Kodaikanal Observatory
Reprint No. 20

# Intensity Fluctuations in the H-Alpha Line Caused by Chromospheric Mottling

M. K. VAINU BAPPU

Reprinted from the *Journal of the Institution of Telecommunication Engineers*, Vol. 10, No. 8, pp. 388-393

# Intensity Fluctuations in the H-Alpha Line Caused by Chromospheric Mottling

M. K. V. BAPPU*

ABSTRACT

**Spectra of the H-alpha line obtained with high dispersion and high spatial resolution are used to study some of the characteristics of chromospheric mottling on the solar disk. The fluctuations in intensity, indicated by the r.m.s. values, are given for $\Delta\lambda = 0{\cdot}6$ A., $\pm 0{\cdot}4$ A., $\pm 0{\cdot}2$ A. as well as the line centre. The fine mottles have sizes less than 1800 km. Values of the total number of mottles visible on the disk are estimated from mottle counts made at slit positions on the solar disk at $\mu = 1{\cdot}00$ and $\mu = 0{\cdot}45$.**

## INTRODUCTION

H-ALPHA spectroheliograms of the solar disk in undisturbed regions are characterized by an abundance of fine and coarse dark mottles. The observations of Deslandres[1] at Meudon and Royds[2] at Kodaikanal have demonstrated the differences between spectroheliograms obtained at different slit settings within the H$\alpha$ line. The fine mottling is visible when spectroheliograms are obtained within $\pm 0{\cdot}4$ A. of the centre of H$\alpha$. As we go farther away from the line centre, the coarse mottling is the main characteristic, until at about $\pm 1{\cdot}2$ A. no difference can be noticed between the spectroheliogram and a white light photoheliogram.

Recent investigations by de Jager[3], Kiepenheuer[4] and Beckers[5] strongly support the concept that the mottles observed on the disc are in reality chromospheric spicules in projection. The validity of such an identification rests on the equivalence of spicule and mottle statistics pertaining to, number on the visible hemisphere, sizes, lifetimes and intensities. In view of the major contribution to chromospheric excitation and support by the spicules, it is important to be able to establish with certainty that the chromospheric mottles are, in reality, spicules on the disk.

The contributions by the spectroheliographic and the filtergram techniques to such a study are obvious since, the two-dimensional picture obtained makes possible the easy evaluation of some of the parameters. The studies of de Jager[3], Rogerson[6] and Beckers[5] are of this nature. An alternate approach is made possible with the modern high-dispersion spectrographs and associated large images. The facility of the two-dimensional evaluation is lost however, in this technique, but it is replaced by the possibility of investigating the change of mottle characteristics at different wavelength positions in the spectral line. The practical limitations imposed on the spectroheliographic technique from considerations of exposure time, image scale and degree of monochromaticity, cease to exist in any direct spectrographic study of the mottling aspects of the quiet chromosphere.

*Manuscript received on* 20 *June* 1964.
*Kodaikanal Observatory, Kodaikanal.

The present study aims at a determination of the r.m.s. fluctuations in the Hα line at different values of Δλ from the line centre. It also contains an evaluation of the total number of mottles on the disk as well as an estimate of mottle sizes.

## THE OBSERVATIONS

The observations were obtained with the horizontal solar telescope and 18 metre spectrograph at Kodaikanal. A two mirror fused quartz coelostat of 60 cm. aperture feeds a visual achromat of 38 cm. aperture and 36 metres focal length. A solar image 34·3 cm. in diameter is formed in the slit-plane of the spectrograph where it is guided to within 1 sec. of arc in R.A. and Declination. The autocollimating spectrograph has a 20 cm. achromat and a Babcock grating of size 135×200 mm. with 600 grooves/mm. and blazed in the fifth order green. Photographs as well as photoelectric scans of the iodine absorption spectrum obtained by Miss Subrahmanyam with this instrument, show well resolved in the fifth order, the iodine doublets in the 5300 A. region that have a separation of 0·009 A. The grating was used in the fourth order for the present study.

The spectra were obtained within two hours after sunrise, when the seeing at Kodaikanal is usually at its best phase for the day. Eastman IV-E plates, together with a Schott RG2 filter for eliminating overlapping orders, enabled good quality spectra to be obtained during the spells of good seeing, with exposure times of 8 sec. and a slit width of 175 μ. The plates were calibrated for photometry with the aid of a six-step wedge and an out-of-focus image of the centre of the solar disk. The plates were run through the observatory microphotometer and reduced to intensity values by the conventional methods of photographic photometry.

Intensity scans were made perpendicular to the dispersion at the positions in Hα of $\Delta\lambda = \pm 0{\cdot}6$ A., $\pm 0{\cdot}4$ A., $\pm 0{\cdot}2$ A. as well as the line centre. The plate dispersion in the fourth order at the wavelength of Hα is 7 mm./A. The dimensions on the plate of the analysing aperture of the microphotometer were 40×40 μ. This corresponds to 0·22 sec. of arc along the length of the slit and about 0·006 A. in the direction of the dispersion.

## RESULTS

*The r.m.s. fluctuations in intensity* — From the reduced intensity traces of the various scans at different wavelength distances from the line centre, the intensities were read off at about 200 equally spaced intervals, corresponding to a spacing of 175 μ on the plate. Figure 1a is a reproduction of one of the spectra of a series obtained on 21 April 1963. Figure 1b is an underexposed print of the same exposure frame that shows the details in the core of Hα. Samples of the intensity fluctuations at the various wavelengths of scan are shown in Fig. 2. One sees the very striking contribution by the larger coarse mottling at $\Delta\lambda = \pm 0{\cdot}6$ A. As one goes to $\Delta\lambda = 0{\cdot}0$, the coarse mottles give way to the fine mottles. Both the fine and coarse mottles show up with fine contrast on the tracings at $\pm 0{\cdot}4$ A. The tracing in the line core has an abundance of the effects of the fine mottles, but one can also detect the presence of the coarse mottled structure. The r.m.s. values of the intensity fluctuations are given in Table 1. These values indicate to some extent the degree of contrast with which the mottling detail is visible along the slit. The larger values at $\Delta\lambda = 0{\cdot}6$ A. are, however, due to the large amplitude intensity fluctuations in the coarse mottling.

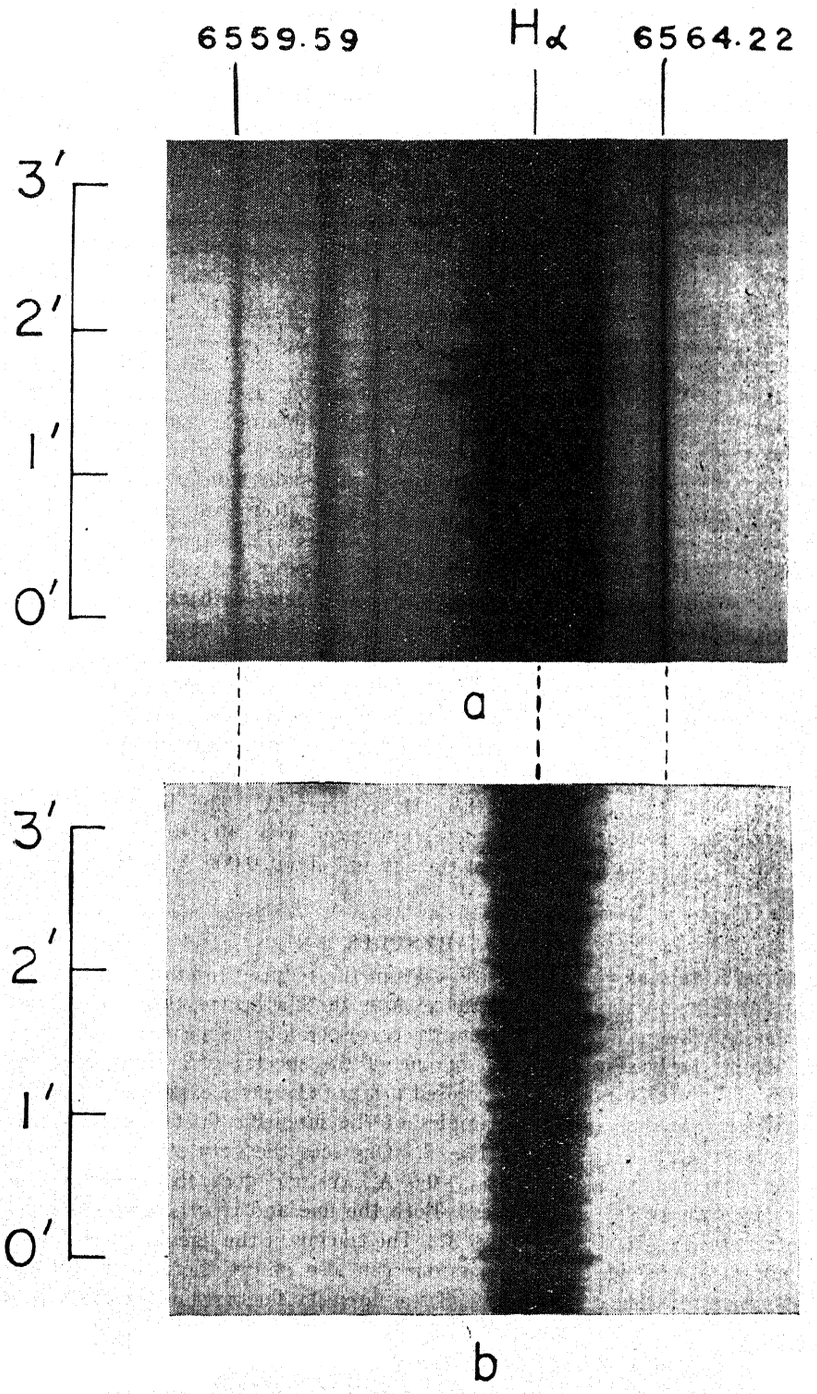


Fig. 1 — Chromospheric mottling in H-alpha ($\mu = 0{\cdot}45$)

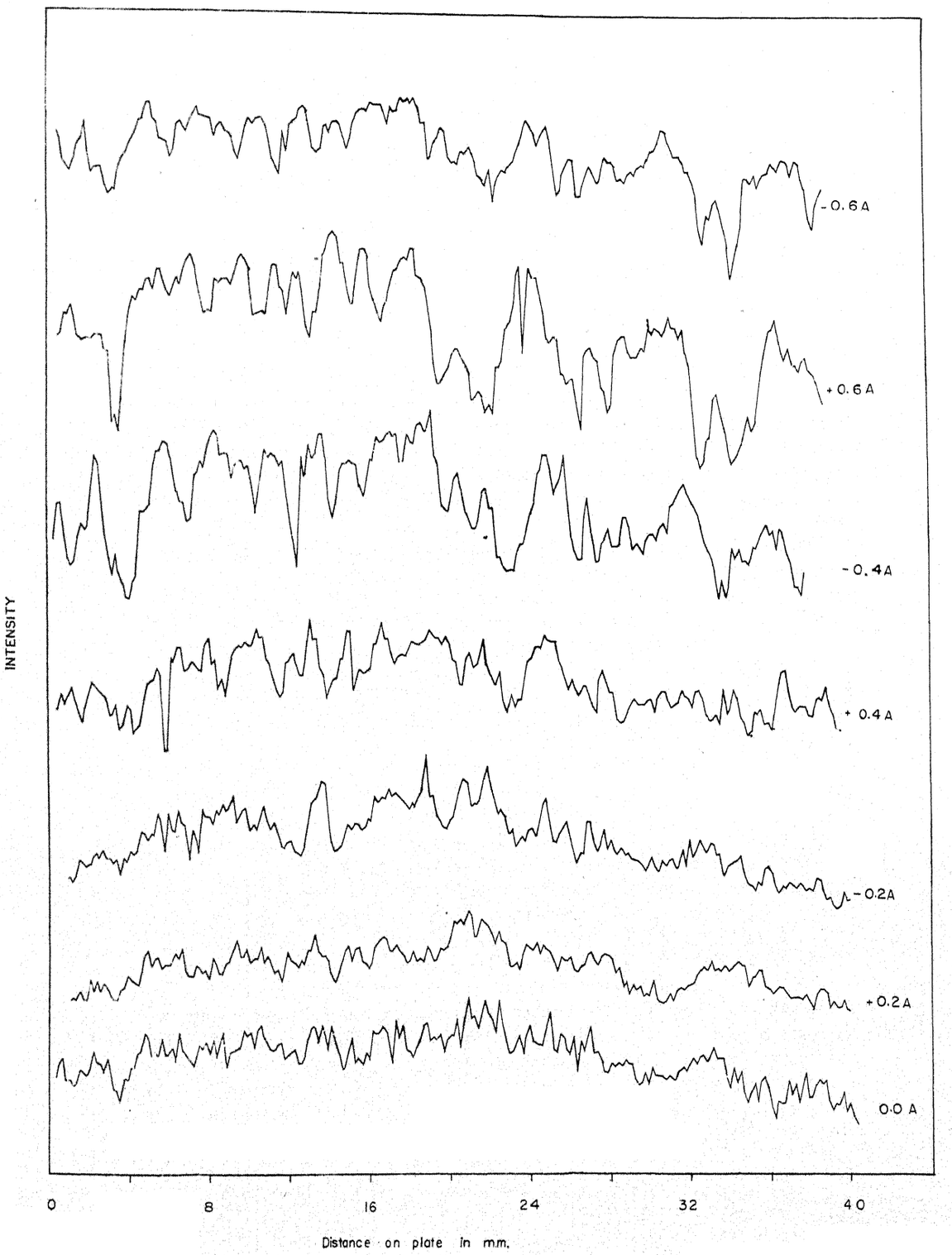


Fig. 2 — Intensity fluctuations in the H-alpha line

TABLE 1

(r.m.s. values of intensity fluctuations at $\mu=0{\cdot}45$)

| $\Delta\lambda$ (A) | r.m.s. (per cent) |
|---|---|
| −0·6 | ±8·71 |
| −0·4 | ±11·00 |
| −0·2 | ±6·14 |
| 0·0 | ±4·44 |
| +0·2 | ±4·86 |
| +0·4 | ±7·85 |
| +0·6 | ±8·63 |

The r.m.s. values of intensity given in Table 1 are uncorrected for broadening, by seeing, as well as by telescope performance. The corrected values would yield a slight increase over the values given here. The correction, however, is likely to be small since the spectra were obtained during spells when the seeing excursions were of the order of 1-1·5 sec. of arc. The 38 cm. objective is also capable of good resolution.

One can compare these values with those obtained by previous investigators. de Jager[3], who has analysed a high quality Meudon spectroheliogram obtained in the line centre, finds an uncorrected r.m.s. value of ±5·0 per cent. A later investigation by de Jager and Servajean[7] assigns a value of 4·7 per cent for the r.m.s. fluctuation at the disk centre and line centre. Rogerson[6] finds similar values of 2·6 and 3·9 per cent from Hα spectroheliograms taken with solar image diameters of 7 and 16·7 cm. respectively. These results are in close agreement with that obtained in the present study, carried out with much greater spatial and spectral resolution.

*Mottle counts* — Counts of the fine structures over a finite length of slit give a first approximation of the total number of mottles on the solar disk. Counts on spectra taken at $\mu = 0{\cdot}45$ yield a total number of $3{\cdot}0\times10^5$ mottles. At $\mu = 1{\cdot}0$ a value of about $4{\cdot}8\times10^5$ mottles is obtained. The number of mottles per unit length of slit appears to be greater at a slit position on the disk of $\mu = 0{\cdot}45$ than at $\mu = 1{\cdot}0$. However, the use of a foreshortening correction in evaluating the area covered by the slit, when it is closer to the limb, is perhaps responsible for reducing the total number on the basis of counts at $\mu = 0{\cdot}45$.

From a study of high resolution Hα filtergrams, Beckers[5] finds that the total number of mottles on the solar disk, at any stage of their evolution, is about $4\times10^5$. Athay's[8] estimate of the total number of spicules on the disk from counts made along the limb at chromospheric heights of 3000 km. and above is $9{\cdot}3\times10^4$. The mottle numbers are roughly of the same order of magnitude as the estimated number of spicules. However, we cannot yet say with certainty, on the basis of number counts, that mottles are spicules seen in projection, until we know more about mottle characteristics at different centre-limb distances.

*Sizes of the fine mottles* — Estimates of widths at half intensity of the fine mottles for six of the narrowest features on the spectrum at $\mu = 0{\cdot}45$ indicate an upper limit of

1800 km. This value is uncorrected for seeing and telescope profile effects. These are about twice the widths reported by Dunn[9] for spicules at the limb.

**ACKNOWLEDGEMENT**

It is a pleasure to acknowledge the very valuable help rendered by P. Viswanadham and A. Thulasidoss in the computations involved in this investigation.

**REFERENCES**

1. Deslandres, H., *Ann. Meudon*, **4** (1940), 1.
2. Royds, T., *M.N.*, **71** (1911), 723.
3. de Jager, C., *B.A.N.*, **13** (1957), 133.
4. Dunn, R. B., Doctoral thesis, Harvard University, 1960.
5. Beckers, J. M., *Ap. J.*, **138** (1963), 648.
6. Rogerson, J. B., *Ap. J.*, **121** (1955), 204.
7. de Jager, C. & Servajean, R., *Handbuch der Physik*, **52** (1959), 132.
8. Athay, R. G., *Ap. J.*, **129** (1959), 64.