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Preliminary reports

DIFFERENTIAL PHOTOMETRY OF EK DRA AND 29 DRA

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SUMMARY: We report on BVR precise photometry of active late-type stars EK Dra and 29 Dra in the spring of 2004. The analysis suggests a reasonable fit with single spot model for both cases in the season as far as the V-curve is concerned. The spots are generally cooler than surrounding photosphere and are at high latitudes. The maximal brightness changes for both stars implying a non-rotating component of activity signatures, the spots. We expect that the spot configuration is stable over the period of approximately three months.

Key words. Stars: individual: EK Dra, 29 Dra – Stars: late-type – starspots

1. INTRODUCTION

The solar analogy of activity has been widely studied on a variety of active late-type stars. These studies bring obviously new look to the atmosphere activity phenomena, as well as the constraints to magneto-hydrodynamical models and physical events (flux tubes, waves etc.). Of these, the important part is the examination of magnetic activity cycles by means of basic spot properties.

The BY Dra star EK Dra (HD 129333, HIP 71631 F8, $m_{V_{aver.}}$=7.61) is a single star classified as Ultra Fast Rotator (known as a young stellar analogue of the Sun) with a period of ~2.60 days and the projected rotational velocity $v \sin i$=17.5 km/s. The system has been studied photometrically, for example by Scheible and Guinan (1994), spectroscopically – producing of Doppler Images – by Strassmeier and Rice (1998), while the solar-like pattern of surface differential rotation was studied by Messina and Guinan (2003). The secular brightness dimming of several mmag. per year was found by Froehlich et al. (2002). The inclination angle has been derived earlier as i=60^0 (equator=90^0); (e.g. Strassmeier and Rice 1998).

The following linear ephemeris (Strassmeier and Rice 1998) has been used

$$MinI = HJD\ 2\ 449\ 403.0 + 2^d.60498\ E \qquad (1)$$

where MinI stands for primary minimum, HJD for the heliocentric Julian date and E for the epoch of the minimum.

The RS CVn type star 29 Dra (HD 160538, HIP 85852, K0III, m_V=6.64) has rather long rotational period of $\sim 31^{d}_{\cdot}5$, as noted for example, by Hall et al. (1982), and is a chromospherically active star. The hot companion is white dwarf, as pointed out by Fekel and Simon (1985). Later on, Fekel et al. (1993) derived the spectroscopic orbit from multisite observations and the period $p_{\rm orbit}$=903.8 days. De Medeiros et al. (2002) derived the projected rotational velocity $v \sin i$=7.2 km/s and all the input data suggest the inclination angle i=22^0, thus shifting the star to the giant HR belt (Hipparcos parallax 9.68 mas). The following linear ephemeris (Hall et al. 1982) has been used

$$MinI = HJD\ 2\ 444\ 445.0 + 31^d.5\ E \qquad (2)$$

2. OBSERVATIONS

(i) EK Dra

The star was monitored during several seasons to obtain the maximal brightness and the phase diagrams using two 0.6m telescopes at Skalnaté Pleso and Stará Lesná observatories equipped with single channel photometers. The standard differential BVR photometry method with the sequence S - V - CH was used as well as the standard reduction process including the corections for differential extinction by using the extinction coefficients. The check star (CH) was SAO 164 63 (BD+64 1020, m_V=9.4, F8) and the standard star (S) was HD 129 390 (SAO 16455, m_V=7.55, F2) and $\sim$ 1 hour night averages were considered. The S-CH ratio was stable within 0.02 mag over the nights. The collected dataset allows us to study spot properties in April 2004 and to make consideration on season 2002.

(ii) 29 Dra

The monitoring is practically completed for the period January-April 2004 and is reported here. The check star was SAO 8858 (HD16128, m_V=7.8, F5), the standard star SAO 8863 (BD+73 783, m_V=9.05, K0) and the S-CH ratio within 0.03 mag all the time.

The contents of the Tables 1, 2, 3 is the following: modified Julian date (MJD) up to two decimal digits because of the 1 hour averages, the V-S (variable-standard) differences in V passband and subsequently the V-S in B passband, the standard deviations from night averages and number of stars' measurements.

Table 1. 29 Dra data in V and B (lower panel) filters.

MJD	phase	$\triangle$m	std. err.	N
53028.33	0.49	-2.121	0.006	10
53056.27	0.37	-2.132	0.004	20
53082.36	0.20	-2.155	0.008	16
53097.35	0.67	-2.122	0.002	20
53098.34	0.71	-2.129	0.002	14
53104.34	0.90	-2.143	0.005	10
53108.36	0.03	-2.168	0.006	14
53110.37	0.09	-2.156	0.002	14
53116.38	0.28	-2.148	0.001	16
53122.37	0.47	-2.123	0.002	18
53028.33	0.49	-2.133	0.009	10
53056.27	0.37	-2.117	0.004	20
53082.36	0.20	-2.158	0.008	16
53097.35	0.67	-2.115	0.005	20
53098.34	0.71	-2.127	0.003	14
53104.34	0.90	-2.141	0.004	10
53108.36	0.03	-2.167	0.005	14
53110.37	0.09	-2.157	0.002	14
53116.38	0.28	-2.142	0.003	16
53122.37	0.47	-2.109	0.002	18

Table 2. EK Dra data in V and B (lower part) filters.

MJD	phase	$\triangle$m	std. err.	N
53097.29	0.16	0.143	0.001	16
53099.29	0.93	0.140	0.003	16
53108.31	0.39	0.177	0.006	12
53110.30	0.16	0.129	0.002	18
53111.31	0.55	0.152	0.001	14
53116.33	0.47	0.186	0.007	14
53119.33	0.62	0.167	0.009	22
53122.32	0.77	0.131	0.001	14
53097.29	0.16	0.373	0.003	16
53099.29	0.93	0.365	0.004	16
53108.31	0.39	0.423	0.010	12
53110.30	0.16	0.367	0.004	18
53111.31	0.55	0.387	0.001	14
53116.33	0.47	0.427	0.008	14
53119.33	0.62	0.421	0.009	22
53122.32	0.77	0.364	0.002	14

Table 3. Dataset in V and R (lower part) filters.

MJD	phase	$\triangle$m	std. err.	N
52570.62	0.98	0.172	0.006	24
52514.43	0.42	0.064	0.002	30
52547.33	0.04	0.136	0.003	32
52616.19	0.48	0.085	0.003	30
52570.62	0.98	0.015	0.006	24
52514.43	0.42	-0.069	0.003	30
52547.33	0.04	-0.007	0.002	32
52616.19	0.48	-0.059	0.003	30

The B passband is replaced by the observations in R filter in Table 3.

The EK Dra has been observed for several seasons but only 4 reliable points were obtained in 2002 and were not included in modelling. However, the max. brightness was estimated from these data (Table 3).

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 direct integration on the visible surface of the star, the projected area of the spots under consideration. The surface flux can be replaced by the fluxes directly from black-body radiation and it was this calibration that we used in the process. The optimization was carried out step-by-step; single spot model from input followed by the iterations using the 'exponential increment' factor of spot properties and finally the least-square solution to look for minimal deviations. We cannot exclude the complex spot configuration on the systems, but we prefer to apply the single spot model as the first approximation for modelling.

Observational errors

The brightness of objects allows us to use 10 sec integration time in single filter. However, the 1 hour averages basically define the time resolution in terms of phases 0.02 and 0.001, for EK Dra and 29 Dra, respectively. Similarly, the magnitude difference errors are defined by the averages, more precisely by the standard deviation from the averages. The original number of counts are typically more than 40000 in all filters and for all stars for the Skalnaté Pleso Observatory (Table 3) and more than 100000 for the Stara Lesná Observatory, so that the internal accuracy was better than 0.01 mag assuming the Poisson photon statistics. If standard deviation values are significantly large, one should consider these values instead, because they very probably reflect the weather conditions. Thus, a possible formula to estimate the error on magnitude can be

$$err.bar = max(0.01, std.err) \qquad (3)$$

with the standard errors listed in the enclosed Tables.

Model errors

The spot modelling always starts with the spot at the equator. The error bar for modelling can be deduced from individual iteration results, and the calibrations involved and are typically 50 K for the temperature and less than 1 degree for the radius and the spot location, if the inclination angle of the star is known very well. This internal error can be easily exceeded by the uncertainty in the inclinations. Assuming the 10% uncertainty in the inclination, the error bar reads 0.005 mag ($\sim$ 8% in spot properties) for both EK Dra and 29 Dra.

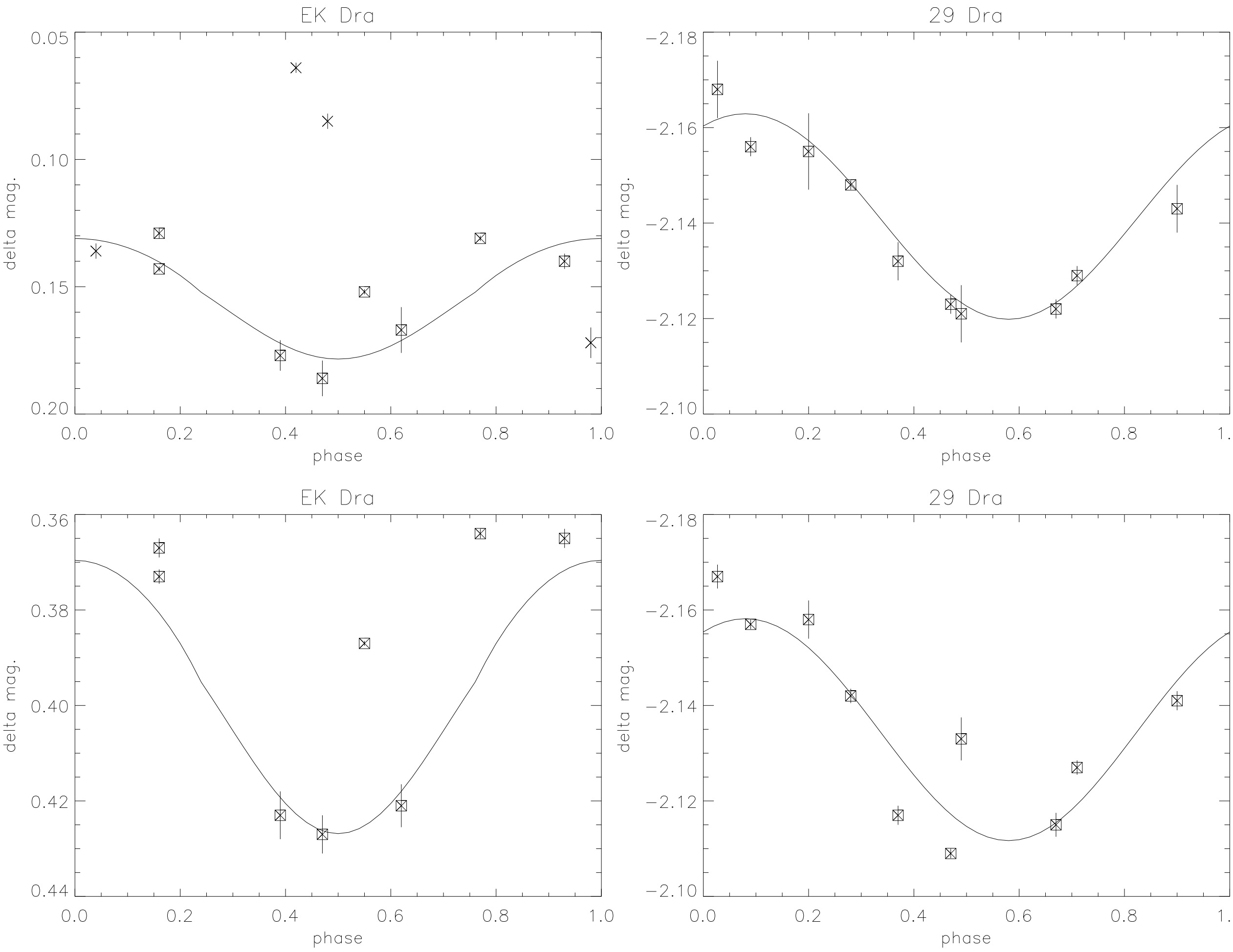

Fig. 1. *Differential photometry in V and B passbands. The V passband dataset (top) the B colour (bottom). Crosses denote observations from 2002 (EK Dra) not modelled.*

Table 4. The single spot solutions.

Star	T_{phot} [K]	radius θ [^{0}]	T_{spot}	latit.	long.[phase]	frac. [%]	$V_{max.}$	$B_{max.}$
EK Dra	5870	27±1	5470±50	75±1	0.00	5.5	7.68	8.27
29 Dra	4700	33±1	3500±50	85±1	0.08	8.0	6.88	7.98

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

4. RESULTS

A reasonable fit was achieved with a single circular spot model and black-body approximation. The results are presented in Table 4. As pointed out earlier, the major error contribution may come from the error in inclination.

In both cases the high latitude spots have been revealed on the stellar surface. Given the maximal brightness of the stars over years, it is almost certain that the spots are possibly a part of non-rotational modulating components of complex spot structure on the surface. As an example, the max. brightness for EK Dra is 7.61 mag. (in V passband) for the season winter 2002. The reasonable fit was achieved for colour indexes using the black-body approximation for observations in each filter. Generally, the code allows to use the surface-brightness relationship to obtain colour indexes but this method is not effective for these indexes partly because of the fact that stars are cool enough for the fluxes differences, the filters overlap and, finally, it is known that the (U-B) and (B-V) indexes can be strongly affected by other activity signatures (plages, flares etc.). We expect that the spot configuration is stable in both cases over a period of approximately three months.

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ДИФЕРЕНЦИЈАЛНА ФОТОМЕТРИЈА ЗА EK DRA И 29 DRA

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Претходно саопштење

Ми извештавамо о BVR прецизној фотометрији (урађеној у пролеће 2004) активних звезда позних класа EK DRA и 29 DRA. Анализа сугерише слагање са моделом једне пеге за оба разматрана случаја и уз то је разматрана V-крива. Пеге су уопштено гледано хладније у односу на околну фотосферу и на вишим су латитудама. Максималне промене сјаја за обе звезде имплицирају неротирајуће компоненте активно означене пеге. Ми очекујемо да је конфигурација пеге стабилна током периода у трајању од приближно три месеца.