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Coordinated observations of the red dwarf flare star EV Lac in 1998

The results of photometric studies of the flare star EV Lac obtained in the course of cooperative observations in 1998 are presented. No significant brightness variations in IR were found from simultaneous observations of the star in UBVRI and H bands, in coincidence with the observed optical flares. Within the framework of the zonal spottedness model of stars the EV Lac surface inhomogeneity parameters are estimated.

КООРДИНИРОВАННЫЕ НАБЛЮДЕНИЯ ВСПЫШЕК КРАСНОГО КАРЛИКА EV Lac В 1998 Г., Алексеев И. Ю., Антов А. П., Авголупис С., Бескин Г. М., Борисов Н. В., Чаленко В. Э., Контадакис М. Э., Гершберг Р. Е., Халак В. Р., Константинова-Антова Р. К., Ларионов В. М., Панферова И. П., Плохотниченко В. Л., Пустыльник Л. А., Романюк Я. О., Сейрадакис Дж.-Х., Сергеев С. Г., Святогоров О. А., Верлюк И. А., Жиляев Б. Е. — Представлены результаты фотометрических исследований вспыхивающей звезды EV Lac, полученные во время совместных наблюдений в 1998 г. При одновременных наблюдениях звезды в UBVRI- и H-полосах не было найдено никаких существенных изменений яркости в ИК-диапазоне, которые бы совпадали с зарегистрированными оптическими вспышками. В рамках зональной модели запятненности звезд оценены параметры неоднородности поверхности EV Lac.

КООРДИНОВАНІ СПОСТЕРЕЖЕННЯ СПАЛАХІВ ЧЕРВОНОГО КАРЛИКА EV Lac У 1998 Р., Алексєєв І. Ю., Антов А. П., Авголупіс С., Бескін Г. М., Борисов М. В., Чаленко В. Е., Контадакіс М. Е., Гершберг Р. Е., Халак В. Р., Константинова-Антова Р. К., Ларіонов В.

М., Панфьорова І. П., Плохотніченко В. Л., Пустильник Л. А., Романюк Я. О., Сейрадакіс Дж.-Х., Сергєєв С. Г., Святогоров О. О., Верлюк І. А., Жиляєв Б. Ю. — Подаються результати фотометричних досліджень спалахуючої зірки EV Lac, отримані під час скоординованих спостережень в 1998 р. При одночасних спостереженнях зірки в UBVRI- та H-смугах не знайдено жодних суттєвих змін блиску в ІЧ-діапазоні, які б збігалися зі спостережуваними оптичними спалахами. В рамках зональної моделі плямистості зірок знайдено параметри неоднорідності поверхні EV Lac.

INTRODUCTION

The campaign of cooperative observations of the flare red dwarf star EV Lac was carried out in the period September 10—16, 1998. As it was in similar previous campaigns [1—3, 8, 10—13], the task of these cooperative observations was to obtain long-duration series of homogeneous photometric data for EV Lac, one of the brightest and the most active object among the UV Ceti-type stars, and other types of observations for which the availability of supported synchronous photometric observations is essential. In this paper we describe in detail all the observations obtained during this campaign, when a principle new point was the careful comparison of photometric monitoring in remote observatories.

OBSERVATIONS AND GENERAL RESULTS

The overall temporal coverage of EV Lac by observations achieved in the international campaign of 1998 is presented in Fig. 1. The times of the brightness maxima of flares are marked with vertical lines, their lengths correspond to the amplitudes of flares measured in stellar magnitudes. The full list of the flares detected at five telescopes are given in Table 1. Due to the different weather conditions for each place during the observational period and through the different telescope apertures (consequently various signal-to-noise ratio was obtained for received data) not all the flares were detected simultaneously in all the operated telescopes with adopted accuracy.

Tabl 1. Detection of flares at different observatories

Date, 1998 and UT of brightness maxima		Flares detected at the Observatories				
		AZT—11, Crimea	60-cm, Terskol	30-inch, Greece	60-cm, Bulgaria	50-inch, Crimea
10.09	$20^h30^m37^s$	+		+		
10.09	23 48 53	+				
10.09	24 03 05	+				
10.09	24 12 06	+		+		
11.09	18 58 16	+				
11.09	19 37 24	+				+
11.09	19 53 20	+				
11.09	21 55 09	+		+		+
11.09	25 05 00	+				
11.09	25 19 36	+				
12.09	20 02 05	+				
13.09	20 39 42		+		+	
14.09	19 08 08	+		+	+	+
14.09	20 05 06		+	+	+	+
14.09	20 44 54		+	+	+	
15.09	20 40 00		+			+
15.09	22 30 24		+	+	+	
15.09	23 00 48		+	+	+	

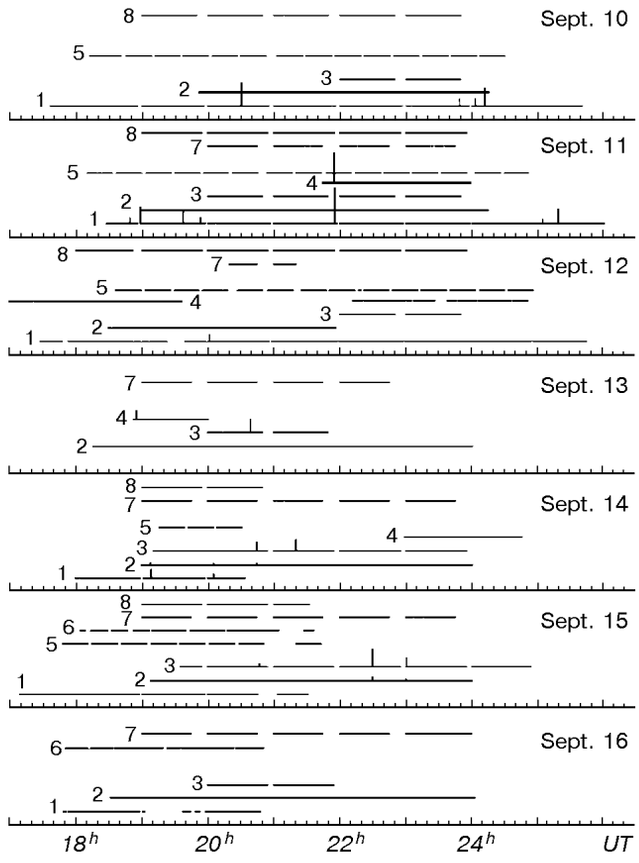

Fig. 1. The temporal distribution of patrol observations of EV Lac in 1998: UBVRI photometric patrol in Crimea at AZT-11 — 1, B band photometry in Greece — 2, photometric patrol at the peak Terskol — 3, U band photometric observations at the 6m telescope in Special Astrophysical observatory — 4, infrared H band photometry in Crimea at AZT-8 — 5, spectral observations at the 2.6 m Shajn telescope in Crimea — 6, U band photometric observations with the 60-cm telescope at Belogradchik observatory — 7; fast U band photometry at the Crimean 50 inch telescope — 8, times of optical flares maxima are indicated by vertical lines, their lengths are proportional to the flares' amplitudes measured in stellar magnitudes

In Crimea the photometric and spectral monitoring was carried out with four telescopes: the 1.25 m reflector AZT-11, the 70 cm telescope AZT-8, the 50 inch telescope and the Shajn 2.6 m reflector.

I. Yu. Alekseev observed with the *UBVRI* photometer-polarimeter described by Piirola [16] and installed on the 1.25 m reflector AZT-11. The *U* band light curves of the star are shown in Fig. 2. In Table 2 the quantitative characteristics of these flares are listed: times of brightness maxima, duration of the flare rise (T_b) and flare decay (T_a), flare equivalent duration $P = \int [(I_f - I_0)/I_0]dt$, where I_f and I_0 — the count rates during the flare and in the quiet state of the star respectively, amplitudes of flares ΔU and colour indices $U-B$ and $B-V$ of pure flare radiation at brightness maxima. In 1998 during 32.9 hours of patrol observations in the *U* band 12 flares were registered and the ratio $\Sigma P_U/T = 0.0313$ was obtained, where T is a total monitoring time. Some details of these observations were given by Alekseev et al. [4].

Fast photometric observations of EV Lac were carried out in the *U* passband simultaneously with the reference star SAO 52355 by V. E. Chalenko,

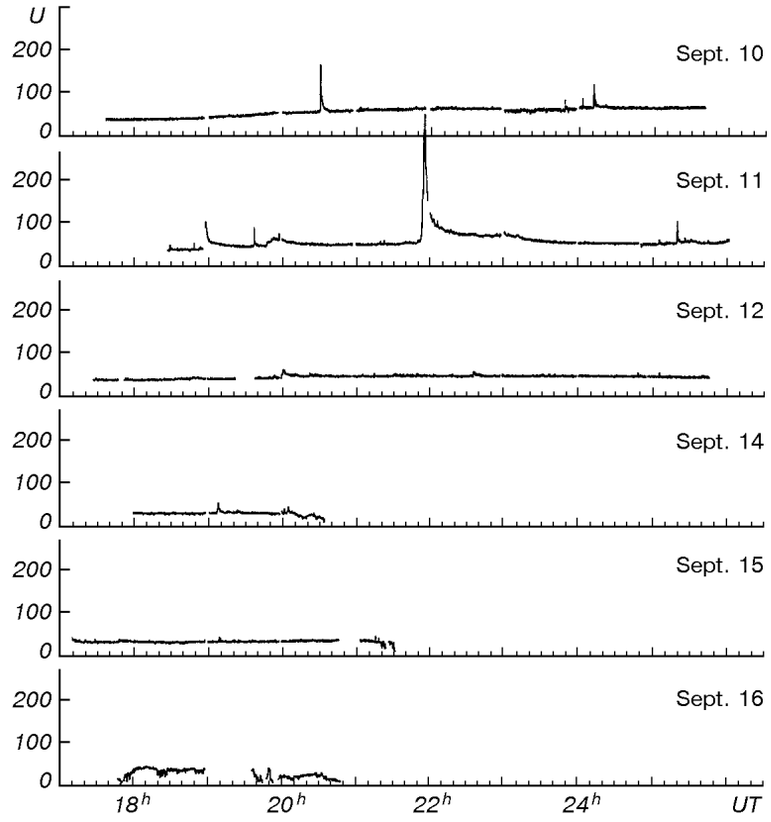

Fig. 2. U band light curves of EV Lac, registered at the telescope AZT-11 in Crimea in 1998

Table 2. Characteristics of flares detected at the AZT-11 in Crimea

Date, 1998 and UT of brightness maxima		T_b, min	T_a, min	P, min	ΔU, mag	U − B, mag	B − V, mag
10.09	$20^h30^m37^s$	0.4	6.5	4.1	1.58		
10.09	23 48 53	0.2	2.2	0.4	0.56		
10.09	24 03 05	0.1	1.6	0.2	0.45		
10.09	24 12 06	0.5	3.3	1.2	0.95		
11.09	18 58 16	4.7	14.1	6.6	1.02		
11.09	19 37 24	0.5	3.1	0.7	0.72		
11.09	19 53 20	5.7	20.9	5.0	0.34		
11.09	21 55 09	3.1	86.2	41.1	2.00	-0.82±0.20	0.21±0.38
11.09	25 05 00	0.2	1.1	0.1	0.20		
11.09	25 19 36	0.5	3.3	0.6	0.68		
12.09	20 02 05	2.0	2.9	1.0	0.31		
14.09	19 08 08	0.6	2.4	0.9	0.57		

Ya. O. Romanyuk and V. R. Khalak at the 50 inch telescope of the Crimean Astrophysical Observatory with the help of the high-speed two-channel automatic photometer [17]. Among the all accumulated observational data with a total duration of 20 hours 5 flares were registered but with low signal to noise ratio.

V. M. Larionov carried out IR monitoring of EV Lac, using the 70 cm telescope AZT-8 of the Crimean Astrophysical Observatory and the IR photometer of the Astronomical Institute of St. Petersburg University with an

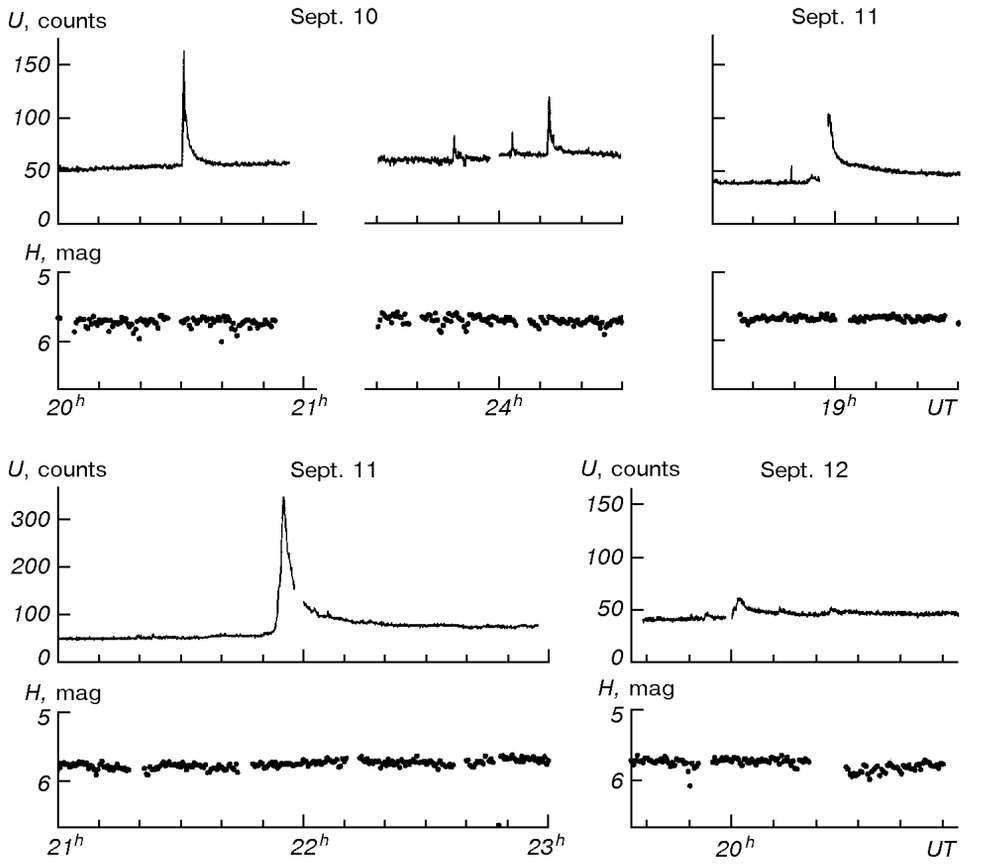

Fig. 3. Fragments of the EV Lac light curves in the U and H bands, registered simultaneously in Cftauft

InSb detector, cooled by liquid nitrogen. Simultaneous monitoring in the optic and IR ranges was carried out similarly to that described by Abranin, Alekseev et al. [2] as shown in Fig. 3. Five flares with ΔU amplitudes in the interval 0.3—2.0 mag were registered in the optical range, while significant brightness variations in the H band was not found in any case. An absence of any effect in the H band during the optical flares is an open question and demands next investigations.

At the Shajn 2.6 m reflector R. E. Gershberg and S. G. Sergeev monitored EV Lac spectrally in the H_β range in the same way as it was done in 1995 campaign [3]. No flares were detected for rather short time of this monitoring. As the September 15th and 16th monitoring suggest the equivalent widths of H_β emission line in the quiet state of the star were equal to 0.36 nm.

At the Stephanion Observatory of the University of Thessaloniki, Greece, EV Lac was monitored by S. Avgoloupis and J.-H. Seiradakis with the 30 inch reflector in the B band. Both the telescope and photometric system and observational technique were described earlier in [15].

Throughout the observational period the weather varied from good to very good with the exception of the night on September 17/18 (additional to programme) for which the mild clouds with high humidity covered the sky. 8 flares were detected during the total monitoring time of 27^h46^m. Their quantitative characteristics are presented in Table 3. The corresponding light

curves are shown in Fig. 4. The time resolution was 1.2 s. It should be noted that on September 13 UT 18:44:15 a short-lived (18 s) brightness increase in the *B* band with a maximum of 0.12 mag was detected. Such an unusual event has not been revealed among other flares observed, although a careful examination of the sky during the observation did not reveals any clouds or other interfering sources of the light.

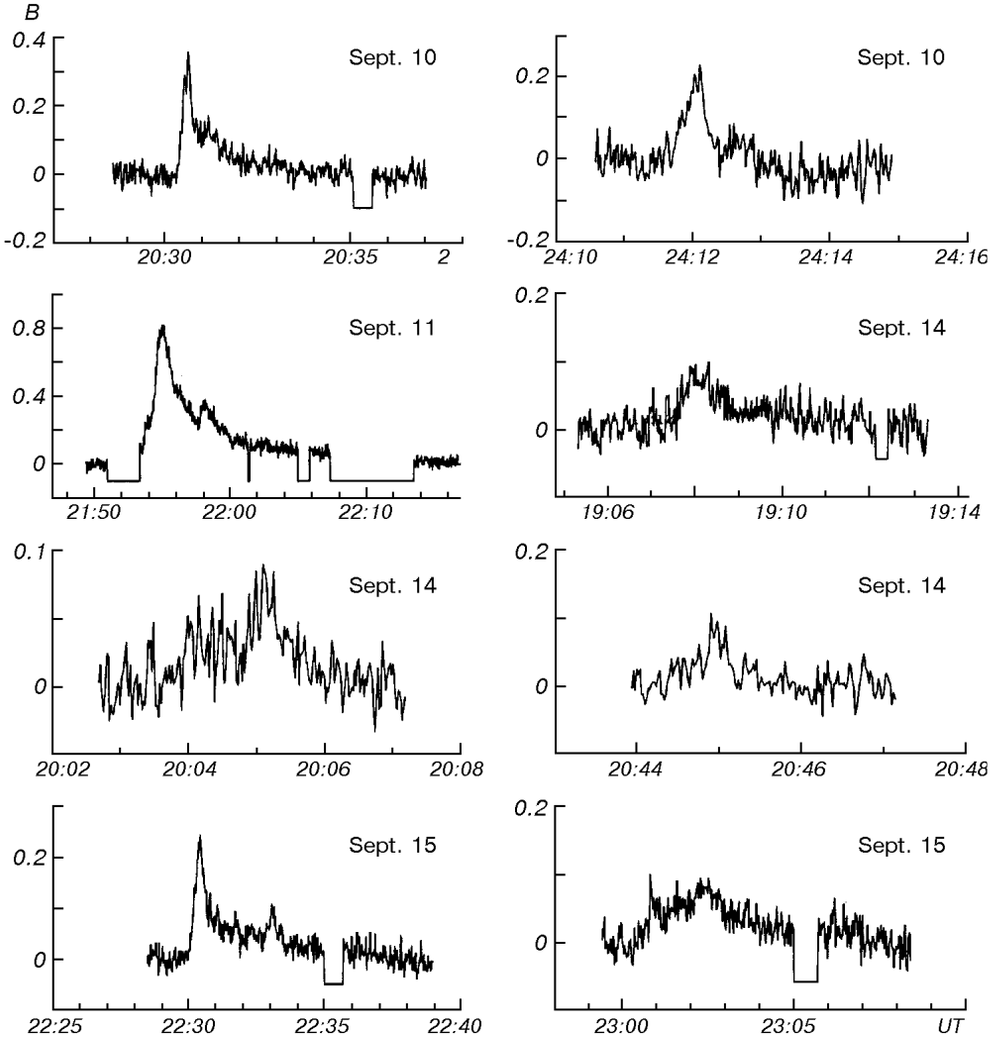

Fig. 4. B band light curves of the EV Lac detected in Greece. The time resolution was 1.2 s

Table 3. Characteristics of flares detected in Greece

Date 1998 and UT of brightness maxima		T_b, min	T_a, min	P, min	ΔB, mag
10.09	$20^h30.6^m$	0.30	2.98	0.23	0.33
10.09	24 12.1	0.39	0.80	0.08	0.22
11.09	21 55.0	4.06	20.70	3.37	0.65
14.09	19 08.3	1.00	4.20	0.13	0.10
14.09	20 05.1	1.47	0.98	0.07	0.09
14.09	20 44.9	0.58	0.62	0.04	0.11
15.09	22 30.4	0.46	6.84	0.32	0.24
15.09	23 00.8	0.42	6.38	0.21	0.10

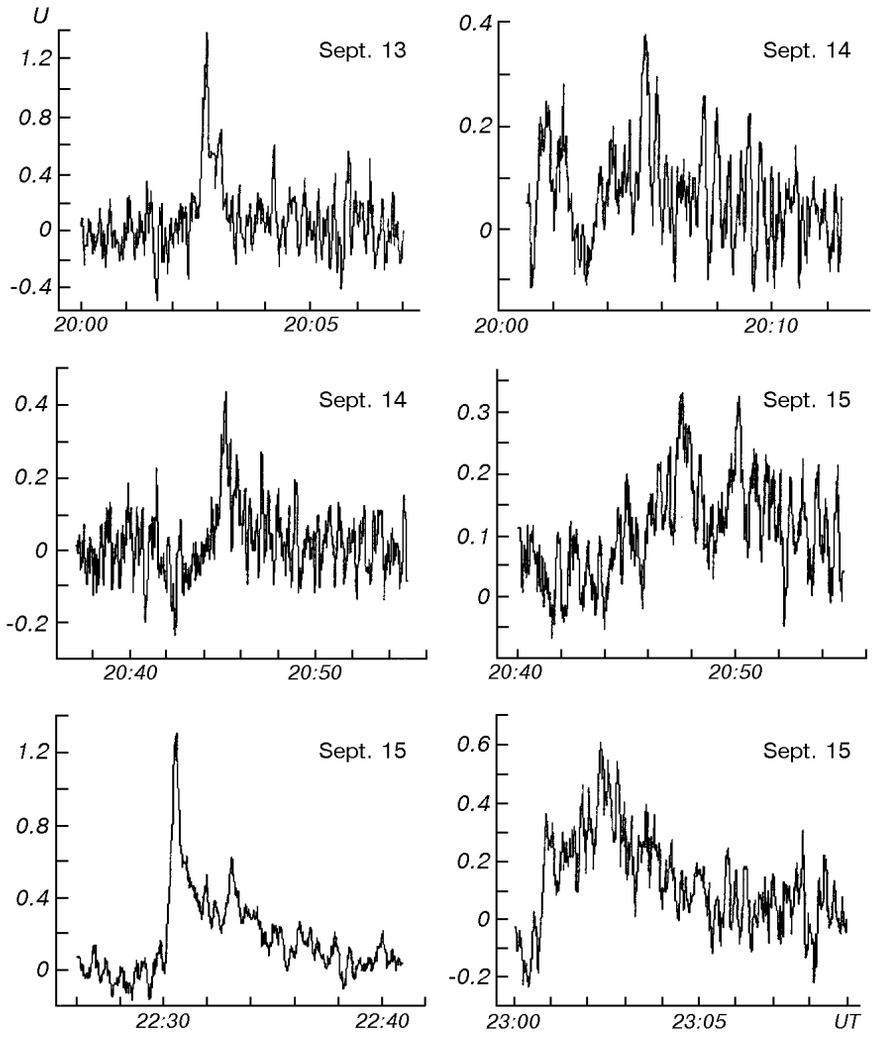

Fig. 5. U band light curves of the EV Lac detected at Terscol

The flare frequency rate observed in 1998 (0.29 flares/hour) was higher than that one in higher than one observed in 1995 (0.13 flares/hour), while it was less than the flare frequency rate found in 1994 (0.58 flares/hour). This result is in accordance with the activity cycle of 5 years determined by Mavridis and Avgoloupis [14].

At the 60-cm telescope of Peak Terskol observational station B. E. Zhilyaev, V. I. Verlyuk and O. A. Svyatogorov monitored this star in the *U* band by the same way as at the 50-inch telescope of CrAO and with the analogous fast photometer. They accumulated 26 time data rows with a whole duration of 23 hours and detected 6 flares (see Fig. 5).

At the Belogradchik observatory in Bulgaria photometric monitoring of EV Lac in U-filter was carried out by A. P. Antov and R. K. Konstantinova-Antova. The 60-cm Cassegrain telescope with a single-channel electrophotometer attached were used. The equipment is described by Antov and Konstantinova-Antova [9]. The integration time was 0.1 sec. The differential photometry method was applied. After every 45 minutes of EV Lac monitoring the measurements of standard star and background were done. Seven flares were

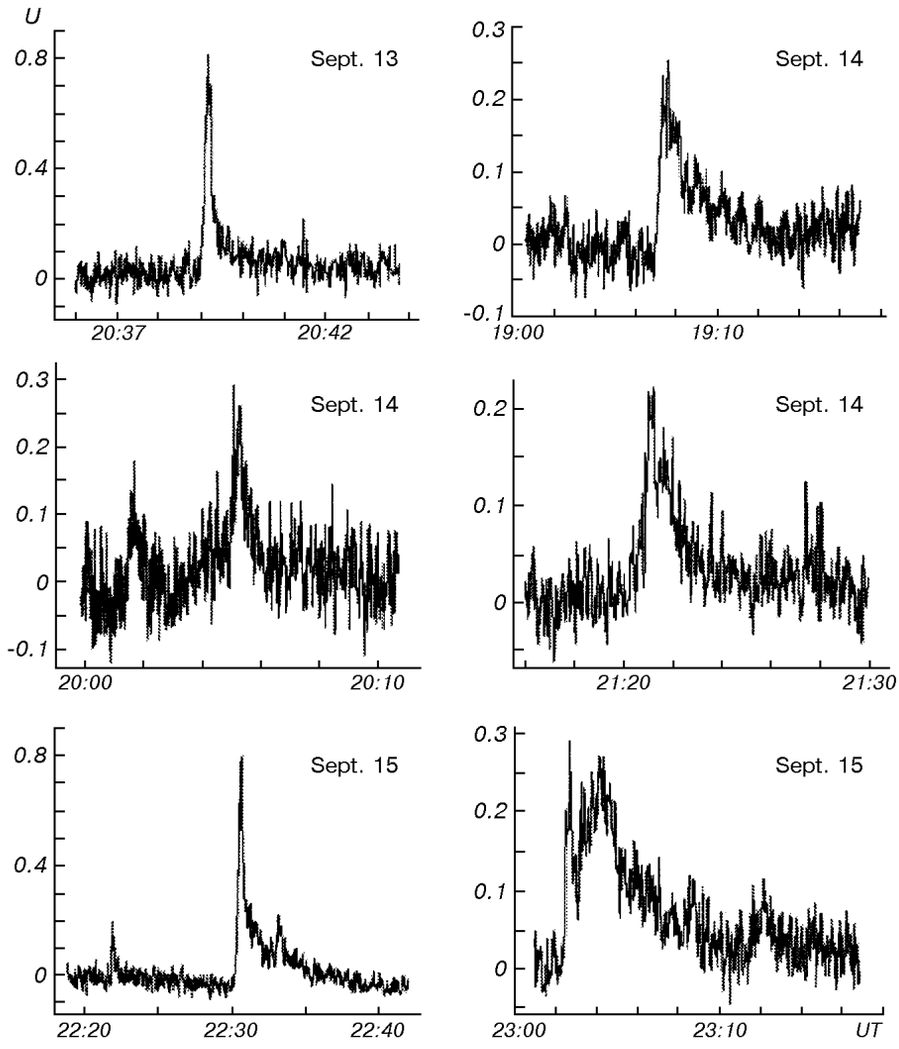

Fig. 6. U band light curves of the EV Lac detected in Bulgaria

detected during 20^h20^m total monitoring time, obtained in the period September 11—18, 1998. Five of them were observed simultaneously with at least one telescope mentioned above. Their light curves are shown in Fig. 6.

L. A. Pustil'nik, G. M. Beskin, N. V. Borisov, I. P. Panferova and V. L. Plokhotnichenko (Special Astrophysical Observatory, Nizhnij Arkhyz, Russia) carried out both the spectral and the *U* band photometric monitoring of EV Lac simultaneously at the 6m telescope, as described by Abdul-Aziz et al. [1]. Two flares were detected for 10^h22^m monitoring time obtained during 4 nights: on September 11 UT 21:55 and on September 13 UT 18:55, with amplitudes 1.79 mag and 0.40 mag, respectively. 532 spectrograms were obtained with an exposure time of 52 s within the spectral range 480—730 nm.

SPOTTEDNESS OF EV LAC IN 1998

The photometric monitoring of EV Lac at the AZT-11 telescope in Crimea was interrupted every 30—40 min for *UBVRI* measurements of the comparison star SAO 52337 (K2, $V = 9.19$, $U - B = 1.02$, $B - V = 1.18$, $V - R = 0.91$, $V - I =$

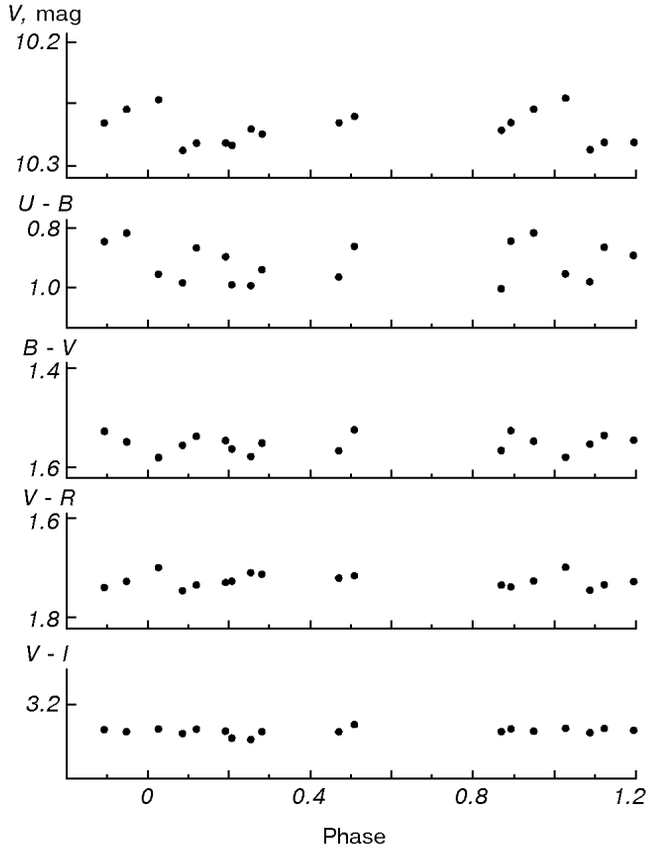

Fig. 7. Nightly averaged magnitudes of EV Lac in the quiet state in 1998 measured in Crimea

1.39). Thus, the data obtained permit to study both the flare activity of the star as well the slow brightness changes of small amplitudes, which appear due to heterogeneities of the star's spottedness. In addition to the program observations we have used the EV Lac quiet state brightness measurements during 9 nights in August-September carried out by I. Yu. Alekseev.

Nightly averaged brightness of EV Lac is shown in Fig. 7. The light curve shows slow variations with a peak to peak amplitude ΔV = 0.04 mag and a mean brightness V = 10.27 mag.

Recently Alekseev and Gershberg [12, 13] have offered and developed a model of zonal spottedness for red dwarfs. In this model both the effect of limb-darkening and absolute maximum of the stellar brightness found from long-term photometric measurements were taken into account [5]. Applying this model to our observations, we found the following estimations concerning the absolute spottedness of the star: in 1998 the brightest hemisphere was covered by star spots up to 9.6 %, and the darkest hemisphere — by 11.6 %; the star spot temperature was 210—220 K lower, compared to the quiet photosphere.

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