Serb. Astron. J. № 178 (2009), 45 - 48
DOI: 10.2298/SAJ0978045L

UDC 520.82 : 524.316 : 524.383
Original scientific paper

LIGHT CURVE ANALYSIS OF THE LATE TYPE BINARY V523 CASSIOPEIAE

O. Latković[1], M. Zboril[2] and G. Djurašević[1]

[1] *Astronomical Observatory, Volgina 7, 11060, Belgrade 38, Serbia*
E–mail: *olatkovic@aob.bg.ac.yu*

[2] *Astronomical Institute, Tatranská Lomnica, 05960, Slovakia*

(Received: March 9, 2009; Accepted: March 24, 2009)

SUMMARY: We present the analysis of V and R light curves of the late type contact binary V523 Cas for the season of 2006. These observations make part of the monitoring program aimed at studying the long-term light curve variability in this system. Our results confirm that the system is in an overcontact configuration, and include a bright spot in the neck region of the cooler and larger primary. We compare these results with the previous solution, obtained for the season 2005 dataset and discuss the differences.

Key words. binaries: close – binaries: eclipsing – Stars: individual: V523 Cas – Stars: late-type – Stars: activity

1. INTRODUCTION

V523 Cassiopeiae (WR16, CSV 5867, GSC 3257-167) is a close binary of W UMa type with one of the shortest periods in this class of systems. It is also noted for large period changes suggesting that V523 Cas is a member of a hierarchical triple system (Samec et al. 2004), and for light curve variability that also appears to be periodic (Zhang and Zhang 2004).

Such a multitude of interesting astrophysical phenomena made this system attractive for research, and a review of early studies can be found in Zhang and Zhang (2004). Photometric studies revealed that the system is in a W-type overcontact configuration, and a recent spectroscopic study (Rucinski et al. 2003) provided an accurate mass ratio.

Since the previous long-term photometric studies of V523 Cas were primarily aimed at explaining the changes of the period of the system, we have started our own program of photometric monitoring, with the goal of studying the activity in the system in more detail. The program was started in 2005, and the analysis of the first light curves can be found in Zboril and Djurašević (2006). In the present paper we analyze new photometric data, collected in 2006, and obtain results significantly different from those in the previous analysis; most notably, the two solutions differ in the inclination, the temperature of the hotter component, the degree of overcontact and the location of the hot spot, which is now found on the larger and cooler primary. We conclude that these differences can be properly explained only by simultaneous analysis of a longer series of observations, which is the long-term goal of our monitoring program.

2. OBSERVATIONS

V523 Cas was observed in V and R passbands with the SBIG ST10 CCD camera at the 0.5m telescope of Stará Lesná observatory, on September the 5th 2006. The comparison and check stars were GSC 3257-1068 and USNO-A2.0 1350-00691230, respectively. The differential photometry was performed with the basic sequence 3xC-3xV-3xCH (where V stands for the variable, C for the comparison and CH for the check star). Details on the instrumentation and data reduction can be found in Zboril and Djurašević (2006). These observations were published in a special issue of IBVS (2007) and are available online at `http://www.konkoly.hu`.

We used the ephemeris from Samec et al. (2004), with a primary minimum epoch from Parimucha et al. (2007):

$$\begin{aligned} \mathrm{MinI} \; = \; & \mathrm{HJD}\,2453943.4294 \pm 0.0001 \\ & + (0.233691049 \pm 0.0000000078)E \\ & + (1.02 \pm 0.10) \times 10^{-11} E^2 \\ & + (0.0364 \pm 0.0050)\sin[(3.87 \pm 0.25) \\ & \times 10^{-5} E - (1.042 \pm 0.094)] \end{aligned} \tag{1}$$

3. THE LIGHT CURVE ANALYSIS

We analyzed the light curves of V523 Cas using Djurašević's program (Djurašević 1992, see also Djurašević et al. 1998). The program incorporates a binary star model based on the Roche geometry and a simultaneous light curve fitting procedure based on Marquardt's (1963) algorithm. The fitting is carried out by an iterative cycle of corrections to model parameters, minimizing the sum of squared residuals between the observed and the synthetic light curve, $\Sigma(O-C)^2$.

We adopted the values of the mass ratio ($q = m_h/m_c = 0.52$), separation ($a = 1.687R_\odot$) and the temperature of the cooler component ($T_\mathrm{c} = 4762$ K) from Samec et al. (2004), and used the standard values for gravity darkening exponents ($\beta_\mathrm{c,h} = 0.08$), appropriate for convective atmospheres.

Our attempts to construct a simple Roche model of the system with no activity failed to produce a satisfactory fit to the observed light curves, which exhibit slight asymmetries. We then assumed the asymmetries are caused by spots on one or both components. The spots are modeled as circular areas characterized by the temperature contrast parameter, angular radius, latitude and longitude. Following the procedure adopted in our 2006 analysis, we decide initial locations and temperature contrasts of spots by first fitting the albedoes of the components as free parameters. After we found that the albedo of the primary is much higher than one would expect from theoretical considerations, we concluded there is a bright spot on the larger, cooler primary. Subsequently, we fixed the albedo values to $A_\mathrm{c,h} = 0.5$, appropriate for convective atmospheres, and adjusted the spot parameters in the fitting procedure.

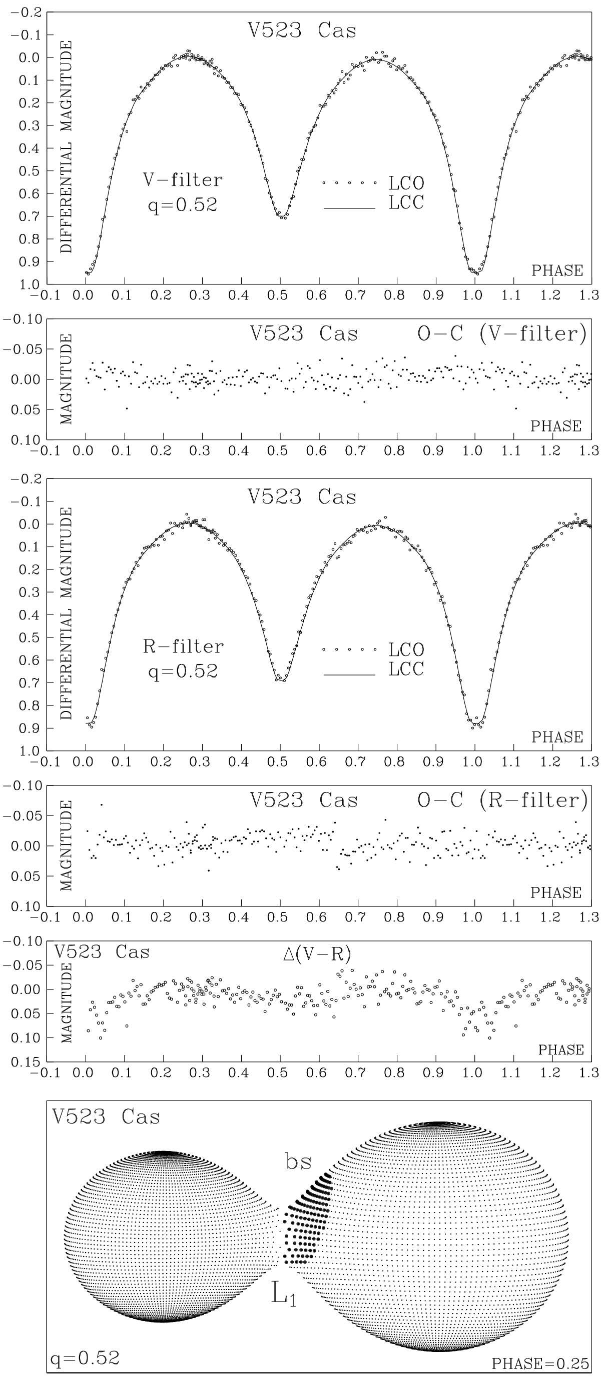

Fig. 1. *Observed (LCO) and synthetic (LCC) light-curves of the V523 Cas with final O-C residuals, obtained by simultaneous analysis of the V and R observations, $\Delta(V-R)$ color curve, and the model with the obtained parameters at orbital phase 0.25.*

Table 1. Results of the simultaneous analysis of the V523 Cas V and R light-curves obtained by solving the inverse problem for the Roche model with a bright spot area on the more-massive (cooler) component.

Quantity		
n	414	
$\Sigma(\mathrm{O-C})^2$	0.0914	
σ	0.0149	
$q = m_\mathrm{h}/m_\mathrm{c}$	0.52	
T_c	4762	
$A_\mathrm{c} = A_\mathrm{h}$	0.5	
$\beta_\mathrm{c} = \beta_\mathrm{h}$	0.08	
$f_\mathrm{c} = f_\mathrm{h}$	1.0	
$\mathrm{A_{bs} = T_{bs}/T_h}$	1.09 ± 0.01	
θ_bs	20.7 ± 1.2	
λ_bs	350.7 ± 2.4	
φ_bs	9.8 ± 3.3	
T_h	5176 ± 18	
F_h	1.025 ± 0.001	
i [°]	84.8 ± 0.3	
$a_1^{\mathrm{c,h}}(\mathrm{V;R})$	$+0.6734, +0.6441;$	$+0.7084, +0.6986$
$a_2^{\mathrm{c,h}}(\mathrm{V;R})$	$-0.8493, -0.6316;$	$-0.7732, -0.6463$
$a_3^{\mathrm{c,h}}(\mathrm{V;R})$	$+1.7369, +1.5110;$	$+1.5146, +1.3522$
$a_4^{\mathrm{c,h}}(\mathrm{V;R})$	$-0.6875, -0.6729;$	$-0.6313, -0.6115$
$\Omega_\mathrm{c,h}$	2.8523	
$\Omega_\mathrm{in}, \Omega_\mathrm{out}$	2.9141, 2.6048	
f_over[%]	20.0	
$R_\mathrm{c,h}[D=1]$	0.421, 0.314	
$\mathrm{L_c/(L_h + L_c)}$	0.540[V]; 0.550[R]	
$M_\mathrm{c}[\mathrm{M}_\odot]$	0.78 ± 0.02	
$M_\mathrm{h}[\mathrm{M}_\odot]$	0.40 ± 0.02	
$R_\mathrm{c}[\mathrm{R}_\odot]$	0.76 ± 0.02	
$R_\mathrm{h}[\mathrm{R}_\odot]$	0.57 ± 0.02	
$\log g_\mathrm{c}$	4.56 ± 0.02	
$\log g_\mathrm{h}$	4.53 ± 0.02	
$M_\mathrm{bol}^\mathrm{c}$	6.21 ± 0.02	
$M_\mathrm{bol}^\mathrm{h}$	6.48 ± 0.03	
$a_\mathrm{orb}[\mathrm{R}_\odot]$	1.687 ± 0.012	

Note: n - total number of the V and R observations, $\Sigma(\mathrm{O-C})^2$ - final sum of squares of residuals between observed (LCO) and synthetic (LCC) light-curves, σ - standard deviation of the observations, $q = m_\mathrm{h}/m_\mathrm{c}$ - mass ratio of the components, $T_\mathrm{c,h}$ - temperature of the cooler and hotter component, $\beta_\mathrm{c,h}$, $A_\mathrm{c,h}$, $f_\mathrm{c,h}$ -gravity-darkening exponents, albedos and nonsynchronous rotation coefficients of the components respectively, $\mathrm{A_{bs}}$, θ_bs, λ_bs and φ_bs - bright spot temperature coefficient, angular dimension, longitude and latitude (in arc degrees), F_h - filling factor for the critical Roche lobe of the hotter component, i [°] - orbit inclination (in arc degrees), $a_1^{\mathrm{c,h}}$, $a_2^{\mathrm{c,h}}$, $a_3^{\mathrm{c,h}}$, $a_4^{\mathrm{c,h}}$ - nonlinear (V;R) limb-darkening coefficients of the components (Claret's formula), $\Omega_\mathrm{c,h}$, Ω_in, Ω_out - dimensionless surface potentials of the components and of the inner and outer contact surfaces respectively, f_over[%] - degree of overcontact, $R_\mathrm{c,h}$ - polar radii of the components in units of the distance between the component centres, $L_\mathrm{c}/(L_\mathrm{h} + L_\mathrm{c})$ - luminosity (V;R) of the more massive cooler star (including the bright spot on the primary), $M_\mathrm{c,h}[\mathrm{M}_\odot]$, $R_\mathrm{c,h}[\mathrm{R}_\odot]$, - stellar masses and mean radii of stars in solar units, $\log g_\mathrm{h,c}$ - logarithm (base 10) of the system components effective gravity, $M_\mathrm{bol}^\mathrm{c,h}$ - absolute bolometric magnitudes of V523 Cas components and $a_\mathrm{orb}[\mathrm{R}_\odot]$ - orbital semi-major axis in units of the solar radius.

4. RESULTS

The analysis of the new light curves has led to a very good fit with $\Sigma(O-C)^2 = 0.0914$. The inclusion of the bright spot on the primary was necessary to model the asymmetries in the light curves, as it was not possible to achieve a satisfactory fit without it.

The observed and the synthetic light curves are given in Fig. 1, together with a plot of the residuals. The shape of the best-fit model for the system, also found in Fig. 1, includes an indication of location and size of the bright spot.

The parameter values are given in Table 1. Note that the errors of parameters arise from the non linear least-squares method used for fitting, and that the real parameter uncertainties may be up to ten times larger than the given estimates.

In Zboril and Djurašević (2006) we published an analysis of the V523 Cas light curves from 2005, similar to the present one. Since we consider the 2005 season to be the start of the monitoring program, we compare here the results of this previous study to the solution we obtained now.

There are considerable differences in the light curves for the two seasons: the later curves have a larger amplitude, while the difference between the primary and secondary maxima is smaller (primary maximum being the one following the primary minimum). In the more recent data, the primary maximum is at a higher level than the secondary, while in the previous season it was the other way round. This type of variations has been reported in other long-term studies, and it arises from the system activity.

However, these variations have a strong impact on system parameters, and our solutions for the two seasons also differ considerably. Most notably, the current solution prefers the bright spot on the primary, while the previous solution placed it on the secondary. The differences in inclination, the temperature of the hotter secondary and the degree of overcontact are also of interest. The comparison is given in Table 2.

The difference in inclination cannot be attributed to an intrinsic change in the binary; after a larger set of observations is analyzed, the inclination may be estimated with better accuracy. The difference in the temperature of the secondary, on the other hand, as well as change in the location of the bright spot, can be interpreted as a result of the exchange of thermal energy between the components

Table 2. Comparison between results for seasons 2005 and 2006.

Quantity	Season 2005	Season 2006
i [°]	83.5	84.8
T_{h}	4991	5176
f_{over}[%]	4.82	20.0
$A_{\mathrm{bs}} = T_{\mathrm{bs}}/T_{\mathrm{h}}$	1.10	1.09
θ_{bs}	40.0	20.7
λ_{bs}	137.6	350.7
φ_{bs}	48.0	9.8
Spot location	secondary	primary

through the neck region of the system. Since the temperatures of the components are substantially different, we suggest that the bright spot area on the cooler primary is the stage in the process of achieving the thermal equilibrium in the common envelope around the components.

5. CONCLUSIONS

Our analysis of the V523 Cas light curves resulted in a new set of system parameters, which include a bright spot area on the cooler primary. We note that the light curves from season 2006 differ from those of season 2005, resulting also in differences of the obtained system parameters. Since V523 Cas is known to exhibit the light-curve variability, we conclude that monitoring of the system must be continued in a strictly standardized, consistent manner over the scale of several years, providing a series of snapshots of the system in various phases of activity. Such a series of carefully calibrated observations could then be analyzed simultaneously to explain the nature of activity in this astrophysically interesting system.

Acknowledgements – This work was partially funded by the Ministry of Science and Technological Development of Serbia through the project No. 146003.

REFERENCES

Djurašević, G.: 1992, *Astrophys. Space Sci.*, **197**, 17.
Djurašević, G., Zakirov, M., Hoajev, A., Arzumanyants, G.: 1998, *Astron. Astrophys. Suppl. Series*, **131**, 17.
2007, *Inf. Bull. Var. Stars*, **5799**, 1.
Marquardt, D. W.: 1963, *J. Soc. Ind. Appl. Math.*, **11**, 431.
Parimucha, S. at al.: 2007, *Inf. Bull. Var. Stars*, **5777**, 1.
Rucinski, S. M. et al.: 2003, *Astron. J.*, **125**, 3258.
Samec, G. R., Faulkner, R. D. and Williams, B. D.: 2004, *Astron. J.*, **128**, 2997.
Zboril, M. and Djurašević, G.: 2006, *Serb. Astron. J.*, **173**, 89.
Zhang, X. B. and Zhang R. X.: 2004, *Mon. Not. R. Astron. Soc.*, **347**, 307.

АНАЛИЗА КРИВИХ СЈАЈА ПОЗНОГ ТЕСНО ДВОЈНОГ СИСТЕМА V523 CASSIOPEIAE

O. Latković[1], M. Zboril[2] and G. Djurašević[1]

[1]*Astronomical Observatory, Volgina 7, 11060, Belgrade 38, Serbia*
E–mail: *olatkovic@aob.bg.ac.yu*

[2]*Astronomical Institute, Tatranská Lomnica, 05960, Slovakia*

УДК 520.82 : 524.316 : 524.383
Оригинални научни рад

Представљамо анализу V и R кривих сјаја позне контактно двојне звезде V523 Cas за сезону 2006. Ова посматрања су део програма праћења са циљем да се проучи дугорочна промена кривих сјаја. Наши резултати потврђују да је систем у контактној конфигурацији са заједничким омотачем, и откривају светлу пегу на хладнијој, већој компоненти. Ове резултате поредимо са решењем добијеним са подацима из сезоне 2005. и дискутујемо њихове разлике.