Spatial and Temporal Evolution of Magnetic Loops on April 15, 1998

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Abstract

The first detections of subsecond type-U bursts are reported by the Beijing Astronomical Observatory using the solar radio spectrometer operating between 2.6-3.8 GHz with a time resolution of 8 msec. The spatial and temporal evolution of these loop-like structures are studied and compared with the relevant observations at optical, X-ray, and radio bands.

Key words:

1. Observations

A very special solar radio burst event was detected on April 15, 1998, between 07:58:34 UT and 08:02:27 UT by the 2.6-3.8 GHz spectrometer of Beijing Astronomical Observatory with time resolution 8 msec for all 120 frequency channels. Fig. 1 shows the time profile of this event in one channel (2.89 GHz).

Meanwhile, in the SGD records, there was a C8.8/SN flare detected by GOES in active region NOAA 8203 at N29W15 between 07:37 UT and 07:54 UT, with a maximum at 07:46 UT. The SN flare was also detected by SVTO in the same location between 07:39-08:06 UT, and maximum at 07:45 UT.

There were also CME events and type II bursts observed by SOHO, WIND and Ulysses on April 15-18, 1998 (Reiner et al., 1998). The C1 experiment of LASCO/SOHO showed a bright point in AR 8203 between 07:34 UT and 08:03 UT, and maximum at 07:51 UT on April 15, after that, C2 and C3 experiments showed a mass ejection started from 08:55 UT up to 12:37 UT.

In the *Yohkoh* observations, a small arcade structure was detected by the SXT in AR 8203 between 08:06:50 UT and 08:16:14 UT (Fig. 2), and a more complicated loop structure appeared before (06:48:44 UT) and after (10:15:56 UT) the flare. The data of the coincident HXR bursts will be processed further (Sato, 1998). This event was also recorded by SSRT in AR 8203 from 07:12 to 09:09 UT and maximum at 08:48 UT (Konovalov, 1998).

The SGD records of solar radio bursts started from 07:41 UT up to 08:07 UT with a series of type III bursts in the spectral observations by SVTO, LEAR, CULG, POTS, IZMI, ONDR, and etc, several diagrams of the type III events were provided by Karlicky (1998), one diagram is shown in Fig. 3.

2. Subsecond type-U bursts

In the time profile with 0.2 s resolution, there are some strong pulsations superposed on the LDE (Fig. 1). Each pulsation corresponds to a type *III* burst in the time-frequency diagrams (Fig.4). If the diagram with high time resolution (8 msec) is checked with respect to each pulsation, a series of subsecond type-U bursts are shown in the spatial and temporal order such as in Fig. 5a and Fig. 6a. The time scale of these loop-like structures is usually several tens to one hundred milliseconds, which is much smaller than the time scale of the type-U bursts at meter bands.

It is interesting that these bursts are usually composed of two or three parallel loop structures, the distance between the loops seems to be close at low frequencies or height (Fig. 5a), and separate at high frequencies or height (Fig. 6a). Some sort of interaction happened between these loops.

3. Millisecond spikes

These type-U bursts are often accompanied by a series of millisecond spikes during the interaction (Fig. 5b-6b). The spikes also take place around the type-U bursts with both negative and positive frequency drifts. The drift rates of the spikes (± 6 GHz/s) are much higher than that of the type-U bursts (10^{2-3} MHz/s). If these spikes are due

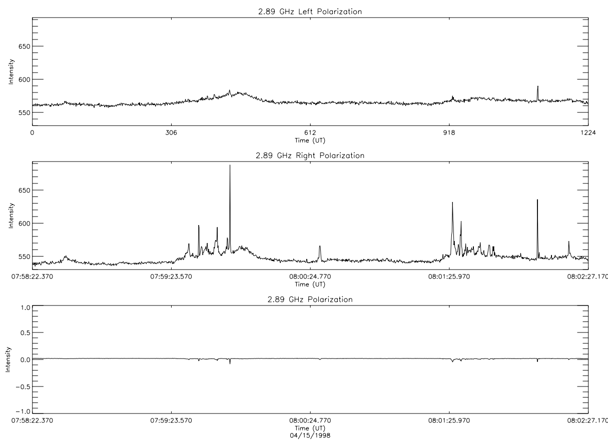

Fig. 1.. The time profile of the event on April 15, 1998 at a selected channel (2.89 GHz).

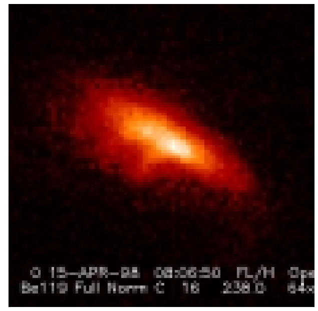

Fig. 2.. The photo of Yohkoh SXR at 08:06:50 UT on April 15, 1998 in AR 8203.

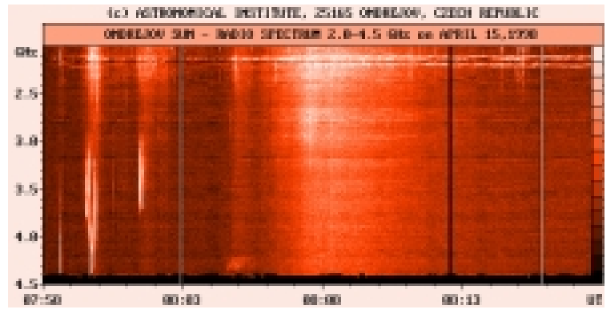

Fig. 3.. The diagram of ONDR 2-4.5 GHz spectrometer at 07:58-08:18 UT on April 15, 1998.

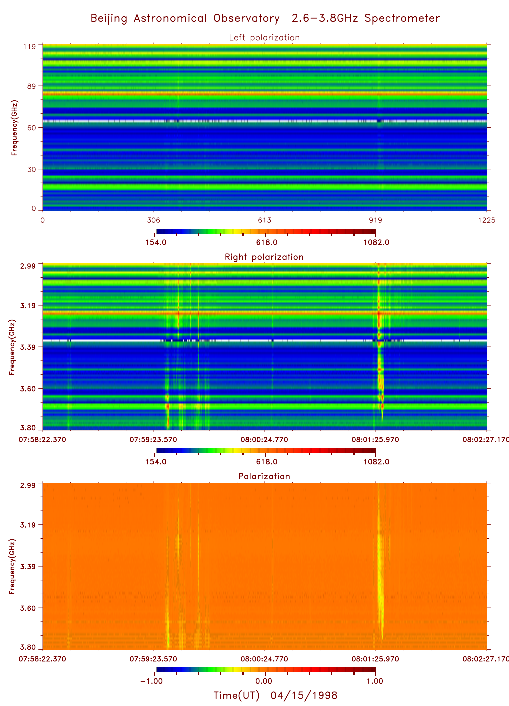

Fig. 4.. The LC, RC, and polarization images of multiple channels with 0.2 s time resolution for the same event.

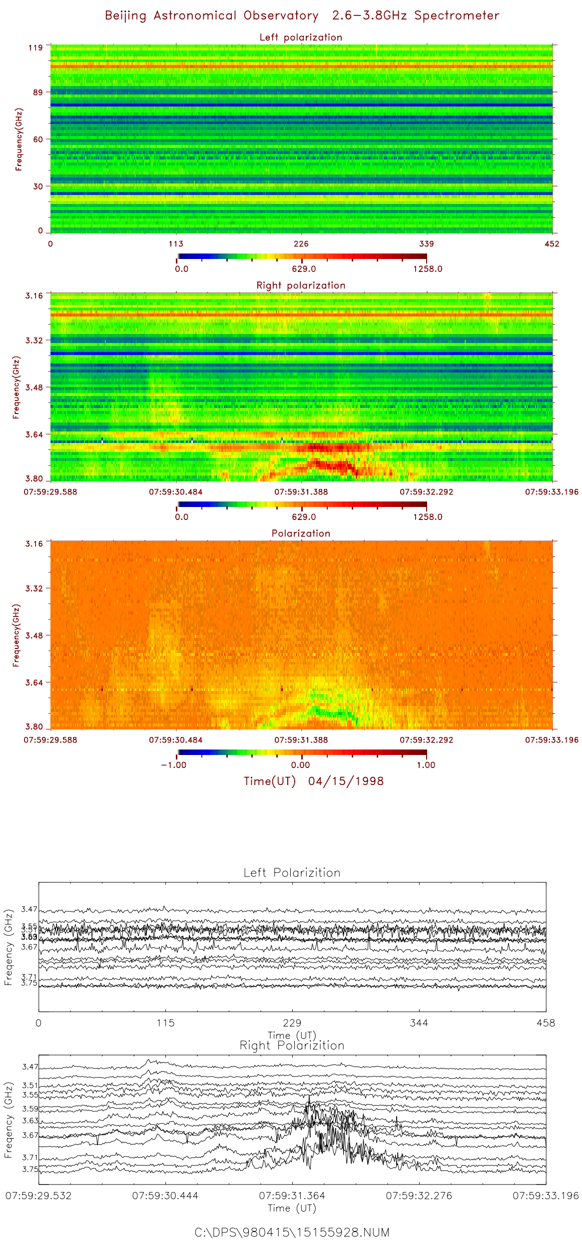

Fig. 5.. An example of a type-U burst in the diagram of multiple channels with 8 ms time resolution: a) color simulation b) time profiles.

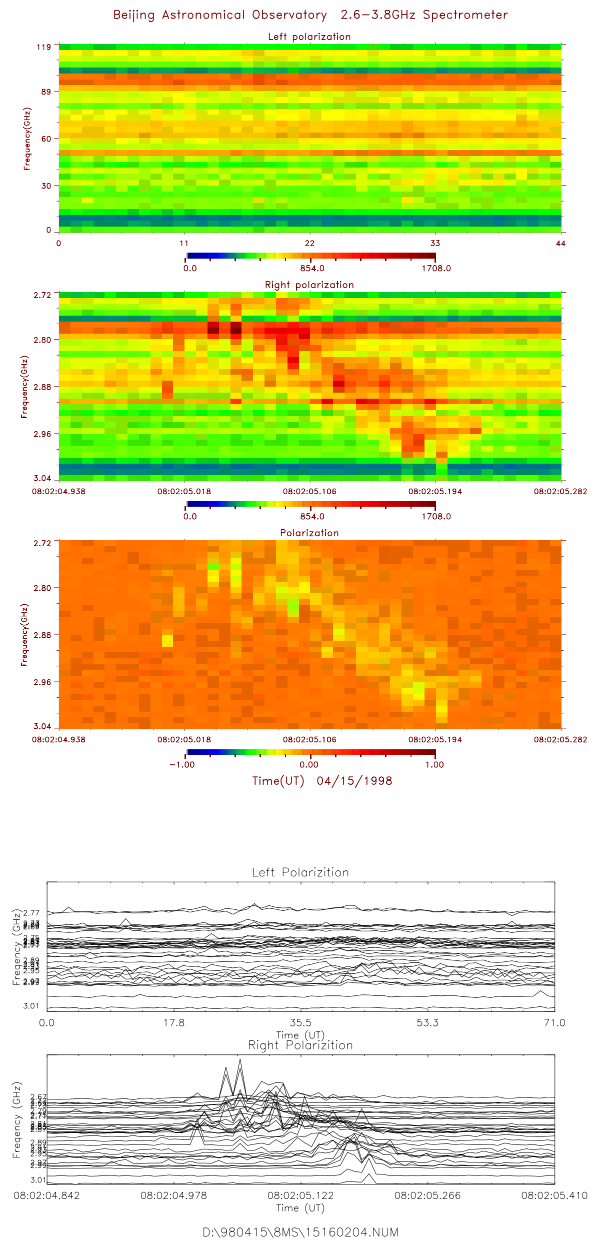

Fig. 6.. Second example of type-U burst in the diagram of multiple channels with 8 ms time resolution: a) color simulation b) time profiles.

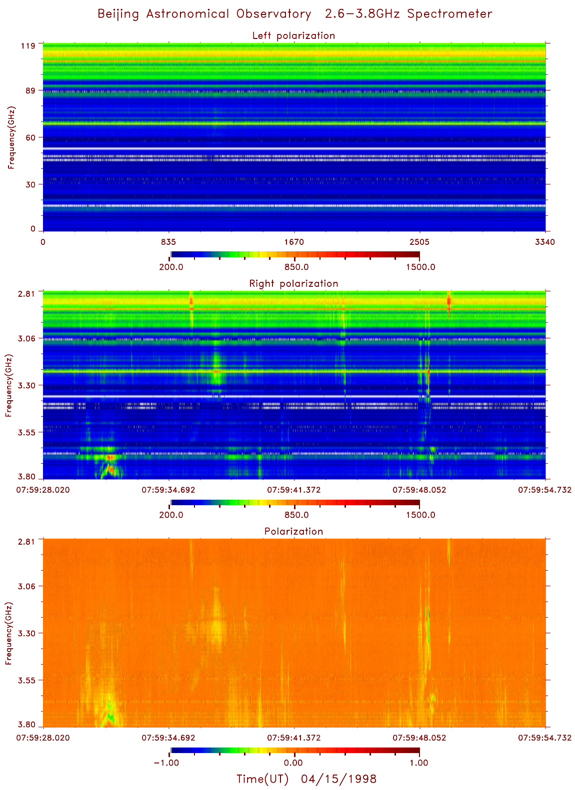

Fig. 7.. The spatial and temporal evolution of the loop-like structures.

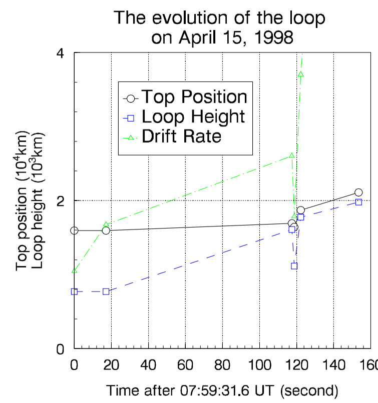

Fig. 8.. The calculation results for the evolution of the top position (solid line), longitudial size (dash line) and drift rate (dot-dash line) of the loop-like structures.

to the nonthermal electrons accelerated in the reconnection of the small parallel magnetic loops, the acceleration mechanism should be more efficient in the direction perpendicular to the magnetic field, because the frequency drift rates are closely associated with the velocity of the nonthermal electrons.

4. Evolution of magnetic loops

Moreover, the top position of the magnetic loop seems to be increasing with time (Fig. 7). The evolution of the arcs is calculated from the relation between frequency and height (Huang et al., 1998):

$$h = d\left[\left(\frac{5.6B_0}{f_{MHz}}\right)^{1/3} - 1\right], \tag{1}$$

or

$$\Delta h = -\frac{d}{3}(5.6B_0)^{1/3} f_{MHz}^{-4/3} \Delta f, \tag{2}$$

where the magnetic field strength of photosphere B_0 is about 2000 G, the depth of the dipole field d is about 3.5×10^4 km. The velocity of the arcs is slow at first (¡1000 km/s), and then suddenly changes to 10000 km/s. In the meantime, the longitudial size of the arcs increases from 800 km to 2000 km, but the time duration with respect to the transvere size decreases from a hundred milliseconds to several tens of milliseconds, so that the drift rate of type-U bursts increases from 100 MHz/s to 1000 MHz/s. All of the results are shown in Fig. 8.

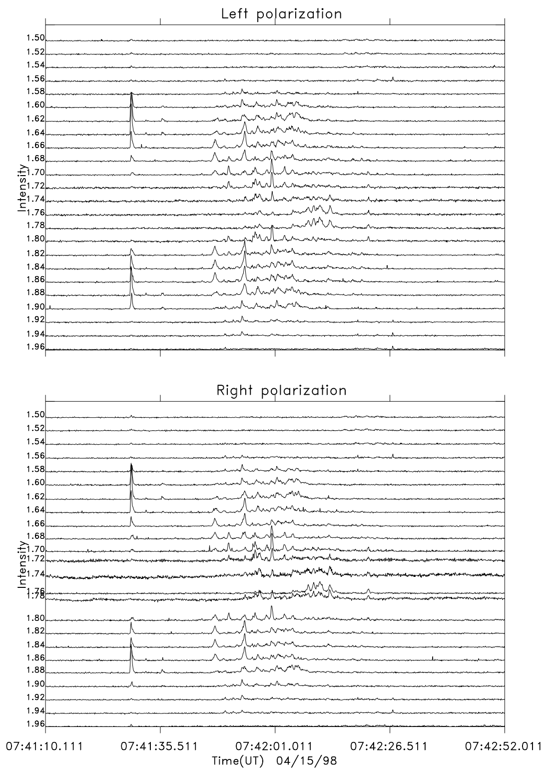

Fig. 9.. 1-2 GHz spectrometer observations of the same event.

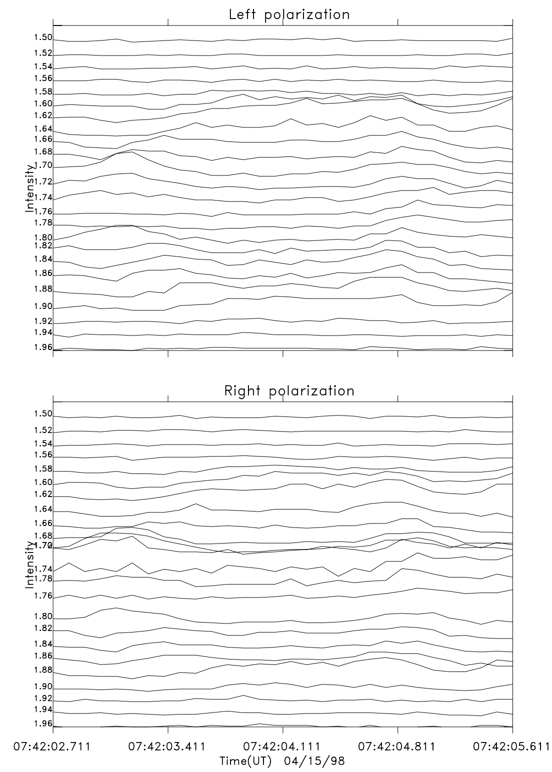

Fig. 10.. A complete loop structure selected and enlarged from Fig. 9.

5. Polarization

Another important characteristic of this event is the strong right circular polarization of these subsecond type-U bursts, as well as the millisecond spikes (Figs. 1, 3-7). However, the polarization of the ambient burst (LDE) is weakly polarized in the left circular sense, which is the same as most of the cases of the type *III* bursts observed by the spectrometer. Therefore, the magnetic diagram will be studied carefully in order to understand the reason for the opposite sense of polarization. It is noted that there were some type-U bursts with a very short time scale (several tens millisecond), which may corresponds to micro-magnetic tubes with scale of tens km.

6. 1-2 GHz spectrometer

The spectrometer of the Beijing Observatory also works at 1-2 GHz with 100 channels and a time resolution only 50 msec. The records at this band between 07:41:10 UT and 07:42:52 UT were quite different from that of 2.6-3.8 GHz. A series of type III bursts with reversed drift rates, and very weak left circular polarization degree (Fig. 9) were observed. The detail diagrams showed some special structures, something like a complete loop with time evolution (Fig. 10).

There were several channels (1.7-1.8 GHz) without bursts at first, and then the bursts start. The region may be associated with a current sheet in which the the electrons are accelerated in two different directions (Huang et al., 1998).

7. Summary

This event may provide evidence of the spatial and temporal evolution of coronal magnetic loops. The scale of these loops may be as small as tens of km, which is beyond the spatial resolution of solar optical or radio telescopes.

The high time and frequency resolution of solar radio spectrometers seems to be necessary for observing the fine structures of the sources of radio bursts. For example, the type-U bursts are observed by the 8 msec resolution diagrams, but only some type *III* bursts appeared in the diagrams with 0.2 s resolution (Fig. 4) as well as those of the ONDR spectrometer (Fig. 3). However, the exact location of the the radio bursts in solar disk cannot be determined by the spectrometers, and should be studied together with the optical, X-ray, or radio telescopes with high spatial resolution.

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