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A double plateau and unprecendented circumstellar variable sodium in the transient SN 2011A

T. de Jaeger[1], J. Anderson[1], G. Pignata[2] and M. Hamuy[1]

[1]Departamento de Astronomía, Universidad de Chile, Casilla 36-D, Santiago, Chile
[2]Departamento de Ciencias Físicas - Universidad Andrés Bello, Avda. República 252, Santiago, Chile.
email: dthomas@das.uchile.cl

Abstract. We present optical photometry and spectrosopy of the transient SN 2011A. Our data spans 140 days after discovery including *BVRIu'g'r'i'z'* photometry and a sequence of 11 spectra. First classified as a type IIn supernova due to the presence of narrow H_α emission, this object shows exceptional characteristics. Firstly, the light curve shows a double plateau; a property only before observed in the impostor object SN 1997bs. Secondly SN 2011A has a very low luminosity for a type IIn supernova placing it between the type IIn supernovae and impostor classes in terms of luminosity. Thirdly, SN 2011A shows low velocity and high equivalent width sodium doublet absorption which increases with time and is most likely of circumstellar origin. This evolution is also accompanied by a change of line profile. When the absorption becomes stronger, a P-Cygni profile appears.

Keywords: circumstellar matter, supernovae: indivudual: 2011A, stars: mass loss,winds.

1. Introduction

The ejected material from a SN explosion is often seen to interact with surrounding circumstellar medium (CSM), left by progenitor mass-loss episodes prior to explosion (Chevalier 1981, Fransson 1982). When the CSM is dense, strong CSM-ejecta interaction can begin shortly after explosion; this is observed as type IIn supernova (Schlegel 1990, Chugai & Danziger 1994). These objects show narrow emission lines superimposed on broader emissions.

2. Photometry

In the light curve presented in Fig. 1 we see an initial plateau which lasts $\sim$ 15 days with a slope $\sim$ 0.42 mag 100 days^{-1} in V. After this first plateau, the light curve declines with a slope $\sim$ 3.4 mag 100 days^{-1}. Then there is a second plateau phase with a slope of 0.28 mag 100 days^{-1}, which is flatter and longer lasting at longer wavelengths. For the remaining observed epochs the light curve declines with a slope of 2.8 mag 100 days^{-1}. The presence of this rare double plateau leads us to speculate that the CSM is composed of two shells ejected by the pre supernova wind. During $\sim$ 15 days there is an initial plateau which corresponds to the interaction between the SN blast wave and the first shell. When the shock reaches the edge of the first shell the light curve drops. Then there is another weaker plateau; which lasts $\sim$ 15 days in the V-band.

Using a supernova distance = 37.70 Mpc we obtain an absolute magnitude without host exctinction of $M_V = -15.15$. Using the measurement of the equivalent width (EW) of NaI D absorption feature and we find an absolute magnitude of -16.4 in V-band, relatively low for SNeIIn but higher than impostors (Van Dyk *et al.* 2000).

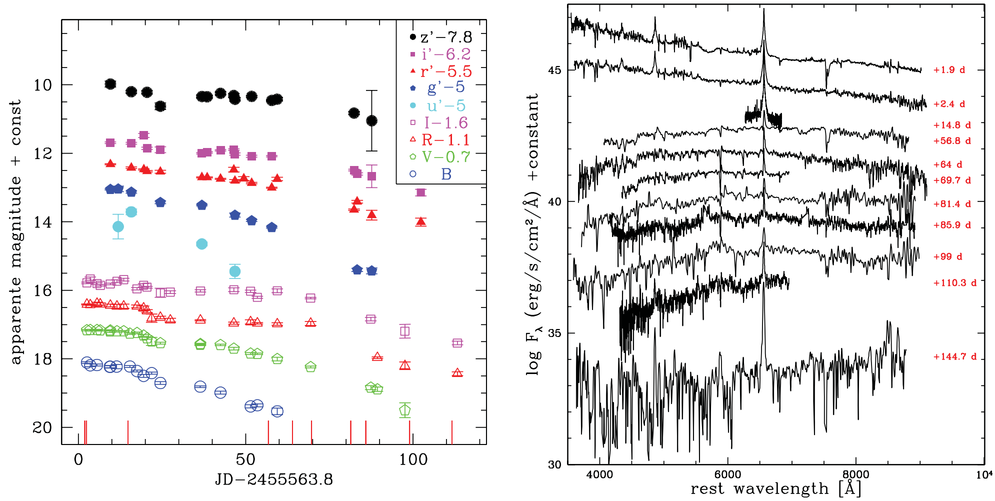

Figure 1. Left figure: *uBgVRrIiz light curve. Epochs are with respect to the discovery date (2011 Jan 2.30 UT= 0 days). Vertical red lines represent optical spectra epochs.* **Right figure**: *Optical spectra of SN 2011A. The epochs after discovery are indicated in red.*

3. Spectroscopy

Our spectral sequence (Figure 1., right figure) shows considerable H_α line evolution with time. From the discovery to 56.8 days after, our spectra are characterised by prominent broad H emission. Then a narrow P-Cygni absorption appears on the top of the broad component. We measured the blueshifted absorption velocity with respect to the host galaxy recession velocity and found low values, between 575 km s^{-1} to 1060 km s^{-1}. It is unlikely that these low velocities can be attributed to the ejecta, which is expected to have velocities of several thousand km s^{-1}. After days 85.9 we see again a H broad emission component. This is coherent with a CSM composing by two shells as discussed to explain the light curve evolution. Note that our spectrum taken 1.9 days after discovery fit perfectly a spectrum of SN 1994W taken 57 days after explosion. This allow us to constrain the SN 2011A explosion date to be $\sim$ 50 days after discovery.
We observe that the NaI D doublet absorption (λ5889.95, 5895.92) becomes stronger with time and has low velocity. Indeed the equivalent width is initially equal to $\sim$ 3 Å and increases to 10 Å after the first 70 days. At the same time, the NaI D profile evolves. First we see only an absorption line then a P-Cygni profile appears. The velocities measured from the doublet center, 5892.43 Å with respect to the host galaxy redshift never gets higher than 700 $km\ s^{-1}$ inconsistent with a ejecta origin, but consistent with a CSM origin interpretation.

References

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