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BVRI PHOTOMETRY OF VW Vul AND NEW COMPARISON STARS

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The dwarf nova VW Vulpeculae is classified as Z Cam (UGZ) in the GCVS (Kholopov et al., 1985–1990), with B magnitudes ranging from 13.1 to 16.27. Shafter (1985) published a spectroscopic study and reported a period of 0.0731 day. However, Thorstensen et al. (1998) computed an orbital period of 0.1687 day from the measurement of $H\alpha$ radial velocities in quiescence. Only a few photometric data are available for this source. Wenzel (1985) found a 19 ± 5 days cycle length on 40 years of archival plates. Bruch & Engel (1994) report $B - V = 0.12$ during the outburst, and $B - V = 0.35$ in quiescence. More recently, Kato (1999) gives the light curve of VW Vul during the 1995 standstill.

With the aim to increase the multi-band photometric database of VW Vul, we observed this source at the Porziano Astronomical Observatory during the summers of 2004 and 2005. The photometric system consists of an 0.35-m Schmidt–Cassegrain telescope, equipped with an HiSIS 23 CCD camera (Kodak Kaf 401E of 762×512 pixels) and B , V , R_c , I_c Johnson–Cousins broad-band filters. The exposure time was 120–300 s depending on the brightness of the object. The frames were first corrected for bias and flat-field, and then processed by a PC-based aperture photometry package developed by one of the authors using DAOPHOT routines (Stetson, 1987).

Few other observations were obtained with the AIT at the Perugia University Observatory (see Spogli et al., 1998 for a description of instruments and data-reduction). There is no evaluable difference between the reduced data obtained with the two different telescopes.

All the data of VW Vul here reported were obtained in differential photometry using the calibration stars given by Misselt (1996) with the numbers M2, M3, M6, M7. Moreover, we calibrated these comparison stars with the I_c filter by observing, on different photometric nights, several standard stars (Landolt, 1992) having $B - V$ from -0.2 to 1.4 , over a wide range of airmass. The weighted averages are: $I_c(M2) = 12.33 \pm 0.05$, $I_c(M3) = 13.61 \pm 0.05$, $I_c(M6) = 13.82 \pm 0.05$, $I_c(M7) = 12.01 \pm 0.05$. All these stars are placed in the East direction of VW Vul, so we included more comparison objects to the sequence. Figure 1 shows the finding chart for the new reference stars that we have found near VW Vul, numbered from C1 to C6. Table 1 gives the V , R_c , I_c data of these new reference stars. The first column gives the number (see Fig. 1), the second and the third columns are the J2000.0 coordinates of the objects, the last column is the number of different nights each new reference star has been calibrated to give the average values reported in columns 4–6.

Table 1: New comparison stars of VW Vul

No.	J2000.0 coord.		V [mag]	R_c [mag]	I_c [mag]	Obs. nights
	α	δ				
C1	20 ^h 57 ^m 32 ^s .82	+25°30'20''3	14.26 ± 0.02	13.86 ± 0.02	13.44 ± 0.03	17
C2	20 ^h 57 ^m 28 ^s .48	+25°33'27''8	15.17 ± 0.05	14.59 ± 0.02	14.03 ± 0.04	16
C3	20 ^h 57 ^m 18 ^s .30	+25°29'49''0	15.39 ± 0.03	14.92 ± 0.01	14.44 ± 0.03	10
C4	20 ^h 57 ^m 20 ^s .95	+25°28'52''5	13.53 ± 0.03	12.49 ± 0.02	11.58 ± 0.03	14
C5	20 ^h 57 ^m 14 ^s .35	+25°29'36''3	16.02 ± 0.05	15.64 ± 0.02	15.27 ± 0.03	5
C6	20 ^h 57 ^m 21 ^s .35	+25°26'34''6	15.41 ± 0.04	14.90 ± 0.03	14.41 ± 0.03	9

Table 2: Photometric data of VW Vulpeculae

UT Date	JD (2453000+)	B	V	R_c	I_c
26/06/2004	182.556	15.08 ± 0.08	14.72 ± 0.04	14.48 ± 0.03	14.24 ± 0.03
27/06/2004	184.421	14.79 ± 0.08	14.50 ± 0.02	14.28 ± 0.02	14.10 ± 0.03
28/06/2004	185.413	14.64 ± 0.09	14.28 ± 0.03	14.11 ± 0.02	13.90 ± 0.03
01/07/2004	188.485	14.34 ± 0.07	13.99 ± 0.03	13.85 ± 0.03	13.59 ± 0.04
02/07/2004	189.457	14.56 ± 0.07	14.25 ± 0.05	14.05 ± 0.03	13.81 ± 0.04
05/07/2004	192.411	15.11 ± 0.08	14.76 ± 0.03	14.48 ± 0.02	14.27 ± 0.04
06/07/2004	193.417		14.84 ± 0.03	14.54 ± 0.04	14.24 ± 0.05
07/07/2004	194.437		14.97 ± 0.03	14.70 ± 0.04	14.37 ± 0.04
09/07/2004	196.475		15.19 ± 0.04	14.85 ± 0.02	14.50 ± 0.03
10/07/2004	197.473	15.38 ± 0.08	14.96 ± 0.02	14.64 ± 0.02	14.38 ± 0.03
13/07/2004	200.437		15.30 ± 0.10	14.98 ± 0.04	14.55 ± 0.04
15/07/2004	202.406	15.28 ± 0.10	14.79 ± 0.02	14.52 ± 0.02	14.18 ± 0.02
17/07/2004	204.471	13.93 ± 0.07	13.71 ± 0.02	13.57 ± 0.02	13.44 ± 0.02
21/07/2004	208.426	14.88 ± 0.08	14.53 ± 0.02	14.30 ± 0.02	14.08 ± 0.02
23/07/2004	210.443	14.68 ± 0.08	14.47 ± 0.05	14.34 ± 0.05	13.99 ± 0.04
14/08/2005	596.525		15.77 ± 0.03	15.39 ± 0.03	15.02 ± 0.04
15/08/2005	597.534	15.77 ± 0.10	15.40 ± 0.04	15.01 ± 0.04	14.61 ± 0.04
16/08/2005	599.441	15.63 ± 0.10	15.15 ± 0.02	14.86 ± 0.02	14.64 ± 0.03
09/09/2005	623.420	15.84 ± 0.05	15.32 ± 0.02	15.03 ± 0.03	14.66 ± 0.03
10/09/2005	624.428	15.65 ± 0.05	15.22 ± 0.03	15.06 ± 0.02	14.71 ± 0.04
23/09/2005	637.415		15.36 ± 0.05	15.06 ± 0.05	14.75 ± 0.04
26/09/2005	640.398		14.61 ± 0.05		14.24 ± 0.04
29/10/2005	673.379		15.17 ± 0.03	14.92 ± 0.02	14.57 ± 0.05
19/11/2005	694.261	14.68 ± 0.07	14.34 ± 0.02	14.16 ± 0.03	13.97 ± 0.03
10/11/2005	695.230	14.95 ± 0.05	14.57 ± 0.02	14.30 ± 0.02	14.10 ± 0.04

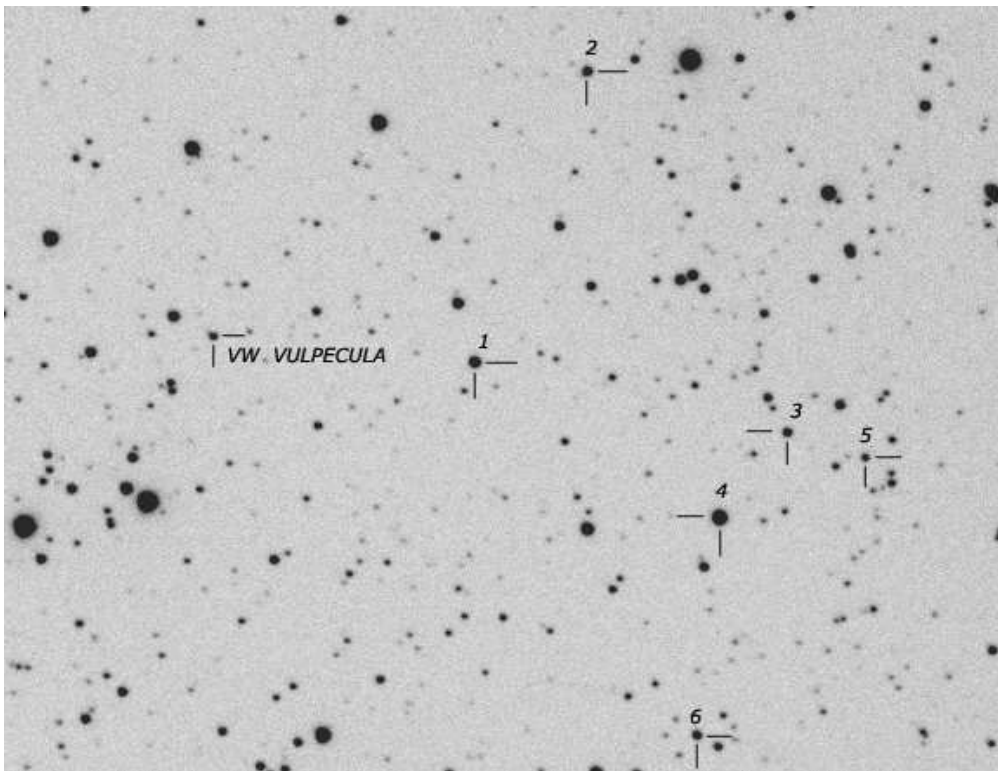


Figure 1. New comparison stars to be added to the Misselt (1996) sequence. North is up and East to the left. The frame is $11' \times 8'$

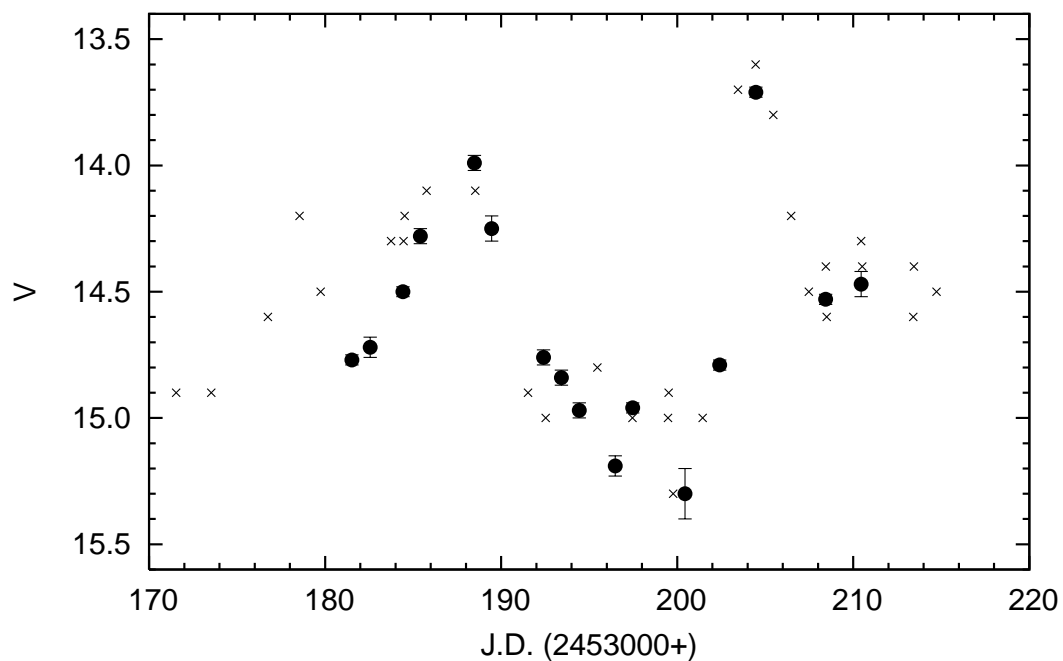


Figure 2. V light curve of VW Vul in summer 2004. Filled circles are our data, while small crosses are visual estimates available from AFOEV (cdsweb.u-strasbg.fr/afoev). The variable was observed during the rise to a low-amplitude outburst, the successive decline and the following fast burst. Error bars show the standard deviations

All the stars have been observed for a minimum of 15 months to a maximum of 19 months, so they can be considered stable.

In 2004, VW Vul has been monitored from June 25 to July 23, for a total of 16 nights (see Figure 2). More observations have been collected in 2005, from August 14 to November 10, so the overall database consists of 26 nights for a total of 95 photometric measurements (Table 2). From these data we can see that VW Vul varies between $V = 13.71 \pm 0.02$ and 15.77 ± 0.03 .

We know that the UV emission of VW Vul during quiescence is dominated by the accretion disk, plus the white dwarf contribution (Henry & Sion, 2001; Urban & Sion, 2006). The strong emission of the disk is evident also in the optical B band, with a relatively low difference in the average $B-V$ color-index: it varies between 0^m30 during the outburst and 0^m45 in quiescence. On the other side, in the infrared part of the spectrum, the emission is usually dominated by the late-type secondary star. The average value of $V - I_c$ varies between 0^m39 and 0^m65 , but the complete variation goes from $V - I_c = 0^m27$ to 0^m79 .

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