The SuperNova Legacy Survey: cosmological results from the first year data set

D. Fouchez

THE SUPERNOVA LEGACY SURVEY : COSMOLOGICAL RESULTS FROM THE FIRST YEAR

D. FOUCHEZ, on behalf of the SNLS collaboration
Centre de Physique des Particules de Marseille, IN2P3-CNRS et Université de la Méditerranée , 13288 Marseille cedex 09, France

The first cosmological results from the SuperNova Legacy Survey are presented. The recipe to obtain the deep, homogenous and complete set of 71 identified type Ia supernovae is described. The construction of the Hubble diagram is supported by precise distance measurement. The steps to obtain this distance are good differential photometry, precise calibration and light-curve modelling. All steps are detailled to present the Hubble diagram. Finally the cosmological parameters are fitted from this diagram. A full error estimation (statistical and systematical) is presented.

1 Introduction

We present the first determination of cosmological parameters performed by the SuperNova Legacy Survey (SNLS) collaboration after analysing the observations of the first year. A large part of the information given in this proceeding has been exposed with more details in the Astier *et al* [1] collaboration paper. The general method used in the past [2 3 4] to derive cosmological parameters from type Ia supernovae (SNIa) using Hubble diagram is supposed known.

2 A deep homogenous and complete set if identified type Ia supernovae

2.1 The observatory facilities

The Supernovae Legacy Survey is based on an imaging survey for the photometric detection and light-curve follow-up in conjunction with a spectroscopic program for the supernova type identification and redshift determination.

The imaging take advantage of the Megacam camera mounted on the 3.6 meter CFHT telescope located in Hawaii which offer a wide field of view of $1^{\circ 2}$. The spectrocopy is done on two main telescopes : The 10-meter VLT and the 8-meter Gemini, plus additional time from the 10-meter KECK.

For the first three year of the SNLS program, about 250 hours per year have been dedicated to the imaging to follow four different fields (as part of the deep survey of the CFHTLS program) and 250 hours per year for the spectroscopy.

2.2 The detection and identification

The detection and follow up of supernovae is performed in the so-called rolling mode search : during each observational period of Megacam at CFHT (around 20 days every month), the same field is observed every 4 days with 4 different filters . Reference images (without supernovae) are built from older nights, then detection and follow-up is automatically performed with those repeated observations.

Due to the rather fast rising of supernova light-curves, a fast detection procedure has to be set up in order to find quickly the supernova candidates we want to observe spectroscopically around their maximum luminosity. Two different pipeline have been designed to do this job, one which is triggered by human scanning, the other which automatically produce a list of candidate by analysing the detection shape and using appropriate selection on light-curve parameters. Both pipeline agree to more than 90% for magnitude above 24.0

When the candidate is choosen, it is observed spectroscopically with a delay that can be as short as 24 hours.

2.3 The current supernova sample

As in March 2006, 440 spectra of candidates have been observed. Among them 231 have been identified as type Ia supernovae.

This is the largest deep and homogenous set of type Ia light-curve sample ever observed. We will develop in the following sections the measurement of the cosmological parameters from the first year of this sample but it is important to mention here that many other scientific studies can be pursued. For example and non exhaustively : Supernova rates [6], supernova rise time, cosmic star formation history [5], progenitors, host galaxies etc

3 Precise measurement of the SNia sample

Only the first year of data has been released and will be presented here. The sample consist of 73 SNIa events. The initial set was 91 SNIa, but 10 where not analysed at the time of the publication due to missing reference images, 6 have only one band and 2 were classified as peculiar.

3.1 Differential photometry

The fluxes are measured using differential photometry [8]: For a given filter, the fluxes of the supernova is extracted from each image with a fit. As a first step, the PSF on each position of each image is described with a kernel [7]. The parameters of the model are the galaxy on a stamp, the position on the sky and the supernova flux on each image. Eq. 1 give the flux ($I(x,y)$), at the pixel level, that has to be adjusted on each image.

$$I(x,y) = Flux \times [Kernel \otimes PSF_{best}](x - x_{sn}, y - y_{sn}) + [Kernel \otimes Galaxy_{best}](x,y) + Sky \quad (1)$$

It result from this fitting procedure a flux measurement image per image with the covariance matrix associated. The errors are found to be about 12% higher that the photon statistics.

3.2 Photometric calibration

First of all, the same differential technique dicussed above is used to measure tertiary standard stars in each field. Then those tertiary stars are measured in same photometric night than some Landolt secondary stars. Using both information, a zero point that can be directly applied to the supernova flux measurement, is derived. The calibration residual found after this procedure are of the order of 1 to 3 %. The primary star is Vega.

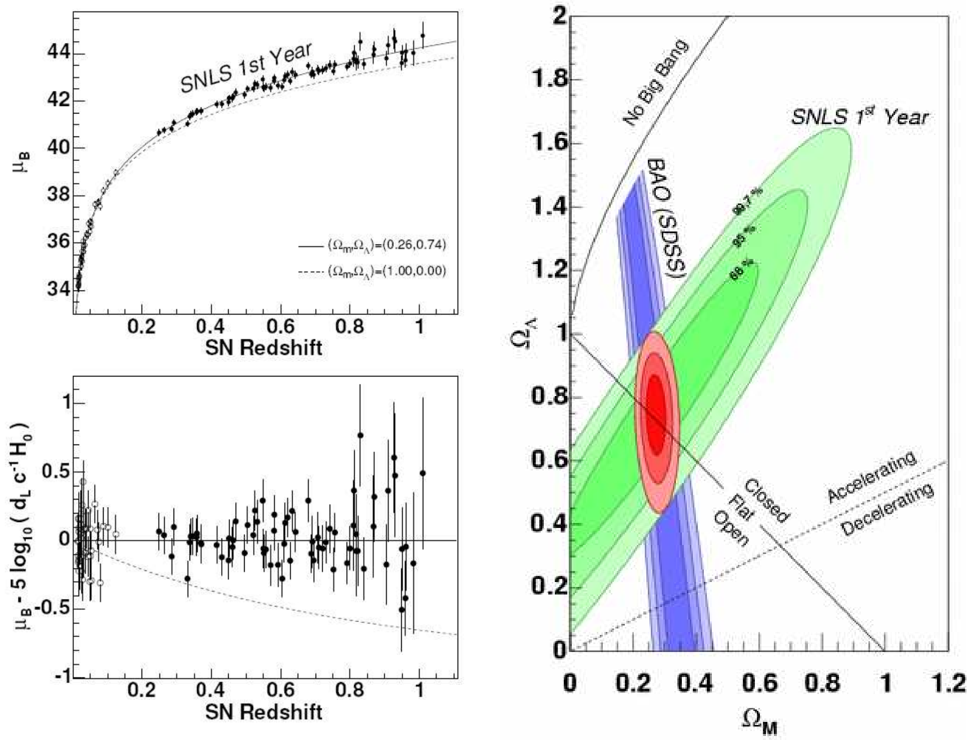

Figure 1: The Hubble diagram of 71 SNLS supernovae plus 44 nearby SNIa (Left) , Confidence level contour for the fit to Ω_M, Ω_Λ in *Lambda* cosmology from the SNIa Hubble diagram (light green) and from the SDSS baryonic oscillations (dark blue) with the combined contour at the intersection (Right).

4 Hubble Diagram and cosmology

4.1 Light-curve modelling and luminosity distance

The light-curves of the four bandpasses are fitted together using the SALT [9] procedure. Two parameters describe the variability of the SNIa light-curve, but the luminosity at maximum : s, the stretch parameter and c the color term. Those two parameters are used to correct for the 'brighter-slower' and 'brighter-bluer' behaviour. Using those two corrections, the SNIa can be standardized [9] and the distance is then derived from the magnitude at maximum in B rest frame , the stretch and the color (see Eq. 2)

$$\mu_B = m_B^* - M + \alpha(s-1) - \beta c \tag{2}$$

4.2 Cosmological fit results

The Hubble diagram is presented in in Fig 1 (left). It uses the SNLS SNIa plus a sample of nearby SNIa that are reanalysed using the same procedure as the SNLS ones. The distance is the one describe in previous section and the redshift is the one determined from the spectroscopic observation of the supernova and/or its host galaxy. The distance is a function of the cosmological parameters which can then be fitted from the Hubble diagram data points. The comological parameters are fitted together with the α and β coefficients on all the light-curves. The cosmological parameter confidence level contours are presented in Fig 1 (right) for a *Lambda* cosmology.

Table 1: the systematic uncertainties

Source	$\delta\Omega_M$ (flat)	$\delta\Omega_tot$	δw (fixed $\delta\Omega_M$)	$\delta\Omega_M$ (with	δw BAO)
Zero points	0.024	0.51	0.05	0.004	0.040
Vega spectrum	0.012	0.02	0.03	0.003	0.024
Filter bandpasses	0.007	0.01	0.02	0.002	0.013
Malmquist bias	0.016	0.22	0.03	0.004	0.025
Sum (syst)	0.032	0.55	0.07	0.007	0.054
U-B color (stat)	0.02	0.12	0.05	0.004	0.024

4.3 Systematic uncertainties

For a more exhautive presentation of systematic uncertainties, check out Astier *et al*[1]. We present here the more representative ones.

From the result of the calibration procedure describe in previous section, a 1% to 3% uncertainty has been found and is accounted to a possible systematic effect in the zero point determination.

A comparison of the characteristics of the low and high z sample didn't show any hint of evolution hence no sytematical effects from evolution have been applied.

The Malquist bias resulting from the selection of the brightest objects at the high z limit of the survey, has been estimated, from Monte Carlo simultions, to change by 0.05 magnitude the highest point of the Hubble diagram

A summary of all the systematic uncertainties, expressed in term of errors on the cosmological parameters is presented on Table 1

Finally, the results on the comological parameters are:
$\Omega_M = 0.263 \pm 0.042(stat) \pm 0.032(syst)$ for a flat cosmology
and
$\Omega_M = 0.271 \pm 0.021(stat) \pm 0.007(syst)$
$w = -1.02 \pm 0.09(stat) \pm 0.054(syst)$ for a flat cosmology with constant equation of state and combined with the BAO SDSS results[10].

Statistical error is still dominant but we are reaching soon the systematic limit, that has to be reduced to take full advantage of the coming 700 SNIa expected at the end of the survey.

References

1. The Supernova Legacy Survey : Measurement of Ω_M, Ω_Λ and w from the first year dataset, Astier *et al* *A&A* **447**, 31 (2006).
2. Riess, A. G. *et al*, AJ 116 (1998), 1009
3. Perlmutter,S *et al*
4. Riess, A. G. *et al*, ApJ 607 (2004), 665
5. M. Sullivan *et al.*, arXiv:astro-ph/0605455.
6. J. D. Neill *et al.*, arXiv:astro-ph/0605148.
7. Alard, C. A& A 144 (2000), 363
8. Fabbro, S., Photométrie de supernovae de type Ia et implication cosmologiques (2001), PhD Thesis, Université Paris VI
9. J. Guy, P. Astier, S. Nobili, N. Regnault and R. Pain, arXiv:astro-ph/0506583.
10. D. J. Eisenstein *et al.*, Astrophys. J. **633**, 560 (2005)