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ENERGETIC ELECTRONS FROM SOLAR FLARES AND ASSOCIATED TYPE III RADIO BURSTS FROM METRIC TO HECTOMETRIC WAVE FREQUENCIES

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ENERGETIC ELECTRONS FROM SOLAR FLARES AND ASSOCIATED TYPE III RADIO BURSTS FROM METRIC TO HECTOMETRIC WAVE FREQUENCIES

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ABSTRACT

Distinct Kev electron events as observed by satellites near the earth are, in general, associated with solar flares which are accompanied by the emission of both metric and hectometric type III radio bursts. The positions of these flares are mainly on the western hemisphere of the sun. These results show that Kev electrons propagate under the control of the magnetic field in the interplanetary space and that, while propagating through this space, these electrons excite type III radio bursts from metric to hectometric wave frequencies.

Emission characteristics of hectometric type III bursts are briefly considered in relation to the positions of associated flares.

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Introduction

Recently, association of type III radio bursts with solar Kev electron events has been reported (e.g., Lin, 1970; Alvarez et al., 1972). This result indicates that the source for the excitation of type III radio bursts is identified with the Kev electrons from associated solar flares.

Observational records for solar type III radio bursts from metric to hectometric frequencies seem to be very useful to examine the association as mentioned above, since we can make use of these records to trace the path of the radio source from the sun to interplanetary space. After launched on 4 July, 1968, the RAE-1 satellite has provided many observational records for isolated type III radio bursts at hectometric frequencies (see, Fainberg and Stone, 1970, 1971). Moreover, distinct $\geq$40 Kev electron events associated with solar flares have been also reported by Lin (1972) during the same period using the Explorer 35 and 41 satellites. During the period between July, 1968 and December, 1969, about 60 distinct Kev electron events were observed and associated flares were identified (Lin, 1972).

By using those observational data as mentioned above, we shall first investigate the relation between solar Kev

electron streams and type III radio bursts from metric to hectometric frequencies. Then we shall examine the emission characteristics of low frequency type III radio bursts and their relation to the path of Kev electron streams in the outer corona and the envelope of the sun.

Type III Radio Bursts and Energetic Electrons from Solar Flares

We have selected the period from July, 1968 to December, 1969 for our study on the relation of Kev electron streams with type III radio bursts from metric to hectometric frequencies from the sun. According to the reports appeared in the Quarterly Bulletin of Solar Activity for the above period, 573 type III radio bursts at metric frequencies were observed. We have tried to identify associated flares for these bursts as well as possible. However, in spite of our effort, we could only make such identification for 322 events. No flare data were available for other 251 events. Therefore, in this paper, we have used 322 type III events to analyze the relation among Kev electron streams, metric and hectometric type III radio bursts. As shown by Lin (1972), about 60 solar $\geq$ 40 Kev electron events were observed at the earth's orbit or in its vicinity during this

period (July, 1968 - December, 1969). At first, we searched for the flares which produced these electron events.

Generally speaking, solar flares which are followed by Kev electron events are associated with type III radio bursts in both metric and hectometric wave frequencies as shown in Fig. 1. Solar flare and metric type III radio bursts in this figure were observed by ground-based instruments, but the hectometric type III bursts were detected by the RAE-1 satellite. The radio source in this case produced both metric and hectometric type III radio bursts while moving outward from the flare region into the interplanetary space. Furthermore, the Kev electron streams were also observed later near the earth (Lin, 1972).

As has been mentioned earlier in this paper, such associations of type III radio bursts with solar Kev electron events were observed about 60 times during the period under consideration. 42 electron events were, however, successfully identified with associated flares and related type III radio bursts. Some of the unidentified events were probably produced from solar flares which occurred beyond the west limb of the solar disk. Among these 42 events, 27 cases were accompanied by both metric and hectometric type III radio bursts, whereas other 15 events were only associated with

metric type III radio bursts. In these latter cases, we could not find evidence for the emission of hectometric type III radio bursts. This fact seems to show that the radio sources were too dispersed to be enough to generating these hectometric bursts in these cases. The positions of these associated flares are distributed over the solar disk as shown in Fig. 2. Solar flares which produced Kev electron events are indicated by solid circles in this figure. Solid circles with cross sign indicate electron flares associated with both metric and hectometric type III radio bursts. Open circles show solar flares which accompanied both metric and hectometric type III radio bursts, but did not produce Kev electron events.

As is evident from this figure, the positions of most solar flares which produced distinct Kev electron events are on the western hemisphere of the sun. Furthermore, the positions of solar flares which were followed by both type III radio bursts and these electron events are mainly concentrated on the northern hemisphere beyond 30^{o} west from the central meridian. This result seems to indicate that these regions of the sun were well channeled with the earth and its vicinity by means of the magnetic field lines in the interplanetary space (Sakurai, 1971; Lin, 1970). Such

channeling does not seem to have been formed in case of the solar flares occurred in the south-western hemisphere of the sun except for the region near the west limb. This non-channeling interpretation also seems to be applied to many solar flares which occurred on the eastern hemisphere and the region near the central meridian of the sun. In fact, they were accompanied by type III radio bursts in both metric and hectometric frequencies, but did not accompany Kev electron events.

The results as mentioned above suggest, therefore, that the agents which excite type III radio bursts from metric to hectometric frequencies are the ≥ 40 Kev electrons associated with solar flares. Similar conclusion has recently been obtained by Alvarez et al. (1972). Our result here obtained supports their conclusion on the association of ≥ 40 Kev electron streams with type III radio bursts in low frequencies.

Emission Characteristics of Hectometric Type III Radio Bursts.

It seems that the positions of solar flares which are accompanied by type III radio bursts in both metric and hectometric frequencies are randomly distributed on the solar surface. By using all the data as shown in Fig. 2 except for electron flares which are indicated by solid circles, the result as shown in Fig. 3 has been obtained on the

longitude distribution of the positions of solar flares which accompany both metric and hectometric type III radio bursts.

This result shows that the distribution of the position of associated flares is not symmetric with respect to the central meridian of the sun. If this distribution is symmetric, the distribution like a curve aa' seems to be obtained, but the observed distribution indicates that, in more than 10 cases, hectometric component was not associated with solar flares which occurred on the eastern hemisphere of the sun.

The result as shown in Fig. 3 suggests that hectometric radio waves generated from the Kev electron stream associated with solar flares on the eastern hemisphere are prevented from approaching near the earth, though we do not know as yet what processes are going on the smoothing-out of these radio waves. Similar tendency is also seen for the kilometric type III radio emissions. This is easily confirmed if we refer to the observed result as obtained by Alvarez et al. (1972).

Alternative to the above interpretation is related to the directivity in the emission of hectometric type III radio bursts. If the emission cone for hectometric waves is slightly inclined eastward, the possibility to detect these

wave emission tends to become lower for solar flares which occur on the eastern hemisphere in comparison with those on the western hemisphere. At present, we do not know which idea is better to explain the observed distribution of the solar flares accompanying type III radio bursts from metric to hectometric wave frequencies.

Concluding Remarks

We have shown that the source for the excitation of isolated type III radio bursts from metric to hectometric frequencies is identified with the $\geq$ 40 Kev electron streams associated with solar flares. Our result obtained in this paper supports the conclusion which has been obtained by Alvarez et al. (1972) on the association between Kev electron streams and type III radio bursts at kilometric frequency.

As shown in Fig. 3, the positions of solar flares which accompanied both metric and hectometric type III radio bursts are asymmetrically distributed over the solar disk with respect to the central meridian plane. This fact seems to be related to either the directivity in the emission of hectometric type III bursts or the propagation characteristics of the hectometric waves in the interplanetary space. Although, at present, we do not know as yet which idea explains correctly such observed results, they would be useful for

the understanding of the physical state of the interplanetary space.

Acknowledgement

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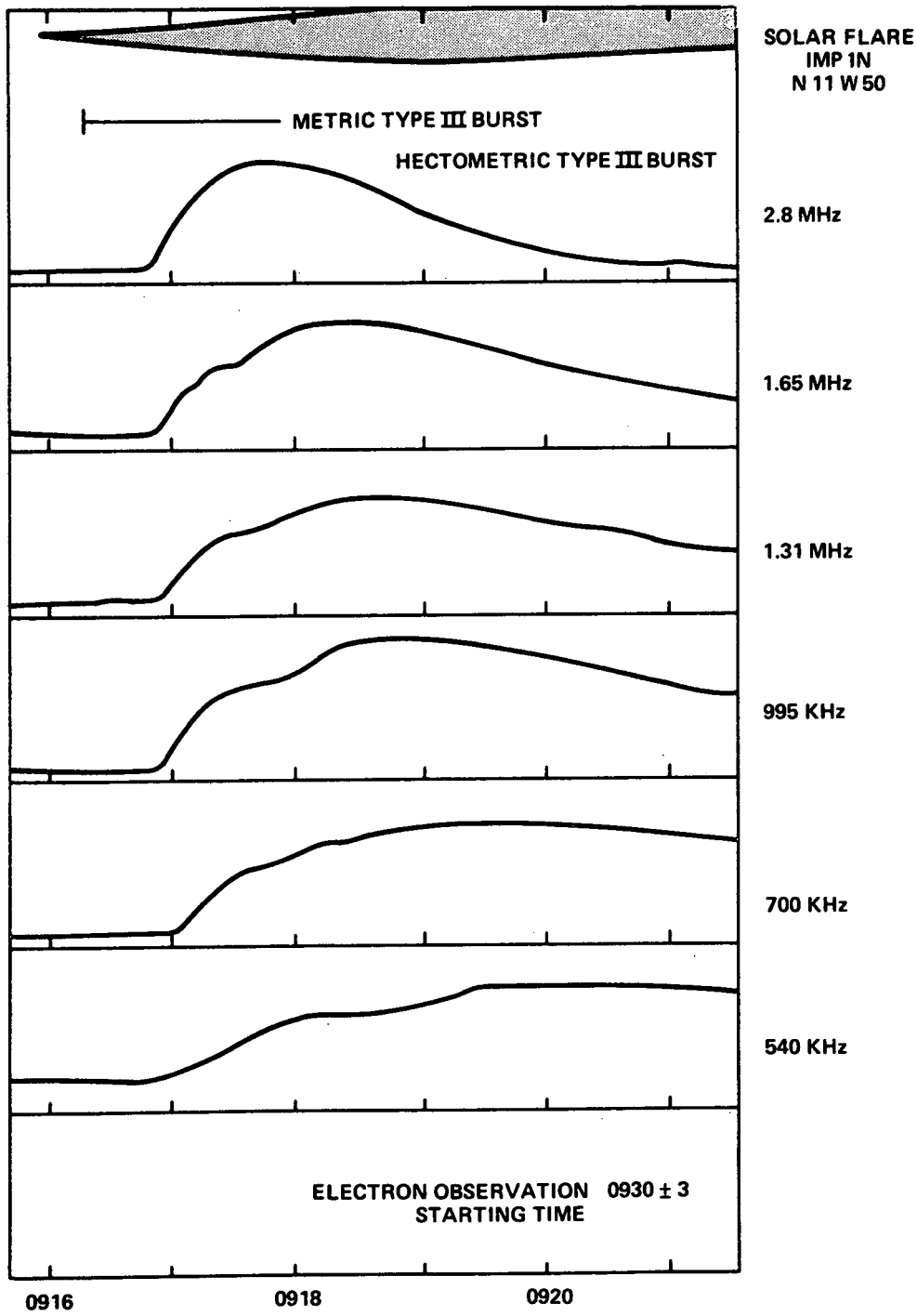

Fig. 1 - An example of type III radio burst from metric to hectometric frequencies associated with the solar flare on 6 September, 1968. About 14 minutes later after the onset of the flare, a distinct ≥ 40 Kev electron event was observed in the vicinity of the earth. Intensity scale for hectometric radio bursts is arbitrary.

✦ ELECTRON FLARES ACCOMPANYING METRIC AND HECTOMETRIC TYPE III BURSTS

• ELECTRON FLARES ACCOMPANYING ONLY METRIC TYPE III BURSTS

◦ NON-ELECTRON FLARES ACCOMPANYING METRIC AND HECTOMETRIC TYPE III BURSTS

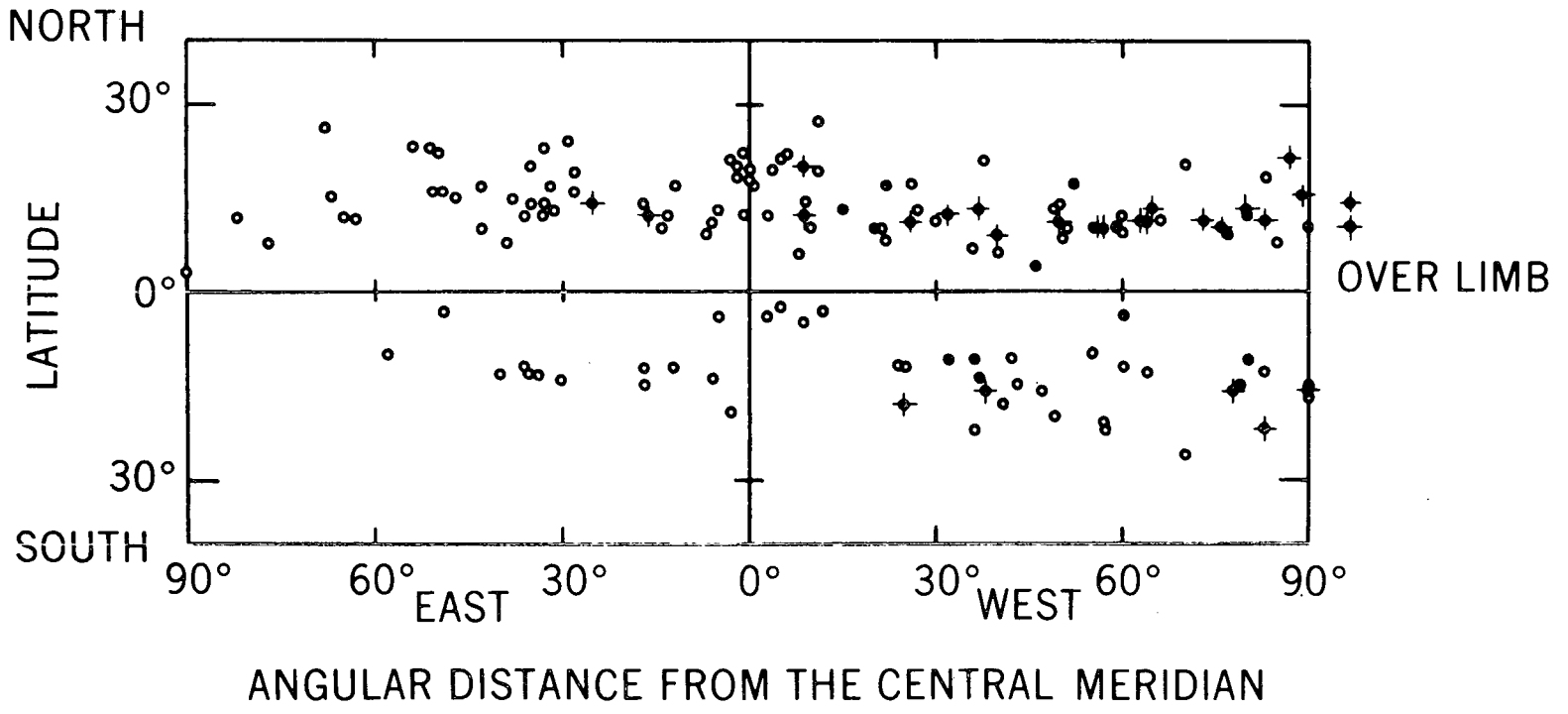

Fig. 2 - Distribution of solar electron and non-electron flares which are accompanied by both metric and hectometric type III radio bursts during the period between July, 1968 and December, 1969.

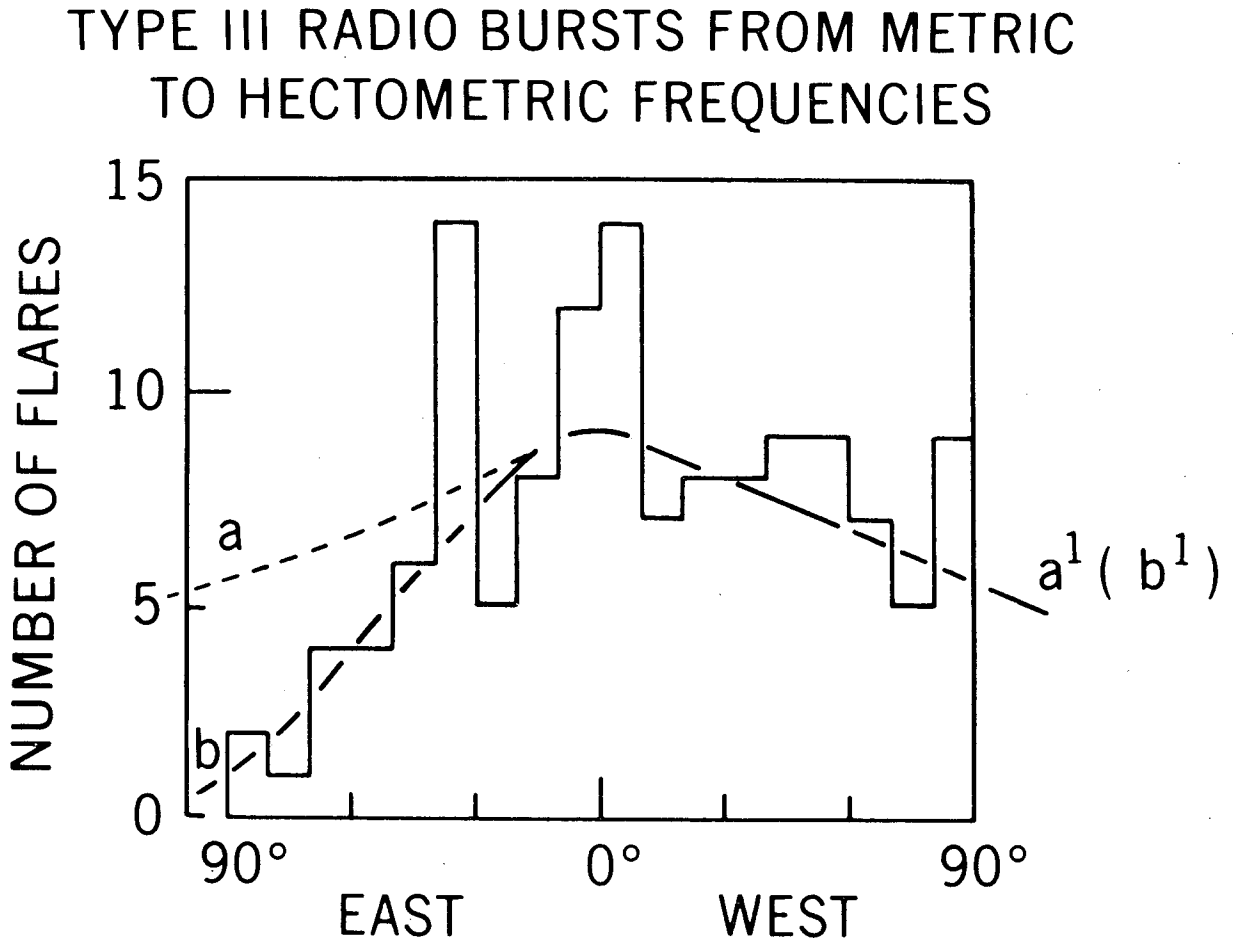

Fig. 3 - Solar longitude distribution of flares which produced both metric and hectometric type III radio bursts in the same events. Curve ab is a curve smoothed for the observed data, and curve aa' is the one which is expected from the symmetric distribution of associated flares with respect to the central meridian of the sun.