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Association of coronal holes with large scale solar magnetic fields

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Abstract. Association of coronal holes with large scale solar magnetic fields has been investigated. It is concluded that coronal holes always form in the large unipolar magnetic field patterns, and no specific polarity rule holds true for low-latitude coronal holes. The coronal holes show a strong tendency to bypass the opposite polarity regions in their location. Coronal holes get fragmented into pieces, if opposite polarity flux encroaches and/or erupts into their boundaries. Migration of coronal holes or their fragments and the growth of coronal holes out of hole fragments are also discussed.

Key words : coronal hole—solar magnetic fields

1. Introduction

Coronal holes are regions with decreased electron density and/or temperature as compared to the surrounding regions and, therefore, one observes decreased coronal emission from them (Munroe & Withbroe 1972). Coronal holes occur over regions of relatively weak magnetic fields (Vaina *et al.* 1973; Altschuler *et al.* 1972) which correspond to open field line systems diverging from photosphere. Bohlin & Sheeley (1978) have noted that the coronal holes do not occur in the absence of perceivable disc activity and have also discussed the formation of coronal holes. Using the data by Bohlin & Rubenstein (1975) and McIntosh (1975), they have also inferred that the coronal holes always occur in unipolar magnetic cells and that the coronal holes do not seem to cross magnetically neutral lines. McIntosh *et al.* (1976) and Bohlin & Sheeley (1978) have enunciated a polarity rule for the coronal holes. According to these authors, the northern hemisphere coronal holes form in positive magnetic cells, whereas the southern hemisphere holes form in the negative magnetic cells.

In these studies, Bohlin & Sheeley (1978) have used a methodology of superposition of H_α synoptic charts on coronal holes. The delineation of magnetically neutral lines and that of the regions of opposing polarities were inferred from these H_α synoptic charts. In comparison to that the use of Stanford large scale magnetic field synoptic charts alongwith helium 10830 Å synoptic charts (which are expected to have a close correspondence with the emissions from coronal holes, *cf.* Harvey *et al.* 1975) would be a much more direct and hence a better approach for such studies. In our investigation, the synoptic charts of the Stanford large scale magnetic field and of the helium 10830 Å taken from the Solar-Geophysical data for the period 1978 December to 1979 August have been used. On the basis of these data we have undertaken a study of the association of coronal holes with the large scale solar magnetic fields (i) to investigate the occurrence of coronal holes within the unipolar magnetic field regions; (ii) to check the magnetic polarity rule for coronal holes; and (iii) to check the past investigations concerning the magnetic field strength in the coronal holes. (iv) As a new aspect of the problem we have tried to go into greater details regarding the development, evolution and fragmentation of coronal holes.

2. Coronal holes and large scale magnetic fields

2.1. Existence of coronal holes within unipolar magnetic cells

In figures 1a–1i, the K.P.N.O. helium 10830 Å synoptic charts of Carrington rotation 1676–1684 are superposed on the corresponding Stanford large scale magnetic field synoptic charts. In figures 1a–1i, the coronal holes show a marked tendency to avoid the pre-existing and newly erupted magnetic regions of opposite polarities. In this regard, the best example is the coronal hole no.1 (CH 1) which was found to be located in the negative polarity region during rotation 1676. A new region A of opposite (positive) polarity appeared later at latitude S 55, longitude 120 in rotation 1677. As a consequence thereof, the shape of CH 1 got adjusted accordingly, leading to an avoidance of this new region of opposite polarity. Other examples are CH 4 (rotation 1682) and CH 4 (rotation 1684).

2.2. The magnetic polarity of coronal holes

The polarities of northern and southern hemisphere coronal holes read out from figures 1a–1i are listed in table 1. Table 1 shows that on the average only about 62.5% of the total northern hemisphere coronal holes form in the positive polarity magnetic field structures, whereas about 66.6% of the total southern hemisphere coronal holes form in the negative polarity field structures. This indicated that the low-latitude coronal holes do not follow a specific polarity rule such as that given by Bohlin &

Table 1. The polarities of coronal holes read out from figures 1a–1i

Carrington rotation	Northern hemisphere coronal holes with		Southern hemisphere coronal holes with	
	+ve polarity	—ve polarity	+ve polarity	– ve polarity
1676	7	3	1	1
1677	2	0	1	0
1678	4	0	2	0
1679	3	1	2	1
1680	3	2	3	4
1681	3	3	4	2
1682	1	3	3	2
1683	1	2	2	1
1684	1	1	2	2

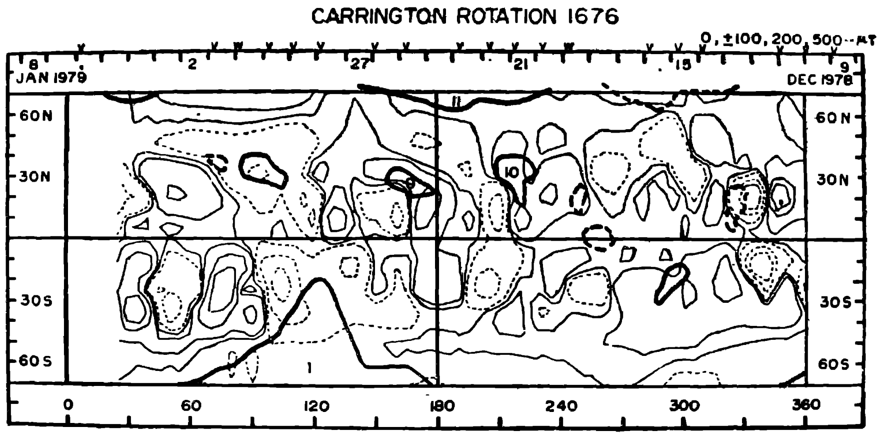

Figure 1a

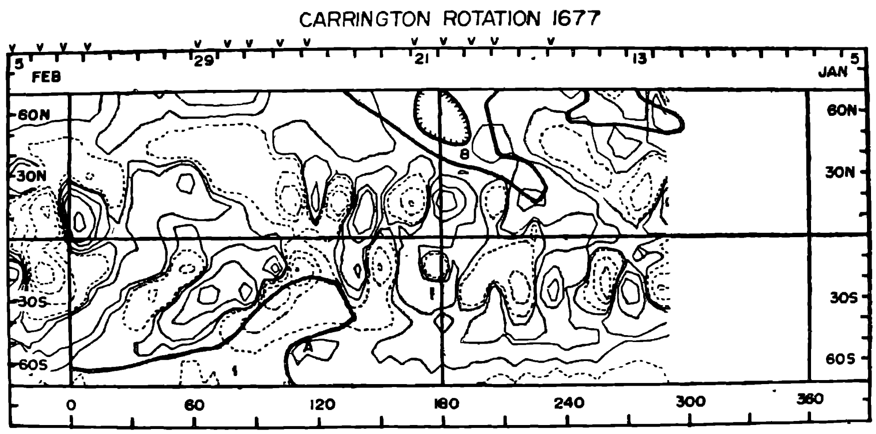

Figure 1b

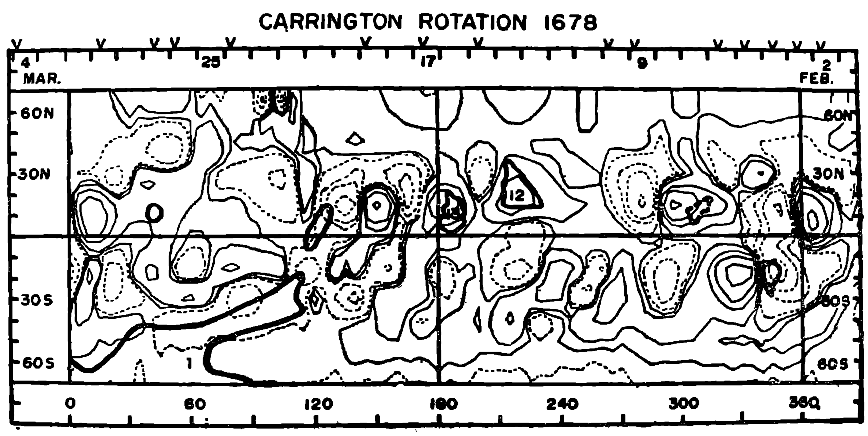

Figure 1c

Sheeley (1978). However, the polarity rule given by these authors appears to be valid only for the polar coronal holes.

2.3. The magnetic field strengths in coronal holes

Inspection of figures 1a–1i leads to some more conclusions regarding the fields within the holes:

CARRINGTON ROTATION 1679

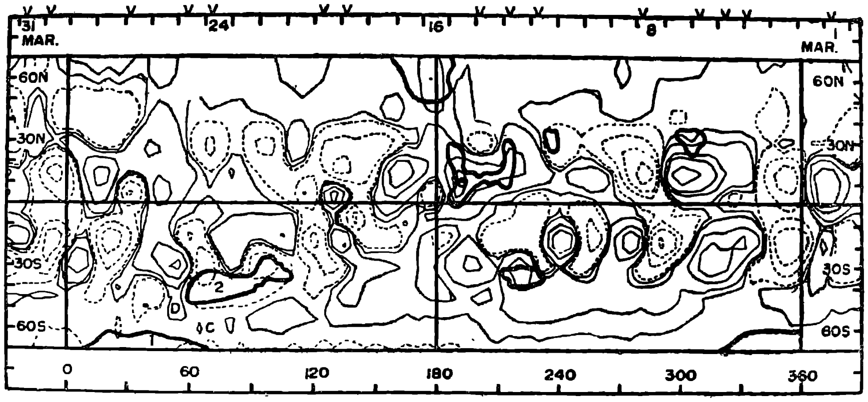

Figure 1d

CARRINGTON ROTATION 1680

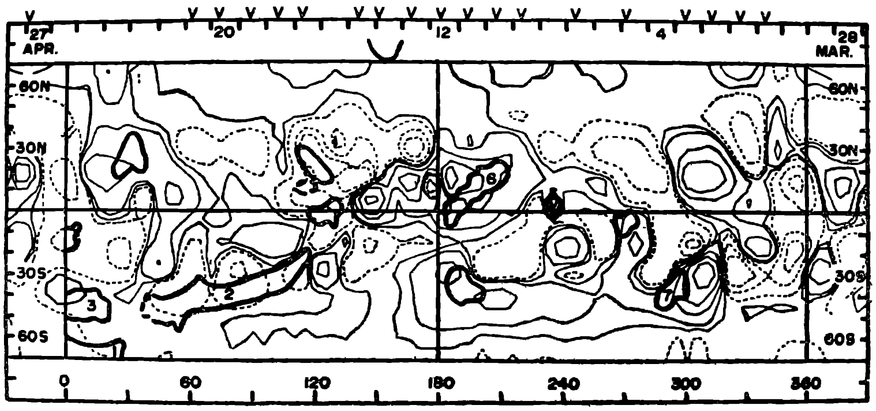

Figure 1e

CARRINGTON ROTATION 1681

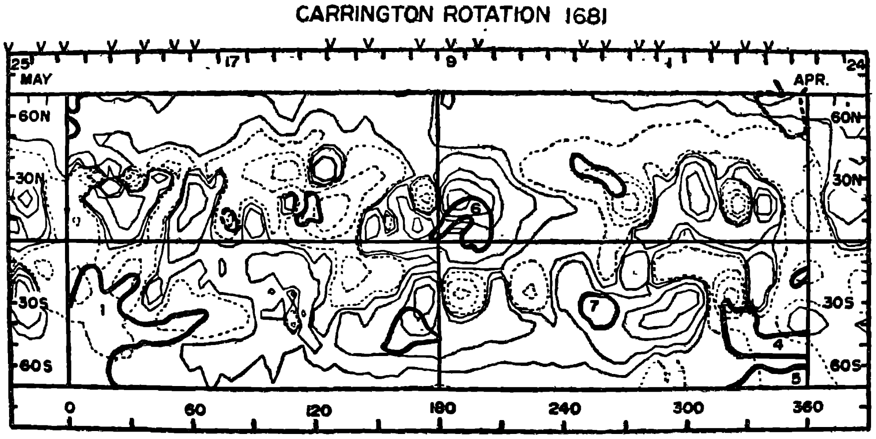

Figure 1f

(i) The field strength is markedly nonuniform within the holes themselves (*e.g.* CH 1 in rotation 1677; CH 2 in rotation 1680; CH 6 in rotation 1679, 1680 and 1681).

(ii) Bohlin & Sheeley (1978) followed a coronal hole over a few solar rotations. They found that its average field decreased in the later rotations. In the data used by us, CH7 in rotation 1680 seems to be a good example which apparently confirms this finding. This hole first appeared in a strong field region at longitude 290 in

CARRINGTON ROTATION 1682

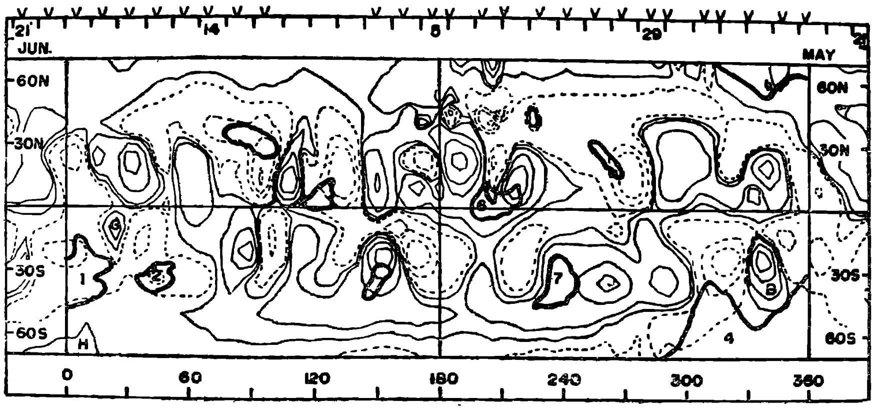

Figure 1g

CARRINGTON ROTATION 1683

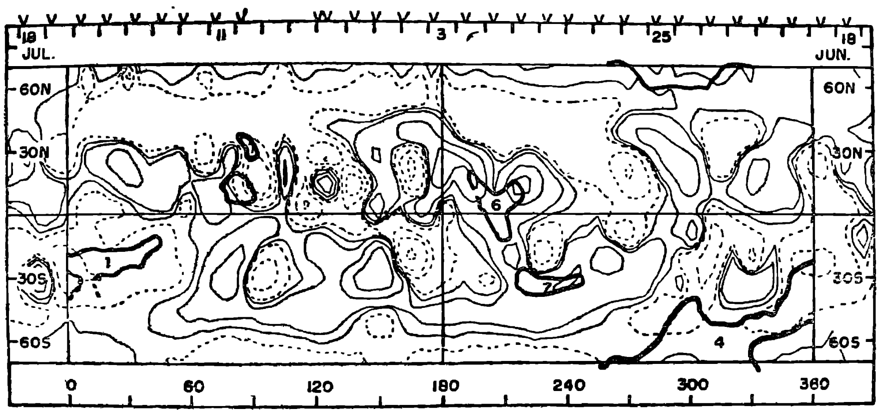

Figure 1h

CARRINGTON ROTATION 1684

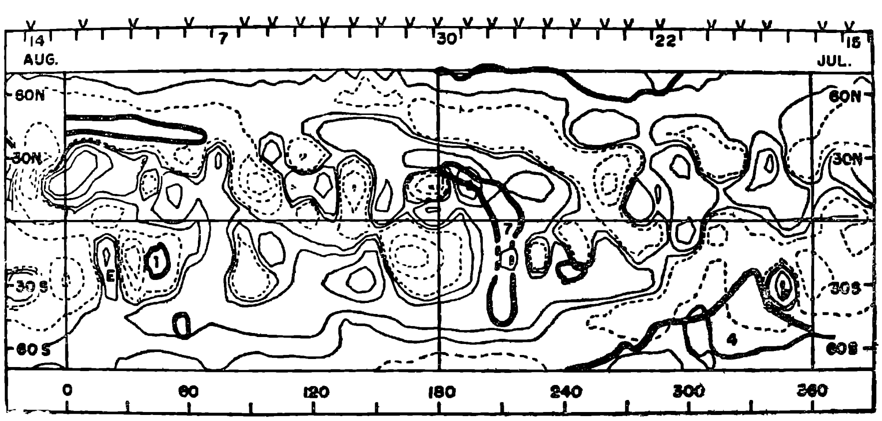

Figure 1i

Figures 1a–1i. Superpositions of helium 10830Å synoptic charts of rotations 1676 through 1684 on the corresponding Stanford large scale magnetic field synoptic charts.

rotation 1680. In the next rotation, 1681, CH 7 appeared to have shifted to the weak field region at longitude 255. This shifting of the hole from stronger to weaker field regions is also displayed in CH 7 of rotation 1683. The appearance of stronger magnetic field region of same polarity in rotation 1683 realigned CH7 from east-west orientation to north-south orientation during rotation 1684, *i.e.* to a region of diminished field strength in rotation 1684. Thus, the decrease in the average field strength in coronal holes during later rotations may be due to a shift of the holes themselves from stronger field regions to weaker field regions.

3. Evolution of coronal holes

3.1. Fragmentation of coronal holes

Coronal holes follow the evolution of unipolar magnetic field structures in which they are located. In the case when an opposite polarity region erupts and/or if neighbouring opposite polarity region encroaches within the hole boundary, then it is most likely that the hole will get fragmented into pieces. This can be seen in case of CH 1 (rotation 1678). This large southern polar hole is fragmented into two pieces during rotation 1679, probably as a result of the appearance of new opposite polarity region C (lat. S 60, long. 65) and also due to an encroachment of neighbouring opposite polariy region D within the boundary of CH 1 itself. Other examples of this fragmentation are found in CH 1 in rotation 1681 and 1682, and also in CH 1 in rotation 1683 and 1684.

3.2. Development af coronal holes

Our study shows that a large coronal hole develops out of the nearby coronal holes if they appear in the same polarity magnetic cell. The best example is CH 8 in rotation 1677 which developed out of three coronal holes, namely CH 9, CH 10 and CH 11 of rotation 1676. Other examples are CH 6 (rotation 1679) which developed out of CH 12 and CH 13 in rotation 1678, and CH 7 (rotation 1684) which developed out of CH 6 and CH 7 of rotation 1680.

3.3. Migration of coronal holes

Consider the coronal hole CH 7 in rotation 1680. This hole appeared at longitude 290° in a strong field region. During the next rotation, CH 7 appeared to have shifted to longitude 255, that is, to a weaker field region. During succeeding rotations till 1684, CH 7 appeared to have got shifted to longitude 210 in rotations 1684. This example may be a pointer to the migration of coronal holes.

4. Conclusions

Briefly, the coronal holes always form in the large scale unipolar magnetic field structures (cells), within the magnetic neutral lines, and exhibit marked tendency to bypass the opposite polarity regions erupting near the boundaries of holes. Under such circumstances the coronal holes change their shapes. In extreme cases, the coronal holes get disrupted and/or fragmented into pieces when opposite polarity flux regions erupt inside the holes or when a neighbouring opposite polarity region encroaches into the holes. The holes or their fragments also have a tendency to shift to comparatively weaker magnetic field regions resulting in the migration of holes towards such regions. Holes or their fragments in the same polarity region join together resulting in a large coronal hole.

Our study also indicates that except for polar coronal holes, mid-latitude holes do not obey specific polarity rule of the kind described earlier by Bohlin & Sheeley (1978).

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