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region) is to be found. And indeed we find in table VII fig. 2 the best marked maxima of the nebulaecurves at about 105° gal. longitude at less than 90 degs. from the Cygnus region and a less strongly pronounced one in the northern hemisphere at 280°.

The available material is certainly not sufficient for us to decide with any probability whether the secondary maxima (at 165° etc.) of the curves of the tables VII and VIII result indeed from the arrangement of the galactic agglomerations or whether they are produced by a merely local accumulation of nebulae. Among such "local deviations" from the uniform distribution we ought then also to reckon the Nubeculae, which apparently have such a great influence on the distribution of the nebulae in the southern galactic hemisphere. It should be borne in mind that the Nubeculae are *not* connected by streams of nebulae with the southern Milky Way and neither probably by streams of stars. Nor is the influence of the vast nest of nebulae, which constitutes the Nubecula Maior perceptible in table VIII.

Finally, if the nebulae in the very distant regions of the system remain in general invisible and hence are not included in the statistical data given here, while they can be more easily photographed, this would in connection with our preceding remarks explain the fact observed by MAX WOLF (*Sitzungsber. Munchen* XXXI, II, p. 126) that the mass of the very faint nebulae photographed by him are scattered more uniformly over the sky than those observed visually.

Physics. — *"Dispersion bands in absorption spectra."* By Prof. W. H. JULIUS.

(Communicated in the meeting of May 28, 1904).

The appearance of absorption lines depends on various circumstances. As to the absorption phenomena in gases and vapours, such conditions as temperature, density, pressure, velocity in the line of sight, intensity and direction of magnetic field, have been fully studied and discussed. In the present paper we purpose to show that anomalous dispersion in the absorbing gas is also, to a great extent, accountable for certain typical features of the dark lines.

An originally parallel beam of light, when passing through a mass of matter, the density of which is unequally distributed, will not remain parallel and, generally speaking, the greatest incurvations will be noticed in those rays, for which the medium has refractive indices differing most from unity, i. e. in those which, in the spectrum, lie closest to the absorption lines on either side. These particular kinds of light, while diverging into space, will spread in many more different directions than the average waves, and, as a rule, a smaller portion of them will fall into the spectroscope, than of waves with refractive indices nearer to unity.

Accordingly, there must always be certain places in the absorption spectrum, from which light is absent owing to dispersion in the absorbing vapour, for it may be taken for granted that the latter is never absolutely homogeneous. These darker parts in the spectrum we shall call *dispersion bands.* It stands to reason that these bands will overlap the regions of real absorption; so they might easily be mistaken for strengthened absorption lines, which no doubt has often been done.

We will now look somewhat closer into the characteristics by which dispersion bands may be distinguished from absorption bands.

The curvature of a ray of light of a definite wave-length, at any point of a non-homogeneous medium, not only depends on the gradient of optical density at that particular spot, but also on the angle which the beam makes with the levels of equal density. Its divergence will be greatest when this angle is zero.

Strong ray-curving through anomalous dispersion in vapours may, therefore, be artificially produced in two ways: first, by using masses of absorbing vapour, presenting in a small space considerable differences in density, such as e.g. occur in the electric arc[1]); secondly in larger spaces where the density varies but moderately, by making the light travel over a considerable distance under small angles with the levels of equal density.

I have chosen the latter method of investigation, especially on account of the extensive use, which may be made of the phenomena presenting themselves, by applying them to the interpretation of numerous peculiarities of the spectra of celestial bodies [1]).

The absorbing medium was a Bunsen flame, of a peculiar shape, containing sodium vapour and so arranged, that the introduction of the salt could be easily regulated.

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[1]) H. Ebert, Wirkung der anomalen Dispersion von Metalldämpfen, Boltzmann Festschrift, S. 443.

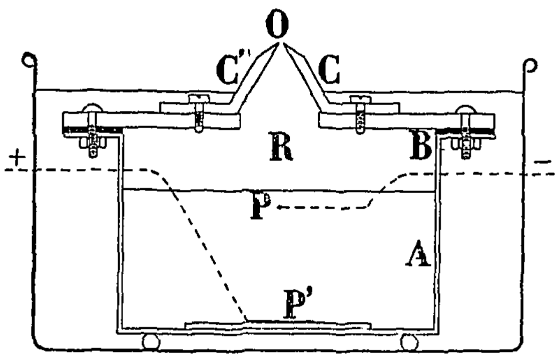

Fig. 1.

Fig. I represents a section of the burner. A is a copper trough, 80 cM. long, 8 cM. wide and 5 cM. deep, thickly coated with varnish and having a broad flange. The planed brass plate B is firmly screwed upon the flange and a leather packing makes the joint air-tight. On this cover, which has a rectangular opening 75 c.M. long and 2 cM. wide, are fixed two brass rulers, C and C', 75 cM. long. They are so adjusted that at O they form a slit, having an exactly uniform width of about 0,1 cM. over the whole length. The prismatic space between C and C' is closed at each end by a small triangular brass plate. The trough is filled to a certain height with a saturated solution of soda, and into the remaining space a mixture of illuminating gas and air is conveyed by means of tubes, entering at both ends. These tubes are fed from a mixing bottle in which the gas and the air are being driven through two separate regulating taps.

If now the flame were left to burn without any further precautions, the slit O would soon be closed in consequence of the onesided heating of the rulers. It was therefore found necessary to place the trough in a vessel with running water, reaching up to the burner In this way a uniform and steady flame was obtained.

A few millimeters below the level of the salt solution a platinum wire P is stretched over the whole length of the lamp. Its ends are soldered to insulated copper wires, which pass through the walls of the trough, and are connected to the negative pole of a storage battery of 20 volts. From the positive pole two insulated wires lead to the ends of a long strip of platinum P', which rests on a glass plate at the bottom of the trough. As soon as the circuit is closed, innumerable minute particles of the fluid rise into the space

[1]) The abnormal solar spectrum of HALE; the peculiar distribution of light in several of the FRAUNHOFER lines, even in normal conditions; the variations in the average appearance of the spot spectrum accompanying the eleven year period, all these phenomena have been easily explained from the considerations here alluded to (See W. H. JULIUS, Proc. Roy. Acad. Amst. IV, p. 589—602; 662—666; V, p. 270—302).

The present investigation is a continuation of the experiments with the long sodium flame, a short account of which has already been given on those former occasions in support of our theory.

R, and cause the flame to emit a beautiful, clear and constant sodium light, the intensity of which can be controlled and regulated by means of an ampèremeter and a variable resistance.

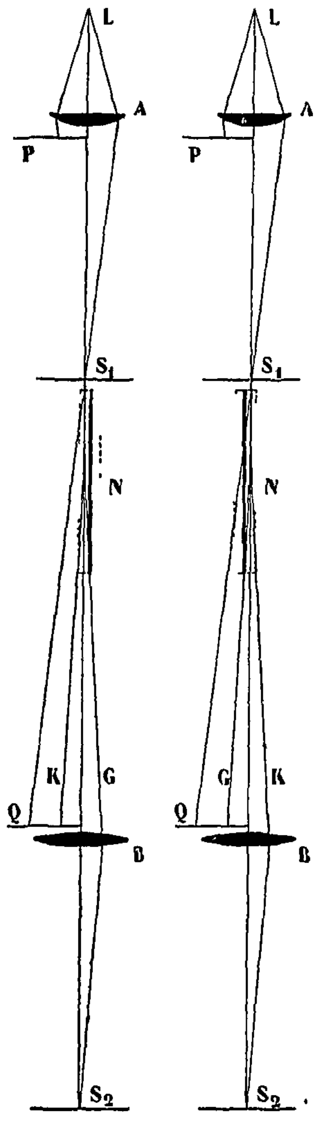

Fig. 2 *a*. Fig. 2 *b*.

In Fig. 2, *a* and *b* are shown two different ways in which the light travels through this long sodium flame. *L* represents the crater of an electric arc of 20 ampères. The lens *A* throws an image of the crater on the slit S_1, which, in its turn, is depicted by the lens *B* on the slit S_2 of a grating spectroscope. About half of the conical beam of light which leaves *A* is intercepted by the screen *P*, and the part, which the slit S_1 allows to pass, falls almost entirely on the screen *Q*, which has been shifted so close to the optical axis of both lenses, that only a narrow streak of light can reach the slit S_2, through the middle of *B*. The large gas burner stands on a horizontal slide, which is movable up and down and round a vertical axis; thus, by means of screws, it can easily be put in any position required.

When the axis of the flame (which we assume to be in its most luminous part, i.e. a little above the blue-green core) coincides with the optical axis of the system of lenses, both the *D*-lines will be seen symmetrically widened in the spectroscope. If not perfect, the symmetry will easily be corrected by slightly shifting the screens *P* and *Q*.

Picture 1 Fig. 3 (see Plate) refers to the case when the flame *N* is not burning; the narrow absorption lines are due to traces of sodium surrounding the carbon points. When the flame is burning, a very weak current passing through the sodium solution will produce the effect shown in 2. The photographs 3, 4 and 5 were obtained with currents of about 1, 3 and 6 ampères, the flame always being in the symmetrical position.

We will now examine the case represented by Fig. 2, *a*. Here the axis of the flame has been shifted 3 m.M. towards the right. The narrow beam of light which reaches S_1, only penetrates that part of the flame, where the density of the sodium vapour *increases* from left to right. In a structure of this kind, waves, for which the vapour has a great index of refraction, deviate towards the right, e.g. S_1G. They are not intercepted by Q and consequently reach the slit S_2. In fact, the presence of the sodium vapour allows similar waves to enter that slit even in larger quantity than they would do without it, for rays of this kind, issuing from the uncovered half of A, which if travelling in a straight line would be intercepted by Q can, when refracted, penetrate the lens B.

The case is entirely different for those kinds of rays for which sodium vapour has refractive indices that are smaller than unity. Such rays deviating towards the left (as shown in S_1K), are intercepted by Q and consequently will be absent from the spectrum.

Nos 6, 8 and 10 are reproductions of photographs taken under these conditions. On the left are seen the smaller, on the right the greater wave-lengths (in fact, in the whole series of photographs the stronger D-line appears on the left side); so it is obvious that really the waves lying on the red-facing side of the D-lines, i.e. those for which the vapour has high refractive indices, are *strengthened* by anomalous dispersion; and that, on the other hand, the waves on the violet side have been considerably *weakened*.

Alternately with 6, 8 and 10 the photographs 7, 9 and 11 were taken. The position of the flame was now as indicated in Fig. 2, *b*, i. e. its axis had been shifted 3 mM. to the left, so that the central beam had to traverse that part of the flame where the density of the sodium vapour *decreases* from left to right. Here we notice that the rays with low refractive indices deviate towards the right and that a larger number of them reach the slit S_2, e.g. S_1K, whilst the rays with high refractive indices, such as S_1G, are intercepted by Q.

Nos 6 to 11 show the effect of a gradual increase in the density of the sodium vapour. In No. 12 we again notice the sharply defined sodium lines after the flame has been extinguished at the end of the series of experiments; they are somewhat stronger than those at the beginning of the series, because much sodium vapour had spread through the room during the operations.

When carefully examining the original negatives it is possible in most of them to distinguish the rather sharp central absorption lines from the overlaying dispersion bands (especially in the photographs, obtained when the position of the flame was symmetrical; the reproductions fail to bring out this peculiarity). Advantage has been taken of this fact in so arranging the twelve photographs here reproduced, that equal wave-lengths occupy corresponding places. Then it is seen that the "centres of gravity" of the two dark bands, as well as the brighter space between them, have been alternately shifted to the left and to the right — a phenomenon which needs no further explanation.

As a matter of course the interposed flame causes the illumination in the plane of the slit S_2 to be very irregular, especially with regard to those radiations undergoing anomalous dispersion in the vapour. It is evident that some kinds of rays which are absent from one part of that plane, will be found in excess at another. The distribution of light in this irregular field of radiation might be explored by moving S_2, together with the spectroscope, within it. The same object can be obtained with less trouble by means of a thick piece of plate glass, mounted vertically between B and S_1 in such a manner, that it may be moved round a vertical axis. When turning it a little we make the whole radiation-field beyond the plate glass shift parallel to itself, thus causing other parts to cover the slit. This influences the aspect of the dispersion bands very materially. In certain positions apparent emission lines of sodium vapour may happen to be seen, which disappear as soon as the arc-light at S_1 is intercepted [1]).

In conclusion we wish to draw attention to a peculiarity we repeatedly observed in the dispersion bands. The dark shading in a dispersion band does *not* become deeper in proportion as we approach nearer to the central absorption line, but seems to reach its maximum obscurity at certain (though not always equal) distances on both sides of the centre; whilst in the space between, the light appears somewhat intensified just as if a wide absorption band had been partly covered by a narrower emission band, the centre of which is again occupied by the fine absorption line. This phenomenon cannot, however, be attributed to radiation emitted by the absorbing sodium flame; for in our arrangement the intensity of the emission from the flame could bear no comparison with that of the arc for corresponding waves. In order to make sure we tried to photograph the emission spectrum of the flame, exposing the plate during the same length of time and under the same conditions as had been done for obtaining the absorption spectrum; but not a trace of any impression could be detected on the photographic plate.

The light on both sides of the central line therefore originates in the carbon points and this we explain on the principle of ray-curving. The kinds of rays which are most strongly refracted in the flame may, under certain conditions, be curved twice or even more

[1]) These bright lines originate in the same manner as the light of the chromosphere. The chromospheric lines are not emission lines, but "bright dispersion bands".

times, when passing nearly parallel to the system of the levels of equal density (in the manner described on a former occasion [1])) and will therefore have a greater chance of reaching the slit S_2, than rays which are less strongly curved. The relative intensity with which the waves, belonging to those central parts of the dispersion bands, appear in the spectrum increases with the distance over which the light has travelled along such a lamellar or tubular structure. Should the true absorption line happen to be exceedingly narrow, the dispersion band may give the impression of a double absorption band, which need not be symmetrical [2]).

We hold that the dispersion bands play an important part in many of the well known spectral phenomena, such as the widening, shifting, reversal and doubling of lines. In a subsequent communication I purpose to examine from this premise various phenomena observed in the spectra of variable stars and other celestial bodies.

Physics. — "*Spectroheliographic results explained by anomalous dispersion.*" By Prof. W. H. JULIUS.

It is not surprising that the scientific world should be highly interested in the beautiful results, obtained by HALE and ELLERMAN with the spectroheliograph [3]). The brilliant method elaborated and applied by these investigators enables us to see at a glance as well as to study in minute details how the light of any selected wavelength was distributed on the total solar disk at any given moment. W. S. LOCKYER, in giving an abstract from the paper here alluded to in Nature N°. 1800, rightly entitles it: "A new epoch in solar physics." Indeed, the spectroheliograph proves capable of providing us with an abundance of new information, which other existing methods could never give and the value of which will remain, whatever may be the ideas on the Sun's constitution derived from it.

But, nevertheless, even the most splendid collection of new facts is useless so long as we have no theoretical ideas connecting them with achieved knowledge. HALE and ELLERMAN, accordingly, in

1) Proc. Roy. Acad. Amst. IV, p. 596.

2) In Fig. 4 on the plate is given an enlargement of one of the photographs obtained by an almost symmetrical position of the flame. It has been somewhat spoiled in the reproduction. The original is less blotchy and the transition of the dispersion bands to the bright background of the spectrum is there much more gradual.

3) G. E. HALE and F. ELLERMAN, "The Rumford Spectroheliograph of the Yerkes Observatory," Publications of the Yerkes Observatory, Vol. III. Part. I, (1903).