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Activity-induced variability in SV Cam, RZ Tau and II Peg in winter 2004/2005

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Abstract. We report on a search for activity-induced variability in two eclipsing systems SV Cam, RZ Tau and a single lined spectroscopic binary II Peg in the winter season 2004/2005. The SV Cam system was modelled with two activity centers-spots on the primary cooler than the surrounding photosphere with total spot coverage ∼20%. On the contrary, the RZ Tau system (its Roche lobe filling factor of order 0.42) displays symmetric light curves and no O'Connell effect is detected. The shape of the II Peg light curve can not be matched easily with a single spot model. Instead, a two spot model (alternatively a non-uniform high latitude spot complex) cooler than the photosphere can model the observed light curves with spot coverage ∼10%.

Key words: late-type stars – activity – spots

1. Introduction

Nowadays many aspects of solar analogy are widely studied on stars. These studies are obviously important to know the atmosphere activity phenomena and also serve as the input data to magneto-hydrodynamical models. Up-date modelling results of thin flux tubes evolution originating in the over-shooting layer to the photospheric layer are more and more available (e.g. Schuessler 2005). Monitoring the activity induced variability is a specific subtopic helping to reveal the behaviour of magnetic activity cycles on solar and late-type stars in practice. In terms of solar analogy the spots are believed to be the uppermost parts of magnetic flux tubes and due to long-term magnetic cycles and stellar rotation they induce both spectroscopic and photometric variabilities. The spots properties on a variety of systems (single stars, binaries, Sun's spots etc.) and their (often unusual) behaviour are from time to time reviewed (Strassmeier 2002, Schuessler 2002).

The active star **SV Cam** (HD44982, sp ∼F8, m_V=9.34) is an eclipsing binary and has been the subject of photometric studies since its discovery in the 30-ties due to magnetic activity possibly on both components and with the role of tidal effects. The activity cycle is expected on the scale of about 10 years (Busso et al. 1985) and therefore we continue monitoring the target aiming at studying the activity cycle. The magnetic cycle was revealed on the amplitude modulation of light curves and the phase displacements. The cycle (and possible tidal effects) are believed to be illustrated directly on the activity centers - the spots. The following linear ephemeris has been used

$$MinI = HJD\ 2\ 449\ 350.3037 + 0.^{d}593071\ \times E, \tag{1}$$

being the same as in our previous papers (e.g. Zboril & Djuraševič 2004).

The SB1 system **II Peg** (HD 224085, K2IVe, $V_{max.}$=7.4) is a well-known chromospherically active star of the RS CVn type. This system shows multi-wavelength line variability, broad-band photometric variability, and significant variability of the hydrogen profile resulting from chromospheric, transition and coronal activity. The star is often used to demonstrate the existence of activity cycles on stars other than Sun, and a very large total spot coverage and the maximal brightness of the star varies with time (Byrne et al. 1995, O'Neal et al. 1998). This star is an example of the most active RS CVn type stars. The following (original) linear ephemeris has been used (Vogt 1981)

$$MinI = HJD\ 2\ 422\ 218.9750 + 6.^{d}7240\ \times E. \tag{2}$$

The star **RZ Tau** (HD285893 sp ∼F8, m_V=10.35) is a W-UMa type eclipsing binary and many minima were observed as well as some light curves solutions were published (e.g. Morris & Naftilan 1997, Yang & Liu 2003). Importantly, the stability of light curves of the system is still an open question. Yang & Liu analysed the O-C diagram of the period changes and found a new ephemeris which we used in our study

$$MinI = HJD\ 2\ 452\ 620.1116 + 0.^{d}41567758\ \times E + 5.5.10^{-11}\ \times E^2. \tag{3}$$

A long-term magnetic cycle has yet to be recognised.

2. Observations

The SV Cam star was monitored during the winter season 2004 using the 0.6m telescopes at Stará Lesná (G2 dome) and Skalnaté Pleso observatories equipped with single channel photometers.

The standard differential V photometry with the sequence ...S − V − CH ...was made as well as the standard reduction process including the corrections for differential extinction. The check star (CH) was SAO 1030 and the standard star (S) was SAO 1045. The complete dataset is available in an electronic form at the http://www.astro.sk/caosp/Eedition/FullTexts/vol36no2/pp77-84.dat/ address. The log of observations is shown in Table 2 where the star name, date,

Table 1. The log of observations.

Star	Date	Filter	Obs.	S−CH
SV Cam	10.12.2004	V	SL-G2	0.02
SV Cam	11.12.2004	V	SP	0.03
RZ Tau	15.12.2004	BV	SL-G2	0.02
RZ Tau	15.01.2005	BV	SL-G2	0.02
RZ Tau	16.01.2005	BV	SL-G2	0.02
RZ Tau	17.01.2005	BV	SL-G1	0.01
RZ Tau	09.02.2005	BV	SL-G1	0.01

filter, code for the observatory and the difference standard minus check star are in the columns.

The II Peg star was also monitored using the 0.6m and 0.5m (G1 dome) telescopes at the Stará Lesná observatories equipped with a single channel photometer and a CCD 1024x1024 Apogee camera respectively. The comparison star (S) was SAO 91586 and the check star (CH) SAO 91593 and the observations (transformed to the international photometric system) are listed in Table 2 again with the following columns: date, filter, Julian date, magnitude difference variable minus check. The difference S-CH was remarkably stable within 0.02 mag.

Table 2. The II Peg observations.

Date	Filter	2400000+	phase	$\triangle$m	Filter	$\triangle$m
15.8.2004	V	53233.406	0.497	7.730 ±0.001	B	8.633 ±0.001
16.8.2004	V	53234.494	0.655	7.720 ±0.005	B	8.626 ±0.006
17.8.2004	V	53235.410	0.795	7.635 ±0.004	B	8.531 ±0.006
27.8.2004	V	53245.374	0.277	7.708 ±0.013	B	8.593 ±0.007
05.9.2004	V	53254.390	0.620	7.701 ±0.005	B	8.604 ±0.004
10.9.2004	V	53259.385	0.360	7.730 ±0.006	B	8.639 ±0.010
5.10.2004	V	53284.307	0.065	7.542 ±0.002	B	8.424 ±0.002
7.10.2004	V	53286.292	0.360	7.719 ±0.003	B	8.628 ±0.004
10.12.2004	V	53350.232	0.870	7.520 ±0.004	B	8.400 ±0.006
11.12.2004	V	53351.176	0.030	7.508 ±0.005	B	8.397 ±0.004
21.12.2004	V	53361.199	0.500	7.769 ±0.005	B	8.688 ±0.004
15.01.2005	V	53386.204	0.220	7.679 ±0.008	B	8.559 ±0.010

The RZ Tau star was monitored with the 0.5m telescope equipped with a CCD camera and with the 0.6m telescope, both in the Stará Lesná Observatory. In the case of CCD observations 4 nearby standard stars were used in the reduction process and the standard star (HD29181) and check star (HD29270) were used in the case of a photoelectric observations reduction. Similarly to the SV Cam system, observational data are available at the URL address.

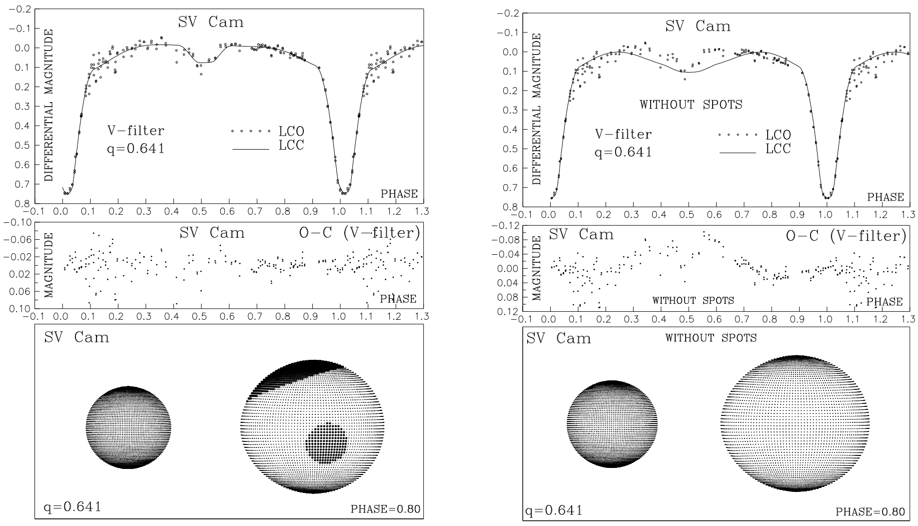

Figure 1. The SV Cam light curves modelling.

3. Analysis

The final analysis of the binaries was made using the code of Djuraševič, see Djuraševič et al. (2004) for the details and Zboril & Djuraševič (2004) for the code application, and SB1 systems such as the II Peg are analysed using the Spotmod code (Zboril 2003). This star is not an eclipsing binary. The graphical output of light curves analysis is in Figures 1, 2, 3 and 4, respectively. Main results are presented in Table 3, detailed results of modelling and main characteristics of stars are in Tables 4, 5, 6 altogether with the original data, all available at the URL address.

3.1. Eclipsing binaries

The SV Cam's light curve was first modelled without spots to demonstrate the signatures of spots or otherwise. However, the light curve does not resemble another one (Djuraševič 1998) from the past which is believed to be minimally distored by the presence of spots. In addition, the modelling technique (the inverse problem) suggests a contradictory temperature for the secondary and the Roche filling factor as well. Consequently, the light curve was modelled with

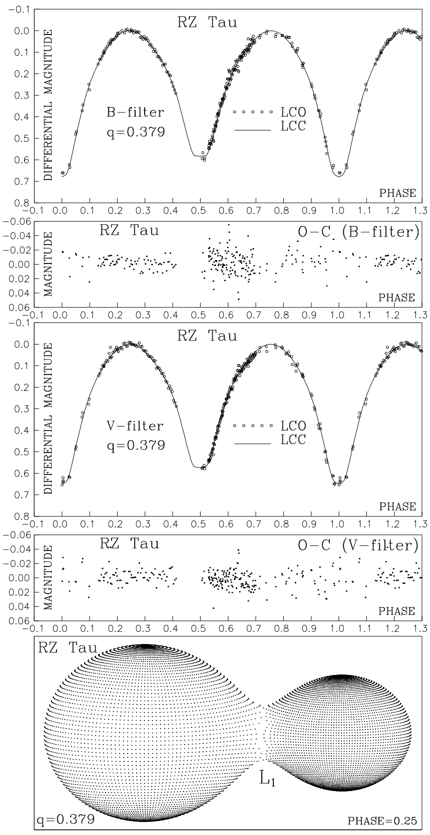

Figure 2. The RZ Tau light curves modelling.

spots and this is illustrated in Figure 1. The SV Cam binary was found to be active in terms of two activity centers-spots located at both low and high latitudes. The monitoring is to be continued to reveal details of an expected 10-year magnetic activity cycle. Recently, high latitude (non-rotational modulating) spot signatures were detected on the (more massive) primary using the Hubble Space Telescope (Jeffers et al., 2005) with absolute calibrated fluxes. These data contribute significantly to describe and understand the behaviour of stellar dynamo. The observations of this star appeared early in the literature, but recent studies are Zboril and Djuraševič (2004), Kjurkchieva et al. (2002). These and previous studies all give the support to the idea of activity centers-spots in the atmosphere of the primary. The RZ Tau does not display the activity centers in the season. The light curves are symmetric and no O'Connell effect is observed. On the contrary, Yang & Liu observed the asymmetry in the winter season 2002 and claimed one spot on the secondary (less massive com-

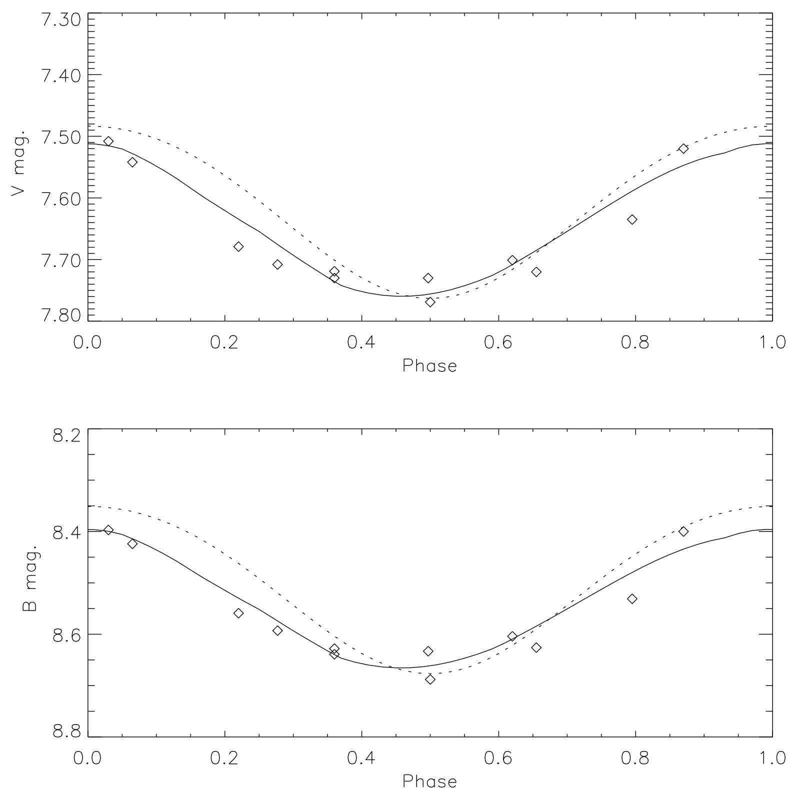

Figure 3. The II Peg B and V light curves modelling. Dots stand for the single spot model.

ponent). This observed effect is, however, not well pronounced, ~0.02 mag. in V filter, but it is the only study desaling with the activity centers-spots up to now. The binary is also interesting with its mass loss rate and possible short-term oscillations on the secondary. The Roche lobe filling factor for this binary is large, about 0.42 and the studies have concentrated so far mainly on orbital parameters determination and the minima timing (Djurašević et al. 1999). Our modelling is presented in Figure 2.

3.2. II Peg star

The modelling obviously started with a small single spot close to the equator and two iterative procedures were used: namely sum-square difference and varying the radius, latitude and temperature, and so called Powell's algorithm. The

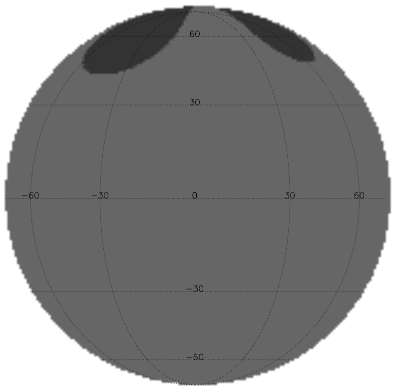

Figure 4. The II Peg two spot configuration at phase 0.50 as seen from the equator (the inclination $i = 90^o$).

Table 3. The activity centers (spots) parameters.

Star	incl. i	Spot	factor f [%]	radius	T$_{eff}$ [K]	phase long.	lat.
SV Cam	89.4	1	17.2	49^o	5065	33^o	68^o
SV Cam	—	2	2.4	18^o	5065	276^o	-14^o
RZ Tau	83.8	—	—	—	—	—	—
II Peg	—	1*	25.0	60^o	4000	180^o	75^o
II Peg	—	1	7.0	31^o	3600	317^o	70^o
II Peg	—	2	3.3	21^o	3600	54^o	65^o

Note: the spot factor f=0.5*(1-cos(radius)), symbol "*" stands for the single spot model

latter can iterate either latitude or radius and we iterated the latitude. Both methods suggested a high latitude spot but more than a single spot are evidently needed. The II Peg (T$_{phot}$=4600K) two spot model is interpreted as an asymetric high latitude spotted pattern. Consequently, our two spot solution may still not be conclusive. However, high latitude spots for particular seasons were confirmed from spectroscopy, for example Gu et al. (2003). The spots seem to survive on a longer time baseline on this object and we found it stable on the scale of $\sim$ four months. These type of studies are also important in inter-comparison with 'historical' light maxima and the magnetic activity cycle has not been determined reliably yet. For example Kjurkchieva and Marchev (1995) indicated $\sim$ 4 yr cycle as based on the light curves maxima only. Similarly, Berdyugina et al. (1999) derived the cycle of 4.65 yr and claimed to a flip-flop phenomenon, all based on Doppler Imaging technique. However, the fit to the long-term light curves used in Kjurkchieva and Marchev gives a longer periodicity, at least 10 yr. Similar technique, namely starspots cycles from long term photometry, was used by Messina and Guinan (2002). By no means we try to derive the activity cycle in this paper but we continue monitoring the object as a first step and offering the analysis in the given season.

4. Conclusions

We presented the analysis of a search for magnetic activity-induced variability on a sample of ($\sim$ solar-type) binaries SV Cam, RZ Tau and the single lined binary II Peg. The analysis relies on multicolor light curve modelling in filters BV, respectively. Monitoring the spot activity is helpful to understand the stellar magnetic activity cycles, and especially in some extreme configurations (like the SV Cam or RZ Tau). Therefore, the monitoring will be continued in future.

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