Aplication of "cumulative histogram method" to sunspot umbral structure determination

Ramón E. Rodríguez Taboada [1], Ernesto R. Rodríguez Flores [1], Jorge Pérez Doval [1]

[1] Instituto de Geofísica y Astronomía. Calle 212 No.2906, La Lisa, C. Habana, CP 11600, Cuba.

Abstract

A high resolution photoheliogram (0.3 arcsec) of the sunspot group numbering 108/77 (Solnechnye Dannye), taken on September 30, 1977 (04h 46m 17s UT) at the "High Mountain Station" of Pulkovo Observatory in Pamir (4.3 km height) was analyzed. The photogram was scanned at 256 grayscale levels and 300 dpi producing a 0.15 arcsec/pixel scale on the resulting image. We found that the intensity cumulative histogram shows a distinctive slope change point. In this paper we analyze this point that lies inside the "classical umbra", and it was interpreted as the real umbra-penumbra border. We didn't found any signature of the classical umbra-penumbra border.

Key words: Astronomy, Solar physics

Resumen

Se analiza un fotoheliograma del grupo 108/77 (según la enumeración de Datos Solares), tomado con alto poder resolutivo (0.3") en la "Estación de Alta-Montaña" de Púlkovo en el Pamir (4.3 km de altura). Esta foto fue digitalizada a 256 tonos de gris y 300 puntos por pulgada de donde resultó una imagen con una escala de 0.15"/pixel. Nosotros hallamos que la curva de intensidad del histograma acumulativo de la imagen tiene un cambio de pendiente notable. En este trabajo nosotros analizamos el punto, que se encuentra en el interior de la "umbra clásica", y que interpretamos como el verdadero borde umbra-penumbra. No encontramos ninguna evidencia que correspondiera a la frontera "umbra clásica"-penumbra.

Palabras clave: Astronomía, Física solar

Introducción

It is known that inside the umbrae there is a complex structure. In the eighteen century, Father Secchi (1875) published sunspot drawings of his observations where inner structures are clearly noticed. Bray and Loughhead (1964) in their book "sunspots" presented the concept of "umbral granulation". In this work we use the term "umbral dots" adopted by Danielson (1968) to describe his observations.

More recently many researchers have reported the existence of different structures inside the umbrae: Soltau (1982) found "faint light-bridges between umbral dots and penumbral filaments", and Garcia de la Rosa (1987) reported that umbral dots aligned forming chains. Livingston (1991) combining properly treated negative of a small sunspot obtained an approximately filamentary structure connecting the umbra with the penumbra, and featureless regions, that he named "voids".

We explored the possibility to detect umbral structures by means of digital image processing (Rodriguez R.E. et al. 1997, Rodriguez E.R., 1995). The Cumulative Histogram Method (CHM), described by T. Pettauer and P. N. Brandt (1997), allows us to detect what we consider evidences of an inner umbral structure, in particular a limiting border between a "reduced umbra" and the penumbra.

Data and methods

The sunspot group was observed on September 30, 1977 at 04:46:17 U.T. from the Pulkovo's (Main Astronomical Observatory of Russia) "High Mountain Station" in Pamir (altitude 4.3 km). The photoheliogram includes the main spot and 8 satellite spots (sunspot group numbering 108/77, Solnechnye Dannye). The solar telescope is a 50-cm aperture and 120 m focal length reflector. This photoheliogram was taken in the 465 nm wavelength with a 40 nm bandwidth on a 2 ASA film (size 100 X 700 mm) with red boundary at 485 nm and maximum sensitivity at 410 nm. The observing conditions were exceptionally good giving spatial resolution of 0.3 arc seconds and high photographic quality. Direct scanning of the photo negative with a 300-dpi resolution, give an image with 0.15 arc second by pixel resolution.

In figure1 we present the selected rectangular area used for cumulative histogram method processing. It includes the main spot only. Using a commercial software the cumulative histogram of the selected area was obtained. In figure 2 the section of interest is shown.
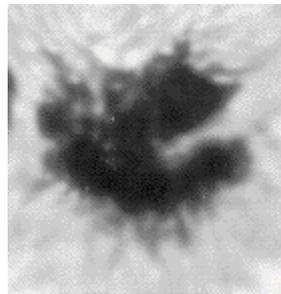

Figure 1.- Selected area in the photoheliogram including the main spot umbrae to which the cumulative histogram procedure was applied.
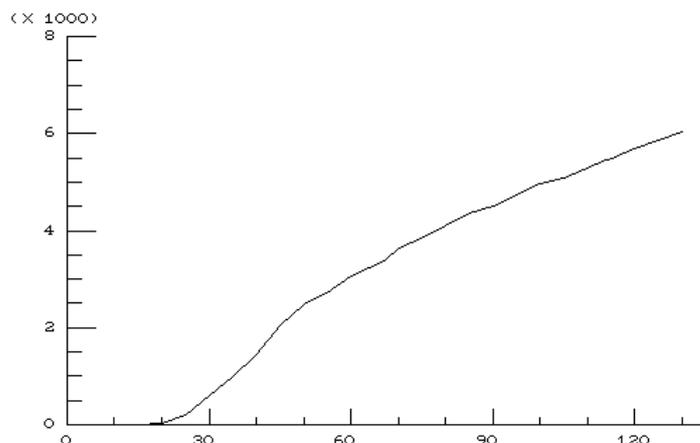

Figure 2.- Cumulative Histogram, number of pixels under a selected gray level (N) vs. gray level (I) for the area showed in figure 1. The slope change is clearly visible in the 50 units gray level range.

Results and discussion

The visual inspection of the histogram shows a distinctive change in the slope of the curve in the 50 units gray level range. A more analytical determination of the point of change was done using regressions in the three sections of the data for the total sunspot, without significant differences with the visual result.

There are other changes in the curve's slope: in the 200 gray level and in the 25 gray level, but we do not analyzed these changes in detail. The 200 gray level slope change appears to be related to the penumbrae-photosphere border, while the slope change in the 25 gray level (whose significance was not analyzed) has not a clear counter part in the morphology of the spot. No other slope change was noticed in the histogram.

To associate the observed changes to the group morphology we proceed to "binarize" the image with the threshold levels determined from the histogram. The "binarizing" procedure changes all the pixels under the level to zero and the pixels over the level to 255 values.

The change of slope is evidence of a significant change of the character of the brightest distribution; that is, a border between two different regions inside the spot. We proceeded to compare the shape of the regions obtained from the binarizing of the image and the classical structure of the spot from its photoheliogram.

It is clear that the border of the region, determined by this method, is significantly different from the umbrae as seen in the photoheliogram (figure 3).
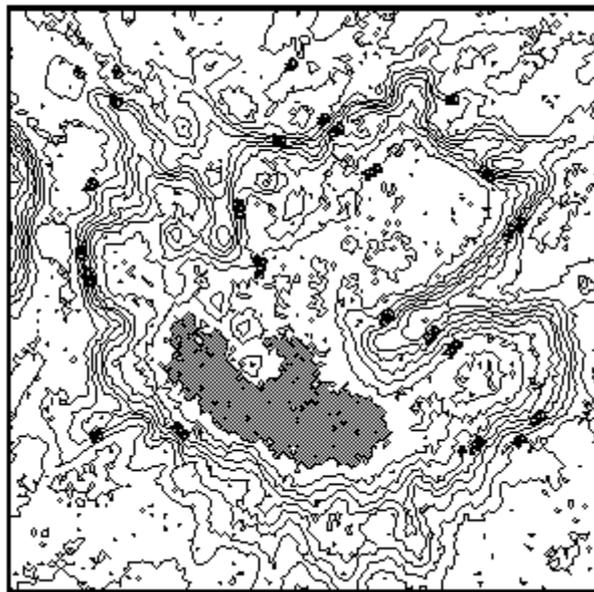

Figure 3.- Isophotes for the selected area showed in figure1. The shadowed area is the under 50 units gray level, delimiting a "reduced umbrae" inside the umbrae. The difference between levels is 20 units.

We can not determine if the reduced umbra determined by the CHM coincides with the Livingston's voids. To compare our result with the results obtained by the classical photo processing method we compared the morphological relations of the sunspots. In particular the classical umbrae area to the area of the voids and the relation of the area of the umbrae to the area of the reduced umbrae determined by the CHM (see Table I). From the agreement of the Au/At relation it is possible to consider that the groups have in general similar structures, and to propose the reduced umbrae coincides with Livington voids. The relation Aru/Au supports this assumption.

Table I.- Dimension of reduced umbrae area (Aru), classical umbrae (Au) and total area (At) for the sunspots analyzed by Livingston and Rodriguez

Image	Aru	Au	At	Au / At	Aru / Au
Livingston	211mm2	435 mm2	914 mm2	0.476	0.485
Rodriguez	2734 pixels	6119 pixels	13911 pixels	0.440	0.447

No matter the usefulness of the CHM to determine the existence of umbral structures was validated, particularly for the search of reduced umbraes, only the direct comparison of a dual processing of the same photoheliogram will probe the coincidence of the reduced umbrae and Livingston voids.

Conclusion

It was shown that the now cheap and common digital scanners and applications, allow to explore photos not specially treated, but with sufficiently good characteristics (as in the case studied) searching for structures and features of astrophysical interest. It is an important result for researchers with a reduced budget, but with access to observatories with great data banks, were digital processing could provide the way to conduce the exploration of the photos.

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