Recent results in the Supernova Legacy Survey
SNLS

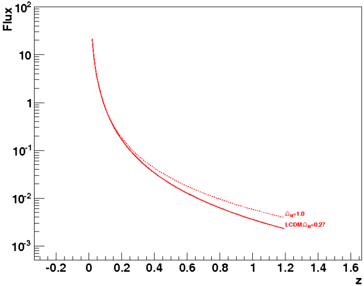
Patrick El-Hage

May 21, 2014

The Hubble Diagram

In a flat universe with constant equations of state, and a constant luminosity L for all objects considered :

$$F = \frac{L}{4\pi d_L^2}$$



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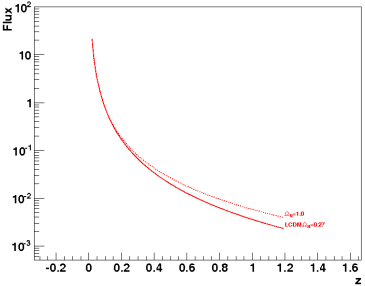

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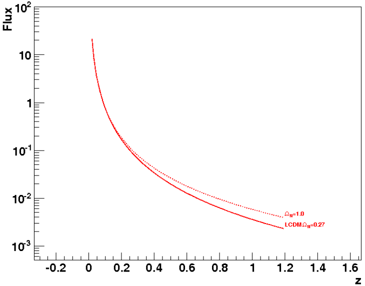

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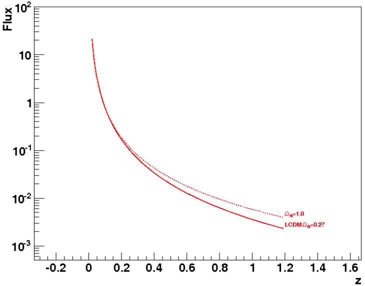
$$\mu = 5 \times log_{10}(d_L) - 5 \times log_{10}(H_0/c)$$



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- In practice use distance modulus μ.

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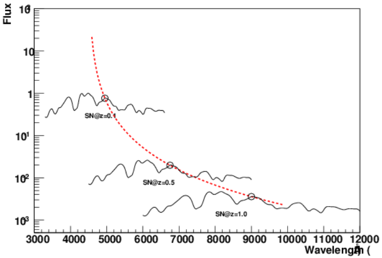

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- For μ to be meaningful, we need L to be constant.
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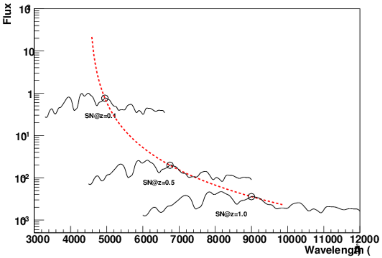
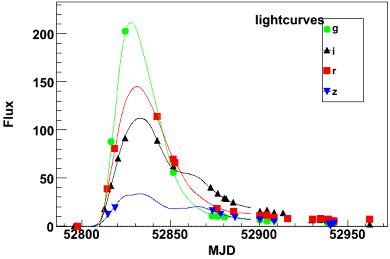
- The solution is to construct lightcurves in different wavelength bands and fit a model to it that spans both color and time.





$$\mu_B = m_B^\star - \mathcal{M}_B + \alpha \times stretch - \beta \times color$$

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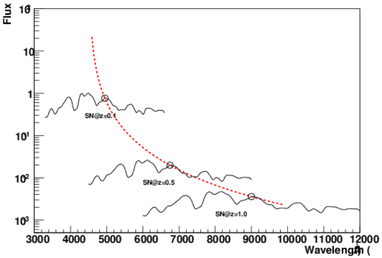

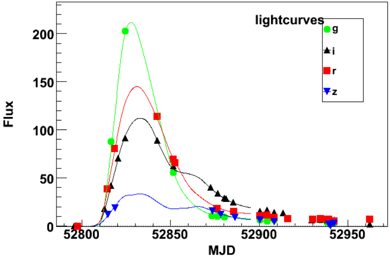

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Such a model allows for standardization corrections (i.e. implementing magnitude corrections based on color and stretch).

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- Begin with naive estimator.

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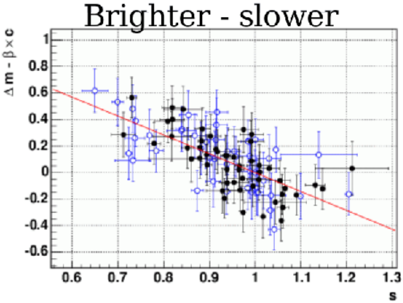

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- Begin with naive estimator.
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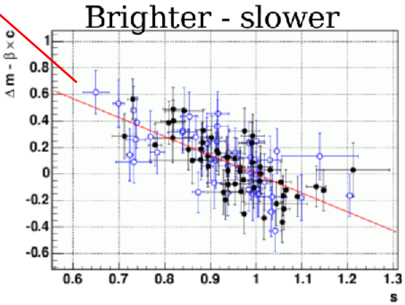

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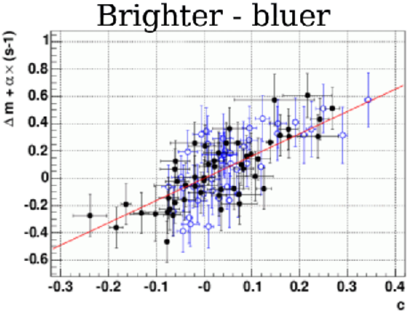
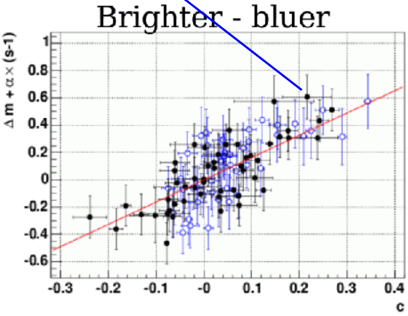
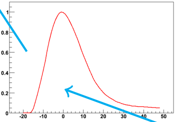
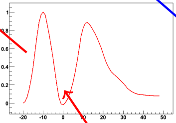


$$\mu_B = m_B^\star - \mathcal{M}_B + \alpha \times \textit{stretch} - \beta \times \textit{color}$$

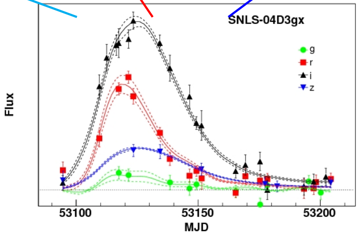
- Begin with naive estimator.
- Add correction based on observed correlation of stretch and magnitude.
- Similarly for color.



$$\mu_B = m_B^\star - \mathcal{M}_B + \alpha \times stretch - \beta \times color$$

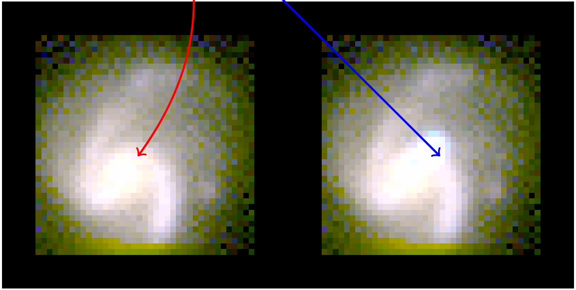
$F = x_0 \times [$  $+ x_1 \times$  $] \times e^{c \times CL(\lambda)}$

- Throughout the event luminosity is measured in different wavelengths ⇒ *Light Curves*.
- Properties extracted by fitting to a model: *SALT2*.
- Apart from apparent magnitude, the fit also tells determines other properties: color & stretch.



A review of the steps

1. Look for the Supernova.



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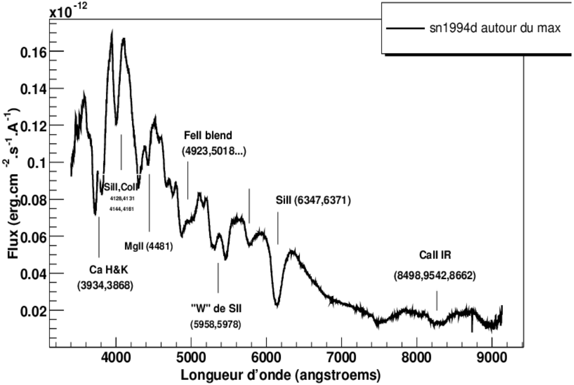
1. Look for the Supernova.
2. Get a spectrum for identification and redshift.



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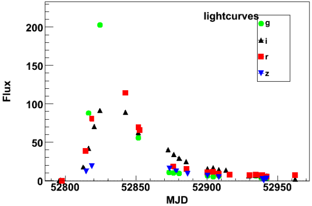

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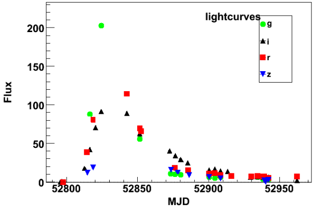

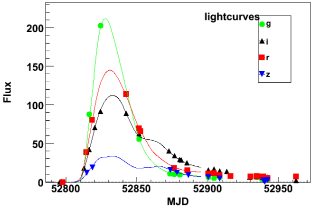

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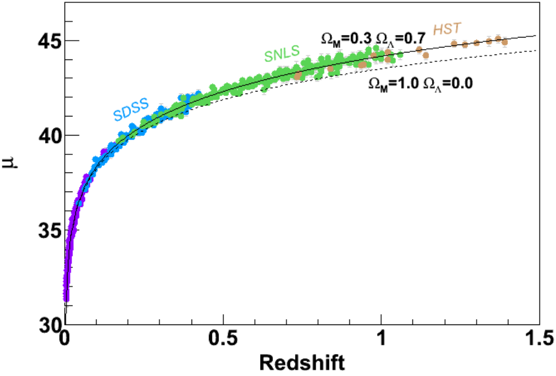
A review of the steps

1. Look for the Supernova.
2. Get a spectrum for identification and redshift.
3. Compute lightcurve.
4. Fit lightcurve model.
5. Construct Hubble diagram.



The SNLS/SDSS JLA working group

Formed to address the issue of measurement systematics

- Transverse working group joining the two main SNe-Ia surveys
- Started in June 2010
- Share data, code and expertise

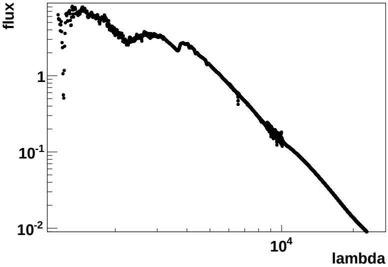
2 main outcomes:

- SNe light curve model: Kessler et al. (2013), Mosher et al. (2014)
  → Validation of the SALT2 model
- Joint photometric calibration analysis: Betoule et al. (2013)
  → Recalibration of the SNLS and SDSS

Calibration

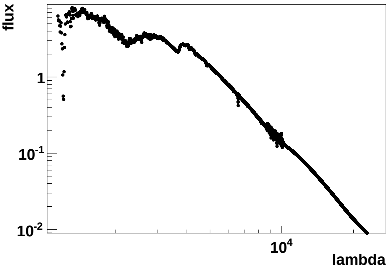
Calibration

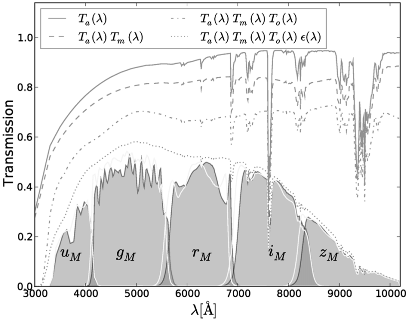
- Consider an object of spectrum : $\phi(\lambda)$



Calibration

- Consider an object of spectrum : $\phi(\lambda)$
- Need to consider the instrumental response : $T(\lambda)$





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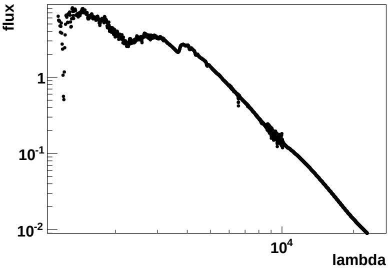

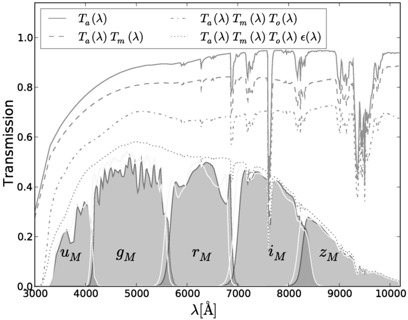

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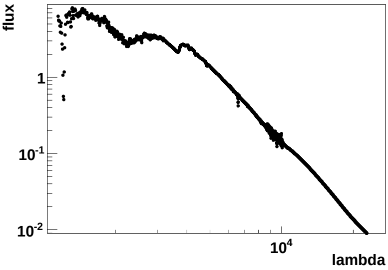
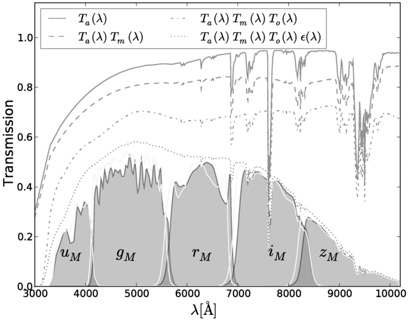
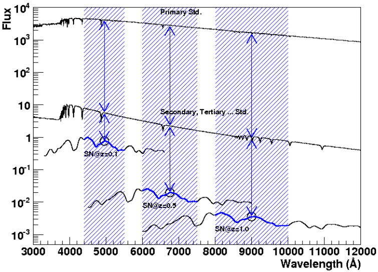
- Need to consider the instrumental response : $T(\lambda)$
- The electrons collected in the CCD are the integrated luminosity of the object in a given band : $\int \phi(\lambda) T(\lambda) \lambda d\lambda$
- To calibrate it, we must compare it to the flux of a known object in the same photometric conditions :

$$\frac{\int \phi(\lambda) T(\lambda) \lambda d\lambda}{\int \phi_S(\lambda) T(\lambda) \lambda d\lambda}$$

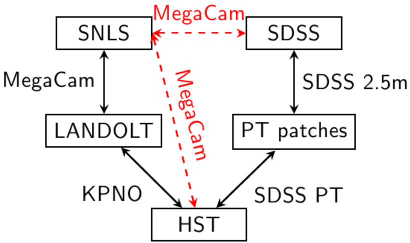


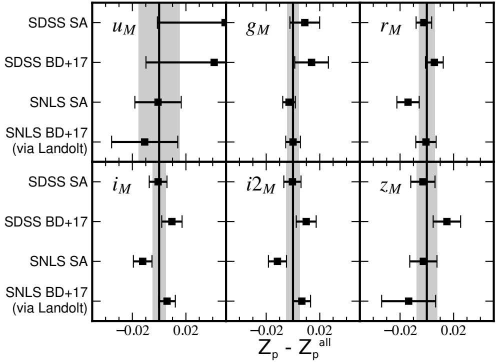




How to reach ∼ 0.5% accuracy in absolute calibration :

Short and redundant paths for calibration transfer





New data

- Direct observation of HST stars
- Direct SNLS/SDSS cross-calibration

Enable:

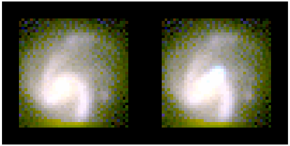
- Comparison of several paths
- 0.3% accuracy in *gri*

Final uncertainty dominated by HST calibration

See Betoule et al. 2013 for more details.

Photometry Improvements

- New PSF photometry algorithm without image resampling.



$$M_{i,p} = \{[f_i \times \phi_{ref}(\vec{x}_p - \vec{x}_{SN}) + gal_{ref}] \otimes K_i\}_p + s_i$$

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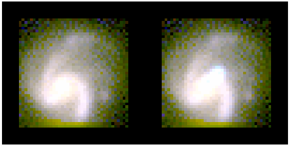
- Simulations guarantee linearity to $(1.34 \pm 2.72) \times 10^{-4}$



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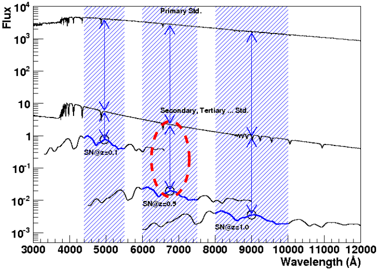

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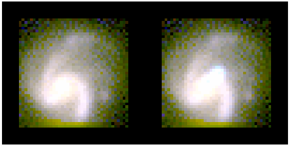
- Largest systematic from zero point computation is 1.3×10^{-4}



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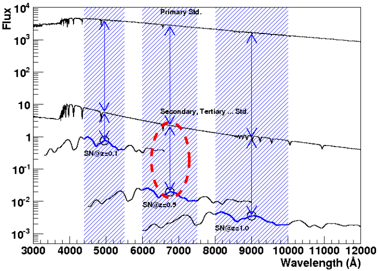

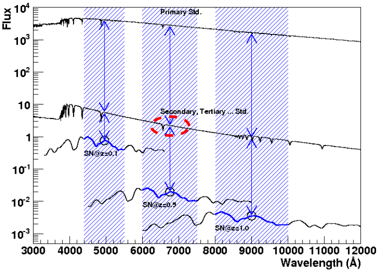

SALT2 Improvements

- Larger data set.

Table: Expanding the training sample.

	JLA	SNLS 5
Lightcurves	221	~ 800
Spectra	482	~ 4000

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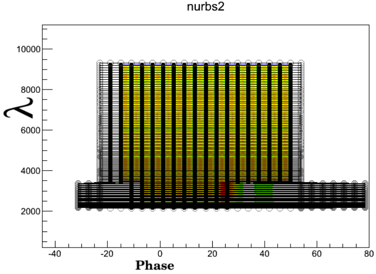
- Exploit larger data set to replace regularization with adapted mesh.



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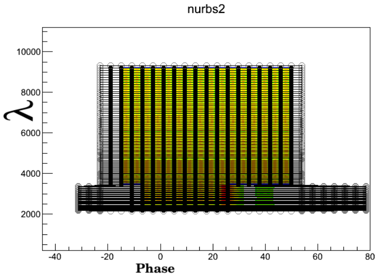
SALT2 Improvements

- Larger data set.
- Exploit larger data set to replace regularization with adapted mesh.
- End-to-end test of the SALT2 method (Mosher et al. 2014.).



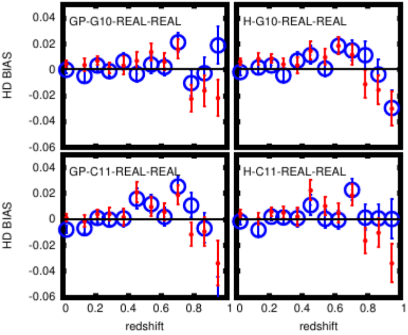


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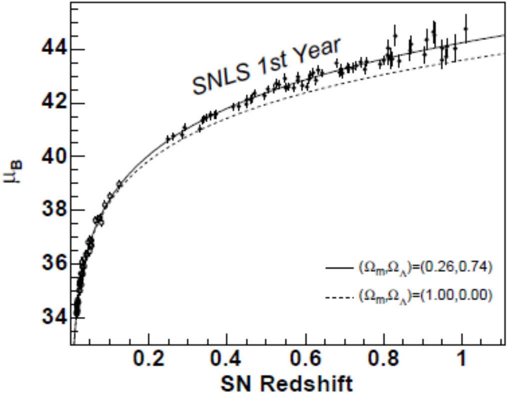
Table: Evolution of the cosmology sample.

	SNLS 1	SNLS 3	JLA	SNLS5
Low z	44			
SDSS	0			
SNLS	73			
HST	0			



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	SNLS 1	SNLS 3	JLA	SNLS5
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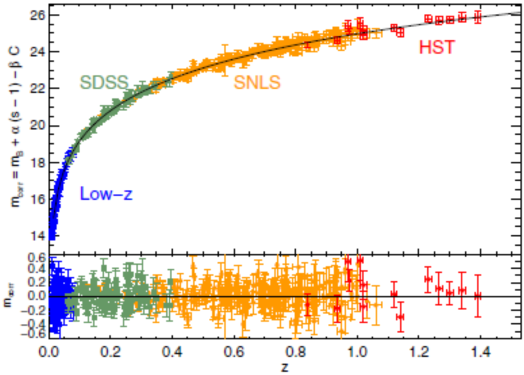
SNLS 1

- Motley crew of low redshift SN.
- Analysis of first year SNLS data.
- With BAO prior we get $w = -1.023 \pm 0.087$

Table: Evolution of the cosmology sample.

	SNLS 1	SNLS 3	JLA	SNLS5
Low z	44	123		
SDSS	0	101		
SNLS	73	231		
HST	0	14		



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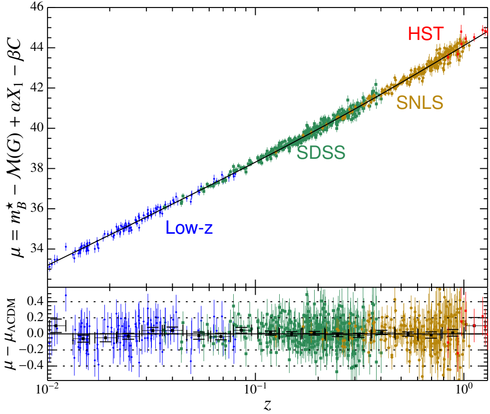
	SNLS 1	SNLS 3	JLA	SNLS5
Low z	44	123		
SDSS	0	101		
SNLS	73	231		
HST	0	14		

SNLS 3

- Bigger SNLS sample.
- Add low redshift surveys.
- Add first SDSS data release.
- With WMAP and BAO prior we get $w = -1.069 \pm 0.7$

Table: Evolution of the cosmology sample.

	SNLS 1	SNLS 3	JLA	SNLS5
Low z	44	123	118	
SDSS	0	101	374	
SNLS	73	231	239	
HST	0	14	9	



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SDSS	0	101	374	
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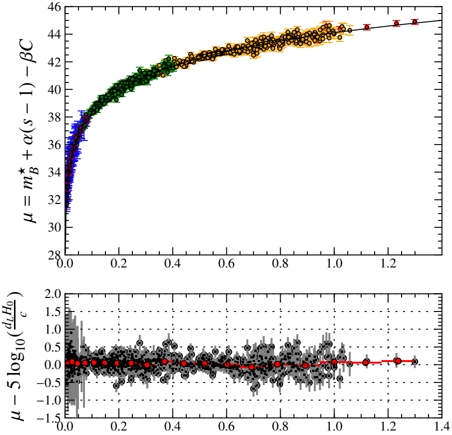
JLA

- New calibration.
- Better understanding of systematics.
- With Planck and BAO prior we get $w = -1.027 \pm 0.55$

Table: Evolution of the cosmology sample.

	SNLS 1	SNLS 3	JLA	SNLS5
Low z	44	123	118	~ 210
SDSS	0	101	374	~ 380
SNLS	73	231	239	~ 400
HST	0	14	9	~ 10



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	SNLS 1	SNLS 3	JLA	SNLS5
Low z	44	123	118	$\sim$ 210
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HST	0	14	9	$\sim$ 10

SNLS 5

- In progress.
- New data alone shaves off $\sim$ 0.5%.
- New training and other improvements could remove another $\sim$ 0.5%.
- No preliminary value on w because analysis is blind.

Current state

- Currently, blind cosmology analysis of full data set underway.
- New training of SALT 2 model.
- Still providing the best measurement of w to date.

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Outlook

- New probes are maturing and giving ever more precise constraints on w. BAO look very promising.
- For SN to remain competitive in 2 generations we need to go to higher redshifts.
- Need space based observations to observe high redshift SN in IR.