CENTRA Seminars
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Lisbon, Portugal

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

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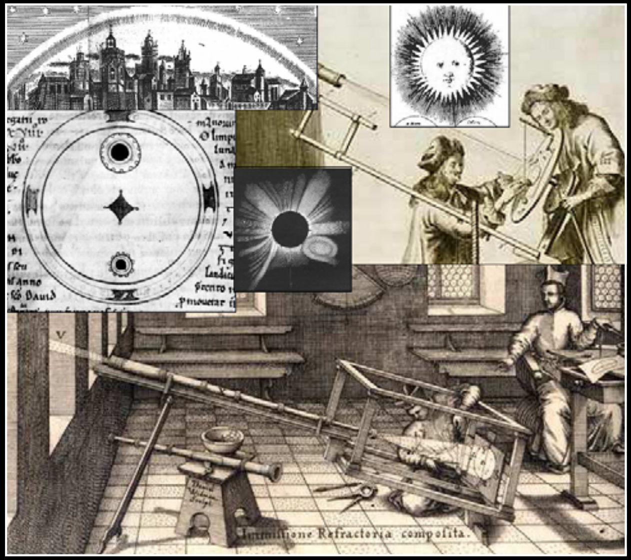
Universidad de Extremadura, Spain



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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[2]*Sodankylä Geophysical Observatory (Oulu unit), University of Oulu, 90014 Oulu, Finland*
[3]*Heidelberger Akademie der Wissenschaften, Institut für Umweltphysik, Neuenheimer Feld 229, 69120 Heidelberg, Germany*
[4]*Department of Surface Waters, EAWAG, 8600 Dübendorf, Switzerland*

Direct observations of sunspot numbers are available for the past four centuries[1,2], 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

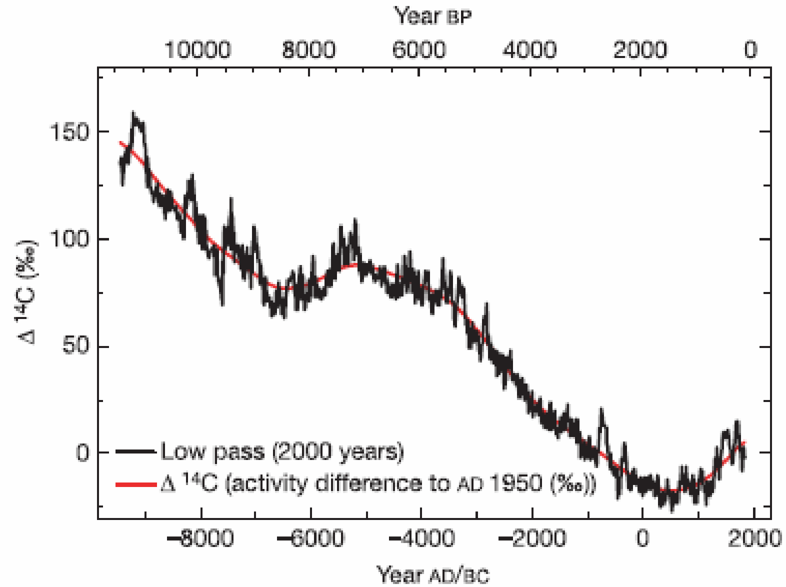
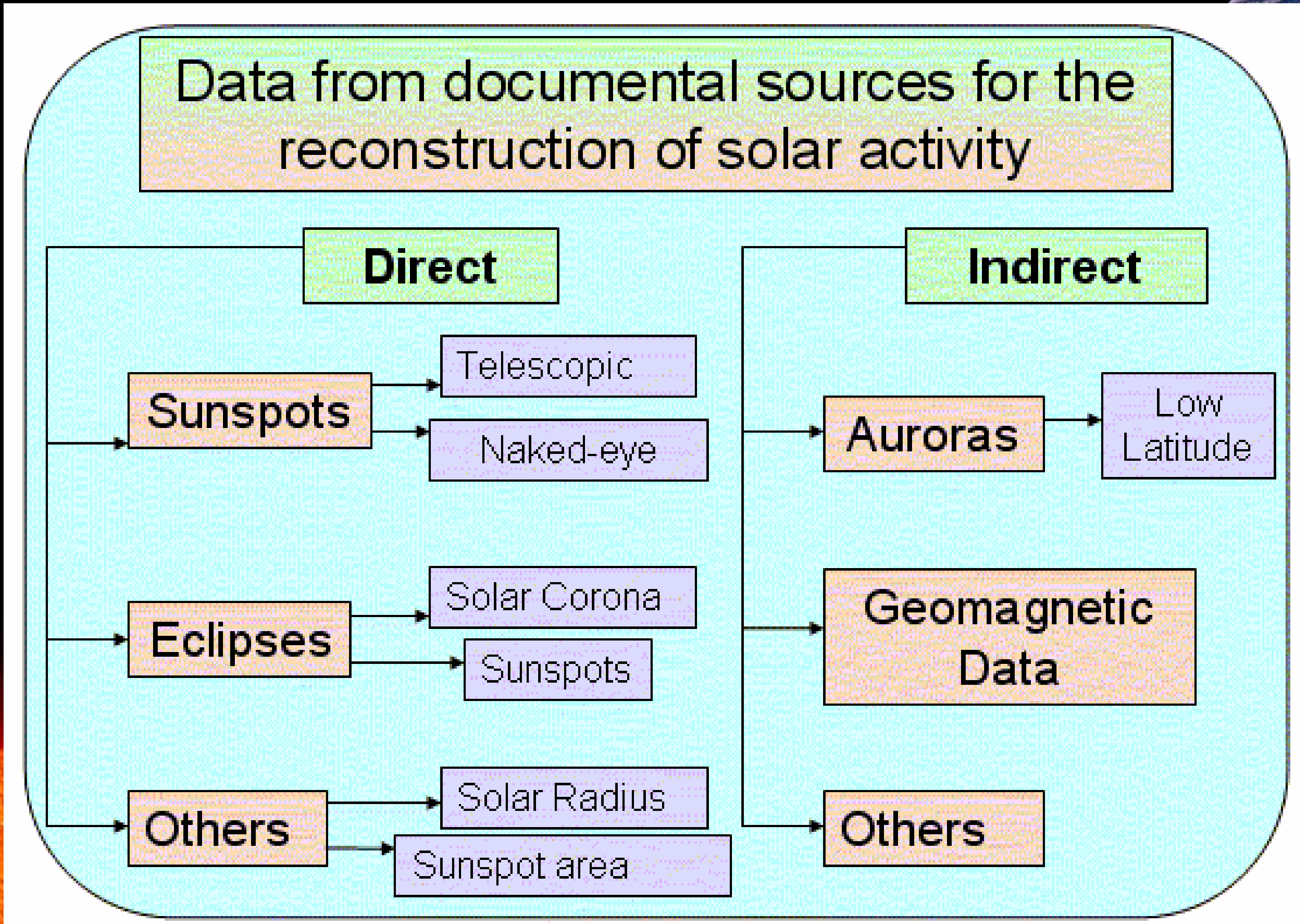
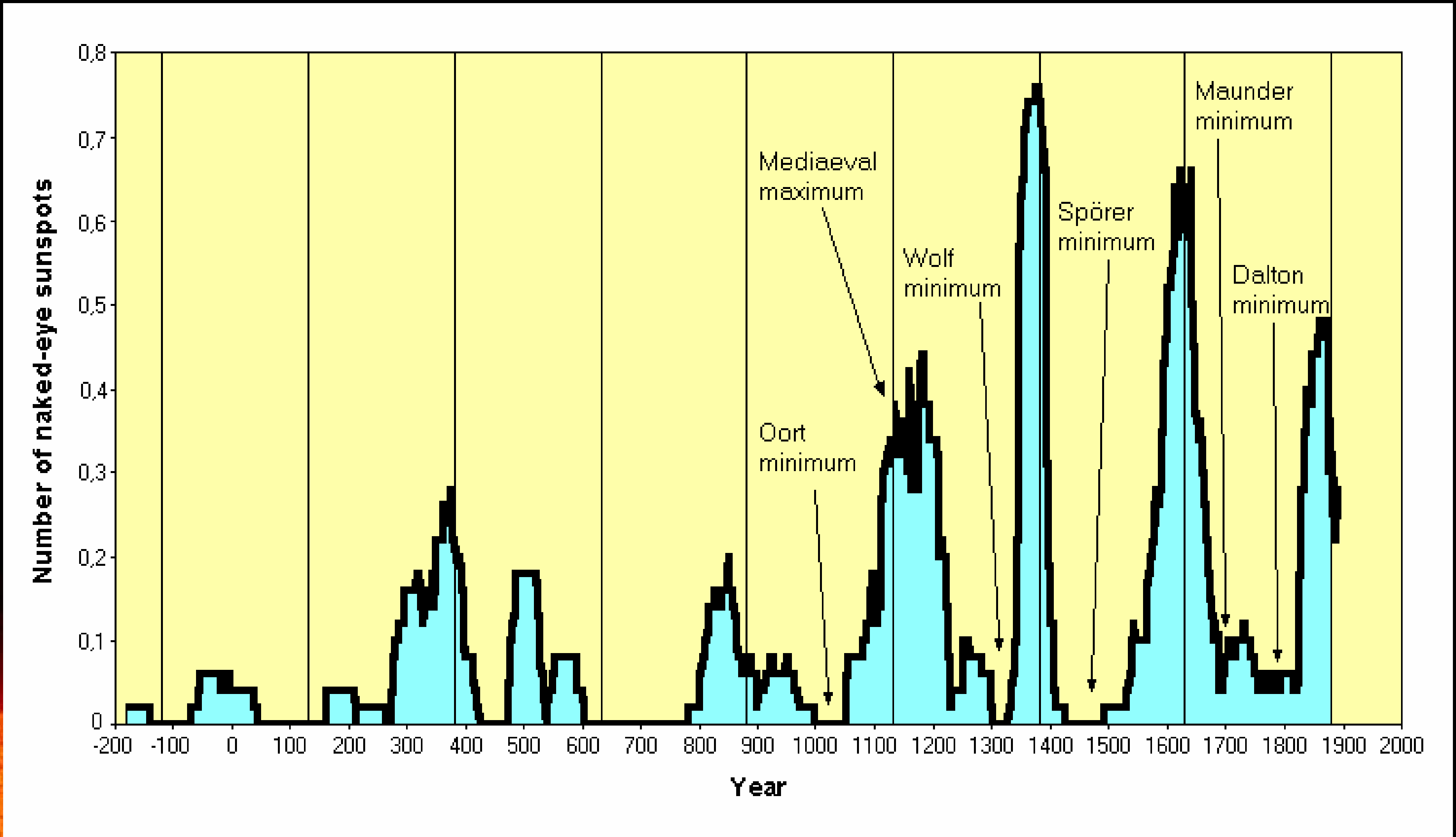
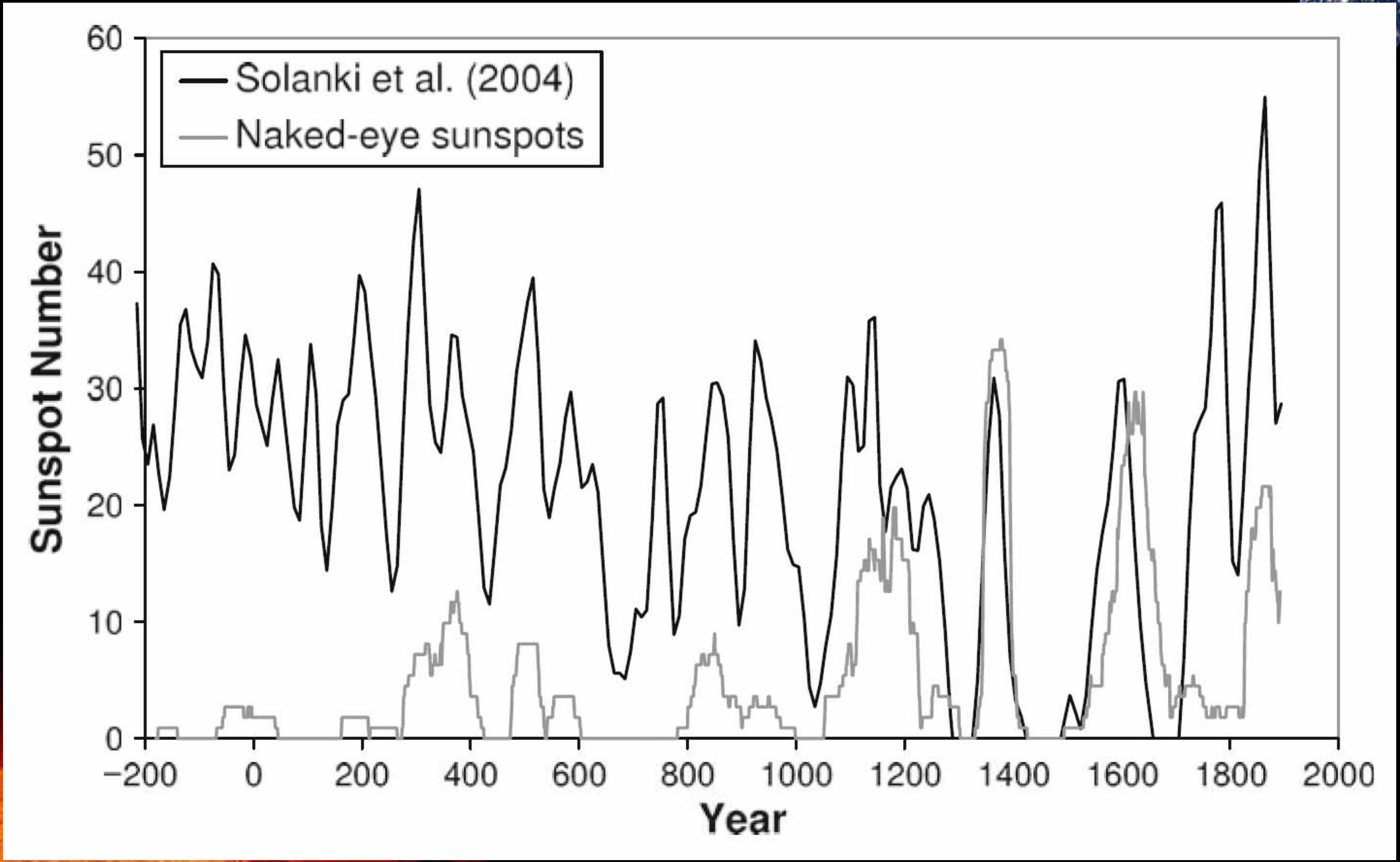


Figure 1 Atmospheric radiocarbon level $\Delta^{14}C$ (expressed as deviation, in ‰, from the AD 1950 standard level[15]) derived from mostly decadal samples of absolutely dated tree-ring chronologies (INTCAL98 data set)[16]. The $\Delta^{14}C$ measurement precision is generally 2–3‰, although in the earlier part of the time series it can reach up to 4–5‰. The INTCAL98 data for times earlier than 11,400 BP 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 ^{14}C 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 BC are shown negative here and in other figures.

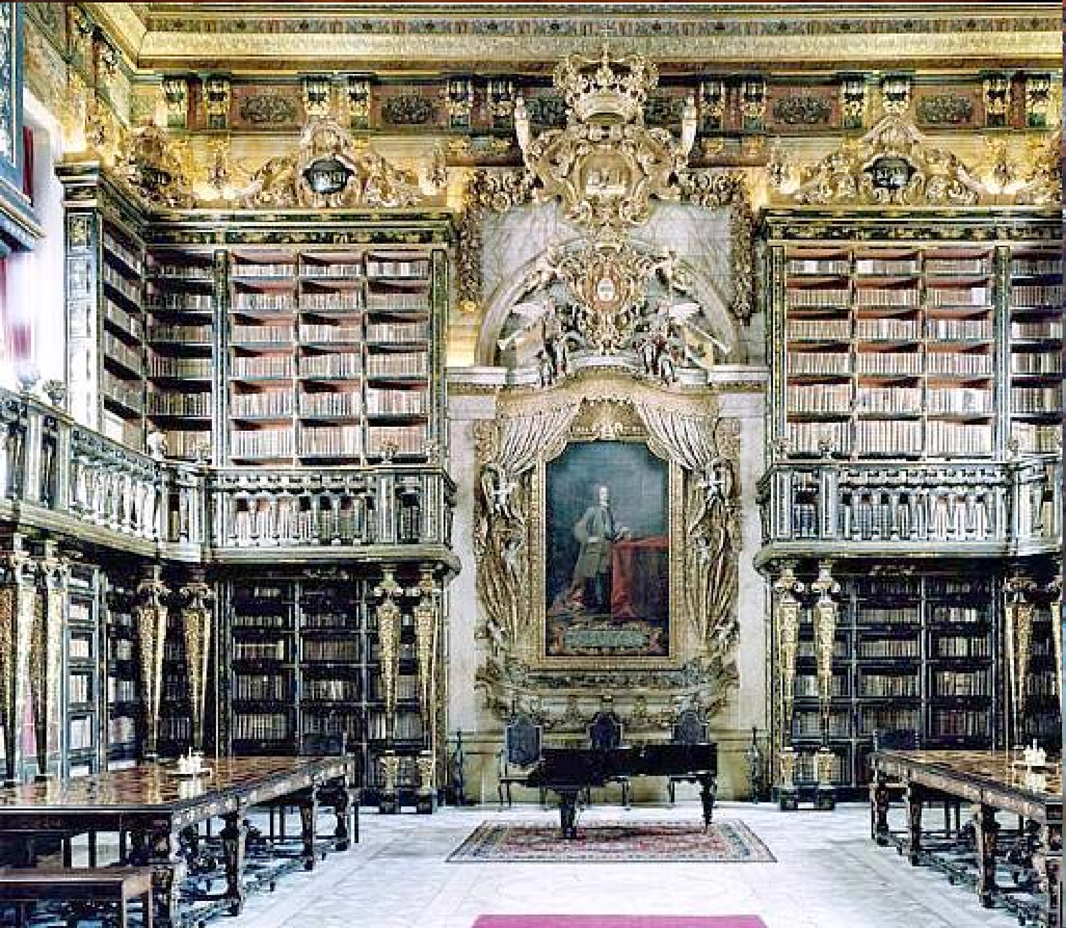

Data from documental sources for the reconstruction of solar activity
Direct
Sunspots
Telescopic
Naked-eye
Eclipses
Solar Corona
Sunspots
Others
Solar Radius
Sunspot area
Indirect
Auroras
Low Latitude
Geomagnetic Data
Others



Vaquero et al. (2002), *Geophys. Res. Lett.*


Solanki et al. (2004)
Naked-eye sunspots
Sunspot Number
Year
60
50
40
30
20
10
0
−200
0
200
400
600
800
1000
1200
1400
1600
1800
2000


P
Q



Outline

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?

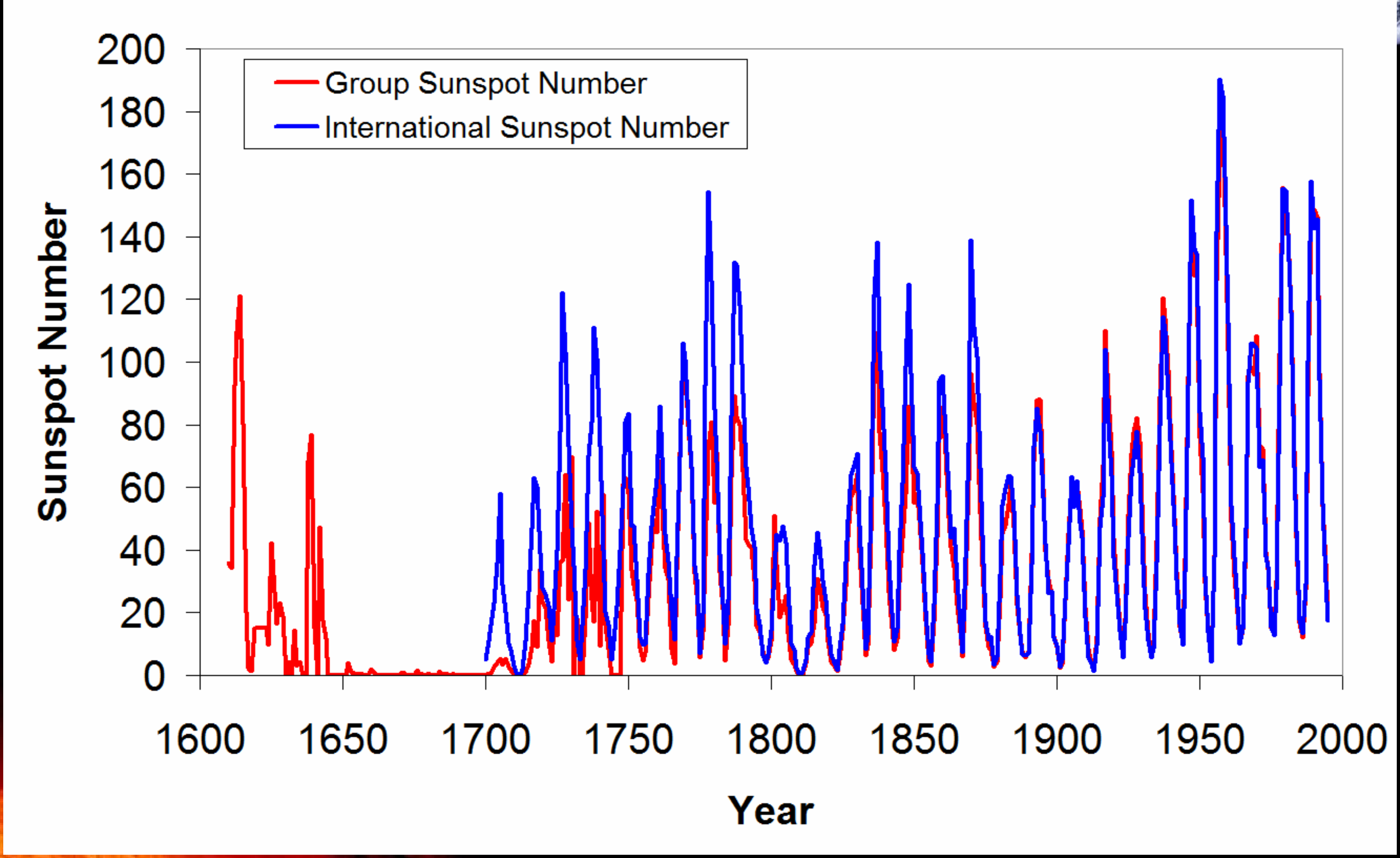
Could we reconstruct Butterfly diagram for last centuries?

How is the long-term evolution of Solar Radius?

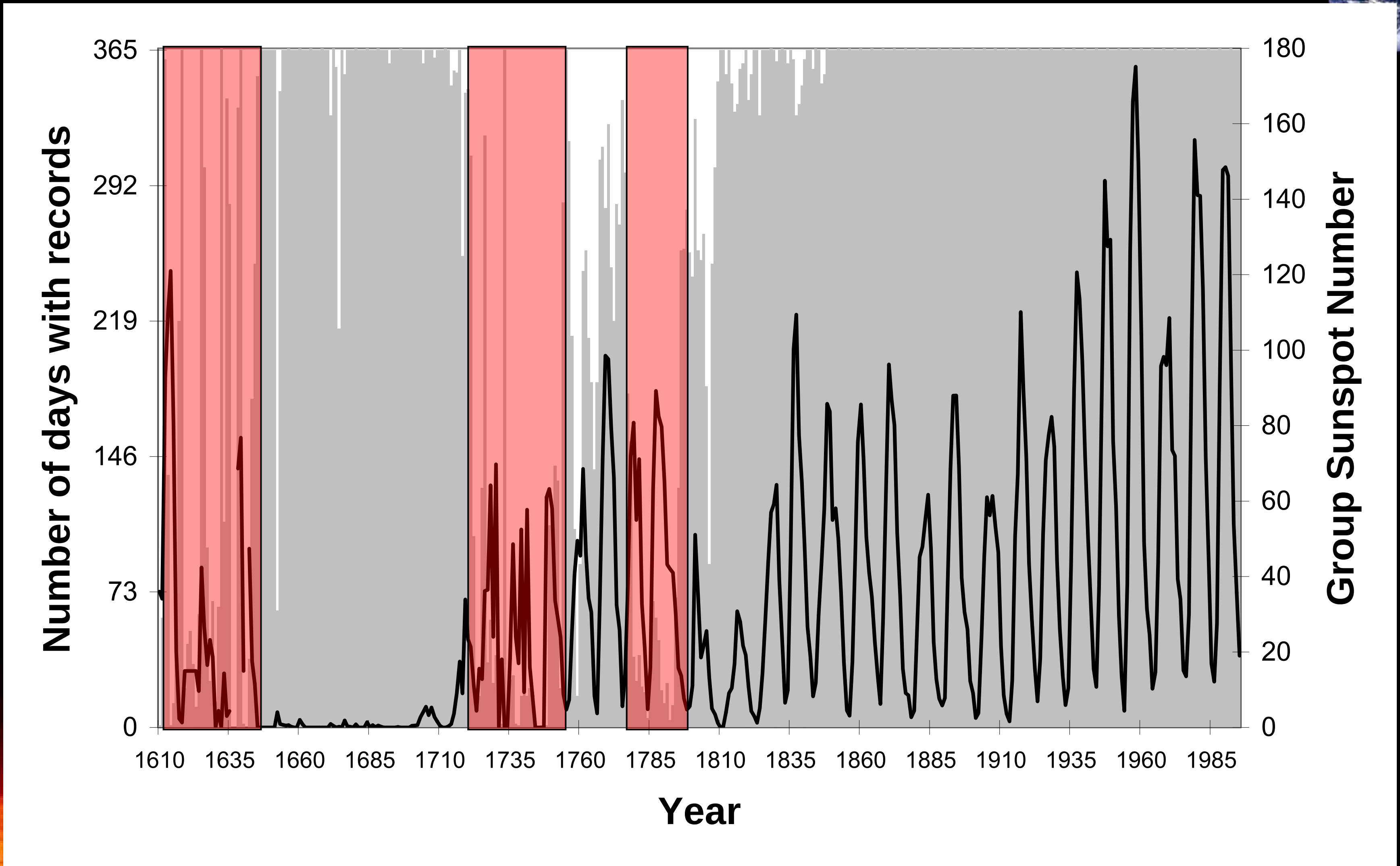
How will be the great space storms in the future?

Was MCA originated by solar activity?

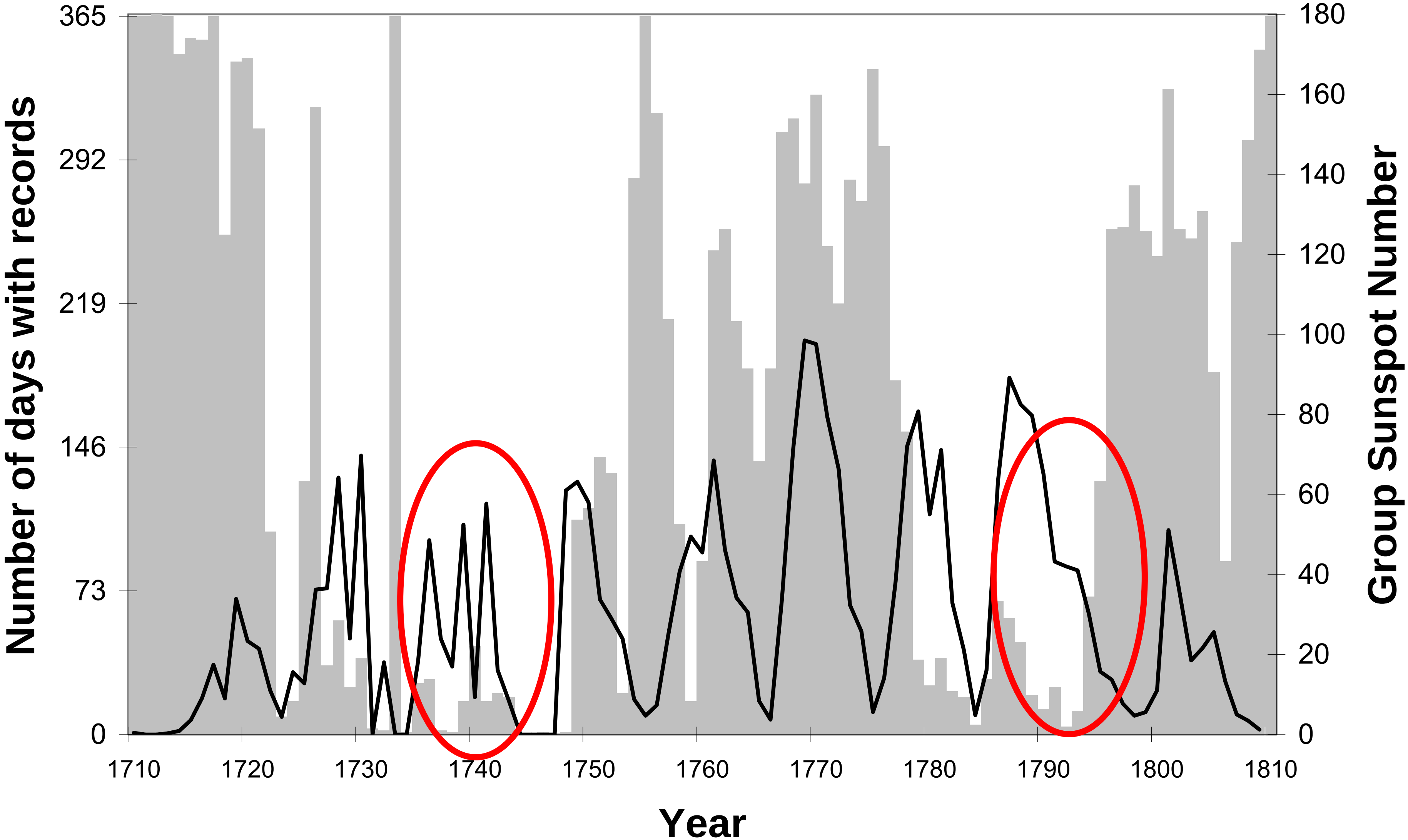
What can we do?



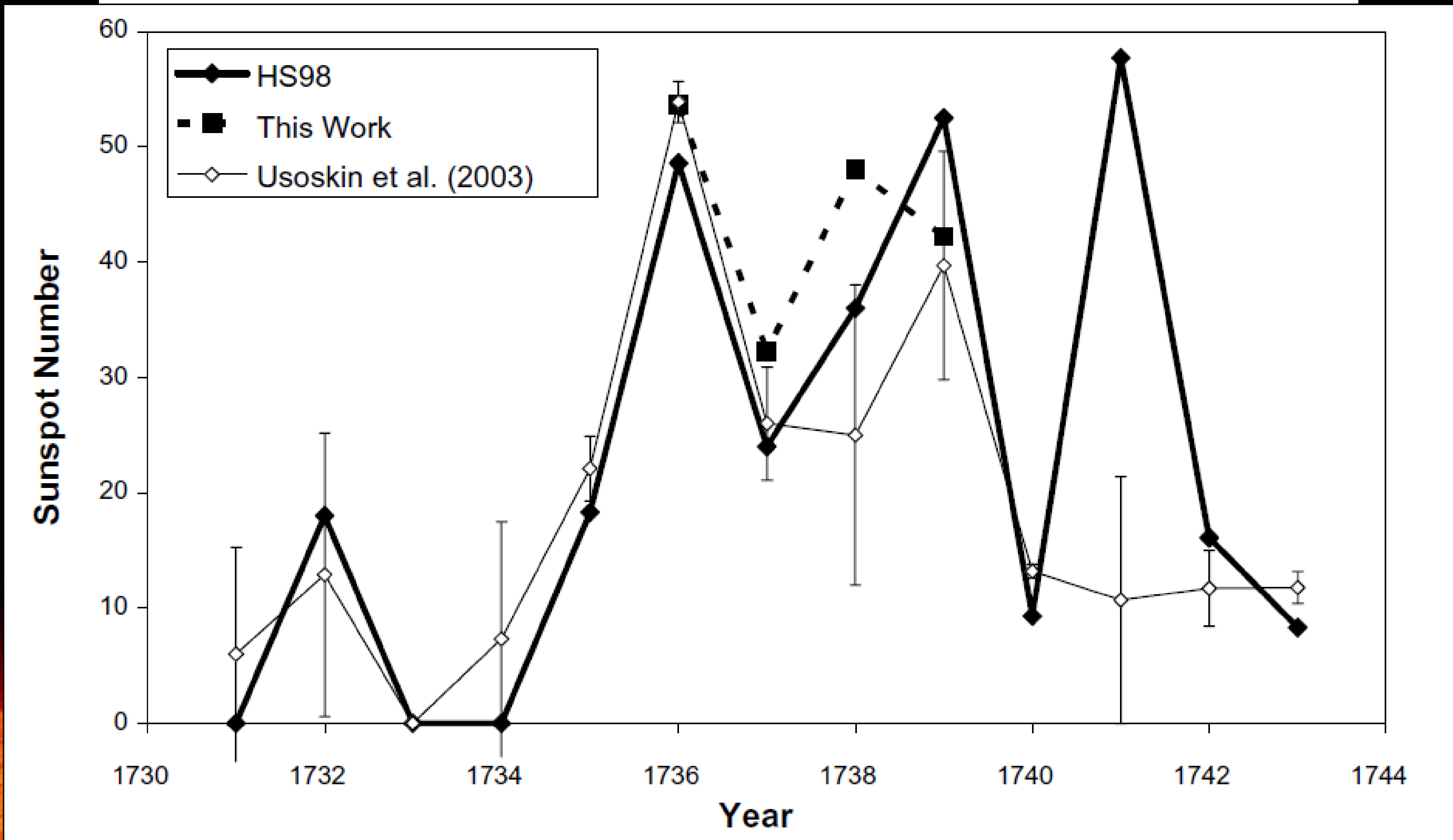
Group Sunspot Number
International Sunspot Number
Sunspot Number
200
180
160
140
120
100
80
60
40
20
0
1600
1650
1700
1750
1800
1850
1900
1950
2000
Year

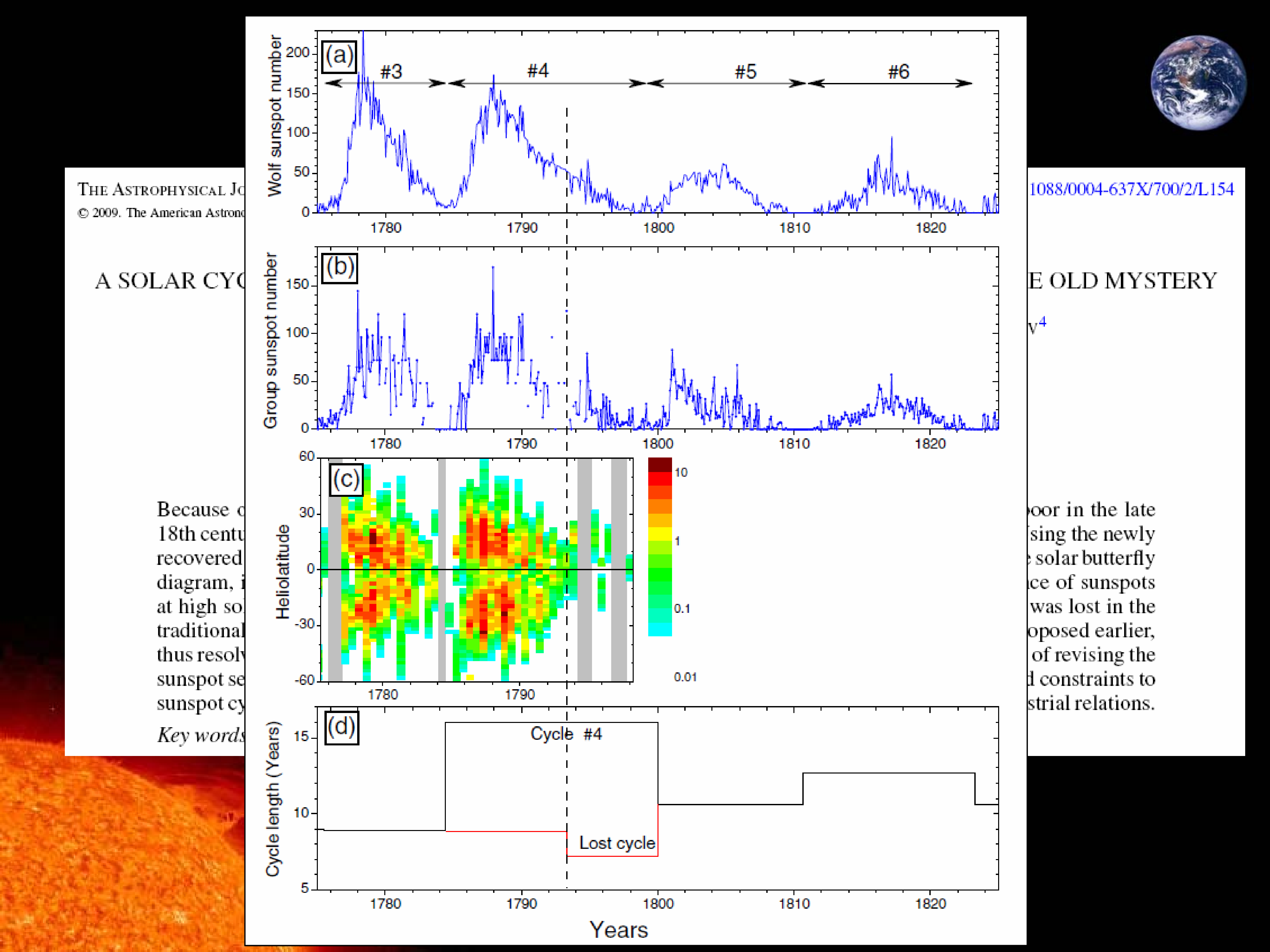


Number of days with records
365
292
219
146
73
0
Group Sunspot Number
180
160
140
120
100
80
60
40
20
0
1610
1635
1660
1685
1710
1735
1760
1785
1810
1835
1860
1885
1910
1935
1960
1985
Year

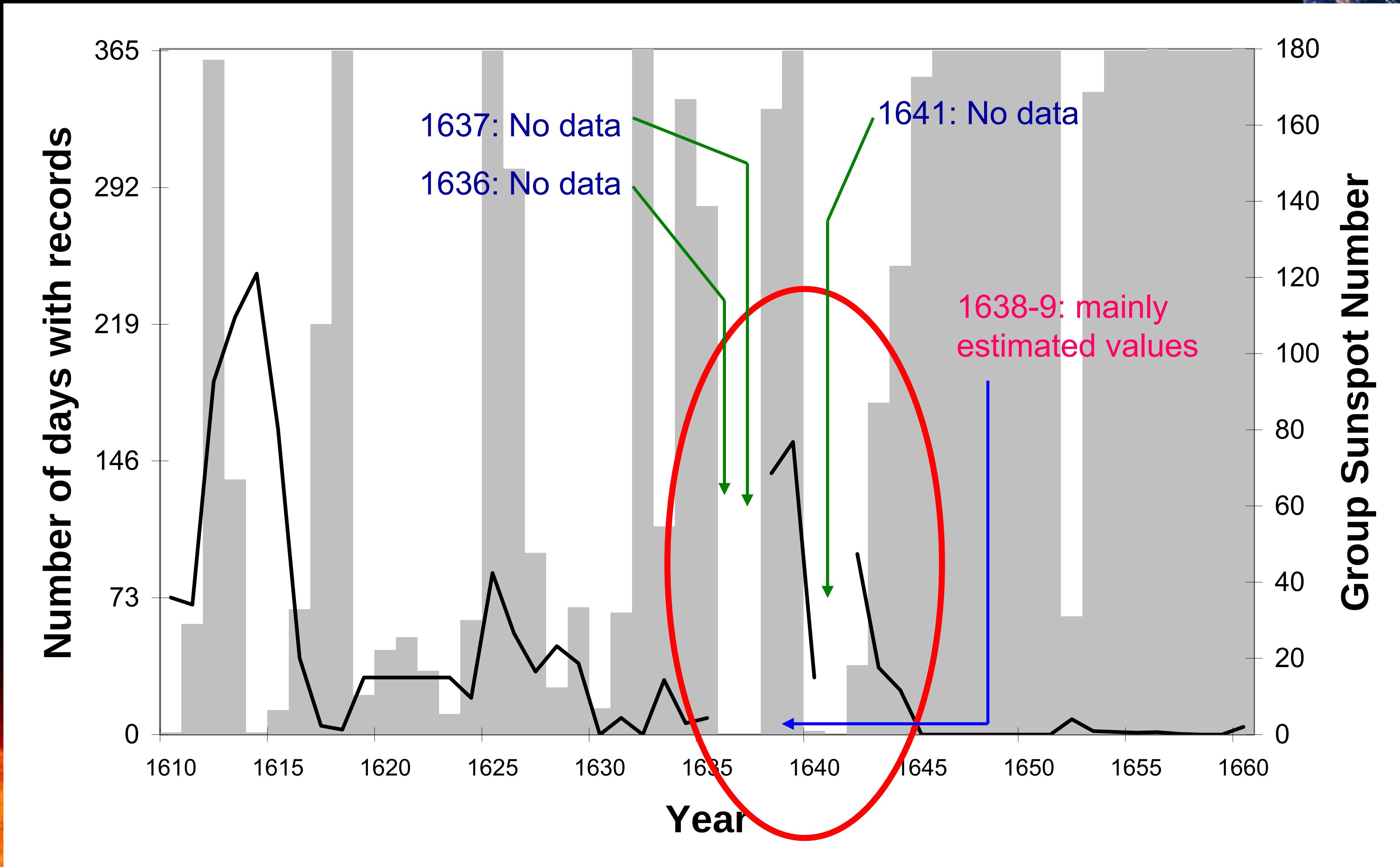


Number of days with records
365
292
219
146
73
0
Group Sunspot Number
180
160
140
120
100
80
60
40
20
0
1710
1720
1730
1740
1750
1760
1770
1780
1790
1800
1810
Year


HS98
This Work
Usoskin et al. (2003)
Sunspot Number
60
50
40
30
20
10
0
1730
1732
1734
1736
1738
1740
1742
1744
Year



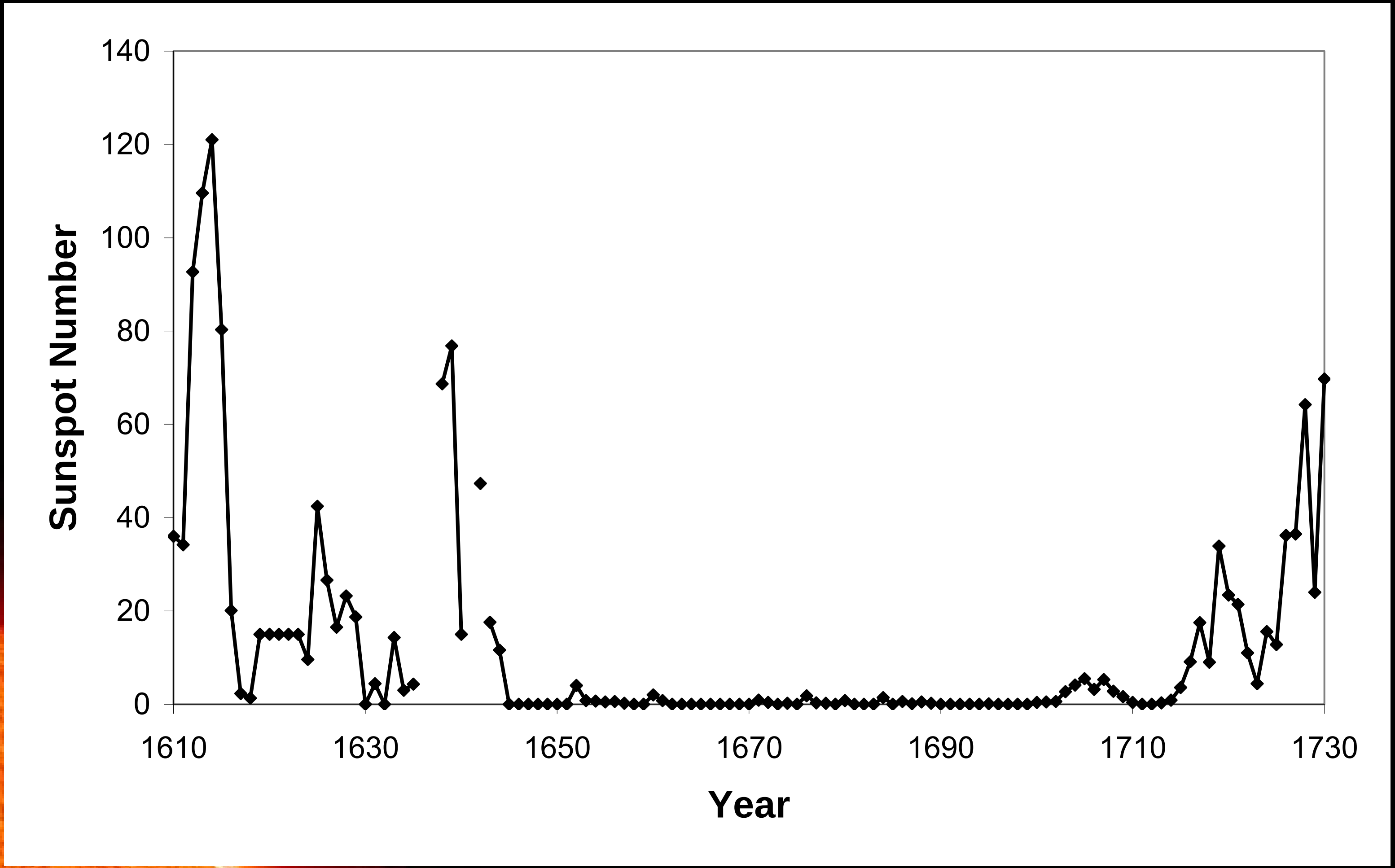
The Astrophysical Jo
© 2009. The American Astrono
1088/0004-637X/700/2/L154
A SOLAR CYC
E OLD MYSTERY
Because o
18th centu
recovered
diagram, i
at high so
traditional
thus resolv
sunspot se
sunspot cy
Key words
oor in the late
sing the newly
solar butterfly
ce of sunspots
was lost in the
oposed earlier,
of revising the
constraints to
strial relations.
(a)
#3
#4
#5
#6
Wolf sunspot number
(b)
Group sunspot number
(c)
Heliolatitude
(d)
Cycle #4
Lost cycle
Cycle length (Years)
Years



365
292
219
146
73
0
Number of days with records
180
160
140
120
100
80
60
40
20
0
Group Sunspot Number
1610
1615
1620
1625
1630
1635
1640
1645
1650
1655
1660
Year
1637: No data
1636: No data
1641: No data
1638-9: mainly
estimated values

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.

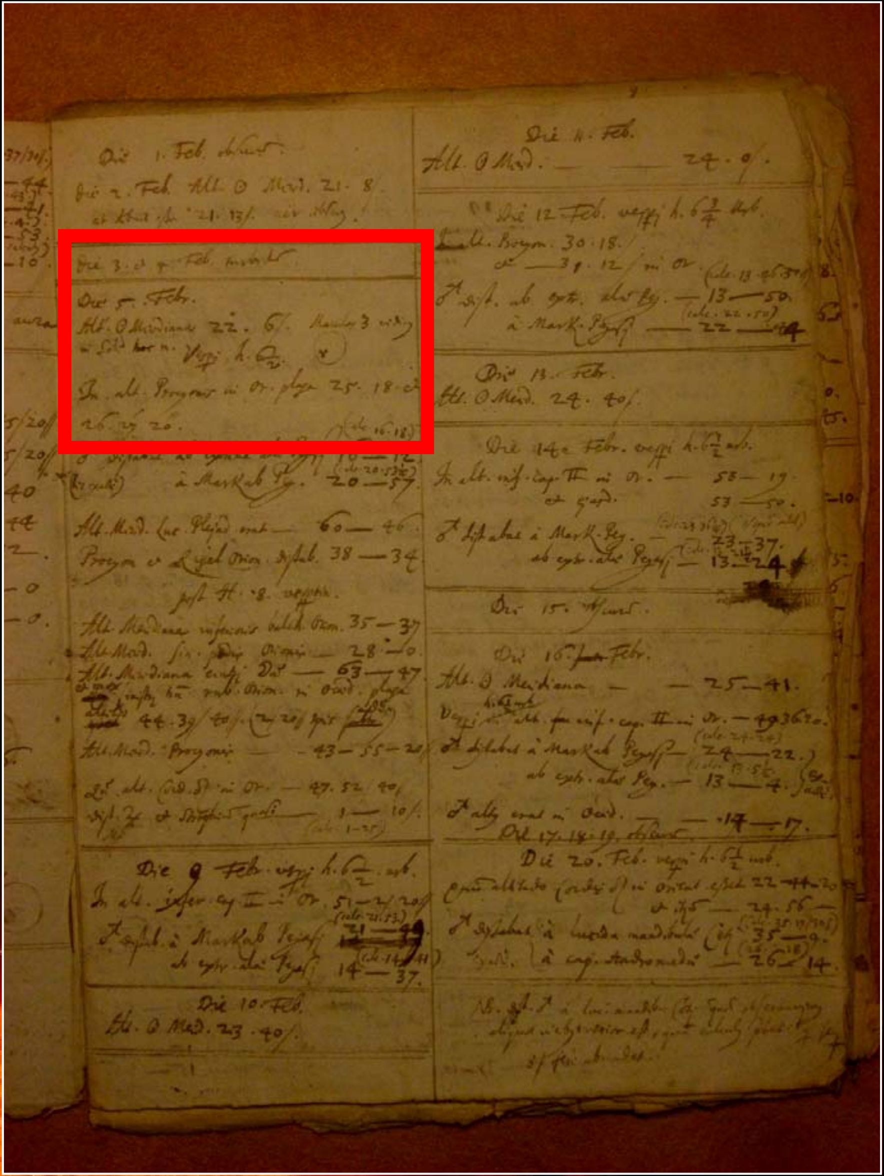
(5) We have changed the **record by Rheita** [1642].

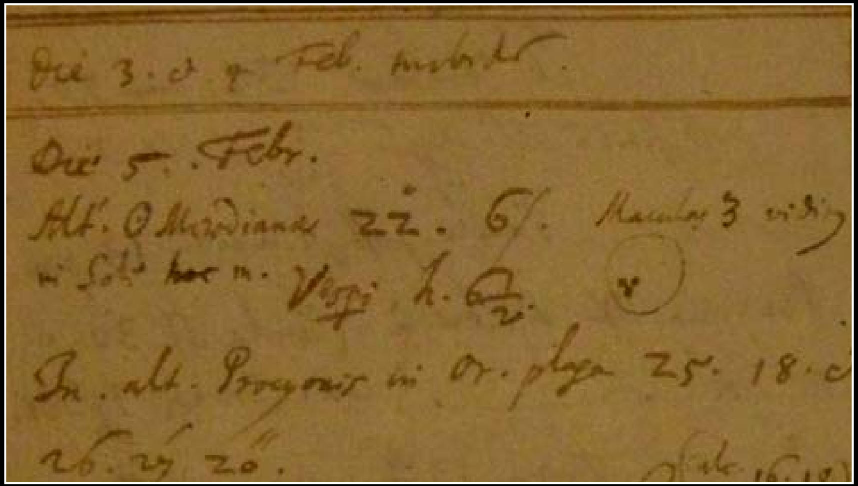
(6) We have **incorporated a sunspot record** by Horrox in 4 December 1639.

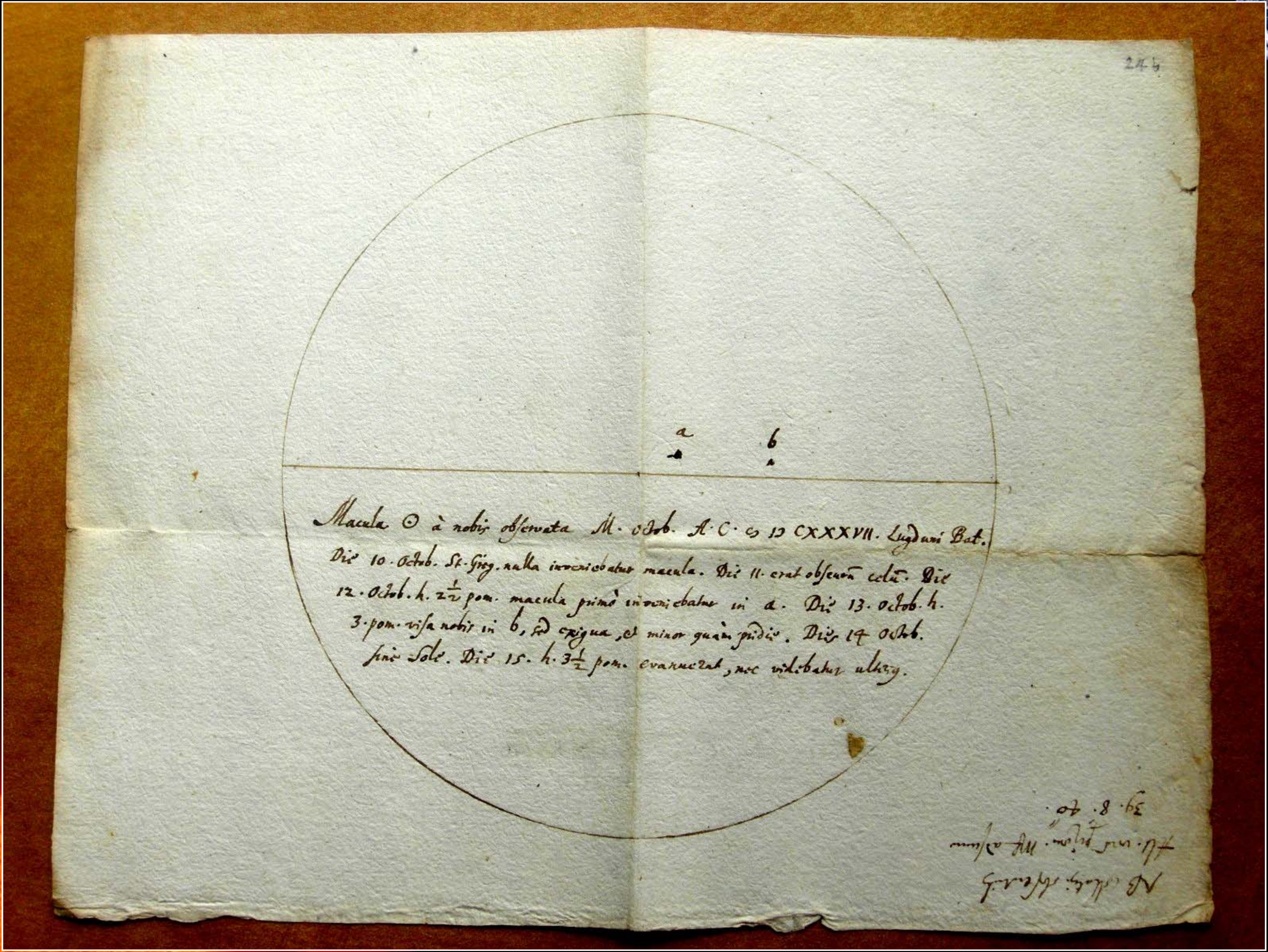
(1) We have added the **Marcgraf sunspot records**

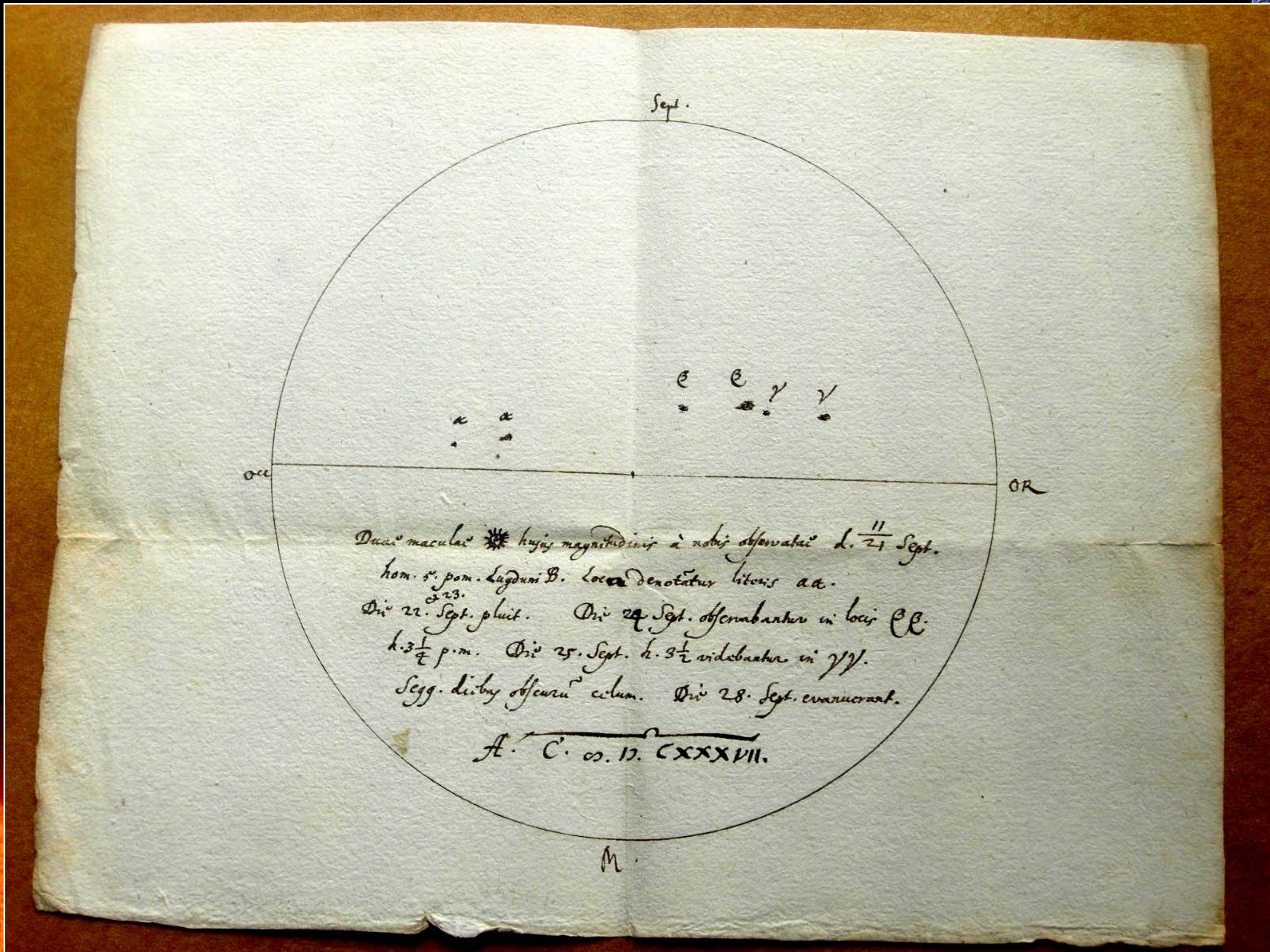
REGIONAAL ARCHIEF LEIDEN

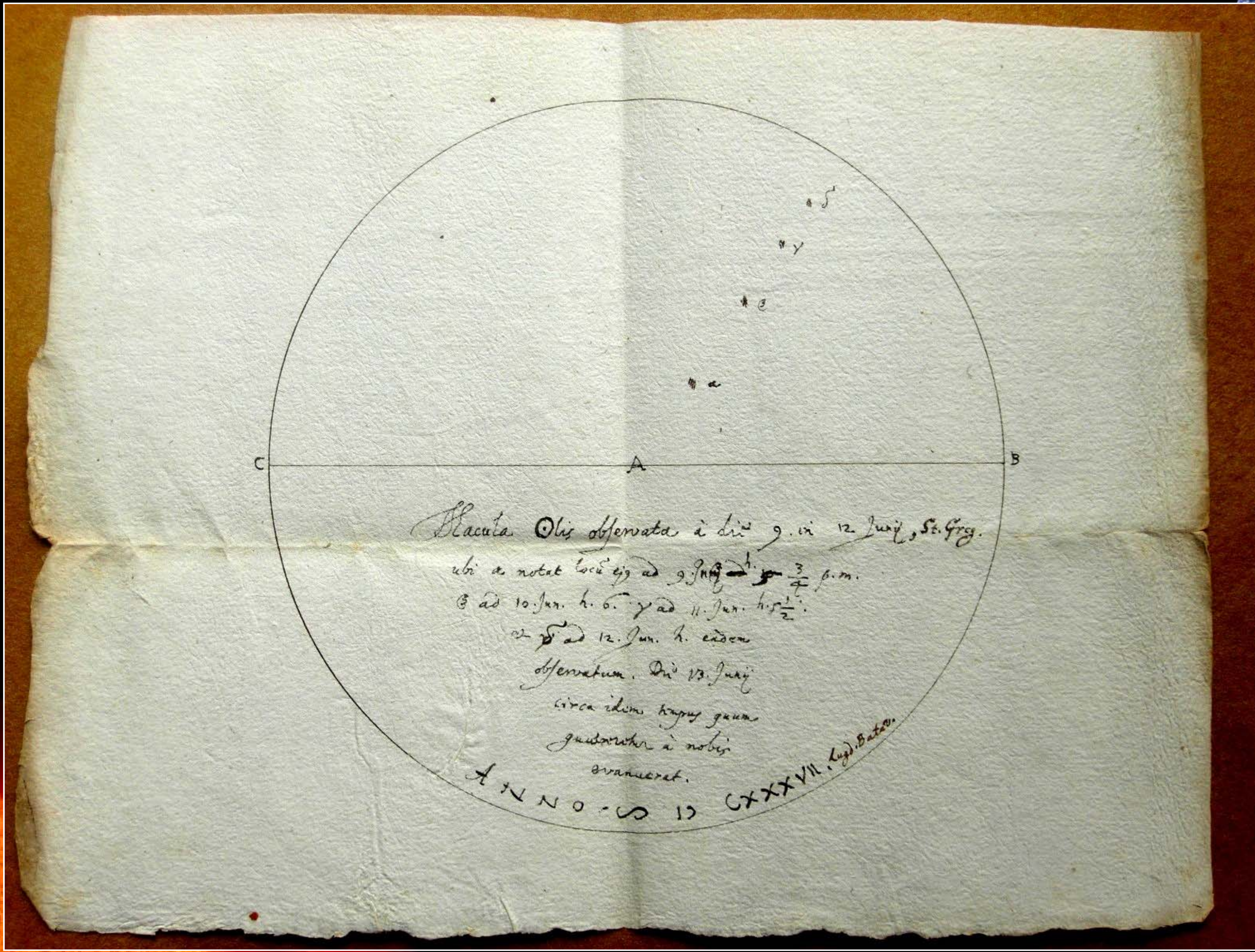
BIBLIOTECA NACIONAL DE PORTUGAL




Die 5. Febr.
26. 27. 20.

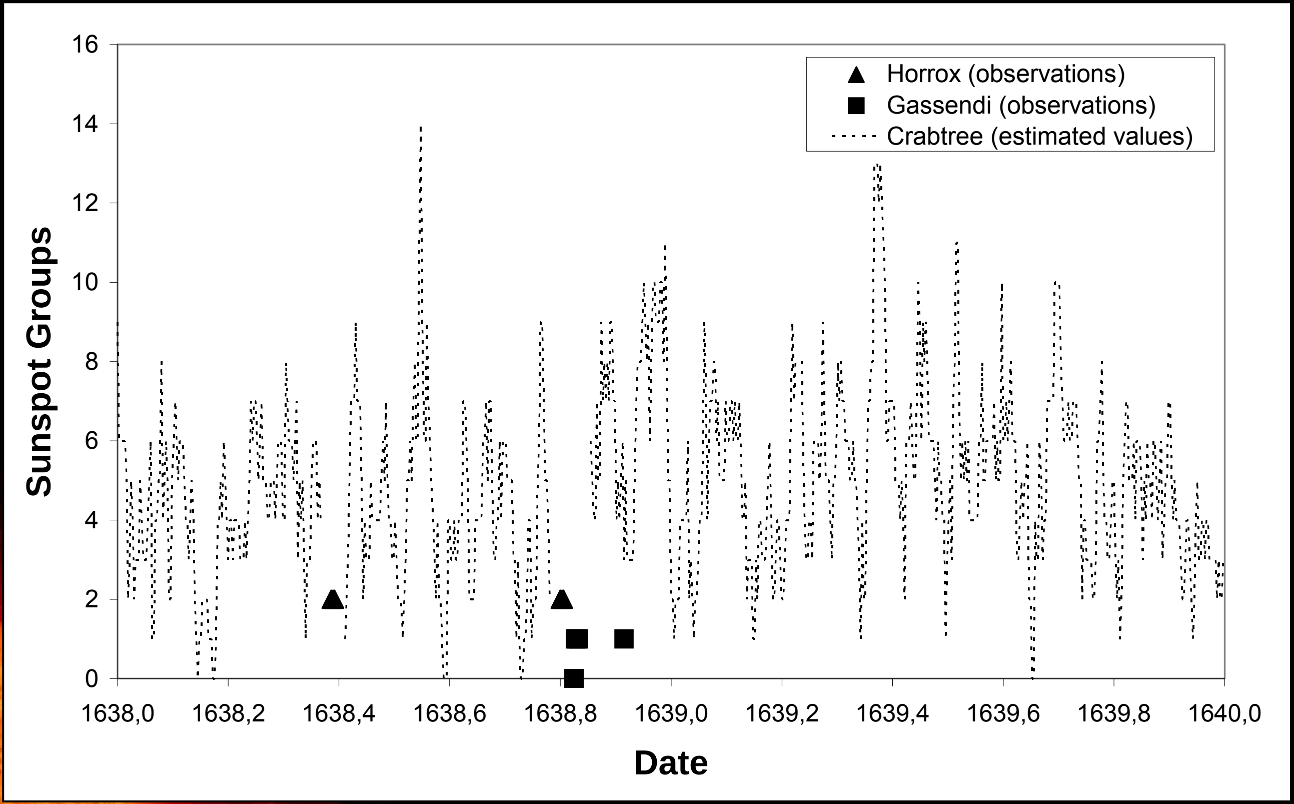

246
a
b
Macula ☉ à nobis observata M. Octob. A. C. CIↄ IↄCXXXVII. Lugduni Bat.
Die 10. Octob. St. Greg. nulla inveniebatur macula. Die 11. erat obscurum celū. Die
12. Octob. h. 2½ pom. macula primò inveniebatur in a. Die 13. Octob. h.
3. pom. visa nobis in b, sed exigua, et minor quam pridie. Die 14 Octob.
sine Sole. Die 15. h. 3½ pom. evanuerat, nec videbatur ulterius.


Sept.
OCC
OR
Duae maculae hujus magnitudinis à nobis observatae d. 11/21 Sept.
hom. 5. pom. Lugduni B. Locus denotatur literis aa.
Die 22. Sept. pluit. Die 24. Sept. observabantur in locis εε
h. 3¼ p.m. Die 25. Sept. h. 3½ videbantur in γγ.
Seqq. diebus obscurum coelum. Die 28. Sept. evanuerant.
A. C. ∞. D. CXXXVII
M.


δ
γ
β
α
C
A
B
Macula Solis observata à die 9. in 12 Junij, St. Greg.
ubi α notat locū ejus ad 9 Junij h. 5 3/4 p.m.
β ad 10. Jun. h. 6. γ ad 11. Jun. h. 5 1/2.
et δ ad 12. Jun. h. eadem
observatum. Die 13. Junij
circa idem tempus quum
quaereretur à nobis
evanuerat.
ANNO CIƆ IƆ CXXXVII. Lugd. Batav.

(2) We have **eliminated the estimated** (not observed) values from Crabtree's comments (1638-1639).

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".



(3) We have corrected the dates and the numbers of sunspot groups of Horrox observations in HS98 (**from Julian calendar to Gregorian Calendar**).

JEREMIÆ HORROCCII,

LIVERPOLIENSIS ANGLI, ex Palatinatu
LANCASTRIÆ,

OPERA POSTHUMA;

viz.

Aſtronomia *Kepleriana*, defenſa & promota,
Excerpta ex Epiſtolis ad *Crabtræum* ſuum.
Obſervationum Cœleſtium Catalogus,
Lunæ Theoria nova.

Accedunt
GUILIELMI CRABTRÆI, *Mancestrienſis*,
Obſervationes Cœleſtes.

In calce adjiciuntur
JOHANNIS FLAMSTEDII, *Derbienſis*,
De Temporis Æquatione Diatriba.
Numeri ad Lunæ Theoriam *Horroccianam*.

LONDINI,
Typis GULIELMI GODBID, Impenſis J. MARTYN Regalis Societatis Typographi, ad inſigne Campanæ in Cœmeterio D. *Pauli*, Anno Domini M.D.CLXXIII.

putaveris te alterum ad Septentrionem, alterum ad Auſtrum conſpexiſſe.

Maii 22, h. 3. P. Radios Solares intromiſi per Tubum Opticum in cameram obſcuratam, (denſis tenebris non opus eſt:) atque in limbo orientali, prope viam regiam (ut puto,) vidi duas nigras maculas. Major diſtabat à Solis margine min. 3′. Maculæ diameter longior erat quaſi min. 30″, brevior quaſi min. 20″, erâtque in forma Ovali.

Maii 23, h. 3. P. Major duarum abfuit à margine min. 1, 20″.

Maii 24, h. 3. P. abfuit min. 0, 25″; jámque facta erat minor quàm reliqua, quæ à margine diſtabat min. 1′.

In magna diſtantia erant hæ maculæ colore cæruleo, cum rubro miſto. Et circa Solis diſcum erat circulus cæruleus, inter exteriorem rubrum, & viridem interiorem, ſicut in Iride; ſed pro varia vitri poſitione ſubinde variabantur hi colores.

Eſſet macula illa, ſi rotunda, Venere major, poſſitque Cometæ inſtar eſſe. Si à Sole projiceretur quantum inde Terra diſtat, adinſtar ſtellæ appareret, niſi forſan à Terrâ nimis diſtaret.

Poſt illos tres dies maculas nullas vidi. Tempus eſt ut reverterentur eædem, ſed nubes impediunt obſervationem.

Eſt autem Tubus hic meus ex vulgaribus unus, pretii 2ſ. 6d, contuli tamen cum duobus aut tribus aliis, quos mutuo habui, ſed meo (quantum ego judico) inferioribus.

Hunc modum exiſtimo egregium fore ad obſervandas Eclipſes. Admittit enim diſcum Solarem tantæ magnitudinis in parva diſtantia, ut ferè minuta ſecunda poſſis obſervare; atque lucem ab umbrâ accuratè diſtinguit, ſi ad juſtam longitudinem educatur.

Stellas fixas dum contueor, nihil video aliud quàm radios undecunq; emiſſos, pro vario vitri poſitione ſitus mutantes.

Mars videtur ejuſdem quaſi magnitudinis cum Jove: *Keplerus* tamen & *Lansbergius* multò majorem faciunt.

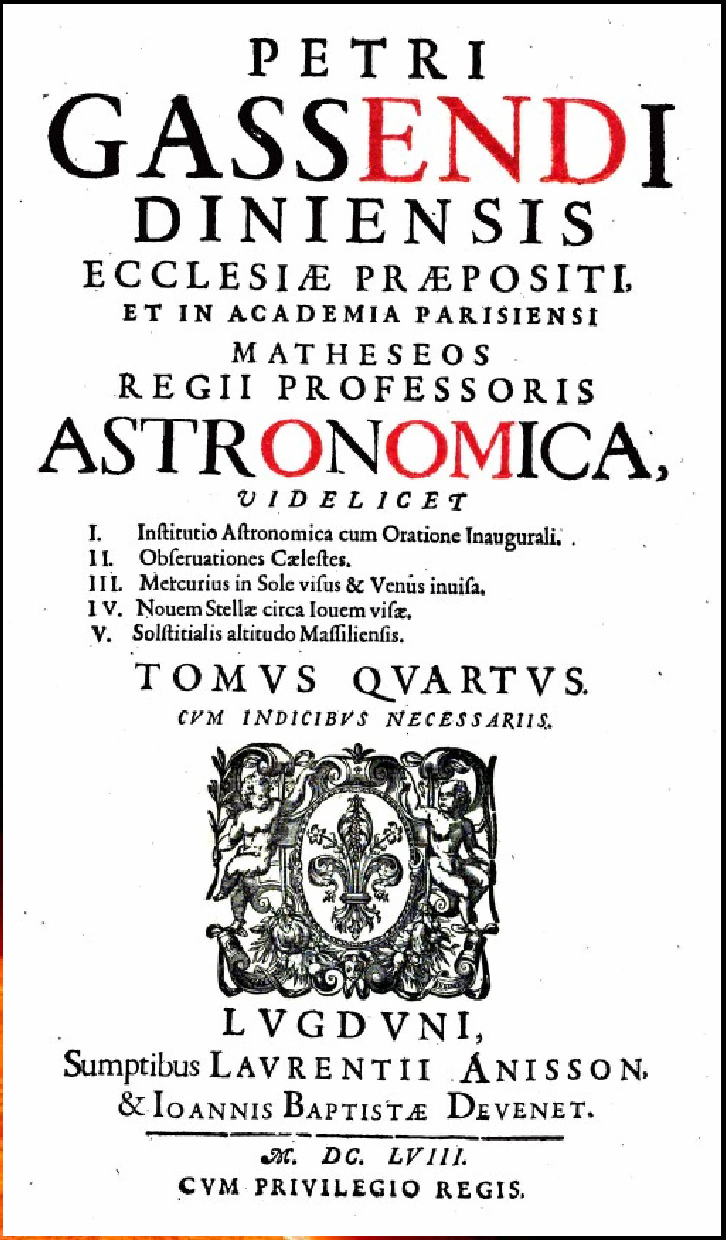
Si Mars ſit Terrâ major, oportet Solis parallaxin multò minorem eſſe quàm vult *Keplerus*.

Ex Epiſt. Julii 25. 1638, Toxtethæ.

POſtquam te viderim, nihil à te accepi, necdum ad te ſcripſi quicquam.

Lingomontanum tandem nactus ſum. Habet ille multas obſervationes Planetarum omnium, præſertim in oppoſitione Solis, ſed breviter deſcriptas.

(4) We have **eliminated one spurious** observation by Gassendi on 1 Dec 1638.

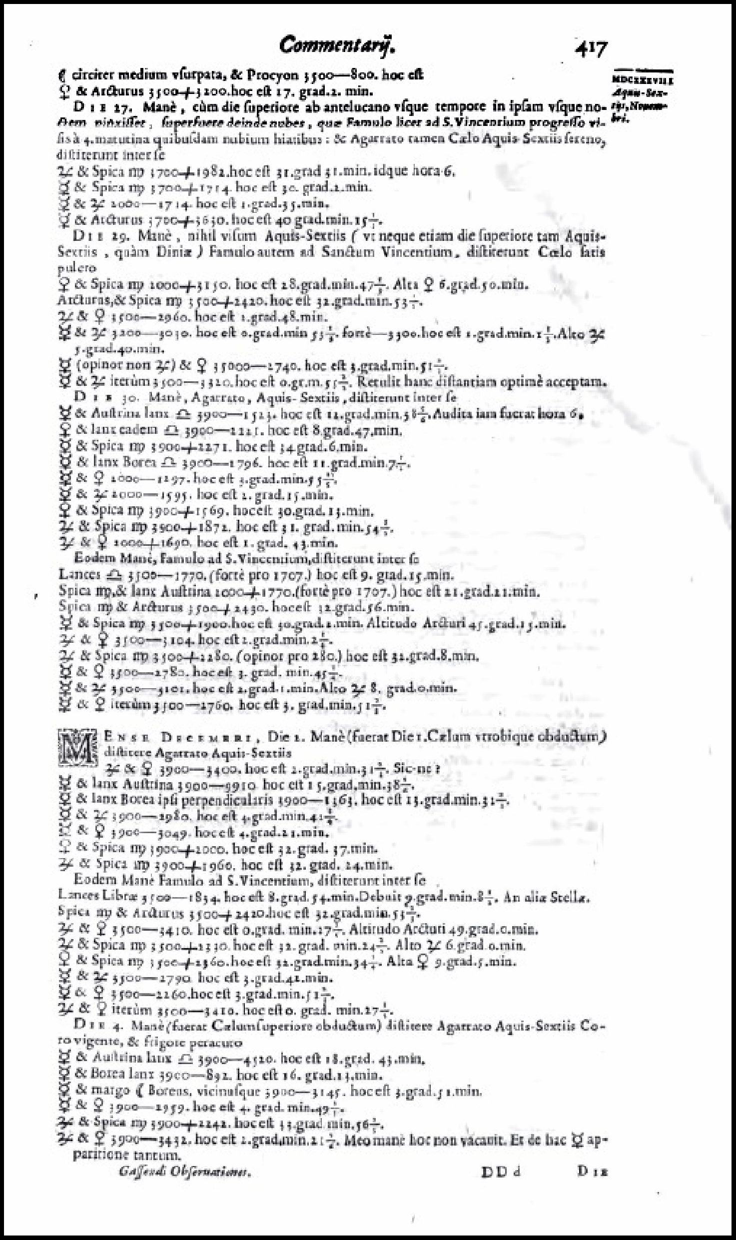


PETRI
GASSENDI
DINIENSIS
ECCLESIÆ PRÆPOSITI,
ET IN ACADEMIA PARISIENSI
MATHESEOS
REGII PROFESSORIS
ASTRONOMICA,
VIDELICET

I. Institutio Astronomica cum Oratione Inaugurali.
II. Obseruationes Cæleſtes.
III. Mercurius in Sole viſus & Venus inuiſa.
IV. Nouem Stellæ circa Iouem viſæ.
V. Solſtitialis altitudo Maſſilienſis.

TOMVS QVARTVS.
CVM INDICIBVS NECESSARIIS.

LVGDVNI,
Sumptibus LAVRENTII ANISSON,
& IOANNIS BAPTISTÆ DEVENET.
M. DC. LVIII.
CVM PRIVILEGIO REGIS.



☾ circiter medium vſurpata, & Procyon 3500—800. hoc eſt
♀ & Arcturus 3500+3200. hoc eſt 17. grad.2. min.

DIE 27. Manè, cùm die ſuperiore ab antelucano vſque tempore in ipſam vſque noctem ninxiſſet, ſuperfuere deinde nubes, quæ Famulo licet ad S. Vincentium progreſſo viſis à 4. matutina quibuſdam nubium hiatibus: & Agarrato tamen Cælo Aquis-Sextiis ſereno, diſtiterunt inter ſe — MDCXXXVIII. Aquis-Sextiis, Nouembri.

♃ & Spica ♍ 3700+1982. hoc eſt 31. grad 31. min. idque hora 6.
☿ & Spica ♍ 3700+1714. hoc eſt 30. grad.2. min.
☿ & ♃ 2000—1714. hoc eſt 1. grad.35. min.
☿ & Arcturus 3700+5630. hoc eſt 40 grad. min. 15 1/2.

DIE 29. Manè, nihil viſum Aquis-Sextiis (vt neque etiam die ſuperiore tam Aquis-Sextiis, quàm Diniæ) Famulo autem ad Sanctum Vincentium, diſtiterunt Cælo ſatis pulcro

♀ & Spica ♍ 1000+3150. hoc eſt 28. grad. min. 47 1/2. Alta ♀ 6. grad. 50. min.
Arcturus, & Spica ♍ 3500+2420. hoc eſt 32. grad. min. 53 1/2.
♃ & ♀ 3500—2960. hoc eſt 1. grad. 48. min.
☿ & ♃ 3200—3010. hoc eſt 0. grad. min 53 1/2. fortè—3300. hoc eſt 1. grad. min. 1 1/2. Alto ♃ 5. grad. 40. min.
☿ (opinor non ♃) & ♀ 35000—2740. hoc eſt 3. grad. min. 51 1/2.
☿ & ♃ iterùm 3500—3320. hoc eſt 0. gr. m. 55 2/3. Retulit hanc diſtantiam optimè acceptam.

DIE 30. Manè, Agarrato, Aquis-Sextiis, diſtiterunt inter ſe

☿ & Auſtrina lanx ♎ 3900—1523. hoc eſt 12. grad. min. 58 1/2. Audita iam fuerat hora 6.
☿ & lanx eadem ♎ 3900—2221. hoc eſt 8. grad. 47. min.
☿ & Spica ♍ 3900+2271. hoc eſt 34 grad. 6. min.
☿ & lanx Borea ♎ 3900—1796. hoc eſt 11. grad. min. 7 1/2.
☿ & ♀ 2000—1297. hoc eſt 3. grad. min. 55 1/2.
☿ & ♃ 2000—1595. hoc eſt 2. grad. 15. min.
♀ & Spica ♍ 3900+1569. hoc eſt 30. grad. 13. min.
♃ & Spica ♍ 3900+1872. hoc eſt 31. grad. min. 54 1/2.
♃ & ♀ 2000+1690. hoc eſt 1. grad. 43. min.

Eodem Manè, Famulo ad S. Vincentium, diſtiterunt inter ſe

Lances ♎ 3500—1770. (fortè pro 1707.) hoc eſt 9. grad. 15. min.
Spica ♍, & lanx Auſtrina 2000+1770. (fortè pro 1707.) hoc eſt 21. grad. 21. min.
Spica ♍ & Arcturus 3500+2430. hoc eſt 32. grad. 56. min.
☿ & Spica ♍ 3500+1900. hoc eſt 30. grad. 2. min. Altitudo Arcturi 45. grad. 15. min.
♃ & ♀ 3500—3104. hoc eſt 2. grad. min. 2 1/2.
♃ & Spica ♍ 3500+2280. (opinor pro 280.) hoc eſt 32. grad. 8. min.
☿ & ♀ 3500—2780. hoc eſt 3. grad. min. 45 1/2.
☿ & ♃ 3500—3101. hoc eſt 2. grad. 1. min. Alto ♃ 8. grad. 0. min.
☿ & ♀ iterùm 3500—2760. hoc eſt 3. grad. min. 51 2/3.

MENSE DECEMBRI, Die 1. Manè (fuerat Die 1. Cælum vtrobique obductum) diſtitere Agarrato Aquis-Sextiis

♃ & ♀ 3900—3400. hoc eſt 2. grad. min. 31 1/2. Sic-ne?
☿ & lanx Auſtrina 3900—9910. hoc eſt 15. grad. min. 38 1/2.
☿ & lanx Borea ipſi perpendicularis 3900—1363. hoc eſt 13. grad. min. 31 1/2.
☿ & ♃ 3900—2980. hoc eſt 4. grad. min. 41 1/2.
☿ & ♀ 3900—3049. hoc eſt 4. grad. 21. min.
♀ & Spica ♍ 3900+2000. hoc eſt 32. grad. 37. min.
♃ & Spica ♍ 3900+1960. hoc eſt 32. grad. 24. min.

Eodem Manè Famulo ad S. Vincentium, diſtiterunt inter ſe

Lances Libræ 3500—1834. hoc eſt 8. grad. 54. min. Debuit 9. grad. min. 8 1/2. An aliæ Stellæ.
Spica ♍ & Arcturus 3500+2420. hoc eſt 32. grad. min. 53 1/2.
♃ & ♀ 3500—3410. hoc eſt 0. grad. min. 27 1/2. Altitudo Arcturi 49. grad. 0. min.
♃ & Spica ♍ 3500+2330. hoc eſt 32. grad. min. 24 1/2. Alto ♃ 6. grad. 0. min.
♀ & Spica ♍ 3500+2360. hoc eſt 32. grad. min. 34 1/2. Alta ♀ 9. grad. 5. min.
☿ & ♃ 3500—2790. hoc eſt 3. grad. 42. min.
☿ & ♀ 3500—2260. hoc eſt 3. grad. min. 51 1/2.
♃ & ♀ iterùm 3500—3410. hoc eſt 0. grad. min. 27 1/2.

DIE 4. Manè (fuerat Cælum ſuperiore obductum) diſtitere Agarrato Aquis-Sextiis Coro vigente, & frigore peracuto

☿ & Auſtrina lanx ♎ 3900—4520. hoc eſt 18. grad. 43. min.
☿ & Borea lanx 3900—892. hoc eſt 16. grad. 13. min.
☿ & margo ☾ Boreus, vicinuſque 3900—3145. hoc eſt 3. grad. 51. min.
☿ & ♀ 3900—2959. hoc eſt 4. grad. min. 49 1/2.
♃ & Spica ♍ 3900+2242. hoc eſt 33. grad. min. 56 1/2.
♃ & ♀ 3900—3432. hoc eſt 2. grad. min. 21 1/2. Meo manè hoc non vacauit. Et de hac ☿ apparitione tantum.

(5) We have changed the **record by Rheita** [1642].

OCVLVS

ENOCH ET ELIÆ

SIVE

RADIVS SIDEREOMYSTICVS

PARS PRIMA

AVTHORE

R. P. F. ANTONIO MARIA

SCHYRLEO DE RHEITA

ORD. CAPVCINORVM CONCIONAT. ET PROVINCIÆ AVSTRIÆ AC BOHEMIÆ QVONDAM PRÆLECTORE.

Opus Philoſophis, Aſtronomis, & rerum cæleſtium æquis æſtimatoribus non tam vtile quàm iucundum:

Quo omnium Planetarum veri motus, ſtationes, & retroceſsiones, ſine vllis epicyclis & æquantibus, tam in Theoria Tychonica, quàm Copernicana compendioſiſſimè & iucundiſsimè demonſtrantur exhibenturque. Hypotheſis Tychonis quoad abſolutam veritatem ſtabilitur ac facilior ipsâ Copernicanâ redditur, reformatur, & ad ſimpliciſſimam normam & formam reducitur.

HISCE ACCESSERVNT

Nouæ harmonicæ determinationes molium & proportionum Planetarum ad inuicem. Item plurimæ aliæ nouitates cælo ab Auctore deductæ. Probabiliſſima cauſa fluxus & refluxus Oceani. Ratio breuis conficiendi Teleſcopium aſtronomicum. Et vltimò Planetologium mechanicum & nouum, quo pauciſſimis rotis veri omnium Planetarum motus iucundè exhiberi queunt.

Quia delectaſti me Domine in factura tua: & in operibus manuum tuarum exultabo. Pſ. 91.

ANTVERPIÆ,

Ex Officina Typographica HIERONYMI VERDVSSII.

M. DC. XLV.

Cum Gratia & Priuilegio.

& Sol morbo illo palloris, & ſæculum triſtiori caligne laborarint. Idem ſub Conſtantino Principe, & Irene contigiſſe ferunt circa annum Chriſti 797. Quorum tempore per 17. integros dies, adeò nuſquam viſus eſt Sol, adeò tenues radios telluri immiſit, vt mundo aut omninò abreptus, aut certè radijs & gratiſsimâ luce ſpoliatus exutuſque crederetur. Enimverò in vaſtiſsimo tunc oceano oberrantes, neque curſum ſuum per tenebras dirigere, neque telluri inſiſtentes cœptum iter & negotiationes humanas proſequi potuerunt.

Iterum Anno 1547. per totam vaſtiſsimam Europæ plagam, Solis radij ſanguineo colore adeò deleti videbantur trium dierum ſpatio; vt mundo vltimum iam quaſi inciperent prænũtiare diem. Denique tempore, quo Rudolphus II. Auguſtus ex humanis abreptus fuerat, Solem per plures dies, ſuâ triſtiſsima facie & luce obfuſcata ingentem terricolis denuò metum & horrorem incuſsiſſe ferunt.

Quidam Solem ſimilem monti Æthnæ putant.

Horum igitur ſolarium prodigiorum meritò cauſam indagare liceat. Aliqui putant Solem inſtar alterius montis Æthnæ, aut Veſuuij recrementa ſua in extimam ſuperficiem proflare, & veluti pluuiâ fauillarum inde adeò conſpergi & vndique circumdari, vt mundo inde quaſi eripiatur dies, ſplendore omni Solis intercepto, donec eructante flammâ agmen illud fauillarum ab extima ſuperficie diſpergatur, aut fauillæ depaſcantur. Quæ ſententia, ſi Solis ignis ſupponatur alimento & pabulo foueri, fortè aliquid probabilitaris obtineret. Quod ſi verò Sol, velut puriſsimum elementum & impermixtus ignis, pabulo nullo indigeat, ſed diuinæ potentiæ, voluntatis & conſeruationis vis ei vtique, vt conſeruetur ſufficiat; non video vnde Soli illa recrementa, & vſtrina materia prouenire queat.

Fortè haud etiam ineptè talium accidentium ratio aſsignari poſſet; ſcilicet ſi dicamus Soli frequentem illum luorem & pallorem, ex macularum, ſeu ſtellarum ſolarium nimiùm quãdoque concurrentiũ agmine cõtingere. Adeò enim quandoque diſcus ſolaris dictis ſtellis & maculis ſcatet, vt mirum haud ſit eius inde lumen notabiliſsimè hebetari debilitarique.

Certè quod iam diximus, propria experientiâ Coloniæ Anno 1642. experti ſumus: dum ingentem ſtellarum ſolarium turmam maiorum & minorum per 14. dies & vltra ſibi inuicem continuâ ſerie ſuccedentium cum ſtupore, ſolarem diſcum adeò occupare vidimus, vt lux eius, maximè media, & intenſiſsima, haud leuiter illis fuerit hebetata. Nam tubo optimo, in medio ſolaris diſci globum perfectiſsimè rotundum, ſubnigrum,

ſubnigrum, pugni magnitudinem quaſi excedentem conſpeximus, idque directiſsimo aſpectu; qui & per octiduum Solis haud exiguam portionẽ eclipſauit: maximaſque aëri turbationes, vtpotè ventos, imbres, & frigora in medio Iunij attulit: prout crebris obſeruationibus iam à multis annis compertum habemus: ſcilicet ferè ſemper aëris inſigniores, & magis notabiles mutationes ex dictarum ſtellarum ſolarem diſcum ſubeuntium agmine contingere & euenire.

Maculæ ſub Sole aëris mutationem cauſant.

Et profecto perfalſum eſt, maculas illas penitiori obtutu directè per optimum & longiorem tubum aſtronomicum, (qui totum ſimul ſolarem diſcum diſcoperiat exhibeatque) conſpectas, aliam quàm circulariſsimam & rotundam figuram oſtendere, vt frequenter experti ſumus. Itaque toties ſemper ſolares eclipſes contingere neceſſe eſt, quoties ſtellæ dictæ Solem ſubeunt; ſubeunt autem frequentiſsimè; ergo multò frequentiores & plures contingunt nobis ſolares eclipſes, quam vulgus arbitratur. Sed quis obſecro talium eclipſium arcanos reſpectu telluris noſtræ effectus hactenus penetrauit? vt quid ergo paupelli illi deceptores Aſtrologi, ex aſtris de futuris contingentibus diuinare non erubeſcunt, cùm multa præſentia in aſtris ignorent ſidera & ita cæcis & falſis ſuis prognoſticis procedant, ac ſi dicta aſtra aut penitus in rerum natura non eſſent; aut ſine influxu eſſent.

Reprehenduntur Aſtrologi iudiciarij.

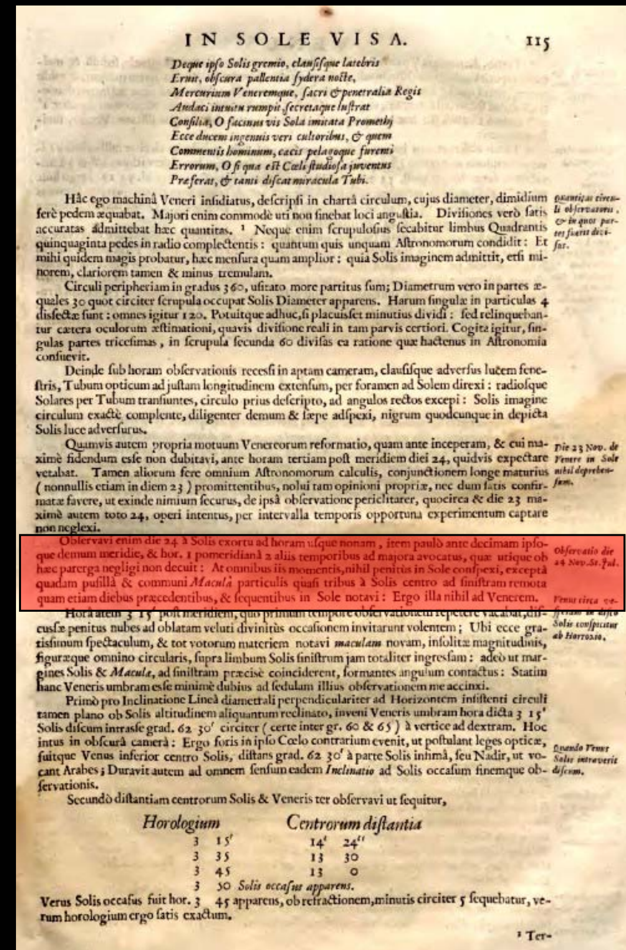
An non inſipientem medicum illum iudicares, qui aut ignoratis penitus, aut ſaltem non attentis interioribus humani corporis mẽbris, eorumque in totum animale corpus naturali & neceſſario influxu; ex ſola inferiorum quorundam inſpectione patienti, longiorem, aut breuiorem vitam præſumeret vaticinare, longiturnum morbum, fortunam & ſimilia? Quâ ergo ratione dictorũ Aſtrologorum pleraque cœli nobiliſsima aſtra eorumque in inferiora influxus & energiam, aut omninò ignorantium, aut ſaltem vix vmbram virtutum illorũ cognoſcentiũ turma cæcò iudicio, & prognoſticis ſuis fictis tantopere hodie mundum excæcare, hominesque inanibus ac mendacibus verbis cæco quaſi verbere ferire non dubitat? Cumque ſemper æquiuocè mentiantur prognoſticando; mirum non eſt ea quæ alias reuerâ caſu tantùm contingunt quandoque, etſi præter intentionẽ prognoſticantium, accidere, ſicque prædictionibus eorum à ſimplicioribus fidem haberi. Certè ipſo ſtatim fronte æquiuoco prædictionum ſuarum produnt, à quo talem diuinationem, ſcientiã, aut veriùs inſipientiam ſuam hauriant; ſcilicet non niſi ab illo, (puta diabolo) qui hoc ipſiſsimo modo quondam famoſum illud & no-

(6) We have **incorporated a sunspot record** by Horrox in 4 December 1639.

JOHANNIS HEVELII
MERCURIUS
In Sole viſus Gedani,
Anno Christiano M DC LXI, d. III Maji, St. n.
Cum aliis quibuſdam rerum Cœleſtium obſervationibus, rariſq; phænomenis.
Cui annexa eſt,
VENUS
In Sole pariter viſa, Anno 1639, d. 24 Nov. St. V.
LIVERPOLIÆ, A JEREMIA HORROXIO:
NUNC PRIMUM EDITA, NOTISQUE ILLUSTRATA.
Quibus accedit ſuccincta
HISTORIOLA,
Novæ illius, ac miræ Stellæ in collo Ceti, certis anni temporibus clarè admodùm affulgentis, rursùs omninò evaneſcentis.
Nec non
GENUINA DELINEATIO,
Paraſelenarum, & Pareliorum quorundam rariſſimorum.

ENARRANT DEI GLORIAM

Cum Privilegio Sac. Cæſareæ, & Regiæ P. & S. Majeſtatum
GEDANI,
AUTORIS TYPIS, ET SUMPTIBUS,
imprimebat SIMON REINIGER.
ANNO M DC LXII.



Deque ipſo Solis gremio, clauſiſque latebris
Eruit, obſcura pallentia ſydera nocte,
Mercurium Veneremque, ſacri & penetralia Regis
Audaci intuitu rumpit, ſecretaque luſtrat
Conſilia, O facinus vis Sola imitata Promethj
Ecce ducem ingenuis veri cultoribus, & quem
Commentis hominum, cæcis pelagoque furenti
Errorum, O ſi qua eſt Cœli ſtudioſa juventus
Præferas, & tanti diſcat miracula Tubi.

Hâc ego machinâ Veneri inſidiatus, deſcripſi in chartâ circulum, cujus diameter, dimidium ferè pedem æquabat. Majori enim commodè uti non ſinebat loci anguſtia. Diviſiones verò ſatis accuratas ádmittebat hæc quantitas. [1] Neque enim ſcrupuloſius ſecabitur limbus Quadrantis quinquaginta pedes in radio complectentis: quantum quis unquam Aſtronomorum condidit: Et mihi quidem magis probatur, hæc menſura quam amplior: quia Solis imaginem admittit, etſi minorem, clariorem tamen & minus tremulam. *Quantitas circuli obſervatorii, & in quot partes fuerit diviſus.*

Circuli peripheriam in gradus 360, uſitato more partitus ſum; Diametrum vero in partes æquales 30 quot circiter ſcrupula occupat Solis Diameter apparens. Harum ſingulæ in particulas 4 diſſectæ ſunt: omnes igitur 120. Potuitque adhuc, ſi placuiſſet minutius dividi: ſed relinquebantur cætera oculorum æſtimationi, quavis diviſione reali in tam parvis certiori. Cogita igitur, ſingulas partes triceſimas, in ſcrupula ſecunda 60 diviſas ea ratione quæ hactenus in Aſtronomia conſuevit.

Deinde ſub horam obſervationis receſſi in aptam cameram, clauſiſque adverſus lucem feneſtris, Tubum opticum ad juſtam longitudinem extenſum, per foramen ad Solem direxi: radioſque Solares per Tubum tranſiuntes, circulo prius deſcripto, ad angulos rectos excepi: Solis imagine circulum exactè complente, diligenter demum & ſæpe adſpexi, nigrum quodcunque in depicta Solis luce adverſurus.

Quamvis autem propria motuum Venereorum reformatio, quam ante inceperam, & cui maximè fidendum eſſe non dubitavi, ante horam tertiam poſt meridiem diei 24, quidvis expectare vetabat. Tamen aliorum fere omnium Aſtronomorum calculis, conjunctionem longe maturius (nonnullis etiam in diem 23) promittentibus, nolui tam opinioni propriæ, nec dum ſatis confirmatæ favere, ut exinde nimium ſecurus, de ipsâ obſervatione periclitarer, quocirca & die 23 maximè autem toto 24, operi intentus, per intervalla temporis opportuna experimentum captare non neglexi. *Die 23 Nov. de Venere in Sole nihil deprehenſum.*

Obſervavi enim die 24 à Solis exortu ad horam uſque nonam, item paulò ante decimam ipſoque demum meridie, & hor. 1 pomeridianâ 2 aliis temporibus ad majora avocatus, quæ utique ob hæc parerga negligi non decuit: At omnibus iis momentis, nihil penitùs in Sole conſpexi, exceptâ quadam puſillâ & communi *Maculâ* particulis quaſi tribus à Solis centro ad ſiniſtram remota quam etiam diebus præcedentibus, & ſequentibus in Sole notavi: Ergo illa nihil ad Venerem. *Obſervatio die 24 Nov. St. Jul.*

Horâ atem 3 15' poſt meridiem, quo primum tempore obſervationem repetere vacabat, diſcuſſæ penitus nubes ad oblatam veluti divinitùs occaſionem invitarunt volentem; Ubi ecce gratiſſimum ſpectaculum, & tot votorum materiem notavi *maculam* novam, inſolitæ magnitudinis, figuræque omnino circularis, ſupra limbum Solis ſiniſtrum jam totaliter ingreſſam: adeò ut margines Solis & *Maculæ*, ad ſiniſtram præciſè coinciderent, formantes angulum contactus: Statim hanc Veneris umbram eſſe minimè dubius ad ſedulam illius obſervationem me accinxi. *Venus circa ſ ſteram in diſco Solis conſpicitur ab Horroxio.*

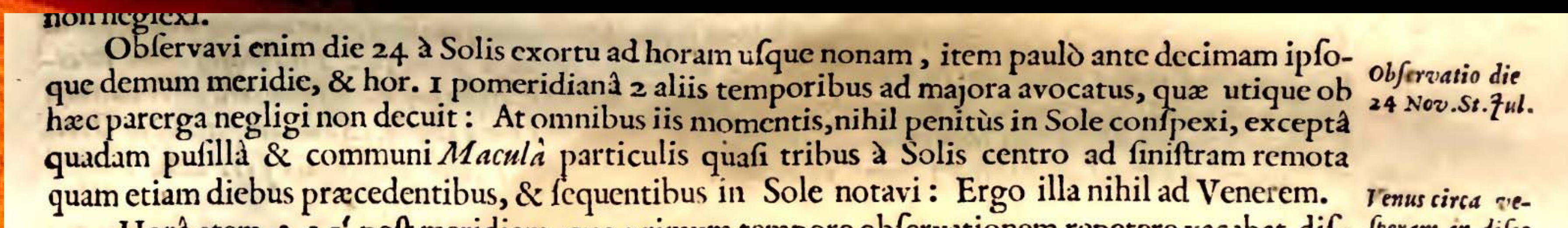
Primò pro Inclinatione Lineâ diametrali perpendiculariter ad Horizontem inſiſtenti circuli tamen plano ob Solis altitudinem aliquantum reclinato, inveni Veneris umbram hora dicta 3 15' Solis diſcum intraſſe grad. 62 30' circiter (certe inter gr. 60 & 65) à vertice ad dextram. Hoc intus in obſcurâ camerâ: Ergo foris in ipſo Cœlo contrarium evenit, ut poſtulant leges opticæ, fuitque Venus inferior centro Solis, diſtans grad. 62 30' à parte Solis infimâ, ſeu Nadir, ut vocant Arabes; Duravit autem ad omnem ſenſum eadem *Inclinatio* ad Solis occaſum finemque obſervationis. *Quando Venus Solis intraverit diſcum.*

Secundò diſtantiam centrorum Solis & Veneris ter obſervavi ut ſequitur,

Horologium		*Centrorum diſtantia*	
3	15'	14'	24''
3	35	13	30
3	45	13	0
3	50	*Solis occaſus apparens.*	

Verus Solis occaſus fuit hor. 3 45 apparens, ob refractionem, minutis circiter 5 ſequebatur, verum horologium ergo ſatis exactum.

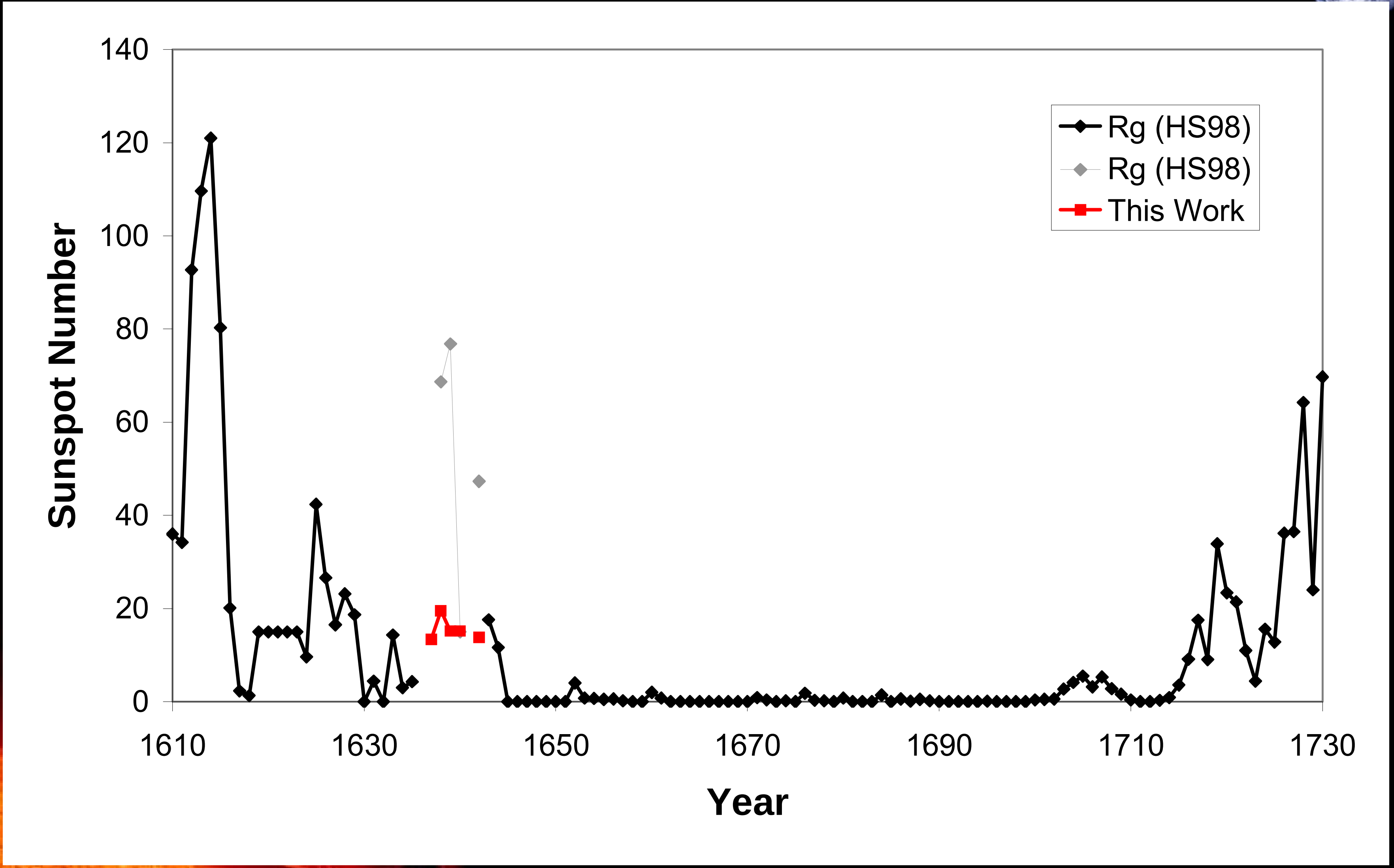
[1] Ter-



non neglexi.

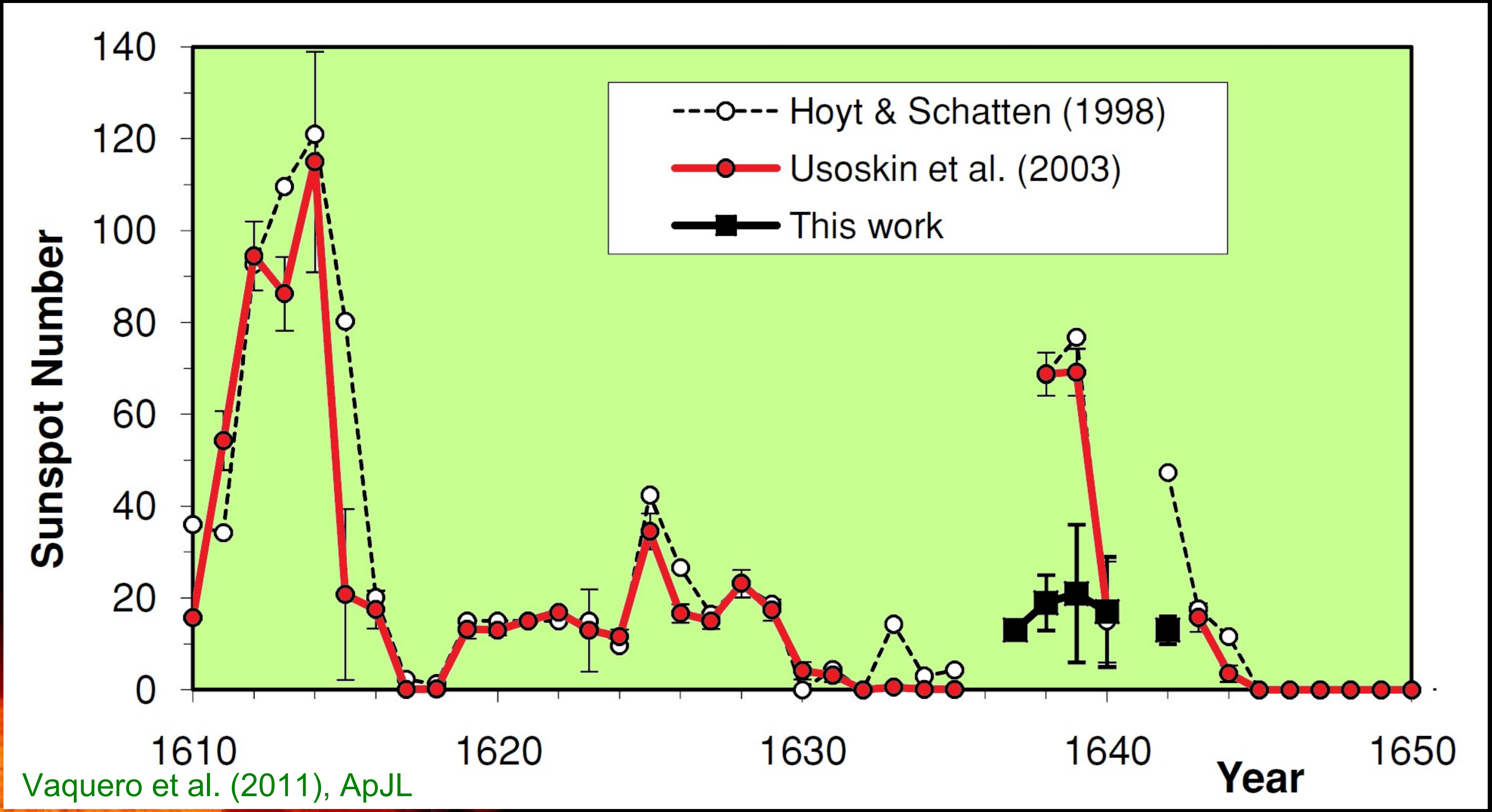
Obſervavi enim die 24 à Solis exortu ad horam uſque nonam, item paulò ante decimam ipſoque demum meridie, & hor. 1 pomeridianâ 2 aliis temporibus ad majora avocatus, quæ utique ob hæc parerga negligi non decuit: At omnibus iis momentis, nihil penitùs in Sole conſpexi, exceptâ quadam puſillâ & communi *Maculâ* particulis quaſi tribus à Solis centro ad ſiniſtram remota quam etiam diebus præcedentibus, & ſequentibus in Sole notavi: Ergo illa nihil ad Venerem. *Obſervatio die 24 Nov. St. Jul.*

Horâ atem 3 15' poſt meridiem, quo primum tempore obſervationem repetere vacabat, diſ- *Venus circa ve- ſteram in diſco*

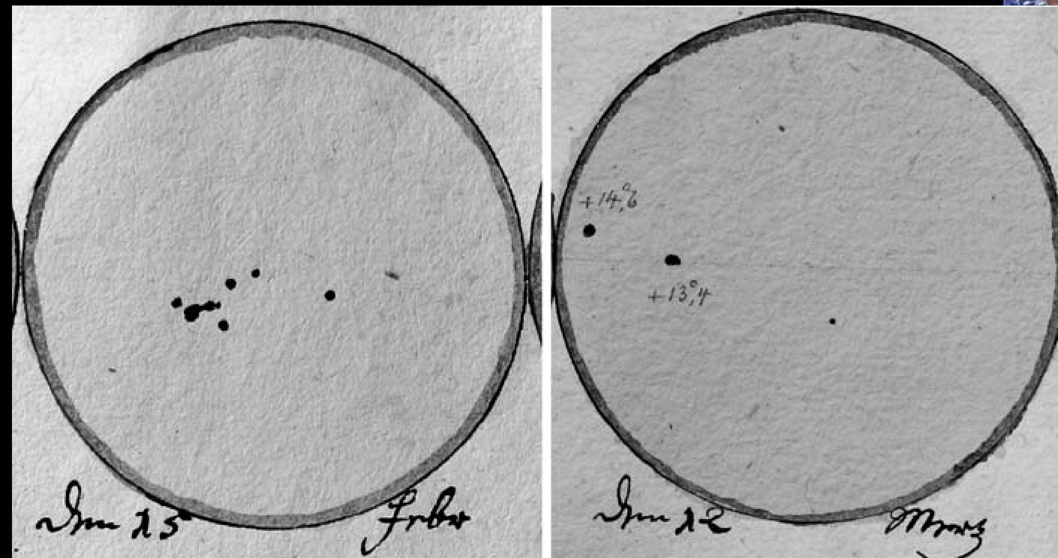


Sunspot Number
140
120
100
80
60
40
20
0
1610
1630
1650
1670
1690
1710
1730
Year
Rg (HS98)
Rg (HS98)
This Work

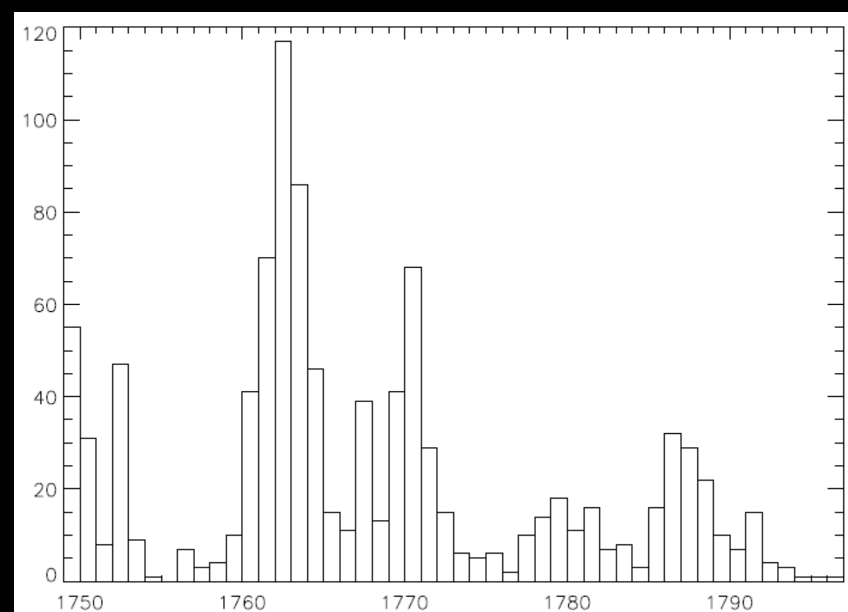
We can use a statistical procedure (Usoskin, Mursula & Kovaltsov, 2003) to reconstruct yearly group sunspot number from sparse daily observation.



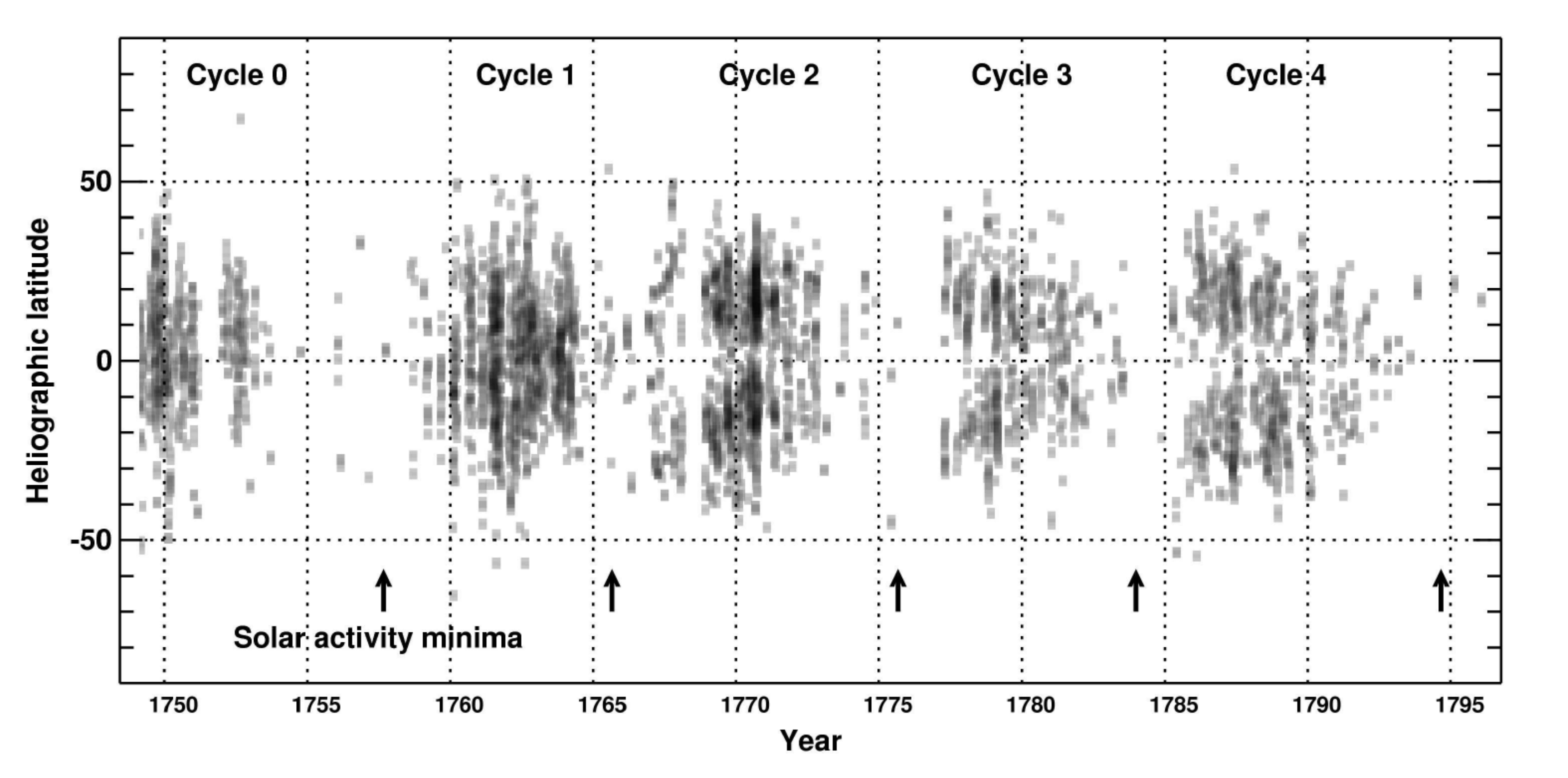
R. Arlt (2008) "Digitization of Sunspot Drawings by Staudacher in 1749 – 1796" *Solar Physics* 247, 399-410.

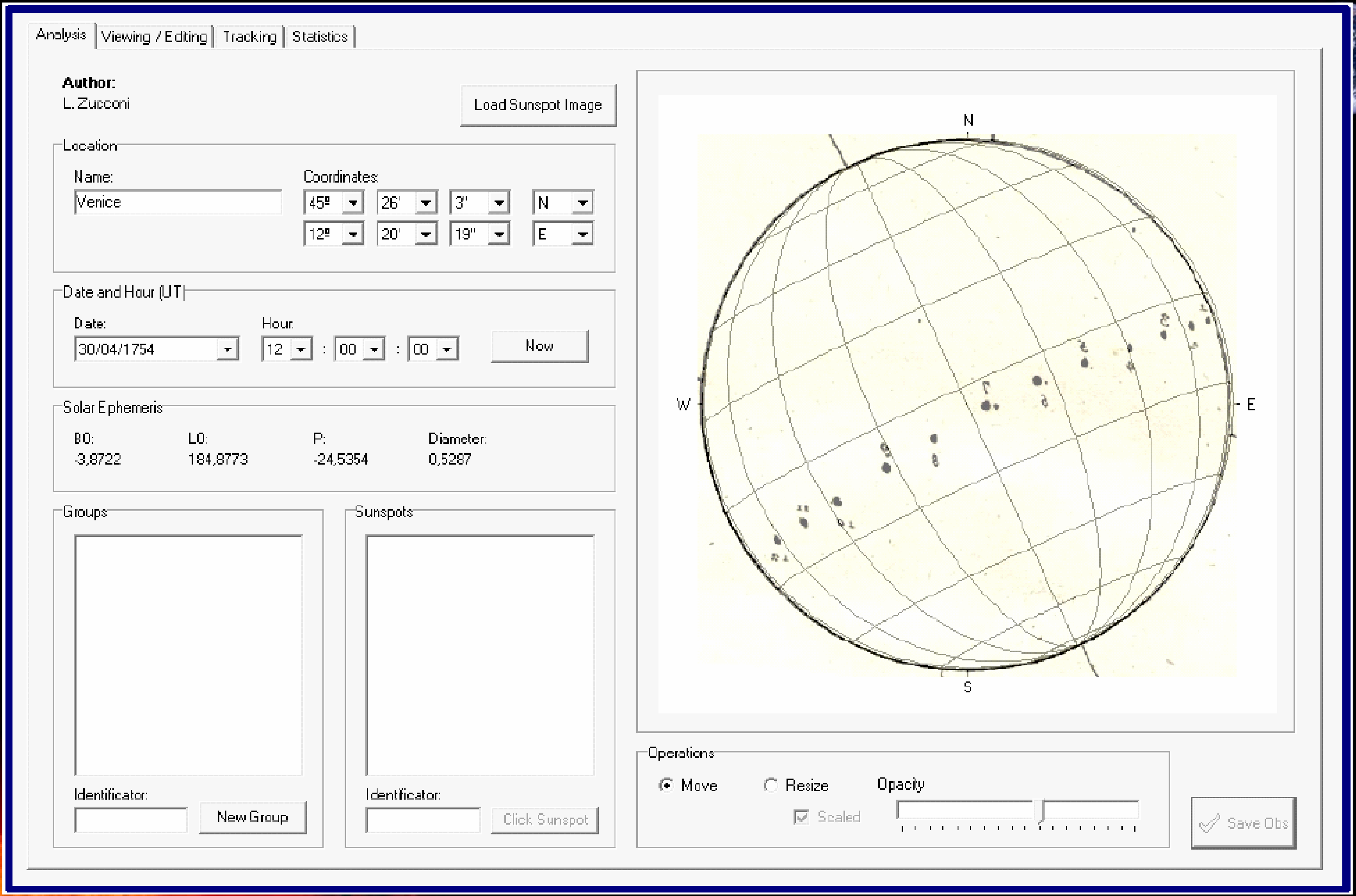


R. Arlt (2008) digitized original drawings by J.C. Staudacher made in the period of 1749 – 1796. Arlt also evaluated the usefulness of the drawings for the determination of sunspot positions for future studies.

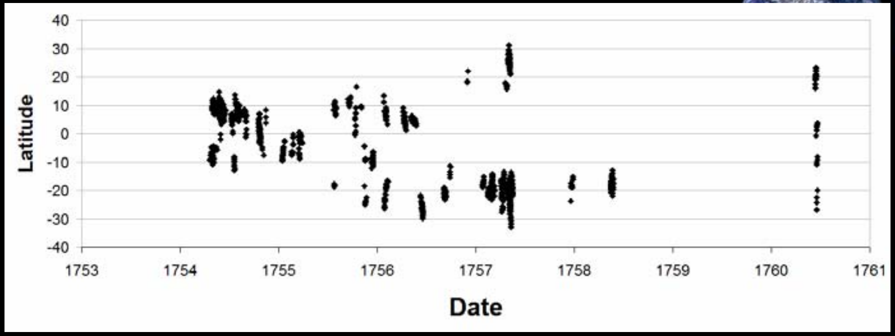


R. Arlt (2009) "The Butterfly Diagram in the Eighteenth Century" *Solar Physics* **255**(1), 143-153, DOI: 10.1007/s11207-008-9306-5

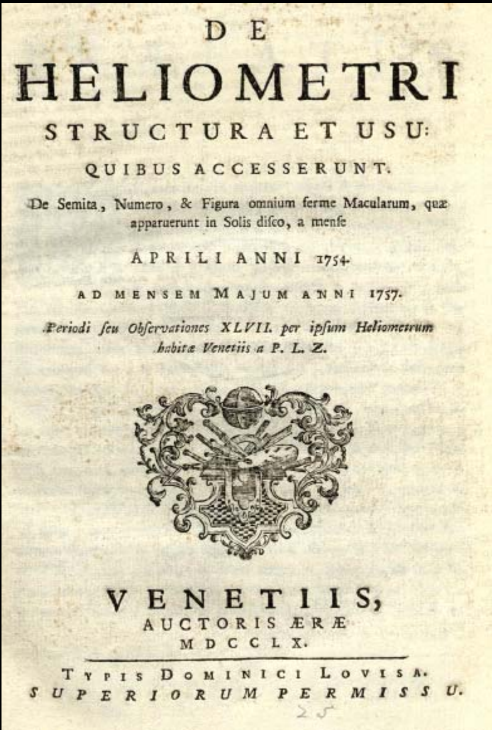




A. Cristo, J.M. Vaquero and F. Sánchez-Bajo (2011) HSUNSPOTS: A TOOL FOR THE ANALYSIS OF HISTORICAL SUNSPOT DRAWINGS, *Journal of Atmospheric and Solar-Terrestrial Physics* 73, 187–190.



Butterfly diagram based on the sunspot latitude estimations obtained from Zucconi drawings (April 1754 – June 1760).



DE

HELIOMETRI

STRUCTURA ET USU:

QUIBUS ACCESSERUNT.

De Semita, Numero, & Figura omnium ferme Macularum, quæ apparuerunt in Solis disco, a mense

APRILI ANNI 1754.

AD MENSEM MAJUM ANNI 1757.

Periodi seu Observationes XLVII. per ipsum Heliometrum habitæ Venetiis a P. L. Z.

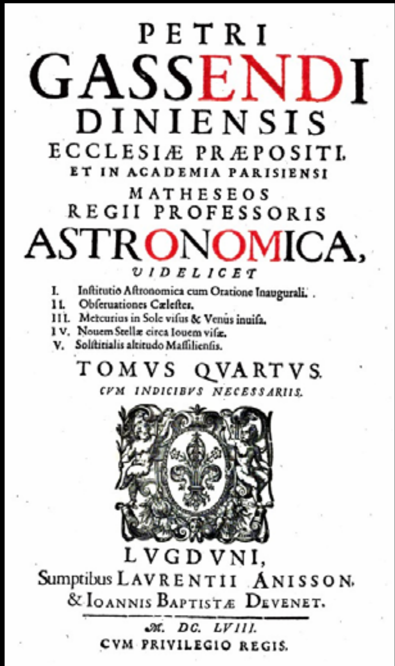
VENETIIS,

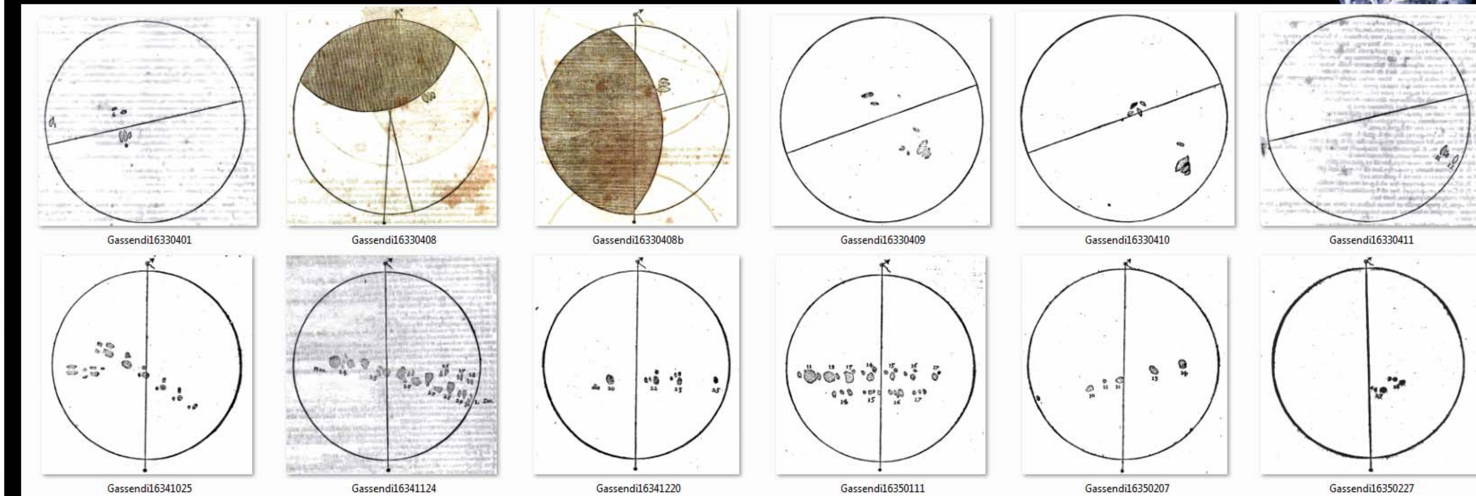
AUCTORIS ÆRE

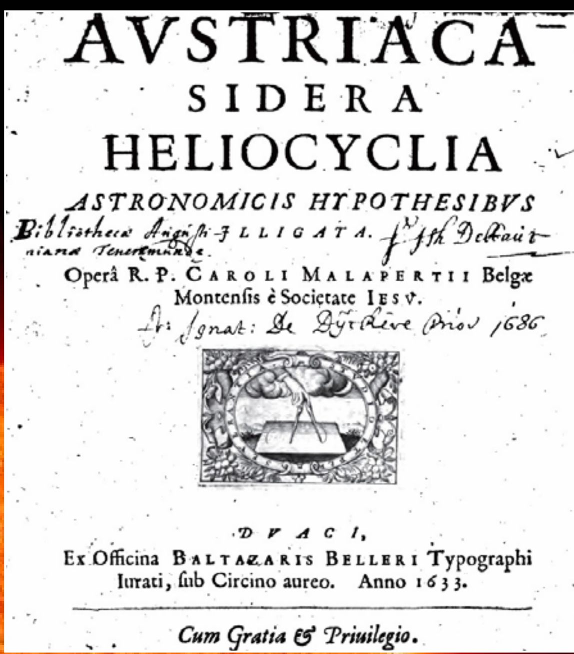
MDCCLX.

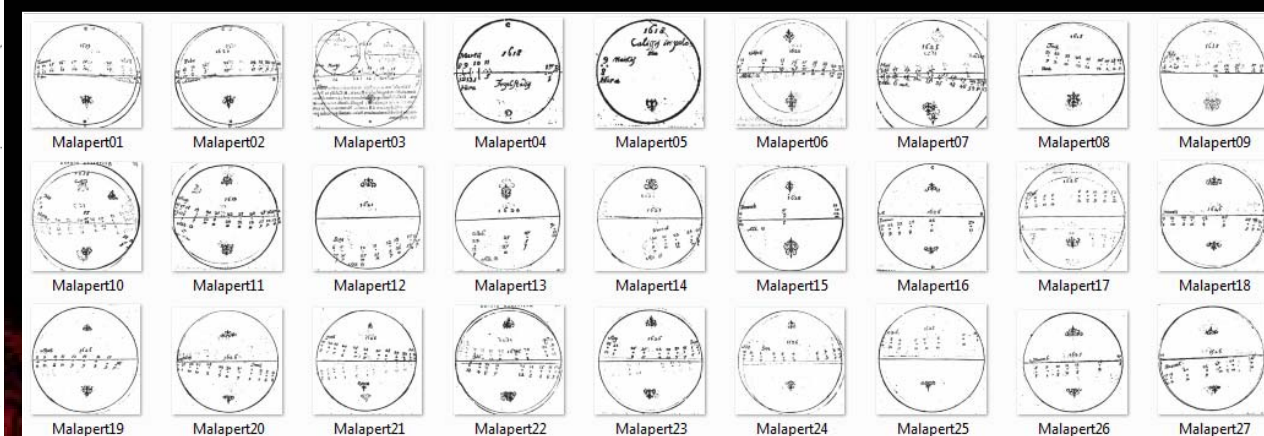
TYPIS DOMINICI LOVISA.

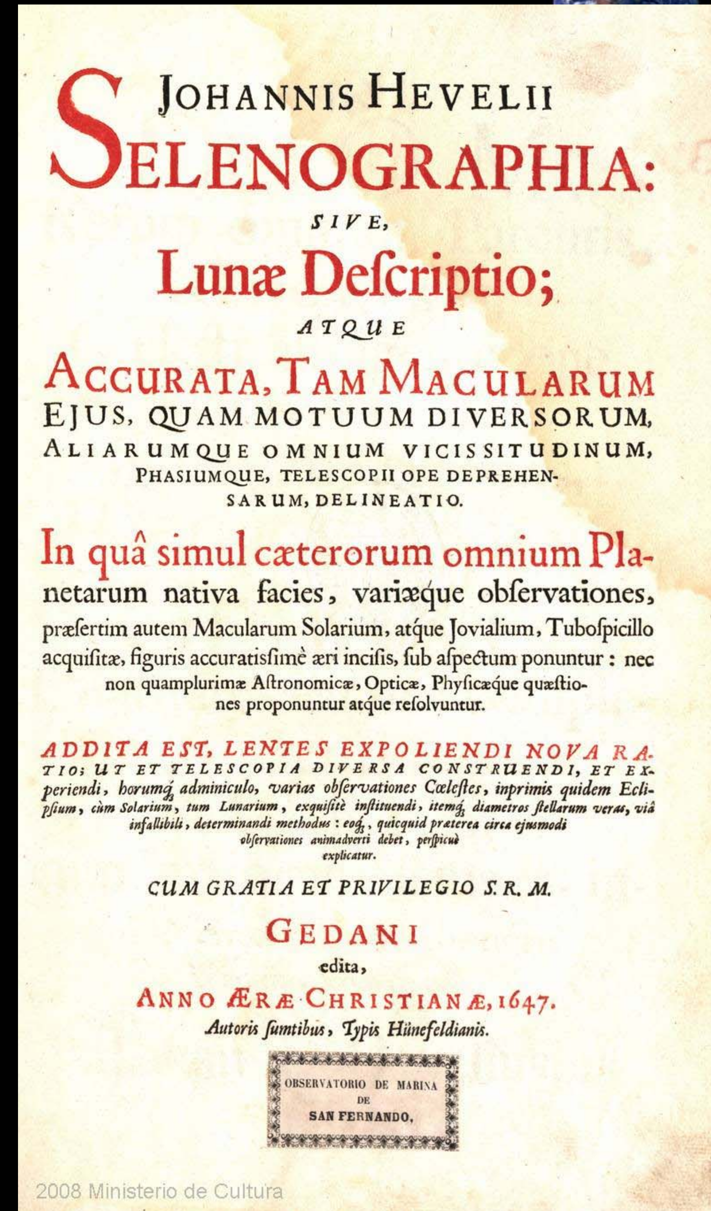
SUPERIORUM PERMISSU.


PETRI
GASSENDI
DINIENSIS
ECCLESIÆ PRÆPOSITI,
ET IN ACADEMIA PARISIENSI
MATHESEOS
REGII PROFESSORIS
ASTRONOMICA,
VIDELICET
I. Institutio Astronomica cum Oratione Inaugurali.
II. Obseruationes Cælestes.
III. Mercurius in Sole visus & Venus inuisa.
IV. Nouem Stellæ circa Iouem visæ.
V. Solstitialis altitudo Massiliensis.
TOMVS QVARTVS.
CVM INDICIBVS NECESSARIIS.
LVGDVNI,
Sumptibus LAVRENTII ANISSON.
& IOANNIS BAPTISTÆ DEVENET.
M. DC. LVIII.
CVM PRIVILEGIO REGIS.




AVSTRIACA
SIDERA
HELIOCYCLIA
ASTRONOMICIS HYPOTHESIBVS
ILLIGATA.
Operâ R. P. CAROLI MALAPERTII Belgæ
Montensis è Societate IESV.
DVACI,
Ex Officina BALTAZARIS BELLERI Typographi
Iurati, sub Circino aureo. Anno 1633.
Cum Gratia & Priuilegio.





JOHANNIS HEVELII

SELENOGRAPHIA:

SIVE,

Lunæ Deſcriptio;

ATQUE

ACCURATA, TAM MACULARUM EJUS, QUAM MOTUUM DIVERSORUM, ALIARUMQUE OMNIUM VICISSITUDINUM, PHASIUMQUE, TELESCOPII OPE DEPREHENSARUM, DELINEATIO.

In quâ simul cæterorum omnium Planetarum nativa facies, variæque obſervationes, præſertim autem Macularum Solarium, atque Jovialium, Tuboſpicillo acquiſitæ, figuris accuratisſimè æri inciſis, ſub aſpectum ponuntur: nec non quamplurimæ Aſtronomicæ, Opticæ, Phyſicæque quæſtiones proponuntur atque reſolvuntur.

ADDITA EST, LENTES EXPOLIENDI NOVA RATIO; UT ET TELESCOPIA DIVERSA CONSTRUENDI, ET EXperiendi, horumq; adminiculo, varias obſervationes Cœleſtes, inprimis quidem Eclipſium, cùm Solarium, tum Lunarium, exquiſitè inſtituendi, itemq; diametros ſtellarum veras, viâ infallibili, determinandi methodus: eoq;, quicquid præterea circa ejusmodi obſervationes animadverti debet, perſpicuè explicatur.

CUM GRATIA ET PRIVILEGIO S. R. M.

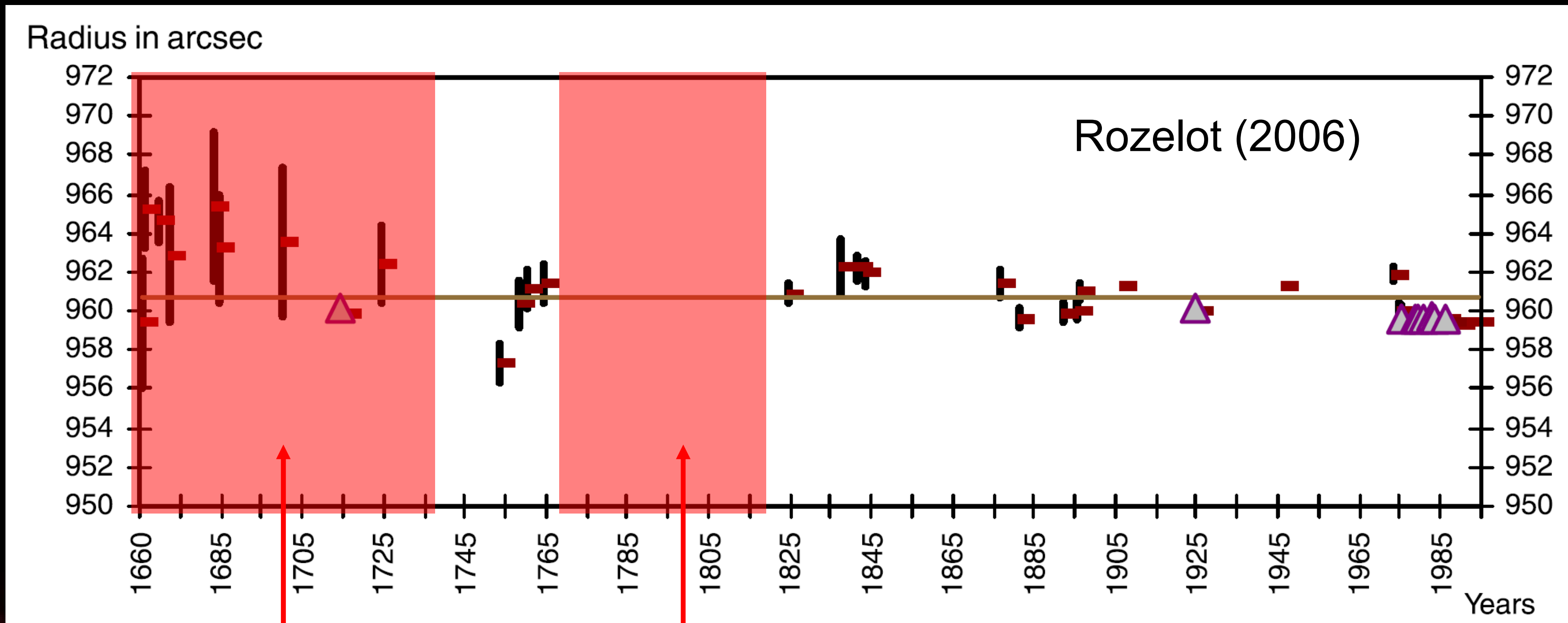
GEDANI

edita,

ANNO ÆRÆ CHRISTIANÆ, 1647.

Autoris ſumtibus, Typis Hünefeldianis.

Evolution of the solar radius variations

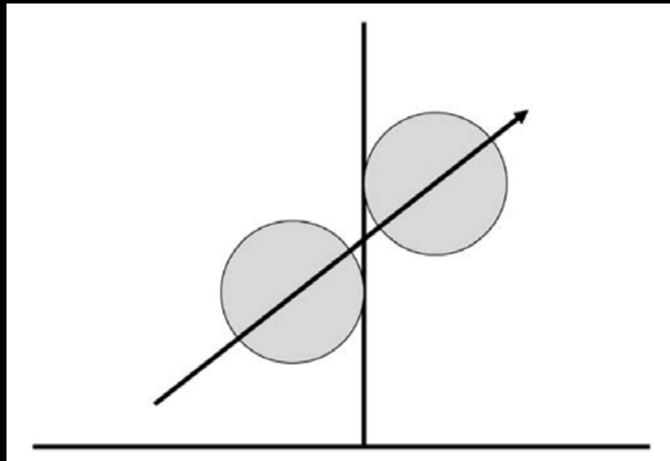


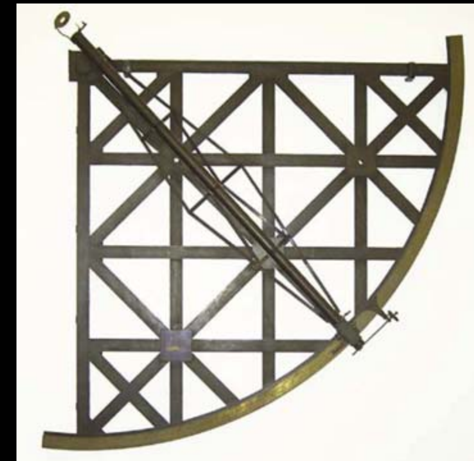
"New" datasets:

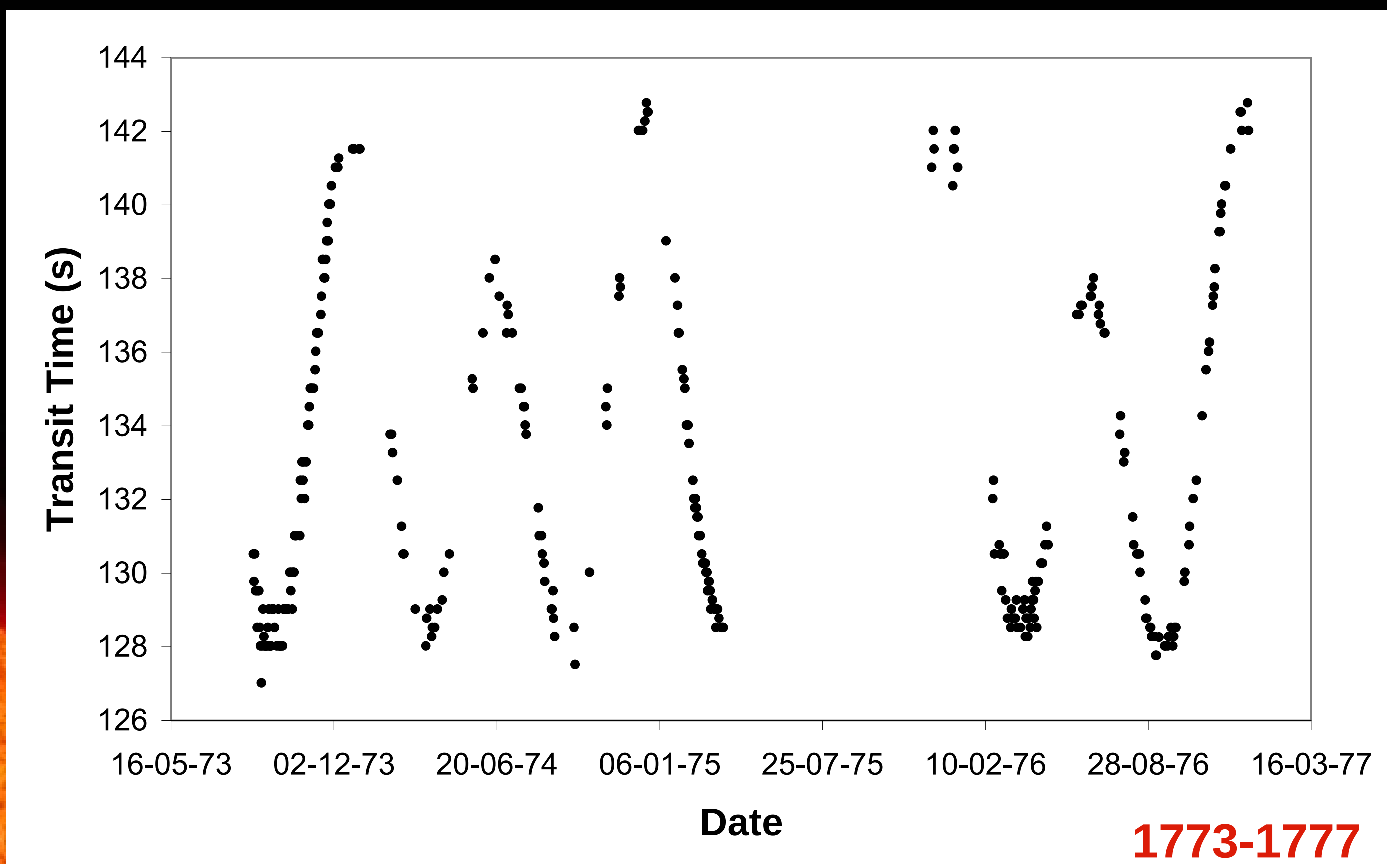
Cádiz Astronomical Observatory

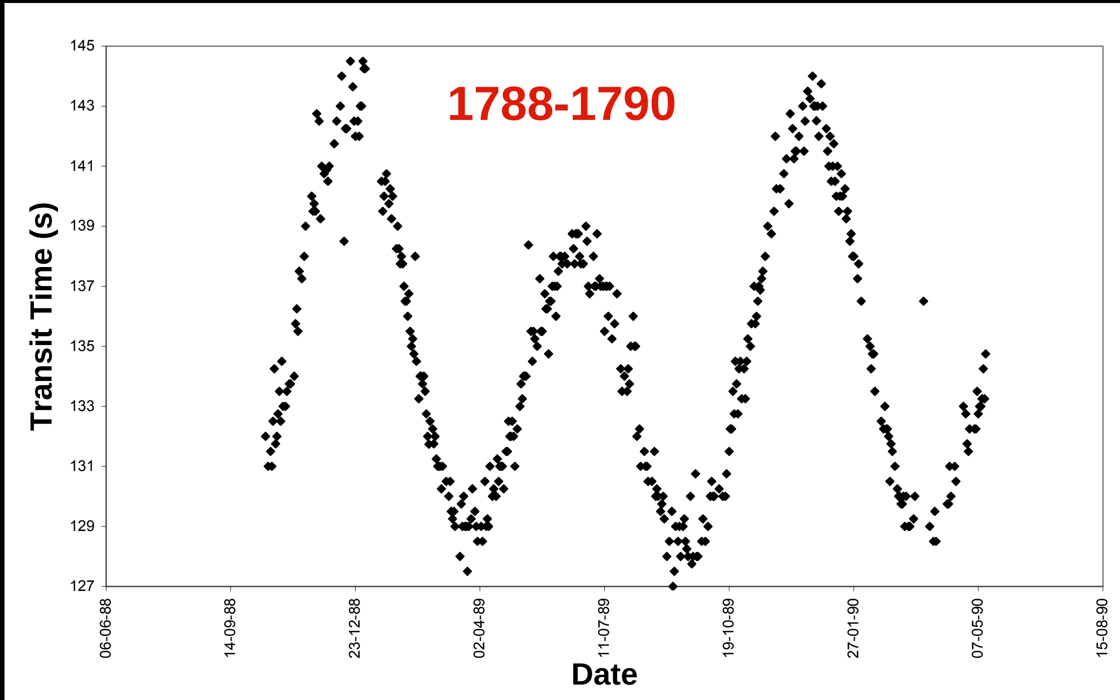
San Petronio Cathedral

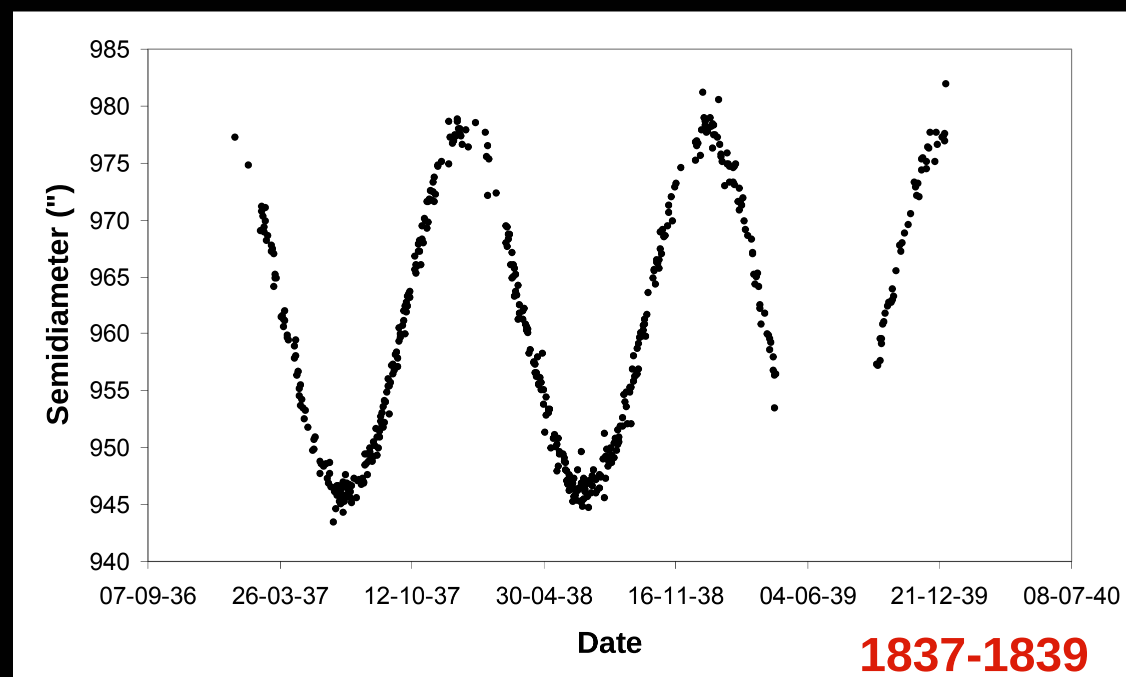
Before MM?



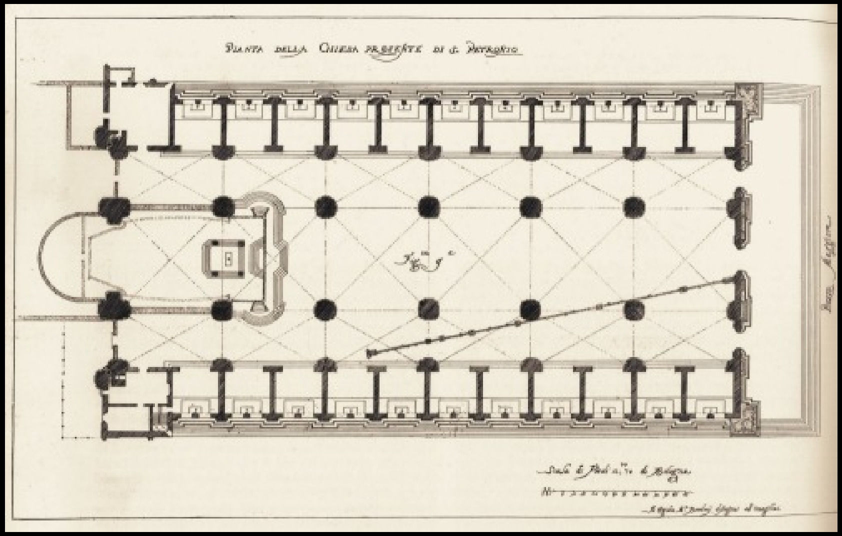


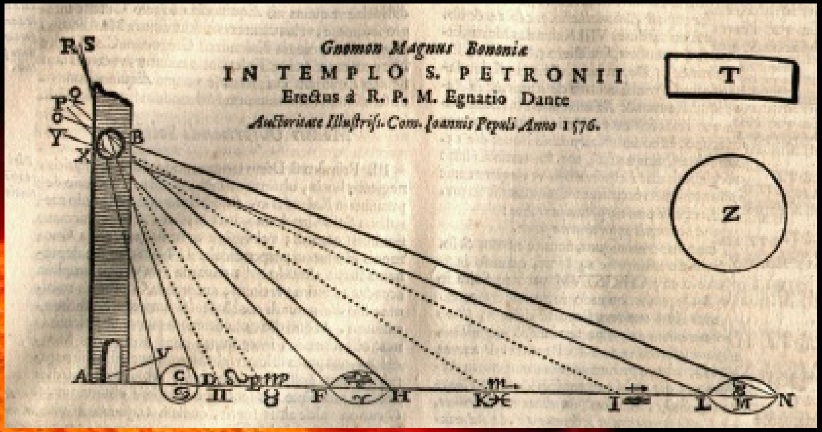

Transit Time (s)
144
142
140
138
136
134
132
130
128
126
16-05-73
02-12-73
20-06-74
06-01-75
25-07-75
10-02-76
28-08-76
16-03-77
Date
1773-1777

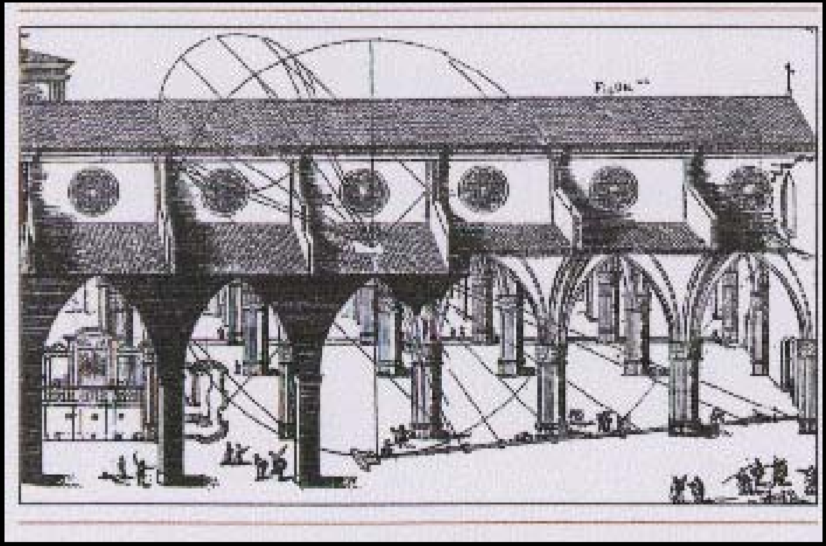

1788-1790
Transit Time (s)
145
143
141
139
137
135
133
131
129
127
06-06-88
14-09-88
23-12-88
02-04-89
11-07-89
19-10-89
27-01-90
07-05-90
15-08-90
Date


Semidiameter (")
985
980
975
970
965
960
955
950
945
940
07-09-36
26-03-37
12-10-37
30-04-38
16-11-38
04-06-39
21-12-39
08-07-40
Date
1837-1839


© Paco Bellido, 2007


Pianta della Chiesa presente di S. Petronio


Gnomon Magnus Bononiæ
IN TEMPLO S. PETRONII
Erectus à R. P. M. Egnatio Dante
Auctoritate Illustriss. Com. Ioannis Pepoli Anno 1576.
T
Z

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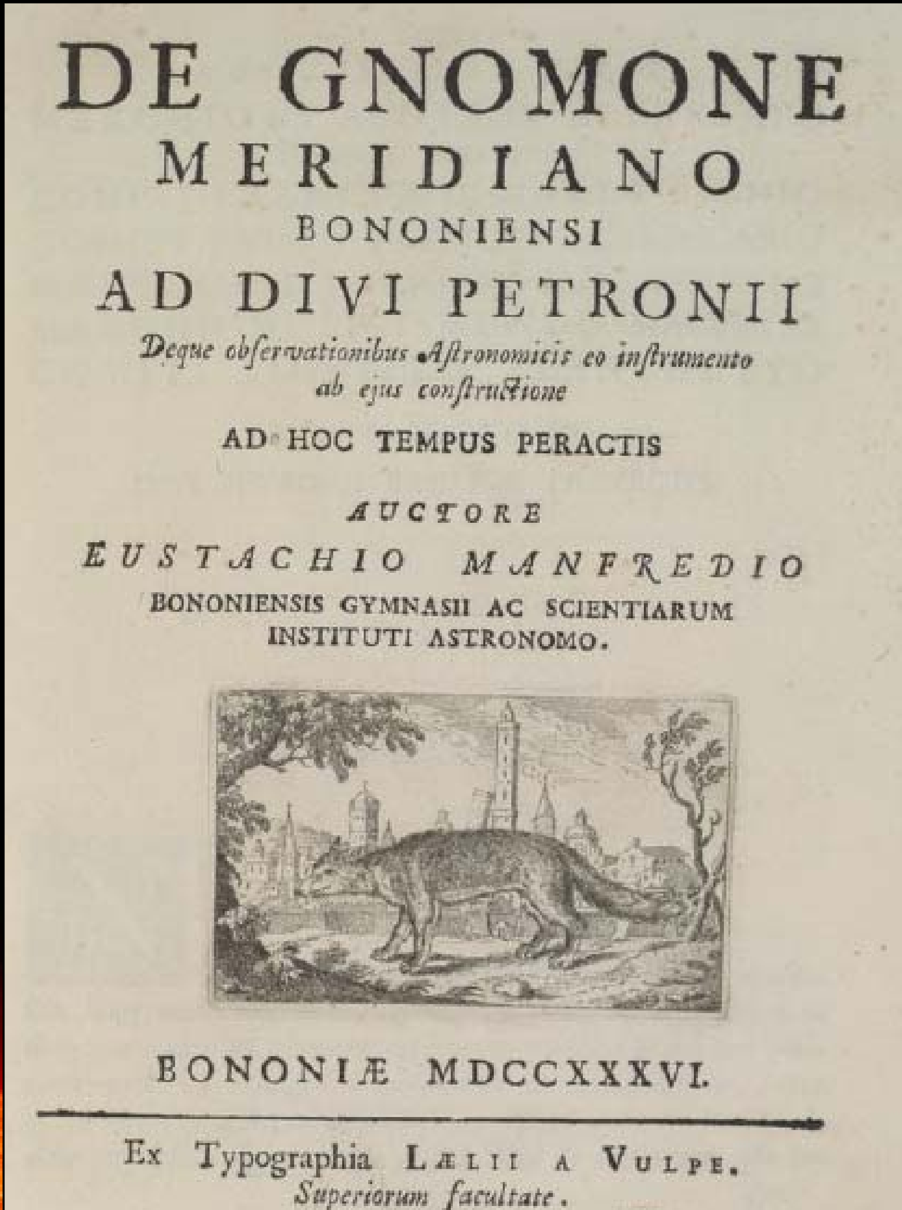
APRILIS
DE
42
43
44
45
46
47
62
64
66
DIE
AVGVST
© Paco Bellido, 200



DE GNOMONE MERIDIANO BONONIENSI AD DIVI PETRONII

Deque observationibus Astronomicis eo instrumento ab ejus constructione

AD HOC TEMPUS PERACTIS

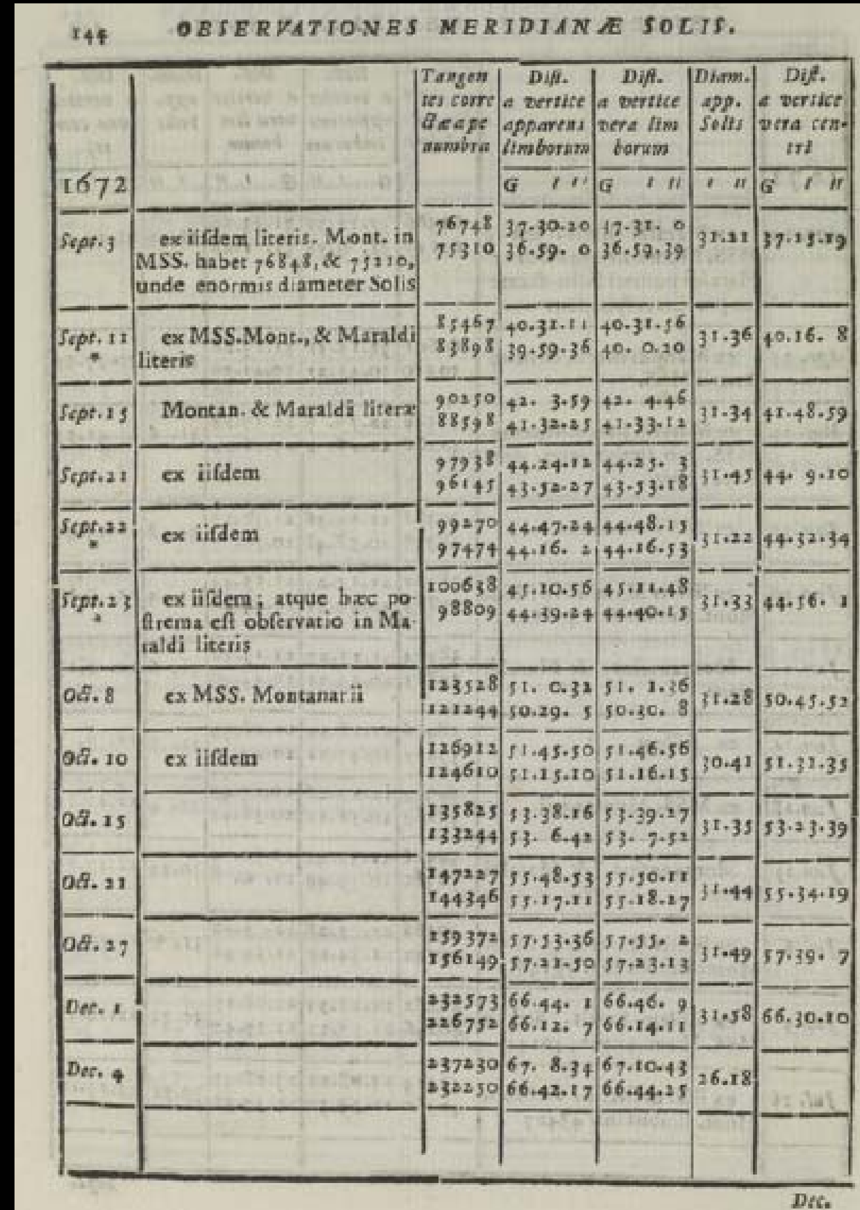
AUCTORE

EUSTACHIO MANFREDIO

BONONIENSIS GYMNASII AC SCIENTIARUM INSTITUTI ASTRONOMO.

BONONIÆ MDCCXXXVI.

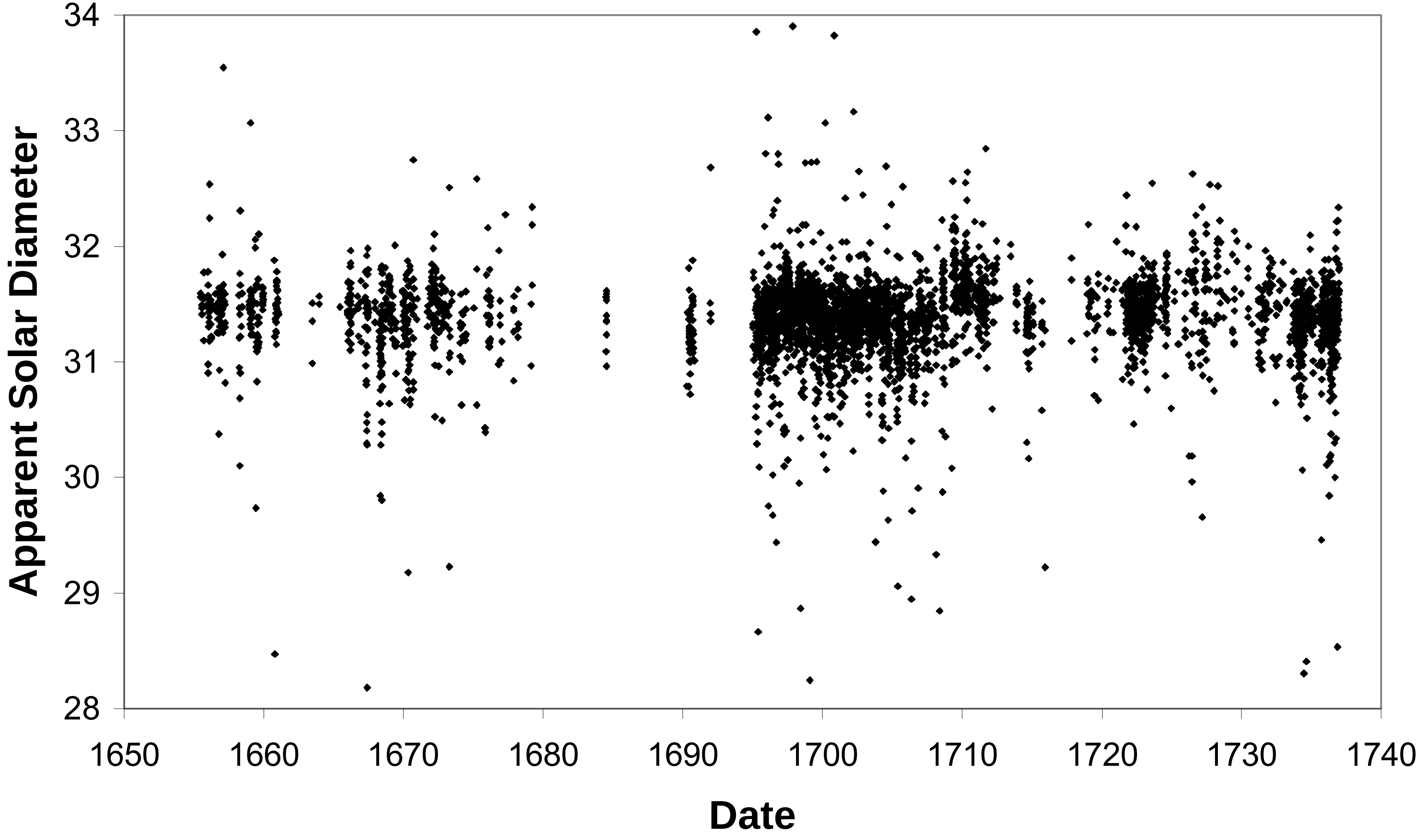
Ex Typographia Lælii a Vulpe.
Superiorum facultate.



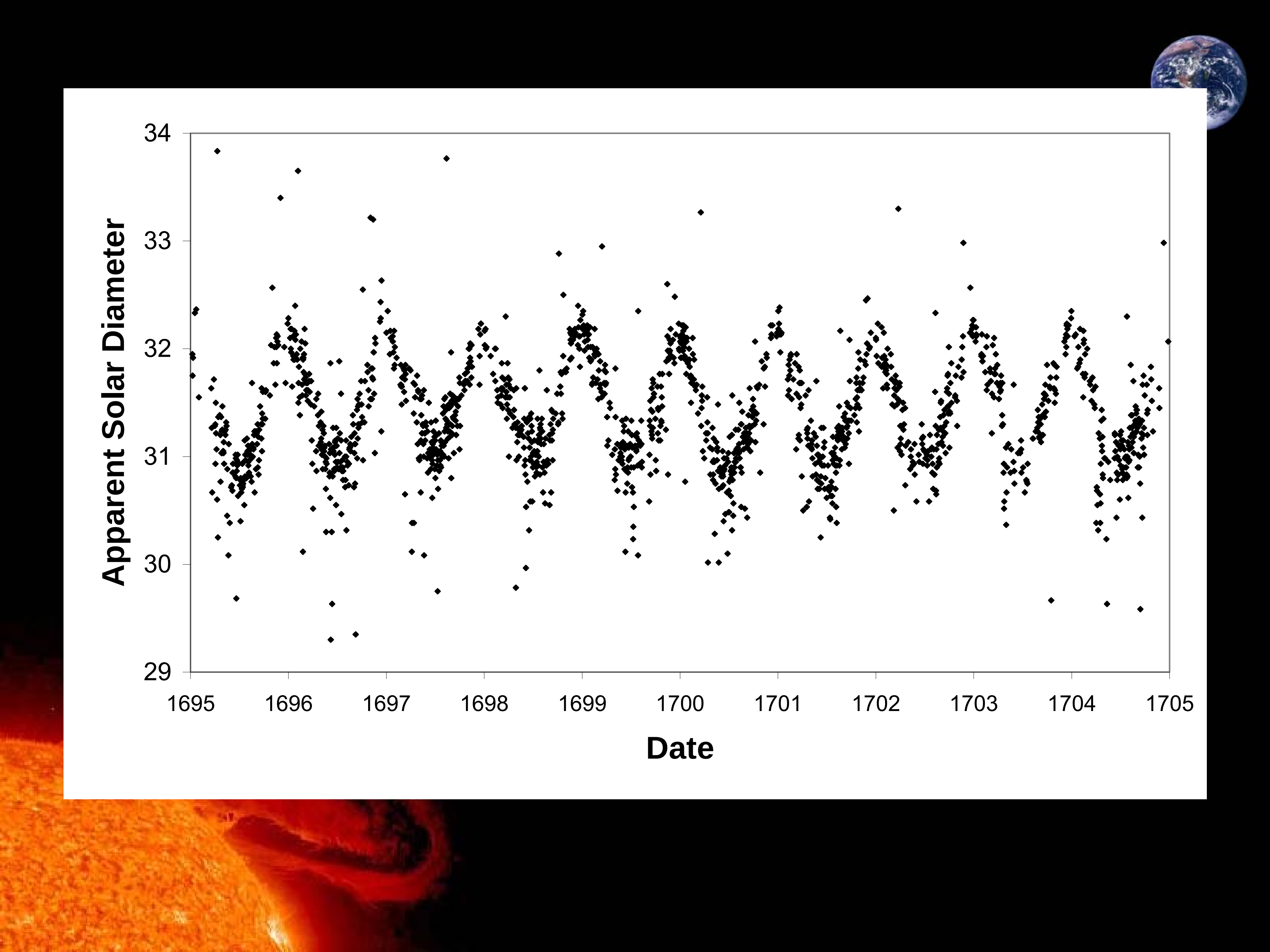
1672		*Tangentes correctæ a pe numbra*	*Dist. a vertice apparens limborum* G ′ ″	*Dist. a vertice vera limborum* G ′ ″	*Diam. app. Solis* ′ ″	*Dist. a vertice vera centri* G ′ ″
Sept. 3	ex iisdem literis. Mont. in MSS. habet 76848, & 75210, unde enormis diameter Solis	76748 75310	37.30.20 36.59. 0	37.31. 0 36.59.39	31.21	37.15.19
Sept. 11 *	ex MSS. Mont., & Maraldi literis	85467 83898	40.31.11 39.59.36	40.31.56 40. 0.20	31.36	40.16. 8
Sept. 15	Montan. & Maraldi literæ	90250 88598	42. 3.59 41.32.25	42. 4.46 41.33.12	31.34	41.48.59
Sept. 21	ex iisdem	97938 96145	44.24.12 43.52.27	44.25. 3 43.53.18	31.45	44. 9.10
Sept. 22 *	ex iisdem	99270 97474	44.47.24 44.16. 2	44.48.13 44.16.53	31.22	44.32.34
Sept. 23 *	ex iisdem; atque hæc postrema est observatio in Maraldi literis	100638 98809	45.10.56 44.39.24	45.11.48 44.40.15	31.33	44.56. 1
Oct. 8	ex MSS. Montanarii	123528 121244	51. 0.32 50.29. 5	51. 1.36 50.30. 8	31.28	50.45.52
Oct. 10	ex iisdem	126912 124610	51.45.50 51.15.10	51.46.56 51.16.15	30.41	51.31.35
Oct. 15		135825 133244	53.38.16 53. 6.42	53.39.27 53. 7.52	31.35	53.23.39
Oct. 21		147227 144346	55.48.53 55.17.11	55.50.11 55.18.27	31.44	55.34.19
Oct. 27		159372 156149	57.53.36 57.22.50	57.55. 2 57.23.13	31.49	57.39. 7
Dec. 1		232573 226752	66.44. 1 66.12. 7	66.46. 9 66.14.11	31.58	66.30.10
Dec. 4		237230 232250	67. 8.34 66.42.17	67.10.43 66.44.25	26.18	

Dec.

Eustachio Manfredio (1736) **De Gnomone Meridiano Bononiensi ad Divi Petronii** (Bononiae, 398 pp.)



Apparent Solar Diameter
34
33
32
31
30
29
28
1650
1660
1670
1680
1690
1700
1710
1720
1730
1740
Date



34
33
32
31
30
29
Apparent Solar Diameter
1695
1696
1697
1698
1699
1700
1701
1702
1703
1704
1705
Date

DE SOLE ALFONSINO RESTITVTO,

SIMVL ET

DE DIAMETRIS ET

PARALLAXIBVS LVMINARIVM, SEMIDIAMETRO QVE VMBRÆ TERÆ

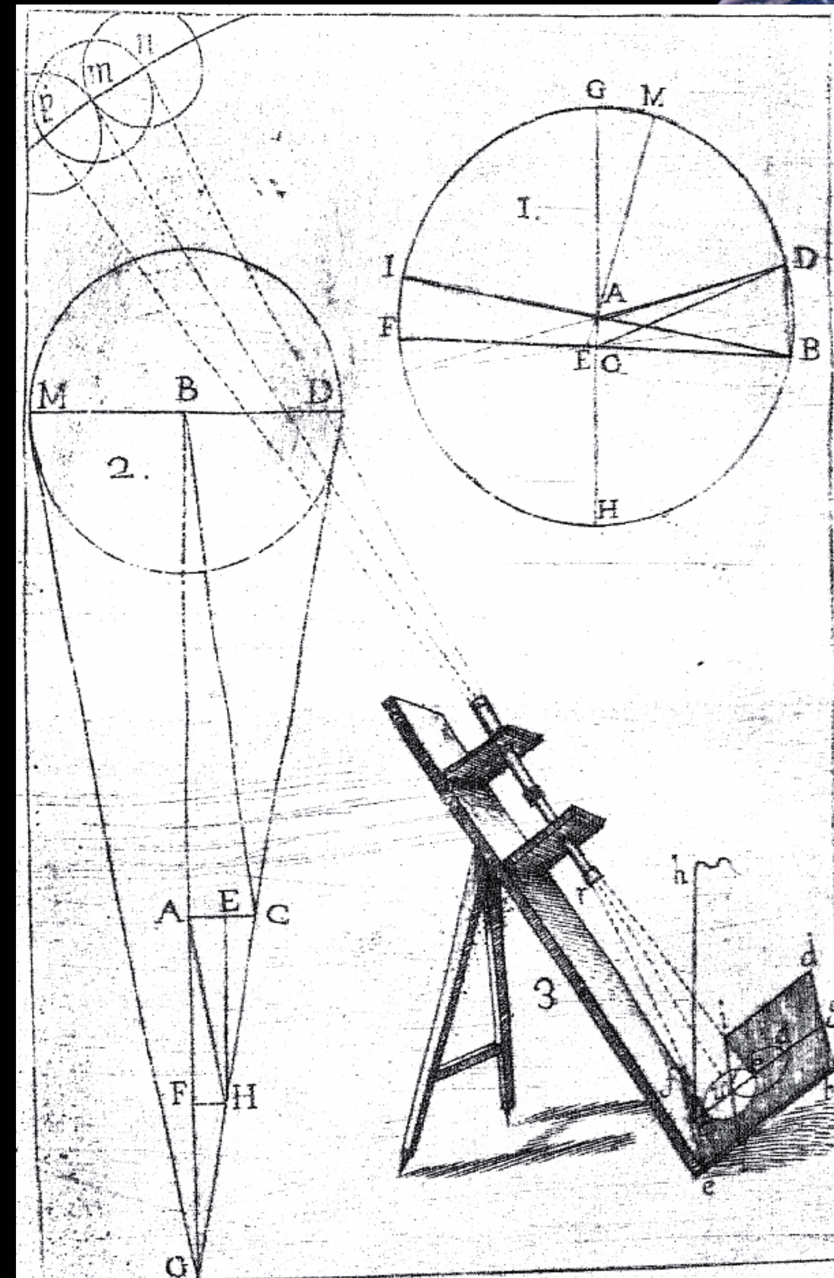
EPISTOLA,

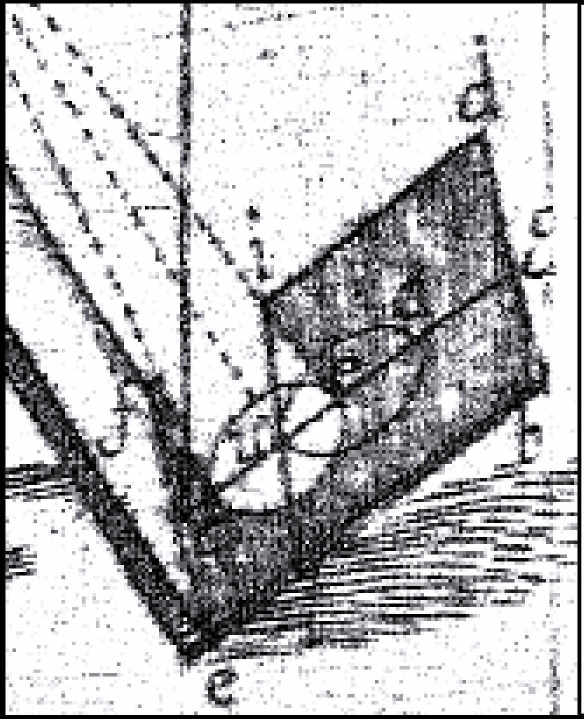
QVAM, AD EXCELL. D. COMITEM STABILEM CASTILIÆ, ET LEGIONIS SCRIBEBAT

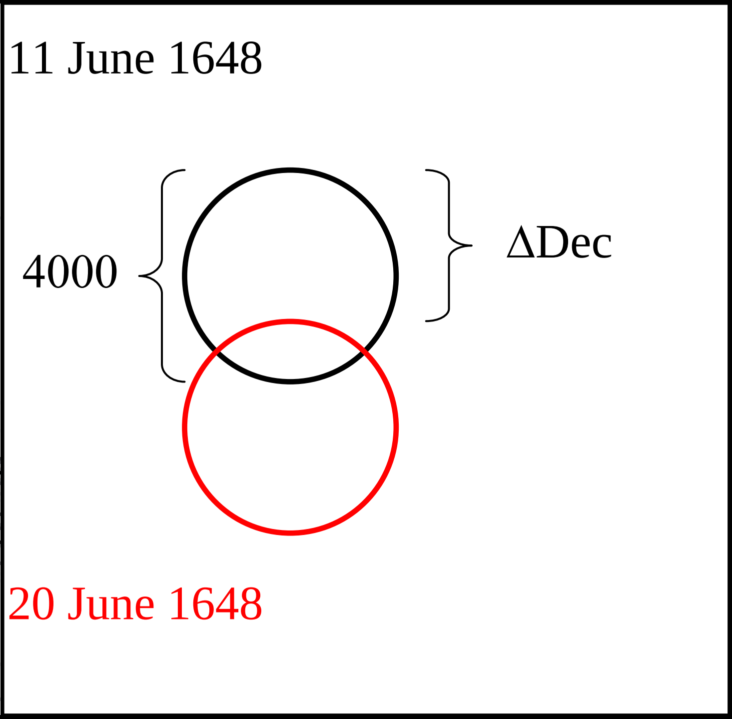
D. VINCENTIVS MVT, INSTRVCTOR MILITIÆ, SIVE SARGENTVS MAIOR MAIORICE, &c.

Anno.  1649.

Palmæ, Typis Petri Guasp Impressoris.







According to Mut (1649):

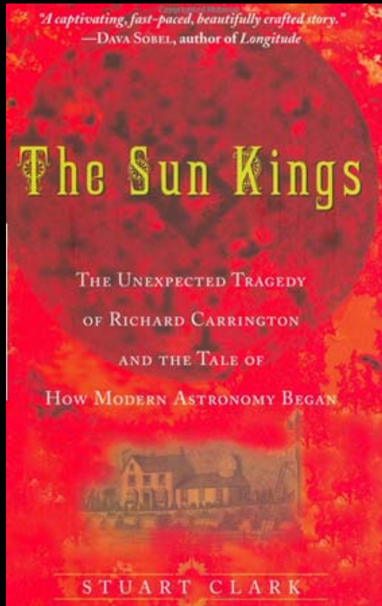
ΔDec=18’ 46”

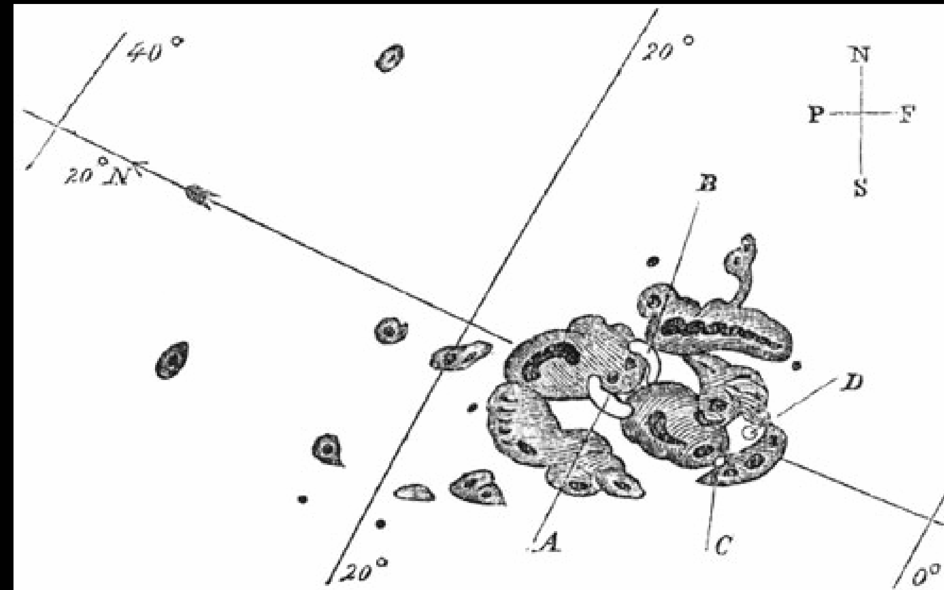
=2395

Therefore, solar diameter is 31’ 21” (11 June 1648).

From Mut values of minimmum and maximum solar radius, we can obtain R=960.6”±8.2”.

This is a value very similar to modern values.





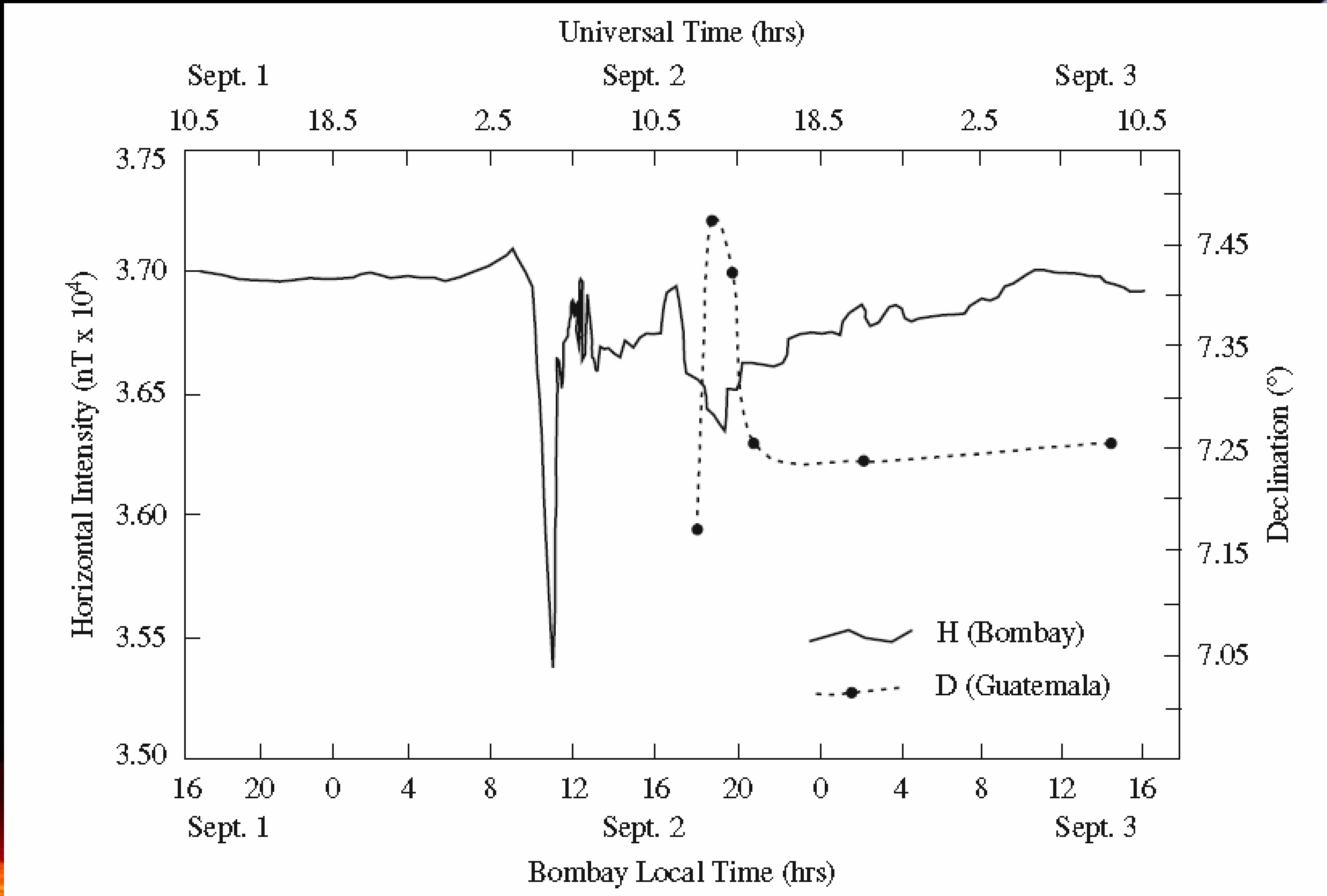
377

meno extraordinario. He aquí algunas posiciones de la aguja magnética en los dias 28 de agosto y 2 de setiembre.

Agosto 28.				
6ʰ mañana	7°	18′	30″
6½ »	7	25	21
12 »	7	8	14
9 noche	7	24	25

Setiembre 2.			
6ʰ mañana	7°	10′	6″
6¼ »	7	28	47
7¼ »	7	25	40
8 »	7	15	42
12 »	7	14	9
9 noche	7	15	42

Ribeiro, Vaquero and Trigo (2011) "Geomagnetic records of Carrington's Storm from Guatemala" ***Journal of Atmospheric and Solar-Terrestrial Physics*** **73, 308–315.**



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.

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 113, A08230, doi:10.1029/2007JA012943, 2008

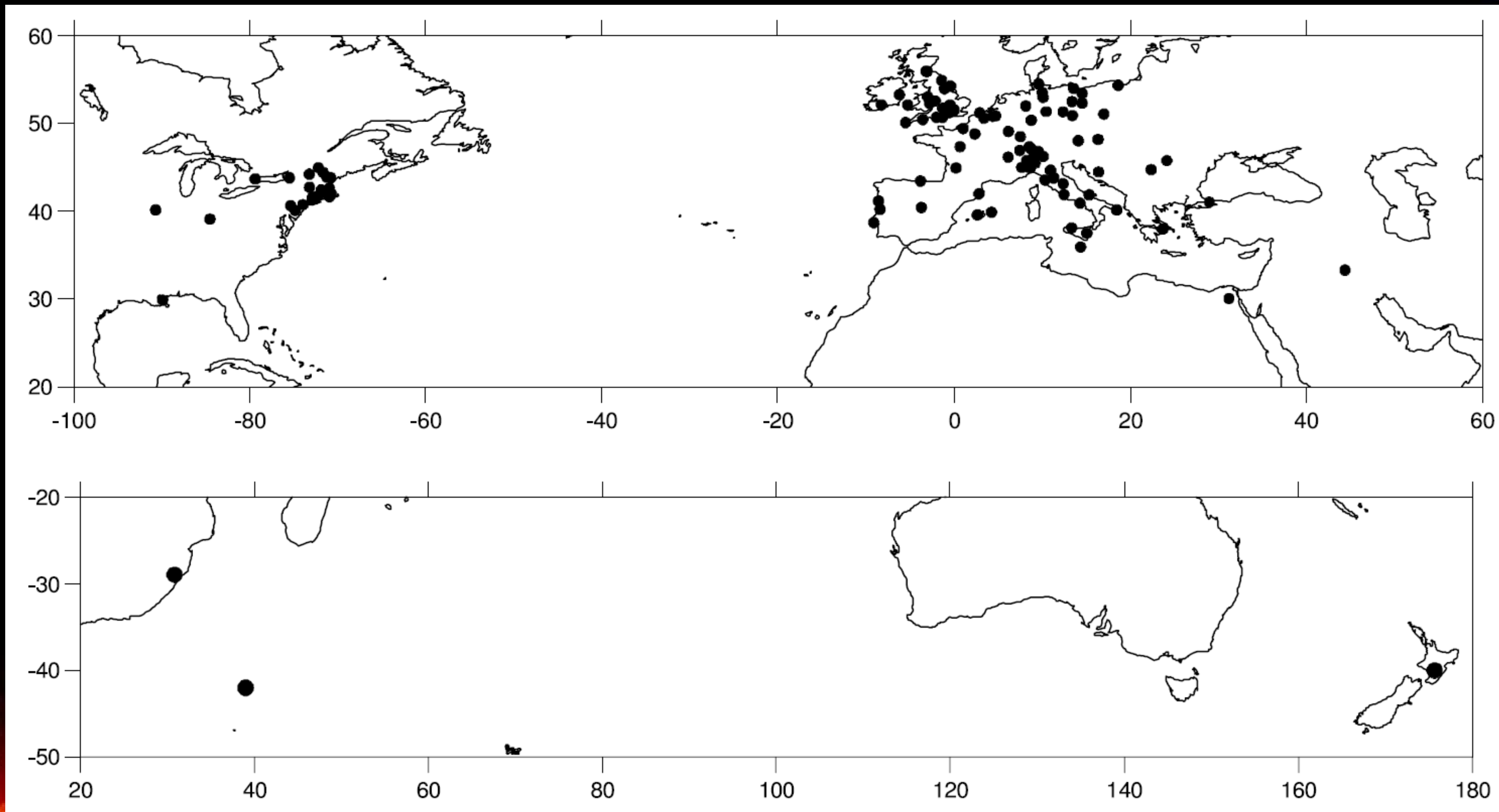
The 1870 space weather event: Geomagnetic and auroral records

J. M. Vaquero,[1] M. A. Valente,[2,3] R. M. Trigo,[3,4] P. Ribeiro,[5,6] and M. C. Gallego[7]

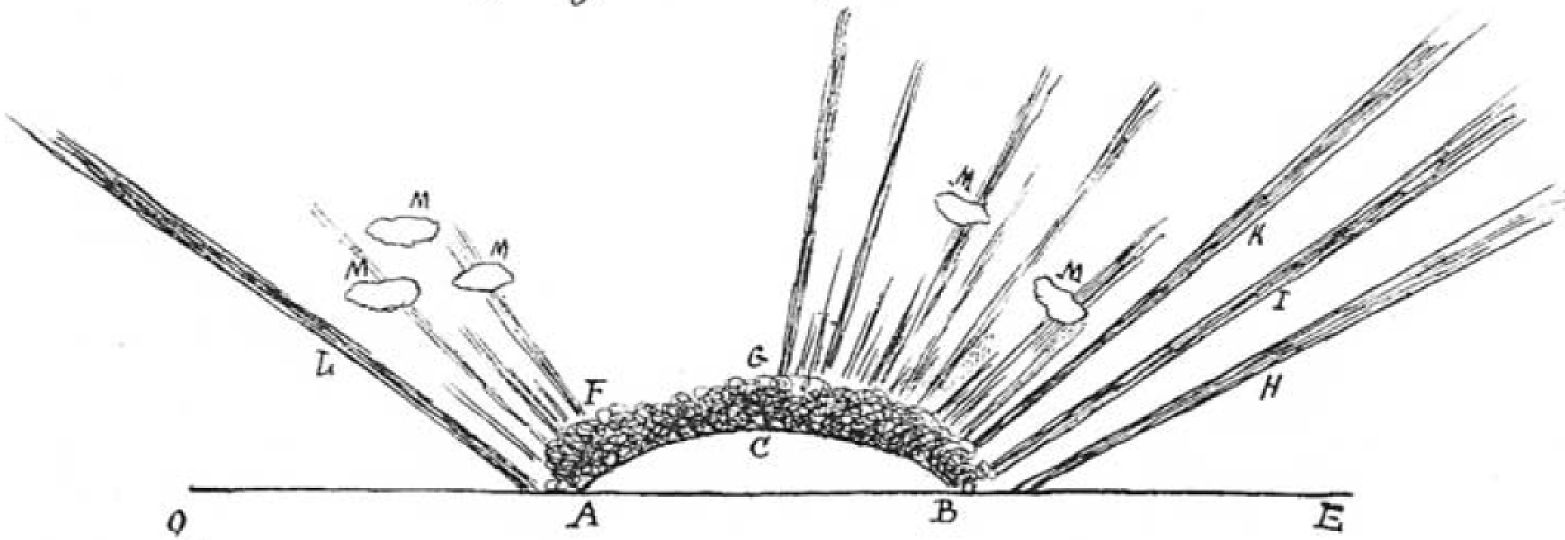
Received 15 November 2007; revised 9 April 2008; accepted 15 May 2008; published 28 August 2008.

[1] 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.

Citation: Vaquero, J. M., M. A. Valente, R. M. Trigo, P. Ribeiro, and M. C. Gallego (2008), The 1870 space weather event: Geomagnetic and auroral records, *J. Geophys. Res.*, *113*, A08230, doi:10.1029/2007JA012943.


60
50
40
30
20
-100
-80
-60
-40
-20
0
20
40
60
-20
-30
-40
-50
20
40
60
80
100
120
140
160
180

Aspect général du phénomène.



E O — Ligne d'horizon

ACB — Segment obscur s'appuyant sur l'horizon.

ACBFG — Arc blanc verdâtre concentrique avec le segment obscur.

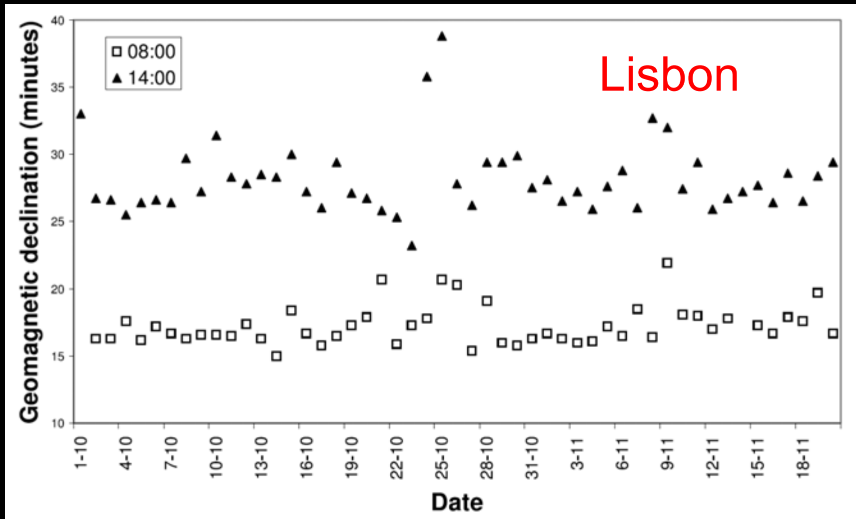
H,I,K. — 3 rayons rouges de l'Est.

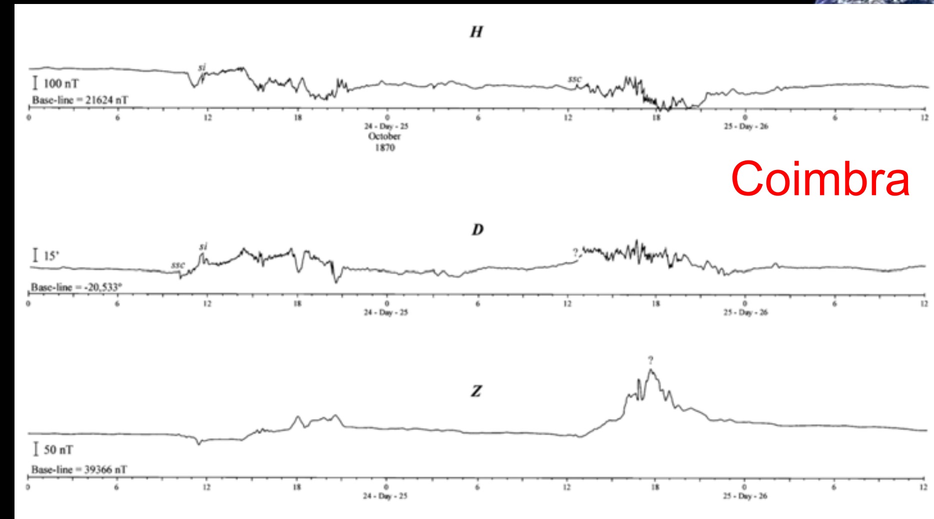
L — Rayon rouge à l'ouest.

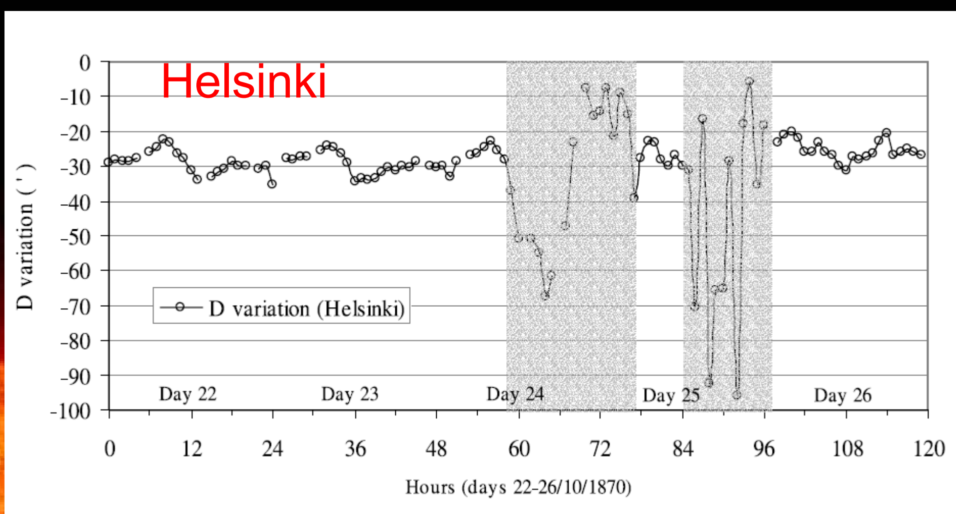
M — Petits cumulus bleu ardoise se détachant très nettement sur la teinte rouge du reste du ciel.

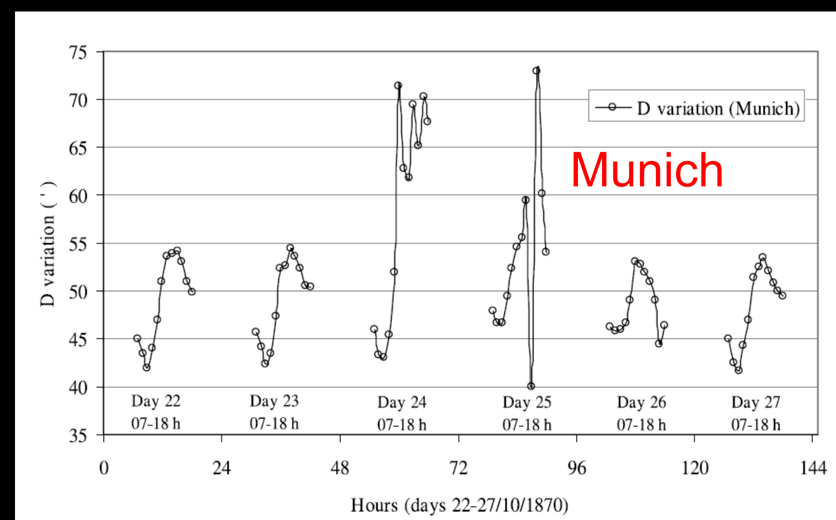
(A suivre)

E. Fron.


Lisbon
Geomagnetic declination (minutes)
08:00
14:00
Date
1-10
4-10
7-10
10-10
13-10
16-10
19-10
22-10
25-10
28-10
31-10
3-11
6-11
9-11
12-11
15-11
18-11


Coimbra
H
100 nT
Base-line = 21624 nT
24 - Day - 25
October
1870
25 - Day - 26
D
15'
Base-line = -20,533°
Z
50 nT
Base-line = 39366 nT


Helsinki
D variation (')
D variation (Helsinki)
Day 22
Day 23
Day 24
Day 25
Day 26
Hours (days 22-26/10/1870)


Munich
D variation (')
D variation (Munich)
Day 22
07-18 h
Day 23
07-18 h
Day 24
07-18 h
Day 25
07-18 h
Day 26
07-18 h
Day 27
07-18 h
Hours (days 22-27/10/1870)

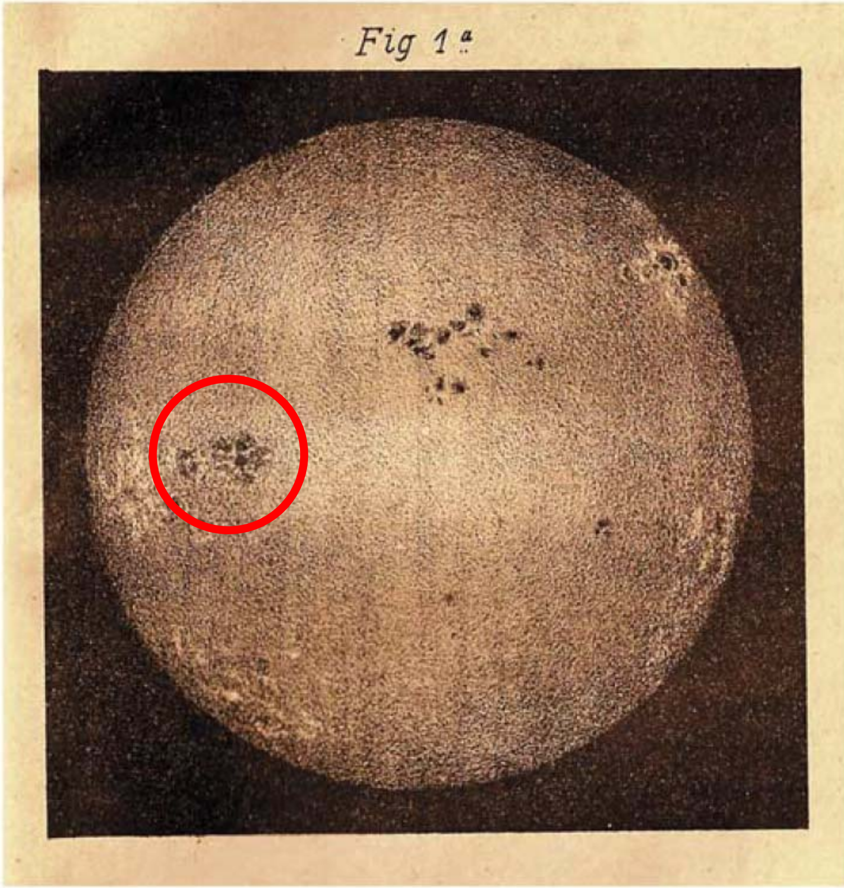
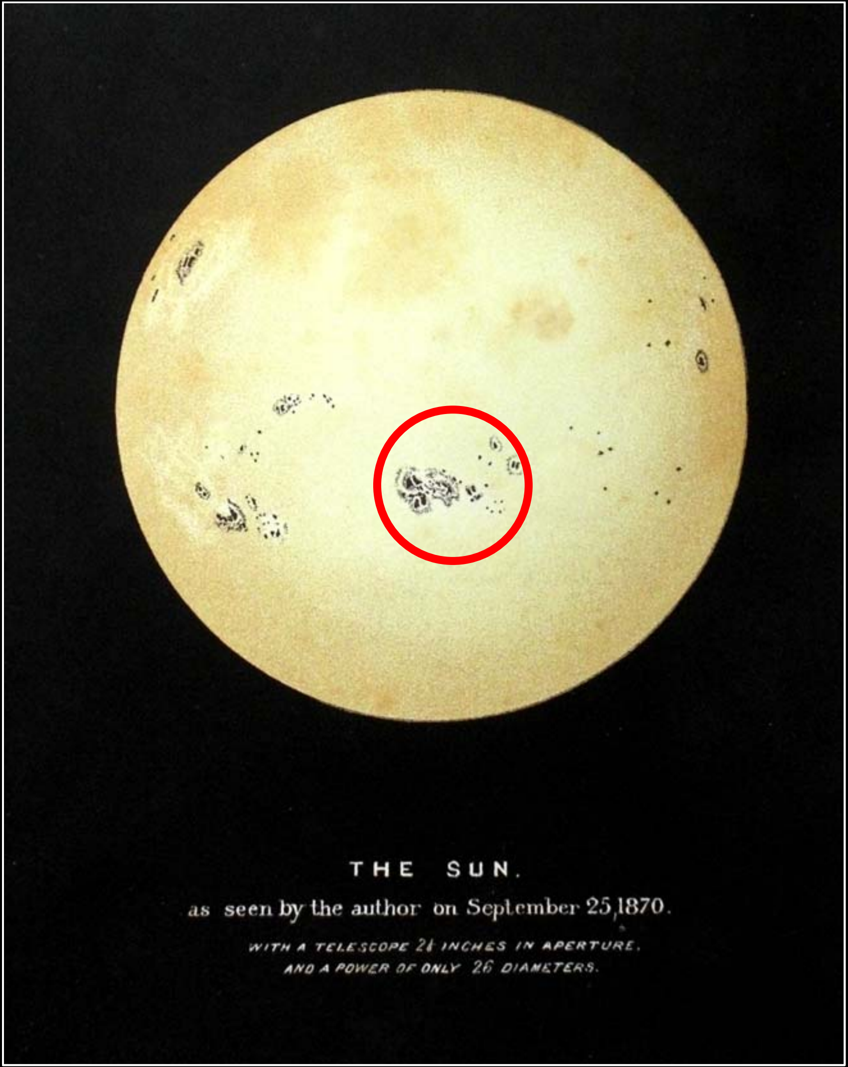
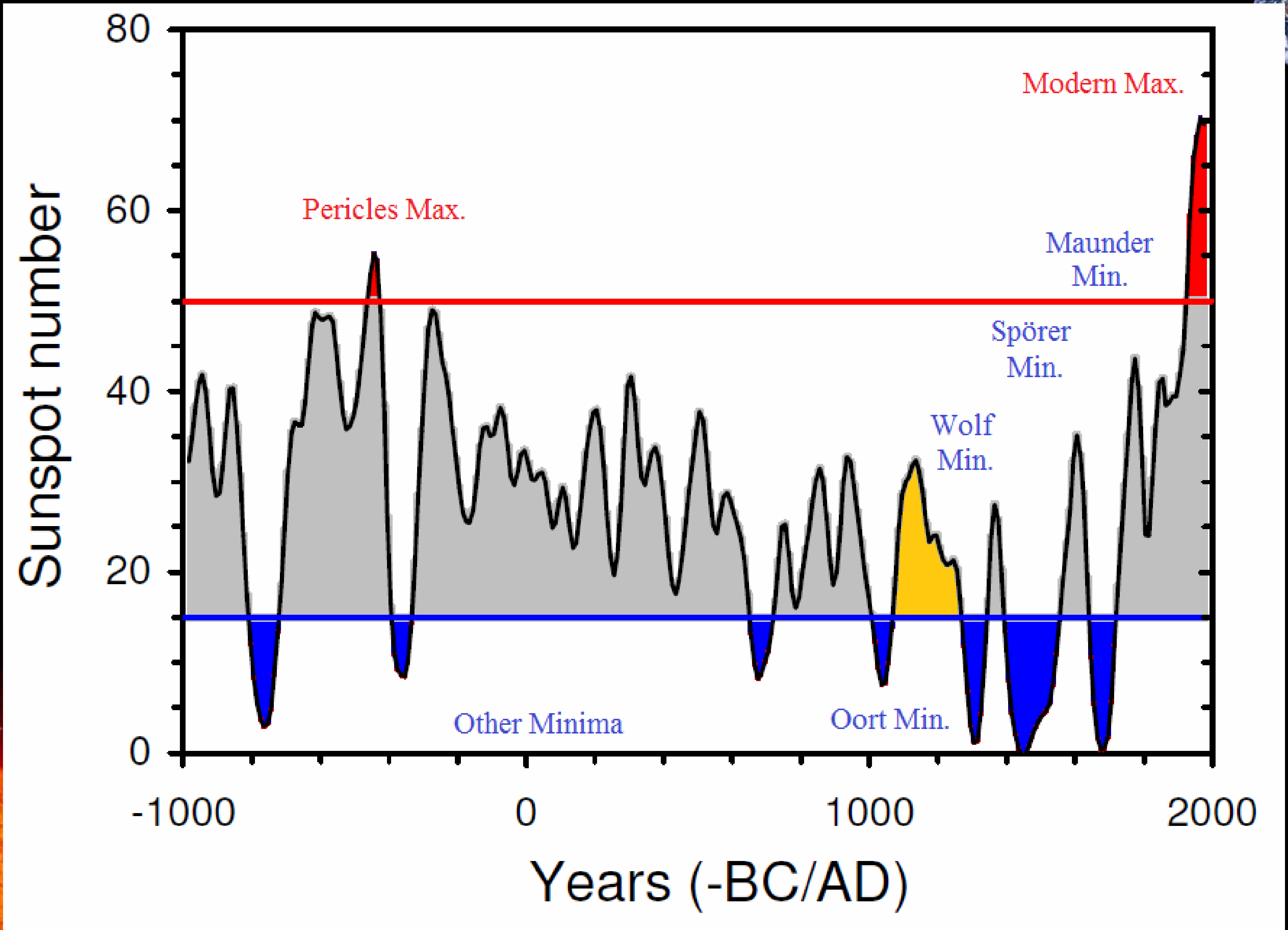
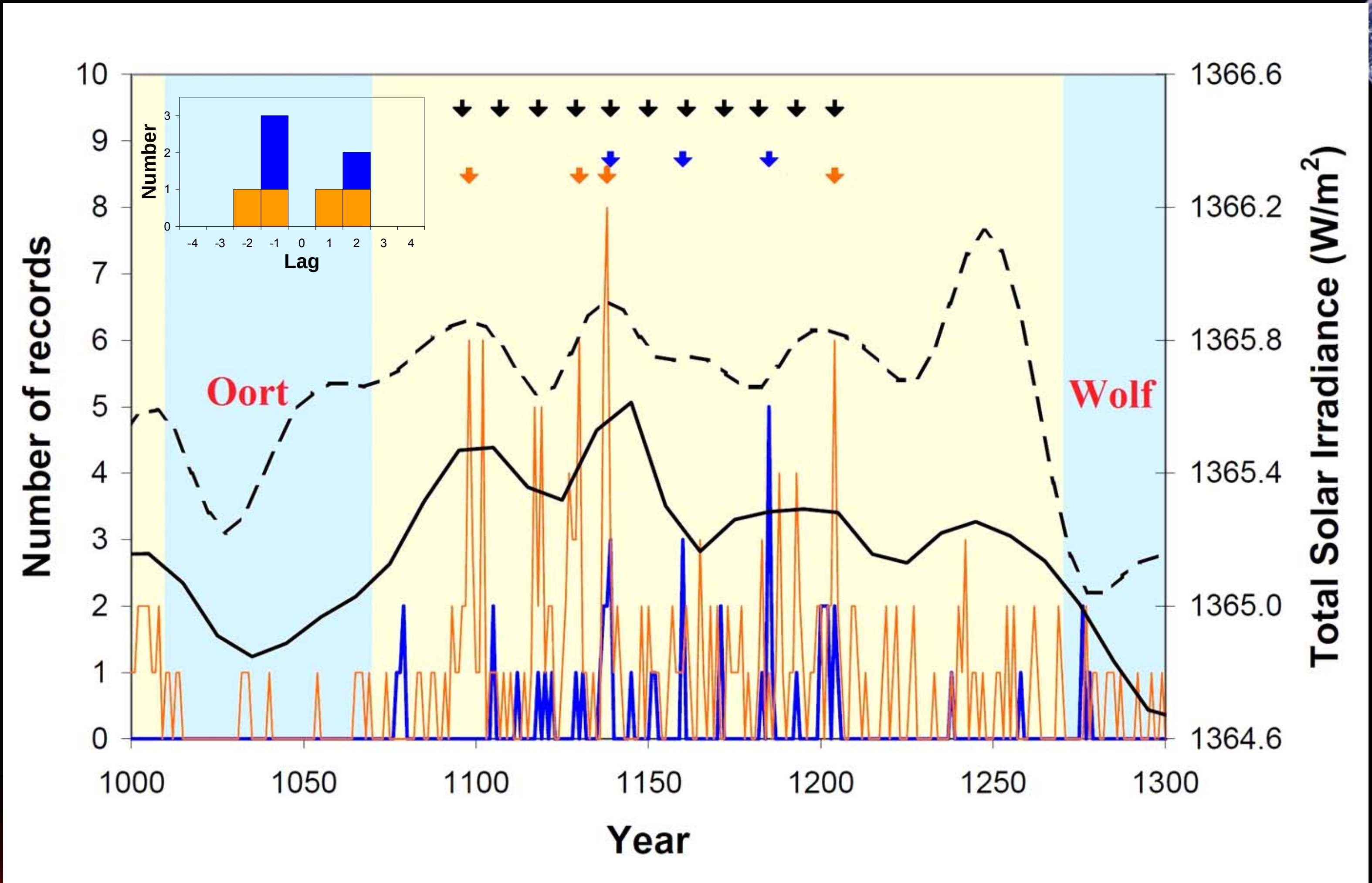


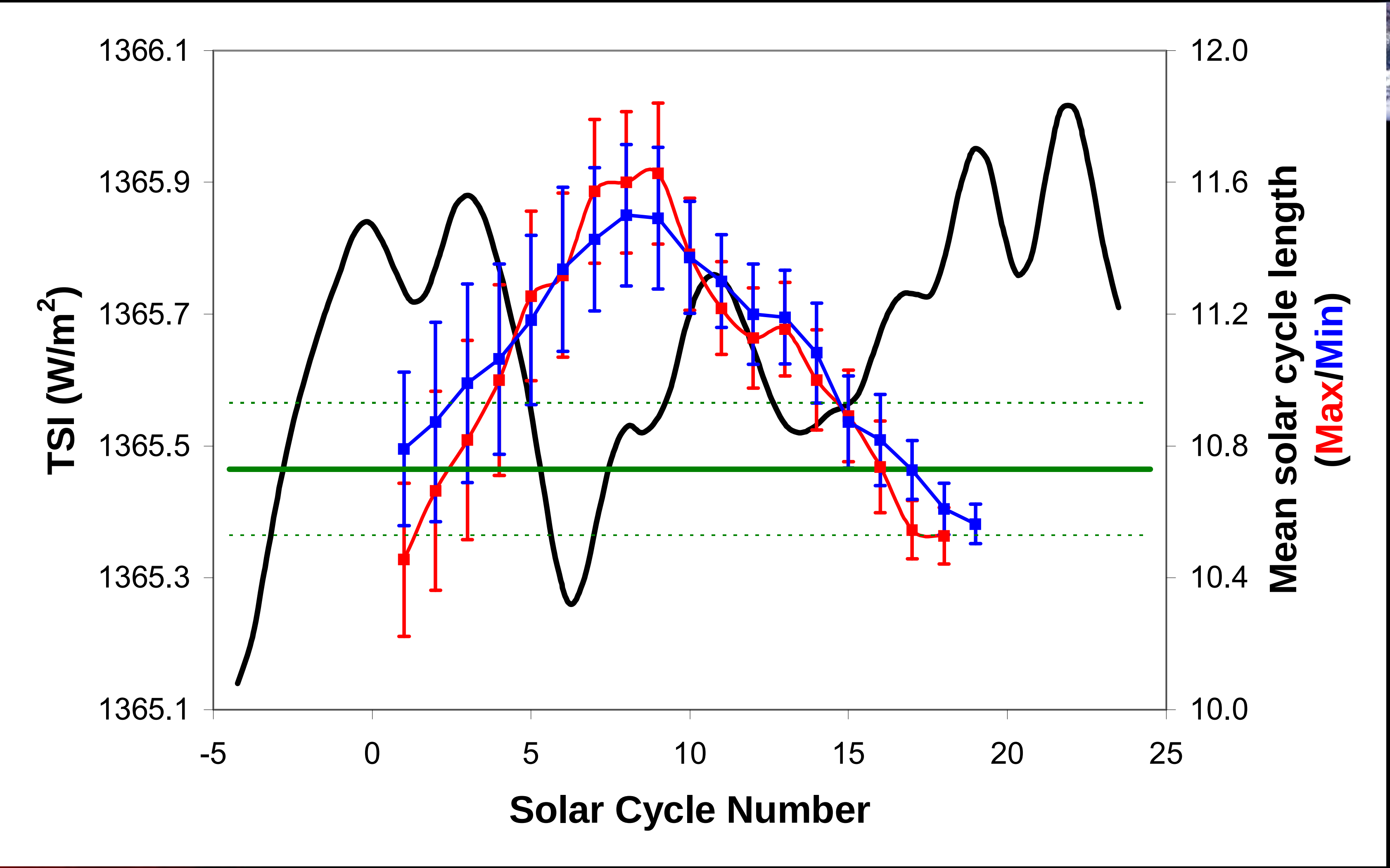
Figure 13. Photograph made by Rutherfurd in New York on 22 September 1870. It was published in the famous book *The Sun* [*Secchi*, 1879, Plate I].




Sunspot number
80
60
40
20
0
-1000
0
1000
2000
Years (-BC/AD)
Pericles Max.
Modern Max.
Maunder
Min.
Spörer
Min.
Wolf
Min.
Oort Min.
Other Minima



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).

MEMORIAS
DA
ACADEMIA REAL
DAS SCIENCIAS
DE LISBOA.

Niſi utile eſt quod facimus, ſtulta eſt gloria.

TOMO I.

DESDE 1780 ATÉ 1788.

LISBOA:
NA TYPOGRAFIA DA ACADEMIA,
1797.
Com licença de S. MAGESTADE.

OBSERVAÇÕES ASTRONOMICAS

Feitas junto ao Caſtello da Cidade do Rio de Janeiro para determinar a Latitude e Longitude da dita Cidade.

POR BENTO SANCHES DORTA.

ESTAS obſervações forão feitas nos annos de 1781, e 1782 com excellentes inſtrumentos. As alturas meridianas do Sol, e Eſtrellas forão tomadas com hum Quadrante Aſtronomico de hum pé de raio, conſtruido por Mr. *Siſſon*, artiſta de Londres, no anno de 1779: Os Eclipſes dos Satellites de Jupiter forão obſervados com occulos achromaticos de *Dollon*, tendo hum de foco $3\frac{1}{2}$ pés, e outro 17 pollegadas. O tempo verdadeiro foi

OBSERVAÇÕES METEOROLOGICAS

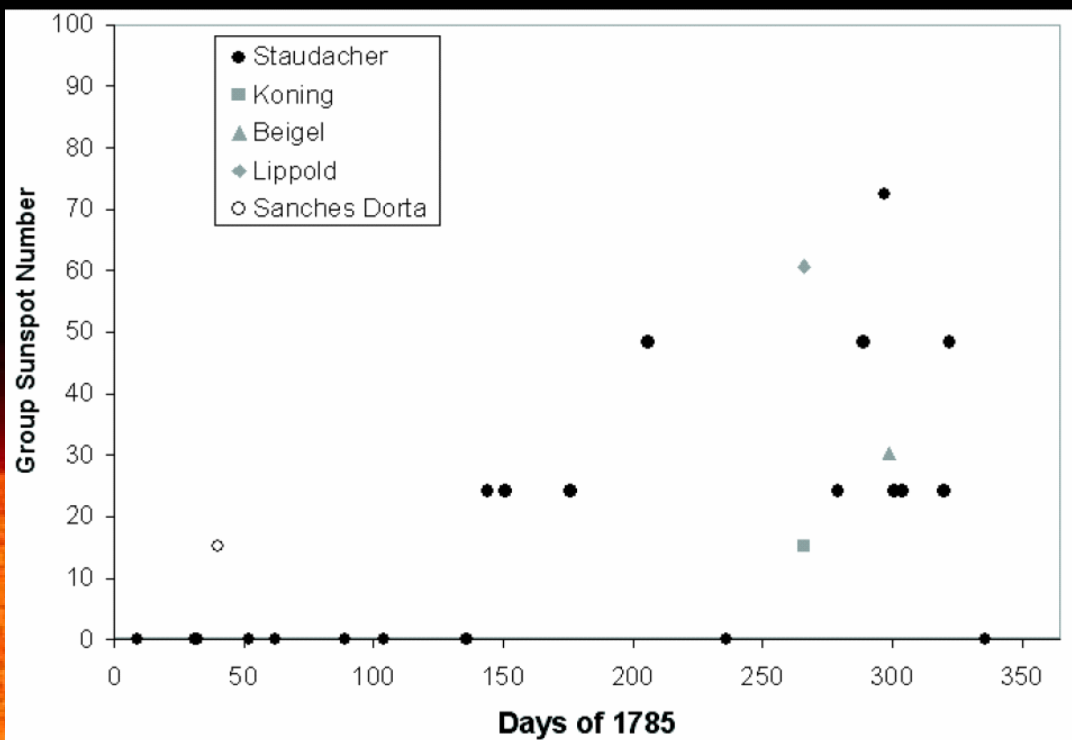
Feitas na Cidade do Rio de Janeiro.

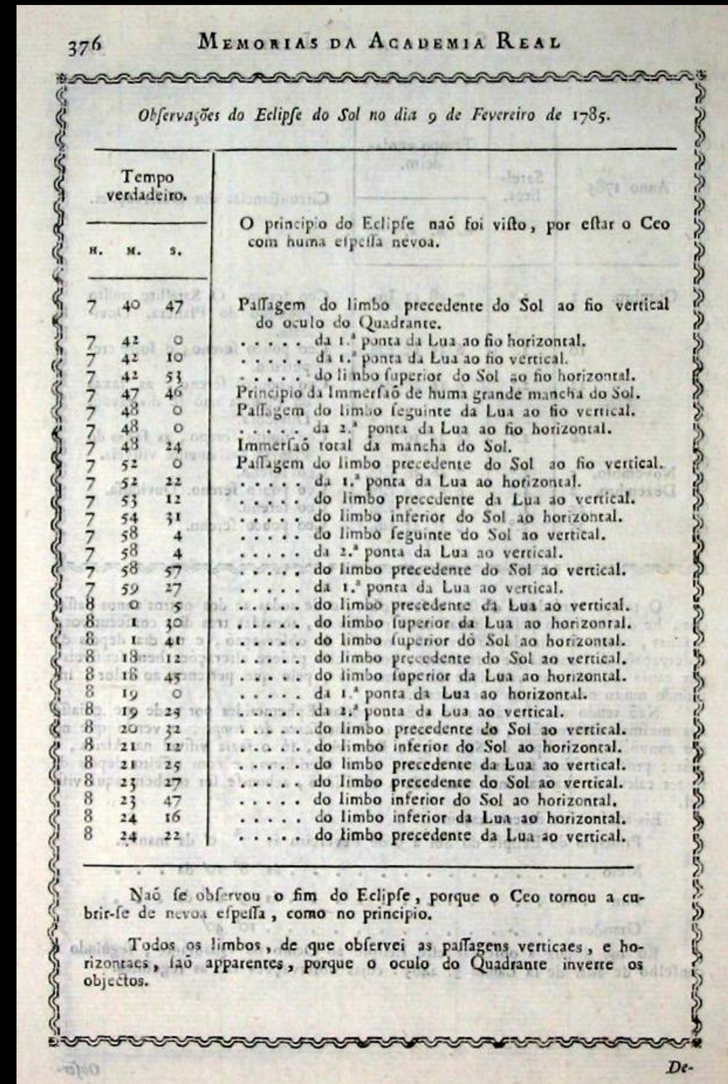
POR BENTO SANCHES DORTA.

SEndo o ocio para mim pouco grato, e cauſando-me hum grande enjôo, reſolvi occupar o tempo em couſa que foſſe util, e que podeſſe dar conta delle, quando me viſſe obrigado a iſſo: e movido das altas obrigações que inſpirão a vaſſallagem, tributada aos melhores dos Soberanos, e o amor que os intereſſes da Patria exigem de todos os que conſtituem o corpo do Eſ-

Early Sunspots observers…

Vaquero, Trigo, Gallego (2005)
Astron. Nachr. 326, 212-214.





376 MEMORIAS DA ACADEMIA REAL

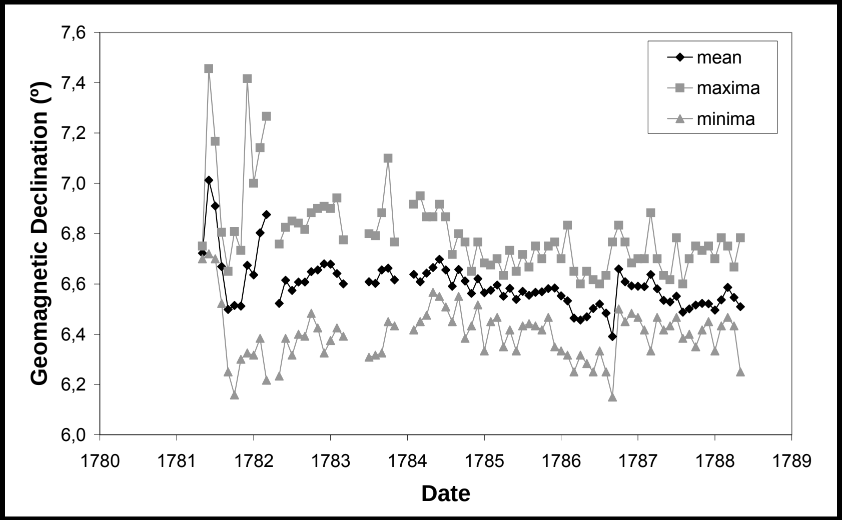
Obſervações do Eclipſe do Sol no dia 9 de Fevereiro de 1785.

Tempo verdadeiro. H.	M.	S.	
			O principio do Eclipſe naõ foi viſto, por eſtar o Ceo com huma eſpeſſa névoa.
7	40	47	Paſſagem do limbo precedente do Sol ao fio vertical do oculo do Quadrante.
7	42	0	. . . . . da 1.ª ponta da Lua ao fio horizontal.
7	42	10	. . . . . da 1.ª ponta da Lua ao fio vertical.
7	42	53	. . . . . do limbo ſuperior do Sol ao fio horizontal.
7	47	46	Principio da Immerſaõ de huma grande mancha do Sol.
7	48	0	Paſſagem do limbo ſeguinte da Lua ao fio vertical.
7	48	0	. . . . . da 2.ª ponta da Lua ao fio horizontal.
7	48	24	Immerſaõ total da mancha do Sol.
7	52	0	Paſſagem do limbo precedente do Sol ao fio vertical.
7	52	22	. . . . . da 1.ª ponta da Lua ao horizontal.
7	53	12	. . . . . do limbo precedente da Lua ao vertical.
7	54	31	. . . . . do limbo inferior do Sol ao horizontal.
7	58	4	. . . . . do limbo ſeguinte do Sol ao vertical.
7	58	4	. . . . . da 2.ª ponta da Lua ao vertical.
7	58	57	. . . . . do limbo precedente do Sol ao vertical.
7	59	27	. . . . . da 1.ª ponta da Lua ao vertical.
8	0	5	. . . . . do limbo precedente da Lua ao vertical.
8	1	30	. . . . . do limbo ſuperior da Lua ao horizontal.
8	1	41	. . . . . do limbo ſuperior do Sol ao horizontal.
8	18	12	. . . . . do limbo precedente do Sol ao vertical.
8	18	45	. . . . . do limbo ſuperior da Lua ao horizontal.
8	19	0	. . . . . da 1.ª ponta da Lua ao horizontal.
8	19	25	. . . . . da 2.ª ponta da Lua ao vertical.
8	20	32	. . . . . do limbo precedente do Sol ao vertical.
8	21	12	. . . . . do limbo inferior do Sol ao horizontal.
8	21	25	. . . . . do limbo precedente da Lua ao vertical.
8	23	27	. . . . . do limbo precedente do Sol ao vertical.
8	23	47	. . . . . do limbo inferior do Sol ao horizontal.
8	24	16	. . . . . do limbo inferior da Lua ao horizontal.
8	24	22	. . . . . do limbo precedente da Lua ao vertical.

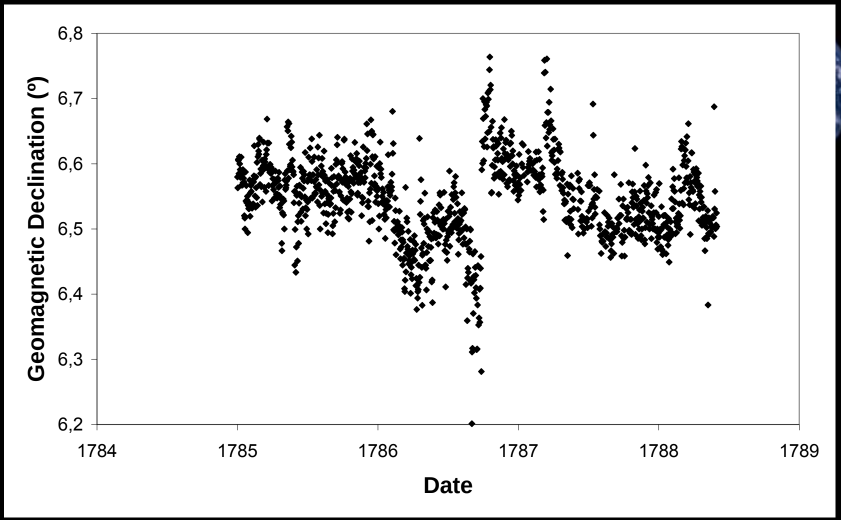
Naõ ſe obſervou o fim do Eclipſe, porque o Ceo tornou a cubrir-ſe de nevoa eſpeſſa, como no principio.

Todos os limbos, de que obſervei as paſſagens verticaes, e horizontaes, ſaõ apparentes, porque o oculo do Quadrante inverte os objectos.

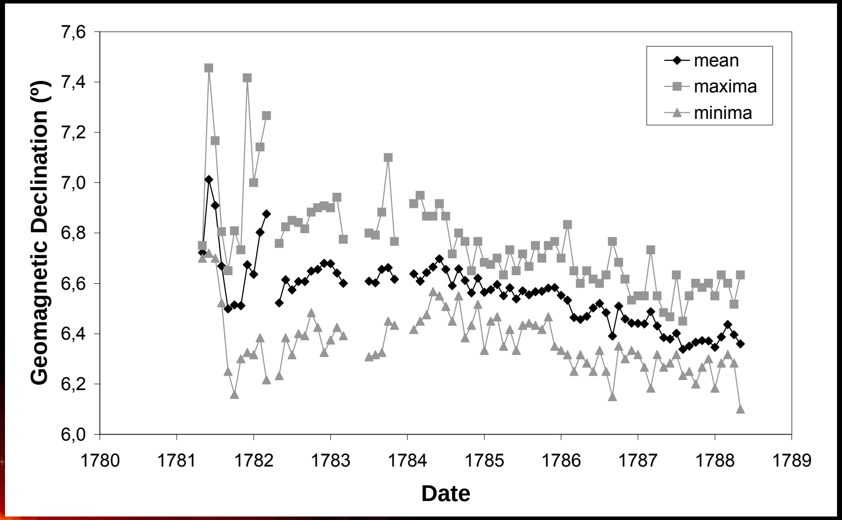
De-



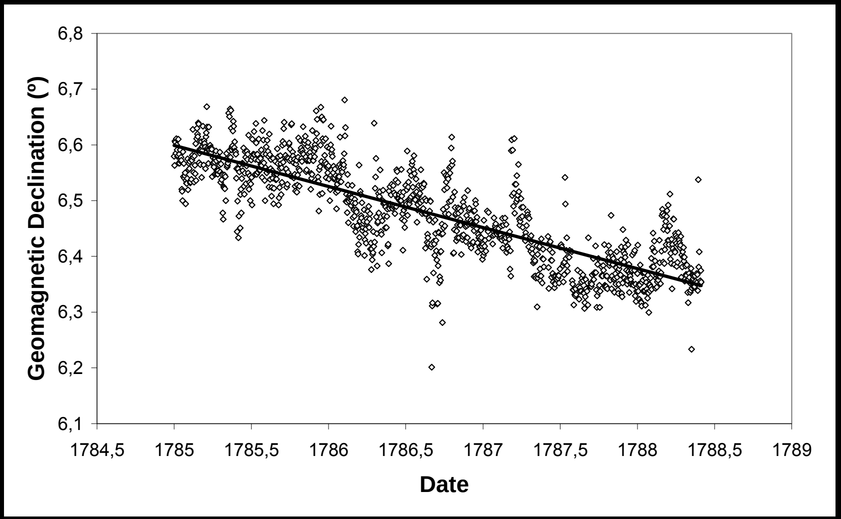
(a)



(b)



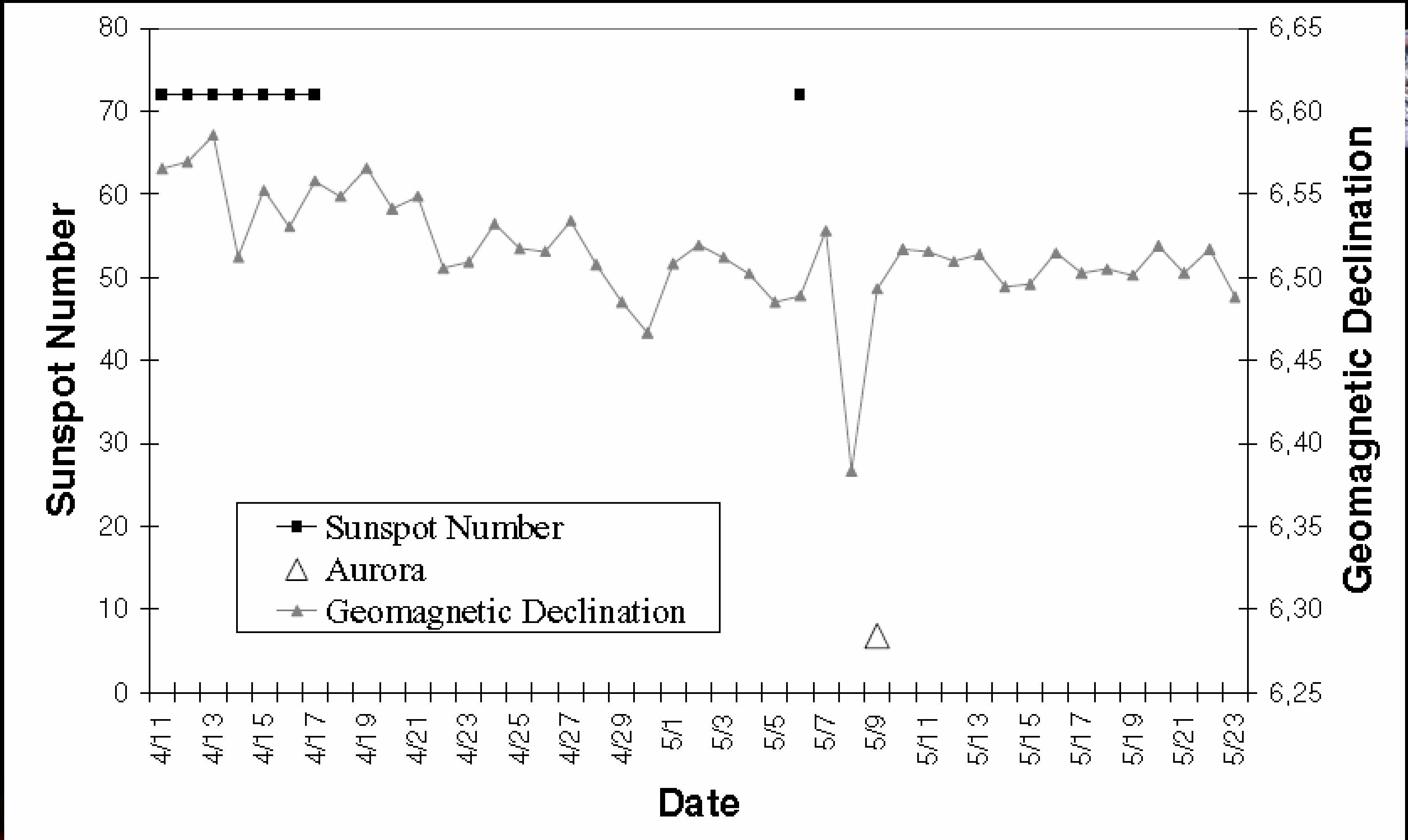
(c)



(d)

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.

Vaquero and Trigo (2005) “Results of the Rio de Janeiro magnetic observations 1781-1788” Ann. Geophys. 23, 1881-1887.

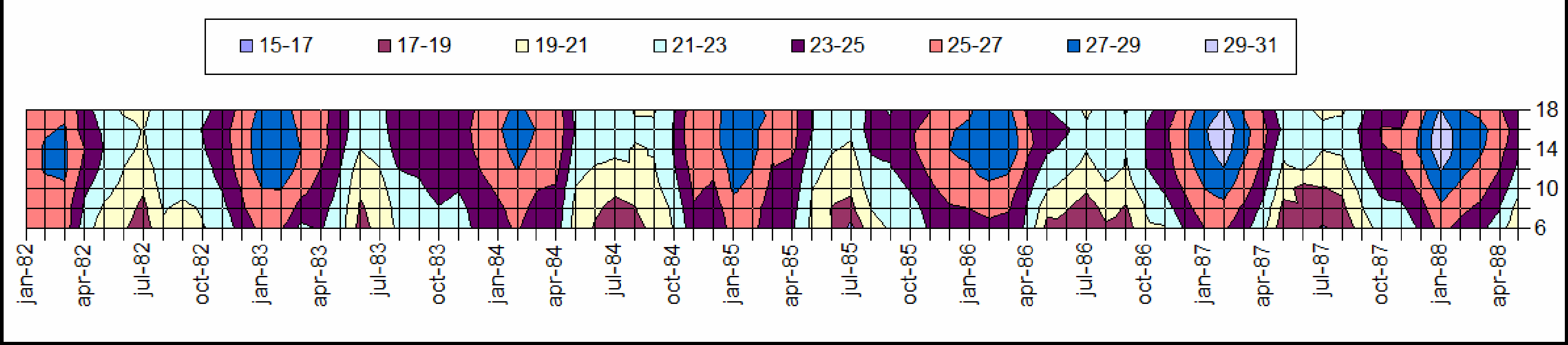


Daily variability of Group Sunspot Number (GSN) and geomagnetic declination between 11 April and 23 May 1788. The triangle corresponds to the aurora episode observed on 9 May 1788.

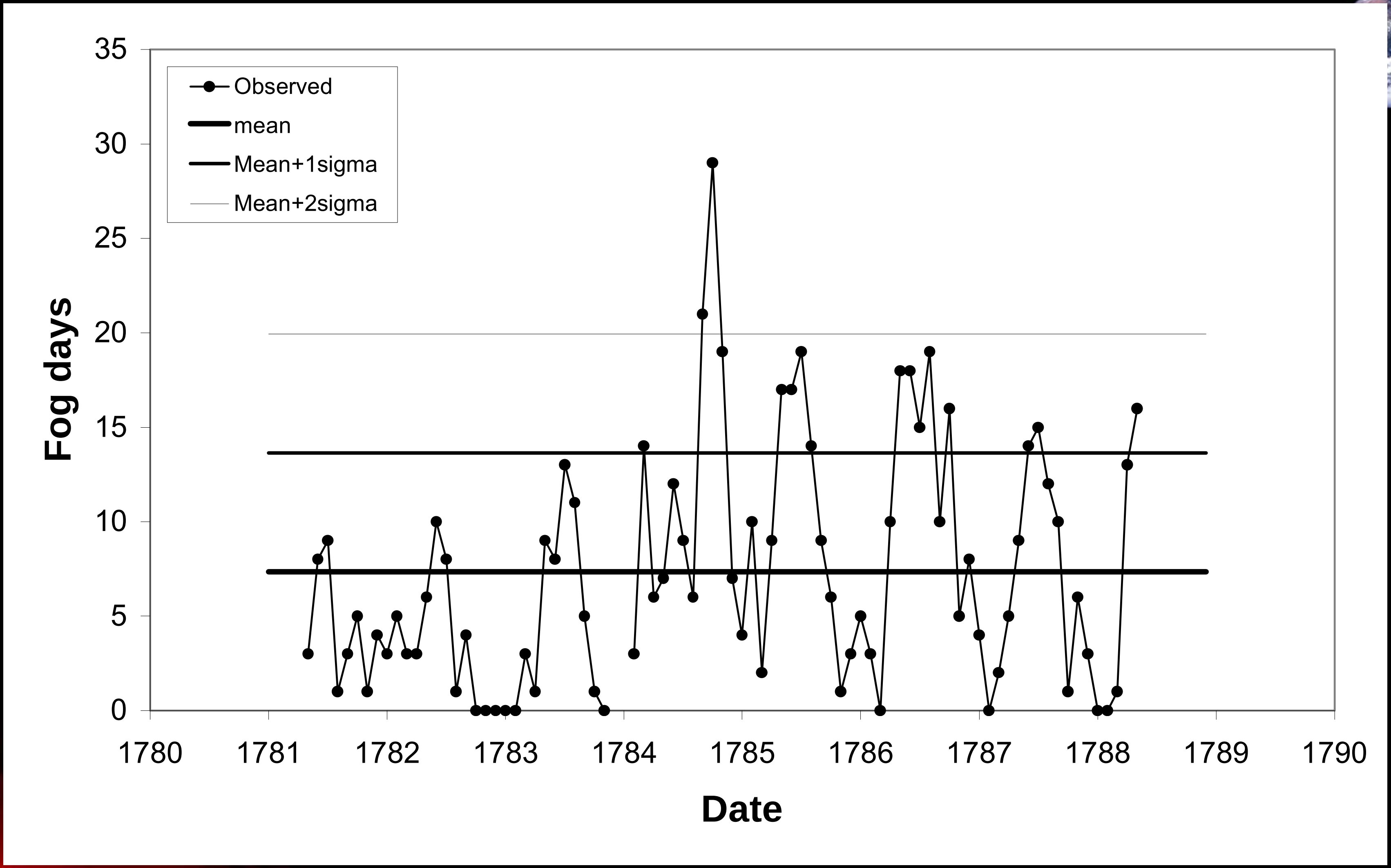
Four large solar storms occurred on 7–9 Feb 1786, 11 Mar 1787, 31 Oct 1787 and 9 May 1788.

Vaquero and Trigo (2006) “Identification of possible intense historical solar storms during the years 1781-1788 inferred from auroras and geomagnetic observations in Rio de Janeiro” Solar Physics 235, 419-432.

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.



Marín-Farrona, Vaquero, Trigo and Gallego “The Meteorological Observations of Bento Sanches Dorta, Rio de Janeiro, Brazil: 1781-1788 ” Climatic Change (in press).



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

Trigo, Vaquero and Stothers (2010) “Witnessing the impact of 1783-1784 Laki eruption in the Southern Hemisphere” Climatic Change 99, 535-546.

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

Neſte anno ſuccedêraõ fenomenos incomparaveis com os dos mais annos. Nos mezes de Setembro, Outubro, e Novembro ſubſiſtio huma nevoa, ou vapor mui denſo, que nos occultou de dia o Sol, de noite as Eſtrellas; de maneira que havendo neſtes tres mezes 48 Eclipſes dos Satellites de Jupiter viſiveis neſte Meridiano, eu naõ pude lograr mais de tres no fim de Setembro. Eſte ne-

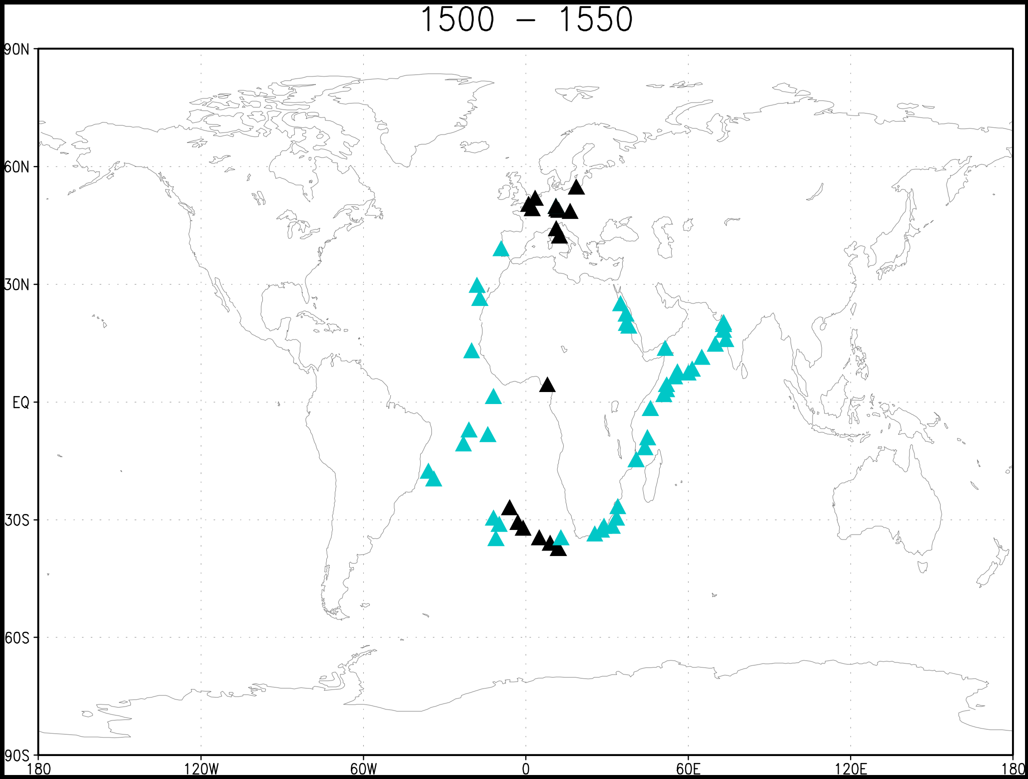
Trigo, Vaquero and Stothers (2010) “Witnessing the impact of 1783-1784 Laki eruption in the Southern Hemisphere” Climatic Change 99, 535-546.

acharem difficuldade grande em diſſipar algumas particulas deſte nevoeiro; o que he tanto mais notavel, quanto nós vêmos, que elles deſtroem promptiſſimamente os nevoeiros humidos ordinarios, que ſe elevão ao cimo d'agua. O Hygrometro de corda de linho, de que me ſirvo, ſempre indicou ſecura na atmosfera. Em todo o tempo que durou eſte nevoeiro os ventos forão variaveis, mas muito brandos.

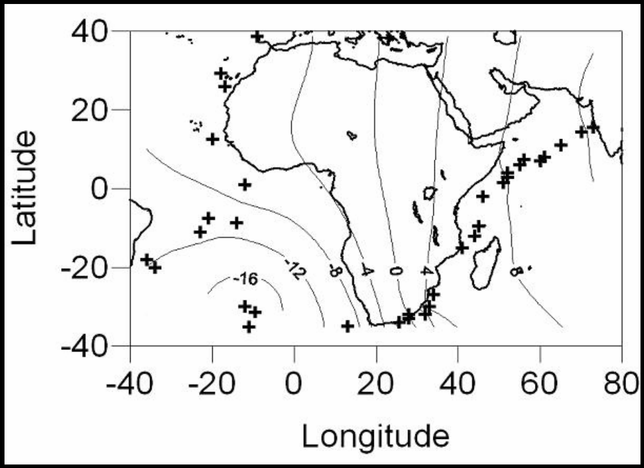
Poderei eu attribuir a cauſa deſta continúa nevoa a huma forte vaporação de partes muito denſas do noſſo Planeta, para ſubirem á região ſuperior da atmosfera; e muito tenues para tornarem a deſcer? Poderei eu attribuir eſte fenomeno a alguma quantidade de fumo exhalado de algum Volcão, ſahido do Mar do Sul na vizinhança deſte Paiz? Mas até agora não temos noticia alguma deſta apparição.

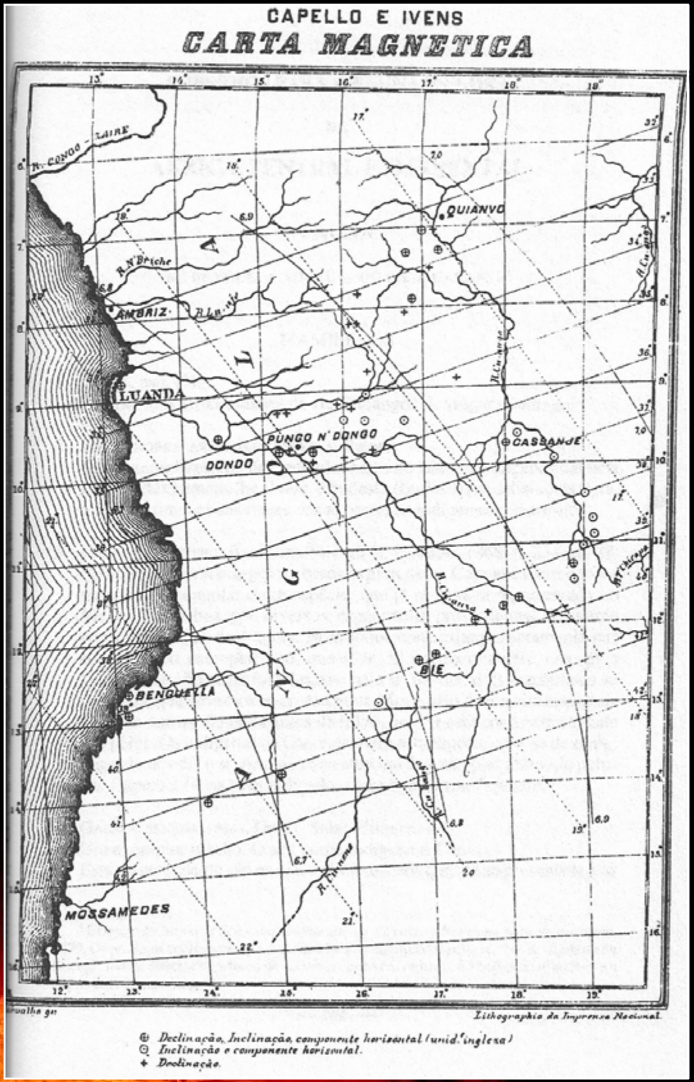
Hum dos meteoros extraordinarios deſte anno, e que

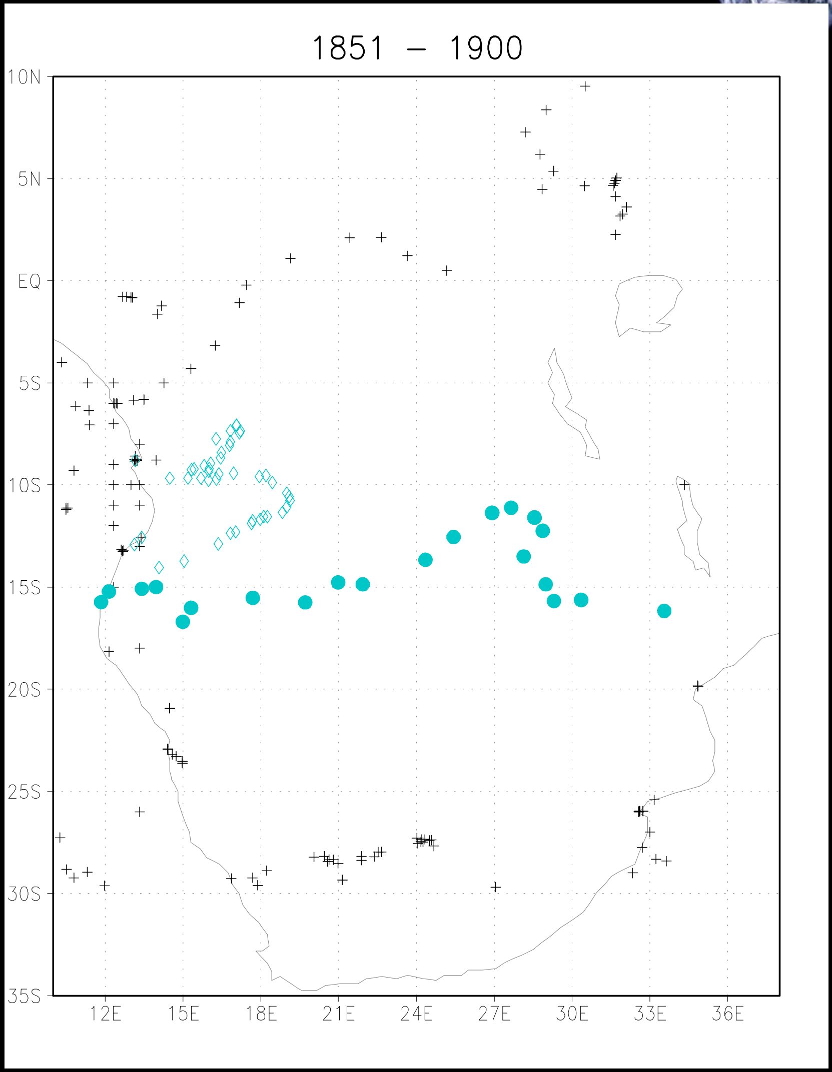
Trigo, Vaquero and Stothers (2010) “Witnessing the impact of 1783-1784 Laki eruption in the Southern Hemisphere” Climatic Change 99, 535-546.



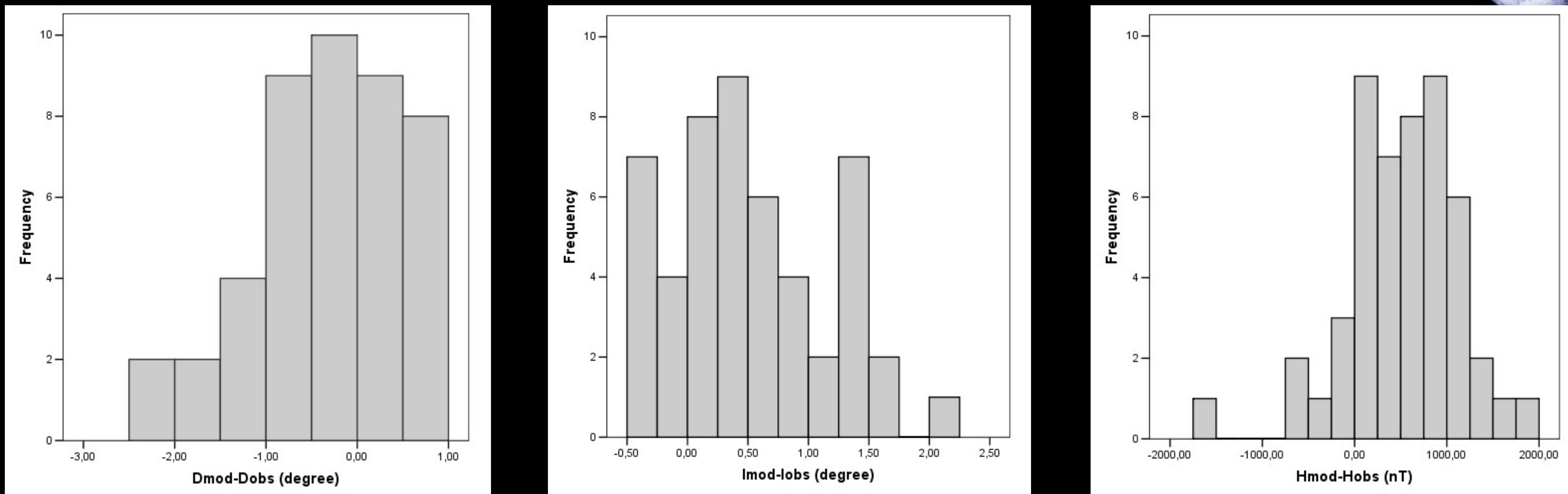
Trigo and Vaquero (2008) “D João de Castro: An unsung hero” Astronomy & Geophysics 49, 2.14-2.16.







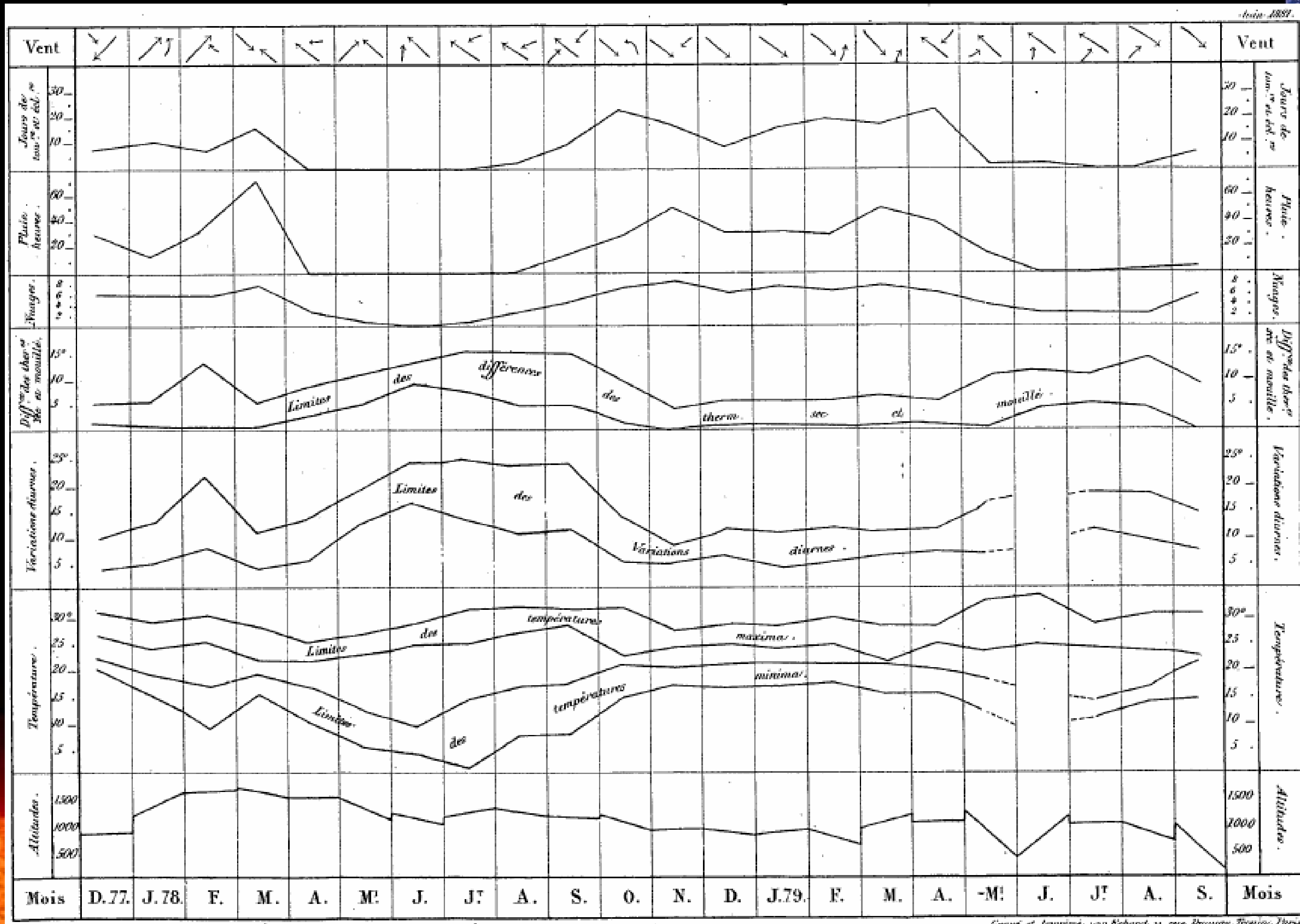
Vaquero and Trigo (2006) "Results of Geomagnetic Observations in Central Africa by Portuguese Explorers during 1877-1885" Physics of the Earth and Planetary Interiors 157, 8-15.



(a) (b) (c)

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

Vaquero and Trigo (2006) “Results of Geomagnetic Observations in Central Africa by Portuguese Explorers during 1877-1885” Physics of the Earth and Planetary Interiors 157, 8-15.


Vent
Jours de tour.te et écl.rs
30
20
10
Pluie. heures.
60
40
20
Nuages.
Diff.ce des ther.es sec et mouillé.
15°
10
5
Limites des différences des therm. sec et mouillé.
Variations diurnes.
25°
20
15
10
5
Limites des Variations diurnes.
Température.
30°
25
20
15
10
5
Limites des températures maxima.
Limites des températures minima.
Altitudes.
1500
1000
500
Mois
D.77.
J.78.
F.
M.
A.
M.i
J.
J.t
A.
S.
O.
N.
D.
J.79.
F.
M.
A.
-M.i
J.
J.t
A.
S.

ANAIS

DO

OBSERVATORIO ASTRONÓMICO

DA

UNIVERSIDADE DE COIMBRA

PRIMEIRA SECÇÃO

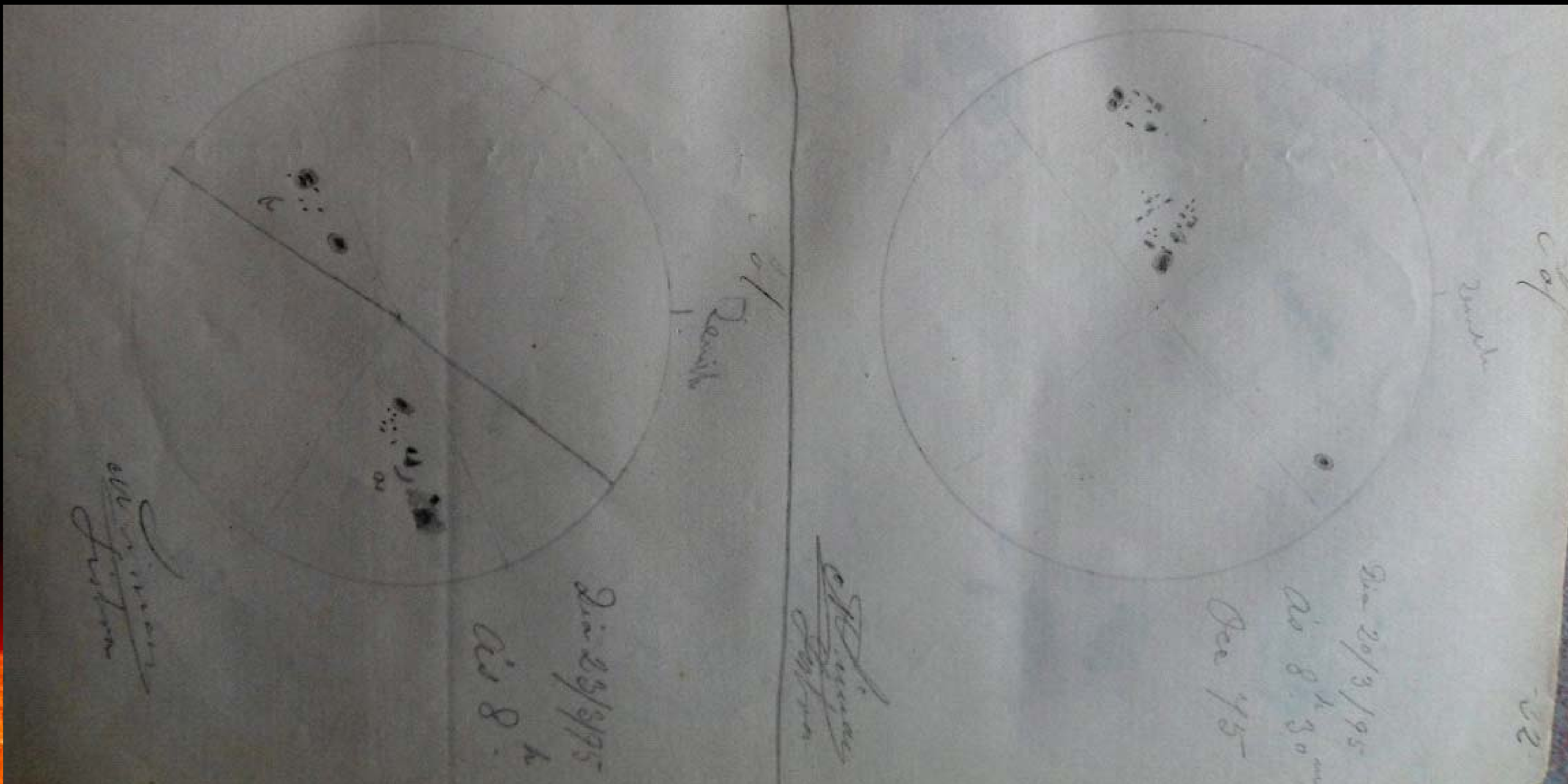
FENÓMENOS SOLARES

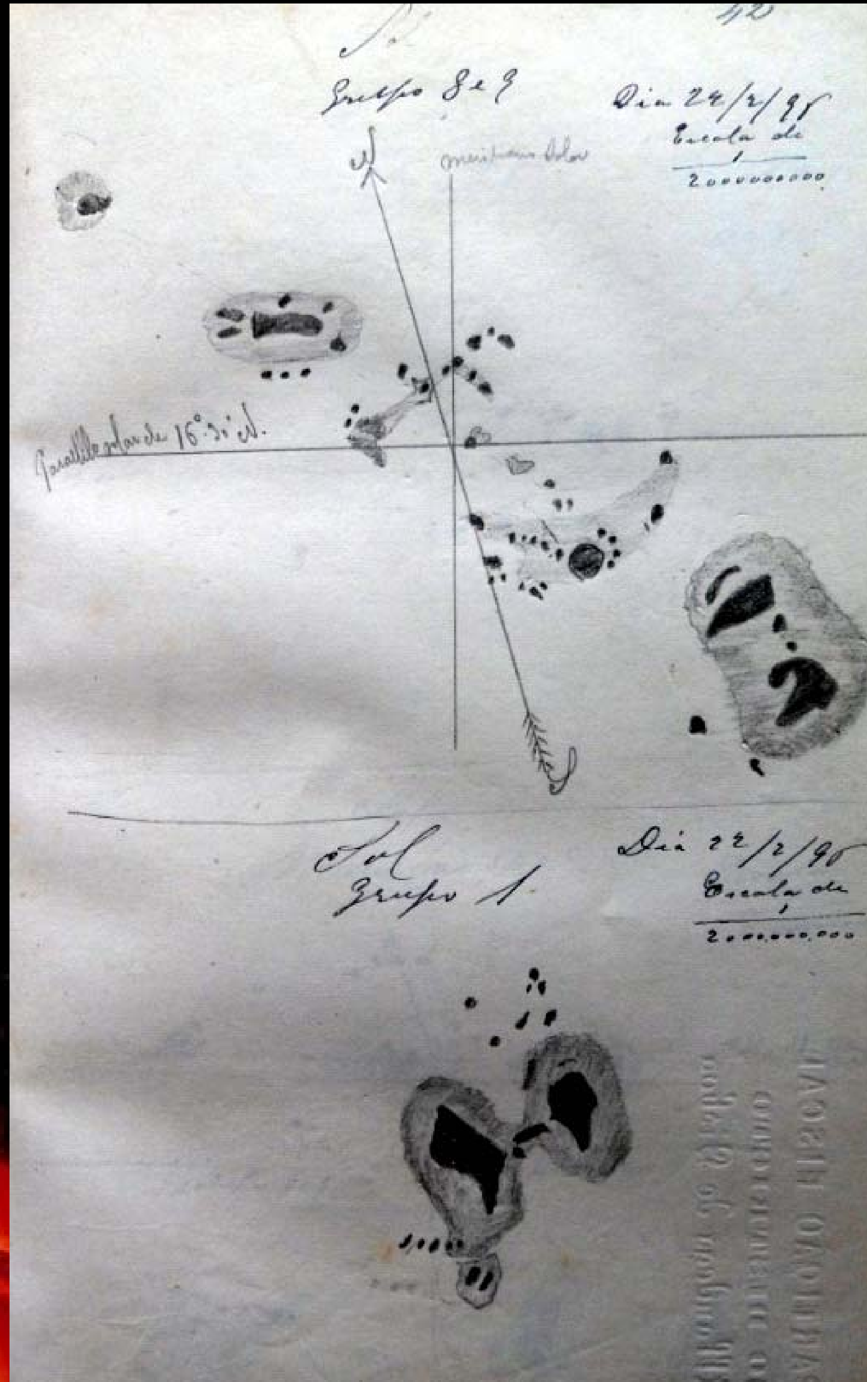
PUBLICADOS PELO DIRECTOR DO OBSERVATÓRIO

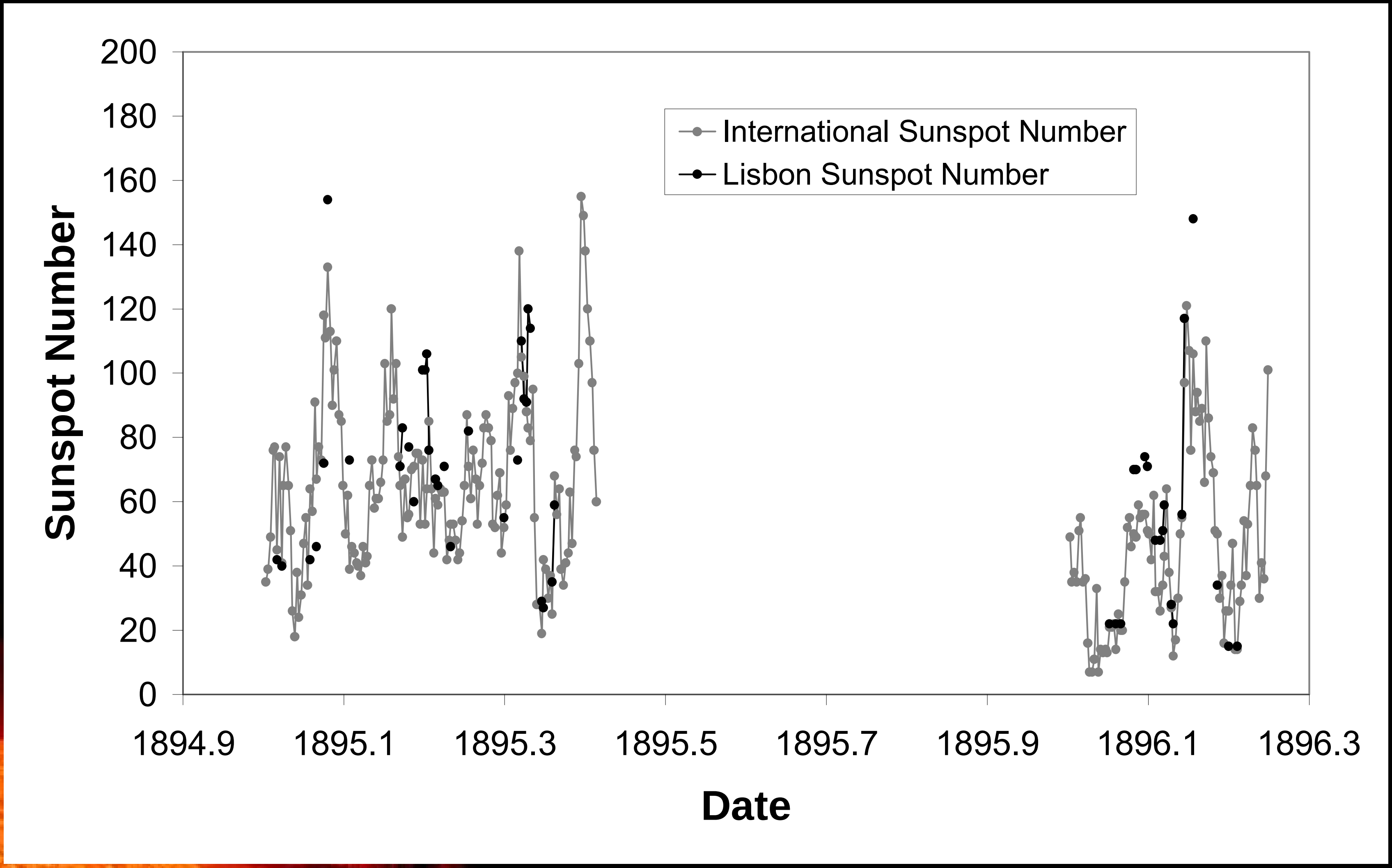
F. M. DA COSTA LOBO

TOMO I

COIMBRA
IMPRENSA DA UNIVERSIDADE
1929




Grupo 8 e 9
Escala de
Sol
Grupo 1
Escala de



International Sunspot Number
Lisbon Sunspot Number
Sunspot Number
Date
200
180
160
140
120
100
80
60
40
20
0
1894.9
1895.1
1895.3
1895.5
1895.7
1895.9
1896.1
1896.3

Main conclusions

- 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.:

jvaquero@unex.es