RESULTS OF MEASURES

MADE AT THE ROYAL GREENWICH OBSERVATORY

OF

PHOTOGRAPHS OF THE SUN

TAKEN AT GREENWICH, THE CAPE

AND KODAIKANAL IN THE YEAR

1952

UNDER THE DIRECTION OF

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ASTRONOMER ROYAL

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GREENWICH PHOTO-HELIOGRAPHIC RESULTS

1952

INTRODUCTION

The photographs from which these measures were made were taken at the Royal Greenwich Observatory, the Royal Observatory, Cape of Good Hope, and the Kodaikanal Observatory, Southern India.

The photographs of the Sun obtained at Greenwich were taken with the 4-inch Photoheliograph, of which the original object-glass had been replaced in 1910 by a Grubb photographic objective. The equivalent focal length of the photoheliograph with its present enlarging system (supplied in 1926 by Ross, Ltd.) is $67\frac{1}{2}$ feet, the diameter of the Sun's image at the secondary focus being approximately $7\frac{1}{2}$ inches. On 1949 May 2 this photoheliograph was moved from Greenwich to Herstmonceux Castle, Sussex. Subsequent photographs continue to be designated "Greenwich" photographs.

The photographs of the Sun obtained at the Cape Observatory were taken under the superintendence of His Majesty's Astronomer at the Cape, Dr. R. H. Stoy, and those from Kodaikanal under the superintendence of the Director, Dr. A. K. Das. At the Cape Observatory the instrument employed was a 4-inch photoheliograph giving an image of the Sun about $7\frac{1}{2}$ inches in diameter; at Kodaikanal a Cooke photo-visual objective of 6 inches aperture was used, the image of the Sun which was obtained being of about the same size.

Photographs of the Sun were available for measurement on 366 days in 1952, those finally selected for measurement being supplied by the different observatories as under:

Greenwich	303
Cape	61
Kodaikanal	2
Total	366

The names of the measurers of the photographs for the year 1952 were as follows:

H. Barton	P. A. Wayman	N. Rhodes
P. S. Laurie	A. S. Milsom	R. W. Teague

At the primary focus of the photoheliographs at Greenwich and the Cape two spider-wires are fixed by which the zero of position-angles on the photographs can be determined. These wires are inclined at an angle of 45° to the celestial equator. In the Kodaikanal instrument there is one wire fixed parallel to the equator.

The precise zero of position-angles for the photoheliographs has been determined by three different methods.

(i) *Zero Photographs.* Plates were 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 thus produced upon the plates. The exposures were so made that the line joining the cusps passed approximately through the centre of the plates and the inclinations of the two spider-wires to this line were measured. A small correction for the inclination of the Sun's path has been applied. Two or three zero photographs were usually taken each month at Greenwich, the Cape, and Kodaikanal.

(ii) *Transits.* At Greenwich and the Cape, transits of the Sun were taken visually, the times of contact of the first and second limbs of the Sun with the two wires being noted by an eye-and-ear method. The ratio of the time taken by the Sun to pass over the NE - SW wire to the time taken to pass over the SE - NW wire was used in order to find the angle made by the Sun's path with the bisectors of the wires. From this, again incorporating a correction to allow for the inclination of the Sun's path, the orientation of the wires with respect to the N - S line could be inferred. Transits were usually taken at Greenwich and the Cape on four or more days during each month.

(iii) *Supplementary Zero Photographs.* At Greenwich supplementary partial images of the Sun were occasionally recorded on otherwise normal photographs, a second exposure being made after clamping the instrument firmly for 130 seconds. The small portion of the Sun's limb visible at the western edge of the plate could be used, together with the main image which it does not intersect, to deduce the orientation of the wires in a way similar to that used for the zero photographs. Six to ten supplementary zero photographs were taken at Greenwich each month. The values for the zero of position-angles deduced from them were given half weight in the adoption of zero-corrections to be used in the reduction of photographs.

The following table gives the zero-corrections determined by the various methods at Greenwich and the Cape during 1952, together with the adopted values.

Greenwich	(i)	(ii)	(iii)	Adopted Value
1952	° ′	° ′	° ′	° ′
January	-0 30	-0 20	-0 12	-0 18
February	-0 19	-0 20	-0 12	-0 18
March	-0 10	-0 16	-0 09	-0 12
April	-0 10	-0 13	-0 18	-0 12
May	-0 16	-0 13	-0 16	-0 15
June	-0 12	-0 12	-0 18	-0 15
July	-0 11	-0 16	-0 22	-0 15
August	-0 16	-0 16	-0 16	-0 15
September	-0 20	-0 18	-0 22	-0 21
October	-0 27	-0 23	-0 19	-0 21
November	-0 25	-0 21	-0 10	-0 24
December	-0 33	-0 26	-0 25	-0 24

Cape	(i)	(ii)	Adopted Value
1952	° ′	° ′	° ′
January	+0 36	+0 36	+0 36
February	+0 33	+0 36	+0 36
March	+0 31	+0 36	+0 36
April	+0 34	+0 35	+0 36
May	+0 32	+0 37	+0 36
June	+0 40	+0 35	+0 36
July	+0 39	+0 35	+0 36
August	+0 34	+0 38	+0 36
September	+0 39	+0 38	+0 36
October	+0 22	+0 34	+0 36
November	+0 29	+0 36	+0 36
December	+0 34	+0 35	+0 36

In the case of the two Kodaikanal photographs individual values were adopted, as indicated by the appropriate zero photographs.

The measures of the photographs were made with a large position-micrometer that can be used for 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 a similar screw-action about a pivot in its circumference. This pivot, 90° distant from that of the upper plate, is mounted on a third circular plate, with a position-circle graduated in divisions of 30 minutes of arc, which may be rotated 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 centre of rotation of the position-circle. When this has been done, a Ramsden eyepiece, having at its anterior 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 adjusted so that the centre of the eyepiece moves diametrically across the photograph, the diaphragm being nearly in contact with the photographic film, so that parallax is negligible. The distance of a spot or facula from the centre of the disk is read from a scale and vernier to 1/250th of an inch, corresponding to 0.001 of the Sun's radius for images 8 inches in diameter. The position-angle is read from 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° below the photograph.

All photographs were measured independently by two measurers, and the means taken.

In the case of large or complex groups of spots, the chief components were measured individually; so also in the case of groups near to the east or west limbs of the Sun where the effects of foreshortening are appreciable. In other cases the position of the centre of a group was estimated by the measurer at the micrometer.

In this respect a difference has been made from the practice during years prior to 1916 when, in the Daily Results (§1.), components of groups were given separately, and in the Ledgers (§3.) combination into groups was made.

When required, corrections have been applied to the measured distances and position-angles to allow for differential refraction. The details of this correction were given in the *Introduction* for 1909. It is necessary to apply this correction to about twenty per cent of the photographs taken at Greenwich in the months October to March.

§1. *Positions and Areas of Sunspots and Faculae for each Day in the Year 1952.*

In this section the measured positions and areas of sunspots and faculæ are given for each day. The positions of sunspots are referred firstly to a system of apparent polar co-ordinates on the Sun's disk and secondly to a system of heliographic co-ordinates. The positions of faculæ are given only in apparent polar co-ordinates.

The calculations of heliographic longitude and latitude are made from formulæ given by W. de la Rue, B. Stewart and B. Loewy, *Phil. Trans.*, 1869. The system of heliographic co-ordinates may be defined as follows. The inclination of the Sun's axis to the ecliptic is assumed to be 82°45′, the longitude of the ascending node of the Sun's equator on the ecliptic for 1952.0 to be 75°05′.4, and the period of the Sun's sidereal rotation to be 25.38 days. The meridian which passed through the ascending node on 1854 January 1, Greenwich mean noon, is taken as the zero meridian and longitudes increase from east to west. The mean synodic rotation-period is 27.2753 days; synodic rotation-periods are counted from 1853 November 9, in continuation of Carrington's series.

Let r be the measured distance of a spot from the centre of the Sun's apparent disk and χ the position-angle of the spot from the Sun's axis, R the measured radius of the Sun on the photograph, S the tabular semi-diameter of the Sun in arc, and ρ, ρ' the angular distances of a spot from the centre of the apparent disk, as viewed from the Sun's centre and from the Earth respectively. ρ - the heliocentric angle - is obtained from the following equations:

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

If B_o and ϕ are the heliographic latitudes and L_o and λ the heliographic longitudes of the Earth and the spot respectively,

$$\sin \phi = \cos \rho \sin B_o + \sin \rho \cos B_o \cos \chi$$
$$\sin (L_o - \lambda) = \sin \chi \sin \rho \sec \phi$$

χ is found from the position-angle measured eastwards from the north point of the Sun's disk by subtracting P, the position-angle of the north end of the Sun's axis also measured eastwards from the north point. The three quantities

P, B_o and L_o for the time of the exposure of each photograph are derived from the *Ephemeris for Physical Observations of the Sun*, given on p.330 of the *Nautical Almanac* for 1952.

§2. *General Catalogue of Groups of Sunspots for 1952.*

This catalogue first contains particulars of every group of sunspots which lasted for two or more days during 1952. The group numbers are in continuation of those given in 1951 and previous years; the Mount Wilson group numbers are also given. The table includes an indication of those groups which may be considered to be members of "recurrent series" of groups, as contained in Ledger I below (§3.).

Spot groups seen on one day only are given in a separate table, where they receive a distinctive numeration.

"Revival" groups of spots have been tabulated in series in a table following the General Catalogue.

§3. *Ledgers of the Areas and Heliographic Positions of Groups of Sunspots for 1952.*

The groups of which details are given in these ledgers have been abstracted from a general ledger of all spot groups seen throughout the year. Apart from the groups, there are printed in a similar manner details of individual 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.

Ledger I. - Recurrent Groups. The groups contained in this ledger were selected upon the following plan, reference being made to the General Catalogue:- If any spot when first seen was 60° or more to the east of the central meridian, the catalogue and, if necessary, the Daily Results also (§1.), were searched some fifteen to 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, a search was made fifteen to sixteen days later. When there appeared to be a case of probable continuity between groups in consecutive rotations of the Sun, the character of the groups, their areas and their longitude and latitude have been carefully compared before accepting them as a recurrent group.

Ledger II. - Non-Recurrent Groups. This ledger contains those groups lasting for six days or longer which are not members of recurrent series.

§4. *Total Areas, Mean Areas and Mean Heliographic Latitudes of Sunspots and Faculæ in the Year 1952.*

This section contains total areas of sunspots and faculæ for each day in the year, together with mean areas and mean heliographic latitudes of sunspots and faculæ for each Rotation of the Sun during 1952. Similar annual mean values are also given.

§5. *Observations of Solar Filaments and Solar Flares made with the Spectrohelioscopes in the Year 1952.*

This section contains (1) measures of line-of-sight velocities of dark $H\alpha$ filaments seen on the Sun's disk near sunspots and (2) observations of solar flares in $H\alpha$ light. The observations were made principally with a spectrohelioscope lent by the Mount Wilson Observatory in the autumn of 1929 and set up at Greenwich in the south attic of the Main Building and, since 1950 February, at Herstmonceux in a spectrohelioscope room forming the ground floor of the dome housing the photo-heliograph. The instrument is of a type described by G. E. Halé in the *Astrophysical Journal*, 70, 265, 1929. The spectrum is formed by a Rowland grating ruled with 14,438 lines to the inch. The first order spectrum around $H\alpha$ is normally used, the scale being 1 mm. = 4.35 A. The width of the second slit is usually 0.1 mm. The diameter of the monochromatic image of the Sun's disk at the second slit is about 50 mm., of which a portion 28 mm. x 6 mm. is rendered visible by the rotating rectangular prisms. The eyepiece used gives an overall magnification of x40, approximately. A second spectrohelioscope of similar design, presented in 1949 by Mr. A. M. Newbegin, is also available when required so that simultaneous observations can be made by two observers. The observations during 1952 were made by H. Barton, P. S. Laurie, N. Rhodes and R. W. Teague.

ROYAL GREENWICH OBSERVATORY

Positions and Areas of Sunspots and Faculæ

For each day in the year

1952

GREENWICH PHOTO-HELIOGRAPHIC RESULTS, 1952

POSITIONS AND AREAS OF SUNSPOTS AND FACULÆ FOR EACH DAY IN THE YEAR 1952.

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 observation – Greenwich (G), Cape of Good Hope (C), Kodaikanal (K). (3) Date of photograph.

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.* Counterclockwise.

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 and expressed 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 for the time of photograph, the position angle of the Sun's axis from the north point, the heliographic longitude and latitude of the centre of the disk and the total areas of spots and faculæ for the day.