RESULTS

OF THE

SPECTROSCOPIC AND PHOTOGRAPHIC OBSERVATION

MADE AT THE

ROYAL OBSERVATORY, GREENWICH,

IN THE YEAR

1888:

UNDER THE DIRECTION OF

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ASTRONOMER ROYAL.

(EXTRACTED FROM THE GREENWICH OBSERVATIONS, 1888.)

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GREENWICH SPECTROSCOPIC AND PHOTOGRAPHIC RESULTS, 1888.

INTRODUCTION.

§ 1. *Spectroscopic Observations in the Year* 1888.

The spectroscope used for these observations was mounted on the South-east equatorial, the object-glass of which (made by Merz and Son of Munich) has a clear aperture of 12·8 inches, with a focal length of about $17^{ft.}\ 10^{in.}$

This section contains:—Measures of Displacement of Lines in the Spectra of Stars, of the planet Mars, and of the Moon and Sun; Collected Results for Motions of Stars in the line of Sight; and Observations of the Spectra of γ Cassiopeiæ, Mira Ceti, α Orionis, α Herculis, β Lyræ, R Cygni and P Cygni, and of Comets a and e 1888.

The measures of displacement of lines in the spectra of stars were made with a micrometer in the viewing telescope of the "Half-prism" Spectroscope. The eye-piece used gives a magnifying power of 14. Estimations of the displacement, in terms of the apparent breadth of the bright comparison-line, were also made; the breadth corresponding to any given width of slit being determined by a careful observation under similar conditions. $1^{rev.}$ of the screw for opening the slit corresponds to 0·01 inch, or 10″. It has not been thought necessary to give in detail all these particulars of the reductions. The values used in each case may be inferred from the observed motion, which is the algebraic sum of the concluded motion and of the Earth's motion. A displacement of one tenth-metre corresponds at D to a motion of 31·7 miles per second, at b to a motion of 36·1 miles, and at F to a motion of 38·4 miles. For comparison with the spectrum of hydrogen or other chemical element, an image of the vacuum tube or electrodes is formed on the slit, by means of a transparent plate of glass placed at an angle of 45° with the axis of the collimator, in connexion with a collimating lens, so that the cone of rays from the comparison-light fills the whole of the object-glass of the collimator.

Whenever the star-line was sufficiently distinct to allow of its being seen at the same time as the bright comparison-line, a direct comparison of the two was made; in other cases the bright line was compared with the pointer of the micrometer which had just previously been placed on the star-line, giving an indirect comparison.

The reading of the position-circle is given, as it is conceivable that the results might be affected by the position of the spectroscope. The slit lies north and south when the reading is 6°.

With regard to the observations of the spectra of Mira Ceti and α Herculis, it is sufficient to remark that a curve has been laid down in the usual manner, connecting micrometer readings and wave-lengths for the Single-prism Spectroscope, and that a correction for index-error has been deduced from observations of comparison-lines, and applied to the observed readings to reduce them to the standard curve from which the corresponding wave-lengths have been read off. In the case of the bright lines in the spectra of Mira Ceti, β Lyræ, R Cygni and P Cygni, the distance of the stellar line from some standard line in its immediate neighbourhood has been determined, and the value in wave-length of a revolution of the micrometer for that point of the spectrum taken out from the standard curve. The tabular wave-lengths of comparison-lines have been taken from Ångström's *Spectre Normal du Soleil.*

§ 2. *Measures of Positions and Areas of Spots and Faculæ upon the Sun's Disk on Photographs taken at the Royal Observatory, Greenwich, at Dehra Dûn in India, and at the Royal Alfred Observatory, Mauritius, in the year* 1888; *with the deduced Heliographic Longitudes and Latitudes.*

The photographs from which these measures were made were taken either at Greenwich; at Dehra Dûn, North-West Provinces, India; or at the Royal Alfred Observatory, Mauritius.

The photographs of the Greenwich series were taken with the Dallmeyer Photo-heliograph returned from the Transit of Venus expedition to New Zealand, which, as now adapted, gives a solar image of 8 inches diameter on the photographic plate.

Bromo-iodized gelatine dry plates with alkaline development have been regularly used throughout the year.

The Indian photographs, which have been forwarded by the Solar Physics Committee to fill the gaps in the Greenwich series, were taken under the superintendence of Colonel C. T. Haig, R.E., Deputy Surveyor General, Trigonometrical Survey of India, with a Dallmeyer photoheliograph giving an image of the Sun nearly 8 inches in diameter. In the process adopted at Dehra Dûn bromo-iodized collodion has been used in connexion with iron development.

The Mauritius photographs were taken under the superintendence of Dr. C. Meldrum, Director of the Royal Alfred Observatory, Mauritius, with a Dallmeyer photoheliograph, giving an image of the Sun about 8 inches in diameter. At the Mauritius Observatory bromo-iodized gelatine dry plates have been used with alkaline development.

Photographs of the Sun were taken at Greenwich on 171 days, and Indian photographs on 170 days with Mauritius photographs on 38 days have been received from the Solar Physics Committee to complete the total of 359 days for which there are either Greenwich, Indian, or Mauritius photographs of the Sun available for measurement in 1888. On 20 days both an Indian and a Mauritius photograph were measured.

The *first* column on each page contains the Greenwich Civil Time at which each photograph was taken, expressed by the day of the year and decimals of a day, reckoning from Greenwich mean midnight January 1d. 0h., and also by the day of the month (civil reckoning), which latter is placed opposite the total area of Spots and Faculæ for the day. The photographs taken in India are distinguished by the letter I, and those taken in Mauritius by the letter M.

The *second* column contains the initials of the two persons measuring the photograph; the initial on the left being that of the person who measured the photograph on the left of the centre of the measuring instrument, and that on the right being that of the person who measured on the right of the centre.

The following are the signatures of those persons who measured the photographs for the year 1888 :—

E. W. Maunder	- M	W. Russell	- WR
H. P. Hollis	- H	S. J. Temple	- ST
A. E. Pilkington	- EP		

The *third* column gives the No. of the group, and the letter for the spot. The groups are numbered in the order of their appearance.

The *next two* columns give the Distance from the Centre of the Sun in terms of the Sun's Radius, and the Position-Angle from the Sun's Axis, reckoned from the Sun's North Pole in the direction n, f, s, p, both results being corrected for the effects of astronomical refraction.

The measures of the photographs were made with a large position-micrometer specially constructed by Messrs. Troughton and Simms for the measurement of photographs of the Sun up to 12 inches in diameter. In this micrometer the photograph is held with its film-side uppermost on three pillars fixed on a circular plate, which can be turned through a small angle, about a pivot in its circumference, by means of a screw and antagonistic spring acting at the opposite extremity of the diameter. The pivot of this plate is mounted on the circumference of another circular plate, which can be turned by screw-action about a pivot in its circumference, 90° distant from that of the upper plate, this pivot being mounted on a circular plate with position-circle which rotates about its centre. By this means small movements in two directions at right angles to each other can be readily given, and the photograph can be accurately centred with respect to the position-circle. When this has been done, a positive eye-piece, having at its focus a glass diaphragm ruled with cross-lines into squares, with sides of one-hundredth of an inch (for measurement of areas), is moved along a slide diametrically across the photograph, the diaphragm being nearly in contact with the photographic film, so that parallax is avoided. The distance of a spot or facula from the centre of the Sun is read off by means of a scale and vernier to 1-250th of an inch (corresponding to 0·001 of the Sun's radius for photographs having a solar diameter of 8 inches). The position-angle is read off on a large position-circle which rotates with the photographic plate. The photograph is illuminated by diffused light reflected from white paper placed at an angle of 45° between the photograph and the plate below.

The following is the process of measurement of a photograph:—By means of the screws attached to the plates carrying the pillars which hold the photograph, the image of the Sun is centred as accurately as possible by rotation. The position-circle is then set to the readings 0°, 90°, 180°, and 270° in succession, and the scale readings taken for the two limbs. The scale being so adjusted that its zero coincides with the centre of rotation of the position-circle, the mean of the eight readings for the limb gives the mean radius of the Sun directly.

At the principal focus of the photoheliograph are two cross-wires which serve to determine the zero of position-angles on the photograph.

The zero of position-angles for the Dallmeyer Photoheliograph, employed at Greenwich, has generally been determined throughout 1888 by the measurement of a plate which had been exposed to the Sun's rays twice, with an interval of about 100 seconds between the two exposures, the instrument being firmly clamped. Two images of the Sun, overlapping each other by a little more than the fifth part of the Sun's diameter, were therefore produced upon the plate, and the exposures having been so given that the line joining the cusps passed through the centre of the plate, the inclination of the wires of the photoheliograph to this line was measured with the position-micrometer, and a small correction for the inclination of the Sun's path was then applied. The following table gives the correction for zero of position for the mean of the two wires as thus determined :—

Date, Greenwich Civil Time.		Correction for Zero.
	h	° ′
1887, December	9. 12	+ 0. 27
1888, March	1. 12	+ 0. 34
	29. 11	+ 0. 30
May	25. 11	+ 0. 46
June	23. 13	+ 0. 31
August	3. 11	+ 1. 1
	15	+ 1. 12
September	11. 14	+ 0. 57
October	8. 12	+ 0. 51
November	10. 11	− 0. 18
December	7. 13	− 2. 3
1889, February	2. 12	+ 0. 4

The zero of position has also been determined on several occasions by allowing the diurnal motion to carry a spot or the Sun's limb along the equatorial wire, a correction for the inclination of the Sun's path being applied to the reading of the position-circle so obtained, and also by running the image along the wire by the use of the R. A. slow motion, the mean of the two determinations,

further corrected for the error of the perpendicularity of the wires, being then taken. The correction for error of perpendicularity of the wires in use up to 1888, November 4, was — 0°. 7′; for the new wires inserted 1888, November 6, it was — 0°. 23′. The following table gives the correction for zero of position of the mean of the two wires as obtained by this method :—

Date, Greenwich Civil Time.		Corrected Zero of Position-Circle from Transit.	Zero of Position-Circle obtained when using R.A. Slow Motion.
	h	° ′	° ′
1887, December	9. 12	+ 0. 36	.....
1888, February	1. 11	+ 0. 27	.....
March	29. 11	+ 0. 24	+ 0. 29
May	25. 11	+ 0. 49	.....
June	23. 11	+ 0. 47	+ 0. 44
July	30. 12	+ 0. 53	.....
August	7. 13	+ 0. 44	+ 0. 48
September	12. 12	+ 0. 50	+ 0. 51
October	8. 12	+ 0. 57	+ 0. 57
November	10. 11	— 1. 20	.....
December	7. 13	— 2. 31	— 2. 32
1889, February	2. 10	+ 0. 3	+ 0. 3

The mean of the values for the zero as determined by these two methods, the method of the photographs with double images of the sun, and that of running a spot or the sun's limb along the wires, has been adopted for the zero.

The vertical wire was found to be broken on November 4, and a new pair of wires were accordingly inserted on November 6. The wire-frame was found to be loose on December 7. The position-circle reading was altered on December 7 after the double-image photographs and transits for the determination of the zero had been taken.

In the use at Greenwich of the Dallmeyer Photoheliograph the position-circle has usually been set to some convenient reading near that for zero, so that the wires are respectively very nearly parallel and perpendicular to the circle of declination, and a correction for zero of position of the photoheliograph for the mean of the two wires

has been applied to the zero of the position-circle of the micrometer. The readings of the position-circle in 1888 have been as follows :—

From 1888, January 1	- - -	356°·0
December 7	- - -	353°·0

The correction for zero of position adopted for any date has been the mean of the determinations of that zero made next before and next after that date. The zero of the position-circle of the micrometer has been determined from the readings of the position-circle for the four extremities of the two wires. The resulting combined correction is applied to all position-circle readings for spots and faculæ, so as to give true position-angles.

In the use of the Photoheliographs at Dehra Dûn and in Mauritius the position-circle has always been set to the zero as determined by allowing the diurnal motion to carry a spot or the Sun's limb along the horizontal wire, and the accuracy of the adjustment has been tested at short intervals. No correction for zero of position of the wires has therefore been applied for the reduction of the photographs taken in India or in Mauritius.

The uncorrected distance from the Sun's centre for spots and faculæ is read off directly to 1-250th of an inch by means of a scale and vernier, the zero of the scale of the new micrometer being adjusted to coincide with the centre of the instrument.

Two sets of measures of the Sun's limb and of spots and faculæ on each photograph have been taken and the mean of the two sets adopted.

No correction has been applied to the photographs on account of distortion.

The correction for the effect of refraction has been thus found, the Sun's image being assumed to be sensibly an ellipse. The refraction being sensibly $c \tan z$ where $c = \sin 57''{\cdot}5 = \frac{1}{3600}$ nearly, and z is the apparent zenith distance, we shall have—

$$\frac{\text{Vertical Diameter}}{\text{Horizontal Diameter}} = \frac{1 - c \sec^2 z}{1 - c} = 1 - c \tan^2 z ;$$

and thus the effect of refraction will be to diminish any vertical ordinate y by the quantity $c \tan^2 z$. Resolving this along and perpendicular to the radius vector r,

and putting v for the position-angle of the vertex, we have for δr and $\delta \theta$, the corrections to radius vector and position-angle for the effect of refraction—

$$\delta r = + c \,.\, \tan^2 z \times r \,.\, \cos^2 (\theta - v) = + c \,.\, \tan^2 z \times r \times \frac{1 + \cos 2 (\theta - v)}{2},$$

$$\delta \theta = - c \,.\, \tan^2 z \,.\, \sin (\theta - v) \,.\, \cos (\theta - v) = - c \,.\, \tan^2 z \, \frac{\sin 2 (\theta - v)}{2}.$$

The quantity δr thus found is the correction, on the supposition that a horizontal diameter of the Sun is taken as the scale. But, as the mean of two diameters at right angles has been used, the scale itself requires the correction $\delta \mathrm{R} = + c \,.\, \tan^2 z \times \mathrm{R} \times \frac{1}{2} \left\{ \frac{1 + \cos 2 (\theta_0 - v)}{2} + \frac{1 + \cos 2 (\theta_0 + 90° - v)}{2} \right\} = + \frac{1}{2} c \,\mathrm{R} \,.\, \tan^2 z$, where R is the Sun's mean radius and θ_0 , $\theta_0 + 90°$ the position-angles of the two diameters measured. Thus the final correction to r becomes—

$$\delta r = + c \,.\, \tan^2 z \times r \times \frac{\cos 2 (\theta - v)}{2}.$$

The quantities $c \tan^2 z$, $- \frac{\sin 2 (\theta - v)}{2}$, and $\frac{\cos 2 (\theta - v)}{2}$ have been tabulated for use as follows, $c \tan^2 z$ being expressed in circular measure and in arc for application to distances and position-angles respectively :—

$c \tan^2 z$.

z.	In Circular Measure.	In Arc.	z.	In Circular Measure.	In Arc.	z.	In Circular Measure.	In Arc.
°		′	°		′	°		′
80	·0089	31	70	·0021	7	60	·0008	3
79	·0073	25	69	·0019	6½	58	·0007	2
78	·0061	21	68	·0017	6	56	·0006	2
77	·0052	18	67	·0015	5½	54	·0005	2
76	·0045	15	66	·0014	5	52	·0005	2
75	·0039	13	65	·0013	4½	50	·0004	1
74	·0034	11½	64	·0012	4	45	·0003	1
73	·0030	10	63	·0011	4	40	·0002	1
72	·0026	9	62	·0010	3	30	·0001	0
71	·0023	8	61	·0009	3			

Factors for Refraction.

$\theta - r$	$\theta - v$	$-\frac{\sin 2(\theta-v)}{2}$	$\frac{\cos 2(\theta-v)}{2}$	$\theta - v$	$\theta - v$	$-\frac{\sin 2(\theta-v)}{2}$	$\frac{\cos 2(\theta-v)}{2}$
°	°			°	°		
0	180	·00	+ ·50	95	275	+ ·09	— ·49
5	185	— ·09	+ ·49	100	280	+ ·17	— ·47
10	190	— ·17	+ ·47	105	285	+ ·25	— ·43
15	195	— ·25	+ ·43	110	290	+ ·32	— ·38
20	200	— ·32	+ ·38	115	295	+ ·38	— ·32
25	205	— ·38	+ ·32	120	300	+ ·43	— ·25
30	210	— ·43	+ ·25	125	305	+ ·47	— ·17
35	215	— ·47	+ ·17	130	310	+ ·49	— ·09
40	220	— ·49	+ ·09	135	315	+ ·50	·00
45	225	— ·50	·00	140	320	+ ·49	+ ·09
50	230	— ·49	— ·09	145	325	+ ·47	+ ·17
55	235	— ·47	— ·17	150	330	+ ·43	+ ·25
60	240	— ·43	— ·25	155	335	+ ·38	+ ·32
65	245	— ·38	— ·32	160	340	+ ·32	+ ·38
70	250	— ·32	— ·38	165	345	+ ·25	+ ·43
75	255	— ·25	— ·43	170	350	+ ·17	+ ·47
80	260	— ·17	— ·47	175	355	+ ·09	+ ·49
85	265	— ·09	— ·49	180	360	·00	+ ·50
90	270	·00	— ·50				

The position-angle of the Vertex v is readily taken from a globe.

The distance from centre in terms of the Sun's radius given in the *fourth* column is then readily found by dividing the measured distance r_0, as corrected for refraction, by the measured mean radius of the Sun, R ; and the Position-Angle from the Sun's Axis given in the *fifth* column is obtained by applying to the Position-Angle (from the N. point) corrected for refraction the Position-Angle of the Sun's Axis derived from the "Auxiliary Tables for determining the Angle of Position of the Sun's Axis, and the Latitude and Longitude of the Earth referred to the Sun's Equator," by Warren De La Rue, F.R.S.

The *sixth* and *seventh* columns give the heliographic longitude and latitude of the spot, which are thus computed.* Let r be the measured distance of a spot from the centre of the Sun's apparent disc, R the measured radius of the Sun on the photograph, (R) the tabular semidiameter of the Sun in arc, and ρ, ρ' the angular distances of a

* Researches on Solar Physics: Heliographical Positions and Areas of Sun Spots observed with the Kew Photoheliograph during the years 1862 and 1863, by W. De La Rue, B. Stewart, and B. Loewy. Phil. Trans. 1869.

spot from the centre of the apparent disk as viewed from the Sun's centre and from the Earth respectively. Then we have—

$$\rho' = \frac{r}{R}(R)\,;\ \text{and}\ \sin(\rho + \rho') = \frac{r}{R},$$

$$\text{whence}\ \rho = \sin^{-1}\frac{r}{R} - \rho'.$$

Log sin ρ and log cos ρ as computed from this formula are given in "Tables for the Reduction of Solar Observations No. 2," by Warren De La Rue, F.R.S. Then, if D, λ are the heliographic latitudes of the Earth and the Spot respectively, referred to the Sun's Equator, and L, l the heliographic longitudes reckoned from the ascending node of the Sun's Equator on the ecliptic, and χ the position-angle from the Sun's axis, we have by the ordinary equations of spherical trigonometry—

$$\sin\lambda = \cos\rho \sin D + \sin\rho \cos D \cos\chi$$
$$\sin(L - l) = \sin\chi \sin\rho \sec\lambda.$$

The quantities L and D are derived from Warren De La Rue's Auxiliary Tables before referred to, in the computation of which the following formulæ have been used—

$$\tan L = \cos I \tan(\odot - N)$$
$$\sin D = \sin I \sin(\odot - N)$$

where I is the inclination of the Sun's Equator to the ecliptic, N the longitude of the ascending node, and $\odot$ the longitude of the Sun.

The position-angle χ is given by the formula—

$$\chi = P + G + H$$

where P is the position-angle from the north point of the Sun, and G and H two auxiliary angles given by the formulæ—

$$\tan G = \tan\omega \cos\odot$$
$$\tan H = \tan I \cos(\odot - N)$$

where ω is the obliquity of the ecliptic.

It will be seen that G is the inclination of two planes through the line joining the centres of the Earth and Sun passing through the poles of the Earth and of the ecliptic respectively, and that H is the inclination of two planes through the same line and the poles of the Sun and of the ecliptic. The values assumed for I, N, ω in the computation of the Tables are 7° 15′, 74°, and 23° 27′·5 respectively.

The Heliographic Longitude of the Spot is found from l, the Heliographic Longitude from Node, by subtracting the Reduction to the Prime Meridian, which is the Longitude

of the Node at the epoch of the photograph, referred to the assumed Prime Meridian, the latter being the meridian which passed through the ascending node at mean noon, 1854 Jan. 1. The period of rotation assumed is 25·38 days.

The Heliographic Longitude and Latitude of the Centre of the Sun's Disk at the time of the exposure of each photograph are also given (in brackets) in the *sixth* and *seventh* columns respectively. The Longitude of the Centre of the Disk is found by subtracting the Reduction to the Prime Meridian from L, the Longitude of the Centre from the Node. The Latitude of the Centre is of course the same as D, the Heliographic Latitude of the Earth.

The measures of areas given in the *last three* columns were made with a glass diaphragm ruled into squares, with sides of one hundredth of an inch, and placed nearly in contact with the photographic film. The integral number of squares and parts of a square contained in the area of a spot or facula was estimated by the observer, two independent sets of measures being made by two observers. The mean of the two sets of measures has been taken for each photograph. The factor for converting the areas, as measured in ten-thousandths of a square inch, into millionths of the Sun's visible hemisphere, allowing for the effect of foreshortening, has been inferred by means of a table of double entry, giving the equivalent of one square for different values of the Sun's radius, and for different distances of the spot or facula from the Sun's centre, as measured by means of the position-micrometer.

The individual spots in a group have in some cases not been measured separately, but combined into a cluster of two or three small spots close together, the position of the centre of gravity and the aggregate area of the cluster being given. The actual number of individual spots is usually stated in the Notes.

§ 3. *Ledgers of Areas and Positions of Spot-groups upon the Sun's Disk deduced from the measurement of the Solar photographs for each day in the year* 1888.

In these Ledgers the daily results for each group are collected together from the measures of the individual spots and given in a condensed form. The first column gives for each day, on which the group was observed, the Greenwich civil time at which each photograph was taken, expressed by the day of the month (civil reckoning) and the decimals of a day reckoning from Greenwich mean midnight. The second and third columns give the sums, for each day, of the projected areas of all the umbræ and whole spots comprised in the group, the projected area being the area as it is measured upon the photograph, uncorrected for foreshortening, and expressed in

millionths of the Sun's apparent disk. The fourth and fifth columns give the sums for each day of the areas of all the umbræ and whole spots comprised in the group, corrected for foreshortening, and expressed in millionths of the Sun's visible hemisphere. The sixth and seventh columns give the mean longitude and latitude of the group, found by multiplying the longitude and latitude of each separately measured component of the group by its area, and dividing the sum of the products by the sum of the areas. The last column gives the mean longitude of the group from the central meridian, and is found by subtracting the longitude of the centre of the disk from the mean longitude of the group. At the foot of these daily results for each group are given the mean areas of umbræ and whole spots and the mean longitude and latitude for the period of observation.

§ 4. *Total Projected Areas of Sun Spots and Faculæ, for each day, and Mean Areas and Mean Heliographic Latitude of Sun Spots and Faculæ, for each Rotation of the Sun, and for the Year* 1888.

This section requires no further explanation.

§ 5. *Total Projected Areas of Sun Spots and Faculæ, for each day, and Mean Projected Areas for each Rotation of the Sun, and for each year from* 1882 *to* 1885.

This section also requires no further explanation.

W. H. M. CHRISTIE.

1889 *October* 23.

DISCUSSION OF PROBABLE ERROR AND PERSONALITY IN MEASUREMENTS OF SOLAR PHOTOGRAPHS.

I.—PROBABLE ERROR IN MEASUREMENTS ON FOUR-INCH PHOTOGRAPHS.

For the determination of probable error in measurements of distance, position-angle and area, six *four-inch* photographs, containing in all 50 spots, which had been already measured twice (on the right and left of the centre) in 1882, 1883, 1884, and 1886 for publication in the daily results, were remeasured on the right and left by each of four observers in 1888 November and December; so that in all ten independent measurements of each photograph were available for comparison. The mean of each set of measures of distance, position-angle, area of umbra, and area of whole spot was then formed; next the discordance of individual measures from the mean; and, finally, the mean discordance. The means and mean discordances are given in the subjoined tables.

The number and small letter in the *first* column of each table is the same as that given in the printed results, the letter I denoting that the spot was measured on an Indian photograph, and the letter M that it was measured on a photograph from Mauritius.

The spots are arranged in the first table in order of distance from the Sun's centre, the quantity $\frac{r}{R}$ in the *second* column giving this distance in parts of the radius of the apparent disk.

In the second table they are arranged according to area of whole spot as given in the *twelfth* column.

In the measures of distance a small correction for zero of scale has been applied. This correction has been derived from the difference between the mean of the readings obtained for the limb of the Sun when the magnifier was on the left of the centre of the measuring instrument, and the mean of those obtained when the magnifier was on the right.

In the measures of position angle it is obvious that the mean discordance depends on the distance of the spot from the Sun's centre. Accordingly in the *seventh* column is given the equivalent at the uniform distance of the Sun's radius (R), obtained by multiplying each term in this column by the corresponding factor in column 2.

The measures of areas are expressed in ten-thousandths of a square inch. It is again obvious that the mean discordance bears some relation to the mean area, the simplest supposition being that it varies directly as the mean area. The results of this supposition are given in columns 10 and 14 respectively, where the mean discordance is exhibited as a per-centage ; but as these are not satisfactorily accordant, another hypothesis was tried, viz., that the mean discordance is proportional to the perimeter of the spot, which would be the case if we suppose it due to the existence of an ill-defined border of constant breadth. The results of this hypothesis are exhibited in columns 11 and 15 respectively, the square root of the area being considered roughly proportional to the perimeter.

TABLE I. (arranged according to distance from Sun's centre).

No. and Letter for Spot.	$\frac{r}{R}$	DISTANCE.		POSITION-ANGLE.			AREA OF UMBRA.				AREA OF WHOLE SPOT.			
		Mean Reading.	Mean Discordance.	Mean Reading.	Mean Discordance.	Mean Discordance at distance R.	Mean Area.	Mean Discordance.	Mean Discordance per cent. of Umbra.	Mean Discordance divided by Square Root of Umbra.	Mean Area.	Mean Discordance.	Mean Discordance per cent. of Whole Spot.	Mean Discordance divided by Square Root of Whole Spot.
		d	d	°	°	°								
I. 718	0·990	492·2	0·60	247·0	0·17	0·168	0·1	0·07	70·0	0·222	3·3	0·89	26·2	0·489
1271	0·969	478·5	0·65	266·9	0·10	0·097	2·0	0·54	27·0	0·383	10·1	1·49	14·8	0·469
M. 1578*a*	0·966	491·8	0·33	67·2	0·08	0·077	0·8	0·18	22·5	0·201	4·2	0·59	14·0	0·288
I. 729	0·966	480·2	0·76	90·7	0·20	0·193	10·5	2·28	21·7	0·704	90·2	10·28	11·4	1·082
M. 1573*a*	0·963	490·3	0·37	253·6	0·08	0·077	0·8	0·34	42·5	0·381	7·1	1·11	15·6	0·417
M. 1573*c*	0·956	486·7	0·36	256·8	0·14	0·134	3·3	0·50	15·2	0·275	22·1	1·57	7·1	0·334
I. 693	0·955	478·4	0·75	273·1	0·16	0·153	1·5	0·24	16·0	0·197	9·3	1·07	11·5	0·351
M. 1573*b*	0·928	472·1	0·56	259·1	0·11	0·102	11·2	1·78	15·9	0·531	48·0	2·00	4·2	0·289
I. 699	0·924	463·1	0·51	82·2	0·14	0·129	2·0	0·24	12·0	0·170	14·1	2·36	16·7	0·629
731	0·911	441·1	0·56	225·8	0·14	0·128	1·2	0·13	10·8	0·118	7·3	0·57	7·8	0·211
I. 726	0·816	405·2	1·04	83·3	0·17	0·139	0·9	0·62	68·9	0·653	10·5	1·64	15·6	0·506
1231*b*	0·814	403·6	1·14	252·9	0·09	0·073	2·4	0·82	34·2	0·529	12·7	1·87	14·7	0·525
726	0·771	373·8	0·67	220·3	0·07	0·054	1·3	0·22	16·9	0·193	7·7	0·92	11·9	0·332
I. 726	0·750	372·9	1·17	87·7	0·39	0·293	2·9	0·43	14·8	0·253	25·4	2·51	9·9	0·498
1284*a*	0·742	366·7	0·50	79·0	0·14	0·104	8·3	0·60	7·2	0·208	50·8	2·98	5·9	0·418

TABLE I.—*concluded.*

No. and Letter for Spot.	$\frac{r}{R}$	DISTANCE.		POSITION-ANGLE.			AREA OF UMBRA.				AREA OF WHOLE SPOT.			
		Mean Reading.	Mean Discordance.	Mean Reading.	Mean Discordance.	Mean Discordance at Distance R.	Mean Area.	Mean Discordance.	Mean Discordance per cent. of Umbra.	Mean Discordance divided by Square Root of Umbra.	Mean Area.	Mean Discordance.	Mean Discordance per cent. of Whole Spot.	Mean Discordance divided by Square Root of Whole Spot.
		d	d	°	°	°								
M. 1572*c*	0·706	359·3	0·45	238·5	0·10	0·071	3·2	0·25	7·8	0·140	13·4	0·62	4·6	0·169
M. 1572*d*	0·697	354·9	0·44	236·4	0·11	0·077	1·8	0·34	18·9	0·254	15·3	1·14	7·5	0·292
I. 697	0·683	342·3	0·70	231·6	0·18	0·123	5·4	0·57	10·6	0·246	44·2	2·58	5·8	0·389
726	0·655	317·9	0·80	75·2	0·09	0·059	4·8	0·34	7·1	0·155	28·9	1·31	4·5	0·244
726	0·654	317·2	0·75	222·0	0·14	0·092	16·8	1·15	6·8	0·280	79·4	4·52	5·7	0·507
I. 697	0·611	306·3	0·51	227·0	0·12	0·073	3·5	0·61	17·4	0·326	32·0	3·31	10·3	0·585
1246*b*	0·600	297·6	0·98	65·6	0·26	0·156	1·2	0·78	65·0	0·709	4·8	1·27	26·5	0·580
1235*a*	0·522	259·0	0·66	298·4	0·14	0·073	4·8	0·44	9·2	0·201	32·5	2·11	6·5	0·370
I. 722	0·522	259·2	0·53	302·0	0·24	0·125	5·0	0·67	13·4	0·299	28·9	2·16	7·5	0·402
734	0·499	242·2	0·38	32·2	0·24	0·120	6·2	0·57	9·2	0·229	37·7	1·76	4·7	0·287
I. 695	0·463	232·1	0·48	31·8	0·33	0·153	0·6	0·31	51·7	0·400	4·5	0·80	17·8	0·377
1235	0·455	225·5	0·54	310·9	0·21	0·096	3·2	0·73	22·8	0·408	16·0	1·40	8·8	0·350
1285*b*	0·454	224·3	0·89	238·9	0·29	0·132	4·0	0·38	9·5	0·190	25·6	3·38	13·2	0·668
729	0·432	209·4	0·53	172·4	0·35	0·151	2·5	0·81	32·4	0·513	12·7	1·32	10·4	0·371
I. 695	0·413	206·8	0·48	22·5	0·24	0·099	3·7	0·62	16·8	0·323	18·2	2·07	11·4	0·485
1235*b*	0·398	197·4	0·58	331·7	0·24	0·096	14·0	0·91	6·5	0·243	97·2	3·00	3·1	0·304
I. 725	0·353	175·6	0·57	64·6	0·32	0·113	0·0	0·00	0·0	0·000	2·4	0·47	19·6	0·303
1243*a*	0·321	159·4	0·56	25·3	0·29	0·093	2·1	0·32	15·2	0·221	8·6	0·94	10·9	0·321
I. 691	0·319	159·6	0·60	265·8	0·27	0·086	13·3	0·91	6·8	0·249	65·5	3·73	5·7	0·461
733	0·302	146·5	0·47	216·3	0·35	0·106	3·1	0·87	28·1	0·494	14·7	1·22	8·3	0·319
M. 1575	0·292	148·8	0·36	97·6	0·38	0·111	1·3	0·49	37·7	0·430	5·6	0·59	10·5	0·249
I. 694	0·285	143·0	0·47	92·6	0·27	0·077	2·9	0·53	18·3	0·312	13·9	0·80	5·8	0·215
M. 1575*b*	0·283	143·8	0·57	92·3	0·48	0·136	3·5	0·70	20·0	0·374	10·5	0·70	6·7	0·216
1281	0·279	137·7	0·59	87·9	0·30	0·084	2·2	0·46	20·9	0·311	6·8	1·12	16·5	0·429
1277*b*	0·274	135·3	0·96	10·0	0·94	0·258	7·9	1·24	15·7	0·441	58·2	2·72	4·7	0·356
1241	0·264	130·7	0·60	105·7	0·38	0·100	0·8	0·42	52·5	0·470	3·2	0·36	11·3	0·201
1277*a*	0·256	126·6	0·94	323·9	0·49	0·125	8·0	1·02	12·8	0·361	46·2	2·55	5·5	0·375
733	0·254	123·3	0·67	206·9	0·30	0·076	1·1	0·12	10·9	0·114	13·6	1·32	9·7	0·358
1277	0·248	122·7	0·72	360·3	0·38	0·094	1·5	0·54	36·0	0·443	5·9	0·67	11·4	0·276
1277	0·248	122·7	0·89	332·3	0·50	0·124	2·8	0·48	17·2	0·287	18·7	1·81	9·7	0·419
I. 728	0·235	116·7	1·69	170·7	1·34	0·315	6·1	0·96	15·7	0·389	33·9	4·51	13·3	0·775
I. 728	0·225	111·6	0·98	137·0	0·68	0·153	8·7	1·36	15·6	0·461	59·5	3·50	5·9	0·454
M. 1575*a*	0·189	96·2	0·48	89·0	0·73	0·138	2·6	0·54	20·8	0·335	7·0	0·71	10·1	0·268
1237	0·119	59·4	0·72	168·7	1·47	0·175	18·5	1·26	6·8	0·293	102·5	3·00	2·9	0·297
1286	0·104	51·1	0·55	101·4	0·99	0·103	1·4	0·30	21·4	0·254	4·8	0·59	12·3	0·270

MEANS OF EACH GROUP IN TABLE I.

	Distance.		Position-Angle.		Area of Umbra.				Area of Whole Spot.			
	Mean $\frac{r}{R}$	Mean Discordance.	Mean Discordance.	Mean Discordance at Distance R.	Mean Area.	Mean Discordance.	Mean Discordance per cent. of Umbra.	Mean Discordance divided by Square Root of Umbra.	Mean Area.	Mean Discordance.	Mean Discordance per cent. of Whole Spot.	Mean Discordance divided by Square Root of Whole Spot.
		d	°	°								
	0·971	0·54	0·13	0·122	2·8	0·68	36·7	0·378	23·0	2·87	16·4	0·549
	0·935	0·55	0·14	0·129	3·8	0·58	14·0	0·258	20·2	1·51	9·5	0·361
	0·779	0·90	0·17	0·133	3·2	0·54	28·4	0·307	21·4	1·98	11·6	0·456
	0·679	0·63	0·12	0·084	6·4	0·53	10·2	0·215	36·2	2·05	5·6	0·320
	0·551	0·61	0·20	0·109	4·1	0·61	22·8	0·353	27·2	2·12	11·1	0·445
	0·443	0·58	0·28	0·126	2·8	0·57	26·6	0·367	15·4	1·79	12·3	0·450
	0·339	0·56	0·29	0·099	6·5	0·60	11·3	0·241	37·7	1·87	9·5	0·342
	0·283	0·59	0·47	0·133	3·6	0·68	22·5	0·374	19·0	1·19	8·8	0·293
	0·254	0·76	0·41	0·104	2·8	0·52	25·9	0·335	17·5	1·34	9·5	0·326
	0·174	0·88	1·04	0·177	7·5	0·88	16·1	0·346	41·5	2·46	8·9	0·413
General Mean	0·5408	0·660	0·325	0·1216	4·35	0·619	21·45	0·3234	25·91	1·918	10·32	0·3955

1 division of scale in measure of distance = $\frac{1}{250}$ in., corresponding to 0·002012 × R.

The areas are expressed in ten-thousandths of a square inch, this unit corresponding to 4·02 millionths of the Sun's visible hemisphere for a spot at the centre of the disk.

TABLE II. (arranged according to area of Whole Spot).

No. and Letter. for Spot.	$\frac{r}{R}$	Distance.		Position-Angle.			Area of Umbra.				Area of Whole Spot.			
		Mean Reading.	Mean Discordance.	Mean Reading.	Mean Discordance.	Mean Discordance at Distance R.	Mean Area.	Mean Discordance.	Mean Discordance per cent. of Umbra.	Mean Discordance divided by Square Root of Umbra.	Mean Area.	Mean Discordance.	Mean Discordance per cent. of Whole Spot.	Mean Discordance divided by Square Root of Whole Spot.
		d	d	°	°	°								
1237	0·119	59·4	0·72	168·7	1·47	0·175	18·5	1·26	6·8	0·293	102·5	3·00	2·9	0·297
1235*b*	0·398	197·4	0·58	331·7	0·24	0·096	14·0	0·91	6·5	0·243	97·2	3·00	3·1	0·304
I. 729	0·966	480·2	0·76	90·7	0·20	0·193	10·5	2·28	21·7	0·704	90·2	10·28	11·4	1·082
726	0·654	317·2	0·75	222·0	0·14	0·092	16·8	1·15	6·8	0·280	79·4	4·52	5·7	0·507
I. 691	0·319	159·6	0·60	265·8	0·27	0·086	13·3	0·91	6·8	0·249	65·5	3·73	5·7	0·461
I. 728	0·225	111·6	0·98	137·0	0·68	0·153	8·7	1·36	15·6	0·461	59·5	3·50	5·9	0·454
1277*b*	0·274	135·3	0·96	10·0	0·94	0·258	7·9	1·24	15·7	0·441	58·2	2·72	4·7	0·356
1284*a*	0·742	366·7	0·50	79·0	0·14	0·104	8·3	0·60	7·2	0·208	50·8	2·98	5·9	0·418
M. 1573*b*	0·928	472·1	0·56	259·1	0·11	0·102	11·2	1·78	15·9	0·531	48·0	2·00	4·2	0·289
1277*a*	0·256	126·6	0·94	323·9	0·49	0·125	8·0	1·02	12·8	0·361	46·2	2·55	5·5	0·375

TABLE II.—*concluded.*

No. and Letter for Spot.	$\frac{r}{R}$	Distance.		Position-Angle.			Area of Umbra.				Area of Whole Spot.			
		Mean Reading.	Mean Discordance.	Mean Reading.	Mean Discordance.	Mean Discordance at distance R.	Mean Area.	Mean Discordance.	Mean Discordance per cent. of Umbra.	Mean Discordance divided by Square Root of Umbra.	Mean Area.	Mean Discordance.	Mean Discordance per cent. of Whole Spot.	Mean Discordance divided by Square Root of Whole Spot.
		d	d	°	°	°								
I. 697	0·683	342·3	0·70	231·6	0·18	0·123	5·4	0·57	10·6	0·245	44·2	2·58	5·8	0·389
734	0·499	242·2	0·38	32·2	0·24	0·120	6·2	0·57	9·2	0·229	37·7	1·76	4·7	0·287
I. 728	0·235	116·7	1·69	170·7	1·34	0·315	6·1	0·96	15·7	0·389	33·9	4·51	13·3	0·775
1235*a*	0·522	259·0	0·66	298·4	0·14	0·073	4·8	0·44	9·2	0·201	32·5	2·11	6·5	0·370
I. 697	0·611	306·3	0·51	227·0	0·12	0·073	3·5	0·61	17·4	0·326	32·0	3·31	10·3	0·585
726	0·655	317·9	0·80	75·2	0·09	0·059	4·8	0·34	7·1	0·155	28·9	1·31	4·5	0·244
I. 722	0·522	259·2	0·53	302·0	0·24	0·125	5·0	0·67	13·4	0·299	28·9	2·16	7·5	0·402
1285*b*	0·454	224·3	0·89	238·9	0·29	0·132	4·0	0·38	9·5	0·190	25·6	3·38	13·2	0·668
I. 726	0·750	372·9	1·17	87·7	0·39	0·293	2·9	0·43	14·8	0·253	25·4	2·51	9·9	0·498
M. 1573*c*	0·956	486·7	0·36	256·8	0·14	0·134	3·3	0·50	15·2	0·275	22·1	1·57	7·1	0·334
1277	0·248	122·7	0·89	332·3	0·50	0·124	2·8	0·48	17·2	0·287	18·7	1·81	9·7	0·419
I. 695	0·413	206·8	0·48	22·5	0·24	0·099	3·7	0·62	16·8	0·323	18·2	2·07	11·4	0·485
1235	0·455	225·5	0·54	310·9	0·21	0·096	3·2	0·73	22·8	0·408	16·0	1·40	8·8	0·350
M. 1572*d*	0·697	354·9	0·44	236·4	0·11	0·077	1·8	0·34	18·9	0·254	15·3	1·14	7·5	0·292
733	0·302	146·5	0·47	216·3	0·35	0·106	3·1	0·87	28·1	0·494	14·7	1·22	8·3	0·319
I. 699	0·924	463·1	0·51	82·2	0·14	0·129	2·0	0·24	12·0	0·170	14·1	2·36	16·7	0·629
I. 694	0·285	143·0	0·47	92·6	0·27	0·077	2·9	0·53	18·3	0·312	13·9	0·80	5·8	0·215
733	0·254	123·3	0·67	206·9	0·30	0·076	1·1	0·12	10·9	0·114	13·6	1·32	9·7	0·358
M. 1572*c*	0·706	359·3	0·45	238·5	0·10	0·071	3·2	0·25	7·8	0·140	13·4	0·62	4·6	0·169
1231*b*	0·814	403·6	1·14	252·9	0·09	0·073	2·4	0·82	34·2	0·529	12·7	1·87	14·7	0·525
729	0·432	209·4	0·53	172·4	0·35	0·151	2·5	0·81	32·4	0·513	12·7	1·32	10·4	0·371
M. 1575*b*	0·283	143·8	0·57	92·3	0·48	0·136	3·5	0·70	20·0	0·374	10·5	0·70	6·7	0·216
I. 726	0·816	405·2	1·04	83·3	0·17	0·139	0·9	0·62	68·9	0·653	10·5	1·64	15·6	0·506
1271	0·969	478·5	0·65	266·9	0·10	0·097	2·0	0·54	27·0	0·383	10·1	1·49	14·8	0·469
I. 693	0·955	478·4	0·75	273·1	0·16	0·153	1·5	0·24	16·0	0·197	9·3	1·07	11·5	0·351
1243*a*	0·321	159·4	0·56	25·3	0·29	0·093	2·1	0·32	15·2	0·221	8·6	0·94	10·9	0·321
726	0·771	373·8	0·67	220·3	0·07	0·054	1·3	0·22	16·9	0·193	7·7	0·92	11·9	0·332
731	0·911	441·1	0·56	225·8	0·14	0·128	1·2	0·13	10·8	0·118	7·3	0·57	7·8	0·211
M. 1573*a*	0·963	490·3	0·37	253·6	0·08	0·077	0·8	0·34	42·5	0·381	7·1	1·11	15·6	0·417
M. 1575*a*	0·189	96·2	0·48	89·0	0·73	0·138	2·6	0·54	20·8	0·335	7·0	0·71	10·1	0·268
1281	0·279	137·7	0·59	87·9	0·30	0·084	2·2	0·46	20·9	0·311	6·8	1·12	16·5	0·429
1277	0·248	122·7	0·72	360·3	0·38	0·094	1·5	0·54	36·0	0·443	5·9	0·67	11·4	0·276
M. 1575	0·292	148·8	0·36	97·6	0·38	0·111	1·3	0·49	37·7	0·430	5·6	0·59	10·5	0·249
1286	0·104	51·1	0·55	101·4	0·99	0·103	1·4	0·30	21·4	0·254	4·8	0·59	12·3	0·270
1246*b*	0·600	297·6	0·98	65·6	0·26	0·156	1·2	0·78	65·0	0·709	4·8	1·27	26·5	0·580
I. 695	0·463	232·1	0·48	31·8	0·33	0·153	0·6	0·31	51·7	0·400	4·5	0·80	17·8	0·377
M. 1578*a*	0·966	491·8	0·33	67·2	0·08	0·077	0·8	0·18	22·5	0·201	4·2	0·59	14·0	0·288
I. 718	0·990	492·2	0·60	247·0	0·17	0·168	0·1	0·07	70·0	0·222	3·3	0·89	26·2	0·489
1241	0·264	130·7	0·60	105·7	0·38	0·100	0·8	0·42	52·5	0·470	3·2	0·36	11·3	0·201
I. 725	0·353	175·6	0·57	64·6	0·32	0·113	0·0	0·00	0·0	0·000	2·4	0·47	19·6	0·303

MEANS OF EACH GROUP IN TABLE II.

	Distance.		Position-Angle		Area of Umbra.				Area of Whole Spot.			
	Mean $\frac{r}{R}$	Mean Discordance.	Mean Discordance.	Mean Discordance at distance R.	Mean Area.	Mean Discordance.	Mean Discordance per cent. of Umbra.	Mean Discordance divided by Square Root of Umbra.	Mean Area.	Mean Discordance.	Mean Discordance per cent. of Whole Spot.	Mean Discordance divided by Square Root of Whole Spot.
		d	°	°								
	0·491	0·68	0·46	0·128	14·6	1·30	9·7	0·354	87·0	4·91	5·8	0·530
	0·485	0·79	0·47	0·148	8·8	1·20	13·4	0·400	52·5	2·75	5·2	0·378
	0·510	0·79	0·40	0·141	5·2	0·63	12·4	0·278	36·1	2·85	8·1	0·481
	0·667	0·75	0·23	0·149	4·0	0·46	12·0	0·234	26·2	2·19	8·4	0·429
	0·423	0·56	0·28	0·100	2·9	0·61	20·8	0·353	16·6	1·53	9·1	0·373
	0·597	0·65	0·18	0·085	2·3	0·39	16·6	0·253	13·5	1·39	10·3	0·379
	0·691	0·71	0·25	0·135	2·1	0·58	32·9	0·424	10·6	1·24	11·8	0·383
	0·631	0·53	0·26	0·098	1·6	0·31	21·2	0·250	7·5	0·85	11·3	0·310
	0·305	0·64	0·46	0·110	1·5	0·51	36·2	0·429	5·6	0·85	15·4	0·361
	0·607	0·52	0·26	0·122	0·5	0·20	39·3	0·259	3·5	0·62	17·8	0·332
General Mean	0·5407	0·662	0·325	0·1216	4·35	0·619	21·45	0·3234	25·91	1·918	10·32	0·3956

1 division of scale in measure of distance $= \frac{1}{250}$ in., corresponding to 0·002012 × R.

The areas are expressed in ten-thousandths of a square inch, this unit corresponding to 4·02 millionths of the Sun's visible hemisphere for a spot at the centre of the disk.

Expressing the Mean Discordance in distance in terms of $\frac{r}{R}$, and the areas and mean discordances in areas in millionths of the Sun's visible hemisphere for a spot at the centre of the disk, we have :—

Distance.		Position-Angle.		Area of Umbra.				Area of Whole Spot.			
Mean $\frac{r}{R}$	Mean Discordance in $\frac{r}{R}$	Mean Discordance.	Mean Discordance at distance R.	Mean Area.	Mean Discordance.	Mean Discordance per cent. of Umbra.	Mean Discordance divided by Square Root of Umbra.	Mean Area.	Mean Discordance.	Mean Discordance per cent. of Whole Spot.	Mean Discordance divided by Square Root of Whole Spot.
		°	°								
0·541	0·001330	0·325	0·1216	17·49	2·488	21·45	0·650	104·16	7·710	10·32	0·795

It appears from these tables that the means of two measures of distance and position-angle as printed may be taken as subject to an uncertainty of less than a unit in the last figure, the probable error in distance $\left(\frac{r}{R}\right)$ being 0·0008, and in position-angle (at distance R) 0°·077. As regards areas of umbræ and whole spots, Tables I. and II. indicate that the mean discordance may be taken to vary as the square root of the measured area, and that it does not sensibly depend on the distance from the Sun's centre. Assuming that the mean discordance varies as the square root of the measured area, the following table gives the values of the probable errors in measures of umbræ, and whole spots for spots of various sizes at the centre of the Sun's disk, the probable error being inferred from the mean discordance by the formula :—.

$$\text{Probable Error} = 0{\cdot}845 \frac{\text{Sum of Discordances}}{\sqrt{10 \times 9}}$$
$$= 0{\cdot}891 \times \text{Mean Discordance.}$$

The similar results obtained in 1885 for the Probable Error of the measurement of positions of spots on *eight-inch* photographs compare as follows with those given above for *four-inch* photographs.

Diameter of Sun's Image.	DISTANCE.			POSITION-ANGLE.	
	Mean $\frac{r}{R}$	Mean Discordance in measured Distance.	Mean Discordance in $\frac{r}{R}$	Mean Discordance.	Mean Discordance at Distance R.
		d		°	°
Eight inches	0·640	0·659	0·000676	0·12	0·053
Four inches	0·541	0·662	0·001330	0·325	0·1216

It appears, therefore, that the error in the measured distance is practically the same for the *four-inch* as for the *eight-inch* photographs, the error in $\frac{r}{R}$ consequently decreasing inversely as the diameter. But the position-angles are slightly more accordant proportionately as well as positively on the larger photographs, indicating that the precision of a reading of position-angle increases a little faster than the distance from the centre at which the pointing is made. Nevertheless, as the probable error of the means of two measures of distance and position-angle on the *four-inch* photographs, as printed in the Photographic Results, though about double that on the *eight-inch* photographs, is less than a unit in the last figure, it does not appear that the precision of measurement of positions has been practically increased by the adoption of the larger scale photographs.

The following results for the probable error in the measurement of the areas of umbræ and whole spots show that for the areas also, as expressed in millionths of the Sun's visible hemisphere, the measurements are sensibly as accurate for the smaller as for the larger photographs.

Umbræ.			Whole Spots.		
Area in Millionths.	Probable Error in Millionths.		Area in Millionths.	Probable Error in Millionths.	
	One Measure.	Mean of Two Measures.		One Measure.	Mean of Two Measures.
1	0·58	0·41	5	1·59	1·13
2	0·82	0·58	10	2·24	1·59
4	1·16	0·82	20	3·16	2·24
6	1·42	1·01	30	3·88	2·75
8	1·64	1·16	40	4·48	3·16
10	1·83	1·30	50	5·01	3·56
15	2·24	1·59	75	6·13	4·35
20	2·59	1·83	100	7·08	5·01
25	2·90	2·06	125	7·92	5·62
30	3·17	2·24	150	8·67	6·13
40	3·66	2·59	200	10·02	7·08
50	4·09	2·90	250	11·19	7·92
70	4·85	3·44	350	13·24	9·40
100	5·79	4·09	500	15·86	11·19
150	7·09	5·03	750	19·40	13·77
200	8·19	5·79	1000	22·37	15·86

The quantities given in the *third* and *sixth* columns represent the mean discordances of the measured areas as given in the Photographic Results for spots seen on *four-inch* photographs near the centre of the disk. For spots at a considerable distance from the centre these quantities should be multiplied by $\frac{1}{\sqrt[4]{1-\left(\frac{r}{R}\right)^2}}$, *i.e.*, by the square root of the factor for the effect of foreshortening, the argument being the area in millionths as given in the Photographic Results.

The following are the values of $\frac{r}{R}$ corresponding to different values of the factor $\frac{1}{\sqrt[4]{1-\left(\frac{r}{R}\right)^2}}$:—

$\frac{r}{R}$	0·000	0·722	0·862	0·922	0·954	0·969	0·988	0·994	0·997	0·998
Factor $\frac{1}{\sqrt[4]{1-\left(\frac{r}{R}\right)^2}}$	1·0	1·2	1·4	1·6	1·8	2·0	2·5	3·0	3·5	4·0

By the help of these tables the probable error may readily be inferred for the area of any spot on a *four-inch* photograph as printed in the Photographic Results.

The results for the Probable Error in measures of the areas of Umbræ and Whole Spots on *four-inch* and *eight-inch* photographs compare as follow :—

UMBRÆ.

Area in Millionths.	Probable Error in Millionths.			
	One Measure.		Mean of Two Measures.	
	Four-inch.	Eight-inch.	Four-inch.	Eight-inch.
1	0·6	0·5	0·4	0·4
2	0·8	0·8	0·6	0·5
4	1·2	1·1	0·8	0·8
6	1·4	1·3	1·0	0·9
8	1·6	1·5	1·2	1·1
10	1·8	1·7	1·3	1·2
20	2·6	2·4	1·8	1·7
30	3·2	3·0	2·2	2·1
40	3·7	3·4	2·6	2·4
50	4·1	3·8	2·9	2·7
70	4·9	4·6	3·4	3·2
100	5·8	5·4	4·1	3·8
150	7·1	6·7	5·0	4·7
200	8·2	7·7	5·8	5·4

WHOLE SPOTS.

Area in Millionths.	Probable Error in Millionths.			
	One Measure.		Mean of Two Measures.	
	Four-inch.	Eight-inch.	Four-inch.	Eight-inch.
5	1·6	1·3	1·1	0·9
10	2·2	1·9	1·6	1·3
20	3·2	2·7	2·2	1·9
30	3·9	3·3	2·8	2·3
40	4·5	3·8	3·2	2·7
50	5·0	4·2	3·6	3·0
100	7·1	6·0	5·0	4·2
150	8·7	7·3	6·1	5·2
200	10·0	8·5	7·1	6·0
250	11·2	9·5	7·9	6·7
350	13·2	11·2	9·4	7·9
500	15·9	13·4	11·2	9·5
750	19·4	16·4	13·8	11·6
1000	22·4	18·9	15·9	13·4

The larger photographs, therefore, show only a very slight advantage in precision over the smaller; and this is probably due to the fact that spots are more frequently measured in groups and clusters on the smaller photographs, and that when so measured it is not always easy to secure that different observers, or the same observer at different times, shall always adopt precisely the same arrangement in measuring.

II.—PERSONALITY IN MEASUREMENT OF AREAS ON EIGHT-INCH PHOTOGRAPHS.

In the preceding investigation the measures of area by the different observers have been considered as comparable, without the application of any correction for systematic differences in habit. Sensible differences of this kind have been suspected, and an investigation of their character and amount as shown in the measurement of *four-inch* photographs was given in the Volume of the Results for 1885. It was then found that these differences were not large as compared with the probable error of observation, and indeed that in the case of Whole Spots they were quite insignificant, whilst their determination was subject to considerable uncertainty.

The following series of comparisons between the different observers in the measurements of areas on *eight-inch* photographs has been made in a precisely similar manner to that for the *four-inch* photographs published in the Volume for 1885. The photographs used for the comparison extend from 1881 November to the end of 1888. The fifth and sixth columns under each heading are referred to below; for the other columns no explanation is required.

For M and H.

	UMBRÆ.					WHOLE SPOTS.					FACULÆ.				
	No. of Obs.	Total Area as measured by M	Total Area as measured by H	$\frac{H}{M}$	$\sqrt{H}-\sqrt{M}$	No. of Obs.	Total Area as measured by M	Total Area as measured by H	$\frac{H}{M}$	$\sqrt{H}-\sqrt{M}$	No. of Obs.	Total Area as measured by M	Total Area as measured by H	$\frac{H}{M}$	$\sqrt{H}-\sqrt{M}$
Under 5 squares	106	293·9	246·1	0·837	− 0·141	Under 10 squares	161	796·7	784·2	0·984	− 0·018	Under 50 squares.....	140	3665·0	4233·0	1·155	+ 0·382
Above 5 & under 10..	70	552·4	443·3	0·803	− 0·293	Above 10 & under 20..	76	1084·5	1051·7	0·970	− 0·057	Above 50 & under 100..	93	6231·0	6475·0	1·039	+ 0·159
Above 10 & under 20	50	771·8	632·8	0·820	− 0·371	Above 20 & under 40..	54	1648·5	1570·3	0·953	− 0·134	Above 100 & under 200	62	8762·0	8743·0	0·998	− 0·013
Above 20 & under 40	15	575·8	493·5	0·857	− 0·410	Above 40 & under 100	82	5488·2	5160·3	0·940	− 0·248	Above 200 & under 400	24	6867·0	6348·0	0·924	− 0·651
Above 40 & under 80	12	745·5	648·5	0·870	− 0·543	Above 100 & under 200	30	3850·0	3677·5	0·955	− 0·256	Above 400 squares	11	6320·0	5492·0	0·869	− 1·624
Above 80 squares ..	7	1231·0	1125·5	0·914	− 0·582	Above 200 & under 400	14	3937·0	3828·0	0·972	− 0·233						
						Above 400 squares....	13	9882·0	9907·0	1·003	+ 0·035						
Total & Means..	264	15·80	13·60	0·830	− 0·274	Total & Means....	130	62·06	60·42	0·967	− 0·105	Total & Means....	330	96·50	94·82	1·066	+ 0·103

For M and J P.

UMBRÆ.

	No. of Obs.	Total Area as measured by M	Total Area as measured by J P	J P / M	√J P − √M
Under 5 squares	10	22·3	28·7	1·287	+ 0·201
Above 5 & under 10..	3	18·8	18·8	1·000	0·000
Above 10 & under 20	2	35·6	29·0	0·815	− 0·351
Above 20 & under 40	3	69·0	61·4	0·890	− 0·271
Above 40 & under 80	1	42·0	37·5	0·893	− 0·257
Above 80 squares....					
Total & Means..	19	9·88	9·23	1·109	+ 0·013

WHOLE SPOTS.

	No. of Obs.	Total Area as measured by M	Total Area as measured by J P	J P / M	√J P − √M
Under 10 squares ..	10	42·5	44·4	1·044	+ 0·045
Above 10 & under 20	8	103·6	101·1	0·976	− 0·043
Above 20 & under 40	4	104·5	109·5	1·048	+ 0·121
Above 40 & under 100	2	131·0	133·0	1·015	+ 0·062
Above 100 & under 200	5	784·5	738·0	0·941	− 0·377
Above 200 & under 400					
Above 400 squares..					
Total & Means..	29	40·21	38·83	1·006	− 0·040

FACULÆ.

	No. of Obs.	Total Area as measured by M	Total Area as measured by J P	J P / M	√J P − √M
Under 50 squares....	19	440·0	493·0	1·120	+ 0·282
Above 50 & under 100	7	490·0	454·0	0·927	− 0·314
Above 100 & under 200	1	114·0	120·0	1·053	+ 0·271
Above 200 & under 400	2	500·0	595·0	1·190	+ 1·437
Above 400 squares..	1	500·0	440·0	0·880	− 1·385
Total & Means..	30	68·13	70·07	1·069	+ 0·164

For M and F.

		M	F	F / M	√F − √M
Under 5 squares	8	17·7	17·9	1·011	+ 0·010
Above 5 & under 10..	5	36·0	34·5	0·958	− 0·056
Above 10 & under 20	6	87·7	88·5	1·009	+ 0·017
Above 20 & under 40	3	84·0	83·0	0·988	− 0·031
Above 40 & under 80	2	122·0	115·0	0·943	− 0·227
Above 80 squares....	1	318·0	310·0	0·975	− 0·226
Total & Means..	25	26·62	25·96	0·990	− 0·034

		M	F	F / M	√F − √M
Under 10 squares....	14	72·8	72·4	0·995	− 0·006
Above 10 & under 20	3	39·6	40·0	1·010	+ 0·018
Above 20 & under 40	5	112·5	115·0	1·022	+ 0·053
Above 40 & under 100	7	448·0	456·0	1·018	+ 0·070
Above 100 & under 200	6	701·4	705·0	1·005	+ 0·028
Above 200 & under 400	2	554·0	543·0	0·980	− 0·166
Above 400 squares..	2	1663·4	1640·0	0·986	− 0·203
Total & Means..	39	92·10	91·57	1·004	+ 0·040

		M	F	F / M	√F − √M
Under 50 squares....	24	557·0	565·7	1·016	+ 0·037
Above 50 & under 100	12	863·0	863·0	1·000	0·000
Above 100 & under 200	13	1687·0	1604·8	0·951	− 0·281
Above 200 & under 400					
Above 400 squares ..	3	1480·0	1395·0	0·943	− 0·647
Total & Means..	52	88·21	85·16	0·992	− 0·091

For M and J H.

		M	J H	J H / M	√J H − √M
Under 5 squares....	25	65·9	61·8	0·938	− 0·053
Above 5 & under 10	12	84·1	71·0	0·844	− 0·215
Above 10 & under 20	16	217·8	195·0	0·895	− 0·197
Above 20 & under 40	9	260·7	250·5	0·961	− 0·107
Above 40 & under 80	3	139·0	135·0	0·971	− 0·099
Above 80 squares....	2	180·0	165·5	0·919	− 0·390
Total & Means..	67	14·14	13·12	0·915	− 0·135

		M	J H	J H / M	√J H − √M
Under 10 squares....	40	177·2	187·5	1·058	+ 0·061
Above 10 & under 20	17	228·9	229·5	1·003	+ 0·005
Above 20 & under 40	18	492·6	522·5	1·061	+ 0·156
Above 40 & under 100	22	1378·2	1325·0	0·961	− 0·154
Above 100 & under 200	13	1835·0	1751·0	0·954	− 0·275
Above 200 & under 400	7	1925·6	1751·0	0·909	− 0·770
Above 400 squares..					
Total & Means..	117	51·60	49·29	1·012	− 0·060

		M	J H	J H / M	√J H − √M
Under 50 squares....	25	586·0	576·0	0·983	− 0·041
Above 50 & under 100	9	591·0	693·0	1·170	+ 0·673
Above 100 & under 200	9	1249·0	1279·0	1·024	+ 0·141
Above 200 & under 400	4	1035·0	1230·0	1·188	+ 1·450
Above 400 squares..	4	2460·0	2240·0	0·911	− 1·135
Total & Means..	51	116·10	118·00	1·034	+ 0·148

For M and S P.

UMBRÆ.

	No. of Obs.	Total Area as measured by M	Total Area as measured by S P	$\frac{SP}{M}$	$\sqrt{SP}-\sqrt{M}$
Under 5 squares	35	95·5	81·8	0·857	− 0·122
Above 5 & under 10	18	125·2	121·5	0·970	− 0·040
Above 10 & under 20	15	234·3	209·0	0·892	− 0·220
Above 20 & under 40	13	374·1	351·0	0·938	− 0·169
Above 40 & under 80	5	286·5	260·0	0·907	− 0·359
Above 80 squares....	1	87·0	85·0	0·978	− 0·107
Total & Means..	87	13·82	12·74	0·903	− 0·142

WHOLE SPOTS.

	No. of Obs.	Total Area as measured by M	Total Area as measured by S P	$\frac{SP}{M}$	$\sqrt{SP}-\sqrt{M}$
Under 10 squares....	57	327·7	349·7	1·067	+ 0·080
Above 10 & under 20	23	322·3	308·0	0·955	− 0·084
Above 20 & under 40	28	828·0	798·0	0·964	− 0·099
Above 40 & under 100	28	1746·6	1635·0	0·936	− 0·257
Above 100 & under 200	20	2897·0	2596·0	0·896	− 0·642
Above 200 & under 400	4	1067·0	1007·0	0·944	− 0·465
Above 400 squares..	2	953·0	920·0	0·965	− 0·381
Total & Means..	162	50·26	47·00	0·985	− 0·141

FACULÆ.

	No. of Obs.	Total Area as measured by M	Total Area as measured by S P	$\frac{SP}{M}$	$\sqrt{SP}-\sqrt{M}$
Under 50 squares....	28	809·0	902·0	1·115	+ 0·301
Above 50 & under 100	34	2343·0	2603·0	1·111	+ 0·449
Above 100 & under 200	18	2469·0	2660·0	1·077	+ 0·444
Above 200 & under 400	9	2560·0	2310·0	0·902	− 0·844
Above 400 squares..	1	1500·0	1380·0	0·920	− 1·582
Total & Means..	90	107·57	109·50	1·082	+ 0·250

For M and W.

		M	W	$\frac{W}{M}$	$\sqrt{W}-\sqrt{M}$
Under 5 squares....	6	18·5	14·0	0·757	− 0·229
Above 5 & under 10..	11	83·6	78·0	0·933	− 0·094
Above 10 & under 20	9	145·5	131·5	0·904	− 0·199
Above 20 & under 40	12	360·2	321·0	0·891	− 0·307
Above 40 & under 80	2	170·0	127·0	0·747	− 1·251
Above 80 squares....					
Total & Means..	40	19·45	16·79	0·878	− 0·260

		M	W	$\frac{W}{M}$	$\sqrt{W}-\sqrt{M}$
Under 10 squares....	25	131·8	107·6	0·817	− 0·222
Above 10 & under 20	5	71·5	72·0	1·007	+ 0·013
Above 20 & under 40	11	285·1	300·0	1·052	+ 0·131
Above 40 & under 100	15	963·4	900·0	0·934	− 0·268
Above 100 & under 200	11	1472·0	1437·0	0·976	− 0·138
Above 200 & under 400	5	1257·0	1248·0	0·993	− 0·056
Above 400 squares..	1	457·0	441·0	0·965	− 0·378
Total & Means..	73	63·53	61·72	0·928	− 0·140

		M	W	$\frac{W}{M}$	$\sqrt{W}-\sqrt{M}$
Under 50 squares....	11	412·0	404·0	0·981	− 0·059
Above 50 & under 100	8	518·0	677·0	1·307	+ 1·152
Above 100 & under 200	10	1244·0	1492·0	1·199	+ 0·062
Above 200 & under 400	3	729·0	686·0	0·941	− 0·466
Above 400 squares..					
Total & Means..	32	90·72	101·84	1·127	+ 0·243

For M and E P.

		M	EP	$\frac{EP}{M}$	$\sqrt{EP}-\sqrt{M}$
Under 5 squares....	135	376·5	394·7	1·048	+ 0·039
Above 5 & under 10	48	366·8	346·4	0·944	− 0·077
Above 10 & under 20	46	691·1	674·5	0·976	− 0·047
Above 20 & under 40	46	1383·1	1279·8	0·925	− 0·209
Above 40 & under 80	11	591·0	574·0	0·972	− 0·106
Above 80 squares....					
Total & Means..	286	11·92	11·43	0·996	− 0·040

		M	EP	$\frac{EP}{M}$	$\sqrt{EP}-\sqrt{M}$
Under 10 squares....	186	875·4	899·7	1·028	+ 0·030
Above 10 & under 20	44	679·0	661·6	0·974	− 0·050
Above 20 & under 40	45	1239·4	1173·2	0·947	− 0·142
Above 40 & under 100	57	3738·5	3532·5	0·945	− 0·226
Above 100 & under 200	28	4095·0	3863·4	0·943	− 0·247
Above 200 & under 400	12	3345·0	3202·0	0·957	− 0·361
Above 400 squares..					
Total & Means..	372	37·56	35·84	0·990	− 0·073

		M	EP	$\frac{EP}{M}$	$\sqrt{EP}-\sqrt{M}$
Under 50 squares....	162	3924·0	4302·5	1·096	+ 0·233
Above 50 & under 100	61	4549·0	4602·0	1·012	+ 0·051
Above 100 & under 200	43	6054·0	6111·0	1·009	+ 0·055
Above 200 & under 400	13	3233·0	3455·0	1·069	+ 0·532
Above 400 squares..					
Total & Means..	279	63·66	66·20	1·063	+ 0·180

For M and W R.

UMBRÆ.	No. of Obs.	Total Area as measured by M	Total Area as measured by W R	$\frac{WR}{M}$	$\sqrt{WR}-\sqrt{M}$
Under 5 squares....	14	42·0	39·1	0·931	− 0·062
Above 5 & under 10	4	22·7	23·6	1·040	+ 0·046
Above 10 & under 20	1	11·6	14·0	1·207	+ 0·336
Above 20 & under 40					
Above 40 & under 80					
Above 80 squares....					
Total & Means..	19	4·02	4·04	0·968	− 0·018

WHOLE SPOTS.	No. of Obs.	Total Area as measured by M	Total Area as measured by W R	$\frac{WR}{M}$	$\sqrt{WR}-\sqrt{M}$
Under 10 squares....	28	130·7	144·0	1·102	+ 0·106
Above 10 & under 20	17	253·9	206·5	0·813	− 0·379
Above 20 & under 40	7	217·5	197·0	0·906	− 0·269
Above 40 & under 100	1	66·0	65·0	0·985	− 0·062
Above 100 & under 200					
Above 200 & under 400					
Above 400 squares..					
Total & Means..	53	12·61	11·56	0·981	− 0·102

FACULÆ.	No. of Obs.	Total Area as measured by M	Total Area as measured by W R	$\frac{WR}{M}$	$\sqrt{WR}-\sqrt{M}$
Under 50 squares....	22	507·0	571·0	1·126	+ 0·293
Above 50 & under 100	12	781·0	836·0	1·070	+ 0·279
Above 100 & under 200	14	1879·0	1968·0	1·048	+ 0·271
Above 200 & under 400	2	450·0	400·0	0·889	− 0·858
Above 400 squares..	1	566·0	620·0	1·095	+ 1·109
Total & Means..	51	81·02	86·18	1·082	+ 0·255

For H and J P.

		H	J P	$\frac{JP}{H}$	$\sqrt{JP}-\sqrt{H}$
Under 5 squares....	60	147·5	170·1	1·153	+ 0·114
Above 5 & under 10	33	225·8	230·6	1·021	+ 0·029
Above 10 & under 20	19	259·9	275·1	1·058	+ 0·106
Above 20 & under 40	8	212·6	232·0	1·091	+ 0·230
Above 40 & under 80	9	485·0	482·5	0·995	− 0·019
Above 80 squares....	2	239·4	240·6	1·005	+ 0·028
Total & Means..	131	11·99	12·45	1·089	+ 0·088

		H	J P	$\frac{JP}{H}$	$\sqrt{JP}-\sqrt{H}$
Under 10 squares....	61	285·6	309·4	1·083	+ 0·089
Above 10 & under 20	17	195·7	216·5	1·106	+ 0·176
Above 20 & under 40	31	866·3	908·9	1·049	+ 0·128
Above 40 & under 100	33	2070·0	1991·7	0·962	− 0·151
Above 100 & under 200	21	2948·6	2904·4	0·985	− 0·090
Above 200 & under 400	11	3460·0	3362·5	0·972	− 0·253
Above 400 squares..	6	3621·0	3434·0	0·948	− 0·643
Total & Means..	180	74·71	72·93	1·034	− 0·006

		H	J P	$\frac{JP}{H}$	$\sqrt{JP}-\sqrt{H}$
Under 50 squares....	39	1223·0	1185·0	0·969	− 0·088
Above 50 & under 100	30	2173·0	2078·0	0·956	− 0·188
Above 100 & under 200	33	4838·0	4546·0	0·939	− 0·371
Above 200 & under 400	15	4508·0	4132·0	0·917	− 0·739
Above 400 squares..	2	970·0	850·0	0·876	− 1·407
Total & Means..	119	115·23	107·49	0·949	− 0·296

For H and F.

		H	F	$\frac{F}{H}$	$\sqrt{F}-\sqrt{H}$
Under 5 squares....	25	78·0	76·9	0·986	− 0·011
Above 5 & under 10	11	64·9	74·6	1·149	+ 0·175
Above 10 & under 20	12	162·0	195·6	1·207	+ 0·363
Above 20 & under 40	12	328·0	381·0	1·162	+ 0·407
Above 40 & under 80	3	164·0	172·6	1·052	+ 0·191
Above 80 squares....	2	323·5	318·0	0·983	− 0·109
Total & Means..	65	17·24	18·75	1·090	+ 0·173

		H	F	$\frac{F}{H}$	$\sqrt{F}-\sqrt{H}$
Under 10 squares....	31	165·8	167·8	1·012	+ 0·013
Above 10 & under 20	10	143·8	141·0	0·981	− 0·038
Above 20 & under 40	10	255·3	263·0	1·030	+ 0·075
Above 40 & under 100	20	1219·7	1200·0	0·986	− 0·063
Above 100 & under 200	12	1811·5	1817·0	1·003	+ 0·017
Above 200 & under 400	9	2439·5	2333·0	0·956	− 0·364
Above 400 squares..	2	1220·0	1226·0	1·005	+ 0·061
Total & Means..	94	77·19	76·04	0·998	− 0·037

		H	F	$\frac{F}{H}$	$\sqrt{F}-\sqrt{H}$
Under 50 squares....	25	722·0	701·0	0·971	− 0·079
Above 50 & under 100	21	1535·0	1417·0	0·923	− 0·335
Above 100 & under 200	12	1609·0	1482·0	0·921	− 0·467
Above 200 & under 400	5	1640·0	1640·0	1·000	0·000
Above 400 squares..	1	800·0	750·0	0·938	− 0·898
Total & Means..	64	98·53	93·60	0·948	− 0·242

For H and J H.

UMBRÆ.						WHOLE SPOTS.						FACULÆ.					
	No. of Obs.	Total Area as measured by H	Total Area as measured by J H	$\frac{J H}{H}$	$\sqrt{J H}-\sqrt{H}$		No. of Obs.	Total Area as measured by H	Total Area as measured by J H	$\frac{J H}{H}$	$\sqrt{J H}-\sqrt{H}$		No. of Obs.	Total Area as measured by H	Total Area as measured by J H	$\frac{J H}{H}$	$\sqrt{J H}-\sqrt{H}$
Under 5 squares....	48	125·5	126·0	1·004	+ 0·006	Under 10 squares....	78	412·4	411·0	0·997	− 0·004	Under 50 squares....	34	1115·0	1115·0	1·000	0·000
Above 5 & under 10	19	146·7	138·0	0·941	− 0·082	Above 10 & under 20	39	540·5	540·0	0·999	− 0·003	Above 50 & under 100	32	2222·0	2624·0	1·181	+ 0·722
Above 10 & under 20	20	293·0	288·0	0·983	− 0·033	Above 20 & under 40	35	955·0	979·5	1·026	+ 0·067	Above 100 & under 200	32	4524·0	4605·0	1·018	+ 0·107
Above 20 & under 40	8	236·0	251·0	1·064	+ 0·171	Above 40 & under 100	40	2378·0	2374·5	0·999	− 0·005	Above 200 & under 400	14	3290·0	3716·0	1·129	+ 0·963
Above 40 & under 80	8	504·0	507·0	1·006	+ 0·024	Above 100 & under 200	21	3044·0	2990·0	0·982	− 0·100	Above 400 squares..					
Above 80 squares....	2	186·0	188·0	1·011	+ 0·051	Above 200 & under 100	13	3940·0	3922·0	0·995	− 0·040						
						Above 400 squares..	5	2377·0	2259·0	0·950	− 0·548						
Total & Means..	105	14·20	14·27	0·993	+ 0·003	Total & Means..	231	59·08	58·34	1·000	− 0·016	Total & Means..	112	99·56	107·68	1·073	+ 0·357

For H and S P.

		H	S P	$\frac{S P}{H}$	$\sqrt{S P}-\sqrt{H}$			H	S P	$\frac{S P}{H}$	$\sqrt{S P}-\sqrt{H}$			H	S P	$\frac{S P}{H}$	$\sqrt{S P}-\sqrt{H}$
Under 5 squares....	131	349·7	331·0	0·947	− 0·043	Under 10 squares....	210	1038·1	1004·9	0·968	− 0·036	Under 50 squares....	97	2993·0	3005·0	1·004	+ 0·012
Above 5 & under 10	65	481·1	510·0	1·060	+ 0·080	Above 10 & under 20	95	1284·5	1235·5	0·962	− 0·070	Above 50 & under 100	114	7704·0	7374·0	0·957	− 0·179
Above 10 & under 20	45	619·5	655·5	1·058	+ 0·106	Above 20 & under 40	85	2431·5	2511·5	1·033	+ 0·086	Above 100 & under 200	55	7561·0	7386·0	0·977	− 0·137
Above 20 & under 40	39	1077·0	1148·0	1·066	+ 0·171	Above 40 & under 100	90	5795·0	5772·0	0·996	− 0·016	Above 200 & under 400	25	6270·0	6150·0	0·981	− 0·153
Above 40 & under 80	21	1292·0	1275·0	0·987	− 0·051	Above 100 & under 200	51	7368·0	7149·0	0·970	− 0·180	Above 400 squares..					
Above 80 squares....	1	90·0	80·0	0·889	− 0·543	Above 200 & under 400	30	8872·0	8673·0	0·978	− 0·193						
						Above 400 squares..	5	2424·0	2340·0	0·965	− 0·385						
Total & Means..	302	12·99	13·24	1·006	+ 0·031	Total & Means..	566	51·61	50·68	0·982	− 0·045	Total & Means..	291	84·29	82·18	0·979	− 0·105

For H and W.

		H	W	$\frac{W}{H}$	$\sqrt{W}-\sqrt{H}$			H	W	$\frac{W}{H}$	$\sqrt{W}-\sqrt{H}$			H	W	$\frac{W}{H}$	$\sqrt{W}-\sqrt{H}$
Under 5 squares	65	162·1	187·8	1·159	+ 0·119	Under 10 squares....	86	376·1	391·6	1·041	+ 0·043	Under 50 squares....	35	1175·0	1120·0	0·953	− 0·137
Above 5 & under 10	33	210·6	244·2	1·160	+ 0·194	Above 10 & under 20	39	538·5	558·0	1·036	+ 0·067	Above 50 & under 100	27	1890·0	1944·0	1·029	+ 0·118
Above 10 & under 20	30	399·0	431·4	1·081	+ 0·145	Above 20 & under 40	32	864·2	938·1	1·085	+ 0·218	Above 100 & under 200	28	3918·0	4030·0	1·029	+ 0·164
Above 20 & under 40	17	428·5	433·0	1·011	+ 0·026	Above 40 & under 100	49	3161·0	3383·6	1·070	+ 0·279	Above 200 & under 400	31	8233·0	8491·0	1·031	+ 0·253
Above 40 & under 80	5	260·0	274·3	1·055	+ 0·196	Above 100 & under 200	28	4153·5	4102·5	0·988	− 0·075	Above 400 squares ..	7	3840·0	3645·0	0·949	− 0·604
Above 80 squares....	2	160·5	179·0	1·115	+ 0·502	Above 200 & under 400	8	2076·0	2070·0	0·997	− 0·023						
						Above 400 squares ..	2	876·0	819·0	0·935	− 0·692						
Total & Means..	152	10·66	11·51	1·123	+ 0·138	Total & Means..	244	49·37	50·26	1·043	+ 0·095	Total & Means..	128	148·87	150·23	1·004	+ 0·052

For H and E P.

UMBRÆ.

	No. of Obs.	Total Area as measured by H	Total Area as measured by E P	$\frac{EP}{H}$	$\sqrt{EP} - \sqrt{H}$
Under 5 squares	272	672·9	723·8	1·076	+ 0·059
Above 5 & under 10	116	799·2	840·5	1·052	+ 0·068
Above 10 & under 20	81	1152·3	1174·1	1·019	+ 0·036
Above 20 & under 40	41	1054·5	1100·0	1·043	+ 0·108
Above 40 & under 80	25	1364·0	1398·0	1·025	+ 0·092
Above 80 squares....	3	255·0	274·0	1·075	+ 0·337
Total & Means..	538	9·85	10·24	1·057	+ 0·064

WHOLE SPOTS.

	No. of Obs.	Total Area as measured by H	Total Area as measured by E P	$\frac{EP}{H}$	$\sqrt{EP} - \sqrt{H}$
Under 10 squares....	266	1349·2	1356·2	1·005	+ 0·006
Above 10 & under 20	112	1578·2	1574·5	0·998	− 0·004
Above 20 & under 40	77	2204·5	2139·0	0·970	− 0·080
Above 40 & under 100	82	5384·0	5291·0	0·983	− 0·071
Above 100 & under 200	34	4547·0	4508·0	0·991	− 0·050
Above 200 & under 400	11	2708·0	2593·0	0·958	− 0·337
Above 400 squares ..					
Total & Means..	582	30·53	30·00	0·994	− 0·026

FACULÆ.

	No. of Obs.	Total Area as measured by H	Total Area as measured by E P	$\frac{EP}{H}$	$\sqrt{EP} - \sqrt{H}$
Under 50 squares....	294	9147·4	8663·2	0·947	− 0·149
Above 50 & under 100	171	12013·0	12315·0	1·025	+ 0·104
Above 100 & under 200	115	14684·0	16542·0	1·126	+ 0·693
Above 200 & under 400	20	4630·0	5344·0	1·154	+ 1·131
Above 400 squares ..					
Total & Means..	600	67·46	71·44	1·010	+ 0·127

For J P and F.

UMBRÆ.

		J P	F	$\frac{F}{JP}$	$\sqrt{F} - \sqrt{JP}$
Under 5 squares....	5	9·4	9·0	0·957	− 0·029
Above 5 & under 10	7	44·8	48·8	1·089	+ 0·110
Above 10 & under 20					
Above 20 & under 40	1	21·0	26·2	1·248	+ 0·536
Above 40 & under 80	1	45·6	47·5	1·042	+ 0·139
Above 80 squares....					
Total & Means..	14	8·63	9·39	1·050	+ 0·093

WHOLE SPOTS.

		J P	F	$\frac{F}{JP}$	$\sqrt{F} - \sqrt{JP}$
Under 10 squares....	7	28·8	31·5	1·094	+ 0·094
Above 10 & under 20	5	64·6	68·4	1·059	+ 0·110
Above 20 & under 40	4	122·6	117·0	0·954	− 0·128
Above 40 & under 100	1	51·0	54·0	1·059	+ 0·207
Above 100 & under 200	1	138·0	146·0	1·058	+ 0·336
Above 200 & under 400	1	239·0	251·0	1·050	+ 0·383
Above 400 squares..					
Total & Means..	19	33·90	35·15	1·049	+ 0·085

FACULÆ.

		J P	F	$\frac{F}{JP}$	$\sqrt{F} - \sqrt{JP}$
Under 50 squares....	8	206·5	206·0	0·998	− 0·006
Above 50 & under 100	3	258·0	217·0	0·841	− 0·769
Above 100 & under 200	1	154·0	165·0	1·071	+ 0·435
Above 200 & under 400	2	402·0	440·0	1·095	+ 0·655
Above 400 squares .					
Total & Means..	14	72·89	73·43	0·983	− 0·044

For J H and S P.

UMBRÆ.

		J H	S P	$\frac{SP}{JH}$	$\sqrt{SP} - \sqrt{JH}$
Under 5 squares....	200	460·4	455·0	0·988	− 0·010
Above 5 & under 10	86	587·1	630·5	1·074	+ 0·094
Above 10 & under 20	80	1086·5	1071·0	0·986	− 0·026
Above 20 & under 40	49	1431·0	1401·0	0·979	− 0·057
Above 40 & under 80	23	1186·0	1173·0	0·989	− 0·040
Above 80 squares....					
Total & Means..	438	10·85	10·80	1·004	− 0·001

WHOLE SPOTS.

		J H	S P	$\frac{SP}{JH}$	$\sqrt{SP} - \sqrt{JH}$
Under 10 squares....	325	1794·2	1737·0	0·968	− 0·036
Above 10 & under 20	133	1854·5	1800·0	0·971	− 0·055
Above 20 & under 40	131	3725·5	3604·0	0·968	− 0·088
Above 40 & under 100	131	8517·0	8570·0	1·006	+ 0·025
Above 100 & under 200	85	12007·0	11965·0	0·997	− 0·020
Above 200 & under 40	27	7807·0	7944·0	1·018	+ 0·149
Above 400 squares..	2	920·0	930·0	1·011	+ 0·116
Total & Means..	834	43·92	43·83	0·979	− 0·030

FACULÆ.

		J H	S P	$\frac{SP}{JH}$	$\sqrt{SP} - \sqrt{JH}$
Under 50 squares....	49	1587·0	1590·0	1·002	+ 0·005
Above 50 & under 100	101	7616·0	7200·0	0·945	− 0·241
Above 100 & under 200	118	17588·0	16909·0	0·961	− 0·245
Above 200 & under 400	58	15335·0	14880·0	0·970	− 0·243
Above 400 squares..	10	4830·0	4860·0	1·006	+ 0·068
Total & Means..	336	139·75	135·24	0·965	− 0·198

For J H and W.

UMBRÆ.						WHOLE SPOTS.						FACULÆ.					
	No. of Obs.	Total Area as measured by J H	Total Area as measured by W	$\frac{W}{JH}$	$\sqrt{W}-\sqrt{JH}$		No. of Obs.	Total Area as measured by J H	Total Area as measured by W	$\frac{W}{JH}$	$\sqrt{W}-\sqrt{JH}$		No. of Obs.	Total Area as measured by J H	Total Area as measured by W	$\frac{W}{JH}$	$\sqrt{W}-\sqrt{JH}$
Under 5 squares	60	131·4	127·3	0·969	− 0·024	Under 10 squares....	95	461·3	447·1	0·969	− 0·035	Under 50 squares....	47	1676·0	1534·0	0·915	− 0·259
Above 5 & under 10	27	223·4	207·0	0·927	− 0·107	Above 10 & under 20	33	475·0	490·0	1·032	+ 0·061	Above 50 & under 100	42	3137·0	2905·0	0·926	− 0·325
Above 10 & under 20	25	371·3	336·4	0·906	− 0·185	Above 20 & under 40	17	492·5	496·6	1·083	+ 0·023	Above 100 & under 200	32	5034·0	4437·0	0·881	− 0·767
Above 20 & under 40	22	620·0	591·0	0·953	− 0·125	Above 40 & under 100	45	2809·5	2910·0	1·036	+ 0·140	Above 200 & under 400	21	6016·0	5664·0	0·942	− 0·503
Above 40 & under 80	7	404·5	385·0	0·952	− 0·185	Above 100 & under 200	22	3048·0	3099·0	1·017	+ 0·098	Above 400 squares ..	3	1400·0	1390·0	0·993	− 0·077
Above 80 squares....	2	214·0	208·0	0·972	− 0·146	Above 200 & under 400	10	2639·5	2765·0	1·048	+ 0·381						
						Above 400 squares ..	3	1488·0	1494·0	1·004	+ 0·045						
Total & Means..	143	13·74	12·97	0·947	− 0·093	Total & Means..	225	50·73	52·01	1·009	+ 0·051	Total & Means..	145	119·06	109·86	0·916	− 0·422

For S P and W.

		S P	W	$\frac{W}{SP}$	$\sqrt{W}-\sqrt{SP}$			S P	W	$\frac{W}{SP}$	$\sqrt{W}-\sqrt{SP}$			S P	W	$\frac{W}{SP}$	$\sqrt{W}-\sqrt{SP}$
Under 5 squares	69	174·5	175·2	1·004	+ 0·003	Under 10 squares....	106	510·0	452·8	0·888	− 0·127	Under 50 squares....	58	1920·0	1705·0	0·888	− 0·331
Above 5 & under 10	31	241·4	230·4	0·954	− 0·065	Above 10 & under 20	33	463·0	477·0	1·030	+ 0·056	Above 50 & under 100	49	3791·0	3317·0	0·875	− 0·569
Above 10 & under 20	22	328·0	310·0	0·945	− 0·108	Above 20 & under 40	35	970·5	916·0	0·944	− 0·112	Above 100 & under 200	30	4109·0	4034·0	0·982	− 0·108
Above 20 & under 40	15	406·0	403·0	0·993	− 0·019	Above 40 & under 100	33	2147·0	2137·0	0·995	− 0·019	Above 200 & under 400	13	3333·0	3213·0	0·964	− 0·291
Above 40 & under 80	5	261·0	246·0	0·943	− 0·211	Above 100 & under 200	30	4067·0	4155·0	1·022	+ 0·125	Above 400 squares ..	2	850·0	879·0	1·034	+ 0·348
Above 80 squares....	2	189·0	208·0	1·101	+ 0·477	Above 200 & under 400	5	1299·0	1342·0	1·033	+ 0·264						
						Above 400 squares ..	3	1421·0	1532·0	1·078	+ 0·834						
Total & Means..	144	11·11	10·92	0·982	− 0·032	Total & Means..	245	44·40	44·95	0·951	− 0·035	Total & Means..	152	92·13	86·50	0·911	− 0·351

For S P and E P.

		S P	E P	$\frac{EP}{SP}$	$\sqrt{EP}-\sqrt{SP}$			S P	E P	$\frac{EP}{SP}$	$\sqrt{EP}-\sqrt{SP}$			S P	E P	$\frac{EP}{SP}$	$\sqrt{EP}-\sqrt{SP}$
Under 5 squares....	32	101·2	94·2	0·931	− 0·063	Under 10 squares....	67	345·5	326·9	0·946	− 0·063	Under 50 squares....	28	917·0	944·0	1·029	+ 0·083
Above 5 & under 10	18	143·5	135·5	0·944	− 0·079	Above 10 & under 20	24	366·0	370·5	1·012	+ 0·024	Above 50 & under 100	25	1730·0	1820·0	1·052	+ 0·190
Above 10 & under 20	17	238·5	226·5	0·950	− 0·096	Above 20 & under 40	18	526·0	512·5	0·974	− 0·070	Above 100 & under 200	18	2496·0	2410·0	0·966	− 0·205
Above 20 & under 40	7	186·0	176·0	0·946	− 0·141	Above 40 & under 100	25	1583·0	1601·0	1·011	+ 0·045	Above 200 & under 400	4	1085·0	1110·0	1·023	+ 0·188
Above 40 & under 80	8	438·0	421·0	0·961	− 0·145	Above 100 & under 200	17	2427·0	2394·0	0·986	− 0·082	Above 400 squares..	1	450·0	400·0	0·889	− 1·213
Above 80 squares....	1	98·0	88·0	0·898	− 0·518	Above 200 & under 400	8	2165·0	2136·0	0·987	− 0·111						
						Above 400 squares..											
Total & Means..	83	14·52	13·75	0·941	− 0·093	Total & Means..	159	46·62	46·16	0·976	− 0·032	Total & Means..	76	87·87	87·95	1·019	+ 0·038

For E P and W R.

UMBRÆ.	No. of Obs.	Total Area as measured by		$\frac{WR}{EP}$	$\sqrt{WR}-\sqrt{EP}$	WHOLE SPOTS.	No. of Obs.	Total Area as measured by		$\frac{WR}{EP}$	$\sqrt{WR}-\sqrt{EP}$	FACULÆ.	No. of Obs.	Total Area as measured by		$\frac{WR}{EP}$	$\sqrt{WR}-\sqrt{EP}$
		EP	WR					EP	WR					EP	WR		
Under 5 squares....	13	34·7	34·5	0·994	− 0·006	Under 10 squares....	20	92·9	106·0	1·141	+ 0·146	Under 50 squares....	12	365·0	362·0	0·992	− 0·022
Above 5 & under 10	3	21·0	20·0	0·952	− 0·063	Above 10 & under 20	13	187·0	194·0	1·037	+ 0·071	Above 50 & under 100	8	638·0	610·0	0·956	− 0·198
Above 10 & under 20						Above 20 & under 40	3	77·0	69·0	0·896	− 0·271	Above 100 & under 200	5	565·0	586·0	1·041	+ 0·196
Above 20 & under 40						Above 40 & under 100	1	48·0	44·0	0·917	− 0·295	Above 200 & under 400	2	460·0	394·0	0·856	− 1·130
Above 40 & under 80						Above 100 & under 200						Above 400 squares..					
Above 80 squares....						Above 200 & under 400											
						Above 400 squares..											
Total & Means..	16	3·48	3·41	0·986	− 0·017	Total & Means..	37	10·94	11·16	1·079	+ 0·074	Total & Means..	27	75·48	72·30	0·980	− 0·116

As in the discussion of personality in the measurement of areas on four-inch photographs, and as in the preceding section in connexion with the probable error of such measurement, two suppositions have been made :—

(1.) That the measures of each observer are to be multiplied by a constant factor to reduce them to a uniform standard, in which case (*a*) the ratio of the areas (as given in each of the third columns) should be constant for the same pair of observers measuring spots of varying area ; and (*b*) the ratios for the various pairs of observers should be accordant, *i.e.*, for any three observers the product of the ratios for each pair taken in order should be unity.

With regard to (*a*) an inspection of the deduced factors shows that there is not always a satisfactory agreement between them, and it is possible that the variation of personality with area may be better represented by some other hypothesis. But the assortment of spots measured in the majority of cases being roughly the same, the mean factor deduced by any uniform method ought still to be subject to the condition (*b*). As in the measurement of the four-inch photographs, however, it has been found that many of the measures bear traces of being not altogether independent, so that the personal factor does not remain constant when the companion observer varies. This is doubtless due to the fact that in order to secure the same grouping of complicated spot-groups by the two measurers, the measures of the first are necessarily referred to by the second, and a certain amount of bias is thus introduced. The effect of this bias is somewhat less marked in the measurement of the eight-inch photographs than in that of the four-inch ; the greater proportion of

the eight-inch photographs having been taken since the time of maximum spot activity, and therefore at a time when extensive and complicated spot-groups were less frequent, and a close attention on the part of the second measurer to the observations of the first was not so frequently demanded.

The accordance of the personal factor in different combinations was actually tested as follows :—The ratios were reduced to algebraical differences by taking logarithms in each case, and these differences were then treated in the same manner as the personal equations in clock-error, as described in the various Introductions to the Greenwich Observations, *i.e.*, the various equations in which the same observer occurs are added together, so that in the resulting equation that observer is affected by a large co-efficient. Then writing for convenience m, h, etc., for log. M, log. H, etc., so that :—

$$h - m = \log.\frac{H}{M} = \left.\begin{matrix}\log.\ 0{\cdot}830\\ \log.\ 0{\cdot}967\\ \log.\ 1{\cdot}066\end{matrix}\right\} = \left\{\begin{matrix}9{\cdot}91908\\ 9{\cdot}98543\\ 0{\cdot}02776\end{matrix}\right\} \text{ for } \left\{\begin{matrix}\text{Umbræ,}\\ \text{Whole Spots,}\\ \text{Faculæ,}\end{matrix}\right.$$

and making M the standard observer, *i.e.*, putting M = 1, or m = O, we obtain the following systems of equations :—

		Umbræ.	Whole Spots.	Faculæ.
$7h - jp - f - jh - sp - w - ep$	=	9·77062	9·96400	0·04625
$3jp - h - f$	=	0·06077	9·99634	0·01370
$3f - h - jp$	=	0·05426	0·02164	9·96587
$4jh - h - sp - w$	=	9·98029	0·01051	0·09869
$5sp - h - jh - w - ep$	=	9·99432	0·00870	0·04185
$4w - h - jh - sp$	=	9·96233	9·96790	9·97507
$4ep - h - sp - wr$	=	0·00204	9·94946	0·04779
$2wr - ep$	=	9·97976	0·02469	0·02546

The solution of these equations gives the following values for m, h, jp, &c.

	Umbræ.	Whole Spots.	Faculæ.
m	0·00000	0·00000	0·00000
h	9·94974	9·98791	0·02881
jp	0·00444	9·99529	0·01528
f	0·00281	0·00161	0·00332
jh	9·96517	9·99391	0·04579
sp	9·96906	9·99184	0·03458
w	9·96158	9·98539	0·02106
ep	9·97449	9·98330	0·03540
wr	9·97713	0·00400	0·03043

and hence the following values of the ratios $\frac{H}{M}$, $\frac{JP}{M}$, &c., M being taken as 1 :—

	Umbræ.	Whole Spots.	Faculæ.
$\frac{H}{M}$	0·891	0·973	1·069
$\frac{JP}{M}$	1·010	0·989	1·036
$\frac{F}{M}$	1·006	1·004	1·008
$\frac{JH}{M}$	0·923	0·986	1·111
$\frac{SP}{M}$	0·931	0·981	1·083
$\frac{W}{M}$	0·915	0·967	1·050
$\frac{SP}{M}$	0·943	0·962	1·085
$\frac{WR}{M}$	0·949	1·009	1·073

The following table exhibits the differences between the values of the ratios for the several pairs of observers found by direct comparison, and those deduced from the solution of the equations :—

Ratio.	Umbræ.			Whole Spots.			Faculæ.		
	Value deduced from		Difference.	Value deduced from		Difference.	Value deduced from		Difference.
	Direct Comparison.	Equations.		Direct Comparison.	Equations.		Direct Comparison.	Equations.	
H ÷ M	0·830	0·891	+ ·061	0·967	0·973	+ ·006	1·066	1·069	+ ·003
JP ÷ M	1·109	1·010	− ·099	1·006	0·989	+ ·017	1·069	1·036	− ·033
F ÷ M	0·990	1·006	+ ·016	1·004	1·004	·000	0·992	1·008	+ ·016
JH ÷ M	0·915	0·923	+ ·008	1·012	0·986	− ·026	1·034	1·111	+ ·077
SP ÷ M	0·903	0·931	+ ·028	0·985	0·981	− ·004	1·082	1·083	+ ·001
W ÷ M	0·878	0·915	+ ·037	0·928	0·967	+ ·039	1·127	1·050	− ·077
EP ÷ M	0·996	0·943	− ·053	0·990	0·962	− ·028	1·063	1·085	+ ·022
WR ÷ M	0·968	0·949	− ·019	0·981	1·009	+ ·028	1·082	1·073	− ·009
JP ÷ H	1·089	1·134	+ ·045	1·034	1·017	− ·017	0·949	0·969	+ ·020
F ÷ H	1·090	1·130	+ ·040	0·998	1·032	+ ·034	0·948	0·943	− ·005
JH ÷ H	0·993	1·036	+ ·043	1·000	1·014	+ ·014	1·073	1·040	+ ·033
SP ÷ H	1·006	1·045	+ ·039	0·982	1·009	+ ·027	0·979	1·013	+ ·034
W ÷ H	1·123	1·028	− ·095	1·043	0·994	− ·049	1·004	0·982	− ·022
EP ÷ H	1·057	1·059	+ ·002	0·994	0·989	− ·005	1·010	1·015	+ ·005
F ÷ JP	1·050	0·996	− ·054	1·049	1·015	− ·034	0·983	0·973	− ·010
SP ÷ JH	1·004	1·009	+ ·005	0·979	0·995	+ ·016	0·965	0·975	+ ·010
W ÷ JH	0·947	0·992	+ ·045	1·009	0·981	− ·028	0·916	0·945	+ ·029
W ÷ SP	0·982	0·983	+ ·001	0·951	0·985	+ ·034	0·911	0·969	+ ·058
EP ÷ SP	0·941	1·013	+ ·072	0·976	0·981	+ ·005	1·019	1·002	− ·017
WR ÷ EP	0·986	1·006	+ ·020	1·079	1·049	− ·030	0·980	0·989	+ ·009

The following table gives the factors for the various pairs of observers, who have measured eight-inch photographs :—

FACTORS BY WHICH THE AREAS (ON EIGHT-INCH PHOTOGRAPHS), AS MEASURED BY THE VARIOUS PAIRS OF OBSERVERS, ARE TO BE MULTIPLIED TO REDUCE TO THE STANDARD OBSERVER, M.

Observers.	Umbræ.	Whole Spots.	Faculæ.
M, H	1·058	1·013	0·966
M, J P	0·995	1·006	0·982
M, F	0·997	0·998	0·996
M, J H	1·040	1·007	0·947
M, S P	1·035	1·010	0·960
M, W	1·044	1·017	0·976
M, E P	1·029	1·019	0·959
M, W R	1·026	0·995	0·964
H, J P	1·047	1·019	0·950
H, F	1·054	1·011	0·963
H, J H	1·103	1·020	0·917
H, S P	1·098	1·024	0·929
H, W	1·107	1·031	0·943
H, E P	1·091	1·033	0·928
J P, F	0·992	1·004	0·978
J H, S P	1·079	1·017	0·911
J H, W	1·088	1·025	0·925
S P, W	1·083	1·027	0·937
S P, E P	1·057	1·029	0·922
E P, W R	1·057	1·015	0·927

(2.) The second hypothesis tried is that each observer has a tendency to add to or subtract from the area of each spot, a ring of constant breadth, owing to the indefinite nature of the border. He is thus characterised by the algebraical excess of the square root of his measure of a spot over the square root of the measure of the standard observer. The sixth column in the tables of comparisons shows the value of this difference, as deduced from the various measures ; so that to reduce the measure of

any observer to that of another we subtract algebraically the mean value of the corresponding sixth column from the square root of his measure, and square the result. These quantities, to be in satisfactory accordance, should fulfil two conditions similar to (a) and (b) above.

The accordance between the results obtained from spots of different area does not appear to be more satisfactory on the second hypothesis than on the first, but the second hypothesis is to be preferred as corresponding to that which is indicated by the results for probable error.

The following are the equations deduced from the above sets of measures by a method similar to that used in the case of factors :—

		Umbræ.	Whole Spots.	Faculæ.
$7\surd H - \surd JP - \surd F - \surd JH - \surd SP - \surd W - \surd EP$	=	$-0{\cdot}771$	$-0{\cdot}070$	$+0{\cdot}210$
$3\surd JP - \surd H - \surd F$	=	$+0{\cdot}008$	$-0{\cdot}131$	$-0{\cdot}088$
$3\surd F - \surd H - \surd JP$	=	$+0{\cdot}232$	$+0{\cdot}088$	$-0{\cdot}377$
$4\surd JH - \surd H - \surd SP - \surd W$	=	$-0{\cdot}040$	$-0{\cdot}097$	$+1{\cdot}125$
$5\surd SP - \surd H - \surd JH - \surd W - \surd EP$	=	$+0{\cdot}015$	$-0{\cdot}149$	$+0{\cdot}260$
$4\surd W - \surd H - \surd JH - \surd SP$	=	$-0{\cdot}247$	$-0{\cdot}029$	$-0{\cdot}478$
$4\surd EP - \surd H - \surd SP - \surd WR$	=	$-0{\cdot}052$	$-0{\cdot}205$	$+0{\cdot}461$
$2\surd WR - \surd EP$	=	$-0{\cdot}035$	$-0{\cdot}028$	$+0{\cdot}139$

Solving these equations we get the following values for $\surd H - \surd M$, &c. :—

	Umbræ.	Whole Spots.	Faculæ.
$\surd H - \surd M$	$-0{\cdot}199$	$-0{\cdot}077$	$+0{\cdot}158$
$\surd JP - \surd M$	$-0{\cdot}068$	$-0{\cdot}077$	$-0{\cdot}001$
$\surd F - \surd M$	$-0{\cdot}012$	$-0{\cdot}022$	$-0{\cdot}073$
$\surd JH - \surd M$	$-0{\cdot}134$	$-0{\cdot}087$	$+0{\cdot}398$
$\surd SP - \surd M$	$-0{\cdot}120$	$-0{\cdot}100$	$+0{\cdot}232$
$\surd W - \surd M$	$-0{\cdot}175$	$-0{\cdot}073$	$+0{\cdot}078$
$\surd EP - \surd M$	$-0{\cdot}111$	$-0{\cdot}113$	$+0{\cdot}263$
$\surd WR - \surd M$	$-0{\cdot}073$	$-0{\cdot}070$	$+0{\cdot}201$

The following table exhibits the differences between the values for the several pairs of observers found by direct comparison, and those deduced from the solution of the equations :—

	Umbræ.			Whole Spots.			Faculæ.		
	Values deduced from		Difference.	Values deduced from		Difference.	Values deduced from		Difference.
	Direct Comparison.	Equations.		Direct Comparison.	Equations.		Direct Comparison.	Equations.	
$\sqrt{H} - \sqrt{M}$	− 0·278	− 0·199	+ ·079	− 0·112	− 0·077	+ ·035	− 0·043	+ 0·158	+ ·201
$\sqrt{JP} - \sqrt{M}$	+ 0·013	− 0·068	− ·081	− 0·040	− 0·077	− ·037	+ 0·164	− 0·001	− ·165
$\sqrt{F} - \sqrt{M}$	− 0·034	− 0·012	+ ·022	+ 0·040	− 0·022	− ·062	− 0·091	− 0·073	+ ·018
$\sqrt{JH} - \sqrt{M}$	− 0·135	− 0·134	+ ·001	− 0·060	− 0·087	− ·027	+ 0·148	+ 0·398	+ ·250
$\sqrt{SP} - \sqrt{M}$	− 0·142	− 0·120	+ ·022	− 0·141	− 0·100	+ ·041	+ 0·250	+ 0·232	− ·018
$\sqrt{W} - \sqrt{M}$	− 0·260	− 0·175	+ ·085	− 0·140	− 0·073	+ ·067	+ 0·243	+ 0·078	− ·165
$\sqrt{EP} - \sqrt{M}$	− 0·040	− 0·111	− ·071	− 0·073	− 0·113	− ·040	+ 0·180	+ 0·263	+ ·083
$\sqrt{WR} - \sqrt{M}$	− 0·018	− 0·073	− ·055	− 0·102	− 0·070	+ ·032	+ 0·255	+ 0·201	− ·054
$\sqrt{JP} - \sqrt{H}$	+ 0·088	+ 0·131	+ ·043	− 0·006	0·000	+ ·006	− 0·296	− 0·159	+ ·137
$\sqrt{F} - \sqrt{H}$	+ 0·173	+ 0·187	+ ·014	− 0·037	+ 0·055	+ ·092	− 0·242	− 0·231	+ ·011
$\sqrt{JH} - \sqrt{H}$	+ 0·003	+ 0·065	+ ·062	− 0·016	− 0·010	+ ·006	+ 0·357	+ 0·240	− ·117
$\sqrt{SP} - \sqrt{H}$	+ 0·031	+ 0·079	+ ·048	− 0·045	− 0·023	+ ·022	− 0·105	+ 0·074	+ ·179
$\sqrt{W} - \sqrt{H}$	+ 0·138	+ 0·024	− ·114	+ 0·095	+ 0·004	− ·091	+ 0·052	− 0·080	− ·132
$\sqrt{EP} - \sqrt{H}$	+ 0·064	+ 0·088	+ ·024	− 0·026	− 0·036	− ·010	+ 0·127	+ 0·107	− ·020
$\sqrt{F} - \sqrt{JP}$	+ 0·093	+ 0·056	− ·037	+ 0·085	+ 0·055	− ·030	− 0·044	− 0·072	− ·028
$\sqrt{SP} - \sqrt{JH}$	+ 0·001	+ 0·014	+ ·013	− 0·030	− 0·013	+ ·017	− 0·198	− 0·166	+ ·032
$\sqrt{W} - \sqrt{JH}$	− 0·093	− 0·041	+ ·052	+ 0·051	+ 0·014	− ·037	− 0·422	− 0·320	+ ·102
$\sqrt{W} - \sqrt{SP}$	− 0·032	− 0·055	− ·023	− 0·035	+ 0·027	+ ·062	− 0·351	− 0·154	+ ·197
$\sqrt{EP} - \sqrt{SP}$	− 0·093	+ 0·009	+ ·102	− 0·032	− 0·013	+ ·019	+ 0·038	+ 0·031	− ·007
$\sqrt{WR} - \sqrt{EP}$	− 0·017	+ 0·038	+ ·055	+ 0·074	+ 0·043	− ·031	− 0·116	− 0·062	+ ·054

For the application of these corrections the following tables have been constructed for the various pairs of observers who have measured photographs; the corrections are applicable algebraically to the areas as printed in the daily results, to obtain the area as measured by the standard observer, M :—

UMBRÆ.

Corrections to be applied to measured area on hypothesis of error varying as perimeter.

Pairs of Observers.

Area.	M, H	M, J P	M, F	M, J H	M, S P	M, W	M, E P	M, W R	H, J P	H, F
1	+ 0·2	+ 0·1	0·0	+ 0·1	+ 0·1	+ 0·2	+ 0·1	+ 0·1	+ 0·3	+ 0·2
2	+ 0·3	+ 0·1	0·0	+ 0·2	+ 0·2	+ 0·3	+ 0·2	+ 0·1	+ 0·4	+ 0·3
4	+ 0·4	+ 0·1	0·0	+ 0·3	+ 0·2	+ 0·4	+ 0·2	+ 0·2	+ 0·6	+ 0·4
6	+ 0·5	+ 0·2	0·0	+ 0·3	+ 0·3	+ 0·4	+ 0·3	+ 0·2	+ 0·7	+ 0·5
8	+ 0·6	+ 0·2	0·0	+ 0·4	+ 0·3	+ 0·5	+ 0·3	+ 0·2	+ 0·8	+ 0·6
10	+ 0·6	+ 0·2	0·0	+ 0·4	+ 0·4	+ 0·6	+ 0·4	+ 0·2	+ 0·9	+ 0·7
20	+ 0·9	+ 0·3	+ 0·1	+ 0·6	+ 0·5	+ 0·8	+ 0·5	+ 0·3	+ 1·2	+ 1·0
30	+ 1·1	+ 0·4	+ 0·1	+ 0·7	+ 0·7	+ 1·0	+ 0·6	+ 0·4	+ 1·5	+ 1·2
40	+ 1·3	+ 0·4	+ 0·1	+ 0·9	+ 0·8	+ 1·1	+ 0·7	+ 0·5	+ 1·7	+ 1·4
50	+ 1·4	+ 0·5	+ 0·1	+ 1·0	+ 0·9	+ 1·3	+ 0·8	+ 0·5	+ 1·9	+ 1·5
70	+ 1·7	+ 0·6	+ 0·1	+ 1·1	+ 1·0	+ 1·5	+ 1·0	+ 0·6	+ 2·3	+ 1·8
100	+ 2·0	+ 0·7	+ 0·1	+ 1·4	+ 1·2	+ 1·8	+ 1·1	+ 0·7	+ 2·7	+ 2·1
150	+ 3·4	+ 0·8	+ 0·1	+ 1·6	+ 1·5	+ 2·3	+ 1·3	+ 0·9	+ 3·3	+ 2·6
200	+ 2·8	+ 1·0	+ 0·2	+ 1·9	+ 1·6	+ 2·5	+ 1·6	+ 1·0	+ 3·7	+ 3·0
250	+ 3·1	+ 1·1	+ 0·2	+ 2·1	+ 1·9	+ 2·8	+ 1·8	+ 1·1	+ 4·2	+ 3·4
300	+ 3·5	+ 1·2	+ 0·2	+ 2·3	+ 2·3	+ 3·1	+ 2·0	+ 1·3	+ 4·7	+ 3·7
350	+ 3·7	+ 1·3	+ 0·2	+ 2·5	+ 2·2	+ 3·3	+ 2·1	+ 1·4	+ 5·0	+ 4·0

Area.	H, J H	H, S P	H, W	H, E P	J P, F	J H, S P	J H, W	S P, W	S P, E P	E P, W R
1	+ 0·4	+ 0·3	+ 0·4	+ 0·3	+ 0·1	+ 0·3	+ 0·3	+ 0·3	+ 0·2	+ 0·2
2	+ 0·5	+ 0·5	+ 0·6	+ 0·5	+ 0·1	+ 0·4	+ 0·5	+ 0·4	+ 0·3	+ 0·3
4	+ 0·7	+ 0·7	+ 0·8	+ 0·6	+ 0·2	+ 0·5	+ 0·6	+ 0·6	+ 0·5	+ 0·4
6	+ 0·8	+ 0·8	+ 0·9	+ 0·8	+ 0·2	+ 0·6	+ 0·8	+ 0·7	+ 0·6	+ 0·5
8	+ 1·0	+ 0·9	+ 1·1	+ 0·9	+ 0·2	+ 0·7	+ 0·9	+ 0·9	+ 0·7	+ 0·5
10	+ 1·1	+ 1·0	+ 1·2	+ 1·0	+ 0·3	+ 0·8	+ 1·0	+ 1·0	+ 0·7	+ 0·6
20	+ 1·5	+ 1·5	+ 1·7	+ 1·4	+ 0·4	+ 1·2	+ 1·4	+ 1·3	+ 1·0	+ 0·8
30	+ 1·9	+ 1·8	+ 2·1	+ 1·7	+ 0·4	+ 1·4	+ 1·7	+ 1·6	+ 1·3	+ 1·0
40	+ 2·2	+ 2·1	+ 2·4	+ 2·0	+ 0·5	+ 1·6	+ 2·0	+ 1·9	+ 1·5	+ 1·2
50	+ 2·4	+ 2·3	+ 2·7	+ 2·2	+ 0·6	+ 1·8	+ 2·2	+ 2·1	+ 1·7	+ 1·3
70	+ 2·8	+ 2·7	+ 3·2	+ 2·6	+ 0·7	+ 2·2	+ 2·6	+ 2·5	+ 2·0	+ 1·6
100	+ 3·4	+ 3·2	+ 3·4	+ 3·1	+ 0·8	+ 2·6	+ 3·1	+ 3·0	+ 2·3	+ 1·9
150	+ 4·1	+ 3·9	+ 4·6	+ 3·8	+ 1·0	+ 3·1	+ 3·8	+ 3·6	+ 2·8	+ 2·3
200	+ 4·7	+ 4·6	+ 5·3	+ 4·4	+ 1·1	+ 3·6	+ 4·4	+ 4·2	+ 3·3	+ 2·6
250	+ 5·3	+ 5·1	+ 6·0	+ 4·9	+ 1·3	+ 4·0	+ 4·9	+ 4·7	+ 3·7	+ 2·9
300	+ 5·9	+ 5·6	+ 6·3	+ 5·4	+ 1·4	+ 4·4	+ 5·4	+ 5·2	+ 4·1	+ 3·2
350	+ 6·3	+ 6·0	+ 7·0	+ 5·8	+ 1·5	+ 4·8	+ 5·8	+ 5·5	+ 4·3	+ 3·4

WHOLE SPOTS.

Corrections to be applied to measured area on hypothesis of error varying as perimeter.

Pairs of Observers.

Area.	M, H	M, JP	M, F	M, JH	M, SP	M, W	M, EP	M, WR	H, JP	H, F
5	+ 0·2	+ 0·2	0·0	+ 0·2	+ 0·2	+ 0·2	+ 0·3	+ 0·2	+ 0·4	+ 0·2
10	+ 0·2	+ 0·2	+ 0·1	+ 0·3	+ 0·3	+ 0·2	+ 0·4	+ 0·2	+ 0·5	+ 0·3
20	+ 0·4	+ 0·4	+ 0·1	+ 0·4	+ 0·4	+ 0·3	+ 0·5	+ 0·3	+ 0·7	+ 0·4
30	+ 0·4	+ 0·4	+ 0·1	+ 0·5	+ 0·5	+ 0·4	+ 0·6	+ 0·4	+ 0·8	+ 0·5
40	+ 0·5	+ 0·5	+ 0·1	+ 0·6	+ 0·6	+ 0·5	+ 0·7	+ 0·5	+ 1·0	+ 0·6
50	+ 0·6	+ 0·6	+ 0·2	+ 0·6	+ 0·7	+ 0·5	+ 0·8	+ 0·5	+ 1·1	+ 0·7
100	+ 0·8	+ 0·8	+ 0·2	+ 0·9	+ 1·0	+ 0·7	+ 1·2	+ 0·7	+ 1·5	+ 1·0
150	+ 0·9	+ 0·9	+ 0·3	+ 1·1	+ 1·2	+ 0·9	+ 1·4	+ 0·8	+ 1·9	+ 1·2
200	+ 1·1	+ 1·1	+ 0·3	+ 1·2	+ 1·4	+ 1·1	+ 1·6	+ 1·0	+ 2·2	+ 1·4
250	+ 1·2	+ 1·2	+ 0·3	+ 1·4	+ 1·6	+ 1·2	+ 1·8	+ 1·1	+ 2·4	+ 1·6
350	+ 1·4	+ 1·4	+ 0·4	+ 1·6	+ 1·8	+ 1·4	+ 2·1	+ 1·3	+ 2·8	+ 1·8
500	+ 1·8	+ 1·8	+ 0·5	+ 2·1	+ 2·3	+ 1·7	+ 2·6	+ 1·6	+ 3·5	+ 2·3
750	+ 2·2	+ 2·2	+ 0·6	+ 2·4	+ 2·7	+ 2·0	+ 3·2	+ 2·0	+ 4·2	+ 2·7
1000	+ 2·5	+ 2·5	+ 0·7	+ 2·8	+ 3·2	+ 2·4	+ 3·6	+ 2·2	+ 5·0	+ 3·2
1250	+ 2·7	+ 2·7	+ 0·8	+ 3·0	+ 3·5	+ 2·6	+ 4·0	+ 2·5	+ 5·4	+ 3·5
1500	+ 3·0	+ 3·0	+ 1·1	+ 3·5	+ 3·9	+ 2·8	+ 4·4	+ 2·7	+ 5·8	+ 3·9
2000	+ 3·5	+ 3·5	+ 1·2	+ 3·9	+ 4·4	+ 3·3	+ 5·0	+ 3·1	+ 6·8	+ 4·4

Area.	H, JH	H, SP	H, W	H, EP	JP, F	JH, SP	JH, W	SP, W	SP, EP	EP, WR
5	+ 0·4	+ 0·4	+ 0·4	+ 0·4	+ 0·2	+ 0·4	+ 0·4	+ 0·4	+ 0·5	+ 0·4
10	+ 0·5	+ 0·6	+ 0·5	+ 0·6	+ 0·3	+ 0·6	+ 0·5	+ 0·5	+ 0·7	+ 0·6
20	+ 0·7	+ 0·8	+ 0·7	+ 0·9	+ 0·4	+ 0·8	+ 0·7	+ 0·8	+ 1·0	+ 0·8
30	+ 0·9	+ 1·0	+ 0·8	+ 1·0	+ 0·5	+ 1·0	+ 0·9	+ 0·9	+ 1·2	+ 1·0
40	+ 1·1	+ 1·1	+ 1·0	+ 1·2	+ 0·6	+ 1·2	+ 1·0	+ 1·1	+ 1·4	+ 1·2
50	+ 1·2	+ 1·3	+ 1·1	+ 1·4	+ 0·7	+ 1·3	+ 1·1	+ 1·2	+ 1·5	+ 1·3
100	+ 1·7	+ 1·8	+ 1·5	+ 1·9	+ 1·0	+ 1·9	+ 1·6	+ 1·7	+ 2·2	+ 1·8
150	+ 2·0	+ 2·2	+ 1·8	+ 2·3	+ 1·2	+ 2·3	+ 1·9	+ 2·1	+ 2·6	+ 2·3
200	+ 2·3	+ 2·5	+ 2·1	+ 2·7	+ 1·4	+ 2·7	+ 2·3	+ 2·4	+ 3·0	+ 2·6
250	+ 2·6	+ 2·8	+ 2·3	+ 3·0	+ 1·6	+ 3·0	+ 2·5	+ 2·7	+ 3·4	+ 2·9
350	+ 3·0	+ 3·3	+ 2·8	+ 3·6	+ 1·8	+ 3·5	+ 2·9	+ 3·2	+ 4·0	+ 3·4
500	+ 3·7	+ 4·0	+ 3·4	+ 4·3	+ 2·3	+ 4·3	+ 3·6	+ 3·9	+ 4·8	+ 4·1
750	+ 4·5	+ 4·9	+ 4·1	+ 5·2	+ 2·7	+ 5·2	+ 4·4	+ 4·7	+ 5·9	+ 5·1
1000	+ 5·2	+ 5·7	+ 4·8	+ 6·0	+ 3·2	+ 6·0	+ 5·0	+ 5·4	+ 6·8	+ 5·8
1250	+ 5·8	+ 6·3	+ 5·3	+ 6·7	+ 3·5	+ 6·7	+ 5·6	+ 6·1	+ 7·6	+ 6·5
1500	+ 6·3	+ 7·0	+ 5·8	+ 7·4	+ 3·9	+ 7·3	+ 6·2	+ 6·6	+ 8·2	+ 7·2
2000	+ 7·3	+ 8·0	+ 6·6	+ 8·5	+ 4·4	+ 8·5	+ 7·1	+ 7·7	+ 9·6	+ 8·2

FACULÆ.

Corrections to be applied to measured area on hypothesis of error varying as perimeter.

Pairs of Observers.

Area.	M, H	M, JP	M, F	M, JH	M, SP	M, W	M, EP	M, WR	H, JP	H, F
10	− 1·0	0·0	+ 0·5	− 2·4	− 1·4	− 0·5	− 1·6	− 1·2	− 0·5	− 0·3
20	− 1·4	0·0	+ 0·7	− 3·4	− 2·0	− 0·7	− 2·3	− 1·8	− 0·7	− 0·4
30	− 1·7	0·0	+ 0·8	− 4·2	− 2·5	− 0·8	− 2·8	− 2·2	− 0·9	− 0·5
50	− 2·2	0·0	+ 1·0	− 5·5	− 3·2	− 1·1	− 3·6	− 2·8	− 1·1	− 0·6
70	− 2·6	0·0	+ 1·2	− 6·5	− 3·8	− 1·3	− 4·3	− 3·3	− 1·3	− 0·7
100	− 3·1	0·0	+ 1·5	− 7·8	− 4·6	− 1·5	− 5·2	− 4·0	− 1·6	− 0·9
150	− 3·9	0·0	+ 1·8	− 8·6	− 5·6	− 1·9	− 6·4	− 4·9	− 2·0	− 1·1
200	− 4·4	0·0	+ 2·1	−11·1	− 6·5	− 2·2	− 7·4	− 5·7	− 2·2	− 1·2
250	− 5·0	0·0	+ 2·3	−12·4	− 7·3	− 2·5	− 8·3	− 6·3	− 2·5	− 1·4
300	− 5·4	+ 0·1	+ 2·5	−13·6	− 8·0	− 2·7	− 9·0	− 6·9	− 2·7	− 1·5
350	− 5·9	+ 0·1	+ 2·7	−14·7	− 8·6	− 2·9	− 9·8	− 7·5	− 3·0	− 1·6
400	− 6·3	+ 0·1	+ 2·9	−15·8	− 9·2	− 3·1	−10·5	− 8·0	− 3·2	− 1·7
500	− 7·0	+ 0·1	+ 3·3	−17·6	−10·3	− 3·5	−11·7	− 8·9	− 3·5	− 1·9
1000	−10·0	+ 0·1	+ 4·6	−25·0	−14·6	− 4·9	−16·5	−12·7	− 5·0	− 2·7

Area.	H, JH	H, SP	H, W	H, EP	J, PF	JH, SP	JH, W	SP, W	SP, EP	EP, WR
10	− 1·7	− 1·2	− 0·7	− 1·3	+ 0·2	− 1·9	− 1·5	− 1·0	− 1·5	− 1·4
20	− 2·4	− 1·7	− 1·0	− 1·8	+ 0·3	− 2·7	− 2·1	− 1·4	− 2·2	− 2·0
30	− 3·0	− 2·1	− 1·3	− 2·3	+ 0·4	− 3·3	− 2·6	− 1·7	− 2·7	− 2·5
50	− 3·9	− 2·7	− 1·7	− 2·9	+ 0·5	− 4·4	− 3·3	− 2·2	− 3·4	− 3·2
70	− 4·6	− 3·2	− 1·9	− 3·5	+ 0·6	− 5·2	− 3·9	− 2·6	− 4·1	− 3·8
100	− 5·5	− 3·9	− 2·3	− 4·2	+ 0·7	− 6·2	− 4·7	− 3·1	− 4·9	− 4·6
150	− 6·7	− 4·7	− 2·9	− 5·1	+ 0·9	− 7·6	− 5·8	− 3·8	− 6·0	− 5·6
200	− 7·8	− 5·5	− 3·3	− 5·9	+ 1·0	− 8·8	− 6·7	− 4·4	− 7·0	− 6·5
250	− 8·7	− 6·1	− 3·7	− 6·6	+ 1·2	− 9·9	− 7·5	− 4·9	− 7·7	− 7·3
300	− 9·5	− 6·7	− 4·1	− 7·3	+ 1·3	−10·8	− 8·2	− 5·3	− 8·5	− 8·0
350	−10·3	− 7·3	− 4·4	− 7·9	+ 1·4	−11·7	− 8·9	− 5·8	− 9·2	− 8·6
400	−11·0	− 7·8	− 4·7	− 8·4	+ 1·5	−12·5	− 9·5	− 6·2	− 9·9	− 9·2
500	−12·3	− 8·7	− 5·2	− 9·4	+ 1·7	−14·0	−10·6	− 6·9	−11·0	−10·3
1000	−17·5	−12·3	− 7·4	−13·3	+ 2·4	−19·8	−15·3	− 9·8	−16·0	−14·6

It will be seen that these corrections are in every case smaller than the probable error of the means of two measures on eight-inch photographs (as given on p. xxiii. of this Introduction and also in the Introduction to the Greenwich Observations, 1885). It seems, therefore, unnecessary to apply them to the measured areas as printed, except in cases of special discussions of changes of area from day to day where extreme accuracy is desired.

As the two senior observers, M and H, have both been engaged in the measurement of eight-inch photographs since 1882, it appeared interesting to enquire whether a comparison of their measures made in different years showed any progressive change of personality. The following table shows that though considerable differences are indicated in the mode of observation of the one observer relative to the other from year to year, yet there has been no regular progressive change. Eight-inch sun pictures were first taken at the Dehra Dûn Observatory, India, during the period 1882 November 7 to December 8. They were then discontinued for about six months, but since 1883 June, the four-inch photographs have been entirely discarded at Dehra Dûn, and the daily series of sun pictures has been always taken on the eight-inch scale. The change from the four-inch to the eight-inch scale was made at the Royal Observatory, Greenwich, on 1884 April 2, and at the Royal Alfred Observatory, Mauritius, on 1885 March 11. As during the year 1883 the measurement of the Greenwich photographs was effected by M with one computer, and that of the Indian photographs by H with another computer, it happens that in no case did M and H both measure the same eight-inch photograph in that year, and there are, therefore, no materials available for determining their personality at that time.

FOR M AND H.

Year	UMBRÆ. No. of Obs.	UMBRÆ. Total Area as measured by M	UMBRÆ. Total Area as measured by H	UMBRÆ. $\frac{H}{M}$	UMBRÆ. $\sqrt{H}-\sqrt{M}$	WHOLE SPOTS. No. of Obs.	WHOLE SPOTS. Total Area as measured by M	WHOLE SPOTS. Total Area as measured by H	WHOLE SPOTS. $\frac{H}{M}$	WHOLE SPOTS. $\sqrt{H}-\sqrt{M}$	FACULÆ. No. of Obs.	FACULÆ. Total Area as measured by M	FACULÆ. Total Area as measured by H	FACULÆ. $\frac{H}{M}$	FACULÆ. $\sqrt{H}-\sqrt{M}$
1882	40	1224·2	1130·0	0·897	−0·193	64	7860·3	7844·1	0·999	−0·004	52	7265·0	6596·0	0·973	−0·319
1884	96	1407·9	1153·6	0·800	−0·305	137	8851·7	8621·4	0·933	−0·165	73	11893·0	11679·0	1·069	+0·103
1885	14	94·2	94·7	0·931	−0·038	26	734·9	754·5	1·068	+0·110	31	2213·0	2581·0	1·205	+0·700
1886	15	153·6	142·1	0·832	−0·190	34	976·4	987·0	0·997	+0·002	28	2121·0	1934·0	1·045	−0·148
1887	85	1123·1	934·0	0·809	−0·304	138	7135·4	6681·2	0·938	−0·183	98	5798·0	6056·0	1·087	+0·232
1888	14	167·4	135·3	0·863	−0·304	31	1128·2	1090·8	1·085	+0·034	48	2555·0	2445·0	1·062	+0·107

A more detailed comparison, giving the separate results for spots and faculæ of different sizes, is given in the following tables :---

For 1882.

	UMBRÆ.					WHOLE SPOTS.					FACULÆ.				
	No. of Obs.	Total Area as measured by M	Total Area as measured by H	$\frac{H}{M}$	$\sqrt{H} - \sqrt{M}$	No. of Obs.	Total Area as measured by M	Total Area as measured by H	$\frac{H}{M}$	$\sqrt{H} - \sqrt{M}$	No. of Obs.	Total Area as measured by M	Total Area as measured by H	$\frac{H}{M}$	$\sqrt{H} - \sqrt{M}$
Under 5 squares	17	59·7	54·8	0·918	− 0·080										
Above 5 & under 10	11	87·4	75·9	0·868	− 0·193										
Above 10 & under 20	6	94·1	81·3	0·864	− 0·279										
Above 20 & under 40	2	57·0	51·0	0·895	− 0·289										
Above 40 & under 80															
Above 80 squares....	4	926·0	867·0	0·936	− 0·493										
Under 10 squares....						18	88·2	88·9	1·007	+ 0·009					
Above 10 & under 20						14	227·8	226·6	0·995	− 0·011					
Above 20 & under 40						9	236·3	243·8	1·032	+ 0·080					
Above 40 & under 100						12	785·0	732·3	0·933	− 0·276					
Above 100 & under 200						6	755·0	800·5	1·060	+ 0·334					
Above 200 & under 400						1	276·0	288·0	1·043	+ 0·358					
Above 400 squares ..						4	5492·0	5464·0	0·995	− 0·009					
Under 50 squares....											14	459·0	480·0	1·046	+ 0·130
Above 50 & under 100											16	1173·0	1100·0	0·938	− 0·271
Above 100 & under 200											12	1721·0	1772·0	1·030	+ 0·176
Above 200 & under 400											5	1292·0	1212·0	0·938	− 0·506
Above 400 squares ..											5	2620·0	2032·0	0·776	− 2·732
Total & Means ..	40	30·61	28·25	0·897	− 0·193	64	122·82	122·56	0·999	− 0·004	52	139·71	126·85	0·973	− 0·319

For 1884.

		M	H	$\frac{H}{M}$	$\sqrt{H} - \sqrt{M}$		M	H	$\frac{H}{M}$	$\sqrt{H} - \sqrt{M}$		M	H	$\frac{H}{M}$	$\sqrt{H} - \sqrt{M}$
Under 5 squares	37	104·5	83·5	0·798	− 0·176	Under 10 squares....	46	231·7	215·3	0·929	− 0·082	Under 50 squares....	20	537·0	645·0	1·201	+ 0·497
Above 5 & under 10	25	195·9	153·6	0·784	− 0·222	Above 10 & under 20	23	306·1	289·6	0·946	− 0·099	Above 50 & under 100	14	955·0	1050·0	1·099	+ 0·401
Above 10 & under 20	18	258·7	205·5	0·795	− 0·412	Above 20 & under 40	19	667·2	583·5	0·875	− 0·385	Above 100 & under 200	21	2986·0	3148·0	1·054	+ 0·319
Above 20 & under 40	8	258·3	212·0	0·821	− 0·535	Above 40 & under 100	30	2100·7	1962·0	0·934	− 0·281	Above 200 & under 400	12	3715·0	3376·0	0·909	− 0·821
Above 40 & under 80	5	285·5	240·5	0·842	− 0·621	Above 100 & under 200	6	797·0	759·0	0·952	− 0·278	Above 400 squares ..	6	3700·0	3460·0	0·935	− 0·819
Above 80 squares....	3	305·0	258·5	0·848	− 0·800	Above 200 & under 400	7	1795·0	1733·0	0·966	− 0·279						
						Above 400 squares ..	6	2954·0	3079·0	1·042	+ 0·465						
Total & Means ..	96	14·66	12·02	0·800	− 0·305	Total & Means ..	137	64·61	62·93	0·933	− 0·165	Total & Means ..	73	162·92	159·99	1·069	+ 0·103

For 1885.

		M	H	$\frac{H}{M}$	$\sqrt{H} - \sqrt{M}$		M	H	$\frac{H}{M}$	$\sqrt{H} - \sqrt{M}$		M	H	$\frac{H}{M}$	$\sqrt{H} - \sqrt{M}$
Under 5 squares	9	22·2	18·7	0·842	− 0·130	Under 10 squares....	13	61·0	64·5	1·057	+ 0·061	Under 50 squares....	9	261·0	357·0	1·368	+ 0·914
Above 5 & under 10	1	8·0	7·0	0·875	− 0·182	Above 10 & under 20	3	38·7	41·0	1·059	+ 0·106	Above 50 & under 100	15	916·0	1050·0	1·146	+ 0·553
Above 10 & under 20	3	37·0	46·0	1·243	+ 0·405	Above 20 & under 40	3	68·2	88·0	1·290	+ 0·649	Above 100 & under 200	5	586·0	644·0	1·099	+ 0·523
Above 20 & under 40	1	27·0	23·0	0·852	− 0·400	Above 40 & under 100	5	322·0	326·0	1·012	+ 0·050	Above 200 & under 400	2	450·0	530·0	1·178	+ 1·279
Above 40 & under 80						Above 100 & under 200	2	245·0	235·0	0·959	− 0·228	Above 400 squares ..					
Above 80 squares....						Above 200 & under 400											
						Above 400 squares ..											
Total & Means ..	14	6·73	6·76	0·931	− 0·038	Total & Means ..	26	28·27	29·02	1·068	+ 0·110	Total & Means ..	31	71·39	83·26	1·205	+ 0·700

For 1886.

	UMBRÆ.				WHOLE SPOTS.					FACULÆ.				
	No. of Obs.	Total Area as measured by M	Total Area as measured by H	$\frac{H}{M}$	$\sqrt{H} - \sqrt{M}$		No. of Obs.	Total Area as measured by M	Total Area as measured by H	$\frac{H}{M}$	$\sqrt{H} - \sqrt{M}$		No. of Obs.	Total Area as measured by M	Total Area as measured by H	$\frac{H}{M}$	$\sqrt{H} - \sqrt{M}$
Under 5 squares....	7	18·3	15·2	0·831	− 0·143	Under 10 squares....	16	71·1	72·0	1·013	+ 0·014	Under 50 squares....	12	283·0	353·0	1·247	+ 0·568
Above 5 & under 10	6	44·3	33·9	0·765	− 0·340	Above 10 & under 20	8	121·5	109·0	0·897	− 0·205	Above 50 & under 100	8	568·0	556·0	0·979	− 0·089
Above 10 & under 20						Above 20 & under 40	6	165·3	177·0	1·071	+ 0·182	Above 100 & under 200	7	1050·0	845·0	0·805	− 1·260
Above 20 & under 40	1	25·0	27·0	1·080	+ 0·196	Above 40 & under 100	2	90·5	93·0	1·028	+ 0·032	Above 200 & under 400	1	220·0	180·0	0·81	− 1·416
Above 40 & under 80	1	66·0	66·0	1·000	0·000	Above 100 & under 200	1	122·0	122·0	1·000	0·000	Above 400 squares..					
Above 80 squares....						Above 200 & under 400											
						Above 400 squares..	1	406·0	414·0	1·020	+ 0·198						
Total & Means ..	15	10·24	9·47	0·832	− 0·190	Total & Means ..	34	28·72	29·03	0·997	+ 0·002	Total & Means ..	28	75·75	69·07	1·045	− 0·148

For 1887.

		M	H	$\frac{H}{M}$	$\sqrt{H} - \sqrt{M}$			M	H	$\frac{H}{M}$	$\sqrt{H} - \sqrt{M}$			M	H	$\frac{H}{M}$	$\sqrt{H} - \sqrt{M}$
Under 5 squares....	33	81·4	66·6	0·818	− 0·151	Under 10 squares....	55	269·5	253·2	0·939	− 0·067	Under 50 squares....	55	1574·0	1774·0	1·127	+ 0·317
Above 5 & under 10	23	189·2	144·4	0·763	− 0·367	Above 10 & under 20	22	312·4	298·0	0·954	− 0·087	Above 50 & under 100	22	1455·0	1532·0	1·053	+ 0·213
Above 10 & under 20	17	276·0	227·5	0·824	− 0·372	Above 20 & under 40	15	444·5	418·0	0·940	− 0·164	Above 100 & under 200	14	1929·0	1920·0	0·995	− 0·025
Above 20 & under 40	6	182 5	153·5	0·841	− 0·458	Above 40 & under 100	27	1812·0	1678·0	0·926	− 0·309	Above 200 & under 400	3	840·0	830·0	0·988	− 0·100
Above 40 & under 80	6	394·0	342·0	0·868	− 0·553	Above 100 & under 200	11	1401·0	1277·0	0·912	− 0·489	Above 400 squares..					
Above 80 squares....						Above 200 & under 400	6	1866·0	1807·0	0·968	− 0·281						
						Above 400 squares..	2	1030·0	950·0	0·922	− 0·899						
Total & Means ..	85	14·48	10·99	0·809	− 0·304	Total & Means ..	138	51·71	48·41	0·938	− 0·183	Total & Means ..	98	59·16	61·80	1·087	+ 0·232

For 1888.

		M	H	$\frac{H}{M}$	$\sqrt{H} - \sqrt{M}$			M	H	$\frac{H}{M}$	$\sqrt{H} - \sqrt{M}$			M	H	$\frac{H}{M}$	$\sqrt{H} - \sqrt{M}$
Under 5 squares....	3	7·8	7·3	0·936	− 0·053	Under 10 squares....	13	75·2	90·3	1·201	+ 0·232	Under 50 squares....	26	551·0	624·0	1·132	+ 0·296
Above 5 & under 10	4	27·6	28·5	1·033	+ 0·043	Above 10 & under 20	6	78·0	87·5	1·122	+ 0·214	Above 50 & under 100	18	1164·0	1187·0	1·020	+ 0·079
Above 10 & under 20	6	106·0	72·5	0·684	− 0·728	Above 20 & under 40	2	67·0	60·0	0·896	− 0·311	Above 100 & under 200	3	490·0	414·0	0·845	− 0·033
Above 20 & under 40	1	26·0	27·0	1·038	+ 0·097	Above 40 & under 100	6	378·0	369·0	0·976	− 0 095	Above 200 & under 400	1	350·0	220·0	0·629	− 3·876
Above 40 & under 80						Above 100 & under 200	4	530·0	484·0	0·913	− 0·511	Above 400 squares..					
Above 80 squares....						Above 200 & under 400											
						Above 400 squares..											
Total & Means ..	14	11·96	9·66	0·863	− 0·304	Total & Means ..	31	36·39	35·19	1·085	+ 0·034	Total & Means ..	48	53·23	50·94	1·062	+ 0·107

ROYAL OBSERVATORY, GREENWICH.

MEASURES OF POSITIONS AND AREAS

OF

SPOTS AND FACULÆ

UPON THE SUN'S DISK

ON

PHOTOGRAPHS

TAKEN WITH THE

PHOTOHELIOGRAPHS

AT GREENWICH, IN INDIA, AND IN MAURITIUS,

WITH THE DEDUCED

HELIOGRAPHIC LONGITUDES AND LATITUDES.

1888.

MEASURES of POSITIONS and AREAS of SPOTS and FACULÆ upon the SUN'S DISK on PHOTOGRAPHS taken at the ROYAL OBSERVATORY, GREENWICH, at DEHRA DÛN in INDIA, and at the ROYAL ALFRED OBSERVATORY, MAURITIUS, in the Year 1888.

NOTE.—The Greenwich Civil Time at which the photograph was taken is expressed by the Day of the Year and decimals of a day, reckoning from Greenwich Midnight, January 1$^{d.}$ 0$^{h.}$

For convenience of reference the Month and Day of the Month (Civil Reckoning) are added.

The letter I. signifies that the photograph was taken in India; the letter M. that the photograph was taken in Mauritius; the time given is Greenwich Civil Time.

The position-angles are reckoned from the North Pole of the Sun's Axis in the direction N., E., S., W., N.

Greenwich Civil Time.	Measurers.	No. of Group, and Letter for Spot.	Distance from Centre in terms of Sun's Radius.	Position Angle from Sun's Axis.	Heliographic		Spots.		Faculæ.
					Longitude.	Latitude.	Area of UMBRA for each Spot (and for Day).	Area of WHOLE for each Spot (and for Day).	Area for each Group (and for Day).
1888.				°	°	°			
0$^{d.}$·484	H,M	2026*a*	0·841	96·8	227·6	−7·4	32	183	128 *s f*
Jan. 1		Centre			(284·7)	(−3·2)	(32)	(183)	(128)
1·450	H,M	2026*a*	0·701	97·1	227·7	−7·3	25	178	
Jan. 2		Centre			(272·1)	(−3·3)	(25)	(178)	(0)
2·451	H,EP	2026*a*	0·519	98·8	227·8	−7·5	28	176	
Jan. 3		Centre			(258·8)	(−3·5)	(28)	(176)	(0)
3·241	M,H		0·887	248·9	310·1	−20·3			20
I.		2026*a*	0·361	101·6	227·6	−7·5	30	167	
		2027	0·711	73·1	205·0	+9·3	3	29	} 81*c*
		2027	0·744	72·0	202·5	+10·8	1	19	
Jan. 4		Centre			(248·4)	(−3·6)	(34)	(215)	(101)
4·468	H,EP	2026*a*	0·099	134·9	228·3	−7·7	16	123	
		2027	0·486	63·4	206·3	+9·2	0	8	
Jan. 5		Centre			(232·3)	(−3·7)	(16)	(131)	(0)
5·271	M,H		0·952	182·8	232·4	−75·5			128
I.		2026*a*	0·135	234·5	228·0	−8·3	20	133	
			0·910	98·3	156·1	−9·2			149
Jan. 6		Centre			(221·7)	(−3·8)	(20)	(133)	(277)
6·183	M,H	2026*a*	0·326	255·6	228·2	−8·4	15	102	
I.		2026	0·272	249·2	224·6	−9·3	0	8	
			0·949	94·6	137·9	−5·6			139
Jan. 7		Centre			(209·7)	(−3·9)	(15)	(110)	(139)
7·218	M,H		0·961	265·4	270·0	−5·6			57
			0·853	264·2	254·6	−7·1			166
I.			0·944	191·3	230·4	−70·9			82
			0·946	179·6	194·4	−75·9			35
		2026*a*	0·536	260·7	228·2	−8·4	16	88	
1888.									
7$^{d.}$·218	M,H		0·879	91·7	134·6	−3·5			165
I.			0·908	104·3	130·8	−14·6			95
Jan. 8		Centre			(196·0)	(−4·0)	(16)	(88)	(600)
8·196	EP,H		0·939	264·7	253·1	−6·4			188
			0·945	191·0	217·6	−71·4			100
I.		2026*a*	0·708	261·7	228·2	−8·8	10	70	
			0·947	91·3	112·1	−2·5			84
			0·952	107·6	110·9	−18·0			59
Jan. 9		Centre			(183·2)	(−4·1)	(10)	(70)	(431)
9·321	EP,M		0·919	281·3	233·9	+8·6			45
			0·849	272·3	221·3	−0·7			187
I.		2026*a*	0·863	262·4	228·1	−8·7	8	49	218 *s*
		2028*a*	0·945	87·6	97·8	+0·9	0	7	} 858 *c*
		2028*b*	0·965	87·8	93·9	+1·0	10	96	
		2028*c*	0·979	89·1	90·4	0·0	0	12	
		2029*a*	0·994	97·5	84·4	−7·9	28	186	422 *c*
Jan. 10		Centre			(168·4)	(−4·2)	(46)	(350)	(1730)
10·283	H,M		0·937	260·9	225·5	−10·1			256
			0·921	271·7	227·0	+14·0			105
I.		2028*a*	0·843	85·8	98·7	+1·2	0	13	} 587 *c*
		2028*b*	0·876	86·7	94·9	+0·8	14	75	
		2029*a*	0·944	97·0	84·8	−8·1	28	134	496 *s*
			0·870	95·3	95·2	−6·7			187
Jan. 11		Centre			(155·7)	(−4·3)	(42)	(222)	(1631)
11·185	H,EP		0·971	270·5	219·8	−0·7			87
			0·966	258·0	219·3	−12·7			89
I.			0·882	282·0	204·4	+8·4			84
		2030*a*	0·171	194·1	146·4	−14·0	4	9	

The Groups of Spots are numbered in the order of their appearance. When there is no number in the third column it is to be understood that there is a Facula unaccompanied by a Spot. The positions of Faculæ relative to the Spots with which they are associated are indicated by the letters *n*, *s*, *p*, *f*, *c*, denoting respectively north, south, preceding, following, concentric. The longitude and latitude of the centre of the disk are given in brackets.

The Areas of Spots and Faculæ are expressed in millionths of the Sun's visible Hemisphere.

Jan. 1 and 5. Photograph taken through mist. Definition poor.

Group 2026, 1887 Dec. 31–1888 Jan. 10. A regular spot, *a*. A faint companion is seen near it on Jan 7.

Group 2027, 1888 Jan. 4–5. Three small spots, of which the first two are measured together on Jan. 4. One small spot on Jan. 5.

Group 2028, Jan. 10–12. Three small spots, *a*. *b*, and *c*, on Jan. 10. *c* has disappeared by Jan. 11. The group consists on Jan. 12 of four small spots in a short stream.

Group 2029, Jan. 10–21. A regular spot, *a*, with one very small companion on Jan. 14 and 17, and two or three on Jan. 15, 16, and 18.

Group 2030, Jan. 12–16. A small spot, *a*, with one small companion on Jan. 13 and 14, and two on Jan. 15 and 16.