Sunspots with Ancient Telescopes

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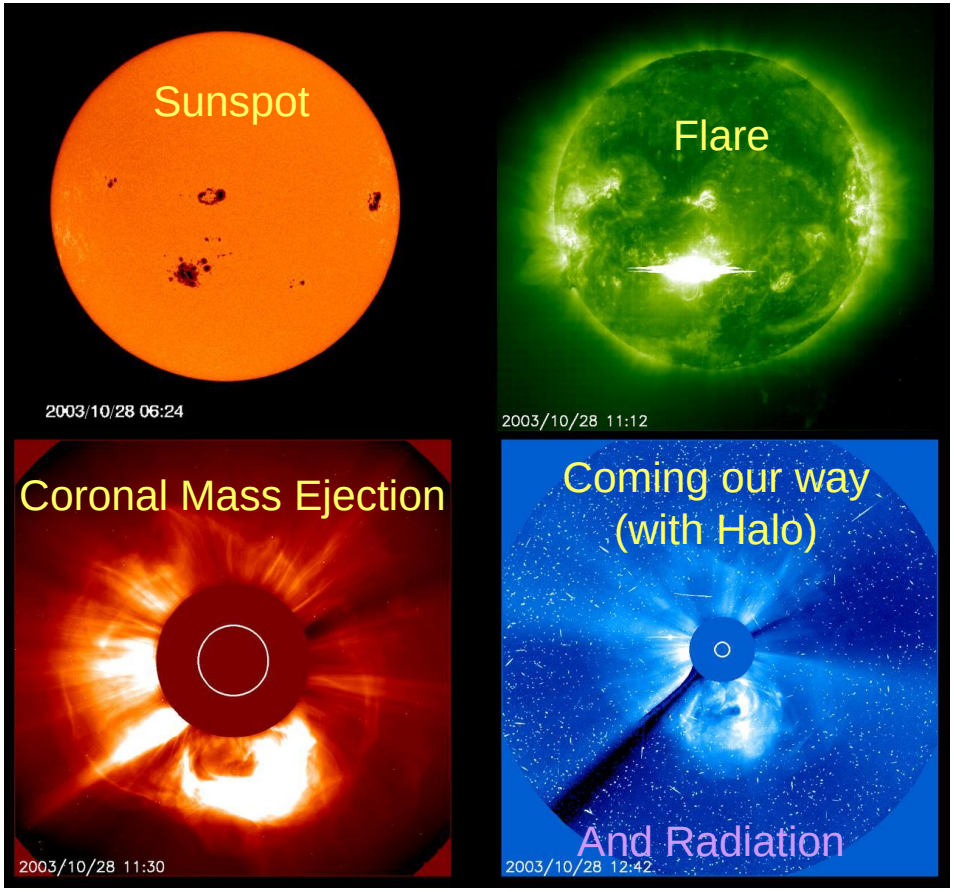
6th Space Climate Symposium, Levi, April 2016
SPD Meeting, Boulder, May 2016
Stanford, June 2016
Mt. Wilson, June 2016

Solar Storms and Consequences

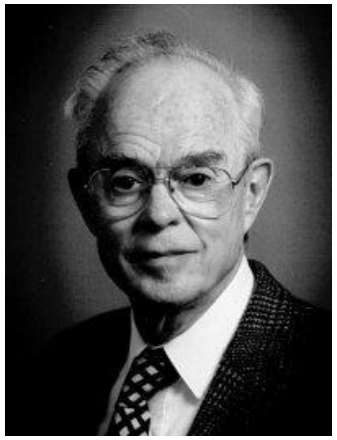
The energy stored in Sunspot Active Regions can be released explosively causing dangerous radiation and plasma hurled into space. If Earth-directed, this ‘debris’ from the explosions can have damaging and disturbing effects on our technological infrastructure



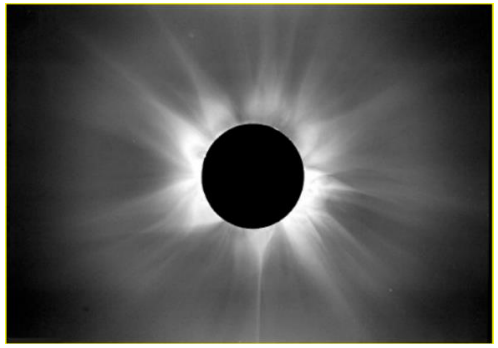
The Solar Wind

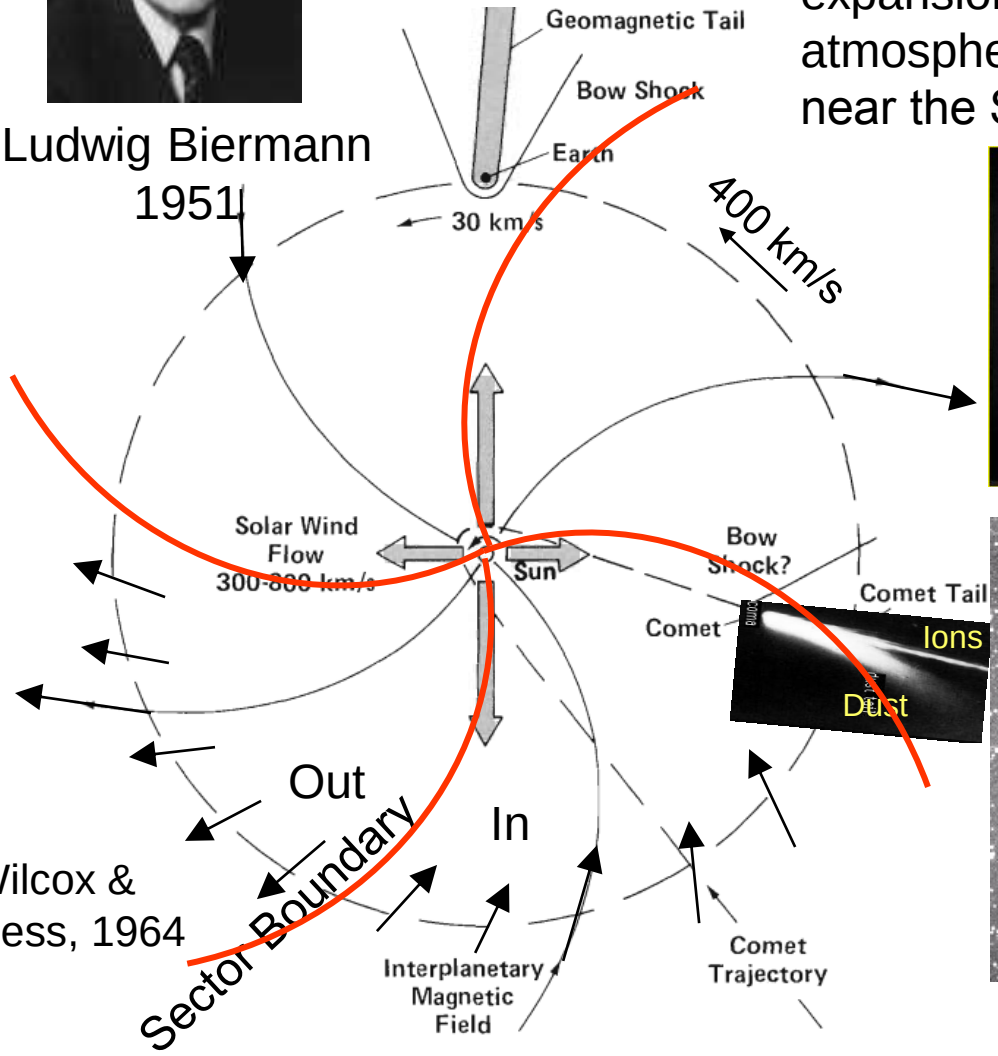
Ludwig Biermann
1951

"Blows" all the time and is the expansion of the extremely hot atmosphere into space, visible near the Sun as the 'Corona':

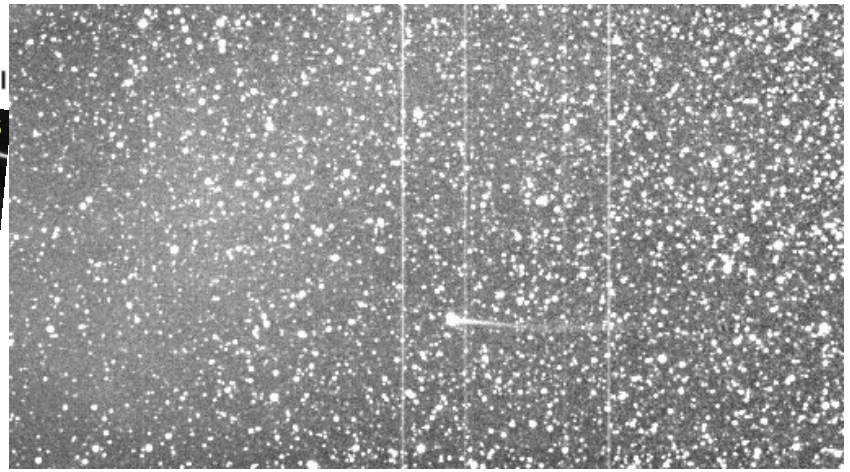


Gene Parker
1958



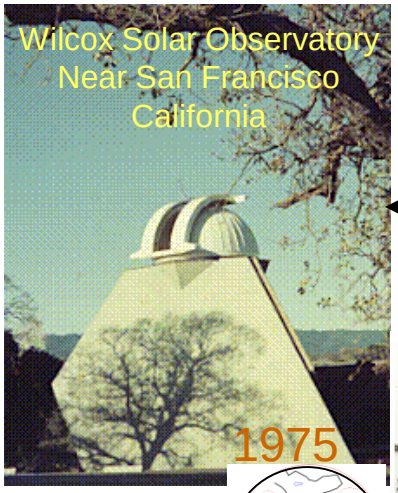


Wilcox &
Ness, 1964

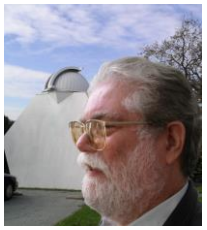


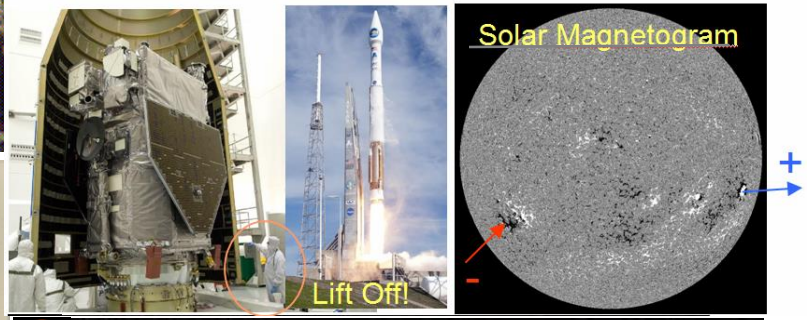
Where Does the Magnetized Solar Wind Come From?

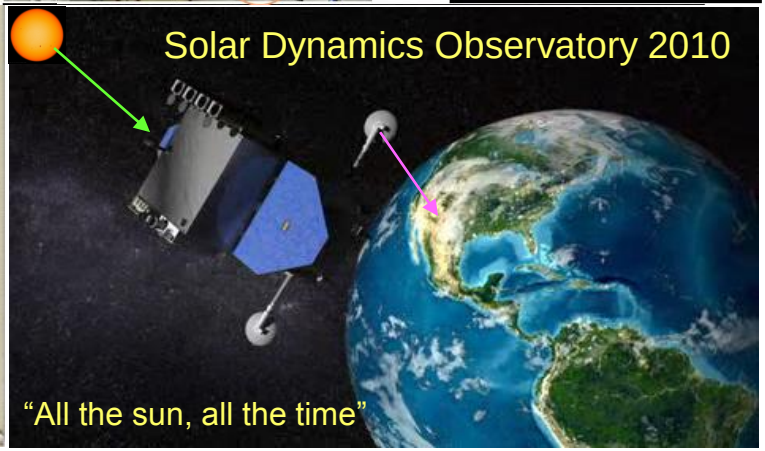
To find out we build Solar Magnetic Field Observatories !



So, we go to sunny California to study the Magnetic Sun

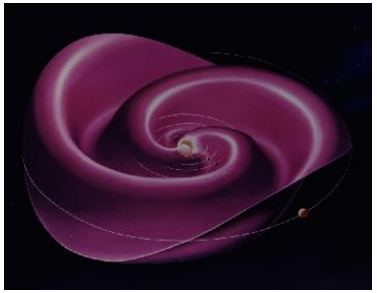


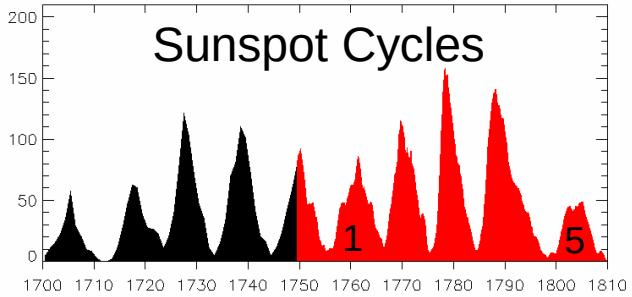


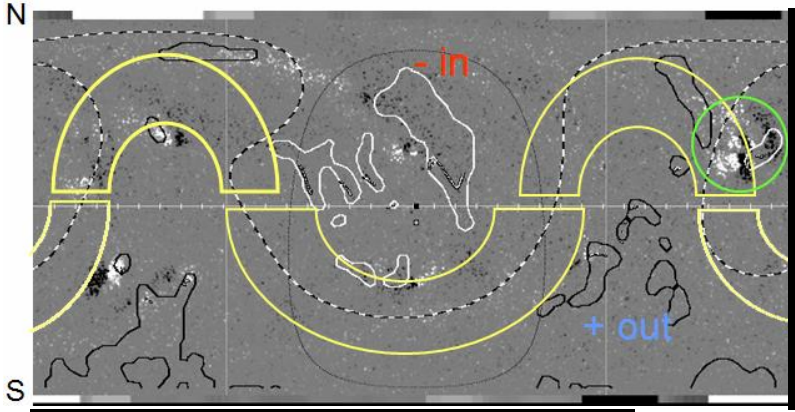


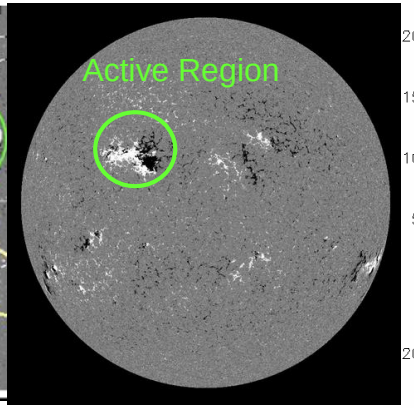
The 11-yr Solar Cycle

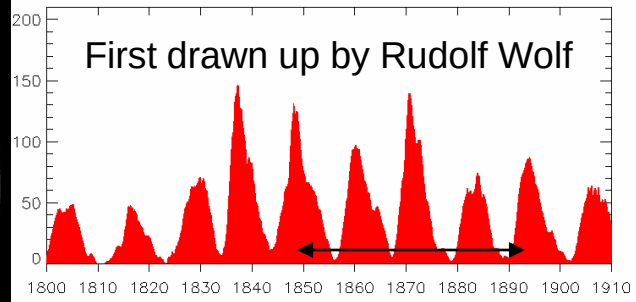
An ‘Active Region’ = Lots of Magnetic Fields

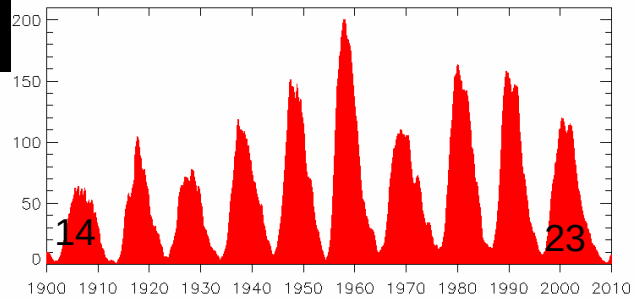


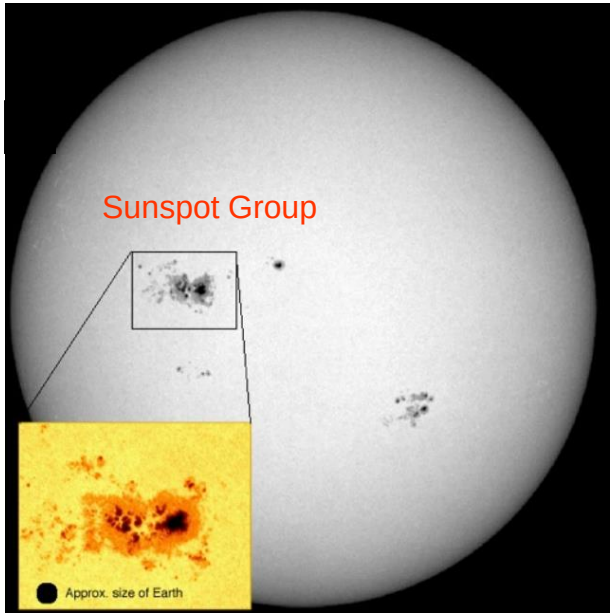


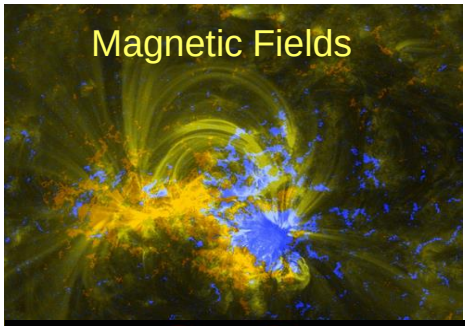


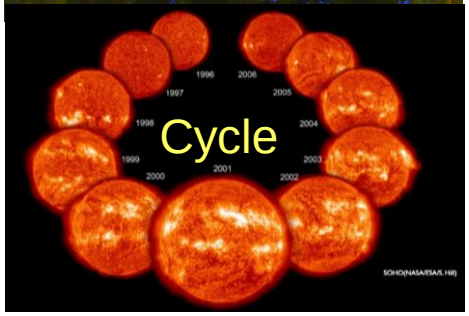


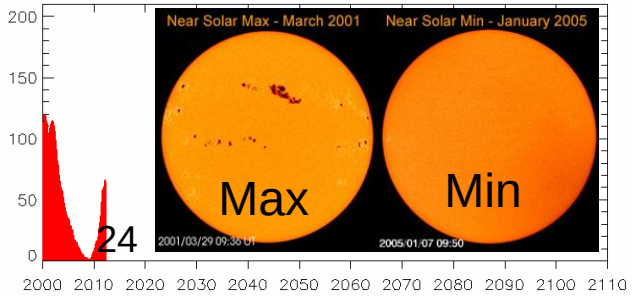






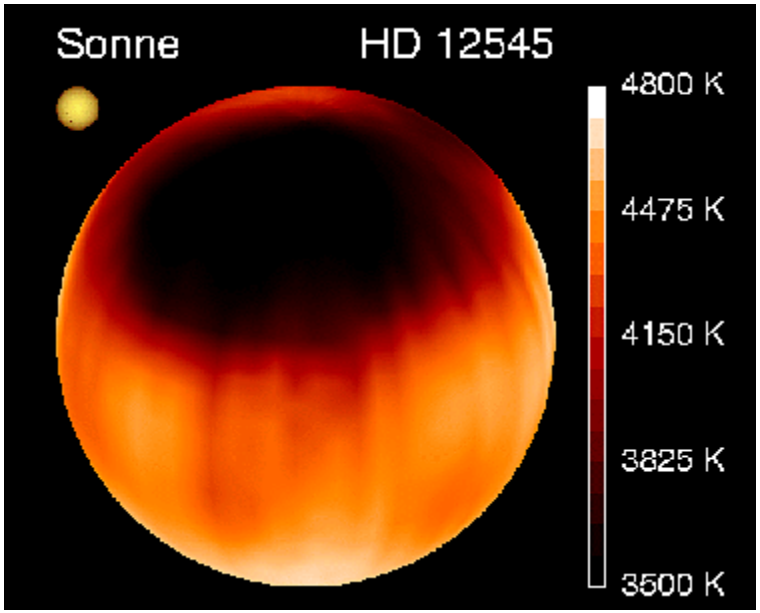


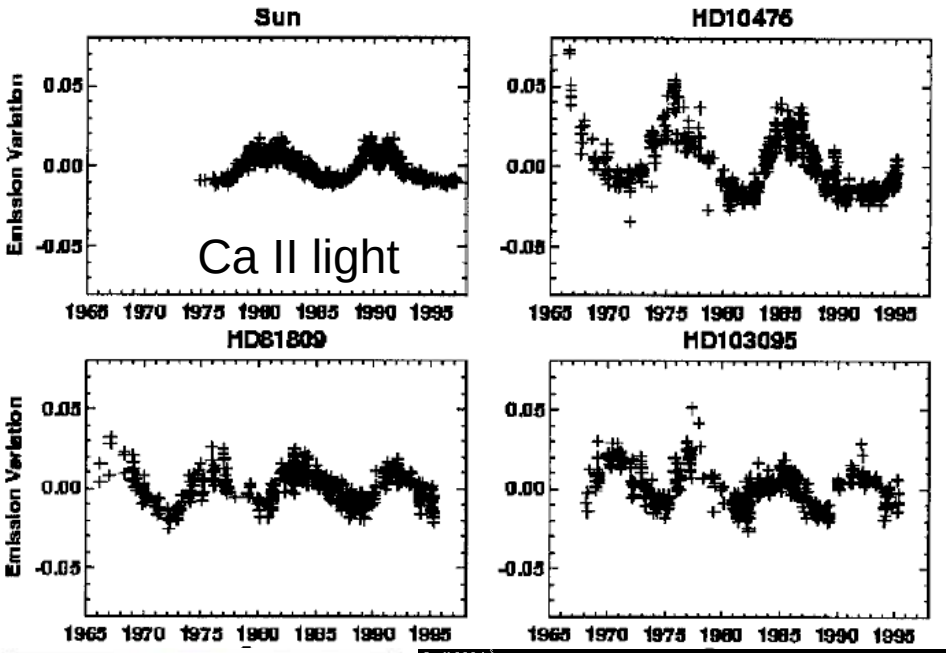


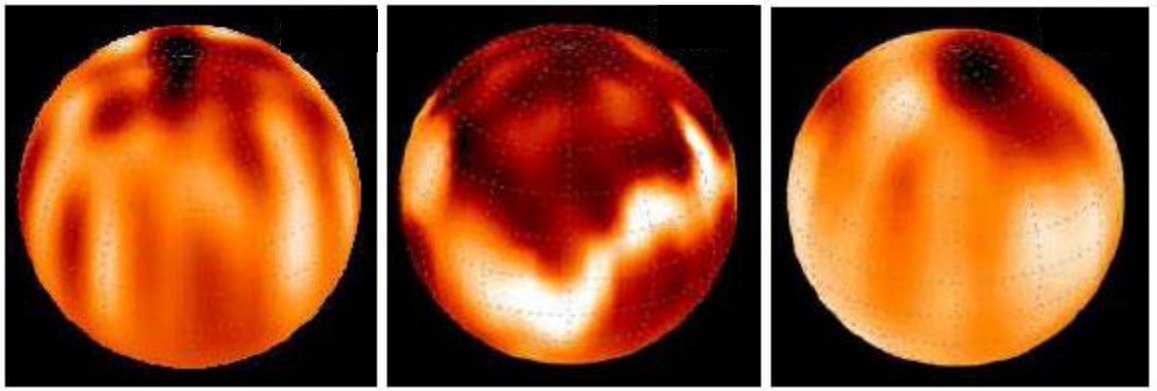


Stars have Spots too

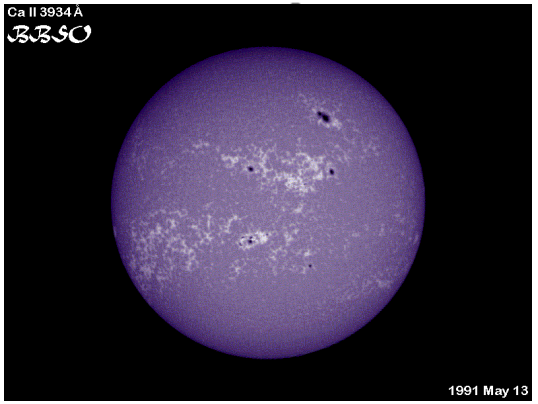
Largest starspot known







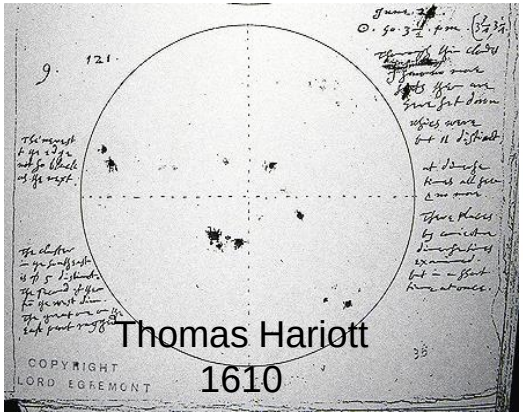
Some other stars

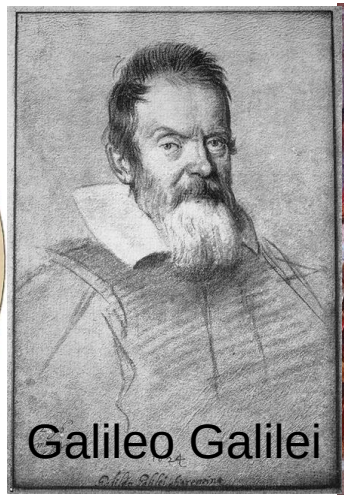


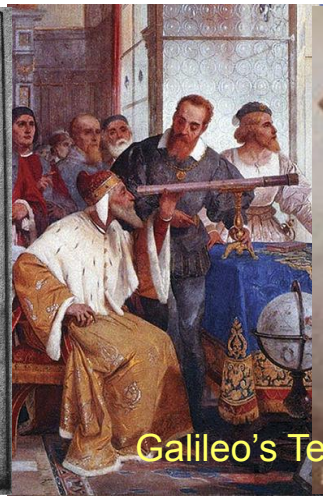
Sun in Ca II light 393 nm

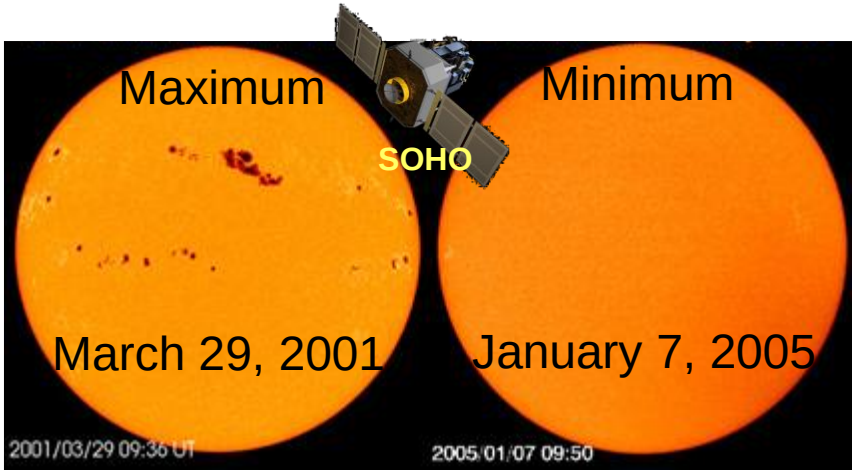
Centuries of Sunspot Observing

We have observed sunspots with telescopes for 400 years

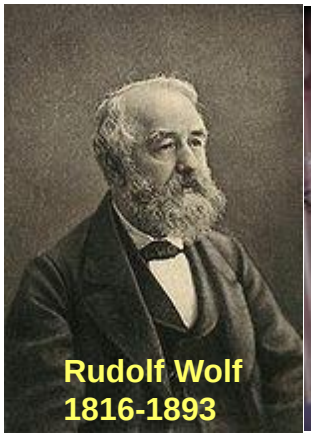








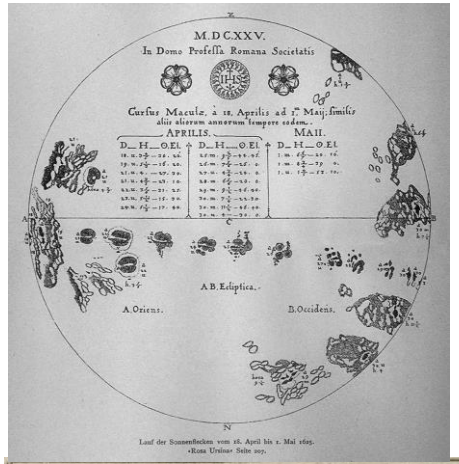
Sunspots observed by Spacecraft



'Compiler' of Sunspot Number

Still used today

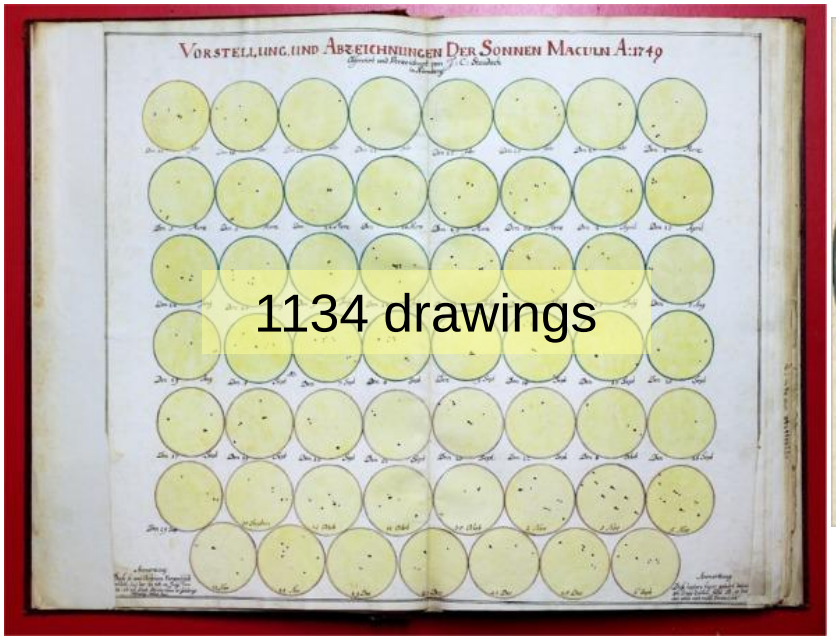
The sunspot number is always determined using small telescopes



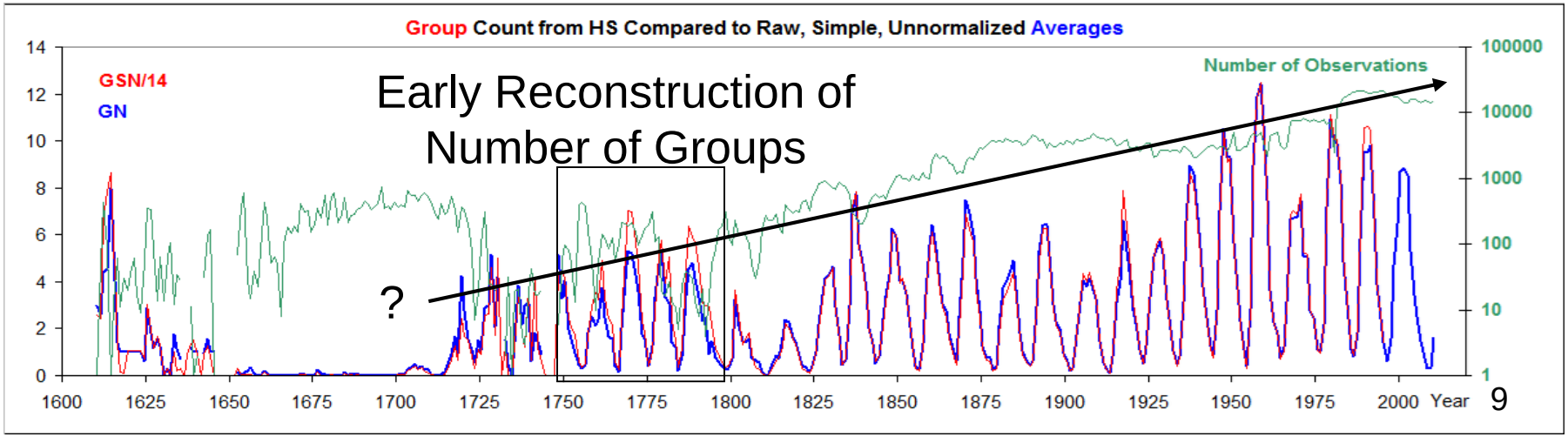
Christoph Scheiner
Rosa Ursina, Anno1630

Helioscope: Projecting the Solar Image

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



13th & 15th February 1760



We are Hostages to the Drawings

The drawings are today stored in the library of the Astrophysikalisches Institut Potsdam, Germany, and are in very good condition. Arlt (2008) has recently photographed the drawings, one by one. Arlt also draws some inference about the telescope used by Staudach. In the material there is a single mention of a telescope (18 February 1775: "when I turned round with my 3-foot sky tube…") hence we may assume that the focal length of the telescope was 3 feet. Achromatic telescopes with a focal length of 92 cm were manufactured by John and Peter Dollond from the late 1750s. With such an (expensive) telescope, however, the distinction between umbra and penumbra should have been possible, and the Wilson effect (elongated spots near the limb) should have been visible. Both were not noted and not drawn by Staudach (using projection onto a sheet of paper).

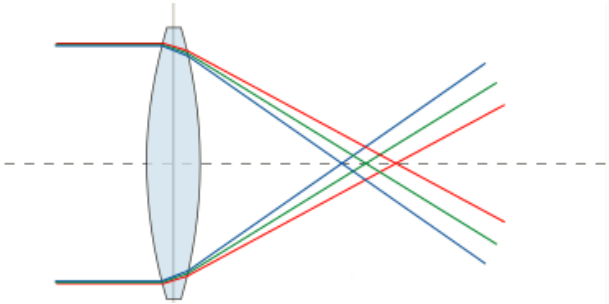
An average telescope used by an amateur at the time probably suffered from fairly strong spherical aberration. Because of a couple of mirrored solar-eclipse drawings, Arlt (2008) suggests that Staudach was using a Keplerian refractor with a non-achromatic objective and that he most likely missed all the tiny A and B spot groups (according to the Waldmeier (1938) classification). Such groups make up 30-50% of all groups seen today. To convert a group count without A and B groups to a full count of groups of all classes, one must thus multiply by 1.65. Taking into account that Staudach's telescope likely suffered from both spherical and chromatic aberration, the actual factor is likely to be somewhat larger. But we don't know how much larger, and **that is the problem**

The Project

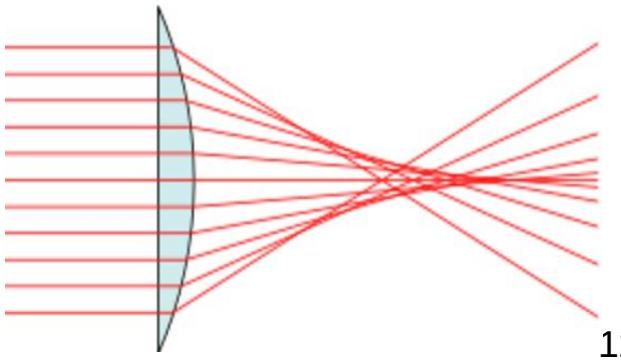
- Find telescopes (from the 18th century or build replicas) with similar characteristics as Staudach's
- Find people willing to observe, i.e. make drawings of what they see (high precision of positions not needed)
- Make systematic observations over some time (many months) perhaps at least one drawing per week, better daily
- If we can find several people, they can share the load (and also make it possible to assess the 'error bar')
- Scan the drawings and communicate them to me (leif@leif.org). Website: http://www.leif.org/research
- I'll process the drawings and produce a scientific paper with the observers as co-authors publishing the result
- Benefits: Exposure of ATS (Antique Telescope Society) and providing an important calibration point for the Sunspot Series (real science)
- First observation 14 January, 2016
- Continuing… (140 days with 185 drawings, so far – June 24th, 2016).
- Observing sunspots is addictive. One observer reported having 'withdrawal symptoms' after a week of overcast prevented observations !

A Telescope from About 1730-1750

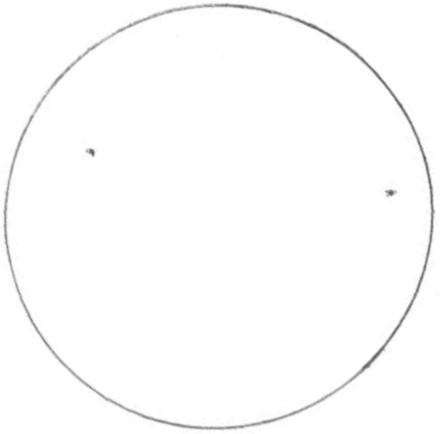
Chromatic aberration



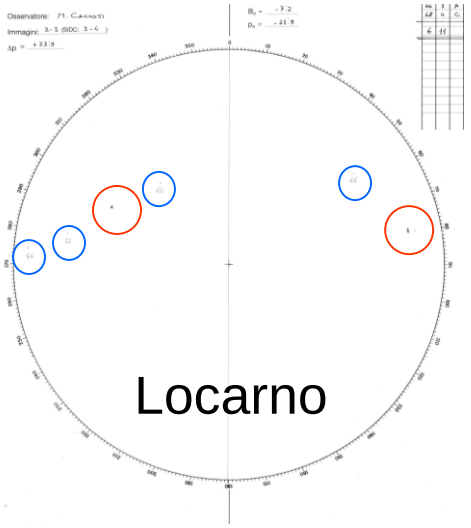
Spherical aberration



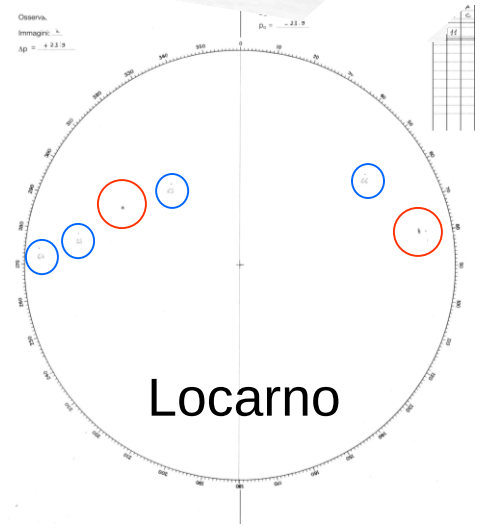
John W. Briggs, Magdalena, NM



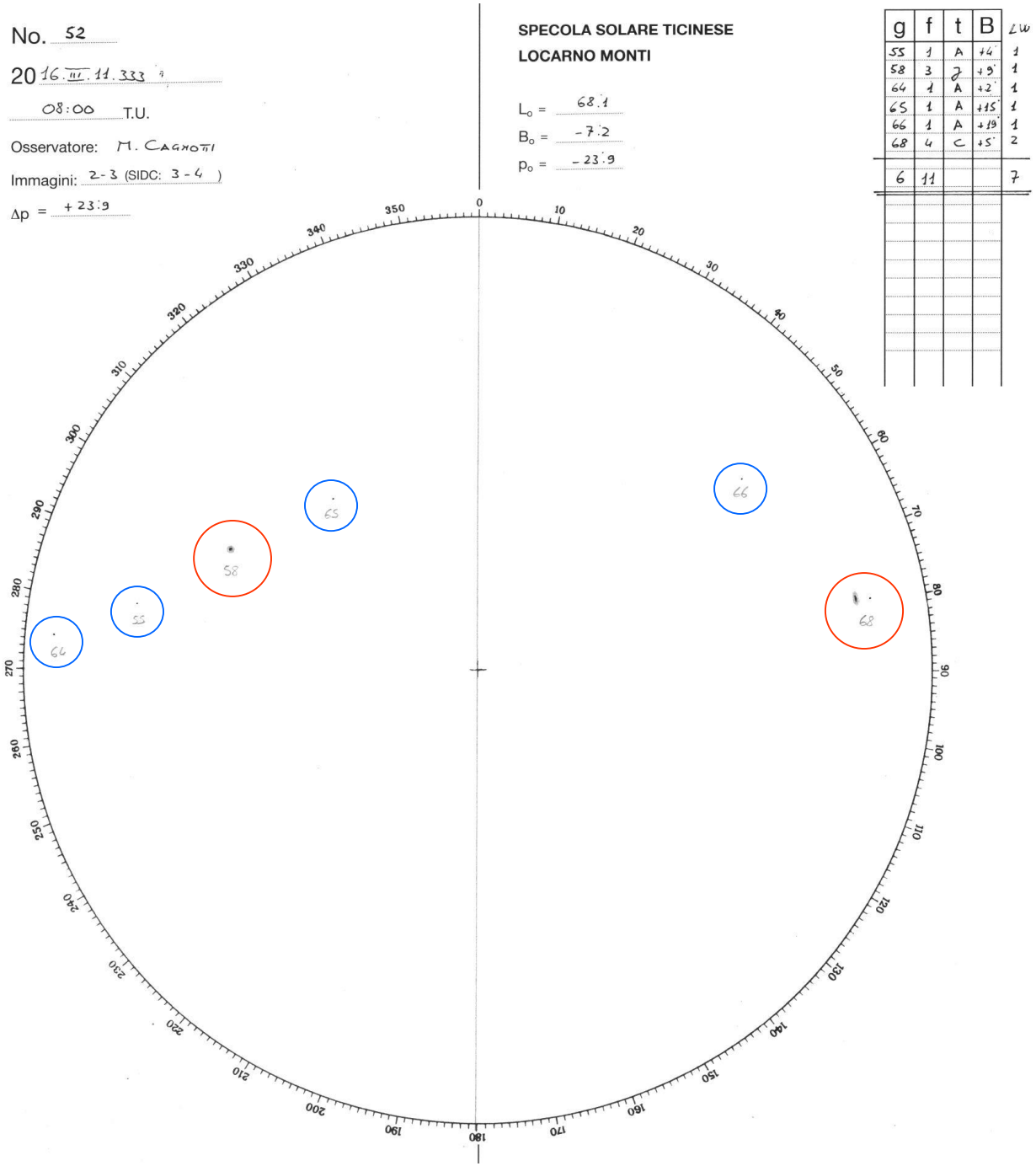
2016-03-11

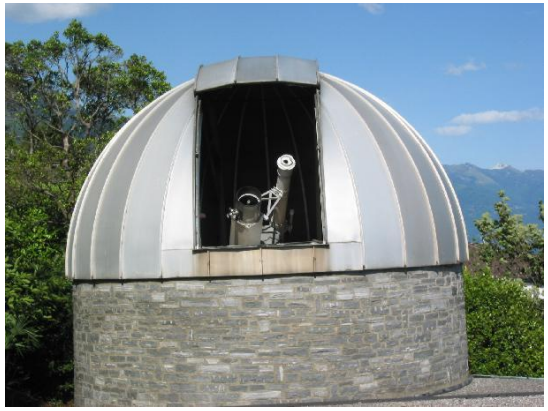


Ken Spencer, Sea Cliff, NY



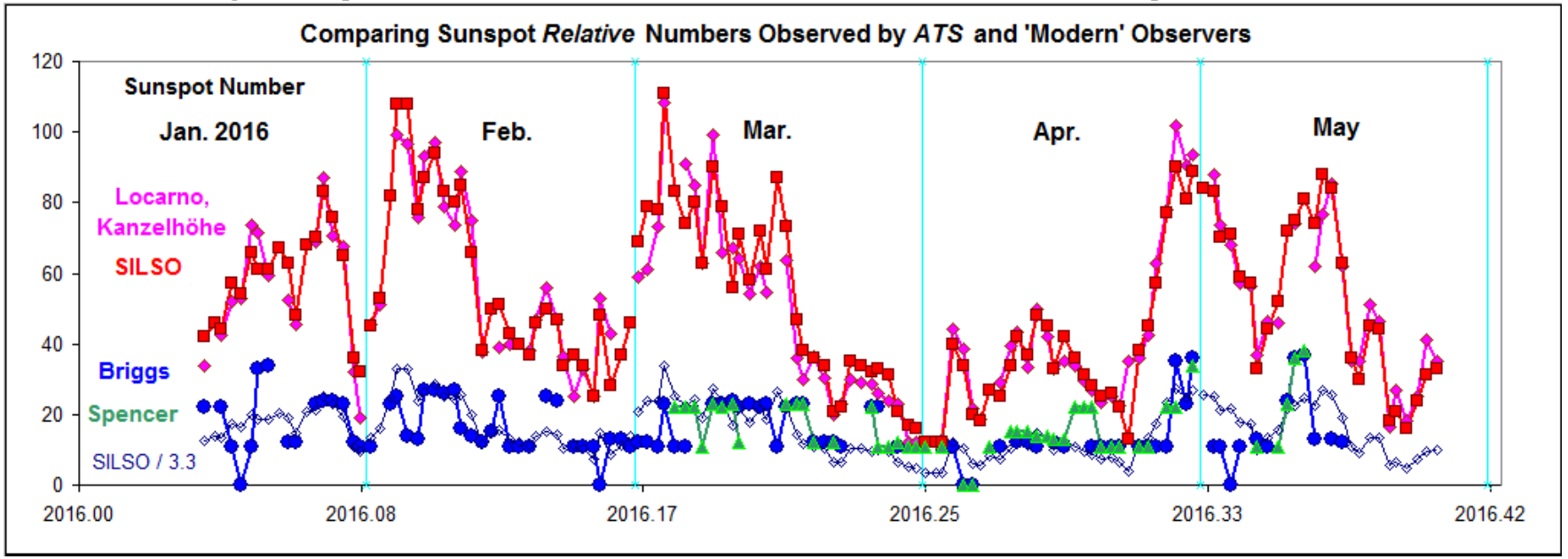
Locarno 2016-03-11

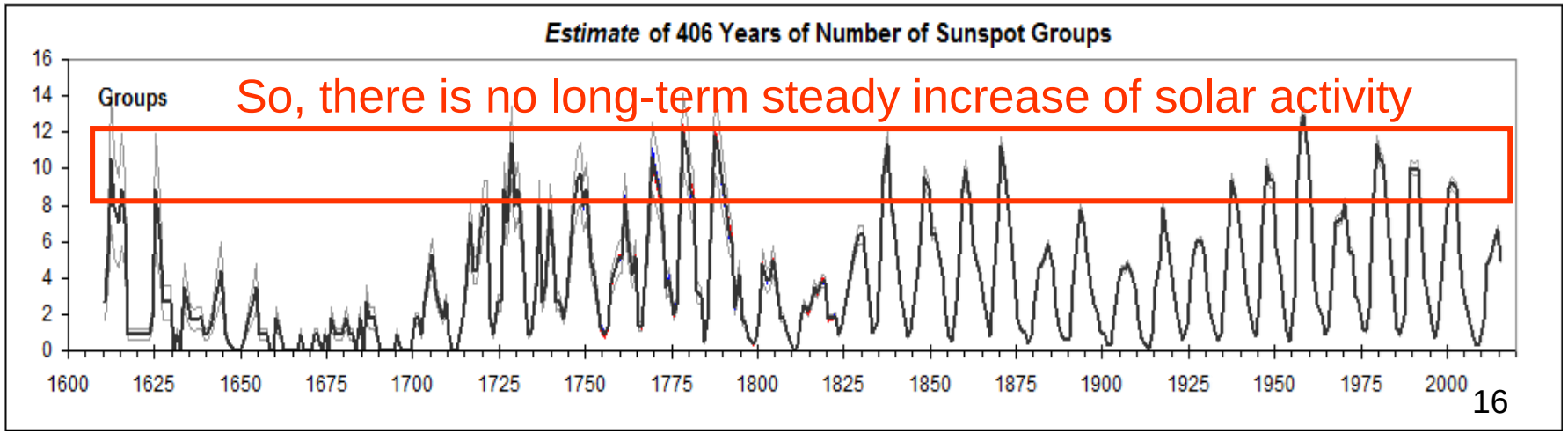




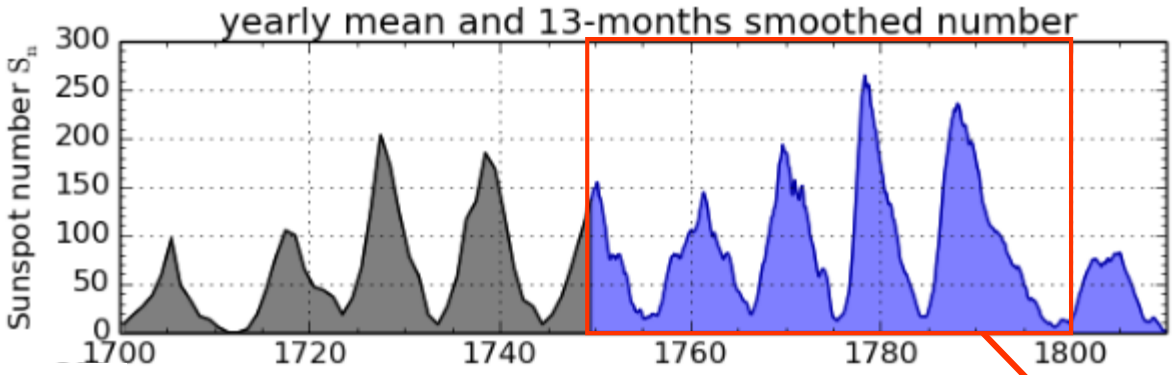
Briggs, Spencer, and (importantly) Staudach simply could not see the tiny groups (in blue circles) with their inferior telescopes

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

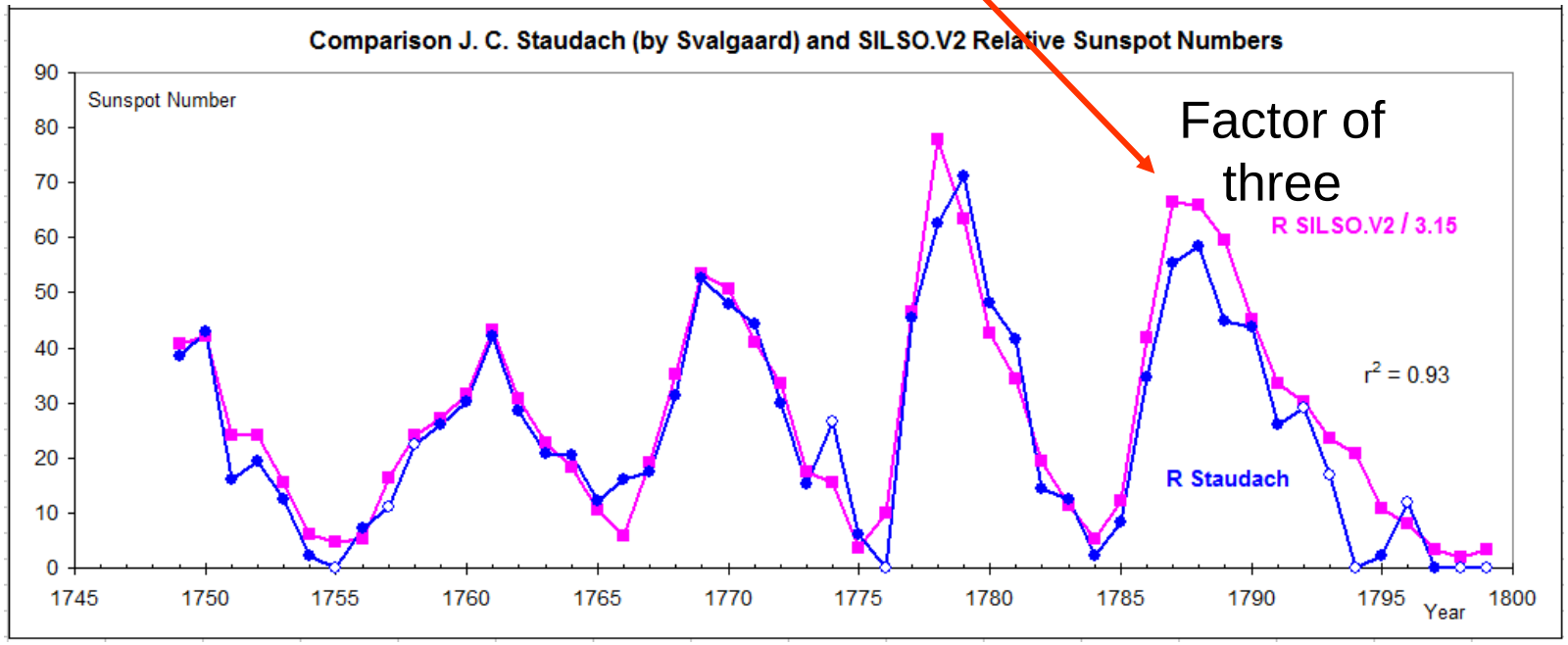


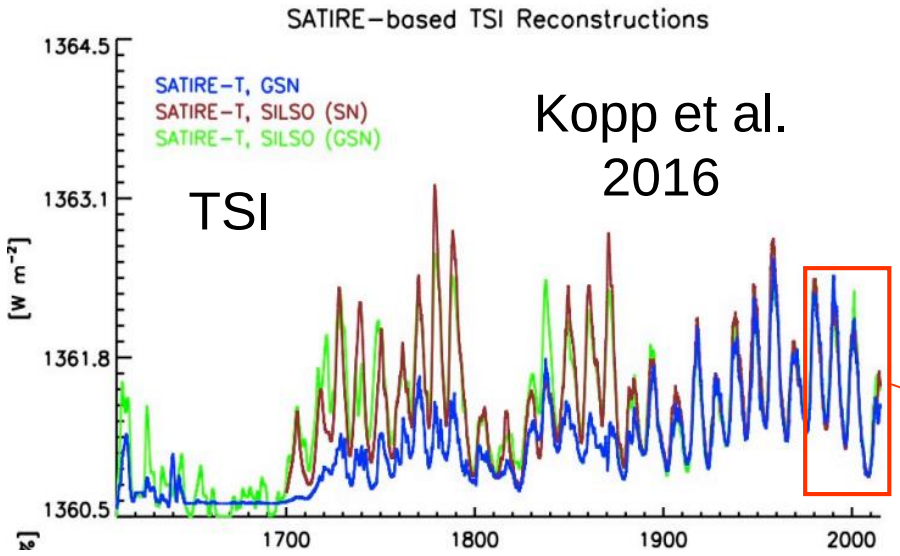


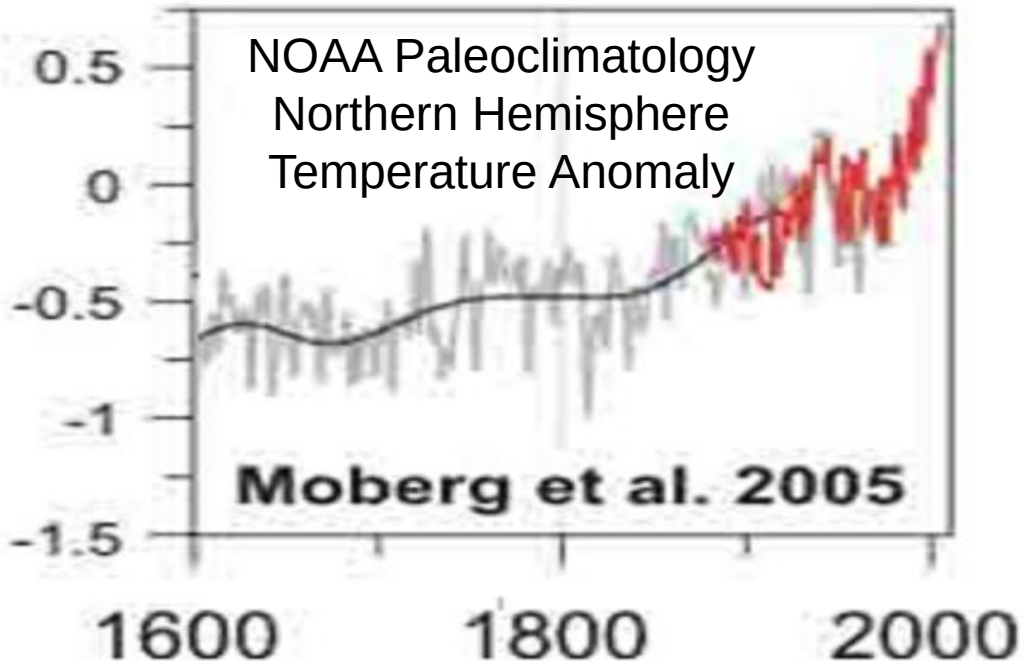
Our Project has Confirmed the ‘New Sunspot Number Series’



A recent revision (Clette et al. 2014) of the Sunspot Number is nicely validated by our observations







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

Science Highlights from Solar Physics Division Meeting 2016

The Sun is a magnetic star. Its magnetic field affects Earth, by causing space weather that affects our technology. Understanding its formation and effects gives rise to some of the most challenging scientific problems of our time. We present four different exciting advances in the search to understand the consequences and origin of the Sun's magnetic field.

First, an exciting new result about the origins of hard-to-predict "Stealth CMEs" that can launch from the Sun and impact Earth without an obvious signature at the surface.

Next new insights into the formation of sunspots, produced via strikingly beautiful simulations of the flows inside the star.

Third, understanding the long-term evolution of the Sun's magnetic field drove one team of scientists to recreate 18th century telescopes in the modern era.

Finally, in the 21st century the titanic four-meter-diameter solar telescope DKIST is nearing completion and will enable new observation of solar magnetism at the very finest scales.

Boulder, June 2016

Conclusions

- 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, and hence that there has been no steady increase of solar activity
- One could even try to replicate Galileo's and Scheiner's observations…