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EAST-WEST ASYMMETRY ON THE SOLAR DISK

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Abstract. The East-West asymmetry of the number of sunspots has been analyzed on the basis of the Debrecen Photoheliographic Data (DPD) for the years 1986-89 and 1993-1998 and also on the basis of the Greenwich Photoheliographic Results (GPHR) for the years 1874-1974. Contrary to the results based on the GPHR, only a slight eastern excess of spots is found by using the DPD . The East-West asymmetry of the number of spots can be detected only for small spots (<20 MSH) near the limb.

Key words: East-West asymmetry - sunspot area distribution

1. Introduction

An East-West asymmetry in the distribution of the sunspots over the solar disk was reported by Mrs. Maunder (1907) at the first time. She described two types of asymmetry. On the one hand more spots are formed on the East than on the West hemisphere, on the other hand at any moment more spots are appearing at the eastern than disappearing at the western limb.

From this time on many other authors investigated the East-West asymmetry using the sunspot group data. The results derived from group data, however, were not unambiguous. Two authors are known who used individual spot data to interpret the East-West asymmetry.

Gleissberg (1945) counted individual spots on the Mount Wilson drawings. He found that the preceding spots show a western excess while the following spots an eastern excess. Archenhold (1940) studied the distribution of individual spots to avoid difficulties arising from the

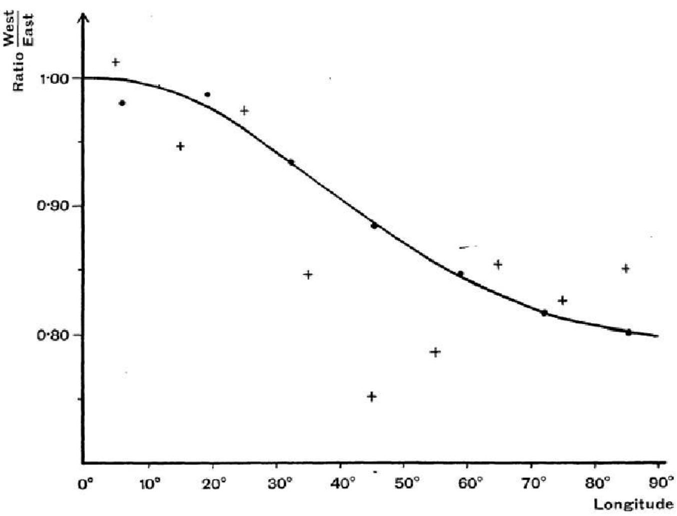

Figure 1: The ratio of numbers of spots (dots) and of groups (crosses) on the western and eastern half of the Sun as a function of longitude (Archenhold, 1940).

complexity of groups. He used the observational data of more than 5000 spots taken from the GPHR in the years 1889,1898,1899 and 1900.

Fig. 1 adapted from his paper shows that the eastern excess of spots and groups is increasing with the longitude from the central meridian. Near the limb the asymmetry is about 20 %.

There were two types of explanation for this asymmetry. One of them explains the asymmetry with the effect of faculae (Maunder, 1907; Sawyer and Haurwitz, 1972). The other type of explanations conclude that the normal axes of the spots were slightly inclined to the solar radius. Minnaert (1946) says that the axes of every spots are sloped downward from the west to the east. The calculation of the inclination was made by using the total area of every spot in some central meridian distance zone (Minnaert, 1946), so this inclination was valid for all spots independently of their size. Gleissberg (1945) came to the conclusion that the axes of preceding spots are sloped downward from east to west while the axes of following spots are sloped downward from west to east.

Recently the volumes of the DPD have become available, which contain the position and area of every observable sunspots thus, in this respect it is the most detailed electronically available sunspot catalogue. The data mining with the help of modern informatics is also easier and quicker now than it was at the time of the publication of the cited articles. In this way, new selection criteria can be added to the investigations. Thus, it is useful to repeat the earlier investigations on a larger database, and compare the results with the old ones.

We introduced a new aspect of investigating the East-West asymmetry of the sunspots, namely we have studied how the asymmetry depends on the sunspot area. For this purpose we used the individual spot data of DPD and the single spots data of GPHR to make more detailed analysis of the East-West asymmetry of the spot number distribution taking into account how this distribution depends on the spot area.

2. The Observational Material

We have taken the data from the DPD for the years of 1986-1989 and 1993-1998 and from the electronic version of the GPHR (ftp address in the references) for the years of 1874-1974. The chosen periods of the GPHR and DPD are not simultaneous, because the GPHR finished at 1976 and DPD is prepared at present for the years 1986-89 and 1993-96.

In this time interval the DPD contains 138482 individual spot data. It is much more than used by Archenhold (5000) or any other authors. The printed version of the GPHR for the years 1884-1916 gives the position and the area of the single spots and the most important individual spots composing the groups. After 1916 the data of the groups are only available. The electronic version of the GPHR gives the position and the area of the spot groups but it does not give that of the individual spots. However, it was possible to select the single spots from the electronic version of GPHR by using the column of "Greenwich group type". Between 1874-1974 46030 single spots were found.

The difference between the available number of spots in DPD and GPHR is clearly shown in Figs. 2 and 3. Fig. 3 shows that in the case of complex spot groups the GPHR does not give position and area data for every spot of the complex spot groups. In the Fig. 3 every individual spot of the spot group is represented by two ellipses referring to the umbra and the penumbra, respectively. The area and position of these ellipses are determined by the GPHR data. The Fenyi's drawing (lower part) and the reconstructed image of the spot group (upper part) have the same scale.

3. Distribution of the number of spots and the number of groups

Table I gives the ratio of total number of spots of DPD and that of the groups of GPHR on the western and eastern half of the Sun (W/E) in the different zones of central meridian distance as we re-counted. We entered the W/E ratio of the groups of the GPHR in the years 1889-1901 in the second column. The third one is the same ratio calculated for the time interval of 1874-1974. The fourth column is different from the previous ones because here we selected those sunspot groups which contain exactly one single spot (for this purpose we used spot groups with Greenwich group type 0). The last column shows the W/E ratio of the individual spots of the DPD.

The second column reproduces nearly the ratios displayed by Fig. 1. The slight difference is that Archenhold plotted zones of 13°, whereas ours are reduced to 10°. On the basis of the values of the second column there is an E-W asymmetry in the number distribution of sunspot groups but this E-W asymmetry disappears in the hundred years interval. The single spots of the GPHR show this asymmetry from the zone of 30° - 40° to the limb zone but in the case of the individual spots of DPD this asymmetry can only be observed in the limb zone.

4. Distributions of the number of spots as a function of the corrected sunspot areas

Zones on both sides of the central meridian were chosen: the eastern zone was $[-L, -L + \Delta L]$ and the western zone was $[L - \Delta L, L]$ where L is the central meridian distance. We counted the spots (DPD) and the groups (GPHR) in each zone with a given corrected area (umbra+penumbra). These numbers were displayed against the corrected area for the eastern and western halves on the same figure. The spots of the corrected sunspot

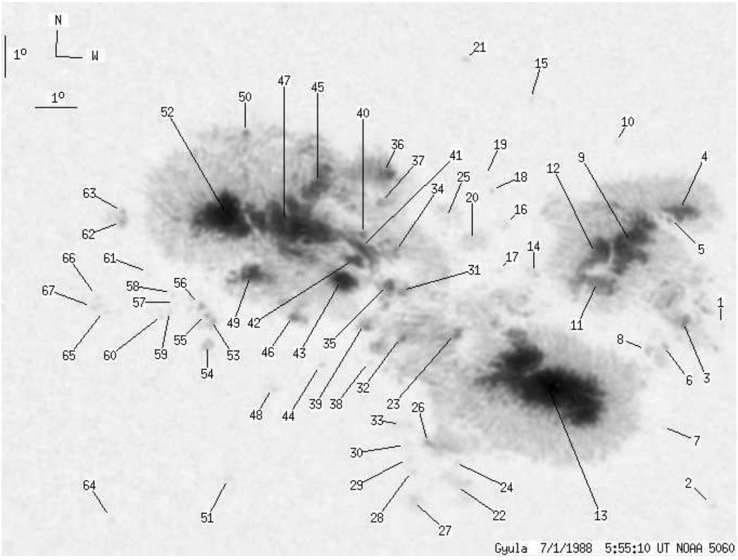

Figure 2: The NOAA 5060 active region in July 1,1988 as given by DPD. Every numbered part of this active region was measured.

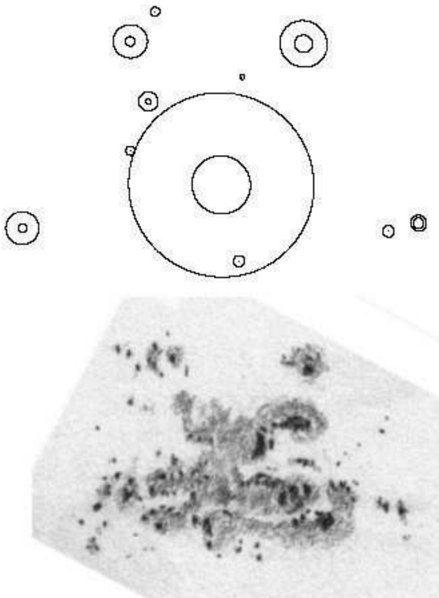

Figure 3: The complex active region observed in Oct. 20, 1906. The upper drawing was plotted on the basis of the GPHR. The lower drawing is the observation taken at Kalocsa Observatory.

Table I: The ratio of the number of spots of DPD and spot groups of GPHR on the western and eastern half of the Sun (W/E) in the different zones of central meridian distance.

CMD	GPHR 1889-1901	GPHR 1874-1974	GPHR single 1874-1974	DPD 1986-89 & 1993-98
0 - 10	0.99	0.99	0.95	1.00
10 - 20	0.95	0.98	0.88	1.02
20 -30	0.94	0.99	0.87	0.98
30 -40	0.95	0.96	0.78	0.96
40 - 50	0.88	0.95	0.76	1.01
50 - 60	0.85	0.95	0.72	1.01
60 -70	0.87	0.95	0.71	0.97
70 - 80	0.88	0.97	0.69	0.96
80 - 90	0.80	0.96	0.72	0.81

area being smaller than 6 millionth of the solar hemisphere ($A_c < 6\,MSH$) were omitted to eliminate any visibility effect due to the tiny spots and solar pores. The corrected sunspot area of 6 millionth of the solar hemisphere corresponds to a measured area of 12 millionth of the solar disk at the disk center and it corresponds to a measured area of 2-3 millionth of the solar disk near the limb. The limit diameter is 4818 km for a spot at disk center corresponding to the diameter of a sunspot with the area of 6 MSH or 6.64$''$ at mean distance.

We scanned all the reasonable L and ΔL value pairs which give the zones containing enough number of spots. The spots of the DPD $A_c \geq 20\,MSH$ do not show any difference between their eastern and western distribution in any zone pair. The spots of DPD $A_c \leq 20\,MSH$ have a small eastern excess and this excess is observable only very near to the limb ($L = 75$ $\Delta L = 10$) as in the case of the spot number distribution. (see Figures 4 and 6). The distribution of the GPHR single spots show this asymmetry from the zone where $L = 30$ and $\Delta L = 10$ and $A_c \leq 30\,MSH$ to the limb zone (see Figures 5 and 7).

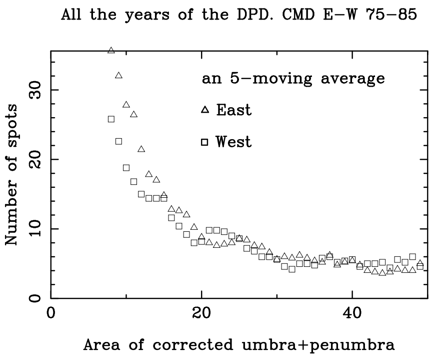

Figure 4: Distribution of the number of the spots of DPD as a function of the corrected sunspot areas near the limb.

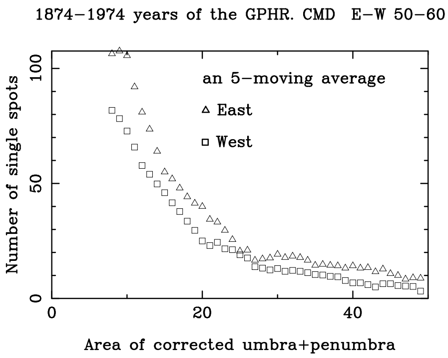

Figure 5: Distribution of the number of the single spots of GPHR as a function of the corrected sunspot areas.

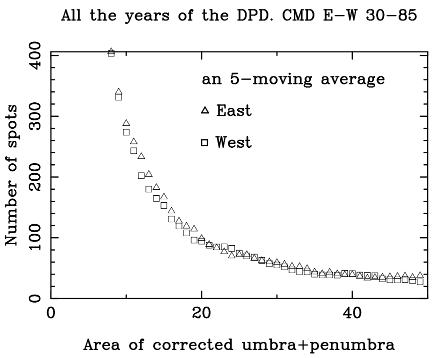

Figure 6: Distribution of the number of spots of DPD as a function of the corrected sunspot areas in a wide zone interval. No significant East-West asymmetry.

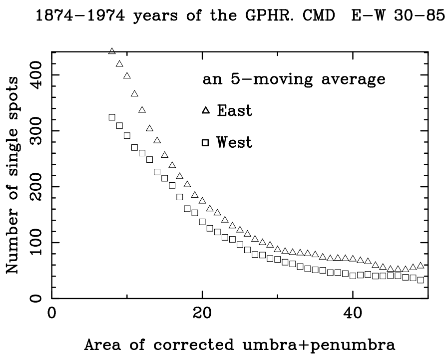

Figure 7: Distribution of the number of the single spots of GPHR as a function of the corrected sunspot areas in a wide zone interval. There is an East-West asymmetry.

5. Discussion

The results show that the rate of E-W asymmetry depends on the catalogues used. Contrary to the GPHR, by using the DPD the East-West asymmetry of the number of spots can be detected only for the small spots (<20 MSH) near the limb. These results also show that the E-W asymmetry found for the sunspot groups is related to the small spots.

The new results on the basis of DPD and of the GPHR single show that simple explanations (Minnaert,1946; Gleissberg,1945) independent from the size of the spots cannot be maintained. They need new type of explanation or some refinements of the earlier ones concerning the tilt of the spots to the local normal and/or contribution of other types of effects.

The full digitization of the GPHR printed version with all the individual spot data would help to explain the different results obtained from the DPD and GPHR. The extension of the study to other catalogues may also help in determining the rate of E-W asymmetry.

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