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SV Cam spot activity in December 2003

M. Zboril[1] and G. Djuraševič[2]

[1] *Astronomical Institute of the Slovak Academy of Sciences*
059 60 Tatranská Lomnica, The Slovak Republic, (E-mail: zboril@astro.sk)

[2] *Astronomical Observatory, Volgina 7, 11160, Belgrade, Yugoslavia*
and Isaac Newton Institute of Chile, Yugoslav branch

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Abstract. We present the analysis of new BV light curves for the active star SV Cam applying the Roche model with spotted areas on the hotter primary component. Two spots at medium latitudes and covering about 14% of the stellar surface were revealed. Both are ∼1000 K cooler than the surrounding photosphere. The comparison with earlier seasons (2000-2003) suggests that the spots probably evolved in area longitude and latitude. Both tidal effect and activity cycle mechanisms may be in action.

Key words: stars – binaries – eclipsing

1. Introduction

Cool spots on other stars than the Sun can be used to trace the magnetic flux that emerges from an unknown dynamo process in the stellar interior. Some advanced techniques have been used to about 36 components in close binary systems (e.g. Strassmeier 2002) with next further distribution in masses, rotational periods and ages. An early theoretical background for high-latitude cool spots came from Schüssler et al. (1996) for example and later from Granzer et al. (2000). Recently, the role of tidal effects in rapidly rotating close binaries has also started as a next further investigation. Holzwarth & Schüssler (2002) predict theoretically the non-uniform spot distribution, this time longitudal in the systems. Generally, because of difference in activity of the Sun and active stars, there may be the difference in field distribution and magnetic flux tubes.

The active star SV Cam (HD44982, p∼0.59d, sp. ∼F8, m_V=9.34) is an eclipsing binary and has been extensively studied since its discovery (Guthnick 1929) due to its asymmetry and overall shape of the light curves and magnetic activity on probably both components. The system has probably the signatures of an active RS CVn system and is a good candidate for study of the basic activity signatures, spots, even from pure photometry. The basic properties of the system (mass ratio, spectral type, radii etc.) are discussed in our previous contribution (Zboril & Djuraševič 2003) and the key properties of the system are in Table 2.

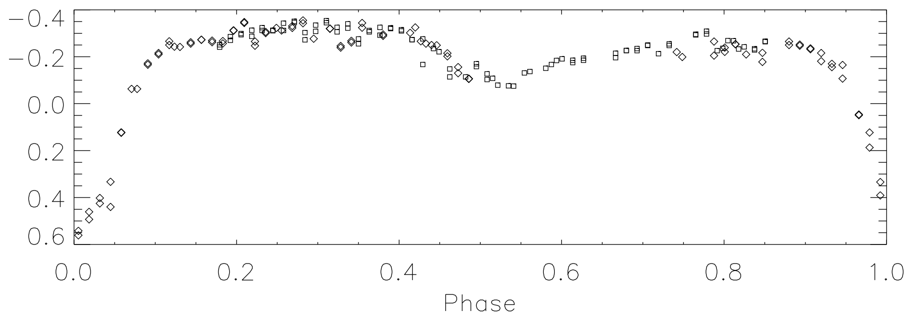

Figure 1. The original SV Cam **V light curves** in the season 2003. **Diamonds**-night 02.12.2003 and **squares**-night 07.12.2003 respectively.

2. Observations

New observation in UBV filters were obtained on 3 nights with two 0.6m telescopes at the Skalnaté Pleso and Stará Lesná observatories in the season December 2003. The detectors were photometers OPTEC SSP-5, HAMAMATSU R4457 and EMI 9789 Q multipliers. The differential photometry was performed with the sequence 3xS-3xV-3xCH and sky background and all corrected for differential extinction. The comparison stars were SAO 1045 (S, standard) and SAO 1030 (CH, check). The reduction process was properly described in previous paper. The BV light curves were analysed from 2 nights and Table 1 gives the basic log of observations and the differences in instrumental magnitudes in V filter between the comparison and check S-CH to demonstrate night stability. Given the check star's visual magnitude and the integration time, we arrived at some scatter (see the STD values) but the stability of the nights is acceptable. The light curves are available upon request on the following URL address *http://www.ta3.sk/caosp/Eedition/FullTexts/vol34no2/pp128-134.dat/*. The photometric phases of the light and colour curves were calculated with the help of the ephemeris (Pojmański 1998) as in previous paper. The ephemeris reads

$$MinI = 2449350.3037 + 0^d.593071 \times E \qquad (1)$$

3. Light curve analysis

To analyze the asymmetric light curves we used the improved version of the Djurašević (1992a) code, which is based on the Roche model and the principles from the paper by Wilson & Devinney (1971). The light-curve analysis was made by applying the inverse-problem method (Djurašević, 1992b) based on

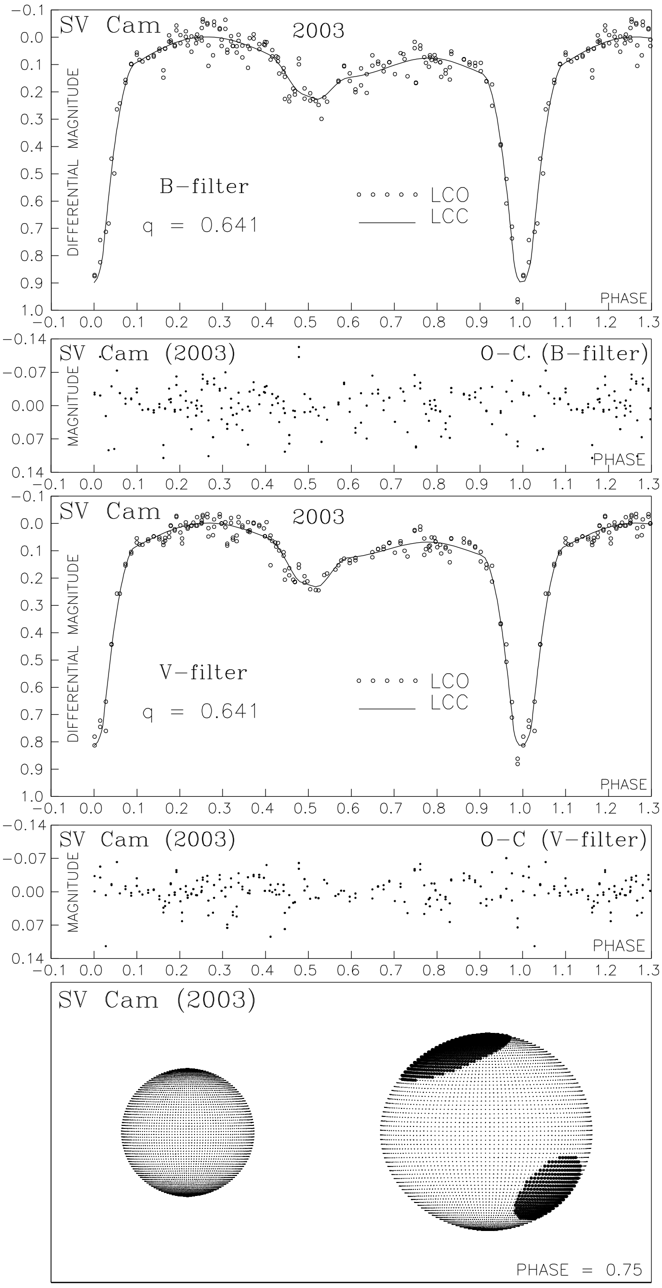

Figure 2. The observed (LCO) and synthetic (LCC) light curves of the SV Cam system in BVR filters respectively. The bottom panel is the Roche model for the system at orbital phase 0.75.

Table 1. Log of observations.

Date	*Filter*	*Obs.*	$S-CH$
2.12.2003	BV	SL	0.281 ± 0.044
7.12.2003	BV	SL	0.275 ± 0.035
9.12.2003	BVR	SP	0.281 ± 0.003

SP-Skalnaté Pleso, SL-Stará Lesná

the modified Marquardt's (1963) algorithm. The recent demonstrations of the code for close binary systems is given in Albayrak et al. (2001) and Zboril & Djurašević (2003), including the SV Cam system with the stellar parameters adopted. The limb-darkening was treated according to Claret's non-linear approximation (Claret & Hauschildt 2003). Table 2 and figure 2 show the final solution with the activity indicators; spots respectively. The order of magnitude of tidal effects is (e.g. Holzwarth & Schüssler 2002)

$$tid \sim 10^{-2}\frac{q}{(q+1)}(\frac{r}{R_\odot})^3(\frac{M}{M_\odot})^{-1}(p)^{-2} \tag{2}$$

These authors simulated the locations of erupting flux tubes for the parameter $tid = 10^{-3}$ (q=1, M=M$_\odot$, $a = 8$R$_\odot$, p=2^d, q is the mass ratio between two components) and found the preferred longitudes. These, however, depend on initial magnetic field strength and stellar latitude as well. The parameter tid is of order 5.10^{-3} for each SV Cam component and this result yields the tidal effects (on spot distribution) probably very significant but the lack of knowledge of the magnetic field properties disables us to make a cut-off conclusion. More general approaches (e.g. gravitational quadrupole-moment) to close binary systems were pointed out by Lanza and Rodonó (2002) for example.

Note to Tab. 2: n - number of observations, $\Sigma(\mathrm{O}-\mathrm{C})^2$ - final sum of squares of residuals between observed (LCO) and synthetic (LCC) light curves, σ - standard deviation of the observations, $q = m_\mathrm{c}/m_\mathrm{h}$ - mass ratio of the components, $f_\mathrm{h,c}$, $\beta_\mathrm{h,c}$, $\mathrm{A_{h,c}}$ - nonsynchronous rotation coefficients, gravity-darkening exponents and albedo of the components, $T_{h,c}$ - temperature of the hotter primary and cooler secondary, $\mathrm{A_{S1,2}}$, $\theta_\mathrm{S1,2}$, $\lambda_\mathrm{S1,2}$ and $\varphi_\mathrm{S1,2}$ - spots' temperature coefficient, angular dimension, longitude and latitude (in arc degrees), $\mathrm{F_{h,c}}$ - filling factors for the critical Roche lobe of the hotter (more-massive) and cooler (less-massive) star, i [°] - orbit inclination (in arc degrees), $a_1^\mathrm{h,c}$, $a_2^\mathrm{h,c}$, $a_3^\mathrm{h,c}$, $a_4^\mathrm{h,c}$ - nonlinear (B;V) limb-darkening coefficients of the components (Claret's formula), $\Omega_\mathrm{h,c}$ - dimensionless surface potentials of the primary and secondary, $\mathrm{R_{h,c}}$ - polar radii of the components in units of the distance between the component

Table 2. Results of the analysis of the SV Cam light curves obtained by solving the inverse problem for the Roche model with two active cool area on the more-massive (hotter) component.

Quantity		
n	368	
$\Sigma(\mathrm{O-C})^2$	0.4656	
σ	0.0355	
$q = m_\mathrm{c}/m_\mathrm{h}$	0.641	
$f_{\mathrm{h,c}}$	1.0	
$\beta_{\mathrm{h,c}}$	0.08	
$\mathrm{A_{h,c}}$	0.5	
$\mathrm{T_h}$	6030	
$\mathrm{A_{S1,2} = T_{S1,2}/T_h}$	0.84	
θ_{S1}	35.1 ± 1.3	
λ_{S1}	335.5 ± 4.3	
φ_{S1}	65.7 ± 1.6	
θ_{S2}	24.4 ± 0.8	
λ_{S2}	216.4 ± 3.4	
φ_{S2}	-36.8 ± 3.2	
$\mathrm{T_c}$	4478 ± 70	
$\mathrm{F_h}$	0.830 ± 0.007	
$\mathrm{F_c}$	0.665 ± 0.005	
i [°]	89.4 ± 1.0	
$a_1^{\mathrm{h,c}}(\mathrm{B;V})$	$+0.4072, +0.4726;$	$+0.6598, +0.6994$
$a_2^{\mathrm{h,c}}(\mathrm{B;V})$	$+0.2248, +0.2809;$	$-0.9938, -0.9230$
$a_3^{\mathrm{h,c}}(\mathrm{B;V})$	$+0.5241, +0.2145;$	$+1.7602, +1.7277$
$a_4^{\mathrm{h,c}}(\mathrm{B;V})$	$-0.2990, -0.1862;$	$-0.4871, -0.6161$
$\Omega_{\mathrm{h,c}}$	3.672, 4.174	
$\mathrm{R_{h,c}[D=1]}$	0.327, 0.213	
$\mathrm{L_h/(L_h+L_c)(B;V)}$	0.928; 0.917	
$\mathcal{M}_\mathrm{h}[\mathrm{M}_\odot]$	1.09 ± 0.05	
$\mathcal{M}_\mathrm{c}[\mathrm{M}_\odot]$	0.70 ± 0.02	
$\mathcal{R}_\mathrm{h}[\mathrm{R}_\odot]$	1.22 ± 0.03	
$\mathcal{R}_\mathrm{c}[\mathrm{R}_\odot]$	0.78 ± 0.03	
$\log g_\mathrm{h}$	4.31 ± 0.03	
$\log g_\mathrm{c}$	4.50 ± 0.03	
$\mathrm{M_{bol}^h}$	4.18 ± 0.03	
$\mathrm{M_{bol}^c}$	6.44 ± 0.05	
$a_{\mathrm{orb}}[\mathrm{R}_\odot]$	3.60 ± 0.05	

centres, $L_h/(L_h + L_c)$ - (B;V) overall luminosity of the hotter star (in both filter systems), $\mathcal{M}_{h,c}[M_\odot]$, $\mathcal{R}_{h,c}[R_\odot]$ - stellar masses and mean radii of stars in solar units, log $g_{h,c}$ - logarithm (base 10) of the mean surface acceleration (effective gravity) for system stars, $M_{bol}^{h,c}$ - absolute bolometric magnitudes of SV Cam components, and $a_{orb}[\mathcal{R}_\odot]$ - orbital semi-major axis in units of solar radius.

The Table 3 gives the basic spot parameters (area in degrees, longitude and latitude, the standard deviation of the observations) for the system in the latest observational seasons. These data are adjoined with another dataset from Albayrak et al. (2001). It is clear that the two main spot areas responsible for the light curves evolved in their basic properties. The spots appear at medium latitudes while Heckert (1996) found low latitudes for the season 1995 and Kjurkchieva et al. (2000) revealed the spots at medium latitudes in 1997. The latter gave also the preferred intervals for spot longitudes, (45-110 degrees) and (240-300) respectively. Importantly, Busso et al. (1985) analysed the light curves (1973 -1984) and found 10 yrs activity cycle (the spots dimension and location). On the other hand, the calculations based on equation (2) give the support to tidal effect on magnetic flux-tubes in the system. Of other systems, for example CN And (p=0.46^d) was studied by Van Hamme et al. (2001), RZ Tau (0.4^d) by Yang & Liu (2003) and BH Vir (0.8^d) by Xiang & Zhou (2004). All these short period systems revealed the spots where the longitude locations are present in (or close to) the interval afore-mentioned.

Table 3. Seasonal spot parameters in V filter.

Date	*spot*1 θ, λ, φ	*spot*2 θ, λ, φ	*err.b.*	*err.b.*	$\sigma(O-C)$
I/II 2000	20, 103, 51	14, 186, −29	0.3, 1.8, 0.9	0.3, 1.5, 2.0	0.011
II/V 2001	13, 323, 11	19, 103, −50	1.0, 11.0, 16.0	1.0, 12.0, 6.0	0.029
II/III 2002	17, 289, 26	13, 206, −11	1.0, 6.0, 15.0	0.7, 8.0, 19.0	0.028
XII 2003	35, 336, 66	24, 216, −37	1.3, 4.3, 2.0	0.8, 3.4, 3.2	0.030

spot dimension θ, longitude λ and latitude φ in degrees.

4. Conclusions

We present a research note on BV light curve analysis from the season December 2003 as a final contribution from a short-term project. The main purpose of such kind of study is to find an evolution of the active regions on a stellar surface, and especially in close binaries, where next further effects can be expected (tidal effects). The model with cool spots on a hotter (larger) component of the system fits satisfactorily all filter light curves. The basic spot properties are the following:

1. two spots on the hot component each covering $\sim 9\%$ and 4% of the stellar surface as a minimum spot coverage.
2. the spots temperature is 1000K cooler than the surrounding photosphere and are at medium latitudes.
3. if the spots are identical to the previous seasons (2000, 2002), they have evolved in area, longitude and latitude.
4. the role of tidal effects can not be ruled out.

It is perhaps another technique (Doppler Imaging) which could improve some basic spot parameters on system such as area and, obviously, to obtain the surface magnetic field configuration the spectropolarimetry of the system would be welcome as well.

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