Advances in Astronomy and Space Physics, **2**, 121-124 (2012)

Search of the radio emission from flare stars at decameter wavelengths

A. I. Boiko,* *A. A. Konovalenko, V. L. Koliadin, V. N. Melnik*

Institute of Radio Astronomy, National Academy of Sciences of Ukraine, Chervonopraporna st., 4, 61002, Kharkiv, Ukraine

Observations of the two M-dwarf flare stars (AD Leonis and EV Lacertae), which were carried out with the radio telescope UTR-2 (Kharkiv, Ukraine) in the range of $16.5 - 33$ MHz, are presented. 167 events of radio emission from AD Leo and 73 events from EV Lac were detected in the period of 2010–2011. These events were considered as stellar emission in ON-OFF regime of observations. The morphology of the probable events in the form of bursts from flare stars is considered and frequency drift rates, durations and fluxes of the bursts are analysed.

Key words: stars: activity, stars: flare, methods: observational

INTRODUCTION

Red dwarf flaring stars are objects of the lower part of the Main Sequence of the HR diagram. The sporadic transient powerful flares are usual for these stars [5]. More than 80 flare stars are known at the present time; more than half of them are situated within 10 pc of the Sun. It is known that flare stars are quite cool ($T_{eff} \approx 3500$ K) and small ($R = (0.1 \div 0.8)R_{\odot}$) in comparison with the Sun, and their luminosities are even 1 % that of the Sun [3]. Comparison of observations in radio, optical, X-ray and ultraviolet ranges showed [5], that there is analogy between physical processes on the Sun and flare stars.

Since the end of 1940th systematical studies of these stars were carried out. On September, 29, 1958 the first radio flare from UV Cet (prototype for all flare stars) was registered by Lowell with 76-metre parabolic antenna. By 1976 more than 70 flare stars were discovered. In the radio range first flare stars were observed at separated frequencies [3, 4, 6]. In the early 1980's observations were carried out with the VLA at 1.4 and 5 GHz. In the decametre range ($10 - 25$ MHz) the first results of the radio burst detection from flare stars were obtained by Abranin et al. [2, 1] during observations with radio telescope UTR-2 in 1986–1995. Detection of the radio emission from several flare stars including AD Leo and EV Lac is one of the general results of these observations. Brightness temperatures of the observed radio bursts from these stars were about 10^{18} K. But it was hard to estimate some other properties (e. g. frequency drift rate) of these bursts because only two operational frequencies of 20 and 25 MHz were used.

*boikoana@yandex.ua

METHOD AND RESULTS

We report on the observations of two flare stars, namely AD Leonis and EV Lacertae, at frequencies $16.5 - 33$ MHz. Radio emission from the flare stars was registered by the radio telescope UTR-2 (Kharkiv, Ukraine) during 2010–2011 observational campaigns. Three sections of the radio telescope UTR-2 with a total area of $30\,000\,\mathrm{m}^2$ were used. Registrations were carried out by the DSP-Z (Digital Signal Processor) [10] with a frequency resolution of 4 kHz and time resolution of 100 ms.

Observations were carried out in regime called ON-OFF method [7]. Three beams of the radio telescope were used (beam 1, beam 3 and beam 5) in the 5-beam operational mode of the UTR-2. The star was followed by the beam 3 (channel ON). Sky regions shifted relative to the star were followed by the beam 1 and beam 5 (channels OFF). The tracking was made simultaneously with 2 minutes step for each beam. Detection of the burst in ON channel and its absence in OFF channels are the evidence that radio emission potentially has stellar nature. Besides multibeam ON-OFF observations help to discriminate stellar radio bursts from the propagation effects of the ionosphere. For each beam we have the following data: signal received with the North – South antenna, signal received with the East – West antenna, cross spectrum and phase spectrum of the signal.

During 2010 and 2011 observational campaigns 167 bursts from AD Leo and 73 bursts from EV Lac were observed. We discuss some properties of decametre radio emission in the case of the flare star AD Leo. Bursts in the dynamic spectra correspond to bands of high intensity in comparison with background. Bursts drift with time from high to low frequencies (negative frequency drift rate) or from low to high frequencies (positive frequency drift rate) of the range. The burst distributions for 2010 and 2011 observational dates are shown in Fig. 1. The most of time profiles of these bursts are either not symmetrical with fast rise and slow decay or symmetrical (Fig. 2). Some bursts have the profile shapes with slow rise and fast decay, but these are rare events. In general the bursts are isolated, but several bursts are observed in pairs, and even in groups. The profile shapes and structure of bursts in the dynamic spectra are similar to solar type III bursts in decametre range. We consider this similarity as the demonstration of analogy of physical conditions and processes which are originated in corona of the AD Leo and of the Sun. We suppose that radio bursts from the flare star are generated by electron beams with velocities of $\sim 0.3c$ (c is the speed of light) as in the case of the solar type III bursts. Thus we use the fact of similarity of bursts from AD Leo and the Sun like one as a criterion to sort out flare star bursts from ionospheric scintillations.

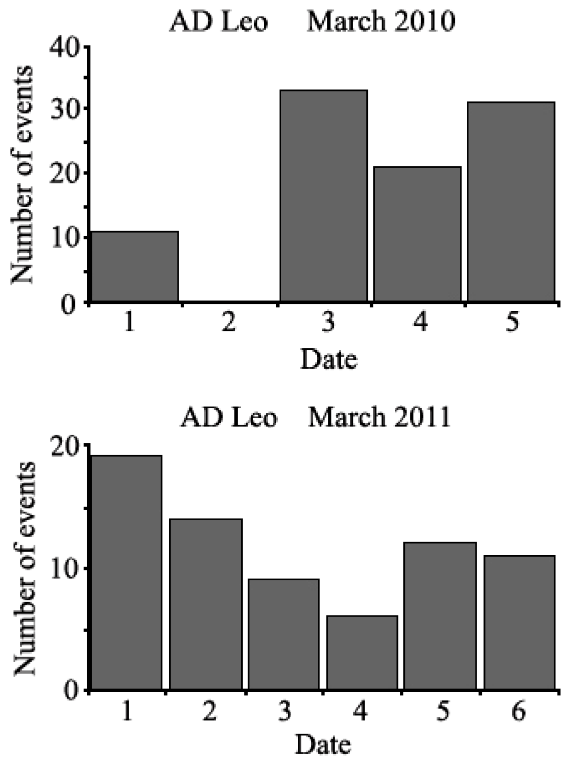

Fig. 1: Burst distribution for observational dates in 2010 (top) and 2011 (bottom).

The whole frequency band from 16.5 to 33 MHz was divided into three frequency sub-bands and all the characteristics were measured at the frequencies of 19, 24 and 29 MHz. Frequency drift rates, durations and fluxes of these bursts were obtained.

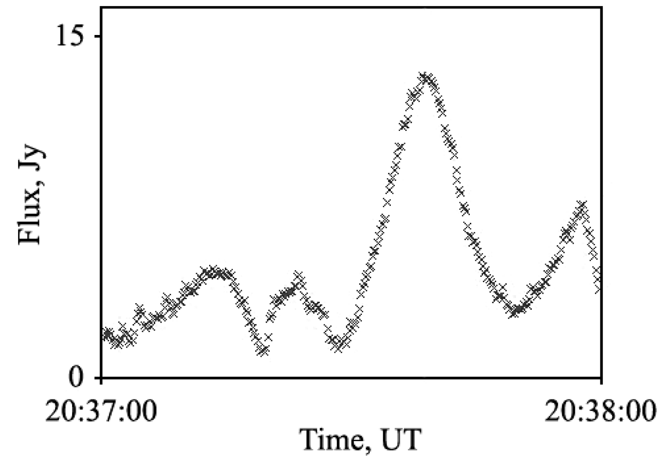

Fig. 2: The time profile of AD Leo burst (20:37:39 UT) at 24 MHz.

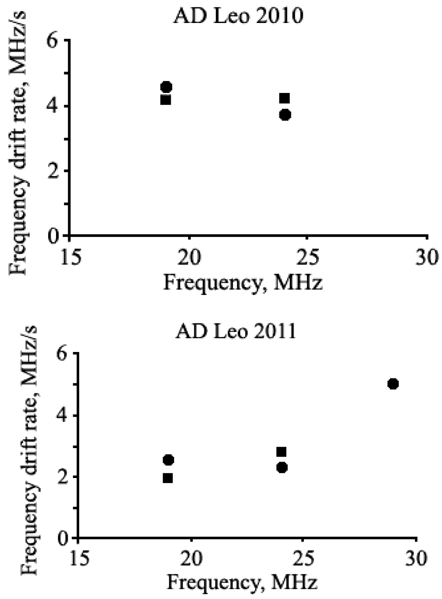

Fig. 3: The dependence of the average frequency drift rate on the frequency for 2010 (top) and 2011 (bottom). Dots correspond to negative drift rate, squares correspond to positive one.

According to our observations the flare star bursts have both positive and negative frequency drifts. Negative frequency drift rates are in the range of $0.2 - 5$ MHz/s, positive ones are in the range of $0.2 - 4.2$ MHz/s. There are several events with sign reversal of frequency drift rate. The dependencies of average drift rates (both negative and positive) on frequency are shown in Fig. 3. It is seen, that positive frequency drift rate increases with frequency. In the case of negative drift we obtained drift rate decrease with frequency for 2010. For 2011 negative drift the slow decrease changed into sharp increase. The presence of both positive and negative drift rates indicates that electrons move towards and away from the AD Leo.

The durations of the flare star bursts is in the range of $2 - 12$ s. We note that durations are close to those from powerful solar type III bursts [8]. The dependence of the average duration on frequency is shown in Fig. 4. Duration of observed bursts has a small decrease with frequency, and in some cases there are no duration changes with frequency. For comparison the dependencies of durations on frequency for the solar type III bursts are more steep. We consider that electron beams which generated stellar radio bursts are expended with the distance from the AD Leo but slower then in the case of the solar decametre type III bursts. The histogram for distribution of the AD Leo bursts on duration for March 4, 2010 at frequency 19 MHz is presented in Fig. 5. We chose this date because it was one of the days with the highest number of bursts observed from AD Leo and the histogram has well-defined maximum. Flare star bursts and the solar type III bursts have very similar distributions on duration (Fig. 5). For the powerful type III bursts we derived almost the same duration range and obtained the shape of the histogram with well-defined maximum of distribution.

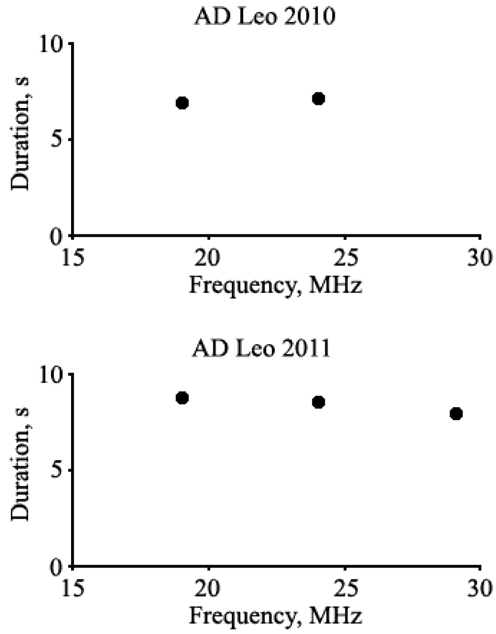

Fig. 4: Dependence of the average duration on frequency in 2010 (top) and 2011 (bottom).

One of important characteristics of flare stars radio emission is a flux. The lowest flux from observed bursts is of 4 Jy (1 Jy= $10^{-26}\,\mathrm{W\,m^{-2}\,Hz^{-1}}$), while the largest flux is of 307 Jy. Large number of bursts have flux of $10 - 50$ Jy. We estimated the brightness temperature of radio emission from AD Leo according to the well-known equation $T_B = \dfrac{I\lambda^2}{2k\Omega}$, where I is the observed flux, λ is the wavelength, k is the Boltzmann constant, Ω is the solid angle. The equation for solid angle is the following: $\Omega = \Theta^2\pi$, where $\tan\Theta = R_{star}/r$ (R_{star} is the radius of the star, r is the distance from the star). Thus the brightness temperature of bursts at frequency 20 MHz with flux of $10 - 50$ Jy are equal to $(1.2 - 5.8) \cdot 10^{16}$ K. This value is two orders of magnitude lower than for the bursts in [2]. It could be explained by the fact that the obtained radio bursts have significantly lower fluxes the the discussed powerful ones with fluxes of hundred Jy. The large brightness temperature from the observed bursts is the evidence for non-thermal mechanism of the radiation generation from flare stars, namely the cyclotron maser mechanism [9] or plasma one [11].

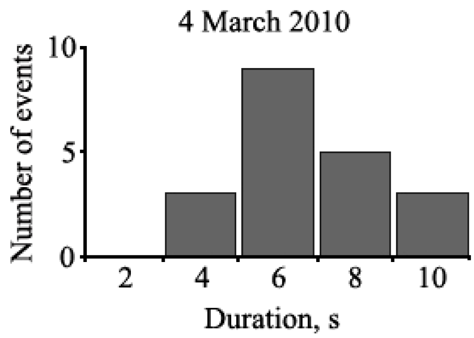

Fig. 5: Distribution of AD Leo bursts on duration for March, 4, 2010 at frequency 19 MHz.

CONCLUSIONS

Observations with unique sensitivity, high time and frequency resolutions on the ground-based radio telescope UTR-2 allowed to detect the radio emission from the flare stars (AD Leo and EV Lac) and to estimate its properties at decametre frequencies. We used two criteria for attributing the obtained radio emission to the star AD Leo. Firstly bursts were filtered out in the dynamic spectrum on the basis of ON-OFF method. Further we used the analogy between the AD Leo and the solar type III bursts. The main properties of the probable flare star bursts at decametre wavelengths ($16.5 - 33$ MHz) were discussed. Our results show, that radio bursts generated by flare star AD Leo have frequency drift rates of both signs (positive and negative), frequency drift rates are in the range of $0.2 - 5$ MHz/s for negative drift rates and changed from 0.2 to 4.2 MHz/s for positive drift rates, their durations are of $2 - 12$ seconds, fluxes are in the range of $10 - 50$ Jy, which corresponds to brightness temperatures of $(1.2{-}5.8)\cdot 10^{16}$ K. We found, that the flare star bursts have structure and some properties similar to solar type III bursts in the decametre range. Finally, we can argue with a high confidence that the detected radio emission is originated from the AD Leo.

ACKNOWLEDGEMENT

The work was partly supported by SOLSPANET project and authors are grateful to Stefaan Poedts for discussion of observational results.

REFERENCES

[1] Abdul-Aziz H., Abranin E. P., Alekseev I. Yu. et al. 1995, A&AS, 114, 509

[2] Abranin E. P., Alekseev I. Yu., Bazelyan L. L. et al. 2001, Radio Phys. and Radio Astron., 6, 89

[3] Bastian T. S. 1990, Solar Phys., 130, 265

[4] Gudel M., Benz A. O., Bastian T. S. et al. 1989, A&A, 220, L5

[5] Gurzadyan G. A. 1973, 'Flare stars', Nauka, Moskva

[6] Jackson P. D., Kundu M. R. & Kassim N. 1990, Solar Phys., 130, 391

[7] Koliadin V. L. 2011, Radio Phys. and Radio Astron., 4, 341

[8] Melnik V. N., Konovalenko A. A., Rucker H. O. et al. 2011, Solar Phys., 269, 335

[9] Mel'nik V. N. 1994, Kinematika i Fizika Nebesnykh Tel, 10, 5, 77

[10] Ryabov V. B., Vavriv D. M., Zarka P. et al. 2010, A&A, 510, A16

[11] Stepanov A. V., Kliem B., Zaitsev V. V. et al. 2001, A&A, 374, 1072