RESULTS OF MEASURES

MADE AT THE

ROYAL OBSERVATORY, GREENWICH

UNDER THE DIRECTION OF

SIR FRANK DYSON, M.A., LL.D., F.R.S.,

ASTRONOMER ROYAL,

OF

PHOTOGRAPHS OF THE SUN

TAKEN

AT GREENWICH, AT THE CAPE, AND IN INDIA

IN THE YEAR

1924.

WITH A

DETERMINATION OF THE SUN'S ROTATION

AND A DISCUSSION OF

THE CHARACTERISTIC MOVEMENTS OF SPOTS

FROM GREENWICH MEASURES, 1878–1923.

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GREENWICH PHOTO-HELIOGRAPHIC RESULTS, 1924.

INTRODUCTION.

§ 1. *Positions and Areas of Sun Spots and Faculæ for each Day in the Year* 1924.

The photographs from which these measures were made were taken at the Royal Observatories of Greenwich or of the Cape; at the Kodaikánal Observatory, Southern India; or at Dehra Dûn, North-West Provinces, India.

The photographs of the Sun obtained at Greenwich were taken either with the Dallmeyer Photo-heliograph, of 4 inches aperture (stopped down to 2·9 inches) or the Thompson Photo-heliograph of 9 inches aperture (usually stopped down to 4 inches). The latter instrument was remounted after its return from Russia on the 26-inch Refractor and was brought into regular use on July 16. Both Photo-heliographs give a solar image of about 10-cm. radius. The two instruments are worked in conjunction; the Dallmeyer Photo-heliograph is of most use in snatching a photograph in breaks on cloudy days, while the Thompson Photo-heliograph is best employed in intervals of good definition.

The photographs from the Cape Observatory were taken under the superintendence of His Majesty's Astronomer at the Cape, Mr. H. Spencer Jones, and those from Kodaikánal under the superintendence of the Director, Dr. T. Royds. The photographs from Dehra Dûn, which have been forwarded by the Solar Physics Committee to fill the gaps in the combined series, were taken under the superintendence of the Deputy Surveyor-General, Trigonometrical Survey of India. At two of the observatories the instrument employed was a Dallmeyer Photo-heliograph giving an image of the Sun about 10 centimetres in radius; at Kodaikánal a Cooke photo-visual object-glass of 6 inches aperture was used, the image of the Sun being on about the same 10-centimetre scale.

Photographs of the Sun were available for measurement upon each day in 1924, those finally selected for measurement being supplied by the different observatories as under :—

Greenwich	212
Cape	147
Kodaikánal	3
Dehra Dûn	4
Total	366

The names of those persons who measured the photographs for the year 1924 are as follows :—

H. W. Newton — Andrina M. Crommelin
H. Barton — Isabel Jackson

At the principal focus of the Photo-heliographs, excepting that at Kodaikánal, two spider-lines are fixed by which the zero of position-angles on the photographs can be determined. These lines are inclined at an angle of 45° to the celestial equator in the Greenwich and Cape Photo-heliographs, and respectively perpendicular and parallel to it in the Dehra Dûn, instrument. In the Kodaikánal Photo-heliograph there is one wire fixed parallel to the equator.

The zero of position-angles for the Greenwich, Cape, and Kodaikánal Photo-heliographs has been determined by the measurement of plates which have been exposed 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 about a fifth part of the Sun's diameter, were therefore produced upon the plates, and the exposures having been so given that the line joining the cusps passed approximately through the centre of the plates, the inclination of the wires of the photo-heliograph to this line was measured with the position-micrometer, and a small correction for the inclination of the Sun's path was then applied.

At Greenwich and the Cape, transits of the Sun were also taken over the two wires; the times of contact of the first and second limbs of the Sun with the two wires being noted. The ratio of the time taken by the Sun to pass over the NE—SW wire to that taken to pass over the SE—NW wire gives the tangent of the angle made by the Sun's path to the latter wire, the wires being assumed to be exactly at right angles to each other. From this angle, when corrected for the Sun's motion in declination, the correction for the zero of position of the wires can be inferred.

The following table gives the correction for zero of position thus determined by the two independent methods for the Greenwich and Cape Photo-heliographs.

Determination of the Zero of Position-Angles.

Month 1924.	Greenwich, Dallmeyer.		Greenwich, Thompson.		Cape.	
	Photographic.	Visual.	Photographic.	Visual.	Photographic.	Visual.
	° ′	° ′	° ′	° ′	° ′	° ′
January ..	—	+ 2. 46 (2)			— 0. 29 (2)	— 0. 24 (4)
February ..	+ 2. 48 (1)	+ 2. 42 (2)			— 0. 28 (2)	— 0. 24 (4)
March ..	+ 2. 33 (1)	+ 2. 42 (2)			— 0. 37 (1)	— 0. 21 (4)
April ..	+ 2. 50 (1)	+ 2. 41 (2)			— 0. 26 (2)	— 0. 20 (4)
May	+ 2. 37 (2)	+ 2. 36 (1)			— 0. 22 (2)	— 0. 17 (4)
June	+ 2. 36 (2)	+ 2. 39 (3)			— 0. 15 (2)	— 0. 18 (4)
July	+ 2. 44 (3)	+ 2. 39 (2)	+ 2. 15 (1)	+ 2. 16 (2)	— 0. 15 (2)	— 0. 17 (4)
August ..	+ 2. 39 (1)	+ 2. 37 (1)	+ 2. 22 (1)	+ 2. 18 (3)	— 0. 13 (2)	— 0. 20 (4)
September ..	+ 2. 43 (2)	+ 2. 50 (1)	+ 2. 08 (1)	+ 2. 21 (4)	— 0. 20 (1)	— 0. 19 (4)
October ..	+ 2. 42 (1)	+ 2. 44 (3)	+ 2. 16 (2)	+ 2. 19 (3)	— 0. 25 (2)	— 0. 21 (5)
November ..	—	+ 2. 43 (1)	+ 2. 32 (1)	—	— 0. 20 (2)	— 0. 24 (3)
December ..	+ 2. 39 (2)	+ 2. 45 (3)			{ — 0. 22 (1) — 0. 38 (1) }	{ — 0. 25 (2) — 0. 35 (2) }

The suffixes indicate the number of zero plates or the number of sets of transits.

New wires were inserted in the Cape Photo-heliograph on December 19.

The zero-corrections used during the year 1924 in the reduction of the photographs taken at Greenwich were as follows :—

		°
Dallmeyer Photo-heliograph	January and February ..	+ 2·75
	March and April	+ 2·7
	May and June..	+ 2·6
	July and August	+ 2·65
	September to December ..	+ 2·7
Thompson Photo-heliograph	July 16—October 31 ..	+ 2·3
	November	+ 2·4

The zero-corrections used in the reductions of the photographs taken at the Cape Observatory were as follows :—

	°
January 1 to March 31	— 0·4
April 1 to September 30	— 0·3
October	— 0·35
November 1 to December 18	— 0·4
December 19—31	— 0·6

The zero-corrections adopted during 1924 for the three Kodaikánal photographs were :—

February 18 and March 26, +0°·2 ; July 28, +0°·3.

The adjustment of the wires in the Dehra Dûn Photo-heliograph was usually tested by stopping the driving clock immediately after a photograph had been taken and making a second exposure some two minutes after the first, a portion of a second image of the Sun, just intersecting the first, being thus obtained upon the plate. The Zero-correction adopted was +0°·4.

The measures of the photographs were made with a large position-micrometer 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 a 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 eyepiece, 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 the 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.

All photographs are measured independently by two persons, and the means taken.

In the case of large or complex groups of spots, the positions of the chief components are measured individually, and also for groups so near the east or west limbs of the Sun that the effects of foreshortening are appreciable. In other cases the position of the centre of a group is estimated in the micrometer. In this respect a difference has been made in the practice during years previous to 1916, where in this section components of groups are given separately and combined into groups in the Ledgers.

When required, corrections are applied to the measured distances and position-angles for differential refraction. The formula is given in the *Introduction* for 1909. It is seldom necessary, however, to apply this correction except to a few photographs taken at Greenwich in mid-winter.

The calculations of heliographic longitude and latitude are made by use of the formulæ given in "Researches on Solar Physics: Heliographical Positions and Areas of Sun Spots observed with the Kew Photo-heliograph during the years 1862 and 1863" by W. De La Rue, B. Stewart, and B. Loewy. *Phil. Trans.*, 1869. If 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 semi-diameter of the Sun in arc, and ρ, ρ' the angular distances of a spot from the centre of the apparent disc as viewed from the Sun's centre and from the Earth respectively, ρ is obtained from the equations:—

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

If D and ϕ are the heliographic latitudes of the Earth and the spot respectively, referred to the Sun's equator, and l the heliographic longitude of the spot from the solar meridian passing through the centre of the disc, longitudes west of the centre being reckoned as positive, and χ the position-angle from the Sun's axis,

$$\sin\phi = \cos\rho\sin D + \sin\rho\cos D\cos\chi$$
$$\sin l = -\sin\chi\sin\rho\sec\phi.$$

The position-angle χ is found from the position-angle from the North Point by subtracting P, the position-angle of the N end of the Sun's axis, measured eastward from the North Point of the disc. The heliographic longitude of the spot is $l+L$, where L is the heliographic longitude of the centre of the disc. The three quantities P, D, and L for the time of the exposure of each photograph are derived from the Ephemeris for Physical Observations of the Sun given on p. 557 of the *Nautical Almanac* for 1924.

The inclination of the Sun's axis to the ecliptic is assumed to be 82° 45′, the longitude of the ascending node for 1924·0 to be 74° 42′·0, and the period of the Sun's sidereal rotation to be 25·38 days; the meridian which passed through the ascending node 1854 January 1, Greenwich Mean Noon, being taken as the zero meridian.

§ 2. *General Catalogue of Groups of Sun Spots for* 1924.

The Catalogue contains every group of spots which lasted for two or more days, and the group numbers are in continuation of those given in 1923 and previous years. Groups seen only once are not included, but appear in the Daily Results with a distinctive numeration.

During the year 1924, a number of groups of spots have been noted in the Catalogue as "Revivals." These have been tabulated in series in a table following the Catalogue. The respective groups of each series are in the same heliographic position, and are seen in consecutive rotations but with definite breaks in their history between each rotation. The latter feature excludes them from being classed as "Recurrent" groups; they differ from "Intermittent" groups in their being of long period intermittency. When a "Recurrent" series forms part of a "Revival" series, a reference is made in the last column of the table. Other groups which are given in detail in Ledger II are also indicated.

§ 3. *Ledgers of the Areas and Heliographic Positions of Groups of Sun Spots for* 1924.

Ledger I.—Recurrent Groups.—This Ledger supersedes the Catalogue of Recurrent Groups of Sun Spots given in years previous to 1916 of the *Greenwich Photo-Heliographic Results*, and the reference numbers of the series are in continuation of those given therein. The groups forming this Ledger have been abstracted from a general Ledger of all spot groups seen throughout the year, and were selected upon the following plan, reference being made to the General Catalogue:—If any spot group when first seen was 60° or more to the east of the Central Meridian, then the Catalogue, and, if necessary, the Daily Results also, were searched some fifteen or sixteen days earlier, to ascertain whether a spot group of similar heliographic longitude and latitude was then near the west limb of the Sun. Similarly, if any spot group when last seen was 60° or more to the west of the Central Meridian, then the Catalogue was searched some fifteen or sixteen days later, to ascertain whether a spot group of similar heliographic longitude and latitude was then near the east limb of the Sun. Both the search forward and the search backward have been made in the case of every spot group that was observed close to both the east and west limbs, in order that no possible case of identity might be overlooked. When there appeared to be a case of probable identity between spot groups observed in two consecutive rotations of the Sun, the character of the second group has been carefully compared with that of the first in each of the three elements—area, longitude, and latitude, before accepting it as a Recurrent Group.

Besides the Ledgers of the groups, there have been printed in a similar manner important components of the principal groups. This has been done in all cases where it appeared probable that an individual component lasted to the second or third rotation after its first appearance.

Both in Ledger I and Ledger II, are given the proper motions of spots in longitude, instead of longitudes according to "System II" based on the formula $\xi=14°\cdot44-2°\cdot13\ \sin^2\phi$ as published in these *Results* for the years 1911 to 1923 inclusive. The determination of the Sun's rotation period from long-lived spots, compiled from the *Greenwich Photo-heliographic Results* for the four cycles 1878–1923 is given in § 5 of these *Results*. The deduced daily sidereal-motion is found to be represented by the formula $\xi=14°\cdot37-2°\cdot60\ \sin^2\phi$, which has been adopted in deriving the proper motions in longitude as described on pages D 38 and D 46.

Ledger II.—Non-Recurrent Groups.—This Ledger contains the most important of those groups which do not last to a second rotation. Individual components are also given after their respective groups, where they are large and distinctive.

§ 4. *Total 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* 1924.

Particulars relating to this section are given in the headings on pages D 56, 60, and 61.

§ 5. *Determination of the Solar Rotation from Long-lived Spots.*

§ 6. *Characteristic Movements of Sun Spots.*

These two discussions on pages D 65–85 are based on the Greenwich Sunspot measures for the four cycles, 1878–1923.

F. W. DYSON.

Royal Observatory, Greenwich,
1925, *October* 7.

ROYAL OBSERVATORY, GREENWICH.

POSITIONS AND AREAS

OF

SUN SPOTS AND FACULÆ.

FOR EACH DAY IN THE YEAR

1924.

GREENWICH PHOTO-HELIOGRAPHIC RESULTS, 1924.

POSITIONS and AREAS of SUN SPOTS and FACULÆ for EACH DAY in the YEAR 1924.

Col. 1. (1) Time when photograph was taken expressed in days and decimals of a day reckoning from midnight at commencement of year. (2) Place of observatory—Greenwich (G), Cape of Good Hope (C), Kodaikánal (K), Dehra Dûn (D). (3) Date of photograph (Civil reckoning).

Col. 2. Number of Spot Group in order of appearance and in continuation of the Group-numbers given in previous years. Groups seen on one day only are distinguished by the number of the Rotation during which they were observed and by a letter given in the order of their appearance. When there is no number in the second column, it is to be understood that there is a Facula unaccompanied by a Spot.

Col. 3. Distance of Spot Group or Faculæ from Sun's centre in terms of the Sun's radius.

Col. 4. Position Angle of Spot Group or Faculæ measured from the North pole of the Sun's axis in the direction N., E., S., W., N.

Col. 5. Heliographic Longitude of the Spot Group derived from the measures.

Col. 6. Heliographic Latitude of the Spot Group similarly derived.

Col. 7. Area of Umbræ corrected for foreshortening in millionths of the Sun's visible hemisphere.

Col. 8. Area of Whole Spots composing the Group similarly expressed.

Col. 9. Area of each group of Faculæ similarly expressed. 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.

In line with the date of each day is given in brackets the position angle of the Sun's axis from the north point: the heliographic longitude and latitude of the centre of the disc; the total areas of Spots and Faculæ for the day.