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# BVRI OBSERVATIONS OF V516 CYGNI IN OUTBURST

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V516 Cyg is a dwarf nova (DN) that varies between $m_{\rm pg} \simeq 13.8$ and $m_{\rm pg} \simeq 16.8$ (Downes & Shara 1993), but only a few photometric observations are available in the literature. We have already analysed this source in Spogli et al. (1998), but in that case we observed the source only during the descending phase after an outburst. In that period it had colour indices of $B-V = 0.1$, $V-R_c = 0.2$, $V-I_c = 0.2$ at the apparent maximum.

We observed this DN at the Astronomical Observatory of Collurania–Teramo during August–September 1998 with the aim to better evaluate the photometric behaviour during all the outburst phase. The instruments used and the photometric techniques have been already described in Spogli et al. (2000).

We re-calibrated the comparison stars in the finding chart reported by Spogli et al. (1998). The standard magnitudes are listed in Table 1. Moreover, we measured the $B$ magnitudes for the stars 2 and 3. Although the star 1 is double, we used it as a comparison star because the aperture size is sufficiently large to collect the light coming from both the sources. Probably one of these is the radio source WSRTGP 2045+4144 (Taylor et al. 1996).

Table 1: $BVR_cI_c$ magnitudes of the selected comparison stars

| No. | $B$ | $V$ | $R_c$ | $I_c$ |
|---|---|---|---|---|
| 1 | $15.05 \pm 0.06$ | $14.20 \pm 0.04$ | $13.71 \pm 0.04$ | $13.25 \pm 0.04$ |
| 2 | $16.56 \pm 0.07$ | $15.34 \pm 0.04$ | $14.72 \pm 0.04$ | $14.15 \pm 0.04$ |
| 3 | $17.07 \pm 0.08$ | $15.57 \pm 0.05$ | $14.82 \pm 0.04$ | $13.91 \pm 0.04$ |

Two stars which are very bright in the infrared band are visible in the field of view, and were used to evaluate colour effects. One star (with $V = 21.0 \pm 0.5$, $R_c = 17.2 \pm 0.1$, $I_c = 13.26 \pm 0.05$) is situated $\simeq 86'$ E and $\simeq 53'$ N with respect to V516 Cyg. The other ($V = 19.2 \pm 0.3$, $R_c = 16.9 \pm 0.1$, $I_c = 13.95 \pm 0.05$) is $\simeq 3'$ W and $\simeq 26'$ N with respect to the DN. We calibrated the magnitudes also at the Astronomical Observatory of Perugia and no relevant differences are noticeable.

The comparison stars were used to find the value of the zero point of the magnitude scale for each CCD image and, then, to measure the dwarf nova standard magnitude and its error. Although for many observational runs we obtained more than one CCD image

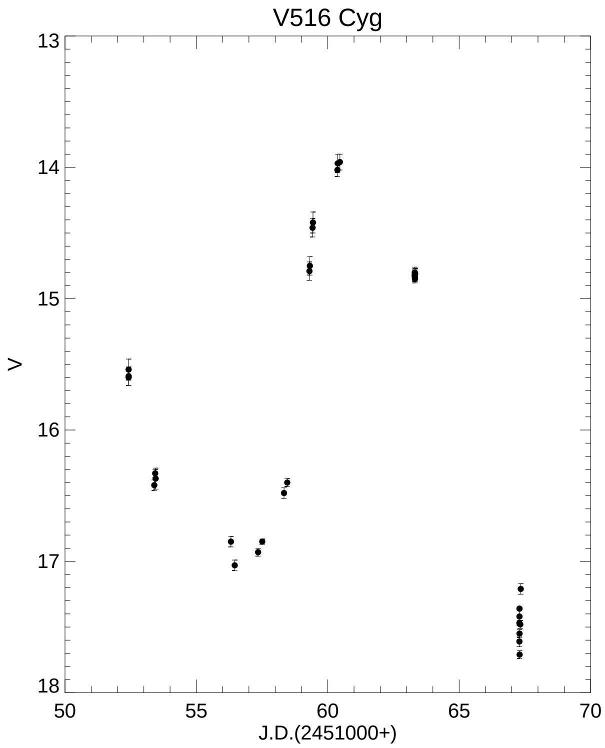


**Figure 1.** *V* light curve of V516 Cyg.

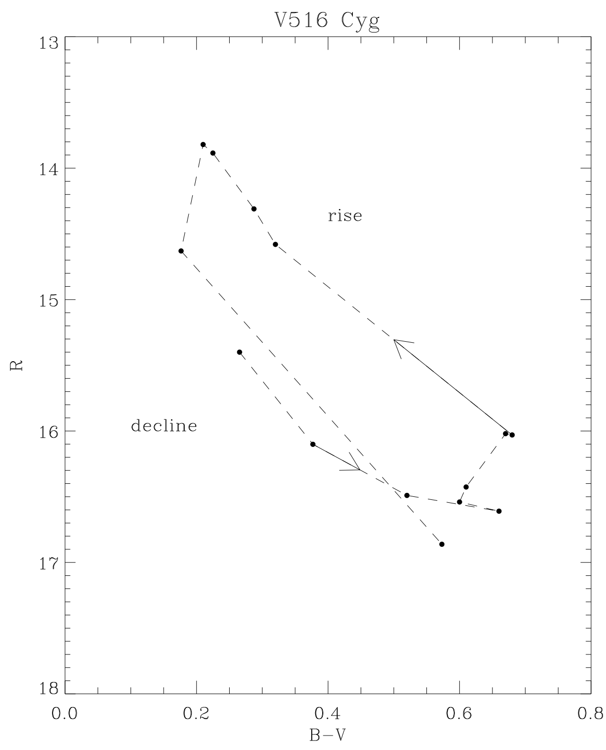


**Figure 2.** Colour index variations of V516 Cyg during the outburst

Table 2: $BVR_cI_c$ magnitudes of V516 Cyg

| JD (2451000 +) | $B$ | $V$ | $R_c$ | $I_c$ |
|---|---|---|---|---|
| 52.4202 | $15.85 \pm 0.03$ | $15.58 \pm 0.04$ | $15.40 \pm 0.02$ | $15.11 \pm 0.03$ |
| 53.4277 | $16.74 \pm 0.07$ | $16.36 \pm 0.02$ | $16.10 \pm 0.01$ | $15.66 \pm 0.01$ |
| 56.3205 | $17.37 \pm 0.03$ | $16.85 \pm 0.04$ | $16.49 \pm 0.01$ | $15.97 \pm 0.05$ |
| 56.4615 | $17.69 \pm 0.02$ | $17.03 \pm 0.04$ | $16.61 \pm 0.02$ | $15.96 \pm 0.04$ |
| 57.3540 | $17.53 \pm 0.02$ | $16.93 \pm 0.03$ | $16.54 \pm 0.02$ | $15.92 \pm 0.02$ |
| 57.5042 | $17.46 \pm 0.03$ | $16.85 \pm 0.02$ | $16.43 \pm 0.01$ | $15.82 \pm 0.03$ |
| 58.3344 | $17.15 \pm 0.04$ | $16.48 \pm 0.04$ | $16.02 \pm 0.01$ | $15.40 \pm 0.02$ |
| 58.4545 | $17.08 \pm 0.02$ | $16.40 \pm 0.03$ | $16.03 \pm 0.02$ | $15.49 \pm 0.03$ |
| 59.3086 | $15.09 \pm 0.02$ | $14.77 \pm 0.05$ | $14.58 \pm 0.01$ | $14.37 \pm 0.01$ |
| 59.4285 | $14.73 \pm 0.01$ | $14.44 \pm 0.05$ | $14.31 \pm 0.01$ | $14.14 \pm 0.02$ |
| 60.3679 | $14.23 \pm 0.01$ | $14.00 \pm 0.04$ | $13.89 \pm 0.01$ | $13.82 \pm 0.02$ |
| 60.4603 | $14.17 \pm 0.01$ | $13.96 \pm 0.06$ | $13.82 \pm 0.03$ | $13.76 \pm 0.05$ |
| 63.3205 | $15.00 \pm 0.03$ | $14.83 \pm 0.01$ | $14.63 \pm 0.01$ | $14.47 \pm 0.03$ |
| 67.3155 | $18.00 \pm 0.05$ | $17.42 \pm 0.01$ | $16.86 \pm 0.07$ | $16.41 \pm 0.02$ |

(usually two in every filter), Table 2 reports only the average values. All photometric $V$ measurements are shown in Figure 1.

At the beginning the dwarf nova was declining from a previous outburst and, at the end of August, it reached the minimum values of magnitude: $B = 17.7$, $V = 17.0$, $R_c = 16.6$ and $I_c = 16.0$. The new rising phase started a few days after and V516 Cyg reached the maximum in the night of September 3rd (JD 2451060), with $B = 14.2$, $V = 14.0$, $R_c = 13.9$ and $I_c = 13.8$. The star returned to minimum on September 10th (JD 2451067) with $V \simeq 17.4$, with a difference between the minimum and the maximum of $\Delta V \simeq 3.4$: our data show that sometimes V516 Cyg becomes fainter than the values listed by many catalogues. In this phase rapid oscillations are evident within a range of almost half a magnitude (see Fig. 1).

Figure 2 shows the almost entire loop of the $B - V$ colour index as a function of magnitude for V516 Cyg. At similar brightness levels, the system is bluer during decline and redder at rise.

Only very few investigations of colour changes in DNe during the full outburst cycle have been carried out up to date. The few observations reported in literature show that some sources follow a loop in the colour–magnitude diagram (see Warner 1995). This behaviour can be well explained with disk instability models. In these models, bursts which begin at a small disk radius (inside-out) produce symmetric light curves with comparable rise and decline times, while eruptions starting at a large disk radius (outside-in) generate asymmetric light curves with short rise times and protracted declines (Cannizzo & Kenyon 1987). The colour–magnitude loop can also be used to separate outside-in and inside-out outburst: in the first case the evolution of the colours is characterised by a large loop in the C–M diagram, while the colour evolution is exactly the same in the rise and decline phase for the inside-out outburst (the loop collapses to a line in the C–M diagram).

The fact that the outside-in outburst produces a reddening in colour when the instability sets in is basically equivalent to the UV delay phenomenon at the onset of outburst (for a review see Osaki 1996). In this case we obviously have a large loop in the colour–

magnitude diagram.

Our data show a large loop in the C–M diagram of V516 Cyg, which suggests that the predicted outside-in outburst of disk instability models are in agreement with the observations presented here.

In conclusion, we can say that the data presented here can be considered a substantial contribution to the poor optical database of V516 Cyg. In particular these measurements complete the preceding data reported in Spogli et al. (1998) covering for the first time the optical multicolour behavior over the outburst cycle.

Our observations are in agreement with outside-in outbursts, as described by Cannizzo & Kenyon (1987) in their disk instability models. The observed outburst probably starts in the outer part of the disk and the heating front propagates from the outside to the inside.

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