On Nova Scorpii 2007 N.1 (V1280 Sco)

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Abstract We present the results of our photometric and spectroscopic observations of Nova Sco 2007 N.1 (V1280 Sco). The photometric data was represented by a single data point in the light curve since the observation was carried out only for one night. The spectra cover two different phases of the objects evolution during the outburst, i.e. pre-maximum and post-maximum. Measurements of the P-Cygni profile on Na I 'D' line (5889 Å) was derived as the velocity of shell expansion, yielding $1567.43 \pm 174.14 \text{ km s}^{-1}$. We conclude that V1280 Sco is a fast Fe II-type nova.

Keywords Stars: novae

1 Introduction

Nova Sco 2007 N.1 (V1280 Sco) is one of the brightest novae in recent years, since Nova Vel 1999 (c.f. Della Valle et al. 2002). Its discovery was reported by Yamaoka et al. (2007) and confirmed spectroscopically by Naito & Narusawa (2007). Found by Nakamura & Sakurai (c.f. Yamaoka et al. 2007) as a 9 mag object on February 4.85 UT, V1280 Sco underwent rapid brightening and eventually reached optical maximum brightness at $\sim 3.7 \text{ mag}$ on February 17th, and remained so for around three days afterwards. Subsequently it gradually faded and is currently back on its original brightness at $\sim 12 \text{ mag}$. Henden & Munari (2007) reported its position as $\alpha_{2000.0} = 16^h57^m41.2^s$, $\delta_{2000.0} = -32^\circ20'35.6"$.

2 Observations

Our observations were carried out at the Bosscha Observatory, during late February 2007. Due to weather restrictions and observing time availability, we managed to cover only three nights for spectroscopy and one night for photometry.

On February 13.9 UT we performed a "snapshot" BVRI photometry on the object, using a Celestron 11" f/10 Schmidt-Cassegrain mounted with SBIG ST-8XME CCD (1530 $\times$ 1020 px, 9 µ pixelsize). The nearby 7 mag star SAO 208228, which was on the same CCD field with V1280 Sco, was used as a comparison star (see Figure 1).

Spectroscopic observations were carried out on February 16.9, 24.9, and 28.9 UT. We used an SBIG DSS-7 spectrograph combined with the Celestron 11" and ST-8XME (February 16th), while on February 24th and 28th the spectrograph was combined with a Celestron 8" f/10 Schmidt-Cassegrain and SBIG ST-7XME-S CCD (765 $\times$ 510 px, 9 µ pixelsize). Due to the absence of internal wavelength comparison source in the spectrograph, we used external sources i.e. skyglow, an Hg lamp, HR 5511, and Arcturus (radial velocity standard...
The combination of our instruments gave a resolution of 5.4 Å per pixel. Effective wavelength coverage was from 3800 to 8000 Å. Throughout the observations the CCD camera was cooled down to −10 C. Integration time was 10 to 20 seconds. Typical sky condition was clear, but not photometric since there were scattered clouds present.

3 Results

3.1 Photometry

During our 1-hour observing session, we obtained 15 science images for each $BVRI$ band, in addition to dark and flatfield frames. Standard reduction of dark-subtracting and flatfielding was employed. We then carried out aperture photometry to both object and comparison on the reduced images using IRAF/APPHOT package.

![Fig. 2](image)

**Fig. 2** Visual-magnitude light curve of V1280 Sco from validated AA VSO database. Red triangle denotes our $V$-band photometry result on Feb. 13.9, while dashed vertical red lines mark the time of our spectroscopic observations.

To determine the zero-point of photometry, we refer the $B$ and $V$ magnitudes of SAO 208228 to the magnitudes from the SAO catalogue. This zero-point was then applied to the instrumental magnitudes of V1280 Sco to transform it into standard magnitudes. Averaging from the 15 frames yielded magnitudes in $B = 6.400 \pm 0.041$ and $V = 6.011 \pm 0.027$. This result is quite in concordance compared to American Amateur Variable Star Observer (AAVSO) database (Figure 2). $R$ and $I$ magnitudes were calculated by assuming $(V-R) = 0.08$ and $(R-I) = 0.01$ for SAO 208228, an A2 star. We obtained for V1280 Sco magnitudes in $R = 5.702 \pm 0.020$ and $I = 5.420 \pm 0.044$.

1IRAF is distributed by the National Optical Astronomy Observatories, which are operated by the Association of Universities for Research in Astronomy, Inc., under cooperative agreement with the National Science Foundation.

3.2 Spectroscopy

Our spectra were dark-subtracted and flatfield-corrected using IRAF. Spectroscopic reduction was carried out using TWDOSPEC and ONESPEC packages in IRAF. This process resulted in wavelength and flux calibrated spectra. The fluxes of Feb. 24 spectra were not calibrated since no standard star was observed during the night. The fluxes of Feb 16 and Feb 28 spectra were calibrated using HR 5511 and Arcturus, respectively. We used calibrated flux values from Hamuy et al. (1992) for HR 5511 and from Breger (1976) for Arcturus.

The spectrum of V1280 Sco on Feb. 16.9, around maximum brightness, showed a stellar-like appearance. The continuum is prominent along with many absorption lines. Balmer lines are apparent but not so strong, and a slight evidence of emission line formation is observable on H$\alpha$.

Spectra obtained from Feb. 24 and 28, after peak brightness, evidently show a different appearance compared to Feb. 16 spectra. The continuum is less pronounced, while the spectrum is dominated by emission lines. The spectra exhibit strong emissions particularly on H$\alpha$, H$\beta$, and Fe II lines. We detected a P-Cygni profile apparent on around $\lambda$5900 Å. This feature was identified as Na I (5889 Å) ‘D’ line (Figure 3).

To derive shell expansion velocity of the object, we carried out measurements on wavelength of the absorption and emission component of the P-Cyg profile. Prior to this, we normalize the continua of Feb. 24 and Feb. 28 spectra. Measurements to absorption profile were carried out by fitting the profile with a Voigt function, while we used a Gaussian function on the emission component. During the fitting, the base of the fitting function was set at the continuum.

To derive radial velocity $v$ for each Na I ‘D’ line component from observed wavelength $\lambda_{\text{obs}}$ given the rest wavelength $\lambda_0$ and speed of light $c$, we used the Doppler relationship

$$\frac{\lambda_{\text{obs}} - \lambda_0}{\lambda_0} = \frac{v}{c}.$$ (1)

Radial velocity derived from this measurement was corrected to radial heliocentric velocity $v_{\text{hel}}$. The difference between radial heliocentric velocities of absorption and emission component, i.e. basically difference of wavelength $\Delta \lambda$, yields expansion velocity $v_{\text{exp}}$. Measurements of three spectra yielded shell expansion velocity as $1567.43 \pm 174.14$ km s$^{-1}$ (Table 1).

4 Discussions

Using the relationship developed by Della Valle & Livio (1995), we were able to crudely approximate the abso-
Table 1  Measurements on Na I 'D' line. All wavelengths are in Å and velocities are in km s$^{-1}$.

| Spectrum | $\lambda_{emi}$ | $v_{hel,emi}$ | $\lambda_{abs}$ | $v_{hel,abs}$ | $\Delta \lambda$ | $v_{exp}$ |
|---------|-----------------|----------------|-----------------|----------------|-----------------|------------|
| Feb. 24 #1 | 5914.03 | 1303.55 | 5884.71 | -189.05 | 29.32 | 1492.59 |
| Feb. 24 #2 | 5917.76 | 1493.42 | 5889.41 | 50.20 | 28.35 | 1443.22 |
| Feb. 28 | 5902.89 | 796.74 | 5868.19 | -979.54 | 34.70 | 1766.48 |

lute magnitude of the nova. V1280 Sco took $t_2 \approx 11$ days, i.e. time to decline $2^{mag}$ from maximum brightness. This decline rate was translated to maximum absolute magnitude $M_V = -8.63$. Interstellar extinction map of Neckel & Klare (1980) indicates that the amount of extinction in the general direction of V1280 Sco ($l = 351.756^\circ$, $b = +0.120^\circ$) is $A_V \gtrsim 2^{mag}$. Applying $A_V = 2^{mag}$, and maximum brightness of $V = 3.7^{mag}$, we estimate the distance of the nova as 1.2 kpc. This corresponds to a small vertical distance of the object to the galactic plane, 2.5 pc.

Using [O I] lines at $\lambda\lambda 5577, 6300, 6364$ we estimated several physical parameters of V1280 Sco. As described in Ederoclite et al. (2006), the optical depth of $\lambda 6300$ line can be calculated from the equation

$$\frac{j_{6300}}{j_{6364}} = \frac{1 - e^{-\tau}}{1 - e^{-\tau/3}}. \quad (2)$$

We found that the value of $\tau_{6300}$ is 5.4, which we used to derive electron temperatures of the ejecta region where [O I] lines originated using equation

$$T_e = \frac{11200}{\log \left( \frac{43\tau}{1-e^{-\tau}} \times \frac{F_{6300}}{F_{5577}} \right)} \times \frac{\tau}{1-e^{-\tau}} F_{6300}. \quad (3)$$

The above equation yield $T_e = 4520$ K. This enabled us to estimate the oxygen mass in the ejecta, in solar mass ($M_\odot$):

$$M_O = \frac{152d_{kpc}^2 \exp \left( \frac{22850}{T_e} \times 10^{1.05E(B-V)} \times \frac{\tau}{1-e^{-\tau}} F_{6300} \right)}{M_\odot}. \quad (4)$$

Taking the total-to-selective absorption ratio $A_V/E(B-V) = 3.1$, corresponding to $E(B-V) = 0.65$, we found that the oxygen mass in the ejecta is in the order of $2 \times 10^{-5} M_\odot$. This result, along with the value of $\tau_{6300}$ and $T_e$, is in accordance with the values derived from other novae (c.f. Ederoclite et al. 2006).

According to the rate of brightness drop, V1280 Sco was classified as a fast nova, which has a typical $t_2$ of less than 12 days (Della Valle & Livio 1998). The derived maximum absolute magnitude and shell expansion velocity were consistent with that of typical fast novae (Gallagher & Starrfield 1978, Osterbrock 1989).
The spectrum of the nova resembles a "Fe II" type nova spectrum, described in Williams (1992). We classified V1280 Sco then as a fast Fe II-type nova. According to Della Valle & Livio (1998), the progenitor of this type of nova originated from a relatively old Population I of thin disk/spiral arm and the associated white dwarf is rather massive with mass between 0.9 and 1 $M_{\odot}$.

Acknowledgements We are very thankful to Dr. H.L. Malasan for both great encouragement and strong criticism. The authors would also like to thank N. Hasanah, P. Irawati, and A.T. Puri Jatmiko for their aid during observations.
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