The Earlier Spectrum of Nova Aquilæ, 1918.

By the Rev. A. L. Cortie, S.J. (Plates 2, 3.)

Through the kindness of the Astronomer Royal, a telegram announcing the discovery of Nova Aquilæ was received on the morning of June 10. The night being on the whole fine, it was possible to begin observations at once. To the naked eye the star appeared brighter than Altair, but less bright than Vega. Two photographs of the spectrum of the star were obtained that night, and one on the following night. The present paper deals mainly with these spectra.

The instrument employed was the Thorp prismatic camera, having an objective prism of 22·5° angle, and 3 inches aperture, made by the late Mr. T. Thorp of Manchester, and a 3-inch achromatic lens made by Cooke of York. The adjustments of the instrument were fully described by Father Sidgreaves in a paper on the spectrum of Nova Persei,* 1901, and the same adjustments were maintained in taking the photographs of the spectra here described, with the exception that the slew of the camera was slightly altered, giving a longer extension of the spectrum, especially in the violet. In the former setting the length of the spectrum from H_β to H_υ was 21 mm.; in the present instance the length was 22·8 mm. The spectra, however, though in very good focus, lack the excellence of focus attained by those taken by Father Sidgreaves. The plates used were Ilford Monarch rapid plates, and the developer Rytol.

Other observers have already remarked on the very rapid scintillations of the star. The same phenomenon was strikingly evident to the writer, and was independent of any possible changes in atmospheric conditions. Professor Newall has described his observations of the spectrum of the star by a direct vision prism without any telescope,† and the extraordinary brightness of the red radiation in the spectrum of the Nova was projected on the sky.

On June 15 the spectrum of the Nova was similarly compared with that of Altair, by means of a transmission grating. While the spectrum of Altair so observed was continuous, with a maximum of brilliancy in the green, that of the Nova was almost entirely confined to the red. This is corroborative evidence as to the extraordinary relative brilliancy of the red hydrogen radiation.

Two plates of the spectrum of the Nova were obtained on June 10, the first exposure being made from 11.0 to 11.30 p.m. G.M.T.; and the second from 11.35 to 12.15 p.m. G.M.T. The magnitude of the star, according to the curve published in the *Journal of the British Astronomical Association* for June 1918, constructed by Mr. C. L. Brook, was about −0·5. The spectrum extends from λ5180 to H_χ, λ3670, in the ultra-violet.

* *Monthly Notices R.A.S.*, 62, 137.
† *Ibid.*, 78, 577, 578.

The extension into the ultra-violet, the spectrum embracing all the hydrogen line series from H_β to H_χ, is noteworthy. The spectrum consists of a series of dark lines, which closely match the spectrum lines of α Cygni, which is classed as A2F peculiar in the Draper Catalogue, and of a series of bright bands, which, as in all Novæ, adjoin the corresponding dark lines on their less refrangible edges. The bright bands became more prominent on June 11 and succeeding dates, when the dark line spectrum was disappearing. The more prominent bright bands on June 10 were those adjoining the hydrogen lines, especially H_β, H_γ, H_δ, and H_ϵ, and those less refrangible about λ5019 and λ4924. There was also a very prominent, narrow bright band between H and K, at about λ3950.

There were two bright bands about the position λ4640, even on this early date in the life-history of the star. They were separated by a dark space. Although they grew greatly in intensity as the star waned in magnitude, they maintained this character, as a double band with dark central absorption, until at least June 30. The bright bands adjoining H_γ, H_δ, and H_ϵ had a very complicated structure, as a reference to the appended table will show. The H_β bright band, which extended from λ4862 to λ4918, had a brighter central portion. The mean width of the four bright bands H_β, H_γ, H_δ, H_ϵ was 55 A.U., and this width they maintained, unaltered apparently, until at least August 13. The permanence of the width of the bright hydrogen bands in new stars is a remarkable phenomenon. It would indicate the cause of the widening to be due rather to pressure than to line-of-sight displacement.

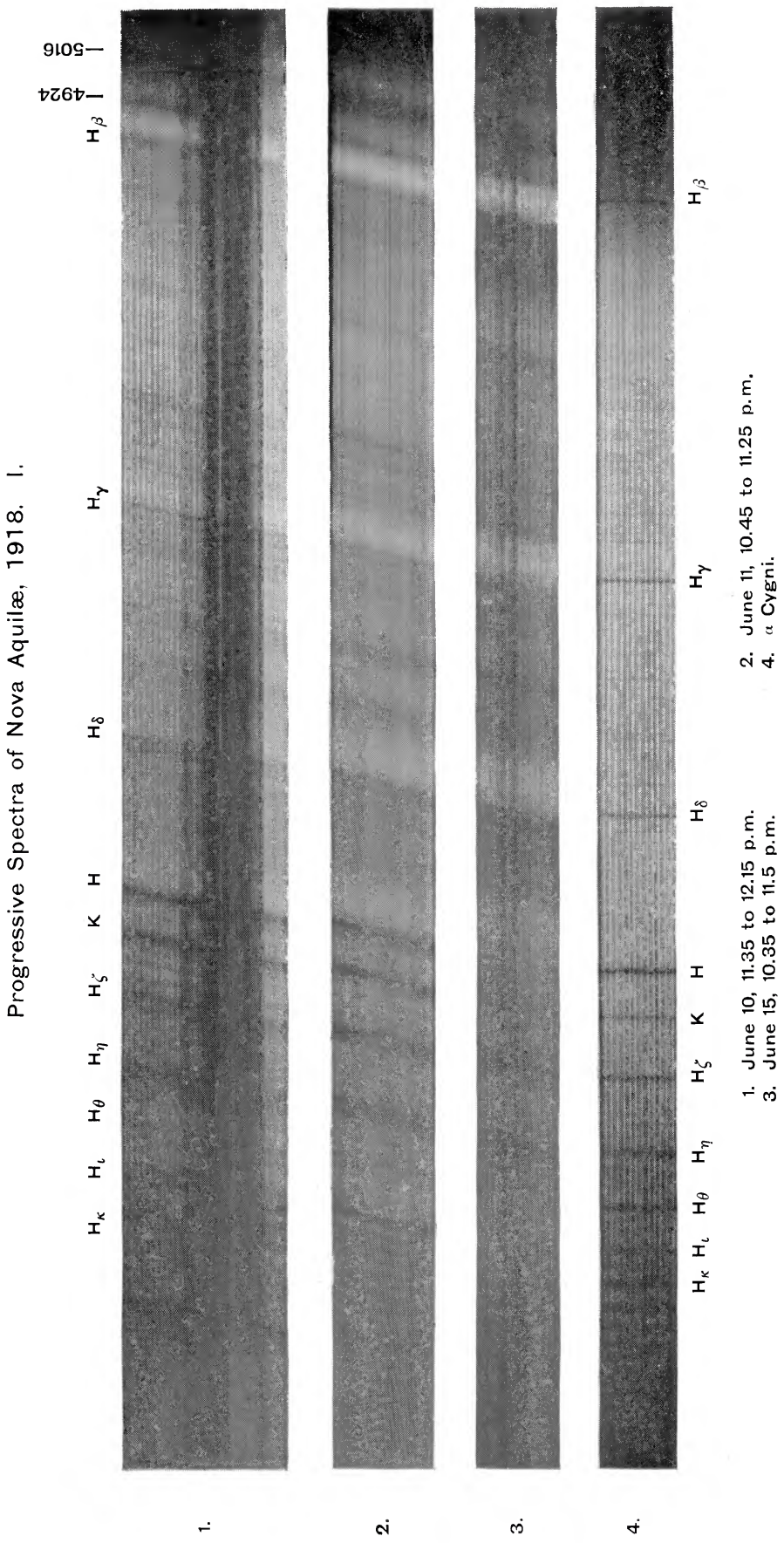
The most striking appearance in the dark line spectrum of the Nova was the double set of displaced hydrogen lines, as usual the displacement being to the violet. The first set, of less displaced lines, was sharper than the second set of more displaced lines, which was hazy and seemed to be itself made up of double lines. This feature was in evidence until at least June 15.

Unless a comparison spectrum is impressed on the plate, it is not possible to get very accurate determinations of the radial velocities. However, several determinations of the radial velocities of the two sets of hydrogen lines have been made by the method due to Orbinski,* which is facilitated by the irrationality of dispersion in the case of a prismatic spectrum. Although several of the results obtained are discordant and puzzling, yet there seems to be sufficient evidence for velocities of about 900 km./sec. for the first set of hydrogen lines, and of 1700 km./sec. for the second set. The latter result is the better of the two. It is intended, however, to return to this subject when the other plates have been measured.

The wave-lengths of the dark lines, and of the bright bands and lines, given in the table were obtained in the following manner:— It was found that the more refrangible edges of the bright bands

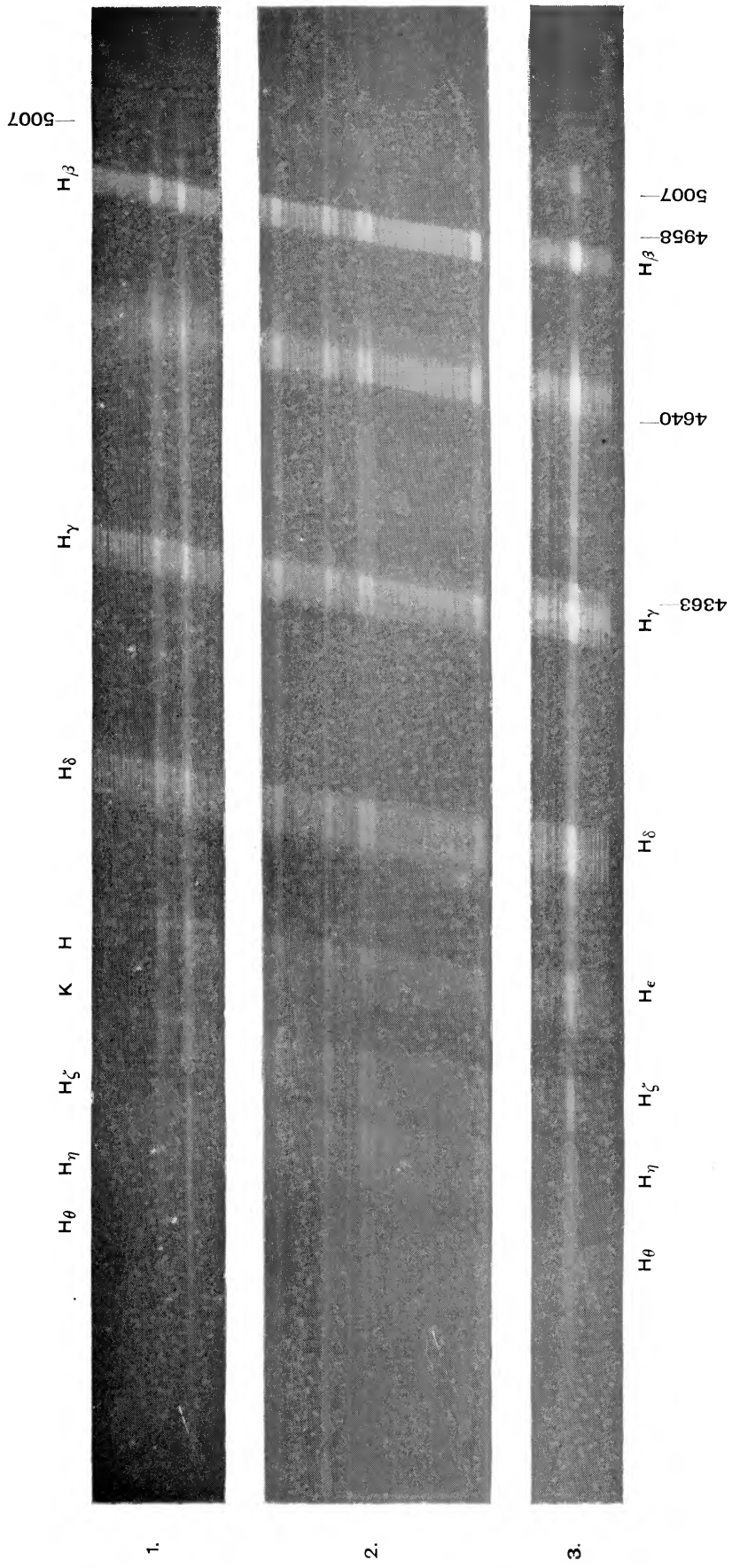
* *The Observatory*, August 1895, p. 303.

Progressive Spectra of Nova Aquilæ, 1918. I.



1. June 10, 11.35 to 12.15 p.m.
2. June 11, 10.45 to 11.25 p.m.
3. June 15, 10.35 to 11.5 p.m.
4. α Cygni.

Progressive Spectra of Nova Aquilæ, 1918. II.



1. June 24. 11.50 to 12.50 p.m.
2. June 30, 10.45 to 12 p.m.
3. July 29, 10.26 to 11.5 p.m.

at H_β, H_γ, H_δ were in exact agreement with the micrometer readings for these lines, which were the means of values from many settings derived from the stars Procyon, Sirius, α Coronæ, and γ Cassiopeiæ. Accordingly, a graph of the Hartmann-Cornu formula, according to the method of Dr. Henroteau, was constructed with these three readings as fiducial points, which was employed between the limits H_β and H_δ, and by extrapolation to H_ϵ.

Furthermore, an excellent spectrum of α Cygni, which had been obtained some years ago by Father Sidgreaves with a different slew of the camera, and therefore had different values in micrometer readings for the differences in linear dispersion between the hydrogen lines, was carefully measured. From the resulting micrometer readings the wave-lengths of the principal lines in this star were obtained by means of a curve which had been constructed for the slew of the camera employed. These values of the wave-lengths of the lines in α Cygni formed a valuable check on the values for the corresponding dark lines in the Nova, which had been independently obtained. They are set down in the fifth column of the table, with their intensities in the sixth column. The agreement between the values of the wave-lengths of the dark lines in the Nova, and the corresponding dark lines in α Cygni, is sufficiently close to warrant the correctness of the former within one or two Angström units.

The wave-lengths of the dark lines in α Cygni also serve the purpose of the identification of the corresponding lines in the Nova. They also show the close similarity between the dark-line spectra in the two stars.

For the wave-lengths of the lines and bands in the Nova beyond H_δ, a curve was constructed, using as fiducial points the series of readings of the wave-lengths of the hydrogen lines from H_δ to $H_\circ$. And in this position of the spectrum the change in the wave-lengths of the dark lines, other than the hydrogen lines, and of the bright bands, due to displacement, was corrected by actual comparison with the corresponding lines in the spectrum of α Cygni. This was facilitated by the employment of six-fold paper enlargements of the spectra of the two stars.

As the edges of the bright bands are in most cases bounded by dark lines, it may be assumed that the wave-lengths given for them, in column three of the table, are also correct. In column seven of the table, the wave-lengths of what were judged to be corresponding lines in the chromospheric spectrum are taken from the Astronomer Royal's Memoir on the spectra obtained at total solar eclipses.* Enhanced chromospheric lines are indicated by an asterisk. The considerable number of such lines which are found in the spectrum of the Nova indicates how closely its earlier spectrum approximates to the solar chromospheric spectrum.

In the table the positions of the double set of displaced hydrogen lines are given with their displaced wave-lengths, as

* *Memoirs, R.A.S.*, Appendix to vol. 57.

determined from the two curves. In the ultra-violet the displaced hydrogen lines of the second, more refrangible set sometimes form blends with the less displaced lines of the first set which follow them. Moreover, some of the other lines, not due to hydrogen, coalesce in these blends, giving the appearance of broad dark lines or bands. It is somewhat difficult to unravel such blends, and for this purpose the enlarged comparison spectrum of α Cygni has been very helpful.

In measuring the spectrum of α Cygni it was noted that many of the lines have a diffused, ill-defined, and hazy appearance, especially in the region between H_δ and H_ϵ. This feature exactly corresponds with many of the dark lines in the spectrum of the Nova, which is another point of similarity between the two spectra. The tables on pp. 18 and 61 of the South Kensington publication *On Some of the Phenomena of New Stars* (Solar Physics Committee, 1914) have been consulted, and some additional coincidences between the lines and bands of the Nova and lines in α Cygni have been noted in the column of Remarks. The origins of the lines are for α Cygni, with some chromospheric lines.

My thanks are due to the Rev. B. Swindells, S.J., for much valuable assistance in the measuring of the plate, and in the reductions of the measures.

Wave-lengths of Dark Lines, and of Bright Lines and Bands in the Spectrum of Nova Aquilæ, 1918 June 10.

Wave-lengths. Dark Lines.	Intensity.	Bright Bands.	Intensity.	α Cygni.	Intensity.	Chromosphere.	Element.	Remarks.
5185	3					84		Positions as far as H obtained by extrapolation.
67	2			5169	6	*69	Fe	
45	2							
18	1							α Cygni lines to 4862 from S. Kensington.
		5080						
		50	8	5057	5			Centre of band.
		25		5019	7	*19	Fe	
5016	3						He	Centre of dark band.
		4970						
		53	8					Centre of bright band.
		37						
4936	3					34	Ba	
4924	4			4924	8	*24	Fe	4922 He.
		4918						
		09	10					Brighter sharp line in band.
		4894						Centre of bright band.
		4862	9	4862	8			
4858	7					62	H	$H\beta_1$.

Wave-lengths of Dark Lines, etc.—continued.

Wave-lengths. Dark Lines.	Intensity.	Bright Bands.	Intensity.	α Cygni.	Intensity.	Chromosphere.	Element.	Remarks.
4854	7	4854						$H\beta_2$.
		45	5					Centre of bright band
4844	6	36						$H\beta_1$.
4835	1					37		
10	1					11		
4776	3					76		*Ti 4780, S. Ken.
41	1					40		
24	1					23		
10	2					10		4713 He.
		4704	3					
		4674						4674 α Cygni, S. Ken.
4673	2					73		
		4672	3					4667, 4641 α Cygni, S. Ken.
		35						
34	2			4633	1	*34	Cr	S. Ken., α Cygni *4630, *4636 Fe, *4634 Cr.
		4634	3					
		24						4624. *Idem.*
22	2			4622	1	23		
		4620						
		10	5					Centre of bright band.
		4589						
4588	4			4587	1	*88	Cr	
		4588	5					*4584 Fe α Cygni, S. Ken.
		76						Narrow bright band.
74	4					75		
		4574	5					*4577 Fe α Cygni, S. Ken.
		67						Narrow bright band.
52	2					*50	Ti Fe	
		4551	6	4550	1			
		4536						
35	2			4536	2	*34	Ti	*4534 Ti α Cygni, S. Ken.
		4535	5					
		23						
4522	3			4523	3	*23	Fe	
18	1					19		
10	2					*09	Fe	
02	2					*02	Ti	

Wave-lengths of Dark Lines, etc.—continued.

Wave-lengths. Dark Lines.	Intensity.	Bright Bands.	Intensity.	α Cygni.	Intensity.	Chromosphere.	Element.	Remarks.
		4502 } 4496 }	4					
4495	1					95		
90	2			4490	2	*89	Fe	
82	6			81	4	*81	Mg	
71	8					*72	He	
		4469 } 46 }	2	4452	1	*51	Ti	S. Ken., α Cygni 4455 Fe.
44	3			44	1	*44	Ti	
		4442 }	3					4434. *Idem.*
		31 }	4	28	1			Maximum.
		20 }	3					
17	4			16	4	*18	Ti	4417* Fe.
05	1	16 } 4398 }	2			05	Fe	Bright band crossed by a dark line.
4397	1			4395	2	*95	Ti	
		4394 } 85 }	3			88	He	Helium band.
83	2			84	5	84	Fe	
		4382 } 74 }	3					
73	2					73		S. Ken. *4375 Ti.
67	2					*68	Ti	
60	1	4366 }	8			60	Cr	Complicated structure of H_γ bright bands.
52	3			53	3	*52	Cr	S. Ken. *4352 Fe.
		41 }		41	8	41		
4338	8							$H_{\gamma 1}$.
		38 } 29 }	8					
4326	6							$H_{\gamma 2}$.
19	2					19		
13	2			16	2	*13	Ti	
04	1			03	1	*04	Fe	
00	6					*00	Ti	Sharp, strong line.
4292	1					92		S. Ken. *4294 Ti.
87	2					*87		
80	1	4286 } 72 }	5	76	1	80		Bright band crossed by a dark line.

Wave-lengths of Dark Lines, etc.—continued.

Wave-lengths. Dark Lines.	Intensity.	Bright Bands.	Intensity.	α Cygni.	Intensity.	Chromosphere.	Element.	Remarks.
4272	1					72	Fe	Close double.
70	1							S. Ken. *4270 Cr.
		4268 61	5					Cr.
4260	1			4262	1	4262*	Cr	
57	1					58		
50	1	55 44	4			50	Fe	Bright band crossed by dark line. S. Kens., 4247 α Cygni, Sc.
43	3			43	2	*43	Cr	
37	1	41 32	5			37		Bright band crossed by dark line.
34	4			34	5	*33	Fe	α Cygni, sharp line.
		30 27	2					Very narrow band.
24	3			27	1	23		S. Ken. *4225 Cr.
21	1					21		
13	2					*12	Zr	
03	2	13 4180	4			03		Bright band crossed by dark absorptions.
00	1					01		
4193	1					4193		
89	1					88		S. Ken. *4188 Ni.
						81	C.	
76	3			4179	6	*79	Fe	α Cygni, broad lines.
72	3			75	6	*72	Ti	*73, Fe.
61	4					*61	Zr	S. Ken. *4164 Ti.
56	1	4160 52	4			*56	Zr	Bright band crossed by dark line.
49	1					*49	Zr	
42	2					*43		4144 He.
36	1	40 31	3			39 36		The H bright band consists of a series of narrow bands crossed by dark lines, and separated by narrow dark spaces.
				30	5	31	Si	
		23 17	2	22	1	21	He	
19	1					19		
						17		

Wave-lengths of Dark Lines, etc.—continued.

Wave-lengths. Dark Lines.	Intensity.	Bright Bands.	Intensity.	α Cygni.	Intensity.	Chromosphere.	Element.	Remarks.
		16				15		
4110	1	08	3	4109	1	*10		S. Ken. *4111 Cr.
06	3					07		
		06	3					Narrow bright band; edge corresponds to normal position of Hδ.
		02		02	9		Hδ	
4097	10							$H\delta_1$.
4084	10							$H\delta_2$.
		4084						Bright band, crossed by dark line.
4079	1	75	4	4077	1	*79	Ti	
								4078 Sr enhanced.
4074	4					74	Fe	S. Ken., α Cygni 4067.
4066	1					*67	Ni	
61	1					61		Close double.
60	2					59		S. Ken. *4058 Fe.
		4057	2	4053	1	*54	Ti	Narrow bright band.
		4052						
50	2							α Cygni; between Hδ and $H\epsilon$ a series of faint bands.
41	3							
		4038	1			*36	V	
		33						
32	2							
26	1			4026	2	27	Ti	He 4026.
21	1					*21	Sc	
09	4			4011	2	09		He 4009.
3999	2			3999	1	*99	Zr V	
		3999						
83	1							
69						70	H	H calcium.
65	10			3969	10	*69	Ca	Centre of dark line.
		63	5					$H\epsilon$.
61								
58								Dark wing to H.
50								$H\epsilon_1$.
		50	8					A very bright space.
		46						
39	1			3937	1			

Wave-lengths of Dark Lines, etc.—continued.

Wave-lengths. Dark Lines.	Intensity.	Bright Bands.	Intensity.	α Cygni.	Intensity.	Chromosphere.	Element.	Remarks.
3933								K calcium.
28	10			3934	.7	*34	Ca	
24								
24								Dark wing to K.
16								
16	4							
		3919	5					K_1 displaced.
		14						
3913	8			3913	5	*14	Ti	
		3908	5					
		3902						
				3905	4			S. Ken. *3906 Cr.
3899	7			3899	4	*01	Ti	
		3895	5					
		3888						
3881	9			3889	10		H	$H\zeta_1$ displaced.
3871	8							$H\zeta_2$,,
		3871	4					
3868	1							Bright band crossed by a dark line.
		3863						
3865		3865	1					Series of sharp bright lines in a broad dark band, possibly carbon band.
		3862	1	3862	3	62	Si	
	4	3858	1	55	4	55	Si	
		53	1	3850	1	50	Ni	S. Ken. *3850 Ni.
49		49	1					
43	2			44	1	44		
		42						
		39				36	$H\eta$	$H\eta$ 3836.
3829				27	3	27		$H\eta_1$ displaced.
20	8							
18	8			19	2	19		$H\eta_2$,,
13	6			13	4	13	Fe	S. Ken. *3915 Ti.
04	1					98	$H\theta$	
3789	8			3787	1	87	V	$H\theta_1$ displaced.
79	7			82	2	82		$H\theta_2$,,
						71	$H\iota$	
62	8							H_1 ,,
59	6			60	5	60	Fe	α Cygni double.

Wave-lengths of Dark Lines, etc.—continued.

Wave-lengths. Dark Lines.	Intensity.	Bright Bands.	Intensity.	α Cygni.	Intensity.	Chromosphere	Element.	Remarks.
3758	8					52	H_κ	H_{ι_2} displaced.
41	8			3741	1	*42	Ti	H_{κ_1} ,,
32	8					34	$H\lambda$	H_{κ_2} ,,
27	8							$H\lambda_1$,,
20	8					22	H_μ	$H\lambda_2$,,
14	8							H_{μ_1} ,,
08	8					12	H_ν	H_{μ_2} ,,
03	8					04	H_ξ	H_{ν_1} ,,
3694	8					97	H_o	H_{ξ_1} H_{ν_2} displaced blend.
89	8					92	H_π	H_{o_1} displaced.
85	8					87	H_ρ	H_{π_1} ,,
81	8					83	H_σ	H_{ρ_1} ,,
76	8					79	H_τ	H_{σ_1} ,,
73	8					76	H_υ	H_{τ_1} ,,
70	8					74	H_ϕ	H_{υ_1} ,,
68	5					71	H_χ	H_{ϕ_1} ,,
65	5							H_{χ_1} ,,
61	5							

Stonyhurst College Observatory:
1918 *November* 1.

The Dark Line Spectrum of Nova Geminorum No. 2.

By Joseph Lunt, D.Sc., F.I.C.

(*Communicated by S. S. Hough, M.A., F.R.S., H.M. Astronomer at the Cape.*)

A by-product of the investigation of the transient dark line spectrum of Nova Aquilæ No. 3 is the unexpected new light which has been thrown on the spectrum of Nova Geminorum No. 2.

Having ascertained that the former spectrum, apart from the strong hydrogen and calcium bands, consisted principally of the enhanced lines of titanium, iron, chromium, scandium, strontium, magnesium, and helium, displaced to the violet by an unprecedented amount, representing a radial velocity of over 1500 kilometres per second on June 11 and 12 (vide *Nature*, **102**, 194), an attempt was made to find lines common to the two spectra. The spectrum of Nova Geminorum has been very fully and care-