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Four-colour photometry of the spotted dMe-star EY Draconis

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Abstract
We present the first four-colour photometry and spot modelling of the fast-rotating active star EY Draconis. In the result of the modelling possible spot evolution can be seen. The observed light curve appeared to be stable through 118 rotational cycles.
Keywords: *starspots – stars:activity – stars:atmospheres – stars:late-type – stars:imaging – stars:individual:EY Dra*

1 Introduction

The history of EY Draconis as an active star dates back until 1991, when the ROSAT X-ray/EUV satellite completed its all-sky survey. One of the WFC sources was RE 1816 + 541, which optical counterpart was identified as EY Draconis. Jeffries et al. (1994) presented spectroscopic measurements, and classified the object as a rapidly rotating dM1-2e star with chromospheric and coronal activity, based on the observed Hα and Ca H & K emission lines. Eibe (1998) studied the Hα line, and detected the presence of plage areas, and a flare. Barnes et al. (2001) presented Doppler imaging based on high-resolution spectroscopy, and derived stellar parameters as well as the image of the stellar surface, where starspots mainly at high latitudes can be seen.

The only photometry published up to now was made by Robb et al. (1995). The Johnson V-band measurements covered 8 days. From the observed light curve – which appeared to be stable through the time of the observations – they concluded that the variations are caused by at least two large spots or spot groups. The authors found a period of 0.459 days in the light variability. Stellar parameters obtained from the mentioned articles are summarised in Table 1.

Table 1: *Stellar parameters of EY Draconis*

spectral type	dM1-2e	Jeffries et al. (1994)
$v \sin i$	61 km s^{-1}	Jeffries et al. (1994)
P	0.459 d	Robb et al. (1995)
distance	45.5 ±2.1 pc	Barnes et al. (2001)
M_V	8.54 ± 0.12	Barnes et al. (2001)
$r \sin i$	0.549 ± 0.002 $R_\odot$	Barnes et al. (2001)
i	70°	Barnes et al. (2001)

2 Observations and data reduction

New observations were made with the 60 cm automatic Cassegrain telescope of the Konkoly Observatory in Svábhegy, Budapest, equipped with a Wright 750x1100 CCD using $BV(RI)_C$ filters, between 8 August and 28 September, 2005 (JD 2 453 584 – 2 453 642), on 33 nights. More than 1000 frames were obtained in each passband. We used GSC 03904-00259 as comparison and GSC 03904-00645 as check star. The images were bias subtracted and flat fielded using IRAF. Magnitudes were retrieved from differential aperture photometry using standard IRAF packages.

We calculated the principal and secondary extinction coefficients based on the work of Hardie (1962) using the star field of EY Draconis, TZ Aurigæ and SS Cancri. The correct determining of the extinction coefficients are badly needed, because only a few thousandths of magnitude errors could cause inconsistent results in the spot temperature modelling. Our analysis showed that the primary extinction coefficient do not play a role because of the small chip size and the proximity of the observed stars, however, we cannot forget about the colour extinction, which appears to be significant only in $B-V$, and its value is $k'' = -0.027$. The constants for transforming to the international Johnson–Cousins system for $B-V$, $V-R_C$, $V-I_C$ and V are 0.90, 1.077, 1.103, 0.092, respectively. The resulting light curves and colour index curves can be seen on Figure 1 (note the small amplitudes!).

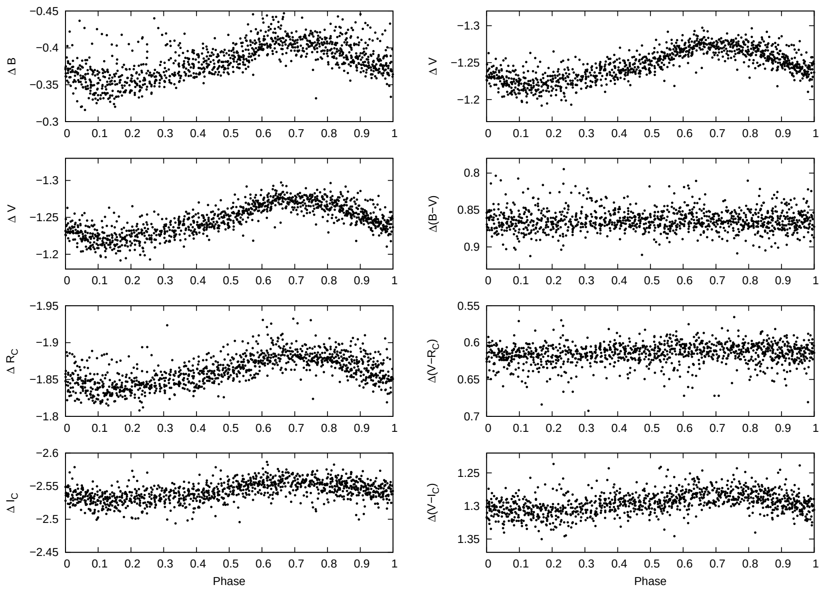

Figure 1: *Light curves and colour index curves of EY Draconis*

3 Spot modelling

The spot modelling was performed using the program SpotModeL (Ribárik et al., 2003). This program is able to determine the position, temperature and size of up to three circular spots with the analytical formulæ from Budding (1977) and Dorren (1987) using multi-bandpass data. The fixed values of some input parameters of the supposed spots (see Table 2) were determined using the Doppler images made by Barnes et al. (2001). Modelling was carried out using four consecutive day's observation blocks covering full rotational light curves, simultaneously in B and V and also in V and I_C, adjusting the spot parameters together with the spot temperature. One of those fits is displayed on Figure 2. As one can see, the fit follows the measurements well in all colours. The modelling results originating from the two different colour sets (B, V and V, I_C) agree with each other usually within 1σ (see Figure 2). The variability of the spot parameters (longitude, latitude and size) in time is plotted on Figure 2. A strong anticorrelation is clearly seen between the spot temperature and size, and the observed magnitudes. Comparing the spot coverage (Figure 3) to the

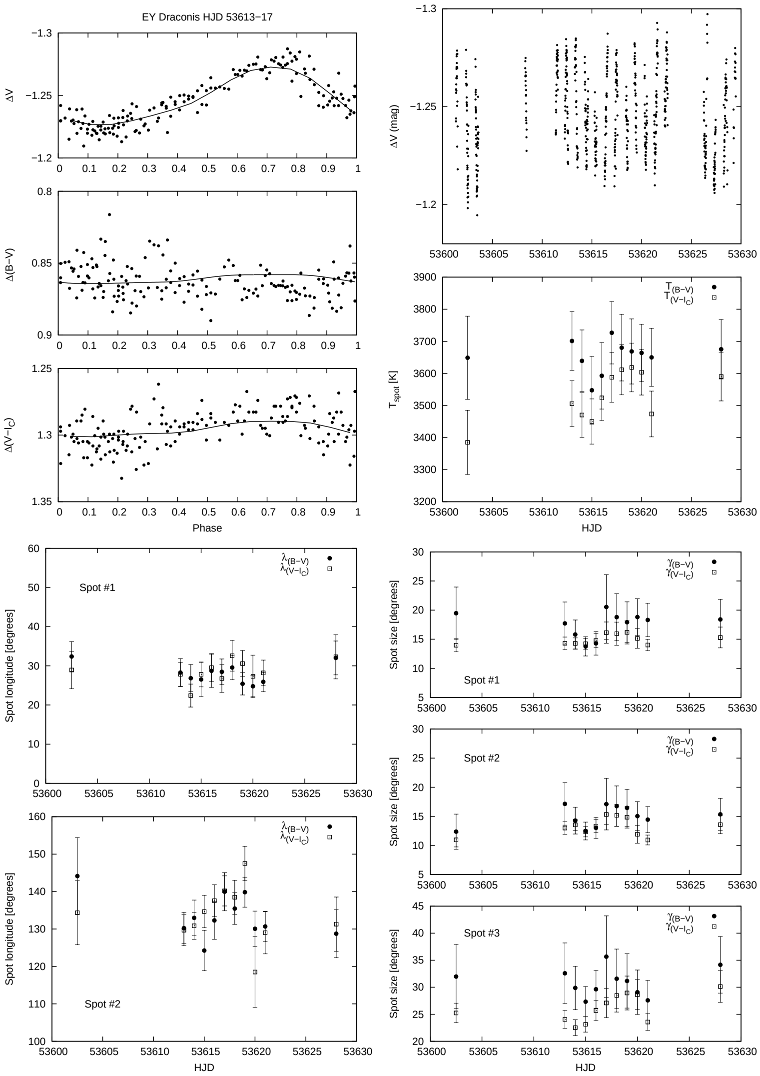

Figure 2: *Result of spot modelling: fitting and the spot parameters*

Table 2: *Input parameters for SpotModeL*

	V	I_C	B
Unspotted intensity (USI)*	-1.3	-2.585	-0.455
Limb darkening (u)**	0.670	0.509	0.763
	Spot #1	Spot #2	Spot #3
Spot longitude (λ) [°]	30	130	360***
Spot latitude (β) [°]	45***	45***	90***
Spot size (γ) [°]	20	20	10
T_{spot}	3900K		

* all fixed
** all fixed (van Hamme, 1993)
*** fixed

spot temperature, it seems that as the temperature grows, so does the spot coverage. This can be explained by the disappearance of a spot or a spot group so that the spot-to-plage ratio decreases, similar to those results in Ribárik et al. (2003).

Looking at Figure 3 one can see that the light curves are stable through the whole set of observations – over 118 rotational phases. This phenomenon is more interesting since, considering the fast stellar rotation, one would suspect, that the evolution of starspots and spot groups are faster – just like in BO (Speedy) Mic (Walter et al., 2005) which shows strongly variable light curves on the timescale of 1-2 stellar rotations. This stability we find on EY Draconis could be explained if we assume that the object is an unresolved binary and the tidal effect forces the activity to appeat at certain positions (see eg. Oláh (2006)), or there may be some other stabilising process present, such as a strong frozen-in magnetic field. The object is worth of further studying as a representative of the rare single, ultra-fast rotating low-mass field stars.

In order to study the stability of the light curve – and so the starspots, additional observations are needed on a longer timescale.

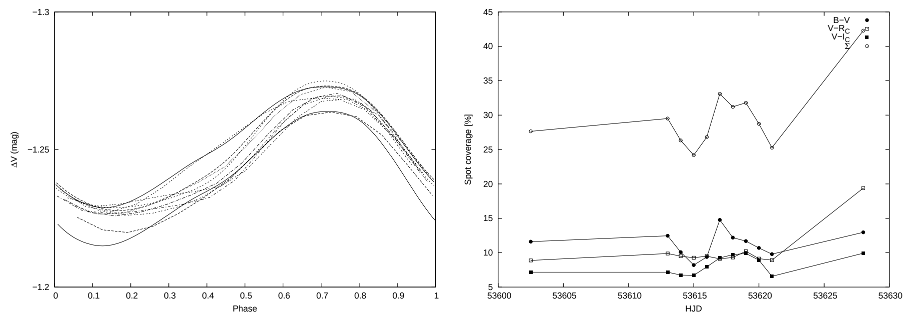

Figure 3: *The stability of the light curve; only the fits to the lisht curves are plotted for clarity (left), and spot coverage from the modelling (right)*

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References

Barnes J. R., Collier Cameron A., 2001, MNRAS, 326, 950

Budding, E., 1977, Ap&SS, 48,207

Dorren, J. D., 1987, ApJ, 320, 756

Eibe M. T., 1998, A&A, 337, 757

van Hamme, W. 1993, AJ, 106, 2096

Hardie, R. H. 1962, in Stars and Stellar Systems, vol. II: Astronomical Techniques, ed. G. P. Kuiper, & B. M. Middlehurst (Univ. of Chicago Press, Chicago, USA), 178

Jeffries R. D., James D.J., Bromage G. E., 1994, MNRAS, 271, 476

Oláh, K., 2006, in: proc. Close Binaries in the 21th Century, June 27–30, Syros, Greece, submitted to Ap&SS

Ribárik, G, Oláh, K., Strassmeier, K. G., 2003, Astronomische Nachrichten, 324,202

Robb R.M., Cardinal R.D. 1995, Informational Bulletin on Variable Stars, 4270, 1

Walter, U., Schmitt, H. H. M. M., van Wyk, F., 2005, A&A435, 261