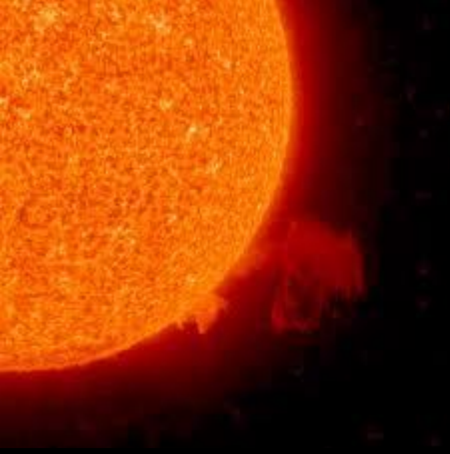
From Galileo through the Maunder Minimum

J.M. Vaquero & E.W. Cliver

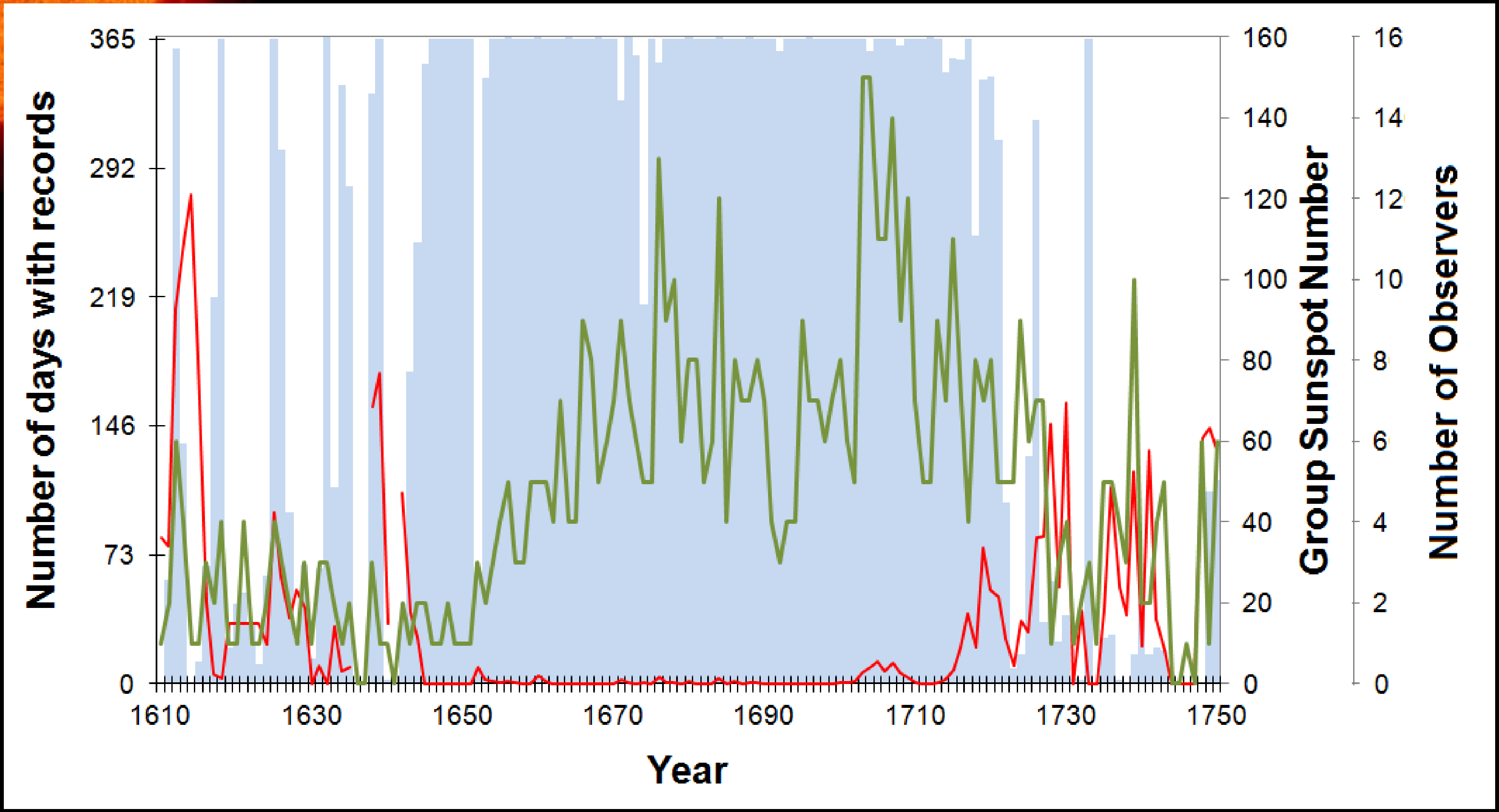
4th SSN Workshop

Locarno 2014

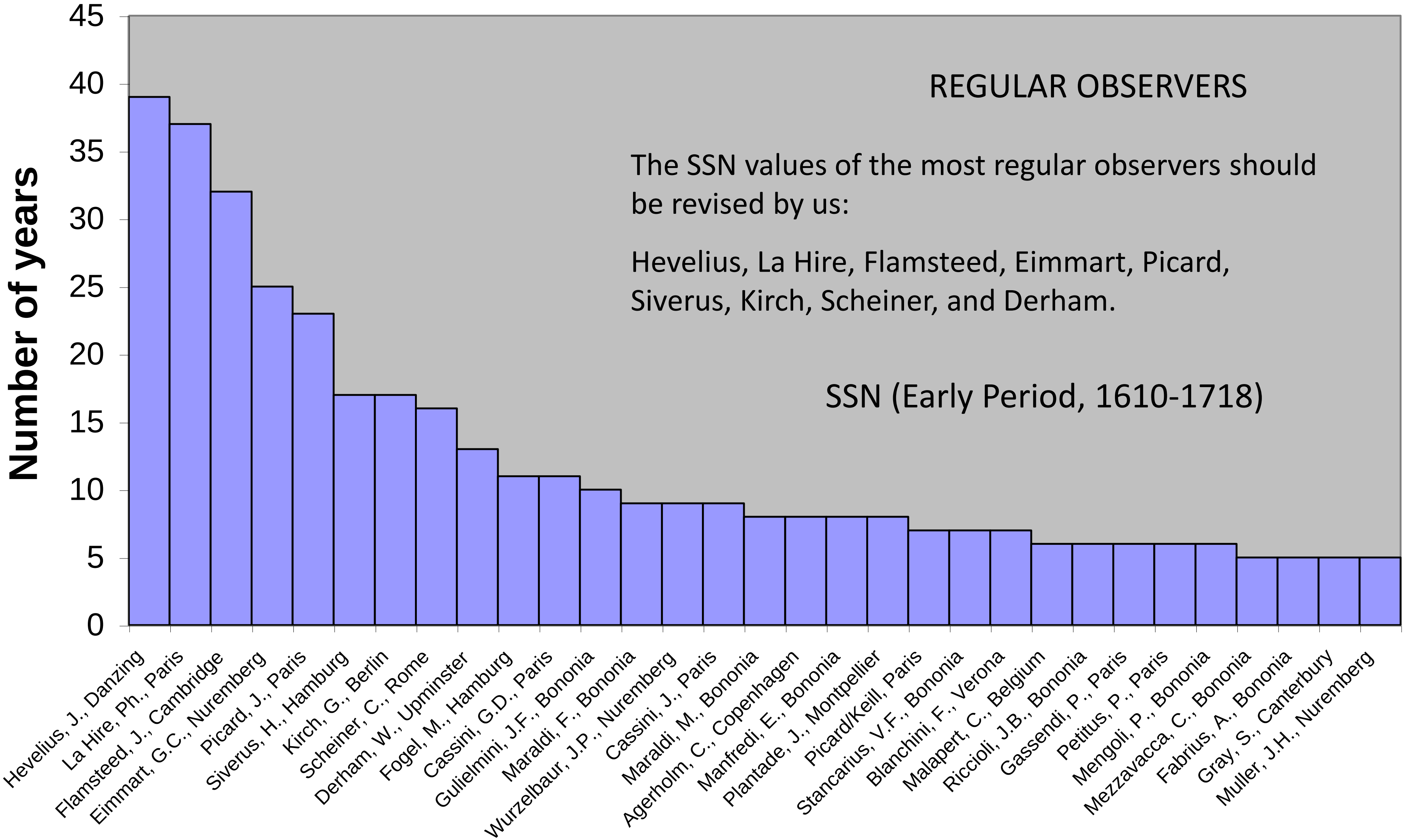


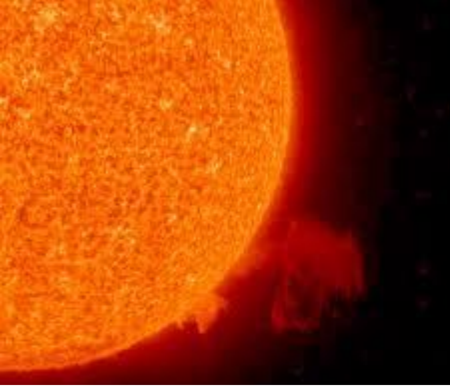
Index

1) Is it possible to use the methodology of backbones in the early part of the SSN series (1610-1800 aprox.)?
2) The case of the Bion’s sunspot (1672).
3) A “modern” example of solar meridian altitude measurements.
4) Modifying the HS98 data base….
5) Conclusions.

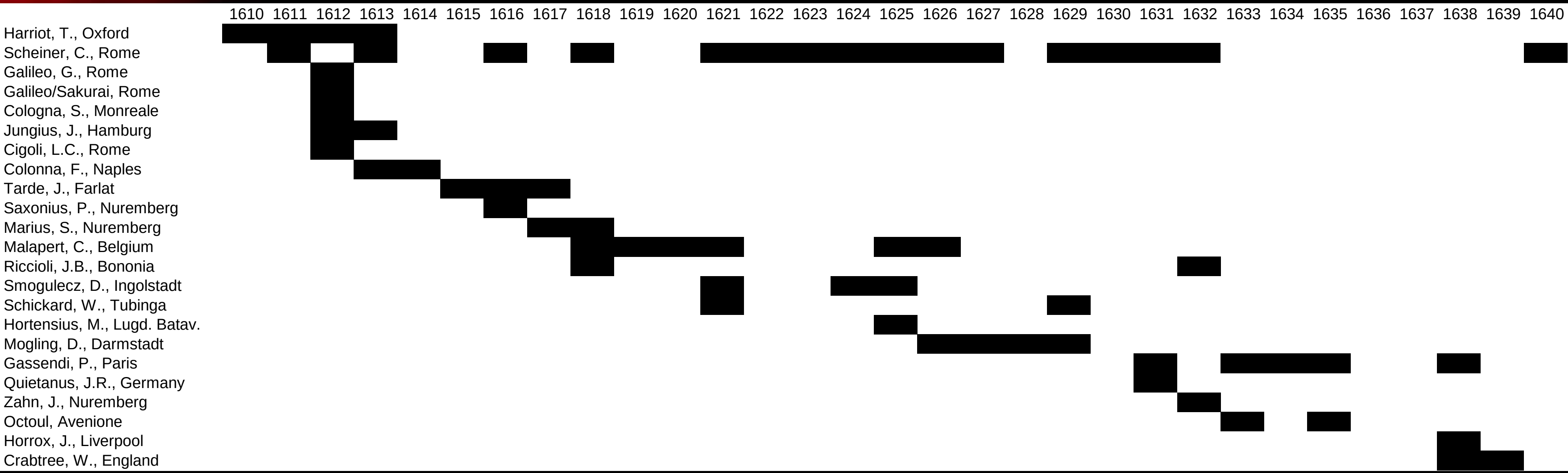


Number of days with records
365
292
219
146
73
0
1610
1630
1650
1670
1690
1710
1730
1750
Year
160
140
120
100
80
60
40
20
0
Group Sunspot Number
16
14
12
10
8
6
4
2
0
Number of Observers


REGULAR OBSERVERS
The SSN values of the most regular observers should be revised by us:
Hevelius, La Hire, Flamsteed, Eimmart, Picard, Siverus, Kirch, Scheiner, and Derham.
SSN (Early Period, 1610-1718)
Number of years
0
5
10
15
20
25
30
35
40
45
Hevelius, J., Danzing
La Hire, Ph., Paris
Flamsteed, J., Cambridge
Eimmart, G.C., Nuremberg
Picard, J., Paris
Siverus, H., Hamburg
Kirch, G., Berlin
Scheiner, C., Rome
Derham, W., Upminster
Fogel, M., Hamburg
Cassini, G.D., Paris
Gulielmini, J.F., Bononia
Maraldi, F., Bononia
Wurzelbaur, J.P., Nuremberg
Cassini, J., Paris
Maraldi, M., Bononia
Agerholm, C., Copenhagen
Manfredi, E., Bononia
Plantade, J., Montpellier
Picard/Keill, Paris
Stancarius, V.F., Bononia
Blanchini, F., Verona
Malapert, C., Belgium
Riccioli, J.B., Bononia
Gassendi, P., Paris
Petitus, P., Paris
Mengoli, P., Bononia
Mezzavacca, C., Bononia
Fabrius, A., Bononia
Gray, S., Canterbury
Muller, J.H., Nuremberg

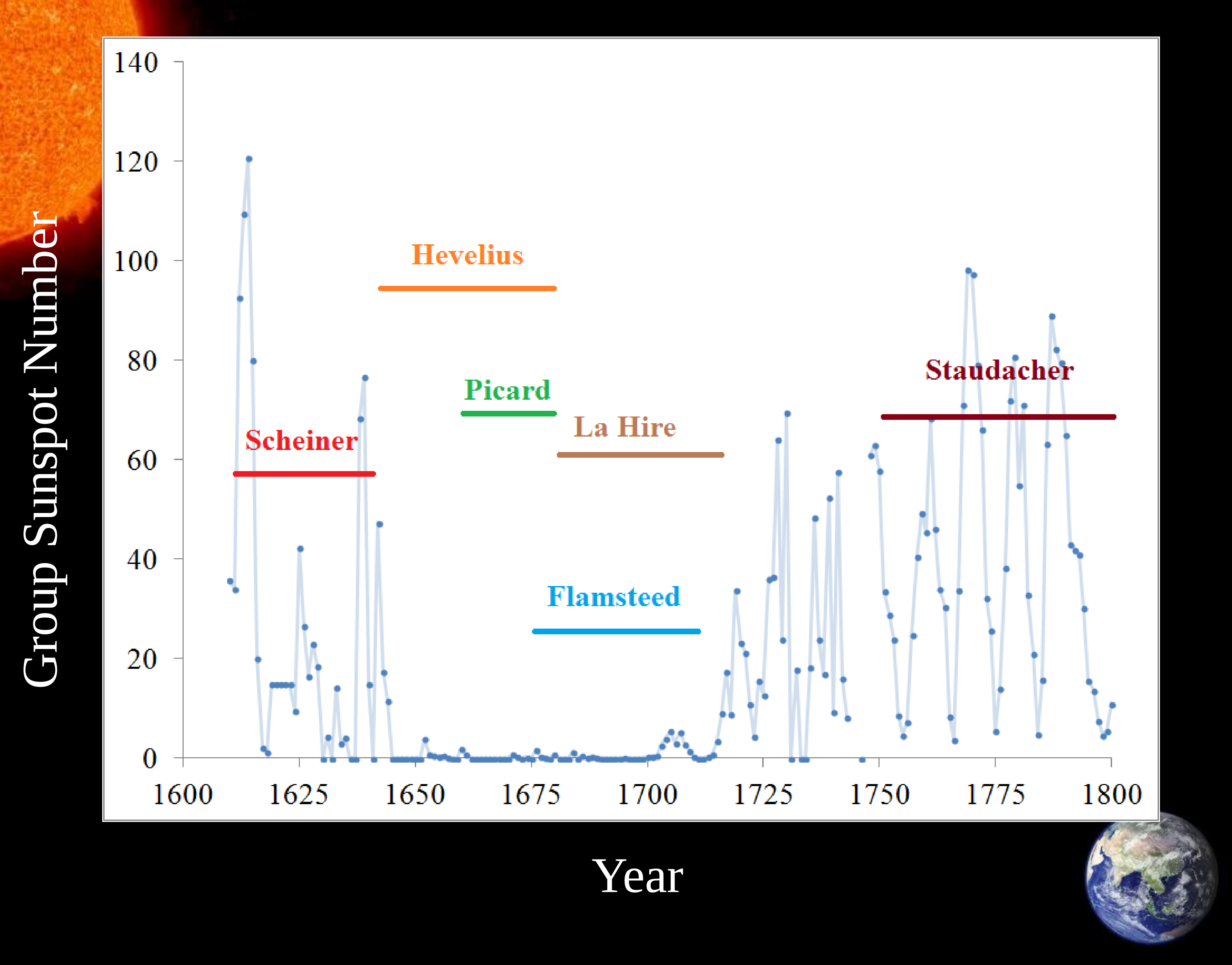


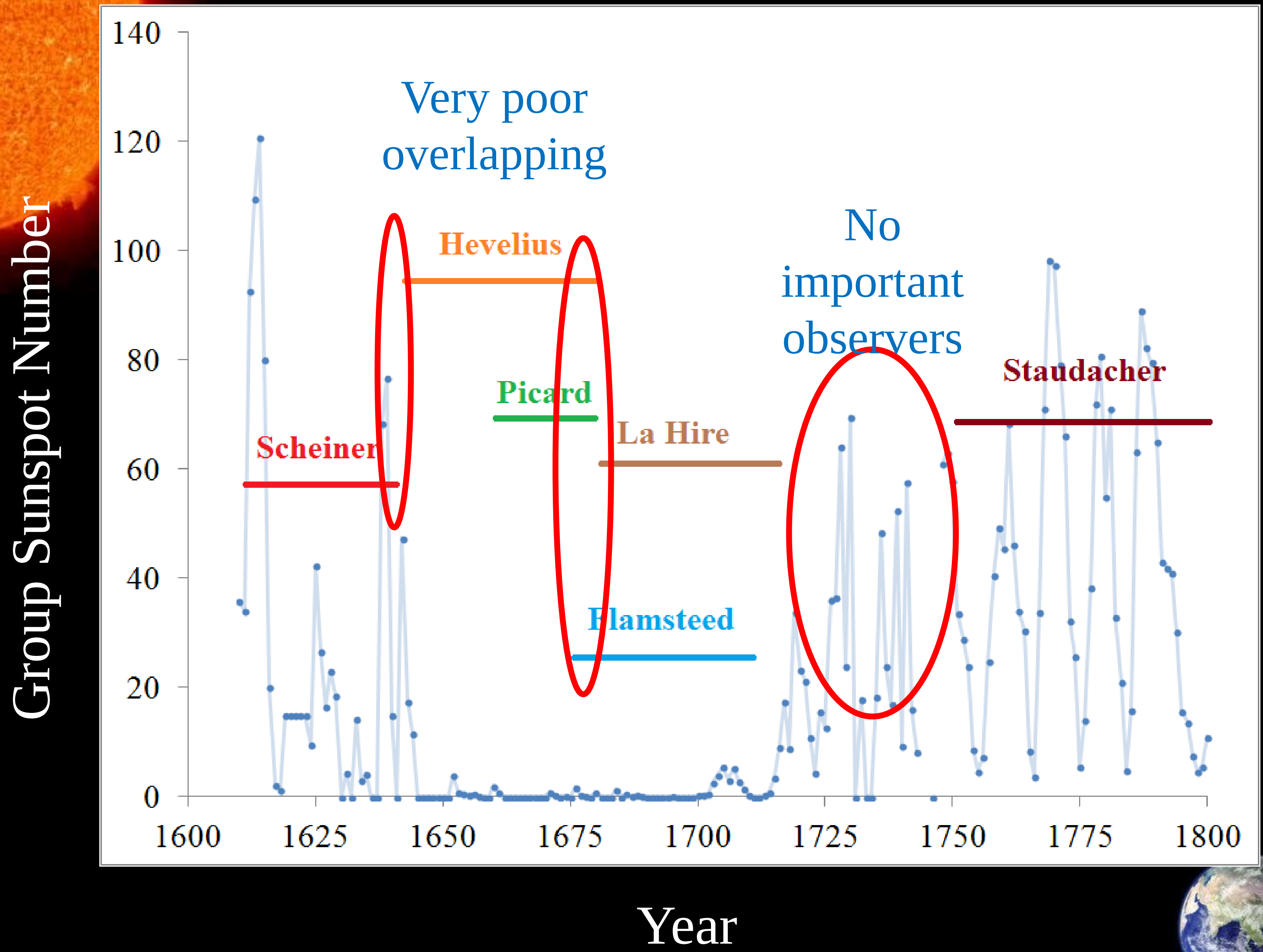
First backbone: Scheiner



Second backbone: Hevelius

Third backbone: La Hire

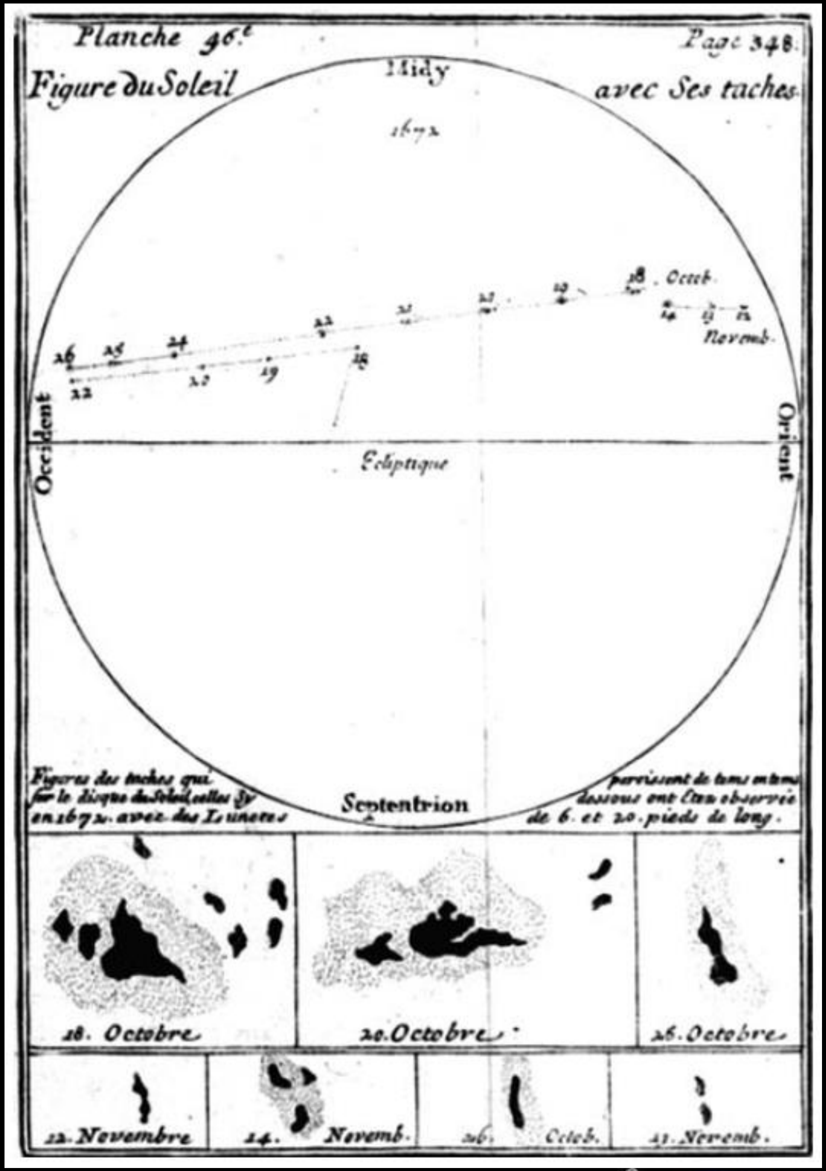

Group Sunspot Number
140
120
100
80
60
40
20
0
1600
1625
1650
1675
1700
1725
1750
1775
1800
Year
Hevelius
Picard
La Hire
Scheiner
Staudacher
Flamsteed


Very poor overlapping
No important observers
Hevelius
Picard
Scheiner
La Hire
Flamsteed
Staudacher
140
120
100
80
60
40
20
0
1600
1625
1650
1675
1700
1725
1750
1775
1800
Group Sunspot Number
Year

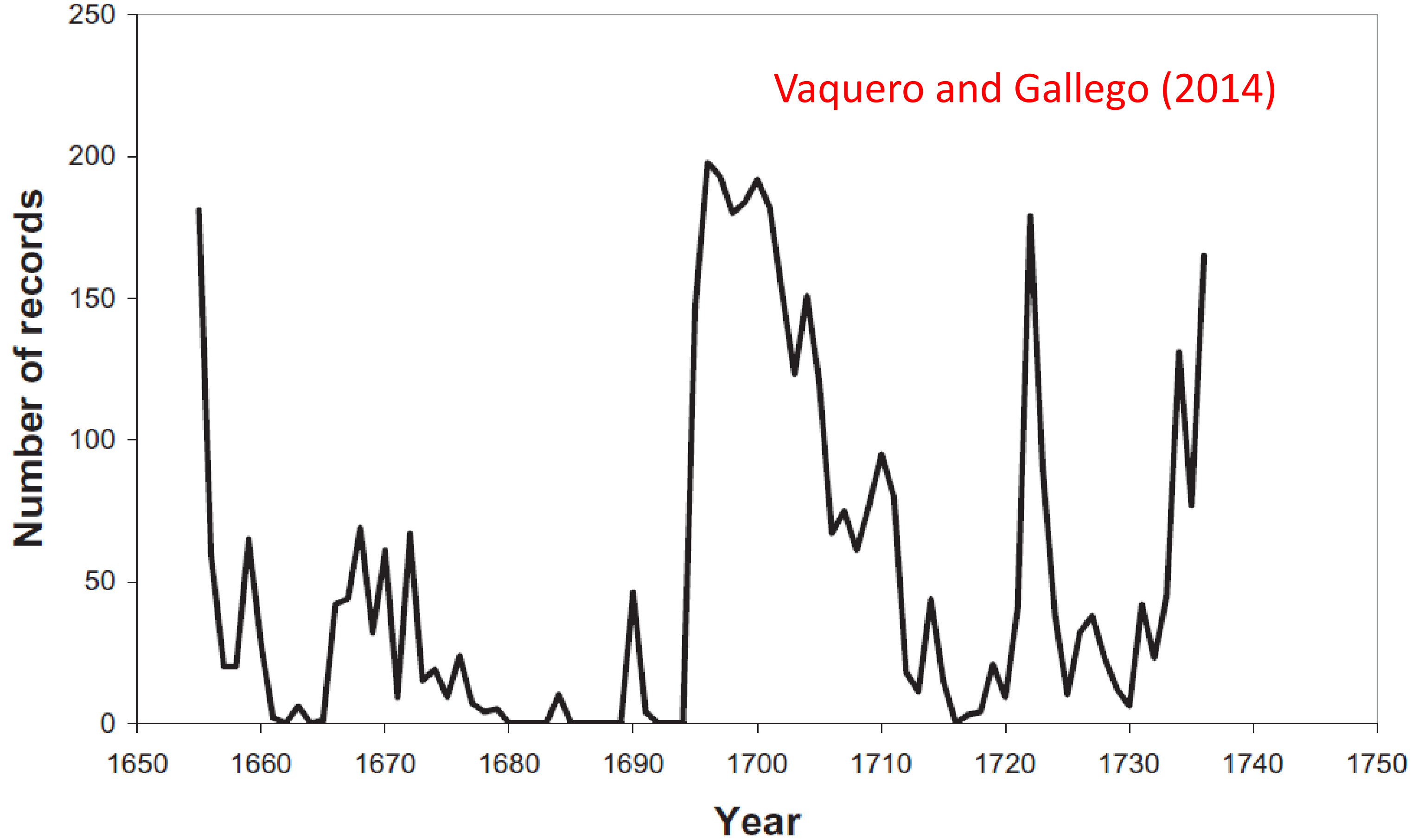
Nicholas Bion (1652-1733)
French instrument maker

Observations of sunspots during October-November 1672.
White, missing data; black, one sunspot group; grey, no sunspots.

Day	Bion	Picard	Hevelius	Montanari	Petitus
18 October					
19 October					
20 October					
21 October					
22 October					
23 October					
24 October					
25 October					
26 October					
12 November					
13 November					
14 November					
15 November					
16 November					
17 November					
18 November					
19 November					
20 November					
21 November					
22 November					

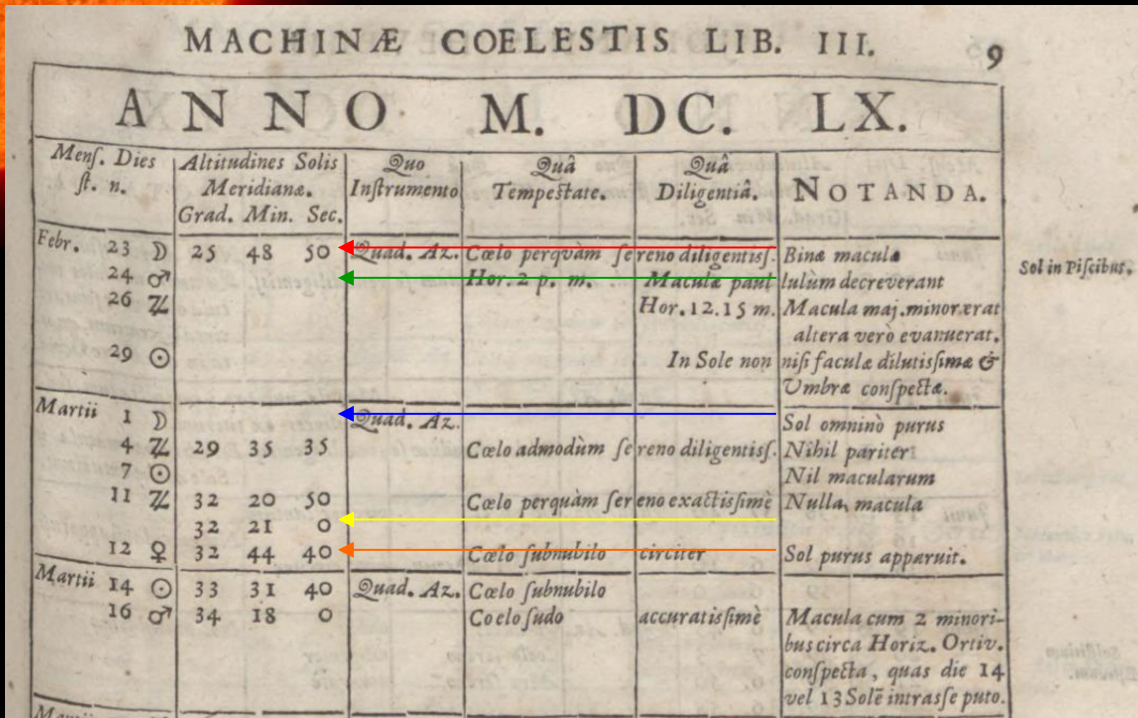


Vaquero (2007)



Number of annual solar meridian observations made in the Basilica of San Petronio recorded in Manfredi (1736).

In Progress…



ANNO M. DC. LX.

Mens.	Dies st. n.	Altitudines Solis Meridianæ. Grad.	Min.	Sec.	Quo Instrumento	Quâ Tempestate.	Quâ Diligentiâ.	NOTANDA.
Febr.	23 ☽	25	48	50	Quad. Az.	Cœlo perqvàm se	reno diligentiss.	Binæ maculæ
	24 ♂					Hor. 2 p. m.	Maculæ paul	lulùm decreverant
	26 ♃						Hor. 12.15 m.	Macula maj. minor erat altera verò evanuerat.
	29 ☉						In Sole non	nisi faculæ dilutissimæ & Umbræ conspectæ.
Martii	1 ☽				Quad. Az.			Sol omninò purus
	4 ♃	29	35	35		Cœlo admodùm se	reno diligentiss.	Nihil pariter
	7 ☉							Nil macularum
	11 ♃	32	20	50		Cœlo perquàm ser	eno exactissimè	Nulla macula
		32	21	0				
	12 ♀	32	44	40		Cœlo subnubilo	circiter	Sol purus apparuit.
Martii	14 ☉	33	31	40	Quad. Az.	Cœlo subnubilo		
	16 ♂	34	18	0		Coelo sudo	accuratissimè	Macula cum 2 minoribus circa Horiz. Ortiv. conspecta, quas die 14 vel 13 Solē intrasse puto.

Sol in Piscibus.

Sunspot record with measurement of solar meridian altitude

Sunspot record without measurement of solar meridian altitude

No sunspot record with measurement of solar meridian altitude

No sunspot record without measurement of solar meridian altitude

No information about sunspot but he measured solar meridian altitude

JOHANNIS HEVELII
IN
Partem Posteriorem
MACHINÆ
COELESTIS
PRÆFATIO
AD
LECTOREM.

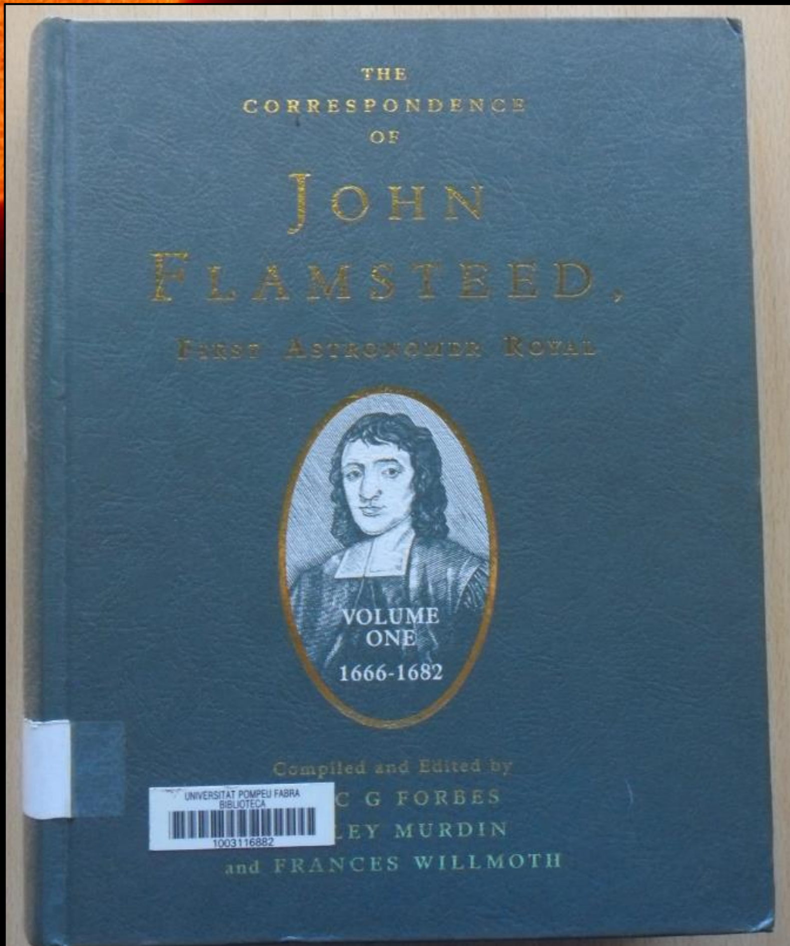
QUintus jam effluxit annus, cùm Partem Machinæ meæ Cœlestis Priorem, Organographiam videlicet, quà Organa nostra universa, hactenus ad Observationes Cœlestes à me adhibita, graphicè delineata, atq; accuratè descripta, in lucem ediderim. Nunc verò cùm DEUS O. M. vitam porrò, sanitatem, otiumq; (pro quibus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

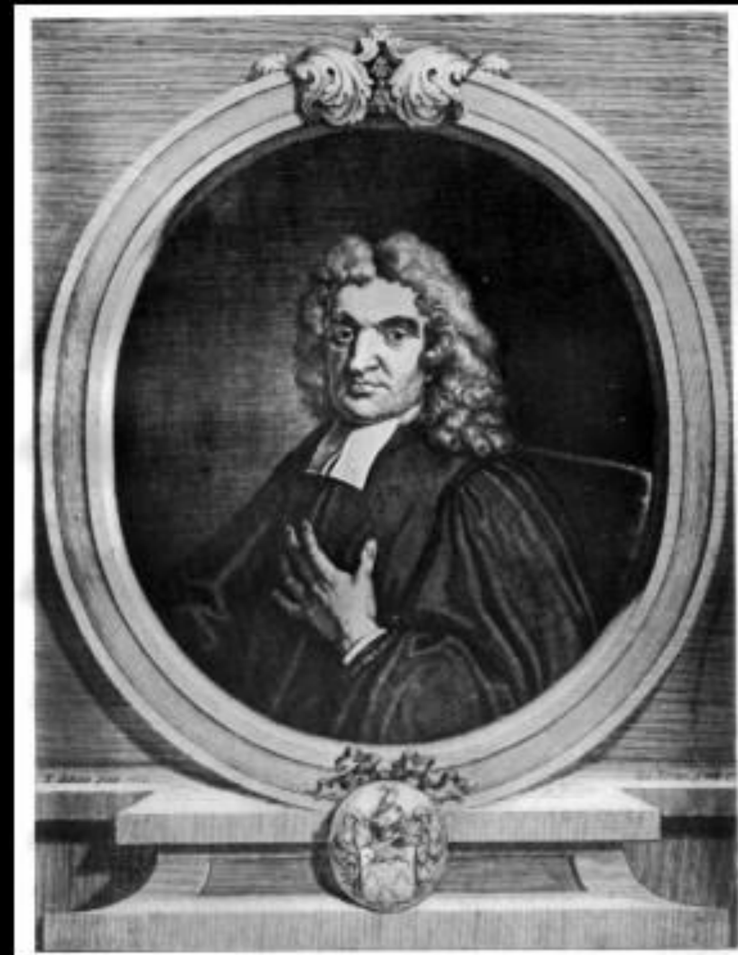
a Machinæ

Be careful!!!

Sunspot records are not associated with measurement of solar meridian altitude!!!

In Progress…

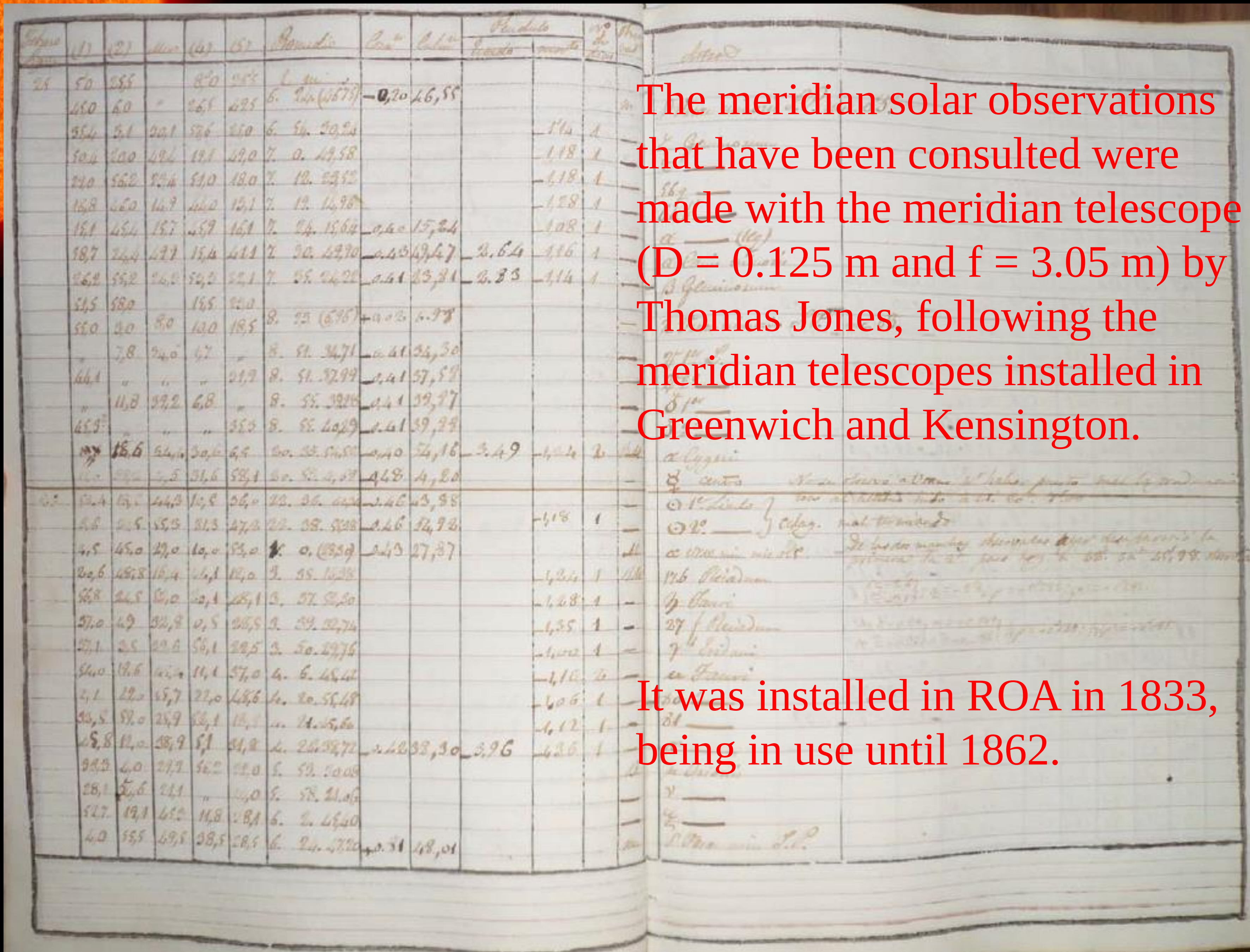




We are revising the sunspot record that appear in the "Correspondence" of Flamsteed. Hoyt and Schatten (1998) did not consult this historical source because was published when they were finishing their work.

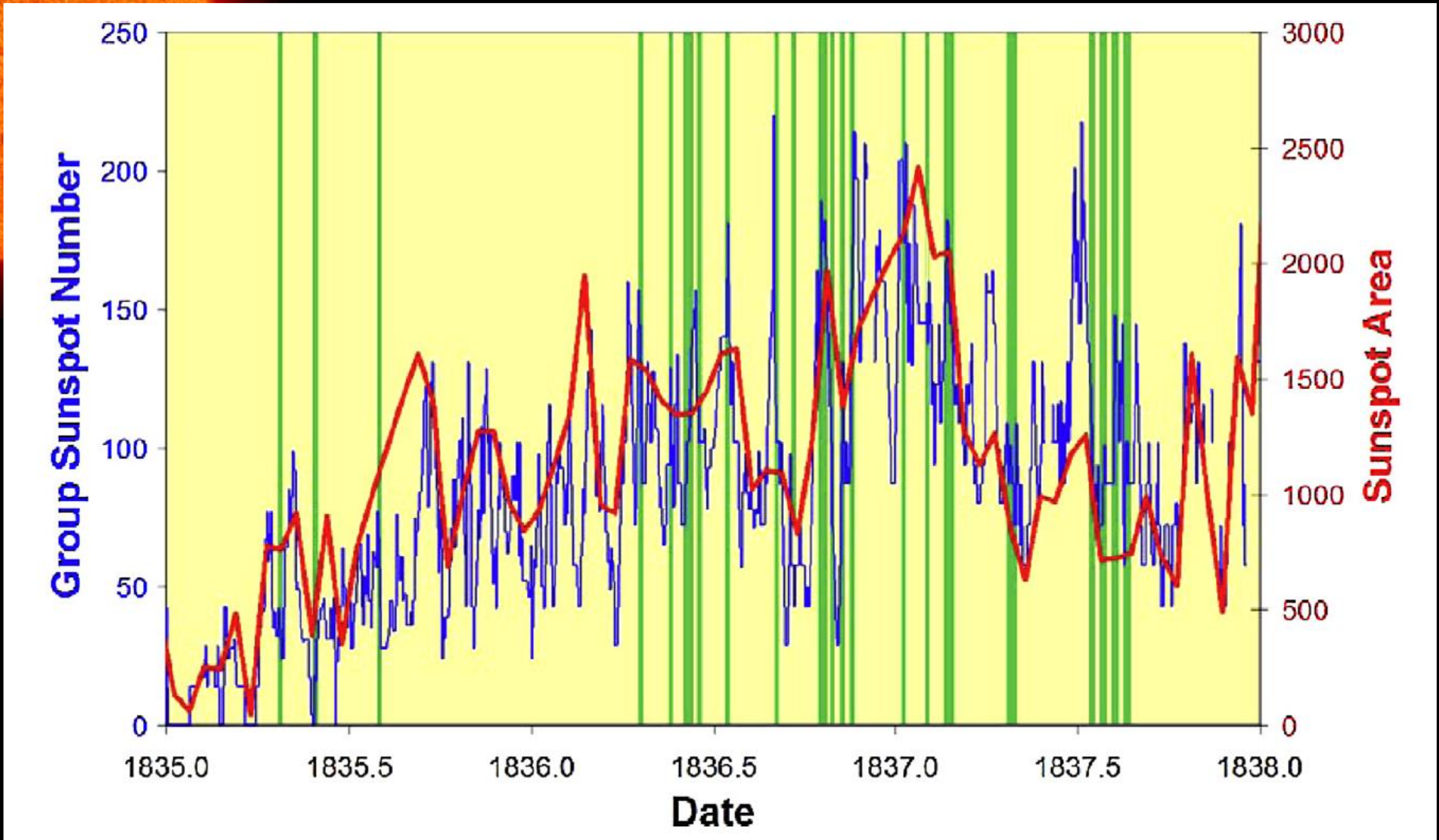
He mentions very few times the absence of spots in the Sun in exact dates!

A “modern” example…

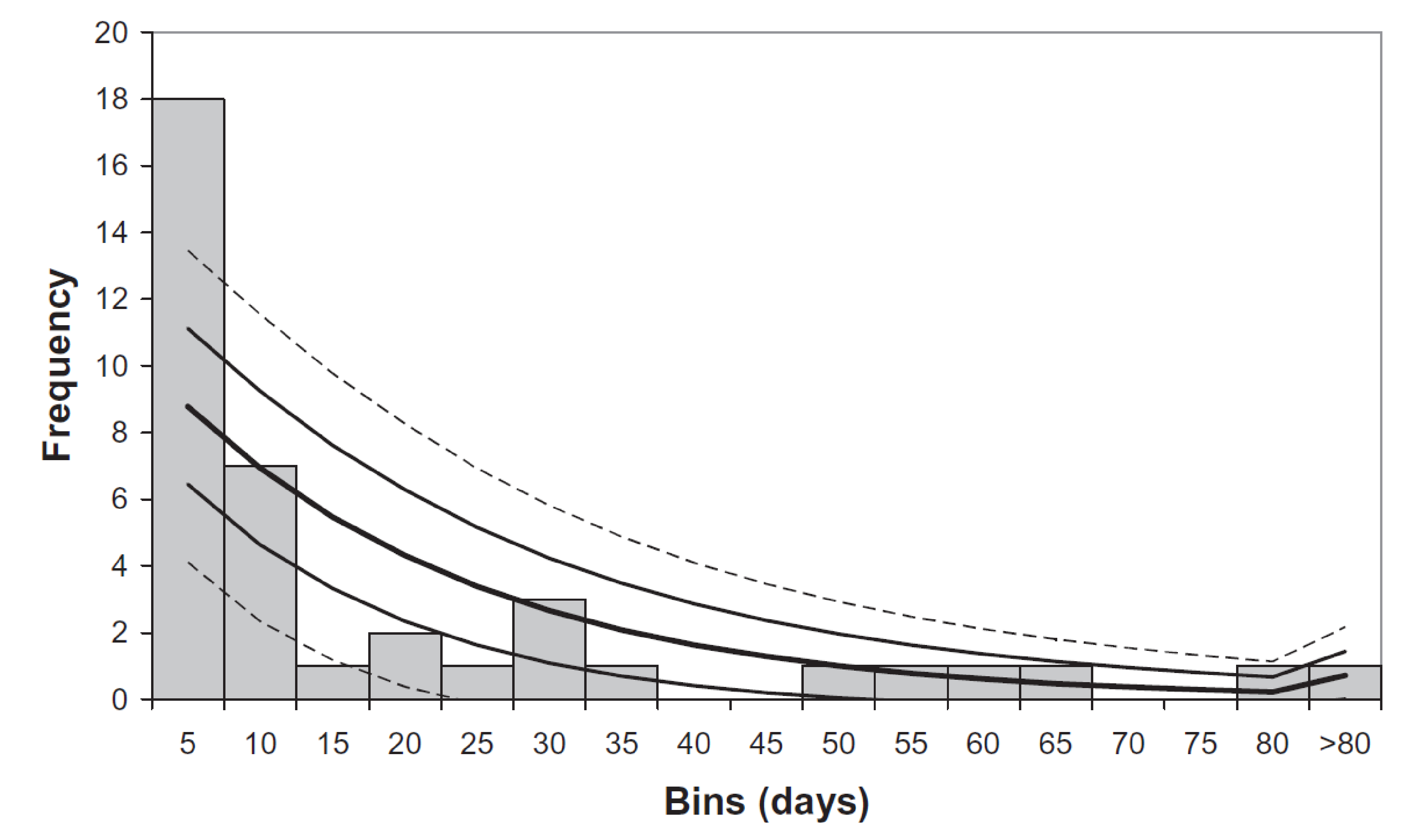


The meridian solar observations that have been consulted were made with the meridian telescope (D = 0.125 m and f = 3.05 m) by Thomas Jones, following the meridian telescopes installed in Greenwich and Kensington.

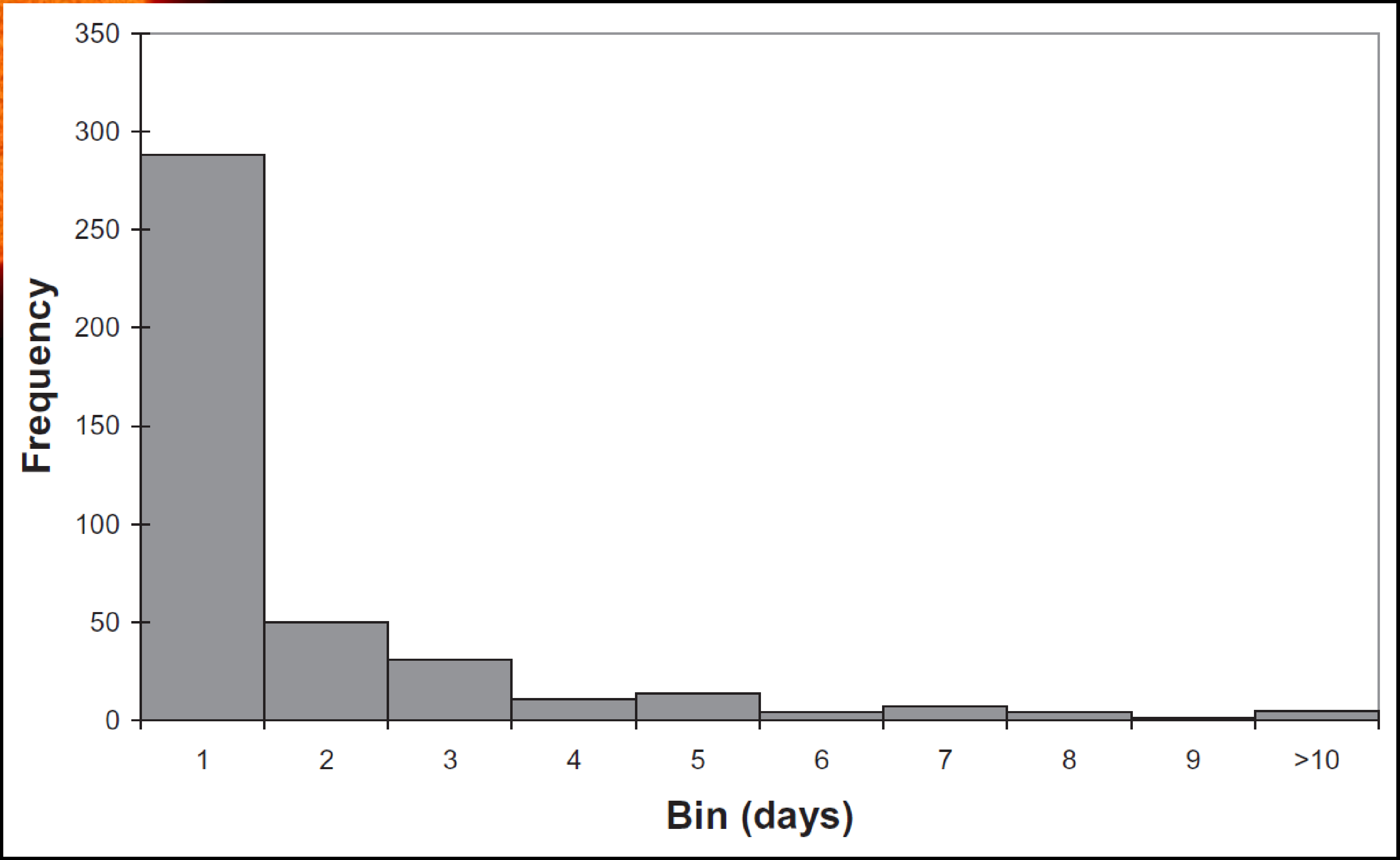
It was installed in ROA in 1833, being in use until 1862.



A comparison between sunspot reports in the meridian solar observations of ROA (green) and two solar indices in the same period: (red) fortnightly values of sunspot area provided by De la Rue et al. (1869) and (blue) daily values of Group Sunspot Number provided by Hoyt and Schatten (1998).



Frequency histogram on the number of cases as a function of the lapse time between sunspot reports. The mean value (thick line) are also shown with the corresponding values associated to ±1σ (thin line) and ±2σ (dashed line) intervals obtained with a Monte-Carlo simulation that have generated 200,000 random time series (constrained with a similar amount of sunspot reports).



Frequency histogram on the days between solar meridian observations made in the ROA from 25 April 1835–23 August 1837.

In Brief…

(i) The descriptions given (in haso.unex.es) should be considered as a list of notable sunspots.

(ii) The sunspot records appear only for the years 1835–1837. Manuscripts of the observations of 1833–1834 and 1838–1840 contain no observations of sunspots.

(iii) Records of sunspots only appear in the manuscripts of the observations. These records do not appear in the printed version of the meridian observations.

(iv) There is even an incorrect record of no sunspot (although we do not know the origin of this error).

(v) There is not a clear relationship between the timing of recorded spots and usual solar activity indices (sunspot area and number).

(vi) There are no notable periodicities in these observations.

In general, solar meridian observations should be used with extreme caution to evaluate past solar activity.

Modifications of the HS98 data base

(i) We have eliminated all the observations made with the camera obscura of San Petronio Basilica. (In total, 4204 “zero” values removed)

(ii) We have eliminated all the record of astronomer that observed during 365 days per year (or almost). (In total 75·365 “zero” values removed, aprox. 27000 values)

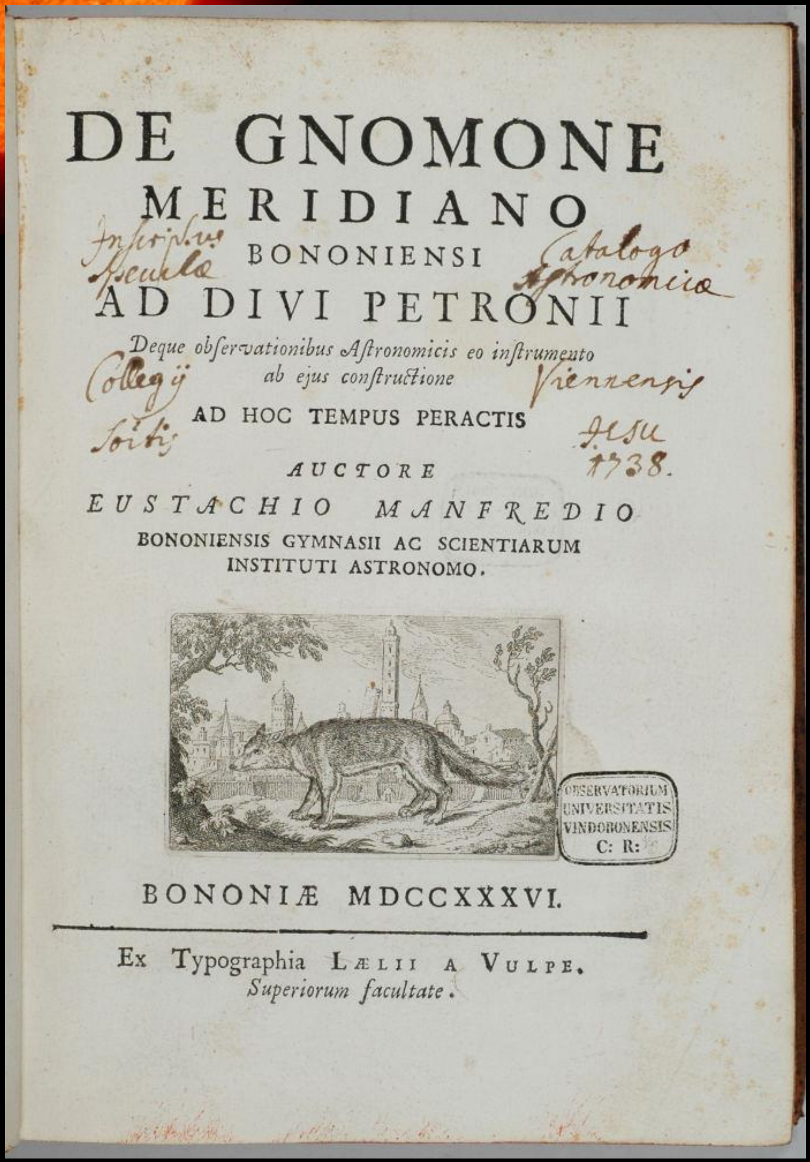
(iii) We have included some “new” observers.

(iv) We have included all the (few) corrections to the HS98 data base published since 1998.

Original HS98 database
58 788 values

Modified HS98 database
32 339 values

(i) We have eliminated all the observations made with the camera obscura of San Petronio Basilica.



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.

Inscriptus Speculae Catalogo Astronomico Collegij Viennensis Soc: Jesu 1738.

OBSERVATORIUM UNIVERSITATIS VINDOBONENSIS C: R:

BONONIÆ MDCCXXXVI.

Ex Typographia LÆLII A VULPE.
Superiorum facultate.

(ii) We have eliminated all the record of astronomer that observed during 365 days per year (or almost).

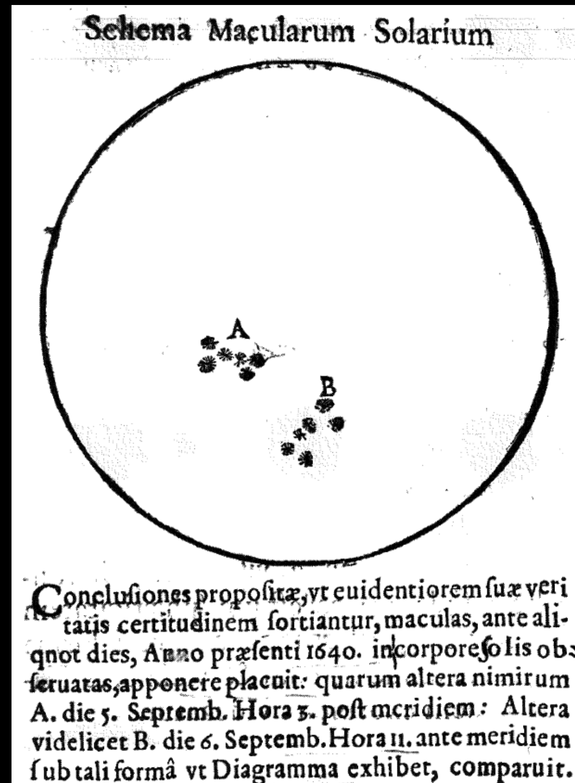
NUMBER OF SUNSPOT GROUPS FOR THE YEAR: 1675
AS OBSERVED BY: SIVERUS, H., HAMBURG

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0
29	0	-99	0	0	0	0	0	0	0	0	0	0
30	0	-99	0	0	0	0	0	0	0	0	0	0
31	0	-99	0	-99	0	-99	0	0	-99	0	-99	0
means:	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

May be in Egypt or Cuba but …

(iii) We have included some "new" observers

Andrea Argoli (Venice) 1634

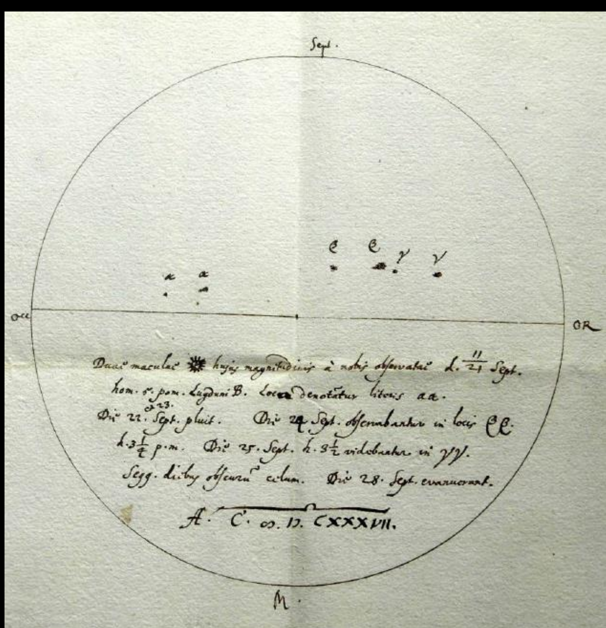

Schema Macularum Solarium

A

B

Concluſiones propoſitæ, vt euidentiorem ſuæ veritatis certitudinem ſortiantur, maculas, ante aliquot dies, Anno præſenti 1640. in corpore Solis obſeruatas, apponere placuit: quarum altera nimirum A. die 5. Septemb. Hora 3. poſt meridiem: Altera videlicet B. die 6. Septemb. Hora 11. ante meridiem ſub tali formâ vt Diagramma exhibet, comparuit.

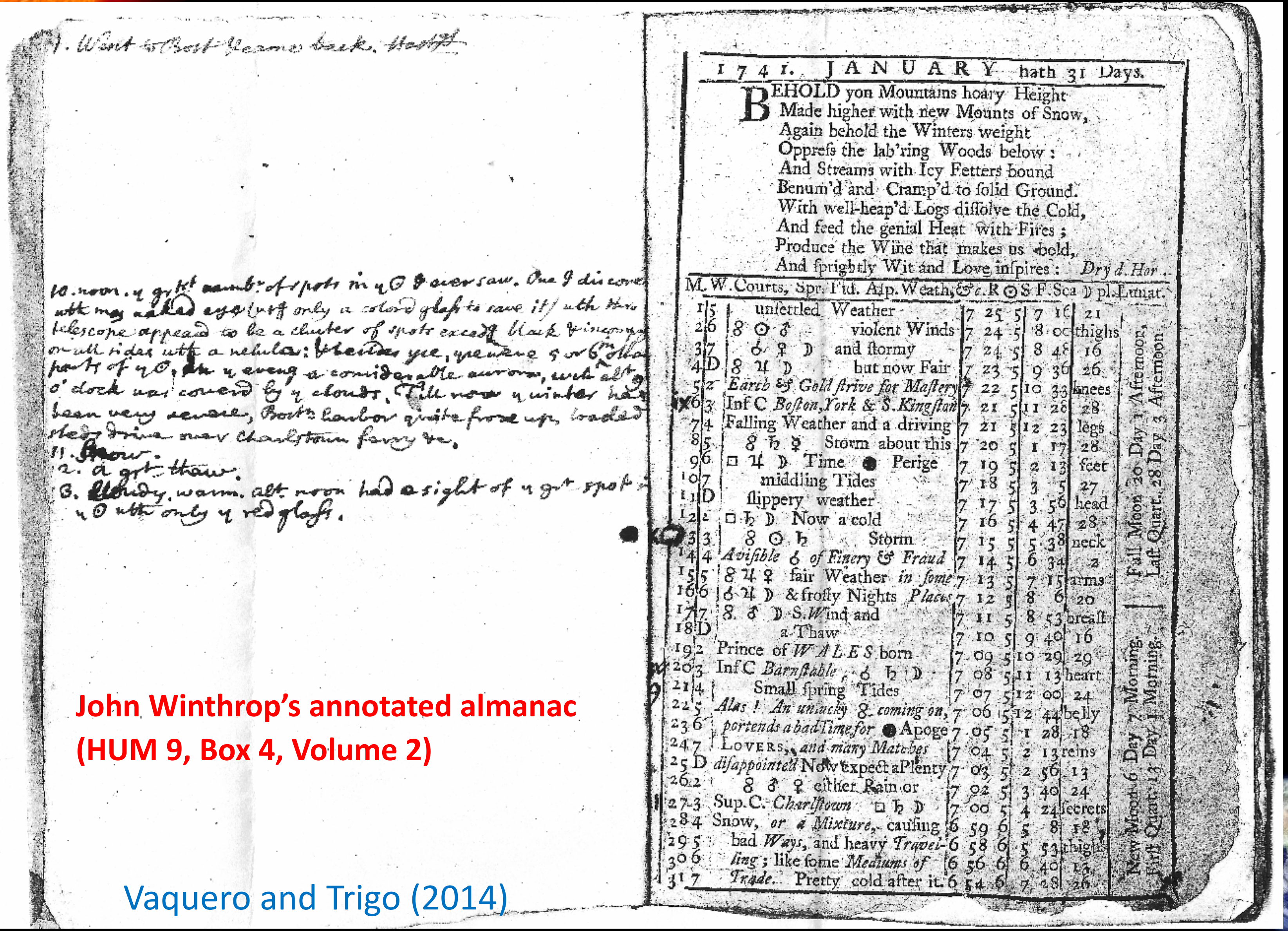
Albert Strazyc (Krakow) 1640



Georg Marcgraf (Leiden) 1637

J. A. Alzate (Mexico) 1780s

(iv) We have included all the (few) corrections to the HS98 data base published since 1998



1. Went to Bost. Came back. Hot

10. noon. y^e gr^test numb^r of spots in y^e ☉ I ever saw. One I discover'd with my naked eye (with only a color'd glass to save it) w^th the telescope appear'd to be a cluster of spots exceed^g black & incompass'd on all sides w^th a nebulae: besides yse, yr were 5 or 6 in oth^r parts of y^e ☉. In y^e even^g a considerable aurora, w^ch ab^t 9 o'clock was cover'd by y^e clouds. Till now y^e winter has been very severe, Bost^n harbor quite froze up, loaded sleds drive over Charlstown ferry &c.
11. Snow.
12. a gr^t thaw.
13. Cloudy. warm. ab^t noon had a sight of y^e gr^t spot in y^e ☉ w^th only y^e red glass.

1741. JANUARY hath 31 Days.

BEHOLD yon Mountains hoary Height
Made higher with new Mounts of Snow,
Again behold the Winters weight
Oppress the lab'ring Woods below:
And Streams with Icy Fetters bound
Benum'd and Cramp'd to solid Ground.
With well-heap'd Logs dissolve the Cold,
And feed the genial Heat with Fires;
Produce the Wine that makes us bold,
And sprightly Wit and Love inspires: *Dryd. Hor.*

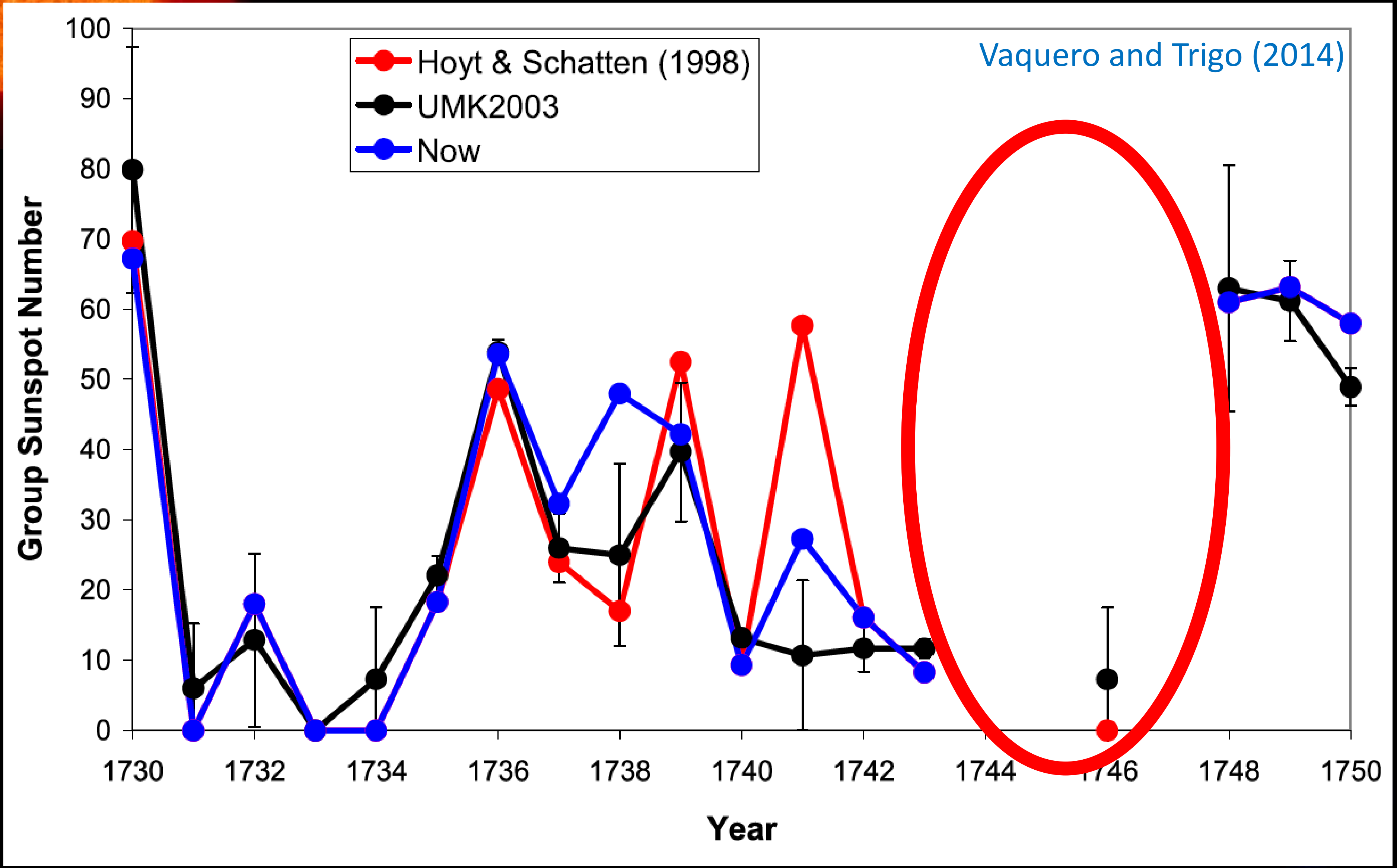
M.	W.	Courts, Spr. Tid. Asp. Weath, &c.	R ☉	S	F. Sea	☽ pl. Lunat.
1	5	unsettled Weather	7 25	5	7 16	21
2	6	☍ ☉ ♂ violent Winds	7 24	5	8 00	thighs
3	7	☌ ♀ ☽ and stormy	7 24	5	8 48	16
4	D	☍ ♃ ☽ but now Fair	7 23	5	9 36	26
5	2	*Earth & Gold strive for Mastery*	7 22	5	10 33	knees
6	3	Inf C *Boston, York & S. Kingston*	7 21	5	11 28	28
7	4	Falling Weather and a driving	7 21	5	12 23	legs
8	5	☍ ♄ ☿ Storm about this	7 20	5	1 17	28
9	6	□ ♃ ☽ Time ● Perige	7 19	5	2 13	feet
10	7	middling Tides	7 18	5	3 5	27
11	D	slippery weather	7 17	5	3 56	head
12	2	□ ♄ ☽ Now a cold	7 16	5	4 47	28
13	3	☍ ☉ ♄ Storm	7 15	5	5 38	neck
14	4	*A visible* ☌ *of Finery & Fraud*	7 14	5	6 34	2
15	5	☍ ♃ ♀ fair Weather *in some*	7 13	5	7 15	arms
16	6	☌ ♃ ☽ & frosty Nights *Places*	7 12	5	8 6	20
17	7	☍ ♂ ☽ S. *Wind* and	7 11	5	8 53	breast
18	D	a Thaw	7 10	5	9 40	16
19	2	Prince of *WALES* born	7 09	5	10 29	29
20	3	Inf C *Barnstable* ☌ ♄ ☽	7 08	5	11 13	heart
21	4	Small spring Tides	7 07	5	12 00	24
22	5	*Alas! An unlucky* ☍ *coming on,*	7 06	5	12 44	belly
23	6	*portends a bad Time for* ● Apoge	7 05	5	1 28	18
24	7	LOVERS, *and many Matches*	7 04	5	2 13	reins
25	D	*disappointed* Now expect a Plenty	7 03	5	2 56	13
26	2	☍ ♂ ♀ either Rain or	7 02	5	3 40	24
27	3	Sup. C. *Charlstown* □ ♄ ☽	7 00	5	4 24	secrets
28	4	Snow, *or a Mixture,* causing	6 59	6	5 8	18
29	5	bad *Ways*, and heavy *Travel-*	6 58	6	5 53	thighs
30	6	*ling*; like some *Mediums of*	6 56	6	6 40	13
31	7	*Trade.* Pretty cold after it.	6 54	6	7 28	26

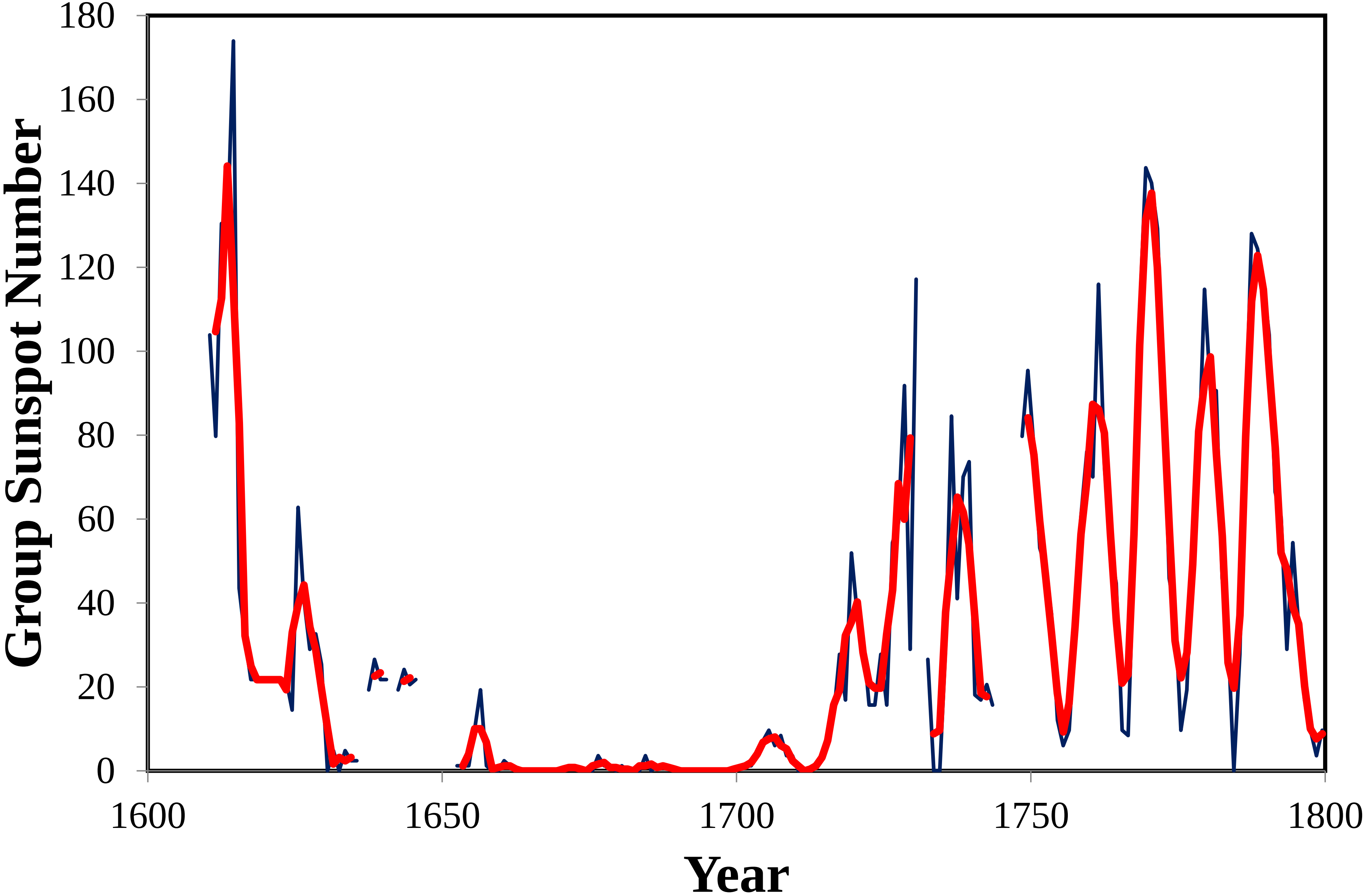
Full Moon 30 Day 1 Afternoon.
Last Quart. 28 Day 3 Afternoon.
New Moon 6 Day 7 Morning.
First Quart. 13 Day 1 Morning.

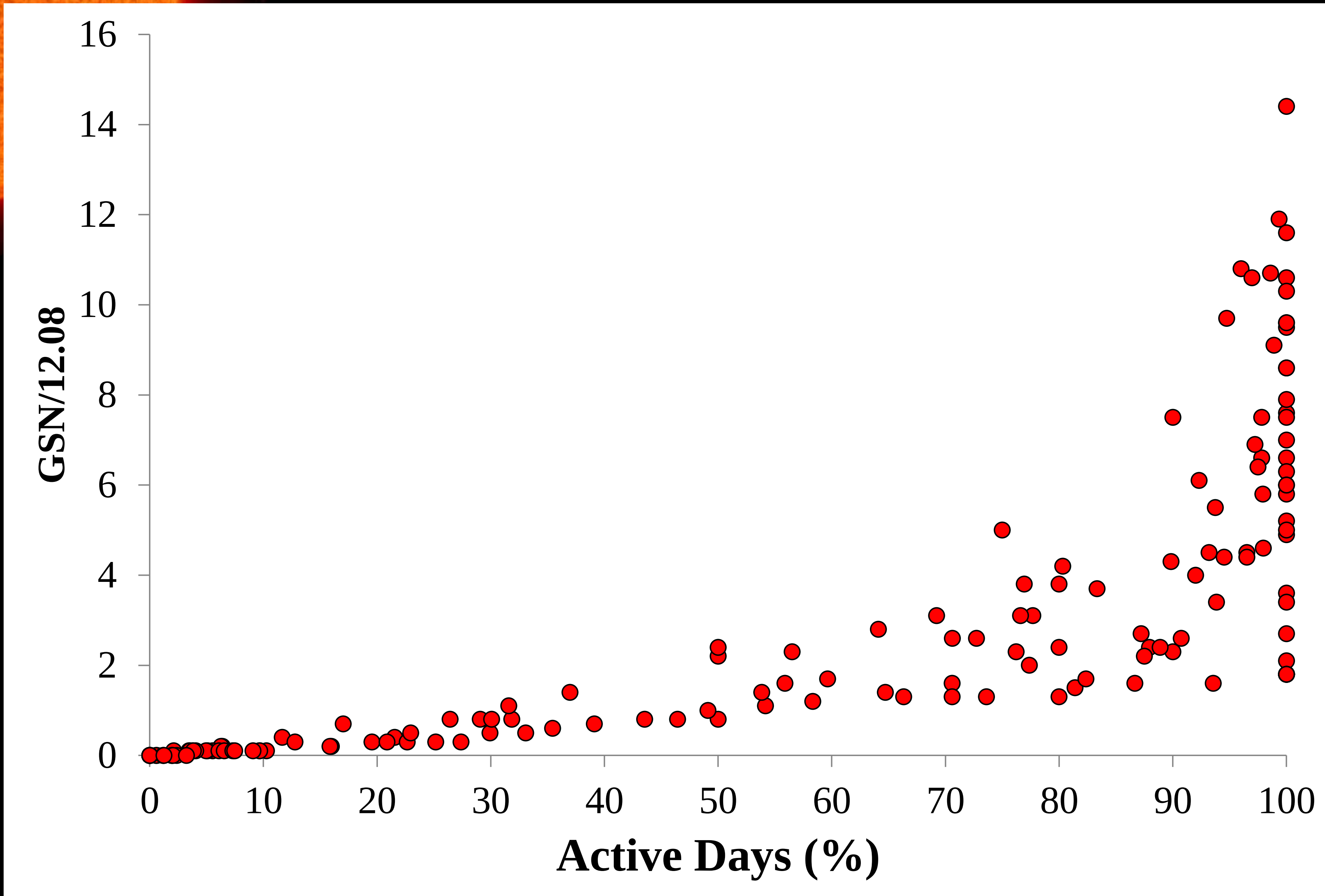
John Winthrop's annotated almanac (HUM 9, Box 4, Volume 2)

Vaquero and Trigo (2014)

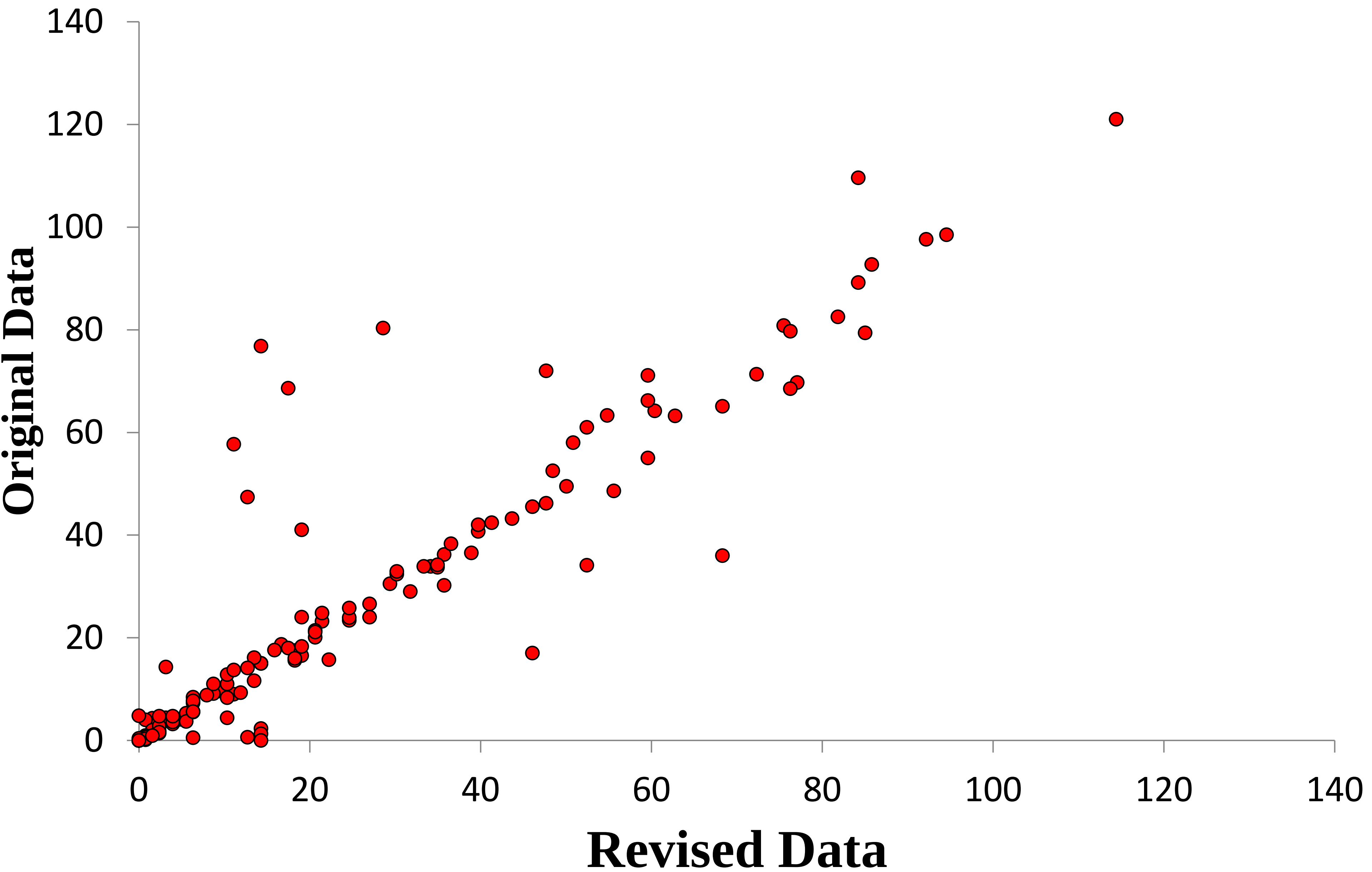
(iv) We have included all the (few) corrections to the HS98 data base published since 1998



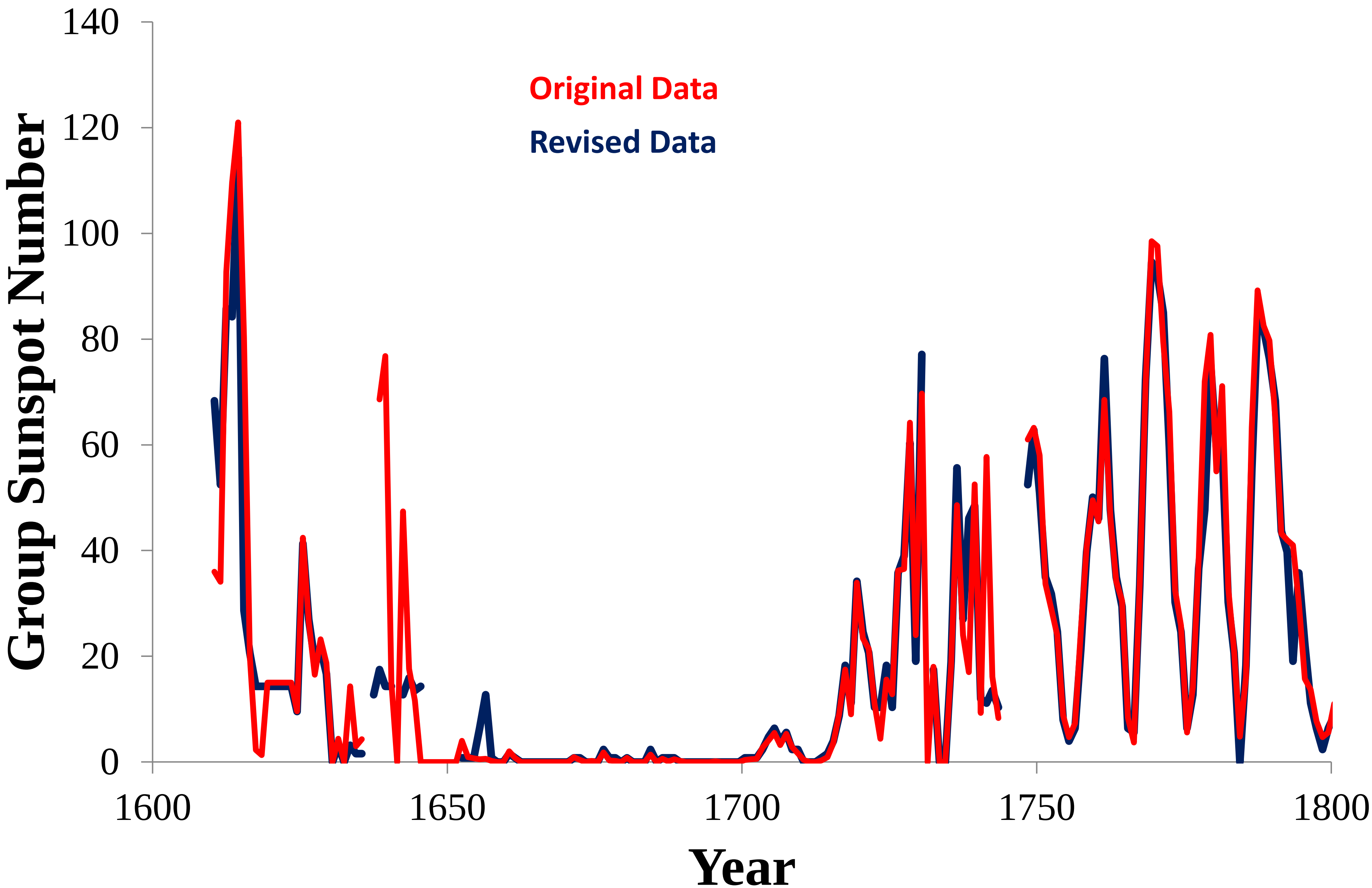

Group Sunspot Number
180
160
140
120
100
80
60
40
20
0
1600
1650
1700
1750
1800
Year



16
14
12
10
8
6
4
2
0
GSN/12.08
0
10
20
30
40
50
60
70
80
90
100
Active Days (%)



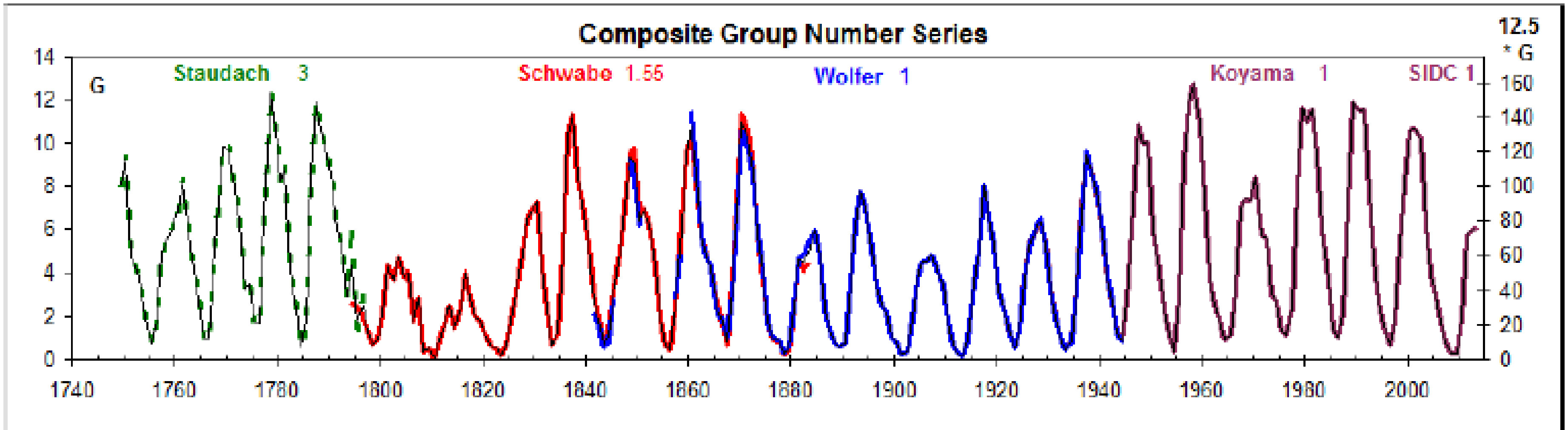
140
120
100
80
60
40
20
0
Original Data
0
20
40
60
80
100
120
140
Revised Data


Original Data
Revised Data
Group Sunspot Number
Year
0
20
40
60
80
100
120
140
1600
1650
1700
1750
1800

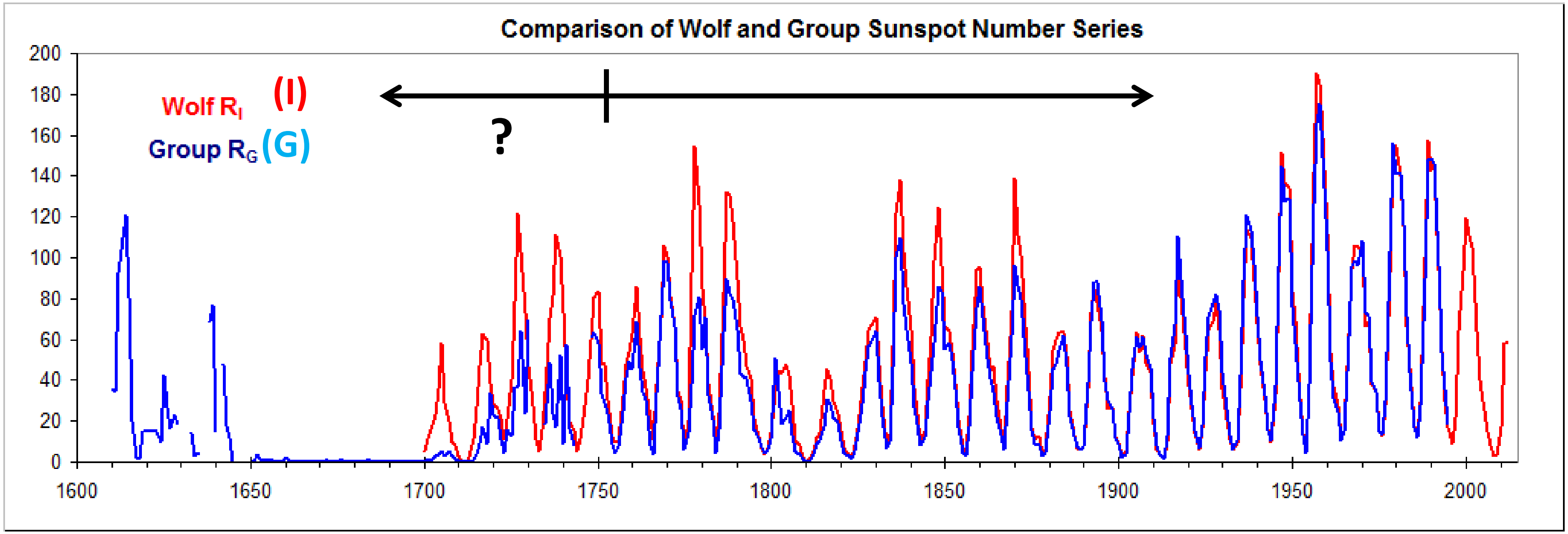
Conclusions (first part)

1) We think that we cannot use the backbone methodology in the early part of the sunspot number series.
2) Solar meridian observations should be used with extreme caution to evaluate past solar activity.
3) We have modified the HS98 data base, improving the quality of the compiled data (we hope!).
4) We will present a preliminary version of SSN series for the last four centuries, attaching the data from the revised database to the Staudach backbone.

Attaching the Maunder Minimum to the Staudach Backbone

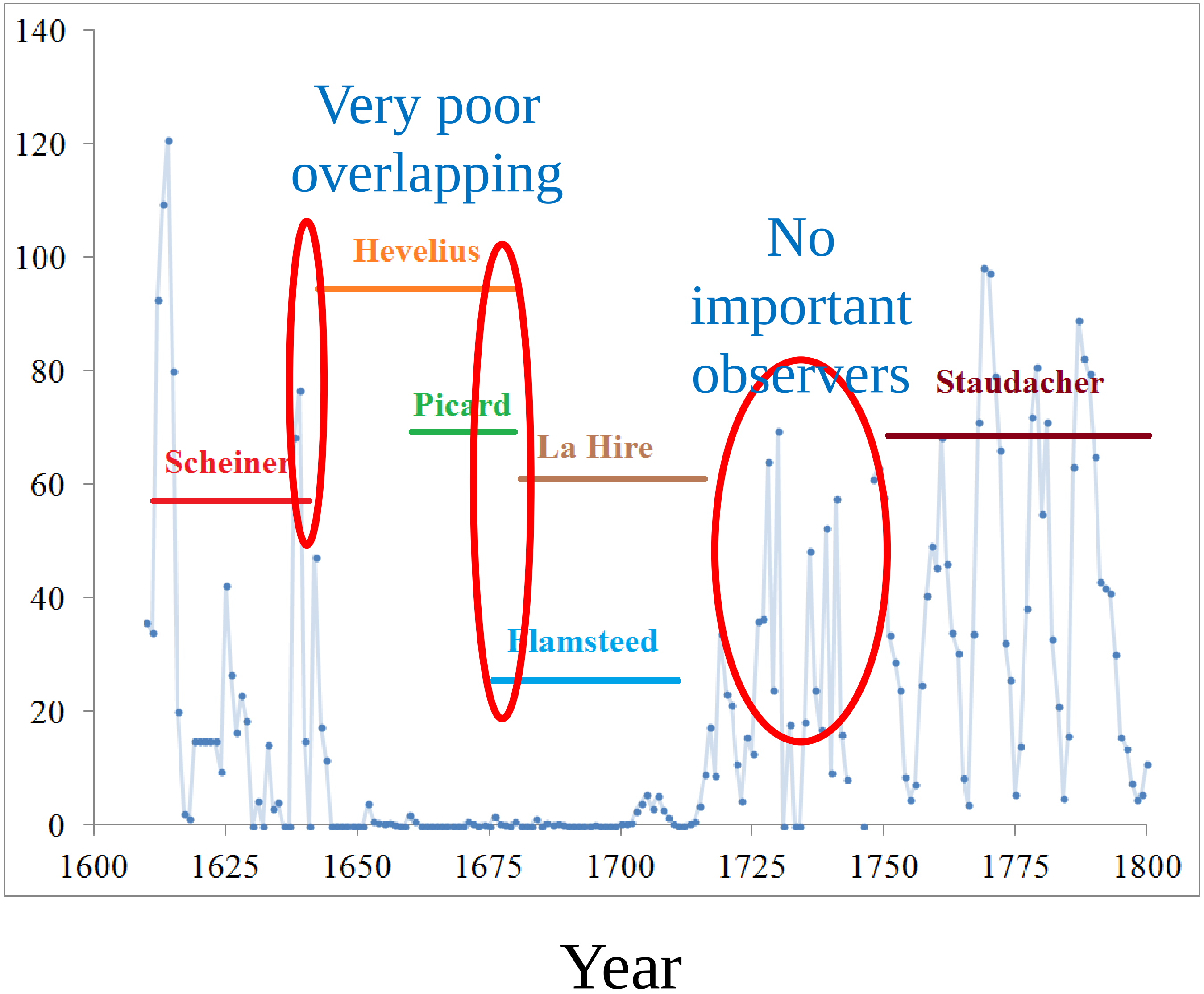


Clette et al. (2014)



Comparison of Wolf and Group Sunspot Number Series
Wolf R_I (I)
Group R_G (G)
?
200
180
160
140
120
100
80
60
40
20
0
1600
1650
1700
1750
1800
1850
1900
1950
2000

Maunder Minimum Vertebrae



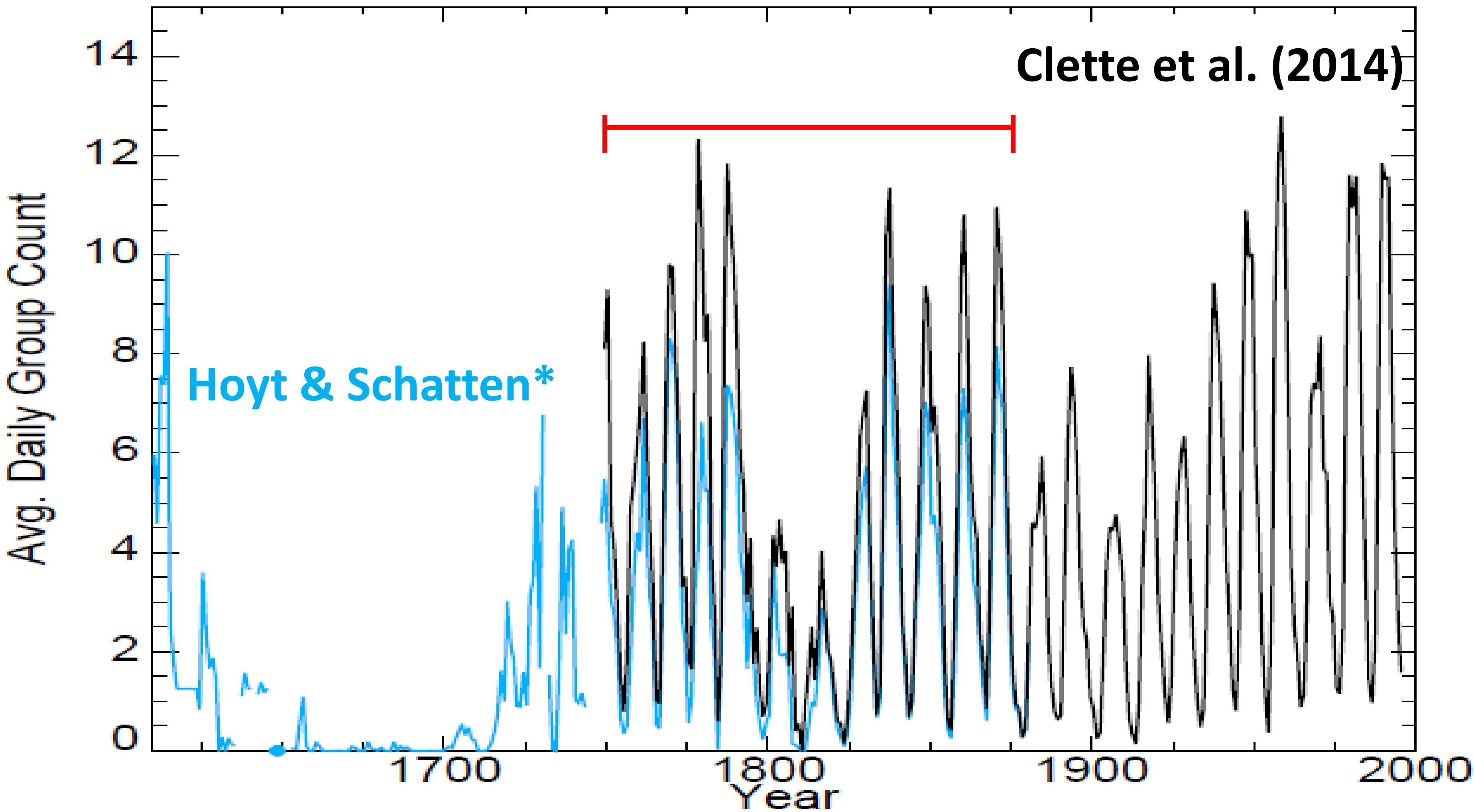
HEVELIUS, J., DANZIG

BOYLE, R., LONDON	7	1660-1660
CASSINI, G.D., PARIS	18	1671-1684
CASWELL (R.S.), LONDON	1	1684-1684
EIMMART, G.C., NUREMBERG	24	1677-1684
FLAMSTEED, J., CAMBRIDGE	45	1676-1684
FOGEL, M., HAMBURG	43	1661-1671
GULIELMINI, J.F., BONONIA	4	1684-1684
HOOK, R., LONDON	1	1676-1676
KIRCH, G., BERLIN	14	1684-1684
LA HIRE, PH., PARIS	13	1684-1684
LALANDE, MEMOIRES, PARIS	6	1672-1676
MACULA IN SOLE, 1678	1	1678-1678
MONTANARI, G., BONONIA	2	1676-1676
MOUTON, G., LYON	50	1659-1661
PETITUS, P., PARIS	9	1652-1676
PICARD, J., MONTPELLIER	2	1674-1674
PICARD, J., PARIS	**225**	**1660-1679**
PICARD/KEILL, PARIS	123	1653-1654
RICHER, CAYENNE	23	1672-1673
SIVERUS, H., HAMBURG	57	1671-1678
STETINI, LEIPZIG	4	1671-1671
UNKNOWN1/MAUNDER/JBAA	59	1652-1654
UNKNOWN2/MAUNDER/JBAA	2	1655-1655
WURZELBAUR, J.P., NUREMBERG	1	1684-1684

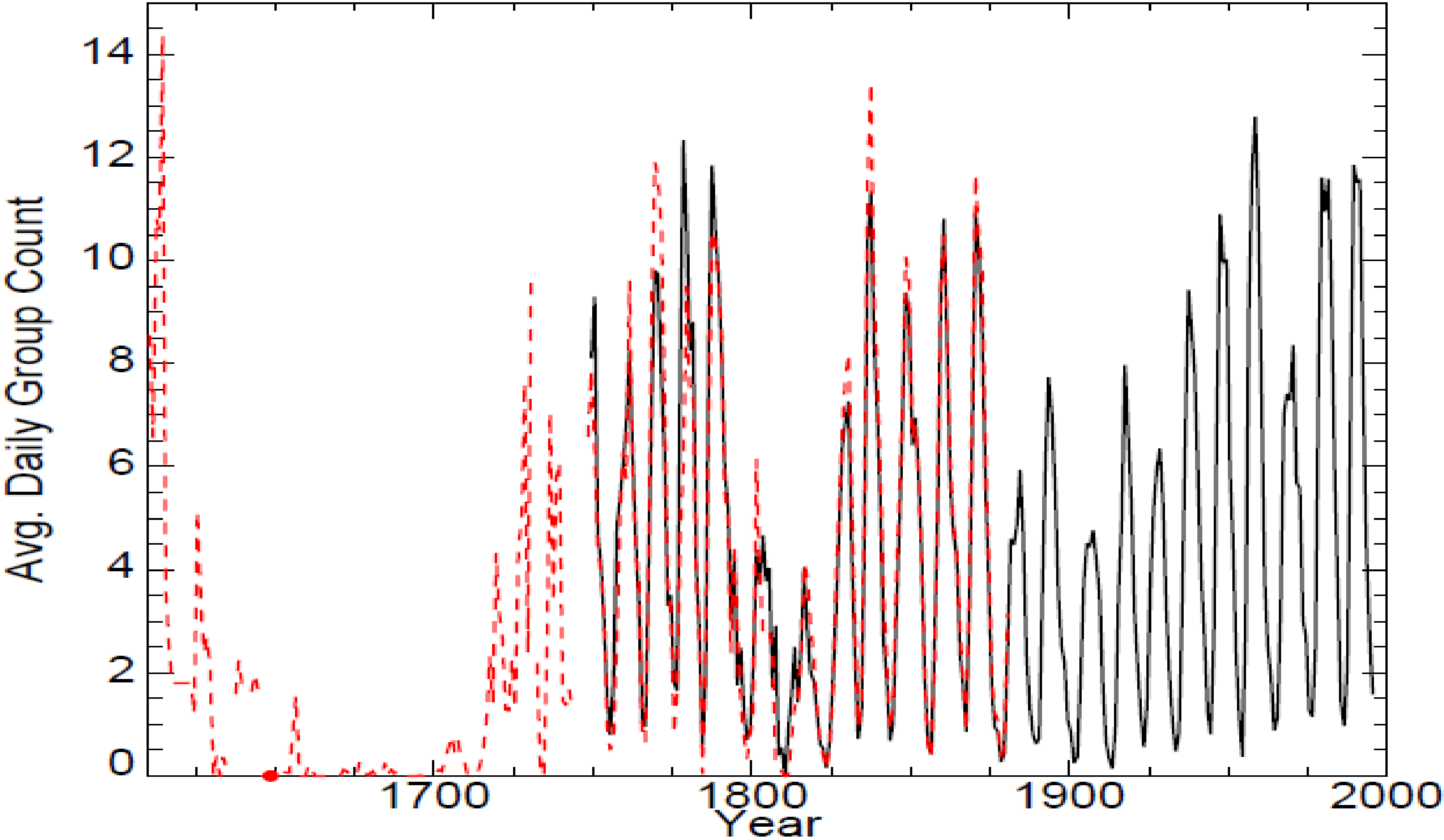
	No. of Sunspots	
	0	1
Hevelius	217	8
Picard	212	13

Year	G.C.	Obs. Days	AD	NAD
1645.5	1.8	1	1	0
1646.5	-1.0	0	0	0
1647.5	-1.0	0	0	0
1648.5	0.0	113	0	113
1649.5	-1.0	0	0	0
1650.5	-1.0	0	0	0
1651.5	-1.0	0	0	0
1652.5	0.1	58	2	56
1653.5	0.1	293	11	282
1654.5	0.1	331	7	324
1655.5	0.8	26	13	13
1656.5	1.6	15	13	2
1657.5	0.1	39	4	35
1658.5	0.0	23	0	23
1659.5	0.0	80	0	80
1660.5	0.2	294	47	247
1661.5	0.1	207	20	187
1662.5	0.0	51	0	51
1663.5	0.0	65	0	65
1664.5	0.0	50	0	50
1665.5	0.0	8	0	8
1666.5	0.0	93	0	93
1667.5	0.0	161	1	160
1668.5	0.0	144	0	144
1669.5	0.0	182	0	182
1670.5	0.0	136	0	136
1671.5	0.1	279	27	252
1672.5	0.1	199	11	188
1673.5	0.0	230	0	23

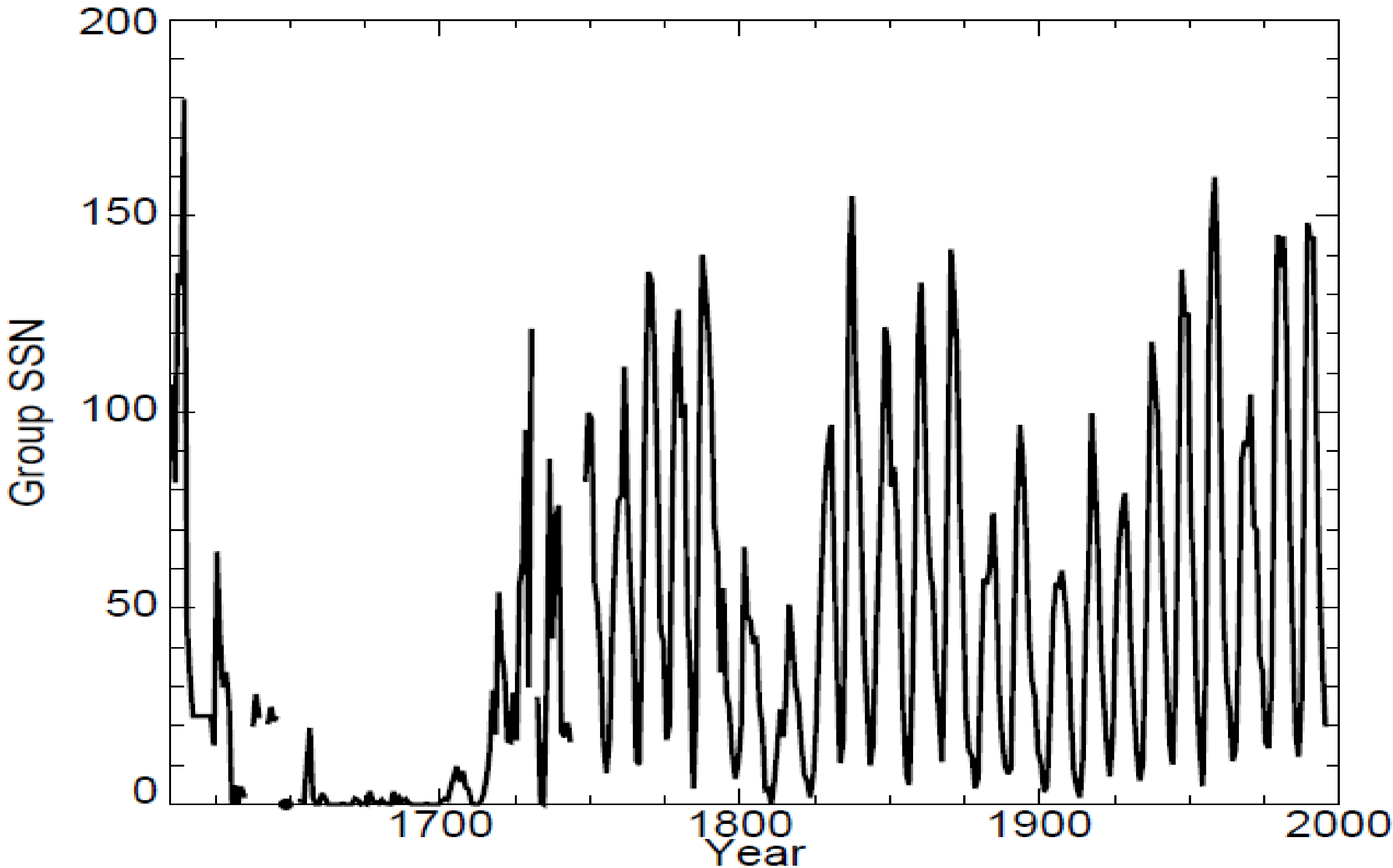
Year	G.C.	Obs. Days	AD	NAD
1674.5	0.0	126	3	123
1675.5	0.0	193	0	193
1676.5	0.3	225	44	181
1677.5	0.1	197	10	187
1678.5	0.1	363	18	345
1679.5	0.0	167	2	165
1680.5	0.1	362	22	340
1681.5	0.0	360	7	353
1682.5	0.0	177	1	176
1683.5	0.0	222	0	222
1684.5	0.3	263	72	191
1685.5	0.0	200	0	200
1686.5	0.1	229	15	214
1687.5	0.1	222	9	213
1688.5	0.1	246	18	228
1689.5	0.0	257	5	252
1690.5	0.0	288	0	288
1691.5	0.0	282	0	282
1692.5	0.0	244	0	244
1693.5	0.0	263	0	263
1694.5	0.0	279	0	279
1695.5	0.0	335	4	331
1696.5	0.0	267	0	267
1697.5	0.0	266	0	266
1698.5	0.0	250	0	250
1699.5	0.0	284	0	284
1700.5	0.0	254	9	245



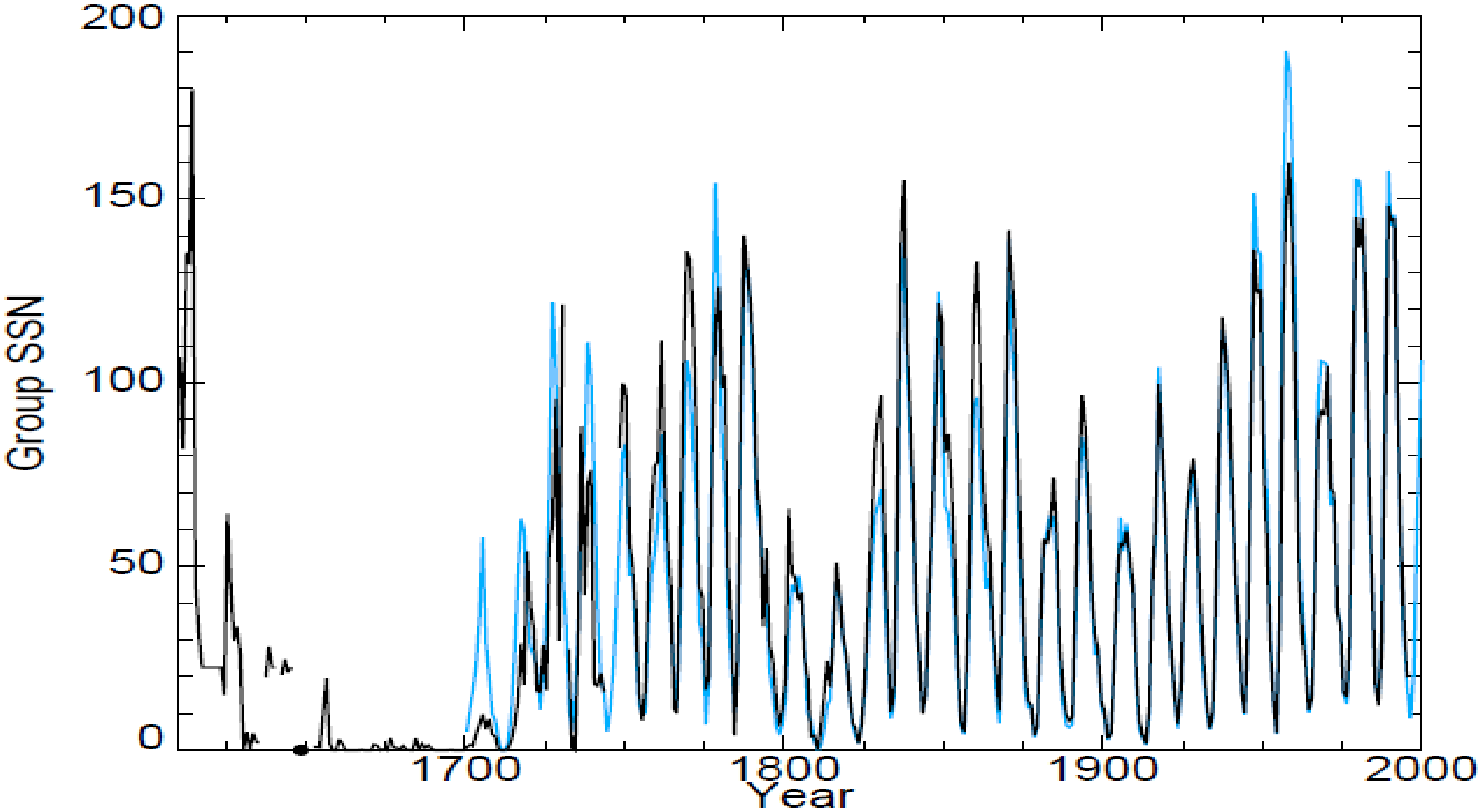
Comparison of H&S Group Counts and Clette et al. Group Counts
For 1750-1880 overlap, <Clette et al.> = 1.43 X H&S



Average the two values for 1750-1880 &
Multiply by 12.5 to convert to Wolf SSN



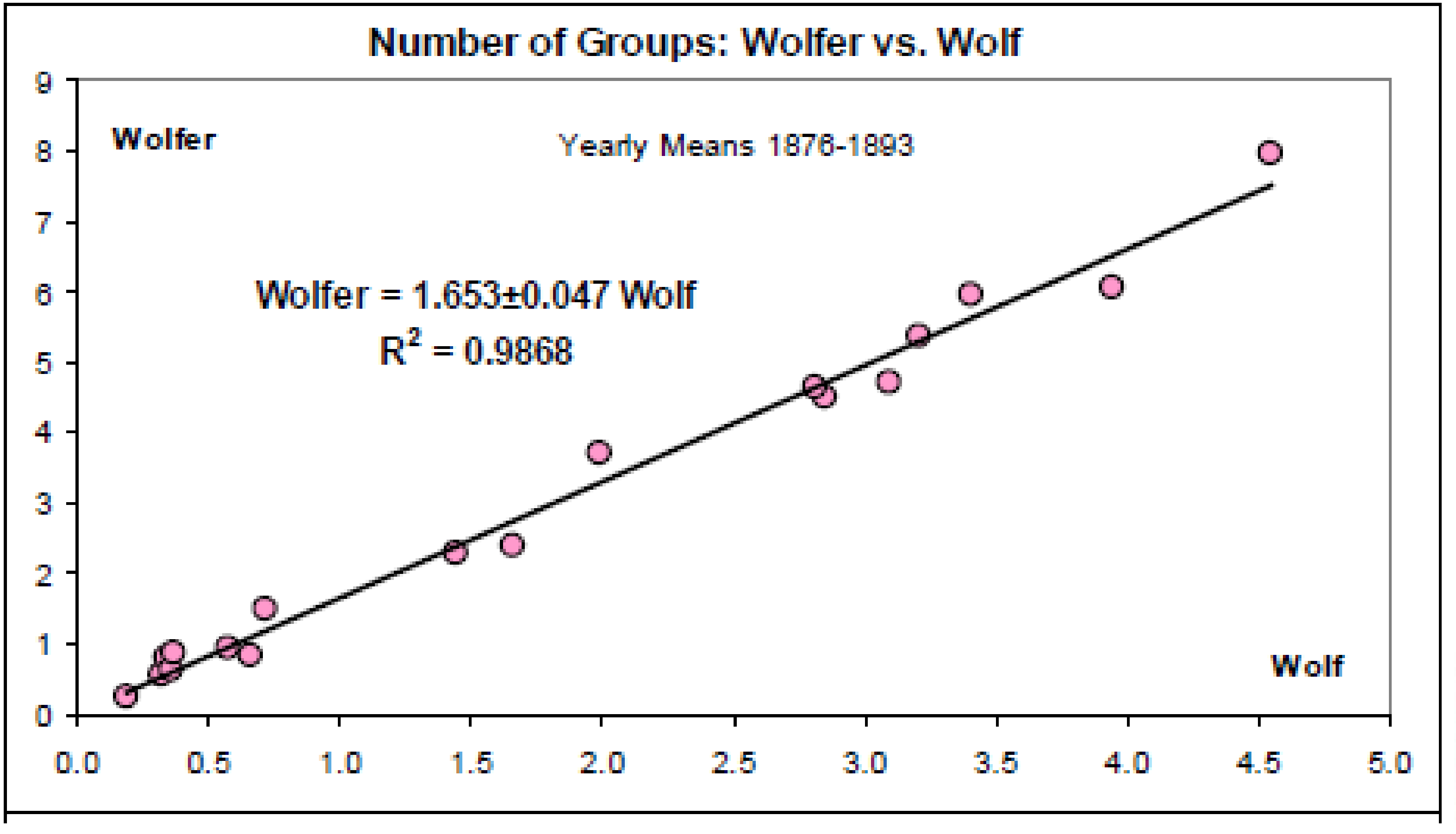
Preliminary Wolf SSN, 1610-Present

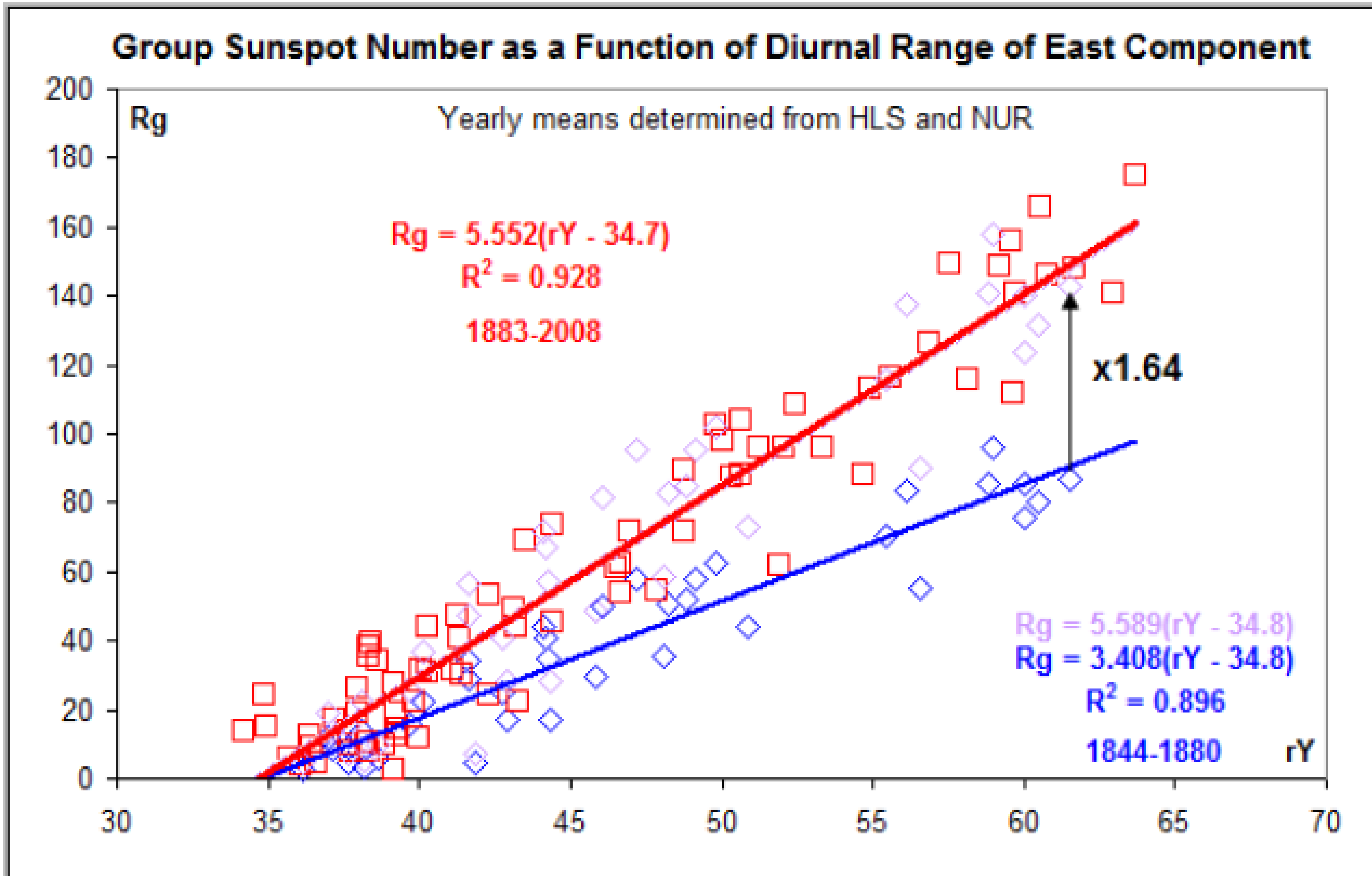


Comparison of Wolf Number with R_I (Brussels)

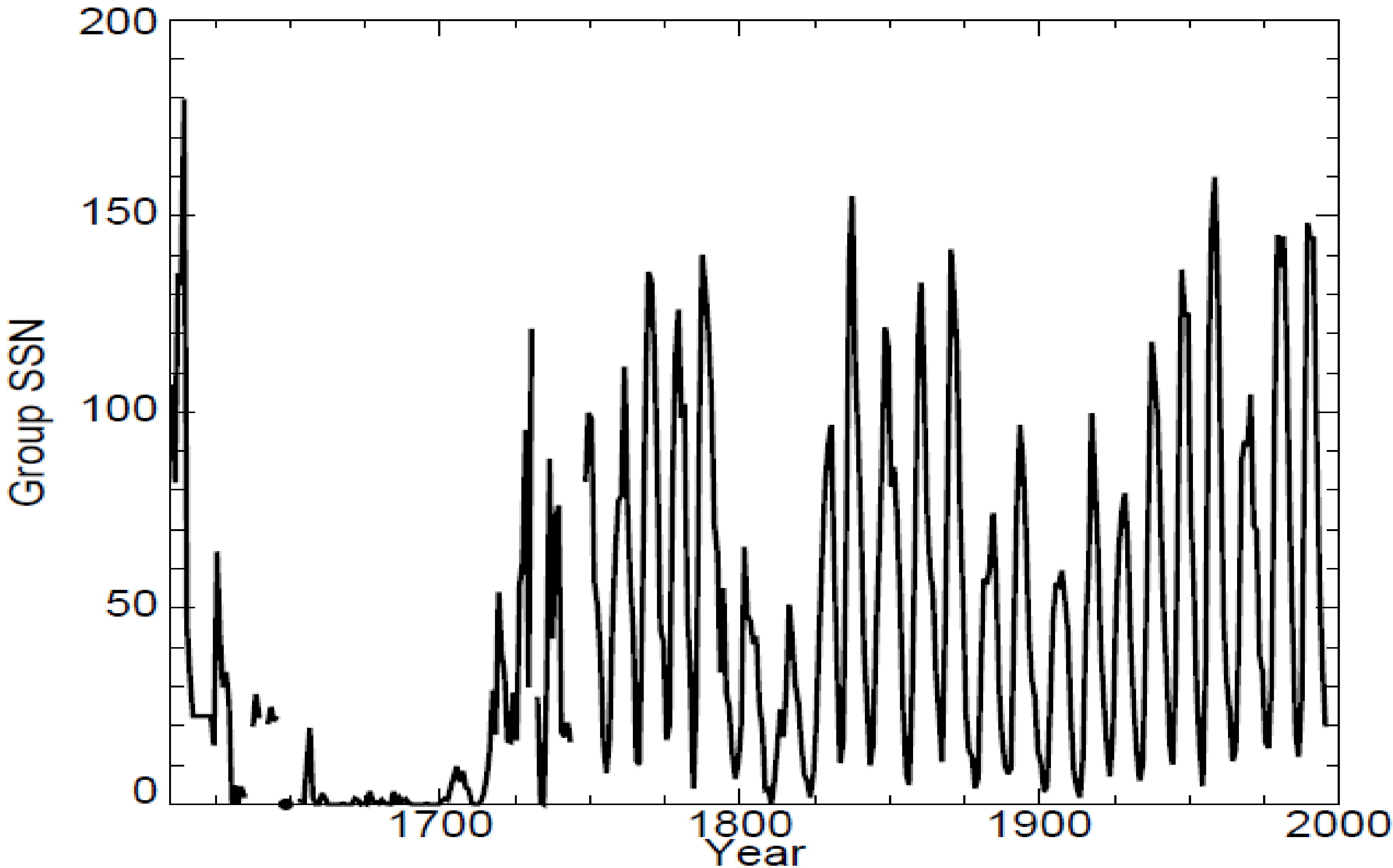
Justification for increasing the H&S Group SSN by ~50% before ~1880

	K	1σ	Observer
298	**1.117**	**.090**	**WOLF, R.** ZURICH (1848-1893)
299	.937	.057	GREISBACH, T.J., ENGLAND
300	.758	.020	SESTINI, GEORGETOWN
...			
336	.796	.049	AGUILAR, MADRID
337	1.021	.063	MONTHLY WEATHER REVIEW
338	**1.094**	**.016**	WOLFER, A. ZURICH (1880-1928)

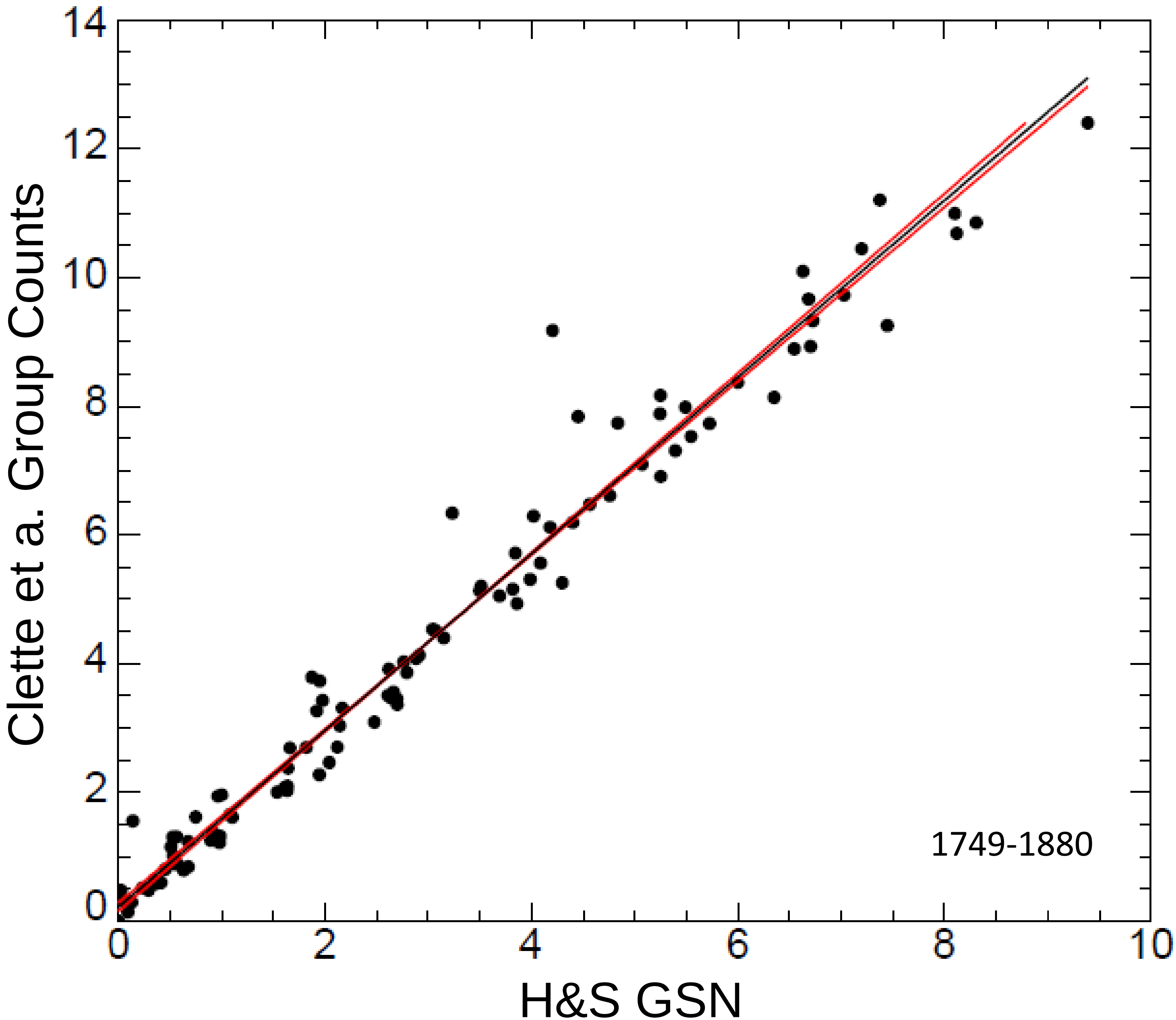




The GSN need to be increased by a factor of 1.64 (±0.15) prior to ~1880 unless the relationship between rY and GSN changed dramatically around that time.



Preliminary Wolf SSN, 1610-Present


Clette et a. Group Counts
H&S GSN
1749-1880
0
2
4
6
8
10
12
14
0
2
4
6
8
10