N87-20912

THE WHITE LIGHT CORONA AND PHOTOSPHERIC MAGNETIC FIELDS

Marie K. McCabe
Institute for Astronomy
University of Hawaii
Honolulu, Hawaii

INTRODUCTION

It is recognized that the structure of the heliospheric current sheet, as computed from the observed photospheric magnetic field using a potential field approximation and as inferred from synoptic maps of the observed coronal polarized brightness (pB), gives essentially the same results (Wilcox and Hundhausen, 1983; Burlaga et al., 1981; Pneuman et al., 1978). Thus, white light observations of the corona are often interpreted as indicating the overall structure of the coronal magnetic field, where bright regions of the corona generally lie over neutral line positions (Sime et al., 1984). It might then be expected that inspection of the coronal brightness distribution would allow inference of the large-scale photospheric field structure and vice versa. To test this hypothesis, Garcia et al. (1984) carried out a statistical study of three solar rotations comparing synoptic maps of the longitudinal component of the photospheric magnetic field at λ6303 with maps showing the pB at heights above 1.3 $R_\odot$. Their analysis revealed that no particular type (i.e., active region or quiet) or orientation of neutral line lay predictably below a bright feature, nor was there any hemispheric preference for a particular sense of polarity across the neutral line. Many coronal features were associated with specific neutral lines, but the conditions necessary and sufficient to establish the correspondence were not found.

In this paper some results are presented from a continuing investigation of the coronal structure vs. the photospheric magnetic field relationship. Two approaches to the problem are considered. First, the individual coronal features recorded at each limb were located on a chart of the magnetic field measured with low spatial resolution, depicting the large-scale or global field configuration. Second, the characteristics of neutral line segments--defined by the presence of Hα filaments--with no associated coronal structure were investigated. Preliminary results will be discussed.

DATA

The inconclusive results of Garcia et al. (1984) suggested the following approach to the problem:

1. The data base was expanded from 3 to 19 solar rotations commencing in January 1982. During this period, the interplanetary magnetic field showed a simple two sector structure for several months, but it was more complex at other times.

2. Instead of using synoptic maps of the coronal polarized brightness (pB) distribution for correlation with neutral lines, coronal features were individually

identified from K-coronameter polar scans at 1.3 $R_\odot$ (for details of Mauna Loa Solar Observatory data products, see Rock and Seagraves, 1982). The heliographic coordinates for each feature were determined from the latitude of maximum brightness and the longitude of the limb at the time of the scan. The positions were plotted as shown in Figure 1, on a chart representing the particular rotation, where the circle sizes indicate three ranges of brightness and the filled and open circles indicate measures of the relative height of each streamer.

3. On the global scale, the solar magnetic field is made up of magnetic cells defined by the large-scale neutral lines, which are also marked by filaments, filament channels, etc. (see Levine, 1977). For the present study, the Stanford Solar Magnetic Field Synoptic Charts (SGD, 1982-83) were used to identify large-scale neutral lines. The relatively low spatial resolution--180 arcsec^2--of the maps more nearly matches that of the coronal measurements, which are one day (13°) apart; further, this avoids the small-scale bipolar regions with field lines that are closed at heights in the corona below those used in this study. The Stanford Magnetic Field Chart for Carrington Rotation 1723 (June 15-July 12, 1982) is shown in Figure 1a on which the positions of the coronal features identified as above are also plotted. The heavy black line designates the large-scale or global neutral line that winds around the Sun.

4. Hα synoptic charts published in Solar Geophysical Data Reports include solar magnetic neutral lines inferred from Hα structures (McIntosh, 1972); they also show where filaments have been observed along the neutral lines. This chart for Carrington rotation 1723 appears in Figure 1b with the coronal features plotted as in Figure 1a. The filled-in filaments are those that were clearly visible on Hα filtergrams as they crossed the disk but had no coronal counterpart, for example, streamers, at either limb.

RESULTS

Coronal Features vs. Neutral Line

As seen in Figure 1, the large-scale magnetic field of the Sun at that time was basically a bipolar system. The neutral line appeared to be tilted with respect to the equator for the greater part of the rotation and then completed the cycle with a convoluted path going north near 360° of longitude and through a rapidly developing active region. This pattern had become established by rotation 1720 (March-April 1982) and was maintained through rotation 1725 (August 1982), after which it became much more complex. By inspection, it appears that coronal features are associated with the large-scale neutral line, even when the pattern is complex. To quantify the results for the 19 rotations, the criterion for a positive association of a coronal structure with the neutral line was that it be no more than 10° distant from the line. This was chosen by considering the 1 day interval between K-coronameter measurements and the unknown projection effects at the limb. The results are shown in Table 1 for two selected rotations--1723 and the more complex system of 1729--with the totals given for all 19 rotations. The number and percentage of associations are shown separately for the streamers--where the pB = 1×10^{-8} contour reaches a height above 1.8 $R_\odot$--and for the bright features, where pB $\geq 15 \times 10^{-8}$ disk center brightness. The last column indicates the number of structures that were both bright and streamer-like.

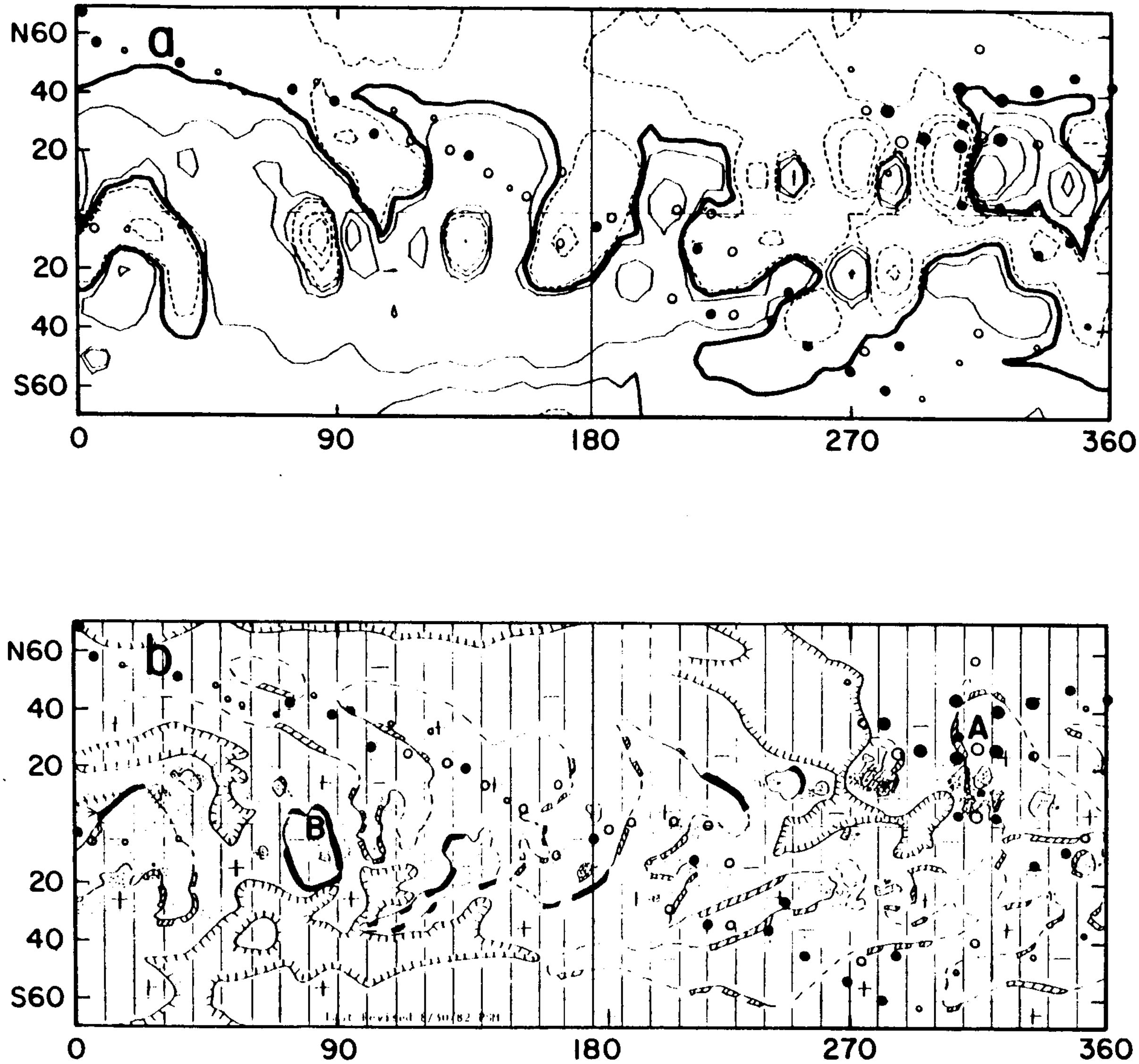

Figure 1. Position of K-coronameter features from East and West limb observations during Rotation 1723 (June 15-July 12, 1982) superimposed on (a) the Stanford Magnetic Field and (b) Hα synoptic charts (SGD, 1982). The circle sizes-large to small-represent $pB \geq 15$, $8 \leq pB < 15$, $pB < 8$ in units of 10^{-8} center disk intensity. The filled and open circles indicate the $pB = 1$ contour reaches heights of at least 1.96 or 1.80 $R_{\odot}$ respectively. The broad line in (a) marks the neutral line of the large scale magnetic field and the filled in filaments in (b) do not have any associated K-corona features.

Table 1

Rotation	Streamers Total	NL Assoc. %	Bright Struc. Total	NL Assoc. %	Streamers with pB > 15
1723	33	82	10	90	7
1729	50	92	45	93	26
1717-35	751	82	296	92	213

Magnetic Neutral Lines vs. Coronal Features

The presence of an Hα filament provides a definite indication of the position of a photospheric neutral line on the solar disk (McIntosh et al., 1972). For 11 rotations in the series above, we have, to date, checked all stable filaments, that is, those observed on daily Hα filtergrams all the way across the disk, and we have recorded whether they were accompanied by coronal feature at one limb or the other. When this test was applied to the well-defined filaments marked A and B in Figure 1b, they were found to be in contrast because of the presence and absence, respectively, of any overlying coronal feature; the same situation was true during adjacent rotations.

A total of 47 Hα filaments were found to exist without associated coronal features, and the magnetic field properties at these neutral lines were investigated with the following results:

1. Nineteen percent showed the direction of polarity reversal in the direction corresponding to the Hale law for the particular hemisphere, and 43% showed the opposite direction, while for the remainder there was uncertainty due to the lines being almost parallel to the solar equator.

2. Forty percent lay on neutral lines enclosing mid-latitude unipolar regions.

3. Ninety-one percent occurred where the field gradient was low, that is, in conditions typical of the quiet Sun, while only 2% were through active regions where the field gradient is usually stronger.

4. Eighty-five percent showed some association with coronal holes, with 62% lying on the neutral line bounding a coronal hole region and close to the hole, and the other 23% forming a closed boundary within the large unipolar region containing a coronal hole.

CONCLUSIONS

The preliminary results of this study on the relationship between coronal structures and photospheric neutral lines lead to two tentative conclusions. First, white light features detected with the K-coronameter tend to be associated with the large-scale global neutral line of the low-resolution (180 arcsec^2) photospheric magnetic field, which changes gradually during a period of several rotations. Second, there are neutral lines that exhibit no coronal enhancement above 1.3 $R_\odot$; they tend to be at the borders of coronal hole unipolar areas or at boundaries of small unipolar regions within them. Thus, by application of a quantitative test, the impression that magnetic field structures are important in ordering the distribution of coronal brightness has been verified. Further, it has been shown that the most important organization is that impressed by the large-scale, global neutral sheet.

There are, of course, other neutral lines identifiable in the photospheric magnetic field, even in the low-resolution description in the Stanford maps. For this epoch, these neutral lines do not lie under bright features in the corona. When the characteristics of the most stable, long-lived set of these (i.e., those bearing filaments) are examined, a particular property is found. They are almost all neutral lines at or near the boundaries of coronal holes or the neutral lines enclosing mid-latitude unipolar regions, often within much larger unipolar regions containing coronal holes. Thus, if an attempt is made to infer anything but the largest scale features of the photospheric magnetic field from the distribution of white light polarized brightness in the corona, it will fail at least by missing these unipolar regions.

This work will be continued by covering more rotations to include periods during which the large-scale magnetic field changes from a simple dipole to a more complex arrangement and other phases of the solar cycle.

Acknowledgments. D. G. Sime and C. J. Garcia have made important contributions to this work. Support was provided by NASA under grant NGL 12-001-011.

REFERENCES

Burlaga, L. F., Hundhausen, A. J., and Zhao, X. P., 1981, J. Geophys. Res., 86, 8893.

Garcia, C. J., Sime, D. G., and McCabe, M. K., 1984, B.A.A.S., 16, 533.

Levine, R. H., 1977, in J. Zirker (ed.), Coronal Holes and High Speed Wind Streams, Colorado Assoc. Univ. Press, Boulder, Ch. 4.

McIntosh, P.S., 1972, Rev. Geophys. Space Phys., 11, 837.

Pneuman, G. W., Hansen, S. F., and Hansen, R. T., 1978, Solar Phys. 59, 313.

Rock, K., and Seagraves, P., 1982, Technical Note NCAR/TN-200 + STR, NCAR, Boulder, Colorado.

Sime, D. G., Fisher, R. R., McCabe, M. K., and Mickey, D. L., 1984, Astrophys. J., 278, L123.

Solar Geophysical Data, 1982, 456 Part I 53, 55, August, 1982, U.S. Department of Commerce (Boulder, CO, USA 80303)

Wilcox, J. M., and Hundhausen, A. J., 1983, J. Geophys. Res., 88, 8095.