Study of cosmological biases induced by Type Ia Supernovae new variabilities

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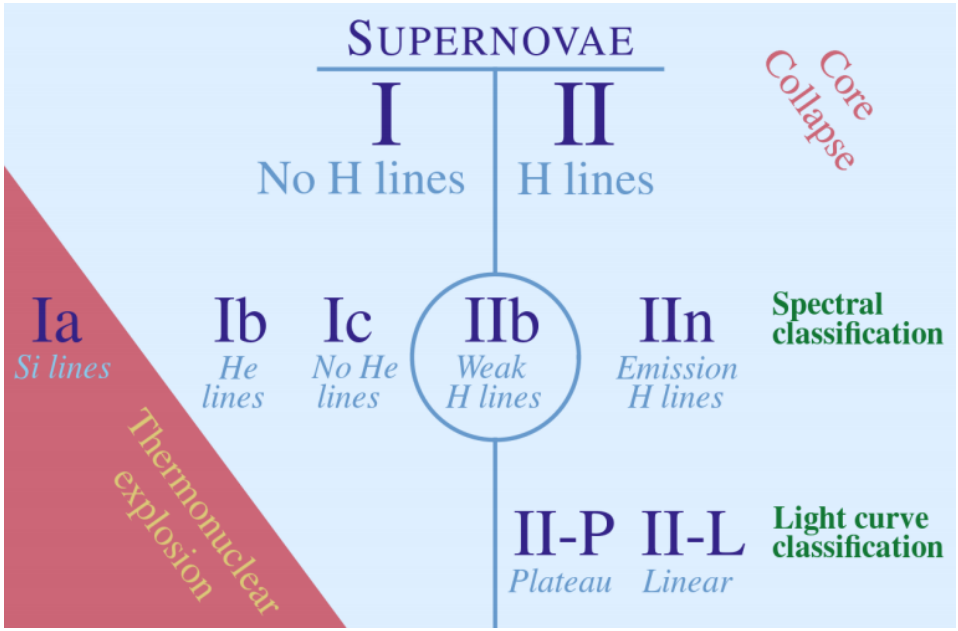
Type Ia Supernovae



- Type Ia Supernovae: explosion of a white dwarf in a binary system
- Their brightness is very similar from one SNIa to another

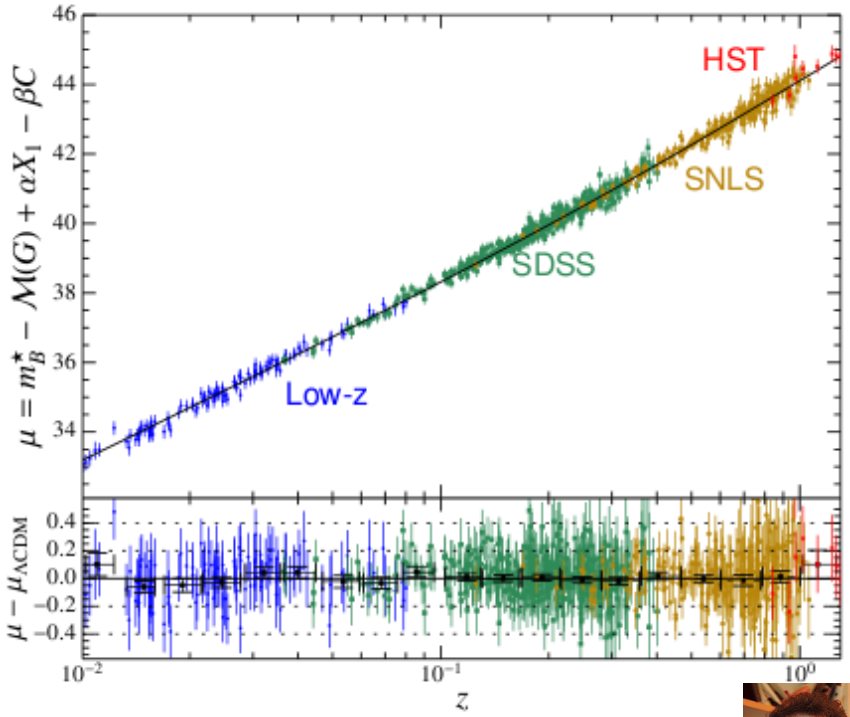
SNIa can be used as standard candles for a cosmological analysis

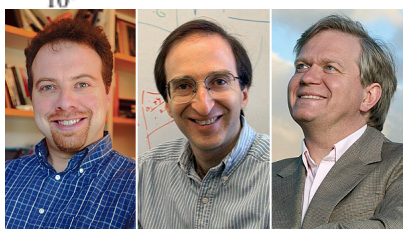
Type Ia Supernovae

Type Ia Supernovae

Cosmology with SNIa

- Hubble Diagram:
  Betoule et al.(2014)





Redshift:

$$1 + z = \frac{\lambda_{obs}}{\lambda_0}$$

Distance modulus:

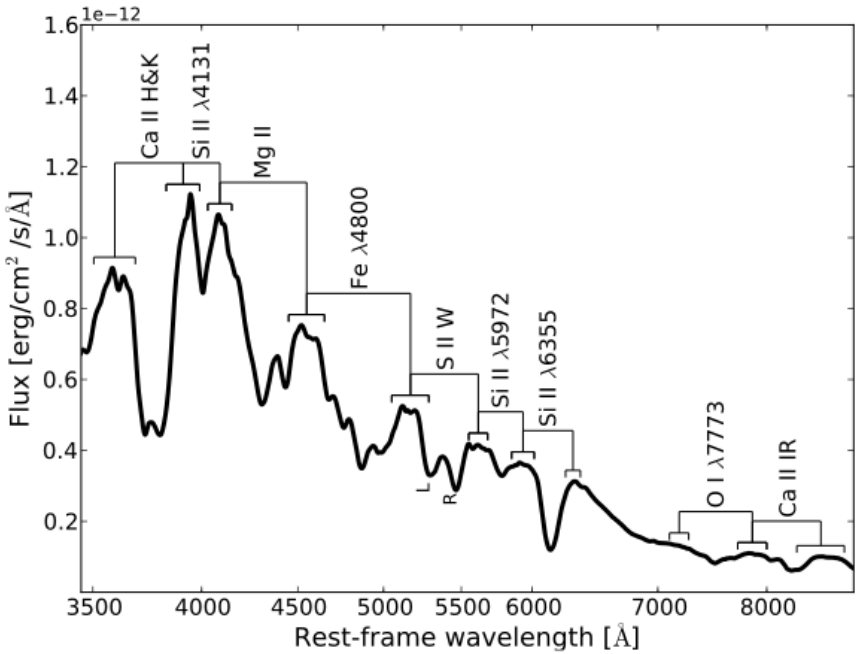
$$\mu_{th} = 5 \log_{10}(d_l) - 5$$

$$F = \frac{L}{4\pi d_l^2}$$

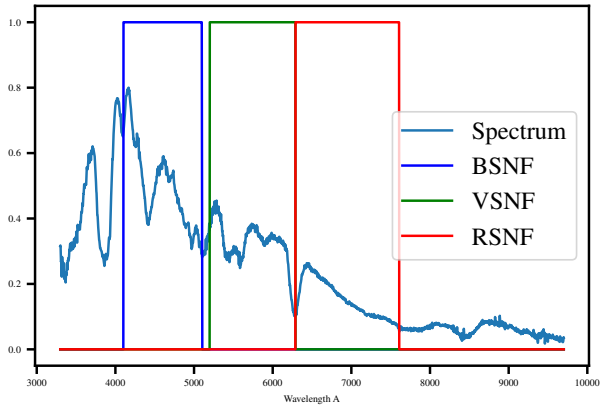
$$d_l = \frac{(1+z)\ c}{H_0} \int_0^z \frac{\mathrm{d}z'}{H(z')/H_0}$$

Observations

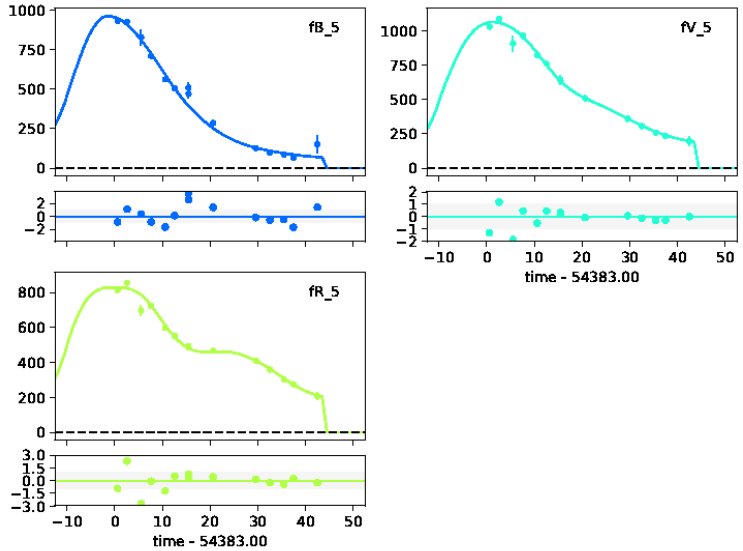
- Spectra



- Photometry

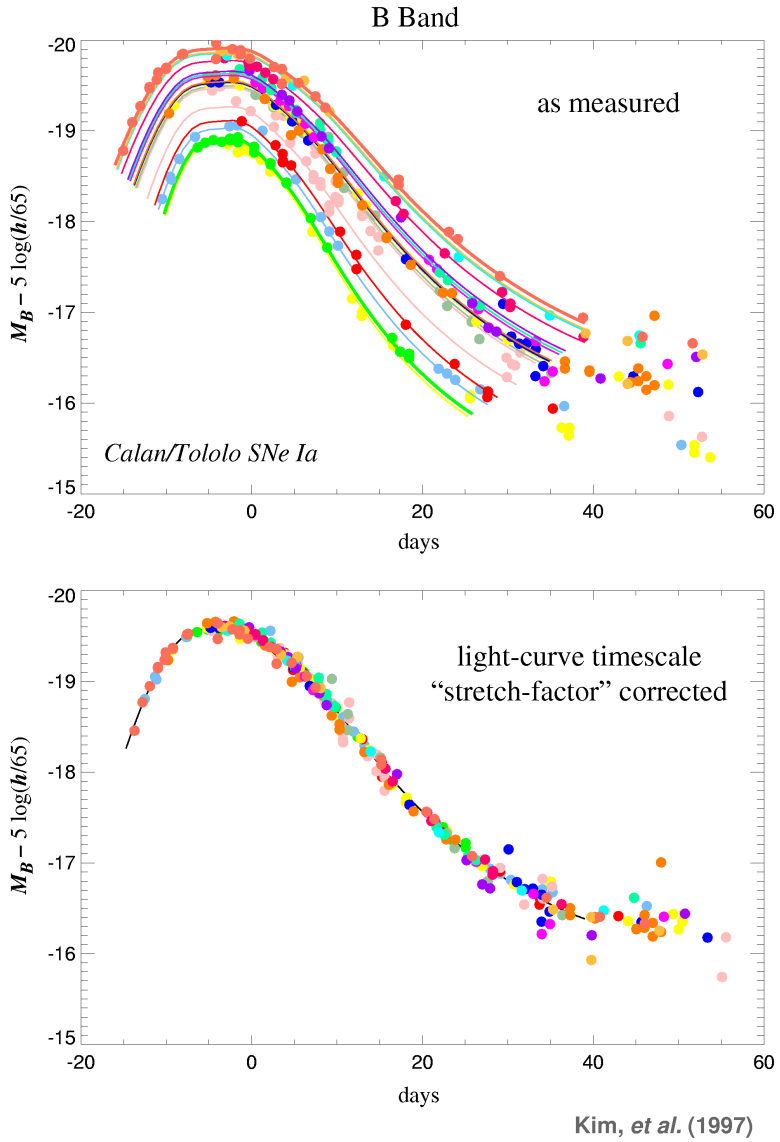


Light curves

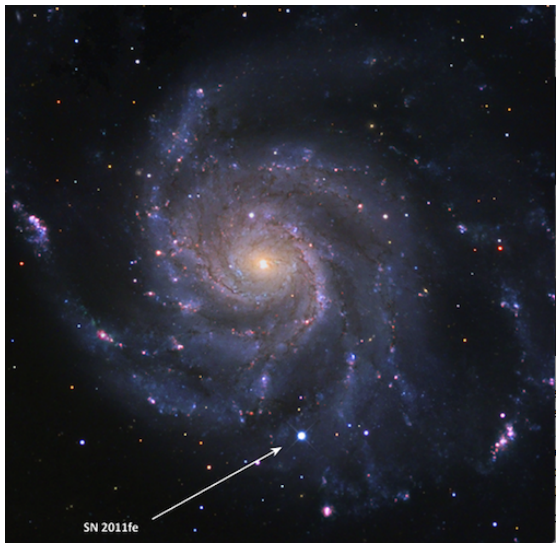


Classification, much information but long acquisition time compare to photometry

SNIa standardization

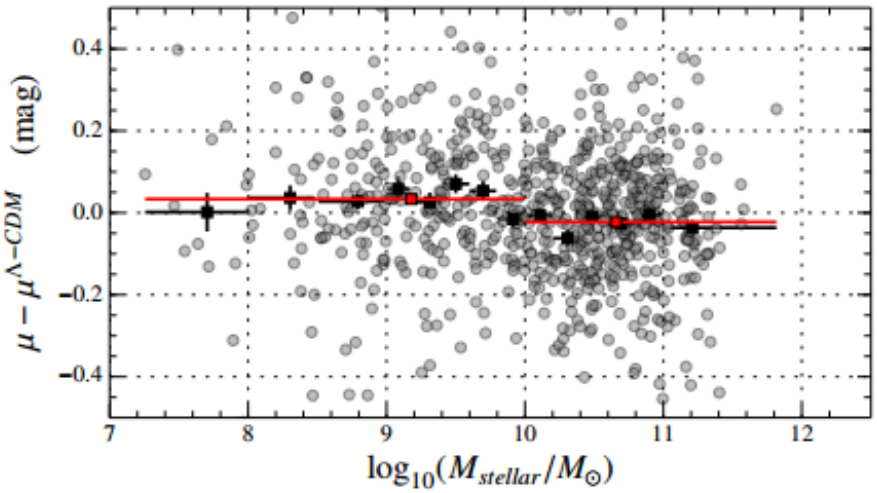


- Standardization:
  $\rightarrow X_1$: Stretch parameter
  $\rightarrow C$: Color parameter
- Fit of this parameter by SALT2 (Spectral adaptative Light-curve Template 2) Guy et al.(2007)

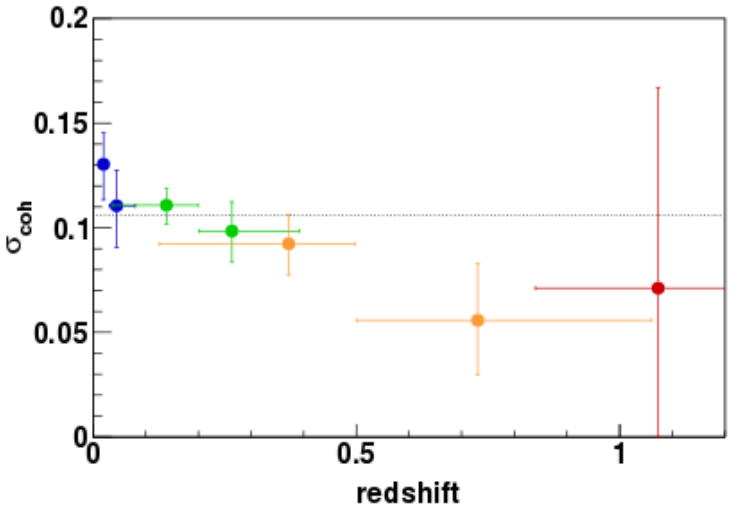


Limit of SALT2 standardization

- Mass step:
  (Betoule et al. 2014)



- Intrinsic variation term:
  (Betoule et al. 2014)

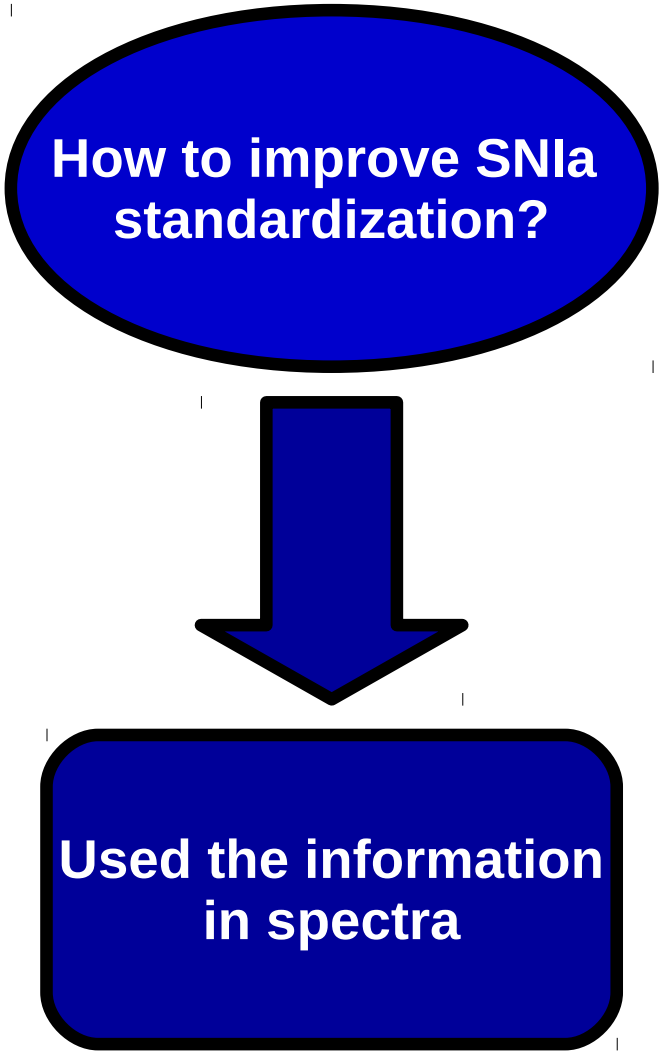


Lowz (Blue)
SDSS (green)
SNLS (orange)
HST (red)

- After standardization intrinsic scatter and a correlation of Hubble residuals with host properties show that SALT2 miss some variabilities

How to improve the standardization?

How to improve the standardization?

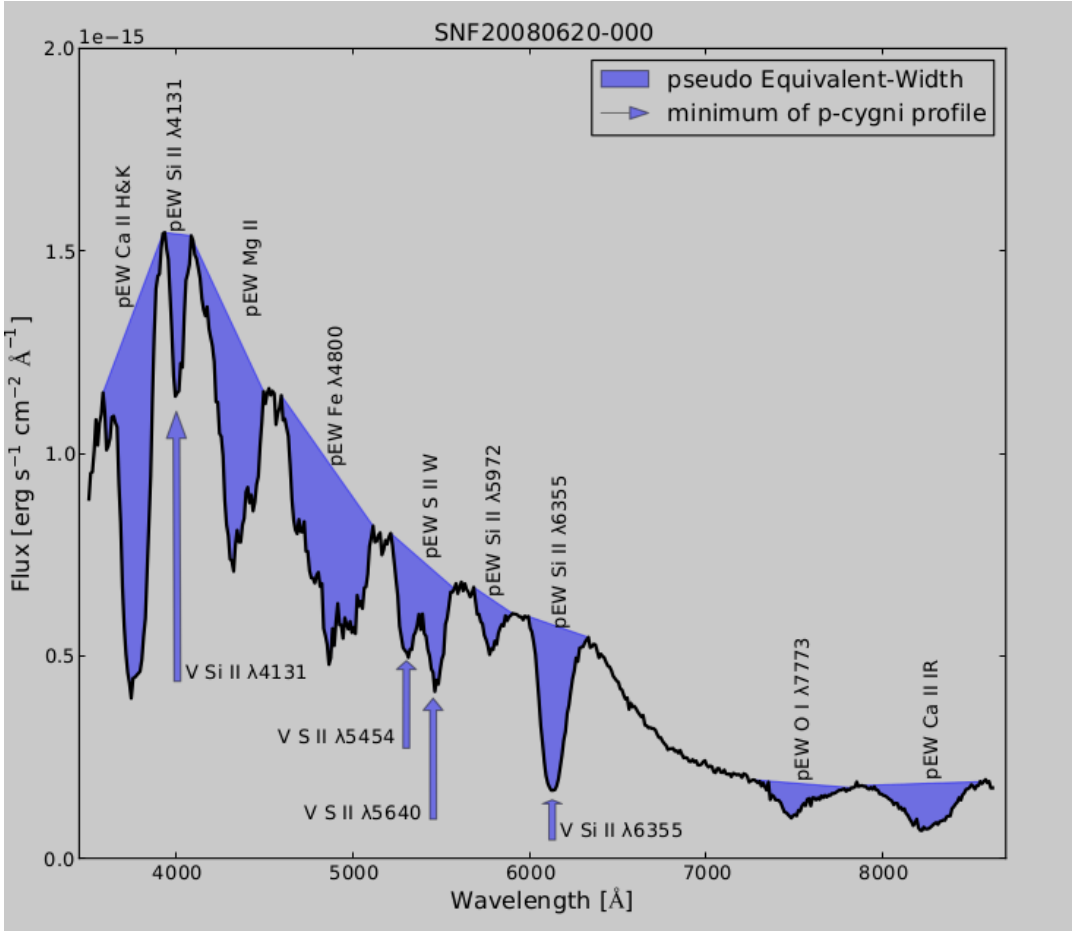


The Nearby Supernova Factory

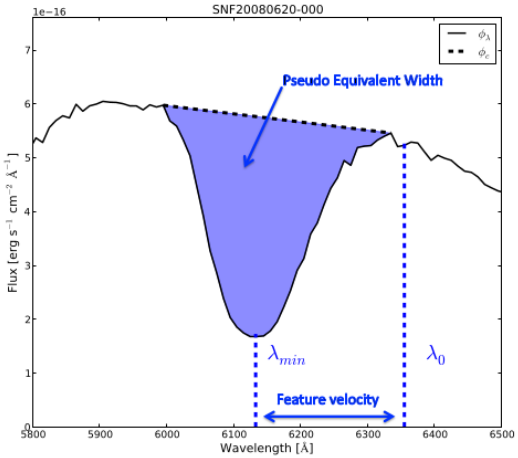
- **Measure nearby SnIa**
- **SnIa search with a 1.2m telescop in Palomar Mountain**
- **Spectrograph used : SNIFS**
- **2.2 Telescop in Hawaii University**

Spectral features to describe SNIa variability

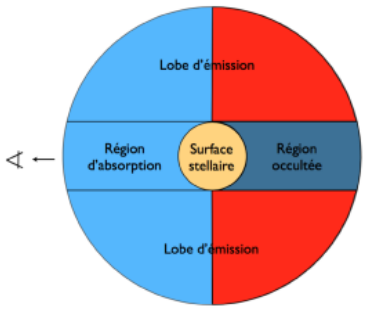
- SNIa spectra

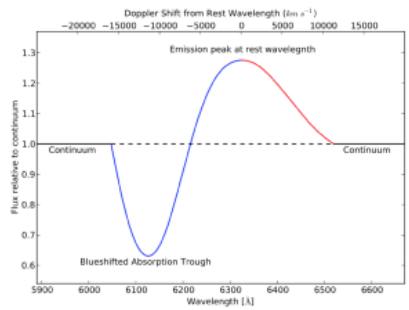


- Pseudo-equivalent width



- P-cygni profile (Chotard et al. 2011)



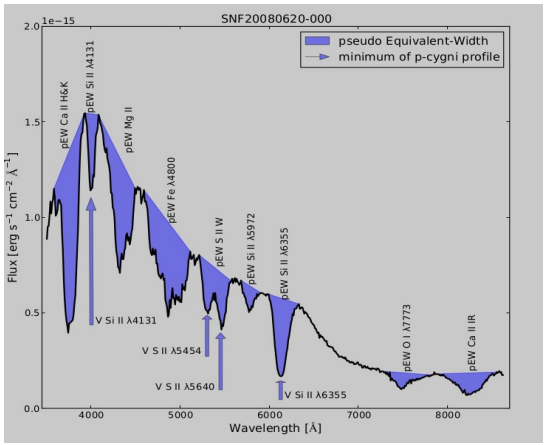


Supernova Useful Generator And Reconstructor (SUGAR)

- SED model done by Pierre-François Léget during his Ph.D. in 2016 based on spectral features (paper in prep.).
- SUGAR model:

$$M_{t,\lambda} = M_{t,\lambda,0} + \sum_{i=1}^{3} q_i \alpha_{t,\lambda,i} + A_V \left(\alpha_\lambda + \frac{1}{R_V} \beta_\lambda \right) + \Delta M_{grey}$$

SUGAR model
Build the model

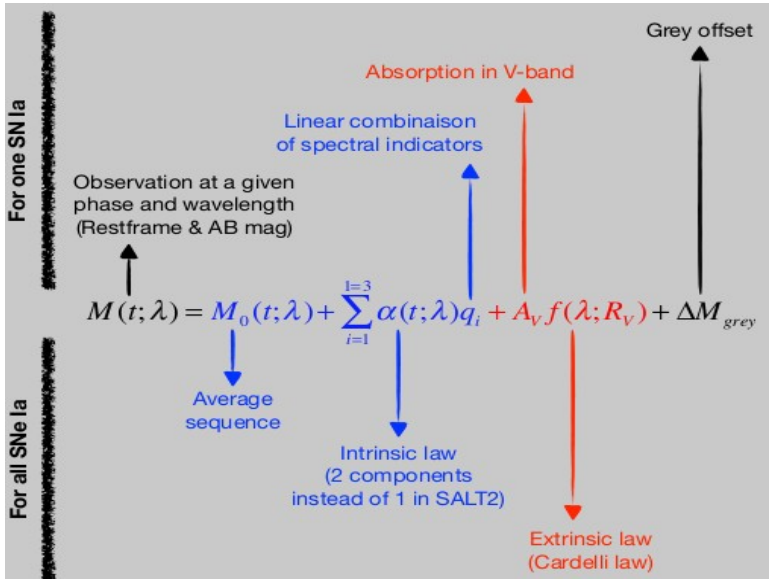


Principal Component Analysis in training set

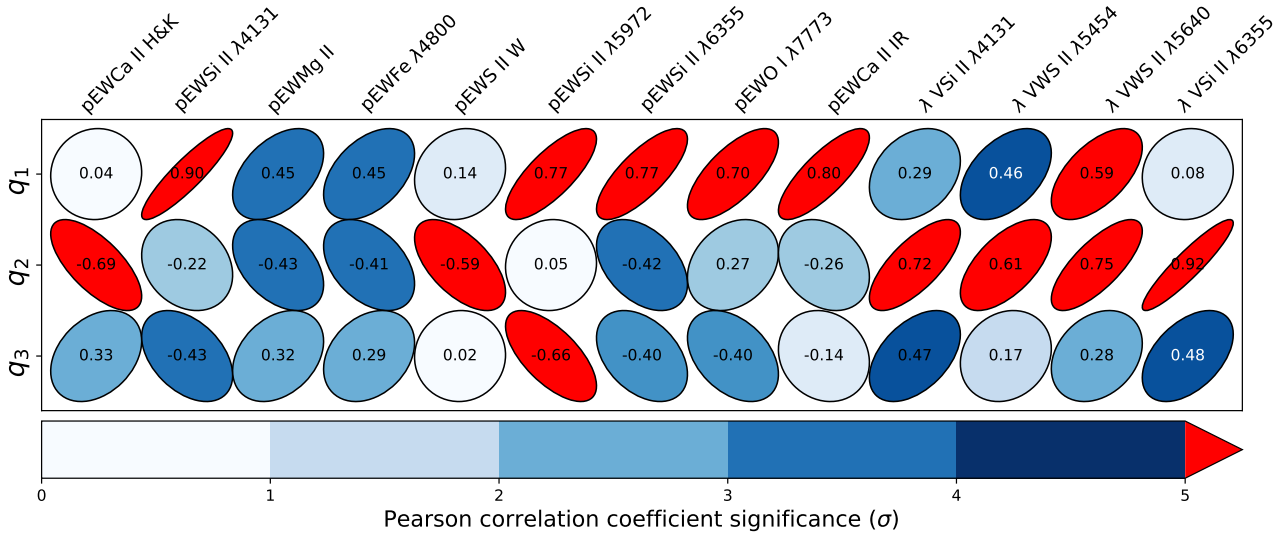
SUGAR parameters q1, q2, q3

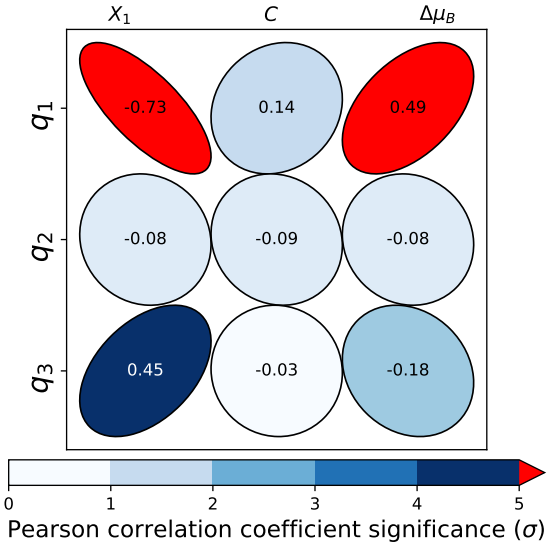
Orthogonal regression

SUGAR model



SUGAR model

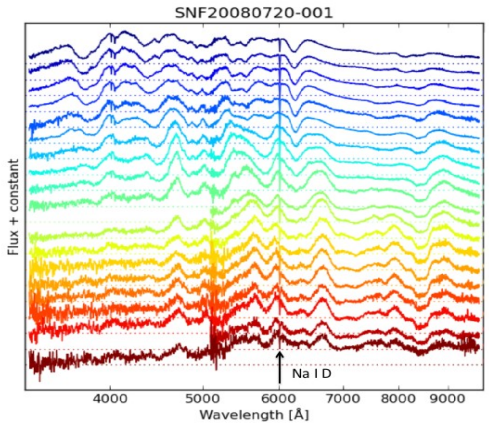


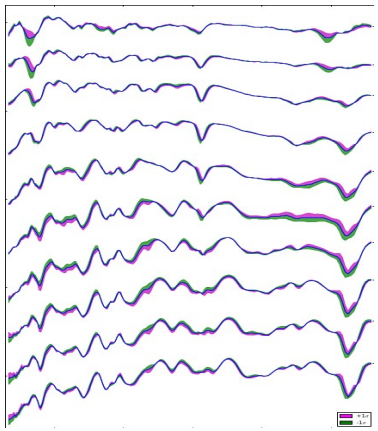


- q1 correlated with pseudo-equivalent widths
- q2 mostly correlated with velocities lines
- q3 is strongly correlated with one pEWSi II

- q1 and q3 are correlated with strech

Fit with SUGAR and spectroscopic data





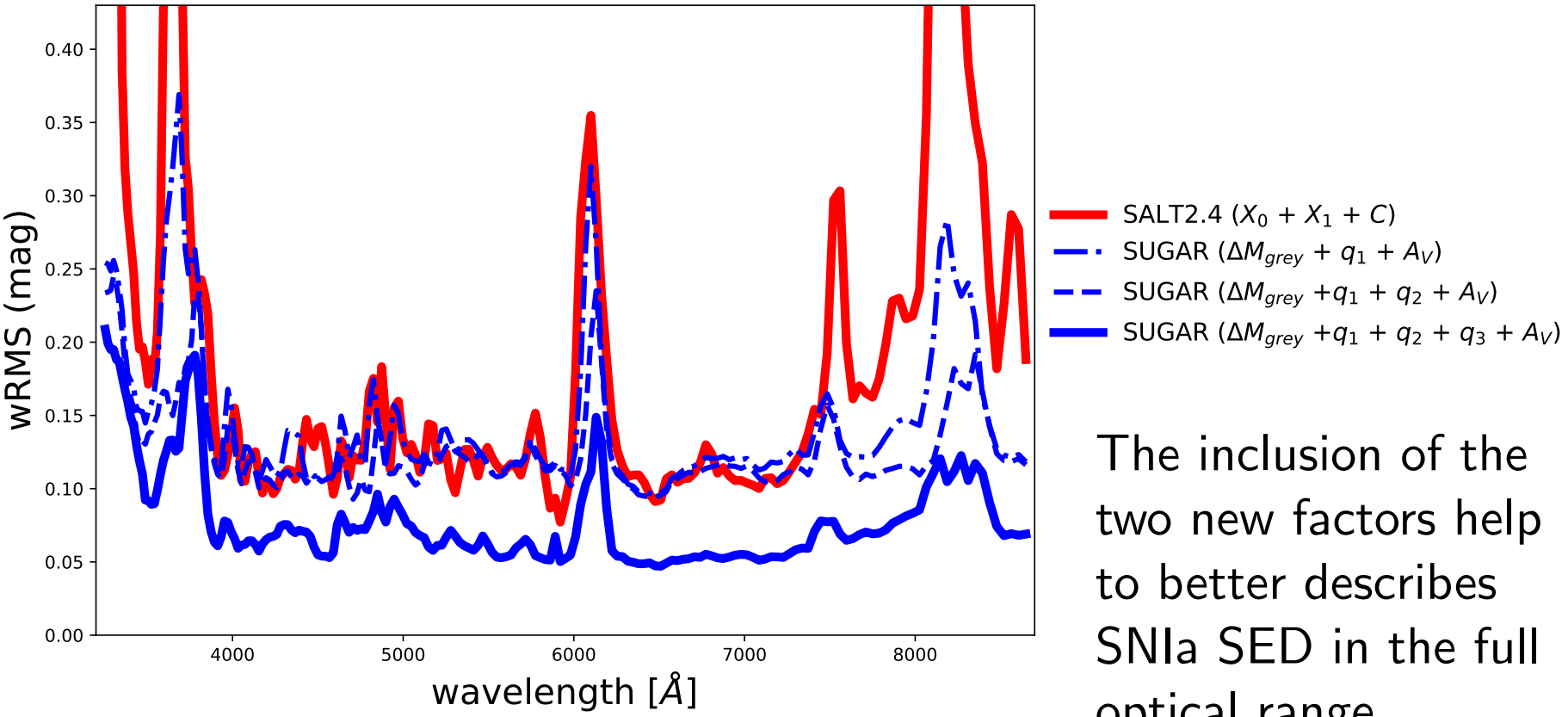
Spectra data

SUGAR model

χ^2 **minimisation**

SUGAR parameters :
- q1
- q2
- q3
- Av

SUGAR model



The inclusion of the two new factors help to better describes SNIa SED in the full optical range.

- Will this model allow to decrease the dispersion in the Hubble diagram fit?

Spectral fit with SUGAR

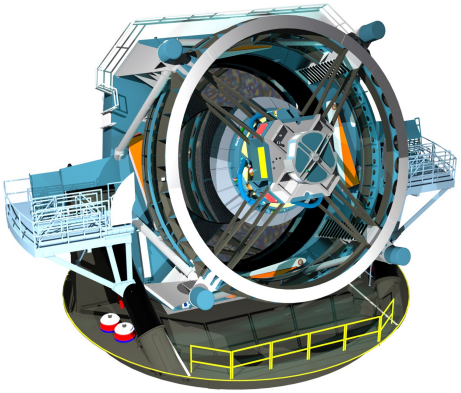
- 103 Supernovae from SNFactory data set
- Hubble fit with :

$$\mu = M_{gr} - cst - \sum_{i=1}^{3} \alpha_i q_i - \beta A_v$$

- Sugar doesn't have an error model (SALT2 has one)

	Salt2 Sncosmo No error model	SUGAR Spectro
σ_{int}	0.1270	0.1173
wrms	0.139± 0.010	0.125± 0.009

LSST: Next generation of cosmological survey

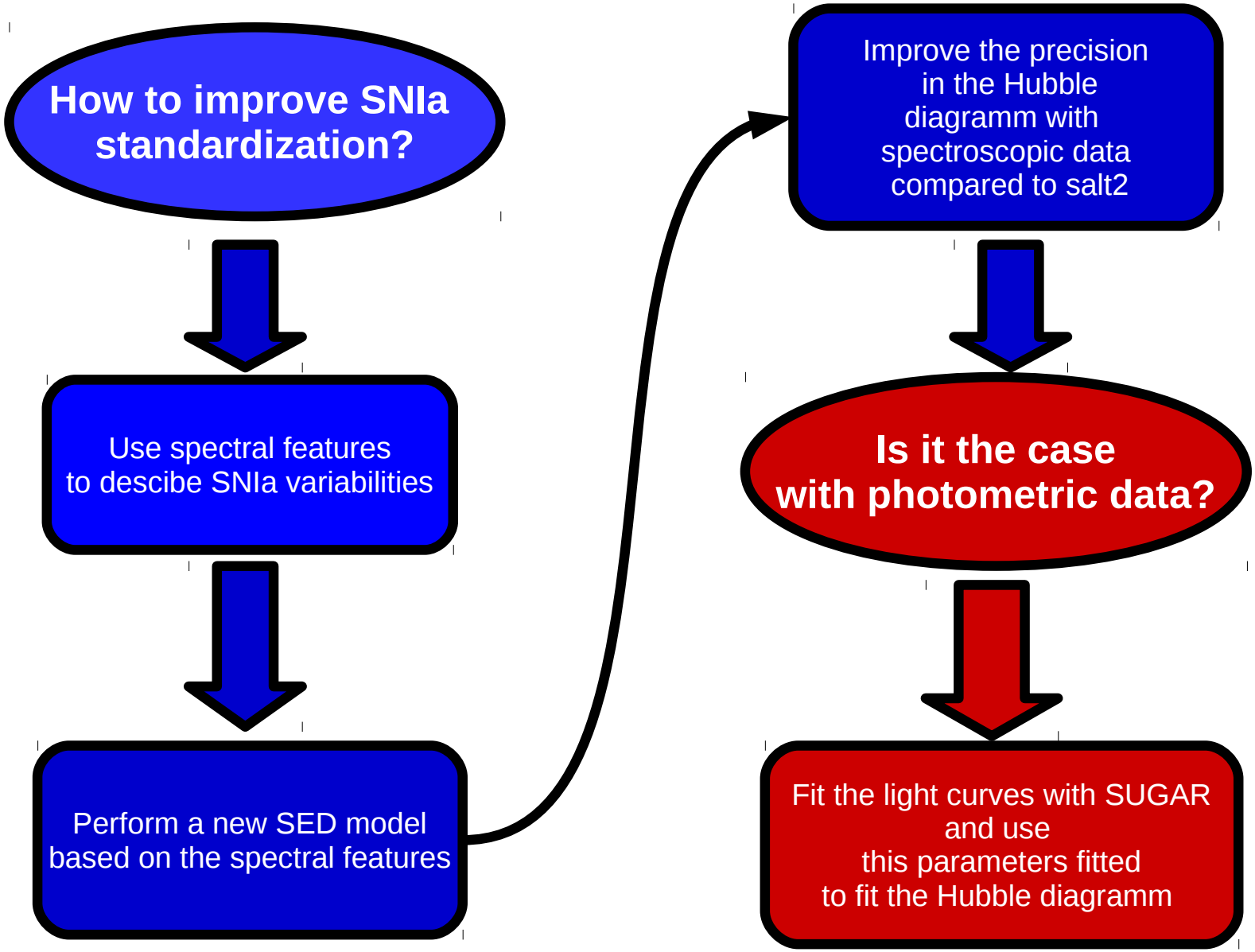


- **8.4 m mirror**
- **Cerro Pachon (Chili), alt = 2682 m**
- **Large fields (9.6 square degrees)**
- **Will visit 20,000 square degrees of the sky**
- **Start of observations: 2020**

SDSS vs LSST

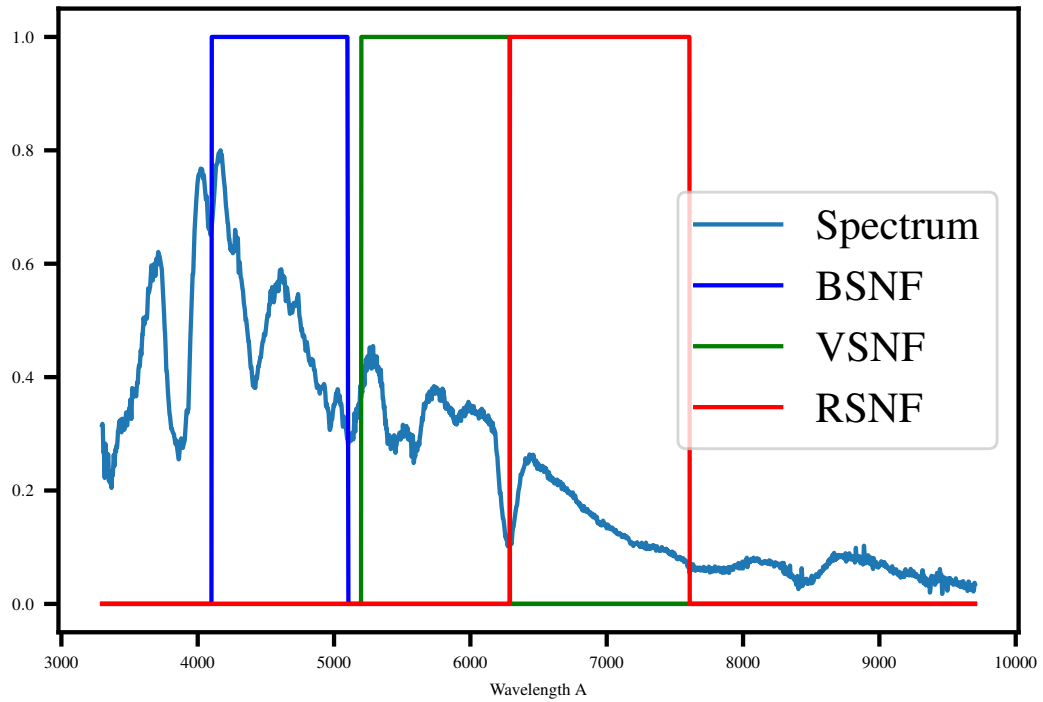
Photometric data only

How to improve the standardization?



Strategy of light curves fitting
Sample used

- Sncosmo
- 100 Supernovae from simulated data
- 103 Supernovae from SNFactory data set
- Bands used : BVR

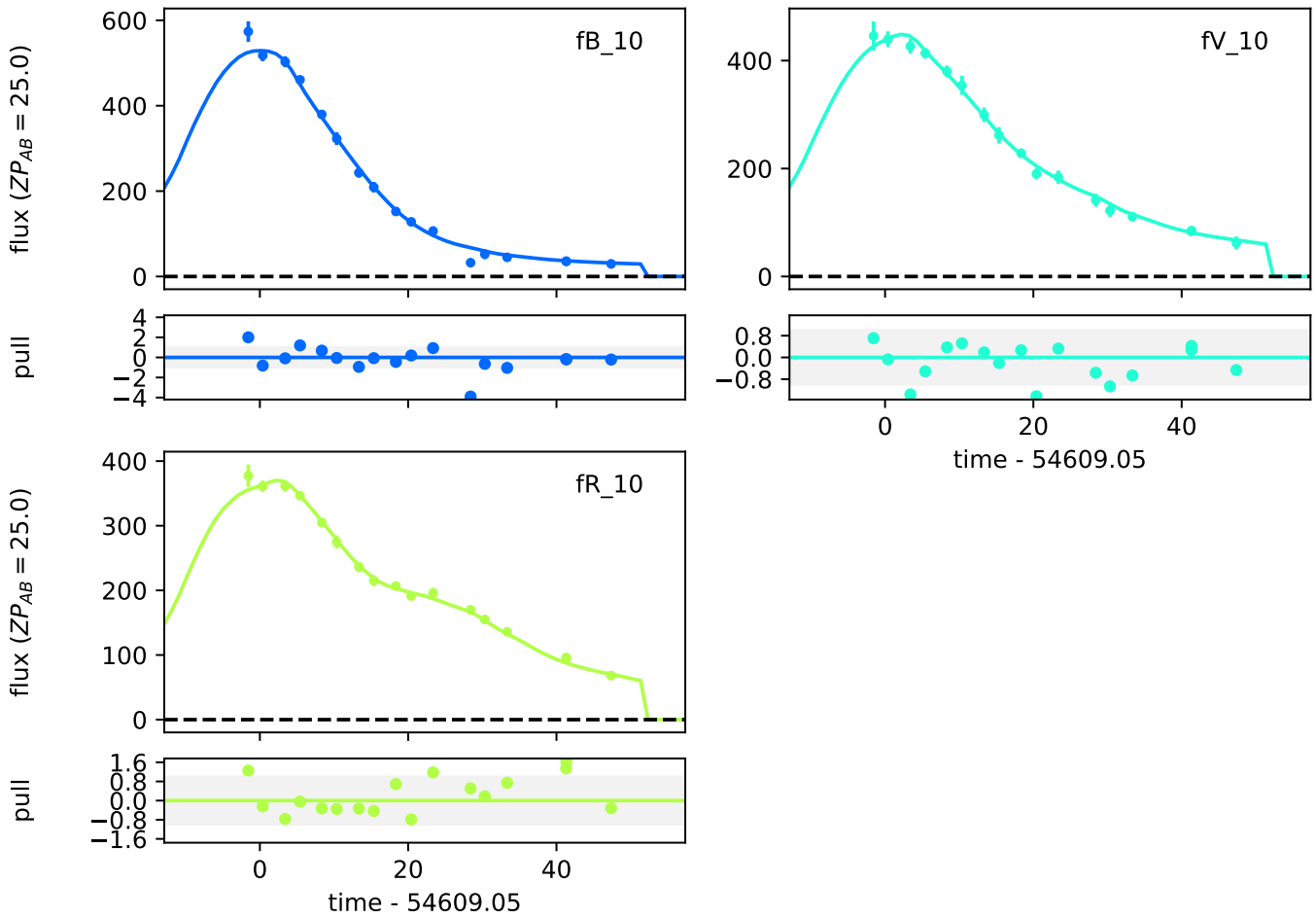


Strategy of light curves fitting

Exemple of fit

$z = 0.074356000$
$t_0 = 54609.045$
$q_1 = -0.10 \pm 0.42$
$q_2 = 1.49 \pm 0.96$
$q_3 = 0.72 \pm 0.29$

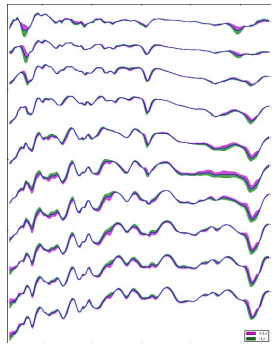
$A = -0.246 \pm 0.048$
$M_g = 37.815 \pm 0.040$
mw $ebv = 0.014300000$
mw $r_v = 3.1000000$



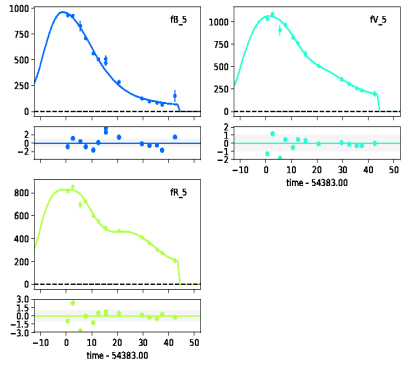
Simulation

Test of the fit with simulated light curves

Pick randomly SUGAR parameters



Build spectra with SUGAR model

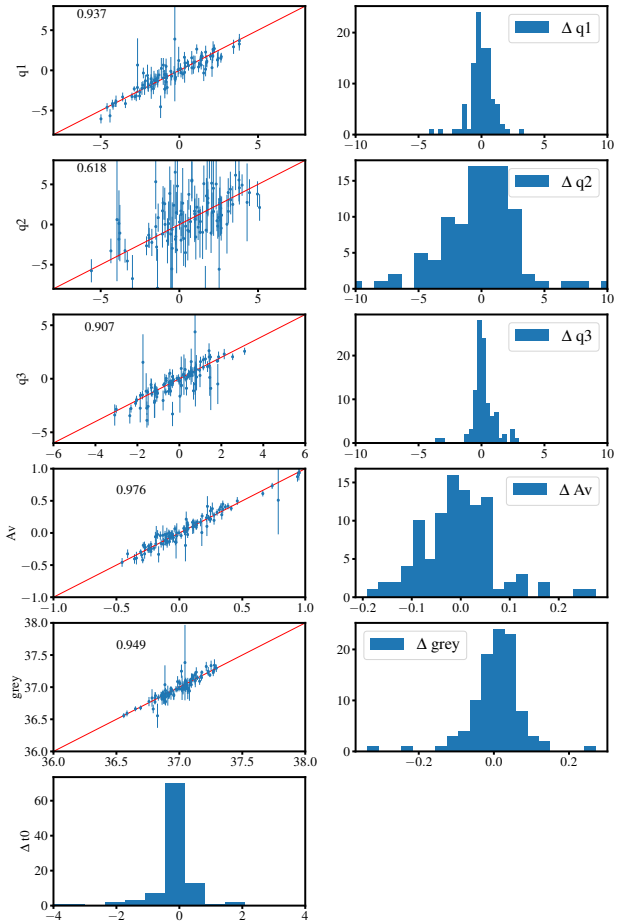


Construct light curves integrating spectra in 3 bands

Fit these light curves with SUGAR and check if we can find the initial parameters

Data quality
Problem of SNF phase

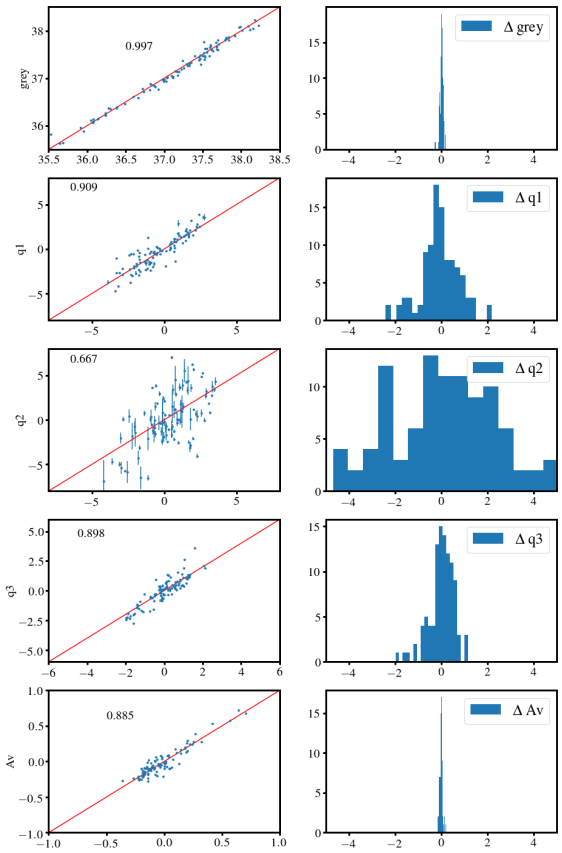
- Results with simulated data / Comparison simulated parameters vs fitted parameters



- Bad reconstruction of q2
- Spread of 2 days in t0 reconstruction

Reconstruction of SUGAR parameters with photometric data

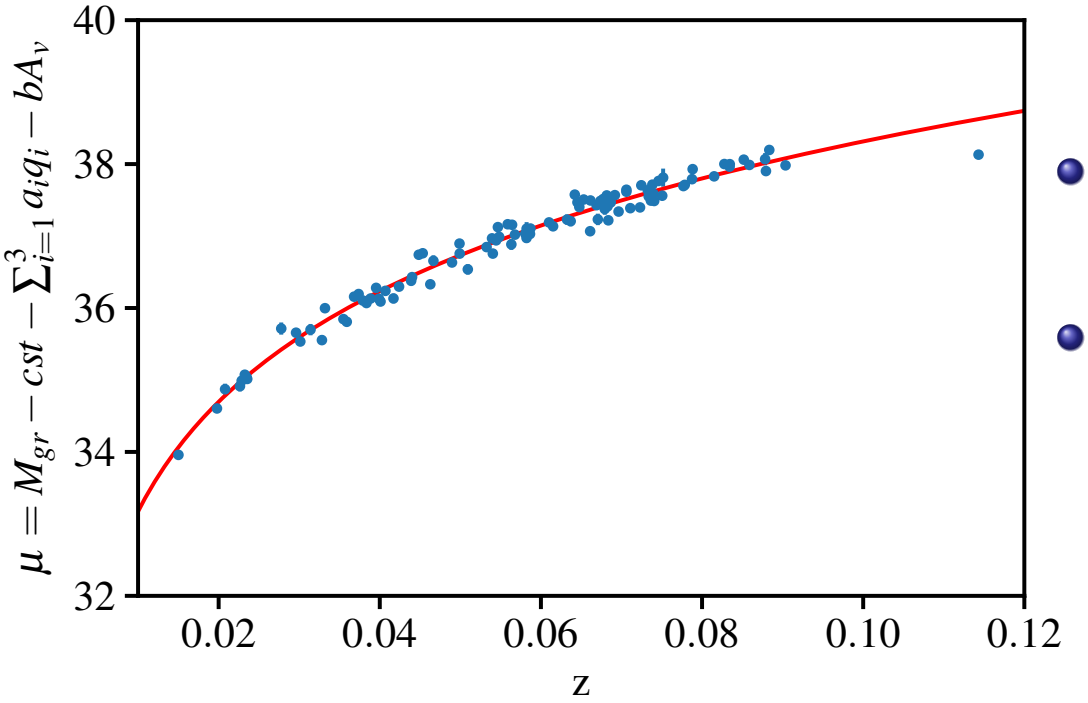
- Results with SNF data / Comparaison with fit spectro



- Bad reconstruction of q2 like in simulation
- q1, q3, Av, Mgrey photo close to spectro

Hubble fit with sugar parameters

Results with 103 SN



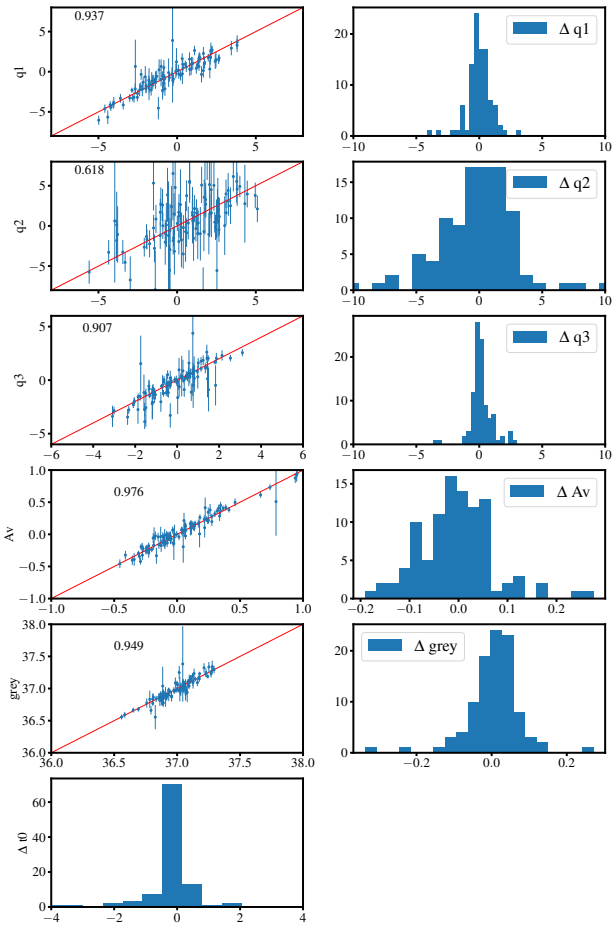
- Hubble fit with intrinsic dispersion
- $\mu = M_{gr} - cst - \sum_{i=1}^{3} \alpha_i q_i - \beta A_v$

	Salt2 Sncosmo No error model	Sugar Spectro	Sugar photo
σ_{int}	0.127	0.117	0.122
wrms	0.139± 0.010	0.125± 0.009	0.132± 0.010

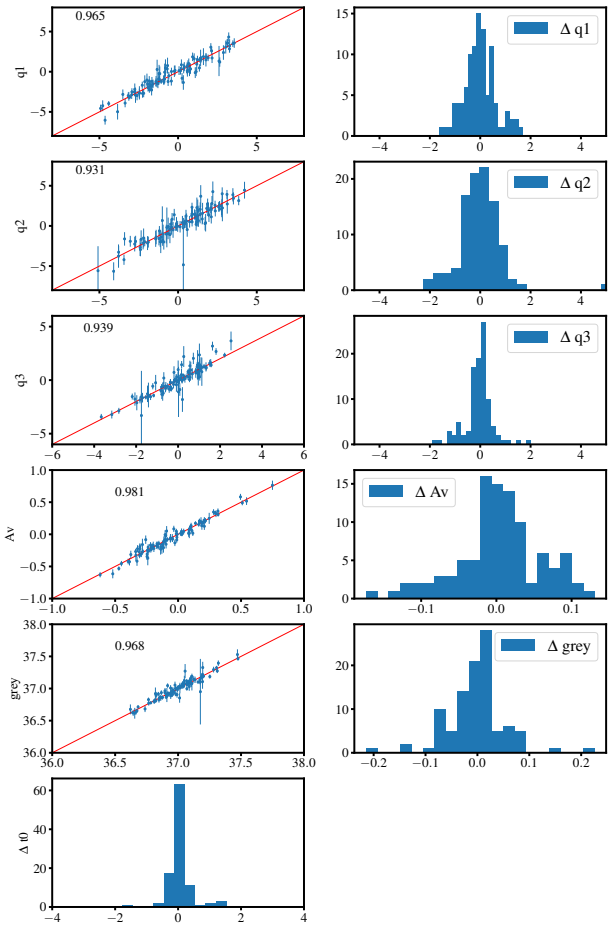
Contribution of the I and U bands

Simulated data with SNF phase

- Fit without U and I band



- Fit with U and I band



Conclusion

- SUGAR reduces the value of the wrms
  - with spectroscopic data
  - Almost as good with photometric data (3 bands)
- Ongoing work:
  - Use I and U bands