RevMexAA (Serie de Conferencias), **35**, 219–220 (2009)

THE LOW-REDSHIFT CARNEGIE SUPERNOVA PROJECT

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RESUMEN

Presentamos el proyecto CSP (Carnegie Supernova Project) de bajo corrimiento al rojo, un programa para el seguimiento de unas 250 supernovas (SNs) cercanas de todos los tipos. Describimos brevemente las observaciones que dan lugar a curvas de luz ópticas y del infrarrojo cercano de excelente muestreo y alta precisión, en un sistema fotométrico bien definido, y complementadas con espectroscopía óptica. Como uno de los principales objetivos del proyecto, mostramos aquí el primer diagrama de Hubble preliminar hecho con una muestra de 30 SNs de tipo Ia.

ABSTRACT

We present the low-redshift Carnegie Supernova Project (CSP), an undergoing program to follow up about 250 nearby supernovae (SNe) of all types. We briefly describe the observations which yield well-sampled, highly precise optical and near-infrared light curves in a well-understood photometric system, complemented with optical spectroscopy. As one of the main goals of the CSP, we preliminarily present the first Hubble diagram using a sample of 30 Type-Ia SNe (SNe Ia).

Key Words: sosmology — galaxies: general — supernovae: general

1. WHY OBSERVING NEARBY SUPERNOVAE?

We live an exciting era for cosmology since SN measurements led to the conclusion that the expansion of the universe is accelerating, driven by a dominant form of energy of unknown origin, the "dark energy" (Riess et al. 1998; Perlmutter et al. 1999).

Several ongoing and future projects aim at filling the Hubble diagram with high-redshift ($z > 0.1$) SNe Ia in order to determine the nature of dark energy by measuring its equation of state parameter $w = P/\rho$. However, the precision required to distinguish among the various proposed models can only be attained by comparing with an equally high-quality sample of low-redshift SNe.

The CSP comes to play a crucial role in this game by introducing a homogeneous sample of well-observed SNe in the local universe. During five years (2004–2009), the CSP will follow up about 250 nearby ($z < 0.08$) SNe of all types with optical and near-infrared (NIR) photometry, and optical spectroscopy. Such a remarkable set of data will allow us to improve methods of distance estimation and address existing concerns about systematic errors that may arise from poorly measured extinction in the host galaxies or possible evolutionary effects due to differing ages and/or metallicities. In addition, by studying all types of SNe, we will have access to independent methods for measuring distances, and we will be able to gain deeper understanding of the physics of these events.

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TABLE 1

NUMBER OF SNE FOLLOWED BY TYPE

No. of SNe	Ia	II	Ib/c	Total
Followed	72	54	16	142
Expected	60	60	15	135

2. OBSERVATIONS AND RESULTS

The CSP uses mainly the facilities of Las Campanas Observatory (LCO), in Chile, and the Swope 1 m telescope as the main workhorse, to observe SNe with Sloan $u'g'r'i'$ and Bessell BV bands in the optical, plus $YJHK$ bands in the NIR. Other telescopes are used to supplement this with spectroscopic follow-up. Details of the observing and data analysis procedures are given in Hamuy et al. (2006).

Table 1 summarizes the amount of SNe followed per type, after the first three years of observations. The numbers are compared to those expected at the start of the project, based on rates of SN discoveries.

In order to obtain high precision light curves, a decisive step of the data processing is the subtraction of the underlying host-galaxy light. This requires observations in all bands done after the SN has become undetectable — typically one year after the explosion. These images are matched and scaled

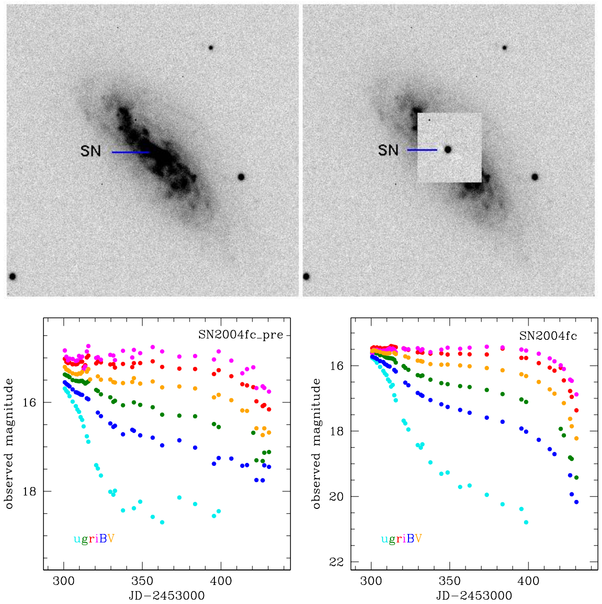

Fig. 1. Example showing the importance of host-galaxy subtractions. *Top left:* A follow-up g'-band image of the Type II-P SN 2004fc. The SN is marked near the galaxy nucleus. *Top right:* The result of the subtraction. The SN is cleanly isolated. *Bottom left:* Preliminary light curves in all optical bands. *Bottom right:* Final light curves, after subtraction. Not only does the precision improve dramatically but also the SN signal as it leaves the pateau phase is recovered.

to each follow-up image before subtraction. Figure 1 shows an example of this procedure which serves to stress its importance, specially in cases when the SN occurs near the nucleus of the host galaxy.

The exceptional set of light curves gathered by the CSP can be viewed at its web site: `http://csp1.lco.cl/~cspuser1/`. Such a complete data set allowed us to identify two peculiar SNe which we studied with the aim of shedding some light on the physics of SNe Ia (see Phillips et al. 2007) and of Type Ib/c SNe and their connection with gamma-ray bursts (see Folatelli et al. 2006).

3. PRELIMINARY HUBBLE DIAGRAM

One of the main goals of the CSP is to build a Hubble diagram –distance versus redshift– with the SNe Ia. The current sample of SNe Ia with definitive data –i.e., after subtraction of the host-galaxy light (see § 2)– amounts to 30 objects. Each SN represents a point in the Hubble diagram.

We obtained the redshifts by measuring Doppler shifts on spectra of the host galaxies, or from catalogued values. We determined distance moduli based on the standard-candle hypothesis. On each band,

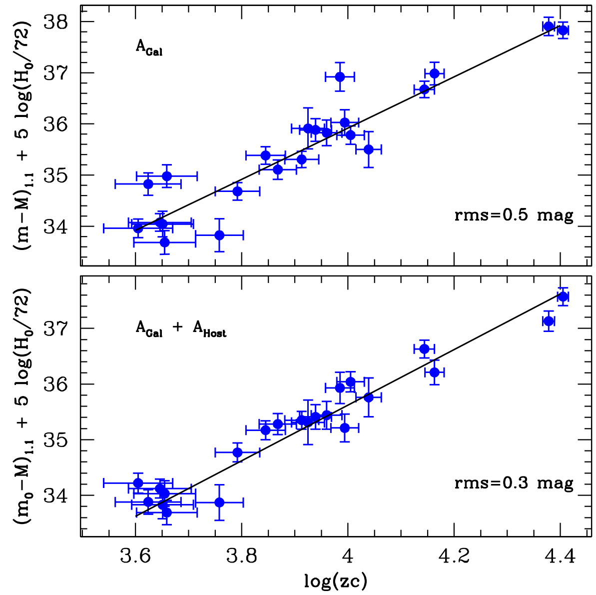

Fig. 2. Hubble diagram in the B band. The absolute magnitude scale was fixed for a value of the Hubble constant of $H_0 = 72\ \mathrm{km\,s^{-1}\,Mpc^{-1}}$, corresponding to the solid line. *Top:* Only K-corrections and Galactic extinction were considered. *Bottom:* The scatter decreased significantly after correcting for extinction in the host galaxies.

we compared the observed magnitude at the time of maximum light with an assumed absolute peak magnitude. We used the well-known fact that peak luminosities of SNe Ia are not equal but can be calibrated with respect to the rate of decline of the light curves (Phillips et al. 1999).

The observed peak magnitudes were corrected to account for the redshift of the SN SED with respect to the observing band using K-corrections. We also corrected for Galactic extinction obtained from Schlegel, Finkbeiner, & Davis (1998). We finally determined extinction in the host galaxy by comparing colors with a subsample of unextincted SNe. Figure 2 shows a preliminary Hubble diagram built using distance moduli computed with B-band magnitudes. A thorough analysis and definitive results can be found in Folatelli et al. (in preparation).

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