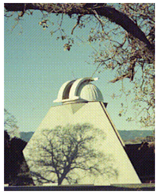

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leif@leif.org

Several Populations of Sunspot Group Numbers – Resolving a Conundrum

Leif Svalgaard, Stanford University

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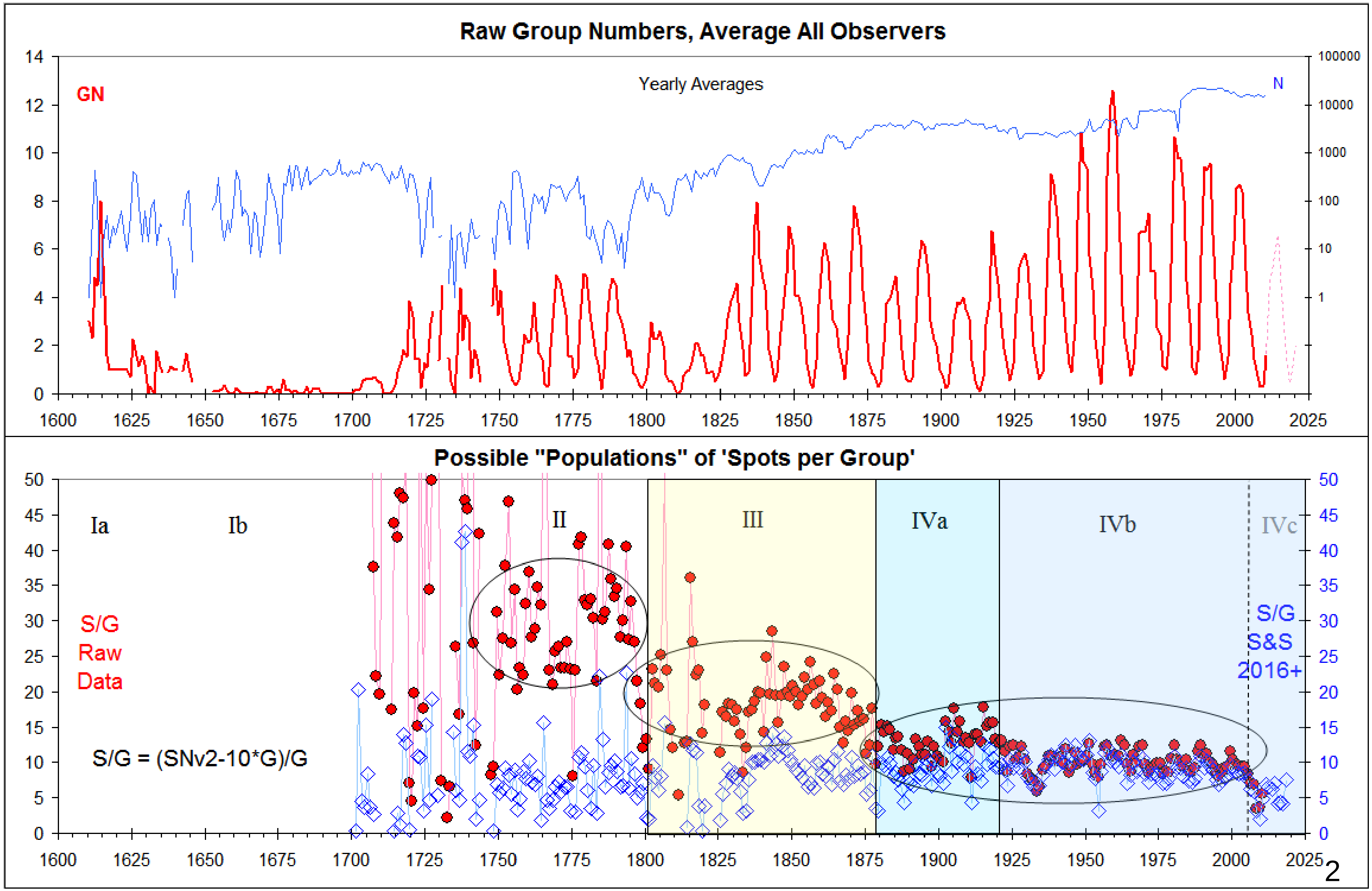
We argue that sunspot observations constitute several distinct *populations* with different properties which explains and enable *correction* of the various discontinuities in the sunspot group series. This is supported by several proxies: diurnal variation of the geomagnetic field, geomagnetic signature of the strength of the heliomagnetic field, and variation of radionuclides.

(Top) Yearly values of the number of groups averaged over all observers (red curve) without any normalization (i.e. ‘raw’ data). The blue curve shows the number of observations in each yearly average. (Bottom) Yearly averages of the number of spots per group calculated using the ‘raw’ average group numbers (red points) and the Svalgaard and Schatten (2016) group numbers (blue open diamond symbols).

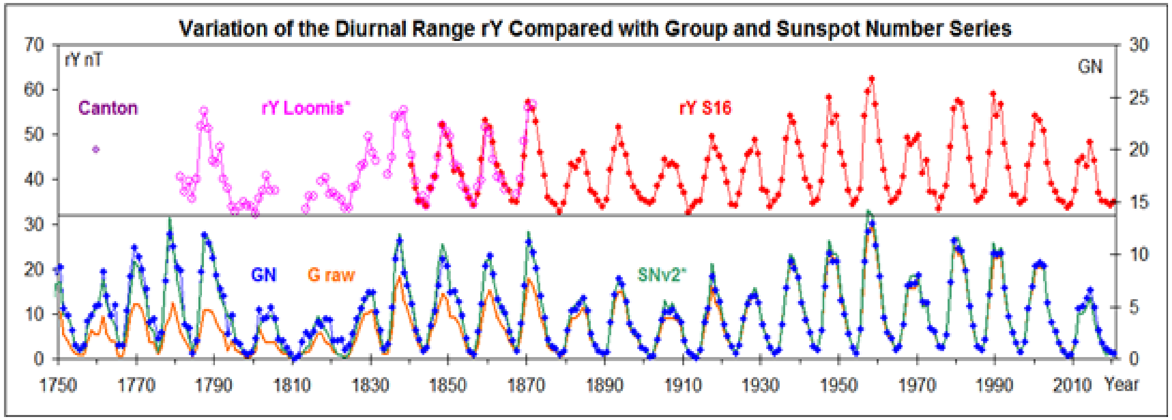


Populations of Solar Observations

We showed in the bottom panel of Slide 2 the ratio P = S/G = (SNv2 – 10×G)/G for the two choices of G ('raw' red; S&S blue). Ideally, the blue data points should all cluster around the same value (about or slightly lower than 10). They do not quite, but are close enough for our purpose here. On the other hand, the P-ratios for the raw averages of all observers cluster roughly in the three ovals shown in Figure 1 (apart from the earliest values with their large scatter). We shall refer to these different 'regimes' as different Populations of sunspot observations. Here we assume with Galton (1907) the usefulness of the "Wisdom of Crowds" to deal with observers of a common phenomenon, laboring under circumstances similar within populations, but different between populations (e.g. major improvement of instruments, such as the advent of cheaper achromatic lenses). We posit the existence of four major populations (I through IV; the first, during the Maunder Minimum (1645-1700), being totally conjectural at this point) with possible (speculative) sub-populations (a, b, … that are not the main focus of the present presentation). The P-ratio for populations II, III, and IV are approximately 30, 20, and 10, respectively (ignoring small differences between sub-populations). At first glance it seems strange that the ratio decreases with time, as instruments were supposed to get better with time. The reason is, of course, that the Zürich Compilers already strove to compensate for changing instruments and counting methods in their construction of the sunspot number, so P must be dominated by an artificial secular increase of the number of groups (being in the denominator), either reported by the observers or determined from their drawings of the spots on the disk. This conclusion hinges on the assumption that the sunspot number series (v2) is, at least, approximately 'correct', that is: a good indicator of solar 'activity', by which we today generally mean manifestations of the 'solar magnetic field'.

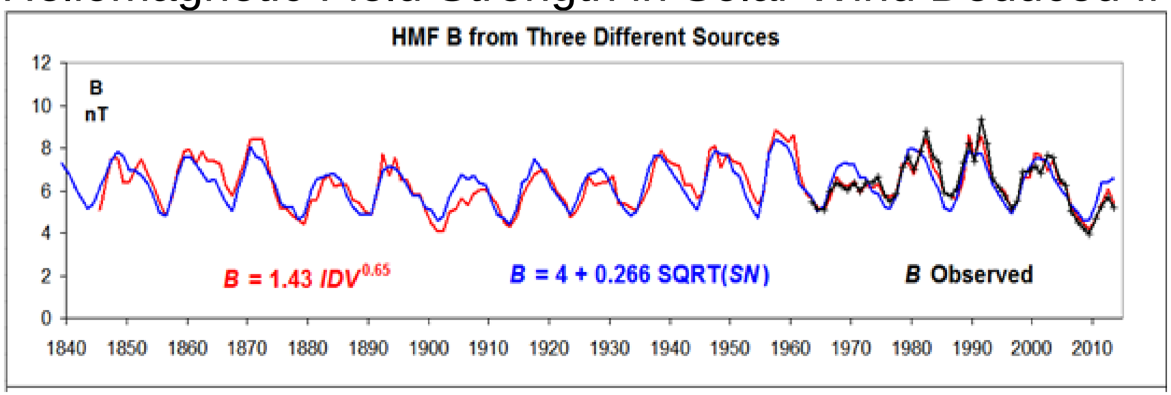
Proxies for the Solar Magnetic Field

Solar Extreme Ultraviolet Radiation and the Diurnal Variation of the Geomagnetic field



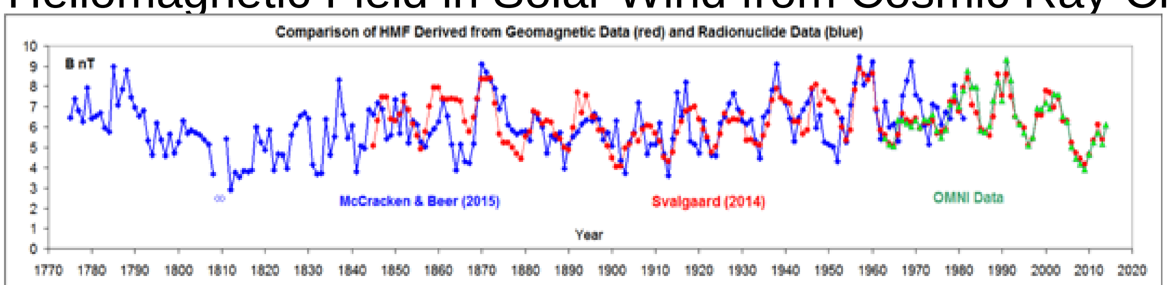
Graham (1724) discovered that the angle between the horizontal component of the geomagnetic field and true north, varied through the day. Wolf (1852) and Gautier (1852), found it to vary with the number of sunspots. Here are yearly values of the diurnal range, *rY*, of variation of the East Component of the geomagnetic field as determined by Canton (1759), Loomis (1870), and Svalgaard (2016)

Heliomagnetic Field Strength in Solar Wind Deduced from Geomagnetic IDV-index



Heliospheric magnetic field, *B*, near the Earth inferred from the IDV-index (red curve), from the sunspot number (v2, blue curve), and observed by spacecraft (OMNI data, black curve). The IDV-index measures the energy content of the Van Allen Belts around the Earth (the ‘Ring Current’) depending directly on the strength of the solar wind magnetic field.

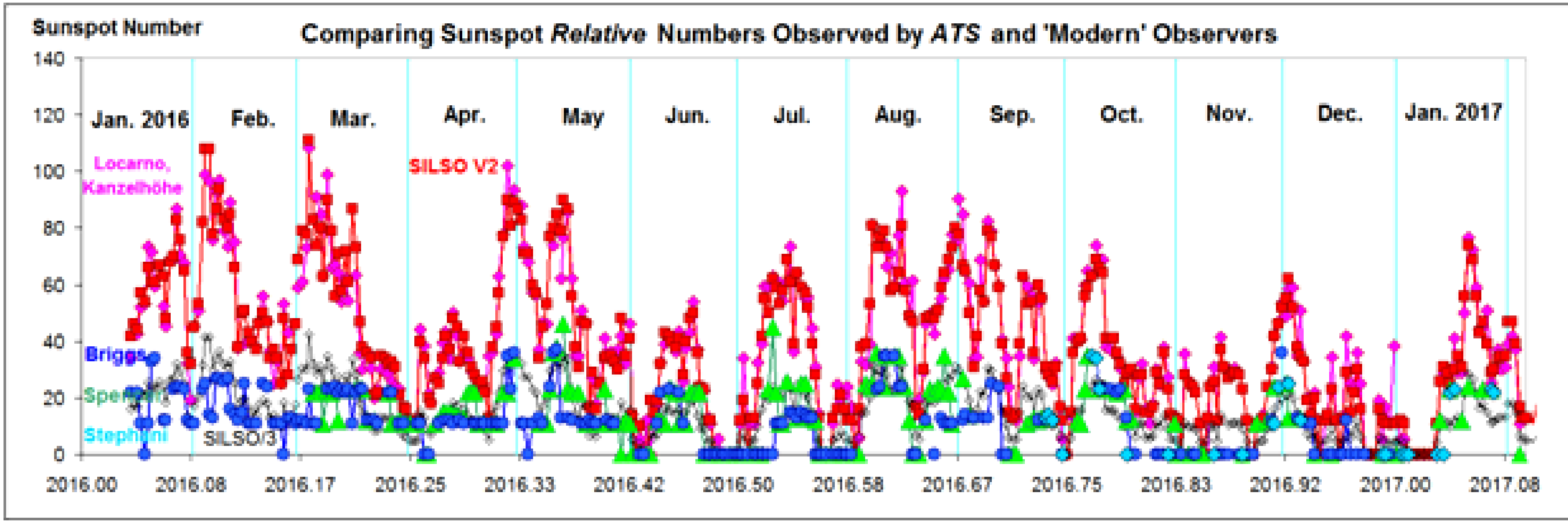
Heliomagnetic Field in Solar Wind from Cosmic Ray-Created Radionuclide Data



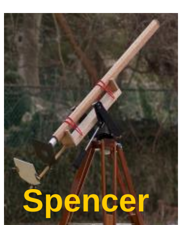
Yearly values of the heliospheric magnetic field, *B*, near the Earth inferred from the IDV-index (red symbols; Svalgaard, 2014), from the cosmic ray record (blue symbols; McCracken and Beer, 2015), and in-situ observed (OMNI data, green triangle symbols).

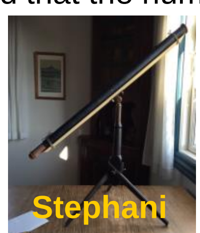
Calibration with ‘Antique’ Telescopes Before 1800

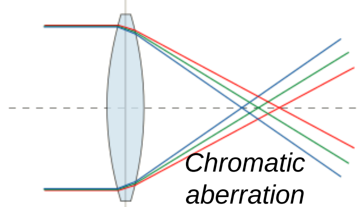
Our knowledge of solar activity during Population II in the 18th century centers on the observations by the amateur astronomer Johann Casper Staudauch who made more than 1100 drawings of the spotted solar disk (Svalgaard, 2017).



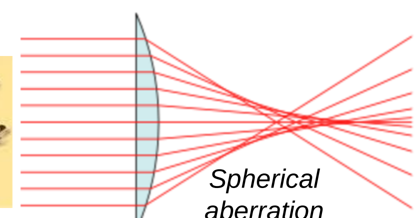
His telescope suffered from spherical and chromatic aberration. We can build replicas with the same optical flaws as telescopes available and affordable to amateurs in the 18th century. On Jan. 16, 2016 we started observations of sunspots with such replicas. Comparing our counts (blue and green) with what modern observers report (red and pink) 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.







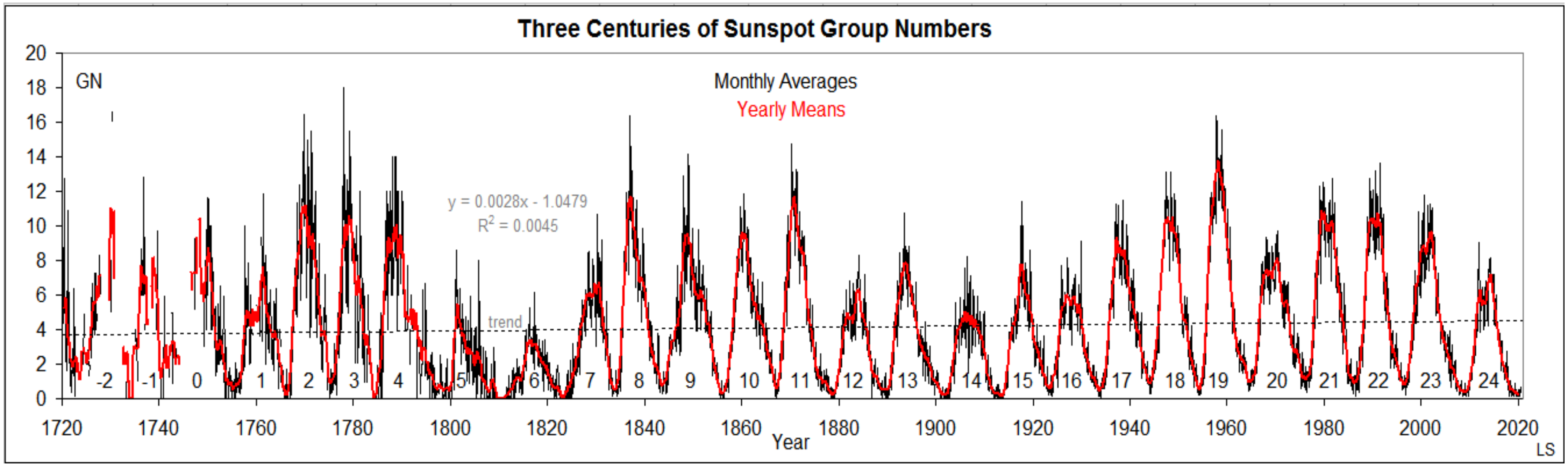
the Antique Telescope Society

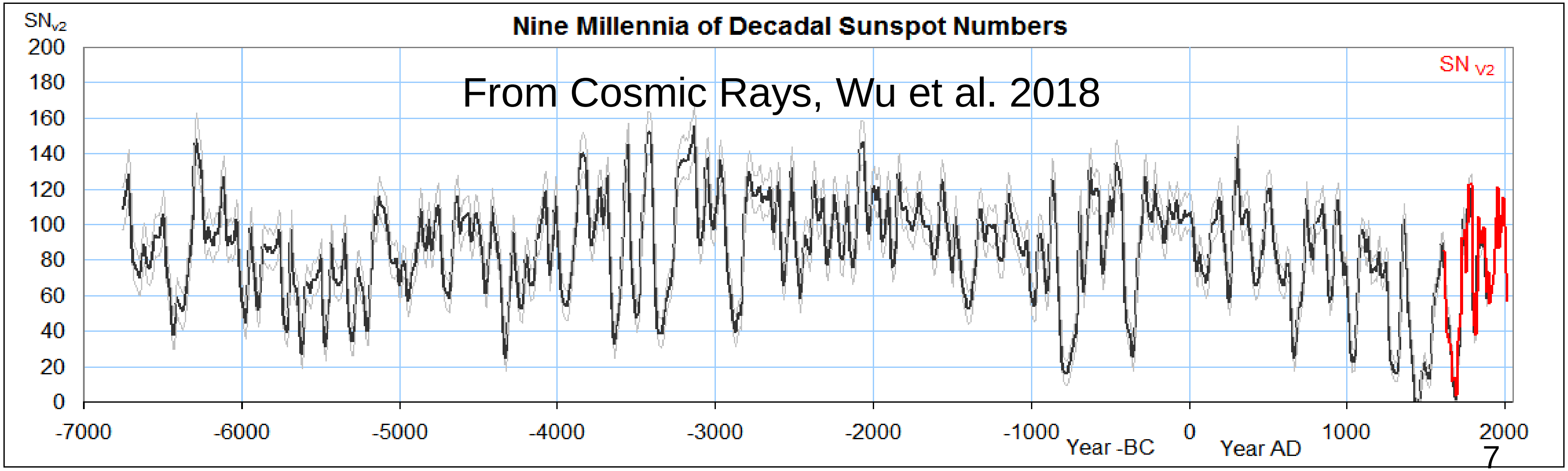


A New Paradigm (Different Populations)

- We shall therefore argue that the set of dissenting Group Number series resembling the old Hoyt & Schatten series actually accurately represents the archived raw observational data (assembled first by Wolf and later by H&S and today curated by Vaquero)
- And that the apparent secular increase (from one population to the next) in archived Group Numbers is due to evolving technology and understanding of what makes a group, rather than to errors and mistakes committed by the researchers
- And that the true evolution of solar activity can only be validated by agreement with other manifestations of said activity (often derisively called ‘proxies’) of which there are many (some shown here)
- With the new paradigm we can with confidence correct and reconstruct solar activity for the past several centuries:
- https://leif.org/research/Several-Populations-of-Group-Numbers.pdf

The Resulting Big Picture





Abstract

The long-standing disparity between the sunspot number record and the Hoyt and Schatten (1998, H&S) Group Sunspot Number series was initially resolved by the Clette et al. (2014) revision of the sunspot number and the group number series. The revisions resulted in a flurry of dissenting group number series while the revised sunspot number series was generally accepted. Thus, the disparity persisted and confusion reigned, with the choice of solar activity dataset continuing to be a free parameter. A number of workshops and follow-up collaborative efforts by the community have not yet brought clarity. We review here several lines of evidence that validate the original revisions put forward by Clette et al. (2014) and suggest that the perceived conundrum no longer need to delay acceptance and general use of the revised series. We argue that the solar observations constitute several distinct populations with different properties which explain the various discontinuities in the series. This is supported by several proxies: diurnal variation of the geomagnetic field, geomagnetic signature of the strength of the heliomagnetic field, and variation of radionuclides. The Waldmeier effect shows that the sunspot number scale has not changed over the last 270 years and a mistaken scale factor between observers Wolf and Wolfer explains the disparity beginning in 1882 between the sunspot number and the H&S reconstruction of the group number. Observations with replica of 18th century telescopes (with similar optical flaws) validate the early sunspot number scale; while a reconstruction of the group number with monthly resolution (with many more degrees of freedom) validate the size of Solar Cycle 11 given by the revised series that the dissenting series fail to meet. Based on the evidence at hand, we urge the working groups tasked with producing community-vetted and agreed-upon solar activity series to complete their work expeditiously.