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The Caltech Core-Collapse Project (CCCP)

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Abstract. The cosmological utility of type Ia Supernovae prompted numerous studies of these events, and they are now well characterized observationally, both as individual objects and as a population. In contrast, all other types of supernovae (i.e. core-collapse events) are not as well observationally characterized. While some individual events have been studied in great detail (e.g. SN 1987A or SN 1998bw), the global properties of the core-collapse SN population are little known. However, in recent years, major drivers for change have emerged, among them the verification of the connection between core-collapse supernovae and long-duration Gamma-Ray Bursts (GRBs), the possible utility of some core-collapse supernovae (type II-P) as independent cosmological probes, and studies of core-collapse supernovae as high redshift targets for missions like the Supernova Acceleration Probe and the James Webb Space Telescope. The Caltech Core-Collapse Project is a large observational program using the Hale 200 inch and the robotic 60 inch telescopes at Palomar observatory to obtain optical photometry, spectroscopy and IR photometry of ~ 50 nearby core-collapse supernovae. The program is designed to provide a complete sample of core-collapse events, with well-defined selection criteria and uniform, high-quality optical/IR observations, as well as radio and X-ray light curves for some events. We will use this sample to characterize the little-studied properties of core-collapse supernovae as a population. The sample will be used as a comparison set for studies of supernovae associated with Gamma-Ray Bursts, to promote and calibrate the use of supernovae II-P for cosmography, and to set the stage for investigations of supernovae at high-z using coming space missions such as the Supernova Acceleration Probe and the James Webb Space Telescope.

1. Introduction

For many decades supernovae (SNe) have been a focus of scientific interest, as sources of heavy elements and cosmic rays, a fundamental process shaping gas dynamics in galaxies, and, more recently, as cosmological distance indicators. SN explosions can be roughly divided into two main categories: Type Ia events (SNe Ia) are believed to be thermonuclear explosions of white dwarf stars, while all other SNe result from core-collapse of massive progenitor stars. The great cosmological utility of SNe Ia (e.g., Riess et al. 1998; Perlmutter et al. 1999; Riess et al. 2004) spurred intensive studies of this SN sub-type. Both detailed studies of individual nearby events, and numerous works characterizing the properties of the SN Ia population, have been published. This is not the case, however, for core-collapse SNe. While some individual core-collapse events are very well studied (e.g., SN 1987A) the properties of the population of these events are not well known - e.g., the average peak magnitude and light curve shape, the distribution around this average, the typical spectroscopic properties and their evolution, etc.

Recently, several possible drivers for change have emerged. The connection between hydrogen-deficient core-collapse SNe (SNe Ib/c) and Gamma-Ray Bursts (GRBs; Stanek et al. 2003; Hjorth et al. 2003; Matheson et al. 2003) resulted in great interest in these events. The possible usefulness of hydrogen-rich core-collapse SNe II-P as distance estimators (e.g., Hamuy & Pinto 2002) may offer an independent method to test type Ia cosmology. The need to know the average properties of core-collapse SNe in order to interpret the results from surveys for SNe at high redshift has been demonstrated by several works (e.g., Dahlen & Fransson 1999; Sullivan et al. 2000; Gal-Yam, Maoz and Sharon 2002; Sharon 2004; Dahlen et al. 2004) and will become even more urgent when larger planned surveys with the the Supernova Acceleration Probe and the James Webb Space Telescope are carried out.

2. Project Design and First Results

The Caltech Core-Collapse Project (CCCP) is a large observational program, designed to study a complete sample of nearby core-collapse SNe, using mainly the Hale 200 inch and the robotic 60 inch telescopes at Palomar Observatory. The program will provide high quality optical ($BVRI$) light curves, as well as multiple-epoch spectroscopy and IR photometry, for *all* nearby ($R_{peak} < 18.5$) core-collapse SNe that are visible from Palomar and that have been discovered young (no more than 30 days after explosion). We select young events using available photometry (e.g., SNe discovered on the rise) or recent non-detections (i.e., SNe that are absent from images obtained no more than 30 days prior to discovery). Young SNe are identified as core-collapse events either through prompt spectroscopy obtained by us (e.g., Leonard et al. 2004) or reported by the community, or using photometric typing methods (e.g., Poznanski et al. 2002; Gal-Yam et al. 2004a; Rajala et al. 2004, in preparation). Including only young events in our sample removes strong selection biases for bright or long-lasting events (such as SNe II-P).

The compilation of well sampled optical light curves, as well as multiple epoch spectra and IR photometry, will allow us to fully characterize, observationally, each event in our complete sample, providing a firm foundation for studies of core-collapse SNe as a population. CCCP also provides data for other SN initiatives pursued at Caltech: multiwavelength studies of SNe Ib/c and their possible connections with GRBs (Soderberg, Kulkarni et al.); and testing SNe II-P as cosmological probes in effort to verify SN Ia cosmology (Ellis and collaborators). CCCP will also support other major efforts by the SN community, e.g., the large cycle 13 Hubble Space Telscope program to study SNe Ia in the UV (PI Filippenko), and a similar cycle 1 Galaxy Evolution Explorer program to study core-collapse SNe in the UV (PI Gal-Yam).

The CCCP project officially began on August 2004, and first results are encouraging. The robotic 60 inch telescope delivers accurate, well sampled $BVRI$ light curves (Figure 1), while the first 200 inch runs supplied high quality spectra and NIR photometry (Figure 2). The project is approved to continue through

July 2005.
More details are available at http://www.astro.caltech.edu/∼avishay/cccp.html

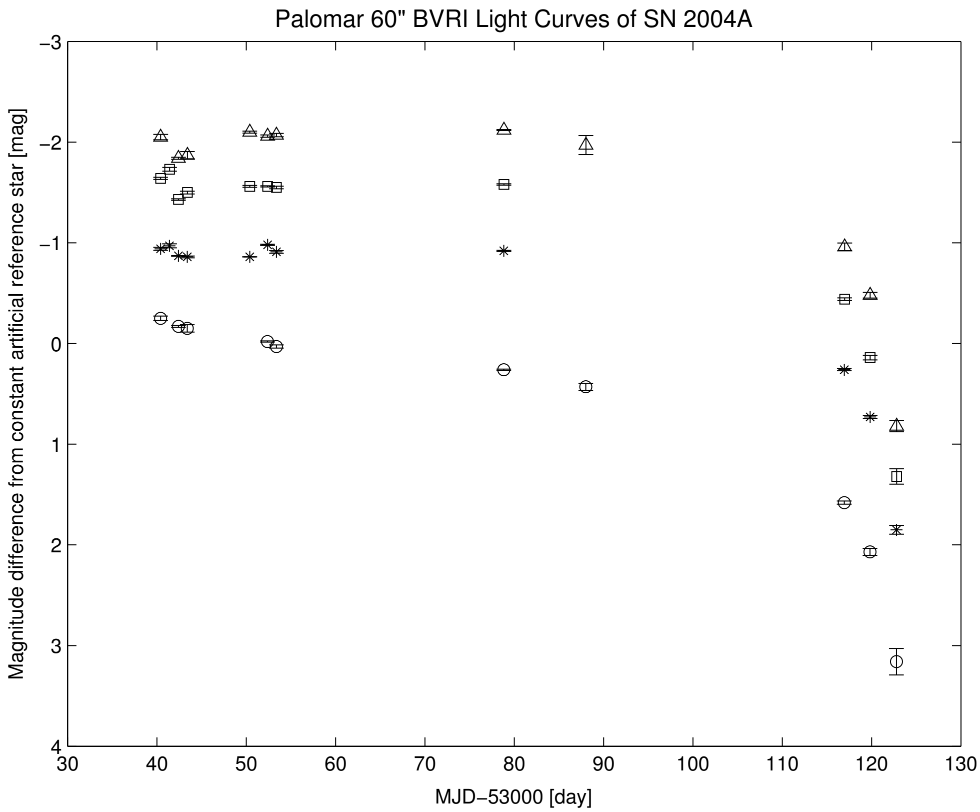

Figure 1. *BVRI* light curves of SN 2004A obtained with the robotic 60 inch telescope at Palomar as part of a pilot study for CCCP. Note the good sampling and accurate photometry obtained during the commissioning and science verification stage of the newly roboticized telescope. Similar data are routinely obtained for CCCP targets starting August 2004. The photometry was calculated using the MKDIFFLC routine (see http://www.astro.caltech.edu/∼avishay/mkdifflc.html and Gal-Yam et al. 2004b for additional details).

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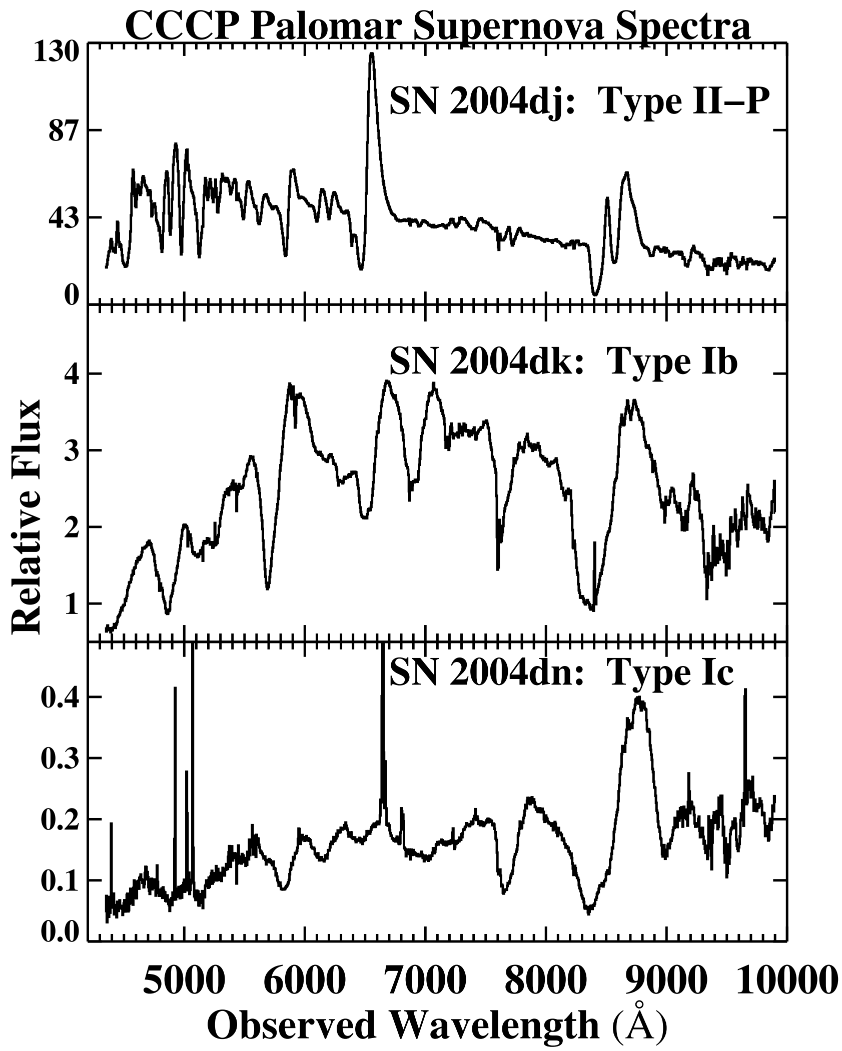

Figure 2. Spectra of some of the first CCCP SNe obtained with the 200 inch Hale telescope at Palomar. A sequence of several such high quality spectra are obtained for each target.

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