Type III bursts traced from the solar surface to 1 AU

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ABSTRACT We trace type III radio bursts from the sun until they can be observed as *in situ* electrons at the ISEE-3 spacecraft. Our study extends over the period of operation of the electron experiment on ISEE-3 from August 1978 to November 1979. Our observations include data from solar flares, kilometric type III burst spectra from ISEE-3, and *in situ* measurements of low energy electrons from ISEE-3. By carefully restricting the data sets involved, we find a peak of 20° width in the number of flares associated with *in situ* electrons near 60° west solar longitude. This peak shows that the electron beams of type III bursts are not spread over a great range of longitudes as earlier studies indicate, but are fairly limited in spatial extent. However, even in that longitude range only 40% of type III-flare events are associated with *in situ* electrons.

I. INTRODUCTION

Type III radio bursts are one of the most basic probes of solar particle acceleration mechanisms and interplanetary plasma radiation process. At metric wavelengths these radio bursts are often temporally and spatially associated with solar flares (Wild et al., 1959, Jackson and Sheridan, 1979, Kundu et al., 1982, Poquerusse, 1988). The actual radio-wave production is caused by the formation of radio emission at the local plasma frequency from a passing stream of electrons accelerated to energies between 10 to 100keV. To prove the point, type III bursts can be traced outward from the sun in metric and kilometric radiation until at 1AU where the electrons which cause the bursts are detected along with oscillations of the local plasma *in situ* (Lin et al., 1974; Fainberg and Stone, 1974; Gurnett and Anderson, 1977).

The rigidity of electrons of these energies will usually cause them to travel along pre-existing coronal and interplanetary magnetic field lines (Anderson, 1981), and thus should confine them to the field lines emanating from near the flare site. In theory, it should therefore be a simple matter to use the positions of solar flares and observations of electrons *in situ* to determine the width of the electron beams which cause type III radio bursts. In several studies, *in situ* electrons have been related to earlier-observed flare longitudes (eg., Lin, 1971; Wang, 1972; Lin et al., 1974). All of these studies find a general association of flares at west longitudes associated with the *in situ* electrons although the random coincidence level is very high, as demonstrated in next section. None of these studies use type III kilometric (km) bursts to restrict the timing of the flare relative to the observed *in situ* electrons.

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Lin (1974) reported that ~80% of his electron flares were associated with radio type III emission. Alvarez et al. (1972) first attempted to trace flare-associated type III bursts by using kilometric (Km) bursts observed by OGO-5 (1968 - 1971) and electrons observed by the Imp 5 and the Explorer 35 spacecrafts. Their results showed that the associated flare longitudes of type III *in situ* electrons are spread over a wide range of west longitudes. However, their data set is small; only 26 *in situ* events were associated with the km type III bursts and flares they observed. No peak in the number of flares at 50° to 70° west longitude was observed. Thus in this scenario, the electron beam must spread over a large distance from the flare site.

We believe that previous studies have often misidentified a given flare as the origin of type III electrons observed *in situ*. Only when strict limits are placed on the association of these flares with type III bursts and the corresponding *in situ* electrons that the number of random coincidences decreases to the point where a true average beam shape can be better discerned. In section II, using observations from the UCal particle experiment and the radio experiments from the ISEE-3 Spacecraft we place strict limits on flares associated with *in situ* electrons and km bursts. Using these associations we determine the longitudinal distribution of the associated flares, and discuss the implications of this result.

II. SOLAR RADIO BURSTS AND ASSOCIATED *IN SITU* ELECTRONS

For the purpose of this study, we are interested in keeping random coincidences to a minimum. Therefore we consider only those events where a flare had an isolated kilometric type III burst onset in progress between the flare onset and its maximum (flare window). Our observations of flare times are obtained from *Solar Geophysical Data (Prompt and Comprehensive Reports)*. We found that approximately one-quarter of the events in our sample were multiply defined: two or more flares differing greatly in longitude fulfilled our association criteria for the same *in situ* electron event. These events were deleted from the histograms in the following sub-sections. We found a high random coincidence level of flares and subflares with electron events. Under ideal observing conditions there was approximately one flare or subflare every 48 minutes during the time interval of the electron events in 1978-1979. In addition, we found that each flare averages approximately 6 minutes in duration from onset to maximum.

II.1 Association of flares to *in situ* electron events

In our study we consider only the *in situ* electrons which occur within 15 to 60 minutes after the flare window. We thus estimate that a purely random coincidence occurs (45+6)/48 or of about 100% of the time. Therefore the histograms giving the flare distribution of electron events must be considered with caution (Lin, 1971 ; Wang, 1972 ; Lin, 1974). Figure 1 shows the distribution of solar flares associated with electron events. Although we estimate a high random coincidence level (dashed line), a slight East-West assymetry is observed.

II.2 Association of flares to kilometric radio bursts.

To further limit the random concidence level, we consider the timing of associated km type III burst. We use the onset of the burst and a 3 min leeway at each end of each flare observation. Thus, the random coincidence level that a type III burst is associated with a flare is (6+6)/48, i.e. 25%. Figure 2 shows the distribution in longitude of flares associated with km type III bursts. This distribution is symet-

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rical with respect to the central meridian. Poquerusse (1988), who undertook a similar study with *metric* type III bursts, found a broad maximum approximately 30° east of the central meridian.

II.3 Association of flares to km bursts and to electron events.

If we assume that only flares with observed km bursts give rise to *in situ electrons*, and we limit the *in situ* electron events to those flares where we observe a km burst, then we cut the random coincidence level to at least 25%. For purely random associations of flares, km bursts and *in situ* events the coincidence level reduces to 100%×25% or 25%. The hatched area in Figure 2 represents the distribution in longitude of the flares associated with km type III bursts and electron events. There are 106 events in this area and 702 events in the overall curve representing the flares associated with km bursts, i.e. a ratio of one over seven. This result is in good agreement with our estimation of the occurrence of km burst, every 2.9 hours, and the occurrence of an electron event every 20.5 hours. The electron-km-flare-histogram shows clearly a peak from 50° to 70° west longitude. However, we observe electrons from east limb flares, and the number of these are well above the random coincidence level. Figure 3 compares the percentage of electron-km-flare events to km-flare events for each 20° longitude, and shows how the propagation along magnetic field lines near the sun and interplanetary space broadens the electron beam in longitude. We note also that even in the preferred longitude range, only 40% of km-flares are associated with *in siti* electrons.

III. CONCLUSION

In this study we have shown that out of 702 flares with associated km radiation, only 106 *in situ* electron events could be anambigiously associated with the preceeding flares – about one third of them being observed between 50° and 70° west longitude. The implication of this result is that the electrons do not spread over a great range of longitudes as earlier studies indicate, but are fairly limited in angular extent. The observed peak in flare longitude distribution is directly related to the most direct path that electrons can take from the sun to earth along the magnetic field Archimedean spiral.

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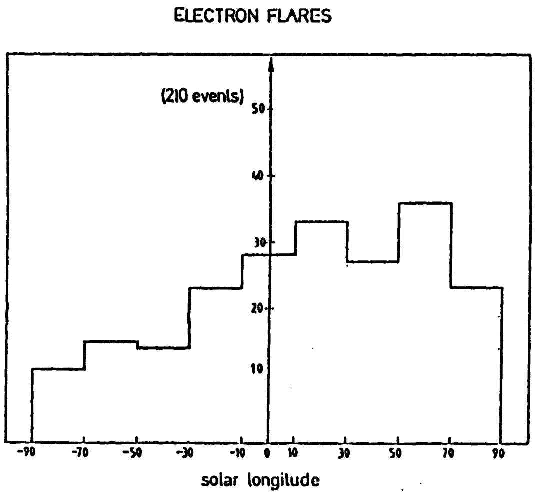

Fig. 1. Longitudinal distribution electron events temporally associated with solar flares.

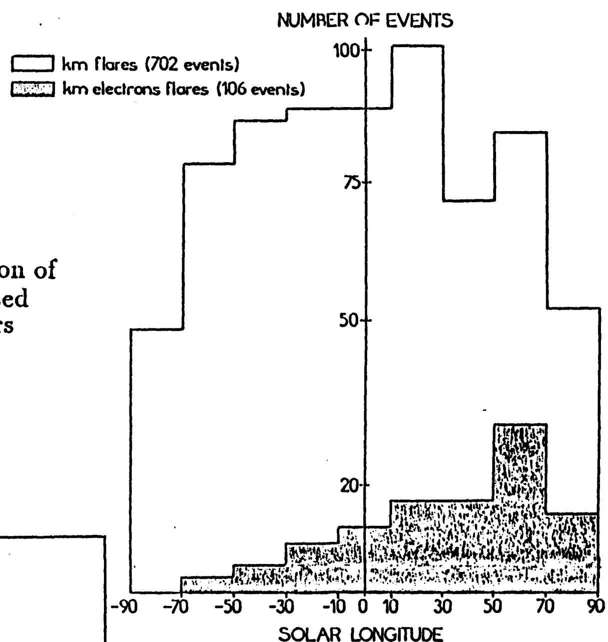

Fig. 2 Longitudinal distribution of km bursts temporally associated with flares. The grey area refers to km bursts associated with flares and electrons events.

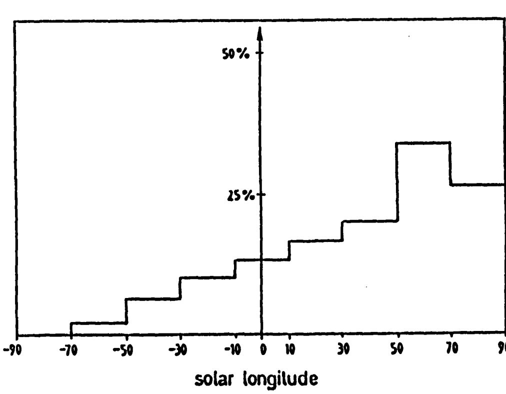

Fig. 3. Longitudinal distribution of the percentage of *in situ* electrons from each 20° longitude.

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