SOLAR SOURCE REGIONS OF ^{3}HE-RICH PARTICLE EVENTS

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ABSTRACT

We use Hα, X-ray, and metric and kilometric radio data to examine the solar sources of energetic (~ 1 MeV/nucleon) ^{3}He-rich particle events observed near earth in association with impulsive 2 to 100 keV electron events. Each ^{3}He/electron event is associated with a kilometric type III burst belonging to a family of such bursts characterized by similar interplanetary propagation paths from the same solar active region. The ^{3}He/electron events correlate very well with the interplanetary low frequency (~ 188 kHz) radio brightnesses of these events, but progressively worse with signatures from regions closer to the Sun. When Hα brightenings can be associated with ^{3}He/electron events, they have onsets coinciding to within 1 min of that of the associated metric type III burst but are often too small to be reported. The data are consistent with the earlier idea that many type III bursts, and now, by implication, the ^{3}He/electron events, are due to particle acceleration in the corona, well above the associated Hα and X-ray flares.

1. Introduction. It is now clear that ^{3}He-rich energetic particle events are distinguished from the solar energetic particle (SEP) events of greater fluxes and energies not only by their anomalous He composition, but also by their lack of association with metric type II bursts and coronal mass ejections (Kahler et al. 1985). A comparison of 12 ^{3}He-rich events with impulsive 2 to 100 keV electron events suggests that ^{3}He ions are impulsively accelerated and injected into interplanetary space along with the electrons (Reames et al. 1985). The low fluxes and slow speeds of the E ~ 1 MeV/nucleon ^{3}He ions make injection times uncertain, but the close association of the particle events with fast-drift type III radio bursts provides the precision of timing needed to make the association of the particle events with solar phenomena.

To learn more about the sources of these events we examine the characteristics of the Hα flares and type III bursts associated with the 12 ^{3}He-rich events studied by Reames et al. (1985)

2. Observations and Analysis. The times of the 12 events are given in Table 1. Several of these events occurred on the same day and in these cases are associated with Hα flares in the same active region. In each case we give the time of the onset and the maximum reported burst size of the associated metric type III radio burst. The approximate flare sites and McMath region numbers, based on both reported Hα flares and inspection of Hα patrol films, are also listed. In three cases we give alternative suspected McMath regions in parentheses. All Hα events were subflares except for the November 8 1B flare.

Each ^{3}He/electron event was associated with a prominent kilometric type III burst observed with the Meudon/GSFC solar radio experiment on ISEE-3. An examination of the kilometric data during the few hours before and after the type III burst reveals that that burst is one of a family of such bursts, all of which show nearly identical solar elongation angles as a function of radio frequency. This suggests that the energetic electrons producing the bursts traverse similar paths from a single solar region through the interplanetary medium. Figure 1 shows an example of such bursts during a 6 hr interval on 1979 August 14. We have listed in Table 1 the number of prominent kilometric type III bursts in each such family during an 18 hr period around the time of the ^{3}He/electron burst. The last column gives the number of bursts possibly associated on the basis of the timings with listed Hα flares in the active region presumed to be the source of the ^{3}He/electron event. Numbers in parentheses are the numbers of bursts possibly associated with listed Hα flares in the alternative active regions for the three dates for which the active region is in some doubt.

TABLE 1

Date	Type III Start UT	Class[e]	Approx. Location	Hα Onset UT	McMath Region	Total km type III	Total with Hα flares
1978							
Nov 8	1751	3GG	N18 E12	1751	643	2	2
Nov 27	2056	3GG	N26 W47[a]	2055	672 (673)	6	0 (4)
Dec 26	1319[b]	-	S21 W41[a,d]	--	721		
Dec 26	2122	WNG[c]	S21 W45[a]	2104	721	4	0
1979							
Feb 10	1818	3GG	N13 W23[a]	< 1800	807 (808)	6	2 (1)
May 17	0558	2G	S35 W78[a]	0551	996 (010)	13	3 (0)
Aug 14	1728	3GG	S18 W45	1728	205		
Aug 14	2048	3GG	S17 W48	2048	205	4	2
Sept 6	0906	2GG	N20 W62	0906	252		
Sept 6	1148	3GG	N18 W67	1148	252		
Sept 6	1332	3GG	N16 W63	1332	252	10	5
Sept 6	1851	2GG	N16 W65[a]	1850	252		

[a] flare not listed in SGD, but found in visual inspection of Hα films.
[b] start time of 1980 kHz burst.
[c] weak intermittent group.
[d] no confirmation with optical data.
[e] GG: > 10 type III bursts; G: < 10 type III bursts.

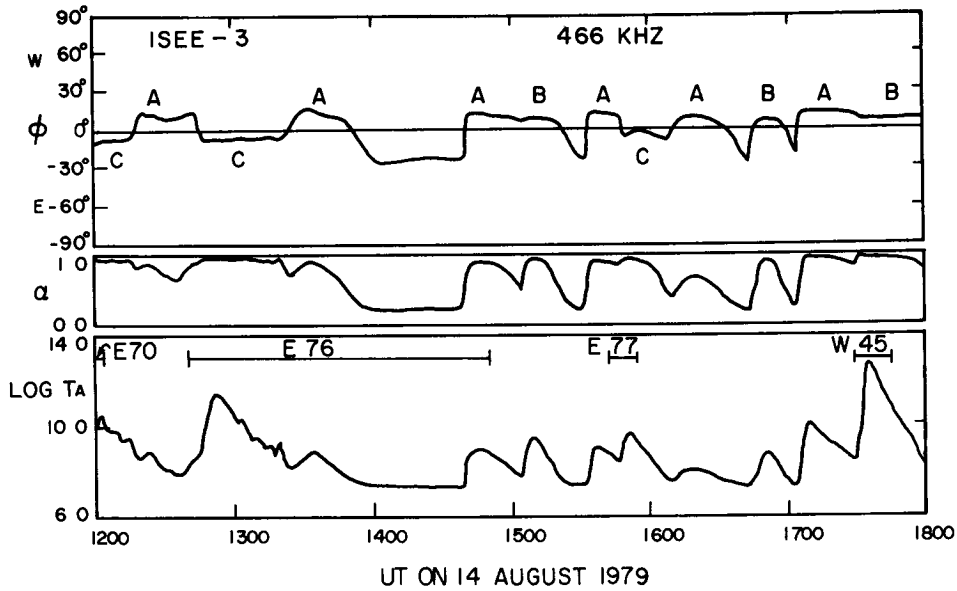

Figure 1. 466 kHz data from 1979 August 14. Three families of bursts labeled A,B, and C were present during the 6-hr interval. B events were associated with McMath 205. ϕ is the solar elongation angle; α a measure of the source size, with 1 being a point source; and T_A the antenna temperature. Associated Hα flare reports are also shown.

In two of the three events with questionable active region associations we see that the Hα flare associations of the alternative regions are worse than for the preferred active regions, although the statistics are limited. Using only these data, we could have selected the preferred region for all the ^{3}He/electron events except for the November 27 event and the two on December 26. In the latter case no choice could be made. On the other hand, by simply looking for listed Hα flares at well connected longitudes, we would have misidentified the source regions in two or three cases.

To get a better idea of the signatures of the ^{3}He/electron events, we have compared reported Hα flares, metric type III bursts, and antenna temperatures of the 1980 and 188 kHz bursts for the kilometric bursts with and without ^{3}He/electron events. We omit the large sample of events on May 17, few of which are associated with Hα flares or metric type III bursts. The results are shown in Figure 2. The contrast between the two groups increases as we consider first the Hα flares and then the progressively lower frequencies of the type III bursts. At 188 kHz the logs of T_A of all but one of the 12 ^{3}He/electron events exceeded 10.5. On the other hand, this value was exceeded by only 3 of the 21 kilometric type III burst group.

3. Discussion. Each kilometric burst family is characterized by the degree of its association with reported metric type III bursts and Hα flares as shown in Table 1. The families of November 8, August 14, and September 6 are well associated, while the others are not. This lack of observed associated Hα activity with several ^{3}He/electron events

suggests a coronal origin for the energetic ^{3}He ions and electrons. Figure 1 shows that the correlation between the occurrence of a ^{3}He/electron event and a solar/interplanetary event increases with increasing distance of the solar/interplanetary event from the sun. This suggests that Hα activity may have little to do with the acceleration of the ^{3}He ions and electrons other than to reflect indirectly the presence of the overlying event, presumably as a result of the precipitation of some fraction of the energized particles as suggested by Kane et al. (1974). We also found a close coincidence between onsets of metric type III bursts and onsets of associated Hα and X-ray flares suggesting that the initial activity of the ^{3}He/electron events begins in the high corona. Observations of type III emission from interplanetary electron beams are complicated by factors involving generation (Lin et al. 1981) and propagation of the bursts, so the situation may prove to be more complex.

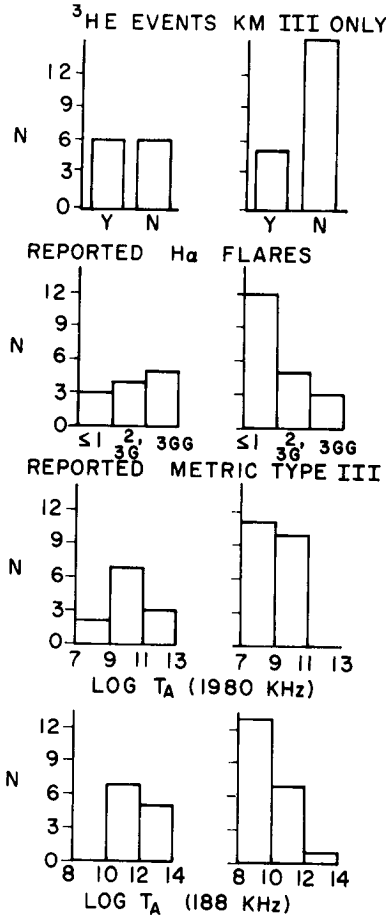

Figure 2. Histograms of Hα flares, metric type III bursts and log T_A for kilometric type III bursts with and without ^{3}He/electron events.

4. Conclusions. Each ^{3}He/electron event is associated with a kilometric type III burst which appears as a member of a family of bursts sharing similar interplanetary propagation paths. The members of each family differ from each other in their associated antenna temperatures at different frequencies and in their metric type III and Hα flare associations. In our study the best empirical indication of the occurrence of a ^{3}He/electron event proved to be a high antenna temperature at 188 kHz. Reported Hα flare observations are a poor guide to the occurrence or origin of these events and in some cases are misleading, perhaps because of inaccurate reporting. The poor association of the ^{3}He/electron events with Hα flares suggests a high coronal origin for at least some of the events.

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