Type IIb Supernova 2011fu: Spectral and light curve evolution

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**ABSTRACT:** Type IIb supernovae (SNe) are a subclass of core-collapse supernovae that appear to be a hybrid between SNe characterized by the presence of H in their spectra (Type II) and Type Ibc SNe (those that do not exhibit H features in their spectra but possibly HeI). We present some preliminary results of the photometric and spectroscopic analysis of type IIb supernova 2011fu. In principle, the characteristics of SN 2011fu are pretty similar to those of canonical type IIb SNe, but its Bessel UBVRI and Sloan ugriz light curves (LCs) present an early peak resembling the unique case of the well studied type IIb SN 1993J (Richmond et al. 1994).

**INTRODUCTION:**
SN 2011fu (Figure 1), of coordinates α=2h08m21.656s and δ=+77.9'30.53'' (J2000), was discovered in the galaxy UGC1626 by F. Ciabattari and E. Mazzoni, on September 23.04 UT 2011. The redshift derived distance to UGC1626 (provided by the NASA/IPAC extragalactic database, NED) is d=77.9 +/- 5.5 Mpc (µ=34.46 +/- 0.15 mag).

SN 2011fu is a target of the NTT-TNG Large Programme (P.I. Stefano Benetti).

**LIGHT CURVES:** In Figures 2 and 3, Bessel UBVRI and Sloan ugriz LCs of SN 2011fu are presented in comparison with those of type IIb SNe 2008ax (Pastorello et al. 2008) and 1993J (Richmond et al. 1994). The most outstanding feature of SN 2011fu LCs is the appearance of a peak at early times in all bands analogous to the first peak in SN 1993J LC. This peak suggests the presence of a low mass H envelope that was heated during shock breakout. For SN 1993J, Woosley et al. (1994) estimated an H mass of 0.2 +/- 0.05 M⊙.

Two subcategories of type IIb supernova were proposed by Chevalier & Soderberg (2010) attending to the appearance or non appearance of a first peak in the LC: larger radius progenitors or extended type IIb (eIIb) having a first peak in the LC, and smaller radius progenitors or compact type IIb (cIIb) not presenting a first peak in the LC. Attending to this subcategorization, SN 2011fu would then belong to the eIIb type. For a better understanding of the first stages of evolution of SN 2011fu, future modelling of the SN light curve is planned. Our photometric analysis will also be extended to the NIR wavelengths.

**SPECTRAL EVOLUTION:** In Figure 4, we present a sequence of optical spectra of SN 2011fu ranging from 9 to 154.8 days after discovery. The earlier spectra are characterized by P-Cygni Balmer features. After maximum, H lines are still present but other features such as the CaII triplet (849.8, 854.2, 866.2nm) and HeI (587.6nm), possibly blended with NaI (588.9 & 589.6nm), become prominent.

In Figure 5, spectra of SN 2011fu at phases 9 and 102.8 days after discovery are compared to spectra of SN 1993J and 2008ax (both type IIb supernova at coreal epochs). As it can be seen in the figure, SN 2011fu and SN 1993J are also very similar spectrosocopically.

**OBSERVATIONAL FOLLOW UP AND DATA REDUCTION:**
- Thanks to a large collaboration (which includes many European institutions), photometric and spectroscopic data of SN 2011fu has been obtained at Liverpool Telescope, Northern Optical Telescope, William Hershel Telescope, Calar Alto Observatory, Asiago Observatory, Faulkes Telescope North (for the optical wavelengths) and Carlos Sánchez Telescope (for the near infrared - NIR - wavelengths).
- The observational data ranges from September 23rd 2011 to February 25th 2012 (after this epoch the SN dissapeared behind the sun). The data has been reduced (corrected of overscan, bias, flat field) in the IRAF environment. Instrumental magnitudes were determined with SNAPFIT (a PSF fitting package developed by E. Cappellaro and F. Patat) and apparent magnitudes were obtained calibrating via standard Landolt fields for the optical wavelengths. We are still working on the NIR data.

**SUMMARY:** We have presented some preliminary results of the analysis of photometric and spectroscopic data of type IIb SN 2011fu. The spectroscopic data does not seem to differ significantly from that of other type IIb SNe although a deeper spectral analysis is yet to be done to interpret possible differences or similarities. From the light curve shape we conclude the supernova arises from an extended progenitor with the presence of a (thin) H envelope. For SN 2008ax, Chevalier and Soderberg (2010) estimated the compact progenitor radius to be of the order of 10^13 cm, while for SN 1993J (Woosley et al. 1994) arrived to a progenitor radius of 4x10^11 cm and a H envelope of 0.2 M⊙. Although we have not yet modeled the light curve of SN 2011fu, from its shape we expect stellar parameters of the progenitor (radius and H envelope) to be closer to the values estimated for SN 1993J than those for SN 2008ax.

We also note that we must complete the study of the observational properties of SN 2011fu in its late phases of evolution. Observational follow up of SN 2011fu will be resumed in July-August 2012, when it becomes visible again after a period of non visibility due to it being behind the sun.