Of these experiments three always gave constant results, and produced respectively *B. stutzeri* NEUMANN and LEHMANN, *B. denitrofluorescens* n. sp. and *B. vulpinus* n. sp.

2nd. *B. stutzeri* deserves attention on account of the unique structure of its colonies, as seen in Fig. 1—5 on our Plate.

3rd. *B. denitrofluorescens* is the first example of a denitrifying, non liquefying fluorescent.

4th. *B. vulpinus* is a chromophorous pigment bacterium, whose pigment only forms at growth in the light.

5th. *B. stutzeri* and *B. vulpinus* behave towards free oxygen like aerobic spirilla, *B. denitrofluorescens* behaves like an ordinary aerobic bacterium.

6th. Like in soil and dung, in which it had also been found by other experimentators, I have established the general distribution of denitrifying bacteria in canal and sewage water.

7th. The denitrifying bacteria can, even with the slightest quantities of various organic substances, cause the disappearance of determined quantities of nitrate under development of free nitrogen.

8th. In one and the same culture medium, where nitrification is produced during aeration, denitrification may be caused by exclusion of air, this holds good also in regard to the soil.

At the end of this paper I want to express my sincere thanks to Professor Dr. M. W. BEIJERINCK for his kind, invaluable guidance and efficacious assistance, afforded me in these researches.

Delft, July 1902.

Physics. — "*An Hypothesis on the Nature of Solar Prominences.*" By Prof. W. H. JULIUS.

The introduction of the principle of anomalous dispersion into solar physics makes it possible to form an idea of the Sun's constitution from which necessarily follow i.a. a great many peculiarities of prominences, which, until now, it has been impossible to deduct in a satisfactory manner from other physical laws. This I will show in the following pages.

In my paper on "Solar Phenomena, etc." read Febr. 24, 1900. I put forth the following hypothesis with respect to that part of the solar atmosphere, situated outside what is called the photosphere [1]):

[1]) W. H. JULIUS, Solar Phenomena, considered in connection with Anomalous Dispersion of Light, Proc. Roy. Acad. Amsterdam, II, p. 585.

"The various elements, whose presence in that atmosphere has been inferred from spectral observations, are much more largely diffused in it than has generally been assumed from the shape of the light phenomena; they may be present everywhere, up to great distances outside the photosphere, and yet be visible in few places only; their proper radiation contributes relatively little to their visibility (with perhaps a few exceptions); the distances, at which the characteristic light of those substances is thought to be seen beyond *the Sun's limb, are mainly determined by their local differences* of density and their power to call forth anomalous dispersion."

How we were to imagine the condition of the matter inside the photosphere, was not considered there. Our hypothesis on the origin of the light of the chromosphere was kept free from any special conceptions as to the nature of the photosphere. Only where the principle of anomalous dispersion was made use of also to explain spectral phenomena observed in sunspots [1]), we had to fall back upon A. SCHMIDT's theory [2]), according to which the Sun is an unlimited gasball, so that the apparent surface of the photosphere should not be considered to be the real boundary of a body, but to correspond to a "critical sphere", defined by the property that its radius equals the radius of curvature of horizontal rays, passing through a point of its surface.

At present, however, in working out the problem of the nature of the chromosphere and the prominences, we likewise will take as a starting point the first of the three Theses, in which SCHMIDT sums up the main points of his theory. Accordingly, we suppose the Sun to be an unlimited mass of gas, in which the density and luminosity (not considering local irregularities) gradually diminish from the centre outward. But our conception of the properties and composition of this gaseous body can in a certain respect be much simpler than would be the case, if we accepted the whole of SCHMIDT's theory.

Indeed, SCHMIDT explains both the edge of the Sun's disk by the laws of regular refraction (or ray-curving) in a stratified medium, and the prominences by refraction in "Schlieren" [3]); but in order to account for the fact that the light from the prominences as well as that from the chromosphere, instead of being white, shows a bright line spectrum of varying appearance, he supposes the strongly radiat-

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[1]) l. c. p. 585.

[2]) A. SCHMIDT, Die Strahlenbrechung auf der Sonne. Ein geometrischer Beitrag zur Sonnenphysik. Stuttgart 1891.

[3]) A. SCHMIDT, Erklärung der Sonnenprotuberanzen als Wirkungen der Refraction in einer hochverdünnten Atmosphäre der Sonne. SIRIUS XXIII S. 97—109, Mai 1895.

ing mass of gases in its outer parts to be composed so as to emit almost exclusively hydrogen-, calcium-, heliumlight, whilst the radiations of sodium, magnesium, titanium, iron are supposed to originate in deeper layers, a.s.o. [1]). We, on the contrary, by the introduction of anomalous dispersion are permitted to suggest, that throughout the gaseous body, as well inside as outside the critical sphere, the various elements are altogether intrinsically mixed (granting that in the mixture the quantity of materials with greater specific gravity must grow with the depth). For wherever there are local differences of density in the mixture, caused by currents, whirls etc., the conditions for irregular ray-curving are present, and it is evident that specially those elements of the mixture, which possess an exceptionnally high dispersing power for certain waves of the transmitted light, will be able to reveal their presence even at great distances from the disk, while other substances, though also present at the same places, remain invisible there. Thus a purely optical explanation may be given of the fact, that the different gases of the sun are *seen* separated, even though we suppose them to *be* thoroughly mixed.

And surely this last supposition is the simpler by far; it even necessarily follows from the fundamental idea, that the Sun may be considered as a rotating, heat-radiating mass of gas, for in such a body the constituent parts must continually mix.

A few months ago the main character of the motion that must go on in a sun, supposed to be gaseous, has been discussed by R. EMDEN [2]). He applies to the Sun the same mathematical deductions, which had been devised by VON HELMHOLTZ for investigating the kind of motion which in our terrestrial atmosphere must result from the united influence of heating by the Sun and of the daily rotation [3]). Though EMDEN supposes the gaseous Sun to be limited by a well-defined surface, and so far accepts the prevailing views on the constitution of this celestial body, still his mathematical formulae are absolutely independent of the existence of a boundary surface, and so are fully applicable to a sun, such as we are considering here.

Radiation causes the outer layers to cool down soonest; they sink inwards and are replaced by ascending hotter gases, so that,

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1) As appears from a paper in the Physik. Zeitschr. 3. S. 259—261: entitled „Ueber die Doppellinien im Spectrum der Chromophäre" SCHMIDT adheres to this conception, even after having taken into consideration the possibility of explaining the light of the chromosphere by anomalous dispersion.

2) R. EMDEN, Beiträge zur Sonnentheorie. Ann. d. Phys. [4] 7, p. 176—197.

3) H. VON HELMHOLTZ, Gesammelte Abhandlungen I, p. 146, III p. 287—355.

if the Sun did not rotate, we could only expect radial convection currents. But the rotation of the sun completely changes this form of motion; the angular velocity of descending masses increases, of ascending masses diminishes; there will be found side by side gas-layers of different densities, and rotating at different speeds.

It has been shown by VON HELMHOLTZ, that during a certain time such gaslayers can flow side by side, sharply separated by a so-called surface of discontinuity (i. e. by a surface, on passing which the values of the velocity and the density change with a leap); but gradually the friction causes this surface to undulate; the waves advance with the more swiftly moving layer, they grow steeper, overhang and break, forming whirls; and thus, by the mingling of the adjacent parts of the two layers a new layer is formed between them, the properties of which will be intermediate between the corresponding properties of the original layers.

From the conditions of the problem we may deduce the position of the surfaces of discontinuity. This has been performed by VON HELMHOLTZ with regard to the air-currents in our atmosphere, and by EMDEN for the rotating layers of the Sun. He arrives at the conclusion, that in the Sun the surfaces of discontinuity must in the main have the shape, figured in the accompanying sketch and reminding us of hyperboloids of revolution [1]).

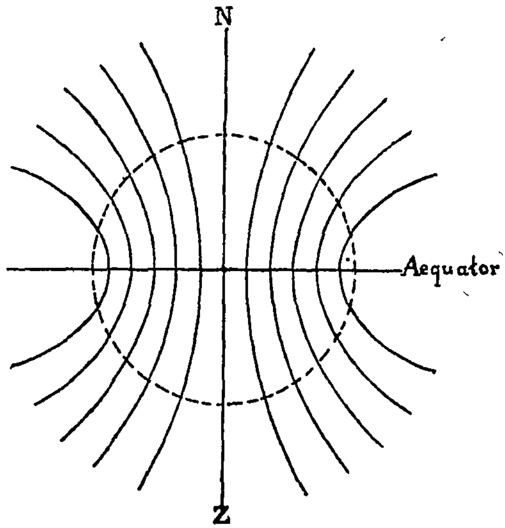

Fig. 1.

1) EMDEN draws the intersections of the surfaces with the plane of the paper only inside the circle, representing the sun's boundary. I have dotted this circle, with a view to indicate, that the border is only a seeming one; accordingly I prolonged the intersections outward.

In every annular layer, bounded by two consecutive surfaces of discontinuity, the moment of rotation of unit mass ($\Omega = \omega r^2$) as well as the so-called potential temperature θ are constant; but in a following layer, farther from the Sun's axis, Ω has a greater and θ a smaller value. Within every layer there exists a velocity potential, but at the separating surfaces the linear velocity changes discontinuously, the difference between the velocities on each side of one and the same separating surface increasing as that surface approaches the axis.

The waves, that are formed in the separating surfaces, will proceed in the direction of the rotation, and when, after growing steeper and steeper, they break, the resulting vortices will have their core-lines perpendicular to the direction of motion of the waves, i.e. coinciding with the generatrices of the surfaces of discontinuity. So, the curves in our figure also give an idea of the position of the vortex-cores.

From the theory follows, as we already mentioned, that at each definite surface of discontinuity the leap of the velocity is greater at a short than at a long distance from the Sun's axis; therefore, the transition from a wave into a whirl must, as a rule, begin in those parts of that wave, which are nearer to the axis, and appear afterwards in the outer parts.

Further it is clear that, because every whirling leads to mingling of the adjacent parts of two layers and to the formation of two new surfaces of discontinuity, there will never exist a complete surface, such as indicated by our sketch. Everywhere we shall meet with pieces of surfaces of discontinuity; only their main character and the average direction of the vortex-cores will correspond to the sketch. And in spite of the continual mixing of layers, which leads to equalization of differing rotational velocities, the motion still remains nearly stationary; for within each layer, temporarily enclosed between two surfaces of discontinuity, the convection currents carry cooled matter inwards and hot matter outwards, by which process the differences in rotational velocity are renewed.

Forced as we are to admit, that such an uninterrupted mixing process is going on in the Sun, the advantage of explaining the chromosphere and the prominences by anomalous dispersion of white light, must appear to us very obvious. All other explanations, that I know of, must start from the hardly tenable supposition, that the different gases of the chromosphere are separately present in large quantities.

Emden has succeeded in deducing many properties of sun-spots from the supposition, that the spots show us the places, where huge whirls attain the Sun's surface. It seems to me that Emden's views on sun-spots would become even much more acceptable, if the notion of a real surface of the Sun were given up and if the consequences of normal and anomalous refraction (better ray-curving) in those whirls were allowed for. But to this subject I desire to come back on another occasion.

For the present we will confine our attention to those parts of the whirls, optically projecting beyond the edge of the Sun's disk, and we propose the hypothesis, *that the whole chromosphere with all its prominences is nothing but this system of waves and whirls, made visible within shorter or longer distances from the Sun's edge by anomalous dispersion of light, coming from deeper layers.*

(Perhaps the structure of the corona, with its polar streamers, arches, etc., might tell us something about the course of the surfaces of discontinuity at very great distances outside the critical sphere; this point too, however, I will only hint at here).

So we ascribe the chromosphere to the smaller vortices, to the continual rolling up of the surfaces of discontinuity; in the prominences we see the whirling, in which the rarer, very large waves of the solar ocean dissipate.

The particular structure of the chromosphere, suggesting the comparison with a grass-field in vertical section, follows immediately from this hypothesis. Prominences likewise nearly always show a tissue of stripes, bands and filaments [1]). These, according to our view, indicate the position of the whirl-cores. In the whole region, where whirling is going on, the density will, of course, vary in a very irregular way; we therefore may expect to find in the spectrum of that region as well the light on the red as that on the violet side of the absorption lines, i. e. the chromospheric and flash lines must be double lines [2]).

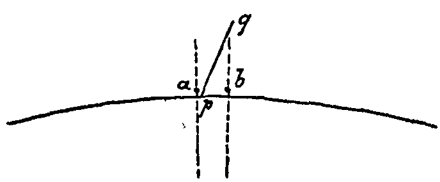

Fig. 2.

Along the core of a vortex the density is a minimum. If, now, a vortex intersect the apparent limb of the sun obliquely, as in Fig. 2, where pq represents the core-line, the light coming from a point a must differ from the light, coming from b. Indeed, following in a the Sun's radius

[1]) J. Fényi S. J., Protuberanzen, beobachtet in den Jahren 1888, 1889 und 1890 am Haynald—Observatorium, p. 5. (Kalocsa, 1902).

[2]) 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. Proc. Roy. Acad. Amst. Vol. III, p. 193.

outward, we at first get into layers of increasing density, whereas, ascending from *b*, we meet with layers of decreasing density. Consequently, in the spectrum of *a* the "violet-facing" components of the double lines must be prominent and in the spectrum of *b* the red-facing ones. If the slit be placed tangentially, through the points *a* and *b*, the two cases will be seen at a short distance on the same spectral lines. And when during a tôtal eclipse of the Sun the chromosheric arc itself functions as a slit (the prismatic camera being used), the same phenomenon may be met with on numerous places of the crescents. Many instances thereof are visible on the plates, obtained in Sumatra by the Dutch expedition for observing the total eclipse of May 18th 1901.

With large prominences the phenomenon sometimes appears very intensely. In the important work by FÉNYI, mentioned before, we read for instance on p. 121, in the description of a carefully observed prominence, the following passage:

.... „Im unteren Teile zeigte die Protuberanz am Anfange ihrer Entwickelung eine grosse Störung in der H_α Linie. Bei engem (tangentiell gestelltem) Spalte reichten zwei Spitzkegel über denselben hinaus, der eine, grössere erstreckte sich gegen rot, der andere kleine gegen blau und stand etwas südlicher. Die Grösse des ersteren betrug 9″ im Gesichtsfelde; auf Grund einer neuen Bestimmung der thatsächlichen Dispersion des Spektroskops ergibt sich daraus für diese Stelle der Protuberanz eine Bewegung *von* uns mit der Geschwindigkeit von 240,4 Klm. in der Secunde. Die Verschiebung gegen blau betrug nach dem Augenmaasse etwa die Hälfte der ersteren gegen rot.

Die entgegengesetzten Bewegungen neben einander und die Kegelförmige Form des veränderten Lichtes würden unschwer die Deutung auf eine Wirbelbewegung am Grunde der Protuberanz gestatten. Aus der Ungleichheit der Kegel würde ein Vorschreiten des Wirbels *von* uns mit der Geschwindigkeit von 180 Klm. sich ergeben. Die Beobachtung steht auch nicht allein da; eine ähnliche Erscheinung wurde von YOUNG am 3. Aug. 1872 (The Sun, p. 210) eine andere von THOLLON in Nizza (C. R. XC p. 87, XCI p. 487) beobachtet; ähnliches wurde auch von mir bei anderen Gelegenheiten beobachtet."

Thus, interpreting the light on both sides of the hydrogen-line after DOPPLER's principle, FÉNYI arrives at the very astonishing conclusion, that the whirling mass of hydrogen moves at a speed of 180 kilometers per second. Moreover, there is a much greater difficulty, not even mentioned by FÉNYI, viz. that the coherent outbuds of the line impose upon him the necessity of supposing that velocity to be very different for the various parts of the whirl, adjacent pieces of the prominence not even taking any part in the enormous motion along the line of sight.

The above-given explanation of the phenomenon by anomalous dispersion solves all these mysteries.

It occurs very seldom that prominences show a rapid sideward motion, i.e. a motion in the meridian of the Sun. Fényi mentions as an exceptional case a sideward velocity of 25 kilometers per sec[1]). As, on the other hand, velocities of 250 kilometers and more in the direction of the parallel (calculated after Doppler) are by no means a great exception, we meet with contradictions — as is admitted also by Fényi — from which it appears impossible to escape, unless we doubt the reality of the velocities.

It is surprising and satisfactory to see how nearly all the peculiarities in the behaviour of prominences, as described by Young, Fényi and many others, appear quite intelligible as soon as we look at these phenomena from our point of view.

Let us choose only a few more examples out of the vast material.

Fényi says (l. c. p. 115): „Schon seit Jahren habe ich bemerkt, dass helle hervortretende Punkte in der Chromosphäre, welche eine kleine Verschiebung gegen blau zeigen, der Ort sind, wo alsogleich der Aufstieg einer Flamme oder einer kleinen Protuberanz erfolgt."

Now the process of whirl-formation in a surface of discontinuity proceeds, as a rule, from the inner parts of the Sun outwards. In the axis of a whirl the density is a minimum. Consequently, at the moment the whirling reaches the apparent edge af the Sun, a minimum of density will be found just projecting beyond the edge. Here we have a place, where the density increases from the photosphere outward and where, therefore, the violet-facing component of the chromospheric double-line temporarily prevails: it seems as if a shifting towards the violet occurs. Shortly afterwards the more distant parts set a whirling and the prominence appears.

In the description of a great prominence, observed by Fényi on the 18th of Aug. 1890, we read i.a. the following particulars[2]):

„Ein ganz besonderes Interesse verleihen dieser an und für sich schon grossartigen Erscheinung die Eigenbewegungen in der Gesichtslinie, die an derselben beobachtet wurden. Eine ungefähr zwischen 40″ und 50″ Höhe liegende Schicht, (deren Lage in der beigegebenen Figur genau bezeichnet ist), zeigte eine heftige Bewegung gegen die Erde zu. Das rote Licht des Hydrogeniums ergoss sich daselbst in verworrenen Formen über den Spaltrand gegen blau hinaus ohne

[1]) Fényi, l. c. p. 114.
[2]) Fényi, l. c. p. 129.

indessen den Spalt ganz zu verlassen. Die Bewegung war durchaus local, die Umgebung zeigte keine Spur einer Bewegung. Die Geschwindigkeit derselben war keine ungewöhnlich grosse; ich erhielt aus 4 mit dem Fadenmikrometer gemachten Messungen zwischen 11 h. 45 m. und 12 h. 15 m. verschiedene, zwischen 94 und 201 klm. schwankende Werthe. Was aber die Erscheinung zu einer besonders merkwürdigen gestaltet ist der Umstand dass, während diese in der Höhe vor sich gehende ganz locale Bewegung nicht einer Ausströmung zugeschrieben werden kann, dieselbe trotzdem doch eine halbe Stunde lang beobachtet wurde! Nehmen wir als Mittelwerth der Geschwindigkeit 150 klm. per Secunde an, so hätte dieser bewegte Teil der Protuberanz während der zwischenzeit von 30 Minuten gegen 270.000 klm. durchlaufen, also wohl auch den scheinbaren Ort ändern müssen."

Of course this contradiction immediately vanishes if we only suppose, that in the part of the prominence, showing the persistent shift of the hydrogen light towards the blue, the density of the solar matter was increasing in the direction from the photosphere outwards. This supposition is quite in harmony, too, with the fact, that the picture of this prominence shows very important whirling *below* the part in question and no disturbance worth mentioning *above* it.

Observers have often been puzzled at the rapid disappearing of enormous prominences and at the perfect calm in the whole region, including the Sun's surface, a short time after such a violent "eruption" had taken place. It was hardly conceivable that the ejected incandescent gases could loose their huge quantities of heat so rapidly, nor that the eruption had no further visible consequences.

In our theory a large prominence is nothing but the visible token, that whirling is going on almost simultaneously over vast regions. The very important varieties of density in the whirling mass may, however, be annulled by displacements of much matter over relatively small distances, which process, of course, may go on without violent movements and yet be accomplished in a short time. So there is no reason whatever to expect, that a great prominence will leave the medium in a highly disturbed condition.

Whosoever wishes to consider prominences as eruptions, must grant, that it is one of the most difficult problems to account both for the tremendous values of the ascending velocities sometimes observed and for the most capricious way, in which the speed often suddenly changes without any conceivable cause. The 20[th] of Sept. 1893 Fényi witnessed a prominence ascending 500000 kilometers in a quarter of an hour, that is at an *average* velocity of more than

550 kilom. per sec. In another case, also observed by FÉNYI (July 15th 1889), in the course of 10 minutes the ascending velocity passed through the values 72, 6, 65, 24, 154 kilometers per second; and with the prominence of Oct. 6th, 1890, in 30 minutes' time through the values 33,8, 79,8, 67,6, 72,7, 127,7 275,5, 242,3, 121, 57,3 kilom. per sec.

Considering the problem from the new point of view we see the difficulties disappear in consequence of the observation, that, properly speaking, we have not to do with velocities at all. We may speak of the velocity with which matter moves or with which a disturbance is transmitted by a medium; but neither of these cases is met with here. Wherever the whirling sets in, it results from local conditions and cannot be considered as directly transmitted from places, where whirling was going on a little earlier. Though it is true that, as a rule, the breaking of a wave begins in those parts of a surface of discontinuity, that are nearer to the Sun's axis, and from there proceeds outwards, yet this does not involve that we should have a right to call this process a transmission of matter or of motion in the direction of the vortex-cores. And where there is no transmission, there is no velocity.

When at the sea-shore a wide wave approaches and breaks, now here, then farther and farther, nobody will speak of the "velocity" with which the foam or the whirling is moving along the coast. Every body knows, that the foam, the visible token of the whirling, is successively formed at different places. Such about is the case with the prominences, the visible spots in the breakers of the solar ocean.

Chemistry. — Professor LOBRY DE BRUYN communicates a paper by himself and Mr. J. W. DITO. "*The boilingpoint-curve of the system: hydrazine + water*".

In a previous report[1]) Mr. DITO has communicated the results of determinations of the densities of mixtures of hydrazine and water; the figures showed that a maximum density corresponds exactly (or nearly so) with the composition N_2H_4-H_2O. At the end of that note it was stated that we would endeavour to determine the boiling-point-curve of the system: hydrazine + water.

We have lately been engaged with that determination; the result is given in the following table and annexed curve.

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[1]) Proc. of April 19, 1902, p. 838.