NOVA Sco 2001 (V1178 SCO) *

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Received 29. June 2001 / accepted 13. August 2001

Abstract. We present intermediate resolution spectroscopy and near infrared photometry of NOVA Sco 2001 (V1178 Sco), which was first detected May 13 th 2001 and reported June 21 st 2001, and obtained by us the same day. We also retrieved very accurate astrometry of the target in this very crowded field. This is needed to be able to do follow up observations of the postnova during the next years. The spectrum shows an overall expansion of 2100 km s⁻¹ and has clearly complex, and most likely nonsymmetric, outflow substructures. We clearly identify this object as classical nova, "Fe II" subclass.

Key words. stars: novae - stars: individual: NOVA Sco 2001 = V1178 Sco

1. Introduction

NOVA Sco 2001 was discovered May 13 th 2001 as a 10.5 magnitude object and reported first June 21 st 2001, 18:03 UT (Hasada et al. 2001). Liller (2001) reports there also first spectroscopic results at low dispersion, confirming a strong Hα line. The variable star name given to the object is V1178 Sco (Samus & Kazarovets 2001). We obtained near infrared images in the Gunn-i, J and Ks band using the DENIS survey instrument (Epchtein et al. 1997) attached to the ESO/LaSilla 1m telescope using 5 magnitude attenuating filters (June 21 st 2001, 23:12 UT). The spectrum was taken using the Danish 1.5m telescope at LaSilla (June 22 nd 2001, 02:46 UT) with the DFOSC mounted. Also a red continuum filter image was obtained there. This filter was selected to have a largely line emission free narrow band image, to get best possible astrometry without effects of color shifts and differential refraction of the surrounding astrometric calibration sources.

2. Astrometry and Cross–identification

To obtain a very accurate astrometry of the target a DFOSC narrow band image was taken. To avoid displacements of sources due to different colors as seen normally in wide band filters, the red continuum filter ESO#840 centered at 683.82 nm and having a FWHM of 8.09 nm was used. The DFOSC is currently equipped with a MAT/EEV 44-82 2k×4k CCD giving, according to the manual, a resolution of 0′′39 per pixel. In fact we measure 0′′3955±0′′00018. The FWHM on the images was 1′′66. As only half the chip is used the field of view is 13×13′. We used only the central part of the image with a radius of 1′ around the target. This provides us with a highly distortion free image. Astrometric calibrators were taken from USNO CCD Astrometric Catalogue (UCAC) (Zacharias et al. 2000). This catalogue contains southern sources with an accuracy of about 20 mas in the red magnitude range 10< m < 14 and still has an accuracy of about 70 mas at the limit of 16. We used 6 stars surrounding the target to obtain the astrometry (Tab. 1). One source corresponds to a TYCHO-2 source. The difference of the position in the 2 catalogues is, after correction for proper motion, approximately 25 mas in both coordinates.

Table 1. Astrometric calibration stars

| UCAC Id. | TYCHO-2 Id. | α (J2000.0) | δ (J2000.0) |
|----------|-------------|-------------|-------------|
| 19383082 | 1837251     | 269.3048774 | -32.4037892 |
| 19383048 |             | 269.2938362 | -32.3957092 |
| 19383013 |             | 269.2828100 | -32.3990684 |
| 19383009 |             | 269.2820474 | -32.3899953 |
| 19382967 |             | 269.2719486 | -32.3798559 |
| 19382984 |             | 269.2773877 | -32.3915264 |

The source extraction on the image was obtained by using SExtractor v2.1.6 (Bertin & Arnouts 1996). The rms of the positions, using a plane astrometry without distortion coefficients, was 41 mas. The 2 largest residuals (up to 71 mas) are found for the two faintest sources. As our S/N was very high even for those sources, we assume that
part of this error originates from the UCAC. These residuals are in the order of magnitude for the input catalogue itself. The 1×1′ region was thus sufficient. It would give us just uncertainties due to distortion increasing the field. As the target is very bright, we assume the accuracy of our coordinates to be 40 mas.: 

\[
\begin{align*}
\alpha_{2000.0} &= 17^h57^m06^s922 \pm 0^s003 \\
\delta_{2000.0} &= -32^\circ25^\prime05^\prime03 \pm 0^\prime04.
\end{align*}
\]

An inspection of the sky survey plates SERC V (1987.590 and 1987.708) and 2nd ed. Equatorial red (1989.674 and 1992.421) shows a source, which is significantly fainter than the red 17′′5 source stated in Hasada et al. (2001). Although this source is faint, we are able to state that there is no variability at a level of 0.025 at those epochs. The CAI MAMA scans provided at CDS give an estimate of B≤20′′5 and R≤18′′2 when using the PSF fitting for decrowding and photometric calibration as described in Kimeswenger & Weinberger (2001). The DENIS Ks images were used together with the accurate astrometry above, to carefully cross–identify the 2MASS sources of the region. We thus are able to definitely exclude the next nearby source 1757066-322305 as possible progenitor. This source is westward to the target still visible on the Ks images. Fig. 2 shows, that the two USNO A2 sources mentioned by Masi (2001) (0523-30816527 and 0525-30186320, one star in fact only) are the same source as the 2MASS source mentioned above. It has a significant offset to the target. The coordinate offset of Masi may originate from the fact that this target, observed from Italy, had a high airmass. He underestimated the effects of differential refraction when comparing his unfiltered CCD image with the USNO red. Queries to different public archives at e.g. ESO, ING, etc. gave no results concerning an earlier CCD image.

3. NIR Photometry

The near infrared photometry was obtained at the DENIS survey instrument (Epchtein et al. 1997) attached to the ESO/LaSilla 1m telescope. We used a Gunn-i (λeff = 0.81 μm) a standard J (λeff = 1.25 μm) and a

\[ K_s (\text{λ}_{\text{eff}} = 2.15 \mu\text{m}) \]  filter. The night was photometric. The standard observations were taken from the survey run. The calibration was not done via the survey pipeline but manually. The methods are similar to those described in Cioni et al. (2000) and Fouqu´e et al. (2000). As the source was just below overexposure in normal survey mode, also images using a 5x2 attenuating filter set were obtained. The calibration of those sets is described in Kimeswenger et al. (2001). Thus in total 10 frames, taking the source at different positions of the detector, were obtained. This was done to minimize effects due to flatfield features and detector flaws.

| Date       | Band | [mag]  | error |
|------------|------|--------|-------|
| June, 21st 2001, 23:12 UT | Gunn-i | 9''75 | 0''03 |
|            | J    | 8''67  | 0''05 |
|            | Ks   | 8''01  | 0''04 |

The colours (i-J = 1''08; J-Ks = 0''66) are completely different from those derived for e.g. CI Aql during the 2000 outburst at a date of about 30 to 40 days after discovery using the same instrument. While the i-J is significantly redder than the value obtained there, the J-Ks is significantly bluer. This may be an indicator of a less dominant Brγ emission.

4. Spectroscopy

The spectra were obtained at the Danish 1.5m telescope at ESO LaSilla/Chile with the DFOSC spectrograph. We were using Grism #7, giving a resolution of 0.145 nm/pixel and a usable range from 450 to 680 nm. The calibration (bias, flatfield, wavelength calibration and response curve)
was done using usual procedures in MIDAS and the calibration data given in the DFOSC manual. The absolute scale was calibrated by using the photometry of Liller (2001) and the standard V filter curve. The spectrum has a S/N of >200 in the continuum over the whole region. As P-Cygni profiles we are able to identify the Balmer series from Hα to Hǫ, FeII λ4176, 4233 and 5169. The high excitation lines NIII λ4640/HeII λλ4686 do not appear in this nova. Remarkably, the iron lines are stronger than e.g reported in CI Aql (Kiss et al. 2001), while [NII] λλ5755 does not appear at all. The Na-D line is very prominent too. Normally blended by HeI λλ5876, this line appears here only as a weak absorption feature at the blue end.

The profiles of the Balmer series lines are widely identical, providing a $V_{\text{max}}$ of 2100 km s$^{-1}$ and two nearly symmetrical features at about 900 km s$^{-1}$. The relative strength of this feature, both in emission as in absorption increases to higher levels. This is an indication for an inner shell not being in thermal equilibrium.

While the structure of the line centered at 5014–5017 Å (FeII(M42), HeI?) follows mostly that of the hydrogen lines (only $V_{\text{max}}$ is lower), the other iron and the sodium lines show much more complex features. The emission maximum is even suppressed by some absorption in case of the Na-D line.

5. Conclusion
The spectrum allows us to classify this object, first called as "novalike variable" in some IAUCs, to be a classical nova of "Fe II" subtype (after Williams 1992). The astrophotometry presented here clearly indicates, that the progenitors discussed in the first IAU circulars are not the correct identifications. This will allow detailed followup after the decline. The outburst here, reaching $\geq 9^m$ is clearly stronger than that of the recent events of CI Aql or V445 Pup. As the discovery was reported with a delay of about one month, we are unable to give colors and accurate photometry of the early phases of the event. Thus the $t_1$ date will be poorly defined. The blue NIR photometry
try suggests $t_2$ is not reached already. This makes it to be a moderately slow nova. Following the discussion in Kiss et al. (2001), one may obtain an absolute magnitude of $-7^{m} 0 < M_V < -8^{m} 0$. As we have no information about the interstellar reddening in this direction, we used the mean extinction method given for Miras and AGB stars in Whitelock et al. (2000). This leads to a crude distance estimate of 3 kpc and $A_V \approx 6^{m}$. This is in agreement with the possible progenitor on the plates to be a late K or early M giant.

The spectroscopy clearly shows a complex structure of the outflow. The velocity field obtained by the hydrogen and helium lines suggest a two shell structure similar to the models of Hanuschik et al. (1993). The metal lines even indicate a more complex, most likely non–symmetric outflow with respect to the line of sight.

Acknowledgements. We thank the referee W. Liller for his helpful suggestions. MA is grateful to IJAF (DK) and KS for the BMfBWK (A) for travel support.

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Fig. 5. The profiles of (from top to bottom) line at $\lambda\lambda 5014–5017$ (Fe II (M42), He I ?), Fe II $\lambda\lambda 5169$ and Na-D; the lines are normalized to local continuum and shifted by 1.0 each (see text).