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PHOTOMETRIC ANALYSIS OF A NEW W UMa SYSTEM IN VULPECULA

CAPEZZALI, DANIELE[1,2]; FIORUCCI, MASSIMO[1]; SPOGLI, CORRADO[1,2]

[1] Physics Dept. University of Perugia, Via A. Pascoli, 06123, Perugia, Italy

[2] Porziano Astronomical Observatory, Piazza S. Chiara 2, 06081, Assisi, Italy

In the last few years we have repetitively observed the variability of GSC2.3 N32O092280 (J2000.0 $\alpha = 20^{\rm h}58^{\rm m}18\overset{\rm s}{.}8$, $\delta = +25^\circ28'14''$) during a program to study the dwarf nova VW Vul (Capezzali et al., 2007). After our accidental discovery, we soon noted that the variability of this source has been already reported in literature by Pojmanski et al. (2005) with the All Sky Automated Survey (ASAS), but the variability type and the period were quite uncertain and needed of a deeper investigation. Intrigued by the strange behaviour of this source, we began observing intra–night variability at the Porziano Astronomical Observatory, Mt. Subasio, Assisi (Italy). We used a 0.35 m Schmidt-Cassegrain telescope equipped with an HiSIS 23 CCD camera (Kodak Kaf 401E of 762×512 pixels) and standard BVR_CI_C Johnson–Cousins broad-band filters. The intra–night observations were taken on 7, 8, 14 and 15 July 2007, with a total of 256 photometric data with the R_C filter. Moreover we observed the variable during the night of September 15th 2007 in the V and I_C broad bands, and our archive contains BVR_CI_C data of sporadic observations done during the years 2004–2007. The total number of observations is 356 (Electronic table 1).

The CCD frames were first corrected for standard de–biasing and flat–fielding, then processed for aperture photometry and differential photometry using the comparison stars already calibrated for VW Vulpeculae (Capezzali et al., 2007). Every magnitude has been obtained by comparison with at least four stars and we have verified that the typical standard deviation is of the order of 0.01–0.02 magnitudes. The time has been converted in Heliocentric Julian Days.

From a preliminary analysis we noted that the intra–night light curves show a variability of a few tenths of magnitude in all the four bands (Table 1), and minima with a typical recurrence time of $0\overset{\rm d}{.}192225$, in agreement with Pojmanski et al. (2005). However, a deeper analysis soon revealed a small difference in magnitude between two consecutive minima, and a variability feature typical of W UMa systems, i.e. continually changing light levels through all phases with primary and secondary eclipses of almost equal depths. The total eclipse has a relatively long duration (0.1 phases) and suggests an extreme mass ratio system in a state of over–contact. The secondary eclipse is slightly less deep and is total, indicating that the inclination is close to 90°. The preliminary value of the orbital period has been obtained by means of the Fourier periodogram:

$$\mathrm{P} = 0.38451 \pm 0.00002\mathrm{days}(9^{\rm h}13^{\rm m}42^{\rm s})$$

$$\Phi_0 = \mathrm{HJD}2454289.2333 \pm 0.0001$$

Table 1: Photometric parameters of the new variable system

filter	N data	max	min
B	13	13.59±0.06	14.12±0.05
V	34	12.82±0.02	13.29±0.01
R_C	276	12.41±0.01	12.86±0.01
I_C	33	12.01±0.02	12.43±0.02

To estimate the mean effective temperature of star 1 (the star eclipsed at primary minimum), we have initially noted that our BVR_CI_C data suggest a temperature of ∼5200 K, while the JHK values reported by 2MASS (Cutri et al., 2003) are consistent with an higher average temperature (∼5800 K). It is extremely probable that the star is reddened by the interstellar matter in the Vulpecula region, so we used the Galactic Extinction $E(B-V) = 0.18$ reported by Schlegel et al. (1998) to estimate $T_1 = 6100$ K, a value that now allows an agreement between optical and near-infrared dereddened color indices.

We analyzed our dereddened observations with the 2003 version of the Wilson-Devinney program (Wilson & Devinney, 1971; Wilson, 1979, 1990). We used mode 3, appropriate for over–contact binaries of this type, and adjusted the parameters shown in Table 2. As explained before, we set the mean effective temperature of star 1 equal to 6100 K. Unadjusted parameters such as the gravity darkening exponents and bolometric albedos were set to their theoretically expected values for this type of star. Limb darkening coefficients were taken from the tables presented by Van Hamme (1993). Only the principal parameters were iterated: phase of the primary conjunction ϕ_0, inclination i, average temperature of the secondary star T_2, surface potential $\Omega_1 = \Omega_2$, mass ratio q, and relative monochromatic luminosity of the primary star L_1 in the V, R_C and I_C bands. Figure 1 shows the best fit to the VR_CI_C normalized flux versus phase. The geometrical representation is given in Figure 2.

It is well established in literature that the Wilson–Devinney code underestimates the errors (see e.g. Maceroni & Rucinski, 1997), and spurious values can be obtained when fits of almost the same quality have been achieved for a large range of mass ratio values (Kreiner et al., 2003). However, in the favorable case of total-annular eclipses an overcontact photometric mass-ratio is very accurate and reliable (Wilson, 1994; Terrell & Wilson, 2005), and we have effectively verified that the fit is sensibly poorer when the mass ratio is changed.

In conclusion, the average parameters reported in Table 2 give effectively the best fit to our photometric data, while the errors should be at least doubled in order to be realistic. Our solution indicates that GSC2.3 N32O092280 is an A-type W UMa contact binary: the primary minimum corresponds to a transit eclipse of the smaller secondary in front of the larger primary component. These variables usually have surface temperatures greater than 6000 K, in agreement with the estimate obtained considering the interstellar extinction. The temperature difference between the two components is relatively small (≃190 K) and this is in agreement with a good thermal contact. The primary component is over five times the mass of the secondary component ($M_2/M_1 = 0.195$).

Further photometric and spectroscopic observations could be useful since the system shows the night-to-night variability that is common for W UMa systems, and the maximum at phase 0.75 is slightly brighter than the maximum at 0.25 (O'Connell effect).

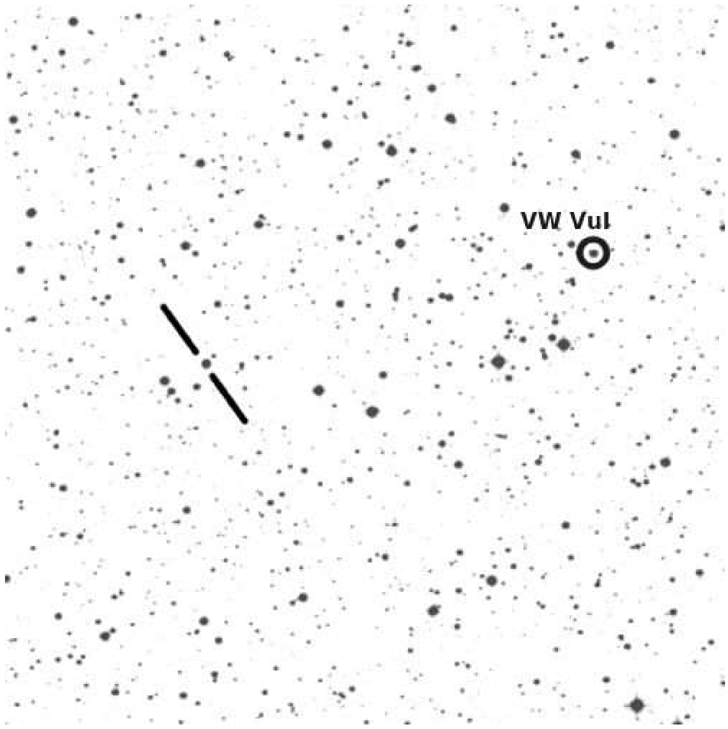

Figure 1. Finding chart of the new variable.

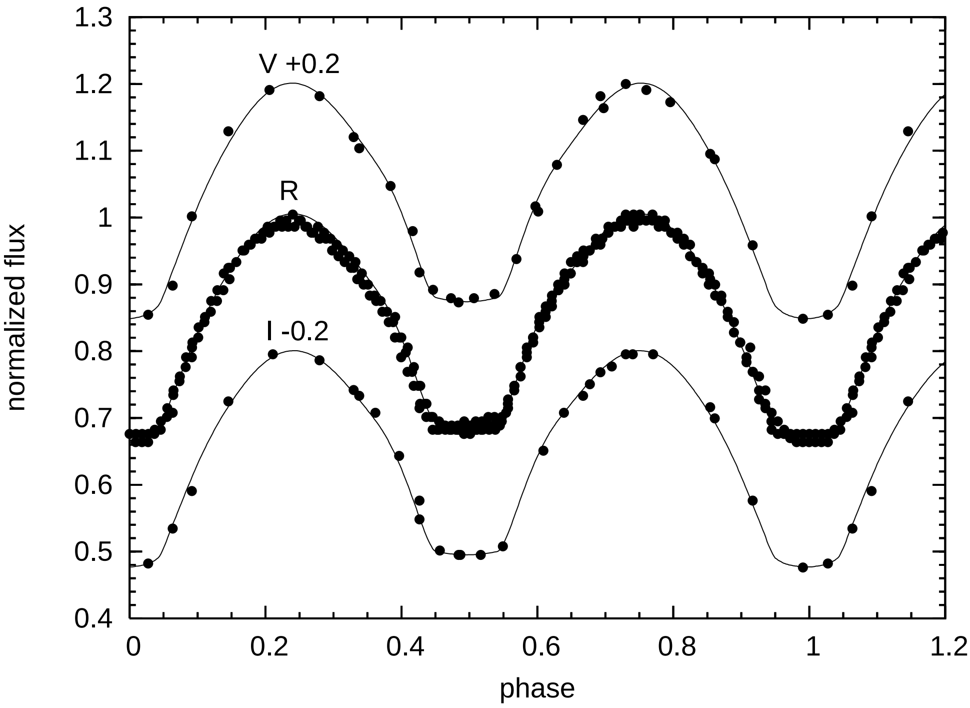

Figure 2. Comparison between theoretical (lines) and observed (circles) VR_CI_C phase diagrams of the new variable system in Vulpecula. The best fit is obtained with the Wilson-Devinney code for an A–type W UMa over–contact binary.

Table 2: Adjusted Parameters from the Wilson-Devinney code

Parameter	Value	Std. Error*
i	89°	1°
T_1	6100 K	(assumed)
T_2	5912 K	49 K
$q = M_2/M_1$	0.195	0.003
Ω_1	2.17	0.01
Ω_2	2.17	0.01
$L_1/(L_1 + L_2)V$	0.829	0.006
$L_1/(L_1 + L_2)R_C$	0.826	0.002
$L_1/(L_1 + L_2)I_C$	0.824	0.005
r_1^{pole}	0.500	0.001
r_2^{pole}	0.244	0.001
r_1^{side}	0.549	0.001
r_2^{side}	0.256	0.001
r_1^{back}	0.575	0.001
r_2^{back}	0.302	0.001

* Formal errors from the differential corrections solution.

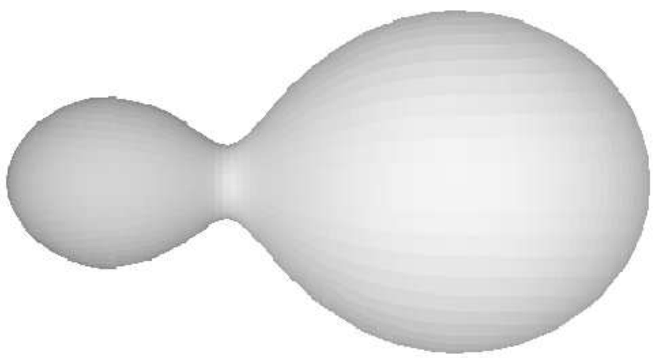

Figure 3. Geometrical representation of GSC2.3 N32O092280 during the maximum

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