SN Ia spectral analyses from the Nearby Supernova Factory

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**25th Rencontres de Blois**
May 29th, 2013

# Concordance cosmology

Standard candels
(SNe Ia)

Large scale structures
(**BAO**, Weak lensing,
Clusters)
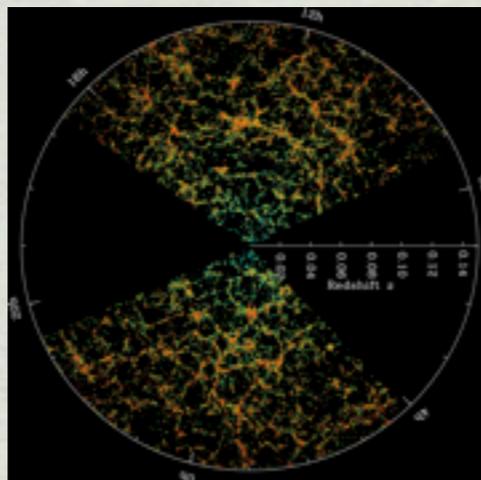
SDSS

CMB

(COBE, WMAP, **PLANCK**)

PLANCK

Hubble diagram

SNLS3: [Conley et al 2011](#)

Hubble diagram

$$H_0^2 L_0$$

$$\Omega_\Lambda, \Omega_M, w, \ldots + H_0^2 L_0$$

HST

SDSS

SNLS

Low–z   High-z

Distance modulus

$m_{corr} = m_B + \alpha\,(s-1) - \beta\,C$

m_{corr}

Redshift

SNfactory

SNLS3: Conley et al 2011
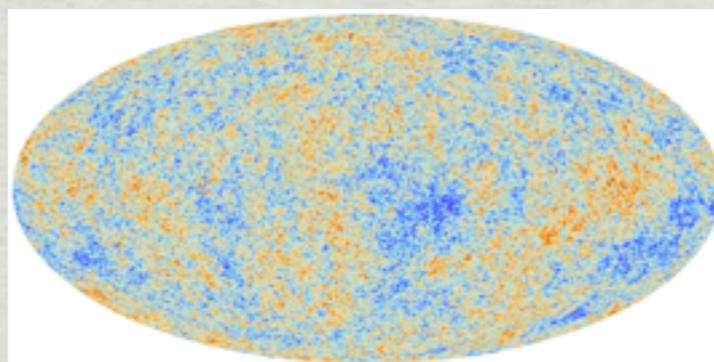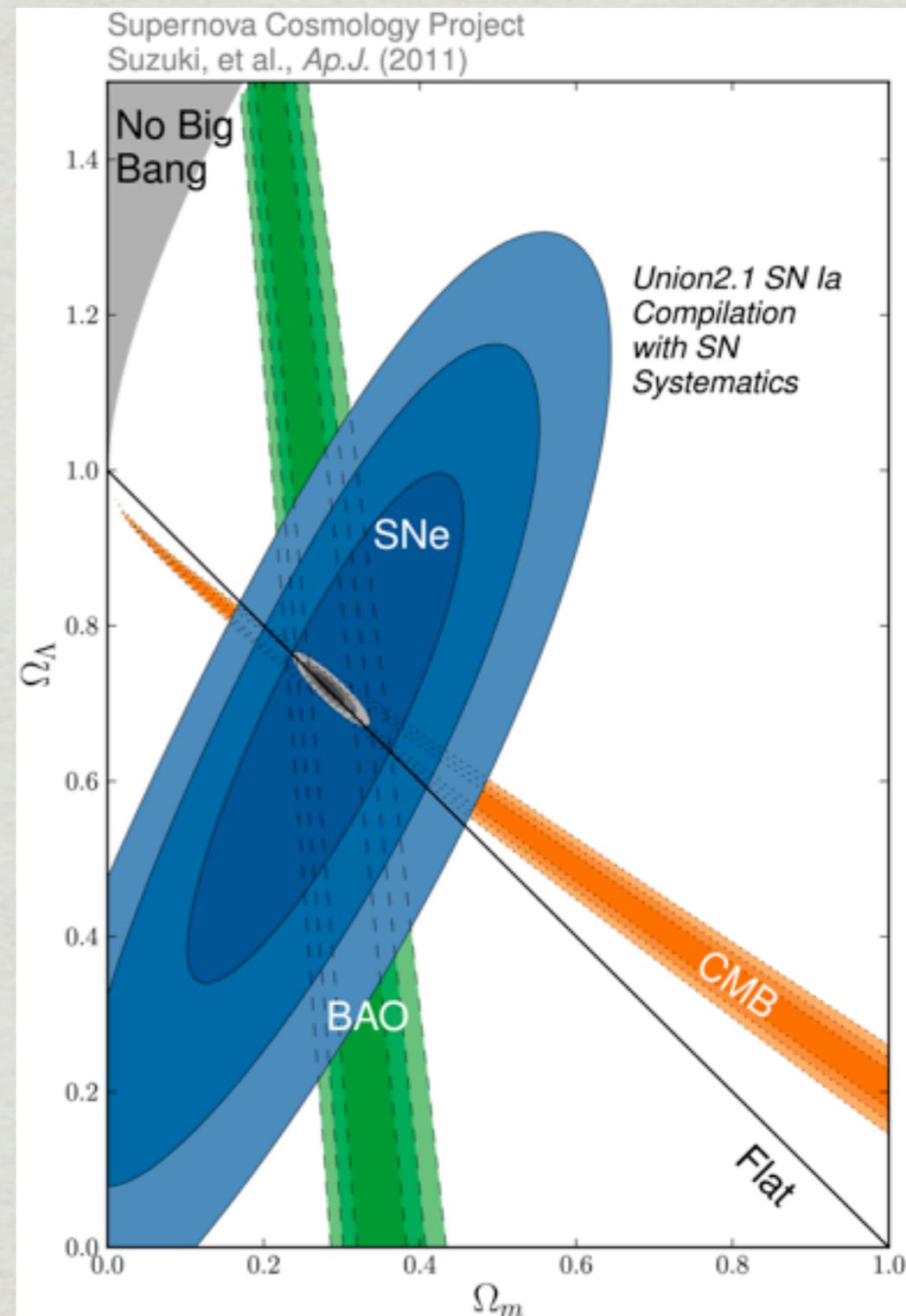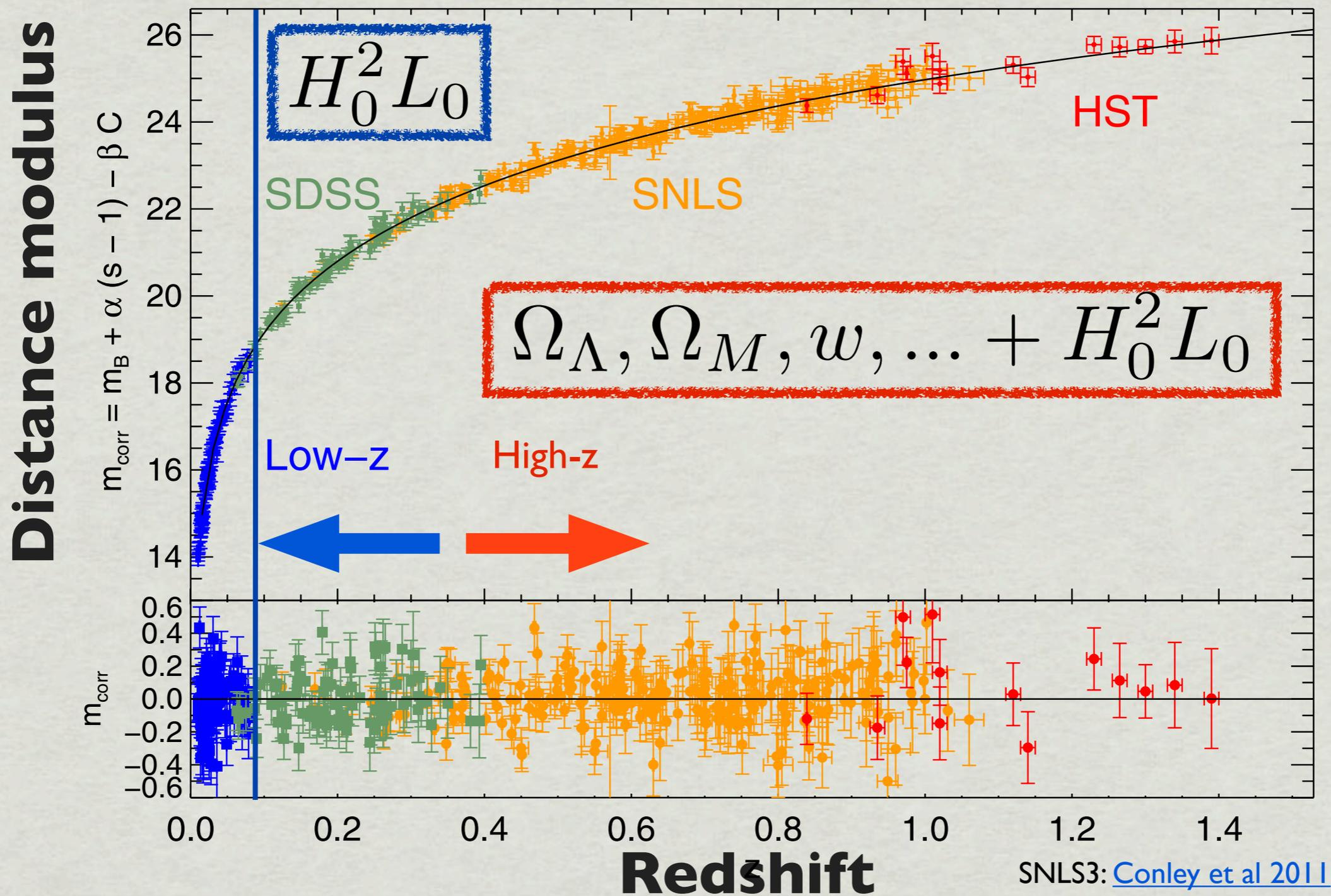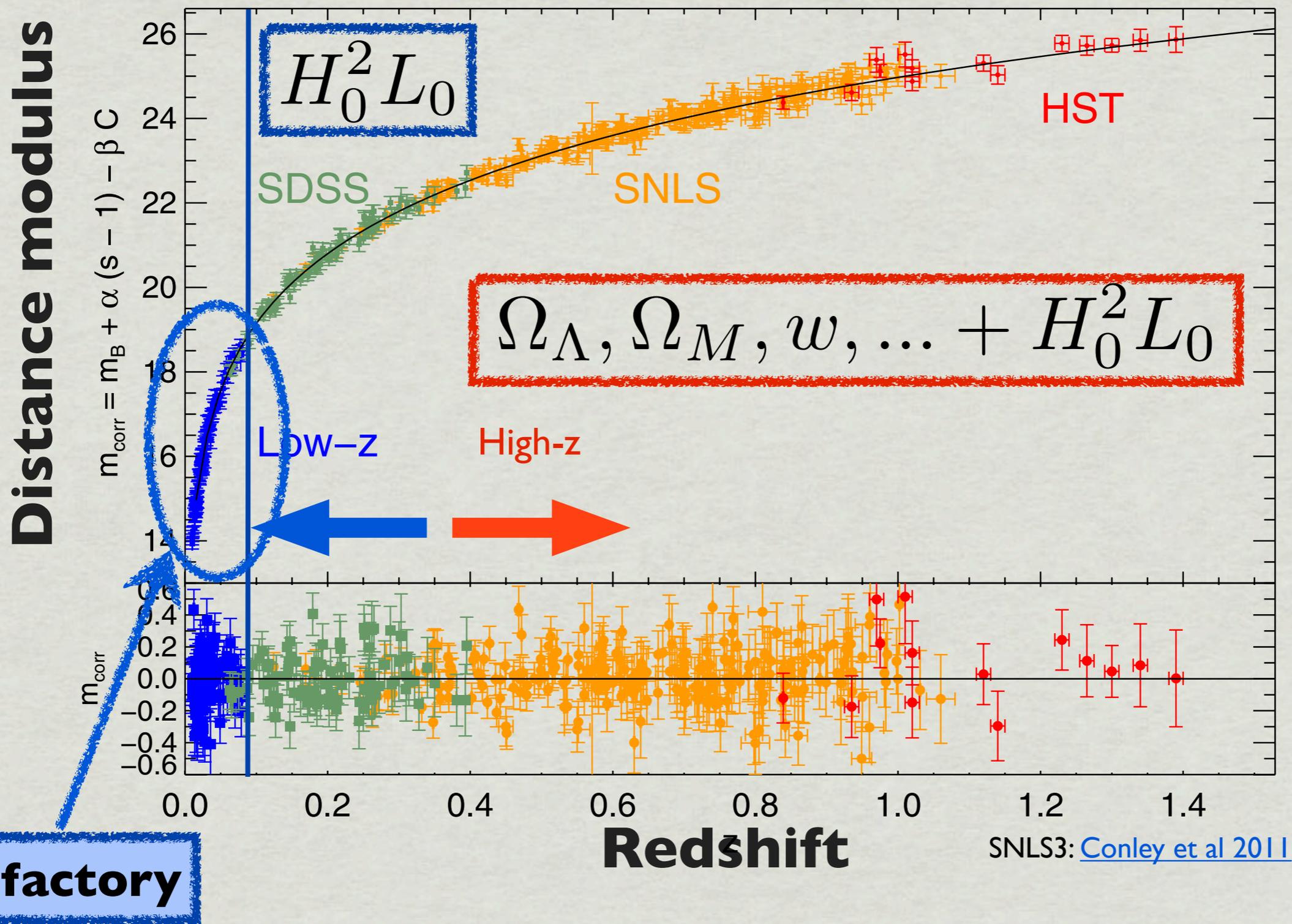
Cosmological uncertainties

SNLS3: Sullivan et al. 2011
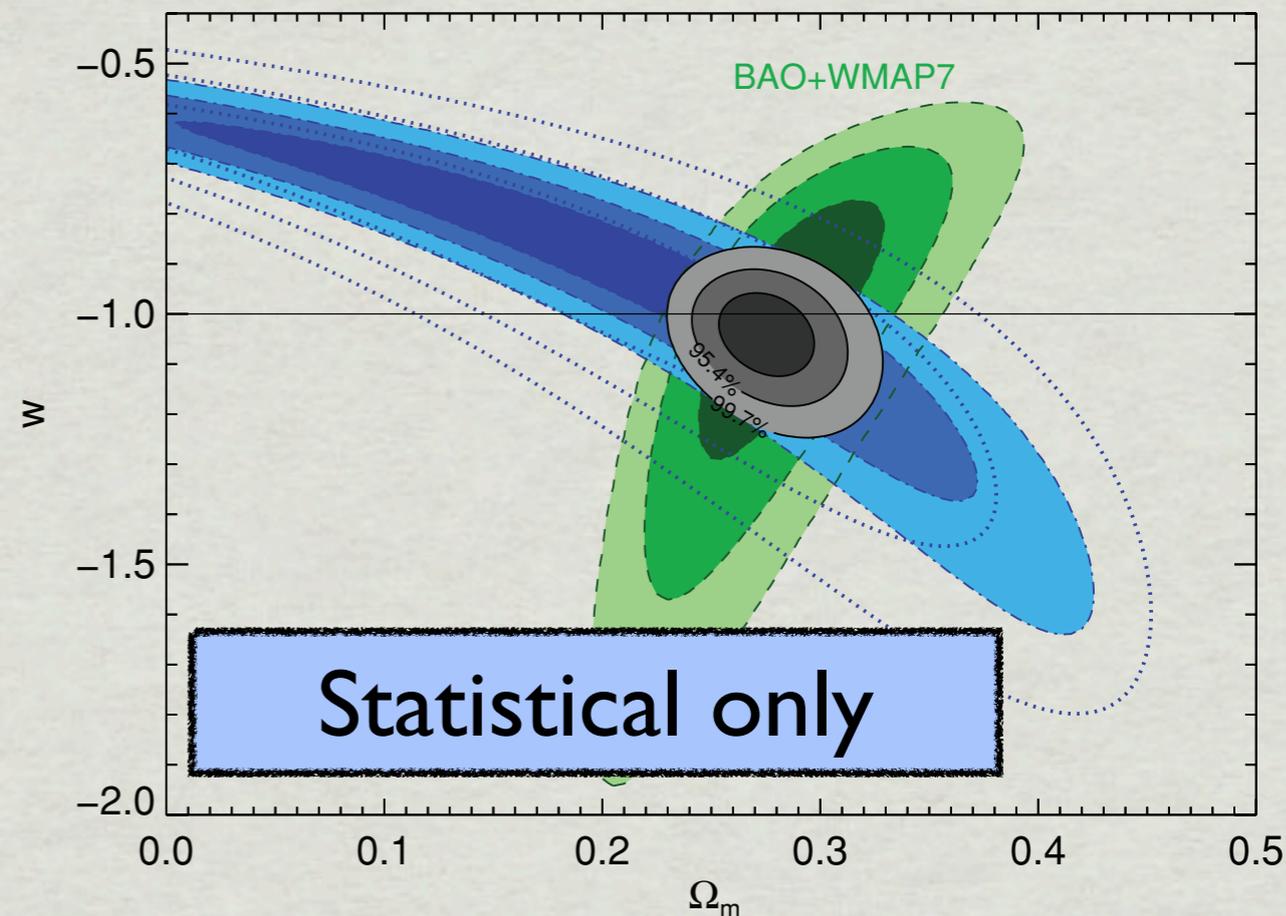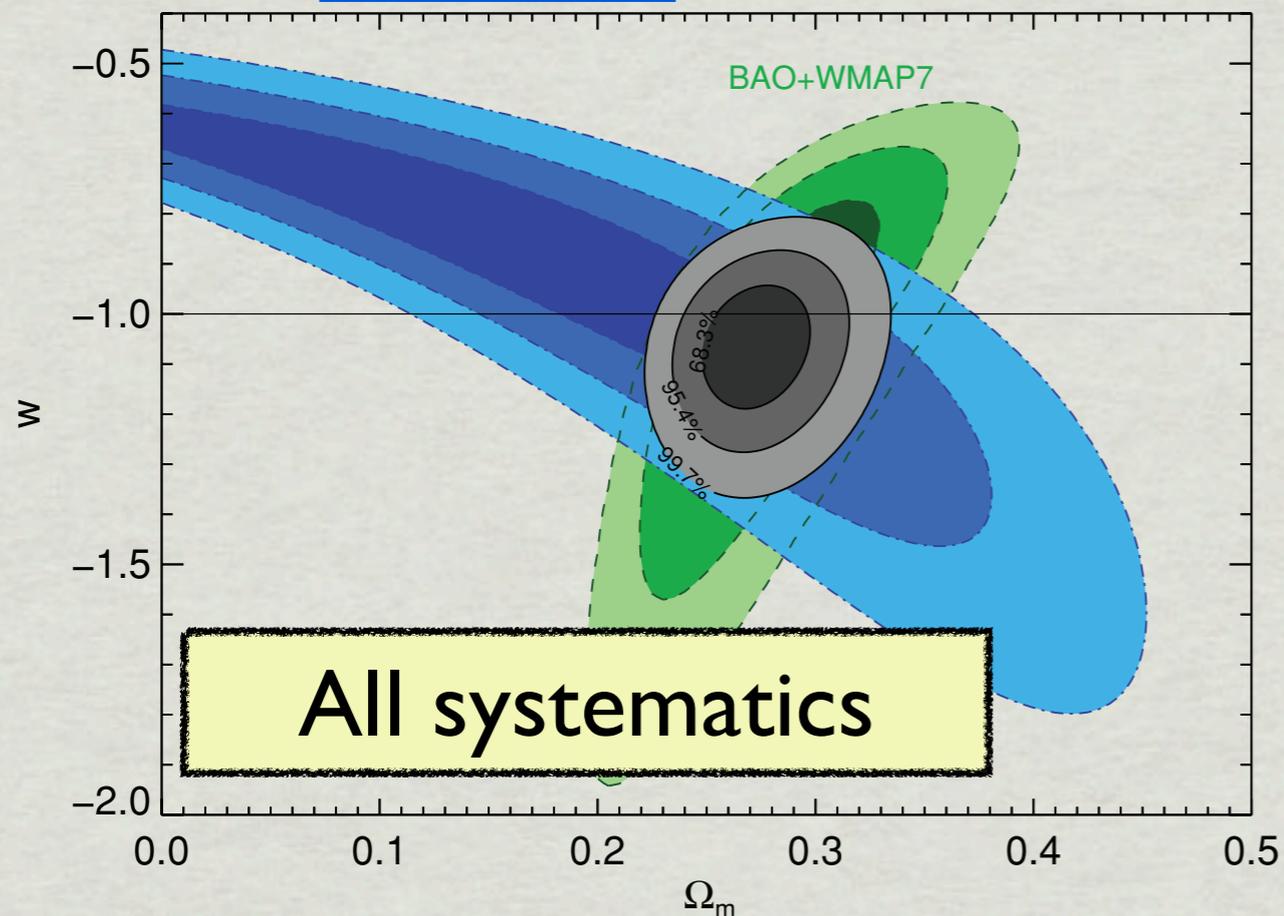
Systematics dominate

High quality data of **low redshift SNe Ia** needed to reduce systematics: **SNfactory**

The Nearby Supernova Factory

*A unique data set of spectrophotometric Type Ia supernovae spectral time series*

SNIFS UH 2.2-m

Every 2-3 nights

SNIFS

IFS spectro+photo

Spectro-photometry of nearby SNe Ia
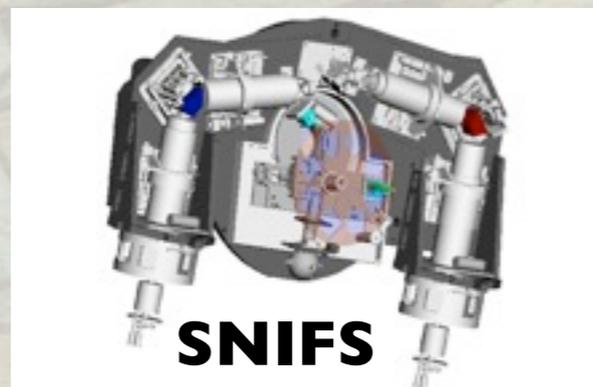
Reduction Calibration

Analyses
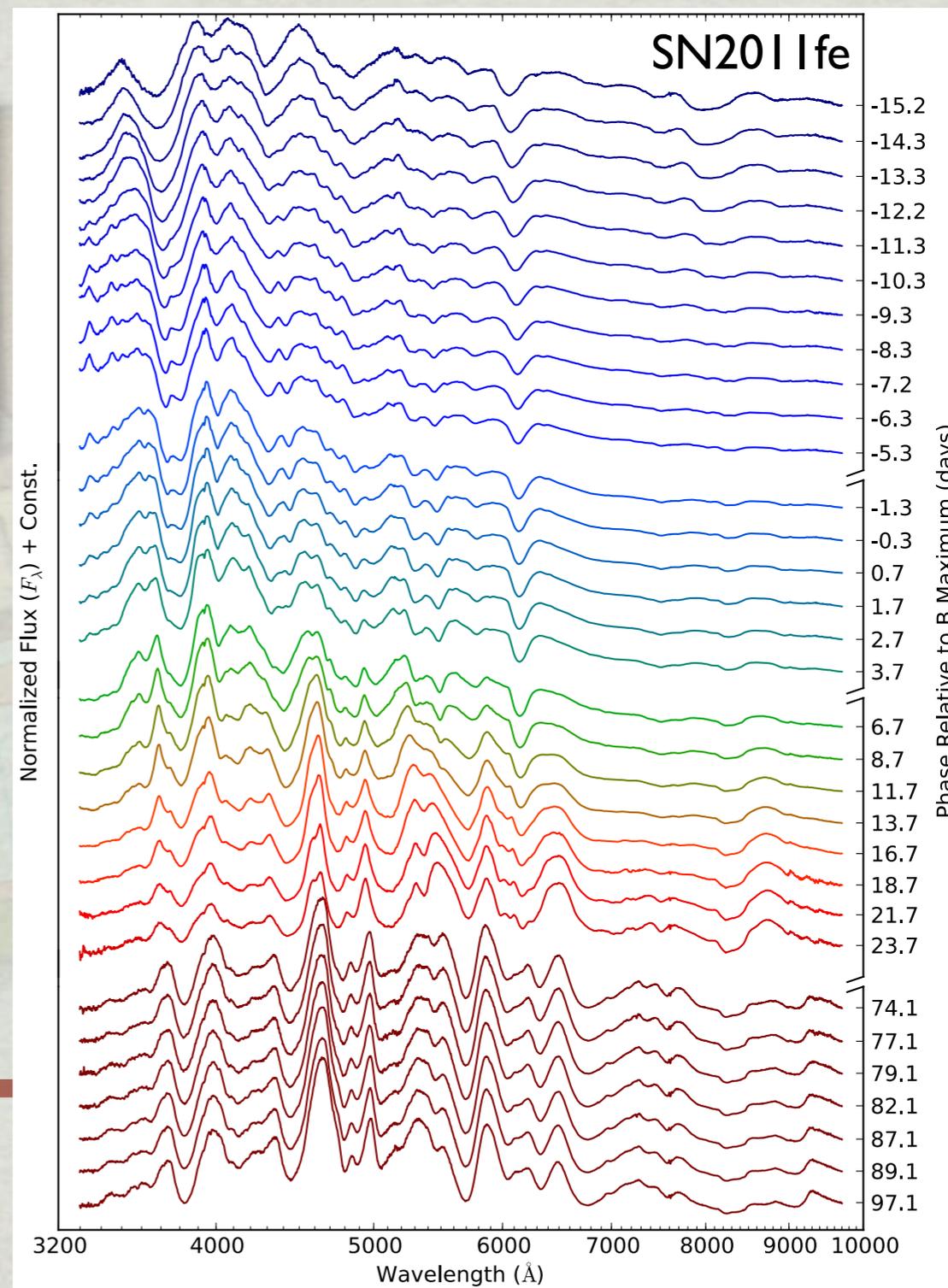
Pereira et al. 2013

The Nearby Supernova Factory

Main goals:

- Anchor the Hubble diagram
- Study of systematics
  - Spectral (K-correction)
  - Calibration
  - Standardisation
  - Spectral properties
  - Extinction
  - Explosion models

Data sample:

- **284 SNe** (> 5 spectra)
- **4625 spectra** [-15,40] days *wrt* max
- 0.01 < redshift < 0.1
- median phase of 1st spec: -4 days
- mean cadence of observation: -3 days
- spectral coverage: 3200 to 9700 Å

Nearby supernova samples (0.01 ≤ z ≤ 0.10)

SNfactory: 234 SNe
LOSS: 138 SNe
SDSS: 11 SNe
CSP: 59 SNe
SCP: 4 SNe
CfA: 120 SNe
Krisciunas+04: 9 SNe
Calán/Tololo: 18 SNe

REDSHIFT

248 light-curves

Date
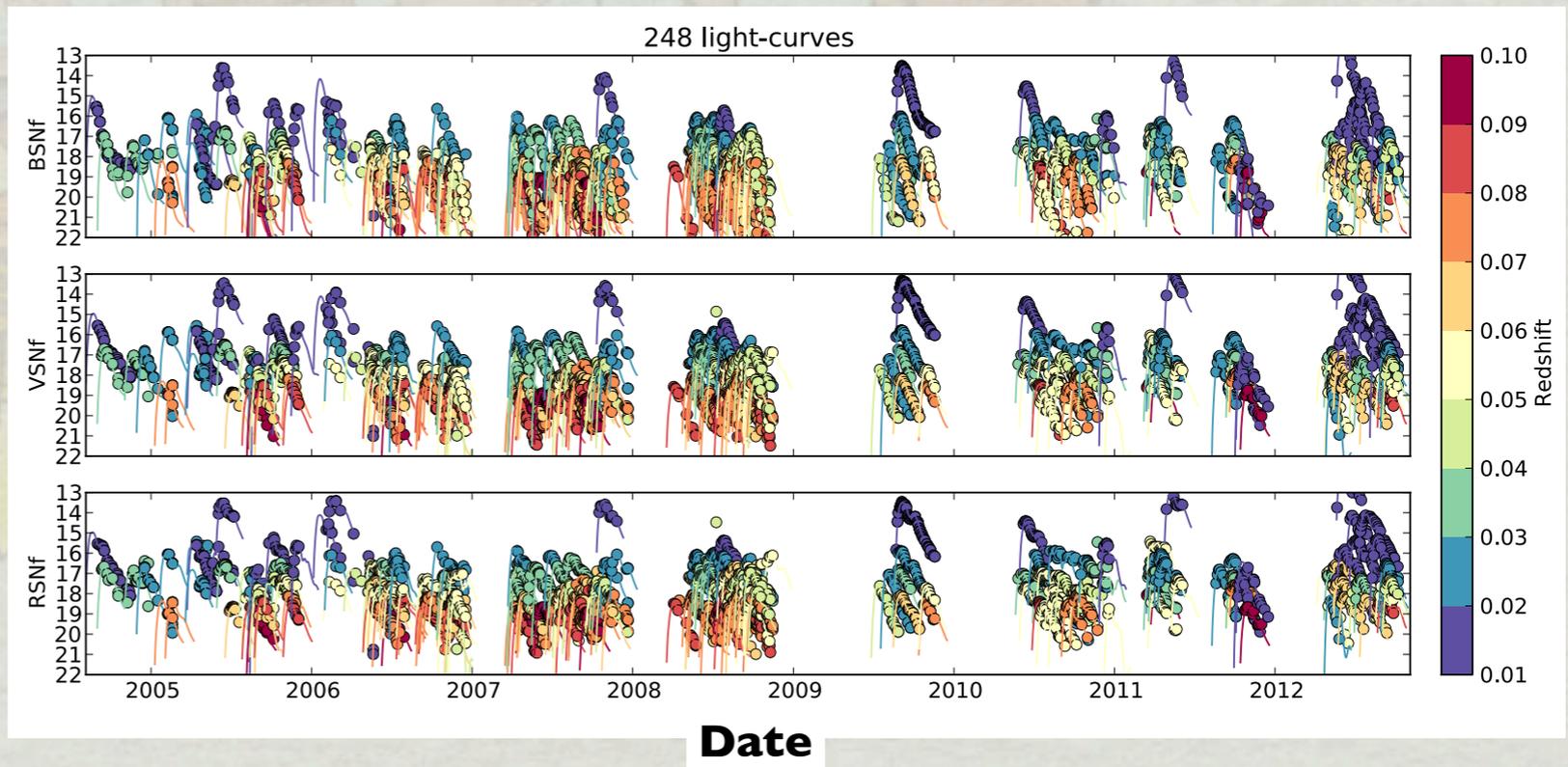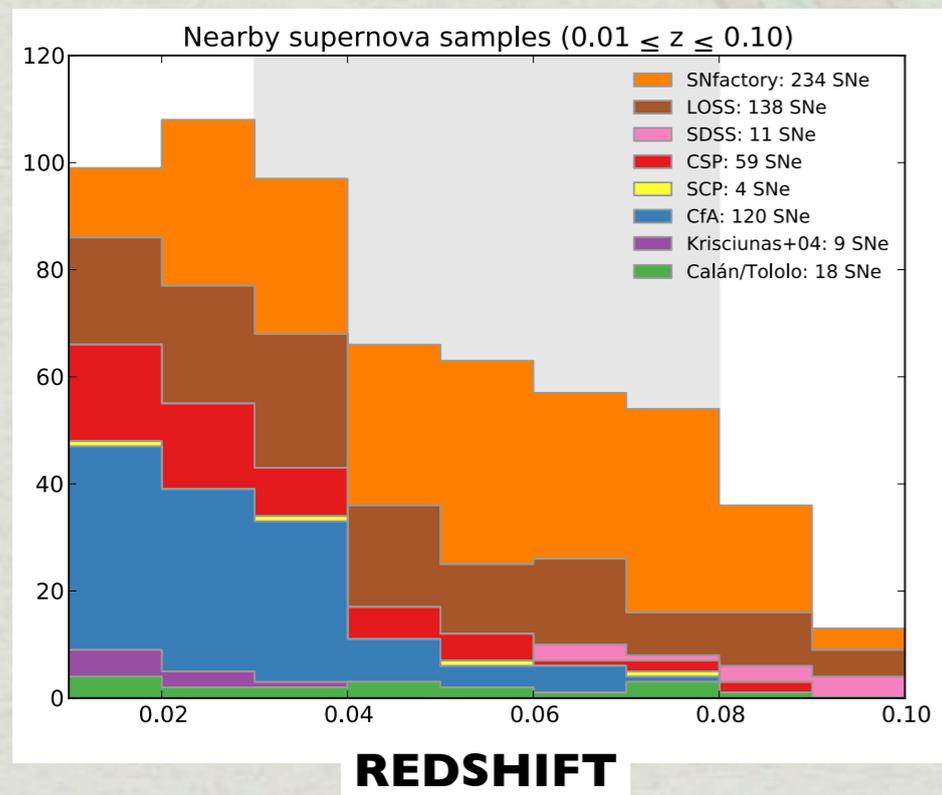
Spectral analyses of SNe Ia

SN Ia variabilities:
intrinsic (progenitor)
&
extrinsic (host galaxy)

•**Spectral indicators :**
• Some are sensitive to extinction
• Other are mixt: (in/ex)trinsic

• **Different uses:**
• Standardisation
• Sub-classification
• Extinction
• etc.
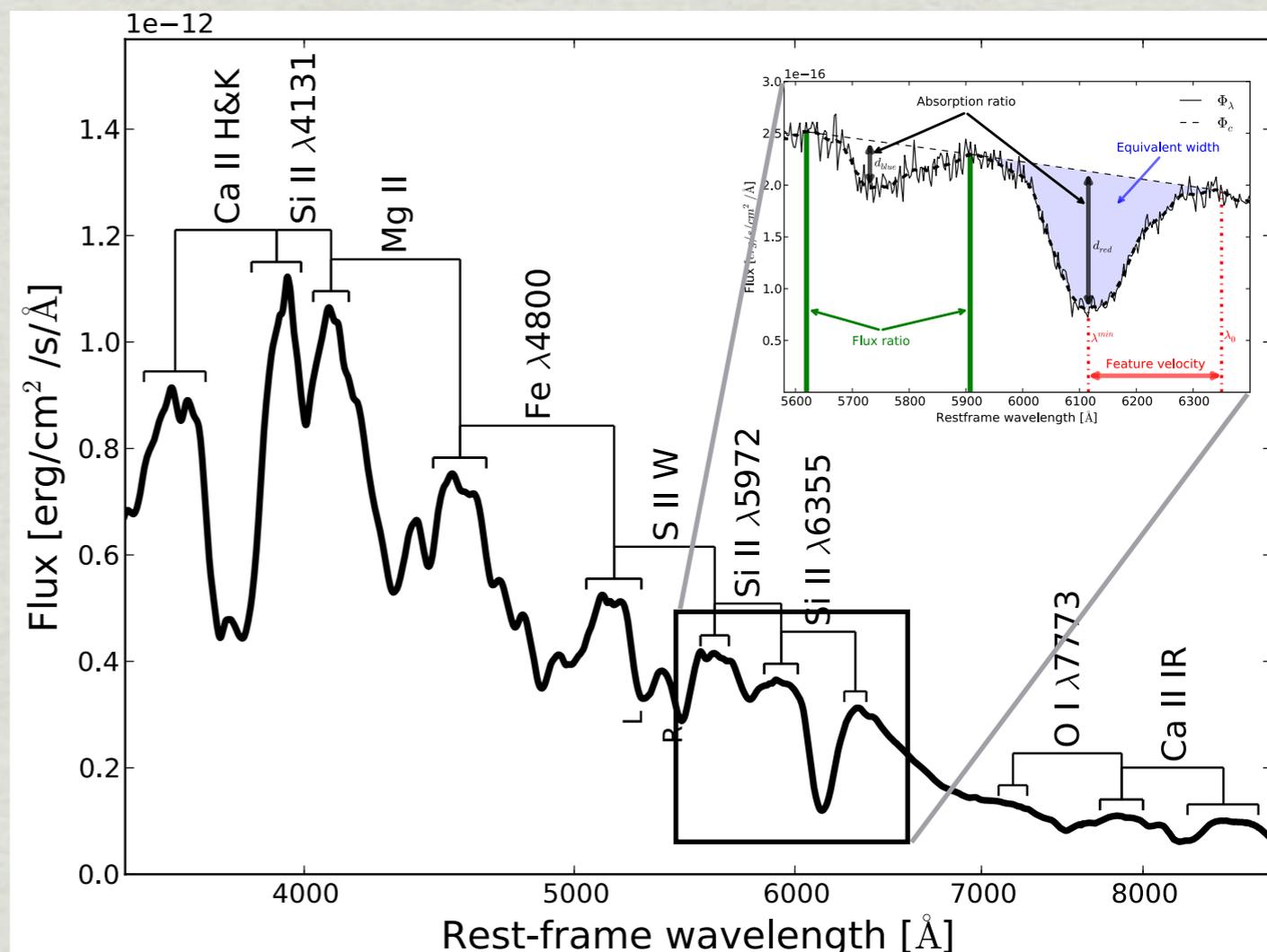
Cosmological systematics/bias studies related to their spectral variabilities

Extinction law
## Chotard et al. 2011

Problem
- Shape + slope of the extinction law: reccurent issue in SN Ia analyses
- Influence on standardisation/cosmology

Analyse
- Intrinsic spectral indicators
- Separation of the ≠ composantes
- Extinction law construction

Conclusions
- SNe Ia color dispersion needed
- Classical extinction law retrieved
- Potential bias
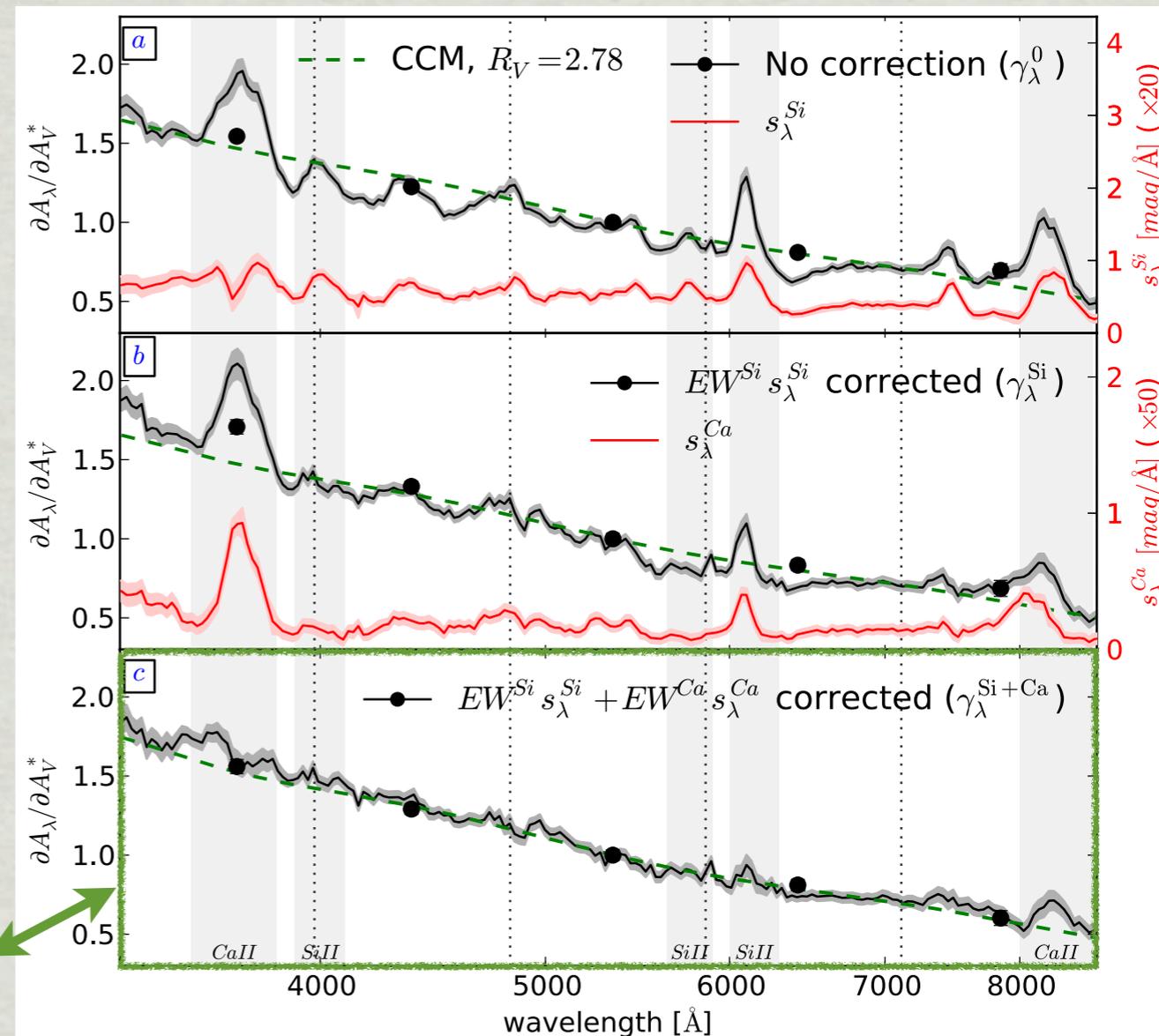
Result taken into account in recent analyses

Spectroscopic standardisation

Chotard et al. 2013a (in prep.)
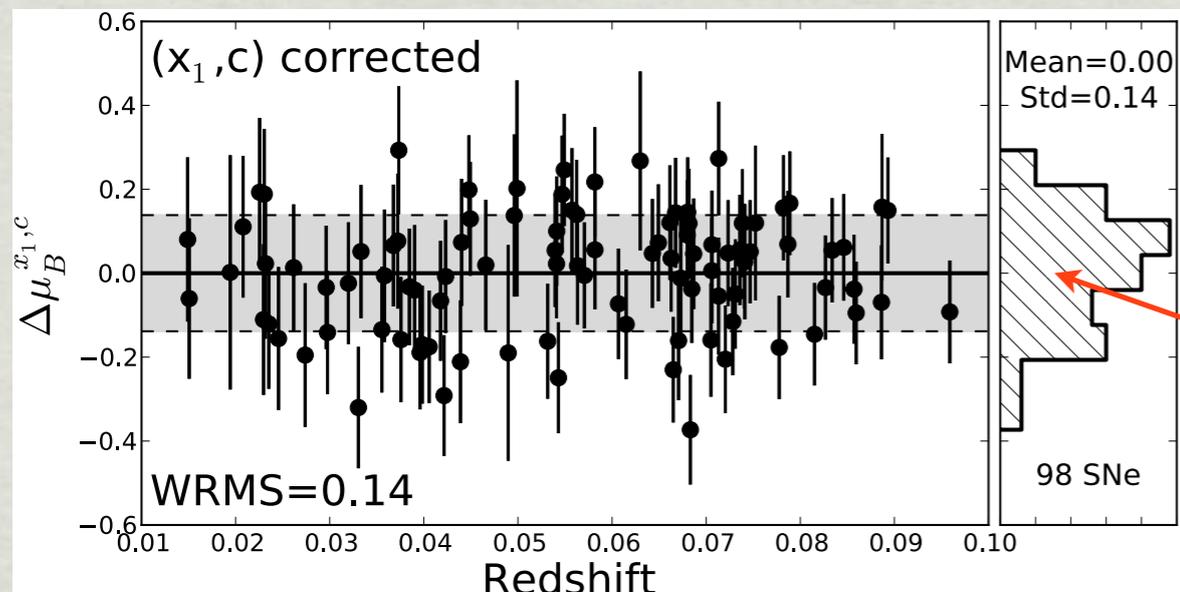
Problem

- Classical photometric methods: color + light curve width
- Limit of the photometric analysis: 15%
- How to use spectral informations?
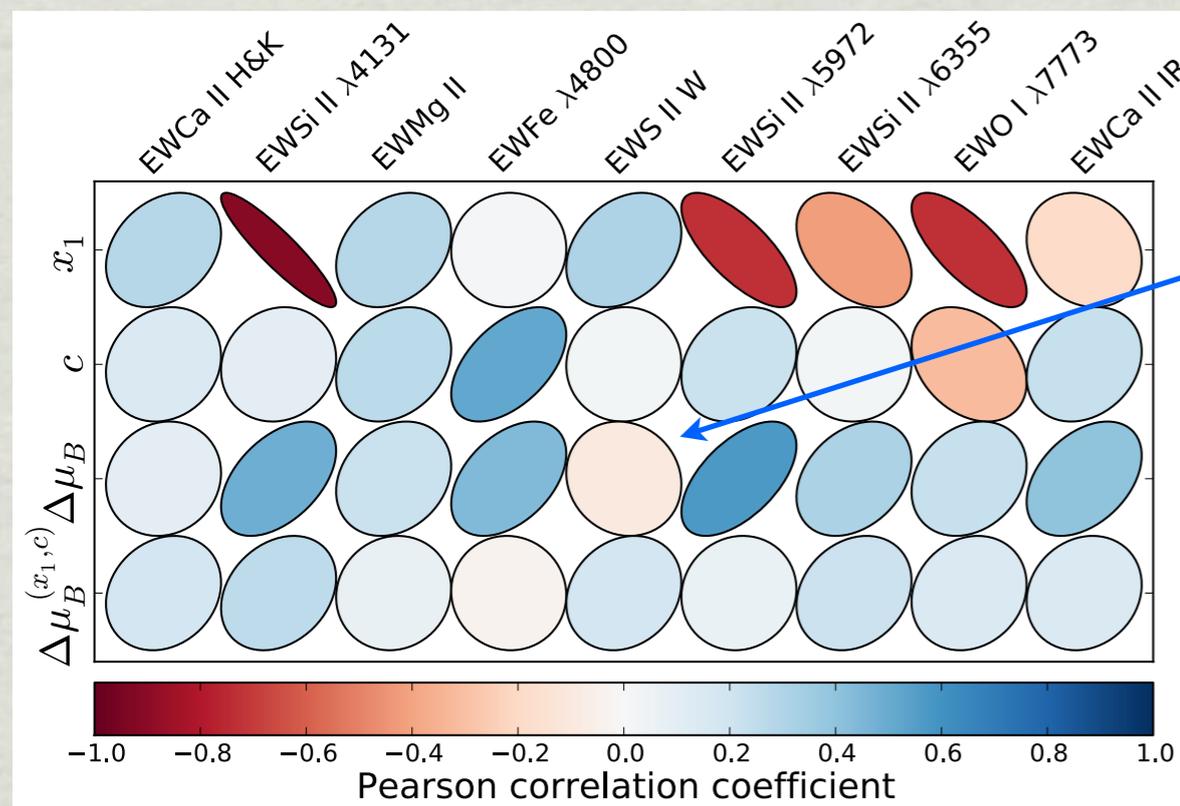
Analyse

- Spectral indicators correlations with photometric parameters
- Standardisation power

Conclusions

- Competitiveness:
  - Only one spectrum needed,
  - But weak improvement

SNe Ia sub-classes
Chotard et al. 2013b (in prep.)

Presence of **sub-classes** could introduce **bias** in **cosmological analyses:**

- ≠ in absolute magnitudes,
- ≠ in color-stretch/magnitude relations
- ≠ intrinsic variablitiy,
- Evolution with redshift

Analyse:

- Sub-classes have been defined using intrinsic spectral indicators

Conclusions :

- No obvious sub-classes, but
- Dispersion ~0.15 to ~0.12 without the <u>SS</u>
- Are this subclass really different?
- Work in progress !
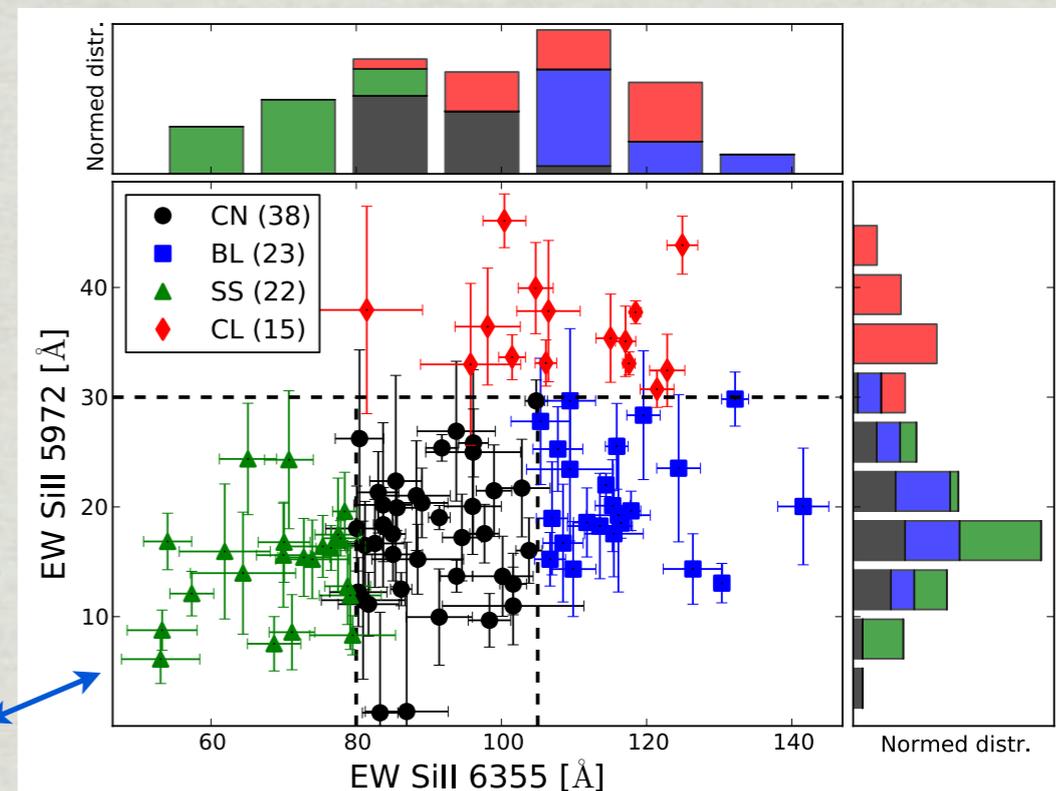
SNfactory analyses
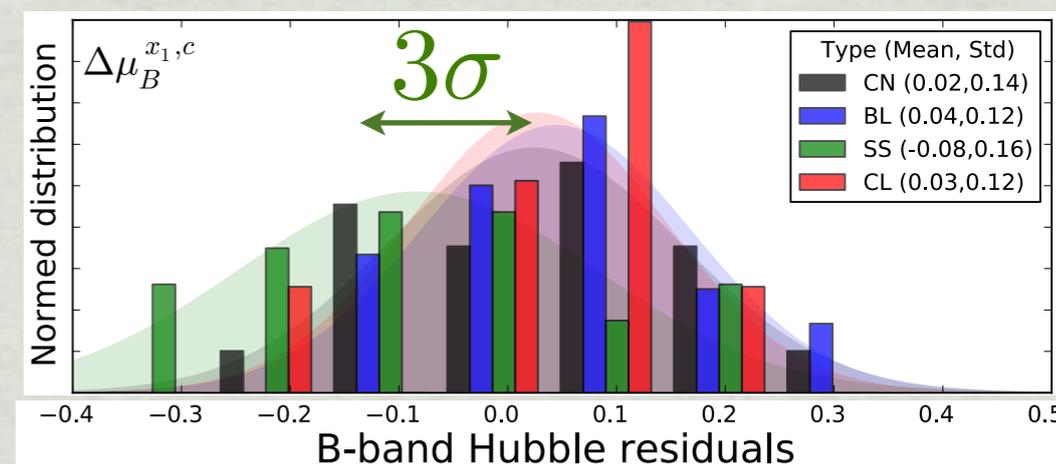
✦**<u>Published analysis:</u>**

✦ Peculiar SNe ([Aldering 06, Thomas 07](#)),

✦ SN 2011fe (PTF11kly) ([Pereira 13](#))

✦ Super-Chandra ([Scalzo 10](#), [Scalzo 12](#)),

✦ Host ([Childress 11](#)),

——— Case studies

✦ Standardization ([Bailey 09](#)),

✦ ***Extinction*** ([Chotard 11](#)),

✦ Carbon-footprint ([Thomas 11](#)),

✦ Constrains on explosion models ([Ropke 12](#)),

✦ Light curve fitters ([Kim 13](#))

——— Spectral analyses

✦ Host galaxies analysis ([Childress 13 a & b](#)),

——— Host analyses

✦ Atmospheric extinction ([Buton 12](#)),

——— Calibration

SNfactory analyses

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✦ Host galaxies analysis (<u>Childress 13 a & b</u>),

✦ Atmospheric extinction (<u>Buton 12</u>),

✦ <u>Ongoing analyses:</u>

✦ ***Standardisation***,

✦ ***Sub-classification***,

✦ ***Reddening / color analyses***,

✦ Host galaxies: local/global comparison

✦ NaID absorption line,

✦ Twin supernovae,

✦ Spectral data / Explosion model comparison,

✦ K-corrections

✦ ...

Summary

✦ **SNfactory Data Sample**

   ✦ ~280 SNe Ia spectrophotometric time series so far,

   ✦ Best and larger sample of his kind

   ✦ SNe Ia spectral observations continue every few days

✦ **SNfactory Analyses**

   ✦ Work is going on on a lot of different aspects using the SNIFS data:

      ✦ Standardisation: improvement has already been achieve

      ✦ Environemental effects: host global *vs* local properties

      ✦ SNe Ia understanting: Spectral analyses, modeling, case studies, twins

   ✦ Several publications recently submited or ready for submission

SN2011fe
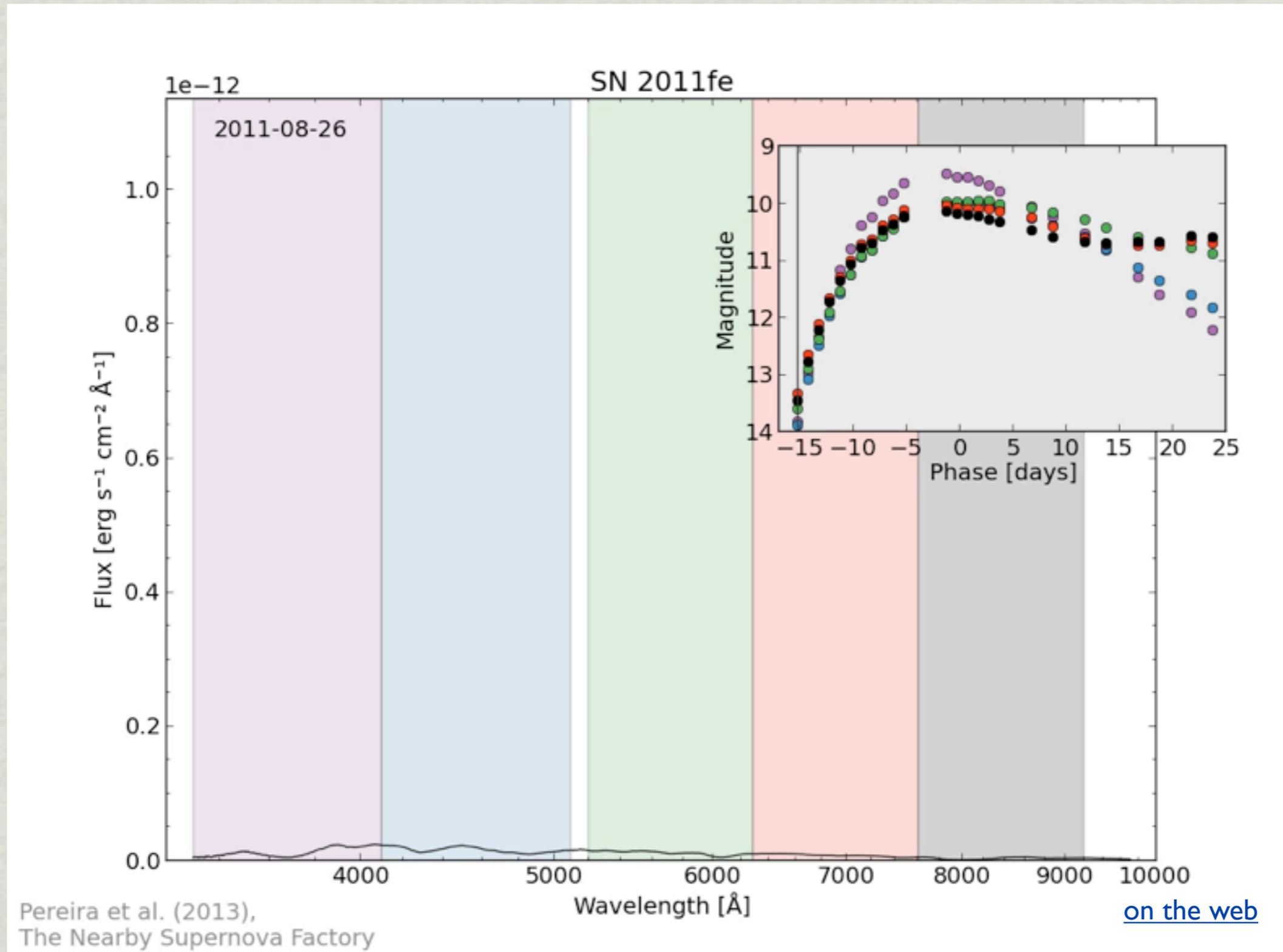
BACKUP

SNe Ia: Standardisable candles

~ 40%

M_B

Dispersion around peak luminosity: 0.41

Stretch

M_B corr

~ 15%

Stretch+**Color** corrected

Dispersion around peak luminosity: 0.15

Rest-frame phase
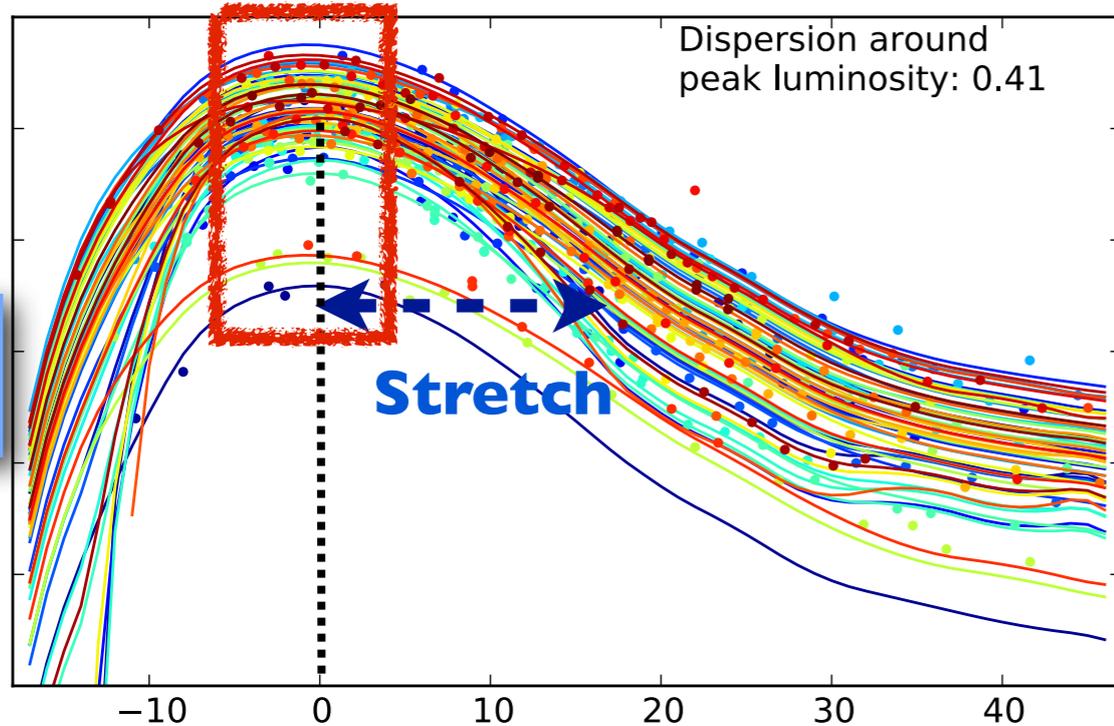
Empirical corrections to reduce the dispersion at maximum light:

✦ *Light curve width: $\Delta m15$, stretch, $x1$, etc.*
 brigther - slower *(intrinsic)*
 * *progenitor composition (metallicity)*
 * *progenitor explosion (^{56}Ni mass)*
✦ *Color: B-V, SALT2 c, CMAGIC, ΔC_{12} etc.*
 brighter - bluer *(extrinsic)*
 * *host interstellar medium extinction*
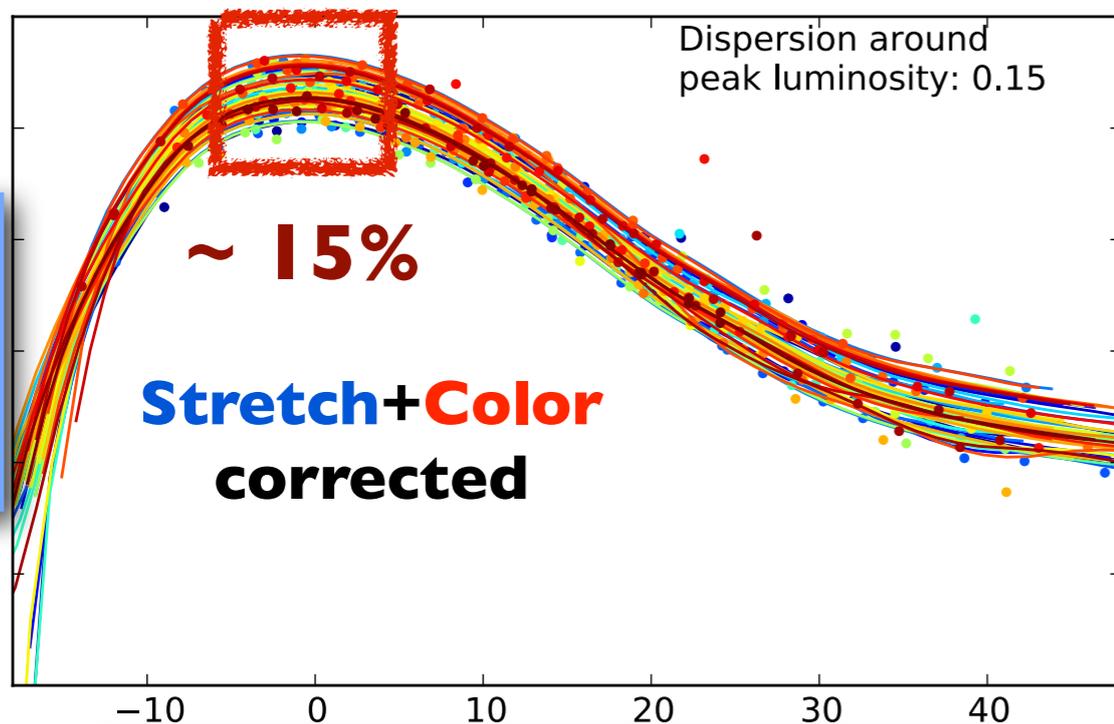
Light curve fitters: usually used to estimate SNe «basic» parameters:
 ✦ *time at maximum light - phase*
 ✦ *color / absorption (Av)*
 ✦ *light curve widths parameter*
 ✦ *normalization parameter / absolute mag*

SALT2, SNooPy, SiFTO, (MLCS2k2) etc.

distance estimator

Hubble diagram

Empirically corrected Hubble diagram

$$\mu_B^i = \boxed{m_B^i} - M_B + \alpha \times \boxed{x_1^i} - \beta \times \boxed{c^i}$$

α, β and M_B optimized
&
disp. in magnitude added to reach

$$\chi^2 = \sum_{i=1}^{N} \frac{[\mu_{B,i}(\alpha,\beta,M) - \mu(z_i; \Omega_M, \Omega_\Lambda, \omega)]^2}{\sigma_{\mu_{B,i}}^2 + \sigma_{int}^2} = 1$$

SNfactory nearby Hubble diagram (2011/06/29)

Before

After

μ_B

○ Raw peak B magnitudes
● Corrected mags (96 SNe, RMS 0.155)

RMS 0.155 +- 0.011

$\Delta\mu_B$

Redshift

$\Delta\mu_B$
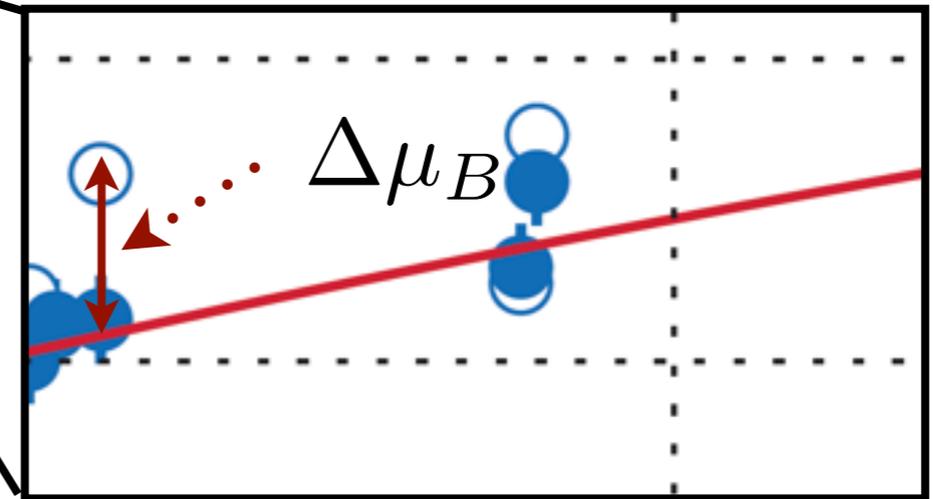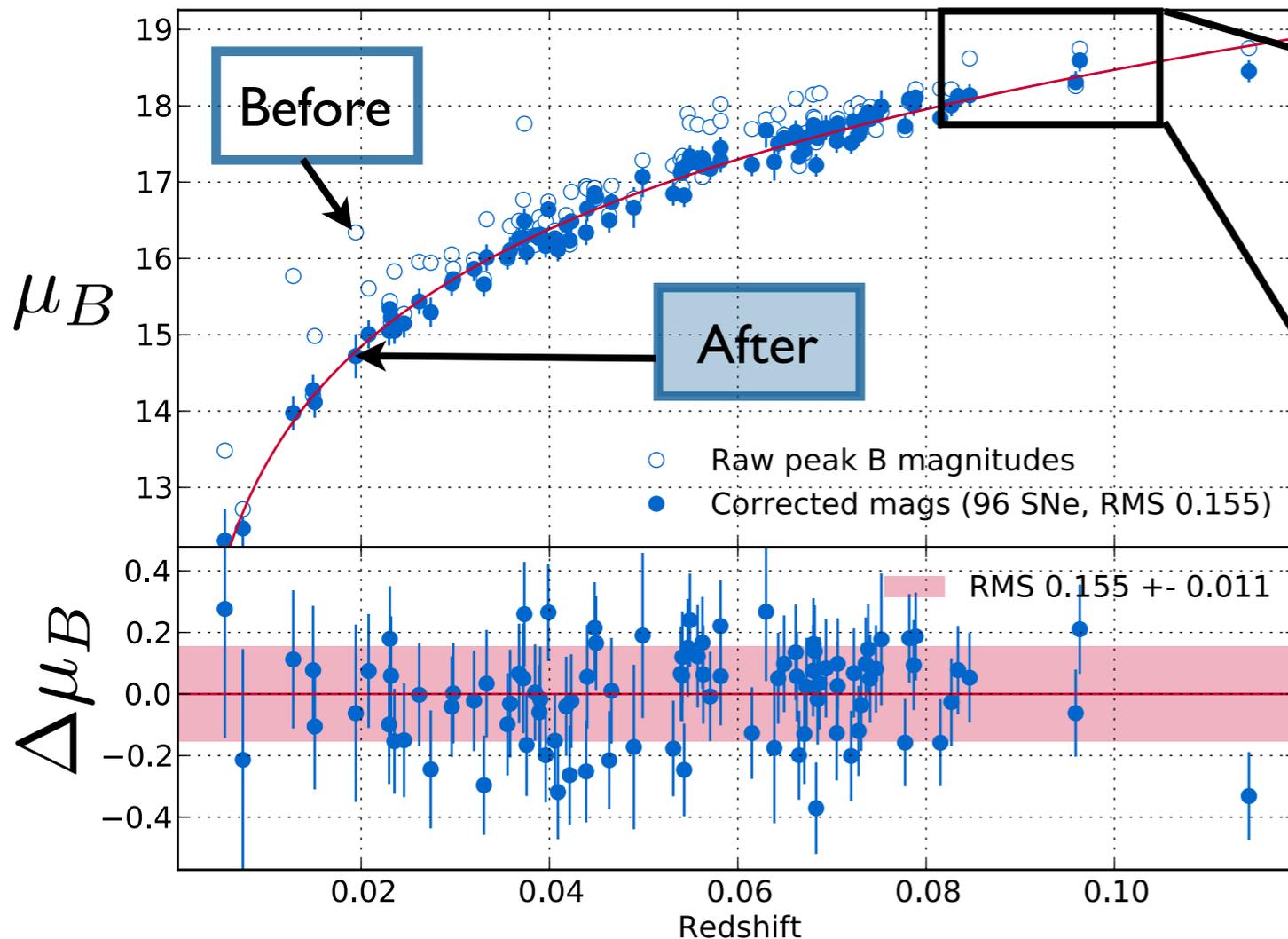
✦ Above : «sub-luminous» $\Delta\mu_B > 0$
✦ Below : «over-luminous» $\Delta\mu_B < 0$

0.40 mag ⟶ 0.16 mag

Dispersion decreases

Spectral time series
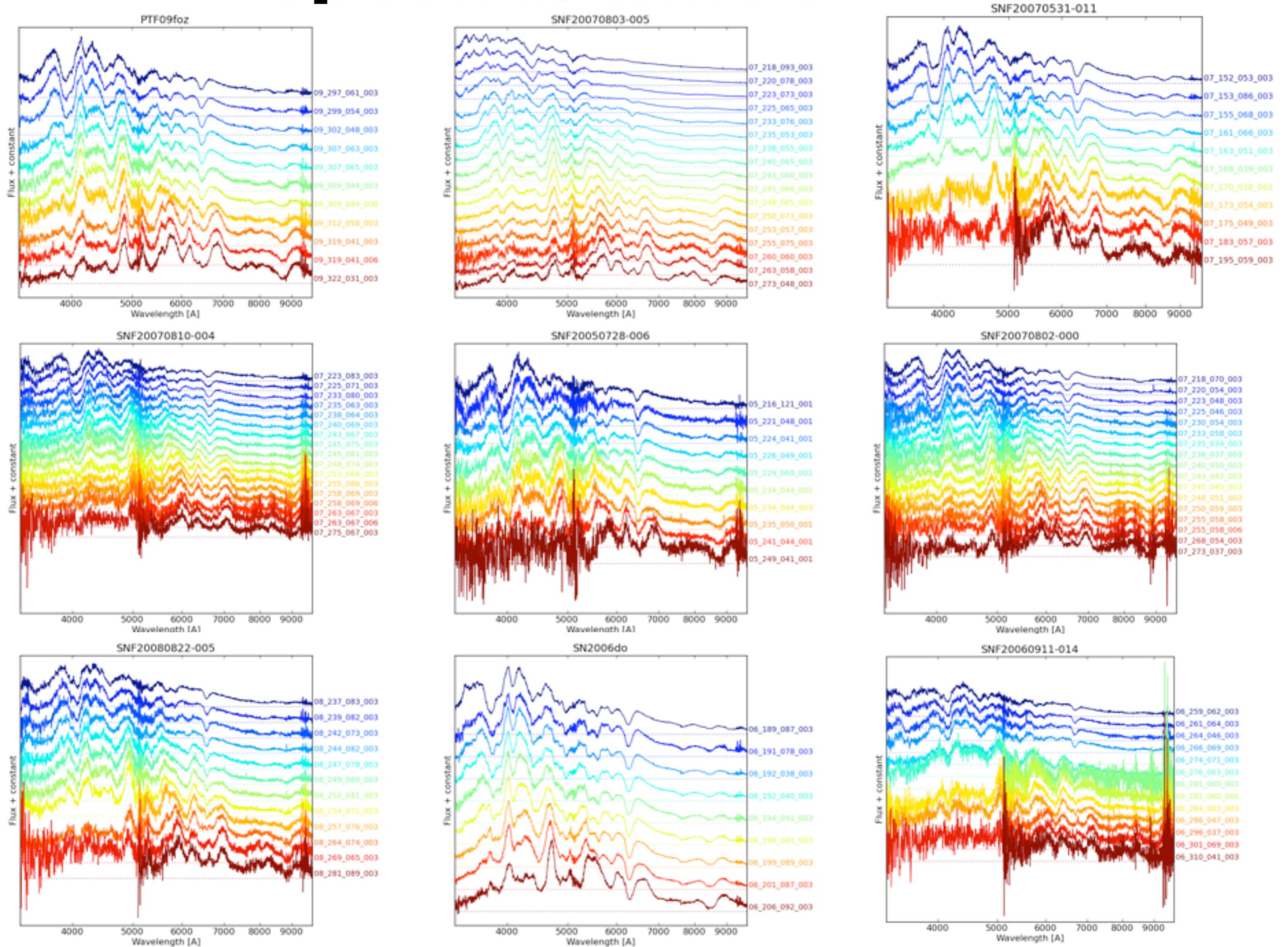
SNFactory: Spectrophotometry
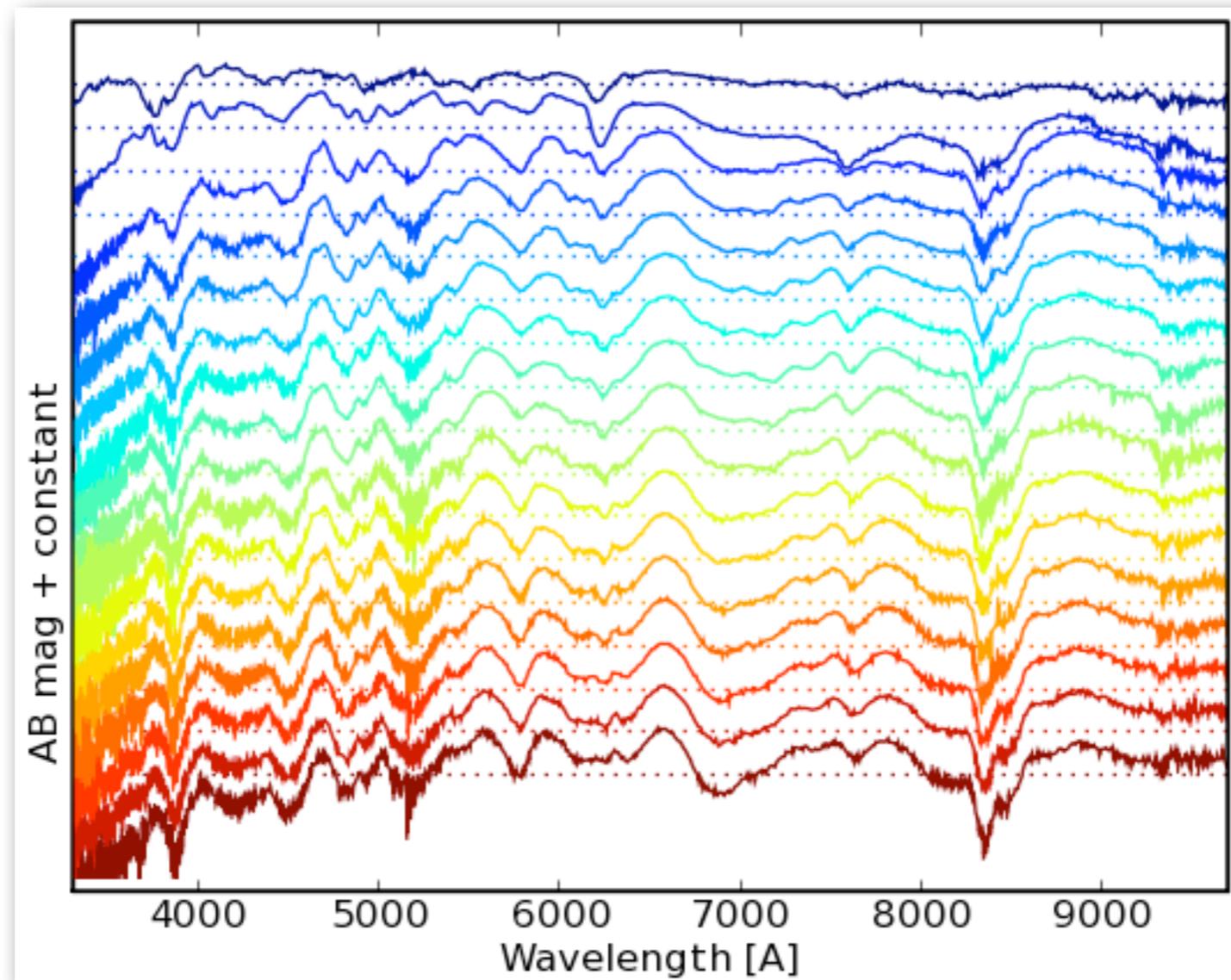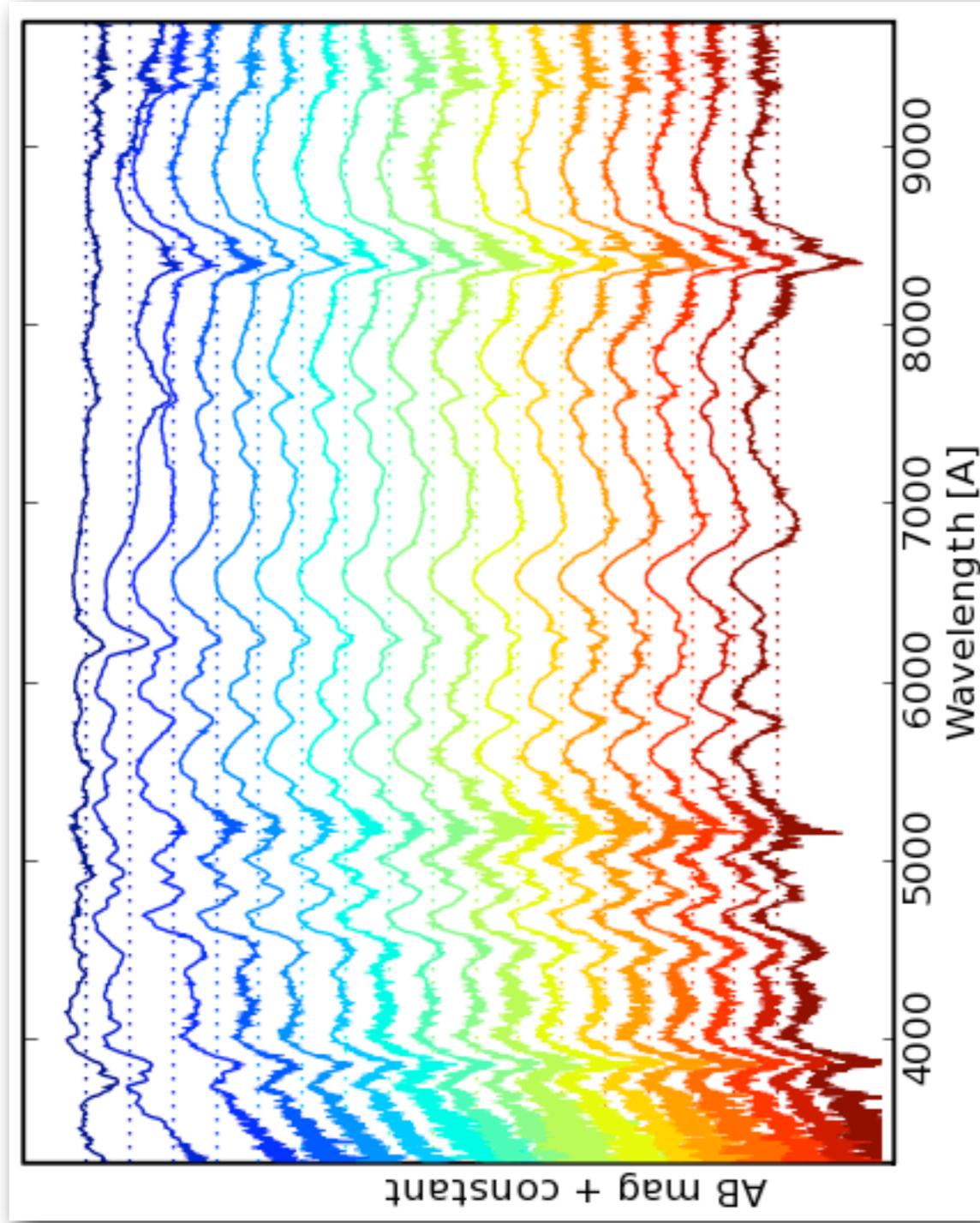
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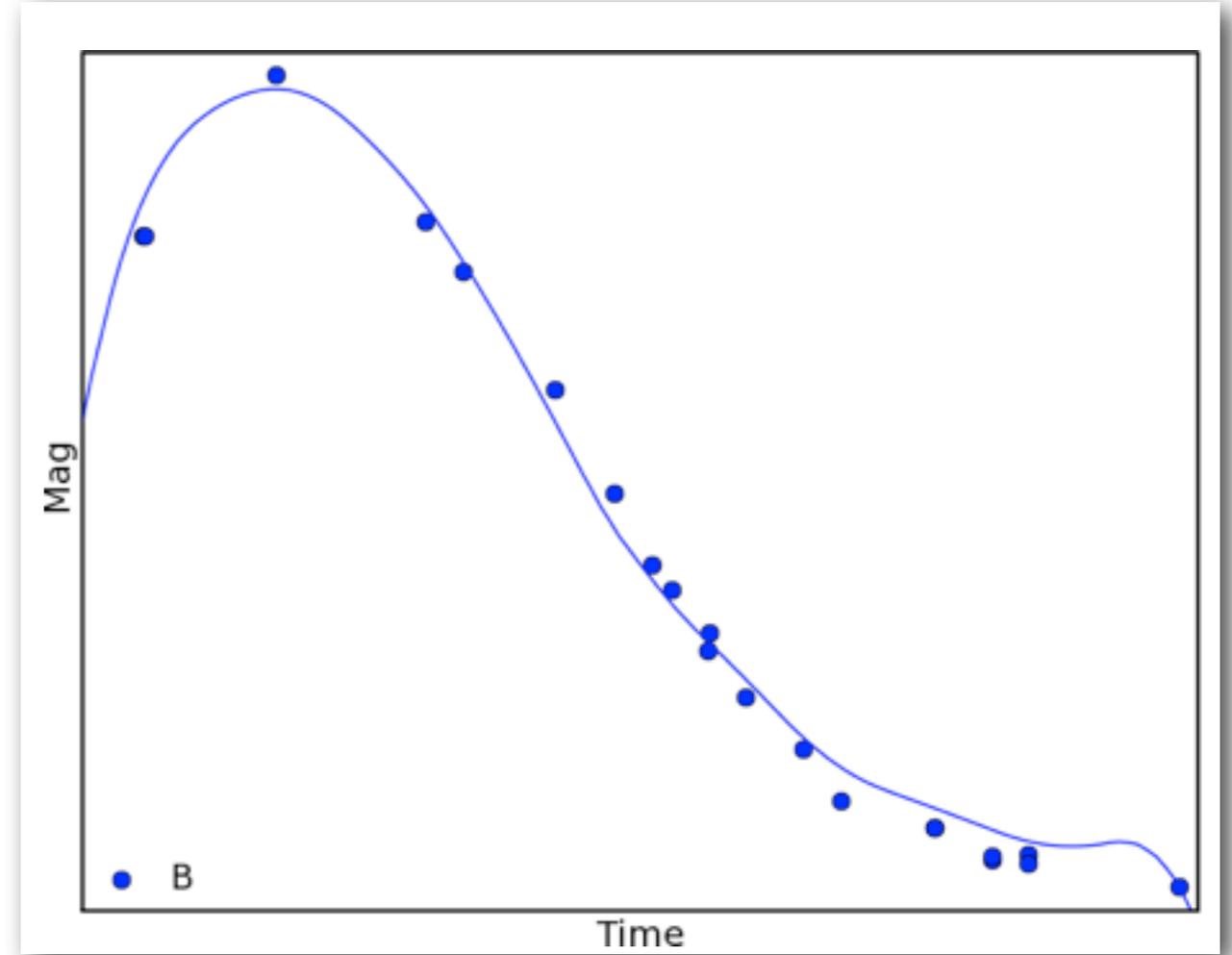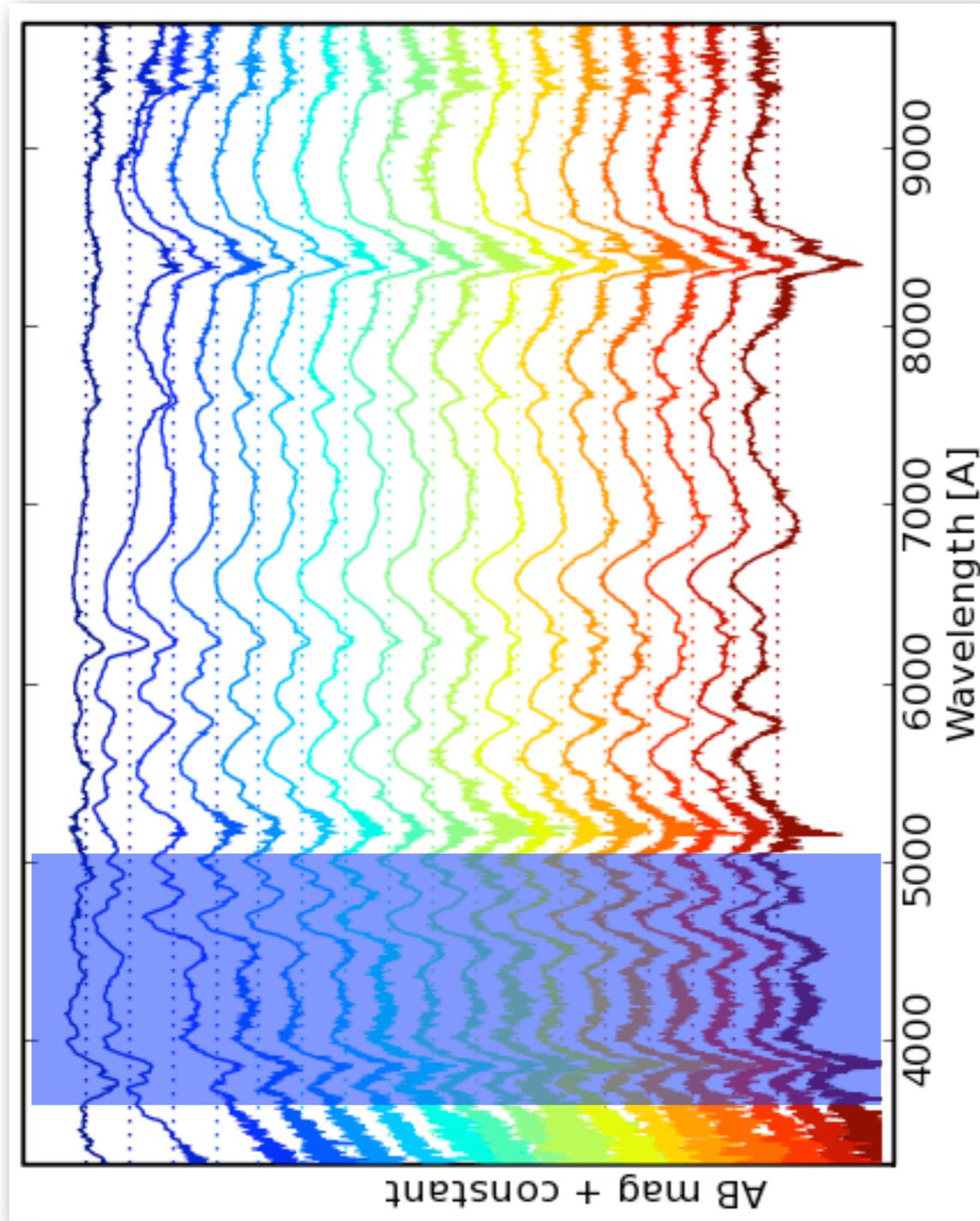
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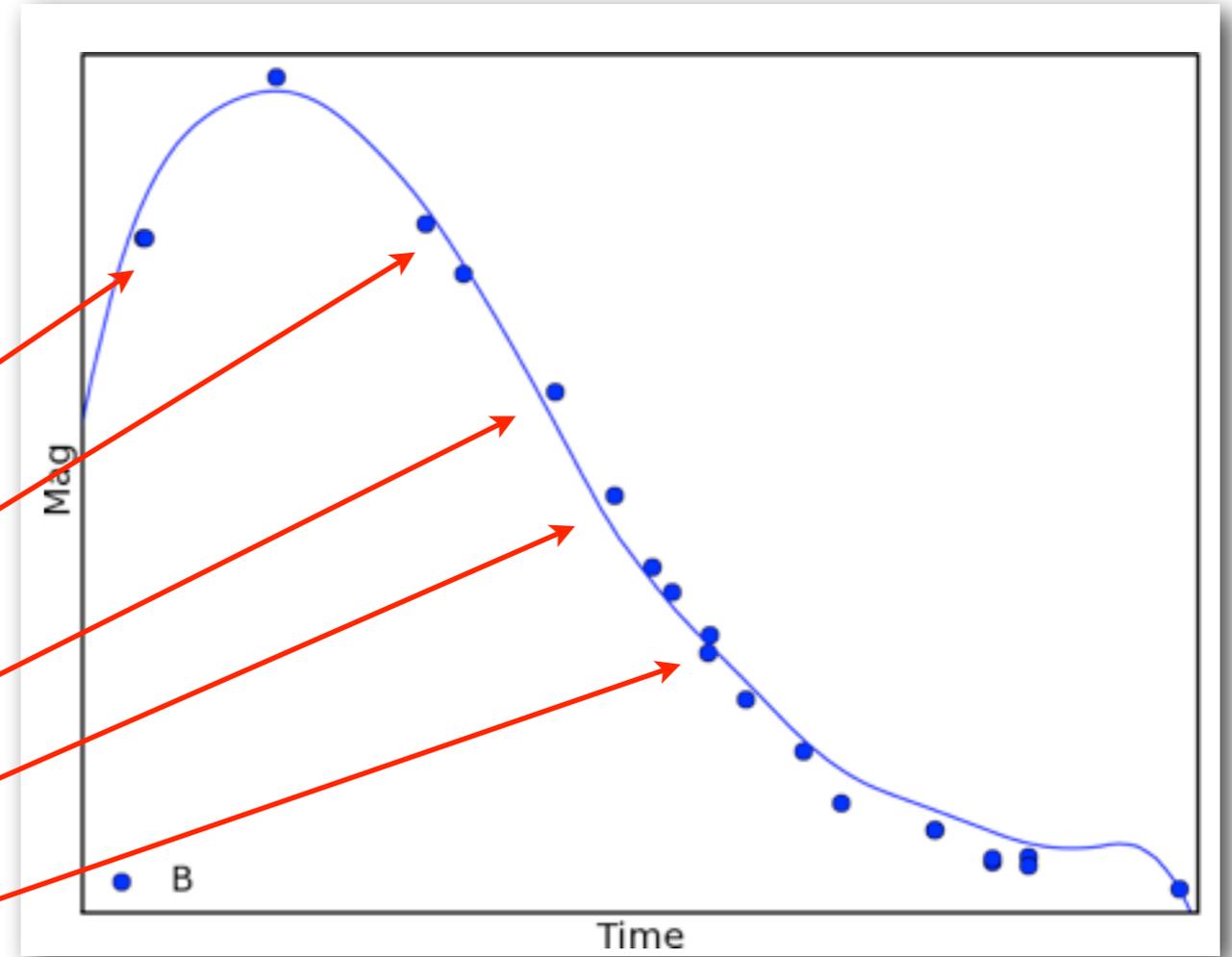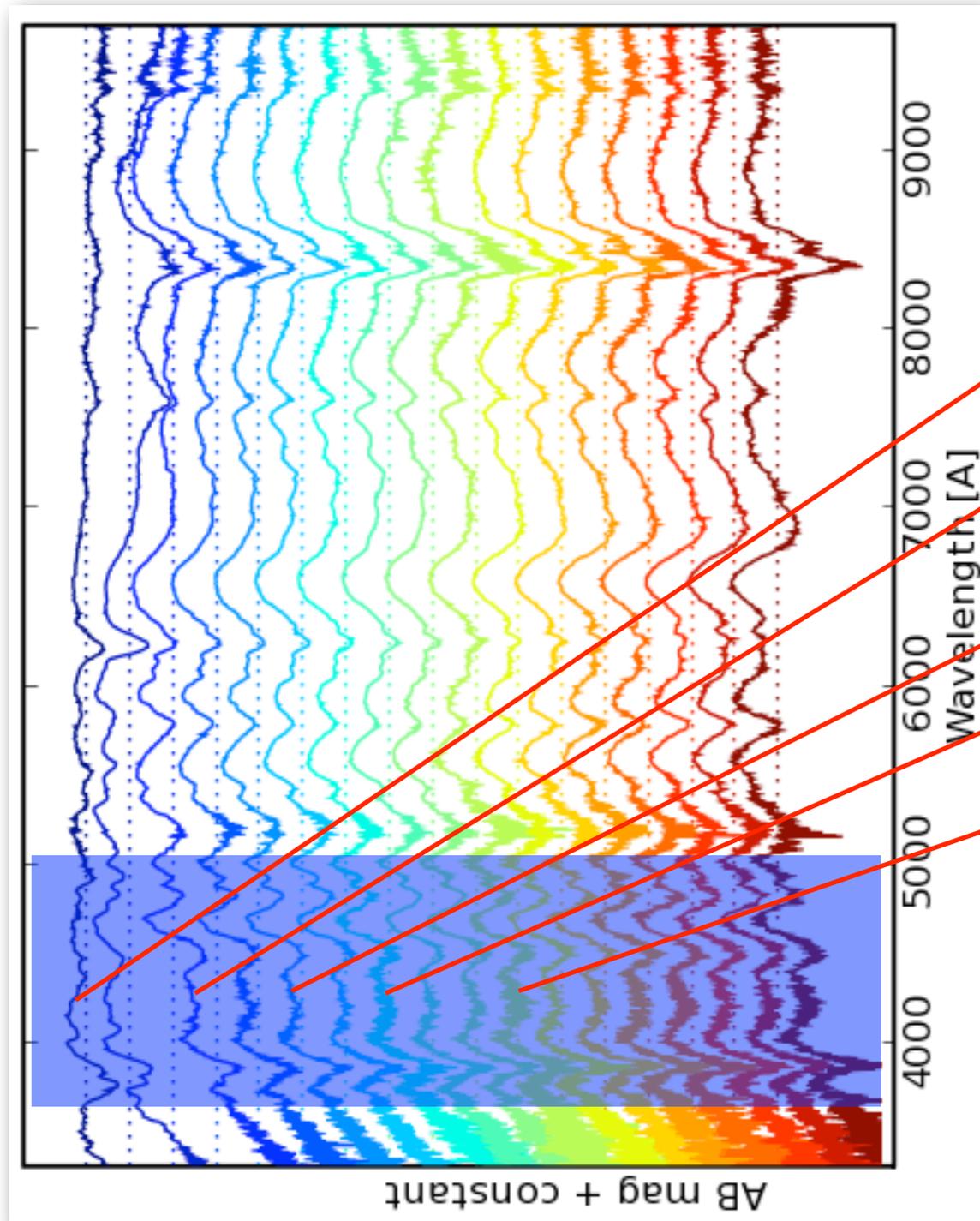
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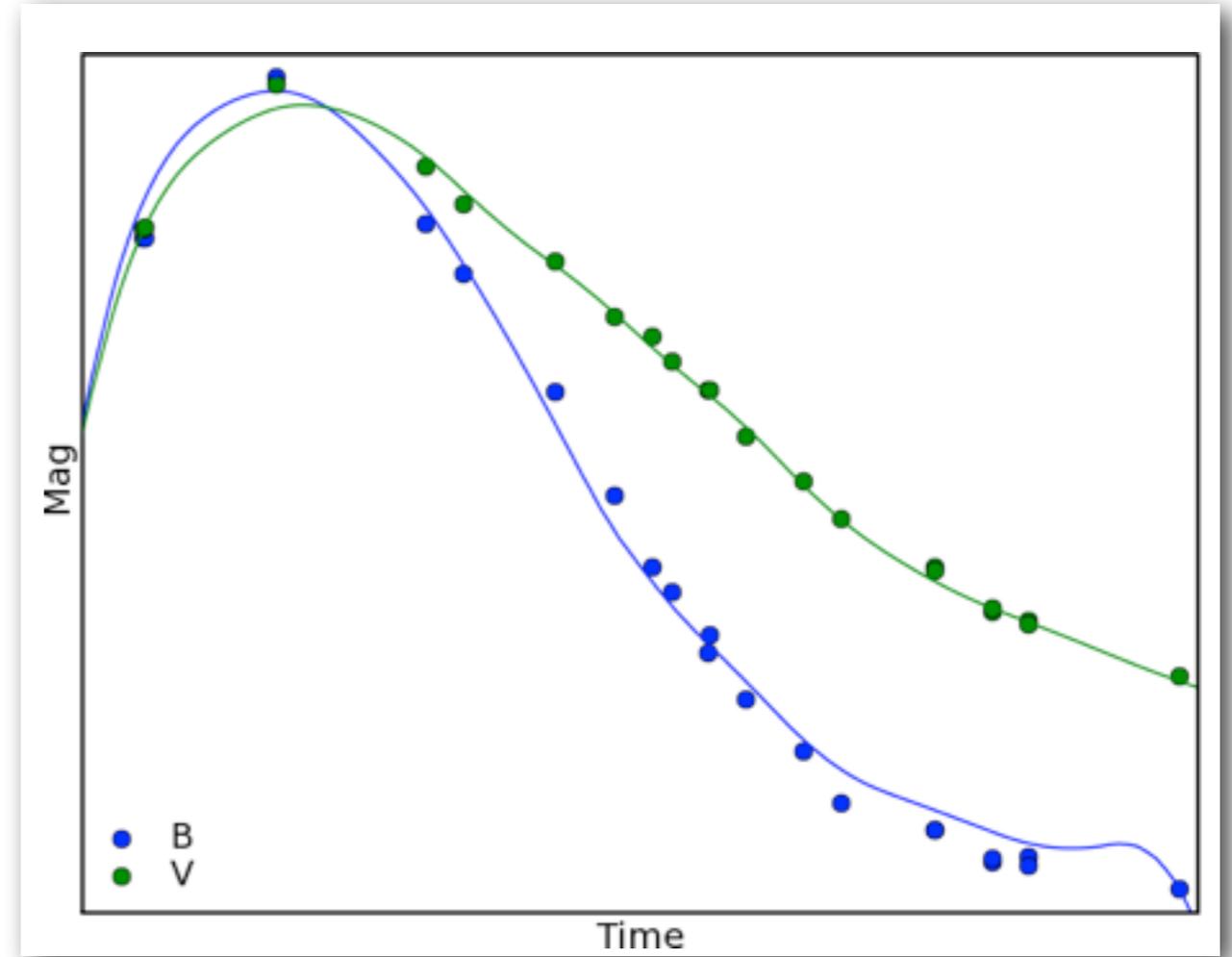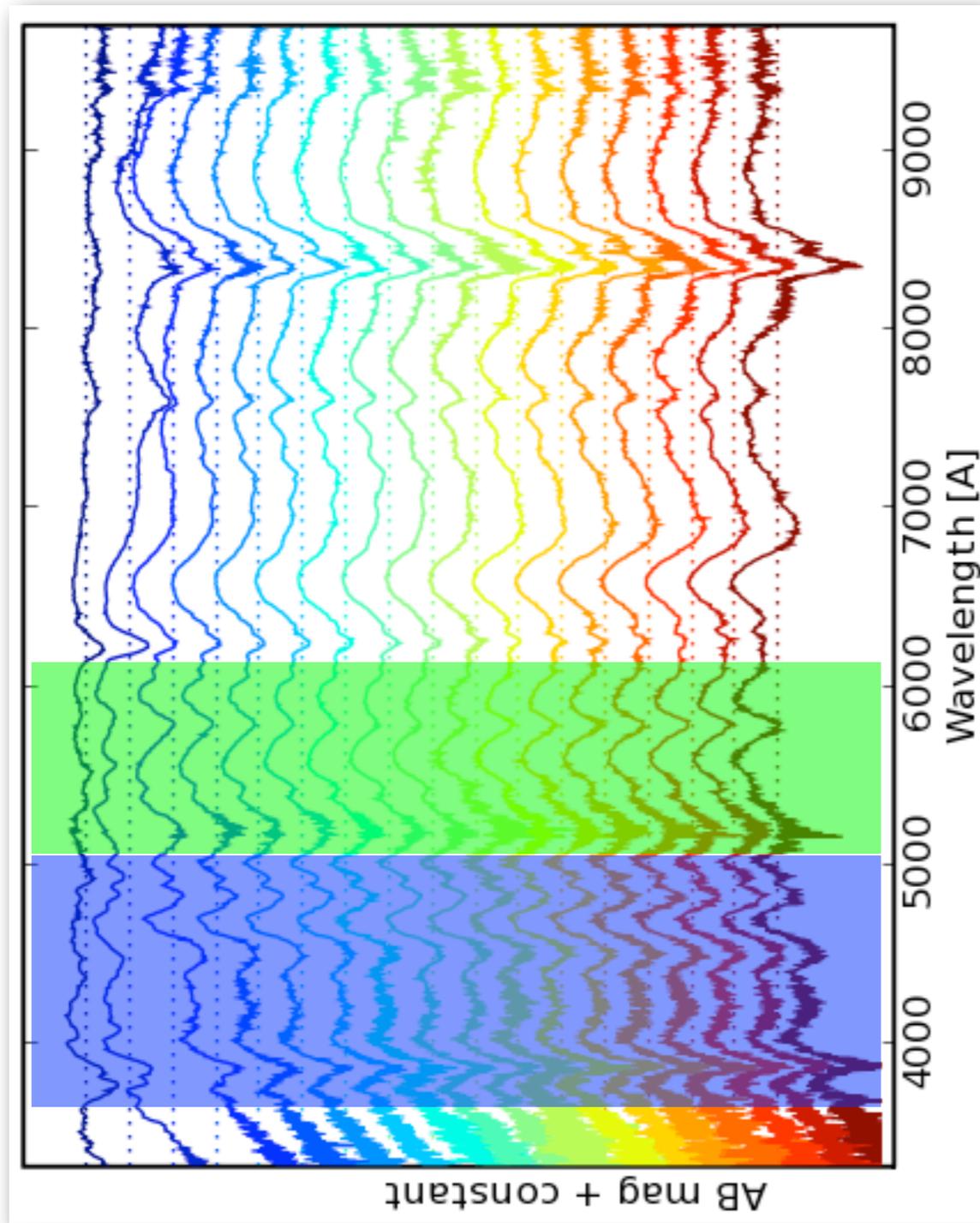
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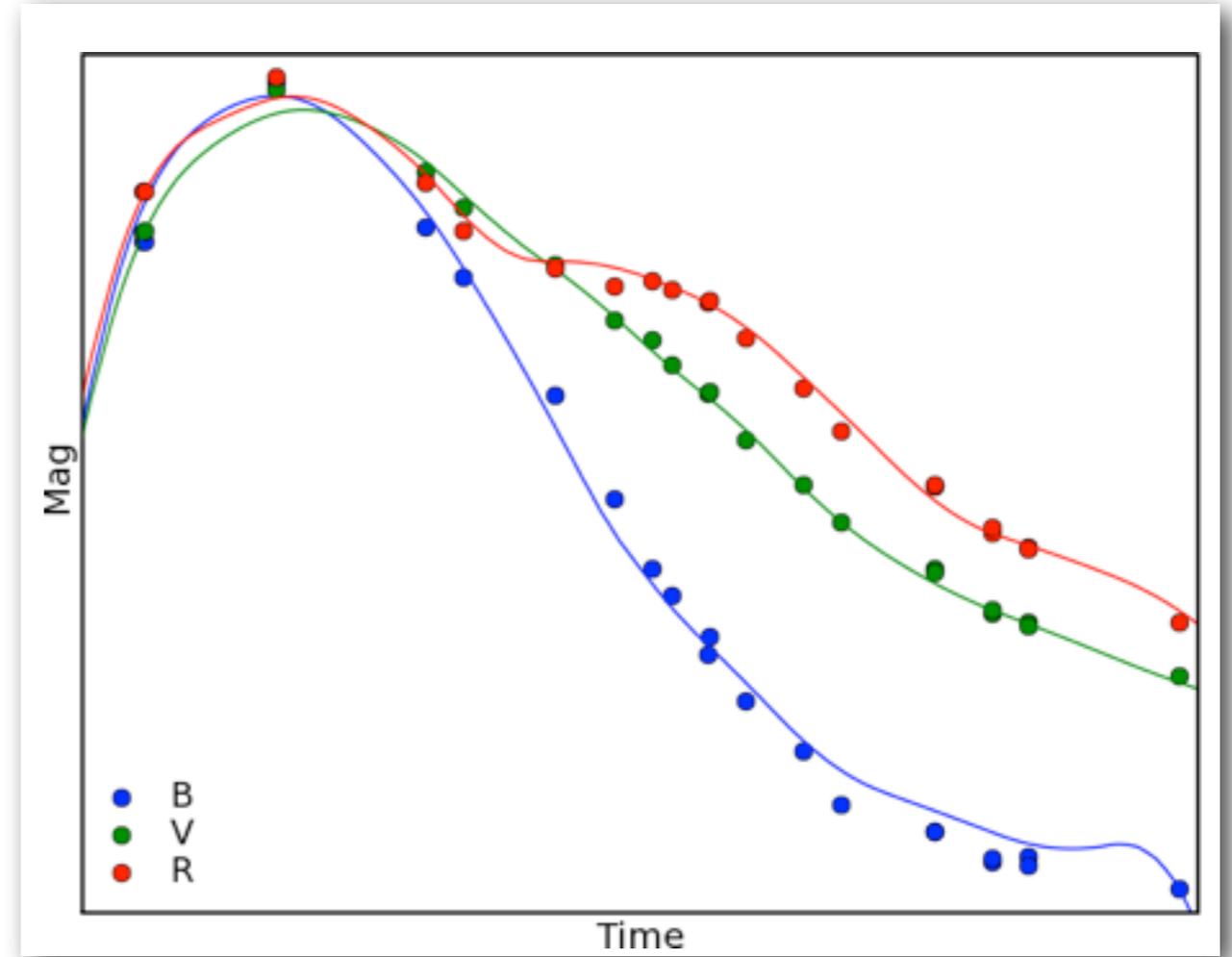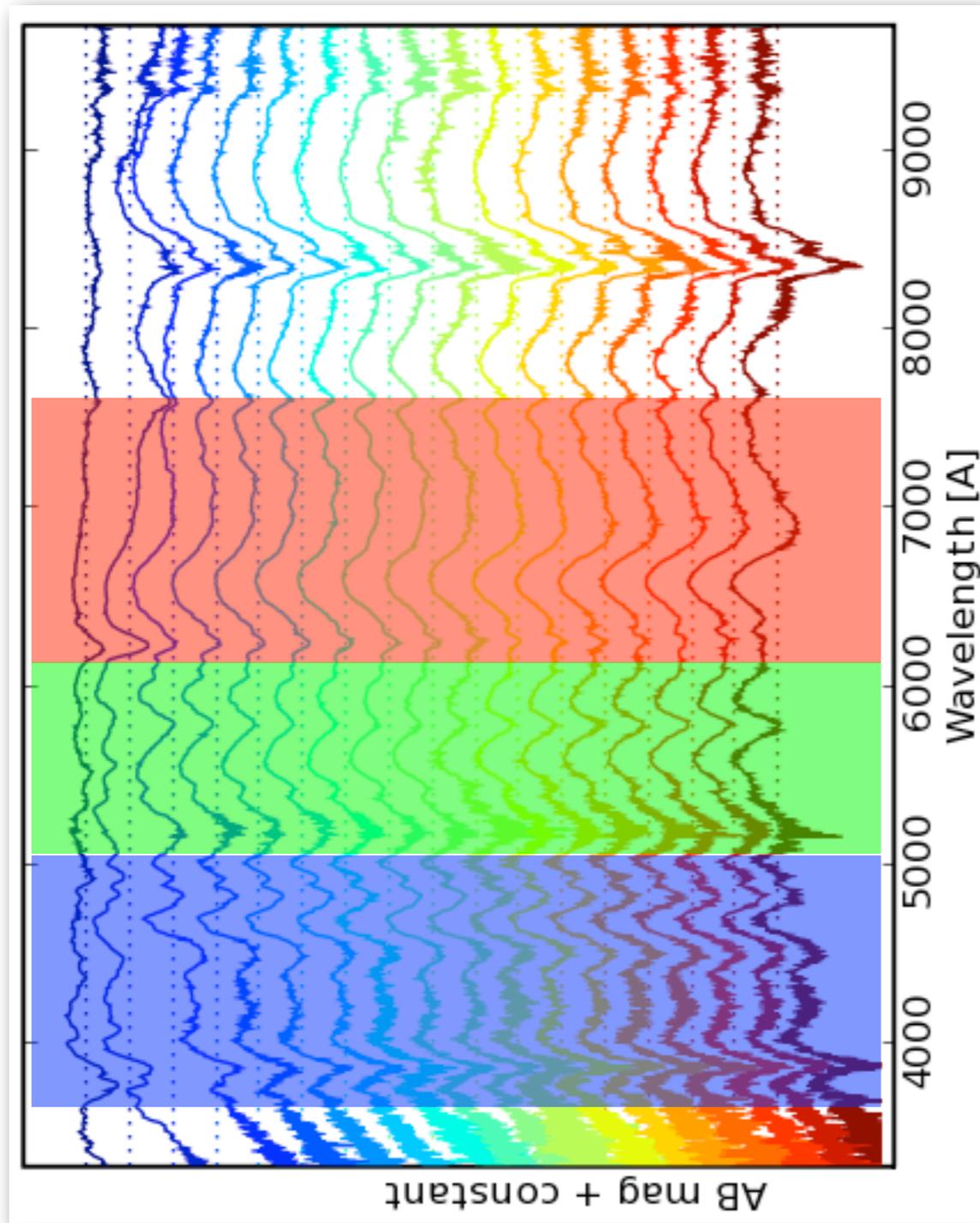
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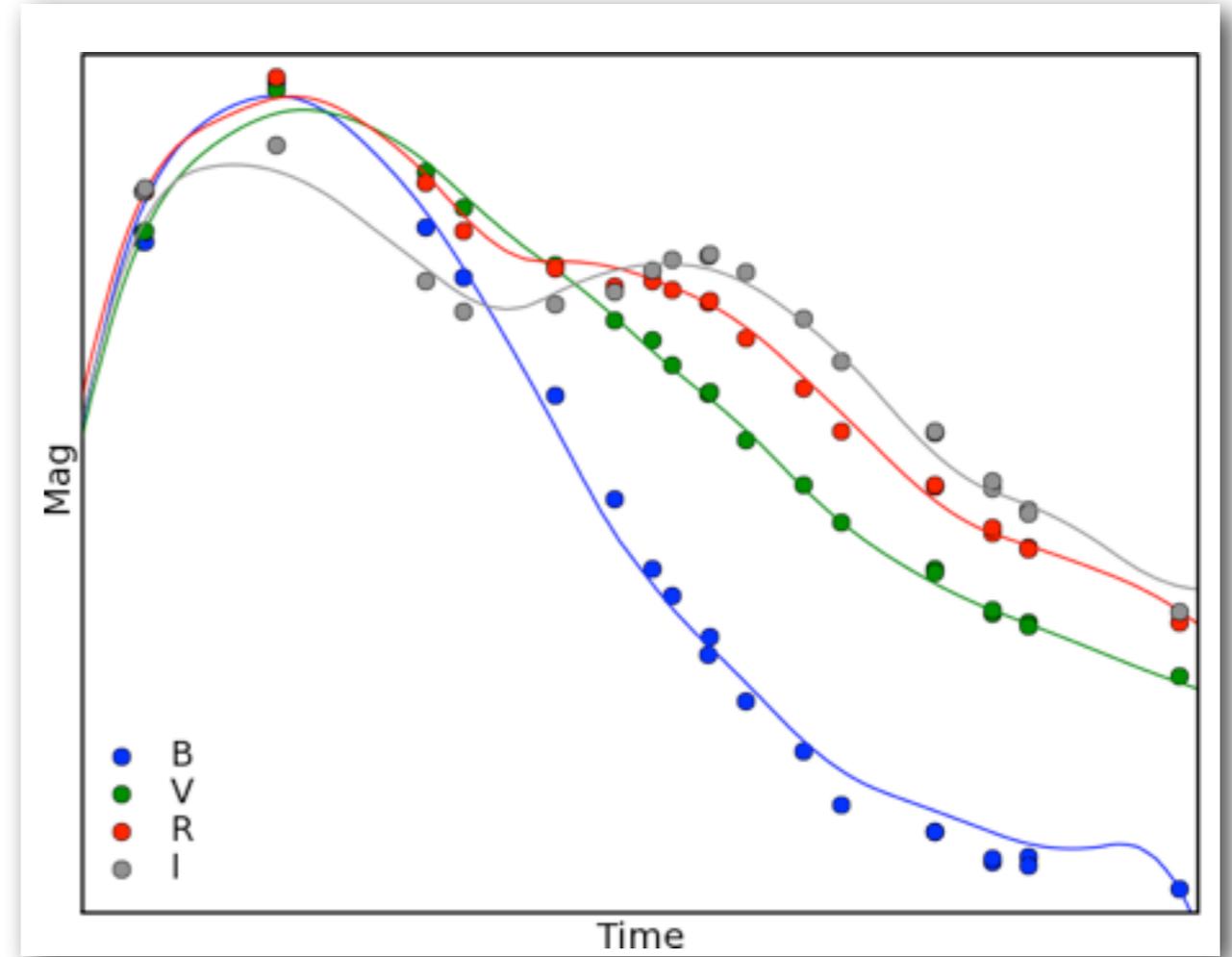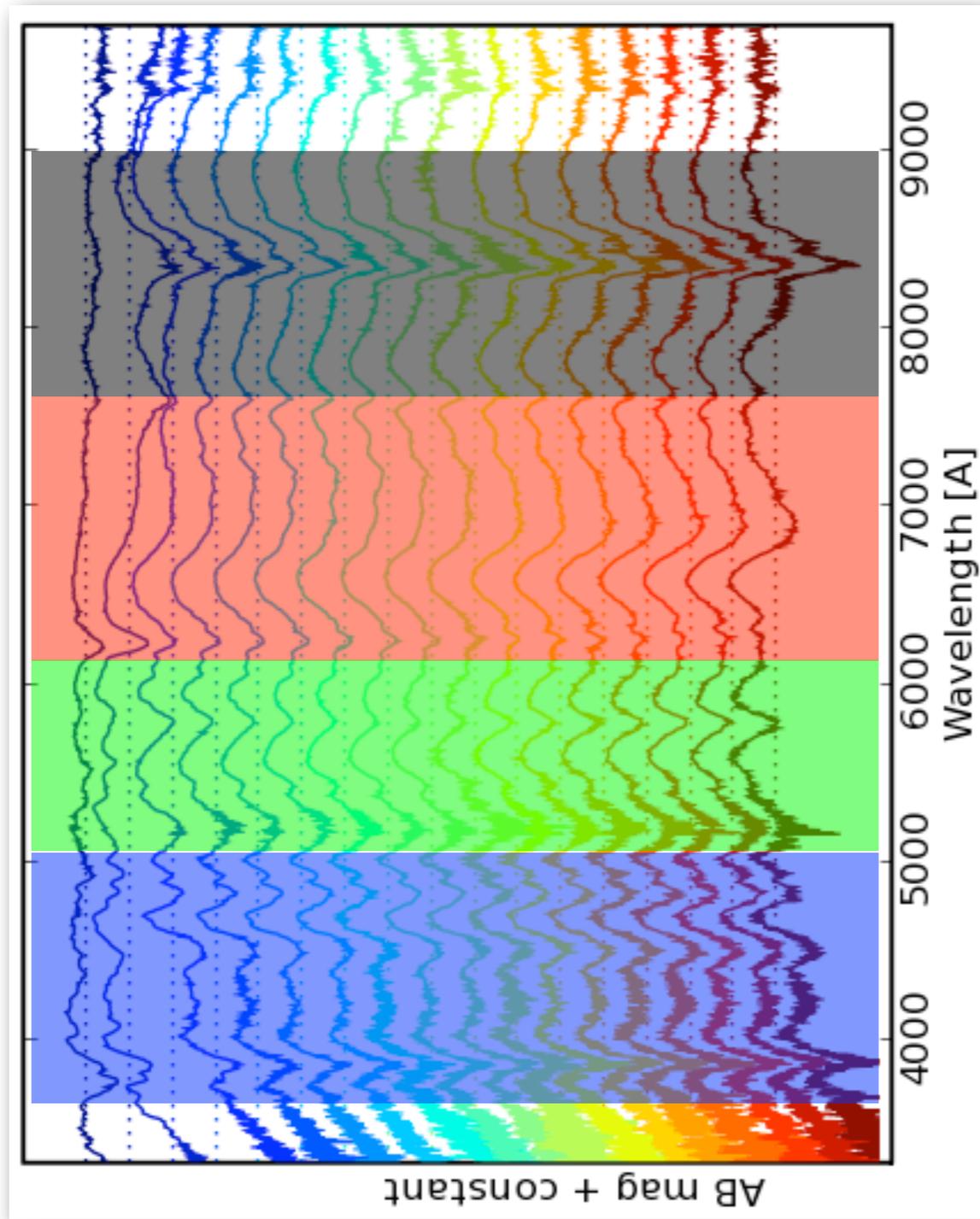
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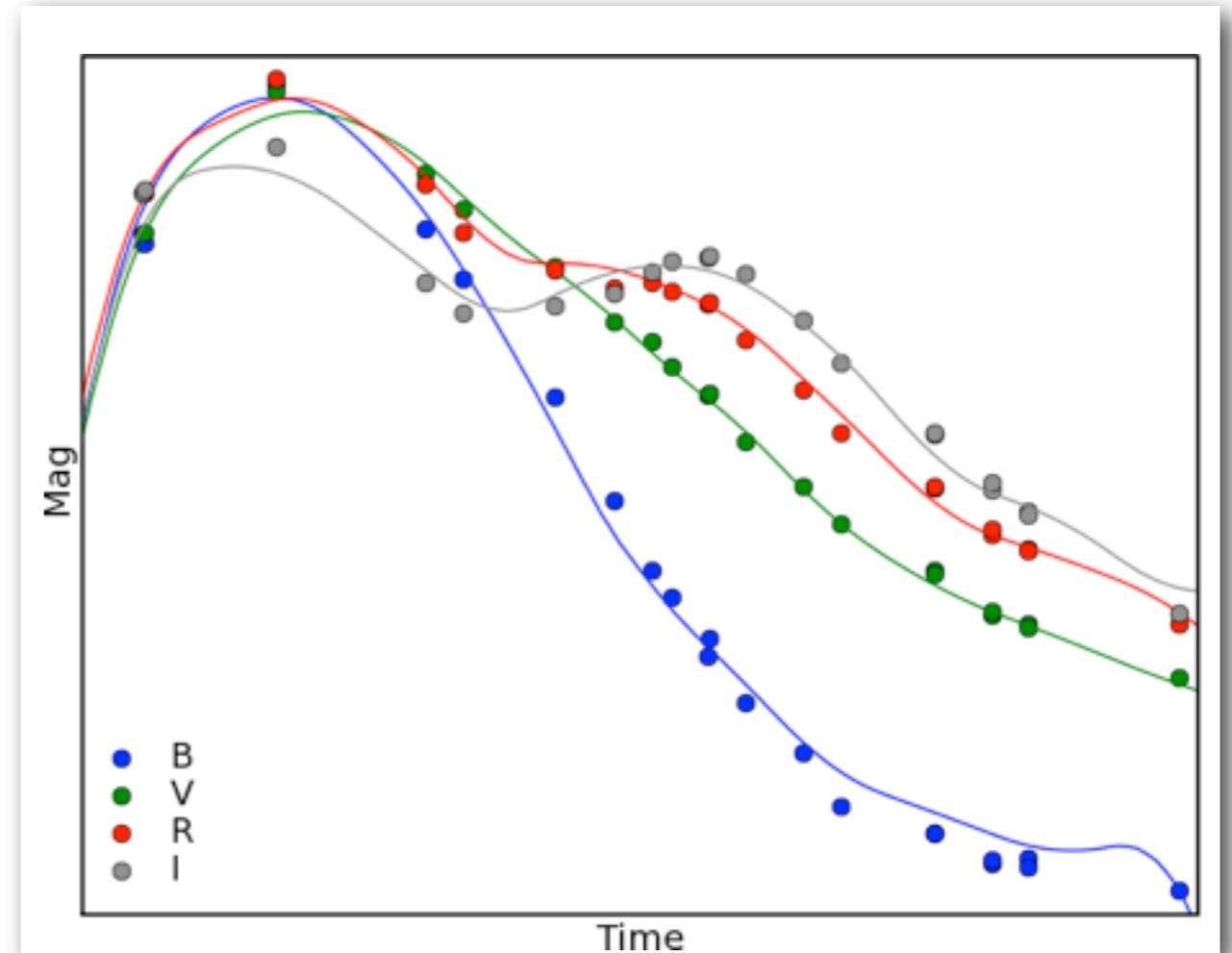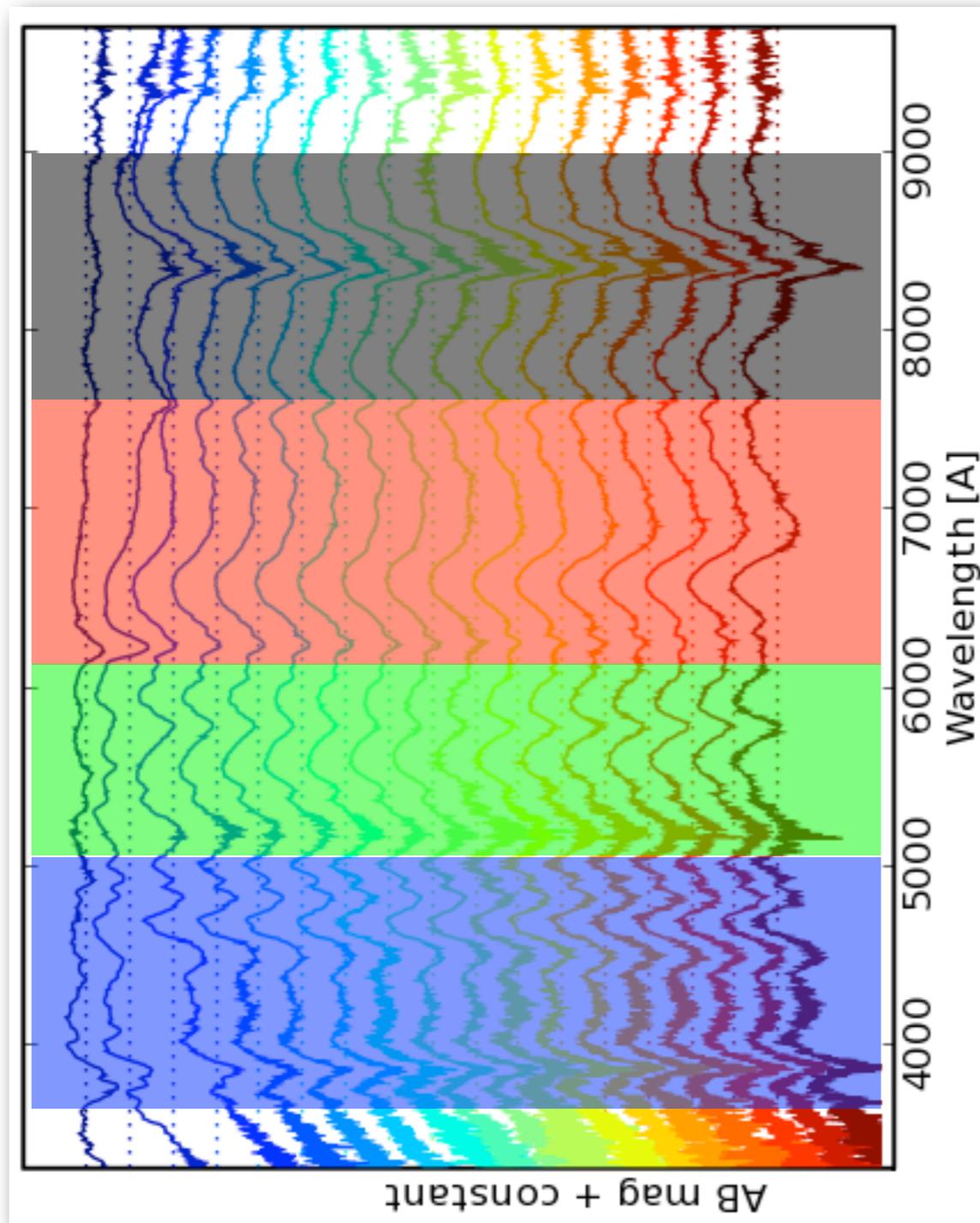
- One spectrum / point / night
- For any filter
- + spectral features