The Spectrum of "Nebulium."¹

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THE papers of Prof. J. W. Nicholson which appeared in the Monthly Notices of the Royal Astronomical Society about ten years ago seemed to hold, at the time, great promise of explaining the lines of unknown origin in the nebulae, and of co-ordinating these phenomena with those of new stars and with that other class of curious and intriguing celestial objects, the Wolf-Rayet stars.

That analytical connexions exist between the spectra of the latter and of the nebulae still remains an outstanding and unexplained contribution of this work, although the hypotheses underlying it seem to have been abandoned completely in the light of subsequent developments in a large number of fields.

by Plaskett, the following paper clearly indicates that the entire set of unknown lines can be arranged in a parabolic form which differs from any atomic series now known, and presents a set of relations that differ from those of any molecular band spectrum hitherto studied.

Taking the list of lines given by Wright in the Publications of the Lick Observatory, vol. 13, 1918, compiled from nine different nebulae, as being the best available source of information, we find 70 lines, 35 of which are of unknown origin and 18 of which are ascribed either to the Balmer series of hydrogen or to the Pickering series of ionised helium. The resolution in nebular spectra is utterly inadequate to distinguish between the Balmer hydrogen lines and

FIG. 1.

These by reason of the atomic number relationships seem to deny the possibility of the existence of transitional elements lying between hydrogen and helium. Although the striking confirmation of Nicholson's work by Fabry and Buisson with respect to the mass of the centres radiating the green nebular line of the Orion nebula is not now regarded as significant, the discovery of unknown nebular lines by Wright and Wolf in the positions actually foretold by Nicholson still remains a source of admiration to those who recall it, and a fact not attributable to coincidence.

Plaskett, in NATURE for September 15, 1923, suggests the hypothesis, very attractive in the light of recent work on band spectra, that the origin of unknown lines in the nebulae may be molecular. But, as he clearly points out, his identifications contain relatively so few lines in any given series that the correctness of his assignment seems still open to question.

Whatever the nature of the source, whether atomic as assumed by Nicholson, or molecular as suggested

the alternate members of the Pickering series which lie very near them in wave-length. Of the remaining lines, there are those of neutral helium, two ascribed to carbon and one to nitrogen.

Since the relationships described below were formulated, Dr. Wright has directed our attention to 11 other lines, 4 discovered by him in the red, and announced in Publications of the Astronomical Society of the Pacific, vol. 32, and 7 from other sources and less accurately known.

These 46 unknown lines (except one referred to later) are plotted in Fig. 1 according to wave numbers in the bottom row of the figure, together with 13 of the lines of ionised helium shown dotted. Taken all together they locate 61 points on five parabolas which cover the entire visible region. The wave numbers are plotted against consecutive integers (index number), and the vertices of the different parabolas have been arbitrarily placed at the same horizontal level, i.e. represented by the same index number, 8.

With the exception of I, these parabolas are as exactly alike as can be determined graphically where the scale is so large (three feet in the original) that

¹ Substance of a communication to the American Physical Society at Washington on April 25.

the accuracy of locating a point on it corresponds to the accuracy with which the wave number is known. The uncertainty of the less well known lines is indicated by dotted circles around their points.

Parabola I is slightly wider than the others. The axes of all are somewhat inclined, and all have quite closely the same inclination.

Curves I to IV were completed with some gaps before information of the 11 additional lines was at hand. Some of these fitted in the gaps awaiting them, and the others appeared to confirm the suspicion that there was one curve with vertex lying well into the ultra-violet which has been dotted in.

The individual branches contain 13+(2), 18+(2), 16+(1), and 8+(1) points respectively, for I, II, III, and IV. The dotted curve contains 6+(2) points, of which but one is known with precision of more than three significant figures. The numbers bracketed are doubtful identifications of points on the parabolas which lie so nearly in the same vertical line with other points, either on the other arm of the same curve or on one of the arms of another curve, as to make the resolution of these as two separate lines in nebular photographs well-nigh impossible.

Thirteen out of a total of 18 of the lines of ionised helium lie somewhat irregularly distributed on the same set of curves. It seems doubtful if the occurrence of so large a number as this can be attributed to an accidental occultation by an ionised helium line of a nebular line that falls very close to the same position. We incline to the interpretation that the radiation of the unknown lines is connected with that of ionised helium in some fashion.

There is but one apparently fortuitous occultation by a neutral helium line, $\lambda 3820 \text{ \AA. U.}$ of a possible position of a nebular line, on curve II. The other lines of neutral helium, carbon or nitrogen, have no relations to the curves. One of the lines of Wright's tables has not been included; this is $\lambda 4711.4$, given as occurring in but one of the nine nebulae from which he assembles the table, and it would seem that it cannot be differentiated with certainty from helium $\lambda 4713.3$, for which there seems to be no place in this arrangement. Of the 61 points on these curves, only one line has been assigned twice to different curves, and $H\beta$ has been used twice, on opposite branches of the same curve.

Because of the slight inclination of the axes of the parabolas, it would appear that their lower branches might intersect in the infra-red. Such extrapolation is very uncertain, but would appear to be not far from the position of the first line of the Pickering series $\lambda 10126.6 \text{ \AA. U.}$

Just what extension of our present atomic theories or what further contributions to our present theories of band spectra will provide an interpretation of these relationships is not clear. The quantising of at least one other property of the radiating source would appear necessary to obtain inclined parabolas in the latter field. We can only emphasise the fact that these are analytical relations distinctly suggestive of those hitherto attributed to molecular radiations. Furthermore, if there be significance in the fact that the ionised helium lines, themselves regulated by a Rydberg type formula, fit also on these parabolic lines, this suggests certain possibilities of

analytical cross relationships between these two radically different types of equation.

Detailed wave-lengths and wave-numbers and the individual line assignments are given in the tables appended.

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SUMMARY OF NEBULAR LINE ARRANGEMENT.

No.	λ .	$1/\lambda$.	H or He ⁺ .	Curve.				
				O.	I.	II.	III.	IV.
1	3313	3018-			(i) h (j)			
2	3342	2992-			k			
3	3346	2989-			g			
4	3426.2	29817			f			
5	3445	2903-		(e)	m			
5'	3629	2755-		f				
5''	3652	2738-		b				
5b	3712	2694-	ν		d			
5c	3722	2687-	μ			h		
6	3726.16	26837				g		
7	3728.91	26817				i		
8	3759	2660-				j		
8a	3771	2652-	ϵ			f		
8b	3798	2633-	θ		q			
8c	3820	2618-	(He)			k		
9	3840.2	26040		g				
10	3868.74	25848				e		
10a	3888.96	25714	ζ			l		
11	3935	2541-			c			
12	3967.51	25202			s	m		
13	4064	2461-				d		
14	4068.62	24578				n		
15	4076.22	24532						
15b	4101.74	24380	δ	h				
15c	4200	2381-	δ'			o		
15'	423-	236--		(i)				
15g	4340.46	23039	γ		t			
16	4353	2297-				c		
17	4363.21	22919				b		
18	4416	2264-			b			
18b	4541.4	22020	γ'				(g) h	
19	4571.5	21875				q	i	
19'	459-	217--						
19''	461-	216--		a				
20	4640.9	21547			u		j	
21	4658.2	21467	He ⁺				e	
22	4685.76	21314		j				
24	4725.5	21162					k	
25	4740.2	21096				(r)	d & l	
25a	4861.32	20574	β			b	m	
26	4958.91	20166				(s)	c & n	
27	5006.84	19973						
27'	518-	193--			a		o	
27''	531-	188--						
27b	5411.3	18480	β'			t		
28	5655	1768-					b	
29	5737	1743-					p	
30	5754.8	17377					q	
31	6302	1587-						d
32	6313	1584-						e
33	6364	1571-						c
34	6548.1	15272					a	g
34a	6562.8	15237	α					
35	6583.6	15189						b
36	6730	14859			a			(h)
37	7009	1426-						i
38	7065	1415-						a
39	7138	1401-					r	
40	7325	1365-						j
Totals	45 Nu	He+13	He ₁	6+(2)	13+(2)	18+(2)	16+(1)	8+(1)

DETAILS OF MISSING LINES.

		$1/\lambda$.	λ .
O.	(c-d)	3000	3333
I.	e	2824	3542
	l	2952	3388
	n	2848	3511
	o	2788	3587
	p	2720	3676
III.	f	2182	4583
IV.	f	1560	6410