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PROCEEDINGS OF THE MEETING

of Saturday October 26, 1901.

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The following papers were read:

Physics. — "*On the origin of double lines in the spectrum of the chromosphere, due to anomalous dispersion of the light from the photosphere*". By Prof. W. H. JULIUS.

A peculiarity, appearing in the photographs which Prof. A. A. NYLAND obtained with the prismatic camera during the total eclipse of 18 May 1901 [1]), caused me to investigate more closely, in the line of my former paper on solar phenomena, what characteristics

[1]) With the consent of Messrs NYLAND and WILTERDINK (the members of our expedition who were most concerned with the spectrographic researches) only this special feature of the photographs will be shortly referred to in this paper. The report, containing a full account of the various observations made by our party, will be published afterwards.

the chromosphere lines must show, when they really derive their light from the photosphere [1]).

At the meeting of 24 Febr. 1900 I developed considerations which lead us to expect, that the light of the chromosphere is to a large extent composed of photosphere light, which has undergone anomalous dispersion in the absorbing vapours of the sun. The wave-length of the bright lines in the spectrum of the prominences, chromosphere and flash cannot, according to this hypothesis, be exactly the same as the wave-length of the corresponding absorption lines of the ordinary solar spectrum. For every bright line belonging to an absorption line of wave-length λ, was supposed to be produced by *two* groups of radiations, whose wave-lengths are respectively all smaller and all larger than λ. The light on the red side of the absorption lines will perhaps in most cases be a little more intense than that on the violet side, because, however variable as to place and time the density relations of the solar gases may be, it is always a little more probable that the average density of the layers which are penetrated by the light that reaches us, *increases* towards the sun's centre, than otherwise [2]). Where powerful "Schlieren" occur, however, the wave groups on the violet side may be the stronger ones.

Further it is clear that from each group, those rays, whose wave-lengths differ much from λ, can in general only be seen close to the sun's edge, for there only a small abnormality in the refractive index is necessary to deflect photosphere rays to our eyes. Light whose wave-length differs less from λ can reach us from a broader strip of the chromosphere; and far from the sun's edge, as a rule, we may expect to see only rays, whose wave-lengths differ very little from λ [3]).

To this rule too exceptions may be found at places, where mighty prominences show us the presence of great irregularities in the density distribution of the sun's gases.

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1) I shall frequently make use of the terms photosphere and chromosphere, but I wish to state emphatically that I mean by them only the white disk of the sun and the more or less coloured edge or light ring, as they appear to our eyes. I do not imply the idea of a sharply limited ball, emitting white light and surrounded by a translucent shell, which itself emits coloured light.

2) W. H. Julius, Proc. Royal Acad. Amsterdam, Vol. II, p. 581 and p. 585, Astron. Nachr Bd. 153, S. 439.

3) Proc. Royal Acad. Amsterdam, Vol. II, p. 581.

Let us now consider what under ordinary circumstances the light distribution in a chromosphere line would be, if we were only concerned with refracted photosphere light, unmixed with any appreciable radiation emitted by the absorbing gas.

In Fig. 1 is given a representation of the form, which the dispersion curve of the absorbing gas will assume in the neighbourhood of one of the absorption lines. The line XX' be the axis of wave-lengths with the value λ at the point O, and let an ordinate zero represent that the refractive index is equal to unity. If no absorption line existed in this part of the spectrum, the dispersion curve would be a nearly straight line NN' at a small distance above XX' and almost parallel to it. But if rays of wave-length λ are strongly absorbed, then the curve consists of two branches of the form represented.

Light with a wave-length λ cannot now occur in the chromosphere spectrum. Rays $\lambda \pm \delta$, in the normal spectrum belonging to positions a and a', will reach us from a chromosphere ring of relatively great width, but naturally with greater intensity from the inner than from the outer parts of the ring. Rays $\lambda \pm 2\,\delta$, belonging to places b and b', come only from a smaller chromosphere ring etc. All these rings have the photosphere for their inner limit. The breadth of the rings from which we can receive light of wave-lengths $\lambda \pm \delta$, $\lambda \pm 2\,\delta$ etc. will depend upon the ordinates of the dispersion curve at the points given by a, a', b, b' etc. We can, as a first approximation, put these widths proportional to the quantities $a_1\,a_2$, $a_1'\,a_2'$, $b_1\,b_2$, $b_1'\,b_2'$, etc. by which these ordinates differ from the ordinates of the normal dispersion curve $N\,N'$.

In recent eclipse work both the slit spectrograph and the prismatic camera (or the objective grating) have been used; up to this time most results have been obtained by the latter. We shall, therefore, investigate the character of a chromosphere line as it must show itself in ordinary circumstances in the prismatic camera.

The prismatic camera gives for every monochromatic radiation, coming from the chromosphere, an image of the crescent, ranging these images according to the wave-lengths. The light distribution in such an image shows us the intensity with which the corresponding radiation comes out of the various parts of the crescent. Consequently a pure monochromatic image will, as a rule, possess the greater intensity on the concave side, where it is limited by the moon's edge, and will gradually fade away on the convex side.

The images due to neighbouring rays will, however, partially overlap. This will be especially noticed with the two ray groups

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which together form a chromosphere line; in this combination of arc images we may expect a quite different distribution of the light than would be found in an image, formed either by monochromatic light or by one simple ray group, such as a more or less rarefied gas would show us in its emission lines.

Let Z (fig. 2) be a portion of the moon's edge at the instant of the second or third contact of a total eclipse. We may now consider the compound light, arising from a small column $Z\alpha$ of the chromosphere, dispersed into a horizontal spectrum parallel to the line PP'. In order to obtain more easily an idea of the share which the various rays contribute to the light distribution in the band, we separate the various rays from one another and represent on distinct lines PP', QQ', RR' .... those parts of the spectrum, where chromosphere light is found of wave-lengths equal respectively to $\lambda, \lambda \pm \delta$, $\lambda \pm 2\,\delta$, etc.

The point O may indicate the place, where the moon's edge would be seen if absolutely monochromatic light of wave-length λ appeared on its left.

The rays of wave-length λ are, however, completely absorbed, so that nothing need be represented on the line PP'.

On the line QQ' we find first the light of wave-length $\lambda - \delta$, which projects the sharp edge of the moon at a and reaches (with decreasing intensity) from there to α, and secondly the light of wave-length $\lambda + \delta$, which reaches from a' to α'.

In the same way we find on RR' the rays $\lambda - 2\,\delta$ and $\lambda + 2\,\delta$, corresponding respectively to the sections $b\beta$ and $b'\beta'$; on SS' the rays $\lambda - 3\,\delta$ and $\lambda + 3\,\delta$ at the sections $c\gamma$ and $c'\gamma'$, etc.

Because the sections $a\alpha$, $a'\alpha'$, $b\beta$, $b'\beta'$... represent the width of the chromosphere rings corresponding to the various sorts of rays, we have considered them proportional to the lengths $a_1 a_2$, $a_1' a_2'$, $b_1 b_2$, $b_1' b'_2$ of fig. 1. Hence the extremities $\alpha, \beta, \ldots$ and $\alpha', \beta', \ldots$ etc. lie on two curves, whose shape is closely related to that of the dispersion curve. The share which all intermediate waves bear in the light distribution is thus shown, if we only notice that for each kind of light the intensity decreases from right to left. This is represented by shading in the upper part of fig. 3. Finally to obtain the light distribution in the chromosphere line, we only need suppose that the figure is compressed in the vertical direction and that thus the light intensities are added together. The resulting intensity is then found to be approximately distributed as is shown by the shading in the spectrum given below. Hence a *double line* is produced, each of the components of which shades off gradually

W. H. JULIUS. „On the origin of double lines in the spectrum of the chromosphere, due to anomalous dispersion of the light from the photosphere."

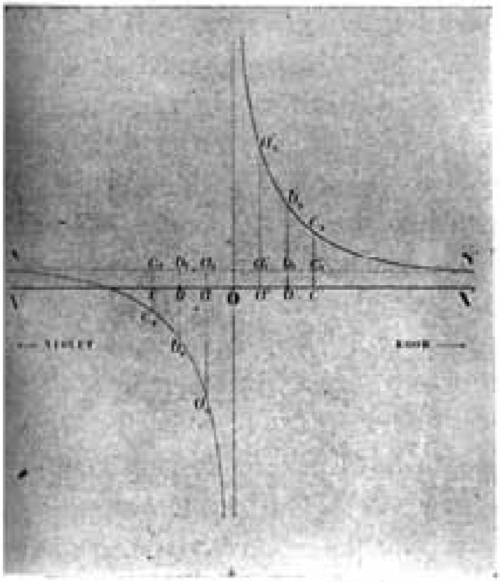

Fig. 1.

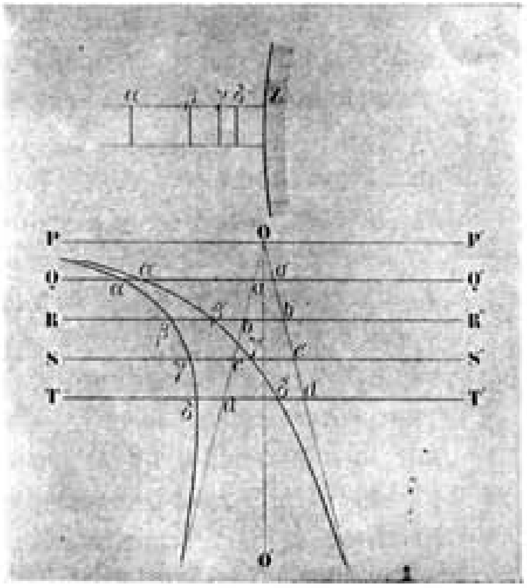

Fig. 2.

Fig. 3.

on each side, so that there is still light of a somewhat considerable intensity in the intervening space.

If the rays whose wave-lengths are less than λ are on the average of the same intensity as those with wave-lengths greater than λ (this case is shown in the figure), the „centre of gravity" of the chromosphere line is shifted a little to the convex side of the image with respect to the place belonging to the absorption line of wavelength λ. If, on the contrary, we consider the inner limit of the crescent, it appears that the line has shifted to the other side. This must involve us in difficulties when trying to find the exact wave-length of a chromosphere line.

Moreover, all kinds of variations may be expected in the intensity distribution. The ray group whose wave-lengths are greater than λ, may be intenser or vice versa. In such a case the displacements of the chromosphere line, both with regard to limit and to position of centre of gravity, may assume quite other values. Such displacements of variable character are actually often observed (by CAMPBELL, FROST, LORD i. a.).

The figure represents a case where on the convex side of the crescent the intensity of the system decreases faster than on the concave side (just otherwise than we should expect from a cursory examination; indeed the chromosphere crescent, observed without a spectroscope, is sharply limited on the concave side). This peculiarity too has been often seen in the chromosphere spectrum (cf. FROST, Astroph. Journ. XII, p. 315, Dec. 1900). In general, many of the irregularities in the form of the lines of the chromosphere and the flash, as given by MASCARI [1]), CAMPBELL [2]), BROWN [3]), LORD [4]), FROST [5]), and also the principal features of the chromosheric spectrum, recently once more discussed by Sir NORMAN LOCKYER [6]), can be easily explained if we suppose the lines to be produced by anomalous dispersion.

A convincing argument for the correctness of our explanation would be obtained if it appeared, that all chromosphere lines were really double lines of the above described character.

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1) MASCARI, Mem. Spettr. 27, p. 83—89; Ref. Naturw. Rundsch. 13, S. 618.
2) CAMPBELL, Astroph. Journ. XI, p. 226—233.
3) BROWN, Astroph. Journ. XII, p. 61—63.
4) LORD, Astroph. Journ. XII, p. 66—67.
5) FROST, Astroph. Journ. XII, p. 307—351.
6) LOCKYER, Recent and coming Eclipses, Chapter X and XVIII, London 1900.

Hence I have repeatedly sought for dark cores in the chromospheric arcs on photographs taken during former eclipses, and have indeed found several indications of them; but a plate where this peculiarity was the rule, where all the chromosphere lines were double, has certainly never before been obtained, for if so, the phenomenon could not have escaped notice.

The Dutch expedition had the fortune to get the first plates which quite clearly show all the chromosphere and flash lines, visible on them, to be *double lines.*

This important result is in the first place due to the great care with which the whole plan of observation with the beautiful prismatic camera of COOKE was designed and elaborated by Prof. NYLAND, and not less to the extraordinary exactness, with which both before and during the eclipse he has performed all necessary manipulations. But besides, it is not impossible that the result was favourably influenced by the in other respects very unfortunate cloudiness of the sky. For if the light had not been considerably weakened, the chromosphere lines would have been found on the plate both broader and in greater number, and the doubling would have been perhaps as little marked as on the plates, obtained on former occasions.

Shortly after the second contact five exposures were made on one plate, each of them during about $^3/_4$ sec. They show each only 9 lines, all double. On the four plates, prepared for the corona spectrum, some of the stronger chromospheric lines are represented by often interrupted arcs. The light of these evidently comes from prominences which project rather far beyond the photosphere. Here it appears not so easy to distinguish the duplication, just as we might expect by our theory; but still it is visible at many places.

On the sixth plate another set of five exposures, of $^3/_4$ sec. each, were taken a little after the third contact. In the first of the spectra thus obtained (reaching from λ 3880 to λ 5000) 150 double chromosphere lines can be counted between λ 3889 and λ 4600, these being also visible in the other four spectra, as far as the increasing scattered light permits [1]).

A little below the continuous spectrum, due to the just appearing edge of the sun, the double lines are most conspicuous. We find there, parallel to the spectrum, a bright narrow streak which appears broader

[1]) On the original negatives the duplication can only be distinguished with a magnifying glass. Enlargements (which were shown in the meeting) will soon be reproduced and published.

in the following exposures and which is probably owing to a small depression in the moon's edge or to a projecting part of the apparent sun's edge. In the fifth exposure, below the light band so produced there appears a similar streak. These bands give so to say repeated spectra of the flash (a fortunate circumstance, for the totality was over sooner than was calculated and the exposures were thus a little later than was intended) so that we obtain at one and the same exposure both the pure flash spectrum and the continuous spectrum of the sun's limb.

Prof. NYLAND and I have discussed together the possibility of ascribing the origin of double lines to disturbing circumstances, such as irregular motion of the siderostat, vibrations of the prismatic camera, light reflections etc. [1]), but we were not able to find any disturbance which could account for the observed phenomena and we must conclude that here we really have a property of the chromospheric lines.

The Fraunhofer lines in the continuous spectrum are weak. This may in part be due to the diffusion of light by the clouds. For the just appeared edge of the photosphere, which plays the same part with the prismatic camera as the illuminated slit with an ordinary spectroscope, was not darkly limited, but surrounded by a marked aureole (this can be seen in some of our corona photographs). The clouds, however, cannot have been the only cause of the faintness of the absorption lines in the first stage after totality, this phenomenon having been also observed in a clear sky [2]). There must therefore be another reason for the partial absence of the lines. Our theory gives such a reason immediately. For the chromosphere spectrum will at the end of totality become more and more like a continuous spectrum, because more bright lines will continually appear, each of which, according to our hypothesis, forms a double band in which the absence of the absorbed waves is not easily perceived. But as soon as a portion of the photosphere appears, the already existing, apparently continuous spectrum will be dominated by a more really continuous spectrum, the source of light of which is limited by two nearly sharp edges (those of the photosphere and of the moon).

In t h i s spectrum the absence of absorbed rays must show in the usual way as Fraunhofer lines. The light of the chromospheric arcs will, of course, partially overlap those lines, but compared with

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1) The mounting of the instruments will be fully discussed in the report of the expedition.

2) CAMPBELL, Astroph Journ. XI. p. 228, April 1900.

the direct photospheric light it is weak enough for the dark lines to be visible. Thus, not considering the presence of clouds, the absorption lines must yet, during the transition from the flash spectrum to the Faunhofer spectrum, at first show very faint and with abnormal relative intensities, then grow stronger, intensities appearing normal.

Because the double lines are not sharply defined objects, it is difficult to give the width of these systems. But we can make settings on the brightest parts of the components and measure their distance with a reading microscope. It differs for the different double lines, still it generally lies between 0.7 and 1.3 ÅNGSTRÖM's units. Wider and narrower systems follow each other in irregular succession, but on an average the distance of the components appears to decrease as we proceed from the green to the violet. Perhaps this fact may be important for dispersion theories.

With some lines the stronger component is that which has the greater, in others that which has the smaller wave-length. It happens that even in the same line (e. g. in the arcs of H_γ and H_δ on our plate) the two cases occur close by one another, which means that in neighbouring places of the sun's atmosphere the density distribution of the absorbing gas is different in this, that at one place the average density along the path of the ray increases, at another decreases towards the sun's centre.

CAMPBELL states [1]) that in some cases where dark and bright lines are to be found together, they are separated from one another by a distance of from 0.4 to 0.5 ÅNGSTRÖM's units. This is about the half of the distance between the components of our double lines. We may here reasonably suppose that CAMPBELL was concerned with cases, where one of the components was strongly marked. A similar case is found on our photograph in H_β, where the component with the greater wave-length is stronger over nearly its whole length than that with the smaller wave-length, and such is the case not only at the third contact but also during the second and even on the four plates, prepared for the corona spectrum, which were exposed for 5, 20, 190 and 60 sec. respectively.

I have not found until now in any chromosphere line a peculiarity in the distribution of the light, which would make it necessary to ascribe even a part of this light to radiations, emitted by incandescent

1) CAMPBELL, Astroph. Journ. XI, p. 229.

chromosphere gases. Now we can hardly assume that these gases really do not emit any light; the question is only, in what cases and how far the intensity of the true chromospheric emission is comparable with the intensity of the abnormally refracted photosphere light.

Perhaps the photographs obtained by our expedition are accidentally so extremely fit to show the part played by anomalous dispersion in causing chromosphere light, that they induce one to overestimate the importance of the new principle.

It would therefore be very interesting if the plates of other expeditions were also studied from this point of view.

Mathematics. — "*Considerations in reference to a configuration of* SEGRE". By Prof. P. H. SCHOUTE (first part).

1. In a treatise published in 1888 "Sulle varietà cubiche dello spazio a quattro dimensioni, ecc" (*Memorie di Torino*) Dr. C. SEGRE proved the following remarkable theorem:

The locus of the right lines cutting any four planes assumed in the space S_4 is a curved space of order three containing besides these four planes eleven planes more; one of these eleven new planes is intersected by all the right lines cutting the four given planes. The fifteen planes pass six by six through one of ten points, which are double points of the cubic locus.

If we call the four given planes $\alpha, \beta, \gamma, \delta$ and if we denote by α' the plane through the three points of intersection $(\gamma\delta)$, $(\delta\beta)$, $(\beta\gamma)$, by β' the plane through the three points of intersection $(\delta\alpha)$, $(\alpha\gamma)$, $(\gamma\delta)$, etc., then the four points of intersection lie in one and the same space ε and the five planes form such a quintuple, that each right line cutting four of these planes, also cuts the fifth.

In a study also published in 1888 "Alcune considerazioni elementari sull' incidenza di rette e piani nello spazio a quattro dimensioni" (*Rendiconti del circolo matematico di Palermo*, vol. 2, pages 45—52) the same writer gives a rather simple geometrical proof of the second part of this theorem, and then ascends to the configuration mentioned in the first part by the indication that the ten points spoken of are the points of intersection of the five planes $\alpha, \beta, \gamma, \delta, \varepsilon$ two by two and the ten new planes