ARE INTERPLANETARY MAGNETIC CLOUDS MANIFESTATIONS OF CORONAL TRANSIENTS AT 1 AU?

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Abstract. Using proxy data for the occurrence of those mass ejections from the solar corona which are directed earthward, we investigate the association between the post-1970 interplanetary magnetic clouds of Klein and Burlaga (1982) and coronal mass ejections. The evidence linking magnetic clouds following shocks with coronal mass ejections is striking; six of nine clouds observed at Earth were preceded an appropriate time earlier by meter-wave type II radio bursts indicative of coronal shock waves and coronal mass ejections occurring near central meridian. During the selected control periods when no clouds were detected near Earth, the only type II bursts reported were associated with solar activity near the limbs. Where the proxy solar data to be sought are not so clearly suggested, that is, for clouds preceding interaction regions and clouds within cold magnetic enhancements, the evidence linking the clouds and coronal mass ejections is not as clear; proxy data usually suggest many candidate mass-ejection events for each cloud. Overall, the data are consistent with and support the hypothesis suggested by Klein and Burlaga that magnetic clouds observed with spacecraft at 1 AU are manifestations of solar coronal mass ejection transients.

1. Introduction

Recently, Burlaga *et al.* (1981) investigated the configuration of the interplanetary magnetic field in a flow behind a shock using Voyager, Helios, and IMP-8 observations. For that single event, they found the configuration to be suggestive of an ordered 'magnetic cloud', approximately 0.5 AU in radial extent and $> 30°$ in azimuthal extent. Further, each spacecraft, as it transited the magnetic cloud, observed that the magnetic-field direction in the cloud changed by rotating nearly parallel to a plane. In a subsequent paper, Klein and Burlaga (1982, hereafter referred to as KB) extended their study of this interplanetary phenomenon, discussing statistically the characteristics of 45 magnetic clouds observed near Earth by a number of individual spacecraft over a solar cycle (1967–1978). They noted that magnetic clouds pass Earth at the rate of at least one every three months and that they possess several common characteristics related to their structure and dynamics. Though the clouds present common characteristics and were thought to represent one phenomenon, they were found in three environments at 1 AU. Therefore, Klein and Burlaga sub-divided the 45 magnetic clouds into three groups: (a) those following shocks (13 examples); (b) those preceding interaction regions (16 examples); and (c) those associated with CME's (i.e., Cold Magnetic Enhancements; 16 examples). Because of the quantitative similarities between their physical parameters (e.g., mass, speed, occurrence rate as corrected for data gaps, and internal magnetic-field strength) and those extrapolated for coronal mass ejections, KB suggested that

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magnetic clouds may be 1-AU manifestations of coronal mass ejections (see also Burlaga and Behannon, 1982; Burlaga *et al.*, 1982a, b).

In an effort to evaluate this hypothesis, we undertook a study of the 35 post-1970 Klein and Burlaga events to ascertain if a one-to-one correlation existed between a magnetic-cloud observation and the occurrence of a candidate solar event thought to be diagnostic of a coronal mass ejection and occurring at the appropriate earlier time. For the clouds following interplanetary shocks, where the obvious proxy solar activity is a meter-wave type II burst (Hundhausen, 1972), our results are consistent with such a one-to-one correlation. Our results allow such a correlation for the other two classes of clouds but do not require it; the appropriate observable solar events which we should consider to be proxy for the observation of a coronal mass ejection are not obvious in these latter two classes.

2. Method

Figure 1 shows a schematic solar cycle for the period of interest and the approximate occurrence dates of the magnetic clouds. In the figure, '×' denotes the occurrence of a pre-1970 cloud not studied in this investigation: '$\bar{R}_z$' is the smoothed Zürich sunspot number. Our study relates particularly to the events which occurred at the time of the dots: (a) 9 clouds following shocks, (b) 13 clouds preceding interaction regions, and (c) 13 clouds associated with CME's. The division into subgroups (a), (b), and (c) is

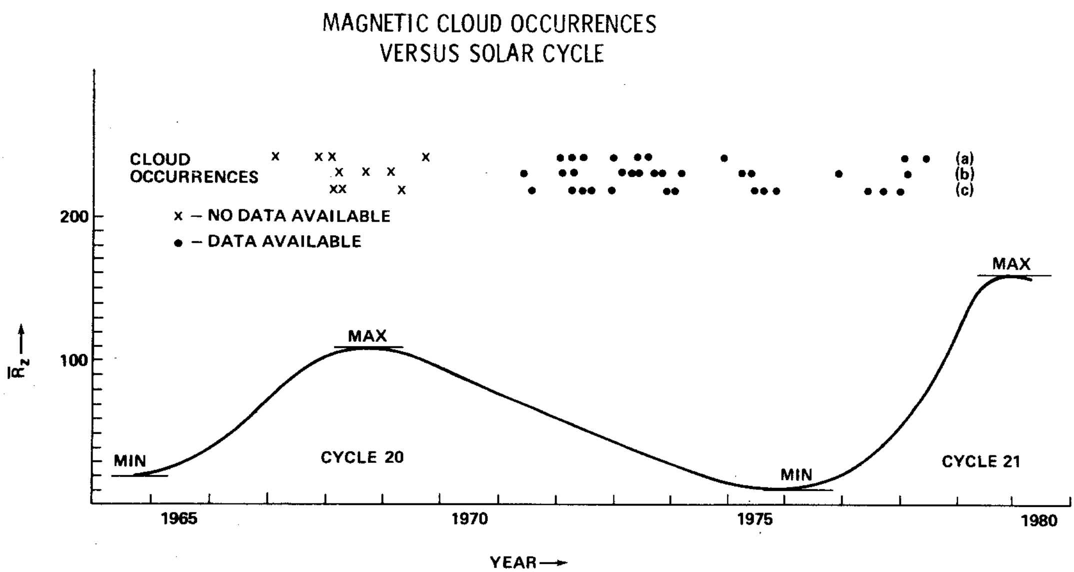

Fig. 1. Magnetic cloud occurrence versus solar cycle (1964–1980). Cycle 20 and the rise-portion of cycle 21 are plotted schematically. Magnetic clouds are indicated by × and • in a 3-tier scheme corresponding to the subgroups of magnetic clouds identified by Klein and Burlaga (1982). The subgroups are: (a) following shocks; (b) preceding interaction regions; and (c) associated with CME's.

made solely on the basis of the environment in which the clouds are found at 1 AU; it is argued in KB that the satellite data do not suggest that there are systematic or causal differences between the clouds of separate subgroups. Therefore, in KB it is suggested that the three types of clouds might to be manifestations of a single phenomenon.

Table I, adapted from KB, identifies the number, average duration, average solar wind speed, and average travel time by subgroup and for all 45 magnetic clouds. The clouds are found to have an average duration of 26 hr, and the average solar wind speed during cloud passages is 416 km s^{-1}. These numbers imply that the average radial extent of magnetic clouds is about 0.25 AU (in contrast to the 0.5 AU radially extended cloud mentioned in Section 1). Average travel time, Sun to 1 AU, is simply 1 AU ($= 1.5 \times 10^8$ km) divided by the average speed. Thus, clouds average about 4.3 days transit time. Solar wind speeds were obtained from tabulations compiled by King (1975, 1977, 1979).

TABLE I

Event information summary (from Klein and Burlaga, 1982)

Subgroup	No. events	Mean duration [a]	Average speed [b]	Average travel time [c]
Magnetic cloud following shock (a)	13	26.2	463.9	92.4
Magnetic cloud preceding an interaction region (b)	16	20.8	411.1	105.0
Magnetic cloud associated with a CME (c)	16	30.0	382.4	109.9
All magnetic clouds	45	25.6	416.2	103.1

[a] Mean duration in hr.
[b] Average speed in km s^{-1}.
[c] Average travel time in hr.

Klein and Burlaga's suggestion that magnetic clouds and coronal mass ejections are closely linked appears to be well-founded, since some of the physical properties of clouds and mass ejections (especially average speed and mass) are quantitatively quite similar. The magnetic clouds' average speed is about 420 km s^{-1}, and their estimated average mass is about 2×10^{15} g; coronal transients' average speed is about 470 km s^{-1} and their average excess mass is in the range 4×10^{15} g (Rust *et al.*, 1980) to 8×10^{15} g (Poland *et al.*, 1981). Also, in KB it was noted that coronal mass ejections are always observed to leave the vicinity of the Sun (apparently never to return) and to expand as they move outward; magnetic clouds similarly move outward and likewise appear to be expanding (even at 1 AU and beyond; Burlaga and Behannon, 1982).

Coronal mass ejections have been associated by many investigators with such solar phenomena as flares, ascending or eruptive prominences, *disparitions brusque*, sprays, surges, types II and IV and gradual-rise-and-fall (GRF) radio events, long-decay X-ray events (LDE), prompt interplanetary protons, and white-light coronal transients (e.g., see Warwick, 1965, and references listed thereunder on p. 179). Indeed, many of these phenomena appear to be closely interrelated; for example, white-light coronal transients have been associated with eruptive prominences and flares, LDE's and GRF's with eruptive prominences (or *disparitions brusque*/disappearing filaments when seen against the solar disk), and types II and IV radio events with flares and eruptive prominences. Thus, our *modus operandi* for investigating the premise that magnetic clouds are the 1-AU manifestation of coronal mass ejections was to search records within appropriate time windows for the occurrence of these phenomena, regarding them as indicative or diagnostic of the occurrence of coronal mass ejections. We extracted the occurrence data regarding solar phenomena from the Prompt Reports and Comprehensive Reports of *Solar Geophysical Data* (SGD).

For each post-1970 cloud defined and tabulated in KB, using solar wind speed data from King's (1975, 1977, 1979) compilations (in particular, the minimum, V_{min}, and the maximum, V_{max}, solar wind speed observed within the cloud), we computed a temporal window within which a diagnostic event would have had to occur at the Sun to signal the initiation of an ejection event capable of reaching the spacecraft observing the cloud. We call these periods 'cloud' windows or 'event' windows. For example, in Table II, event 5 is a magnetic cloud that commenced on January 21 at 03:00 UT (January 21.125) and continued to pass over the spacecraft for about 21 hr. The cloud's $V_{min} = 416$ and $V_{max} = 472$ km s^{-1}. Thus, the event-window start is January 21.125 minus the Sun-to-Earth travel time, presuming a constant V_{min} over the distance, January 21.125 − 1 AU/V_{min} = January 16.952. Similarly, the solar event-window end time for this cloud is January 21.125 − 1 AU/V_{max} = January 17.447. Then, using the SGD, we listed reports of phenomena we took to be diagnostic of mass ejection events occurring within the windows. Because we believed that the association between proxy solar events and coronal mass ejections is poor, we adopted a 'grab-bag' approach and listed all those phenomena which could easily be tabulated using SGD. These were: locations, sizes, and rise and fall times of flares (especially flares annotated with the letter codes *H*, *L*, *R*, *U*, and *V* meaning 'flare accompanied by a high-speed dark filament', 'existing filaments show signs of sudden activation', 'marked asymmetry in Hα line suggests ejection of high-velocity material', 'two bright branches, parallel or converging', and 'occurrence of explosive phase', respectively); type II and IV radio events; radio gradual-rise-and-fall (GRF) events; and soft X-ray events. Finally, we grouped the reported phenomena that arose from a single event. For example, along with the observance of a flare might go reports of type II and IV emission and a GRF, all arising about the same time, presumably from nearly the same solar location. We assume that such an event, with a multiplicity of reported diagnostic phenomena, is more likely to indicate the presence of an accompanying coronal mass ejection than is a solar event for which only a single diagnostic phenomenon is reported.

We similarly examined control periods when no magnetic clouds were emitted earthward and listed the same 'diagnostic' solar activity phenomena as for the cloud windows. Using these data, we compared the frequency, the types, and the locations of solar activity which occurred when magnetic clouds were not emitted earthward with the

TABLE II

Magnetic clouds following shocks

(a) Cloud summary

Event No.[a]	Date of cloud occurrence (month/day/year)	Cloud passage begin time[b]	Cloud passage duration[c]	V_{min}[d]	V_{max}[d]	V_{avg}[d]	TT[e]	Event window begin	Event window end	Window duration[f]	Hα[g]	Radio[g]
5	01/21/72	03:00	21	416	472	444	93.8	01–16 (23:00)	01–17 (11:00)	12	0	18
6	02/02/72	05:00	38	380	414	397	105.0	01–28 (16:00)	01–29 (01:00)	9	0	0
7	03/22/72	03:00	15	325	353	339	122.9	03–16 (19:00)	03–17 (05:00)	10	0	0
8	11/01/72	02:00	22	389	662	526	79.2	10–27 (22:00)	10–29 (15:00)	41	196	299
9	04/13/73	00:00	48	342	575	459	90.8	04–08 (06:00)	04–10 (04:00)	46	89	0
10	05/21/73	04:00	17	589	754	672	62.0	05–18 (06:00)	05–18 (22:00)	16	0	115
11	10/12/74	12:00	10	398	518	458	91.0	10–08 (05:00)	10–09 (05:00)	24	3	0
12	01/04/78	10:00	34	464	673	569	73.2	12–31 (19:00)	01–01 (22:00)	27	268	0
13	04/03/78	18:00	21	430	515	473	88.1	03–30 (18:00)	03–31 (10:00)	16	236	0

[a] Numbering is as in KB.
[b] Time in Universal Time (UT).
[c] Time in hours.
[d] Velocity in km s^{-1}.
[e] Travel time (TT) in hours.
[f] Window duration in hours.
[g] Observing outages within the window total the number of minutes listed.

frequency, types, and locations of activity which occurred around the time when clouds were emitted.

A control period, called a 'pre-cloud' window, was selected for each reported cloud as follows. Because the average durations of cloud windows are 22, 22, and 18 hr for clouds of subgroups (a), (b), and (c), respectively, we considered pre-cloud windows of 24 hr duration. For a target period ending 72 hr before the event window began, we verified the existence of 1 AU solar wind data at the appropriate (transit) time later. We required an absence of a listed cloud in KB, but that the solar wind data be good enough (i.e., no gaps in the solar wind coverage) to detect the passage of a magnetic cloud had it occurred. The appropriate transit time was taken to be the average transit time of the class of clouds being considered; that is, for pre-cloud windows paired with subgroup (a) cloud windows, we used the average transit time of the subgroup (a) clouds. The target period became the pre-cloud window if it satisfied the requirements; gaps in the associated solar wind data caused us to shift from our target period sufficiently earlier or, rarely, later in time to ensure good solar wind data at 1 AU a transit time later. The shifted 24-hr period became the pre-cloud window in these cases. This procedure enabled us to be confident that no cloud was emitted earthward during a pre-cloud window. Once the pre-cloud windows were identified, solar activity phenomena were catalogued exactly as already described for the cloud windows.

The results of these data compilations and the implications which flow from them are presented and discussed in the next section of the paper, in particular for clouds following shocks, subgroup (a).

3. Results and Discussion

The outcome of our search for proxy solar phenomena which would indicate the existence of coronal mass ejections is shown in Tables II and III, where Table II summarizes information regarding the post-1970 magnetic clouds for subgroup (a) and Table III summarizes information pertinent to the phenomena which might serve as proxies for mass-ejection events. The A portion of Table III is for the windows during which the magnetic clouds were emitted from the Sun, while the *B* portion refers to the selected control periods. We note the number of: flares (as reported in the SGD Comprehensive Report); annotated flares (recall the *H*, *L*, *R*, *U*, and *V* descriptions); GRF's; X-ray events (as suggested by the tables of outstanding occurrences and/or plots that are contained in the SGD); and type II and/or IV spectral radio events. Further, we note the number of events for which two or more diagnostic phenomena were observed and those for which three or more were observed.

The notes below the *A* portion of Table III refer to candidate solar events which might possibly be associated with the listed interplanetary magnetic clouds. The notes identify the Hα importance, solar coordinates, date and start time (UT) of each flare; the *H*, *L*, *R*, *U*, and *V* annotations, if any; the duration in minutes of any GRF's; the X-ray class; and the occurrence of type II and/or IV radio events. The candidate solar events listed in the notes to the tables are those with three or more reported diagnostic phenomena (except for clouds 7, 11, and 13).

Examination of the A and B portions of Table III shows that typically there are many proxy phenomena for each magnetic cloud, and almost equally many proxy phenomena during the pre-cloud windows, when no near-Earth clouds were reported at the appropriate later times. Logically, two explanations are allowed by this profusion of proxy phenomena in both cloud and pre-cloud windows: (1) if indeed the selected, proxy phenomena indicate the existence of coronal mass ejections, then there were mass ejections not only near the time of magnetic cloud emission from the Sun but also at times when no magnetic cloud was reported; or (2) perhaps the selected solar phenomena are poor proxies for the existence of coronal mass ejections.

To sort out these possibilities, we examine the subgroup (a) events, clouds following interplanetary shocks, more closely. If we ignore the interplanetary shocks initiated by dynamical processes in the solar wind, then we expect that interplanetary shocks are typically the outwardly propagating remnants of solar coronal shocks. Meter-wave type II bursts are diagnostic of coronal shocks (Hundhausen, 1972), and the shocks may be traced from the corona into the interplanetary medium by observing at lower and lower frequencies as the shocks propagate into regions of ever-decreasing density (e.g.,

TABLE IIIA

Magnetic clouds following shocks

(a) Event correlation summary

Event No.	Number of flares in window	Number of annotated flares	Number of GRF's in window	Number of X-ray events in window	Number of type II's in window	Number of type IV's in window	Possible number of associations ≥2/≥3	Notes
5	8	1	2	3	1	0	5/1	(1)
6	11	2	2	3	1	0	4/2	(2)
7	3	1	0	1	0	0	1/0	(3)
8	41	6	23	7	1	0	18/6	(4)
9	57	6	19	13	0	1	12/3	(5)
10	11	0	4	2	1	0	4/2	(6)
11	32	1	6	**	1	1	6/1	(7)
12	14	2	8	10	1	0	5/2	(8)
13	5	1	1	2	0	0	2/1	(9)

Notes: ** No X-ray data available.

1. SF/S 15 E49 16/22:55, C1, II.
2. SF/S 10 W60 (H) 28/17:39, GRF (70), C1.
   1B/S 10 E26 (U) 29/00:16, C1, II.
3. SN/N 10 E59 (H) 16/22:51, CO.7.
4. 1B/S 16 E22 (L) 28/04:22, GRF (19.5), M1.
   SN/S 15 E18 28/09:23, SF/S 14 E18 (L) 28/09:43 } GRF (117), C9 (MP)[a].
   SN/S 06 W88 28/12:39, GRF (>151), C5.
   SN/S 07 E14 28/15:31, GRF (7), C5.
   SN/S 10 E10 (H) 28/18:05, C4, II.
   SB/S 10 E00 29/09:28, GRF (23.4), C7.
5. SN/S 08 E34 (U) 08/14:15, GRF (79.5), C3, C4.
   SN/S 08 W04 08/17:33, GRF (83.1), IV.
   SN/S 08 E20 09/17:43E, GRF (220), M2.
6. 1B/N 07 E43 18/15:27, GRF (165), M2, II.
   SB/N 10 E33 18/21:54, GRF (30), M7.
7. SN/N 11 E42 08/13:11, GRF (10), IV.
   SF/N 07 E47 08/15:50, II.
8. 1N/S 22 E16 31/23:28, GRF (120), M1.
   2N/S 21 E06 (UV) 01/21:45, C2, II.
9. SB/S 26 W27 30/20:48, GRF (30), C1.
   SN/S 29 W28 (H) 30/23:32, C2.

[a] MP: Multiple peak.

TABLE IIIB

Pre-magnetic cloud event windows: clouds following shocks

Pre-event window No.	Year	Begin	End	Number of flares in window	Number of annotated flares	Number of GRF's in window	Number of X-ray events in window	Number of type II's in window	Number of type IV's in window	Possible number of associations $\geq 2/\geq 3$
5	1972	01–12 (05:00)	01–13 (05:00)	4	0	1	0	0	0	0/0
6	1972	01–25 (03:00)	01–26 (03:00)	32	3	4	4	0	0	4/2
7	1972	03–12 (19:00)	03–13 (19:00)	4	0	1	0	0	0	0/0
8	1972	10–24 (10:00)	10–25 (10:00)	46	6	22	13	0	0	13/8
9	1973	04–04 (06:00)	04–05 (06:00)	15	4	7	1	2[a]	0	3/1
10	1973	05–14 (23:00)	05–15 (23:00)	10	1	4	0	0	0	0/0
11	1974	10–01 (20:00)	10–02 (20:00)	19	2	0	NXRA[c]	1	0	0/0
12	1977	12–27 (19:00)	12–28 (19:00)	10	4	5	8	3[b]	0	4/1
13	1978	03–26 (19:00)	03–27 (19:00)	7	1	1	0	0	0	0/0

[a] Probably only 1 event (11:54, 12:03 UT start times).
[b] 3 separate events? (03:54, 07:35, 08:00 UT).
[c] NXRA means no X-ray available.

McLean, 1974). Meter-wave type II bursts are also diagnostic of the occurrence of coronal mass ejections (Munro *et al.*, 1979). Thus we can expect that meter-wave type II bursts are the proxy solar phenomenon which should serve as the linchpin in establishing a connection between the clouds of subgroup (a) and coronal mass ejections.

When we look at Tables IIIA and IIIB, we find that type II radio bursts occurred in six of the nine cloud windows and occurred in three of the nine pre-cloud windows. Checking the central meridian distance of the flares and sub-flares (approximately equal numbers) from which these radio bursts presumably originated, we find that the radio bursts in the six cloud windows all occurred within 49° of central meridian, while the radio bursts occurring during the pre-cloud windows were located farther than 63° from central meridian. Surprisingly, all six of the radio bursts associated with clouds occurred in the eastern hemisphere. To restate, of the nine magnetic clouds following interplanetary shocks, six had type II radio bursts within 49° of central meridian in the temporal window during which the magnetic cloud was emitted from the Sun. In contrast, not one of the nine pre-cloud windows had a meter-wave type II burst within 63° of central meridian passage.

These findings are entirely consistent with and support the idea that fast coronal mass ejections, expelled nearly radially from the Sun and accompanied by coronal shocks, propagated through the interplanetary medium to become the magnetic clouds detected at 1 AU and reported as subgroup (a) events.

The choice of the 'right' proxy solar phenomenon or phenomena for the 26 magnetic clouds of subgroups (b) and (c) is not so obvious. The meter-wave type II bursts which were so dramatically correlated with the clouds following shocks are not expected to correlate well with the clouds of subgroups (b) and (c) which are without shocks. This expectation is proven by the data (see Wilson and Hildner, 1983); type IIs occurred in only one of these 26 cloud windows and in only three of the corresponding 26 pre-cloud windows. None of these four radio bursts for the (b) and (c) subgroups can be associated with flares or sub-flares within 47° of central meridian; since all the radio burst events associated with subgroup (a) clouds occurred within 49° of central meridian, it is not surprising that clouds were not associated with these four radio bursts.

Motivated by the proven association between coronal mass ejections and gradual-rise-and-fall radio and LDE soft X-ray events (Sheeley *et al.*, 1975; Kahler, 1977; Smith *et al.*, 1979a) and the belief that long-duration X-ray events tend to be associated with long-duration Hα events (e.g., Drake, 1971; Krieger *et al.*, 1972; Wilson, 1984), we examined Hα duration and central meridian distance for each of the flares occurring during each of the cloud and pre-cloud windows. For subgroup (a), long-duration Hα flares occurring during the cloud (pre-cloud) windows were clustered around (away from) central meridian. However, no such pattern emerged for subgroups (b) and (c). Combining the three cloud subgroups together, we find no indication that long-duration Hα flares were more prevalent near central meridian during cloud windows than during pre-cloud windows. Thus, even when coupled with longitude of occurrence, Hα duration of flares is not a good proxy phenomenon with which to correlate the existence of interplanetary magnetic clouds, and other proxy phenomena do not suggest themselves to us. Despite this situation, we believe that the longitudinal distributions of the sites of cloud-associated and non-cloud-associated type II radio bursts will yield information on the size and directionality of emission of the clouds. In the non-association between solar events and observed magnetic clouds, and in the tendency for subgroup (b) and (c) clouds to be slower, we believe there are further clues regarding the connection between coronal mass ejections and magnetic clouds. We intend to pursue these matters in a subsequent paper. Also, we are investigating the association between magnetic clouds and X-ray LDE's.

4. Conclusions

The most satisfying outcome of the present study would be to find that each magnetic cloud had a single candidate solar event which indicated that a single coronal mass ejection occurred on the Sun in the right place and at the right time to become the observed interplanetary magnetic cloud, and that no such candidate event occurred when no cloud was reported. In the near one-to-one association between meter-wave, solar, type II radio bursts and magnetic clouds following interplanetary shocks we have found this satisfying outcome. For six of nine such magnetic clouds studied, there occurred a meter-wave type II radio burst within 49° of central meridian in the temporal window during which the cloud was emitted from the Sun. In the entire collection of 35 pre-cloud windows, during which no cloud was expected to be emitted, no meter-wave type II radio bursts were found closer to central meridian than E 63 or W 47. Thus, for clouds following shocks, meter-wave type II radio bursts occurring near central meridian accompanied the emission of magnetic clouds, whatever the cloud's near-Sun appearance. Because meter-wave type II radio bursts are well associated with coronal mass ejections (Munro *et al.*, 1979), we believe them to be diagnostic of the emission of coronal mass ejections. Therefore, we find *support* for the hypothesis that magnetic clouds are 1 AU manifestations of coronal mass ejections in the case of magnetic clouds following shocks.

For magnetic clouds preceding interaction regions (subgroup (b)) and clouds associated with cold magnetic enhancements (subgroup (c)), it is less clear what proxy solar phenomena should be expected to link clouds with coronal mass ejections. For these clouds, we find a rather large number of proxy solar events around the times when the magnetic clouds were emitted toward Earth, but also nearly equal numbers during selected control periods when clouds presumably were not emitted Earthward. Thus, these proxy events are of little value for diagnosing or predicting the existence of magnetic clouds. The profusion of solar phenomena which we believe give proxy indications of the existence of coronal mass ejections is consistent with but does not compel us to believe the hypothesis that magnetic clouds are 1 AU manifestations of coronal mass ejections.

In summary, we have shown that for the generally faster clouds following interplanetary shocks, meter-wave type II radio bursts give good evidence that coronal mass ejections occurred in the right places and times to become the magnetic clouds detected at 1 AU. We also note the one reported case of a fast coronal mass ejection which was observed by Burlaga *et al.* (1982b) to leave the limb of the Sun and at the appropriate later time (about 42 hr to travel 0.5 AU) to pass over the Helios spacecraft as a magnetic cloud following a shock. Klein and Burlaga argue quite reasonably that all magnetic clouds are manifestations of the same phenomenon. Therefore, we believe that coronal mass ejections, even slow ones, do become interplanetary magnetic clouds.

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