Kodaikánal Observatory.

BULLETIN No. XXII.

NOTE ON THE MAGNETIC FIELD IN THE SUNSPOT OF SEPTEMBER 1909.

Photographs of the red end of the spectrum of the large spot of September 1909 were obtained here on September 23rd, 24th, and 25th, using a Michelson 6-inch grating in the 3rd and 4th orders. The scale of the 4th order plates is about 1 Å = 2·3 mm and the lines 6173·55 and 6302·71 are shown in these as triplets, whilst the line 6213·64 appears as a clearly resolved double over the large umbra.

The amount of separation in the triple lines is difficult to estimate as the side components are very wide and ill defined under the micrometer microscope. The components of the line 6213·64 on the other hand are fairly well defined and this seems to be a very suitable line for gauging the effect of the magnetic field in sunspots, and the approximate strength of the field in the region of iron absorption.

Measures of the separation of the components of this line give sensibly constant values on the three successive days as is shown below:—

Greenwich Civil Time.						$\Delta\lambda$	Distance of spot from the centre of disc. Radius = 1.	
1909	September	23^d	5^h	07^m	... .	0·112 Å	0·25	E
,,	,,	24	4	13	... ...	0·101	·20	W
,,	,,	25	6	05	... ...	0·104	·26	W

These values are distinctly smaller than the result given by Prof. Hale. In a comparison of iron doublets photographed in the laboratory and in sunspots he gives the value $\Delta\lambda = 0{\cdot}136$ for this line in spots, * presumably measured in spots situated not very far from the centre of the sun's disc, or observed approximately along the axis of the assumed electric vortex.

My results would seem therefore to indicate for this particular spot a magnetic field of less intensity than that estimated by Hale, which is presumably an average value. While it is certain that the magnetic fields observed in spots are much too small to have any direct effect in producing magnetic storms on the earth, it is perhaps surprising that a spot which was associated with one of the greatest storms on record should be characterised by a relatively weak field.

But it may be questioned whether the magnetic field is really a constant quantity in spots. In examining recently some plates of the H and K region in the spectrum of this same spot, I came across an interesting piece of evidence which tends to show that at times when there is a great outburst of gases the magnetic field may be very largely increased.

On the date September 28th, between $10^h\ 30^m$ and $11^h\ 30^m$ Indian Standard Time (5^h to 6^h Greenwich Civil Time) the first assistant, Mr. Sitarama Aiyar, was fortunate enough to witness such an outburst directly over the umbra of the spot, and accompanied by motions in the line of sight attaining to 100 km. per second in the direction of approach. This eruption also appears very distinctly on our series of K_3 spectroheliograms

* Astrophysical Journal, XXVIII., 326. The wave length of the line is given by Hale and by King as 6213·14, but this appears to be a mistake.

which show the entire spot region to have suddenly become covered with intensely luminous calcium vapour. This remarkable outburst and the accompanying magnetic disturbance which was registered on our magnetograph has already been described in detail by Prof Michie Smith *

At $10^h\ 1^m$, about half an hour before the eruption was first noticed, I obtained a photograph of the spot spectrum in the H and K region, and at $11^h\ 9^m$ and $11^h\ 12^m$ I obtained two more images on another plate, fortunately before the disturbance had entirely subsided. The earlier plate shows nothing at all remarkable, but in the later plate the H and K lines are intensely bright over the umbra and with an extremely narrow absorption line in their centres They are not displaced from their normal positions but there is a faint indication of wings, especially on the more refrangible side of each; and the hydrogen line ϵ which is bright, is distinctly winged on both sides, the wings extending about 1 Å towards the red and rather more towards the violet. The most interesting feature of this plate consists however in the Zeeman effect which can be seen in both the images in a few of the lines The iron lines at 3923·05 and 3930·45 are distinctly doubled over the umbra, the amount of separation of the components being 0·19 Å and 0·18 Å respectively. The iron line at 3928·07 seems to be diffused and displaced towards the more refrangible side, possibly it is also doubled but the line at 3928·23 would interfere with the red component Finally the silicon line at 3905·66 appears to be doubled, but the spectrum at this point is much under-exposed and it is not so easily detected. The spectrum extends from 3899 to 4010 and in this range no other lines but those mentioned are doubled; the Fe line 3920·41 is much widened and the Fe lines 3899 85 and 3903·09 appear to be weakened and diffused over the umbra.

That the obvious doubling of the two iron lines 3923 and 3930 implies a very strong temporary magnetic field in the spot is shown by the fact that these lines are not even appreciably widened in the plate exposed an hour earlier, nor are they at all affected in a plate of this region taken on September 23rd and exposed about one hour before the plate showing the Zeeman effect in the line 6213·6.

I have since examined a large number of plates of the H and K region in various large spots which have appeared during 1909 and later but have failed to detect any similar case of doubling, or even of widening of these ultra violet lines. But none of the photographs were taken during a great eruption such as that of September 28th, 1909 It appears then that under normal conditions the magnetic field is much too weak to affect any of the iron lines in the region near K.

It is possible to form an estimate of the strength of the field in this exceptional case if we may apply Preston's law, $\frac{\triangle\lambda}{\lambda^2}$ = const. to the two lines 3923 and 6213. Taking Hale's value of $\triangle\lambda$ for the line 6213, which is 0·136 Å the corresponding value for the line 3923 will be

$$\triangle\lambda = \frac{3923^2 \times 0{\cdot}136}{6213^2} = 0{\cdot}054\ \text{Å}.$$

The observed value is 0·19 Å or 3·5 times greater. According to Hale's results the approximate strength of field corresponding to his value of $\triangle\lambda$ in the line 6213 is 2,900 gausses. The strength of the field in the September spot on the 28th of the month and at a time when a great eruption had just taken place would therefore be of the order of 2,900 × 3·5 or say 10,000 gausses But this involves the assumption that the two lines belong to the same series.

A direct comparison with the results of measures of Zeeman separations recently published by Dr. King † and which include the lines 3923 05 and 3930·45 gives a smaller value of the field (8,300 gausses). The spectrum in King's work was observed across the lines of force, and the separations measured in these lines refer to the side components of triplets, which however are said to be the same as the separations of the doublets observed along the lines of force.

As the spot lines appear to be doublets it is to be presumed that the light came more or less along the lines of force in the solar magnetic field The spot was near the west limb and 69° from the centre of the disk, from which it may be inferred that the axis of the temporary electric whirl must have been very far from being normal to the sun's surface.

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* Monthly Notices of the Royal Astronomical Society LXX., 28.

† Astrophysical Journal, XXXI., 441.

Notwithstanding the strong magnetic effect recorded on the plate, no apparent change seems to be roduced in the normal radial outflow of the gases of the reversing layer in the spot. The plate is however nsuitable for measuring this effect as the slit of the spectrograph made an angle of about 45° with the line oining the spot and the centre of the sun's disc, whereas the greatest effect is found with the slit early in the direction of the centre. Also the sun's image was very poorly defined on the slit plate so that o clear image of the penumbra is seen on the photograph, but any large increase in the radial movement ould probably be noticeable in an unusual displacement of the lines on each side of the umbra.

The interesting photograph of September 28th emphasises once again the great need of securing records f solar phenomena as continuously as possible by co-operation of observers in different longitudes, and specially during periods of spot activity.

During the great magnetic storm of September 25th, 1909 which began at about 5 P.M. local time, no solar bservations were made at this observatory. Our photograph of the Zeeman double line at 6213·6 was btained $5\frac{1}{2}$ hours before at a time when there was no special disturbance in the spot. So far as I can iscover no spectroscopic observations of the spot appear to have been made at any observatory at the time of eginning of the great storm. Spectroheliograms were obtained by Dr. Slocum at Yerkes Observatory during he progress of the storm and several hours after its commencement and these show nothing remarkable The bservations of W J. S. Lockyer * and of Fowler † on the previous day show that there was an outburst of the ame character as that described above on that day, and this eruption is connected by Dr. Lockyer with the agnetic storm which began 26 hours later, but whether the eruption was accompanied by increased Zeeman ffects it is not possible to say.

It would be of great interest to establish the connection suggested in our photograph of September 28th etween solar eruptions and simultaneous magnetic effects, not only on the earth but also in the sun itself.

* Monthly Notices LXX., 17.

† Nature 81, 396.

KODAIKÁNAL OBSERVATORY,
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J. EVERSHED.

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