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CORONAL MASS EJECTIONS ASSOCIATED WITH INTERPLANETARY SHOCKS AND THEIR RELATION TO CORONAL HOLES

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RESUMEN

A partir de varios años de observaciones combinadas de la corona solar y de frentes de choque que viajan en el medio interplanetario, se obtuvo un grupo de 49 eyecciones de masa coronal (EMC) que estuvieron relacionadas con los choques. En este trabajo se estudió la posible relación espacial de estas EMC con hoyos coronales y/o regiones activas en el Sol así como con eventos explosivos superficiales como ráfagas y filamentos que desaparecieron. Encontramos que en la mayoría de los casos un hoyo coronal se encontraba entre $\pm$ 30° de longitud del limbo sobre el que se observó la EMC. Presentamos un posible escenario en el Sol donde todos los eventos relacionados podrían ocurrir como resultado de una desestabilización MHD de una gran región de la atmósfera solar que contenga diferentes tipos de estructuras magnéticas. En particular, proponemos que las EMC provienen de regiones magnéticamente cerradas, mientras que los choques se forman a partir de los hoyos coronales. Se describe el porqué de la ocurrencia conjunta de ambos efectos, pero se muestra que no están relacionados causalmente. Se presenta también evidencia observacional de la asociación entre choques interplanetarios y hoyos coronales.

ABSTRACT

From an extensive study of coronal mass ejections (CMEs) observed by the Solwind coronagraph on board of *P78-1* satellite from 1979 to 1982, combined with the interplanetary observations of *Helios 1* spacecraft, a set of 49 CMEs was confidently associated with interplanetary shocks. Here we look for some possible spatial association of these CMEs with coronal holes and/or active regions at the Sun, and consider also their spatial association with the surface explosive events (flares or disappearing filaments) related to them. We found that in most of the cases when a CME was associated with an interplanetary shock, a coronal hole is found between $\pm$ 30° of longitude from the corresponding limb. We outline a possible scenario where all the related events could take place as a result of an MHD destabilization of a large region containing different kinds of magnetic structures and discuss the results reanalyzing the association between CMEs and interplanetary shocks. In particular we find that the observations are consistent with the idea that mass ejections come from closed regions, most probably helmet streamers. But we think that they do not necessarily drive the observed interplanetary shocks. We propose that shocks are instead produced by the sudden increase in the flow velocity of the solar wind from the adjacent coronal hole also affected by the global change in the coronal magnetic structure. Observational evidence supporting the association of interplanetary shocks with sudden changes in coronal holes is presented as well.

Key words: **SUN - ACTIVITY — SUN - CORONA — SOLAR WIND**

1. INTRODUCTION

Coronal mass ejections (CMEs) are now conidered by some authors as the solar phenomena 'hich eventually could lead to an interplanetary hock. In correlated studies combining both coronal and interplanetary observations (e.g., Sheeley et al. 1985) almost every interplanetary shock observed can be related to a CME, but the contrary is not so: there are many CMEs which cannot be connected to shocks and so a selective association must be found. This is not clear yet and even small and low velocity CMEs have appeared associated with interplanetary shocks (Sheeley et al. 1985).

The very origin of CMEs is not yet well understood and most probably, as there are many different classes of them, they have different origins. According to the Skylab and SMM observations (Wagner 1983), only 10–17% of the CMEs observed can be associated with flares and just 30–34% can be associated with eruptive prominences. This leaves a large fraction, 30–48%, of CMEs unrelated to near surface explosive events, including many of those associated with interplanetary shocks. More recently St. Cyr & Webb (1991) presented the statistical results of the analysis of 73 CMEs observed from SMM between 1984 and 1986 and reported that slightly less than half of the CMEs had association with other forms of solar activity (flares, eruptive prominences, X-ray events, etc.). They considered that the difference is due to the fact that more slow mass ejections were observed in this period and this type of CMEs are seldom associated with other forms of solar activity. Nevertheless, as CMEs can most easily be observed on the limb of the Sun, it is possible that the absence of related surface manifestations is due to the fact that they occurred on the hemisphere of the Sun that cannot be observed from Earth. It must be born in mind, however, that even when CMEs and surface explosive events can be associated, surface events commonly start well after the onset of the CME and then cannot be thought as the cause of the CME (see for instance Jackson & Hildner 1978; Jackson 1981; Wagner 1983; Gopalswamy & Kundu 1989). At present it seems more likely that CMEs are the result of a re-arrangement of the large scale coronal magnetic fields which may eventually lead also to an explosive event at the Sun's surface (e.g., Priest 1988; Kahler et al. 1988; St. Cyr & Webb 1991). In this sense, it is more interesting to look at the magnetic structure of the corona around the site of the CME.

The tracking of interplanetary disturbances carried out for about one year by means of the IPS technique in the University of Cambridge showed that the regions at the Sun where the interplanetary shocks originate always contain coronal holes (see for instance Hewish, Tappin, & Gapper 1985; Hewish & Bravo 1986). The precision of this tracking method in positioning the solar source of an interplanetary disturbances is not very high, and so the size of the estimated source regions exceeds that of the hole in it, but, as a coronal hole is always in the region, these authors have proposed that holes are the sources of the shocks. From other studies (Hundhausen et al. 1980; Bravo et al. 1988) the galactic cosmic ray modulation (undoubtedly associated with interplanetary disturbances) appears to be associated also with the evolution of coronal holes, and so is the occurrence of geomagnetic perturbations related to aurorae (Bravo & Otaola 1990). Recently, Bravo, Mendoza, & Pérez-Enríquez (1991a,b) made a comparative analysis of flares and eruptive filaments on the one hand and coronal holes on the other as the possible sources of many interplanetary shocks leading to sudden commencements of geomagnetic storms and obtained a much better correlation with coronal holes.

If interplanetary shocks are actually coming from coronal holes, as suggested by previous analyses, there should be a close spatial relationship between the regions where the CMEs associated with shocks are observed and the locations of coronal holes. In this paper we gathered the information available in relation to the association of these CMEs with other solar structures and events as well as to interplanetary shocks, in order to move toward a better understanding of the shock generation process.

2. THE OBSERVATIONS

For our study we took the list reported by Sheeley et al.(1985) of 49 CMEs observed by the Solwind between 1979 and 1982 which they consider to be confidently associated with shocks detected later by the *Helios 1* spacecraft in the interplanetary space within a longitudinal band of about 30° to each side of the limbs. Their list is reproduced in Table 1 where the date, the central latitude, and the latitudinal span of each CME are quoted as well as the corresponding limb (east or west) where they were observed; the central latitude of most of the CMEs lays between $\lambda \pm 40°$ but some were located at higher latitudes, including one at S70. Also shown in this table are the positions of the flare/X ray events and/or eruptive prominences associated by these authors with the CME. Notice that such association could be made only for 24 of the cases that is for 49% of all the observed CMEs related to interplanetary shocks.

In order to search for a possible relation of these CMEs with coronal holes and/or active regions, we have looked at the corresponding Carrington synoptic charts showing both types of features. Some of them were obtained from the Solar Geophysical Data issues and many others from McIntosh (1990). The number of the Carrington rotation related to each event is also shown in the last column of Table 1.

As the longitudinal position of the CME is not known, and the observed CMEs could be on either side of the limb, we took as a reference the position of the corresponding (east or west) limb at the time of the first observation of the CME. This was compared with the position of the flare/X-ray or eruptive prominence associated by Sheeley et al.

TABLE 1

CORONAL MASS EJECTIONS ASSOCIATED WITH INTERPLANETARY SHOCKS

CME				Flare/X-Ray	Carrington Rotation
No.	Year	Date	Location	Location	No.
1	1979	27 May	N15(+25)-W	no	1681
2		9 June	S40(+40)-W	no	1682
3		3 July	N30(+40)-W	no	1683
4		19 July	N45(+45)-W	no	1683
5		10 Oct	S08(+18)-W	no	1686
6		13 Dec	N30(+35)-E	N25E16	1689
7	1980	27 Feb	S40(+30)-E	S12E55	1692
8		2 March	S70(+90)-E	?	1692
9		19 March	S30(+30)-E	?	1693
10		27 March	S20(?)-E	N28E69	1693
11		18 June	N00(+50)-W	no	1696
12		20 June	N35(+50)-W	no	1696
13		9 July	N25(+25)-W	no	1696
14		18 July	S20(+70)-W	no	1697
15		29 July	S20(+40)-W	S28W60	1697
16		1 Sept	N10(+50)-W	no	1698
17		14 Nov	N25(+50)-W	N12W116?	1701
18		17 Nov	N10(+30)-W	?	1701
19	1981	25 Jan	S25(+65)-E	S12E85?	1704
20		26 Jan	N00(+30)-E	?	1704
21		26 Feb	S05(+45)-E	S15E50	1705
22		6 March	N00(+50)-E	?	1706
23		19 March	N40(+35)-E	?	1706
24		6 April	N30(+35)-E	N20E88	1707
25		10 April	N20(+45)-E	N11E43	1707
26		18 April	S45(+25)-E	?	1707
27		8 May	N25(+60)-E	N09E37	1708
28		10 May	N05(+40)-E	N11E90	1708
29		13 May	N15(+40)-E	N11E58	1708
30		16 May	360	N14E14	1708
31		20 July	S10(+50)-W	S26W75	1710
32		22 July	S30(+40)-W	?	1710
33		15 Aug	S25(+30)-W	?	1711
34		18 Oct	N40(+40)-W	no	1713
35		15 Nov	N05(+50)-W	N16W49	1714
36		18 Nov	N00(+60)-W	?	1715
37		19 Nov	N25(+25)-W	N20W100?	1715
38	1982	10 Jan	N25(+25)-E	N28E(EPL)	1717
39		10 Feb	N35(+20)-E	N16E54	1718
40		23 Feb	S20(+40)-E	no	1719
41		3 June	N20(+30)-E	S09E72	1722
42		5 June	N30(+90)-E	?	1722
43		19 July	S10(+30)-W	N20W45	1724
44		19 July	S30(+50)-W	. .	1724
45		22 July	N25(+45)-W	N16W89	1724
46		22 Nov	. . . -W	S11W36	1728
47		26 Nov	N00(+35)-W	S11W87	1728
48		8 Dec	S10(+60)-W	?	1729
49		19 Dec	N00(+50)-W	N10W75	1729

.985) and with that of coronal holes and active ›gions in the maps. In Figure 1 Carrington maps ›rresponding to events 2, 12, 15, 19, 32, 42 in 'able 1 are shown as a sample. The vertical dashed lines show the central meridian on the day when the CME was first observed and the vertical bars indicate the position of the (east or west) limb over which the CME was detected; these bars are centered at the central latitude of the CME as reported by Sheeley et al. and their size indicates the latitudinal span of the CME as quoted in Table 1. Also shown are the contours of coronal holes and active regions and when a flare was associated with the CME, its position is indicated with an asterisk.

We took the longitudinal distances from the position of the limb where the CME was observed to the surface event (flare or disappearing filament) and to the nearest feature (coronal hole or active region) within the longitudinal span of the CME. The results are summarized in Table 2 and displayed in three different histograms. Figure 2 shows the resulting histogram for the flare/X-ray event or prominence eruption associated by Sheeley et al. to 24 of the CMEs (not withstanding their latitude). The histogram shows a significant dispersion of the values obtained, the longitudinal distances ranging from ≤10° to >60°. In the case of coronal holes, most of the associations were with low- or mid-latitude holes because the CMEs associated with ecliptic interplanetary shocks are rarely centered at high latitudes. The resulting histograms for coronal holes and active regions are drawn in Figures 3 and 4, respectively, where we have not considered longitudinal distances greater than 60°. As it can be seen, a sharper distribution is found for the association with coronal holes including about 60% of the events within a longitudinal distance ≤10°. The relation with active regions shows also a peak for short distances, but this only includes 35% of the events.

As the actual longitudinal position of the CME is unknown, the longitudinal distance from the limb is possibly not very meaningful. For the purpose of relation of CMEs to underlying structures we have to consider a wider region. In a similar analysis Harrison (1990) considered certain "windows" to look for possible associations between CMEs and active regions and/or coronal holes. His windows

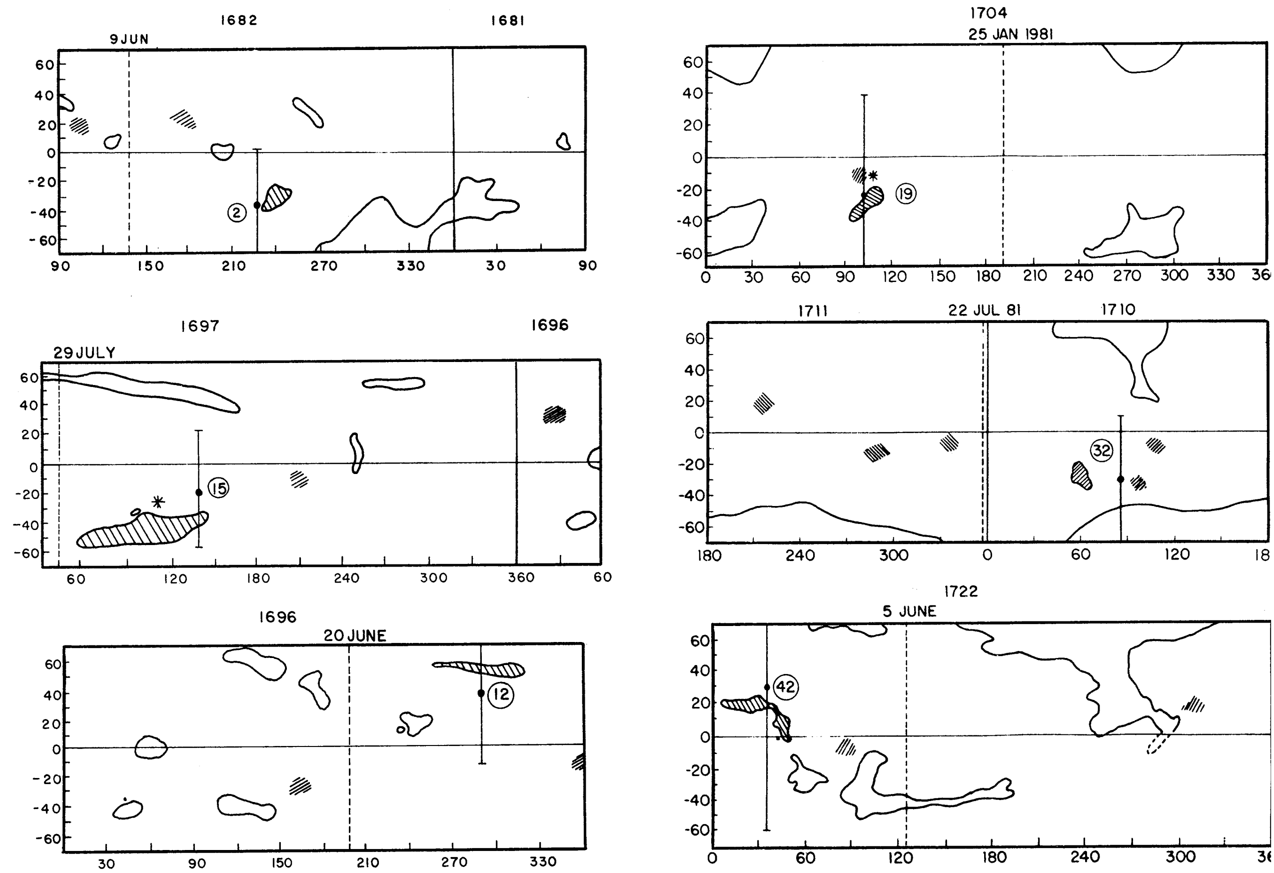
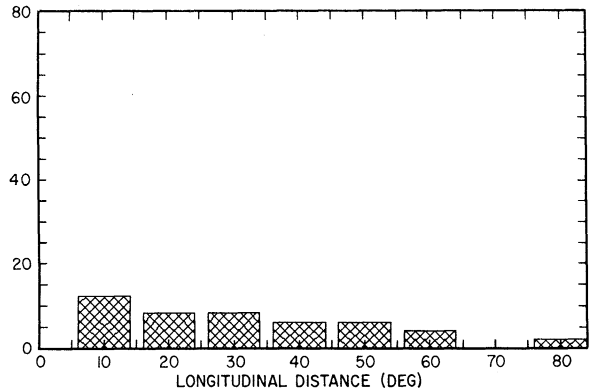
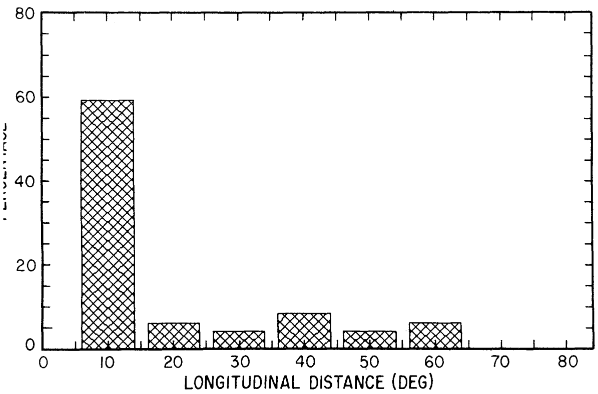


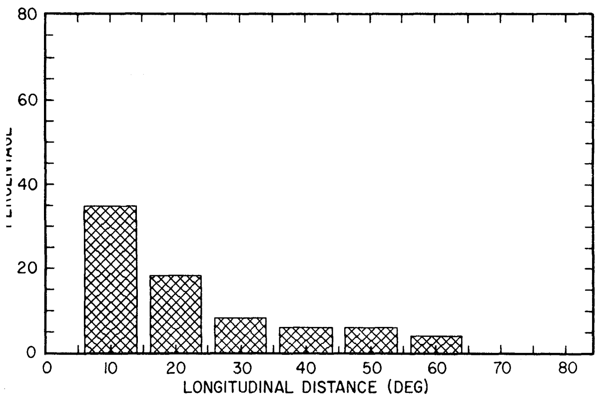
Fig. 1. Carrington Rotations 1682, 1696, 1697, 1704, 1710, and 1722 showing He I 10830 A coronal hole borders and active regions. Dashed vertical lines show central meridian on the day of the CME observation and solid bars indicate the position of the (east or west) limb over which the CME was observed; the bar is centered at the central latitude of the CME (indicated by a dot) and its extension shows its latitudinal span as quoted in Table 1. The asterisks in CR 1697 and 1704 charts show the position of flares that happened on 29 July 1980 and on 25 January 1981, respectively. The crosshatched coronal hole in each figure is the one considered to calculate the longitudinal distance.



g. 2. Histogram showing the distribution of longitudi-
ıl distances from the limb where a CME associated with
ı interplanetary shock was observed to the flare/X-ray
ent or eruptive prominence associated to it by Sheeley
al. (1985).



ig. 3. Histogram showing the distribution of longi-
ıdinal distances from the limb where a CME associated
ith an interplanetary shock was observed to the nearest
ronal hole border within the latitudinal span of the
ME.



ig. 4. Histogram showing the distribution of longitudi-
al distances from the limb where a CME associated with
n interplanetary shock was observed to the nearest active
egion within the latitudinal span of the CME.

extend 30° in longitude on either side of the relevant limb. As any CME which originates farther from the limb should be very bright in order to be observed, and as the longitudinal band of the *Helios 1* positions was about the same, we considered it convenient to use the same criteria. When doing so, we find that 61% of the CMEs are associated with active regions while 70% are associated with coronal holes. It is interesting to notice that in most of the cases when active regions were within the window of association, a coronal hole was also present (see Table 2).

3. CMEs AND CORONAL HOLES

From the results of our study, we think that a significant relation exists between those CMEs association with interplanetary shocks and the nearby presence of a coronal hole. It can be argued that such relation with holes is only a matter of chance as holes are spread all along the solar surface. It must be reminded, however, that for the association we considered only those holes within the latitudinal span of the CME, which reduce the number of holes suitable for association. On the other hand, it is easy to see on the maps in Figure 1 and imagine a great number of possible positions of the bars where no close correlation to holes can be found. Moreover, the spatial correlation between coronal holes and CMEs investigated by Harrison (1990) considered all kinds of CMEs (not only those leading to shocks) for a period of three years, and he found no significant correlation between these and coronal holes. The percentage of CME events related to holes in his study was about 40% (the same percentage than in his control window). However, when considering only those CMEs related to interplanetary shocks, as in this paper, the percentage of associations almost doubled as mentioned above. We consider this as significant although, for a more conclusive research, it would be necessary to do the same study also for CMEs not related to shocks. Unfortunately, a list of these is not available to the authors.

For those CMEs taking place at high latitudes, about the border of a polar coronal hole, it could be thought that a close longitudinal association with the hole is very likely whatever the longitude of the CME, for polar coronal holes cover the entire pole. However, as the period considered in this study was around solar maximum, polar coronal holes were very small or absent and even the highest latitude event (No. 8 in the list) was considered as non-associated with a coronal hole because no solar latitudes higher than 70° could be seen at that time and we cannot tell whether or not a polar coronal hole was present.

In relation to this, it is interesting to note

TABLE 2

LONGITUDINAL DISTANCE OF FLARES OR FILAMENTS, ACTIVE REGIONS, AND CORONAL HOLES TO CORONAL MASS EJECTIONS

LONGITUDINAL DISTANCE TO CME LIMB (DEG)				LONGITUDINAL DISTANCE TO CME LIMB (DEG)			
CME No.	Flare/ Filament	Coronal Hole	Active Region	CME No.	Flare/ Filament	Coronal Hole	Active Region
1	...	30	...	26	...	35	...
2	...	2	...	27	51	37	15
3	...	0	...	28	0	59	0
4	...	15	50	29	30	35	35
5	...	50	40	30	16	0	5
6	71	...	15	31	11	0	0
7	35	...	...	32	...	10	5
8	...	...	...	33	...	0	5
9	...	...	...	34	...	0	...
10	21	...	...	35	41	10	30
11	...	1	30	36	...	0	0
12	...	0	60	37	1	0	5
13	...	3	15	38	3	23	0
14	...	0	...	39	34	12	40
15	30	0	60	40	...	45	0
16	...	2	50	41	18	12	20
17	23	52	10	42	...	0	45
18	...	9	0	43	43	0	15
19	8	0	0	44	...	0	15
20	...	0	0	45	1	38	0
21	40	10	30	46	54	0	0
22	...	3	25	47	1	0	0
23	...	...	15	48	...	5	...
24	4	7	15	49	13	10	0
25	44	60	20	...	...	...	...

that CMEs tend to occur at higher latitudes in time of maximum activity when they encompass a wide range of latitudes, extending even to solar polar regions (MacQueen, Hundhausen, & Conover 1986). This is precisely the time when polar coronal holes grow smaller and contract to higher polar latitudes apparently accompanied by CMEs. Another interesting and significant observation has to do with the way in which CMEs propagate through the corona at different times in the solar activity cycle. While the CMEs observed with the *Skylab* coronagraph near the minimum show an average motion toward the equator, as found earlier by Hildner (1977), the CMEs observed with the SMM coronagraph near sunspot maximum show no such tendency (MacQueen et al. 1986). It is well known that at the minimum of solar activity, the large coronal holes occupying the Sun's polar regions have fluxes whose divergence is much more than radial and bend towards the equator as shown by eclipse images and theoretical simulations (see for instance Munro & Jackson 1977; Bravo & Mendoza 1989). Thus, in terms of an association of CMEs with coronal holes, this type of motion is expected. At times of high solar activity and small polar coronal holes, the solar wind flowing at low heliospheric latitudes is provided by mid- and low-latitude holes and the overall configuration of flux and field lines is quite different. MacQueen et al. (1986) also consider the possibility that the propagation of CME events is influenced by the background magnetic and flow patterns and that the difference between *Skylab* and SMM events is due to the well known contrast in coronal hole structure between sunspot minimum and maximum.

Nevertheless, though the relation between coronal holes and those CMEs associated with interplanetary shocks seems significant to us, we do not think that coronal holes are originating the observed CMEs. The amount of mass involved in these events is too large to be thought as coming

·om the open flux tube of a hole. It seems more kely that CMEs are actually the "release" of huge mounts of material previously confined near the un's surface by closed magnetic field lines. What e deduce from the association found is that the resence of a coronal hole seems to be necessary ɔr the formation of an interplanetary shock and ıis suggests to us that they actually are involved ·ith the formation of the shock. This conclusion is ıpported by the fact that the association between 'MEs and interplanetary shocks is not as straight-ɔrward as could be thought and we analyze this in ıe following section.

4. CMEs AND INTERPLANETARY SHOCKS

Many authors think at present that CMEs are istons that are physically responsible for the in-ːrplanetary shocks, but when analyzing in detail ıe wide scope of observations presented by Sheeley t al. (1985) relative to the association between MEs and interplanetary shocks, things do not ppear very clear. These authors found that only 7% of the *Helios* shocks could be associated with ear-equatorial CMEs that span at least 36° of ıtitude on the limb toward *Helios*. These were uoted as "confident" associations and are the ones nalyzed here. But 33% of the shocks could be as-ɔciated in time only to CMEs whose smaller sizes nd/or unfavorable positions made them seem less kely to be physically related to the shock; they ılled these associations as "possible" but emphasize ıat some (or all) of them may be valid. They also ɔund that 2% of the shocks clearly lacked CMEs.

An analysis of the velocities of the CMEs (V_{cme}) nd the shocks at Helios (V_{sh}) for the confi-ent associations shows that in 43% of the cases $_{sh} \gg V_{cme}$, in 47% $V_{sh} \ll V_{cme}$ and in 10% $_{sh} \cong V_{cme}$, which indicates a poor correlation be-ween CMEs speeds with *in situ* shock speeds. More-ver, in 15% of the cases the CMEs were rath-r slow, with V_{cme} < 400 km s^{-1}. When con-ıdering the average transit velocity of the shock V_{ave}) computed by taking the time between the rst observation of the CME and the time of de-ːction of the shock at *Helios*, it turns out that in 4% of the cases $V_{ave} < V_{sh}$ and for the remaining 6% $V_{ave} > V_{sh}$. This leads to the conclusion that ɔmetimes the shock accelerates in its way into the ıterplanetary space, but most of the times they ecelerate on route from the Sun to *Helios*. How-ver, none of the CMEs observed decelerated in the ɔronagraph field of view.

Although a detailed analysis of type II or type IV adio bursts was not made by the authors for the ample of CMEs confidently associated with shocks, ıey do comment that the association is not signifi-ant and that some very fast CMEs lack metric type II bursts. They arrive at the conclusion that some of the disturbances do steepen into shocks as they propagate out into the inner heliosphere. When the shock was followed up to six hours later by highly disturbed plasma showing the typical signatures of a driver gas (i.e., Schwenn, Rosenbauer, & Mulhauser 1980; Zwickl et al. 1983), the authors considered that the shock was piston driven. They reported that only 46% of the shocks had clear pistons, 36% clearly had not, and 18% were indeterminate. The cases for piston coincided mainly (in 83% of the cases) with those events when a surface eruptive event accompanied the CME. It is also important to recall that the shape and extension of the coronal shocks sometimes observed in front of CMEs do not coincide with those of interplanetary shocks.

5. A PROPOSED SCENARIO

We do not consider that all the above discussion leads necessarily to abandon the idea that CMEs are driving the interplanetary shocks and many arguments can be and have been posed trying to find satisfactory or plausible explanations to the whole set of observations in defense of that idea. But in view of the previous discussion we think that interplanetary shocks associated with the CMEs are not necessarily physically related to the motion of the CME and that the presence of a nearby coronal hole has actually something to do with the formation of the shock. It is possible that a shock is actually formed in the flux tube of the coronal hole by the same cause which produces a mass release (a CME) in its bordering closed region: for example, the emergence of new magnetic flux with different polarity. When this occurs, an alter-ation of the hydromagnetic conditions is driven in a broad region as a consequence of the necessary re-arrangement of field lines.

If, for example, different polarity material e-merges at one side of an originally closed large scale magnetic region, such as a helmet streamer, this re-arrangement may lead to the opening of some (or all) of its field lines and to the release of part (or all) of the mass contained in it, producing a CME. If this closed region is beside a coronal hole (as commonly are), the restructuring of its lines also affects the structure of the nearby hole. More specifically, the opening of its lines makes the coronal hole base to grow larger while the upper part of the hole, limited by the neutral sheet, remains practically the same (see Figure 5). This leads to a decrease of the divergence of the flux lines in the hole. The dependence of a coronal hole flow on its divergence has been studied by several authors (see for instance Pneuman 1973; Durney & Pneuman 1975; Pneuman 1976) and they have shown that the outflow velocity of the solar wind from the hole increases as the divergence

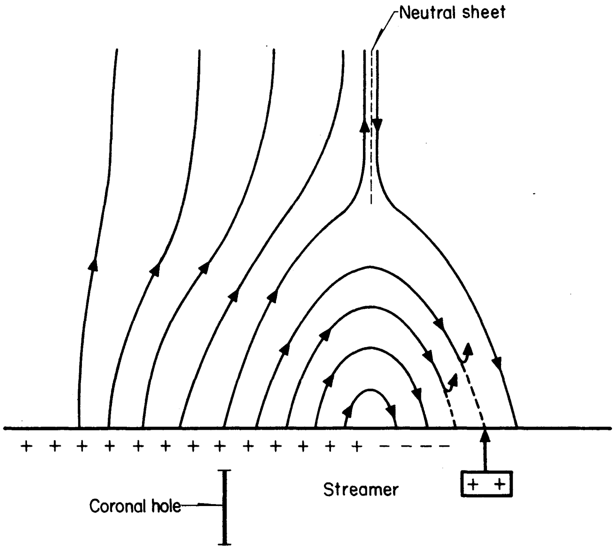


Fig. 5. Scheme showing the disconnection of some of the closed field lines of a streamer due to the emergence of field of different polarity. The original border of the adjacent coronal hole moves to the right to include the newly open field lines and the divergence of the hole's flux tube decreases.

decreases. In this way, the flow from the hole after the extension of its base would be faster than before. Dryer, Wu, & Han (1980) have simulated numerically the effect in the interplanetary space of such an event by assuming a big and rapid change in the solar wind velocity taking place for a long period of time, and they found that a shock front travelling in the interplanetary space forms.

As an observational support, Kaigorodov & Fainshtein (1991) have reported on the association of increases in coronal hole areas from one day to the next, as deduced from daily photospheric magnetograms, with the formation of interplanetary shocks. More recently Watanabe et al. (1994) reported on the solar observations made with *YOHKOH SXT* which show the sudden extension of a low latitude coronal hole associated with the eruption of a filament and the occurrence of an X-ray flare on 28 September 1991. They mention a growth rate of the coronal hole area of about 3×10^5 km^2 s^{-1}, which is about twenty times faster than that of the coronal magnetic field in the normal condition. A solar wind disturbance with a speed of 400–570 km s^{-1} was observed by IPS on early October 1, and the sudden commencement of a geomagnetic storm was also reported later.

In the scenario proposed here, the sometimes related occurrence of the disruption of an underlying or nearby prominence can also be understood in terms of the loss of equilibrium of the whole region caused by the disconnection and reordering of the magnetic field lines. In the same way, a flare can als be triggered as the consequence of the emergence o the new magnetic flux of different polarity if an ac tive region is located there. If this is the case, the as sociated flare should be observed at one side of th CME spread as Harrison (1986) found to happen In another paper, Harrison et al. (1990) reported as a result of the Coronal Mass Ejection Program that the observations confirm that CME onsets pre cede any related flare activity and that the associate flaring commonly lies to one side of the CME span

Nevertheless, if the nearness of a coronal hol is actually needed to have shocks travelling fron the Sun into the interplanetary medium, there is problem in our study with those events for whicl a near coronal hole was not found. When lookin at the interplanetary shock properties as observe by *Helios* and reported by Sheeley et al. (1985) no obvious differences are found for these event with respect to those with a coronal hole in thei source region. One limitation of our study is tha we considered the coronal holes as recorded i He I 10830 A maps which reflect mainly the siz and shape that the holes have while crossing Sun' central meridian, and we relate these with near t the limb phenomena about a week's time difference All the changes in the holes along their transit fron limb to limb are not taken into account, includin the possible presence of a hole disappearing befor crossing the central meridian and the appearanc of a new one after passing through it. The latte case, the birth of a coronal hole, would be only particular case in the scenario presented above.

It is also possible that the resulting nearnes of a coronal hole to the region of emission o the CME is only due to the fact that holes ar commonly beside the closed coronal structure where CMEs are likely to be emitted from, and tha they have really nothing to do with the formatio of the interplanetary shock. But in this case, th relation between CMEs and coronal holes would b statistically the same for CMEs associated and no associated with interplanetary shocks. Our result suggest that this is not the case, but an extende study would be worthwhile.

6. CONCLUSIONS

In summary, we think that the observation analyzed here suggest the idea that CMEs and in terplanetary shocks are related by-products of common cause affecting two adjacent but differen kinds of coronal regions, namely a magneticall closed one (most probably a helmet streame consistent with Kahler & Hundhausen 1992) wher the CME is originated, and an open one from wher the interplanetary shock is formed. In the scenari proposed, the coronal shocks sometimes observe ıear the compressive leading edge of CMEs would ıot necessarily be the same as the shocks observed ater in the interplanetary space. Although we lo not find this study as conclusive, we do think t should serve to encourage further observational ınd modelling efforts concerning coronal holes, oronal mass ejections and interplanetary shocks in ırder to be able to understand better how they are elated to each other.

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