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Sunspot Activity During the Current Cycle—*A Review*

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A NEW cycle of sunspot activity commences with the appearance of small spots on the sun's surface at about latitude 30°. As the cycle advances the spots increase in size and frequency and at the same time show a progressive drift towards the solar equator until at the end of the cycle the average latitude of the spots is about ± 8°. Even before the end of a cycle, spots pertaining to the next cycle begin to appear at higher latitudes so that at the epoch of sunspot minimum there are four zones of activity upon the sun, two at about latitude 8° on either side of the equator and two between latitudes 25° and 35° in the two hemispheres. The duration of a cycle is the interval between two successive minima. The average value of this is 11.2 years, although individual cycles have been noticed with periods ranging from 9 to 13.6 years. The rise of activity from minimum to maximum is generally steeper than the fall from maximum to minimum.

Sunspot Activity During the Current Cycle.

The last sunspot minimum marking the commencement of the present cycle occurred about the middle of the first half of 1944. Since then the rise of activity has been steeper than usual. Table 1 which is based on the visual and photographic observations at Kodaikanal gives the number of days on which the sun's disc was free from spots, the number of new sunspot groups observed and the mean daily number of sunspot groups seen on the sun's disc during each month for the period Januray 1944 to May 1947.

During 1944 the sun's disc was absolutely free from spots on a little less than half the number of days in the year. In 1945 the number of such days was only 35, while since the beginning of 1946 there has not been a single spot-free day.

Fig. 1 gives a graphical representation of the growth of sunspot activity during the current cycle. The steep rise in activity since the last minimum is well brought out by the curve in the lower half of the diagram.

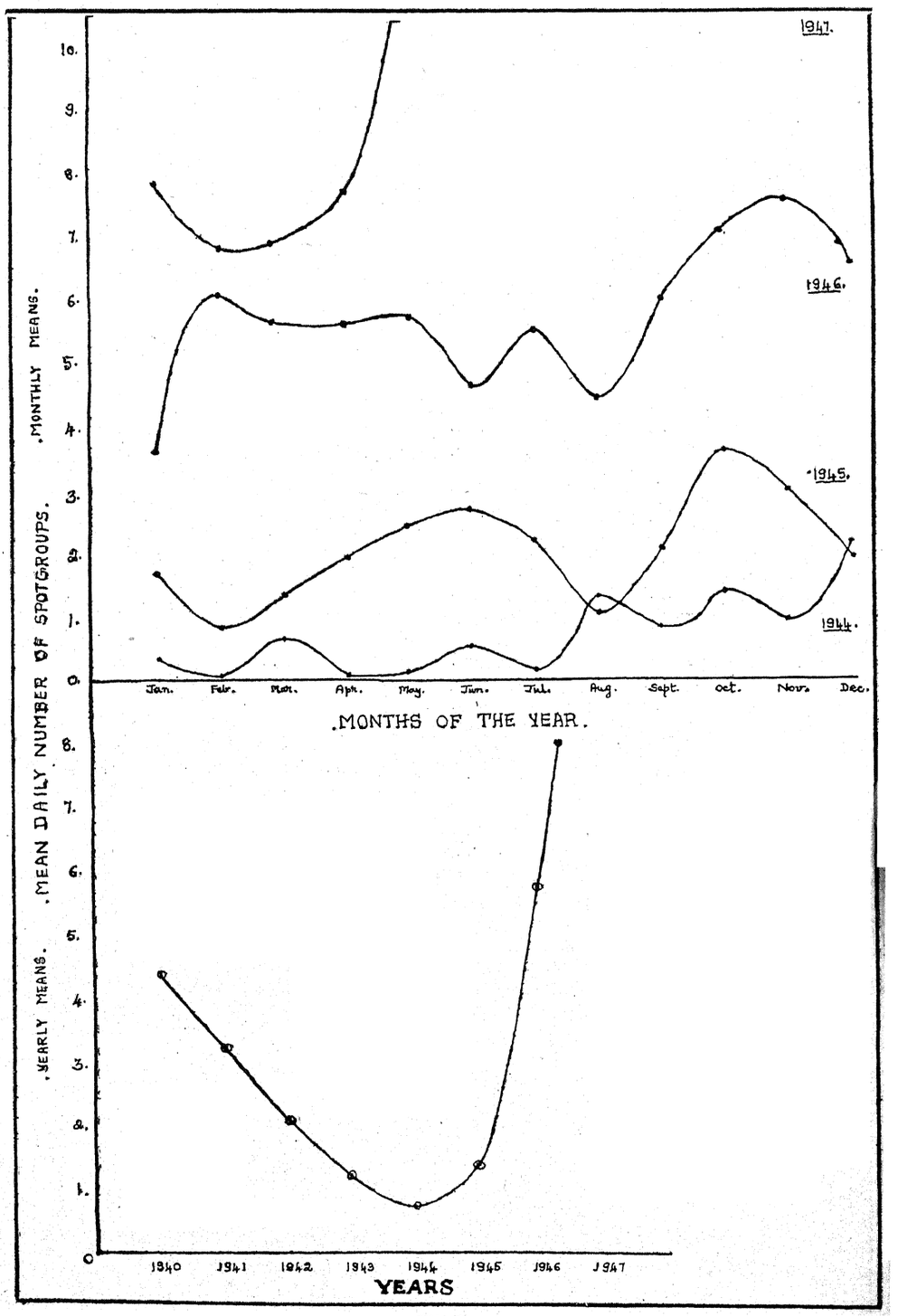
The Great Spot Groups of the Current Cycle.

A very significant feature of the current cycle has been the appearance of very large sunspot groups,-larger than any hitherto observed during nearly the last three quarters of a century. Two such groups appeared in 1946, one in February and the other in July.

(a) *Groups of 1946:-* The February group (Kodaikanal No. 8015) appeared at the east limb of the sun in the northern hemisphere on January 30th at a mean latitude of 27°. It crossed the central solar meridian on February 5th-6th and was last seen at the west limb of the sun on February 12th. This group consisted of two large spots, the following member being about twice the size of the leader. The group covered an area of approximately 4400- millionths of the sun's visible hemisphere as measured on the photoheliogram taken at Kodaikanal on the morning of February 5th. It stretched across the sun's disc over about 30° of longitude nearly in an east-west direction. This group reappeared a second time with greatly diminished

Table I.

Year.	No. of days on which sun was observed.	No. of days on which sun's disc was free from spots	No. of new sunspot groups observed. N. Hemisphere.	S. Hemisphere.	Total.	Mean daily number of sunspot groups. Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual Mean.
1944	290	156	13	30	43	0·33	0·04	0·69	0·03	0·10	0·54	0·17	1·33	0·84	1·36	0·92	2·17	0·71
1945	305	35	42	70	112	1·6	0·8	1·3	2·0	2·5	2·7	2·2	1·0	2·0	3·6	2·9	1·9	2·0
1946	292	0	136	156	292	3·6	6·1	5·6	5·6	5·7	4·6	5·5	4·4	5·9	7·1	7·5	6·5	5·7
1947 Jan.-May.	129	0	73	100	173	7·8	6·8	7·0	7·7	10·7	—	—	—	—	—	—	—	—


1947.
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.MONTHS OF THE YEAR.
.MONTHLY MEANS.
.MEAN DAILY NUMBER OF SPOTGROUPS.
8.
7.
6.
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3.
2.
1.
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1940
1941
1942
1943
1944
1945
1946
1947
YEARS
.YEARLY MEANS.

Fig. 1

area between February 27th to March 12th when the leader had broken up into a number of tiny spots while the following spot had been reduced to a third of its original size. The group was again seen during two more successive rotations of the sun between the periods March 29th to April 10th and April 26th to May 8th. At its last appearance, it was no more than a single spot comparable in size to many observed in daily photographs.

The second large sunspot group of 1946 (Kodaikanal No. 8146) traversed the solar disc from July 20th to August 2nd. This was also in the northern hemisphere at a mean latitude of 22° and crossed the central meridian on July 27th when it had an area of 3900-millionths of the sun's visible hemisphere. It was a complex group composed of a few well-defined major spots and several smaller ones. This group reappeared in the second half of August much diminished in area and resolved into five or six distinct spots

(b) *The group of* 1947:- In February 1947 a bipolar spot group (Kodaikanal No. 8327) appeared in the southern hemisphere of the sun between latitudes 17° and 26°. Although larger in size than the usually observed spot groups, it was, however, only less than half the size of the group of July 1946. This group was visible from February 5th to 18th crossing the central meridian on the 11th. It was noticed again during three successive rotations of the sun in March, April and May. During its second appearance (March 3rd to 17th; Fig. 2), it had grown to nearly 2½ times its previous size and extended from latitude 17° to 27°. On March 10th when the group was over the central meridian of the sun its area was only slightly smaller than that of the large spot group of February 1946. The group appeared for the third time at the east limb of the sun on March 31st and crossed the central meridian on April 7th when it extended from latitude 17° to 31°. Unfavourable weather conditions associated with a cyclonic storm in the Bay of Bengal prevented observations from 11th to 14th during which period the group disappeared at the west limb. As measured on the photo-heliogram of April 6th, the group had a total area of 4900-millionths of the sun's visible hemisphere - *thus surpassing the record area of the spot group of February* 1946. This giant group of 1947 retained its bipolar character

Table II.

(All times in I.S.T. = G.M.T. + 05h. 30m.)

Year and month.	(a) Solar flares.	(b) Radio fade-outs.	(c) Magnetic storms.
1947 February.	7th - 08h. 28m. - Slight intensity; SE quadrant. 13th - 08h. 33m. - Slight intensity; SW quadrant.		16th to 17th: Storm of great intensity preceded by quiet conditions commenced at 08h. 29m. of 16th.
1947 March	7th - 08h. 17m. - Slight intensity; SE quadrant. 12th - 08h. 15m. - Slight intensity; SW quadrant. 14th - 08h. 50m. - Moderate intensity; SW quadrant. 15th - 08h. 10m. - Slight intensity SW quadrant.	3rd - 11h. 30m. to 13h. 30m. - Partial fade-out. 4th - 09h. 00m. to 16h. 30m. - Complete fade-out of all BBC frequencies. 5th - 06h. 30m. to 13h. 30m. - Partial fade-out at first and complete fade-out of all stations later. 6th - 07h. 30m. to 13h. 00m. - Partial fade-out of BBC frequencies. 10th - 09h. 00m. to 13h. 00m. - Partial fade-out. 16th - 13h. 00m. to 13h. 15m. - Dellinger type of fade-out. No trace of BBC, Australia and A.I.R. regional stations.	2nd to 4th : Storm of moderate intensity commenced at 09h. 29m. of 2nd and continued till 16h. 00m. of 4th. 8th to 9th: Moderate disturbance from 11h. 30m. of 8th to 03h. 30m. of 9th. 15th: Sudden disturbance from 14h. 12m. to 22h. 00m.

(a) Observed at Kodaikanal with the spectrohelioscope in Hα (b) Information kindly supplied by the Research Department of the A.I.R. (c) Recorded at the Magnetic Observatory, Alibag, Bombay.

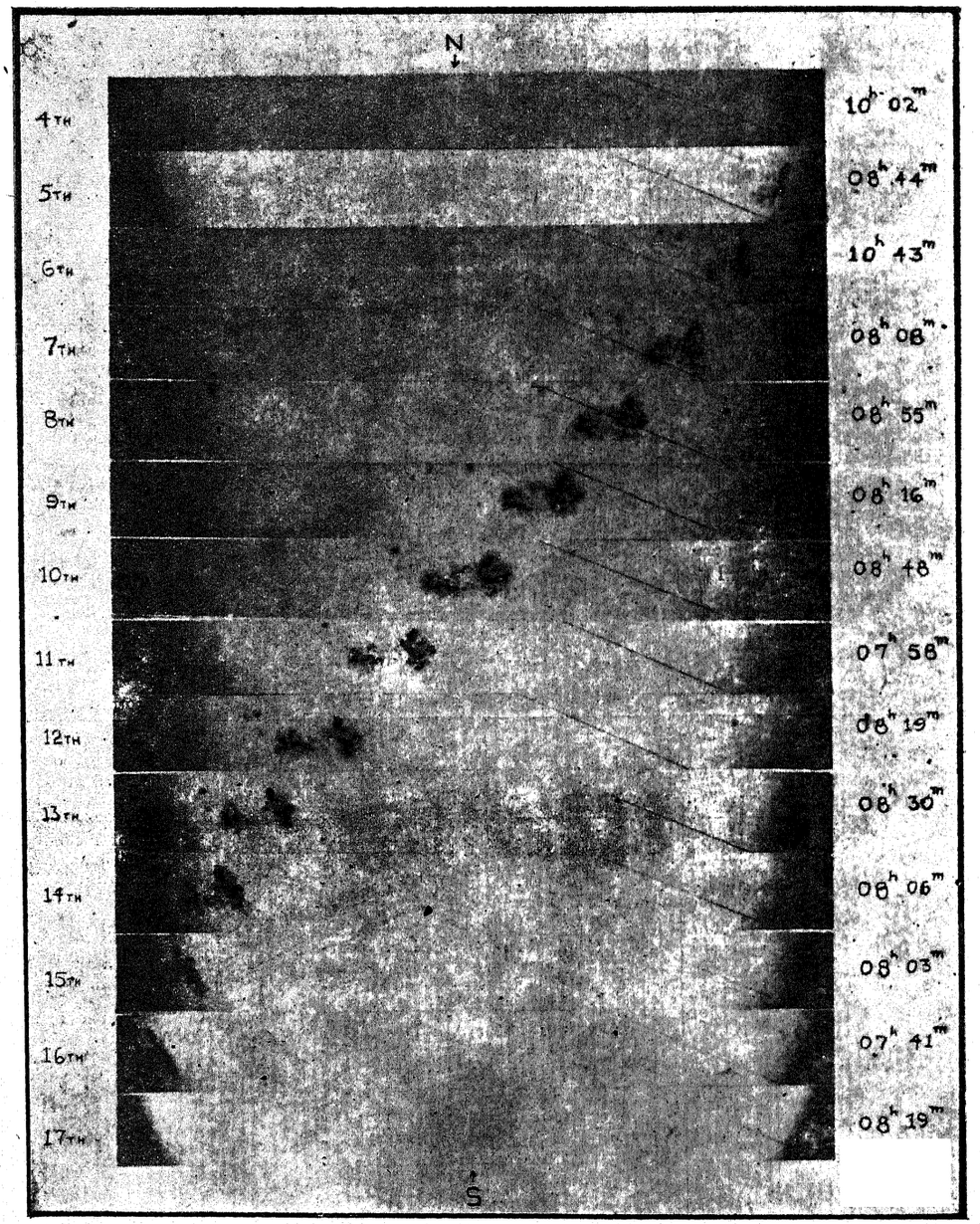

Fig. 2.—The Large Sunspot Group Of March 1947.

throughout its life history. During its first appearance in February, the leader was over twice as big as the follower. In March and April the following spot had grown enormously while the leader, though larger than in February was less marked in development. The following spot was about $2\frac{1}{2}$ times the size of the leading spot during the third appearance of the group in April. The group made its fourth and last reappearance between April 28th and May 11th, when it had very much dwindled in size and was no more conspicuous than the spots commonly observed on the sun.

(c) *Solar flares, terrestrial effects, etc., associated with the great spot group of* 1947:- Information relating to solar flares, short wave radio fade-outs and magnetic disturban-

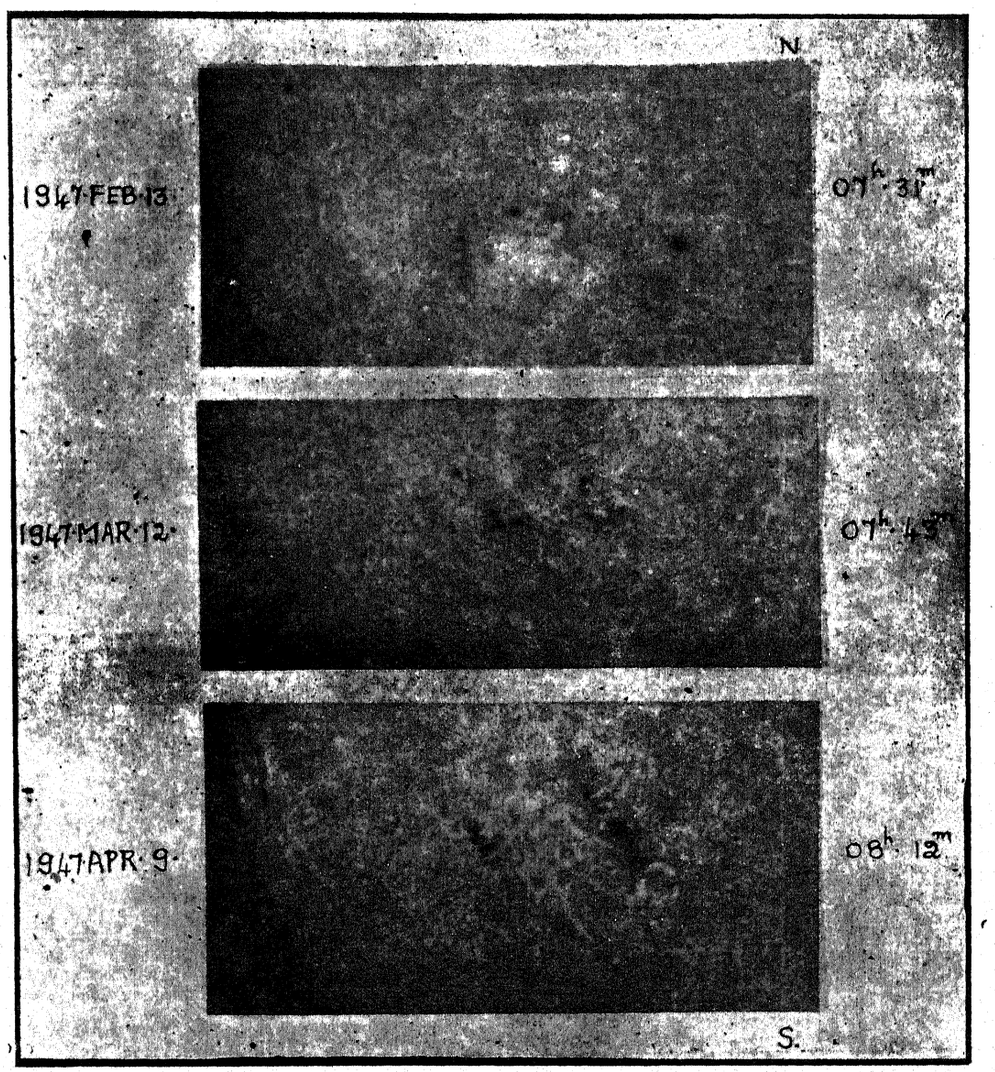

Fig. 3.—Spectroheliograms taken in the red (Hα) line of Hydrogen of the great sunspot group of February-March-April showing dark filaments and bright Hydrogen flocculi surrounding the sunspot group.

ces observed during the period of activity of the large spot group of 1947 are given in Table II. As compared with the group of February 1946, the group of March-April 1947 was markedly less active in these respects.

Typical spectroheliograms taken at Kodaikanal in the red ($H\alpha$) light of hydrogen which are reproduced in Fig. 3 bring out clearly the

Table III.

Kodaikanal No. of spot group.	Date of photo-heliogram on which area measured	Extent of spot group in latitude and mean latitude	Extent of spot group in longitude	Area.* (corrected for foreshortening.) Umbra.	Area.* (corrected for foreshortening.) Total.	Total area of group in terms of cross-sectional area of earth.	Total area/area of umbra.	Dimensions of follower.†	Dimensions of leader.†	Overall length of the group.†
8015	1946 Feb. 5.	20°-33°N (27°N)	30°	740	4400	104	5·9	74 X 52	65 X 30	189
8146	1946 July. 27.	17°-26°N (21°N)	21°	560	3900	92	6·9	—	—	135
8327	1947 Feb. 12.	17°-25°S (21°S)	22°	340	1700	40	5·0	33 X 27	54 X 35	166
	1947 Mar. 10.	17°-27°S (22°S)	24°	660	4200	96	6·2	61 X 49	57 X 38	122
	1947 Apr. 6.	17°-31°S (24°S)	27°	740	4900	116	6·6	89 X 51	31 X 28	189

* Expressed in millionths of the sun's visible hemisphere.
† In units of thousands of miles.

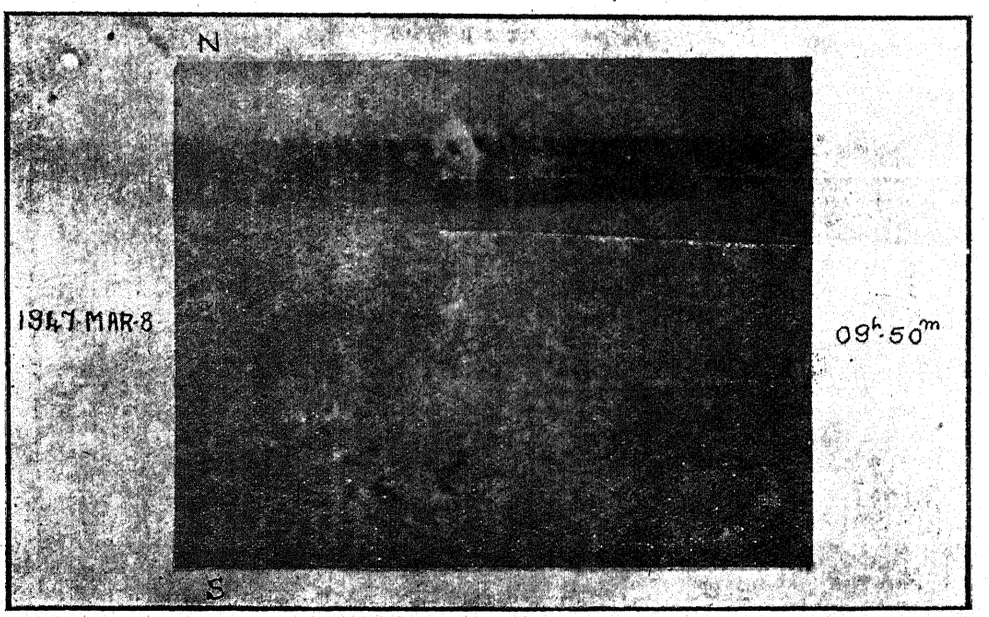

Fig. 4.—Spectroheliogram taken in the red (H_1) line of Hydrogen on 1947 March 8 showing a brilliant "Solar flare" in a sunspot group at the top of the photograph. The large sunspot group of March 1947 can be seen at the bottom of the photograph.

vortical structure of the hydrogen filaments in the neighbourhood of the spot group during its appearances in February, March and April.

The Hα spectroheliogram taken at 09 h. 50 m. on 1947 March 8 revealed a brilliant solar flare in a sunspot group at heliographic latitude 13°N and longitude 30°E. This can be seen at the top of Fig. 4. At the bottom part of the picture can be seen the great spot group of March 1947 before its central meridian passage.

(d) *Comparative dimensions of the spot groups:-* Table III gives the comparative dimensions of the three large spot groups of the current cycle.

Fig. 5 shows the appearance of the spot groups at about the time of their central meridian passage.

Comparison of Areas of Spot Groups as Measured at Kodaikanal, Greenwich and Mount Wilson.

On comparing the area of the sunspot group of February 1946 as measured at Kodaikanal with the corresponding figures reported by Greenwich[1] and Mount Wilson[2], it was found that the Kodaikanal value (4400-millionths) is lower than the other two by 500 and 1000-millionths respectively. Even after allowing for the uncertainty in the measurement of areas it was felt that the discrepancy between the Kodaikanal and Mount Wilson measurements was too large. In this connection the areas of some of the large groups listed in Nicholson's pamphlet[2] were measured on the Kodaikanal plates and also compared with the areas given by Greenwich. A comparative statement of the values is given in Table IV:-

From the table it will be seen that there is generally closer agreement between Kodaikanal and Greenwich values than between Kodaikanal and Mount Wilson values. The reason for the very large discrepancy between Kodaikanal and Mount Wilson figures for the area of the spot group of February 1946 is not clear. In a recent publication Elizabeth Srernberg Mulders[3] has given the figure of 5478-millionths of the visible solar hemisphere for the area of this spot group as determined by the U. S. Naval Observatory. Repeated measurements of our photoheliogram of 1946 February 5 by at least three different persons have failed to give an area which is appreciably higher than the figures given in Tables III and IV.

Magnetic Field of the Spot Group of April 1947.

Systematic photographs of the spectrum of the large spot group of April 1947 were taken with the newly constructed 20-foot grating spectrograph of this Observatory in the fourth order during the period 3-4-1947 to 8-4-1947. The spectrogram in the red region obtained on April 7 is shown in Fig. 6 (a). The central strip (marked 1) in the top half of the Figure is the spectrum of the penguin-shaped umbra of the preceding spot (Fig. 7); the photospheric spectrum (marked 2) is given on either side of it for comparison. The lower half (Marked 3) is the spectrum of the umbra of the spot and of the surrounding penumbral and photospheric regions taken simultaneously with a long slit.

Table IV.

Date.	Mean latitude of spot group.	Area. (millionths of the sun's visible hemisphere. Kodaikanal.	Greenwich.	Mt. Wilson.	Kodaikanal minus Greenwich	Kodaikanal minus Mt. Wilson.
1905 Oct. 20.	+ 14°	2900	2900	3000	0	— 100
1907 Feb. 12.	— 17°	1900	2200	2600	— 300	— 700
1907 June 20.	— 14°	1900	2200	2500	— 300	— 600
1925 Dec. 29.	+ 23°	2400	2800	2900	— 400	— 500
1926 Jan. 24,	+ 21°	3200	3400	3700	— 200	— 500
1928 Sept. 27.	— 15°	2500	2200	2600	+ 300	— 100
1937 Jan. 31.	— 10°	2100	2200	2500	— 100	— 400
1937 July 29.	+ 32°	3000	3000	2800	0	+ 200
1937 Oct. 5.	+ 9°	2800	>3000	2700	≈ —200	+ 100
1938 Jan. 18.	+ 17°	3100	3100	3100	0	0
1938 July 15.	— 11°	2300	2500	2500	— 200	— 200
1938 Oct. 12.	+ 17°	2900	≈2900	3000	0	— 100
1939 Sept. 10.	— 15°	2600	2400	2500	+ 200	+ 100
1946 Feb. 5.	+ 27°	4400	4900	5400	— 500	—1000
1946 July 27.	+ 22°	3900	≈4000	3700	≈ —100	+ 200

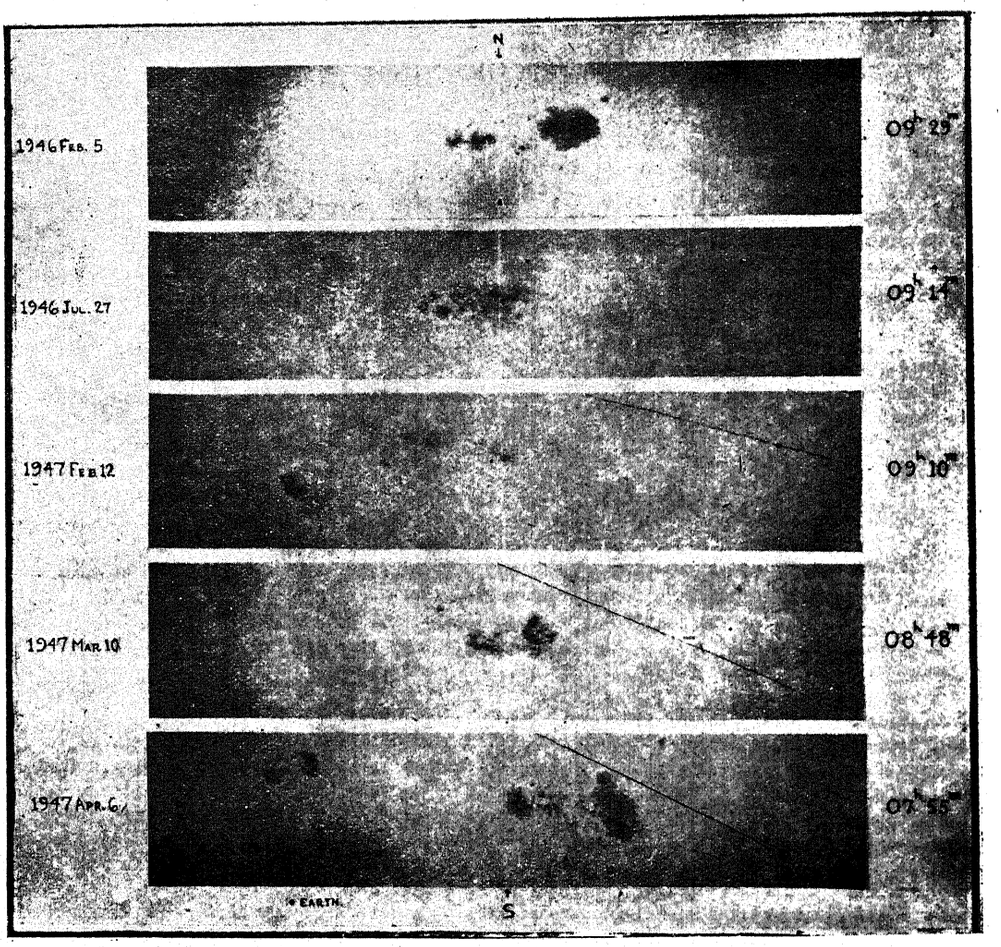

Fig. 5.—The Great Sunspot Groups Of 1946 and 1947.

As compared with the spectrum of the photosphere, the spectrum of the spot reveals many interesting features. Many photospheric lines appear considerably broadened in the spot while some of the lines appear as doublets or triplets. In addition to this, the spot spectrum shows several new lines which are absent in the photospheric spectrum. On the original negative the iron line λ6173.348 appears as a clear triplet in the spectrum of the spot (Fig. 6b), while the iron line λ6213.443 appears as a doublet (Fig. 6c). The magnitude of the separation between the extreme components of the triplet and those of the doublet were measured with a view to estimating the intensity of the magnetic field in the spot which is responsible for the splitting of these two lines. Assuming the figures given by Hale and coworkers[4] for the magnetic splitting of these two lines in laboratory experiments the maximum value of the field strength at the centre of the umbra of the preceding spot of 1947 April 7 works out to be about 3300 gauss.

References

1. H.W. Newton, *The Observatory*, 1946, 66, 267.
2. Seth B. Nicholson, *Astronomical Society of the Pacific*, Leaflet No. 207-May 1946; Seth B. Nicholson and Joseph O. Hickok, *Publ. of the Astro. Soc. Pacific*, 1946, 58, 86.

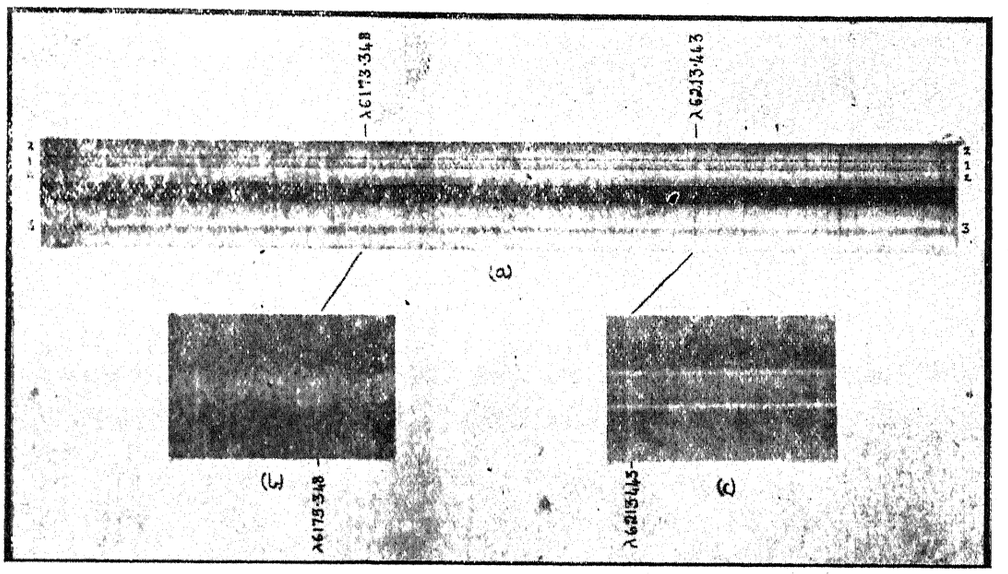

Fig. 6.—Spectrum of the giant sunspot group of 1947 April 7 taken with the newly constructed 26 feet grating spectograph, in the 4th order red region showing the magnetic splitting of the iron lines λ 6173.348 (triplet) and λ 6213.443 (doublet).

Fig. 7.—An enlarged photograph of the great spotgroup of April 1947—*the biggest sunspot observed during the last three quarters of a century*—just before its central meridian passage. The black disc at the bottom left corner represents the relative size of the earth.

3. Elizabeth S. Mulders, *Publ. of the Astro. Soc. Pacific.* 1947, 59, 12.

4. G.E. Hale, *Astro. Jour.*, 1908, 28, 326; G.E. Hale, F.H. Seares, A. Van Maanen, and F. Ellerman, *Hid*, 1918, 47, 235.