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Variation in Continuum Brightness and Equivalent Widths of Lines in Sunspot Penumbrae

A. Bhatnagar

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Variation in the continuum brightness and in the equivalent widths of lines have been observed in the sunspot penumbral spectra. Darker regions in the continuum of the penumbrae show widening of lines, while the brighter parts show decrease in widths. A negative correlation between the continuum brightness and the equivalent widths of lines is obtained. The brightness variation in the penumbrae suggests that it is due to aggregates of individual penumbral filaments.

Introduction

It is well established that the continuum brightness fluctuations in a solar spectrum taken under good seeing conditions are due to the solar granulation, and that the 'wiggles' in the Fraunhofer lines manifest the Doppler displacements of the granulation. Recently, Servajean (1961) and Edmonds (1962) have shown that besides the variation in the continuum brightness and in Doppler shifts, conspicuous variation in equivalent width of lines also occurs in the photospheric spectrum. Correlation studies by Servajean (1961) have revealed that the dark (cooler) elements show larger equivalent width, while the brighter (hotter) regions show smaller line width. Edmonds (1962) has confirmed the findings of Servajean (1961). During our investigation on the spatial distribution of velocity fields in spots, we noticed fluctuations in brightness and line width in the penumbral spectrum – similar to those in granulation spectra. The brightness fluctuations observed in the penumbral region do not represent the individual penumbral filaments, as observed by Danielson (1961) on the Stratoscope II photographs, but probably are due to aggregates of several penumbral filaments.

Photometric analysis

The instrumental details of this study are described elsewhere (Bhatnagar, 1964). The atmospheric conditions do not permit it to obtain details $< 0''.75$ to $1''.0$. Some of the spot spectra, having 8 mm per Å dispersion near 4912 Å, show details down to $\sim 1''.0$. The brightness variations of the photosphere and the 'wiggles' of the lines are very conspicuous in

these spectra. The spectra used for this study were obtained on February 14, 1963 with the slit crossing the sunspot umbra centrally and the penumbra of the spot on either side.

Considerable variation in the widths of all the lines and in the continuum brightness, is observed in the spectrum of the penumbra. For a quantitative analysis equivalent widths of three lines (4912.02 NiI, 4911.784 FeI, and 4911.501 FeI) were measured at several places along the slit. All the spectra were calibrated with a Hilger step wedge. To determine brightness variation in the penumbral continuum, microphotometer scans were obtained perpendicular to the dispersion. The variations of the continuum brightness and the equivalent widths for

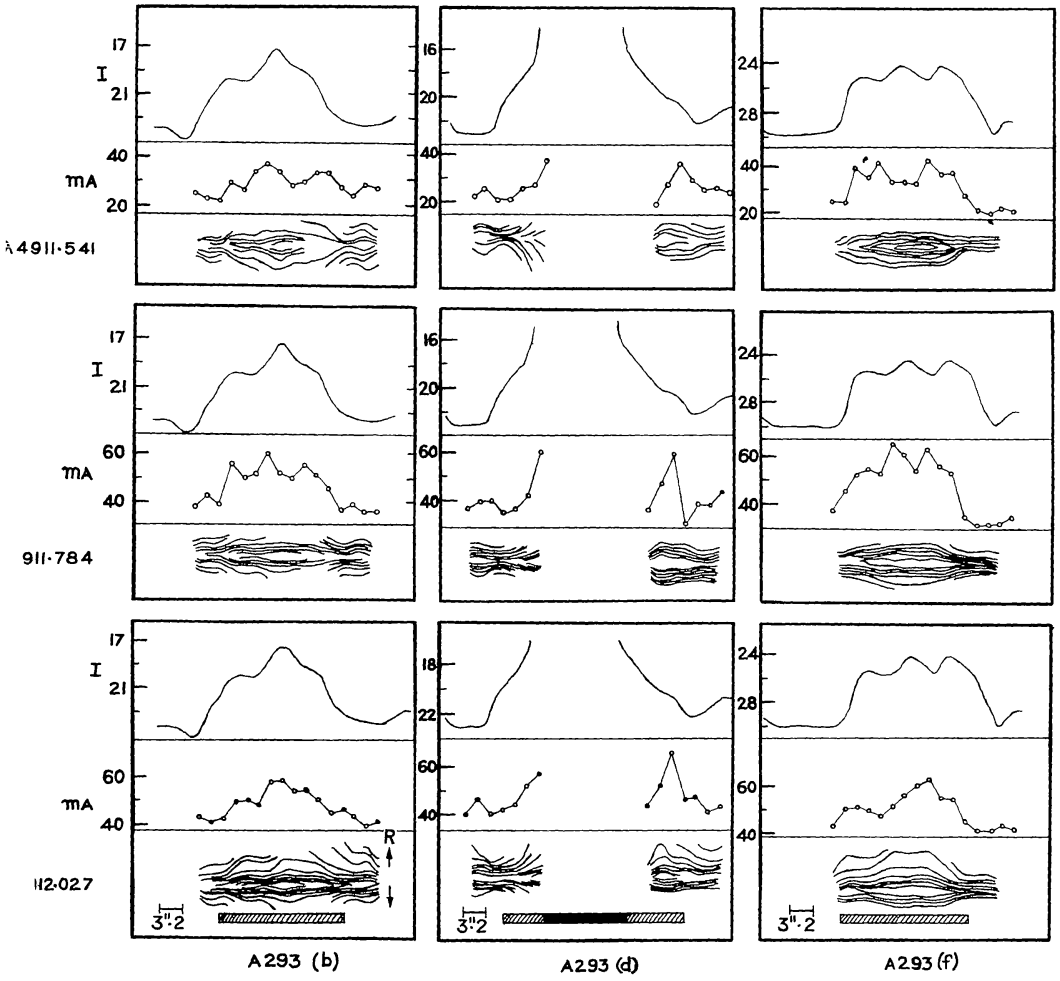

Fig. 1. Variation of continuum brightness and equivalent line widths in the penumbra of a sunspot, for three slit positions. A293 (b) and A293 (f) refer to spectra obtained with the slit crossing the disc-centre side of the penumbra and the limb-ward side respectively; the spectrum A293 (d) was obtained with the slit crossing the umbra centrally. Umbra and penumbra are indicated by dark and hatched regions. Isophotes of λλ 4912.027, 4911.784 and 4911.541 are also given

three slit positions and for the three lines are given in Fig. 1. The extension of umbra and penumbra are marked by dark and hatched regions respectively in the figures.

Discussion

Considerable variation in the continuum brightness occurs in the penumbra, three distinct humps being observed along the slit crossing only the penumbral region. Intensity variations of 6 to 7 per cent are noticed. Just outside the penumbral border a narrow region about 4 per cent brighter than the photosphere is seen, which seems to represent the bright ring around the penumbra, first observed by WALDMEIER and later confirmed by DAS and RAMANATHAN (1953). Besides the variations in the continuum brightness, fluctuations in the equivalent widths of lines are also seen in the penumbral region. In Fig. 1 a close correspondence exists between continuum brightness and the equivalent widths of lines. Darker (cooler) penumbral regions show large equivalent widths, compared to the brighter (hotter) regions. In the region of the bright ring around the penumbra, a considerable decrease in equivalent widths is observed compared to the surrounding photospheric region. This has been reported by HOLMES (1963) also.

Correlation coefficients of brightness variation with equivalent line widths were obtained for all three lines and slit positions (Table). All the correlation coefficients R(I−W) are systematically negative. Although the negative R(I−W) correlation is not the same for all three lines and slit positions, it is nevertheless significant. The negative correlation between the continuum brightness and the equivalent line widths, indicates that in the darker (cooler) interspaces, the lines widen, while in the brighter (hotter) regions lies they become narrow, similar to observations in the photosphere. It is certain that the brightness variations observed in the penumbra do not correspond to the individual penumbral filaments, which according to DANIELSON (1961) are ~ 300 km wide. The features observed on our penumbral spectra are probably due to aggregates of the fine penumbral filaments.

Table. *Correlation coefficients between the continuum brightness and the equivalent widths of lines in the penumbra*

Wavelength Å	Slit Positions A 293 b	A 293 d	A 293 f
4912.027	—0.23	—0.64	—0.67
4911.784	—0.28	—0.35	—0.67
4911.541	—0.17	—0.41	—0.72

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Dr. A. BHATNAGAR
Kodaikanal Observatory
Kodaikanal (India)