The Maunder Minimum: some recent progress

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Exactly 40 years ago…

18 June 1976, Volume 192, Number 4245

SCIENCE

The Maunder Minimum

The reign of Louis XIV appears to have been a time of real anomaly in the behavior of the sun.

John A. Eddy

It has long been thought that the sun is a constant star of regular and repeatable behavior. Measurements of the radiative output, or solar constant, seem to justify the first assumption, and the record of periodicity in sunspot numbers is taken as evidence for the second. Both records, however, sample only the most recent history of the sun.

When we look at the longer record—of the last 1000 years or so—we find indications that the sun may have undergone significant changes in behavior, with possible terrestrial effects. Evidence for past solar change is largely of an indirect nature and should be subject to the most critical scrutiny. Most accessible, and crucial to the basic issue of

The Sunspot Cycle

Surely the best-known features of the sun are sunspots and the regular cycle of solar activity, which waxes and wanes with a period of about 11 years. This cycle is most often shown as a plot of sunspot number (Fig. 1)—a measure of the number of spots seen at one time on the visible half of the sun (*1*). Sunspot numbers are recorded daily, but to illustrate long-term effects astronomers more often use the annual means, which smooth out the short-term variations and average out the marked imprint of solar rotation.

There is as yet no complete physical explanation for the observed solar cycle.

zero. In contrast, in the years around a sunspot maximum there is seldom a day when a number of spots cannot be seen, and often hundreds are present.

Past counts of sunspot number are readily available from the year 1700 (*3*), and workers in solar and terrestrial studies often use the record as though it were of uniform quality. In fact, it is not. Thus it is advisable, from time to time, to review the origin and pedigree of past sunspot numbers, and to recognize the uncertainty in much of the early record.

A Brief History

Dark spots were seen on the face of the sun at least as early as the 4th century B.C. (*4*), but it was not until after the invention of the telescope, about 1610, that they were seen well enough to be associated with the sun itself. It would seem no credit to early astronomers that over 230 years elapsed between the telescopic "discovery" of sunspots and the revelation of their now obvious cyclic behavior. In 1843, Heinrich Schwabe, an amateur, published a brief paper reporting his own observations of spots on the sun for the period 1826 to 1843 and pointing out an apparent period of about 10 years between maxima in their number (*5*).

Rudolf Wolf, director of the Observa-

Astron. Astrophys. 276, 549–563 (1993)

ASTRONOMY AND ASTROPHYSICS

The solar sunspot cycle in the Maunder minimum AD 1645 to AD 1715

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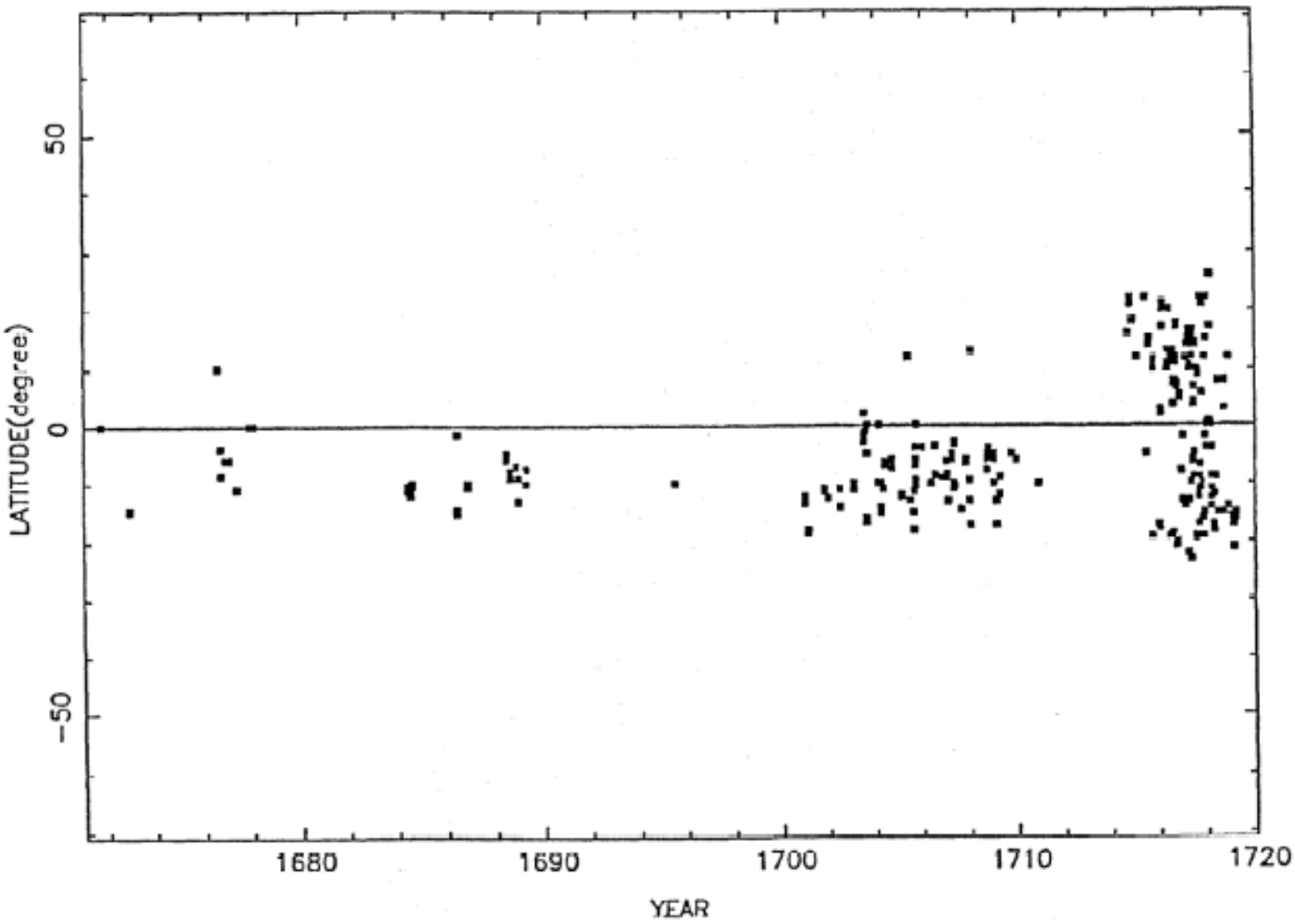
Received April 15, accepted May 18, 1993

Abstract. We present a unique collection of quantitative sunspot observations recorded at the Observatoire de Paris from 1660-1719. These data contrast significantly with that of earlier observers who bequeathed us a sporadic set of drawings from before the Maunder Minimum in that they are quantitative measurements, they span most of the Maunder Minimum uninterrupted. About 8000 daily observations were made from 1660 to 1719, on which we base our description of solar activity properties. Sunspot numbers, butterfly diagrams, active longitudes and rotation rates are all reconstructed and compared to modern ones, and the comparison with modern observations of the 11-year solar cycle provides us with a better understanding of the solar cycles over the Maunder Minimum.

Key words: the Sun – solar cycle – differential rotation

of Nantes in 1685 marked the onset of a slow decline in french domination, causing the departure of the protestant intelligentsia abroad. Leadership then gradually shifted to the northern countries of England, Holland and Germany (Hazard 1961). In the early 1660's, however, France was still the uncontested power. One of the first initiatives of the Academy of Sciences, in 1667, was to create l'Observatoire de Paris, which remains the oldest observatory still existing in the world. Colbert invited to the observatory J.D. Cassini, who acted as director, and Ch. Huygens. Cassini gathered around him a school of brilliant scientists, one of the foremost of whose was J. Picard, who instituted a number of new techniques that made astronomy a quantitative science.

Picard deserves special mention because he took the initiative of improving observational techniques and started the systematic solar watch program.


LATITUDE(degree)
50
0
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1680
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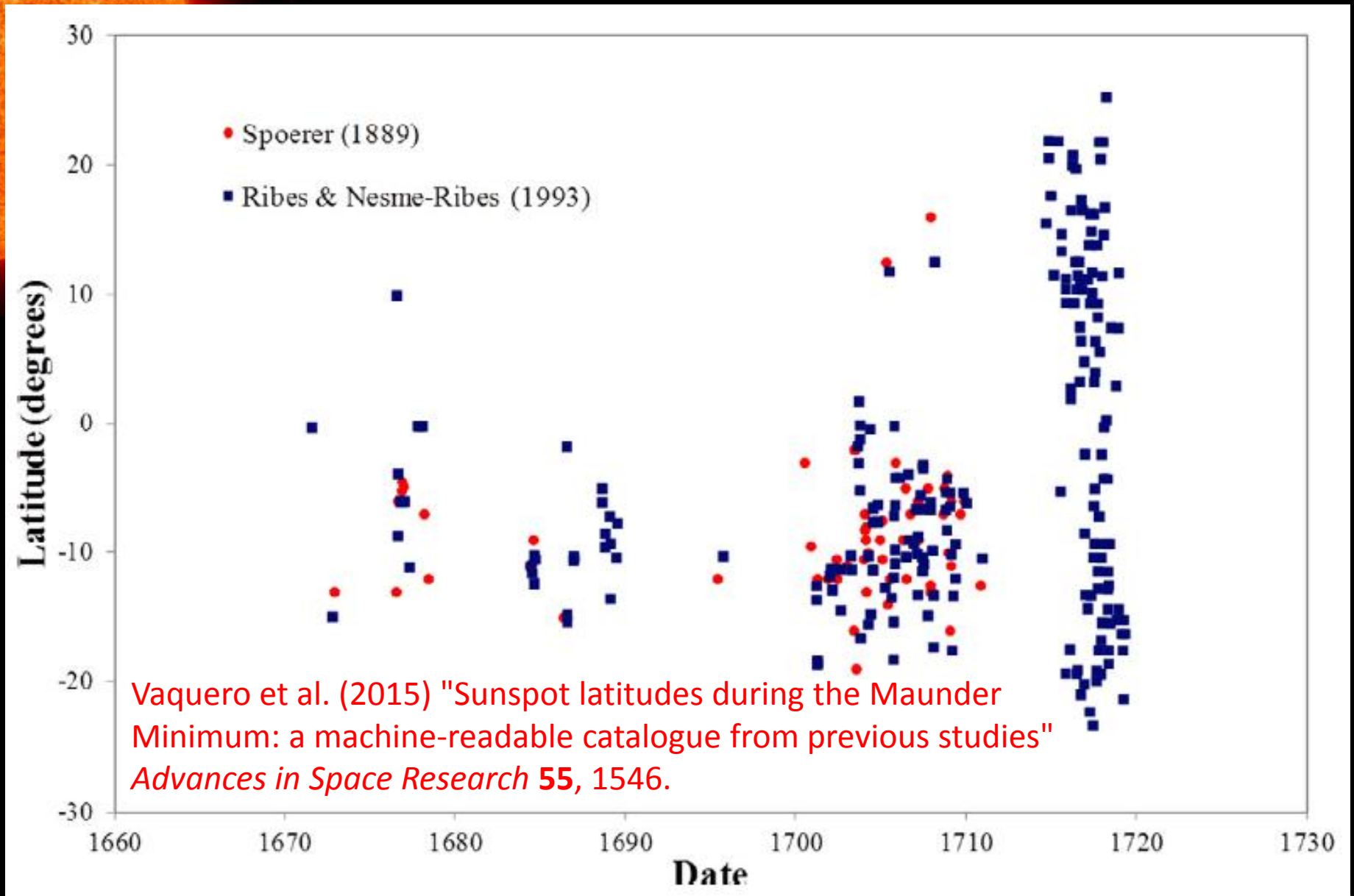
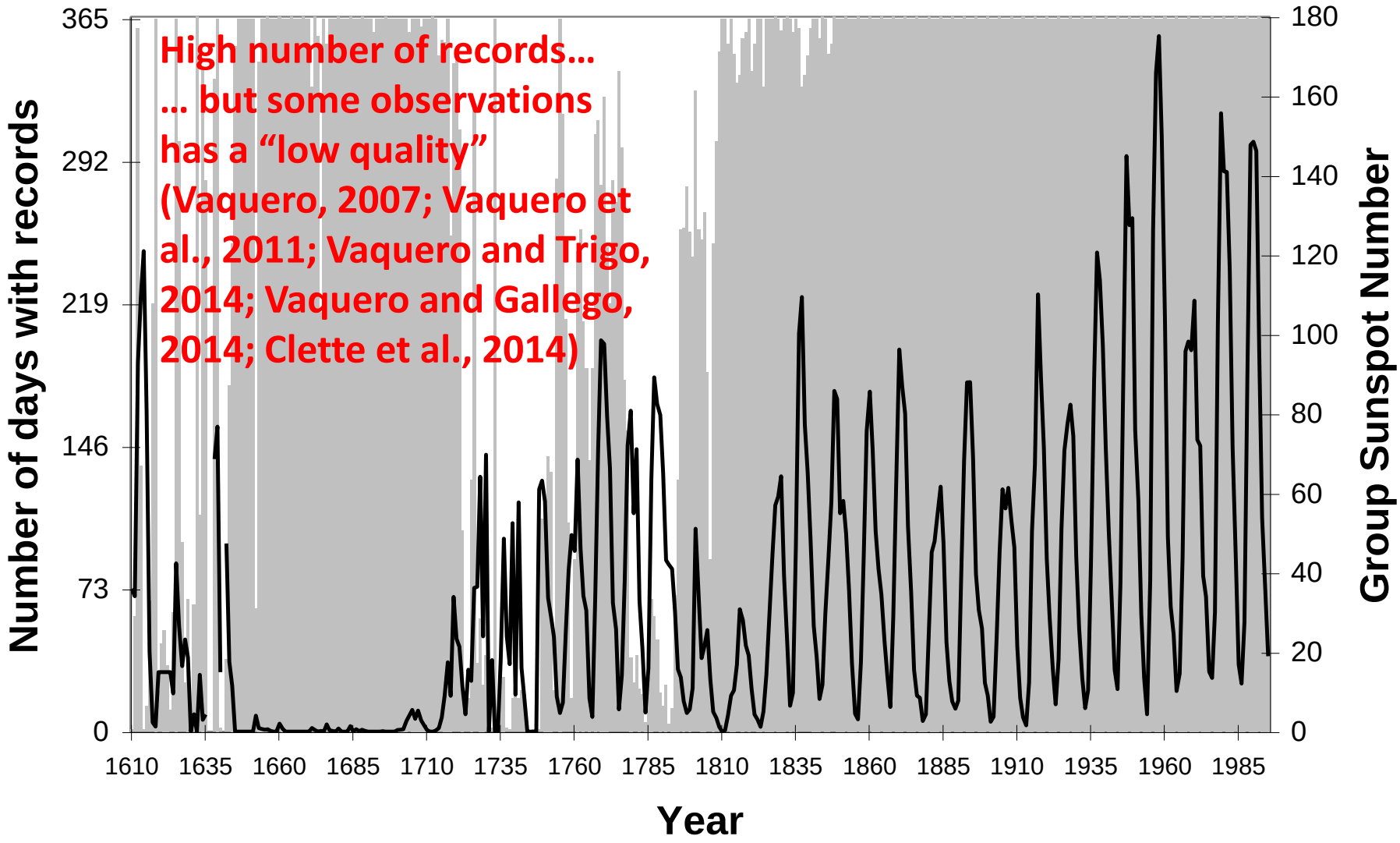
1700
1710
1720
YEAR

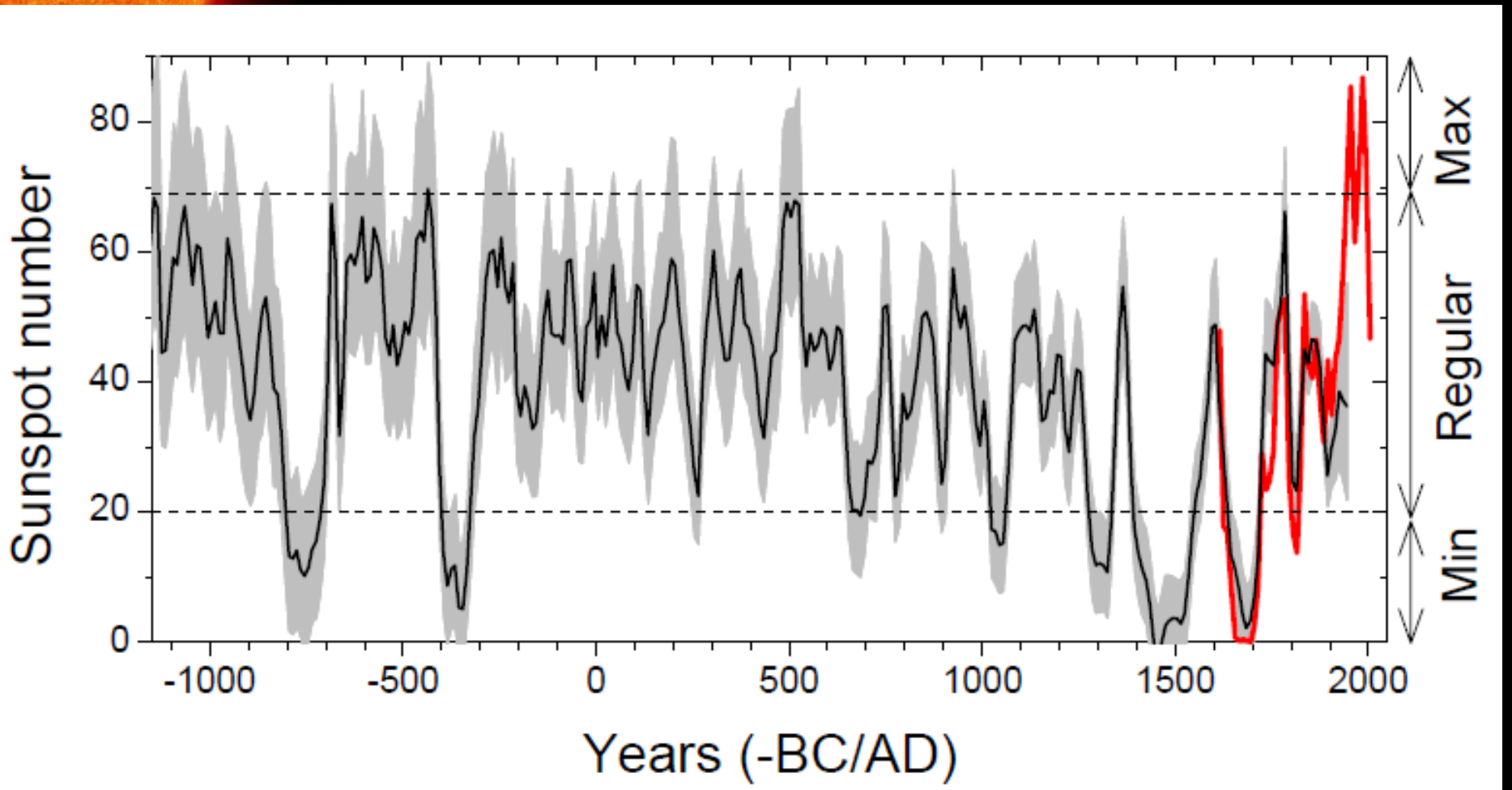


Vaquero et al. (2015) "Sunspot latitudes during the Maunder Minimum: a machine-readable catalogue from previous studies" *Advances in Space Research* **55**, 1546.

http://haso.unex.es



Hoyt and Schatten (1998)



Usoskin *et al*. (2014) *A&A*

The **Maunder Minimum** (1645-1715 approximately) was a period of

- ✓ very low solar activity and
- ✓ a strong hemispheric asymmetry, with most of sunspots in the *southern hemisphere*,
- ✓ corresponding to the special mode of a Grand minimum.

The Astrophysical Journal, 800:42 (14pp), 2015 February 10 doi:10.1088/0004-637X/800/1/42

THE MAUNDER MINIMUM IS NOT AS GRAND AS IT SEEMED TO BE

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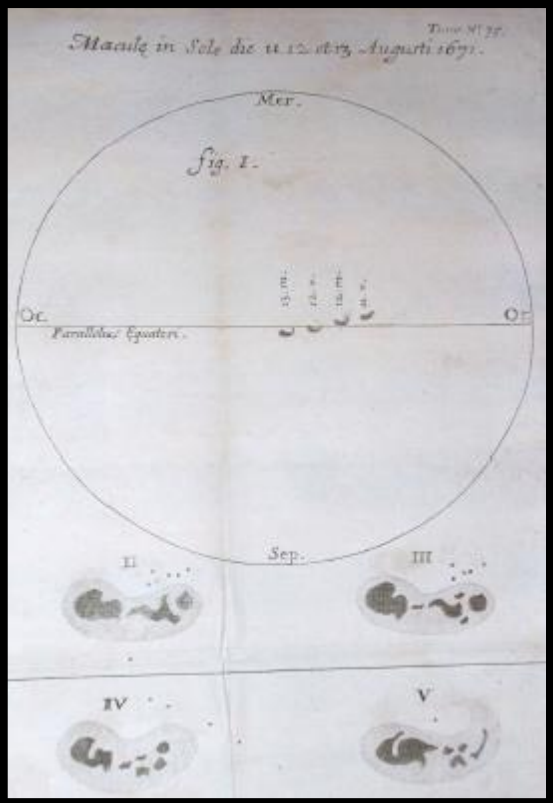
Received 2014 August 18; accepted 2014 December 9; published 2015 February 6

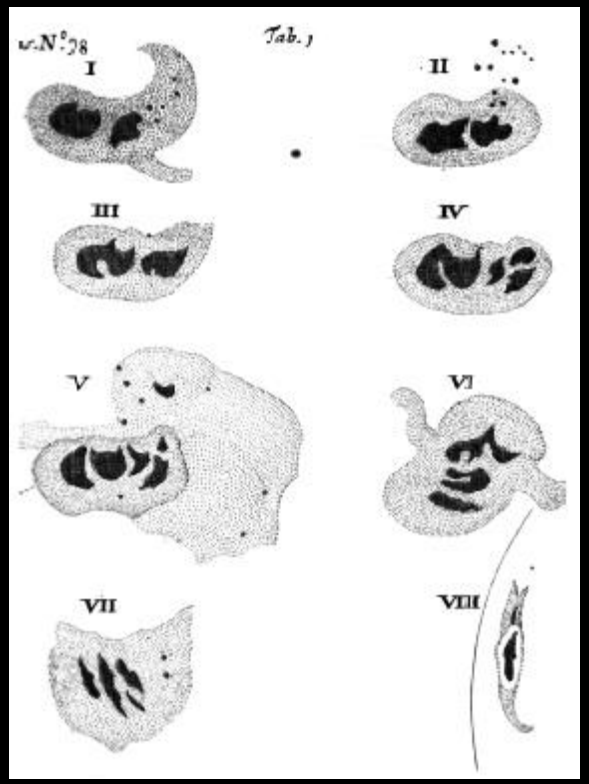
ABSTRACT

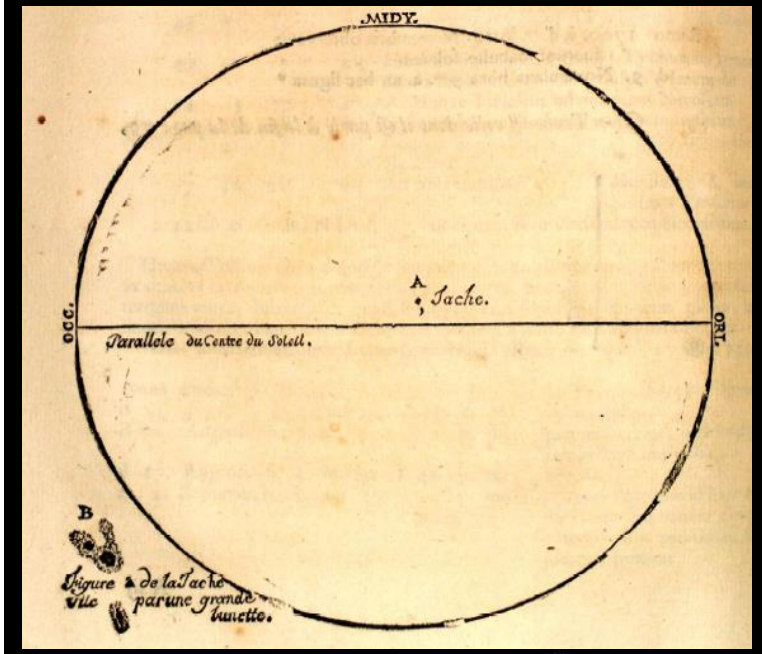
The Maunder Minimum (MM), which occurred between 1645 and 1715, is mainly known as an almost spotless period on the Sun. We analyze the nominal number of sunspot groups for each observer individually. Comparing the sunspot drawings and textual reports, we conclude that the latter underestimate the number of sunspots. We also argue that the different points of view of observers in the seventeenth century on the origin of sunspots resulted in the underestimation of sunspot groups or even gaps in observational reports. We demonstrate that Jean Picard and Giovanni Domenico Cassini of the Paris Observatory did not report any sunspots, while other observers reported on the occurrence of spots. Moreover, compared with other observers, La Hire underestimated the solar activity. The MM looks like an ordinary secular minimum with a depressed 11 yr solar cyclicity.

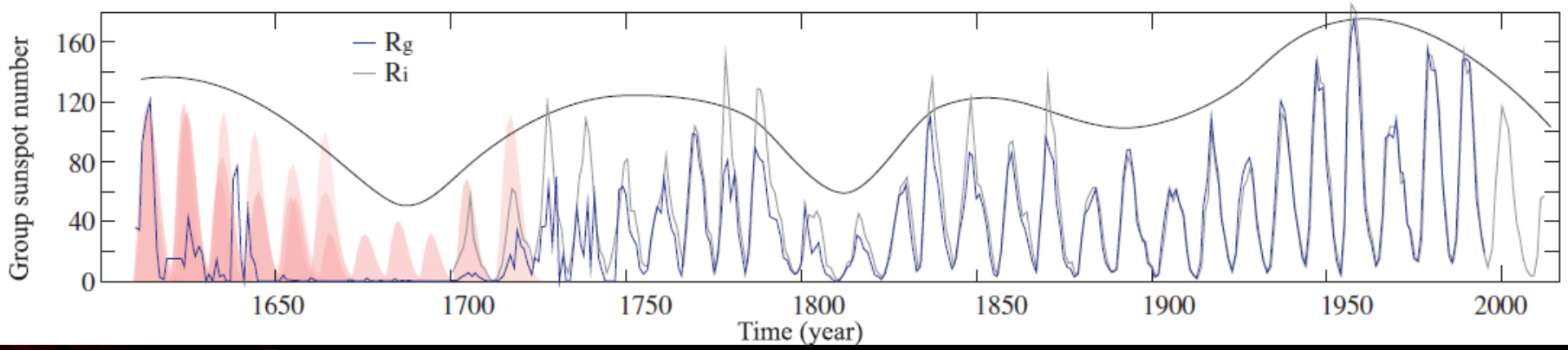
Key words: Sun: activity – sunspots

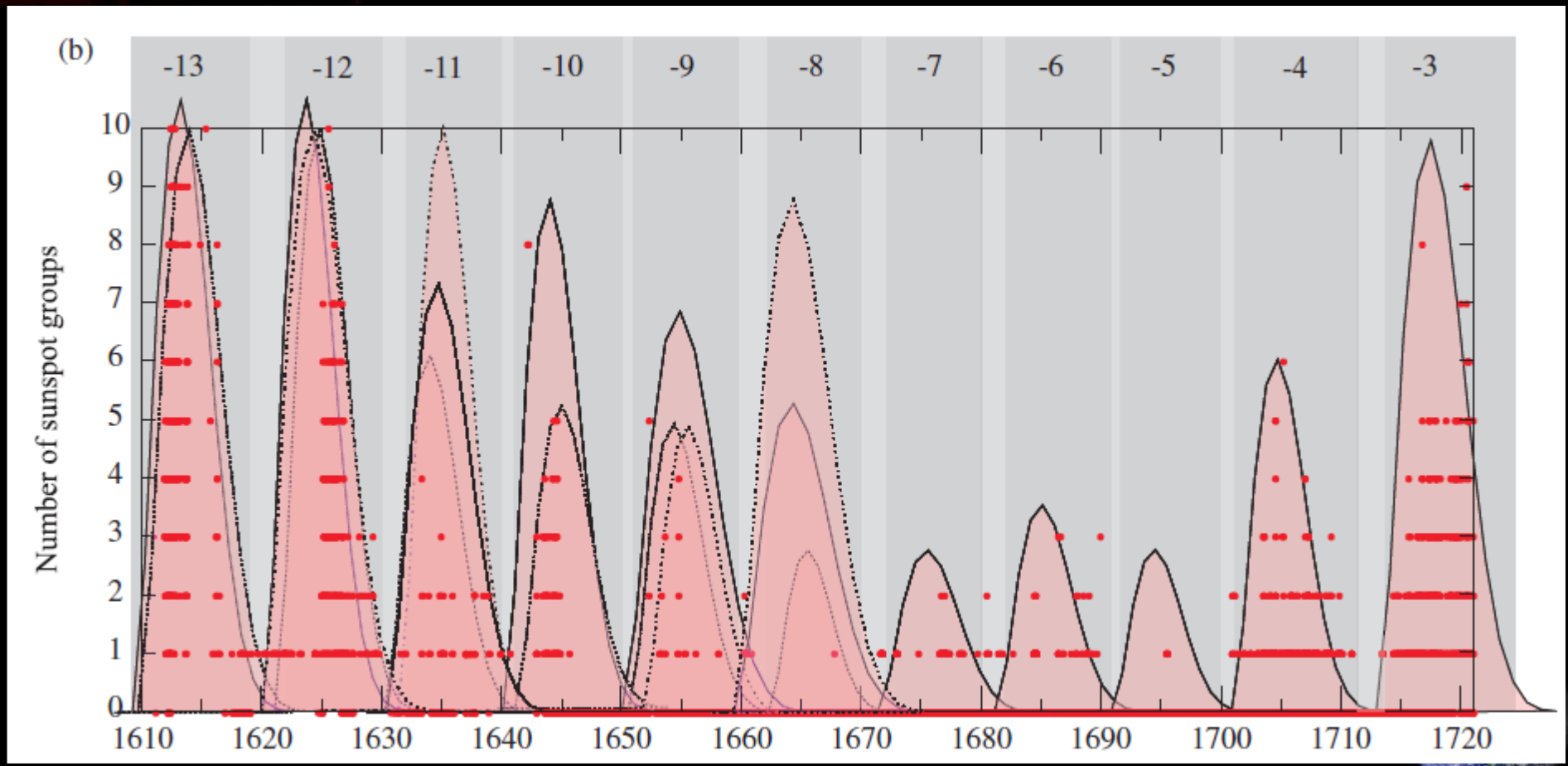
Usoskin et al. (2015) The Maunder minimum (1645–1715) was indeed a Grand minimum: A reassessment of multiple datasets, *A&A* **581**, A95.





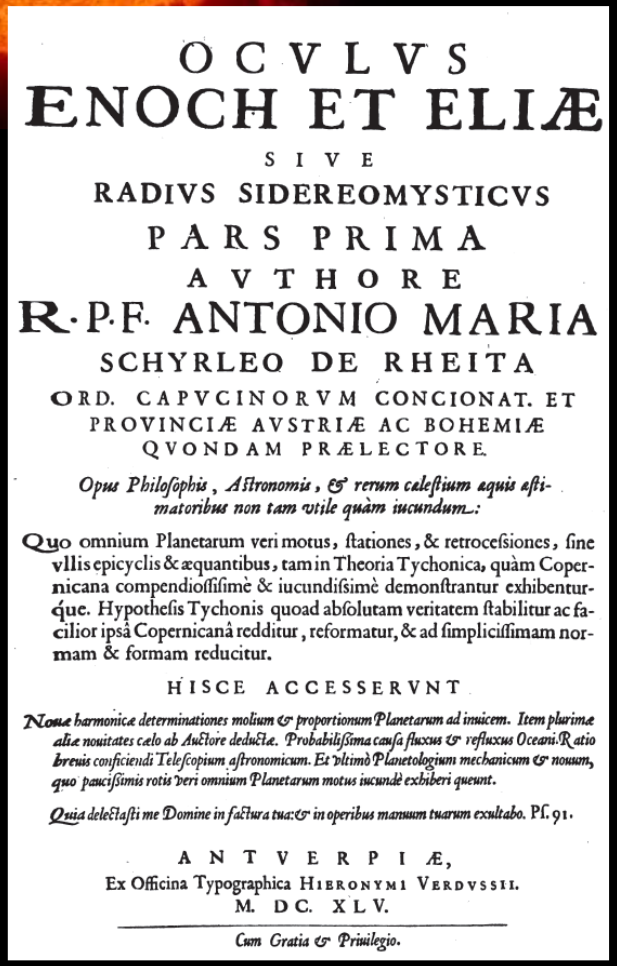






Zolotova & Ponyavin (2014)

Gómez & Vaquero (2015) The sunspot observations by Rheita in 1642, *The Observatory* **135**, 220.
http://arxiv.org/abs/1502.06772



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 aquis 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.

242 LIBER QVARTVS.

& Sol morbo illo palloris, & sæculum tristiori caligine 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.

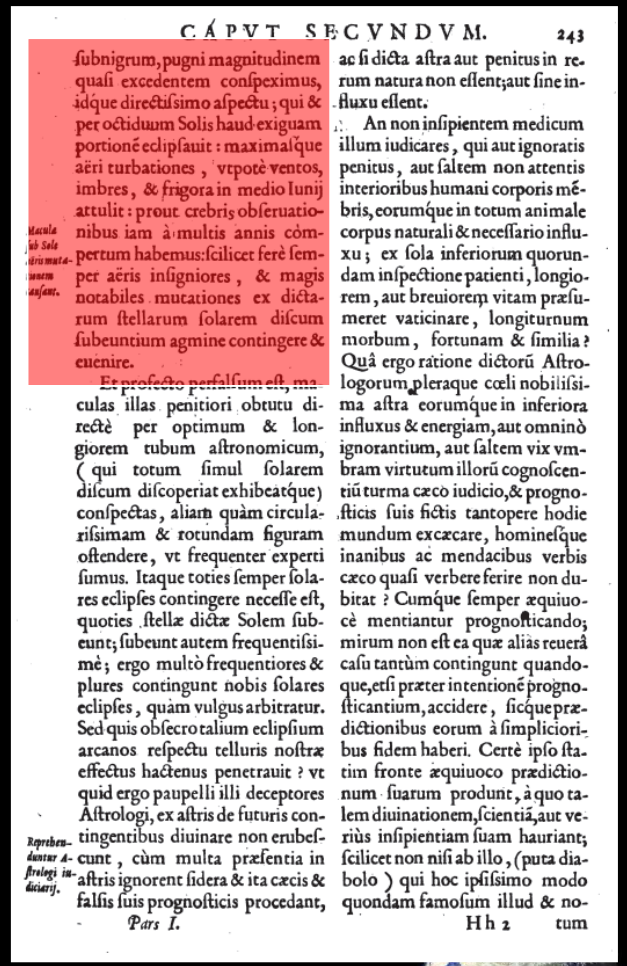
Iterum Anno 1547. per totam vastissimam Europæ plagam, Solis radij sanguineo colore adeò deleti videbantur trium dierum spatio; vt mundo vltimum iam quasi inciperent prænütiare diem. Denique tempore, quo Rudolphus II. Augustus ex humanis abreptus fuerat, Solem per plures dies, suâ tristissima facie &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

Quidam Solem similem monti Ætnæ putant.

Horum igitur solarium prodigiorum meritò causam indagare liceat. Aliqui putant Solem instar alterius montis Æthnæ, aut Vesuij 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 probabilitatis 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 debilitariq́ue.

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,



CAPVT SECVNDVM. 243

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

Macula ab Sole diris mutationem afferunt.

Et profecto perfalsum est, maculas illas penitiori obtutu directè per optimum & longiorem tubum astronomicum, (qui totum simul solarem discum discoperiat exhibeatq́ue) 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, quàm 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 fidera & ita cæcis & falsis suis prognosticis procedant,

Reprehenduntur Astrologi iudiciarij.

Vaquero & Trigo (2014) "Revised Group Sunspot Number Values for 1640, 1652, and 1741" *Solar Physics* **289**, 803. http://arxiv.org/abs/1307.2725

Illustribus Viris,

PETRO GASSENDO,

&

ISMAELI BULLIALDO,

Philosophis ac Mathematicis

nostri seculi summis, amicis suis officiosè honorandis,

JOHANNES HEVELIUS

S.

VOs tot tantosq; inter Martis adversos tumultus, quibus Gallia Vestra jam ab aliquot annis acerbissimè affligi-

Atq; ita restat ampliùs nihil, nisi quòd admonendum insuper censeo, durante hac Eclipsi, ut & totâ eà die, nihil prorsus in Sole macularum apparuisse; quanquam die 1. Aprilis, horâ 11. 45'. in disco Solis quinq; visæ fuerint maculæ: duæ quidem debilissimæ non procul à limbo orientali, dilutioribus concomitantibus faculis umbrisq; ; tres autem satis densæ, circa centrum, in latitudine Boreali. Ex quibus posterioribus die 3. Aprilis tantùm duæ conspectæ, quæ die sextâ in faculas penitus degeneravére; reliquæ verò duæ debiliores, die 7. omnino etiam sunt exstinctæ.

Sed & deniq; ut hac de nostrâ quali quali observatione quilibet eò certior esse possit, subjungam simul adhuc geminam ejusdem Eclipseos annotationem, hic item Gedani, alteram ab Excellentissimo, & Præclarissimo viro D. L. Eichstadio, amico nostro singulari; alteram

Atq; ita restat ampliùs nihil, nisi quòd admonendum insuper censeo, durante hac Eclipsi, ut & totâ eà die, nihil prorsus in Sole macularum apparuisse; quanquam die 1. Aprilis, horâ 11. 45'. in disco Solis quinq; visæ fuerint maculæ: duæ quidem debilissimæ non procul à limbo orientali, dilutioribus concomitantibus faculis umbrisq; ; tres autem satis densæ, circa centrum, in latitudine Boreali. Ex quibus posterioribus die 3. Aprilis tantùm duæ conspectæ, quæ die sextâ in faculas penitus degeneravére; reliquæ verò duæ debiliores, die 7. omnino etiam sunt exstinctæ.

We have some doubts about the quality of the sunspot records during the Maunder Minimum

What can we do?

Stablish “models” or sub-sets of the Hoyt & Schatten database

Vaquero et al. (2015) A&A

Use of “high” quality observers

Hevelius

Flamsteed

Vaquero et al. (2015) “Level and length of cyclic solar activity during the Maunder minimum as deduced from the active day statistics” *A&A* **577**, A71. http://arxiv.org/abs/1503.07664

Sunspot Group Database by Hoyt and Schatten (1998)

Loose model (ML)
it ignores all the generic statements (longer than a month) in the HS98 database, and considers only explicit statements that mention exact dates of observations.

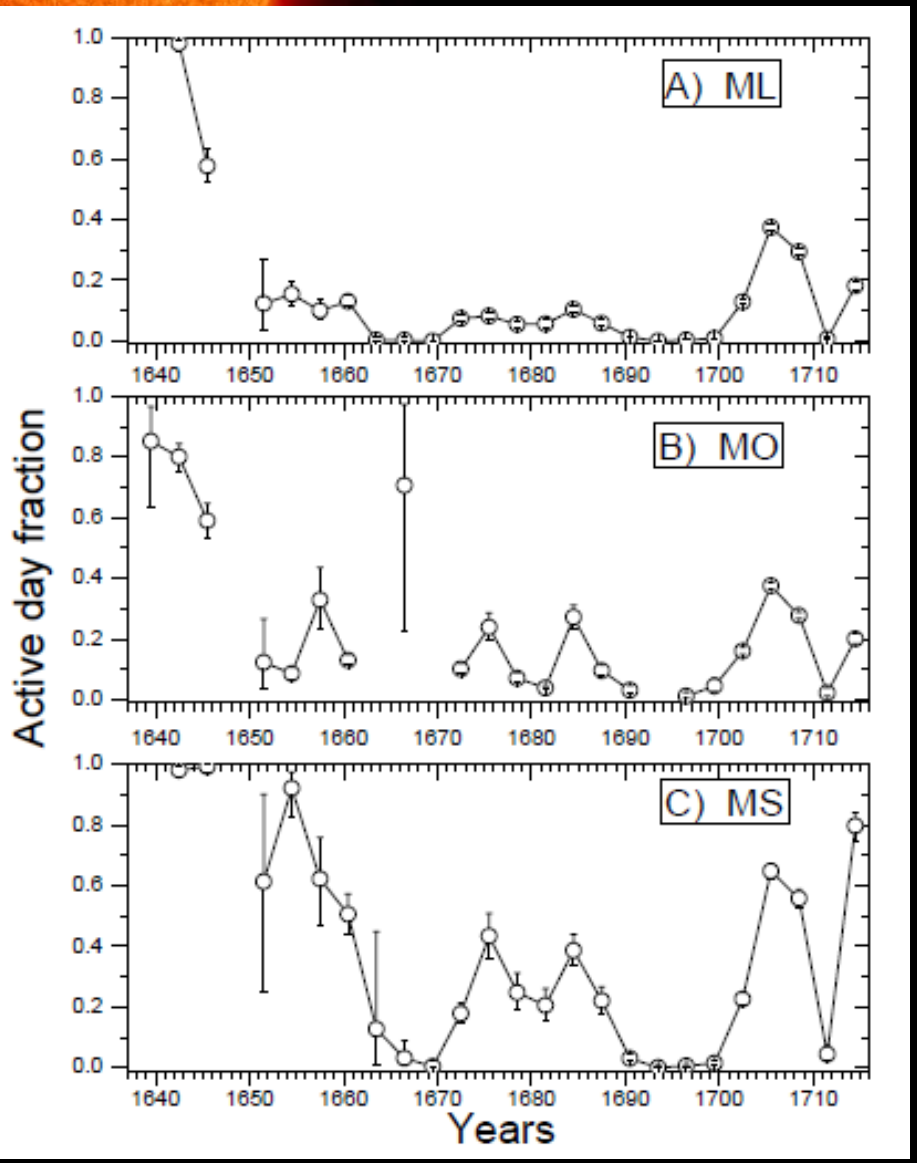
It includes 13512 observational days, which is nearly half of the HS98 database.

Optimum model (MO)
For each year, we considered observations of only those observers who reported at least one sunspot group at any day of the year, which would prove that the observer was “active”.

It includes 8089 observational days for the period analysed, which is roughly one third of the full HS98 database.

Strict model (MS)
we consider as inactive only those days when at least two observers independently reported that the Sun was spotless and when there were no other records of sunspots.

This model includes 5159 daily records or one fifth of the full HS98 database.



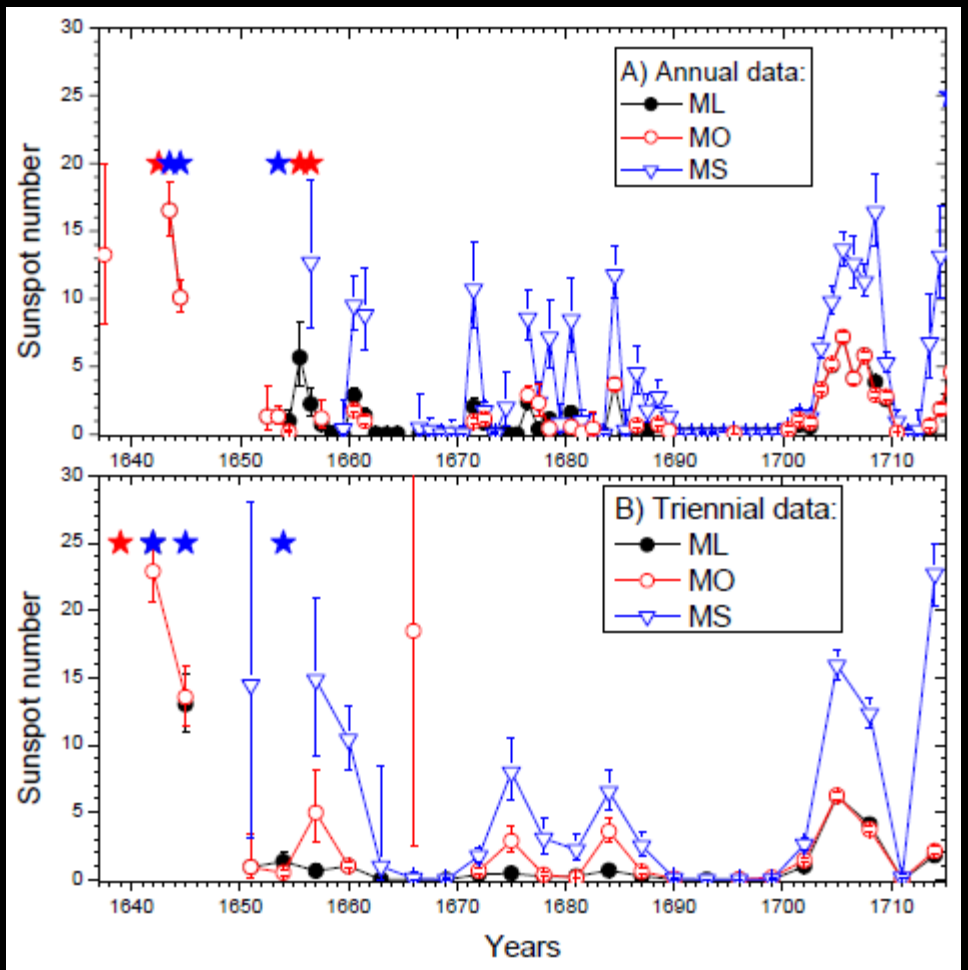


Fig. 6. Annual (panel **A**)) and triennial (panel **B**)) sunspot numbers reconstructed in the three models as denoted in the legends. Years with low statistics ($N_T < 10$) are not shown. Stars indicate that the sunspot number cannot be assessed from the active-day fraction (see text) and is greater than 18/23 for the annual/triennial data.

Carrasco, Villalba Álvarez and Vaquero (2015) "Sunspots during the Maunder Minimum from *Machina Coelestis* by Hevelius" *Solar Physics* **290**, 2719.

JOHANNIS HEVELII

MACHINÆ COELESTIS

PARS POSTERIOR;

Rerum Uranicarum

OBSERVATIONES,

Tam Eclipsium Luminarium, quàm Occultationum Planetarum, & Fixarum,

Nec non

Altitudinum Meridianarum Solarium, Solstitiorum, & Æquinoctiorum;

Unà cum

Reliquorum Planetarum, Fixarumq; omnium hactenus cognitarum, Globisq; adscriptarum, æquè ac plurimarum hucusq; ignotarum

OBSERVATIS;

Pariter quoad

Distantias, Altitudines Meridianas, & Declinationes;

Additis

Innumeris aliis notatu dignissimis, atquè ad Astronomiam excolendam maximè spectantibus rebus,

Plurimorum annorum, summis vigiliis, indefessoque labore, ex ipso æthere haustas, permultisquè Iconibus, Auctoris manu, æri incisis, illustratas, & exornatas,

TRIBUS LIBRIS,

exhibens.

Cum Gratiâ & Privilegio Sac. Regiæ Majest. Polon.

GEDANI.

In ædibus AUCTORIS, ejusq; Typis, & Sumptibus Imprimebat

SIMON REINIGER.

ANNO M DC LXXIX.

JOHANNIS HEVELII

IN

Partem Posteriorem

MACHINÆ COELESTIS

PRÆFATIO

AD

LECTOREM.

QUintus jam effluxit annus, cùm Partem Machinæ meæ Cœlestis Priorem, Organographiam videlicet, quâ Organa nostra universa, hactenus ad Observationes Cœlestes à me adhibita, graphicè delineata, atq; accuratè descripta, in lucem ediderim. Nunc verò cùm DEUS O. M. vitam porrò, sanitatem, otiumq; (pro quibus omnibus ex toto corde Ipsi & ago & habeo gratias) sub tantà negotiorum, & molestiarum mole, clementissimè mihi concesserit, Tuis quoq;, mi Astrophile, citiùs enim ob varia impedimenta, immensumq; laborem typis exscribi haud potuit) Partem

Quo anno Pars Prior Machinæ Cœlestis typis fit divulgata.

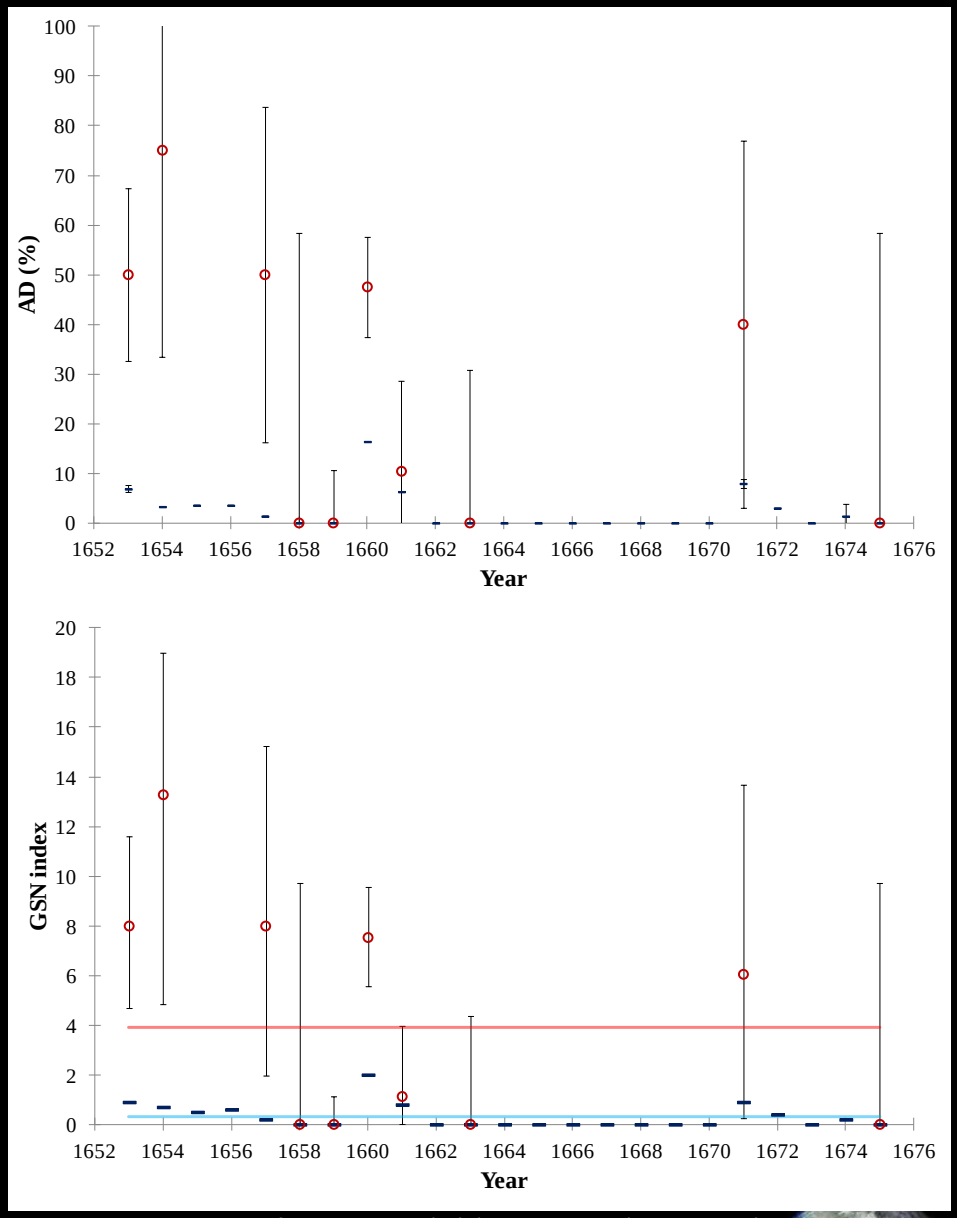
ANNO M. DC. LIX.

	Mens.	Dies		Altitudines Solis Meridianæ. Grad.	Min.	Sec.	Quo Instrumento	Quâ Tempestate.	Quâ Diligentiâ.	NOTANDA.
Sol in Ariete.	Martii	29	♄	39	5	35	Quad. Az.	Coelo vix satis sereno	diligentiss.	tamen. Nil prorsus
		30	☉							Nulla macula
	Aprilis	6	☉	42	10	25		Ratione alicujus impedimenti dub.		Nulla macula
		10	♌	43	39	10		Aëre sereno	diligentissimè	Nil macularum
		12	♄	44	24	0		Coelo sereno	accuratissimè	Nihil
Sol in Tauro.	Aprilis	16	☿	45	50	35	Quad. Az.	Aëre sereno	diligentissimè	Nihil
		26	♄	49	13	45		Coelo sereno	diligenter	Nulla macula
		30	☿	50	28	15				Nil macularum
	Maji	4	☉	51	40	30		Coelo sereno		Sol purus omninò
		5	☽	51	56	50		Cœlo annuente		
	Maji	7	☿	52	31	36	Quad. Az.	Coelo sereno	diligentissimè	Nil macularum
		11	☉	53	34	45		dub. jam Sol	Merid. transf.	erat. Nil macularum
		13	♂							Nil macularum
		14	☿	54	18	50		Coelo sereno	diligentissimè	Nil penitùs
		18	☉	55	15	0		Coelo sereno	diligenter	Nil macularum
Sol in Geminis.	Maji	24	♄	56	27	15	Quad. Az.			Nihil penitùs in Sole
		25	☉	56	38	30		Coelo quidem ser.	sed vix sat. dil.	Nihil in Sole apparuit.
		27	♂	56	58	50				Nil macularum
		29	♌	57	17	40				Nil prorsus deprehensum
	Junii	2	☽	57	51	20	Quad. Az.	Coelo sereno	diligentissimè	Nil macularum
		4	☿	58	6	30		Aëre sereno	accuratissimè	Nihil
		6	♀	58	19	50		Aëre sudo	diligentissimè	Nulla macula
		13	☿	58	53	10		Cœlo annuente	accuratissimè	Sol mundus
		16	☽	59	1	40		Coelo sereno	diligentissimè	Nil macularum
Solstitium Æstivum.	Junii	19	♌	59	5	45	Quad. Az.	Cœlo subnubilo	satis diligenter	Nil in Sole
		20	☿	59	6	35			diligenter	Sol purus
		22	☉	59	6	35		Aëre sereno	diligentissimè	Nulla macula
		28	♄	58	57	15		Coelo subnubilo	mediocriter	(vert.
		30	☽	58	51	0		Cœlo sereno	diligentissimè	Nihil in Sole animad-
Sol in Leone.	Julii	9	☿	58	2	30	Quad. Az.	Cœlo subnubilo	circiter tantùm	Nil in Sole exitit.
		12	♄	57	43	20		Coelo nubeculis ob	ducto, diligenter	Sol omninò purus
				57	43	25				
		20	☉	56	20	40		Coelo nubiloso		Nil macularum
Sol in Virgine.	Augusti	9	♄	51	32	10	Quad. Az.	Cœlo vix satis sereno	diligenter	Sol vacuus
		11	☽	50	57	30				Nulla macula
		17	☉	49	6	10				Nulla macula penitùs
		27	☿	45	43	25		Cœlo sereno	diligentissimè	Nihil deprehensum
		29	♀	45	1	15		Coelo sudo	diligenter	Omninò nihil apparuit
Æquinoctium Autumnale. Sol in Libra.	Sept.	14	☉	39	2	30	Quad. Az.			Nil macularum
		22	☽							Nulla macula in Sole
		24	☿	35	11	45	Quad horiz.	Cœlo subnubilo		
		25	♌	34	47	50	Quad. horiz.	Coelo nubiloso		
	Octobr.	1	☿	32	26	45	Quad. Az.	Vix satis sereno		
				32	26	40	Quad. horiz.		Dn. Kretzmerus	
		15	☿	27	5	20	Quad. Az.			
		16	♌	26	43	20				
Sol in Scorpione	Nov.	7 & 8								Nil macularum
		14	♀	17	23	40	Quad. horiz.		sed dubia	

ANNO M. DC. LX.

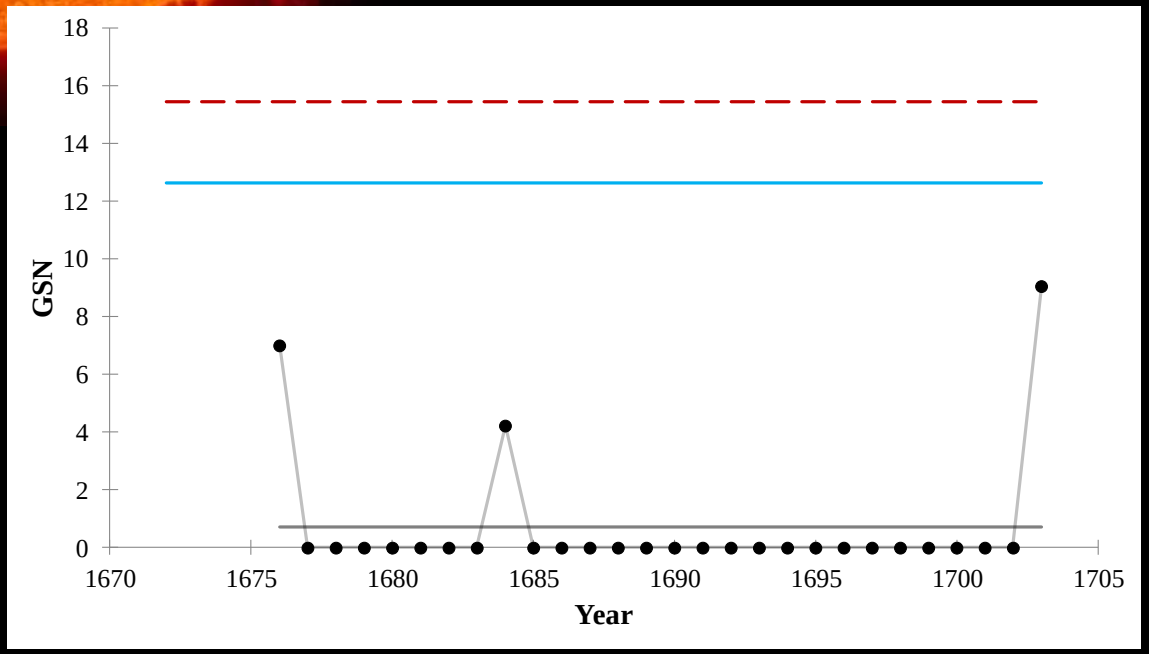
	Febr.	13	♀	22	18	45	Quad. Az.	Cœlo sereno	diligentissimè	
				22	18	50				
Sol in Piscibus.		22	☉	25	27	30		Aëre sereno	diligentissimè	Notabilis macula rotun
								da cum minori in	medio Solis dis	co apparuit, qualem vi
								memini ab aliquot	annis me obser	vasse.

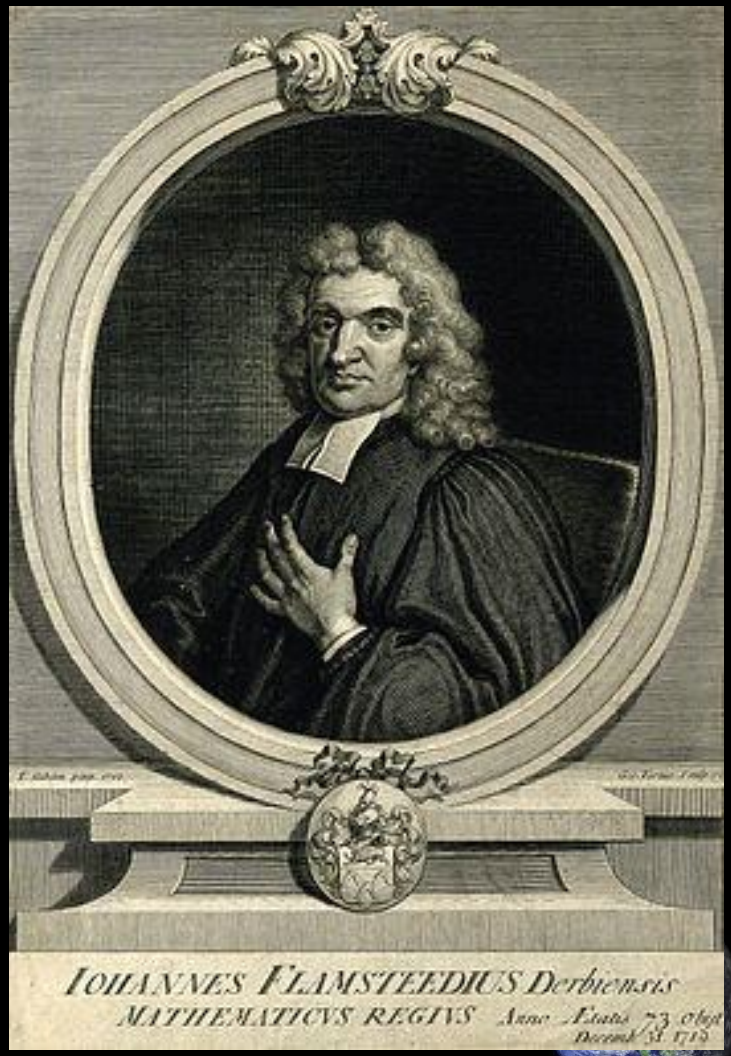
Ann



Temporal evolution of active days (%) (upper panel) and GSN (lower panel) during the period 1653-1675. Red (blue) symbols represent the values obtained in this work (by Hoyt and Schatten, 1998). The red (blue) solid line represents the mean value of GSN obtained in this work (by Hoyt and Schatten, 1998). Error bars represent a 99% confidence interval

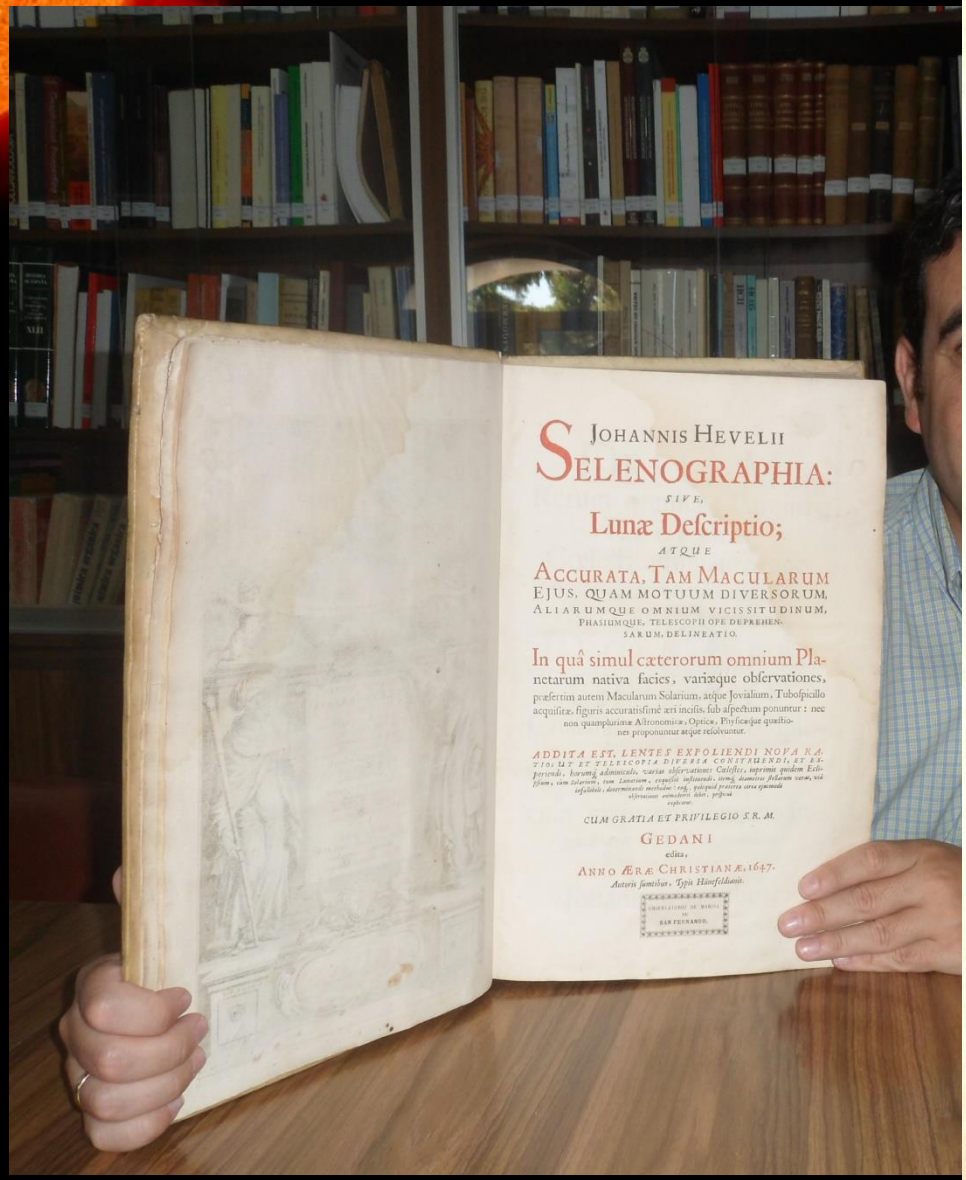
Carrasco and Vaquero (2016) Sunspot Observations during the Maunder Minimum from the Correspondence of John Flamsteed, *Solar Physics*, in press.



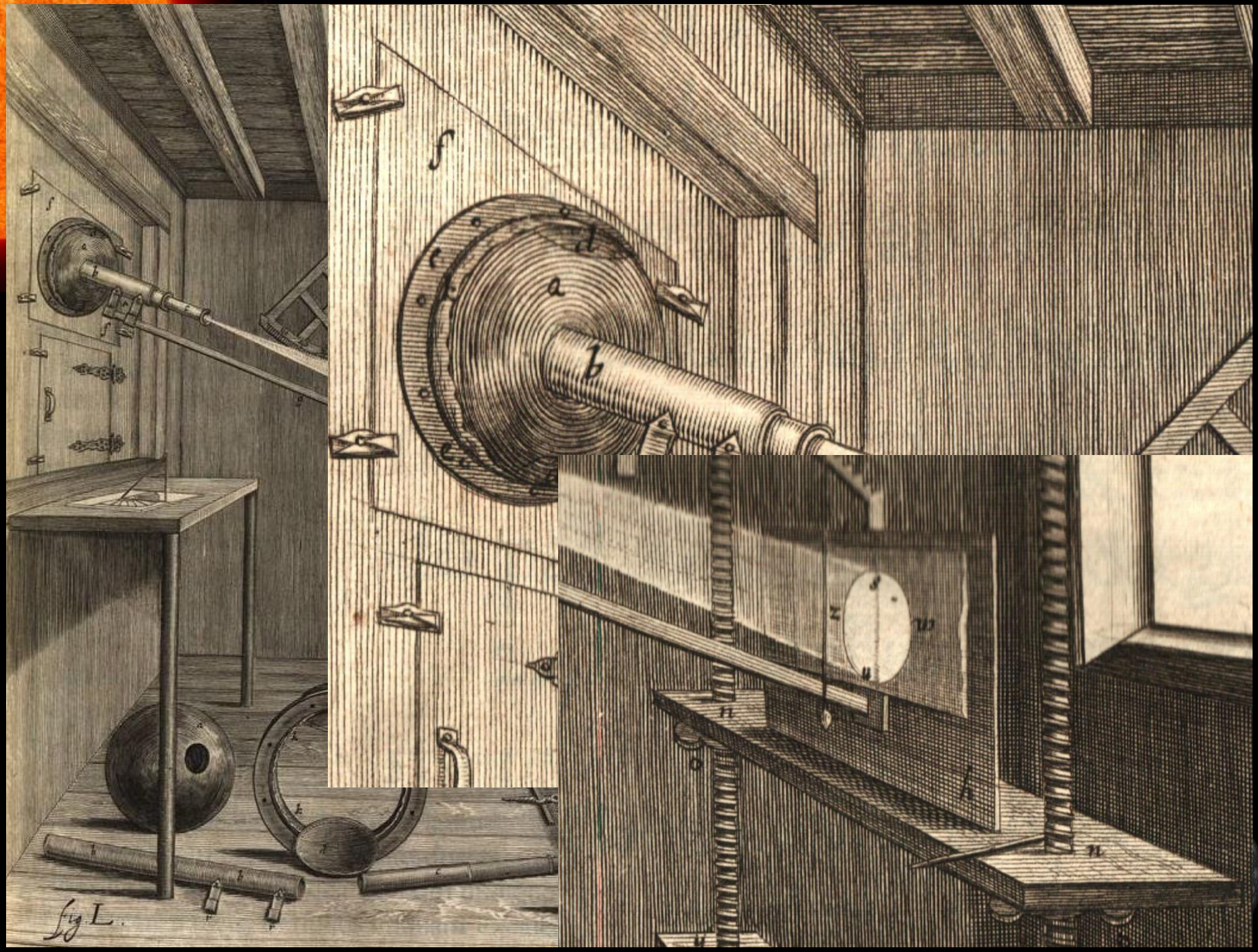


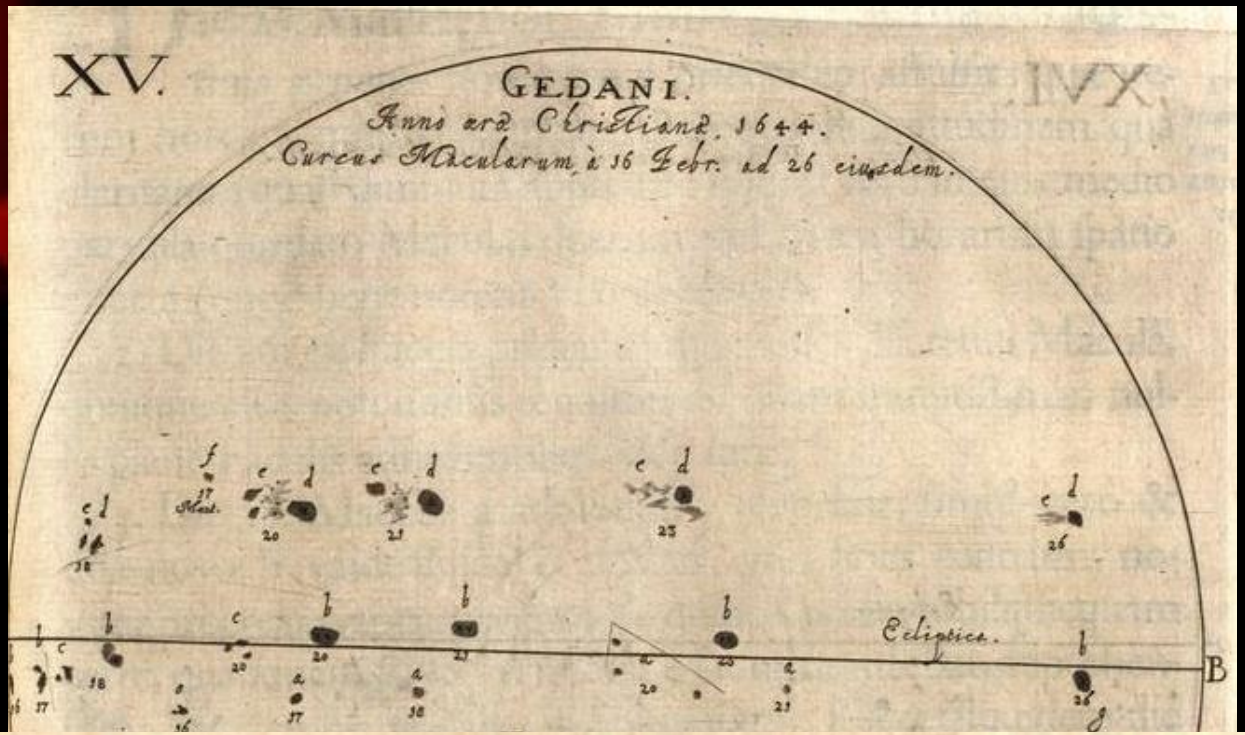
Group Sunspot Number (black dots) calculated from solar observations made by John Flamsteed according to Hoyt and Schatten (1995) and the average value (grey line) for the period 1676 – 1703. Average group sunspot number (solid blue line) and upper limit with a confidence interval of 99 % (dashed-red line) obtained in this work

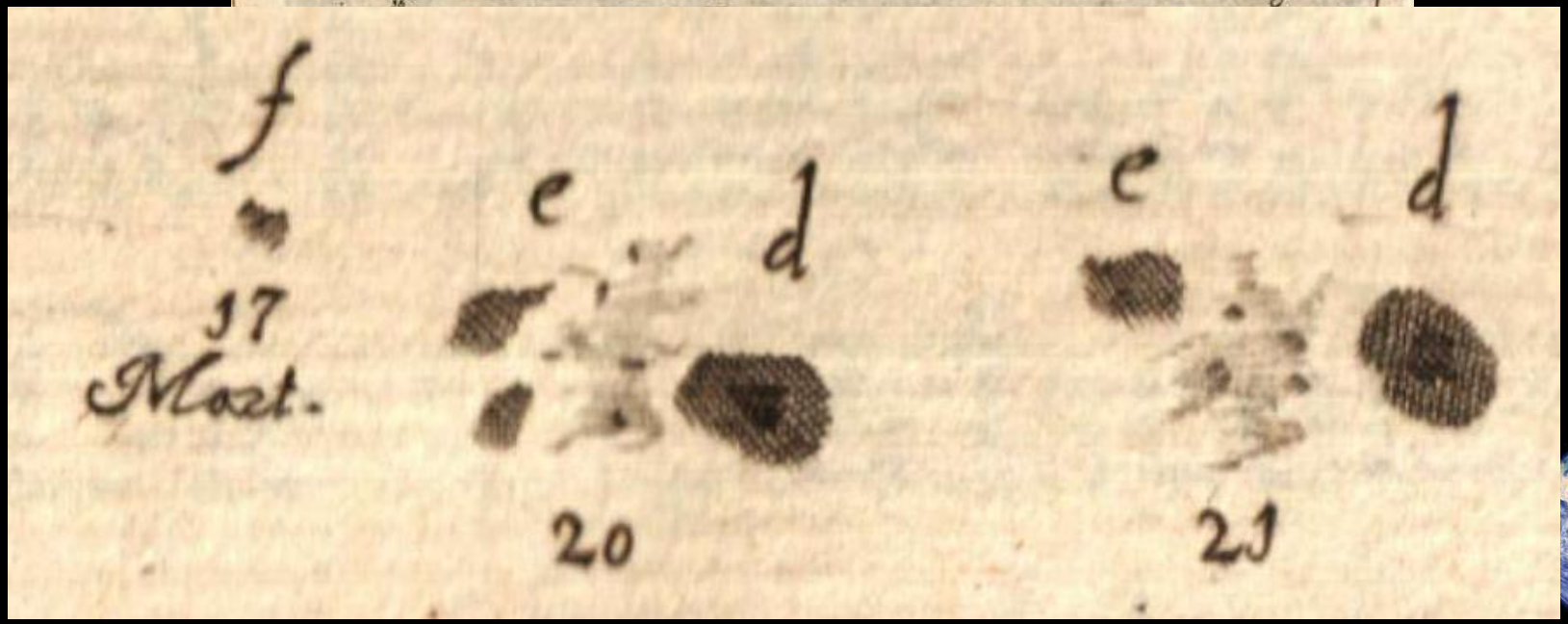
Work in progress...!!!



JOHANNIS HEVELII
SELENOGRAPHIA:
SIVE,
Lunæ Descriptio;
ATQUE
ACCURATA, TAM MACULARUM
EJUS, QUAM MOTUUM DIVERSORUM,
ALIARUMQUE OMNIUM VICISSITUDINUM,
PHASIUMQUE, TELESCOPII OPE DEPREHEN-
SARUM, DELINEATIO.
In quâ simul cæterorum omnium Pla-
netarum 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 quæſtio-
nes proponuntur atque reſolvuntur.
ADDITA EST, LENTES EXPOLIENDI NOVA RA-
TIO; UT ET TELESCOPIA DIVERSA CONSTRUENDI, ET EX-
periendi, horumq; adminiculo, varias obſervationes Cœleſtes, inprimis quidem Ecli-
ſium, 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.
OBSERVATORIO DE MARINA
DE
SAN FERNANDO,


f
d
c
a
b
Fig L.


XV.
GEDANI.
Anno æræ Christianæ 1644.
Circus Macularum à 16 Febr. ad 26 eiusdem.
Ecliptica.
B


f
17
Mart.
e
d
20
e
d
21

Animadversiones super I. Maculatum Solarium periodo.

1. ANno à nato Christo, 1642. die 26. Octob. in Sole nihil Macularum apparuit.

2. Die 27. Octobris cœlum non favit.

Insignis Macula simplex conspecta est.

3. Die 28. Octob. magnam, oblongam, densam, pulcherrimamq; Maculam a, halone haud vulgari undique cinctam, animadverti; præter hanc autem unicam nihil prorsus in Sole deprehensum.

4. Die 29. & 30. Oct. ob aëris turbulentiam, Maculam istam notabilem, die præcedente conspectam observare non licuit.

5. Die 31. Octobris, altera vice. Maculam suprà dictam, sed in formâ ampliori, duobusque nucleis densissimis prædictam, nobis videre obtigit.

6. Die 1. Nov. illa ipsa Macula, tum quâ figuram, tum splendorem magnitudinemque nihil planè se immutaverat.

7. Die 2. Novembris, nullus Sol affulsit.

8. Die 3. Nov. non solùm ulteriùs occasum versùs in Solis disco progressa erat; sed & magis magisq; ad Aquilon. deflectebat.

9. Die 4. Novembris, nihil quicquam adhuc mutata visa fuit.

10. Die 5. Nov. Cœli inclementia observationi fuit impedimento.

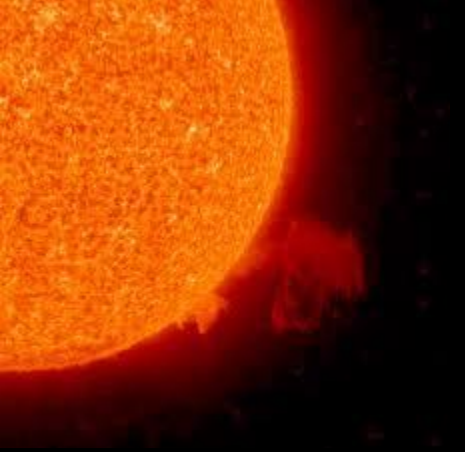
11. Die 6. Nov. paululùm oblongior videbatur; tum, & circa ortum tres novæ minores spectabantur, quæ in sequens schema reservantur.

12. Die 7. Novembris, aër fuit turbidus.

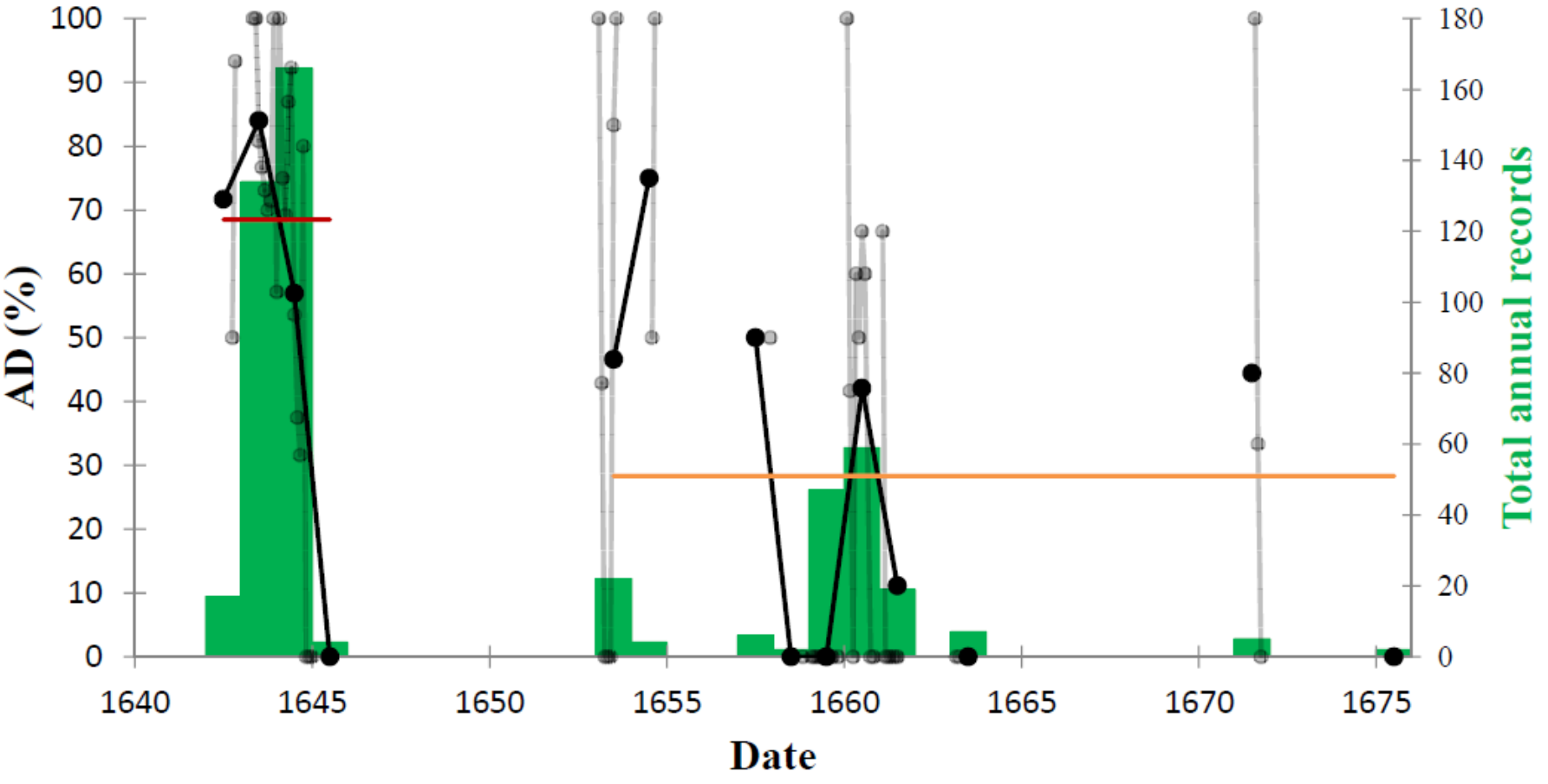
13. Die 8. Novemb. exitum hujus insignis Maculæ perquàm libenter observassem, sed frustrà fuit, quia jam exiverat, sic ut nec vestigium amplius de eâ apparuerit in Peripheriâ. Cursum quod attinet Maculæ, quantum colligere licet, fuit 12. tantummodo dierum. Præterea, ex hoc motu satis superque liquet, viam hujus Maculæ fuisse concavam, Aquilonem Borealem, & convexam Austrum occidentalem versùs.

Macula conspecta in totidem.

Qui sit inspexit?



Selenographia Machina Coelestis



In Brief…

Sunspot Number during the Maunder Minimum

(**order of magnitude**)

100 Zolotova & Ponyavin (2015)

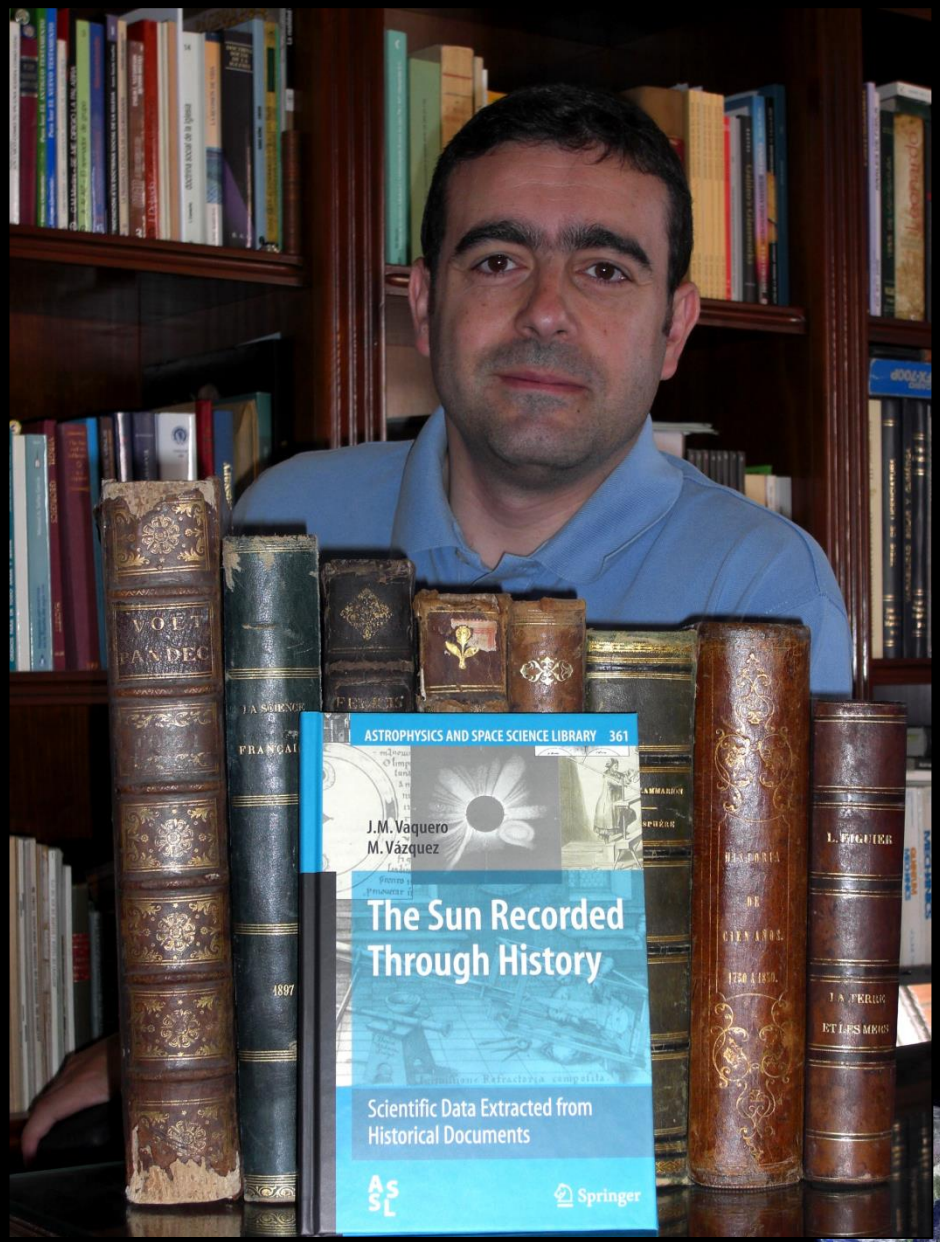
Svaalgard & Schatten (2016)

10 Vaquero et al. (2015)
Carrasco et al. (2015)
Usoskin et al. (2015)
Carrasco & Vaquero (2016)

Isotopes

1 Hoyt & Schatten (1998)
(no Solar Cycle)

Thank you very much!



Comments, suggestions, etc.:

jvaquero@unex.es