## Feature Story: ALPO Solar Section

# A Report on Carrington Rotations 2164 and 2165

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## Overview

The first thing that one should note is that the longitudes of maximum activity for Carrington Rotation CR2164 and Carrington Rotation 2165 were pretty much the same, thereby indicating that the active regions were persistent. Even so, the activity levels were anemic compared to solar cycle maxima going back into the 19th century. Some professional astronomers have even predicted that we are on the cusp of another prolonged "Maunder Minimum" (Livingston et al, 2011; Livingston et al, 2008) based in part on the nature of the sunspot of this cycle (Livingston et al, 2009). This makes it critically important that solar activity be monitored during the last half of the current cycle and into Cycle 25.

Throughout this report the ALPO Solar Section will be referred to as "the Section" by this author. Carrington Rotations of the Sun (enumerated with an arbitrary "0" longitude on 8 February 1832) will simply be called "CR" as in CR2164 and CR2165. Likewise, Active Regions, enumerated by the National Oceanic and Atmospheric Administration (NOAA), will be designated as "ARs" using only the last 4 digits. Most of the compiled statistics used in this report will be from NOAA. All times will be Coordinated Universal Time (GMST for us old-timers!) and dates will be reckoned accordingly.

Two terms that seem to cause the most confusion are "leader" and "follower". More developed sunspot groups usually have two main spots arranged roughly on an east-west line. When in the center of the disk, for example, the "leader" would cross the meridian before the "follower". White-light observations will be indicated by "w.l.", Hydrogen-Alpha by "H-a" and Calcium K-line by "CaK".

Dates will be expressed numerically, for instance as "6/11", which represents first the month (June in this example) and then the calendar date (11, in this example).

All areas on the disk will be expressed in the standard measurement of millionths of the disk (a naked eye spot generally being about 1,000 millionths. Spot classifications are the ones defined by Patrick McIntosh of NOAA (McIntosh 1981, 1989) and detailed in an article in the Journal of the Assn of Lunar & Planetary Observers (JALPO) Vol. 33

### How Are Sunspot Measured

Astronomers measure the sizes of sunspots as fractions of the Sun's visible area. Their favorite units are "millionth's." A sunspot that registers 1 millionth has a surface area equal to 0.000001 times the area of the Sun's Earth-facing hemisphere. Typically, a big sunspot measures 300 to 500 millionths. The entire surface area of the Earth is only 169 millionths of the solar disk. Source: *http://www.space-weather.com/sunspots/history.html*

**Table of Contributors to This Report**

| Observer | Location | Telescope (aperture, type) | Camera | Mode | Format |
|---|---|---|---|---|---|
| Tony Broxton | Corwall, UK | 127mm, SCT | N.A. | w.l. | dwg |
| Howard Eskildsen | Ocala, FL, USA | 80mm, RFR | DMK42AU02 | Ca-K | d.i. |
| Rik Hill | Tuscon, AZ, USA | 90mm, MCT | Skris 445M | w.l. | d.i. |
| David Jackson | Reynoldsburg, OH, USA | 124mm, SCT | | w.l. | d.i. |
| Jamey Jenkins | Homer, IL, USA | 102mm, RFR<br>125mm, RFR | | w.l.<br>Ca-K | d.i. |
| Monty Leventhal | | 250mm, SCT | N.A. | w.l., H-a | dwg, d.i. |
| Theo Ramakers | Oxford, GA, USA | 40mm, RFR<br>40mm, RFR<br>80mm, RFR | DMK42AU02 | H-a<br>Ca-K<br>w.l. | d.i. |
| Randy Tatum | Bon Air, VA, USA | 180mm, RFR<br>180mm, RFR | DFK31AU | w.l., p.p.<br>H-a | d.i. |
| David Tyler | Buckinghamshire, UK | 178mm, RFR<br>90mm, RFR | ZWO | w.l.<br>H-a | d.i. |

NOTE: Telescope types: RFR (refractor), SCT (Schmidt-Cassegrain), MCT (Maksutov-Cassegrain)
Mode types: w,l. (white light), Ca-K (calcium chloride), H-a (hydrogen alpha), p.p. (pentaprism)
Format types: dwg (drawings), d.i. (digital images)

(Hill 1989). This classification system is also detailed by the author on the Section website at http://www.alpo-astronomy.org/solar/wlft.html in an article on white light flare observation.

Observers contributing to this report and their modes of observing are summarized in the table on the first page of this report. It will be used as a reference throughout this report rather than repeating this information on every image or mention.

## References:

Hill, R.E., (1989) Journal of the Assn. of Lunar & Planetary Observers, Vol. 33, 10

Livingston, W., Penn, M.; (2008) "Sunspots May Vanish by 2015." *https://wattsupwiththat.files.wordpress.com/2008/06/livingston-penn_sunspots2.pdf*

Livingston, W., Penn, M. (2009) "Are Sunspots Different During This Solar Minimum?", Transactions American Geophysical Union, Volume 90, Issue 30, pp. 257-258

Livingston, W.; Penn, M.; Svalgard, L., (2011) "A Decade of Diminishing Sunspot Vigor", Bulletin of the American Astronomical Society, Vol. 43, 2011

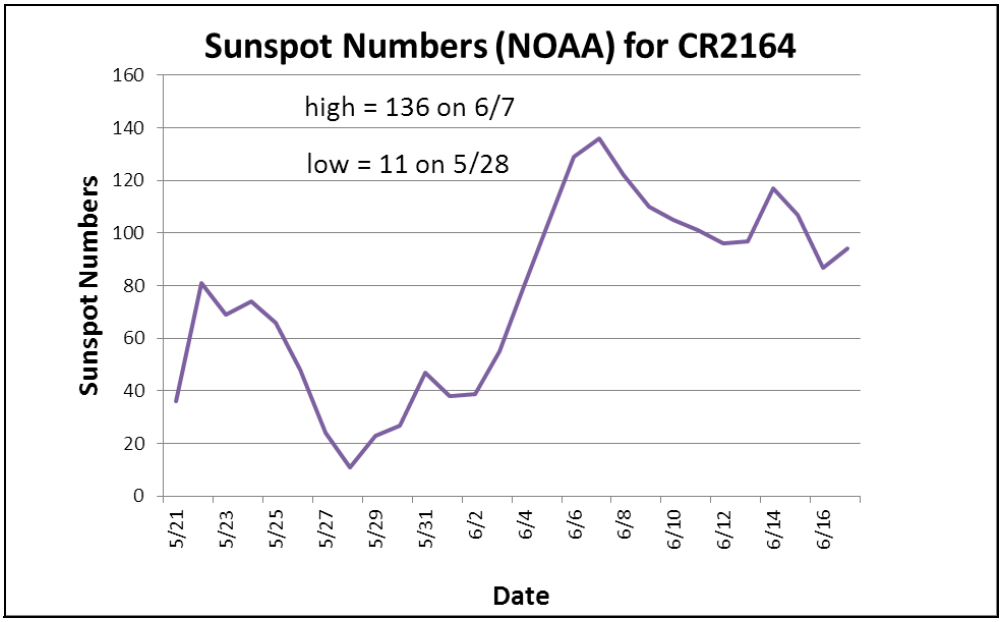
McIntosh, Patrick S., (1989) "The Classification of Sunspot Groups", Solar Physics, Vol. 125, Feb. 1990, pp. 251-267.

McIntosh, Patrick S., (1981) The Physics Of Sunspots, Sacramento Peak National Observatory, Sunspot, NM; L.E. Cram and J.H.Thomas (eds.), p.7.

## Activity for Solar Rotation 2164

### *2015 5 21.4 > 2015-06-17.6*

This rotation saw two peaks of activity. The first peak was caused by numerous groups with areas less than 100 millionths of the Sun's disk and few spots that had penumbrae and smaller umbral spots surrounding. A couple groups got to D-class but not beyond that in evolution.




The second peak (6/7) saw 10 groups, with one over 200 millionths. But in general, in both peaks, while there were plentiful sunspot groups, the numbers of spots within them were relatively less than in the previous solar cycle. One group got to E-class, but most of the larger ones only got to C-class.

AR2353 Popped into view late on 5/22 as a new Bxo group, with no associated sunspot group in the previous rotation. Another smaller group followed it. Neither was designated (by NOAA) until the 5/23. On that date, Broxton showed this region in a whole-disk drawing. The group was composed of a leader spot with tight penumbra surrounding followed by 4-5 umbral spots. Its size at this time was 40 millionths and it was classed as Cro.

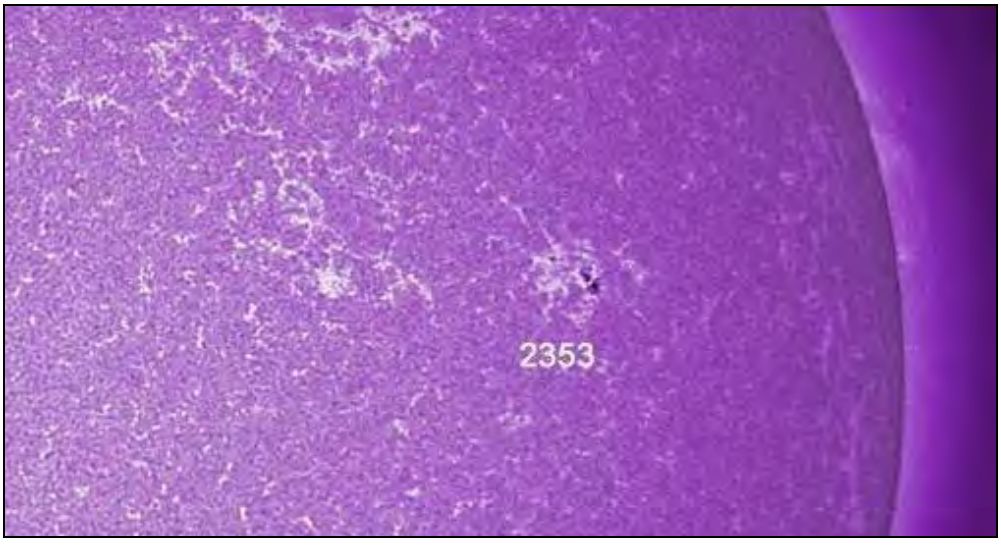



Figure 1. A subsection of a Ca-K image by Howard Eskildsen of Ocala, FL (USA) taken on May 25, 2015 at 12:25 UT, showing AR2353 approaching the solar limb.

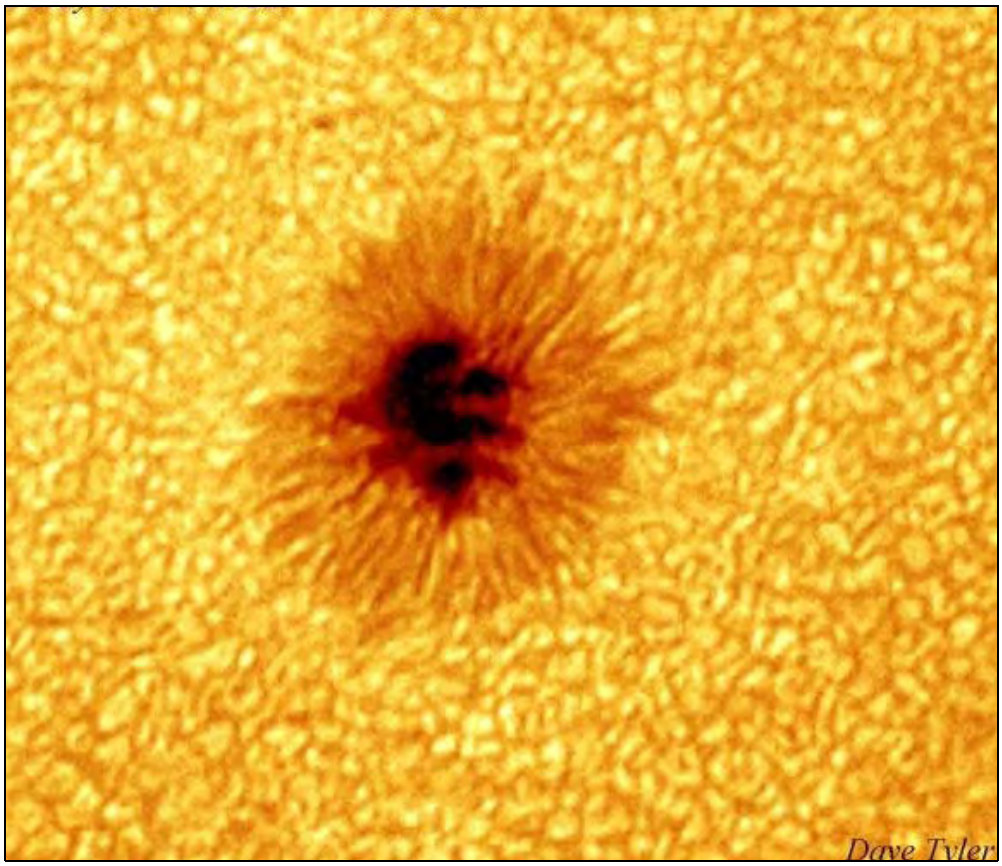



Figure 2. AR2348 as shown in a digital image by David Tyler of Buckinghamshire, UK, taken on May 21, 2015 at 09:12 UT.

There was little development the next day, and on 5/25, a CaK image by Eskildsen (Figure 1) shows an unremarkable appearance with a very small plage structure about the AR. It was then listed as a Dao group of only 60-70 millionths, but there were no recorded flares from this region.

The other largest region of this first peak in activity was AR2348. It was first seen as 100 millionths and had no previously associated group in the previous rotation. It was a classic example of the decay of a sunspot group where the leader spot is all that's left. In such case, the umbra becomes quasi-circular and surrounded by a radially symmetrical penumbra. It remained unchanged until it left the disk on 5/26. These Hhx and Hsx "groups" can remain this way for many days as they slowly decrease in size. This one is well shown in a spectacularly detailed image by Tyler on 5/21 (Figure 2) showing all the typical features of an Hsx sunspot.

The second peak numbers were driven by three active regions, AR2361, 2362 and 2360. Of the three, AR2360 was the leading and most interesting and achieved the maximum and most active development. However, all three put on a spectacular show as this triangle of regions crossed the Sun's visible disk.

AR2360 was first to come into view on 6/2 but was not designated by NOAA until the next day when it was seen as a Dao group of some 50 millionths. It was already producing numerous C- and M-class flares by this time. A couple of these flares were noted by Broxton in the first few days of its passage and were beautifully imaged by Ramakers on 6/5 (Figure 3) in an H-a image that shows the triangle created by these three ARs. From this point on, AR2362 went through a process of slow decay as shown in a wonderful five day image series by Tyler seen in Figure 4.

On 6/5, all three regions produced flares but by far, AR2360 out-produced the aggregate total of the other two regions by a factor of two. Over the next two days, this increased to a factor of three. AR2361 was increasing only a little in flare production.

AR2360 attained maximum development and activity on 6/8, when it took up 140 millionths of the disk, had a MacIntosh class of Eac and produced no less than 30 flares. Magnetically it was classified as "beta-gamma", which indicates a very active flare producing region. (It needs to be pointed out that while this was maximum development for this region and was being reported in solar websites and e-mail lists as a "giant sunspot", it was nothing of the sort except in relative terms for this paltry Solar Cycle. A sunspot needs to be near 1,000 millionths to be naked-eye visible for most people and cannot be called "giant" short of that.) Tyler has a good image of this region on the 6/8 and it shows instability taking place. Penumbrae are not well-organized on the side of each spot towards the center of the region, the site of much of the energy transfer going on in the flares. This site is well-shown in the insert on the Tyler image from Leventhal where he notes the site in color in his H-alpha filtergram.

June 8 was also the day of peak sunspot numbers for this rotation. For the next several days, this situation remained much the same, with a very slow decrease in size of the w.l. group but no change in the level flare activity. On 6/11 all the attention that had been focused on ARs2360-62 was divided when a new beta-gamma flare producer, AR2367, class Dao, began its show

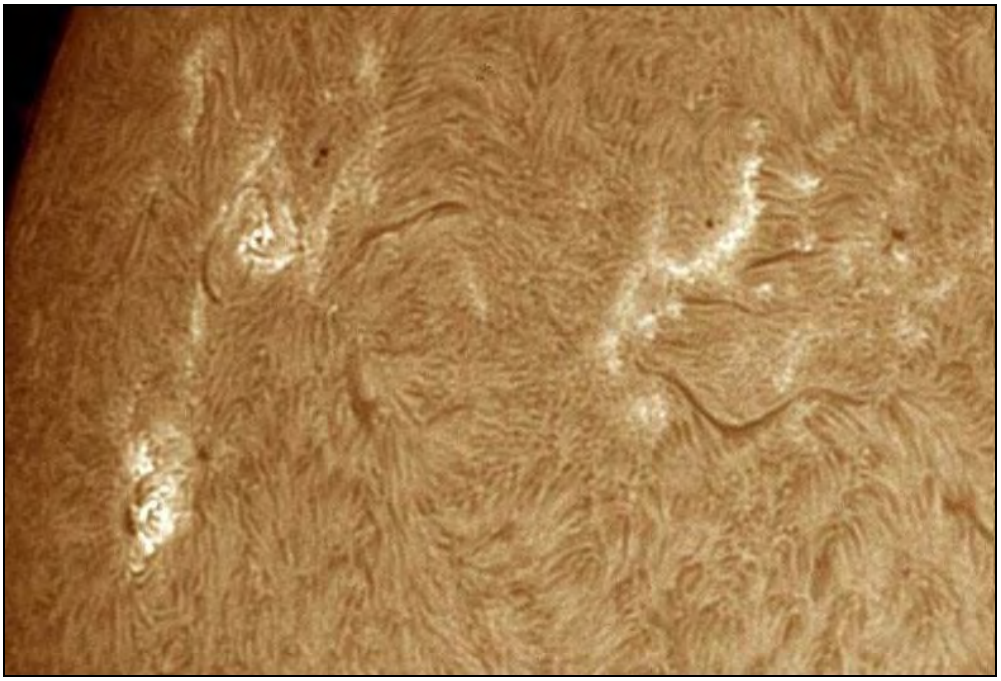


Figure 3. From left to right, AR2360, AR2361 and AR2362 as imaged by Theo Ramakers of Oxford (near Atlanta), Georgia (USA) on June 6, 2015 at 13:19 UT, using a Coronado SolarMax 40 H-alpha telescope with a 3x Klee barlow and an ASI 120 camera.

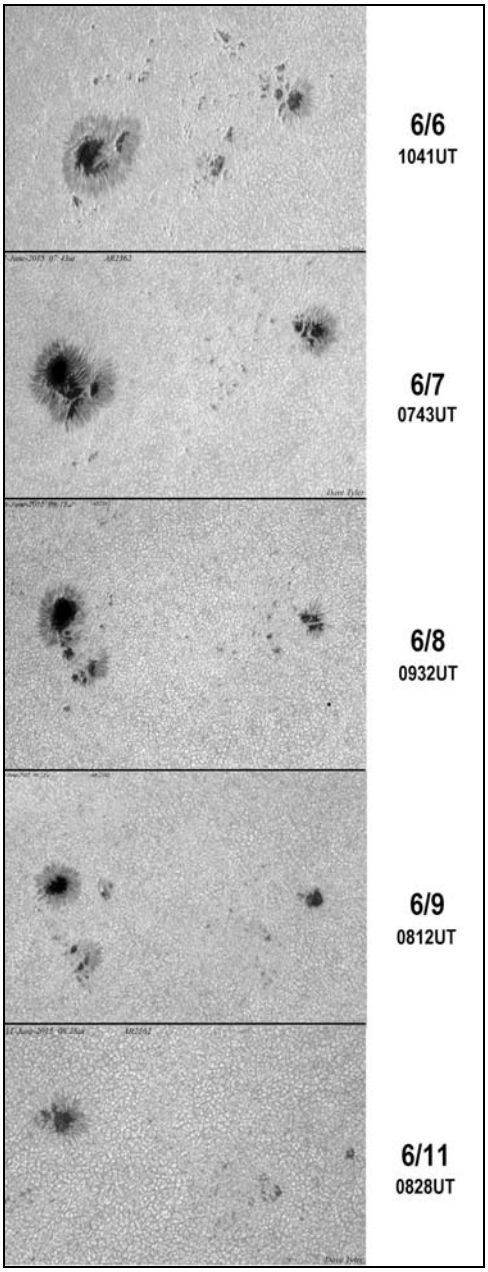



Figure 4. Images taken over five days by Tyler showing dissolution of AR2362.

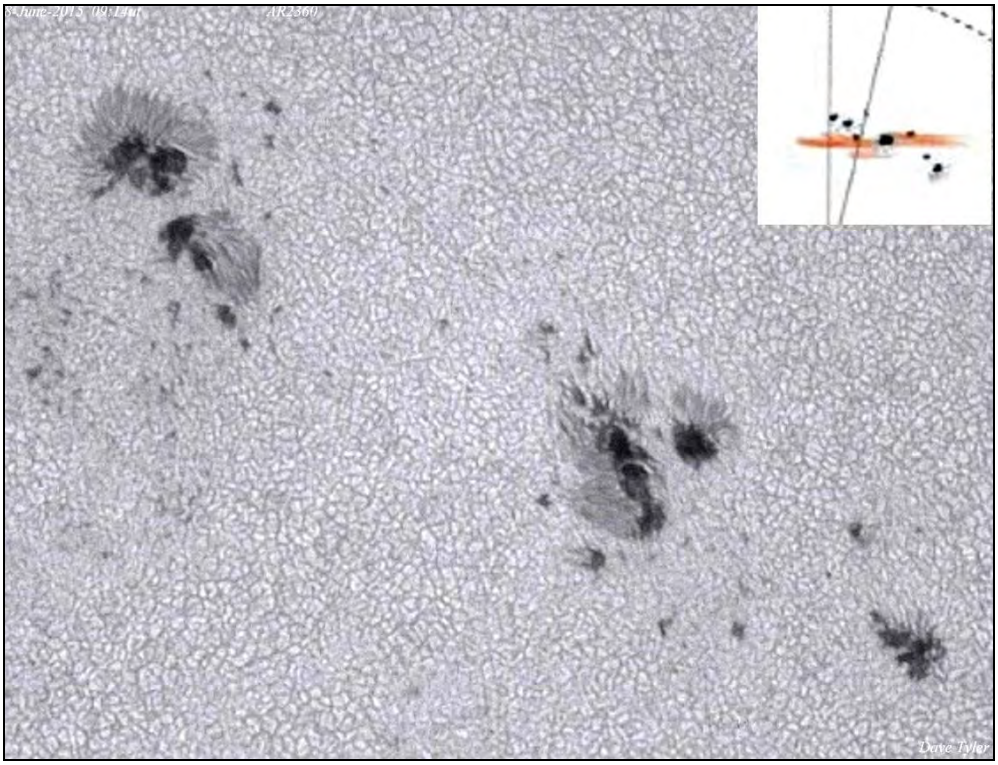


Figure 5. White-light image by Tyler taken on June 8, 2014 at 09:14 UT showing maximum development of AR2360; see also the insert at top right from a whole-disk drawing by Leventhal.

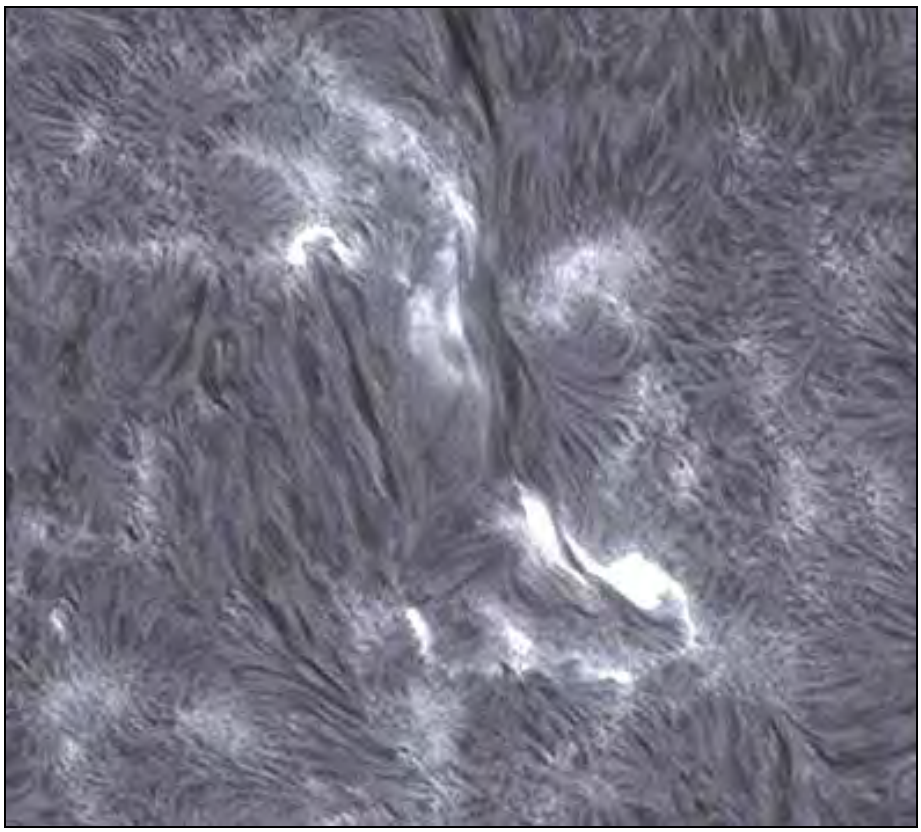


Figure 6. Flares in and around AR2362 on June 11, 2015 as imaged by Tyler.

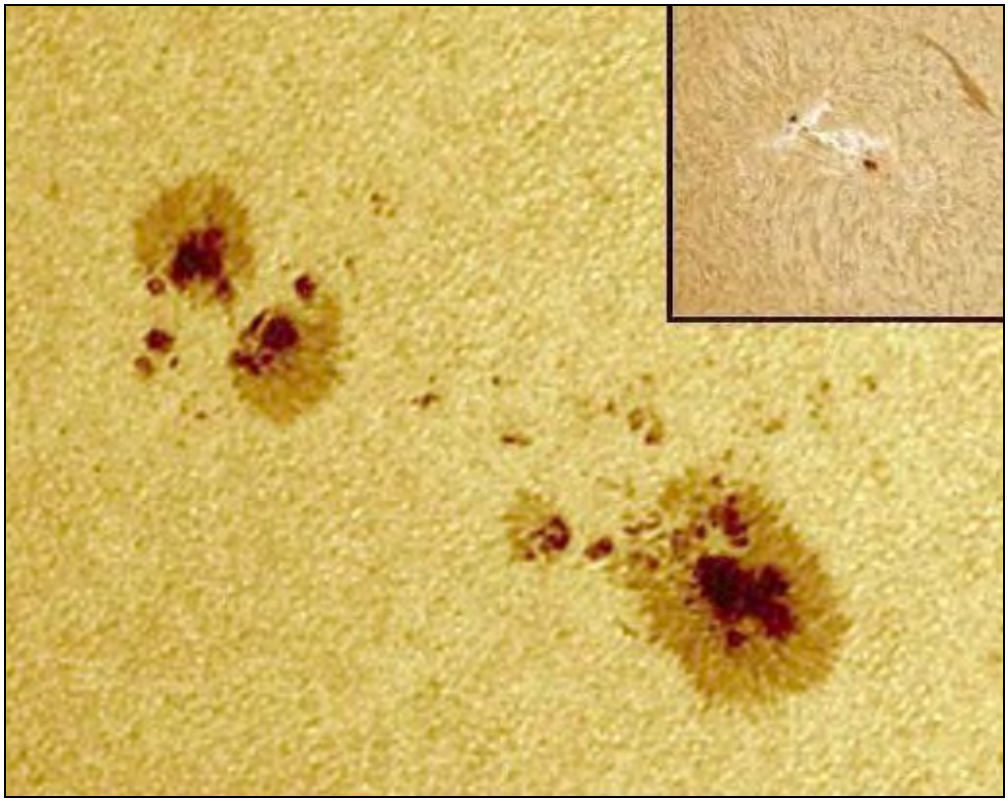


Figure 7. Two images by Ramakers showing state of AR2367 on June 21, 2015 at 15:00 UT (white-light) and 14:29 UT (H-alpha in the inset). See Table 1 for instrumentation details.

(discussed below). On 6/11, Tyler got an H-a image of a couple of small flares near AR2362 as seen in Figure 6.

Leventhal on 6/13 2240 UT, showed AR2360 on the limb with much extensive faculae surrounding. Flare production was still very high. This was the last observation of this region. The other two regions of the original triangle were greatly reduced, with AR2361 being only a plage region between AR2362 and AR2365.

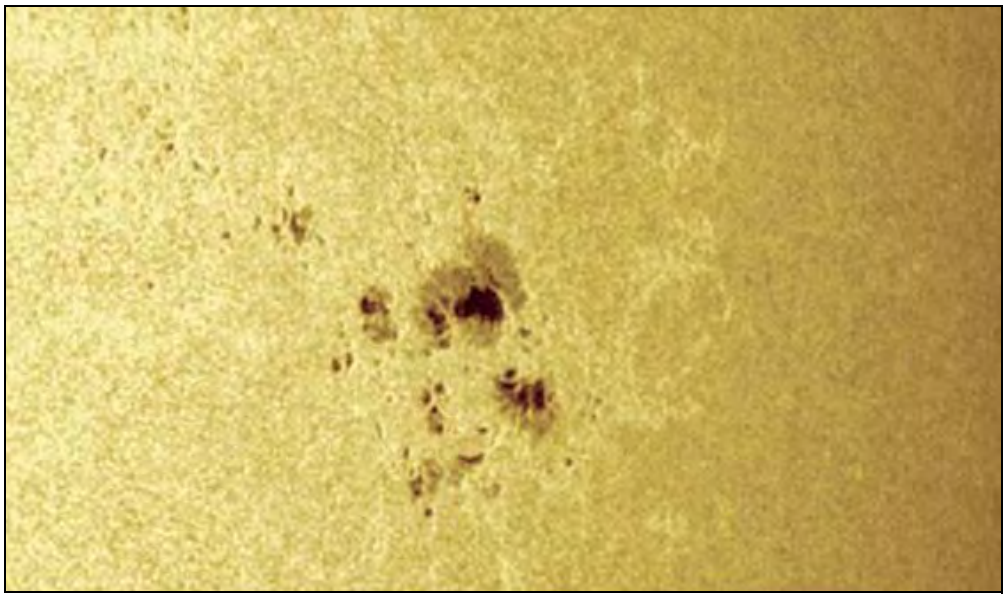


Figure 8. AR2367 as imaged by Ramakers on June 20, 2015 at 14:01 UT.


Figure 9. Final digital image of AR2367 by Tyler on June 22, 2015 at 14:41 UT.

Towards the end of the rotation, there was another short spike in activity. As the previous regions were approaching the preceding limb on 6/11, a large area of faculae was seen on the opposite limb in the southern hemisphere, heralding the approach of another large active region that would be designated AR2367. On 6/12, AR2367 was first observed by Ramakers in a whole-disk H-alpha image. On that day, it was classed as a Dao group, magnetic class beta with an area of 30 millionths of the disk. It was already the major flare producing region on the Sun and caught in the act in the Ramakers image. It grew rapidly to over 200 millionths on the 6/13 when Leventhal observed it flaring in a drawing done at 2240 UT. By 6/14, the area had grown by 50% to 300 millionths with a class of Eki. It was now flaring on average every two hours. A very nice white-light image was obtained by Ramakers at 1436 UT on that date. It shows all the features of its class very nicely (MacIntosh 1981, Hill 1989).

Images by Ramakers (Figure 7) and a sketch by Broxton on 6/15 showed the region mostly unchanged with an area of 340 millionths and a class of Ekc. Even though it was still a beta-gamma region, the flare production was a third of the peak seen several days earlier. The area increased to 400 millionths the next day, as imaged by Hill and Ramakers, but dissolution was beginning as the follower spots were breaking up into smaller spots. The leader spot was pretty much the same but a bit smaller. Then on the 6/17, the follower spots had been reduced to just a string of small spots trailing the leader, several with rudimentary penumbra, and many just pores and umbral spots. The leader itself

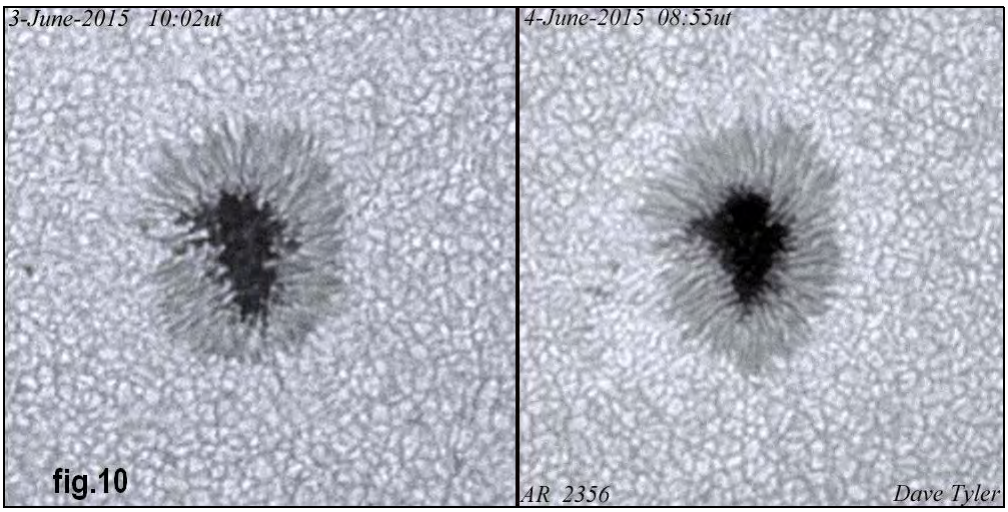



Figure 10. Images by Tyler taken on two successive days. See text for details.

was becoming more circular in shape, a clear sign the peak had passed. The area was now 360 millionths and the class Ehc. This process continued until the follower spots were completely gone on 6/20. At this time, the official class was listed as Eki but it appeared to be more a Dai or Dac. The area was now only 290 millionths and falling rapidly (Figure 8).

Tyler was the last to digitally image this region on 6/22 and Broxton got the last look in his sketch a day later. He saw it as just three umbrae on the extreme limb.

Before leaving this rotation, there is one observation by Tyler (Figure 10) that serves to teach a couple of lessons in solar observation. He imaged AR2356 on two consecutive days. At first glance, it appears much like AR2348 as described above, an old decaying region that has become a simple umbra with a radially symmetric penumbra. It would be unlikely to show much change over many days, just reducing in area until it dissolved completely. However, a pair of images shows a phenomenon that is very worthy of note and further observation, especially as we head into the minimum of this solar cycle. On the 6/3 (left), we see the sunspot with a mottled umbra composed of "umbral dots" with its symmetrical penumbra in a field of granulation all of the same granule size right up to the penumbra. But a day later the umbra is darker, the penumbral filaments are more dense and there is a region of granulation surrounding the spot, about the same width as the penumbra, where the granules are brighter and about half the size of the ones in the rest of the photosphere. This is most evident on the left side of the spot and not as pronounced on the right but still visible.

Observers should be alert to these kinds of changes. They may well herald other changes such as a sudden dissolution of the spot or a break up all due to some change in energy transport in the photosphere, all well worth recording.

## Activity for Solar Rotation 2165

### *2015-06-17.6 > 2015-07-14.8*

This rotation opened with AR2367 dominating the center of the disk as described in the previous rotation. But on the following limb, AR2371 was just coming into full view. It was first seen by Ramakers on 6/15 as bright points on the limb in his H-a whole-disk image on that date (Figure 11). The next day Broxton, Leventhal, Ramakers and Tyler all observed it and starting on 6/16, Hill followed it through of its passage across the visible disk (Figure 12). On 6/16, it was shown as a well-developed Dso group (beta) of 190 millionths area with a large leader followed by two east-west parallel lines of smaller spots with penumbrae on the outer edges away from the center of the sunspot group. It was already producing numerous flares with around 50 for the 16th alone!

The next day saw the follower spots beginning to coalesce, with the class increasing to Ekc (beta-gamma) and the area more than doubled to 520

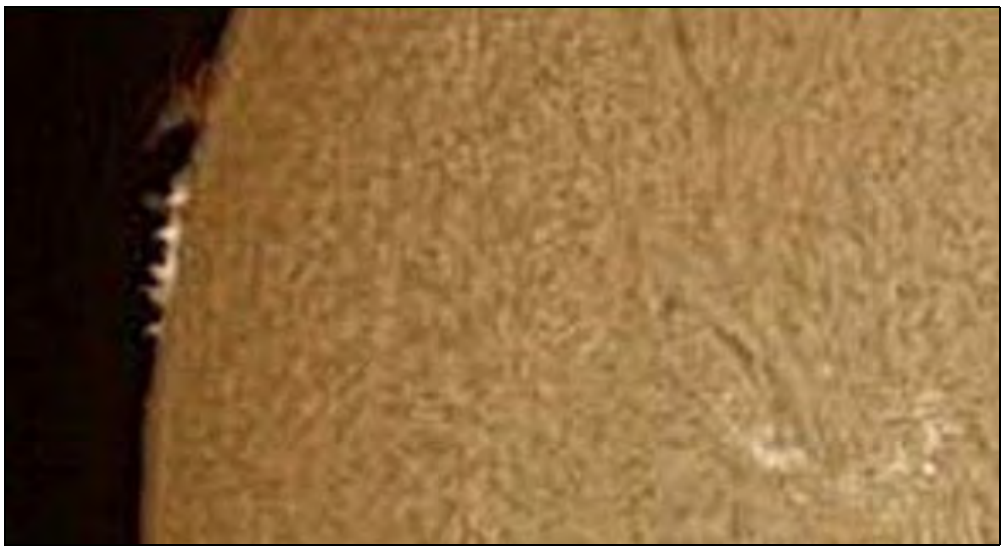


Figure 11. First observation of AR2371 by Ramakers as bright points on the solar limb in this H-alpha image taken on June 15, 2015 at 14:29 UT.

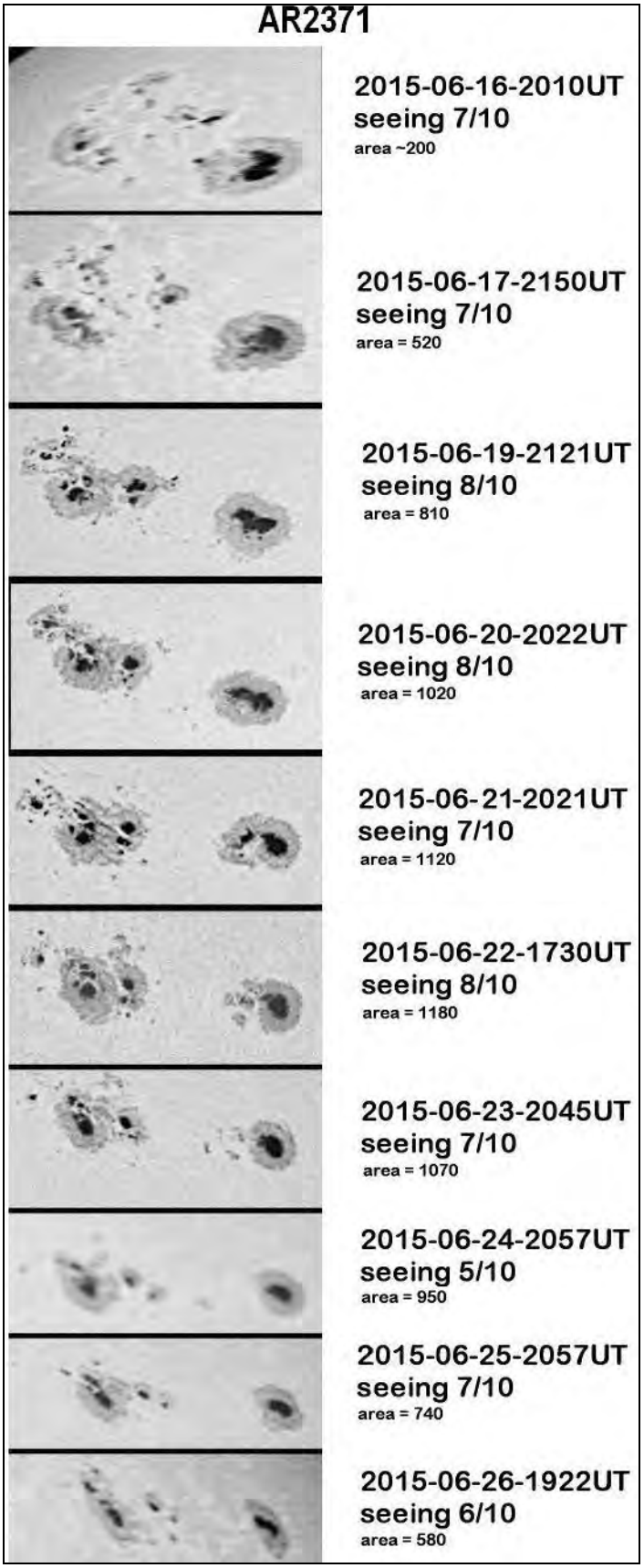



Figure 12. White-light date/time sequence of AR2371 by Hill.

millionths. The coalescing of the follower spots was the main action over the next several days until the follower spot was larger than the leader. By 6/18, observers on the solar observing e-mail lists were noting AR2371 as being "naked *eye*". The area had grown to over 800 millionths but its class remained Ekc (beta-gamma-delta, producing several flares per hour). The number of umbral spots nearly doubled on this date. There is an excellent 3-frame look at this region by Ramakers (Figure 13). The two monochromatic images show the plages and flares and level of activity for this region.

The coalescing of the follower spots into a single mass was mostly complete by 6/19. During this day, the measured area was increased to over 1,000 millionths making it easily "naked-*eye*" for most observers. A day later, the growth of AR2371 reached 1,120 millionths, class Ekc (beta-gamma-delta) and oddly enough, flare production was decreasing along with the growth rate. The follower spots were now the most consolidated that they would be for this region. Maximum area development was on 6/21 with 1,180 millionths and the class was increased to Fkc (magnetic class unchanged), making vigorous flare production a certainty but still was not as good as the 6/19. The number of umbral spots, like the area, was also a maximum on this date. It was being heavily observed by Ramakers, Tyler, Tatum, Broxton, Leventhal and Hill.

Dissolution was definitely taking place by 6/22. The number of umbral spots was decreased as was the size of the spots. Light bridges in the follower collection of spots were widening and increasing in number. The area of the whole region was largely unchanged, 1,170 millionths (beta-gamma-delta), and the class was still Fkc. It still produced around 40 flares but only a few were M-class flares. It should be pointed out that this group, while nice and active, produced no X-flares, underscoring a point in the previous rotation that while this was a good sunspot group, by standards of previous cycles it was only average. Cycle 22 at its peak was far more active.

On 6/23 we have a superb image by Tatum showing AR2371 in the process of breaking up. The portion of the leader that separated has been reduced to just a few umbrae and the follower is criss-crossed by hot active light bridges, the source for most of the flares this day. The area was now down to 950 millionths, but the McIntosh-Zurich and magnetic classes were unchanged. Flare production was down with only 2 M-class flares seen.

The decay continued over the next few days, with the follower separating into smaller spots that were dissolving and the leader becoming more consolidated. Flare production decreased and by the 6/26, the magnetic class was reduced to beta-gamma though the McIntosh-Zurich class was still Fkc. On this date, the area was measured 580 millionths.

The last look at AR2371 was by Tyler on 06/27 in w.l. at 0702 UT. The area had been reduced to 430 millionths and the class was Ekc (still beta-gamma). There were no observations of this region submitted for 6/28 and by 6/29, it had left the disk.

These next months are as good as things will get for the next few years. ALPOSS observers are well-placed to record the activity (or note the lack of it) on a day-to-day basis. If any observers or prospective observers need help with equipment or techniques, they should contact our staff and we will be only too happy to help.

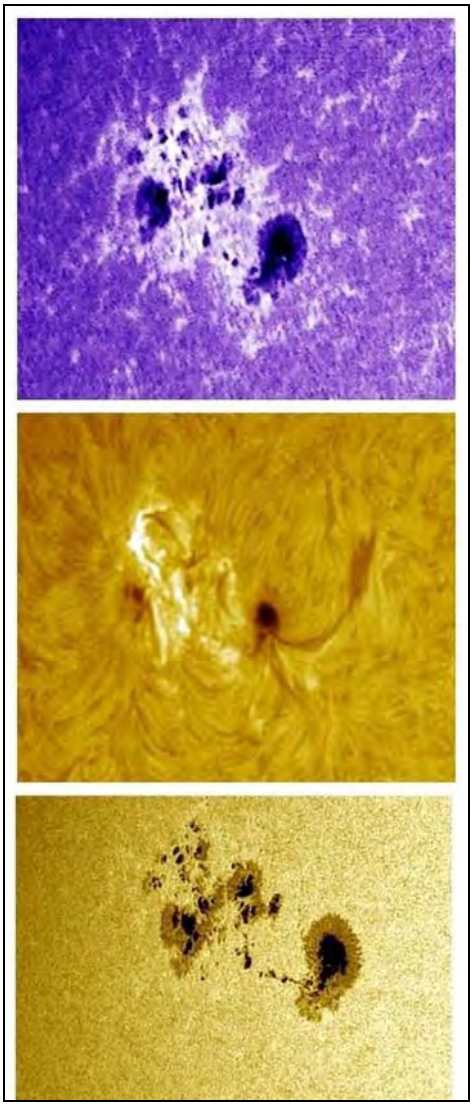


Figure 13. A "snapshot" of AR2371 by Ramakers on June 18, 2015 at 14:36 UT at top, an H-alpha of the same region at 14:28 UT in the middle, and a white-light image of the area taken at 14:50 UT below that.

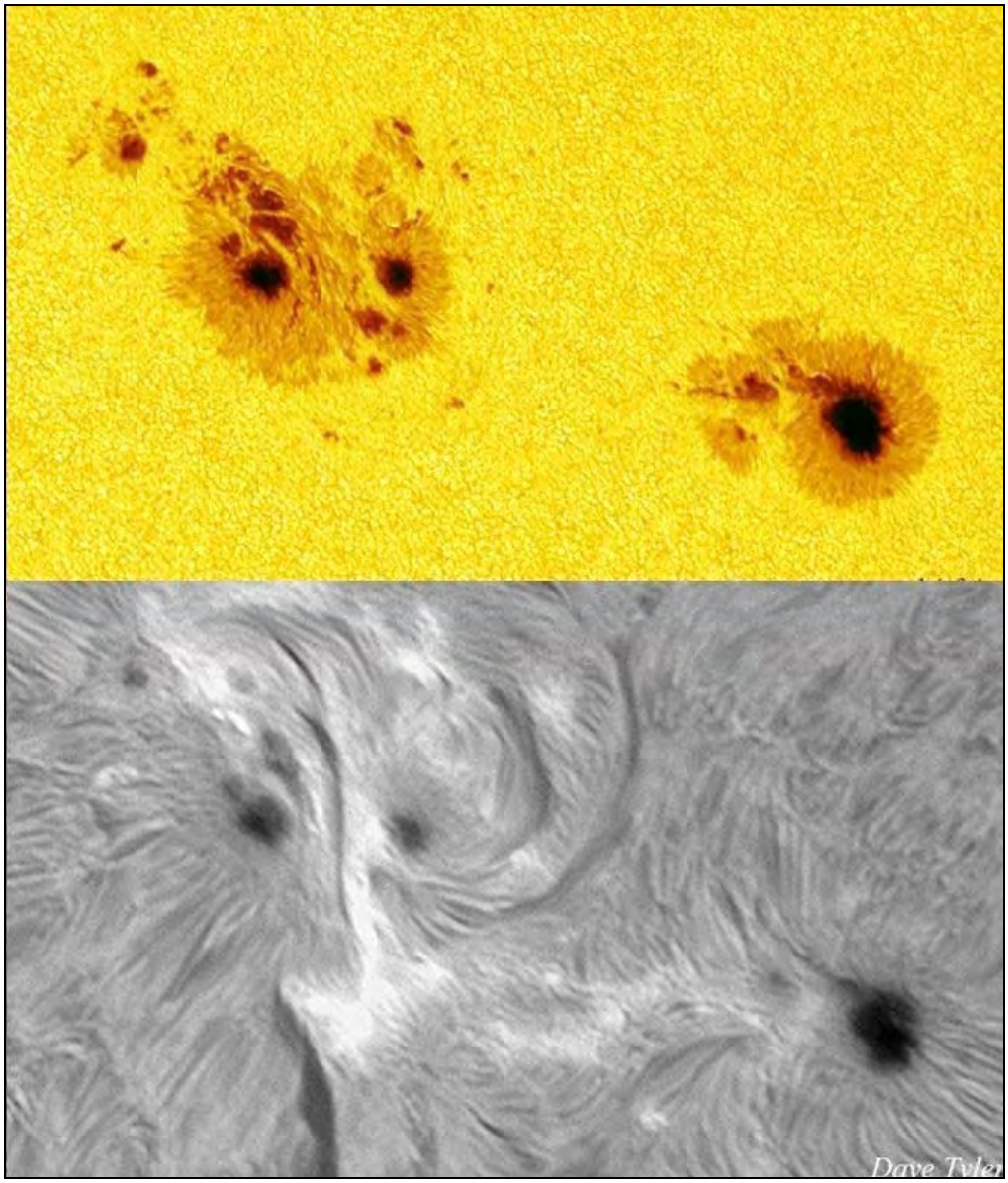



Figure 14. Two images of AR2371 by Tyler on June 22, 2015. The top one in false color was taken at 14:34 UT, and the bottom one in H-alpha was taken at 15:09 UT.

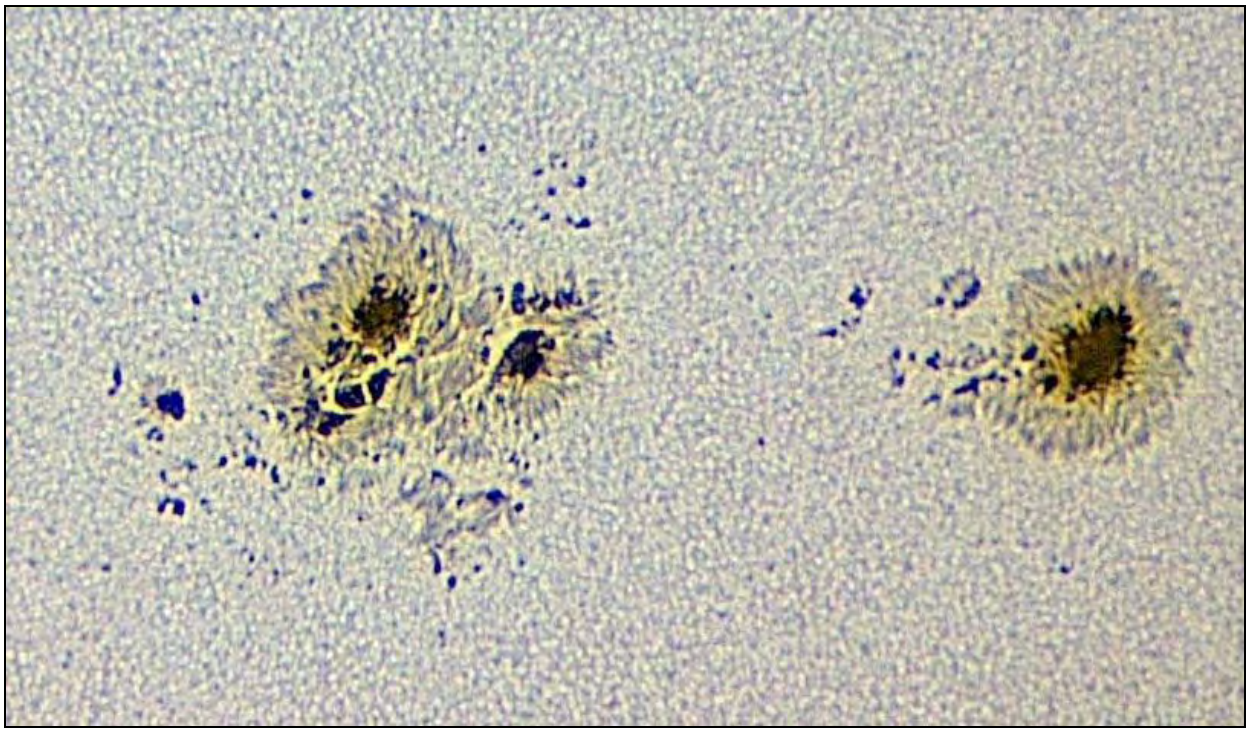


Figure 15. AR2371 as imaged by Tatum on June 23, 2015 at 15:05 UT using an antique Mogey refractor equipped with a pentaprism (acting somewhat like a Herschel wedge). The color scheme used here was done to show more interior detail within the umbrae.

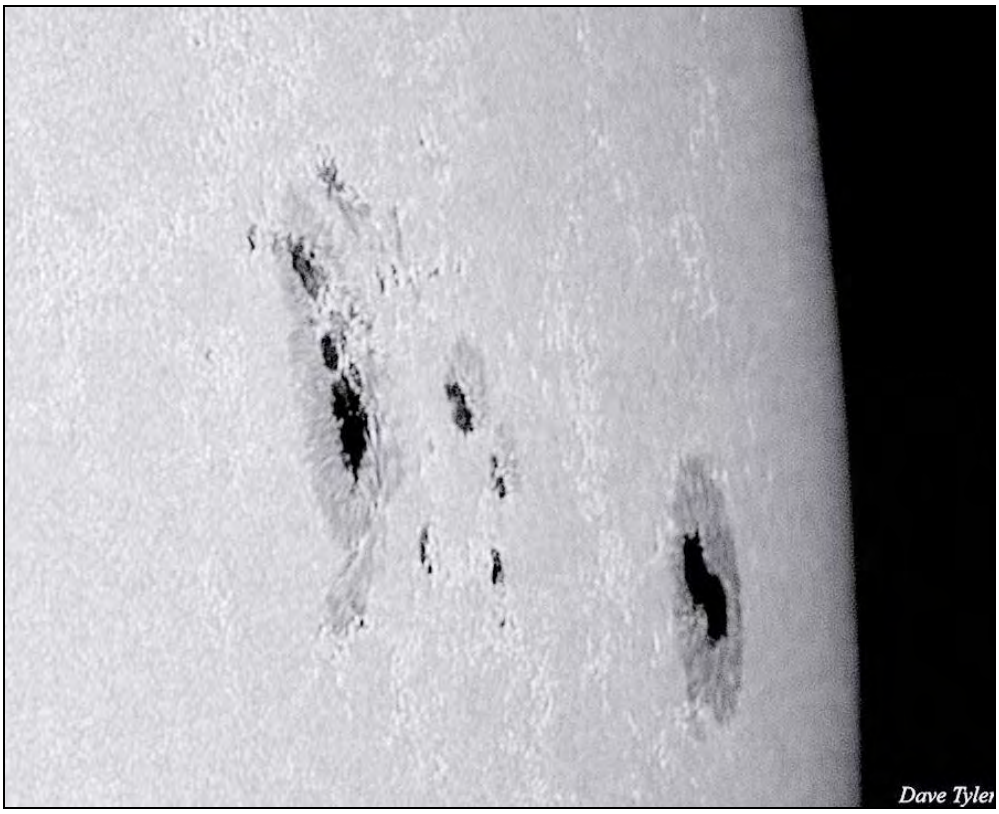



Figure 16. The last look at AR2371 by Tyler on June 27, 2015 at 07:02 UT. Note how the entire region is in a complex filigree of faculae.