



Feature Story: ALPO Solar Section A Report on Carrington Rotations 2174 thru 2177

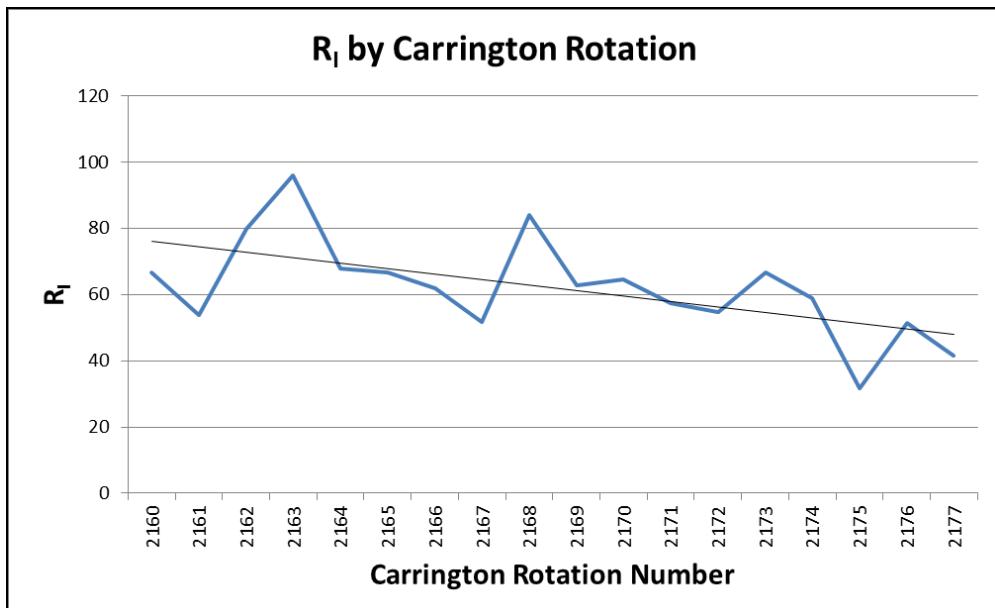
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Overview

Solar activity continued its long slide towards a minimum predicted for 2020-21. The rotational sunspot number never rose to 70 during this reporting period as evidenced in plot.1. At the time of this writing (CR 2076), we have already experienced a number of days with a count of 11, which is the lowest possible number above zero, since the formula for determining the Wolf number is $10g + s$ (or 10 times the number of sunspot groups plus the number of spots). For individual observer sunspot counts, a “personal factor” is usually applied by the tabulator, reckoned from many days of observing by that observer.

The average daily sunspot number for this reporting period (Oct. 15, 2015 - Feb. 17, 2016) was 61.2 — a drop from the 65.8 of the previous reporting period with a high of 108 (on 02/04 & 05) and a low of 12 (on 10/10).

As in the last two reports, the ALPO Solar Section will be referred to as “the Section” here. Carrington Rotations (2069-73) will be called CRs. Similarly, Active Regions will be called “ARs”, using only the last four digits of the full number. “Groups” will apply to the visible light or “white light” collection of sunspots while “Region” or “Active Region” will apply to all phenomena associated with the particular sunspot



group. Statistics used in this report are compiled by the WDC-SILSO* at the Royal Observatory of Belgium which is responsible for the International Sunspot Number used here. All times will be Coordinated Universal Time and dates are reckoned from that. Dates will be expressed numerically with month/day such as “9/6” or “10/23”.

The terms “leader” and “follower” will be used here instead of east or west on the Sun. “W-L” may be used to indicate White Light observations while Hydrogen-Alpha may be “H-a” and Calcium K-line “CaK”, abbreviations well-familiar to the experienced solar observer. An important point, “naked eye” here means the ability to see a feature on the Sun through a **proper and safe** solar filter with no other optical aid. You should never look at the Sun, however briefly, without proper filtration.

All areas on the disk will be expressed in the standard measurement of millionths of the disk, with a naked-eye spot generally being about 1,000 millionths for the average person. Spot classifications are the ones defined by Patrick McIntosh of NOAA (McIntosh 1981, 1989) and detailed in an article in JALPO (Vol.33, Hill 1989). This classification system is also detailed by the author on the Section website in an article on white light flare observation.

Observers contributing to this report and their modes of observing are summarized in Table “1. Contributors to This Report” on page 29 of this report. It will be used as a reference throughout this report rather than repeating this information on every image or mention.

Carrington Rotation 2174

Dates: 2016 02 18.1722 to 2016 03 16.4986

Avg. $R_I = 59.0$

High $R_I = 111$ (3/4)

Low $R_I = 25$ (2/25)

The RI maximum in this rotation was

caused by a numerous (at least six) small A to C class groups with many umbral spots. Only two regions exceeded an area of 100 millionths, AR 2505 and AR 2506. Of the two, AR 2506 was better covered by the Section observers. The evolution of this region is well-shown in a montage by Ramakers (Fig. 1), observed

first by Broxton and Leventhal in solar drawings on 2/23 a day before NOAA designated it. (Well done, guys!) Over the next few days, these two observers followed the region as it developed a leader with radially symmetrical penumbra and went from McIntosh A-class to C-class in both their estimations. The first images we have of this region were on 2/26 by Corban (H-a), Tyler (w-l) and Ramakers (w-l, H-a, CaK), in fact, the latter observer may have caught low-level flaring at 15:55 UT in an H-a image. At this time, the group was listed as Cao and producing one flare every two hours on average. The area was 30 millionths and the magnetic class only beta. There was a leader spot with rudimentary penumbra followed by a couple umbral spots and a few pores. The next day, the area and class were the same but flare production had dropped to only half of the previous value. Now the leader consisted of two small spots with penumbrae surrounded by umbral spots and pores, with a follower that was a single spot twice the size of either leader spot. Connecting the leaders and follower spots was a line of umbral spots arcing north of the group. On 2/28, the day of central meridian passage, the flare production was the same but the area had doubled. It was now a Dai class group but still magnetically beta. The leader was still the two spots but the penumbrae were losing their organization and all the umbral spots and pores were following the leaders. The follower was largely unchanged from the previous day and the clear line of umbrae and pores connecting the two was reduced to two umbral spots between the leader and follower to the south.

Ramakers showed a fairly quiescent plage in CaK, surrounding the region. It was very interesting on the 29th that the leader spots had coalesced into one spot with a much more radially symmetrical penumbra shown in a Tyler image at

Table 1. Contributors to This Report

Observer	Location	Telescope (aperture, type)	Camera	Mode	Format
Michael Borman	Evansville, IN	102mm, RFR 90mm, RFR 102mm, RFR	Point Grey GS3	W-L H-a CaK	digital images
Richard Bosman	Enschede, Netherlands	110mm, RFR 355mm, SCT	Basler Ace 1280	H-a W-L	digital images
Tony Broxton	Cornwall, UK	127mm, SCT	N/A	W-L	drawings
Gabriel Corban	Bucharest, Romania	120mm, RFL-N	Point Grey GS3-U3	H-a W-L	digital images
Franky Dubois	West-Vlaanderen, Belgium	125mm, RFR	N/A	visual sunspot reports	—
Howard Eskildsen	Ocala, FL	80mm, RFR	DMK41AF02	W-L wedge CaK	digital images
Joe Gianninoto	Tucson, AZ	115mm, RFR 80mm, RFR	N/A	W-L H-a	drawings
Guilherme Grassmann	Curitiba, Brazil	60mm, RFR	Lumenera Skynyx 2.0	H-a	digital images
Richard Hill	Tucson, AZ	90mm, MCT 120mm, SCT	Skyris 445m	W-L	digital images
Bill Hruedy	Grand Cayman	200mm, RFL-N 60mm, RFR	ASI174MM	W-L H-a	digital images
David Jackson	Reynoldsburg, OH	124mm, SCT	N/A	W-L	digital images
Jamey Jenkins	Homer, IL	102mm, RFR 125mm, RFR	DMK41AF02	W-L CaK	digital images
Pete Lawrence	Selsey, UK	102.5mm, RFR	ZWO ASI174MM	H-a	digital images
Monty Leventhal	Sydney, Australia	250mm, SCT	N/A Canon-Rebel	W-L/H-a H-a	drawings digital images
Efrain Morales	Aguadilla, Puerto Rico	50mm, RFR	Point Grey Flea 3	H-a	digital images
German Morales C.	Bolivia	200mm, SCT	N/A	visual sunspot reports	—
Theo Ramakers	Oxford, GA	80mm, RFR 11" SCT 40mm, H-a PST 40mm, CaK PST	ZWO ASI174MM DMK41AU02AS DMK21AU03AS DMK21AU03AS	H-a W-L H-a CaK	digital images
Ryc Rienks	Baker City, OR	203mm, SCT 40mm, H-a PST	N/A	W-L H-a	drawings
Chris Schur	Payson, AZ	152mm, RFR 100mm, RFR	DMK51	CaK W-L (CaK-off-band continuum) H-a	digital images
Avani Soares	Canoas, Brazil	120mm, RFR	ZWO-ASI 224	W-L	digital images
Randy Tatum	Bon Air, VA	180mm, RFR	DFK31AU	W-L-pentaprism	digital images
David Teske	Starkville, MS	60mm, RFR	N/A Malincam	W-L, H-a W-L	digital images
David Tyler	Buckinghamshire, UK	178mm, RFR 90mm, RFR	ZWO	W-L H-a	digital images

NOTE: Telescope types: Refractor (RFR), Newtonian Reflector (RFN), Schmidt Cassegrain (SCT), Maksutov-Cassegrain (MCT), Cassegrain (Cass)

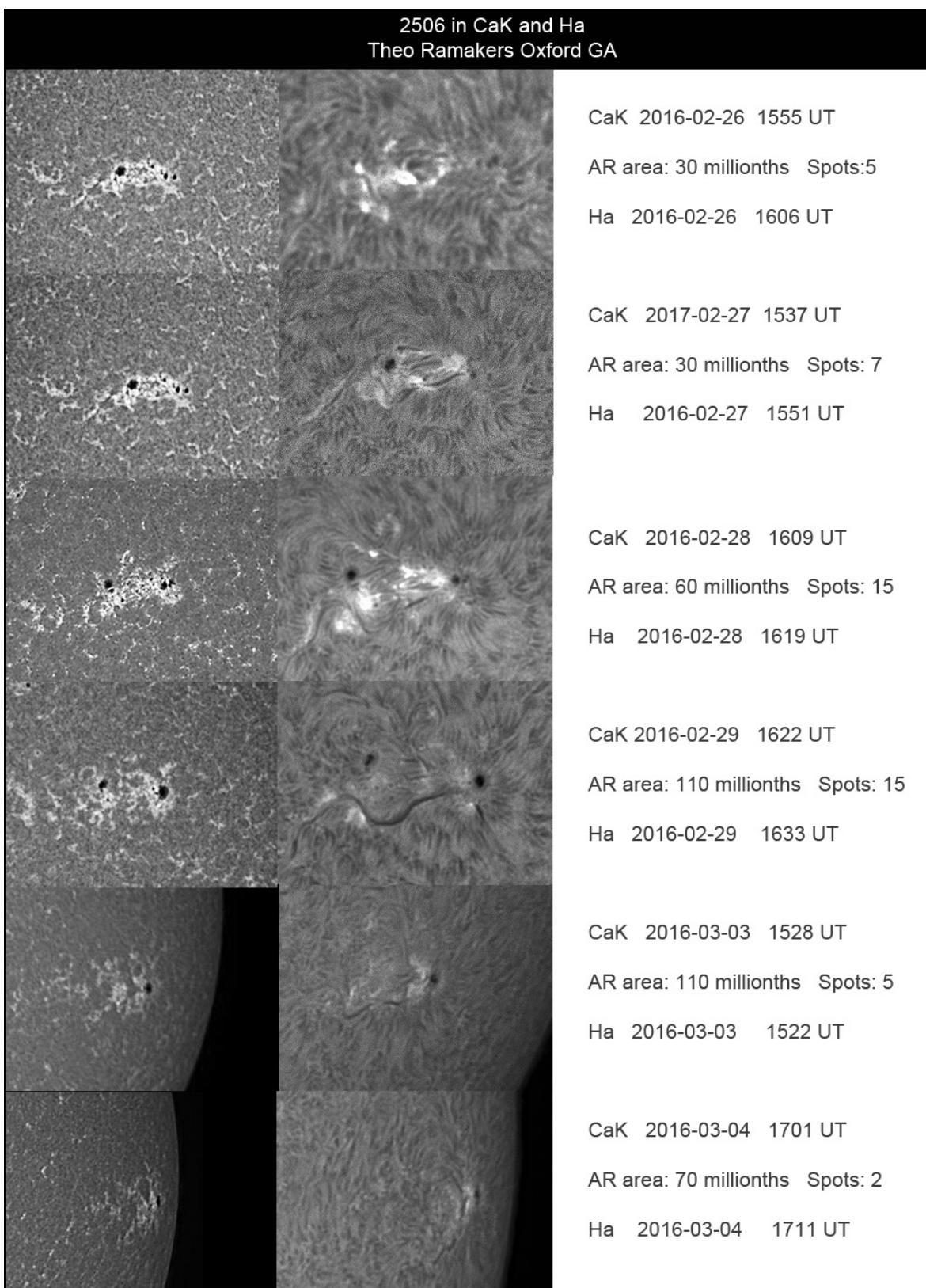


Figure 1. CaK and H-alpha views following the development of AR2506 by Ramakers on the dates and times listed on the image. Instrumental details can be found in Table 1.

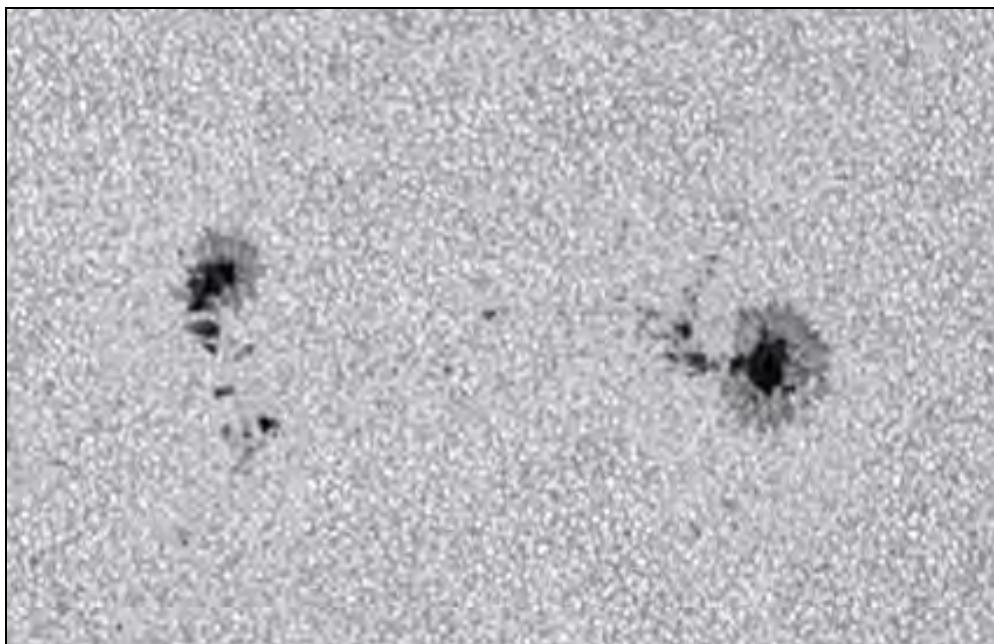


Figure 2. A nicely detailed white light image by Tyler with his 178mm RFR of AR2506 at 2016-02-29-10:33 UT. Details on equipment are in Table 1.

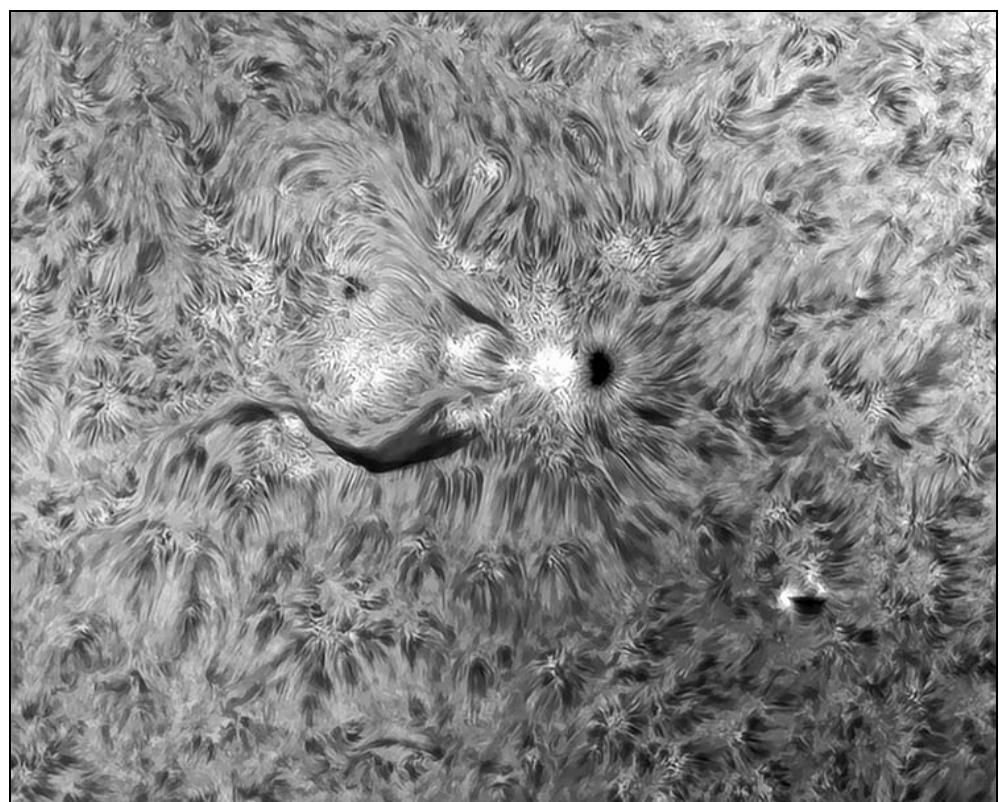
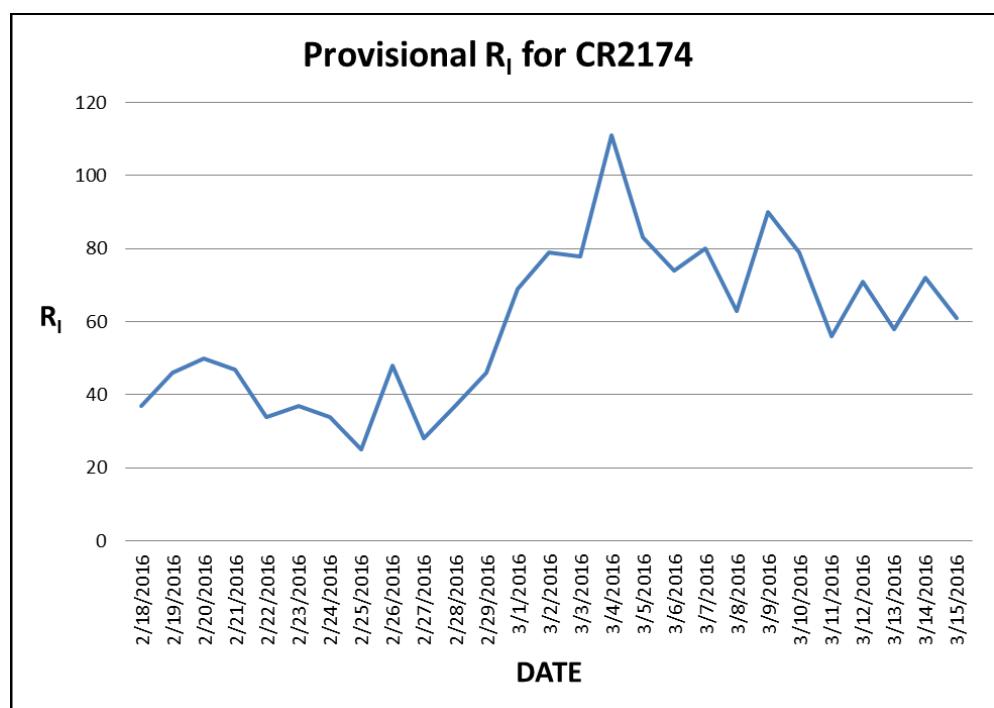


Figure 3. An exquisite H-alpha image of AR 2506 by Corban on 2016-03-01-11:28 UT. Further information can be found in Table 1.

10:33 UT (Fig. 2). This was followed by a couple of small umbral spots with a few penumbral bits. The follower was largely unchanged but the spots between the two were gone. The magnetic class was now beta-gamma though flares were down to about a dozen in a 48-hour period. The area of the region had grown to 110 millionths even with fewer spots an increase of 50 millionths, but still classed as Dai.

The month of March opened with this region having grown another 20 millionths with the same McIntosh Class, but the magnetic class had dropped to just beta and the flare list was only a half-dozen now. Leventhal showed in his combined w-l/H-a drawing, that the leader and follower were roughly equal in size and form now. A spectacular Corban H-a image at 11:27 UT (Fig. 3) showed the follower to be about half the size of the leader and in two parts divided by a thin light bridge. On 3/2, the leader spot, very round now, was followed by three roughly equal sized umbral spots in a bent line with a few pores scattered about shown well in images by Tyler and Corban and a sketch by Leventhal. Clearly dissolution was taking place. The area fell back to 110 millionths with an unchanged magnetic class and less than a half-dozen flares in the previous 48 hours. This continued on the 3rd with the sunspot group class now Hsx and the area 70 millionths. Magnetic class was reduced to alpha and only four flares were noted. A Tyler H-a image at 10:04 UT showed a small hot plage immediately following the leader spot. In his w-l image at 10:14 UT, the leader was seen to have an east-west elongated umbra divided into three unequal pieces (the center piece being the smallest) by two, very thin light bridges. This was all in a nice symmetrical penumbra with one detached piece following closely. Bright facular spots could be seen in the area



that was the H-a plage. There were a few scattered tiny umbral spots and pores following all this. As this region was leaving the disk Ramakers got a good H-a image of it on 3/4. The only big changes were the loss of all the follower spots, and the plage was now reduced to just a few bright points. In CaK, the plage was a bit more extensive but not like a few days earlier. The area was now 60 millionths with a class of Cso though it looked more like the Hsx class of a couple days earlier.

Carrington Rotation 2175

Dates: 2016 03 16.4986 to 2016 04 12.7896

Avg. R_I = 31.8

High R_I = 87 (3/16, first day of the rotation)

Low R_I = 12 (4/2 & 4/3)

After attaining a high on the opening day of this rotation, activity rapidly dropped and spent most of the rotation with daily counts at or below 42. The high was due to two larger groups, one of which was well-observed by the Section, AR 2524.

This region came onto the disk on the opening day of the rotation but no observations were submitted. It was first shown well in a w-l Tyler image at 10:11 UT (Fig. 4) the next day. Corban also took a remarkable image of it on 3/17 at H-a 11:34 UT. At this point it was listed as an Eao sunspot group rather than the Hsx that was officially listed the day before. (NOAA must not have seen the follower spot.) The leader consisted of a single round spot with a large umbra and radially symmetrical penumbra, consistent with an Hsx spot. This was followed by what was obviously a large complex spot with multiple umbrae in a complex non-symmetrical penumbra with penumbral bits, umbral spots and pores around. Flare production was a promising 12 in 48 hours from this magnetic class beta region.

On 3/18, Corban had another very dramatic image of this region in H-a (Fig.5). The leader appeared to be a single round spot with symmetrical penumbra and a follower that was similar size and shape with a bright plage between them and closer to the follower.

This was confirmed in a w-l drawing by Broxton and a combined w-l and H-a by Leventhal. The group was now classed as Eao at 230 millionths area and the magnetic class was beta. There was no data on the 19th but on 3/20, Jenkins in a whole-disk w-l image showed the situation to be little changed, two fairly equal sized round spots. Tyler in a w-l image on 3/21 at 1027 UT, showed the leader to be round with a full penumbra while the follower umbra was now triangular, with one corner broken off, all in a penumbra that was still radially symmetrical. About 10 minutes earlier, Corban got a nice H-a image that showed the two spots looking fairly quiescent with plages between them. The plage closest to the follower was brighter and probably the site for any flaring. Two hours later, Corban showed further breakdown in his w-l image of the region at 12:52 UT. Ramakers CaK and H-a images at 14:32 and 14:38 UT respectively, confirmed the earlier appearance. The class was now Eso with an area of 240 millionths and a magnetic class that was still beta with 10 flares over the previous two days. It was the only action on the disk at this time.

The follower breakup and dissolution continued on 3/22 as seen by Tyler and Ramakers. A Tyler image at 14:36 UT showed a very thin light bridge bisecting the follower spot. Pieces were breaking off on several sides of the umbra and the penumbra was becoming less organized. The two plages were still seen in H-a and CaK image by both observers but the brighter one was now the one closest to the leader spot. The area and classes remained the same but flare production had increased slightly. AR 2524 straddled the central meridian at 21:10 UT as observed in a Leventhal drawing. The area decreased to 210 millionths on the 23rd but all classes were the same. The following plage was breaking down

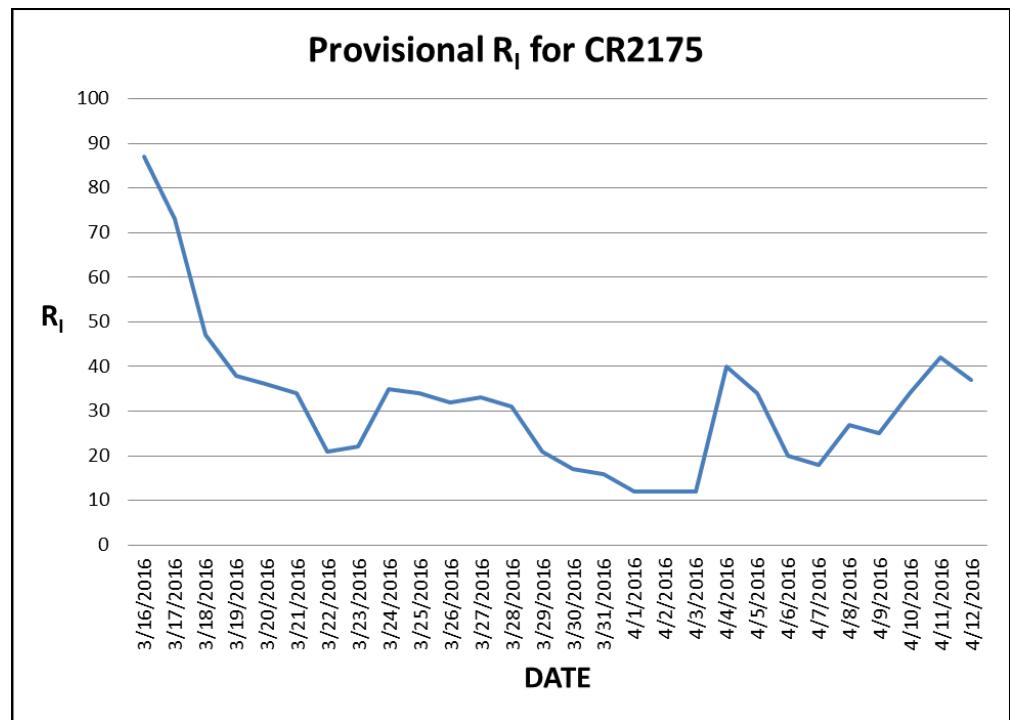


Figure 4. A remarkable image by Tyler of the full appearance of AR 2524 on 2016-03-17-10:11 UT using his 178mm refractor detailed in Table 1. Note the 3-dimensional appearance of the penumbra in the leading spot.

rapidly as seen in several Ramakers H-a images. Late on this day, Leventhal, in a combined w-l/H-a drawing noted that several pieces had broken off the follower. There were no observations for 3/24 but on 3/25, Broxton (w-l drawing)

showed the leader unchanged while the follower was smaller with a small penumbra. Leventhal (w-l/H-a drawing) showed the penumbra gone at 21:30 UT. The area had dropped to 100 millionths with a group class of Eso and a

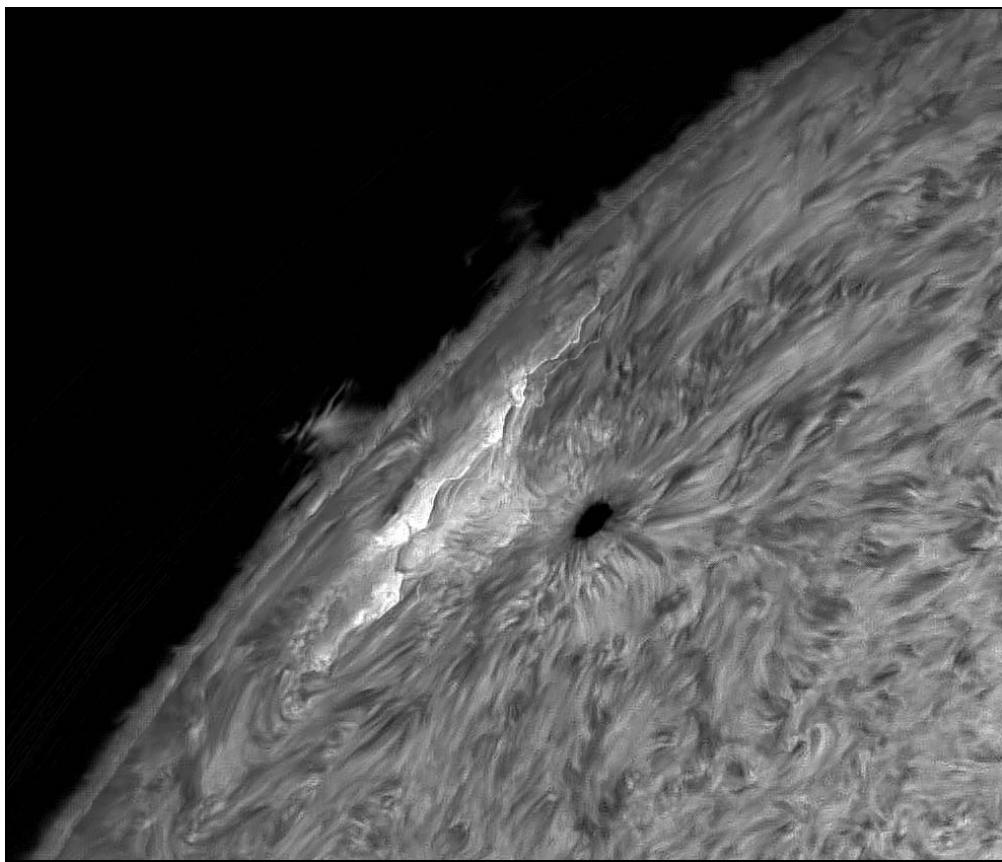


Figure 5. A phenomenal image of AR 2524 on 2016-03-17-11:35 UT by Corban. Note the curtain of material obscuring the plage near the follower spots. Information on his equipment is found in Table 1.

magnetic class of beta with 10 flares. This group class seems rather generous and would better as Dso or Cso. Jenkins, in a whole disk w-l image on the 26th, showed the follower gone altogether. Now the class was Hsx with an area of 80 millionths and a magnetic class of alpha. Leventhal confirmed this in a drawing later this day. Ramakers got a final image of this singular Hsx spot on the limb on 3/28 at 15:36 UT.

Carrington Rotation 2176

**Dates: 2016 04 12.7896 to
2016 05 10.0368**

Avg. $R_I = 51.4$

High $R_I = 90$ (4/28)

Low $R_I = 22$ (4/23)

While peak activity in terms of RI appears to have occurred in the second

half of this rotation, that was mostly due to numerous groups with less than 100 millionths area and lots of individual spots. The region that was most heavily observed was AR 2529 though AR 2542 played a pretty close second.

Ramakers was the first to observe this region in H-a, CaK and w-l, on the limb on 4/7 in a previous rotation. It was listed as an Hkx group only because it was on the limb and its true extent could not be seen yet, with an area of 330 millionths and a magnetic class of alpha. Even with this latter class it produced, on average, one flare per hour! Starting on 4/8 we have a six-day Ramakers H-a/ CaK montage covering the disk passage and evolution of this region (Fig. 6). On the 8th, both in Ramakers H-a and CaK, there was a large sunspot followed by a

bright plage. This was confirmed in a w-l image by Hrudey in his four-day w-l montage (Fig. 7). On 4/9 Tyler, in a w-l image at 11:07 UT, and Eskildsen, in a w-l image at 13:26 UT and CaK image at 13:19 UT (Fig. 8), showed the leader to be a large spot in penumbra followed by a cluster of umbrae with rudimentary penumbrae on the sides away from the middle of the cluster. The follower collection of spots were wreathed in and followed by much faculae in w-l and a plage in CaK. About the time of the Eskildsen image, Ramakers was showing low-level flaring taking place in this follower cluster. The official classification was Dhi, with an area of 350 millionths while Leventhal gave it a class of Chi. He, too, was noting minor flaring at 22:05 UT. The magnetic class was beta with a flare per hour on average. On 4/10, w-l images by Tyler (09:12 UT), Ramakers (21:59 UT) and Hrudey, showed the leader spot was more or less the same, but the follower had inverted itself so that the penumbral material was on the inside of the cluster while the umbrae were following. In the Tyler image, in middle of the group was an island of detached penumbra. It was gone by the time of the Ramakers image. These islands of penumbrae are usually this short-lived. A Corban H-a image the previous day showed the leader spot in a whirlpool of filaments. By this day, however, there were filaments arching away from the spot radially to about two spot diameters out. The area of the group now had jumped to 850 millionths and the class was Eki with a magnetic class of beta and 40 flares in the previous 48 hours. This would remain the same for the next two days. There was one observer reporting that this was a naked-eye spot, but that is unlikely. For most of us mere mortals, 900-1000 millionths for a SPOT is the threshold. This was 850 millionths for the whole spot GROUP.

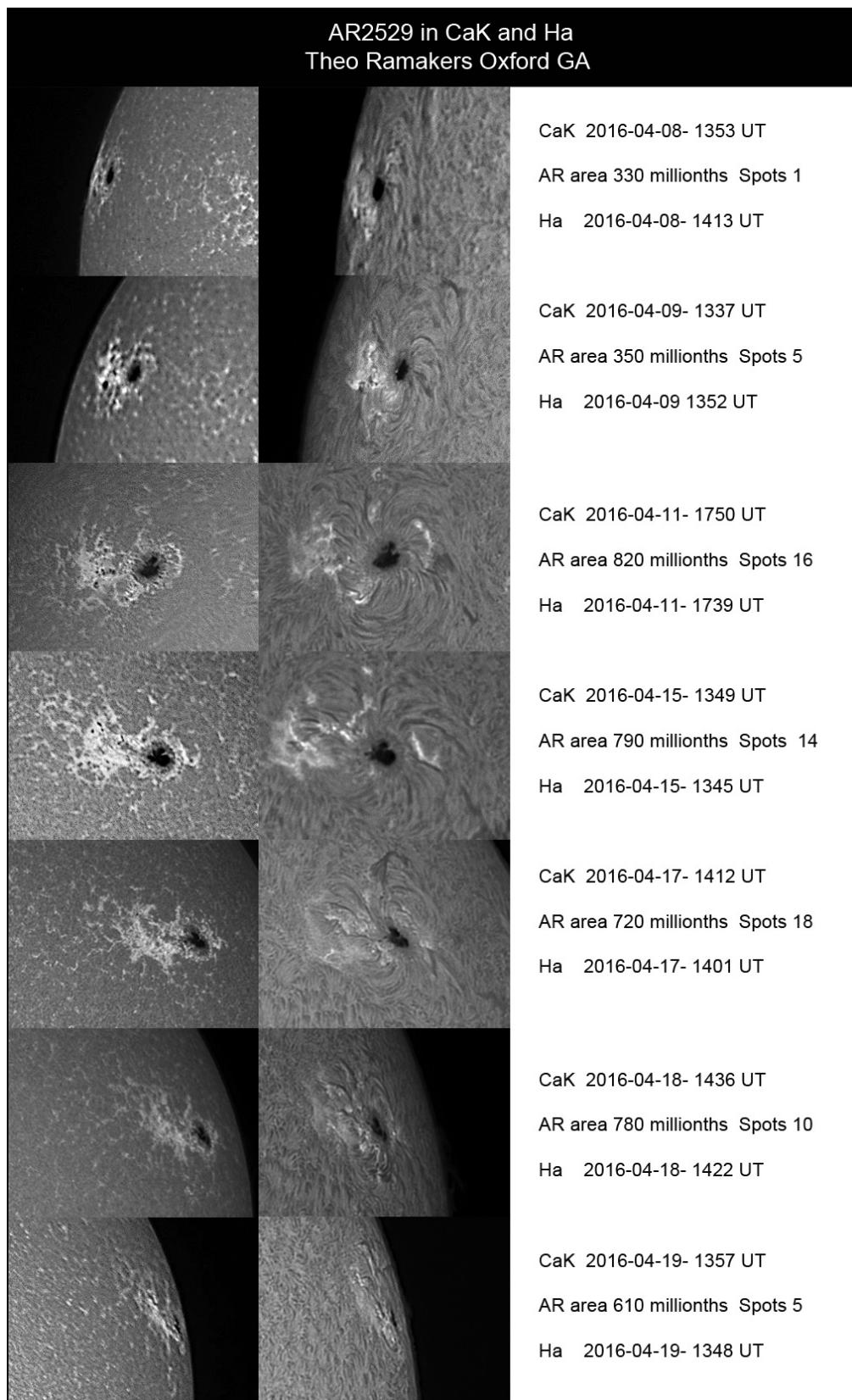


Figure 6. Another evolutionary montage in CaK and H-alpha by Ramakers this time on AR 2529 at the dates and times shown on the images. His equipment specifications can be found in Table 1.

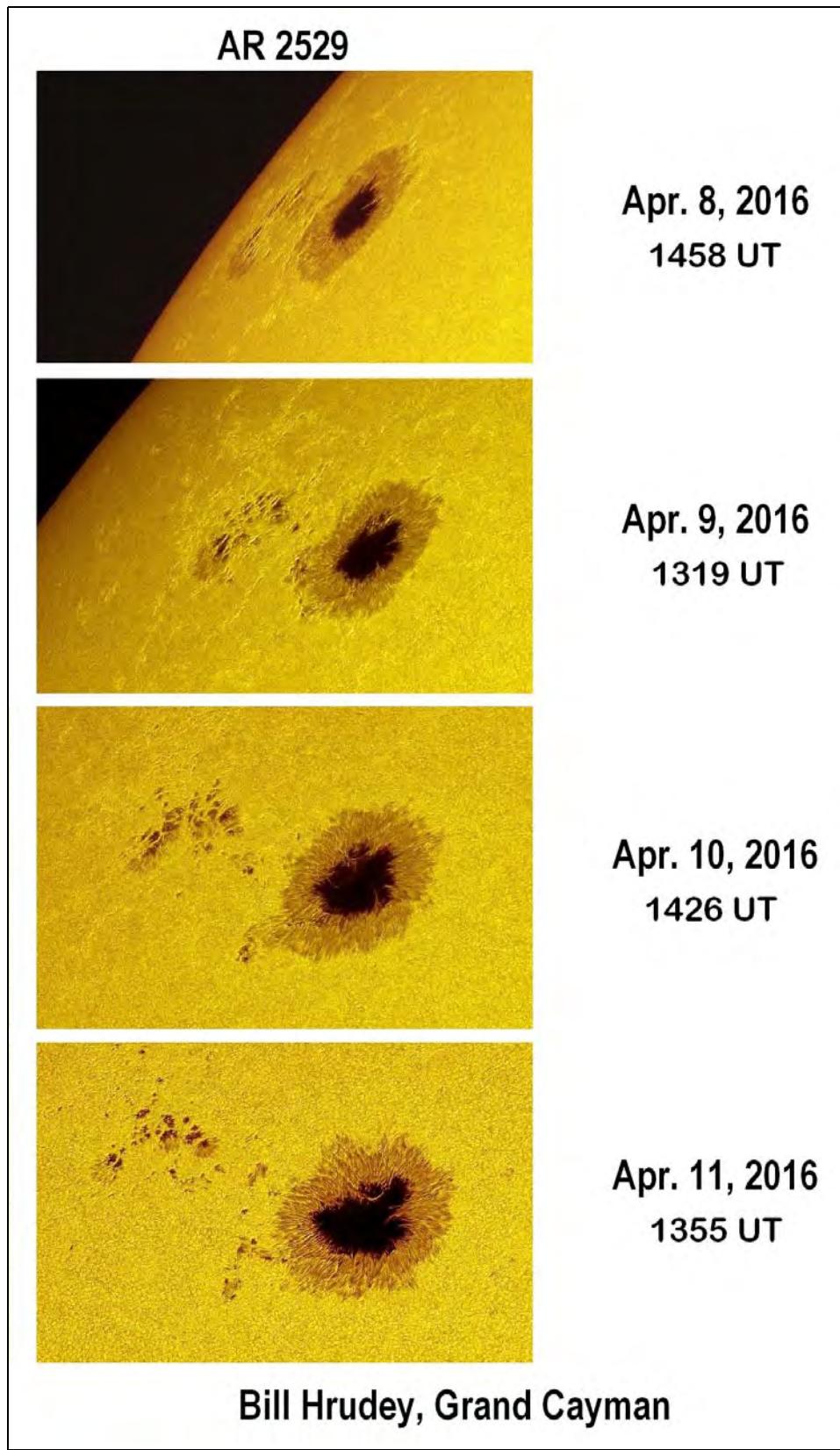
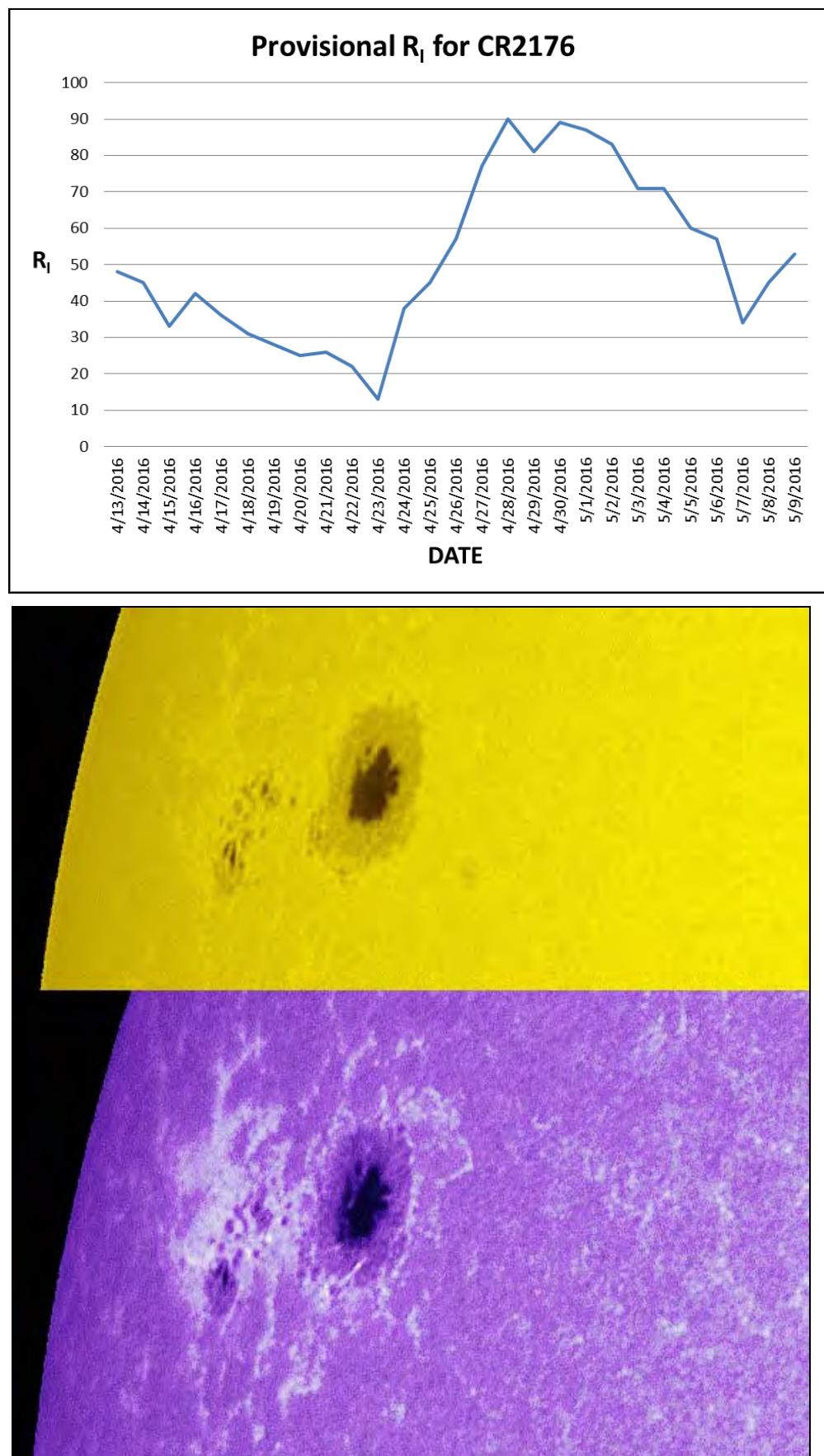


Figure 7. An excellent quality white-light evolutionary 4-day montage of AR 2529 by Hrudey using the 200mm solar Newtonian with equipment listed in Table 1.



There was little change on the 11th except that the umbra in the leader took on the shape of a heart on its side as a light bridge began invading from the leading side. In H-a, several observers saw a bright north-south line preceding the whole region. This was probably a site for some of the flares. Maximum development was on this day. The next day, there was almost no change except that the light bridge in the leader's umbra was wider and deeper into the umbra. A w-l, six-day montage by Hill began on this date and served to show the late evolution as this group began its decline and headed for the limb (Fig. 9) Then on 4/13, we were treated to a spectacular sub-arc-second view of this group thanks to Tyler (Fig. 10). The light bridge is beautifully shown and had now almost cut off one corner of the umbra. The class was now Eho and the area had fallen to 780 millionths with only 30 flares in 48 hours. Grassman, in a CaK image, showed the large plage encompassing the follower spots was still there. The vertical bright line preceding the whole region was still there and still quite bright. On the 14th, the leader had some penumbra breaking off to the north but otherwise things were much the same. A w-l image by Hill shows this as well as the scattering of umbral spots and pores following the leader. Tatum, on 4/15 in a w-l image, showed the separated penumbral bits to have developed some small umbrae adding to the scattering of spots that followed. This was all showing disruption of the main umbra, a clear indication of decline. The area had fallen to 740 millionths but the class was still Eki and the magnetic class was now beta-gamma, though flare production had fallen to around 25 in 48 hours. H-a

Figure 8. A two-pane image of AR 2529 by Eskildsen. The upper white-light image was taken at 2016-04-09-13:26 UT and the lower CaK image a few minutes earlier at 13:19 UT. Details about the equipment used is available in Table 1.

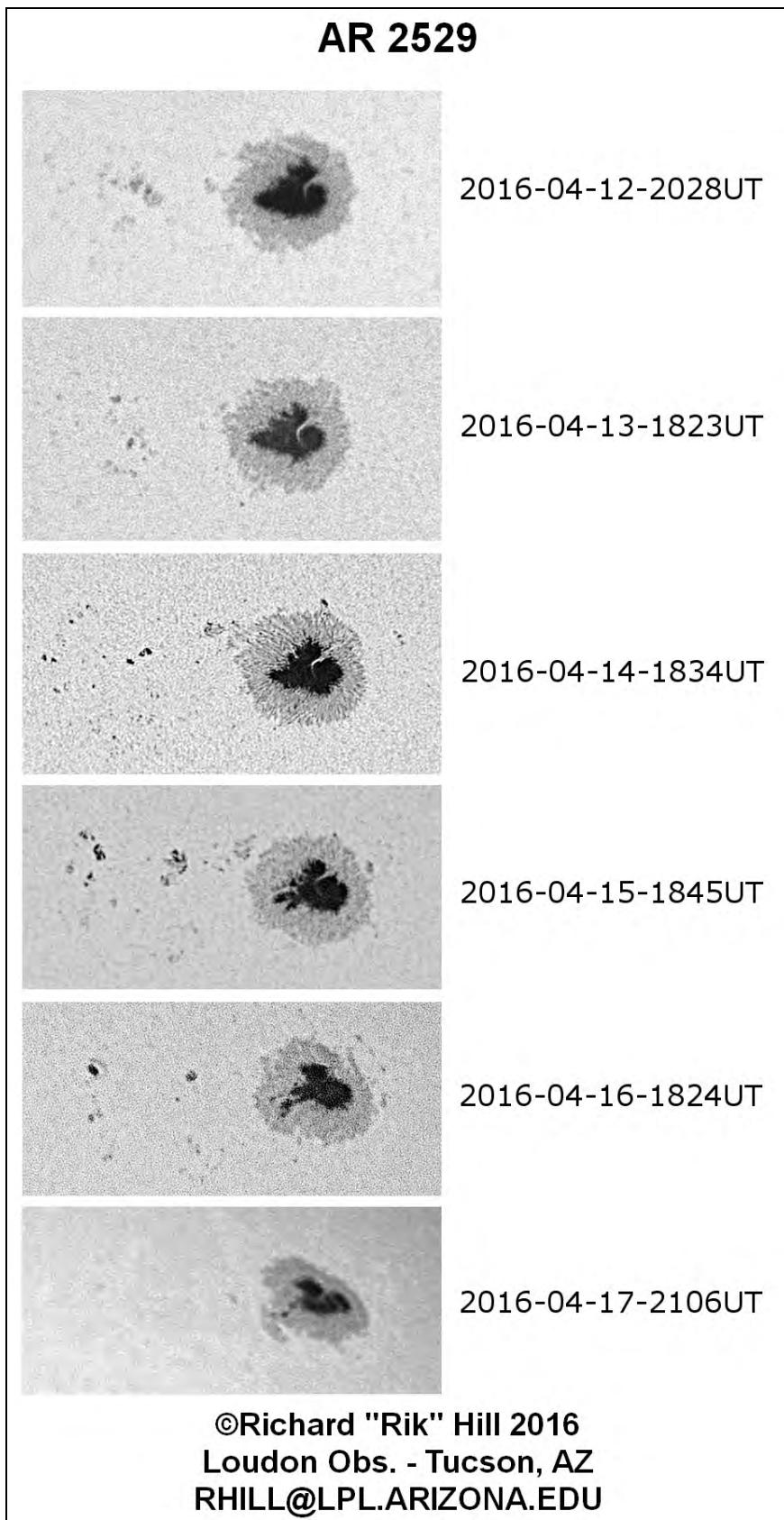


Figure 9. A white-light evolutionary montage by Hill on the dates and times shown. Done with a Questar details are in Table 1.

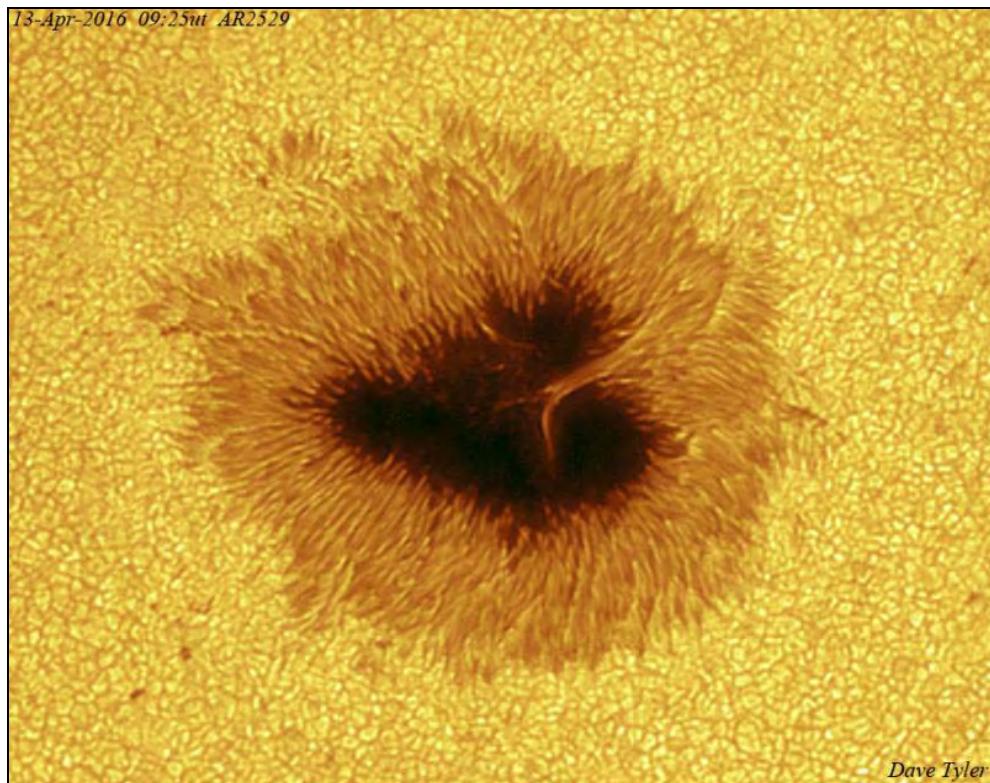
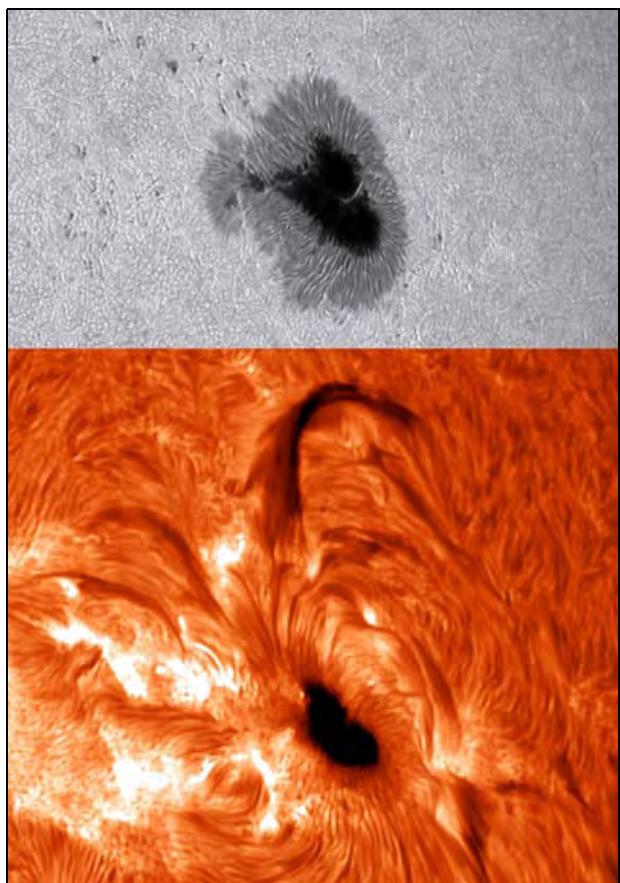


Figure 10. A spectacular image of AR 2529 on 2016-04-13-09:25 by Tyler using equipment listed in Table 1. Note the details in the light bridge on the right half of the umbra.



observations by several observers on the 16th showed the main spot at the focus of a spiral of 4-6 filaments. The following plage was breaking down and was much smaller now in both CaK and H-a.

The leader had taken on an east-west teardrop shape on 4/17 as pieces of the umbra were separating and taking bits of penumbra with them. A montage of two Tyler images, w-l (10:01 UT) and H-a (11:42

Figure 11. A two pane white-light (10:01 UT) and H-alpha (11:42 UT) view of AR 2529 by Tyler on 2016-04-17 showing the dramatic appearance in H-alpha of what was an unremarkable white-light spot group. Details of equipment used can be found in Table 1.

UT), show this and the fantastic filament structure (Fig. 11). As AR 2529 neared the limb on 4/18, there was only the main spot that was the former leader, and a very few tiny umbral spots around and following. The main umbra was now crossed by at least three light bridges, one particularly bright as shown in Ramakers and Tatum w-l images. The last view of this once-great region was by Ramakers in an H-a image on 4/20 at 15:42 UT when it was on the limb (Fig. 12). It would have been nice to see a disk occulted prominence image as I'm sure there were some nice loops and prominences.

Carrington Rotation 2177

Dates: 2016 05 10.0368 to 2016 06 06.2479

Avg. $R_I = 41.4$

High $R_I = 90$ (5/14)

Low $R_I = 0$ (6/3)

This rotation opened with promise but rapidly sunk to the lowest levels of activity in the reporting period. AR 2546 was the region that most observers worked on for this rotation. It was first seen very near the limb by Leventhal in one of his combined w-l/H-a images of 5/13 at 2220 UT. It was not seen by Gianninoto at 15h UT nor captured in an H-a image by Borman at 19h UT, so this was another nice catch by Leventhal. He estimated the class at Hsx which is very close to the official Hhx assigned to it on 5/14 by NOAA. On that day the area was listed as 250 millionths with a magnetic class of alpha and was already producing about one flare every 2 hours. There were four smaller regions on the Sun that were capturing everyone's attention, but on 5/15 at 11:31 UT, Ramakers took a great H-a image of this region showing nice long filaments radiating out from the large spot with a plage following. Grassmann, in CaK at 12:03 UT the same day, captured the

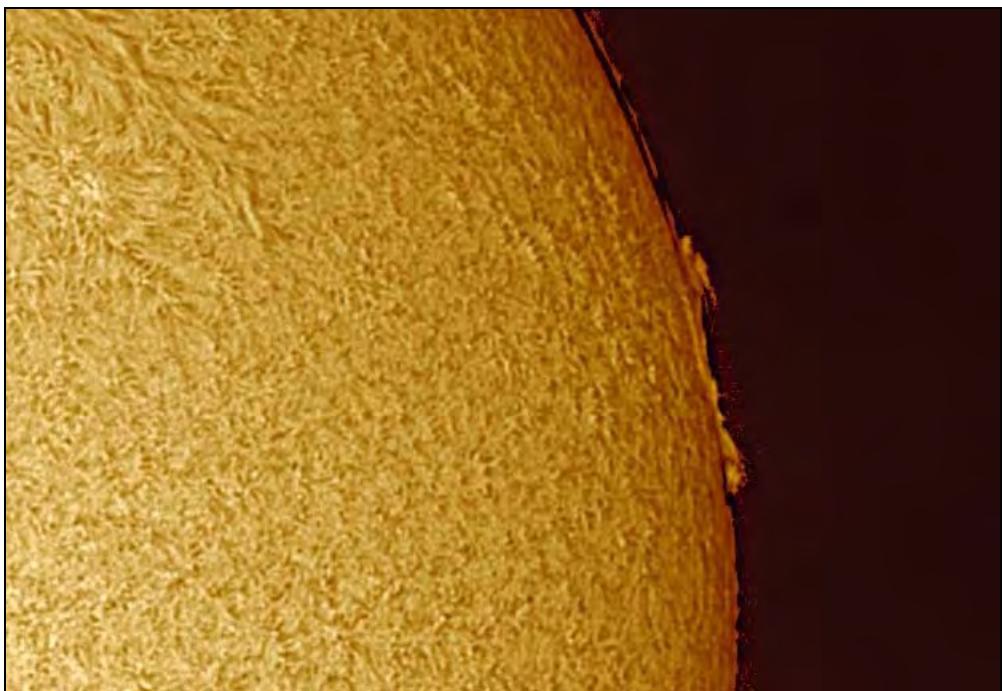
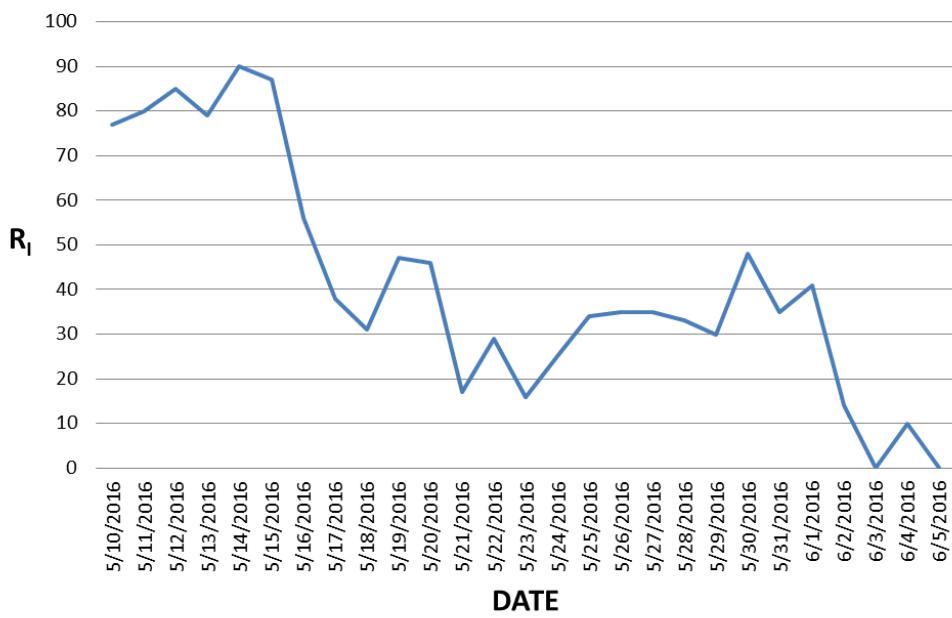


Figure 12. A Ramakers H-alpha view of AR 2529 as it was passing around the limb on 2016-04-20-15:42 UT. Equipment details can be found in Table 1.

Provisional R_I for CR2177



following plage in more detail as it surrounded the penumbra of the main spot. By 5/16, the area had jumped to 410 millionths with the same classes. Images by Ramakers and Corban (w-l, H-a and CaK) captured a single large spot

with radially symmetrical penumbra followed by a north-south oriented crescent-shaped plage, the obvious site for flares. Flare production levels remained the same. On the 17th, Corban took a remarkable H-a image

(Fig. 13) of this region showing great detail in the following crescent. It was now listed as Cho with an increased area of 540 millionths. The magnetic class was beta-gamma. The only observation on 5/18 was from Leventhal. He classed the group as Cki (versus Cko officially) with two umbrae in a single penumbra. The next day, a Corban w-l image hinted at this split. But the highlight of this day was a splendid H-a image by Lawrence. (Fig. 14) It showed how the former bright crescent was now a chevron pointing away from the main spot. There were beautiful filaments radiating away from this spot in nearly every direction, a very impressive sight. The group was still Cho, but the area had fallen to 440 millionths and magnetic class was beta. Flare production was now below 20 in 48 hours.

On 5/20, this region was on the central meridian and very nearly dead-center of the disk. In a Grassmann H-a image, the bright region was now just a line extending from the following edge of the main spot to the south. The area had increased to 520, but all classes and flaring was the same. Over the next couple days the morphology of this group remained largely unchanged but the area increased slightly to 550 millionths. Even so, flare production dropped below 20 in 48 hours. Starting on 5/22, we have a three-day panel of w-l and H-a images by Tyler that serve to note the end of this region. It had, on the 23rd, dropped to 460 millionths and the class was a more realistic Hhx, indicative of a decaying sunspot group where the remaining large spot gets more round and simply decreased in area. During this three-day period, CaK image by Corban, Jenkins, Ramakers and Schur showed the plage following the large spot to be decreasing in area and intensity. Three observers (Borman, Grassmann and Ramakers) got good CaK images of this

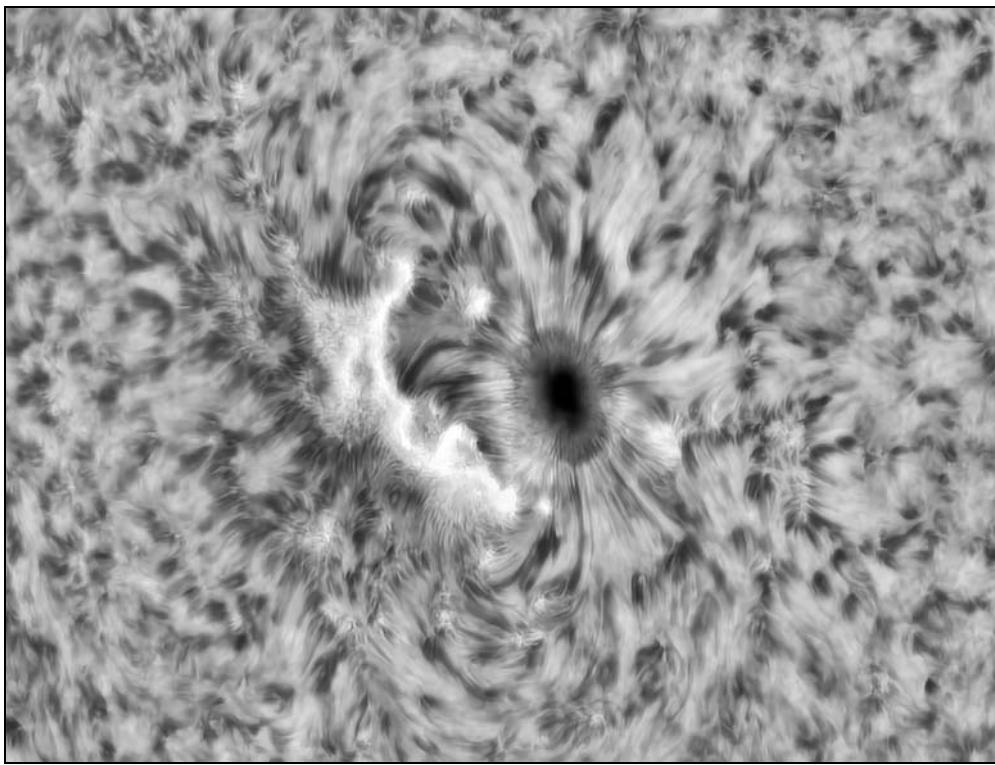


Figure 13. A breathtaking H-alpha image of AR 2546 by Corban showing remarkable following plage in great detail at 2016-05-17-18:16 UT. His equipment is listed in Table 1.

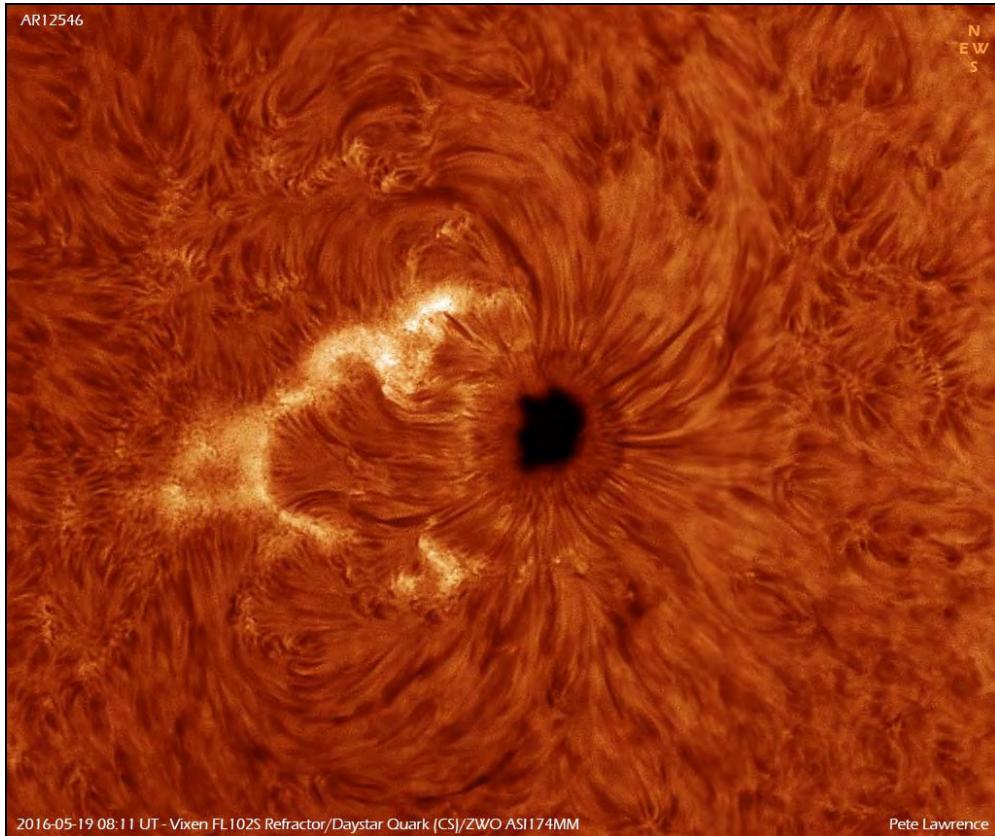


Figure 14. A beautifully detailed H-alpha image by Lawrence of AR 2546 taken on 2016-05-19-08:11 UT using equipment listed in Table 1.

region on 5/22-24 (Fig. 16) showing the slow decay of this region in that light as it approached the limb. Gianninoto got the last look at this region on the limb in one of his w-l/H-a drawings at 1420 UT. By 22:30 UT, Leventhal saw nothing at this location.

Conclusion

It is abundantly clear that solar activity has decreased from previous reporting periods, hinting that we may be heading into an early and possibly protracted minimum if some solar astronomers' predictions are borne out (Livingston & Penn 2008). The quality of the observations being submitted is far and away better than anything we saw in previous years. All observers are to be commended for such high quality, diligent work!

So what's to do as things wind down? Take heart, there is much to observe. Projects that include observing the evolution of granulation, pores and the development of smaller sunspot groups are still of value and the monitoring of plage formation, whether or not it results in the formation of sunspots, is always useful. The search for polar faculae and plages during a quiet Sun is another project of interest, as well as watching for the first activity of the next cycle happening at higher latitudes (around +/- 40° or higher).

So don't give up through the solar minimum, just look forward to the coming of the next Cycle!

References:

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

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

McIntosh, Patrick S., (1989) "The Classification of Sunspot Groups" Solar Physics, Vol. 125, Feb. 1990, p. 251-267. <http://link.springer.com/article/10.1007/BF00158405>

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

<http://adsabs.harvard.edu/abs/1981phss.conf.....C>

Further references used in the preparation of this report:

Solar Map of Active Regions <https://www.raben.com/maps/date>

SILSO World Data Center <http://sidc.be/silso/home>

SILSO Sunspot Number <http://www.sidc.be/silso/datafiles>

The Mass Time-of-Flight spectrometer (MTOF) and the solar wind Proton Monitor (PM) Data by Carrington Rotation <http://umtof.umd.edu/pm/crn/>

NOAA Solar Indices Data <http://www.ngdc.noaa.gov/nndc/struts/results?t=102827&s=1&d=8,4,9>

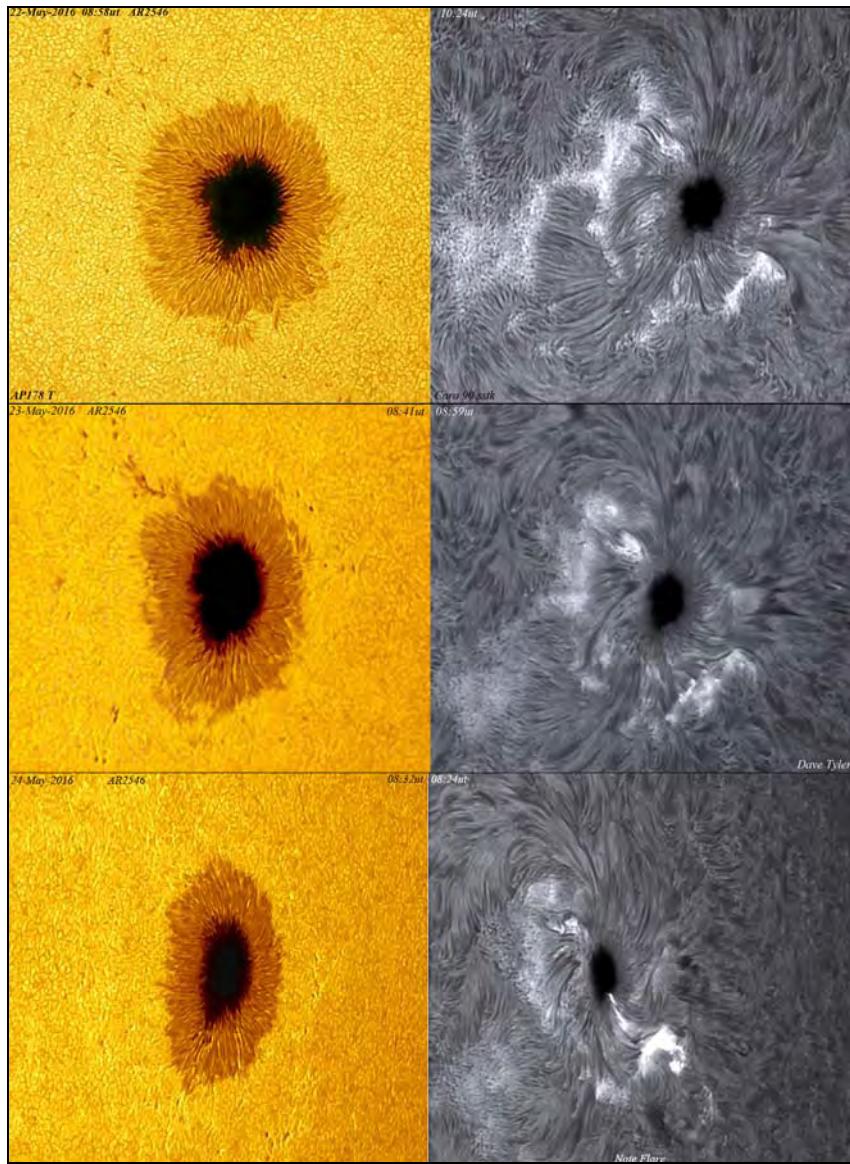


Figure 15. A 3-day evolutionary sequence in white-light and H-alpha of AR 2546 by Tyler. From top to bottom, left to right the dates and times are: 2016-05-22-08:58 and 10:24 UT, 2016-05-23-08:41 and 08:59 UT, and bottom is 2016-05-24-08:32 and 08:24 UT. Equipment details are listed in Table 1.

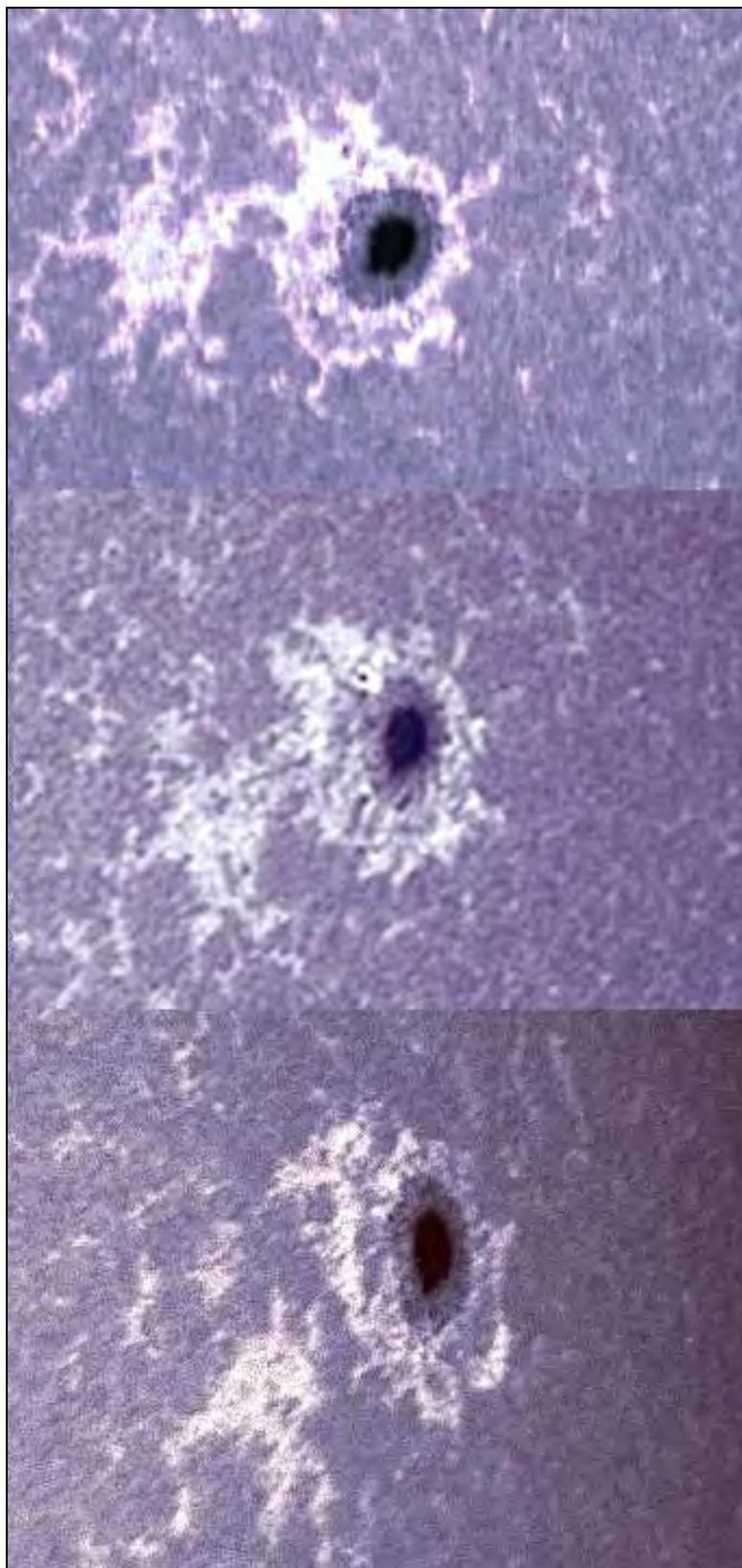


Figure 16. Three days of AR 2546 in CaK. At top, we see the view on 2016-05-22-19:16 UT by Borman; in the middle, 2016-05-23-13:28 UT by Grassmann; and at bottom, 2016-05-24-09:24 by Ramakers. Details of their equipment can be found in Table 1.