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STRUCTURAL CHANGE OF RADIO SOURCES DURING EARLY PHASE OF SMALL BURSTS

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Abstract

Morphological developments of several small radio bursts are studied using Nobeyama Radioheliograph. In some events, only one source is involved in the event. In other events, more than two sources are involved and they show different temporal developments especially in the early phase. We studied the emission mechanism of each component sources by considering temporal behavior, polarization degree and also soft X-ray images taken simultaneously by Yohkoh satellite. We identified thermal free-free and nonthermal gyrosynchrotron emissions in the radio bursts and studied their relations.

1. Introduction

The Nobeyama Radioheliograph can make maps of the full disk solar images every 1 second (or 50 msec) with 15 arcsecond spatial resolution both in intensity and circular polarization at 17 GHz. Due to its high sensitivity, early phase of the radio bursts can be studied even for small events. Generally small flares have rather simple structure than that of big flares. We selected several small events and studied their spatial structure development in the course of flare development. As the radio emission is sensitive to magnetic field, it is a very good tool to study the relation between the magnetic field and flare source. In the following section, we will show examples of single source events and multiple source events and discuss the morphological relation between multiple sources.

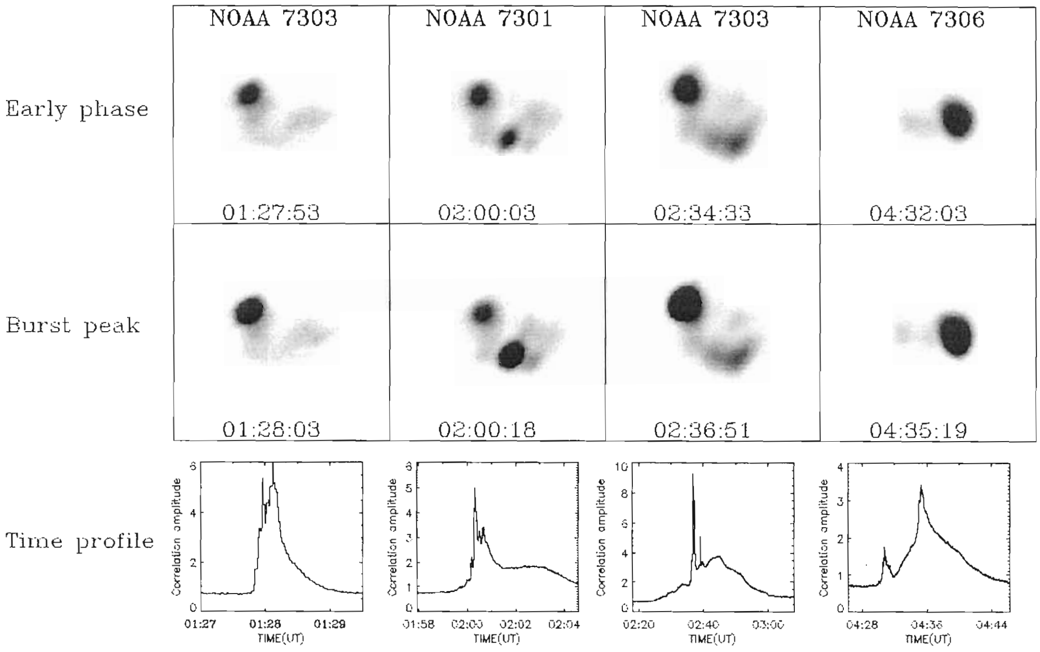


Fig. 1. Radio burst images on October 8, 1992, at early phases and their peaks.

2. Single source events

Several radio bursts were detected on October 8, 1992 by the Nobeyama Radioheliograph. Radio images of these events are shown in figure 1. All these events are in the class C or less by the GOES soft X-ray classification and less than 1N by the H-alpha classification. They occurred at different active regions: NOAA 7301, 7303 and 7306. In all four events, the main components are single, although the active region sources are complex.

3. Multiple source events

3.1. Event in NOAA 7441 on March 5, 1993

A small burst started around 0400 UT on March 5, 1993 in NOAA 7441. Figure 2 shows the evolution of the burst both in intensity and in circular polarization. Two components participated in this event. They have the same sense (left handed circular) of polarization. One of the component (A) had been existing before the flare with peak brightness temperature of $5 \times 10^4 K$. No polarization was detected larger than 1 %. In the early phase of the event, a small component (B) appeared to the north west of A with high degree of circular polarization (40 %). The component A also started to brighten simultaneously and was weakly polarized (10 %). At the peak, they had similar peak brightness temperature ($1 \times 10^5 K$). In the decay phase, B disappeared. The source size of the two are less than or equal to the beam size at the burst peak, and the size of A increased in the decay phase. Their characteristics are summarized as follows. A: existed in pre burst phase as active region source, low degree of circular polarization (10 % LCP), peak brightness temperature of $1 \times 10^5 K$(burst enhancement is $5 \times 10^4 K$). B: short lived source which appeared only during main phase of the event, high degree of circular polarization (40 % LCP), peak brightness temperature of $1 \times 10^5 K$.

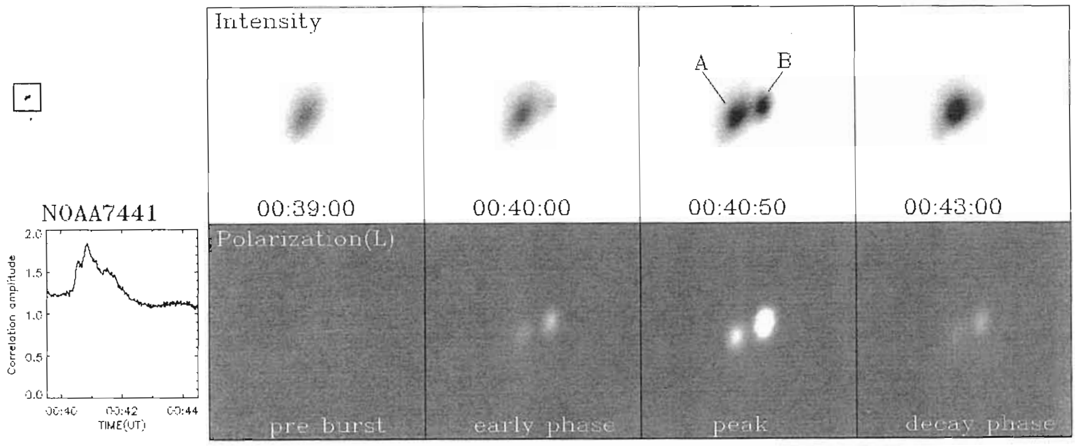


Fig. 2. Radio images of an event in NOAA 7441 of March 5, 1993.

Based on these characteristics, we interpret these components as follows. The component A is located at loop top or among bundle of loops. The emission mechanism is thermal free-free from high density plasma. On the other hand, B is located at the footpoint of the loop, and the emission mechanism is gyrosynchrotron from high energy electrons which penetrate into the strong magnetic field.

3.2. Event in NOAA 7435 on March 4, 1993

A gradual event started at around 0100 UT on March 4, 1993 in NOAA 7435. This event was also observed by Yohkoh Soft X-ray Telescope (SXT) in flare mode. Temporal evolution of radio intensity (I), circular polarization (V) and SXT images are shown in figure 3. Radio images show several components in I and V maps.

In the early phase of the burst, two compact components appeared, one of which was highly polarized (A, 30 % polarization) and the other is not polarized (B, less than 1 % polarization). In the V map, there are two components. One is associated with A (R1) and the other has no isolated source in the I map (R2, 15 % polarization). The relation between these components are schematically drawn in figure 3. The SXT images show bifurcated bright loops and an extended diffuse loop like structure and two bright knots. These two knots co-align well with A and B. At the peak, one of the soft X-ray knot which co-aligned with A disappeared. The component B gradually developed and reached at maximum brightness of $2 \times 10^5 K$ in the later phase. In the V map, another component appeared at the west end of the diffuse loop. The polarization sense is left handed circular and the degree is up to 50 % (L1) near the west edge.

We interpret these sources as follows based on the above images. The component B is thermal free-free emission from dense and hot plasma which are seen as the soft X-ray knot and part of bright loops. This is located near the top of the magnetic loop, where magnetic field is weak and show no circular polarization. On the other hand, A (R1) is nonthermal gyrosynchrotron emission from accelerated electrons which penetrate into the lower atmosphere. The sign of the energetic electrons can be seen as soft X-ray knot near the end of the loop (Hudson et al., 1994). Only one knot was found in this event, which means uni directional acceleration. The emission measure of this knot is not large enough to produce the radio brightness temperature of $1.5 \times 10^5 K$ by thermal free-free emission.

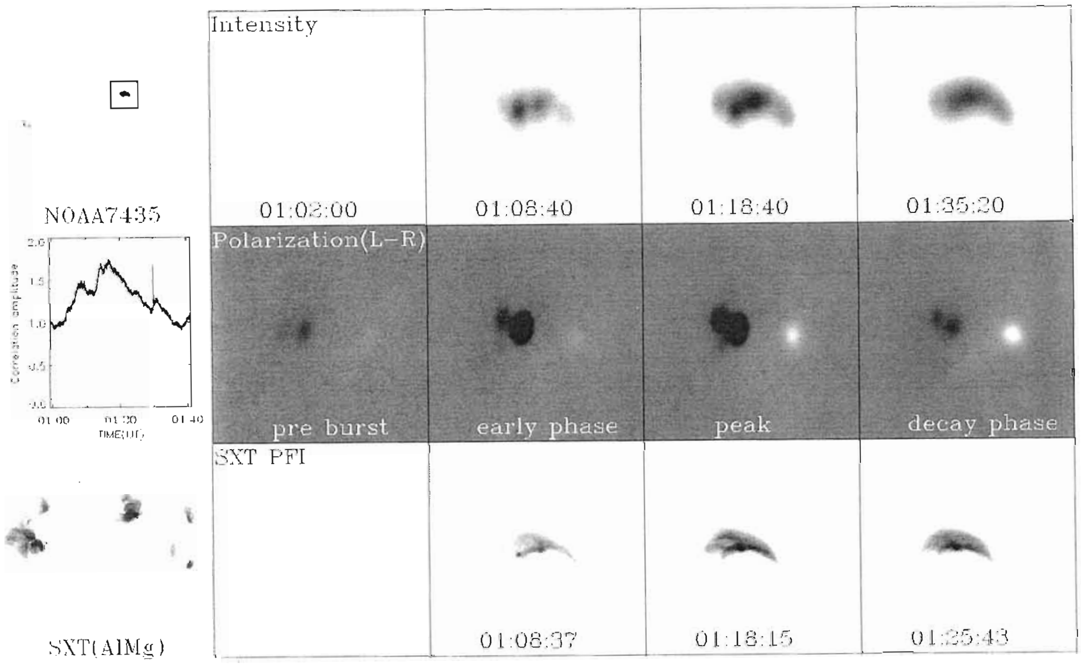
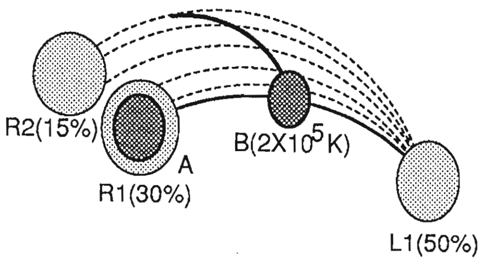


Fig. 3. Radio and Soft X-ray images of the event in NOAA 7435 on March 4, 1993 (top), and schematic drawing of the relation between radio and soft X-ray sources (right).



4. Summary and conclusion

In case of single source events, there are two possibilities which we cannot distinguish. One is a real single source event, and the other is an event whose size is smaller than the observed beam size. In the time plots of correlation amplitude, multiple source events have tendency of longer duration than single source events, but some of single source events also have longer duration. This may reflect the mixture of small scale multiple source events and real single source events.

In multiple source events, we could identify several components and could study their physical nature by comparing intensity, polarization and also soft X-ray images. The event of NOAA 7435 consisted of several components and we could identify each emission mechanism. The thermal loop-top source (B) and nonthermal foot-point source (A) started to brighten simultaneously. Radio components show very good spatial agreement with soft X-ray knots both for thermal and nonthermal sources. Heating and acceleration took place simultaneously in this event.

References

1. Hudson, H.S. et.al., 1994, *Astro. Phys. J.* **422**, L25.