Solar Bulletin

THE AMERICAN ASSOCIATION OF VARIABLE STAR OBSERVERS
SOLAR SECTION

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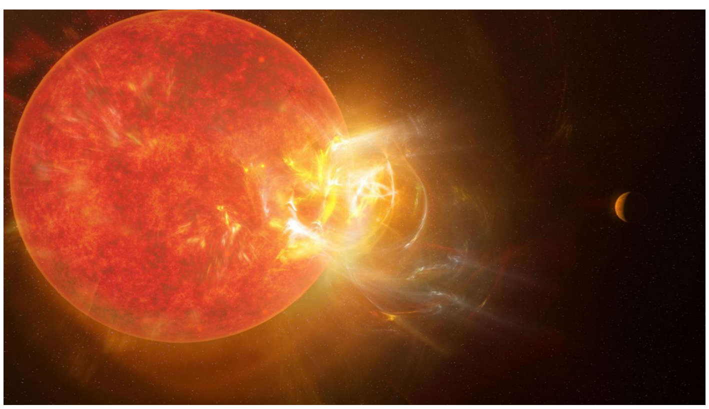
ISSN 0271-8480

Volume 77 Number 4 April 2021

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 Flares on Proxima Centauri are not like Solar flares on our sun



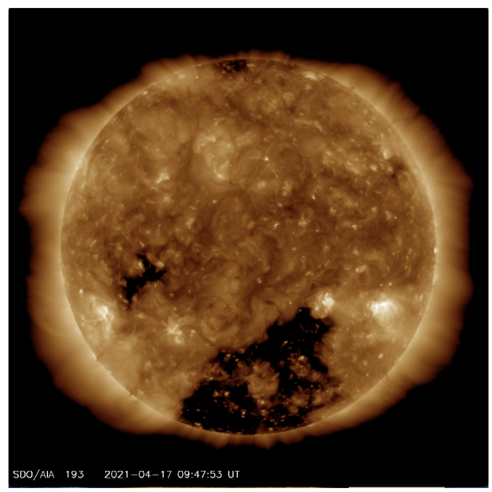


Figure 1: Left panel is a image of Proxima Centauri, right panel is our quiet sun.

A recent flare (huge) from Proxima Centauri: (`https://www.msn.com/en-us/news/technology/proxima-centauri-shoots-out-humongous-flare-with-big-implications-for-alien-life/ar-BB1g25DR`). See a detailed description of Proxima Centauri at: (`https://en.wikipedia.org/wiki/Proxima_Centauri`).

The right panel above, shows the beginning of cycle 25 (of our sun) with a few scattered sunspots from the 19th of April to the 22nd of April, 2021. For a few 'rough' days this April 2021, see Figure 3 of the SID report section, and the End Notes section of this Solar Bulletin. Compare the sun flares to what astronomers think a flare looks like on Proxima Centarui about 4 light years from Earth.

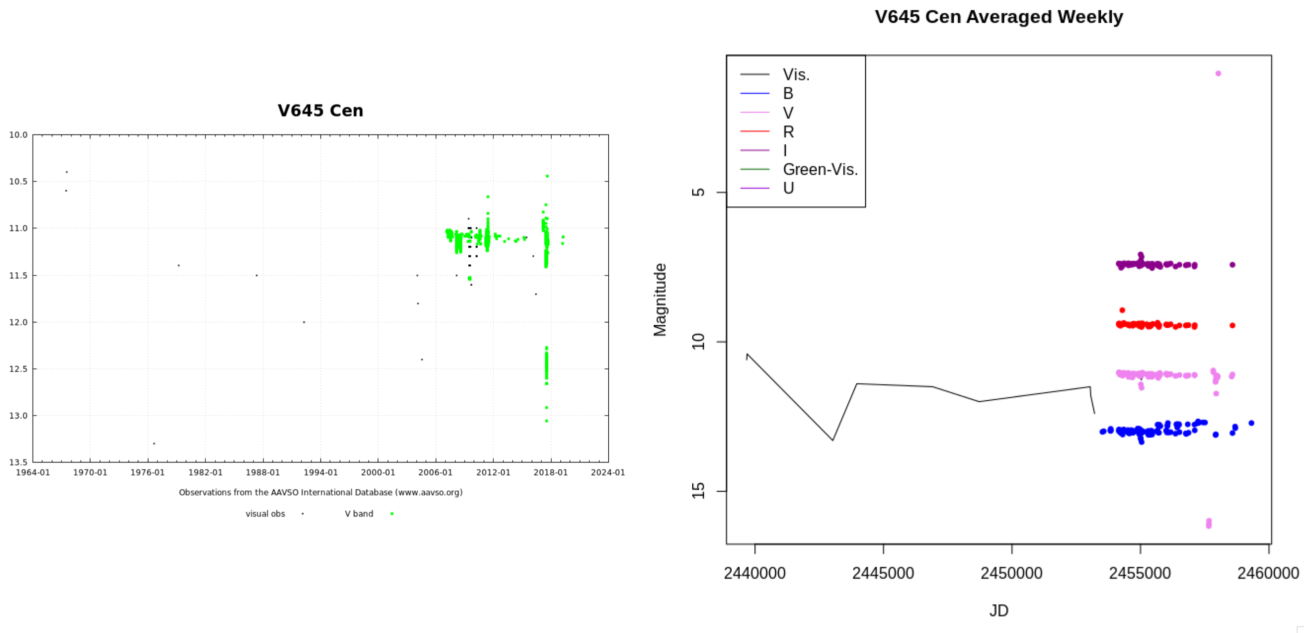


Figure 2: (left) shows AAVSO visual and V filter data for Proxima Centauri (V645 Cen) from 1964, (right) shows Proxima Centauri weekly visual light curve data from 1964 and then photometry observations from 2006 to present.

The AAVSO visual and photometric data for Proxima Centauri (V645 Cen) are pretty sparse until around 2006 when more observations were taken with photometric filters. This star is faint, around 12 magnitude in the visual and V band, but looks to be quite bright in the red and infra-red as it is a cool M type star. (`http://simbad.u-strasbg.fr/simbad/sim-basic?Ident=V645+Cen&submit=SIMBAD+search`)

AAVSO light curve data were pulled with the Perl program LCplot.pl version 1.3 written by Hernan De Angelis. (`https://figshare.com/articles/code/LCplot_-_a_program_to_plot_light_curves_of_variable_stars/6964760`). The weekly average light curve data come from R programs written by Mark Heiple.

2 Sudden Ionospheric Disturbance (SID) Report

2.1 SID Records

April 2021 (Figure 3): Roberto Battaiola recorded 5 C-class flares on the 22nd.

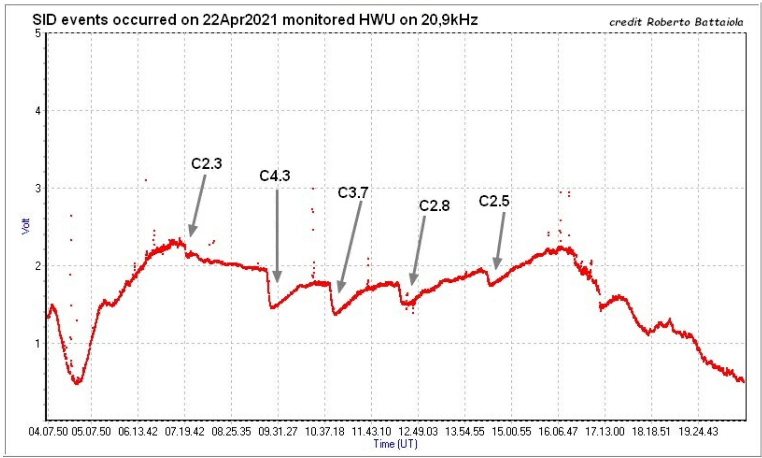


Figure 3: VLF recording from Milan, Italy

2.2 SID Observers

In April 2021 we had 16 AAVSO SID observers who submitted VLF data as listed in Table 1.

Table 1: 202104 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
J Karlovsky	A131	NSY ICV
R Green	A134	NWC
S Aguirre	A138	NPM
R Rogge	A143	GQD
K Menzies	A146	NAA
R Russel	A147	NPM
L Pina	A148	NML
L Ferreira	A149	NWC
J Wendler	A150	NAA
H Krumnow	A152	HWU GQD DHO

Figure 4 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.

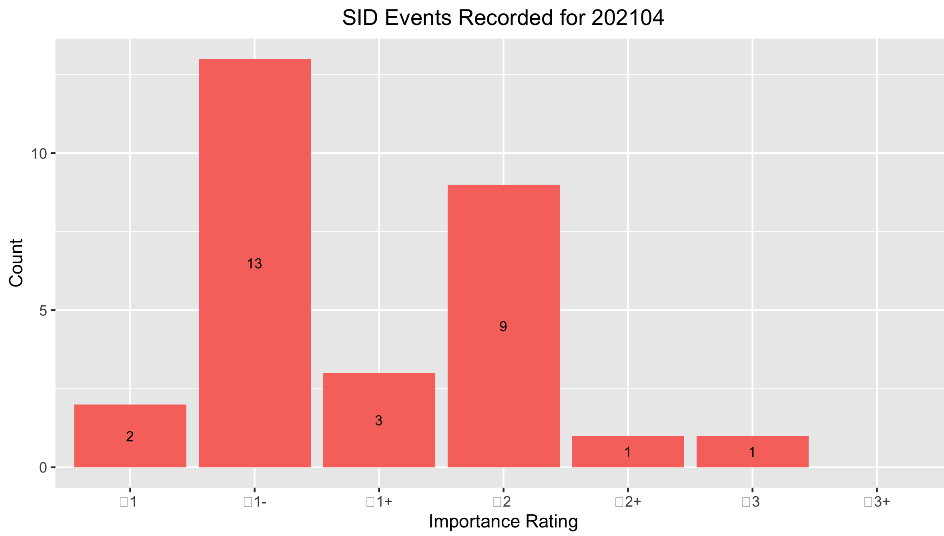


Figure 4: VLF SID Events.

2.3 Solar Flare Summary from GOES-16 Data

In April 2021, there were 184 GOES XRA flares, 162 B-Class, 21 C-Class and one M-Class flare. Far more flaring this month compared to last, with 11 days of no flares. (see Figure 5).

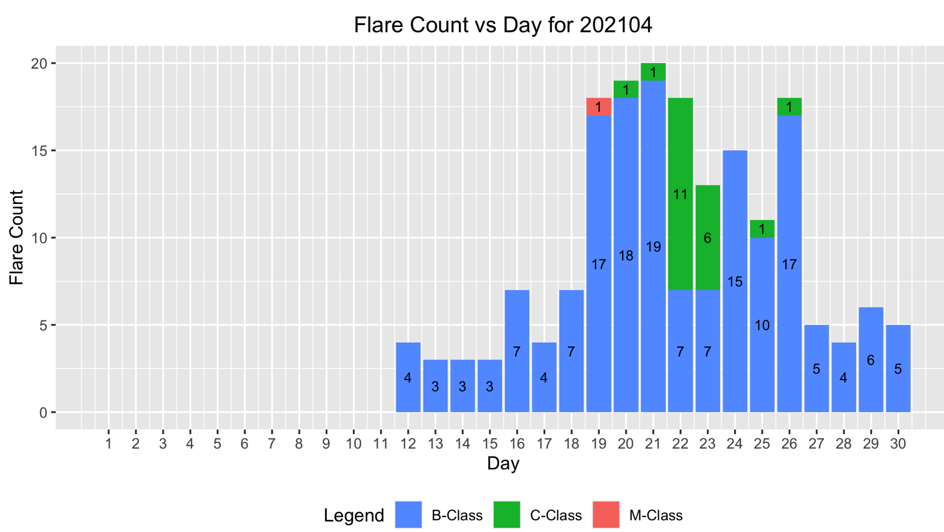


Figure 5: GOES-16 XRA flares

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 a Structured Query Language (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 2021. 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 6.

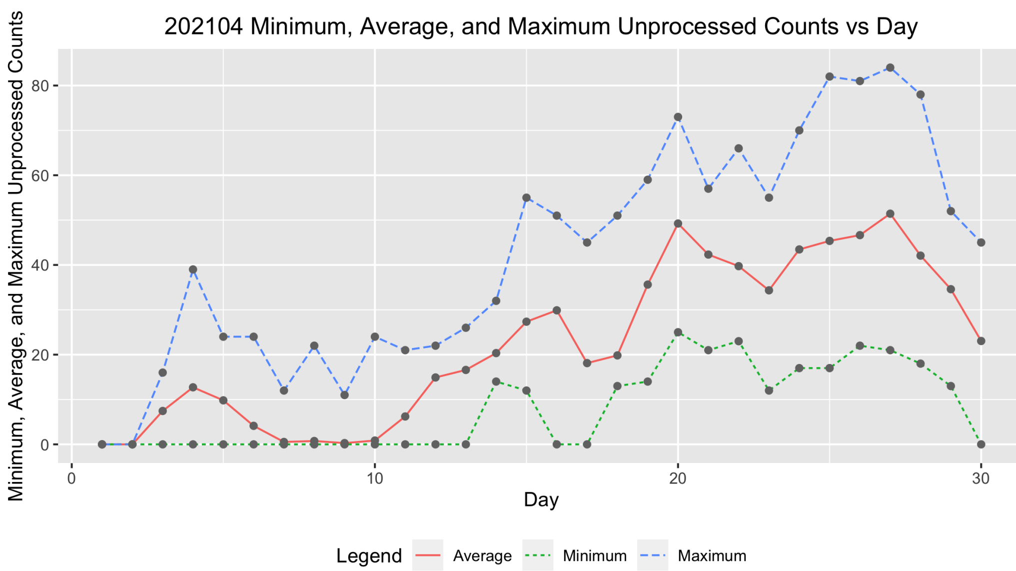


Figure 6: Raw Wolf number average, minimum and maximum by day of the month for all observers.

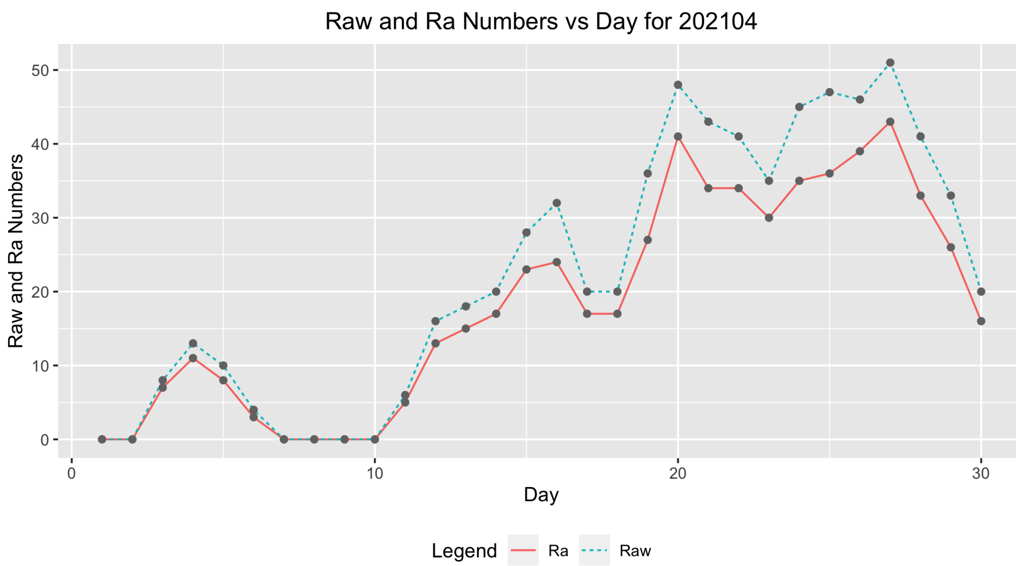


Figure 7: Raw Wolf average and R_a numbers by day of the month for all observers.

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 7, 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: 202104 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
1	47	0	0
2	50	0	0
3	43	8	7
4	50	13	11
5	43	10	8
6	46	4	3
7	43	0	0
8	44	0	0
9	39	0	0
10	41	0	0
11	37	6	5
12	46	16	13
13	49	18	15
14	40	20	17

Continued

Table 2: 202104 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
15	40	28	23
16	35	32	24
17	44	20	17
18	48	20	17
19	45	36	27
20	46	48	41
21	48	43	34
22	52	41	34
23	50	35	30
24	48	45	35
25	47	47	36
26	51	46	39
27	44	51	43
28	38	41	33
29	37	33	26
30	44	20	16
Averages	44.5	22.7	18.5

3.3 Sunspot Observers

Table 3 lists the Observer Code (column 1), the Number of Observations (column 2) submitted for April 2021, and the Observer Name (column 3). The final row gives the total number of observers who submitted sunspot counts (71), and total number of observations submitted (1349).

Table 3: 202104 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
AAX	26	Alexandre Amorim
AJV	5	J. Alonso
ARAG	30	Gema Araujo
ASA	24	Salvador Aguirre
ATE	25	Teofilo Arranz Heras
BARH	15	Howard Barnes
BATR	11	Roberto Battaiola
BERJ	23	Jose Alberto Berdejo
BLAJ	5	John A. Blackwell
BMF	20	Michael Boschat
BRAF	17	Raffaello Braga
BROB	29	Robert Brown
CHAG	27	German Morales Chavez
CKB	19	Brian Cudnik

Continued

Table 3: 202104 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
CMOD	6	Mois Carlo
CNT	29	Dean Chantiles
CVJ	4	Jose Carvajal
DARB	11	Aritra Das
DEMF	15	Frank Dempsey
DJOB	16	Jorge del Rosario
DMIB	22	Michel Deconinck
DROB	1	Bob Dudley
DUBF	28	Franky Dubois
EHOA	21	Howard Eskildsen
ERB	23	Bob Eramia
FDAE	11	David Fox
FERJ	17	Javier Ruiz Fernandez
FLET	20	Tom Fleming
GIGA	27	Igor Grageda Mendez
HALB	10	Brian Halls
HAYK	16	Kim Hay
HMQ	22	Mark Harris
HOWR	19	Rodney Howe
IEWA	19	Ernest W. Iverson
JDAC	12	David Jackson
JENJ	16	Jamey Jenkins
JENS	11	Simon Jenner
JGE	2	Gerardo Jimenez Lopez
KAND	16	Kandilli Observatory
KAPJ	17	John Kaplan
KNJS	30	James & Shirley Knight
LEVM	27	Monty Leventhal
LGEC	6	Georgios Lekkas
LKR	9	Kristine Larsen
LRRA	24	Robert Little
MARC	16	Arnaud Mengus
MCE	25	Etsuiku Mochizuki
MILJ	13	Jay Miller
MJAF	28	Juan Antonio Moreno Quesada
MJHA	27	John McCammon
MMAY	30	Max Surlaroute
MMI	30	Michael Moeller
MUDG	7	George Mudry
MWU	27	Walter Maluf
OAAA	19	Al Sadeem Astronomy Obs.
ONJ	19	John O'Neill
PEKT	8	Riza Pektas

Continued

Table 3: 202104 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
RFDA	25	Filipp Romanov
SDOH	30	Solar Dynamics Obs - HMI
SNE	8	Neil Simmons
SONA	20	Andries Son
SQN	24	Lance Shaw
STAB	29	Brian Gordon-States
SUZM	24	Miyoshi Suzuki
TESD	26	David Teske
TST	20	Steven Toothman
URBP	27	Piotr Urbanski
VARG	30	A. Gonzalo Vargas
VIDD	10	Dan Vidican
WGI	8	Guido Wollenhaupt
WILW	22	William M. Wilson
Totals	1349	71

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. For more details, *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 8 shows the monthly GLMM R_a numbers for a rolling eleven-year (132-month) window beginning within the 24th solar cycle and ending with last month's sunspot numbers. 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 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 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.

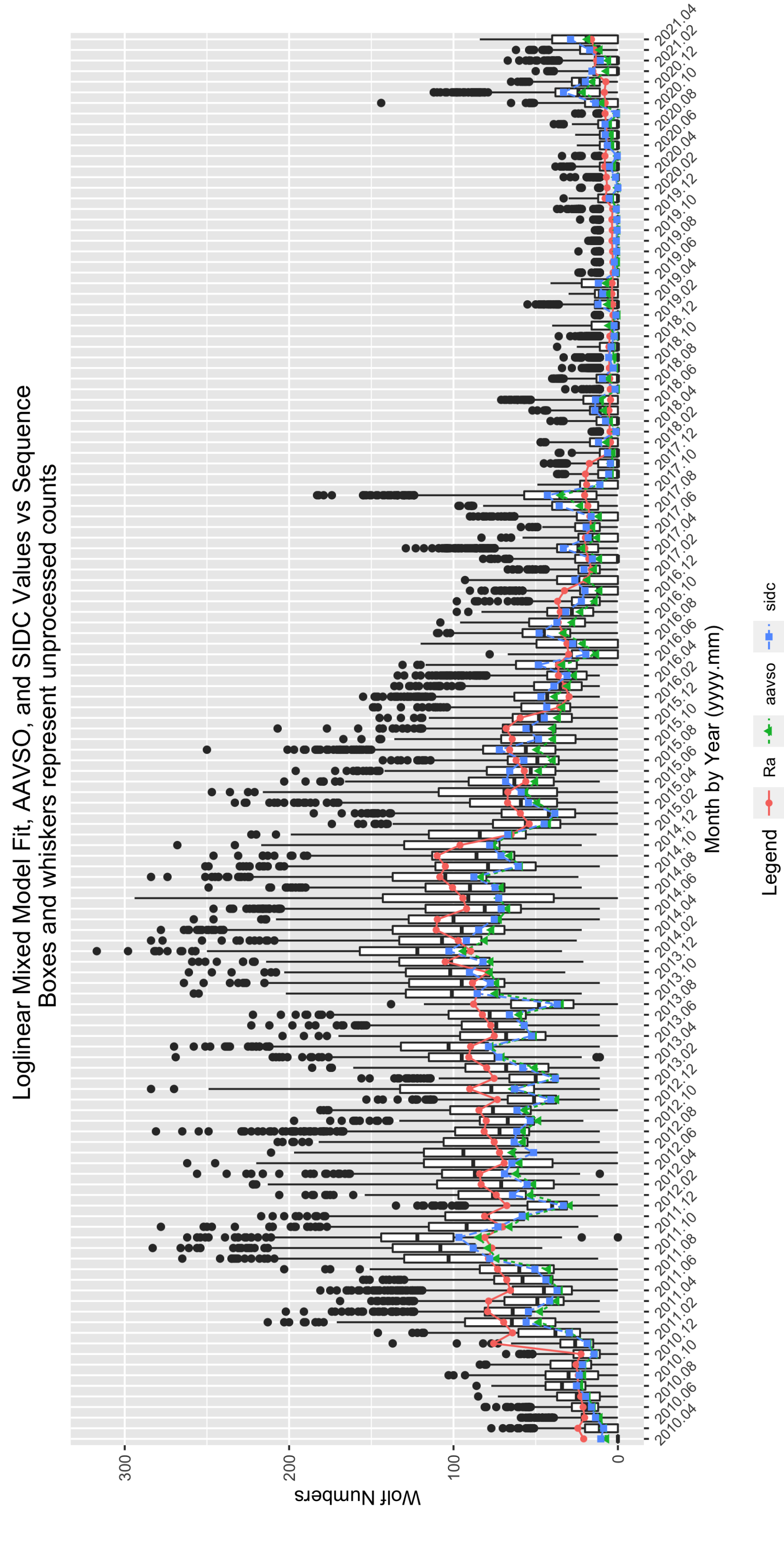


Figure 8: GLMM fitted data for R_a. AAVSO data: https://www.aavso.org/category/tags/solar-bulletin. SIDC data: WDC-SILSO, Royal Observatory of Belgium, Brussels

4 Endnotes

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

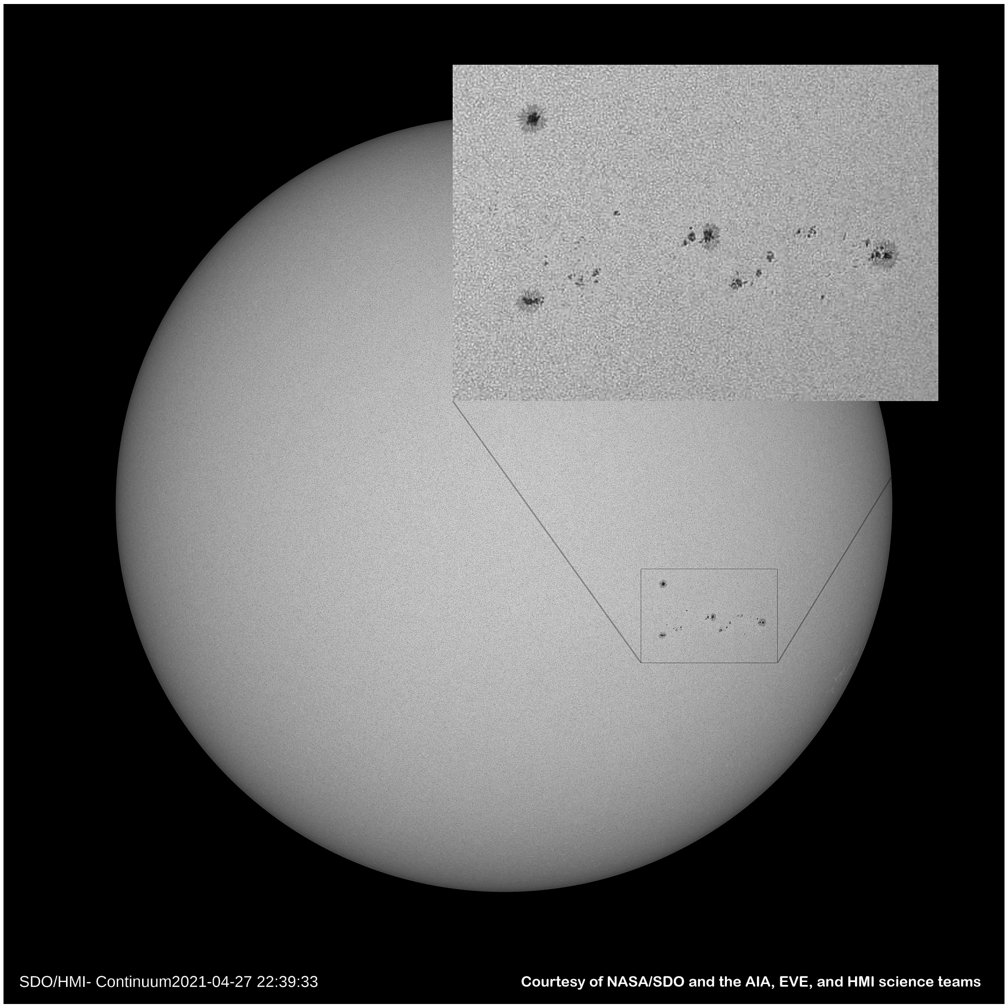


Figure 9: Here's an example of a large extended group of sunspots that could easily be divided into more than one group! This is a montage of a highlight from the 27th of April from an image of SDO (Solar Dynamics Observatory) satellite. (`https://sdo.gsfc.nasa.gov/data/`).
Thanks to Max Surlaroute (MMAY)