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SOLAR MICROWAVE SPIKE EMISSION AND CHANGE OF MAGNETIC TOPOLOGY

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INTRODUCTION

Electron cyclotron maser (ECM) instability is today's most favoured process for microwave spike emission. Although ECM looks attractive, the emission mechanism is still unclear due to the imperfection of present theories, inadequacy of observational data, and uncertainty as to conditions in the source region. To find solar active phenomena, both statistically and individually coincident with radio spike events, is essential for understanding the ambient conditions needed for generating spike emission, locating sites where spike emission is produced, and providing clues for particle acceleration and energy release in flares.

In this paper, evidence for an association between spike emission at 21 cm and fast variation of the magnetic configuration in post-flare loops is presented. Such associations may be helpful for solving the questions mentioned above.

OBSERVATIONS

2.1 A large flare occurred at about 0040-0300 UT on 1989 August 17. It was a solar limb-event, with post-flare loops enduring for more than one day. The flare occurred in AR 5629, located at $10^o - 13^o$ behind west limb of solar disk. Using the Solar Magnetic Field Telescope (SMFT) of Huairou Solar Observatory of BAO (Li, W., 1990), it was found with H_β observations after 0132 UT that a post-flare loop system (PFLS) 10^4 km high and 1.8×10^4 km wide had formed above the west limb. By 0238 UT the PFLS had reached 6.2×10^4 km high.

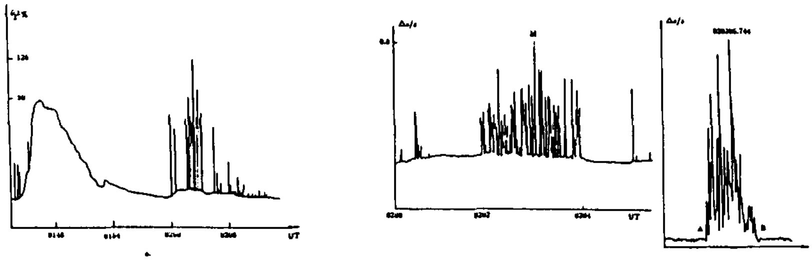

Figure 1. Time profiles of the August 17, 1989 event at 1420 MHz. a. time profile in sec time scale; b. the compressed profile of msec spike group between 0200-0206 UT; c. the extended profile of the group M indicated in Fig. 1b. The time interval between A and B is 432 msec.

2.2 The 10m dish radiotelescope (10MRT) at 21 cm at YAO has high temporal resolution (8 msec) and high sensitivity (0.2 *s.f.u*). (Gong, et al., 1989). Figure 1a (Gong, et al., 1990) shows parts of the post-peak and gradual descending phases of the burst. Several fast spike groups were recorded between 0200-0206 UT. Figure 1b shows compressed profiles of the spike groups, and Figure 1c shows extended profiles (with duration of 432 msec) of the group labelled M in Figure 1b, which contained the strongest spike in the event, with flux density about 200 *s.f.u.*. Spikes obviously appear in groups. In the major section of Figure 1b between 0202:09-0204:07, a 118 sec time interval, there continually appeared more than 1500 spikes divided into about 40 groups. Most of groups lasted several hundred msec and had 10-30 spikes. The duration of individual spikes was about 20-40 msec. The repetition rate was 48/sec in the most crowded section. The amplitude of spikes was about $50-100\%$ of S_o, where $S_o = 161$ *s.f.u.* was the 21 cm quiet solar flux density of this day. The amplitude and duration of the most intense spike were 200 *s.f.u.* and 30 msec.

2.3 At 0132 UT a PFLS composed of at least 11 loops had been formed above the solar west limb. The direction in the photographs are: left-north; right-south; up-west; and down-east. In general the north feet of PFLS are pole N, and south feet are pole S. Figure 3 gives schematic drawings of Figure 2 for clairty, in which some key features are marked. The main H_β phenomena coincident with the 21 cm spike groups are as follows:

1) Loop B appeared 5 min before the occurrence of the spike groups (Fig. 3b);

2) The rising speed of loop B was about 20 km/sec, faster than that of PFLS. When it caught up with loops of PFLS, the processes of magnetic loop coalescence and reconnection began, causing the brightening of the top of loop B and forming spot C (Fig. 3c and 3d). Brightening of spot C began a little before the appearing of radio spike groups;

3) A catastrophic change of magnetic topology occurred between 0200:52-0205:49 UT, causing the disappearance of loop B, the appearance of loop D, and the top of loop D contacted with PFLS and the bright strip E was formed (Fig. 3d and 3e). This change of magnetic structures was simultaneous with the appearance of spike groups. It is likely that the violent change in magnetic structures, and contact, coalescence and reconnection of magnetic loops caused the spike emission.

DISCUSSION

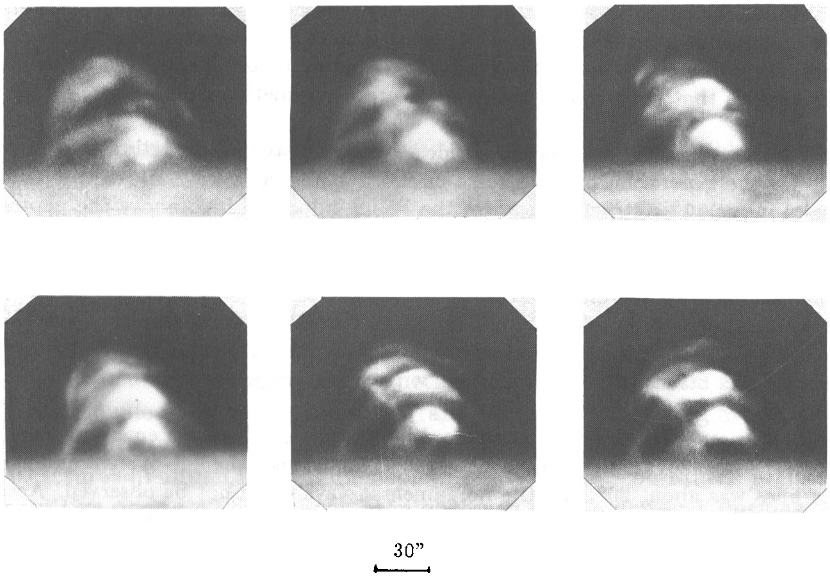

Figure 2. A sequence of H_β images coincident to spike groups.

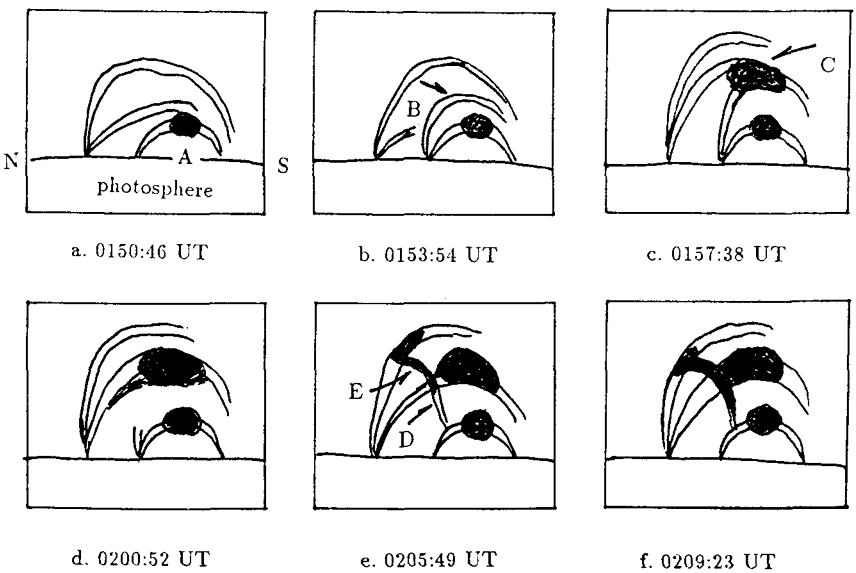

Figure 3. Schematic drawing of Figure 2.

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The existence of energetic electrons is seen as a necessary condition for generating spike emission in different theoretical mechanisms. Thus, the appearance of spike emission means that there must exist a process to produce energetic particles. Most spike emission events appear in pre-impulsive and impulsive phases. A number of msec spike emission events have been observed in the gradual descending phase of radio bursts by 10MRT. This implies that the particle accelerating process sometimes takes place in the decay phase.

The event on 1989 August 17 provided evidence that the energetic electrons responsible for the generation of msec spike emission were produced coincident with drastic change in magnetic structures. Since the PFLS is located high above the photosphere ($3 - 4 \times 10^4$ km in the 1989 August 17 event, It is the layer which electron plasma frequency is in the short dm waveband) spike emission in the descending phase is liable to happen in the short dm waveband.

According to Benz (1986), the duration of spikes is comparable to the electron-ion collision time. In our case, with $\nu = 1.42\ GHz$, and taking $T = 1.3 \times 10^5\ K$, then $\tau = 33\ msec$, which is consistent with the average duration of spikes observed, 20-40 msec.

If the msec spike emission was caused by interactions between emerging small loops and the original PFLS on the limb, then the angle between the line-of sight and magnetic field lines was about 90^o, and the fundamental wave could not be observed. According to Winglee and Dulk (1986), the emission could be in x-mode at the second harmonic.

According to Winglee and Dulk (1986), the fastest growth rate for second harmonic x-mode occurr when $0.6 \leq \omega_p/\Omega_e < \sqrt{2}$. Assuming $\omega_p/\Omega_e = 1.4$, the magnetic field strength in the source region, $B = 180G$, at the bottom of the loop system and $n_e = 6.1 \times 10^9 cm^{-3}$, can be deduced.

From deduced B and n_e, then the Alfven speed, $V_a = 5 \times 10^3\ km/s$, can be obtained. Assuming the radiation mechanism propagated with Alfven speed, then the source diameter $l = 160\ km$, can be deduced.

Using deduced l and observed strength of spike emission ($\sim 200\ s.f.u.$), the brightness temperature of spike source can be estimated

$$T_b = 3.6 \times 10^{13} K \quad (for\ \ l = 160\ km)$$

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