NARROWBAND dm-SPIKES OBSERVED DURING THE 15 JUNE 1991 FLARE

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Abstract. We performed a statistical analysis of the dm-spikes that were present for an exceptionally long period (more than 10 min) during the 15 June 1991 flare. We realized that the polarization degree, the duration and the mutual delay of the R- and L-components were nearly the same for both CW and ACW cases. CW (ACW) means the clockwise (anti-clockwise) sense of the loop in the $R-L$ versus $L+R$ plots, when the data of a single spike are considered according to the time sequence. The presence of such a loop is determined by the delay of the weaker (stronger) polarimetric component in respect to the other one. The increase of the polarization percentage started first at 610, then at 408 and afterwards at 327 MHz. It was found that the duration of spikes was almost completely independent from the polarization degree. The mean duration of spikes at different frequencies corresponds to that computed using the formula of Güdel and Benz. Like the mean duration, also the mean delay decreased with increasing frequency. The CW/ACW ratio varied simultaneously for the frequencies we recorded during an interval of about three minutes. Spikes were considered as the radio manifestation of superthermal electrons accelerated in the MHD cascading waves. The evolution of spikes and their parameters were qualitatively interpreted within the flare reconnection model with turbulent plasma outflows.

1. Introduction

Many papers have been devoted to the study of narrowband dm-spikes, mainly for their exceptionally high brightness temperature ($T_b \approx 10^{15}$ K) and for their short duration (≤ 0.1 s, see the review by Benz, 1986). Besides the papers describing the observational characteristics of these bursts (e.g., Slottje, 1981; Karlický, 1984; Stähli and Magun, 1986; Benz, Zlobec, and Jaeggi, 1982), there are theoretical papers with two different interpretations: in the former group of papers the narrowband dm-spikes are considered radio manifestations of plasma emission and acceleration processes (Kuijpers, Van der Post, and Slottje, 1981; Tajima *et al.*, 1990; Wentzel, 1991); in the latter the spikes are explained by the electron-cyclotron maser mechanism (Holman, Eichler, and Kundu, 1980; Melrose and Dulk, 1982, Aschwanden, 1990; Fleishman and Yastrebov, 1994). It was also suggested that the dm-spikes are the result of radio emission of superthermal electrons accelerated in turbulent MHD cascading waves generated in the magnetic field reconnection outflows (Karlický, Sobotka, and Jiřička, 1996). It seems consis-

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tent with positional measurements of dm-spikes (Krucker, Benz, and Aschwanden, 1996). Namely, the spike sources are found near open magnetic field lines and near regions with a slightly enhanced SXR flux relative to the ambient plasma.

To find further information about the spike emission mechanism, observations of the polarization and the harmonic structures have also been analyzed (Nonino *et al.*, 1986, Güdel and Zlobec, 1991; Krucker and Benz, 1994).

Recently, Benz and Pianezzi (1997) have studied the relative arrival times of the left and of the right circularly polarized spike components. They found that in all cases the weaker component was delayed by a fraction of a millisecond. The delay was interpreted as the difference in the group velocity of the two components due to the dispersion in the coronal plasma. It was suggested that the radiation is polarized in the ordinary mode at the location in which the polarization originates.

In the present paper we continue such research. We decided to analyze the group of spikes that were recorded during the strong type IV event on 15 June 1991 for three reasons: the first is that the period when they were present was exceptionally long, since it lasted about 10 min (from $8^{h}23^{m}$ to $8^{h}34^{m}$ UT) and some of the spikes were extremely strong. The second reason concerns the change of the polarization during the interval taken into account, and the fact that this change was not synchronous for the frequencies considered at 237, 327, 408, and 610 MHz. At the beginning the spikes were almost unpolarized or weakly polarized right-handed, afterwards this polarization increased. Finally, it is worthwhile to mention that the type IV event was quite exceptional and for such a reason it was studied in detail (see Akimov *et al.*, 1996).

2. Observations

The radiopolarimetric data were recorded at Trieste Astronomical Observatory with digitization rate of 1 and 50 Hz. At Ondřejov Observatory the spectrum was recorded from 100 to 1000 MHz (see Figure 1). On this spectrum a cloud of narrowband (10 – 60 MHz) dm-spikes can be seen. Drifting features were observed at some frequency ranges and time intervals, such as at $8^{h}30^{m}30^{s}$ in the 400 – 500 MHz frequency range in which spikes drifting towards lower frequencies (-5 MHz s^{-1}) were present.

Figure 2 shows the radio emission at 237, 327, 408, and 610 MHz during the interval of interest. Since the digitization rate was low (1 Hz) single spikes are not seen but, as they normally appeared in groups, they can be found in the enhancements. Figure 3 gives an example of data recorded every 20 ms. These spikes (at 610 MHz) were very strong and placed next to one another and sometimes also superposed. The top of the figure shows the left-handed (L) circular polarization channel and the bottom part the right-handed (R) one.