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Optical studies of Type IIb SN 2011dh

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Abstract. UBVRI photometry and low resolution optical spectroscopy of the type IIb SN 2011dh in M51 are presented, covering the first year after the explosion. The peak absolute magnitude in V-band of -17.12±0.18 mag indicates SN 2011dh to be a normal bright type IIb event. The peak quasi-bolometric luminosity indicates that $\sim$ 0.06 M$\odot$ of ^{56}Ni was synthesized in the explosion. The He I lines were detected in the spectra much before the maximum light in B-band. The nebular spectra of SN 2011dh show a box shaped emission in the red wing of [OI] 6300, 6363 line due to Hα emission excited because of shock-wave interaction. The analysis of the nebular spectra indicates a progenitor with a main sequence mass of 10-15 M$\odot$.

Keywords. supernovae: individual: SN 2011dh

1. Introduction

SN 2011dh was discovered by A. Riou on 2011 June 01.89 in the nearby spiral galaxy M51 and was classified as a type IIb supernova (Silverman *et al.* 2011, Marion *et al.* 2011). SN 2011dh has been followed extensively from radio to X-rays (Arcavi *et al.* 2011; Soderberg *et al.* 2012). The search for progenitor star in the HST/ACS archive, led to the detection of a luminous star at the supernova location (Van Dyk *et al.* 2011).

2. Results

Imaging and spectroscopic observations of SN 2011dh were obtained, during one year after explosion, with the 2m Himalayan Chandra Telescope of Indian Astronomical Observatory, Hanle, India.

2.1. *Photometry*

The light curves of SN 2011dh in U, B, V, R and I bands are plotted in Figure 1(a). The maximum in B-band occurred on JD 2455732.6±0.35, ∼19.6 days after explosion, at an apparent magnitude of 13.39±0.02 mag. A significant steepening of the late time light curve in B-band is noticed. Light curve decline rate changes from 1.09±0.15 mag/100 days in the early phase to 1.71±0.13 mag/100 days during the late phase.

V-band peak absolute magnitude of SN 2011dh estimated adopting reddening $E(B-V)$ = 0.035 and distance 8.4±0.7 Mpc is -17.12 ± 0.18 mag, which is $\sim$ 1 mag fainter than the mean peak absolute magnitude of the entire sample of the stripped-envelope CCSNe, and is $\sim$ 0.3 mag fainter than the type IIb sample (Richardson *et al.* 2006). The peak bolometric luminosity is $1.267\times\ 10^{42}$ erg sec^{-1}, leading to an estimate of 0.06 M$\odot$ of ^{56}Ni synthesized in the explosion, using Arnett's rule (Arnett 1982).

2.2. *Spectroscopy*

The pre-maximum spectrum of SN 2011dh shows blue continuum with well developed P-Cygni absorption of hydrogen Balmer lines, CaII H&K, CaII NIR triplet (refer

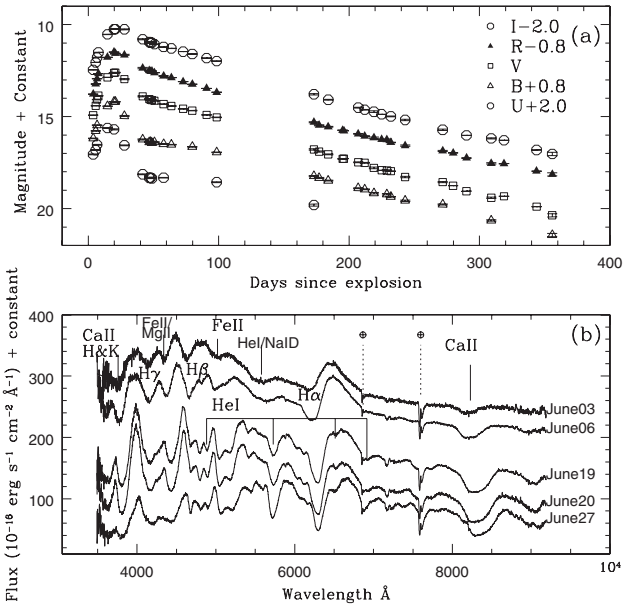

Figure 1. (a) UBVRI light curves of SN 2011dh, (b) Pre-maximum and early post-maximum spectra of SN 2011dh.

Figure 1(b)). The spectrum at *B*-band maximum shows that the supernova has already entered into a phase wherein the lines due to HeI become prominent. During the transitional phase the continuum becomes redder, the Balmer lines become sharper and lines due to HeI become stronger. The nebular phase spectra of SN 2011dh are dominated by emission lines of MgI], [OI], [CaII], OI, blend of [FeII] lines at $\sim$ 5000Å and CaII NIR triplet. A box-shaped emission in the red wing of [OI] 6300, 6364 line due to Hα is clearly identified. Presence of circumstellar material as revealed by X-ray (Campana & Immler 2012) and radio observations (Bietenholz *et al.* 2012), and high expansion velocity of the forward shock, indicate that shock wave interaction may be the most plausible mechanism for the observed Hα emission in the late phase.

The minimum mass of oxygen required to produce the observed [OI] emission in the nebular spectra is estimated as 0.22 M$\odot$. With metallicity a few tenths that of solar, the oxygen mass indicates the progenitor is a low-mass star of $\sim$13– 15 M$\odot$, in a binary system.

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