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Solar activity reconstruction from the Georg Eimmart archive of 1616 – 1720

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Abstract. Historical sunspot records provide piece by piece more information on solar variability on a centennial scale. In this work, we analyze sunspot observations from the archives of Georg Christoph Eimmart, which is the second-richest data set of the Maunder minimum after the archives of the Paris observatory. Comparing the dates of the blank solar disk from the database by Hoyt & Schatten (1998) with dates of observations at the Eimmart observatory, we find that spotless days reports originate from astrometric observations. A comparison of the observations by La Hire and Müller of 1719 suggests that the observations by La Hire were for astrometric purposes as well, rather than aimed at sunspot counting.

Keywords. History and philosophy of astronomy, (Sun:) activity, (Sun:) sunspots

1. Introduction

The first-order feature of the Maunder minimum known to the astrophysics community is a blank solar disk during the majority of the observations from 1645 to 1715 (Hoyt & Schatten 1998). Figure 1a shows the fractional distribution of raw daily group counts reported by all the observers during the Maunder minimum. For this period, the collection of group counts (Vaquero *et al.* 2016) currently contains 20541 reports: 89% of them (18198 observations) are spotless. The majority of the observations was carried out at the Paris observatory (Ribes & Nesme-Ribes 1993). Figure 1b shows the fraction of spotless observations reported by Jean Picard, Phillippe de La Hire, Gian Domenico Cassini, and Jacques Cassini between 1653 and 1715. Out of 9492 observations, 93% (8844 observations) are days with no sunspots. Figure 1c analyzes the second-richest archive of the Eimmart observatory, Nuremberg, Germany. Georg Christoph Eimmart, his daughter Maria Clara Eimmart, and her husband Johann Heinrich Müller from 1677 to 1709 reported 2477 spotless days which is 97% out of 2546 observations.

59 volumes of Eimmart's archiver are gathered in Collection 998 of the Manuscript Department of the National Library of Russia, St. Petersburg (MD NLR 1958). Recently, Hayakawa *et al.* (2021a,b) and Vokhmyanin & Zolotova (2023) analyzed this collection and evaluated sunspot and sunspot-group numbers, areas, and positions. Hayakawa *et al.* (2021a) argued that the majority of the observations were not sunspot observations but rather solar-altitude and solar diameter measurements instead.

Complementing these findings, we would like to hypothesize that the observations at the Paris observatory may also have been aimed primarily at astrometric purposes.

2. Archival source of spotless days reports

For the Eimmart observatory, raw daily group counts collected by Hoyt & Schatten (1998) and those from the revised collection by (Vaquero *et al.* 2016) are identical. We compare tables of group counts extracted from observation at the Eimmart observatory in 1677 – 1709 with

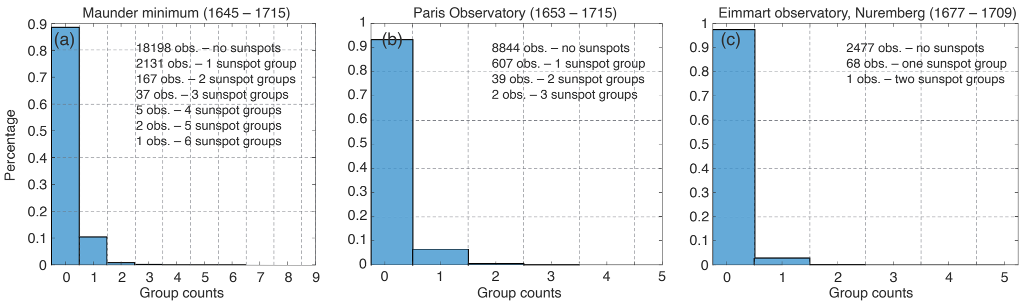
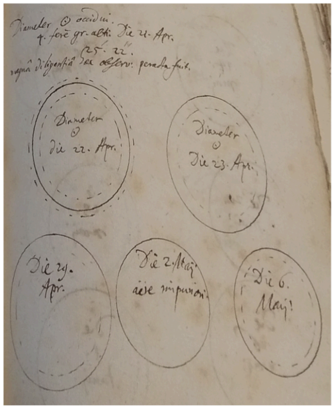


Figure 1. Fractional distribution of daily group counts: (a) all the observers during the Maunder minimum, (b) astronomers of the Paris observatory, (c) those of the Eimmart observatory.

NUMBER OF SUNSPOT GROUPS FOR THE YEAR: 1683
AS OBSERVED BY: EIMMART, G.C., NUREMBERG

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	-99	-99	-99	-99	-99	0	-99					
2	-99	-99	-99	-99	0	-99	-99					
3	-99	-99	-99	-99	-99	0	-99					
4	-99	-99	-99	-99	-99	0	-99					
5	-99	-99	-99	-99	-99	-99	-99					
6	-99	-99	-99	-99	0	0	-99					
7	-99	-99	-99	-99	0	-99	-99					
8	-99	-99	-99	0	0	-99	-99					
9	-99	-99	-99	0	-99	-99	-99					
10	-99	-99	-99	-99	-99	0	-99					
11	-99	-99	-99	-99	-99	-99	-99					
12	-99	-99	-99	-99	-99	-99	0					
13	-99	-99	0	-99	-99	-99	-99					
14	-99	-99	-99	-99	0	0	-99					
15	-99	-99	-99	0	-99	-99	-99					
16	-99	-99	-99	-99	-99	-99	-99					
17	-99	-99	-99	-99	0	-99	0					
18	-99	0	-99	-99	-99	-99	-99					
19	-99	-99	-99	-99	-99	-99	-99					
20	-99	0	-99	-99	0	-99	0					
21	-99	0	-99	-99	-99	-99	-99					
22	-99	-99	-99	0	-99	-99	-99					
23	-99	-99	-99	0	0	-99	-99					
24	-99	0	-99	-99	-99	-99	-99					
25	-99	-99	-99	-99	-99	-99	0					
26	-99	-99	-99	-99	0	-99	-99					
27	-99	-99	-99	-99	-99	-99	-99					
28	-99	-99	-99	-99	-99	0	-99					
29	-99	-99	-99	0	-99	-99	0					
30	-99	-99	-99	-99	-99	-99	-99					
31	-99	-99	-99	-99	-99	-99	-99					



NUMBER OF SUNSPOT GROUPS FOR THE YEAR: 1704
AS OBSERVED BY: EIMMART, M-C., NUREMBERG

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
1	-99	-99	-99	-99						
2	-99	-99	-99	-99						
3	-99	-99	-99	-99						
4	-99	-99	0	-99						
5	-99	-99	0	-99						
6	-99	-99	-99	-99						
7	-99	-99	-99	-99						
8	-99	-99	-99	-99						
9	-99	-99	-99	-99						
10	-99	-99	-99	-99						
11	-99	-99	-99	-99						
12	-99	-99	-99	0						
13	-99	-99	0	-99						
14	-99	-99	0	-99						
15	-99	-99	-99	-99						
16	-99	-99	-99	-99						
17	-99	-99	-99	-99						
18	-99	-99	-99	-99						
19	-99	-99	-99	-99						
20	-99	-99	-99	-99						
21	-99	-99	0	-99						
22	-99	-99	0	-99						
23	-99	-99	0	-99						
24	-99	-99	0	-99						
25	-99	-99	-99	-99						
26	-99	-99	-99	-99						
27	-99	-99	0	-99						
28	-99	-99	-99	-99						
29	-99	-99	0	-99						
30	-99	-99	-99	-99						
31	-99	-99	-99	-99						

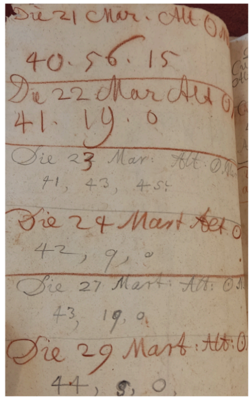


Figure 2. Examples of the annual tables of sunspot-group counts provided by Hoyt & Schatten (1998) and their apparent historical origins (Eimmart Archive Coll. 998, v. 48, f. 160 and v. 35, f. 45).

the original observational reports. Figure 2 provides two examples: solar-diameter and solar-altitude measurements. In tables, red marks days for which we apparently found their source in the original reports. The majority of spotless days originates from solar-altitude measurements, the minor portion — from solar-diameter measurements.

The diameter measurements were carried out at local noon. Drawings are accompanied by date and weather conditions like clear or misty air. From solar-diameter measurements conducted at the Paris observatory, we know that a quadrant was fitted with telescopic sights. A similar technique might have been used at the Eimmart observatory.

Solar-altitude measurements were also made at local noon. For these purpose, gnomon and quadrant were exploited. Apparently, a telescope was not used, since it was not mentioned. Therefore, we confirm the conclusion by Hayakawa *et al.* (2021a) that solar-altitude observations recorded without any mention of sunspots can be interpreted as spotless days with caution as rather speculative.

Figure 3 compares sunspot group counts defined from reports by Gabriel-Phillipe de La Hire and Johann Christoph Müller. In the bibliography, Hoyt & Schatten wrote that for La Hire the primary source is a re-examination of original notebooks by Elizabeth Nesme-Ribes. Analyzing the fine structure of a sunspot drawn by La Hire (apparently Phillippe de La Hire), Ribes & Nesme-Ribes (1993) suggested that any sunspot larger than one arcsecond could not

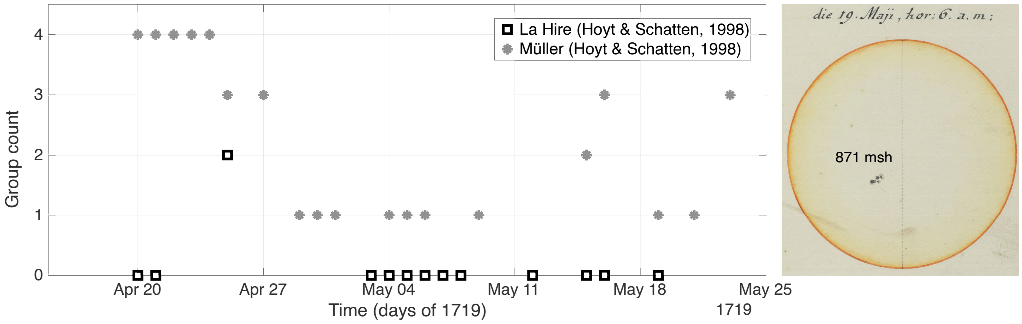


Figure 3. Sunspot-group counts defined by Hoyt & Schatten (1998) from La Hire's and Müller's observations. On the right, an example of Müller's drawing of 19 May 1719 (Eimmart Archive Coll. 998, v. 56) and the area of the sunspot group are reproduced.

be missed with the Parisian telescopes. According to these observations, during the month of 1719, the solar disk was blank, excluding one day. On the other hand, Müller drew sunspots up to 871 msh. The discrepancy in sunspot-group counts reported by La Hire and Müller can be resolved if we hypothesize that these Parisian reports were made for different purposes, not sunspot observations. Similarly to the Eimmart observatory, it might be solar-altitude or solar-diameter measurements.

3. Conclusions

We analyze archives of the Eimmart observatory stored in the National Library of Russia, St. Petersburg. Comparing the dates of the blank solar disk from the database by Hoyt & Schatten (1998) with dates of observations at the Eimmart observatory, we find that these zeros originate mainly from the solar-altitude measurements. These observations apparently were carried out without a telescope. The minor portion of zeroes originates from the solar-diameter measurements, which potentially were performed using a telescope. We confirm the conclusion by Hayakawa *et al.* (2021a) that altitude measurements can be interpreted as spotless with caution as speculative.

We also compared counts of sunspot groups from observations by La Hire and Müller. Due to reports by La Hire being spotless, while Müller drew sunspots, we hypothesize that the Parisian reports may not have been sunspot observations but rather were the solar-altitude or solar-diameter measurements. For the benefit of an open discussion, the processed drawings will be available at `https://geo.phys.spbu.ru/~ned/History.html`.

4. Acknowledgments

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