Status of the SNLS 3-year Analysis

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on behalf of the SNLS Collabotation

LPNHE - IN2P3 - CNRS - University Paris 6 and Paris 7

XIXe Recontres de Blois, 2007/05/24

Outline

Outline

The Supernova Legacy Survey

$O(1000)$ SNe Ia – $10\times$ present statistics

- detected before maximum
- followed-up in 4 passbands (g_M, r_M, i_M, z_M) ($\sim$ SDSS bands)
- a good sampling of the lightcurves (1 point every 3 days)
- spectroscopic identification of all the SNe Ia

Justifications

- Large statistics $\longrightarrow$ better control of the systematics
- One detector $\longrightarrow$ control of calibration & selection bias
- Multiband obs. $\longrightarrow$ follow same spectral region @ different z

BV @ $z \sim 0$	$\longrightarrow$	gr @ $z \sim 0.2$
	$\longrightarrow$	ri @ $z \sim 0.4$
	$\longrightarrow$	iz @ $z \sim 0.8$

- Multiband obs. $\longrightarrow$ redundant measurements of distances

A Large Photometric Survey . . .

$\sim$ 300h / year on a 3.6-m

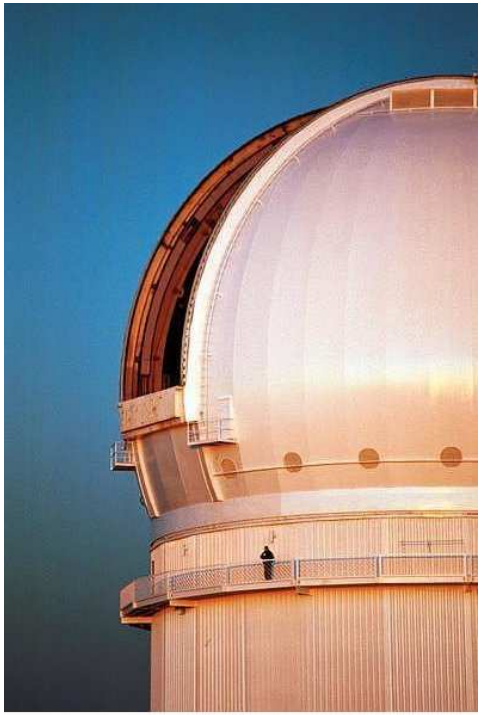
- CFHT @ Hawaii

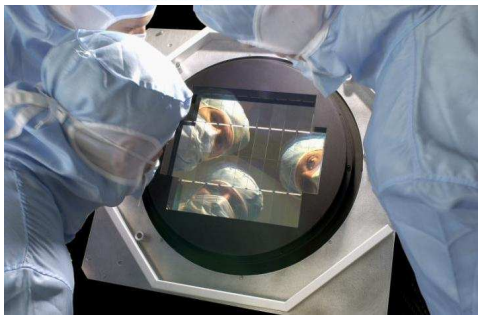
Wide Field Camera

- Megacam (CEA/DAPNIA)
- 1 deg^2, 36 2k$\times$4k CCDs
- Good PSF sampling 1 pix = 0.2"
- Excellent image quality: 0.7" (FWHM)

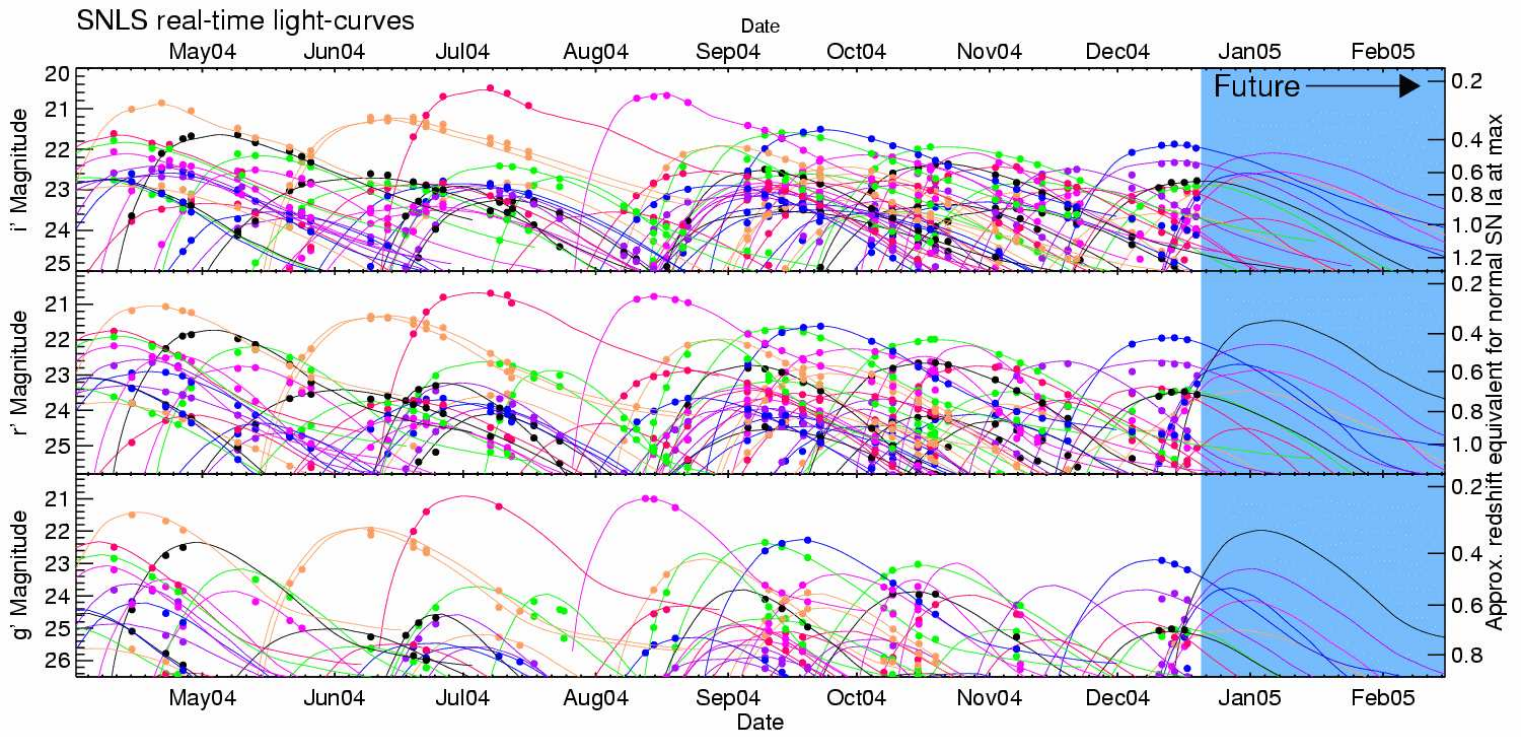
Rolling search **mode**

- Component of the CFHTLS survey
- 40 nights / year during 5 years
- Four 1-deg^2 fields
- repeated observations (3-4 nights)
- in 4 bands (*griz*)
- queue observing (minimize impact of bad weather)





. . . Operated in Rolling Search Mode



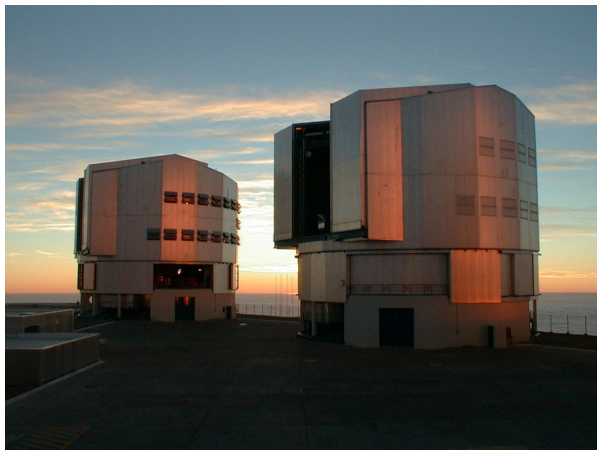
A Large Spectroscopic Survey

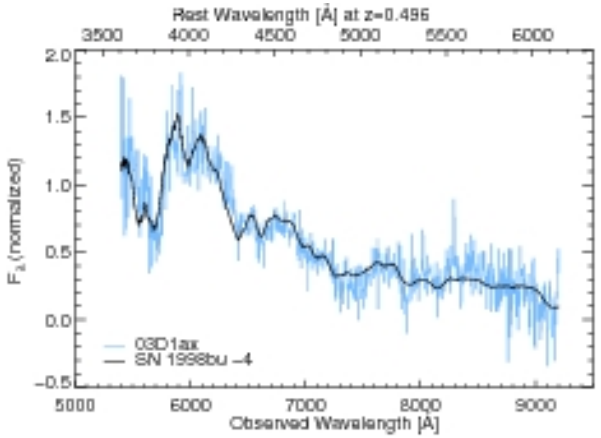
Goals

- spectral identification of SNe Ia ($z < 1$)
- redshift determination (host galaxy lines)
- complementary programs
  - detailed studies of SNe Ia

Telescopes

- VLT large program (80h / semester)
- Gemini (60h / semester)
- Keck (30h / semester, Spring Semester)





(Howell et al, 2005 – ApJ 634, 1190)

Statistics

Public list of candidates:
http://legacy.astro.utoronto.ca

Sept. 2006

Telescope	SNIa (/?)	SNII (/?)	Total SN (/?)	Other	Total
Gemini	96	9	151	0	151
Keck	77	21	139	4	143
VLT	120	22	235	13	248
Total	293	52	525	17	542

$\sim$ 300 Identified Type Ia Supernovae on disk

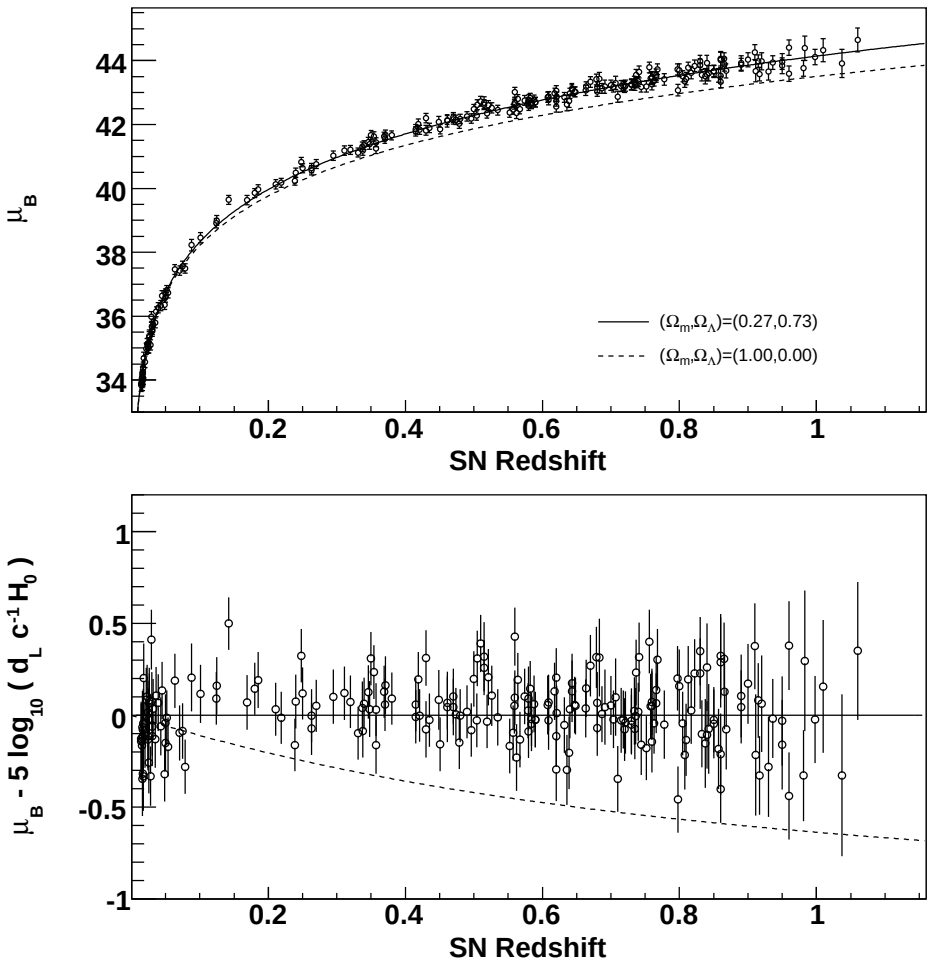
$\sim$ 500 Identified Type Ia Supernovae at the end of the Survey

Outline

Offline Photometric Pipeline

- Differential photometry
- PSF photometry of the field stars
- Calibration of the DEEP fields
- Fit of multicolor lightcurves
- Luminosity Distance Estimation
- Cosmological Results
- Systematics

SNLS 3 Year Hubble Diagram – Preliminary



Distance Estimator

$$\mu_B = m_B^\star - \mathcal{M} + (\alpha - 1)\, s - \beta\, c$$

Objects

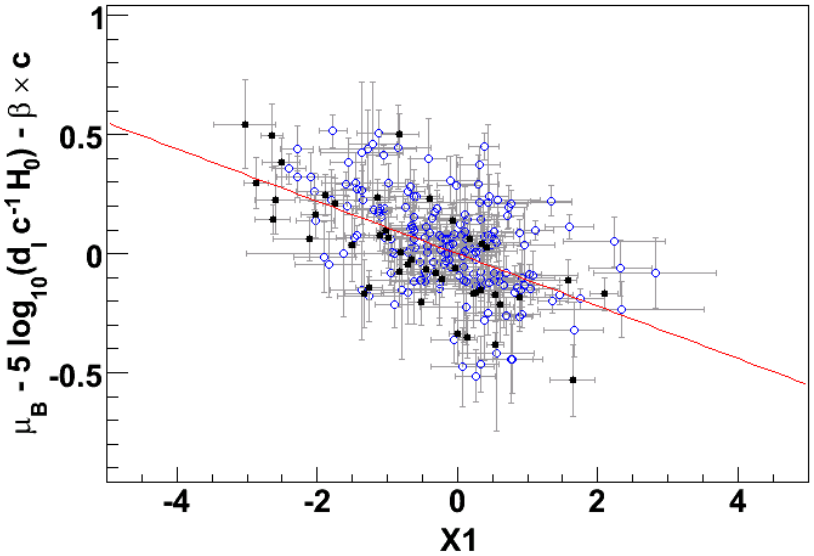
- 44 nearby SNe Ia
- $\sim$ 250 SNLS SNe Ia

Cosmology

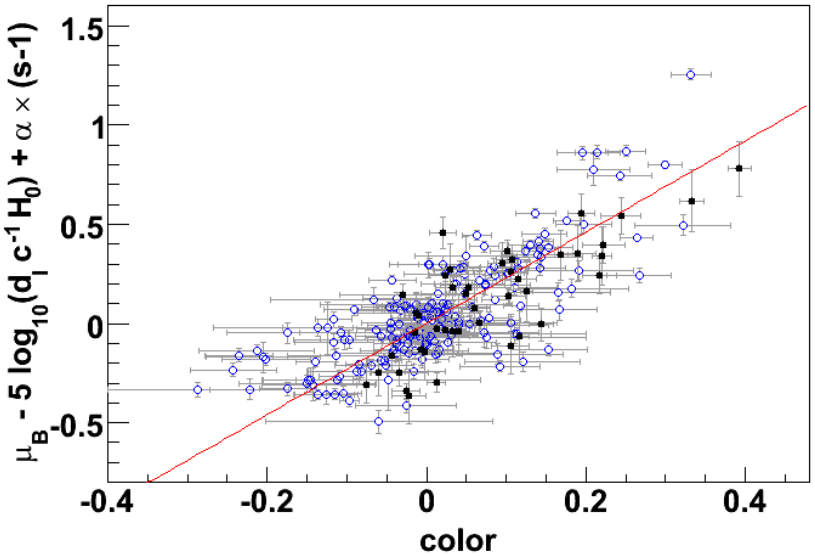
$$\chi^2 = \sum_i \frac{\mu_{B_i} - 5\log_{10} d_L(\theta, z_i)^2}{\sigma^2(\mu_{B_i}) + \sigma_{int}^2}$$

- Minimize w.r.t. θ, α, β and $\mathcal{M}$.
- σ_{int} so that $\chi^2 = \mathrm{NDOF}$
- marginalize over α, β and $\mathcal{M}$.

Standardization Relations



Hubble diagram residuals
(no stretch corrections applied)
as a function of stretch.



Hubble diagram residuals
(no color corrections applied)
as a function of color.

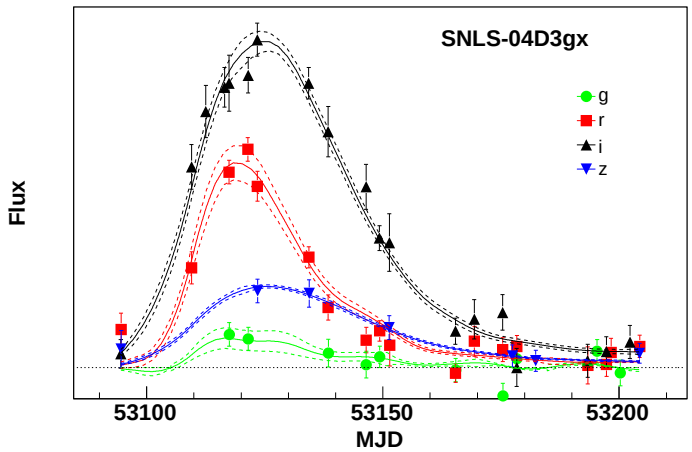
brighter-bluer and brighter-slower relations
at $z = 0$ (blue points)
and $z \sim 0.6$ (black points) are compatible.

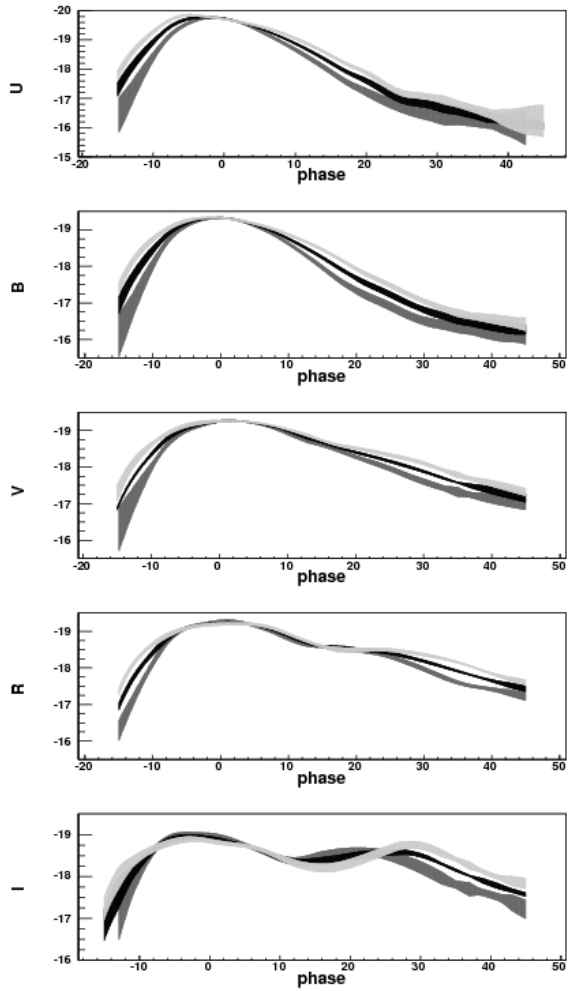
SALT2: modeling SN Ia SED in the far-UV

J. Guy et al, 2006

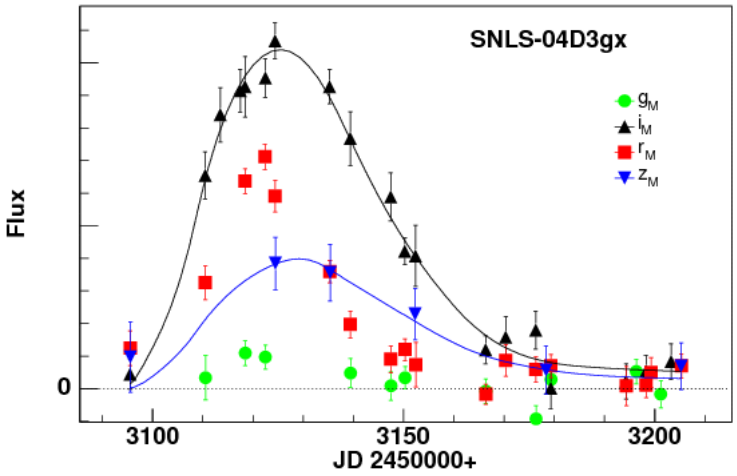
SALT2: J. Guy et al, 2006

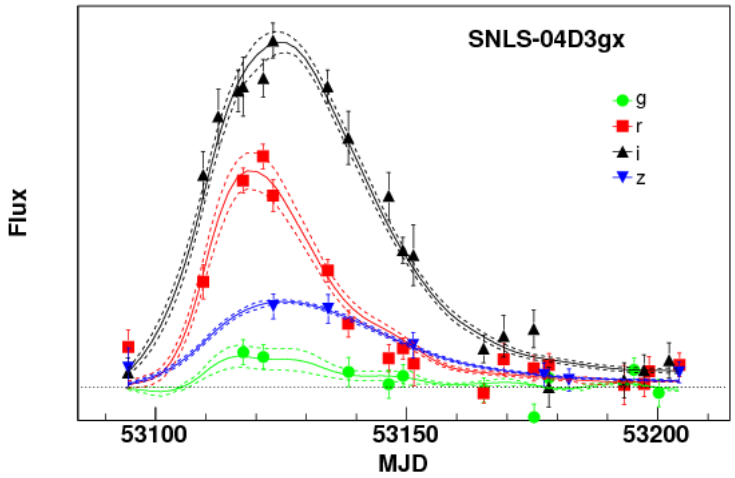
- Use photometric and spectroscopic data
- PCA to describe SN variability
- Derive model uncertainties
- Modeling of SN Ia SED in the far UV

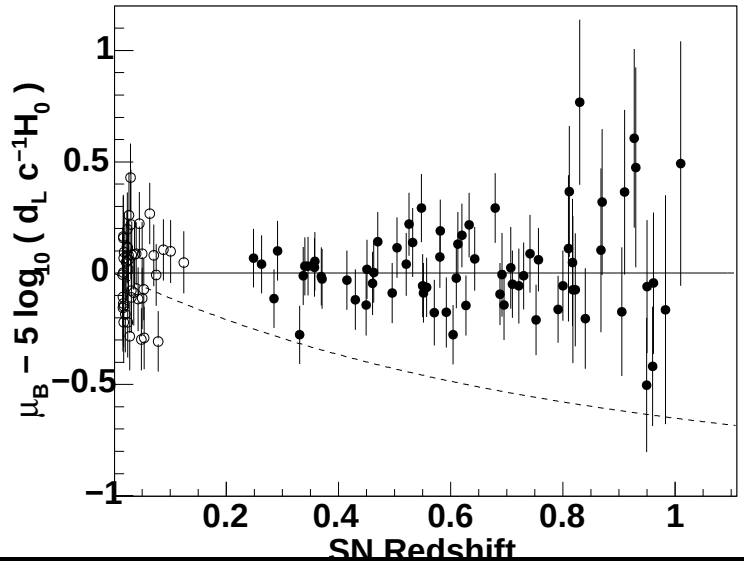


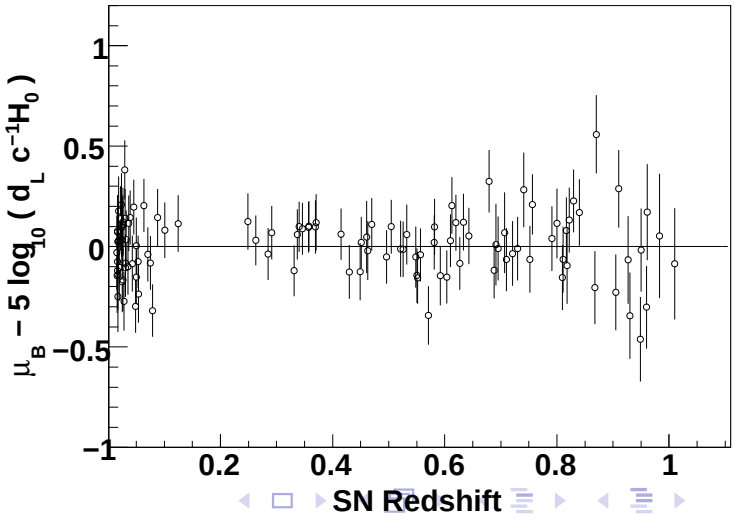


SALT2

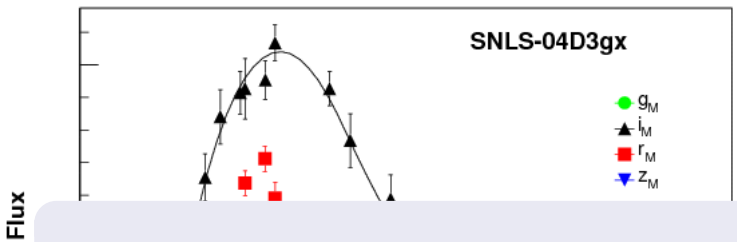

SNLS-04D3gx
g_M
i_M
r_M
z_M
Flux
0
3100
3150
3200
JD 2450000+

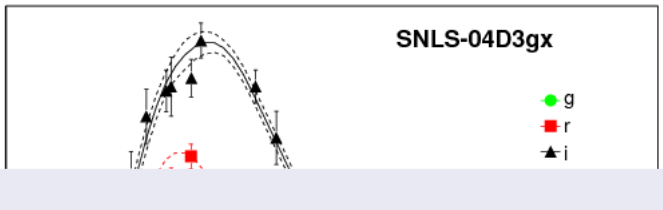

SNLS-04D3gx
g
r
i
z
Flux
53100
53150
53200
MJD


$\mu_B - 5\log_{10}(d_L\, c^{-1}H_0)$
1
0.5
0
−0.5
−1
0.2
0.4
0.6
0.8
1
SN Redshift

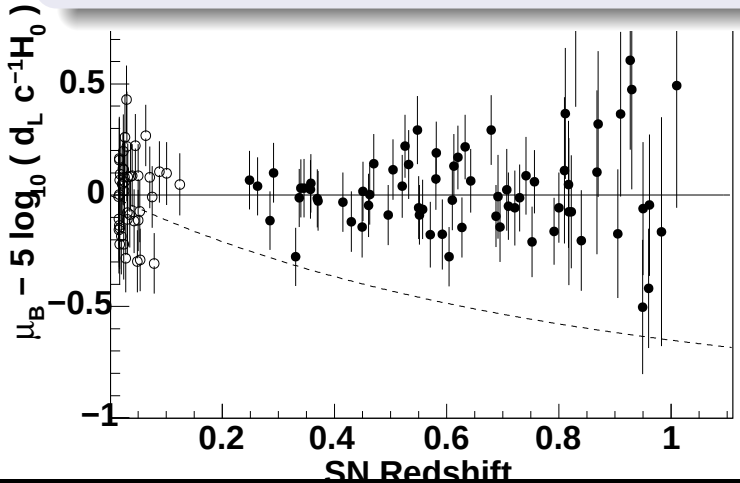

$\mu_B - 5\log_{10}(d_L\, c^{-1}H_0)$
1
0.5
0
−0.5
−1
0.2
0.4
0.6
0.8
1
SN Redshift

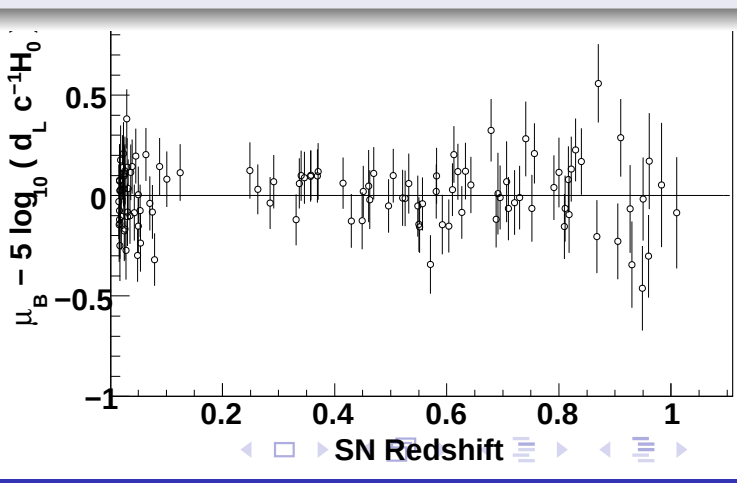
SALT2





- Same cosmology
- rms of Hubble diagram residuals 0.16 (0.20 in 1st year analysis)
- $\sigma(w)$ reduced by $\sim 20\%$
- figure of merit of DETF improved by 35%

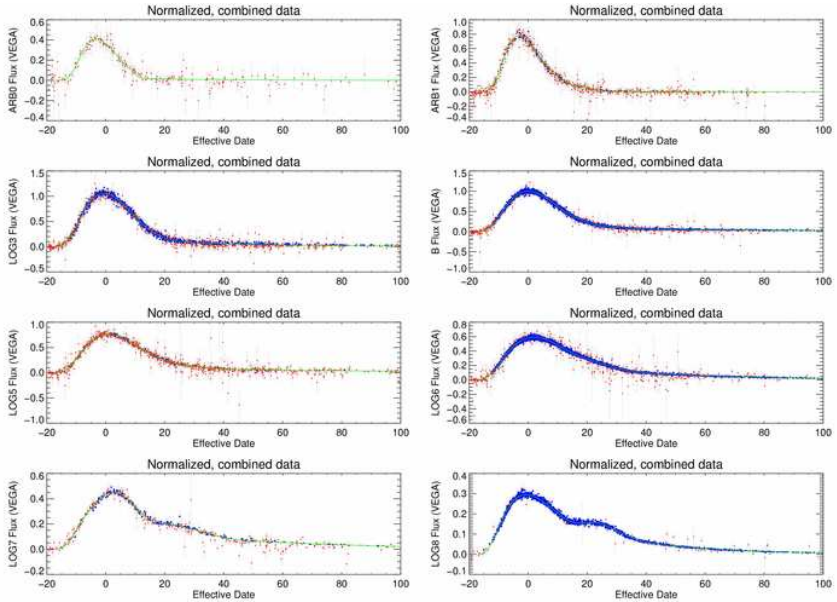




SIFTO
Canadian SALT

Objects

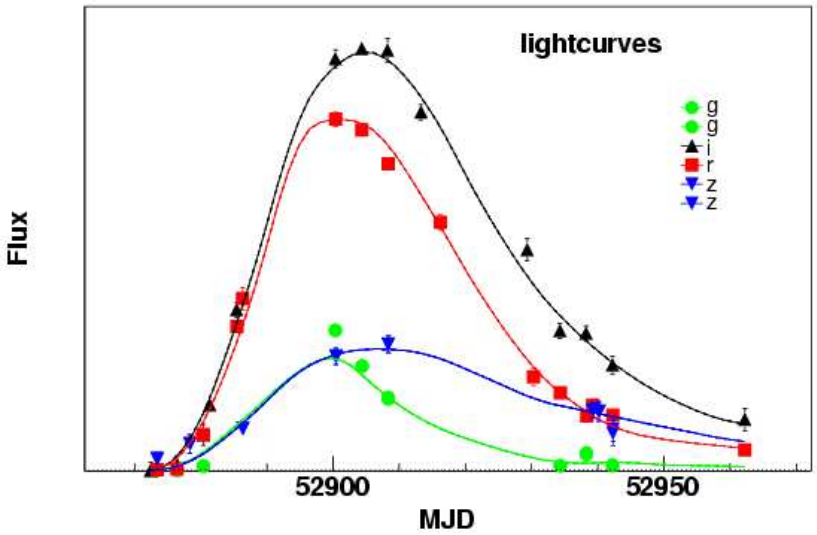
- Spectral sequence of (Hsiao et al, 2007)
- Lightcurve templates with dense filter set
- Trained w/ SNLS and Nearby SN photometry



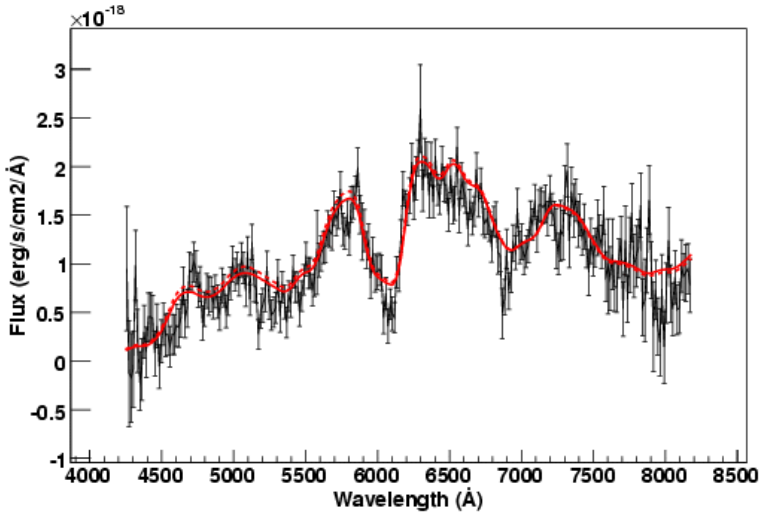
SALT2 and SN Ia Identification

Combined fit of Lightcurves and Spectra

03D4dy at $z = 0.604$



Lightcurve fit (SALT2)



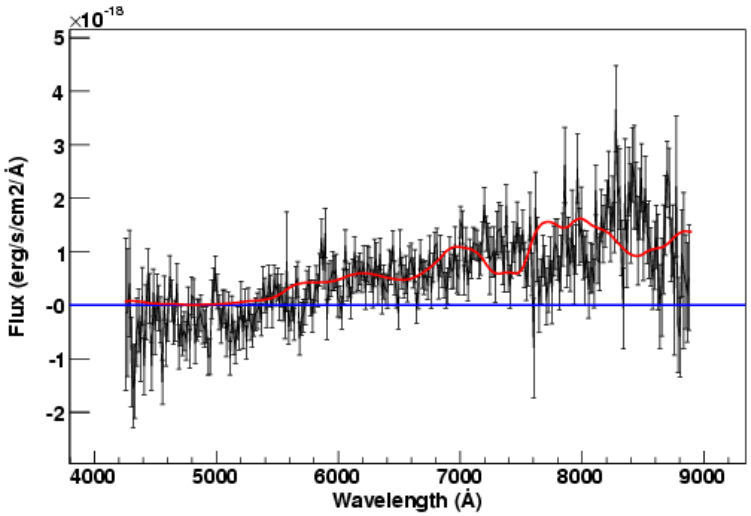
Spectrum fit (same model)

(Balland, Baumont, in prep).

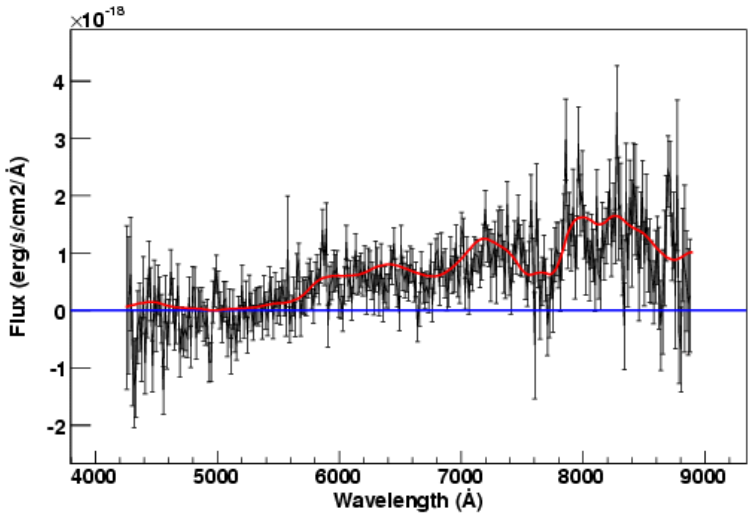
SALT2 and SN Ia Identification

Combined fit of Lightcurves and Spectra

04D4dw



04D4dw at $z = 0.96$



04D4dw at $z = 1.03$

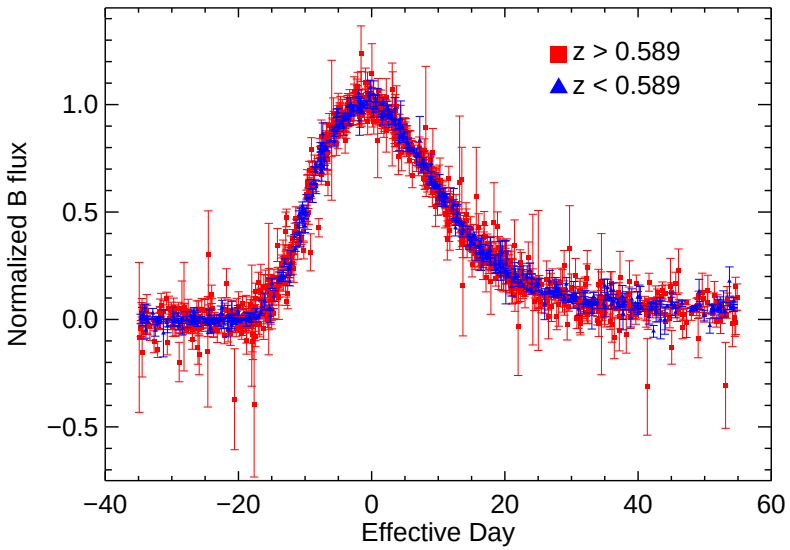
(Balland, Baumont, in prep).

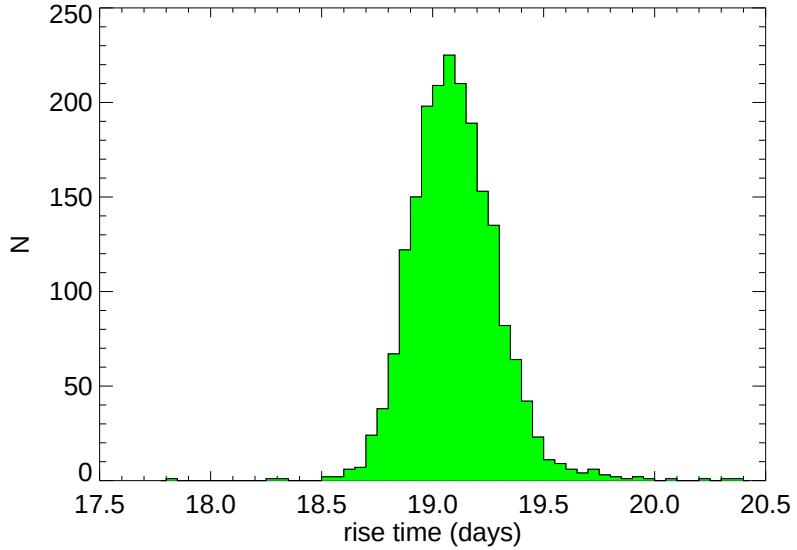
SN Ia Lightcurve Rise Time

Conley et al, 2006

SN Ia evolution check

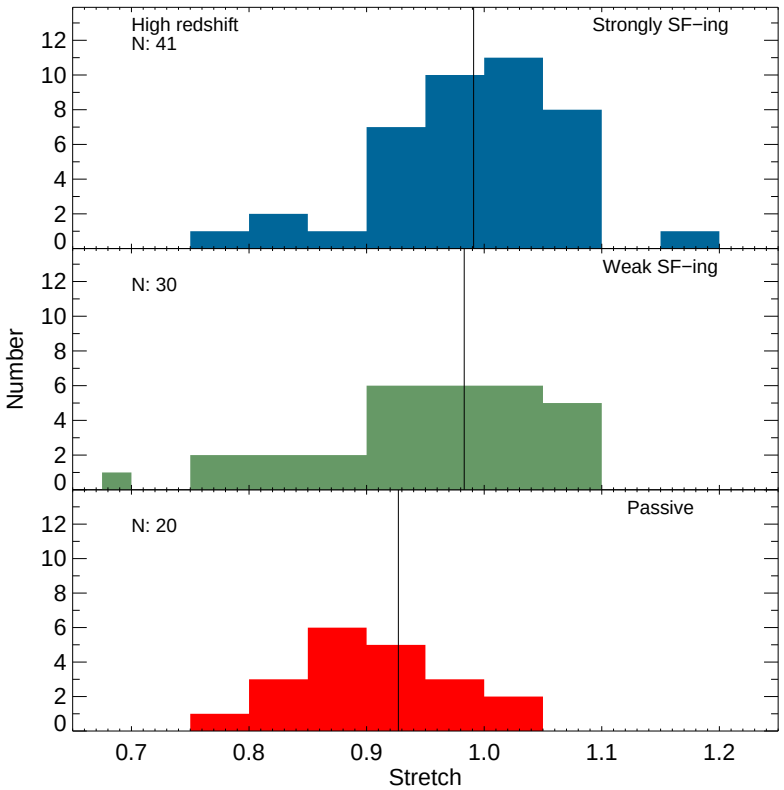
- Compare nearby and distant SN early lightcurve shape (B-band)
  - nearby: 19.58 ± 0.2
  - distant: $19.10 \pm 0.2(stat) \pm 0.2(sys)$





SN Ia Properties and Host Galaxies

Sullivan, LeBorgne et al, 2006



SNe exploding in a high SFR environment

- display a larger stretch (and are brighter)

$\Rightarrow$ younger progenitors produce brighter SNe Ia ?

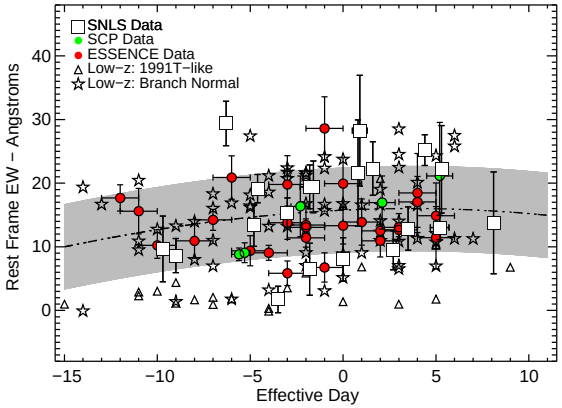
no impact on the distance measurement for the 1 year sample

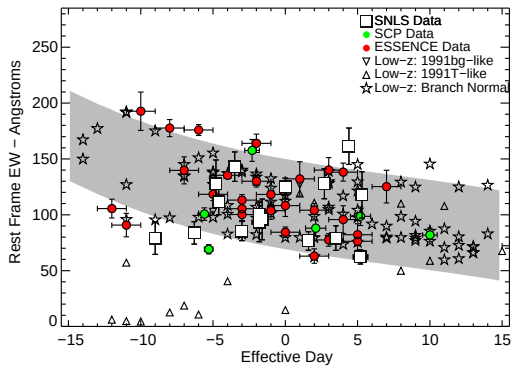
Spectroscopic Measurements

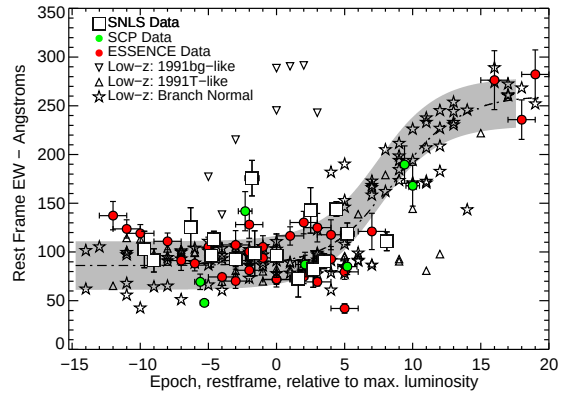
Bronder et al, ApJ accepted

SN Ia evolution check (relying on spectroscopic measurements)

- No systematic offset
- Dispersion increases with z: likely to be S/N







Identified Sources of Systematics

- Photometric calibration & modeling of the passbands
- Empirical modeling of lightcurves
  - restframe region used: $(B, V)) \rightarrow (U*, B)$ at large z
  - modeling of the SED in the far-UV is crucial for $z > 0.8$
- Detection biases
  - simulation of the detection pipeline
- Contamination
- Evolution effects
  - study of SN Ia properties as a function of Host Galaxy
  - comparison of nearby and distant SNe Ia
- Extinction by intergalactic dust
- Gravitational lensing

Systematics

Evolution

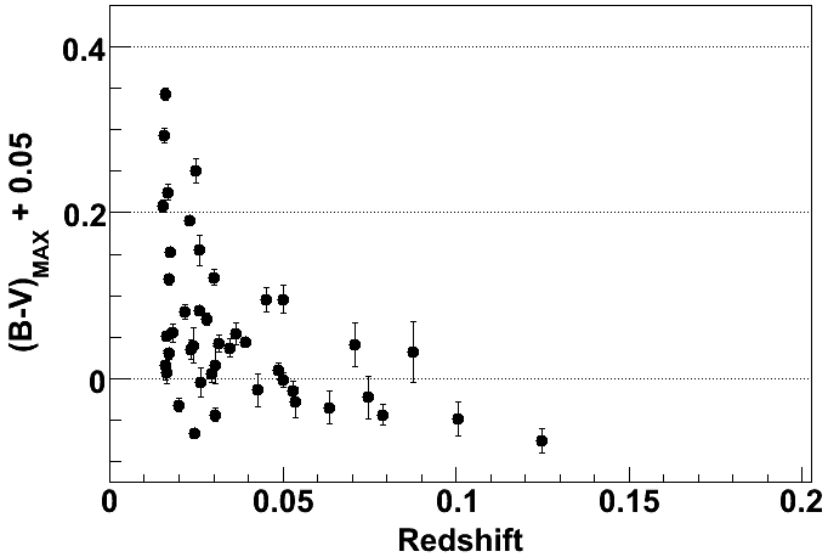
- We should see its effects when looking at the properties of SNe as a function of their host type (Sullivan et al.)
- Fit as many Hubble diagrams as there are types of galaxies
- Degrades statistical uncertainties

Two major sources of systematic uncertainties today

- Flux calibration: how to convert mags into fluxes ?
- The nearby SN sample

Nearby Supernova Sample

- Only ~ 40 SNe with good lightcurve coverage at $z \sim 0,05$
- Evidences for systematic calibration errors in the U-band
- Selection bias of the nearby sample ?

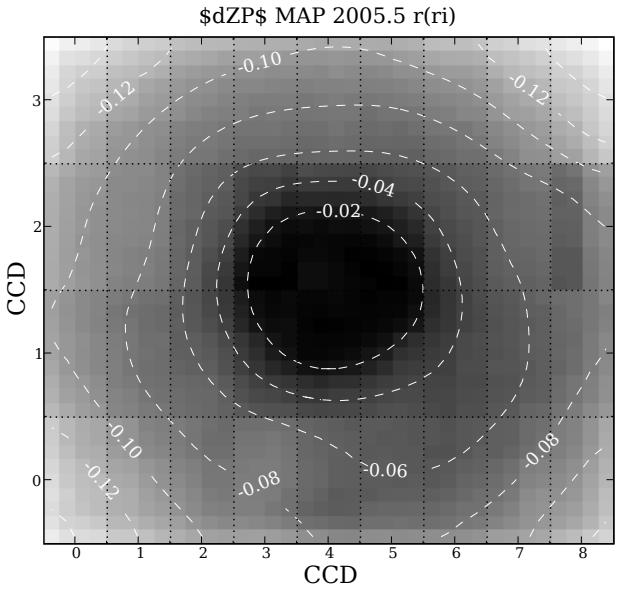


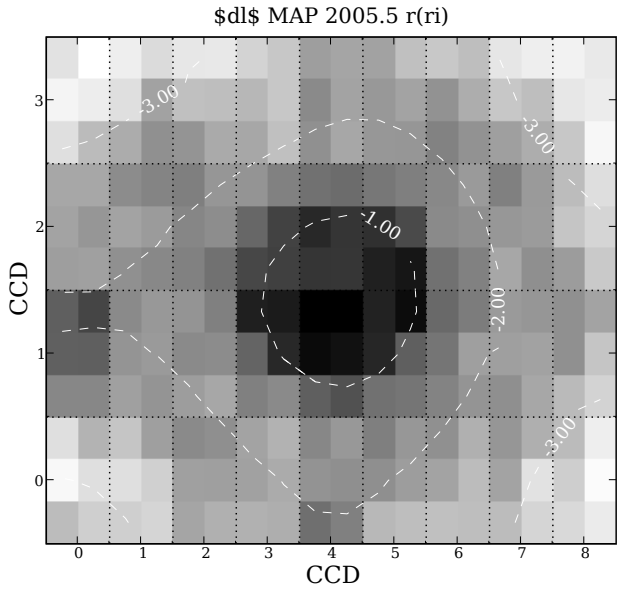
Is there a Hubble Bubble ?

- (Jha et al, 2007) says $H_0(cz < 7400\ \mathrm{km/s}) < H_0(\text{homogeneous universe})$
- Local void in the mass density distribution
- (Conley et al, 2007), (Wang et al, 2007) show it is an artifact of the extinction corrections

Photometric Calibration (I)

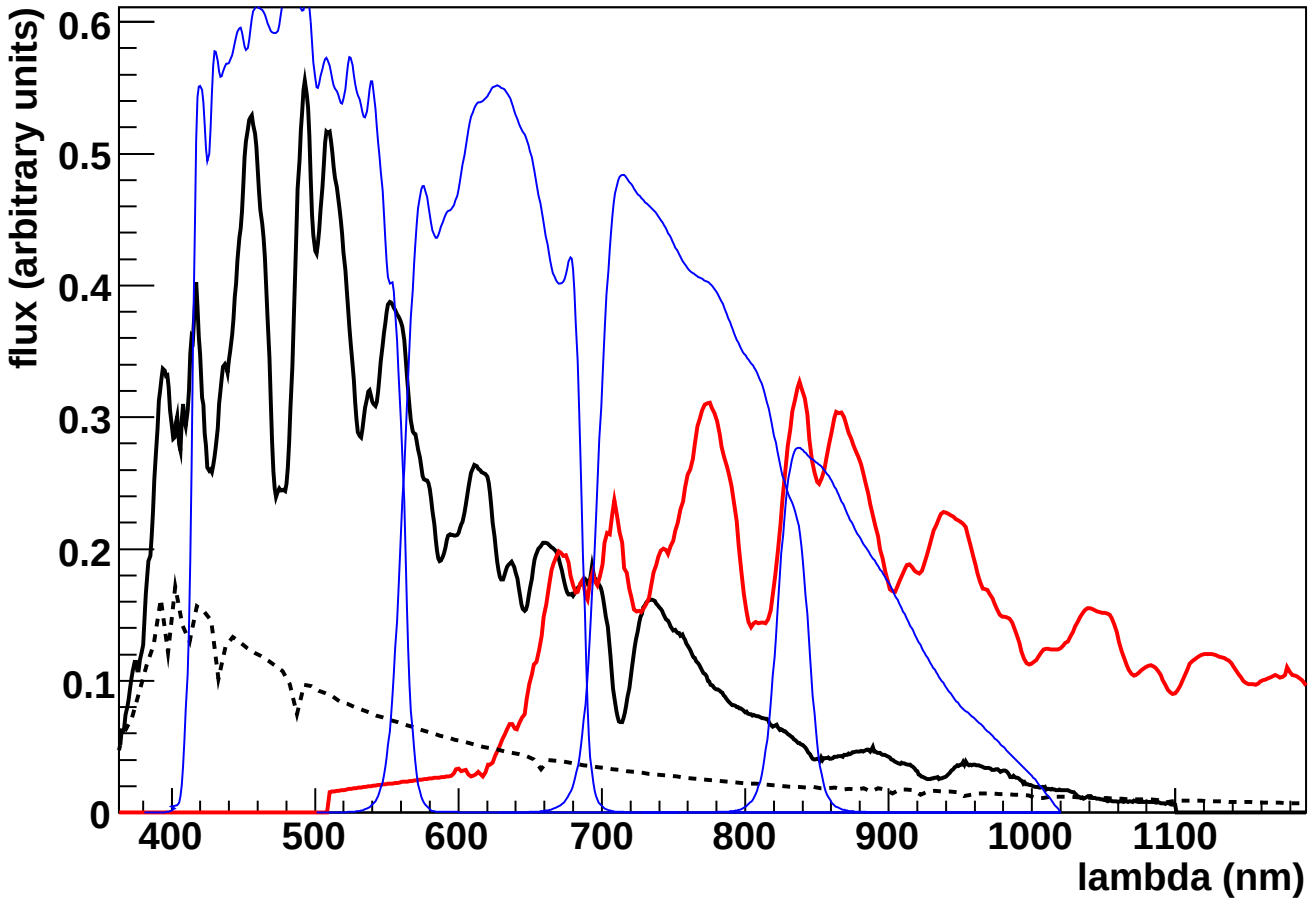
Instrument uniformity





Photometric Calibration (II)

Passband Intercalibration



Conclusion

SNLS is doing well

- $\sim$ 300 identified SNe Ia on disk
- $\sim$ 500 identified SNe Ia at the end of the survey (mid-2008)
  - impact of wheather on data taking (!)

Close to a 3-year Cosmology Analysis

- We have learned a lot during the last 3 years
  - SN modeling (UV), SN properties versus host
  - Large effort on calibration
- Statistical uncertainties improved by a factor $\sim$ 2
- Close to the systematics limit
- Data quality allow us to improve on systematics