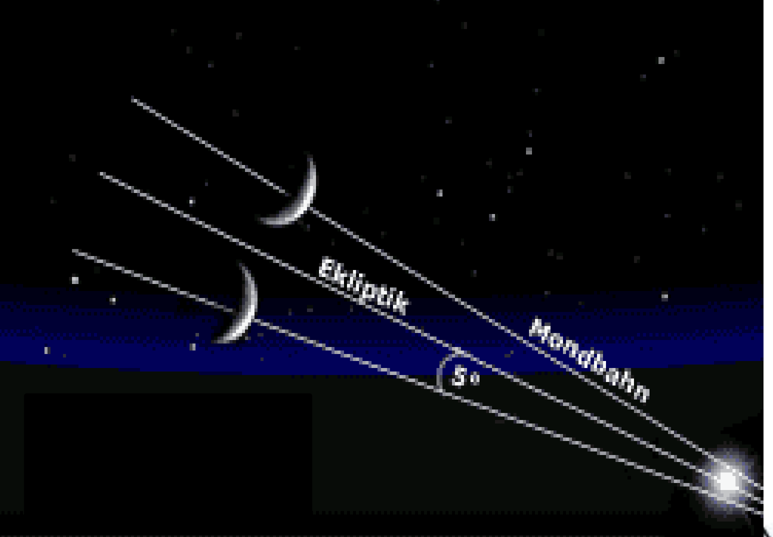
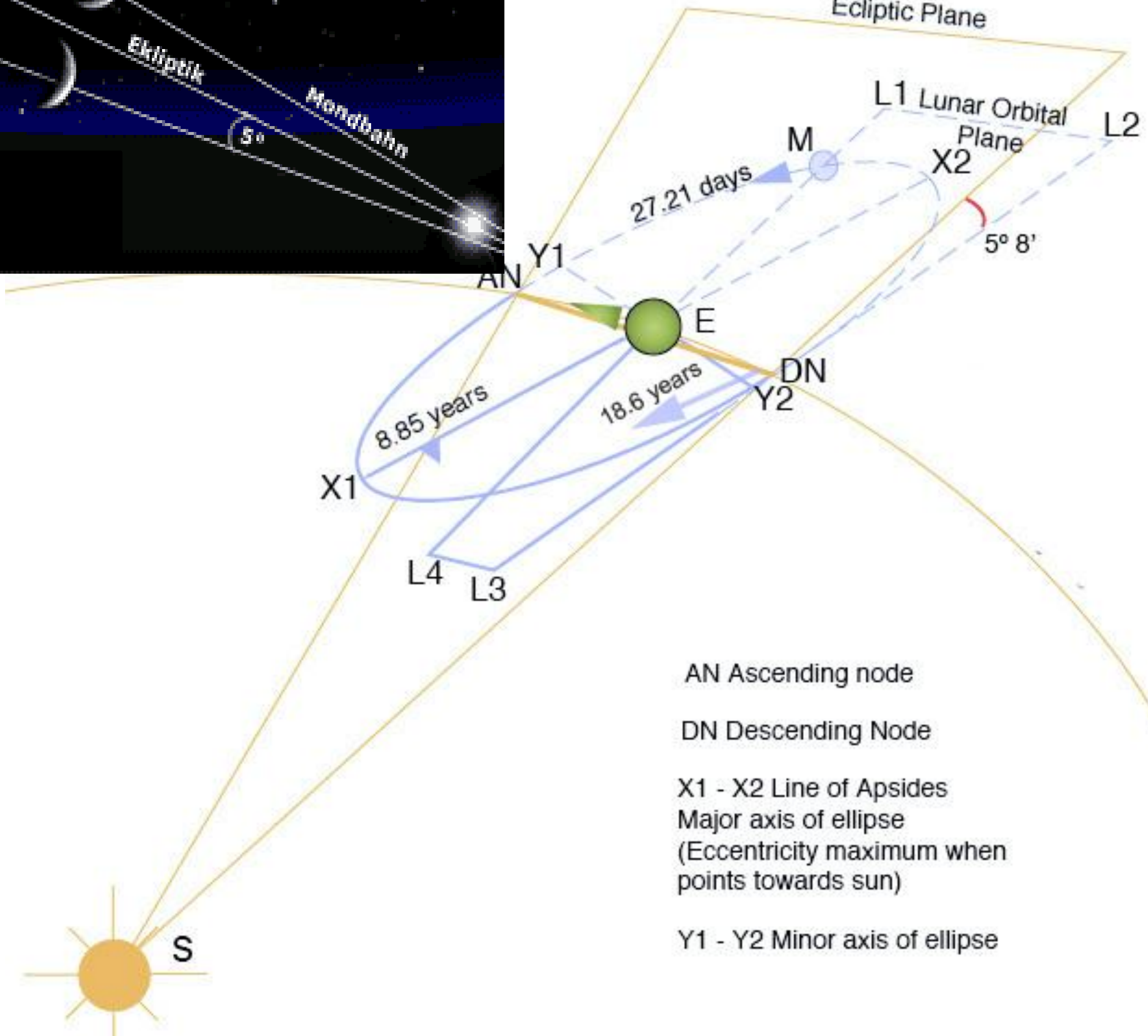
Erst:
Erdrotationsvariation aus historischen Finsternissen (Folie 2-13)

Dann:
Einführung in Sonnenaktivität
(ab Folie 14)

Erdrotationsvariation aus historischen Finsternissen

(Folien vom 6.4.2017)


Ekliptik
Mondbahn
5°


Ecliptic Plane
L1
Lunar Orbital
Plane
L2
M
X2
27.21 days
5º 8'
Y1
AN
E
DN
Y2
18.6 years
8.85 years
X1
L4
L3
S
AN Ascending node
DN Descending Node
X1 - X2 Line of Apsides
Major axis of ellipse
(Eccentricity maximum when
points towards sun)
Y1 - Y2 Minor axis of ellipse

Moon altitude above horizon versus difference in azimuth (direction) between sun and moon (at sunset)

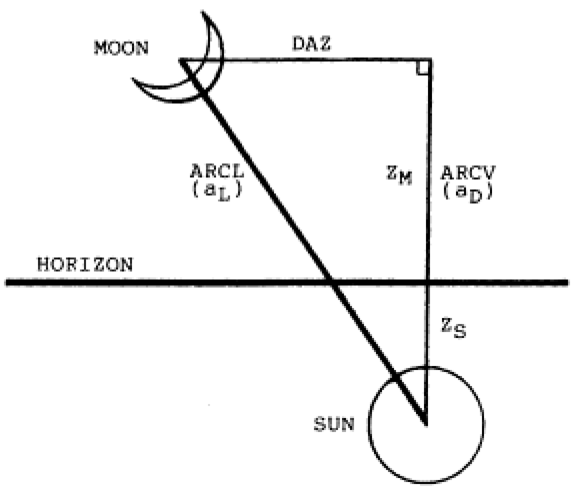


FIG. 1. Position of the Moon after sunset with various celestial arcs: ARCL (arc of light), a_L, is ecliptic longitude separation between Moon and Sun ($\lambda m - \lambda s$); ARCV (arc of vision or arc of descent), a_D, is Moon's altitude separation from the Sun ($h+s$ or ΔA); DAZ, ΔAz, is azimuth separation of the Moon from Sun; arc of separation, a_s, is equatorial separation in right ascension for Moon and Sun ($\alpha_m - \alpha_s$) and is related to a_D and ϕ (latitude of observation place) by $a_D = a_s \cos\phi$.

(Ilyas 1994, QJRAS 35, 425)

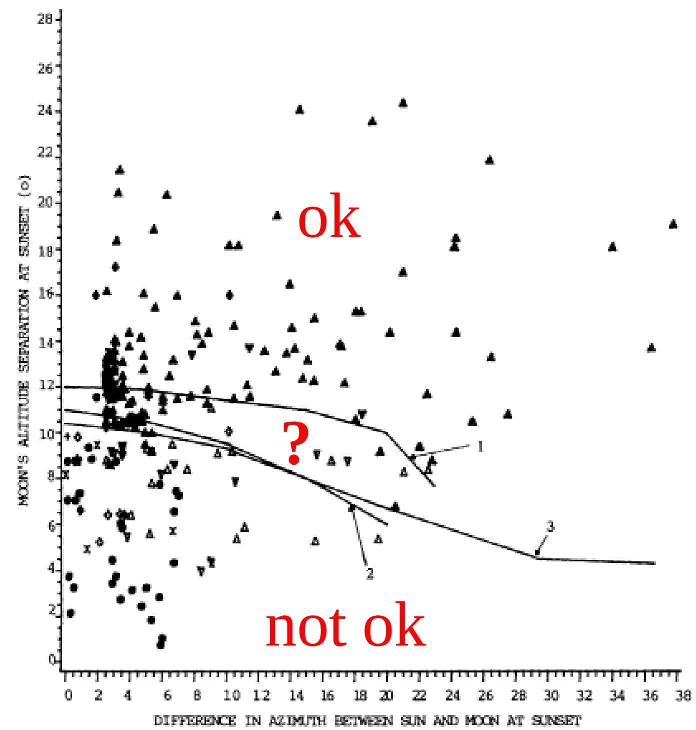


FIG. 8. Comparison of the reported sighting reports available in the literature with the three criteria [1: Fotheringham (1910); 2: Maunder (1911); 3: Ilyas-composite

Änderung der Erdrotation

No. -357

BM 36913(=80-6-17,654) Artaxerxes III year 1

Photo: Pl. 22] XI [

'Obv.

1' [....] ⸢x⸣ [....]
2' [....]+1/2 KÙŠ *sin* 8 ⸢SI⸣ [....]
3' [....] *ana* NIM GUB GE$_6$ 10+[x ....]
4' [....] ⸢GÙ U AN⸣ *né-ḫi* PISAN *i* DIB GE$_6$ 10+[x ....]
5' [....] NU PAP *ina* 40 ME *ana* ŠÚ *šamáš* AN-KU$_{10}$ *sin* BAR DIB US[AN
6' [.... GE$_6$ 15] *sin* SIG DELE *šá* IGI ABSIN 2 KÙŠ 15 MÚL-BABBAR *ana*
[....]

Rev.'

1 [....] 1 KÙŠ 8 SI 17 AN-BAR$_7$ *ni-di* Á ⸢x⸣ [....]
2 [.... D]IB' TA 12 EN 18 ILLU 1/2 KÙŠ LAL-*is* GE$_6$ 19 ⸢x⸣ [....]
3 [.... PISA]N' MAḪ DIB GÙ U *i in* EN 19 AN *ana* ŠÚ *ki* U[Š-*a* ....]
4 [.... GE$_6$] 21 *ina* ZALÁG *sin ár* MÚL KUR *šá* KIR$_4$ *šil-taḫ* PA-BIL ⸢x⸣ [
5 [....] KÙŠ DU' GE$_6$ 24 USAN GÍR *ina* ULÙ GÍ[R ....]
6 [....] ⸢x⸣ 16 ME *ana* ŠÚ-*e šamáš šamáš* AN-KU$_{10}$ Á [....]
7 [....] *u* ZALÁG *ina* AN-KU$_{10}$-*šú* ULÙ *šá* [....]
8 [....] ⸢x x⸣ [....]

Calendar

Artaxerxes III year 1 XI 0 -356 Jan 31/Feb 1

Comments

Rev. 6: Eclipse of -356 Feb. 29.

ASTRONOMICAL
DIARIES AND RELATED TEXTS
FROM BABYLONIA

BY THE LATE
ABRAHAM J. SACHS

COMPLETED AND EDITED BY
HERMANN HUNGER

No. -357

'Obv.

1' [....] .... [....]
2' [....]+1/2 cubit, the moon being 8 fingers [....]
3' [....] stood to the east. Night of the 10+[x]th, [....]
4' [....] thunder, slow rain, a little PISAN DIB. Night of the 10+[x]th, [....]
5' [....] I did not watch. At 40° before sunset, lunar eclipse, ..., omitted; first pa[rt of the night, ...]
6' [.... Night of the 15th,] the moon was 2 cubits below γ Virginis. The 15th, Jupiter's acronychal rising [....]

Rev.'

1 [....] 1 cubit 8 fingers. The 17th, around noon, a cloudbank to the side of .... [....]
2 [....] .... From the 12th to the 18th, the river level receded 1/2 cubit. Night of the 19th, ... [....]
3 [....] much [PISA]N DIB, a little thunder. Around the 19th, when Mars became stationary to the west, [....]
4 [.... Night] of the 21st, last part of the night, the moon was [....] behind ϑ Ophiuchi [....]
5 [....] cubits .... Night of the 24th, first part of the night, lightning flashed in the south [....]
6 [....] .... At 16° before sunset, solar eclipse on the [....] side [....]
7 [....] and clearing; during its eclipse, the south wind which [....]
8 [....] .... [....]

Date

The not too abbreviated writings LAL-*is* (rev. 2) and *šil-taḫ* PA-BIL (rev. 4) suggest a date before the beginning of the Seleucid era. At the end of the month in question there was a solar eclipse; in the middle of the month, a lunar eclipse was omitted. Furthermore, a second stationary point of Mars on the 19th (rev. 3) and an acronychal rising of Jupiter on the 15th (obv. 6') are attested. These data suffice to identify the date as Artaxerxes III year 1 month XI.

Stephenson et al. 2017 APS

Änderung der Erdrotation

ASTRONOMICAL
DIARIES AND RELATED TEXTS
FROM BABYLONIA

BY THE LATE
ABRAHAM J. SACHS

COMPLETED AND EDITED BY
HERMANN HUNGER

6′ GE$_6$ 9 *ina* ZALÁG *dele-bat e* RÍN *šá* ULÙ 14 SI *dele-bat* 1+[....]
7′ 12 DIR AN ZA GE$_6$ 13 13 DIR AN ZA GE[$_6$ ....]
8′ *ki* TAB-*ú ina* 21 GE$_6$ *gab-bi-šú*
9′ RÍN *šá* ULÙ *a-dir ina* AN-KU
10′ MAŠ-MAŠ IGI 1 KÙŠ *in* EN 1
11′ *ina* ZALÁG *sin ina* IGI GÌR *á*
12′ AN *ḫa-an-ṭiš* PISAN *i* DIB 26
13′ *ina* IGI GENNA 1 KÙŠ *ana* Š
14′ [x] ⌜x 1 GUR⌝ ZÀ 1(b) ⌜ŠE-GI

6′ Night of the 9th, last part of the night, Venus was 14 fingers above α Librae, Venus being 1+[x ....]
7′ The 12th, clouds were in the sky. Night of the 13th (and) the 13th, clouds were in the sky. Ni[ght .... lunar eclipse ....]
8′ when it began, after 21° night all of it was eclipsed. 20° night [....]
9′ α Librae (the moon) was eclipsed. In its eclipse, there was lightning, thunder, rain [....]
10′ 1 cubit [....] of α Geminorum. Around the 18th, when Jupiter became stationary to the east [.... Night of the 22nd,]
11′ last part of the night, the moon was 2/3 cubit in front of β Virginis, in front of [....]
12′ rain quickly a little PISAN DIB. The 26th, cold north wind [....]
13′ it stood 1 cubit in front of Saturn to the west; Mercury [....]
14′ [....] .... 1 kur; cress, 1 sūt; sesame, [....]

Left edge

1 Diary from month I to the end of month X[II ....]

Date

A total lunar eclipse occurred in month VIII (rev. 8′f.); in the same month around the 18th, Jupiter reached its first stationary point. On the 9th, Venus was next to α Librae.

Stephenson et al. 2017 APS

Änderung der Erdrotation

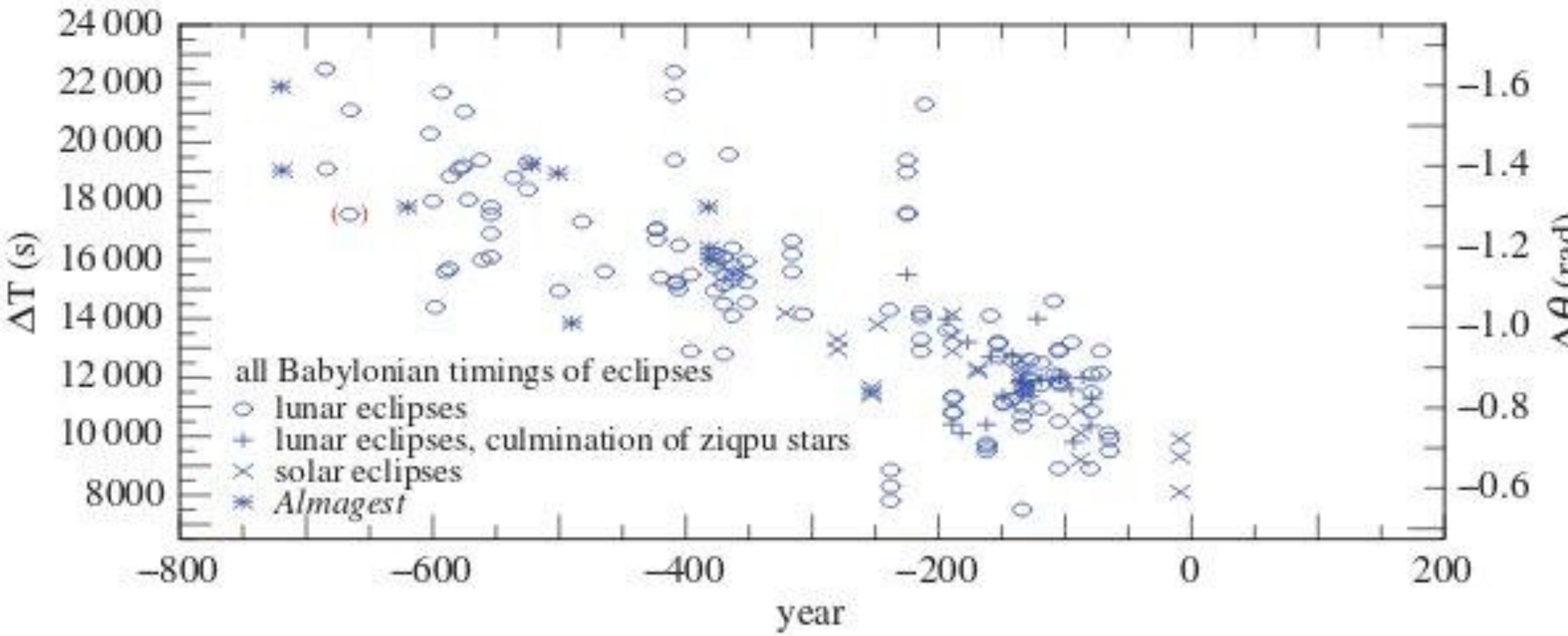


Figure 2. Values of ΔT for all the Babylonian-timed observations −720 to −9 listed in the electronic supplementary material, tables S1–S4. (The conversion factor for deriving the sidereal rotational displacement angle of the Greenwich meridian, $\Delta\theta$, measured in radians, from ΔT, measured in seconds of mean solar time, is $-7.29 \times 10^{-5}\ \Delta T$.) The observation in parenthesis was not used in fitting curves to the data (see electronic supplementary material section S4, −666).

Stephenson et al. 2017 APS

Änderung der Erdrotation

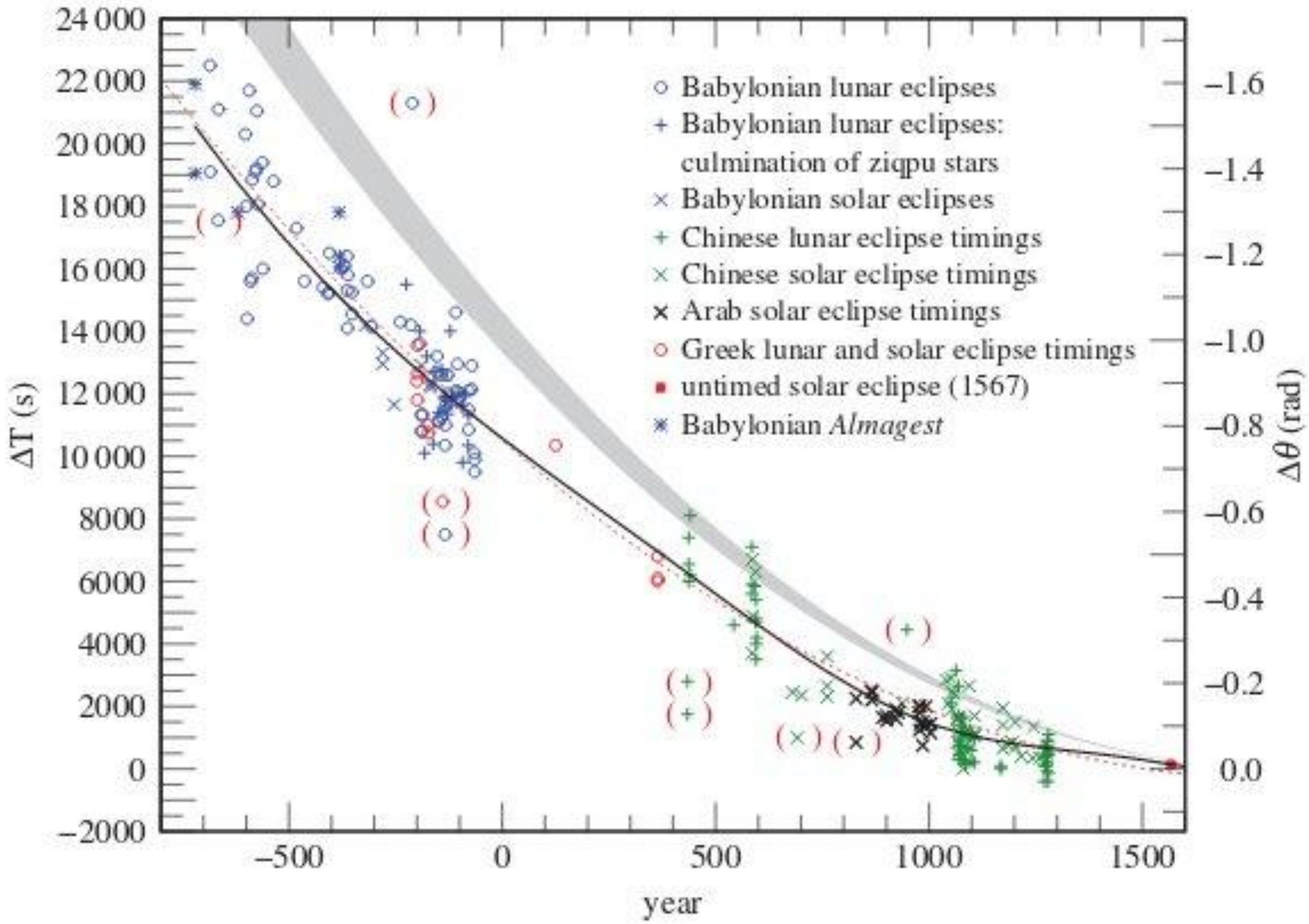


Figure 9. Results for ΔT for collected timed observations −720 to 1280 and the untimed total solar eclipse of 1567. The dotted red curve is the parabola given by equation (4.1). The black curve is the spline curve described in §4b. The grey curve is the parabola (equation (1.5)), predicted on the basis of tidal friction. The observations in brackets were treated as outliers, apart from a Babylonian observation in −666 which is intrinsically doubtful.

Stephenson et al. 2017 APS

Änderung der Erdrotation

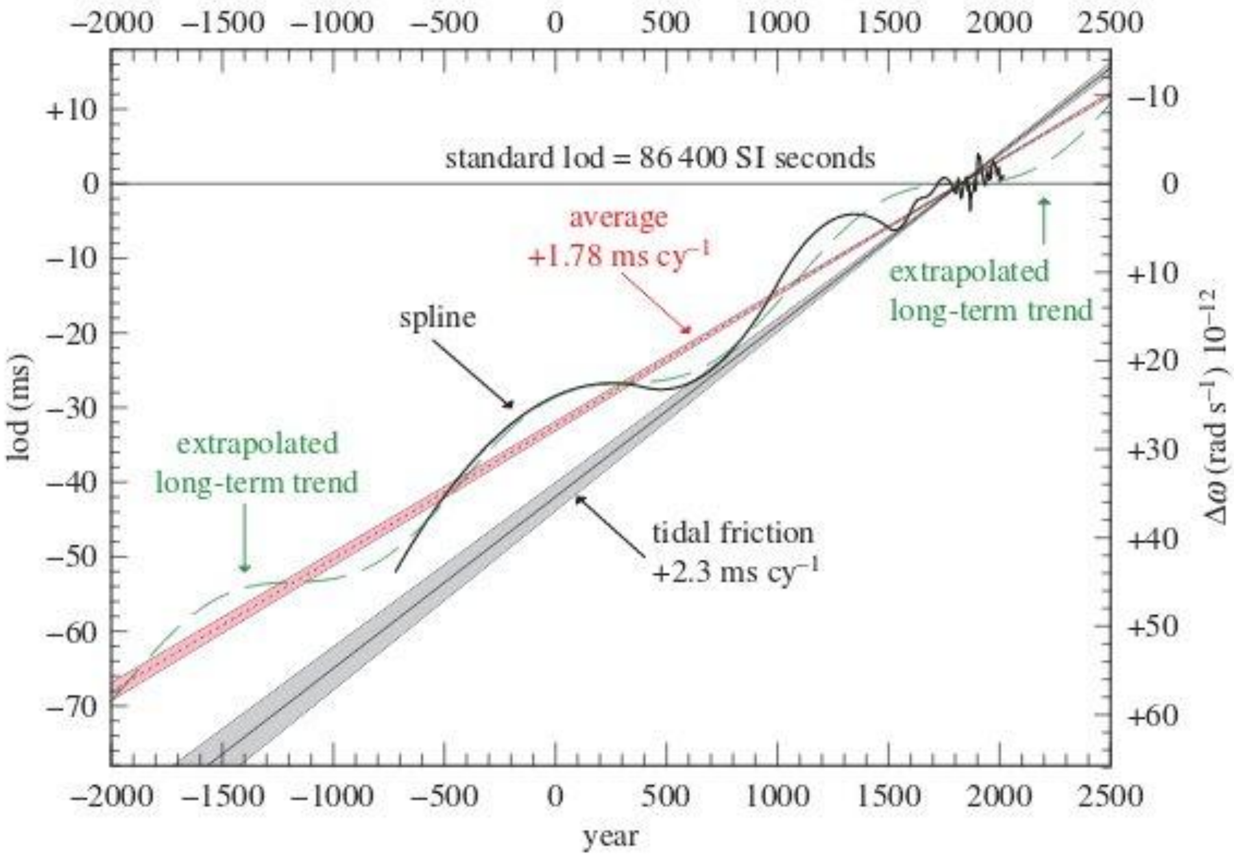
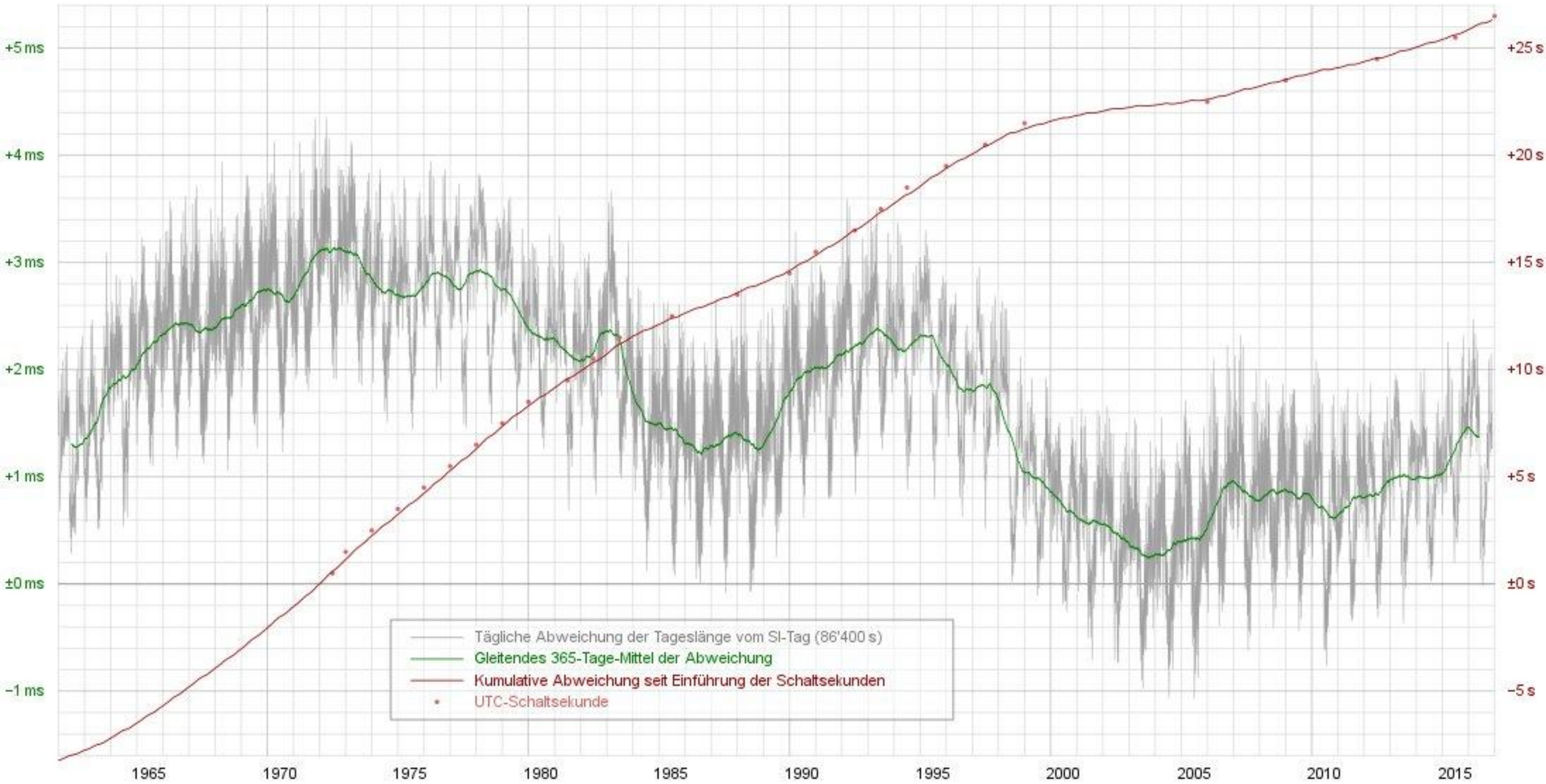


Figure 18. lod −2000 to 2500. The dotted red line is the average measured rate of change in the lod, $+1.78 \pm 0.03$ ms cy^{-1}, which is equivalent to an acceleration of $-4.7 \pm 0.1 \times 10^{-22}$ rad s^{-2}. The shaded grey area shows the change expected on the basis of tidal friction, $+2.3 \pm 0.1$ ms cy^{-1}, equivalent to $-6.2 \pm 0.4 \times 10^{-22}$ rad s^{-2}. The black curve is the slope on the spline fit shown in figures 9 and 10. The green-dashed curve is the extrapolation of the oscillation (equation (5.1)).

Stephenson et al. 2017 APS

Änderung der Erdrotation



Änderung der Erdrotation

Annalen von St. Bertin (AD 840):
Eclipsis [MS D: Eclypsis] solis iii nonas maii ante nonam diei horam multis in locis a plurimis visa est.

Annalen von Xanten (AD 840):
On the eve of Ascension there was so great an eclipse of the sun around the seventh and eighth hour of the day that even the stars could be seen because of the veiling of the sun, and terrestrial objects changed colour.

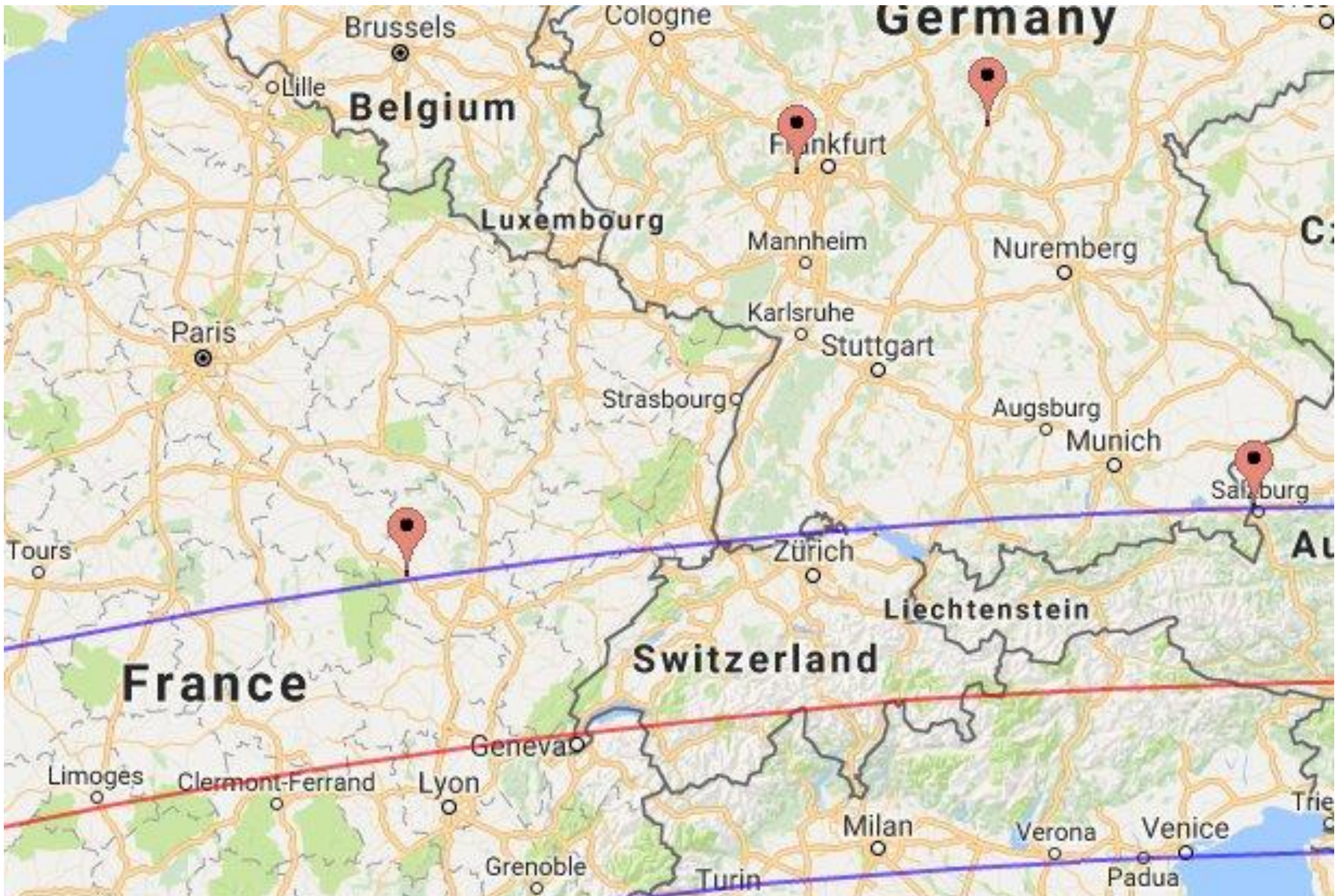
Annalen von Fulda (AD 840):
the third Rogation Day, the was an eclipse of the sun in the ninth hour, and the stars were as clearly visible in the sky as at night.

[Änderung der Erdrotation]

Anonymer Astronom (AD 840):
At that time there was a most unusual disappearance of the sun on the third day of the Greater Litany; darkness so prevailed with the receding of the light that, in truth, it seemed to differ not at all from night. The determined order of the stars was preceived such that no star seemed to suffer from the extinguishing of the sun's light except perhaps the moon, which lay opposite the sun. But as the moon moved gradually to the east, a little horn of light was restored to the sun's western parts, as in the case when it is seen at first or second light. Thus, little by little the whole circle (disk) got back its total beauty.

Änderung der Erdrotation

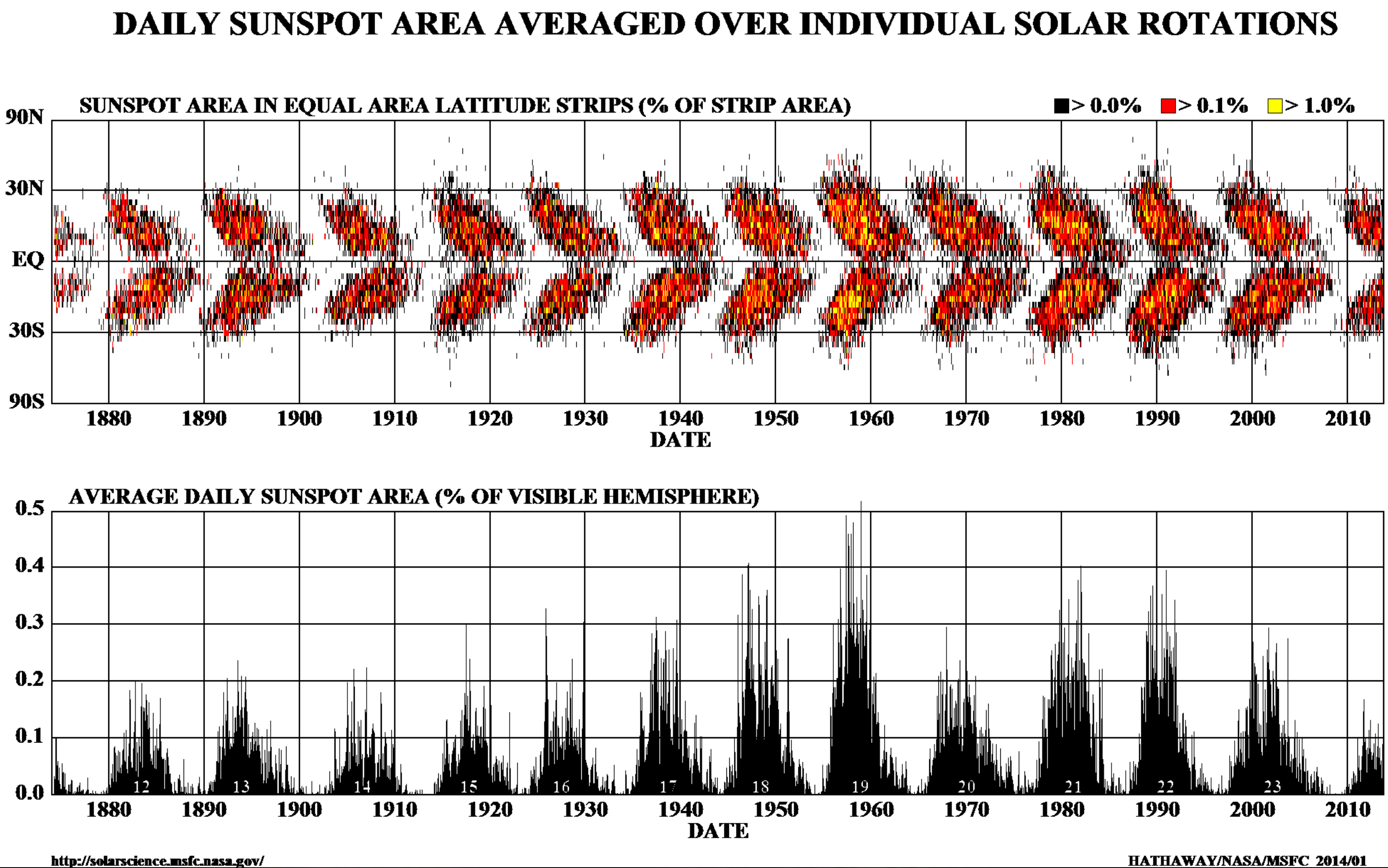
Annalen von St. Bertin:
Eclipsis [MS D: Eclypsis] solis iii nonas maii ante nonam diei horam multis in locis a plurimis visa est.



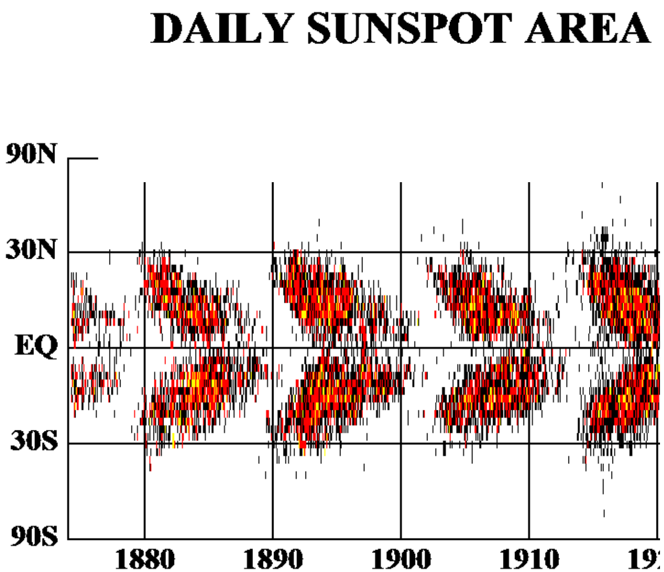
Einführung in Sonnenaktivität

(Folien der Vorlesung vom 10.4.2017)

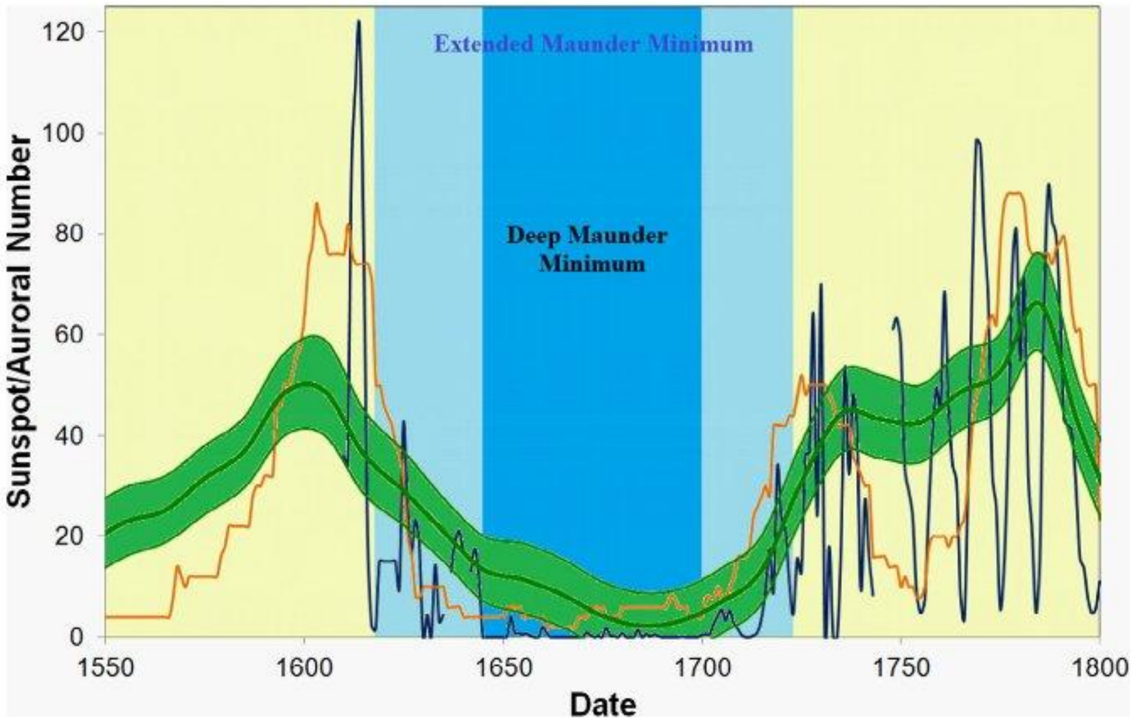
Schwabe Zyklus seit 1750: 10.4 +/- 1.2 yr

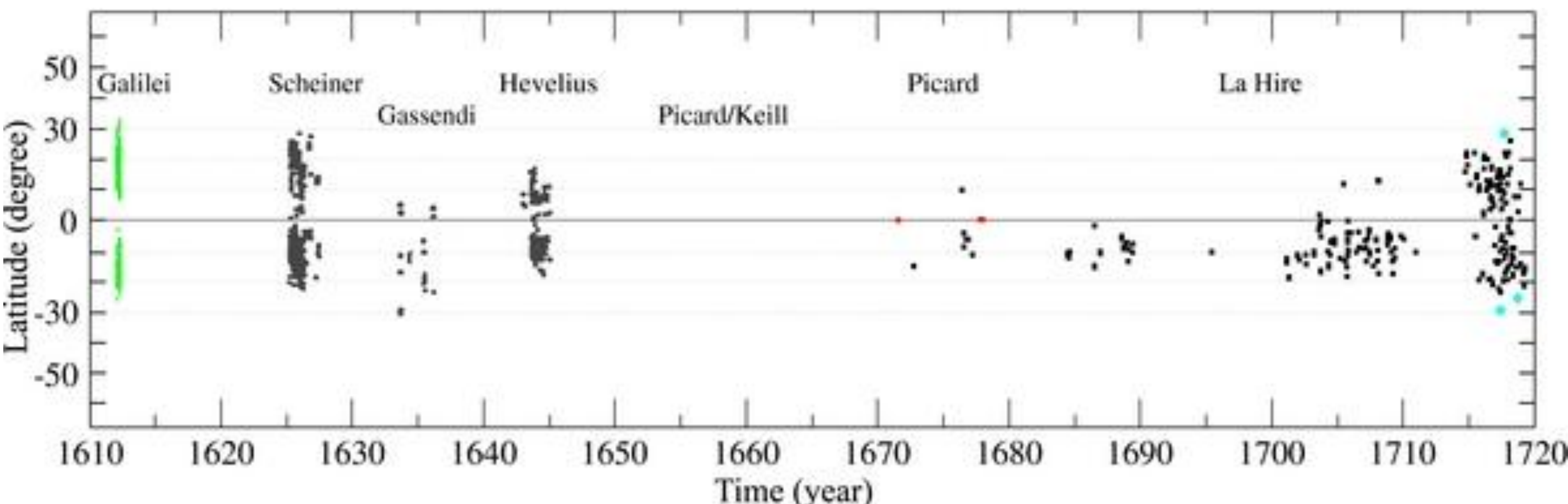


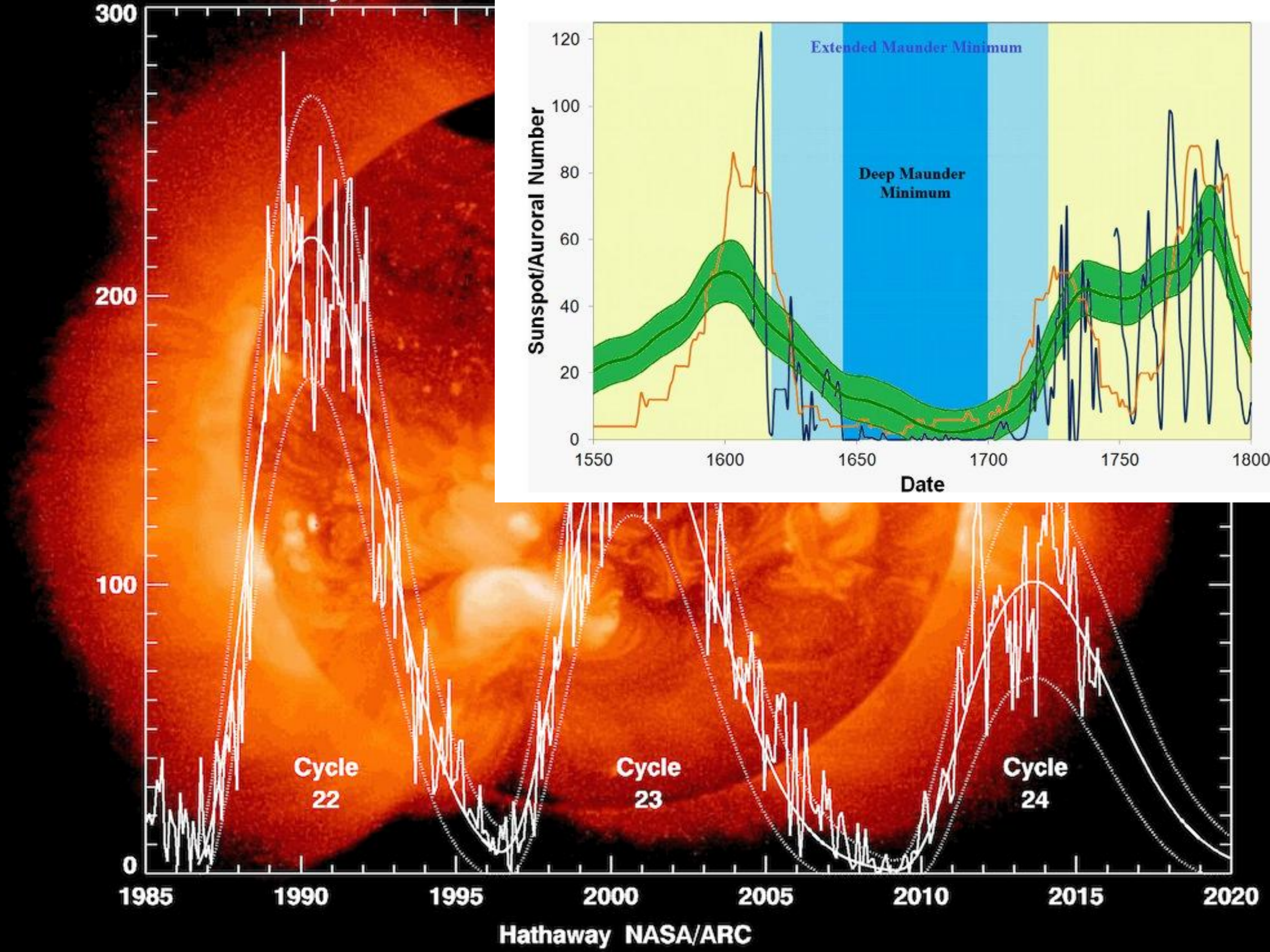
Schwabe cycle

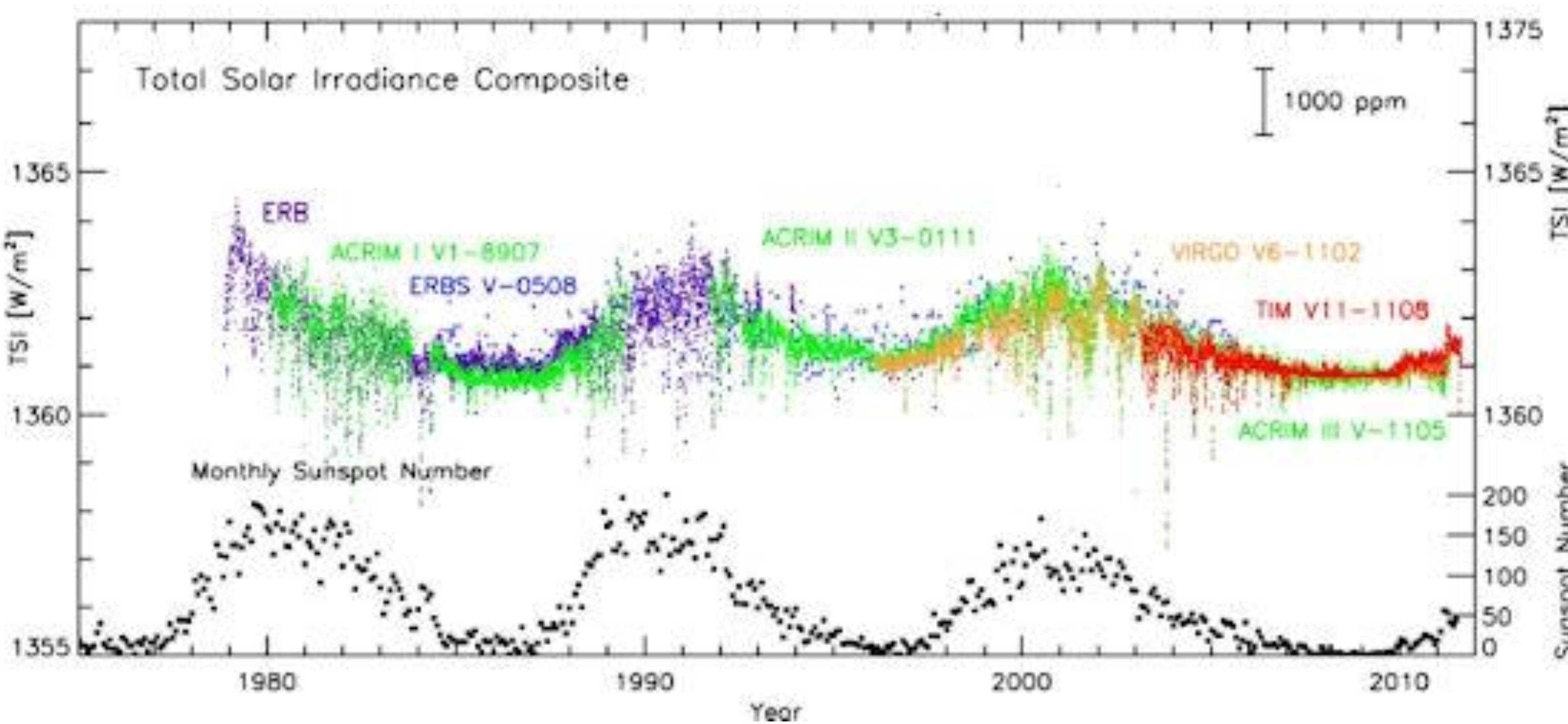


J.M. Vaquero, R.M. Trigo / New Astronomy 34 (2015) 120–122



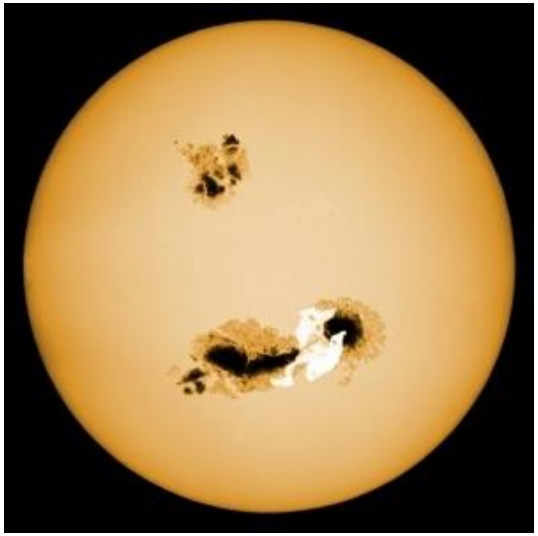


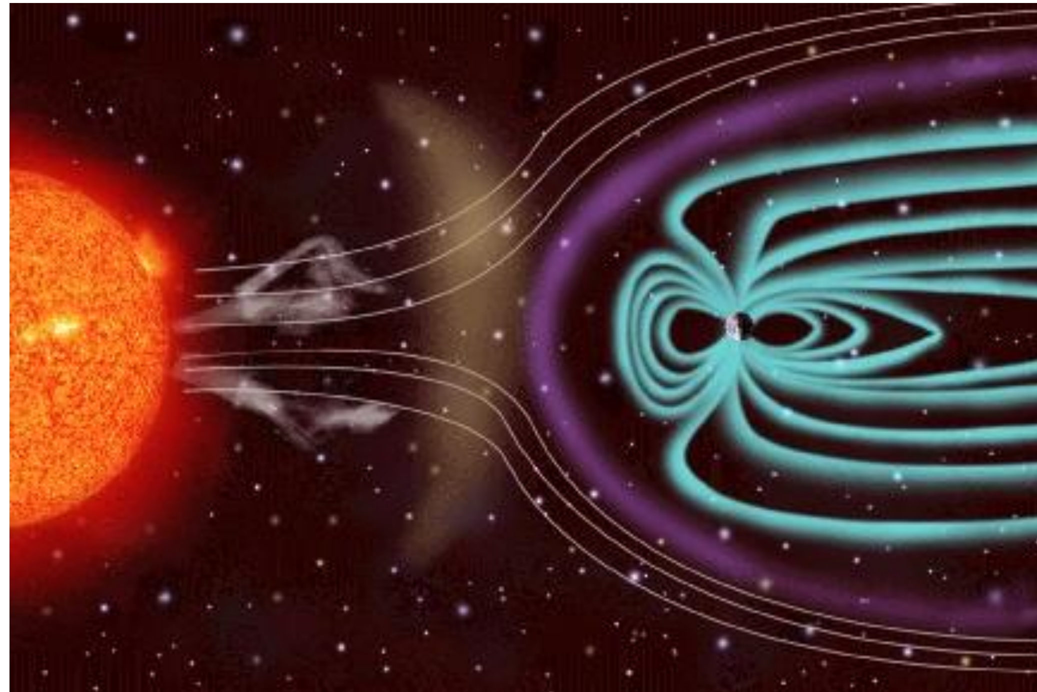

300
200
100
0
Cycle 22
Cycle 23
Cycle 24
1985
1990
1995
2000
2005
2010
2015
2020
Hathaway NASA/ARC
Extended Maunder Minimum
Deep Maunder Minimum
Sunspot/Auroral Number
120
100
80
60
40
20
0
1550
1600
1650
1700
1750
1800
Date



Total Solar Irradiance Composite
1000 ppm
ERB
ACRIM I V1-8907
ERBS V-0508
ACRIM II V3-0111
VIRGO V6-1102
TIM V11-1108
ACRIM III V-1105
Monthly Sunspot Number
TSI [W/m²]
Sunspot Number
Year
1355
1360
1365
1375
0
50
100
150
200
1980
1990
2000
2010

Mehr Sonnen-Aktivität (Flecke UND koronale Löcher)
➔ mehr Sonnen-Wind ➔ Geo-magnetische Aktivität und Aurorae





Je stärker der Sonnen-Wind,
desto weniger kosmische Strahlung
kommt ins Sonnensystem.

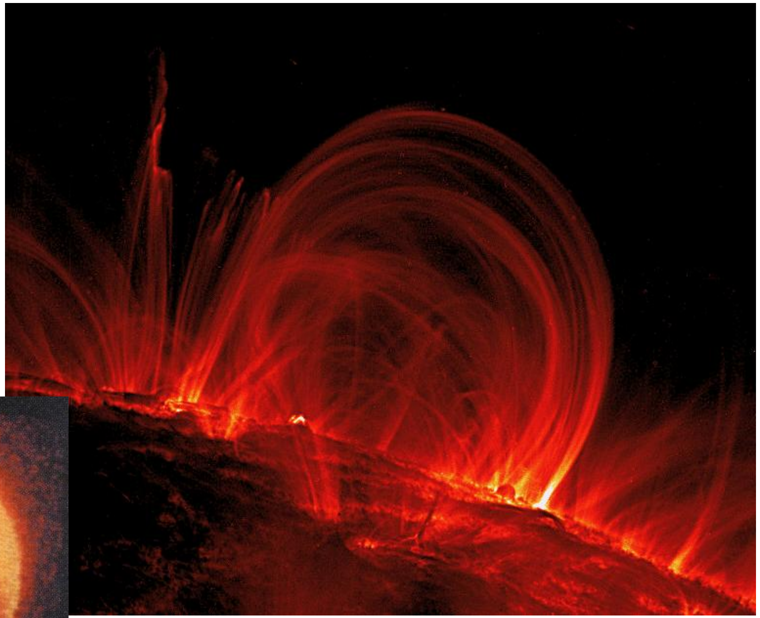
Weniger aktive Sonne, mehr kosm. Str.

➔ 10-11 jährige Modulation von
Flecken, Aurorae und kosm. Strahlung.
(Schwabe Zyklus)

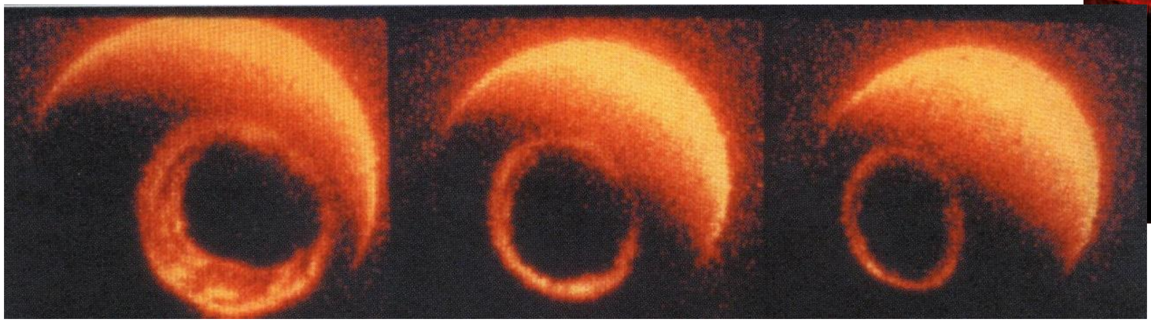




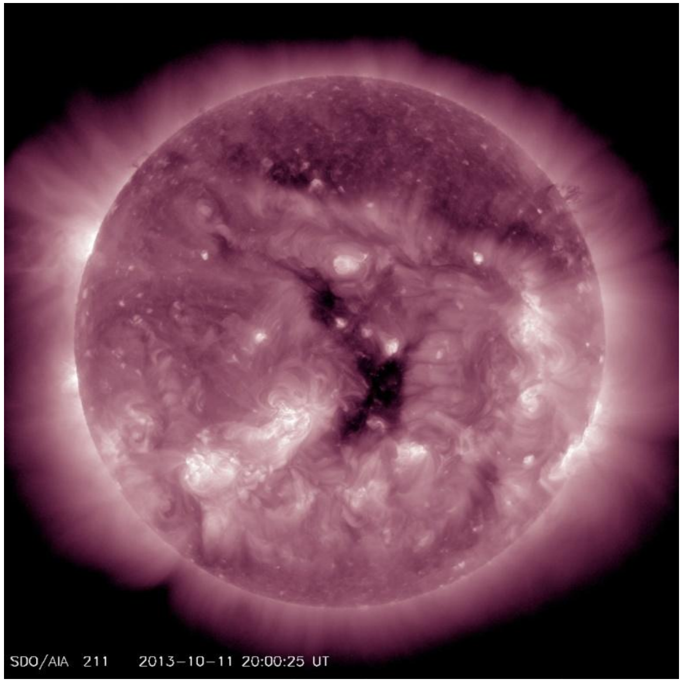

Arten von Aurorae:



➔ Transiente Schock-Aktivität wie
Coronal Mass Ejections (CMEs): ~ 1/3



➔ Stabile koronale Löcher + Hochgeschw.-Wind: ~ ½



➔ Andere:
- Neutral current sheet crossing
- Stabe aurora red arcs
  (due to ring current disturbence)

Kriterien: Farbe (z.B. rot), nördlich, Dynamik, Nacht

Our aurora catalogue:

→ **at night** (+ constellations / 0 twilight / - close to moon)

→ **towards north** (0 east-west / - south)

→ **colour** (+ red, green,blue,blood / 0 white,black,bright)

→ **dynamics** (+ fire,fight / 0 rays)

→ **repetition in next night(s)**

→ N = 0 potential

N = 1 possible

N = 2 very possible

N = 3 probable

N = 4 very probable

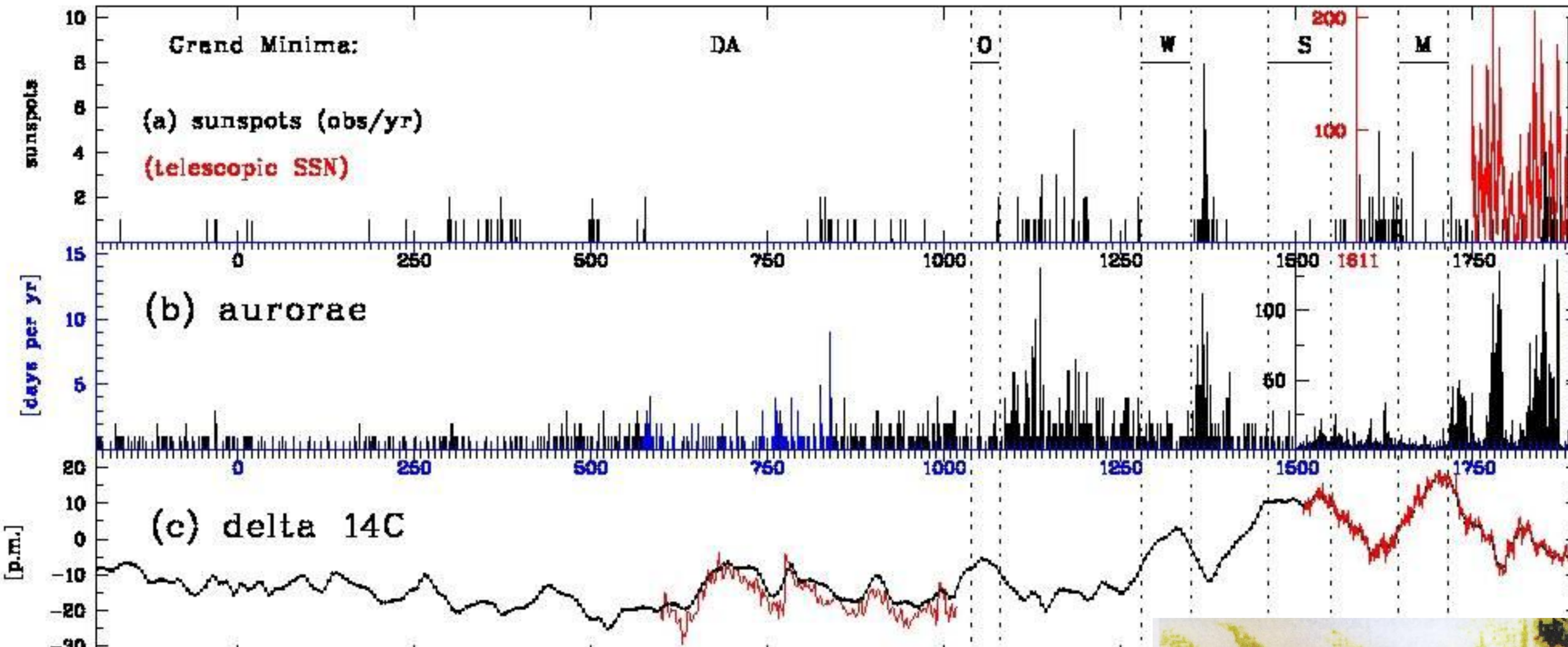
N = 5 certain

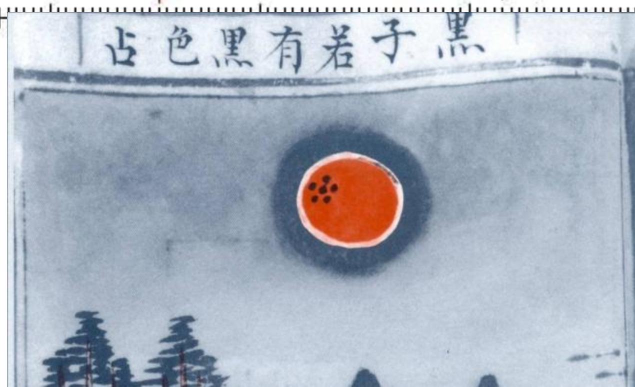
Neuh & Neuh 2015

Reconstruction of solar activity for the last 3000+ years with sunspots, aurorae, and radioisotopes

Grand Minima:

Oort **W**olf **S**pörer **M**aunder





Year	Mo	Dy	Mo	Dy	Loc.	G	S	Reference(s)
−164	3	-	5	-	China	1		YS WX XPJ Xu83 Schove50

WX: The Character 'Wang' (King) appeared in the sun. XPJ: Within the Sun there was the character 'wang" [– possibly a halo display]

XPJ: Emperor Wen of Han, 15th year of the Quanyuan reign period, in spring (Mar-May in WX and XPJ, but Jan-Apr in YS)

Year	Mo	Dy	Mo	Dy	Loc.	G	S	Reference(s)
−42	5	5	6	3	China	1		YS

YS: The Sun was pale blue (blue-white) in colour and cast no shadows. Right in the middle (of the Sun) frequently there were shadows and no brightness. That summer was cold until the 9th month, the Sun then regained its brightness. The contemporary Ching-fang I-ch'uan commented: '... As to the strange darkness of the Sun, even with the gale blowing and the sky cloudless, yer the sunlight was dimmed. It is not difficult to give the explanation. It was said that a dark patch as large as a pellet was seen situated off center on the Sun [– possibly volcanic activity, Scuderi (1990)]

YS: Yung-kuang reign period, 1st year, 4th month

Year	Mo	Dy	Mo	Dy	Loc.	G	S	Reference(s)
−31	3	8	4	6	China		1	WX YS XPJ Xu1983

YS: (When Emperor Ai) was about to confer nobility on Shang, a cousin of the Empress grandmotherFu, Chend-cu'ung, remonstrated, 'When Emperor Ch'eng enfeoffed his maternal uncles as Marquises, the sky became orange and there was darkness by day; within the Sun there was a black vapour. XPJ: ... the sky became orange and then the daylight was dusky; within the Sun there was a black vapour. WX: ... the Sunlight was dim, and a black vapour was in the sun.

XPJ: Emperor Chen of Han, 1st year of the Jianshi reign period, 2nd month ... When Emperor Chen the Filial enfeoffed his maternal uncles as Marquises, the sky became orange ... (YS: Mar 8 to Apr 5, XPJ & WX: Mar 8 - Apr 6)

Year	Mo	Dy	Mo	Dy	Loc.	G	S	Reference(s)
−27	5	10			China	1		WX YS XPJ Xu1983 CS78 Kei

WX: On a yi-wei day the Sun was yellow at rising, and a black vapour as large as a cash (coin) was observed at its centre. Kei: When the Sun appeared, it was yellow. The black spot, as large as a coin, was in the Sun.

XPJ: Emperor Chen of Han, 1st year of the Heping reign period, 3rd month, day yi-wei (32) (should be ji-wei (56) day)

15

Year	Mo	Dy	Mo	Dy	Loc.	G	S	Reference(s)
579	4	3	4	6	China	1		YS WX XPJ Xu83 CS Kei

WX: shortly after sunrise and shortly before sunset, on both occasions, a black patch as large as a hen's egg was seen in the Sun, and it lasted for four days. Kei: When the sun was about to rise as well as to set, a spot of black colour, as large as a hens egg was in the Sun. It vanished after four days.

XPJ: Emperor Xuan of Northern Zhou, 1st year of the Daxiang reign period, 2nd month, day gui-wei (20)

Year	Mo	Dy	Mo	Dy	Loc.	G	S	Reference(s)
807	3	17	3	24	Germany		1	WX Xu83 Schove83

WX: The star Mercury was seen on 17 March in the Sun like a small black spot, slightly above the center of that celestial body, which was visible to us for eight days. When it first entered or left (the Sun) could not be noted by us due to clouds [– neither Mercury nor Venus transit that year, hence a spot]

Date in Annales Regni Francorum given as *on the 16th calends April* in AD 807, which is Mar 17.

Year	Mo	Dy	Mo	Dy	Loc.	G	S	Reference(s)
826	5	7			China	1		YS WX XPJ Xu83 CS Kei

WX: Within the Sun there was a black vapour (mass) like a cup. Kei: In the Sun there was a black vapour like a wine glass.

837	12	22	1	2 24	China	1	YS WX XPJ Xu83 CS Kei

WX: In the Sun there was a black spot as large as a hens egg, and the Sun was red like ochre. YS: In the Sun there was a black spot as large as a hen's egg, and the Sun was red like ochre, darkened the day, and murk lingered till day gui-wei (20) Kei: Nov. 21 (the calendar of Tang Dynasty), a black spot as large as a hens egg was in the sun. The sun was red as riddle, and darkened the day, and murk lingered till [Dec] 23.
XPJ: Emperor Wenzong of
gui-wei (20)) = AD 837 De

840	5	25	8	23

WX: [Ghars al-Niᶜma Muh
handwritings of Jaᶜfar b. a
appeared a black spot close
and when two days had gor
on the Sun for 91 days [i.e.
that this spot was due to the
above-mentioned time inter
19 Rajab in year 225 Hijra
and May 25 was indeed

841	12	30

WX: Within the Sun th
XPJ: Emperor Wuzong
(1873) gave Dec 31 (M

851	12	2

WX: The Sun had no p
brilliance (YS: Sun wa
XPJ: 1st year of the N
(WX: Dec 22)

1128	12	8	England	2	VV09 Stephenson & Willis (1999)

... on Saturday, December 8, there appeared from the morning right to the evening two black spheres against the Sun (lat.: quasi due nigre pile infra solis orbitam). The first was in the upper part and large, the second in the lower and small, and each was directly opposite the other as this diagram shows.
John of Worcester: *In the 3rd year of Lothar, emperor of the Romans, in the 2oth year of King Henry of the English, in the 2nd year of the 470th Olympiad, 7th indiction, 25th moon, on Saturday, 8 December*, ..., which is AD 1128 Dec 8, indeed a Saturday, even though the Olympiad and the lunar phase are wrong (Stephenson & Willis 1999)

1129	3	22	4	14	China	1	YS WX XPJ Kei

WX: Day of the new moon, there was a black mole on the Sun (Jin shi). Kei: Mar 1 (Chinese calendar) there was a black spot in the Sun, and on the 24th it vanished at last. XPJ: There was a black sot on the Sun. Not until day ren-yin (59) did the black spot disappear [– possibly volcanic activity (Scuderi 1990)]
XPJ: Emperor Gaozong of Song, 3rd year of the Jianyan reign period, 3rd month, day ji-mao (16) = 1129 Mar 22 until day ren-yin (59) = Apr 14 [new moon 1129 Mar 21/22] (Williams (1873) gave AD 1129 Apr 21 from Ma Twan Lin)

1905	10	31			China	1	YS

YS: On the Sun there was a black spot.
YS: Kuang-hsu reign-period, 31st year, 10th month, 4th day

1911	1	30			China	1	YS

YS: Within the Sun there was produced a black spot.
YS: Hsuan-tung reign-period, 3rd year, 1st month, 1st day

1916	7/8		9/10		China	1	YS

YS: Within the Sun there was a black spot.
YS: 5th year of the republic, autumn (YS: Jul/Aug to Sep/Oct)

1917	2	11			China	1	YS

YS: Within the Sun there was a black spot like a hens egg.
YS: 6th year of the republic, 1st month, 20th day

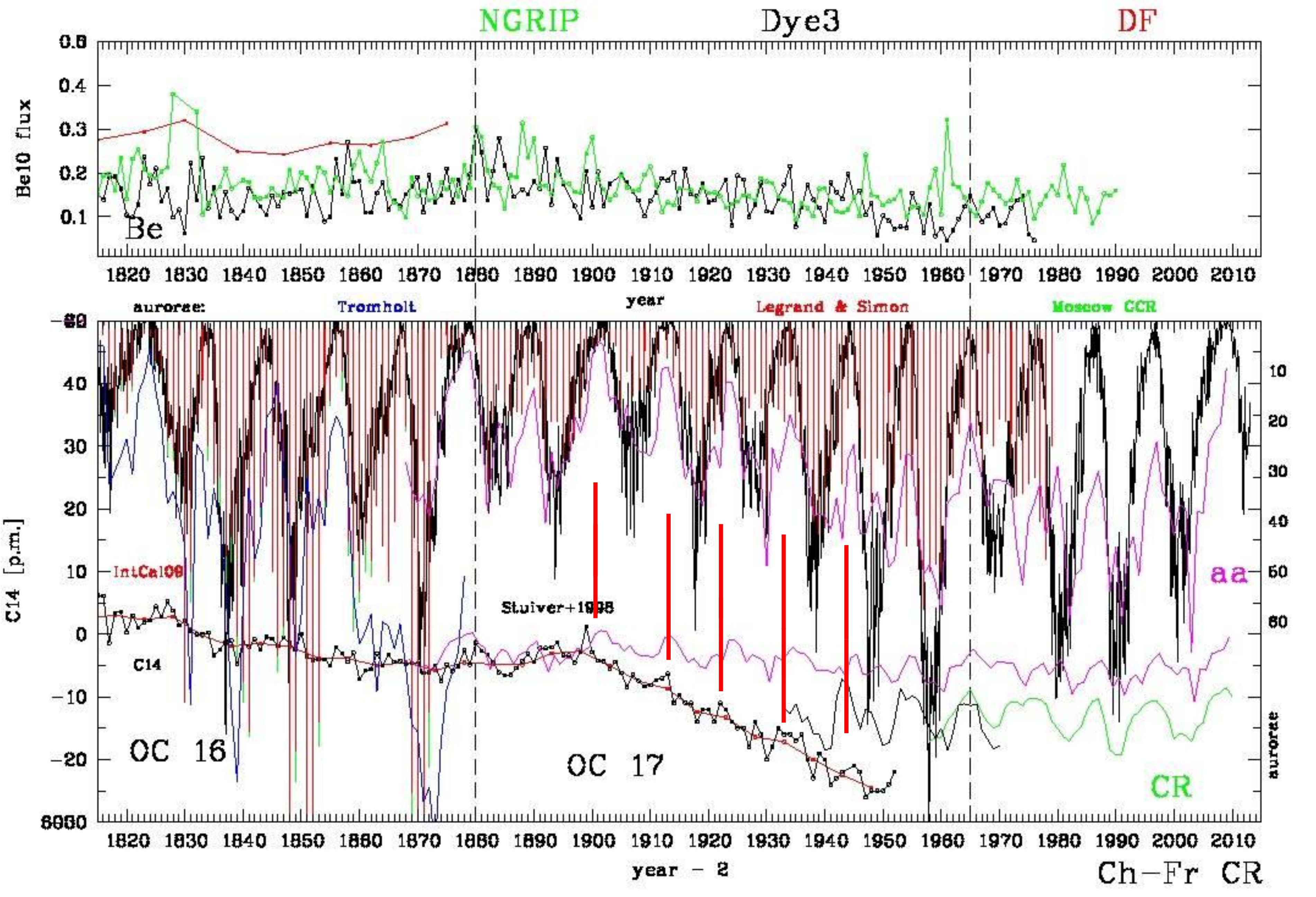
1918	2	11	2	13	China	1	YS

YS: A black spot was seen within the Sun. It disappeared after several days.
YS: 7th year of the republic, 1st month, 1st day (for several, i.e. at least 3 days)

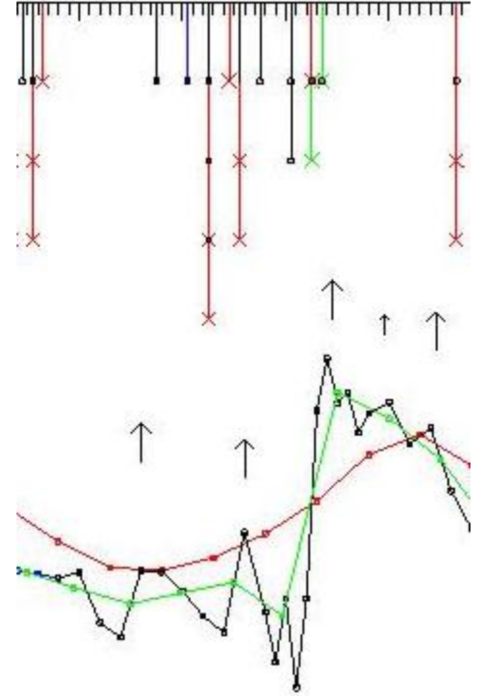
Rekonstruktion der Sonnenaktivität:

- ➔ **Sonnenflecken**
- ➔ **Aurorae**
- ➔ **C-14 und Be-10 (also kosmische Strahlung)**
- ➔ **Kometen:**
  Schweiflänge, Helligkeit, Sichtbarkeitsdauer, Häufigkeit
- ➔ **Sichtbarkeit bzw. Helligkeit der Korona bei totaler SoFi**
- ➔ **Helligkeit von reflektierenden (Klein-)Körpern im SoSy.**

OC (Octave Cycle) = 8 Schwabe cycles (here: AD 1810 – 2010)



What is the cause of the ^{14}C variation ?



A supernova ? Not observed, no remnant

A gamma-ray burst ? Possible, but very rare

A comet impact ? Did not happen

A solar super-flare ? Dubious, if possible at all (no spots, no aurorae)

What else ? **A fast strong drop in solar activity**

➔ less solar wind ➔ more cosmic rays and ^{14}C

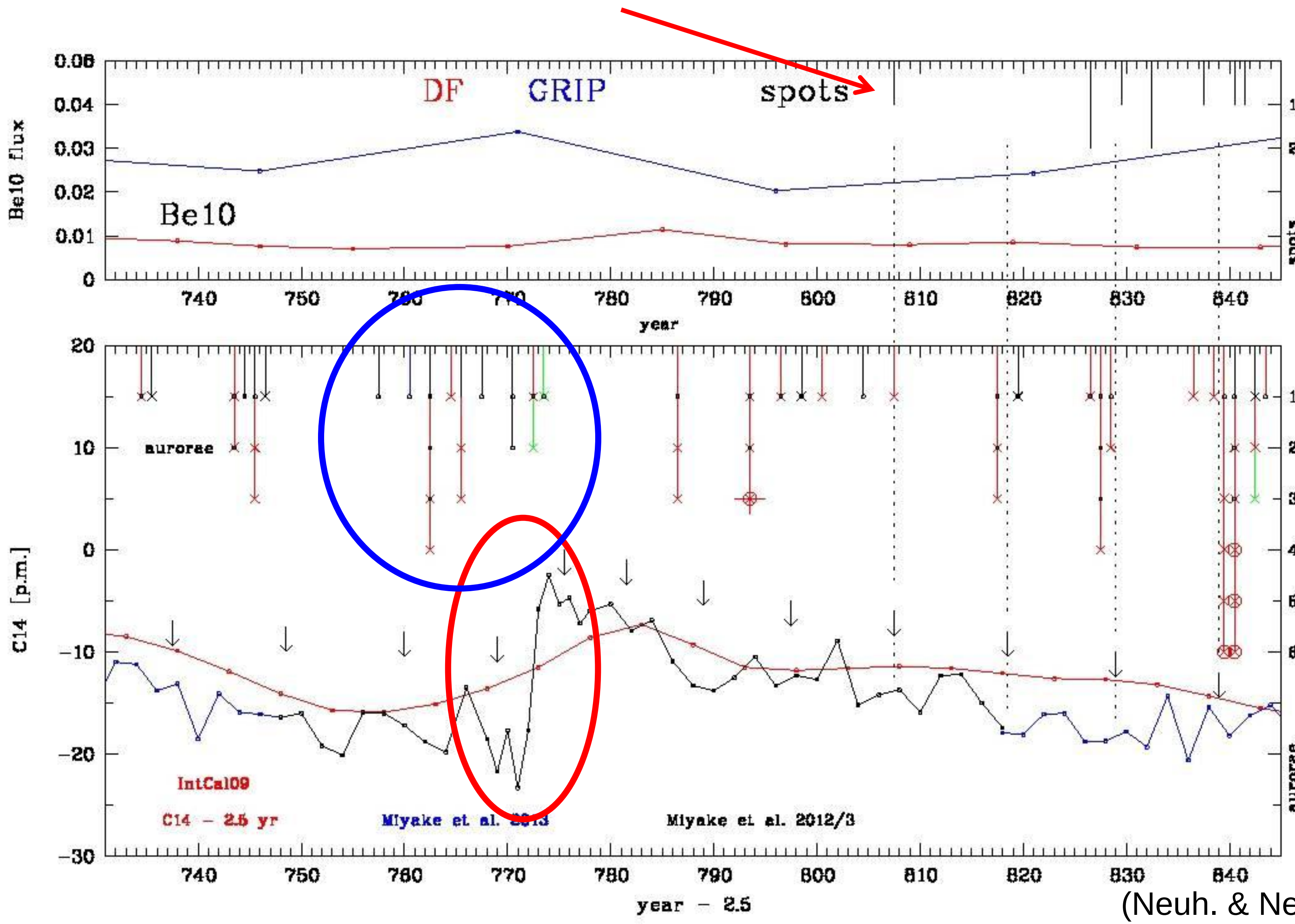
(similar to the sudden start of the Dalton minimum
and maybe also BC 671, ~ once per millenium)

Neuh & Neuh 2015a
arXiv:1503.01581
+
Neuh & Neuh 2015b
arXiv:1508.06745

Timing ? When a weak short cycle happens after a strong cycle …

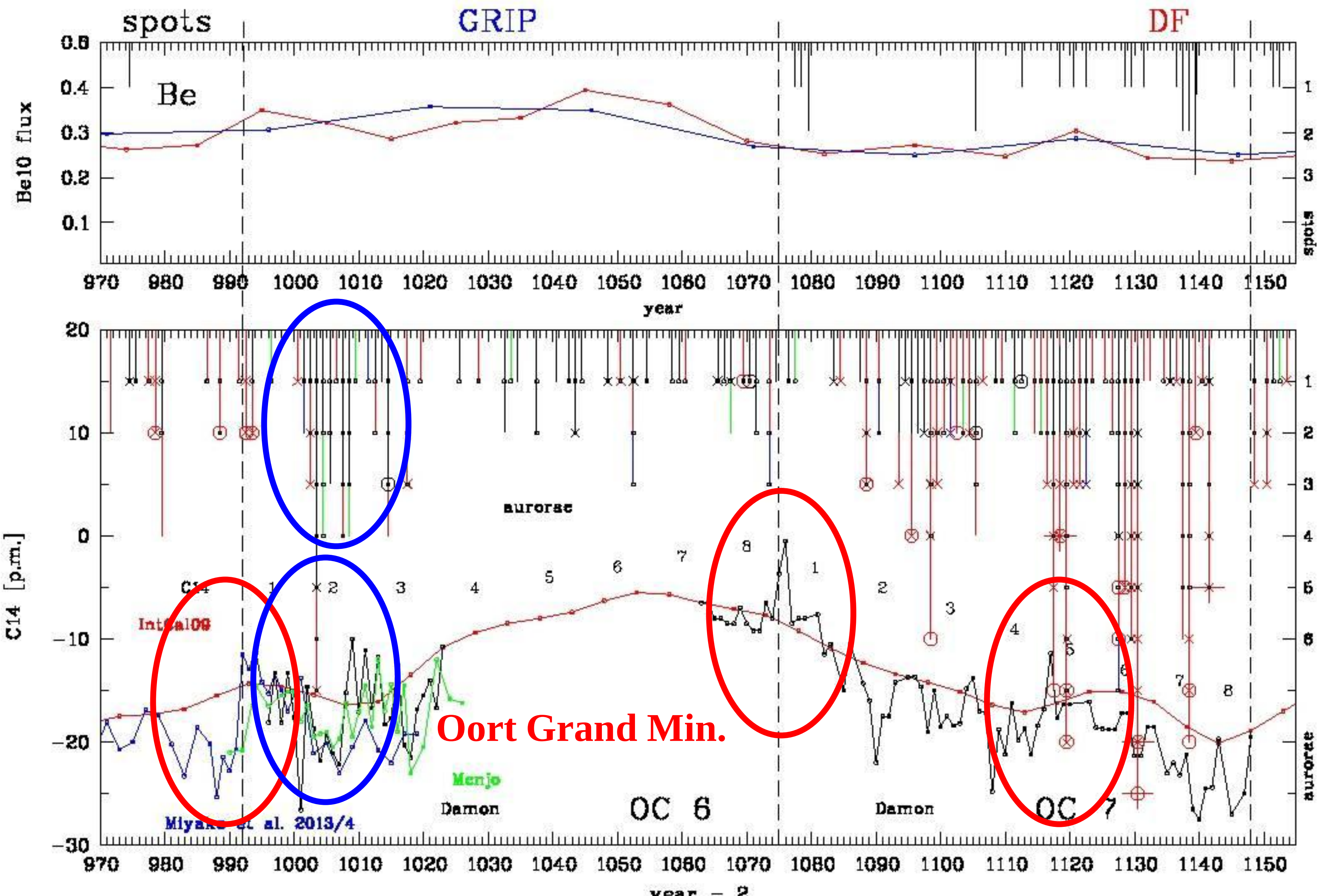
also AD **994**

Am 26. Feb war wieder eine MoFi,, und es erschienen in dieser Nacht große Schlachtreihen …
Und der Stern Merkur wurde am 17. März vor der Sonne gesehen wie ein kleiner schwarzer Fleck, etwas über dem Zentrum, und zwar 8 Tage lang, aber als er erstmals davor zog und als es wegzog, behinderten Wolken die Sicht. (Fränkische Reichschronik)

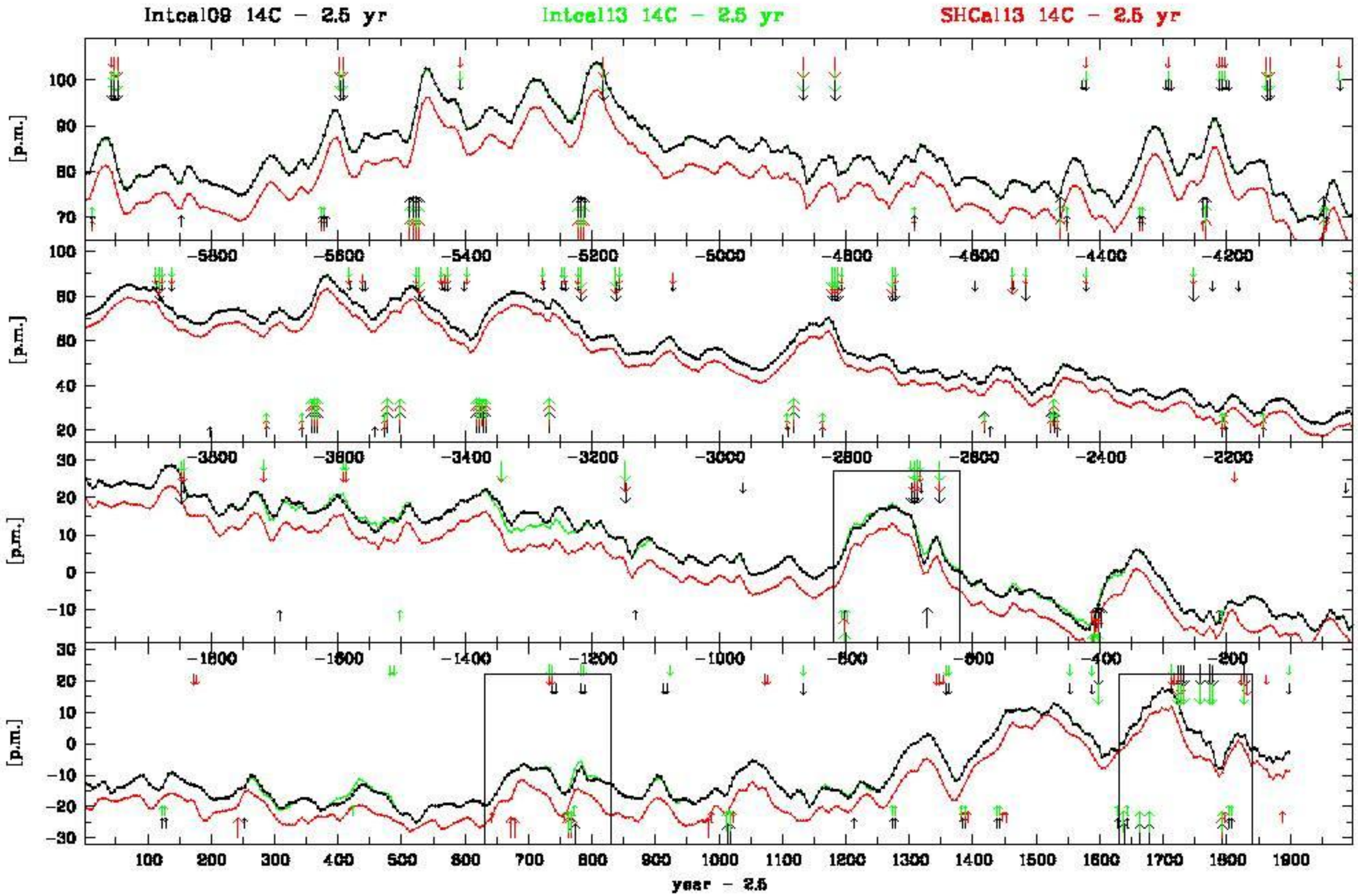


(Neuh. & Neuh. 2015)

AD 994 / 5

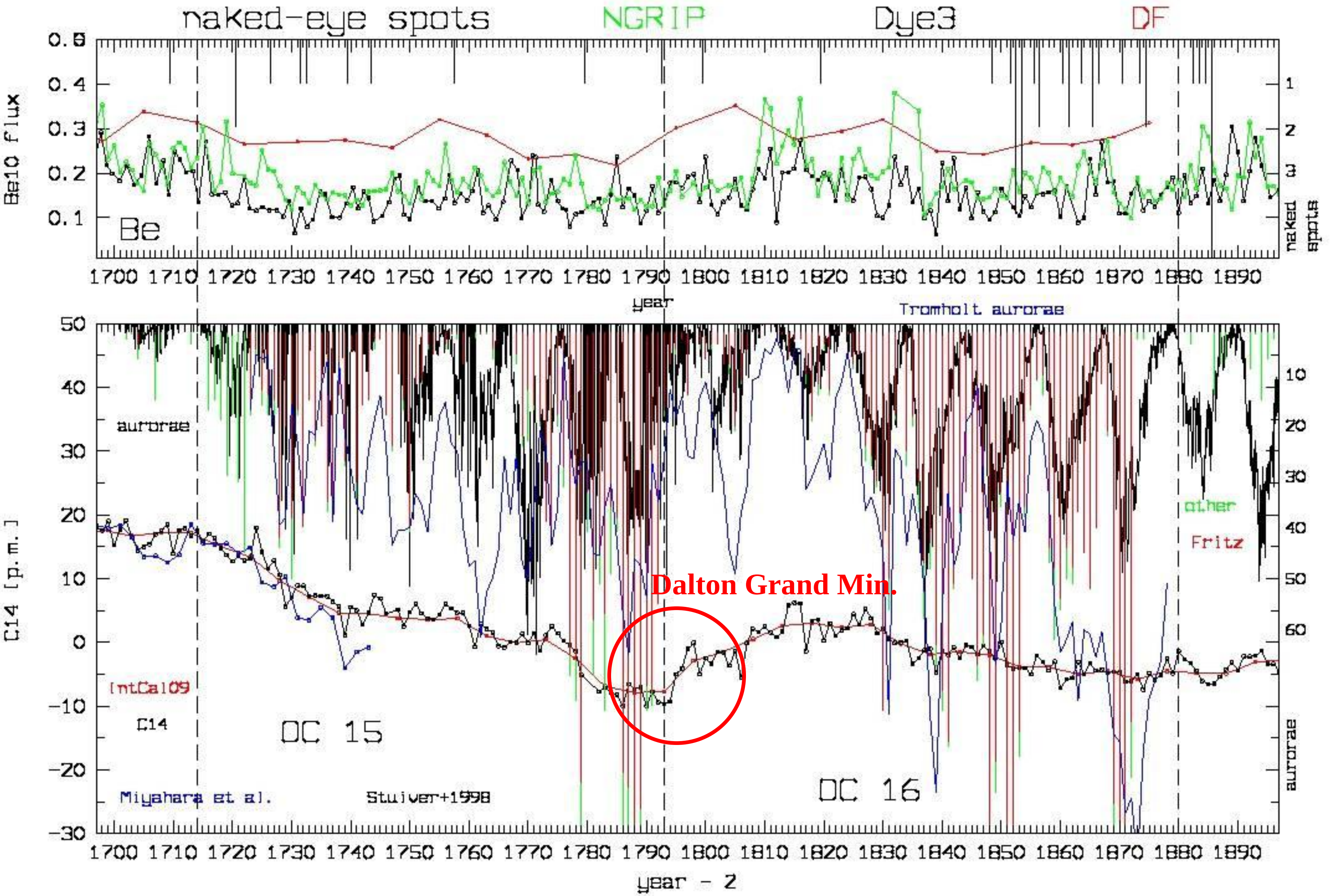


A fast strong drop in solar activity ➔ less solar wind ➔ more cosmic rays and ^{14}C



Intcal09 14C - 2.5 yr
Intcal13 14C - 2.5 yr
SHCal13 14C - 2.5 yr
[p.m.]
year - 2.5

AD 1700 – 1900

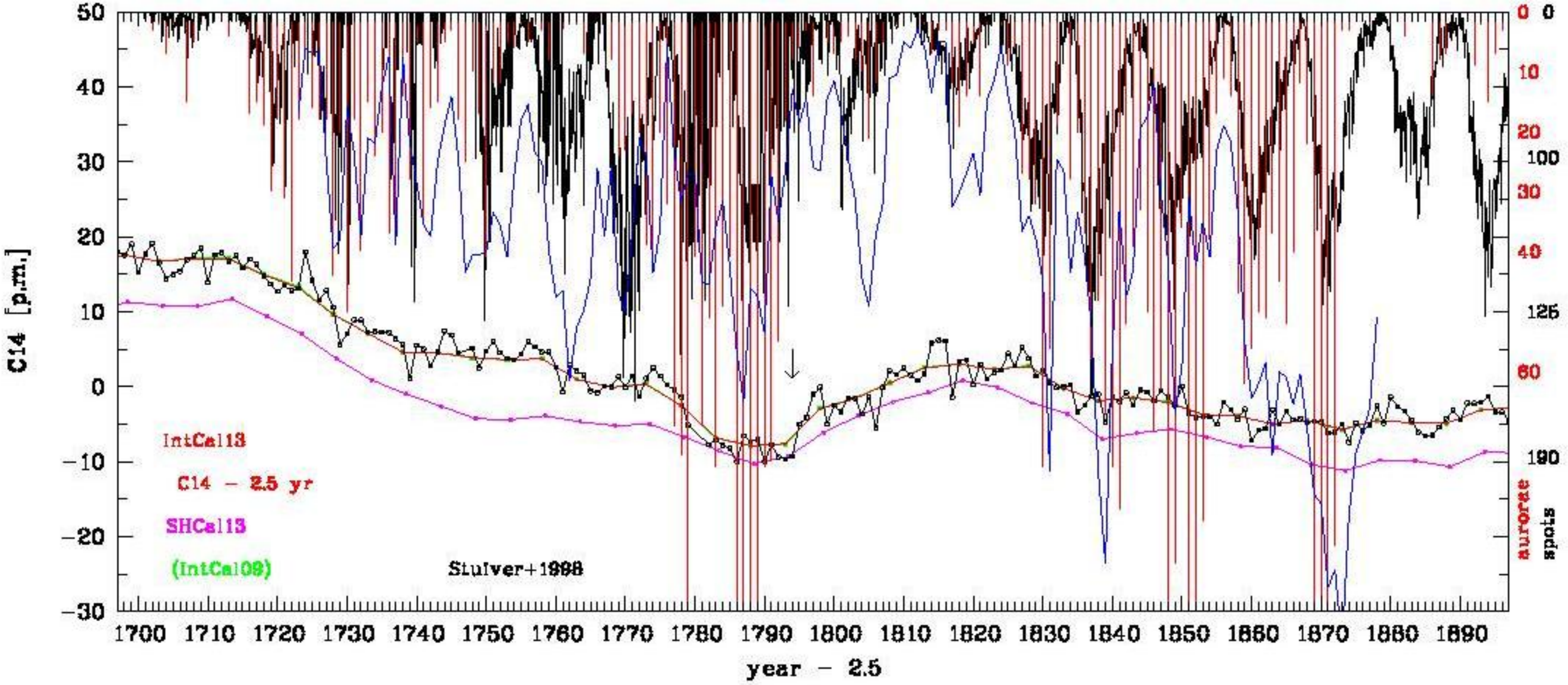


naked-eye spots
NGRIP
Dye3
DF
Be10 flux
Be
naked spots
year
Tromholt aurorae
aurorae
other
Fritz
Dalton Grand Min.
IntCal09
C14
C14 [p.m.]
DC 15
DC 16
Miyahara et al.
Stuiver+1998
aurorae
year - 2

Maunder Minimum ended AD 1712/15.

Aurora level increases from cycle minimum to minimum.

sunspots, aurorae (Tromholt, Fritz), ^{14}C



(1) At the end of the Grand Maximum (~1790) ➔ low ^{14}C level

(2) Decline of strong Schwabe cycle no. 4 (~ 1793) ➔ ^{14}C rises

(3) Weak activity in Dalton (~1800-1830) ➔ ^{14}C level high

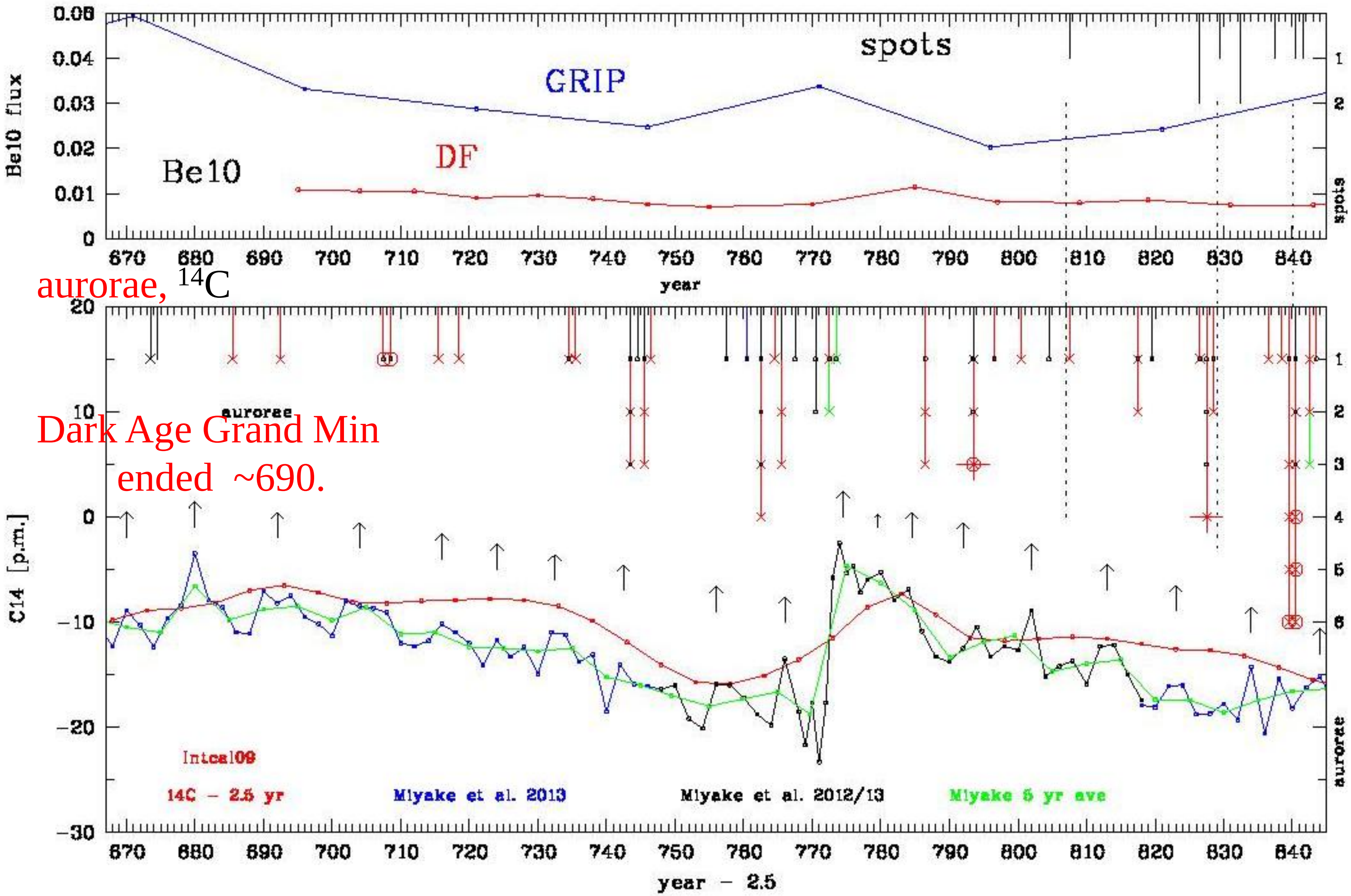
Maunder Minimum ended AD 1712/15.

Aurora level increases from cycle minimum to minimum.

sunspots, aurorae, ^{14}C

Same around AD 774/5 ?

(1) At the end of the Grand Maximum (~1790) ➔ low ^{14}C level
(2) Decline of strong Schwabe cycle no. 4 (~ 1793) ➔ ^{14}C rises
(3) Weak activity in Dalton (~1800-1830) ➔ ^{14}C level high

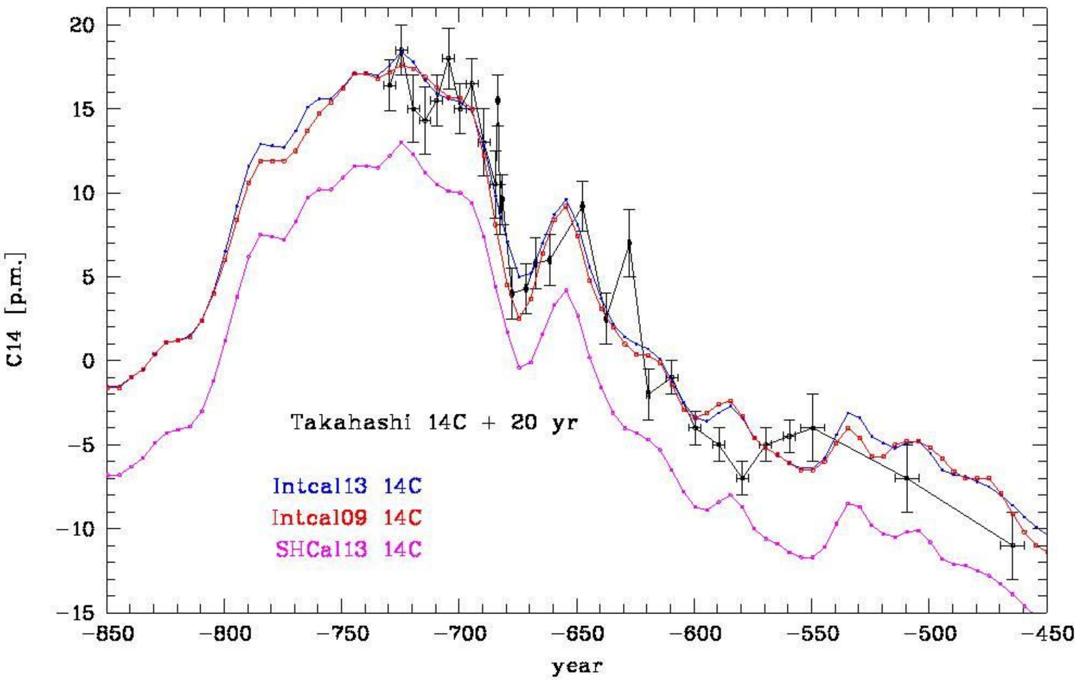


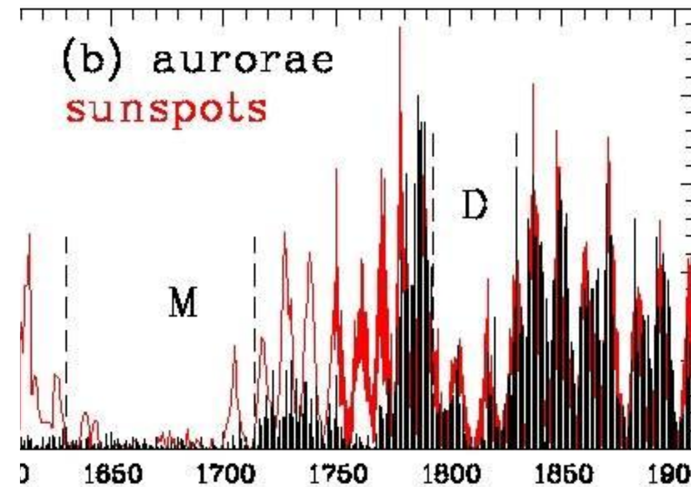
(1) At the end of the Grand Maximum (~770) ➔ low ^{14}C level

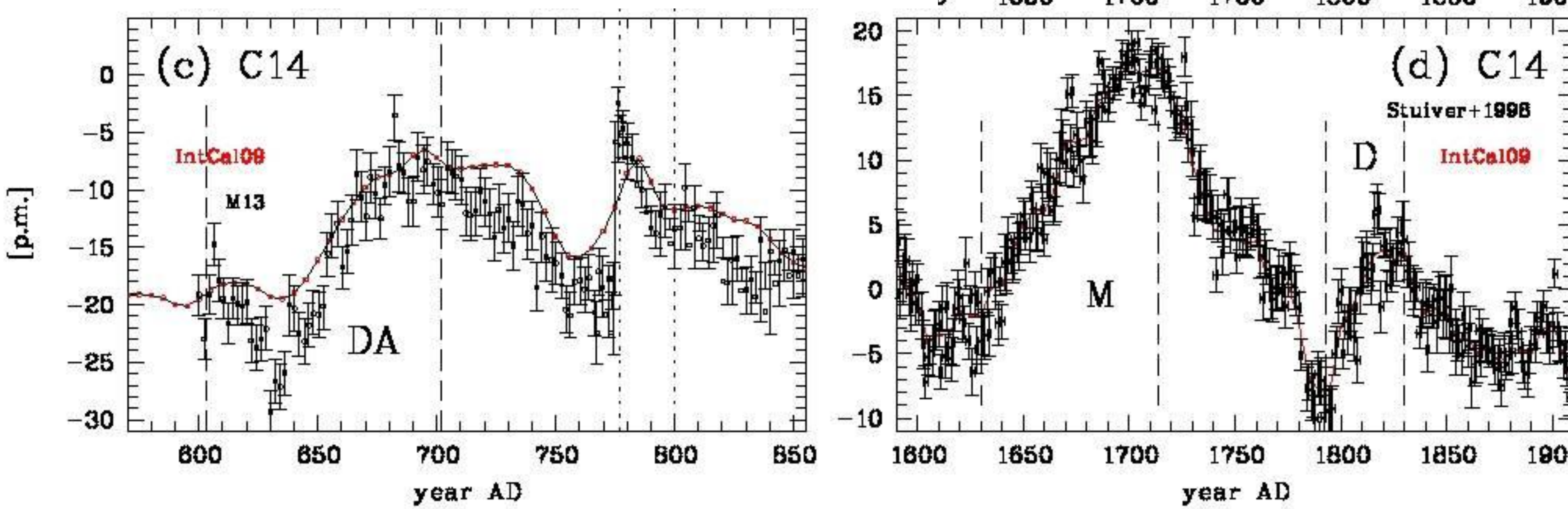
(2) Decline of strong Schwabe cycle no. 4 (~ 774) ➔ ^{14}C rises

(3) Weak activity ➔ ^{14}C level high

Neuh & Neuh 2015


Takahashi 14C + 20 yr
Intcal13 14C
Intcal09 14C
SHCal13 14C
C14 [p.m.]
year

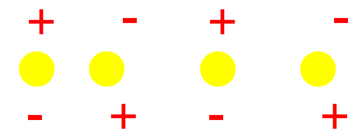

(b) aurorae
sunspots
M
D

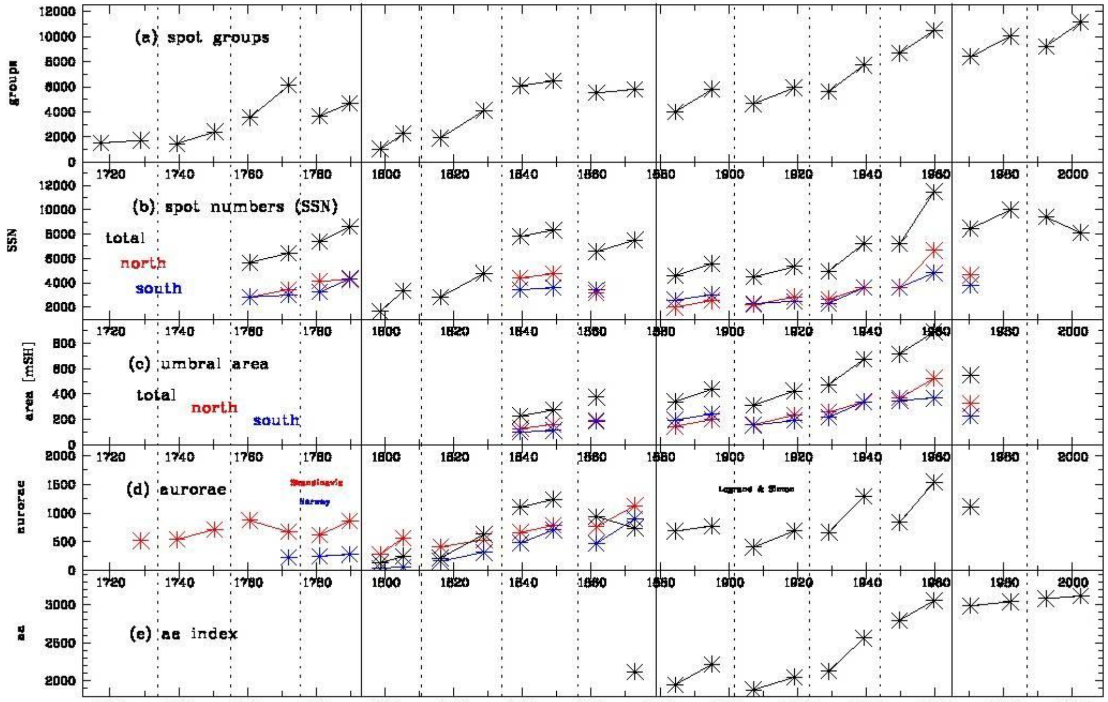

(c) C14
IntCal09
M13
DA
[p.m.]
year AD
(d) C14
Stuiver+1998
IntCal09
M
D
year AD

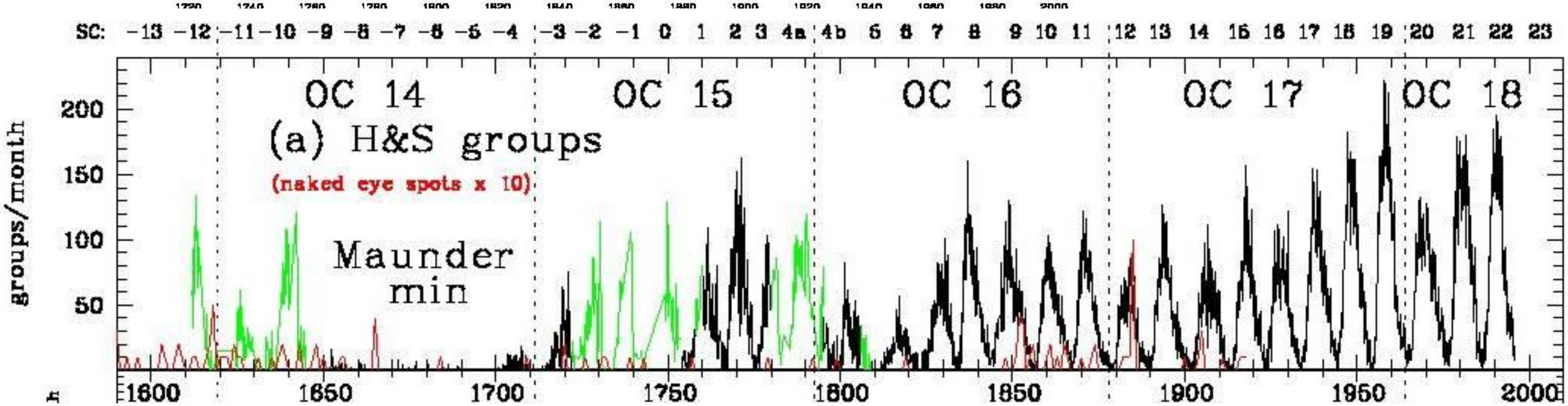
Schwabe Cycle: 10-11 year sunspot cycle (Schwabe 1844)

Magnetic Hale cycle (Hale 1938): <u>1st sub-harmonic of Schwabe</u>

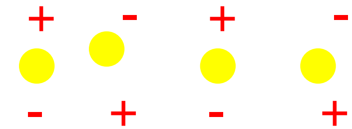
Gnevyshev – Ohl odd – even rule







Schwabe Cycle: 10-11 year sunspot cycle (Schwabe 1844)



Magnetic Hale cycle (Hale 1938): 1st sub-harmonic of Schwabe

Four-Schwabe-Cycles in hemispheric spot distribution – 2nd sub-harmonic

(Pulkkinen et al. 1995, Zolotova et al. 2010)

770 N.V. Zolotova et al.: Secular variation of hemispheric phase differences in the solar

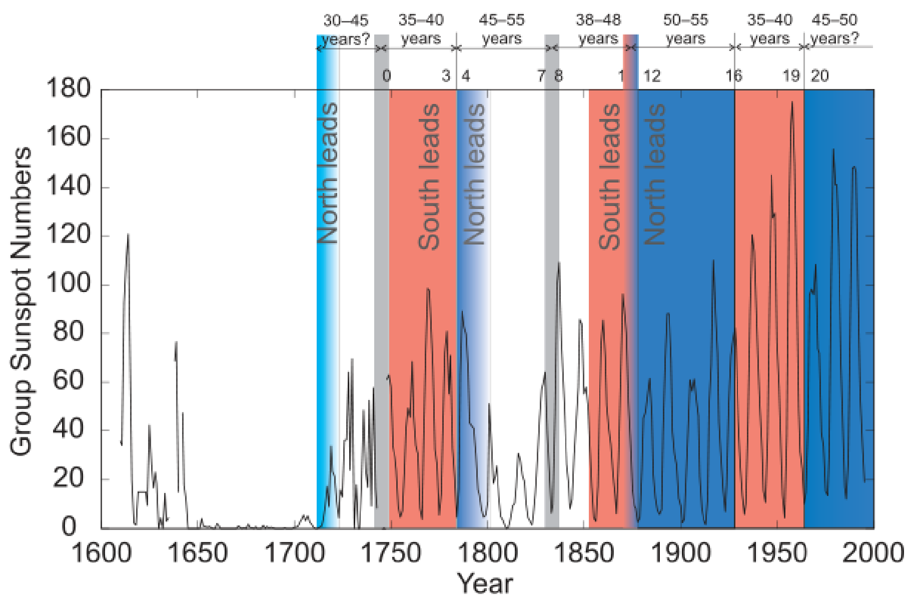
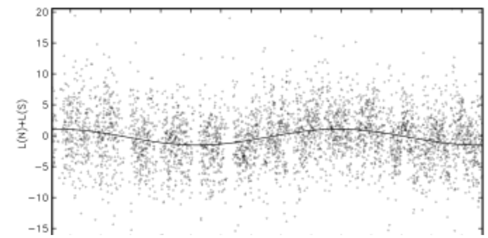
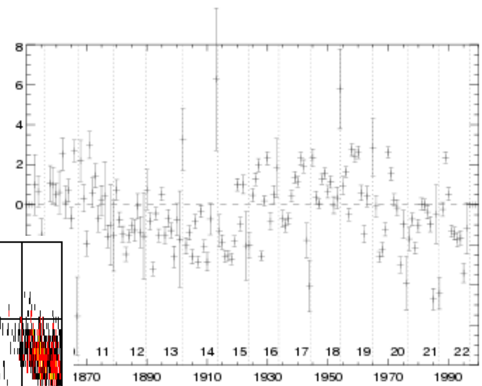


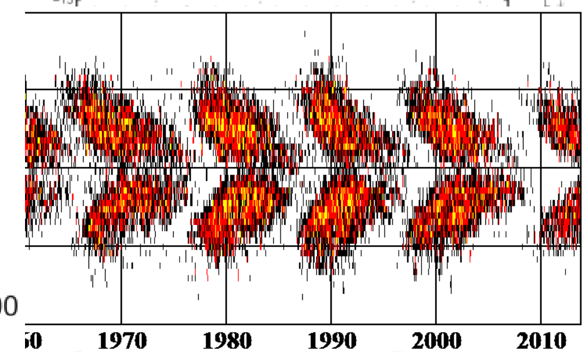
Fig. 4 (online colour at: www.an-journal.org) Yearly group sunspot numbers versus time. Periods of the northern hemisphere preceding the southern one are marked by blue colour, periods when the southern hemisphere precedes the northern one are marked by red colour. Vertical lines denote the sign changes of the phase difference. Grey bars indicate probable sign changes. The cycle numbers refer to the Zürich numbering.

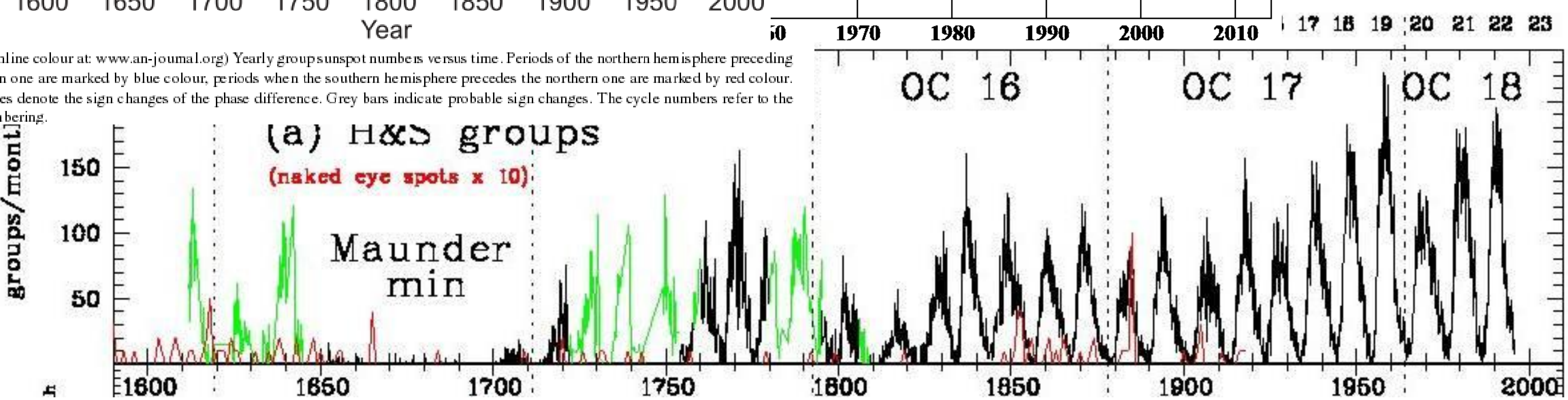
P.J. Pulkkinen et al.: Long-term variation of sunspot latitudes L45





…early averages of the difference $\langle\lambda_N\rangle_{365} + \langle\lambda_S\rangle_{365}$. The ver-…ed lines denote beginnings of sunspot cycles which are num-…the lower part





8-Schwabe Cycle Pulsation (Richard 2004 SoPh)

Richard (2004) only for last 300 yr, only for sunspots

THE EIGHT-SCHWABE-CYCLE PULSATION

JEAN-GUILLAUME RICHARD

(R

Abstract. The shape of
additional Schwabe cycle
taken into account in the te
cycle, a saw-tooth of exac
last sunspot maximum of
as high as its first maxim
Pulsation is defined as a s
cycle is a result of long-te

Solar Physics **223:**

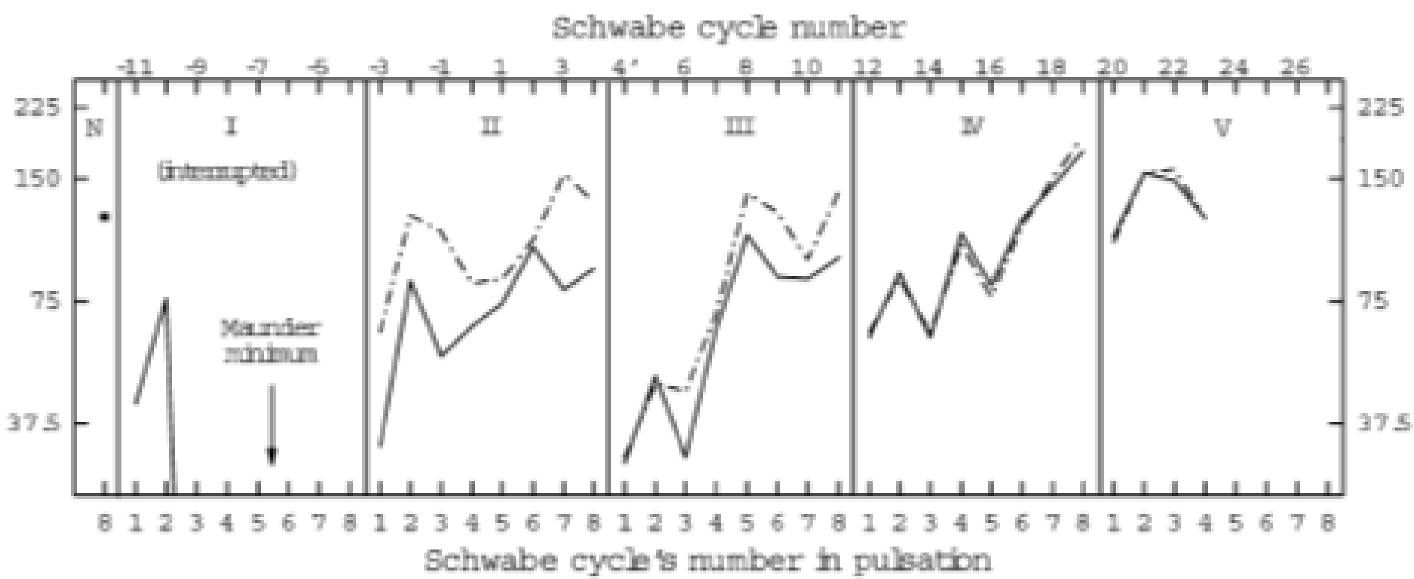
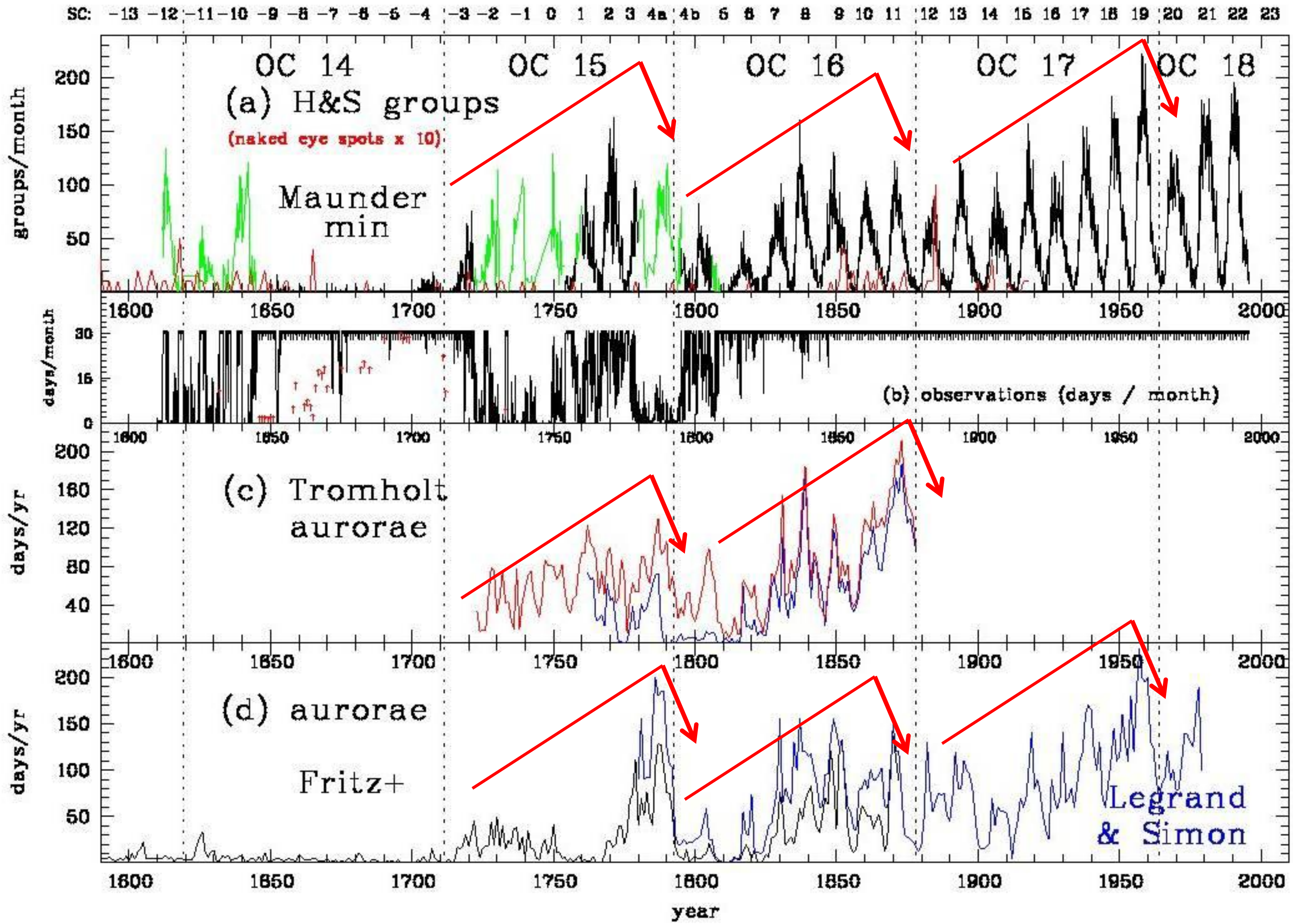


Figure 1. Telescopic record of Schwabe's yearly mean sunspot maxima. Group (Rg) maxima from 1610 to 2000 (*solid line*) and International (Rz) maxima from 1712 to 2000 (*dash-dotted line*) are plotted on a logarithmic scale according to Schwabe cycle number (*top abscissa*), after data in Tables I, II, and III. Both lines are broken between the 8th and the first maxima of two successive 'Pulsations' (*bottom abscissa*) so as to clearly show the suggested chronological boundaries (*vertical lines*) of Pulsations N, I, II, III, IV, and V. Maunder Minimum maxima, which are lower than 6, are not shown (suggested anomalous 'interruption' of Pulsation I).

Octave sequence = 8 Schwabe cycles (here: AD 1600 – 2000)



Timing of fast strong increase in 14C (fast strong drop in solar wind):

At 1795 after a GO even-odd pair (1st harm. of Schwabe, like Hale cycle)

and after a package of 4 Schwabe cycles (2nd harm.) w/ same hem. leadership

770 N.V. Zolotova et al.: Secular variation of hemispheric phase differences in the solar cycle

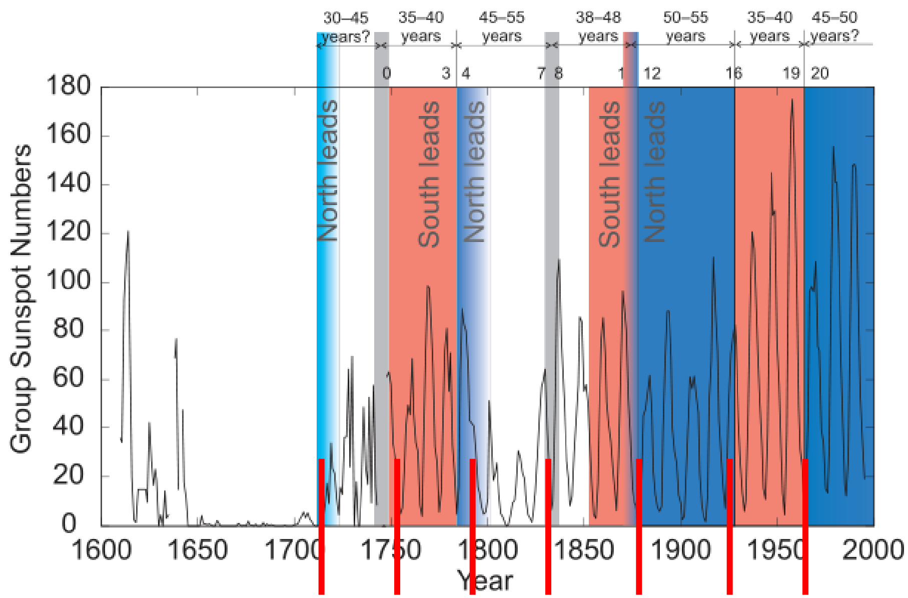
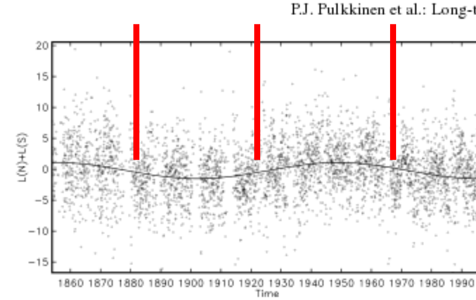
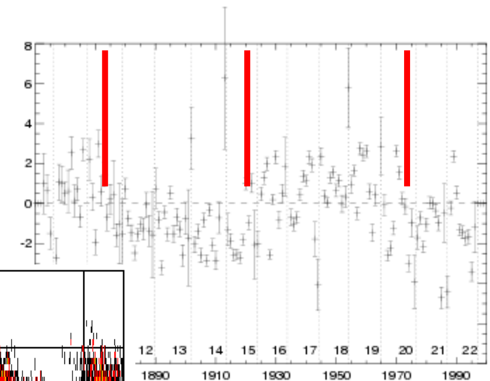


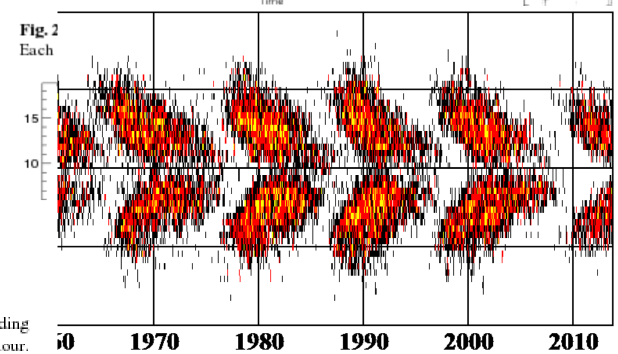
Fig. 4 (online colour at: www.an-journal.org) Yearly group sunspot numbers versus time. Periods of the northern hemisphere preceding the southern one are marked by blue colour, periods when the southern hemisphere precedes the northern one are marked by red colour. Vertical lines denote the sign changes of the phase difference. Grey bars indicate probable sign changes. The cycle numbers refer to the Zürich numbering.

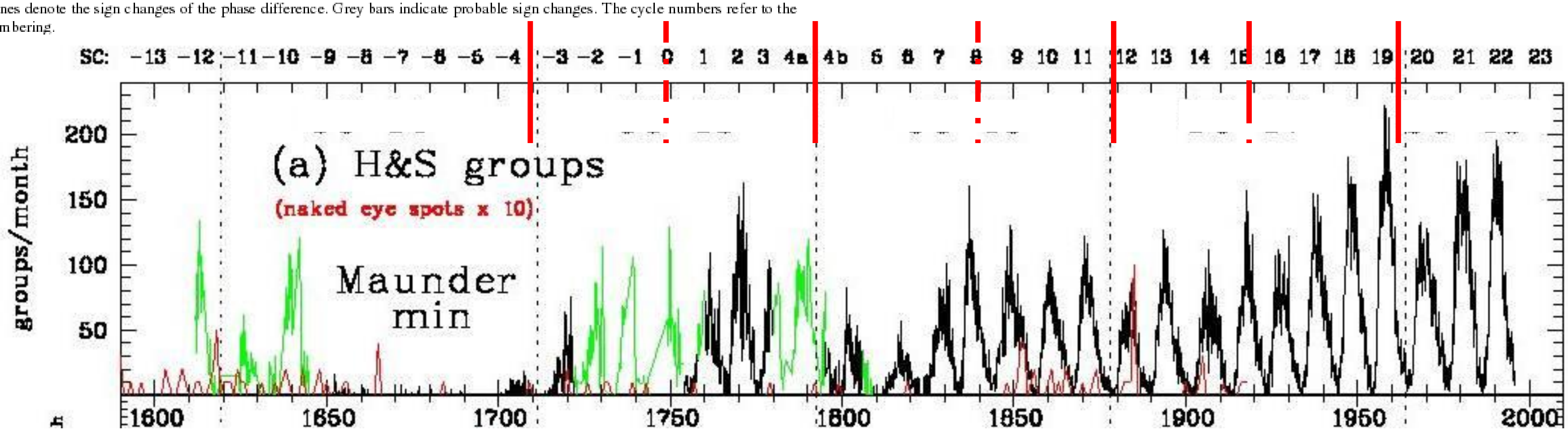
P.J. Pulkkinen et al.: Long-term variation of sunspot latitudes L45



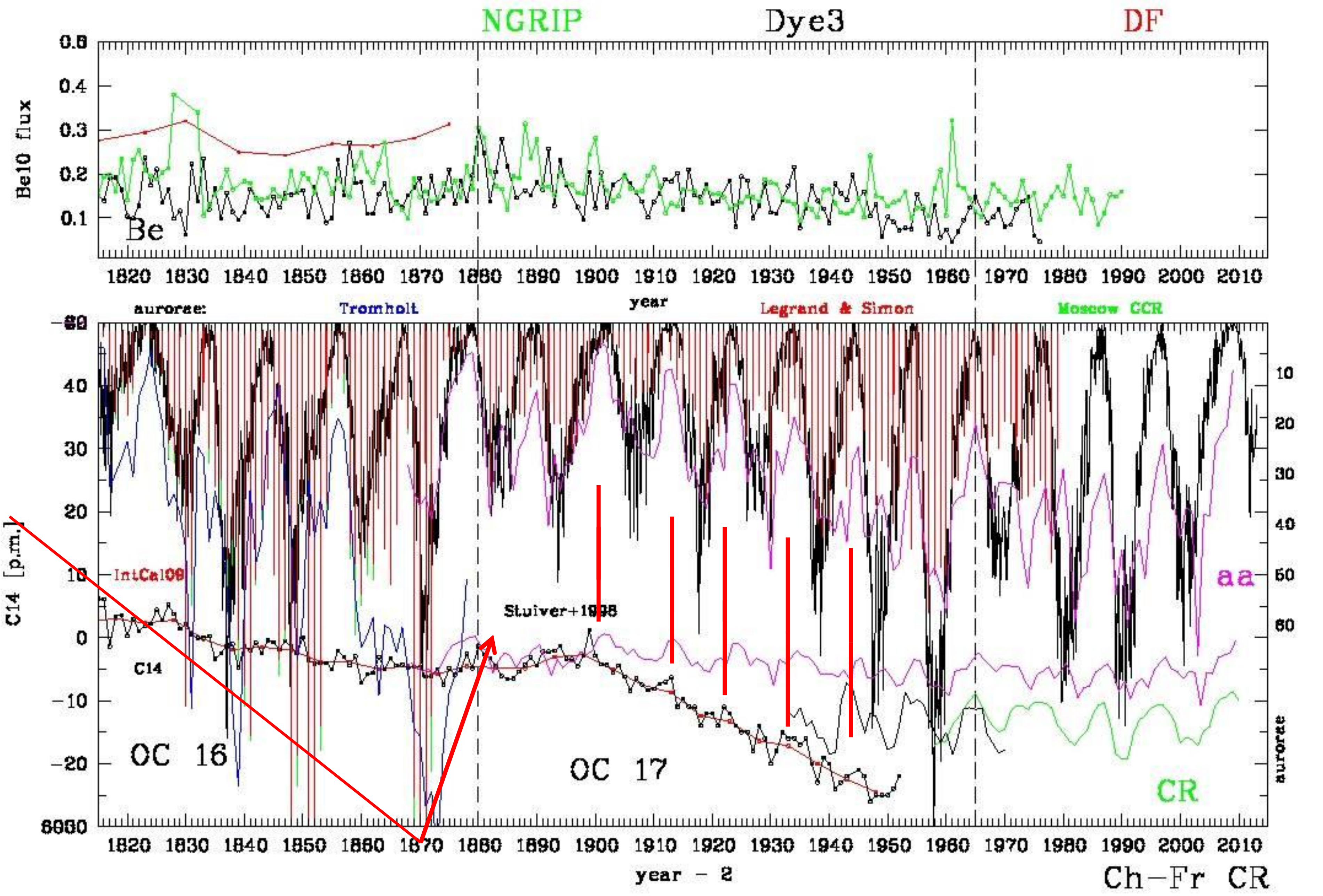


…rages of the difference $\langle\lambda_N\rangle_{365} + \langle\lambda_S\rangle_{365}$. The ver… denote beginnings of sunspot cycles which are num… …r part



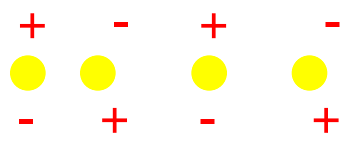


OC (Octave Cycle) = 8 Schwabe cycles (here: AD 1810 – 2010)

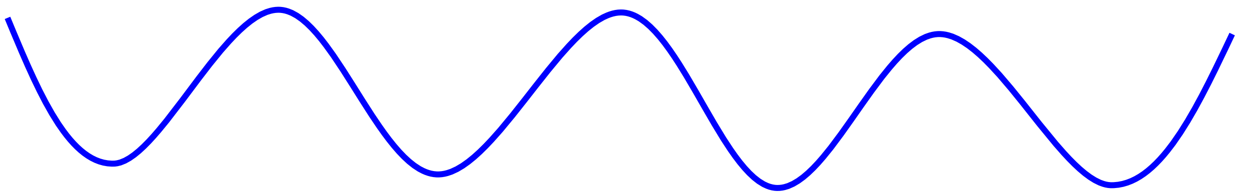


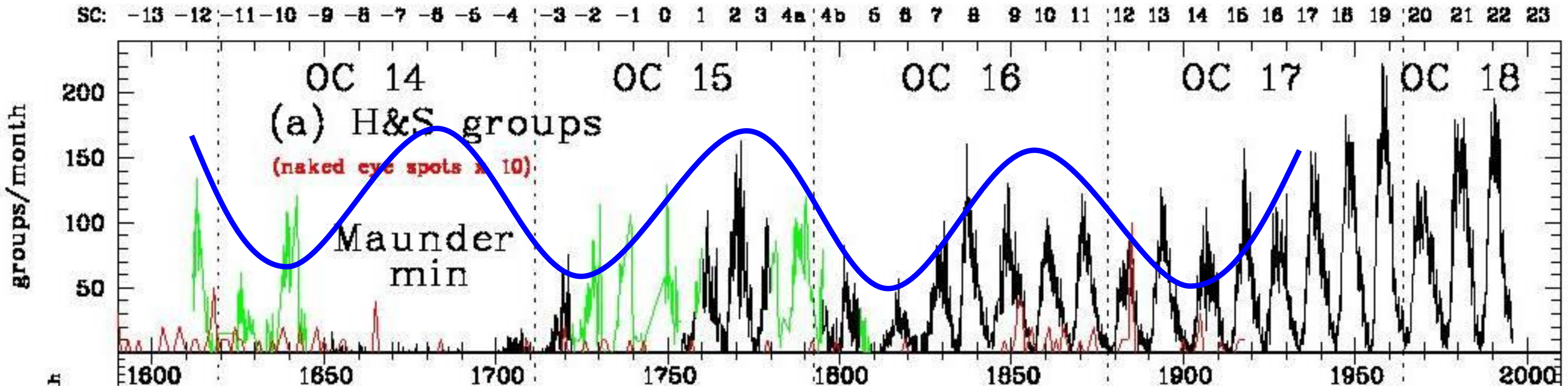
Schwabe Cycle: 10-11 year sunspot cycle

Magnetic Hale cycle: <u>1st sub-harmonic of Schwabe</u>
Gnevyshev – Ohl odd – even rule



<u>Octave Sequence = Gleissberg cycle ???</u>





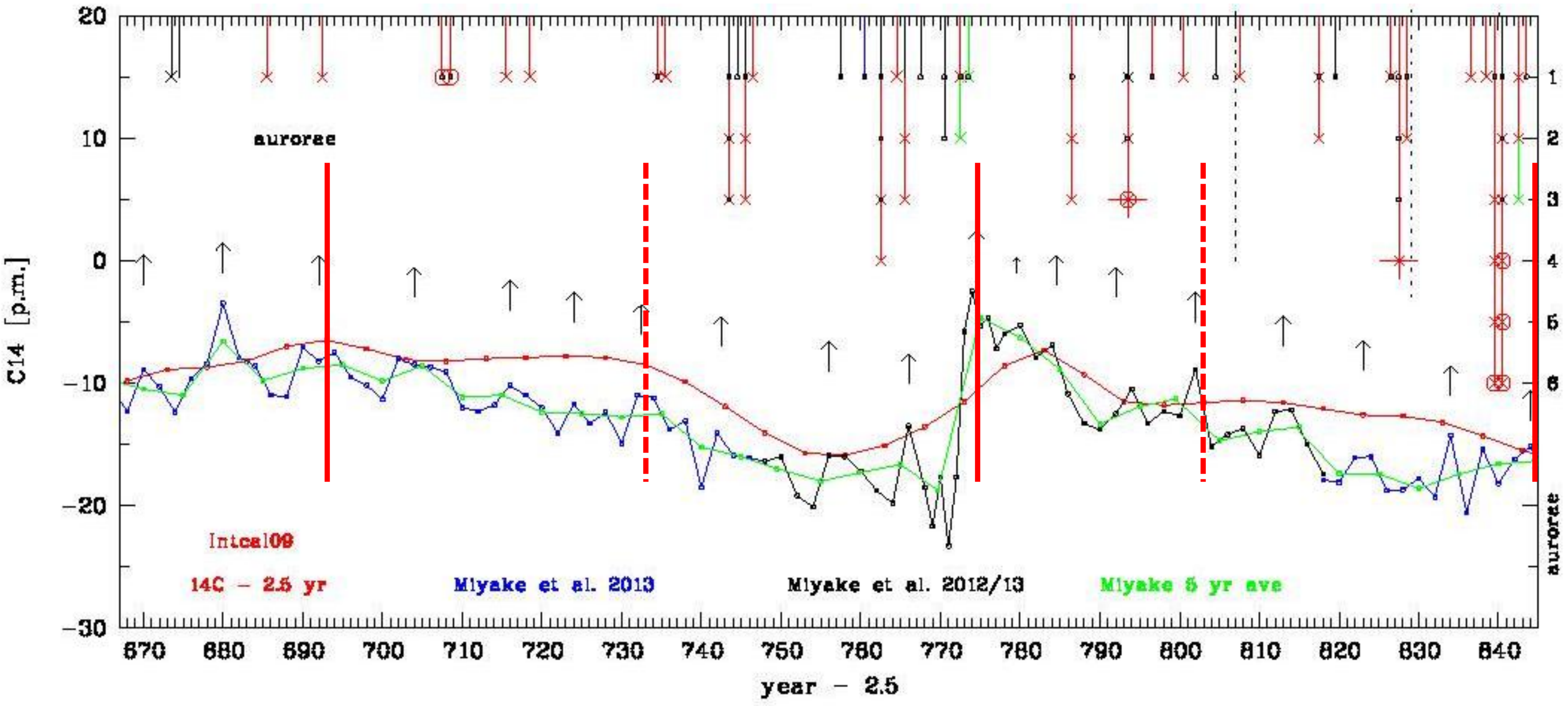
<u>No, Gleissberg is symmetric</u> and does not work thru Maunder Minimum !
Gleissberg: Cycle length is 25 to 125 yr …

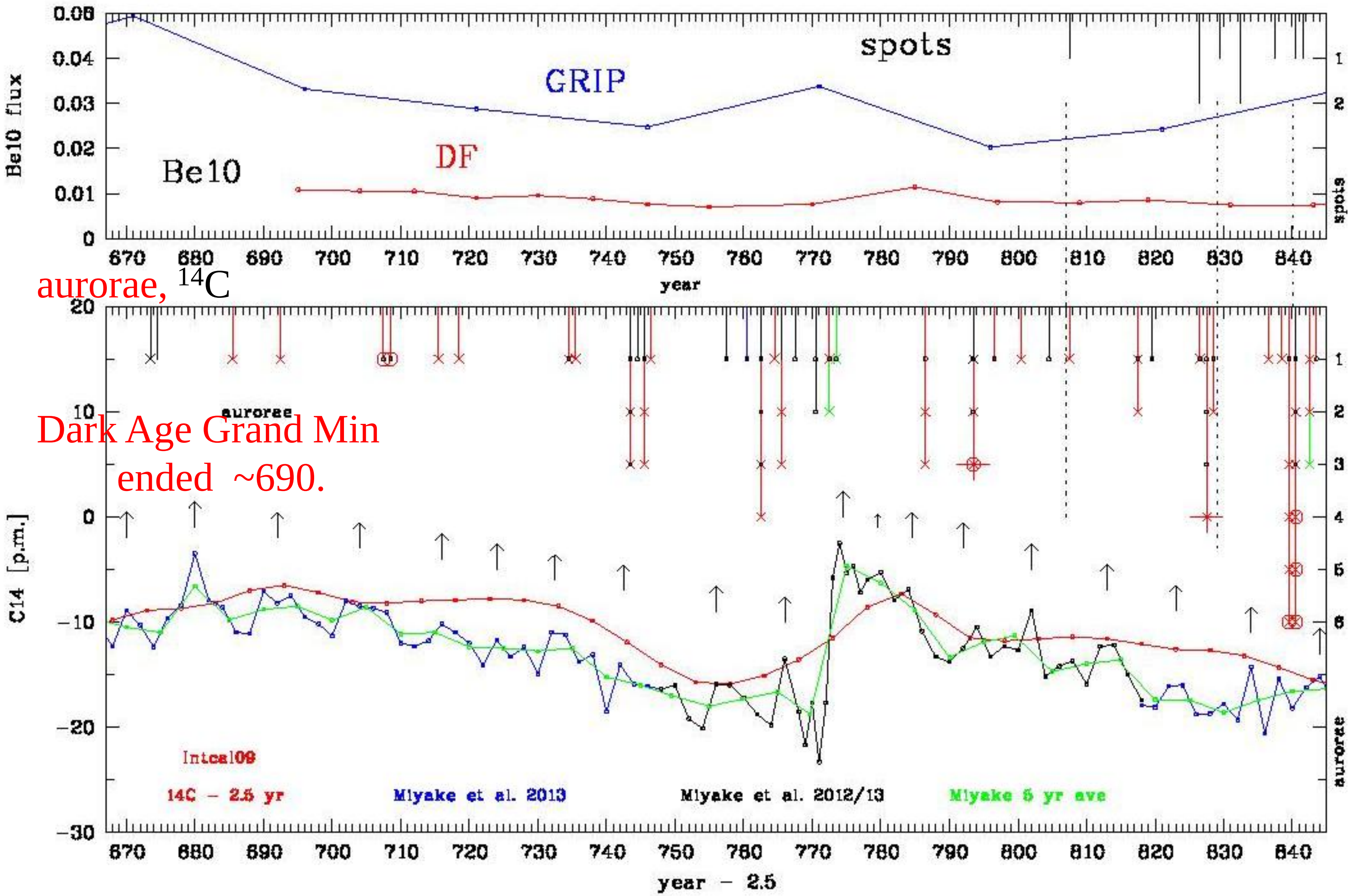
<u>Octave Sequence is asymmetric – always 8 Schwabe Cycles !</u>

Same around AD 775 ?

8 Schwabe cycles Grand Max after the Dark Age Grand Min
= 2 times 4 cycles with same hemispheric leadership …

aurorae, ^{14}C





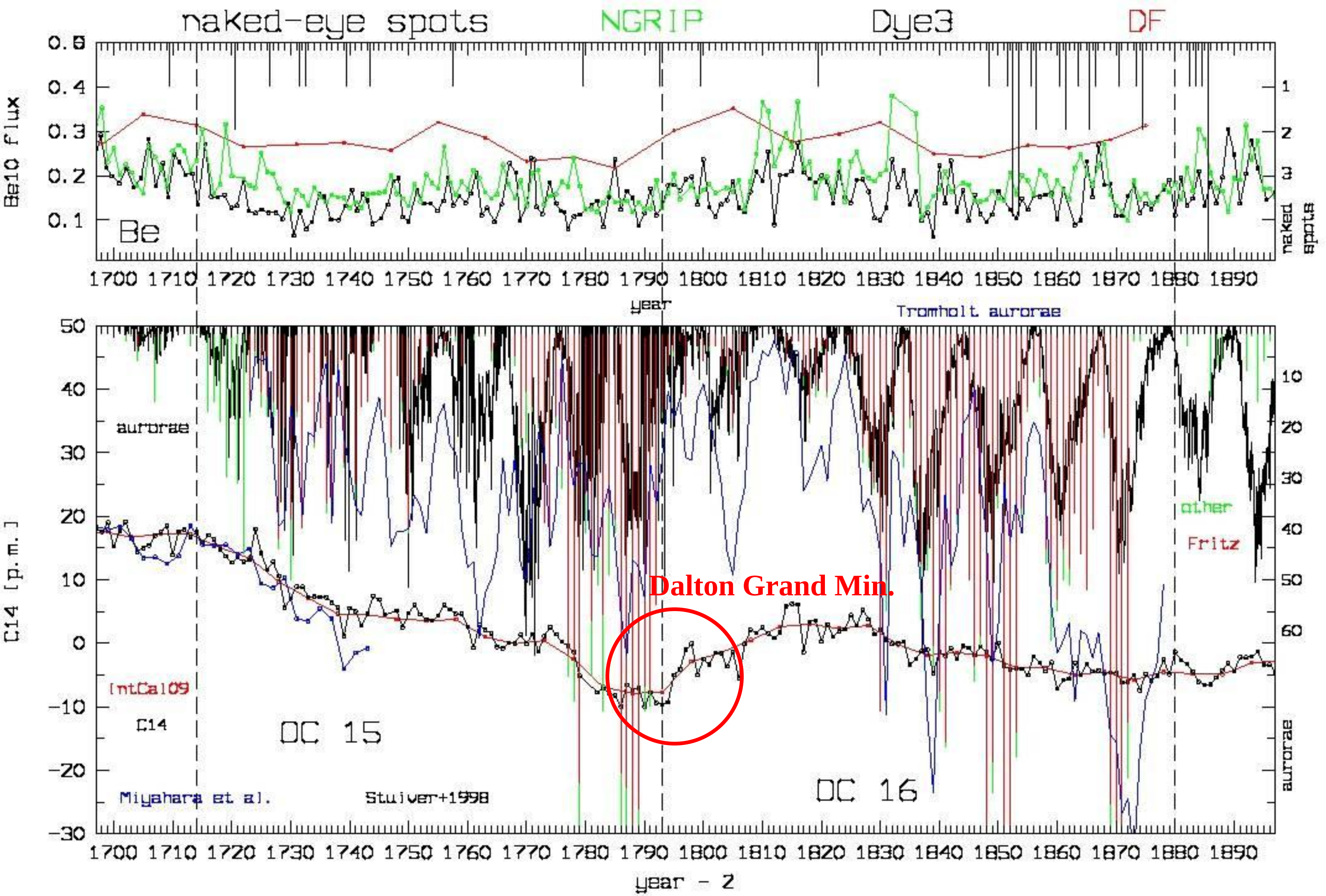
(1) At the end of the Grand Maximum (~770) ➔ low ^{14}C level

(2) Decline of strong Schwabe cycle no. 4 (~ 774) ➔ ^{14}C rises

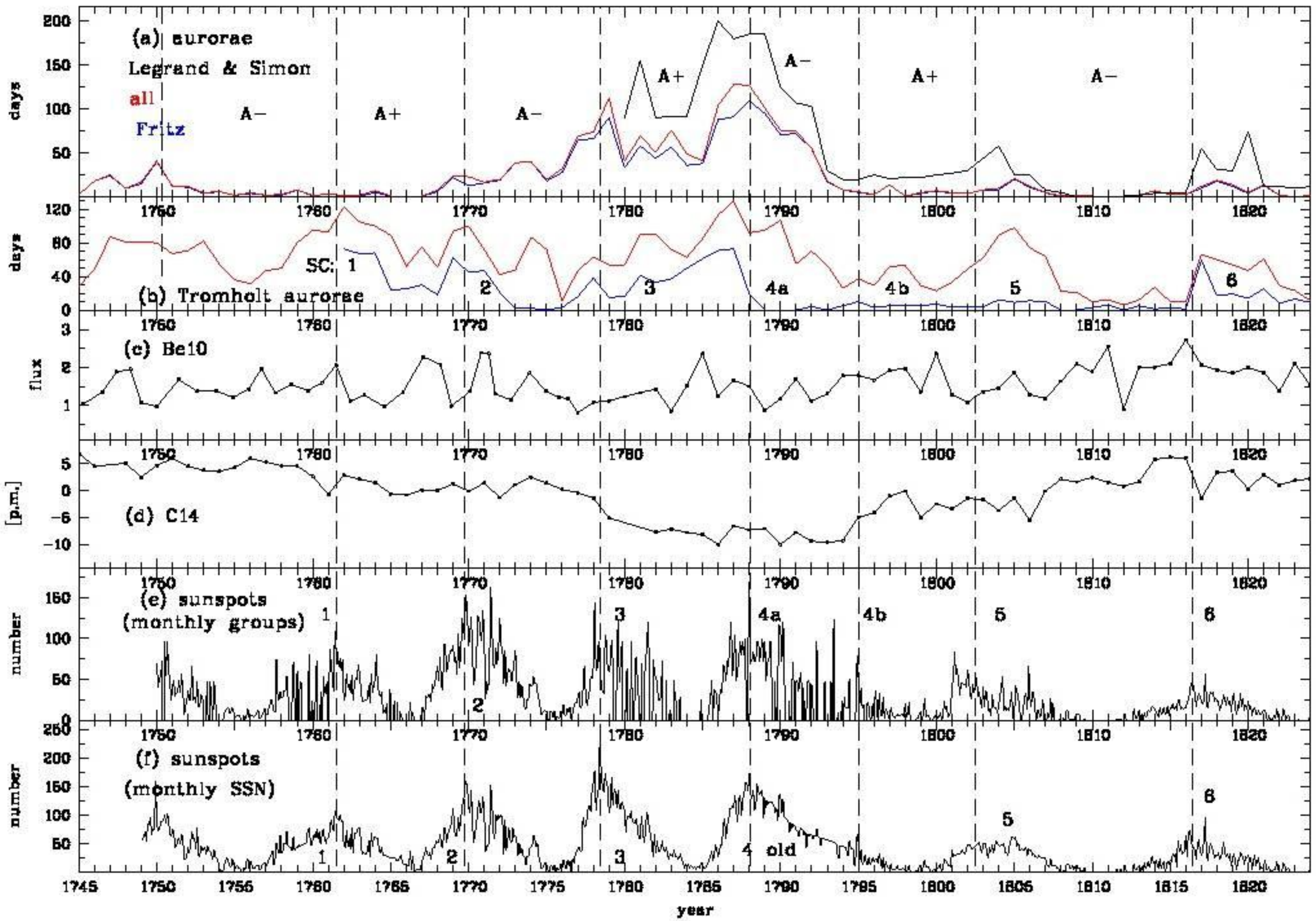
(3) Weak activity ➔ ^{14}C level high

Neuh & Neuh 2015

AD 1700 – 1900

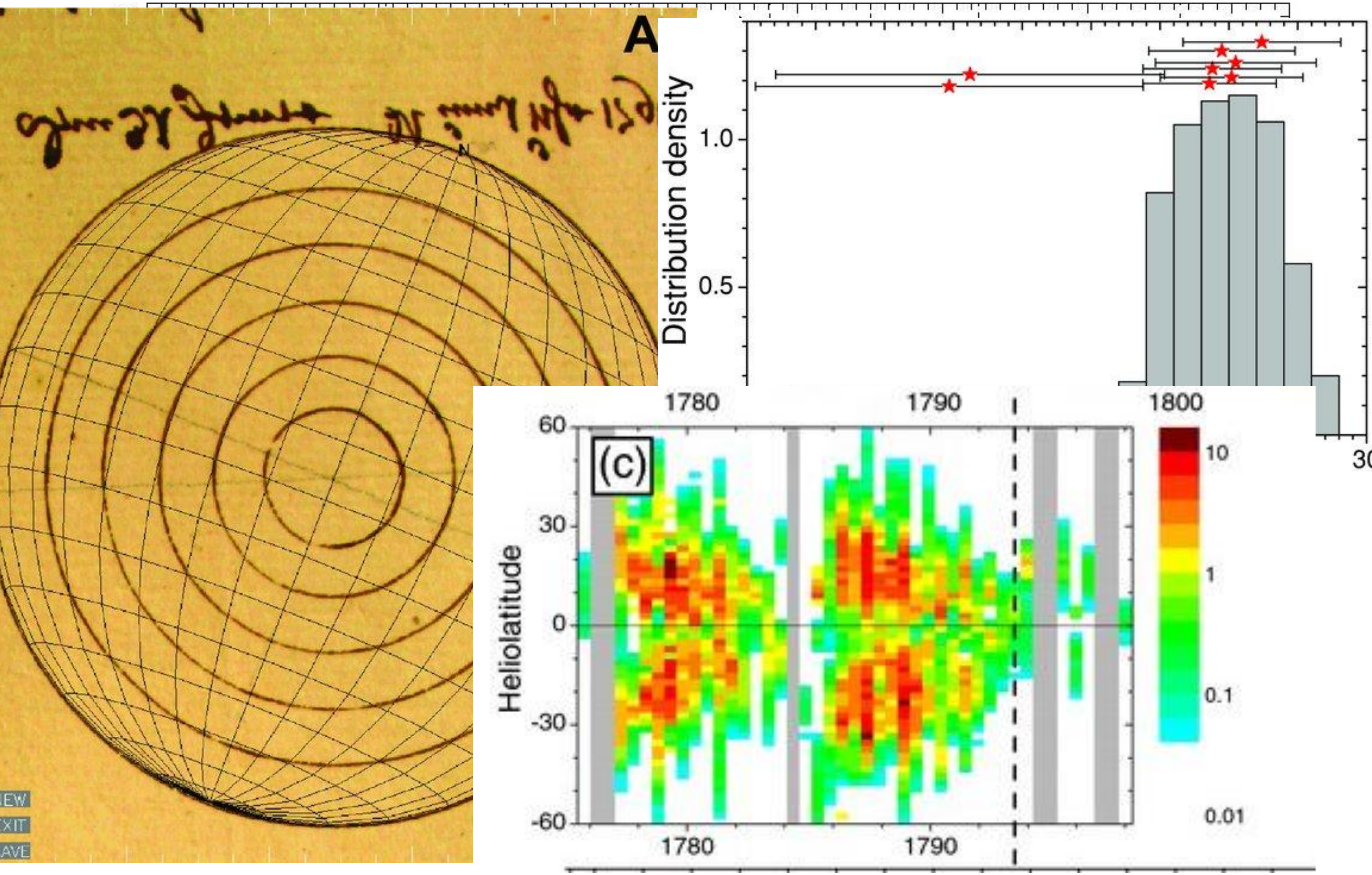

naked-eye spots
NGRIP
Dye3
DF
Be10 flux
Be
naked spots
year
Tromholt aurorae
aurorae
C14 [p. m.]
other
Fritz
Dalton Grand Min.
IntCal09
C14
DC 15
DC 16
Miyahara et al.
Stuiver+1998
aurorae
year - 2

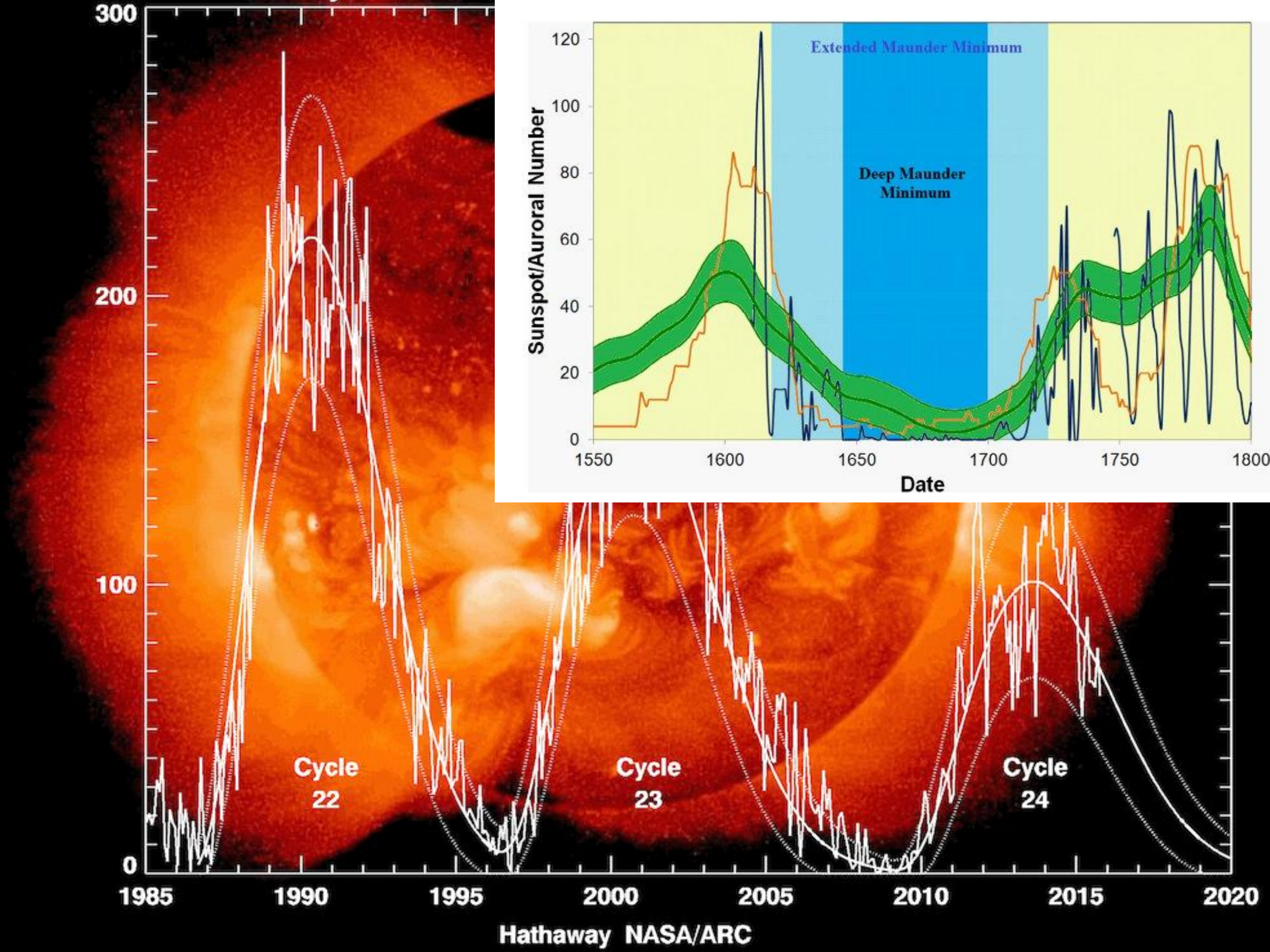
Long old Schwabe Cycle 4 (~17 yr) is made up of 2 short Schwabe Cycle



Long old Schwabe Cycle 4 (~17 yr) is made up of 2 short Schwabe Cycle

(Usoskin, Arlt … 2009)




300
200
100
0
1985
1990
1995
2000
2005
2010
2015
2020
Cycle 22
Cycle 23
Cycle 24
Hathaway NASA/ARC
Extended Maunder Minimum
Deep Maunder Minimum
Sunspot/Auroral Number
120
100
80
60
40
20
0
1550
1600
1650
1700
1750
1800
Date