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Carnegie Supernova Project: Spectroscopic Observations of Core Collapse Supernovae

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Abstract. The Carnegie Supernova Project (CSP) has performed, during the period 2004-2009, the optical and NIR follow up of 253 supernovae (SNe) of all types. Among those, 124 were core collapse events, comprising 93 SNe of type II and 31 of types Ib/Ic/IIb. Our follow up consisted of photometric observations suitable to build detailed light curves and a considerable amount of optical spectroscopy.
The bulk of our observations is carried out at Las Campanas Observatory, while access to other facilities is also provided thanks to our strong collaboration with the Millennium Center for Supernova Studies (MCSS).
Our spectroscopic observations were primarily aimed at typing possible new SNe, and follow-up the evolution of CSP targets. One of the goals of the follow-up of type II SNe is the application of independent distance indicators such as the Standard Candle (SCM) and the Expanding Photosphere (EPM) methods. Moreover, through the study of the spectroscopic evolution of these objects, from as early as possible after explosion to the nebular phases, we hope to contribute to their further understanding. Specific analysis of particular objects is underway by members of the CSP and an extended collaboration.

Keywords. (stars:) supernovae: general, techniques: spectroscopic

1. Introduction

The CSP (Hamuy *et al.* (2006)) conducted, between 2004 and 2009, 5 campaigns devoted to build detailed optical and NIR light curves of nearby ($z < 0.07$) SNe of all types.

Most of CSP targets came from the SN searches carried out at Lick (LOSS), Chile (CHASE) and those conducted by amateur astronomers such as Tim Puckett, Berto Monard, Tom Boles, Koichi Itagaki and more recently, the BOSS collaboration.

Optical spectroscopy was a key complement of the project. As soon as possible after a new SN was announced, a spectrum was obtained in order to determine its type, phase and redshift. This information was used to decide about which targets would be subject of dedicated follow-up, preference being given to young events, such as type Ia SNe before maximum brightness, and core collapse SNe soon after explosion.

Further spectral observations, in coincidence with the photometric follow up, were obtained as often as possible (always prioritizing the typing of new candidates) in order to study the spectroscopic evolution of CSP targets.

Spectral sequences of Type II SNe allow independent distance determinations via the Expansion Photosphere Method (Kirshner & Kwan (1974), Jones *et al.* (2009)) and the Standard Candle Method (Hamuy & Pinto (2002), Olivares (2008)).

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Multiple epoch spectroscopic observations of stripped core-collapse (Ib/Ic/IIb) SNe, combined with our complete sets of light curves, can be used to get further insight into the physical properties of these rare objects.

2. Observations

Most of the CSP spectroscopic observations have been carried out using the facilities available at LCO, i.e. the du Pont telescope (+WFCCD and Boller and Chivens spectrographs), as well as both Magellan telescopes (+LDSS3, IMACS, and MagE spectrographs).

Additional observations were obtained at CTIO, ESO and Gemini facilities.

Reductions have been carried out through IRAF † routines, usually via a set of specially designed scripts, including wavelength and flux callibration as well as telluric line removal.

Along the 5 CSP campaigns we obtained 770 spectra of 137 core collapse SNe (although not all of them were selected for CSP follow-up).

3. Results, work in prgress and CSP II

Some of the most conspicuous CSP targets have already been analysed in several papers (SN 2005bf: Folatelli *et al.* 2006; SN 2007Y: Stritzinger *et al.* 2009; SN 2009bb: Pignata *et al.* 2011). One of the best observed type IIP SNe ever, SN 2008bk, was the subject of extensive photometric and spectroscopic follow-up by CSP and other groups, from soon after discovery (Morrell & Stritzinger 2008) until well into the nebular phase. Its progenitor has been identified as a red supergiant (Van Dyk *et al.* 2012). Results from more than 3 years of observations by CSP and MCSS will be presented in a forthcoming paper (Pignata *et al.*, in preparation).

Detailed analysis of other CSP targets is underway by members of the CSP and their collaborators. After release, the CSP spectroscopic database will be publicly available at The Online Supernova Spectrum Archive (SUSPECT). Sample light curves can be found at the CSP website: http://csp1.lco.cl/∼cspuser1/PUB/CSP.html

After 2009 we continued to obtain spectroscopic observations aimed at typing SNe candidates and follow-up selected targets in collaboration with MCSS.

In October 2011 we started the first CSP II (Carnegie Supernova Project II) campaign comprising optical and NIR imaging of our targets, as well as optical and NIR spectroscopy. While mostly focused on type Ia SNe, we still need to type new candidates, and we continue to do follow-up of selected SNe of different types.

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