FAST DRIFT KILOMETRIC RADIO BURSTS AND SOLAR PROTON EVENTS

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ABSTRACT

We present initial results of a comparative study of major fast-drift kilometric bursts and solar proton events from Sep 1978 - Feb 1983. We find that only about half of all intense, long duration ($\geq$ 40 min above 500 sfu) 1 MHz bursts can be associated with E > 20 MeV proton events. However, for the subset of such fast-drift bursts accompanied by metric Type II and/or IV activity (~ 40 % of the total), the degree of association with > 20 MeV events is 80 %. For the reverse association, we found that proton events with J(> 20 MeV) $\geq 10^{-2}$ pr cm^{-2} s^{-1} sr^{-1} MeV^{-1} were typically (~ 80 % of the time) preceded by intense 1 MHz bursts that exceeded the 500 sfu level for times $\geq$ 20 min (median duration ~ 35 min).

1. Introduction For both scientific and practical reasons, it is useful to identify solar phenomena that typically accompany energetic proton events. Radio signatures identified thus far include metric Type II and Type IV bursts (cf., Cliver et al., 1985). Cane et al. (1981) drew attention to a class of intense, long duration, fast-drift kilometric bursts observed by the low frequency radio experiment on ISEE-3 that occurred in conjunction with metric Type II emission. They suggested that the electrons exciting the fast-drift kilometric emission were accelerated by a coronal shock; subsequently these events were referred to as "shock associated" or SA events. Cane et al. reported that all of the SA events they identified were associated with solar energetic particle (SEP) events while more than half of the proton events detected at 1 AU during the period of their study were associated with possible SA events. Cliver et al. (1983) and Kahler et al. (1985) have recently used the SA signature and the position angle data from the ISEE-3 low frequency experiment to trace SEP events back to atypical origins -- in one case > 500 MeV protons to a weak impulsive phase flare and in the other prompt > 50 MeV protons to a disappearing filament. Thus there is reason to believe that the SA event may serve as an indicator of energetic proton acceleration/escape in flares. To date, however, no detailed comparison of low frequency (< 2 MHz) radio events and SEP events has been made. Thus we do not know whether all major fast-drift kilometric bursts signal the occurrence of a solar proton event or if, conversely, all significant SEP events are preceded by large low frequency

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*Also: University of Maryland, College Park, Maryland 20742 USA bursts. It is also unclear at present if the so-called SA events can be distinguished from the kilometric extension of long metric Type III bursts (Kundu et al., 1985). In this study, we address such questions.

2. Data Analysis A description of the Meudon/GSFC kilometric radio astronomy experiment on ISEE-3 is given in Knoll et al. (1978). The > 20 MeV proton data were obtained by the GSFC detectors on IMP-8 and ISEE-3. To do the study, we began with a sample of large kilometric bursts and examined their proton associations and then reversed the procedure.

A computer generated list of 658 candidate SAs occurring from Sep 1978 - Feb 1983 was provided by R. MacDowall. This list consisted of all 1 MHz bursts with durations, defined to be the time interval that the intensity (after background subtraction) remained above 500 solar flux units (sfu), of ≥ 20 min. From this list we selected the subset of 110 events with durations ≥ 40 min. We divided these events into two classes: those associated with metric Type II and/or IV bursts and those unaccompanied by such activity. We made the meter-λ associations using data reported only by Ft. Davis, Culgoora, or Weissenau in Solar Geophysical Data (data unavailable for two events). Approximately 40 % (46/108) of the candidate SAs were associated with metric Type II and/or Type IV bursts. For 15 of these 46 cases, either no fresh injection of protons was observed during a time that the > 20 MeV background was enhanced (> 10^{-4} pr cm^{-2} s^{-1} sr^{-1} MeV^{-1}) due to an event in progress (possibly masked event) or an apparently related proton event is more likely to have originated in another solar flare (ambiguous cases). No proton data were available for one low frequency event. Eighty percent (24/30) of the remaining events, originating anywhere on the sun, were associated with a > 20 MeV event at 1 AU. For the non-Type II/IV-associated events (62/108 cases), approximately 30 % (11 of 35 events with "clean" proton circumstances) could have been associated with a > 20 MeV proton event at Earth. Only three of the eleven flare associations are of high confidence and two of these flares had accompanying continuum (but not Type II or IV) metric emission. The non-II/IV events were associated in most cases with groups of metric Type III bursts. There is no marked difference between the durations of the 1 MHz bursts in our sample that were associated with metric Type II/IV bursts and those unaccompanied by such activity. The II/IV-associated events tend to be slightly longer with a median duration ~ 50 min vs. 46 min for the non-II/IV events. A significant difference does exist between the distributions of the time averages of the logarithm of the 1 MHz flux-densities (sfu) for the two groups of events. Obtaining a mean-flux-density value by this procedure reduces the effect of short but intense peaks in the burst time profile. The median value of this parameter is 4.16 for the II/IV-associated events and 3.85 for the non-II/IV group. Thus, for the big events with durations ≥ 40 min, the mean-flux-densities, as defined here, of the II/IV-associated events are statistically higher by a factor of two.

For the reverse association -- beginning with the proton events -- we examined the ISEE-3 low frequency data at the times of the parent flares of all proton events with J(> 20 MeV) ≥ 10^{-2} pr cm^{-2} s^{-1} sr^{-1} MeV^{-1} occurring during this period that could be reasonably well associated with a solar event. Flare associations were made without reference to the low frequency data. For each of the 48 events with available 1

MHz data, we found associated bursts that had durations above 500 sfu ranging from < 10 min to > 60 min. Approximately 80 % (39/48) of the bursts had durations > 20 min (median duration ~ 35 min). The distribution of durations is given in Fig. 1. Events with lower confidence parent flare associations are cross-hatched. For two higher confidence events the 1 MHz MHz bursts were only ~ 10 min long.

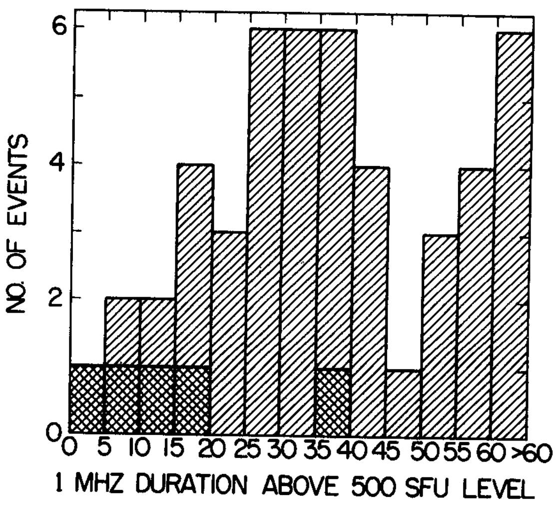

Fig. 1 Histogram of 1 MHz durations (min) for 48 proton events.

In an attempt to gain insight into the question of whether the electrons responsible for the 1 MHz emission in these proton flares were accelerated by shocks or impulsively accelerated in association with metric Type III bursts, we determined the composite fraction of time that the 1 MHz bursts had concomitant metric Type II and Type III emission, respectively. Type II emission covered ~ 45 % of the total combined durations of the 1 MHz bursts while Type III bursts covered anywhere from 32 - 65 %, depending on how weak intermittent activity and storms that may begin well before the kilometric event are treated. An example of good time correspondence between a metric Type II burst and intense 1 MHz emission observed in a major proton flare is given in Fig. 2. Even for this event,

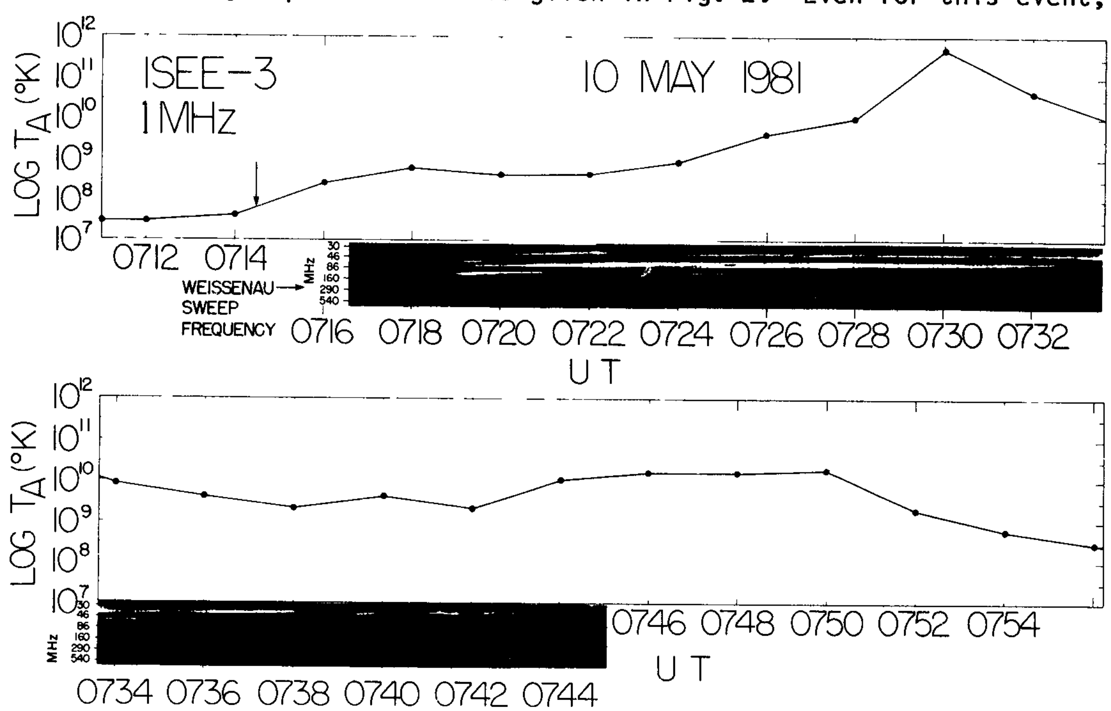

Fig. 2 The ISEE-3 1 MHZ time profile and the Weissenau meter-λ sweep frequency record for the 10 May 1981 proton flare.

however, for which no Type III emission was observed, the 1 MHz event starts earlier (arrow indicates time at which 500 sfu level crossed) than the metric Type II and the possibility of a Type III burst with starting frequency in the 2 - 20 MHz gap between ground-based and ISEE-3 observations cannot be ruled out.

3. Discussion Our preliminary results from this study of the relationship between major fast-drift kilometric bursts and SEP events are as follows: (1) only about half (35 of 65 "clean" cases) of all intense, long duration ($\geq$ 40 min above 500 sfu) 1 MHz bursts are associated with E > 20 MeV proton events, (2) for the subset of such fast-drift bursts accompanied by metric Type II and/or IV activity ($\sim$ 40 % of the total), the degree of association with > 20 MeV events is 80 %, and (3) $\sim$ 80 % of proton events with J(> 20 MeV) $\geq 10^{-2}$ pr cm^{-2} s^{-1} sr^{-1} MeV^{-1} are associated with 1 MHz bursts with durations of $\geq$ 20 min above the 500 sfu level (median duration $\sim$ 35 min).

In terms of the well-established impulsive/second phase paradigm for particle acceleration in solar flares (Wild et al., 1963; Lin, 1970; Svestka and Fritzova-Svestkova, 1974), it seems logical to ascribe at least some of the intense 1 MHz emission that typically accompanies significant proton flares to escaping shock-accelerated electrons. At the same time, it appears that the majority of the long duration kilometric events are simply low frequency extensions of "impulsive phase" Type III bursts (cf., Kundu et al., 1985). The 1 MHz bursts associated with proton events were accompanied by metric Type II bursts for $\sim$ 45 % of their composite durations and by metric Type IIIs for 32 - 65 %. The contribution of impulsively accelerated electrons to the kilometric bursts accompanying proton flares will have to be clarified using actual meter-λ sweep frequency records instead of the SGD compilations we have relied on thus far. It remains to be seen if low frequency bursts due to impulsively accelerated electrons can be distinguished from kilometric activity excited by SA electrons on the basis of differences in such parameters as burst time-profiles, spectra, or drift-rates, none of which were addressed herein. We have noted that the Type II/IV-associated events with durations $\geq$ 40 min had significantly higher (factor of two) mean-flux-densities than non-II/IV-associated events. While this may indicate the presence of an additional acceleration mechanism, i.e., a coronal shock wave, it may also be a Big Flare Syndrome (Kahler, 1982) result in that the larger flares that generate Type IIs and IVs might be expected to have stronger impulsive phases and thus higher mean-flux-densities at 1 MHz.

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