UBV Photometry on BY Draconis Type Stars in 1992-2000

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Abstract

This work is based on results of the systematic and very homogeneous photometric observations, obtained for three active stars of BY Dra type at Rozhen National Astronomical Observatory (NAO) during the period 1992 - 2000. BY Dra, YZ CMi and EV Lac were monitored and three different cases of stellar activity are discussed. During the flare monitoring in U-band several flares were detected and their parameters were estimated. BY Dra was studied for spot-modulation of brightness. V, U-B, and B-V curves for 1996, 1997, 1998 and 1999 are shown. Significant changes of these curves, both in amplitude and shape, were found. The photometric minimum shift probably indicates spot migrations and differential rotation of the star. The long-term V light variations for BY Dra have been presented since 1898. The analysis of the photometric history shows no explicit evidence for a spot-cycle existence.

Introduction

UV Cet type stars are characterized by occasional flares with amplitudes in the U-band up to 7 mag and duration usually of several minutes to several hours. Most of these objects are emission-line red dwarfs, located in the lower part of the main sequence and they show phenomena similar to solar activity. The spotted flare stars of BY Dra type variables are a part of UV Cet's, which show also low-amplitude quasi-periodic light variability outside of flares (so-called BY Draconis syndrome) due to rotational modulation of brightness by cool starspots.

As a part of a program aimed at studying the stellar activity on late type stars, UBV photometry of the BY Dra stars started in Rozhen NAO in early 1980's.

In this work we present some results collected during the last 9 years for BY Dra, YZ CMi and EV Lac in two aspects of their activity manifestation - sporadic flares, as well as spot-modulation of brightness. We also discuss possible solar-like activity cycles.

1 Equipment, Observatons and Data Reduction

The observations presented in this paper were obtained with the 60-cm Cassegrain telescope at the Rozhen NAO during 1992-2000. The telescope feeds

Table 1: Schott glass filters combination used.

Filter		Components
	U band:	UG 2 / 1mm + BG 38 / 2mm
	B Band:	BG 12 / 1mm + BG 38 / 2mm + GG 385 / 2mm
	V Band:	OG 515 / 2mm + BG 18 / 1mm

the single-channel photon-counting photometer (Fig.1) with Schott glass filters that match standard Jonson's UBV-system (Table 1). The flare monitoring was carried out in U-band with an integration time of 1 sec. The flare magnitude was computed with respect to the quiescent stellar intensity I_0 (sky background 'SB' subtracted) as:

$$\Delta m[\mathrm{mag}] = 2.5 \log \frac{I_{0+f}}{I_0}. \tag{1}$$

By numerical integration of the flare light curve, the equivalent duration of each flare was calculated from:

$$ED = \int_{flare} I_f(t) dt. \tag{2}$$

The flare energies were obtained by the relation:

$$\log E_f = \log ED + \log E_q^U, \tag{3}$$

where E_q^U is the quiescent stellar luminosity.

The differential observations were usually taken through a diaphragm $20''.6$ (0.75 mm). The data were corrected for a dead-time and atmospheric extinction, and transformed to the standard UBV-system. Each differential observation consists of 4 consecutive 10 s integrations. After SB subtraction, a mean nightly point was obtained.

For long-term history we use the annual peak-to-peak amplitudes of V light curve.

2 A Brief Outline of the Program Stars

The prototype **BY Dra** (HD 234677 = HIP 91009, d = 14.1 pc, Sp=M0Ve+M0Ve) is a non-eclipsing triple star system. It is also classified as an SB2 system with strong $H\alpha$ and $CaIIH$ and K emission in the spectra of both components. The mean value of the photometric (resp. the star rotation) period is 3.836 days [3], while the orbital one is longer: 5.976 days [2]. The lack of synchronization of these periods indicates that BY Dra is a very young system.

YZ CMi (HIP 37766, d = 5.9 pc, Sp = dM4.5e) is one of the most extensively observed BY Dra type stars during the past years. The rotational period determined from spot light curves is 2.77 days [9] and the duration of its long-term variability is about 30 years [1].

EV Lac (HIP 112460, d = 5.0 pc, Sp = dM3.5e) is also one of the well-known spotted flare stars. Its photometric period is 4.375 days [9]. During the past decades EV Lac has been in the focus of many international observing campaigns.

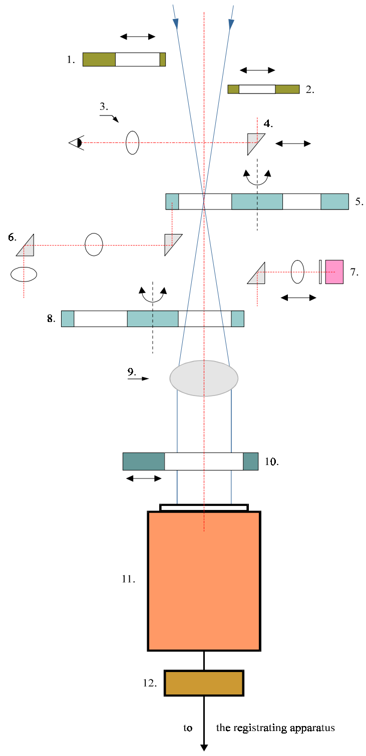

Figure 1. Scheme of the photoelectric photometer.

1,2 – neutral filters, 3 – eyepiece, 4 – mobile prism, 5 – disk with diaphragms, 6 – microscopical eyepiece, 7 – standard source, 8 – disk for filters, 9 – Fabri lens, 10 – protective shutter, 11 – photomultiplier, 12 – wide-band pulse amplifier.

3 Results and Discussion

Our observations were obtained during 72 nights from 1992 to 2000. Here we present some of them in three different aspects of photometric variability.
Stellar flares are manifestation of chromospheric activity, due to the release of magnetic energy in the upper chromosphere and corona. The total monitoring times and detected flares for program stars are as follow: BY Dra - $18^h.0186$ / 3 flares, YZ CMi - $9^h.5892$ / 7 flares, EV Lac - $34^h.8286$ / 15 flares. The flare parameters are given in Table 2.

- Fig.2 shows one of flares on EV Lac.
- Fig.3 shows *multi-peak flare* on EV Lac.
- Flare No.6 of YZ CMi, shown in Fig.4, is an example of a *rapid spike-flare* with rise-time of 2 sec and total duration of 4 sec.

Table 2: Flare No.6 of YZ CMi, shown in Fig.2, an example of a rapid spike-flare with rise-time of 2s and total duration of 4s.

Object	No.	Date	T_{max}	t_{rise}	Duration	Amlitude	Δm	$\log E_f$
		[UT]	[UT]	[sec]	[m:s]	$\frac{I_{0+f}-I_0}{I_0}$	[mag]	[ergs]
YZ CMi	6	09 Mar 2000	$17^h50^m20^s$	2^s	0^m04^s	5.34	2.00	29.64
EV Lac	1	02 Aug 1992	01:08:05	37	8:00	12.52	3.21	31.91
EV Lac	2	30 Aug 1992	23:49:20	16	11:13	18.38	2.83	32.49

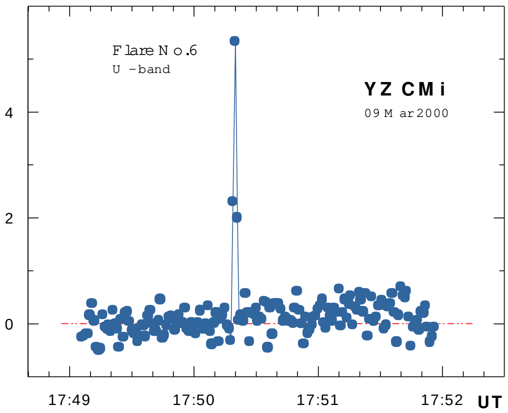

Figure 2. The U-band rapid spike flare of YZ CMi

Spot-modulation of brightness is a result of inhomogeneous photosphere. Due to the rotation of the star, the light is modulated with the period of rotation. The light curves presenting the rotational modulation of BY Dra for the mean epochs 1996, 1997, 1998 and 1999 are plotted in Fig.5. Phases are reckoned from the photometric ephemeris HJD = 2442819.612 + 3.836 E [3]. In 1994 BY Dra was in a state of very low photometric amplitude (0.02 mag), which then increased and reached 0.06 mag in 1996 and 1997. In 1998 and 1999 the amplitude of rotational modulations decreased again. One can also see that the light curves change in phase. This is probably a result of small changes of the photometric period, due to differential rotation and spot-migrations.

Long-term photometric behaviour of BY Dra during the last 100 years is shown in Fig.6. The photometric history has been studied, using 2 photographic plate collections, as well as several sets of photoelectric data, including published and our own photoelectric observations. Symbols denote the yearly mean photographic and photoelectric data. The yearly peak-to-peak amplitudes from the photoelectric light curves are indicated by bars. Although in the past many suggestions for possible activity cycles of BY Dra have been done, we believe the situation is still inconclusive and further observational effort is needed to detect the period of this cycle, if it exists.

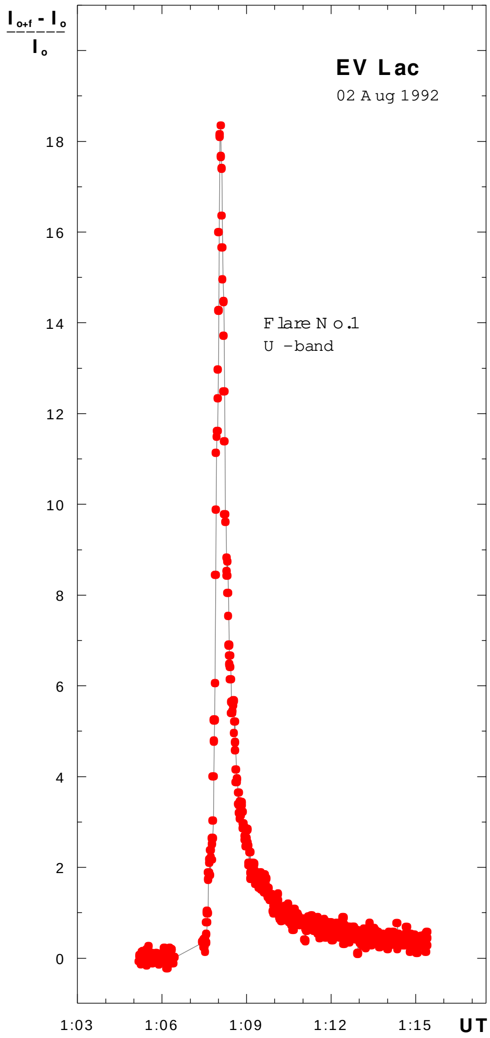

Figure 3. *U*-band light curve of EV Lac flare No.1

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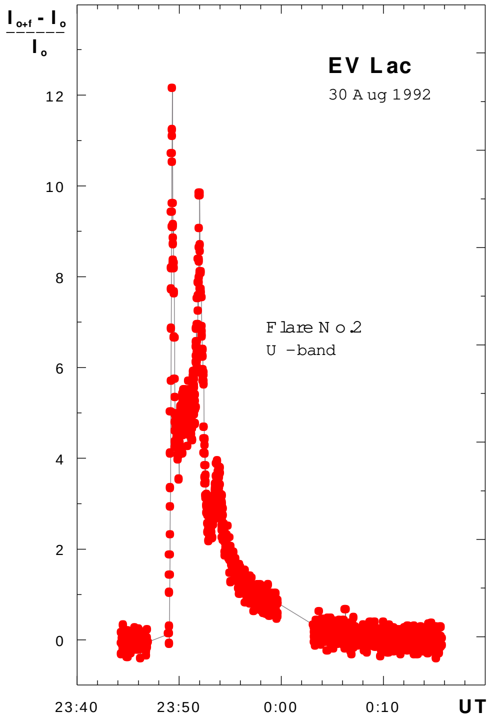

Figure 4. *U*-band multi-peak light curve of EV Lac flare

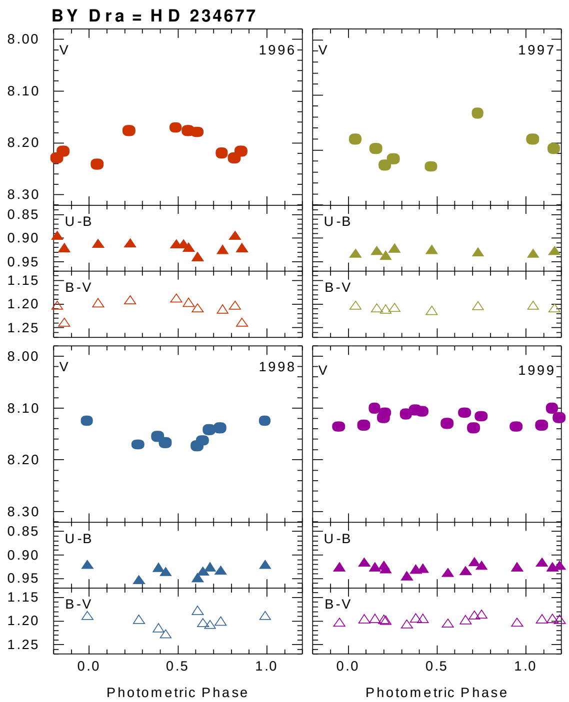

Figure 5. Spot-modulations of brightness of BY Dra (1996-1999).

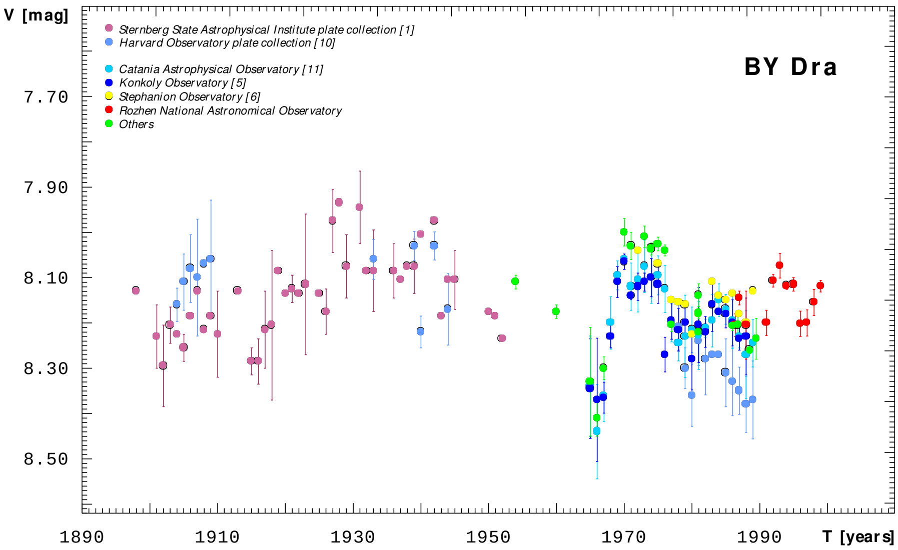

Figure 6. The long-term history of BY Dra in *V*-band from 1898 to 2000.