Are Early Solar Observations Useful To Space Climate Researchers? Some Recent Progress

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Are early observations useful for us?

Unusual activity of the Sun during recent decades compared to the previous 11,000 years

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Direct observations of sunspot numbers are available for the past four centuries1,2, but longer time series are required, for example, for the identification of a possible solar influence on climate and for testing models of the solar dynamo. Here we report a reconstruction of the sunspot number covering the past 11,400 years, based on dendrochronologically dated radiocarbon concentrations. We combine physics-based models for each of the processes connecting the radiocarbon concentration with sunspot number. According to our reconstruction, the level of solar activity during the past 70 years is exceptional, and the previous period of equally high activity occurred more than 8,000 years ago. We find that during the past 11,400 years the Sun spent only of the order of 10% of the time at a similarly high level of

Figure 1 Atmospheric radiocarbon level Δ14C (expressed as deviation, in ‰, from the AD 1950 standard level3) derived from mostly decadal samples of absolutely dated tree-ring chronologies (INTCAL98 data set)4. The Δ14C measurement precision is generally 2–3‰, although in the earlier part of the time series it can reach up to 4–5‰. The INTCAL98 data for times earlier than 11,400 years are not directly employed for the reconstruction because of larger errors and uncertainties in the carbon cycle acting at that time. See Supplementary Information for more information on the data set, initial conditions used for the reconstruction, and error estimates. The long-term decline (indicated by the red curve) is caused by a reduction in 14C production rate due mainly to an increase in the geomagnetic shielding of the cosmic ray flux. The short-term fluctuations (duration one to two centuries) reflect changes of the production rate due to solar variability. Years 0 and 1950 are shown negative here and in other figures.
Data from documental sources for the reconstruction of solar activity

Direct

- Sunspots
  - Telescopic
  - Naked-eye
- Eclipses
  - Solar Corona
  - Sunspots
- Others
  - Solar Radius
  - Sunspot area

Indirect

- Auroras
  - Low Latitude
- Geomagnetic Data
  - Others

Others
1. Sunspot Number
2. Sunspot Positions
3. Solar Radius
4. Great Historical Space Weather Events
5. A look on solar activity during MCA
6. Data from Portugal

How was the transition to Maunder Minimum? Sudden?
Could we reconstruct Butterfly diagram for last centuries?
How is the long-term evolution of Solar Radius?
How will be the great space storms in the future?
Was MCA originated by solar activity?
What can we do?
A SOLAR CYCLE MISTERY

Because of the peculiarities of the late 18th century, the earlier cycle was not recovered in the old sunspot series. In this diagram, one can see an unusual dip at high solar latitudes, which is similar to the butterfly effect. The cycle of sunspots was lost in the record, only to be proposed earlier. The key word is "lost cycle". 

Key words: Sunspots, Solar Cycle, Lost Cycle.
<table>
<thead>
<tr>
<th>Year</th>
<th>Number of days with records</th>
</tr>
</thead>
<tbody>
<tr>
<td>1637</td>
<td>No data</td>
</tr>
<tr>
<td>1636</td>
<td>No data</td>
</tr>
<tr>
<td>1641</td>
<td>No data</td>
</tr>
<tr>
<td>1638-9</td>
<td>mainly estimated values</td>
</tr>
</tbody>
</table>
Accepted general scenario for Maunder Minimum (Usoskin, 2008):

(1) transition from the normal activity to the deep minimum was sudden, 
(2) a 22-year cycle was dominant in sunspot, and 
(3) the recovery of the sunspot activity from the deep minimum to normal activity was gradual.
We are trying to improve the sunspot number around 1636-1642:

(1) We have added the **Marcgraf sunspot records**.
(2) We have **eliminated the estimated** (not observed) values from Crabtree's comments (1638-1639).
(3) We have corrected the dates and the numbers of sunspot groups of Horrox observations in HS98 (**from Julian calendar to Gregorian Calendar**).
(4) We have **eliminated one spurious** observation by Gassendi on 1 Dec 1638.
(5) We have changed the **record by Rheita** [1642].
(6) We have **incorporated a sunspot record** by Horrox in 4 December 1639.
(1) We have added the Marcgraf sunspot records
Drei 3. Febr. 1915, Fels verkauft.

Drei 5. Febr.
Mt. O. Meridian 22. 67. Norden 3 vor
in See her n. Ñupi 5. 0.

Im alt. Prager in 0. 25. 18. 0

6. 25. 0.

Duum maculæ, quæ magnitudinis s. robor sermonis, l. 21. Sept. 
æst. c. v. ora. sparsus I. loco desolatus iles. æt. 

A. 9. 17. CXXXVII.
Hoyt and Schatten (1998) wrote in their Bibliography: “According to a letter by Crabtree the average number of spot groups seen in 1638 and 1639 were 4–5 per day. The database has Greenwich fill values to give 4–5 groups per day. This substitution technique was used to simplify the analysis. This is the only place in the entire database where we do this type of substitution”.

(2) We have eliminated the estimated (not observed) values from Crabtree's comments (1638-1639).
(3) We have corrected the dates and the numbers of sunspot groups of Horrox observations in HS98 (from Julian calendar to Gregorian Calendar).
We have eliminated one spurious observation by Gassendi on 1 Dec 1638.
We have changed the record by record by Rheita.
We have incorporated a sunspot record by Horrox in 4 December 1639.
We can use a statistical procedure (Usoskin, Mursula & Kovaltsov, 2003) to reconstruct yearly group sunspot number from sparse daily observation.

Vaquero et al. (2011), ApJL

R. Arlt (2008) digitized original drawings by J.C. Staudacher made in the period of 1749 – 1796. Arlt also evaluated the usefulness of the drawings for the determination of sunspot positions for future studies.

<table>
<thead>
<tr>
<th>Location</th>
<th>Coordinates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Venus</td>
<td>4°57'19.66'' N 5°00'12.25'' E</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Date and Hour (UT)</th>
<th>Date</th>
<th>Hour</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>00:04:17.754</td>
<td>12</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Solar Ephemeris</th>
<th>( \Omega )</th>
<th>( L_0 )</th>
<th>( P )</th>
<th>Diameter</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3,8722</td>
<td>184,9773</td>
<td>-24,5284</td>
<td>0,5287</td>
</tr>
</tbody>
</table>
Butterfly diagram based on the sunspot latitude estimations obtained from Zucconi drawings (April 1754 – June 1760).
Selenographia: Sive, Lunæ Descriptio; Accurata, Tam Macularum Ejus, Quam Motuum Diversorum, Aliarumque Omnium Vicis Situtinum, Phænomenorum, Telescopii Ope Deprehension, Harum, Delinatio.

In qua simul ceterorum omnium Planetarum nativa facies, variaeque observationes, præterest autem Macularum Solarium, ætque Jovialium, Tubo speculo acquisita, figuris accuratissime ari incisis, hab æque ponuntur: nec non quomplurimæ Astronomicae, Opticae, Physicæque quaestiones proponuntur æque resolvuntur.


Cum Gratia et Privilegio S.R.M.

Gedani, Anno æ. Christianæ, 1647.

Authoribus: Typis Hainfeldiani.
Evolution of the solar radius variations

“New” datasets:
- Cádiz Astronomical Observatory
- San Petronio Cathedral
- Before MM?
Eustachio Manfredio (1736) *De Gnomone Meridiano Bononiensi ad Divi Petronii* (Bononiae, 398 pp.)
DE SOLE
ALFONSI NO
RESTITVTO,
SIMVL ET
DE DIAMETRIS ET
PARALLAXIBVS LUMINARIUM, SEMIDIAMETRO QVE
VMBRAE TERRÆ

EPISTOLA,

QUAM AD EXCELL D.COMITEM STABILEM CASTILÆ
ET LEGIONIS SCRIBEBAT

D. VINCENIVS MVT, INSTAVCTOR MILITIAE, SIVESAR
GENTVS MAJOR MAIORICE,

Anno 1642

Palmae Typis Petri Guasp Imprentor.
According to Mut (1649):
\[ \Delta \text{Dec} = 18' 46'' = 2395 \]
Therefore, solar diameter is 31’ 21” (11 June 1648).

From Mut values of minimum and maximum solar radius, we can obtain \( R = 960.6'' \pm 8.2'' \).
This is a value very similar to modern values.
The Bombay magnetogram for the 1–2 September 1859 (adapted from Tsurutani et al., 2003) and the available declination values showing great disturbances during the second phase of Carrington’s storm at the Guatemala observatory.
The 1870 space weather event: Geomagnetic and auroral records

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Received 15 November 2007; revised 9 April 2008; accepted 15 May 2008; published 28 August 2008.

The great solar storm that took place on 24–25 October 1870 is not well known and has been almost absent from previous studies. In this work, a large amount of information that was registered at the time is compiled and analyzed, including early geomagnetic data and several comprehensive descriptions of the auroras observed during these two nights. These descriptions reveal unusual characteristics for a typical low-latitude aurora. For example, unlike most low-latitude auroras (generally red and diffuse), this event was mostly characterized by a variable palette of colors, including greenish and white. The geomagnetic records analyzed from Lisbon and Coimbra (Portugal), Greenwich (United Kingdom), Munich (Germany), and Helsinki (Finland) clearly show an intense geomagnetic disturbance on 24–25 October. The Coimbra magnetograms reveal that this disturbance consisted of two distinct geomagnetic storms, the first on 24 October (with amplitudes of 37° in D and 182 nT and 48 nT in H and Z, respectively), and the second on 25 October (with amplitudes of 33° in D and 281 nT and 192 nT in H and Z, respectively). Finally, from early photographic solar observations made during 1870, we have identified a long-lived group of sunspots that are most likely related to the solar source of this great event of space weather.

Aspect général du phénomène.

EO  Ligne d’horizon
ACB  Segment obscur s’appuyant sur l’horizon
ACBFG  Arc blanc verdâtre concentrique avec le segment obscur.
H, I, K  Rayons rouges de l’est.
L  Rayon rouge à l’ouest.
M  Détails cumulus bleu-ardoise se détachant très nettement sur la teinte rouge du reste du ciel.

(À suivre)
E. From.
Figure 13. Photograph made by Rutherfurd in New York on 22 September 1870. It was published in the famous book *The Sun* [Secchi, 1879, Plate 1].
Different solar activity proxies during the period 1000–1300: TSI reconstructed by Steinhilber et al. (2009) (dashed black line), TSI reconstructed by Vieira et al. (2011) (continuous black line), annual number of naked-eye observations of sunspots (Vaquero et al., 2002) (blue line), and annual number of auroral nights (Křivský and Pejml, 1988) (orange line). Black arrows are evenly spaced and correspond to our estimated maxima of solar cycle. Arrows correspond to estimated maxima of solar cycle using naked-eye observations (blue) and auroral nights (orange). Graphic inserted shows, using the same colour code, a histogram of the delays (in years) between the fitted and estimated maxima of solar cycle.
Evolution of mean SCL during the three centuries using (red) max to max or (blue) min to min estimations. Each value represents the estimation of mean SCL for ten consecutive solar cycles (110 years approximately) and the error bars the corresponding standard error. Black line represents the TSI from Steinhilber et al. (2009). Green line shows our estimation of mean SCL during MCA including the standard error (dashed lines).
OBSERVAÇÕES ASTRONOMICAS
Feitas junto ao Castelo da Cidade do Rio de Janeiro para de
terminar a Latitude e Longitude da dita Cidade.
POR BENTO SANCHES DORTA.

Estas observações foram feitas nos annos de 1781,
e 1782 com excellentes instrumentos. As alturas me-
ridianas do Sol, e Estrellas foram tomadas com hum
Quadrante Astronomico de hum pé de raio, construido
por Mr. Sillon, artista de Londres, no anno de 1779:
Os Eclipse dos Satellites de Jupiter foram observados
com occulos achronmaticos de Dollon; tendo hum de fo-
co 3 ½ pés, e outro 17 pollegadas. O tempo verdadeiro foi

OBSERVAÇÕES METEOROLOGICAS
Feitas na Cidade do Rio de Janeiro.
POR BENTO SANCHES DORTA.

Endo o ocio para mim pouco grato, e causando-me
hum grande enjoo, resolvi ocupar o tempo em cou-
sa que fosse util, e que podesse dar conta della,
quando me vihe obrigado a isso: e movido das altas
obrigações que inspirio a vasallagem, tributada aos me-
lhores dos Soberanos, e o amor que os interesse da Pa-
tria exigem de todos os que constituem o corpo do Ef-
Early Sunspots observers...

Vaquero, Trigo, Gallego (2005)
Original measurements of geomagnetic declination performed by Sanches Dorta at the (a) monthly and (b) daily scales and after the correction at (c) monthly and (d) daily scales.

Daily variability of Group Sunspot Number (GSN) and geomagnetic declination between 11 April and 23 May 1788. The triangle corresponds to the aurora episode observed on 9 May 1788.

Four large solar storms occurred on 7–9 Feb 1786, 11 Mar 1787, 31 Oct 1787 and 9 May 1788.

Monthly mean temperature record taken by Bento Sanches Dorta at 6:00, 8:00, 10:00, 12:00, 14:00, 16:00, and 18:00.

Monthly values of number of fog days recorded by BSD between 1781 and 1788.

rometro he composto de duas escalas huma Franceza, e outra Ingleza, e que eu me sirvo da primeira.

Neste anno succederão fenómenos incomparáveis com os dos mais annos. Nos mezes de Setembro, Outubro, e Novembro subliamse huma nevoa, ou vapor muy denso, que nos occultou de dia o Sol, de noite as Estrellas; de maneira que havendo nestes tres mezes 48 Eclipues dos Satellites de Jupiter visiveis neste Meridiano, eu n'apudeme lograr mais de tres no fim de Setembro. Este ne-

Histograms of the differences between model (gufm1) and observed values for (a) geomagnetic declination, (b) geomagnetic inclination and (c) horizontal component.

ANAIIS
DO
OBSEJvarTORIO ASTRONOMICO
DA
UNIVERSIDADE DE COIMBRA

PRIMEIRA SECAO
FENOMENOS SOLARES

PUBLICADOS PELO DIRETOR DO OBSERVATORIO
F. M. DA COSTA LOBO

TOMO I

COIMBRA
IMPRESA DA UNIVERSIDADE
1920
• There is interesting information that is still buried in archives and libraries on sunspot positions, solar radius, great historical space weather events, etc.

• Transition from normal solar activity to Maunder Minimum was gradual (no sudden).

• Estimated mean solar cycle length during Medieval Warm Period is 10.72±0.20 years.
Thank you very much!

Comments, suggestions, etc.:

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