

SOLAR VORTICES.

SOME preliminary investigations of Prof. Hale on the gyratory forms assumed by the hydrogen flocculi on the sun were described in a recent number of *NATURE* (vol. lxxviii., p. 200). The photography of the sun, through the hydrogen line $H\alpha$, using specially bathed red sensitive plates, by means of the 5-foot spectroheliograph of the Mount Wilson Observatory, gave promise of being of great value. Already the promise is kept. A copy of a paper which is to appear as No. 26 in a series of "Contributions from the Mount Wilson Solar Observatory" has been forwarded, together with illustrative photographs. After realising the advantage of the $H\alpha$ line over the line $H\delta$ previously used, the daily programme was modified to allow of a full series of photographs under the new conditions. A distortion due to heating of the mirror, now more continuously used, was eliminated by the use of a smaller aperture.

After obtaining new slits adapted to the $H\alpha$ line, the first photograph of the entire solar disc by the modified method was obtained on March 28, 1908. The remarkable solar "vortex" previously reproduced in *NATURE* was secured by Mr. Ellerman, who was in charge of the routine work with the instrument, on April 30. Further information relative to this phenomenon appears in the more recent communication. On a less successful exposure made on April 29 the same large storm area is fairly well shown. A comparison with the afternoon photograph of April 30 recently made in the stereocomparator, together with the measurement of the latitude and longitude of objects identified on both dates, "seem to show the existence of a gyratory motion, in a direction opposite to that of the hands of a watch (north, east, south, west)." In Prof. Hale's first note on the same object, he remarks (*NATURE*, vol. lxxviii., p. 200) of the dark flocculi surrounding this area that "their appearances strongly suggest the effect of a great whirl rotating clockwise." The identification of objects on both plates is a matter of great difficulty, and the evidence for direction of rotation is admittedly weak. Further discussion of these plates is postponed until additional data become available.

The present communication from Prof. Hale is concerned chiefly with the phenomena recorded, by the aid of $H\alpha$, in the neighbourhood of a spot which reached the east limb of the sun at 8h. 16m. a.m. on May 26, 1908. The changes which took place about it, in many cases rapid though not especially violent, were followed until June 2, when the attendant "whirl" was very marked. A long dark flocculus had persisted near the spot during this period. "On June 3, in an interval of about ten minutes, a remarkable transformation occurred. The long dark flocculus, which had been gradually changing in form and position, was suddenly drawn into the spot." The three photographs here reproduced illustrate this remarkable occurrence. They were taken on July 3 at 4h. 58m. 16s., 5h. 13m. 54s., and 5h. 22m. p.m. respectively. The times given refer to the transit of the spots across the primary slit of the spectroheliograph, while the scale is such that the sun's diameter would be represented by 14 inches. The definite incurving of the eastern end of the flocculus almost precludes the idea that it is a casual change at a level remote from that of the spots. Spectroscopic evidence of the motion of the flocculus down into the spot, during the period, would have been of interest. The records were obtained by Dr. C. E. St. John with the 5-foot spectroheliograph during Mr. Ellerman's absence on vacation. When the whirl was

best seen its radius was about equal to the distance of the western extremity of the flocculus. Apparently the eastern end did not fall definitely under the influence of the whirl until its distance was about 140,000 km. from the spot. The fact that the western extremity lay, during the whole period, outside this magic radius may account for its escape. The mean of six

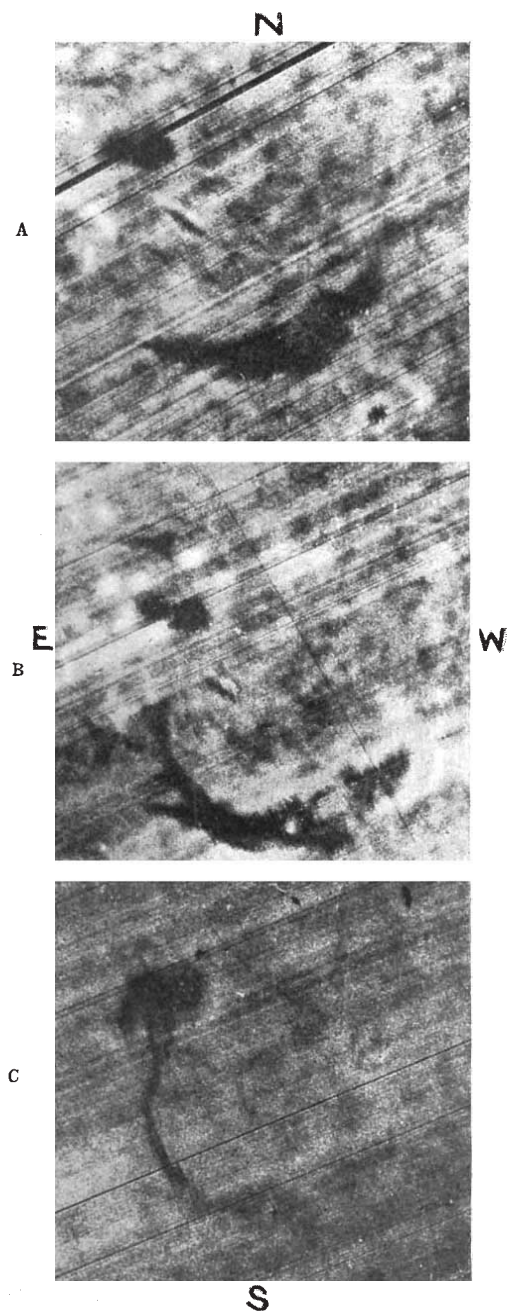


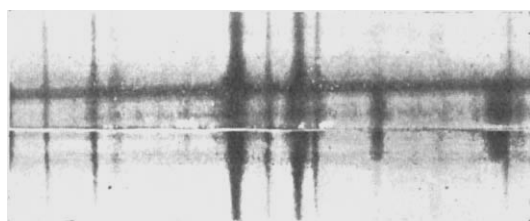
FIG. 1.—A hydrogen flocculus drawn into a solar whirl. A at 4h. 58m. 16s. p.m.; B at 5h. 13m. 54s. p.m.; C at 5h. 22m. p.m.

measures of the velocity of approach of the flocculus gives 106 km. per second, which, it is suggested, is the order of the maximum velocity in the vortex. It is stated that, except in the case of the large flocculus, motion towards the spots, even along apparent lines of flow, has not made itself obvious.

Many visual observations of the drawing of photospheric matter into spots have been made, among others by Sir Norman Lockyer more than forty years ago, who described the apparent drawing of a willow leaf into a dark spot,¹ and the late Father Secchi, who was convinced that a swirl and a kind of suction existed in them.

A notable feature of a photograph taken after this indrawing, on June 5, is the amount of "bright eruptive hydrogen in the region surrounding the two spots." These opposite phenomena together strongly suggest Sir Norman Lockyer's sun-spot theory of a cooler central downrush with the later encircling splash of dissociated matter.² A gyratory motion in spots has been suggested by many observers. A number of problems as to the levels at which the activities recorded take place are suggested by the photographs. The remarkable fact of the non-participation of the high-level hydrogen in the differential rotation with latitude would at once follow if the equatorial acceleration were due to a fall of material from greater equatorial heights in the solar atmosphere. If the hydrogen is ascending in consequence of dissociation from the denser materials of the fall, it cannot show the same forward velocity as the falling material, to which velocity Lockyer ascribes the more rapid equatorial movement of the photosphere.³

The known correlation of the meridian passage of large spots or disturbed areas and the sudden changes in the magnetic elements has given currency to theories of the magnetic nature of this spot influence.



6302.71

FIG. 2.—Widening of spot line due to Zeeman effect.

A direct magnetic effect was negated by Lord Kelvin on account of the excessive amount of energy required. A causal relation of this nature, whatever the intermediate step or steps, has been almost undoubted.

It is suggested by Prof. Hale that a segregation of positively or negatively charged particles caught into the stream of a solar vortex would give rise to magnetic lines of force at right angles to the plane of the swirl.

If such a field of force existed in a spot, the analogy of terrestrial experiment would suggest that the period of vibration of the ions emitting light in such a field should suffer modification. The light emitted from a spot near the sun's centre would be along these lines of force. The doubling of spectrum lines with the components circularly, and oppositely, polarised would be expected. Prof. Hale promised to make spectroscopic search for this Zeeman effect on the first opportunity. In a more recent letter he announces the complete success of his search.

Spectra of the light of a spot and of the photosphere were taken with the tower telescope and 30-foot spectrograph, having a Fresnel rhomb and Nicol prism mounted in front of the slit. The Zeeman doublets in the spot spectrum photographed under

these conditions should change in relative intensity as the Nicol is rotated. When the spot was near the limb of the sun the results were uncertain, but when about 45° from the centre the characteristic changes were observed. The accompanying figure shows a pair of photographs in the region of the iron line λ 6302.71 taken on June 27. They are enlargements, the resulting scale being 1 Ångström = 9 mm. The widening in the central spot bands of the line marked represents a true doubling. In the reproduction it will probably only be seen with difficulty that the relative intensities of the components are reversed in the two photographs due to the turning of the Nicol through 45° .

The separation of the components ranges from 0.018 to 0.216 Ångströms. In several cases a tripling of lines was observed.

Every care was taken, of course, that the variations were not instrumental. Similar effects were found with other lines, though a remarkable and unexplained paucity of them occurred in the blue and violet regions. Further details are promised in a forthcoming paper of these exceedingly interesting discoveries.

The systematic recording of the solar magnetic fields for comparison with simultaneous records of terrestrial magnetism is suggested as desirable.

The ease, apparently, with which these varied records of solar activity can be obtained gives hope that soon will exist ample material for the discussion, and it is to be hoped the solution, of many of the outstanding solar problems.

From the perfect equipment at Mount Wilson much is expected, but no one will think of minimising the great credit due to Prof. Hale for the progress towards more intimate knowledge of the stupendous activities in the neighbourhood of the sun.

T. F. C.

SOLAR MAGNETIC FIELDS AND SPECTRUM ANALYSIS.

PROF. GEORGE E. HALE, of Mount Wilson Solar Observatory, with great kindness has sent me a letter of date July 6, together with a copy of a manuscript destined for publication in *NATURE*, on "Solar Vortices and the Zeeman Effect." Prof. Hale's paper is accompanied by two photographs on glass of the double lines in the spot spectrum between two comparison spectra of penumbra and photosphere of the region λ 6250– λ 6360. The position of the Nicol in the arrangement used was changed 45° between the first and the second of these photographs.

Prof. Hale asks me to examine the photographs of spectra, and to send a note to *NATURE* expressing my opinion as to the interpretation of the results. I can say at once that I have come to the conclusion that Prof. Hale has given what appears to be decisive evidence that sun-spots are strong magnetic fields, the direction of these fields being mainly perpendicular to the sun's surface. Light received from a spot at the centre of the sun would in this case be parallel to the lines of force.

A source of light in the laboratory, and placed in a uniform magnetic field, emits, in the most simple case covered by the elementary Lorentz theory, parallel to the lines of force, two rays circularly polarised in opposite directions. Each spectral line is split up into a doublet of two circularly polarised lines, the one polarised clockwise, the other anti-clockwise. We may imagine that for further analysis a Fresnel rhomb and Nicol are mounted before the slit of the spectroscope, the arrangement actually used by Dr. Hale. The two circular vibrations of the doublet are

¹ *Monthly Notices*, vol. xxv., June, 1865, p. 236.

² "The Chemistry of the Sun," p. 412. (Macmillan and Co., 1887.)

³ *Ibid.*, pp. 422 and 424.