IX. *Wave-length Determinations and General Results obtained from a Detailed Examination of Spectra Photographed at the Solar Eclipse of January* 22, 1898.

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[Plates 10–12.]

THE results are here given of a detailed study and measurement of a series of ten spectra, photographed by me with a small prismatic camera, at the eclipse camp of the British Astronomical Association stationed at Talni, India.

The instrument referred to had an aperture of 50 millims., and a focal length of about 890 millims. It was fitted with two crown-glass prisms, each of 60° angle, placed in front of an ordinary visual objective, the component lenses of which were slightly separated in order to shorten the focus of the ultra-violet rays relatively to those of the visible spectrum.

[The prisms, which were set at minimum deviation for K, were originally intended for use in a spectroheliograph designed by Professor HALE, and were used by him in an attempt to photograph the corona in sunlight. They were made by the Zeiss Optical Company, of carefully selected glass, and are 59 millims. in height and 65 millims. measured on the faces, giving an effective aperture of about 42 millims. The total thickness of glass, or mean length of path traversed by the rays in glass, is therefore 65 millims.—*March* 9, 1901.]

The camera box was fitted with a long sliding plate-holder, moved by rack and pinion across the field of the lens and at right angles to the length of the spectrum. By this means it was possible to change the plates and make the successive exposures at very short intervals of time.*

In all the eclipse negatives obtained with this instrument, the extension of the spectra in the ultra-violet is greater than had been anticipated, and the density of the silver deposit is surprisingly uniform throughout the spectrum. In this connection it is of interest to compare the eclipse plates with a series of trial plates made

* For a full description of the methods of working see 'Report on the Indian Eclipse of 1898,' published by the British Astronomical Association.

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in England for the purpose of securing a good focus over the greatest possible range of spectrum. In these preliminary trials the prismatic camera was mounted in front of a large reflecting telescope, the eyepiece of which was replaced by a slit receiving light from a clear sky.

All the spectrum photographs obtained in this way are very dense in the region near G compared with other parts of the spectrum, and those which are correctly exposed for G give only a very feeble impression of the spectrum in the ultra-violet above K. A very long exposure gave an extension nearly as great as in the eclipse negatives, but the image is extremely feeble at O (λ 3441), whilst the whole of the lower spectrum from λ 3700 down to D is very greatly over-exposed.

In the eclipse negatives, on the other hand, there is only a slight indication of over-exposure at G, and yet the lines are strongly shown up to the limits of the plates, one of which extends to λ 3340. (Compare fig. 2 with figs. 1 and 3 in Plate 10.) The same kinds of plates were used in both cases, and the very satisfactory results obtained at the eclipse are probably to be attributed to the extreme dryness of the air in Central India at the time of the eclipse.

The following table gives the approximate exposure times, the plates used, and the limits to which the spectra can be traced in the ten eclipse negatives. As I was working without any assistance, the times of exposure could only be very roughly estimated. In the case of the four cusp spectra, the times have been calculated from measures of the width of the strip of continuous spectrum.

Number.	Exposure times.		Plate used.	Spectrum photographed.	Limits of wave-length.
		seconds.			λ. to λ.
1	Second contact	− 20 (inst.)	Edwards' isochromatic medium	Cusp	336 to 590
2	,, ,,	− 10 (inst.)	Ditto	Cusp	340 ,, 590
3	,, ,,	− 2 to + 2	Ditto, instantaneous	Flash	334 ,, 600
4	,, ,,	+ 8 (inst.)	Ditto	Chromosphere	343 ,, 580
5	,, ,,	+ 40 to + 75	Ditto	Corona	335 ,, 590
6	,, ,,	+ 76 to + 85	Ditto, snapshot	{ Corona and	350 ,, 590
7	,, ,,	+ 86 to + 110	Ditto	chromosphere	344 ,, 656
8	Third contact	+ 1 (inst.)	Sandell triple coated	Flash	345 ,, 530
9	,, ,,	+ 9 (inst.)	Ditto	Cusp	345 ,, 530
10	,, ,,	+ 19 (inst.)	Ditto	Cusp	345 ,, 530

All the exposures made yielded good negatives, and Nos. 1, 2, 3, 4, and 7 were selected for measurement. The first five spectra of the series are nearly perfect in focus between the limits λ 390 and λ 340, but the remaining five, exposed after mid-eclipse, are not quite so satisfactory, the focus being good only in the extreme ultra-violet, from 370 to 340.

Owing to the imperfect chromatic correction of the lens used, it was found necessary to incline the plate-holder about 7 degrees from the normal to the axis of the instrument in order to obtain a good focus over a long range of spectrum, and the slight shift of the whole spectrum in the direction of its length, which occurred when the chromosphere arcs changed from the east side of the sun to the west, was sufficient to spoil the focus for most of the spectrum, and shift the region of good focus further towards the more refrangible end than had been allowed for.

It was found possible, however, to make fairly good measures of all the lines shown in No. 7 spectrum.

Photographs of the Cusp before Totality.

Spectra Nos. 1 *and* 2 (Plate 10, fig. 1).—The first two photographs of the series are images of the cusp spectrum, the exposures being made 20 and 10 seconds before totality respectively. At the moment when the first exposure was made, the strip of photosphere still uncovered had a width of 8″ at the centre of the cusp, and this had diminished to 4″ only when No. 2 was exposed. The cusp therefore acted the part of an exceedingly fine slit, and gave beautiful images of the Fraunhofer lines.

The two images obtained may be considered together as they are alike in every respect, excepting in the width of the continuous spectrum. This is 5·20 millims. in No. 1, and 4·78 millims. in No. 2, the moon's diameter on the plate measuring 8·45 millims. The continuous spectrum shows most of the features of the ordinary Fraunhofer spectrum, the dark lines being represented by very sharply defined curved arcs. These are, however, very much less dark than the lines in the spectrum of ordinary sunlight, and the hydrogen lines β, γ, and δ are not present as dark lines at all. H and K are broad and dark, with an irregular reversal at one point showing motion in the line of sight.

With the exception of the absent hydrogen lines the relative intensities of the dark lines in these spectra appear to be identically the same as in the Fraunhofer spectrum throughout the whole region photographed, but the cusp spectra have a pale "washed-out" appearance when placed beside photographs of the spectrum of ordinary daylight, and this peculiarity does not seem to be due to any accident of exposure or development.* (Compare the dark lines in figs. 1 and 3, Plate 10, with the corresponding lines in fig. 2.)

* [After returning to England a set of photographs of the Fraunhofer spectrum was obtained with the same prismatic camera, for comparison with the cusp spectra. These were obtained in the same manner as the preliminary trial plates mentioned above, using a reflecting collimator and a slit.

In order to reproduce as closely as possible the form of the solar cusp a circular slit was used, this was formed by a round hole cut in a plate of brass and nearly covered by a circular disc of slightly larger diameter. The hole was made to subtend an angle of 32′ at the prisms, and the ratio of the diameters of the hole and disc was made the same as that of the sun and moon at the eclipse.

In making the exposures the slit was simply directed to a clear sky at a considerable altitude. Fig. 2, Plate 10, is a reproduction of one of the spectra so obtained, in which the breadth of the band is the same as that of the cusp spectrum in fig. 1. The angular width of the slit was therefore the same as that of the solar cusp at the moment when the cusp spectrum was photographed (about 8″ at the middle point).—*March* 9, 1901.]

The bright radiations of the chromosphere are in no cases strong enough to show as bright lines upon the continuous spectrum, although they are strongly impressed along the borders, where they form in many cases a continuation of the dark arcs of the Fraunhofer spectrum. The very strong bright arcs, H and K, can be traced round the limb of the moon for a greater distance than any others.

No. 2 spectrum appears to have been under-exposed and the bright arcs are rather difficult to detect upon it, although the exposure was made within 10 seconds of second contact.

Measures were not made of the bright lines in either spectrum as they are not very well adapted for accurate determinations. All of them can be identified with the stronger lines in No. 3 spectrum.

Methods of Measurement and Reduction of the Spectra.

The Fraunhofer spectrum was carefully measured in both cusp spectra and identified line by line with HIGGS's photographic map of the normal solar spectrum.

As these measures form the basis for the determination of wave-lengths in spectra No. 3 (flash) and No. 4, it is desirable to give a brief account of the methods adopted.

I am indebted to Dr. RAMBAUT for the loan of an excellent millimetre micrometer belonging to the Radcliffe Observatory.

This instrument consists of a microscope mounted on a sliding frame, and moved by a long screw with a pitch of 1 millim. The head of the screw is divided into 100 parts, and by estimation can be read to ·001 millim. All the measures were made upon this micrometer.

Each spectrum was measured completely three times over, using different sections of the screw and different readings of the head each time. By this means any systematic differences due to errors in the screw were eliminated in the mean result, and accidental mistakes in reading the divisions were readily found and corrected. No evidence of any systematic error in the screw was, however, detected, and the three sets of measures of spectra Nos. 1 and 2 showed a very satisfactory accordance throughout the whole length measured.

In measuring a line, the mean of three settings of the spider lines was taken as the scale reading of the line, and in the final mean result, in which the two cusp spectra are combined, every line represents eighteen settings of the spider lines.

The measures of the two cusp spectra when compared were found to agree as closely as two separate measures of either spectrum, thus proving that no change had occurred in the dispersion from any cause. The two spectra were therefore considered to be identical, and the measures were combined.

From the final mean of the six sets of measures about thirty well-defined and isolated lines were selected as standards; these are all distributed through the ultra-violet portion of the spectrum more refrangible than H. In the region between

H and F about twenty-six lines were used, which are, however, not so well defined or so satisfactory as standards as the others.

In constructing a scale of wave-lengths for the reduction of the bright-line spectra (Nos. 3 and 4), the best defined known lines between D and H in these spectra were also selected as standards, and used together with the twenty-six cusp spectrum lines. But in the ultra-violet the scale depends entirely upon the standards of the cusp spectrum, the whole of the lines in this region in Nos. 3 and 4 (including the hydrogen lines) being treated as unknown. A careful comparison made between measures of known lines in Nos. 3 and 4 spectra and the mean measures of the two cusp spectra shows that it is safe to assume that all the spectra obtained before mid-eclipse may be considered to be identical as regards dispersion.

A sufficient number of standards well distributed throughout the entire spectrum being thus obtained, the approximate relation between scale reading and wave-length at all points in the spectrum was next determined by graphical methods, and from the interpolation curve obtained it was easy to compute the scale reading corresponding to a number of definite points in the spectrum separated by equal intervals of wave-length.

The scale reading corresponding to each 50 tenth-metres of wave-length was in this way computed, taking in each case the mean result given by three or four standard lines situated near; and the values thus obtained were finally slightly corrected by smoothing differences until fifth differences were made to increase in a regular progression.

The smoothed values in no case differ from the values derived from the measures by quantities greater than the uncertainties of the measures themselves. The mean difference in the best defined portion of the spectrum λ 4100 to λ 3400 is ·0016 millim., and the greatest difference ·005 millim., the latter corresponding to ·15 tenth-metre at λ 4100 and ·07 tenth-metre at λ 3400.

In the visible spectrum the definition under the microscope is very poor in all the negatives except No. 4, and the measures in consequence are not very consistent, but for the sake of completeness every line has been measured, and an accurate scale of wave-lengths constructed for the entire range of spectrum photographed.

From the accordance between the different sets of measures of the bright lines in No. 3 spectrum the probable errors of the wave-length determinations given in Table I. (p. 404 *et seq.*) would appear to be about ·15 tenth-metre at λ 4000, decreasing to ·05 tenth-metre at λ 3400.

The Bright-line Spectra.

Spectrum No. 3 (Plate 11, fig. 1).—This negative was exposed at the moment when the dark lines of the Fraunhofer spectrum were seen to disappear and innumerable bright lines flashed out across the strip of continuous spectrum which still remained visible.

I was observing with a slitless spectroscope attached to a 3-inch equatorial, and made the exposure as nearly as I could judge 2 seconds before the last trace of continuous spectrum vanished. The plate was given an exposure of at least 4 seconds in order to impress the fainter details.

In the photograph the strip of continuous spectrum is divided into four parts by longitudinal dark bands due to irregularities in the moon's limb. Most of the bright lines of the chromosphere and flash spectra are visible as bright lines upon the continuous spectrum, but the helium lines at λ 4026·5 and λ 4713·2 are an exception, and they cannot be traced even in the dark spaces between the strips of continuous spectrum, although strongly impressed on either side. The helium line at λ 4472 is visible, but weaker in the intermediate dark spaces. No trace of any absorption lines can be detected in any part of the continuous spectrum.

The total depth of the chromosphere as indicated by the calcium lines H and K is 11″·6, these lines extending over an arc of 124 degrees. The hydrogen lines β, γ, δ, ς, and the titanium lines at λ 3761·5, λ 3759·3, and λ 3685·3, as well as the helium line D‴, extend over an arc of about 102 degrees, implying a depth of 8″·2.

The bright arcs of the flash spectrum proper are approximately of the same length. On the north side of the continuous spectrum they are cut off abruptly by a dark band, due to a projecting lunar mountain, and two similar bands interrupt the lines on the south side.

Most of the fainter flash lines can be traced over an arc of 40 degrees of the sun's limb, indicating a depth of 1″·3, or nearly 600 miles.

A great many of the stronger lines, however (chiefly titanium, iron, and magnesium lines), extend faintly far beyond this limit, and can be traced over an arc of nearly 70 degrees, the depth implied in this case exceeding 4″, or 1800 miles.*

A few very faint lines due to the very lowest layers of the chromosphere are also indicated in the best defined portion of the negative. These are visible only upon the strips of continuous spectrum, and do not extend beyond.

Probably only a small proportion of the finer lines which were actually present at second contact are shown in this photograph. In the green region near *b* this is certainly the case. The most striking feature seen when observing the spectrum under high dispersion and without any slit was the immense number of excessively fine bright arcs which appeared in a short section of the spectrum (including the *b* lines) at the moment when the exposure was made. Yet very few of these lines appear on the photograph, partly perhaps on account of the poor focus in this region.

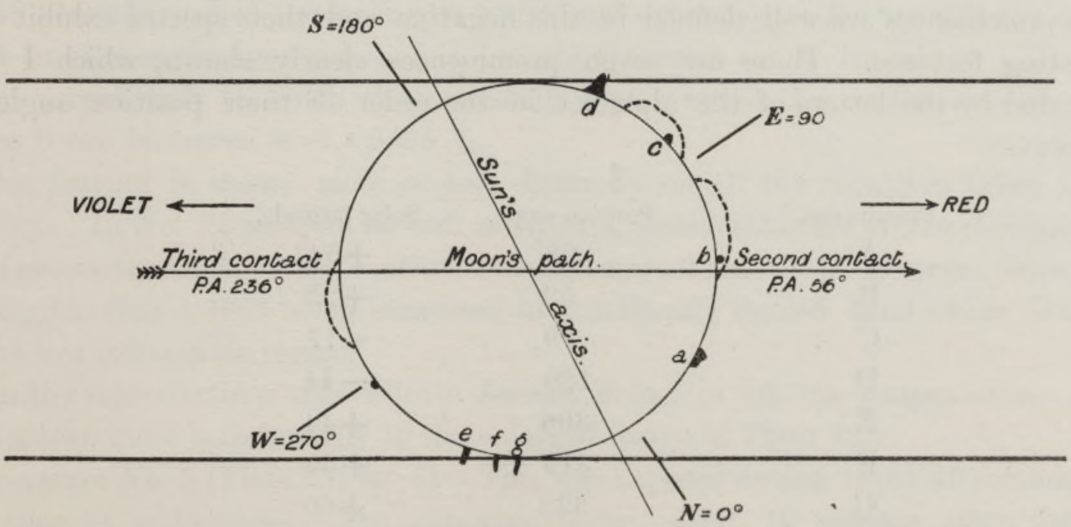
* [In estimating depths from the lengths of the arcs the moon's apparent semi-diameter is taken at 997″·0 and that of the sun 974″·9. A uniform distribution of the gases round the limb is of course assumed, and the results from No. 3 spectrum indicate the depth measured from the photosphere to the upper limit to which each particular radiation can be traced. The depth of photosphere left uncovered by the moon in this photograph being quite inappreciable, the limb of the moon may be considered as being coincident with that of the sun at the point of second contact.—*March* 9, 1901.]

The continuous spectrum of the corona is strongly marked on this photograph, but only one true corona line is visible, the green line at λ 5303. This line can be traced only on the eastern portion of the moon's limb, and, unlike the chromosphere arcs, it is very variable in intensity, being strongly marked about the position angles 60° to 70°, and 100°, where the continuous spectrum is also strong, but extremely weak or entirely absent in other parts of the limb.

The results of measures of the corona line on this plate and No. 7 spectra are given on p. 401.

[In the reproductions of the bright-line spectra shown in Plate 11, the position angles may be inferred from the fact that the direction of dispersion is also the direction of the moon's path across the sun, the point of second contact (P.A. 56°) being at the centre of the arcs on the right-hand side, and third contact (P.A. 236°) at the centre on the left. The angles are reckoned from the north point through east, south, and west.

The upper edge of each spectrum, therefore, represents the south-east limb, and the lower edge the north-west limb. The diagram below, showing the prominences in their correct positions, will make this clear. The broken lines indicate the positions where the green corona line is strongest on the negatives. In the reproductions it can be faintly traced on the east limb, where it persists throughout totality, thus proving it to be a true coronal radiation, since the chromosphere on this limb was entirely hidden by the moon after mid-eclipse.



In fig. 5 the interrupted coronal arc is perhaps best seen; it almost meets the oppositely curved chromosphere arc D‴.

The wave-length scale at the top of Plate 11 must be understood as applying only to fig. 1, for which it was constructed. The designation of the principal lines in the spectra are given underneath fig. 5, at the bottom of the plate.

For further facilitating references to the bright lines a plate is given of the ultra-violet region of the spectrum of the lower chromosphere. In this a wave-length scale is given above and the designation of some of the principal lines below. The plate has been prepared by purely automatic methods from the original negative taken at second contact. By photographing a longitudinal section of this negative with a cylindrical lens interposed, the short sections of the chromosphere arcs are spread out into straight lines.

Great care was taken to exclude spurious lines due to defects in the film or to dust on the slit. By using a rather wide slit these imperfections have been reduced to a minimum, although this involved a slight sacrifice of definition and loss of detail.—*March* 9, 1901.]

Spectrum No. 4 (Plate 11, fig. 2).—The exposure in this photograph was probably less than half a second duration, and was made several seconds after closing No. 3 exposure.

The continuous spectrum of the corona is faintly impressed* and the green line is just traceable at the points where it is strongest in No. 3 spectrum. The chromosphere arcs H and K and the hydrogen series are narrow and well defined, the latter both in the visible spectrum and the ultra-violet. The three titanium lines at λλ 3761·5, 3759·3, and 3685·3 are shown as exceedingly fine threads, extending over an arc of about 60 degrees; they are distinctly stronger than the line Hη but fainter than Hζ. The hydrogen lines β, γ, δ and the calcium lines H and K can be traced over nearly the same extent of the limb as in No. 3 spectrum.

The prominences are well defined in this negative and their spectra exhibit some interesting features. There are seven prominences clearly shown, which I have designated by the letters of the alphabet in the order of their position angles, as follows:—

Prominence.	Position angle.	Solar latitude.
A	28°	+54°
B	59	+23
C	99	−17
D	126	−44
E	306	+44
F	315	+53
G	322	+60

All these prominences are about equally intense in the calcium lines H and K; D is the largest and B and C are the smallest images.

* In preparing a plate suitable for reproduction it was found necessary to intensify the image with uranium. This has made the continuous spectrum of the corona appear very much stronger than it is in the original negative.

In the hydrogen images A, and the group E, F, G are much fainter than the others, and in the ultra-violet the images of these four are very difficult to trace beyond the line $H\theta$. A is however very faintly indicated in the three titanium lines above mentioned.

The prominence C is much brighter in hydrogen than the foregoing and can be traced to the line $H\mu$. The three titanium lines are also clearly shown.

The prominences B and D are the strongest of all in hydrogen, and although very different in size and general character (as observed in $H\alpha$ about an hour before totality) they give practically the same spectra.

The prominence B being situated very near the point of second contact (P.A. 56°) its spectrum falls almost exactly along the centre of the photograph. It is, therefore, in the best position for accurate measures ; and as the images in the ultra-violet are well defined circular black spots, much smaller and more definite than the corresponding images of the large prominence D, the wave-lengths given in Table II. are deduced from measures of this prominence only. (See p. 411 *et seq.*)

Nearly all the lines measured can however be traced also in D ; there are fifty-two altogether and all of these are accounted for by the elements H, He, Mg, Al, Ca, Sc, Ti, Fe, and Sr.

A remarkable feature in the spectra of the prominences B and D is well shown in this negative. The prominence D shows traces of a continuous spectrum in the region less refrangible than H, which is absent in B. Both prominences, however, give a strong continuous spectrum in the extreme ultra-violet, beginning abruptly at λ 3668 near the end of the hydrogen series, and extending as far towards the smaller wave-lengths as the impression of the corona spectrum can be traced.

The actual limit to which the extremely narrow streak due to the smaller prominence B can be traced is at λ 3435 ±.

This feature is shown more or less distinctly on all the negatives taken during totality. In No. 3 spectrum as well as No. 7 a considerable arc of the chromosphere itself shows the ultra-violet continuous spectrum, all the flash spectrum lines more refrangible than λ 3668 being immersed in a uniformly shaded band which is absent in the less refrangible region.

(In the reproductions this delicate feature is lost in all the images except fig. 2. It is shown more satisfactorily in the enlarged image in Plate 12.)

Spectrum No. 5 (Plate 11, fig. 3).—This was exposed during about 40 seconds near the time of mid-eclipse. The exposure began about 10 seconds after the disappearance of the chromosphere on the east limb and ended immediately after its partial reappearance on the west limb.

The continuous spectrum of the corona is strongly impressed, and can be traced as far as λ 3300 in the ultra-violet. The green corona line is well shown on the east limb; it is distinguished from radiations due to the chromosphere by its diffuse character and distinct maxima of intensity corresponding with the brighter regions of the inner corona ; it is most intense at position angles 60° to 78° and 95° to 105°. On the west side it can be traced at about position angle 250°, but is extremely faint here.

No trace of any true corona line can be made out in the blue or violet part of the spectrum, but there is a fairly distinct impression of a line near the end of the plate at λ 3388, where faint maxima of intensity are indicated on the east limb at the same position angles as the maxima of the green line.

The chromosphere in this negative is represented by the lines H and K only, which form arcs extending over the western limb (P.A. 182°–289°). The prominence C gives the principal hydrogen, helium, and titanium, lines in addition to H and K.

Spectrum No. 6 (Plate 11, fig. 4).—The exposure in this case was of 10 seconds' duration, beginning about 2 seconds after closing No. 5.

The chromosphere arcs have reappeared in the hydrogen and helium lines on the west limb, and the former can be traced to Hπ. The three strongest titanium lines are also visible, extending over an arc of 60°. The prominence C shows the streak of continuous spectrum starting at λ 3668 and extending as a fine thread far into the ultra-violet.

The green corona line is faintly impressed both on the east and west limbs, but no other corona line can be made out with any certainty. There is, however, a doubtful impression of a line extending pretty uniformly over the west limb at a point in the spectrum a little less refrangible than H (λ 398/399). It cannot be traced at all on the east limb, at the points where the green line is most intense, and if it is a real corona line, the substance producing it is evidently not the same as that which gives the green line.

Spectrum No. 7 (Plate 11, fig. 5).—The exposure of 20 seconds' duration was started immediately after the last and ended only 3 or 4 seconds before the photosphere appeared.

In the chromosphere spectrum Hα is well shown, and in the ultra-violet the hydrogen lines can be clearly traced to Hω. Many of the stronger flash-spectrum lines are visible along the central portion of the photograph extending over arcs of from 40° to 60°. The wave-lengths deduced from measures of these lines are given in Table I., and in the region between λ 340 and λ 360, where the focus is good, the results are as accurate as those obtained from No. 3 spectrum.

A conspicuous feature in this photograph is the shaded band of continuous spectrum in which the more refrangible lines of the flash spectrum are immersed. It is absent in the region less refrangible than λ 3668, and corresponds to the fine streak or tail which the prominence C shows in all the photographs obtained during totality.

The green corona line is better defined in this photograph than in any of the others. The positions of maximum intensity correspond precisely with the bands of continuous spectrum due to the brightest regions of the inner corona. The position angles measured on this plate are as follows :—

	Position angle of maximum intensity.
East limb	57° to 78°
	94 ,, 100
West limb	235 ,, 254

As in No. 6 spectrum there is an exceedingly faint impression of a corona line near H and extending over the west limb, but excepting this no trace of any other lines are visible. The image, unfortunately, is too feeble in the extreme ultra-violet to show the line at λ 3388 found on No. 5 spectrum.

Spectrum No. 8.—This negative was exposed for about half a second almost at the moment of third contact. The reappearing photosphere has been impressed as four very narrow streaks of continuous spectrum. The flash spectrum is well developed, and the whole length of the spectrum is crowded with bright lines extending between and across the strips of continuous spectrum. The majority of the lines due to the lower chromosphere extend over an arc of 55°, the depth implied in this case being 2″·5.

The focus in this negative is unfortunately very poor throughout the spectrum, and no measurements were made for determining wave-lengths. The spectrum was, however, carefully compared with No. 3 by means of enlargements of each spectrum, which were made to correspond approximately in scale. Superposing one spectrum upon the other it was found that the two appeared to be identical in all respects. If any differences exist at all between the spectra of the east and west limbs of the sun they can only be found in the finer details, which in No. 8 are lost by reason of the imperfect focus.*

The Cusp Spectra after Totality.

Spectra Nos. 9 *and* 10 (Plate 10, fig. 3).—These were given an exposure of less than half a second at about 10 and 18 seconds after third contact respectively. They are both very similar to the first two spectra of the series, but apparently the exposures were appreciably of longer duration than those made before totality, and the bright lines bordering the continuous spectrum of the photosphere are in consequence much more strongly marked than in Nos. 1 and 2.

As in all the spectra of the west limb the focus is imperfect except in the ultra-violet region more refrangible than λ 360. The bright lines are, however, fairly well defined along the south edge of the cusp.

The Fraunhofer spectrum is not nearly so well developed in these spectra as it is in Nos. 1 and 2. This may be due to over-exposure as well as poor focus, but at the ultra-violet end where the spectrum is less dense and the focus good, the dark lines,

* No figure is given of this photograph as it was found impossible to produce a satisfactory plate suitable for reproduction.

although clearly visible, are not nearly so strongly marked as in the corresponding negatives of the east limb before totality.

All the more conspicuous lines which are characteristic of the flash spectrum can be distinguished along the south edge of the cusp in both No. 9 and No. 10 spectra.

General Results and Conclusions.

The Flash Spectrum.

In comparing the wave-length values of No. 3 and No. 7 spectra given in Table I. with Rowland's wave-lengths of the absorption lines in the solar spectrum, it is at once apparent that practically every strong line in the latter is present in the lower chromosphere as a bright line. In the region between λλ 3340 and 4410 there are 58 strong dark lines with an intensity exceeding 8 on Rowland's scale of intensities. In the flash spectrum (No. 3 photograph) 44 of these lines are certainly present as bright lines; 6 are probably present, 6 are too near to strong hydrogen lines to be separately distinguishable, and 1 is obscured by H. One line only of the 58 is unaccountably absent, that at 3788·046 (Fe, intensity 9).

It is further to be observed that of the bright lines of the lower chromosphere (hydrogen and helium lines being excluded) the great majority appear to be coincident with dark lines having an intensity on Rowland's scale not less than 3, and two lines only λ 3584·37 and 3812·79 occur in a blank space in the solar spectrum where the lines are weaker than intensity 0.

It may be said generally therefore, with regard to the ultra-violet region, that the bright lines of the flash spectrum are reversals of Fraunhofer lines, including *all* the very strong lines (intensity 10 and upwards).

Whilst the positions of almost all the bright lines appear to coincide with dark lines in the solar spectrum, the relative intensities of the lines in the latter are widely departed from in the flash spectrum. A negative of No. 3 spectrum is therefore very unlike a positive of the solar spectrum.

When, however, the flash spectrum is analysed into its separate constituents it is found that the relative intensities of the lines of any one element correspond very closely with the intensities of the dark lines of that element. In the iron and titanium spectra, which claim more lines of the flash spectrum than any other elements, this correspondence is most clearly shown. There are, as might be expected, many cases where the intensities are abnormal, but by taking the average intensity on Rowland's scale of *all* the dark lines corresponding to each unit of intensity in the flash spectrum the effects of these are eliminated. These abnormal intensities are probably due to the superposition of closely adjacent lines.

The following tables prove the general close correspondence of intensities in the flash and solar spectrum for iron and titanium. The first column gives the number of flash lines having the estimated intensity given in column 2, whilst the average intensity of the corresponding dark lines is given in column 3. Although the intensities of the bright lines, estimated on a scale of 1 to 10, are not comparable with those of ROWLAND ranging from 1 to 1000, the relation between the bright and dark line spectra is, nevertheless, clearly indicated by the regular progression of the figures in the last column of both tables corresponding with the progression between 0 and 5 in the middle column :—

Intensities of Iron and Titanium Lines in the Chromosphere and in the Solar Spectrum.

Iron Lines.

Number of lines in flash spectrum.	Photographic intensity.	Average intensity of the corresponding dark lines in ⊙ (ROWLAND).
17	0	5·5
33	1	7·5
25	2	11 3
10	3	25·3
Total 85	Weighted mean 1·3	Weighted mean 10·2

Titanium Lines.

Number of lines in flash spectrum.	Photographic intensity.	Average intensity of the corresponding dark lines in ⊙ (ROWLAND).
5	0	1·6
9	1	3·4
13	2	4·2
9	3	5·4
4	4	7·7
1	5	10·0
Total 41	Weighted mean 2·0	Weighted mean 4·5

The mean intensities given at the bottom of each column show the greater intensity of the Ti lines in the chromosphere compared with Fe, and the much greater average intensity of the Fe dark lines in the solar spectrum compared with the Ti lines.

The striking dissimilarity in the relative intensities of the lines of different elements in the bright-line and dark-line spectra is probably due to the *unequal heights* to which the gases of the various elements ascend in the chromosphere.

The intensities as they appear in photographs of the flash spectrum are evidently largely determined by the relative depths of the various gaseous strata, the more extensively diffused gases giving the strongest bright arcs simply by reason of the greater radiating area. The low-lying gases, on the other hand, although they may be intrinsically more luminous and denser, give fainter arcs because of the excessively small angular width of the radiating area.

It is to be borne in mind that the flash-spectrum arcs or "lines" obtained with a prismatic camera are not true images of the strata producing them, but diffraction images more or less enlarged by photographic irradiation. The deepest layers subtend an angle of only 2″, representing on the sun about 900 miles, and monochromatic radiations from such strata will produce lines which are as narrow as instruments of ordinary resolving power are capable of defining. The diffraction image of a shallower stratum will not be narrower in proportion but simply less bright. A layer of gas 9 miles in depth would, if sufficiently dense, be capable of producing strong absorption lines in the solar spectrum, yet it would have to be 100 times more luminous than a stratum extending for 2″ above the photosphere to give equally strong bright lines in the photograph, even were the moon to remain stationary at the contact and allow of equal exposures.

But it is obvious that, for the shallow layers, the time during which the plate is exposed to any radiation is proportional to the depth of the luminous layer, the advancing limb of the moon cutting off the shallow strata during the exposure; consequently, for an exposure timed from the moment of second contact and lasting until the whole depth of 2″ had been occulted, the plate would be exposed to the 9-mile stratum for only $\frac{1}{100}$th of the whole exposure. This layer would therefore need to be 10,000 times more luminous to give lines of equal intensity to those of the deepest layers.

[In the *absorption* spectrum the relative intensities between the different elements must depend on the total number of absorbing molecules of each element encountered by a ray of light in its passage outward from the photosphere, and not on the relative state of diffusion or depth of the different gases.

To illustrate these points, which appear to me to be of great importance in elucidating the relationship between the emission and absorption spectra, we may consider the typical cases of iron and of titanium in the chromosphere.

The total number of iron molecules encountered by a ray of photospheric light probably vastly exceeds the number of titanium molecules, since the absorption lines of the former are among the strongest and broadest in the spectrum, whilst those of the latter are narrow and mostly weak lines. But the iron vapour is concentrated in a stratum close down upon the photosphere, whilst titanium is diffused through the entire depth of the chromosphere. Hence the *apparent* intensities of the emission lines of iron fall considerably below those of titanium.

If the relative distribution of these two elements were reversed without changing the total quantity of each, the absorption lines would probably not be materially altered in intensity, but the bright lines of iron would then rival those of calcium in H and K, whilst the titanium lines would be difficult to detect in the flash spectrum.—*March* 10, 1901.]

It thus appears that the intensities found in these spectra by no means represent the actual intrinsic intensities of the bright lines of the different elements. Could we obtain a sample of the incandescent gas from near the base of the flash-spectrum layer and examine it close at hand with a slit spectroscope, it is certain that the relative intensities would differ widely from those in the flash spectrum as observed at an eclipse, and it is possible that they would be found to correspond much more closely with the relative intensities in the Fraunhofer spectrum.

From the foregoing considerations it is clear that the emission lines from the lowest levels of the flash layer must be very difficult to observe, however bright they may be intrinsically. The wide divergence between the flash and Fraunhofer spectra, with respect to intensities, would appear, therefore, to afford no ground for abandoning the original interpretation of the flash proposed by Professor YOUNG from his observation in 1870, and the evidence of these photographs certainly indicates that the flash does, in fact, represent the upper, more diffused portion of a true reversing stratum.

In the flash-spectrum photograph (No. 3) fifteen elements can be identified with certainty in the lower chromosphere, in addition to hydrogen and helium, and there are three elements doubtfully represented.

Arranged according to their relative intensities, the following four groups occur :—

Group I.

(Lines strong in flash and in solar spectrum.)

Na . . .	atomic weight	23·0
Mg . . .	,, ,,	24·3
Al . . .	,, ,,	27·1
Ca . . .	,, ,,	40·0

Group II.

(Lines strong in flash but comparatively weak in solar spectrum.)

Sc . . .	atomic weight	44·1
Ti . . .	,, ,,	48·1
V . . .	,, ,,	51·2
Cr . . .	,, ,,	52·1
Mn . . .	,, ,,	55·0
Sr . . .	,, ,,	87·6
Y . . .	,, ,,	88·7

Group III.

(Lines relatively weak in flash, very strong in solar spectrum.)

Fe . . .	atomic weight	56·0
Ni . . .	,, ,,	58·7

Group IV.

(Lines weak in flash and in solar spectrum.)

Zr . . .	atomic weight	90·6
C* . . .	,, ,,	12·0

The elements of which the identifications are somewhat doubtful are—

Si . . .	atomic weight	28·4	One line only λ 3905·660
Co . . .	,, ,,	59·0	Many Co lines seem unaccountably absent in the flash
La . . .	,, ,,	138·5	Two lines only λ 4123·384 and λ 3649·654

It is probable that the elements of Group I. are diffused throughout the entire depth of the flash-spectrum layer, but become denser near the photosphere. Those of Group II. are possibly absent from the very lowest strata, but are widely diffused in the higher regions; whilst the elements Fe and Ni (Group III.) would appear to be mostly concentrated in the lowest strata where the density is great enough to produce the winged absorption lines.

Group IV. probably represents low-lying elements of small density.

The bright lines of the flash spectrum corresponding to Group II. may be considered to be true reversals of the dark solar lines of these elements; that is to say, the whole of the matter concerned in the absorption contributes to the emission spectra, and the bright and dark lines are practically of equal width.

But in the emission lines of Groups I. and III. the radiation from the very lowest region, where the density of each element is considerable, contributes very little indeed to the total light, most of which comes from the higher more extensive regions of low density; consequently the lines appear narrow and without appreciable shading. These lines, therefore, can only be considered as partial reversals of the corresponding absorption lines.

The metallic elements found in the lower chromosphere (including those doubtfully identified) include all the known metals having atomic weights between 20 and 60, with the single exception of potassium. Arranged according to their atomic weights, they are :—

Na . . .	approximate atomic weight	23
Mg . . .	,, ,, ,,	24
Al . . .	,, ,, ,,	27
Ca . . .	,, ,, ,,	40
Sc . . .	,, ,, ,,	44
Ti . . .	,, ,, ,,	48
V . . .	,, ,, ,,	51

* Probably the compound cyanogen.

Cr	. . . approximate atomic weight				52
Mn	. . .	,,	,,	,,	55
Fe	. . .	,,	,,	,,	56
Ni	. . .	,,	,,	,,	59
Co ?	. . .	,,	,,	,,	59
Sr	. . .	,,	,,	,,	88
Y	. . .	,,	,,	,,	89
Zr	. . .	,,	,,	,,	91

Taking the whole series of known elements having atomic weights from 1 to 100, all the metals are here represented excepting the following :—

Li	. . . approximate atomic weight				7
Be	. . .	,,	,,	,,	9
K	. . .	,,	,,	,,	39
Cu	. . .	,,	,,	,,	64
Zn	. . .	,,	,,	,,	65
Ga	. . .	,,	,,	,,	70
Ge	. . .	,,	,,	,,	72
Rb	. . .	,,	,,	,,	85
Nb	. . .	,,	,,	,,	94
Mo	. . .	,,	,,	,,	96

Of the nineteen known metalloids, the only ones indicated in these spectra are—

H	. . . approximate atomic weight =				1
He	. . .	,,	,,	,,	4
C	. . .	,,	,,	,,	12
N	. . .	,,	,,	,,	14
Si ?	. . .	,,	,,	,,	28

None of the elements with atomic weights exceeding 91 appear to be represented in the flash spectrum, unless we include lanthanum (at. wgt. 138). It is probable, however, that with instruments of much greater aperture and focal length than the one employed in this research photographs would be obtained which would bring to light many of the heavier metals which doubtless exist in the lowest strata of the flash-spectrum layer.

Although it would seem from the above statement that there is a general, inverse, relation between the atomic weight of an element and the extent of diffusion of its vapour above the photosphere, it is evident that among the elements actually found in the chromosphere this relation does not always hold ; thus calcium and titanium ascend to far greater elevations than the three elements of smaller atomic weight, sodium, magnesium and aluminium.

Unknown Lines.—Only a small proportion of the lines in Table I. remain to be identified. In the region between λλ 3340 and 4000 there are 29 such lines in a total of 225, and all of them are weak lines. The strongest (intensity 2) correspond in position with dark lines in ROWLAND's table which have not been identified with any element, and these are given in the following list:—

Wave-length in flash.	Intensity.	Wave-length in ⊙.	Intensity.
3567·77	2	3567·835	4
3589·72	2	3589·773	5
3645·35	2	{3645·429	3
		3645·475}	3
3655·78	1	3655·801	3

These are the only unknown lines in the flash spectrum with an intensity greater than 1, and it is just possible that they belong to the same element.

The Hydrogen Spectrum.

The wave-lengths of the hydrogen lines taken from Tables I. and II. are entered separately in Table III., together with the values computed from BALMER's formula. The latter were computed for a vacuum and corrected for air in accordance with a table of RUNGE (' Astronomy and Astro-physics,' vol. 12, No. 5).

In the formula

$$\lambda = \frac{S^2}{a(S^2 - 4)},$$

S is the series number of the line, and a is a constant derived from ROWLAND's measures of the lines Hα, Hβ, and Hγ in the solar spectrum reduced to a vacuum, the mean value adopted being $a = 27418{\cdot}75$.

In obtaining the mean values given in column 4, equal weights are given to No. 3 and No. 4 spectra, both of which are in good focus beyond K, and give equally consistent measures in this region. No. 4 spectrum is, however, much the better of the two in the visible region, where the images are comparatively small, well-defined spots. This spectrum, as already mentioned, consists of a series of images of a very small bright prominence, and very consistent measures were obtained throughout. The good agreement of the wave-lengths of the metallic lines with ROWLAND's values will be seen on referring to Table II.

The very close agreement of the hydrogen lines with the computed values is shown in column 6 of Table III. (observation — calculation). It will be noticed, however, that the wave-lengths of the more refrangible members of the series are appreciably smaller than the theoretical values, the differences increasing towards the limit of the series. This may be due to the greater uncertainty of measurement of the fainter lines, which are apt to be confused with other lines closely contiguous, or it may possibly be due to a slight progressive error in the scale value for this region.

The results obtained for No. 7 spectrum given in column 7 appear to confirm the values of the more refrangible lines in No. 3, although they were obtained by quite independent methods of reduction. The measures of this plate, however, cannot be given the same weight as those of the other two, the definition being poor owing to imperfect focus.

The lines in the visible spectrum Hα, β, γ, and δ are entered for the sake of completeness, but they are not to be compared in accuracy with the ultra-violet lines. This is largely due to the difficulty in measuring the broad over-exposed lines β, γ, and δ on No. 3 spectrum, and partly to the small dispersion in this region.

The line δ appears in all the measures to be largely displaced towards the red, but this is probably accidental. It is remarkable, however, that in ROWLAND's table of the solar lines Hδ is given at λ 4102·000, which is also less refrangible than the theoretical position, the difference being ·10 tenth-metre. The almost perfect agreement of the other absorption lines in his table, and the very close agreement of the best defined ultra-violet lines in Nos. 3 and 4 spectra with the positions assigned by the formula, suggests that the wave-length of this line has been erroneously estimated. Mr. JEWELL, however, who made the measures of ROWLAND's plates, while admitting some uncertainty in estimating the centre of the line in the solar spectrum, finds on re-examining his measures, no justification for altering his original estimate (' Astro-Physical Journal,' vol. 9, p. 211).

It is very desirable that accurate measures be made of Hδ in the upper chromosphere where the line is narrow and free from interfering lines.

The limit of the hydrogen series defined by the formula when $s = \infty$ is at λ 3646. But in the chromosphere spectra the lines fade away to invisibility long before reaching this point. I would call particular attention, however, to the very remarkable band of continuous spectrum shown by the prominences and lower chromosphere, beginning near the end of the tabulated series and extending indefinitely towards the more refrangible end of the spectrum. The interspaces between the hydrogen lines are quite clear of this continuous spectrum, which begins abruptly at about 3668. (See Plate 12.)

It seems probable that this faint spectrum may be itself due to hydrogen. In the *absorption* spectrum of white stars of Type I., Sir WILLIAM HUGGINS has observed an analogous feature. This consists in the "rather sudden fall of intensity of the continuous spectrum at about the place of the end of the series of dark hydrogen lines. The enfeebled spectrum continues to run on without further enfeeblement until it is stopped by the absorption of our atmosphere."*

This seems clearly to be the absorption effect of the matter giving the faint continuous spectrum in my plates, and the fact that the feature is characteristic of white stars in which the hydrogen absorption is very strong points to its being due to hydrogen itself.

* 'An Atlas of Representative Stellar Spectra' (Sir WILLIAM and Lady HUGGINS), p. 85.

Helium and Hydrogen in the Lower Chromosphere.

The part played by helium and hydrogen in the lower chromosphere may next be considered. Helium is probably absent from the very lowest strata, if indeed it is present at all in the flash-spectrum layer. The lines at λλ 3634·4, 4026·3, 4471·6, and 4713·2 are very weak, or quite invisible upon the continuous spectrum at the centre of the photograph (No. 3) although strong on either side, whilst the majority of the lines of the flash spectrum proper are strongly impressed right across the continuous spectrum. This would point to the absence of helium from the region within 2″ of the photosphere.

[But the lines at λλ 4922·1 and 5015·7 appear on the other hand to be strong on the continuous spectrum and weak at the sides. It is to be remarked, however, that these lines belong to two series of lines in the spectrum of clèveite gas which have been ascribed to *parhelium* by RUNGE and PASCHEN.* It would seem, therefore, that these "parhelium" lines, whatever their origin, are produced under conditions existing only in the lower levels.—*March* 10, 1901.]

The absence of appreciable absorption due to helium in the solar spectrum seems also to favour the view that this element exists only in a rarefied condition in the upper chromosphere. This peculiarity in the spectrum certainly does not necessarily imply equality of temperature between the radiating gas and the photospheric background; for the hydrogen spectrum affords a demonstration that chromospheric gases at a lower temperature than the photosphere, can emit strong bright lines without corresponding absorption lines. Thus, in the visible spectrum the dark lines corresponding to Hα, β, γ, and δ are sufficient evidence that hydrogen in the chromosphere is cooler than the photosphere. But in the ultra-violet the absorption becomes inappreciable at Hζ, and beyond this point there are no dark hydrogen lines corresponding with the strong bright lines in this region.

In the emission spectrum of the chromosphere there is a progressive diminution of intensity of the hydrogen lines towards the smaller wave-lengths. Nevertheless, the lines Hη, θ, ι, κ are still among the strongest lines in the spectrum beyond K. In the ultra-violet, therefore, hydrogen behaves exactly like helium in the visible spectrum.

The disappearance of the hydrogen absorption lines in the ultra-violet has been ascribed by ROWLAND to excessive diffuseness or widening of these lines, and if this view is correct it follows, as Sir WILLIAM HUGGINS has pointed out, "that the hydrogen absorption in the sun must be restricted to a narrow region low down and close upon the photosphere itself,"† the hydrogen in the higher regions contributing little or nothing to the absorption.

This view, however, which seems to imply the complete independence between

* RUNGE and PASCHEN, "On the Spectrum of Clèveite Gas," 'Astro.-Physical Journal,' vol. 3, No. 1 (1896).

† 'An Atlas of Representative Stellar Spectra,' p. 150.

the emission and absorption lines in the sun, is extremely difficult to reconcile with the ordinary appearance of the lines C and F at the sun's limb. With a radial slit the emission lines are seen to correspond exactly both in width and in absolute intensity with the dark lines, and it is difficult to avoid the conclusion that the *whole depth* of the chromosphere is effective in producing the absorption.*

The progressive diminution of intensity of the emission lines in passing from the visible spectrum towards the ultra-violet appears to be in itself sufficient to account for the disappearance of absorption beyond H. The total quantity of hydrogen above the photosphere is probably too small to produce appreciable absorption when the lines have a certain limiting intensity, although the same lines when viewed at the sun's limb may be strikingly conspicuous, chiefly by reason of the wide diffusion of the gas as already explained in the case of the metallic lines in the flash spectrum, and also on account of the enormous depth of radiating gas through which the line of sight passes.

Unlike helium, hydrogen is very conspicuous in the lower chromosphere, and the fainter more refrangible lines are much more strongly impressed in the photographs obtained near the times of the two internal contacts than in those taken near mid-eclipse with much longer exposures. The intensity of the lines evidently increases rapidly towards the photosphere, but they still remain narrow and well defined even within 1″ of the photosphere.

The Corona Spectrum.

Although the continuous spectrum of the corona is strongly shown on most of the plates exposed during totality, the green line is the only one of which it was possible to obtain measures. The faint line near H in Spectrum No. 6 becomes quite invisible under the microscope, and the new line in the extreme ultra-violet, shown in No. 5, was not discovered until some time after making the measures; the wave-length of this line was estimated by superposing No. 5 spectrum upon No. 3, the hydrogen lines and H and K being made coincident; the position of the new line was then obtained with reference to the fine lines of the flash spectrum.†

The following are the wave-lengths obtained for the green line which was measured on negatives No. 3 and No. 7 :—

No. 3 spectrum λ	=	5307·0
No. 7 ,,	=	5299·7
Mean λ	=	5303·3

* The same may be said of the calcium lines H and K. In the upper chromosphere these lines are narrow and well defined, and correspond exactly with the narrow dark lines at the centres of the broad absorption lines.

† It is impossible in the reproductions to show the corona lines here mentioned, except the green line.

This result is in satisfactory agreement with the value found by Mr. FOWLER on the plates obtained by Sir NORMAN LOCKYER. The difference between the two measures above is due to the opposite displacement of the line in the photographs taken at second and third contacts, the point measured being situated about 2′ above the moon's limb. This apparent displacement affects all lines of a diffuse character where the moon's limb is not well defined.

The three corona lines shown on these plates are therefore—

1. 3388.
2. Near H (on less refrangible side).
3. 5303·3.

The ultra-violet line is similar to the green line in distribution round the limb, and is probably due to the same substance, whilst the line near H differs from the others in showing no maxima of intensity, the substance producing it being evenly distributed on the west limb.

There is no trace whatever of any other coronal line on any of the plates.

SUMMARY OF RESULTS.

The principal results obtained from the study of these photographs are stated briefly in the following paragraphs :—

1. Practically every strong dark line in the solar spectrum is present as a bright line in the flash spectrum.

2. Almost all the flash-spectrum lines (excepting those due to hydrogen and helium) coincide with dark lines in the solar spectrum.

3. The relative intensities of the lines of any one element in the flash spectrum are practically the same as those of the same element in the solar spectrum.

4. The relative intensities between groups of lines belonging to different elements are widely different in the flash and in the solar spectrum.

5. The apparent intensity of the radiation from any element in the lower chromosphere is determined by the extent to which that element is diffused above the photosphere ; and the real relative intensities between the different elements cannot be judged in photographs of the flash spectrum.

6. The flash spectrum may be considered to represent the upper more extensively diffused portion of a stratum of gas which, by its absorption, gives the Fraunhofer dark-line spectrum.

7. Nearly all of the known metals having atomic weights less than 60 are represented in these spectra, and no element having a higher atomic weight than 92 is certainly represented.

8. All the strong lines in the flash spectrum can be identified with known elements, and the small proportion of unidentified lines are weak lines.

9. The wave-lengths of the hydrogen lines in the ultra-violet agree closely with those derived from BALMER'S formula.

10. The prominences and lower chromosphere emit a strong continuous spectrum in the ultra-violet, beginning near the limit of the hydrogen lines and extending indefinitely in the more refrangible region.

11. The ultra-violet hydrogen lines increase in intensity towards the photosphere, but remain narrow lines in the flash-spectrum layer.

12. Some of the helium lines decrease in intensity towards the photosphere, others increase.

In conclusion, I have to acknowledge my indebtedness to Dr. RAMBAUT for much valuable help and advice in the preparation of this paper, and for the kind interest he has taken in the work throughout.

I have also to acknowledge the great assistance rendered to me by Mr. L. E. JEWELL, of the Johns Hopkins University, who made a careful and exhaustive study of some positive copies of my plates.

In identifying the lines given in the tables, I have been guided almost entirely by his results; and I am also indebted to him for supplying me with revised values of many of the solar lines given in the last column of each table.

TABLE I.—*Flash Spectrum Wave-lengths compared with the Dark Lines of the Solar Spectrum.*

In this table the wave-lengths deduced from the measures of No. 3 and No. 7 spectra are entered in the first two columns. The third column gives the photographic intensities for No. 3 spectrum. These were estimated on a scale ranging from 1 to 10; 1 representing very weak lines, and 10 representing the strongest lines in the spectrum. Very faint traces of lines difficult to measure are designated 0 in this column.

In column 5 the wave-lengths of the solar lines are given with which the bright lines have been identified with a greater or less degree of probability. The intensities as given by ROWLAND are entered in column 6, and the element corresponding to the solar line in the last column. The wave-lengths of the helium lines are placed within brackets; they are taken from the tables of RUNGE and PASCHEN.

The columns 5, 6, and 7 are taken from ROWLAND'S tables of solar lines published in the 'Astro-Physical Journal' for 1895, 1896, and 1897, and supplemented by more recent determinations supplied to me by Mr. JEWELL. In a few instances the identifications and intensities will be found to differ from those given in the tables.

In column 4 an (S) means a sharply defined line, well identified, and suitable to be taken as a standard line in wave-length determinations. A (?) in this column indicates that the identification with the solar line is extremely doubtful.

In the last column a ? means that the element in question has not been identified with certainty with the solar line.

TABLE I.

Wave-lengths in flash spectra. No. 3.	Wave-lengths in flash spectra. No. 7.	Photographic intensity. No. 3.	Character. No. 3.	Wave-length, solar spectrum. ROWLAND.	Intensity.	Element.
3342·3	—	2	. . . .	{3342·062 42·358	7 3	Ti Fe Ti
47·0	—	0	(One measure only)	{46·882 47·066	5 2	Ti Co
49·4	—	4	Long . . . . (S)	49·558	12	Ti
54·0	—	2 }	Faintly extended	53·875	4	Sc
58·5	—	2 }		58·649	4	Cr
61·4	—	3½	Long . . . . (S)	61·327	12	Cr ? *Ti*
68·3	—	3	Long	{68·193 68·319	5 1	Cr Mn
73·0	—	4	Long . . . . (S)	72·948	12	Ti
80·4	—	3	Short	{80·424 80·722	6 6	Ti Ni
84·0	—	4	Long . . . . (S)	83·892	10	Ti
88·1	—	3	Long . . . . (S)	87·988	5	Ti
92·1	—	1½	(One measure only)	92·109	2	Zr
94·7	—	3	Long . . . . (S)	94·716	6	Ti
99·3	—	1	Short	{99·376 99·489	2 3	Fe Zr Fe
3403·45	—	3	Faintly extended . . . . . . (S)	3403·404	3	Cr
05·17	—	1	Short	05·217	2	Co
07·32	—	1	Short . . . . (?)	07·597	4	Fe
08·97	—	3	Long . . . . (S)	08·911	3	Cr
10·24	—	1	Visible on south side only	—	—	—
13·0 ?	—	0	Not measured; w-l estimated	—	—	—
15·01	—	1	Visible on south side only	14·911	15	Ni
21·42	—	3½ }	Equal pair; long . . . . . . (S)	21·353	4	Cr
22·94	—	3½ }	(S)	22·892	4	Cr
25·46	—	0 }	One measure only; very short	—	—	—
26·97	—	0 }		—	—	—
28·73	—	0 }		—	—	—
30·61	—	1	Short	30·671	1	Zr
33·54	—	4	Long	{33·453 33·715	3 8	Cr Ni
38·40	—	2	Short	38·376	2	Zr
40·93	—	3	Faintly extended	{40·762 41·155	20 15	Fe Fe
42·24	3442·1	4	Long . . . . (S)	42·112	6	Mn
44·39	—	3	Faintly extended . . . . . . (S)	44·467	4	Ti
46·34	—	2 }	Ill defined	46·406	15	Ni
52·86	53·3	2 }		53·039	6	Ni
56·55	—	2 }	Ill defined; short	56·528	3	Ti
58·58	—	1 }		58·601	8	Ni
60·53	60·4	3	Long . . . . (S)	60·460	4	Mn
61·68	61·7	2	Faintly extended	{61·633 61·801	5 8	Ti Ni
63·05	—	1	Interrupted; very short	62·950	6	Co
64·32	—	1	ditto ditto	{64·275 64·608	1 1	Fe Sr ?
65·87	—	2	Very faintly extended	{65·900 66·015	4 6	Co Fe

TABLE I.—*continued.*

Wave-lengths in flash spectra. No. 3.	Wave-lengths in flash spectra. No. 7.	Photographic intensity. No. 3.	Character. No. 3.	Wave-length, solar spectrum. ROWLAND.	Intensity.	Element.
3467·46	—	0	Stronger south than north of centre . (?)	—	—	—
68·72	—	0	Ditto	3468·821	2	Fe
71·36	—	1	Equal pair, short and interrupted	71·404	3	Fe, Zr
72·58	—	1		72·680	5	Ni
74·28	3474·26	3	Long (S)	74·287	2	Mn
75·67	—	2	Short	75·594	10	Fe
77·26	77·31	3	Long	77·323	5	Ti
79·48	—	1½	Ill defined; short	79·531	2	Zr
81·20	—	1½		81·302	2	Zr
83·08	83·02	3	Long (S)	83·047	5	Mn
88·85	88·84	3	(S)	88·817	4	Mn
91·16	91·10	3	A very faint line is visible about λ 3490 ±	91·195	5	Ti
93·22	93·21	2	Ill defined; faintly extended	93·114	10	Ni
94·60	—	1	Short (?)	94·815	2	Fe
96·17	96·11	3	Long (?)	95·853	2	Ti
				95·974	2	Mn
97·82	97·71	2	Short	97·668	3	Mn
				97·982	8	Fe
99·14	—	0	Interrupted (?)	99·248	0	Ti
3500·45	—	1	Short	3500·474	3	Ti
02·30	—	0	Short (one measure only)	02·394	3	Co
05·06	3505·01	3½	Long equal pair (S)	05·036	5	Ti
10·96	11·10	3½	(S)	10·985	5	Ti
13·95	—	2	Short	13·965	7	Fe
15·15	15·40	2	Faintly extended (S)	15·206	12	Ni
17·37	—	2		17·446	3	V
20·26	—	2½	Short	20·397	2	Ti
21·44	—	1		21·410	8	Fe
21·84	—	1	On continuous spectrum north of centre only	21·748	4	Co
24·67	24·72	3½	Long (S)	24·677	20	Ni
26·22	—	1	Close pair very short	26·183	6	Fe
26·59	—	1		—	—	—
30·80	30·93	1	Faintly extended	30·919	3	V
31·83	—	1	Short (?)	31·982	3	Mn
				32·143	4	Mn
33·35	—	0	Short	33·345	6	Fe
35·64	35·68	3	Faintly extended (S)	35·554	4	Ti
41·17	—	1	Short, fine lines	41·237	7	Fe
42·24	—	1		42·232	6	Fe
45·25	45·39	2	Faintly extended	45·336	2	V
48·08	—	1	Interrupted	47·941	5	Mn
				48·175	3	Mn
				48·332	5	Mn, Ni
49·07	—	2	Short (?)	49·151	2	Y ?
51·93	—	2		52·098	1	Zr
53·15	53·87	0	. . . .	—	—	—
55·02	—	1	On continuous spectrum	55·079	9	Fe
56·82	56·94	2½	Faintly extended	56·738	2	Zr
58·61	58·63	2		58·672	8	Fe
60·88	—	0	Invisible to north side (?)	61·037	4	Co
61·82	—	1	Short	61·898	3	Ni

TABLE I.—*continued.*

Wave-lengths in flash spectra. No. 3.	Wave-lengths in flash spectra. No. 7.	Potographic intensity. No. 3.	Character. No. 3.	Wave-length, solar spectrum. ROWLAND.	Intensity.	Element.
3565·52	3565·64	2		3565·535	20	Fe
66·25	—	1		66·522	10	Ni
67·77	68·08	2	Long lines . . . . (S) (lines 3565·52–72·61)	67·835	4	?
70·21	70·24	$2\frac{1}{2}$		70·273	20	Fe
72·61	72·63	$2\frac{1}{2}$		72·676	6	Sc
73·75	73·98	1	Short	73·874	3	Ti
76·51	76·52	3		76·527	3	Sc
78·76	78·88	2	Long . . . . (S) (lines 76·51–81·16)	78·832	10	Cr
81·16	81·37	3		81·349	30	Fe
84·37	—	1	More distinct in clear spaces than on continuous spectra.	—	—	—
85·45	85·46	$2\frac{1}{2}$	. . . .	85·479	7	Fe
87·08	—	1	. . . .	87·130	8	Fe
87·71	87·51	0	Difficult to measure; visible only on continuous spectrum on north side. (?)	87·370	7	Co
89·72	—	2	Very faintly extended . . . . . . (lines 89·72–90·43)	89·773	5	?
90·43	—	2		90·509	2	C
92·07	—	2	Faintly extended . . . . (?)	92·169	2	V ?
93·55	93·84	2	Long . . . . (S)	93·636	9	Cr
94·81	—	1	Short	94·784	6	Fe
96·05	96·39	2	Long	96·195	4	Ti
97·72	—	1	Short	97·854	8	Ni
3600·71	99·59	$2\frac{1}{2}$	Faintly extended	3600·880	3	Y
01·90	—	2	Short . . . . (?) (lines 01·90–03·67)	02·060	1	Y
03·67	3603·97	1		03·922	3	Cr ?
05·35	05·64	2	Long . . . . (S)	05·479	7	Cr
06·48	—	0	Short . . . . (?)	06·838	6	Fe
08·98	09·00	2	Long . . . . (S)	09·008	20	Fe
11·05	—	2	Short	11·189	2	Y
13·91	14·00	$3\frac{1}{2}$	Narrow strong line with shading. Long	13·947	4	Sc
18·98	19·01	3	Probable double (width ·92). . . Long	18·919 19·539	20 8	Fe Ni
21·26	—	1	Short	21·244	3	?
21·62	—	1	Short	21·612	6	Fe
23·45	—	0	Very short	23·362	5	Fe
24·86	25·02	$2\frac{1}{2}$	Faintly extended	24·979	5	Ti
28·71	—	1	Fine and sharp on continuous spectrum; does not extend beyond	28·847 28·967	2 2	Y La
30·85	—	$2\frac{1}{2}$	Long . . . . (lines 30·85–31·50)	30·876	4	Ca ?
31·50	31·37	2		31·605	15	Fe
33·11	—	2	Very fine and distinct; ends abruptly at sides of continuous spectrum	33·277	2	Y
34·19	34·54	1	Long; almost invisible upon continuous spectrum	(3634·393)	—	He
35·11	—	0	Very short on continuous spectrum only (lines 35·11–36·50)	35·091	3	Ni
36·50	—	0		36·608	4	Cr ?
41·32	41·65	$2\frac{1}{2}$	Long, sharply defined . . . . . (S)	41·473	4	Ti
42·70	42·81	3	" " "	42·820 42·912	7 2	Ti Sc
45·35	—	2	Very faintly extended	45·475	3	Sc ?
47·86	47·77	2	Long . . . . (S)	47·988	12	Fe
49·86	—	1	Short; stronger on continuous spectrum (?)	49·654	5	La

TABLE I.—*continued.*

Wave-lengths in flash spectra. No. 3.	Wave-lengths in flash spectra. No. 7.	Photographic intensity. No. 3.	Character. No. 3.	Wave-length, solar spectrum. ROWLAND.	Intensity.	Element.
3651·65	3652·46	2	Very faintly extended, a line at 3653·4 ± just visible . . . . (?)	3651·614	7	Fe
—	—	—		51·940	4	Sc
55·78	—	1	Very short; stronger on continuous spectrum	55·801	3	?
59·58	—	2	Faintly extended . . . . (?)	59·663	5	Fe
61·16	—	1	In clear spaces on south side only . . .	—	—	H_{31}
62·14	—	2	Probably a line superposed on hydrogen line	62·378	5	Ti, H_{30}
63·40	63·42	1	Long lines, not very sharply defined . .	—	—	H_{29}
64·71	64·67	2				H_{28}
66·15	66·07	2				H_{27}
67·70	67·65	2½				Hω
69·52	69·54	2½				Hψ
71·45	71·58	3				Hχ
73·77	73·80	3				Hφ
76·32	76·50	3				Hυ
77·64	78·6	2	Short; narrower than hydrogen lines (?)	77·764	5	Fe
				77·831	3	Cr
				77·991	3	Cr
79·41	79·43	3½	Probably a Fe line on less refrangible side	—	—	Hτ
82·80	82·82	3	Long	—	—	Hσ
85·28	85·17	5	Very long; well defined . . . . .(S)	85·339	10	Ti
86·98	86·81	3½	Long	—	—	Hρ
89·48	—	0	Short; interrupted . . . . (?)	89·614	6	Fe
91·67	91·67	3½	Long	—	—	Hπ
93·83	—	1	Short	—	—	
97·26	97·20	4	Long. A very faint line is visible half-way between Ho and Hξ λ3701 ±	—	—	Ho
3703·87	3703·85	4		—	—	Hξ
05·92	—	3	Faintly extended	3705·708	9	Fe
				06·175	6	Ca ?
07·66	—	0	Very short; interupted; not visible (?) on continuous spectrum (?)	07·702	2	Ti
09·09	—	1		09·389	8	Fe
10·14	—	2	Short . . . . (?)	10·431	3	Y
12·10	12·00	4	Long	—	—	Hν
15·32	—	2	Very faintly extended	15·319	2	Cr ?
				15·615	4	V ?
18·10	—	0	On continuous spectrum only.	—	—	—
19·82	19·96	3	Long, very sharply defined . . . (S)	20·084	40	Fe
22·05	21·89	4½	Long	—	—	Hμ
24·48	—	1	Very short, continuous spectrum only .	24·526	6	Fe
27·40	27·64	2½	Short . . . . (?)	27·778	4	Fe
34·55	34·54	4½	Narrower on continuous spectrum . . .	—	—	Hλ
36·94	37·18	3½	Long	37·281	30	Fe
39·11	—	0	Short			
41·51	41·83	3	Long	41·205	4	Ti
				41·791	4	Ti
43·26	43·31	1	Short, very narrow line	43·508	6	Fe
45·58	45·69	3	Long	45·401	2	Co
				45·717	8	Fe
				46·058	6	Fe
48·01	—	1	Faintly extended, narrow	48·408	10	Fe
50·29	50·18	4½	Narrower on continuous spectrum . .	—	—	Hκ
57·57	—	2	Ill-defined, short. . . . . (?)	57·824	4	Cr,Ti

TABLE I.—*continued.*

Wave-lengths in flash spectra. No. 3.	Wave-lengths in flash spectra. No. 7.	Photographic intensity. No. 3.	Character. No. 3.	Wave-length, solar spectrum. ROWLAND.	Intensity.	Element.
3759·32	3759·34	4	Very long, well defined . . . . (S)	3759·447	12	Ti
61·46	61·25	4½	Longer than Hι, and narrower . . (S)	61·464	7	Ti
63·66	—	1½	Long, faint, visible on continuous . . .	63·945	10	Fe
66·84	—	1	Long, faint, not visible on continuous. .	67·341	8	Fe
70·77	70·77	6	Narrower on continuous spectrum . . .	—	—	Hι
74·03	—	2½	Short	74·473	3	Y
75·79	—	0	Very short	75·717	7	Ni
83·28	—	1	Short	83·674	6	Ni
86·6 ±	—	0	Short (wave-length estimated)	88·046	8	Fe
88·53	89·57	2	Short . . . . (?)	88·839	2	Y ?
90·0 ±	—	0	Short (wave-length estimated).			
94·72	—	0	Short	95·147	8	Fe
97·98	98·07	7	Diffuse outside, narrower on continuous spectrum.		—	Hθ
3805·19	—	0	Trace of lines or band, poorly defined .	3805·486	6	Fe
07·46				07·681	6	Fe
12·79	—	2	Faintly extended			
14·22	—	1	Short	14·698	8	Fe ?
15·70	3815·92	2	Faintly extended	15·987	15	Fe
20·23	20·17	3	Long, nearly equal to Hη. . . . (S)	20·586	25	Fe
24·16	24·91	2	Ill-defined pair, faintly extended . . .	24·591	6	Fe
25·51	25·73	2		26·027	20	Fe
27·4 ±	—	0	(Wave-length estimated)	—	—	—
29·32	29·28	3	(S)	29·501	10	Mg
32·13	32·06	3	Long, nearly equal to Hη	32·450	15	Mg
35·58	35·14	7	. . . .	—	—	Hη
38·36	38·32	3	Long, nearly equal to Hη . . . (S)	38·435	25	Mg
40·61	—	1	Short	40·580	8	Fe
49·94	—	1	Short, hazy	50·118	10	Fe
56·21	56·36	2	Long	56·524	8	Fe
59·96	60·00	3	Long . . . . (S)	60·055	20	Fe
72·09	73·1 ?	1	Ill-defined, wide, faintly extended . . (?)	72·639	6	Fe
78·29	78·7	2	Long	78·152	8	Fe
82·75	—	1	Ill-defined short	78·720	7	Fe
89·34	89·1	8	Narrower on continuous spectrum . . .	—	—	Hζ
95·29	—	2	Faintly extended	95·803	7	Fe
3900·25	3900·7	3	Long (Ti is the predominating element) (S)	3900·681	5	(Fe?)Ti
06·11	—	1	Wide, short, probably two lines . . (?)	05·660	12	Si
13·55	13·6	3	Long (Ti is the predominating element) (S)	13·609	5	Ti(Fe)
19·90	—	1	(?)	20·410	10	Fe
22·23	22·8	1	Short	—	—	—
27·52	—	1				
34·4	33·1	10	(K) width of line 2·95	33·825	1000	Ca
44·0	44·4	2½	Faintly extended . . . . . . (S)	44·160	15	Al
50·1 ±	—	1	Centre of group	50·102	5	Fe
56·9	—	1	Ditto	56·476	4	Co, Ti
				56·819	6	Fe
61·6	—	3	Long . . . . (S)	61·674	20	Al
69·8	68·3	10	(H) width of line 3·92	68·625	700	Ca
		5		70·177		Hε
82·6	83·6	1	Short . . . . (?)	82·742	3	Y
90·6	—	1	Short	—	—	—
98·8	—	1	Group of lines	98·790	4	Ti

TABLE I.—*continued.*

Wave-lengths in flash spectra. No. 3.	Wave-lengths in flash spectra. No. 7.	Photographic intensity. No. 3.	Character. No. 3.	Wave-length, solar spectrum. ROWLAND.	Intensity.	Element.
4005·5	—	1	Short	4005·408	7	Fe
12·7	—	1	Ditto	12·541	4	Ti
26·56	4026·8	3	Long, not visible upon continuous . . .	(4026·342)	—	He
30·7 }	—	2 }	Groups of short lines	30·918	10	Mn
34·4 }	—	2 }		33·224	8	Mn
46·3	46·5	2½	Long, visible across continuous . . (S)	45·975	30	Fe
54·7	54·1	1		—	—	—
63·9	63·7	2 }	Faintly extended . . . . (S)	63·759	20	Fe
72·1	—	1 }	(S)	71·908	15	Fe
78·3	78·1	4	Long . . . . (S)	77·885	8	Sr
4102·5	4102·4	7	Very diffuse on violet side	4102·000	40	Hδ
09·9	—	1		—	—	—
18·9 }	21·4 {	1 }	Group of faint lines . . . . . . (?)	23·384	12	La
23·6 }		1 }				
28·0 }	—	1 }	Very faint group.	—	—	—
33·9 }	—	1 }				
43·4	—	2 {	Probable double	(4143·919)	—	He
			Visible on continuous	44·038	15	Fe
63·6	—	0	. . . .	63·818	4	Ti
72·9	—	0 }	Ill-defined . . . . (?)	72·923	4	Fe
77·7	—	0 }				
4216·3	4215·8	4	Long . . . . (S)	4215·703	5	Sr
26·9	27·0	3 }	. . . .	26·904	20	Ca
				{ 33·328	4	Fe
33·3	—	2 }	Long	{ 33·772	6	Fe
47·5	46·7	3 }	. . . . (?)	46·996	5	Sc ?
54·8	—	2	. . . .	54·505	8	Cr
60·4	—	1	. . . .	60·640	8	Fe
73·6	74·5	2	Probably a group of lines.			
90·2	91·7	2 }	. . . . (?)	91·114	3	Ti
97·1	—	1 }	Probably faintly extended.			
				{ 4300·211	3	Ti
4300·5	4300·9	2 }	. . . .	{ 00·732	2	Ti
				{ 07·907	3	Ca
08·2	—	2 }	(G)	{ 08·081	6	Fe
13·7	15·1	1 }	Faintly extended lines	15·138	3	Ti
21·3	—	1 }	. . . .	20·907	3	Sc
26·1	—	2 }	. . . .	25·939	8	Fe
41·4	41·3	7	Best defined on red side	40·634	20	Hγ
				{ 51·216	3	Cr
51·7	—	2	Short	{ 51·930	5	Cr
58·7	—	1				
75·2	—	2 }	Faintly extended	75·103	2	V, Mn
83·6	—	2 }		83·720	15	Fe
				{ 95·201	3	Ti
95·5	95·2	2	Long	{ 95·413	2	V, Zr
4400·6	—	0 }	Very difficult	—	—	—
05·4	—	0 }		—	—	—
16·8	4417·0	1		—	—	—
26·4	—	0				
35·7	—	0	. . . .	4435·851	4	Ca
44·1	43·8	2	Long	43·976	5	Ti
50·4	—	0		—	—	—

TABLE I.—*continued.*

Wave-lengths in flash spectra. No. 3.	Wave-lengths in flash spectra. No. 7.	Photographic intensity. No. 3.	Character. No. 3.	Wave-length, solar spectrum. ROWLAND.	Intensity.	Element.
4455·3	—	0		—	—	—
72·0	4472·1	3	Long, well-defined on R side, very diffuse on B side, weak over continuous spectrum	(4471·646)	—	He
82·0	—	0				
90·8	—	0		—	—	—
4501·6	4501·6	2	. . . .	4501·448	5	Ti
09·3	—	0		—	—	—
15·9	—	0		—	—	—
23·2	—	0		—	—	—
34·9	34·5	2	. . . .	34·953	4	Ti
51·6	46·0	2		—	—	—
55·2	55·0	2	. . . .	55·662	3	Ti
62·0	—	2	Group of lines, faintly extended.			
66·0	65·0			—	—	—
69·9	—	2	Ditto.			
74·0	72·9			—	—	—
87·7	88·4	1		—	—	—
90·7	—	0		—	—	—
4629·4	—	1	. . . .	4629·521	6	Ti, Co
46·6	—	0	. . . .	46·347	5	Cr
68·0	—	0		—	—	—
85·6	86·3	0		—	—	—
4713·2	4713·4	2	Long, not visible on continuous spectrum	(4713·252)	—	He
4805·3	—	0		—	—	—
25·0	—	0		—	—	—
60·3	4860·9	5	. . . .	4861·527	30	$H\beta$
4922·0	—	2	Visible across continuous spectrum. . .	(4922·096)	—	He
33·5	4930·2	2		—	—	—
57·4	—	0	Very difficult.	—	—	—
5017·4	5016·1	2	Visible across continuous spectrum. . .	(5015·732)	—	He
5164·7	5167·3	3	(b'' b''' b^{iv}) Long	5167·497	15	Mg
73·0	74·7			72·850	20	Mg
83·5	83·9	3	(b') Long	83·791	30	Mg
			. . . .	5204·680	5	Cr
5205·3	—	1	. . . .	06·215	5	Cr
			. . . .	08·596	5	Cr
27·7	—	0		—	—	—
35·1	—	0		—	—	—
70·0	—	0		—	—	—
5307·0*	5299·7*	1	Very diffuse (corona line).			
15·4	—	1	(1474 K)	5316·790	4	Fe
26·5	—	0		—	—	—
35·5	—	0		—	—	—
5876·0	5875·9	5	(D''')	(5875·870)		He
93·7	—	2	(D', D'')	5890·186	30	Na
				96·357	20	Na
—	6563·0		(C) strong on No. 7 plate	6563·045	40	$H\alpha$

* Apparent centre of line displaced to red at second contact, and to blue at third contact. Mean position = 5303·3.

TABLE II.—*Spectrum of Prominence.*

The wave-lengths given in the first column of this table are deduced from measures of the images of a very small bright prominence in spectrum No. 4. This prominence was situated almost at the point of second contact at position angle 59° (solar latitude + 23°).

The photograph was exposed at the beginning of totality immediately after the disappearance of the flash spectrum.

The prominence images are well defined circular spots in all radiations except the calcium and brighter hydrogen rays, which show wings due to motion in the line of sight.

The columns of this table are arranged as in Table I., and the intensities in column 2 were estimated in the same way as those of No. 3 spectrum given in Table I.

The helium wave-lengths given within brackets in column 4 are from RUNGE and PASCHEN.

TABLE II.

Wave-length No. 4 spectrum.	Intensity.	Remarks.	Wave-length, solar spectrum. ROWLAND.	Intensity.	Element.
3435	—	Limit to which continuous spectrum of prominence can be traced			
3534 3537	—	Continuous spectrum is much brighter at this point	3535·554	4	Ti
3614·0	0	. . . .	3613·947	4	Sc
3618·9	0	. . . .	3618·919	20	Fe
3625·3	0	One measure only	3624·979	5	Ti
3631·6	1	. . . .	3631·605	15	Fe
3634·6	1	. . . .	(3634·393)	—	He
3668 ±	—	Beginning of continuous spectrum in prominences	—	—	—
3669·52	0	. . . .	—	—	Hψ
3671·61	0	Rather difficult to measure	—	—	Hχ
3673·92	0	Silver deposit very weak	—	—	Hφ
3676·55	0	. . . .	—	—	Hυ
3679·55	1	. . . .	—	—	Hτ
3683·06	1	. . . .	—	—	Hσ
3685·34	3	. . . .	3685·339	10	Ti
3687·12	1	. . . .	—	—	Hρ
3691·75	1	. . . .	—	—	Hπ
3697·18	1	. . . .	—	—	Ho
3704·11	1	. . . .	—	—	Hξ
3705·86	1	Well-defined and very small circular dots . .	3705·708	9	Fe
3712·19	2	. . . .	—	—	Hν
3720·02	1	. . . .	3720·084	40	Fe
3722·07	2	. . . .	—	—	Hμ
3734·52	2	. . . .	—	—	Hλ
3737·27	1	. . . .	3737·281	30	Fe
3741·79	1	. . . .	3741·205 3741·791	4 4	Ti Ti

TABLE II.—*continued.*

Wave-length No. 4 spectrum.	Intensity.	Remarks.	Wave-length, solar spectrum. ROWLAND.	Intensity.	Element.
3745·98	1	. . . .	3745·717 3746·058	8 6	Fe Fe
3748·47	0	. . . .	3748·408	10	Fe
3750·21	2	. . . .	—	—	Hκ
3759·53	2	Well-defined and very small dots	3759·447	12	Ti
3761·40	2	. . . .	3761·464	7	Ti
3770·80	2	. . . .	—	—	Hι
3798·12	3	. . . .	—	—	Hθ
3820·09	1	Not well defined	3820·586	25	Fe
3825·77	0	(Not well defined)	3826·027	20	Fe
3829·39	0	. . . .	3829·501	10	Mg
3832·56	1	. . . .	3832·450	15	Mg
3835·63	3	. . . .	—	—	Hη
3838·56	2	Well-defined nearly circular dots	3838·435	25	Mg
3860·14	1	Slightly winged	3860·055	20	Fe
3889·09	4	. . . .	—	—	Hζ
3900·5	0	. . . .	3900·681	5	Ti(Fe? Zr?)
3913·2	0	. . . .	3913·609	5	Ti(Fe)
3933·8	10	K, triangular black spot	3933·825	1000	Ca
(3944·0)	0	Not measured wave-length in No. 3 spectrum	3944·160	15	Al
3968·6	10	H, triangular black spot	3968·625	700	Ca
4026·3	2	Fairly good definition	(4026·342)	—	He
4077·8	2	(Fairly good definition)	4077·885	8	Sr
4102·2	5	Circular black spot with wings due to motion in line of sight	4102·000	40	Hδ
4215·7	2	. . . .	4215·703	5	Sr
4340·6	5	Same as Hδ	4340·634	20	Hγ
4471·8	3	Well-defined spot	(4471·646)	—	He
4713·1	1	. . . .	(4713·252)	—	He
4861·5	5	Circular spot slightly winged	4861·527	30	Hβ

TABLE III.—Hydrogen Lines.

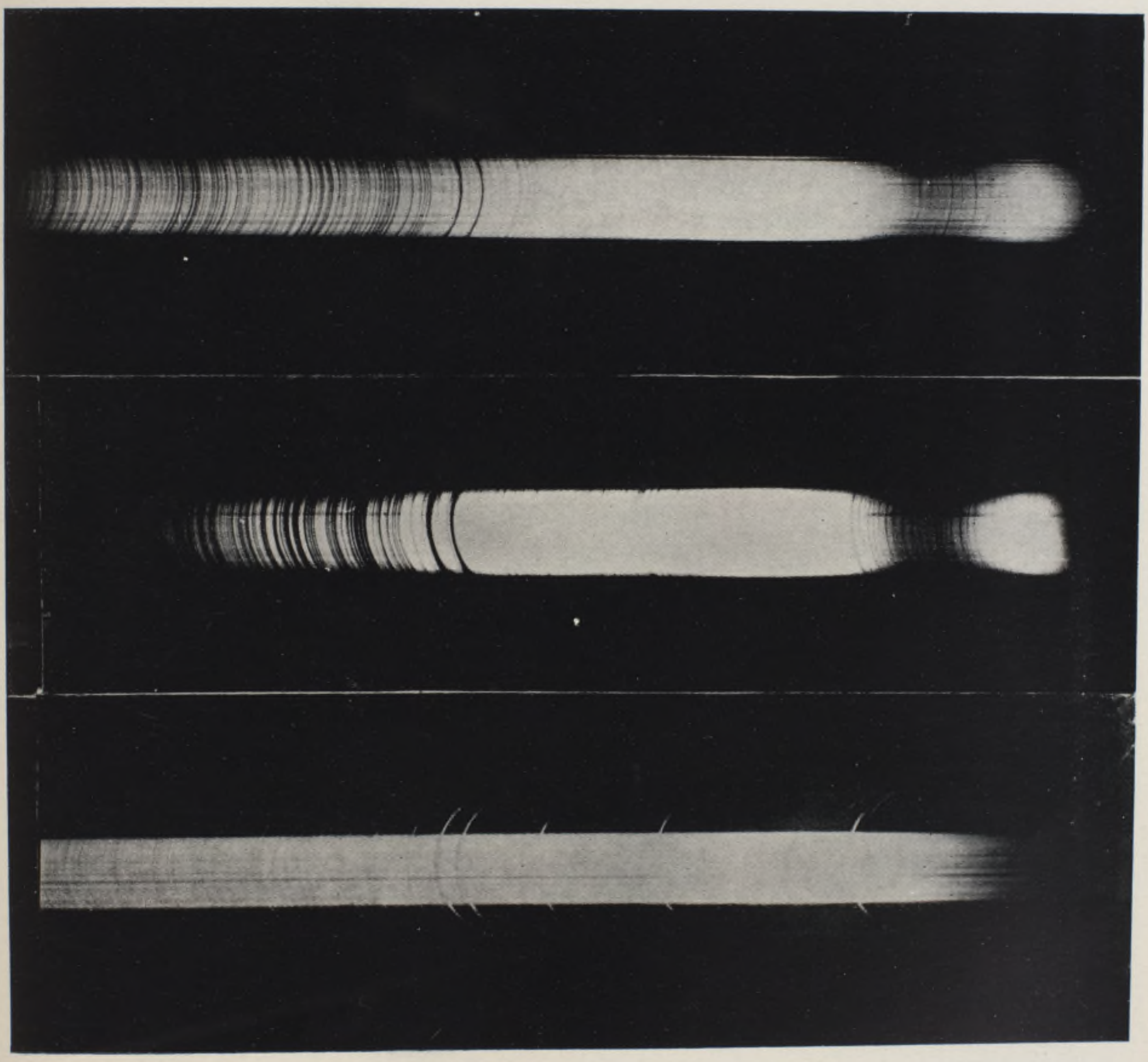
Designation.	Spectrum No. 3.	Spectrum No. 4.	Mean of 3 and 4.	Computed.	O – C.	Spectrum No. 7.
α	—	—	—	6563·07	—	(6563·07)
β	4860·3	4861·5	4860·9	4861·52	– ·6	4860·9
γ	4341·4	4340·6	4341·0	4340·63	+ ·4	4341·3
δ	4102·5	4102·2	4102·3	4101·90	+ ·4	4102·4
ε	Obscured	by H	—	3970·22	—	—
ζ	3889·34	3889·09	3889·21	3889·20	+ ·01	3888·87
η	3835·58	3835·63	3835·60	3835·53	+ ·07	3835·05
θ	3797·98	3798·12	3798·05	3798·04	+ ·01	3797·97
ι	3770·77	3770·80	3770·78	3770·77	+ ·01	3770·70
κ	3750·29	3750·21	3750·25	3750·30	– ·05	3750·15
λ	3734·55	3734·52	3734·54	3734·51	+ ·03	3734·50
μ	3722·05	3722·07	3722·04	3722·08	– ·02	3721·85
ν	3712·10	3712·19	3712·14	3712·11	+ ·03	3712·05
ξ	3703·87	3704·11	3703·99	3704·00	– ·01	3703·86
ο	3697·26	3697·18	3697·22	3697·29	– ·07	3697·24
π	3691·67	3691·75	3691·71	3691·70	+ ·01	3691·71
ρ	3686·98	3687·12	3687·05	3686·97	+ ·08	3686·75
σ	3682·80	3683·06	3682·93	3682·95	– ·02	3682·87
τ	3679·41	3679·55	3679·48	3679·49	– ·01	3679·47
υ	3676·32	3676·55	3676·43	3676·50	– ·07	3676·53
φ	3673·77	3673·92	3673·84	3673·90	– ·06	3673·84
χ	3671·45	3671·61	3671·53	3671·48	+ ·05	3671·59
ψ	3669·52	3669·52	3669·52	3669·60	– ·08	3669·54
ω	3667·70	—	3667·70	3667·82	– ·12	3667·67
27*	3666·15	—	3666·15	3666·24	– ·09	3666·08
28	3664·71	—	3664·71	3664·82	– ·11	3664·68
29	3663·40	—	3663·40	3663·54	– ·14	3663·27
30	3662·14	—	3662·14	3662·40	– ·26	—
31	3661·16	—	3661·16	3661·35	– ·19	—
∞	Limit	of series	(theoretical)	3646·13		—

* Series number, α = 3.

Fig. 1. Spectrum No. 1.

Fig. 2. Artificial cusp.

Fig. 3 Spectrum No. 9.



Comparison between cusp spectra photographed during the solar eclipse, and artificial cusp photographed in ordinary daylight—to show the relative faintness of the Fraunhofer lines in the eclipse spectra, and the great extension of the latter in the ultra-violet. (The absence of lines between F and H in each spectrum is due to over-exposure.)

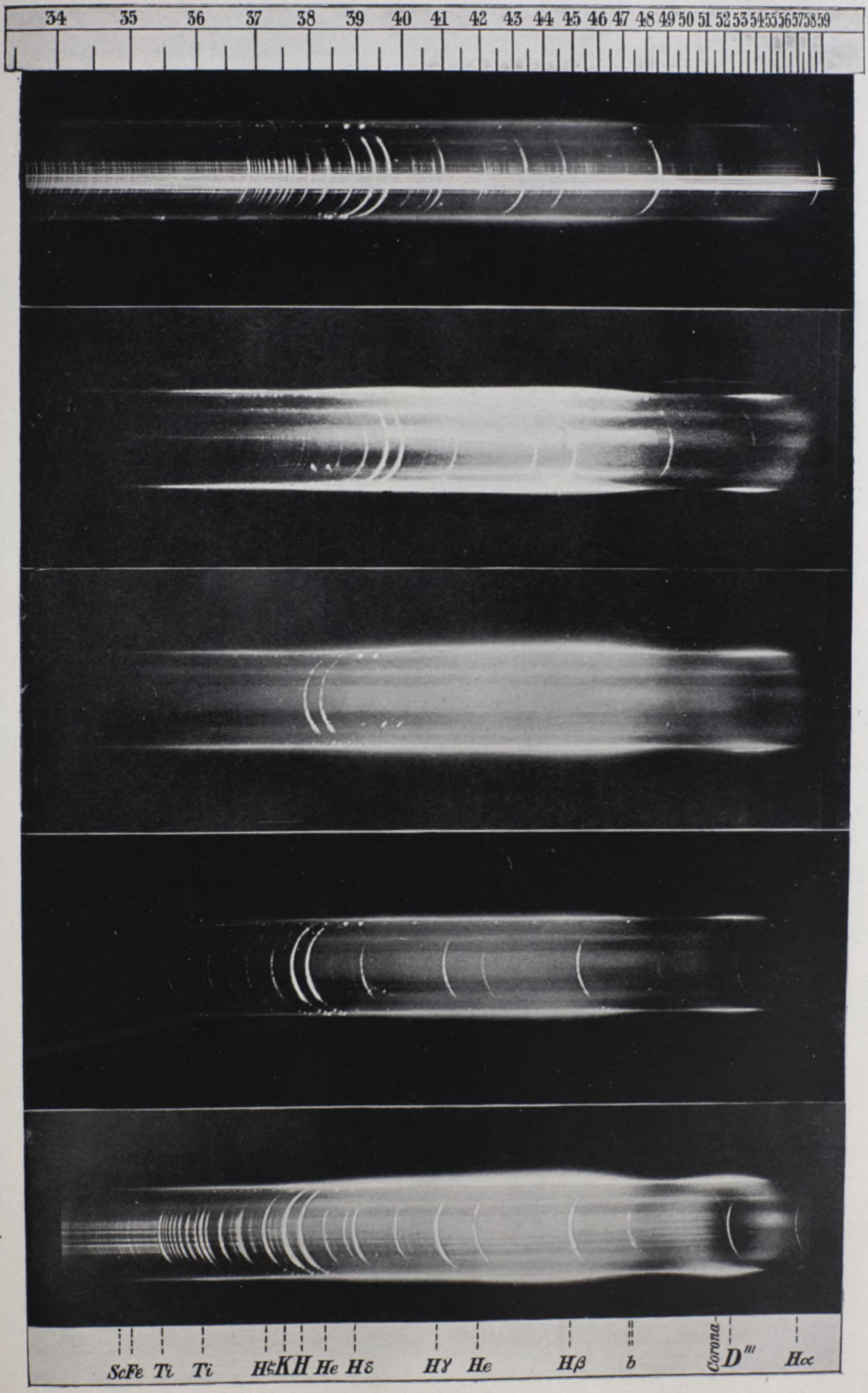


Fig. 1. Spectrum No. 3.

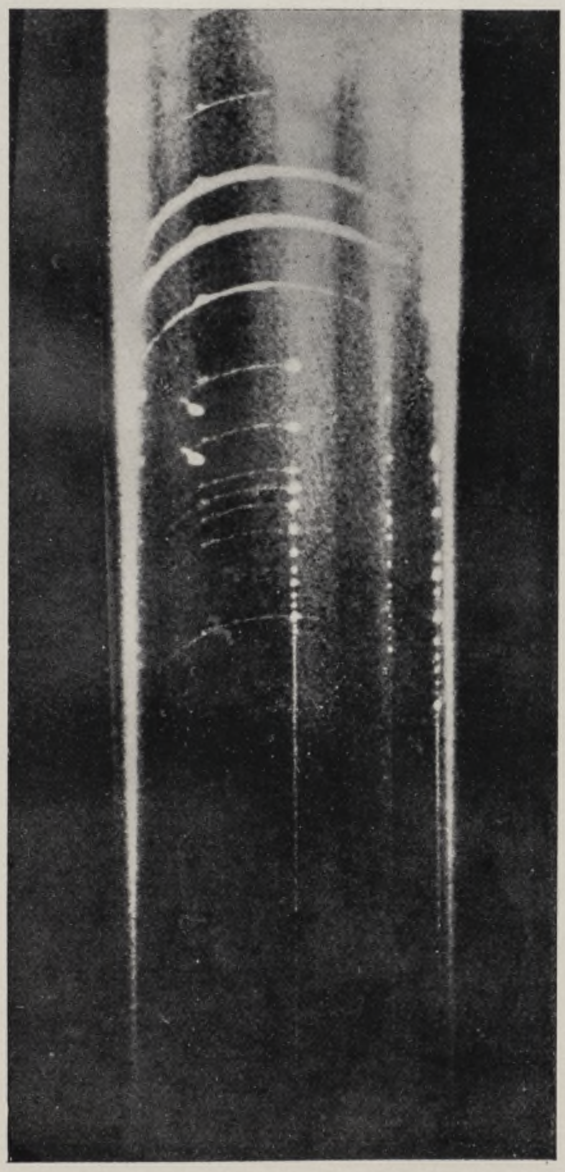
Fig. 2. Spectrum No. 4.

Fig. 3. Spectrum No. 5.

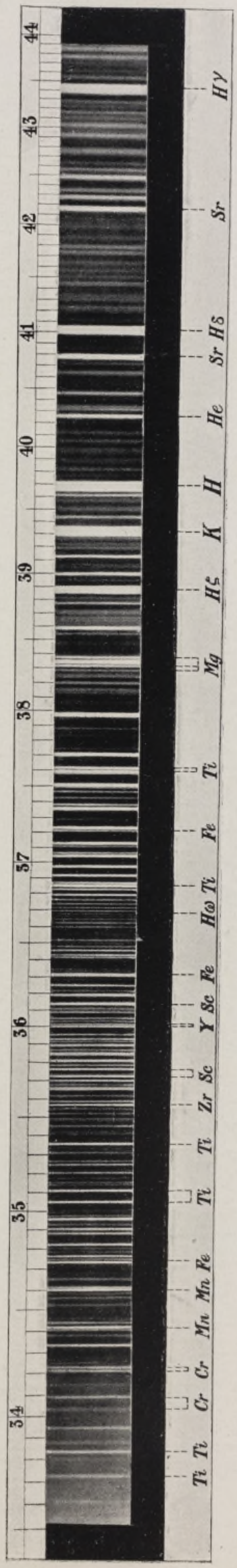
Fig. 4. Spectrum No. 6.

Fig. 5. Spectrum No. 7.

Spectra photographed during total phase. Eclipse of January 22nd, 1898.



Spectrum No. 4.—Ultra-violet region, enlarged five times. Showing continuous spectrum of prominences beginning at the end of the hydrogen series of lines.



Spectrum of Lower Chromosphere—ultra-violet region. From photograph taken with a 2-inch prismatic camera at the Solar Eclipse of January 22nd, 1898.