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A photometric study of the contact binaries V523 Cas and TY UMa

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ABSTRACT

Broad-band *V* and *I* photometry of the short-period W UMa-type contact binaries V523 Cas and TY UMa are reported. From the light curves, the system parameters have been determined and evidence is presented for extensive spot activity in both systems, with V523 Cas being the more active system. A compilation of all the available photoelectric and CCD-based timings of eclipse minima is made; the O–C diagrams show evidence for an increasing period in the case of V523 Cas and a decreasing period in TY UMa. In addition we derive a more accurate astrometric position for V523 Cas from our CCD images.

Key words: stars: activity – stars: atmospheres – binaries: eclipsing – stars: fundamental parameters – stars: late-type.

1 INTRODUCTION

The W UMa group of short-period eclipsing binaries are important test beds for theories of stellar evolution and magnetic dynamo processes. The evolution towards shorter orbital periods and into contact is thought to occur by means of angular momentum loss via magnetic braking (see for example Rucinski 1994; Sarna & Fedorova 1989). After contact has been established, the systems are expected to oscillate about shallow contact via thermal relaxation oscillations (the TRO theory, cf. Lucy 1976; Vilhu 1982; Rucinski 1986; Eggleton 1996). Many of the W UMa systems show evidence for period changes but on time-scales that are several orders of magnitude shorter than that predicted by TRO theory.

A possible explanation for these shorter-period variations has been proposed by Applegate (1992). This mechanism explains these orbital modulations as gravitational coupling of the orbit to variations in the shape of a magnetically active star during the course of a magnetic cycle. Whilst this mechanism has the potential to explain the short-term period behaviour of W UMa systems, there is a lack of the necessary high-quality observational data for many systems and too short a time base of available accurate timings of eclipse minima to make a serious test of the Applegate mechanism.

In their review of the subject area, Maceroni & van't Veer (1996) noted that only about 15 per cent of the 561 stars listed as W UMa type binaries in the Fourth General Catalogue of Variable Stars have relatively complete studies. Of these 78 systems, less than half have spectroscopic mass ratios derived with modern techniques. Although there has been some significant improvement recently (Lu & Rucinski 1999; Rucinski & Lu 1999), there is clearly a great deal of scope for improvement. As part of a continuing programme investigating magnetic activity on detached and contact binaries with high-precision photometry, we have examined the contact systems V523 Cas and TY UMa.

V523 Cas ($m_V = 10.6$–11.4, spectral type K5V) was discovered to be variable by Weber (1958). It has been studied photometrically by several groups (Bradstreet 1981; Hoffman 1981a; Samec, van Hamme & Bookmyer 1989) and radial velocity measurements were made by Milone, Hrivnak & Fisher (1985). Samec et al. (1989) found a discrepancy between the mass ratio derived from spectroscopy and that derived from photometric solutions.

TY UMa (=SVS 366, $m_V = 11.5$–12.1) was found to be a W UMa-type variable by Beljawsky (1933) and has only been the subject of very few further studies (Broglia & Conconi 1981; Hoffman 1981b; Broglia & Conconi 1983) in the years following discovery. Broglia & Conconi (1983) found evidence for asymmetries in the light curve and slight inequalities in the heights of the two maxima indicating the likely presence of starspots in the system.

2 OBSERVATIONS AND DATA REDUCTION

2.1 Photometry

The photometric observations of V523 Cas and TY UMa were obtained with the 0.9-m James Gregory Telescope (JGT) at the University Observatory, St Andrews, and a Wright Instruments CCD camera mounted at the Cassegrain focus. Full details of the equipment and the photometric reduction procedures employed may be found in Bell, Hilditch & Edwin (1993). Data were obtained in the *V* and *I* filters and exposure times varied from 20 to 60 s depending on the seeing and the filter in use. Typical photometric errors in both filters were ±0.004 mag. The details of the observations are shown in Tables 1 and 2.

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Table 1. Journal of photometric observations of V523 Cas in 1998–99.

UT Date	HJD–245 0000.0	No. of obs.	Filter	Phase coverage
1998 November 24/25	1142.25–1142.44	122	V	$\overline{18}.54$–$\overline{17}.74$
1998 November 28/29	1146.38–1146.64	227	V	$\bar{0}.87$–0.23
1998 December 14/15	1162.29–1162.53	366	I	67.19–68.24
1998 December 23/24	1170.24–1170.41	237	I	105.51–106.23
1999 January 25/26	1204.31–1204.42	139	I	247.02–247.47

Table 2. Journal of photometric observations of TY UMa in 1999.

UT Date	HJD–245 0000.0	No. of obs.	Filter	Phase coverage
1999 March 24/25	1262.31–1262.71	342	V	$\bar{0}.18$–0.94
1999 March 27/28	1265.32–1265.71	621	I	8.36–9.40
1999 December 18/19	1531.42–1531.57	114	V	758.85–759.26

Table 3. Times of minima for V523 Cas and TY UMa.

Time of minima (HJD–2400000.0)	Object	Filter	Type of minima
51142.26200	V523 Cas	*V*	Secondary
51146.46946	V523 Cas	*V*	Secondary
51146.58551	V523 Cas	*V*	Primary
51162.36093	V523 Cas	*I*	Secondary
51162.47682	V523 Cas	*I*	Primary
51171.35786	V523 Cas	*I*	Primary
51262.37684	TY UMa	*V*	Primary
51262.55370	TY UMa	*V*	Secondary
51265.39007	TY UMa	*I*	Secondary
51265.56764	TY UMa	*I*	Primary
51531.47882	TY UMa	*V*	Primary

The data for V523 Cas were initially phased with the ephemeris of Samec et al. (1989):

$$\mathrm{HJD(Min}\,I) = 244\,6708.771\,2 + 0.233\,691\,45E.$$

For TY UMa the only available ephemeris is that of Broglia & Conconi (1983):

$$\mathrm{HJD(Min}\,I) = 243\,9532.496\,5 + 0.354\,538\,609E.$$

These gave phase offsets of ~0.08 and ~0.1 respectively on phasing our data with these ephemerides. We determined several new times of minimum using a bisecting chord code written by one of us (TAL) and these are given in Table 3. The data were phased with the following ephemerides:

$$\mathrm{HJD(Min\,I)} = 245\,1146.585\,60 + 0.233\,691\,45E \quad \mathrm{(V523\ Cas)},$$

and

$$\mathrm{HJD(Min\,I)} = 245\,1262.376\,84 + 0.354\,538\,609E \quad \mathrm{(TY\ UMa)},$$

and the light curves are shown in Figs 1 and 2. In some cases, sections of the light curves have been observed on more than one night, giving rise to complex features. Our check–comparison differential magnitudes are stable to $\leq$0.01 mag and so these features are likely to be intrinsic to the stars and could possibly be caused by re-arrangement of spots on the stellar surface. The raw data is available upon request.

2.2 Astrometry

As the position listed by SIMBAD for V523 Cas was only accurate to arcminutes in declination, we elected to perform astrometry on our CCD frames using the Starlink packages PISA (Draper & Eaton 1998) for object detection and ASTROM (Wallace 1998) to compute the astrometric solution. A six-coefficient plate solution was used and the resulting position for V523 Cas is RA $(2000.0) = 00^{\mathrm{h}}\ 40^{\mathrm{m}}\ 06\overset{\mathrm{s}}{.}21$, Dec. $(2000.0) = +50°\ 14'\ 15\overset{''}{.}6$, with rms errors derived from the reference stars of $0\overset{\mathrm{s}}{.}04$ in RA and $0\overset{''}{.}10$ in Dec.

3 SYSTEM PARAMETERS

We used the well-known LIGHT2 synthesis code (Hill 1979; Hill & Rucinski 1993) to establish values for the geometrical system parameters, namely the orbital inclination, i, the stellar radii relative to the semimajor axis of the relative orbit r_1, r_2 and the temperature ratio of the two stars, T_1/T_2 (yielding component temperatures when combined with an estimate of T_1 derived from a spectral type for example).

Since the data were not obtained simultaneously in each filter and the LIGHT2 code is unable to handle data with non-simultaneous phases, we used a least-squares cubic spline code to interpolate the raw V and I data to provide 200 points in each filter at equal intervals in phase. These interpolated V and I curves were solved simultaneously by LIGHT2 for each system.

Although the filter set used at the JGT has been shown to closely match the Cousins *VRI* set, our data have not been transformed to a standard system. Consequently we could not use our V and I data alone to estimate spectral types or temperatures. As a starting point we used the temperatures derived by previous investigators of each system, i.e. Samec et al. (1989) (V523 Cas) and Broglia & Conconi (1983) (TY UMa), and adjusted the primary temperature and the secondary temperature difference to obtain the best fit.

In addition, since the eclipses are not total in either system, it is not possible to solve for the mass ratio and the inclination simultaneously and so an initial value of q had to be adopted. For V523 Cas the mass ratio was initially fixed at the value derived by Samec et al. (1989), namely $q = 0.571$.

With V523 Cas we experienced problems obtaining a

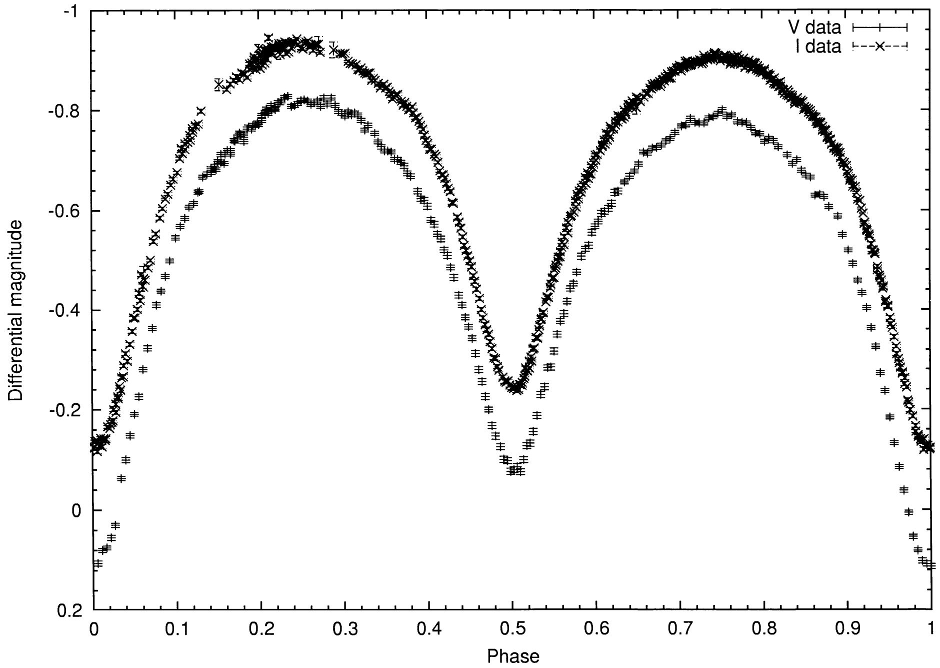

Figure 1. *V*-(bottom) and *I*-(top) band light curves for V523 Cas taken in 1998 November–December. The *I*-band light curve has been shifted by 0.2 mag for clarity.

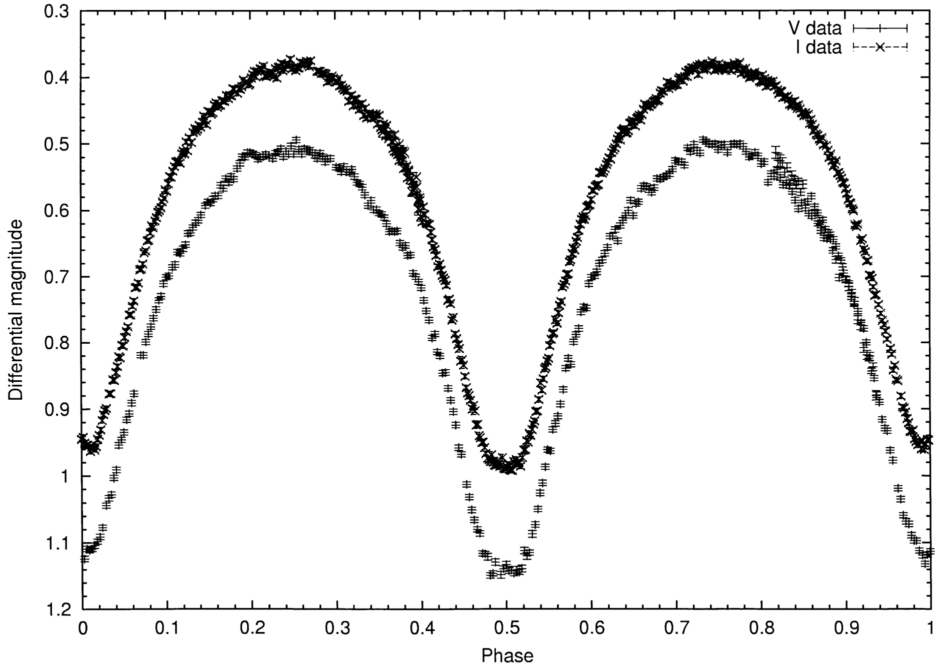

Figure 2. *V*-(bottom) and *I*-(top) band light curves for TY UMa taken in 1999 March. The *I*-band light curve has been shifted by −0.6 mag for clarity.

satisfactory fit to both quadratures simultaneously, because of the unequal maxima (O'Connell effect) and LIGHT2's standard assumption of immaculate photospheres. To solve this problem we performed two sets of fits, specifically

(i) 2nd quadrature points removed (phases 0.6–0.9) and
(ii) 1st quadrature points removed (phases 0.1–0.4).

We found much better fits, in terms of lower values of chi-squared, when the 1st quadrature points were removed and the resulting system parameters are shown in Table 4 along with those of Samec et al. (1989). There is the possibility of an arrangement of spots that could produce a symmetric distortion which would invalidate our assumption of having one undistorted quadrature and could give incorrect system parameters. However, because of the non-uniqueness of spot solutions, especially from photometric data alone, we have elected to proceed under the assumption that the second quadrature is cleaner and will produce system parameters that more accurately reflect the true parameters. The derived parameters agree quite well with those of Samec et al. (1989), the main differences being slightly larger radii and a

Table 4. System parameters for V523 Cas along with the simultaneous fit (Model 3) of Samec et al. (1989).

Parameter	Samec et al. (1989)	LIGHT2 solution (i) (phases 0.6–0.9 removed)	LIGHT2 solution (ii) (phases 0.1–0.4 removed)
r_1/a (polar)	0.406 ± 0.001	0.4335 ± 0.015	0.4184 ± 0.015
r_2/a (polar)	0.324 ± 0.001	0.3296 ± 0.012	0.3136 ± 0.012
i	83°.7 ± 0°.1	83°.97 ± 0°.04	83°.67 ± 0°.04
$q = m_2/m_1$	0.571 ± 0.005	0.53 ± 0.02	0.53 ± 0.02
fillout	13%	29.5%	11.4%
T_1 (polar)	4200 K	4434 K	4434 K
T_2 (polar)	4407 K	4711 K	4720 K
χ^2 of fit	N/A	3.915E-04	2.876E-04

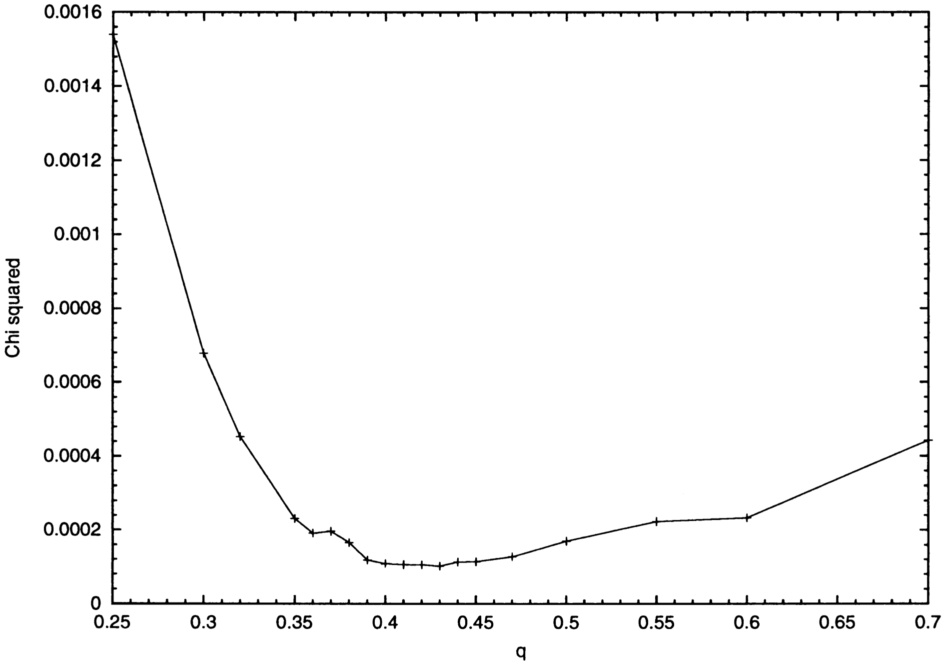

Figure 3. Plot of chi-squared against mass ratio, q, for TY UMa.

Table 5. System parameters for TY UMa.

Parameter	Broglia & Conconi (1983)	LIGHT2 solution
r_1/a (polar)		0.4499
r_2/a (polar)		0.3127
i	83°.3 ± 1°	80°.38 ± 0°.02
$q = m_2/m_1$	0.40 ± 0.02	0.43 ± 0.05
fillout	12%	27.5 ± 0.5%
T_1 (polar)	5550 K	5650 K
T_2 (polar)	5545,5672,5849 K	5892 K

slightly lower mass ratio. As noted by Samec et al. (1989), the mass ratio derived from photometry is discrepant with that derived spectroscopically by Milone, Hrivnak & Fisher (1985) and we also find evidence for a higher mass ratio of $q = 0.53$, in broad agreement with the results of Samec et al. (1989).

This discrepancy between mass ratios determined photometrically and spectroscopically has been seen in several systems and was investigated to some extent by van Hamme & Wilson (1985). They found that neglect of the eclipse and proximity effects can significantly alter the radial velocities and derived mass ratio. We note here that the spectra of Milone et al. (1985) were obtained at relatively low dispersion on photographic plates and no correction for the proximity and eclipse effects were reported. As V523 Cas has the second shortest period of all the W UMa contact binaries, this system warrants a new spectroscopic investigation with modern equipment to try and resolve this discrepancy.

In the case of TY UMa there are no radial velocity data available and only one photometrically determined mass ratio (Broglia & Conconi 1983) and we elected to perform a grid of solutions with a range of q of 0.1–0.7 and the results are shown in Fig. 3.

We show the derived system parameters for TY UMa along with those of Broglia & Conconi (1983), who carried out a fit to their B- and V-band data (although they did not derive radii for the stars), in Table 5.

We found a minimum chi-squared for TY UMa at a mass ratio of $q = 0.43 \pm 0.01$ which is not too discrepant from that found by Broglia & Conconi (1983) of $q = 0.40 \pm 0.02$. However we find the degree of overcontact, defined to be $(\Omega_{\mathrm{inner}} - \Omega)/(\Omega_{\mathrm{inner}} - \Omega_{\mathrm{outer}})$, to be significantly different at 27.5 per cent compared to their value of just 12 per cent. The reasons for this large apparent change in the degree of contact in the 18 yr separating the two

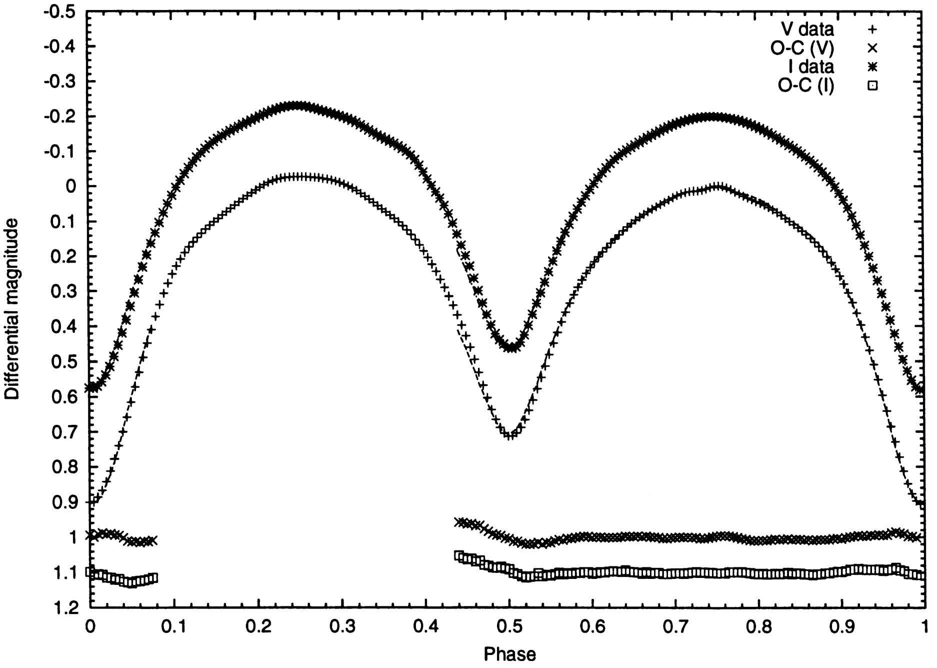

Figure 4. *V*-(bottom) and *I*-(top) band light curves for V523 Cas formed from the normal points, along with the LIGHT2 model fits. The *I*-band light curve and fit have been shifted by −0.2 mag for clarity. The (observed model) curves have been shifted by 1.0 and 1.1 mag for *V* and *I* respectively.

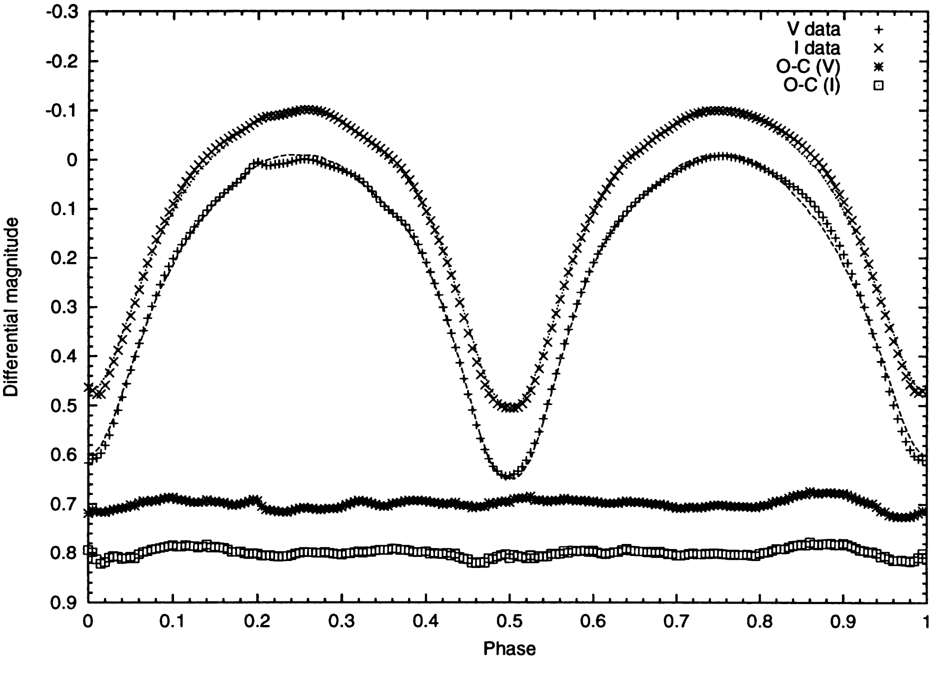

Figure 5. *V*-(bottom) and *I*-(top) band light curves for TY UMa formed from the normal points, along with the LIGHT2 model fits. The *I*-band light curve and fit have been shifted by −0.1 mag for clarity. The (observed model) curves have been shifted by 0.7 and 0.8 mag for *V* and *I*, respectively.

investigations is unclear and the system obviously merits further study.

The normal points used to solve for the system parameters, along with the LIGHT2 fits and O–C light curve residuals, are shown for both systems in Figs 4 and 5.

4 LONG-TERM TRENDS

We have collected all the times of minima based on photoelectric or CCD data that are available in the literature for V523 Cas and TY UMa. The ephemeris of Lavrov & Zhukov (1976), HJD $(\mathrm{Min}\,I) = 244\,1220.303\,6 + 0.233\,690\,5E$, was used as the reference ephemeris for V523 Cas. For TY UMa we used that given by Broglia & Conconi (1983), HJD $(\mathrm{Min}\,I) = 243\,9532.496\,5 + 0.354\,538\,609E$, and times of minima and O–C residuals were computed relative to these ephemerides. The times of minima and the O–C residuals are shown in Tables 6–7 and are plotted in Figs 6–7, along with least-squares quadratic fits to the data.

Table 6. Published times of minima for V523 Cas and residuals calculated from the ephemeris of Lavrov & Zhukov (1976).

HJD−240 0000.0	Cycle No.	Computed	O−C residuals(days)	Reference
41213.52710	−29.0	41213.52658	0.000524	Lavrov & Zhukov (1976)
41220.30360	0.0	41220.30360	0.000000	Lavrov & Zhukov (1976)
41223.45700	13.5	41223.45842	−0.001422	Lavrov & Zhukov (1976)
41225.44300	22.0	41225.44479	−0.001791	Lavrov & Zhukov (1976)
41226.49440	26.5	41226.49640	−0.001998	Lavrov & Zhukov (1976)
41585.44470	1562.5	41585.44501	−0.000306	Lavrov & Zhukov (1976)
41588.24700	1574.5	41588.24929	−0.002292	Lavrov & Zhukov (1976)
41593.39010	1596.5	41593.39048	−0.000383	Lavrov & Zhukov (1976)
41599.35030	1622.0	41599.34959	0.000709	Lavrov & Zhukov (1976)
41942.52470	3090.5	41942.52409	0.000610	Lavrov & Zhukov (1976)
41945.33000	3102.5	41945.32838	0.001624	Lavrov & Zhukov (1976)
41945.44800	3103.0	41945.44522	0.002779	Lavrov & Zhukov (1976)
41950.35350	3124.0	41950.35272	0.000778	Lavrov & Zhukov (1976)
41966.36060	3192.5	41966.36052	0.000079	Lavrov & Zhukov (1976)
41968.46400	3201.5	41968.46374	0.000264	Lavrov & Zhukov (1976)
41972.55310	3219.0	41972.55332	−0.000220	Lavrov & Zhukov (1976)
41973.48760	3223.0	41973.48808	−0.000481	Lavrov & Zhukov (1976)
41975.59250	3232.0	41975.59130	0.001204	Lavrov & Zhukov (1976)
41983.41880	3265.5	41983.41993	−0.001128	Lavrov & Zhukov (1976)
41985.52150	3274.5	41985.52314	−0.001642	Lavrov & Zhukov (1976)
42036.46680	3492.5	42036.46767	−0.000871	Lavrov & Zhukov (1976)
42037.16870	3495.5	42037.16874	−0.000043	Lavrov & Zhukov (1976)
44060.81340	12155.0	44060.81163	0.001772	Bradstreet (1981)
44062.80040	12163.5	44062.79800	0.002403	Bradstreet (1981)
44102.76090	12334.5	44102.75907	0.001828	Bradstreet (1981)
44117.71800	12398.5	44117.71526	0.002736	Bradstreet (1981)
44132.67420	12462.5	44132.67146	0.002744	Bradstreet (1981)
44133.84240	12467.5	44133.83991	0.002491	Bradstreet (1981)
44136.64690	12479.5	44136.64419	0.002705	Bradstreet (1981)
44136.76330	12480.0	44136.76104	0.002260	Bradstreet (1981)
44136.88010	12480.5	44136.87789	0.002215	Bradstreet (1981)
44140.73520	12497.0	44140.73378	0.001421	Bradstreet (1981)
44154.64090	12556.5	44154.63836	0.002537	Bradstreet (1981)
44154.75730	12557.0	44154.75521	0.002091	Bradstreet (1981)
44162.58580	12590.5	44162.58384	0.001960	Bradstreet (1981)
44162.70302	12591.0	44162.70069	0.002334	Bradstreet (1981)
44191.32910	12713.5	44191.32777	0.001328	Hoffman (1981a)
44194.48280	12727.0	44194.48259	0.000207	Hoffman (1981a)
44195.53630	12731.5	44195.53420	0.002099	Hoffman (1981a)
44200.32620	12752.0	44200.32486	0.001344	Hoffman (1981a)
46706.66820	23477.0	46706.65547	0.012731	Samec & Bookmyer (1987)
46707.71910	23481.5	46707.70708	0.012024	Samec & Bookmyer (1987)
46707.83670	23482.0	46707.82392	0.012779	Samec & Bookmyer (1987)
46707.95310	23482.5	46707.94077	0.012334	Samec & Bookmyer (1987)
46708.65440	23485.5	46708.64184	0.012562	Samec & Bookmyer (1987)
46708.77120	23486.0	46708.75868	0.012517	Samec & Bookmyer (1987)
51142.26200	42457.5	51142.21800	0.043996	this work
51142.37950	42458.0	51142.33485	0.044651	this work
51146.46946	42475.5	51146.42443	0.045027	this work
51146.58551	42476.0	51146.54128	0.044232	this work
51162.36093	42543.5	51162.31539	0.045543	this work
51162.47682	42544.0	51162.43223	0.044588	this work
51171.35786	42582.0	51171.31247	0.045389	this work

Both O−C diagrams clearly show evidence of period change, with the period increasing in the case of V523 Cas and decreasing in the case of TY UMa. Although TY UMa has suffered from a lack of study, one noticeable feature is the large apparent jump of ~0.02 d in the ~1000 d between the results of Agerer & Huebscher (1998) and our results. Agerer & Huebscher (1997) also list times of minima for TY UMa, which differ from the later results of Agerer & Huebscher (1998) by ~0.001 d. However, no indication is given as to whether the times of minima of Agerer & Huebscher (1998) are corrections of the earlier ones. We have used the values in Agerer & Huebscher (1998) as these gave the smaller O−C residuals. We carried out two fits to the TY UMa residuals, one with all the data weighted equally and one with the data of Agerer & Huebscher (1998) given half weight and these are also shown in Fig. 7. The one time of minima we obtained in 1999 December fits better with the other minima times obtained in this work, but clearly additional eclipse timings would be very valuable in determining whether this abrupt period increase is real.

Using a quadratic ephemeris of the form $c_0 + c_1\epsilon + c_2\epsilon^2$ and the relation $\dot{P} = 2c_2/P_{\mathrm{le}}$, where $\dot{P}$ is the rate of change of orbital period with time and P_{le} is the reference epoch, we obtain $c_2 = (5.216 \pm 0.146) \times 10^{-10}$ and $c_2 = (-8.63 \pm 1.56) \times 10^{-10}$ for V523 Cas and TY UMa (from the fit with all data weighted equally) respectively. This corresponds to a period increase for V523 Cas of $\dot{P}/P = (1.910 \pm 0.053) \times 10^{-8}\,\mathrm{d}^{-1}$ and a period decrease of $\dot{P}/P = -(1.37 \pm 0.25) \times 10^{-8}\,\mathrm{d}^{-1}$ for TY UMa.

Table 7. Published times of minima for TY UMa and residuals calculated from the ephemeris of Broglia & Conconi (1983).

HJD−240 0000.0	Cycle No.	Computed	O–C residuals(days)	Reference
39532.49710	0.0	39532.49650	0.000600	Broglia & Conconi (1981)
39532.67270	0.5	39532.67377	−0.001070	Broglia & Conconi (1981)
39561.56850	82.0	39561.56877	−0.000271	Broglia & Conconi (1981)
39562.45450	84.5	39562.45512	−0.000621	Broglia & Conconi (1981)
39563.51790	87.5	39563.51874	−0.000840	Broglia & Conconi (1981)
39566.53280	96.0	39566.53233	0.000471	Broglia & Conconi (1981)
39614.39550	231.0	39614.39521	0.000285	Broglia & Conconi (1981)
39643.46730	313.0	39643.46749	−0.000186	Broglia & Conconi (1981)
39648.43060	327.0	39648.43104	−0.000444	Broglia & Conconi (1981)
39673.42470	397.5	39673.42611	−0.001406	Broglia & Conconi (1981)
39676.44070	406.0	39676.43970	0.001005	Broglia & Conconi (1981)
39681.40230	420.0	39681.40325	−0.000954	Broglia & Conconi (1981)
44634.49830	14390.5	44634.50279	−0.004487	Broglia & Conconi (1983)
44634.67400	14391.0	44634.68006	−0.006057	Broglia & Conconi (1983)
44635.56210	14393.5	44635.56641	−0.004307	Broglia & Conconi (1983)
44641.58880	14410.5	44641.59358	−0.004785	Broglia & Conconi (1983)
44642.47520	14413.0	44642.47993	−0.004735	Broglia & Conconi (1983)
44649.38900	14432.5	44649.39346	−0.004462	Hoffman (1981b)
44649.56400	14433.0	44649.57073	−0.006732	Hoffman (1981b)
44723.48700	14641.5	44723.49230	−0.005299	Broglia & Conconi (1983)
44724.37350	14644.0	44724.37865	−0.005149	Broglia & Conconi (1983)
44725.43660	14647.0	44725.44227	−0.005669	Broglia & Conconi (1983)
44730.40050	14661.0	44730.40583	−0.005327	Broglia & Conconi (1983)
50192.52780	30067.5	50192.62464	−0.096843	Agerer & Huebscher (1998)
50193.58940	30070.5	50193.68826	−0.098862	Agerer & Huebscher (1998)
50194.47970	30073.0	50194.57461	−0.094912	Agerer & Huebscher (1998)
50195.36510	30075.5	50195.46096	−0.095862	Agerer & Huebscher (1998)
50195.54170	30076.0	50195.63823	−0.096532	Agerer & Huebscher (1998)
51262.37684	33085.0	51262.44876	−0.071921	this work
51262.55370	33085.5	51262.62603	−0.072331	this work
51265.39007	33093.5	51265.46235	−0.072280	this work
51265.56764	33094.0	51265.63962	−0.071980	this work
51531.47882	33844.0	51531.54454	−0.065717	this work

Since we have not derived absolute values of the masses of the two components for either system, a calculation of the mass transfer rate is not possible. We also note that the available time-scales of about 12 000 d (~30 yr) of accurate times of minima is not long enough for a discriminating test of the Applegate mechanism.

5 DISCUSSION

We have obtained complete high precision *V*- and *I*- band light curves for two W UMa systems and derived system parameters. For V523 Cas we find that the mass ratio obtained is compatible with that derived from other photometric studies, but discrepant with the only spectroscopic study that has been carried out to date. In addition we have derived a new, more accurate astrometric position for this object.

In the case of TY UMa, these data are only the second set of light curves and the first set of complete system parameters to be published. We find a mass ratio for this system which is close to that derived by Broglia & Conconi (1983) but find a large difference in the derived fill-out factors. Further analysis of the astrophysical parameters of this object and investigation into this discrepancy will require spectroscopic data to enable a more accurate mass ratio to be determined.

Both systems show evidence for spot activity and unequal heights of the maxima, with V523 Cas being the more active system, as could be naively expected from its later spectral type and shorter period. The O–C residual diagrams show evidence for period changes in both systems with a period increase in the case of V523 Cas and a decrease for TY UMa. The time-scales of these changes are many orders of magnitude too short for these changes to be explained by TRO or angular momentum loss (AML) theories but a possible explanation in terms of the Applegate mechanism is not yet feasible because of the short baselines of the observations.

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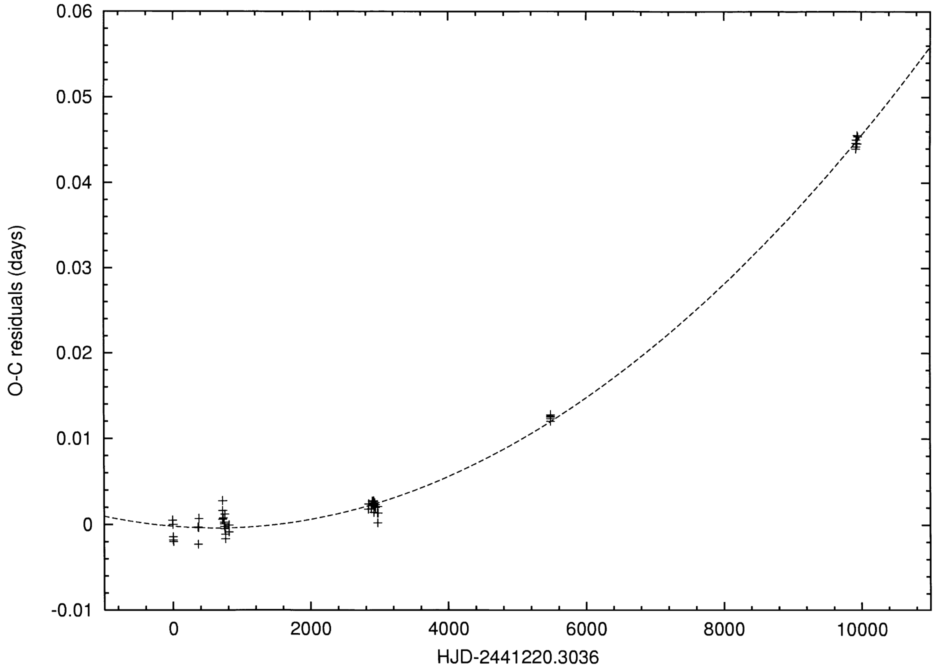

Figure 6. O–C residuals diagram for V523 Cas along with a quadratic fit to the data.

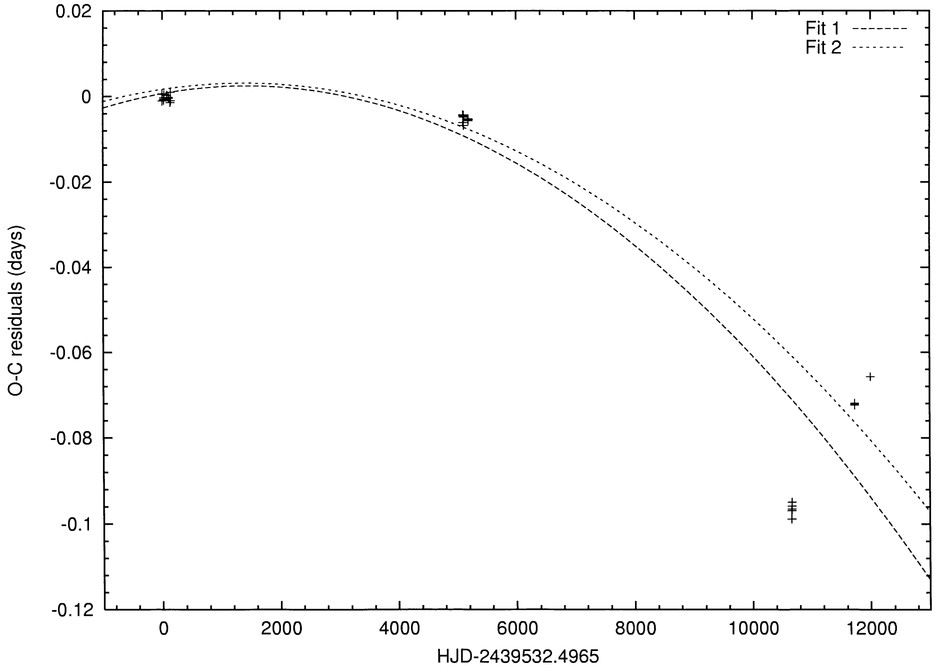

Figure 7. O–C residuals diagram for TY UMa along with quadratic fits to the data. Fit 1 has all the data weighted equally, Fit 2 is with the data of Agerer & Huebscher (1998) given half weight.

REFERENCES

Agerer F., Huebscher J., 1997, Inf. Bull. Variable Stars, 4472,

Agerer F., Huebscher J., 1998, Inf. Bull. Variable Stars, 4562,

Applegate J. H., 1992, ApJ, 385, 621

Beljawsky S., 1933, NNVS, 4, 196

Bell S. A., Hilditch R. W., Edwin R. P., 1993, MNRAS, 260, 478

Bradstreet D. H., 1981, AJ, 86, 98

Broglia P., Conconi P., 1981, Inf. Bull. Variable Stars, 1949

Broglia P., Conconi P., 1983, A&AS, 51, 97

Draper P. W., Eaton N., 1998, PISA, Starlink User Note 109.9, Rutherford Appleton Laboratory

Eggleton P. P., 1996, in Milone E. F., Mermilliod J.-C., eds, ASP Conf. Ser., Vol. 90, The origins, evolution, and destinies of binary stars in clusters. Astron. Soc. Pac., San Francisco, p. 257

Hill G., 1979, Publ. Dominion Astrophys. Obs., 15, 297

Hill G., Rucinski S. M., 1993, in Milone E. F., ed., Lightcurve modelling of eclipsing binary stars. Springer-Verlag, Berlin, p. 135

Hoffman M., 1981a, Inf. Bull. Variable Stars, 1976

Hoffman M., 1981b, Inf. Bull. Variable Stars, 1978,

Lavrov M. I., Zhukov G. V., 1976, Pub. Kazan Univ. Obs., 42, 46

Lu W., Rucinski S. M., 1999, AJ, 118, 515

Lucy L. B., 1976, ApJ, 205, 208

Maceroni C., van't Veer F., 1996, A&A, 311, 523

Milone E. F., Hrivnak B. J., Fisher W. A., 1985, ApJ, 90, 354

Rucinski S. M., 1986, in Cottrell P. L., Hearnshaw J. B., eds, IAU Symp. 118, Instrumentation and Research Programmes for Small Telescopes. Reidel, Dordrecht, p. 159

Rucinski S. M., 1994, Sahade J., McCluskey J. E., Kondo Y., eds, The Realm of Interacting Binary Stars. Kluwer, Dordrecht, p. 111

Rucinski S. M., Lu W., 1999, AJ, 118, 2451

Samec R. G., Bookmyer B. B., 1987, PASP, 99, 1310

Samec R. G., van Hamme W., Bookmyer B. B., 1989, AJ, 98, 2287

Sarna M. J., Fedorova A. V., 1989, A&A, 208, 111

van Hamme W., Wilson R. E., 1985, A&A, 152, 25

Vilhu O., 1982, A&A, 109, 17

Wallace P. T., 1998, ASTROM Starlink User Note 5.17, Rutherford Appleton Laboratory

Weber R., 1958, J. Obs., 41, 74

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