Citation:

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KNAW, Proceedings, 12, 1909-1910, Amsterdam, 1910, pp. 584-596

This expeeiment was started on July 14th 1908; the incisions were ready and the plates were pushed in at 9.30 a.m. At 10 a.m. the leaves were already drooping and they remained so throughout the day.

In the course of the five following days, in cool dry weather, the leaves gradually recovered. On the 7th day of the experiment the foliage began to wither from the top downwards; many yellow leaves also appeared in the crown. In all these days the temperature had not risen above 18° in the neighbourhood of the tree. On the 9th day the temperature rose in the afternoon to more than 26°, and probably as a result of this the number of yellow leaves now increased rapidly. Those leaves which had remained green also began to droop again. The tops of the branches in the upper part of the crown withered completely.

The 3 following days were warm and sunny with temperature maxima of 27° and 28°. Most of the leaves now fell off, while in the upper half of the crown the foliage withered completely.

After this time cooler weather supervened and the few remaining green leaves recovered and remained in good condition until the autumn.

That the tree had not suffered greatly however from the incisions, was shown in the following summer, for then the foliage developed as well as before the experiment, and remained fresh throughout the entire season.

Wageningen, Dec. 13th 1909.

Physics. — *"The magnetic separation of absorption lines in connexion with Sun-spot spectra."* (I). By Prof. P. Zeeman and Dr. B. Winawer.

1. As a consequence of the intimate connexion between emission and absorption, there exists closely corresponding to the magnetic separation of emission lines, a magnetic division of absorption lines. The dark lines which appear in a continuous spectrum, if a beam of white light traverses an absorbing flame, are divided and polarized under the influence of magnetic forces in exactly the same way as the emission lines. This correspondence between emission and absorption was shown to exist already in some of the first experiments on the subject by one of the present authors. Our knowledge of emission spectra under magnetic influence has since been extended considerably. The experimental study however of the inverse effect i. e. the magnetic division of absorption lines has less advanced.

After the first experiments of the first named of the authors of this paper, the change of absorption lines in a magnetic field was studied by KÖNIG [1]) and COTTON [2]); RIGHI [3]) gave an elaborate study of the subject, to which we have to return later on. It contains the only investigation of the magnetic effect in a direction inclined to the lines of force. Closely connected with our subject are finally some observations by LODGE and DAVIES [4]) on the influence of a magnetic field on flames, emitting "reversed" lines.

The consideration of the inverse effect forms the basis of VOIGT's magneto-optical theories [5]); and it is considered also by LORENTZ [6]) in his investigation of the magnetic separation in a direction inclined to the line of force.

Theory indicates different points, which may be tested by experiment. The inverse effect has become of supreme interest in solar physics, since HALE's [7]) discovery that the dark lines of the sun-spot spectrum exhibit the characteristic phenomena of magnetic separation.

The experiments we intend to describe in the present communication relate to the division of the sodium lines D_1 and D_2. Some of our results may already be found in the work of the cited authors.

In order to present the subject in a connected form it seemed necessary not to exclude these.

The facts now ascertained in combination with former results appear to be of some value in explaining peculiarities observed in sun-spot spectra. Some instances will be given later on.

2. Type and relative amount of the magnetic division of the sodium emission lines, D_1 and D_2, are given in Fig. 1.

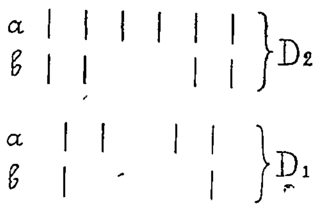

Fig. 1.

a represents the observations when the line of sight is at right angles to the magnetic field, *b* when it is parallel to the field.

In a weak magnetic field D_2 exhibits the triplet type, at right angles to the

1) KÖNIG. Ann. d. Phys. Bd. **62**. 240. 1897.

2) COTTON. Éclairage Electrique. 5 et 26 mars. 1898.

3) RIGHI. Sul fenomeno di ZEEMAN nel caso generale d'un raggio luminosa comunque inclinato sulla direzione della forza magnetica. Mem. di. Bologna. 17 Dicembre 1899.

4) LODGE and DAVIES. Proc. R. Soc. **61** 413. 1897.

5) W. VOIGT. Magneto- und Elektrooptik. Chapter IV and the papers there cited.

6) H. A. LORENTZ. These Proceedings, Vol. XII, p. 321, 1909.

7) G. E. HALE. On the probable existence of a magnetic field in sun-spots. Contributions from the Mount Wilson Solar Observatory Nr. 30. 1908.

field; the doublet type if the light is examined parallel to the lines of force. D_1 seems to exhibit a doublet in both principal directions.

The FRAUNHOFER lines in the spectra of sun-spots investigated by HALE are either broadened, or changed to doublets (often incompletely resolved quartets), or to triplets. The resolutions exhibited by sodium vapour are therefore the very types of special importance to astrophysics; this and also the facility of producing sodium vapour in the magnetic field induced us to commence our experiments with this substance.

3. The explanation of the inverse effect is easily understood by means of the well known law of resonance. If there are in a flame under the influence of a magnetic field three periods of free vibrations, then we may expect that from incident white light vibrations of these very three periods will be taken away. The absorption is a selective one, with this peculiarity that the selection refers not only to the period but also to the direction of vibration. Consider for example the central component of a triplet which in the emission spectrum is due to vibrations parallel to the field. From incident white light only vibrations, corresponding as to period as well as to direction of vibration with the middle component, are absorbed. Vibrations, perpendicular to the field, though of the period of the unmodified line, pass unimpeded.

On the contrary white light of periods coinciding with those of the outer components is only deprived of its vertical constituents.

It will be clear from these very simple considerations what we may expect to observe with white light under the conditions of the experiment. The arrangement was the following: White light of the incandescent positive pole of an arc-lamp traverses a sodium flame, placed between the poles of a DU BOIS-electromagnet. This light is analysed by means of a stigmatic spectroscope with large ROWLAND grating. The observations are made in the first order.

If the observation is made at right angles to the lines of force, we see in the continuous spectrum 4 dark components in the case of D_1, 6 dark components in the case of D_2, as represented for both lines under *a* in the diagrammatical Figure 1.

In order to observe all these components the field must be strong and the vapour density adapted to the field.

The groups of lines indicated by *b* are seen, if the light is examined axially.

All these components, if narrow, are seen only diffuse and not black. From the considerations above given the reason will be clear at once; each of the components absorbs only *half* the incident natural light.

With very diluted vapour no absorption at all or only very weak traces of absorption are seen.

4. The introduction of a Nicol in the beam before or after the field entirely changes the phenomenon. The absorption lines can then be seen very narrow and black.

Let the observation be made at right angles to the horizontal field, then, if the Nicol is placed with its plane of vibration vertical D_1 exhibits its two, D_2 its four outer components.

After a rotation of the Nicol over 90° both D_1 and D_2 give only the two horizontally vibrating components.

Let a beam of natural white light traverse axially the magnetized vapour placed between the perforated poles of an electromagnet. Then by means of a quarter-wave plate and a Nicol we may quench either the right-handed or the left-handed circularly polarized component.

A combination of a quarter-wave plate and a Nicol, converting incident light into right-handed circularly polarized light may be called a right-handed circular analyser. The absorption line corresponding to a right-handed circularly polarized component is seen with both increased clearness and darkness by examining it with a right-handed circular analyser.

We introduce here this simple matter because there has been occasionally some confusion on this subject.

5. The behaviour of horizontal and vertical vibrations may be studied simultaneously by using according to the suggestion of Cornu and König a calcspar rhomb. By means of it we can obtain two oppositely polarized images of a horizontal slit of suitable width, placed near the magnetic field.

Right-handed and left-handed circular vibrations can be separated on the same plan by the introduction of a Fresnel rhomb between the calcspar and the slit of the spectroscope.

It is, however, of considerable interest to examine also the behaviour of the lines in natural light. A separate examination after the removal of the polarizers might be made. The vapour density ought to be the same in both experiments. It seems difficult to realise this.

The desired end is secured more simply and surely, and with only half the labour, by adopting the width of the horizontal slit and the thickness of the calcspar in such a manner that the two images given by the calcspar partially overlap. We now obtain three stripes; the central one exhibits the phenomena as seen without polarizing apparatus. (See fig. 2).

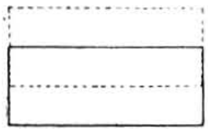

Fig. 2.

The upper and lowest stripes show the influence of polarized light on the phenomenon.

The observations given in this communication have been made by the described method. By its use all particulars of the phenomenon are simultaneously exhibited; we also succeeded in photographing the essential points. Examples of our photographs are given on the plates annexed to our paper.

6. If the absorption lines are not narrow or if the magnetic field is weak, the components of a magnetically divided line will partially overlap. This partial superposition is the cause of some particularities, especially manifest in the inverse effect and probably also apparent in sun-spot spectra.

The nature of these particularities may be illustrated by a few examples. We will consider the case of the magnetic triplet and the magnetic doublet.

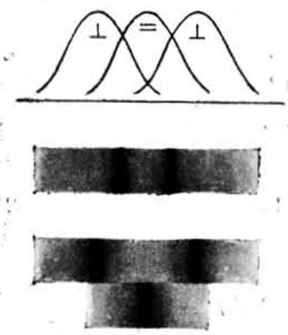

Fig. 3.

In Fig. 3 the curves show the distribution of intensity of the three components of a triplet, if the light is examined at right angles to the lines of force. If natural light traverses a source of light placed in a magnetic field, two black bands are seen, corresponding to the wavelength, for which vertical as well as horizontal vibrations are absorbed.

These black bands are surrounded by less dark parts, which absorb only one of the principal vibrations, the other proceeding unimpeded. (cf. §§ 3 and 4).

If now a Nicol with its plane of vibration vertical, is introduced two black bands are again seen. The darkest part of these components corresponds to the maximum of the curves relating to vertical vibrations.

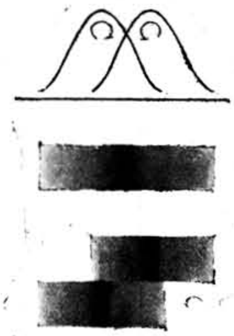

Fig. 4.

As a general rule the distance of the components exceeds that of the lines first considered.

7. Parallel to the lines of force a partial, not too small, overlapping of the components produces a black line limited by two less dark parts. This case is illustrated diagrammatically in Fig. 4.

The two components may be separated by a circular analyser.

These considerations may be applied to the magnetic division in sun-spot spectra; as a general rule we may expect that the separation of lines in spot spectra becomes more distinct and of larger amount by the use of analysers.

The introduction of a Nicol in the beam may also reveal lines invisible without analyser.

Several peculiarities observed in the distribution of intensity in spot lines, remind one of the now specified superposition phenomena [1]); cf. § 19 below.

8. Superposition effects of nearly, though not exactly, the same nature occur if lines with the same direction of vibration are superposed and if the continuous source of light emits unpolarised light. In the more complicated divisions the now specified superposition occurs also. It is just possible that the superposition of the outer components of the sextet, type D_2, produces only dark, that of the inner and the next outer components, black lines in the continuous spectrum.

It is easily seen that also in the case of the quartet, type D_1, black lines may be produced. The darkest parts may be seen somewhat nearer to the middle of the complete figure, than the outer components of the quartet.

It seems unnecessary to illustrate this by figures. Examples of the specified actions will be given presently.

9. Our observations and spectrograms relate besides to the two principal directions (parallel and at right angles to the lines of force), also to directions inclined to the field.

In the present, first, communication, observations are discussed, relating to 5 different angles between the field and the direction of propagation of the beam (Voigt's φ, Lorentz's ϑ).

These values are: 90°, 0°, 60°, 45°, 36°—39°.

The results of the work relating to these angles have been recorded on nearly 100 spectograms.

10. *Observations perpendicular to the field.*

In the upper of the three stripes which are present in the field of view (see § 5), the light vibrates vertically; in the lowest one horizontally, whereas the middle part relates to natural light.

Under the influence of the magnetic field we therefore see the vertically vibrating components as narrow black lines. The quartet of the D_1 line, the sextet of the D_2 line, may be seen very clearly

[1]) A figure equivalent to the one now given concerning the influence of superposition of magnetically divided components was already drawn for *emission* lines in Zeeman. Doublets and Triplets in the Spectrum produced by external magnetic forces. Phil. Mag. July 1897 § 7.

by this method. A small disturbance is produced by the narrow reversed lines due to the electric arc light. The intensity of these lines depends upon somewhat variable circumstances of the arc itself. In some cases these lines are almost invisible, in other ones more prominent. They are to be seen on some of our reproductions; with our present subject they have nothing to do.

As regards the central stripe we refer to the remark previously made, that the image of the separation must become, on account of the only partial absorption, rather indefinite and weak. (§ 3).

The partial superposition of components gives, at least in the case of diluted vapour, the most conspicuous lines. (§§ 6 and 7).

In the case of the quartet, for example, one sometimes sees instead of four, only two components, situated between the inner and outer ones.

We made experiments with different vapour densities. The observed phenomena may be classified under three phases:

1. The vapour is *very dilute.* The components are clearly visible in the upmost and lowest stripe. In the central stripe the absorption is either hardly perceptible (Plate I, Fig. 1) or the components of the quartet and the sextet are seen as separate, but weak lines. (Plate I, Fig. 2).

In this phase of the phenomenon the great difference of definiteness of the central and outer regions is very remarkable. This contrast is still more marked with eye observation.

In order to obtain good photographs, it was necessary to increase the density of the vapour above the one required for the observation of the very first trace of absorption.

2. Vapour of *intermediate* density.

The components in the upmost and lowest stripes are now no more separately visible or only in the case of the quartet. In the central stripe a superposition of the kind mentioned in § 6 takes place. In place of the quartet an apparent doublet is seen, the components of which are situated between the outer and inner components of the quartet. This case is very clearly represented in Plate I, Fig. 3.

The phenomena exhibited by the sextet (D_2 line) become rather complicated.

The superposition phenomenon is often very distinct. The D_2 line on Plate I, Fig. 3 shows sufficiently the appearance.

3. With still *denser* vapour, the components become very broad and the magnetic change hardly visible. The *polarisation of the edges* of the broad line may be recognized. This phase is represented in Plate I, Fig. 4. It corresponds to the emission effect as it was first discovered: a slight change of broad lines in a weak field.

With still greater absorption the influence of the field becomes imperceptible.

All these phases appear with great regularity. If the intensity of the field is known, it seems possible, the resolving power of the spectroscope being given, to deduce the density of the vapour from the nature of the observed phenomena.

The magnetic division phenomena hitherto observed in sun-spots appear to fall under the second and third phases above mentioned. HALE from measurements of spot lines, compared with laboratory experiments, deduces a maximum intensity of the spot field of 4500 Gauss. Hence, one would be inclined to think that the density in the layers, which bring about the absorption in the sun-spot spectrum can only be small. Moreover, the non-uniformity of the field of sun-spots produces by itself a widening of the components. Light from a limited portion of the spot would give perhaps very narrow spectral lines. In the light, however, of the critical remarks of KAYSER [1]) concerning our knowledge of the influence of pressure and of temperature on spectra all such considerations most be put forward with great diffidence.

11. *Observations parallel to the lines of force.*

In the present experiments the absorbing vapour subjected to magnetic forces is placed between perforated poles.

After putting on the current, one sees in the continuous spectrum, 2 dark bands in the case of D_1, 4 in the case of D_2, according to the diagrammatical figure 1. The absorption is incomplete also now, because of some wave-lengths only right-handed circularly polarized light, but not left-handed is absorbed and the reverse. In order to observe the separation and the polarization a FRESNEL rhomb is placed with its principal plane at an azimuth of 45° with the horizon, a horizontal slit being placed in one of the perforated poles. The FRESNEL rhomb converts circularly polarized into plane polarized light. By means of a calcspar rhomb also now three stripes are obtained. The first phase (very dilute vapour) is represented in Plate I, fig. 5.

Vapour of intermediate density (second phase) exhibits the superposition phenomena mentioned in §§ 7 and 8, and diagrammatically illustrated by Fig. 2. In the central strip *one* line, at the position of the unmodified one, surrounded by feebly absorbing regions, is

[1]) KAYSER. Handbuch. Kapitel V. Bd. II.

seen. Plate I, Fig. 6 shows these lines for the doublet and the quartet; especially with D_2 the effect is very marked.

12. *Observations in directions inclined to the field.*

According to LORENTZ's elementary theory of magnetic division one generally observes in a direction, which is oblique under an angle ϑ with the lines of force, a triplet with elliptically polarized outer components [1]).

The ellipse, which characterizes the state of polarization of the components with period $T_0 + v$, is the projection on the wave-front of the circle perpendicular to the field, in which the electron with period $T_0 + v$ is moving. v is a small quantity. The direction of the motion of the moving electron also determines the motion in the ellipse. The ratio of the axes is as 1 to $\cos \vartheta$. For the other outer component with period $T_0 - v$ holds *mutatis mutandis* the same reasoning.

The central line with the unmodified period T_0 always remains linearly polarized. The vibrations of the middle component are in the plane determined by the ray and the line of force and the amplitude of the vibrations is proportional to $\sin \vartheta$.

If we put $\vartheta = 0$, i. e. in the case of the longitudinal effect, only circular motions remain.

All this applies to very narrow spectral lines in a strong field, the distance of the components being much greater than their width.

According to VOIGT and LORENTZ we must expect some interesting particularities if this restriction be discarded. We return to this point later on.

As a general rule the deductions from the elementary theory are verified. Also in the case of the quartet and the sextet the outer components become elliptically polarized, as has been observed already by RIGHI [2]).

In contradiction with the elementary theory, though not strictly applicable to the case, is the very slight diminution of intensity of the middle components of the quartet even for $\vartheta = 45°$.

13. *Observations at* $\vartheta = 60°$.

If the observation is made with a calcspar rhomb, the image

[1]) cf. RIGHI l. c.

[2]) RIGHI's observations l. c. all refer to an angle of nearly 55°, the angle at which according to the elementary theory the three components of the triplet are of equal intensity.

remains as with the transversal effect. Yet the presence of elliptic polarization ought to manifest itself by the appearance in the lowest stripe of lines, corresponding to the outer components.

With very dilute vapour and with that of intermediate density as good as no trace of it is seen.

Fig. 7, Plate II shows the first phase with dilute vapour, Fig. 8 the second phase with denser vapour. Only traces of absorption, indicative of elliptic polarization can be seen near D_2, Fig. 8.

The ellipticity is, however, undoubtedly proved by means of the FRESNEL rhomb, placed with its principal plane at an azimuth of 45° with the horizon. Fig. 9 shows the appearance.

The outer components of the quartet towards the red or towards the violet, dependent upon the stripe and the direction of the field, are now considerably weakened; in the case of the sextet they have vanished altogether. All this proves the elliptical polarization of the outer components. For, if the polarisation were linear, as might be inferred from observations with the calcspar alone, then the observation with calcspar and rhomb combined, ought to show no difference between the upmost and lowest stripe. The light of all plane polarized components would issue circularly polarized from the rhomb and, the calcspar making no selection between right-handed and left-handed polarizations, the components towards red and towards violet would all be alike. Such a condition is disproved by photographs such as Fig. 9.

14. One point must be considered somewhat more in detail. What is the reason that the ellipticity is not shown by the calcspar rhomb alone, whereas its existence is most clearly demonstrated by means of the FRESNEL rhomb?

Let an elliptic vibration with vertical axis b, horizontal axis a, be incident upon the rhomb, the principal plane of which is at an azimuth of 45°.

It is easily proved that the elliptic vibration issuing from the FRESNEL rhomb has its axes in the same direction as the original motion and a ratio of the axes $\frac{a_1}{b_1} = \frac{b-a}{b+a}$, the original ratio being $\frac{a}{b}$.

If a be small in relation to b (an elongated ellipse), then, the light issues from the FRESNEL as a more circular vibration, which is more easily analysed.

It depends upon the magnitude of a, whether $\frac{a}{b}$ is *greater* or *less* than $\frac{b-a}{b+a}$.

We distinguish the following cases:

1. a very small, then $\frac{b-a}{b+a} > \frac{a}{b}$.

2. $a = 0{,}414\ b$, then $\frac{b-a}{b+a} = \frac{a}{b}$.

3. $a > 0{,}414\ b$, then $\frac{b-a}{b+a} < \frac{a}{b}$.

We shall apply these results to the interpretation of our observations. Two cases dependent upon the magnitude of a are of principal importance.

In the first case we can observe the effect of both the axes of the ellipse by means of the combination of the FRESNEL rhomb and the calcspar (*this is the case of the quartet*) (D_1 Fig. 9), whereas without FRESNEL rhomb no effect of the small axis is visible. In the second case the effect of the small axis becomes apparent by the use of the calcspar, whereas its existence cannot be demonstrated with the FRESNEL, the value of $\frac{b-a}{b+a}$ being too small. *This case is represented by the sextet*, (D_2 Fig. 9).

If the observation is made by means of the calcspar rhomb, we indeed see with dense vapour new components in the lowest stripe (see Fig. 8, D_2). The theoretical import of this result will be discussed on another occasion.

After introduction of the FRESNEL rhomb the component to the left of the central line (small axis of the ellipse) remains invisible. (Fig 9, D_2, inferior stripe).

Hence we may conclude that at the angle now investigated the ellipticity of the outer components of the *sextet* (the ratio $\frac{a}{b}$) exceeds that of the quartet (and is also larger than 0,414).

15. *Observations at* $\vartheta = 45°$.

The photographs taken with the calcspar alone, show very clearly the ellipticity of the outer components.

With vapour of intermediate density the phenomenon is already very marked, especially in the case of D_2 (Plate II, Fig. 10). Very remarkable is the slight diminution of intensity of the inner components of the quartet. According to the elementary theory the intensity of the central component of *a triplet* ought to have diminished already to less than *half* the original value.

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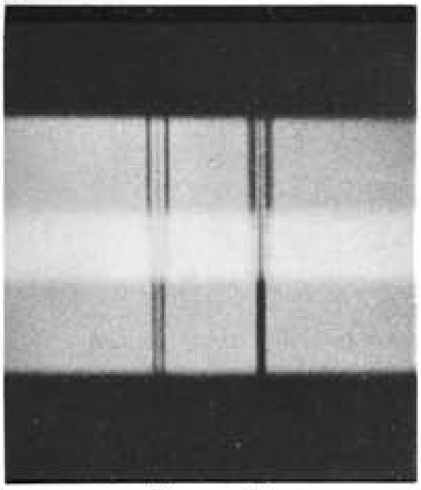
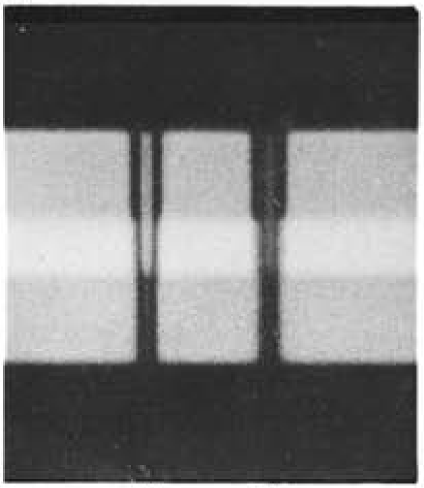
1.



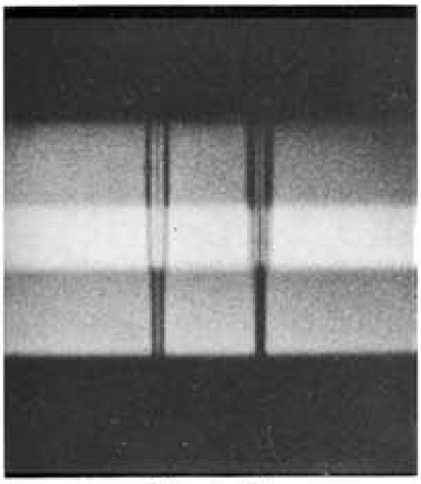
D_1 D_2

3.



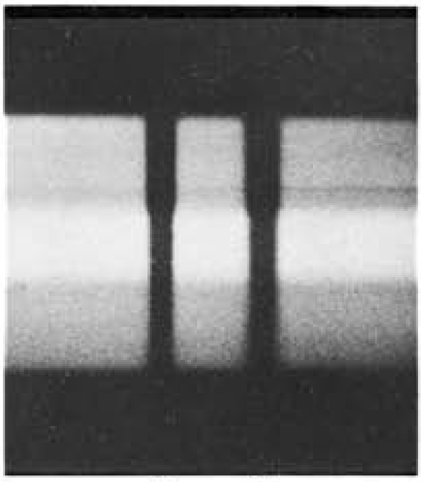
D_1 D_2

2.



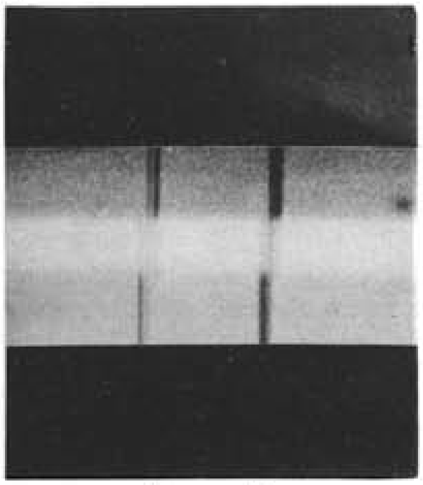
D_1 D_2

4.



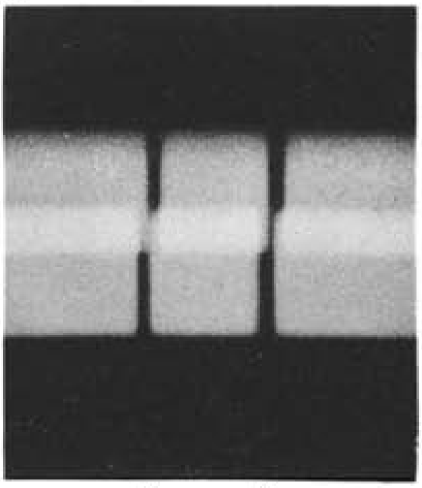
D_1 D_2

5.



D_1 D_2

6.



D_1 D_2

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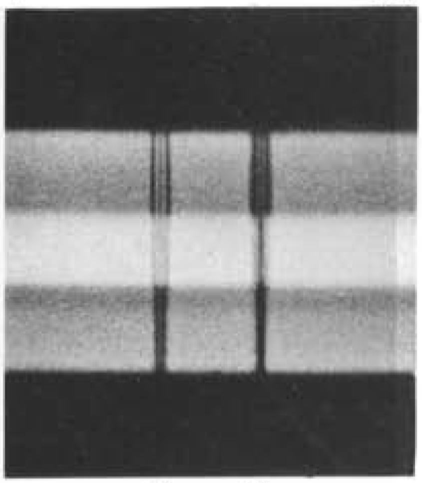
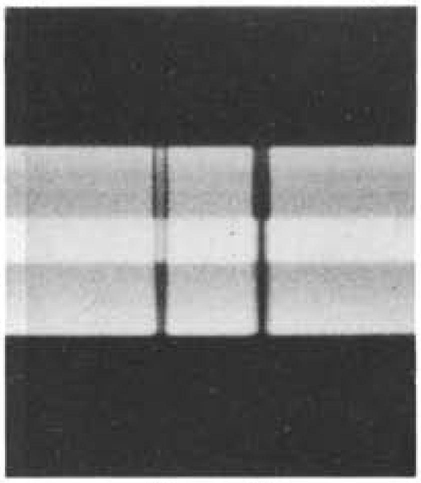
PLATE II.

7. (60°)



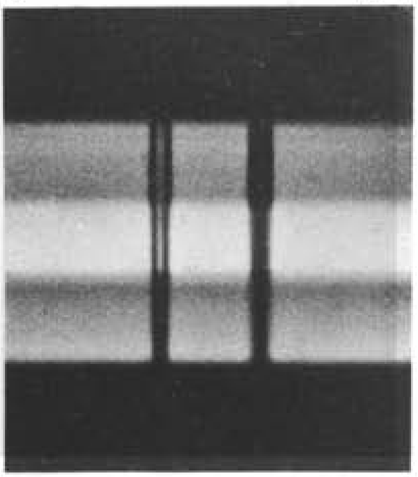
D_1 D_2

10. (45°)



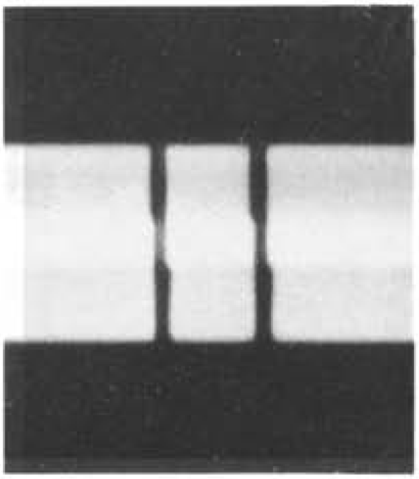
D_1 D_2

8. (60°)



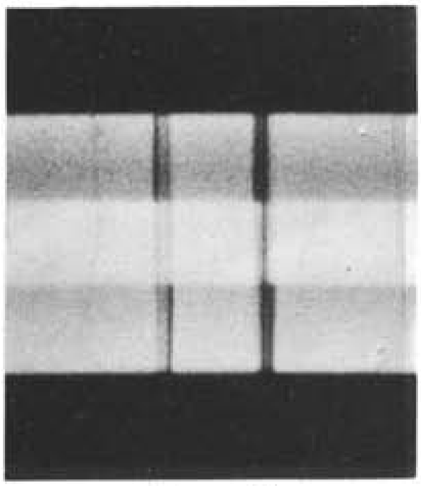
D_1 D_2

11. (45°)



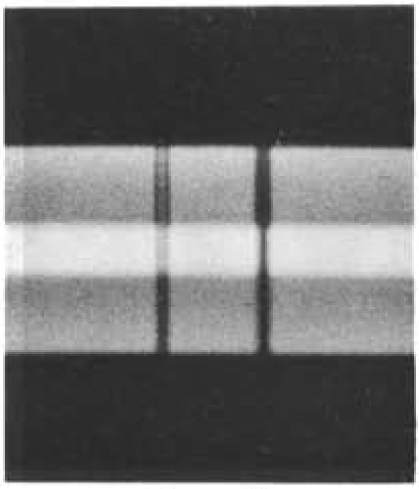
D_1 D_2

9. (60°)



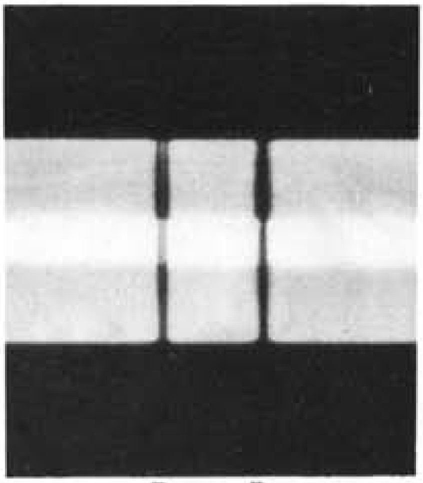
D_1 D_2

12. (39°)



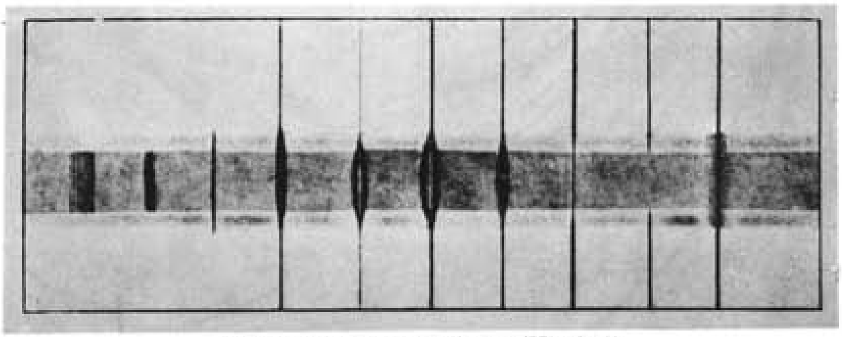
D_1 D_2

13. (39 º)



D_1 D_2

14. 1 2 3 4 5 6 7 8 9 10

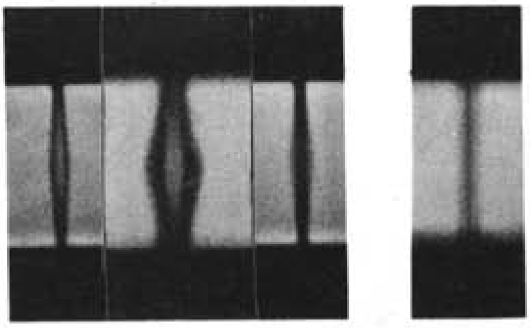


Types of sun-spot lines. (Mitchell)

5, 6. Widened lines with centres reserved bright.

7. Widened and weakened line. 10. Winged line.

15. 5^1 6^1 7^1 10^1



5', 6', 7'. Types of magnetic resolutions in non-uniform fields.

10'. Superposition of magnetic components.

16. If a FRESNEL rhomb combined with a calcspar rhomb is introduced in the beam, one of the components of the quartet also entirely disappears. At an angle of 60° this was only the case with the sextet. (Plate II, Fig. 11).

17. *Observations at* $\vartheta = 39°$.

The elliptic polarisation tested by means of the calcspar rhomb is very marked, even with dilute vapour (Plate II, Fig.12, Plate III, Fig.13).

The inner components of the quartet are now decidedly less intense than the outer ones.

Plate III, Fig. 13 especially shows the smaller intensity of the components of D_1 in the lowest stripe. Indeed, they are unmistakably thinner than those in the upmost stripe.

18. According as the angle between the ray and the lines of force is diminished, the intensity of the field must diminish at the same time. In order to make it possible for the rays to traverse the field under smaller angles the vertex semiangle of the cones must deviate more and more from the theoretical optimum of nearly 55°.

The decrease of the magnetic separation is clearly shown in our photographs.

We intend to communicate on another occasion experiments under smaller angles ϑ and to enter upon some details concerning the case in which the components of the triplet are not neatly separated. Some measurements of the ellipticity of the components will also be given. On the present occasion we only intended to give a general survey of the inverse effect, illustrating it by some particular cases.

19. *Types of separation in spot and laboratory.*

In one direction we shall now enter upon some more details. The magnetic separation of lines in a *non-uniform* field has been treated on a former occasion. [1]) The results then obtained and our present observations may be of some interest in connection with certain phenomena observed by HALE. We intend to return to this subject. Presently it seems interesting to allude to MITCHELL's descriptions of the various types of spot lines as indicated in the diagram published in the Transactions of the International Solar Union [2]).

Our Fig. 14, Plate III has been copied from this source. The types 5, 6, 7, and 10 of the Figure are very characteristic. Type 9 perhaps falls under the type of lines invisible without Nicol mentioned

1) ZEEMAN. These Proceedings, April 1906, November 1907.

2) Transactions Intern. Union Solar Research, p. 199 etc. 1908.

§ 7 above. In Fig. 15 are represented some separations observed in the laboratory *without* Nicol or other analyzer, 5′, 6′, 7′ have been taken in non-uniform fields. 5′ is the quartet of D_1 observed across the field; 6′ the sextet of D_2 observed axially in a non-uniform, in the central part very strong, field; 7′ also refers to D_2 in a weaker field, the observation being made across the lines of force. The type 10′ refers to the D_2 line, when observed in a direction parallel to the field. The field is uniform. The separation gives an example of the superposition phenomenon mentioned in § 7.

The analogy of the type 10′, Fig. 15 and the type of the "winged line" seems very remarkable. Of course observation of the state of polarization would be necessary in order to prove the analogy.

EXPLANATION OF PLATES I—III.

The figures 1—13 are about thirteenfold enlargements of the images given by the grating of the absorption lines D_1 and D_2 in a magnetic field.

The upmost and lowest of the three stripes of these figures relate to (oppositely) polarized light; in the central part the phenomenon is represented as it is seen in natural light.

PLATE I. 1, 2, 3, 4, observations ⊥ lines of force with different vapour density.
5, 6, observation // lines of force with different vapour density.

PLATE II. 7, 8, observation at $\vartheta = 60°$ calcspar rhomb alone.
9, $\vartheta = 60°$, calcspar combined with FRESNEL rhomb.
10, 11, $\vartheta = 45°$.
12, $\vartheta = 39°$.

PLATE III. 13, $\vartheta = 39°$.
14, Types of sun-spot lines (adopted from MITCHELL).
15, 5′, 6′ 7′, separations in non-uniform laboratory fields. 10′ superposition phenomenon § 7.

Physics. — "*The thermomagnetic properties of elements.*" By Prof. H. E. J. G. DU BOIS and Prof. KŌTARŌ HONDA. (Communication from the Bosscha-Laboratory).

(Communicated in the meeting of January 29, 1910.)

In 1895 CURIE[1]), though he had investigated relatively few substances, believed that he could formulate his results in the following rules:

1. For paramagnetic substances the specific susceptibility is inversely proportional to the absolute temperature.

2. For diamagnetic substances, on the contrary, the susceptibility is almost independent of temperature.

3. For the latter class of substances, changes of physical state generally have hardly any influence.

[1]) P. CURIE, Ann de Chim. et de Phys. (7) 5 p. 289. 1895. – Oeuvres p. 232 Paris 1908.