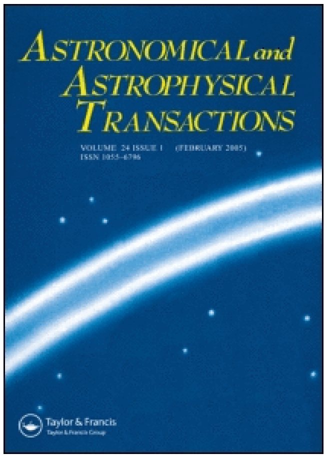

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SOME RESULTS OF INTERNATIONAL CAMPAIGNS INITIATED BY THE CRIMEAN ASTROPHYSICAL OBSERVATORY FOR INVESTIGATIONS OF FLARE STARS*

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In 1967–1973 and in 1986–1995, two sets of international cooperative programmes were initiated by the Crimean Astrophysical Observatory for studying UV Cet-type flare stars. The first was devoted to photometric observations with the purpose of studying the temporary distribution of flares and their power; during the second series of campaigns the photometric monitoring of one of the most active stars of this type EV Lac was accompanied by various observations (spectral, polarimetric, ultraviolet, infrared and radio) of this object. A brief list of data received, some results on their astrophysical analysis and its later development are given.

Keywords: Flare stars; International campaigns

1 1967–1973

In 1967 at the 13th General Assembly of IAU, the Working Group on Flare Stars was organized under the initiative of the Crimean Astrophysical Observatory. The aim of the Working Group was to organize international cooperative monitoring of selected UV Cet-type stars to research the temporary distribution of flares of these objects. The Working Group regularly published in the Information Bulletin on Variable Stars the timetable of such observations, but beforehand a list of the participants was not determined, and the results of observations were published independently in the Information Bulletin on Variable Stars or in the bulletins of various observatories. During 1967–1973, 36 campaigns were carried out and some dozens of observers from 19 observatories in Great Britain, Hungary, Greece, India, Italy, New Zealand, Poland, USSR, USA, Chile, Yugoslavia, South Africa and Japan took part. During these campaigns, eight flare stars were monitored for about 3000 h and several hundreds of flares were recorded. The collected data were used for an analysis of the temporary and power characteristics of flares.

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1.1 Temporary Distribution of Flares

The most detailed study of the temporary distribution of flares on the basis of cooperative monitoring of UV Cet and YZ CMi have been carried out by Oskanian and Terebizh (1971a). They considered the numbers of flares in fixed time intervals and temporary gaps between flares and have not confirmed the earlier proposed assumption on the periodicity of flares; in general the temporary distribution of flares corresponded to a Poisson distribution with the highest probability, but with some excess of a number of flares that are very close in time. Later similar results were received from a larger amount of more homogeneous data and, as a result of the excess of close flares, it was realized that there were stellar analogues to solar sympathetic flares.

1.2 The Energy Spectra of Flares

The statistics of the flare energy based on cooperative observations for the four most active stars, namely UV Cet, AD Leo, YZ CMi and EV Lac, were considered by Oskanian and Terebizh (1971b) and by Chugainov (1972) almost simultaneously and independently. Byurakan researchers have estimated the optical luminosity range of flares and their total energies, have considered the flare amplitude and energy distributions, have constructed their frequency functions and for the first time have estimated the possible contribution of weak (below the limit of detection) flares in the total flare radiation; they have also noted that rare power flares provide the main contribution to the total flare radiation.

Chugainov (1972) proposed to use accumulated frequencies for the statistics of flares and has found the power law of the flare energy spectrum of flares with a sharp break near the limit of certain detection. This has allowed him to choose the part of the energy spectrum of sufficiently strong flares, that is free from observational selection (Fig. 1) and to compare the results of independent observers. On the basis of the results of the cooperative campaigns and other photometric observations we have constructed energy spectra of flares of several tens of flare stars within the M_V range from magnitude 8 up to magnitude 17 (Gershberg, 1972; Gershberg and Shakhovskaya, 1983). Korotin and Krasnobabtsev (1985) considered photographic observations of flare stars in the closest open stellar clusters and have also

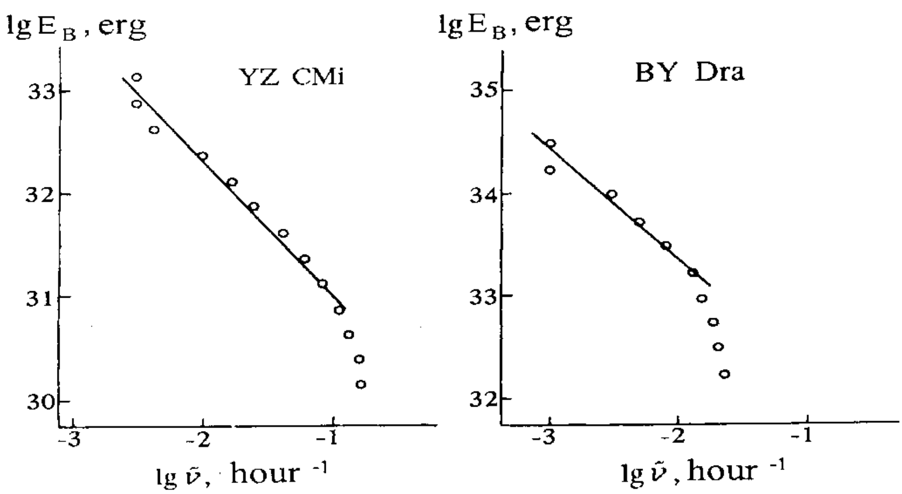

FIGURE 1 The energy spectra of the YZ CMi and BY Dra flares in the B band (Gershberg and Shakhovskaya, 1983).

found the power spectra of flares. It allowed to construct a common picture of the flare activity of stars within the range of ten orders of magnitude (Fig. 2). In the plot in Figure 2, only physically significant parts of flare energy spectra are given for stars within the solar vicinity, for several flare star groups in the Pleiades and Orion clusters and for the solar flares. A systematic application of the formalism of a general power spectrum found turned out to be very fruitful and was used later by many investigators.

So it was shown that for observable spectral indices of flare energy spectra the main flare energy release was as a rule due to rare strong flares, and this flare energy is approximately several per cent of the quiet luminosity of stars (Gershberg and Shakhovskaya, 1983). Then the total flare energy release is within an order of magnitude of the chromospheric and coronal luminosities (Gershberg and Shakhovskaya, 1983; Shakhovskaya, 1989). When this fact was found by three independent research centres (Doyle and Butler, 1985; Skumanich, 1985; Whitehouse, 1985), it became the initial point for the hypothesis about coronal heating by numerous microflares.

Finally, a comparison of spectral indices of flare energy spectra of stars in stellar clusters of different ages provided grounds for suggesting the evolution trend of the index shown in Figure 3. In any case, the spectral index of the solar flares at the solar maximum corresponds to young clusters while the index at the solar minimum corresponds to older clusters (Gershberg, 1989).

Influenced by our results, Kurochka (1987) found the power energy spectrum of the solar optical flares as shown in Figure 2, where the spectrum was constructed by using 15,500

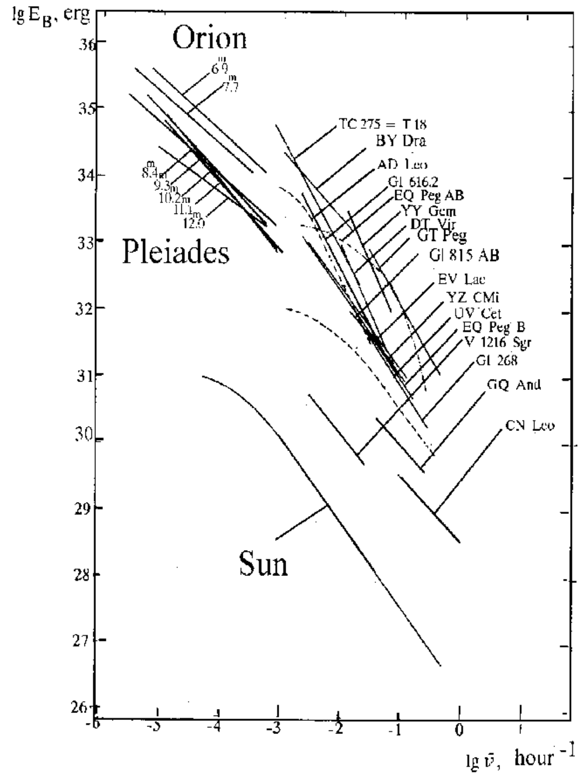

FIGURE 2 The energy spectra of stellar flares on flare stars in the solar vicinity and in the Pleiades and Orion clusters and the energy spectra of the solar flares (Gershberg et al., 1987). The numbers near the cluster group spectra indicate the magnitude of the mean brightness of the star in each group.

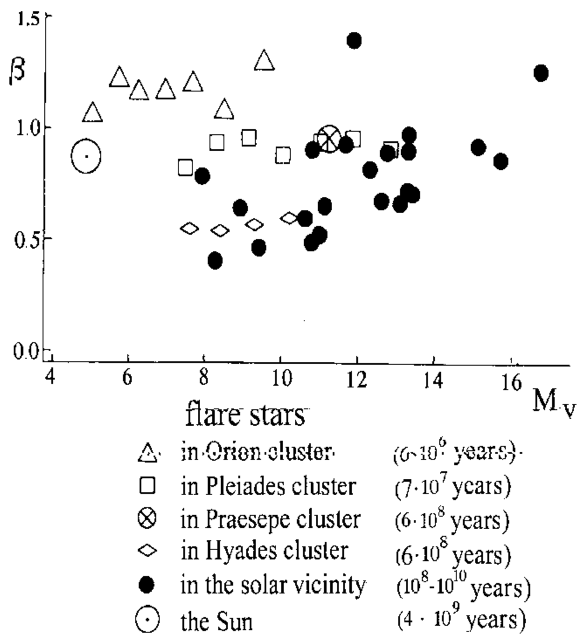

FIGURE 3 Spectral indices of flare energy spectra of flare stars in the solar vicinity and in stellar clusters of different ages and of the solar flares (Gershberg, 1989).

flares. Then Kasinsky and Sotnikova (1989) found the same character of the energy spectra for soft-X-ray solar flares. Moreover, these Irkutsk researchers discovered a close correlation between the spectral index and the Wolf numbers, that is the systematic variations in the index over rather a short time scale. In turn, because of this result, the 20 year series of EV Lac monitoring was analysed at the Crimean Astrophysical Observatory and the periodic variation in the stellar spectral index was found to have a period of about 7.5 years (Alekseev and Gershberg, 1997a,b).

Unfortunately, the hope of resolving the problem of the stellar flare energy source or the mechanism of energy release by consideration of the spectral indices was not realized. It was found that the power law of a flare energy spectrum fits semiqualitative concepts on dissipation in flares of both the magnetic (Pustil'nik, 1988) and the kinetic (Kasinsky and Sotnikova, 1988) energy, modern models of flares within the framework of the avalanche theory (Lu and Hamilton, 1991) and the theory of phase transitions in turbulent plasma (Pustil'nik, 1997).

The observations gathered during the course of these cooperative campaigns form considerable contributions to the general databank on flare stars.

2 1986–1995

The cooperative campaigns in 1986–1995 were devoted to comprehensive investigations of EV Lac, one of the brightest and most active flare stars of the northern sky. Having a declination of about +44°, this star can be observed on autumn nights continuously for 8–9 h, and the idea behind these yearly campaigns consists of long photometric monitoring for several nights and parallel spectral, polarimetric, infrared (IR), UV and radio observations. In contrast with the campaigns of 1969–1973, participation in the campaigns of 1986–1995 was organized by preliminary personal contacts. Complete reports on the second series were published in summary articles on each campaign by Gershberg et al. (1991a,b, 1993), Alekseev et al. (1994), Abdul-Aziz et al. (1995), Berdyugun et al. (1995) and Abranin et al. (1998a,b). The basic results of these cooperative research studies are as follows.

2.1 Optical Photometric Results

In the optical range, photometric monitoring was carried out at the Crimean Astrophysical Observatory (CrAO) (Crimea, Ukraine), at the Stephanion Observatory (Greece), in Catania (Italy), at the Special Astrophysical Observatory (SAO) (Nizhny Arkhyz, Russia), in Rozhen and Belogradchik (Bulgaria), in Byurakan (Armenia), in the Canary Islands (Spain) and at the Galilee Sea Astrophysical Observatory (Israel). In Crimea 227 flares were detected in 307 h of monitoring, at the Stephanion Observatory 40 flares in 145 h, in Italy, Bulgaria and Russia about two dozen flares in each in about 40, 50 and 20 h respectively, at the NORDIC telescope (Spain) nine flares in 23 h and in Armenia two flares in more than 15 hours. As was mentioned, photometric investigations were firstly planned as auxiliary observations for other kinds of research; however, the data gathered have presented independent information.

The rather large set of homogeneous data obtained at the 1.25 m reflector AZT-11 of the CrAO, equipped with a UBVRI photometer–polarimeter, contained, as already mentioned, 227 flares that were used for different investigations.

To clarify the nature of the flare emission, a colorimetric analysis was applied at the CrAO to the strongest flares, when for all UBVRI bands the signal was sufficiently large. For this task for the ascending branches, the brightness maxima and the beginning of the descending branches of such flares, the colour indices U − B, B − V, V − R and V − I of a pure flare emission were found and compared with the theoretically calculated indices for different radiation sources: for black bodies of different temperatures, for synchrotron emissions with different indices of energy spectra of relativistic electrons, for radiation of hydrogen plasmas of different temperatures, densities and optical thicknesses at the Balmer continuum and for radiation of the upper layers of a stellar atmosphere which have been heated by fluxes of fast particles (Chalenko, 1999). The comparison of these calculations with observable characteristics of flares (Fig. 4) permits the following conclusion.

(i) None of the considered radiation mechanisms can alone reproduce the flare radiation observed within the whole UBVRI range at any flare phase.
(ii) Near the brightness maxima of strong flares the UBV flare radiation is rather close to the black-body maxima for temperatures from 10,000 to 25,000 K.
(iii) In the longer-wavelength regions for the brightness maxima and in the UBV bands at flare decay phases the contribution of the hydrogen plasma of some optical thicknesses increases.

We have noted above the use of the Crimean monitoring observations to search for the periodicity in the spectral index of the EV Lac flare energy spectra.

Several flares that had been recorded at the SAO with the fast photometry mode have been analysed to search for the existence of high-frequency components but, within the range from 1 ms to 10 s, no such components were found (Beskin et al., 1995).

2.2 Infrared Research

Within the framework of the cooperative campaigns of 1991–1993, M. R. Kidger carried out the EV Lac photometric monitoring in the near-IR (the K band) with the single-channel

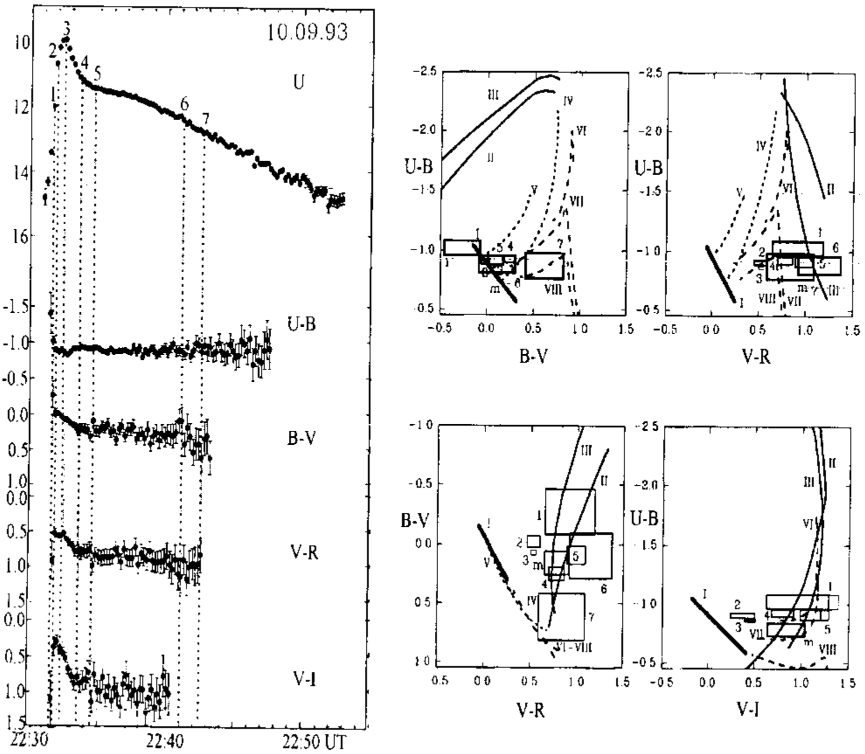

FIGURE 4 Curves of light and colour indices of the powerful EV Lac flare on September 10, 1993, at universal time (UT) 23:32 and colour–colour diagrams of the pure flare radiation: curves I, black-body radiation for temperatures ranging from 6000 to 20,000 K; curves II and III, emission of hydrogen plasmas optically thin in the Balmer continuum (Ba_C) hydrogen plasmas with $T = 10{,}000$ K and $n_e = 10^{12}$ and $10^{14}\,cm^{-3}$ respectively; curves IV and V, emission of hydrogen plasmas optically thick in the Ba_C with $T = 10{,}000$ and 15,000 K respectively; curves VI, VII and VIII, radiation emitted by upper layers of the dwarf stars' atmospheres heated with proton fluxes with energies higher than 1, 3 and 5 MeV respectively. The numbers labelling the rectangles corresponds to the numbers on the dotted vertical lines in the left-hand plot (Abranin et al., 1998a,b).

chopping photometer mounted at the Cassegrain focus of the 1.5 m Carlos Sanchez telescope that operated on the Canary Islands. In 1994–1995, IR monitoring was carried out in the K band by G. Cutispoto et al., at the 91 cm reflector of the Institute of Astronomy, Catania University, Catania, Italy. In 1995, V. M. Larionov carried out IR monitoring in the H band using the 70 cm telescope AZT-8 of the CrAO and the IR photometer of the Astronomical Institute of St Petersburg University.

During the listed campaigns, IR monitoring covered one strong (September 10, 1993) and more than two dozen faint flares detected in the U band. However, no synchronous variations in IR and optical radiation were detected. It became obvious that the IR brightness decrease found by Rodono (1986) as well as its increases noted by Bruevich et al. (1980) are not general characteristics of the UV Cet-type flares. However, later D. N. Shakhovskoy carried out UBVRI monitoring of EV Lac within the framework of the B. E. Zhilyaev's (Zhilyaev et al., 1998) programme at the AZT-11 and certainly found two components of the flare on October 5, 1996: the traditionally recorded emission component that was the most visible in the U band, and the absorption component that was more prolonged and symmetric around the emission component and with amplitudes increasing toward longer wavelengths (Fig. 5). After that we reconsidered previous IR records obtained in the cooperative monitoring during optical

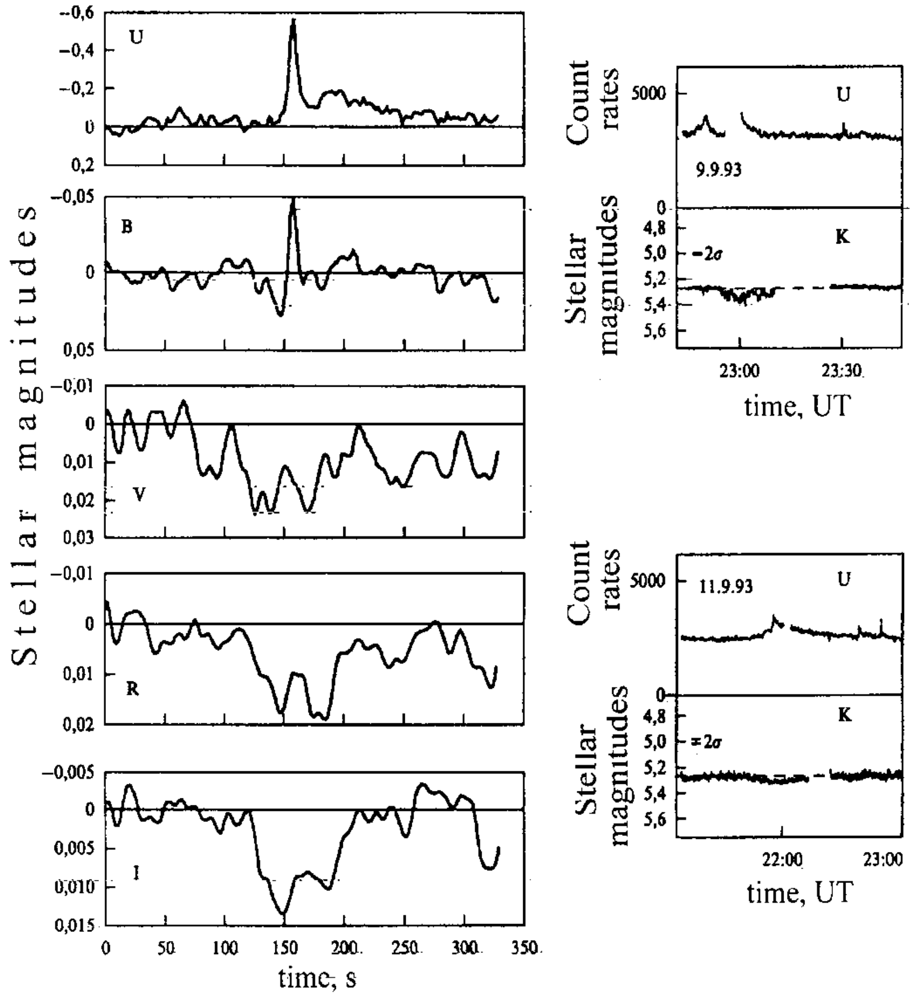

FIGURE 5 UBVRI light curves of the EV Lac flare on October 5, 1996, and segments of light curves of EV Lac flares registered in the U band (Crimea) and in the K band (Canary Islands) (Gershberg, 1998).

flares and found similar IR brightness decreases during faint flares (Fig. 6). The physical meanings of these events remain unclear, but the idea of ‘an emission peak in an absorption saucer’ permits us from a single point of view to present many known colorimetric features that have no single-valued interpretation yet (Gershberg, 1998).

2.3 Polarimetry

Measurements of the linear polarization of EV Lac were carried out by N. M. Shakhovskoy (CrAO), at the Cassegrain focus of the 2.6 m Shajn reflector with a single-channel polarimeter. During the 1989 and 1991 campaigns the polarimetry of 13 flares of EV Lac were obtained. The analysis of the U-band flare polarimetry has shown that for all flares the polarization is less than 5% at 10 s time resolution and less than 2–3% at 50 s time resolution. The most powerful observed flare imposes more stringent constraints on the quoted values: 2% and

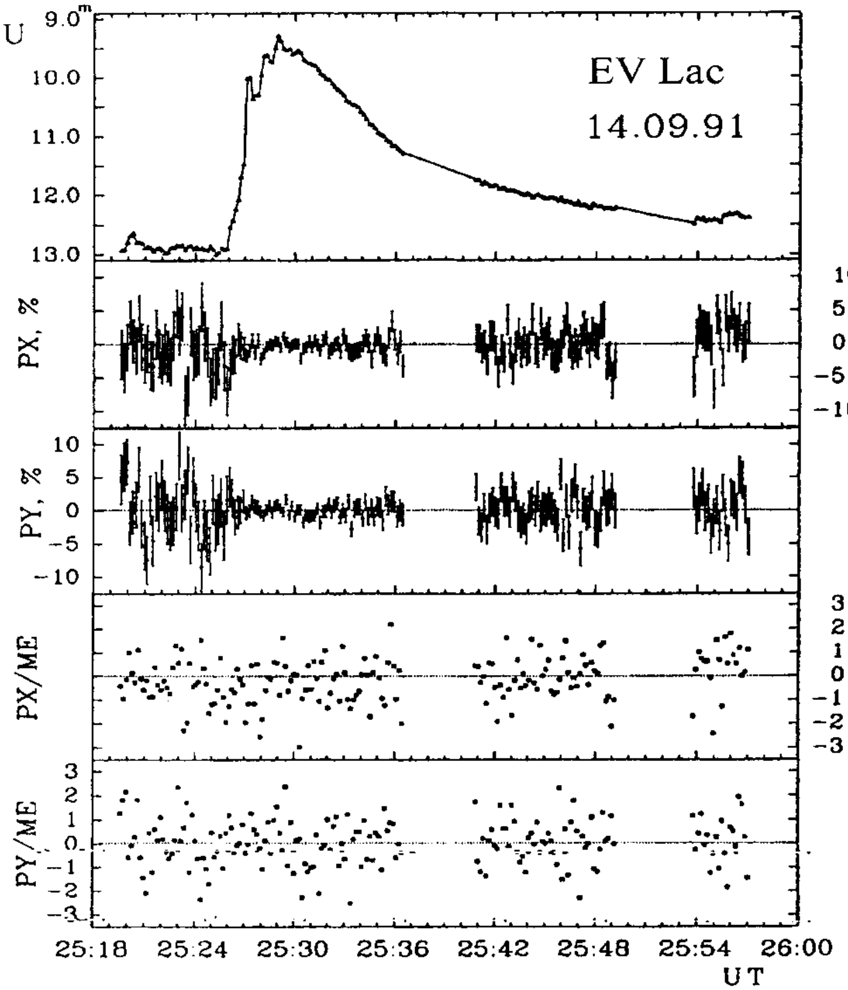

FIGURE 6 Photometric and polarimetric measurements of EV Lac during the most powerful flare on September 14, 1991 at UT 25:29 recorded with 10 s time resolution: (a) the U-band light curve; (b), (c) the normalized Stokes parameters P_X and P_Y for which their mean squared errors (MEs) were computed by quantum statistics; (d), (e) the ratios P_X/ME and P_Y/ME of these parameters to their errors (Alekseev et al., 1994).

1% respectively. Therefore, this, which is the clearest result of very long observational attempts, suggests that the intrinsic optical radiation of flares is not polarized (see Fig. 6).

2.4 Spectral Investigations

The spectral observations of EV Lac during the cooperative campaigns were carried out at the 2.6 m Shajn telescope of the CrAO (spectrographs with a low resolution in the Nasmyth focus and with a high resolution in the Coude focus were used), at the 6 m telescope of the SAO and at the NORDIC telescope (Canary Islands) with the echelle spectrograph SOFIN that was manufactured in Crimea.

In 1986 and 1987, EV Lac were observed at the Shajn telescope in the Hα line region. In 1986 we found clear anticorrelation between the stellar brightness and the equivalent width of the line in the quiet state of the star. In 1987 this anticorrelation disappeared; the brightness

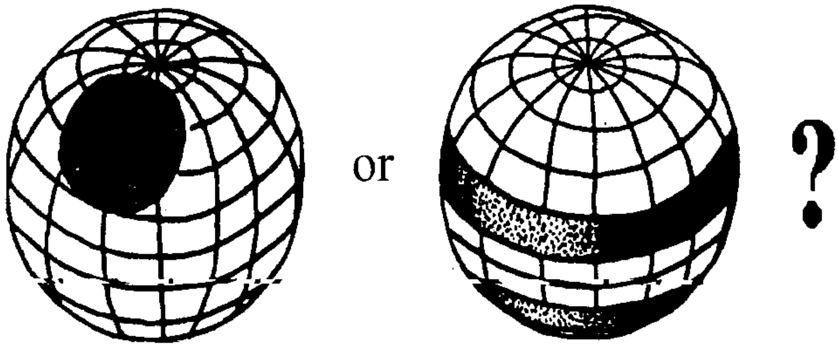

FIGURE 7 The traditional model of the stellar spottedness of a star with one to two large spots and a model of zonal spottedness (Alekseev and Gershberg, 1996c).

of the star and the amplitude of rotational modulation had decreased but the Hα flux had increased. These variations did not fit the traditional scheme of stellar spottedness that is due to one or two compact star spots; in such a scheme the total brightness decrease should (if the spots are not too close to a pole) be accompanied by an increase in the amplitude of rotational modulation.

This contradiction between observations and the traditional spottedness model was the starting point for the concept suggested by Alekseev and Gershberg (1996b, 1997b), namely the zonal spottedness of a red dwarf, in which instead of the parameters of one or two compact stellar spots, to which the whole photometric effect of the stellar brightness decrease is attributed, a general picture of a stellar spottedness is considered (Fig. 7); the observable features of EV Lac for these years were explained by the increase in total spottedness and the more uniform arrangement of the spots along longitudes. To date, within the framework of this spottedness model the UBVRI observations of 25 red dwarfs for more than 340 epochs have been successfully presented, some correlation between the parameters of the models and the global stellar characteristics have been found, and the solar spottedness features fit these correlations (Fig. 8) (Alekseev, 2001).

In 1989 at the 6 m telescope the rotational modulation of emission features in the EV Lac spectrum was detected while constancy of absorption spectral features occurred. In 1991 this result was confirmed. This means that the emissions are located unevenly within separate active regions while absorptions are located evenly over the stellar surface.

In Crimea in 1990 the Hα profiles were recorded during three strong flares; in two cases the red wing spread up to $+130\,\mathrm{km\,s^{-1}}$ and in the third case the blue wing spread to $-100\,\mathrm{km\,s^{-1}}$ with an undisturbed red wing. The decay of one of these flares was observed at the 6 m telescope, and the decay rate of the Hδ line was found to be 1.5 faster than the Hβ decay rate; this was due to less opacity of the flare in the Hδ line.

In 1992 at the Shajn telescope, earlier rare detected or non-detected emissions of Fe II, Fe I, Mg I were recorded in flare spectra. The Hβ profile analysis in moderate power flares has shown that line broadening was negligible at the half-maximum level, that it became noticeable at 20% of the maximum level and that it became best visible at 10% of the maximum level. Broadened profiles could be formally represented by two Gaussians with very different widths or by a set of three to seven Gaussians of the instrumental width with a dispersion of maximum wavelengths of about 400–700 $\mathrm{km\,s^{-1}}$ on the velocity scale.

Very interesting data have been obtained in Crimea during the night of August 31–September 1, 1994; they are given in Figure 9. In Figure 9(a) the light curve in the U band of the star is shown, on which half a dozen characteristic fast flares with different ampli-

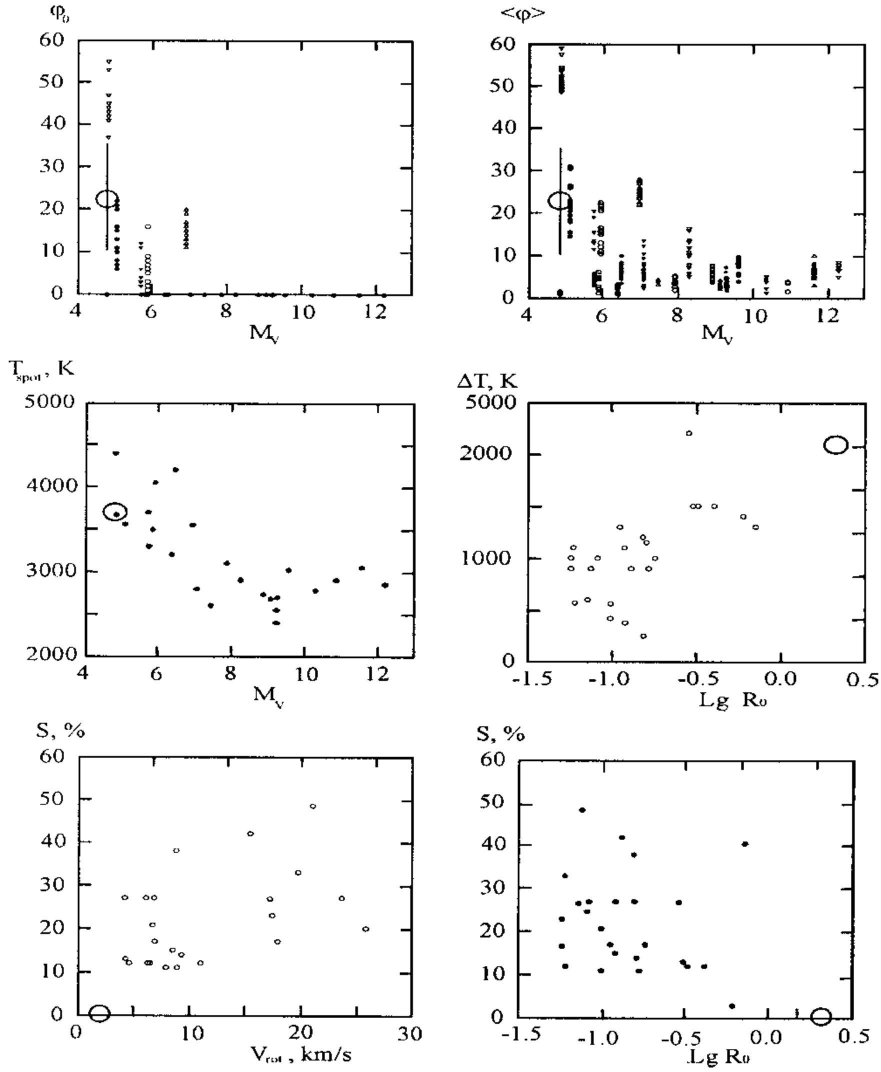

FIGURE 8 Comparison of the calculated parameters of zonal models of spottedness of the red dwarf stars, namely the lowest latitudes ϕ_0 of spotted belts, the average latitudes $\langle\phi\rangle$ of spots, the temperatures T_{spot} of spots, the differences ΔT between the temperatures of the photosphere and the spots and the spottedness degrees S of stellar surfaces, and the global stellar parameters, namely the absolute magnitudes M_V of the star, the velocities v_{rot} of stellar rotation, and the Rossby numbers R_0 (Alekseev, 2001).

tudes and with durations of several minutes are clearly visible and the stellar brightness increase that took place in about 3 h.

Figure 9(b) demonstrates the equivalent widths of the Hβ line which correlate with fast flares, but strengthening of this emission during the long increased stellar brightness is predominating. The equivalent widths of the emission blend Fe II + Mg I shown in the Figure 9(e) shows behaviour similar to $W_{H\beta}$ with a correlation coefficient of 0.94.

Figure 9(c) displays the equivalent width of the neutral helium line ($\lambda = 4471$ Å). The comparison of this plot with those on Figures 9(a) and (b) shows that this line reacts more clearly to separate fast flares than Hβ does, although the coefficient of correlation between these two emissions is 0.76.

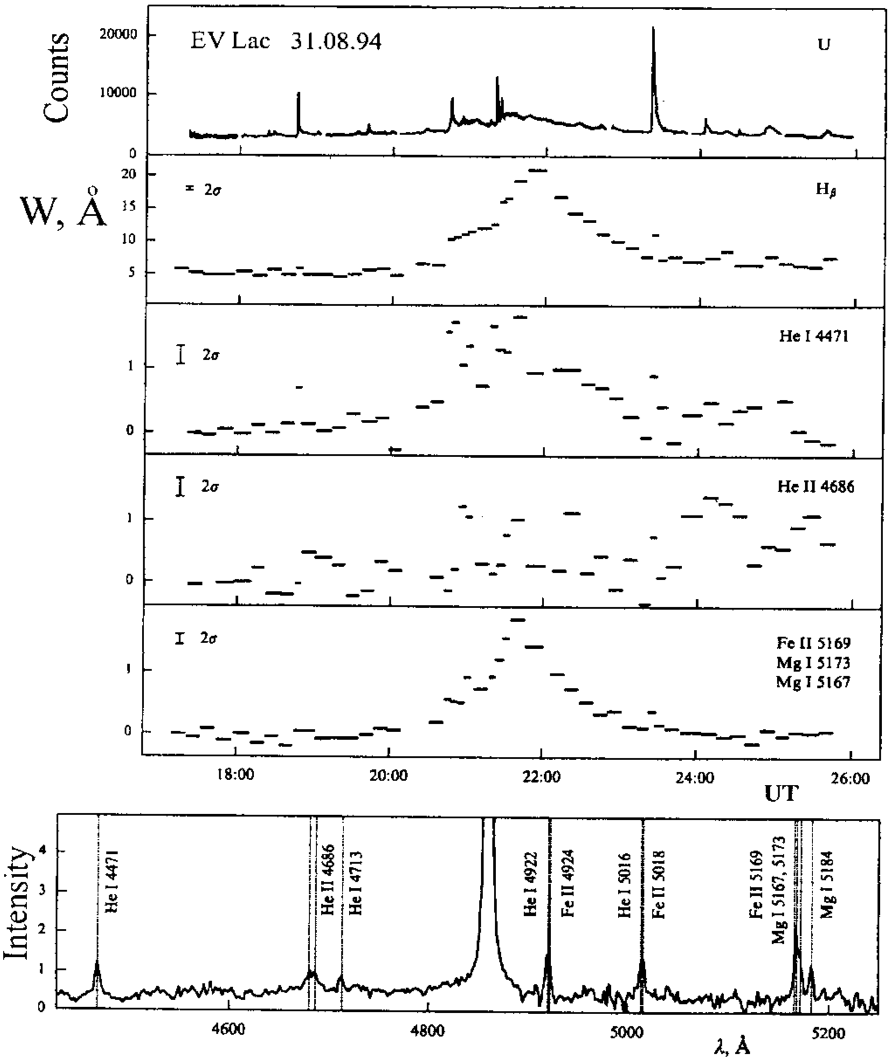

FIGURE 9 Results of photometric and spectral monitoring of the red dwarf star EV Lac obtained on the night of August 31–September 1, 1994, in Crimea: (a) the count rates in the U band; (b)–(e) the equivalent widths of the emission lines (b) Hβ, (c) He I ($\lambda = 4471$ å), (d) He II ($\lambda = 4686$ å) and (e) the combined metallic lines; (f) the combined spectrum of the star in the active states (Gershberg, 1998).

The most interesting and unexpected results were obtained by monitoring the ionized helium $\lambda = 4686$ Å emission (Fig. 9(d)). Formally, this line does not correlate with the emissions considered above; its correlation coefficients lie within the range 0.2–0.3. However, closer consideration shows that the strengthening of this emission is delayed by 15–30 min with respect to fast flares.

The second intriguing feature of the He II emission is represented in Figure 9(f), where the combined spectrum of all active states of the star recorded during the 1994 campaign is shown. A sharp splitting of the He II emission is clearly seen in the plot; the long-wavelength component is in the normal position while the short-wavelength component is shifted by $-400\,\mathrm{km\,s^{-1}}$. Apparently, the short-wavelength component of the line can emerge in a transition region between the stellar chromosphere and corona or inside the lower corona and corresponds to driven structures that are similar to the solar transients thrown out in interplanetary space.

Spectral observations of EV Lac at the Shajn telescope in 1994 and 1995 in the Hα, Hβ, Hγ and He I ($\lambda = 4471$ Å) regions were used by Baranovsky et al. (2001) to construct semiempirical models of the quiet chromosphere of the star and its flares: distributions of temperature, electronic and complete densities in the atmosphere of the star. The qualitative new results of this modelling were that the temperature plateaux (the area with a small vertical gradient of temperature) were found both in the quiet chromosphere and in the flares.

Then the spectra of the star obtained in campaign of 1994 at the NORDIC telescope were analysed with the help of the same algorithm (Alekseev et al., 2003). Owing to the high spectral resolution, the wide wings of emission lines were found when the star was in a quiet state according to broad-band photometry. These wings are similar to those observed in the spectra of flares. The obtained data were interpreted as due to the existence of permanent microflares on the star, which were earlier suspected from observations of UV C IV and Si IV lines at the Hubble telescope, and a semiempirical model of these phenomena was constructed for the first time.

A comparison of these models with models of flares and active chromospheres has shown that the structures of the microflares found and the flares individually recorded (the energy of which exceeds the energy of microflares by one to two orders of magnitude) are rather similar, but the flares and microflares are located much more deeply in the stellar atmosphere, their electronic densities are higher by two orders of magnitude, and the temperature are higher by some thousands of degrees than those in the active chromosphere regions. So the constructed semiempirical models of active regions, flares and microflares are given in Figure 10.

2.5 Radio Monitoring

During some campaigns EV Lac was monitored using several radio telescopes. In 1986 and 1987 the star was observed at 8.2 mm with the 22 m radio telescope of the CrAO; with a noise

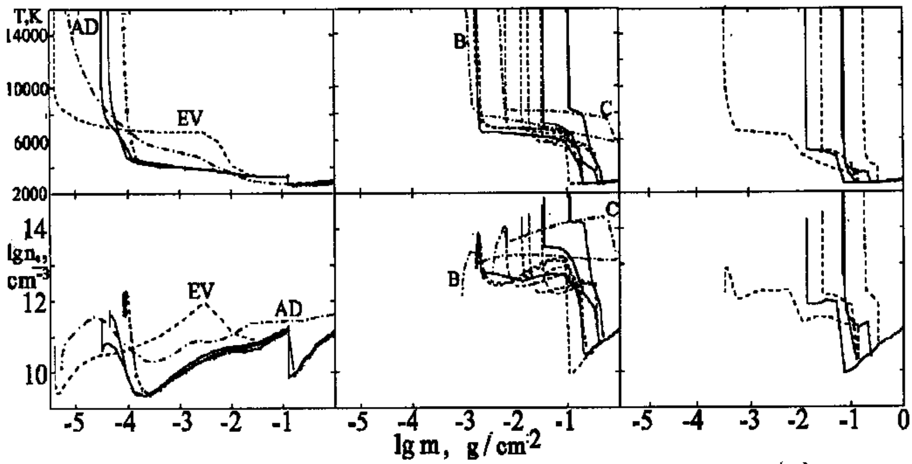

FIGURE 10 Semiempirical models of the emission structures of flare stars: (left) the models of homogeneous chromosphere of AD Leo and EV Lac and of a set of active regions covering about a fifth of the surfaces of EV Lac (——, in the quiet state of the star; —·—, during the flare); (middle) models of flares AD Leo (B and C) and EV Lac; (right) models of the microflares before (——) and after (- - - - -) the flare EV Lac on August 30, 1994, at UT 23:19 (Alekseev et al., 2003).

level of 30–50 mJy, stellar radio emission was not detected. In 1990, observations near 21 cm have been fulfilled with the radio-optical telescope ROT 32/54/2.6 in Armenia; with a noise level of 6–8 mJy flare, no radio signals were found. In 1992, radio monitoring of EV Lac has been carried out at 6 cm with the broad-band Jodrell Bank interferometer, UK; this monitoring permitted us to estimate an upper limit of stellar flux as 5 mJy.

In 1992, radio observations of EV Lac were begun in the decametric range with the UTR-2 radio telescope of the Radio Astronomy Institute of the Ukrainian Academy of Science. The UTR-2 output is supplied by two two-channel radiometers at 25 and 20 MHz; a third similar radiometer was used to monitor an area shifted from EV Lac along the declination by 1°. During 30 h of EV Lac monitoring, more than 30 bursts have been detected. About half of these were identified as terrestrial interference. The rest were individual bursts of 3 s duration and often less than 1 s or compact groups of bursts of about 10 s duration. Eight radio bursts were found to be coincident in time with optical flares and therefore were regarded as those with a high probability of stellar origin. Groups of bursts were detected only during the night when the optical activity level of the star was high; during the other nights with low optical activity, only weak individual bursts were detected.

If one supposes that a radio source size is equal to the stellar disc, the fluxes detected correspond to brightness temperature of 4×10^{17}–1×10^{18} K. Thus, the probability of detection of decametric emission from EV Lac seemed to be high. Six weak bursts were recorded in the next year for 20 h of observations, but the probability that they were of stellar origin was insignificant.

In the 1994 campaign, UTR-2 and analytical parts of the decametric observations were essentially modernized; in particular, four independent criteria of the selection of events of a non-terrestrial origin were applied. During 33 h monitoring, 18 radio bursts were detected. Only the burst of August 26, 1994, at UT 22:08 with a duration of 10 s coincided with an optical flare with ΔU of magnitude 0.5 and fitted to all criteria of selection to the stellar event with the highest probability. The brightness temperature of the burst was estimated as 10^{18} K and a mechanism of plasma oscillation was proposed for its interpretation (Abranin et al., 2001).

2.6 Space Research

The pointing system of the Soviet space station ASTRON allowed us to observe EV Lac only in February. Therefore these observations were carried out beyond the framework of the general cooperative programmes; however, because of photometric monitoring at the CrAO, they were incorporated in the described cooperative researches on this star. During two of four sessions we have recorded flares.

During the session on February 24, 1984, a very short flare of total duration 2.4 s was recorded within the range 1700–6500 Å as a strong burst in four successive telemetric intervals of 0.61 s each (Gershberg and Petrov, 1986). In that time the reality of such short flares was questionable, but later their existence was certainly confirmed by the fast photometry at the 6 m telescope (Beskin et al., 1988).

During the session on February 6, 1986, the strong flares of EV Lac with ΔU of approximate magnitude 3 was recorded at ASTRON within the ranges 1536–1564, 2420–2448 and 1700–6500 Å. The flare was recorded with the highest temporal resolution for that time in UV (less than 1 s) and because of this the flare in the C IV resonance line ($\lambda = 1550$ Å) was detected 7 s before the beginning of the flare in the continuum, and a very fast burst of the line intensity was recorded that was identified later to be a phenomenon similar to solar explosion processes (Burnasheva et al., 1989; Katsova and Livshits, 1989).

In 1993 the ground-based observations of EV Lac were partly overlapped with monitorings by two space missions: IUE and EUVE. EUVE detected the EV Lac flare in the region $\lambda = 70–180$ Å (Ambruster et al., 1994).

Acknowledgements

Our deep thanks are due to all participants of these cooperative programmes for fruitful collaborations.

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