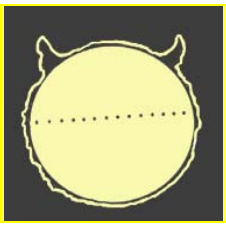

Feature Story: ALPO Solar Section

A Report on Carrington Rotations 2184 through 2187 (2016 11 16.7354 to 2017 03 06.0597)

By Richard (Rik) Hill,
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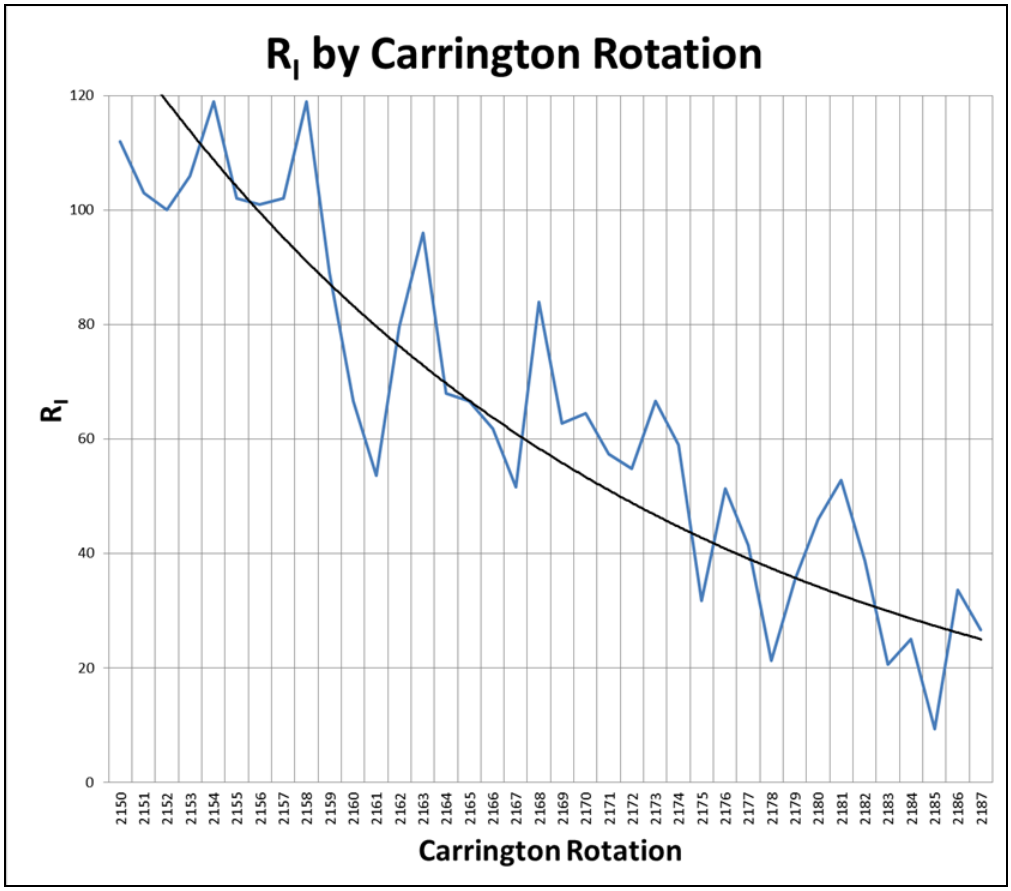


Overview

This reporting period was characterized by the lowest activity since the last solar minimum. The largest region of the period was AR 2612 which attained an area of 230 millionths on 11/25 in CR 2184, the first rotation of the report. For the other three rotations, no region attained an area of 200 millionths. Most regions popped up, attained maximum development in one or two days and rapidly dwindled away. Some popped up and were designated and gone 24 hours after that! This does not mean that strong activity will not happen until we pass minimum (2019-2020), as AR 2645 proved in April with a maximum area of 700 millionths and plenty of flare activity.

Terms and Abbreviations Used In This Report

This short section is similar to the same in earlier reports but should be at least briefly scanned. The ALPO Solar Section will be referred to as "the Section" and Carrington Rotations will be called "CRs". Active Regions are designated by the National Oceanic and Atmospheric Administration (NOAA) and will refer to all activity in all wavelengths for that region and will be abbreviated "AR" with only the last four digits of the full number being used. The term "groups" refers to the visible light or "white light" sunspots associated with an active region. Statistics compiled by the author have their origin in the finalized daily International Sunspot Number data published by the WDC-SILSO (World Data Center - Solar Index and Long Term Solar Observations) at the Royal Observatory of Belgium. All times used in this report are Coordinated Universal Time and dates are reckoned from that. Dates will be expressed numerically with month/day such as "9/6" or "10/23". Carrington Rotation commencement dates are from the table listed on the Section webpage on the ALPO website under the link "Solar Ephemerides and Rotations".

The terms "leader" and "follower" are used here instead of "east" or "west" on the Sun to avoid confusion. The abbreviation to indicate white-light observations is "w-l", while hydrogen-alpha is "H-a" and calcium K-line is "CaK". Though there were no reports of naked-eye sunspots during this period, it is nevertheless important to point out that this term means the ability to see a feature on the Sun through proper and safe solar filtration, with no other optical aid. You should never look at the Sun, however briefly, without such filtration. Orientation of images shown here will be north up and celestial west to the right (northern hemisphere chauvinism). The cardinal directions (north, south, east, west) will often be abbreviated as N, S, E, W.

Areas of regions and groups are expressed in the standard units of millionths of the solar disk, with a naked-eye spot generally being about 900-

Table 1. Contributors to This Report

Observer	Location	Telescope (aperture, type)	Camera	Mode	Format
Michael Borman	Evansville IN	102mm, RFR	Point Grey GS3	w-l	digital images
		90mm	"	H-a	digital images
		102mm, RFR	"	CaK	digital images
Richard Bosman	Enschede, Netherlands	110mm, RFR	Basler Ace 1280	H-a	digital images
		355mm, SCT	"	w-l	digital images
Raffaello Braga	Milano, Italy	112mm,RFR	PGR Chameleon mono 2.0	H-a	digital images
Tony Broxton	Cornwall, UK	127mm, SCT	N/A	w-l	drawings
Jean-Francois (Jeff) Coliac	France	30mm, Projection	N/A	w-l	drawings
Gabriel Corban	Bucharest, Romania	120mm, RFL-N	Point Grey GS3-U3	H-a	digital images
		"	"	w-l	digital images
Brennerad Damacenco	Sao Palo, Brazil	90mm, MCT	ASI224MC	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	digital images
		80mm, RFR	DMK41AF02	CaK	digital images
Joe Gianninoto	Tucson, AZ	115mm, RFR	N/A	w-l	drawings
		80mm, RFR	N/A	H-a	drawings
		90mm, MCT	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	Skyris 445m	w-l	digital images
		120mm, SCT	"	"	"
Bill Hrudey	Grand Cayman	200mm, RFL-N	ASI174MM	w-l	digital images
		60mm, RFR	ASI174MM	H-a	digital images
David Jackson	Reynoldsburg, OH	124mm, SCT	N/A	w-l	drawings
Jamey Jenkins	Homer, IL	102mm, RFR	DMK41AF02	w-l	digital images
		125mm, RFR	""	CaK	digital images
Pete Lawrence	Selsey, UK	102.5mm, RFR	ZWO ASI174MM	H-a	digital images
Monty Leventhal	Sydney, Australia	250mm, SCT	N/A	w-l/H-a	drawings
		250mm, SCT	Canon-Rebel	H-a	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	ZWO ASI174MM	H-a	digital images
		11 in. SCT	DMK41AU02AS	w-l	digital images
		40mm, H-a PST	DMK21AU03AS	H-a	digital images
		40mm, CaK PST	DMK21AU03AS	CaK	digital images
Ryc Rienks	Baker City OR	203mm, SCT	N/A	w-l	drawings
		40mm, H-a PST	N/A	H-a	drawings
Chris Schur	Payson, AZ	152mm, RFR	DMK51	CaK	digital images
		152mm, RFR	DMK51	w-l (CaK-offband continuum)	digital images
		100mm, RFR	DMK51	H-a	digital images
Randy Shivak	Prescott, AZ	152mm, RFR	ZWO-ASI174	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	W-L/H-a	drawings
		"	Malincam	W-L	digital images
James Kevin Ty	Manila, Philippines	TV101, RFR	ZWO-ASI 120MM	H-a	digital images
David Tyler	Buckinghamshire, UK	178mm, RFR	ZWO	W-L	digital images
	"	90mm, RFR	ZWO	H-a	digital images

NOTE: Telescope types: Refractor (RFR), Newtonian Reflector (RFL-N), Schmidt Cassegrain (SCT) Maksutov-Cassegrain (MCT), Meade Personal Solar Telescope (PST).

1,000 millionths for the average observer. The modified Zurich classifications used here are the ones defined by Patrick McIntosh of National Oceanic and Atmospheric Administration (referred to in this report as "NOAA") (McIntosh 1981, 1989) and detailed in an article in the JALPO Volume 33 (Hill 1989). This classification system is also detailed by the author on the Section website at: *http://www.alpo-astronomy.org/solarblog/?page_id=200* in an article on white light flare observation. Lastly, the magnetic class of regions is assigned by NOAA and will be abbreviated as "mag. class".

Included here is a table of Section observers, most of whom contributed to this report. The table summarizes their modes of observing as well as their locations. 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) "A Three-Dimensional Sunspot Classification System" Journal of the Assn of Lunar & Planetary Observers, Vol. 33, p. 10. *http://articles.adsabs.harvard.edu/cgi-bin/nph-iarticle_query?1989JALPO..33...10H&data_type=PDF_HIGH&whole_paper=YES&type=PRINTER&filetype=.pdf*

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, 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.

Additional references used in the preparation of this report:

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

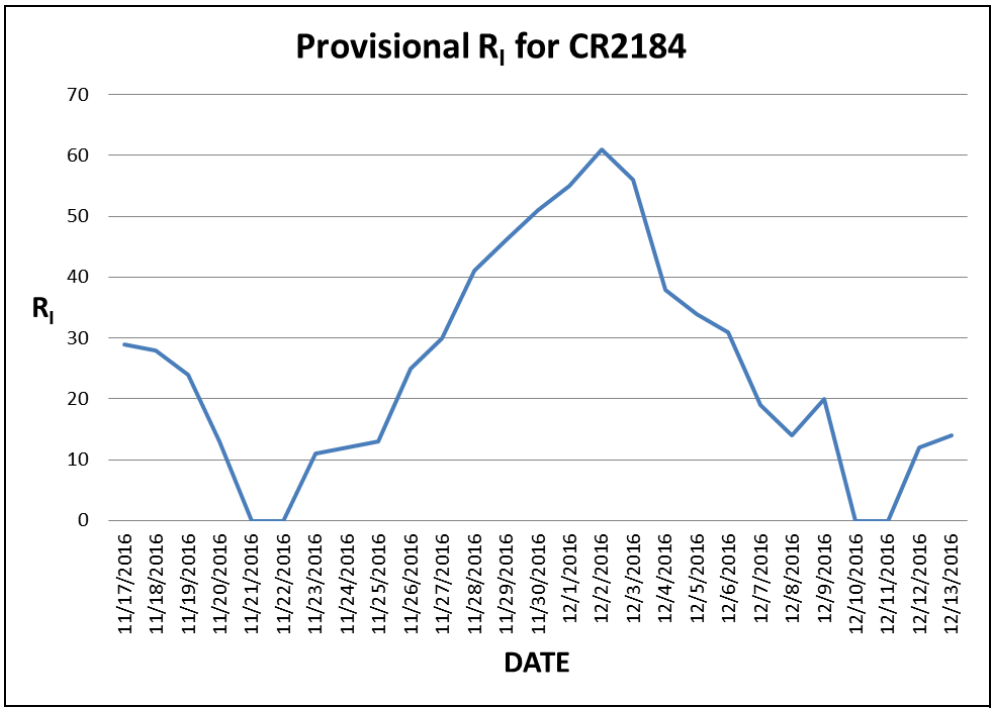
SILSO World Data Center
http://sidc.be/silso/home

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/

Carrington Rotation 2184

Dates: 2016 11 16.7354 to 2016 12 14.0521
Avg. R_I= 25.1
High R_I = 61 (12/2)
Low R_I = 0 (4 days)

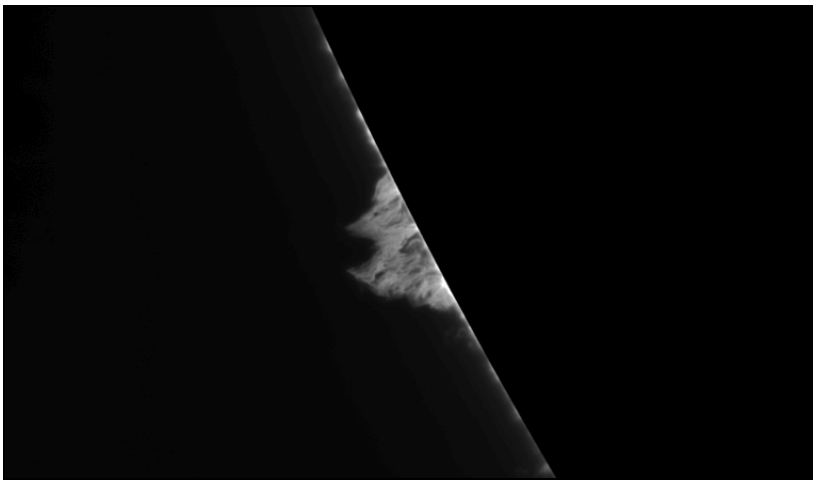


Activity or the average R_I for this rotation was higher than average R_I for the previous rotation (20.7) but still very low. This low activity has not been seen since early 2010. During this rotation, nine Active Regions were designated by NOAA, AR2609 to AR2617. This rotation had two active regions that contributed most to the activity, AR2612 and AR2615. They were both on the disk along with AR2614 on 12/02 when the finalized sunspot number was 61.

AR 2612 came onto the disk with a class of Hsx and an area of 120 millionths (mag. class "alpha") on 11/23. Levinthal, Teske and Gianninoto all observed it the first day and noted the same class. Thanks to the Gianninoto drawing, it was possible to make a positive identification of a Shivak image of a prominence over this region (Fig. 1). It is not unusual for a sunspot group to be given an H-class when on the limb and before all the spots can be seen and the true nature is known. But in this case, it retained that classification for four days. By the second day, the three aforementioned observers had given it a C-class designation, as it could be seen that it was two collections of umbrae in one broken penumbra.

In H-a and Cak images, Grassmann showed the region to be followed by a bright vertical plage. His image on the 25th showed this even better (Fig. 2). By then, the area had grown to 230 millionths (mag class unchanged) which

See Table 1 for equipment details for the following images.



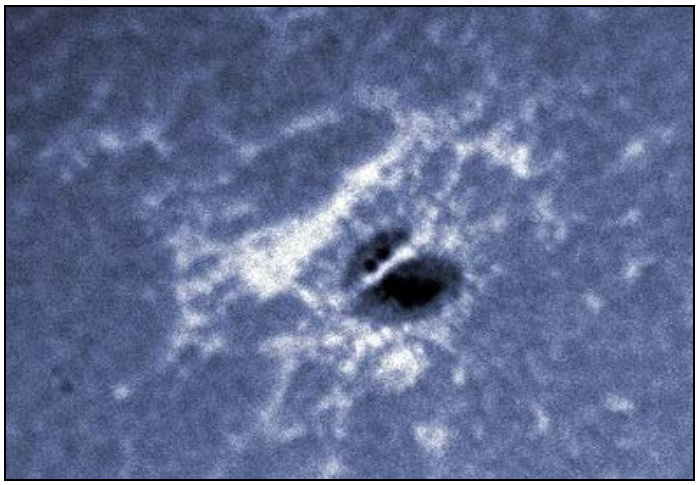


Figure 1 (left) - A limb prominence captured by Shivak over AR 2612 as it came into view on 2016-11-23 at 18:05 UT.
Figure 2 (right) - CaK of AR 2612 pm 2016-11-25 at 11:12 UT by Grassmann.

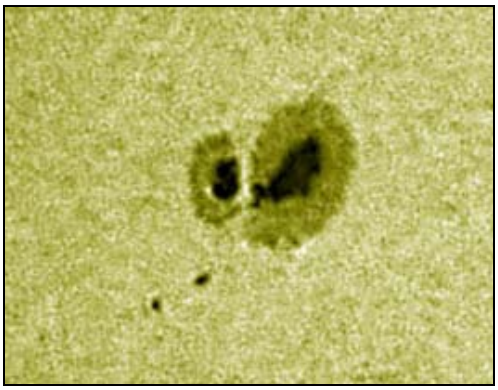
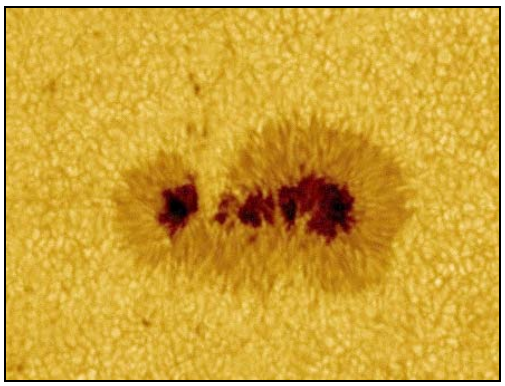
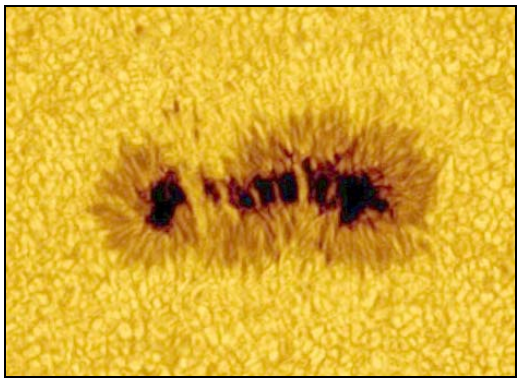




Figure 3 (left) - AR 2612 in white light by Ramakers on 2016-11-26 at 14:33 UT.
Figure 4 (center) - A white-light image of AR 2612 taken by Tyler on 2016-11-28 at 11:34 UT using a Baader solar filter, continuum filter, and IR blocker. Further instrumental information can be found on Table 1.
Figure 5 (right) - AR 2612 in white light on 2016-11-29 at 10:15 UT by Tyler.

would be the maximum development for this region. It was only producing about one flare every six hours, which is pretty low activity. A Ramakers w-l image the next day showed that the two spots had separated and the light bridge between them in his image is quite bright (possibly a white-light flare?) (Fig. 3). The following bright vertical plage remained.

On 11/28, the day of meridian passage, we have a good detailed w-l image by Tyler of this region. The two collections of umbrae, each in their own penumbra with a quiescent light bridge in between, overlapped on the southern edges (Fig. 4). The area had dropped to 170 millionths, but NOAA was now classifying the group as Cao, which our own observers had been doing for two days.

Flare production was even lower, as the region was beginning to break down. On the 29th, another light bridge cut the larger leading spot in half again and we had three collections of umbrae — each with separate penumbra. It looked like a caterpillar working its way across the Sun! (Fig. 5). From here it continued to decrease in area until on 12/02, the day of maximum sunspot number for this rotation, it was Dao class of 120 millionths area (beta mag class), producing only one flare in every eight hours on average.

As AR 2612 was crossing the meridian, AR 2615 popped into view on 12/29. It was first seen on that date by Broxton at 10:17 UT as a Bxo group. NOAA designated it as Dsi a few hours later, indicating rapid growth and development. The area on this day was listed as 30 millionths (mag class beta) with 45 flares in the first day! A w-l image on that first day at 11:11 UT showed three main spots with rudimentary penumbra (Fig. 6). The leader was slightly closer to the equator while the other two were at a latitude of S08. All had rudimentary or fragmentary penumbra and there were a couple outlier spots to the north as well.

The whole region was wreathed in faculae, and H-a and Cak images by Grassmann showed an active plage following the main leader with numerous bright points in that plage. The region doubled in size each of the next two days, with the leader growing while a strong neutral line snaked from the southern edge of the middle spots to the north edge of the follower spots. This was the site for many flares as seen by our observers. On 12/01, in w-l, the leader spot was a larger umbra with a symmetrical penumbra followed by naked umbrae and penumbral bits and pores well-shown in an image by Ramakers at 14:29 UT (Fig. 7).

AR 2615 crossed the meridian on 12/03 as a Dao (mag class still beta) group

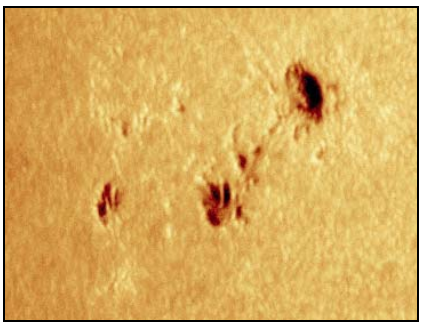
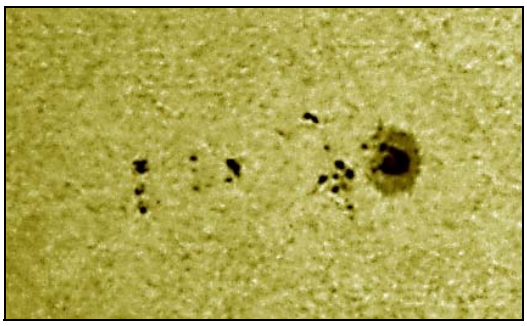
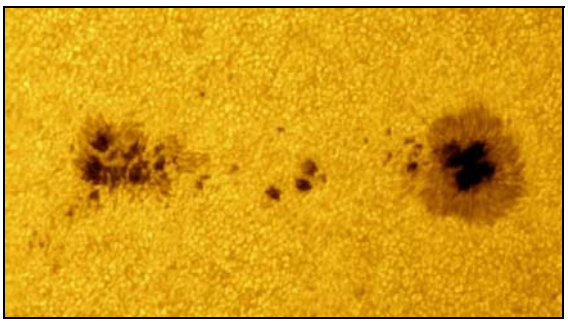




Figure 6 (left) - A Tyler white light image of AR 2615 on 2016-11-29 at 11:11 UT.
Figure 7 (center) - AR 2615 as imaged in white light by Ramakers on 2016-12-01 at 14:29 UT.
Figure 8 (right) - A remarkable white-light image of AR 2615 taken on 216-12-05 at 1056 UT in excellent seeing.

with an area of 110 millionths. Flare production had decreased to half of what it was three days earlier, now being only one every two hours or so. Teske was the only observer to note meridian passage in a w-l drawing. Maximum development for this region was on 12/05 when the class was Dai (mag class still beta) with and area of 200 millionths. The leader spot was a large, four-lobed umbra in a radially symmetrical penumbra followed by a middle collection of three naked umbrae and a follower spot that was a group of at least 10 umbrae in scattered rudimentary and fragmentary penumbra seen in another Tyler image at 10:56 UT (Fig. 8).

The middle and follower spots were all in a plage but flare production was still about the same shown in a Grassmann CaK image the next day at 12:26 UT (Fig. 9). From this point on, the activity decreased further as the region approached the limb and left the disk on 12/09, then a Cao group of 60 millionths area in a web work of faculae. We had some nice limb prominence images about that time but no effort was made to identify the limb or to associate them with any particular AR, so it's not clear at all that they were due to AR 2615!

Carrington Rotation 2185

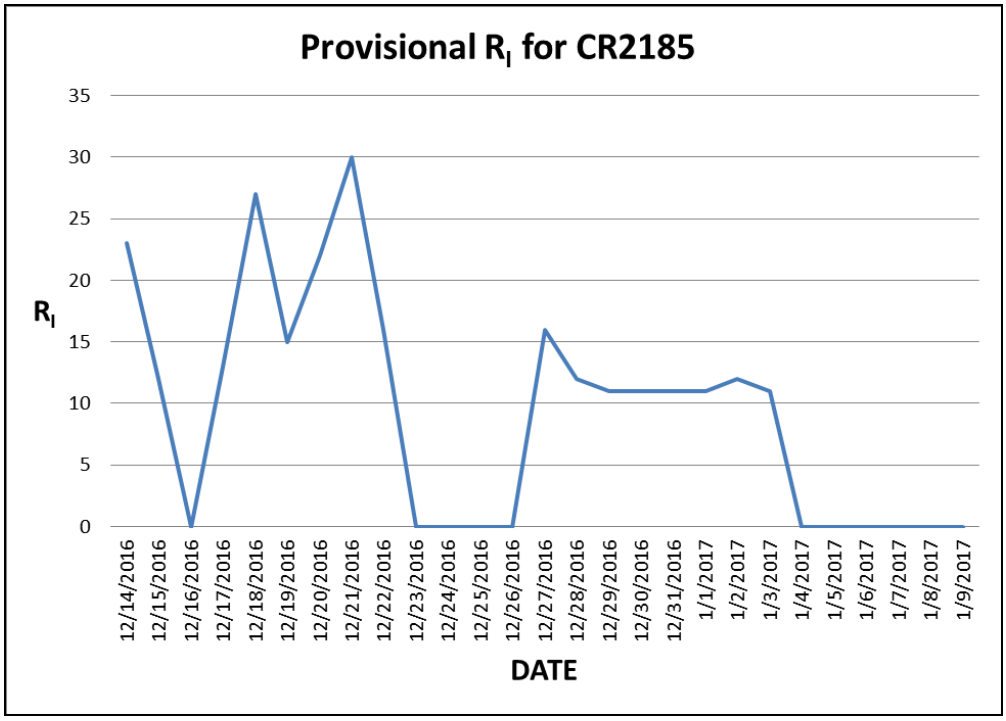
Dates: 2016 12 14.0521 to 2017 01 10.3840

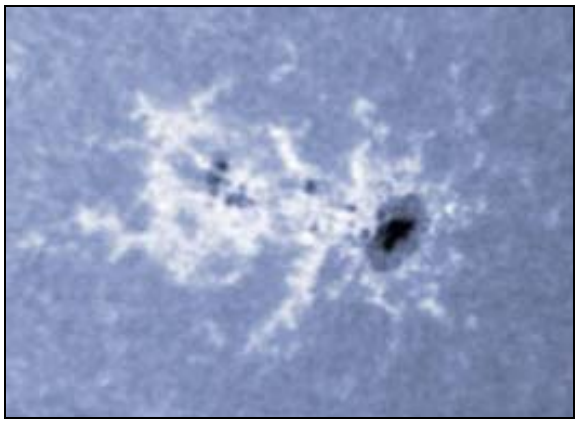
Avg. R_I= 9.4

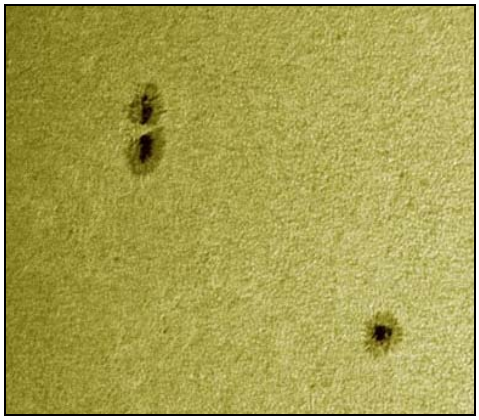
High R_I = 30 (12/21)

Low R_I = 0 (11 days)

Activity for this rotation dropped to exceptionally low levels. The highest final daily R_I was only 30, and as can be seen in the plot below, it dropped quickly from that. No regions exceeded 70 millionths and the one that attained that was AR 2617 on the first day of the rotation as it was leaving the disk. It demonstrated only three flares in its last 48 hours on the disk. We had no good images of this group or region beyond whole disk images. This level of activity could be a peek at what is coming in the next few years.







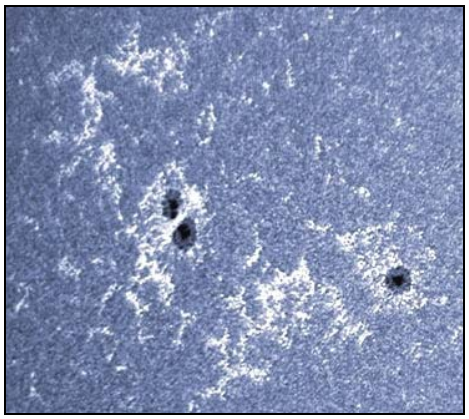
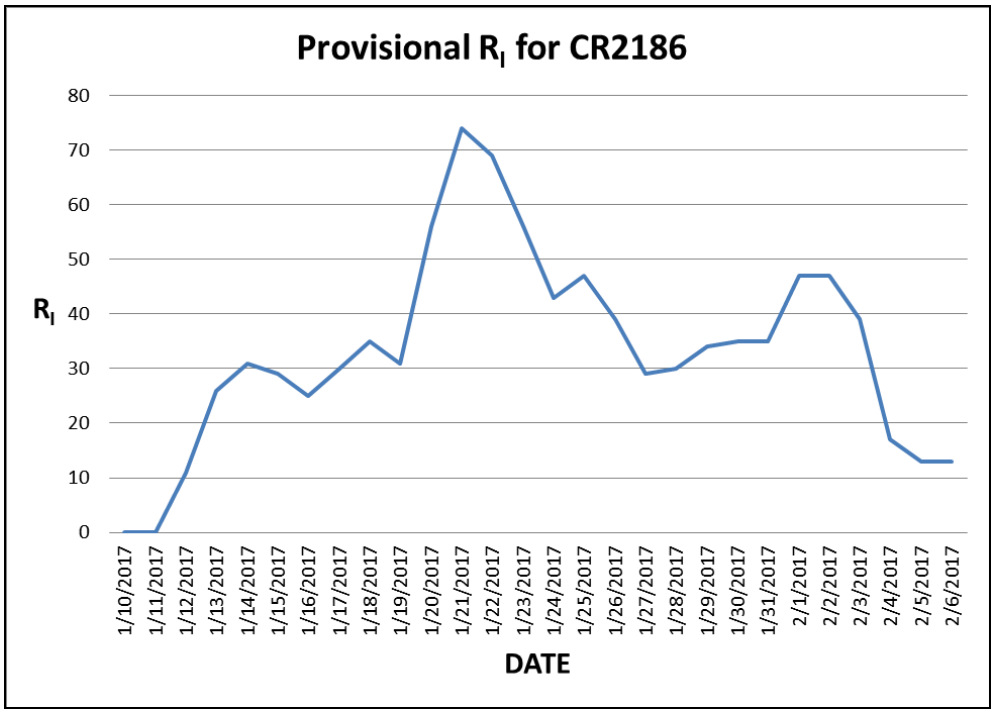


Figure 9 (left) - A Grassmann CaK image of AR 2615 on 2016-12-06 at 12:26 UT.
Figure 10 (center) - ARs 2625 and 2626 on 2017-01-15 at 15:13 UT by Ramakers.
Figure 11 (right) - A CaK view of ARs 2625 and 2626 by Grassmann on 2017-01-16 at 12:00 UT.

Carrington Rotation 2186

Dates: 2017 01 10.3840 to 2017 02 06.7250

Avg. R_I= 33.6
High R_I = 74 (1/21)
Low RI = 0 (1/10, 1/11)



Though the rotation opened with two days of zero sunspots, there was nevertheless an increase in activity with the number of groups being about the same, but larger in areas and numbers of spots. The day of highest R_I was 1/21 when the count was 74. Still only one region attained an area in excess of 200 millionths of the disk.

AR 2626 entered the disk as Hsx with an area of 20 millionths on 1/13 and in three days jumped to 140 millionths (mag class alpha) with only one flare in 48 hours. This situation remained unchanged through the 15th after which it began declining and left the disk as Aax with an area of 10 millionths. We have a good w-l image of this region and AR 2625 south of it from Ramakers on 1/15 at 15:12 UT (Fig. 10) and a nice CaK image from Grassmann the next day showing both regions in a plage filigree at 12:00 UT (Fig. 11).

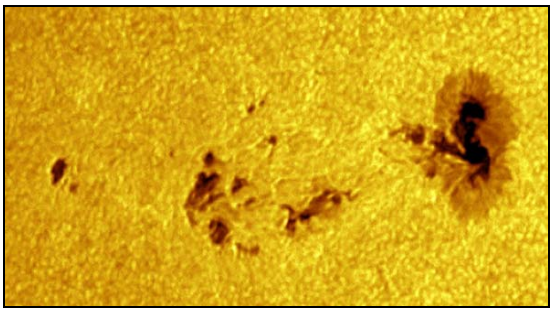
AR 2628 became the largest region of this rotation. It formed on the disk on 1/20 as a Bxo group of 20 millionths (mag class beta), but produced 20 flares in its first two days! It was first observed by Broxton in a w-l drawing at 10:32 UT on that day. By 1/21, it had rapidly grown to Dai (mag class beta-gamma) with an area of 120 millionths.

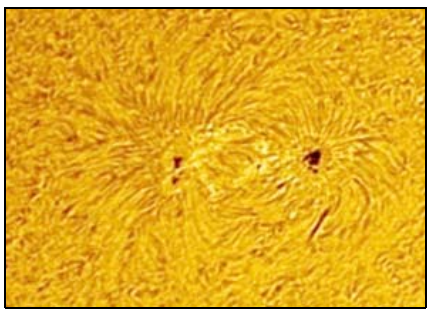
It consisted of a leader that was a N-S oriented umbrae in a well-organized penumbra followed by a scattering of fragmentary umbrae and penumbral bits and a final follower of a single medium-sized naked umbra and pore as seen in a Tyler image on that date (Fig. 12). By 1/23, the classes were unchanged but the area had grown by 100 millionths as it crossed the central meridian (Fig. 13).

Then on 1/24, it began to show signs of weakening when flare production dropped to only one in 48 hours and a class was Dso (mag class only beta) with an unchanged area.

This continued the next day, 1/25, when the class went up to Eao (mag class still beta) while the area decreased slightly to 210 millionths. A curious umbral tail followed the leader spot as shown in a Ramakers w-l image (Fig. 14). Flare production was now zero, which was odd considering the McIntosh class. AR 2629 was now the big flare producer on the disk.

On 1/26, the class for AR 2628 dropped to Cao with an area of 180 millionths and still no flares. The class stayed the same on the 27th with a further decrease in area to 120 millionths and then to 110 millionths a day later. As it neared the limb on 1/29, the area





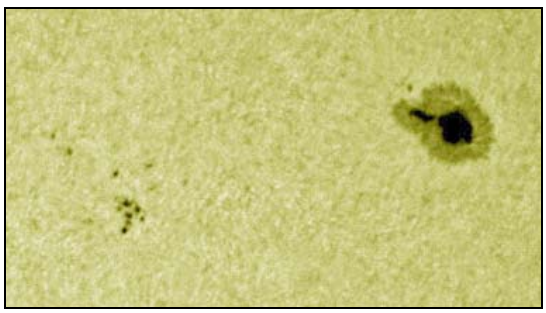


Figure 12 (left) - A Tyler white light image of AR 2628 on 2017-01-21 at 11:27 UT.
Figure 13 (center) - A Grassmann H-alpha image of AR 2628 on 2017-01-22 at 19:49 UT.
Figure 14 (right) - A white-light view of AR2628 on 2017-01-25 at 1507 UT as imaged by Ramakers.

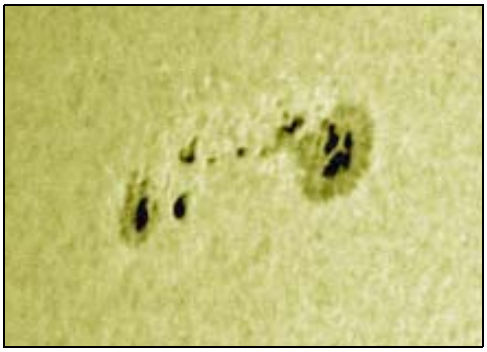


Figure 15 - Another Ramakers white-light image, this time of AR 2629 on 2017-01-25 at 15:08 UT.

stayed the same but the class was now Hsx. This is how it left the disk on 1/30.

The last region of note during CR 2186 was AR 2629. It rapidly formed on the disk on 1/24, growing to Cao with an area of 70 millionths in the first day. Ramakers showed the leading spot on the leading edge of a circular ring of faculae. In Eskildsen and Ramakers H-a and CaK images, the facular region is seen as a very intensely bright plage, possibly low-level flaring. This was particularly true in the CaK images. It was at this time producing one flare every two hours on average.

The next day, 1/25, was maximum development for this region. The class was Dao with an area of 180 millionths as seen in a Ramakers w-l image taken at 15:08 UT (Fig. 15). The leader consisted of a collection of four umbrae within a well-organized penumbra followed by one spot with four small umbrae and rudimentary penumbra and then another four umbrae in the mid-region. The follower spot was a half-dozen small umbrae in poorly organized penumbra. The entire region was covered with faculae and in H-a, the hot region appeared to be on the leading edge of the follower spot.

Flare production was about the same and this region was the leading flare producer on the Sun at this time. Over the next few days, flare production dropped off while the area slowly decreased in area. At meridian passage on 1/29, the class was Dao with an area of 130 millionths and it only produced one flare in 48 hours. The next day it dropped to Cso with an area of 120 millionths and then on 1/31, it lost the follower spots and became class Hsx with an area of only 60 millionths. It stayed more or less the same until it left the disk on 2/3.

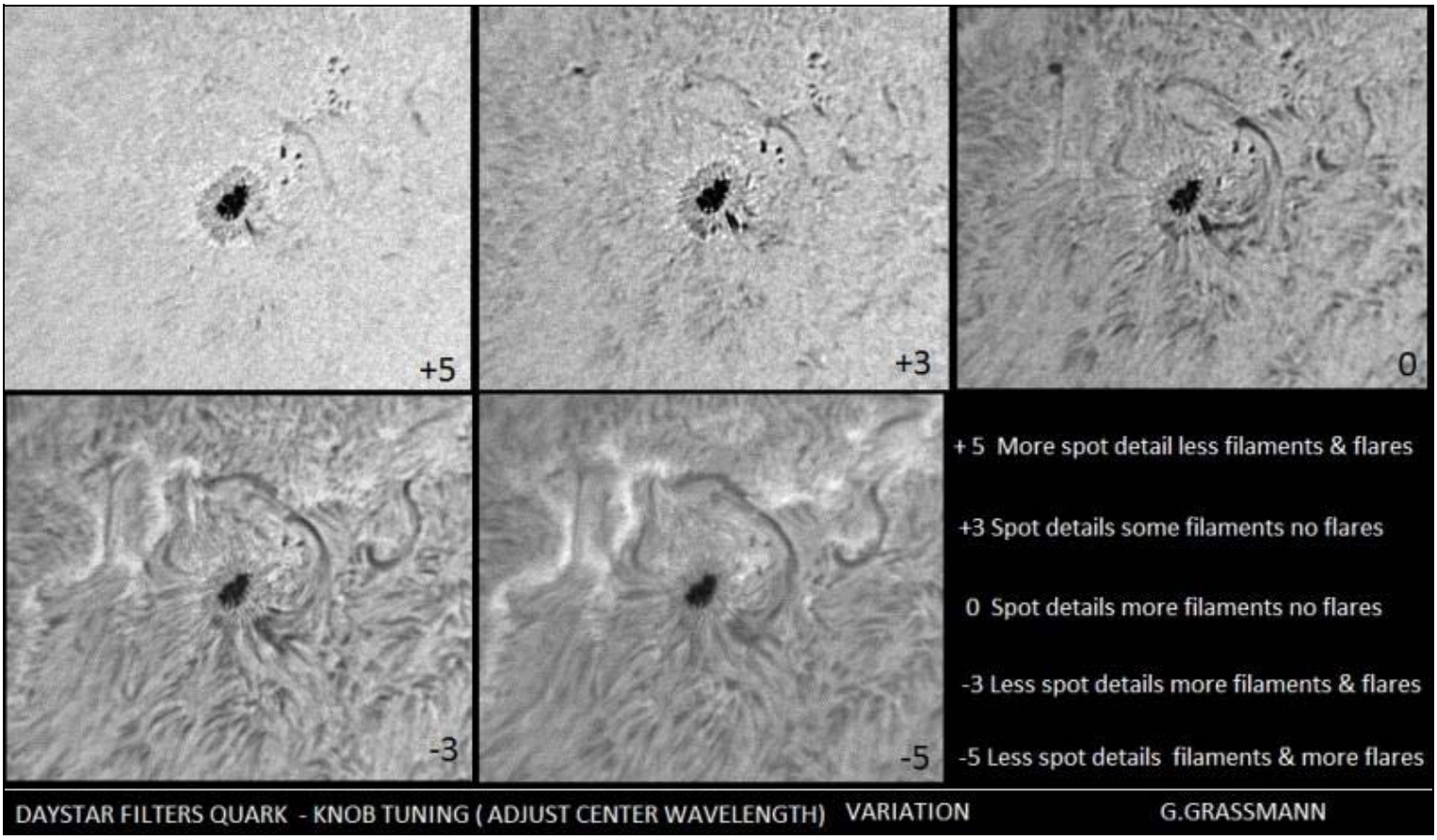
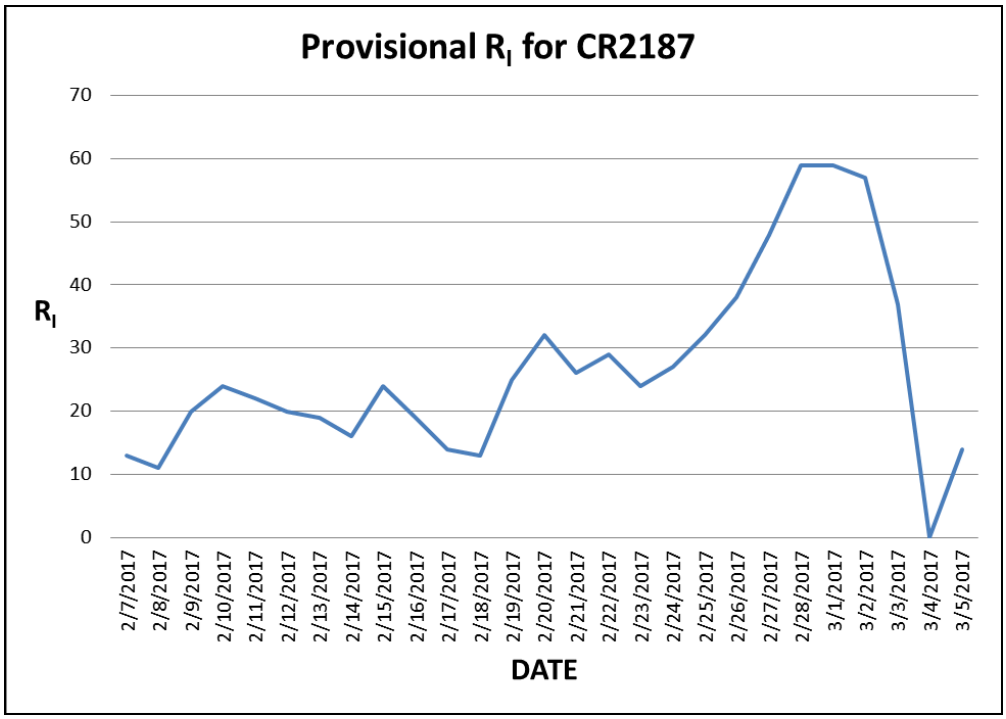


Figure 16 - A multi-panel H-alpha montage of images of AR 2638 by Grassmann as he went from off-line on the red side to off-line on the blue side by the same amount. The red-shift image shows features that are moving away, while the blue shows to the opposite.

Carrington Rotation 2187

Dates: 2017 02 06.7250 to 2017 03 06.0597

Avg. R_I = 26.7
High R_I = 59 (2/28, 3/1)
Low R_I = 0 (3/4)



As with the last rotation, no single region was dominant during CR 2187. In fact, no region exceeded 150 millionths!

The largest region for this rotation, AR 2638, formed on the disk on 2/20 and within 24 hours was Dao with an area of 80 millionths. By 2/22 it had nearly doubled in area and was now Dso, generating one flare every four hours on average. Grassman has an interesting grouping of H-a images showing the changing appearance as he adjusted his filter from off-band (continuum) through the center of the H-alpha line (Fig. 16).

Maximum development was on 2/24, a day before meridian passage with an officially listed class of Cso and an area of 150 millionths, but it only produced about one flare every six hours on average.

However, I have to agree with Gianninoto's designation of Hsx on this date. There were a few pores near the main spot, a large umbra in a radially symmetrical penumbra which is pretty much the definition of Hsx. It is shown in a w-l image by Tyler on this date (Fig. 17). This is the classic form many spot groups take on as they are decaying. They retain the H-class form while shrinking in area until they are gone.

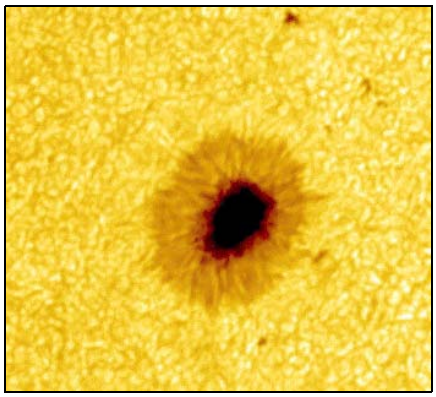
Two days later, NOAA changed the class to Hsx and over the next 12 days it did just what I described until it left the disk on 3/9 as only a plage. Braga showed an interesting filament that had formed to the north of the spot on 2/26 (Fig. 18). It was so straight it caught the eye. But by the next day, Ty showed it to be breaking down and becoming more sinuous (Fig. 19).

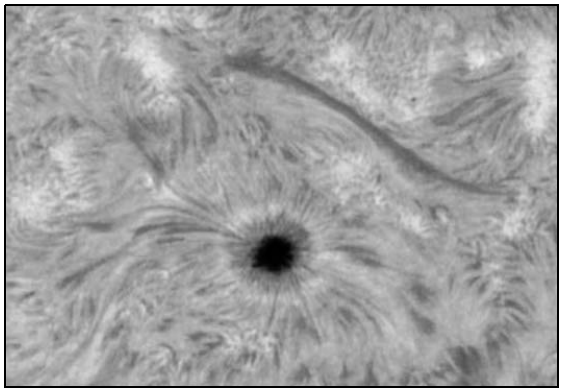
This was the last notable activity from this region.

Conclusion

While activity was lackluster during this reporting period, as mentioned earlier, we can still get occasional regions that will provide a good show.

Observers need to remain vigilant during solar minimum. The solar community is split right now on how deep this upcoming minimum will be and for how long. There seems to be some agreement on a protracted minimum with some researchers predicting another Maunder-type minimum! The solar minimum is also a good time for honing techniques and equipment in preparation for the inevitable rise to the next solar max.





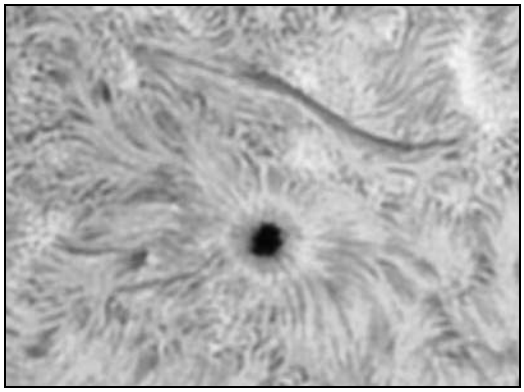


Figure 17 (right) - AR 2638 as imaged by Tyler showing a classic H-class form. The image was taken on 2017-02-24 at 11:36 UT
Figure 18 (center) - A large filament that formed to the north of AR 2638 as imaged by Braga on 2017-02-26 at 10:50 UT.
Figure 19 (right) - The filament to the north of AR 2638 on 2017-02-27 at 10:53 UT as imaged by Ty.

A.L.P.O. Solar Section

OBSERVER_____

ADDRESS_____

DATE/TIME_____UT

SEEING_____ CLOUDS_____ WIND_____

APERTURE_____mm FOCAL LENGTH_____mm TYPE_____

EYEPIECE_____mm FILTRATION_____

OBSERVATION: *DIRECT* OR *PROJECTED*? (CIRCLE ONE)

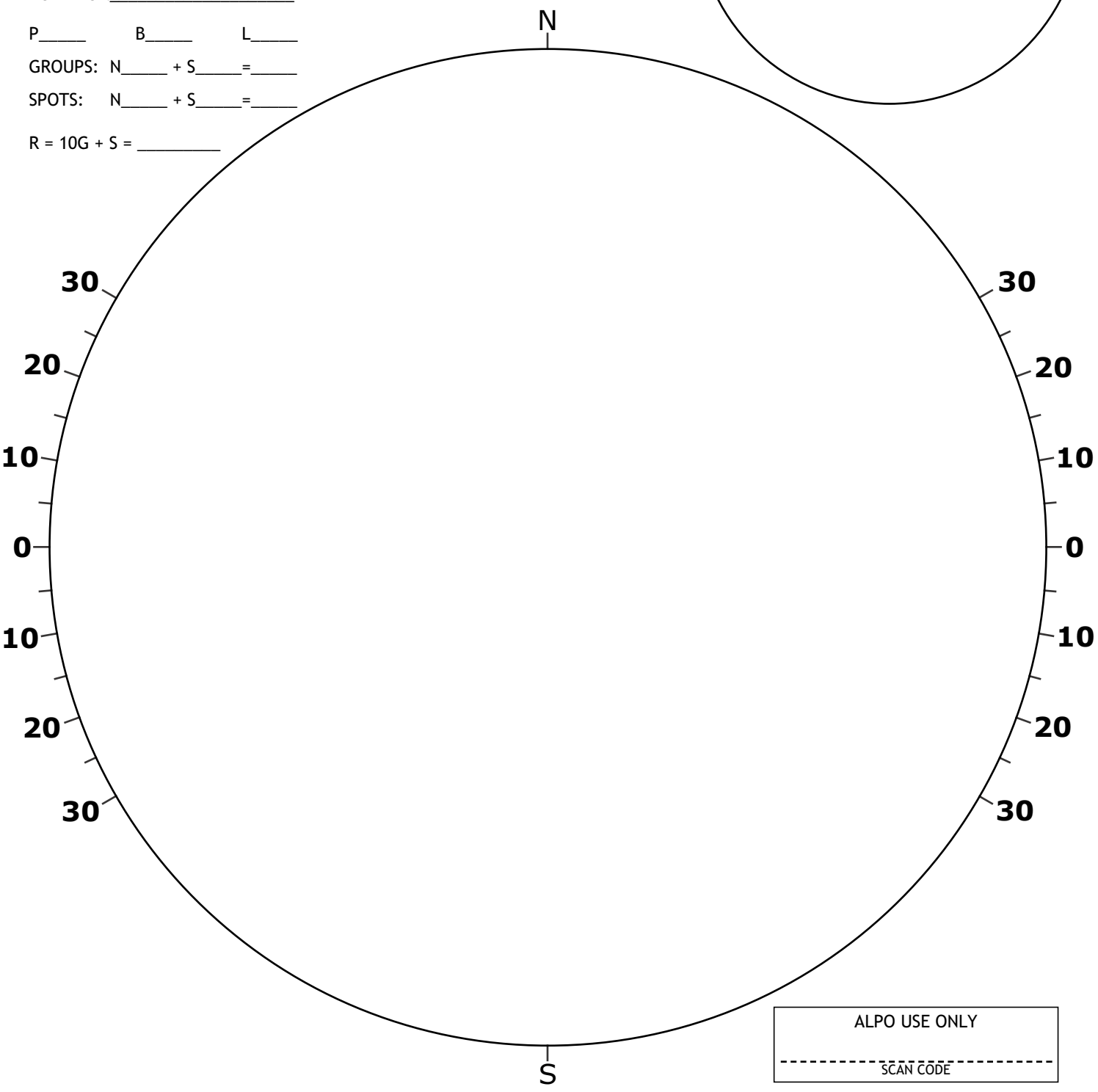
ROTATION_____

P_____ B_____ L_____

GROUPS: N_____ + S_____=_____

SPOTS: N_____ + S_____=_____

R = 10G + S = _____



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