ACTIVE REGIONS AND THE INTERPLANETARY MAGNETIC FIELD*

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ABSTRACT

The relation of solar active regions to the large-scale sector structure of the interplanetary field is discussed. In the winter of 1963–64 (observed by the satellite IMP-1) the plage density was greatest in the leading portion of the sectors and lesser in the trailing portion of the sectors. The boundaries of the sectors (places at which the direction of the interplanetary magnetic field changed from toward the Sun to away from the Sun, or vice versa) were remarkably free of plages. The very fact that since the first observations in 1962 the average interplanetary field has almost always had the property of being either toward the Sun or away from the Sun (along the Archimedean spiral angle) continuously for several days must be considered in the discussion of large-scale evolution of active regions. Using the observed interplanetary magnetic field at 1 AU and a set of reasonable assumptions the magnetic configuration in the ecliptic from 0·4 AU to 1·2 AU has been reconstructed. In at least one case a pattern emerges which appears to be related to the evolution of an active region from an early stage in which the magnetic lines closely couple the preceding and following halves of the region to a later stage in which the two halves of the region are more widely separated.

Spacecraft observations from the time of the first extended observation of the interplanetary medium by Mariner 2 in 1962 to the present time have indicated that the sector structure is almost always a prominent feature of the interplanetary magnetic field. The sector property of the interplanetary field is defined to be its tendency to remain for several consecutive days predominantly directed either away from the Sun or toward the Sun. The average direction of the field is usually close to the theoretically predicted Archimedes spiral. Large dynamic deviations from the Archimedes spiral are frequently observed; nevertheless the field can usually still be clearly characterized as being either directed predominantly toward the Sun or away from the Sun.

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The interplanetary sector structure observed by IMP-1 in the winter of 1963–64 during the decline of the last 11-year sunspot cycle was a quasi-stationary pattern during several solar rotations. This is presumably related to the low level of solar activity and the resultant small amount of perturbing influences on the sector pattern. The sectors observed at this time had on the average an internal structure such that the efflux of solar wind plasma and the strength of interplanetary magnetic field were largest in the preceding portion of the sectors. The position of active regions on the Sun with regard to the interplanetary sector pattern has been investigated in the following way. A cross-correlation analysis by Ness and Wilcox (1966) showed that the average time lag from the appearance of a photospheric magnetic feature at central meridian to the observation of this feature by the spacecraft at 1 AU was about $4\frac{1}{2}$ days. Thus, if a sector boundary is observed by a spacecraft at 1 AU on a certain date, the date at which this boundary on the Sun was near central meridian can be obtained by subtracting this $4\frac{1}{2}$-day lag. When the date at which a sector boundary is near central meridian on the Sun has been determined by this method, the Fraunhofer Institute daily map of the Sun for this day provides the location of plages on the disk. A photographic superposition is obtained of the plage locations for all days

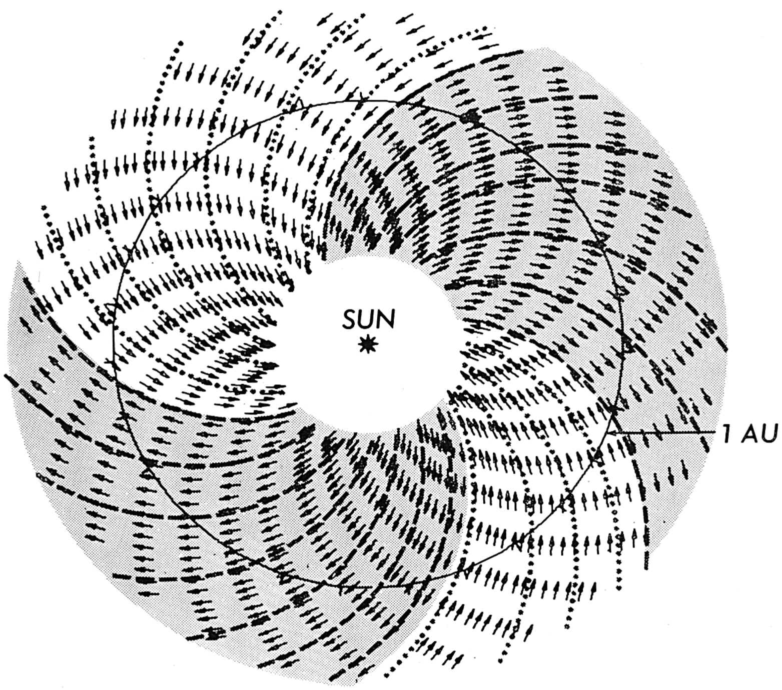

FIG. 1. *Map in ecliptic plane of average interplanetary magnetic-field sector structure observed by IMP-1. The extrapolation technique is described in the text. Each arrow represents an equivalent magnetic flux of 5 gamma for 6 hours.*

on which a sector boundary was near central meridian. This superposition indicates that the probability of occurrence of a plage is greatest in the preceding portion of a sector, and declines in the trailing portion of a sector, with the sector boundaries being relatively free of plages. Details of the method have been given by Wilcox and Ness (1967); see in particular their Figure 4.

The birth of an away sector within a large toward sector has been observed with the following method. A map of the configuration of the interplanetary field projected onto the ecliptic in the radial interval from 0·4 to 1·2 AU has been constructed by extrapolating satellite measurements at 1 AU. The radial component of the field is assumed to scale as $1/R^2$ and the azimuthal component of the field is assumed to scale as $1/R$. An Archimedes spiral is a special case of this assumption, as shown in Figure 1, which is a map of the average sector structure observed by IMP-1. Figure 1 is included to assist in explaining the method of analysis. It can be seen in Figure 1 that if the observations at 1 AU are assumed to consist of field directed at 45° to the Earth–Sun line the Archimedes spiral is recovered, and the sector boundaries remain as sharp discontinuities in the direction of the field. The extrapolation is meaningful for those features of the interplanetary field which do not change significantly in the 2- or 3-day

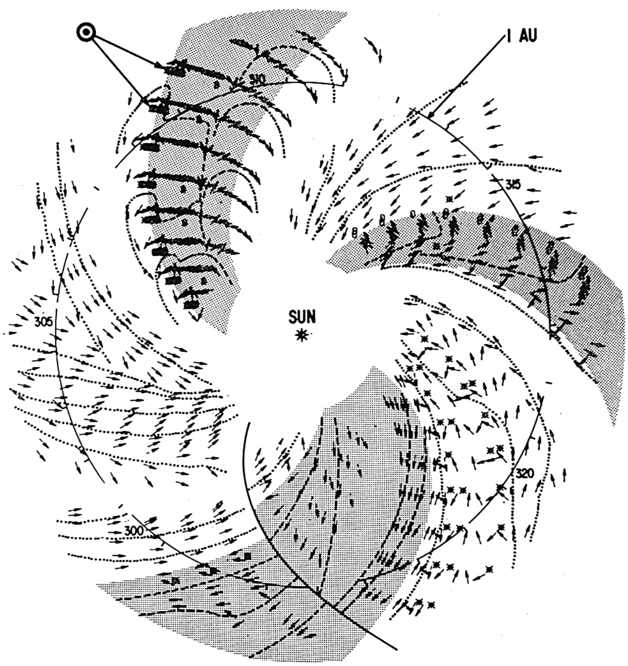

FIG. 2. *Map in ecliptic plane of interplanetary magnetic field observed by IMP-3 during Carrington solar rotation 1500. Intervals in which the field is directed more than 45° from the ecliptic are indicated with small circles. Intervals in which the field fluctuates to a large extent within the averaging interval are indicated with small stars.*

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interval required for the solar wind to flow from 0·4 AU to 1 AU. Since the sector pattern has often been quasi-stable over several solar rotations it can be expected that there will be significant features of the interplanetary field which will be invariant over a 2- or 3-day interval.

The method described above has been used to construct a map of the interplanetary field actually observed by IMP-3 during solar rotation 1500 in 1965, and the results are shown in Figure 2. The arrows are produced by the scaling process described previously, and the dashed lines are drawn by hand to represent typical field lines. The absolute magnitude of the field vector is represented by the spacing of the arrows, not by their length. Sector areas with field directed predominantly away from the Sun are shaded. The solid curved line near the bottom of the figure represents the cut between the beginning of observations on October 24 and the end of observations on November 20.

The away-from-the-Sun (shaded) sector near the top of Figure 2 is of interest for the present discussion. This represents a new away sector, since in the previous solar rotation this region was part of a large toward sector. The field configuration within this new sector is in the form of magnetic loops which are being convected away from

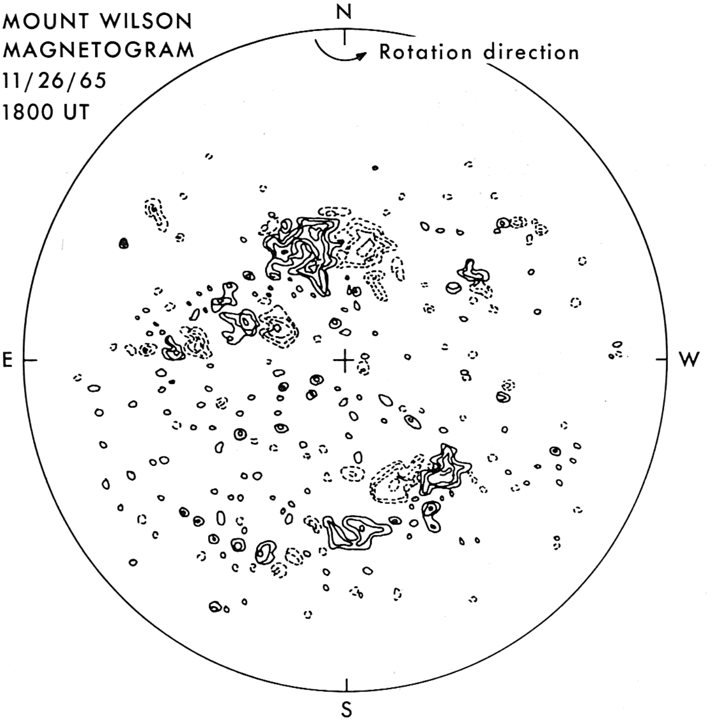

FIG. 3.

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the Sun by the solar wind plasma. In the subsequent solar rotations this sector develops into a substantial away sector having on the average an Archimedes spiral configuration. The loop structure in this sector is observed only in the rotation shown in Figure 2. The central portion of the loop structure, which has magnetic flux directed away from the Sun, is centered at 1 AU on day 310, 0 hours.

Seven days earlier on day 302, 2300 UT, Mt. Wilson Observatory obtained the daily solar magnetogram shown in Figure 3, which displays the line-of-sight component of the photospheric magnetic field. The contours levels are 6, 12, 20 and 30 gauss with solid lines representing fields directed out of the Sun. The large bipolar region near central meridian extending from 15°N – 30°N appears to be the source of the magnetic loops shown in Figure 2. This bipolar region first appeared on the Sun two rotations before the time of Figure 3, and was observed in the next solar rotation to be somewhat dispersed and expanded. The amount of the magnetic flux convected away from the Sun in the loop structure of Figure 2 appears to be in reasonable agreement with the magnetic flux contained in and near the bipolar region shown in Figure 3. A more detailed discussion will be given in a paper presently under preparation.

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