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The Spectrum of $ \gamma $ Cygni

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VII. *The Spectrum of γ Cygni.*

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[Plate 1.]

In a paper on "The Chemical Classification of the Stars," communicated to the Royal Society on May 4, 1899,* one of us indicated that it was then possible to classify the stars according to their chemistry. In the case of type stars of some of the groups lists have been given† of the wave-lengths and probable origins of the lines on which the classification is based. The type stars thus dealt with represent the groups of higher temperature, viz., α Cygni (Cygnian), Rigel (Rigelian), ζ Tauri (Taurian), Bellatrix (Crucian), ε Orionis (Alnitamian), and Sirius (Sirian).

The spectrum of stars of the Polarian type—representing a temperature stage next lower than that of α Cygni,—is, so far as the relative intensities of the metallic lines are concerned, closely allied to that of the chromosphere. It is also interesting as the connecting link between the spectrum of the Aldebarian stars, in which the arc lines of the metallic elements predominate, and that of α Cygni, chiefly composed of the enhanced lines of some of the metals. It has hence been thought important to make a careful reduction of the spectrum of a star of this group. Of the existing photographs of Polarian type spectra at Kensington, that of γ Cygni is the best for the purpose of reduction, and for this reason has been selected.

Method of Reduction.

The wave-lengths have been determined by measuring the relative positions of the lines on the plate with a micrometer, and subsequent use of Hartmann's interpolation formula. In selecting the lines to be used as bases for the reduction, only sharply-defined lines with well-authenticated origins, and of the simple nature of which there

* 'Roy Soc. Proc.,' vol. 65, p. 186.

† 'Catalogue of 470 Brighter Stars,' published by the Solar Physics Committee.

is little doubt, were taken; lines which were suspected, however slightly, of having a double or complex origin were rejected. A list of the lines used is here given :—

λ.	Origin.	λ.	Origin.
3900·68	*p* Ti	4501·45	*p* Ti
4012·54	*p* Ti	4584·02	*p* Fe
4215·70	*p* Sr	4657·38	*p* Ti
4415·29	Fe	4780·20	*p* Ti

The result of a previous reduction of the spectrum of α Cygni, already published, serves as a valuable check on the accuracy of the reduced wave-lengths, as there are many lines common to the two spectra, and there can be no doubt as to the identity of most of the stronger α Cygni lines with enhanced lines of some of the metals, as has been shown in a previous paper.*

In the table at the end of the paper the γ Cygni lines are compared with those reduced at Kensington from the spectrum of α Cygni and that of the chromosphere, and also with those recorded by PICKERING† in the spectrum of δ Canis Majoris. The latter star is selected by PICKERING as typical of Group XIIIc. in his classification, in which group he also includes γ Cygni. In the case of the chromosphere, in order to keep the table within moderate limits, only those lines which agree with γ Cygni lines have been inserted, but of the chromospheric lines omitted none are prominent except those of helium.

Comparison of γ Cygni and Chromosphere.

Reference to the table will show that the metallic and protometallic lines have, speaking broadly, about the same relative intensities in the spectra of γ Cygni and the chromosphere. It would thus appear that the temperature and electrical conditions prevailing in the chromospheric vapours which furnish the metallic lines are nearly identical with those appertaining to the absorbing atmosphere of γ Cygni. To arrive at any conclusion as to which of the two light sources in question represents the higher temperature, it is necessary to study in detail the comparative intensities of well-known lines. For this purpose, two sets of lines have been considered: (1) the strongest unenhanced lines of the metals represented; (2) the most marked enhanced lines of the metals. In the following table a comparison is given of the intensities of the strongest lines of iron, manganese, chromium, cobalt, barium, calcium, aluminium, and titanium, as they occur in γ Cygni and the chromosphere.

* 'Roy. Soc. Proc.,' vol. 64, p. 321.

† 'Annals Harv. Coll. Obs.,' vol. 28, Part I., p. 79.

COMPARATIVE Intensities of the Strongest Metallic Lines in γ Cygni and the Chromosphere.

Strongest arc lines. λ.	Origin.	Intensity.		Strongest arc lines. λ.	Origin.	Intensity.	
		γ Cygni. Max. = 10.	Chromosphere. Max. = 10.			γ Cygni. Max. = 10.	Chromosphere. Max. = 10.
{ 4045·98	Fe	8	7	4528·80	Fe	4	3
{ 4063·76	Fe	8	6–7	4030·92	Mn	5	5
{ 4071·91	Fe	5	6	4033·22	Mn	4	3–4
4132·24	Fe	5–6	3	3995·46	Co	5	3–4
4144·04	Fe	8	5–6	4226·90	Ca	8	7
4202·20	Fe	5	3	3989·91	Ti	4	2–3
4260·64	Fe	6	4	3998·79	Ti	5	4
4271·33	Fe	6 }	4–5	3944·16	Al	3–4	5
4271·93	Fe	6 }		3961·67	Al	5–6	6
{ 4383·72	Fe	4–5	5	4554·21	Ba	5–6	7–8
{ 4404·93	Fe	3–4	4	4254·51	Cr	4	6
{ 4415·29	Fe	5–6	4	4274·96	Cr	4	5

These intensities cannot be accepted as absolute, but as the same limits (1 to 10) are used in the two spectra, it may be conceded that the intensities are roughly comparable. It will be noticed that in the majority of cases the lines appear to be somewhat weaker in the chromosphere than in γ Cygni. Notable exceptions, however, to this are the lines of aluminium, chromium, and barium.

In the next table, the intensities of the more prominent enhanced lines of iron, magnesium, chromium, titanium, and strontium are similarly compared.

COMPARATIVE Intensities of Enhanced Lines in γ Cygni and the Chromosphere.

Enhanced lines. λ.	Origin.	Intensity.		Enhanced lines. λ.	Origin.	Intensity.	
		γ Cygni. Max. = 10.	Chromosphere. Max. = 10.			γ Cygni. Max. = 10.	Chromosphere. Max. = 10.
4233·33	*p* Fe	7–8	6–7	4399·94	*p* Ti	5–6	5–6
{ 4508·46	*p* Fe	4	5	4443·98	*p* Ti	9	7
{ 4515·51	*p* Fe	4	4	4450·65	*p* Ti	4	5
{ 4520·40	*p* Fe	3	3	4468·66	*p* Ti	6	6
{ 4522·69	*p* Fe	4	4	4501·45	*p* Ti	6	7
4549·64	*p* Fe	8	7–8	4534·14	*p* Ti	6	7–8
4584·02	*p* Fe	8	7	4549·81	*p* Ti	8	7–8
3900·68	*p* Ti	4–5	4	4563·94	*p* Ti	4–5	7–8
3913·61	*p* Ti	4	6	4572·16	*p* Ti	6–7	7
4012·54	*p* Ti	5	5–6	4558·83	*p* Cr	3	3–4
4161·68	*p* Ti	6–7	3	4588·38	*p* Cr	3	3
4163·82	*p* Ti	5–6	4	4077·89	*p* Sr	8	10
4300·21	*p* Ti	6	5	4215·70	*p* Sr	9	10
4321·20	*p* Ti	8	5	4481·30	*p* Mg	5–6	—
4338·08	*p* Ti	9	5				

Here we find that of the 29 lines included 12 have a greater intensity in γ Cygni, 11 in the chromosphere, while 6 have been estimated as having equal intensities in the two spectra, thus showing a very evenly-balanced state of affairs.

Taking the two comparisons together, it would appear that the evidence points to the unenhanced lines being, upon the whole, somewhat weakened in the chromosphere at the expense of the enhanced lines. This result tends to show that if any distinction is to be made between the temperature conditions of the two light sources in question, the chromosphere must be placed on a slightly higher level.

The most marked difference between the spectrum of γ Cygni and that of the chromosphere occurs in the case of the helium lines. There is no evidence of their presence in the former spectrum, while in the latter the stronger helium lines are quite conspicuous. We do not, however, know much about the relative positions of the helium vapour and the metallic vapours in the chromosphere, and it is quite possible that the temperature conditions of the two are vastly different. Another notable difference between the two spectra is in regard to the well-known enhanced line of magnesium, λ 4481·3. This is fairly prominent in γ Cygni, but appears to be entirely lacking in the chromospheric spectrum. As the enhanced lines of other elements are well developed in the chromospheric spectrum, this is a very curious result, and difficult to account for, especially as the line in question is well marked in both γ Cygni and α Cygni, between which the chromosphere must apparently be placed from temperature considerations.

In the transition from stars resembling the Sun, through γ Cygni (Polarian), the chromosphere, to α Cygni (Cygnian), the gradual strengthening or weakening of well-known groupings of metallic lines can be traced. There cannot be any doubt about the authenticity in the spectra of γ Cygni and the chromosphere of such groups and pairs of metallic lines as the aluminium pair ($\lambda\lambda$ 3944·16, 3961·67), manganese triplet ($\lambda\lambda$ 4030·88, 4033·22, 4034·64), iron triplets ($\lambda\lambda$ 4045·98, 4063·76, 4071·91) and ($\lambda\lambda$ 4383·72, 4404·93, 4415·29), chromium triplet ($\lambda\lambda$ 4254·51, 4274·96, 4289·89), and the enhanced iron quartette ($\lambda\lambda$ 4508·46, 4515·51, 4520·40, 4522·69).

Moreover, reference to the Kensington publications of eclipse results,* in addition to those of FROST,† EVERSHED,‡ MITCHELL,§ and HUMPHREYS|| will show that there is a general consensus of opinion that the chromospheric lines have, upon the whole, metallic origins. This is entirely at variance with the conclusion arrived at by Professor DEWAR, and embodied in his Presidential Address to the British Association, 1902, that the chromospheric lines are to be accounted for by the lines of krypton, xenon, and those of the most volatile atmospheric gases. In this connection,

* 'Phil. Trans.,' A, vol. 197, p. 208.

† 'Astrophysical Journal,' vol. 12, p. 307.

‡ 'Phil. Trans.,' A, vol. 197, p. 381.

§ 'Astrophysical Journal,' vol. 15, p. 97.

|| 'Astrophysical Journal,' vol. 15, p. 313.

he says,* "In the 'Astrophysical Journal' for June last is a list of 339 lines in the spectrum of the corona, photographed by HUMPHREYS. . . . . Of these, no fewer than 209 do not differ from lines we have measured in the most volatile gases of the atmosphere, or of krypton, or xenon, by more than one unit of wave-length on ÅNGSTRÖM's scale, a quantity within the limit of probable error."

It may be here pointed out that HUMPHREYS' list of 339 lines referred to the spectrum of the solar chromosphere, and not to that of the corona. The latitude allowed (one tenth-metre) in comparing the wave-lengths of the lines in the solar and terrestrial spectra is far greater than can be accepted in modern exact work, and as the average error of HUMPHREYS' wave-lengths is probably less than 0·2 tenth-metre, it is obvious that, until Professor DEWAR can give the wave-lengths of his lines to a greater accuracy than that of the nearest tenth-metre, little weight can be attached to the results of his comparison. His conclusion, moreover, appears to have been based merely on apparent similarity of wave-lengths, without taking into account the relative intensities of the lines in the spectra compared, or of the correspondence of conspicuous groupings of lines, which would certainly tend to clear matters.

The extreme limits of HUMPHREYS' 339 eclipse lines are, roughly speaking, 2000 tenth-metres apart, which gives an average interval of 6 tenth-metres. In Professor DEWAR's three lists of gaseous lines there occur between the same limits 564 lines, with an average interval of 4 tenth-metres. If we assume, then, that the lines of each set are evenly distributed over the region involved, there will be certain to be a large number of lines in the two sets which agree in position within the limits of error allowed (one tenth-metre).

Many lines have gaseous origins assigned to them which have been hitherto universally acknowledged by the various workers in the subject to be representatives of well-known metallic lines, and groups of lines previously given as due to some particular metal are split up by Professor DEWAR's analysis, some members being ascribed to krypton, others to xenon, &c., while other members remain clear of his gaseous lines. The following table contains several groups of chromospheric lines, which are all included in both HUMPHREYS' list† and that given in the Kensington eclipse publication,‡ and which have been ascribed to the same metals in the two records. In the comparison column, LIVEING and DEWAR's gaseous lines are given which agree within one tenth-metre (this being the difference accepted by Professor DEWAR in his analytical comparison) with the chromospheric lines.

* 'Nature,' vol. 66, p. 475.

† 'Astrophysical Journal,' vol. 15, p. 318.

‡ 'Phil. Trans.,' A, vol. 197, p. 208.

COMPARISON of Groups of Chromospheric Lines belonging to Various Metals with LIVEING and DEWAR'S Gaseous Lines.

Chromosphere (HUMPHREYS). λ.	Origin.		Atmospheric Gases (LIVEING and DEWAR).		
	HUMPHREYS.	Kensington.	Most volatile.	Xenon.	Krypton.
{ 3829·5	Mg	Mg	3830	3829	—
{ 3832·5	Mg	Mg	—	—	—
{ 3838·4	Mg	Mg	—	—	—
{ 3944·0	Al	Al	—	3944·0	—
{ 3961·6	Al	Al	—	—	—
{ 4046·0	Fe	Fe	4047	—	4045
{ 4063·7	Fe	Fe	—	—	—
{ 4071·9	Fe	Fe	—	—	—
{ 4077·9	Sr	*p* Sr	—	—	—
{ 4215·7	Sr	*p* Sr	—	4215	—
{ 4254·5	Cr	Cr	—	—	—
{ 4274·9	Cr	Cr	—	—	—
{ 4289·9	Cr	Cr	4290	—	—
{ 4383·6	Fe	Fe	—	—	—
{ 4404·9	Fe	Fe	—	—	—
{ 4415·2	Fe	Fe	4415	—	—
{ 4508·5	Fe ?	*p* Fe	4508	—	—
{ 4515·5	—	*p* Fe	—	—	—
{ 4520·7	Fe ?	*p* Fe	—	—	—
{ 4522·9	Ti	*p* Fe	4523	—	—

From this comparison it would appear that Professor DEWAR claims for xenon, one member of the magnesium triplet (λλ 3829·5–3838·4), one component of the aluminium double (λλ 3944·0, 3961·6) and one member of the strontium pair (λλ 4077·9, 4215·7); for krypton one member of the iron triplet (λλ 4046·0–4071·9); and for the most volatile gases, one member of the magnesium triplet, one of each of two iron triplets, one of a chromium triplet, and two members of the enhanced iron quartette (λλ 4508·5–4522·9). It is, of course, quite possible that some of these gaseous lines may account for the coronal lines; but that the chromospheric lines are, in the main, produced by metallic vapours, there can be no doubt.

Comparison of γ Cygni and α Cygni.

It will be seen that there is a much greater number of lines in the spectrum of γ Cygni than in that of α Cygni. The lines occurring solely in γ Cygni which have been traced to any terrestrial origin are found to be attributable to the ordinary metallic arc lines, as distinguished from the enhanced lines. These, which occur so prominently in α Cygni, are, with certain exceptions, present also in γ Cygni, so that the latter spectrum practically consists of the α Cygni spectrum (with modifications of the intensities of the enhanced lines of various metals) with the ordinary arc lines added, and the two sets are of about equal importance. This is a condition of affairs intermediate to that of the Aldebarian stars—in which the ordinary lines are well-developed and the proto-metallic lines weak or missing—and α Cygni, where the enhanced lines are very prominent, to the nearly total exclusion of the metallic arc lines.

The only line of any prominence which occurs solely in α Cygni is the silicium line λ 4131·1 This is one component of the silicium double which is so conspicuous in the spectra of α Cygni, Rigel, Sirius, &c. There is certainly a line in γ Cygni apparently coincident with the other component λ 4128·1, but in the absence of its companion it must be concluded that the γ Cygni line in question has probably an origin entirely distinct from silicium. The silicium double mentioned is also absent from the chromospheric spectrum, which closely resembles that of γ Cygni.

In a paper "On the Order of Appearance of Chemical Substances at different Stellar Temperatures,"* it was pointed out that the enhanced lines of the various metals attained a maximum intensity at varying levels of the stellar temperature sequence. The present detailed investigation of the γ Cygni spectrum confirms this result, the enhanced lines of strontium, scandium, and titanium being at their strongest in γ Cygni and much stronger than in α Cygni, while in the latter spectrum the enhanced lines of iron, chromium, and magnesium, attain their maximum intensity, being more prominent than in γ Cygni.

Of the better known arc lines of some of the metals which are prominent in γ Cygni, but very weak or lacking in α Cygni, the following may be mentioned: the iron triplets (λλ 4045·98, 4063·76, 4071·91) and (λλ 4383·72, 4404·93, 4415·29); the manganese quartette (λλ 4030·92, 4033·22, 4034·64, 4035·80); the chromium triplet (λλ 4254·51, 4274·96, 4289·89); the aluminium pair (λλ 3944·16, 3961·67); the calcium line, λ 4226·90; and the barium line, λ 4554·21.

General Conclusions.

The investigation of the photographic spectrum of γ Cygni in its relation to other spectra has led to the following conclusions:—

1. The majority of the lines are due to metallic vapours, the enhanced lines and the arc lines being of about equal prominence.

2. The temperature conditions are thus intermediate between those of Aldebaran

* 'Roy. Soc. Proc.,' vol. 64, p. 396.

(arc lines prominent, enhanced lines weak or absent) and those of α Cygni (enhanced lines prominent, arc lines weak or absent).

3. The enhanced lines of scandium, strontium, and titanium are better developed than in α Cygni, but those of iron, chromium, and magnesium are less conspicuous than in α Cygni.

4. The relative intensities of the metallic and proto-metallic lines are about the same as in the spectrum of the solar chromosphere, which, if anything, represents a slightly higher temperature.

Wave-lengths, Intensities, and Probable Origins of γ Cygni Lines, compared with those of δ Canis Majoris, the Chromosphere, and α Cygni.

γ Cygni (Kensington).				δ Canis majoris (Harvard).		Chromosphere (Kensington).		α Cygni (Kensington).		Remarks.
λ.	Intensity. Max. =10.	Probable origin.	λ of probable origin.	λ.	Intensity. Max. =220.	λ.	Intensity. Max. =10.	λ.	Intensity. Max. =10.	
3872·9	5	Fe	3872·64	3872·7	7	3872·6	4	3872·4	3	
76·0	3	Fe	76·19	—	—	76·1	1–2	—	—	
78·8	7	Fe	78·72	78·5	5	78·7	3	78·7	4	
80·6	1–2	—	—	—	—	80·8	2	80·5	1–2	
82·4	3	—	—	—	—	82·5	2	82·2	2	
83·5	1	? C	83·55	83·2	3 ?	83·4	4	—	—	
85·1	2	Fe	84·81 85·29	— —	— —	— —	— —	84·5 —	1–2 —	 ? double.
86·9	3–4	Fe	87·20	—	—	87·2	2–3	86·3	2	
89·1	5	H	89·15	89·1	11 ?	89·1	8	89·1	10	Hζ.
91·1	1	Fe	90·99	—	—	91·4	2	—	—	
91·9	2–3	Fe	92·07	—	—	92·2	2	—	—	
93·6	1–2	Fe	93·54	—	—	94·0	2	—	—	? double.
96·1	4–5	Fe	95·80	—	—	95·7	3	95·8	2	? fine double.
98·0	3–4	Fe Y	98·03 98·15	—	—	98·0	2	98·1	1–2	
99·4	3	*p* V	99·30	99·9	2	99·2	2	—	—	
3900·7	4–5	*p* Ti	3900·68	3900·7	7	3900·7	4	3900·7	5–6	
03·2	4–5	Fe	03·09	03·1	3	03·1	2–3	03·4	2	
03·8	2	Fe	04·05	—	—	—	—	—	—	
05·6	4	Si *p* Cr	05·66	—	—	05·3	2	05·7	4	
06·7	4	Fe	06·63 06·89	06·6	4	06·8	2	06·7	2	
08·7	2–3	Cr	08·90	—	—	08·4	1	09·0	1	
09·8	2–3	Fe	09·80 09·98	—	—	09·6	<1	—	—	
11·0	3	Fe V	10·98	—	—	—	—	11·5	1	
12·4	2	? Ni	12·45	—	—	—	—	—	—	
13·6	4	*p* Ti	13·61	13·6	3	13·6	6	13·6	4–5	
14·5	4	Fe Ti	14·43 14·48	—	—	—	—	14·5	3	
16·1	4	Cr	15·95	—	—	16·2	3	16·4	<1	
16·7	4	Fe	16·88	—	—	—	—	—	—	
18·7	4–5	Fe	18·46 18·56 18·79	—	—	18·6	3	18·8	<1	? double.
20·7	4	Fe	20·44	—	—	20·4	3	20·4	1	? double.
22·9	3–4	Fe	23·05	—	—	23·1	3	23·1	<1	
26·2	3	Fe	26·09	—	—	25·9	2	26·2	1	Broad line.
—	—	—	—	—	—	—	—	28·2 30·4 32·1	1 2–3 1	Probably masked in γ Cygni by broad K line.

Wave-lengths, Intensities, and Probable Origins of γ Cygni Lines, compared with those of δ Canis Majoris, the Chromosphere, and α Cygni—*continued.*

γ Cygni (Kensington).				δ Canis majoris (Harvard).		Chromosphere (Kensington).		α Cygni (Kensington).		Remarks.
λ.	Intensity. Max. =10.	Probable origin.	λ of probable origin.	λ.	Intensity. Max. =220.	λ.	Intensity. Max. =10.	λ.	Intensity. Max. =10.	
3933 ·8	10	Ca	3933 ·83	3933 ·8	220	3933 ·8	10	3933 ·8	10	
—	—	—	—	—	—	—	—	36 ·0 37 ·3 38 ·6 39 ·3	3 1 3 3	Possibly masked in γ Cygni by broad K line.
41 ·0	2–3	Fe	41 ·03	—	—	—	—	41 ·8	<1	
42 ·5	3	Fe	42 ·59	—	—	41 ·9	1–2	42 ·6	<1	
44 ·1 45 ·2	3–4 6	Al *p* Y Fe Fe	44 ·16 44 ·94 45 ·03 45 ·26	44 ·1 — — 45 ·2	3	44 ·2 45 ·2	5 2	44 ·2 45 ·2	<1 3	
—	—	—	—	—	—	—	—	47 ·2	1	
47 ·9	1	? Ti	47 ·92	—	—	—	—	—	—	
48 ·9	2–3	Ti Fe	48 ·82 48 ·93	49 ·0	3	48 ·6	2–3	—	—	
50 ·1	4	Fe	50 ·16	—	—	50 ·3	2–3	—	—	
51 ·3	4	Fe	51 ·31	—	—	51 ·8	1	—	—	
52 ·7 to 53 ·3	6	Fe Fe Mn Co Fe Cr	52 ·75 52 ·85 53 ·04 53 ·12 53 ·30	53 ·0	4	52 ·3	3–4	52 ·1	1–2	Broad hazy line, probably including all the solar lines given.
55 ·5	1	Fe	55 ·48	—	—	—	—	54 ·4	<1	
56 ·6	6	Co Ti Fe Fe	56 ·48 56 ·60 56 ·82	56 ·6	2	56 ·6	4	56 ·6	1	Probably compound line.
58 ·4	4–5	Ti	58 ·36	58 ·4	2	58 ·2	4	59 ·0	1	
60 ·0	1	—	—	—	—	—	—	—	—	
61 ·7	5–6	Al	61 ·67	61 ·6	3	61 ·7	6	61 ·6	2	
63 ·3	2	Fe	63 ·25	—	—	63 ·3	1	—	—	
— —	— —	— —	— —	— —	— —	— —	— —	64 ·9 66 ·4	1 1	Possibly masked in γ Cygni by broad H line of calcium.
68 ·6 70 ·2	10	Ca H	68 ·63 70 ·18	68 ·6 70 ·2	180	68 ·6 70 ·2	10 10	68 ·6 70 ·2	10 10	
—	—	—	—	—	—	—	—	71 ·4	1	Possibly masked in γ Cygni by broad H line of calcium.
73 ·8	4	Ni Zr Fe Ca *p* V	73 ·70 73 ·80 73 ·86	—	—	73 ·5	2	74 ·0	3–4	
74 ·9	4	Co Fe	74 ·90	—	—	—	—	—	—	
76 ·8	3–4	Fe Cr	76 ·77 76 ·84	76 ·8	2	76 ·7	1	—	—	
77 ·9	2–3	Fe	77 ·89	—	—	77 ·8	2	77 ·3	1	
78 ·6	2	—	—	—	—	78 ·1	Tr	—	—	
79 ·7	3	*p* Cr Co Fe	79 ·66 79 ·78	—	—	79 ·3	1	79 ·6	3	
81 ·9	7	Ti	81 ·92	82 ·0	6	82 ·0	6	82 ·0	2–3	Very broad line.
84 ·0	3–4	Cr Fe	84 ·06 84 ·11	—	—	83 ·8	1	—	—	
86 ·2	3	Fe	86 ·32	—	—	86 ·3	1–2	—	—	
87 ·3	3	? Mn	87 ·24	87 ·0	3	—	—	—	—	
88 ·6	3	—	—	—	—	88 ·3	1	—	—	
89 ·9	4	Ti Fe	89 ·91 90 ·01	—	—	89 ·9	2–3	—	—	
91 ·1	3-4	Cr Zr	91 ·33	91 ·6	2	91 ·3	3	—	—	
92 ·1	1–2	—	—	—	—	—	—	—	—	

Wave-lengths, Intensities, and Probable Origins of γ Cygni Lines, compared with those of δ Canis Majoris, the Chromosphere, and α Cygni—*continued*.

γ Cygni (Kensington).				δ Canis majoris (Harvard).		Chromosphere (Kensington).		α Cygni (Kensington).		Remarks.
λ.	Intensity. Max. =10.	Probable origin.	λ of probable origin.	λ.	Intensity. Max. =220.	λ.	Intensity. Max. =10.	λ.	Intensity. Max. =10.	
3993 ·7	2	—	—	—	—	—	—	3993 ·7	<1	
95 ·5	5	Co	3995 ·46	3995 ·5	3	3995 ·2	3–4	95 ·7	<1	
97 ·3	5	Fe	{ 97 ·11 97 ·55 }	97 ·6	} 6	{ 97 ·7	3	97 ·3	1	
98 ·9	5	Ti	98 ·79	98 ·8		98 ·8	4	—	—	
4000 ·1	3	—	—	—	—	4000 ·4	1–2	4000 ·0	1	
01 ·8	3–4	Fe	4001 ·81	—	—	—	—	—	—	
03 ·0	3	—	—	4003 ·0	3	03 ·3	1	02 ·7	3–4	
04 ·0	2	Ce Fe Ti	03 ·91	—	—	—	—	—	—	
—	—	—	—	—	—	—	—	04 ·9	<1	
05 ·4	8	Fe	05 ·41	05 ·3	4	05 ·4	5	05 ·5	2–3	
06 ·8	1	—	—	—	—	06 ·8	1–2	—	—	
09 ·9	2–3	Fe	09 ·86	09 ·4	1	09 ·5	2–3	09 ·4	1	
12 ·5	5	*p* Ti	12 ·54	12 ·6	3	12 ·5	5–6	12 ·5	4	
14 ·4	2	Fe	14 ·42	—	—	} 14 ·5	3	14 ·1	<1	
14 ·8	3–4	Fe	14 ·68	14 ·7	3					
15 ·8	2	—	—	—	—	—	—	15 ·7	2–3	
17 ·2	3	{ Un Fe	17 ·24 17 ·31 }	—	—	17 ·5	2	17 ·2	<1	
18 ·1	3–4	Mn	{ 18 ·23 18 ·27 }	18 ·4	2	18 ·5	1	—	—	
20 ·6	1–2	{ Sc Fe	20 ·55 20 ·64 }	—	—	20 ·6	<1	—	—	
22 ·0	3–4	Fe	22 ·02	22 ·0	2	21 ·6	3	—	—	
23 ·2	3–4	—	—	—	—	23 ·1	1	23 ·6	1–2	
24 ·8	7	{ Ti Fe	24 ·73 24 ·88 }	24 ·8	5	24 ·7	3	24 ·6	3	
25 ·7	1	—	—	—	—	—	—	25 ·2	1	
28 ·5	4	*p* Ti	28 ·50	28 ·5	2	28 ·5	2–3	28 ·5	3	
29 ·8	2	Fe	29 ·80	—	—	—	—	—	—	
30 ·8	5	Mn	30 ·92	30 ·8	5	30 ·9	5	30 ·9	1	
33 ·2	4	Mn	33 ·22	33 ·2	2	33 ·2	3–4	33 ·2	2–3	
34 ·6	3	Mn	34 ·64	34 ·6	1	34 ·6	3–4	34 ·6	<1	
35 ·9	2	{ Mn *p* V	35 ·80 35 ·80 }	35 ·8	1	35 ·9	1	35 ·8	2	
37 ·3	1	—	—	37 ·2	1	37 ·7	1	—	—	
—	—	—	—	—	—	—	—	38 ·3	1–2	
40 ·8	2–3	Fe	40 ·79	40 ·8	2	40 ·8	4	40 ·4	<1	{ Close double, components merging into each other.
41 ·5	5	Mn	41 ·53	—	—	—	—	41 ·9	<1	
43 ·0	1–2	? La	43 ·05	—	—	43 ·4	1	—	—	
44 ·4	1	{ Fe Fe	44 ·06 44 ·77 }	—	—	44 ·4	1	44 ·4	1–2	{ Probably close double.
46 ·0	8	Fe	45 ·98	45 ·9	4	45 ·9	7	46 ·0	3–4	
47 ·5	1	Fe	47 ·46	—	—	—	—	—	—	
48 ·9	4	{ *p* Fe Mn Cr	48 ·82 48 ·91 }	48 ·9	1	49 ·0	3	48 ·9	3	
50 ·6	2	—	—	50 ·8	1	51 ·0	1	—	—	
52 ·5	2	Fe	{ 52 ·45 52 ·65 }	52 ·6	1	—	—	52 ·3	2	
54 ·0	4–5	{ *p* Ti *p* V	} 53 ·98	53 ·8	2	53 ·8	3	53 ·9	3	
55 ·2	2	{ *p* Ti *p* Fe	55 ·19 55 ·63 }	—	—	55 ·6	2	—	—	
56 ·2	2	—	—	—	—	—	—	—	—	
57 ·6		{ Fe	57 ·50	—	—	57 ·4	1–2	57 ·6	1	} ? Double.
to	} 2	Co Fe	58 ·37	—	—	58 ·2	1–2	—	—	
58 ·8		Fe Cr	58 ·92	59 ·0	1	59 ·2	1–2	—	—	
61 ·3	2	? Ni	61 ·24	—	—	61 ·2	1–2	—	—	

Wave-lengths, Intensities, and Probable Origins of γ Cygni Lines, compared with those of δ Canis Majoris, the Chromosphere, and α Cygni—*continued.*

γ Cygni (Kensington).				δ Canis majoris (Harvard).		Chromosphere (Kensington).		α Cygni (Kensington).		Remarks.
λ.	Intensity. Max. =10.	Probable origin.	λ of probable origin.	λ.	Intensity. Max. =220.	λ.	Intensity. Max. =10.	λ.	Intensity. Max. =10.	
4063 ·8	8	Fe	4063 ·76	4063 ·7	7	4063 ·7	6–7	4063 ·8	2	
65 ·2	1–2	Mn Ti Fe	65 ·24 65 ·54	—	—	—	—	—	—	
67 ·3	8	Fe *p* Ni Fe	67 ·14 67 ·30 67 ·43	67 ·0	5	67 ·3	3	67 ·2	4	
70 ·9	1	Fe	70 ·93	—	—	—	—	70 ·0	1	
71 ·9	5	Fe	71 ·91	71 ·9	4	71 ·8	6	71 ·9	2	
73 ·7	3–4	? Fe	73 ·92	—	—	73 ·9	1	—	—	
75 ·6	2	—	—	75 ·0	1	75 ·3	1	75 ·6	1	
77 ·9	8	*p* Sr	77 ·89	77 ·9	8	77 ·9	10	77 ·9	3	
79 ·4	2	Fe Mn	79 ·34 79 ·39	—	—	—	—	—	—	
80 ·4	1–2	Fe	80 ·37	—	—	80 ·3	1–2	80 ·0	<1	
82 ·8	1–2	Sc Fe Ti Mn	82 ·59 83 ·10	—	—	83 ·1	2	82 ·0	<1	
83 ·7	4–5	Fe Mn Y	83 ·72 83 ·78	83 ·8	2	84 ·0	1	—	—	
85 ·3	4–5	Fe	85 ·16 85 ·47	85 ·4	1	85 ·0	1–2	86 ·2	<1	Probably close double.
86 ·9	4–5	? La	86 ·86	87 ·2	3	86 ·7	3			
89 ·0		Fe	88 ·73 89 ·37	—	—	—	—	—	—	
90 ·5	3	—	—	90 ·2	1	—	—	—	—	
92 ·6	4	Fe Co Mn V	92 ·43 92 ·55 92 ·82	92 ·7	1	92 ·5	2	92 ·5	1	
94 ·6	1	—	—	—	—	—	—	94 ·5	<1	
96 ·2	4	Fe Fe	96 ·13 96 ·26	96 ·2	2	96 ·2	1–2	—	—	Rather broad, possibly double.
98 ·5	4	Fe	98 ·34	98 ·5	1	98 ·2	1	—	—	
4100 ·6	2	? Fe	4100 ·90	—	—	—	—	4100 ·3	1	Merging into H_δ.
02 ·0	8	H	02 ·00	4101 ·8	11	4101 ·9	10	01 ·8	10	H_δ.
04 ·1	2	Fe	04 ·29	—	—	—	—	—	—	
05 ·2	1	? V	05 ·32	—	—	—	—	—	—	
06 ·6	3	Fe Fe	06 ·42 06 ·58	06 ·6	1	—	—	—	—	
07 ·8	3	Fe	07 ·65	—	—	07 ·6	2	—	—	
09 ·9	5	V Fe	09 ·91 09 ·95	10 ·4	4	09 ·9	3	—	—	
11 ·5	4	—	—	11 ·0	?	11 ·9	1	11 ·2	2	
13 ·5	3	—	—	13 ·1	1	—	—	13 ·3	<1	
15 ·4	3–4	V	15 ·33	14 ·7	1	—	—	—	—	
17 ·5	1	—	—	—	—	—	—	—	—	
18 ·9	5	Fe	18 ·71	18 ·9	4	18 ·7	3–4	19 ·7	<1	
20 ·3	3	Fe	20 ·37	—	—	—	—	21 ·0	1	
22 ·0	1–2	Fe	21 ·96	—	—	—	—			
23 ·0	4	—	—	22 ·8	3	23 ·0	3	22 ·9	3–4	
23 ·8	4	Fe	23 ·91	—	—	—	—	—	—	
25 ·0	2	—	—	—	—	—	—	24 ·7	1–2	
26 ·2	2	Fe	26 ·04 26 ·34	—	—	—	—	25 ·8	1	
28 ·0	5	Fe Fe V	27 ·77 27 ·97 28 ·25	28 ·1 28 ·5	5	28 ·0	3	28 ·1 28 ·6	5–6 2–3	α Cygni line 4128·1 undoubtedly due to silicium.
29 ·2	4	—	—	—	—	29 ·6	2–3	—	—	
30 ·6	2	? Ba	30 ·80	—	—	—	—	—	—	
—	—	—	—	—	—	—	—	31 ·1	5–6	
32 ·2	5–6	Fe	32 ·23	32 ·2	3	32 ·4	3	32 ·4	1	

Wave-lengths, Intensities, and Probable Origins of γ Cygni Lines, compared with those of δ Canis Majoris, the Chromosphere, and α Cygni—*continued*.

γ Cygni (Kensington). λ.	γ Cygni Intensity. Max. = 10.	γ Cygni Probable origin.	γ Cygni λ of probable origin.	δ Canis majoris (Harvard). λ.	δ Canis majoris Intensity. Max. = 220.	Chromosphere (Kensington). λ.	Chromosphere Intensity. Max. = 10.	α Cygni (Kensington). λ.	α Cygni Intensity. Max. = 10.	Remarks.
4134·8	3-4	Fe	4134·84	4134·8	3	4134·8	3	—	—	Hazy, probably double.
36·9	5	Fe / Fe	36·68 / 37·16	—	—	—	—	—	—	
				37·4	3	37·5	3	—	—	
37·9	5	Fe	37·81	—	—	—	—	4138·4	1	
40·1	3	Fe	40·09	—	—	40·1	1	—	—	
42·3	3	Fe / Cr	42·03 / 42·33	—	—	42·3	1	—	—	
43·8	8	Fe / Fe	43·57 / 44·04	43·9	5	43·8	5-6	43·9	1-2	
46·0	2-3	Fe	46·23	—	—	46·0	1	46·0	2	
47·7	3	Mn / Fe	47·65 / 47·84	—	—	47·5	1	—	—	
49·4	5-6	Fe	49·53	49·5	2	49·4	3-4	49·7	<1	? double.
50·4	1	—	—	—	—	—	—	—	—	
52·3	3	Fe	52·34	—	—	52·1	2	—	—	
54·5	5	Fe	54·07, 54·67, 54·98	54·9	2	54·8	2-3	—	—	Broad, probably compounded of the three solar Fe lines.
56·7	6	—	—	56·7	2	56·5	3	—	—	Probably identical with unknown solar line 4156·47.
57·9	1	Fe	57·95	—	—	57·8	1	—	—	
59·2	3	Fe / Un	58·96 / 59·35	—	—	58·9	1	—	—	Un = strong solar line, to which ROWLAND assigns no origin
60·5	3	—	—	—	—	—	—	—	—	
61·7	6-7	*p* Ti	61·68	61·7	3	61·7	3	61·7	1-2	
—	—	—	—	—	—	—	—	63·0	<1	
63·8	5-6	*p* Ti	63·82	63·9	2	63·8	4	63·8	3-4	
65·5	3-4	Fe	65·55	—	—	—	—	—	—	
67·6	3-4	—	—	67·5	1	67·5	2-3	67·6	1	Probably identical with strong solar line 4167·44, to which ROWLAND assigns no origin.
—	—	—	—	—	—	—	—	69·8	<1	
71·2	1-2	Fe / *p* Ti	71·07 / 71·21	—	—	—	—	—	—	
72·1	3-4	*p* Ti	72·07	—	—	72·1	3-4	72·0	2-3	
73·6	4-5	*p* Fe / *p* Ti	73·52 / 73·70	72·9 / 73·6	13	73·5	4-5	73·5	6-7	Probably close double.
75·4	1	—	—	—	—	—	—	—	—	
77·7	4	*p* Y	77·75	77·8	3	77·3	5	77·8	2-3	
79·0	5	*p* Fe	78·95	79·5	4	79·0	4-5	79·0	6-7	
81·9	4-5	Fe	81·92	82·0	1	81·9	3	81·8	<1	
84·5	5	*p* Ti	84·40	85·0	2	84·6	2-3	85·0	<1	? double.
87·2 / 87·8	6	Fe / Fe	87·20 / 87·94	87·6	4	87·6	4-5	88·0	2	Close double.
90·7	1	—	—	—	—	—	—	—	—	
91·7	5	Fe / Fe	91·59 / 91·84	91·8	3	91·7	3-4	92·0	1	
93·4	1	—	—	—	—	—	—	—	—	
95·5	4	Fe	95·49	—	—	95·5	1	—	—	

Wave-lengths, Intensities, and Probable Origins of γ Cygni Lines, compared with those of δ Canis Majoris, the Chromosphere, and α Cygni—*continued.*

γ Cygni (Kensington).				δ Canis majoris (Harvard).		Chromosphere (Kensington).		α Cygni (Kensington).		Remarks.
λ.	Intensity. Max. =10.	Probable origin.	λ of probable origin.	λ.	Intensity. Max. =220.	λ.	Intensity. Max. =10.	λ.	Intensity. Max. =10.	
4196 ·4	4	Fe	4196 ·37	4196 ·8	3	4196 ·4	2–3	—	—	
98 ·9	7	Fe	98 ·49	98 ·5	4	98 ·8	4	4198 ·5	1	
		Fe	98 ·80							
		Fe	99 ·27							
4201 ·1	1	Fe	4201 ·09	—	—	—	—	—	—	
02 ·2	5	Fe	02 ·20	4202 ·2	3	4202 ·2	3	4202 ·3	1	
03 ·9	1	? Fe	04 ·10	—	—	—	—	—	—	
		? La	04 ·16	—	—	—	—	—	—	
05 ·0	5–6	*p* Y	04 ·89	—	—	—	—	—	—	
		p V	05 ·24	05 ·3	3	05 ·1	3	05 ·2	1	
06 ·9	3	Fe	06 ·86	06 ·9	2	07 ·1	1	—	—	
			07 ·29							
09 ·2	4–5	? Zr	09 ·14	08 ·8	2	09 ·6	2–3	—	—	
10 ·5	3	Fe	10 ·49	10 ·5	2	10 ·9	1	10 ·8	< 1	
12 ·0	3	? Zr	12 ·05	12 ·1	1	12 ·4	1	—	—	
13 ·7	2	Fe	13 ·81	—	—	—	—	—	—	
15 ·7	9	*p* Sr	15 ·70	15 ·7	5	15 ·7	10	15 ·7	2	
17 ·2	3	—	—	17 ·6	1	17 ·0	< 1	—	—	
19 ·5	3–4	Fe	19 ·52	19 ·6	1	19 ·4	2	—	—	
20 ·4	3	Fe	20 ·51	—	—	—	—	—	—	
22 ·4	5–6	Fe	22 ·38	22 ·4	1	22 ·4	3	22 ·2	< 1	
24 ·2	3	Fe	24 ·34	24 ·7	1	—	—	—	—	
25 ·2	3	—	—			—	—	24 ·9	1	
26 ·9	8	Ca	26 ·90	27 ·0	5	26 ·9	7	27 ·2	1	
29 ·8	3	Fe	29 ·68	—	—	29 ·4	< 1	—	—	
		Fe	29 ·93							
—	—	—	—	—	—	—	—	30 ·7	1	
32 ·2	1–2	—	—	—	—	—	—	32 ·1	< 1	
33 ·3	7–8	*p* Fe	33 ·33	33 ·6	3	33 ·3	6–7	33 ·3	8	
36 ·1	5–6	Fe	36 ·11	36 ·0	2	35 ·9	4	35 ·7	1	
—	—	—	—	—	—	—	—	37 ·6	< 1	
39 ·0	5	Fe	38 ·97	—	—	38 ·0	1–2	39 ·2	< 1	
40 ·1	3	Mn	39 ·89	40 ·0	3	40 ·3	1	40 ·6	< 1	
		Fe	40 ·04							
42 ·6	5	*p* Cr	42 ·62	42 ·5	1	42 ·8	2–3	42 ·6	3–4	
45 ·5	2	Fe	45 ·42	—	—	45 ·0	1–2	45 ·0	1	
47 ·0	7	Sc	47 ·00	47 ·3	4	47 ·0	7	47 ·2	3	
50 ·3	4	Fe	50 ·29	—	—	50 ·4	4–5	—	—	
50 ·9	4	Fe	50 ·95	51 ·0	2			51 ·0	1	
52 ·5	2–3	? Co	52 ·47	53 ·0	?	—	—	53 ·1	2	Possibly double.
54 ·5	4	Cr	54 ·51	54 ·5	2	54 ·5	6	54 ·5	1–2	
56 ·2	3	—	—	—	—	55 ·6	1–2	—	—	
58 ·4	6	Fe	58 ·48	58 ·7	2	58 ·2	2	58 ·6	3	
60 ·6	6	Fe	60 ·64	60 ·5	2	60 ·6	4	60 ·7	< 1	
62 ·1	3	*p* Cr	—	62 ·2	1	61 ·6	1–2	62 ·2	3	
64 ·2	1	Fe	64 ·37	—	—	64 ·6	1–2	64 ·4	< 1	
65 ·1	1	Fe	64 ·90	—	—	65 ·5	< 1	—	—	
67 ·3	2	—	—	—	—	67 ·7	2–3	67 ·5	< 1	
69 ·5	2–3	—	—	70 ·0	1	69 ·8	1	69 ·8	1–2	
71 ·2	6	Fe	71 ·33	71 ·7	4	71 ·6	4–5	71 ·7	1	
71 ·9	6	Fe	71 ·93							
73 ·5	3	Fe	73 ·48	73 ·8	1	73 ·8	1	73 ·6	3	
		Zr	73 ·64							
75 ·1	4	Cr	74 ·96	75 ·0	3	75 ·0	5	75 ·0	< 1	
75 ·6	4	—	—	75 ·0	3	—	—	75 ·8	2	
—	—	—	—	—	—	—	—	76 ·3	1	
77 ·6	2	—	—	—	—	—	—	—	—	Faint close double.
78 ·4	2	Fe	78 ·39	78 ·4	1	—	—	78 ·4	2	
80 ·4	2	—	—	80 ·5	1	80 ·2	1–2	—	—	Faint close double.
81 ·0	2	—	—	—	—	—	—	—	—	

Wave-lengths, Intensities, and Probable Origins of γ Cygni Lines, compared with those of δ Canis Majoris, the Chromosphere, and α Cygni—*continued.*

γ Cygni (Kensington).				δ Canis majoris (Harvard).		Chromosphere (Kensington).		α Cygni (Kensington).		Remarks.
λ.	Intensity. Max. =10.	Probable origin.	λ of probable origin.	λ.	Intensity. Max. =220.	λ.	Intensity. Max. =10.	λ.	Intensity. Max. =10.	
4282·8	5	{ Fe Ca	4282·57 83·17 }	4282·9	1	4283·0	2–3	4282·8	1	
84·4	2	—	—	84·4	1	—	—	84·4	2	
—	—	—	—	—	—	—	—	86·8	<1	
88·0	3–4	? Ti	88·04	88·1	2	87·6	1	88·3	2	
90·1	9	{ Cr *p* Ti	89·89 90·38	89·8	4	90·2	6–7	90·4	4	
92·2	1–2	—	—	—	—	—	—	92·4	1	
94·2	6	{ *p* Ti Fe	94·20 94·30 }	94·3	2	94·2	5	94·2	4	
96·7	5	*p* Fe	96·74	97·1	2	96·7	2–3	96·7	4	
99·4	4	Ti Fe	99·41	—	—	—	—	—	—	
4300·2	6	*p* Ti	4300·21	4300·2	5	4300·2	5	4300·2	5	
—	—	—	—	—	—	—	—	02·1	2	
03·3	6	*p* Fe	03·34	02·6	5	03·0	4	03·3	5	
05·8	5–6	—	—	05·8	1	05·8	1–2	06·0	1	
—	—	—	—	—	—	—	—	07·6	1	
08·1	5	{ Ca Fe *p* Ti	07·91 08·08 08·10 }	08·0	2	08·1	5	08·1	4	
09·6	5	Fe	09·54	09·5	2	—	—	09·7	1	
11·3	1	—	—	—	—	—	—	10·9	1	
13·0	5	*p* Ti	13·03	—	—	13·0	2	13·1	2–3	
14·3	7–8	Sc	14·25	14·3	2	14·0	2	—	—	
15·1	7–8	{ *p* Ti Fe	15·13 15·26 }	15·2	5	15·1	4–5	15·1	4	
17·0	3–4	*p* Ti	16·96	17·0	1	—	—	17·2	1	
—	—	—	—	17·6	1	—	—	—	—	
18·8	3–4	Ca	18·82	—	—	18·3	2	—	—	
—	—	—	—	—	—	—	—	19·9	1	
21·2	8	{ Sc *p* Ti	20·91 21·20 }	21·0	3	21·2	5	21·2	2–3	
23·4	1	—	—	—	—	—	—	—	—	
26·0	9	Fe	25·94	26·0	5	25·8	6	26·0	3–4	{ Apparently close double.
27·3	2	Fe	27·27	—	—	—	—	—	—	
30·6	7	*p* Ti	{ 30·50 30·87	30·9	2	30·6	2–3	30·7	2	
34·0	4–5	? La	33·93	—	—	33·9	3	—	—	
38·1	9	*p* Ti	38·08	37·6	10	38·1	5	38·1	4	
40·6	10	H	40·63	40·7	11	40·7	10	40·7	10	H_γ.
44·3	4–5	{ *p* Mn *p* Ti	44·19 44·45 }	44·7	1	44·3	3	44·3	2	
46·8 48·0	1 1	Fe Fe	46·72 48·00	— —	— —	} 47·4	<1	— —	— —	
—	—	—	—	—	—	—	—	49·1	1–2	
51·9	7	{ *p* Fe Cr Mg	51·93 52·08 }	52·0	5	51·9	6	51·9	7	
55·2	3–4	Ca	55·26	55·3	1	55·0	1–2	54·9	1	
58·7 — 59·8	3 — 3	Fe *p* Y Cr	58·67 58·88 59·78	— — 59·9	— — 3	} 59·2	3–4	{ 57·8 — 60·0	2 — 1	
62·3	1–2	*p* Ni	62·40	—	—	62·0	1	62·4	1–2	
64·6	1	—	—	—	—	64·1	1	64·0	1	
—	—	—	—	—	—	—	—	65·4	<1	
67·8	4	{ Fe *p* Ti	67·75 67·84 }	67·9	1	67·8	2–3	67·9	1–2	
—	—	—	—	—	—	68·7	?	—	—	
69·9	3	Fe	69·94	70·0	1	70·2	2–3	69·9	2	
71·7	2–3	—	—	71·5	1	—	—	71·7	1	

Wave-lengths, Intensities, and Probable Origins of γ Cygni Lines, compared with those of δ Canis Majoris, the Chromosphere, and α Cygni—*continued.*

γ Cygni (Kensington).				δ Canis majoris (Harvard).		Chromosphere (Kensington).		α Cygni (Kensington).		Remarks.
λ.	Intensity. Max. =10.	Probable origin.	λ of probable origin.	λ.	Intensity. Max. =220.	λ.	Intensity. Max. =10.	λ.	Intensity. Max. =10.	
4374·7	8	Sc *p* Ti	4374·63 74·90	— 4374·7	— 9	— 4374·9	— 7	— 4374·9	— 2	
76·1	2	Fe	76·11	76·1		—	—	—	—	
79·4	3	V	79·40	79·4	1	79·7	2	78·9	<1	
—	—	—	—	—	—	—	—	80·4	1	
83·7	4–5	Fe	83·72	83·7	8	83·7	5	83·7	2	
85·3	5–6	*p* Fe	85·55	85·2	4	85·5	3	85·5	5–6	
87·0	1	? Ti	87·01	—	—	—	—	—	—	
88·6	1	Fe	88·57	—	—	88·1	1–2	88·1	1	
91·2	4	Fe *p* Ti	91·12 91·19	90·5	2	91·2	2–3	91·0	2–3	
94·1	2	? Ti	94·22	—	—	—	—	93·6	1	
95·2	6	*p* Ti V	95·20 95·41	95·3	7	95·2	7	95·2	5	
98·2	3	? Yt	98·18	—	—	—	—	98·0	1	
4400·2	5–6	*p* Ti Sc	99·94 4400·55	4400·2	7	99·9	5-6	99·9	3	Probably close double.
01·0	2	—	—	—	—	—	—	—	—	
03·3	1	—	—	—	—	—	—	4402·8	1	
04·9	3-4	Fe	04·93	05·0	2	4404·9	4	04·9	1–2	
08·4	3	V Fe V	08·31 08·58 08·68	08·5	2	08·1	3	—	—	
09·3	4	? Fe	09·29	—	—	—	—	—	—	
11·3	3	*p* Ti	11·20	11·5	2	11·2	1–2	11·2	1	
13·6	1	—	—	—	—	—	—	13·5	1	
15·3	5–6	Fe	15·29	15·3	4	15·3	4	15·3	<1	
—	—	—	—	—	—	—	—	17·0	5	
17·9	6–7	*p* Ti	17·88	17·9	6	17·9	4–5	17·9	2–3	
—	—	—	—	—	—	—	—	19·5	<1	
20·7	1–2	—	—	—	—	—	—	—	—	
22·7	3–4	Fe Y	22·74	22·8	3	22·7	3	22·0	1	
25·6	1	Ca	25·61	—	—	25·6	1	—	—	
27·4	3–4	Ti Fe	27·27 27·48	27·4	2	27·4	3	—	—	
—	—	—	—	—	—	—	—	28·7	<1	
30·6	3	Fe	30·78	30·8	2	30·1	2–3	—	—	
33·4	1–2	Fe	33·39	—	—	—	—	—	—	
—	—	—	—	—	—	—	—	34·4	1	
35·5	4–5	Ca	35·13 35·85	35·2	2	35·5	4–5	—	—	Probably close double.
38·5	1	Fe	38·51	—	—	—	—	—	—	
41·8	1–2	V	41·88	—	—	41·8	1–2	41·8	1	
42·5	4–5	Fe	42·51	42·5	9	—	—	—	—	
44·0	9	*p* Ti	43·98	44·0		44·0	7	44·0	4–5	
47·5	3	Fe	47·30 47·80	47·7	1	47·0	1	47·8	1	
50·7	4	*p* Ti	50·65	50·6	3	50·6	5	50·6	2–3	
55·0	4–5	Ca *p* Fe	54·95 55·30	55·0	2	55·0	5	55·3	2	
59·3	2–3	Fe	59·30	60·0	1	59·9	1–2	—	—	
62·0	5	Fe	61·82 62·17	62·0	2	62·3	3	61·8	1–2	
64·8	3	*p* Ti	64·62	64·8	1	64·6	2–3	64·5	1	
66·7	2	Fe	66·73	—	—	66·5	<1	—	—	
68·7	6	*p* Ti	68·66	69·5	3	68·7	6	68·7	4	
70·7	3	? Ni Zr	70·65	71·0	2	—	—	—	—	

Wave-lengths, Intensities, and Probable Origins of γ Cygni Lines, compared with those of δ Canis Majoris, the Chromosphere, and α Cygni—*continued.*

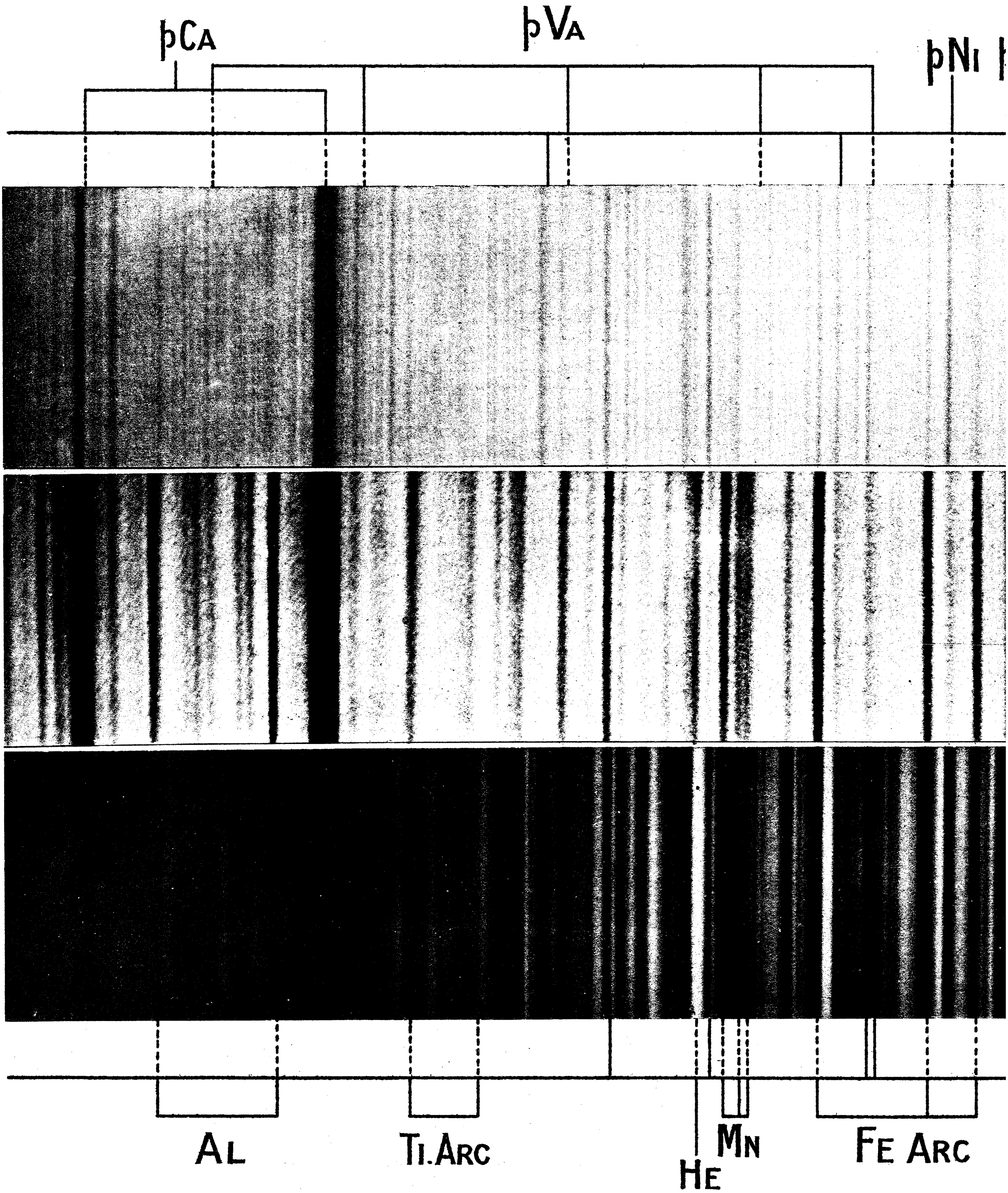
γ Cygni (Kensington).				δ Canis majoris (Harvard).		Chromosphere (Kensington).		α Cygni (Kensington).		Remarks.
λ.	Intensity. Max. = 10.	Probable origin.	λ of probable origin.	λ.	Intensity. Max. = 220.	λ.	Intensity. Max. = 10.	λ.	Intensity. Max. = 10.	
—	—	—	—	—	—	—	—	4471 ·6	1–2	Probably He 4471 ·65.
4473 ·0	2–3	Fe	4472 ·88	4473 ·0	1	—	—	73 ·1	1–2	
76 ·2	3	Fe	76 ·19	76 ·2	1	4476 ·2	3	—	—	
80 ·3	2	Fe	80 ·31	—	—	80 ·6	1–2	—	—	
81 ·3	5–6	*p* Mg	81 ·30	82 ·0	4	—	—	81 ·3	8	
82 ·3	1–2	Fe	—	—	—	82 ·3	4	—	—	
—	—	—	—	—	—	—	—	84 ·0	<1	
85 ·2	1	—	—	—	—	—	—	86 ·6	<1	
88 ·6	4	*p* Ti	88 ·49	—	—	} 89 ·3	3	89 ·0	3	
89 ·4	4	*p* Fe	89 ·35	89 ·6	3					
91 ·6	3	*p* Fe	91 ·57	91 ·6	3	91 ·6	2–3	91 ·6	3–4	
94 ·7	3–4	Fe	94 ·74	94 ·8	2	94 ·3	2	—	—	
97 ·6	3–4	—	—	97 ·0	2	96 ·8	—	—	—	
99 ·6	1	—	—	—	—	—	—	—	—	
4501 ·5	6	*p* Ti	4501 ·45	4501 ·5	4	4501 ·5	7	4501 ·5	3–4	
07 ·0	1	—	—	—	—	—	—	—	—	
08 ·5	4	*p* Fe	08 ·46	08 ·5	3	08 ·5	5	08 ·5	5	
12 ·9	1	Ti	12 ·91	—	—	12 ·3	1	12 ·3	<1	
15 ·5	4	*p* Fe	15 ·51	15 ·4	2	15 ·5	4	15 ·5	5	
18 ·2	2	Ti	18 ·20	—	—	18 ·3	1	18 ·2	1	
20 ·4	3	*p* Fe	20 ·40	23 ·0	1	20 ·4	3	20 ·4	4	
22 ·8	4	*p* Fe	22 ·69	22 ·9	1	22 ·7	4	22 ·7	5	
25 ·3	2	Ti	27 ·49	—	—	—	—	25 ·5	<1	
28 ·8	4	Fe	28 ·80	28 ·8	2	28 ·8	3	—	—	
29 ·5	2	? Fe	29 ·85	—	—	—	—	29 ·6	1	
31 ·2	2	{ Co Fe	31 ·12 31 ·33 }	31 ·2	1	31 ·0	1	—	—	
—	—	—	—	—	—	—	—	32 ·2	<1	
34 ·1	6	*p* Ti	34 ·14	34 ·2	4	34 ·1	7–8	34 ·1	5	
36 ·0	2–3	Ti	{ 35 ·74 36 ·09 36 ·22 }	—	—	35 ·9	2	—	—	
—	—	—	—	—	—	—	—	38 ·8	<1	
40 ·1	3	—	—	—	—	40 ·0	1–2	—	—	
41 ·4	4	*p* Fe	41 ·40	41 ·6	2	41 ·7	3	41 ·4	3	
44 ·8	4	{ Cr Ti	44 ·79 44 ·86 }	44 ·9	2	44 ·8	3	45 ·0	<1	
48 ·0	1–2	Fe	48 ·02	—	—	—	—	47 ·2	<1	
49 ·7	8	{ *p* Fe *p* Ti	49 ·64 49 ·81 }	49 ·7	3	49 ·7	7–8	49 ·8	7	
52 ·6	2	? Ti	52 ·63	—	—	—	—	52 ·8	<1	
54 ·2	5–6	Ba	54 ·21	54 ·2 }		{ 54 ·2	7–8	—	—	
					5	—	—	55 ·3	2	
56 ·2	5–6	{ *p* Fe Fe	56 ·06 56 ·31 }	56 ·0 }		56 ·1	3–4	56 ·1	5	
58 ·8	3	*p* Cr	58 ·83	58 ·9	1	58 ·8	3–4	58 ·8	5	
61 ·6	1	—	—	—	—	61 ·3	<1	61 ·6	1	
63 ·9	4–5	*p* Ti	63 ·94	64 ·0	4	63 ·9	7–8	63 ·9	3	
65 ·8	3	{ Cr Co Fe	65 ·69 65 ·84 }	—	—	66 ·3	1	66 ·0	<1	
68 ·9	3	Fe	68 ·94	—	—	—	—	68 ·0	<1	
—	—	—	—	—	—	—	—	70 ·6	<1	
72 ·2	6–7	*p* Ti	72 ·16	72 ·2	3	72 ·2	7	72 ·2	4	
74 ·9	1	Fe	74 ·90	—	—	—	—	74 ·9	<1	
76 ·5	3	*p* Fe	76 ·51	76 ·5	1	76 ·5	3	76 ·5	3–4	
—	—	—	—	—	—	—	—	77 ·2	<1	
80 ·6	3–4	{ V Fe Ni	80 ·59 80 ·76 }	80 ·0	1	80 ·0	2	80 ·3	2	
—	—	—	—	—	—	—	—	83 ·0	2	

Wave-lengths, Intensities, and Probable Origins of γ Cygni Lines, compared with those of δ Canis Majoris, the Chromosphere, and α Cygni—*continued.*

γ Cygni (Kensington).				δ Canis majoris (Harvard).		Chromosphere (Kensington).		α Cygni (Kensington).		Remarks.
λ.	Intensity. Max. =10.	Probable origin.	λ of probable origin.	λ.	Intensity. Max. =220.	λ.	Intensity. Max. =10.	λ.	Intensity. Max. =10.	
4584·0	8	*p* Fe	4584·02	4584·0	5	4584·0	7	4584·0	7	
—	—	—	—	86·1	1	—	—	86·0	<1	
88·4	3	*p* Cr	88·38	—	—	88·4	3	88·4	4	
90·2	2–3	*p* Ti	90·13	—	—	90·1	3	90·2	1–2	
92·5	3–4	{ *p* Cr Fe	92·25 92·84 }	92·8	1	92·5	3	92·5	2–3	
94·1	1	? V	94·30	—	—	—	—	—	—	
95·6	1	Fe	95·54	95·9	2	95·1	2	—	—	
—	—	—	—	—	—	—	—	96·6	1-2	
98·1	1	? Fe	98·30	—	—	—	—	—	—	
4600·7	4	—	—	—	—	4600·8	3	—	—	
03·2	2	Fe	4603·13	—	—	03·0	2	—	—	
05·2	1	Ni	05·17	—	—	05·5	2	—	—	
13·9	2–3	—	—	4613·5	1	13·3	2	—	—	
16·9	3–4	*p* Cr	16·80	16·9	1	—	—	4616·8	2	? double.
19·2	4	{ Fe *p* Cr Fe	18·97 19·47 }	19·2	4	19·0	3–4	19·1	3	
20·2	3–4	—	—	—	—	—	—	21·1	2	
—	—	—	—	—	—	—	—	23·5	<1	
—	—	—	—	—	—	—	—	24·9	1	
26·2	2	Cr	26·36	25·8	1	—	—	26·6	1	
29·5	6	*p* Fe Ti Co	29·52	29·9	4	29·5	5–6	29·6	5–6	
32·8	1–2	—	—	—	—	32·8	1–2	32·6	1	
34·2	2–3	*p* Cr	34·25	34·8	1	34·3	1–2	34·3	3	
—	—	—	—	—	—	—	—	35·6	2	
—	—	—	—	—	—	—	—	38·9	1	
42·6	1	—	—	—	—	42·8	1	—	—	
46·3 to 49·0 }	4	{ Cr Fe Ni	46·35 47·62 48·84	46·3 — 48·9	1 — 1	46·3 — 48·4	4–5 — 2	— — —	— — —	{ Band probably consisting of the three well-marked solar lines whose λλ are given.
52·5	3	Cr	52·34	—	—	51·8	3-4	—	—	
55·3	2	—	—	—	—	55·4	2	—	—	
57·4	4–5	*p* Ti	57·38	57·0	4	57·4	3–4	57·4	2	
60·6	1	—	—	—	—	—	—	60·8	<1	
63·6	2-3	—	—	63·7	2	64·5	2	63·8	2	
—	—	—	—	—	—	—	—	66·5	<1	
67·4	8	{ ? Fe ? Ti	67·63 67·77 }	68·0	3	67·6	3–4	67·2	2–3	
70·4	7	Sc	70·4*	70·0	3	70·8	3–4	70·5	2	{ *THALEN'S spark λ corrected to ROWLAND.
73·5	1	Fe	73·35	—	—	74·0	1	73·5	<1	
75·6	1–2	? Ti	75·29	—	—	76·0	1	—	—	
78·1	3	? Cd	78·35	79·0	1	—	—	—	—	
82·5	3–4	*p* Y	82·60	82·2	1	82·5	2–3	—	—	
86·0	1	—	—	—	—	—	—	—	—	
89·2	1	—	—	—	—	—	—	—	—	
91·6	1–2	{ Ti Fe	91·52 91·61	— 91·6	— 1	— 91·6	— 3	—	—	
99·6	4–5	—	—	98·8	2	99·5	2–3	—	—	
4703·4	4–5	Mg	4703·18	4703·1	2	4703·2	3–4	—	—	
08·6	5	—	—	09·0	3	{ 07·8 09·6	2–3 2–3 }	—	—	Broad and hazy.
15·0	3	—	—	14·5	1	—	—	—	—	
17·8	1–2	—	—	—	—	18·5	1	—	—	
19·6	3	—	—	20·5	1	—	—	—	—	
28·3	3	—	—	27·6	1	27·7	2	—	—	

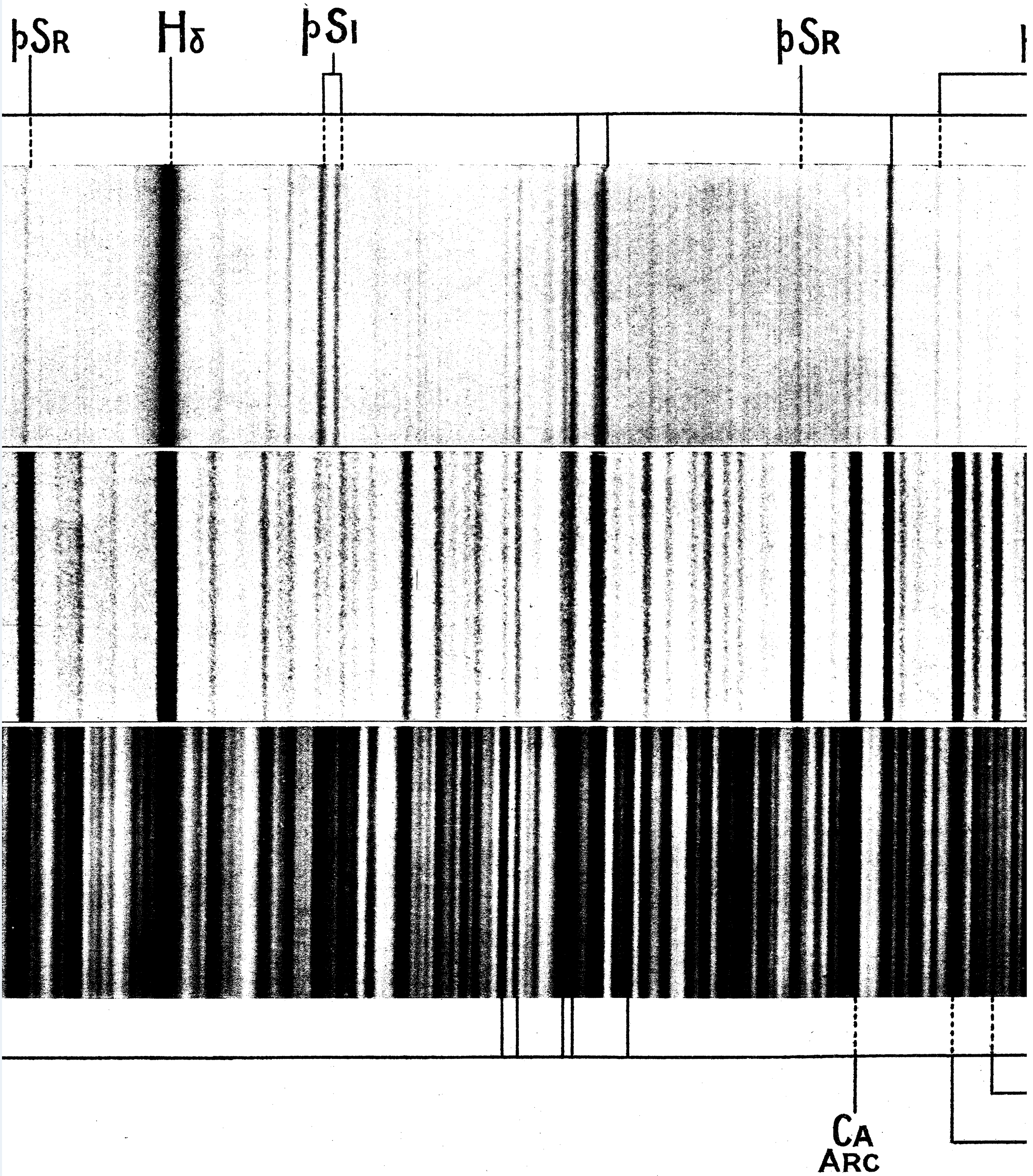
Wave-lengths, Intensities, and Probable Origins of γ Cygni Lines, compared with those of δ Canis Majoris, the Chromosphere, and α Cygni—*continued.*

γ Cygni (Kensington).				δ Canis majoris (Harvard).		Chromosphere (Kensington).		α Cygni (Kensington).		Remarks.
λ.	Intensity. Max. =10.	Probable origin.	λ of probable origin.	λ.	Intensity. Max. =220.	λ.	Intensity. Max. =10.	λ.	Intensity. Max. =10.	
4731·3	4	—	—	4731·7	1	4731·4	3–4	4731·7	3·4	
34·1	2–3	? Fe	4733·78	—	—	33·8	1	—	—	
37·6	4	—	—	37·0	1	37·0	3	—	—	
40·9	1	—	—	—	—	40·5	2	—	—	
44·9	1	—	—	—	—	45·5	1	—	—	
48·6	1–2	—	—	—	—	48·0	1	—	—	
52·2	2	—	—	—	—	—	—	—	—	
—	—	—	—	54·2	1	—	—	—	—	
55·3	3	—	—	—	—	—	—	—	—	Broad, probably double.
64·2	7	Ti Ni	64·11	64·1	8	—	—	—	—	
67·8	1	—	—	—	—	67·0	2	—	—	
71·2	2	—	—	71·8	1	—	—	—	—	
80·2	3–4	*p* Ti	80·20	80·1	1	79·9	3–4	80·1	2	
83·1	2–3	—	—	—	—	83·1	2	—	—	
86·7	2–3	—	—	86·8	1	86·7	2–3	—	—	
98·7	2–3	—	—	98·7	2	98·7	2	—	—	
4805·2	3	*p* Ti	4805·25	4805·2	3	4805·2	5	4805·2	2	
11·0	3	—	—	—	—	11·0	3	—	—	
24·3	7	Fe *p* Cr	24·33	24·0	5	24·3	6	24·3	4	
40·4	2	—	—	—	—	40·4	2–3	—	—	
48·4	3–4	*p* Cr	48·44	48·4	3	48·5	3	48·4	3–4	
55·4	5	—	—	55·7	3	55·0	2–3	—	—	
61·5	8	H	61·49	—	—	61·5	10	61·5	10	H_β.



I.

MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES
THE ROYAL SOCIETY A
PHILOSOPHICAL TRANSACTIONS OF



α CYGNI 2. CHROMOSPHE

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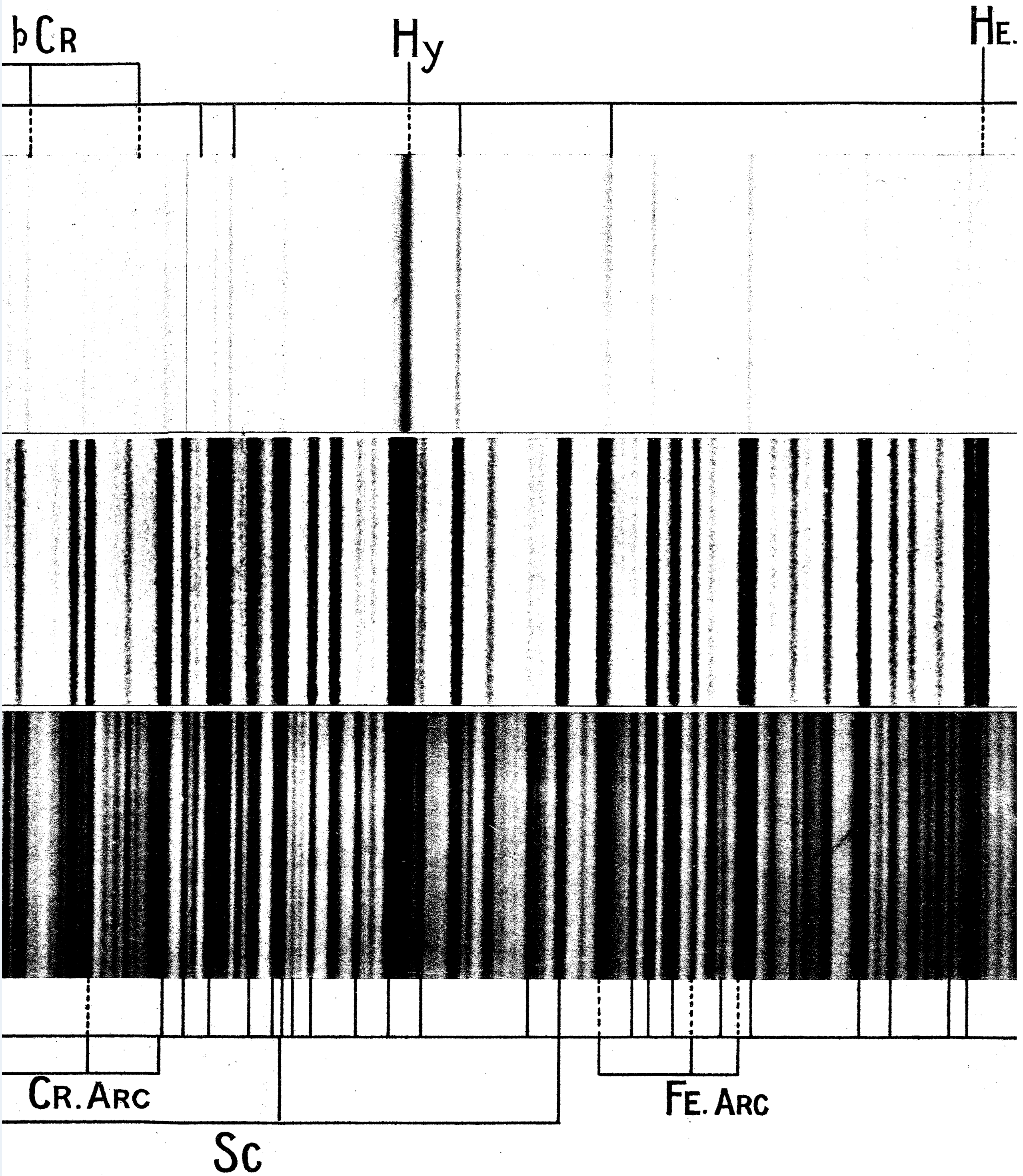
PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES



RE 3. γ CYGNI
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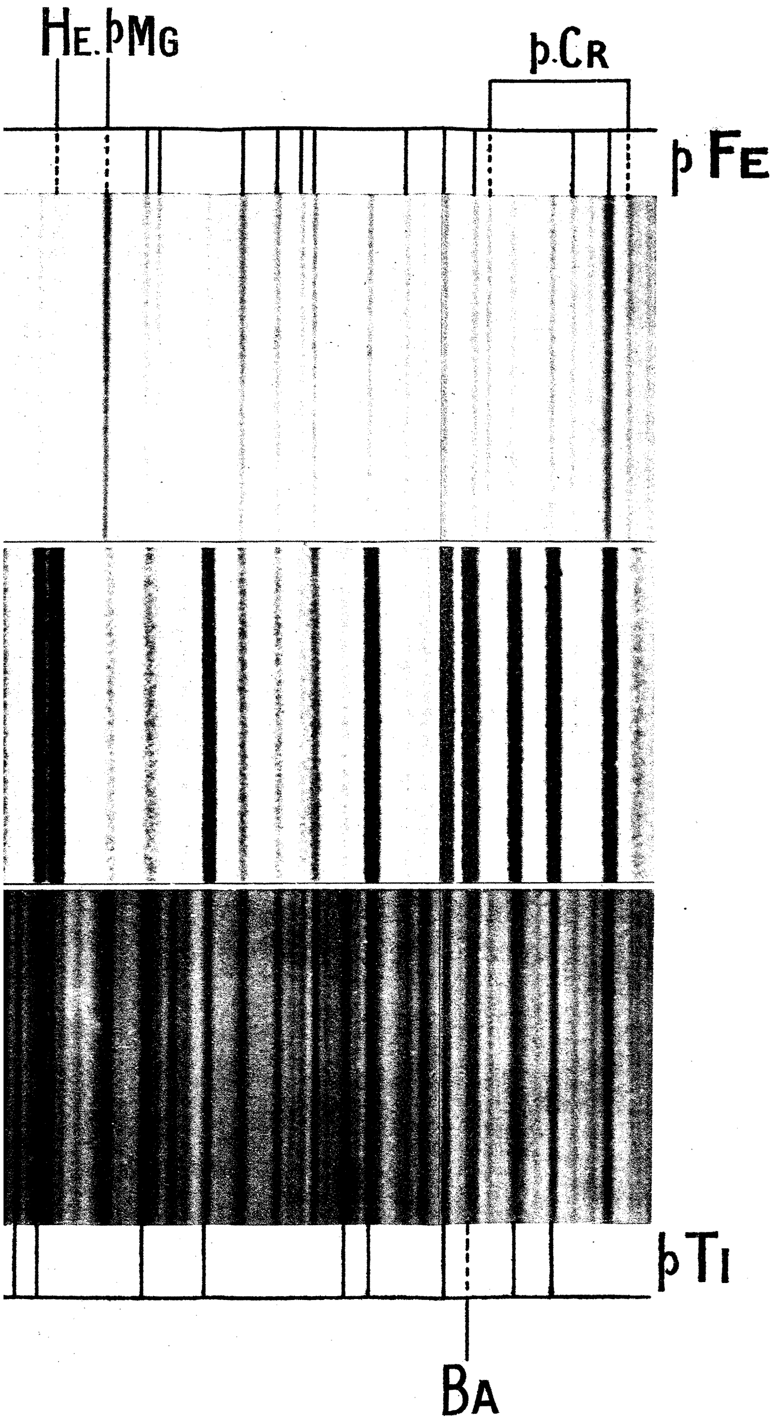
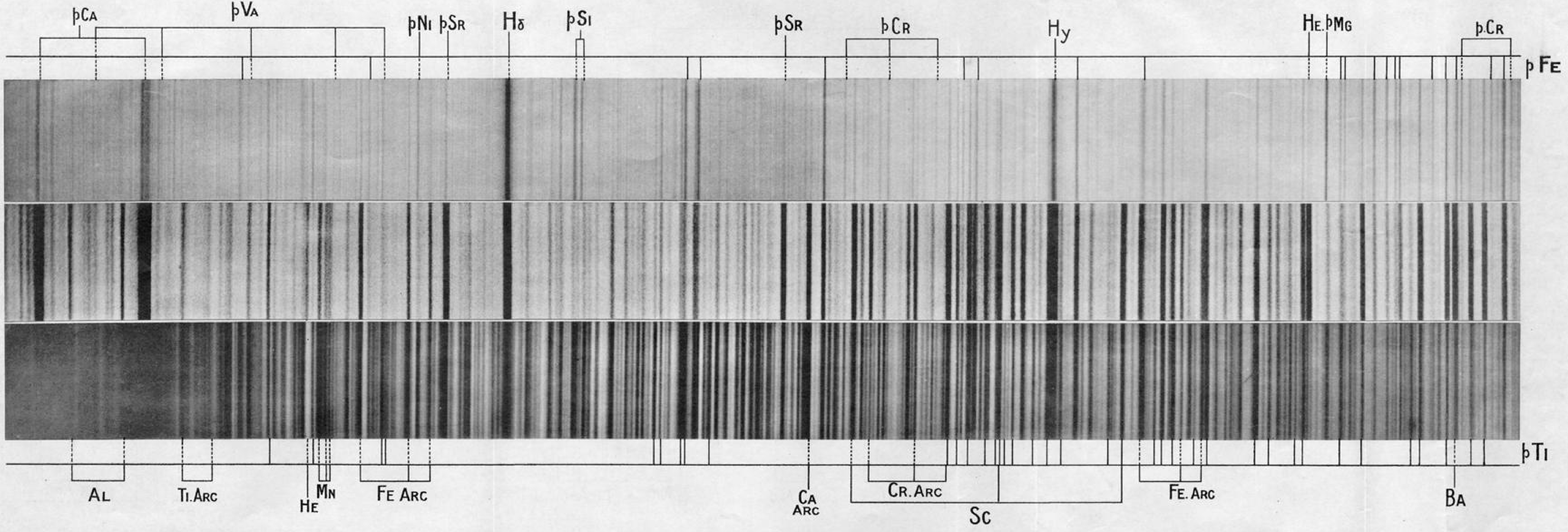
PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

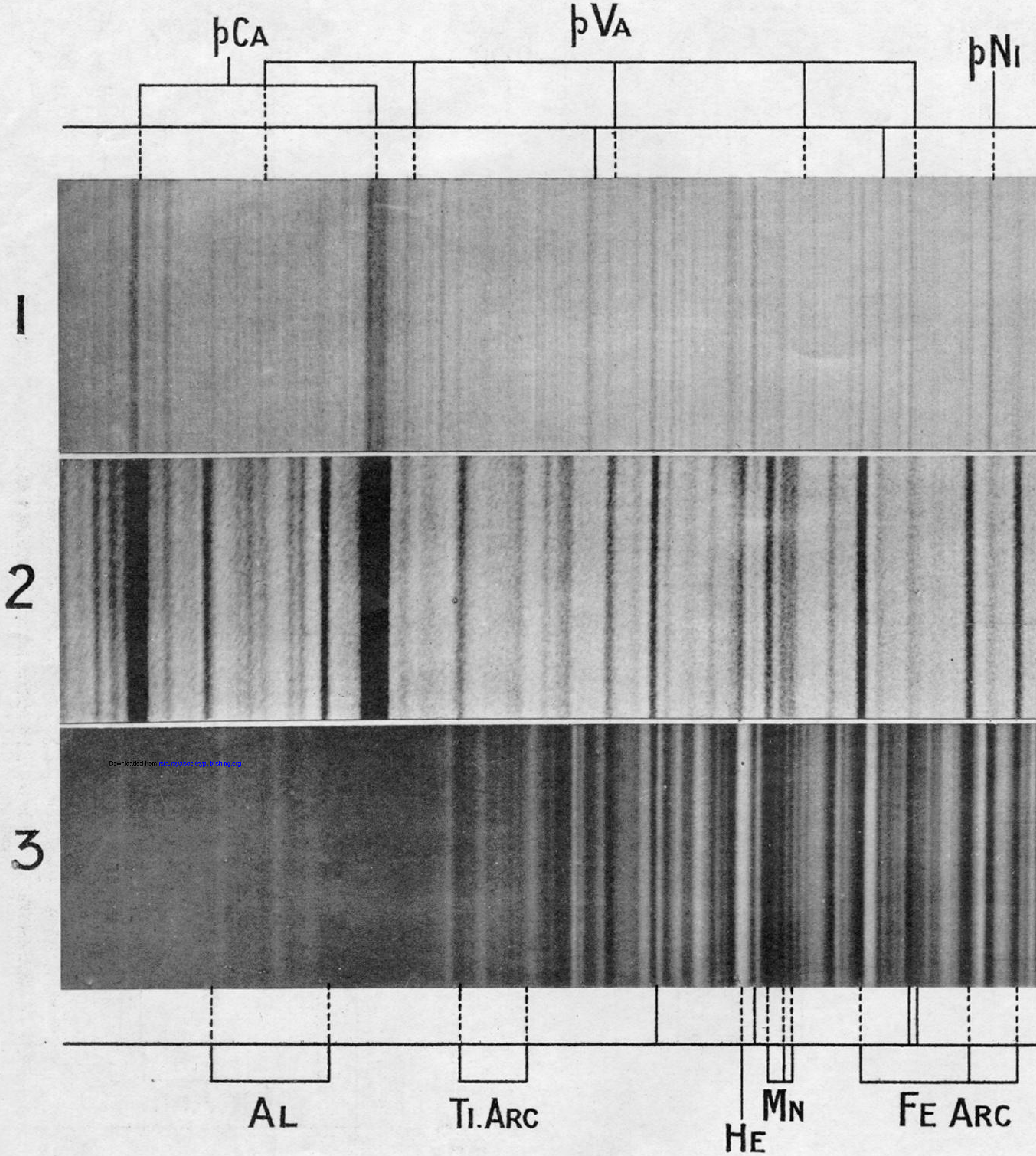


PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES



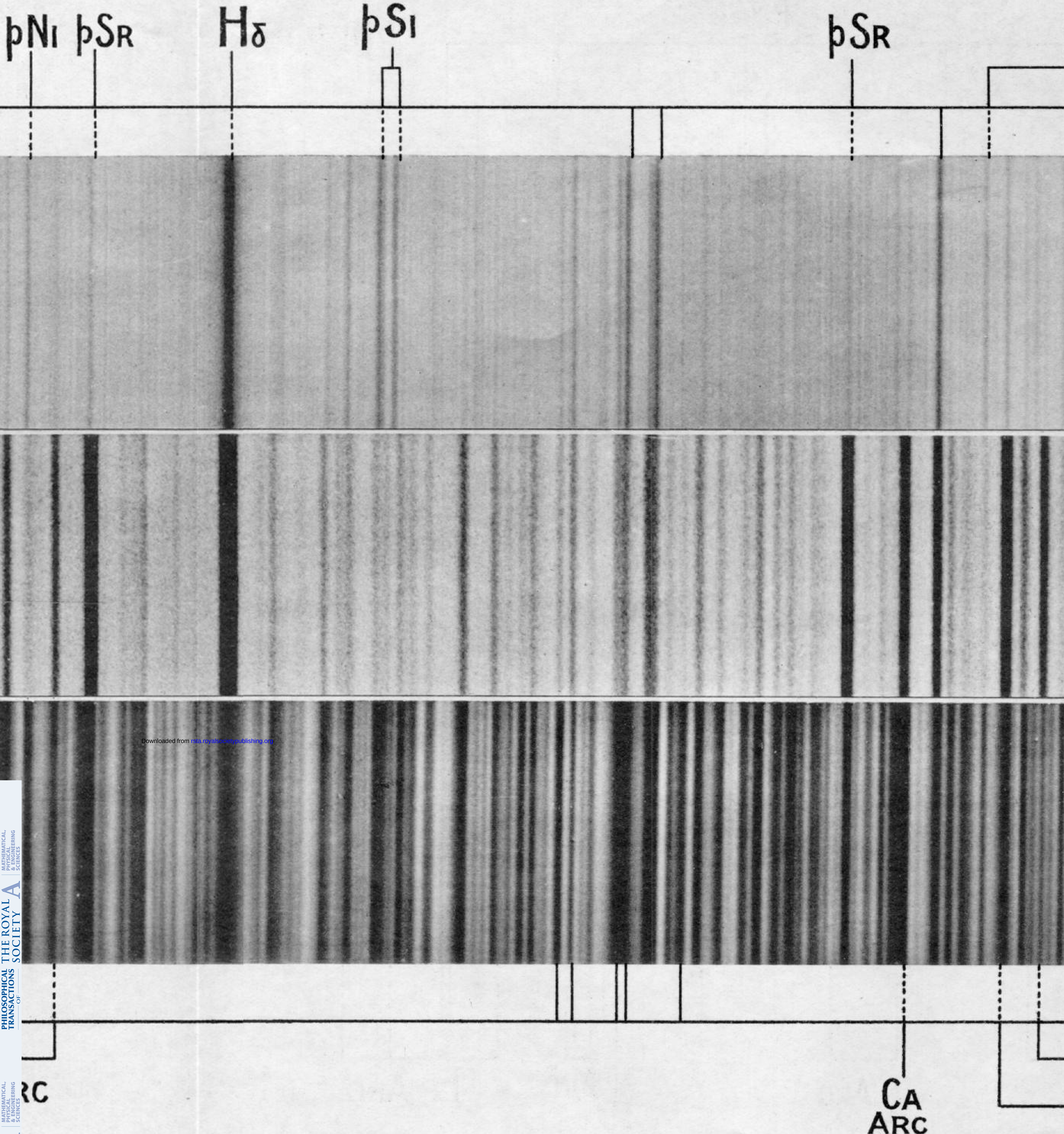
1. α CYGNI 2. CHROMOSPHERE (PHOTOGRAPHICALLY REVERSED) 3. γ CYGNI

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES



I.

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES



1. α CYGNI 2. CHROMOSPHE

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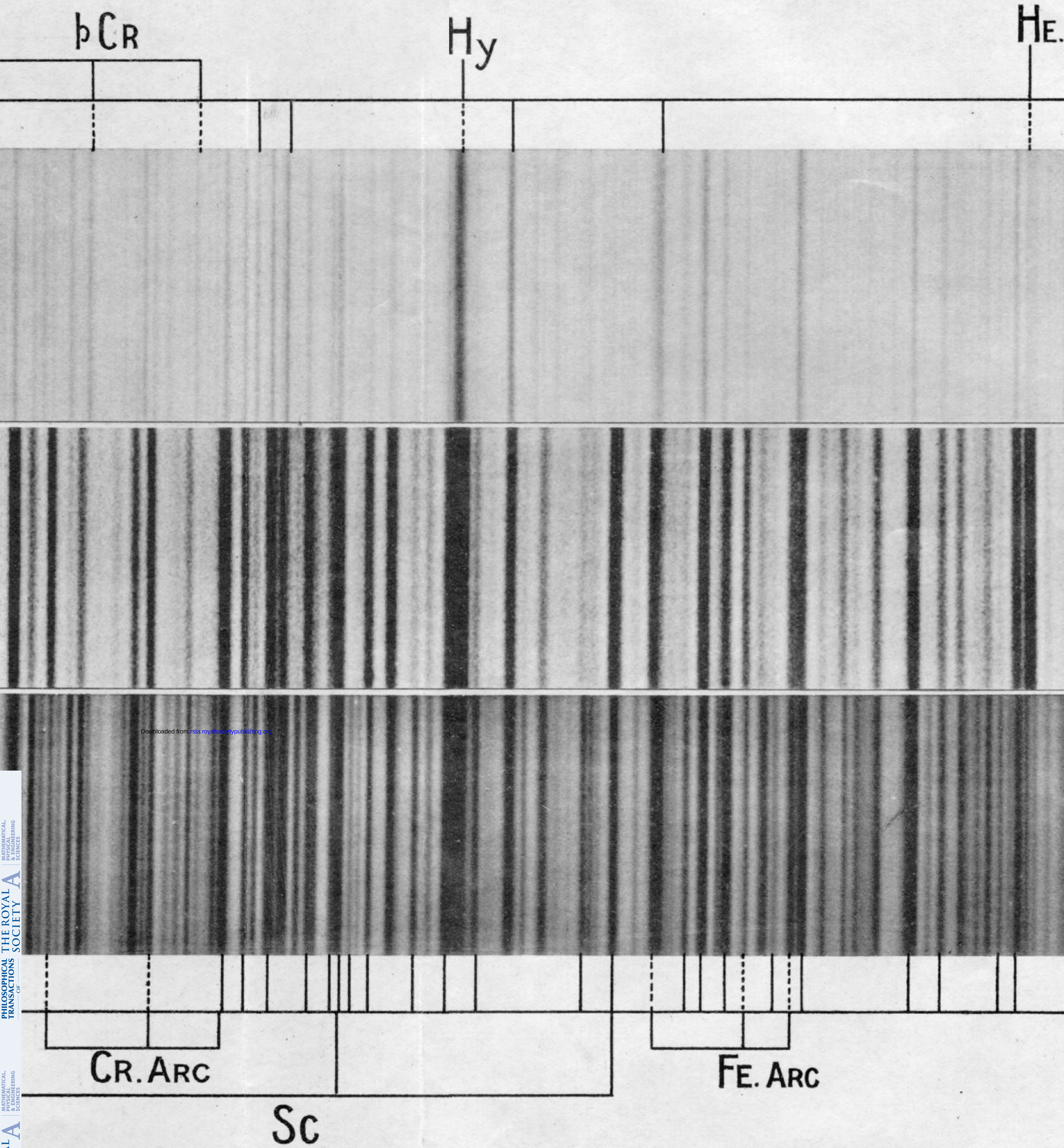

ERE 3. γ CYGNI

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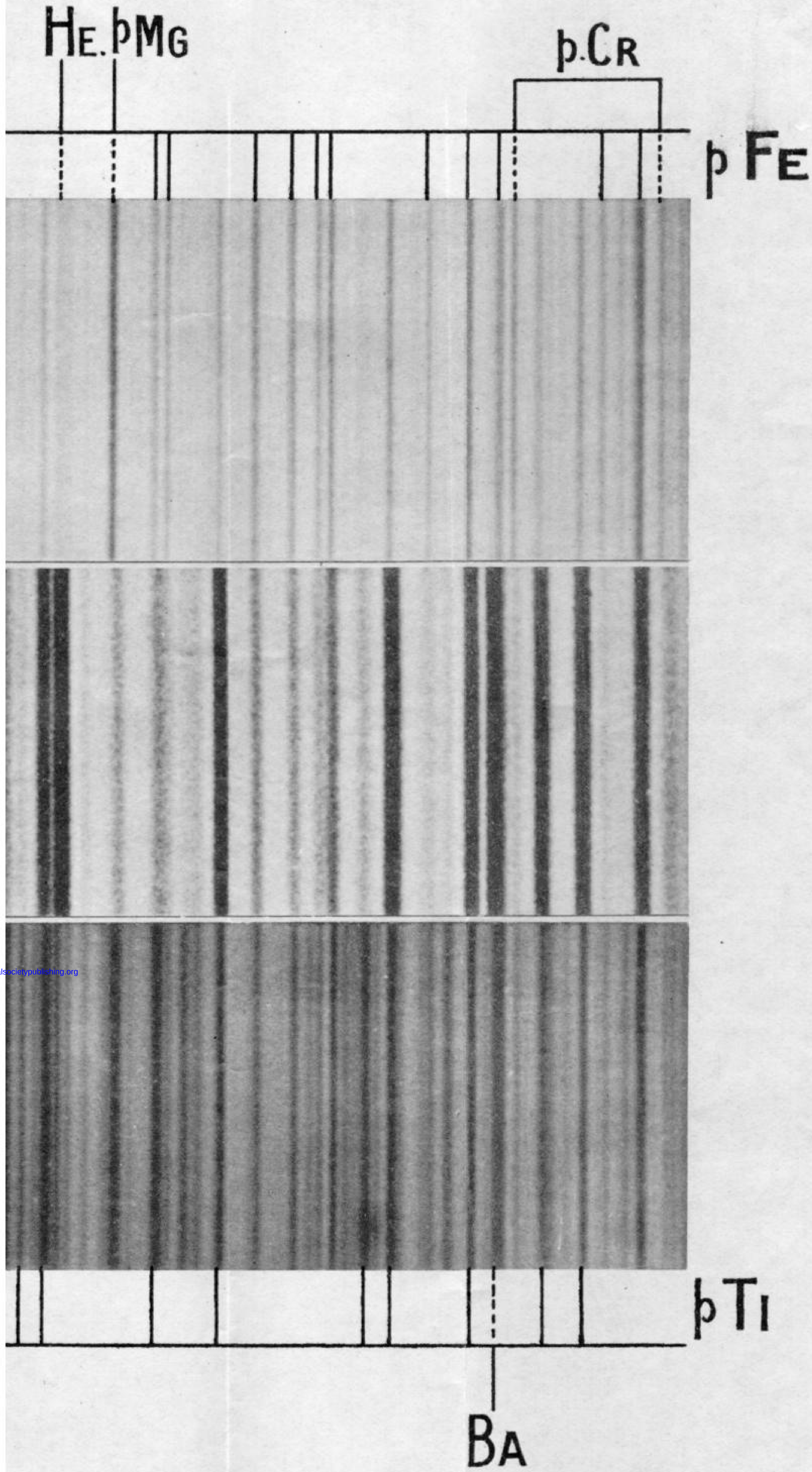

He. þMg
þ.Cr
þFe
þTi
Ba