Solar Bulletin

THE AMERICAN ASSOCIATION OF VARIABLE STAR OBSERVERS
SOLAR SECTION

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The Solar Bulletin of the AAVSO is a summary of each month's solar activity recorded by visual solar observers' counts of group and sunspots, and the VLF radio recordings of SID Events in the ionosphere. Section 1 gives contributions by our members. The sudden ionospheric disturbance report is in Section 2. The relative sunspot numbers are in Section 3. Section 4 has endnotes.

1 Compare the AAVSO Ra index with SIDC R index for cycle 24 and cycle 25 minimums.

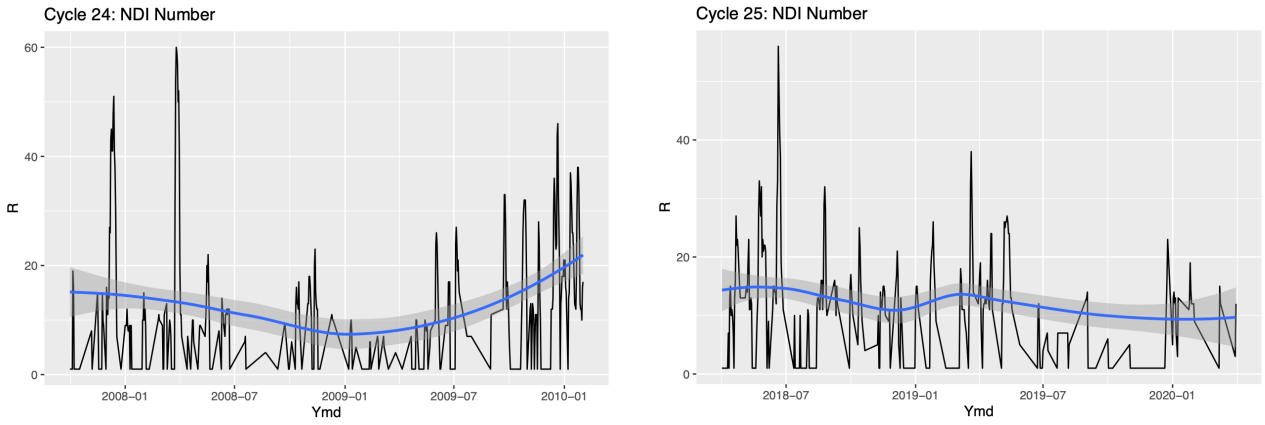

Figure 1: (left) shows the Normalized Difference Index (NDI) of the AAVSO Ra and SIDC R index numbers from 2008-2010 - cycle 24, (right) shows the NDI of the Ra and R indices from 2018-2020 solar minimum to-date, cycle 25.

The AAVSO Ra index (of all visual observers' calculated Wolf numbers), is from daily data showing solar cycles 24 and 25 solar minimums (`https://www.aavso.org/sites/default/files/solar/NOAAfiles/daily.csv`), and the SIDC R index is for the same time frame, (`http://www.sidc.be/silso/datafiles`). The black spikes are the NDI = (Ra - R)/(Ra + R) for non-zero days, and the blue lines are the lowess smoothing of the Normalized Difference Indices.

The NDI somewhat exaggerates the difference between the two data sets and helps bring out solar activity during these two solar cycle minimums.

2 Sudden Ionospheric Disturbance (SID) Report

2.1 SID Records

April 2020 (Figure 2): There were no SID events recorded here in Fort Collins, Colorado for the month of April, nor on the 23rd of April, even though two A-class solar flares were recorded during the day. (Please note the y-axis values in these SID graphs are non-dimensional.)

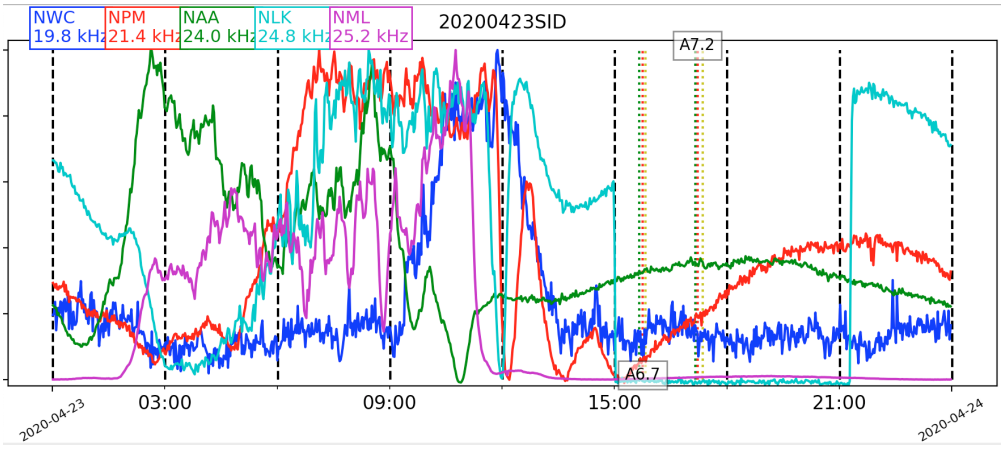

Figure 2: VLF recording at Fort Collins, Colorado.

2.2 SID Observers

In April 2020 we had 13 AAVSO SID observers who submitted VLF data as listed in Table 1. There were no observers who recorded SID events this month, which matched to GOES-15 XRA and FLA events.

Table 1: 202004 VLF Observers

Observer	Code	Stations
J Wallace	A97	NAA
L Loudet	A118	DHO GBZ
J Godet	A119	GBZ
B Terrill	A120	NWC
F Adamson	A122	NWC
S Oatney	A125	NML NLK NAA
J Karlovsky	A131	NSY ICV
R Green	A134	NWC
S Aguirre	A138	NPM
G Silvis	A141	HWU NAU
R Rogge	A143	GQD
K Menzies	A146	NAA
L Ferreira	A149	NWC

Figure 3 depicts the importance rating of the solar events. The duration in minutes are -1: LT 19, 1: 19-25, 1+: 26-32, 2: 33-45, 2+: 46-85, 3: 86-125, and 3+: GT 125.

Figure 3: VLF SID Events.

2.3 Solar Flare Summary from GOES-16 Data

In April 2020, there were three A-class and 7 B-class flares recorded from GOES-16. More flaring this month compared to last. There were 23 days this month with no GOES-16 reports of flares (see Figure 4).

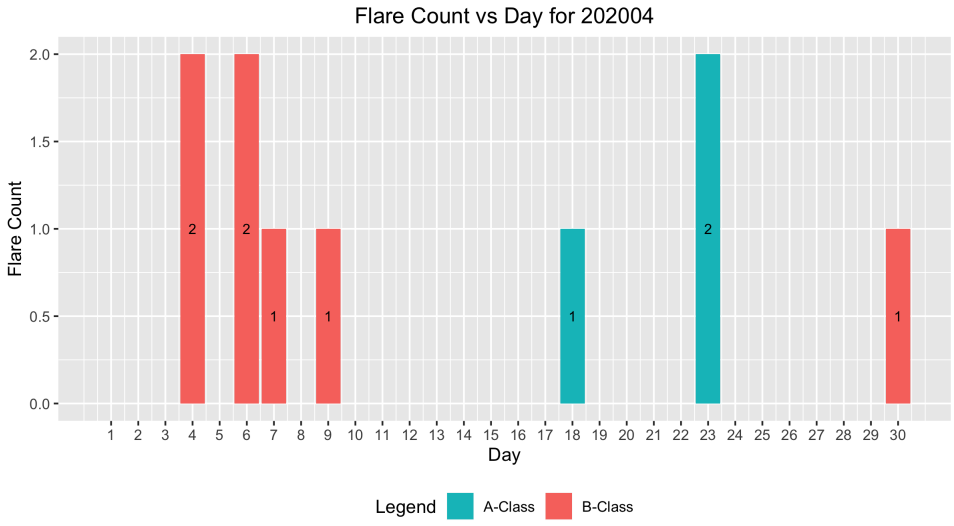

Figure 4: GOES-16 XRA flares

3 Relative Sunspot Numbers (R_a)

Reporting monthly sunspot numbers consists of submitting an individual observer's daily counts for a specific month to the AAVSO Solar Section. These data are maintained in an SQL database. The monthly data then are extracted for analysis. This section is the portion of the analysis concerned with both the raw and daily average counts for a particular month. Scrubbing and filtering the data assure error-free data are used to determine the monthly sunspot numbers.

3.1 Raw Sunspot Counts

The raw daily sunspot counts consist of submitted counts from all observers who provided data in April 2020. These counts are reported by the day of the month. The reported raw daily average counts have been checked for errors and inconsistencies, and no known errors are present. All observers whose submissions qualify through this month's scrubbing process are represented in Figure 5.

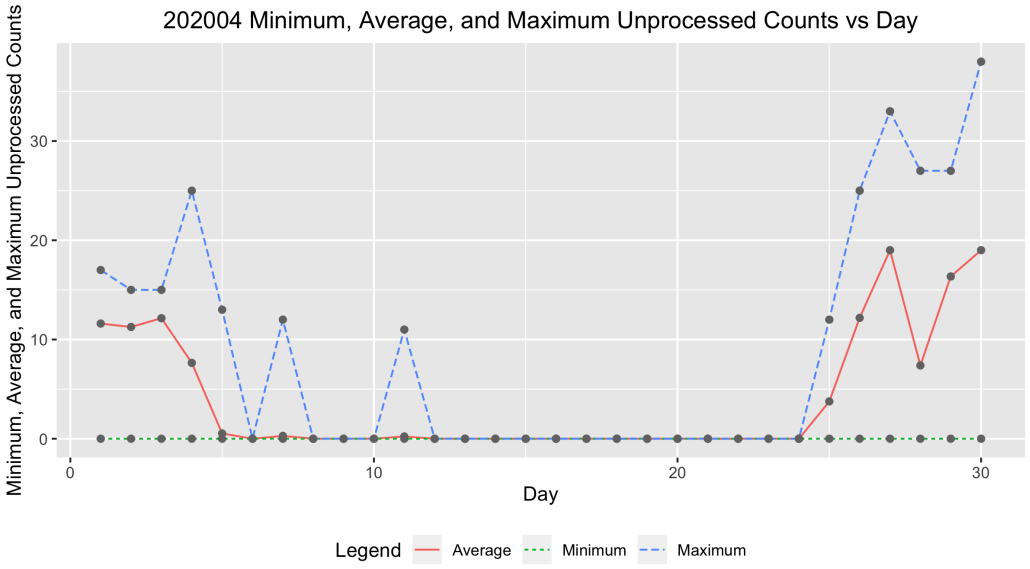

Figure 5: Raw Wolf number average, minimum and maximum by day of the month for all observers.

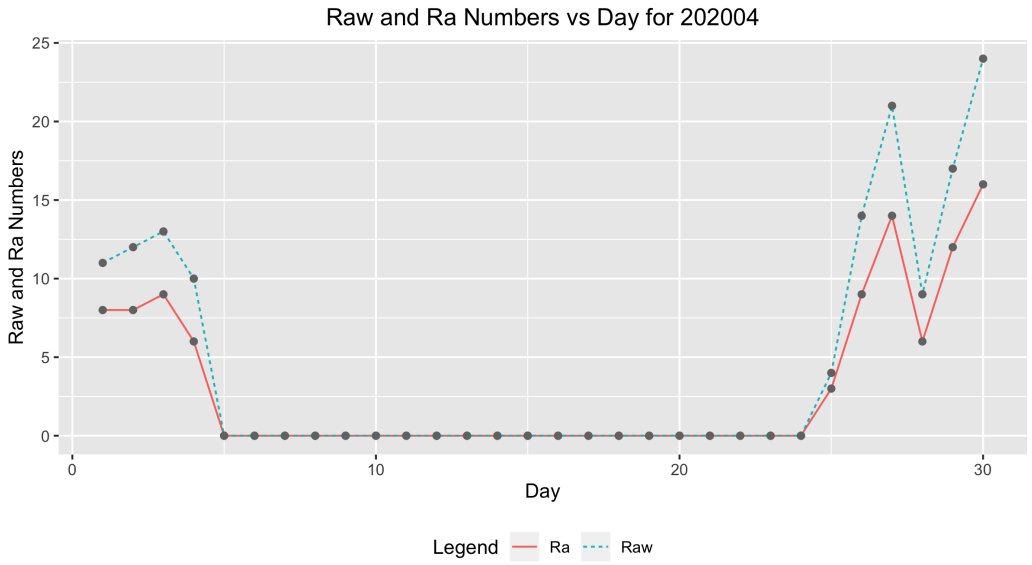

Figure 6: Raw Wolf average and R_a numbers by day of the month for all observers.

3.2 American Relative Sunspot Numbers

The relative sunspot numbers, R_a, contain the sunspot numbers after the submitted data are scrubbed and modeled by Shapley's method with k-factors (`http://iopscience.iop.org/article/10.1086/126109/pdf`). The Shapley method is a statistical model that agglomerates variation due to random effects, such as observer group selection, and fixed effects, such as seeing condition. The raw Wolf averages and calculated R_a are seen in Figure 6, and Table 2 shows the Day of the observation (column 1), the Number of Observers recording that day (column 2), the raw Wolf number (column 3), and the Shapley Correction (R_a) (column 4).

Table 2: 202004 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
1	38	11	8
2	46	12	8
3	41	13	9
4	45	10	6
5	45	0	0
6	46	0	0
7	42	0	0
8	43	0	0
9	42	0	0
10	46	0	0
11	48	0	0
12	37	0	0
13	35	0	0
14	41	0	0

Continued

Table 2: 202004 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
15	40	0	0
16	45	0	0
17	38	0	0
18	37	0	0
19	32	0	0
20	40	0	0
21	39	0	0
22	39	0	0
23	37	0	0
24	38	0	0
25	50	4	3
26	44	14	9
27	44	21	14
28	39	9	6
29	40	17	12
30	37	24	16
Averages	41.1	4.5	3

3.3 Sunspot Observers

Table 3 lists the Observer Code (column 1), the Number of Observations (column 2) submitted for April 2020, and the Observer Name (column 3). The final rows of the table give the total number of observers who submitted sunspot counts and the total number of observations submitted. The final rows of the table give the total number of observers who submitted sunspot counts (61), and the total number of observations submitted (1234).

Table 3: 202004 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
AAX	30	Alexandre Amorim
AJV	19	J. Alonso
ARAG	30	Gema Araujo
ASA	26	Salvador Aguirre
ATE	22	Teofilo Arranz Heras
BARH	14	Howard Barnes
BERJ	24	Jose Alberto Berdejo
BMF	23	Michael Boschat
BRAD	27	David Branchett
BRAF	18	Raffaello Braga
BROB	24	Robert Brown
CHAG	28	German Morales Chavez

Continued

Table 3: 202004 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
CIOA	12	Ioannis Chouinavas
CKB	23	Brian Cudnik
CNT	27	Dean Chantiles
CVJ	5	Jose Carvajal
DEMF	11	Frank Dempsey
DIVA	25	Ivo Demeulenaere
DJOB	22	Jorge del Rosario
DMIB	25	Michel Deconinck
DROB	3	Bob Dudley
DUBF	30	Franky Dubois
EHOA	17	Howard Eskildsen
ERB	23	Bob Eramia
FERJ	13	Javier Ruiz Fernandez
FLET	23	Tom Fleming
FUJK	23	K. Fujimori
HAYK	17	Kim Hay
HMQ	19	Mark Harris
HOWR	19	Rodney Howe
HRUT	28	Timothy Hrutkay
JDAC	7	David Jackson
JENS	12	Simon Jenner
KADB	2	Andrea de Oliveira Kovacs
KAPJ	16	John Kaplan
KNJS	29	James & Shirley Knight
LEVM	17	Monty Leventhal
LGEC	14	Georgios Lekkas
LKR	5	Kristine Larsen
MARC	20	Arnaud Mengus
MARE	13	Enrico Mariani
MCE	25	Etsuiku Mochizuki
MILJ	17	Jay Miller
MJAF	29	Juan Antonio Moreno Quesada
MJHA	24	John McCammon
MUDG	11	George Mudry
MWU	29	Walter Maluf
OAAA	18	Al Sadeem Astronomy Observatory
ONJ	18	John O'Neill
SDOH	30	Solar Dynamics Obs - HMI
SNE	15	Neil Simmons
STAB	29	Brian Gordon-States
SUZM	25	Miyoshi Suzuki
TESD	26	David Teske
TPJB	7	Patrick Thibault

Continued

Table 3: 202004 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
TST	19	Steven Toothman
URBP	29	Piotr Urbanski
VARG	30	A. Gonzalo Vargas
VIDD	25	Daniel Vidican
WGI	19	Guido Wollenhaupt
WILW	24	William M. Wilson
Totals	1234	61

3.4 Generalized Linear Model of Sunspot Numbers

Dr. Jamie Riggs, Solar System Science Section Head, International Astrostatistics Association, maintains a relative sunspot number (R_a) model containing the sunspot numbers after the submitted data are scrubbed and modeled by a Generalized Linear Mixed Model (GLMM), which is a different model method from the Shapley method of calculating R_a in Section 3 above. The GLMM is a statistical model that accounts for variation due to random effects and fixed effects. For the GLMM R_a model, random effects include the AAVSO observer, as these observers are a selection from all possible observers, and the fixed effects include seeing conditions at one of four possible levels. More details on GLMM are available in the paper, *A Generalized Linear Mixed Model for Enumerated Sunspots* (see "GLMM06" in the sunspot counts research page at http://www.spesi.org/?page_id=65).

Figure 7 shows the monthly GLMM R_a numbers for the 24th solar cycle to date. The solid cyan curve that connects the red X's is the GLMM model R_a estimates of excellent seeing conditions, which in part explains why these R_a estimates often are higher than the Shapley R_a values. The dotted black curves on either side of the cyan curve depict a 99% confidence band about the GLMM estimates. The confidence band uses the large sample approximation based on the Gaussian distribution. The green dotted curve connecting the green triangles is the Shapley method R_a numbers. The dashed blue curve connecting the blue O's is the SILSO values for the monthly sunspot numbers.

The tan box plots for each month are the actual observations submitted by the AAVSO observers. The heavy solid lines approximately midway in the boxes represent the count medians. The box plot represents the InterQuartile Range (IQR), which depicts from the 25^{th} through the 75^{th} quartiles. The lower and upper whiskers extend 1.5 times the IQR below the 25^{th} quartile, and 1.5 times the IQR above the 75^{th} quartile. The black dots below and above the whiskers traditionally are considered outliers, but with GLMM modeling, they are observations that are accounted for by the GLMM model.

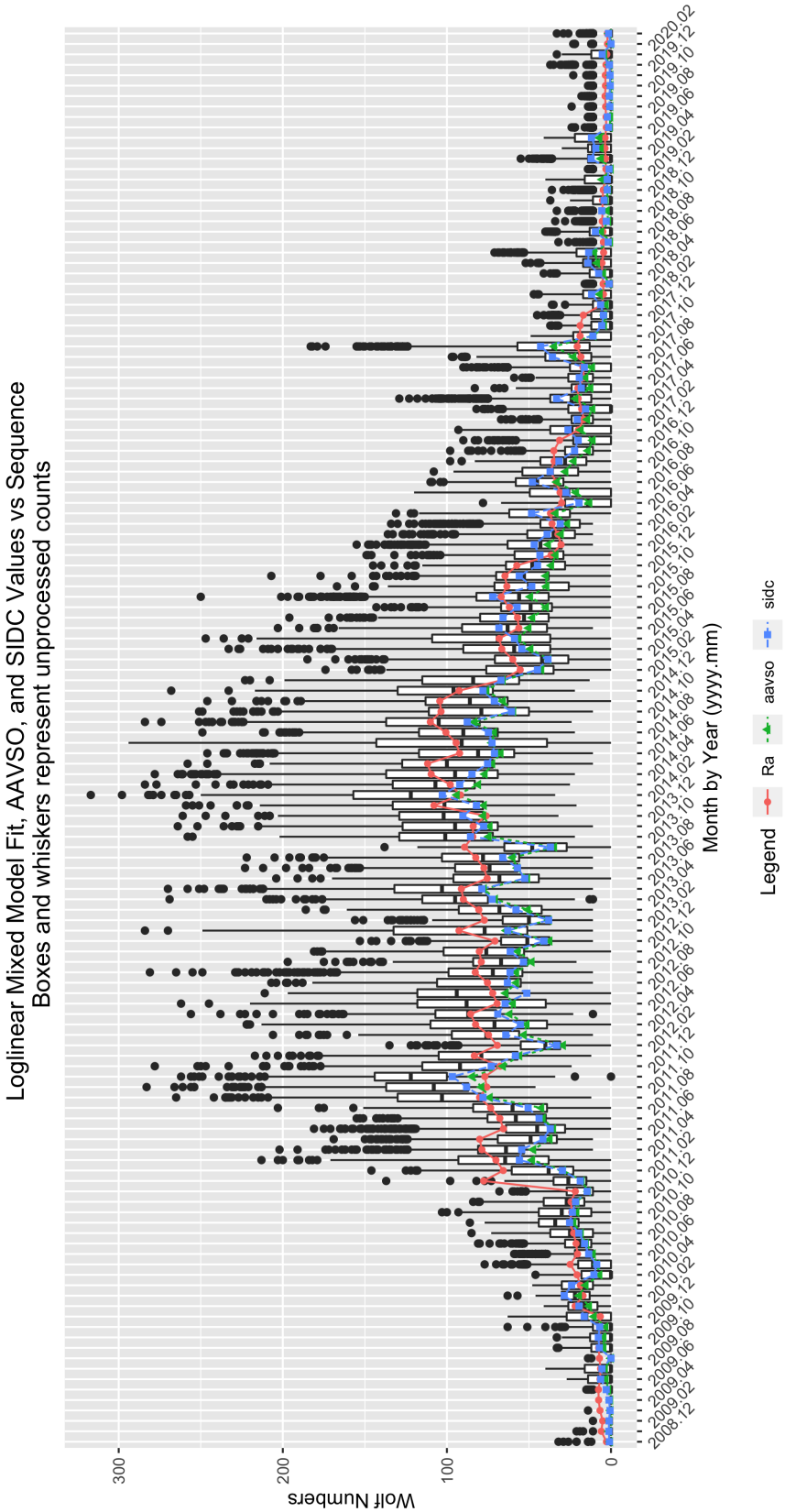

Figure 7: GLMM fitted data for R_a. AAVSO data: https://www.aavso.org/category/tags/solar-bulletin. SILSO data: WDC-SILSO, Royal Observatory of Belgium, Brussels

4 Endnotes

- Sunspot Reports: Kim Hay solar@aavso.org
- SID Solar Flare Reports: Rodney Howe ahowe@frii.com

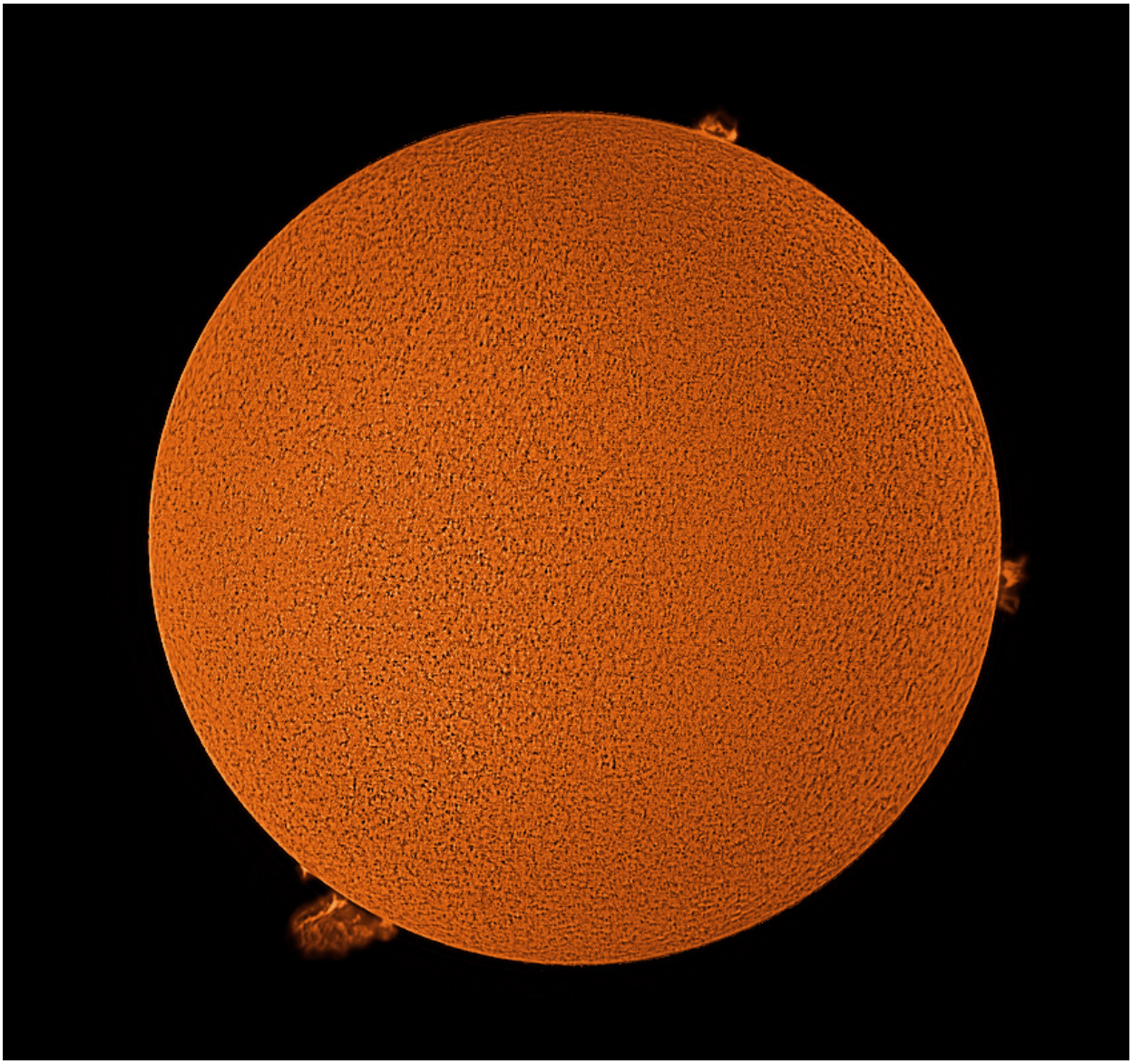

Figure 8: Jon Wallace takes this image of a day of no sunspots, but there are filaments on the limbs

No flares detected again this month. I did take a bunch of solar images and yesterday's (5/4/2020) was particularly good so I am attaching it. I also captured the three active areas on 4/29 - one of which is cycle 24 and the other two cycle 25 - thought that was fun to have both cycles close together in an image... Anyway, it helps keep me amused... Take care and please stay safe and well! Jon