The First 420 Days With Sunspot Observations by ATS

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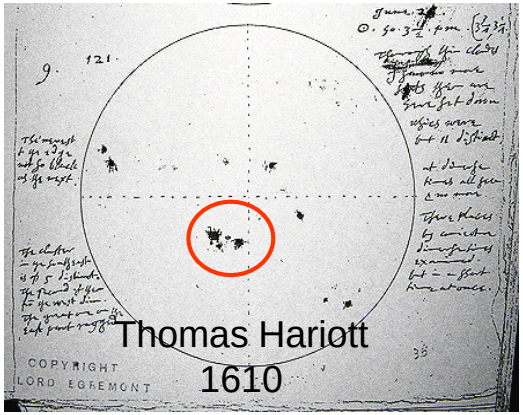
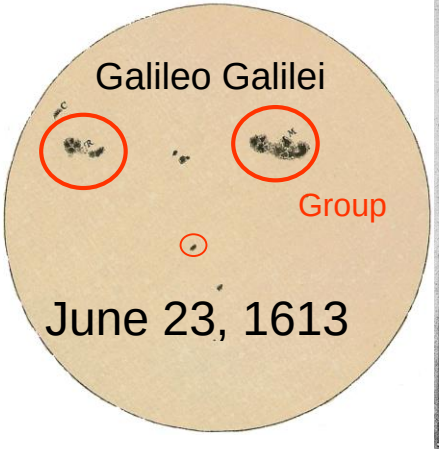
Stanford University, USA

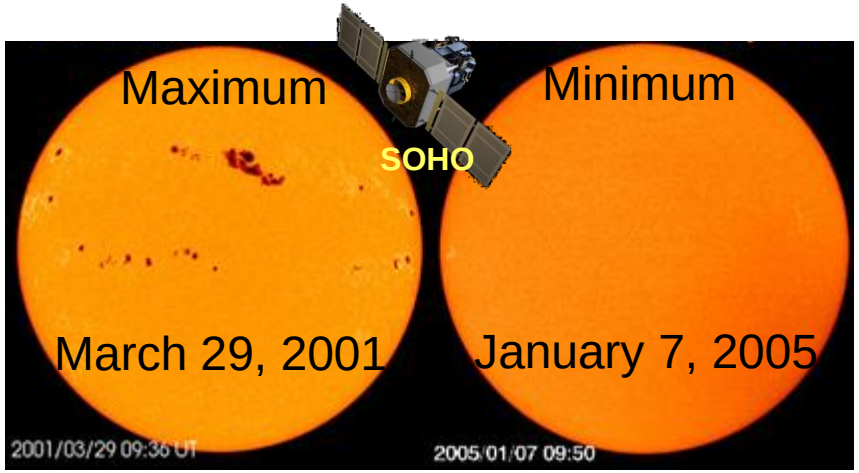
Antique Telescope Society Meeting
Mount Wilson Observatory, 7 Oct. 2017

Centuries of Sunspot Observing

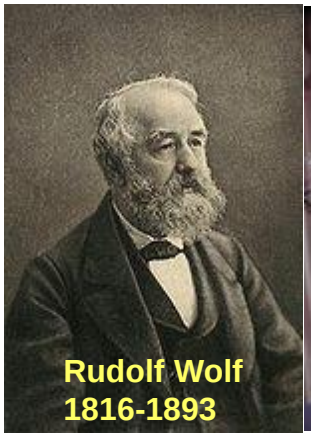
We have observed sunspots with telescopes for 400 years







Sunspots observed by Spacecraft



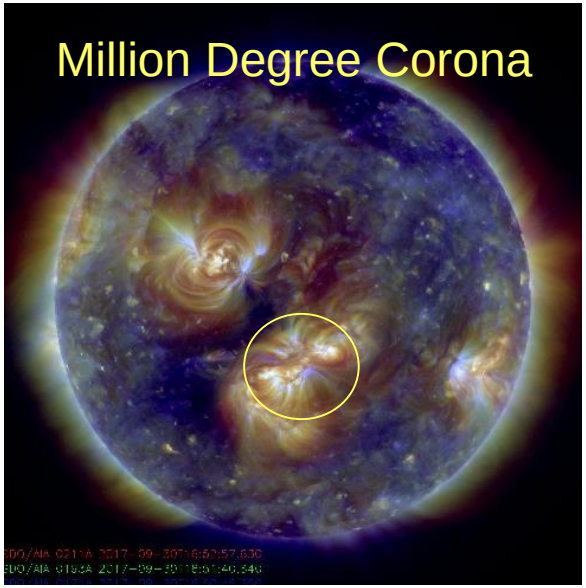
'Compiler' of Sunspot Number

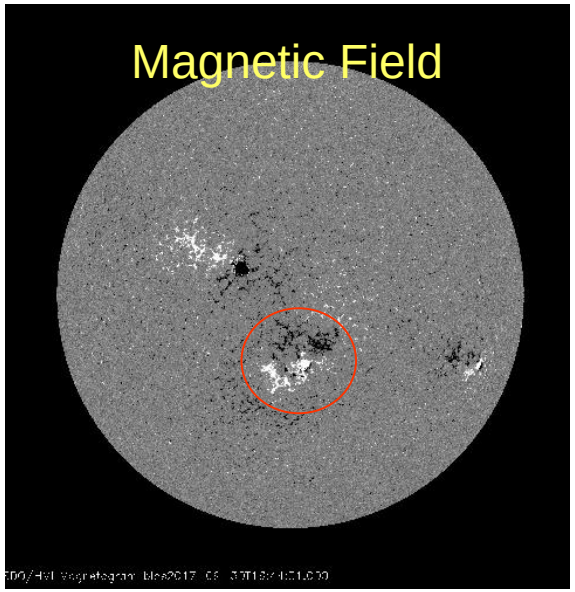
Still used today

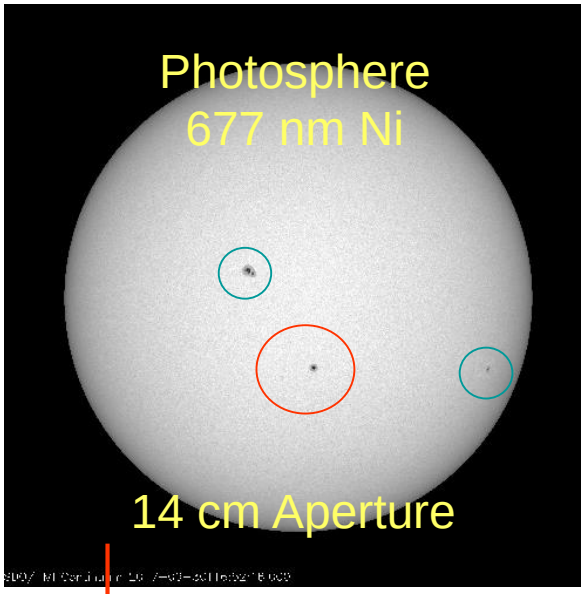
The sunspot number is always determined using small telescopes

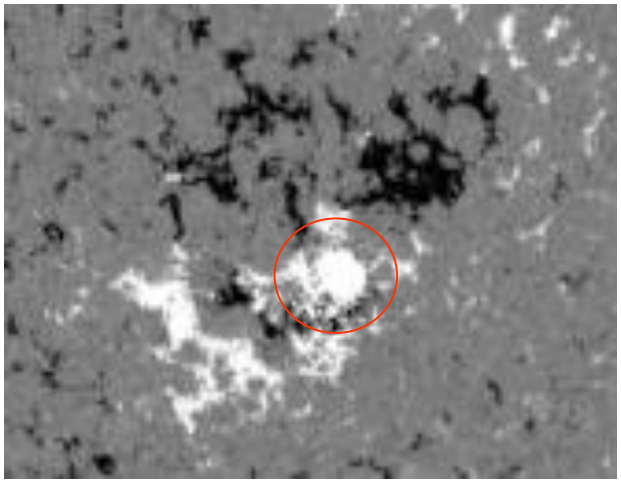
Groups With Our Current Satellite, SDO

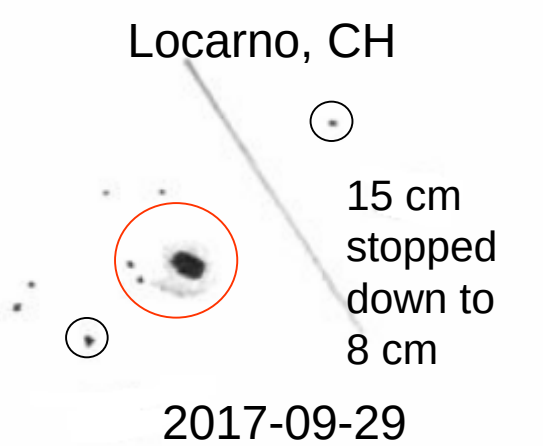
a week ago

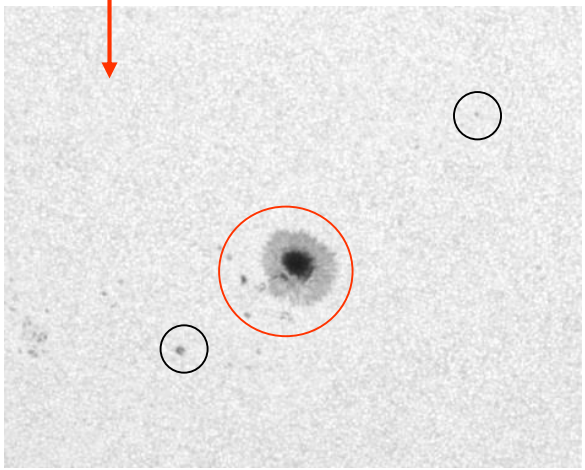






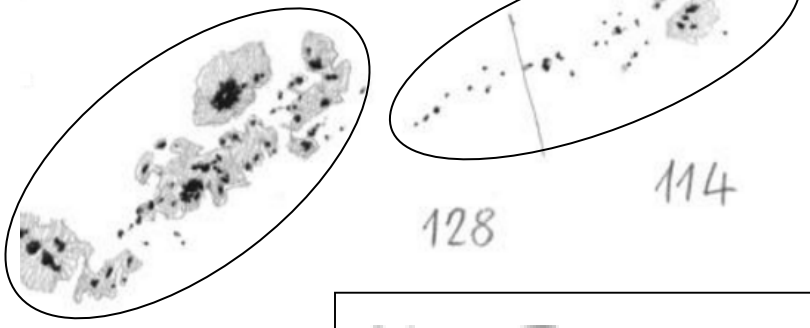


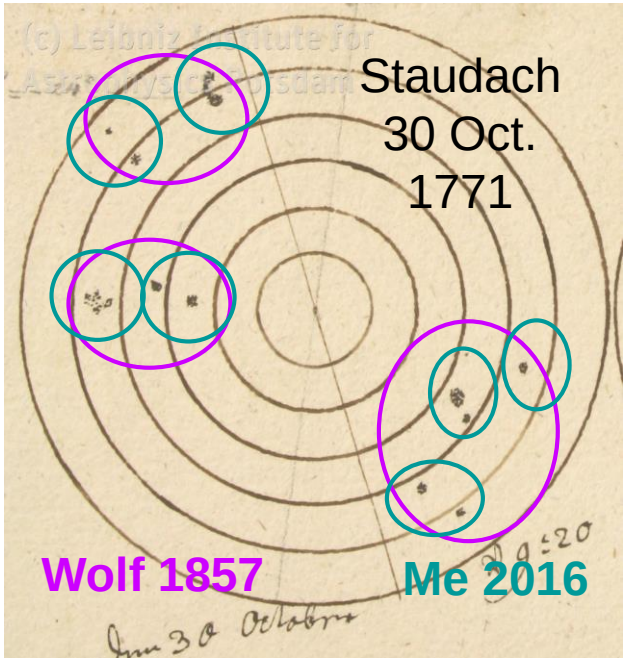




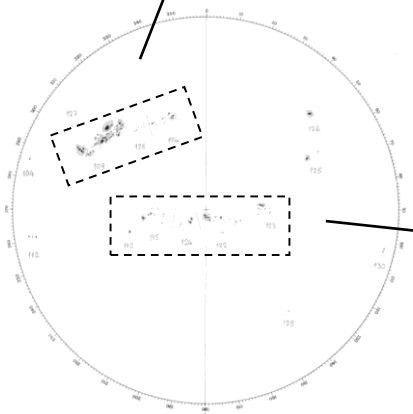
Fundamental Issue: What Is a Group?

Definition has changed over time





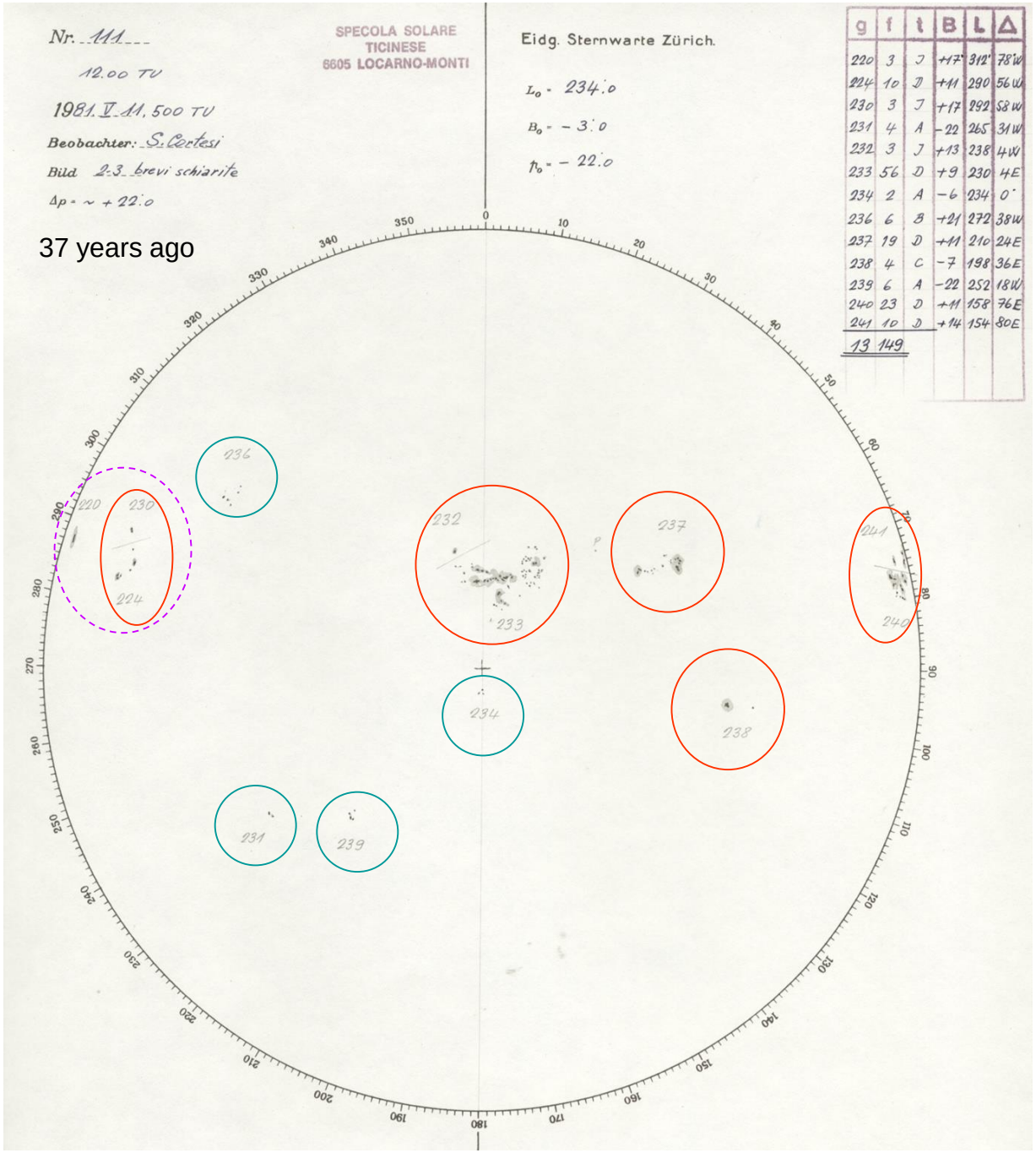
Contrary to common belief, counting spots is easy, counting groups is **hard**



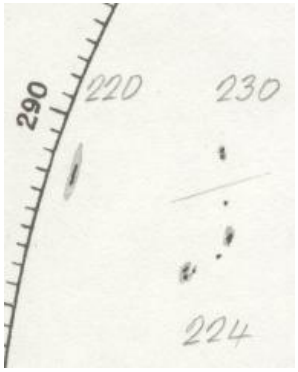
Locarno

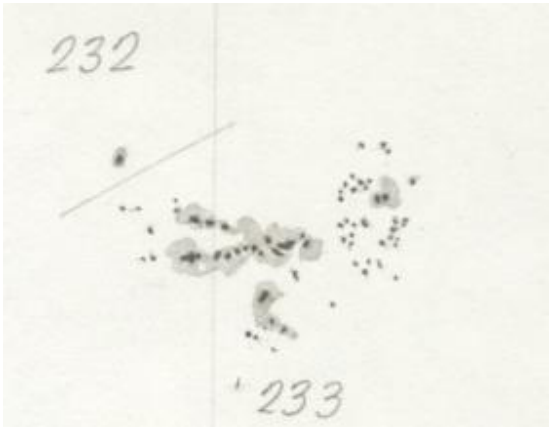
Cortesi counted 8 groups. Early observers would likely have counted only 5 groups

Splitting Groups



g	f	t	B	L	Δ
220	3	J	+17	312	78W
224	10	D	+11	290	56W
230	3	J	+17	292	58W
231	4	A	−22	265	31W
232	3	J	+13	238	4W
233	56	D	+9	230	4E
234	2	A	−6	234	0
236	6	B	+21	272	38W
237	19	D	+11	210	24E
238	4	C	−7	198	36E
239	6	A	−22	252	18W
240	23	D	+11	158	76E
241	10	D	+14	154	80E
13	149				



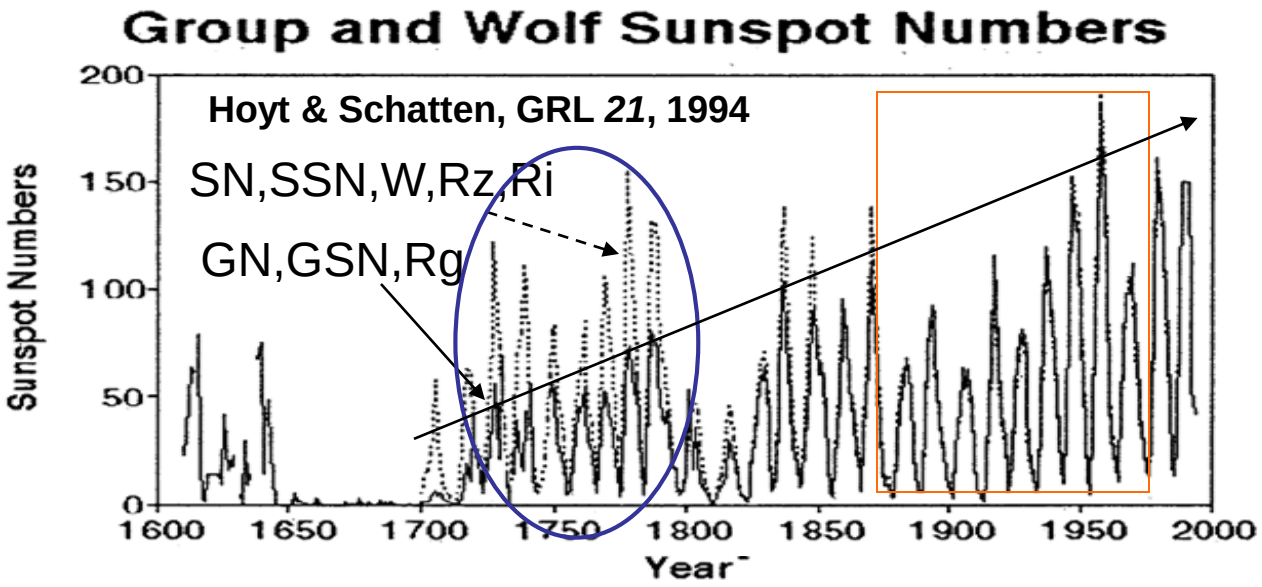


Modern count 13

Ancient count 5 [or 6]

Could not see 4

A Problem: Two Very Different 'Sunspot Series'. Which One to Use?



Original (1851) Wolf Number: W_o = Groups + 1/10 Spots

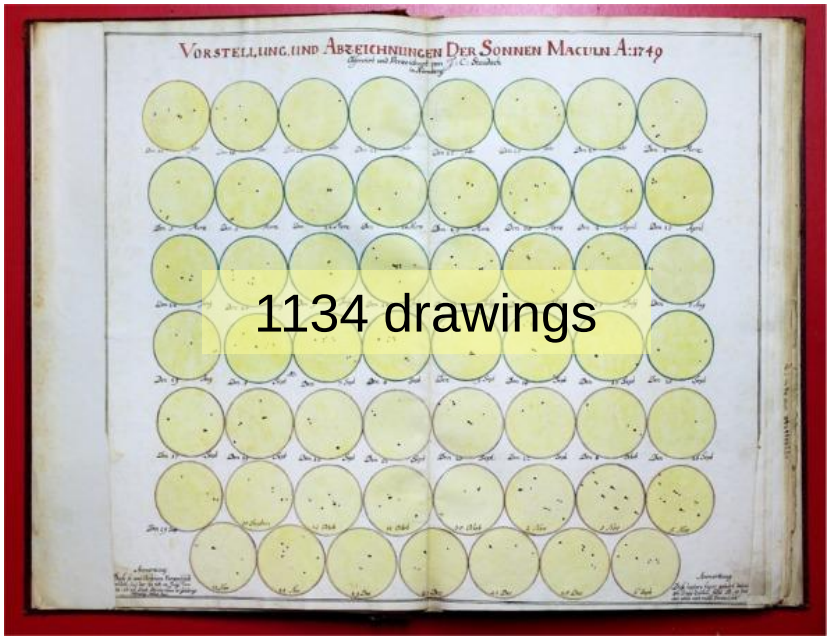
('1/10 Spots' was assumed to be a measure of the area of the group)

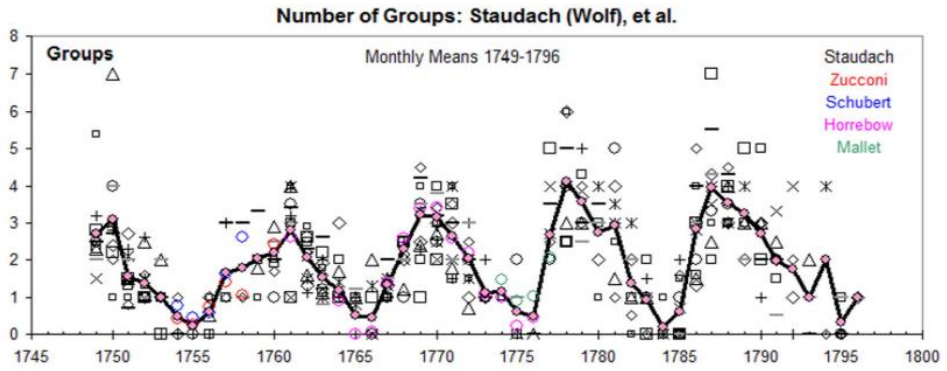
Later (in 1856) streamlined to $W = k (10 G + S)$

The 'k-factor' was originally set to 1 for Wolf himself. Wolf did not count the smallest spots in order to be partly compatible with Heinrich Schwabe who used a smaller telescope. Wolf also counted a collection of spots within a common penumbra as just a single spot and thus did not take the structure and splitting of the umbra into account. His successor, Wolfer, argued that all spots should be counted, and found that [and adopted] a k-factor of 0.6 on his counts would put his Sunspot Numbers on Wolf's scale, to maintain the homogeneity of the series. **This has been the cause of much confusion since**, and has been removed in the latest revision of the sunspot series

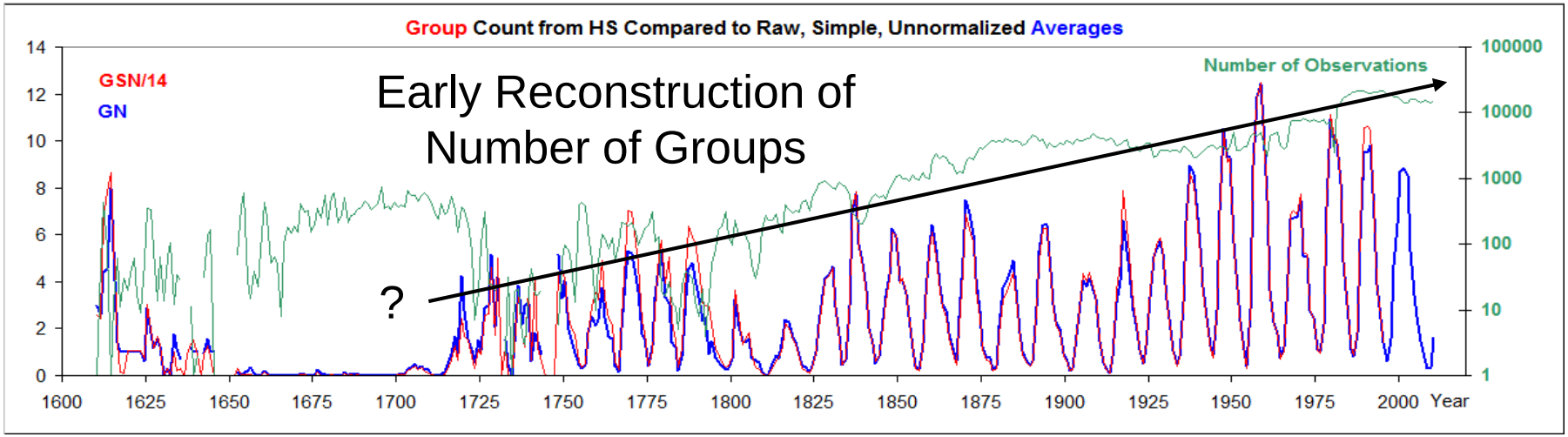
Hoyt & Schatten's [H&S] GSN = 12 * G where the '12' was chosen to make the GSN = W for the interval 1874-1976, so forcing an overall match with W for that.

Our Knowledge of Sunspots in the 18th Century is Based on J.C. Staudach's Drawings 1749-1799





The problem is: How do we connect these observations to modern values and concepts about what a Group is?



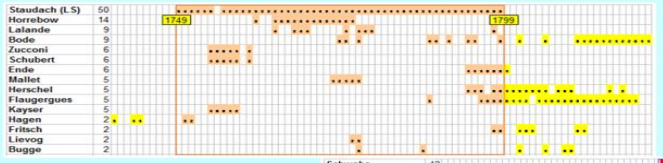
Building Backbones

Building a time series from observations made over a long time by several observers can be done in basically two ways:

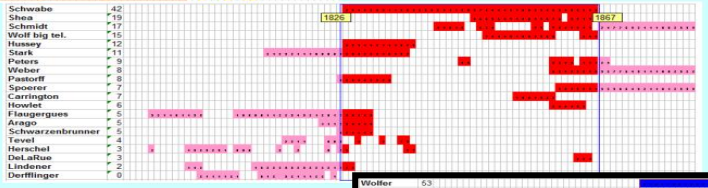
- Daisy-chaining: successively joining several intermediate observers to the ‘end’ of the series, based on overlap with the series as it extends so far [accumulates and **propagates** errors]
- Back-boning: find a ‘good’ primary observer for a certain [long] interval and normalize all other observers individually to the primary based on overlap with **only** the primary [no accumulation of errors]. Several, but few, independent backbones can then be daisy-chained together for the long series.

We [Ken Schatten (of H&S) and I] have applied the Backbone method to reconstruct the Group Sunspot Number [using essentially the Hoyt & Schatten data supplemented with newer data.] with the goal of avoiding the pitfalls of H&S.

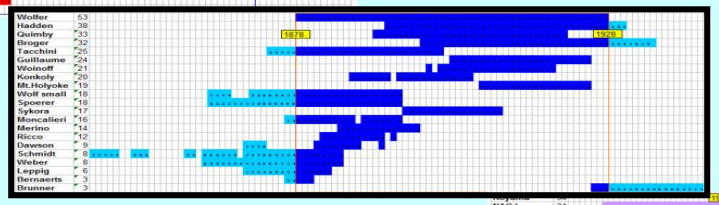
The Backbones



Staudach 1730-1749-1799-1822



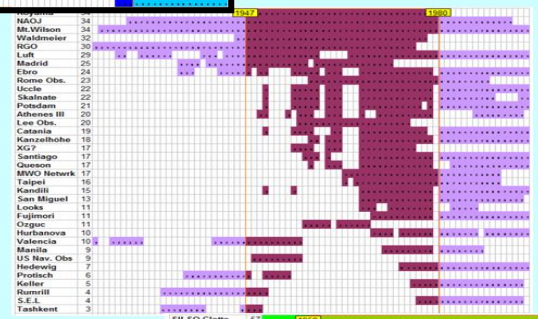
Schwabe 1794-1826-1867-1883

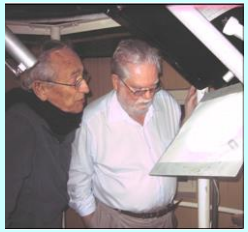


Wolfer 1841-1876-1928-1945

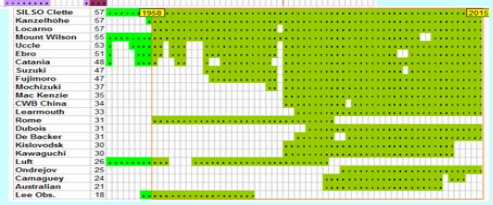
← Standard 'Norm' Backbone

Koyama 1920-1947-1980-1996



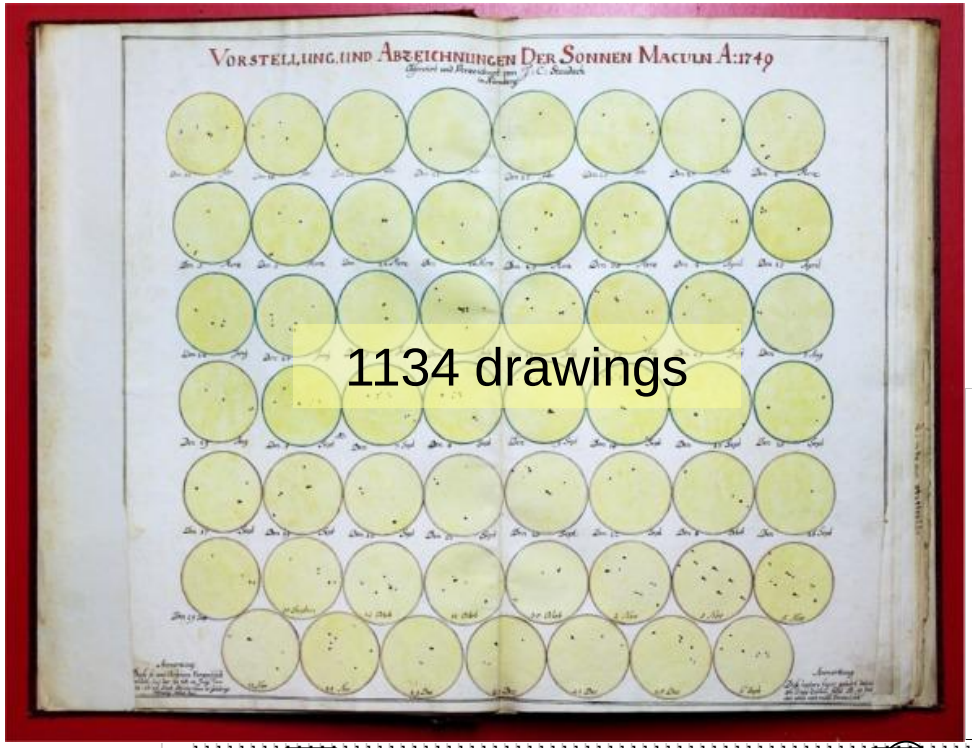


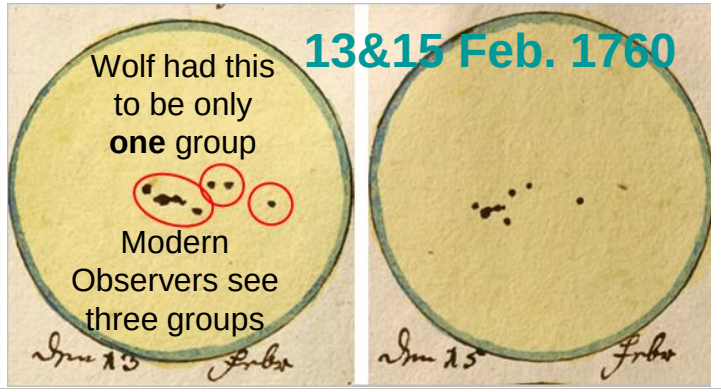
Locarno 1950-1958-2015-2015

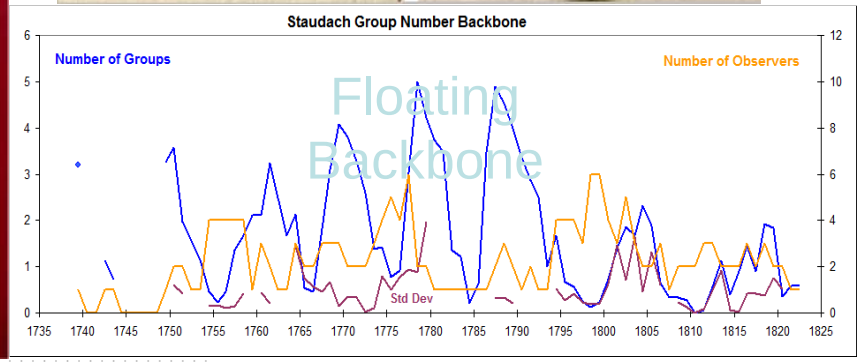


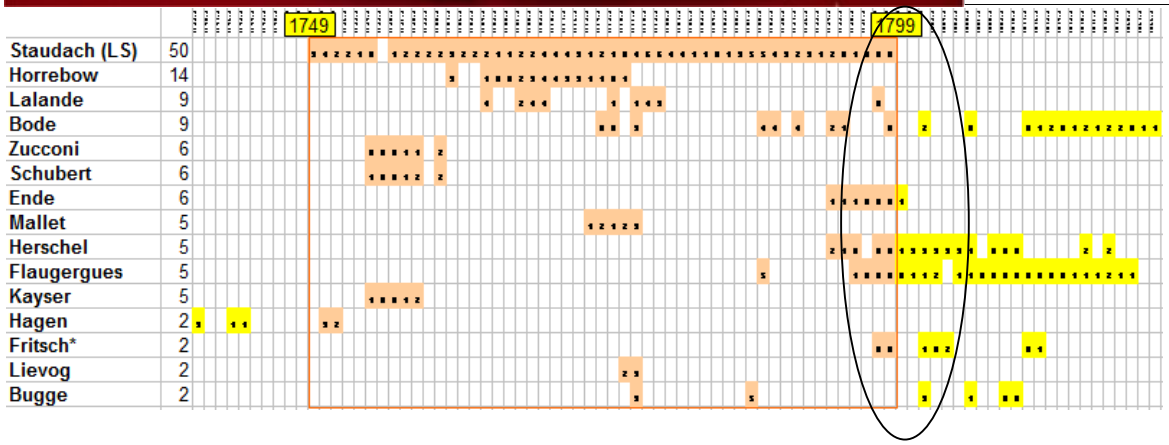
106 unique 'observers' [some are assemblies of many individual observers, e.g. RGO]

The ‘Floating’ Staudach Backbone









The weak point: the **Staudach Backbone** is ‘floating’ and is not firmly calibrated to link up with the neighboring [later] Schwabe Backbone

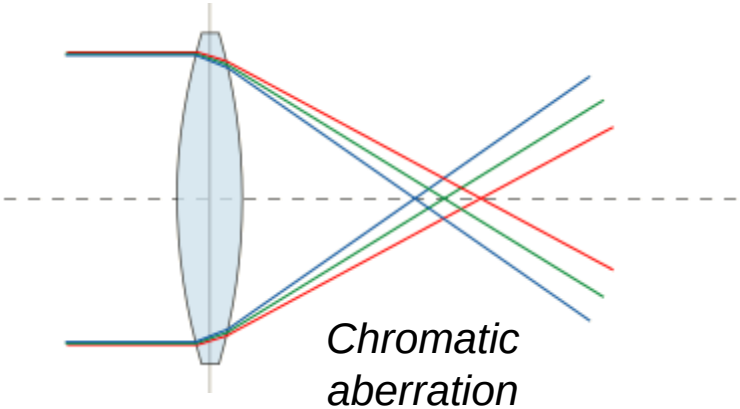
Staudach's Telescope(s)

In the Staudach material there is a mention of a telescope (18 February 1775: "when I turned round with my 3–shoe sky tube…") hence we may assume that the focal length of the telescope was about three feet. Achromatic telescopes with a focal length of 92 cm were manufactured by John and Peter Dollond from the late 1750s. With such a [very expensive] telescope, however, the distinction between umbra and penumbra should have been possible, but it is not present on the drawings.

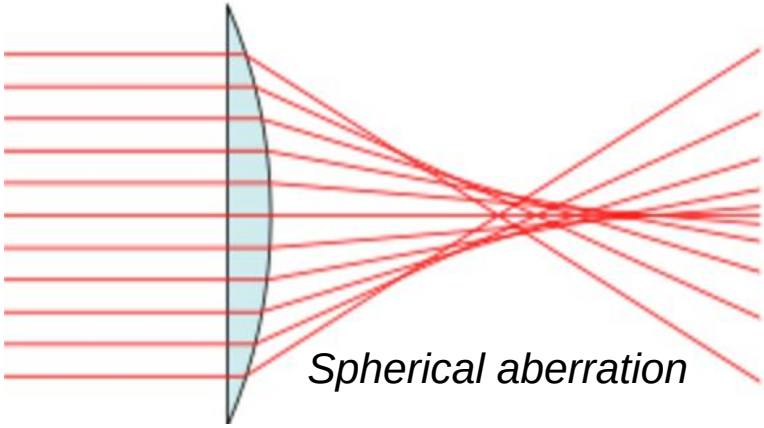
Haase (1869) also reviewed the Staudach material and reports that a 4-foot telescope was used, but that it was not of particular good quality and especially seemed not to have been achromatic, because he quotes Staudach remarking on his observation of the Venus transit in 1761 that "for the size and color of the planet there was no sharp edge, instead it faded from the same black-brown color as the inner core to a still dark brown light red, changing into light blue, then into the high green and then to yellow".

So we assume that the telescope(s) suffered from spherical and chromatic aberration. **We can build replicas with those same flaws.**

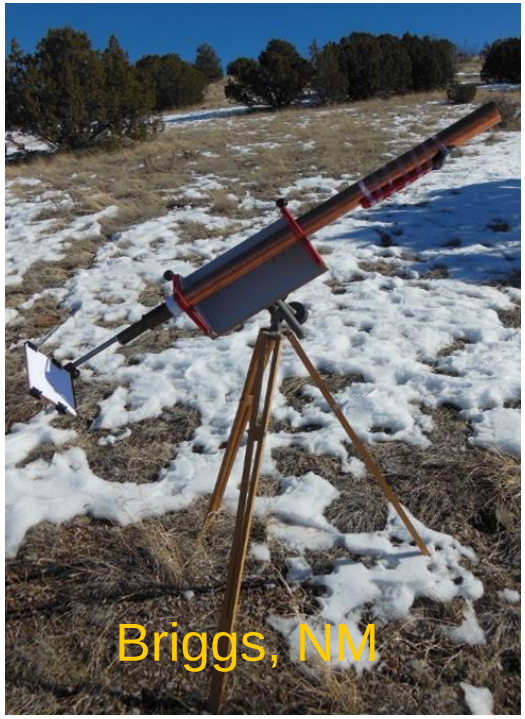
Aberrations of Singlet Lenses



Chromatic aberration



Spherical aberration

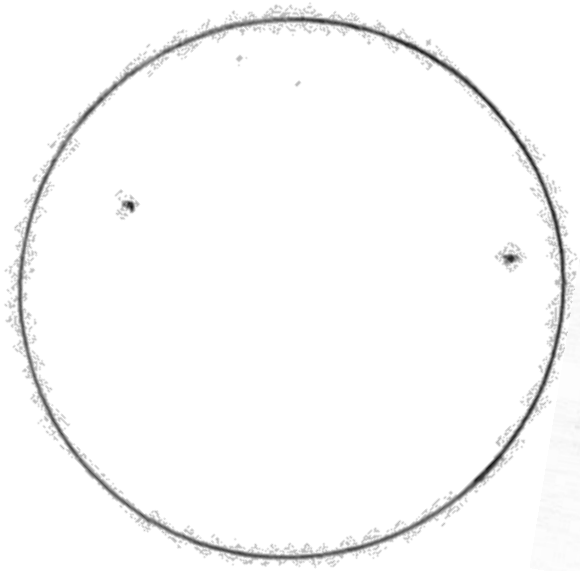


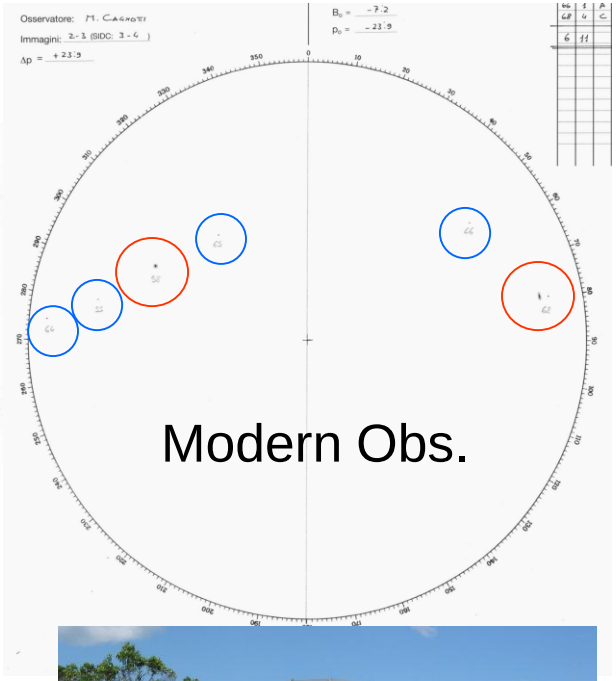
Briggs, NM

Spencer, NY

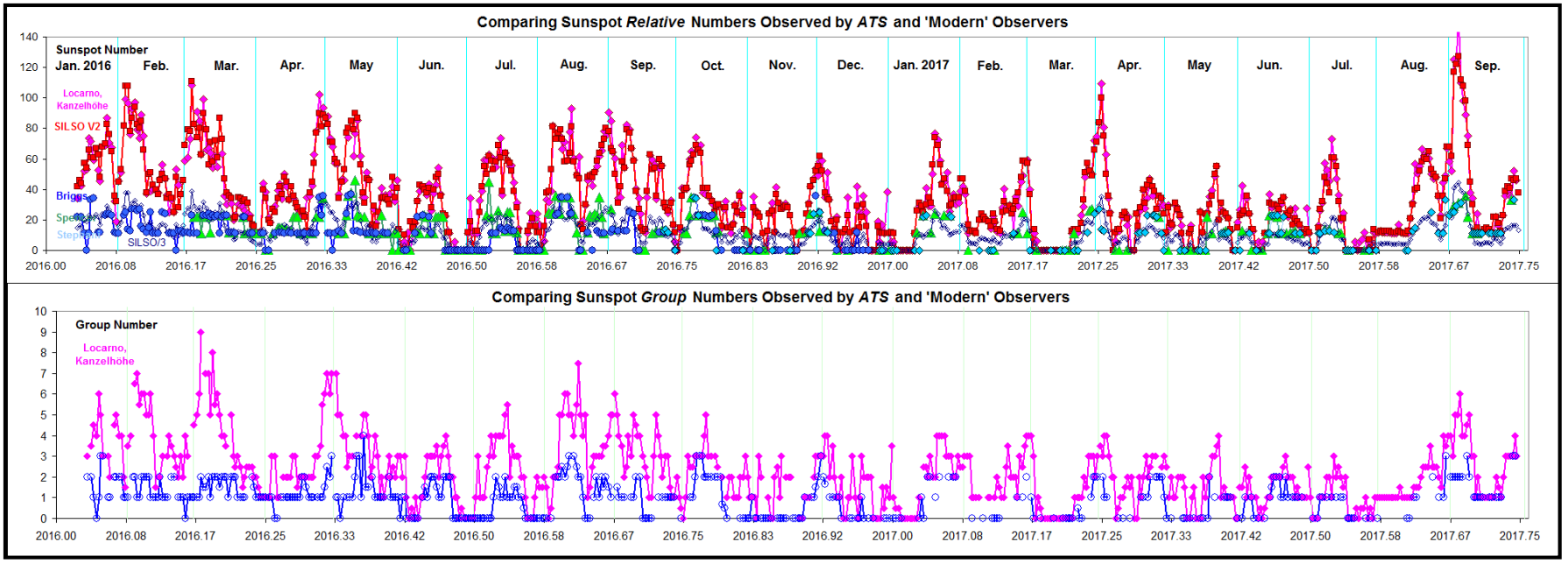
Stephani, Germany

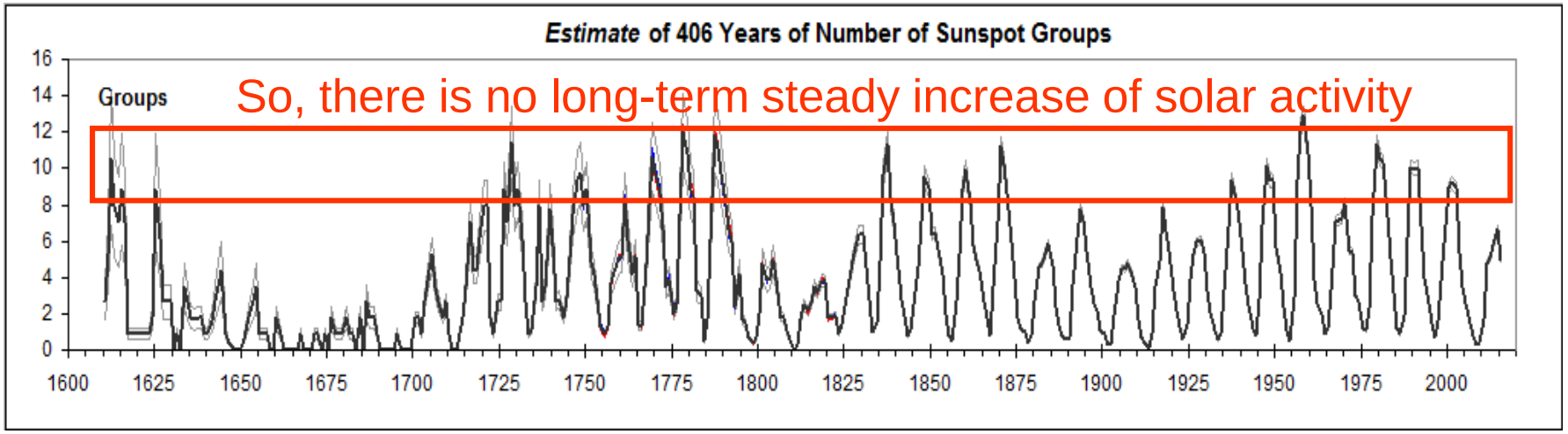
Sunspots 2016-03-11



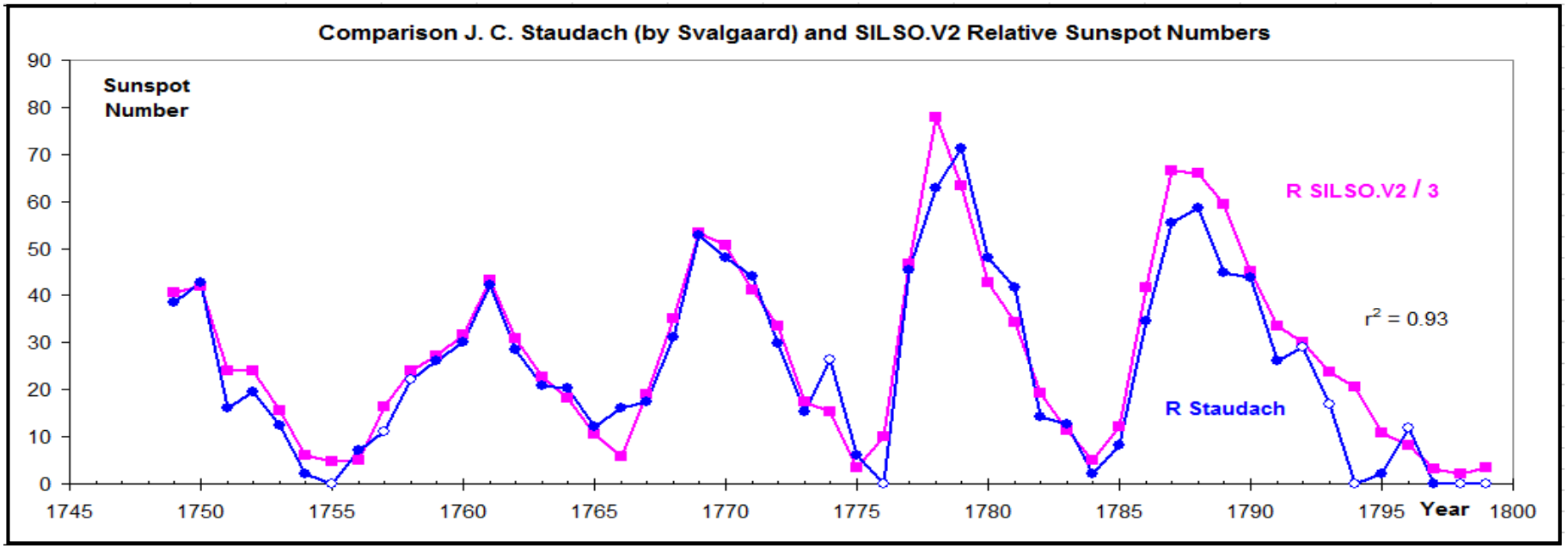


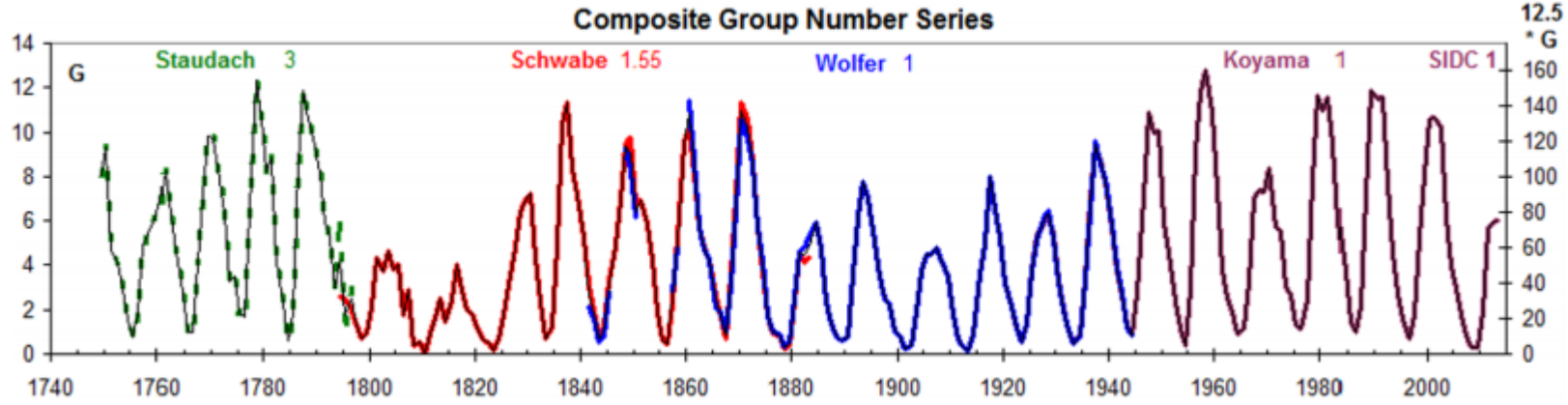
Modern Observers See Three Times as Many Spots as The Old Telescopes Show



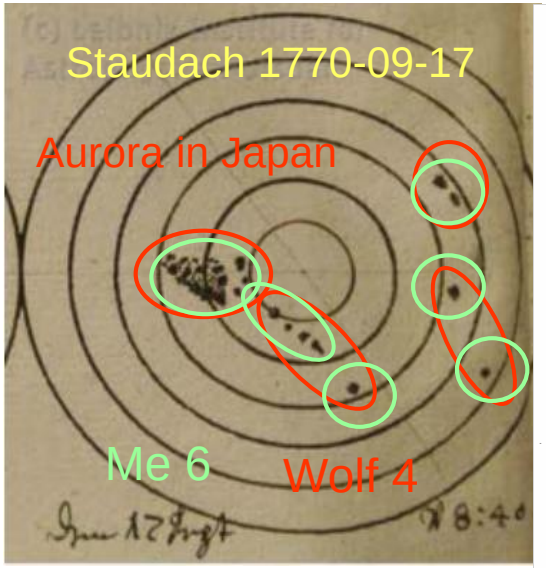


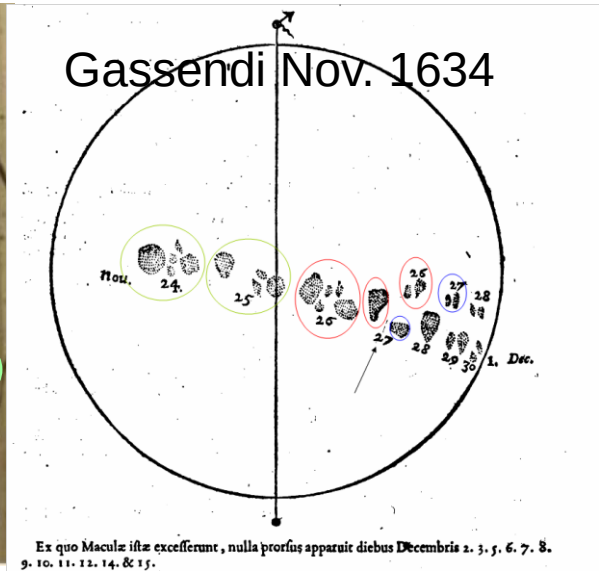
Factor of Three is Confirmed

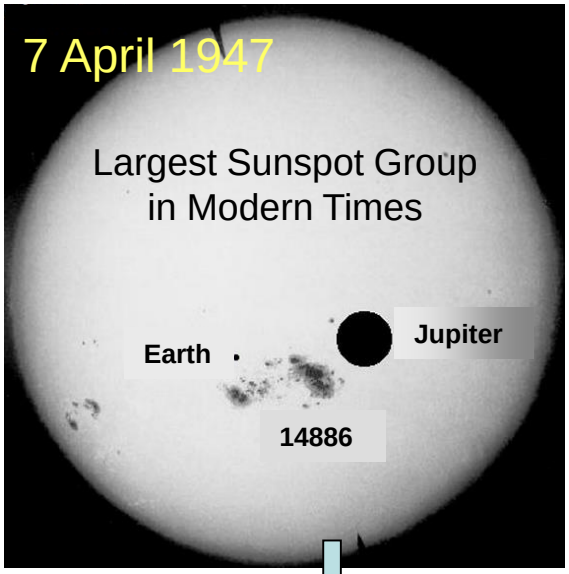


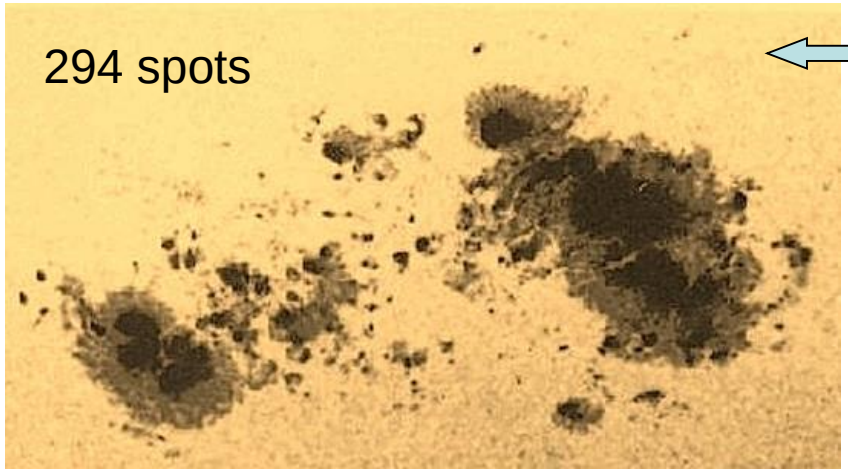


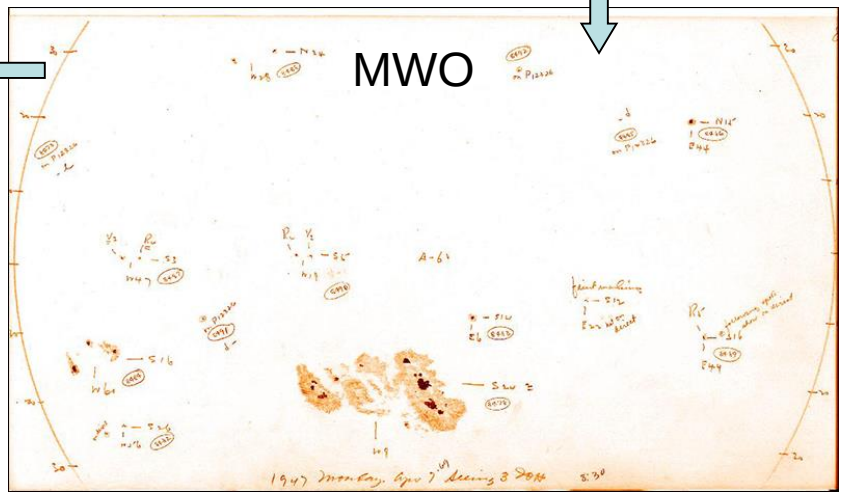
Records of Extreme Sunspots



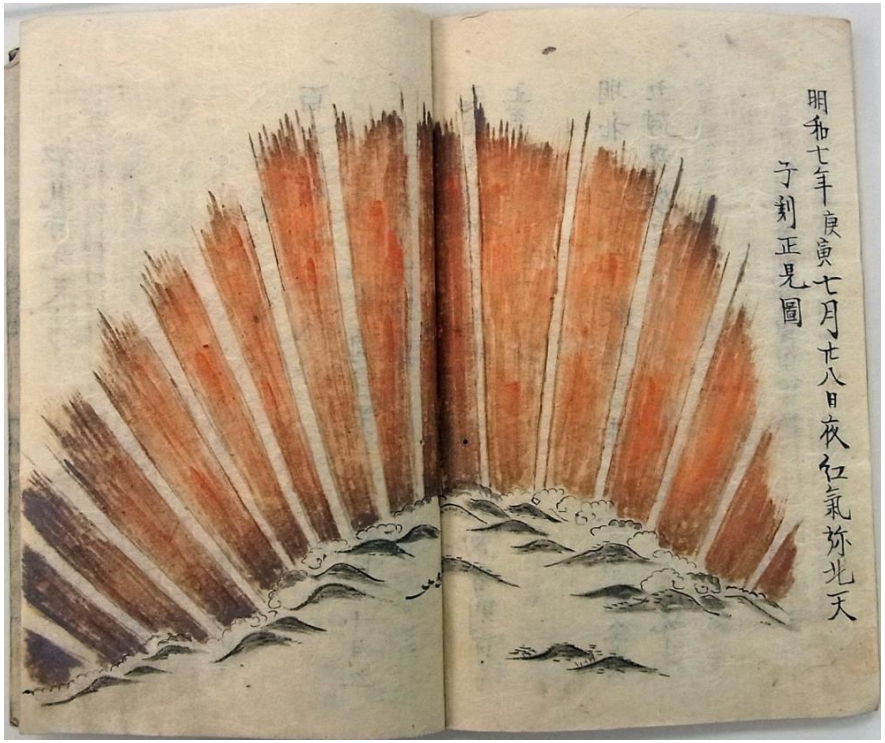




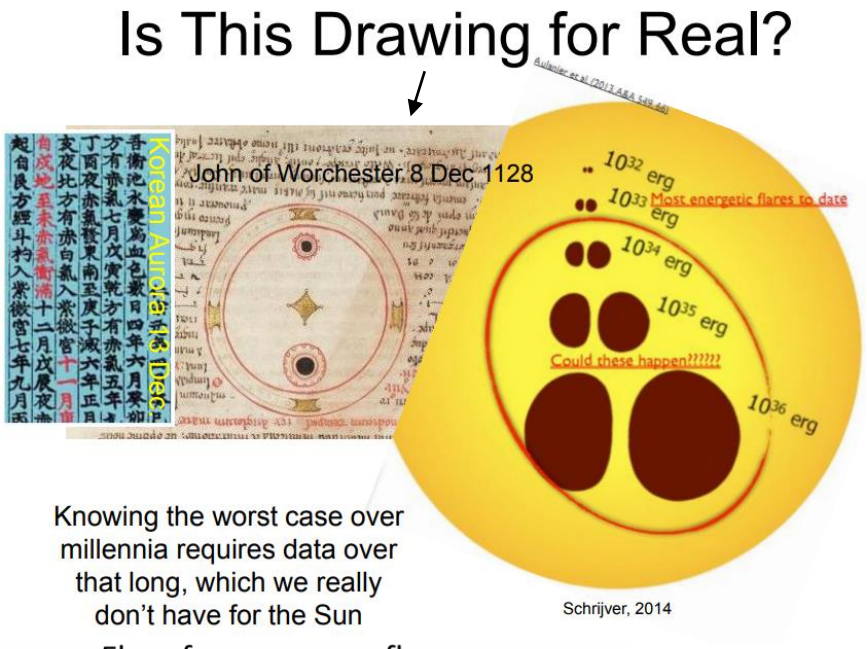


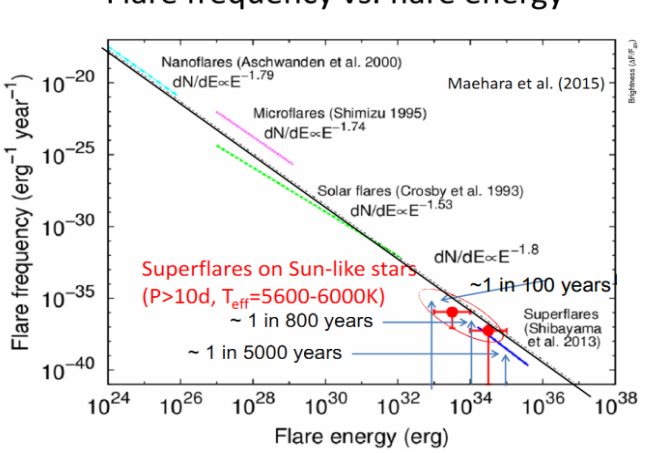


Superflares. Can they Occur on the Sun?



Very rare aurora observed in Japan 17 September 1770

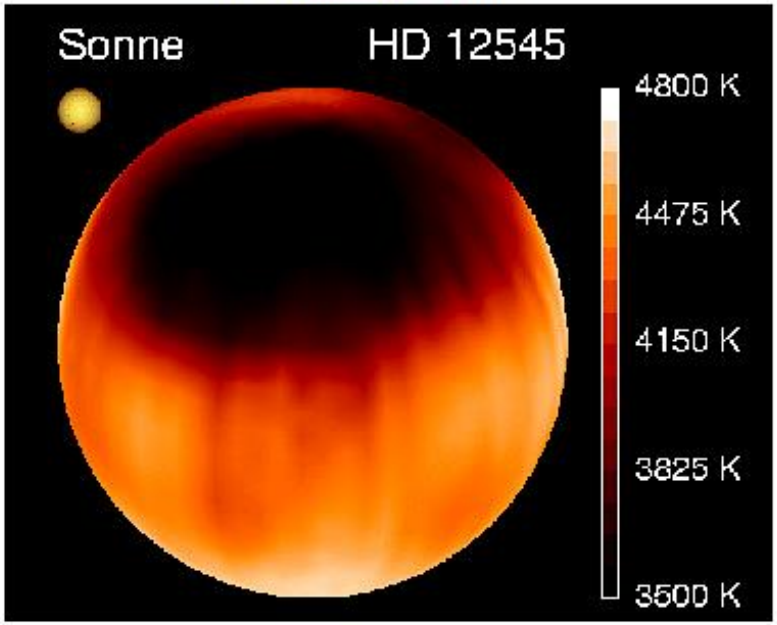


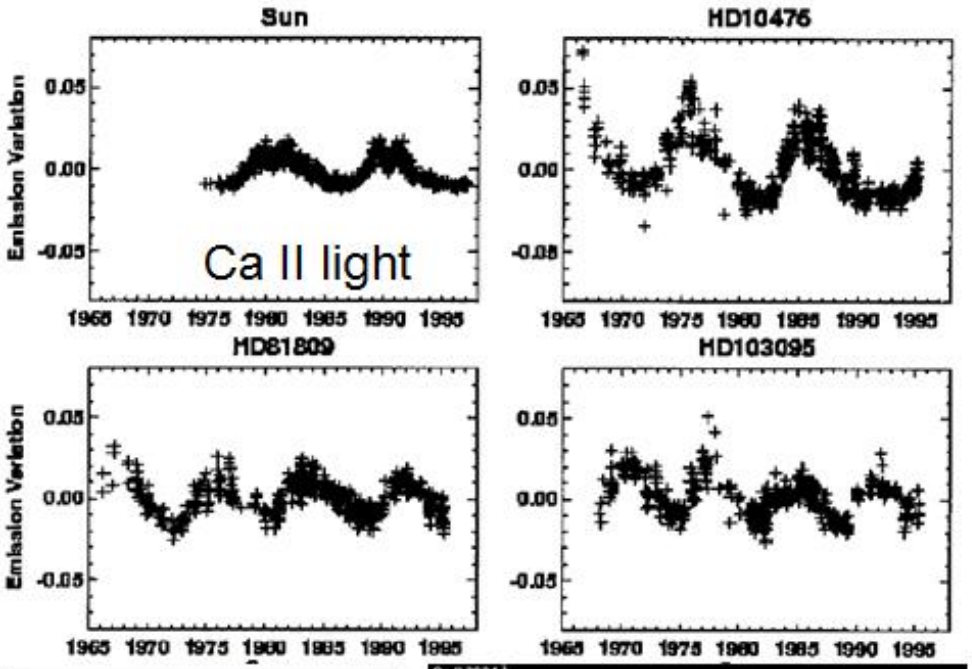


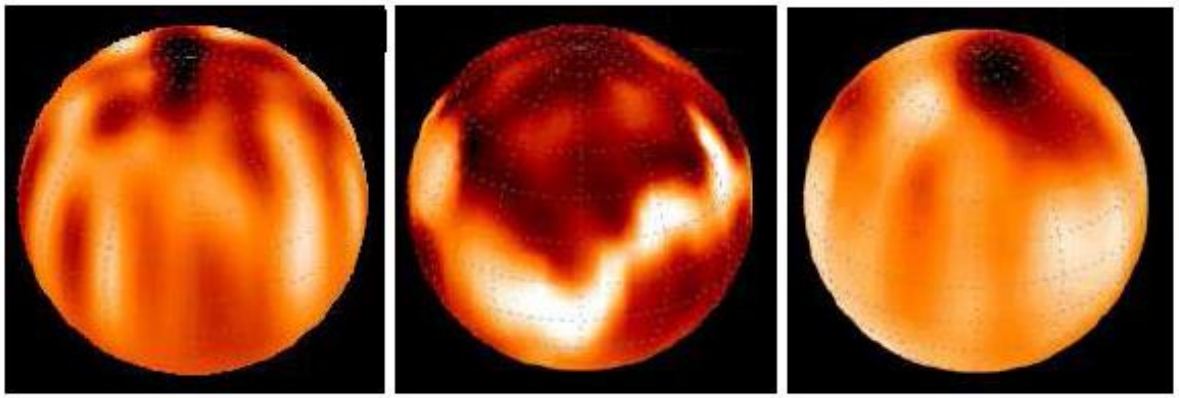
Superflares may just be rare

Stars have Spots too

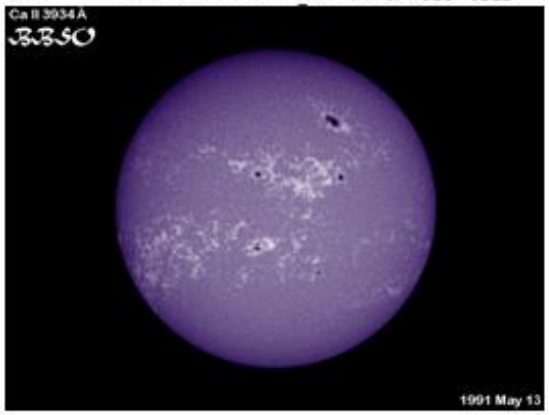
Largest starspot known



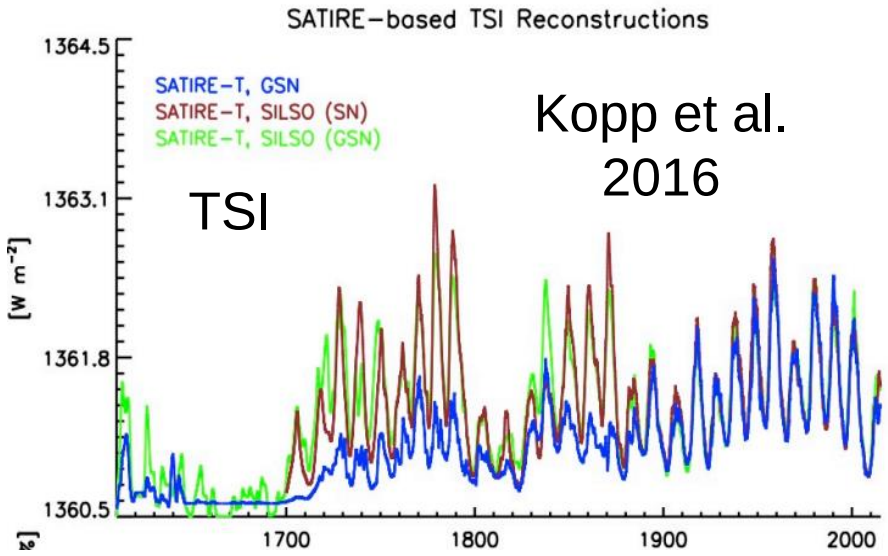


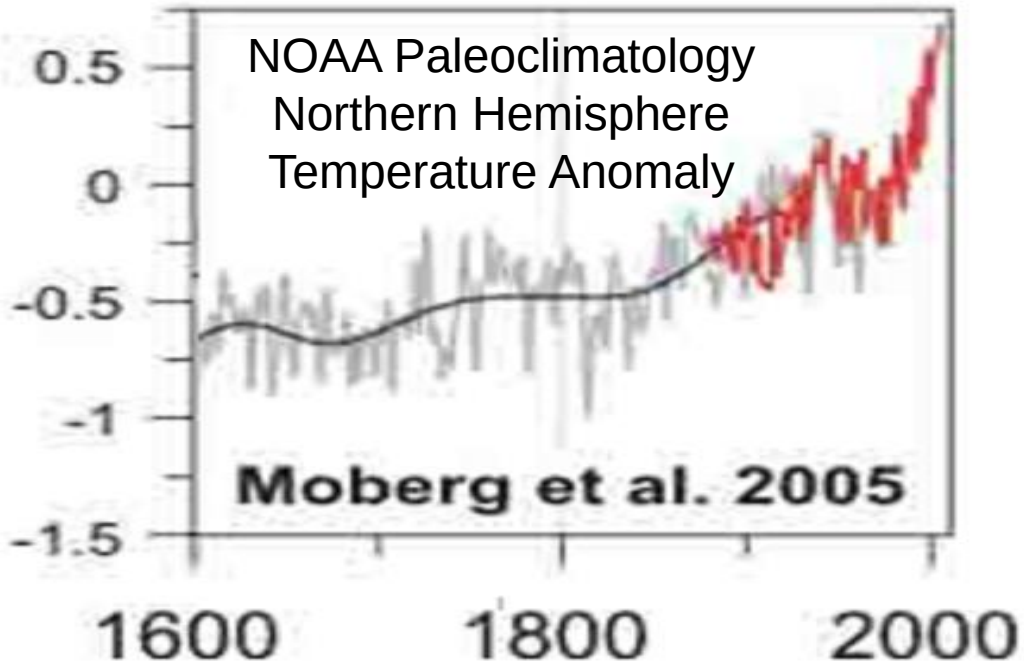


Some other stars



Sun in Ca II light 393 nm

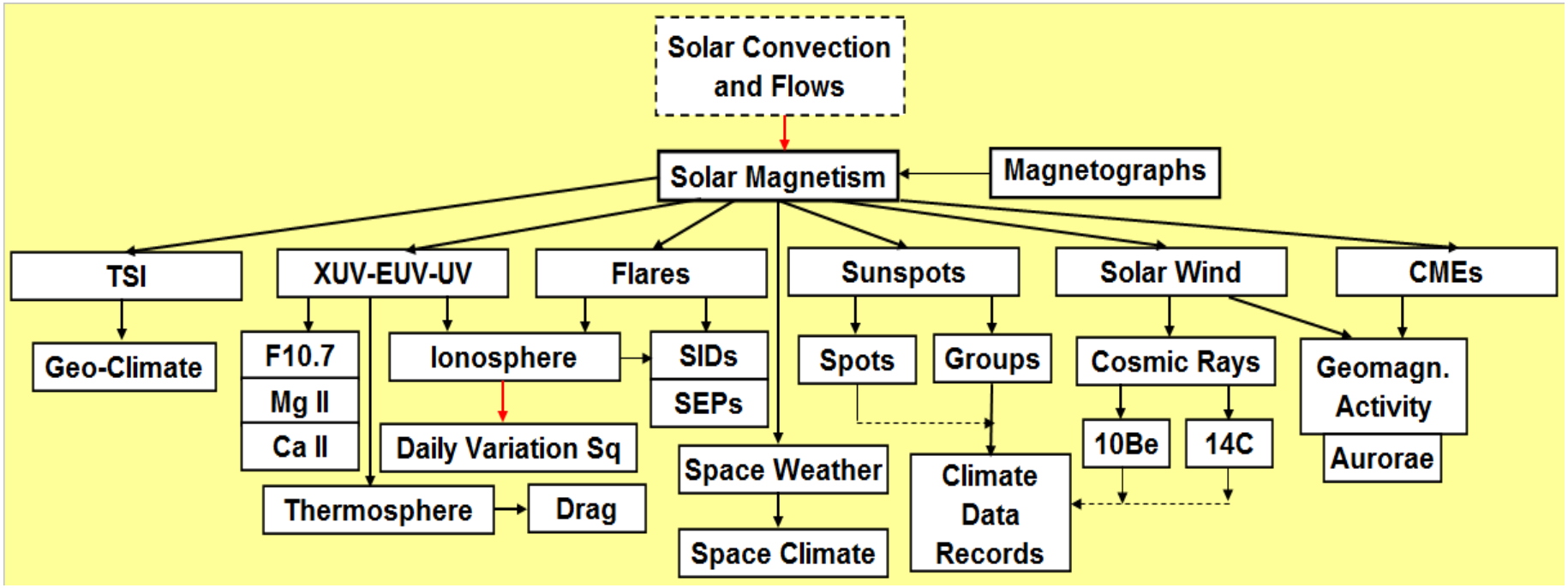




Why Is This Important?

1. The Total Solar Irradiance (output of heat) in the past before satellite measurements is reconstructed from the sunspot numbers and is used as input to climate models
2. Predictions of future solar activity, damaging solar storms, and our general understanding of the sun rely on knowledge about its past behavior

A Systems Approach: Everything Must Fit



Faraday wrote to R. Wolf on 27th August, 1852: “I am greatly obliged and delighted by your kindness in speaking to me of your most remarkable enquiry, regarding the **relation existing between the condition of the Sun and the condition of the Earths magnetism**. The discovery of periods and the observation of their accordance in different parts of **the great system, of which we make a portion**, seem to be one of the most promising methods of touching the great subject of terrestrial magnetism...

Conclusion

Observations with telescopes suffering from the same spherical and chromatic aberrations as we think Staudach's 'sky tube' did, validate the factor of about three that we previously found was needed to normalize the 18th century amateur observations to the modern scale.

We need to continue observing through the coming sunspot minimum to confirm that the factor stays about the same as activity decreases.

The end

Abstract

On Jan. 16, 2016 we started observations of sunspots with replicas of antique telescopes from the 18th century. Four observers have made drawings of the solar disk by projecting the sun onto a sheet of paper. We count the number of individual spots as well as the number of groups they form. We believe our replicas have the same optical flaws as telescopes available and affordable to amateurs in the second half to the 18th century. Comparing our counts with what modern observers report for the same days we find that the sunspot number calculated from the count by modern observers is three times larger as what our intrepid observers see, and that the number of groups is 2.5 times as large. This suggests that we can calibrate the 18th century observations in terms of the modern level of solar activity by multiplying by the above factors. Even as solar activity in the coming years will be low, it is still important to continue our observations to check if the calibration factors are dependent on the activity of the Sun. So we are making a plug for more observers joining us in this endeavor which has great scientific value.