Recent Results of Meter-decameter Wave Observations of Solar Flares

N. Gopalswamy and M. R. Kundu
Astronomy Program, University of Maryland,
College Park, MD 20742

Abstract

We present recent results from meter-decameter imaging of several classes of solar radio bursts: Preflare activity in the form of type III bursts, correlated type IIIs from distant sources, and type II and moving type IV bursts associated with flares and CMEs.

1. Introduction

Most of the meter-decameter radio bursts are signatures of distrubances such as electron beams, shock waves and plasmoids moving through the solar corona. Type III bursts are prompt indicators of acceleration of 10-100 keV electrons. Type II bursts indicate in situ particle acceleration in shock waves during many flares and coronal mass ejections (CMEs). Moving type IV bursts are due to nonthermal electrons trapped in moving magnetic structures in the corona. As temporal association of many of these bursts could lead to misleading conclusions, positional information alone can shed light on the exact physical relation between these disturbances. In this paper, we review some recent results from the Clark Lake multifrequency radioheliograph which contributed to the understanding of these phenomena.

2. Precurser Type IIIs.

Type III emission in the preflare stage could be a signature of preflare electron acceleration (e.g., Kundu, 1986; Kane and Pick, 1976). A comparison of the location of these preflare type IIIs with those of impulsive phase could tell us about the changes in the magnetic field structure between the preflare and impulsive phases.

Fig. 1A shows the type III bursts during February 3, 1986 flare in a) preflare, b) preflash, c) impulsive (early), d) impulsive (late) and e) decay phases, showing good temporal correlation with the impulsive bursts in hard X-rays and microwaves. As seen in Fig. 1B the source positions of the preflare and impulsive phase type III bursts appear very close, but there is a definite displacement of the source position towards the flare site. The movement of the acceleration region or its expansion due to resistivity increase in the impulsive phase or both might have caused this shift. The source displacement is larger at lower frequencies suggesting the presence of diverging magnetic field lines from the flare site. Enhanced soft X-ray emission was also detected during the preflash type III bursts, implying a possible link between particle acceleration and plasma heating (Kundu et al., 1988). The number of elctrons involved in producing a type III burst and the average electron energy are obtained using the measured characteristics of the radio bursts as ~ 3-5 x 10^{33} and 10-25 keV respectively (Gopalswamy and Kundu, 1987).

A type IV burst and a flare behind the limb were associated with the 1984, June 27 CME with precursors in soft X-rays, Hα, and radio. The flare occurred ~ 25 min after the CME onset and about 7 min after the start of

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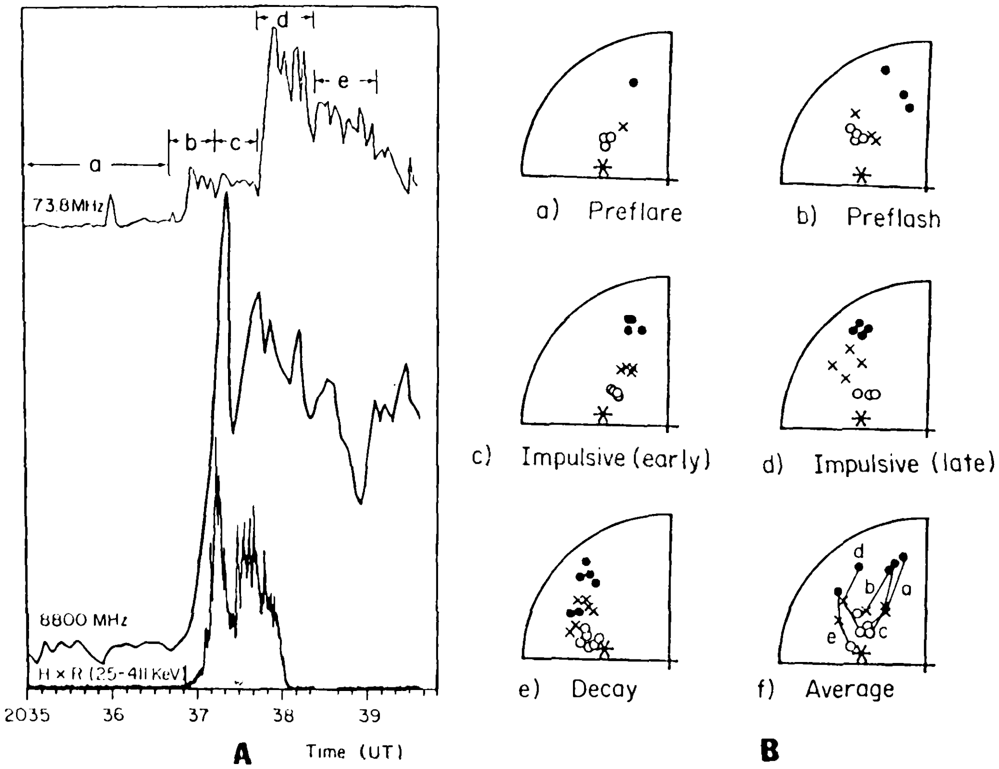

Fig. 1A: Type III, microwave and hard X-ray bursts; B) Type III centroids at different phases.

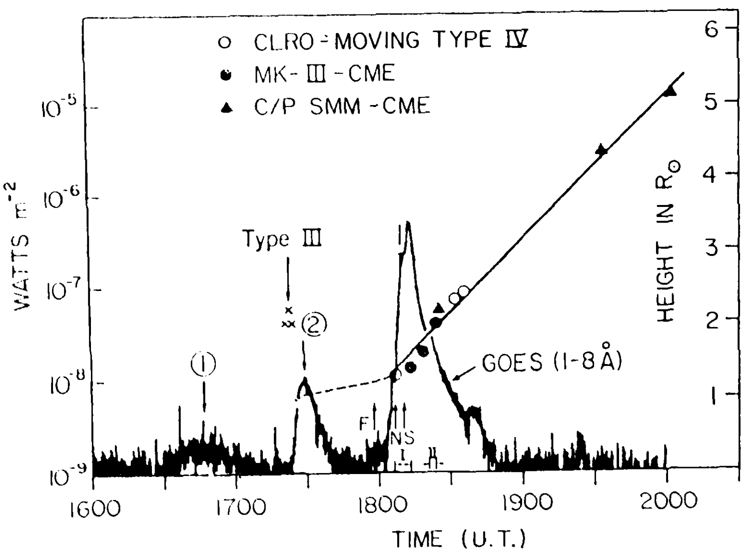

Fig. 2: Type III and soft X-ray (1 and 2) precursors with CME height time plot. F,S,N denote the start of the filament activity and southern and northern sprays respectively. I and II denote periods of impulsive flare and type II burst.

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prominence motion. The presence of type III bursts and soft X-rays prior to the flare onset indicate the presence of particle acceleration and heating in the inner corona (Fig. 2). The observation of type III precursors is significant in that, the soft X-ray precursor itself could have been caused by the heating due to accelerated particles. In this case also, the precursor type IIIs were weak compared to impulsive phase ones and they occurred in the same general location in both phases. The number of electrons responsible for producing type III bursts, is ~ 10^{32} (Gopalswamy and Kundu, 1988).

3. Correlated type IIIs

Figure 3(a) shows the variation of brightness temperature with time of three type III bursts A, B and C. During each of these peaks, the radioheliograph images show three sources, one towards north (N) and two towards west (W1 and W2) having similar time profiles (Fig. 3(b)). It is important to note that emission occurs simultaneously at locations which are ~ 10^6 km apart. Both N and W1 are of the same intensity at 38.5 MHz and at 50 MHz, W1 stronger than N during the peak B and the opposite is true during the next peak (C). There is no delay between N and W1 which is expected to be $\gtrsim$ 4 s if

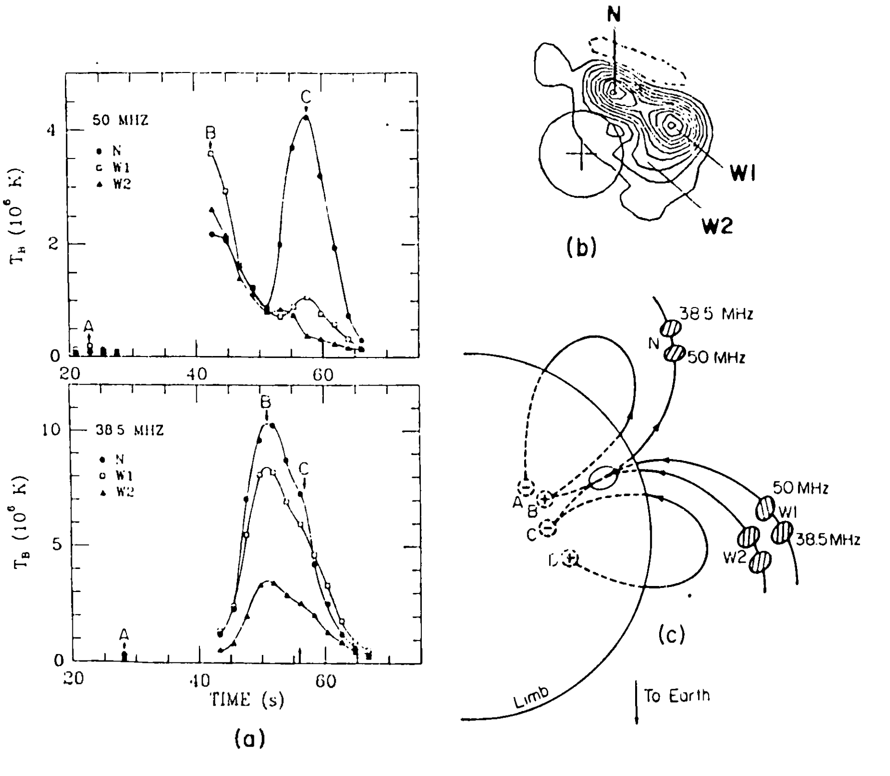

Fig. 3: a) Brightness temperature of type III bursts; b) location of N, W1, W2 sources; c) model of source region.

they constitute a direct and reflected source pair. The observed drift rates do not suggest a U-burst type of magnetic field. The possibile structure of magnetic field lines emanating from the acceleration region is shown in Fig. 3c. The angular extent covered by these field lines must be very large, ~ 26°, in order that the electrons propagating along these lines produce the observed correlated sources (Kundu and Gopalswamy, 1987).

4. Relation Among CME, Type II, Type IV

It is presently believed that flare is a secondary process in a CME event and the lift-off of the latter is supposed to precede the flare by a few minutes (see e.g. Wagner, 1984). A flare blast wave can produce type II bursts. A super Alfvenic CME can also produce a shock ahead of it. This demands a specific spatial relation between CME or moving type IV and type II - the type II must be at or ahead of the CME and move with nearly same speed. Simultaneous observations show that the type II location could be ahead of CME because its higher speed and also can have different location with respect to CME or moving type IV.

On February 17, the SMM C/P coronagraph observed a streamer disruption event on the east limb. The Clark Lake radioheliograph detected the onset of a type II burst at the NE limb at 20:25 UT (Figure 4(a), marked A) followed by a moving source (B) after 10 min below the type II, with a sped of ~ 200 km s^{-1}. Fig. 4(b) shows that the type II burst (A) has a parallel to limb motion

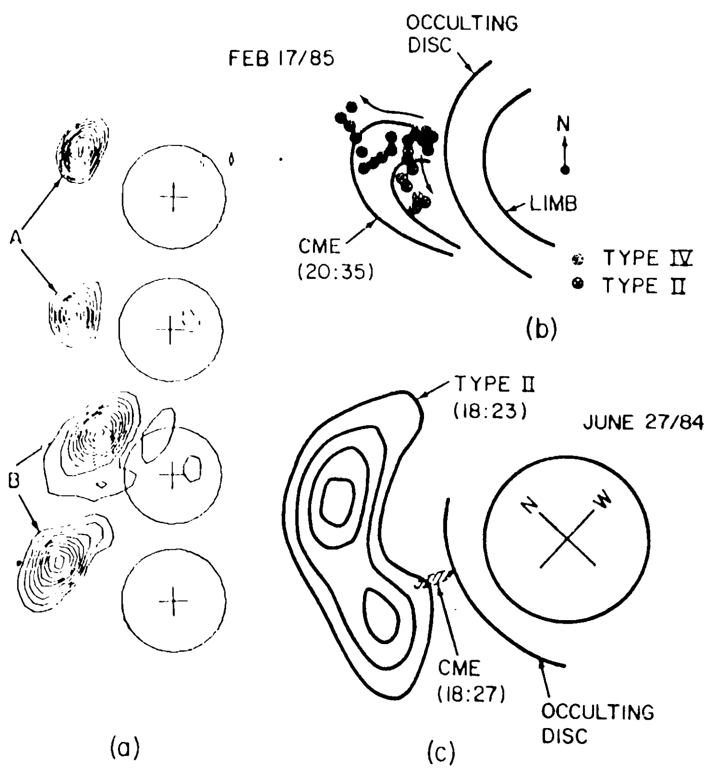

Fig. 4: a) Type II (A) and moving type IV (B) bursts; b) their centroids of February 17, 1985 event; c) type II and CME of June 27, 1984.

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and moving type IV has a nearly radial motion. There was no significant surface activity reported in association with this event. A small GOES soft X-ray flare (importance B1.2) occurred at 20:06 UT, and may well indicate the start of the event. If we assume a blast wave initiated at the time of the GOES flare, the implied velocity needed to reach 50 MHz level at the observed onset time is 1000 km/s, which is the normal type II speed. From parallel to limb motion of the type II centroid one can estimate a speed of ~ 1300 km/s, clearly much higher than the moving type IV speed. The type II and moving type IV do not seem to have a physical relation as one might expect in a piston driven case. Therefore, both positional analysis and speed show that the type II is created by a decoupled shock. The energetic particles responsible for type IV might have come from either reconnection during lift-off of the CME or due to the passage of type II shock through the CME.

Figure 2 provides a summary of the time history of the June 27, 1984 CME as observed in both radio and white light. The CME appeared as a single clump of material moving out with a speed of ~ 350 km s^{-1}. Both type IV radio sources and white light CME follow the same direction and are co-spatial. The type II burst observed at 18:22 UT has a large extended structure with two prominent centroids, one ahead of the CME and the other far north of it. The centroids are separated by a distance of ~ 2.2 R_0. The overall size of the type II source is ~ 20 times bigger than the visible ejection. Fig. 4c shows that the nearest centroid type II at 18:23 UT is ~ .4 R_0 ahead of the CME leading edge at 18:27 UT and the farthest one was ~ 1.5 R_0 away. Clearly the CME could not have generated such a huge shock. On the other hand, if the shock were generated during the impulsive phase of the flare, then it takes ~ 9 min to reach the observed height implying a speed of ~ 1500 km s^{-1}. This is ~ 5 times larger than the speed of the CME (and type IV) and hence might have overtaken the CME.

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