A MODEL COMBINING THE POLAR AND THE SECTOR STRUCTURED SOLAR MAGNETIC FIELDS

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Abstract. A phenomenological model of the interplay between the polar magnetic fields of the Sun and the solar sector structure is discussed. Current sheets separate regions of opposite polarity and mark the sector boundaries in the corona. The sheets are visible as helmet streamers. The solar sector boundary is tilted with respect to central meridian, and boundaries with opposite polarity change are oppositely tilted. The tilt of a given type of boundary [(+, −) or (−, +)] changes systematically during the sunspot cycle as the polarity of the polar fields reverses. Similar reversals of the position of the streamers at the limbs takes place.

If we consider (a) a sunspot cycle where the northern polar field is inward (−) during the early part of the cycle and (b) a (+, −) sector boundary at central meridian then the model predicts the following pattern; a streamer at high northern latitudes should be observed over the west limb together with a corresponding southern streamer over the east limb. The current sheet runs now NW-SE. At sunspot maximum the boundary is more in the N-S direction; later when the polar fields have completed their reversal the boundary runs NE-SW and the northern streamer should be observed over the east limb and the southern streamer over the west limb.

Observational evidence in support of the model is presented, especially the findings of Hansen, Sawyer and Hansen and Koomen and Howard that the K-corona is highly structured and related to the solar sector structure.

1. Introduction

Several new observations – some of them with new techniques – of the corona and the solar wind from the solar surface to beyond the Earth can be interpreted in a unifying phenomenological model of the interplay of large-scale magnetic regions on the Sun. In the following sections we outline the model and the observational evidence supporting it. We adopt a simple approach which seems to be justified *a priori* by the apparent success of the model in organizing the observational data.

2. The Model

The magnetic field of the Sun exhibits two large-scale organized features: the polar fields and the solar sector structure. Both features have large spatial extent and can exist on time scales up to several years. In both cases the magnetic field intensity is weak and hence the structures are characterized by open field lines carried out by the solar wind. Between regions containing oppositely directed open field lines neutral sheets or current sheets are expected to occur to separate the fields. The intersection of these sheets with the ecliptic at 1 AU can be observed with spacecraft and are normally referred to as 'sector boundaries' (Wilcox, 1968). Comparisons between the photospheric magnetic field and the interplanetary field near the ecliptic seem to suggest that the sector boundaries on the Sun are approximately in the north-south direction

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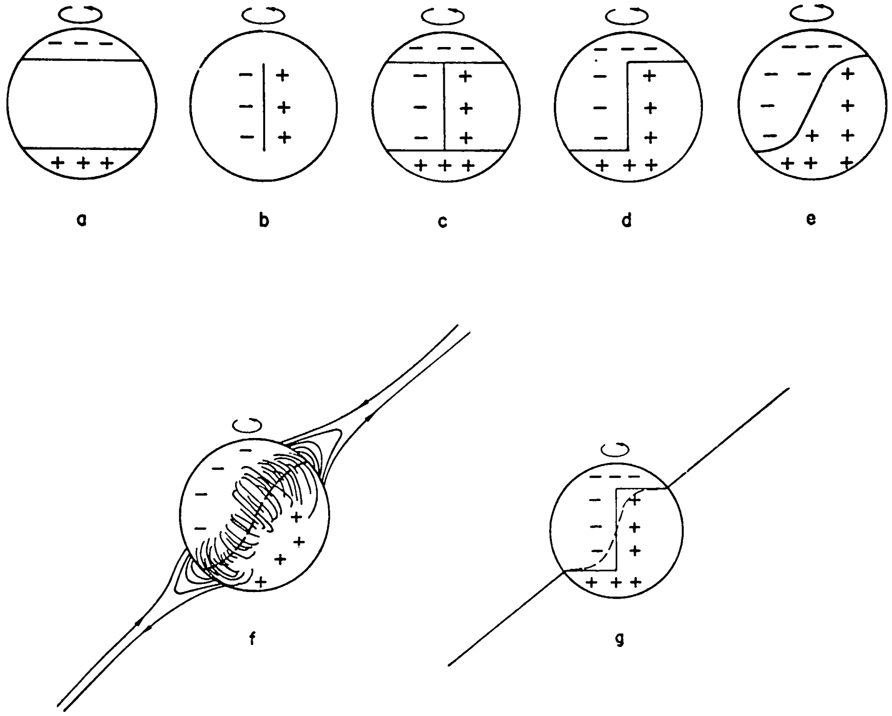

Fig. 1a–g. Stages leading to our model of a solar sector boundary on the solar disk. (a) Dipolar polar fields. (b) North-south sector boundary, (+, −). (c) Superposition of (a) and (b). (d) Schematic of boundary between opposite fields. (e) More realistic sector boundary. (f) Magnetic field line arcade and corresponding helmet streamers in the outer corona over the solar sector boundary. (g) Schematic representation of (f).

crossing the equator and having a considerable extent in latitude, perhaps up to 40° on both sides of the equator (Schatten *et al.*, 1969). Traditionally the polar fields have an approximately east-west oriented boundary or limit at times extending down to 55° latitude (e.g., Severny, 1971). Figures 1a and 1b are schematic diagrams outlining these large-scale properties of the polar fields and of the sector structure respectively. We will in the beginning assume that we are dealing with a two-sector structure.

Since both features – the polar field and the sector structure – can co-exist we may superpose Figure 1a and 1b to get Figure 1c. By removing lines which do not separate opposite polarities we are led to Figure 1d. The remaining lines are expected to define the projection of current sheets separating oppositely directed fields. Actually we might expect that the current sheet runs more smoothly over the photosphere in the outer corona. It is even conceivable that the 'S' shaped boundary in Figure 1e may be closer to the real physical situation.

Large open magnetic field structures in the corona are generally believed to manifest themselves as helmet streamers. The rounded, inner forms of the helmet delineate closed field lines of a magnetic arch with foot points in regions of opposite magnetic polarities. The narrower, outward extension of the helmet into a streamer marks field lines which are open and expanding with the solar wind. In this model of the helmet streamer a current sheet separates the open field lines of opposite magnetic polarity in the outer corona (Pneuman and Kopp, 1971). Such a current sheet might be most clearly visible when seen edge-on because we would expect a density enhancement in the sheet to balance the magnetic pressures. If the density is high enough it might even be possible to identify the sheet as a fan-like structure when seen side-on.

From the foregoing discussion we can then sketch (Figure 1f) the magnetic field structure near the boundary. A two-sector structure is assumed here. Near the photosphere we have a magnetic arcade of low-lying closed field lines straddling the boundary. In the outer corona this arcade has opened up and a current sheet marks the boundary in the expanding plasma. At the limbs this sheet will be seen as two helmet streamers in opposite hemispheres when the sector boundary crosses the center of the disk. Identification of magnetic arcades with sector boundaries has been suggested by Newkirk (1972) and Wilcox and Svalgaard (1974a). For the sake of the discussion a schematic of the boundary and the streamers associated with it is shown in Figure 1g.

If we combine the model outlined in Figure 1 with the generally accepted sunspot cycle change of the polar fields, some interesting conclusions may be drawn. In the beginning of the cycle the polar fields are assumed to be quite regular and strong, being of opposite polarity in the two hemispheres. Near the maximum of the cycle the polar fields are considerably weakened and shortly after maximum they reverse (Babcock, 1961; Wilcox and Scherrer, 1972) and increase in strength and extent during the declining phase of the sunspot cycle. Using the procedure described in the above paragraph we construct diagrams like Figure 1g for various parts of the sunspot cycle and for both kinds of sector boundaries (+, − or away-toward; −, + or toward-away). The result is shown in Figure 2. The left-hand panel shows the situation early in the cycle, while the right-hand panel shows the situation well after sunspot maximum. The upper panel may be interpreted as showing the ‘visible disk’, and the lower panel will then display the ‘invisible disk’, or the corresponding upper-panel diagrams after one half solar rotation.

If the north polar field is inwards (−) in the early part of the cycle we would expect a helmet streamer at high northern latitudes on the west limb when a (+, −) sector boundary is at central meridian and a corresponding southern streamer on the east limb (Figure 2a). The current sheet runs approximately NW-SE with an appreciable tilt with respect to the central meridian. At sunspot maximum, when the organized polar fields tend to disappear the current sheet should be oriented more in the N-S direction (Figure 2b). Later, when the polar fields have completed their reversal the current sheet runs NE-SW, now having a tilt opposite to the pre-maximum one (Figure 2c). Therefore the northern streamer would be expected at the east limb and the corresponding southern streamer should appear over the west limb. For the same kind of sector boundary (here: +, −), the position of the high latitude streamers should change during the sunspot cycle, reversing when the polar fields reverse. An analogous pattern is of course expected for the other kind of sector boundary (−, +; see Figures 2d–f).

Let us now turn to the patterns we would get by rotating one of the model diagrams, for instance the diagram in Figure 2c. Seven days of solar rotation will bring this

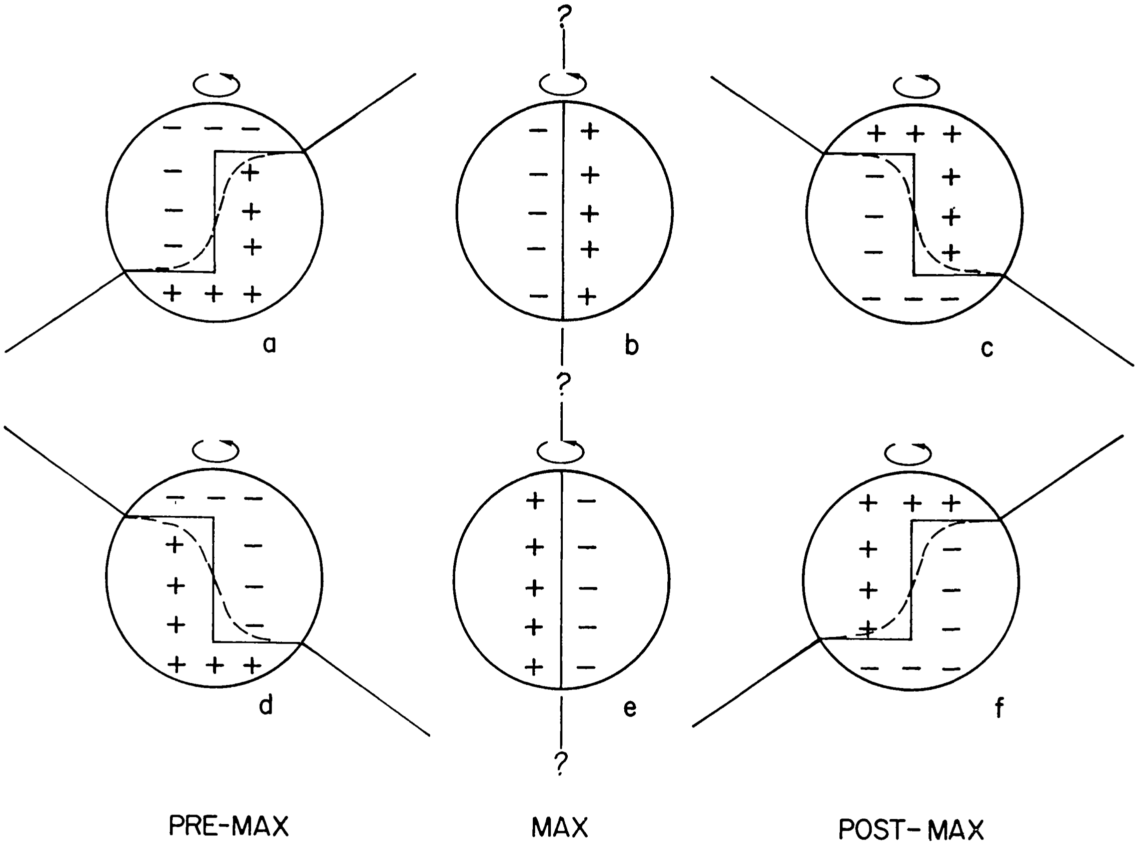

Fig. 2a–f. Sunspot cycle changes in the position of coronal streamers related to solar sector boundaries. The figure is representative for an even numbered cycle such as the present.

sector boundary and its associated current sheet to the limb, where we will see the sheet side-on. If the electron density is high enough the sheet may be visible as a fan-structure centered on the equator and extending to higher latitudes both north and south of the equator. Figure 3 shows the anticipated appearance of the current sheet and the magnetic polarity of the large scale fields through one solar rotation. It may very well be that the fan has a rather uniform brightness without too much internal structure, but this all depends on how the electron density varies along the sheet. The fan is, however, expected to be more conspicuous near the equator than at very high latitudes. This is a consequence of a combination of two effects. First, if the iso-density curve is a heliocentric circle on the current sheet, any tilting of this circle would make it appear elliptical with the major axis along the tilt axis, i.e., an equatorial diameter. Secondly, the density in the current sheet is conceivably higher at low latitudes than at very high latitudes; this means that the iso-density curve itself will be somewhat elliptical as to further enhance the equatorial brightness of the fan.

To the right of each solar diagram in Figure 3 is shown the condition of the interplanetary magnetic field as it would be observed near the Earth – first 4 days and then 11 days after the corresponding solar structure shown to the left. If we consider for example the structure in Figure 3b, we would expect to see equatorial fans in the K-corona and the solar magnetic mean field would be negative; after about 4 days the

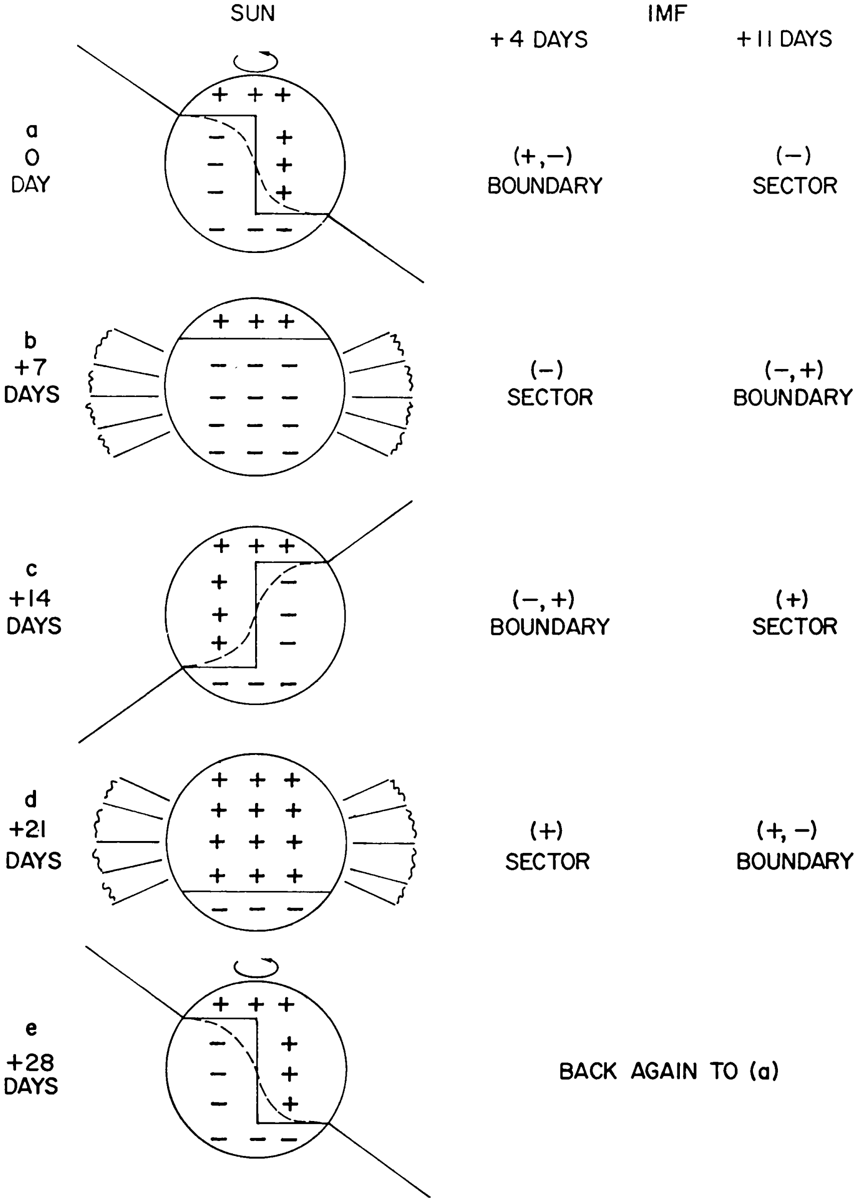

Fig. 3a–e. Changes in apparent location of streamers and sector boundaries during one solar rotation assuming two sectors. At the right is shown the condition of the interplanetary magnetic field (IMF) near the Earth following 4 days and 11 days respectively after the corresponding solar configuration at the left.

Earth is embedded in this wide interplanetary negative sector, and after further 7 days (a total of $11=7+4$) the (−, +) sector boundary which was on the east limb in diagram 3b will be observed to sweep by the Earth.

Since the sector boundaries on the Sun are assumed to be tilted and since the solar equator is not in the ecliptic plane, we expect that the interplanetary sector boundaries observed near the Earth will be systematically shifted in time depending on the heliographic latitude of the Earth. Consider the tilted (−, +) solar magnetic boundary in Figure 4a. If the Earth is to the north of the solar equator the sector boundary as

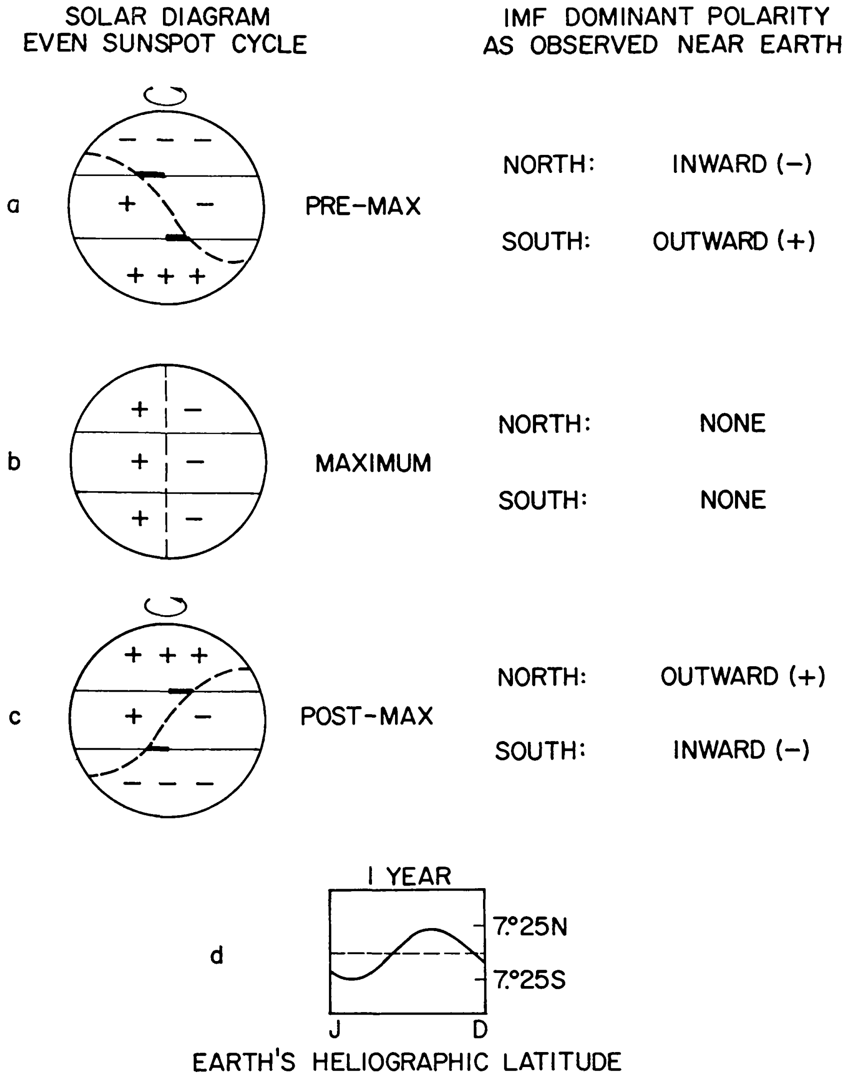

Fig. 4a–d. Annual changes in the dominant polarity of the IMF due to the combined effect of tilted solar sector boundaries and the annual change of the heliographic latitude of the Earth. The horizontal lines across the solar disk diagrams show schematically the intersection of the ecliptic with the disk at the maximum northern latitude of the Earth (+ 7.°25 at September 7) and at maximum southern latitude (− 7.°25 at March 7).

observed at the Earth will be observed later than if the heliographic latitude of the Earth was zero. This delay is indicated by a heavy line on Figure 4a. Similarly the sector boundary would be observed earlier when the Earth is to the south of the solar equator. In other words, the interplanetary sector with the same polarity as the north polar region would be observed at Earth to be wider when the Earth is to the north of the equatorial plane of the Sun and to be narrower when the Earth is to the south of the solar equator. When one sector is wider than the other in the two-sector pattern, one polarity will predominantly be observed. This polarity will be that of the north polar region when the Earth is to the north of the solar equatorial plane and vice versa, as indicated in the right-hand panel in Figure 4.

So far we have been discussing the structural features for the case of only two magnetic sectors of opposite polarity per solar rotation. It is straightforward to extend the discussion and the predictions derived from it to a four-sector structure. The paired northern and southern streamers would then be about 90° apart in longitude instead of 180° as in the case with two sectors. Similarly the systematic change of the coronal structure shown in Figure 3 would repeat twice during the solar rotation. The magnetic structure in the photospere might be similar to the schematic diagram in Figure 5b for four sectors, while Figure 5a might be representative for a two-sector structure.

It is seen that generally we could consider the sector boundary to be one unbroken curve on the Sun. The sector structure can then be thought of as imposing a warping of the heliomagnetic equator. A similar idea based on theoretical considerations has been proposed by Schulz (1973).

Finally we will emphasize that the current sheets discussed above are related to magnetic structures on a very large scale. It is understood that numerous current or neutral sheets are present in the inner corona due to the complicated magnetic structure in this region with many polarity reversals. With increasing height the magnetic field structure becomes increasingly simpler as more and more field lines close and no longer

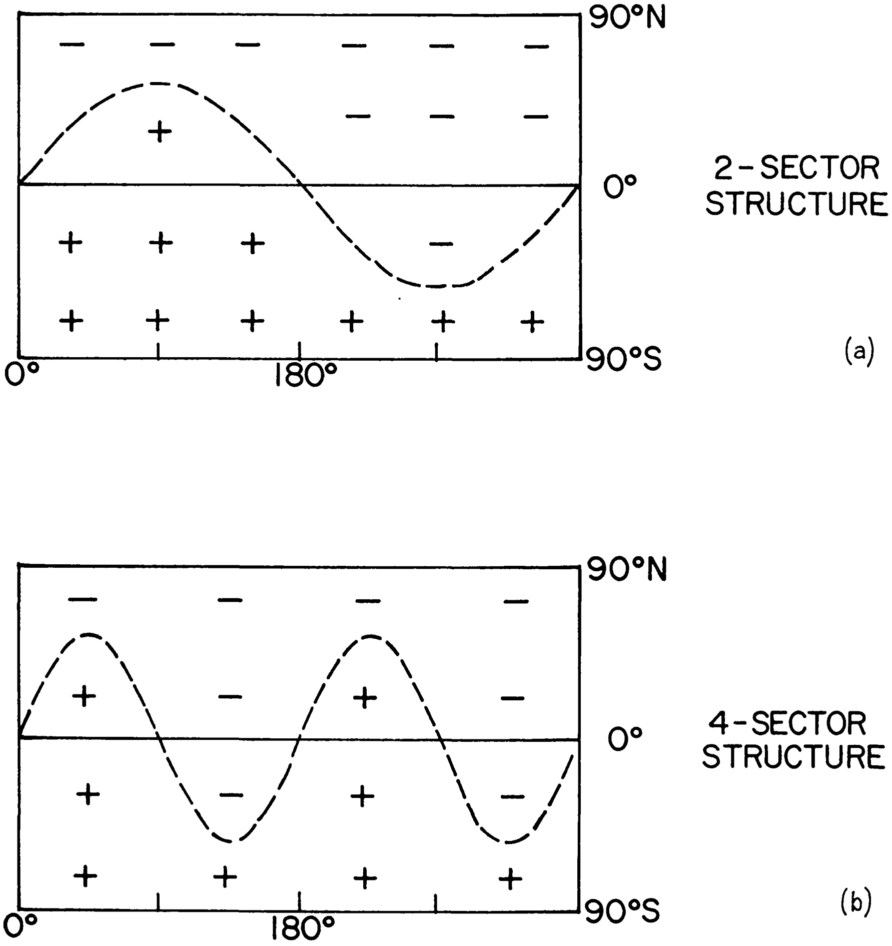

Fig. 5a–b. 'Synoptic map' – type diagrams outlining solar sector boundaries in latitude and longitude for the two- and four-sector structure.

contribute to the flux; the interplanetary magnetic field is thus related to this simplified structure in the outer corona rather than to the complicated features found in the photosphere or in the chromosphere.

3. Observations

The simple model we have outlined in the previous section seems to organize a large body of otherwise somewhat puzzling data. In this section we will present these observational data in support of the model.

Wilcox and Svalgaard (1974a) examined the computed coronal magnetic field (Newkirk *et al.*, 1973) associated with a very stable (+, −) sector boundary recurring for about 25 solar rotations during 1968 and 1969. During these years the polar fields were very weak and fluctuating, often in unison (Howard, 1972). We would then expect a north-south aligned sector boundary as shown schematically in Figure 2b, and in fact this is actually observed. Figure 6 shows the clear signature of this boundary in the magnetic field of the inner corona. The north-south oriented magnetic arcade is very

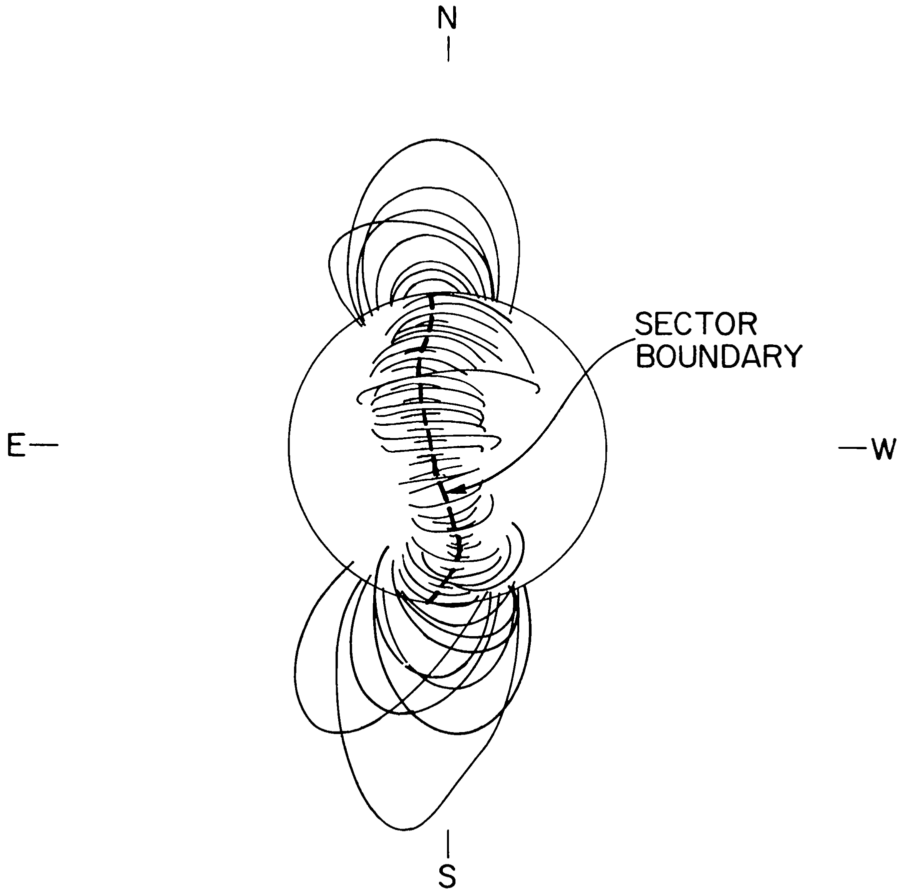

Fig. 6. Magnetic arcade loop structure for 1.5 March 1969 redrawn from the weak field map of the coronal field atlas (Newkirk *et al.*, 1973). The dashed line is the sector boundary drawn through the middle of the lowest loops. Field lines away from the boundary region are omitted. (From Wilcox and Svalgaard, 1974a).

evident; also it is worth noting that the boundary seems to be marked by a row of low-lying closed coronal magnetic loops.

Examining the maps of calculated potential magnetic fields of the corona published by Newkirk *et al.* (1973), the orientation of the current sheets between oppositely directed fields can be inferred easily by following the magnetic arcades of closed loops at the base of the sheets. In Figure 7 we show four solar sector boundaries determined by extrapolating sector boundaries observed at the Earth back to the Sun. The average transit time was 5 days, but in each case the coronal field line map was chosen when the intersection of the magnetic arcade with the ecliptic was closest to central meridian. We see that central meridian at the time of a sector boundary separates a pair of high-latitude coronal loop-systems which we assume are the base of corresponding coronal streamers. One system of loops is in the northern and the other in the southern hemisphere. When one loop-system is at the east limb or near it, the other system is at or near the west limb and vice versa. By noting that the left-hand panel repesents observations *before* sunspot maximum while the right-hand panel has been observed *after* maximum, we find that the calculated coronal structures are consistent with our model (compare with Figure 2). The examples we have presented here are typical of

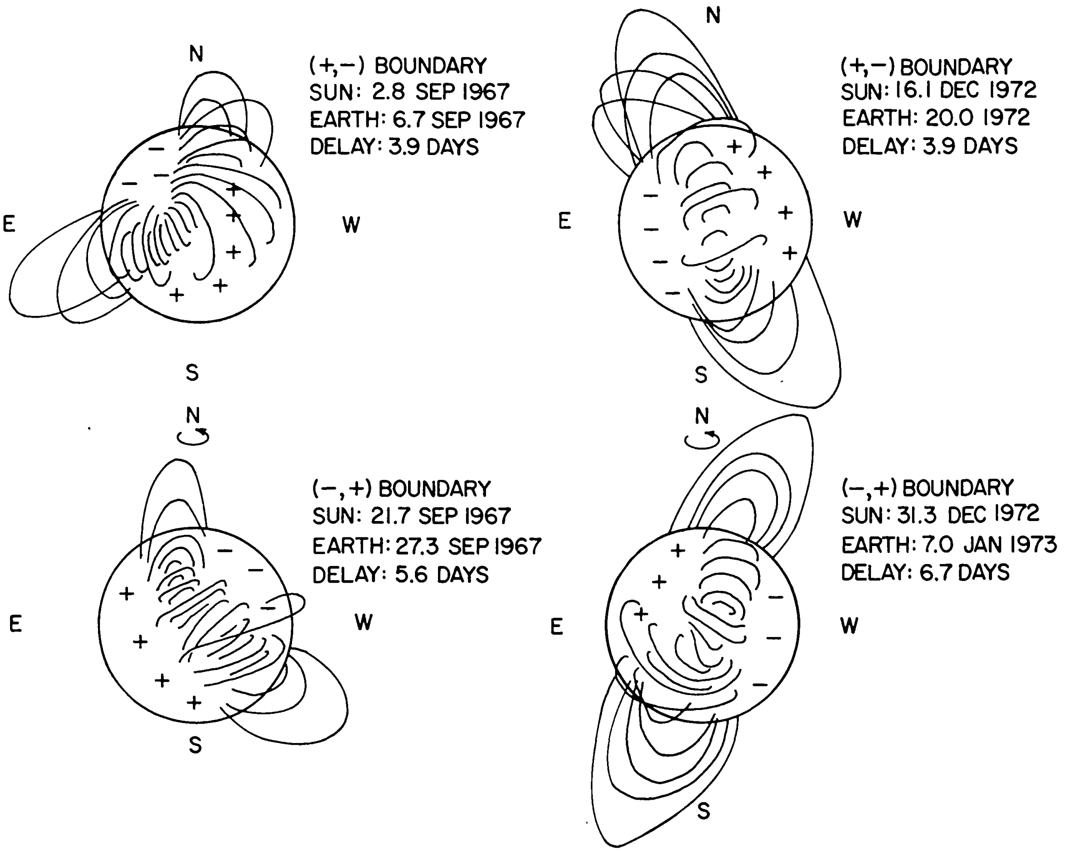

Fig. 7. Magnetic arcade loop structures for four sector boundaries. The left-hand panel shows maps before sunspot maximum, while the right-hand panel shows maps after sunspot maximum. Field lines away from the boundary regions are not drawn.

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very many others as may be seen from an inspection of the calculated coronal field line atlas. Taken by itself, this field line structure might be ascribed to artifacts in the computational procedure used in deriving the coronal field structure. Seen in the wider perspective of our model and of the observations of the green line corona discussed below, we may infer that the association implied in Figures 6 and 7 has considerable physical significance.

The green line emission (Fe XIV at 5303 Å) from the corona is normally observed very close to the limb at 1.03 solar radii heliocentric distance. Often the emission forms loop-like structures and on the whole the intensity of the green line is determined by the density of the coronal ions having a temperature in the rather narrow range producing this particular emission. We would generally associate higher density regions with closed field lines trapping the plasma, and low density regions with open field lines. The closed field line loops are often observed in connection with active regions and hence the green line emission is correlated with solar activity. Analyses of the rotation rate of the green line corona suggest (e.g., Sýkora, 1971; Antonucci and Svalgaard, 1974a) a two component structure. One component rotates with the rotation rate characteristic of short-lived magnetic fields is the photosphere, showing a considerable degree of differential rotation and is probably directly related to active regions. The other component seems to rotate rigidly with a nearly constant period (near 27 days synodic) independent of latitude up to at least $\approx 55°$. We would associate this rigidly rotating component with emission from plasma condensations trapped on closed field lines across the rigidly rotating solar sector boundaries (Wilcox and Howard, 1968).

If this is so, a considerable correlation should exist between the green line intensity observed at high northern latitudes and at high southern latitudes respectively. From Figure 2 we would infer that high emission at about 45° N should be followed by high emission at about 45° S after a delay of about 14 days for a two-sector structure; for four sectors, high emission at 45° N should be followed by high emission at 45° S after delays of 7 days and $14+7=21$ days, or stated differently at 14 ± 7 days.

Sýkora (1971; personal communication, 1973) has prepared synoptic tables of the green line intensity for the period 1947–1970. The tables give the average emission for six latitude zones each 20° wide extending from about 60° N to 60° S and giving one value per day as the average of the emissions at the east limb seven days before and at the west limb seven days later. The expected correlation discussed above has been investigated by cross correlating the emission in the two high latitude zones (Antonucci and Svalgaard, 1974b). Figure 8 shows that the highest correlation ($+0.14$ for the entire 24-yr data set) was found at lags of about $\pm$ 15 days thus confirming our expectations for a two-sector structure. Smaller peaks of high correlation could be seen at 6 days and 9 days on either side of the 15-day peaks indicating the influence of four sectors. These delays are sufficiently close to the expected 14 days and 14 ± 7 days that we consider the green line observations in support of our model. The very fact that *any* correlation exists between the two high latitude zones in opposite hemispheres at a lag significantly different from zero strongly suggests that the green line corona in-

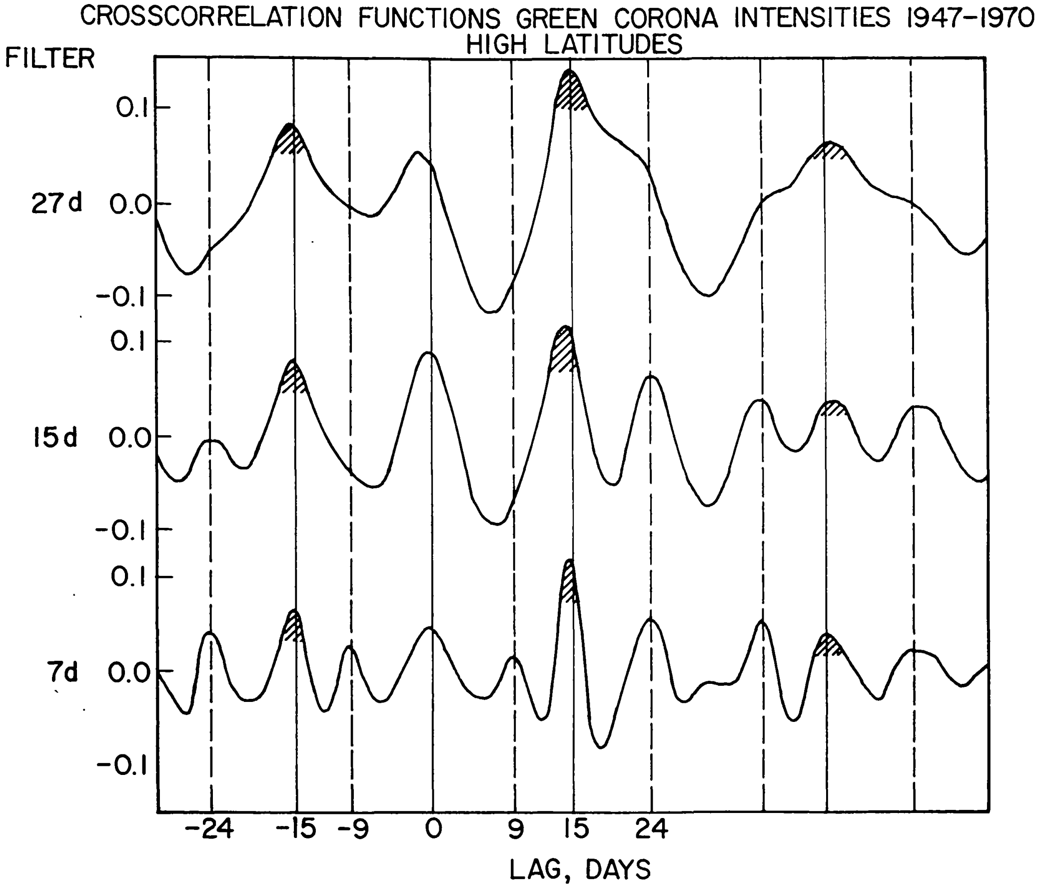

Fig. 8. Cross correlation functions of green line corona emission for the interval 1947–1970. The emission in the zone 57°.5 N–37°.5 N is cross correlated with the emission in the zone 37°.5 S–57°.5 S for lags varying from − 30 to + 60 days. The peak at zero lag is presumably due to random noise which is common to both latitude zones, such as varying sky transparency, change of observatory from which the reported green line emission was derived, etc. Long-term variations have been removed by subtracting a running mean over 27 days for the top curve, 15 days for the middle curve and 7 days for the bottom curve. This successively sharpens the peaks corresponding to short period variations. The dashed vertical lines identify peaks 6 and 9 days from the principal peaks which are shaded. (After Antonucci and Svalgaard, 1974b).

cludes a component which is organized on the largest scale possible; and the quantitative agreement of the observed delays with the expected values is encouraging.

By comparing the overall structural form of the inner K-corona (from 1 to 2 solar radii, $R_\odot$) at times when solar sector boundaries are at central meridian during the ascending part of the 20 th sunspot cycle (1964-1970), Hansen *et al.* (1973, 1974) found that central meridian at the time of a sector boundary separates a pair of high-latitude K-corona brightness enhancements which they associate with coronal helmet streamers (see also Hansen *et al.*, 1972), one located in the northern and the other in the southern hemisphere, and separated in longitude by as much as 90° or more. A striking difference was indicated in the analysis between (+, −) and (−, +) boundaries. A (+, −) boundary (compare with Figure 2a) was generally separating a northern helmet streamer in the western hemisphere from a southern streamer to the east of the boundary. On the other hand, a (−, +) boundary (compare with Figure 2d) generally

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falls between a northern streamer to the east of the boundary and a southern high-latitude helmet streamer in the western hemisphere. These observed features are precisely what we would expect for the early part of cycle 20 before the polar fields reverse. According to Howard (1972) and Gillespie *et al.* (1973) the polar regions reversed magnetic polarity beginning in 1971, hence the findings by Hansen *et al.* are consistent with the coronal structure for the appropriate part of the sunspot cycle as evidenced by Figures 2a and 2d. We should note that our model differs significantly from the *model* implied in Hansen *et al.* (1973) as will be discussed below (see also Figure 9).

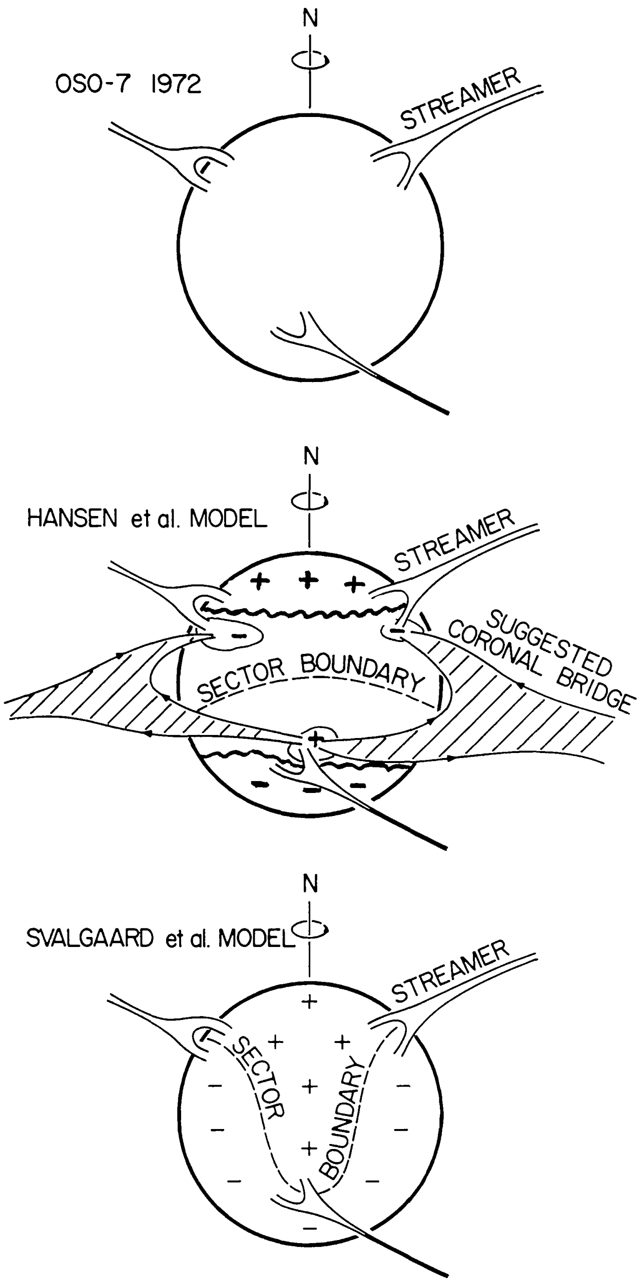

Fig. 9. Schematic diagram showing the locations of coronal streamers inferred from OSO-7 observations of the four-sectored structure in 1972. Below is shown the interpretation of these observations in terms of the model of Hansen *et al.* (1973) and of the model presented in this paper.

Further evidence consistent with our model comes from a very important study by Howard and Koomen (1973) – following a suggestion by S. F. Hansen. On daily images of the white light corona obtained by the OSO-7 coronagraph from 3 to 9 $R_\odot$ they found high latitude streamers and equatorial fans recurring in a systematic way for many solar rotations. (See also Howard *et al.*, 1974). These were virtually the only stable features seen at 3–9 $R_\odot$. Occasionally a short-lived streamer could be seen, but most of the observed streamers were persistent and showed a regular pattern of alternation between northern and southern streamers (at a given limb), separated frequently by the appearance of an equatorial fan. The streamers appear to be sheets seen edge-on rather than a tubular structure since they remain for some days over the limb before fading away. As they fade away they move slightly towards the equator and are replaced by the equatorial fan, which then is seen for a few days before finally a streamer becomes visible in the other hemisphere. During most of 1972 the OSO-7 observations showed a persistent structure consisting of two northern streamers about 180° apart in longitude and a similar pair of southern streamers shifted 90° in longitude. Precisely such a pattern would be expected for a stable four-sector structure. Near the end of 1972 the coronal pattern appeared to be breaking up into only one northern and one southern streamer per rotation. This structure became well established in 1973 and should be the signature of a two-sector structure.

Comparison of the coronal patterns with the sector structure as inferred from polar geomagnetic observations (Svalgaard, 1972; Wilcox, 1972; Wilcox and Svalgaard, 1974b) results in a correlation of northern streamers at the east limb with a (+, −) sector boundary near central meridian, and of southern streamers at the east limb with a (−, +) sector boundary near central meridian, and finally of an equatorial fan with a sector centered on central meridian (Howard and Koomen, 1973; Howard *et al.*, 1974). Furthermore the interplanetary structure changed abruptly from four sectors to two sectors per rotation following the change in the coronal pattern at the end of 1972. The sector concept is here used in the stricter sense of meaning the longitudinal extent in the ecliptic of a large-scale solar region of one polarity. Since the polarity of the northern polar region is positive (outwards) during the years of the OSO-7 observations – 1972 and 1973 – the correlations are consistent with our model (see Figure 3). It is significant that the coronal structure observed during 1972–1973 by OSO-7 at the times of central meridian passage of sector boundaries is reversed compared with the structures observed by Hansen *et al.* (1973) for the interval 1964–1970, i.e., before the polar fields reversed polarity.

In their model of the coronal structure of sector boundaries Hansen *et al.* (1973) suggests the existence of huge, ordered coronal structures with magnetic footpoints in the unipolar magnetic regions of opposite hemispheres. They call these structures coronal bridges and assume them to be the source of interplanetary magnetic field reversals, i.e., sector boundaries. This interpretation of the data is contrasted to our model in Figure 9, which shows the two different interpretations of the four-streamer structure observed by OSO-7 during 1972. A principal difference is that the sector boundaries inferred from the two models are nearly perpendicular near the ecliptic.

In addition the two models differ fundamentally in their explanation of the same observational data in the sense that the model by Hansen *et al.* starts with small to medium scale features (bipolar regions) and from interplay of these features with the polar fields constructs stable structures on the largest scale with lifetimes of the order of years, while our model explains the stability and size of the structures by insisting on an interplay between features which are inherently large-scale from the beginning.

From a few years of spacecraft observations of the interplanetary magnetic field, Rosenberg and Coleman (1969) showed that there is an annual variation in the predominant polarity of the interplanetary field observed near the Earth. This effect was confirmed by Wilcox and Scherrer (1972) using the sector polarities inferred from polar geomagnetic data back to 1926 (Svalgaard, 1972). At the time when this Rosenberg-Coleman effect was first observed by spacecraft the number of days with toward the Sun polarity (−) in each solar rotation varied in phase with the heliographic latitude of the Earth (see Figures 4 and 10). Wilcox and Scherrer showed that on the average $2\frac{2}{3}$ yr after sunspot maximum this phase relation reverses and suggested that the reversal was related to the reversal of the polar fields on the Sun. The phase reversal is clearly seen in Figure 10, as well as a lack of any clear annual variation during 1968–1969 where the polar fields were weak and unorganized. The qualitative agreement between these observations of the Rosenberg-Coleman effect and the predictions of our model (Figure 4) is taken as further observational support. Quantitatively the observed effect is larger than we might expect from a reasonably tilted solar sector boundary.

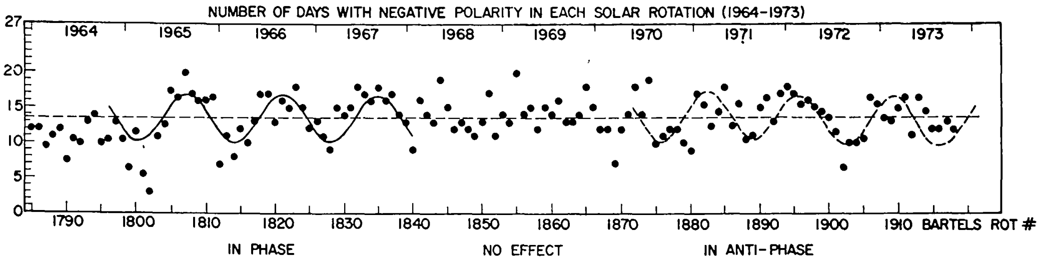

Fig. 10. Number of days with negative polarity observed in the inferred interplanetary magnetic field for each Bartels 27-day rotation since 1964. Before sunspot maximum the amount of negative polarity observed varies in phase with the heliographic latitude of the Earth, but after maximum the two variations are out of phase.

In Figure 11 the dashed curve (a) is a schematic of the sector boundary on the Sun. To explain the magnitude of the Rosenberg-Coleman effect the current sheet at larger distances should appear more like the dotted curve (c). We could suggest some interaction with solar activity in the sunspot zones pushing the low-latitude current sheet towards the equator; how this can happen is at present not understood. The fact that it is possible to see the current sheet side-on as an equatorial fan in the OSO-7 observations might suggest that the sheet beyond, say, 3 $R_\odot$ is indeed bent like curve (c) in Figure 11, because in this case the line-of-sight density near the equator will automatically be enhanced.

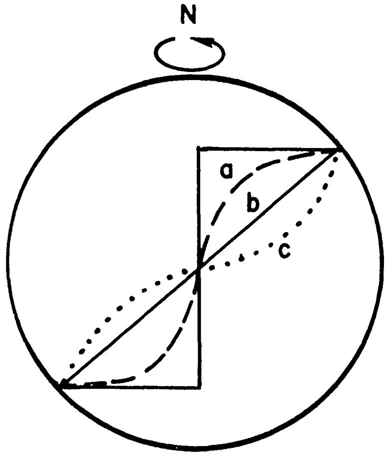

Fig. 11. Hypothetical change of solar sector boundary between the inner corona (a) and the outer corona (c). (See text.)

It is well known that the K-corona is nearly spherical near sunspot maximum while it is appreciably flattened near minimum. We propose that at least part of this variation is caused by the systematic displacements of the sector boundary current sheets during the sunspot cycle implied by our model. When the polar fields are strong the current sheets do not extend to very high latitudes and the K-corona appears more elliptical, while at maximum – when the polar fields disappear – current sheets extend across the polar regions resulting in a more spherical appearance of the coronal brightness.

We have presented a number of observations supporting our model. The model suggests further observational tests such as superposing solar magnetograms at times of sector boundary central meridian passage. It is here important that the two kinds of boundaries [(+, −) and (−, +)] are analyzed separately, and that the first half and the last half of the sunspot cycle are treated separately. If this separation is not done, the oppositely tilted boundaries will on the average appear to be in the north-south direction consistent with the results of many previous investigations.

Acknowledgements

Shirley F. Hansen first noticed that observations of the K-corona could be correlated with the interplanetary magnetic sector structure. Preparation of the present paper was stimulated by a discussion with Martin J. Koomen and profited from discussions with Shirley F. Hansen and Richard T. Hansen. We thank the people just mentioned and Constance B. Sawyer and Russell A. Howard for communicating their results to us in advance of publication.

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