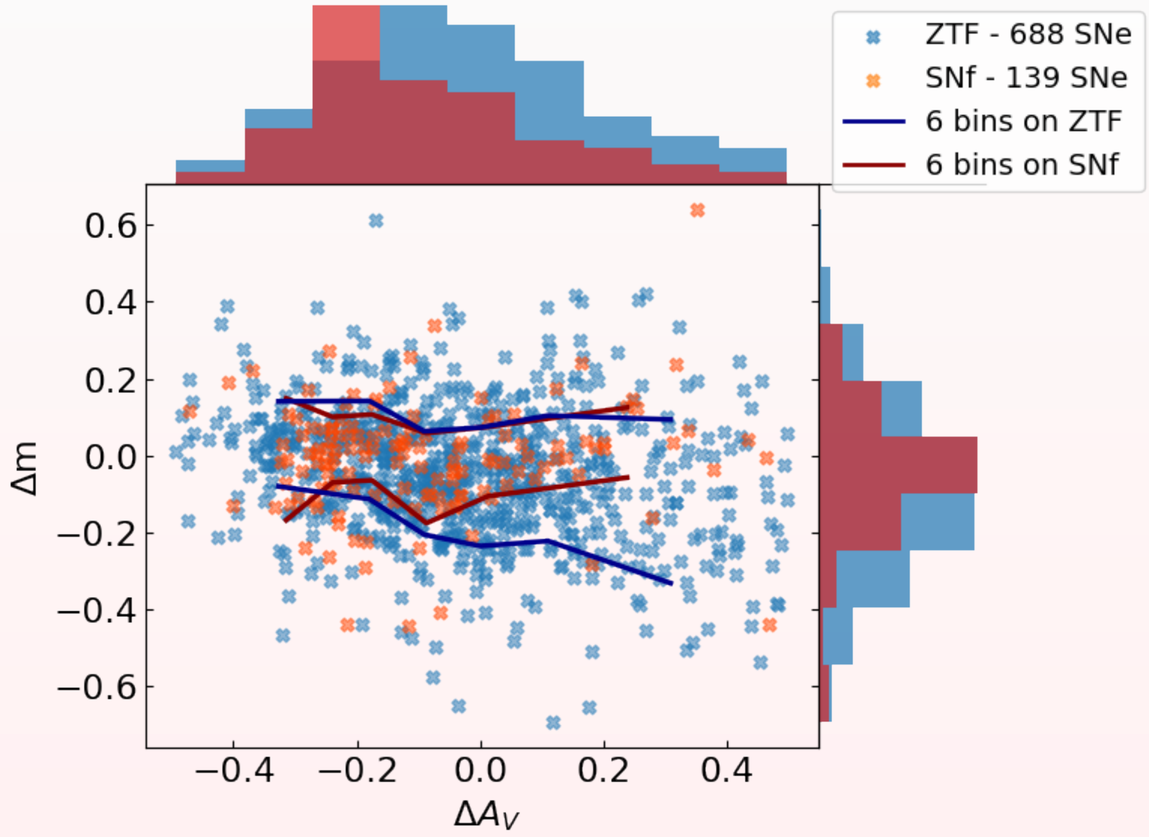
Twins Embedding - *Applied to ZTF*

1. **Shift spectra at phase=0**

2. **RBTL - fit one offset Δm_i *and a color* $\Delta A_{V,i}$ *outside the lines***

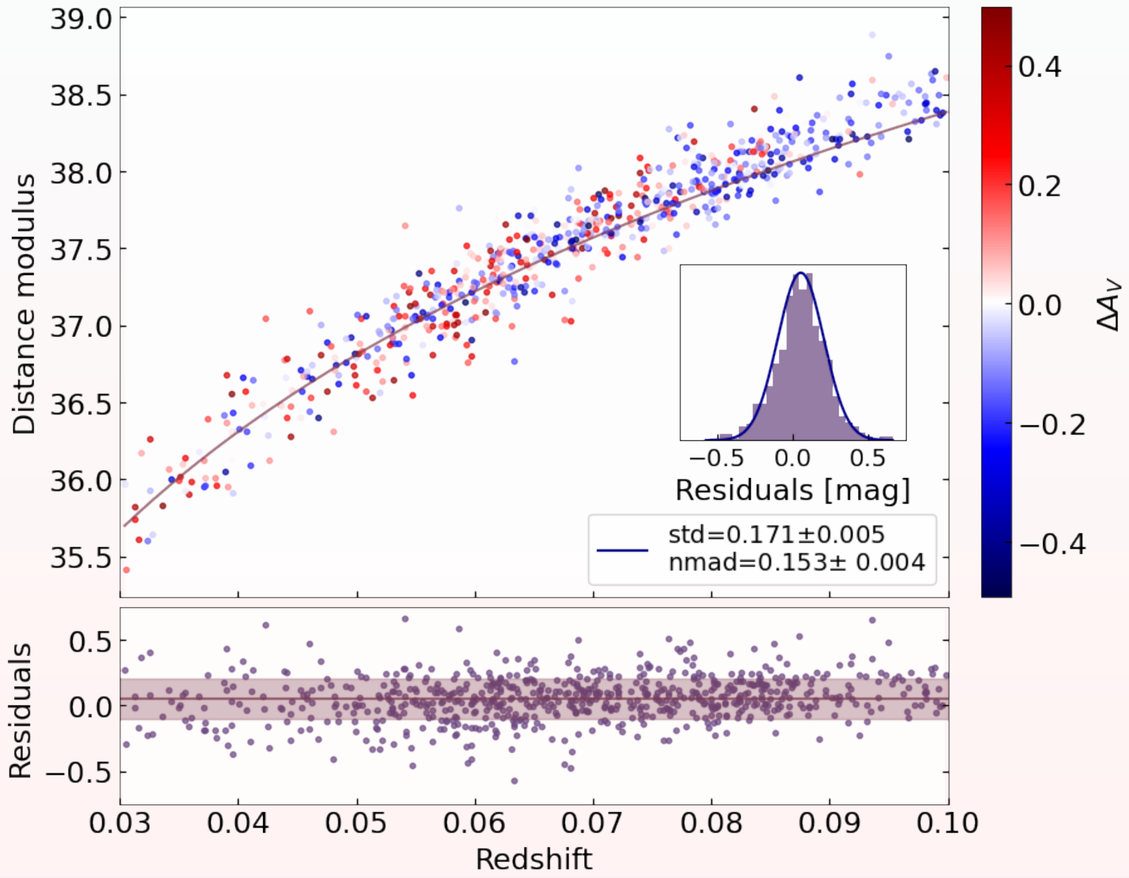


- More dispersion in Dm for ZTF
- More ‘red’ SNe in ZTF sample
- Remaining correlation between RBTL parameters for ZTF



Twins Embedding - *Standardisation in color*

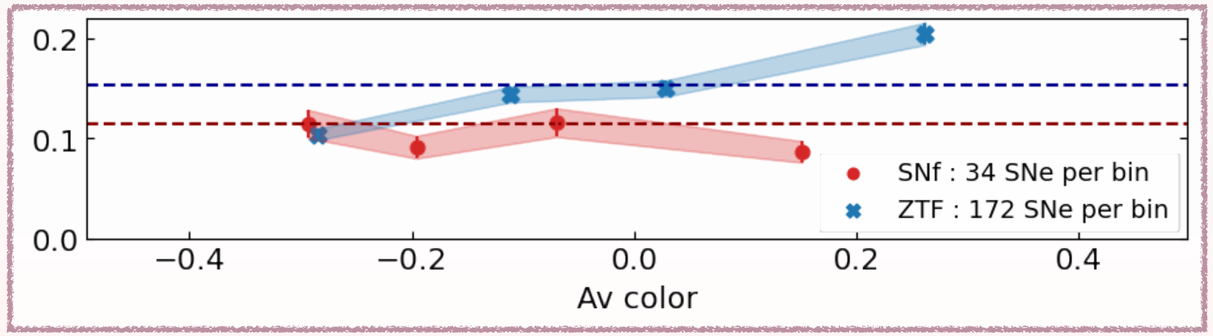
RBTL standardisation :
linear color correction - one parameter



Hubble Diagram after RBTL standardisation, for ZTF : 688 SNe

—> 0.153 mag for ZTF : with 1 parameter only
0.114 for SNf

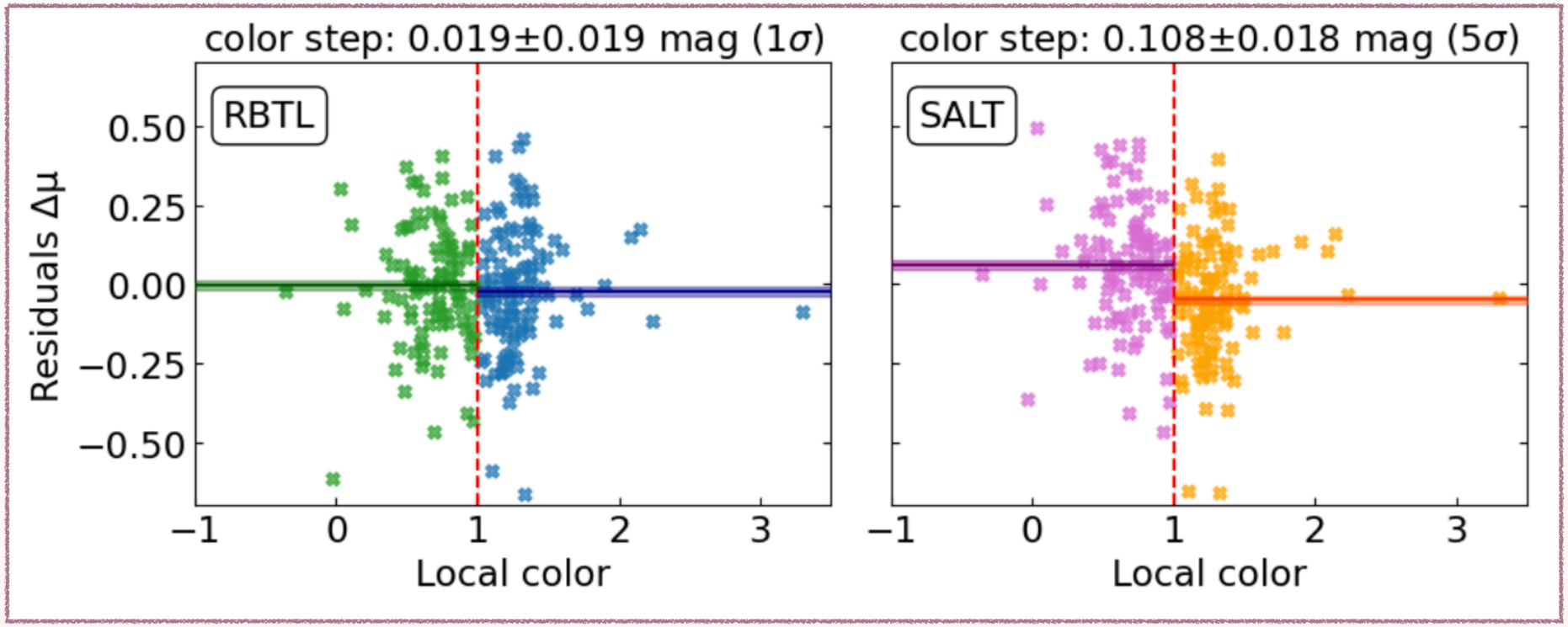
Test of the robustness



SNe with high color are not well standardised in ZTF

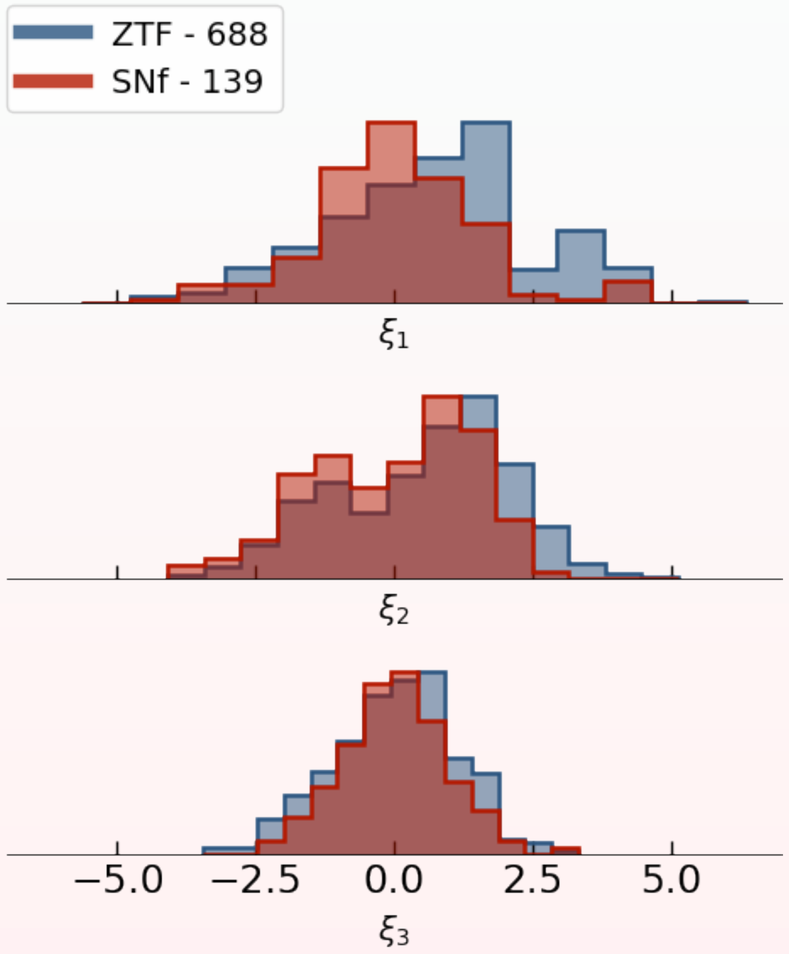
Twins Embedding - *Host residuals*

Astrophysical biases mitigated



Twins Embedding - *Isomap parameters*

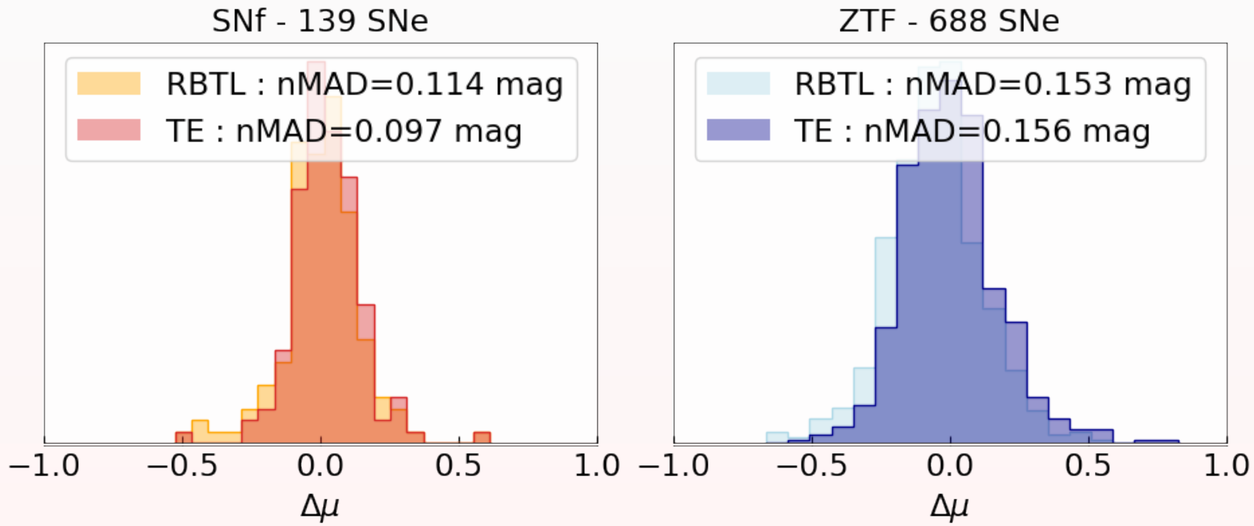
3. Fit three Isomap parameters $\vec{\xi}$ per SN



Normalised distributions of Isomap parameters

Manifold standardisation

color (#1)+ δm^{GP} (#3)



Residuals for 688 ZTF SNe and 139 SNf SNe

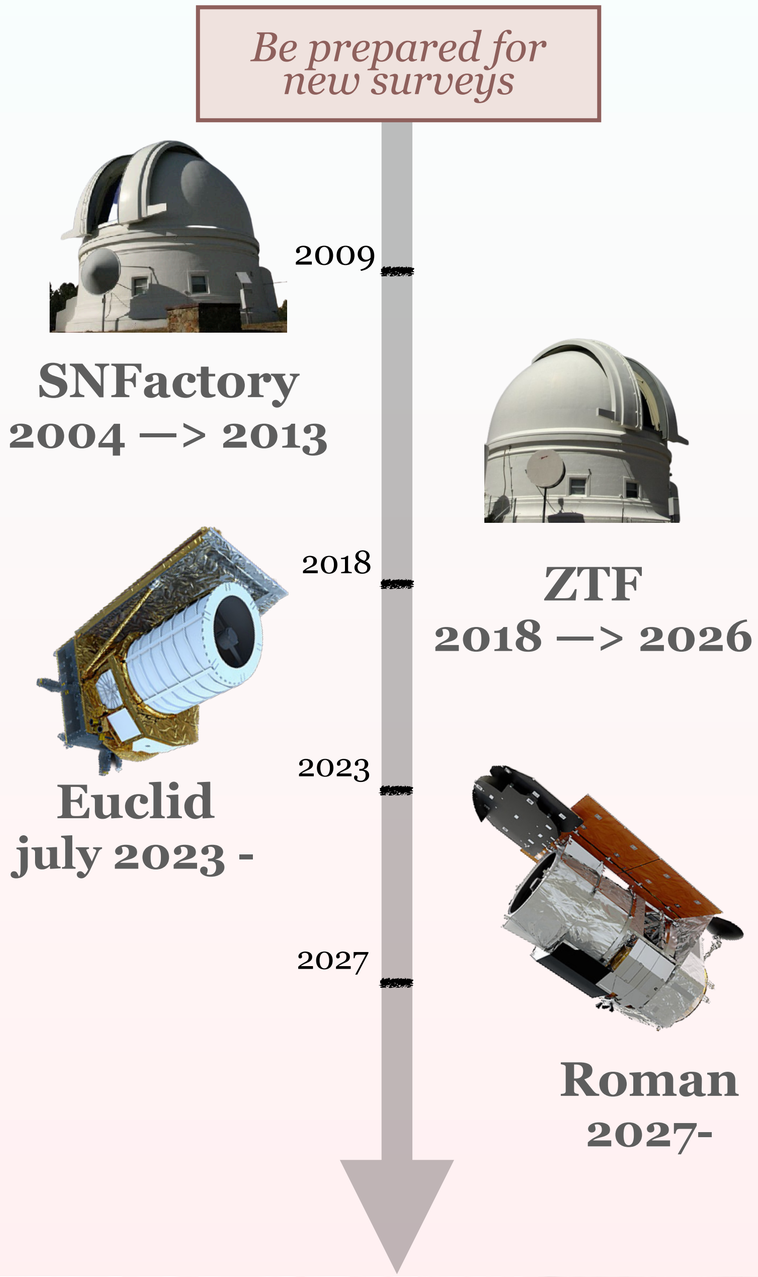
Gaussian Process δm^{GP} doesn't decrease the dispersion on ZTF

Conclusion

First non-SNfactory twinning standardisation

- 1607 ZTF spectra flux-calibrated at 0.07 mag
- ZTF TE sample has 4x more SNe that SNf
- RBTL standardisation works for ZTF

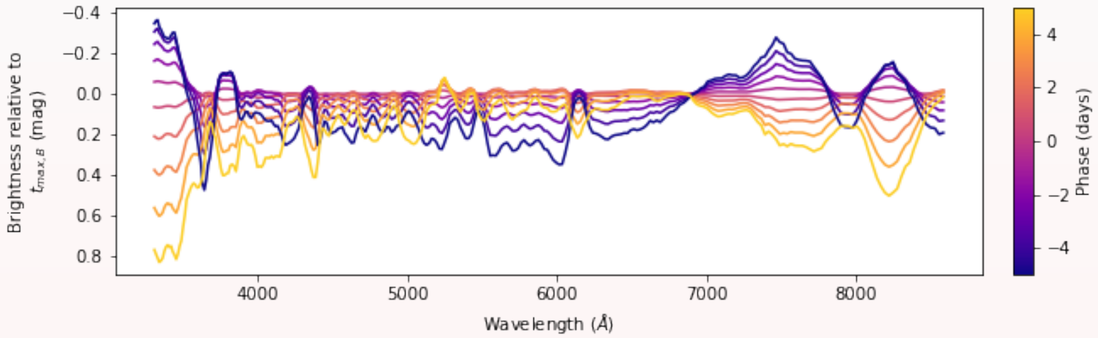
  —> 0.153 mag | ~0.1 mag for the bluest
- Ganot et al. *in prep*



Twins Embedding - *Applied to ZTF*

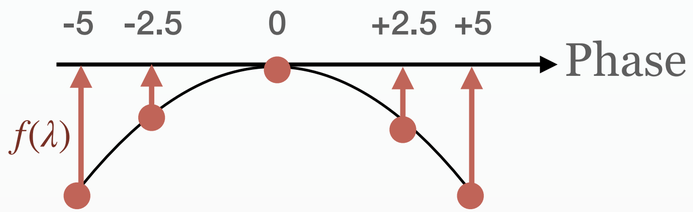
1. Shift spectra at phase=0

$$m_i(p;\lambda_k) - m_i(0;\lambda_k) = p \cdot c_1(\lambda_k) + p^2 \cdot c_2(\lambda_k)$$

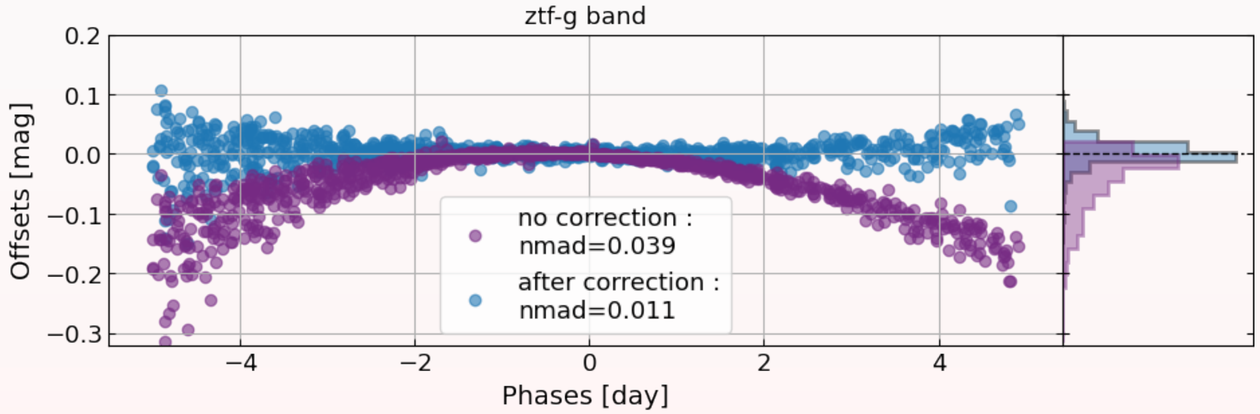


Quadratic evolution in phase of SN Ia spectra

*Capture 85% of the spectral **time evolution** variance common to every SNe between -5 and 5 days*



On bessell-b Lightcurve



—> estimated precision of 0.011 mag for ZTF in ztf-g band

*855 spectra at phase p for **784** SNe*

Twins Embedding - *Standardisation*

$$\delta m_i^{\mathrm{GP}} = GP\left(\mu(m_{\mathrm{ref}}, \omega \cdot \Delta A_{V,i}); \sigma(\vec{\xi}_i, \vec{\sigma}^2_{p.v.,i}, \sigma_u^2)\right)$$

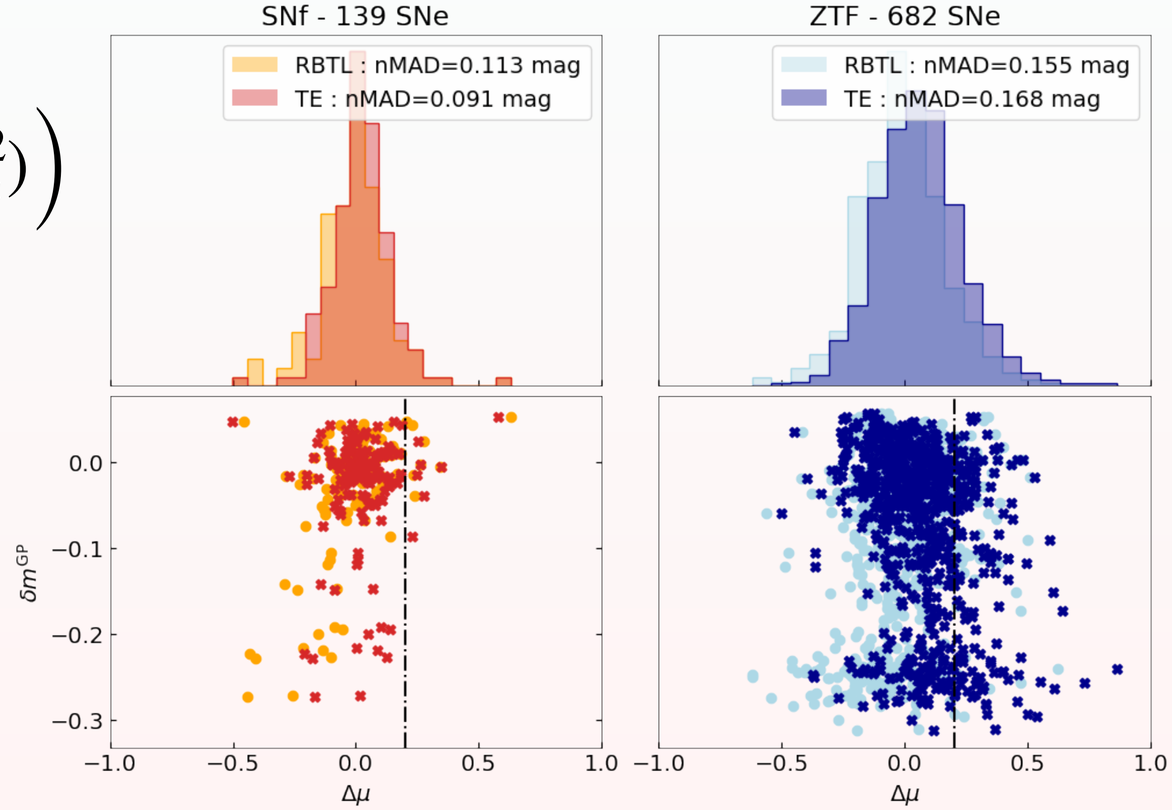
We fix omega to zero

Manifold standardisation

color (#1)+ δm^{GP} (#3)

$$\Delta\mu_{\mathrm{TE},i} = -\left[\Delta m_i - \beta_{\mathrm{RBTL}} \cdot \Delta A_{V,i} - \delta m^{\mathrm{GP}}(\vec{\xi}_i)\right]$$

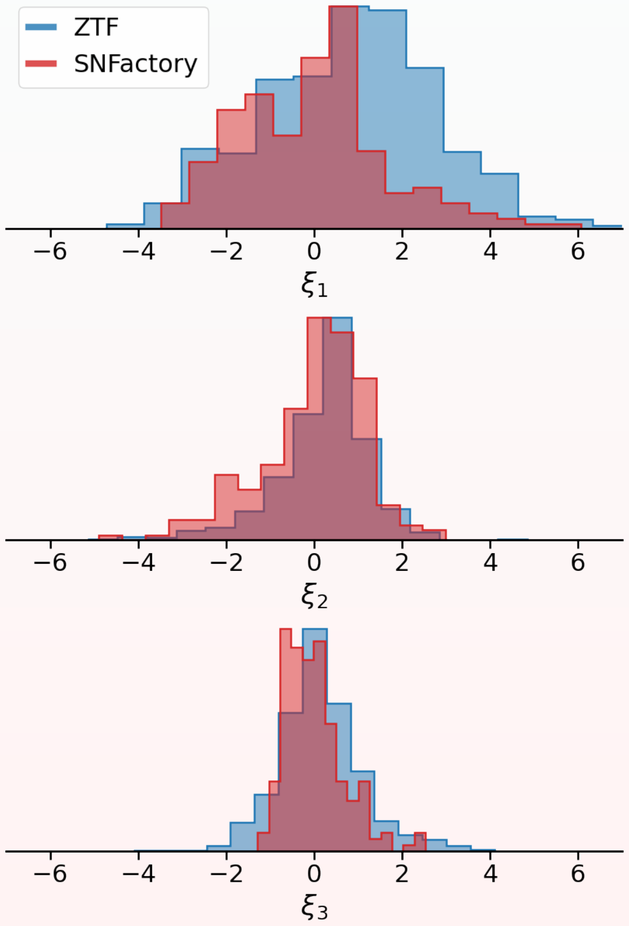
Residual prediction by GP



Gaussian Process δm^{GP} doesn't decrease the dispersion on ZTF

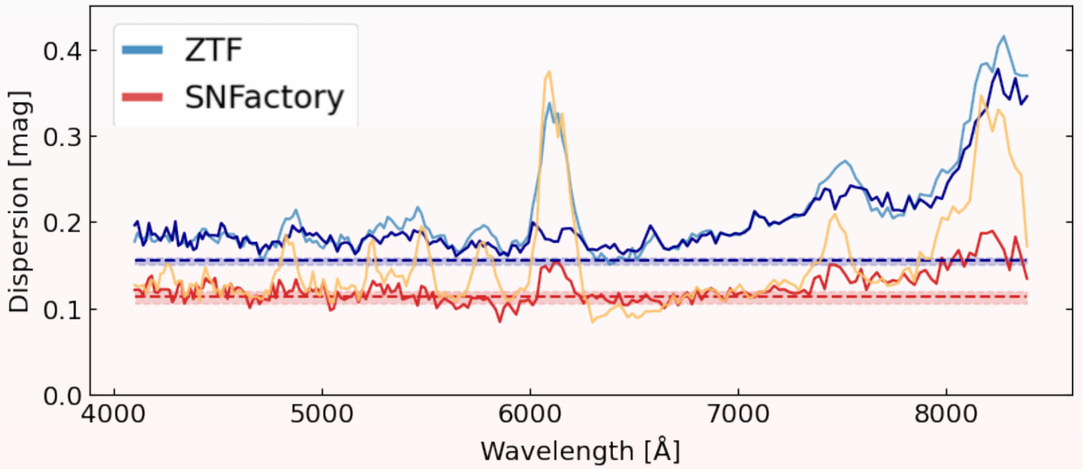
Twins Embedding - *Isomap parameters*

3. Fit three Isomap parameters $\vec{\xi}$ per SN



*Normalised distributions of Manifold components for **ZTF** and **SNf***

$GP(\lambda)(\vec{\xi}_i)$ modelling lines (not a standardisation)



Spectral dispersion for 682 ZTF SNe and 139 SNf SNe after RBTL standardisation with/without line correction