HELIOGRAPHIC DISTRIBUTION OF SUNSPOTS, 1988–1999

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Abstract

The heliographic latitude and longitude of 1338 penumbral sunspots observed by the author during cycle 22 were plotted on a Mercator-style map of the solar surface in order to study their distribution. Scarcity of spots along the equator and in high latitudes was evident, as were dense clumps and spot-free areas elsewhere. Analysis suggests that the sunspot distribution may not be completely random, but may be somewhat related to photosphere dynamics and interior convective processes.

1. Introduction and method

The purpose of this research was to answer the following questions: (a) In the usual sunspot zones, are the spots randomly or evenly distributed?; (b) Are they confined to certain well-defined areas?; (c) Are there areas where there have been no spots during the whole of cycle 22? This paper answers these questions and attempts to provide some explanation for the results. Observations were made using the 4" polar axis refractor of the Maple Observatory (Thompson 1996). A 7-inch circle was drawn on a sheet of paper fastened to the sun screen mounted on the side of the telescope console. A solar image of the same size was then projected onto the sheet by means of a diagonal, the drive started, the image centered in the circle, and the sunspots traced on the paper. Following this, the drive was stopped and a convenient spot allowed to drift for a few inches, its beginning and ending positions being marked to give a true E–W direction. Since the sun screen does not move with the telescope tube, field rotation is present, but the few minutes it takes to trace the spots does not result in any appreciable inaccuracy.

The longitude of the center of the sun's disk and the position angle of the equator were obtained from the *Observers' Handbook* (Bishop 1988–1999) of the Royal Astronomical Society of Canada. These are given for five-day intervals, and a Lagrangian interpolation computer program written in BASIC was used to obtain intermediate values. Using rulers and a large protractor, the western point and the position of the equator were marked on the circumference of the circle. The sheet was then laid over the appropriate Stonyhurst disk and the equator traced in. For a routine sunspot count, this is my usual procedure.

For the present project it was necessary to place most of the many hundreds of daily solar tracings over the relevant Stonyhurst disks, line up the equators, and estimate the latitudes and longitudes of the spots. An effort was made to employ estimates near the center of the disk to avoid errors due to the perspective effect at the limbs, where the meridians become crowded. It was also important correctly to identify each spot on successive daily sheets so that there were no duplications. Where large and complex groups were involved, the position was considered to be the center of the main penumbral area. Short-lived spots with no penumbra were ignored.

The outcome was a list of 1338 latitudes and longitudes which were typed into a spreadsheet. For graphing, the X-axis ran from 0 to 360 degrees, representing solar longitude, and the Y-axis went from -40 through zero to +40 degrees, representing solar latitude. The resulting graph was, in effect, a Mercator-type map of the solar surface. While it is true that this kind of projection produces a distortion in high latitudes, the majority of the spots are not in high latitudes, so that the over-all effect is reasonably accurate. There is also the question of differential rotation. The sun's visible surface does not rotate uniformly like the earth's. But since we are recording spots over a period substantially longer than a single rotation, and since spot positions are defined once only, it was felt that this approach would have some validity.

My first solar observations for the AAVSO were from July 1988. Eleven years later, in June 1999, I had the idea of plotting the positions of all observed penumbral spots to see how they were distributed. The graph of my own estimates of the monthly sunspot number (Figure 1) shows that the count for June 1999 (last point) was slightly past its relative position on the curve for July of 1988 (first point). This set of data, therefore, comprises a complete solar cycle, even though it is not exactly centered about the maximum of cycle 22.

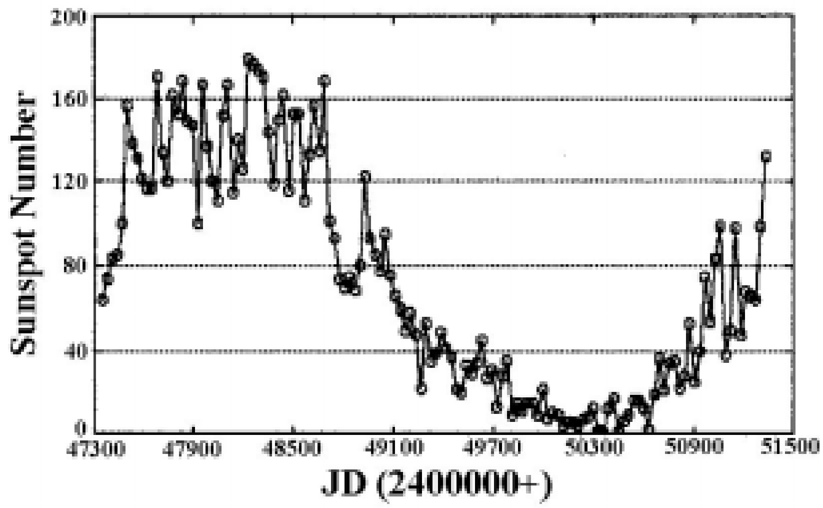

Figure 1. Monthly Sunspot Number, Maple Observatory, July 1988–June 1999. The graph of raw monthly sunspot numbers (unsmoothed) indicate that the data cover slightly more than one cycle, though not centered about the cycle's maximum.

2. Results

Figure 2 shows immediately the scarcity of spots in high latitudes and along the equator. Some of the spots near the forties may actually be the first arrivals of cycle 23. Those near the equator are probably late-comers from the current cycle. The gradual movement of spots from high to low latitudes during a cycle has been known for some time. When you plot spot latitudes against time, you obtain the famous Carrington or "butterfly" diagrams which show graphically the movement of spotted regions towards the equator as the cycle progresses. These, however, do not indicate the exact heliographic position of the spots on the solar surface since their X axis shows time rather than heliographic longitude.

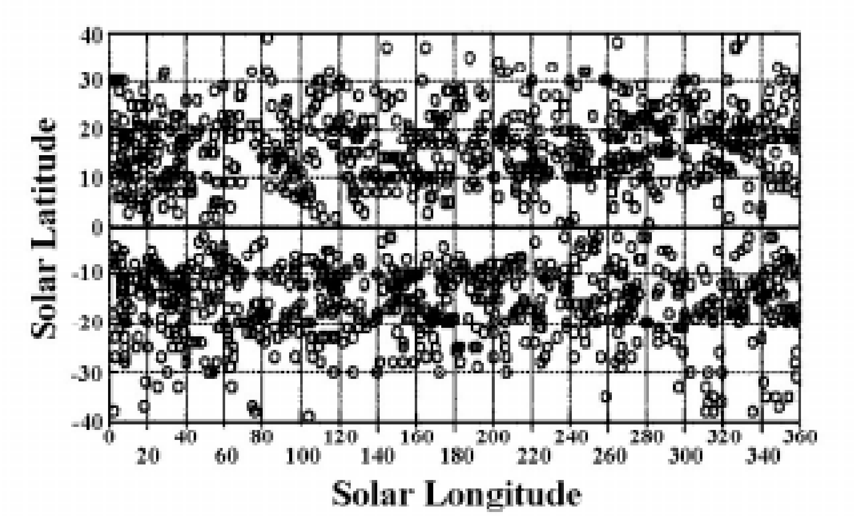

Figure 2. Sunspot Distribution, 1988–1999. The scarcity of spots along the equator and in high latitudes is evident, as are the dense clumps and spot-free areas. But some ordered aspects suggest that the distribution may not be completely random.

A closer look at the map provides the answers to my last two questions. The spots are quite dense in some areas and entirely absent in others. Both the dense clumps and the spot-free zones are about the same size—from ten to fifteen degrees in extent. There is also visible a string of spot-free regions stretching along the fifteenth parallel in both hemispheres. Then there are two prominent blank spaces stretching northeast from the equator all the way to latitude 20 degrees, one starting at longitude 80 degrees and one at longitude 120 degrees. The dense concentrations are widely scattered, with rather more visible in the southern hemisphere. The heaviest clustering of all, however, is found in both hemispheres from longitude 300 through 0 to 60 degrees.

3. Conclusions

The structure, behavior, and magnetic nature of sunspots has been well known for a long time, but their underlying cause is still not fully understood. A model introduced in the 1960's postulated tubes of magnetic force that wrapped themselves around beneath the photosphere under the influence of differential rotation. Where such a tube broke through the surface, two spots of opposite polarity would be produced (Pasachoff 1989). A more recent theory (McIntosh and Leinbach 1988) is of convection cells, also immediately below the visible surface, that generate magnetic fields by what is called dynamo action. When such fields are close enough to the surface, sunspots appear.

The latter hypothesis does seem to have some relevance to the problem of sunspot distribution. McIntosh and Leinbach (1988) suggest that, "Giant convective cells beneath the solar surface generate and expel the magnetic fields that cause sunspots....When the spots are observed over many months, some regions can be seen to have more spots than others. These 'preferred' active areas likely reveal the size and distribution of the underlying convective cells." It is also possible that the oscillations detected by solar seismology give rise to the disturbances that influence the locations of sunspots (Harvey *et al.* 1987).

Finally, it is necessary to consider whether the distribution of spots in Figure 2 might not, after all, be purely random. Fortunately home computers can now do many interesting things with the random-number distribution (RND) function, which generates pseudo-random numbers. A simple BASIC program was written in which the RND command was used to distribute 1338 small circles at random over a designated area of the screen representing the sun's surface. Figure 3 shows one such result. We did not include the scarcity of spots at the equator and near the poles, but even so the qualitative similarity to Figure 2 is startling. The clumps are there, and the empty spaces are there. There are also one or two large empty areas in both. However, there are some obvious differences. Whether these are likely to be accidents or the result of deterministic processes cannot be decided without statistical tests beyond the scope of this paper.

Thus it does appear possible that some aspects of the irregular distribution of spots may be related to the dynamics of the solar photosphere, or to processes even deeper in the sun's interior, the most likely cause being the action of convective cells. If any readers have further information on this subject, the author would be interested in hearing from them at <rayt@interlog.com> or the mailing address above.

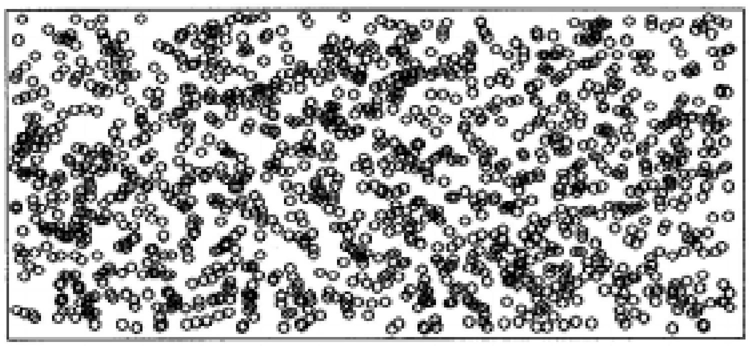

Figure 3. A computer-generated random distribution of "sunspots." A BASIC program used the RND function to place small circles in random locations in a designated area of the screen. The similarity to Figure 2 is readily apparent, but there are significant differences.

4. Acknowledgements

The author gratefully acknowledges the assistance of his wife Ilse who, over the course of several weeks, made all 1,338 estimates of heliographic positions and entered them into the spreadsheet.

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