Solar Bulletin

THE AMERICAN ASSOCIATION OF VARIABLE STAR OBSERVERS
SOLAR SECTION

Rodney Howe, Kristine Larsen, Co-Chairs
c/o AAVSO, 185 Alewife Brook Parkway,
Cambridge, MA 02138 USA

Web: http://www.aavso.org/solar-bulletin
Email: solar@aavso.org
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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 Very Low Frequency (VLF) radio recordings of SID Events in the ionosphere. The sudden ionospheric disturbance report is in Section 2. The relative sunspot numbers are in Section 3. Section 4 has endnotes.

1 Kepler star KIC10414643 and 100 days of AAVSO solar data

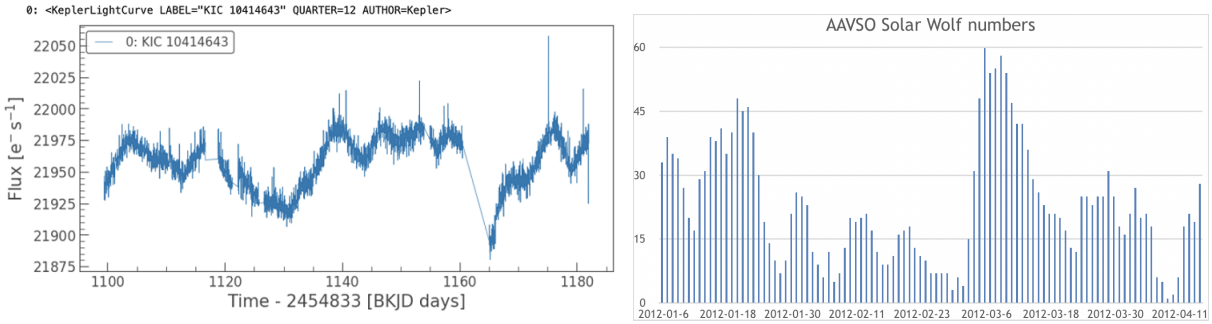

Figure 1: Kepler data (Kluyver et al. 2016; Saunders, 2020), compared to AAVSO Solar data for the same 100 day time series during solar cycle 24.

KIC10414643 is a star with a similar rotation period to the Sun. Kepler recorded data on this star from 2009 to 2012. In solar cycle 24 (December 2008 through 2019), there is a 100-day period of KIC10414643 (Zhang et. al, 2020) that matches the same 100 days of AAVSO Wolf numbers on our Sun.

2 Sudden Ionospheric Disturbance (SID) Report

2.1 SID Records

February 2023 (Figure 2): on the 17th, there was a long-term, 3-hour X2.2 flare recorded by Nathan Towne in Magdalena, New Mexico.

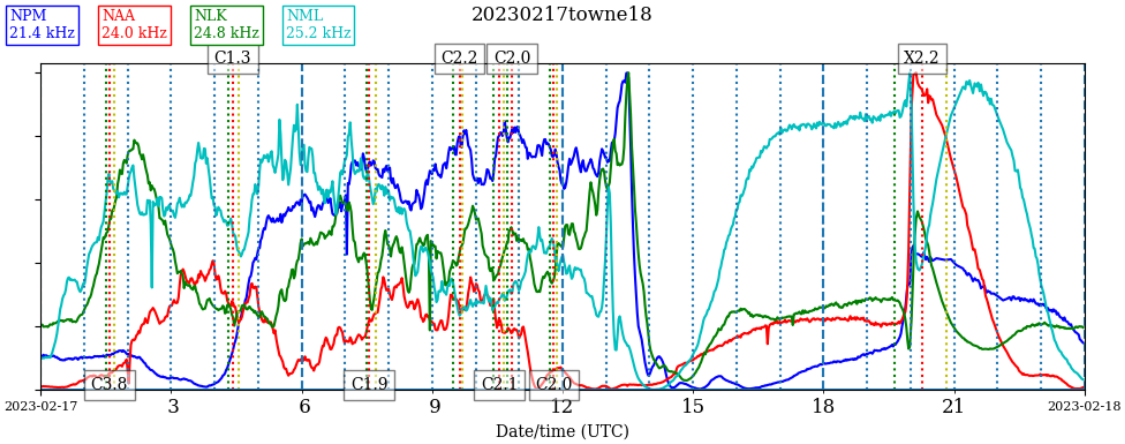

Figure 2: VLF recording from Magdalena, New Mexico.

2.2 SID Observers

In February 2023, 14 AAVSO SID observers submitted VLF data as listed in Table 1.

Table 1: 202302 VLF Observers

Observer	Code	Stations
R Battaiola	A96	HWU
J Wallace	A97	NAA
L Loudet	A118	DHO
J Godet	A119	GBZ GQD ICV
F Adamson	A122	NWC
J Karlovsky	A131	DHO NAA TBB
R Mrllak	A136	GQD NSY
S Aguirre	A138	NPM NAA
G Silvis	A141	NAA NML NLK
K Menzies	A146	NAA
L Pina	A148	NAA NLK NML
J Wendler	A150	NAA
H Krumnow	A152	FTA GBZ HWU
J DeVries	A153	NLK
R Mazur	A155	NLK NML

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.

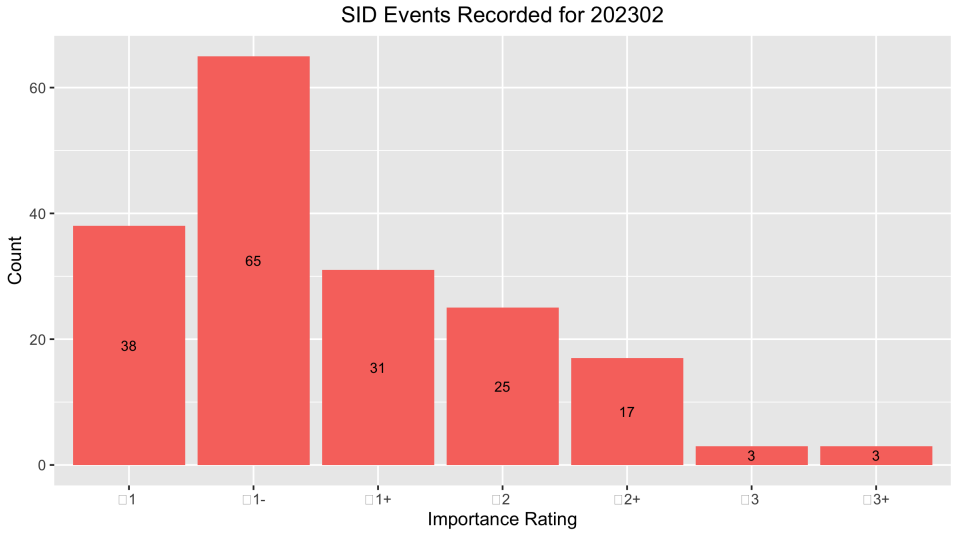

Figure 3: VLF SID Events.

2.3 Solar Flare Summary from GOES-16 Data

In February 2023, there were 261 GOES-16 XRA flares. Two X-class, 49 M-class, 207 C-class and 3 B-class flares. More flaring this month compared to last (Figure 4).

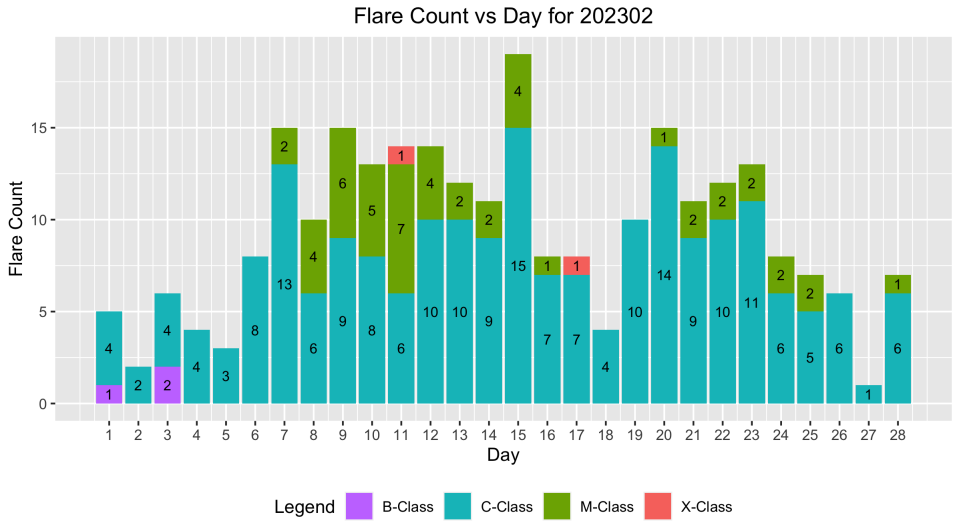

Figure 4: GOES-16 XRA flares

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 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 February 2023. 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.

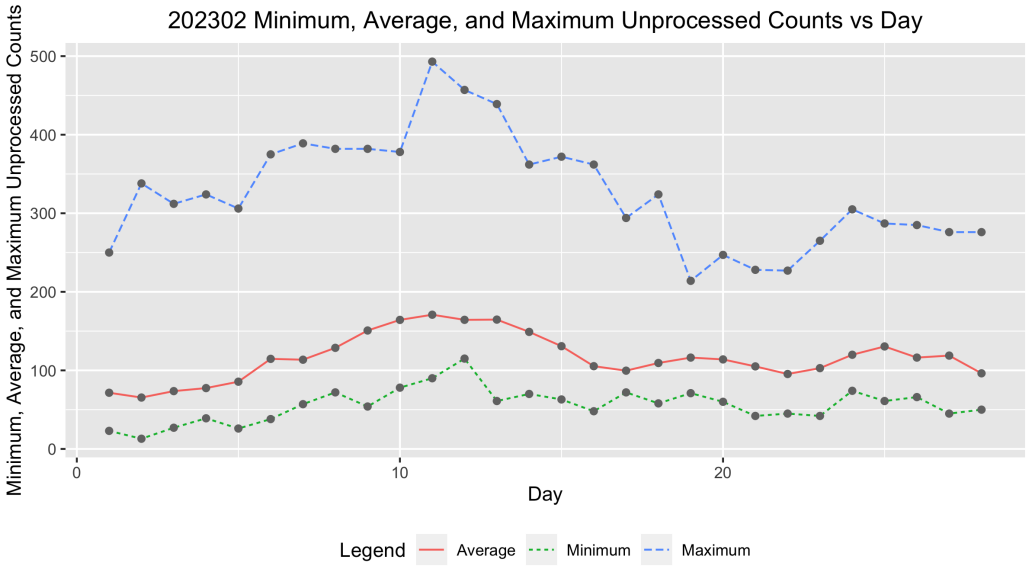

Figure 5: Raw Wolf number average, minimum, and maximum by day of the month for all observers.

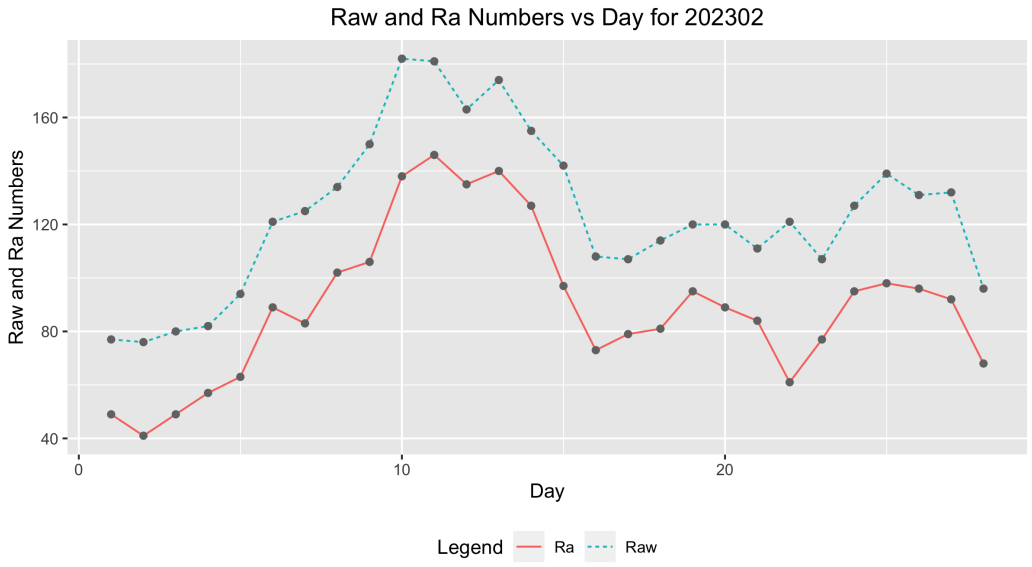

Figure 6: Raw Wolf average and R_a numbers by day of the month for all observers.

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: 202302 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
1	32	77	49
2	28	76	41
3	31	80	49
4	32	82	57
5	32	94	63
6	33	121	89
7	29	125	83
8	35	134	102
9	25	150	106
10	38	182	138
11	42	181	146
12	38	163	135
13	41	174	140
14	41	155	127

Continued

Table 2: 202302 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
15	30	142	97
16	28	108	73
17	33	107	79
18	37	114	81
19	35	120	95
20	28	120	89
21	29	111	84
22	21	121	61
23	20	107	77
24	29	127	95
25	26	139	98
26	28	131	96
27	28	132	92
28	27	96	68
Averages	31.3	123.9	89.6

3.3 Sunspot Observers

Table 3 lists the Observer Code (column 1), the Number of Observations (column 2) submitted for February 2023, and the Observer Name (column 3). The final row gives the total number of observers who submitted sunspot counts (63), and total number of observations submitted (876).

Table 3: 202302 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
AAX	23	Alexandre Amorim
AJV	16	J. Alonso
ARAG	28	Gema Araujo
ASA	13	Salvador Aguirre
ATE	23	Teofilo Arranz Heras
BATR	9	Roberto Battaiola
BMF	15	Michael Boschat
BMIG	23	Michel Besson
BROB	19	Robert Brown
BXZ	19	Jose Alberto Berdejo
BZX	18	A. Gonzalo Vargas
CKB	22	Brian Cudnik
CMAB	15	Maurizio Cervoni
CNT	24	Dean Chantiles
CVJ	3	Jose Carvajal
DARB	14	Aritra Das

Continued

Table 3: 202302 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
DELS	9	Susan Delaney
DFR	6	Frank Dempsey
DJOB	7	Jorge del Rosario
DJSA	9	Jeff DeVries
DMIB	21	Michel Deconinck
DUBF	20	Franky Dubois
EGMA	5	Georgios Epitropou
EHOA	17	Howard Eskildsen
ERB	10	Bob Eramia
FERA	7	Eric Fabrigat
FLET	18	Tom Fleming
GIGA	22	Igor Grageda Mendez
HALB	7	Brian Halls
HKY	15	Kim Hay
HOWR	20	Rodney Howe
IEWA	15	Ernest W. Iverson
ILUB	5	Luigi Iapichino
JSI	6	Simon Jenner
KAND	16	Kandilli Observatory
KAPJ	8	John Kaplan
KNJS	27	James & Shirley Knight
LKR	4	Kristine Larsen
LRRA	17	Robert Little
MARC	6	Arnaud Mengus
MARE	12	Enrico Mariani
MCE	22	Etsuiku Mochizuki
MJHA	26	John McCammon
MLL	4	Jay Miller
MMI	28	Michael Moeller
MSS	9	Sandy Mesics
MUDG	5	George Mudry
MWU	5	Walter Maluf
OAAA	6	Al Sadeem Astronomy Obs.
ONJ	9	John O'Neill
PLUD	14	Ludovic Perbet
RJV	19	Javier Ruiz Fernandez
SDOH	28	Solar Dynamics Obs - HMI
SNE	2	Neil Simmons
SQN	1	Lance Shaw
SRIE	17	Rick St. Hilaire
TDE	21	David Teske
TNIA	7	Nick Tonkin
TPJB	4	Patrick Thibault

Continued

Table 3: 202302 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
TST	21	Steven Toothman
URBP	13	Piotr Urbanski
VIDD	9	Dan Vidican
WWM	13	William M. Wilson
Totals	876	63

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 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 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.

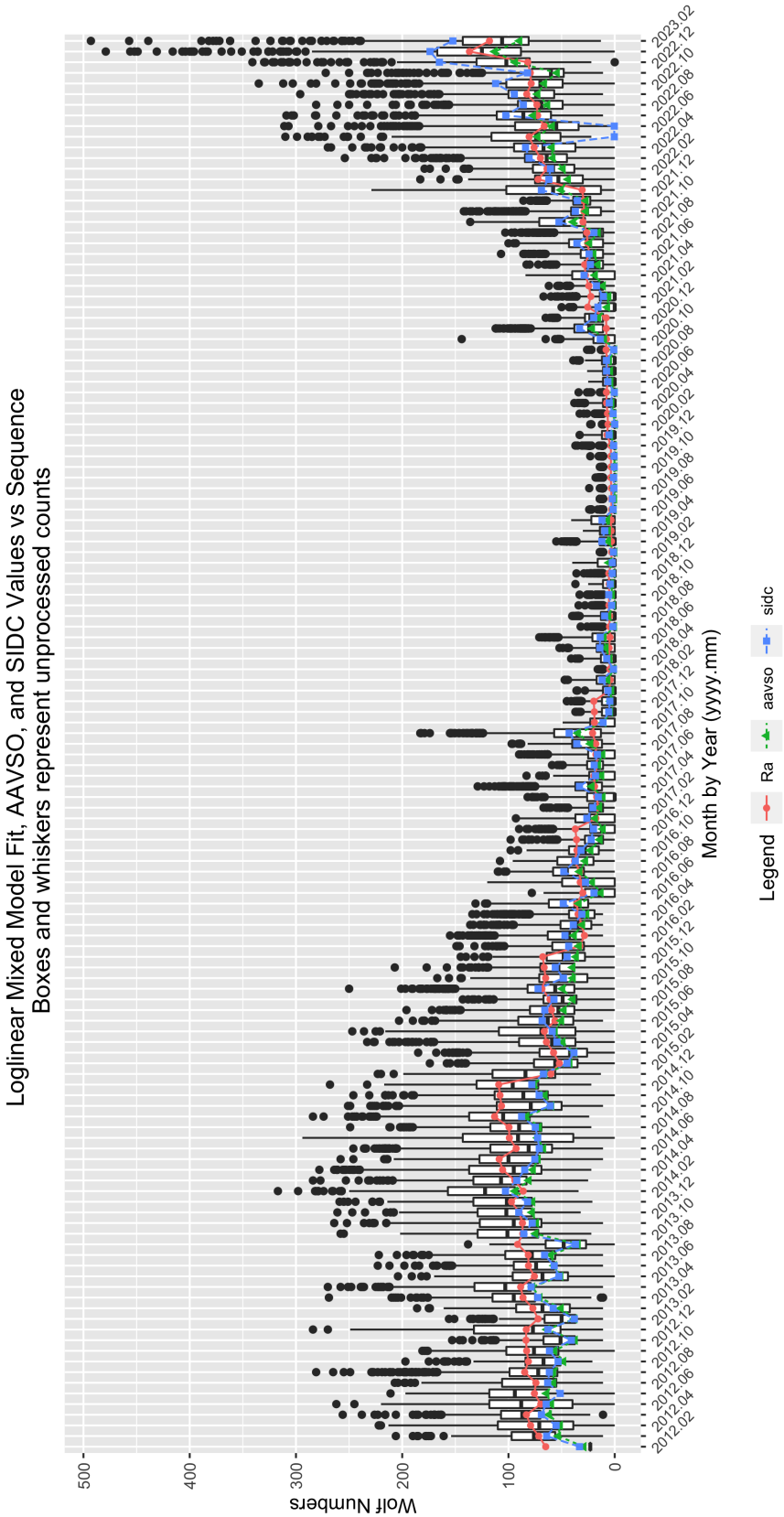

Figure 7: GLMM fitted data for R_a. AAVSO data: https://www.aavso.org/category/tags/solar-bulletin. SIDC data: WDC-SILSO, Royal Observatory of Belgium, Brussels

4 Endnotes

- Sunspot Reports: Kim Hay solar@aavso.org
- SID Solar Flare Reports: Rodney Howe rhowe137@icloud.com

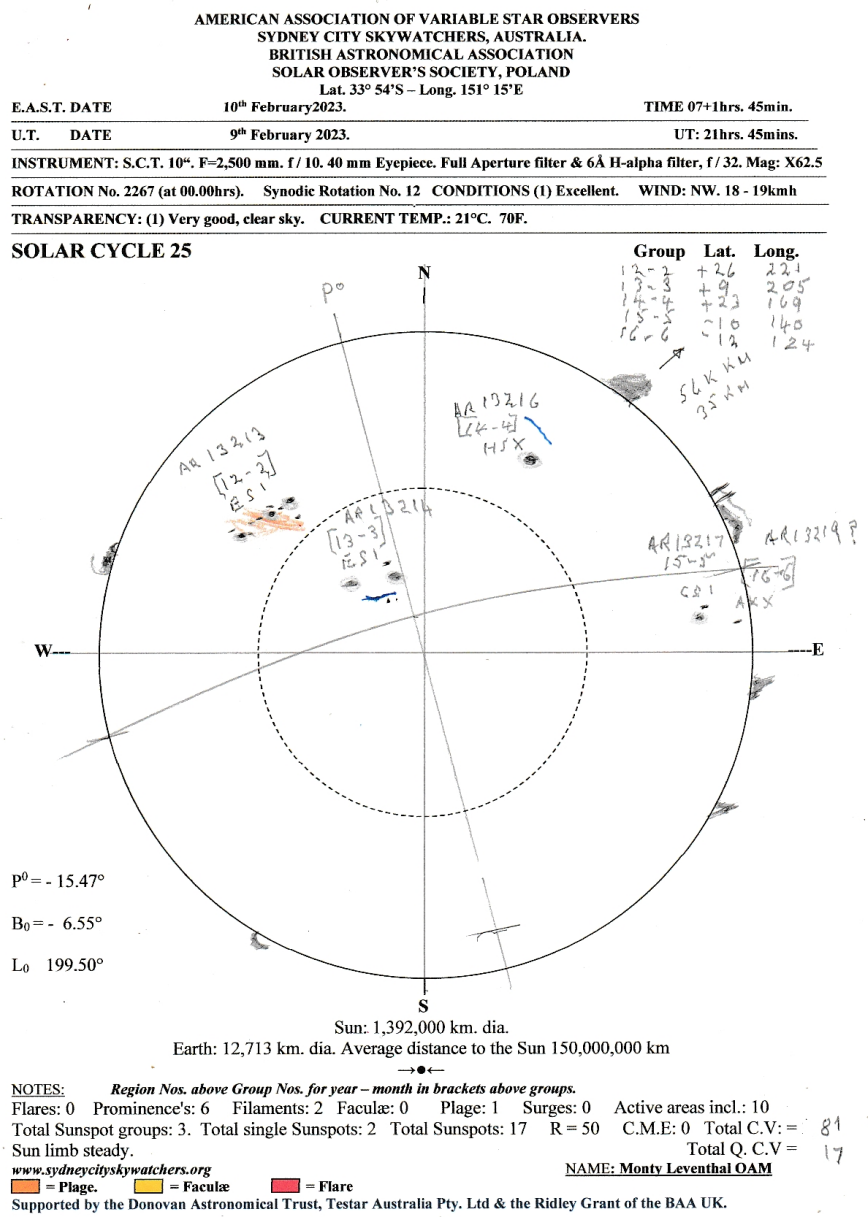

Figure 8: from Monty Leventhal (OAM).

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