X.—On the Spectrum of Nova Persei and the Structure of its Bands, as photographed at Glasgow. By L. Becker, Ph.D., Professor of Astronomy in the University of Glasgow. (With Three Plates.)

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The spectrum of the new star in Perseus, which Dr ANDERSON, of Edinburgh, discovered 1901 February 21, was photographed at the Glasgow Observatory from 1901 March 3 till 1903 January. From the early photographs one gains the impression that the spectrum consists of a number of bright bands of different lengths, fading towards the ends, and overlapping each other, thus producing a series of maxima and minima of brightness. Near wave-length 5000 the intensity rapidly falls off towards the less refrangible side, and the bands appear detached. The middle of each of the three most intense maxima approximately coincide with the hydrogen lines H_β , H_γ , H_δ , and on two photo-plates, March 18 to 20 and March 25, each of the bands is crossed by a sharp Fraunhofer line. On the photo-plates taken after 1901 August 1 the bands are all detached; some, including the two bands whose middles approximately coincide with the principal nebular lines, have almost the same lengths, and suggest a line spectrum in which the lines have been broadened into bands, others are considerably longer and have pronounced maxima.

While it was probable that the three hydrogen lines and the two principal nebular lines were represented in the spectrum by bands, it remained to be proved that the wave-length of a definite point of the band bore a definite relation to the wave-length of the line to which it belonged. As a result of my investigations, founded on micro-metric measurements and estimates of intensity, I shall show that the bands which contain a series of reversals are similar in type, and that the ratio of the distance between any two points in a band to that between corresponding points in another band is the ratio between the wave-lengths. The spectrum of Nova Aurigæ resembled that of Nova Persei very closely; its changes followed the same course, and it showed the considerable broadening of the lines into bands, the structure of which has, however, never been investigated. The systematic broadening of the spectral lines into bands, which for Nova Persei amounted to a 35th of the wave-length in March and April, and a 100th after August, seems to be a feature of new stars, and ought to be accounted for in an explanation of these objects.

2. *The Spectrograph*.—The spectrograph of 8 cm. aperture is connected to the Breadalbane reflector of 51 cm. aperture and 446 cm. focal length. The equatorial mounting of this instrument, probably made by the late Thomas Grubb some fifty years

ago, is remarkable in so far as its inclined stand anticipates the chief structural feature of the Potsdam astrographic refractor. The reflector, which had proved useless in its old condition, obtained in 1895 a new silver-on-glass mirror, driving clock with electric control, driving sector and declination clamp with slow motion, all from the works of Sir Howard Grubb. The mounting of the spectrograph was supplied by a local smith. A platform forming a right-angled triangle extends from the upper end of the tube to the free end of the declination axis, and its plane is inclined 35 degrees to the optical axis. Parallel to it, the central ray of the reflector is reflected by a plane mirror. The platform is a stiff structure for its weight. It consists of two layers of corrugated iron, with the corrugations crossed and bolted at every point of contact, and it is strengthened by thin sheet steel ribs. To it is clamped a quarter-inch steel sole-plate, with adjustable bearings for the two tubes of the spectrograph, and on this sole-plate a small cast-iron table carrying the prism-box can be adjusted and clamped. The platform rests at its upper end, a corner of the triangle, on a casting which is bolted to the tube of the reflector; at its lower end, the shortest side of the triangle, it is screwed to a strong cast-iron arm, which is fixed to the declination axis, in place of the balancing weights, at right angles to this axis and the axis of the tube. As I had the declination axis lengthened, and the telescope tube shortened and placed more favourably in its cradle, the movable part of the instrument weighs now less than in its old condition.

The object-glass of the collimator has an aperture of 8.2 cm. and focal length of 74 cm.; that of the camera, a Cooke triplet, 8.9 cm. by 149 cm. The focal length of both combined has a large temperature coefficient, 0.13 mm. for a degree centigrade. The prism made by Hilger of white Jena flint glass measures 16.5 cm. on a side, and is 9.5 cm. in height. Since it was re-annealed its separating power is most satisfactory. The central portion of the spectrograph is enclosed in a box, and by means of a small heating apparatus the temperature of the prism and the object-glasses can, at least to some extent, be kept under control. Unfortunately, the instrument cannot be used in summer after a sunny day, because in the iron dome the large prism is heated in such a way that the definition becomes too bad for accurate work.

The jaws of the slit are formed by the two halves of a circular mirror 2.5 cm. in diameter, and they open symmetrically 0.15 mm. for a revolution of the screw. The width here employed was usually 0.018 mm. The plane of the mirrors which form the jaws of the slit is inclined 7 degrees to the plane normal to the central ray. If the image of the star does not fall on the slit, the rays are reflected towards a small mirror which is fixed to the telescope tube, and thence towards a viewing "telescope" (which is focussed on the slit) of 7 cm. aperture and 30 cm. focal length (two object-glasses mounted close together). It lies almost parallel to the collimator. Owing to the large size of the jaws of the slit, the effective field is half a degree, which is a great convenience in finding a star and setting it on the slit. The spark apparatus is hinged to the platform in front of the slit. When turned into position, the optical axis of its lens coincides with that of the collimator.

The collimator lens, though a fine object-glass, F/9, did not prove to be achromatised for photographic rays; the focal curve of the spectrograph runs along zero from D to H β , then gradually rises, and at wave-length 3700 the ordinate is 2.8 cm. I had therefore to incline the photographic plate up to 30°.

When the telescope is turned through twenty-four hours of hour-angle, the image in the focal plane of the spectrograph oscillates in simple harmonic motion, with an amplitude of 0.8 mm., along a line which is slightly inclined to the spectral lines. I compensated this deficiency of the mounting by making the plate-holder adjustable in the direction of the spectral lines, and at right angles to them, the motion being effected by two micrometer screws of 0.5 mm. pitch. The plate-holder takes the plate, 11 by 4 cm., in its upper half, which lies central in the camera, and in the space below it carries an eye-piece with stout cross wires. As fiducial line for keeping the plate stationary with regard to the spectrum, I employed the magnesium line 4481, which is almost covered by the stout wire in the eye-piece. A split spring, which presses against the jaws of the slit, cuts out a short line from the upper portion of the slit 1.5 cm. above the optical axis, and the magnesium terminals are placed close to it, inside a short glass tube, to guard the slit against tarnishing. By these means I am able to keep a line of the spectrum always on the same place of the photographic plate, and to replace the plate after days in its old position. The differential change of dispersion due to changes of temperature is, of course, not taken into account. During an exposure of the plate I moved the plate-holder every time 0.01 revolution of the micrometer screws, at intervals given by a table, and checked the position once an hour direct on the magnesium line. To illustrate the efficiency of this method, I mention that on photo-plate No. 23, comparison lines at a distance of 0.04 mm. appear separated, though they were exposed on twelve different occasions, five seconds each time, on two days, and at different hour-angles.

At the time the new star was announced, wave-length 5200 t.m. was in the centre of the field of the camera, and 4000 at the end of the plate. No change was made in the position of the camera until the beginning of October 1901, when wave-length 4170 was placed in the centre.

The distance of the hydrogen lines H β and H γ is 20 mm. on the plate, and one tenth-metre or Angstrom unit is represented on the plate by 0.1 mm. at $\lambda = 3500$, 0.05 mm. at $\lambda = 4300$, and 0.025 mm. at $\lambda = 5200$ t.m.

3. *The Measurements and their Reduction to Wave-Lengths.*—The plates taken in March and April 1901, and again those after January 1902, were difficult to measure,—the former, owing to the gradual change of intensity of the spectrum, which presented few definite points to set on; the latter, owing to the faintness of the spectrum, some parts of which could barely be distinguished from the accidental markings on the film. I finally adopted the rule to measure every point to which the eye was drawn, except those which I thought to be defects in the film. With respect to these, I became more careful as the work advanced; and it is possible that the earlier plates may contain

more than were actually measured of the minima, or reversals, which were present in the spectrum during the whole period. On the plates taken between August 1901 and January 1902 the structure of the bands, including the minima, is easily seen, and in some bands it is visible to the unaided eye. The intensity of the spectrum between every two points measured was estimated on an arbitrary scale, the estimated "degrees" of intensity increasing with the intensity. In this paper the "intensity of the spectrum" stands for the intensity of blackness on the negative, while "intensity of radiation" is used for the intensity of light in the focal plane of the spectrograph. I measured each plate about four times, alternately in opposite directions. Each series includes a number of settings on the lines of the comparison spectrum, iron-calcium until September, and iron-titanium afterwards. The points measured on the same plate were then identified by a graphical process, and all those were discarded which had not been repeatedly observed. Only on plate No. 5 I made an exception, where, after the discussion was finished, I included two minima which had only once been measured. Since the measuring occupied about half a year, and no measurements were taken after the reductions were begun, the results of the different plates may be considered independent. For each plate I reduced each series of measurements separately to wave-lengths, and then combined them to mean values. The tables used in the reductions give the position of the micrometer screw of the measuring apparatus, referred to an arbitrary zero, for each wave-length at an interval of 1 tenth-metre; they are based on Ketteler's formula of dispersion,* and were prepared for the angles of inclination at which the plates were exposed.

The comparison spectrum determines the correction curve of the zero of the table.

THE SPECTRUM IN MARCH AND APRIL 1901.

4. *Results of Measurements.*—The results derived from the measurements made on the photo-plates Nos. 1 to 7 are given in Table I. The first column contains the mean wave-length, the second the average difference of one measurement from the adopted mean value, and the third, under the heading "Intensity," the estimated degrees of intensity. The notation $\frac{9}{7}$ indicates that the intensity gradually changes from degree 9 to 7.

* *Annalen der Physik und Chemie*, 1881, 12.

TABLE I.

Photo-Plate No. 1, 1901 March 3.

Angle of inclination of plate = 0° ; width of slit 0.018 mm.; orthochromatic plate; exposure 2.4 hours; the spectrum was measured 6 times and referred to 50 standard lines; good definition of spectrum; the more refrangible end beginning at $\lambda = 4500$ is increasingly out of focus.

λ	v	Intensity.	λ	v	Intensity.	λ	v	Intensity.	λ	v	Intensity.
3967		5	4317.7	0.5	4	4844.4	0.7	9	5007	1.6	3
3972	1.3	6	4320.2	0.6	3	4847.6	0.8	} = 15	5024	6	3
4010	2.4	5	4321.8	0.4	6	4850.3	1.5		5046	2	1
4049	1.2	4	4325.5	0.3	8	4851.6	1.0	} 14 = 15	5121	2	0.3
4077.8	0.8	2	4329.3	0.6	12	4852.9	0.5		5143	2	1
4086.2	1.1	5	4334.1	0.8	11	4854.8	1.2	} = 15	5160	1	0
4090.5	0.8	10	4359.7	0.7	10	4869	1.4		5210	1.6	1.5
4097.7	0.4	9	4367	1.5	9	4873.2	0.5	} 14	5241	3	0.5
4117.9	0.4	9	4412.8	0.8	7	4883.2	0.7		5271	1.6	1
4123.7	0.8	7	4435	2	6	4890.0	0.8	} 8	5306	6	3
4145.6	0.6	6	4454.2	1.0	7	4896.9	0.5		5347	2	3
4161.3	1.2	5	4476	1.7	7	4902	1	} 2.5	5362	1	1.5
4186.5	0.7	7	4584 *	3	10	4907	1.3		5381	2	0
4200.8	0.9	6	4619	4	6	4925.0	0.7	} 5	5520	2	4
4209	1.6	5	4640	7	7.5	4934.2	0		5544	9	4.5
4221.6	0.5	4	4686	3	8	4934.2	0	} 3	5586	1	4
4253.6	1.0	5	4801	2	7	4943.1	0.8		5678	3	3
4281	5	4	4835.2	0.5	6	4959	4	} 1	5711	4	2
4312.5	0.5	5	4839.3	0.9	4	4981	2		5747	3	1
4317.7	0.5	4	4844.4	0.7	3	4985	8	} 0.3			
					8	5007	1.6				0.3

* The enlargement shows a maximum within this space.

Photo-Plate No. 2, 1901 March 6 and 8.

Angle of inclination of plate = 0° ; width of slit 0.018 mm.; orthochromatic plate; exposure 1.8 hours, 1 h. on March 6 and 0.8 h. on March 8; the plate was intensified and is slightly fogged; the spectrum is not so dark as on No. 1; it was measured 4 times, 3 times on the intensified plate, and referred to 22 standard lines; good definition; focus same as on No. 1.

λ	v	Intensity.	λ	v	Intensity.	λ	v	Intensity.	λ	v	Intensity.
4089	2	2	4359.2	0.4	4	4545	3	4	4852.3	0	} 10
4118.2	0.3	0	4365.7	0.7	3	4600	1.8	4	4855.4	0.9	
4296	2	1	4375.6	1.3	2	4616.7	0.4	3	4857.7	0.3	7
4319	1.5	0	4392.0	0.2	1	4643.6	0.6	4	4861.8	0.4	10
4324.6	0.4	3	4413.1	0.4	2	4691	2	3	4861.8	0.4	8
4328.6	0.4	} 8	4466.0	0.7	0	4720.2	1.1	2	4870	2	10
4337.8			4477	5	2	4840	3	1	4879.7	0.9	7
4347	2	9	4499	4	3	4846.4	0.7	0	4881.8	1.1	4
4355.5	0.6	6	4528.0	0	3.5	4849.9	0.7	2	4883.3	0.1	2
4359.2	0.4		4545	3	3	4852.3	0	7	4892	2	1
								} 10	4928	3	0.5

Table I. is continued at the top of the next four pages.

TABLE I.—*continued.**Photo-Plate No. 3, 1901 March 18 and 20.*

Angle of inclination of plate = 13° ; width of slit 0.018 mm.; Imperial plate; exposure 4.4 hours, 1.2 h. on March 18 and 3.2 h. on March 20; clear negative; the spectrum was measured 6 times, the H-bands 12 times, and referred to 50 standard lines; good definition.

λ	v	Intensity.	λ	v	Intensity.	λ	v	Intensity.	λ	v	Intensity.
4028	1.5	1	4251	4	7	4512	4	10.5	4871.0		13 = 9
4034.8	0.4	1.5	4260	4	6	4535	2	10	4875.1		13 = 9
4037.3	1	2	4284.7	0.8	6	4551	2	10	4879.4		13 11
4044.0	0	2	4315.31		7 = 0	4562	4	11	4883.9		8
4055	2	3	4318.4		7	4590	2	10	4895	2	7
4061	3	3.5	4319.03		0	4602	3	9	4900		6
4080.76		4	4319.6		9	4607.2	0.1	8	4911.4		3
4081.51		0	4326.9		11	4611	1.3	9	4922		4
4082.2		6	4335.6		12	4620	3	10	4931.2	0.2	3.5
4085.7		7	4340.9		13	4643	6	10	4941.0	0.5	3
4090.4		8	4343		14	4679	8	10	4956	2	2
4097.8		9	4348.7		14 = 10	4700	3	8	4978	1	1
4102.7		10	4358.0		12	4735	7	6	5003	4	1.5
4117.9		10	4368.9		10	4794	7	5	5025	2	2
4121.1		9	4382	5	9	4833.46		5 = 0	5042	3	1.5
4132	5	6	4396	1.4	9	4836.5		5	5042	3	1
4148		6	4423	3	10	4837.43		0	507-	6	0.5
4154.5	1.1	5	4427.8	0.6	9	4838.4		8	509-	10	0.2
4165	2	6	4442	2	9	4844.1		10	5133		0.3
4187	3	5.5	4459	3	10.5	4849.4		13	5154		0
4203.9	0.7	5	4473	3	11	4855.8		9	5175		0.2
4219	1.3	6	4492	3	10.5	4858.0		13	5188		0.5
4233	1.6	7	4502	6	10	4864.1		13 = 9	5207		0.1
4251	4		4512	4		4871.0		13 = 9	5265		0
									5295		0.1

5. *The three H-bands.*—On photo-plates Nos. 3 and 4 three well-defined Fraunhofer lines are a prominent feature, appearing respectively in the neighbourhood of the hydrogen lines H_β , H_γ , H_δ , and the difference between the wave-length of a Fraunhofer line and that of a corresponding H-line is proportional to the wave-length. Towards the less refrangible side of the Fraunhofer lines there are bright bands, which also occur on the other five photo-plates. If the wave-lengths of corresponding points of the three bands be compared with the wave-lengths of the three hydrogen lines, the differences are found also to be proportional to the wave-lengths. I conclude that the

TABLE I.—*continued.**Photo-Plate No. 4, 1901 March 25.*

Angle of inclination of plate = 13° ; width of slit 0.020 mm.; Imperial plate; exposure 4 hours; the plate is fogged and the spectrum is much fainter than on plate No. 3; the spectrum was measured 4 times and referred to 30 standard lines; the definition is not so good as on plates Nos. 1, 2, 3, 5.

λ	v	Intensity.	λ	v	Intensity.	λ	v	Intensity.	λ	v	Intensity.
4041.5	0.1	0.2	4318.7	0.2	0	4540	4	4	4851.8	0.9	8
4049	1.4		4320.0	0.6		4559.7	0.3		4858.0		
4056.4	0.2		4325	1.3	3.5	4589	1.3	5.5	4859.6		3
4065.0	0.5	1	4328.9	0.4	4.5	4613	2	3	4863.4	0.7	8
4072.6	0.7	2	4335.2		5.5	4617	1.1	3.5	4865.0	0.4	2
4081.1	0.4	3	4337.8		3	4626.6	0.8	6	4866.1		8
4083.4	1.1	0	4344.9	0.4	7	4648.4	0.7	8	4871.0		0
4092.5	1.0	4	4354.0		8	4660	2	7	4872.8		7.5
4100.8	0.9	5.5	4354.6		0	4669.1	0.6	5	4879.9	0.7	4
4109	1.6	6	4360.0	0.3	7	4682	4	6	4882		1
4115.6	1.0	5	4365.2	0.3	6	4691.0	0.5	8	4884		3
4119	2	4	4372	1.2	5	4701	3	7	4885.5	0.7	2
4122.0	1.0	3	4384	1.7	4	4722.0	0.8	6	4894	1	
4135	1.8	2	4398	5	3.5	4729	1.8	4	4905.7	0.6	1.5
4157	3	1	4428.7	0	2	4739.9	0.4	2.5	4912		0
4165	1.6	0	4434	1.3	2.5	4750	1.1	2	4929		1.2
4207	5	1	4454.6	1.0	3	4770	4	1.5	4947	1.1	1
4261	1.6	2	4459.3	0.7	4	4826.3	0.9	1	4968	1.5	0.3
4277	1.7	1	4480.5	0.4	5	4834.4	1.1	0.3	4986.2	0.2	0.1
4282.8	0.8	1.5	4493	4	6	4836.1		2	5006	6	0.3
4307	1.7	2.5	4503.9	0.8	5	4837.9	0.1	0	5020	4	0.5
4317.7	0.2	3	4527	3	4	4846.2	0.6	3	5045.8	0.8	0.4
4318.7	0.2	0	4540	4	4.5	4851.8	0.9	5			

bands are due to hydrogen radiations, which, under ordinary conditions, would produce the three hydrogen lines. Tables II., III., IV. prove the statement.

Let λ_0 be the wave-length of a hydrogen line, λ the observed wave-length of a point in the band, s the correction for the orbital motion of the earth, then

$$(1) \quad \lambda + s = \lambda_0 + \alpha_0 \frac{\lambda}{4500}$$

determines α_0 , belonging to a certain point of a band, and it must be shown that α_0 has the same value for corresponding points of all three bands. In Table II. the values of α_0 are compiled. The positions of the first, third, fourth and fifth minima agree as

TABLE I.—*continued.**Photo-Plate No. 5, 1901 March 25.*

Angle of inclination of plate = 13° ; width of slit 0.020 mm.; Imperial plate; exposure 3.2 hours; the plate is badly fogged; the spectrum was measured 5 times and referred to 35 standard lines; good definition.

λ	v	Intensity.	λ	v	Intensity.	λ	v	Intensity.	λ	v	Intensity.
4032.9	0.3	0.5	4235.0	0.8	5	4377	5	7	4825.5	0.7	6
4038.2	0.5	1	4248	1.1	4.5	4405.5	0.9	6	4839.9	0.2	8
4054.4	0.8	1.5	4279	3	4	4427.2	0.6	7	4846.0		0
4062.7	1.0	2.5	4298.4	0.4	5	4454	1.2	8	4848.8	0.5	11
4082	1.8	4	4313.8	0.5	6	4471.3	0.8	8.5	4855.8	0.8	11 max.
4089	1.2	6	4325.2 *		7	4477.3	0.8	9	4867.9	0.8	11 max.
4099.1	0.4	7	4326.9	0.5	3	4486.3	0.9	8	4874.5	0.8	9
4106	1.3	min.	4336.5	0.4	8.5	4507	2	7.5	4878	2	7
4113	1.3	8 min.	4337.3		6	4556	4	7	4887	1.4	4
4117.3	0.4		4343.5	1.0	9	4582	4	8	4898.9	1.0	2
4124.6	0.2	7	4345.9		7	4605.7	0.5	6	4910.1	1.0	0.5
4129	1.2	5	4353.3	0.3	10	4615.4	0.6	7	4932	1.7	2
4145	1.7	4.5	4358.4	0.5	9	4660	3	9	4941.6	0.7	1.5
4163.5	0.5	4	4362.0		8.5 = 4	4697.8	0.5	8	4950.6	0.9	0.5
4179	1.3	5	4364.5	0.6	8.5	4724.7	0.8	7	4963	2	1
4220.9	0.1	3.5	4366.5		4	4753.8	1.0	5.5	5037	1.6	0.5
4235.0	0.8	4	4377	5	8	4806	2	5	5090.7	1.0	0.2
					7	4825.5	0.7	4			
								3.5			
								3			

* One measurement.

closely as may be expected from the accuracy of the measurements. The sixth minimum appears as such only in two bands on photo-plates Nos. 5 and 6, but each being measured repeatedly and independently, there can be no doubt that it really exists; besides, the other five settings made at this point appear to me to suggest that it existed also at those places, though it was not appreciated. The second minimum is questionable, because both positions rest on only one measurement.

The estimated degrees of intensity at corresponding points of the same H-band do not agree on the seven plates. The observations are too few to determine the reductions to an average scale of the estimated degrees of intensity as a function of the degrees; but since the differences of the estimates made on two plates at corresponding places are almost the same for all degrees, I reduce the estimates to the scale employed on photo-plate No. 3 by adding to the degrees on plates Nos. 1, 2, 4, 5, 6 respectively 0, 4, 5, 2, 5. The result is given in Table III.

TABLE I.—*continued.**Photo-Plate No. 6, 1901 April 1 and 5.*

Angle of inclination of plate = 0° ; width of slit 0.020 mm.; orthochromatic plate; exposure 6 hours, 3.2 h. on April 1 and 2.8 h. on April 5; plate was intensified and the spectrum is faint; the spectrum was measured 4 times and referred to 30 standard lines; fair definition; focus same as on plate No. 1.

λ	v	Intensity.	λ	v	Intensity.	λ	v	Intensity.	λ	v	Intensity.
4087	?		4442	4		4731	1.6		4933	1.3	
4101	?	0.5	4462.2	0.7	3	476—	8	0.5	4943	3	0.5
4114	?	0.8	4483	1.3	3.5	4800	3	0.3	5037	6	0
4310.7	0.1	0	4498	3	3	4846.5	0.6	1 2	5063	3	1 ?
4328.4	0.8	3	4512	?	2.5	4853	1.8	5	5160	2	0
4337.5	1.6	=0 4	4563	?	*	4863.8	0.6	7	5177.0	0.1	0.2 ?
4344	1.8	5	4568	3	3	4865.1	0.6	0	5299	6	0
4350	1.6	7	4593	3	3.5	4870.7	0.1	8	5383	4	0.2
4355.9	0.5	6 =0	4614	2	3	4876.1	1.0	9 =0	5447	7	0.5
4358.8	0.9	4	4638	4	3.5	4878.9	0.9	5 4	5498	7	1
4370	2	2	4663.1	0.8	4	4882	2	3	5578	2	0.3
4385.1	0.2	0.2 1	4678.1	0.8	3.5	4895.4	0.7	1	5604	3	0
4402.4	0.5	0.5	4690.0	0.6	3	4911	4	0.2	5677.7	0.1	0.5
4430.5	0.4	2	4709.4	0.7	2.5	4925	1.7	0.5	5713	1.7	0.8
4442	4	2.5	4731	1.6	1	4933	1.3	0	5739	4	0.2

* Defect in film?

Photo-Plate No. 7, 1901 April 10 to May 3.

Angle of inclination of plate = 0° ; width of slit 0.020 mm.; orthochromatic plate; exposure, near horizon, 9 hours on 7 days; the plate is fogged; the spectrum was measured twice and is very faint; bad definition.

λ	Intensity.	λ	Intensity.	λ	Intensity.	λ	Intensity.	λ	Intensity.
4325		4455		4614		4845		5005	
4360	3	4504	1	4718	3	4882	3	5021	1
		4536	3						

In Table IV. I have combined the results obtained from three plates to mean values, in order to exhibit the agreement in position of corresponding points of the three H-bands as reduced to $\lambda = 4500$, and also to show in what manner the observed degrees differ. Towards the less refrangible end H_γ declines in intensity 4 degrees on 25 tenths-metres and passes into a bright spectrum, while H_β decreases 8 degrees and fades into

TABLE III.

Table giving the Reduced Degrees of Intensity at Corresponding Points of the H-bands.

	No. of Point.	H δ .						H γ .						H β .							
		Index Number of Plate.						Index Number of Plate.						Index Number of Plate.							
		1	2	3	4	5	6	1	2	3	4	5	6	7	1	2	3	4	5	6	7
1. Minimum	1	4	...	3.5	6	3.5		5	?	7	7.5	6	?		5	?	5	?	5	6	
	2	4	...	4	7	4.5		5	5	7	7.5	7	?		5	?	5	?	5		
	3	4	...	4	8	4.5		4	5	7	8	8	?		5	?	5	7	8		
	4	2	...	0	0	6		4	?	0	0		?		4	?	0	0	8		
	5	2	...	6	9			3	?	9	8.5		?		3	6	8	8	10		
	6	5	...	7	9	8	5	6	?	9	8.5	9	?		3	6	8	8	10	7	
	7	...	...	...	...			...	...	...	...	5			...	...	...	...	2	...	
	8	5	...	7	9	8	5	8	7	11	9.5	10.5	8		9	11	10	10	13	10	
	9	10	6	8	10.5	9	5	12	12	11	10.5	10.5	9		14	14	13	13	13	12	
	10	...	...	...	...			...	10	...	8	8	<5		...	...	9	8	...		
	11	9	6	9	10.5	10	6	11	12	12	12	11	10		12	14	13	13	13	12	
	12	...	...	...	...	min.	...	...	...	...	...	9	...		...	...	9	7	...	<5	
	13	9	6	10	11	10	6	11	12	14	13	12	12		12	12	13	13	13	13	
	14	...	...	...	...			...	...	10	...	...	<5		8	...	9	5	...	<5	
	15	9	6	10	10	10	6	11	13	14	13	12	11		14	14	13	13	13	14	
	16	...	...	...	...	min.		...	...	...	5	...	...		...	...	9	...	...	...	
	17	9	6	10	9	10		11	13	14	12	11	11		14	14	13	13	11	10	
	18	9	...	10	8	9		11	10	12	12	10.5	9		14	11	11	9	9	9	
	19	7	...	9	7	9		10	8	...	11	10.5	7		8	6	9	7	6	6	
	20	6	...	6	7	7		9	7	10	10	10	6		8	5	7	6.5	4	6	
	21	6	...	6	7	6.5		9	...	10	9	...	5		2.5	...	6	6	2.5	5	
		6	...	6	7	6.5		9	6	9	9	9	5		2.5	...	6	6	2.5	5	

a faint band. The difference cannot be due to a change in sensitiveness of the photographic film, as its effect is inappreciable within the extent of a band. On the other hand, it will be proved from the later plates that these bands must be similar also in intensity, and therefore other radiations must be superposed on the hydrogen radiations at the ends of the bands.

TABLE IV.

Mean of the Results from three Plates, Nos. 3, 4, and 5, showing the Similarity of Structure of the three H-bands and the more rapid Falling-off in Intensity of the H β -band.						
No. of Point, Tables II., III.	H δ		H γ		H β	
	a_0	Inty.	a_0	Inty.	a_0	Inty.
1	-43	4	-44	7		5
2	-32	5	-32	7	-33	5
3	-23	5	-24	8	-24	7
4*	-21	0	-22	0	-21	0
5	-18	7		9		9
6		8	-16	9	-16	9
7	-14	8	-14	5	-14	2
8	-12		-12	10	-11	11
9		9	-6	11	-5	13
10	-4	10	-4	8	-3	9
11			+2	12	+1	13
12	+1	min.	+4	9	+3	8
13		10		13	+8	13
14	+7		+8	=10	+10	7
15		10	+13	13		13
16	+13	min.	+14	5	+12	=9
17	+17	10	+18	12		12
18	+21	9	+20	11.5	+16	10
19	+25	8	+25	11	+21	9
20	+31	7	+30	10	+26	8
		6		9.5	+33	7
		6		9.5		6
21	+36	6	+38	9		5
		6				5

TABLE V.

Mean Structure of Bands.			Number of Bands showing Minimum.	Index Nos. of Plates.
No.	a_0	Inty.		
1	-73	0	5	3,4
2	-55	5		
3	-43	6		
4	-31.5	7		
5	-23.9	0		
6*	-21.8	8	6	
7	-17.5	9	2	5
8	-16.6	3		
9	-14.4	11		
10	-12.0	13		
11	-5.8	7		
12	-3.8	13	7	2,3,4,5,6
13	+1.2	7	5	3,4,5,6
14	+3.2	12.5	6	1,3,4,6
15	+6.8	7		
16	+9.5	12.5		
17	+12.4	7		
18	+13.0	11.5		
19	+16.8	10	3	3,4,5
20	+20.1	8		
21	+25.1	7		
22	+31.7	5.5		
23	+34	3.5		
24	+36.4	2.5	1	
25	+40.5	0.5		
26	+56			

* The Fraunhofer lines occur only on Plates Nos. 3 and 4, March 18 to 20 and March 25.

6. *The Continuous Spectrum.*—The question whether the continuous spectrum has a share in these radiations is settled by photo-plate No. 1, which was orthochromatic. There are five minima recorded between wave-length 496 and 538, whose intensities range between 0 and 0·3 degrees. I obtain the reduction for relative sensitiveness for different wave-lengths from a series of exposures on the sky spectrum. On the supposition that the intensity curves of the spectrum of the sky and of the star are identical, the intensity of the continuous spectrum of the star does not reach 1 degree within the area photographed, and probably is less, considering the observed colour of the star. Not to complicate the problem unnecessarily, I have disregarded the continuous spectrum, and it will be seen from what follows that the only effect this omission can have on the result is to increase slightly the calculated degrees of intensity of the bands.

7. *Mean Structure of the Bands.*—The continuous spectrum being very faint, the difference under discussion must be caused by superposed bands. From the plates taken after August I shall prove that not only the H-bands, but all the bands, are similar. I assume that the same holds good for the earlier plates, and that therefore the superposed bands are similar to the H-bands. The unknown structure of the bands thus enters not only the H-bands, but also the bands overlapping their ends, and that structure must be so determined as to give the observed degree of intensity. In the solution of this problem two other questions are involved: First, in what way does the intensity curve of the band vary if the intensity of its maximum alters? Secondly, what is the resultant intensity on my degree scale if two radiations which singly produce certain degrees of intensity on the photograph be superposed?

The two bands, $\lambda = 4902$ to 4959 and $\lambda = 4981$ to 5046 , agree in extent and in position of their maxima with the bands calculated from the bands of Table IV. by formula (1), and the wave-lengths of their zero, λ_0 , are found respectively to be 4922 and 5016 . I compared the observed degrees of the H_β -band, which in first approximation served as standard, with those at corresponding points of the faint bands $\lambda_0 = 4922$ and 5016 , discarding the points where the bands overlap, and deduced by interpolation the relations given in Table VI. For instance, a band which has at different points the

TABLE VI.—*Corresponding Degrees of Intensity.*

13	11	9	7	5	3	1
11	9·3	7·5	5·8	4·1	2·3	0·6
9	7·5	6·1	4·6	3·1	1·7	0·2
7	5·8	4·6	3·4	2·2	1·0	
5	4·1	3·1	2·2	1·3	0·4	
3	2·3	1·7	1·0	0·4		
1	0·6	0·2				

degrees of intensity 13, 11, 9, 7, etc., has at corresponding points the degrees, say, 5, 4.1, 3.1, 2.2, etc. (Also see § 9.)

The bands contained on the first seven photographs here under discussion give no evidence as to the second question. On the later plates there are two bands which can with certainty be identified as consisting each of two bands, while the structure of the standard band is independently determined from detached bands. From Table XII., where the later observations are compiled along with the calculated bands, it will be seen that the sum of the calculated degrees of intensity due to radiations of the same wave-length nearly agrees with the observed intensity. I adopt this additive rule here as a working hypothesis, the accuracy of which will be investigated in § 9.

I deduce the common structure of the bands by successive approximation. Choosing first the H_β -band of Table IV., I calculate the band for $\lambda_0 = 4922$, and employing Table VI., reduce the degrees of intensity so that the degree of intensity of the maximum of this band agrees with the observed intensity of the maximum. I then subtract the calculated degrees from their observed values, and find the degrees of intensity at the different points of the H_β -band freed at its less refrangible end from the superposed band 4922. From the corrected H_β -band I calculate the band for $\lambda_0 = 4265$, which a preliminary discussion had shown to overlap the more refrangible end of the H_γ -band, and proceeding as before, I obtain the intensities at different points of the more refrangible end of the H_γ -band. In second approximation I combine these results, and repeating the calculation, find the mean structure as contained in Table V., the values a_n being the means, with regard to weights, of the measurements given in Table II.

8. *Resolving of the Spectrum into Bands.*—I set myself the problem to find the wave-lengths λ_n of the zero of each band, and the degree of intensity of its maximum, which I shall call the intensity of the band, so that the superposed bands represent the observed intensity curve. I found this research on the following basis:—1. The continuous spectrum is faint and may be neglected. 2. The bands are similar to the band given in Table V., and determined by formula (1), λ_0 being unknown. 3. The intensity curve of each band is defined by the unknown maximum intensity and the data contained in Tables V. and VI. 4. At places where bands are superposed, the resultant degree of intensity is the sum of the degrees of intensity which the radiations would singly produce on the photographic plate.

The last assumption is merely a convenient rule, which, though not strictly correct, is sufficient for our purpose, as will be proved in § 9. I may mention here the considerations which induced me to undertake a research which at first sight appears to be hopeless. I suppose that two bands have been identified in the spectrum, and draw their intensity curves as calculated from Tables V. and VI., together with the observed intensity curve of the spectrum. The length, in the direction of the axis of wave-lengths, of the area bordered by the three curves is independent of the manner in which the ordinates of the two bands are deducted from those of the observed intensity curve.

If this length agrees with the extent of one band, which is almost constant for the brighter bands, the position of a band can be adjusted in this area, *i.e.* the wave-length, λ_0 , of the zero of the band can be found. Fainter bands are shorter in length, and two or more fainter bands may be combined so that their total extent is that of a bright band. On the understanding that a band selected in the manner described may be replaced by two or more fainter bands whose values of λ_0 differ little, the wave-length of the zero of the band is independent of the rule according to which the degrees of intensity are combined, and depends only on the wave-lengths λ_0 of the zeros of the two adjoining bands. The error of the rule will appear only in the residuals. To a lesser degree, this holds also good for a space belonging to two or more bands, and the greater the space to be covered, the more important it will be that the intensities be correctly compounded. For this reason I have divided the spectrum between H_β and H_γ into four parts, introducing three bands, whose maxima I make to coincide with pronounced maxima of the observed intensity curve. The intermediate spaces were explained by as few bands as possible, with the intention that each could afterwards be replaced by two or more fainter bands, should this improve the agreement of the spectrum with one which otherwise resembled it.

A. For the discussion of the spectrum between H_β and H_γ I employ the intensity curves of photo-plates Nos. 3 and 4. As before, I add 5 to the degrees of intensity of No. 4 to refer them to the same scale as was chosen for No. 3. The spectrum on No. 4 differs somewhat from those on the other plates, of which No. 3 is the best representative.

On plate No. 4 there are four prominent maxima between H_β and H_γ , viz., 4459 to 4480, intensity 6; 4560 to 4589, intensity 5.5; 4627 to 4648, intensity 8; 4682 to 4691, intensity 8; all of them fading off several degrees towards both sides. I assume that they are due to bands whose λ_0 is respectively 4470, 4574, 4637, 4687, and I calculate the intensity curves of these bands from the data given in Tables V. and VI. The calculated degrees of intensity were written out at intervals of two tenth-metres, and subtracted arithmetically from the observed intensities. To explain the residuals, I chose, in accordance with the above, as few bands as possible, and introduced further the condition that the same bands be selected for both photo-plates. Between 4341 and 4470 at least three bands were required for plate 3 and two for plate 4; between 4470 and 4574 three for plate 3 and two for plate 4; between 4574 and 4637 one each for plates 3 and 4; between 4637 and 4687 one for plate 3 and none for plate 4; between 4687 and 4861 two bands for both plates. By a lengthy process of trials in which the wave-lengths and the intensities of the bands were altered, including those of the above bands, I found the wave-lengths λ_0 of the zeros of the bands and the degrees of the intensity of their maxima, as given in Table VII. under the heading A. The three intensity curves calculated from these data at intervals of two tenth-metres are represented on Plates I. and II. under A, together with the observed curves, which are dotted. The straight lines drawn at the top of the plates show the extent of each band and the number of superpositions at each point.

Table VII. further contains the hydrogen spectrum observed by WILSING and the spectrum of Nova Aurigæ by VOGEL, both copied from the table in WILSING's memoir *Untersuchungen ueber das Spectrum der Nova Aurigæ*. I ought to mention here that during the progress of my work I did not consult any previous researches or observations on new stars, and that I arrived at the result A without bias. Between 4067 and 4341 the wave-length λ_0 of the zeros of the bands agree well with the wave-lengths measured in the spectrum of Nova Aurigæ, and the two lines 4922 and 5016 are also present in both. On the other hand, there are marked differences between H_β and H_γ , the region which, owing to the large interval between two identifiable bands, presented the greatest difficulty to division into bands. The same remarks apply to the hydrogen spectrum. It is of no moment that some of the lines, as 4388, 4472, etc., are found intensely bright, because, in accordance with the above, each might be split into two or more fainter lines. The fact that the hydrogen line 4581 is the only bright line of intensity above 6 which is not represented in the spectrum of Nova Persei, while it occurs in the spectrum of Nova Aurigæ, appears to suggest that the observed maximum 4560 to 4589 is not due to the band $\lambda_0 = 4570$, which is one of those used in subdividing the spectrum.

B. I therefore repeated the work between H_β and H_γ , and subdivided the spectrum, as before, but chose 4581 instead of 4570; 4634 instead of 4637; and 4684 instead of 4687. I further introduced the condition that as few lines as possible should be chosen, and that where the wave-length of the zero of a band fell near that of a hydrogen line, the wave-length of the H-line should be taken. The introduction of the line 4581 instead of 4570 as zero of a band changed the position of all the bands as far as the H_γ -band; 4570 being the mean of 4559 and 4581, the two bands belonging to them share almost equally in producing the maximum formerly ascribed to 4570. Each band entails the introduction of a series of bands fitting into one another, and there are thus 14 bands required to represent the intensity curve compared with 7 bands before. In other regions I altered some of the wave-lengths slightly to make them agree with those of hydrogen. The band $\lambda_0 = 4768$, which does not occur in the hydrogen spectrum, is perhaps due to a series of faint lines. The result of this new analysis is given in Table VII., B, and the intensity curve calculated at intervals of 2 tenth-metres is drawn on Plates I. and II. under B. It is remarkable that the lines of the hydrogen spectrum, which I have been forced to take from WILSING's table as being within 3 t.m. of the zeros of bands actually obtained, include all the hydrogen lines whose intensities exceed 2 between 4341 and 4861, though no heed was taken of their intensity. The spectrum as defined by λ_0 agrees well with that of Nova Aurigæ. In the same table I have further entered all the lines of helium except those of the two second subordinate series. All of them have corresponding lines in the Nova spectrum.

On the assumption of the additive rule, the brightest lines of the hydrogen and helium spectrum represent the intensity curve, each line being broadened according to Table V. and formula 1; and I consider the conjecture that hydrogen actually pro-

duced the spectrum not only possible, but probable, for these reasons:—(1) Towards the more refrangible side of H_γ , lines coinciding within admissible limits with prominent H-lines, were found without any bias, and they belong to that region of the spectrum which from the outset offered the least difficulty to the splitting up of the intensity curve into bands. (2) The intensity curve of the band belonging to 4637 or 4634, also detected without bias, follows the intensity curve of the March 25 plate in that part of the spectrum without requiring the introduction of another bright band, and this line is, together with H_β , H_γ , H_δ , the most prominent line of the hydrogen spectrum. (3) If, instead of the line 4570 found under A, which does not occur in the hydrogen spectrum, the prominent H-line 4581 is introduced, the lines then required to represent the intensity curve agree in position more closely than before with those of Nova Aurigæ, *i.e.* a star whose spectrum is, as I shall show, identical with that of Nova Persei after August. (4) The lines of the hydrogen spectrum, which I have been forced to take from WILSING'S table as being within 3 t.m. of the zeros of bands actually obtained, include all the hydrogen lines whose intensities exceed 2 between 4341 and 4861, though no heed was taken of their intensities.

9. *Proof that the Error of the Additive Rule does not affect the Result of § 8.*—The results just derived rest on the assumption that the radiations of intensity $i_1 \dots i_n$ which individually give on the photo-plate a blackness of degree $m_1 \dots m_n$ for the same exposure t produce if acting together during the same time t a blackness equal to Σm . It is, however, well known that this cannot be correct for all degrees of blackness. With the view of determining the error introduced by the use of the additive rule, I exposed several plates on a continuous spectrum, each plate containing five spectra, the exposures of which were proportional to 1, 2, 4, 8, 16. I estimated the degrees of blackness of the spectra in the same way as done on the star photographs. Any two degrees of blackness could then be superposed, and compared with those estimated for another exposure. I find that for the degrees of blackness occurring on the star photographs, the blackness of the film is about proportional to the time of exposure for a constant intensity of radiation, and that the degrees of my scale are about proportional to the blackness. Since this relation cannot hold good for the highest degrees of blackness, I take it to be only approximately true for the lowest degrees, and put

$$(2) \quad \frac{t_1}{t_2} = \frac{f(m_1)}{f(m_2)} \text{ for a radiation of constant intensity } i,$$

and choose

$$(3) \quad f(m) = 10^{am} - 1,$$

where m is the degree of blackness, t the time, and a a constant.

SCHEINER'S *Die Photographie der Gestirne* contains on p. 246 a table, the results of experiments by MICHALKE, which gives the times of exposure for intensities of radiation varying from 1 to 36, to produce the same degree of blackness on the photographic film. I find this table is sufficiently well represented by

$$(4) \quad t^b = \text{constant} \quad b = 1.08, \text{ for a constant blackness } m.$$

TABLE VII.—*Spectrum of Nova Persei in March and April 1901.*

Nova Persei.								Hydrogen * (Wilsing).			Helium.			Nova Aurigæ * (Vogel).	
A. Intensity.			B. Intensity.												
λ_0 .	March 3.	March 18 and 20.	March 25.	λ_0 .	March 3.	March 18 and 20.	March 25.	λ .	I.		λ .	I.	Series.	λ .	I.
4026	5	1	5	4026	5	1	5	4027	4	3	4026	5	II, 1		
								4044	3	0					
								4055	3	2					
								4063	6	6					
4067	...	..	2.5	4067	...	...	2.5	4067	5	5				4067	b 3
								4070	5	5					
								4088	3	1					
								4097	2	1					
4102	9	10	10	4102	9	10	10	4101	5	1				4102	b 3
4122	2	2	2	4132	3	3	3	4132	4	2				4125	2
4145	2	2	2	4145	...	1	1	4145	3	1	4144	2	II, 1		
				4160	1.5	1.5	1.5	4157	5	2				4158	2
								4163	5	2					
								4171	4	3					
4174	6	6	6	4177	5.5	4.5	4.5	4177	8	8				4176	vb 3
								4182	3	0					
								4189	2	1					
								4196	3	3					
								4205	6	4					
4210	2	2	3	4208	1.5	1.5	1.5	4213	7	5					
								4222	4	3					
4234	4.5	4.5	4.5	4233	4.5	5	5	4233	3	1				4230	b 3
								4243	1	1					
								4253	2	1					
4265	3.5	4.5	4.5	4265	3.5	4.5	4.5	4265	1	0				4262	vb 3
								4293	1	0				4288	b 3
4304	1	3	3	4305	1	3	3	4305	3	3				4315	b 3
								4312	2	0					
								4330	2	0					
4341	9	10.5	10.5	4341	9	10.5	10.5	4341	13	3				4341	b 4
				4364	2	3	2								
				4377	1	...	2	4377	0	1				4383	3
								4382	2	0					
4388	8.5	8.5	8.5	4388	5.5	4.5	4	4389	2	1	4388	3	II, 1		
								4402	2	1					
4410	...	2	...	4410	4	5	3	4410	4	3					
								4413	2	0					
								4419	2	0				4417	b 3
4436	5	5	3.5	4425	1	2.5	2	4425	4	4				4435	b 3
				4448	3.5	3	3	4448	2	4				4445	2
				4459	...	3	3.5	4459	3	4					
4472	4	8.5	9	4472	3	4	3				4472	6	I, 1	4473	b 2

I. = intensity.

I = helium, II = parhelium, p = principal series, 1 = first subordinate series.

In the last column b = broad, 3 = bright, 4 = very bright.

* Copied from *Publicationen des Astrophysikalischen Observatoriums zu Potsdam*, xii. p. 96.

TABLE VII.—*continued.*

Nova Persei.								Hydrogen (Wilsing).		Helium.			Nova Aurigæ (Vogel).	
A. Intensity.				B. Intensity.										
λ_0 .	March 3.	March 18 and 20.	March 25.	λ_0 .	March 3.	March 18 and 20.	March 25.	λ .	I.	λ .	I.	Series.	λ .	I.
4502	5	3	...	4488	3	3	4	4482	1	1			4480	
				4500	3	4	1	4488	2	4			4495	b 3
								4498	2	0			4507	2
4520	5	6	6	4522	2.5	3	5	4501	2	4			4520	
				4535	4	3	2	4521	2	2			4530	b 3
								4523	1	3				
4558	4	2.5	2	4559	6	5	4	4535	2	2				
4570	7	8	8	4581	3	5.5	5	4551	2	2			4557	b 2
				4608	2	4	1	4555	2	2			4583	b 3
4612	3.5	5	3	4634	5	6	9	4581	6	10				
4637	3.5	3.5	8	4662	2.5	2.5	...	4597	2	1			4628	b 3
4660	3	6	...	4672	...	3	...	4608	2	1				
4687	5	5.5	10	4684	5	6	10	4619	2	1				
								4634	9	15				
4725	4.5	4.5	5	4724	4	4	6	4662	1	2				
4768	5.5	5.5	5.5	4768	5.5	5.5	5.5	4672	1	3				
								4684	3	3				
4861	13	13	13	4861	13	13	13	4710	2	2			4862	b 3
4922	4	4	4	4922	4	4	4	4719	2	2			4924	2
								4724	2	3				
5016	3.5	0.5	2	5016	3	0.5	2	4797	0	1	4922	4	II, 1	
5132	1			5132	1			4862	7	2				
5178	2			5178	2			4932	0	2				
5200	2			5200	2			4973						
								5014			5016	6	II, p	5016
5327	2			5327	3			5055						
5456	3			5405	2			5388						
				5451	3									
5500	2.5			5495	2.5			5481						
5544	4			5537	4			5499						
5589	3			5584	3			5505						
5635	2.5			5640	3			5537						
5680	2			5689	2			5689						

The hydrogen lines 4973 to 5689 were measured by Hasselberg.

On p. 247 Prof. SCHEINER further gives the results of his experiments on artificial stars produced by means of a Zoellner photometer. He finds that if the time of exposure be increased 2.5 times, the faintest stars recorded on the plate are only 0.7 mg. fainter than before, therefore $b = 1.4$.

Let a radiation of intensity i produce a degree of blackness m , and a radiation of intensity i' a blackness m' , both in time t . Let t' be the time required for i to produce m' , then by (2) and (4)

$$t i^b = t' i'^b \quad \text{and} \quad \frac{t}{t'} = \frac{f(m)}{f(m')}, \quad \text{therefore}$$

$$(5) \quad \frac{f(m)}{f(m')} = \left(\frac{i}{i'}\right)^b \quad \text{for the same exposure on radiations of intensities } i \text{ and } i'.$$

I assume that the broadening of the lines into bands is due to the same physical cause, and that the ratio of the intensities of the radiations at any two corresponding points of two bands is a constant for these two bands; therefore by (5)

$$(6) \quad \frac{f m}{f(m')} = \frac{f \mu}{f(\mu')} = \text{constant}, \quad \text{and} \quad \frac{f(m)}{f(\mu)} = \frac{f(m')}{f(\mu')} = \text{constant},$$

where μ and m are the degrees of blackness at two points of a band, and μ' and m' those at corresponding points of a second band. By means of (6) I determine the constant α in $f(m)$ from the observed corresponding degrees of blackness contained in Table VI. The result is $\alpha = 0.04$, with which I have calculated the following table.

TABLE VIII.

Calculated corresponding degrees of blackness for $\alpha = 0.04$.

μ	13	11	9	7	5	3	1
m	11	9.2	7.4	5.7	4.0	2.3	0.7
	9	7.4	5.9	4.5	3.1	1.8	0.5
	7	5.7	4.5	3.4	2.2	1.2	0.4
	5	4.0	3.1	2.2	1.5	0.8	0.2
	3	2.3	1.8	1.2	0.8	0.4	0.1
	1	0.7	0.5	0.4	0.2	0.1	

For instance, if the maximum of a band of degree 13 is reduced to degree 5 in another band, blacknesses 7 and 5 at other points of the band become respectively 2.2 and 1.5, while Table VI. gives 2.2 and 1.3. The quantities in this table differ from those in Table VI. for all degrees of blackness greater than 0.8 by less than 0.2 degrees, and the average error is 0.1, but the differences increase to 0.4 for the degrees lower than 0.8. The function (3) therefore represents the observations satisfactorily. For $\alpha = 0.03$ and 0.05 the residuals are respectively 30 and 50 per cent. higher than for $\alpha = 0.04$, and for

$\alpha = 0.07$ they increase to $2\frac{1}{2}$ times the amount for $\alpha = 0.04$. For double the exposure the degrees of blackness 1, 3, 5 and 10 become respectively 1.9, 5.3, 8.4 and 15.

Let the intensities of radiation $i_1 \dots i_n$ give respectively the blacknesses of degree $m_1 \dots m_n$ when exposed time t . The question is, what is the degree m_0 if a radiation of intensity Σi be exposed the same time t ? Formula (5) gives

$$(7) \quad \begin{aligned} i_n F(m_0) &= F(m_n) \Sigma i & \text{where} \quad F(m) &= (f(m))^{\frac{1}{b}}, & \text{therefore} \\ F(m_0) &= \Sigma F(m_n). \end{aligned}$$

An extract of the F-Table is given below.

TABLE IX.

$m.$	$F(m).$		$m.$	$F(m).$	
	$b = 1.08.$	$b = 1.4.$		$b = 1.08.$	$b = 1.4.$
0	0.00	0.00	8	1.08	1.06
1	0.11	0.19	9	1.27	1.20
2	0.23	0.32	10	1.47	1.34
3	0.35	0.44	11	1.68	1.49
4	0.47	0.56	12	1.92	1.65
5	0.61	0.68	13	2.17	1.82
6	0.75	0.81	14	2.45	2.00
7	0.91	0.93			

For instance, radiations which would singly give the degrees 1, 2, 3, 4 produce when superposed $m_0 = 8.4$ for $b = 1.08$ (by Table IX., $F(m_0) = 0.11 + 0.23 + 0.35 + 0.47 = 1.16$) and 11.1 for $b = 1.4$, as compared with $\Sigma m = 10$.

The difference $m_0 - \Sigma m$ depends on Σm and the number of radiations which are superposed. It varies most for the intensity curve which shows the greatest range between maxima and minima, and which has a different number of superposed bands at different places. On this account the calculated intensity curve, Σm , belonging to photoplate No. 4, which on hypothesis B has from 3 to 6 superposed radiations in the region between H_β and H_γ is the most likely to differ from an intensity curve m_0 calculated by formula (7). I assume the same bands, and in first approximation the same degrees m which contribute to the Σm -curve of Plate I., but I compound them according to formula (7). The resulting m_0 -curve is then brought to agreement with the observed intensity curve by suitable changes of the intensities of the bands, and the question is whether this curve satisfies the observed curve as well as the Σm -curve does. Table X. contains the calculation in detail at an interval of 10 t.m., while it was made for every 5 t.m. The first columns show, under the heading m , the degrees of blackness at each point which the radiations would singly produce on the film. Σm is the ordinate of the calculated intensity curve on Plate I., which was made to agree as near as possible with the observed intensity curve (see § 8); m_0 is the resultant if the degrees m be compounded

according to formula (7). $m_0 - \Sigma m$ ranges between -0.6 and -2.2 for $b = 1.08$, and between $+0.4$ and $+2.4$ for $b = 1.4$.

Let $\delta m_1 \dots \delta m_n$ be the corrections of the degrees $m_1 \dots m_n$ which change the degree of blackness m_0 by δm_0 therefore,

$$(8) \quad \Sigma \frac{dF(m_n)}{dm_n} \delta m_n = \frac{dF(m_0)}{dm_0} \delta m_0.$$

A change δm_1 at wave-length λ of band 1 can be brought about only by all the degrees of blackness being changed at every place of this band. I express δm_1 by the change $\delta \mu_1$ of the degree of blackness μ_1 of the maximum of band 1; μ_1 being the quantity which was shortly called the intensity of the band, and I do the same for all the indices 1 to n . Employing (6) I replace in (8) δm_n by $\delta \mu_n$ and eliminate function f by F .

$$(9) \quad \Sigma F(m_n) \frac{d \log F(\mu_n)}{d\mu_n} \delta \mu_n = \frac{dF(m_0)}{dm_0} \delta m_0.$$

To reduce the work of calculating, I change the degrees of the maximum of every band by an amount $\delta \mu_n$ determined by

$$(10) \quad x = \frac{d \log F(\mu_n)}{d\mu_n} \delta \mu_n,$$

and obtain from (9) and (7)

$$(11) \quad x = \frac{d \log F(m_0)}{dm_0} \delta m_0$$

$$(m_0) = m_0 + \delta m_0.$$

I determine x by (11) with $\delta m_0 = \Sigma m - m_0$, and calculate δm_0 at each point from the mean value of x . For $b = 1.4$, μ of band $\lambda_0 = 4425$ was reduced by 1 in addition to $\delta \mu$, and the intensities of the last four bands were not changed at all. $(m_0) = m_0 + \delta m_0$ which appears in Table X. is then the calculated intensity curve if the degrees of blackness of the maxima of the bands given in Table VII. be changed by certain amounts to be calculated from (10), and the degrees at each point be compounded according to (7). The last three columns give the residuals left in the observed intensity curve. Σm differs from the observed intensity curve on an average 0.58 degree, (m_0) differs 0.57 for $b = 1.08$, and 0.63 for $b = 1.4$, while (m_0) differs on an average 0.26 from Σm . The observed intensity curve is therefore equally well represented by Σm and by (m_0) , and therefore the hydrogen lines of Table VII. represent the spectrum, no matter whether the degrees of intensity of their bands be compounded by mere addition, or according to formula (7). Combinations of bands which, if compounded according to the additive rule, leave inadmissible residuals in the observed intensity curve, must give errors of the same order if formula (7) be employed; and I conclude that if this formula had been used at the outset in analysing the spectrum into bands, the result would have been identical with that contained in Table VII.

A similar calculation for the intensity curve of photo-plate No. 3, assumption A, gave an average error, observed $m - \Sigma m = 0.63$, observed $m - (m_0) = 0.59$ for $b = 1.08$, and 0.58 for $b = 1.4$, while (m_0) differs on an average 0.25 from Σm for both values of b . This agreement proves again that the use of the additive rule cannot have influenced the analysing of the spectrum into bands.

TABLE X.

*Calculated Intensity Curves, Σm and (m_0) , for Photographic Plate
No. 4.*

λ	$O =$ Observed Intensity + 5.	Intensity Curves of the different Superposed Bands.							$\Sigma m.$	(m_0) by Formulae (7) and (11).						Residuals.		
		$m_1.$	$m_2.$	$m_3.$	$m_4.$	$m_5.$	$m_6.$	$b=1.08.$			$b=1.4.$			$O - \Sigma m.$	$O - (m_0).$			
								$m_0.$		$\Sigma m - m_0.$	$(m_0).$	$m_0.$	$\Sigma m - m_0.$		$(m_0).$	$b=1.08.$	$b=1.4.$	
4360	12	6.5	2.0	0.7	1.6	0.4		11.2	9.4	+1.8	10.8	12.2	-1.0	10.7	+0.8	+1.2	+1.3	
70	9.5	4.2	1.9	2.1	2.0	0.6		10.8	8.9	+1.9	10.2	12.2	-1.4	10.7	-1.3	-0.7	-1.2	
80	9		1.2	1.9	4.0	1.0		8.1	7.2	+0.9	8.3	9.6	-1.5	8.3	+0.9	+0.7	+0.7	
90	8.2	0.2		1.6	3.8	1.4		7.0	6.4	+0.6	7.4	8.4	-1.4	7.2	+1.2	+0.8	-1.0	
4400	7	0.4	0.4	0.5	3.8	3.0		8.1	7.2	+0.9	8.3	9.6	-1.5	8.0	-1.1	-1.3	-1.0	
10	7	0.6	0.9		1.9	3.0	0.6	7.0	6.2	+0.8	7.2	8.8	-1.8	7.0	0.0	-0.2	0.0	
20	7	1.0	2.0	0.4		2.8	0.8	7.0	6.3	+0.7	7.3	9.0	-2.0	6.7	0.0	-0.3	+0.3	
30	7.5	1.4	1.9	0.5	0.4	1.5	1.3	7.0	6.2	+0.8	7.2	9.4	-2.4	7.1	+0.5	+0.3	+0.4	
40	8	3.0	1.6	0.6	0.8	0.5	1.7	8.2	7.0	+1.2	8.1	10.4	-2.2	8.2	-0.2	-0.1	-0.2	
50	8	3.0	0.4	1.1	1.2		3.5	9.2	7.8	+1.4	9.0	10.8	-1.6	9.1	-1.2	-1.0	-1.1	
60	10	2.8		1.6	2.3	0.4	3.5	10.6	8.7	+1.9	10.0	12.0	-1.4	10.5	-0.6	0.0	-0.5	
70	11	1.1		2.2	3.0	1.3	3.3	10.9	8.9	+2.0	10.2	12.2	-1.3	10.7	+0.1	+0.8	+0.3	
80	10		0.1	4.0	2.8	1.7	1.5	10.1	8.4	+1.7	9.7	11.4	-1.3	9.9	-0.1	+0.3	+0.1	
90	10		1.0	3.8	1.5	2.2		8.5	7.4	+1.1	8.6	10.0	-1.5	8.6	+1.5	+1.4	+1.4	
4500	8	0.6	1.0	3.6	0.5	2.7	0.1	8.5	7.3	+1.2	8.3	10.4	-1.9	9.0	-0.5	-0.3	-1.0	
10	9	0.8	0.9	2.1		4.1	0.4	8.3	7.2	+1.1	8.3	10.0	-1.7	8.6	+0.7	+0.7	+0.4	
20	9	1.1	0.2	1.0	0.4	5.0	0.9	8.6	7.6	+1.0	8.8	10.4	-1.8	9.0	+0.4	+0.2	0.0	
30	9.5	1.6			1.3	4.8	2.0	9.7	8.4	+1.3	9.7	11.0	-1.3	9.6	-0.2	-0.2	-0.1	
40	9.5	2.1			1.7	3.8	1.9	9.5	8.0	+1.5	9.2	10.8	-1.3	9.4	0.0	+0.3	+0.1	
50	8.5	4.0			2.2	1.5	1.6	9.3	7.9	+1.4	9.1	10.6	-1.3	9.2	-0.8	-0.6	-0.7	
60	8	4.0			2.7		0.4	7.1	6.5	+0.6	7.5	8.1	-1.0	6.9	+0.9	+0.5	+1.1	
70	10.5	3.8	1.9		5.0			10.7	9.0	+1.7	10.3	11.2	-0.5	10.0	-0.2	+0.2	+0.5	
80	10.5	2.1	3.2		5.0			10.3	8.8	+1.5	10.1	11.0	-0.7	10.0	+0.2	+0.4	+0.5	
90	8	1.0	3.9	0.2	4.8			9.9	8.5	+1.4	9.8	10.8	-0.9	10.3	-1.9	-1.8	-2.3	
4600	8		3.9	1.0	2.7			7.6	6.8	+0.8	7.9	8.6	-1.0	8.1	+0.4	+0.1	-0.1	
10	8	0.4	5.3	0.9	1.5			8.1	7.2	+0.9	8.3	9.4	-1.3	9.1	-0.1	-0.3	-1.1	
20	11	2.4	7.5	0.8				10.7	9.5	+1.2	10.8	11.2	-0.5	11.2	+0.3	+0.2	-0.2	
30	13	3.6	9.3					12.6	11.0	+1.6	12.5	12.4	+0.2	12.4	+0.4	+0.5	+0.6	
40	13	4.4	8.6					13.0	11.1	+1.9	12.6	12.6	+0.4	12.6	0.0	+0.4	+0.4	
50	12	4.8	7.3					12.1	10.4	+1.7	11.9	11.8	+0.3	11.8	-0.1	+0.1	+0.2	
60	10.5	6.0	3.5	0.8				10.3	9.2	+1.1	10.5	11.0	-0.7	11.0	+0.2	0.0	-0.5	
70	11	8.4	1.3	1.7				11.4	10.1	+1.3	11.5	11.8	-0.4	11.8	-0.4	-0.5	-0.8	
80	11	10.0		2.2				12.2	11.2	+1.0	12.7	12.2	0.0	12.2	-1.2	-1.7	-1.2	
90	13	9.6		2.5				12.1	11.0	+1.1	12.3	12.0	+0.1	12.0	+0.9	+0.7	+1.0	
4700	12	8.8	0.2	3.4				12.4	10.9	+1.5	12.4	12.4	0.0	12.4	-0.4	-0.4	-0.4	

THE SPECTRUM FROM 1901 AUGUST 1 TO 1902 NOVEMBER.

10. *The Mean Spectrum.*—The results derived from the photo-plates Nos. 8 to 21, 1901 August 1 to 1902 January, agree closely with each other, and it is unnecessary that the results be given separately. Those derived from the later plates, Nos. 22 to 27, are considerably less accurate, owing to the faintness of the spectrum, but they suffice to show that the bands did not change in position. Their results are also not printed separately. The changes which the spectrum underwent belong to the intensity, and they appear for the whole period in Table XVII.

I combined the wave-lengths and the estimates of intensity to mean values, which are given in the first columns of Table XII. For most bands seven to eight plates contributed to the mean, and for the band near H_γ thirteen plates, all belonging to the period August to November. The two bands at wave-lengths 386 and 397 were outside the range of the plate until the beginning of October, and they rest on the results of the plates Nos. 18, 19, 21. In Table XII. the intensities of the bands, therefore, do not belong to the same epoch. The average error of a tabulated wave-length is 0.3 t.m.

With reference to the faint bands, whose intensities do not exceed 1.5, and which were difficult to measure, most of the detail had to be discarded, because it was seen only on one plate. The neglected measurements are about five per cent. of the total number. The wave-lengths of these faint bands may be several tenth-metres wrong.

11. *The Common Structure of the Bands.*—Of the detached bands, the first two have the most pronounced intensity curve (see Plate III.). I shall show (see § 12) that their structure is similar, and further, that the similarity extends to all the other bands. The wave-lengths of the lines to which the bands belong being unknown, I introduce λ_m , the mean of the wave-lengths of the three minima, and determine a_m from

$$(12) \quad \lambda = \lambda_m + a_m \frac{\lambda}{4500}.$$

a_m is given in Table XIII. for the first two bands, and two other prominent bands, whose zeros λ_m equal 4364 and 4726. The latter merge into fainter bands, which overlap their more refrangible ends; the intensities at these places are bracketed in the table, and I do not take them into account here. The adopted values of Table XIV. are the means of the figures contained in Table XIII., with the exception of a few which were corrected so as to represent other bands better. I have also calculated a_m for all the other bands except one, and drawn on Plate III. their intensity curves with a_m as abscissa.

12. *The Calculated Spectrum.*—I decide whether all the brighter bands are of the same type by calculating the different points of the bands from a_m of Table XIV. by means of formula (12). About six well-defined points contributed to the final λ_m , and its calculated error is on an average 0.2 t.m. The degrees of intensity have been obtained from Tables VIII. and XIV. I have given the calculated bands in Table XII. Including all points, I find that the calculated wave-lengths differ from the observed wave-lengths on an average 0.5 t.m., as compared with a calculated average error of 0.3 t.m. for λ , of

TABLE XI.—*Photographic Plates, 1901 August to 1903 February.*

Index Number of Plate.	Date.	Exposure. Hours.	Range of Temperature. Degrees Centigrade.	Definition.		Remarks.	Number of Points Measured.		Number of Reversals.	Measurements of Plate.
				Star.	Fe.		Star.	Fe, Ti.		
8	1901. Aug. 1	1.7	0.5	4	3	Intensified	35	25	4	6
9	Aug. 15	4.0	2.0	2	2	Intensified	93	24	15	8
10	Aug. 21	6.5	2.9	2	2		98	32	14	6
11	Aug. 26	5.8	1.8	2	2		109	40	18	4
12	Aug. 27	5.9	1.5	3	3	Intensified	77	24	10	3
13	Aug. 30	4.3	1.8	2	2	Intensified	94	25	14	4
14	Sept. 4	7.7	1.9	2	2	Very clear	114	33	20	4
15	Sept. 20	4.7	0.2	4 F	3	Intensified	49	17	5	2
16	Oct. 2	3.7	3.0	4 F	3	Intensified	45	25	2	2
	Oct. 4	1.9								
17	Oct. 6	7.0	1.3	2	2	Intensified	108	40	15	4
18	Oct. 31	8.5	1.2	2	2		64	30	12	4
19	Nov. 1	6.0	0.2	2	2		77	36	12	4
20	1901. Nov. 13	5.5	0.5	2	2	Intensified	133	45	17	4
21	1902. Jan. 12	5.8	1.1	2	1	Intensified	87	50	5	4
22	Jan. 26	1.6	0.7	F	2	Intensified	77	45	2	4
	Jan. 28	6.3								
23	Jan. 29	7.6	2.2	F	1	Intensified	80	35	1	4
	Jan. 31	7.6								
24	Feb. 9	4.8	2.0	F	2	Intensified	81	42	4	4
	Feb. 11	4.8								
	Feb. 12	4.3								
	Mar. 21	2.0								
25	April 1	2.6	5.0	v F	1	Intensified	78	52	2	4
	April 2	1.8								
	April 17	1.5								
	April 26	1.5								
	April 30	0.8								
	May 1	0.9								
	May 2	1.4								
26	Oct. 20	2.2	3.3	F	2	Intensified	98	48	3	4
	Oct. 26	9.0								
	Oct. 30	3.3								
	Nov. 1	8.5								
27	Nov. 17	6.7	1.7	v F	1	Intensified	46	32	2	4
	Nov. 18	6.7								
	Nov. 20	6.9								
	1902. Nov. 21	2.2								
	1903. Jan. 7	0.5								
	Jan. 24	0.5								
	Feb. 1	0.5								

Width of slit:—0.018 mm. for plates Nos. 8 to 25; 0.020 mm. for plate No. 26; and 0.022 mm. for No. 27.

Angle of inclination of plate:—13° for Nos. 8 to 17; 16° for Nos. 20, 22, 23, 25; 30° for Nos. 18, 19, 21, 24, 26; 8° for No. 27.

Definition:—1 excellent, 4 inferior, F faint.

TABLE XII.

The Observed Spectrum, 1901 August 1 to 1902 January, and the Calculated Bands.

Observed.		Calculated.			Observed.		Calculated.		
λ	Intensity.	No. of point Table XIV.	λ	Intensity.	λ	Intensity.	No. of point Table XIV.	λ	Intensity.
3813	0.5		$\lambda_m = 3869.5$					$\lambda_m = 3968.0$	
3835	0								
3853.5	3	1	53.6	2.1	3978.5	6	14 }	78.0	6.2
3856.0	4	2	56.3	3.2	3980.7	2	15 }	80.3	2.6
3858.1	7	3	58.1	9.5	3982.3	1	16	81.9	0.9
3859.4	11	4	59.6	11.5	3986	0	17	85.8	
3861.1	8	5	61.4	9.5	4027	1	18		
3862.6	1	6	62.7	1.1	4045	0			
3863.8	3	7	63.9	2.1	4063	0.5			
3865.2	11	8	65.2	10.5	4071.5	1			
3867.9	6	9	68.3	5.3	4079.7	0		$\lambda_m = 4103.4$	
3870.8	10	10	70.5	10.5	4082.6	2	1	86.1	0.4
3872.9	9	11	72.8	9.5	4088.3	1.5	2	89.4	0.7
3874.1	5	12	74.1	3.2	4091.1		3	91.3	2.6
3876.5	10	13	76.4	8.4			4	92.9	3.4
3878.9	8	14 }	79.2	7.4		3	5	94.8	2.6
3881.4	3	15 }	81.5	3.2	4095.8	1	6	96.2	0.2
3883	1	16	83.1	1.1			7	97.5	0.4
3889	0.3	17	86.9		4098.1	2.5	8	98.8	3.0
3900	0	18			4102.8	0.7	9	02.1	1.2
3936.6	0.5		$\lambda_m = 3968.0$		4105.3	2.5	10	04.5	3.0
3943.2	1						11	06.9	2.6
3951.8 ?	0.4	1	51.3	1.7	4109.2	0.5	12	08.3	0.7
3954.3	2	2	54.4	2.6	4110.4	2.5	13	10.7	2.2
3955.7	4	3	56.3	8.0			14 }	13.7	1.9
3957.5	10	4	57.9	9.9	4115.3	1.5	15 }	16.2	0.7
3959.4	7	5	59.7	8.0			16	17.8	0.2
3961.4	2	6	61.1	0.9	4121.3	0	17	21.8	
3963.9	10	7	62.2	1.7	4140 $\pm$	0.5	18		
3966.5	4	8	63.6	9.0	4165 $\pm$	0			
3969.3	9	9	66.8	4.4	4220 $\pm$	0.5			
	3	10	69.0	9.0	4265 $\pm$	0			
3972.9	3	11	71.3	8.0	4300 $\pm$	0.3			
3974.4	7	12	72.8	2.6	4306	0.7			
		13	75.0	7.1	4314.2	1			

TABLE XII.—*continued.*

Observed.		Calculated.								
λ	Intensity.	No. of Point Table XIV.	λ	Intensity.	No. of Point Table XIV.	λ	Intensity.	No. of Point Table XIV.	λ	Intensity.
4636.4	5				7	35.3	0.8			
					8	36.8	5.0	10	(36.5)	5.0
4641.1	3				9	40.6	2.2	11	(39.2)	4.3
4643.5	5				10	43.2	5.0	12	(40.9)	1.2
4645.3								13	(43.6)	
	4.5				11	45.9		14	(47.0)	3.8
							4.3	15		3.3
4648.9					{ 12	47.6	1.2	16	(49.7)	
	4				{ 13	50.3	3.8			1.2
4652.0					{ 14	53.7		17	(51.6)	
	3.5				{ 15		3.3			0.4
4655.0	3				16	56.4	1.2	18	(56.1)	
4658.4	1		$\lambda_m = 4687.8$		17	58.3	0.4			
4669.1	3	1	68.1	0.9	18	62.8				
		2	71.8	1.4						
4673.6	5	3	73.9	4.8						
		4	75.8	6.2						
		5	78.0	4.8						
4678.8	1	6	79.7	0.5						
		7	81.0	0.9						
4681.1	6	8	82.6	5.5						
4687	5	{ 9	86.3	2.5						
		{ 10	89.1	5.5						
4691.4	4	11	91.8	4.8		$\lambda_m = 4715.6$				
4694.2	2	12	93.4	1.4	1	95.8	0.9			
4697.2	5	13	96.1	4.2						
4699.7		{ 14	99.6		2	99.5	1.4			
		15		3.6	3	01.7	4.8			
	7	16	02.4	1.4	4	03.5				
4704.0	6	17	04.3				6.2			
				0.5	5	05.7			$\lambda_m = 4726.1$	
4707.4	2.5				6	07.4	4.8	1	06.3	1.4
		18	08.8		7	08.8	0.9			

TABLE XII.—*continued.*

Observed.		Calculated.								
λ	Intensity.	No. of Point Table XIV.	λ	Intensity.	No. of Point Table XIV.	λ	Intensity.	No. of Point Table XIV.	λ	Intensity.
4710.2	9				$\lambda_m = 4715.6$			$\lambda_m = 4726.1$		
4712.5					8	10.4	5.5	2	09.9	2.2
	11				9	14.1	2.5	3	12.1	7.1
4717.2	7				10	16.9	5.5	4	14.0	8.8
								5	16.2	7.1
4721.0	10				11	19.6	4.8	6	17.9	0.7
4725.0	7				12	21.3	1.4	7	19.3	1.4
					13	24.0	4.2	8	20.9	8.0
4727.0	9				14 } 27.4			9	24.6	3.8
					15 }			10	27.4	8.0
	2				16	30.3	1.4	11	30.1	7.1
4731.7					17	32.2	0.5	12	31.8	2.2
4735.4	5.5				18	36.8		13	34.5	6.2
								14 }	38.0	
4740.3	3							15 }		5.4
4742.6	1							16	40.8	2.2
4747.3	0.5							17	42.7	0.7
4757	0.3							18	47.3	
4768	0									
4776	0.5									
4786	0									
4799	0.5									
4810	0									
4824	0.5									
4834.2	1									
4840.3	0				$\lambda_m = 4862.8$					
4842.5	1	1	42.4	0.7						
4845.4	2.7	2	46.2	1.1						
4848.3	5	3	48.4	4.0						
		4	50.4	5.0						
4851.9	4.5	5	52.6	4.0						
4853.8	1	6	54.4	0.4						
		7	55.8	0.7						
4856.9	4	8	57.4	4.5						
4861.7	1.5	9	61.3	2.0						

TABLE XII.—*continued.*

Observed.		Calculated.			Observed.		Calculated.		
λ	Intensity.	No. of Point Table XIV.	λ	Intensity.	λ	Intensity.	No. of Point Table XIV.	λ	Intensity.
4864.2	4.0	10	64.1	4.5			$\lambda_m = 4959.4$		
4866.6	3.5	11	66.9	4.0			14 }	71.9	
		12	68.6	1.1	4973	0.8	15 }		1.2
4870.0		13	71.4	3.4	4978		16	74.8	0.4
	2.8	14 }	75.0			0.2	17	76.8	0.1
4875.4	1.5	15 }		2.9			18	81.7	
4878.7	1	16	77.9	1.1			$\lambda_m = 5007.2$		
		17	79.9	0.4	4986.2	0.5	1	86.2	0.7
4883.1	0	18	84.6				2	90.1	1.1
4886	0.5				4992.1		3	92.4	4.0
4900	0					5	4	94.4	5.0
4917	0.3	$\lambda_m = 4959.4$			4998.3	0.5	5	96.7	4.0
4924	0.5						6	98.6	0.4
4938	1	1	38.6	0.3			7	00.0	0.7
		2	42.4	0.4	5001.0	4	8	01.6	4.5
4944.8		3	44.7	1.7	5006.5	0	9	05.6	2.0
	2.5	4	46.7	2.3	5009.9		10	08.5	4.5
		5	49.0	1.7		3	11	11.4	4.0
4950.5	0.4	6	50.8	0.1	5017.5		12	13.2	1.1
		7	52.3	0.3		2.8	13	16.1	3.4
4954.2		8	53.9	2.0			14 }	19.8	
	2	9	57.9	0.8			15 }		2.7
		10	60.7	2.0	5022.0	1.7	16	22.8	1.1
4964.0		11	63.6	1.7	5026.1	0.7	17	24.8	0.4
	1	12	65.4	0.4	5031	0.3	18	29.7	
		13	68.2	1.5	5053				

TABLE XIII.—*Table of a_m of Corresponding Points of Four Bands and of the Intensities, showing that the Bands are similar in regard to their Wave-Lengths after August 1, 1901.*

No.	a in Tenth-metres.				Degrees of Intensity.			
	λ_m				λ_m			
	3869.4	3968.0	4364.4	4726.3	3869.4	3968.0	4364.4	4726.3
1	-18.5				3			
2	-15.6	-15.5	-15.3	-15.3	4	2	(9)	(9)
3	-13.1	-13.9	-13.1	-13.1	7	4	(12)	(11)
4	-11.6	-11.9			11	10	(12)	(11)
5	-9.6	-9.8	-9.3		8	7	7	(11)
6	-7.9	-7.5	-7.2	-8.7	1	2	1	(7)
7	-6.5				3	2	1	(7)
8	-4.9	-4.6	-5.6	-5.1	11	10	10	10
9	-1.7	-1.7	-1.1	-1.2	6	4	5	7
10	+1.6	+1.5	+0.9	+0.7	10	9	10	9
11	+4.1		+3.6		9	9	8	9
12	+5.5	+5.6	+5.6	+5.1	5	3	3	2
13	+8.3	+7.3	+7.6	+8.7	10	7	8	5.5
14	+11.0	+11.9	+10.4		...	...	5	...
15			+11.6		8	6	7	5.5
16	+14.0	+14.4	+14.4	+13.3	3	2	3	3
17	+15.8	+16.2	...	+15.5	1	1	(3)	1
18	+22.8	+20	+18.1	+20.0				

TABLE XIV.—*Structure of the Bands after August 1901.*

Mean a_m T. M.	Adopted Degrees of Intensity.
-18.9	2
-15.4	3
-13.3	9
-11.5	11
-9.4	9
-7.8	1
-6.5	2
-5.0	10
-1.4	5
+1.2	10
+3.8	9
+5.4	3
+8.0	8
+10.7	5
+11.9	7
+14.0	3
+15.8	1
+20.2	

0.2 t.m. for a_m , and 0.2 t.m. for λ_m . The observed degrees of intensity also agree satisfactorily with the calculated ones, or their sums at those places where two or three bands are superposed. The average difference, apart from signs, is 0.7 degrees of intensity; 91 of the discrepancies lie between 0 and 0.5, 60 between 0.5 and 1, 26 between 1, and 2 and 6 are greater. I consider it therefore proved that the bands are in every way defined by λ_m , the degree of intensity of their maximum, and the quantities given in Table XIV.

13. *Permanency of Structure.*—Table XV. gives the number of observations of a minimum, and the period during which it was observed. The bands $\lambda_m = 3869$ and 3968 were outside the range of the photo-plates Nos. 8 to 17. Their position is nevertheless well determined, since the plates Nos. 18 and 19 contain all the six minima, and Nos. 20 and 21 each four. The first minimum appears to have been the most pronounced. In all, it was recognised 90 times, against 47 for the second minimum and 38 for the third minimum. Of the total of 177 minima, 158 belong to the 1901 plates. The number of the minima that have been found seems to depend on the brightness of the bands, and still more on the linear width of the minimum, which at wave-length 3870 was 0.23 mm., and at 5006 only 0.08 mm. In conformity with this, the

majority of the minima detected on the plates of 1902 belongs to the first two bands, which at first were the brightest of the spectrum, and then second in brightness only to the 5006-band. They are present on each of the three photo-plates on which they were in focus, plates Nos. 21, 24, 26, 1902 January to November. During this time there is also no change in the extent and the position of the maximum of the bands. The evidence therefore points to the conclusion that from August 1 1901 to the end of 1902 the structure of the bands remained unchanged.

TABLE XV.—*Table showing the Number of Photo-Plates on which the Minima have been measured, and the Periods to which they belong.*

λ_m of Bands.	Minimum 1.			Minimum 2.			Minimum 3.		
	Number.	Period.		Number.	Period.		Number.	Period.	
3869.5	6	1901 Oct.	to 1902 Mar.	4	1901 Oct.	to 1902, Mar.	4	1901 Oct.	to 1902 Nov.
3968.0	4		Oct. to Jan.	6		Oct. to Nov.	4		Oct. to Jan.
4103.4	7		Aug. to Nov.	6		Aug. to 1903 Jan.	5		Aug. to May
4341.0	8		Aug. to 1901 Nov.	7		Aug. to 1902 Nov.	5		Aug. to 1901 Nov.
4364.5	13		Aug. to 1902 Jan.	9		Aug. to 1901 Nov.	7		Aug. to Nov.
4612.6	1		Sept. 4.	3		Aug. to Nov.	1		Aug. 15.
4642.0	4		Aug. to 1901 Sept.	1		Aug. 26.	...		
4687.8	9		Aug. to Nov.	...			8		Aug. to Nov.
4715.6	11		Aug. to Nov.	...			...		
4726.1	8		Aug. to Nov.	5		Aug. to Nov.	3		Oct. to 1902 Mar.
4862.8	7		Aug. to Oct.	2		Aug. 21, Sept. 4.	...		
4959.4	4		Aug.	1		Nov. 13.	...		
5007.2	8		Aug. to 1903 Jan.	3		Aug. to 1901 Sept.	1		Sept. 4.

A fourth minimum was measured twice in band $\lambda_m = 4364.5$ on 1901, August 21 and 26.

14. *Identification of the Bands.*—The wave-lengths λ_m of the zeros of the principal bands are compiled in the first column of Table XVI. Five of these can with certainty be identified as the hydrogen lines H_β , H_γ , H_δ , and the two principal nebular lines. λ_m is the wave-length of an arbitrary zero of the band, viz., approximately the mean of the wave-lengths of the three minima. I change the zero and make it coincide with the wave-length λ_0 of the line to which the band would be reduced under ordinary conditions. Let $[s]$ be the mean of the corrections for the orbital motion of the earth on the days on which the photographs were taken, then

$$\lambda = \lambda_0 + a_0 \frac{\lambda}{4500} = \lambda_m + [s] + a_m \frac{\lambda}{4500}$$

$$(13) \quad \delta a_m = a_0 - a_m = \frac{4500}{\lambda} (\lambda_m + [s] - \lambda_0)$$

$$\lambda_0 = \lambda_m - \frac{\lambda}{4500} \delta a_m + [s]$$

TABLE XVI.

δa_m			
λ_m	[s]	λ Hydrogen and Nebulæ.	δa_m
3869.5	+ 0.1		
3968.0	0.0		
4103.4	+ 0.3	4101.8	+ 2.1
4341.0	+ 0.3	4340.7	+ 0.6
4364.5	+ 0.3		
4612.6	+ 0.4		
4642.0	+ 0.4		
or (4635.3)	+ 0.4	(4633.8)	
4687.8	+ 0.4		
4715.6	+ 0.4		
4726.1	+ 0.4		
4862.8	+ 0.4	4861.5	+ 1.6
4959.4	+ 0.4	4959.0	+ 0.7
5007.2	+ 0.4	5007.0	+ 0.6

The five lines mentioned above give on an average $\delta a_m = +1.1$ t.m. λ_0 calculated by the third formula is comparable with the wave-lengths of elements, and also with the λ_0 derived from the March-April plates (Table VII.). The motion of the new star in the line of sight is here eliminated. If one should succeed in deriving from experiments, or theoretical considerations, the wave-length λ' of a certain point a_0 of the band belonging to a line λ'_0 , a' can be calculated from $a' = (\lambda' - \lambda'_0)4500/\lambda'$, and the ratio $(a_0 - a')/4500$ is the ratio of the velocity in the line of sight and the velocity of light.

The residuals entered in the column headed "Difference" of Table XVII. exceed the quantity that might be expected from the average error of λ_m , and perhaps the fact that they rest on fewer minima than those of the brighter bands made them less accurate than the latter. Some of the bands call for special remarks. The zero of the second band lies 1.6 t.m. from the calcium line 3968.6, and 3.2 t.m. from the hydrogen line 3970.2. Owing to the good definition of its minima and its isolated position, its wave-length is one of the best determined of the spectrum, and its error is not likely to be greater than the calculated average error. As δa_m cannot be so much in error, I take the band to belong neither to calcium nor to hydrogen. The bright band whose zero has the wave-length 4641.3 cannot be identified. This band overlaps the band, $\lambda_0 = 4611.9$, and only two of the three minima were measured. The zero would almost agree with the bright hydrogen line 4633.8 if the observed minima were not the first and second of the standard band, but the second and third; an assumption which changes the wave-length of the zero by the distance of two minima. This identification is bracketed as an alternative, though it is questionable, because the first calculated maximum of the band has not been observed (see Table XII.). The next band, $\lambda_0 = 4687.1$, is certainly

not due to the hydrogen radiation of wave-length 4684. Near $\lambda_0 = 4725.3$ is the hydrogen line 4723.6, which in the March-April spectrum was identified with a band

TABLE XVII.—*Spectrum of Nova Persei from 1901 August 1 to 1903 January.*

λ_0	Difference.	NOVA PERSEI.								Planetary Nebulae.		Nova Aurigæ.	
		Degree of Intensity of Maximum of Band on Photo-Plate.				I Relative Intensities of the Radiations.				(Campbell).		(Campbell).	
		1901, August 1 to October 6.	1901, October 31 to November 13.	1902, January.	1902, October to November.	1901, August 1 to October 6.	1901, October 31 to November 13.	1902, January.	1902, October to November.	λ	I	λ	I
3868.7			11.0	7.0	0.4		30	24	5	3868	4, 5		
3967.0			9.5	5.0	0.8		25	18	8	3969	4, 5	396	0.5
4102.7	+0.9	3.1	1.3	0.7	0.8	7	5	4	8	4101.8	5, 6	4098	2
4340.2	-0.5	5.2	3.8	3.0	0.5	11	11	11	6	4340.7	5, 6	4336	1
4363.7		10.1	7.7	2.3		20	20	9		4363.8	2, 4	4358	8
4611.9		1.4	1.7	0.2	0.3	4	5	2	4	4610	0, 1	460	1
4641.3		5.5	3.1	1.0	0.1	11	9	5	2				
or (4634.6)										4637	0, 2	4630	7
4687.1		5.2	4.0	1.2	0.3	11	11	6	4	4687	2, 5	4681	4
4714.8		6.5	2.6	0.5	0.1	13	8	3	2	4715	2, 4	471	1
4725.3		5.3	6.0	1.2		11	16	6					
4862.0	+0.5	4.8	1.5	0.3	0.1	10	5	2	2	4861.5	v. b	4857	10
4958.6	-0.4	2.6	2.0	0.5	0.4	6	6	3	5	4959.0	v. b	4953	30
5006.4	-0.6	4.9	3.5	2.5	1.0	10	10	10	10	5007.0	v. b	5002	100
Faint Bands.													
3813 - 3835					0.5				6				
3889 - 3952			0.2		0.2		1		3	3889	0, 4		
4027 - 4045				0.8				4		4026	0, 4		
4063 - 4080		0.6	0.1	0.5	0.1	2	1	3	2				
4140 - 4165		0.5		0.2		2		2					
4220 - 4265		0.5	0.5	0.5	0.3	2	2	3	4	424	0, 1	423	1
										4265	0, 1	426	1
4300 - 4323		0.8	0.8	0.2	0.1	2	3	2	2				
4382 - 4398		0.8	0.8	0.3	0.3	2	3	2	4	4390	0, 4	438	1
4405 - 4488		1.3	1.5	0.7	0.4	3	5	4	5	4472.6	0, 5	4466	1
4503 - 4590		0.9	1.0	0.7	0.3	3	4	4	4	4574	0, 2	451	1
										4597	0, 1		
										4662	1, 4		
4747 - 4768		0.4	1.5	0.6	0.1	2	5	3	2	4744	2, 4		
4776 - 4786			1.0	0.5	1.0?		4	3	10?				
4799 - 4810				0.6	0.5			3	6				
4824 - 4840		0.3		0.6		1		3					
4886 - 4900		0.1		0.5	0.3	0		3	4				
4917 - 4938		0.1	0.7	0.3	0.3	0	3	2	4				
5031 - 5053		0.1	0.5	0.3		0	2	2					

of medium intensity. As neither the wave-length nor the intensity of the maximum agree with those of the hydrogen line, it probably is not due to hydrogen, though the

possibility is not excluded that the March-April identification is wrong, and that both the earlier and the later bands belong to the same radiations.

In the second half of the table appear the twelve corresponding lines which Campbell photographed in the spectra of five planetary nebulae, and the range of their intensities in these five spectra, 1 standing for "faint," and 6 for "very bright." Besides these, there are only two lines, $\lambda = 4662$, intensity 1 to 4, and $\lambda = 4744$, intensity 2 to 4, which Campbell found present in each of the five nebulae. The first falls within the range of the two bright bands $\lambda_0 = 4642$ and 4688 of the Nova spectrum, and if faint, would be masked by them; while the second is probably not represented by the faint band 4747 to 4768 of the Nova spectrum lower down in the table. All the prominent lines of the nebulae spectrum are present in that of the Nova, 3868 and 4364 , in addition to the principal nebular lines and the hydrogen lines, and their wave-lengths agree within their probable errors. I have already said that the second line of Nova Persei could not be the hydrogen line 3970.2 . The planetary spectrum is not decisive on this point. All the hydrogen lines are bright, and the intensity of 3969 fits into their series, while its wave-length may be a t.m. in error. If it were the hydrogen line, the Nova spectrum after January 1902 could be reconciled with it. It is possible that a faint hydrogen band was superposed on the bright band $\lambda_0 = 3967.0$, and that after January 1902, when the band faded and the measurements became difficult and less accurate, its principal constituent was the band $\lambda_0 = 3970$. The only prominent band of the Nova spectrum which has no counterpart in the nebular spectrum belongs to wave-length 4725.3 .

15. *Variation of the Bands and of the Radiations in Intensity.*—The degree of intensity μ of the maximum of a band determines the intensity curve of the band. It alone requires to be discussed. From 1901 August 1 to October 6 the observed values of μ agree with each other within their probable errors, and I have combined them to mean values. In this period the photo-plates Nos. 8 to 17 were all taken at the same angle of inclination. I have also combined the estimates made in three other periods, using in each period photo-plates taken at angles of 30° and 16° , and discarding those estimates which belong to bands out of focus. The results, which are corrected for the superposed bands, are tabulated in Table XVII.

By means of the formulæ given in § 9 the relative changes in intensity of the radiations which produced the bands can be calculated. Let a radiation of intensity i in the focal plane of the spectrograph produce in time t a degree μ of blackness on a photographic plate whose sensitiveness is s for the wave-length of this radiation, and I designate these conditions by (i, s, μ, t) , and let a radiation i_0 produce in the same time t on the same plate, for sensitiveness s_0 a degree μ_0 of blackness (i_0, s_0, μ_0, t) , and for sensitiveness s a degree μ'_0 , (i_0, s, μ'_0, t) .

I define sensitiveness by $st = \text{constant}$ for the same intensity of radiation and the same degree of blackness. i/i_0 is the quantity wanted. I apply formula (5) to (i, s, μ, t) and (i_0, s, μ'_0, t) .

$$\left(\frac{i}{i_0}\right)^b = \frac{f(\mu)}{f(\mu'_0)}$$

$f(\mu'_0)$ can be eliminated by $f(\mu_0)$. I apply formula (2) to (i_0, s_0, μ_0, t) and (i_0, s, μ'_0, t) , which can be replaced by $(i_0, s_0, \mu'_0, \frac{ts}{s_0})$, then

$$(14) \quad \frac{s}{s_0} = \frac{f(\mu'_0)}{f(\mu_0)}$$

$$(15) \quad \frac{1}{I_0} = \frac{i s^{\frac{1}{b}}}{i_0 s_0^{\frac{1}{b}}} = \frac{F(\mu)}{F(\mu_0)}$$

Since the sensitiveness is constant for the same wave-length, I/I_0 suffices for our purpose. It appears in Table XVII., where it is referred to the intensity of the radiation at $\lambda_0 = 5007$.

Compared with the March-April spectrum all the bright bands except the three H-bands, and perhaps the bands $\lambda_0 = 4634.6$ and 4611.9 , have come into existence, or have grown much in intensity. The radiation at $\lambda_0 = 4363.7$ is twice as intense as that of the three H-bands, which in the spring were the most prominent bands of the spectrum. The other bands observed in the spring have almost entirely disappeared. None of the radiations faded at a slower rate than the nebular radiation $\lambda = 5007$. Several radiations began to decrease already in October, and others started in November. The decline of the bands $\lambda = 4363.7$ and 4725 in the two months 1901 November 13 to 1902 January 12 is further remarkable. Four radiations faded at the same rate, H_δ , 4612 , 4959 , 5007 , and perhaps H_γ , while H_β certainly decreased at a much greater rate in October. I may mention that I calculated s_0/s by (14) from estimates of degrees of blackness made on a photograph of the sky spectrum. The values i/i_0 calculated by (15) show that, with the only exception of the radiation at $\lambda_0 = 3869$, that at $\lambda = 5007$ was the most intense already in August 1901.

In October and November 1902 the relative intensities agree better with those of the nebular spectrum than before. It must of course be borne in mind that the spectrum on the last plates was extremely difficult to see, the intensity of the maximum of the band $\lambda_0 = 5007$ being only of degree 1, and that the figures belonging to that period are only a rough approximation. The trend of the table is certainly to show that the intensities are approaching those of the average nebular state.

16. *The Faint Bands*.—One may conclude by analogy that the faint bands would be reduced to lines under ordinary conditions. In that case, on account of their breadth, several must be due to multiple lines. On a whole they agree fairly well with the maxima of the intensity curve observed in March and April. Considering the uncertainty of the wave-lengths of these faint bands, about 5 t.m., a convincing proof as to their origin cannot be brought, though it is probable that they are the remnants of the bright spectrum in the first months. It may be mentioned that the hydrogen lines given under B in Table VII. also explain them, provided seven of them be excluded.

17. *Last Visual Observation of the Spectrum.*—On March 3 1903 I inspected the spectrum of Nova Persei in the focal plane of the spectrograph without using an eyepiece, a method which I usually employed prior to the exposure, to make sure that the proper star had been set on the slit. I saw only one bright spot in the whole range of the spectrum which coincided with the air band at 5004. Several times I gained the impression that there was a faint spot near the place of the magnesium line 4481. The comparison was made in this way, that when the eye had been fixed on the spot the spark was switched on for an instant.

18. *Curious relation between λ^{-1} of Four Prominent Lines.*—The wave-lengths of the zeros of the brightest bands are 3869, 3967, 4364 and 5007. The oscillation frequencies of the first, third, and fourth zeros almost form an arithmetic series, which, continued to the less refrangible side, gives the wave-length of the helium line D_3 , a line which was measured by others in the spectrum of the new star, and also belongs to the nebular spectrum. In the following table I give the wave-length of the helium line, Keeler's determination of the nebular line, and my determination of the other two lines, reduced to the two nebular lines as standards.

The formula

$$\lambda^{-1} = 17014.2 + 2957.6n - 5.5n^2, \quad n = 0, 1, 2, 3$$

determines λ as entered in the last column. The agreement is perfect. Should this be merely a casual coincidence?

λ	$\frac{1}{\lambda}$ Vacuum.	Difference.	Calculated λ .
3869.2	25837.8		3869.2
4364.3	22906.8	2931.0	4364.3
5007.05	19966.3	2940.5	5007.05
5875.87	17014.2	2952.1	5875.87

19. *Similarity of the Structure of the Bands in March-April 1901 and after August 1901.*—I add $\delta a_m = +1.1$ t.m. to a_m of Table XIV., which reduces them to the same zero as was employed for the March-April bands. Both bands are given in Table XVIII., and also on Plate II. I include the second minimum of the March-April band, though it rests on only two single measurements in two bands, because it seems to fill up a gap in the order of the minima. The extent of the maximum and the position of the minima agree with each other. There is only this difference, that while the March-April band declines to nothing from $a_0 = -12$ to -73 t.m., and from $+13$ to $+56$ t.m., the later bands fade abruptly on 6 t.m. Between April and August the ends of the bands have therefore decreased at a greater rate than the central maximum portion. I repeat again that from August 1901 to January 1902 no change took place in the structure, and that the extent of the maximum remained unaltered during 1902. It appears that the spectrum converges towards a nebular spectrum, in which each line is broadened 27 t.m.

TABLE XVIII.—*The Structure of the Bands in March-April 1901, and after August 1901, referred to λ_0 as zero, and reduced to $\lambda_0 = 4500$.*

Structure of the Bands.				Reversals.					
March-April.		After August.		March-April.			After August.		
λ_0	Intensity.	λ_0	Intensity.	λ_0	Number of Bands containing Reversals.	Number of Plates.	λ_0	Number of Bands containing Reversals.	Index Number of Plates.
T.M.		T.M.		T.M.			T.M.		
-73	0								
-55	5								
-43	5								
-31.5	6								
-23.9	7								
-21.8	0*			-22.8 *	8	3			
-17.5	8	-17.8							
-16.6	9	} -14.3	2	-15.5 ±	2	1			
-14.4	3								
-12.0	11	-12.2	3						
		-10.4	9						
	13	-8.3	11						
		-6.7	9						
-5.8		-5.4	1	-4.8	7	5	-5.3	89	8 to 24
	7	-3.9	2						
-3.8	13	-0.3	10						
+1.2	7	+2.3	5	+2.2	5	4	+1.0	48	9 to 27
+3.2		+4.9	10						
	12.5	+6.5	9						
+6.8	7	+9.1	3	+8.1	6	4	+7.8	38	9 to 26
+9.5	12.5	+11.8	8						
+12.4	7	+13.0	5	+12.7	3	3	+12.4	2	10 and 11
+13.0		+15.1	7						
	11.5	+16.9	3						
+16.8	10	+21.3	1						
+20.1	8								
+25.1	7								
+31.7	5.5								
+34	3.5								
+36.4	2.5								
+40.5	1								
+56	0.5								

* Sharp Fraunhofer line, 1901, March 18-20 and March 25.

20. *Results*.—1. The spectrum consists of a line spectrum in which each line is broadened into a band, the broadening being proportional to the wave-length of the line and independent of the element. Tables V. and XIV. give the common structure of the bands.

The position of the maxima and of the minima or reversals remains unchanged during the whole period 1901 March to 1902 November. (See Table XVIII. and Plate II.)

2. The intensity curve of the spectrum in March and April is satisfied by the hydrogen and helium lines, some of which vary in intensity during this period. (See Table VII. B, and Plates I. and II.) It is probable that the spectrum is due to hydrogen and helium.

3. From August 1 1901 to the end of 1902 the bands belong to the lines of the spectrum of planetary nebulae, and their relative intensities converge towards those of the average nebular spectrum. (See Table XVII. and Plate II.) Probably the March-April spectrum is also faintly present during the whole period.

I wish to acknowledge the help I have received from my Assistant, Mr JAMES CONNELL, who attended to the guiding of the telescope and plotted the curves given in the plates accompanying this paper.

BECKER: ON THE SPECTRUM

Intensity curves of the spectra of Nova Persei

calculated ———.

observed ———.

OF NOVA PERSEI. — PLATE I.

, 1901, March 3, March 18-20, and March 25.

BECKER: ON THE SPECTRUM OF NOVA PERSEI. — PLATE II.

Intensity Curve, 1901, March 3 — continued.

Spectrum of Nova Persei reduced to lines.

BECKER: ON THE SPECTRUM OF NOVA PERSEI. — PLATE III.

Curves of observed intensity of 12 bands in the spectrum of Nova Persei.
1901 August to November. abscissæ a_m (see § 11)

Wave-lengths λ_m of zero of bands