SN Ia spectral analyses from the Nearby Supernova Factory (SNfactory)

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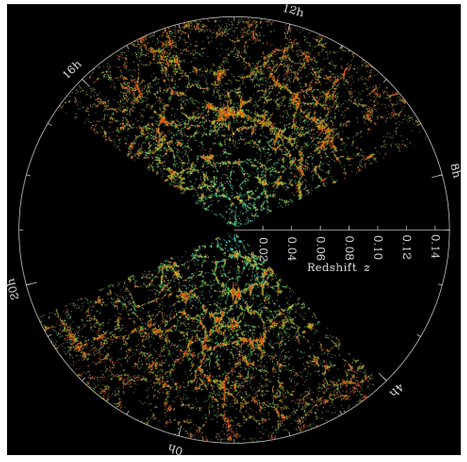
22ème congrès général de la SFP

July 4th, 2013

Concordance cosmology

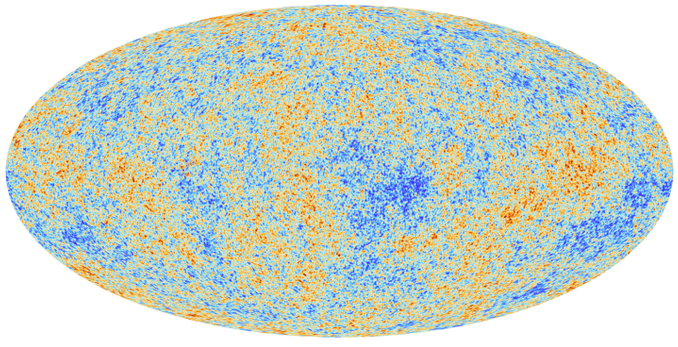
Standard candles
(SNe Ia)

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



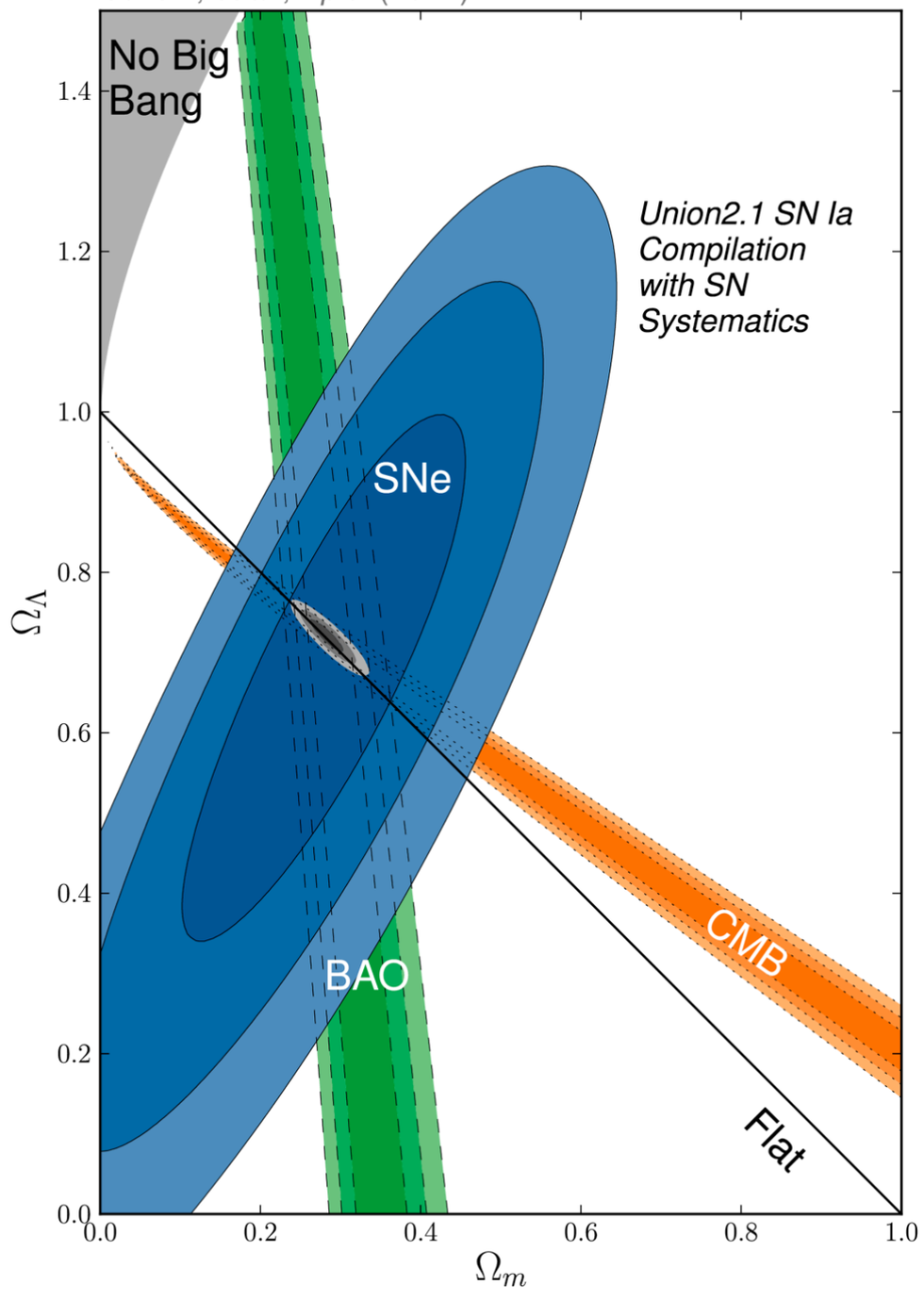
SDSS

CMB
(COBE, WMAP, **PLANCK**)



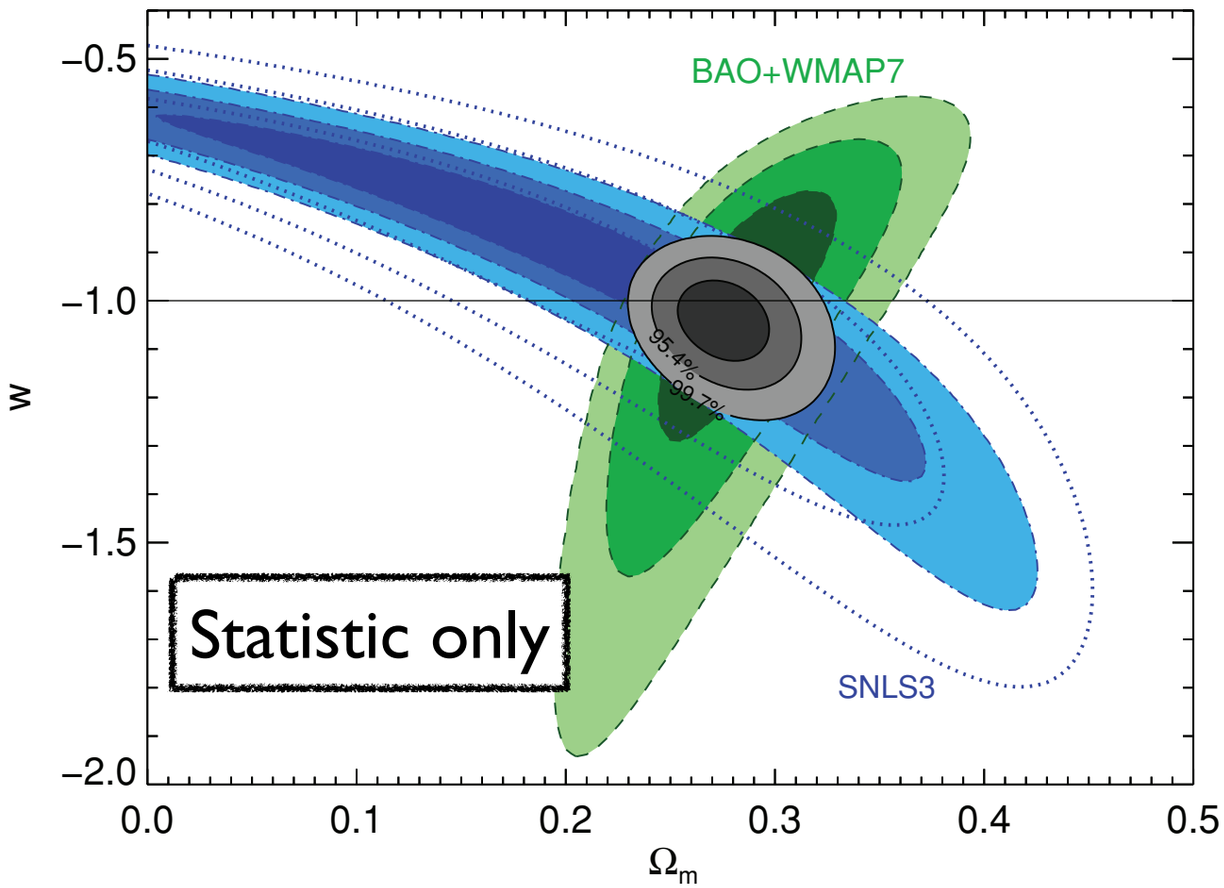
PLANCK

Supernova Cosmology Project
Suzuki, et al., *Ap.J.* (2011)



Cosmological uncertainties

SNLS3: Sullivan et al. 2011



Systematics dominate

Calibration

+

“SNe Ia”

Cosmological uncertainties

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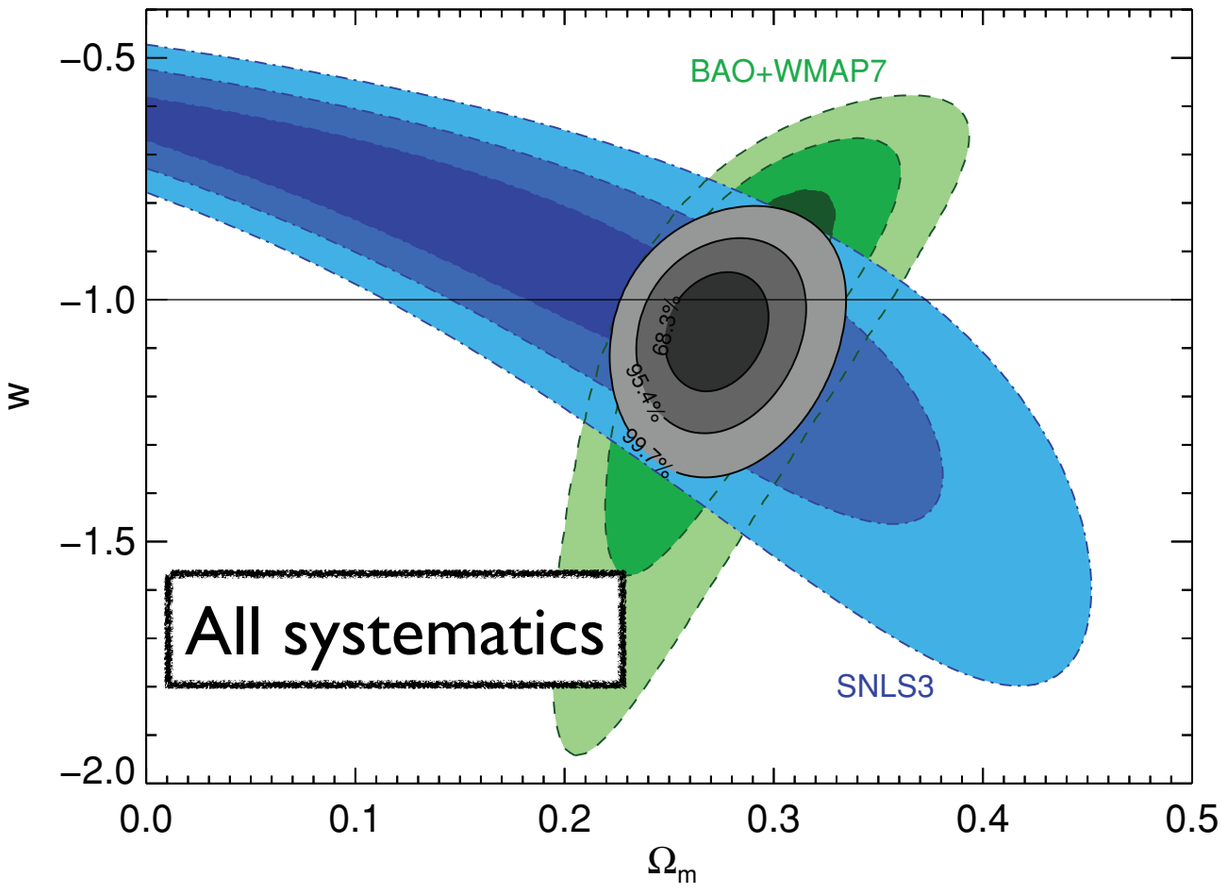

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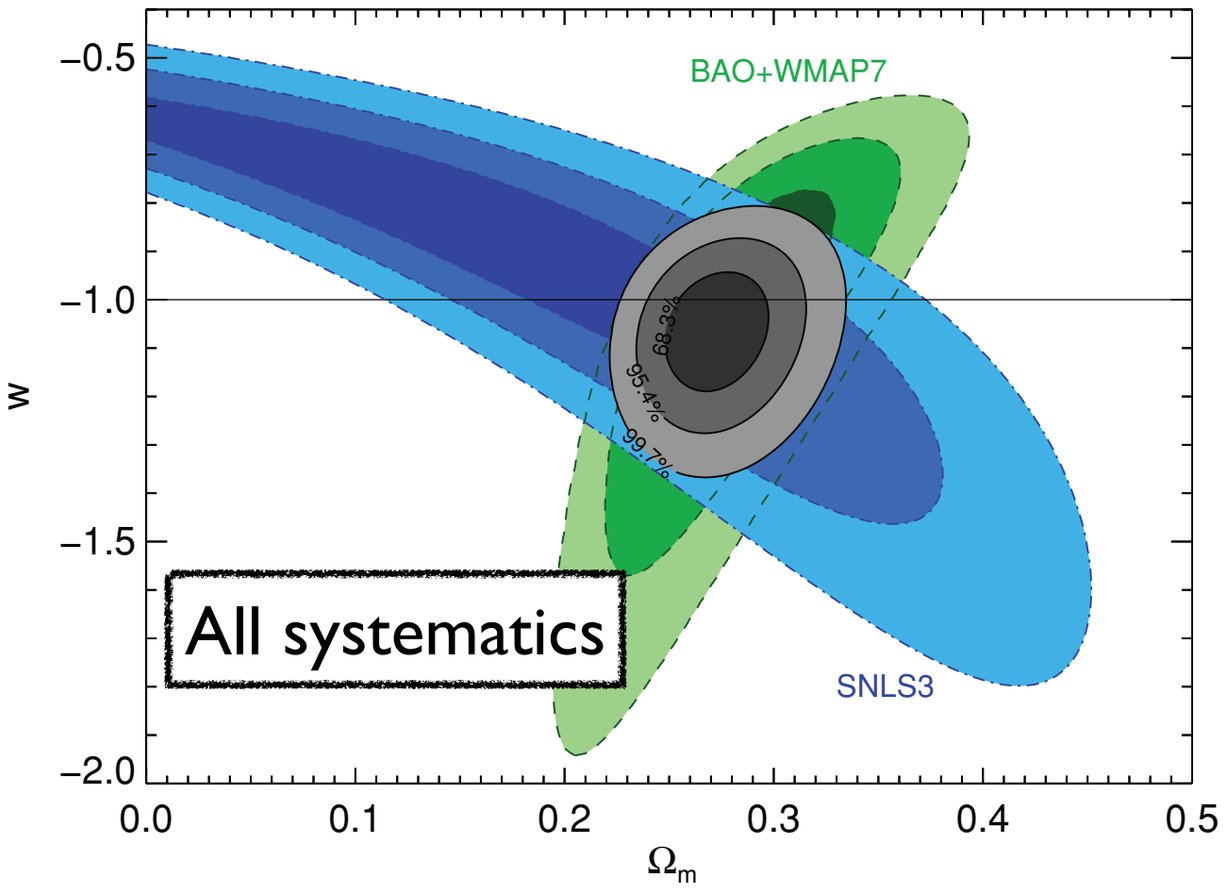

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"SNe Ia"

Need **better understanding** of:

- the SNe Ia as astrophysical objects: sub-classes? intrinsic variabilities (progenitors issues)? z-evolution? etc.
- the SN environment: Host galaxy extinction and properties

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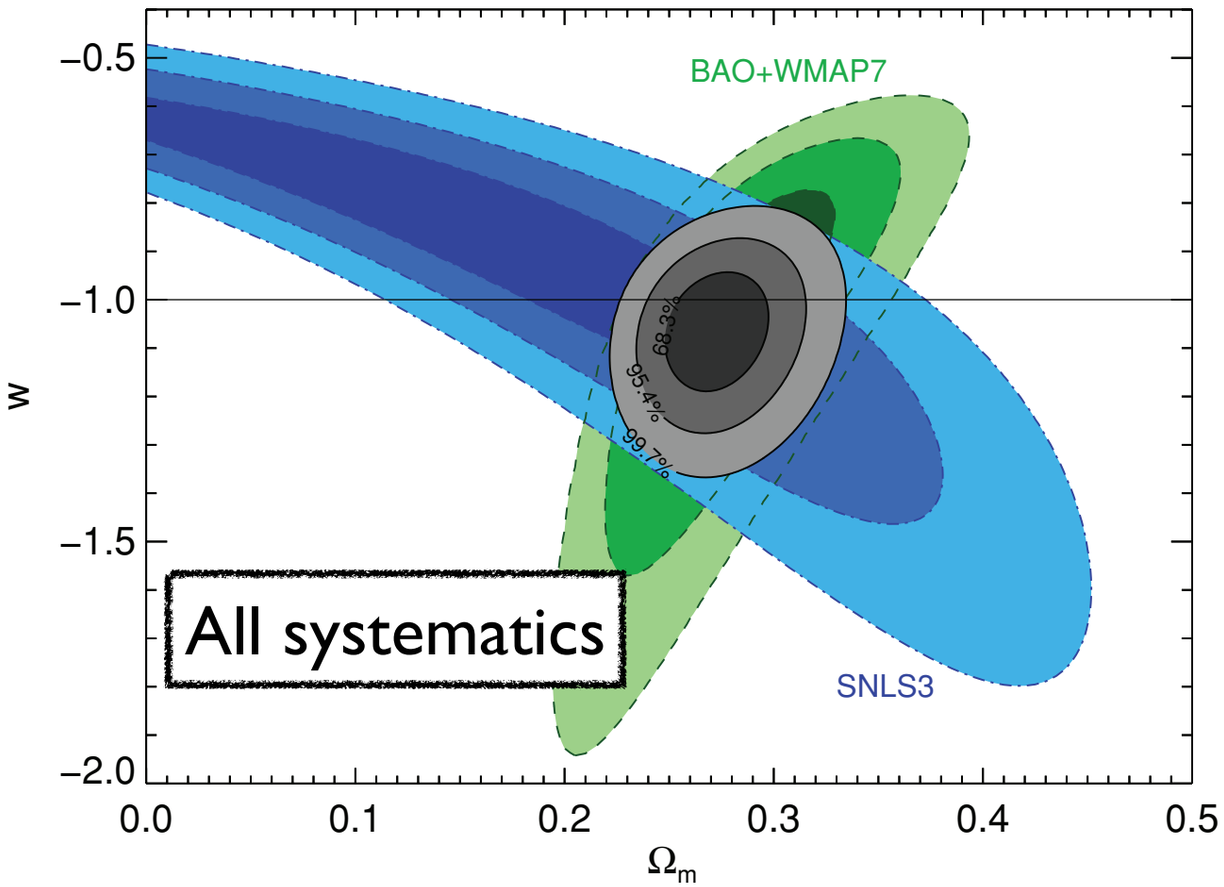

Systematics dominate

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

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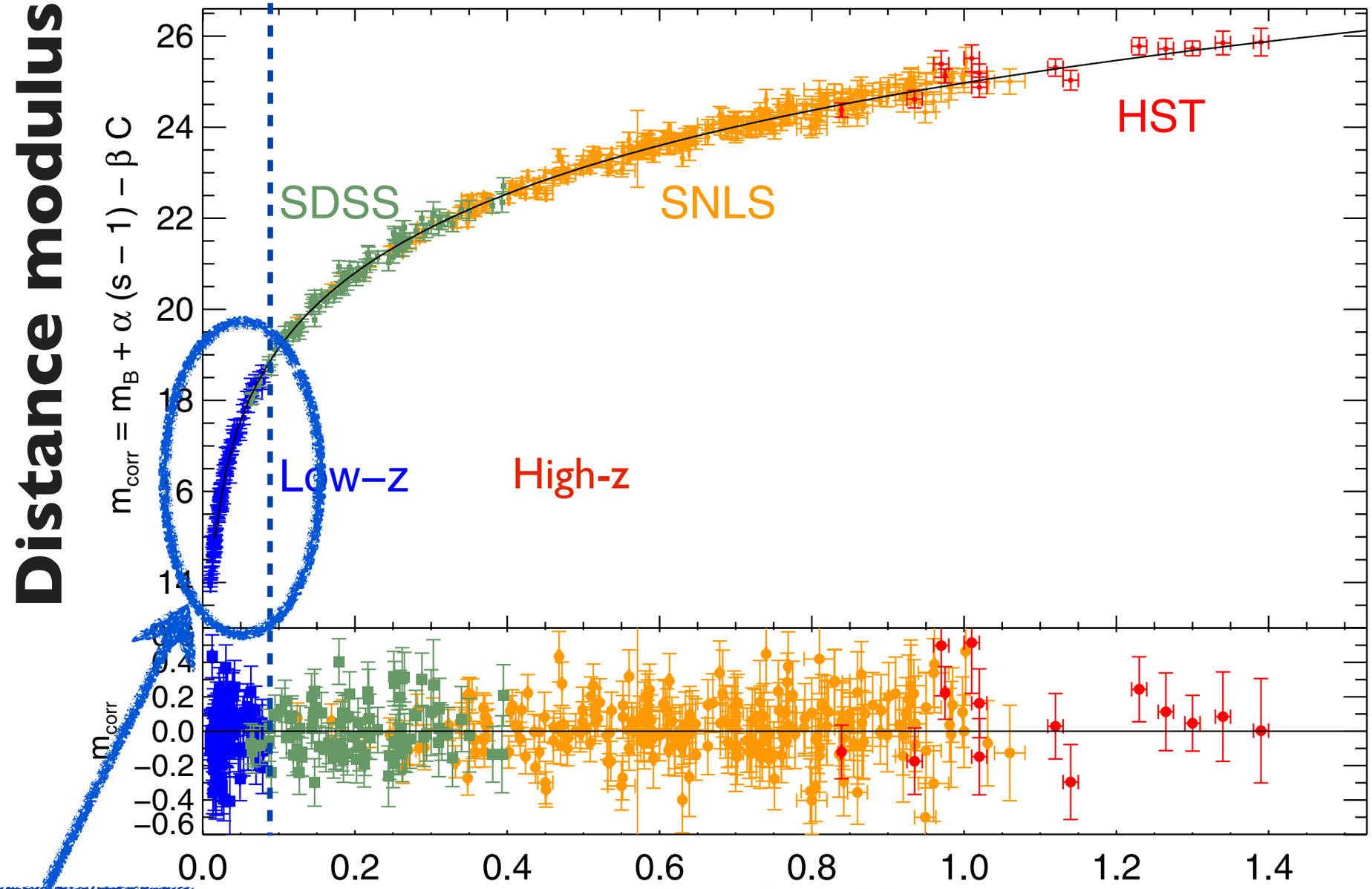
- the SN environment: Host galaxy extinction and properties

Hubble diagram

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



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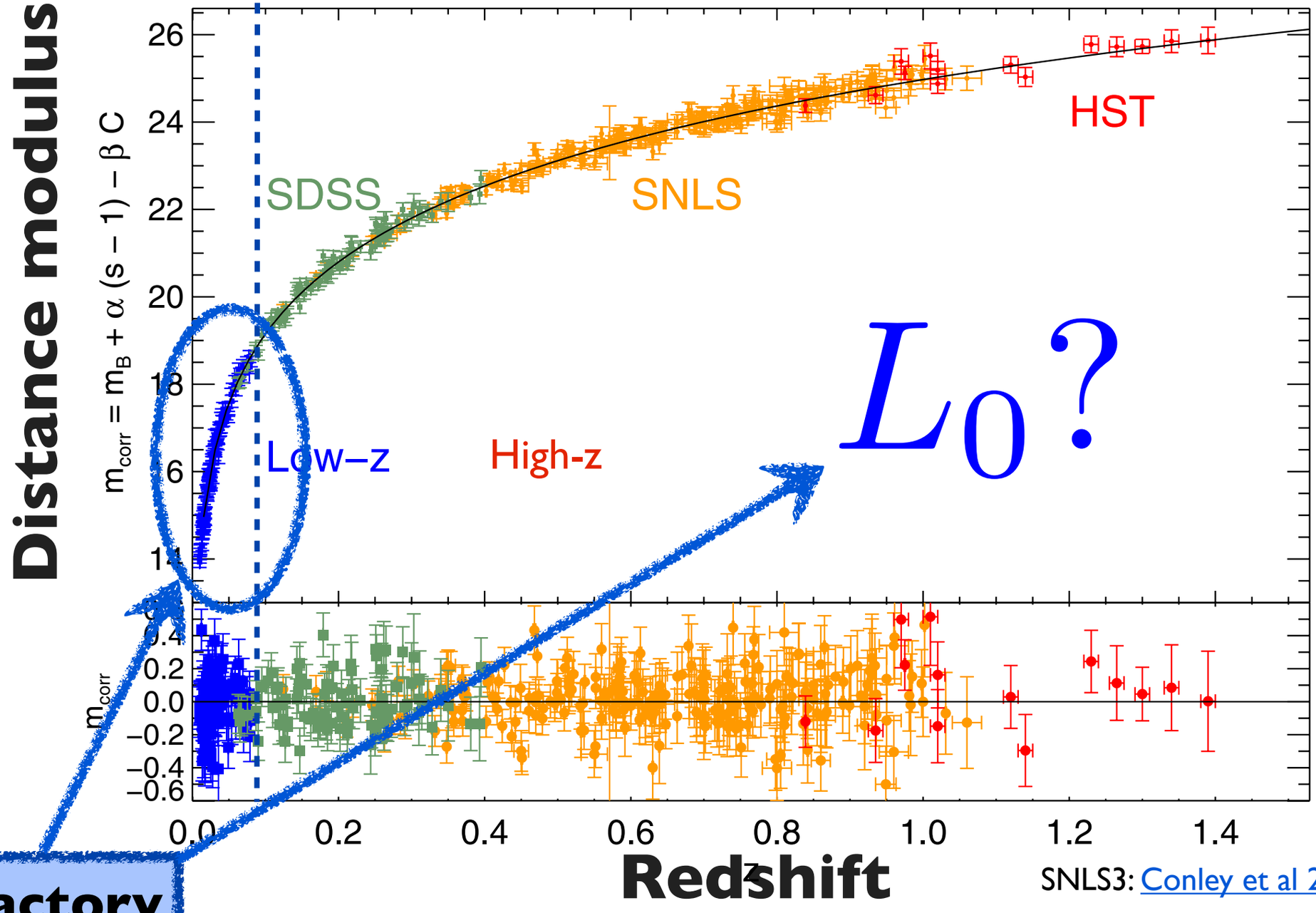
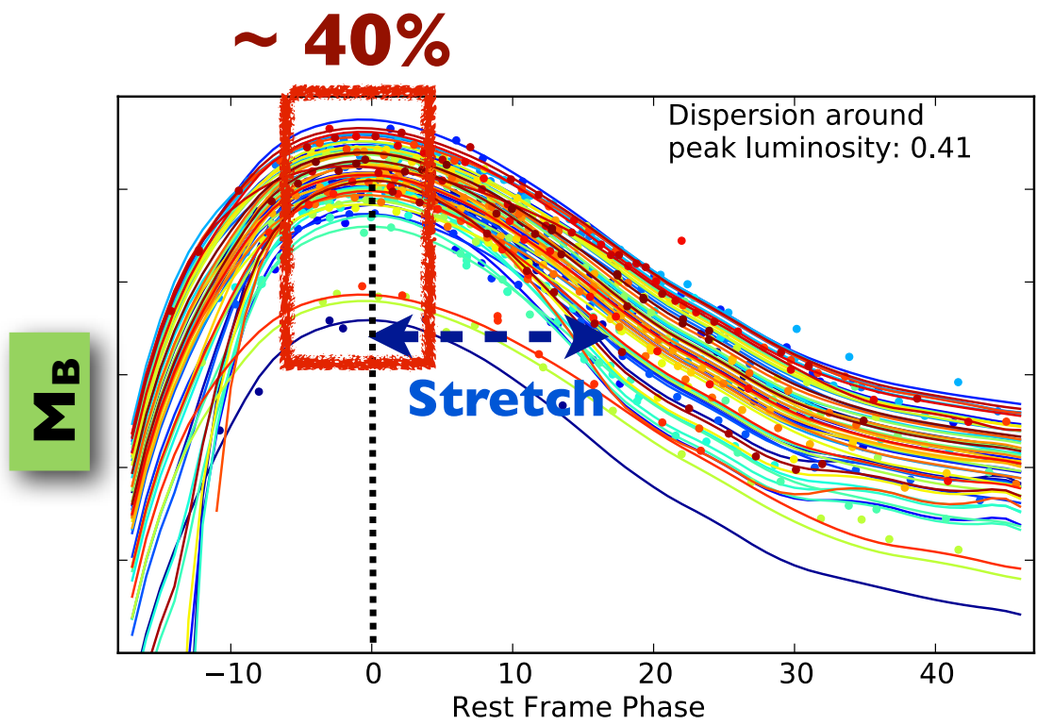


SNfactory

SNLS3: Conley et al 2011

SNe Ia: standardizable candles

- **Brighter - slower:** Light-curve width
  - *progenitor composition/explosion (intrinsic)*
- **Brighter - bluer:** Color (B-V)
  - *host interstellar medium extinction (extrinsic)*



Light curve fitters give:

- time at maximum light - phase
- *color / absorption (Av)*
- *light-curve width parameter*
- *normalization parameter / absolute mag*

(SALT2, Guy et al 2007)

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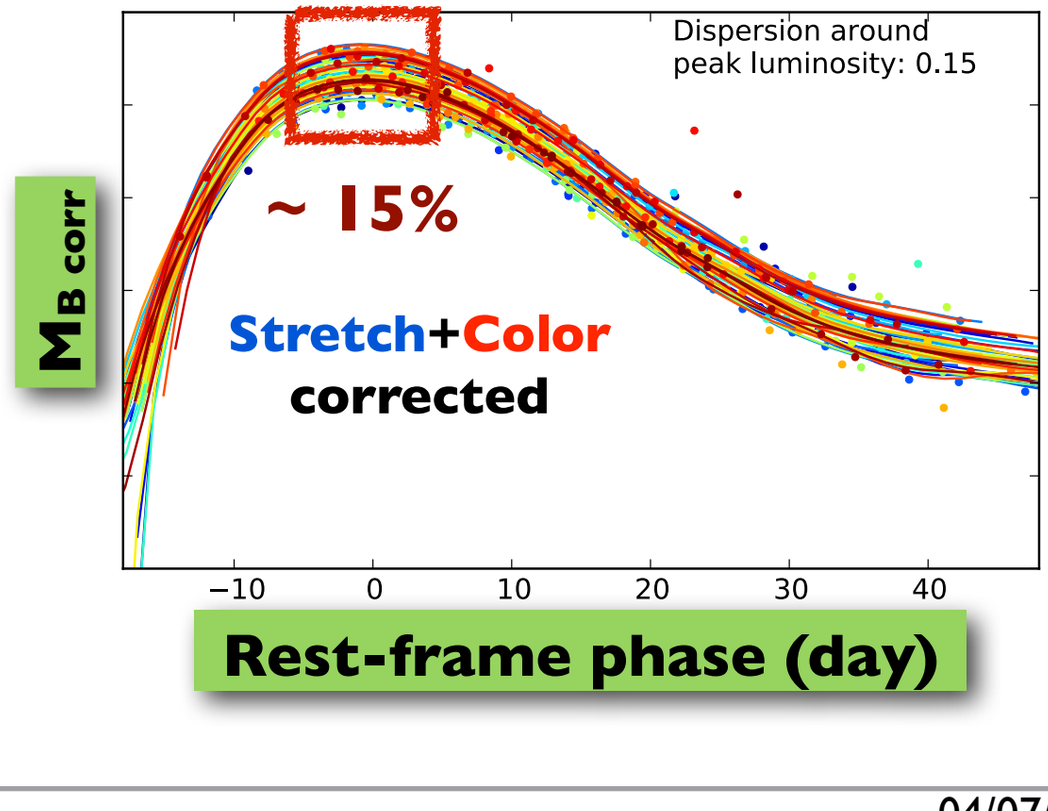

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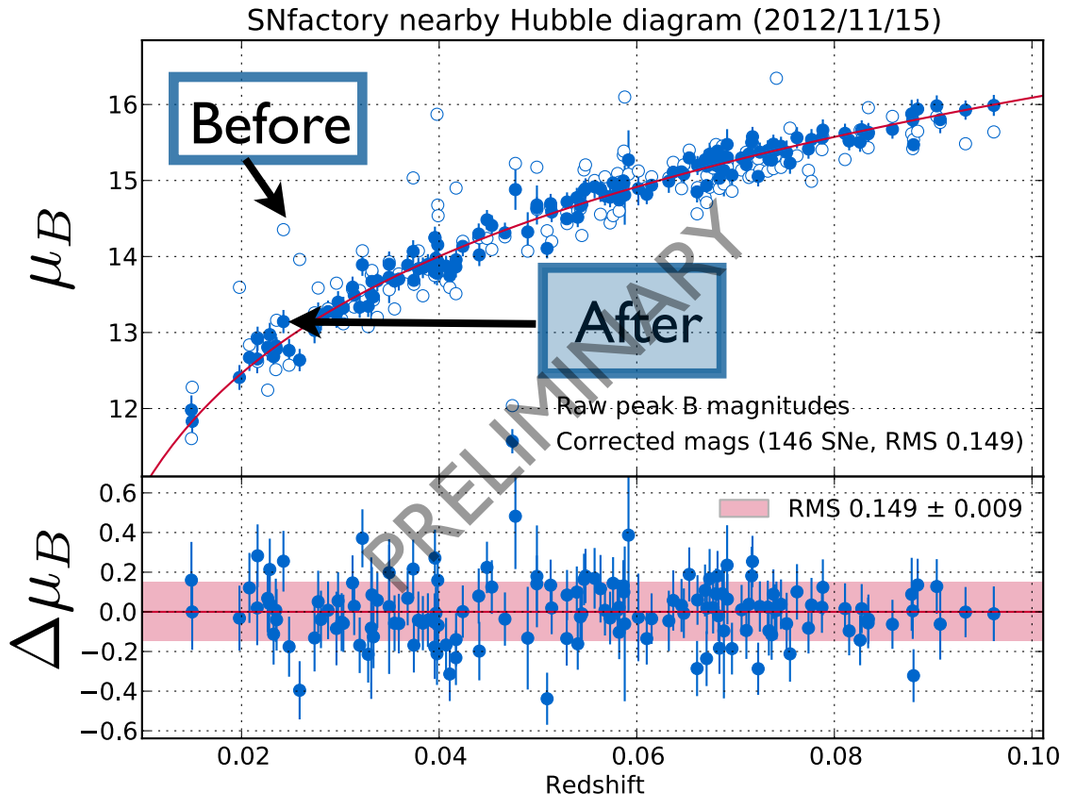

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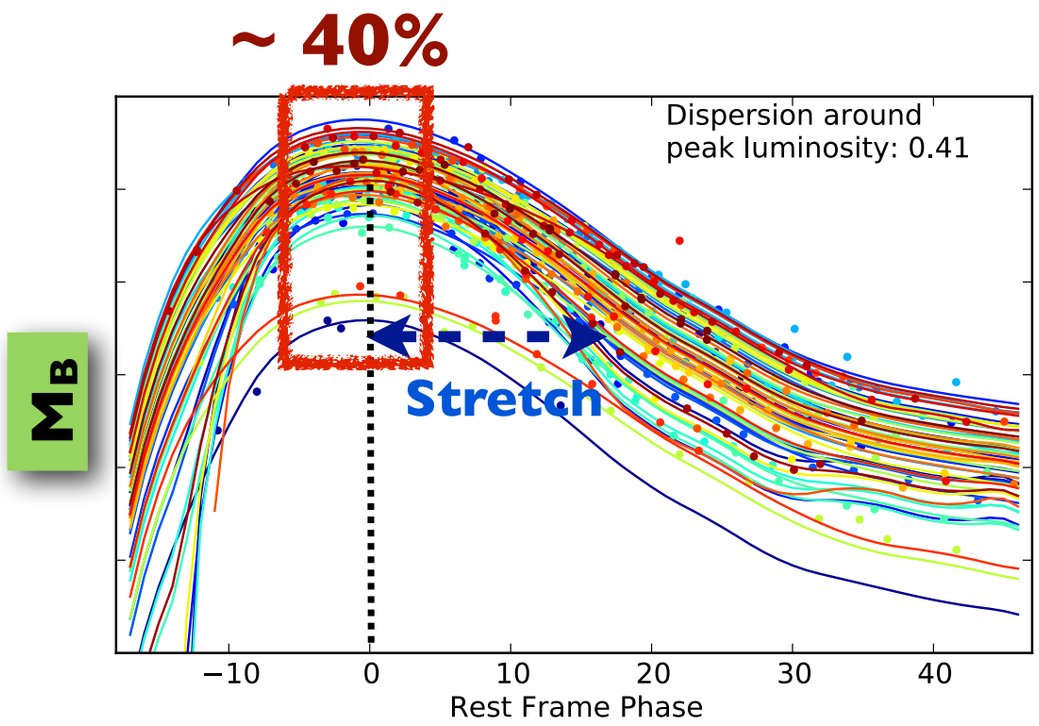
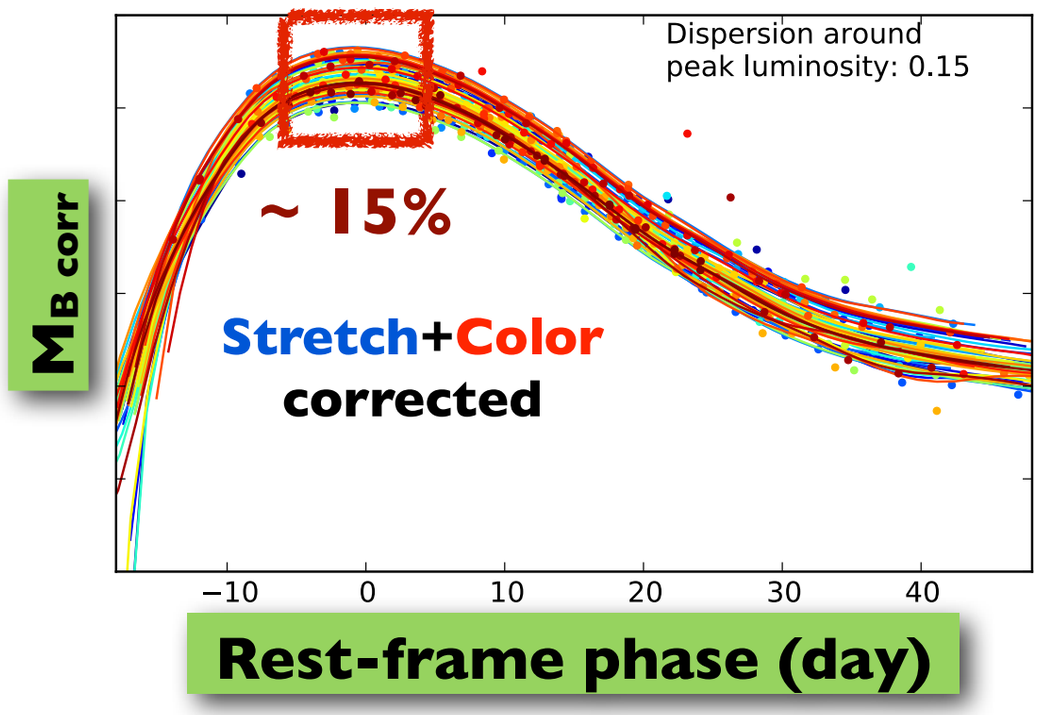


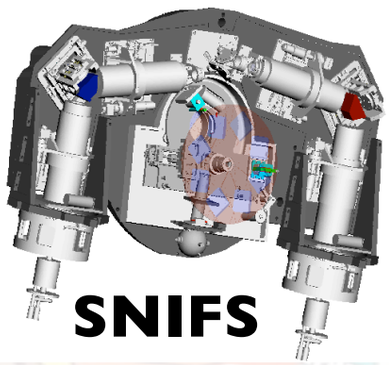


The Nearby Supernova Factory

A unique data set of spectrophotometric Type Ia supernova spectral time series

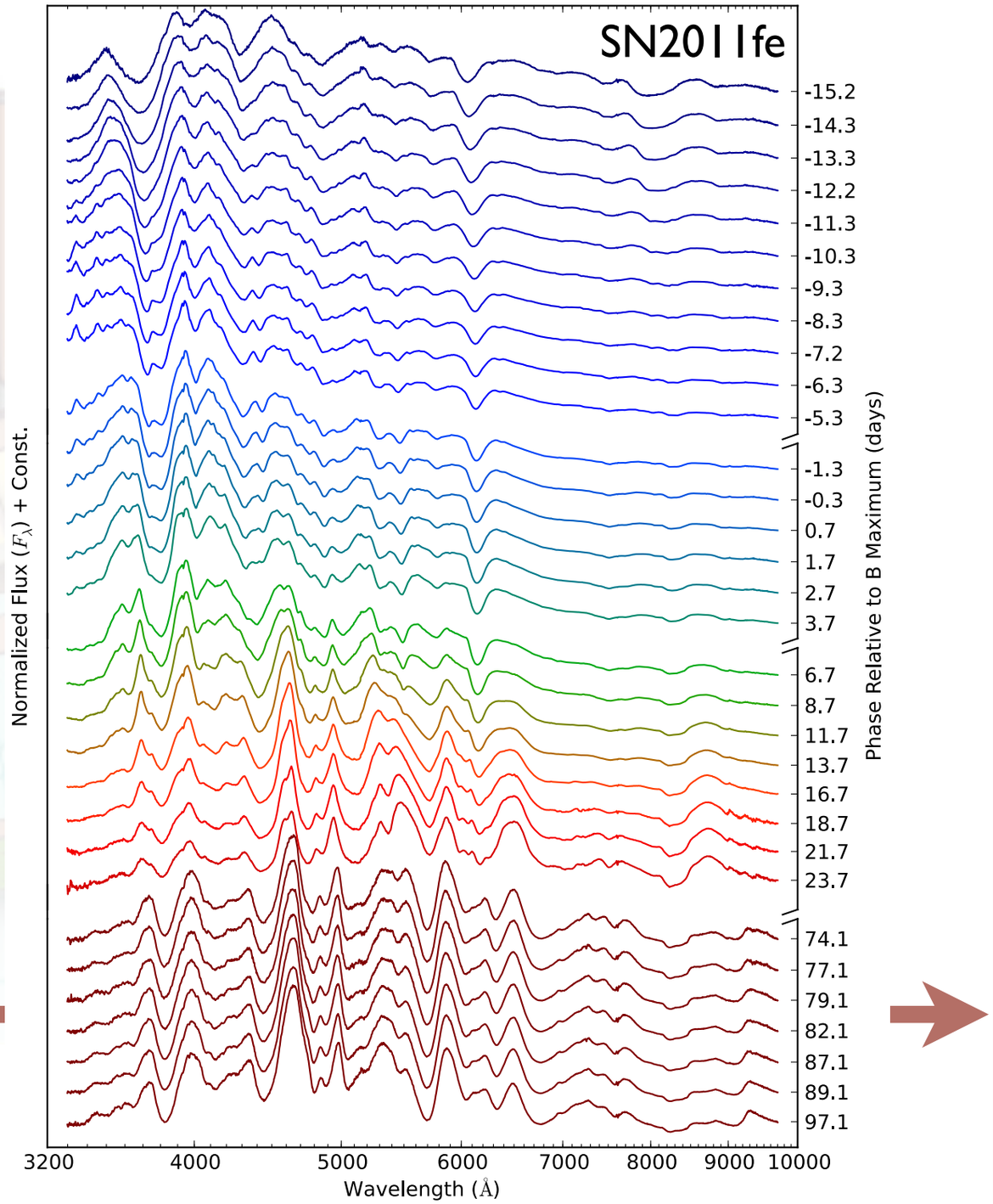
Spectro-photometry of nearby SNe Ia

IFS spectro+photo



Reduction Calibration

Analyses



Pereira et al. 2013

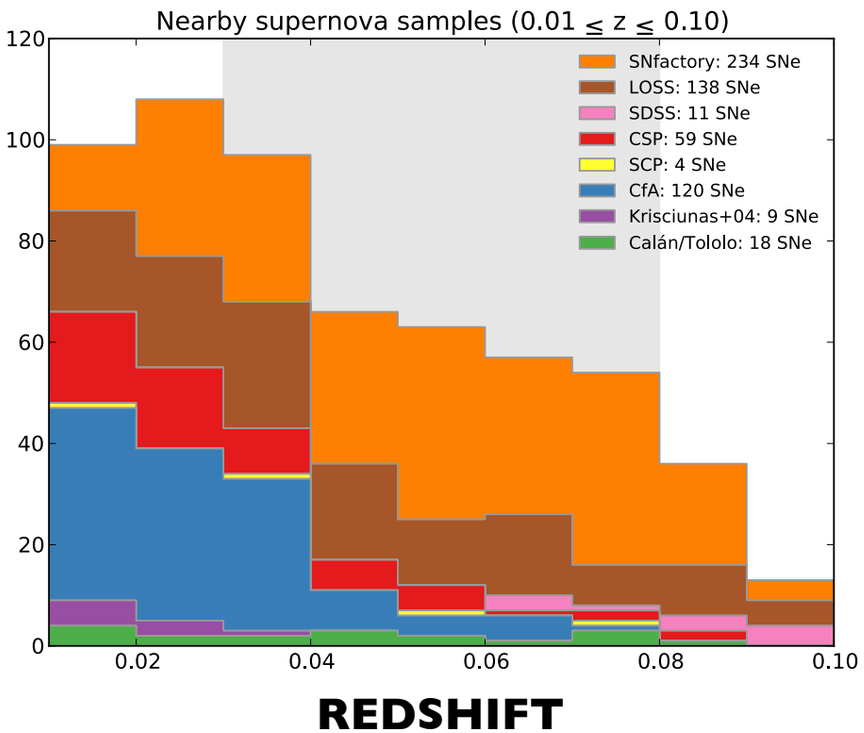
The Nearby Supernova Factory

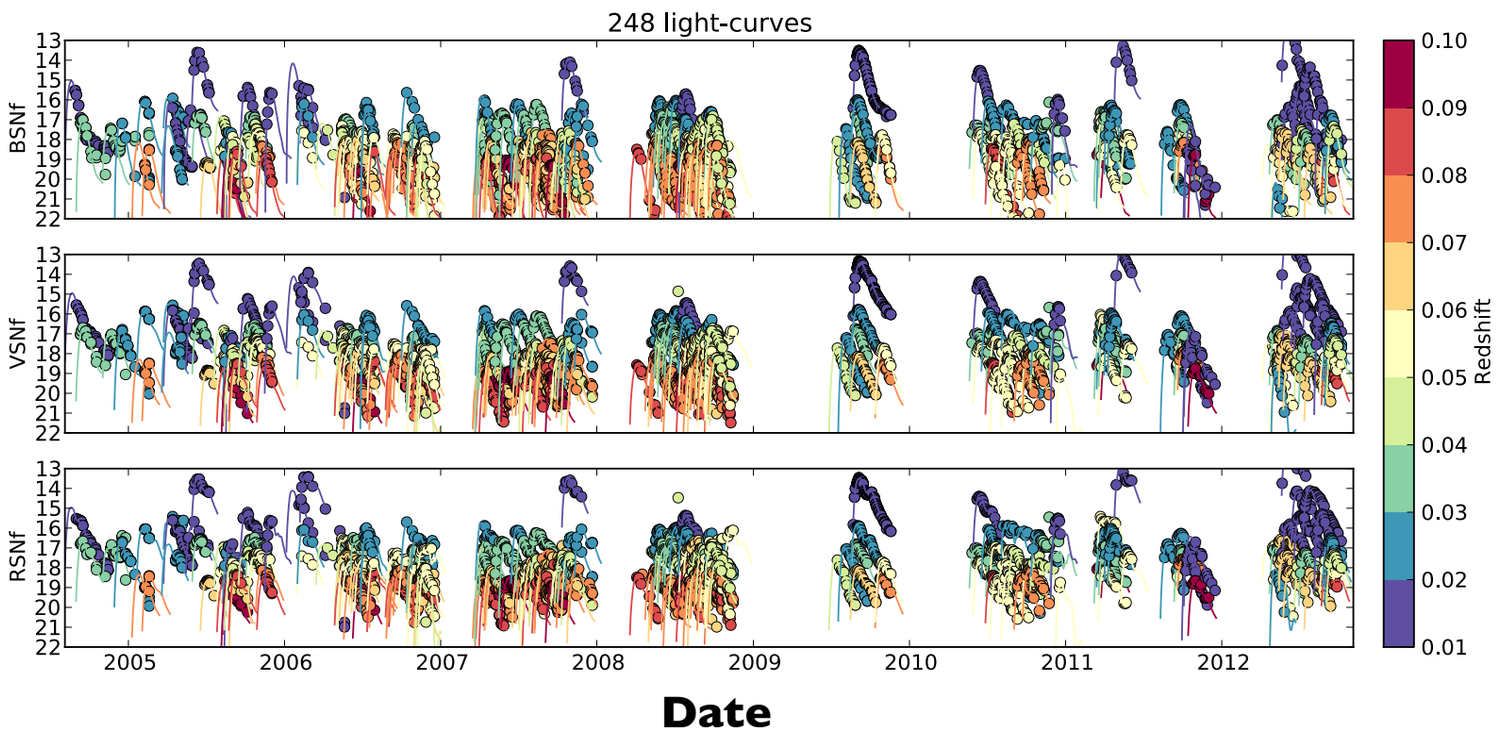
Main goals:

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

Data sample:

- 0.01 < redshift < 0.1
- **~250 SNe** (> 5 spectra)
- median phase of 1st spec: -4 days
- mean cadence of observation: -3 days
- **~4600 spectra** [-15,40] days *wrt* max
- ~15 spectra / SNe in average
- spectral coverage: 3200 to 9700 Å



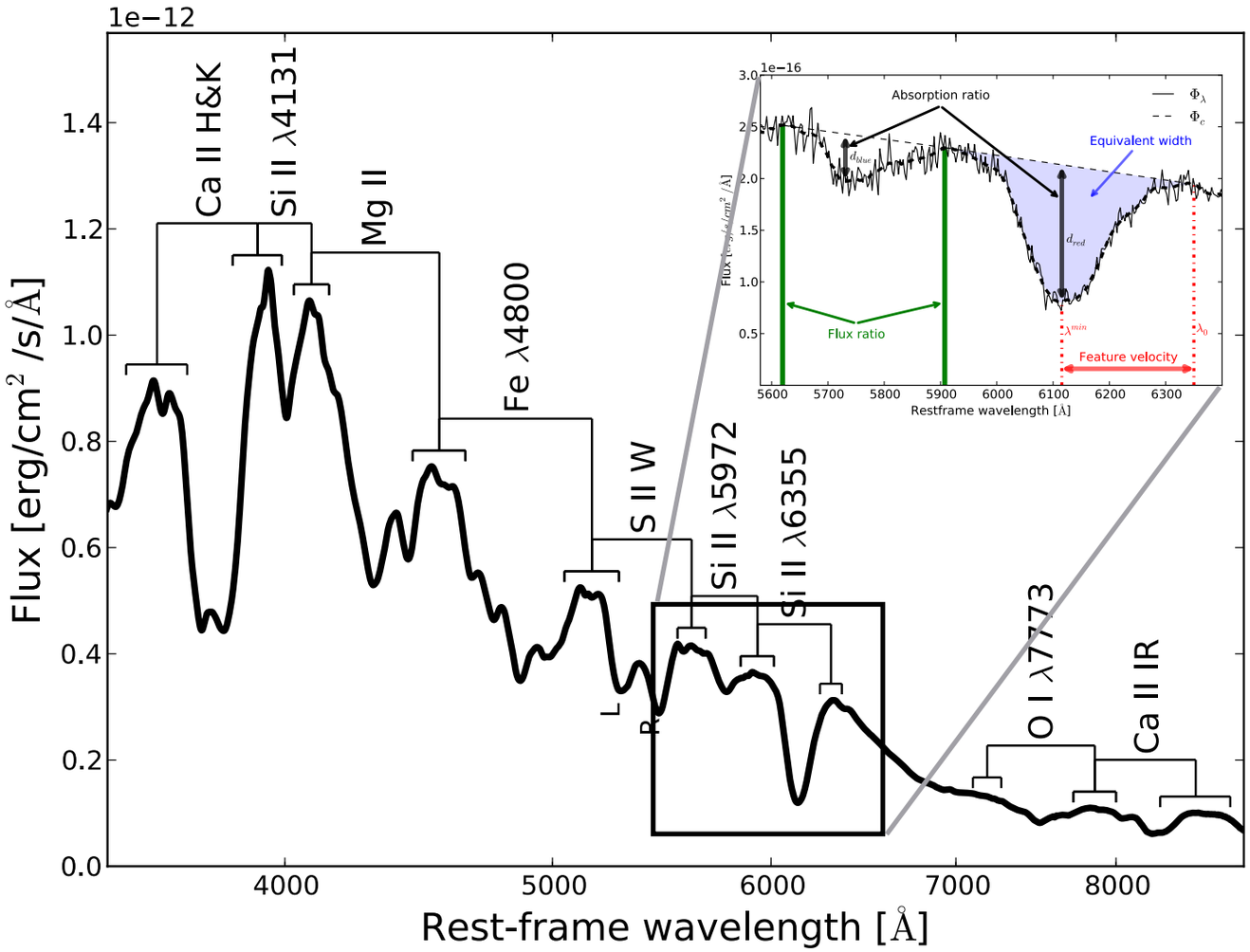


Spectral analyses of SNe Ia

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

- **Spectral indicators :**
  - Some are sensitive to extinction
  - Others are mixed: (in/ex)trinsic

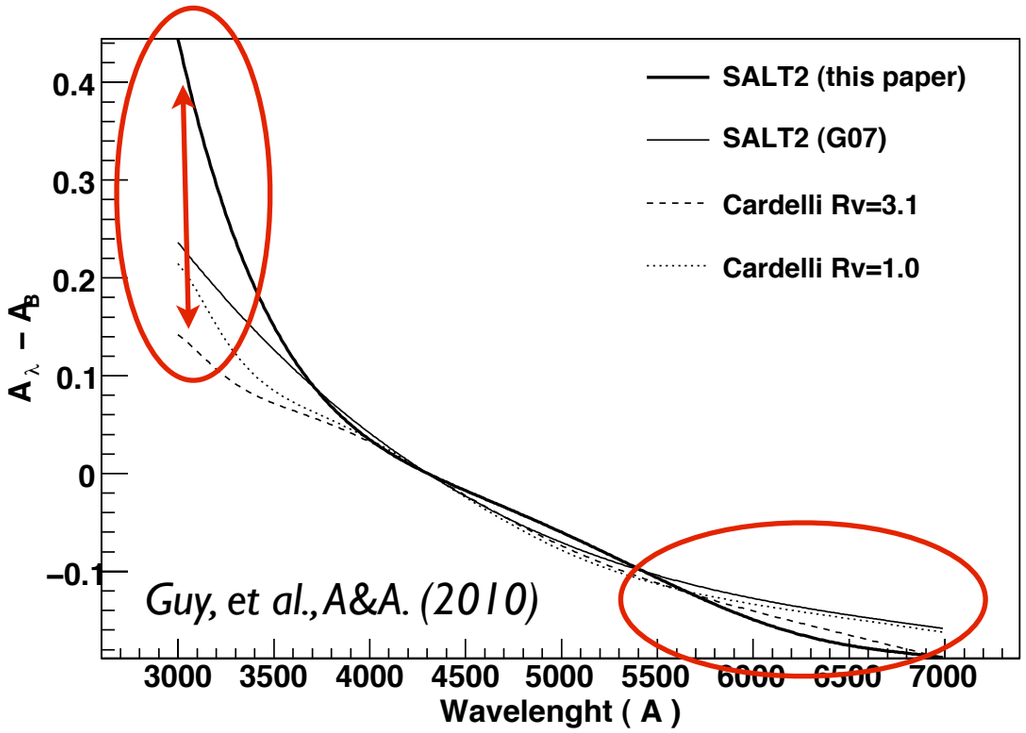
- **Different uses:**
  - Standardization
  - Sub-classification
  - Extinction
  - etc.



Cosmological systematics/bias studies related to their spectral variabilities

Which extinction law for SNe Ia?

- **SNe Ia dispersion dominated by extinction variability**
- **Recurrent issue** in SNe Ia analysis: **extinction law or 'Rv'?**



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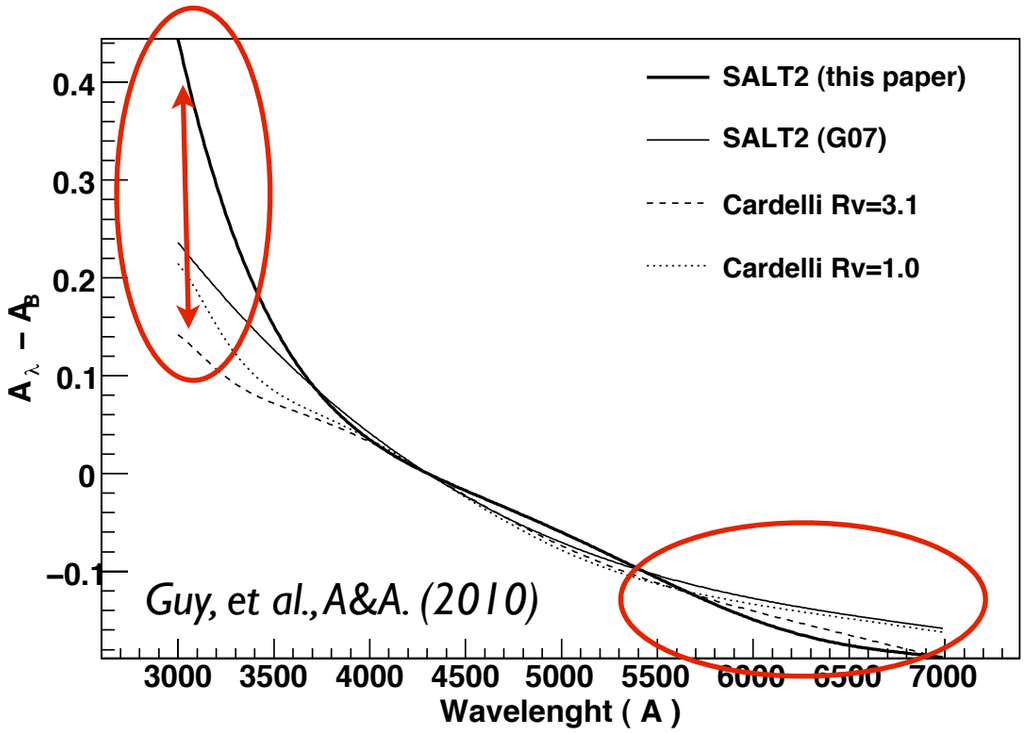

1. Intrinsic spectral indicators

2. Separation of the ≠ components

$$\delta A_\lambda = \Delta\mu_\lambda - \delta I$$

3. Extinction law construction

$$\delta A_\lambda(i) = \gamma_\lambda \; \delta A_V^*(i) + \eta_\lambda$$

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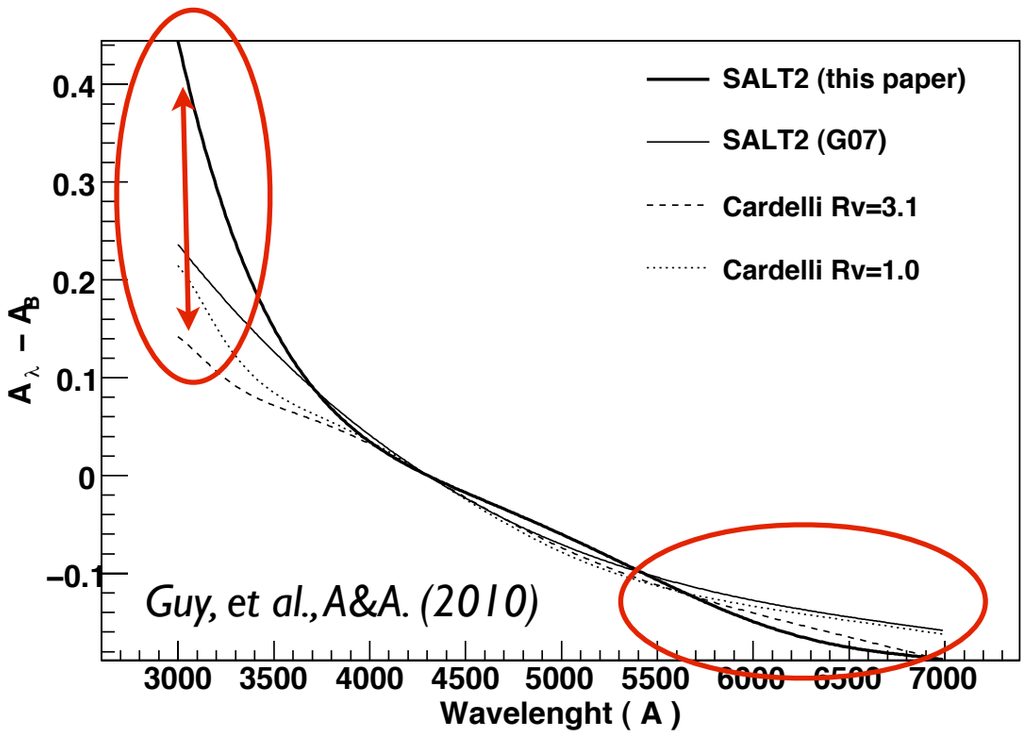

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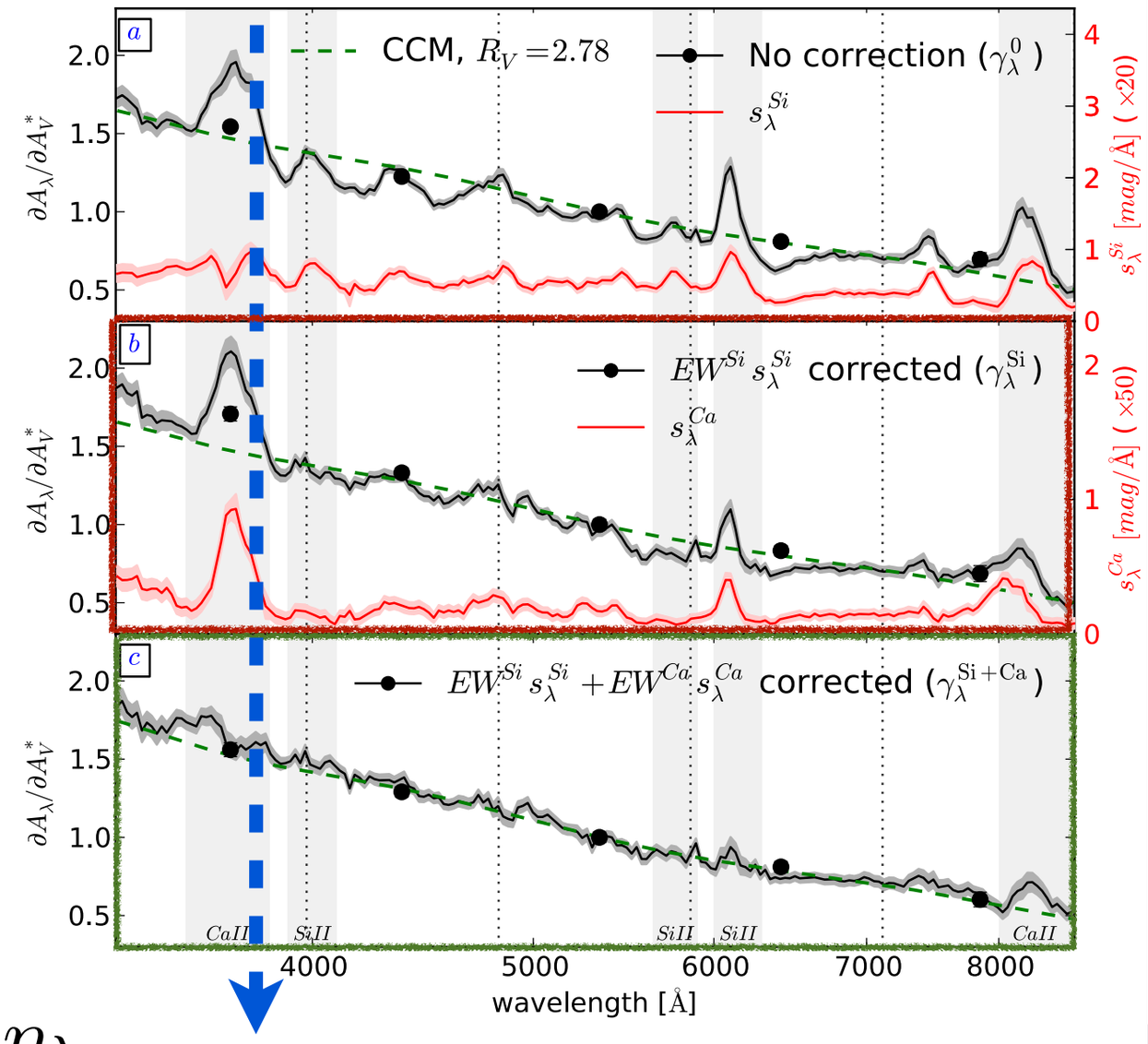

Chotard et al. 2011

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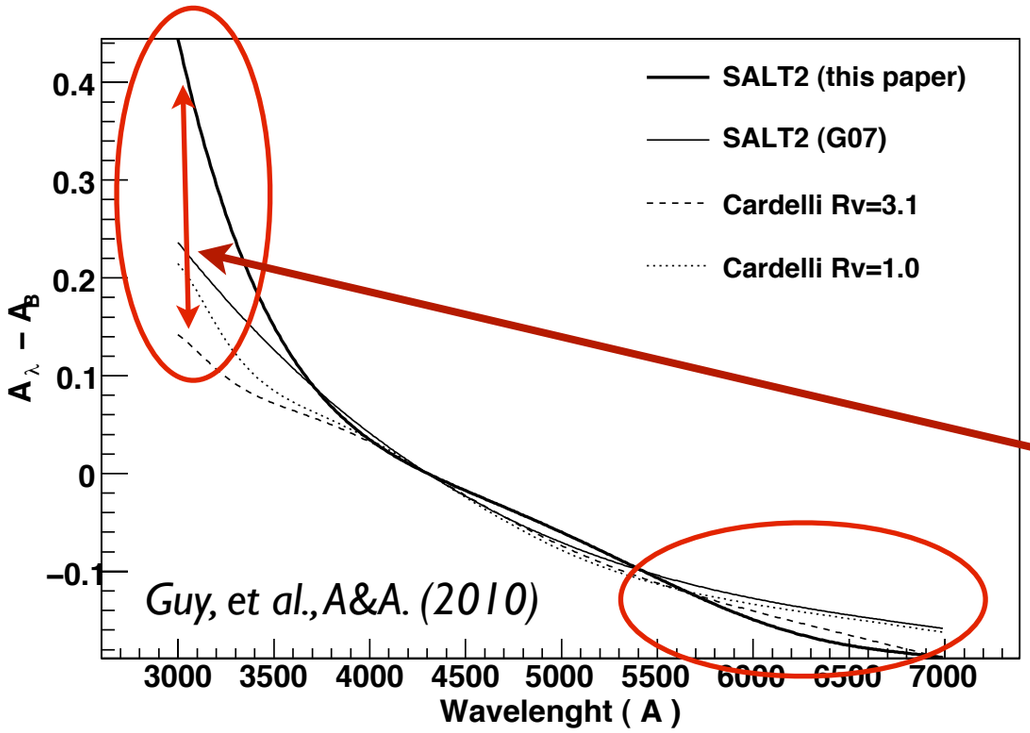

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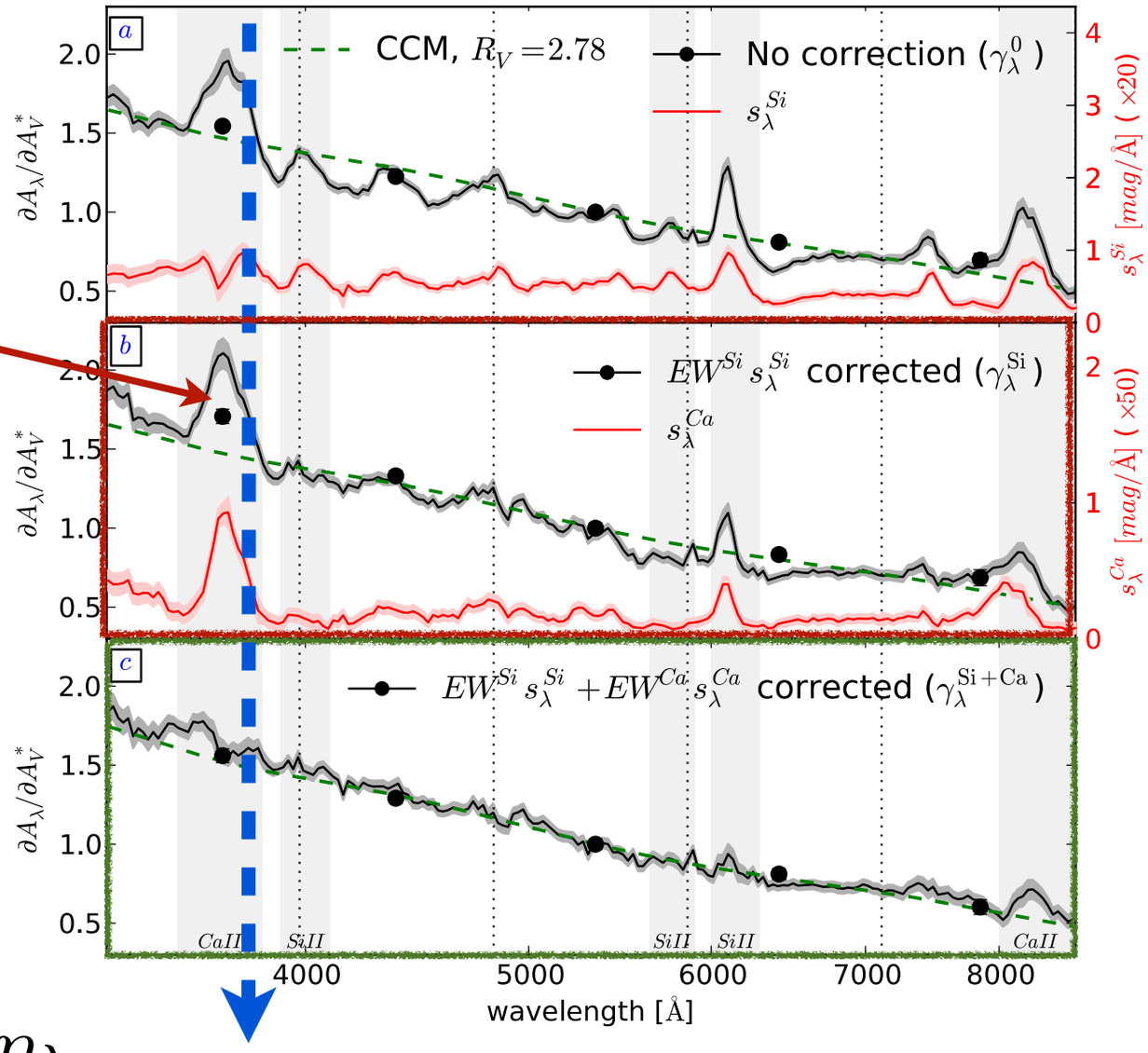

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Classic extinction law
+
$R_V = 2.6 \pm 0.4$

SNe Ia intrinsic color dispersion matrix introduced.
Result taken into account in recent analyses (Light Curve fitter)

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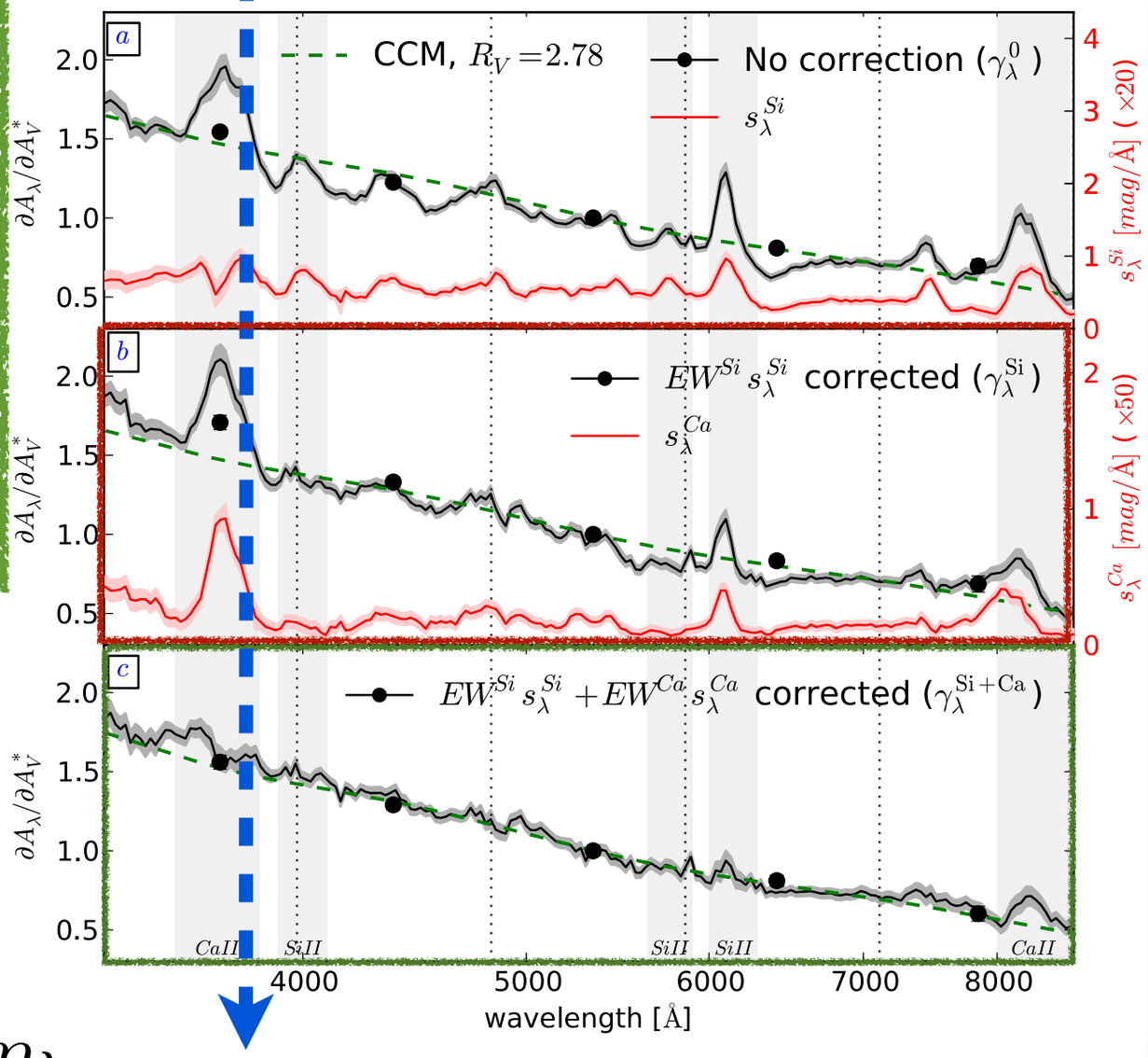
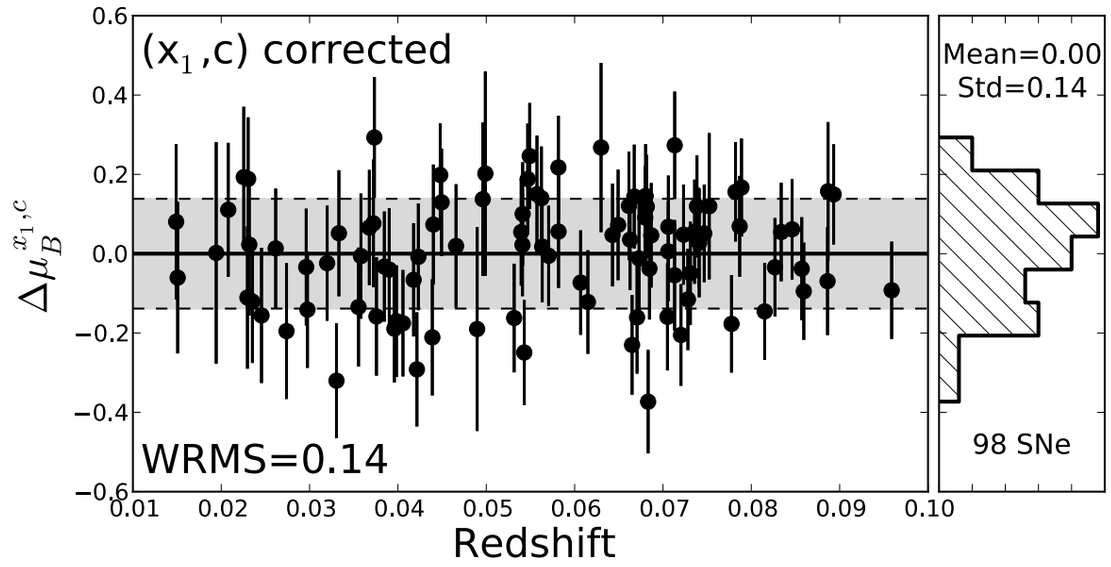


Chotard et al. 2011

Spectroscopic standardization

Problematic

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



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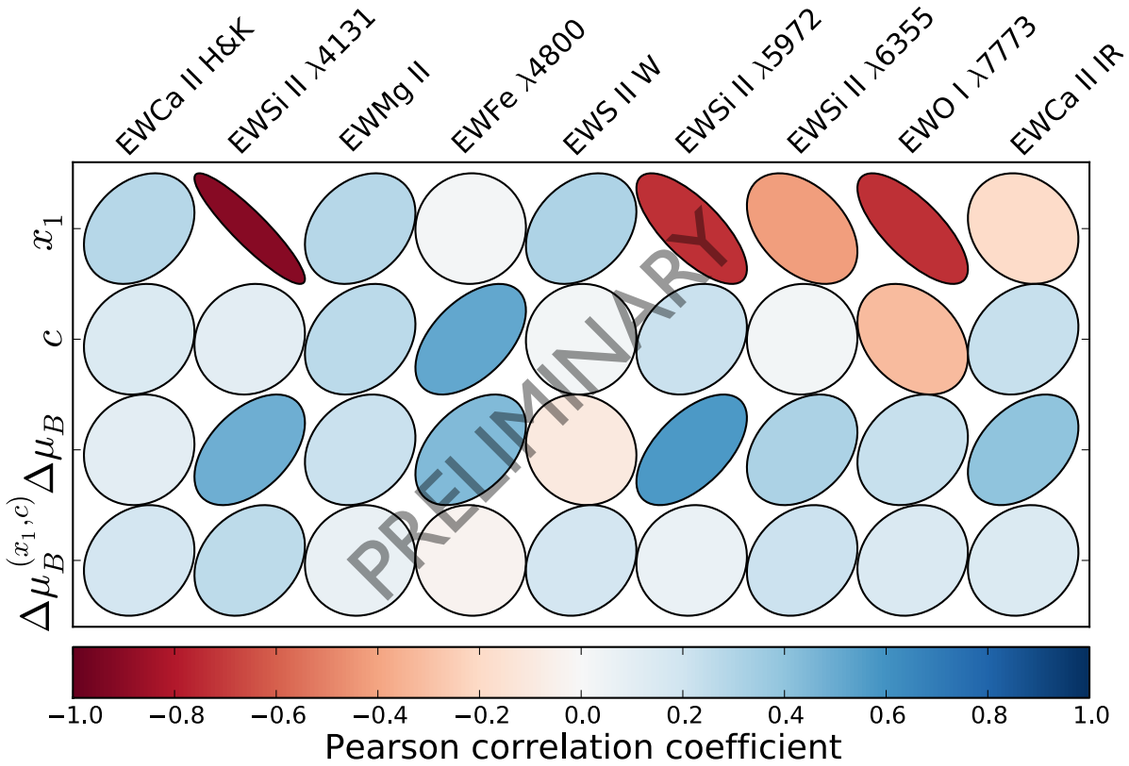

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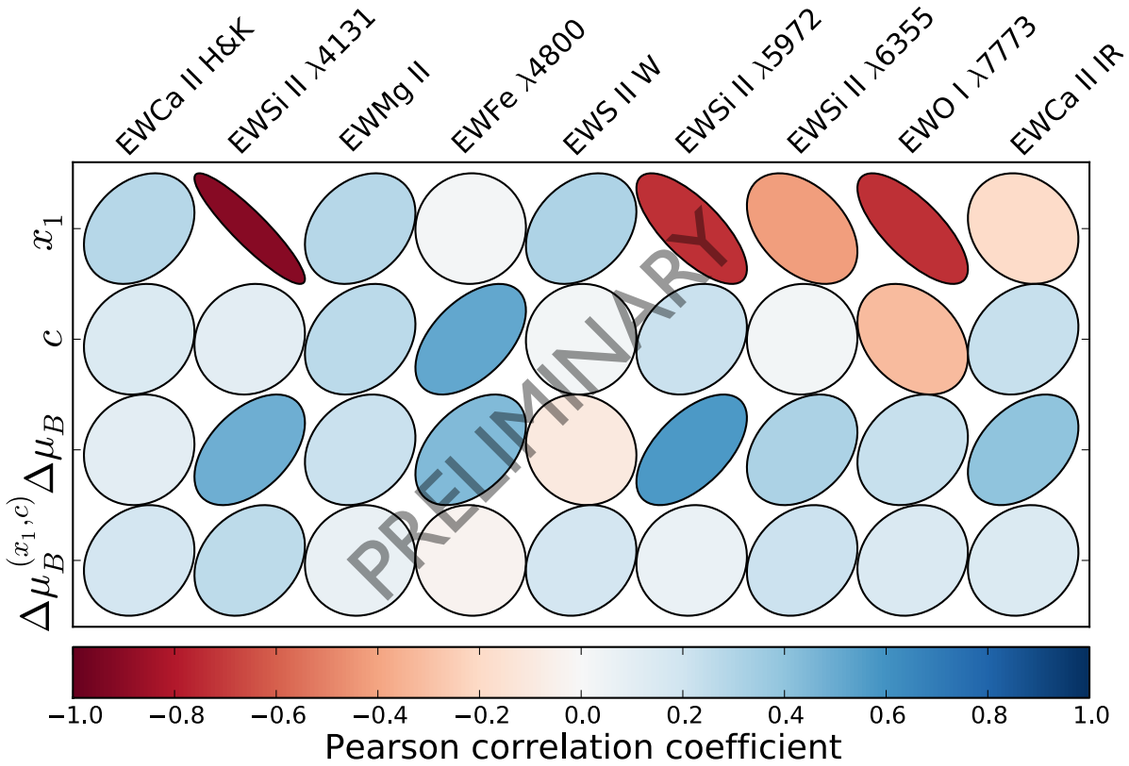

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Photometric parameters

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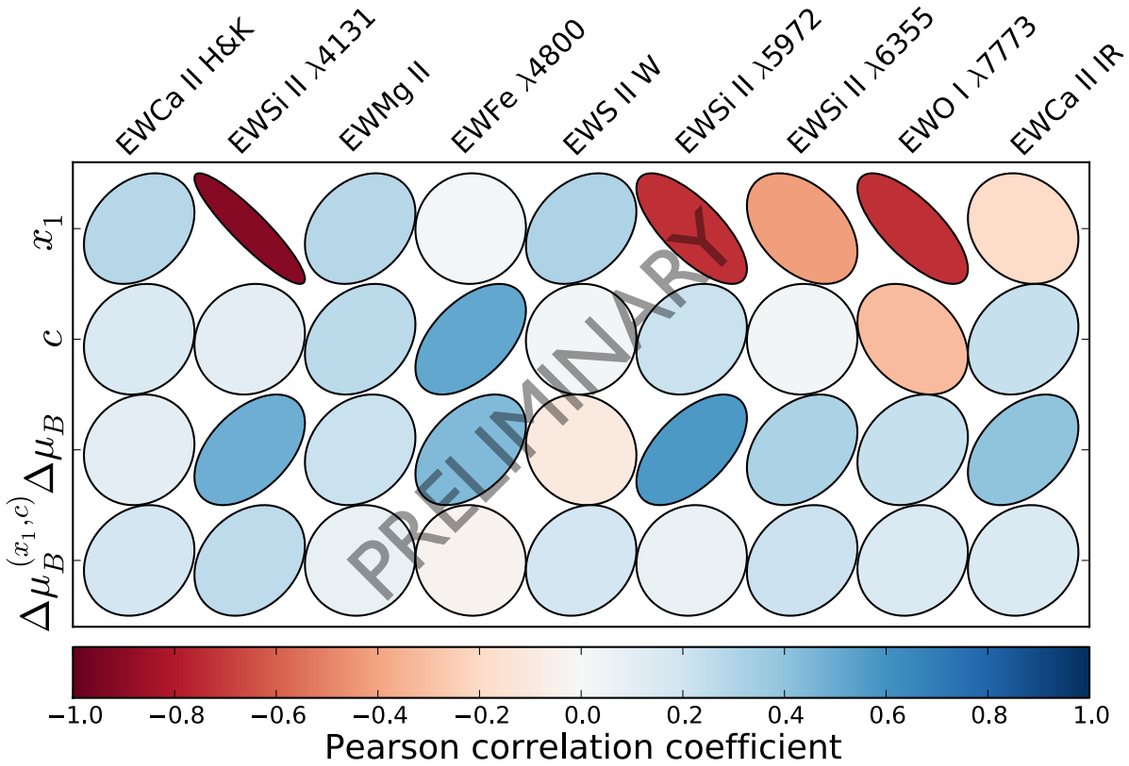

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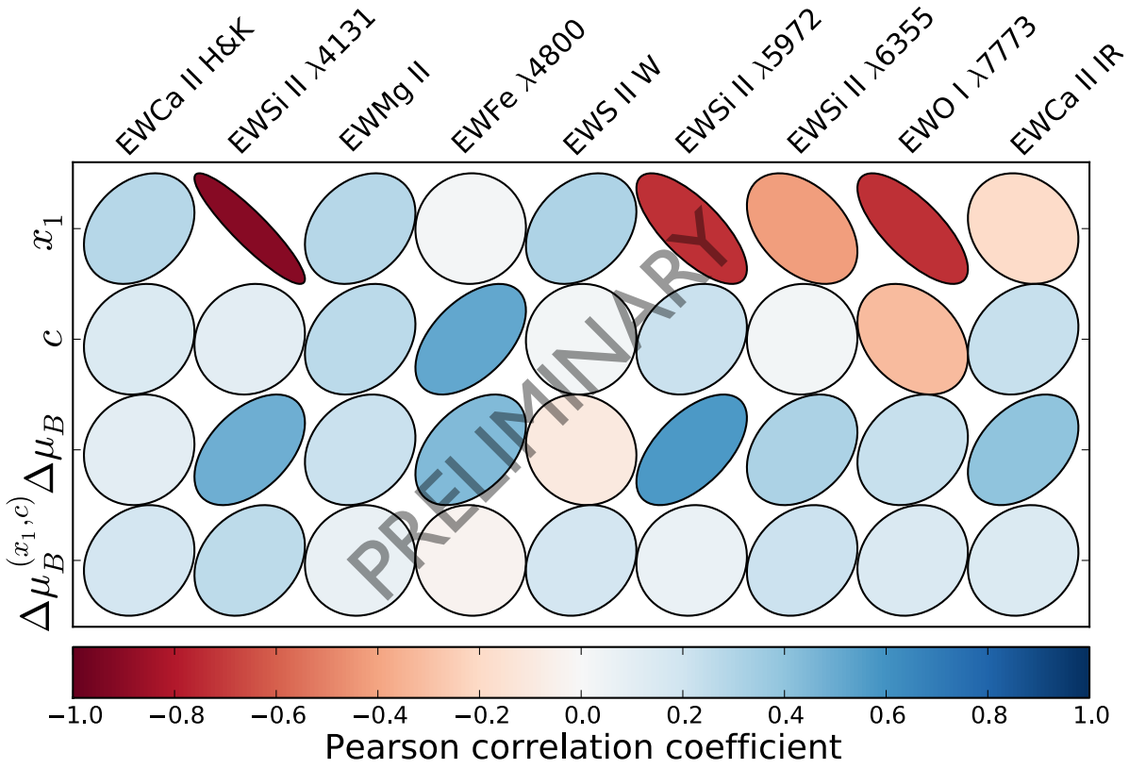

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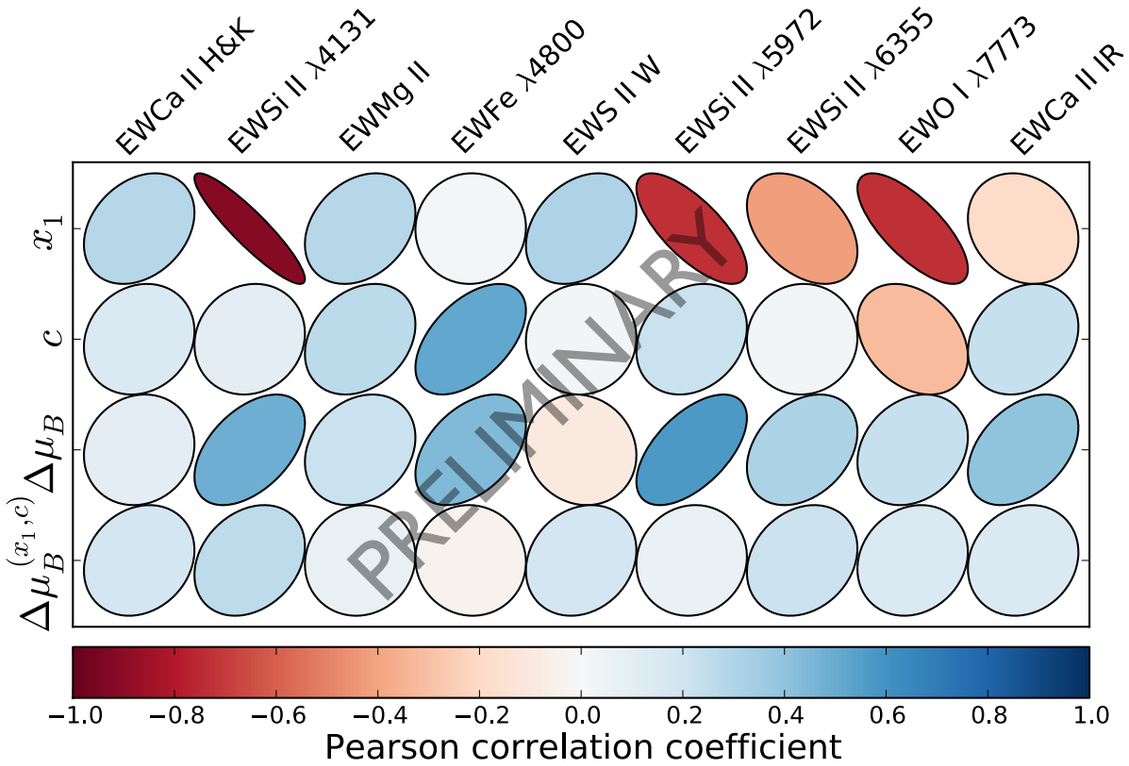

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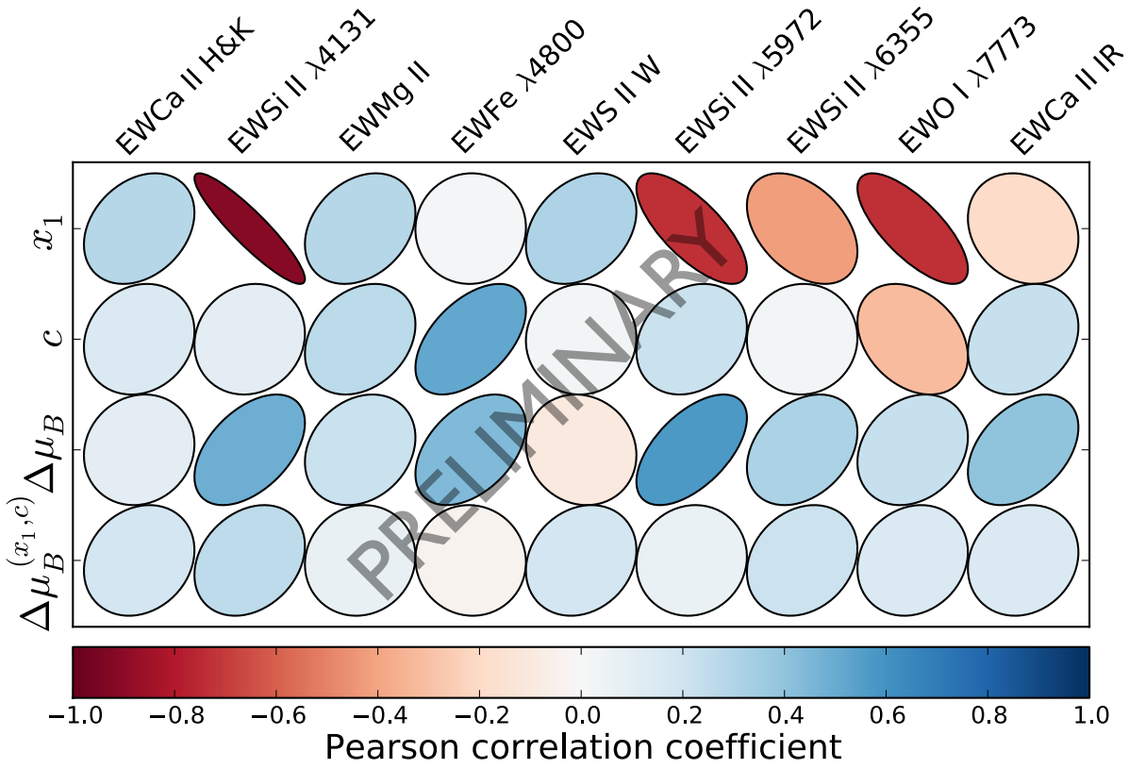

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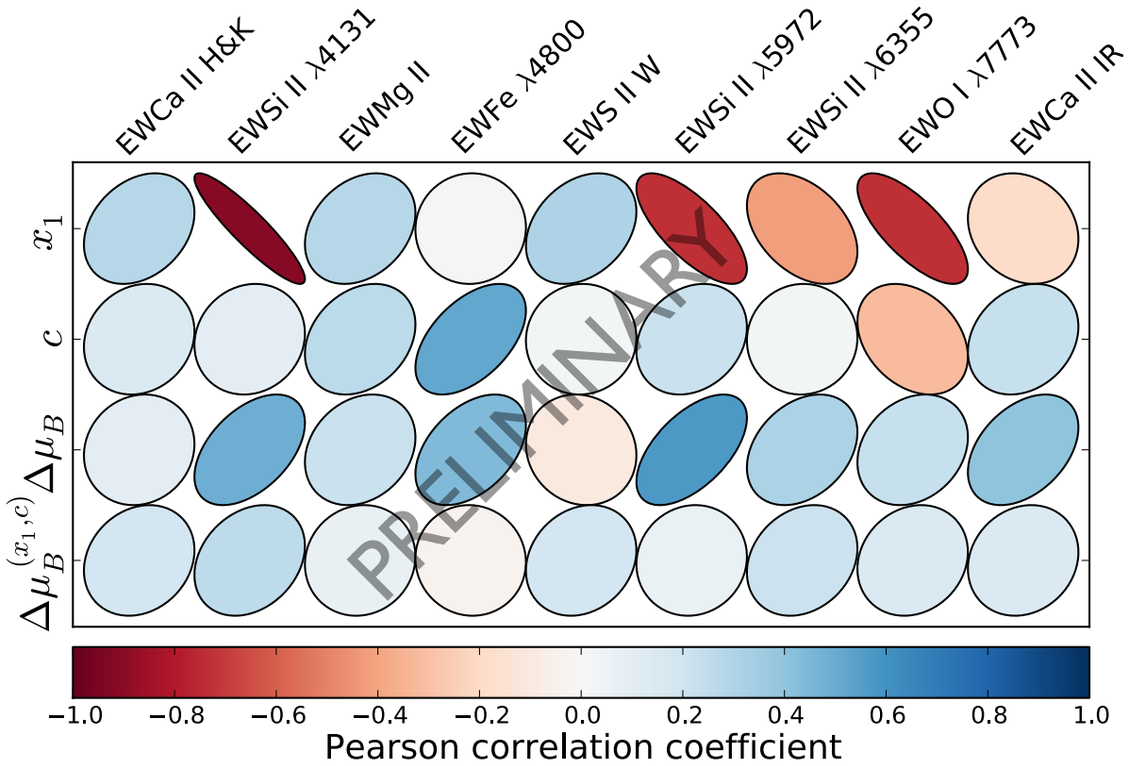

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Photometric parameters **Spectral indicators**

Conclusions

- Slight **improvement** using **spectral corrections**, down to 0.12 mag (2σ)
- Only **one spectrum needed** instead of entire light curves

SNfactory analyses

- **Published analyses:**

Case studies
- Peculiar SNe (Aldering 06, Thomas 07),
- SN 2011fe (PTF11kly) (Pereira 13)
- Super-Chandra (Scalzo 10, Scalzo 12),
- Host (Childress 11),

Spectral analyses
- Standardization (Bailey 09),
- ***Extinction*** (Chotard 11),
- Carbon-footprint (Thomas 11),
- Constrains on explosion models (Ropke 12),
- Light curve fitters (Kim 13)

Host analyses
- Host galaxies analysis (Childress 13 a & b),

Calibration
- Atmospheric extinction (Buton 12),

SNfactory analyses

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Ongoing analyses:

- ***Standardization***,
- ***Sub-classification***,
- ***Reddening / color analyses***,
- Host galaxies: local/global comparison
- NaID absorption line,
- Twin supernovae,
- Spectral data / Explosion model comparison,
- K-corrections
- Anisotropies in the local universe
- ...

Summary

SNfactory Data Sample

- **~250 SNe Ia spectrophotometric time series** so far,
- **Best and largest nearby sample**, unique in its kind
- SNe Ia **spectral observations continue** every 2-3 days

SNfactory Analyses

- Study of known or potential new systematics
- Work is ongoing on a lot of different aspects using the SNIFS data:
  - Standardization: improvement has already been achieved
  - Environmental effects: host global *vs* local properties
  - SNe Ia understanding: Spectral analyses, modeling, case studies, twins, etc.

SNfactory dataset will be a landmark for futur SN Ia analyses