SOLAR LARGE-SCALE POSITIVE POLARITY MAGNETIC FIELDS AND GEOMAGNETIC DISTURBANCES

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ABSTRACT

Unlike the negative polarity solar magnetic field large-scale regular features that correlate with enhanced solar activity regions, the positive polarity regular formations formed in the weak and old background magnetic fields seem to correlate well with geomagnetically enhanced periods of time (shifted for 4 days), which means that they seem to be the source of the quiet solar wind. This behavior of the large intervals of heliographic longitude with prevailing positive polarity fields may be followed to the end of the 18th cycle, during the declining part of the 19th cycle, and during the first half of the present 20th cycle of solar activity.

INTRODUCTION

In Chapter 1 (p. 31), we tried to demonstrate some characteristic behavior of the large-scale negative polarity magnetic fields on the sun, and some consequences of the demonstrated properties of these photospheric fields in the interplanetary magnetic fields. We now discuss some characteristics of the large-scale positive polarity distribution that seem to be in a pronounced correlation with the interplanetary field and the geomagnetic disturbances. We use the same observational data as in the earlier discussion, complemented by the geomagnetic character index C9.

Bumba and Howard [1969] have mentioned the striking similarity in the 27 days Bartel's geomagnetic data recurrences with the 27 days rotational period of rows and streams of solar magnetic fields of both polarities. In an earlier note [*Bumba and Howard*, 1966] it was shown that the large geomagnetic disturbances with slow commencement tend to correlate with so-called unipolar magnetic regions (UMRs), each of which is one of several morphological characteristics of a very complex magnetic situation connected with the development of a complex of activity in active longitudes. *Ambrož et al.* [1971] recently noted the dynamics of development of so-called "supergiant" structures in individual polarities of opposite active longitudes to which again the UMRs are in a close relation. Each of the mentioned effects is only one side of this complex pattern developing in the photospheric magnetic fields, and we are only trying to complete this picture by still more information.

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POSITIVE POLARITY DISTRIBUTION

Contrary to the fact that the positive rows and streams on magnetic synoptic charts mounted successively are less pronounced and much broader than the negative polarity streams, the "giant" regular structures (30° to 35° in diameter), which may be accepted as an effect of convective motion in giant cells on the magnetic field redistribution [*Bumba,* 1970], are much better seen in the positive polarity during the preceding 19th cycle of activity (positive was the leading polarity on the more active northern hemisphere). On the other hand, independent of the cycle of activity, the "supergiant" structures (100° to 180° in length) again are better and more often observable in the negative polarity fields.

In heliographic longitude the concentration of opposite polarity fields in streams on opposite sides of the sun is frequently recognized [*Ambrož et al.*, 1971]. As far as the latitudinal distribution is concerned, our synoptic charts suggest that the positive polarity is less widely distributed in heliographic latitudes than the negative one, and that it tends to be more concentrated to the equator in the preceding as well as in the present cycle.

CORRELATION OF POSITIVE POLARITY WITH GEOMAGNETIC DISTURBANCES DURING THREE CYCLES

It has been shown that the frequent concentration of opposite polarity fields in streams on opposite sides of the sun or in separated active longitudes is not the only difference between the polarities. If we compare the distribution of fields of the two polarities with the distribution of activity as seen in the synoptic charts made from the Freiburg daily solar maps, we may see good coincidence of activity concentrations with concentrations of negative polarity fields [*Ambrož et al.,* 1971]. If we compare the daily geomagnetic disturbances, shifted 4 days to account for the travel time of solar wind plasma from the sun to the earth, with the magnetic synoptic charts we again see a fairly close correlation of these magnetic characteristic figures with the positive polarity magnetic features (figs. 1 and 2). This correlation may be seen practically always when the daily geomagnetic character figures C9, published by the Geophysikalisches Institut Göttingen, display the long-lasting strips of enhanced geomagnetic activity with strongly kept 27-day recurrence, as may be observed especially during the decay time of the 19th cycle.

These regular strips of greater values of geomagnetic character figures are common to this phase of solar activity cycles. The same is true of the 18th cycle during the end of which measurements of solar magnetic fields were made (1952–1954) by *Babcock and Babcock* [1955]. If we redrew their figure 9, the diagram presenting "evidence tending to relate terrestrial magnetic storms of the sequential type to UM regions on the Sun," and take again into account the 4-day travel time of plasma we may see the coincidence of large-scale positive solar fields with the enhanced figures of

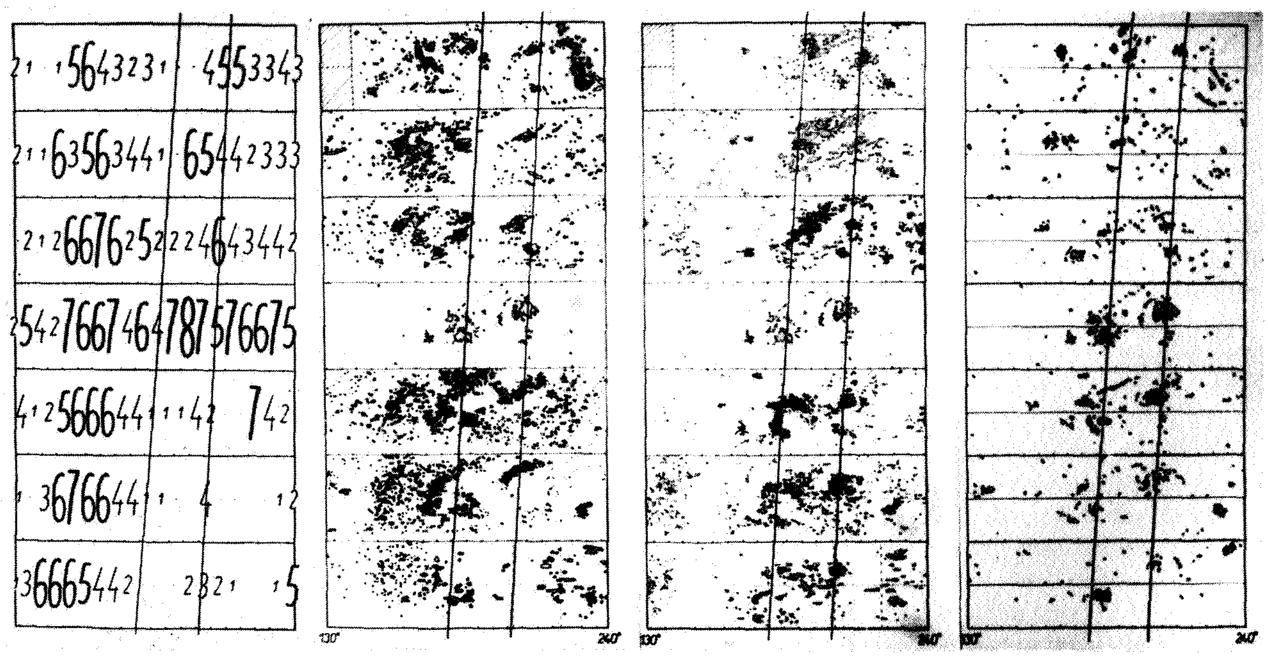

Figure 1. *Portions of magnetic synoptic charts for rotations 1439–1442, drawn in separated polarities (plus to the left, minus to the right), compared with the large-scale solar activity distribution (Fraunhofer Institute, Freiburg) and the geomagnetic activity distribution (Institut für Geophysik, Göttingen) for the same time interval. (The 4 days needed by the solar wind plasma to arrive at the earth are taken into account.) The close relation of young negative fields to the actual activity, as demonstrated by calcium plages, and the relation of areas of older positive fields to the geomagnetically disturbed days may be seen.*

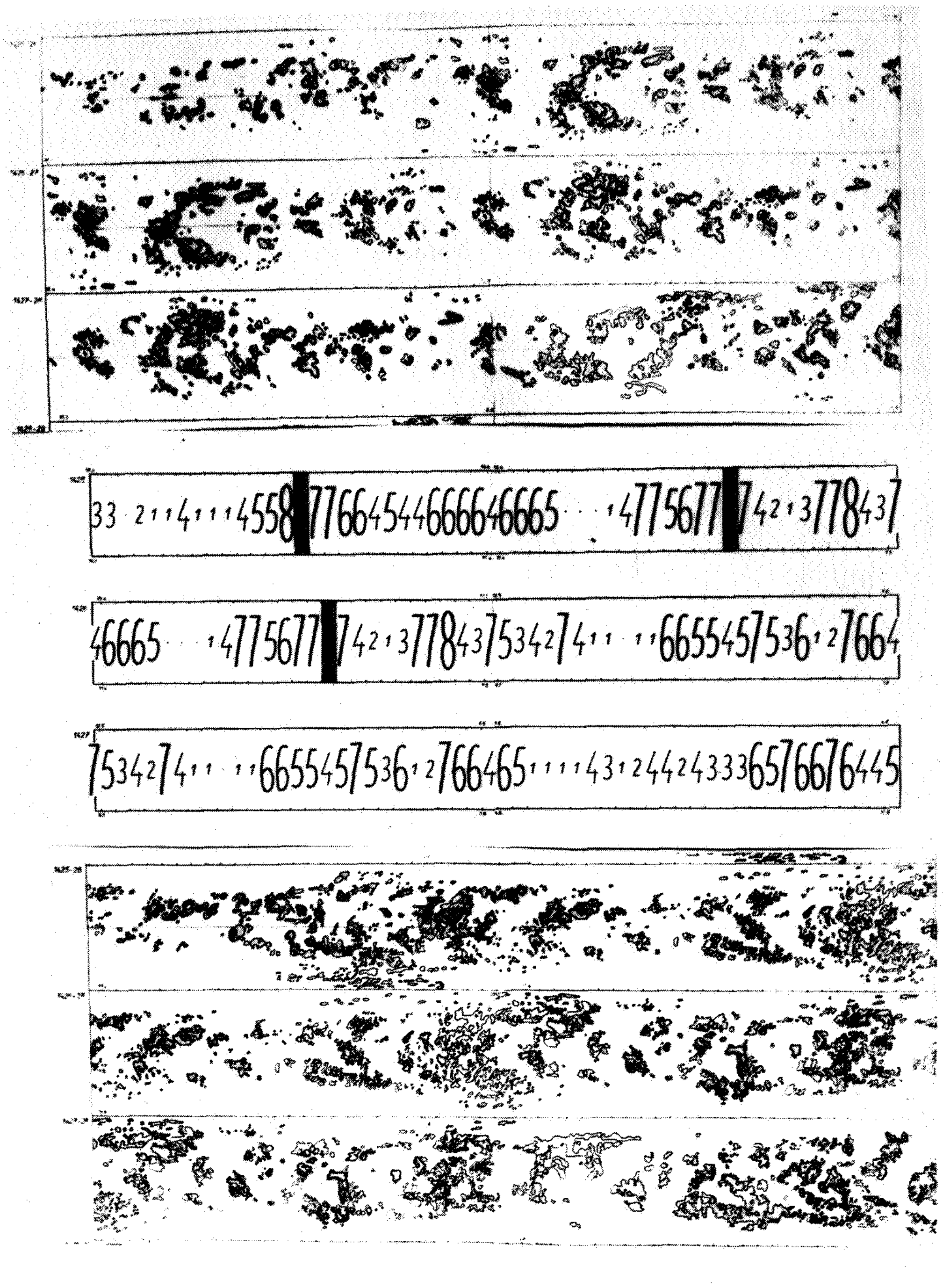

Figure 2. *The same comparison of different polarity distribution with the geomagnetic activity distribution for rotations 1425–1428 from the preceding cycle. For integration two consecutive maps, one of which is repeated, are overlapped and drawn twice for better visualization of large-scale features. The negative polarity in the upper part of the picture demonstrates well-developed "supergiant structure," the presence of which diminished the geomagnetic activity. The intervals of enhanced geomagnetic activity (shifted by 4 days) correlate well with the positive polarity large-scale magnetic fields shown in the lower part of the picture.*

geomagnetic activity, and relatively good coincidence of regions with prevailing negative polarity features with the time periods of very low geomagnetic activity (fig. 3).

During the growth of the 20th cycle such sequences of enhanced geomagnetic activity may be followed very rarely. But when they are observed, they again tend to correlate mostly with the positive polarity large-scale fields on the sun. The complex situation during the maximum of the 20th cycle will be discussed separately.

During the phase of growth of the present cycle of solar activity the polarity of the interplanetary magnetic field was observed [*Wilcox and Colburn,* 1970]. Making a histogram (fig. 4) of the geomagnetic character figures distribution in dependence on this polarity we may see that also in the interplanetary space the geomagnetic disturbances tend to be related more to the positive polarity than to the opposite one, although the positive and negative values are practically equally frequent.

From the histogram of the occurrence frequency of positive and negative polarity in the interplanetary field we may possibly see one more piece of information: the largest secondary maximum of the histogram giving for the frequent time interval of the sector of one polarity of about 6 days—on the sun about 80°—is again in good correlation with the large-scale structures of the field of one polarity on the sun (fig. 5).

THE CORRELATION OF GEOMAGNETIC DISTURBANCES WITH THE PHOTOSPHERIC FIELD IN 1968

For the time of about four solar rotations during the first half of 1968, *Severny et al.* [1970] made a detailed

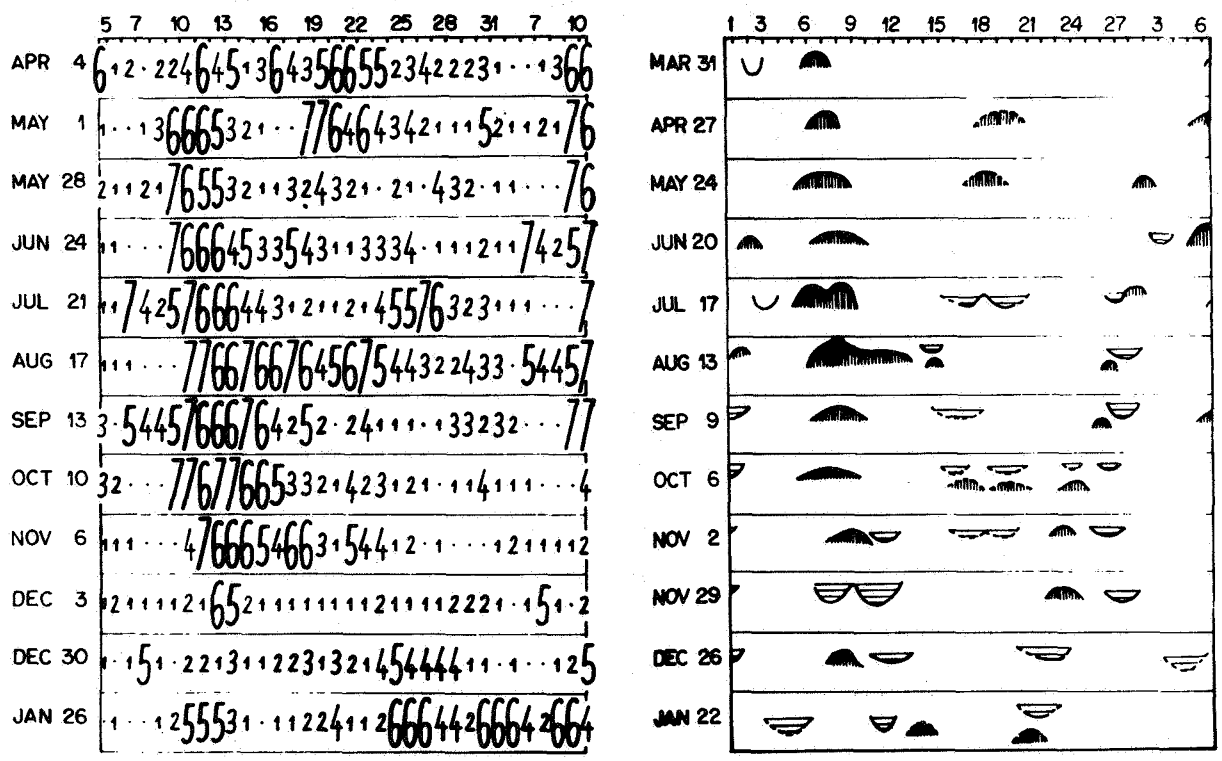

Figure 3. *Comparison of geomagnetic activity distribution with the large-scale magnetic field distribution of opposite polarities on the sun for the year 1953 (the 18th cycle) [fig. 9, Babcock and Babcock, 1955]. The same manner of daily geomagnetic figures presentation as in figures 1 and 2 was used, taking into account the 4 days of plasma travel time. The positive polarity fields have been indicated by U-shaped convex upward curves with the vertical hatching, the negative polarity fields by convex downward curves and horizontal hatching. The correlation of large-scale positive solar fields with the enhanced geomagnetic activity as well as the coincidence of prevailing negative polarity fields with the calm periods of geomagnetic activity may be seen.*

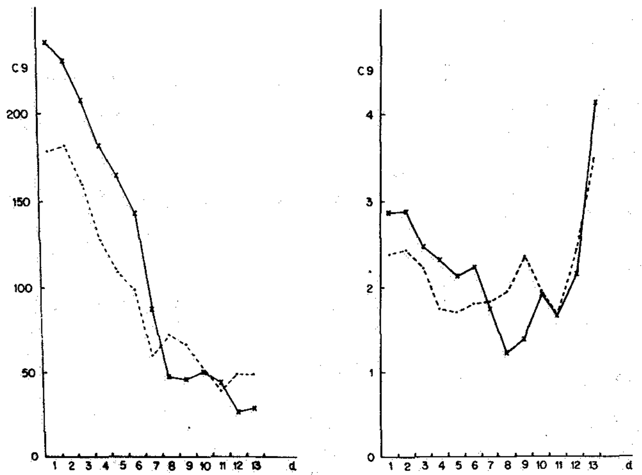

Figure 4. *The histogram of the geomagnetic character figures distribution in dependence on the polarity of interplanetary magnetic field [Wilcox and Colburn, 1970]. In the left picture the sum of geomagnetic character figures and the length of the sector in days is shown, and in the right picture the mean value of the character figures and the length of the sector in days. The full line represents in both pictures the positive polarity, the dashed line the negative polarity distribution.*

comparison of the mean photospheric magnetic field of the sun seen as a star measured at the Crimean observatory with the interplanetary magnetic field observed with spacecraft near the earth. If we correlate the geomagnetic activity shifted for 4 days with the situation on the sun and in interplanetary space in still more detail, we may see that there are enhanced geomagnetic figures in coincidence with both the positive and the negative polarity of solar and interplanetary magnetic fields (fig. 6). Only the separation of both polarities on magnetic synoptic charts and their comparison with solar activity demonstrates that there exists on one side of the sun the normal enhancement of geomagnetic figures due to the large-scale regions of older activity plus polarity in which only smaller solar activity occurs, and on the other side of the sun another enhancement follows the regions of the greater solar activity connected with the prevailing large-scale negative polarity fields. Later we will find that in this negative polarity sector several particle-emitting flares occur, and that the enhanced geomagnetic activity more often starts with sudden commencements.

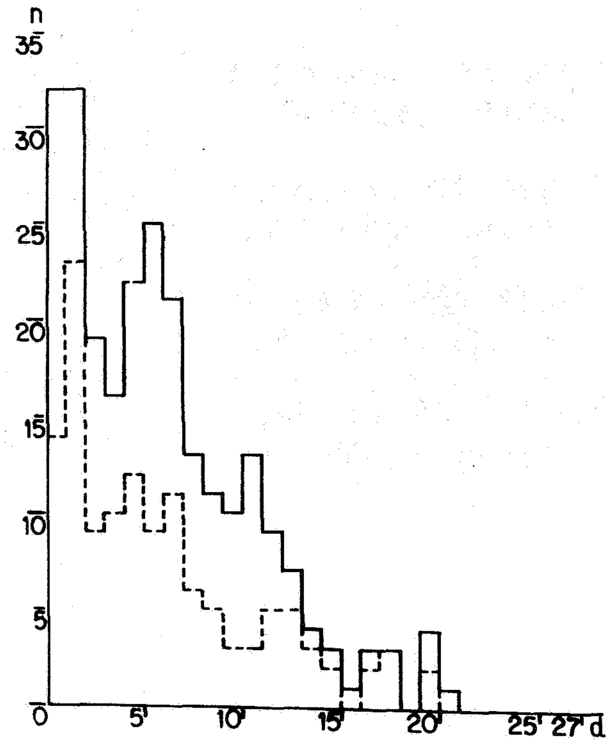

Figure 5. *The histogram of positive and negative polarity occurrence frequency in the interplanetary magnetic field. The most frequent lengths of sectors may be seen from this picture. Again the full line represents the positive polarity and the dashed line the negative polarity distribution.*

CONCLUSIONS

Summarizing the above demonstrated observational data, we may come to the conclusion that there are large-scale features of opposite polarity magnetic fields on the sun, frequently developed in separated active longitudes. To the negative polarity fields new and great activity formations including large flares are bounded, and they tend to be the source of sudden commencement geomagnetic disturbances. The positive polarity structures, usually with less and older activity, correlate with geomagnetic enhanced periods of time, which means that they are sources of the quiet solar wind.

Because of the more complex situation and new formations in regions with the prevailing negative polarity field, we may expect greater gradients of field, and the lines of force may be more closely bounded to the surface of the sun, connecting not very distant regions of opposite polarity, although certain portions of these lines of force must go farther into the interplanetary space. The positive polarity regions on the sun seem to have less complicated magnetic field situations, and the field lines may go without greater complications farther

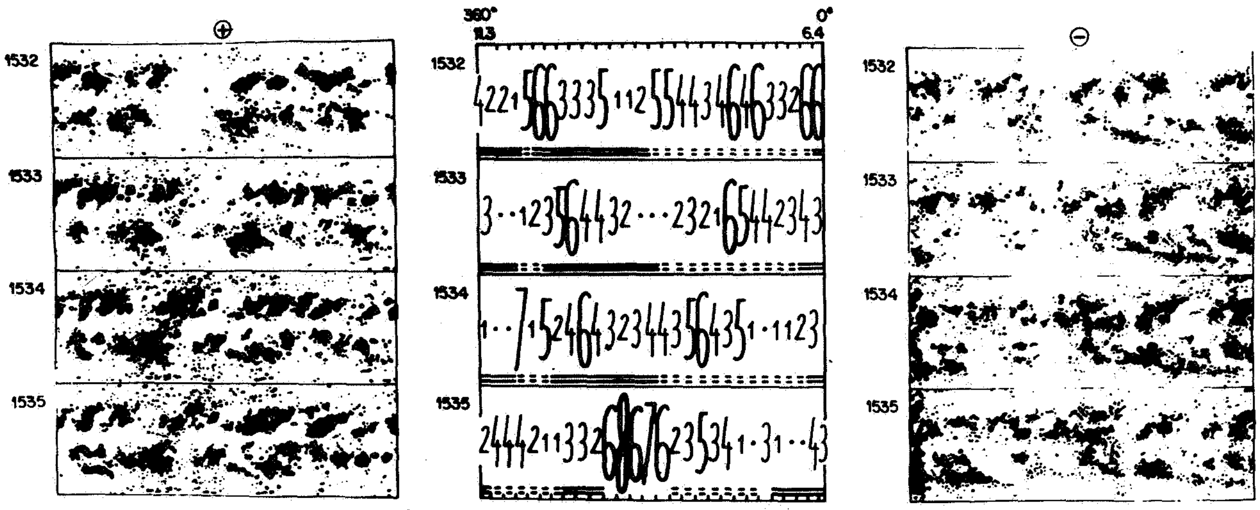

Figure 6. *Comparison of solar magnetic field opposite polarity distribution with the geomagnetic activity and interplanetary magnetic field distribution as measured by Severny et al. [1970] for the rotations 1532–1535 [1968]. For integration two consecutive magnetic maps, one of which is repeated, are overlapped. The positive polarity is to the left and the negative polarity distribution to the right. In the central part of the picture the daily geomagnetic character figures with the 4-day shift and the positive polarity (full double line) and the negative polarity (dashed double line) of interplanetary field are presented. The predominance of the minus polarity in the right part of the synoptic charts is clearly visible. From the comparison of the plus polarity distribution we may see that in the right part of synoptic charts the positive polarity will be cancelled by the negative polarity, while in the left part of the charts it will be superior to that polarity.*

into space. This means that on the sun observed as a star, during the period of negative polarity field observations we may expect enhancement of some spectral lines due to the greater activity, as well as enhanced X–and radio–emission. On the other hand, positive polarity formations on the sun are the source of the undisturbed solar wind. How far the analogy with the stars may go is a question for further research.

Considerable experimental work is still needed to obtain more information, but we think there are already some problems that require some theoretical approach for interpretation.

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DISCUSSION

P. McIntosh The results that I haven't had time to talk about yet agree very well with what Dr. Bumba is presenting–that the times of enhancement of geomagnetic activity in the last several months seem to be coming in between the active longitudes for major flares. These major flares have been coming within the negative polarity sectors. This says, then, that the geomagnetic recurrent storms come in positive sectors. Furthermore, what chance I've had to look at the evolution of the sectors related to what is on the sun seems to imply that the negative sectors are being formed from proton active centers, which again is in agreement with what Dr. Bumba has had to say.