Session 1–2. Flares in Late–Type Stars

Convener: Prof. Roald Gershberg (CrAO MESU, Ukraine)

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

R. E. Gershberg and N. I. Shakhovskaya

Crimean Astrophysical Observatory, Ministry of Ukraine for Education and Science
Naukove, 98409 Crimea, Ukraine
e-mail: gershberg@crao.crimea.ua, nish@crao.crimea.ua

In 1967–73 and in 1986–95, two sets of international cooperative programs were initiated by the Crimean Astrophysical Observatory for study of the UV Cet-type flare stars. The first set was dedicated to photometric observations, the second one was concerned the researches supported by the photometric patrol. We list the participants of the programs and the main scientific results both based on collected data and stimulated by them.

I

In 1967, on the Crimean Astrophysical Observatory's initiative, the XIII General Assembly of the IAU set up the Working Group on flare stars within the framework of the 27th Commission on variable stars. The aim of the Group was to organize an international cooperative monitoring of selected UV Cet-type stars to clarify a temporal distribution of flares in these objects. The schedules for 10–20 days sets of such observations have regularly published by IBVS. During 1967–1973 the 36 cooperative campaigns were carried out. Several dozens of observers from Abastumani Astrophysical Observatory (USSR, now Georgia), Armagh Observatory (Northern Ireland, UK), Belgrade Astronomical Observatory (Yugoslavia), Auckland Observatory (New Zealand), Boyden Observatory (Republic of South Africa), Byurakan Astrophysical Observatory (USSR, now Armenia), Catania Astrophysical Observatory (Italy), Crimean Astrophysical Observatory (USSR, now Ukraine), Department of Geodetic Astronomy, University of Thessaloniki (Greece), Konkoly Observatory (Hungary), Mt John Observatory (New Zealand), Mt Cuba Observatory, University of Delaware (USA), Observatorio Inter–Americano de Cerro Tololo (Chile), Steward Observatory, University of Arizona (USA), Tokyo Astronomical Observatory (Japan), Uttar Pradesh State Observatory (India), Vermilion River Observatory, University of Illinois (USA), Warsaw University Observatory (Poland) have participated in the campaigns. During all campaigns the eight program stars were monitored for more than 3000 hours and several hundreds of flares were registered.

The most detailed study of the temporal distributions of flares based on cooperative patrol for UV Cet and YZ CMi has been carried out by Oskanyan and Terebizh (1971a). They considered flare numbers within fixed time intervals and time durations between flares and showed that suggestion on a periodicity of flares proposed by some observers was not confirmed: in total the temporal distribution of flares corresponds to the Poisson's one with the highest probability, but numbers of very close flares exceed numbers expected for such a distribution. Oskanyan and Terebizh suggested that this excess was due to several bursts of the same flares. Similar results based on more homogeneous and larger data for more stars have been obtained later and the stellar analogs of the solar sympathetic flares as a cause of the excess of close flares was also considered.

The statistical features of the flare energy activity based on cooperative observations for the most active 4 observed stars – UV Cet, AD Leo, YZ CMi and EV Lac – were considered by Oskanyan and Terebizh (1971b)

Inauguration paper by Prof. Roald Gershberg, the UAA Laureate of 1997–2000 yrs "For the Outstanding Contribution for Advancement of Astronomy in Ukraine".

and Chugainov (1972) practically simultaneously and independently.

Byurakan researchers estimated an optical luminosity range of flares and their total energies that covered 4–5 orders of magnitude. They considered distributions of the flare amplitude and energy, and constructed their frequence functions. An essential difference of these statistical characteristics for the absolutely faintest UV Cet star from characteristics of brighter AD Leo, EV Lac and YZ CMi stars was noted because of fainter flares in UV Cet which were not possible to detect on the brighter stars. For the first time Oskanyan and Terebizh estimated a possible contribution of flares behind the detection threshold in total flare emission. They estimated that this total emission in the B band was about 1% of a quiet stellar luminosity and noted that rare but power flares give the main contribution into this total flare emission.

Chugainov (1972) proposed to use the accumulated frequencies for flare statistics and found the power law of the flare energy spectrum with a sharp break near a threshold of a certain flare detection (see Fig. 1). This circumstance has permitted to exclude certainly a region of faint flares, where flare statistics are affected with observational selection, to pick out a region of flare energy spectrum not affected with this distortion and to confront results of various observers. We converted observable magnitudes into absolute luminosities and construct flare energy spectra for several tens of flare stars within the range of M_V from 8^m to 17^m both for program stars of cooperative campaigns and for other ones (Gershberg, 1972; Gershberg and Shakhovskaya, 1983). Korotin and Krasnobabtsev (1985) have considered photographic observations of flare stars in the closest open stellar clusters and found there the power law of flare energy spectra as well. Then a general picture of the flare activity of stars within the range of 10 orders of magnitude was constructed (see Fig. 2); only physically significant regions of flare energy spectra are given in the plot for stars within the solar vicinity, for several flare star groups in Pleiades and in Orion cluster and for the solar flares. A systematical application of formalism of the detected general power spectrum turned out to be very fruitful and used by many investigators.

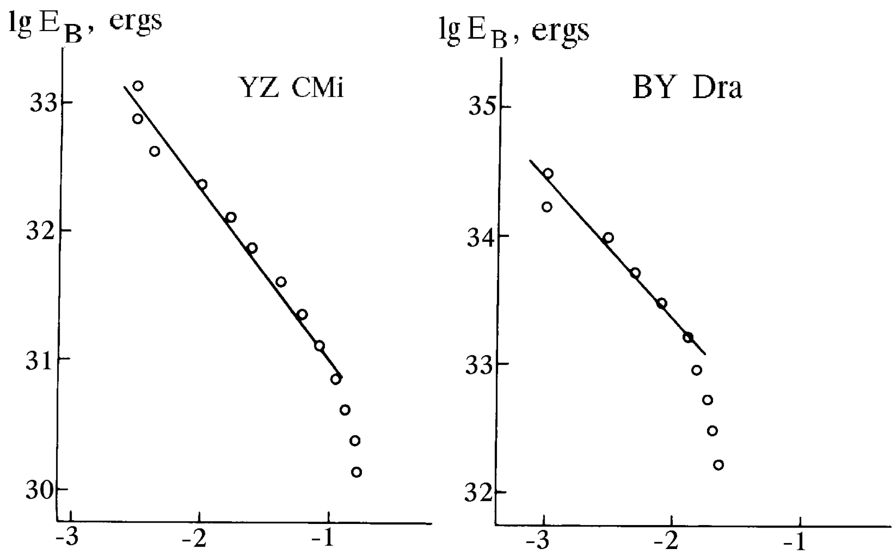

Figure 1: The energy spectra of YZ CMi and BY Dra flares in the B band (Gershberg and Shakhovskaya, 1983)

Thus, it was shown that the main flare energy release for observable spectral indices of flare energy spectra is connected strongly with rare but strong flares, and this flare energy is about several percents of the quiet luminosity of stars (Gershberg and Shakhovskaya, 1983). Then, the total flare energy release is close by an order of magnitude to chromospheric and coronal luminosities (Gershberg and Shakhovskaya, 1983; Shakhovskaya, 1989). When this result was confirmed by three independent research centers too (Whitehouse, 1985; Skumanich, 1985; Doyle and Butler, 1985), it became an 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 various ages gave a ground to suggest an evolution trend of the index (see Fig. 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).

Referring to our results, Kurochka (1987) found the power energy spectrum of the solar optical flares (see Fig. 2), where such a spectrum was constructed with use of 15500 flares. Then Kasinsky and Sotnikova (1989) found the same character of the energy spectra for the solar flares at the soft X-ray. Moreover, these Irkutsk

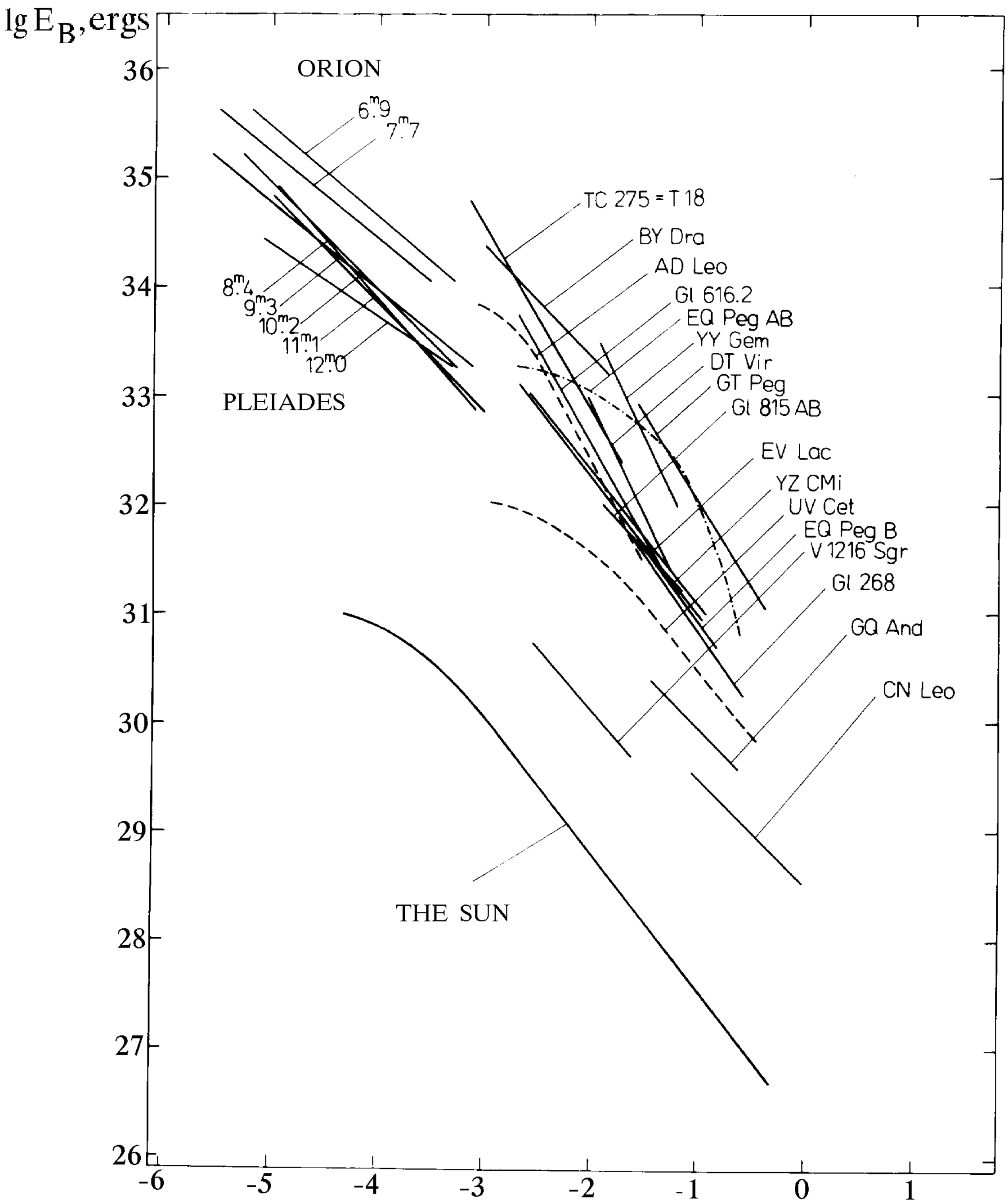

Figure 2: The energy spectra of stellar flares on flare stars in the solar vicinity and in Pleiades and Orion clusters and the energy spectra of the solar flares (Gershberg, Mogilevsky and Obridko, 1987)

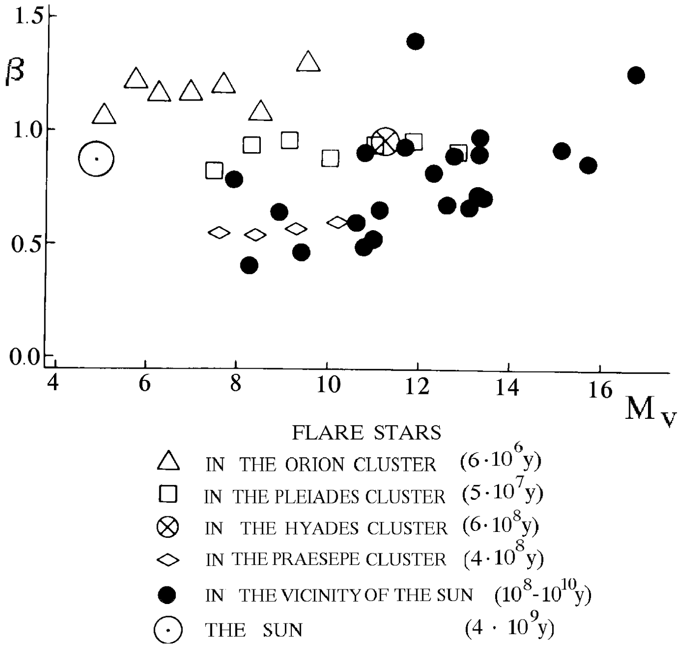

Figure 3: Spectral indices of energy spectra of stellar flares in the solar vicinity and in stellar clusters of different ages and of the solar flares (Gershberg, 1989)

researchers discovered a close correlation between the spectral index and the Wolf number, that is the systematic variations of the index over rather short time scale. Referring to this result, the 20 year series of the EV Lac monitoring were analyzed in the Crimean Astrophysical Observatory and the periodic variations of the stellar spectral index with $P \sim 7\overset{y}{.}5$ were found (Alekseev and Gershberg, 1997).

Unfortunately, our hope to resolve the problem of a stellar flare energy source through consideration of spectral indices has been failed. It turned out that the power law of a flare energy spectrum fits to semi–qualitative concepts on dissipation in flares both magnetic (Pustil'nik, 1988) and kinetic (Kasinsky and Sotnikova, 1988) energy, to modern models of flares within the framework of the avalanche theory (Lu and Hamilton, 1991) as well as to the theory of the phase transitions in turbulent plasma (Pustil'nik, 1997).

II

In 1986–1995 the cooperative campaigns were dedicated to comprehensive investigations of EV Lac, one of the most active flare star in the Northern hemisphere. Having the declination about +44°, this star at the time of its opposition to the Sun in autumn nights can be uninterruptedly monitored for 8–9 hours. The ideology of these campaigns was to carry out a photometric patrol yearly for several nights allowing to fix the times of flares and time of quiet state of the star that is necessary for observations of other kinds. During these campaigns, the photometic patrol in the optical range was accompanied by the spectral, polarimetric, IR, UV observations and researches at the radio frequencies. Summary reports on the campaigns of 1986 and 1987 were published by R. E. Gershberg, V. P. Grinin, I. V. Ilyin, N. S. Nesterov, N. I. Shakhovskaya, R. G. Getov, M. S. Ivanova, K. P. Panov, M. K. Tsvetkov, A. G. Tsvetkova and G. Leto (Gershberg, Grinin *et al.*, 1991) and by R. E. Gershberg, I. V. Ilyin and N. I. Shakhovskaya (1991); on the campaign of 1989 – by A. V. Berdyugin, R. E. Gershberg, I. V. Ilyin, V. P. Malanushenko, N. I. Shakhovskaya, N. M. Shakhovskoy, I. Pagano, I. P. Panferova and L. A. Pustil'nik (Berdyugin, Gershberg *et al.*, 1995); on the campaign of 1990 – by R. E. Gershberg, I. V. Ilyin, A. N. Rostopchina, N. I. Shakhovskaya, G. A. Garbuzov, B. R. Pettersen, T. Korhonen, S. Avgoloupis, L. N. Mavridis, J. H. Seiradakis, R. K. Konstantinova–Antova, A. P. Antov, A. S. Melkonian, I. P. Panferova, L. A. Pustil'nik, P. M. Herouni and A. V. Oskanian; on the campaign of 1991 – by I. Yu. Alekseev, R. E. Gershberg, I. V. Ilyin, N. I. Shakhovskaya, N. M. Shakhovskoy, S. Avgoloupis, L. N. Mavridis, J. H. Seiradakis, M. R. Kidger, I. P. Panferova and L. A. Pustil'nik (Alekseev, Gershberg *et al.*, 1994); on the campaign of 1992 – by H. Abdul–Aziz, E. P. Abranin, I. Yu. Alekseev, S. Avgoloupis, L. L. Bazelyan, G. M. Beskin, A. I. Brazhenko, N. N. Chalenko, G. Cutispoto, J. J. Fuensalida, R. E. Gershberg, M. R. Kidger, G. Leto, Yu. F. Malkov, L. N. Mavridis, I. Pagano, I. P. Panferova, M. Rodonó, J. H. Seiradakis,

S. G. Sergeev, R. E. Spencer, N. I. Shakhovskaya and D. N. Shakhovskoy (Abdul–Aziz, Abranin *et al.*, 1995); on the campaign of 1993 – by E. P. Abranin, L. L. Bazelyan, I. Yu. Alekseev, R. E. Gershberg, S. Avgoloupis, J. H. Seiradakis, L. N. Mavridis, G. M. Beskin, S. N. Mitronova, I. P. Panferova and M. R. Kidger (Abranin, Bazelyan *et al.*, 1998); on the campaigns of 1994 and 1995 – by E. P. Abranin, I. Yu. Alekseev, S. Avgoloupis, L. L. Bazelyan, S. V. Berdyugina, G. Cutispoto, R. E. Gershberg, V. M. Larionov, G. Leto, V. N. Lisachenko, G. Marino, L. N. Mavridis, S. Messina, V. N. Mel'nik, I. Pagano, S. V. Pustil'nik, M. Rodonó, G. Sh. Roizman, J. H. Seiradakis, G. P. Sigal, N. I. Shakhovskaya, D. N. Shakhovskoy and V. A. Shcherbakov (Abranin, Alekseev *et al.*, 1998). The EV Lac monitorings were carried out at several observatories during some nights in vicinity of program dates, and results of these additional patrols were also included in the campaign reports.

The main results of these campaigns are following.

OPTICAL PHOTOMETRIC RESULTS

In 1986–95 the photometric patrol was carried out at the Crimean Astrophysical Observatory in the optical range in the UBVRI bands; in 1990–95 at the Stephanion Observatory of the University of Thessaloniki (Greece) in the B band; in 1987, 1989, 1992, 1994 and 1995 at the Astrophysical Observatory in Catania (Italy) in the UBV bands; in 1989–93 at the Special Astrophysical Observatory (Nizhny Arkhyz, USSR, now Russia) in the UB bands; in 1986–87 at the Rozhen Astronomical Observatory (Bulgaria) in the U band; in 1990 at the Byurakan Astrophysical Observatory (Armenia) in the U band; in 1990 at the Belogradchik Astronomical Observatory (Bulgaria) in the U band; in 1990 at the Instituto de Astrofisica de Canarias Nordic telescope (Spain) in the UBVRI bands; in 1995 at the Galilea Sea Astrophysical Observatory (Israel) in the BVR bands. In Crimea the 227 flares were detected for 307 hours of monitoring, at the Stephanion Observatory – 40 flares for 145 hours, in Catania, in Bulgaria and at the 6-m telescope in Russia – in of about 2 dozens of flares each for about 40, 50 and 20 hours, respectively, at the NORDIC telescope – 9 flares for 23 hours, in Armenia – 2 flare for more than 15 hours. It is important to emphasize that photometric investigations have been planned as auxiliary observations for other kinds of researches; however, the data gathered have presented an autonomous interest.

Rather large and homogeneous data obtained at the 1.25-m reflector AZT–11 of the Crimean Astrophysical Observatory with the UBVRI Piirola's photometer–polarimeter (1984) were used for different studies.

To clarify the nature of flare emission, the strongest of them were analyzed colourimetrically. For this task the colour indices U–B, B–V, V–R and V–I of a pure flare emission have been found at the ascending branches, at the brightness maxima and at the beginning of descending branches. On the other hand, such indices have been detected for different sources of radiation: for the black bodies of various temperatures, for synchrotron emissions with different indices of energy spectra of relativistic electrons, for radiation of hydrogen plasma of different temperatures, densities and optical thickness at the Balmer continuum (Chalenko, 1999). The confrontation of these calculations with observable characteristics of flares (see Figs. 4 and 5) permits to conclude that 1) none of considered radiation mechanisms can alone reproduce the flare radiation observed within the whole UBVRI range at any flare phase; 2) the UBV flare radiation is rather close to the black body ones for temperature from 10000 to 25000 K near brightness maxima of strong flares; 3) the hydrogen plasma of some optical thickness contribution increases in the longer wavelength regions from the brightness maxima and in the UBV bands as a flare decays. Mean parameters of the most powerful 9 flares from these data are following:

DU (mag)	colour indices of the pure flare radiation at brightness maxima (mag)				T_{bb} (K)	area (cm^2)
	U – B	B – V	V – R	V – I		
2.1	-0.87 ± 0.05	0.03 ± 0.02	0.47 ± 0.05	0.78 ± 0.18	14000	10^{19}

We have noted above the usage of the crimean patrol observations to detect periodicity in the spectral index of the EV Lac flare energy spectra.

Several flares that had been registered at the Special Astrophysical Observatory with the fast photometry mode have been analyzed for a search of an existence of high frequence components, but such components were not found within the range from 1 mcs to 10 s (Beskin *et al.*, 1995).

INFRARED STUDIES

In 1991–1993 the near IR monitoring was carried out in the K band by M. R. Kidger with a single channel chopping photometer mounted at the Cassegrain focus of the 1.5-m Carlos Sanchez telescope that operated on the island of Tenerife in the Spanish Observatorio del Teide of the Instituto de Astrofisica de Canarias.

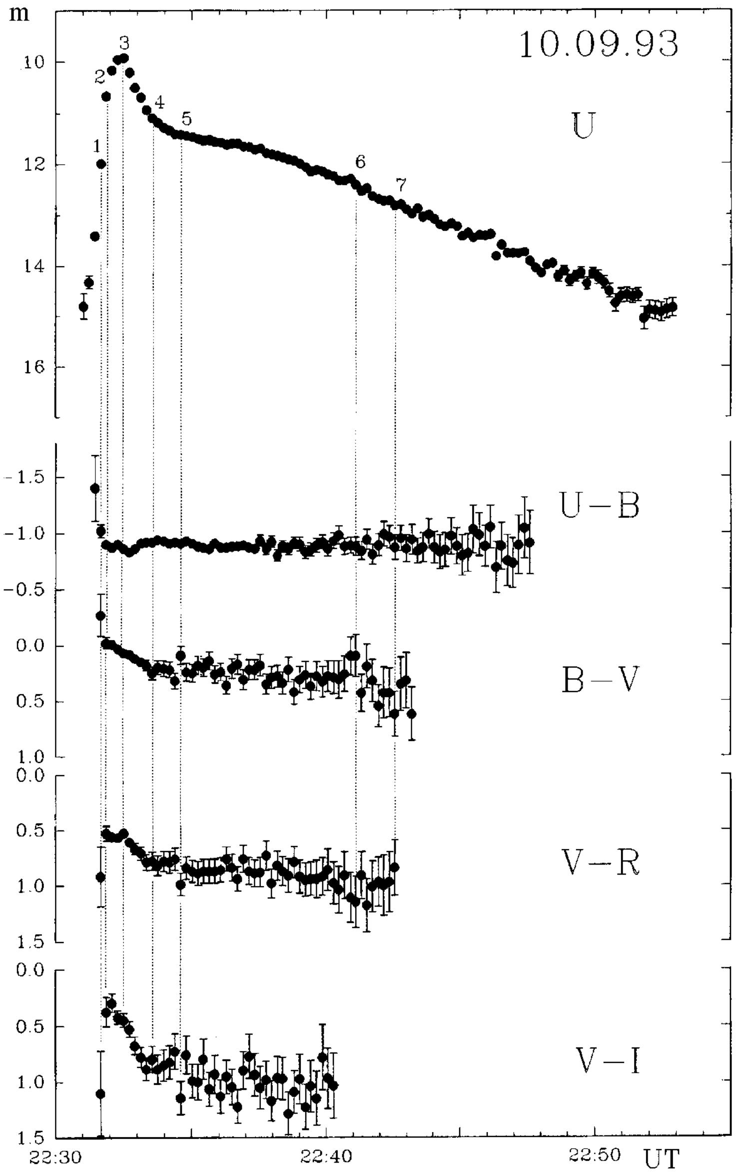

Figure 4: Light and colour indices' curves of the powerful EV Lac flare on September 10, 1993 at UT 23:32 (Abranin, Bazelyan *et al.*, 1998)

In 1994–1995 the IR patrol was carried out in the K band by G. Cutispoto, G. Leto, G. Marino, S. Messina, I. Pagano and M. Rodonó at the 91-cm reflector of the Astrophysical Observatory and Institute of Astronomy of Catania University, Catania, Italy.

In 1995 V. M. Larionov carried out the IR monitoring in the H band using the 70-cm telescope AZT-8 of the Crimean Astrophysical Observatory and the IR photometer of the Astronomical Institute of St. Petersburg University.

During all these campaigns the IR patrol covered one strong (September 10, 1993) and more than two dozens of faint flares detected in the U band. However, no synchronous variations of IR and of optical radiations were detected. It proves that IR brightness decrease found by Rodonó (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 the UBVRI monitoring for EV Lac within the framework of the B. E. Zhilyaev's program at the AZT-11. He found certainly two components of the flare on 5.10.96: the traditionally registerable emission component, which is the most visible in the U band, and the absorption component, which is more long, and is located

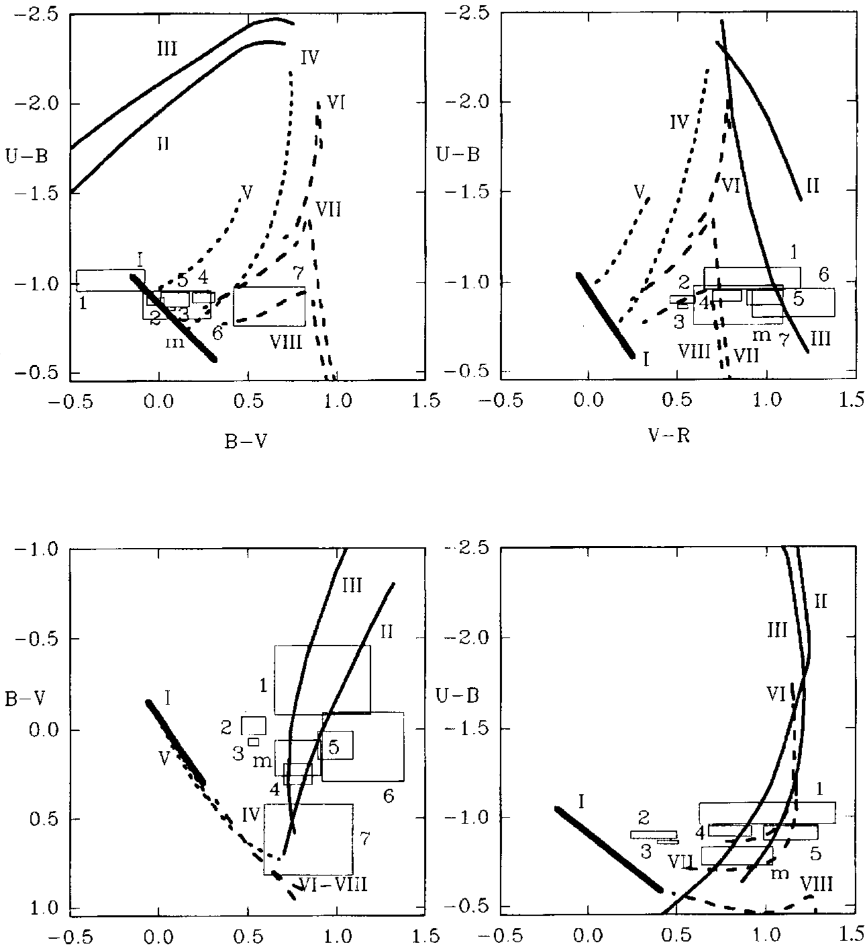

Figure 5: Colour–colour diagrams of the pure flare radiation of the EV Lac flare on September 10, 1993 at UT 23:32. I – black body radiation for the temperatures ranging from 6000 to 20000 K; II and III – emission of optically thin hydrogen plasmas in the Balmer continuum (Ba_C) with T = 10000 K and n_e = 10^{12} and 10^{14} cm^{-3}, respectively; IV and V – emission of optically thick hydrogen plasmas in the Ba_C with T = 10000 and 15000 K, respectively; VI, VII, and VIII – radiation emitted by upper layers of dwarf stars heated with proton fluxes with energies higher than 1, 3 and 5 MeV, respectively. Numeration of rectangles corresponds to numbers of dotted vertical lines in Fig. 4 (Abranin, Bazelyan *et al.*, 1998)

symmetrically around emission component with amplitudes increasing toward longer wavelengths (Zhilyaev *et al.*, 1998). Then we revised previous IR records obtained in the cooperative monitorings during optical flares and found similar IR brightness decreases during faint flares (see Fig. 6). The physical meaning of these events remains unclear, but from the author's point of view the structure of appearance of "an emission peak in an absorption saucer" allows to present a lot of known colourimetric features that had no one–valued interpretation (Gershberg, 1998).

POLARIMETRY

Measurements of a linear polarization of EV Lac were carried out by N. M. Shakhovskoy, Crimean Astrophysical Observatory, 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 the polarization is less than 5% at 10 s time resolution and less than 2–3% at 50 s time resolution for all flares. The most powerful observed flare imposes more stringent constraints on the quoted values: 2% and 1%, respectively. Therefore, this the most clear result obtained in process of long observations suggests that the intrinsic optical radiation of flares is not polarized (see Fig. 7).

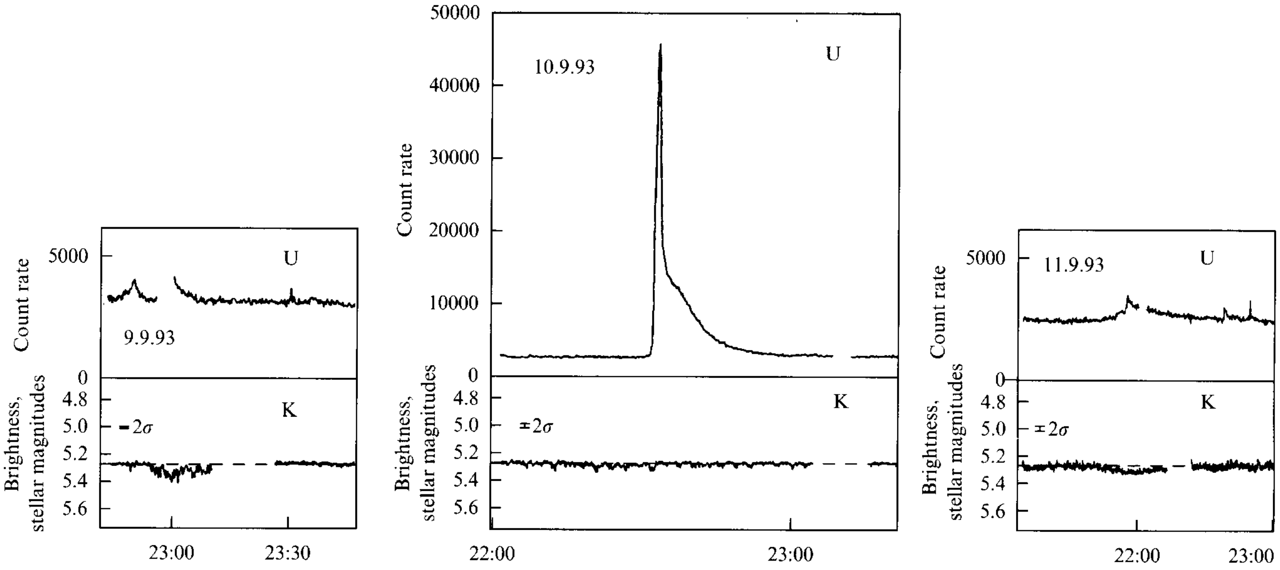

Figure 6: Segments of light curves of the EV Lac flares observed in the U band (Crimea) and K band (Canary) (Gershberg, 1998)

SPECTRAL INVESTIGATIONS

In 1986, 1987, 1990, 1992, 1994 and 1995 the spectral observations of EV Lac were carried out at the 2.6-m Shajn telescope in the Crimean Astrophysical Observatory. The CCD spectrographs with a low resolution in the Nasmyth focus and with a high resolution in the coude focus have been used. In 1989–1993 the spectral monitorings were fulfilled at the 6-m telescope of the Special Astrophysical Observatory, Nizhny Arkhyz, Russia. There the light beam from a star was splitted at the Nasmyth focus toward two devices: the spectrograph with a TV scanner covering the wavelength range from 3700 to 5200 ÅÅ and the fast photometer. In the 1994 campaign the spectral monitorings were carried out at the NORDIC telescope, Canary, with the echelle spectrograph SOFIN made in Crimea.

In 1986 and 1987 EV Lac was observed at the Shajn telescope in the H_α 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 the brightness of the star has decreased but an amplitude of rotational modulation also has decreased simultaneously, the H_α flux has increased slightly and the aforementioned anticorrelation has disappeared in such a state. These variations did not fit to a traditional scheme of stellar spottedness that is due to one or two compact starspots: if the spots are not too close to a pole in such a scheme that total brightness decrease should be accompanied with an increase of an amplitude of rotational modulation. In this connection the data obtained were interpreted as a result of an increase of the total spottedness with simultaneous more regular distribution of starspots along stellar longitudes. This conclusion initiated a development of a zonal model of red dwarf spottedness (Alekseev and Gershberg, 1996 ab, 1997b), in which a general picture of a stellar spottedness is determined instead of parameters of one or two compact starspots in traditional schemes. Up to date the UBVRI observations of 25 red dwarfs for more than 340 epochs are successfully processed within the framework of this spottedness model, some correlations between parameters of the models and global stellar characteristics are found, and the solar spottedness features fit to these correlations (Alekseev and Gershberg, 2000).

In 1989 the rotational modulation of emission features in the EV Lac spectrum were detected at the 6-m telescope while the constancy of absorption spectral features took place. In 1991 this result was confirmed.

In 1990 the H_α profiles were registered in Crimea during 3 strong flares: in two cases the red wing spread to +130 km/s and in the third case the blue wing spread to –100 km/s with undisturbed red wing. The decay of one of these flares was observed at the 6-m telescope, and a decay rate of H_δ line was found to be 1.5 faster as compared to the H_β decay rate. In 1992 emissions of Fe II, Fe I, Mg I in flare spectra, which were earlier rare detected or not detected, were registered at the Shajn telescope. The H_β profile analysis in moderate power flares has shown that the line broadening was negligible at the half maximum level, it became noticeable at the level of 20 maximum. The broadened profiles could be formally represented both by two Gaussians with different widths and by a set of 3–7 Gaussians of instrumental width with dispersion of maximum wavelengths

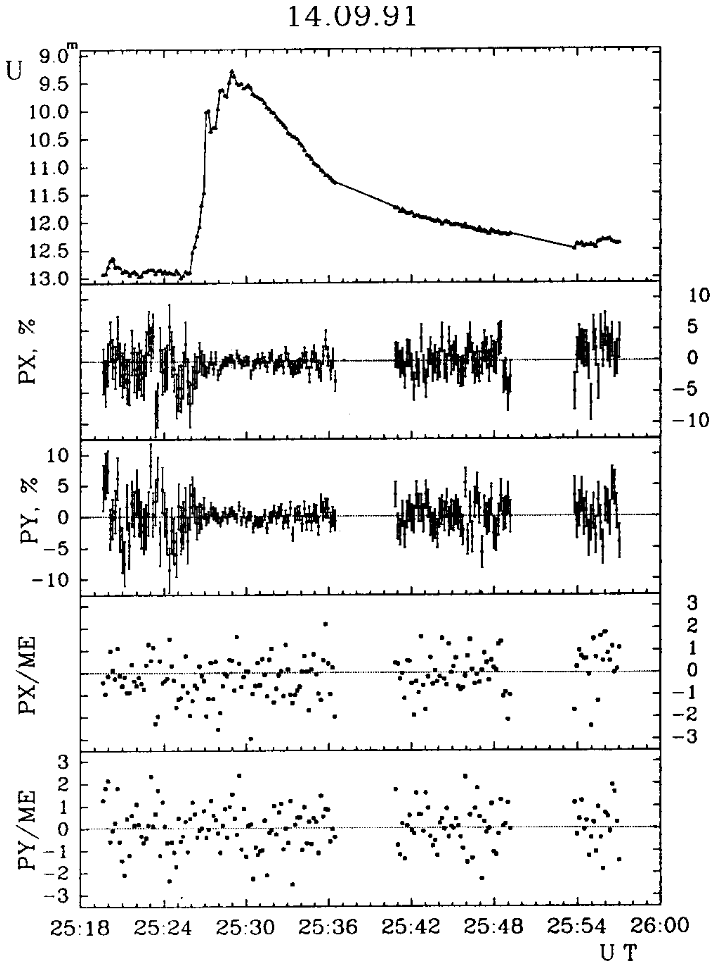

Figure 7: Photometric and polarimetric measurements of EV Lac during the most powerful flare on September 14, 1991 at 25:29 registered with 10 s time resolution: U band light curve (upper panel), normalized Stokes parameters PX and PY with their mean squared errors computed by quantum statistics (middle panel), and ratios of these parameters to their errors PX/ME and PY/ME (lower panel) (Alekseev, Gershberg *et al.*, 1994)

about 400–700 km/s in the velocity scale.

The very interesting data were obtained in Crimea during the night August 31/September 1, 1994, they are given in Fig. 8. The light curve of the star is shown in the top panel of the figure. A half of dozen of characteristic fast flares with different amplitudes and durations of several minutes are clearly visible. Also we see a long–lived glow that started at UT 20:46 and lasted at least until the strongest flare of the night at UT 23:24. The next panel demonstrates the equivalent widths of the H_β line. A close inspection of these two plots reveals the reaction of the line on separate flares. But the main feature of the temporal behavior of W_{H_β} is a dominating maximum connected with the enhanced stellar brightness over almost three hours. The equivalent widths of the Fe II + Mg I emission blend shown in the fifth panel of the figure shows the behavior similar to W_{H_β} with correlation coefficient 0.94. The third panel of the figure displays the equivalent width of the neutral helium line $\lambda\tilde{4}471$ Å. The comparison of this plot with the previous two ones shows that this line reacts more clearly to separate fast flares than H_β although these lines correlate mutually with the correlation coefficient 0.76.

The most interesting and unexpected results were obtained by patrolling the ionized helium λ 4686 Å emission (see the fourth panel in Fig. 8). Formally, this line does not correlate with the emissions considered above: its correlation coefficients lie within the range from 0.2 to 0.3. However, more close comparison of W_{HeII} with the stellar light curve reveals that almost all spectra with enhanced He II line were obtained during 15–30 minutes after the fast flares. The second intriguing feature of the He II emission is represented

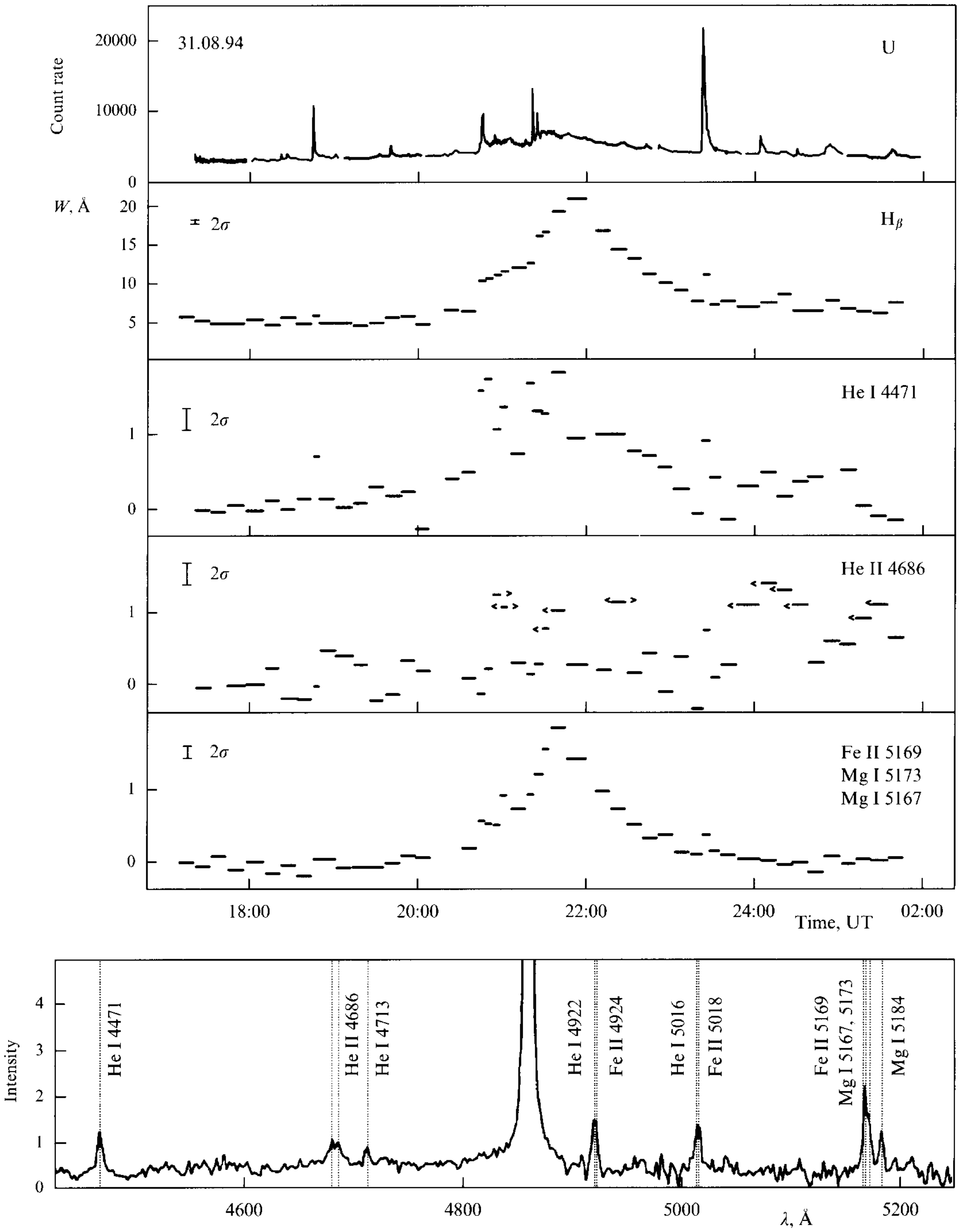

Figure 8: Results of photometrical and spectral monitorings of EV Lac obtained on the night of August 31/September 1, 1994, in Crimea. There are shown the count rate in the U band, the equivalent widths of the H_β, He I λ 4471 Å, He II λ 4686 Å emission lines and the blend of metallic lines; the spectrum of active states of the star is also presented (Gershberg, 1998)

in the bottom panel of the figure, where the added spectrum of all active states of the star registered during the 1994 campaign is shown. A sharp splitting of the He II emission is clearly seen in the plot: the long–wavelength component has a normal position while the short–wavelength one is shifted by -400 km/s. Among spectra obtained in the night considered, the eight spectra demonstrate only the short–wavelength component, two spectra show both components and one spectrum has only the long–wavelength component; these features are marked in the figure by <, <> and >, respectively. The meaning of these observations is not clear yet. 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 during the formation of moving structures, whose solar analogs produce transients in the interplanetary space.

In 1995 EV Lac was observed in Crimea in the H_α region. Results of this and previous campaigns were used by Baranovsky *et al.* (2000) to construct semi–empirical models of the quiet chromosphere of the star and its flares. The new qualitative results of this modelling are that a region with a significant spread along the height with a small vertical temperature gradient exists in the chromosphere of the cool dwarf – the similarly as in the solar chromosphere. This is the so-called a temperature plateau, where the most Balmer lines' fluxes are originated. Similar structure was also found in constructed flare models but in deeper layers.

RADIO MONITORING

During some campaigns, the EV Lac star has been monitored with several radio telescope to detect its radio emission. In 1986 and 1987 the star was observed at 8.2 mm with 22-m radio telescope of the Crimean Astrophysical Observatory; a stellar radio emission was not detected with a noise level of 30–50 mJy. In 1990 observations near 21 cm were fulfilled with the radio – optical telescope ROT 32/54/2.6 in Armenia; flare radio signals were not found with a noise level of 6–8 mJy. In 1992 the radio patrol for EV Lac was carried out at 6 cm with the broad–band Jodrell Bank interferometer, Great Britain. The patrol permitted to estimate a high limit of a stellar flux as 5 mJy.

In 1992 radio observations of EV Lac were begun at the decametric range with the radio telescope UTR–2 of the Institute of Radio Astronomy of the National Academy of Science of Ukraine.

The UTR–2 output is supplied by two two–channel radiometers at 25 and 20 MHz, the third similar radiometer was used to monitor an area shifted from EV Lac along the declination by 1°. During 30 hours of the EV Lac monitoring more than 30 bursts have been detected. About half of them were identified with terrestrial interference. The rest of them were individual bursts with durations of 3 s and often less than 1 s or compact groups of bursts with durations of about 10 s. The eight radio bursts were found to be coincident in time with optical flares and, therefore, were regarded as ones with the high probability of stellar origin. Groups of bursts were detected only during the one night when the optical activity level of the star was high. Only weak individual bursts were detected during the other nights with moderate and low optical activity; these two types of bursts exhibit different signal intensities as well. If one supposes that a radio source size is equal to the stellar disk, the fluxes detected correspond to the brightness temperature of 4×10^{17} to 1×10^{18} K. Thus, probability of detection of decametric emission from EV Lac seemed to be high, although some doubts should be kept.

During 20 hour monitoring in 1993 the 6 faint bursts were detected, but contrary to 1992 campaign, they could not be regarded as certain candidates for stellar sporadic decametric emission.

In 1994 campaign both the technical and analytical parts of decametric radio observations were essentially improved. During 33 hour monitoring the 18 radio bursts were detected and 4 criteria were applied to them to select bursts of non–terrestrial nature. As a result, the burst on August 26 at UT 22:08 was selected as one of probable stellar origin. Its duration is of about 10 s. It coincides with the optical flare with $\Delta U = 0\overset{m}{.}5$ and satisfies to the majority of criteria mentioned. This event with brightness temperature of about 10^{18} K, apparently, can be explained with plasma mechanism of radiation.

SPACE RESEARCH

The ASTRON space mission had the pointing and offset guiding system that did not permit to study EV Lac in a convenient autumn time. By this reason, we carried out such observations during 4 rather short sessions in Februaries of 1984, 1986 and 1987 with parallel photometric patrols from the Crimean Astrophysical Observatory. During two of these sessions we have registered flares.

During the session of February 24, 1984 a very short flare of a total duration of 2.4 s was registered as a strong burst in 4 successive telemetric records of 0.61 s each (Gershberg and Petrov, 1986). In that time a reality of such short flares was questionable, but later their existence was certainly confirmed by the fast photometry at the 6-m telescope (Beskin, Gershberg *et al.*, 1988).

During the session of February 6, 1986 the strong flare with $\Delta U \sim 3^m$ was registered in $\lambda\lambda$ 1536–1564 ÅÅ and $\lambda\lambda$ 2420–2448 ÅÅ regions and in the $\lambda\lambda$ 1700–6500 ÅÅ reference channel. The flare was registered in UV with the highest for that time temporal resolution less than 1 s. The analysis of this flare allowed to find two new qualitative features: the flaring of the CIV λ 1550 Å line begun 7 s before the beginning of the flare in continuum and the very fast and power burst of the line was registered at the beginning phase of the flare. This burst is similar to fast bursts of this line in the solar active regions but exceeded them by hundred times in respect areas, by several orders of magnitude in respect energy and it was an order of magnitude shorter (Burnasheva, Gershberg *et al.*, 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 $\lambda\lambda$ 70–180 ÅÅ region. Up to date preliminary results were published only (Ambruster *et al.*, 1994).

Our deep thanks to all participants of the all cooperative programs for fruitful collaboration.

REFERENCES

[1] *Abdul–Aziz H., Abranin E. P., et al.* // Astron. and Astrophys. Suppl. Ser.–1995.–**114**.–P. 509.

[2] *Abranin E. P., Alekseev I. Yu., et al.* // Astron. and Astrophys. Transactions.–1998.–**17**.–P. 221.

[3] *Alekseev I. Yu., Gershberg R. E., et al.* // Astron. and Astrophys.–1994.–**288**.–P. 502.

[4] *Alekseev I. Yu. and Gershberg R. E.* // Astron. Rep.–1996a.–**73**, N 4.–P. 579–589.

[5] *Alekseev I. Yu. and Gershberg R. E.* // Astrofizika.–1996b.–**39**.–P. 67. (in Russian).

[6] *Alekseev I. Yu. and Gershberg R. E.* The Earth and the Universe / Eds G. Asteriadis, A. Bantelas, M. E. Contadakis, *et al.*–Thessaloniki: Ziti Editions, 1997a.–P. 43.

[7] *Alekseev I. Yu. and Gershberg R. E.* // Astron. Rep.–1997b.–**74**, N 2.–P. 240.

[8] *Alekseev I. Yu. and Gershberg R. E.* // 2000.–in preparation.

[9] *Ambruster C. W., Brown A., Pettersen B. R. and Gershberg R. E.* // Bull. Amer. Astron. Soc.–1994.–**26**.–P. 866.

[10] *Baranovsky E. A., Gershberg R. E. and Shakhovskoy D. N.* // Astron. Rep.–2000.–(in press).

[11] *Berdyugin A. V., Gershberg R. E., et al.* // Bull. Crimean Astrophys. Obs.–1995.–**89**.–P. 81.

[12] *Beskin G. M., Gershberg R. E., et al.* // Bull. Crimean Astrophys. Obs.–1988.–**79**.–P. 71.

[13] *Beskin G. M., Mitronova S. N. and Panferovo I. P.* Flares and Flashes / Eds J. Greiner, H. W. Duerbeck and R. E. Gershberg.–Lecture Notes in Physics.–**454**.–P. 85.

[14] *Bruevich V. V., Burnashev V. I., Grinin V. P., et al.* // Bull. Crimean Astrophys. Obs.–1980.–**61**.–P. 90.

[15] *Burnasheva B. A., Gershberg R. E., et al.* // Astron. Rep.–1989.–**66**.–P. 328.

[16] *Chalenko N. N.* // Astron. Rep.–1999.–**76**.–P. 529.

[17] *Chugainov P. F.* // Bull. Crimean Astrophys. Obs.–1972.–**46**.–P. 14.

[18] *Doyle J. G. and Butler C. J.* // Nature.–1985.–**313**.–P. 378.

[19] *Gershberg R. E.* // Astrophys. and Space Sci.–1972.–**19**.–P. 75.

[20] *Gershberg R. E.* // Mem. Soc. Astron. Ital.–1989.–**60**.–P. 263.

[21] *Gershberg R. E.* // Physics. Uspekhi.–1998.–**41**.–P. 807. (in Russian).

[22] *Gershberg R. E. and Shakhovskaya N. I.* // Astrophys. and Space Sci.–1983.–**95**.–P. 235.

[23] *Gershberg R. E. and Petrov P. P.* Flare stars and related objects / Ed. L. V. Mirzoyan.–Yerevan: Publ. House Armenian Acad. Sci., 1986.–P. 37.

[24] *Gershberg R. E., Mogilevsky E. I. and Obridko V. N.* // Kinematics and Physics of Celestial Bodies.–1987.–**5**.–P. 3.

[25] *Gershberg R. E., Grinin V. P., et al.* // Sov. Astron.–1991.–**68**.–P. 548. (in Russian).

[26] *Gershberg R. E., Ilyin I. V. and Shakhovskaya N. I.* // Sov. Astron.–1991.–**68**.–P. 959. (in Russian).

[27] *Gershberg R. E., Ilyin I. V., et al.* // Sov. Astron.–1993.–**70**.–P. 984. (in Russian).

[28] *Kasinsky V. V. and Sotnikova R. T.* // Issledovaniya po geomagnetismu, aeronomii i fizike Solntsa.–1988.–**83**.–P. 99. (in Russian).

[29] *Kasinsky V. V. and Sotnikova R. T.* // Solar and stellar flares: Proc. IAU Coll. N 104, Stanford, Aug. 15–18, 1989 / Eds B. M. Haisch and M. Rodonó.–Catania Astrophys. Obs. Special Publ., 1989.–P. 255.

[30] *Korotin S. A. and Krasnobabtsev V. I.* // Bull. Crimean Astrophys. Obs.– 1985.–**73**.–P. 131.

[31] *Kurochka L. N.* // Sov. Astron.–1987.–**64**.–P. 443. (in Russian).

[32] *Lu E. T. and Hamilton R. J.* // Astrophys. J.–1991.–**380**.–P. L89.

[33] *Oskanian V. S. and Terebizh V. Yu.* // Astrofizika.–1971a.–**7**.–P. 83. (in Russian).

[34] *Oskanian V. S. and Terebizh V. Yu.* // Astrofizika.–1971b.–**7**.–P. 281. (in Russian).

[35] *Pustil'nik L. A.* // Letters Sov. Astron.–1988.–**14**.–P. 940. (in Russian).

[36] *Pustil'nik L. A.* // Astrophys. and Space Sci.–1997.–**252**.–P. 325.

[37] *Rodonó M.* Flare stars and related objects / Ed. L. V. Mirzoyan.–Yerevan: Publ. House Armenian Acad. Sci., 1986.–P. 19.

[38] *Shakhovskaya N. I.* // Solar Phys.–1989.–**121**.–P. 375.

[39] *Skumanich A.* // Austral. J. Phys.–1985.–**38**.–P. 971.

[40] *Whitehouse D. R.* // Astron. and Astrophys.–1985.–**145**.–P. 449.

[41] *Zhilyaev B. E., Verlyuk I. A., et al.* // Astron. and Astrophys.–1998.–**334**.–P. 931.