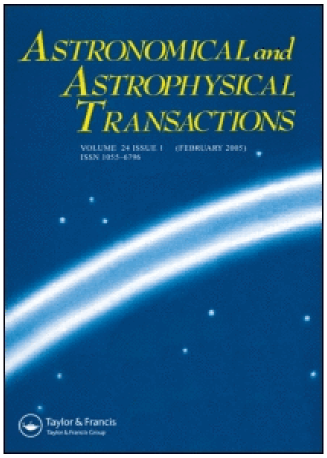

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On the correspondence between the coronal green-line brightness, magnetic field strength and some sunspot activity indices

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The coronal green-line brightness and strength of the large-scale magnetic field on synoptic maps have been compared with the areas and positions of sunspots. Good correspondence is shown to exist between these parameters in some periods close to the sunspot minimum. However, this is not a general rule, and the correspondence is violated in the epochs of high solar activity. One may suggest that this is the effect of the existence of solar magnetic fields of different spatial scales.

Keywords: Sun; Corona; Coronal green line; Coronal magnetic field; Sunspots

1. Introduction

Solar activity is mainly associated with magnetic fields. In order to establish how the magnetic field controls the physical processes in the corona, it is necessary to estimate quantitatively its relationship with various activity indices.

It is natural to suggest that the structure of the corona, and in particular the brightness distribution of the coronal green line Fe XIV ($\lambda = 530.3$ nm) is closely related to the magnetic field. Various researchers arrived earlier at the same conclusion (see, for example, [1–3]). However, the careful comparison of the spatial distribution of the coronal green-line brightness (CGLB) and magnetic field strength in different phases of the cycle and in different latitudinal zones [4] showed that this relationship is rather complicated. The correlation coefficient for the family of space-coinciding points on the synoptic maps under examination behaves differently during a cycle inside and outside the sunspot formation zone. In the latitudinal zone $\pm 30°$, the correlation coefficient is always positive. It is largest at the activity minimum and decreases significantly by the maximum. At higher latitudes (outside the sunspot zone), on the contrary, the correlation coefficient reaches the largest positive values at the maximum of the cycle. Then, it decreases rapidly, passing through zero at the end of the descending phase, and becomes negative at the minimum phase.

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The dependence of correlation between the CGLB and magnetic field strength during a cycle explicitly indicates that fields of different scales have different effects on the generation of the green-line emission. This paper continues the study of the relationship between the magnetic fields of different scales and the green-line emission in the lower corona. The study was carried out using the synoptic maps of CGLB constructed by Badalyan *et al.* [5] with the database of Sýkora [6, 7] and the magnetic synoptic maps at $1.1R\odot$ [4] based on Stanford photospheric observations. We have also used the Greenwich data on sunspot coordinates and areas. Sunspots have been regarded as the regions of emergence of concentrated local magnetic fields. The sunspot areas and positions have been compared with the CGLB and magnetic field strength at the height of the line emission.

2. Comparison of the coronal green-line brightness and magnetic field strength with the positions and areas of sunspots

Three periods, each covering six Carrington rotations, have been selected for comparison. These are rotations 1667–1672 (April–September 1978, beginning of the maximum phase

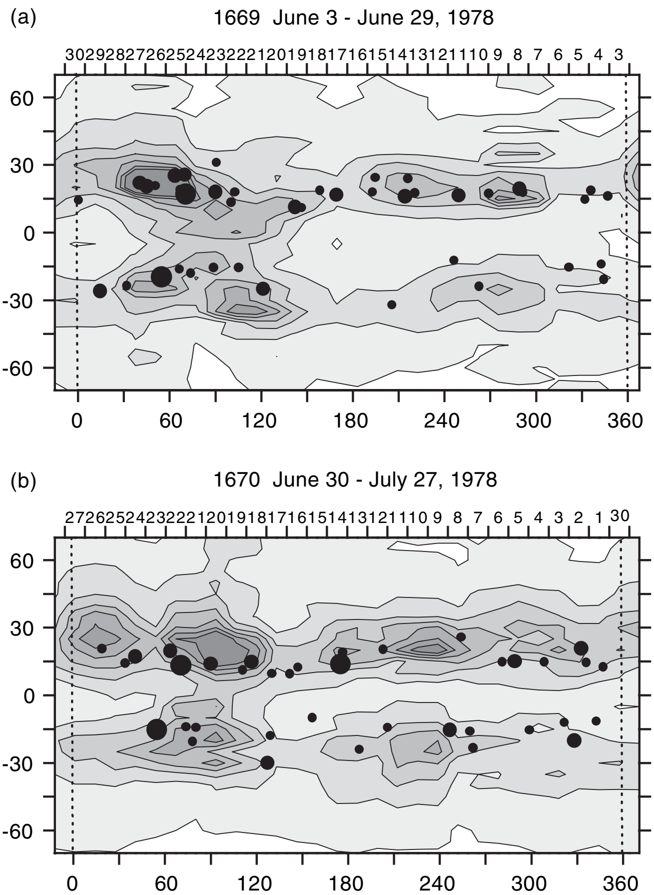

Figure 1. Maps of distribution of the CGLB in two successive rotations and sunspot positions. Darker areas on the maps correspond to higher brightness. Sunspots are shown as full circles. The size of the circle approximately corresponds to the maximum observed sunspot area.

of cycle 21), 1690–1695 (January–May 1980, cycle 21 maximum) and 1767–1772 (October 1885–March 1986, in the vicinity of the minimum of cycle 21).

The mean coordinates have been determined for the sunspots observed for more than three days during their passage over the solar disc. Then, these spots were plotted on the corresponding synoptic maps of the coronal green line brightness and magnetic field strength. Examples are illustrated in figures 1–3. Sunspots are shown as full circles. The size of the circle approximately corresponds to the maximum observed sunspot area.

Figures 1(a) and (b) represent the CGLB maps with sunspots marked on them for two successive rotations 1669 and 1670 respectively. One can see that most sunspots observed in the northern hemisphere in rotation 1669 fall on the region of enhanced green–line emission at longitudes 30°–70°. It is important to emphasize that these are mainly sunspots of large area. In the next rotation 1670, the sunspots, although tending to the sites of enhanced green-line brightness, do not fully coincide with them. This particularly concerns the greatest spot in the northern hemisphere at about 180°, which lies outside the brightest regions.

The agreement between the sunspot positions and the regions of increased magnetic field in the same rotations 1669 (figure 2(a)) and 1670 (figure 2(b)) is still worse. On the map for rotation 1669, for example, the sunspots in the northern hemisphere discussed above fall on the region of decreased field strength. In general, on both maps represented in figure 2, the

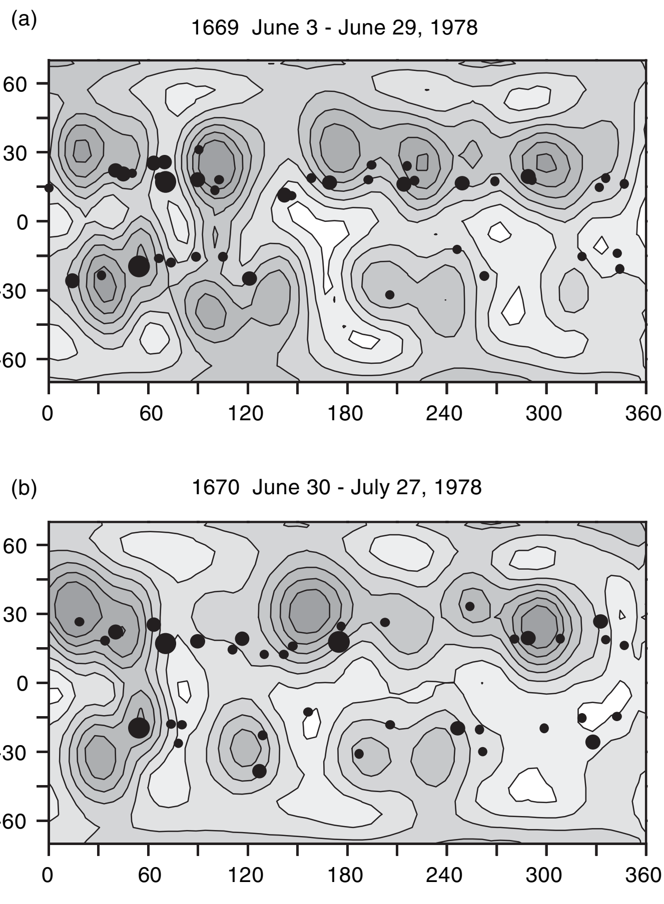

Figure 2. Maps of magnetic field strength and sunspot positions. Darker areas on the maps correspond to stronger fields.

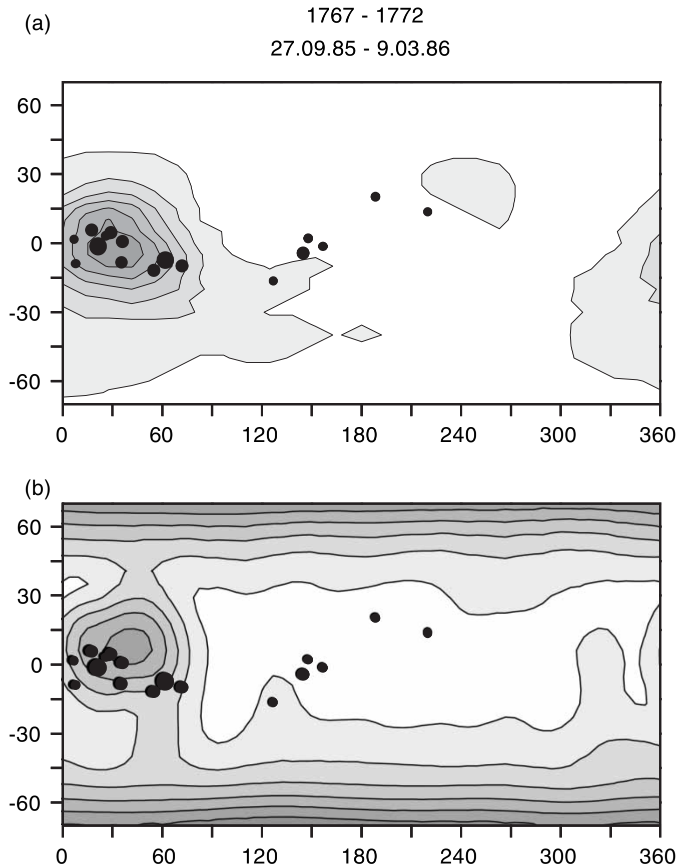

Figure 3. Maps of distribution of (a) the CGLB and (b) the magnetic field strength and sunspot positions in the phase of minimum solar activity. The data are averaged over six Carrington rotations.

latitudinal band where sunspots are concentrated in the given phase of the cycle lies below the centres of enhanced magnetic field.

Quite a different picture is observed in the epoch of minimum activity. Figures 3(a) and (b) illustrate the maps of distribution of the CGLB and magnetic field respectively with sunspots marked on them. Since the number of sunspots is very small at the minimum of the cycle, the maps were plotted using the mean data for rotations 1767–1772. As seen from figure 3, all more or less significant spots fall, in fact, on the regions of enhanced brightness and field strength. Note that a similar averaging for the periods near the cycle maximum does not improve the agreement between the distributions under discussion and sunspot positions.

To estimate quantitatively the agreement between the mapped parameters and the sunspot positions and areas, we have calculated the corresponding correlation coefficients. For this purpose, we have found for each map the mean values of the CGLB and magnetic field strength as well as the total maximum sunspot areas in the 30° longitudinal bands separately in the northern and southern hemispheres. In latitude, these bands were confined to the sunspot formation zone ±30°. Note that the moments of the green-line and magnetic field observations may not coincide with the moments of maximum development of sunspots.

The correlation coefficients obtained are represented in tabular form. As seen from table 1, the correlation is actually absent in most rotations. The correlation between the CGLB and total sunspot area becomes significant in rotations 1669 (discussed above) and 1690 in the northern

Table 1. Correlation coefficients.

Carrington rotation	North		South	
	$I - S_p$	$B - S_p$	$I - S_p$	$B - S_p$
1667	0.130	0.293	−0.424	−0.145
1668	−0.082	0.387	−0.105	−0.190
1669	0.854	−0.184	0.387	0.735
1670	0.083	0.251	0.004	0.500
1671	0.520	0.566	0.490	0.179
1672	−0.316	0.424	0.800	0.190
1690	0.686	0.458	0.346	0.600
1691	0.400	0.332	0.190	0.374
1692	0.548	0.064	0.221	0.057
1693	−0.073	0.583	0.436	0.020
1694	−0.114	0.303	0.469	−0.057
1695	0.219	0.387	0.424	0.251

hemisphere and in rotation 1672 in the southern hemisphere. When comparing sunspot data with the coronal magnetic field, we can only isolate rotation 1669 (northern hemisphere) and, with lesser reliability, rotations 1693 (northern hemisphere) and 1690 (southern hemisphere).

Check calculations were also performed for the successive rotations 1669 and 1670, for which the tabulated coefficients differ significantly. In these calculations, the total sunspot areas were determined for the moments of the green-line and magnetic observations. The general pattern that we obtained as a result proved in fact to remain the same. The correlation coefficients did not change within their statistical reliability. A high correlation between the mean brightness and total sunspot area in the northern hemisphere in rotation 1669 remained as well as the lack of correlation between these parameters in rotation 1670.

3. Conclusion

As follows from our analysis, the widespread opinion that the brightness of the coronal green line is always enhanced over sunspots is not quite correct. Although the Wolf numbers (and all other sunspot indices) vary in phase with the CGLB, a detailed investigation makes it clear that the relationship between the CGLB and the local magnetic fields is much more complicated. In particular, a one-to-one correspondence does not exist between the size of a sunspot and the CGLB above it.

Analysis of the maps and tabulated results shows that the correlation between sunspots, magnetic field and coronal emission sometimes varies significantly over a short time interval. This suggests that, although the long-term correlation between the main activity indices is high enough, their characteristic times may not coincide on shorter intervals of one or two rotations.

Special attention should be paid to the discrepancy between the local sunspot fields in the photosphere and the calculated magnetic field strength in the lower corona at the activity maximum. Perhaps, it would be useful to calculate the fields with greater spatial resolution. However, these problems are not simple and require further investigation.

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