The larger sunspot groups of Cycle 24

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A report of the Solar Section. Director: Lyn Smith

Using observations submitted to the BAA Solar Section, the largest sunspot groups of Solar Cycle 24 are discussed and example images shown. The characteristics of the cycle are also described and a comparison is performed between the sizes of its larger sunspot groups and those of previous cycles, stretching back over 100 years.

Introduction

In many areas of amateur astronomy it is the brighter objects that attract the most attention, whether these be bright comets, novae or supernovae. In the case of solar observing, the large sunspot groups are of greatest interest, even to amateur astronomers who do not routinely monitor the Sun in white light or in narrow bands such as Hydrogen-alpha (Hα) or Calcium K (CaK). As large sunspots groups are usually responsible for most solar flares, their impact on the Earth's magnetic environment may lead to the appearance of aurora and they can be monitored at radio wavebands, including Very Low Frequencies (VLF).

This paper firstly examines the characteristics of Solar Cycle 24, which began in 2009, using observations submitted to the BAA Solar Section. A list of the larger sunspot groups from the cycle is then provided, followed by descriptions and images for the five largest groups. Finally, a comparison is performed of the larger sunspot groups from Cycle 24 with those of previous cycles, dating back to the start of the 20th century.

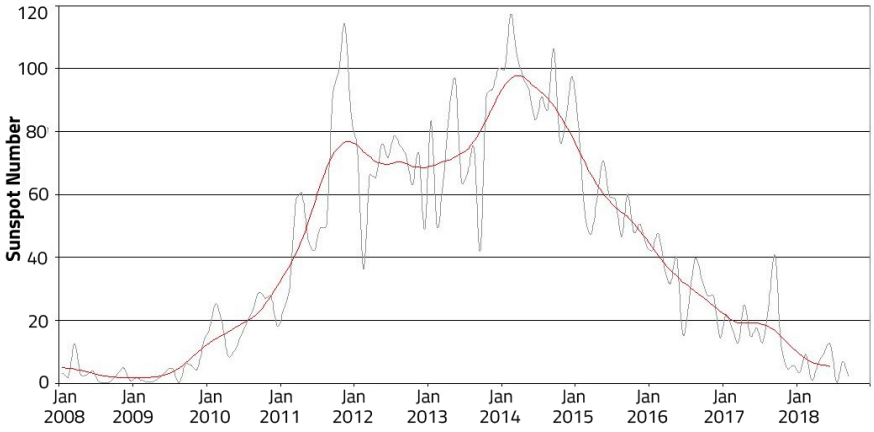


Figure 1. Variation of the BAA relative sunspot number with time, for Cycle 24 (monthly and smoothed). *Prepared by John Cook.*

WARNING

Never look at the Sun with the naked eye or with any optical instrument unless you are familiar with safe solar observing methods.

Cycle 24

After a prolonged solar minimum, Cycle 24 began in 2009 and peaked in early 2012 & mid-2014, as shown in Figure 1 (based on BAA Solar Section observations). In comparison with previous cycles, Cycle 24 was the smallest since Cycle 14 which peaked in 1906 (based on the International Sunspot Number).

Although not unique, the double peak of Cycle 24 was quite pronounced. As Figure 2 illustrates, this was the result of differing activity between the northern and southern solar hemispheres. It can be clearly seen that northern activity led to the first peak and southern activity to the second. The plot also shows that the fall to minimum, expected in 2019, was faster for the southern hemisphere than for the northern.

BAA solar observers record a variety of features in Hα, including prominences on the limb of the Sun. The monthly Mean Daily Frequency (MDF) for prominences during Cycle 24 is shown in Figure 3; even at solar minimum there were prominences, while during the cycle itself prominence activity followed a similar trend as for sunspots.

The BAA Radio Astronomy Group use VLF receivers to record the number of Sudden Ionospheric Disturbances (SIDs) caused by solar flares; *e.g.* see Cook (2018).[1] The detected SIDs are classified according to solar flare class. This is depicted in Figure 4 where C-class flares are shown in green, M-class in orange and the most energetic X-class in magenta. The number of SIDs generally follows that of sunspots, although it can be seen that the X-class flares can occur throughout the solar cycle. For example, towards the end of the cycle four SIDs were recorded

Table 1. The larger sunspot groups of Cycle 24

Active Region	*Date*	*Max. Area (MSH)*	*Lat. (°)*	*Long. (°)*	*Long. length (°)*	*CMD (°)*	*Type*
12192	2014 10 26	2750	S13	248	17	W46	Fkc
11967	2014 02 04	1580	S13	113	18	W24	Fkc
11944	2014 01 08	1560	S09	99	18	W17	Fkc
11339	2011 11 04	1540	N19	105	17	E45	Fkc
11520	2012 07 12	1460	S16	85	20	W09	Fkc
11302	2011 09 24	1300	N13	280	17	E47	Fkc
11429	2012 03 07	1270	N18	300	10	E15	Dkc
12403	2015 08 25	1190	S14	192	17	W31	Fki
12371	2015 06 21	1180	N12	302	16	W00	Fkc
11654	2013 01 11	1100	N08	148	17	E31	Fki
12209	2014 11 18	1100	S15	251	27	E07	Fkc
12242	2014 12 19	1080	S18	239	15	W29	Ekc
12673	2017 09 08	1060	S09	119	10	W70	Dkc
11476	2012 05 09	1050	N11	183	19	E22	Fkc
11726	2013 04 25	1000	N13	327	17	W85	Fkc

in 2017 September that were associated with X-class flares (from complex Ekc group AR12673). Solar flares are usually associated with the larger and more complex sunspot groups, such as those described in this paper.

The larger sunspot groups

The USAF/NOAA Solar Region Summary (SRS) gives a daily list of all the visible sunspots groups,[2] giving active region number (AR);[3] location (latitude, central meridian distance and longitude); area in millionths of the Sun's visible hemisphere (MSH);[4] group type;[5] longitude extent; number of sunspots and magnetic type. The SRS report for the previous day is available at 00:30 UT and provides the characteristics for each active region compiled from up to six observatories that report to the NOAA Space Weather Prediction Center (SWPC), in near-real-time. Note that if the same group is seen on another solar rotation of approximately 27 days, it is assigned a different AR number.

The SRS reports have been used to determine those sunspot groups from Cycle 24 with a maximum area of 1000MSH or more, as shown in Table 1. The area, longitude length, central meridian distance and group type correspond to the date when the maximum extent occurred, while the latitude and longitude are the average values during the group's passage across the solar disk.

Type Fkc refers to a bipolar group, with a longitude extent of > 15° and a large asymmetric leader > 2.5° in size, with many spots between leader and follower. A Dkc group is similar to Fkc, except that the longitudinal extent is between 10° & 15°; an Fki group has fewer sunspots between the leader and follower.

Table 1 shows that sunspot groups with maximum areas of 1000MSH or more occurred over a period of six years, from 2011 September to 2017 September. The highest number of large sunspots was attained during 2014, when there were five. The number was slightly higher in the latter three years (when there were eight) compared with the first three years (when there were seven).

Based on observations submitted to the Section, the passages across the solar disk of the largest five groups are herewith described in further detail, in date order. Most images are orientated such that north is at the top and east is to the right (*i.e.*, the same as the naked eye view of the Sun in the Earth's northern hemisphere at local noon).

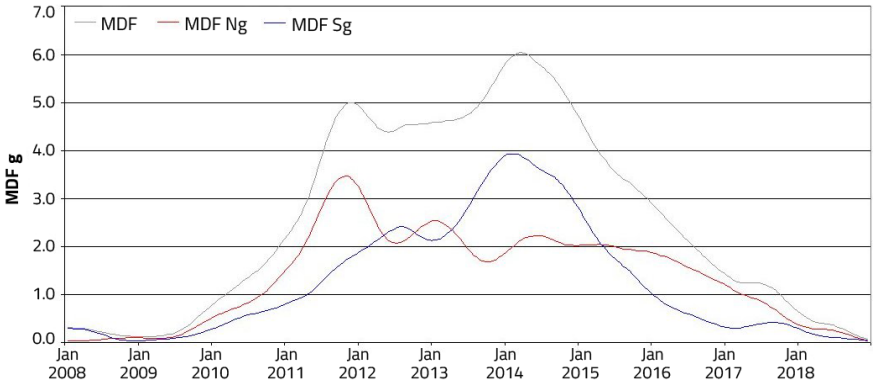


Figure 2. BAA number of sunspot groups for Cycle 24 (smoothed). *Prepared by John Cook.*

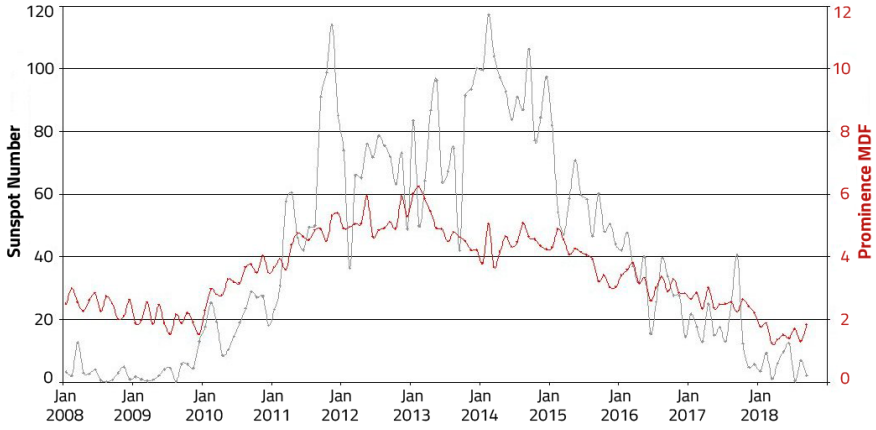


Figure 3. BAA number of prominences for Cycle 24 (monthly). *Prepared by John Cook.*

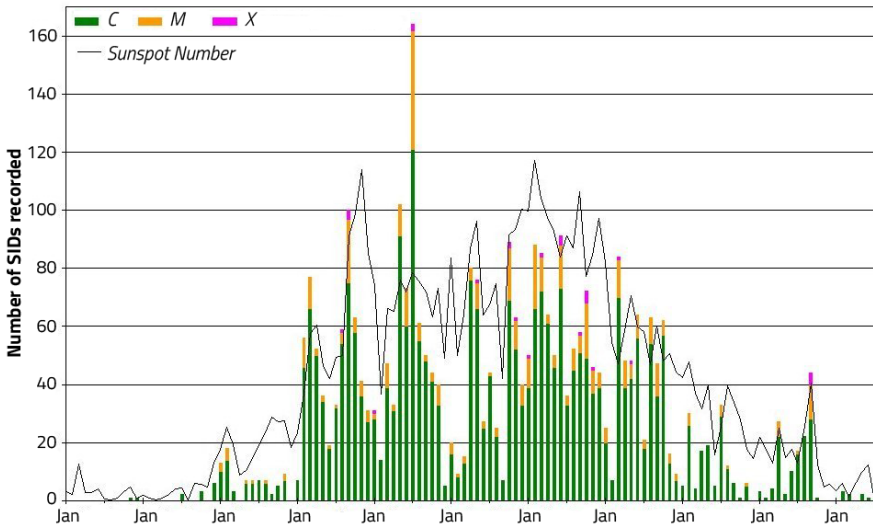


Figure 4. Number of Sudden Ionospheric Disturbances recorded by the BAA for Cycle 24 (monthly). *Prepared by John Cook.*

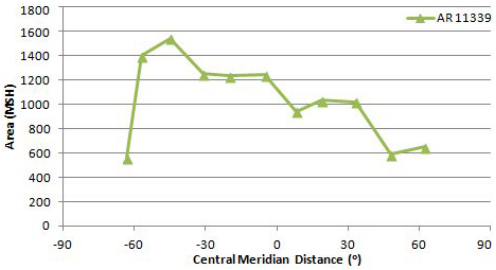


Figure 6. The area profile of AR11339, based on NOAA SRS data. *Prepared by Peter Meadows.*

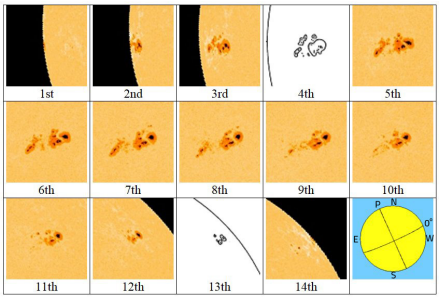


Figure 5. The passage of AR11339 between 2011 Nov 1 & 14. *Drawings by Peter Meadows; images: SDO HMI Continuum, NASA SDO.*

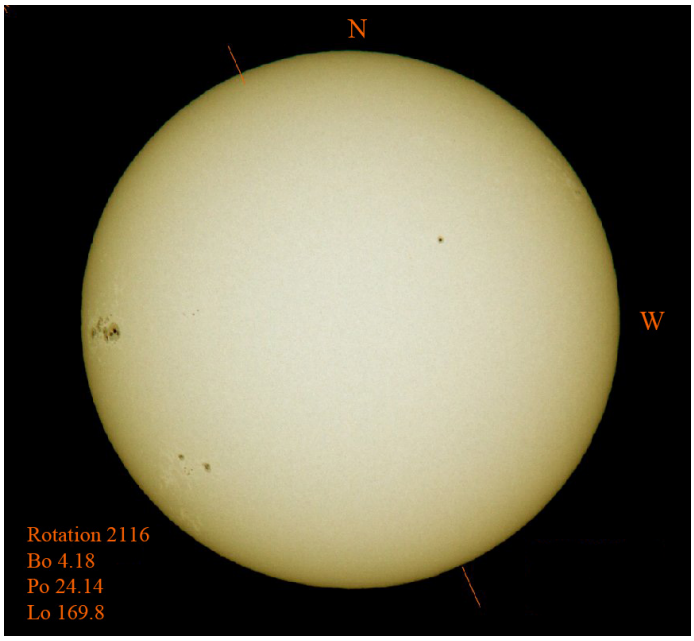


Figure 7. Full disk in white light, showing AR11339 on 2011 Nov 3, 09:59 UT. *Kevin Kilburn*

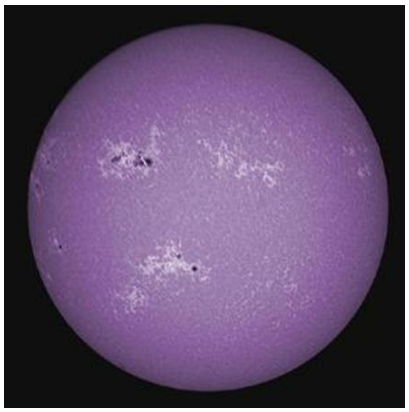


Figure 9. Full disk in CaK on 2011 Nov 6. *Sheri Lynn Karl*

Active Region 11339 (2011 November)

The appearance of AR11339 during its passage across the solar disk is shown in Figure 5, while the daily change in sunspot group area based on NOAA SRS data is shown in Figure 6 (from Nov 2–12 inclusive).

AR11339, located at N19°/105°, was first reported on Nov 3 as a large sunspot group of type Eki (Figure 7). On this date, BAA observers recorded six groups and a relative sunspot number of 100 (the first time this had occurred during Cycle 24). By the following day, the group was more complex and had enlarged to type Fkc, with an irregularly shaped main sunspot and several smaller penumbral spots to the north and east. The group had a total area of 1600MSH. On Nov 6 the group was easily visible to the protected naked eye and consisted of three main components (Figure 8). The group crossed the central meridian on Nov 8 and by Nov 9 the group was still described as 'imposing' (although the number of components had reduced to two).

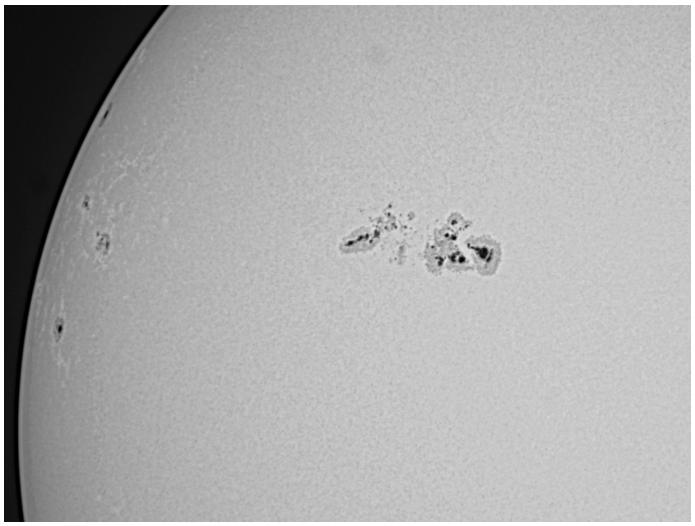


Figure 8. AR11339 on 2011 Nov 06. *Dave Storey*

The group started to reduce in size on Nov 11 and it was type Dac by Nov 12, nearing the western limb on Nov 13. It was not seen on Nov 15.

There was an extensive region of plage around AR11339 on Nov 6,[6] seen in CaK as shown in Figure 9. On Nov 3 the region produced a type 3b flare,[7] which started at 23:30 UT, peaked at 23:40 and ended at 00:05 on Nov 4. It had an X-ray class of M2.2. Flares were also reported on Nov 6 & 9. On Nov 13, a flare was seen at 12:40 UT on the western limb.

AR11339 was seen on the subsequent rotation (as AR11364 at N18°/104°) on Nov 30, in the north-east quadrant near to the eastern limb. It was then a single penumbral sunspot of type Hsx. It remained unchanged until it entered the north-west quadrant, where it grew briefly to type Cso before returning to a single penumbral spot as it approached the western limb.

Active Region 11520 (2012 July)

The appearance of AR11520 during its passage across the solar disk is shown in Figure 10, while the daily change in sunspot group area is shown in Figure 11 (from Jul 7–17 inclusive).

AR11520, located

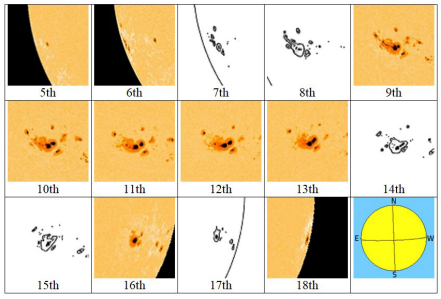


Figure 10. The passage of AR11520 between 2012 Jul 5 & 18. *Drawings by Peter Meadows; images: SDO HMI Continuum, NASA SDO.*

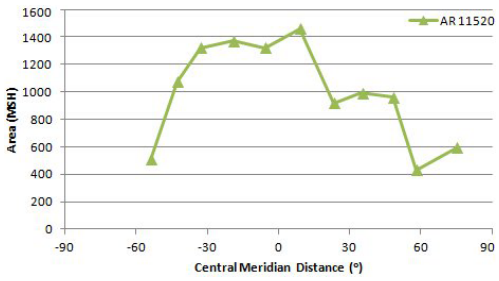


Figure 11. The area profile of AR11520, based on NOAA SRS data. *Prepared by Peter Meadows.*

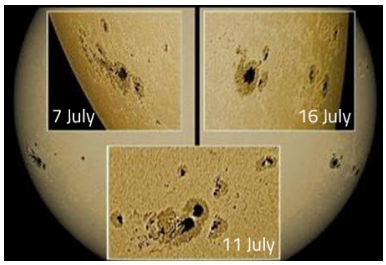


Figure 12. AR11520 on 2012 Jul 7, 11 & 16. *Peter Paice*

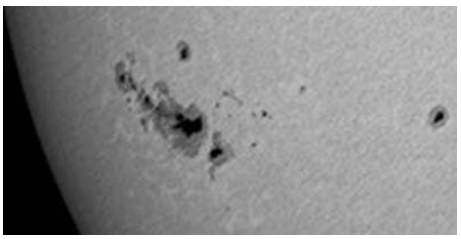
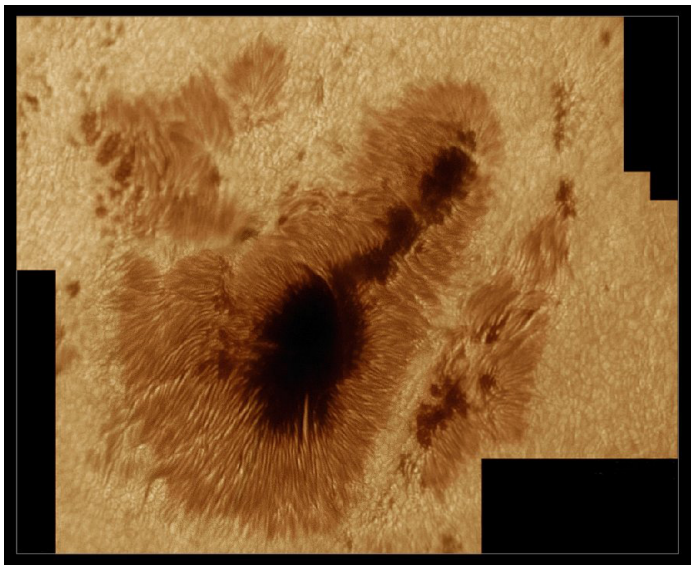


Figure 13. White light image of AR11520 in the SE quadrant, on 2012 Jul 8. *Ron Johnson*



Left: **Figure 14.** Close-up white light image of AR11520 on 2012 Jul 15. *Damian Peach*

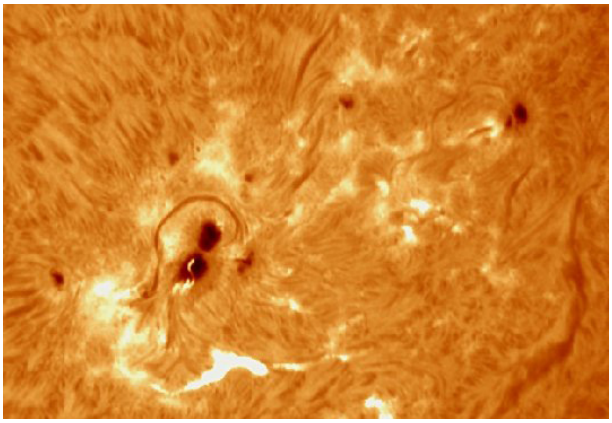


Figure 15. Hα image showing C1 & C3 flares in AR11520, on 2012 Jul 12. *Mick Nicholls*

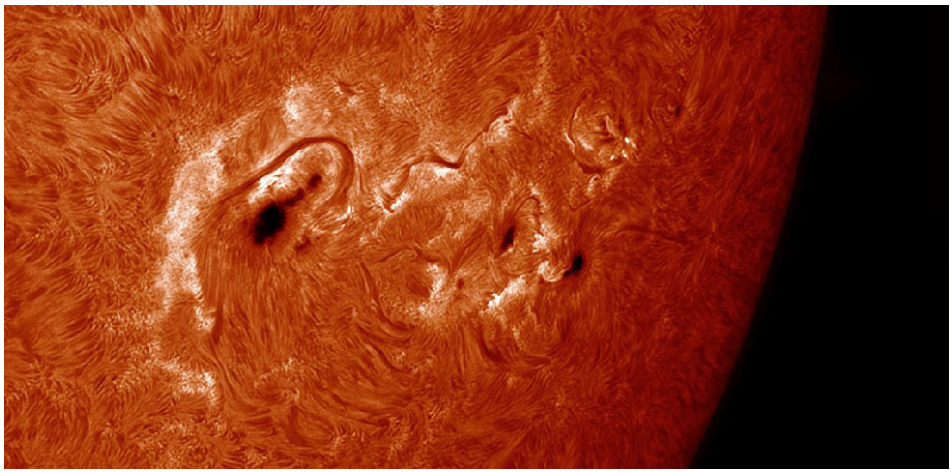


Figure 16. AR11520 and filaments on 2012 Jul 15, 08:50 UT. *Dave Tyler*

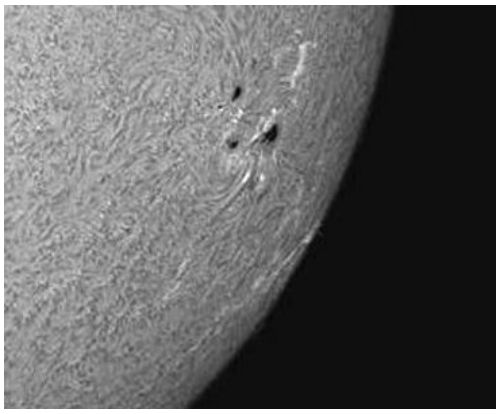


Figure 17. Hα image of AR11504 on 2012 Jun 19, at 12:06 UT. *Bill Leatherbarrow*

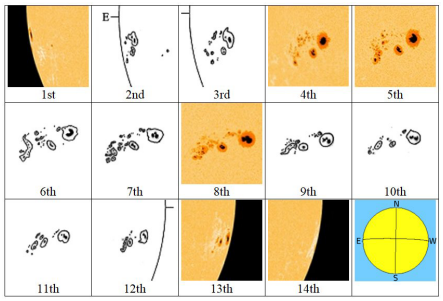


Figure 18. The passage of AR11944 between 2014 Jan 1 & 14. *Drawings by Peter Meadows; images: SDO HMI Continuum, NASA SDO.*

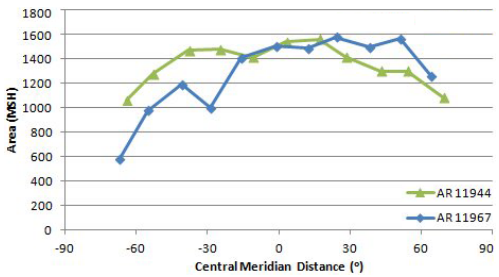


Figure 19. The area profile of AR11944 & 11967, based on NOAA SRS data. *Prepared by Peter Meadows.*

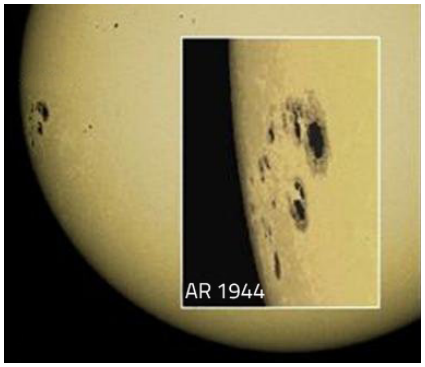


Figure 20. AR11944 near the eastern limb, on 2014 Jan 2. *Peter Paice*

at S16°/085°, was seen close to the south-east solar limb on Jul 7 after 'huge' amounts of faculae were reported at that location on the previous day (Figure 12). The group was strongly suspected to be visible with the protected naked eye, despite its proximity to the limb. By Jul 8 this group was type Fkc, with an area of 1190MSH. The largest penumbral sunspot was near the centre of the group, with a thin following extension and other surrounding sunspots. Several umbrae were seen within the main sunspot and in a region of photosphere (see Figure 13).

By Jul 12 the solar disk was dominated by this imposing sunspot group straddling the central meridian. Thirty separate sunspots were counted, including two large umbrae within a very large asymmetrical penumbral area mid-group. By Jul 14, the two umbrae had joined to form a single, large umbra within an expansive, rambling penumbra containing many small spots. This was now positioned towards the following part of the group, but the total area of the group was slightly smaller at 1000MSH.

Fine details within AR11520 from Jul 15 can be seen in Figure 14. The group was last seen close to the south-west limb on Jul 17; type Fkc. It displayed light bridges from Jul 10 to Jul 16 inclusive, and was observable with the protected naked eye on Jul 11, 12, 13, 14 & 15.

A pronounced east-west filament was seen in association with AR11520 to the north of the main penumbral sunspot on Jul 12, 14 & 15. See Figures 15 & 16, where solar flares and plage can also be seen.

On the previous rotation the group – then referred to as AR11504, at S15°/085° – was first seen on Jun 9 rounding the south-east

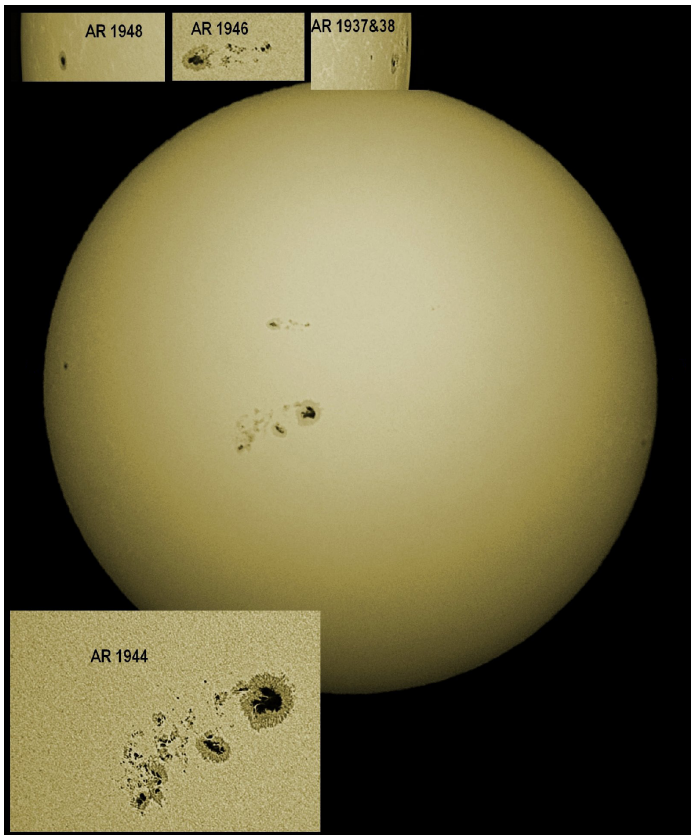


Figure 21. AR11944 on 2014 Jan 6, 20:52 UT. *Richard Hill*

limb as type Dsc. It was of similar appearance the following day, but by Jun 13 had developed into a bipolar group; the main sunspots were the leader and follower with an arc of smaller sunspots between. The group was now classified as type Ekc with a total area estimated at 450MSH.

On Jun 14 some of the smaller sunspots had developed into a penumbral spot. By Jun 16, three penumbral sunspots dominated the group with leader and followers of almost equal size; the estimated total area was 610MSH. The group was of similar size on Jun 17 and was type Eac. By Jun 19, with the group nearing the western limb, it had reduced to 430MSH (Figure 17) and was finally seen on Jun 20 as a Dac group. AR11504 was seen with the protected naked eye from Jun 12–18 inclusive.

Active Region 11944 (2014 January)

Figure 18 shows the appearance of AR11944 as it progressed across the solar disk, with the daily change in sunspot group area shown in Figure 19 (from Jan 2–12 inclusive), together with that for the same group on its next rotation when it was referred to as AR11967 (from Jan 28 to Feb 7 inclusive).

Located at S09°/099°, AR 11944 was on Jan 2 a complex and moderately large sunspot group near the eastern limb, of type Ekc (see Figure 20). More of this group could be seen on the following day, when it was of type Fkc: the irregular leader was the largest sunspot within the group and there were many smaller follower penumbral spots. By Jan 4 the group was type Ehi and was quite impressive when next reported on Jan 6, being some 19° in length and with an estimated total area of 1580MSH. Although the leader was the largest sunspot, there was now a very elongated, irregular follower spot in the north-south direction. In-between, there were many smaller penumbral sunspots, as shown in Figure 21.

On Jan 7 the leader was on the central meridian and now had several umbrae within it, while the follower had decayed into many penumbral sunspots. The total area had reduced slightly, to 1310MSH.

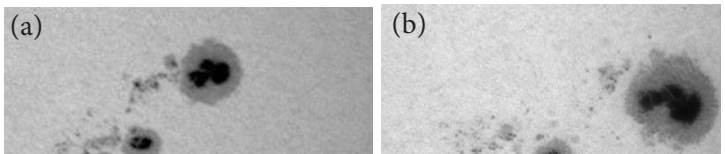


Figure 22. (a) AR11944 on 2014 Jan 8. *Ron Johnson.* **(b)** A close-up view of AR11944, on 2014 Jan 10. *Brian Halls*

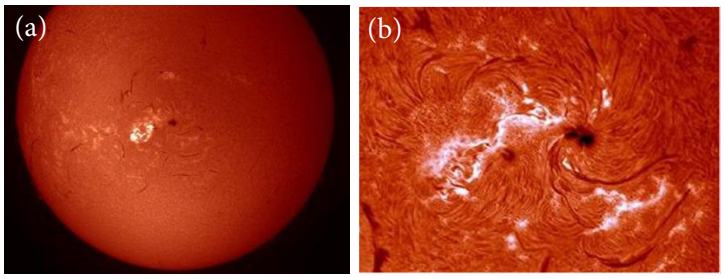


Figure 23. (a) Hα image of AR11944 with an M7.2 type 2b flare, on 2014 Jan 7, 10:30 UT. *Andy Devey.* **(b)** AR11944 on 2014 Jan 9, 12:04 UT. *Dave Tyler*

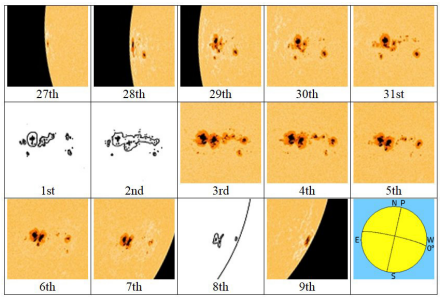


Figure 24. The passage of AR11967 between 2014 Jan 27 & Feb 9. *Drawings by Peter Meadows; images: SDO HMI Continuum, NASA SDO.*

Figure 22a shows AR11944 on Jan 8. By Jan 9 both the leader and following sunspots had changed slightly and the total area had reduced again, to 1010MSH. There were further slight changes over the next few days as the group progressed towards the western limb (Figure 22b). It was last reported on Jan 12 with an area of 1000MSH.

AR11944 was seen with the protected naked eye on Jan 3 as one sunspot, on Jan 6, 7 & 9 as two spots and on Jan 10 as one spot. For the observations when two naked-eye sunspots were seen, the leader sunspot appeared darker and more prominent compared to the follower.

M-class flares were observed to be associated with AR11944 on Jan 3. Many small, curved filaments were seen around AR11944 on Jan 6 & 7, together with bright plage. Also, on Jan 7, a M7.2 flare was imaged (shown in Figure 23a). On Jan 9 several long and short filaments were seen in association with AR11944, as was plage (Figure 23b). A filament was present through the trailing penumbral area, surrounded by plage on Jan 11. A broad north-south filament also trailed the group.

Active Region 11967 (2014 January/February)

The appearance of AR11967 is shown in Figure 24, while the daily change in sunspot group area is shown in Figure 19. Located at

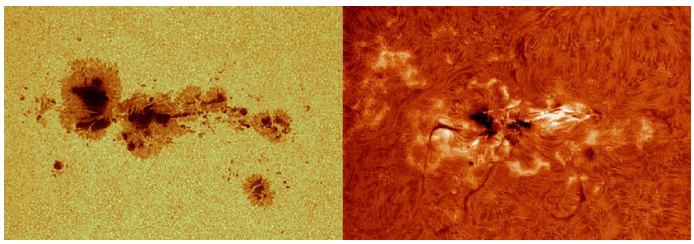


Figure 25. White light and Hα close-up images of AR11967 on 2014 Feb 2, 10:37 & 11:31 UT. *Dave Tyler*

S13°/113°, AR11967 (second rotation of AR 11944) reappeared over the south-east limb on Jan 28. It was still a very large and complex group, with the following portion being the largest. The group was type Fkc on Jan 29 and was reported as visible to the protected naked eye on Jan 31.

This group dominated the disk at the start of February, approaching the central meridian on Feb 1. It appeared as a complex Fkc group comprising small penumbral sunspots at the leading part of the group, a large asymmetric follower and an irregular penumbral spot in-between. It had an estimated area of 1200MSH. On the following day, the three portions had merged to form a large, very irregular elongated sunspot (Figure 25). Within this there were many umbrae, the largest of which were towards the middle and following parts. Several small penumbral sunspots and pores surrounded the main sunspot and the total area was 1620MSH – an impressive sight.

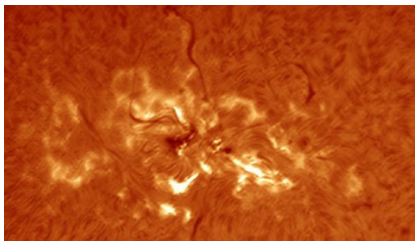


Figure 27. C1.5 flare and AR11967 on 2014 Feb 2, 09:53 UT. *Mick Nicholls*

On Feb 5 the group was sprawling across the south-west quadrant, still dominated by the extensive asymmetric follower. On Feb 6, AR11967 was still the dominant group on the disk, as shown in Figure 26. By Feb 8 only an irregular Hkx sunspot was observed, nearing the western limb. AR11967 was seen with the protected naked eye on Feb 1, 2, 3, 4, 5, 6 & 7.

In Hα, AR11967 continued to exhibit bright streams of plage on Feb 1. The following day, a bright X-shaped plage was seen just north of the following sunspot of AR11967. Bright plage lines were also seen. On Feb 5, an east-west filament was to the north of the trailing section of AR11967. Several flares were observed to be associated with the region, especially on Feb 2 (Figures 25 & 27); from 14:02 UT until the clouds interrupted at 14:05 UT a compact bright region was seen within AR11967 (an M1.7 flare). Later the same day, a type 3b flare of class M1.5 was seen starting at 21:30 UT, peaking at 22:00 and ending at 22:45. A similar type flare was recorded on Feb 6 from the same group, starting at 23:00 UT, peaking at 23:10 and ending at 23:40.

Figure 28 shows extensive plage around AR11967 on Feb 4. Figure 25 clearly illustrates the near-simultaneous differences in the appearance of AR11967 in white light and Hα.

AR11990 at S13°/106° (AR11944/AR11967) returned for its third rotation as a single penumbral Hkx sunspot on the south-east limb on Feb 24. By Feb 26 (Figure 29) it could be seen that the group had decayed significantly since its previous rotation, with an area of only 160MSH. On Feb 27 it had grown slightly to 220MSH, when a couple of leading pores were also seen. By the end of the month, the group developed smaller sunspots to the south-east of the main sunspot and was of type Dkc.

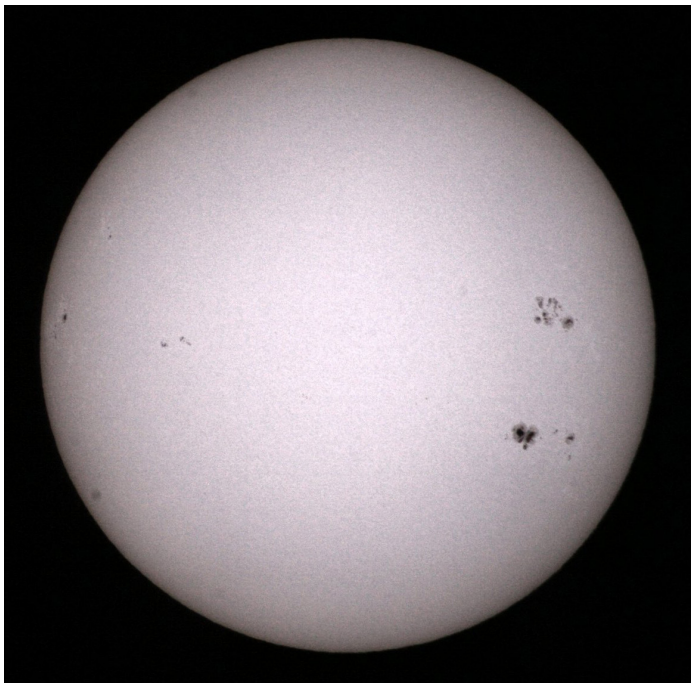


Figure 26. White light image from 2014 Feb 6, showing AR11967 (lower) & AR11968 (upper) approaching the western limb. *Denis Buczynski*

The group crossed the central meridian on Mar 2 and thereafter the leading penumbral sunspots started to decay, the group being type Cso by Mar 4. The group continued to decay, becoming a single Hsx sunspot by Mar 8 before rounding the south-west limb on Mar 9.

Active Region 12192 (2014 October)

The appearance of AR12192 – the largest group of Cycle 24 – during its passage across the solar disk is shown in Figure 30, while

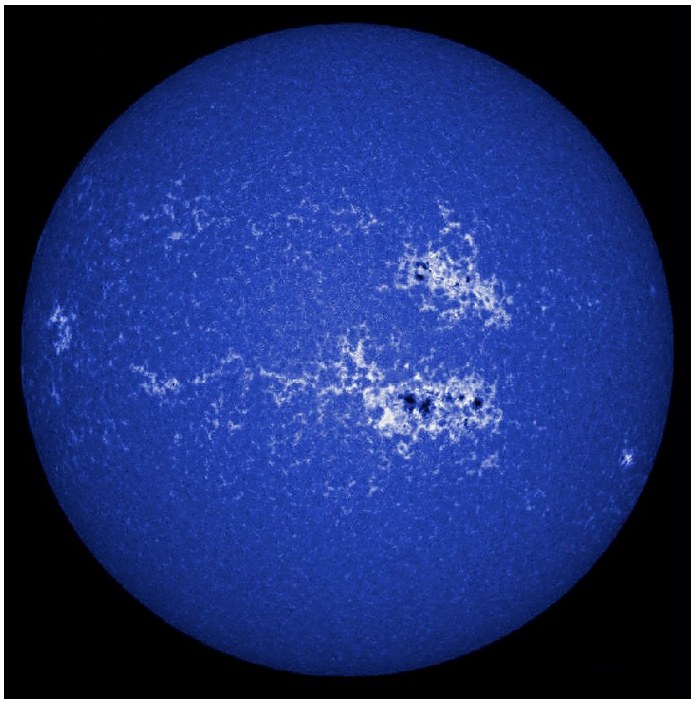


Figure 28. Full disk CaK image of AR11967 & 11968 on 2014 Feb 4. *Peter Paice*

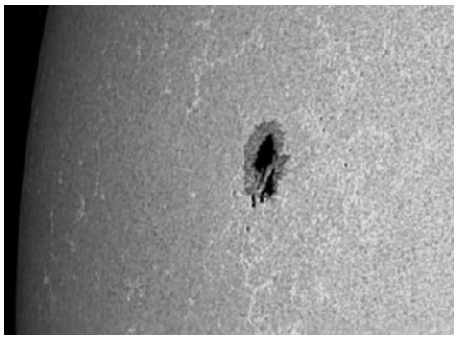


Figure 29. White light image of AR11990 on 2014 Feb 26, 10:43 UT. *Dave Tyler*

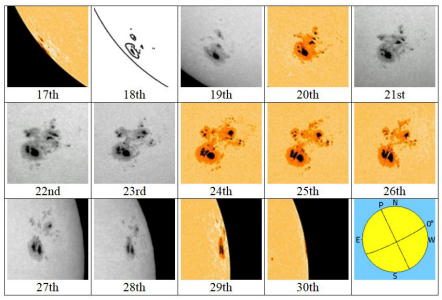


Figure 30. The passage of AR12192 between 2014 Oct 17 & 30. *Drawing and monochrome images by Peter Meadows; colour images: SDO HMI Continuum, NASA SDO.*

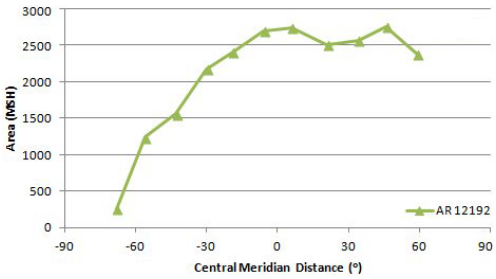


Figure 31. The area profile of AR12192, based on NOAA SRS data. *Prepared by Peter Meadows.*

the daily change in sunspot group area is shown in Figure 31 (from Oct 17–27 inclusive).

Located at S13°/248°, AR12192 was first reported on Oct 17 rounding the south-east limb. Even at this stage the group looked impressive and measured around 170,000km north-to-south; it exhibited three large sunspots and was of type Dki. By the following day, the group was type Fkc and estimated to be 2200MSH in area, with the follower being the largest sunspot. On Oct 19 the active region was fully on the disk (Figure 32), with more of the follower being seen, including a large main penumbral sunspot and several smaller spots. A bright patch was noted within the northern penumbra of the main sunspot, with lighter-coloured mottling to the west.

By Oct 21 the group had become more complex, with many umbrae and several regions of photosphere within the main penumbral sunspot. Its area had grown to 2770MSH. Two very bright spots were seen within the umbra. The group sprawled across the central meridian on Oct 23 (Figure 33) and Oct 24. Figure 34 shows AR12192 on Oct 25, in both white light and Hα. By Oct 27 there had been a split, with the follower still being the largest (Figure 35). The group was now 2280MSH in extent and was approaching the south-west limb on Oct 28, crossing the limb on Oct 29. Needless to say, the group was visible to the protected naked eye throughout its transit from Oct 19–28 (from Oct 21–23 it was seen as an elongated sunspot while on Oct 25 two distinct naked eye sunspots were observed; on Oct 27 & 28 it was again seen as one sunspot).

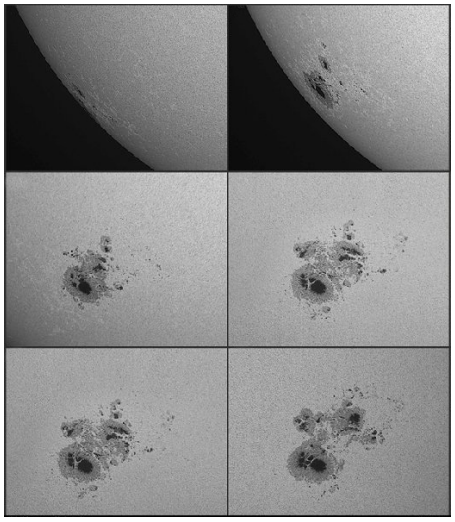


Figure 32. AR12192 on 2014 Oct 17, 18, 20, 21, 22 & 24. *Pete Lawrence*

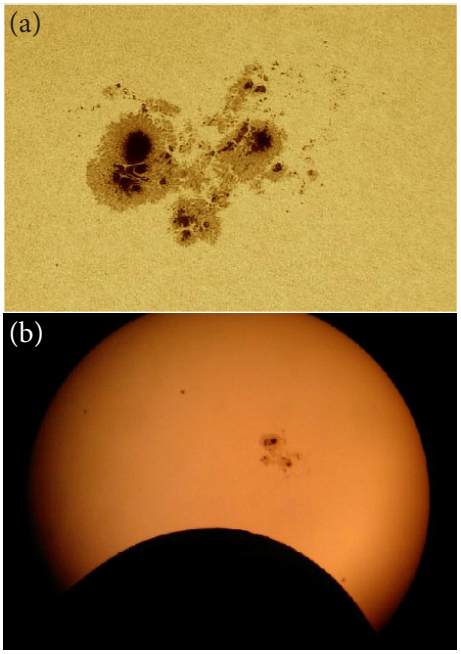


Figure 33. (a) AR12192 in white light on 2014 Oct 23. *Paul Haese.* **(b)** Partial eclipse and AR12192, viewed from the USA on 2014 Oct 23. *Nick James*

The group was responsible for several X class flares recorded by NOAA: on Oct 19, X1.1; 22, M8.7 & X1.67; 24, X3.19; 25, X1.0 & 26, X2.0. BAA solar observers noted several flares (Figures 36–38), including a type 4b event (X-ray class X3) which commenced at 20:40 UT, peaked at 21:35 and ended at 00:50 on Oct 25. An X2.0 solar flare was also recorded on Oct 27. This observation began at 14:20 UT when multiple bright regions were seen within the group. The size and brightness of these changed rapidly over the next 10 minutes, as the flare developed past type X1 at 14:25 UT towards a broad X2 peak at 14:47 UT. A switch from visual Hα observation to imaging showed flares within the main penumbral sunspot (close to the two main umbrae, in a region between the leader and follower), together with a thin strand of bright hydrogen towards a circular flare region to the south-west, away from the group itself. These bright regions gradually faded towards the end of the observing period at 15:30 UT, when the flare was still of type M4 (see Figure 38). Extensive CaK plage was noted around AR12192, as shown in Figure 39.

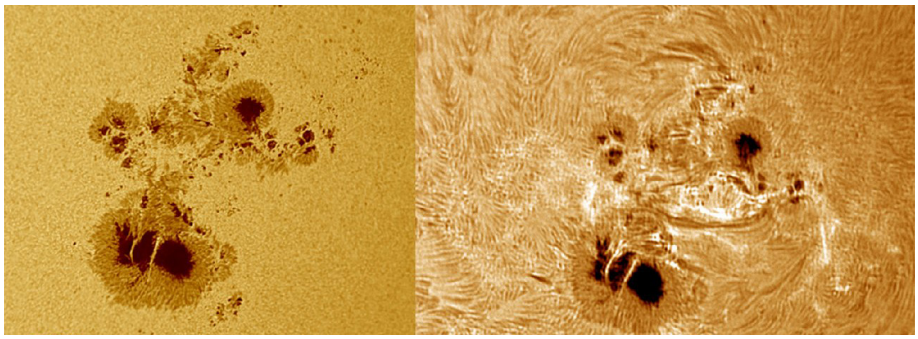


Figure 34. Comparison of AR12192 in white light and Hα, on 2014 Oct 25. *Mick Jenkins*

On the previous solar rotation, there were three nearby groups close to the location of AR12192. On Sep 19, AR12171 & 12172 were visible at S10°/263° and S09°/239°, both of type Eac and with the latter being near the eastern limb. On Sep 26, AR12172 was straddling the central meridian and was the larger at 610MSH (AR12171 was just 100MSH). AR12171 was a bipolar group with many small

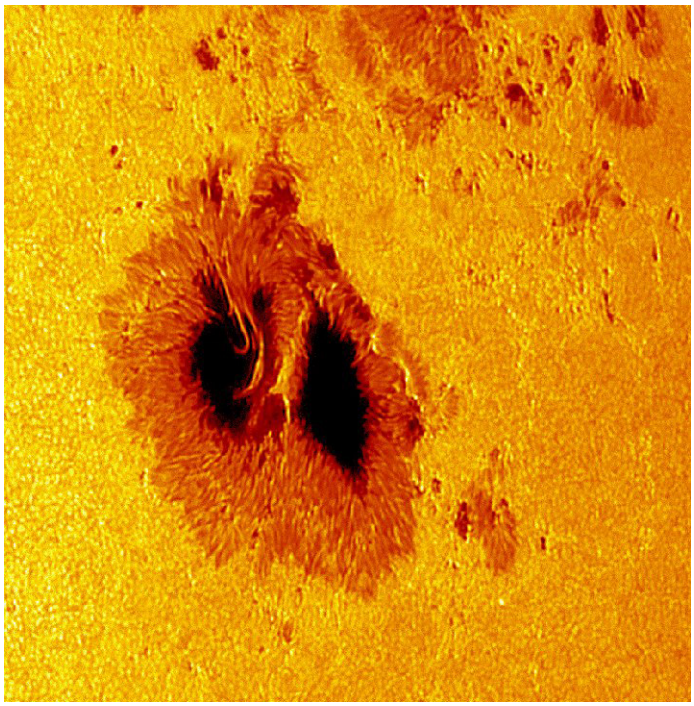


Figure 35. Close-up image of AR12192 in white light, on 2014 Oct 27 at 09:15 UT. *Dave Tyler*

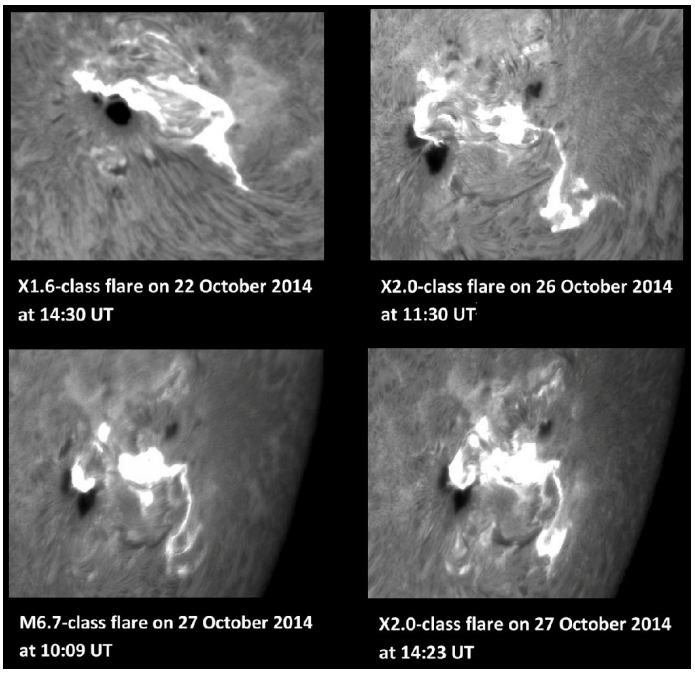


Figure 36. Four large solar flares within AR12192, in 2014 Oct. *Andy Devey*

sunspots between the leader and follower. It was then of type Ekc, while AR12172 was a small Eac group. Another group, AR12173 (of type Cri) had developed just to the south and between these groups at S15°/250°. By Sep 28, AR12173 had become type Dac at 250MSH, while AR12172 was now type Fac at 470MSH, with AR12171 of type Cso and at just 40MSH. These three groups had the appearance of a complex collection of sunspots all at a similar latitude; they spanned some 35° in longitude approaching the south-west limb.

On the subsequent rotation, AR12192 became AR12209 at S13°/243°. It was initially seen as an extensive area of faculae near the south-east limb on Nov 12. The group started to appear over the limb on Nov 13 and was fully on the disk by Nov 14; type Fkc. By Nov 18 the solar disk was dominated by the group, consisting of a medium-sized penumbral leading sunspot with a large, complex penumbral sunspot following. On Nov 19 the irregular following sunspot consisted of several umbrae, together with a region of photosphere near the centre of the spot. In the following days, the configuration of this sunspot resembled that of a 'bear's paw', as shown in Figure 40.

On Nov 20 the group had an estimated area of 1050MSH and was type Fko. By Nov 24 AR12209 was approaching the south-west limb, but still retained its 'bear's paw' configuration. The group crossed the limb on Nov 26. It was reported to be visible to the protected naked eye on this date, and also on Nov 20, 22 & 24.

Comparison with previous solar cycles

As shown in Table 1 and described above, the largest sunspot group in Cycle 24 had an area of 2750MSH (AR12192). How does this compare with the larger sunspot groups from previous cycles?

As Figure 41 shows, Cycle 24 was the weakest since Cycle 14 (Cycle 19 was the strongest, peaking in 1958 March). Sunspot group area data from the Royal Greenwich Observatory up to 1977,[8] and NOAA since,[8,2] have been used to determine the largest five groups from each solar cycle since 1900. The results are given in Table 2, which shows the following:

– With the exception of the previous cycle (Cycle 23, peaking in 2004 April), the largest sunspot group of each cycle was larger than that for Cycle 24. With the exception of Cycle 18 (peaking in 1947 May), the larg-

Table 2(a). The larger sunspot groups of cycles 14–17

Date	*Max. Area (MSH)*	*Date*	*Max. Area (MSH)*	*Date*	*Max. Area (MSH)*	*Date*	*Max. Area (MSH)*
1905 02 02	3339	1917 02 14	3590	1926 01 19	3716	1938 01 21	3627
1905 10 19	2995	1917 08 09	3178	1925 12 31	2934	1938 07 20	3379
1905 03 07	2572	1920 03 23	2690	1928 09 27	2587	1937 10 05	3340
1907 02 16	2555	1920 01 27	2037	1926 09 22	2142	1937 07 28	3303
1907 06 15	2472	1920 09 08	1991	1925 12 27	2124	1941 09 21	3088
Cycle 14		Cycle 15		Cycle 16		Cycle 17	

Table 2(b). The larger sunspot groups of cycles 18–21

Date	*Max. Area (MSH)*	*Date*	*Max. Area (MSH)*	*Date*	*Max. Area (MSH)*	*Date*	*Max. Area (MSH)*
1947 04 08	6132	1959 01 08	2805	1968 02 01	3202	1982 06 14	3100
1946 02 07	5202	1959 11 29	2622	1974 04 16	2706	1982 07 12	2870
1951 05 19	4865	1959 01 24	2502	1970 11 17	2511	1982 02 06	2640
1946 07 29	4720	1957 10 16	2480	1971 08 21	2330	1984 04 26	2590
1947 03 12	4554	1959 06 18	2385	1969 10 21	2274	1981 10 17	2301
Cycle 18		Cycle 19		Cycle 20		Cycle 21	

est areas ranged from 2805–3716MSH, *i.e.* 2–35% larger than for Cycle 24.

– Excluding AR12192, the second to fifth largest groups from Cycle 24 were considerably smaller than those of any previous cycles dating back to 1900. Indeed, none were larger than 2000MSH, whereas all but two of the largest groups from every cycle since Cycle 14 were larger. This is even the case for Cycle 14 (of a similar strength as Cycle 24), where the fifth largest group had an area of 2472MSH.

– Interestingly, for Cycle 19 – the most active cycle as measured by the International Sunspot Number – the largest group had an area of just 2805MSH (similar to AR12192).

– Cycle 18 was unique in having large sunspot groups, with the top five being above 4500MSH (this does include two rotations of the same group).

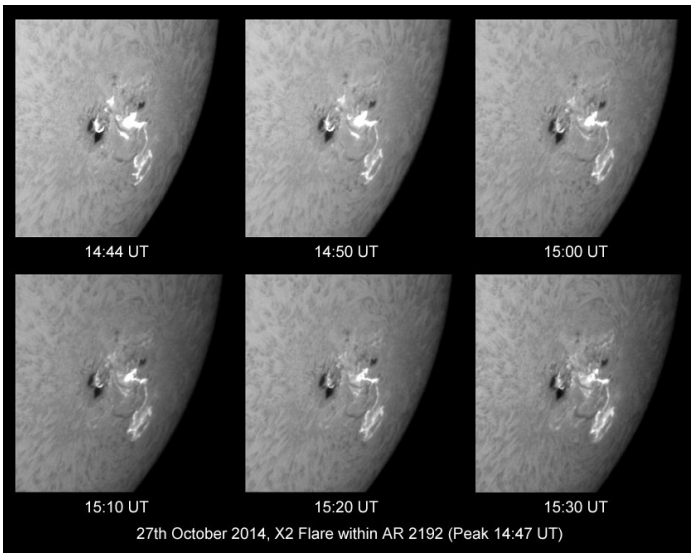


Figure 38. X2 flare within AR12192 (peak at 14:47 UT). *Peter Meadows*

Summary

This paper initially provided an overview of Solar Cycle 24 based on observations submitted to the BAA Solar Section, where it was noted that this cycle was the smallest (based on the International Sunspot Number) for over 100 years. The double-peak nature of the cycle was shown to be due to asymmetric activity between the northern and southern hemispheres. A table of the largest sunspot groups from the cycle, based on NOAA SRS data (to ensure consistency over the cycle), was then given.

The largest group, AR12192, appeared in 2014 October and it had a maximum area of 2750MSH. The largest five groups were then described based on Solar Section observations, including images in white light, Hα and CaK. The appearance of these groups on previous or subsequent solar rotations was also described.

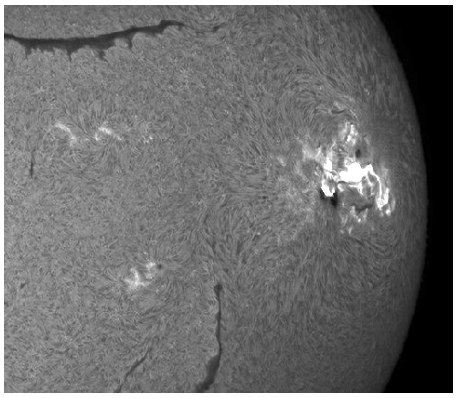


Figure 37. Hα image of AR12192 on 2014 Oct 27, 10:34 UT. *Peter Garbett*

The final part of the paper compared the sizes of the largest groups, for cycles stretching back to the early part of the 20th Century. This showed, for example, that (excluding AR12192) the second to fifth largest groups from Cycle 24 were considerably smaller than those for any of the previous cycles dating back to 1900.

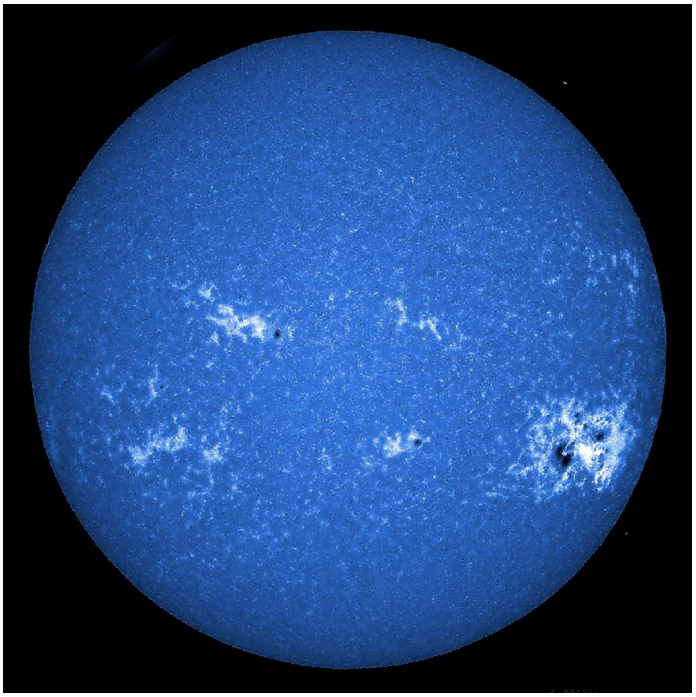


Figure 39. CaK image, showing AR12192 approaching the W. limb on 2014 Oct 27. *Peter Paice*

Table 2(c). The larger sunspot groups of cycles 22–24

Date	*Max. Area (MSH)*	*Date*	*Max. Area (MSH)*	*Date*	*Max. Area (MSH)*
1989 03 17	3600	2003 10 29	2610	2014 10 26	2750
1989 09 03	3080	2001 03 29	2440	2014 02 04	1580
1990 01 18	3080	2000 09 19	2140	2014 01 08	1560
1988 06 29	2900	2004 07 21	2010	2011 11 04	1540
1988 10 10	2540	2002 08 12	1990	2012 07 12	1460
Cycle 22		Cycle 23		Cycle 24	

Acknowledgements

The *Solar Dynamics Observatory* (SDO) Helioseismic & Magnetic Imager (HMI) Continuum images are courtesy of NASA/SDO and the HMI science team. All the contributors to the BAA Solar Section during Cycle 24 – whether they provided daily statistics, drawings, images or other data – are thanked for submitting their observations.

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References & notes

1 Cook J. A., 'The Radio Astronomy Group in 2017', *J. Brit. Astron. Assoc.*, **128**(2) 116–118 (2018)

2 USAF/NOAA Solar Region Summary: **https://www.swpc.noaa.gov/products/solar-region-summary**

3 An active region (AR) number assigned to a sunspot group during its disk passage. *Note*: the AR number reached 10,000 in 2002 July. However, NOAA Space Weather Prediction Center (SWPC) products continue to use four-digit region numbers, with leading zeros. The BAA and many other solar organisations use the AR number to identify sunspot groups (and in the shortened four-digit format for groups since 2002 July). This paper uses the full five-digit format.

4 Total corrected area of the group in millionths of the solar hemisphere (MSH). The smallest sunspot detected with amateur equipment – such as an 80mm refractor using the projection method to view a 6″ diameter disk – is 30MSH, while 500MSH is considered the minimum size for a sunspot to be seen with the protected naked eye. The largest recorded sunspot group had an area of 6100MSH, in 1947 April.

5 Modified Zurich classification of the group, as described in: McIntosh P. S., 'The classification of sunspot groups', *Sol. Phys.*, **125** 251–267 (1990). Available on the SAO/NASA Astrophysics Data System at: **http://articles.adsabs.harvard.edu//full/1990SoPh..125..251M/0000251.000.html**.

6 Plage are bright chromospheric features, usually associated with sunspot groups. Unlike the white light counterpart, faculae, plage are also visible in narrow-band telescopes away from the solar limb.

7 The visual classification is based on the area of the flare. The types are S, 1, 2, 3 or 4, where S is a sub-flare with area less than 100MSH; 1 is for an area between 100 & 250MSH; 2 is for between 250 & 600MSH; 3 is for between 600 & 1200MSH and 4 is for greater than 1200MSH. In addition, there are intensity types f (faint), n (normal) or b (bright). The classification is taken at maximum intensity, rather than maximum area.

8 Royal Observatory, Greenwich – USAF/NOAA Sunspot Data: **https://solarscience.msfc.nasa.gov/ greenwch.shtml**

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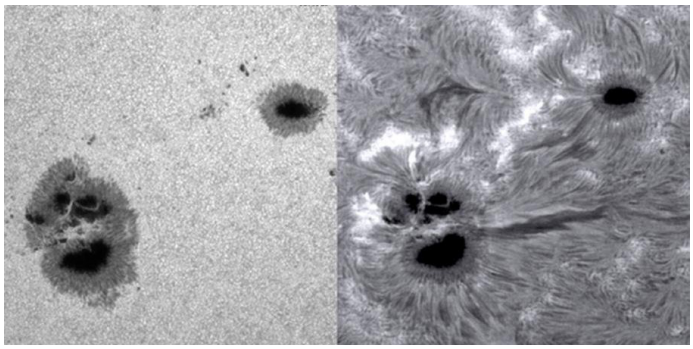

Figure 40. Comparison images of AR12209 in white light and Hα, taken on 2014 Nov 18 at 13:05 UT. *Dave Tyler*

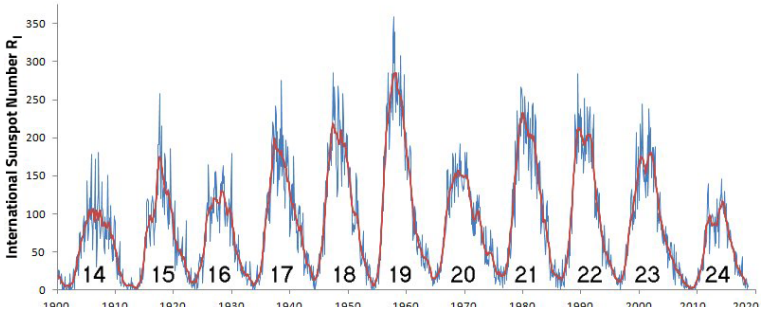

Figure 41. The monthly (blue) and smoothed (red) International Sunspot Number. *Prepared by Peter Meadows.*