Astron. Astrophys. 334, 931–934 (1998)

ASTRONOMY
AND
ASTROPHYSICS

Research Note

New features in the EV Lacertae flares discovered by fast high precision UBVRI photometry

B.E. Zhilyaev[1], I.A. Verlyuk[1], Ya.O. Romanyuk[1], O.A. Svyatogorov[1], R.K. Konstantinova-Antova[2], A.P. Antov[2], R.S. Bachev[2], I.Yu. Alekseev[3], V.E. Chalenko[3], and D.N. Shakhovskoy[3]

[1] Main Astronomical Observatory, National Academy of Sciences, Golosiiv, 252650, Kyiv-650, Ukraine
[2] Institute of Astronomy, Bulgarian Academy of Sciences, 72 Tsarigradsko shose, BG-1784 Sofia, Bulgaria
[3] Crimean Astrophysical Observatory, Nauchny, Crimea 334413, Ukraine

Received 29 December 1997/ Accepted 27 January 1998

Abstract. The flares fine structure lies often below the detection limit for photometry data. UBVRI high-speed observations combined with synchronous monitoring at two telescopes situated far from each other allowed us to detect new small-amplitude features in the flare activity of EV Lac. Digital filtering of the light curves with a Gaussian window was used. We found that some flare events are composed of a flare and an intensity drop having a crater-shaped structure centered at the flare peak. Fading amplitudes extend from 0.1 to 0.01 mag.

Key words: stars: individual: EV Lac – stars: flare – stars: variables: others

1. Introduction

The well-known flare star EV Lac shows a wide variety of activity phenomena at different time scales. Several hundreds of classical solar-like flares were registered on it by a number of observers. However, the classical flares are not such a frequent phenomenon for EV Lac as one uses to think. As mentioned by Roizman and Kabitchev (1985), a considerable fraction of flares shows a complicated multipeak structure with sudden onset and decay. Periodic light variations with a period of 4.378 days and an amplitude 0.07 in V-magnitude were reported by Pettersen (1980) as caused by starspots and rotation. New data on this kind of variations were summarized recently by Contadakis (1995) who indicates that a long-term restructuring of the starspot areas takes place on EV Lac. Careful analysis of the quiet-state luminosity variations of the star showed the presence of occasional short-period oscillations as well as of irregular variations on a time basis of 2 hours with an amplitude of a few tenths of a magnitude (Mavridis and Vargolis, 1993). In recent years, a few reports appeared about observations of short-time outbursts in EV Lac with a duration of 0.1 to several seconds. These results were summarized briefly by Zhilyaev (1994). The history of flare stars photometry yields many examples of a pre-flare dip phenomenon. The first pre-flare dips observations in YZ CMi were reported by Rodono et al. (1979) and confirmed by Cristaldi et al. (1980). They are characterized by an amplitude of a few tens of percent in optical bands and durations of a few seconds. A low amplitude pre-flare dip with an exceptionally long duration of 36 min was detected in the light curve of V1054 Oph by Ventura et al. (1994). Recent results on this topic were summarized by Ventura et al. (1995). A new kind of flares in EV Lac was reported by Zhilyaev and Verlyuk (1995). A few events showed a flare in the U band accompanied by a dip in the V band at the same time with a duration of a few seconds and fading amplitudes of a few hundredths. To clarify the situation international campaigns for simultaneous observations of EV Lac were carried out in the years 1995-96 at three Observatories in Ukraine, Russia and Bulgaria. The results of these campaigns are reported here.

Send offprint requests to: B.E. Zhilyaev, (zhilyaev@mao.kiev.ua)

2. Observations

We present EV Lac photometric observations carried out at three observatories in Ukraine, Russia and Bulgaria. The 60-cm Cassegrain telescope with a high-speed two-channel photometer (Zhilyaev et al. 1992) was used for all the data obtained at the Peak Terskol High-Altitude Observatory (North Caucasus, elevation 3100 m). The photometer has two independent synchronous channels with a photon counting system. Two operating modes are available. In the first mode two stars can be observed simultaneously. In the second one a single star can be observed in both channels by using the beam-splitter. Both operating modes were used for the photometry of EV Lac in the UBV bands, with a time resolution down to 0.05 s. Regular observations of EV Lac revealed the existence of a flare fine structure detected for first time on 1990 August 27 (Fig. 1). To refine our understanding of this phenomenon series of coordinated observations of EV Lac were carried out in Bulgaria, at Peak Terskol and in Crimea in 1995-96.

In Bulgaria the photometric observations were carried out at the Belogradchik Observatory, equipped with a 60-cm Cassegrain telescope and a single-channel photon-counting photometer (Antov and Konstantinova-Antova, 1995). The instrument operates in a semi-automatic mode. UBV and uvby photometric systems are available. The integration time used for EV Lac observations was 0.1 s. The monitoring was done synchronously with the 60 cm telescope at Peak Terskol. The time synchronization accuracy was of 1 s. The distance between both observatories is approximately 1500 km.

At the Crimean Astrophysical Observatory the photometric monitoring was carried out with a time resolution of 0.1 s using the 1.25 m reflector AZT-11 equipped with the UBVRI photometer-polarimeter described by Piirola (1984) and Kalmin & Shakhovskoy (1995). The sky background was subtracted from all the data presented here. The UBVRI data were converted in a magnitude scale with respect to the mean values of quiescent fluxes.

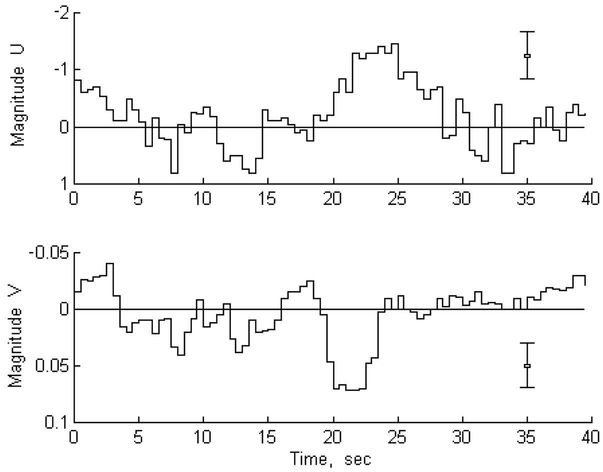

Fig. 1. EV Lac on 1990 Aug. 27, 00:45 UT. U band (top), V band (bottom). Peak Terskol. The bar indicates the rms deviation for the quiet state

3. Methods and results

To recognize features in flares one usually requires an amplitude of the order of 0.1 mag (Gershberg 1986; Ventura et al. 1995; Konstantinova-Antova and Antov, 1995). The digital filtering technique (FT) enables an appreciable increase in the photometric quality of the light curve by reduction of atmospheric and photon noises. The FT can be made by convolving the series of counts n(i) with the filter pulse response characteristic coefficients h(i)

$$n_f(k) = \sum_{i=-\infty}^{\infty} h(i)n(k-i) \qquad (1)$$

Here the index f refers to the counts modified by filtering. For typical noise spectra that have approximately an uniform spectral density, the initial and the postfiltered variances σ^2 and σ_f^2 satisfy the condition (Jenkins et al. 1969)

$$\sigma^2 = \sigma_f^2\tau; \qquad (2)$$

$$\tau = (\sum_{i=-\infty}^{\infty} h^2(i))^{-1}, \qquad (3)$$

where τ is the correlation interval of the filtered series. The quantity τ can also be considered as a time-resolving power in the post-filtered data or as the effective filter band width. We consider filter the data by a low-pass filter with a Gaussian window

$$h(i) = \frac{\sqrt{2}}{m} exp[-2\pi(\frac{i}{m})^2], \qquad (4)$$

where m is expressed in units of the sampling time Δt. According to (3), the correlation interval of the filtered series is then $\tau = 2m\Delta t$. This filtering technique allows to reach an accuracy comparable or even below that due to counting statistics at the cost of decrease in time resolution. Using the FT, our observations revealed small-scale features in flare events of EV Lac with limiting amplitude lower by a factor at least of the order of 3 compared to usual observations.

Fig. 1 shows the light curves of EV Lac detected on 1990 August 27, 00:45 UT in the U and V bands simultaneously. The observations presented here were obtained at Peak Terskol with the two-channel photometer and a time resolution of 0.5 s. The prefiltering technique developed by Zhilyaev et al. (1994) was applied for detection of small-scale activity. The standard deviations of $\pm 1\sigma$ for quiet state are shown. It is particularly remarkable that the classical flare event in the U band with an amplitude of -1.2 mag was accompanied by a dip in the V band at the same time. The decay and the rise times in V are of 2 to 3 s. The fading duration is of about 5 s and has an amplitude of 0.07 mag. The U flux increase and decrease are roughly exponential. The time span of the flare event in U equals about 10 s.

Fig. 2 exhibits a more extreme case of flare on EV Lac observed on 1995 August 4, 23:23:20 UT. This remarkable event was registered at two distant telescopes operated simultaneously. The U-band light curve was obtained at Peak Terskol. The B-band monitoring was carried out at the Belogradchik Observatory in Bulgaria. Raw U data indicate a flare with an effective width of 0.6 s and an amplitude of -1.5 $\pm$ 0.2 mag. We could not identify any significant variations in the raw B data prior to filtering. After filtering a drop by 0.09 $\pm$ 0.03 mag for 1.5 s was found at the time of the flare. The light curves shown in Fig. 2, have been smoothed by a Gaussian filter with an effective bandwidth of 0.6 s. The bars shown are the standard deviations for the filtered data in the quiet state of the star.

The EV Lac observations, shown in Fig. 3 were made with the 1.25 m telescope AZT-11 in Crimea and the UBVRI photometer-polarimeter described by Piirola (1984) and Kalmin & Shakhovskoy (1995) on 1996 October 5, 23:47:23 UT. The monitoring was carried out in UBVRI simultaneously with a time resolution 0.1 s. The detected flare event is notable for many reasons, including its unique behavior in the different colors. The emission flare itself is of short duration and appears

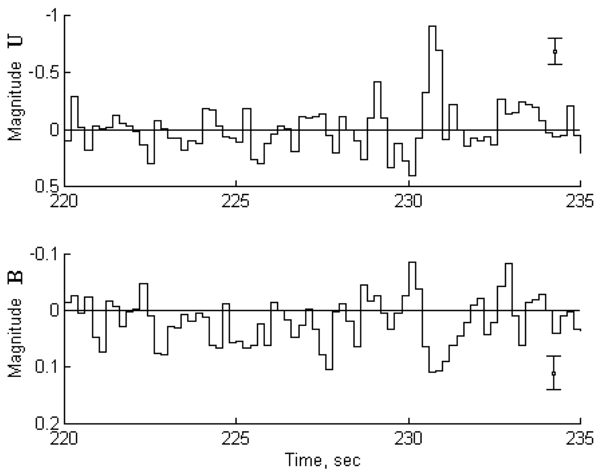

Fig. 2. EV Lac on 1995 Aug. 4, 23:00 UT. U band, Peak Terskol (top), B band, Belogradchik (bottom). The bar indicates the rms deviation for the quiet state

with amplitudes of -0.55, -0.05, -0.01, -0.007, -0.005 in UBVRI bands respectively. The time delay between the flare in RI and in UBV is about 10 s. There is a clear post-flare emision in U lasting for more than 150 s. Before and after the flare there is an intensity drop visible in V,R and I and partly in B. The I band drop has clearly defined boundaries with e-folding decay and rise time of about 20 s and 90 s long. The situation with the other bands is more uncertain due to lower signal to noise ratios. It is obvious that such fadings are phenomenon related to the flare beginnings before and with a minimum at the flare peak. Note that the fading amplitudes in the BVRI bands are quite small and ranged from 0.02 to 0.01 mag. Such low amplitude variations lie usually below the detection limit for raw photometric data. Their discovery became possible by use the filtering technique.

4. Conclusions

Multicolor high-speed observations combined with synchronous monitoring at two distant telescopes allow one to detect new fine-scale features in flare activity of EV Lac. Our photometric data and the filtering technique make possible the detecting of events with amplitudes as small as 0.01 mag, comparable to the limit of counting statistics. A new kind of flares observed for first time by Zhilyaev and Verlyuk (1995) is confirmed. These events are composed of a flare and a related intensity drop in the B to I bands. That crater-shaped structure is centered at the flare peak. A decrease of the star luminosity occurs before the flare itself. The pre-flare dip mentioned by many observers can be considered as part of this fading. It is of interest that this activity is common to both short-lived and long-duration flare events. These results should yield new insights into the physics of stellar flares.

Acknowledgements. This research was partially supported by a grant from the American Astronomical Society.

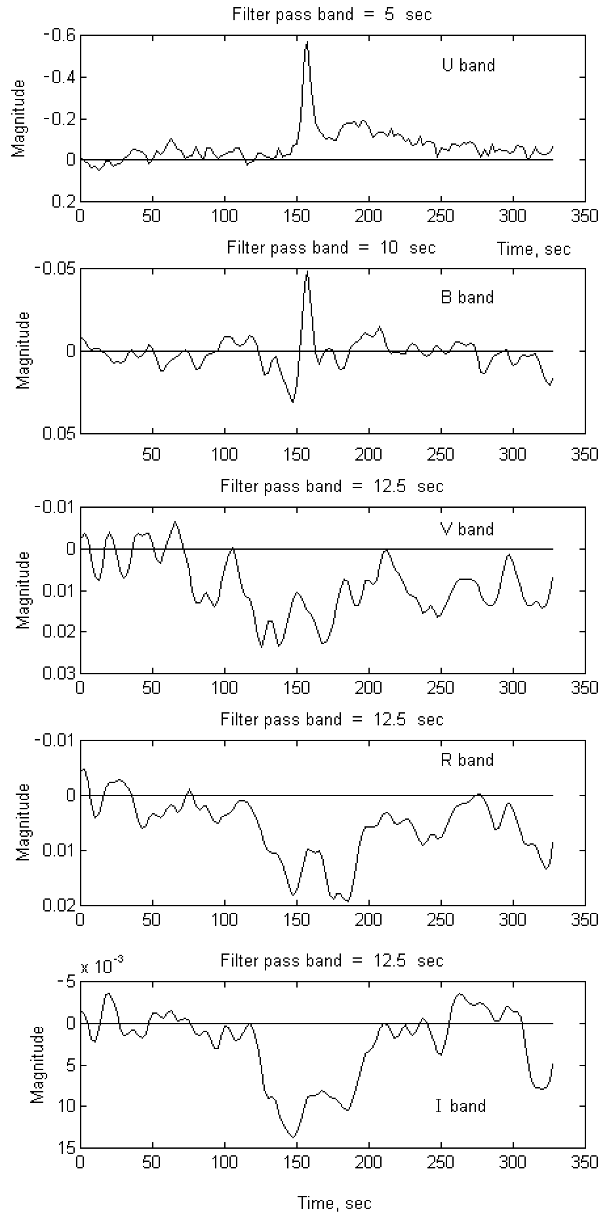

Fig. 3. EV Lac on 1995 Oct. 5, 23:47:36 UT. UBVRI bands from top to bottom. Crimean Astrophysical Observatory

References

Antov A. and Konstantinova-Antova R., 1995, in: Robotic observatories, edited by M.F.Bode, 69, Praxis Publishing Ltd. Chichester, England

Contadakis M.E., 1995, A&A 300, 819

Cristaldi S., Gershberg R.E., Rodono M., 1980, A&A 89, 123

Gershberg R.E., 1986, in: Flare Stars and Related Objects, edited by Mirzoyan, 162. Publishing House of Acad. of Sci., Yerevan

Jenkins G.M. and Watts D.G., 1969, Spectral Analysis and its Applications, (Holden-Day: San Francisco)

Kalmin S.Yu., Shakhovskoy D. N., 1995, Kinematika i Fizika Nebesnyh Tel, 11, No 3, 85

Konstantinova-Antova R. and Antov A.P., 1995, in: Flares and Flashes, eds.J.Grainer, H.W.Duerbeck and R.E.Gershberg, 87, Springer-Verlag Berlin

Laskaridis P. (ed.) Proc. First Panhellenic Astron. Meeting, National Astron. Committee, Athens, 203
Pettersen G.S., 1980, AJ 85, 871
Piirola V., 1984, Observ. Astrophys. Lab. Univ. Helsinki Report No 6, 151
Rodono M., Pucillo M., Sedmak G., De Biase G.A., 1979, A&A 76, 242
Roizman G.S., Kabichev G.I., 1985, AZh 62, 1095
Ventura R., Pagano I., Peters G., et al., 1995, in: Flares and Flashes,eds. J. Greiner, H.W. Duerbeck and R.E. Gershberg, 108, Springer-Verlag Berlin
Ventura R., Peres G., Pagano I., Rodono M., 1995, A&A, 303, 509
Zhilyaev B.E., Romaniuk Ya.O., Svyatogorov O.A., 1992, AZh 69, 895
Zhilyaev B.E., 1994, Kinematika i Fizika Nebesnyh Tel, 10, No 1, 32
Zhilyaev B.E., Romaniuk Ya.O., Svyatogorov O.A., 1994, Kinematika i Fizika Nebesnyh Tel, 10, No 6, 88
Zhilyaev B.E., Verlyuk I.A., 1995, in: Flares and Flashes, eds. J. Greiner, H.W. Duerbeck and R.E. Gershberg, 80, Springer-Verlag Berlin