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MONITORING ACTIVE STARS 29 DRA, 12 CAM AND COLOUR EXCESS OF II PEG

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SUMMARY: We present the BV light curves analysis of late-type, long-period stars 29 Dra, 12 Cam for the season 2005/2006, and shorter-period star II Peg for the same season. High latitude spots (alternatively spot configuration) cooler than surrounding photosphere were able to explain the light curves. The II Peg colour-index shift in H-R diagram is probably a consequence of stellar metallicity. Other associated mechanisms are briefly discussed.

Key words. Stars: late type – starspots – Stars individual: 29 Dra, 12 Cam, II Peg

1. INTRODUCTION

Magnetically induced forms of solar activity, including sunspots, and prominences, have stellar counterparts, often on a dramatically enhanced scale. Starspots are analogues of sunspots wherein strong coherent magnetic fields radically alter subphotospheric convection, reducing the efficiency of energy transport and simultaneously removing subphotospheric energy in the form of waves to accelerate winds. Thus, the starspots properties are worth studying because useful information on stellar dynamo can be revealed. Systematic observations (let us say monitoring) of spotted stars thus emerged and this type of scientific programme was adopted in many observatories. Naturally, monitoring progressed later to fully robotic observations.

To make a contribution to the databases, we had monitored several selected active late-type stars (often with really poor previous record) with an aim to determine basic spot properties such as the temperature, area and location, on a sample of active late-type stars using photometric methods. These techniques are particularly powerful in the case of eclipsing binaries and are occasionally used for single stars. For example a spot signature can be revealed, and physical properties such as overall magnetic cycle, differential rotation, or 'flip-flop' phenomenon, may be estimated from the light curves alone on longer time bases.

2. OBSERVATIONS

New observations in BVR filters were obtained with 0.6m telescopes equipped with photoelectric photometers at Stará Lesná (SL) and Skalnaté Pleso (SP) observatories in the season 2006/2007. The differential photometry was performed with basic sequence 3xS-3xV-3xCH and with sky background; S stands for standard star, V for variable star and CH for comparison (check) star respectively. Data reduction details and main characteristics of the instruments, as well as the photometric error analysis can be found, for example, in Zboril (2005). The targets were included in the list because of the need for long term monitoring and because the database of observations may not be sufficient as well. Tables 1, 2 list our observations. The tables include: modified Julian date, the phase, the magnitude difference (S-V), the standard deviation of the magnitude, number of the observations in a given night, filter used and the (S-CH) magnitude difference, respectively.

Table 1. 29 Dra data in B and V passbands.

MJD	phase	$\triangle m$	std. err.	N	Filter	S-CH
53433.306	0.340	8.135	0.006	15	B	8.321
53638.413	0.850	8.042	0.004	15	B	8.410
53653.229	0.320	8.154	0.007	8	B	8.390
53668.289	0.803	8.017	0.010	10	B	8.407
53672.237	0.928	8.027	0.011	11	B	8.289
53685.485	0.349	—	—	—	B	—
53698.319	0.756	8.064	0.005	14	B	8.395
53743.308	0.180	8.124	0.003	12	B	8.397
53773.290	0.136	8.112	0.010	9	B	8.397
53834.317	0.073	8.093	0.007	12	B	8.386
53864.489	0.031	8.061	0.007	16	B	8.301
53919.375	0.774	8.059	0.009	14	B	8.310
53942.427	0.506	8.132	0.020	12	B	8.308
53991.287	0.056	8.144	0.002	14	B	8.375
54004.255	0.468	8.055	0.003	12	B	8.375
53999.388	0.314	—	—	—	B	—
54067.585	0.479	—	—	—	B	—
54072.190	0.625	8.095	0.008	14	B	8.286
53433.306	0.340	7.014	0.005	15	V	7.810
53638.413	0.850	6.938	0.002	15	V	7.791
53653.229	0.320	7.046	0.007	8	V	7.791
53668.289	0.803	6.927	0.009	10	V	7.789
53672.237	0.928	6.935	0.009	11	V	7.785
53685.485	0.349	7.024	0.006	11	V	—
53698.319	0.756	6.954	0.005	14	V	7.772
53743.308	0.180	7.019	0.002	12	V	7.781
53773.290	0.136	6.989	0.003	9	V	7.766
53834.317	0.073	6.996	0.006	12	V	7.773
53864.489	0.031	6.968	0.003	16	V	7.802
53919.375	0.774	6.947	0.005	14	V	7.794
53942.427	0.506	6.982	0.004	12	V	7.804
53991.287	0.056	7.031	0.004	14	V	7.781
54004.255	0.468	6.960	0.003	12	V	7.774
53999.388	0.314	7.043	0.007	7	V	7.822
54067.585	0.479	6.969	0.006	20	V	7.800
54072.190	0.625	6.989	0.006	14	V	7.794

Table 2. 12 Cam data in B and V passbands.

MJD	phase	$\triangle m$	std. err.	N	Filter	S-CH
53433.268	0.79	7.192	0.003	16	B	10.048
53284.502	0.96	7.173	0.009	12	B	10.050
53350.357	0.77	7.156	0.004	10	B	10.042
53386.376	0.21	7.232	0.004	14	B	10.062
53387.220	0.22	7.220	0.002	12	B	10.045
53462.418	0.15	7.230	0.001	10	B	10.051
53638.342	0.33	7.145	0.003	12	B	10.070
53653.272	0.51	7.019	0.006	10	B	10.052
53668.235	0.70	7.041	0.008	12	B	10.078
53698.275	0.07	7.305	0.003	12	B	10.053
53743.213	0.63	7.072	0.003	12	B	10.052
53807.332	0.42	7.124	0.010	10	B	10.088
53433.265	0.79	6.219	0.004	16	V	9.697
53284.496	0.96	6.238	0.011	12	V	9.712
53350.356	0.77	6.188	0.003	10	V	9.694
53386.376	0.21	6.256	0.002	14	V	9.710
53387.220	0.22	6.250	0.003	12	V	9.694
53462.418	0.15	6.265	0.001	10	V	9.701
53638.344	0.33	6.191	0.002	12	V	9.711
53653.272	0.51	6.090	0.006	10	V	9.697
53668.240	0.70	6.125	0.009	12	V	9.730
53698.275	0.07	6.328	0.003	12	V	9.696
53743.215	0.63	6.120	0.004	12	V	9.697
53807.332	0.42	6.160	0.008	10	V	9.722

3. PHOTOMETRIC ANALYSIS

The data analysis was made by using the code SpotMod (Zboril 2003). The code uses the effective temperature vs. colour index calibration and subsequently the surface brightness flux vs. colour index calibration to compute colours and fluxes. The program calculates by integration on the visible surface of the star the projected area of the spots under consideration. Some photometric light curves were successfully analysed with this software earlier (Zboril 2005).

29 Dra

The RS CVn type star 29 Dra (HD 160538, HIP 85852, K0III, m_V=6.64) has rather long rotational period of ~31.5 day and is a chromospherically active star. Spectroscopic measurements revealed that the object was in fact binary, the red giant accompanied by a white dwarf with the orbital period 903.8 days (Fekel et al. 1993, De Medeiros et al. 2002). Possibly because of the long rotational period, the object has not extensive photometric record. Similarly to Zboril (2005), we used the following linear ephemeris

$$\text{Min I} = \text{HJD } 2444445.0 + 31^d.5 \times E. \quad (1)$$

The light curve is based on the observations from March 2005 to November 2006; the sub-interval (season 2006) covering three complete stellar rotations is particularly well covered.

12 Cam

The active RS CVn type star 12 Cam (HD 323 57, HIP 23743, K0III, m_V=6.09) also has a long rotational period of ~80 days. Its photometric variability was revealed in 1980 and the star appeared in the catalogue of chromospherical active stars in the same year (Eaton et al. 1980, Glebocki et al. 1980). Multiwavelength observations often reflecting the chromospheric activity were obtained by Montes et al. (2000). Recent photometric observations are published in Zboril and Djurašević (2006) and have been used in this paper. The following linear ephemeris has been used (Hall et al. 1993)

$$\text{Min I} = \text{HJD } 2448110.84 + 80^d.895 \times E. \quad (2)$$

The light curve covers the season March 2005 to March 2006 and covers about three complete stellar rotations. Hall et al. (1995) estimated parameters of this SB1 system ($M1=1.1M_\odot$, $M2=0.6M_\odot$) and derived spot migration for particular season.

II Peg

II Peg (HD 224085, K2IVe, m_V=7.4) is well known chromospherically active RS CVn SB1 system. The system displays multi-wavelength photometric variability, variability of the hydrogen profile resulting from chromospheric, transition and coronal activity. The star is often used to demonstrate very high total spot coverage and is the example of the most active RS CVn type stars. Its photometric period is ∼6.7 days (Vogt 1981). Interestingly enough, high spot coverage on active late type stars is somewhat of a problem to explain, and if compared to the Sun. Basically, the detection methods for total spot coverage are the following: 'historical' light maxima and colour-colour index, TiO spectroscopy and Doppler imaging. It is very difficult to catch 'historical' light maximum of target. Having in mind these objectives we examined colour-colour index to recognise and classify effects associated with it. The II Peg photometry (November 2005 to February 2006) is available at the URL address `http://www.ta3.sk`. The observed data were phased according to the ephemeris given in the paper Zboril and Djurašević (2006):

$$\text{Min I} = \text{HJD } 2422218.9750 + 6^d.7240 \times E \qquad (3)$$

4. RESULTS

Given the general trend that long-period active stars are considerably under-observed, with observations of the present paper we contributed to the database to fill in the gap in existing observations. The 12 Cam light curve is slightly assymetric but of sinusoidal form and therefore we modelled it with single spot. The light curve of 29 Dra changed considerably in comparison with the season 2004. It covers more than 12 stellar rotations but it seems to maintain the light curve's basic shape. While it was possible to reasonably model the light curve from the season 2004 with a single high latitute spot, the shape of light curve for the current season can be modelled both with middle and high latitude spot (a spot configuration cannot also be excluded). In modelling we considered results from previous studies. For example, Hall et al. (1995) derived $v \sin i$ (15 km/s), mass ratio and radius of giant 12 Cam. Adding up the rotational periods, this yields the stellar inclination of about 30 degrees. These values and 'canonical' difference in the temperature of the spot and surrounding photosphere (∼ 1000 K) typical for active stars were considered as starting iterate. Finally, the H-R diagram constructed for the active late-type star II Peg proved to be significant indicator of stellar activity. Main results from the study are presented in Table 3 and are the following:

1. 29 Dra, the light curve changed its shape in comparison with the season 2004, in depth, phase (longitude) and probably the latitude and total spot area, the spot temperature may be similar to those in the season 2004 and the maximal brightness is approximately the same, if compared to the season 2004. The example of fit with middle latitude single spot is given in Fig. 1. Both middle and high latitude spot configuration can fit the observed light curves.

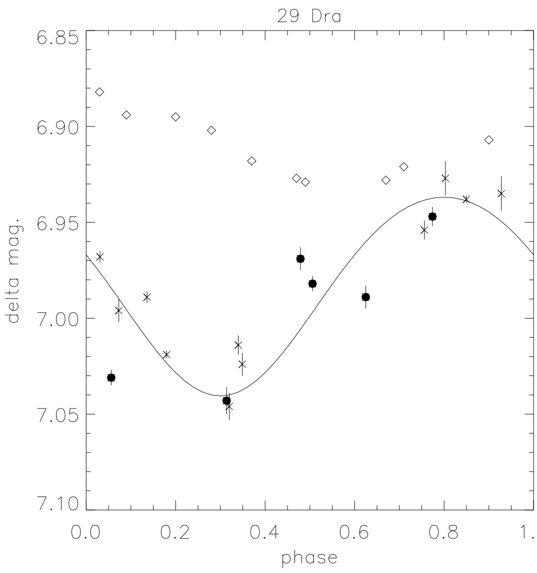

Fig. 1. *Observed and synthetic light curves of the 29 Dra in V passband. Filled circles stand for the season 2006 and diamonds for the season spring 2004. See text.*

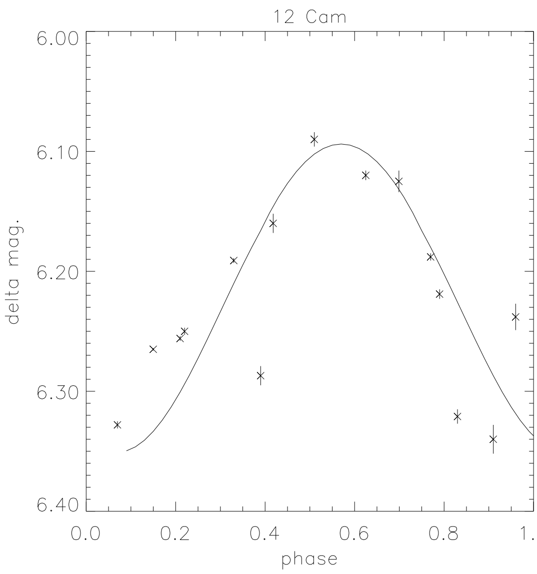

Fig. 2. *Observed and synthetic light curves of the 12 Cam in V passband.*

2. 12 Cam, the light curve is of simple sine-like form, single spot modelling suggests a spot at high latitude, with the temperature of 3800K. The changes of the light curve in phase and shape were already reported earlier (Hall et al. 1995) for different

seasons. In this case we iterated all spot parameters, and stellar inclination was considered to be i=30 degrees, according to that paper. Final fit with single spot model is given in Fig. 2, suggesting a high latitude spot and an inclination of i=15 degrees, but the solution with the inclination 30 degrees is also included in the final results (having comparable rms).

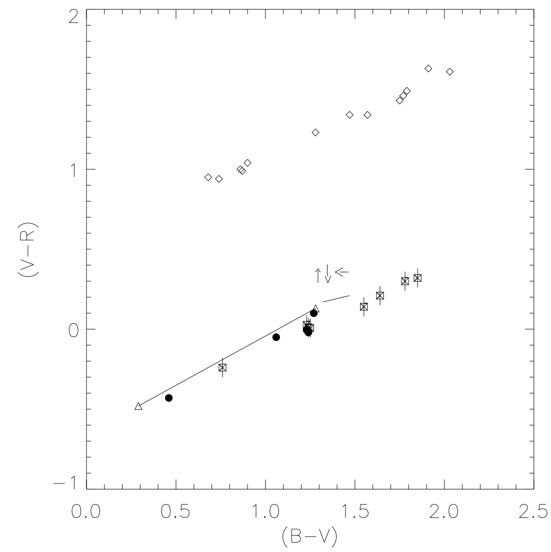

Fig. 3. *Colour-colour diagram for II Peg. Diamonds-giants from Simbad database, filled circles - dwarfs, squares - giants, triangles - metal defficient stars, short line - II Peg in both light minimum and maximum. Arrows - cumulative effects of nonstandard atmosphere. See text.*

3. II Peg, the local H-R diagram for the star suggests colour excess, and, consequently, a rather atypical atmosphere of the star. Since the observed comparison stars are bright, internal photometric accuracy is very high. Error bars on giants indicate the error from different observations, and nights. Also all stars are at distances less than 100 pc. The observations of II Peg and standard dwarfs and giants are in Fig. 3 together with bright giants with colours from Simbad database. In both datasets linear fit is excelent (98% and 99% confidence level). Metal defficient linked dwarfs ([Fe/H]=-0,75 and [Fe/H]=-0.43) may indicate the effect of metallicity, first upside-arrow (the dwarf with colour excess is actually K3V+K3V system with angular separation less than 3 arcsec., HD223778). Large total spot coverage was studied by computing theoretical colours from degraded fluxes using the formula

$$\mathrm{F_{tot}} = A.F_s + (1-A).F_Q\,, \tag{4}$$

where A stands for total spot coverage and F_s denotes the flux from spot. The effect is visualized by downside-arrow.

The effect of stellar activity, in terms of UV excess, flaring, chromospheric emission, faculae etc. has been subject of numerous studies. Data from catalogue of chromospherically active stars (Strassmeier et al. 1993) suggest for example at least the direction of the cumulative effect; the active stars cooler than G8 have lower both (U-B) and (B-V) indices, see leftside-arrow.

Among various possible activity sources for II Peg, metallicity is probable candidate to explain the colour-colour excess. The light curve modelling with single spot is presented in Fig. 4. As in the previous case, the high latitude spot (or spot configuration) is able to account for the light curve.

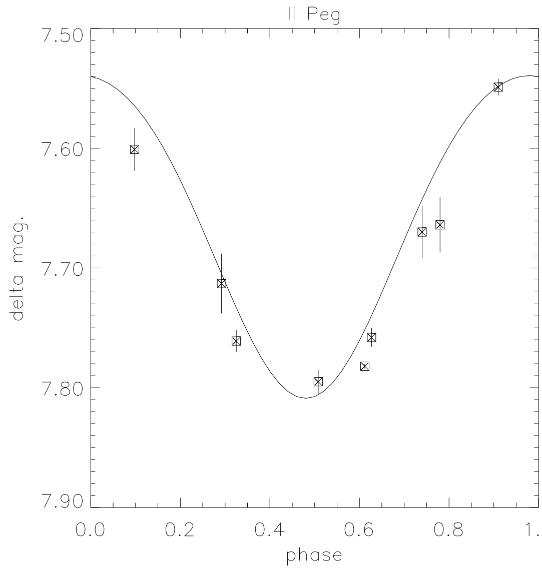

Fig. 4. *Observed and synthetic light curves of the II Peg in V passband.*

Table 3. The spot solutions for 29 Dra and 12 Cam.

Star	Tphot. K	radius [^{o}]	$T_{\rm spot}$	latit.	long. [phase]	frac [%]	$V_{\rm max.}$	$B_{\rm max.}$
29 Dra^{2004}	4700	33	3500	85	0.08	8.0	6.88	7.98
29 Dra	4700	20	3600	56	-0.25	3.0	6.93	7.99
12 Cam$^{i=15}$	4800	60	3800	70	0.57	25.0	6.12	7.02
12 Cam$^{i=30}$	4800	27	3800	50	0.57	5.5	—	—
II Peg	4600	60	4200	70	-0.02	25.0	~7.55	—

Note: frac=0.5(1-cos(θ)), R_{29Dra}=12$\mathrm{R}_\odot$

5. CONCLUSIONS

We performed the light curve modelling of long-period binaries 29 Dra, 12 Cam and well studied chromospherically active star II Peg. Single circular spot should be treated rather as an approximation (complex spot pattern is certainly closer to the real situation).

Monitoring of spotted targets helps to match and understand magnetic cycle and stellar dynamo associated with it. Such studies are especially needed to fill in the gap in the observations, and this is certainly the case of long-period binaries where monitoring has failed so far to offer conclusive results. Many results already proved the power of monitoring: this is certainly the case with monitoring of starspots as tracers of differential surface rotation, starspots cycles from long-term photometry etc. Monitoring the activity induced variability and specific spot modelling on stars (single or binaries) thus remains necessary to understand better observational aspects of these phenomena.

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ПРАЋЕЊЕ АКТИВНИХ ЗВЕЗДА 29 DRA, 12 CAM И КОЛОР ЕКСЦЕСА II PEG

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Стручни чланак

У раду је представљена анализа кривих сјаја у B и V филтеру дугопериодичних двојних звезда позног спектралног типа 29 Dra, 12 Cam и II Peg за сезону 2005/2006. Присуство пеге (или групе пега) ниже температуре у односу на околну фотосферу, може да објасни изглед кривих сјаја. Колор-индекс помак звезде II Peg на X-P дијаграму вероватно је последица металичности. Други могући механизми су кратко размотрени.