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 two distributions of the Hurdle model for cycle 24.

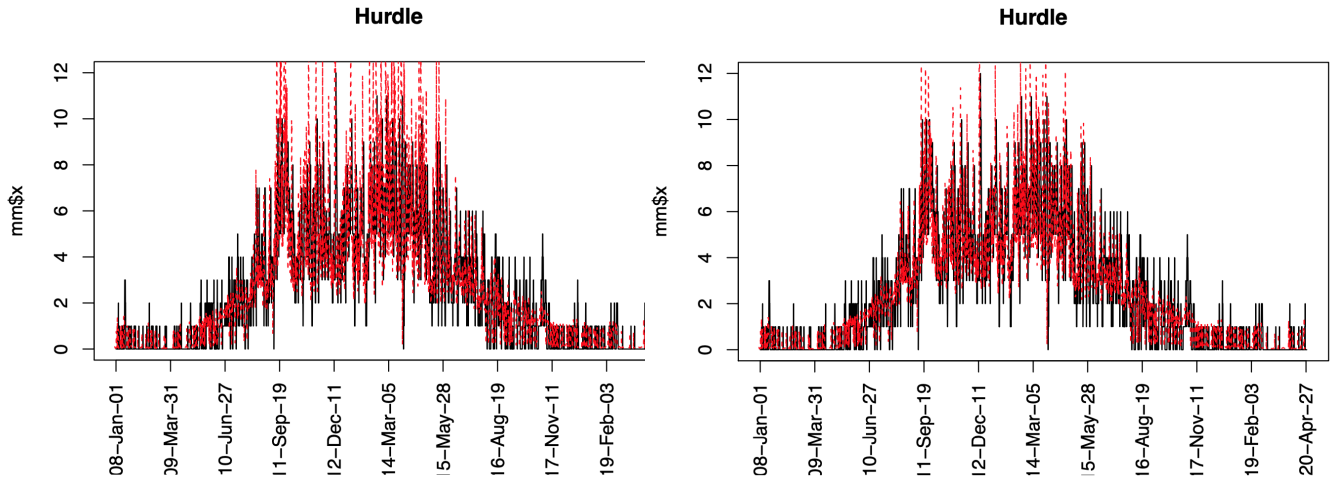

Figure 1: (left) shows geometric distribution for cycle 24, (right) shows a negative binomial distribution for cycle 24. Graphs by Mark Heiple.

The Hurdle model is used when there are zero values in the observational data which may skew the fit from a normal bell curve-like distribution (`https://data.library.virginia.edu/getting-started-with-hurdle-models/`); as the solar cycle somewhat looks like a normal bell curve, it cannot be normal with so many zero sunspot days before and after the cycle (`https://rdrr.io/rforge/countreg/man/hurdle.html`). The red lines are how the geometric and negative binomial distributions try to fit to the AAVSO Wolf numbers from 2008 - 2020 when there may be zero sunspot count days.

The geometric model fills in with higher estimates and does not fit the solar cycle as well as the negative binomial distribution.

2 Sudden Ionospheric Disturbance (SID) Report

2.1 SID Records

May 2020 (Figure 2): There were no SID events recorded here in Fort Collins, Colorado for the month of May, even though on the 29th of May, 11 solar flares were recorded during the night and 4 during day. (Please note the y-axis values in these SID graphs are non-dimensional.)

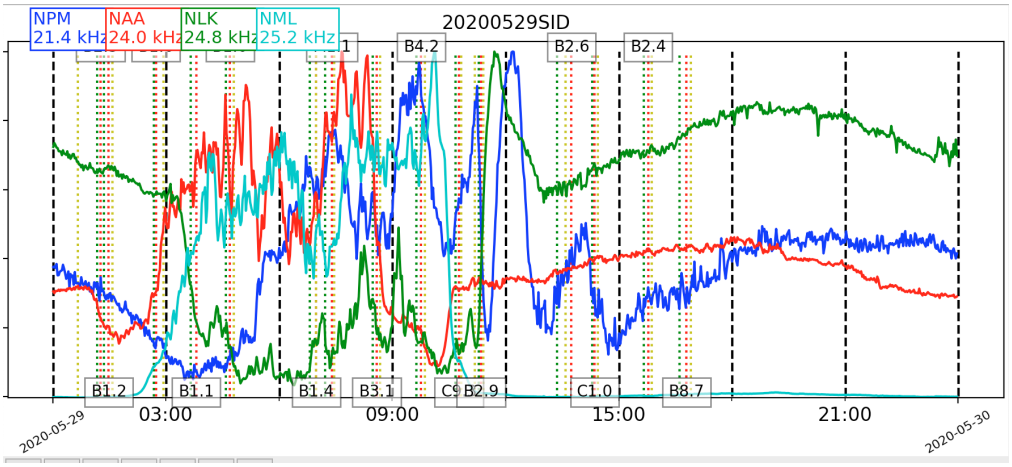

Figure 2: VLF recording at Fort Collins, Colorado.

2.2 SID Observers

In May 2020 we had 15 AAVSO SID observers who submitted VLF data as listed in Table 1. There was one observer (Frank Adamson, A122) in Australia who recorded a SID event this month from NWC, which matched to GOES-16 XRA and FLA events.

Table 1: 202005 VLF Observers

Observer	Code	Stations
R Battaiola	A96	HWU
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
R Russel	A147	NPM
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 May 2020, there were two A-class and 17 B-class, two C-class and one M-class flares recorded from GOES-16. More flaring this month compared to last. There were 25 days this month with no GOES-16 reports of flares (see Figure 4).

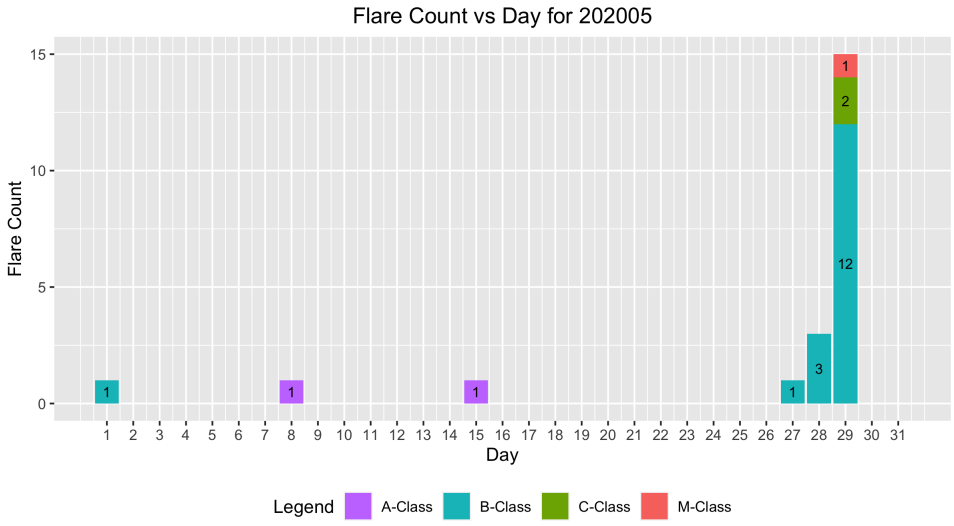

Figure 4: GOES-16 XRA flares

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 May 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.

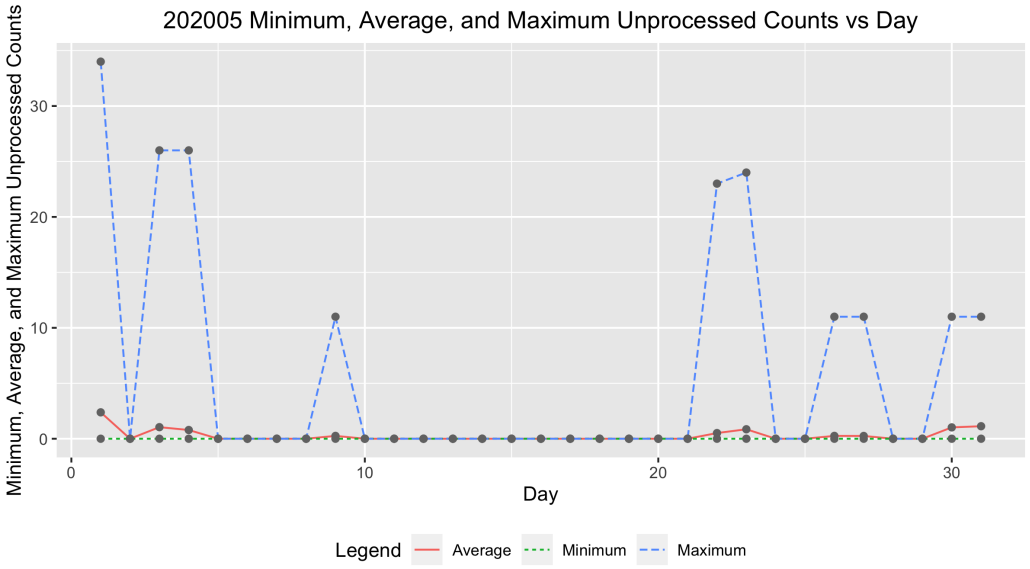

Figure 5: Raw Wolf number average, minimum and maximum by day of the month for all observers.

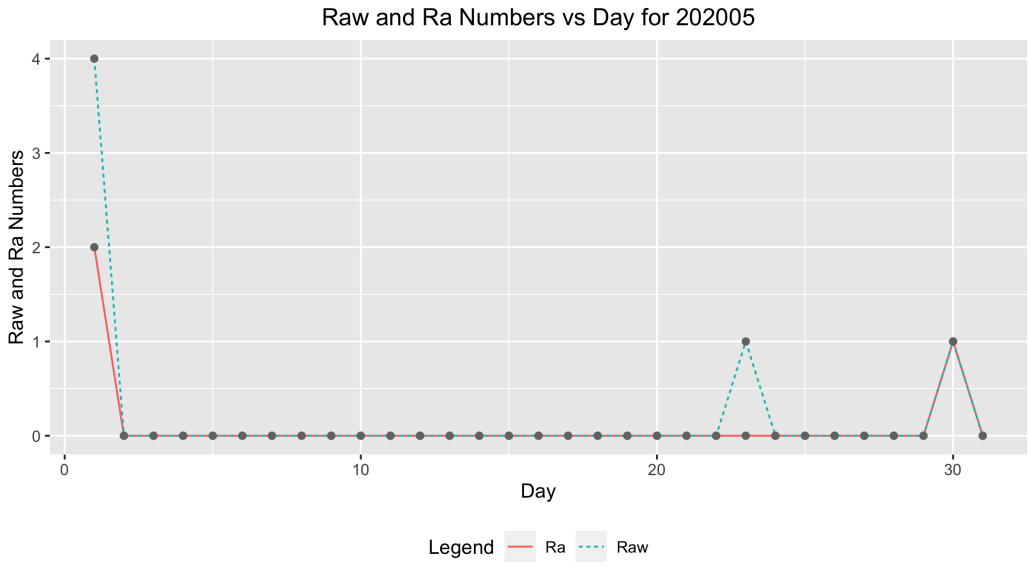

Figure 6: Raw Wolf average and R_a numbers by day of the month for all observers.

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: 202005 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
1	50	4	2
2	48	0	0
3	46	0	0
4	47	0	0
5	46	0	0
6	47	0	0
7	51	0	0
8	48	0	0
9	43	0	0
10	32	0	0
11	39	0	0
12	42	0	0
13	43	0	0
14	41	0	0

Continued

Table 2: 202005 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
15	39	0	0
16	38	0	0
17	43	0	0
18	42	0	0
19	45	0	0
20	46	0	0
21	45	0	0
22	45	0	0
23	41	1	0
24	46	0	0
25	39	0	0
26	43	0	0
27	44	0	0
28	41	0	0
29	45	0	0
30	43	1	1
31	39	0	0
Averages	43.5	0.2	0.1

3.3 Sunspot Observers

Table 3 lists the Observer Code (column 1), the Number of Observations (column 2) submitted for May 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 (65), and the total number of observations submitted (1348).

Table 3: 202005 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
AAX	28	Alexandre Amorim
AJV	26	J. Alonso
ARAG	31	Gema Araujo
ASA	27	Salvador Aguirre
ATE	22	Teofilo Arranz Heras
BARH	15	Howard Barnes
BERJ	26	Jose Alberto Berdejo
BMF	25	Michael Boschat
BRAD	24	David Branchett
BRAF	24	Raffaello Braga
BROB	25	Robert Brown

Continued

Table 3: 202005 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
BSAB	26	Santanu Basu
CHAG	20	German Morales Chavez
CIOA	11	Ioannis Chouinavas
CKB	27	Brian Cudnik
CNT	31	Dean Chantiles
CVJ	13	Jose Carvajal
DEMF	12	Frank Dempsey
DIVA	24	Ivo Demeulenaere
DJOB	20	Jorge del Rosario
DMIB	18	Michel Deconinck
DUBF	30	Franky Dubois
EHOA	19	Howard Eskildsen
ERB	24	Bob Eramia
FERJ	20	Javier Ruiz Fernandez
FLET	27	Tom Fleming
FTAA	10	Tadeusz Figiel
FUJK	19	K. Fujimori
HAYK	22	Kim Hay
HMQ	27	Mark Harris
HOWR	27	Rodney Howe
HRUT	29	Timothy Hrutkay
JDAC	2	David Jackson
JENS	15	Simon Jenner
JGE	9	Gerardo Jimenez Lopez
KADB	2	Andrea de Oliveira Kovacs
KAPJ	11	John Kaplan
KNJS	31	James & Shirley Knight
LEVM	20	Monty Leventhal
LGEC	14	Georgios Lekkas
LKR	2	Kristine Larsen
LRRA	16	Robert Little
MARC	20	Arnaud Mengus
MARE	7	Enrico Mariani
MCE	21	Etsuiku Mochizuki
MILJ	19	Jay Miller
MJAF	31	Juan Antonio Moreno Quesada
MJHA	30	John McCammon
MUDG	15	George Mudry
MWU	28	Walter Maluf
OAAA	23	Al Sadeem Astronomy Observatory
ONJ	31	John O'Neill
SDOH	31	Solar Dynamics Obs - HMI
SNE	16	Neil Simmons

Continued

Table 3: 202005 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
STAB	30	Brian Gordon-States
SUZM	21	Miyoshi Suzuki
SVAE	10	Valery Stanimirov
TESD	30	David Teske
TPJB	7	Patrick Thibault
TST	19	Steven Toothman
URBP	30	Piotr Urbanski
VARG	29	A. Gonzalo Vargas
VIDD	12	Daniel Vidican
WGI	9	Guido Wollenhaupt
WILW	27	William M. Wilson
Totals	1348	65

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.

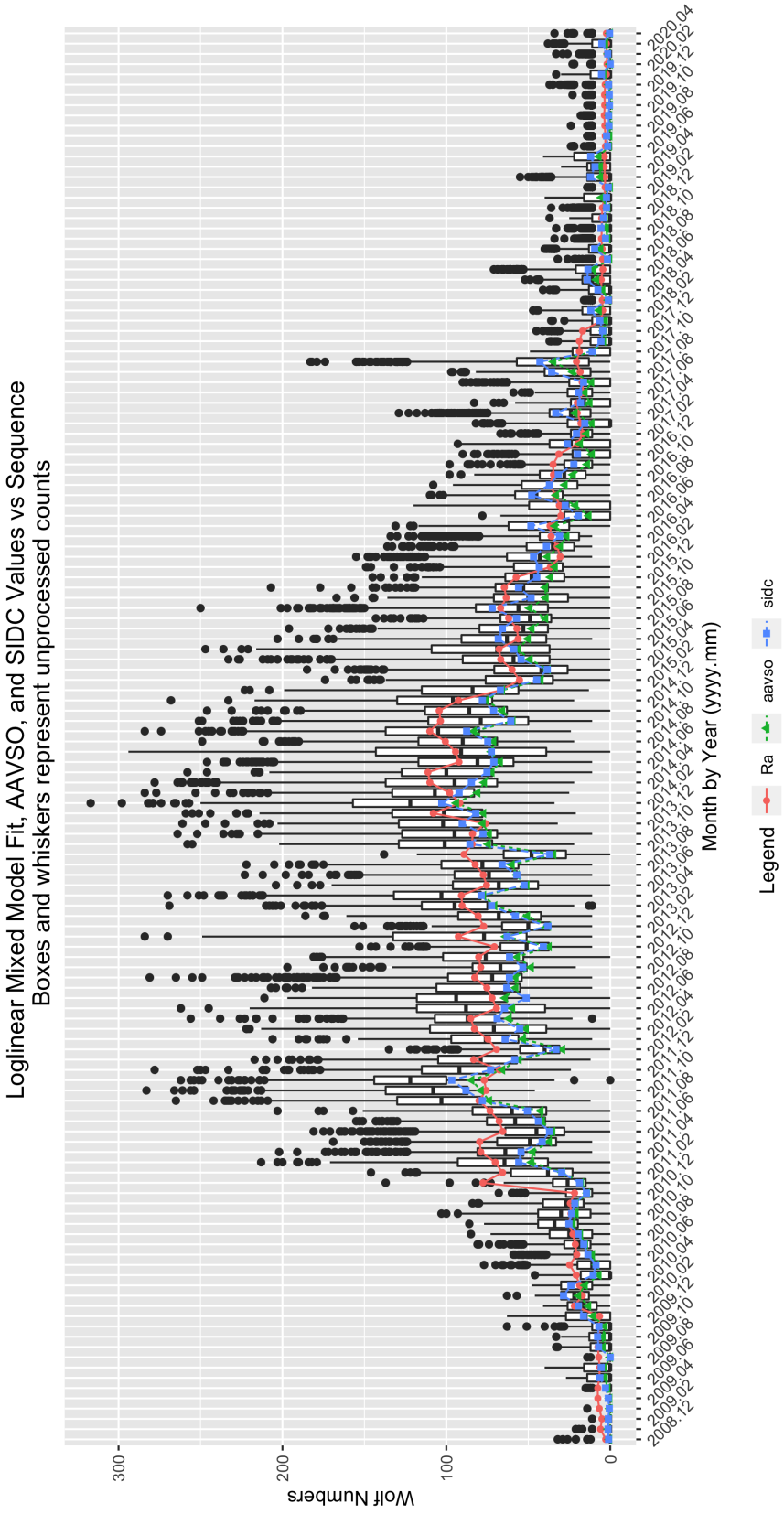

Figure 7: GLMM fitted data for R_a. AAVSO data: https://www.aavso.org/category/tags/solar-bulletin. SILSO data: WDC-SILSO, Royal Observatory of Belgium, Brussels

4 Endnotes

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

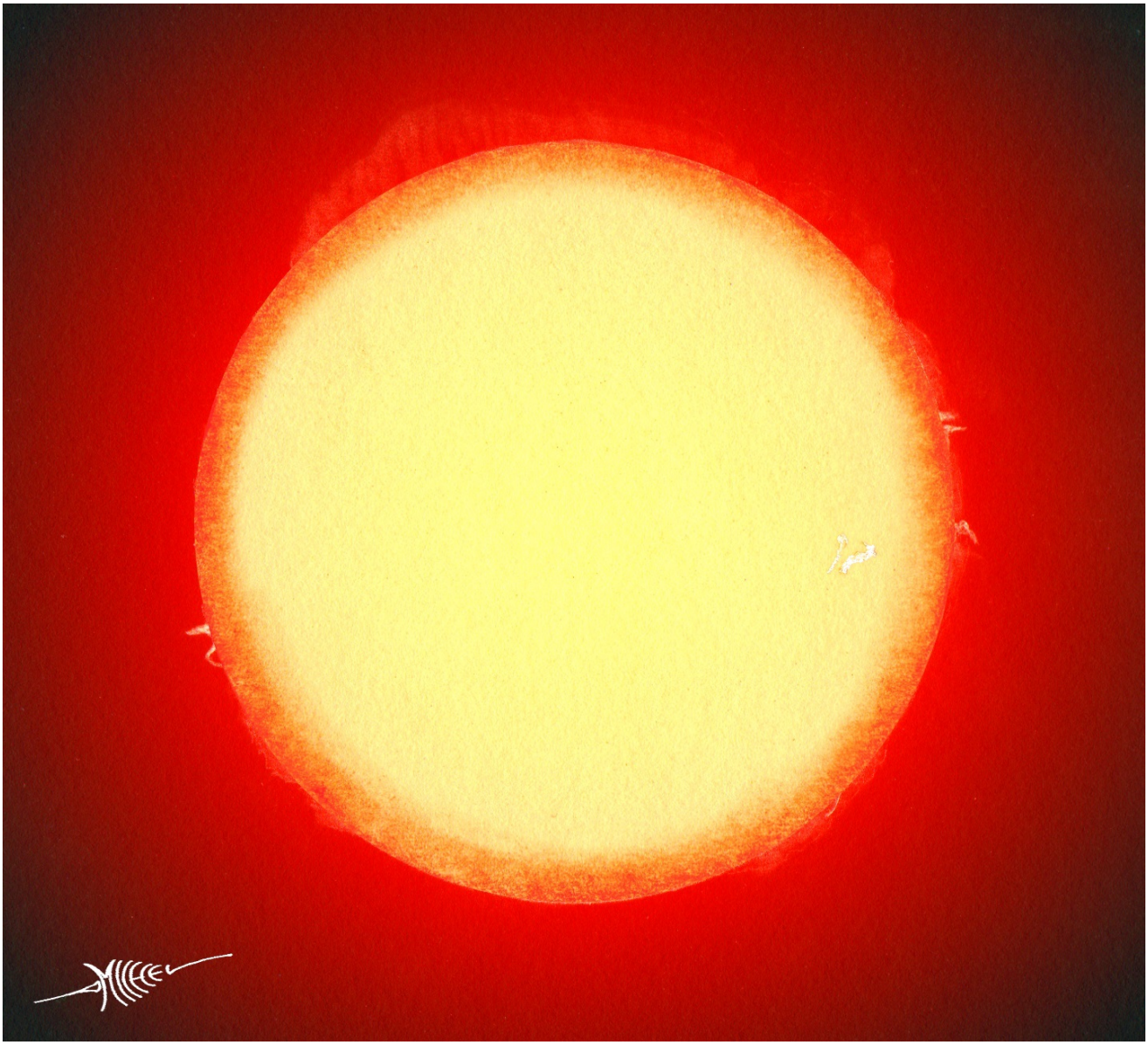

Figure 8: Michel Deconinck put some H-alpha artwork with filaments on the limbs.

May was a strange month of bad weather here, so I didn't make a lot of observations, on top of that, the sun was particularly calm this month. So, if in white light, the sun was spotless, in H alpha, I made colored sketches of pretty proms, see attached

Best

Michel Deconinck. (`https://astro.aquarellia.com`)