The five greatest sunspot groups

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Remarkably, the five largest recorded sunspot groups all occurred during a period of just over five years, from 1946 February to 1951 May, during Solar Cycle 18. These are the only groups known with areas greater than 4,500 millionths of the Sun's visible hemisphere. This paper examines the white-light activity of the groups.

Introduction

Most BAA solar observers will be aware that the largest recorded sunspot group appeared during 1947, and perhaps will know that it had an area of about 6,000 millionths of the Sun's visible hemisphere (msh). They have probably seen a photograph of the group, such as that shown in Figure 1.

This paper shows the white-light development of this great sunspot group,[1] and four other great sunspots groups that were observed between 1946 February to 1951 May, during Cycle 18. All five groups had areas greater than 4,500msh and these are the only examples recorded with such large extents.[3] Various sources of material have been used in this research, such as reports and papers from past issues of the BAA *Journal*, as well as solar drawings made at Mt Wilson Observatory, USA and by the Japanese solar observer Hisako Koyama, together with other material belonging to the author and available online.

The paper begins by describing Solar Cycle 18, based on the compiled BAA group mean daily frequencies, together with dates for when the five great sunspot groups occurred during the cycle. This is followed by a description of the passage of the five groups, including their appearance on previous and/or subsequent solar rotations.

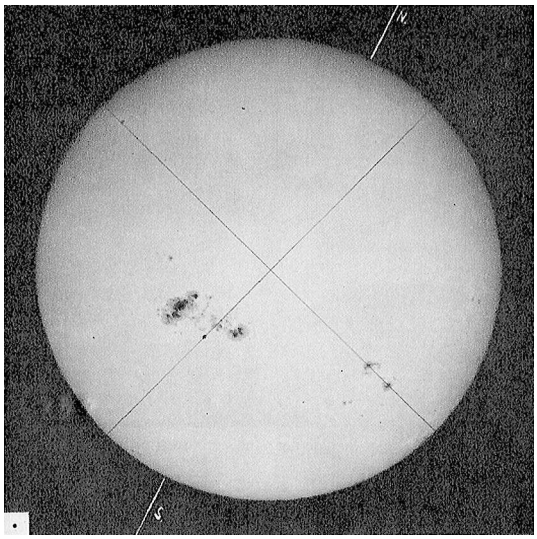

Figure 1. The Great Sunspot of 1947 (Greenwich group number 14886). Photograph from the Royal Observatory, Greenwich, 1947 Apr 7.[7]

Cycle 18

Based on the peak smoothed International Sunspot Number,[8] Cycle 18 was the third-strongest solar cycle of the 20th century (after Cycle 19, peaking in early 1958, and Cycle 21, peaking in late 1979). The cycle began in 1944 February, peaked in 1947 May with a smoothed International Sunspot Number of 219 and ended in 1954 April. Figure 2 shows in blue the average number of groups over Carrington synodic periods (approximately 27 days), from the BAA *Journal*.[9–16] (Unfortunately, these synodic rotation averages were not included in the *Journal* solar report covering the period from 1950 June.[16]) The red curve gives the smoothed number of groups. Finally, the green vertical lines represent the dates of the five great sunspot groups – note that two of these occurred on the rise to maximum, two close to maximum and one on the latter part of the declining phase. This distribution of large sunspots within a cycle is unusual – two-thirds of large sunspot groups occur after sunspot maximum.[17]

The two great groups from 1946, referred to by their Greenwich numbers 14417 & 14585, are probably the same group from different solar rotations. The two great groups from 1947 – 14851 & 14886 – are from successive rotations. These four great groups, together with the one from 1951, are described separately below.

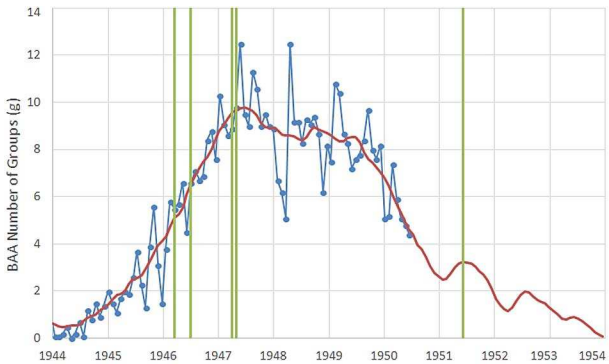

Figure 2. BAA mean daily frequency for the number of groups and dates of the five greatest sunspot groups.

Greenwich group 14417 (1946 February)

This great sunspot group appeared around the eastern limb on 1946 Jan 29 as a single, irregularly shaped penumbral sunspot at a heliographic latitude of 26°N. As Figure 3 illustrates, based on Mt Wilson drawings,[17,18,19] and a photograph,[20] by the next day a following penumbral sunspot appeared on the limb. When the follower sunspot had fully rotated onto the disc on Jan 31, the bipolar nature of this group could be seen, with the follower being the largest sunspot. Several umbrae were present within the two main penumbral sunspots.

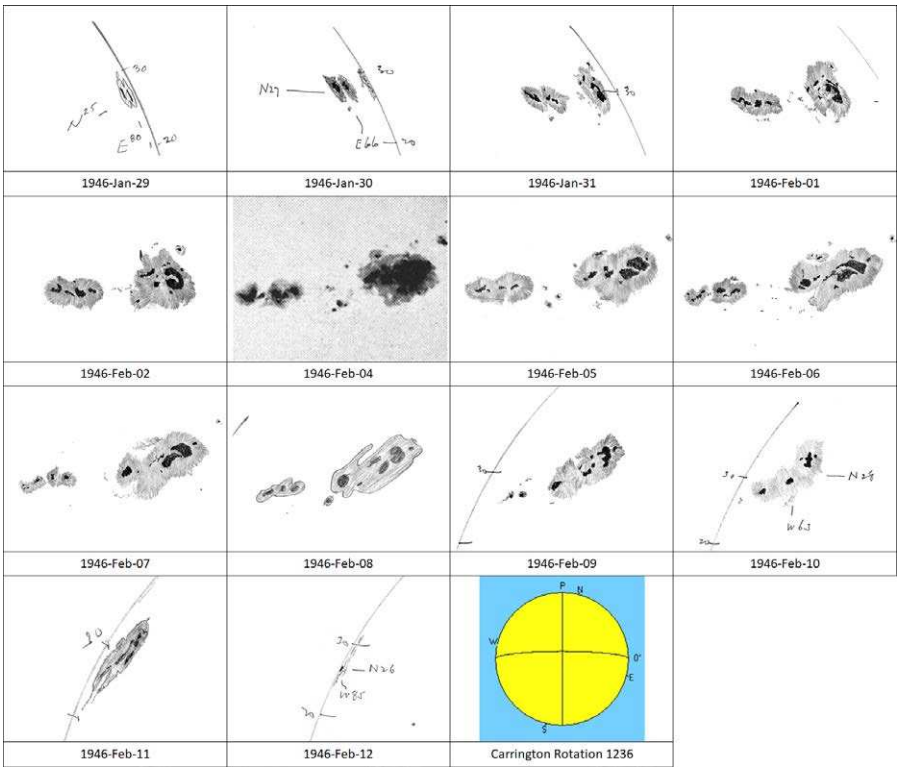

Figure 3. Passage of Greenwich group 14417 based on drawings,[18,19] and a photograph,[20] from Mt Wilson.

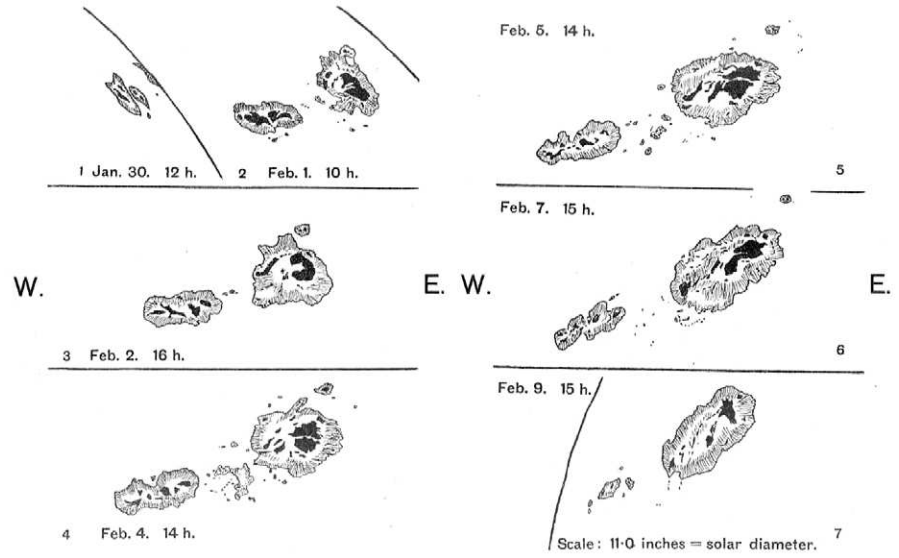

Figure 4. Drawings of the Great Sunspot of 1946 February, by Dr M. A. Ellison.[21]

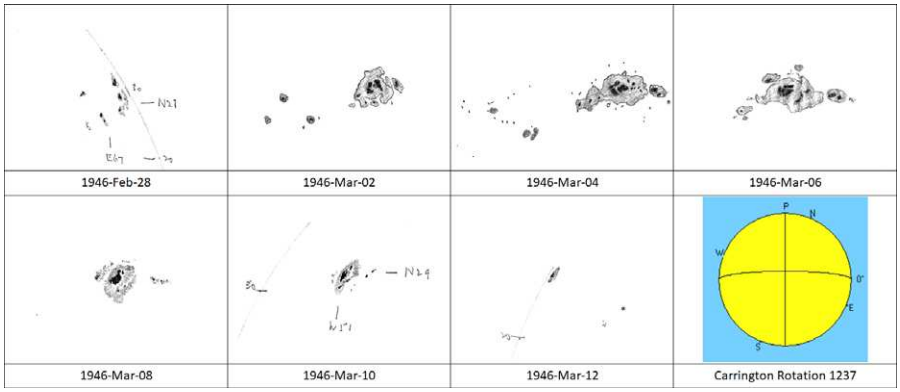

Figure 5. Passage of Greenwich group 14451, based on Mt Wilson drawings.

On Feb 1, the group had an area of 4,799msh (based on Greenwich sunspot group data).[4] As it neared the central meridian, a few small penumbral sunspots and pores appeared between the two main sunspots and at the following (east) part of the group. The main umbra of the following sunspot had separated into two between Feb 2 & 5. The leader sunspot had split by Feb 6, although it appeared as one penumbral sunspot again by Feb 8. The group obtained its maximum area of 5,202msh on Feb 7 (see Table 1), when it also obtained its maximum longitudinal extent of 27° (330,000km). The leader had decayed by Feb 9 and rotated off the disc on Feb 10. The follower remained on the disc for a further two days, with it last seen as a very slender sunspot near the limb on Feb 12 – its latitudinal extent remained undiminished.

Note that for Figure 3 and similar figures, the sub-image scale of drawings and photographs are all the same – approximately 30° in longitude by 23° in latitude when near the central meridian. The drawing orientation is shown in the bottom right of each figure (the rotation axis being vertical and east to the right). The Mt Wilson drawings were typically drawn at a local time of 10h or 18h UT. Figure 3 also shows differences in drawing styles and detail between Mt Wilson observers.

Figure 4 shows drawings of the passage of group 14417 by BAA member Dr Ellison, using a disc diameter of 11 inches.[21] These show similar or in some cases more detail than the Mt Wilson drawings, although some days are missing due, presumably, to cloudy weather in February.

As Table 1 shows, the great sunspot returned on two subsequent rotations as Greenwich group numbers 14451 & 14478, albeit at reduced areas. Figure 5 shows the passage for the second rotation (every other day) – the largest sunspot was still the follower, with a maximum area on Mar 4 of 1,741msh and a longitudinal extent of 31° (376,000km). As the group progressed towards the western limb, all the leader sunspots decayed such that on Mar 11 the area was just 850msh and there was a much-reduced longitudinal extent of 7°. A single, small penumbral sunspot was close to the western limb on Mar 12.

On the third rotation (Figure 6), the group was much diminished and without any particular structure – it appeared as a collection of small penumbral sunspots and pores. Its total area obtained a maximum for this rotation on Apr 2, at 768msh (the group would have still been visible with the protected naked eye). On this date, the longitudinal extent of the group was 11°. Figure 7 shows the evolution of group area for the three rotations (area is plotted against central-meridian distance, with east being negative; hence time increases left to right).

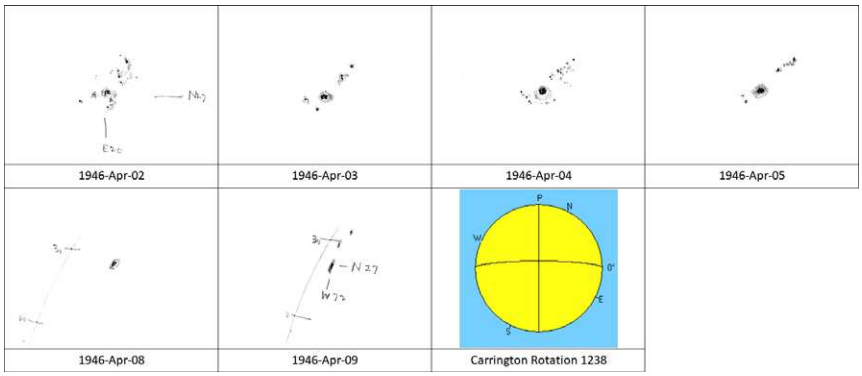

Figure 6. Passage of Greenwich group 14478, based on Mt Wilson drawings.

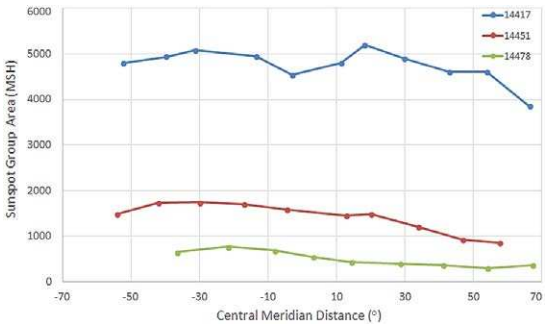

Figure 7. Greenwich sunspot area for groups 14417, 14451 & 14478 (1946 January to April).

Table 1. Information on group 14417 & subsequent rotations

Greenwich group number	*Mt Wilson group number*	*Appearance & disappearance dates*		*Mean lat. (°)*	*Mean long. (°)*	*Max. area (msh)*	*Max. area date*	*Carrington rotation*
14417	**7943**	**1946 Jan 29**	**1946 Feb 12**	**26.3**	**294.8**	**5202**	**1946 Feb 7**	**1236**
14451	7978	1946 Feb 28	1946 Mar 12	28.0	276.0	1741	1946 Mar 4	1237
14478	8006	1946 Mar 29	1946 Apr 9	26.8	259.6	768	1946 Apr 2	1238

Greenwich group 14585 (1946 July)

A few months after the first great sunspot group of Cycle 18, the second appeared around the eastern limb on 1946 Jul 19, as shown in Figure 8 and with details given in Table 2. By the following day it became clear that this group, at latitude 22°N, would be a large, complex, single penumbral sunspot. As the sunspot progressed towards the central meridian, more individual penumbral sunspots appeared to break away from the original.

As shown in Figure 9, on Jul 25 there were many nearby penumbral sunspots throughout the group (the 'N' and 'S' indicate the north and south magnetic fields as determined at Mt Wilson). Changes within the penumbra and in the size and position of umbrae occurred from day to day. Figure 10 shows the group on Jul 27, observed by BAA member Mr E. J. Harris using an 8-inch refractor (stopped down to 1.5 inches) at Temple Observatory, Rugby.[12] The group obtained its maximum area of 4,720msh on Jul 29 as it neared the western limb, when its longitudinal extent was 18° (223,000km). It appeared to break apart on Jul 31 and it was last seen on Aug 2, as a slender leader with two smaller followers.

This group reappeared on Aug 17 as group 14620, with a much-reduced size and with the follower being the larger sunspot.

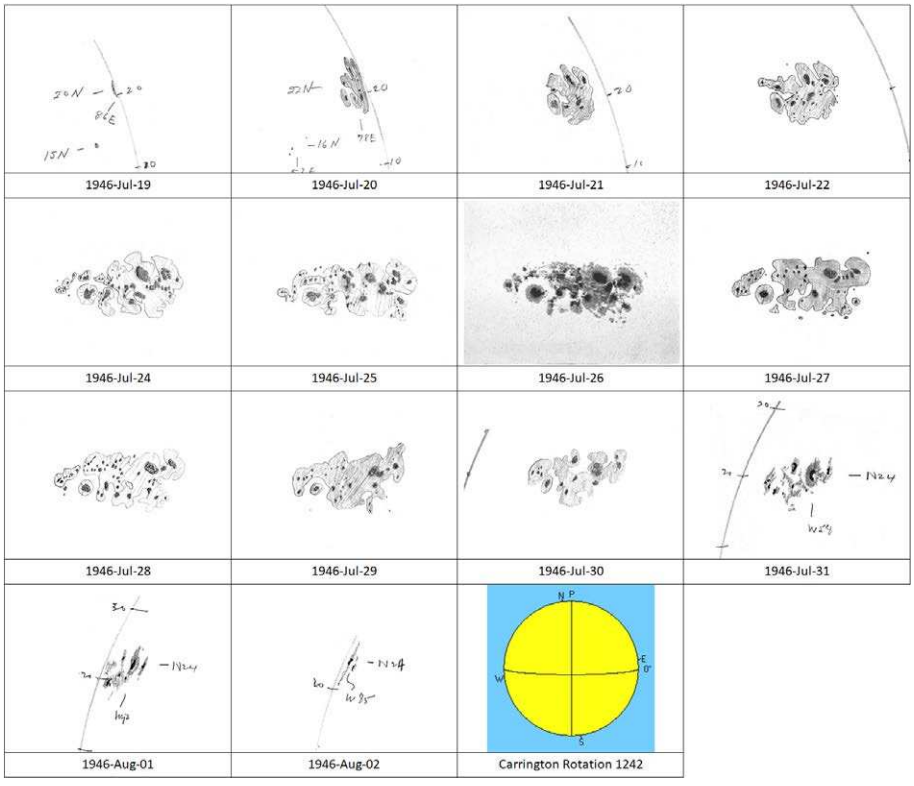

Figure 8. Passage of Greenwich group 14585, based on Mt Wilson drawings and a photograph.[22]

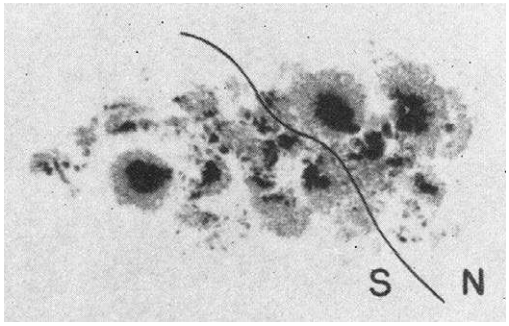

Figure 9. Mt Wilson photograph from 1946 Jul 25.[23]

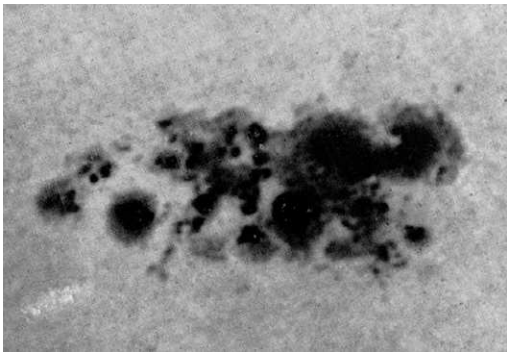

Figure 10. Group 14585 on 1946 Jul 27, by BAA member Mr E. J. Harris.[12]

Table 2. Information on group 14585 & subsequent rotation

Greenwich group number	*Mt Wilson group number*	*Appearance & disappearance dates*		*Mean lat. (°)*	*Mean long. (°)*	*Max. area (msh)*	*Max. area date*	*Carrington rotation*
14585	**8129**	**1946 Jul 19**	**1946 Aug 02**	**22.1**	**197.0**	**4720**	**1946 Jul 29**	**1242**
14620	8163	1946 Aug 17	1946 Aug 30	23.3	182.1	988	1946 Aug 20	1243

Figure 11 shows the passage of the group – including the development of a number of the leading penumbral sunspots and the splitting of the follower into two parts. Greenwich data indicate that the maximum area was obtained on Aug 20 (Table 2), at 988msh (an easy protected-naked-eye group). On Aug 24, a maximum longitudinal extent was obtained of 23°. As it neared the western limb, the number and size of sunspots within the group diminished.

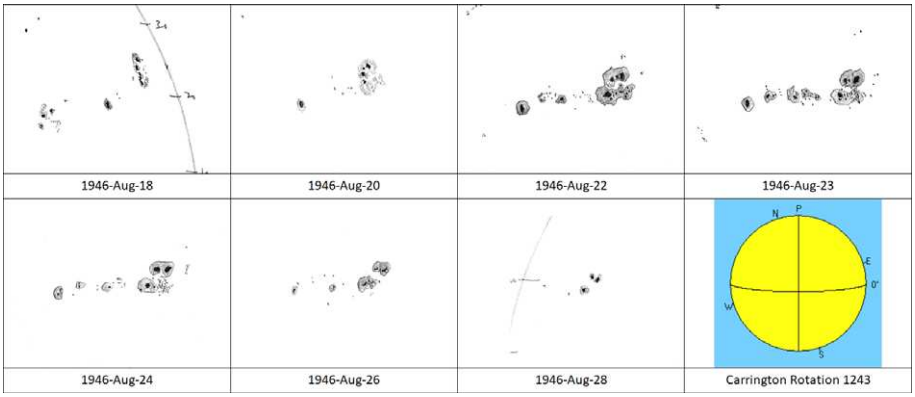

Figure 11. Passage of Greenwich group 14620, based on Mt Wilson drawings.

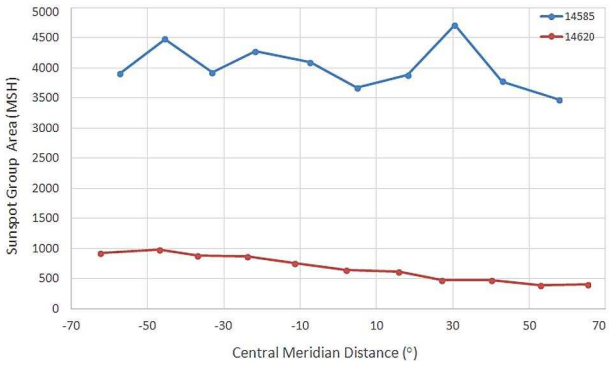

Figure 12. Greenwich sunspot area for groups 14585 & 14620 (1946 July and August).

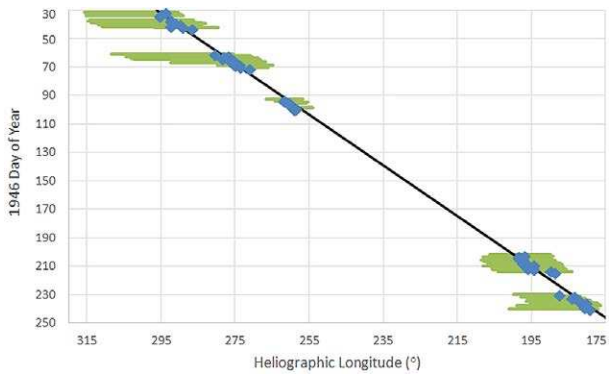

Figure 13. Longitude evolution of groups 14417 & 14585, including subsequent rotations.

Figure 12 shows the change in group area for both rotations – there was some daily variation for the first rotation, while there was a steady decrease for the second.

Tables 1 & 2 include the mean latitude and longitude of the group based on Greenwich data. It can be seen that there was a longitude drift from rotation to rotation. This is expected as the longitude is based on a fixed rotation rate, whereas differential rotation occurs for a gaseous body such as the Sun.

Figure 13 shows the evolution of the longitudinal extent of the two 1946 great groups and for their subsequent rotations. The blue diamonds give the longitude of the largest sunspot, while the green lines indicate the longitudinal extent of the group. These values have been derived using full-disc Mt Wilson drawings and the program *Helio Viewer* to measure the various longitudes.[24] It is clear that there is a constant drift for all of the five rotations. This was pointed out at the time,[25] with the conclusion that the two 1946 great sunspot groups were actually from the same region of the photosphere. The mean reduction in longitude per synodic rotation is 15.3° (based on the mean longitude of the largest sunspot within the group for all five rotations, as shown by the black line in Figure 13). This is significantly higher than would be indicated by differential rotation alone, indicating a proper motion of at least 7° per rotation.[17]

Greenwich group 14851 (1947 March)

On 1947 Feb 6, a small collection of sunspots was seen close to the eastern limb at a latitude of 21°S (group 14813). As shown in Figure 14, based on disc drawings from Mt Wilson and Hisako Koyama,[26–28] this group developed rapidly, with several following penumbral sunspots appearing by Feb 8 and throughout the whole group by Feb 10, when it had its maximum area of 2,944msh (Table 3). It reached the central meridian on Feb 11. The area of the group changed little as it neared the western limb – it had an area of 2,938msh on Feb 15, when it had a longitudinal extent of 23° (283,000km). The group rotated off the disc three days later as a single, slender penumbral sunspot.

On the next rotation, two penumbral sunspots appeared near to the eastern limb on Mar 3, at a similar latitude and longitude to those of the group observed on the previous rotation. When this group, 14851, had rotated further onto the disc (Figure 15), it primarily consisted of three nearby penumbral sunspots, with the southern two sunspots being quite irregularly shaped. On Mar 5, the total area was already 2,579msh. Over subsequent days, the penumbral sunspots appeared to merge and extend in longitude

Table 3. Information on group 14851 & previous rotation

Greenwich group number	*Mt Wilson group number*	*Koyama group number*	*Appearance & disappearance dates*		*Mean lat. (°)*	*Mean long. (°)*	*Max. area (msh)*	*Max. area date*	*Carrington rotation*
14813	8392	18	1947 Feb 5	1947 Feb 18	–21.2	84.9	2938	1947 Feb 10	1249
14851	**8438**	**40**	**1947 Mar 3**	**1947 Mar 16**	**–23.3**	**91.2**	**4554**	**1947 Mar 12**	**1250**

(sunspots to the northeast and northwest were from other groups). Some regions of photosphere were seen within the main sunspot, especially when the group was in the western hemisphere. Figure 18 shows group 14851 when it was just before the central meridian on Mar 9. The group had an area of slightly over 4,500msh on Mar 11 & 12 before reducing in size slightly as it neared the western limb, although its longitudinal extent was just over 20° (246,000km). Throughout its passage, group 14851 had many umbrae within the main sunspot and pores around it. On Mar 16, the group appeared as a highly elongated sunspot close to the western limb.

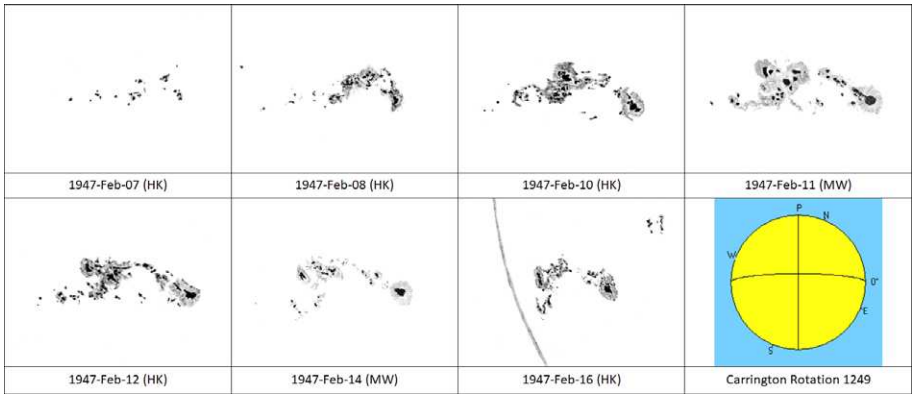

Figure 14. Passage of Greenwich group 14813, based on Mt Wilson (MW) and Hisako Koyama (HK) drawings.[26–28]

Greenwich group 14886 (1947 April)

Group 14851 from 1947 March reappeared around the limb on Mar 30 as a single penumbral sunspot (Figure 16) – this was the start of the passage of the largest recorded sunspot group. By the following day, a much larger, irregularly shaped sunspot had appeared around the limb. The complete group, 14886, was not on the disc until Apr 1, when it already had an area of 5,400msh. The group was quite irregular, with regions of photosphere seen between the leader and follower penumbral sunspots. Many umbrae were present throughout the group, as were a small number of pores. The central portion changed the most as it crossed the central meridian on Apr 7 (Figure 18). It obtained its maximum area of 6,132msh on Apr 8, with a longitudinal extent of 25° (300,000km). As the group progressed towards the western limb, the leading penumbral sunspot reduced in size to leave a few small leaders and a large, irregular following penumbral

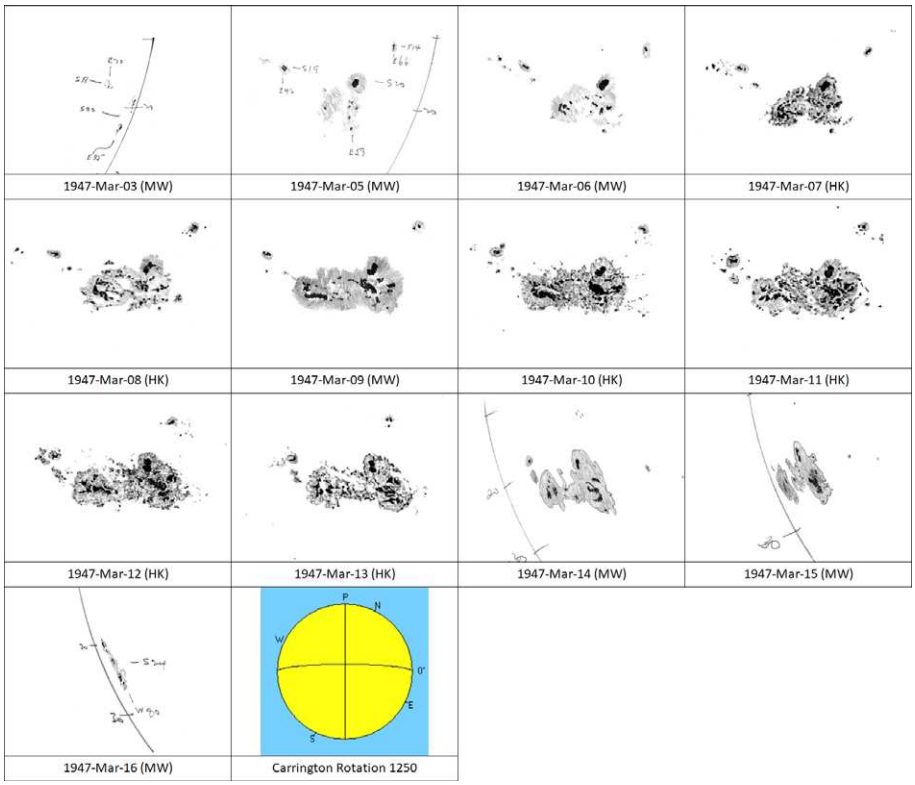

Figure 15. Passage of Greenwich group 14851, based on Mt Wilson (MW) and Hisako Koyama (HK) drawings.

Table 4. Information on group 14886 & subsequent rotation

Greenwich group number	*Mt Wilson group number*	*Koyama group number*	*Appearance & disappearance dates*		*Mean lat. (°)*	*Mean long. (°)*	*Max. area (msh)*	*Max. area date*	*Carrington rotation*
14886	**8478**	**59**	**1947 Mar 30**	**1947 Apr 14**	**–24.5**	**81.9**	**6132**	**1947 Apr 8**	**1251**
14933	8527	86	1947 Apr 29	1947 May 11	–24.8	67.7	782	1947 May 1	1252

sunspot on Apr 13 (area 3,617msh). The group was last seen on Apr 14 (Table 4).

On the fourth and last rotation, the greatest sunspot group had diminished significantly, as shown in Figure 17. It still obtained a maximum area of 782msh on May 1 (Table 4), although its longitudinal extent was almost unchanged at 21°. The evolution in sunspot area over the four rotations is shown in Figure 19.

The longitude evolution of the four 1947 rotations given in Tables 3 & 4 is shown in Figure 20. Based on the evolution of the largest sunspot (the black line), it can be seen that there is a difference between the first rotation (group 14813) and the other three rotations (groups 14851, 14886 & 14933). Projecting the black line back to the first group shows that only the leading part of group 14813 overlaps with the other three subsequent rotations. This is illustrated in Figure 21, where the blue box shows the location of the region of photosphere that matches the subsequent rotations, assuming the same longitudinal drift as the last three rotations and a longitudinal extent of 20°. This includes only the leading part of group 14813 (Koyama group 18) but also Koyama group 20.

There is a longitude drift of 12.1° per rotation based on the largest sunspot, and 7.8° per rotation based on the mean longitude of the group. At a mean latitude of 24.5°S, the drift is close to that expected for the largest sunspot's differential rotation and 4° of proper motion per rotation, based on the mean longitude (all from the last three rotations).[17]

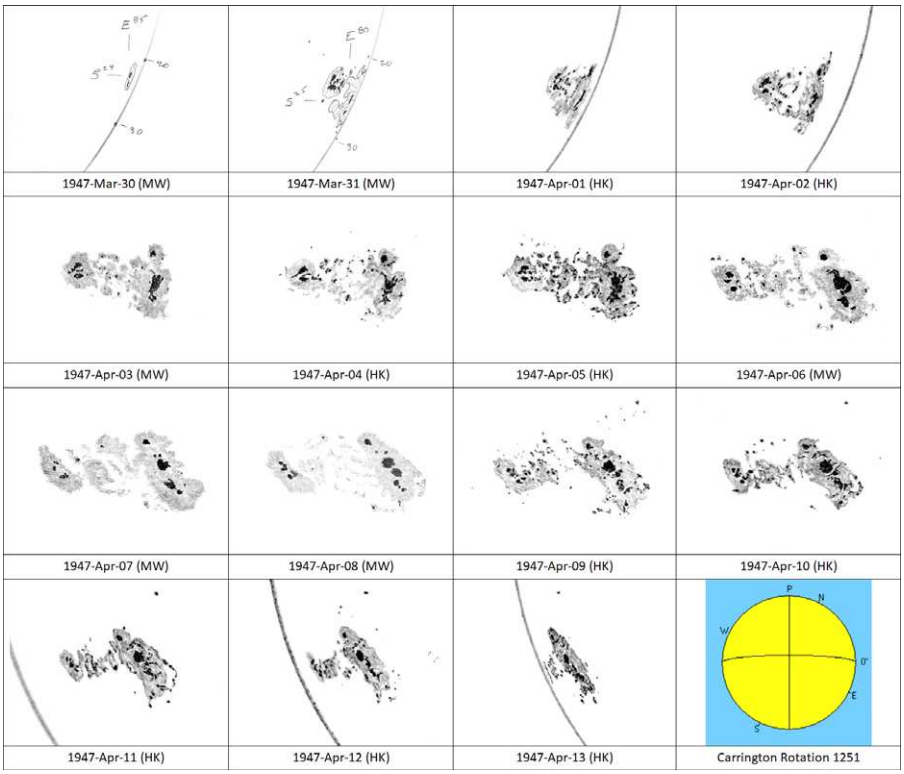

Figure 16. Passage of Greenwich group 14886, based on Mt Wilson (MW) and Hisako Koyama (HK) drawings.

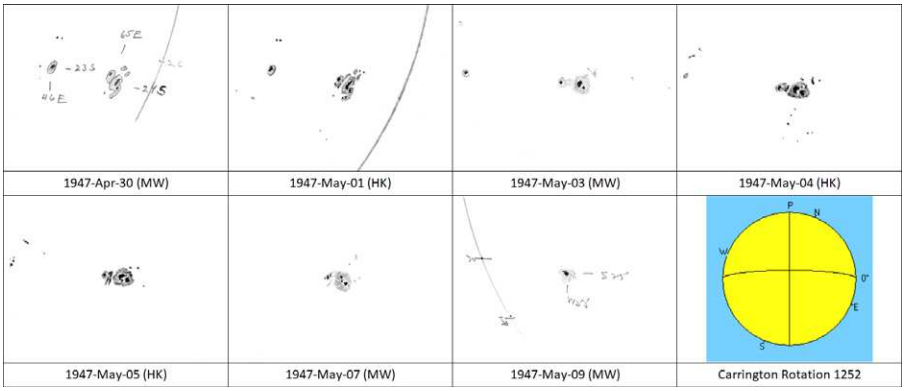

Figure 17. Passage of Greenwich group 14933, based on Mt Wilson (MW) and Hisako Koyama (HK) drawings.

Greenwich group 16763 (1951 May)

On 1951 Apr 12, two irregularly shaped penumbral sunspots appeared around the eastern limb at latitude 12°N. As these rotated further onto the disc on Apr 14, as shown in Figure 22, it could be seen that they formed a moderately sized bipolar group, with the follower being the more irregularly shaped sunspot – this was group 16745 (Table 5). As the group progressed towards the central meridian, the follower grew in size and included many umbrae and a few surrounding pores. This follower then appeared to decay into several parts. The group obtained its maximum area of 2,553msh on Apr 19, when it had a longitudinal extent of 13° (155,000km). As the group neared the western limb, only several small penumbral sunspots were seen – both the larger leader and follower sunspots had decayed.

On the next rotation, a single small penumbral sunspot appeared on the eastern limb on May 9 (group 16763) at latitude 13°N. By the next day, an irregular following penumbral sunspot with a much larger latitudinal extent appeared. It was not until May 11 that the full extent of the group was seen and then it had an area of 2,500msh. As shown in Figure 23, the following penumbral sunspot rapidly grew in size and contained many large umbrae. On May 16, the group was near the central meridian

Table 5. Information on group 16763, with previous & subsequent rotations

Greenwich group number	*Mt Wilson group number*	*Koyama group number*	*Appearance & disappearance dates*		*Mean lat. (°)*	*Mean long. (°)*	*Max. area (msh)*	*Max. area date*	*Carrington rotation*
16745	10639	998	1951 Apr 12	1951 Apr 25	12.1	87.9	2553	1951 Apr 19	1305
16763	**10662**	**1009**	**1951 May 9**	**1951 May 22**	**13.0**	**86.8**	**4865**	**1951 May 19**	**1306**
16792	10690	1023	1951 Jun 5	1951 Jun 18	13.7	89.0	1354	1951 Jun 6	1307

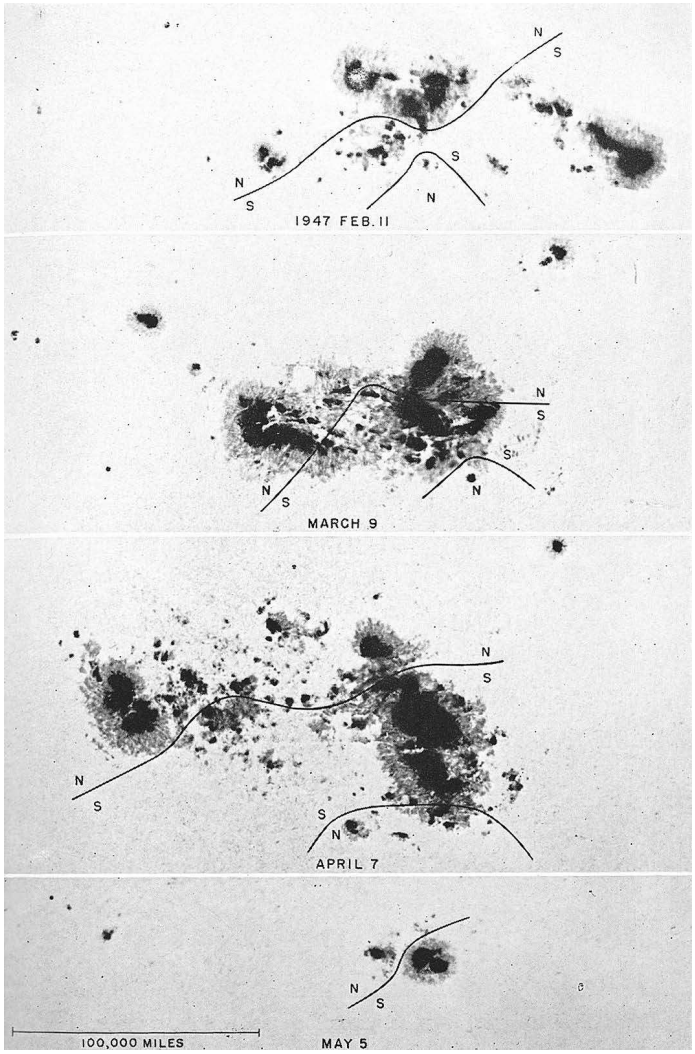

Figure 18. Mt Wilson photographs of groups 14813, 14851, 14886 & 14933 (1947 February to May).[29]

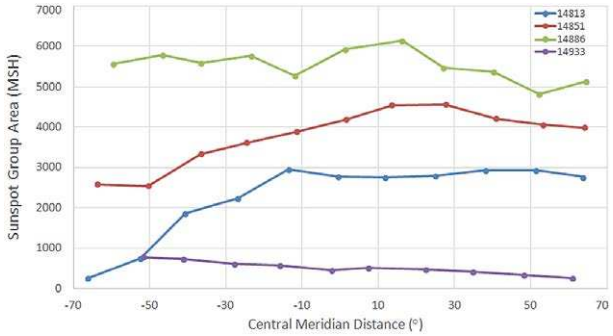

Figure 19. Greenwich sunspot area for groups 14813, 14851, 14886 & 14933 (1947 February to May).

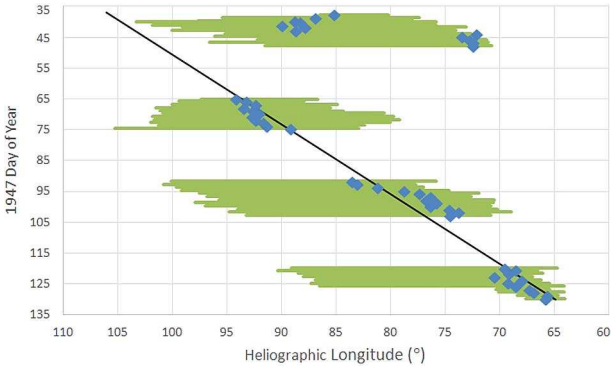

Figure 20. Longitude evolution of groups 14851 & 14886, including previous and subsequent rotations.

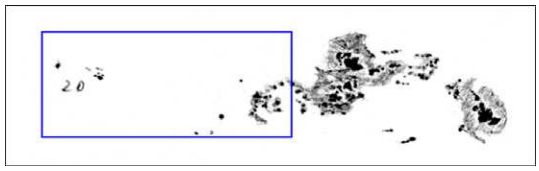

Figure 21. Expected location of groups 14851 & 14886 on 1947 Feb 10 (Hisako Koyama drawing).

and just over 4,000msh; it had a longitudinal extent of 17°. Two other groups were seen to the east and south of the follower sunspots. A fine photograph of this group on May 17 is shown in Figure 24.

As it progressed towards the west it continued to grow, obtaining a maximum size of 4,865msh on May 19. When nearing the western limb, the follower remained approximately of a similar shape and it was last seen on May 22 as a slender penumbral sunspot.

On the third and final rotation, a collection of sunspots without any particular structure was seen (see Figure 25). The northern set of sunspots comprised the remains of the May great sunspot group, which must have decayed while on the averted disc. By the time this group, 16792, approached the western limb, just a few small penumbral sunspots remained.

The area evolution of groups 16745, 16763 & 16792 is shown in Figure 26, while the longitude evolution over the three rotations is shown in Figure 27. For the largest sunspot (blue diamonds) there was no obvious longitudinal drift with time (unlike the great sunspots in 1946 and 1947), while for the longitudinal extent, the three rotations all gave similar results, *i.e.*, there was very little drift in longitude. Indeed, the expected change in rotation rate due to differential rotation is just 1.4° per rotation (for 13° latitude).[17]

Summary

This paper has shown the evolution of the five largest-recorded sunspots groups, which all occurred during Solar Cycle 18. This has been possible through reports and photographs in the BAA *Journal*, online drawings from Mt Wilson Observatory and from the Japanese solar observer Hisako Koyama, and sunspot group data from the Royal Observatory, Greenwich. Previous and/or subsequent rotations of these groups have also been shown, together with the evolution in group area, the longitude of the largest sunspot and the group's longitudinal extent.

Acknowledgments

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Long-term Solar Observations (SILSO), Royal Observatory of Belgium, Brussels.

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References & notes

1 The term 'great sunspot group' generally refers to a group with a mean area for the solar disc-passage greater than or equal to 1,500msh (see ref. 2). This size is about three times larger than that of a sunspot just visible with the protected naked eye.

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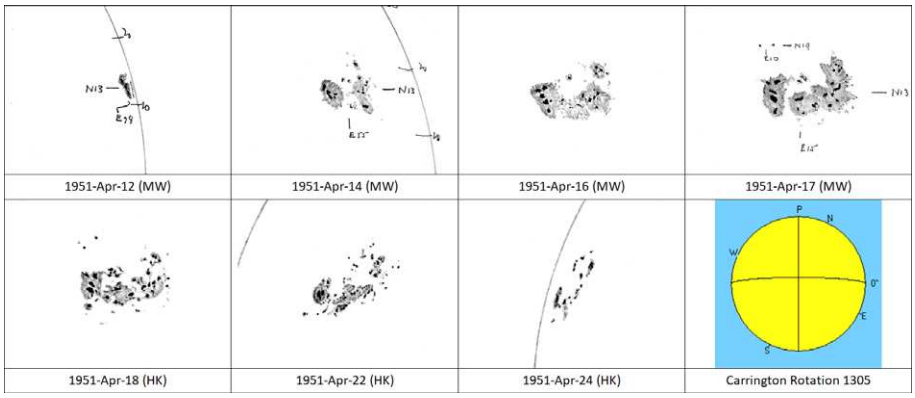

Figure 22. Passage of Greenwich group 16745, based on Mt Wilson (MW) and Hisako Koyama (HK) drawings.

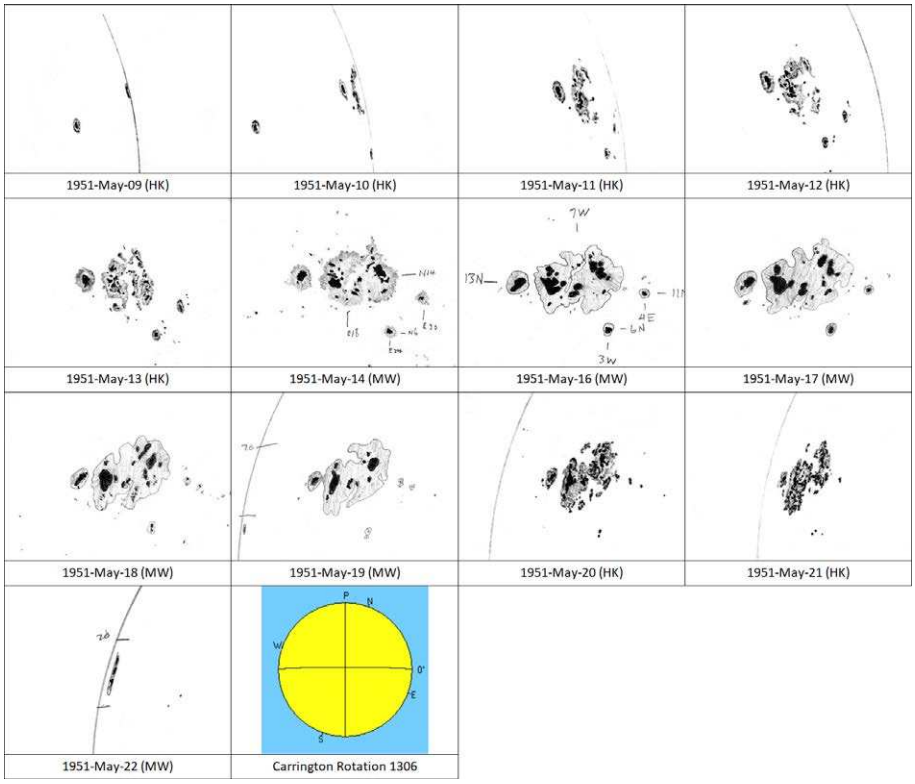

Figure 23. Passage of Greenwich group 16763, based on Mt Wilson (MW) and Hisako Koyama (HK) drawings.

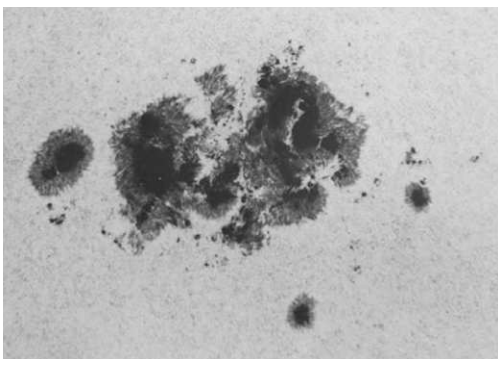

Figure 24. Mt Wilson photograph, taken on 1951 May 17.[30]

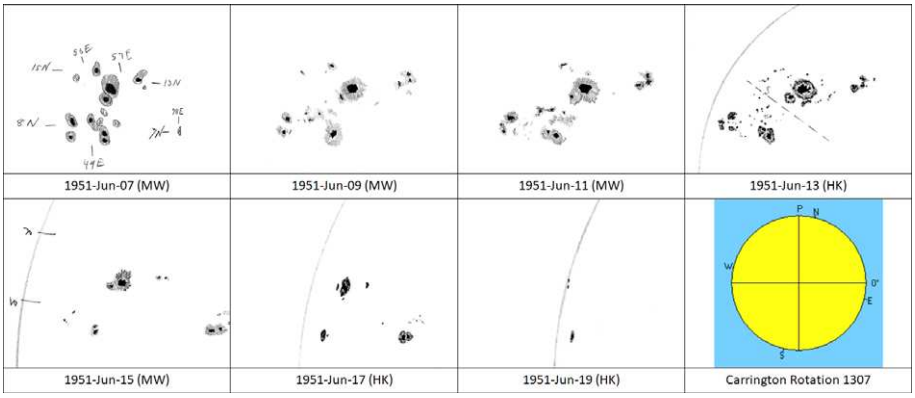

Figure 25. Passage of Greenwich group 16792, based on Mt Wilson (MW) and Hisako Koyama (HK) drawings.

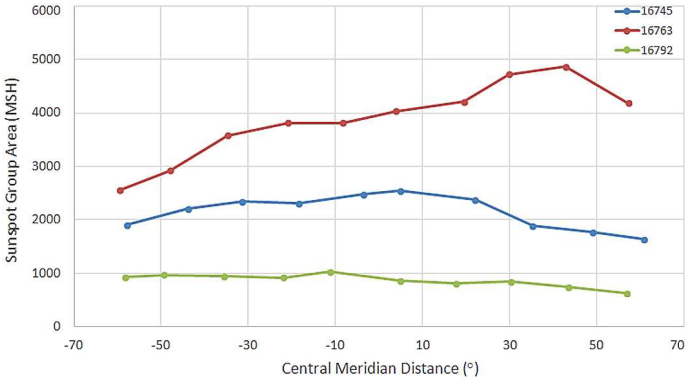

Figure 26. Greenwich sunspot area for groups 16745, 16763 & 16792 (1951 April to June).

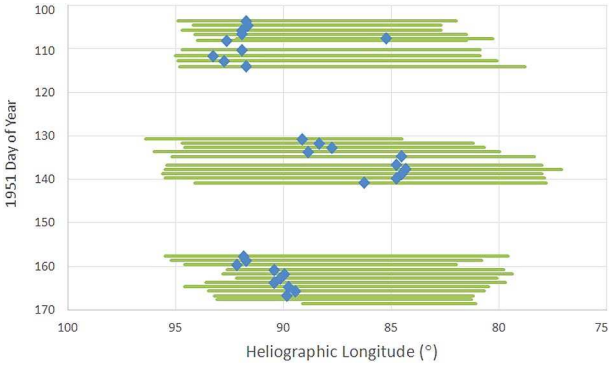

Figure 27. Longitude evolution of group 16763, with previous and subsequent rotations.

17 For further information, please see a more detailed version of this paper at **http://petermeadows.com/solarpapers**. This includes a comparison of Greenwich, Mt Wilson and Hisako Koyama sunspot areas as well as various appendices. These are on the distribution of large sunspot groups within solar cycles, a cycle sunspot number as a better way to characterise the strength of a solar cycle, a description of how the Mt Wilson and Koyama drawings have been used to extract the position and size of the great groups, and differential rotation models for proper-motion estimation.
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