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THE OPTICAL BEHAVIOUR OF DELTA SCORPII

OTERO, SEBASTIÁN¹; FRASER, BRIAN²; LLOYD, CHRISTOPHER³

¹ Liga Iberoamericana de Astronomía (LIADA), e-mail: varsao@fullzero.com.ar

² Sunninghill Observatory, Sandton, South Africa, e-mail: fraserb@Intekom.co.za

³ Space Science & Technology Department, Rutherford Appleton Laboratory, Oxfordshire, UK,
e-mail: c1@astro1.bnsc.rl.ac.uk

Delta Scorpii (7 Sco, HR 5953, HD 143275, HIP 78401, IDS 15544-2220) normally resides at $V = 2.32$, $B - V = -0.12$ (according to measurements in the General Catalogue of Photometric Data, GCPD, Mermilliod et al., 1997) and has a spectral type of B0.2IV. Although δ Sco is probably a close binary, a bewildering array of possible components have been suggested. Hanbury Brown et al. (1974) first (re)discovered δ Sco to be multiple, with a companion $\sim 1^m.9$ fainter. The *Bright Star Catalogue* (Hoffleit, 1982) followed by the Washington Double Star catalogue (WDS, Worley & Douglass, 1997) and others, quote occultation results giving four components at separations of 0.01 mas ($V = 5.0$), 0".1 ($V = 3.3$) and 0".186 ($V = 4.9$). However, it should be pointed out that the closest companion apparently lies inside the primary, which has a diameter of 0.46 mas (Hanbury Brown et al., 1974), and is clearly an error. According to the Multiple Star Catalogue (MSC, Tokovinin, 1997) δ Sco comprises a spectroscopic binary (Levato et al., 1987) and the brighter companion at 0".1. Optical interferometric measurements and a thorough analysis of the previous results by Bedding (1993) showed convincingly that all the observations referred to just two components in an elliptical orbit with a ten-year period. Modern speckle interferometry observations reveal that the components ($H_p = 2.39$ and 4.62) have a very eccentric orbit, with $e = 0.92$, $a = 0''.107$, $P = 10.583$ years and $T_0 = 1979.41$ (Hartkopf et al., 1996), although the orbit was difficult to determine. Periastron passage occurred recently in July 2000. Although the secondary is over two magnitudes fainter than the primary it probably has a spectral type no later than about B3, if it lies on the main sequence.

The early literature on δ Sco contains several references to velocity variations (e.g., van Hoof et al., 1963). In the *Bright Star Catalogue* (Hoffleit, 1982; see also Smith, 1986) δ Sco is given as a possible SB1 with a period of ~ 20 days. Levato et al. (1987) made new observations, and also gave it as an SB1, but were unable to find a reliable period, the best was ~ 83 days, and did not provide an orbit. Smith (1986) found line-profile variations which were interpreted as being due to relatively short-lived, complex non-radial oscillations. In effect the star is a β Cephei variable, but it does not show consistent, periodic variations. The velocity variations are small, 10–20 km s⁻¹, and the corresponding light variations are very low. δ Sco was included in the Be-star mass-loss survey with *Copernicus* (Snow, 1981), although it was not known to show any Be-star

characteristics. It showed barely detectable mass loss, indicating at most only marginal $H\alpha$ emission. $H\alpha$ spectra given by Heasley & Wolff (1983), probably obtained around the same time, shown no indication of any emission. In 1990 Coté & van Kerkwijk (1993) observed broad $H\alpha$ emission wings around the absorption core and proposed δ Sco as a Be star. They also noted that prior to this observation there had been no mention of any activity at $H\alpha$. According to unpublished observations by Hartkopf (quoted by Fabregat et al., 2000b) $H\alpha$ emission has been visible on several occasions during the past five years.

In June and July 2000 visual observations of δ Sco by Otero (2000) showed a slow increase in brightness typical of a γ Cas-type outburst. Further visual observations were made regularly and these were later supported by photoelectric observations by Fraser made using a 20-cm F10 SCT with an Optec SSP3 photometer, with B and V filters. The comparison star used was ω^1 Scorpii ($V = 3.95$, $B - V = -0.04$) and the check star HIP 77911 ($V = 6.86$, $B - V = 0.04$). The data are available at the IBVS website as 5026-t1.txt.

The light curve of δ Sco is shown in Figure 1. The first observations at the end of June suggest that δ Sco was slightly above its usual level of $V = 2.3$ but it then brightened to a maximum of $V = 1.9$ (at \sim JD 2451755) over some 25 days. During August it faded steadily to $V \sim 2.15$, and it then recovered during September, mimicking its initial rise. At the end of the observing season in mid October it had just started to decline from the second maximum (at \sim JD 2451823, $V = 1.87$), which was probably brighter than the first.

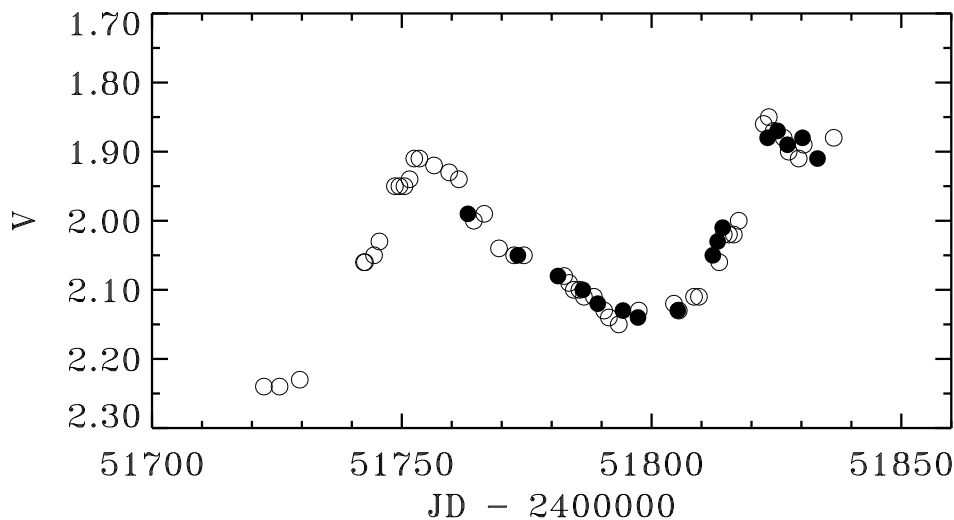


Figure 1. The light curve of δ Sco showing the visual (open circles) and photoelectric (filled circles) observations from this paper

Prompted by the optical brightening, spectroscopic observations in mid July by Fabregat et al. (2000a) show $H\alpha$ purely in emission, confirming δ Sco as a Be star. Further spectra obtained by Fabregat et al. (2000b) and by the Be-star Spectroscopic Survey Project (only available electronically, see Buil, 2000) show only modest changes in the $H\alpha$ profile while the star brightened by 0^m.4. Indeed the the emission is seen fully developed

on 2000 June 4 (see Buil, 2000), before the star had brightened significantly. During July the emission line developed a double peak but was otherwise largely unchanged.

The compilation of photometry in the GCPD shows that all the measurements of δ Sco lie close to $V = 2.32$ except for an isolated value of $V = 2.21$ (Hogg, 1958) recorded in 1958. As mentioned before, periastron passage of the speckle binary occurred in July (2000.58), and it is interesting to note that it also occurred in 1989.99, 1979.41, 1968.83, and 1958.24. *Hipparcos* observed δ Sco for over two years from just after the 1989.99 periastron passage and these observations, shown in Figure 2, suggest that δ Sco was slightly brighter than its normal value. According to the *Hipparcos* catalogue δ Sco shows possible micro variability but the most obvious variation in Figure 2 is a small, slow oscillation and fade. There does not appear to be any photometry at the other epochs but it raises the question of whether the optical outburst is triggered by the close approach of the secondary.

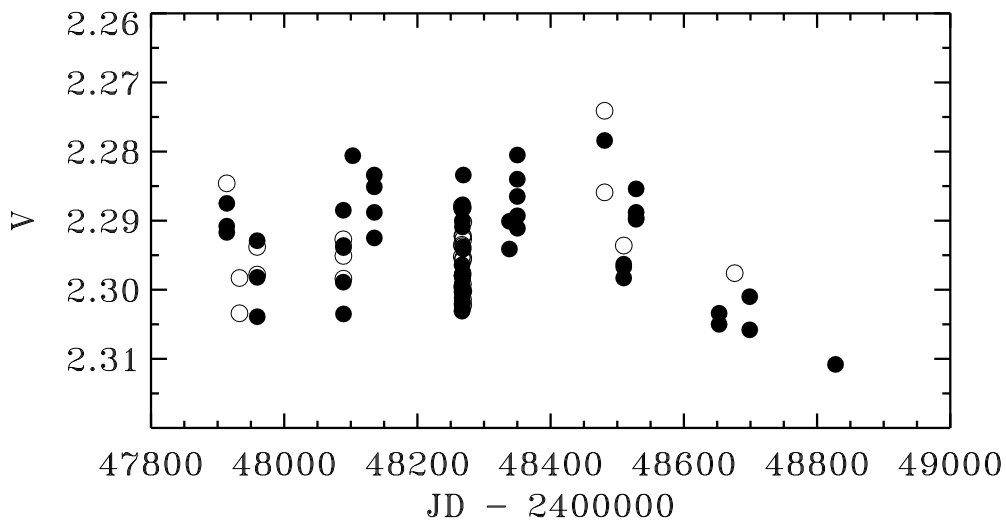


Figure 2. *Hipparcos* light curve of δ Sco showing the unflagged (filled circles) and flagged (open circles) observations. The *Hipparcos* (Hp) magnitudes are transformed to V

The total mass of the system can be calculated from the orbital period, 10.583 ± 0.075 yr and the semi-major axis, 106.7 ± 6.7 mas of the speckle orbit and the distance of the system, $\pi = 8.12 \pm 0.88$ mas (123 ± 13 pc) from *Hipparcos*, as $20.3 \pm 7.6 M_{\odot}$. The primary alone probably has a mass $\sim 20 M_{\odot}$ and the secondary, if it is as early as B3, could contain $8 M_{\odot}$, which is accommodated by the uncertainty. As the two speckle components seem to more than adequately account for the total mass of the system there appears to be no room for any other fainter components or spectroscopic binary companions. At this distance the radius of the primary, from Hanbury Brown et al.'s measurement is a just acceptable $R = 6.1 \pm 0.9 R_{\odot}$.

The separation of the components at periastron is ~ 1 AU, which does not seem very close, but the speed of approach will be $\sim 150 \text{ km s}^{-1}$. Whether the rapid approach of such a star could disrupt the atmosphere of the primary is not clear.

The relationship between the optical outburst and the $H\alpha$ emission is also not clear. $H\alpha$ emission has been seen at some level for all of the past cycle, about ten years, but

was apparently absent during the previous cycle. Apart from the current outburst and the possible event in 1958 the luminosity has apparently remained constant throughout most of both cycles. Even after the 1989.99 periastron passage there was only low level activity. The current optical outburst is unlike anything previously seen, in terms of both magnitude and duration. The $H\alpha$ emission is also stronger than previously observed, but in detail it does not show a strong correlation with the brightness variations, which suggests that the mass loss and luminosity are not strongly coupled.

Observation of δ Sco during solar conjunction with *SOHO* (Farrell, 2001) and the most recent visual observations, during January 2001, suggest that the star remains in outburst, and may indeed be brightening. Further photometric and spectroscopic observations are encouraged.

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References:

- Bedding, T.R., 1993, *AJ*, **106**, 768
- Buil, C., 2000, *Be Star News*, No. 34, 42
<http://www.limber.org/benews/volume34/buil/buil0.html>,
 spectra <http://astroccd.com/terre/buil/us/catalog/7sco.htm>
- Coté, J., van Kerkwijk, M.H., 1993, *A&A*, **274**, 870
- Fabregat, J., Reig, P., Otero, S., 2000a, *IAU Circ.*, No. 7461
- Fabregat, J., Reig, P., Tarasov, A., 2000b, *Be Star News*, No. 35
<http://www.limber.org/benews/volume35/fab/fab0.html>
- Farrell, F., 2001, vsnet-chat No. 3939
<http://www.kusastro.kyoto-u.ac.jp/vsnet/Mail/chat3000/msg00939.html>
- Hanbury Brown, R., Davis, J., Allen, L.R., 1974, *MNRAS*, **167**, 121
- Hartkopf, W.L., Mason, B.D., McAlister, H.A., 1996, *AJ*, **111**, 370
- Heasley, J.N., Wolff, S.C., 1983, *ApJ*, **269**, 634
- Hoffleit, D., 1982, *The Bright Star Catalogue; fourth revised edition*, Yale University Observatory
- Hogg, A.R., 1958, *Mount Stromlo Obs. Mimeo.*, No. 2
- van Hoof, A., Bertiau, F.C., Deurinck, R., 1963, *ApJ*, **137**, 824
- Levato, H., Malaroda, S., Morrell, N., Solivella, G., 1987, *ApJS*, **64**, 487
- Mermilliod, J.-C., Mermilliod, M., Hauck, B., 1997, *A&AS*, **124**, 349, General Catalogue of Photometric Data (GCPD)
- Otero, S.A., 2000, vsnet-obs No. 28454 & vsnet-obs No. 28777 & vsnet-alert No. 5302
<http://www.kusastro.kyoto-u.ac.jp/vsnet/Mail/obs28000/msg00454.html>
 & .../msg00777.html
<http://www.kusastro.kyoto-u.ac.jp/vsnet/Mail/alert5000/msg00302.html>
- Smith, M., 1986, *ApJ*, **304**, 728
- Snow, T.P., 1981, *ApJ*, **251**, 139
- Tokovinin, A.A., 1997, *A&AS*, **124**, 75, Multiple Star Catalogue 1997-1999 (MSC), CDS III/191 1999 revision
- Worley, C.E., Douglas, G.G., 1997, *A&AS*, **125**, 523, The Washington Visual Double Star Catalogue, 1996.0 (WDS)