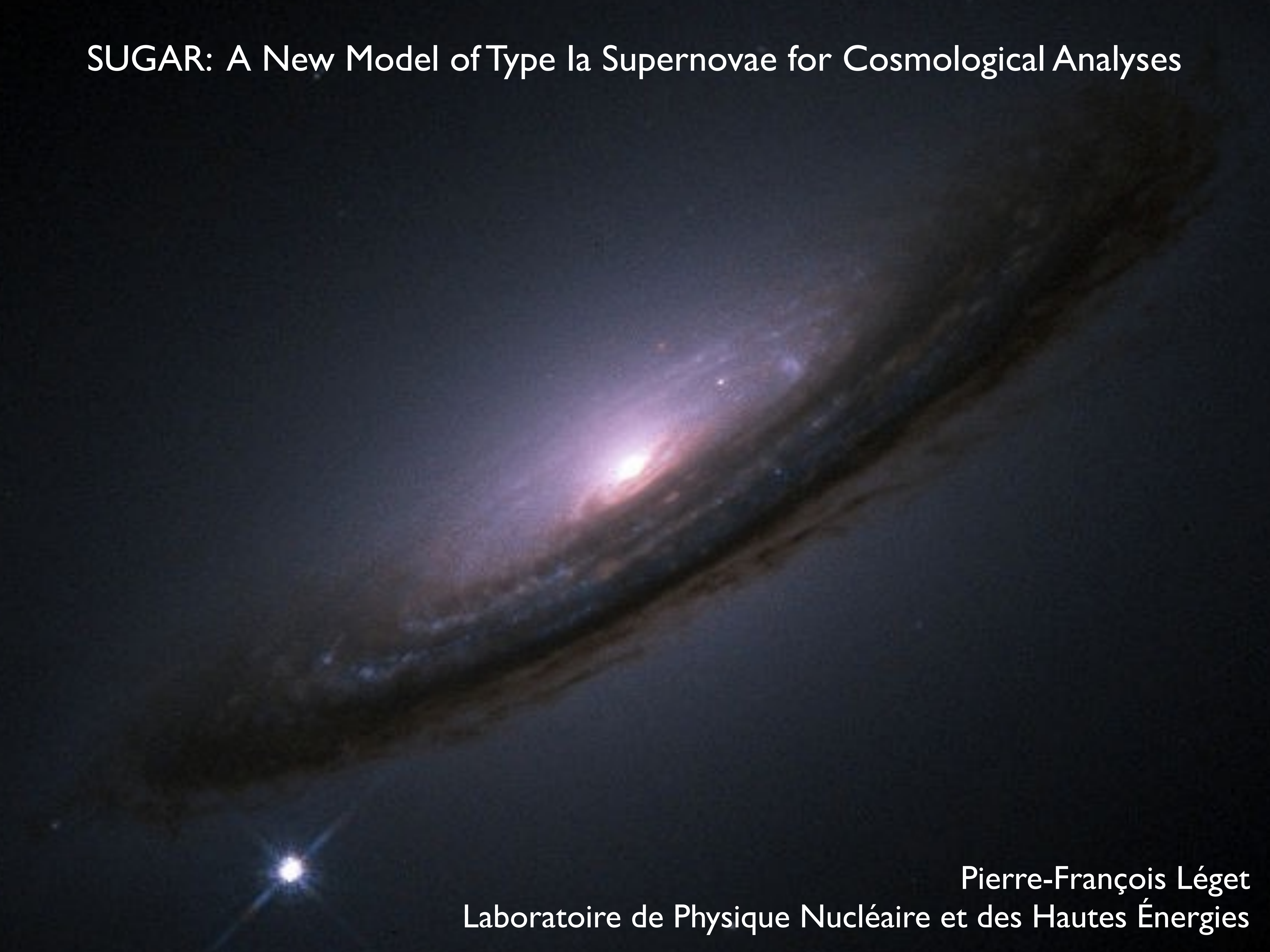
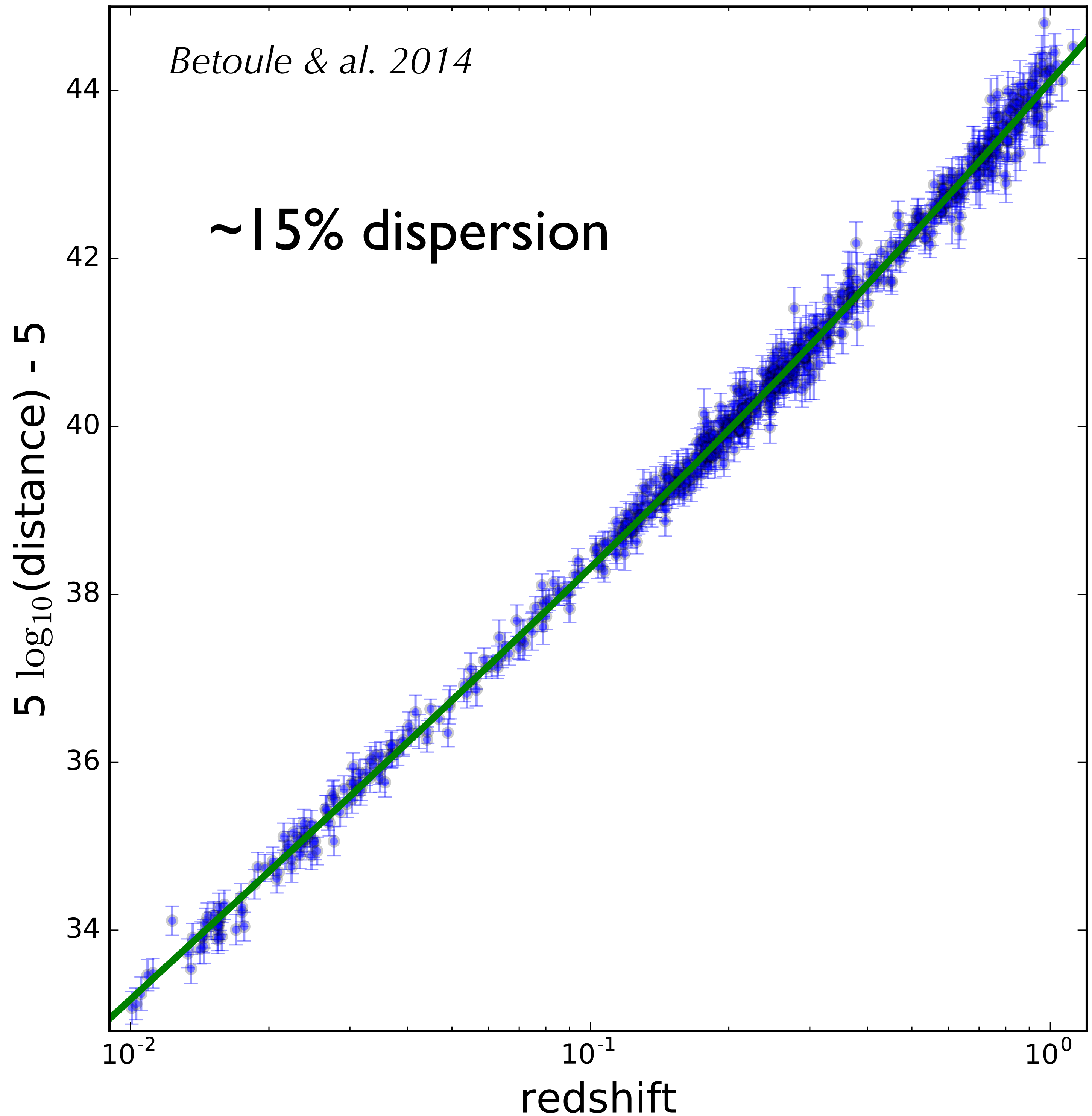


SUGAR: A New Model of Type Ia Supernovae for Cosmological Analyses

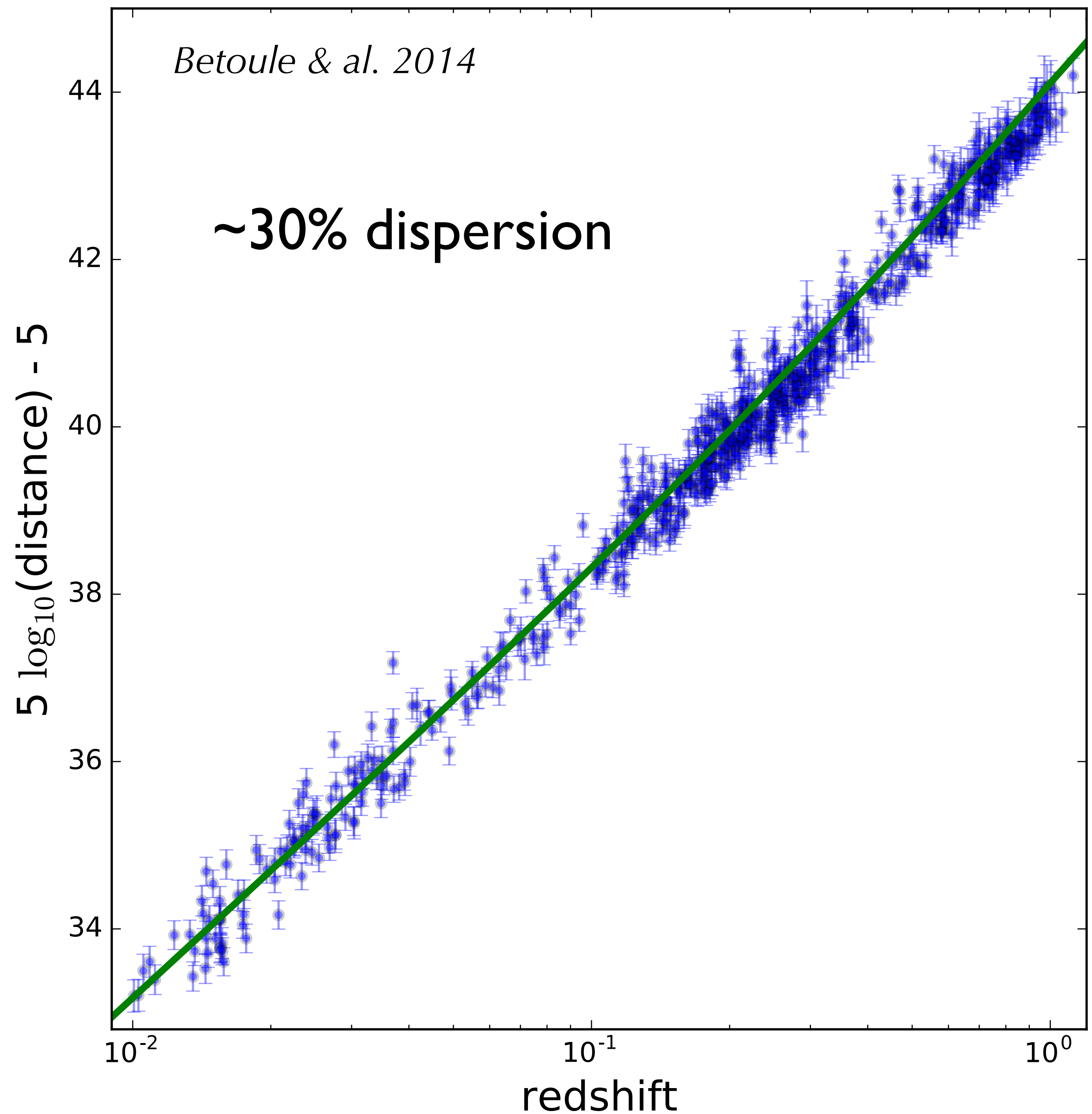
Pierre-François Léget
Laboratoire de Physique Nucléaire et des Hautes Énergies

SNIa are standard candle



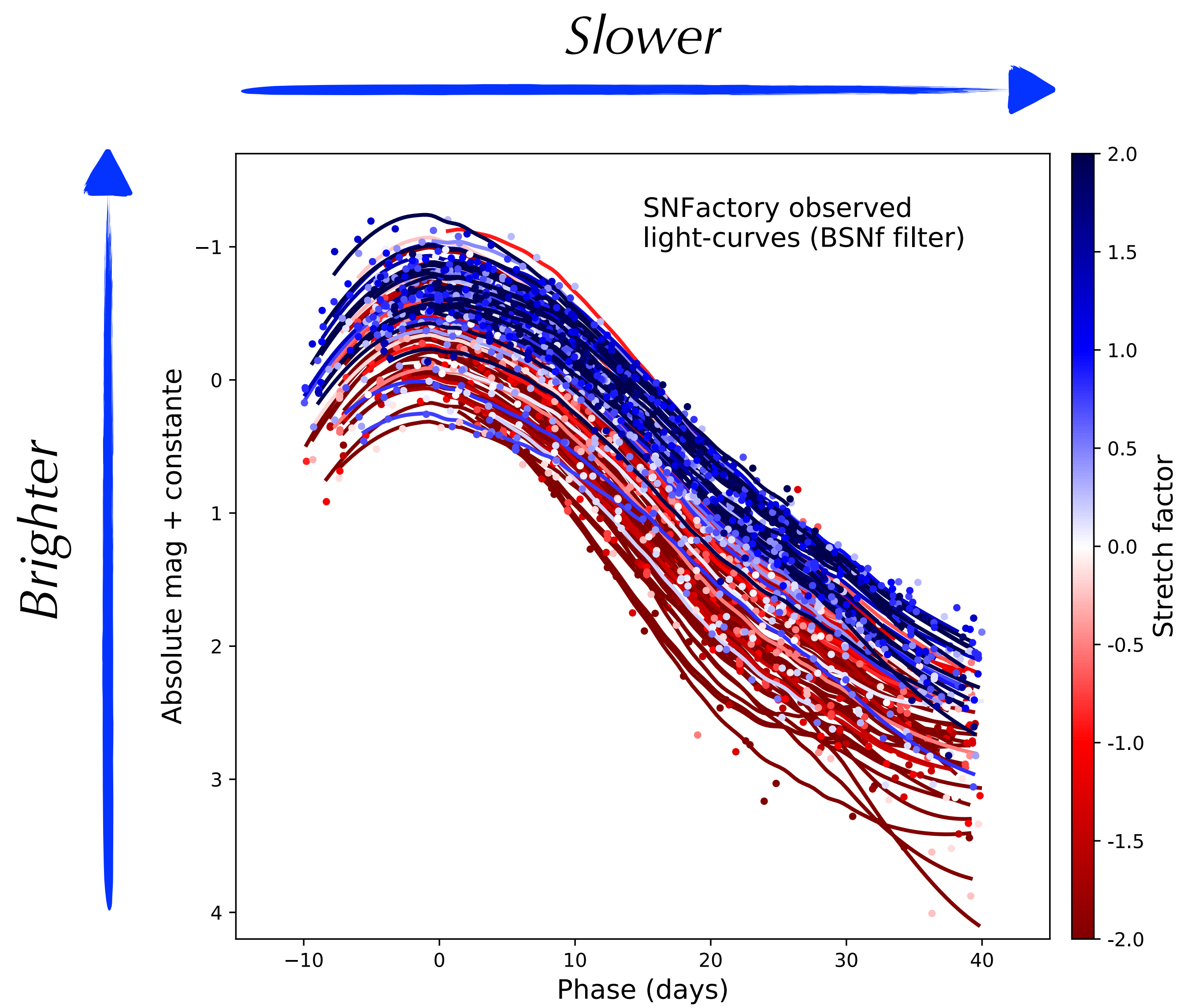
~~SNIa are standard candle~~

SNIa are quasi-standard candle



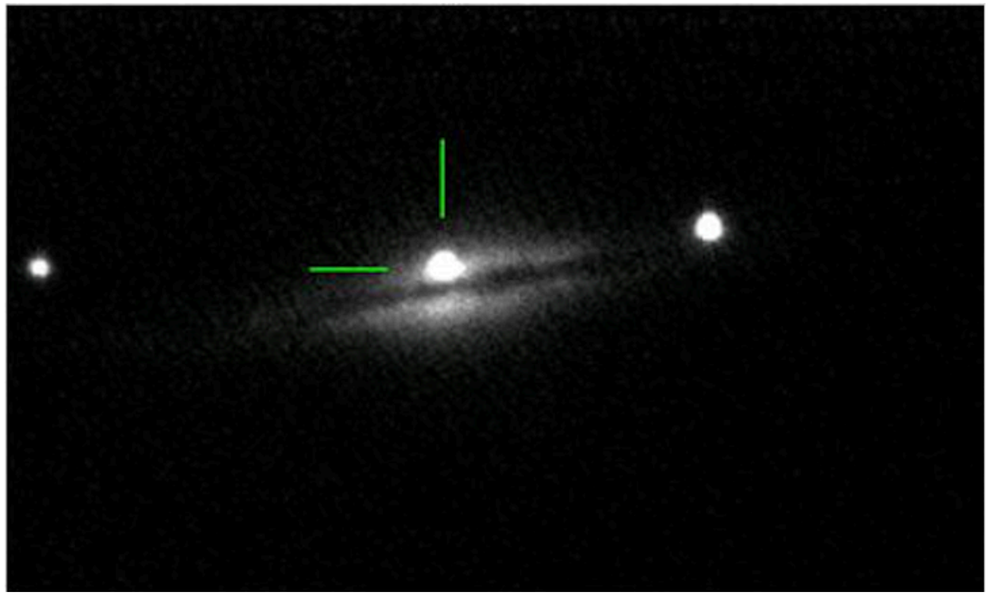
Stretch effect: Intrinsic variability

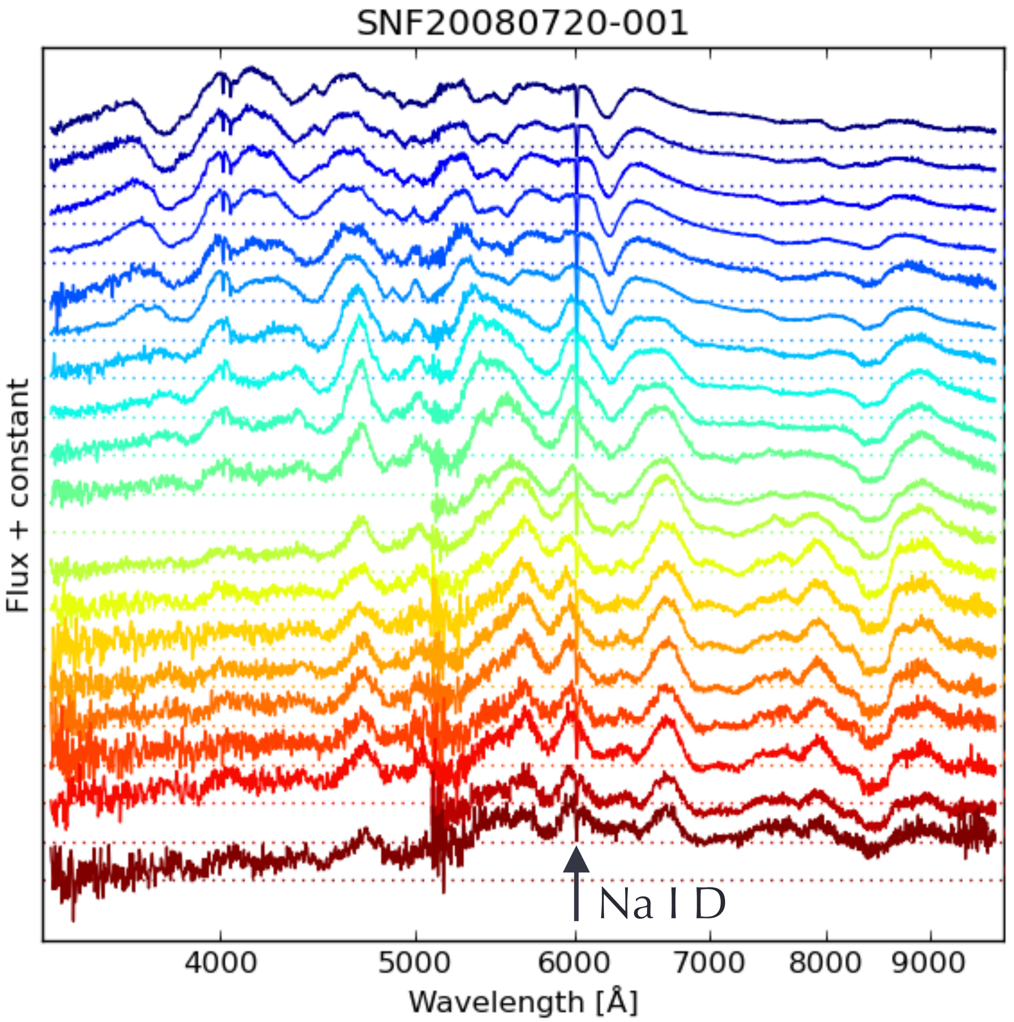
- Related to the explosion physics
- ~ Masse of progenitor
- ~ Quantity of ^{56}Ni
- Known since the 70's:
  - β (Pskovskii 1977)
  - ΔM_{15} (Philips 1993)
  - X_1 (Guy el al. 2007)



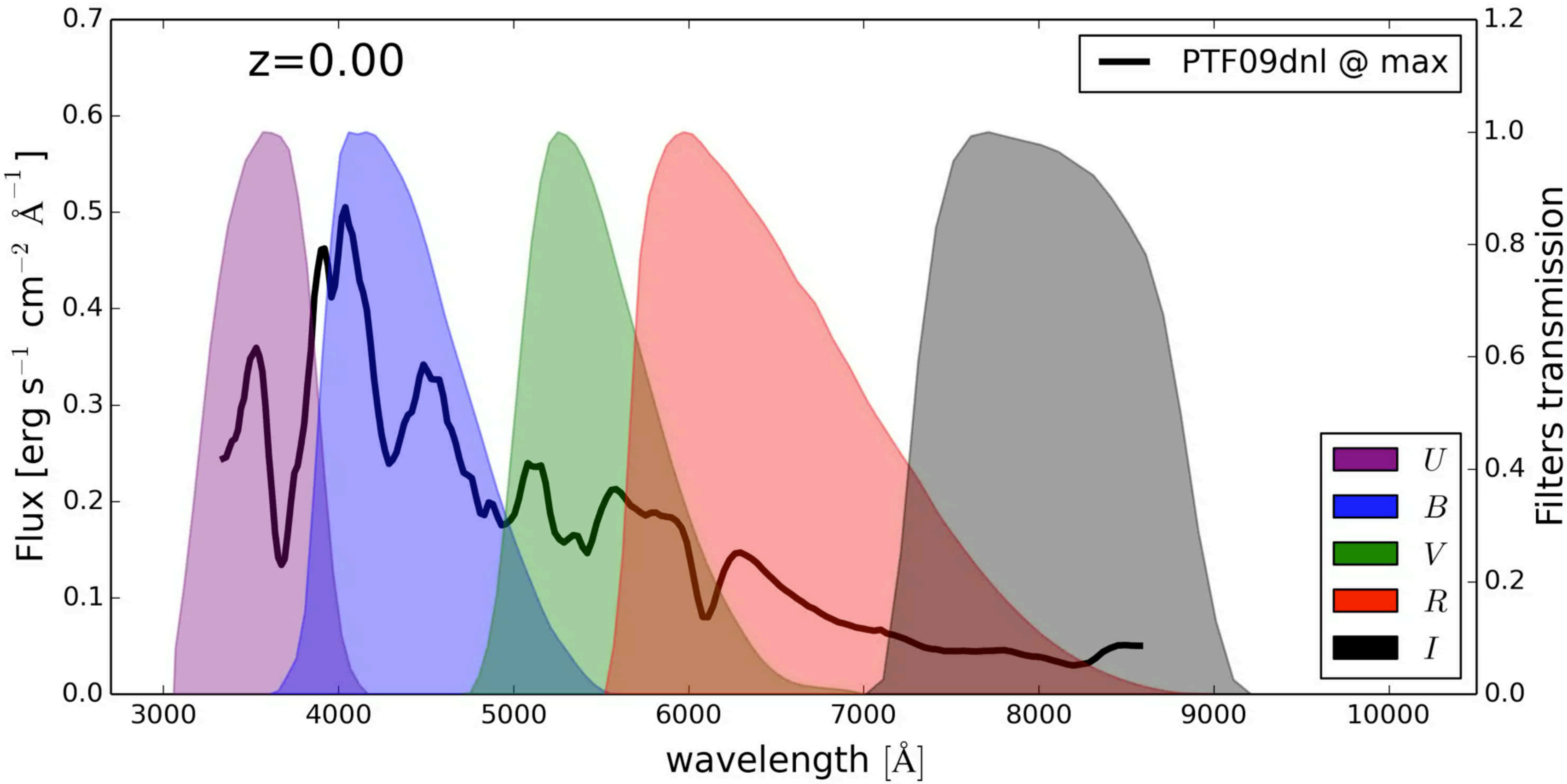
Color: extrinsic properties

- Mainly extinction due to host dust
- Become more red
- Can be accompanied by ISM absorption line of sodium
- Known since the 90's





K-correction



- Stretch & color: Measured on light curves with photometric survey
- Need a SNIa model to take into account redshift effect

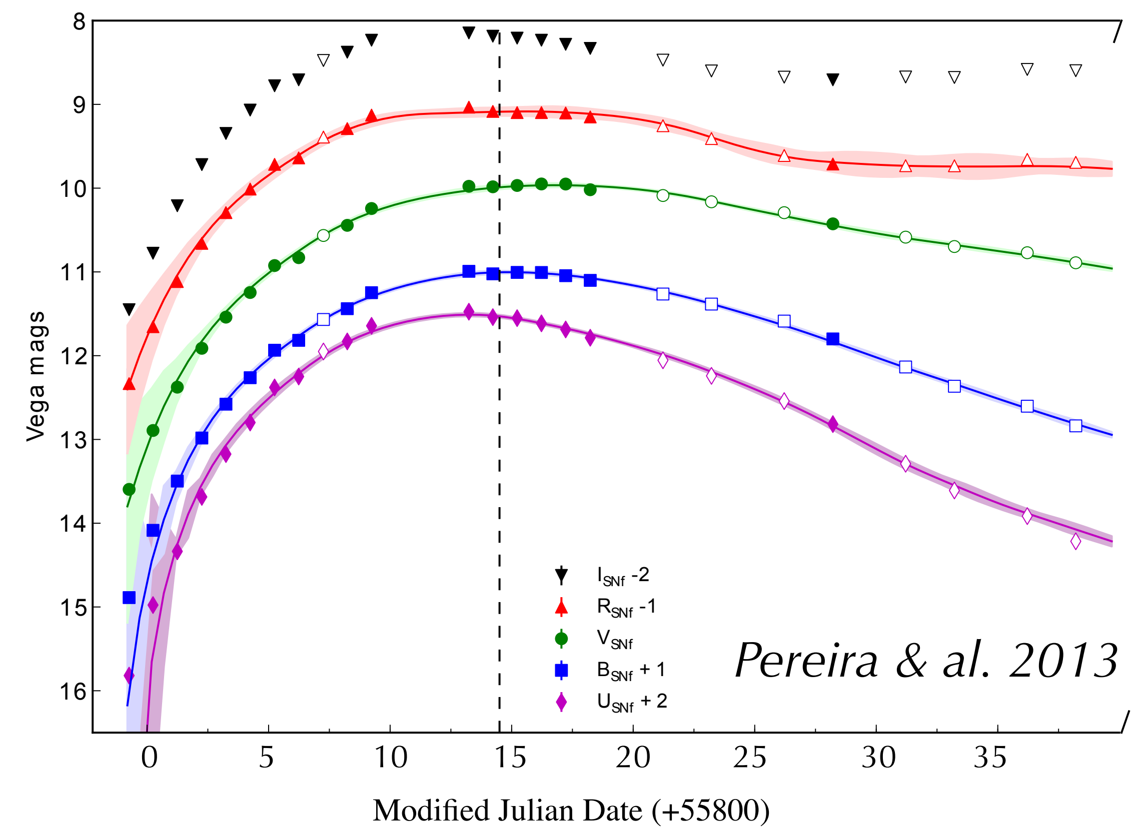
SALT2 (*Guy et al. 2007*):

$$F(t;\lambda) = X_0\left[S_0(t;\lambda) + X_1 S_1(t;\lambda)\right] \times \exp\left[C \times CL(\lambda)\right]$$

X_0: Correlated to redshift

X_1: Stretch effect, associated with intrinsic variability

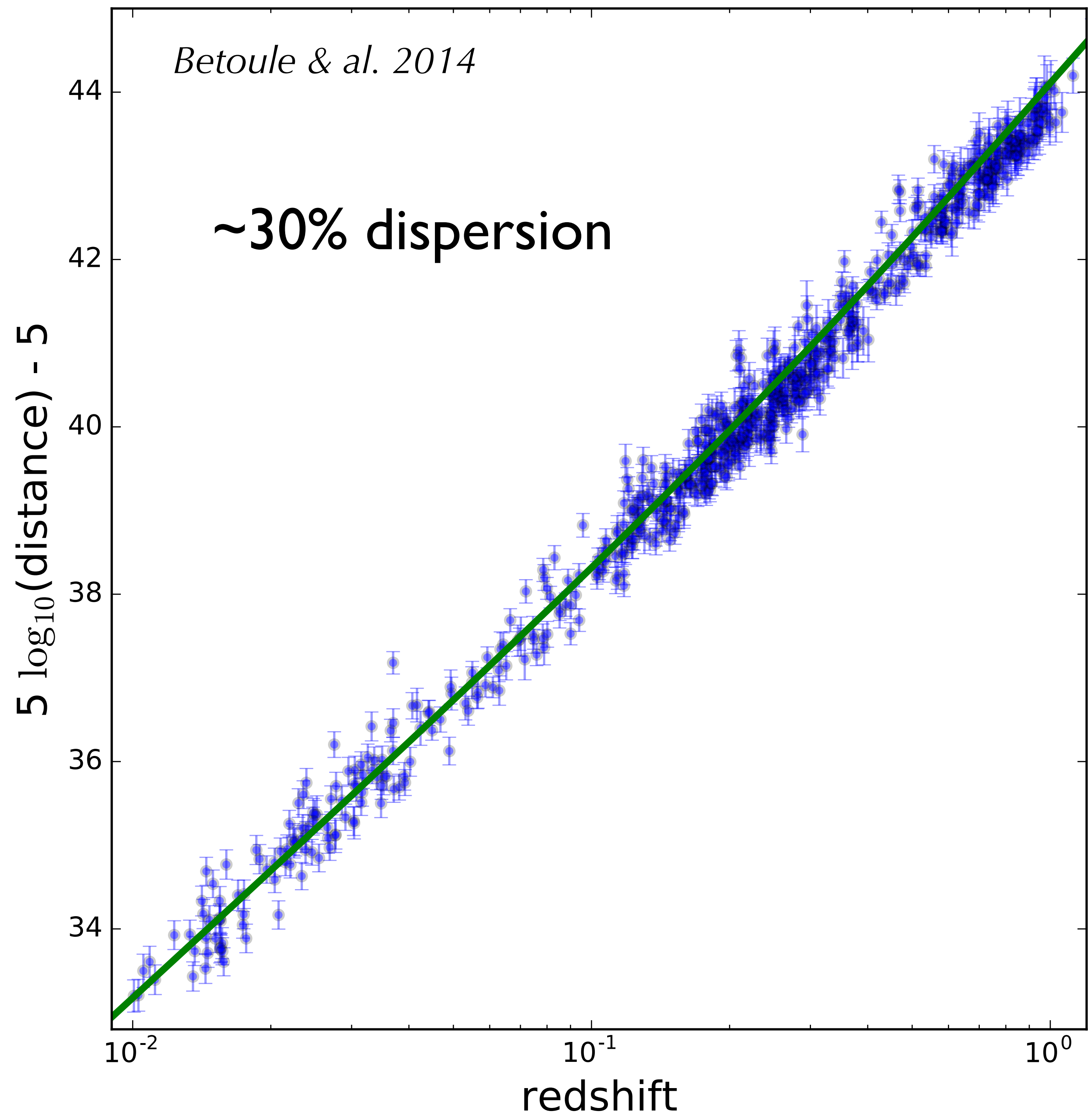
C: Color effect, which adjusts the global SNIa color (intrinsic and extrinsic color)



Standardisation

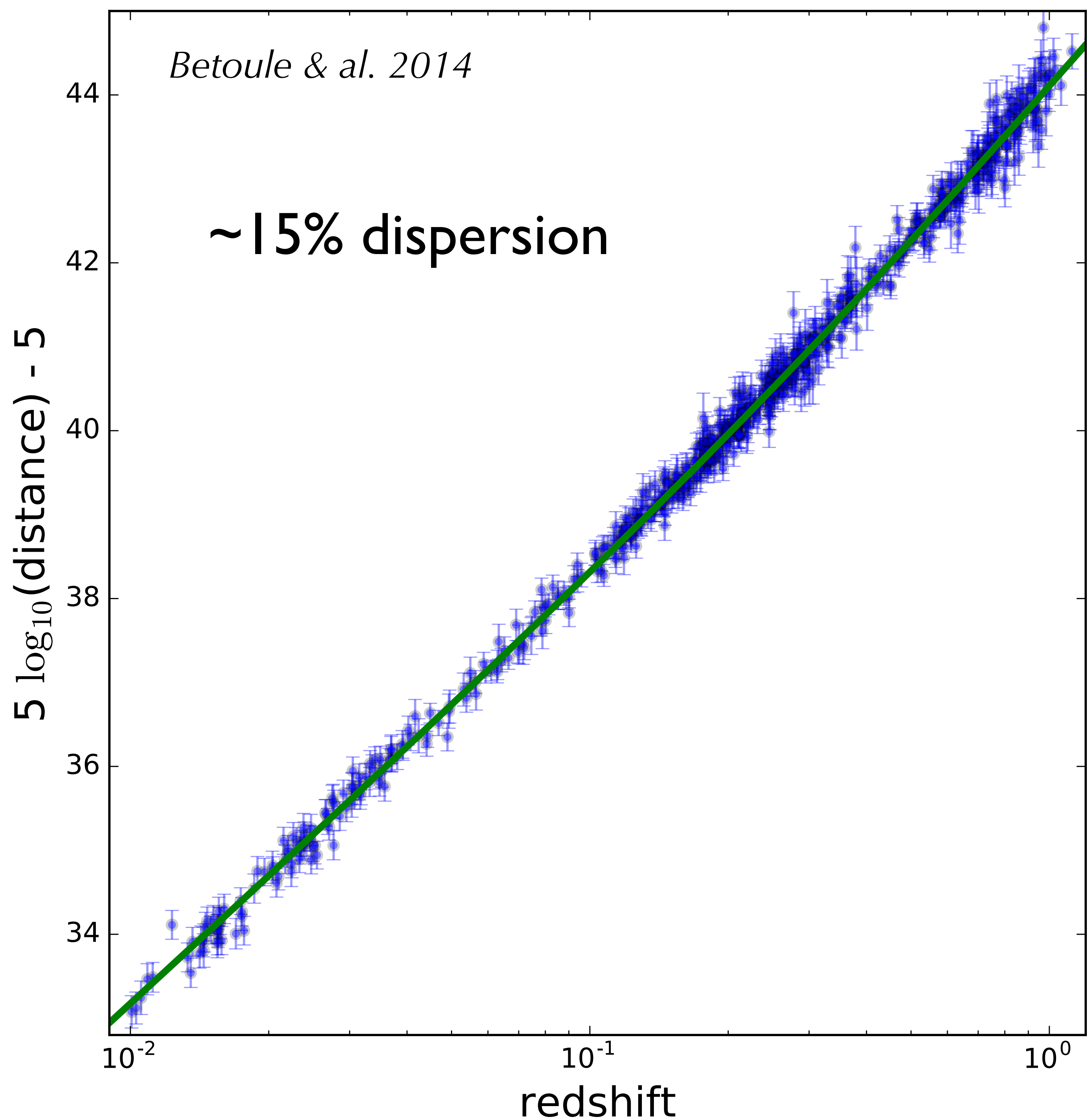
Without any correction

~30% dispersion



Standardisation

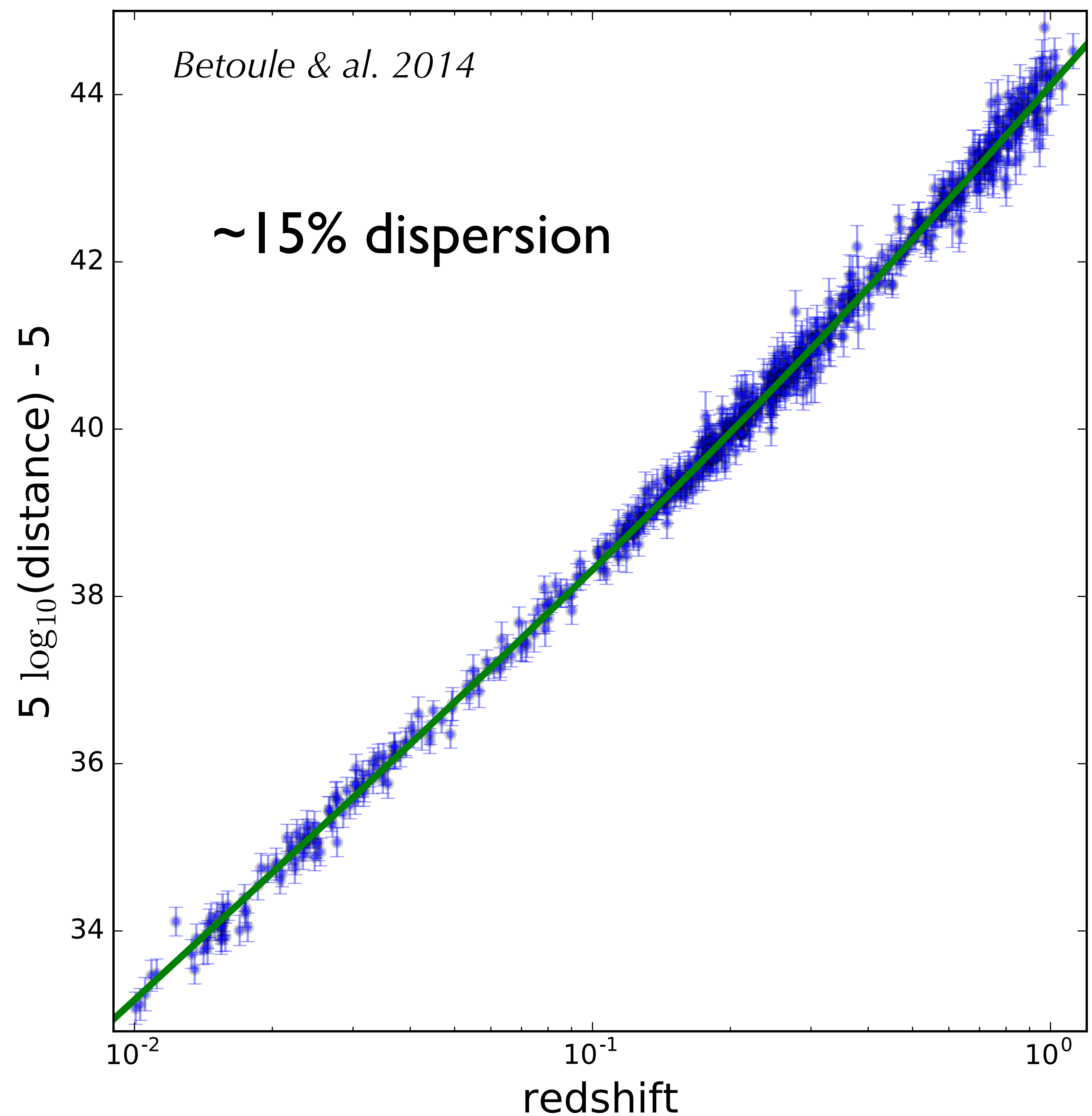
Stretch and color corrected



Standardisation

Stretch and color corrected

remaining dispersion not explained by the noise variance, and other problems…



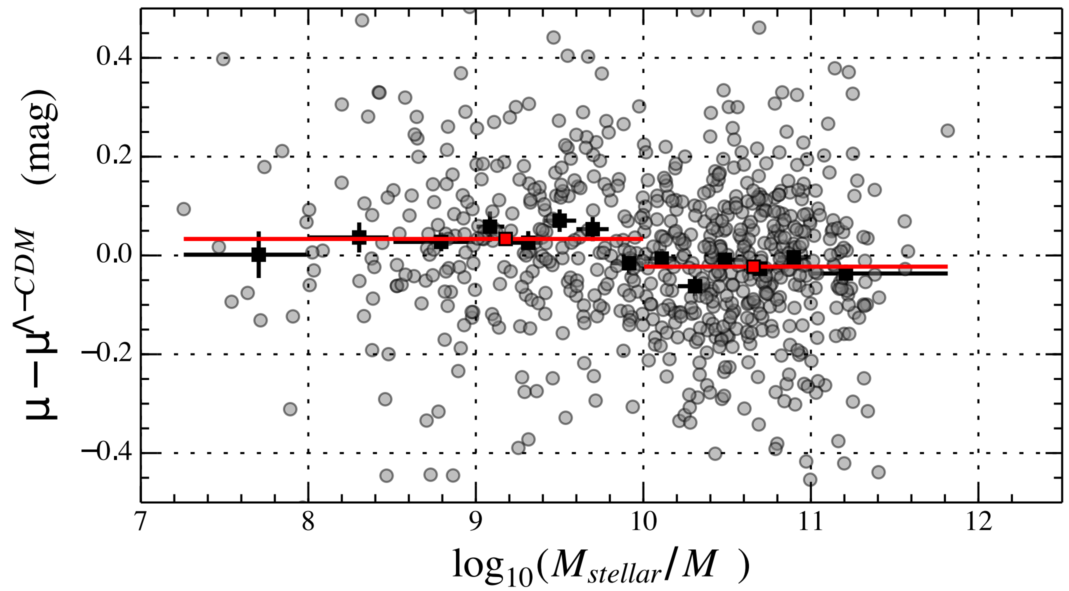
Host properties

- Dependency of Hubble residuals after standardisation with Host mass

- Correlated to local Host properties

- Bias in the cosmology analysis: Host mass added to standardise SNIa

Betoule & al. 2014



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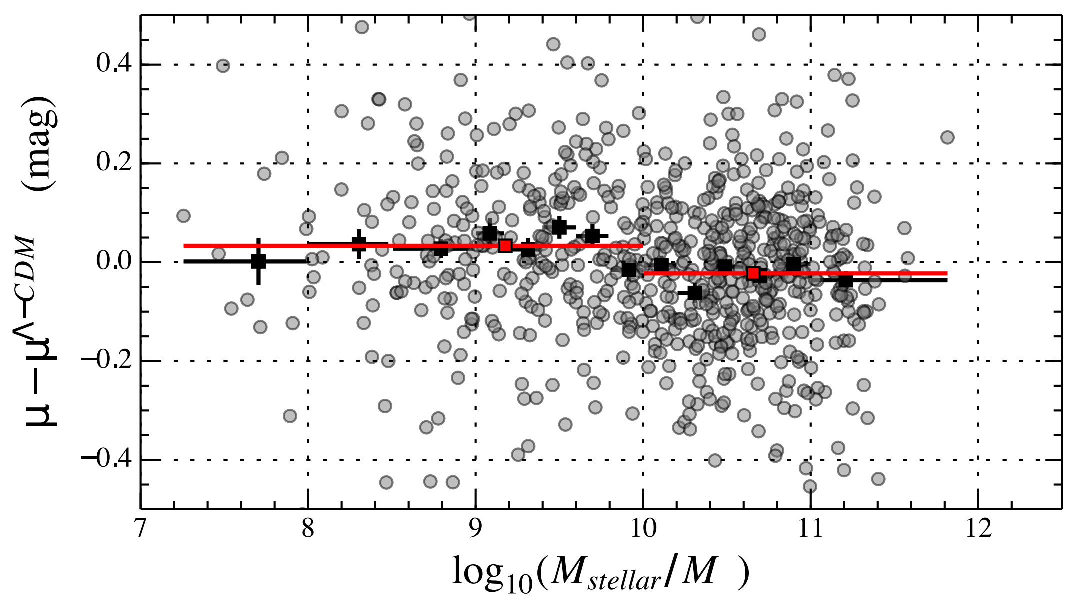
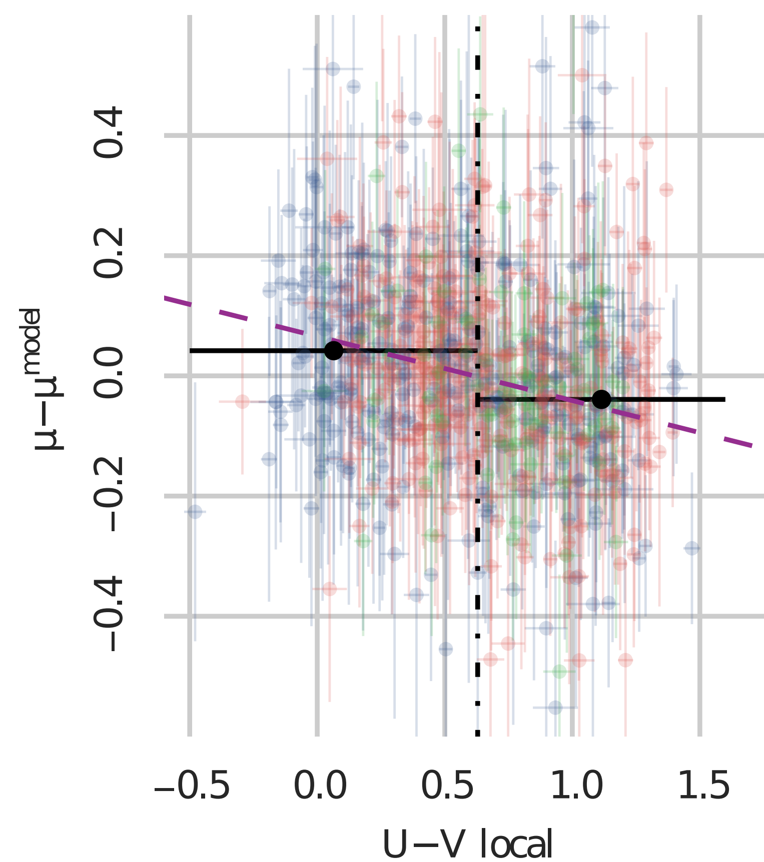


Roman & al. 2017



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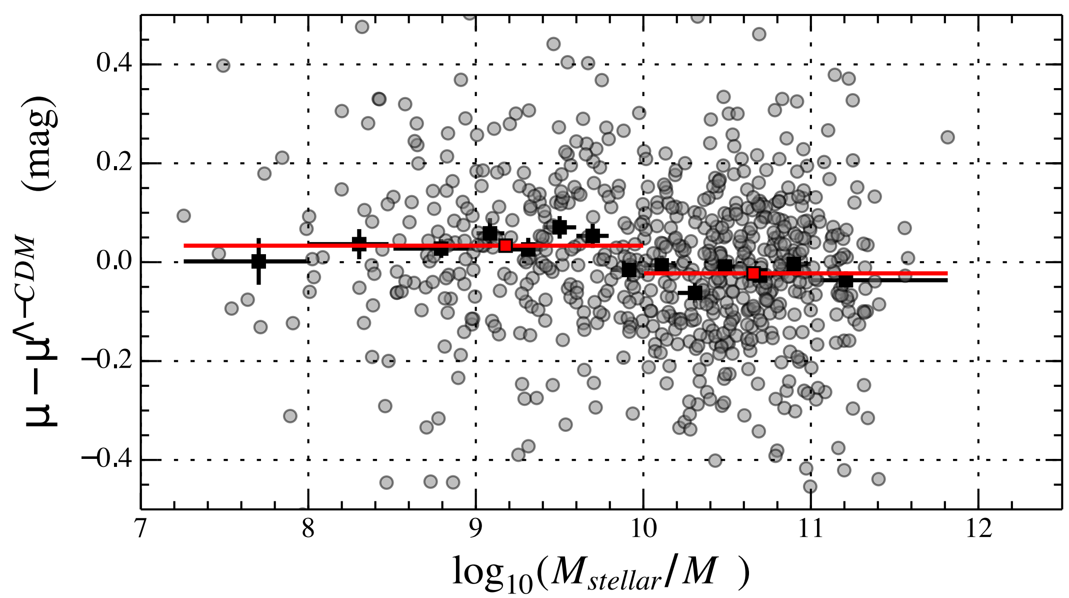

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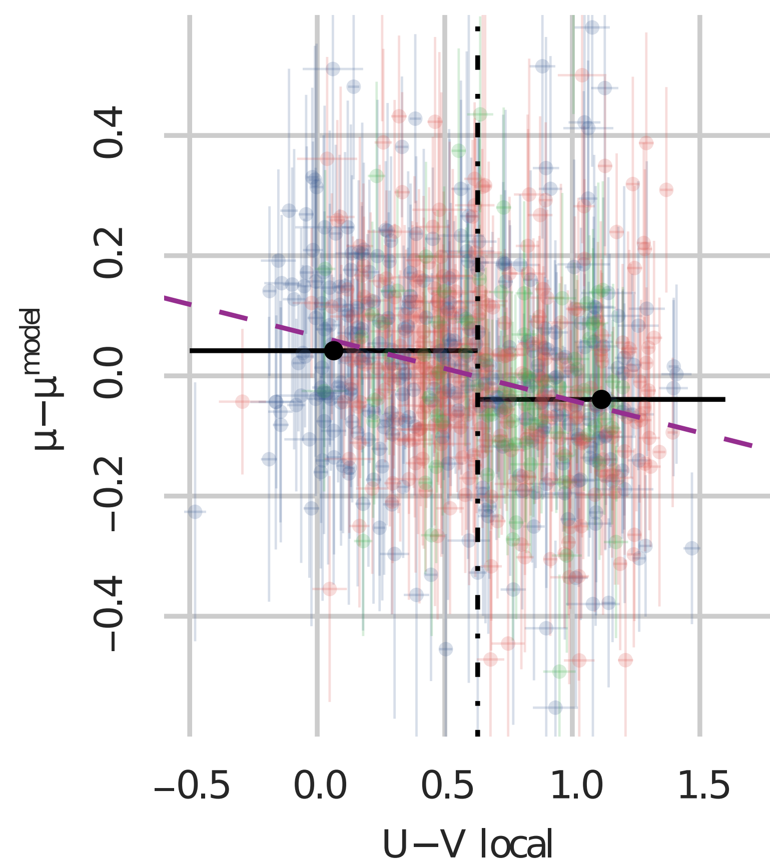
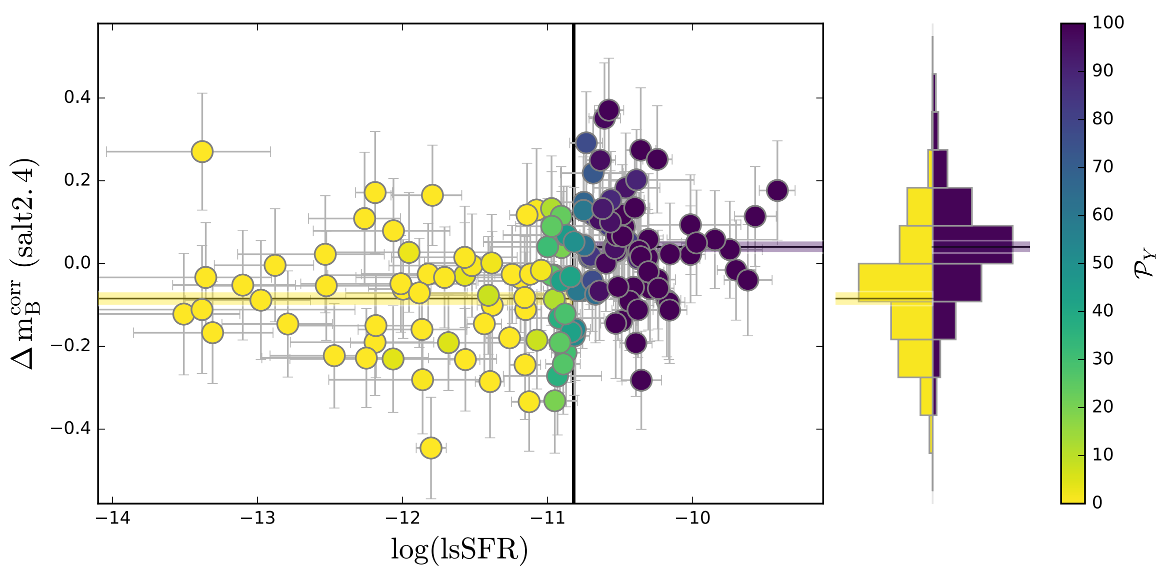


Rigault & al. 2018



Residual dispersion
source of systematics

Different ways to improve
distance measurement

Studies host properties

New SNIa model

Residual dispersion
source of systematics

Different ways to improve
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Studies host properties

New SNIa model

The Nearby Supernova Factory

- UH88 + Supernova Integral Field Spectrograph (SNIFS)
- SNIFS Gives high quality spectro-photometry time series (Great example: SN2011fe, *Pereira et al. (2013)*)
- ~300 supernovae at low redshift (z<0.1)
- Best data that provide tools to standardize SNIa or build empirical SED model

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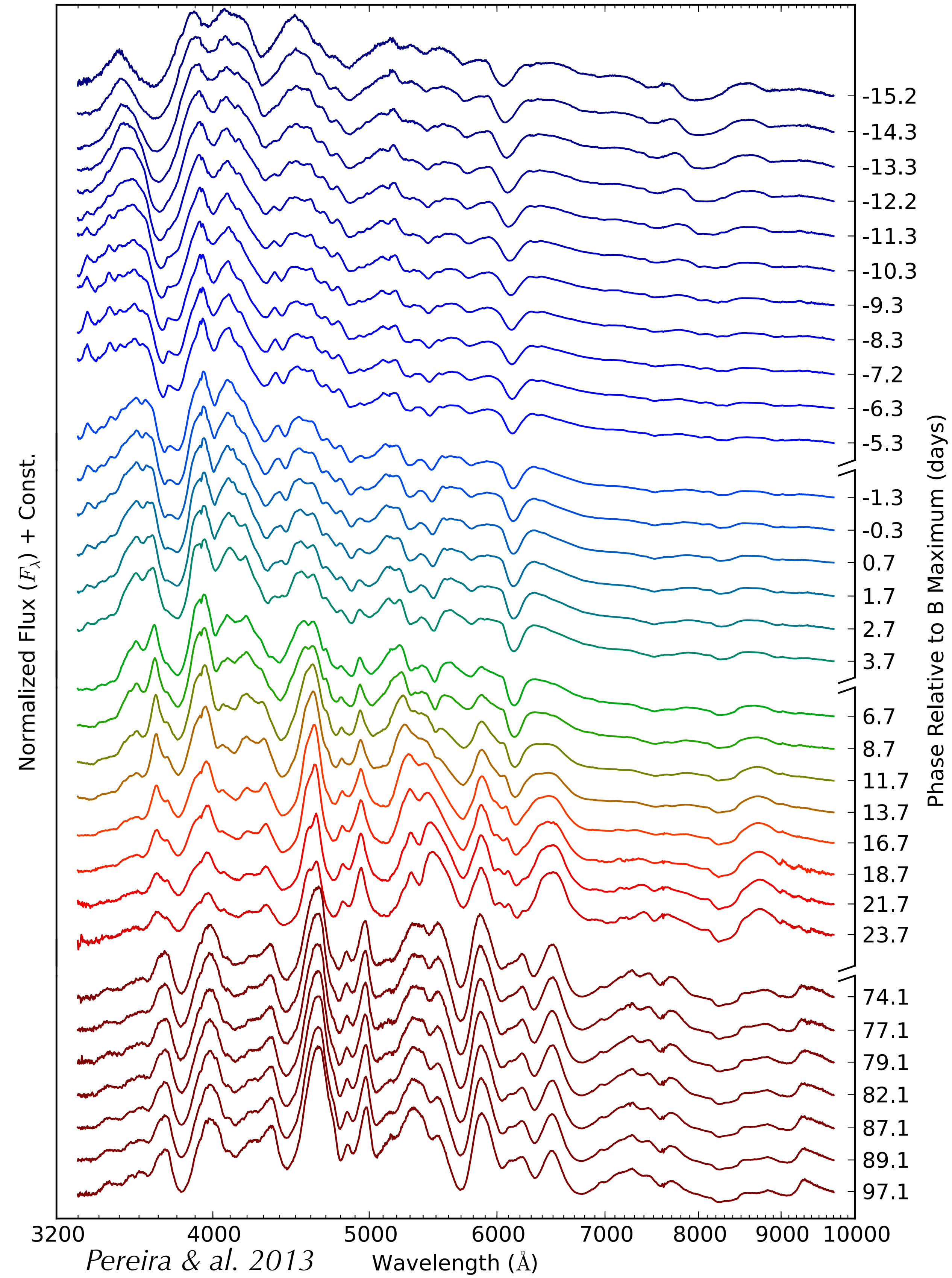
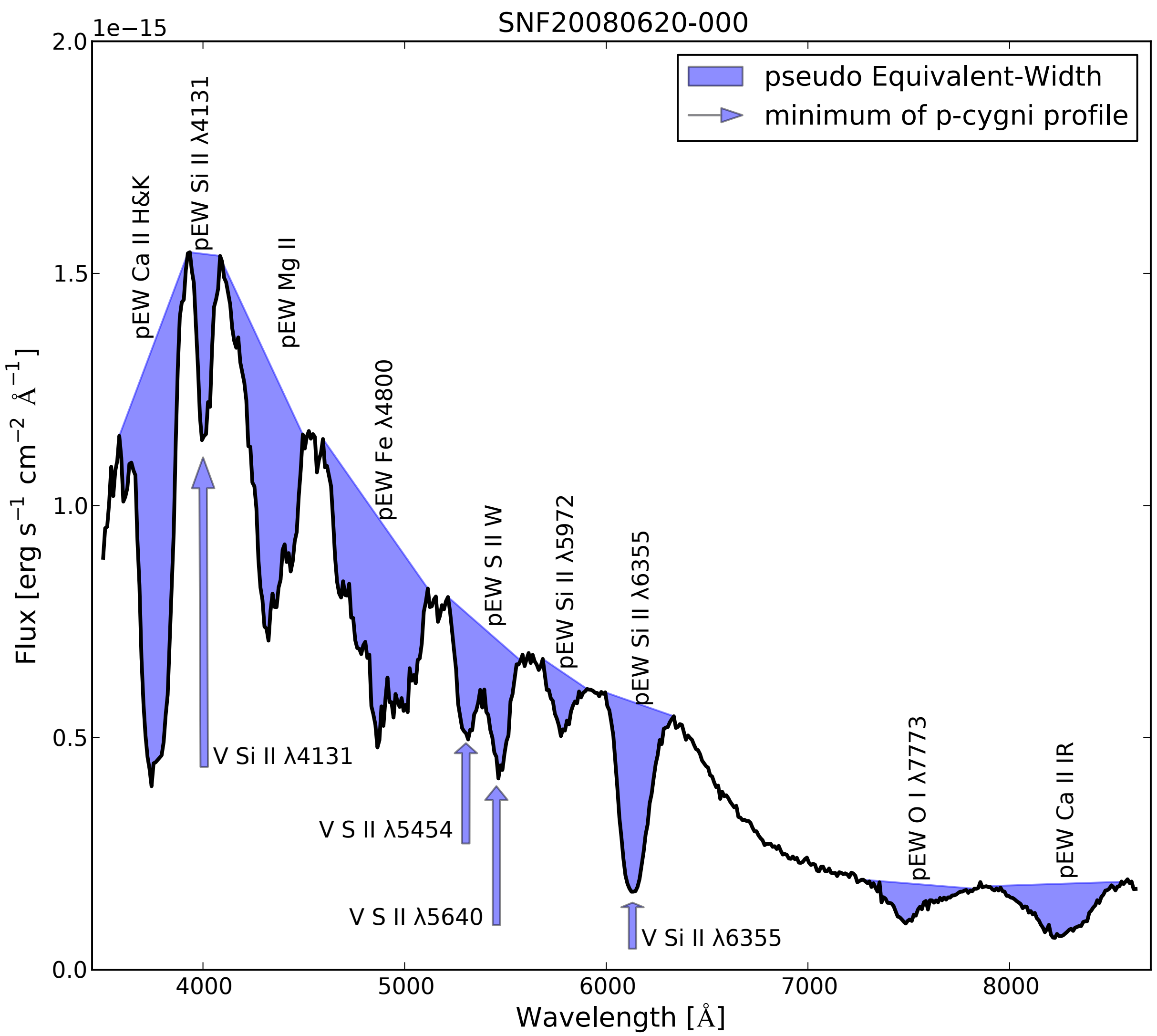


Pereira & al. 2013

SUpernova Generator And Reconstructor (SUGAR)

Léget & al. in prep ; Léget Ph.D. 2016

Basic idea of SUGAR modeling —> Used spectral features measured at maximum light in B-band to describe intrinsic variability of SNe Ia:



- Spectral features are related only to the physics of the explosion
  - Pseudo-equivalent width
  - Minimum position of p-cygni profile
- Do not depend on host dust
- Do not depend on distance
- 13 computed at maximum light and used to train the SUGAR model

SUpernova Generator And Reconstructor (SUGAR)

Léget & al. in prep ; Léget Ph.D. 2016

$$M(t;\lambda) = M_0(t;\lambda) + \boxed{\sum_{i=1}^{1=3} \alpha(t;\lambda) q_i} + A_V f(\lambda; R_V) + \Delta M_{grey}$$

3 components
instead of 1 for SALT2

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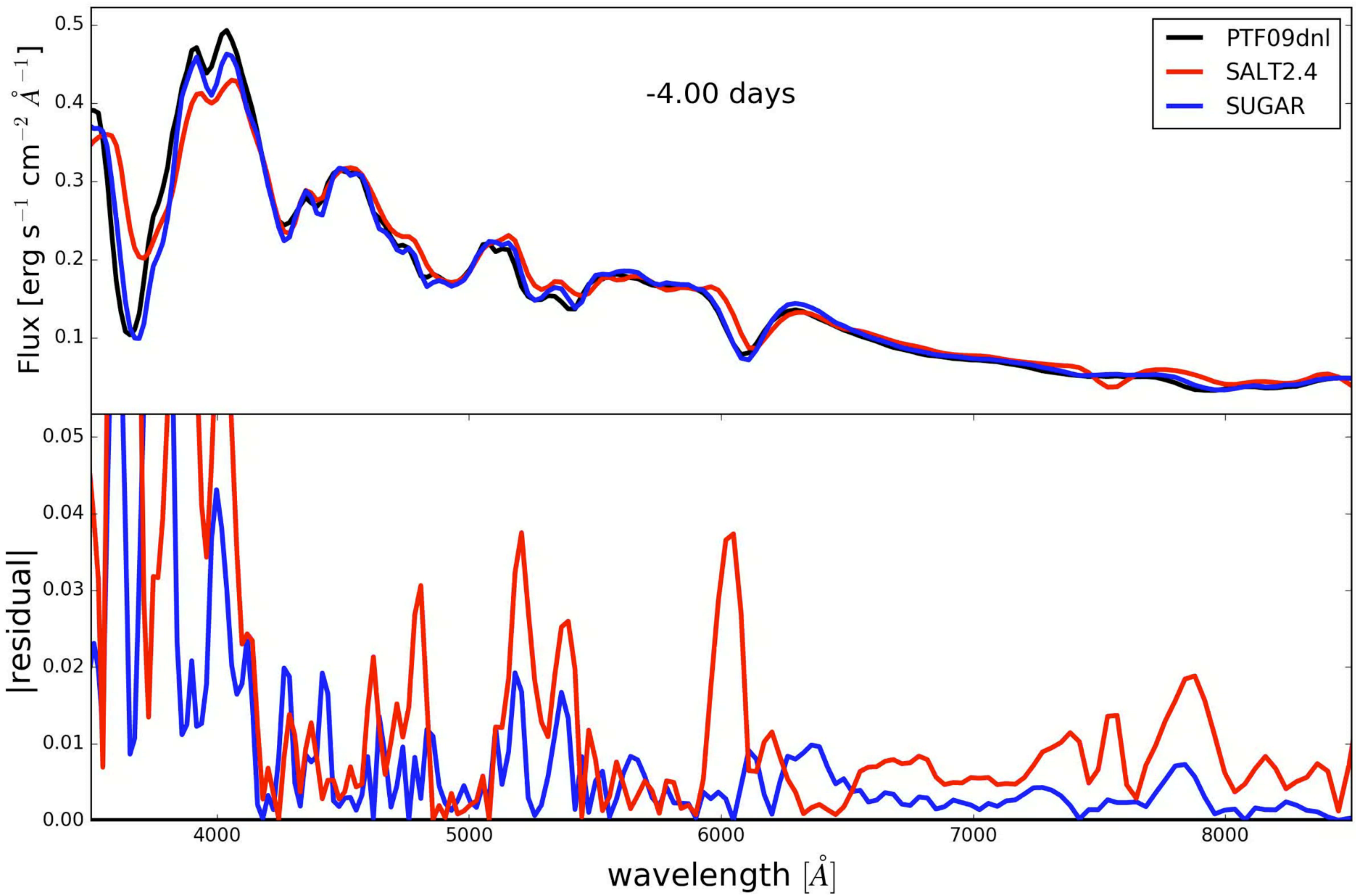

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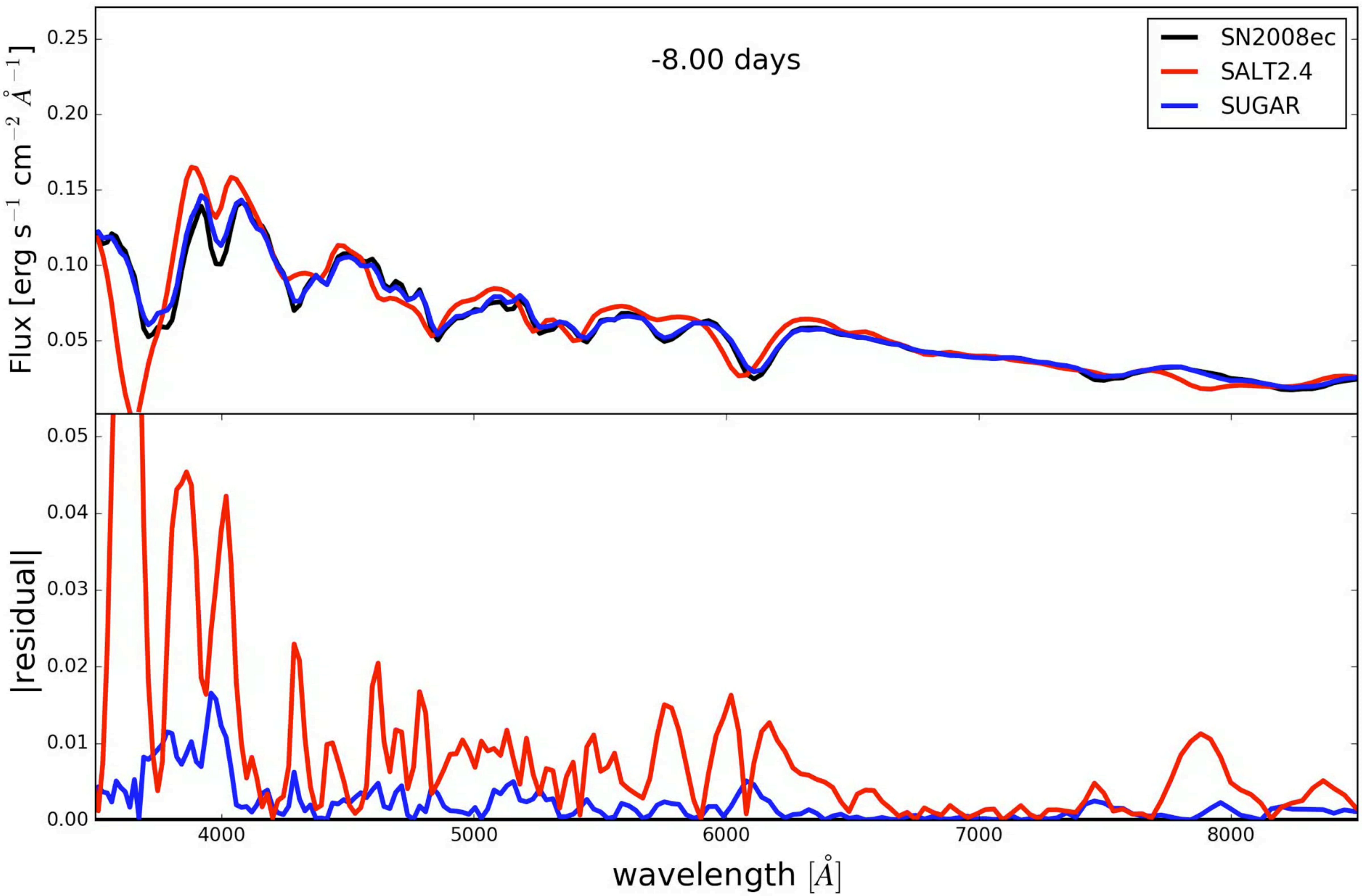

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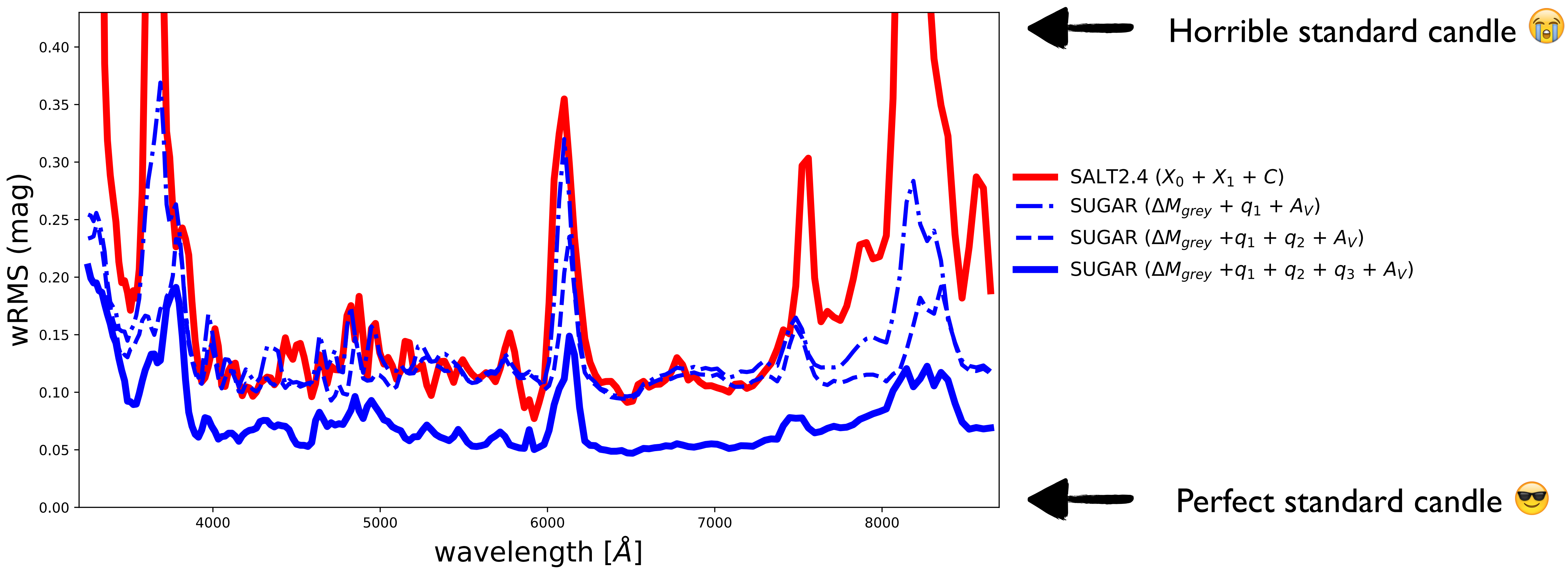
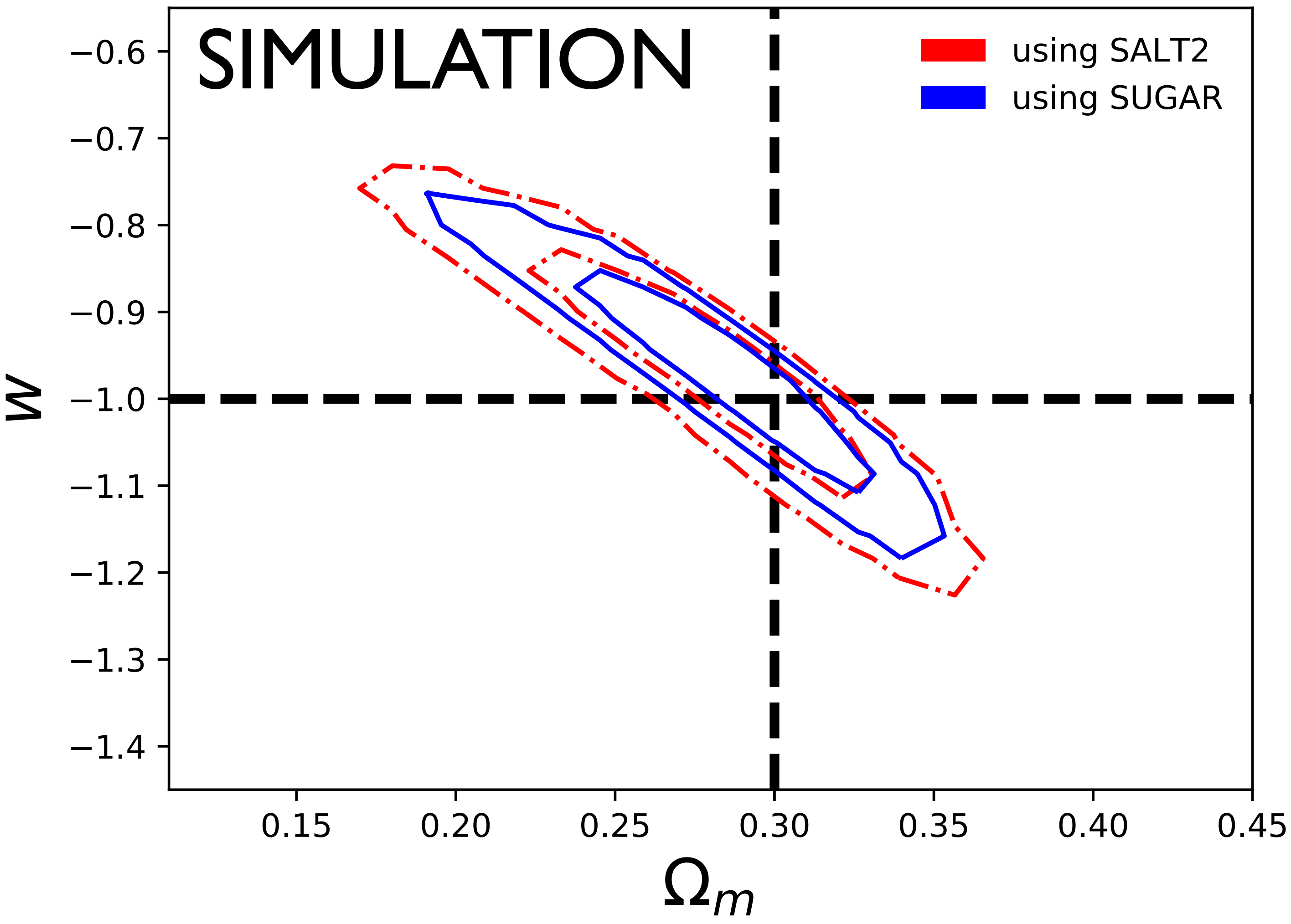


SUGAR improves SNIa spectral variability description in all spectral range!

SUGAR and cosmology:

- Dispersion of the model can be propagated to make simulations
- SALT2 and SUGAR simulation are done for a given cosmology
- SUGAR improves on simulation constraint on dark energy
- ~30% reduction of the error on w (SNIa alone)



Conclusions:

- **New SED model: SUGAR**
  - 3 intrinsic components instead of the classical stretch effect

- **Model performances:**
  - Better spectral description
  - Residual spectral dispersion reduced by ~0.05 mag
  - Could improve significatively the constraint on dark energy (with SNIa alone)

- **New tools for cosmology analysis**
- Use SUGAR as a light-curve fitter (Done by Florian Mondon @ LPC-Clermont)
- Study correlation with host properties
- Extend the model in the UV