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Decametric radio bursts associated with the 13 July 2004 CME event at frequencies 10–30 MHz

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We report on the observations of solar type IV burst and its precursors on the 13 of July 2004 at frequencies 10 − 30 MHz. The radio telescope UTR-2 observational data compiled from SOHO, WIND, NDA, RHESSI, GOES data were used. The main properties (frequency drift rate, duration, flux) of type IV burst and its precursors, namely solar type III and type II bursts, are analysed. We consider the type IV burst connected with appearance of the coronal mass ejection, which occurrence coincides with the type IV burst beginning. Several physical characteristics of this CME were estimated.

Key words: Sun: activity; Sun: Coronal Mass Ejections (CMEs); Sun: radio radiation

OBSERVATIONS

The observations of solar type IV burst and its precursors on the 13 of July 2004 at frequencies 10 − 30 MHz was chosen among recordings of 40 type IV bursts observed by UTR-2 (Kharkov, Ukraine) during 2002 − 2006. This event shows the most complete phenomena of the solar type IV burst at decametric wavelengths [8]. Three sections of the radio telescope UTR-2 with a total area of 30000 m^2 were used for these observations. It provides a beam of 1° × 13°. Registrations were carried out by the 60-channel receiver with a frequency resolution of 300 kHz and time resolution of 10 ms.

The time profile at frequency 26.15 MHz of the 13 of July 2004 event is shown in Fig. 1. Sequence of events shown in Fig. 1 is the following: type III bursts, bursts in absorption, type II burst, type IV burst. All these events will be considered in the same sequence.

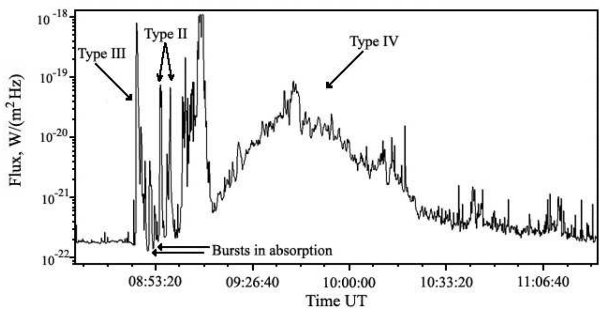

Fig. 1: The 13 of July 2004 event time profile.

On the 13 July 2004 four active regions (Fig. 2), which could be responsible for the type IV radio emission and associated type III and II bursts, were on the solar disc (85° and 40° to the East and 5° and 50° to the West from the central meridian). Decametric radio bursts observed at that day are associated with active region N 121 [NOAA 10646], located 50° to the West from the central meridian.

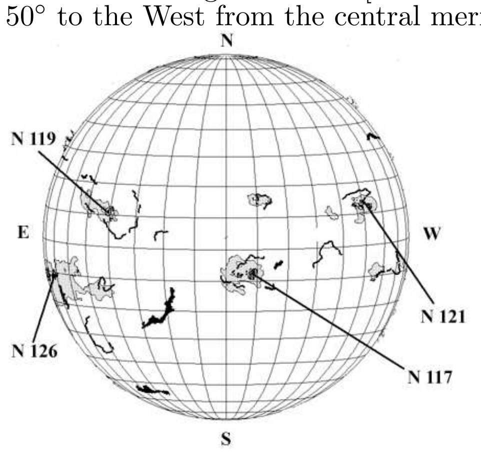

Fig. 2: Location of the active regions on the solar disc on the 13 July 2004.

For the statistical analysis we divided the whole frequency band from 10 to 30 MHz into the frequency sub-bands 10 − 13 MHz, 13 − 15 MHz, 15 − 20 MHz, 20 − 25 MHz, 25 − 30 MHz. We marked all the characteristics for every solar burst type on

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the average frequencies of each sub-bands.

On the 13 of July 2004 nine type III bursts as precursors of the type IV burst were observed. It should be noted, that one of these bursts was powerful (with flux $1.6 \cdot 10^{-18}$ $\mathrm{W\,m^{-2}\,Hz^{-1}}$) [7]. Time profiles of type III bursts observed during this event are not symmetrical, as it is seen in Fig. 3.

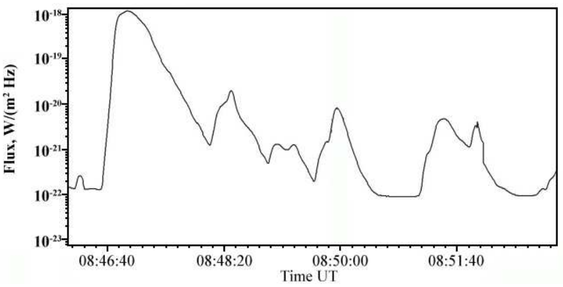

Fig. 3: Type III bursts (08:46:55, 08:49:50, 08:51:20 UT) time profile at frequency 19.2 MHz.

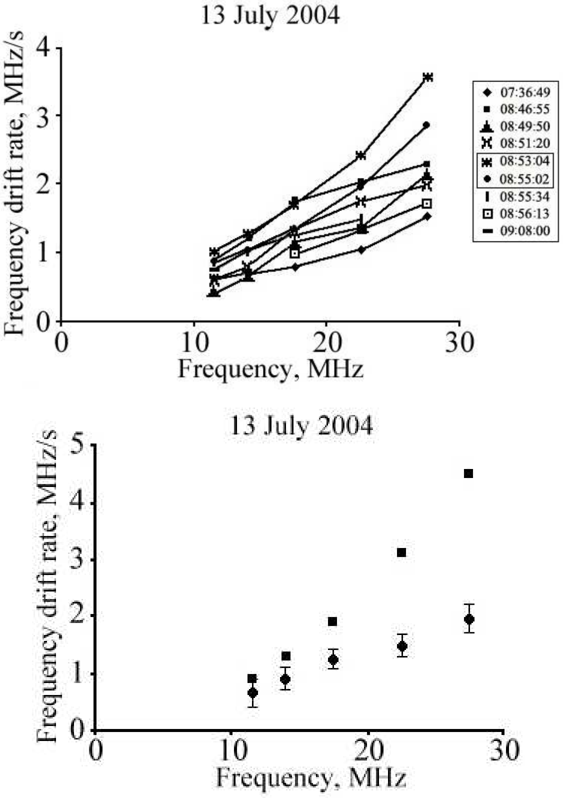

Fig. 4: Drift rate dependencies on frequency for each type III burst (top) and for average values (bottom) (dots represent observational data and squares represent data obtained with empirical dependence $df/dt = -0.01f^{1.84}$ [1])

In the range of $10 - 30$ MHz all these bursts have negative frequency drift rates (bursts drift from high to low frequencies). From Fig. 4a it is seen, that most of the bursts have linear drift rate dependence on frequency, but there are two out-of-order curves. We assume that these two type III bursts (at 08:53:04 UT and 08:55:02 UT) do not originate from active region N121. So, these two bursts were excluded from statistical analysis. According to our observations type III bursts have frequency drift rates in the range of $1 - 3$ MHz/s. The dependence of average drift rate on frequency for type III bursts is shown in Fig. 4b. We draw attention to the difference between derived and generally accepted dependence. Drift rates are almost the same at frequencies $10 - 15$ MHz, but they considerably differ by a factor of about 2 at frequencies $20 - 30$ MHz.

The duration of type III bursts analysed lies within the range of $15 - 20$ s, which is higher than usually accepted type III burst duration ($4 - 12$ s). The average duration dependence on frequency is shown in Fig. 5.

After a group of the type III bursts two solar bursts in absorption [3] were observed (at 08:50:53 UT and 08:52:40 UT). Duration at frequency 22.5 MHz for first burst is of 32 s, and for second one is of 19 s. In the range of $10 - 30$ MHz drift rates were -1.5 MHz/s and -1.2 MHz/s for first and second burst correspondingly.

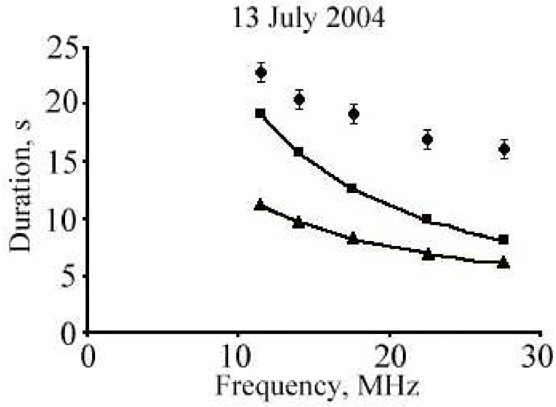

Fig. 5: The type III bursts duration dependence on frequency (circles represent average observational duration values, solid line with squares represents $T = 220/f$ dependence [9], solid line with triangles represents $T = 60 \cdot f^{-2/3}$ dependence [2]

The type II burst started at 30 MHz at about 08:56:10 UT and it had two harmonics [6]. On 13 July 2004 observations of the Sun were carried out with HiRAS (Hiraiso Radio Spectrograph) in the frequency range of $25 - 2500$ MHz. We completed these observations with the low-frequency observations from UTR-2. Due to this result we determined characteristics of type II burst in a wide frequency range. In Fig. 6 the frequency drift rate dependencies on frequency for UTR-2 and HiRAS are shown. The frequency drift rate in the range of $10 - 30$ MHz for fundamental component is -34 kHz/s, while for second and third harmonics these values are

−58 kHz/s and −57 kHz/s correspondingly. The type II burst drift rate increases with frequency. The frequency drift rate values at higher frequencies for the fundamental harmonic of type II burst are much higher: in the range of $50-100$ MHz it is 256 kHz/s, while in the range of $100-200$ MHz it is 769 kHz/s.

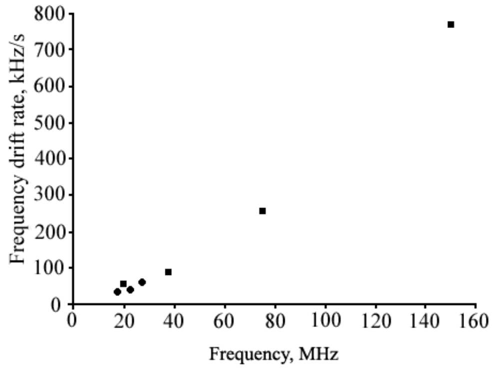

Fig. 6: The frequency drift rate dependencies on frequency for the type II burst fundamental component observed on July 13, 2004 (circles represent UTR-2 observational data, squares represent HiRAS observational data).

Type II bursts are caused by shock waves. The leading edge of the CME (coronal mass ejection) corresponds to shock wave, which was formed at about 08:46:00 UT according to our calculations. The linear velocity of the shock wave is 253 km/s at the distance of about 7 solar radii from the Sun (estimates were made using SOHO data). Our calculations of the frequency drift rate of the fundamental component of type II burst show, that the velocity of the shock is 365 km/s at distance 1.5 solar radii. So we conclude that the shock was slowing down moving from the Sun.

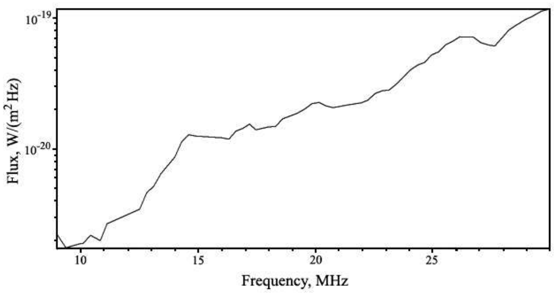

Fig. 7: The type IV burst frequency profile, measured in burst maximum.

Type IV burst observed on 13 July 2004 began over the frequency range $10-30$ MHz nearly at 09:11:00 UT and lasted of about 2 hours. It has the fine structure in the form of drifting sub-bursts (so-called fiber bursts) [5]. In the range of $10-30$ MHz the duration of type IV burst increases with frequency: the type IV's duration is about 30 min at 15 MHz, but at frequency 30 MHz it increases up to 2 hours 20 min. Drift rate of this burst measured using the forward edge has negative value and equals to about 15 kHz/s. The average flux value is 24 *s.f.u.* (1 *s.f.u.* $= 10^{-22}$ $\mathrm{W\,m^{-2}\,Hz^{-1}}$). The frequency profile (Fig. 7) shows that the flux increases with frequency. The type IV burst emission on the 13 July 2004 at frequencies $20-60$ MHz was strongly polarized according to Nancay data. Observed type IV burst accompanies the CME [4] with a velocity 713 km/s. Using our data we calculated velocity of the CME using type IV burst leading edge. At the distance of 1.5 solar radii (at frequency 30 MHz) the velocity is about 90 km/s.

CONCLUSIONS

Observations of the decameter type IV bursts by the radio telescope UTR-2 with unique sensitivity, high time and frequency resolutions allowed us to define the type IV bursts properties at low frequencies. Observational data in the wide frequency range ($25-2500$ MHz) agree with low frequency ($10-30$ MHz) observations. The main properties of type III bursts, bursts in absorption, type II burst and type IV burst observed on 13 July 2004 were analysed. Velocity of the CME associated with 13 July 2004 event calculated using decameter type IV burst leading edge is equal to 90 km/s. Shock wave velocity calculated using fundamental component frequency drift rate of type II burst is of 365 km/s.

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