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BVRI OBSERVATIONS OF V503 CYGNI IN SUPEROUTBURST

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Dwarf novae (DNe) are a subclass of cataclysmic variables characterized by the presence of sudden increases of brightness (outbursts) in the optical light curve. Normal outbursts have amplitudes in the range 2–5 mag and they occur at irregular intervals of time, typically ranging from about ten days to some months. Some dwarf novae show "superoutbursts" in the light curve, which are characterized by a larger amplitude and a longer duration than normal outbursts. Superoutbursts occur at regular, but not strictly periodic intervals of time (see, e.g., Osaki 1996).

Since the behaviour of most DNe is unpredictable, it is very difficult for astronomers to monitor these variables systematically. During DN outburst, the rise is very rapid (typically less than a day), the maximum stands for 2-3 days, and the decline has a typical duration of 4-5 days (Szkody and Mattei, 1984) but it can be as long as a month or more (Warner 1995). Therefore, for the observation of DNe during all the outburst cycle, we need a total availability of the telescope for a considerable amount of time. For this reason most of the optical observations of DNe were carried out by amateur astronomers through visual estimations or, recently, with small telescopes equipped with CCD cameras. However, the important data so collected are generally unfiltered or obtained with only one filter.

Multi-band monitoring is of special interest in order to extend the work done by amateurs, to study the spectral behavior of the optical continuum, and to explore the physics of accretion disks. For this reason in a previous paper (Spogli et al. 1998) we reported BVR_cI_c observations of a small sample of dwarf novae during the descending phase after an outburst. The most relevant conclusion was that the optical spectral distribution of DNe sometimes cannot be well described by steady-state, optically thick, accretion disk models.

V503 Cygni is a dwarf nova of the SU Ursae Majoris class, characterized by short outbursts lasting $\simeq$ 3 days and recurring with a period $\simeq$ 30 days, and superoutbursts lasting $\simeq$ 10 days and spaced by $\simeq$ 88 days (see, e.g., Harvey et al. 1995). Rises to maximum light take only $\simeq$ 1 day for both types of eruption. During quiescence a periodic signal of very large amplitude is evident, with a period of 109 minutes (Szkody et al. 1989, Szkody & Howell 1993). Superhumping is also evident during superoutbursts, with a peak-to-trough amplitude of 0.1 mag and a period of 116.7 minutes (Harvey et al. 1995).

We observed this DN at the Astronomical Observatory of Collurania-Teramo during August-September 1998. The observations were taken with the 0.72-m Ritchey–Chrétien reflector, equipped with a Tektronix 512 CCD camera and B, V (Johnson),

Table 1: BVR_cI_c magnitudes of the selected comparison stars

No.	B	V	R_c	I_c
1	15.15 ± 0.05	14.22 ± 0.04	13.72 ± 0.04	13.25 ± 0.04
3	15.82 ± 0.06	14.95 ± 0.04	14.41 ± 0.04	13.90 ± 0.04
4	11.75 ± 0.05	11.12 ± 0.04	10.78 ± 0.04	10.50 ± 0.04
5	13.98 ± 0.05	13.33 ± 0.04	12.89 ± 0.04	12.45 ± 0.04

Table 2: BVR_cI_c magnitudes of V503 Cyg

JD (2451000 +)	B	V	R_c	I_c
52.4199	13.89 ± 0.03	13.82 ± 0.02	13.66 ± 0.05	13.67 ± 0.02
53.3317	13.80 ± 0.02	13.75 ± 0.01	13.61 ± 0.05	13.64 ± 0.02
53.4180	13.76 ± 0.01	13.67 ± 0.03	13.58 ± 0.05	13.56 ± 0.06
56.2881	14.02 ± 0.04	13.94 ± 0.02	13.76 ± 0.01	13.78 ± 0.02
56.4324	14.12 ± 0.04	14.01 ± 0.01	13.94 ± 0.02	13.92 ± 0.01
57.3275	14.40 ± 0.01	14.19 ± 0.02	14.03 ± 0.01	14.16 ± 0.01
57.4824	14.39 ± 0.04	14.33 ± 0.02	14.20 ± 0.01	14.24 ± 0.03
58.2997	14.28 ± 0.03	14.28 ± 0.02	14.16 ± 0.02	14.22 ± 0.01
58.4364	14.45 ± 0.01	14.37 ± 0.02	14.23 ± 0.02	14.19 ± 0.02
59.2819	14.33 ± 0.03	14.29 ± 0.02	14.18 ± 0.02	14.19 ± 0.03
59.4048	14.49 ± 0.04	14.40 ± 0.01	14.25 ± 0.01	14.26 ± 0.01
60.3307	14.57 ± 0.05	14.61 ± 0.01	14.40 ± 0.01	14.37 ± 0.05
63.2908	14.90 ± 0.02	14.83 ± 0.01	14.64 ± 0.02	14.65 ± 0.04
67.2803	18.10 ± 0.03	17.71 ± 0.02	17.44 ± 0.01	17.64 ± 0.02

R_c, I_c (Cousins) filters. Each CCD frame was corrected using bias and dark frames obtained before and after each series of BVR_cI_c exposures. The usual flat-field correction was obtained with twilight sky flat fields.

The CCD frames were processed with MIDAS using typical photometry packages that calculate the instrumental magnitudes through synthetic aperture photometry. Although the telescope scale was relatively small (0.5 arcsec/pixel), all the magnitudes reported in this paper have been obtained using an aperture radius of 4 arcsecs for sake of homogeneity since this is the same we used in Spogli et al. (1998). This aperture size is equal to about four times the typical image FWHM and, since we used the same value for the DN and comparison standard stars, no aperture corrections were necessary.

We performed differential photometry using some comparison stars present in the field and reported by Misselt (1996). In order to check the B, V, R_c calibrations and to obtain I_c secondary standard sequences, the comparison stars were calibrated by observing, on photometric nights, several standard stars (Landolt 1992) having $B - V$ from -0.2 to 1.4, over a wide range of airmasses. The standard magnitudes of the comparison stars reported in Table 1 are the weighted means of the values obtained during at least three photometric nights. The serial numbers reported are as in Misselt (1996). Considering the standard deviation, our data are in agreement with the measurements carried out by Misselt (1996), Henden & Honeycutt (1997) and Harvey et al. (1995): the differences are always within two standard deviations. Moreover we have included the calibration for the I_c filter.

We observed V503 Cyg during the maximum and the phase of decline from a superoutburst. Probably the superoutburst started less than a day before our first observation, and the observed maximum was $V \simeq 13.7$ (JD 2451052), a value which can be considered quite typical. During the night are well evident variations probably due to superhumping. In Table 2 we report the BVR_cI_c magnitudes, while the V light curve can be found in Fig. 1.

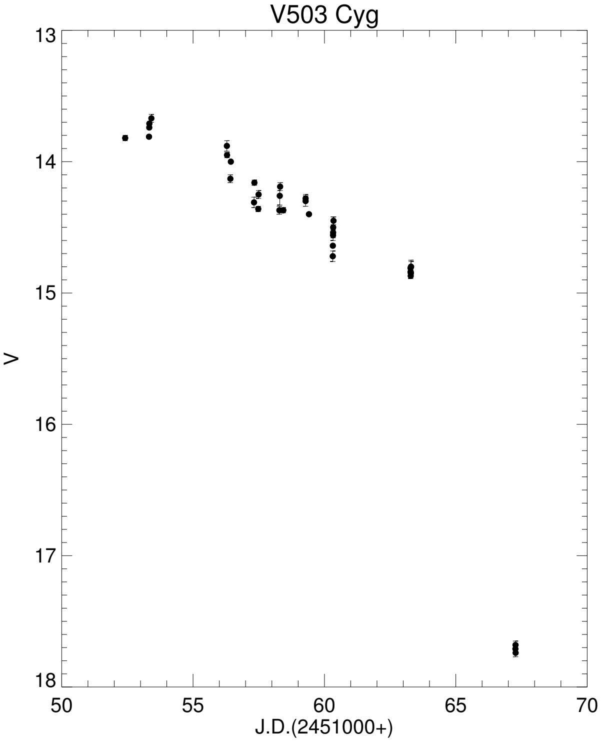

Figure 1. V light curve of V503 Cyg.

During the first week after the maximum (from JD 2451053 to 2451060) the mean colour indices were $B - V = 0.1$, $V - R_c = 0.1$, $V - I_c = 0.1$, and the light curve showed on average a linear decay with the following rates:

$$\begin{aligned} \mathrm{d}m(B)/\mathrm{d}t &= 0.11 \pm 0.01 \text{ mag/day} \\ \mathrm{d}m(V)/\mathrm{d}t &= 0.11 \pm 0.01 \text{ mag/day} \\ \mathrm{d}m(R_c)/\mathrm{d}t &= 0.10 \pm 0.01 \text{ mag/day} \\ \mathrm{d}m(I_c)/\mathrm{d}t &= 0.10 \pm 0.01 \text{ mag/day} \end{aligned}$$

These values are quite similar to those recorded in the superoutbursts for AL Com, WZ Sge (Patterson et al. 1996), and V660 Her (Spogli et al. 1998). After this phase the decline was very rapid and in September 10th we observed the minimum ($V \simeq 17.7$).

Our current knowledge and understanding of the physical processes, that form the basis of the DN outburst mechanism, are still subject to a lot of controversy. Although disk-instability models are the most favoured models, some aspects are still unclear and more observations are required. BVR_cI_c observations of dwarf novae allow to evaluate the optical spectral behaviour and, therefore, they can be used as a test to compare theoretical models of accretion disk emission. In particular they can be used to verify the often quoted theoretical flux distribution of a stationary (infinitely) large accretion disk whose surface elements radiate as a black body spectra ($F(\nu) \propto \nu^{1/3}$, see, e.g., Warner 1995). In disk instability models the accretion disk can accumulate a certain amount of gas before it gets unstable. When instability is reached, the accretion of matter to the white dwarf increases dramatically and this explains the outburst. When the accretion disk has lost enough mass, it becomes stable again and the dwarf nova returns to minimum magnitude (see, for example, Cannizzo et al. 1986). One important feature of the disk instability picture is that the disk is never in a steady state: the quiescent disk is rarely close to steady-state, with temperature distribution usually flatter than $T(R) \propto R^{-3/4}$, where R is the radial distance from the center of the disk. Systems in eruption more closely resemble, but never achieve, the steady-state temperature distribution (Robinson et al. 1999; Kenyon 1999). If the temperature distribution is flatter, then the disk spectrum is naturally flatter and the predicted spectral slope is $\alpha \leq 0.33$.

To study the behaviour of the optical continuum of the observed DN during the outburst, we converted the BVR_cI_c magnitudes in fluxes using the conversion factors reported by Bessell (1979). For V503 Cyg we can neglect the extinction coefficient (Szkody 1985). Using the flux values so obtained we note that at the minimum the spectral distribution is dominated by the emission of the secondary star, while at the maximum the spectral distribution follows a power law ($F(\nu) \propto \nu^{\alpha}$). For V503 Cyg we obtain a spectral slope α in the range between 0.5 and 0.8 during the outburst, a value that is greater than expected.

Our data confirm that for some sources the steady-state accretion disk models do not provide a good representation of the optical continuum during the outburst (see, for example, Spogli et al. 1993, 1998). This is a clear evidence about our poor knowledge of the true radiative transfer solution in accretion disk, and more efforts must be made to obtain multi-wavelength observations of DNe.

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