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Evolution of the Type IIb SN 2011fu

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Abstract. The *UBVRI* photometric follow-up of SN 2011fu has been initiated a few days after the explosion, shows a rise followed by steep decay in all bands and shares properties very similar to that seen in case of SN 1993J, with a possible detection of the adiabatic cooling phase at very early epochs. The spectral modeling performed with `SYNOW` suggests that the early-phase line velocities for H and Fe II features were $\sim$ 16000 km s^{-1} and $\sim$ 14000 km s^{-1}, respectively. Studies of rare class of type IIb SNe are important to understand the evolution of the possible progenitors of core-collapse SNe in more details.

Keywords. Supernovae: general - supernovae: individual (SN2011fu)

1. Introduction

It is commonly recognized that core-collapse supernovae (CCSNe) represent the final stages of the life of massive stars ($M > 8-10$ times to that of Sun) Heger *et al.* (2003), Anderson & James (2009), Smartt (2009). Massive stars show a wide variety in these fundamental parameters, causing diverse observational properties among various types of CCSNe. After the discovery of SN 1987K, another class, termed as Type IIb Woosley *et al.* (1987), was included in the CCSN zoo, and the observational properties of these SNe closely resemble those of Type II SNe during the early phases, while they are more similar to Type Ib/c events at later epochs. Type IIb and Type Ib/c SNe are collectively known as "stripped envelope" CCSNe as the outer envelopes of hydrogen and/or helium of their progenitors are partially or completely removed before the explosion. There are several studies about the discovery of the progenitors of Type IIb SNe but the debate about how they manage to keep only a thin layer of hydrogen, is still on and there are very few SNe of this class have been studied in great detail.

In this presentation, we discuss the results from photometric and spectroscopic monitoring of SN 2011fu starting shortly after the discovery and extending up to nebular phases Kumar *et al.* (2013).

2. Overview

The photometric and low-resolution spectroscopic monitoring of the Type IIb SN 2011fu, presented are the earliest ones reported for this event. The early photometric

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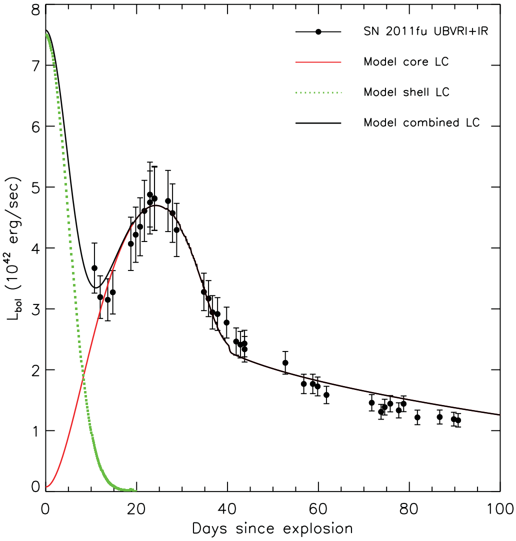

Figure 1. Comparison of the observed bolometric light curve (dots) with the best-fit two-component diffusion-recombination model. The red and green curves show the contribution from the He-rich core and the low-mass H-envelope, respectively, while the black line gives the combined light curve.

observations strongly suggest the presence of the early-time decline of the light curve (which is thought to be related to the shock break-out phase) as seen in case of SN 1993J. The color evolutions of SN 2011fu were studied using our *UBVRI* band observations. Our data showed that during the very early phases the $B - V$ color was very similar to that in SN 1993J. SN 2011fu seems to be the most luminous event in comparison to a sample of other well-observed type IIb SNe.

The quasi-bolometric light curve was computed by integrating the extinction-corrected flux values and the Infra-red contribution was approximated by assuming black-body flux distributions. The bolometric light curve was fitted by the semi-analytic light curve model of Arnett & Fu (1989), suggesting that the progenitor had an extended ($\sim 1 \times 10^{13}$ cm), low-mass ($\sim 0.1\ M_{\odot}$) H-rich envelope on top of a dense, compact ($\sim 2 \times 10^{11}$ cm), more massive ($\sim 1.1\ M_{\odot}$) He-rich core. The nickel mass synthesized during the explosion was found to be $\sim 0.21\ M_{\odot}$, slightly larger than seen in case of other Type IIb SNe.

The spectra of SN 2011fu taken at eight epochs were analyzed using the multi-parameter resonance scattering code SYNOW. The derived parameters describe the evolution of the velocities related to various atoms/ions and the variation of the black-body temperature of the pseudo-photosphere.

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