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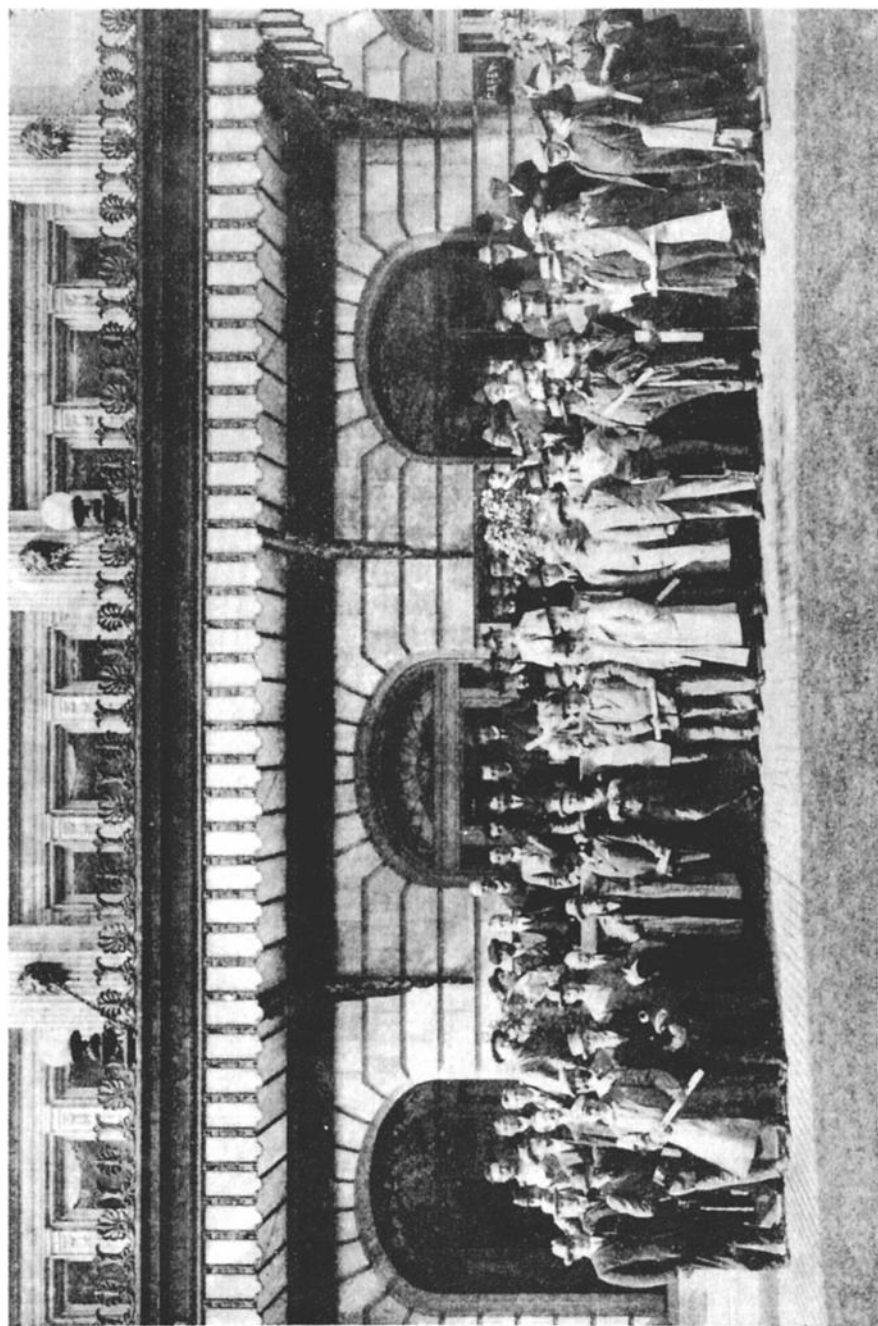
PRELIMINARY NOTE ON AN ATTEMPT TO DETECT THE GENERAL MAGNETIC FIELD OF THE SUN.

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In 1908, shortly after magnetic fields had been found in Sun-spots, an attempt was made to observe the Zeeman effect due to the general magnetic field of the Sun with the 60-foot tower telescope and 30-foot spectrograph of the Mount Wilson Solar Observatory. Although slight shifts of certain solar lines, such as might be caused by a magnetic field, were found on measuring the photographs, the quantities were too small to command confidence, and the work was postponed until more perfect polarizing apparatus could be provided.

The investigation was resumed in October, 1911, but no certain evidences of the Zeeman effect were detected. On the completion of the 150-foot tower telescope and 75-foot spectrograph, observations were begun with this instrument in January of the present year. The objective of 150 feet focal length now used with this telescope was not then ready, and, accordingly, the 12-inch objective of 60 feet focal length, belonging to the 60-foot tower telescope, was temporarily transferred to the new tower. This forms an image of the Sun 6.7 inches in diameter on the slit of the spectrograph. After passing through the slit the light descends vertically into a well, excavated in the earth beneath the tower, to a depth of 75 feet, where it falls upon the objective which serves for both collimator and camera of the auto-collimating spectrograph. We were fortunate in having a large grating of the finest quality, ruled by Michelson, which gives almost theoretical resolution in the third order spectrum. Here the scale is 4.9 mm to the Ångström unit, corresponding to a distance of 29 mm between the D lines.

Let us assume the Sun's magnetic field to be similar to that of



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a magnetized sphere, with magnetic poles coinciding in position with the poles of rotation. If the field were strong enough, and if the observer could look along the Sun's axis, and form an image of one of the magnetic poles on the slit of a powerful spectrograph, he would find certain solar lines split into doublets, with components circularly polarized in opposite directions. If a Nicol prism were placed in front of the slit of the spectrograph with its long axis parallel to the slit, in combination with a quarter-wave plate set with its principal section at an angle of 45° , one of the components of the magnetic doublets would be extinguished, while the other would be transmitted by the Nicol. If we assume the red component to be transmitted, rotation of the quarter-wave plate through an angle of 90° would cause this to be extinguished and the violet component to be transmitted. Consequently, if the quarter-wave plate were built up of mica strips 2 mm wide, mounted so that the principal sections of successive strips make an angle of 45° with the slit and 90° with each other, the Nicol would transmit (say) the red component for the odd strips and the violet component for the even strips. In a photograph of the spectrum the lines would have a zigzag appearance, the magnitude of the separation of the components shown on successive strips varying directly with the strength of the field. If the slit of the spectrograph were directed, not at the Sun's pole, but at a point in 45° latitude, the effect would still be clearly observable, though the transformation of the circularly polarized light of the components into elliptically polarized light would result in less complete extinction by the Nicol.

In practice, on account of the weakness of the Sun's magnetic field, in comparison to the fields of Sun-spots, complete separation into doublets is not to be expected. The superposition of the components would result in a slightly widened line, with edges elliptically polarized in opposite directions. It was hoped that a spectrograph of very high dispersion might reveal slight shifts of the lines, caused by the extinction of the red and violet edges by the successive strips of the quarter-wave plate. The increasing ellipticity of the light, in passing from high to low latitudes, would involve less and less complete extinction. This, coupled with the decrease in the total magnetic intensity toward the equator, would be indicated by decreasing displacements of the line. The sign of the displacements should be reversed in passing from the northern to the southern hemisphere.

With the aid of the polarizing apparatus described above, a series of photographs of the region near the D lines in the third order spectrum was made with the slit at various latitudes on the central meridian of the Sun. The photographs were measured by Miss Lasby, who had acquired much experience in the measurement of extremely small displacements of solar lines. The measures were made without possible bias, as the latitude corresponding to the plate was not known to the observer. With very few exceptions, the displacements were found to be positive in the northern hemisphere and negative in the southern hemisphere of the Sun, the magnitude of the displacements decreasing from a maximum near 50° north or south latitude, to zero near the equator.

The conditions were extremely favorable for the detection of very small shifts of the solar lines, as the spectrograph is very massive and stable, the grating is mounted in a region of practically constant temperature about 75 feet below the level of the ground, and the method of observation is a purely differential one, the displacements measured being those of sections of the same line corresponding to adjoining strips of the quarter-wave plate. As a check upon the results, atmospheric lines were measured, and found to give shifts rarely exceeding 0.0002 Ångström, while some of the solar lines gave shifts as great as 0.003 Ångström. Nevertheless, there were certain peculiarities about the results which make it advisable to take every possible precaution to check their reliability.

The most marked of these peculiarities lay in the fact that only a few of the solar lines seemed to be affected, the others showing no shifts, although they were known to give large Zeeman effects in the laboratory. In our work on the spectra of Sun-spots, it is true, we had found that the magnetic field is very strong at low levels, but decreases rapidly in passing upward through the spot vapors. If some analogous condition exists in the case of the general field, certain low-level lines may show it, while those corresponding to higher levels may fail to do so.

As a check on the question whether the displacements of the solar lines might safely be attributed to a magnetic field, a half-wave plate was inserted between the compound quarter-wave plate and the Nicol. Leaving the quarter-wave plate and Nicol untouched, it should be possible to reverse the sign of the displacement in any given case by turning the half-wave plate through an angle of 45° . A number of tests were made in this way, and in all

cases Miss Lasby's measurements showed shifts such as would occur if the edges of the lines were circularly or elliptically polarized. A similar test was applied by omitting the half-wave plate, and inverting the compound quarter-wave plate, so as to bring its lower face uppermost. This also reversed the sign of the displacement, and proved so satisfactory a means of checking the observations that the plan of taking all plates in pairs, corresponding to the two positions of the quarter-wave plate, was subsequently adopted.

Up to this time all of the measures had been made by Miss Lasby, except for a few check measures by Mr. Adams. As it seemed desirable to have a complete series of independent measures of the plates, several members of the Observatory staff undertook the work. It was found, however, that while in many cases the measures showed excellent internal agreement, there was no general harmony among the observers. It was evident that with the lines in question systematic errors were likely to occur, frequently of such a magnitude as to reverse the sign of the measured displacement. Two attempts to avoid this difficulty were accordingly made. A parallel plate micrometer, in which the line corresponding to one of the strips of the compound mica plate is displaced to right or left by inclining a plate of plane parallel glass, mounted immediately above the negative, was substituted for the ordinary measuring machine used in the previous work. With this simple device, the use of which for this purpose was suggested by Mr. Pease, the line is shifted until it coincides with the line on an adjoining strip of the spectrum, and the magnitude of the displacement is read off on a graduated arc, which measures the angle through which the plate is turned.

All of the plates of the first series have been measured with this instrument by Dr. Van Maanen, with results agreeing well with those of Miss Lasby, except that there appears to be a systematic tendency toward smaller values for the displacements on the part of Dr. Van Maanen. Thus, while the true magnitude of the displacement for a given latitude is still open to further investigation, there is no question as to the reversal of the sign of the displacements in the two hemispheres, and the decrease in their magnitude from middle latitudes toward the equator.

In order to obtain further light on the question of systematic errors, the simple expedient was adopted of displacing a line by a known amount, and then measuring the displacement by settings

on the line itself. In this way it is possible to obtain the personal equation of any observer for lines of any width or intensity. The results indicate that a slight peculiarity in the plates may often introduce systematic errors, capable of reversing the sign of the displacement. This probably accounts for some of the discrepancies encountered in the measurement of the plates.

In spite of the fact that the results obtained are precisely such as the existence of a magnetic field would lead us to expect, and the apparent impossibility of attributing them to any other cause, some difficulties remain unexplained. A long series of photographs, made in the second order in May and June, has been measured by Dr. Van Maanen with the parallel plate micrometer. The second order was chosen because of the greater sharpness of the solar lines, but it is doubtful whether this policy was a wise one. The displacements on these photographs are much smaller than those of the first series, though it is extremely improbable that the strength of the Sun's field would change materially between the two sets of observations. As all of the photographs were made in pairs (quarter-wave plate inverted), it is possible to test the magnetic nature of the displacements. Thirty-eight pairs of plates give reversed signs for the displacements, while 10 pairs do not. In view of the very small magnitude of the displacements, which rarely exceed 0.003 mm, the evidence is decidedly in favor of an actual reversal of sign produced by inversion of the quarter-wave plate.

I am unable to account for the greatly decreased magnitude of the displacements on these plates, unless it is due to the use of the second order spectrum instead of the third. On the average, the displacements are only about one-quarter as great (when reduced to the third order) as those obtained by Dr. Van Maanen for the first series of plates. In this connection, and as a necessary check on all of the observations, a careful study has been made of the elliptical polarization due to the reflection of the sunlight on the two silvered mirrors of the coelostat. The polarization phenomena vary with the declination and hour angle of the Sun, but in no case do they appear to be of such a character as to influence appreciably the magnitude of the displacements.

Another series of observations is now in progress, using the third order of the grating and the $16\frac{1}{2}$ -inch image of the Sun given by the object-glass of 150 feet focal length. The displacements, as far as measured, are much larger than those on the

second order plates, and the results clearly confirm those of the first series.

As the matter now stands, further observations will be required to prove conclusively whether or not the observed displacements are due to the Sun's magnetic field. It may be interesting to inquire, however, as to the sign of the charge and the corresponding polarity indicated by the observations already obtained. Knowing the direction of the Sun's rotation, and assuming, for example, that the field is produced by the rotation with the Sun of two opposite and equal charges distributed through the Sun's mass and contained within spheres whose radii differ slightly, we may deduce the sign of the outer charge required to produce such line displacements as have been observed.¹ This outer charge is found to be negative, which would imply that the north and south poles of the Sun agree in magnetic polarity with those of the Earth. As for the strength of the field, a knowledge of the Zeeman effect for the lines in question is necessary to determine this. It happens that all of these lines are too faint in the spark to appear in our photographs, but another effort is being made by Mr. Babcock to observe their behavior in the magnetic field.

The investigation is being pushed forward as rapidly as possible, in view of the quiet condition of the Sun, since the appearance of Sun-spots, with their very powerful magnetic fields, will tend to introduce troublesome perturbations.

Pasadena, Cal., December 5, 1912.

¹ SCHUSTER, A., A Critical Examination of the Possible Causes of Terrestrial Magnetism, *Proc. Phys. Soc. London*, April 15, 1912; SWANN, W. F. G., The Earth's Magnetic Field, *Phil. Mag.*, July, 1912, v. 24, p. 80; BAUER, L. A., On the Origin of the Earth's Magnetic Field, *Terr. Mag.*, September, 1912, p. 136.