TYPE IV BURSTS AND CORONAL MASS EJECTIONS*

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Abstract. The relationship of moving type IV bursts and coronal mass ejections (CMEs) is of interest, because it may yield insights into the origin and the physics of the ejecta. We discuss the statistical association of moving type IV bursts and CMEs, and find that about one-third to one-half of the IVs occur in association with CMEs, while only about 5% of the CMEs are accompanied by moving type IVs. We also find that the mean speed of the moving IVs is smaller than the mean speed of CMEs, and conclude that the type IVs move out with the bulk of the ejecta.

1. Introduction

The relationship of type II and IV radio bursts to coronal mass ejections (CMEs) is of interest, since it is expected to shed light on the dynamics of the corona. Unfortunately, few simultaneous, spatially resolved observations of CMEs and type II and/or type IV radio bursts are available. Thus, most studies carried out to date have been statistical in nature. The relationship of type II bursts with coronal mass ejections has been explored, e.g., by Kahler *et al.* (1984), Gergely (1984), and others. Kahler found that $\sim 67\%$ of the type IIs were associated with CMEs that occurred within 30° of the limb. The association decreased towards the center of the disk, where CMEs are more difficult to detect. Gergely (1984) found that the average velocity ratio of type IIs to CMEs was $\langle v_{\rm II} \rangle / \langle v_{\rm CME} \rangle \sim 1.6$. The relationship of moving type IV bursts and CMEs is of particular interest, because it may yield some insights into the origin and the physical state of the ejecta. In this paper we briefly explore two topics: (1) What fraction of CMEs are associated with type IV bursts, and viceversa. (2) The relative velocities of moving type IV bursts and CMEs.

2. Association of CMEs and Type IV Bursts

Preliminary statistical studies (Gosling *et al.*, 1976, Vlahos *et al.*, 1982) indicate that the fraction of CMEs associated with moving type IV bursts increases with speed of the CME. These studies were based on the relatively small number of CMEs observed with the Skylab coronagraph. The reverse association, the fraction of type IV bursts that occur with/without CMEs has not been explored. Unlike type II bursts, which may be recognized on the basis of dynamic spectra alone, the identification of *moving* type IV bursts requires positional measurements. At meter–decameter wavelengths such measurements may only be obtained at present with the Clark Lake and the Nançay radioheliographs. Since coverage of the Sun with these instruments is limited, some alternative criterion is desirable to identify moving type IV bursts, in the absence of positional measurements. One possible such criterion is the duration of the bursts. Robinson (1978) summarized the properties of a large number of moving type IV bursts

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observed with the Culgoora radioheliograph. Of 21 bursts observed at 80 MHz only 3 lasted longer than one hour, the average duration and rms dispersion of all bursts was 41 ± 48 min. The large dispersion is due to three long duration events. Eliminating these, we obtain 28 ± 16 min for the remaining events. On the other hand, stationary type IV bursts usually last several hours, or even days.

In order to explore the type IV-CME association, we investigated the period 10 April – 21 June, 1981 (STIP Interval XII). We used the following criterion to identify moving type IV bursts. Type IV bursts listed in the metric and/or decametric band of the 'Spectral Observations' section of *Solar Geophysical Data*, with a duration less than one hour were considered 'moving'. A list of CMEs that were observed during this period with the SOLWIND coronagraph aboard the P78-1 satellite was supplied by Howard (1985). We considered that a type IV burst was CME associated when a CME was observed within one hour of the onset of the radio burst, and its speed was in the range 400–1400 km s^{-1}. For a large number of CMEs only one image was obtained. In these cases we estimated a speed from the height of the CME at the time of the observation, and the time of onset of the type IV burst. An association was considered uncertain if a CME was observed 1–5 h after the onset of the type IV, and its speed was in the above range.

A total of 17 type IV bursts occurred during the time period studied. Nine bursts lasted less than 1 hr, 3 of these were CME associated, while no CME was observed in association with 3 others and 3 bursts had uncertain associations. The remaining bursts ranged from 61 to 617 min in duration, 2 were CME associated, 2 were not, and the association of 4 bursts was uncertain. Based on our limited sample, it appears that ~ 33–50% of moving type IVs are associated with CMEs. Some moving type IV bursts certainly do occur without CMEs. The case of a type IV burst that occurred on 14 April, 1981 is significant in this regard. This type IV was associated with a 1B/M3 flare, which occurred at N 14 E 76. A CME that originated at that location would certainly have been detected by the coronagraph. The duration of the radio burst was 23 min, close to the average duration of moving IVs, it was preceded by a type II. 86 CMEs were observed by the coronagraph during the period considered. Clearly, only a small percentage ($\sim 5\%$) of the CMEs were associated with moving type IV bursts. Velocities were available for three of the moving type IV associated CMEs. All were faster than 775 km s^{-1}, their mean velocity was 870 km s^{-1} confirming that type IV bursts are more likely to be associated with fast CMEs.

3. The Relative Velocities of Type IV Bursts and CMEs

A statistical distribution of the speeds of type IV bursts, obtained from a literature search, which included the period 1968–1982 is shown in Figure 1. The distribution of the speeds of CMEs observed during 1979–1981 with the Solwind coronagraph was discussed by Howard *et al.* (1985). A list of type II associated CMEs was given by Sheeley *et al.* (1984). In Table I we compare some parameters of the speed distributions of the type IV bursts and of the type II associated CMEs, which we assume to be

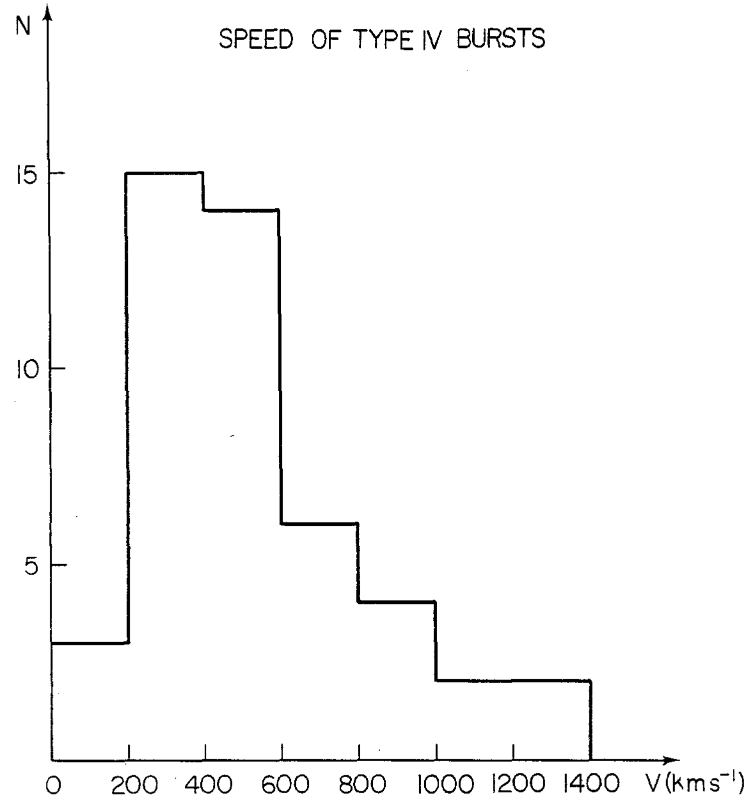

Fig. 1

TABLE I

Comparison of speeds of type II burst associated CMEs and type IV bursts

	CMEs	Type IV bursts
Number of events	40	46
Lowest speed (km s^{-1})	400	100
Highest speed (km s^{-1})	1500	1300
Mean speed (km s^{-1})	825	515
R.m.s. dispersion (km s^{-1})	293	286

representative of the speeds of type IV associated CMEs. We also assume that the velocity distribution of the type IVs is representative of the subset associated with CMEs. We have no reason to suspect that the speed distribution of the CME-associated type IVs differs from the distribution of all bursts. We find that: (1) The mean speed of the type IVs is less than the mean speed of the CMEs. Moving type IV bursts, therefore, appear to move out slightly behind, or along with the leading edge of the CMEs. (2) The r.m.s. dispersion of the speed distribution of CMEs and type IVs are identical.

We note that type IV speeds are independent of coronal density models. Further, moving type IVs sometimes reach great heights, of the order of 5–6 $R_{\odot}$, before fading. This is the same range where most CME velocities are measured. Finally, only a handful of instruments were used to determine the type IV's speeds, and therefore they are fairly homogeneous.

Howard *et al.* (1986) classified CMEs by structural class in ten different categories, and gave mean speeds for each. The mean speed of the curved front, loop, halo and complex shaped CMEs exceeds the mean speed of type IVs, while those in the other categories are lower.

4. Summary

Moving type IV bursts have been used in some cases to derive the physical properties (e.g., electron densities and magnetic fields) in coronal mass ejections (CMEs). It is therefore important to understand the relationships of CMEs and type IV bursts. From the limited sample examined by us it appears that about 5% of all CMEs are associated with moving type IV bursts, while 33–50% of moving type IVs are associated with CMEs. The mean speed of moving type IVs is less than the mean speed of the leading edge of CME, thus it appears that type IV bursts move out with the bulk of the material, behind the leading edge. This conclusion is borne out by the few detailed studies dealing with spatially resolved, simultaneous optical and radio observations of CMEs (e.g., Gergely *et al.*, 1984; Stewart *et al.*, 1982).

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