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 New year 2021 and a new observer from December 2020

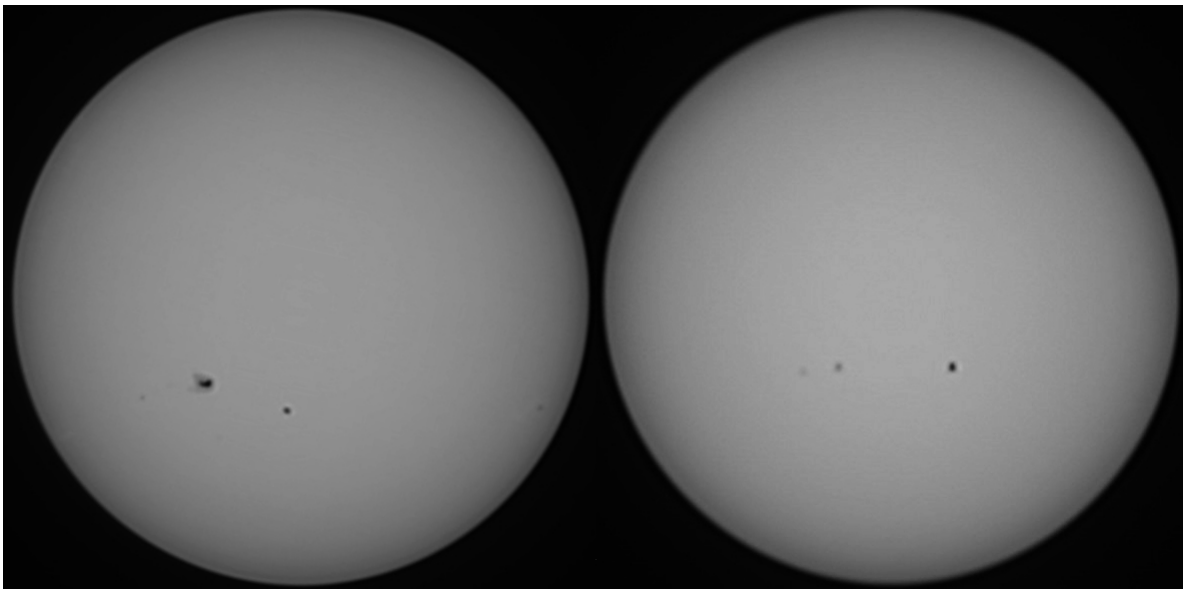

Figure 1: Images from new AAVSO observer Filipp Romanov (RFDA) who used a small 60/700-mm refractor with a self-made solar filter made from Baader AstroSolar film.

Filipp writes, "from Yuzhno-Morskoy - near Nakhodka, Primorsky Krai, Russia: Here is a comparison of photos of the same large sunspot AR 2786/AR 2794 visible to the naked eye on November 28 and December 28, 2020. I made a 640x480 video around 03:30 UT on these dates with my Canon EOS 60D camera, on a tripod, with a 135mm lens and with Baader AstroSolar film, and then stacked it into Registax 5.1. This spot was easily visible with the naked eye through a solar film." (`https://www.solarham.net/regions/2794/index.htm`).

2 Sudden Ionospheric Disturbance (SID) Report

2.1 SID Records

December 2020 (Figure 2): Although there were C-Class flares on the 5th of December none were strong enough to show a SID Event.)

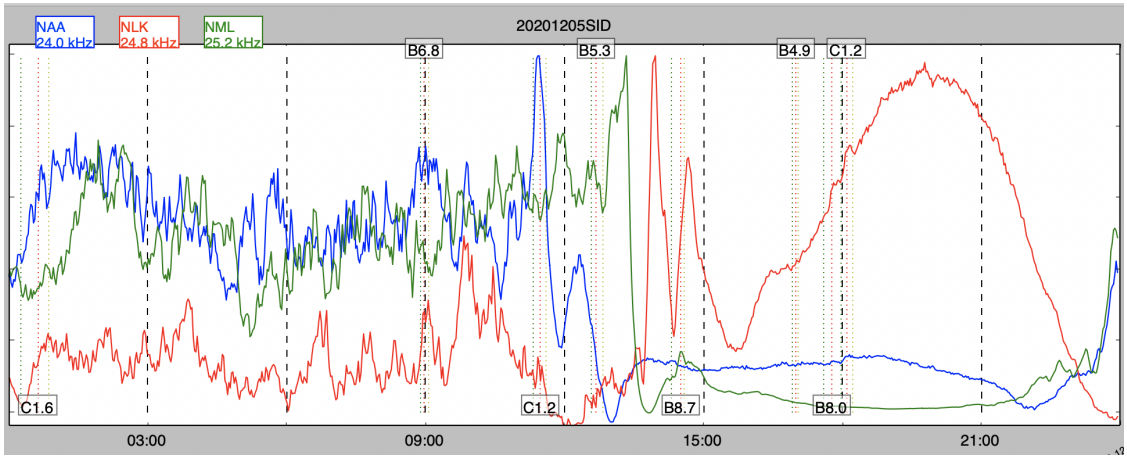

Figure 2: VLF recording from Fort Collins, Colorado.

2.2 SID Observers

In December 2020 we had 15 AAVSO SID observers who submitted VLF data as listed in Table 1.

Table 1: 202012 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
G Silvis	A141	NAA NML
R Rogge	A143	GQD
K Menzies	A146	NAA
L Pina	A148	NML
L Ferreira	A149	NWC
H Krumnow	A152	HWU GQD DHO

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 December 2020, there were 125 XRA flares detected from the GOES 16 satellite: 113 B-Class and 12 C-Class flares. About half the flaring this month compared to last. There were 3 days this month with no GOES-16 reports of flares (see Figure 4).

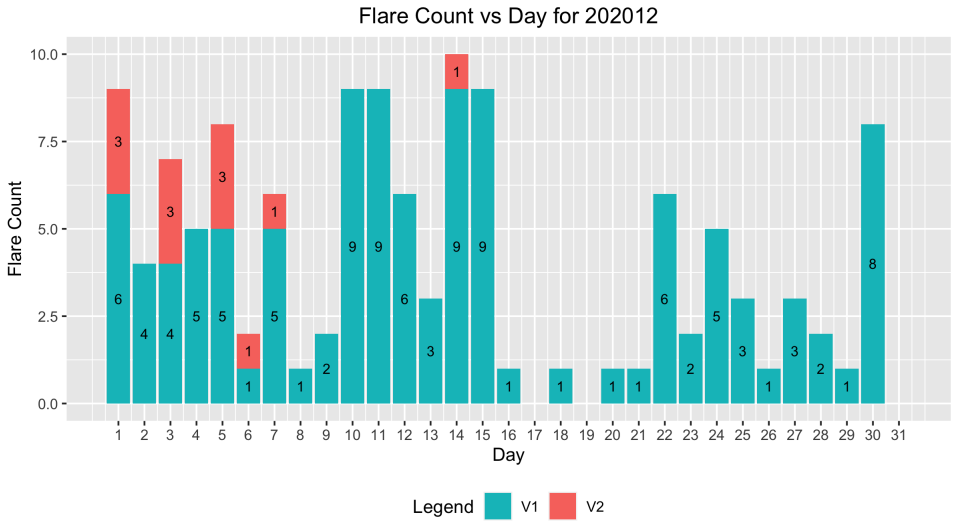

Figure 4: GOES-16 XRA flares

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 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 December 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.

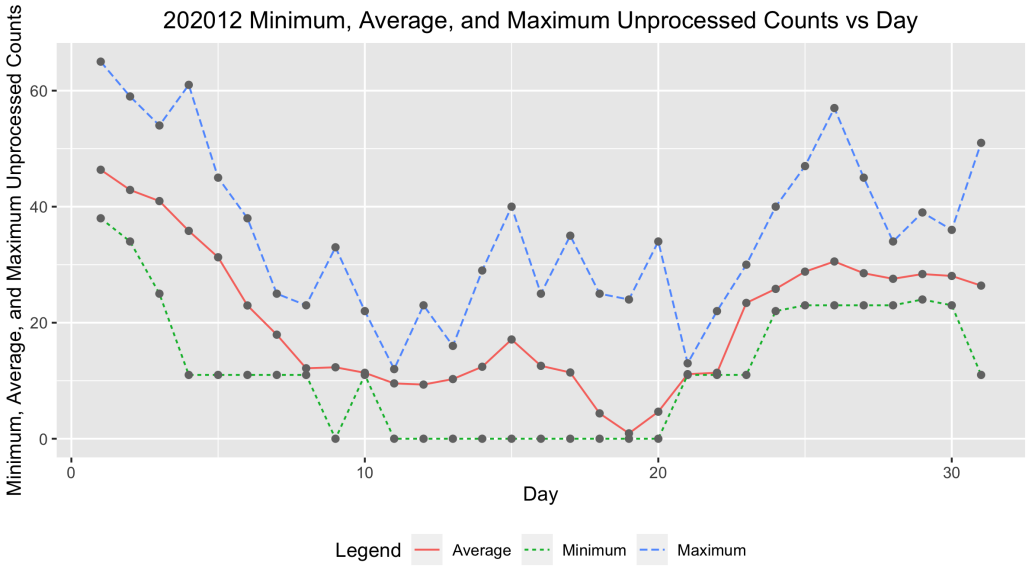

Figure 5: Raw Wolf number average, minimum and maximum by day of the month for all observers.

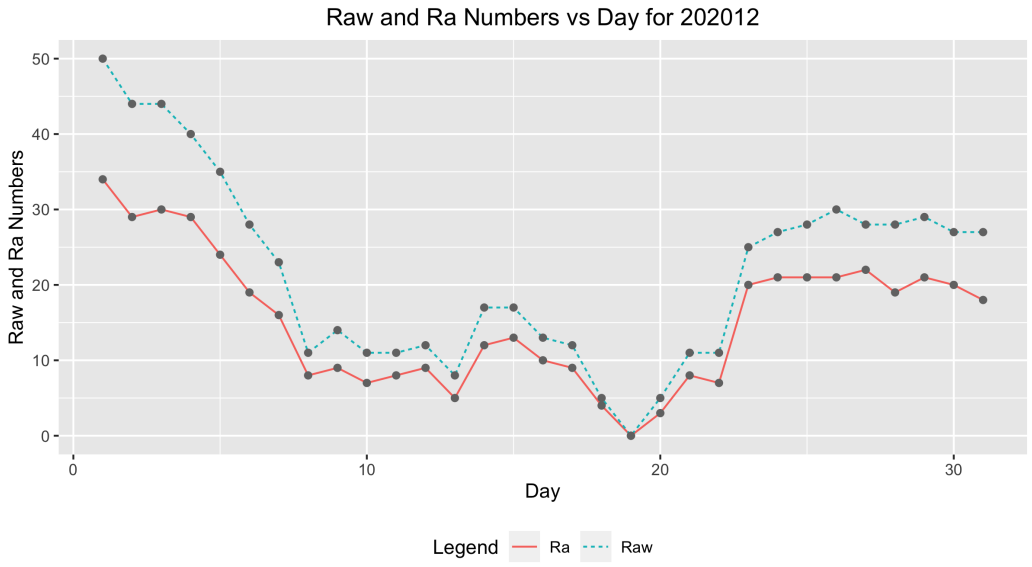

Figure 6: Raw Wolf average and R_a numbers by day of the month for all observers.

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: 202012 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
1	33	50	34
2	34	44	29
3	32	44	30
4	35	40	29
5	36	35	24
6	34	28	19
7	30	23	16
8	35	11	8
9	38	14	9
10	33	11	7
11	26	11	8
12	27	12	9
13	28	8	5
14	32	17	12

Continued

Table 2: 202012 American Relative Sunspot Numbers (R_a).

Day	Number of Observers	Raw	R_a
15	37	17	13
16	23	13	10
17	31	12	9
18	35	5	4
19	26	0	0
20	29	5	3
21	31	11	8
22	40	11	7
23	34	25	20
24	35	27	21
25	35	28	21
26	38	30	21
27	32	28	22
28	30	28	19
29	39	29	21
30	34	27	20
31	28	27	18
Averages	32.6	21.6	15.4

3.3 Sunspot Observers

Table 3 lists the Observer Code (column 1), the Number of Observations (column 2) submitted for December 2020, and the Observer Name (column 3). The final row gives the total number of observers who submitted sunspot counts (68), and total number of observations submitted (1010).

Table 3: 202012 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
AAX	22	Alexandre Amorim
AJV	11	J. Alonso
ARAG	28	Gema Araujo
ASA	19	Salvador Aguirre
ATE	27	Teofilo Arranz Heras
BARH	12	Howard Barnes
BATR	2	Roberto Battaiola
BERJ	27	Jose Alberto Berdejo
BLAJ	4	John A. Blackwell
BMF	21	Michael Boschat
BRAF	7	Raffaello Braga
BROB	27	Robert Brown
CHAG	25	German Morales Chavez

Continued

Table 3: 202012 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
CKB	20	Brian Cudnik
CMOD	2	Mois Carlo
CNT	23	Dean Chantiles
CVJ	6	Jose Carvajal
DARB	20	Aritra Das
DEMF	3	Frank Dempsey
DIVA	7	Ivo Demeulenaere
DJOB	17	Jorge del Rosario
DMIB	18	Michel Deconinck
DUBF	22	Franky Dubois
EHOA	17	Howard Eskildsen
ERB	12	Bob Eramia
FERJ	13	Javier Ruiz Fernandez
FLET	20	Tom Fleming
FTAA	5	Tadeusz Figiel
GIGA	25	Igor Grageda Mendez
HALB	8	Brian Halls
HAYK	11	Kim Hay
HMQ	18	Mark Harris
HOWR	20	Rodney Howe
IEWA	18	Ernest W Iverson
JDAC	4	David Jackson
JENS	1	Simon Jenner
JGE	3	Gerardo Jimenez Lopez
KADB	1	Andrea de Oliveira Kovacs
KAND	14	Kandilli Observatory
KAPJ	14	John Kaplan
KNJS	31	James & Shirley Knight
LGEC	6	Georgios Lekkas
LKR	5	Kristine Larsen
LRRA	13	Robert Little
MARE	3	Enrico Mariani
MCE	27	Etsuiku Mochizuki
MILJ	15	Jay Miller
MJAF	29	Juan Antonio Moreno Quesada
MJHA	25	John McCammon
MUDG	6	George Mudry
MWU	23	Walter Maluf
OAAA	25	Al Sadeem Astronomy Observatory
ONJ	14	John O'Neill
PEKT	4	Riza Pektas
RFDA	13	Fillpp Romanov
RMW	10	Michael Rapp

Continued

Table 3: 202012 Number of observations by observer.

Observer Code	Number of Observations	Observer Name
SDOH	31	Solar Dynamics Obs - HMI
SNE	8	Neil Simmons
SONA	5	Andries Son
SQN	23	Lance Shaw
STAB	21	Brian Gordon-States
TESD	22	David Teske
TPJB	4	Patrick Thibault
TST	17	Steven Toothman
URBP	5	Piotr Urbanski
VARG	29	A. Gonzalo Vargas
WGI	2	Guido Wollenhaupt
WILW	20	William M. Wilson
Totals	1010	68

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 months) 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 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.

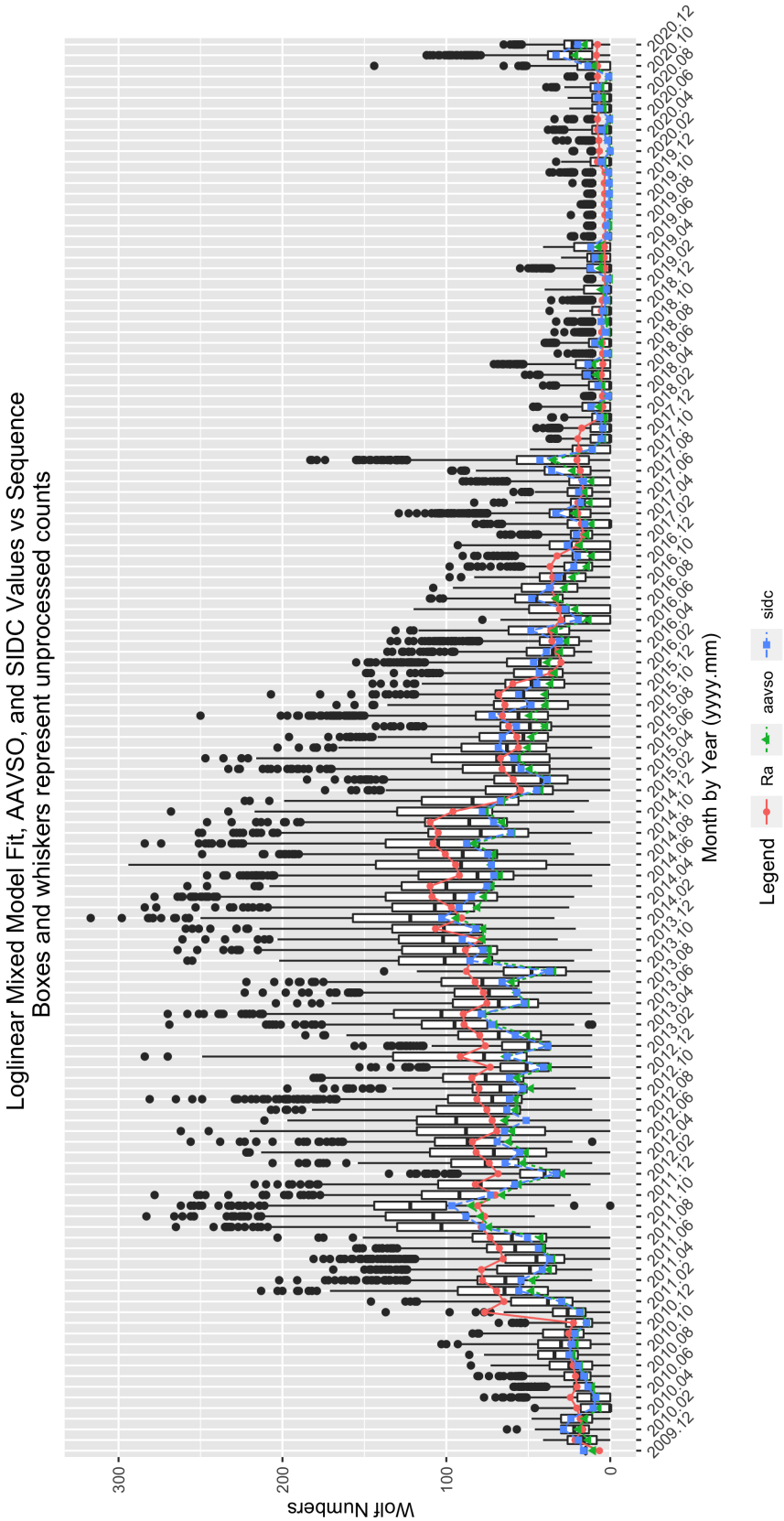

Figure 7: GLMM fitted data for R_a. AAVSO data: https://www.aavso.org/category/tags/solar-bulletin. SIDC data: WDC-SILSO, Royal Observatory of Belgium, Brussels

4 Endnotes

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

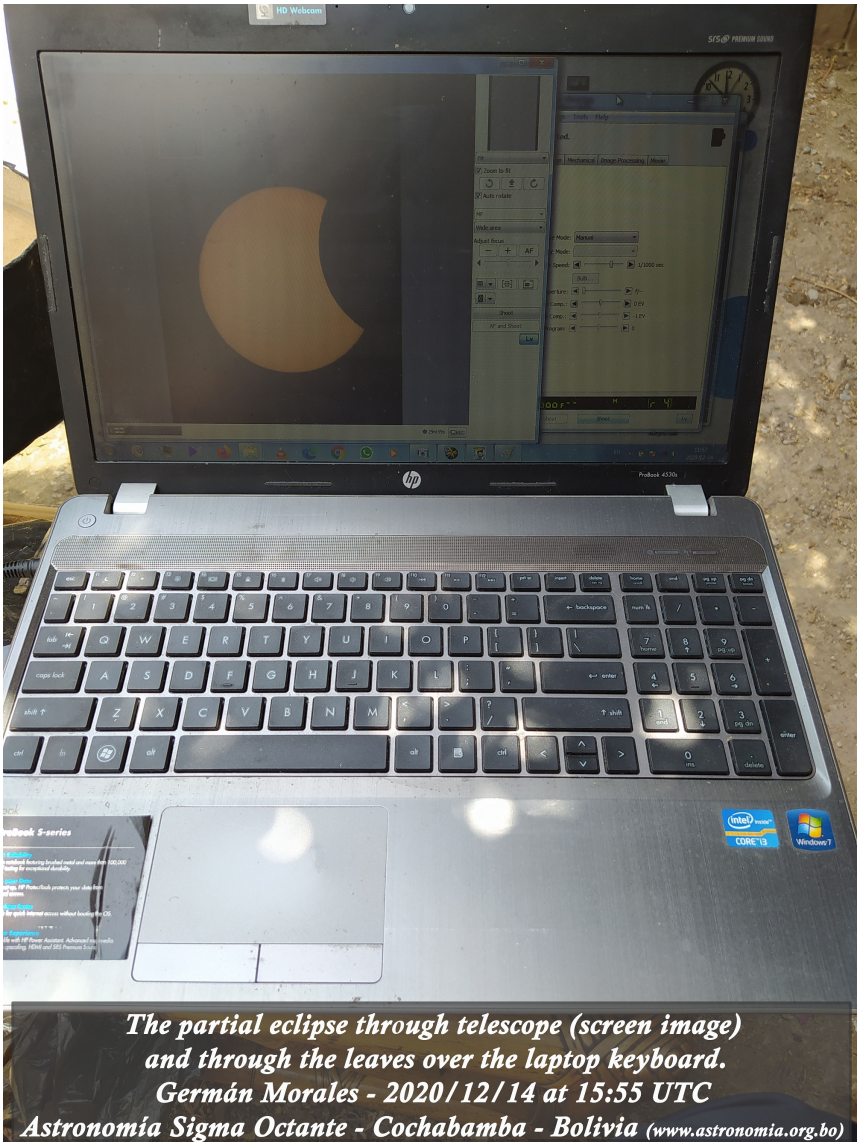

Figure 8: Partial solar eclipse from Bolivia, by German Morales. (`www.astronomia.org.bo`)