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Millisecond solar radio spikes observed at 1420 MHz

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Abstract. We present results from observations of narrowband solar millisecond radio spikes at 1420 MHz. Observing data were collected between February 2000 and December 2001 with the 15-m radio telescope at the Centre for Astronomy Nicolaus Copernicus University in Torun, Poland, equipped with a radio spectrograph that covered the 1352–1490 MHz frequency band. The radio spectrograph has 3 MHz frequency resolution and 80 microsecond time resolution. We analyzed the individual radio spike duration, bandwidth and rate of frequency drift. A part of the observed spikes showed well-outlined subtle structures. On dynamic radio spectrograms of the investigated events we notice complex structures formed by numerous individual spikes known as chains of spikes and distinctly different structure of columns. Positions of active regions connected with radio spikes emission were investigated. It turns out that most of them are located near the center of the solar disk, suggesting strong beaming of the spikes emission.

Key words. Sun: radio radiation – Sun: flares – Sun: magnetic fields – Sun: X-rays, gamma rays

1. Introduction

Decimetre radio spikes are short (usually a few tens of ms) and narrowband (a few percent of the centre frequency) peaks in the radio spectrum (Dröge 1977). They appear in multi-element groups, typically up to many thousands of individual events each (Benz 1986). The short duration and narrow bandwidth suggest a small source size (Bárta & Karlický 2001). The dynamical radio-spectra of the spikes show their very fast drifts in frequencies, with a wide scatter of the drift rates over positive and negative values (the negative drift is defined as a change of the observed frequency from higher to lower) but usually the negative drifts dominate. However, observed drifts of the emission frequency of the individual spikes or groups of spikes can be construed not only as a result of the motion of the exciting factor through the plasma but also as a local change of physical parameters of the emitting plasma (Benz 1986).

Theoretical models of the radio spike emission are based mainly on plasma emission and on electron-cyclotron maser emission. The emission of the radio spikes is undoubtedly related to fine scale elementary processes of magnetic fields annihilations and energy releases, occurring in very short time scales and evidently in very small spatial scales (Aschwanden & Benz 1997; Robinson 1991; Benz et al. 2001).

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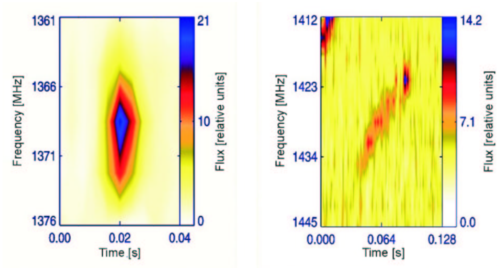

Fig. 1. The left plot shows the decimetre radio spike without internal structure recorded on 11 July 2000, the right plot the decimetre radio spike with internal structure recorded on 23 April 2000.

2. Instrument and Observations

The results presented here were obtained with 15-m Torun radio telescope equipped with a fast radio spectrometer – the Pulsar Machine II (Cadwell 1997) that covers the range of 1352 MHz to 1490 MHz. The spectrometer has 3 MHz frequency resolution (46 channels) and 80 μs time resolution.

In the period from February 2000 to December 2001 (during nearly 2000 hours of observation) we have observed 13 events with radio spikes. The presented observations of the spikes in the decimetre band have probably the highest time resolution obtained ever. We have evaluated main observational parameters of 5199 individual spikes: the duration, bandwidth and drift. The mean duration time of spikes is 36 ms, the mean value of bandwidth of spikes is 9.96 MHz, the mean value of velocity of the negative drift is –776 MHz s^{-1} and of the positive drift is 1608 MHz s^{-1} (Dabrowski et al. 2005).

Using X–ray, UV and ground based observations we have analysed main properties of the active phenomena correlated in time with the observed spikes (Dabrowski et al. 2005).

3. Discussion of the results and conclusions

(1) We have found that radio spikes (in different radio events) were emitted during increase, impulsive, peaks and gradual phases of the solar flares.

(2) Thanks to the very high temporal resolution of the radiospectrograph used, we have found spikes, called by us spikes without internal structure, that have a simple form of a single increase of radio flux, limited in time and frequency and spikes showing a well outlined subtle internal structure, consisting of a few local, internal maxima (Fig. 1). We will refer to them arbitrarily as to spikes with internal structure.

(3) On the dynamic spectrum we have found chains of spikes. They are formed by tight groups of spikes with their emission band drifting in frequency (i.e. chains with drift) or emitted in a constant band (chains without drift) (Fig. 2). The durations of the chains of spikes observed vary from 67 ms up to 509 ms.

(4) On the dynamic spectrum we have found a new structure called by us column (Fig. 3). The columns are formed by numerous individual spikes, emitted in very short time range on various frequencies.

(5) The estimated size of emission source of radio spike in analysed events (in the assumption of plasma emission) was around 142 km. We did not find any relationship between the linear source size and its position on the solar disc.

(6) Most of the active regions (10 out of 13 analysed radio events) connected with the emission of radio spikes were found at a close distance from the centre of the solar disc (Fig. 4).

(7) The estimated height of the source of radio spikes was around 3.2×10^3 km above the photosphere. This corresponds to a lower layer of the corona.

(8) We found that the spikes related to the solar flares are emitted from events of various morphologies, various scenarios of evolution and various configurations of the interacting magnetic fields.

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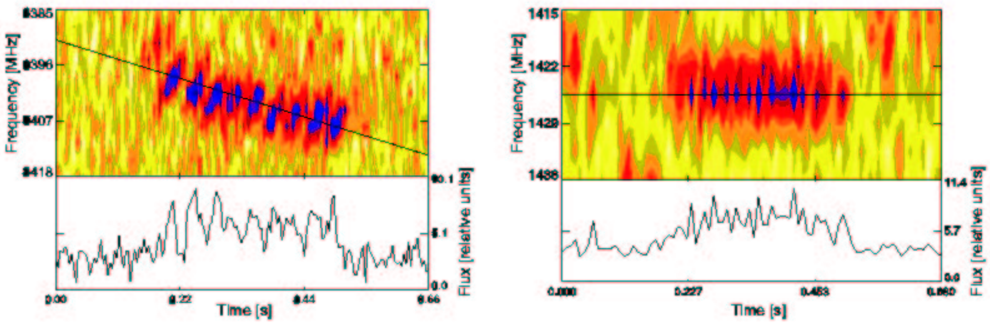

Fig. 2. On the left is shown a chain of spikes with a drift in frequency recorded on 26 March 2000 (beginning at 10:38:00.6 UT). In the upper panel presented is its dynamic spectrum. In the lower panel are shown the changes of signal intensity (along the sloped line across the upper part) vs. time and frequency. The range of the relative flux is from 0 (white) to 9.1 (blue). On the right is a chain of spikes without a drift in frequency recorded on 26 April 2000 (beginning at 14:10:13.96 UT). In the upper panel presented is its dynamic spectrum. In the lower panel the changes of signal intensity (at the frequency where we observed the highest signal for this chain of spikes) is shown. The range of the relative flux is from 0 (white) to 10.4 (blue).

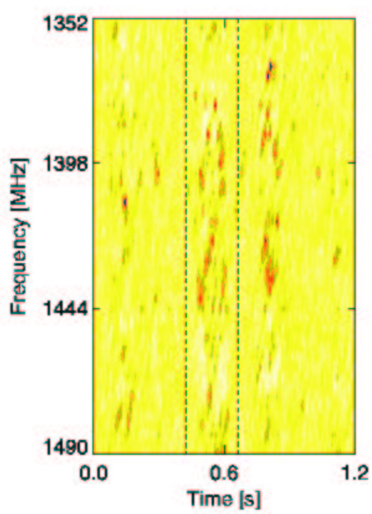

Fig. 3. The columns of spikes recorded on 22 March 2001 (beginning at 13:11:18.2 UT). One can see a clear column of the spikes (marked with broken lines) on the dynamic spectrum. The range of the relative flux is from 0 (white) to 25.9 (blue).

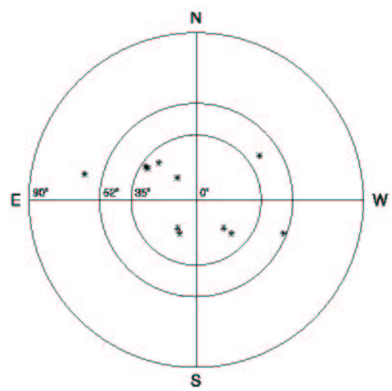

Fig. 4. Distribution of active regions connected with radio spike emission on the Solar disc. The active regions where we found spikes are marked with stars. The concentric circles are drown at 35°, 52° and 90° from the disc centre.

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