Citation:

W.H. Julius, Dispersion bands in the spectra of Orionis and Nova Persen, in:
KNAW, Proceedings, 7, 1904-1905, Amsterdam, 1905, pp. 323-328

The conditions of a short period of oscillation combined with a relatively high internal resistance are fulfilled by only one instrument besides the string galvanometer, as far as is known to me, namely by the oscillograph. Here the damping is effected by means of oil which is heated [1]).

The temperature of the oil determines its viscosity and the regulation of the degree of damping is consequently obtained in the oscillograph by regulating the temperature of the oil. It is doubtful whether the instrument would greatly gain in practical usefulness if the oil with the heating arrangement were done away with and replaced by a condenser.

In the string galvanometer the condenser method will be successfully applied in cases where it is desired to measure variations of current of very short duration. Taking a very short and strongly stretched quartz-thread, it will be possible to obtain deflections whose quickness leaves little to be desired. Without a condenser these would be useless for many purposes on account of the oscillations, whereas now they may become useful for a number of physical and electrotechnical investigations by a judicious damping. In these cases the string galvanometer will for equal quickness of deflection appear to be a much more sensitive apparatus than the oscillograph.

Also in a number of electrophysiological investigations we can avail ourselves of the condenser method, while the study of sounds will be particularly facilitated by it. I hope to make a nearer communication on this subject in a following paper.

Physics. — *"Dispersion bands in the spectra of δ Orionis and Nova Persei"*. By Prof. W. H. JULIUS.

When light, giving a continuous spectrum, passes through a selectively absorbing, non-homogeneous mass of gas, the spectrum of the transmitted light contains places which, according to circumstances, may contrast as bright or as dark regions with their surroundings [2]). Though resembling emission and absorption lines, these bands have a wholly different origin. They are due to anomalous dispersion and, therefore, the name *dispersion bands* has been suggested for them [3]).

---

1) Also a mixture of two liquids is used, of which one has a great, the other a small viscosity. The mixture is so chosen that the desired viscosity is just obtained.

2) Proc. Roy. Acad. Amst. II, p. 580 (1900).

3) Proc. Roy. Acad. Amst. VII, p. 134—140 (1904).

Dispersion bands always appear in the proximity of absorption lines, covering them more or less symmetrically; they show great variety in width and strength, and the distribution of the light in them may be irregular, so as to give the impression that one is witnessing cases of shifting or doubling or complicate reversal phenomena of widened absorption lines. All these cases can be produced almost at pleasure in the absorption spectrum of sodium vapour by merely varying the structure of the non-homogeneous medium through which the light is made to travel.

In the spectrum of the various parts of the solar image dispersion bands play an important part [1]). We can scarcely doubt that they are also present in stellar spectra; for the light coming from the stars must, as a rule, have travelled through immense gaseous envelopes and suffered ray-curving and anomalous dispersion, just as well as the light from the Sun.

Taking for granted that most of the visible stars are *rotating* gaseous bodies, with or without a solid core, we must suppose them to have a structure, describable by surfaces of discontinuity with waves and vortices, and resembling the peculiar structure of the Sun, by which it has proved possible to explain solar phenomena [2]). Consequently, the stars too give existence to "irregular fields of radiation" rotating with them. Our line of sight continually cuts other parts of the refracting mass; it may pass closely along surfaces of discontinuity, now on the one, now on the other side of them; so the light reaching us must vary in strength and in composition.

The variability of many stars is very likely to result from this cause; and from the same principle it necessarily follows that their spectral lines should be liable to every kind of change in place and in appearance.

In many cases where the application of DOPPLER's principle leads to very unsatisfactory conclusions, the dispersion bands afford a plain solution. Let us consider, for instance, the spectrum of δ Orionis.

In this spectrum rapid changes in the position of the lines had been observed by DESLANDRES (1900), who concluded from them that δ Orionis was a spectroscopic binary having a revolving period of 1.92 days. Some observations made by J. HARTMANN [3]) did not agree with this period. Professor HARTMANN, therefore, submitted the

---

1) Proc. Roy. Acad. VII, p. 140—147 (1904).

2) Proc. Roy. Acad. Amst. V, p. 162—171; 589—602; VI, p. 270—302 (1903).

3) J. HARTMANN. Untersuchungen über das Spectrum und die Bahn von δ Orionis. Sitzungsber. der Kön. Preuss. Akad. d. Wissenschaften, XIV, S. 527—542, März 1904.

star to an extensive spectographic investigation in the winter months of 1901—2 and 1902—3, and, from the 42 plates obtained, drew the following conclusions.

The spectrum contains chiefly the lines of hydrogen and helium; besides a few belonging to silicium, magnesium, calcium.

The calcium line at λ 3934 (corresponding to K of the solar spectrum) is extraordinarily weak, but almost perfectly sharp; all the other lines (nineteen in number) are very diffuse and dim, often appear crooked and unsymmetrical, sometimes indeed double. While every prepossession of the observer was most strictly avoided during the measurements, it was found, that the centres of the diffuse lines really oscillate, the period being 5,7333 days; but, owing to the unsymmetrical appearance of many of the lines, no evidence could be obtained that the values of the displacements were in mutual agreement for all the lines on one and the same plate. From the average displacements HARTMANN calculated the "variable velocity in the line of sight", and finally the elements of the orbit.

An utterly surprising result, yielded by the measurements, was that the calcium line at λ 3934, does not share in the periodic displacements of the other lines, but shows a constant shift corresponding to a velocity in the line of sight of + 16 km. (reduced to the Sun).

HARTMANN rejects the idea that this line should have originated in the Earth's atmosphere; also the assumption that it belongs to the second component of the binary system. He is thus led to the hypothesis that at some point in space in the line of sight between the Sun and δ Orionis there is a cloud of calcium vapour which recedes with a velocity of 16 k.m. By examining the spectra of neighbouring stars no further information as to the existence of such a cloud was obtained.

A quite similar phenomenon, however, had been exhibited by the spectrum of Nova Persei in 1901: the lines of hydrogen and other elements were enormously broadened and displaced and continually changing their appearance, but during all the time the two calcium lines at λ 3934 and λ 3969, as well as the D-lines, were observed as perfectly sharp absorption lines, yielding the constant velocity of + 7 km. HARTMANN therefore assumes that also in the line of sight between the Sun and Nova Persei there exists a nebulous mass consisting, in this case, of calcium and sodium vapour, and moving from the Sun at the rate of 7 km. a second.

It must be admitted that these hypothetical clouds do not form a satisfactory solution to the problem.

A much simpler explanation of the phenomena may be derived from our conception of the irregular fields of radiation caused by the stars.

We need only suppose that the outer parts of δ Orionis and of Nova Persei, like those of so many other stars, contain much hydrogen and helium, little calcium and sodium. The currents and vortices in the gaseous mass, which produce the irregularities of the field of the star's radiation, bring about very broad dispersion bands in the vicinity of the lines of hydrogen, helium, etc. The darkest parts of these bands will be displaced when, by the star's rotation, masses in which the density is variously distributed, pass our line of sight. The dispersion bands of calcium and sodium, on the other hand, are so narrow, that the varying position of their darkest parts cannot be distinguished from the fixed position of the corresponding absorption lines. The constant displacement of the latter indicates that δ Orionis recedes from the Sun with a velocity of 16 km., Nova Persei of 7 km. a second.

According to our opinion δ Orionis, therefore, is *no* spectroscopic binary.

In the spectra of a great many stars oscillations and duplications have only been observed with diffuse lines. In those cases too the displacements are, as usual, expressed in so many kilometers a second, because no other interpretation than motion in the line of sight is thought of. From the above considerations it follows, however, that the observed oscillations are very likely to be executed by dispersion bands and not by the absorption lines; then no sufficient ground remains for classing such stars among spectroscopic binaries and for calculating orbital elements.

Several difficulties to which the conclusions derived from DOPPLER's principle lead us, will then disappear at the same time. How, for instance, are we to realize the physical conditions of the orbital motion in such so-called binaries as ι Orionis, 57 Cygni, θ Orionis and many others, all of which are involved in nebulous matter, but whose motion in the line of sight is nevertheless — according to FROST and ADAMS — subject to periodical variations of 70, 90, 140 km. a second, in spite of our physical notions concerning resistant media? When, on the other hand, the observed displacements of spectral lines, as well as the oscillations of the brightness of similar stars, are supposed not to result from motion in orbits, but from irregularities in their fields of radiation, there remains nothing astonishing in the fact that such variations often occur with stars involved in nebulosity.

In order to explain certain peculiarities in the spectra of Novae the principle of anomalous dispersion has already been applied by H. EBERT [1]). A characteristic of those spectra, viz. the presence of double lines consisting of a bright and a dark component, the bright one being displaced towards the red, the dark one towards the violet, is very suggestively explained by this author in connection with the theory of SEELIGER. According to this theory the appearance of a Nova results from a dark or faintly luminous celestial body entering at a great velocity into a cosmic nebula. During this process the front part of the star's surface will become excessively heated and luminous, and a dense gaseous atmosphere will be formed, in which, as EBERT shows, the incurvation of the rays must necessarily be such as to cause the dispersion bands appearing in the spectrum to be *bright* on the red-facing and *dark* on the violet-facing side of the absorption lines.

EBERT expresses the opinion that displacements and duplications of lines in the spectra of many variables of short period might be explained in a similar way, i.e. by admitting that the radiating power of such bodies is very unequal in different parts of their surface, and that they are surrounded by dense atmospheres. Their rotation will then cause us to see, as it were, the phenomena of the Novae periodically repeated.

In certain cases this interpretation may undoubtedly account for the peculiarities observed in the spectra of variables; nevertheless we cannot generalize the idea without meeting with some serious difficulties. First, it is not easy to form a clear conception of the physical conditions prevailing in a star, the incandescent surface of which is supposed to contain, permanently large regions radiating very much less than the rest. The Sun with its spots may certainly not be adduced as an analogous case. Moreover, there are plenty of instances that in the spectrum of a variable, bright bands appear at the *violet* side, dark bands at the *red* side of the absorption lines, i.e. just the reverse of the phenomenon presented by the Novae; and it happens that with one and the same star bright and dark dispersion bands change places in course of time with respect to the average position of the absorption lines. This occurs e.g. in the spectrum of Mira Ceti, as will appear when comparing the observations made by VOGEL and WILSING in 1896 (Sitzungsber. der Berl. Akad. XVII) with those made by CAMPBELL in 1898 (Astroph. Journ. IX, p. 31) and by STEBBINS in 1903 (Astroph. Journ. XVIII, p. 341);

[1]) H. EBERT, Ueber die Spektren der neuen Sterne. Astron. Nachr. Nr. 3917. Bd. 164, p. 65, 1903.

also in the spectrum of θ Orionis observed by HUGGINS in 1894 and 1897 (An Atlas of representative Stellar Spectra, p. 140), etc. In those cases the explanation suggested by EBERT would require the addition of special hypotheses.

Our fundamental hypothesis that the structure of most stars is similar to that of the Sun (it being admitted, of course, that the stars may greatly differ as to the extent of their respective gaseous envelopes, the average steepness of the density gradients in them, their chemical composition, temperature, etc.) seems to admit of the interpretation of a greater variety of facts. It makes displacements of the dispersion bands towards the long and the short waves almost equally probable — if we leave the asymmetry in the form of the dispersion curves out of question and provisionally assume the directions of the axes of the stars to be distributed at random through space.

The direction in which we see a star may be regarded as a steady line in space, allowance being made for aberration and parallax. If, now, the distribution of the matter constituting that celestial body remains nearly unchanged for a long time, then after each rotation of the star our line of sight will again pass through the same points of the "optical system", and we shall observe an accurately periodical course in the star's brightness and in the appearance of its spectral lines. In most cases, however, currents and vortices will cause more or less considerable alterations to arise in the distribution of the density of the gaseous mass, and, consequently, in the composition of the beam of light reaching the Earth at a given phase of the star's rotary motion. Thus the strictly periodical succession of phenomena is open to any degree of disturbance. The very irregular and sometimes rapid changes in the brightness of objects like *o* Ceti, SS Cygni, μ Cephei, etc. are much more intelligible from this point of view, than from interpretations based on the assumption of violent eruptions, large spots, or eclipses caused by dark companions. And it is so difficult to make a sharp distinction between variables of long period and Novae, that we should not resent the idea of comparing even the appearance of a new star to the sudden gleam of a revolving coast-light when the optical system, giving to the beam a considerable decrease in divergence, passes our line of sight.

Chemistry. — Prof. C. A. LOBRY DE BRUYN presents a paper of J. OLIE JR.: "*The transformation of the phenylpotassium sulphate into p-phenolsulphonate of potassium*".

(Communicated in the meeting of June 25, 1904).

(This paper will not be published in these Proceedings).