ABOUT THE FORESHORTENING EFFECT
ON SUNSPOT UMBRAL DOTS
(Research Note)

A. ADJABSHIRZADEH* and S. KOUTCHMY**
SAS-Institut d'Astrophysique, CNRS, 98 bis, Bd Arago-F. 75014 Paris

(Received 5 February, 1981)

Abstract. Using high-resolution pictures of the core of a unipolar sunspot observed with several cos \( \theta \) values, we studied the center limb effect on the form of the bright umbral dots. The ratio of the apparent sizes in radial and tangential direction do not show the foreshortening effect typically observed in granular structures.

1. Introduction

Since the first quantitative analysis of the umbral dot phenomena by Beckers and Schröter (1968), no accepted theory appeared for explaining or modeling these permanent and very characteristic features of the sunspot core. However, the problem of the origin of sunspot has recently attracted the attention of several theoreticians so we urgently need more information, especially on the dot phenomena occuring in the umbral core. The bright umbral dots, sometimes named 'umbral granulation', (Bumba et al., 1975), either are believed to be of convective origin, like the photospheric granules or, conversely, of magnetically connected wave phenomenon origin. The hypothesis which considers umbral dots like granules can be checked in a first approximation by measuring the variation of their form as a function of this distance from the center of the solar disc. The well known phenomenon of foreshortening for granules, see Schlosser and Klinkmann (1974) for example, which makes the size in a radial direction shorter than in the tangential direction by a ratio equal to cos \( \theta \), where \( \theta \) is the angle between the line of sight and the solar radius. This effect will now be considered for the case of bright umbral dots.

2. Observations

Observations were carried out at the prime focus of the Sacramento Peak vacuum telescope. White-light picture at \( \lambda = 6000 \, \text{Å} \) and \( \Delta \lambda = 60 \, \text{Å} \) were obtained with high-speed cinematography during moments of very good seeing. By putting a beam splitter near the focal plane, we controlled the quality of the images simultaneously on several monitors using a chalnicon TV-camera and a suitable image

* On leave from University of Tabriz, Iran.
** Observational part of this work was done during a stay of S.K. at Sacramento Peak Observatory, U.S.A., as NRC Resident Research Associate.
Fig. 1. Upper part: Large-scale picture of the spot observed in October 1975 (cos $\theta = 0.70$). Lower part: Restored negative print of the core of the umbra showing umbral dots.
scale. Several thousands of pictures with a scale of 3.75 (arc sec min^{-1}), including picture of the core of the spot observed during 3 consecutive days, were obtained. Several sequences of umbral core pictures showing dots are definitely excellent, without traces of speckled images of dots, indicating that images of nearly diffraction limited quality were achieved. For these pictures, a small amount of atmospheric distortion, the amplitude of which is of the order of 0.1 arc sec still exists, so a careful examination of the best pictures is required to select the picture with a minimum amount of distortion over a large enough area. As a rule, this picture is also the picture showing a maximum amount of dots, confirming the fact that dots are almost resolved. Figure 1 is a print showing, in the upper part, a large scale positive picture of the studied sunspot and, in the lower part, a restored negative picture of the core of the picture. Restoration was performed using an analog method, (Coupiac and Koutchmy, 1979) given results similar to those obtained by the method described by Koutchmy (1978).
3. Results

Each picture was suitably enlarged on a $18 \times 24 \, \text{cm}^2$ film material with a contrast factor near unity with respect to the original. Both positive and negative duplicates were furthermore used to get measurements of the diameter in 2 orthogonal direction, the tangential one $\delta_\parallel$, and the radial one, $\delta_\perp$, with respect to the limb. These measurements were performed using a contour of each dot drawn by hand and corresponding to a level of intensity rather higher than the half value of the maximum modulation produced by the dot. Exactly the same procedure was applied to all the 3 pictures with different cos $\theta$ values. The results are shown on Figure 2 in comparison with the ‘predicted’ values for ‘granules’ of similar sizes.

4. Discussion

From the examination of Figure 2, we deduced:

(a) The apparent measured diameters of dots seem to become smaller when cos $\theta$ decreases. This effect is especially pronounced when the data of cos $\theta = 0.70$ are compared with data of cos $\theta = 0.535$; further, for cos $\theta = 0.32$, diameters seem not to decrease, probably because the limitation imposed by the diffraction limited images.

(b) The ratio $\delta_\perp/\delta_\parallel$ do not follow the predicted foreshortening effect. This is already clear from the examination of data for cos $\theta = 0.70$ and is now recognized also for lower values of cos $\theta$.

Consequently, we are inclined to consider umbral dots like a definite ‘entity’ having properties rather different from the properties of granules, as far as the foreshortening effect is concerned.

References