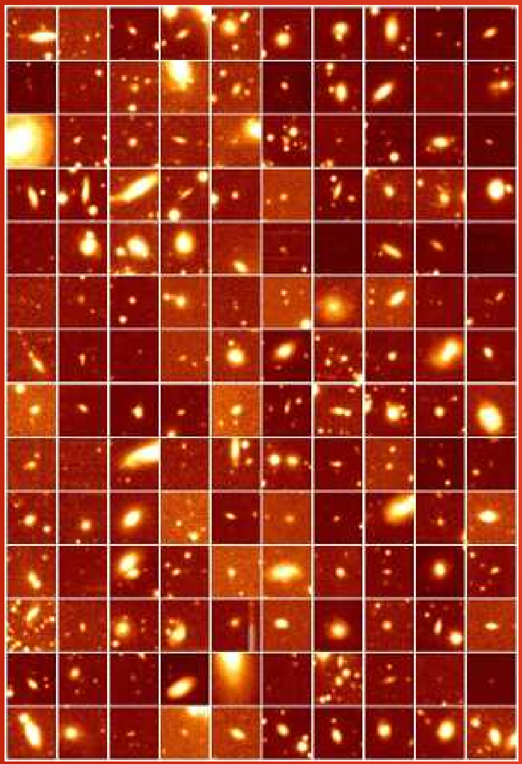
The SNIa U spectrum

The transient universe as seen by iPTF and ZTF

Jakob Nordin

Nearby Supernova Factory I & II



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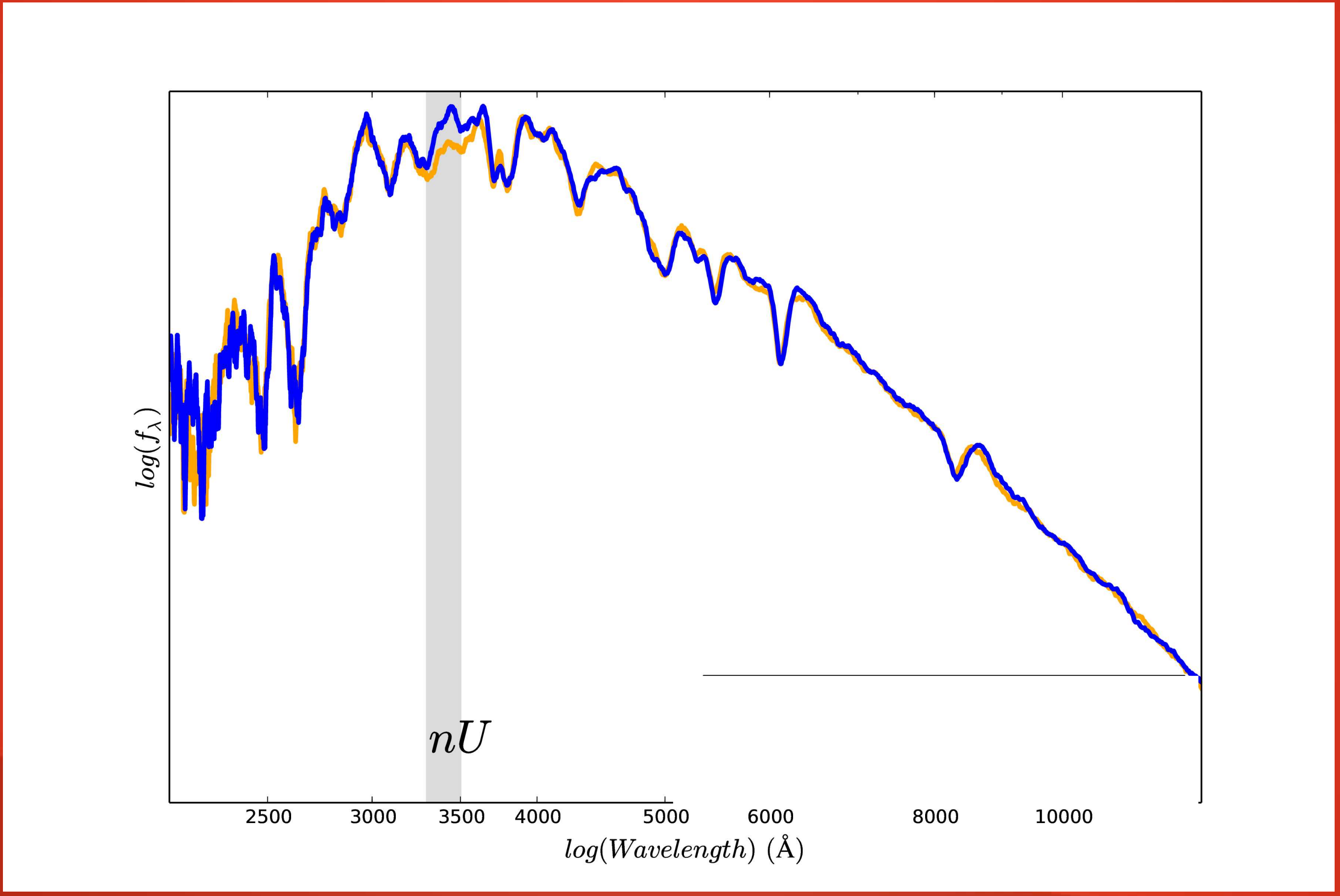
Outline

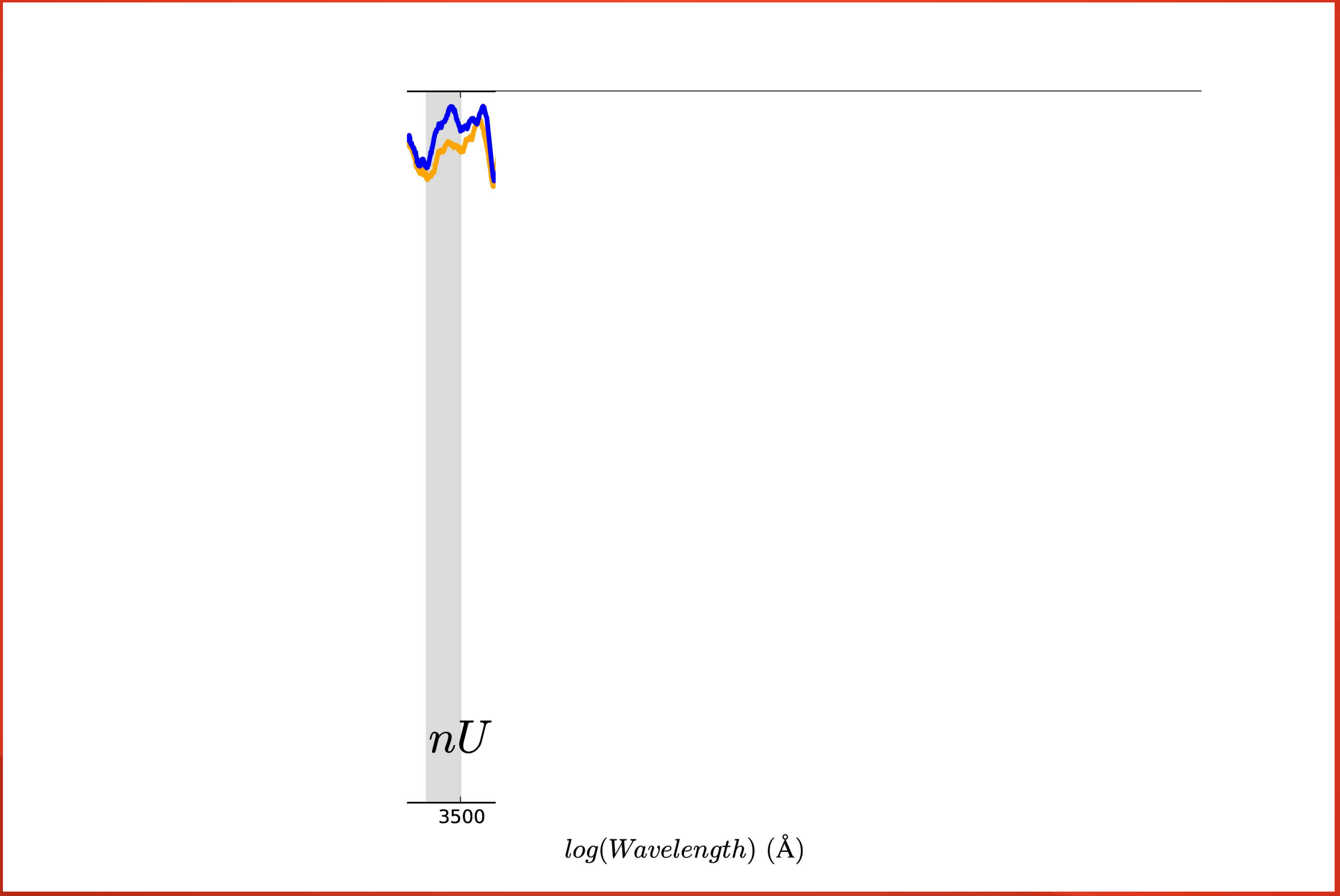
- The nU region
- Clues to a physical cause
- Remarks regarding lightcurve shape, litterature SNe and cosmology
- SNFactory results (if time permitting)
- Summary

Multi-wavelength?



Focus on narrow part of U-band (nU): ~3200-3600

Multi-wavelength?



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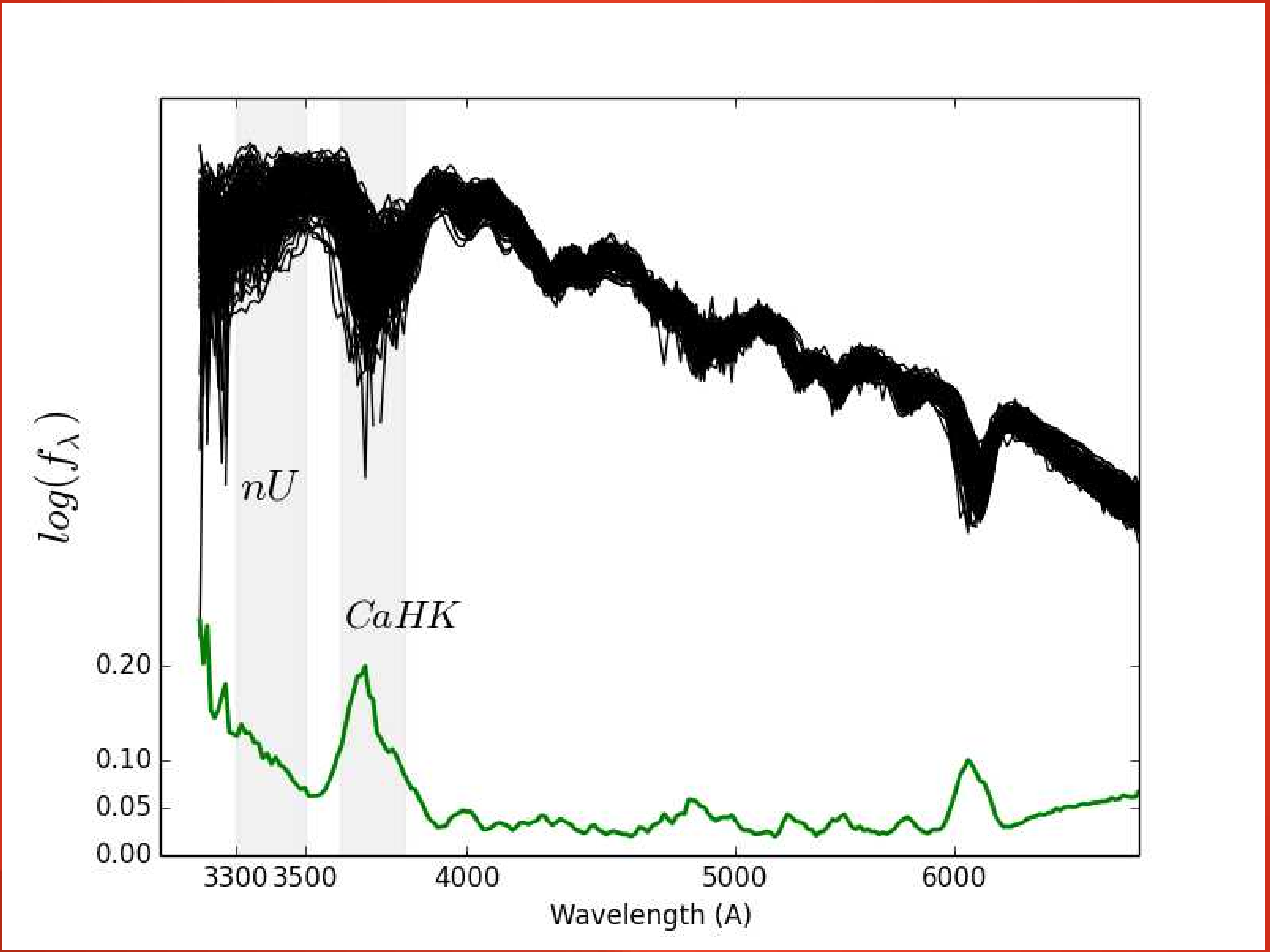
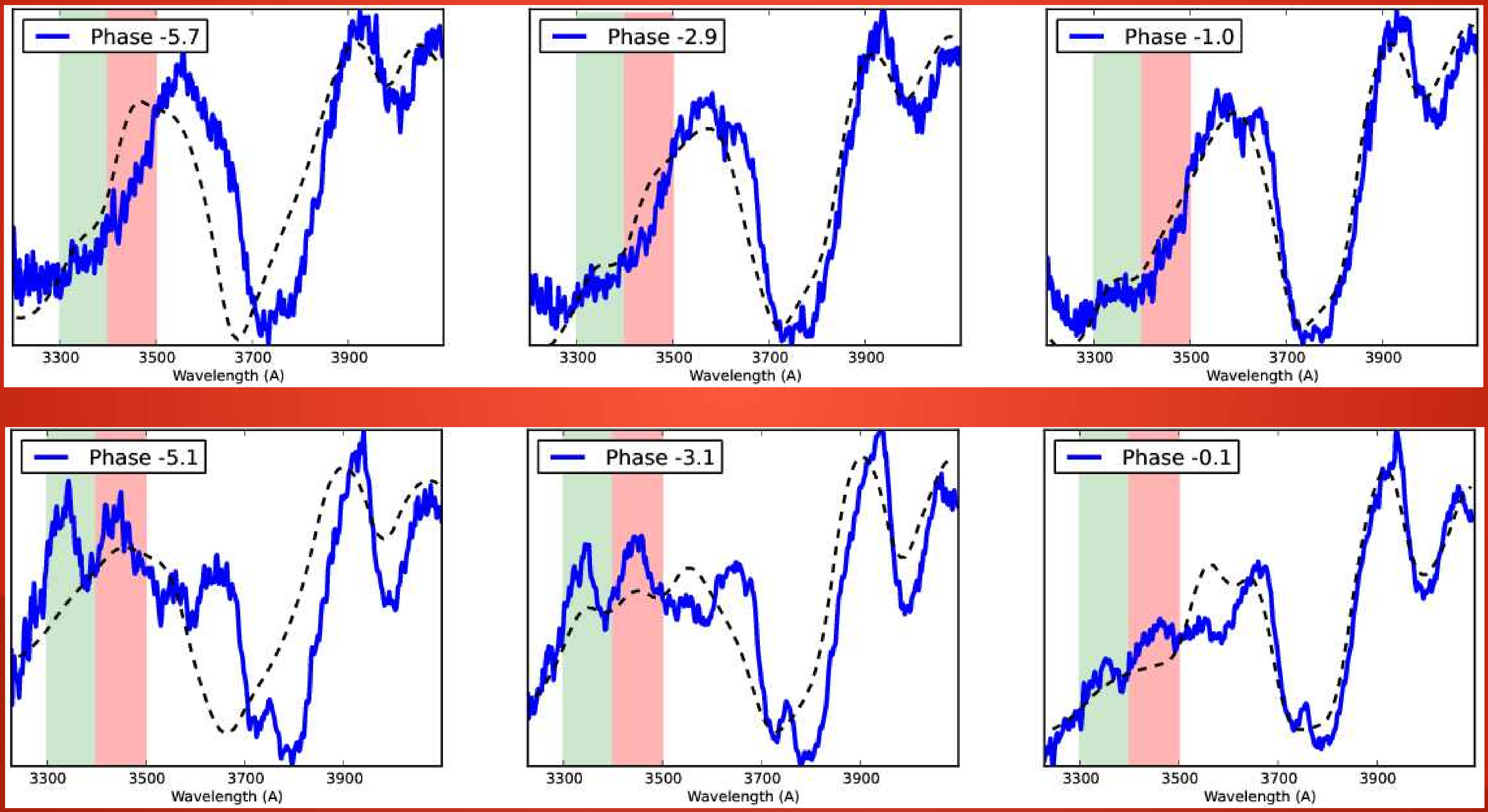
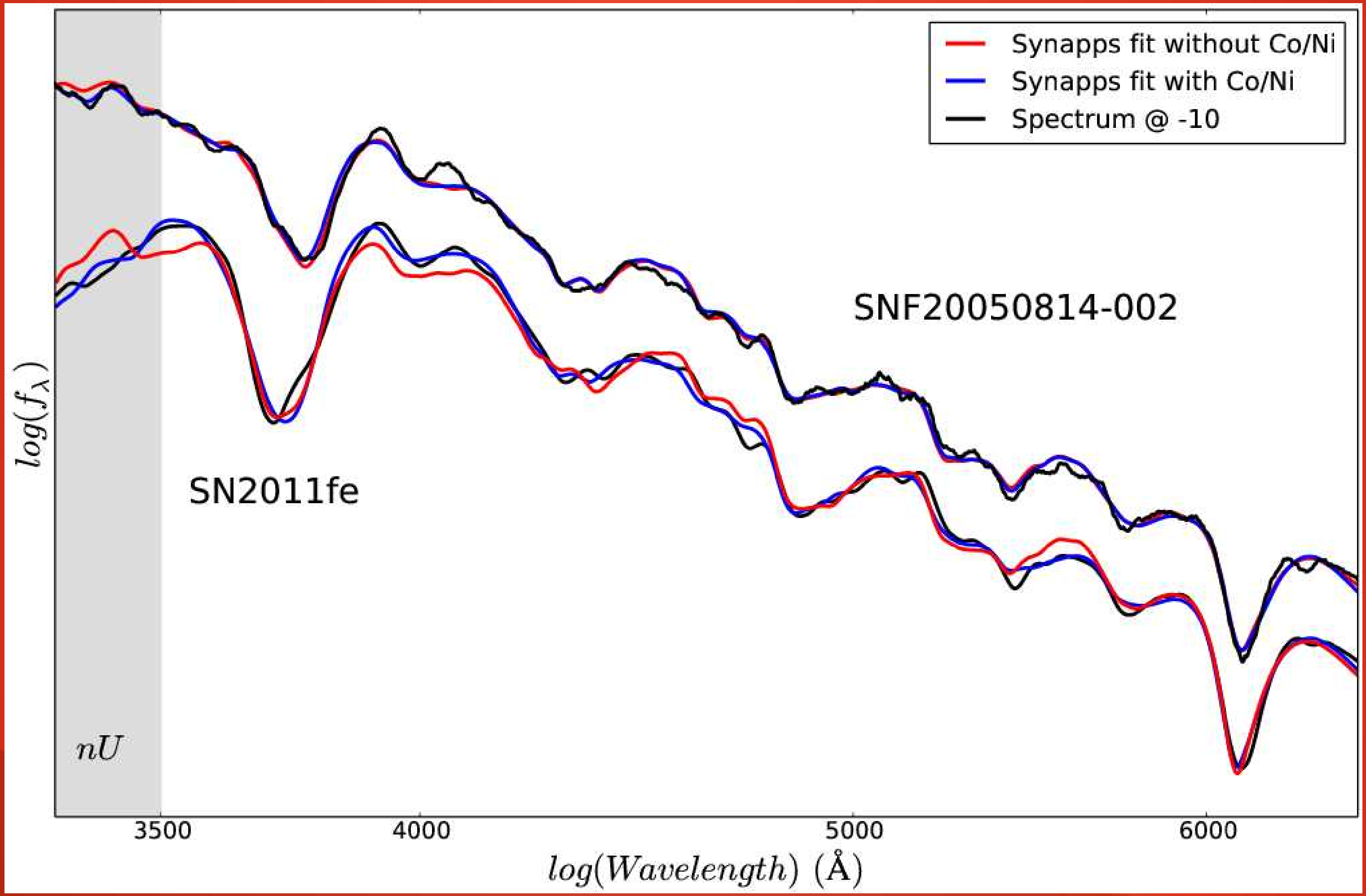


Compilation of pre-peak spectra + rms

A closer look at two SNe

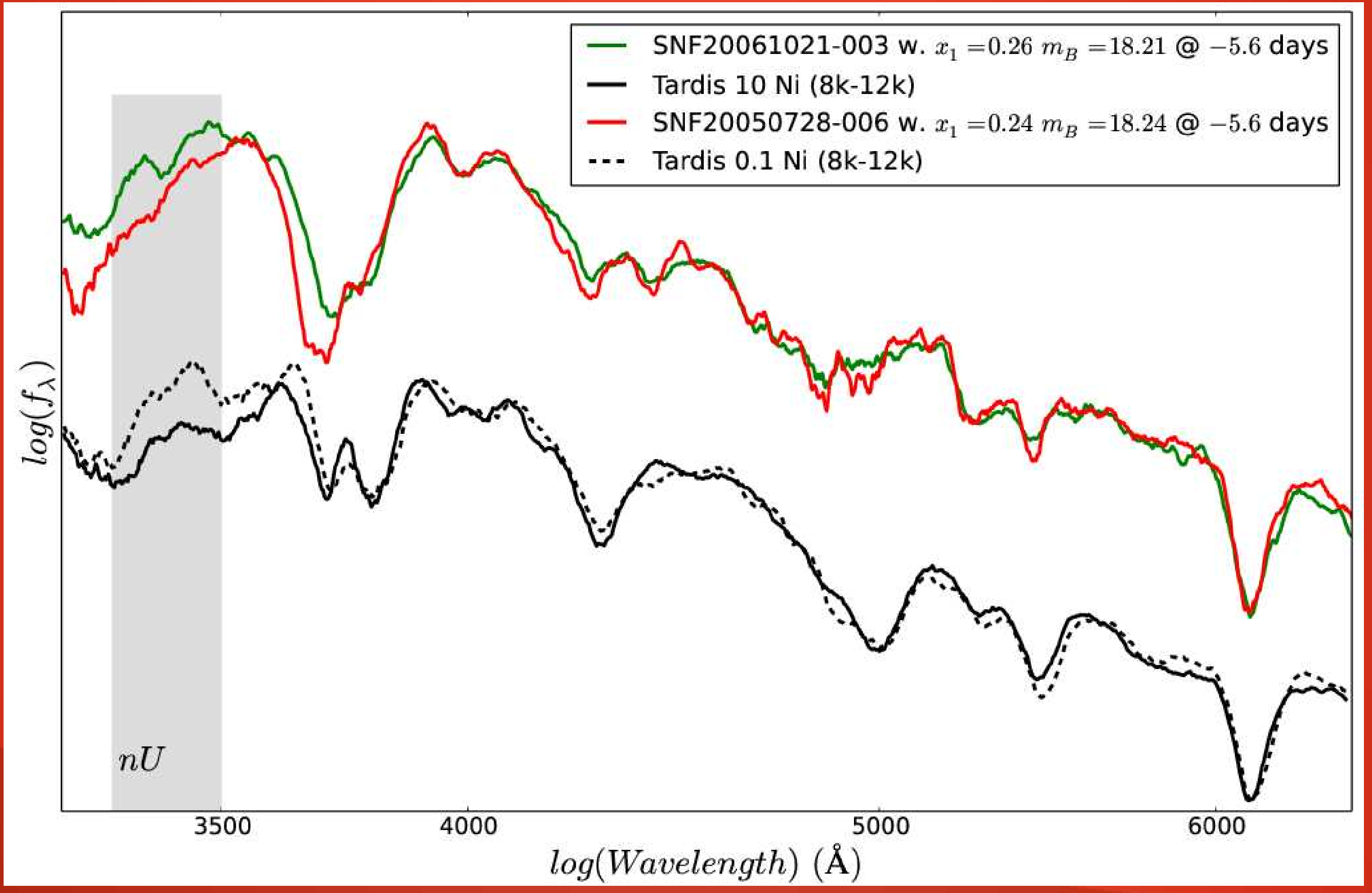


Physical cause - SYNAPPS



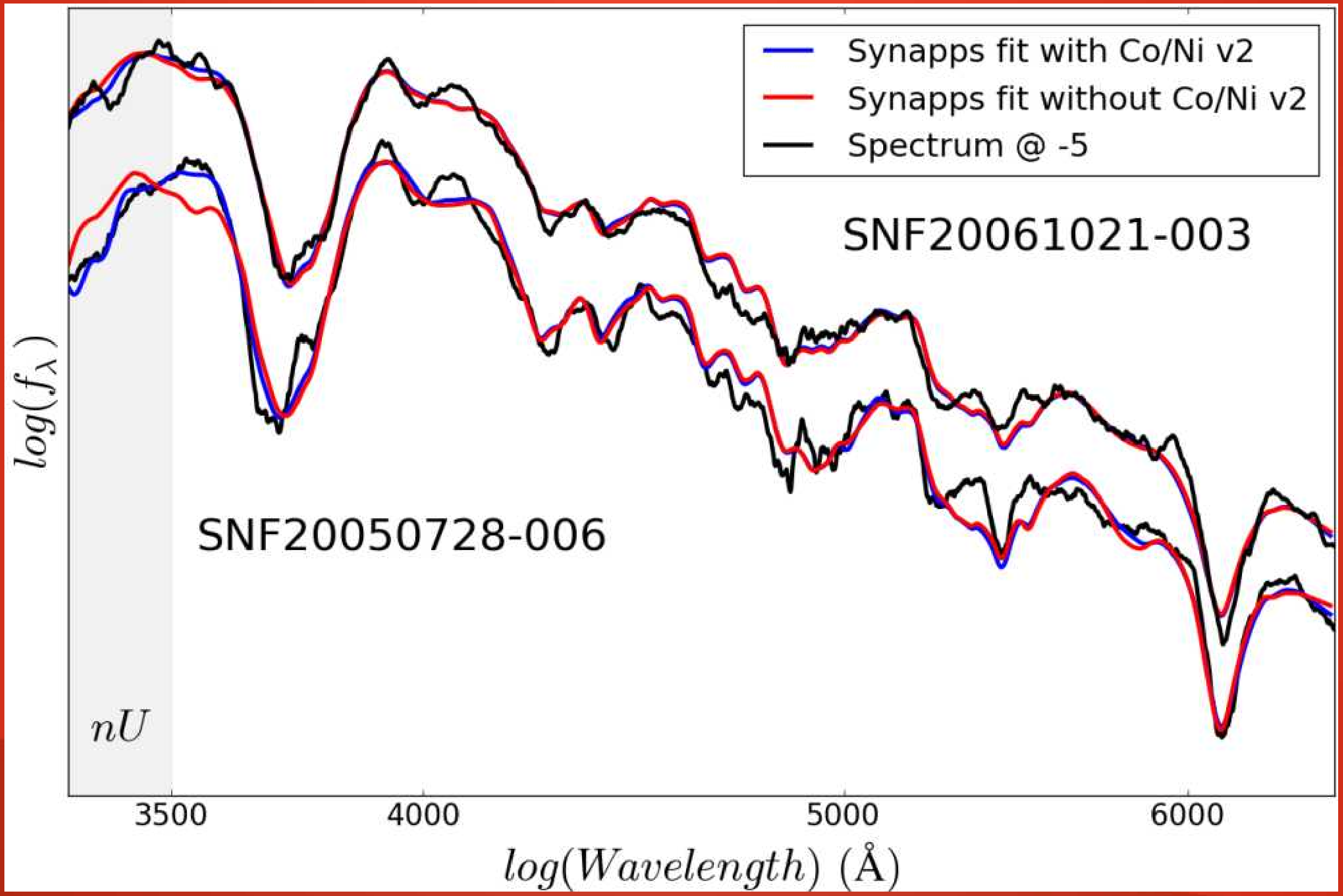
- SYNAPPS (SYNOW) explanation in terms of Co (decayed Ni)

Physical cause - TARDIS



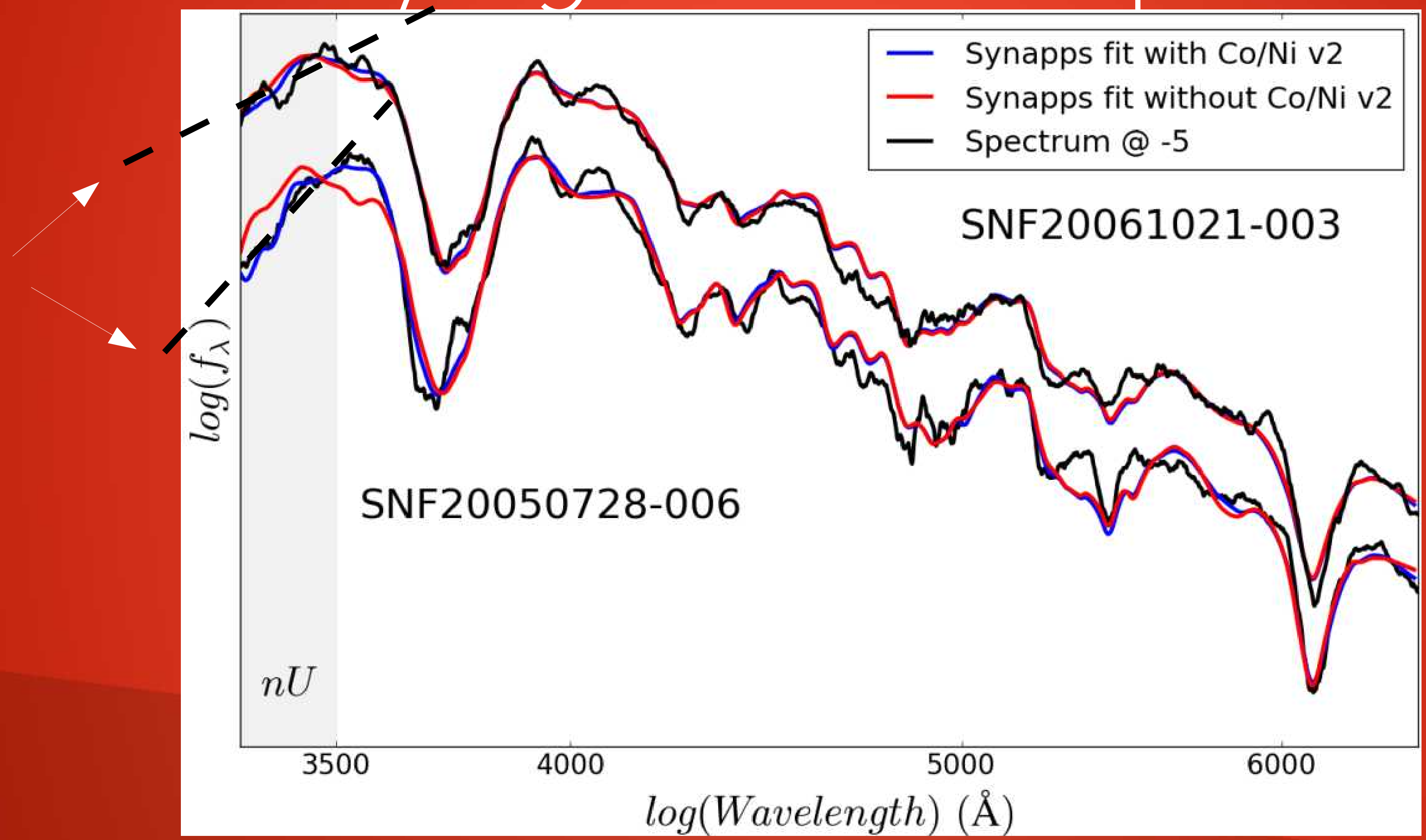
- TARDIS: Changing Ni fraction in W7 produce similar change

Physical cause - SYNAPPS II



- Compatible SYNAPPS results

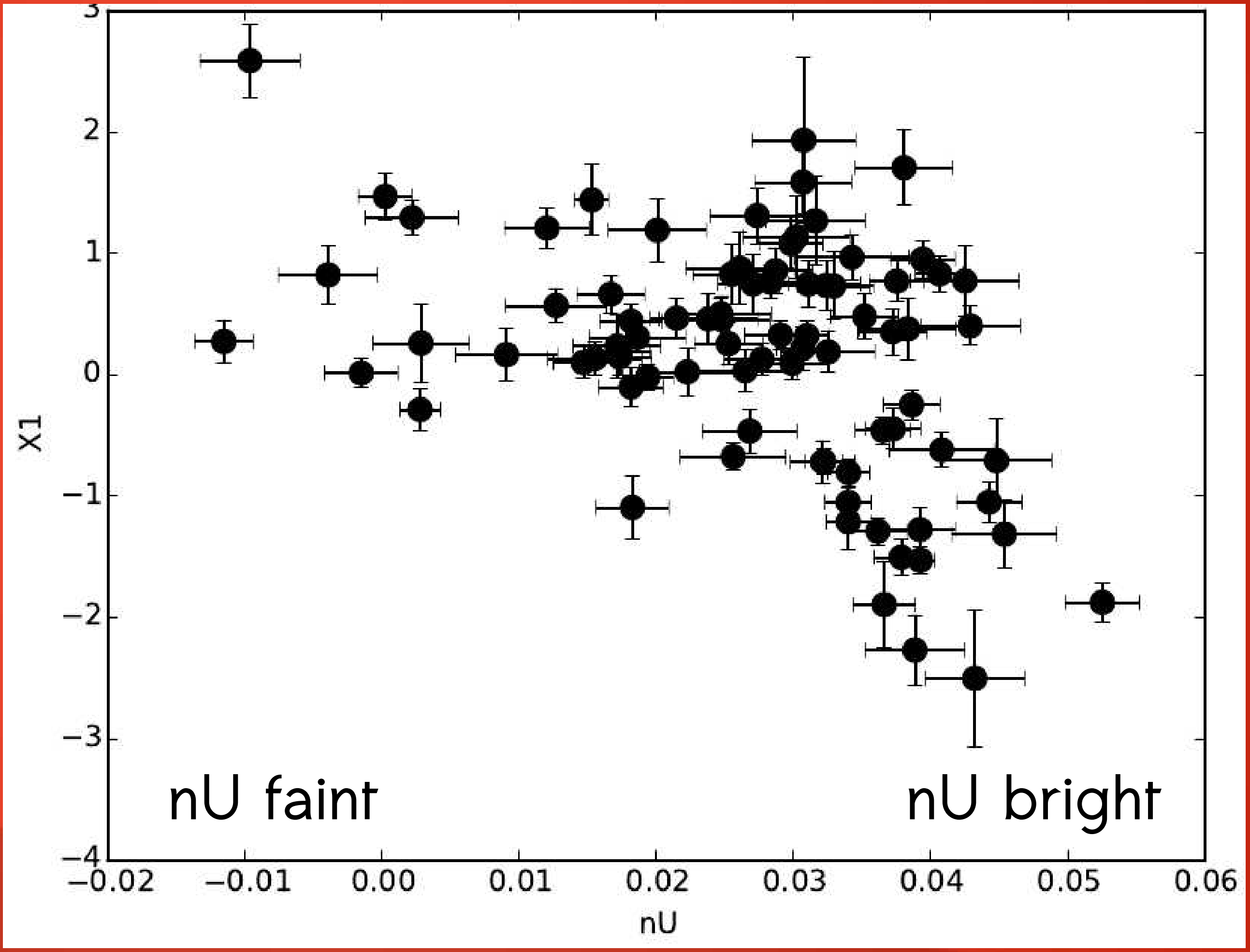
Quantifying nU as slope



- Weighted average of pre-peak obs.

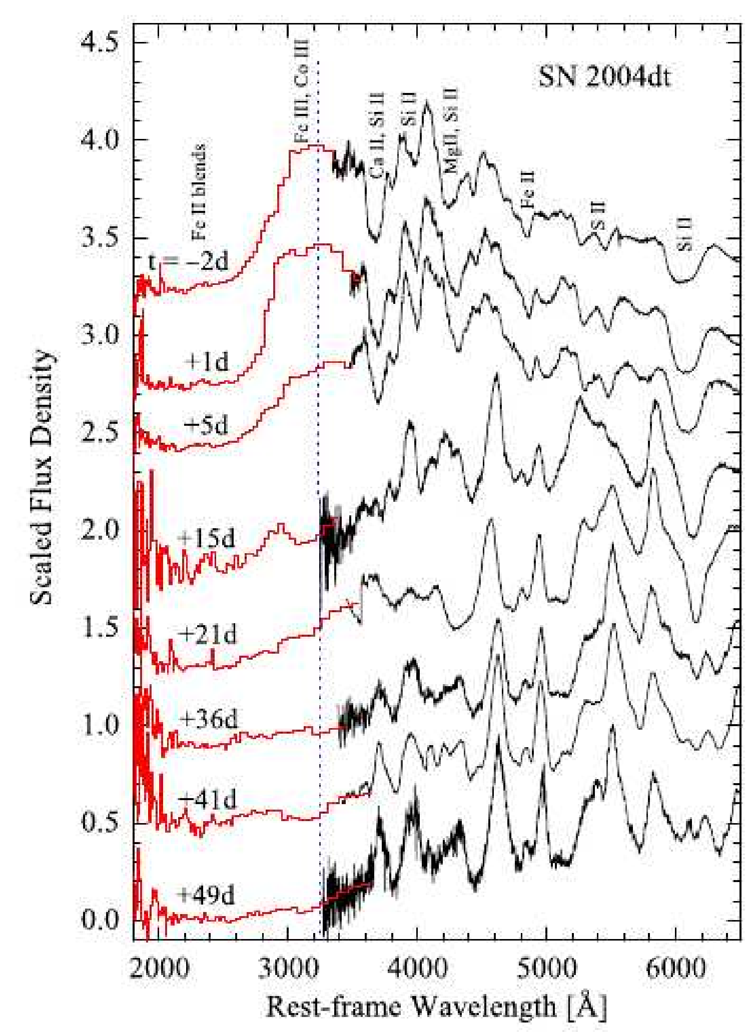
nU parameterization

- Lightcurve width correlation
- Skinny SNe are never nU faint



nU in the litterature: SN2004dt

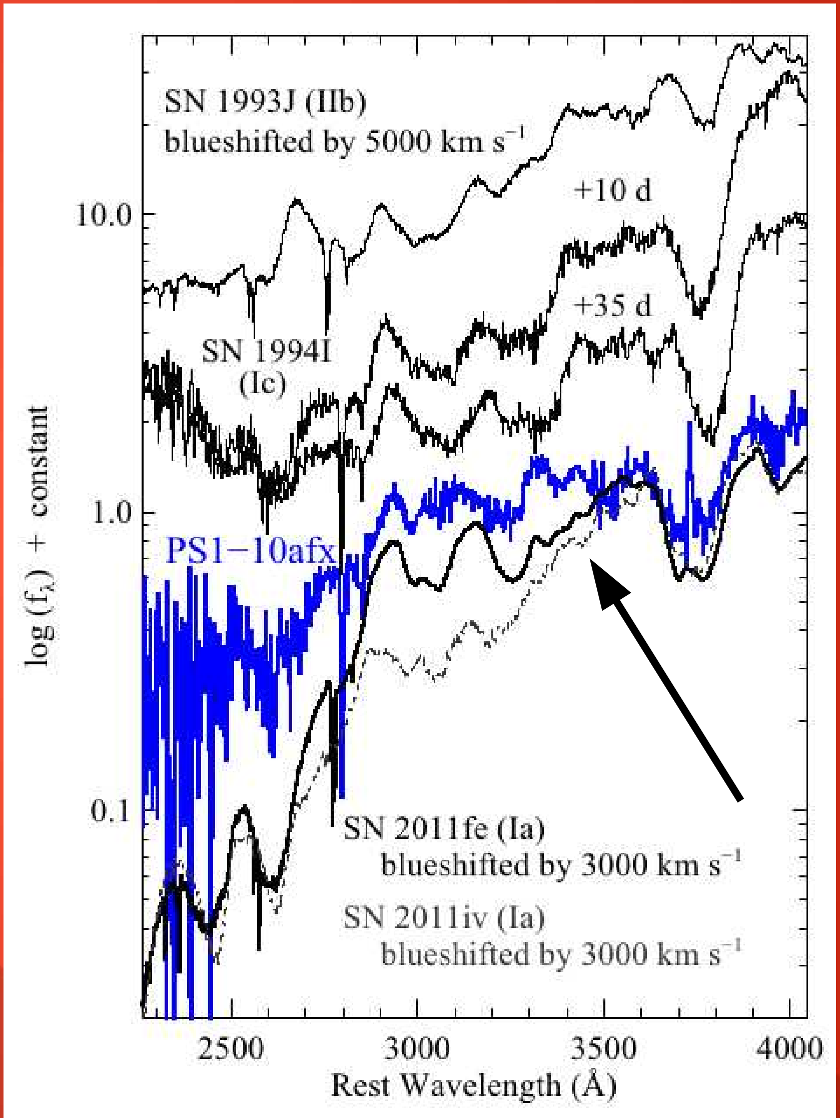
- Ground based spectra rarely go <3700 A.
- Space UV observations have trigger delays (phase>0)
- Until resently, best case was SN2004dt
  - low ACS grism resolution



Wang etal 2011

nU in the litterature: PS1-10afx

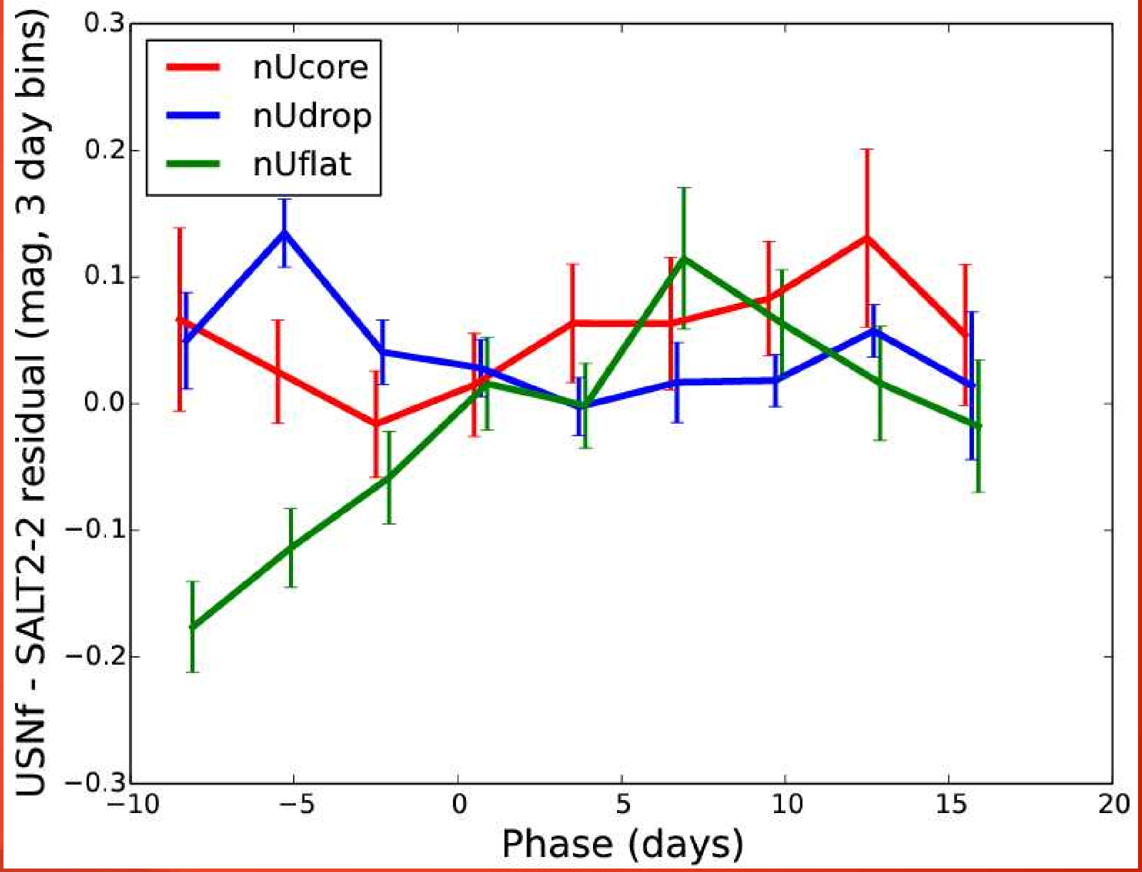
- PS1-10afx turns have all characteristics of nU-bright SNeIa
- One reason for the initial classification as non-Ia



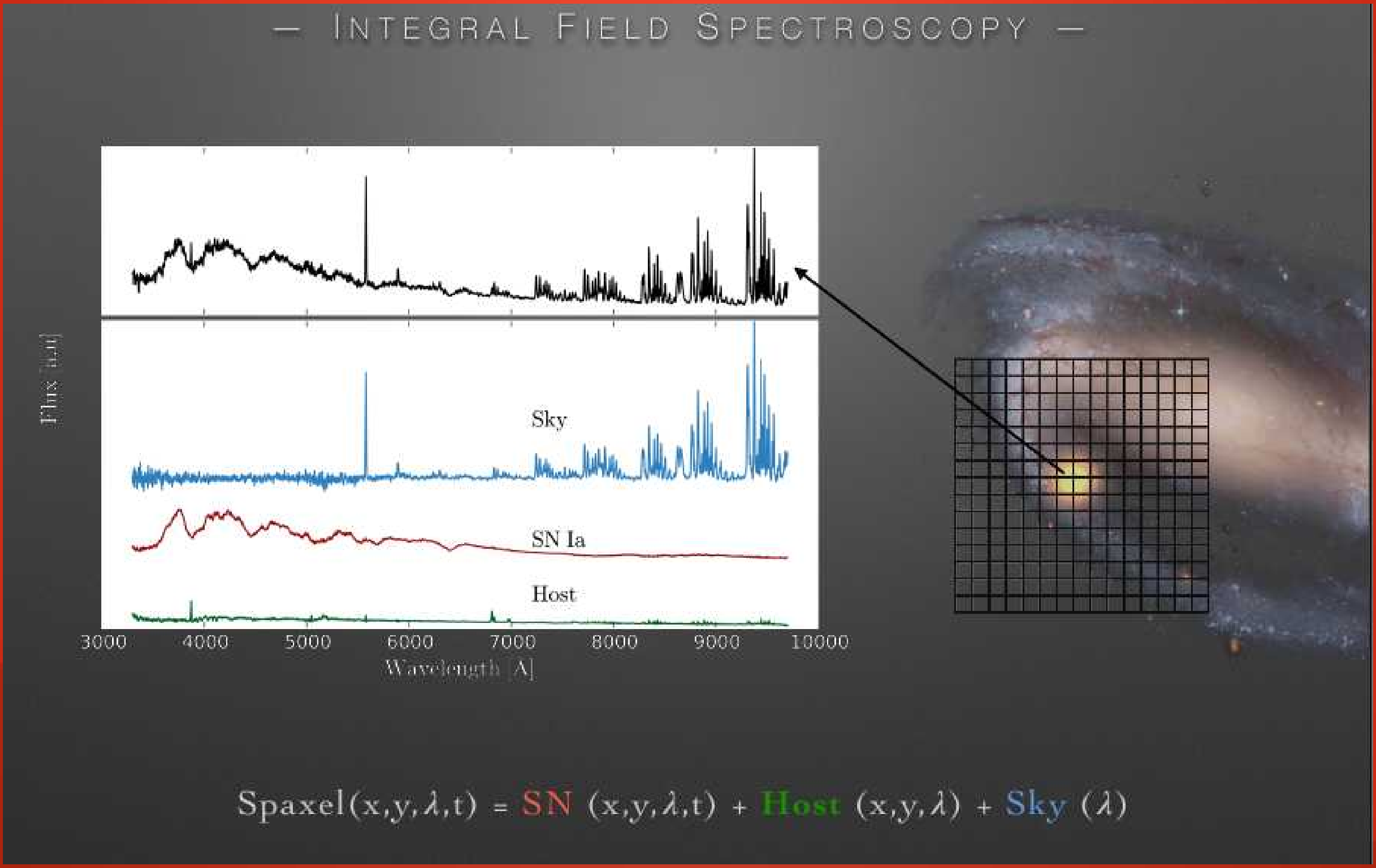
Chornock etal 2013

Cosmology

- U variations independent of e.g. X1 and C
- SALT bias when relying on U-band
- Quantified in Saunders et al (in prep)



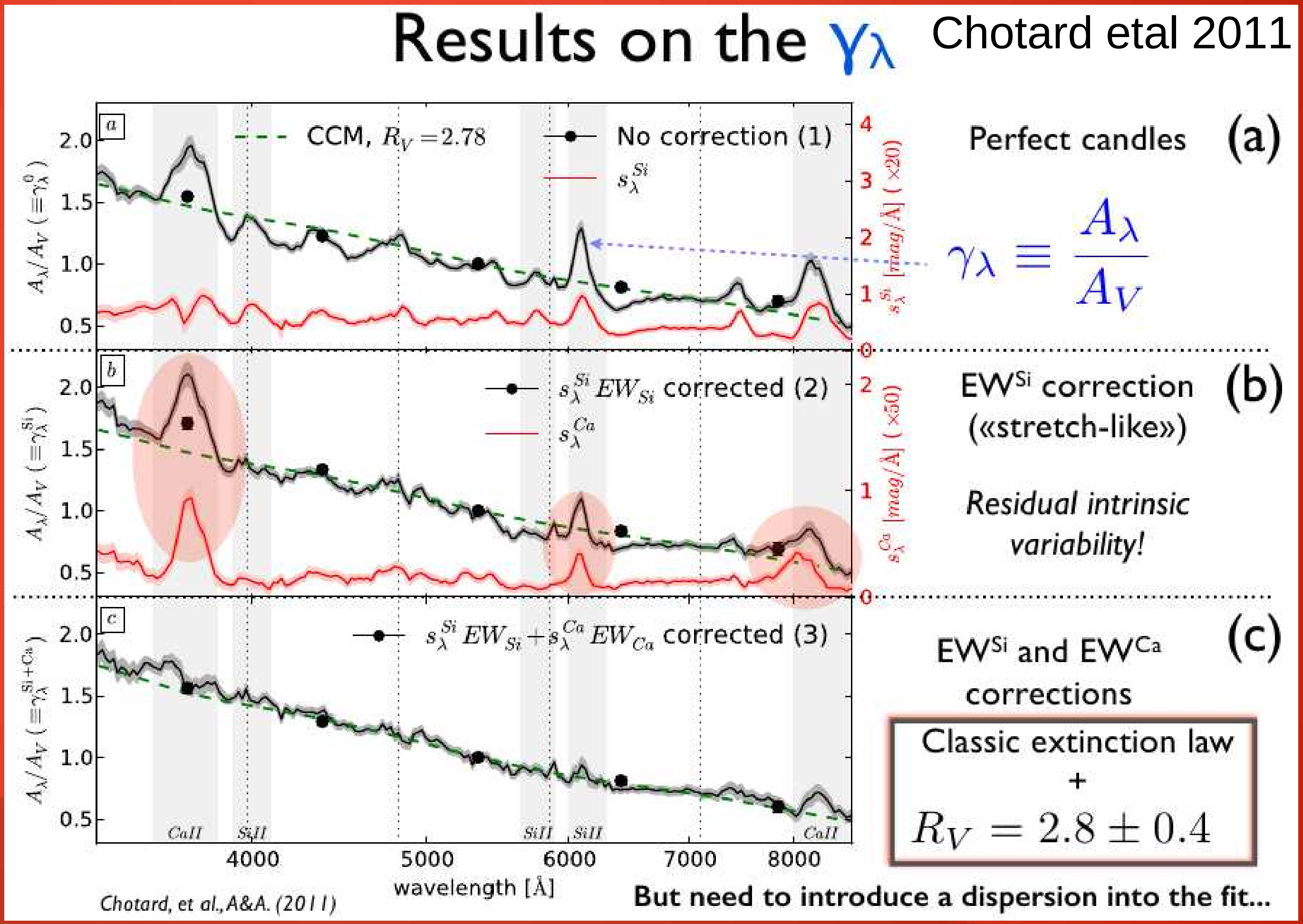
SNIFS @ UH 88


— INTEGRAL FIELD SPECTROSCOPY —
Flux [a.u]
Sky
SN Ia
Host
3000
4000
5000
6000
7000
8000
9000
10000
Wavelength [A]
Spaxel(x,y,λ,t) = SN (x,y,λ,t) + Host (x,y,λ) + Sky (λ)

CCM extinction law works

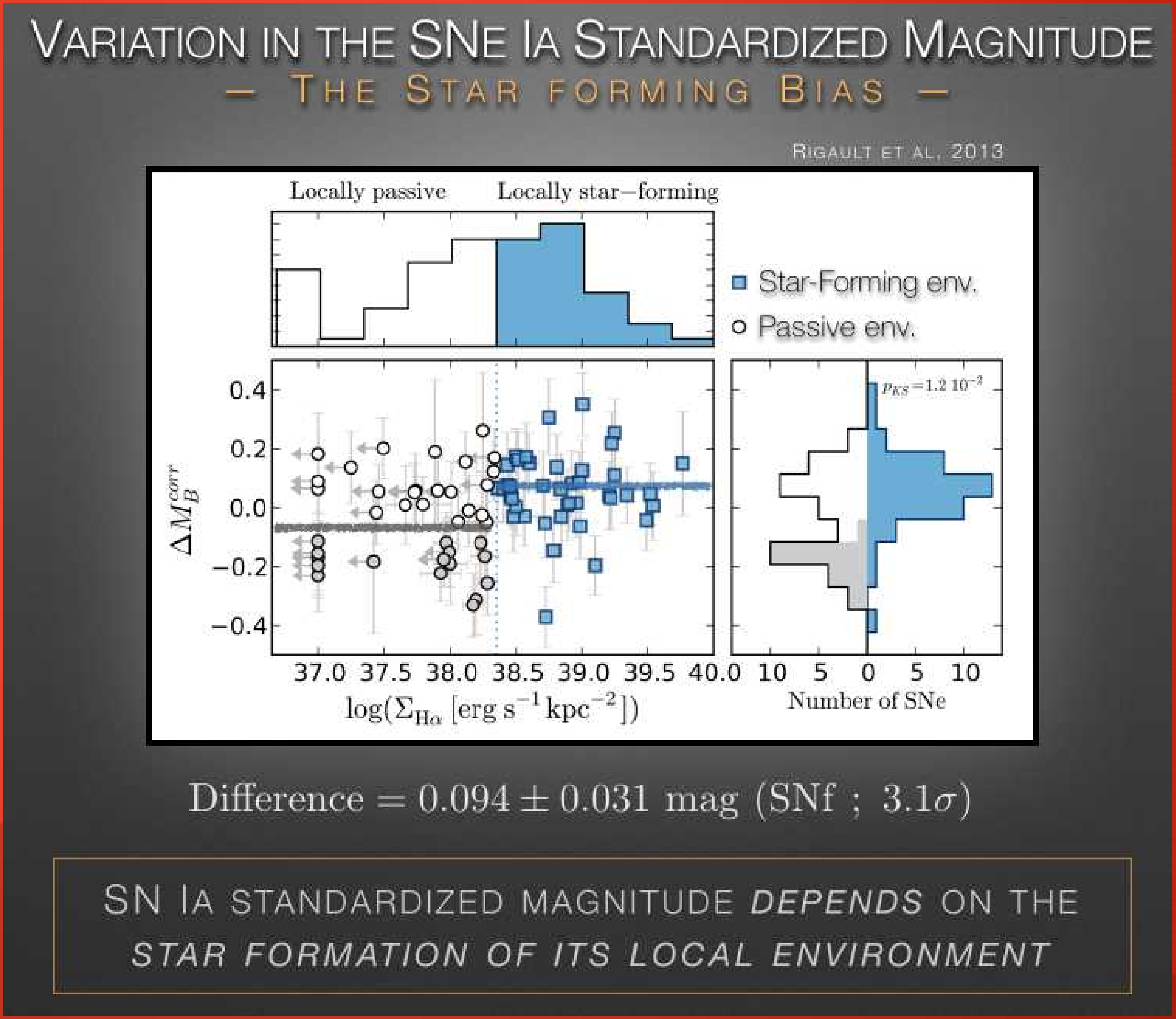
$$\delta A_\lambda = \Delta\mu_\lambda - \delta I$$

- After accounting for Si, Ca variations
- For moderately reddened SNe
- In B,V,R



A local SFR magnitude bias

- Hα at the SN site related to *corrected* magnitude
- Cosmology bias if related to mass step



Rigault etal 2013

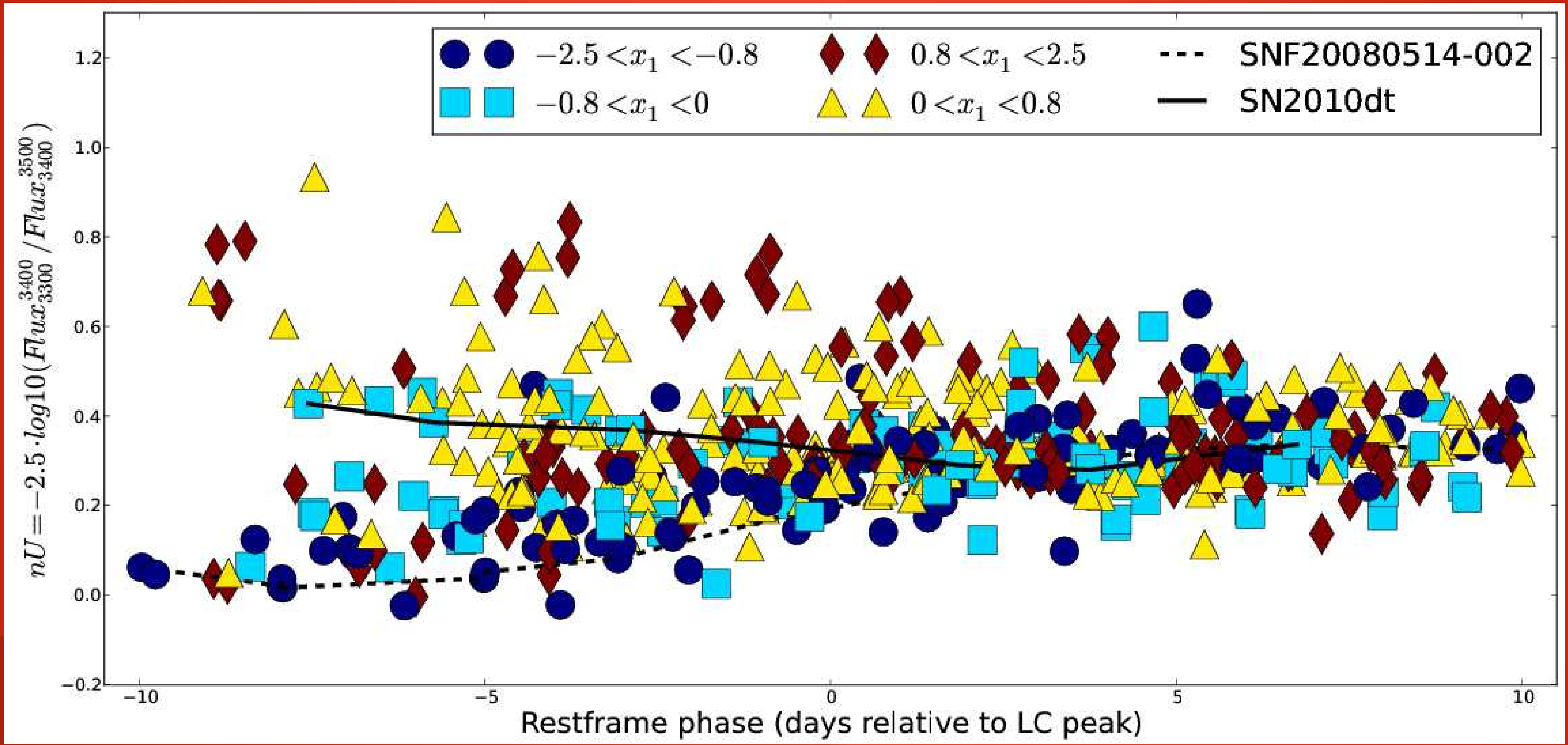
Summary

- Variations in the ~3200 to 3600 region of SNeIa are systematic and caused by explosion differences (rather than e.g.extinction).
- SYNAPPS/TARDIS studies of SN pairs imply that nU probes the amount of unstable Fe elements
- Fast declining SNe are never U faint (~ never Co rich)
- No appropriate models for high-z cosmology using U-band

Stay tuned for iPTF13asv tomorrow!

Backup

nU parameterization



- nU = evolution of flux(3300-3400) / flux(3400-3500)

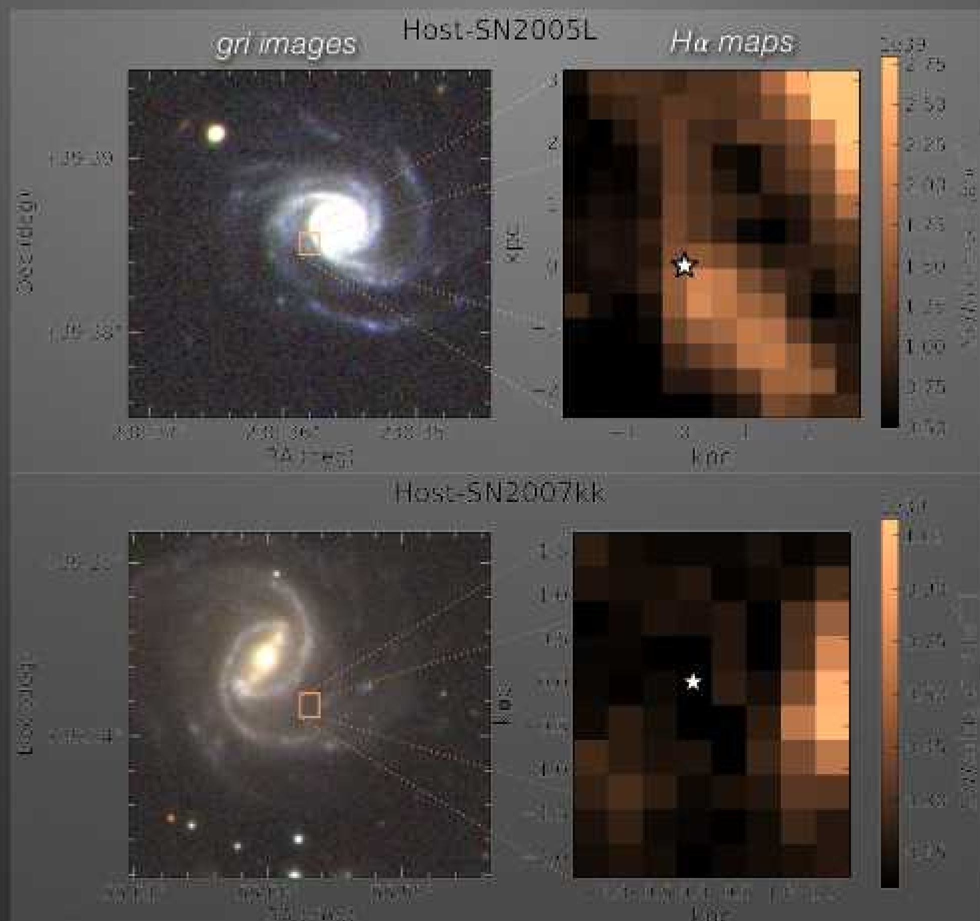
Backup

Environmental Perspectives

— Global vs. Local —

Globally

2 spiral star forming hosts



Rigault et al. 2013

Locally

Star-forming environment
—
Young Stars

Passive Environment
—
Older Stars

The SF-Bias and Global Analyses

— On the Origin of the Mass-Step —

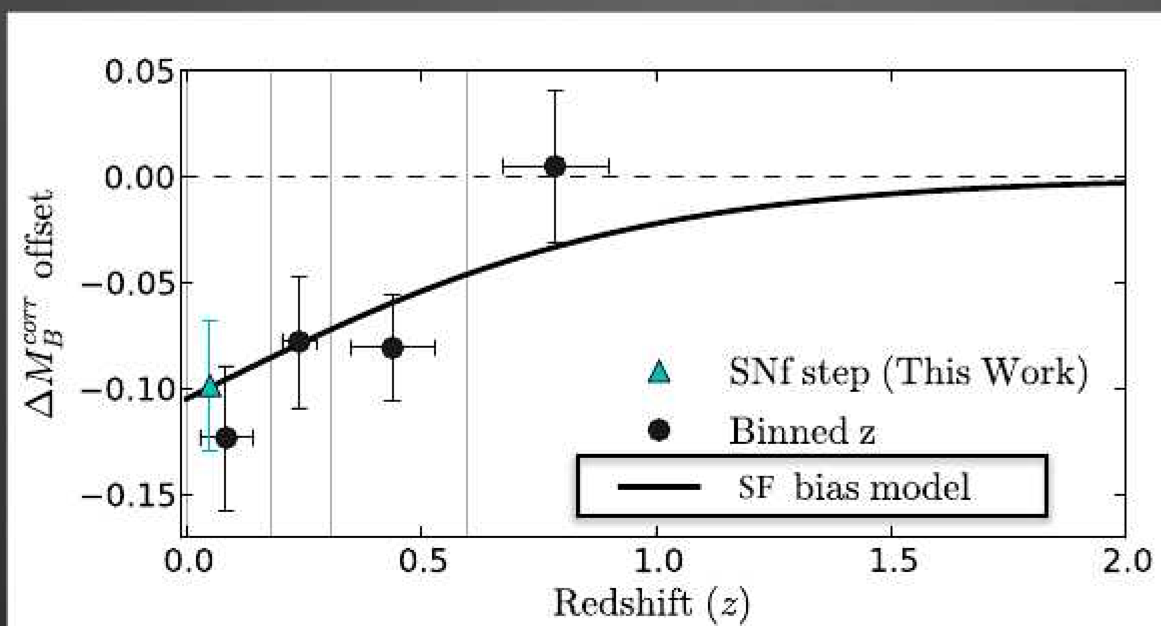
Galaxies

More massives = Greater Fraction of old stars

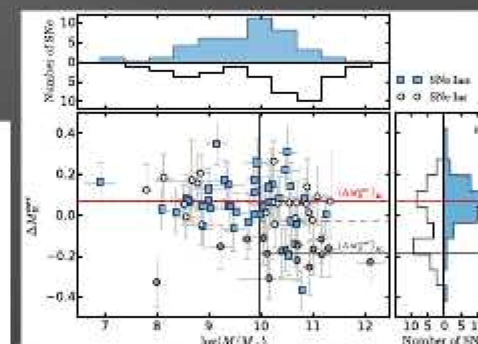
Supernovae

Older Environment = Brighter (SF-bias)

More Massive Galaxies should host Brighter Standardized Type Ia Supernovae



Rigault et al. 2013



Kelly et al 2009

Sullivan et al. 2010

Gupta et al 2011

Childress et al 2013

Betoule et al 2014

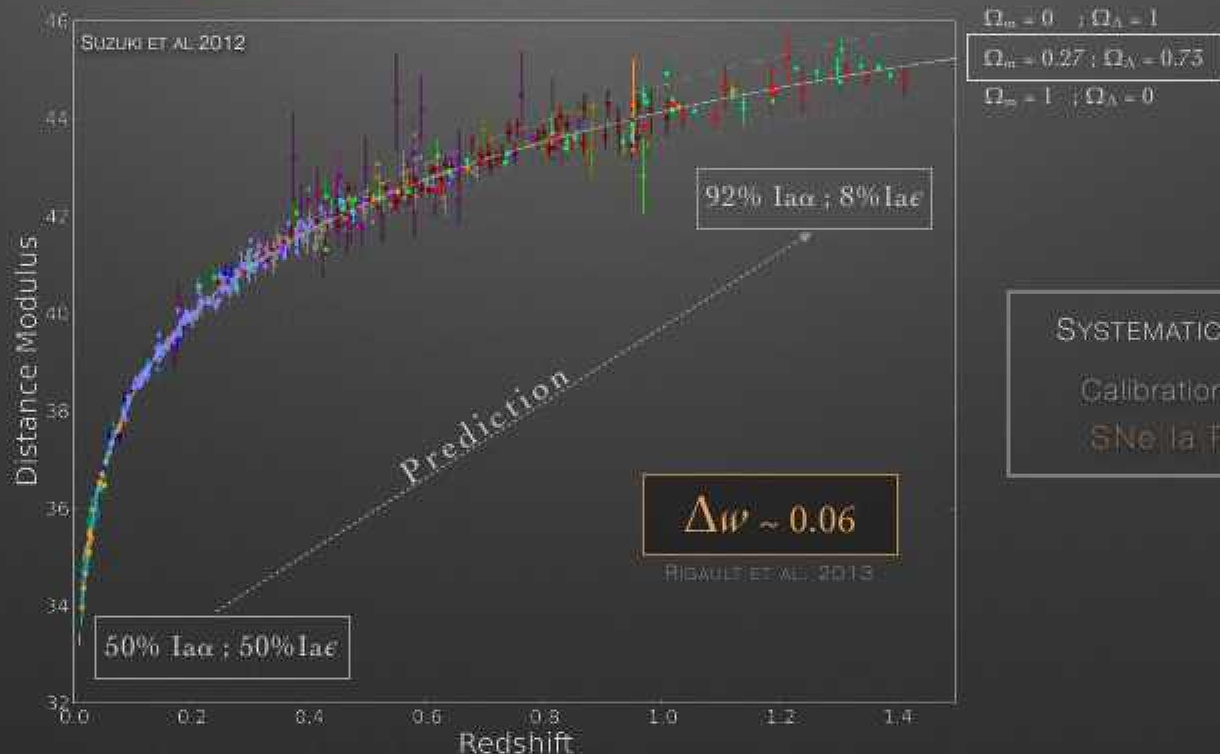
Consequence of the SF-Bias

— The equation of state parameter w —

Higher redshift galaxies are more star forming

SNe Ia from star forming environments are brighter after standardization (SF-bias)

$$\mu(d_L)\{z\ ;\ H_0^2\ \langle \cancel{L_{SN}} \rangle\}\ \ L_{SN}(z) \longrightarrow \mu(d_L)\{z\ ;\ \mathbf{\Omega}_i,\ w\ ,H_0^2\ \langle \cancel{L_{SN}} \rangle\}\ \ L_{SN}(z)$$



Systematic Sources

Calibration (~0.05)

SNe Ia Physics

Extinction law construction

1st step: Decompose the Hubble residuals into intrinsic variabilities and relative absorptions δA_λ

$$\boxed{\delta A_\lambda = \Delta\mu_\lambda - \delta I}$$

Two intrinsic corrections

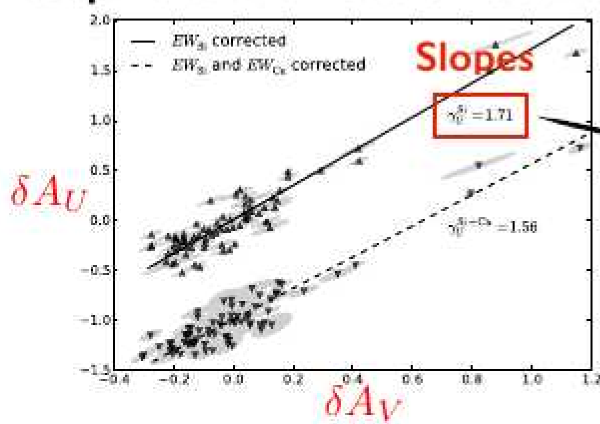
$$\Delta\mu_\lambda = \begin{cases} \delta A_\lambda^0 & (a) \\ s_\lambda^{\mathrm{Si}}\mathrm{EW}^{\mathrm{Si}} + \delta A_\lambda^{\mathrm{Si}} & (b) \\ s_\lambda^{\mathrm{Si}}\mathrm{EW}^{\mathrm{Si}} + s_\lambda^{\mathrm{Ca}}\mathrm{EW}^{\mathrm{Ca}} + \delta A_\lambda^{\mathrm{Si+Ca}} & (c) \end{cases}$$

(a) SNe Ia are **perfect candles** : purely extrinsic variability

(b) Intrinsic variability described by a **«stretch-like» parameter** : $\mathrm{EW}^{\mathrm{Si}}$

(c) Intrinsic variability described by **two parameters:** $\mathrm{EW}^{\mathrm{Si}}$ and $\mathrm{EW}^{\mathrm{Ca}}$

2nd step: Use the relation between the δA_λ to construct the law



Linear model

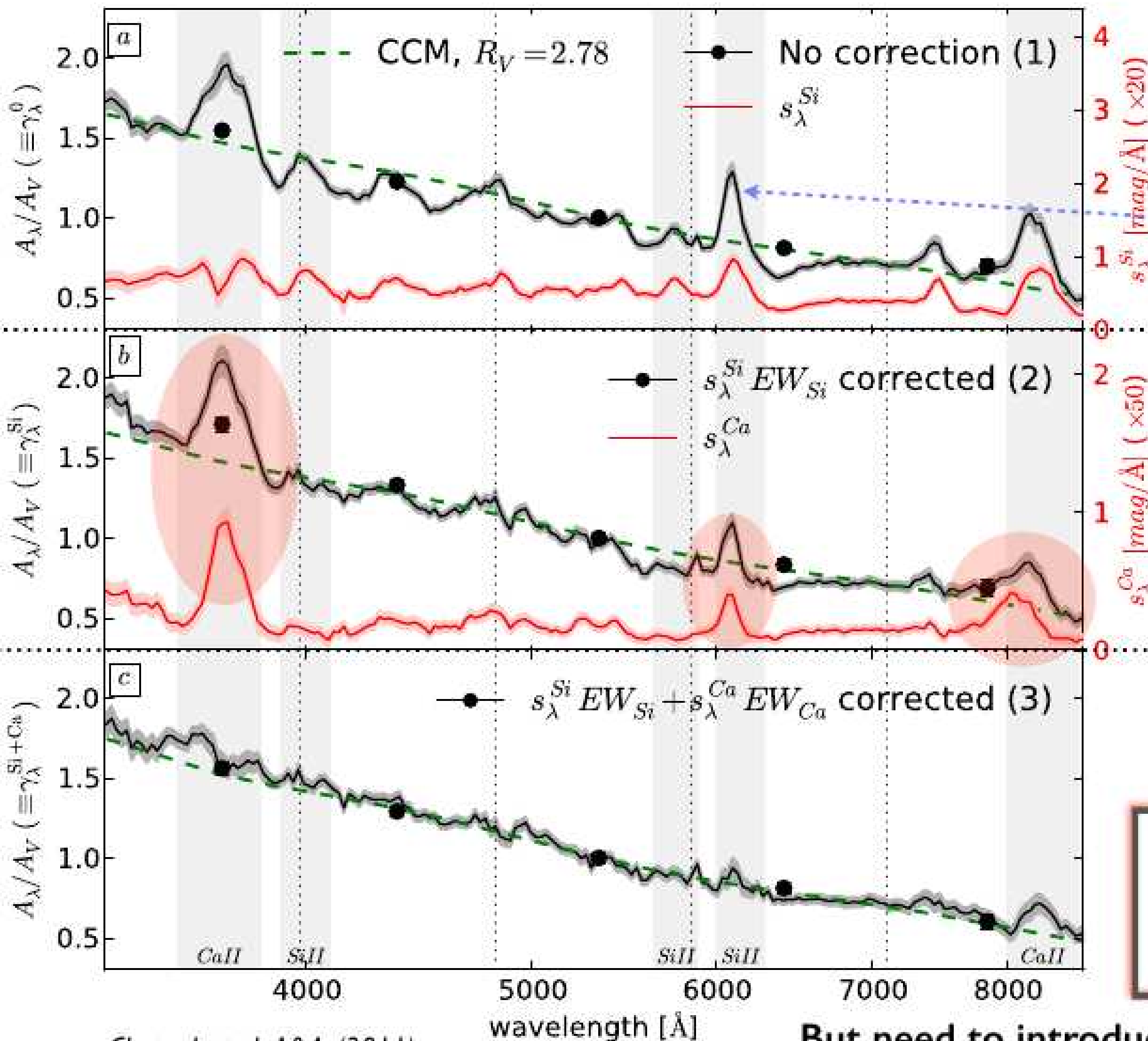
$$\boxed{\delta A_\lambda(i)} = \boxed{\gamma_\lambda}\, \delta A_V^*(i) + \eta_\lambda$$

Measured

Extinction law

Extinction

Results on the γ_λ



Perfect candles (a)

$$\gamma_\lambda \equiv \frac{A_\lambda}{A_V}$$

EW^{Si} correction («stretch-like») (b)

Residual intrinsic variability!

EW^{Si} and EW^{Ca} corrections (c)

Classic extinction law
+
$R_V = 2.8 \pm 0.4$

Chotard, et al., A&A. (2011)

But need to introduce a dispersion into the fit...

Covariance matrix

Why?

- Using the measured covariance matrix only: $X^2 >> 1$
- Extra dispersion matrix needed to set the X^2 to 1 (as in all cosmological fits with SNe Ia)

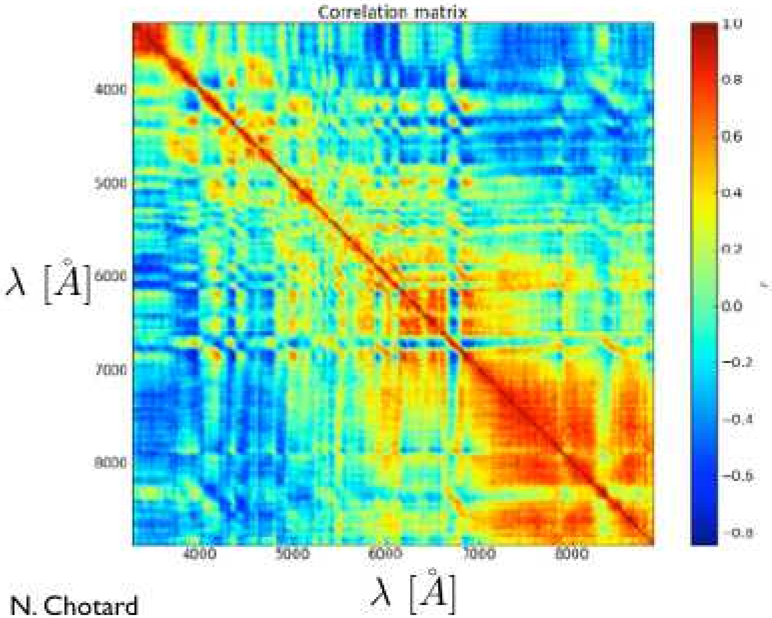
How?

- Using the residual $r_\lambda(i)$ to the γ_λ fit to construct the additionnal covariance matrix
- Introduction of a **color dispersion**, not usually used

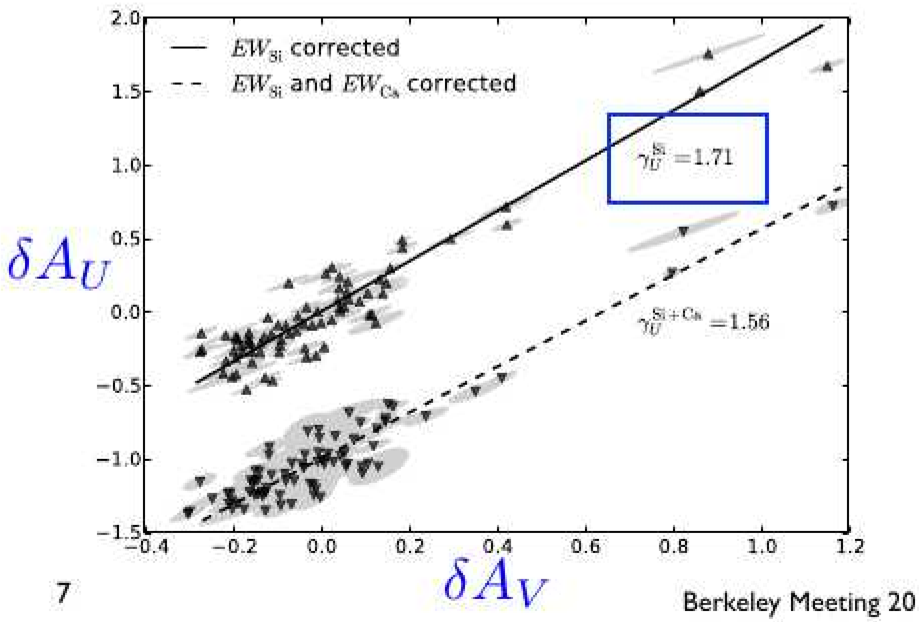
Results

- Anti-correlation mostly increases with the wavelength differences
- Same pattern for broad filters and narrow band (spectral) correlations

For the case (c): 2 intrinsic corrections

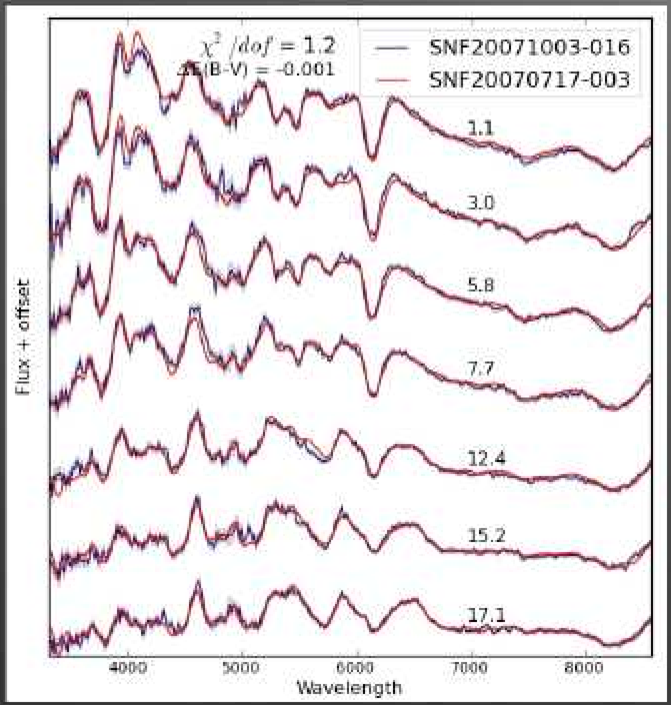


Reminder: $\delta A_\lambda(i) = \gamma_\lambda \, \delta A_V^*(i) + \eta_\lambda \; (+r_\lambda)$



New analyses

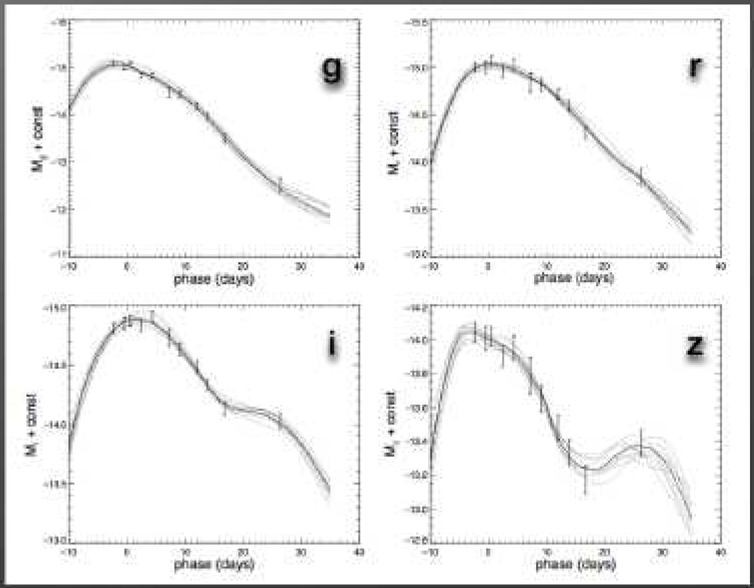
Twins analysis



Concept — SN Ia Twins enable an extremely accurate distance measurement.

FAKHOURI IN PREP.

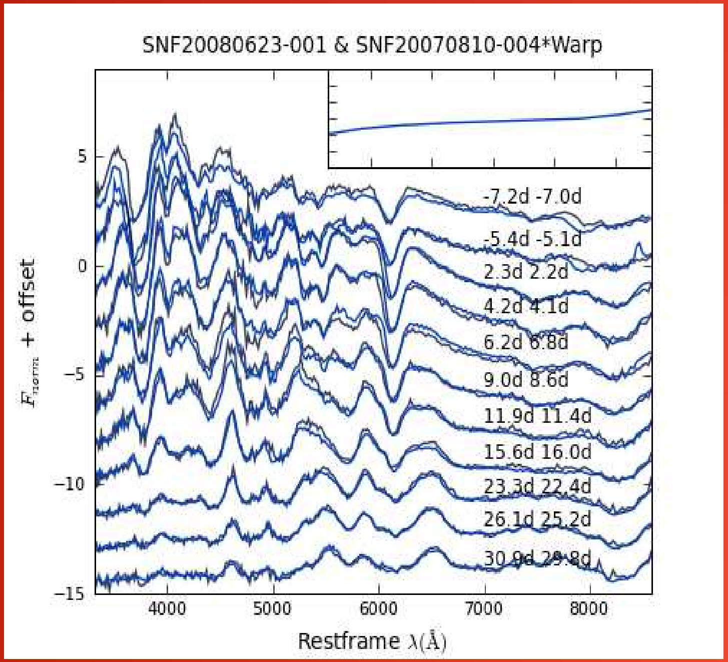
Gaussian Process *lightcurve fitting*

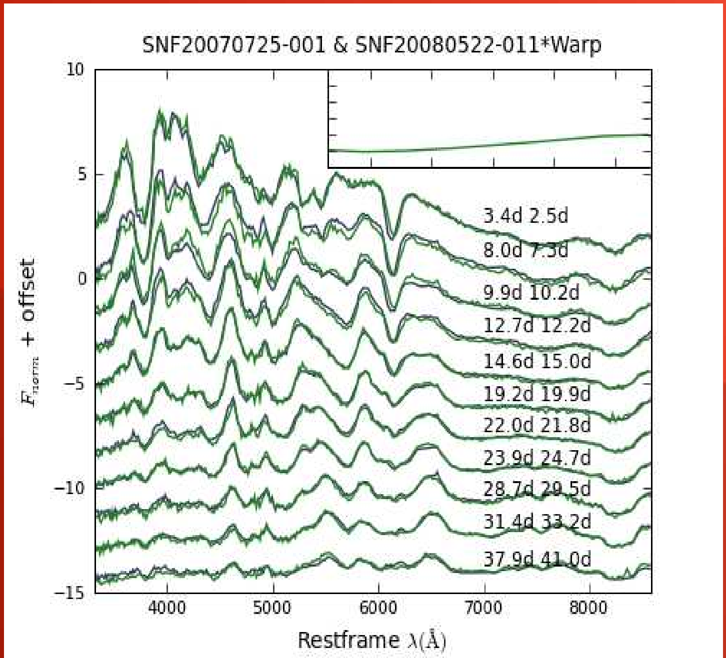


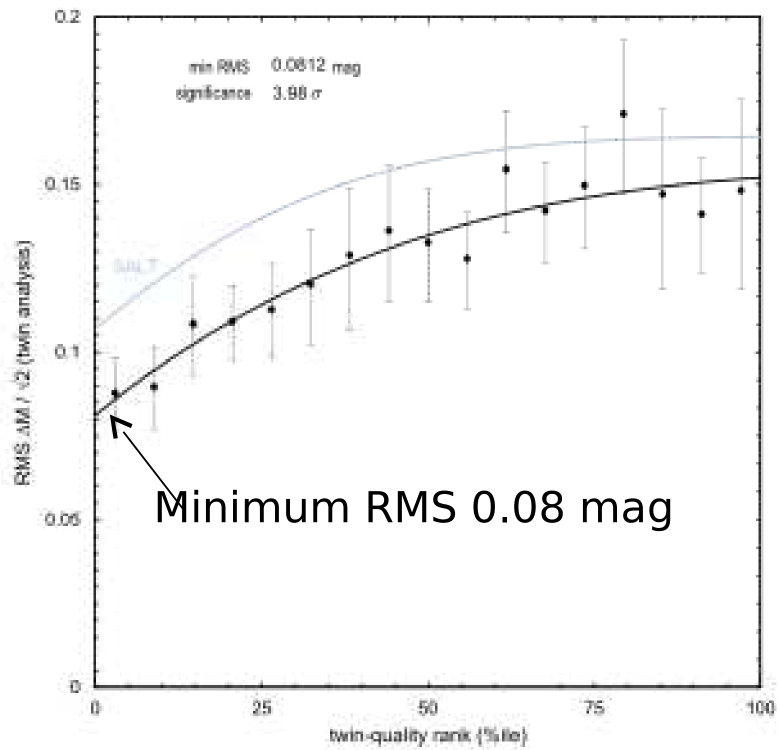
Concept — Gaussian process to reconstruct lightcurves at any redshift. GP trained on SNfactory's spectra.

KIM ET AL. 2013

Twin SNe Are Even Better







Better □ Twinness □ Worse

- Compare SNe that are spectroscopic “twins”
- Used blind analysis methods
- Dispersion is 0.08 mag
- 2x better than SALT!
- As good as infrared!

Fakhouri (*SNfactory*)