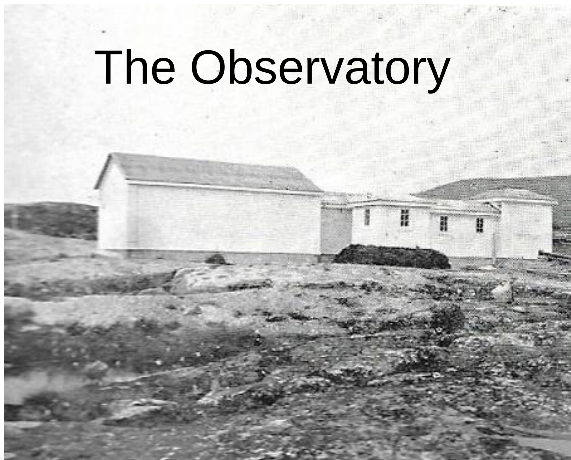
The Olsen Rotating Dipole Revisited

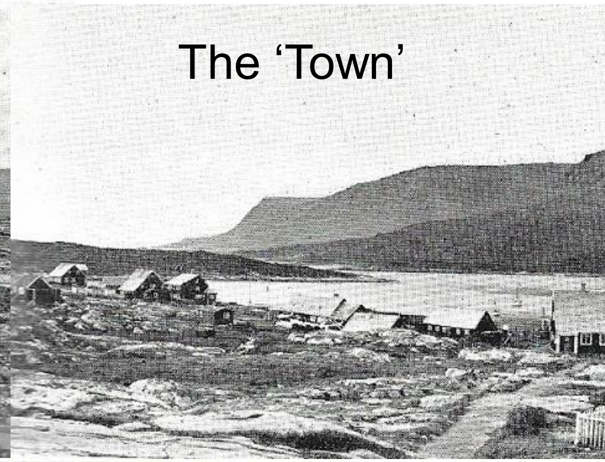
Leif Svalgaard

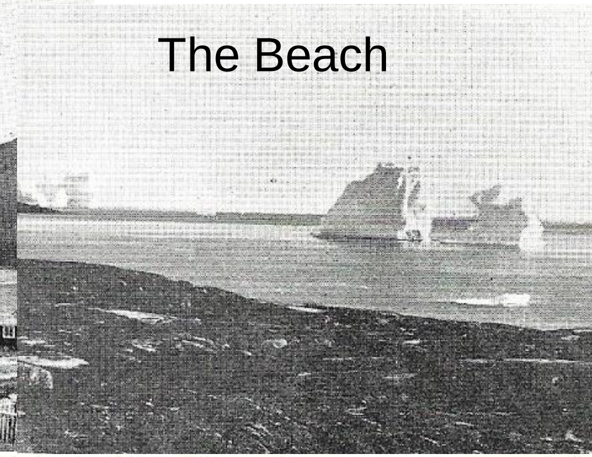
Stanford University

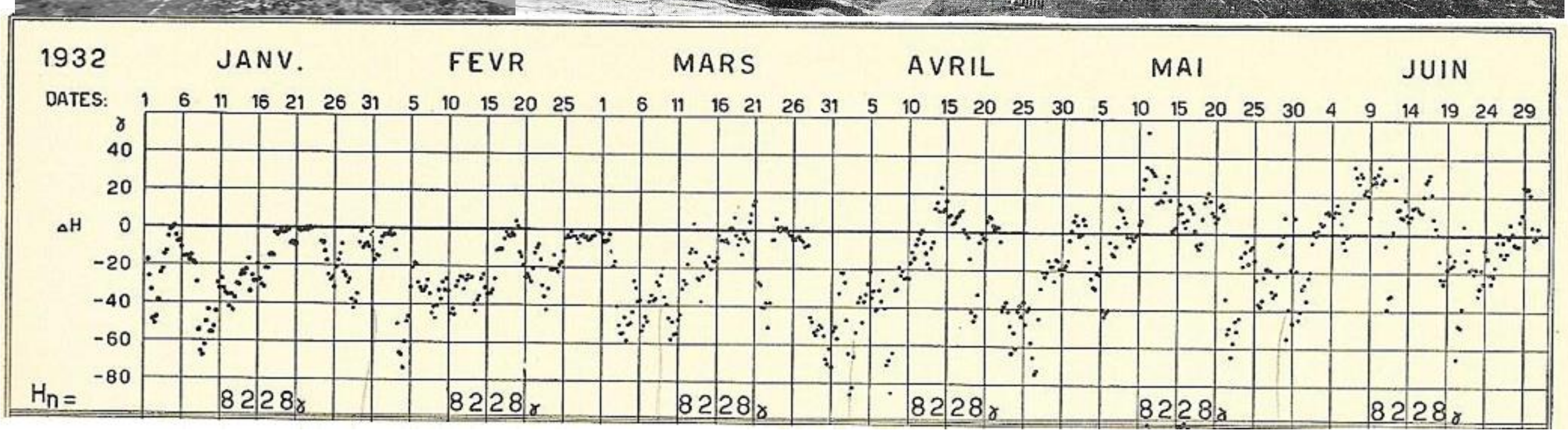
2 Aug. 2016

The Story Begins Here at Godhavn, Greenland in 1926









The variation of the Horizontal Component in the minimum year 1932. The recurring ‘dips’ are not magnetic storms. In fact, nobody knew what they were at the time.

Johannes Olsen (1894-1991) drew Attention to those Recurrent Dips

PERSISTENT SOLAR ROTATION-PERIOD OF 26 7/8 DAYS AND SOLAR-DIURNAL VARIATION IN TERRESTRIAL MAGNETISM

BY JOHANNES OLSEN

Summary—An examination of the daily means of the horizontal force at Godhavn Greenland, during the years 1926 to 1941 shows that there seems to exist a recurrence-tendency for the mean values of *H* with a period of 26 7/8 days during that epoch, the values being rather low in the first half of the period and rather high in the latter half.

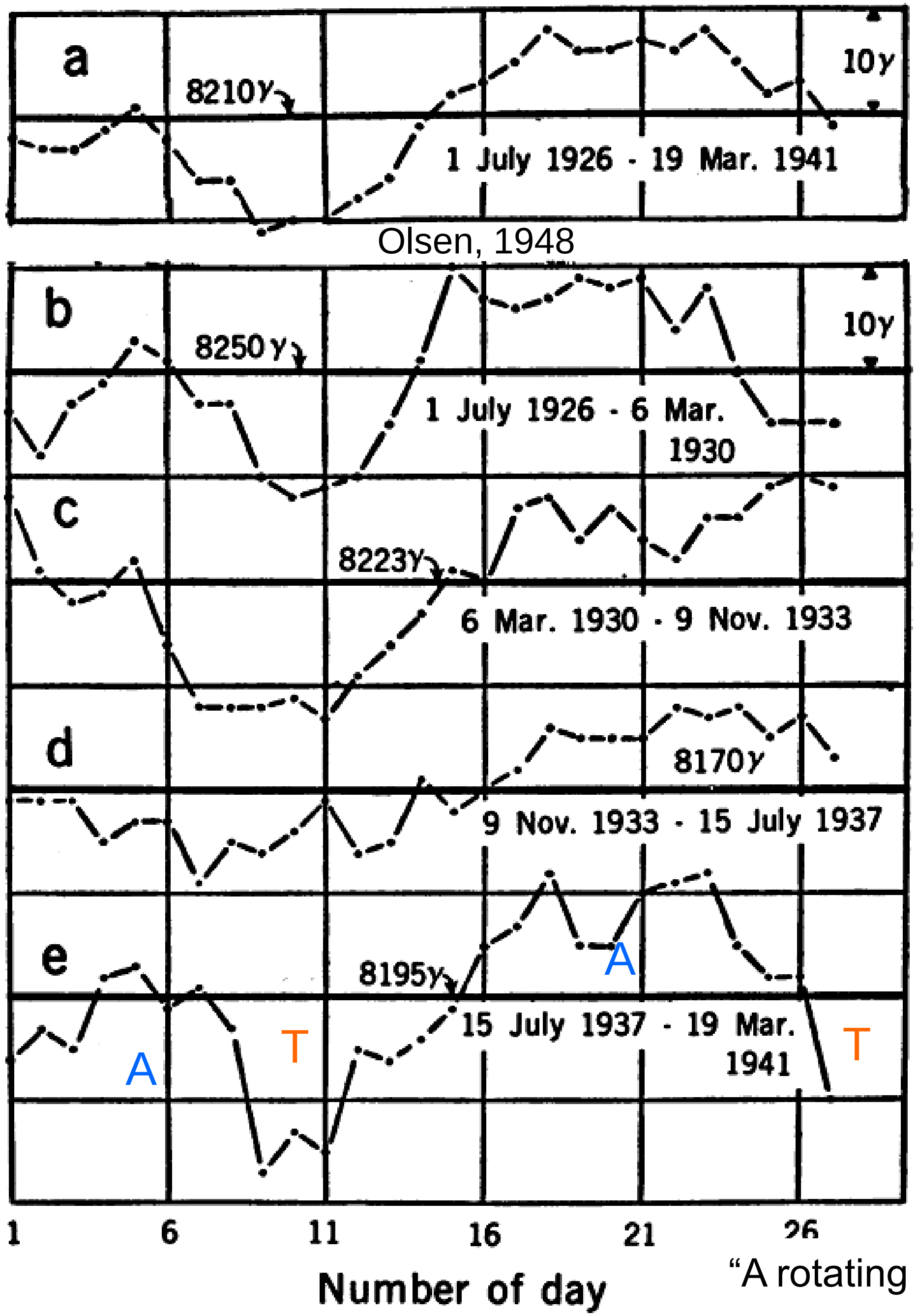
Terrestrial Magnetism and Atmospheric Electricity [now JGR], **53**(2), 123-134, doi:10.1029/te053i002p00123

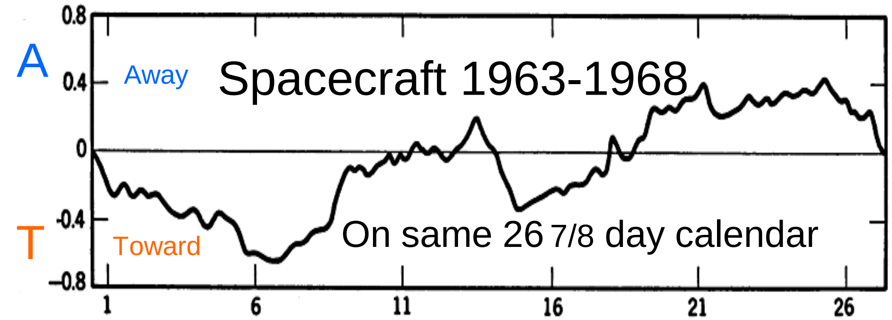
Olsen concluded:

The persistence of a fixed period during 15 years points to the possibility that the origin of the effect is to be found in a layer on the Sun with a fixed rotation-period during a long time.

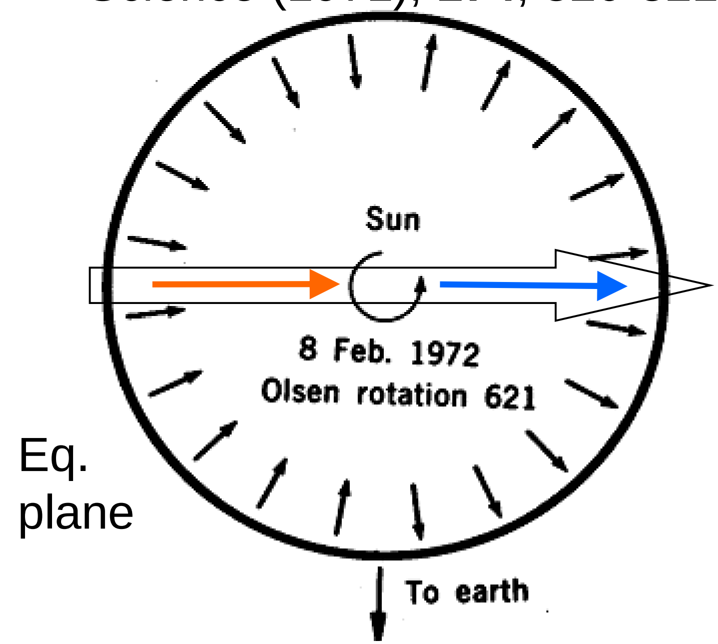
And there the finding languished for 23 years with no citations at all

Enter Wilcox & Gonzales, 1971





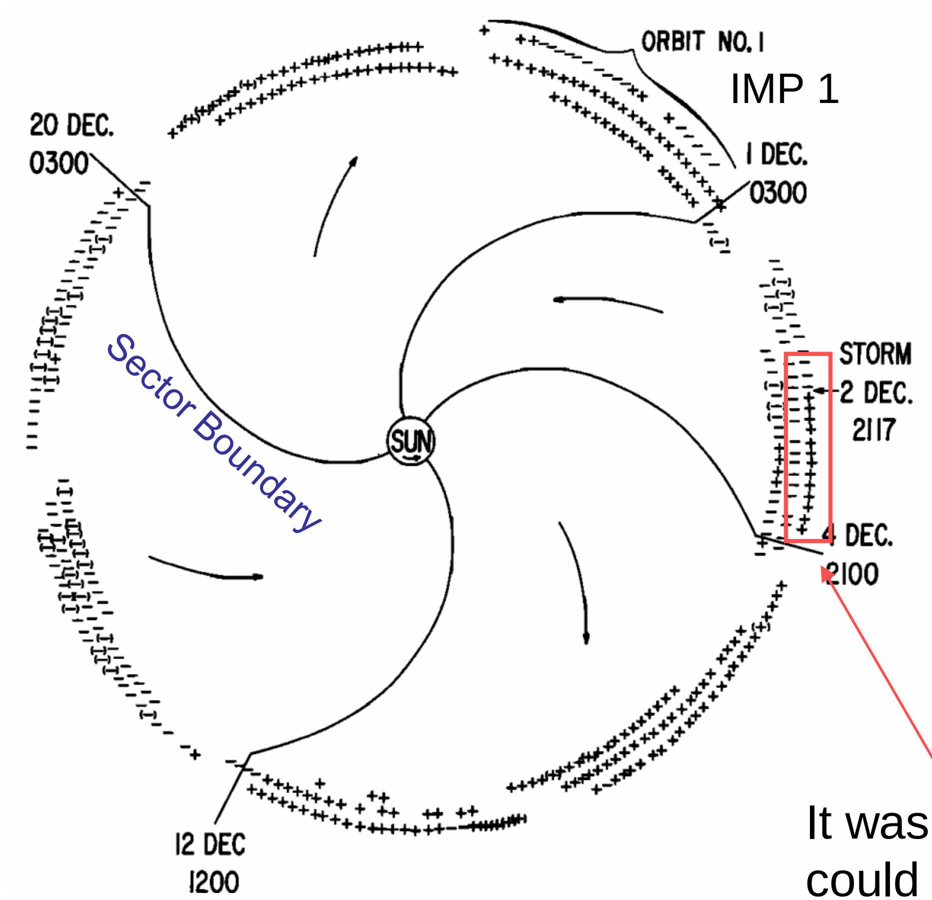
Science (1971), **174**, 820-821



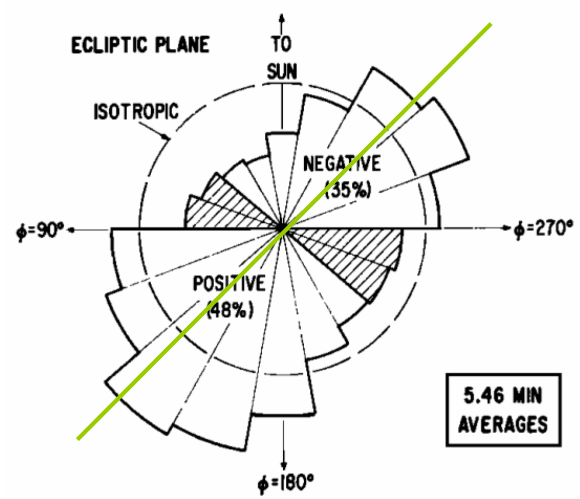
“A rotating magnetic dipole may be lurking within the sun”

Discovery of Sector Structure

Quasi-Stationary Corotating Structure in the Interplanetary Medium
John M. Wilcox & Norman F. Ness (1965), JGR, **70**, 5793.

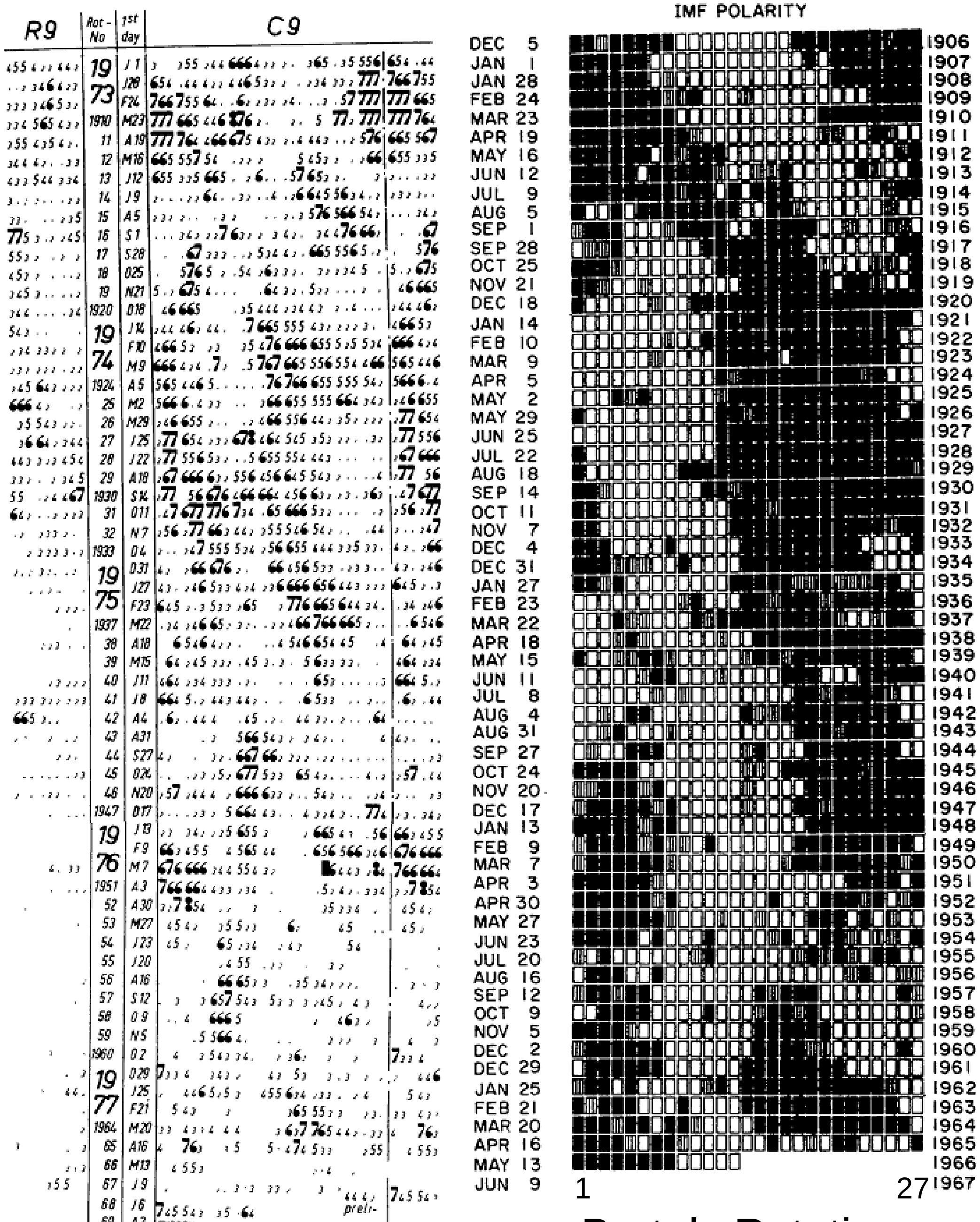


The large-scale structuring of the IMF was a surprise at the time

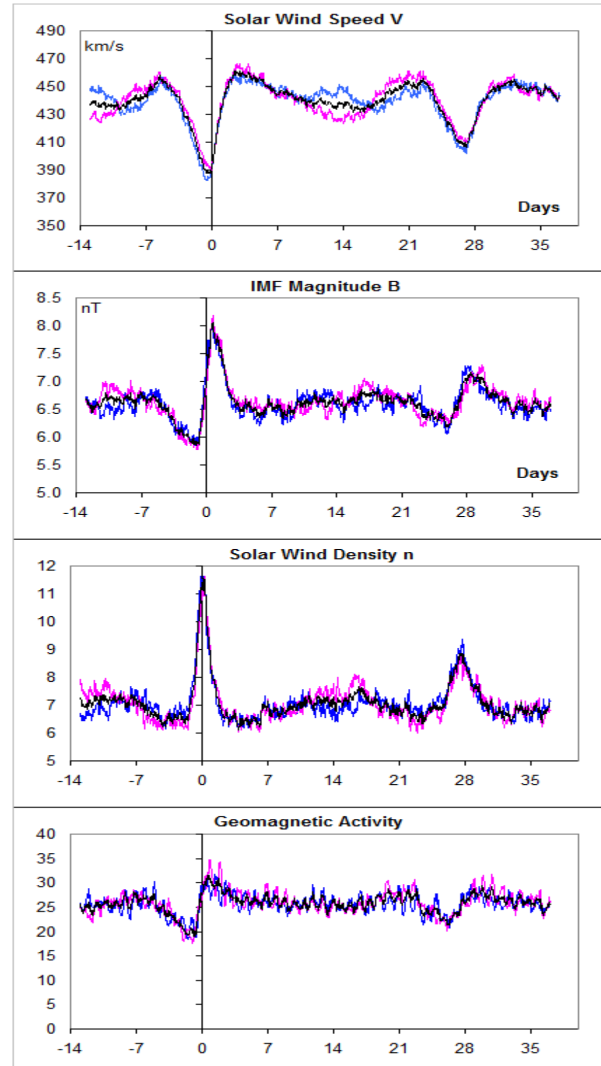


It was also noted that solar storms could briefly disrupt the structure

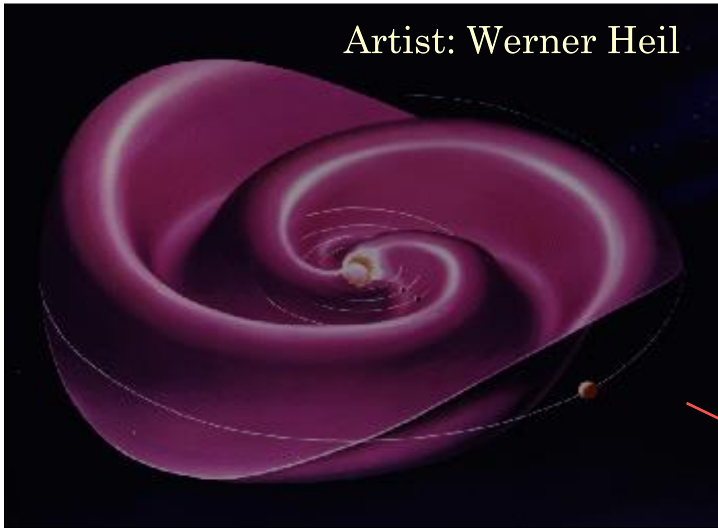
Rotation Plots of the Sector Polarity

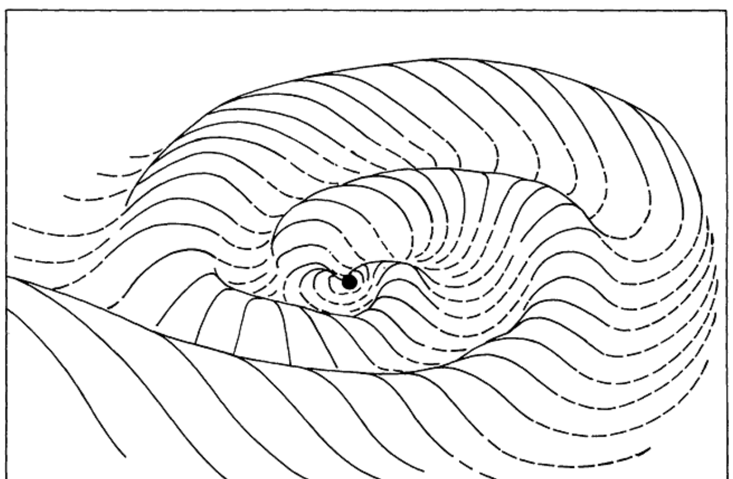


Bartels Rotations

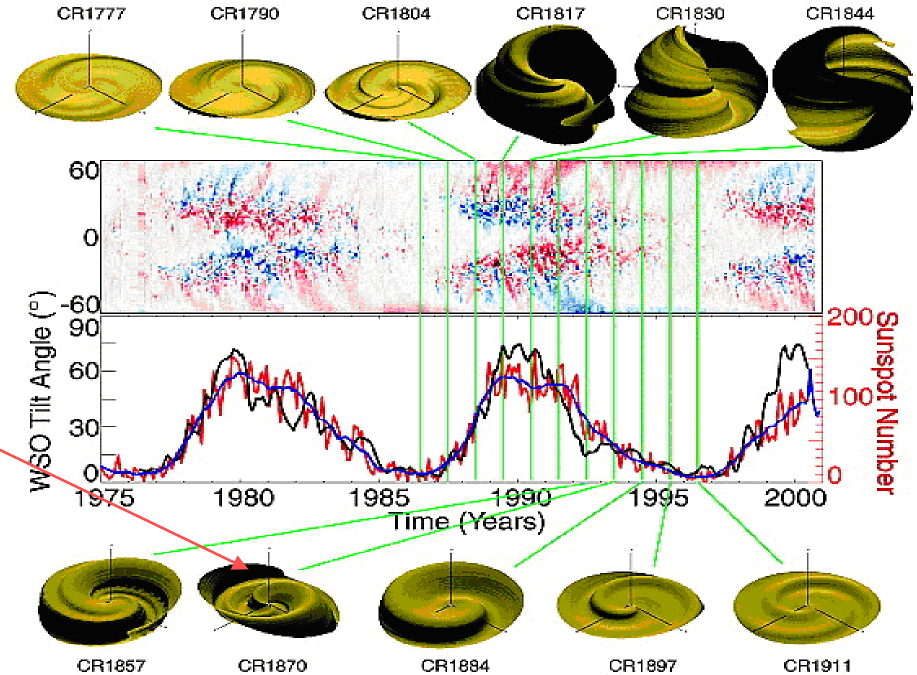


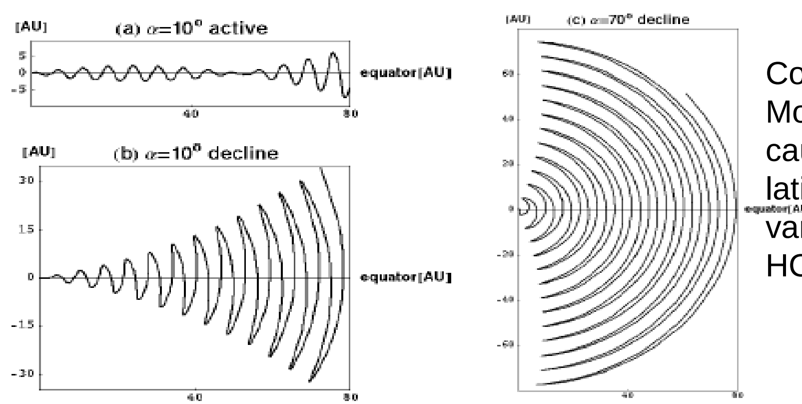
The Heliospheric Current Sheet





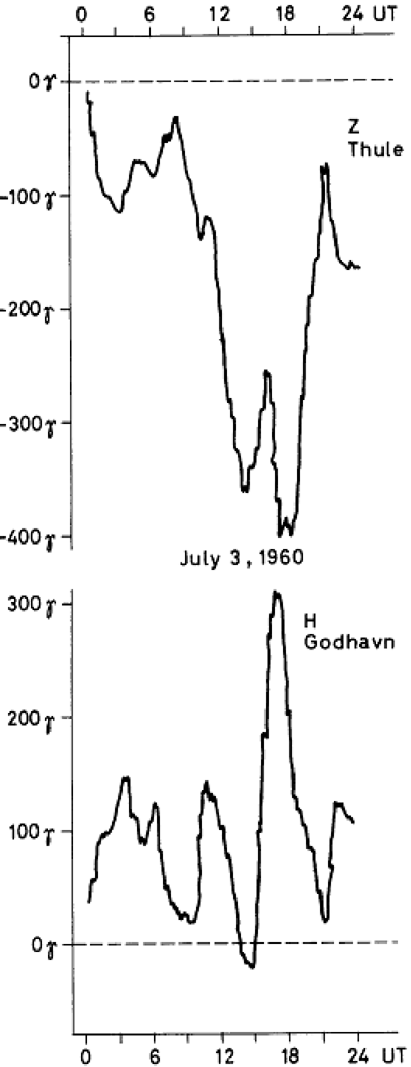
Svalgaard & Wilcox, *Nature*, 1976

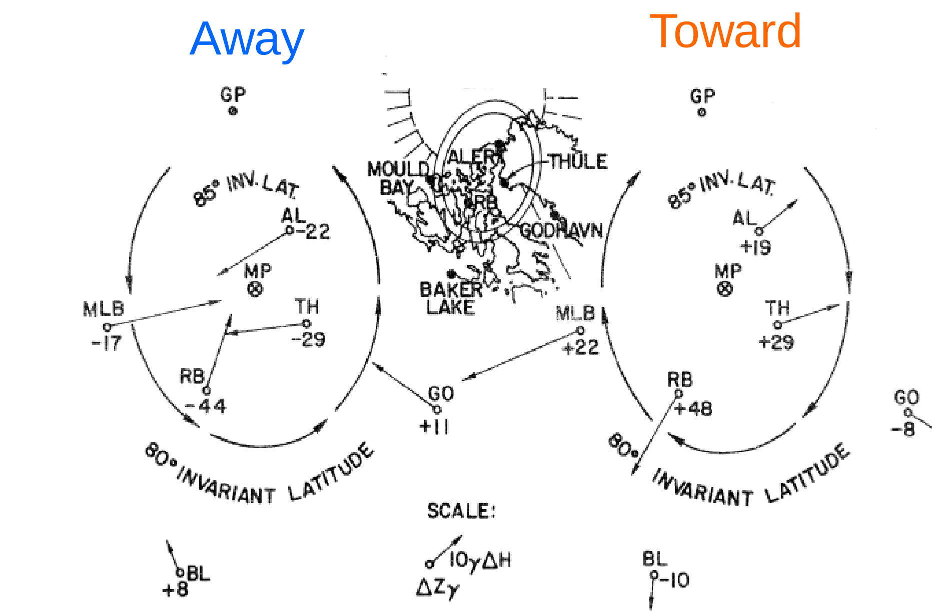




Cosmic Ray Modulation caused by latitudinal variation of HCS and CIRs

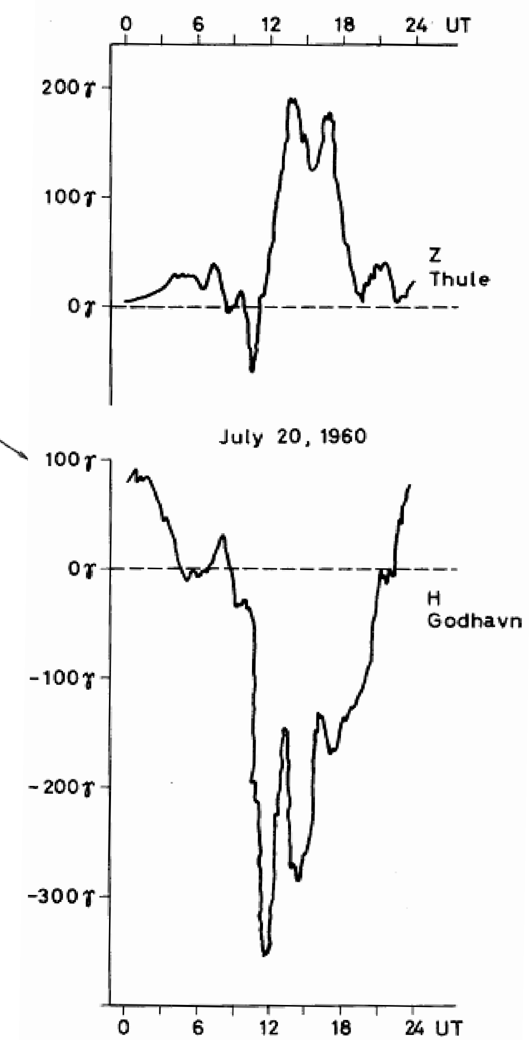
Where did W&G get the Idea to look at the IMF Polarity?





POLAR CAP DISTURBANCES AT 18h UT FOUND DURING IMF AWAY POLARITY.

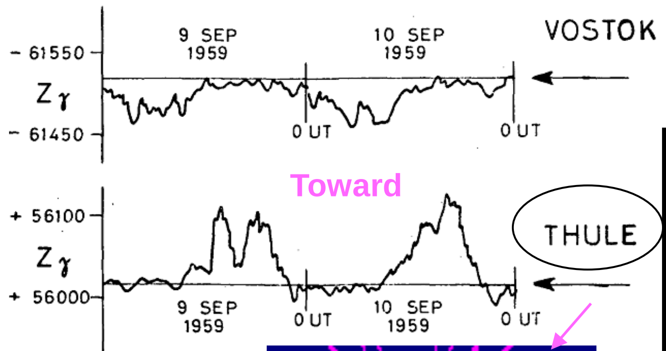
POLAR CAP DISTURBANCES AT 18h UT FOUND DURING IMF TOWARD POLARITY.



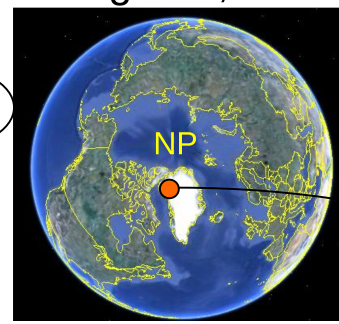
From the then recently (1968) discovered Svalgaard-Mansurov Effect caused by a current circulating around the magnetic pole, changing direction when the IMF polarity changes.

Magnetic Fields on Earth and in Space

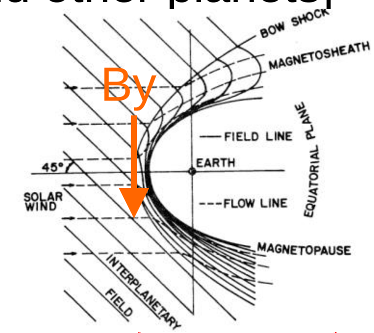
The solar system is permeated by magnetic fields coming from the Sun with the Solar Wind and connecting with the field of the Earth [and other planets]



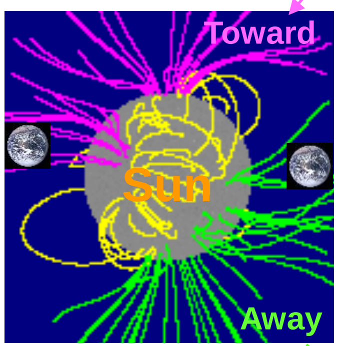
Svalgaard, 1968

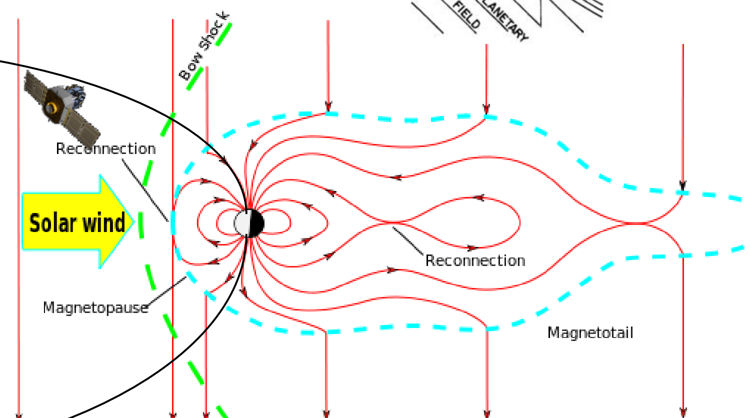


HMF is draped over the 'nose' of magnetosphere

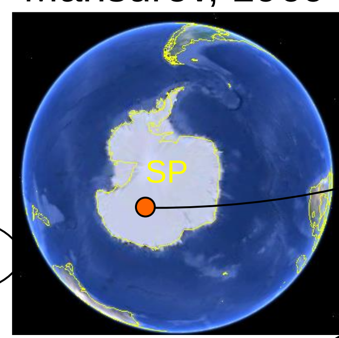


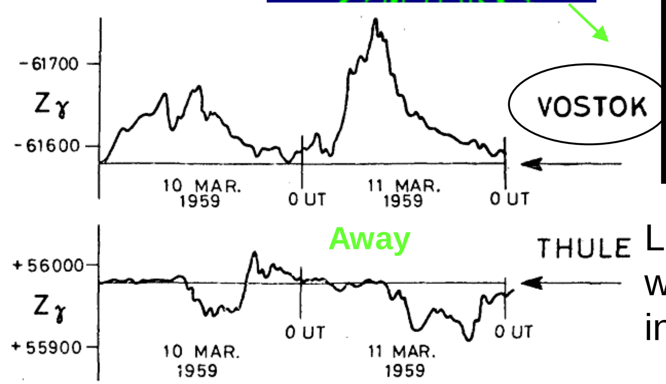
The records from Earth's polar regions show the Sun's fields



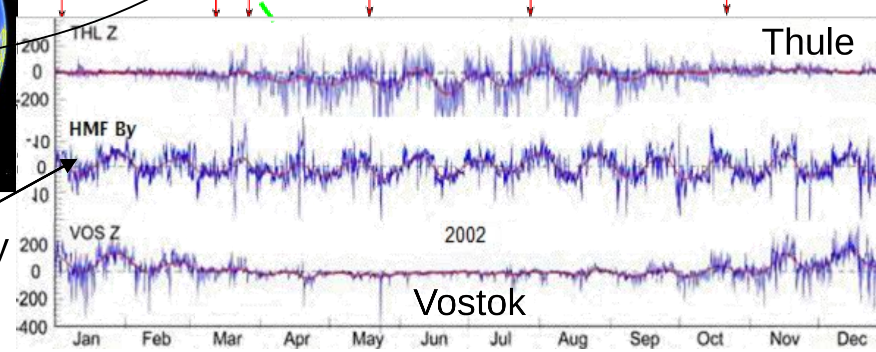


Mansurov, 1969

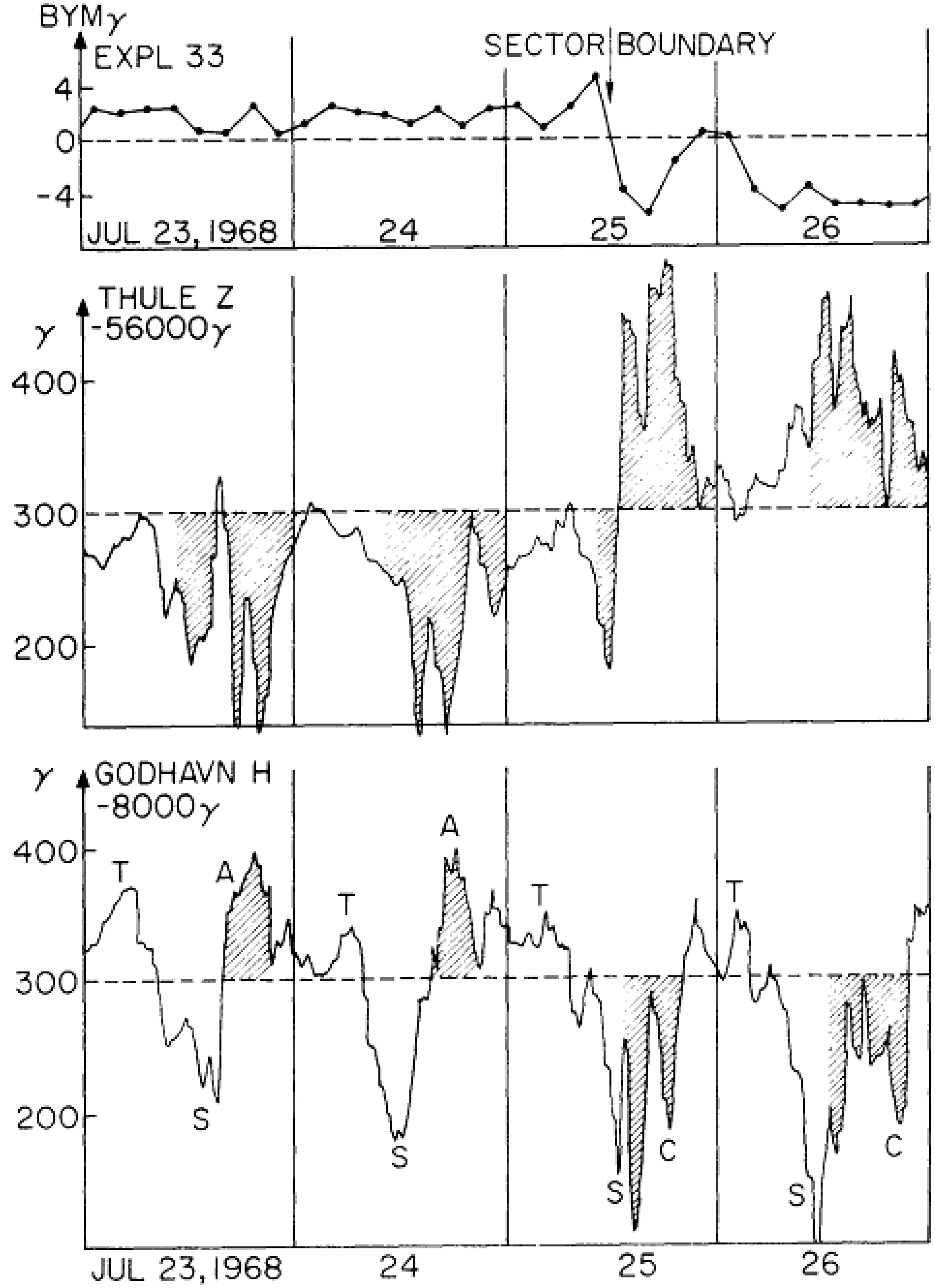


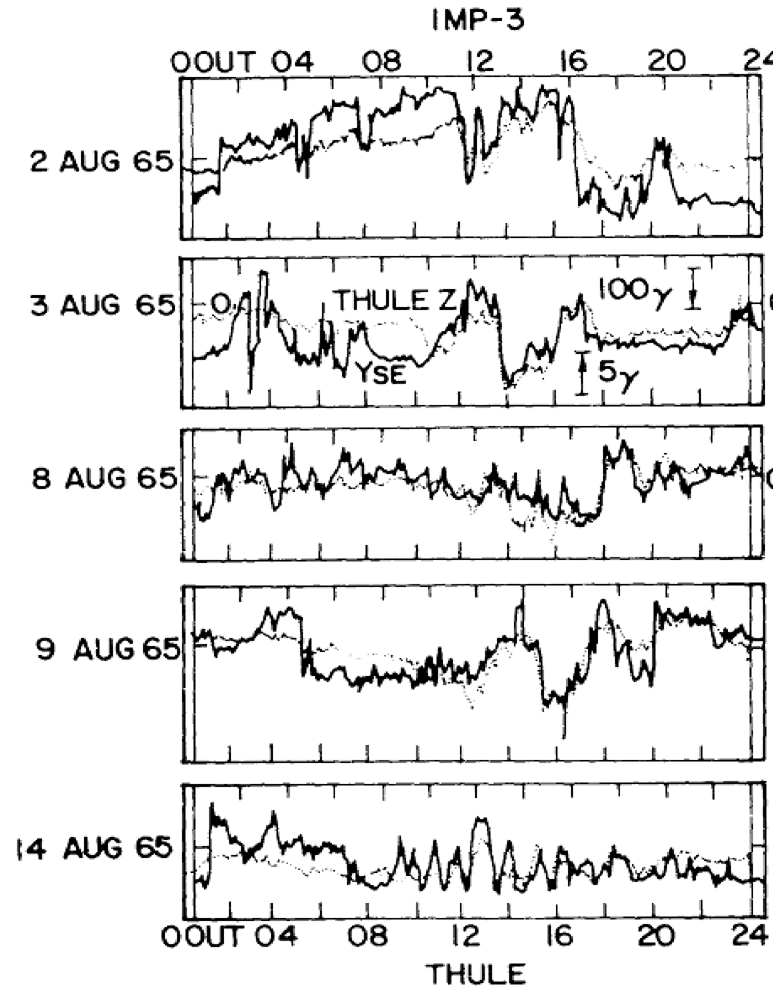


Look how accurately we can see the field in space from Earth



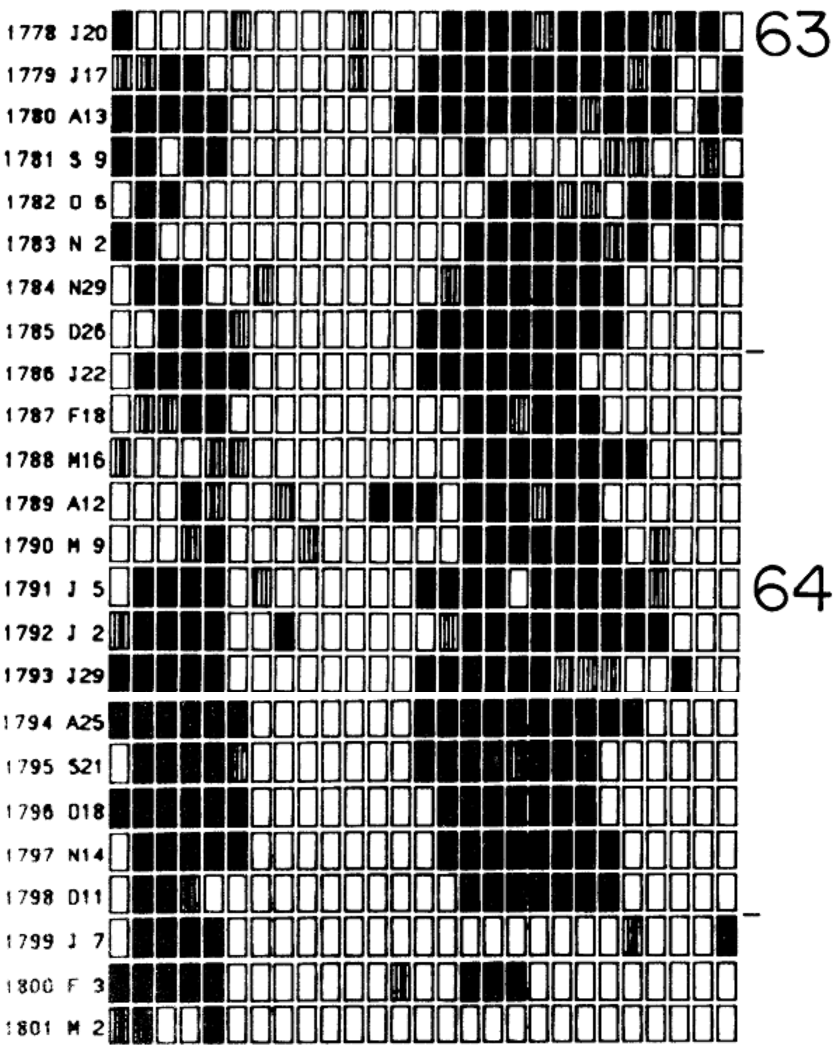
A Very Direct Relationship



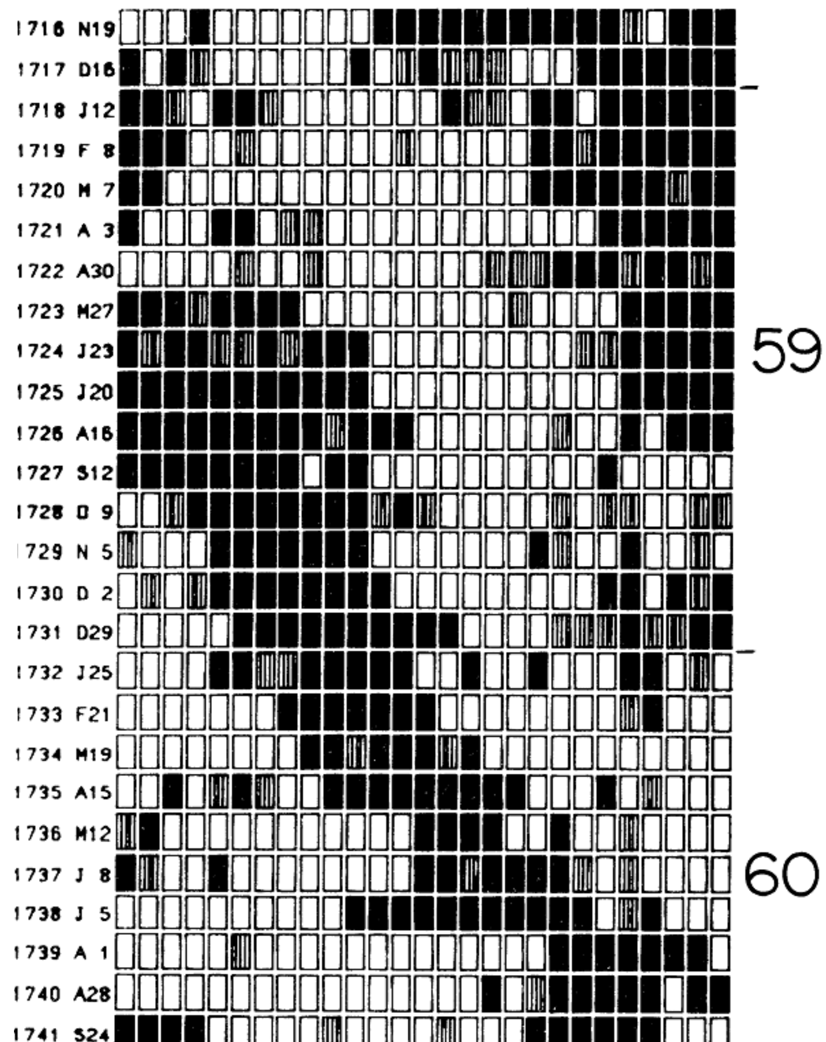


20 minute Lag, adjusted for

27-day

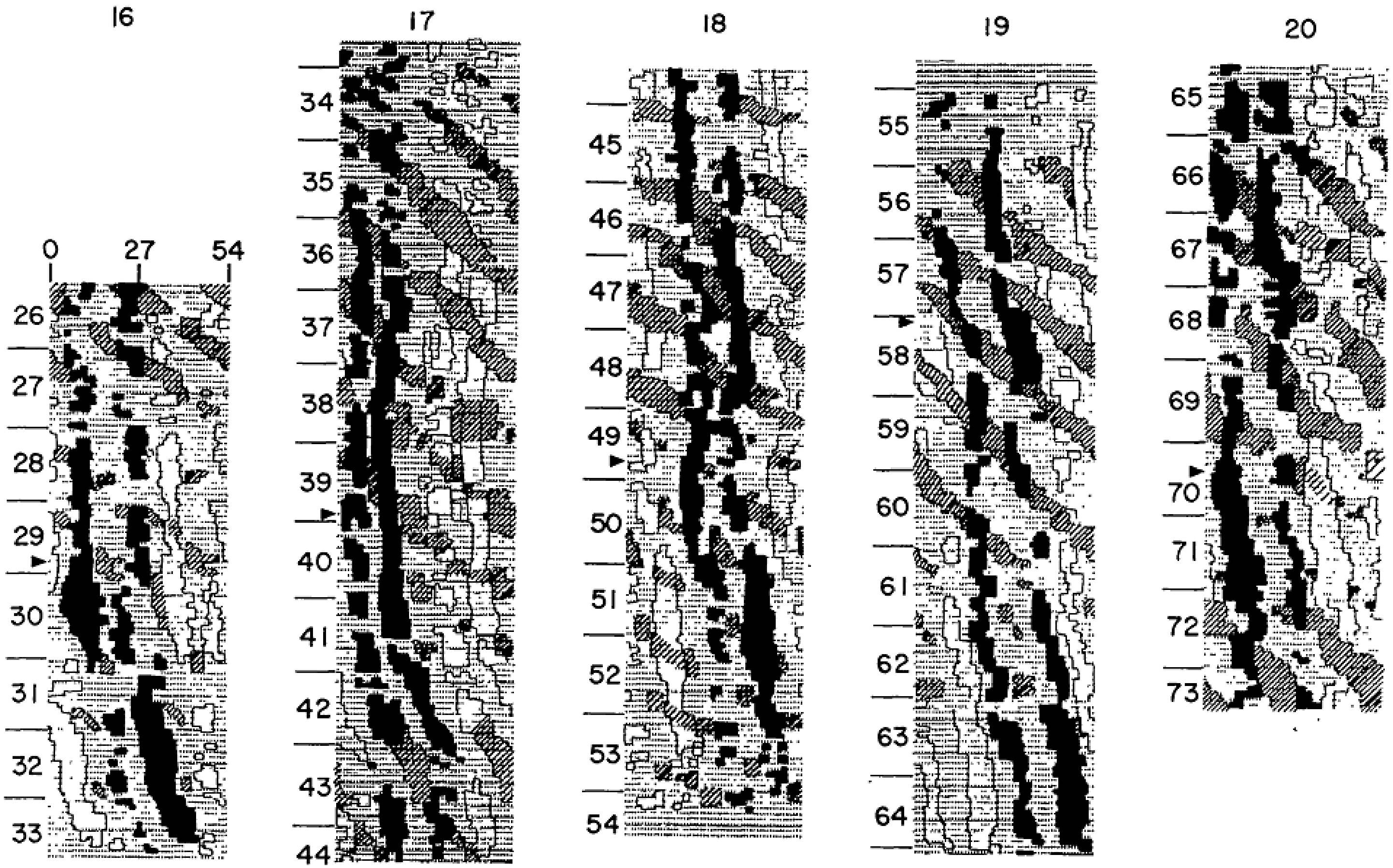


28.5-day



Long-term Evolution of Sector Structure (Hand-drawn)

INFERRED SOLAR MAGNETIC SECTOR STRUCTURE DURING FIVE SUNSPOT CYCLES



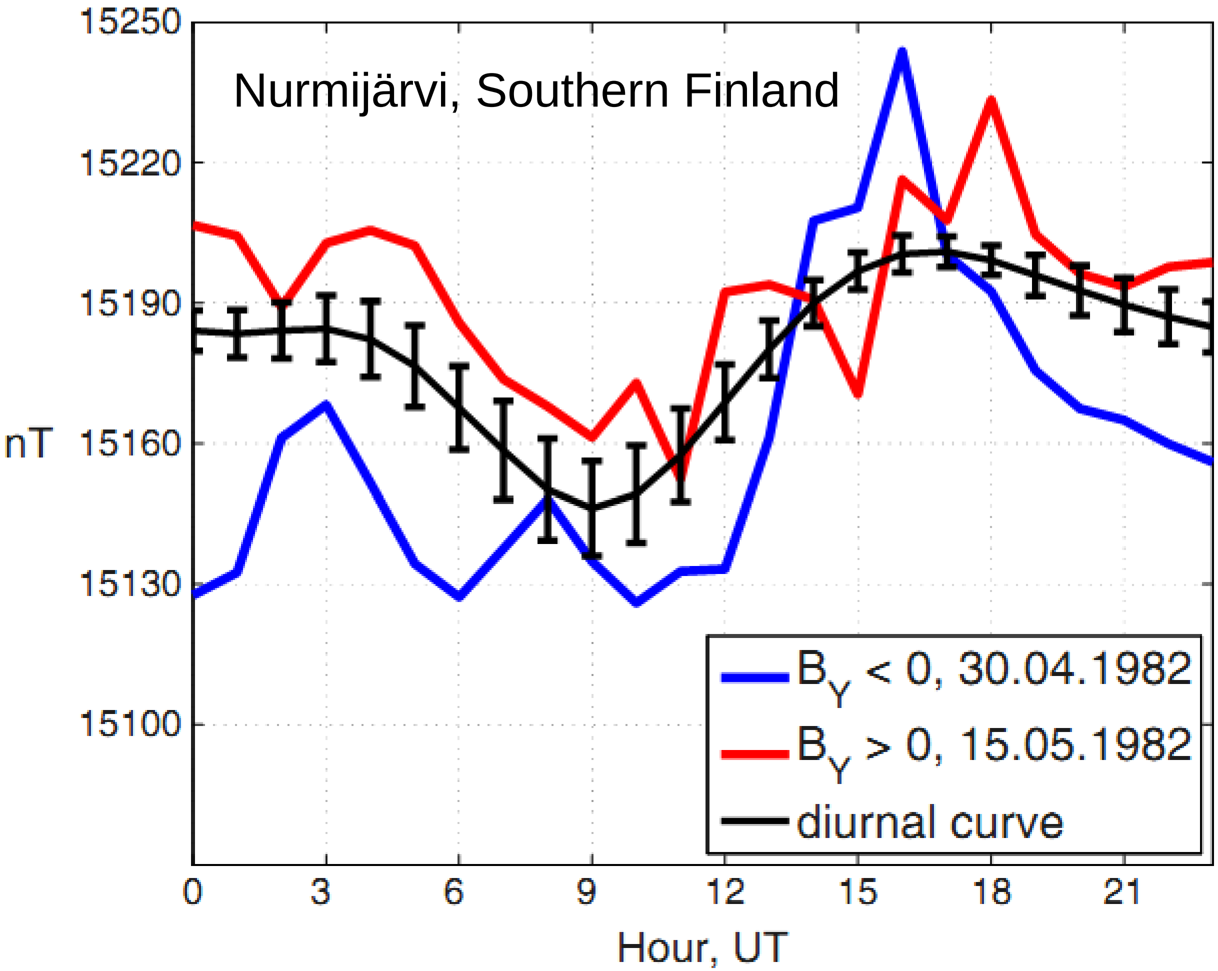
26.84 DAYS CALENDAR SYSTEM STARTING FEB 19, 1926

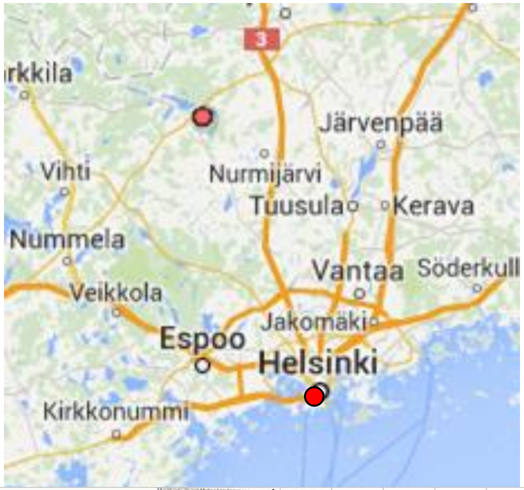
Alignments are Easy (Phil)

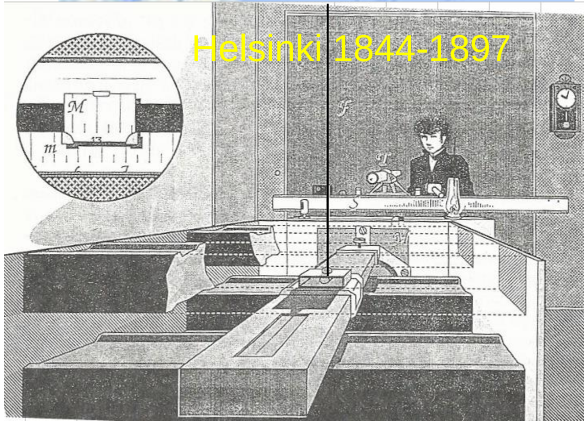
Can We Extend the Sector Data to Before 1926?

Yes: M. V. Vokhmyanin and D. I. Ponyavin

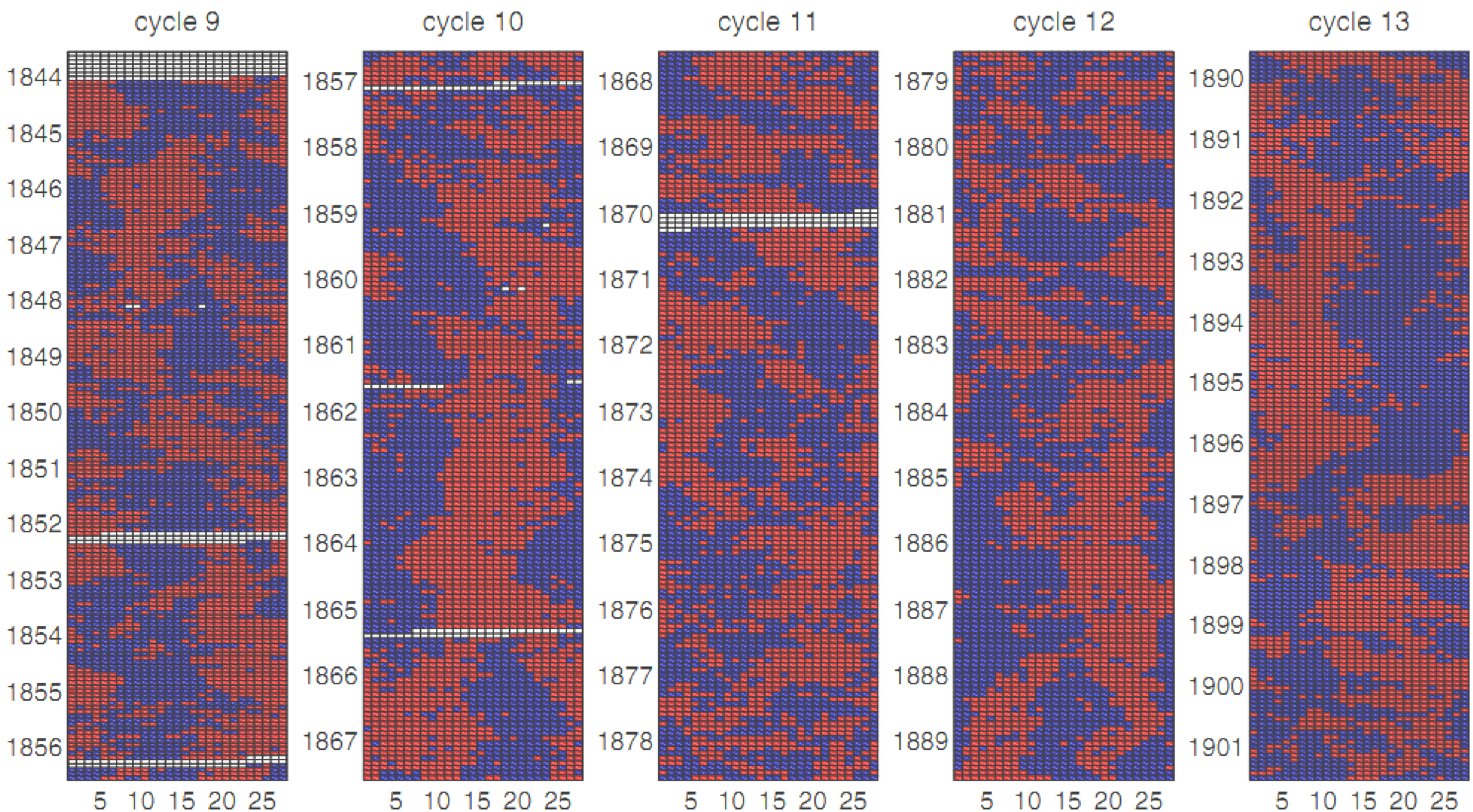
Sector structure of the interplanetary magnetic field in the nineteenth century, Geophysical Research Letters, **40**, 3512–3516, doi:10.1002/grl.50749, 2013







Both ‘27-day’ and ‘28.5-day’ Structures in the Early Data



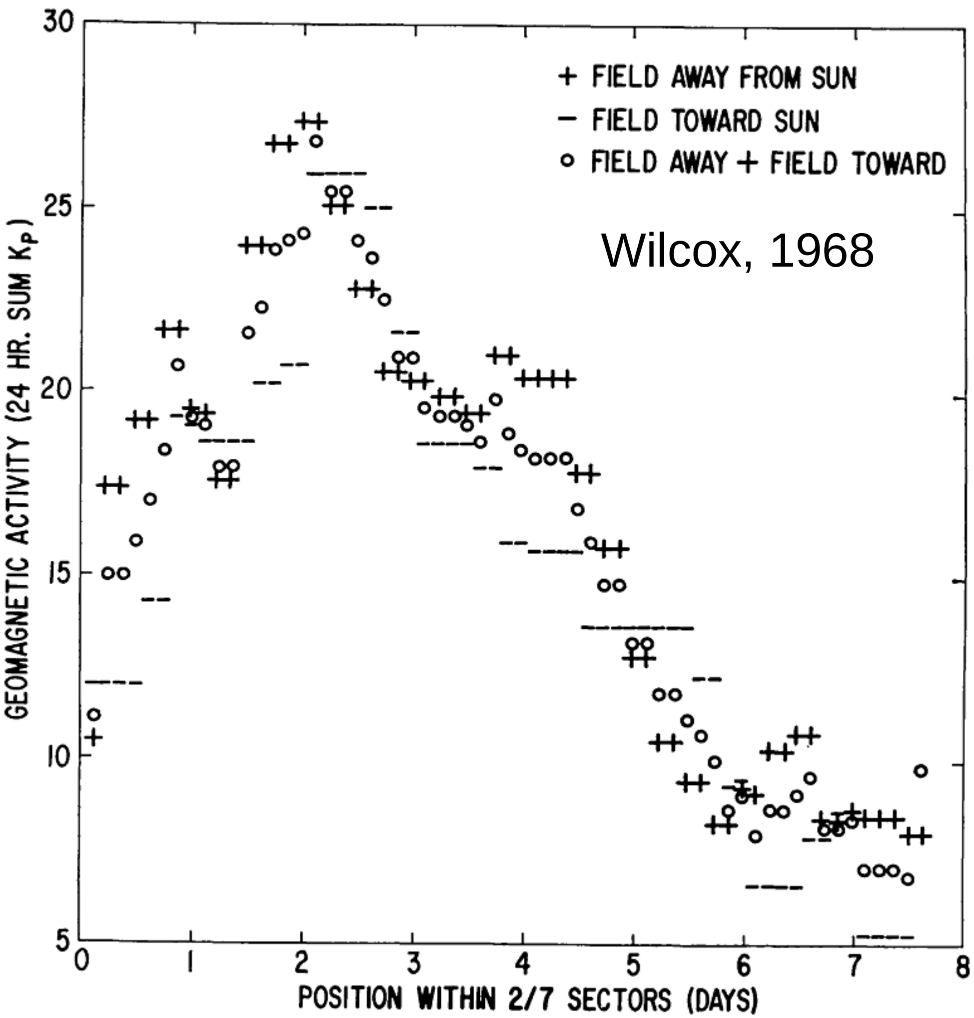
Are the early data (including mine) reliable? This we investigate next

Using the Inferred Sector Structure we [the computer] can make a List of Well-Defined Sector Boundaries

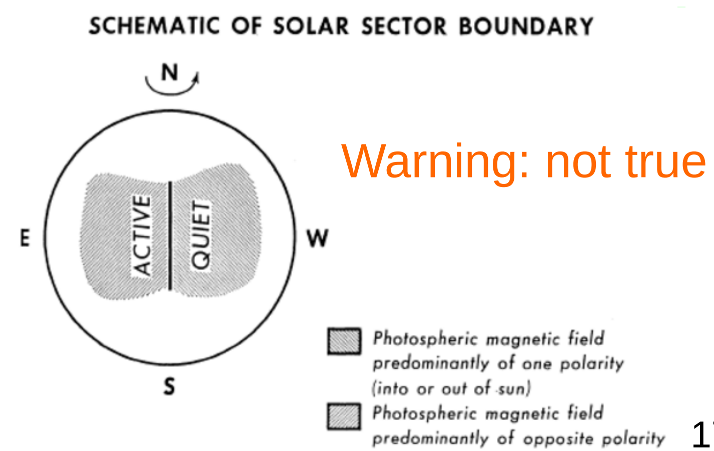
+,-	1844	07	14	21	9		-,+	2016	02	26	11	9
-,+	1844	07	23	9	8		+,-	2016	03	06	9	6
+,-	1844	08	09	7	14		-,+	2016	03	22	7	11
-,+	1844	08	23	14	14		+,-	2016	04	02	11	6
+,-	1844	09	06	14	14		-,+	2016	04	08	6	4
+,-	1844	10	04	10	17		+,-	2016	04	12	4	6
-,+	1844	10	21	17	10		-,+	2016	04	18	6	12
+,-	1844	10	31	10	16		+,-	2016	04	30	12	15
-,+	1844	11	16	16	11		-,+	2016	05	15	15	12
+,-	1844	11	27	11	17		+,-	2016	05	27	12	15
-,+	1844	12	14	17	13		-,+	2016	06	11	15	11
+,-	1844	12	27	13	4		+,-	2016	06	22	11	9
-,+	1845	01	11	9	11		-,+	2016	07	07	4	13
+,-	1845	01	22	11	13		+,-	2016	07	20	13	

Covering the entire period from 1844 to the present (2016)

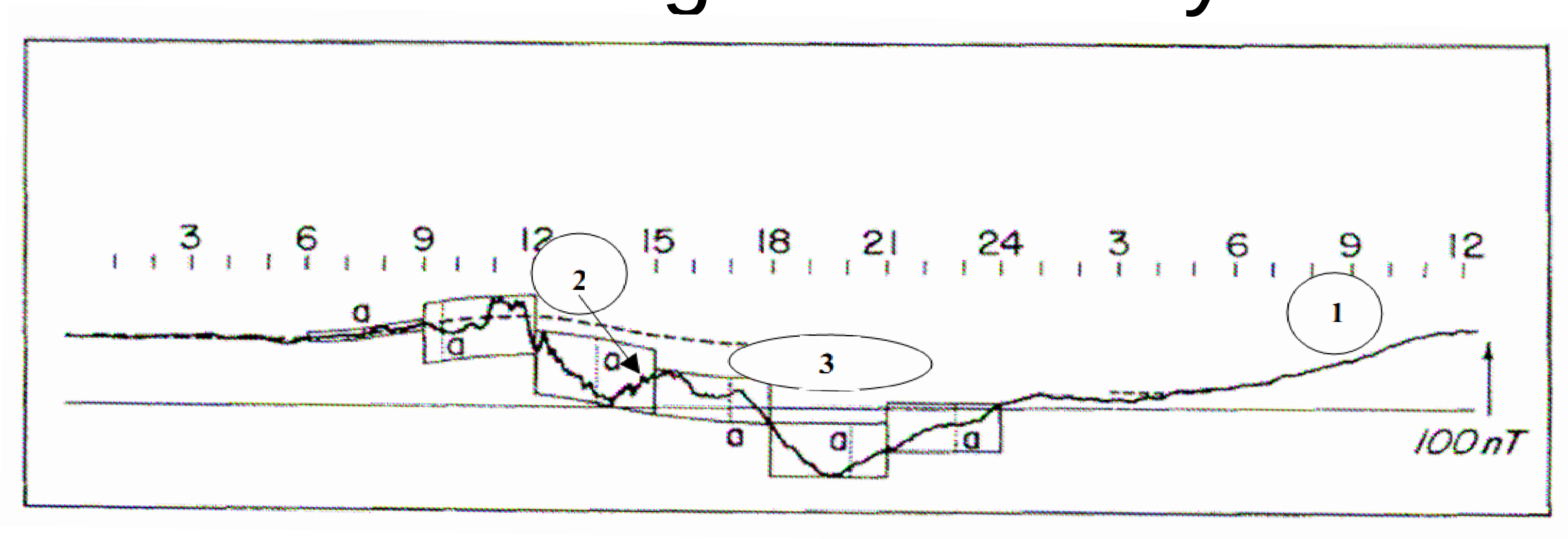
The Geomagnetic Response to the Passage of Sector Boundaries



Geomagnetic Activity is modulated by the sector structure. An early analysis showed an increase in activity following a sector boundary (that was misinterpreted as a solar property), and there did not seem to be any difference between the response for different polarity. However, it is not that simple…



Measuring and Modeling Geomagnetic Activity



[Momentum, Reconnection, Modulations]

$$a = k\,(nV^2)^{1/3}\,(BV)\,q(\alpha, f)\,S(\Psi)$$

B = Interplanetary Magnetic Field strength

V = Solar Wind Speed

q = function of angle α between IMF and Earth's magnetic field

f = variability $= \sqrt{(\sigma_{Bx}^2 + \sigma_{By}^2 + \sigma_{Bz}^2)}/\sigma_B$

The K-index is a quasi-logarithmic measure of the amplitude, a:

K ≈ log (a)

K runs from 0 to 9

Geomagnetic Activity Data

P.-N. Mayaud has derived the well-known aa-index using magnetograms from two antipodal observatories. The index is available from 1868 to the present (2016).

H. Nevanlinna has extended the series back in time to 1844-1897 using the data from Helsinki, Finland.

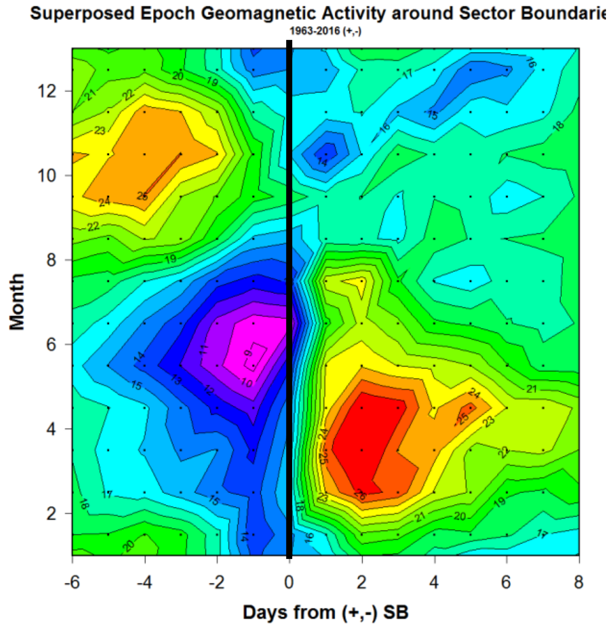
Data from Russian observatories 1850-1862 is also available, although slightly less reliable.

Mayaud’s superb am-index (1959-Present) is available too.

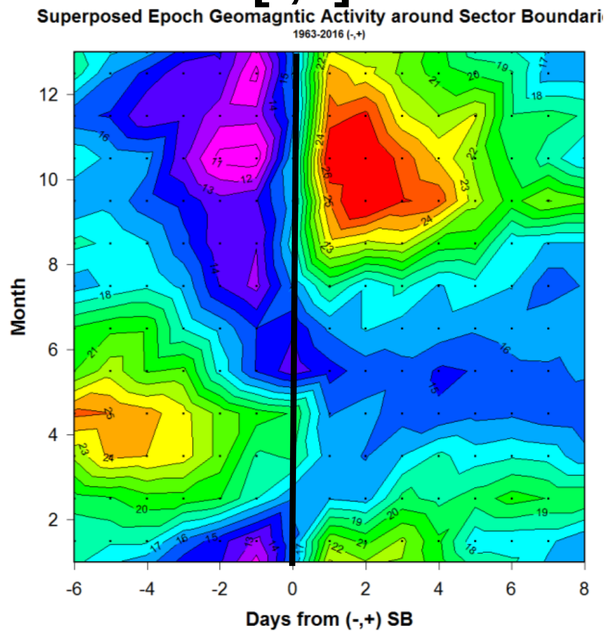
I have constructed a composite of all available data for the entire interval 1844-2016. The data consists of 3-hour K-values with a third-unit resolution (0o, 0+, 1-, 1o, 1+, 2-, 2o, 2+, …, 8-, 8o, 8+, 9-, 9o).

Superposed Epoch of Geomagnetic Activity around Sector Boundaries During Space Age 1963-2016

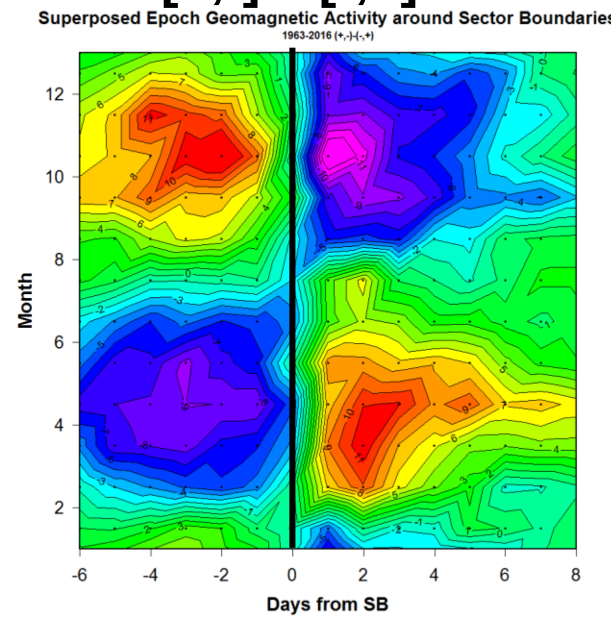
[+,-]

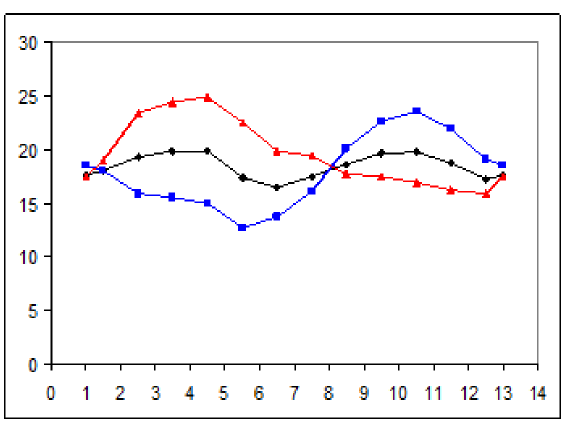


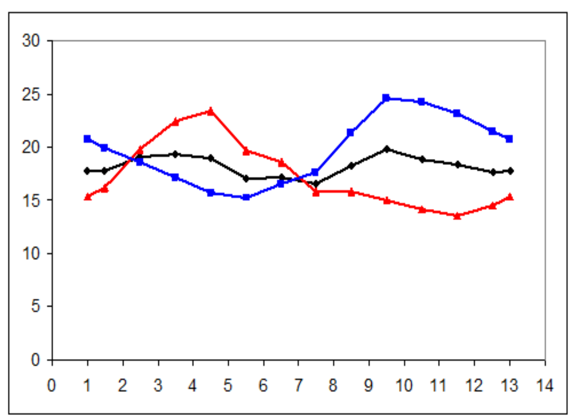
[-,+]

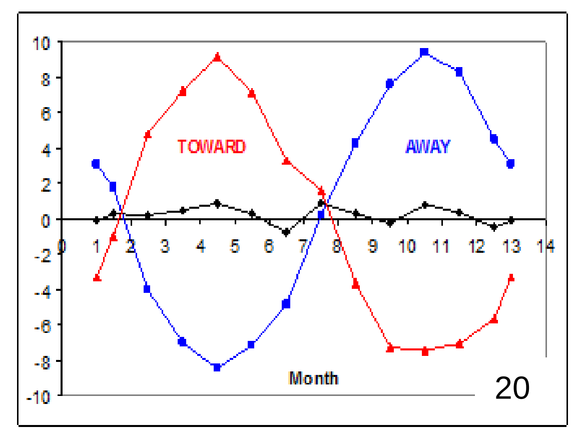


[+,-] – [-,+]



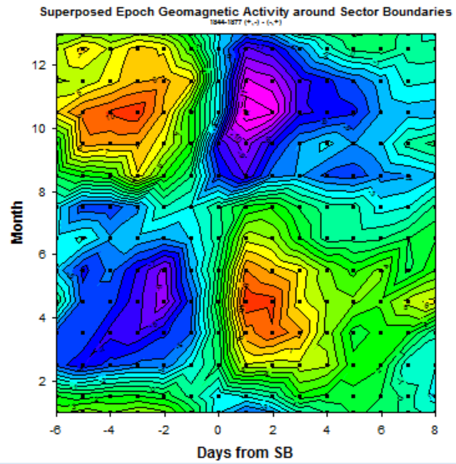






We see the same pattern in each subset of the Sector Polarity Data

k-1844-1877-pm-mp.grf

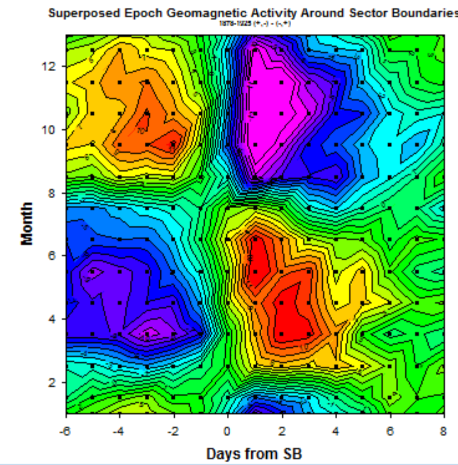


Nevanlinna

1844-
1877

Cycles
9-10-
11

k-1878-1925-pm-mp.grf

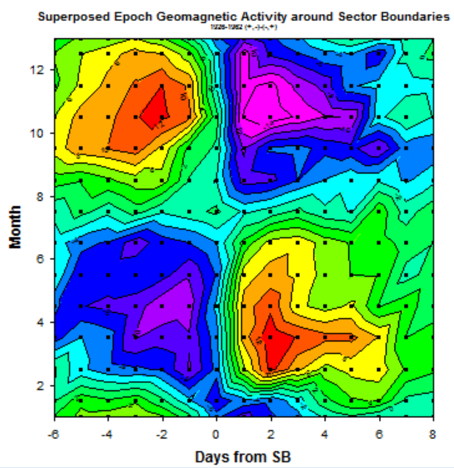


Mayaud

1878-
1925

Cycles
12-13-
14-15

k-1926-1962-pm-mp.grf

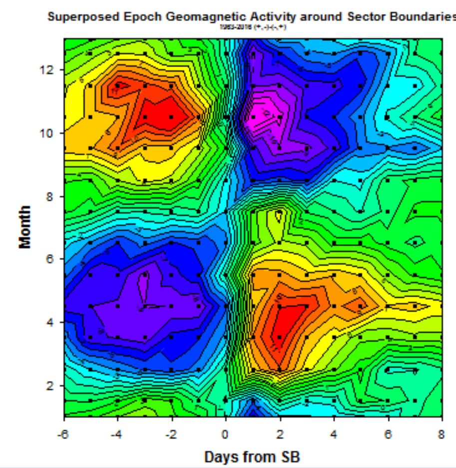


Svalgaard

1926-
1962

Cycles
16-17-
18-19

k-1963-2016-pm-mp.grf1



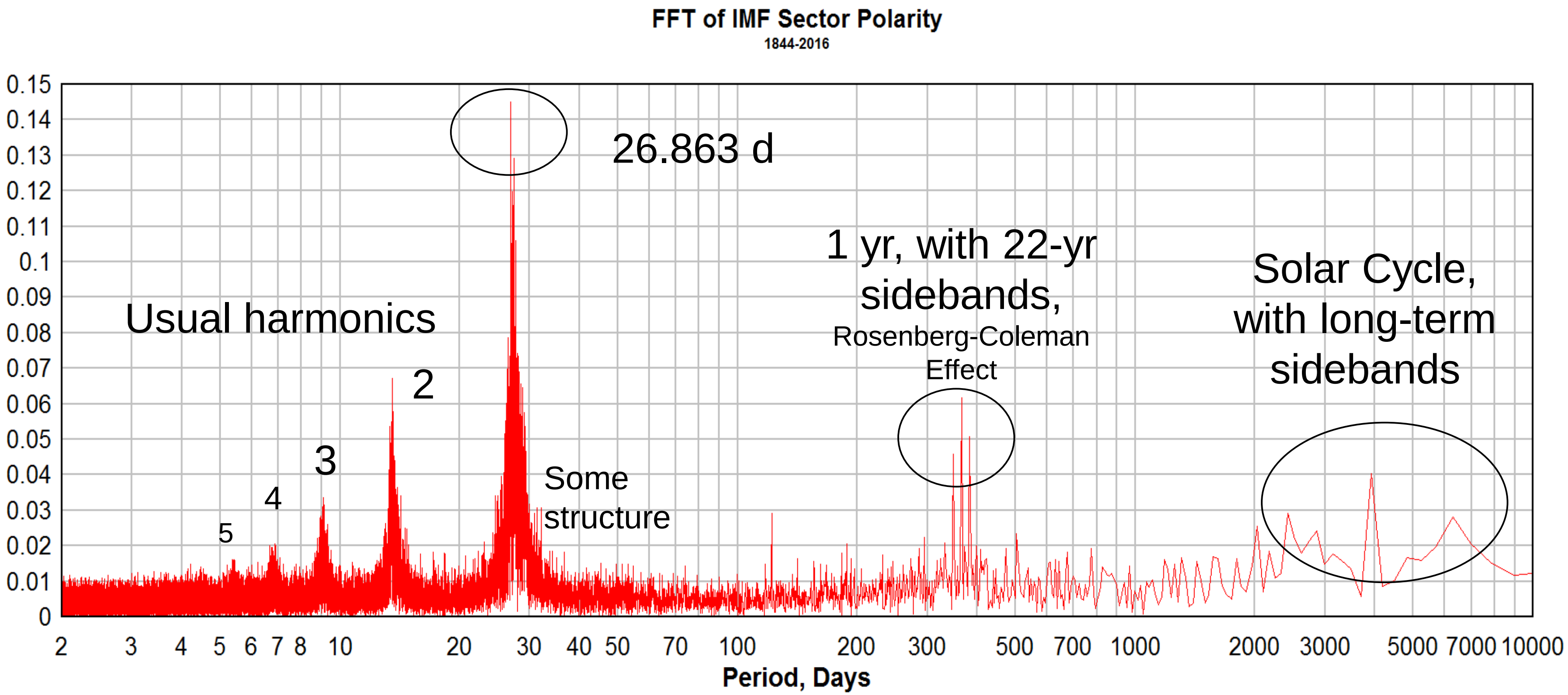
Space age

1963-
2016

Cycles
20-21-
22-23-
24

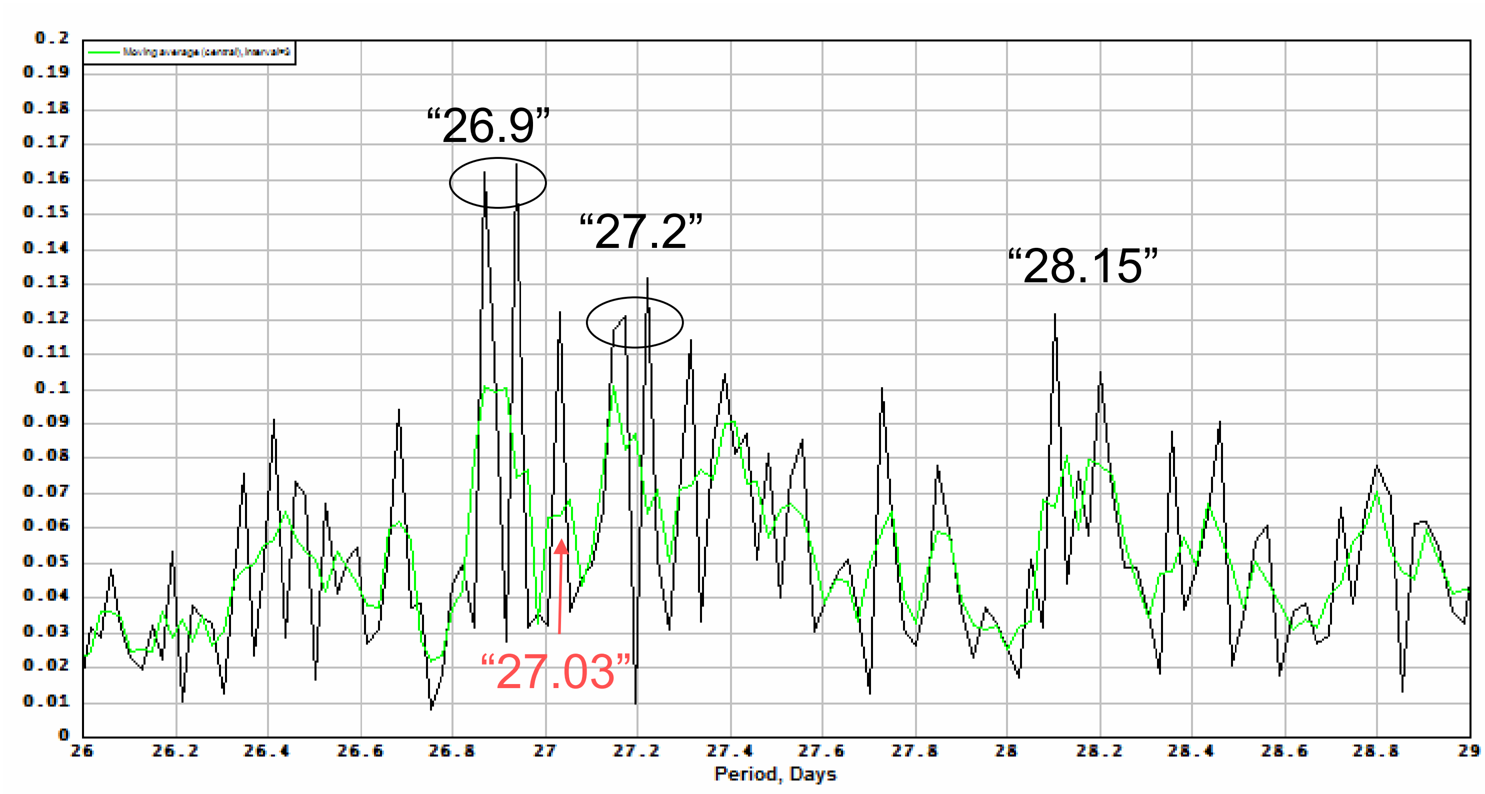
I interpret that to mean that the data is good

Justifying Calculating the FFT



For the entire interval 1844-2016

Recurrence Peak: Fine Structure



The 27.03 line is an artifact having contributions from the 26.9 and 27.2 lines

This was an early run using 1926-2013 data, can now be extended

Average Recurrence Period in Solar Wind Data

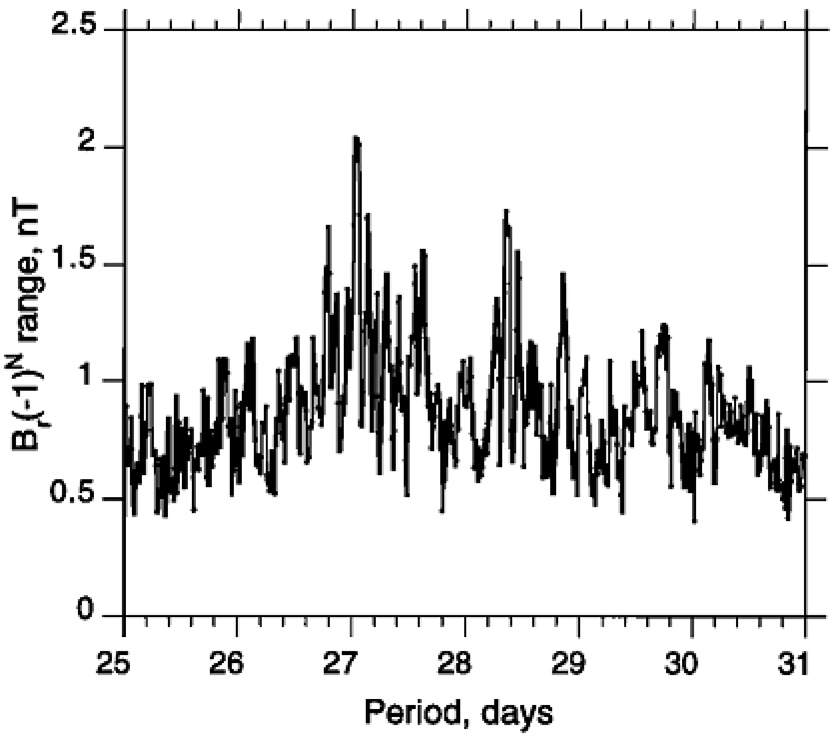
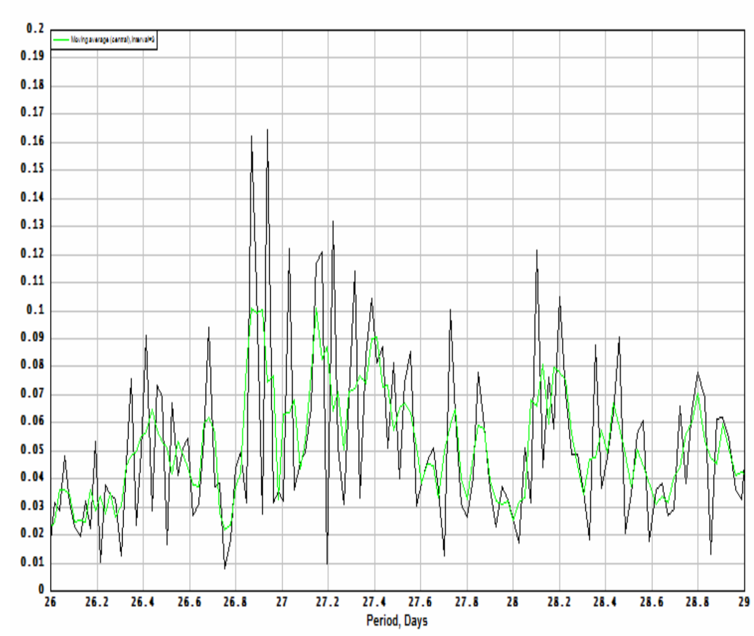


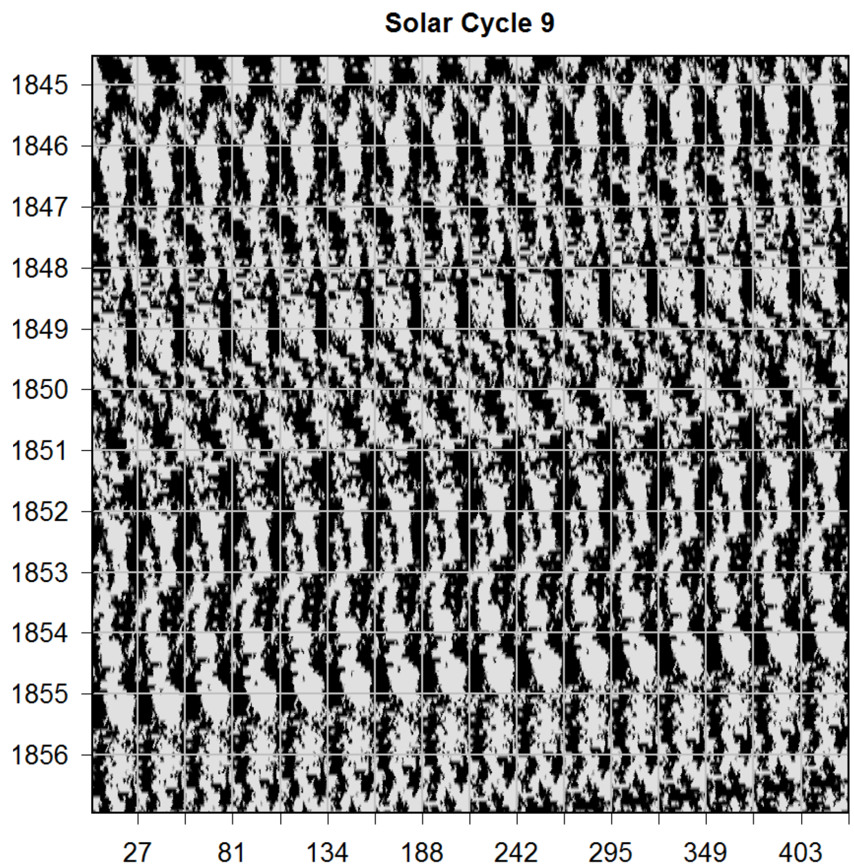
Figure 5. The difference between the highest and the lowest values of $B_r(-1)^N$ for the time-averaged $B_r(-1)^N$ versus longitude curves as a function of solar rotation period from 25 to 31 days.

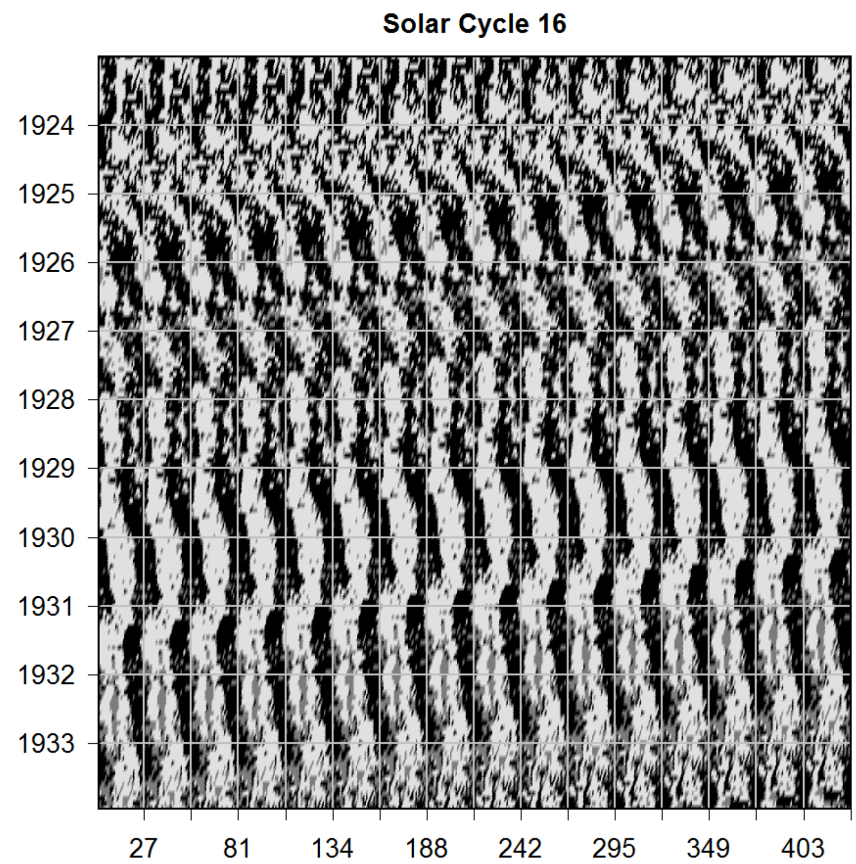
Neugebauer et al., 2000

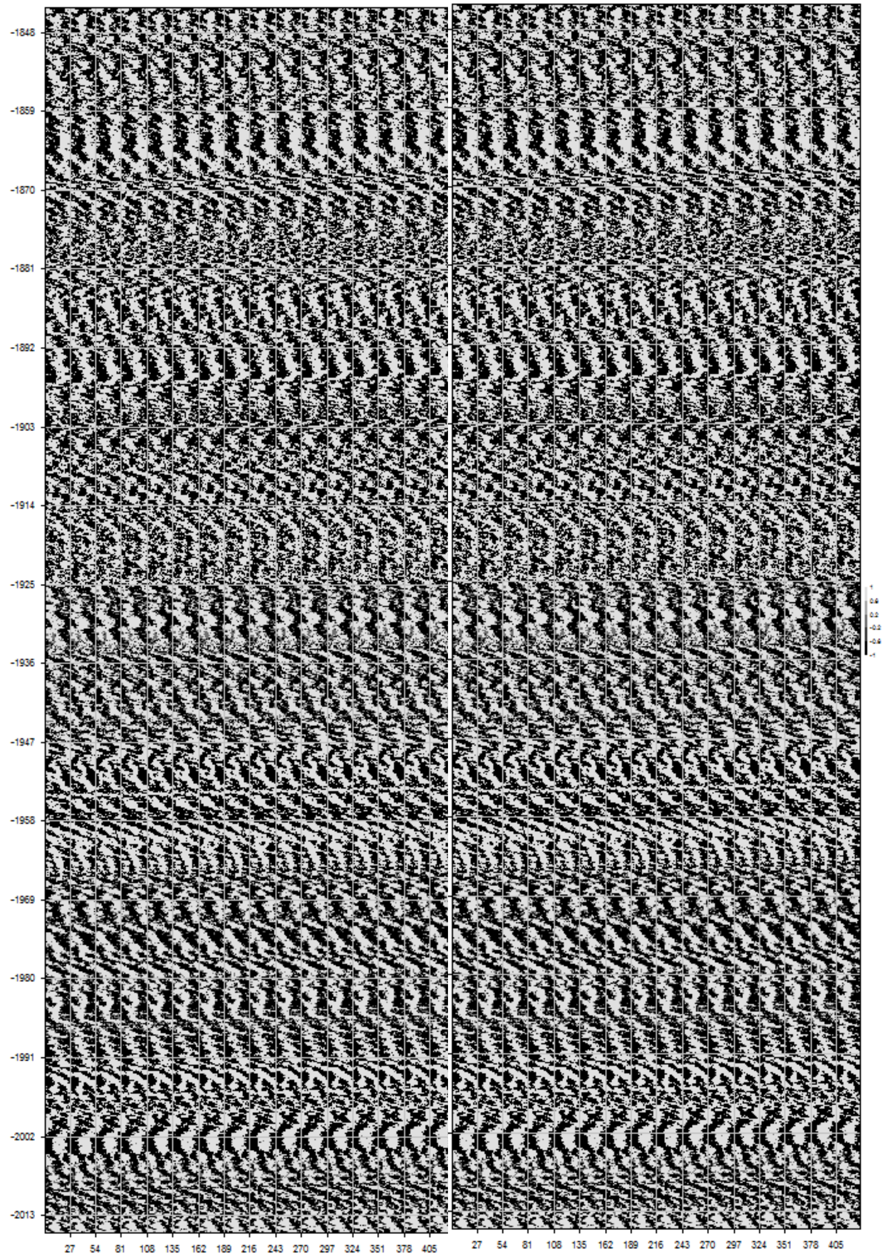


"On average, solar magnetic field lines in the ecliptic plane point outward on one side of the Sun and inward on the other, reversing direction approximately every 11 years while maintaining the same phase. The data are consistent with a model in which the [equatorial] solar magnetic dipole returns to the same longitude after each reversal."

We can now make the 26.863 d Calendar Recurrence Plots



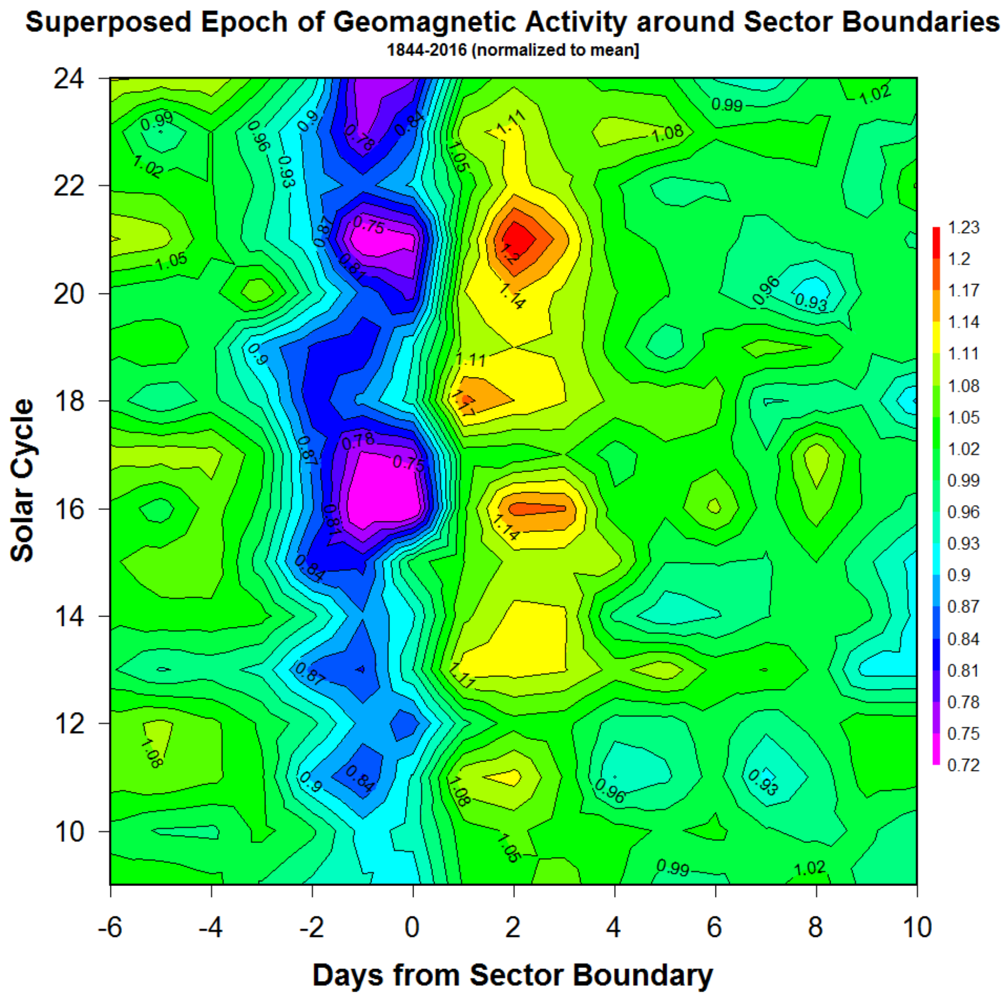




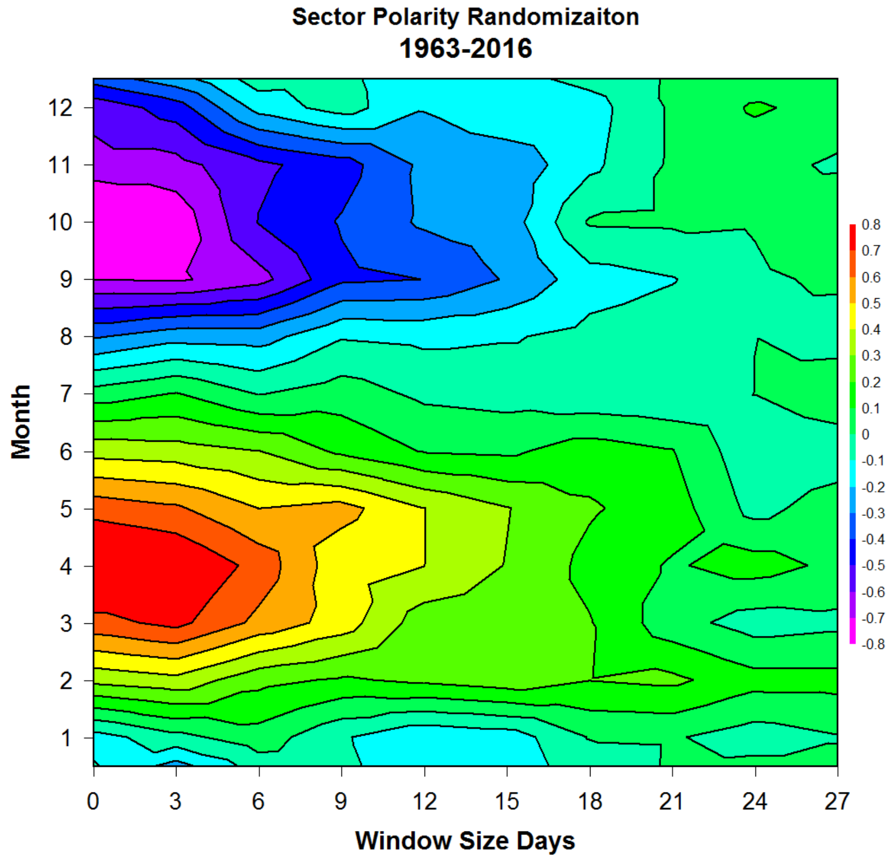
And even a Douglas-style Superplot

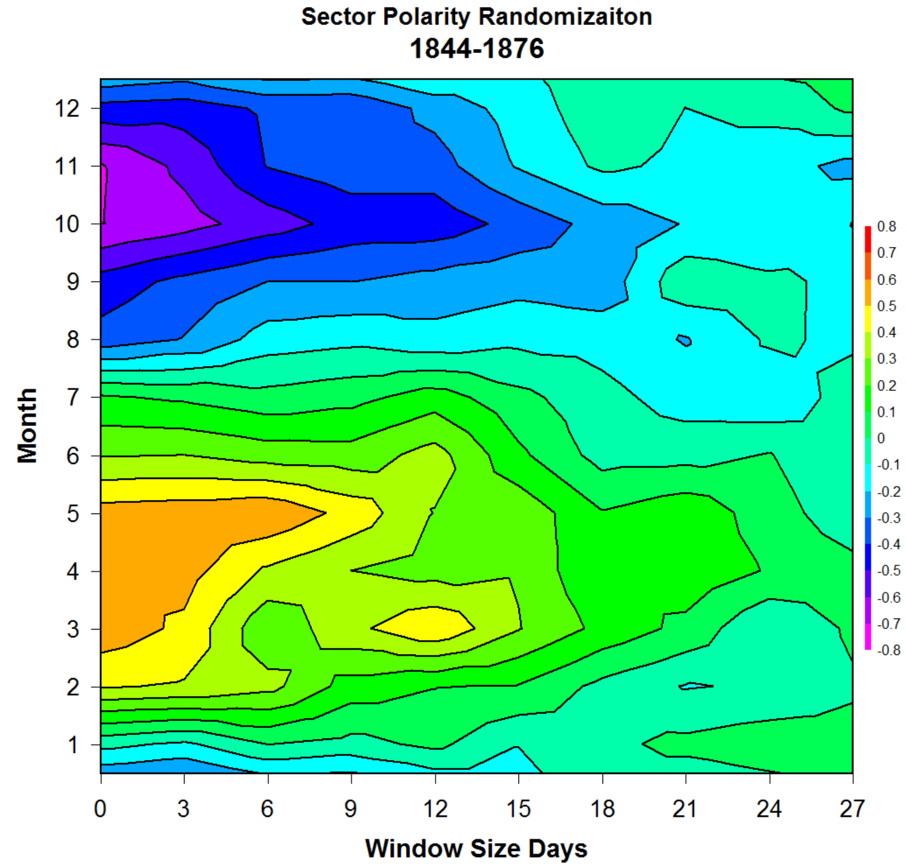
And begin hunting for alignments

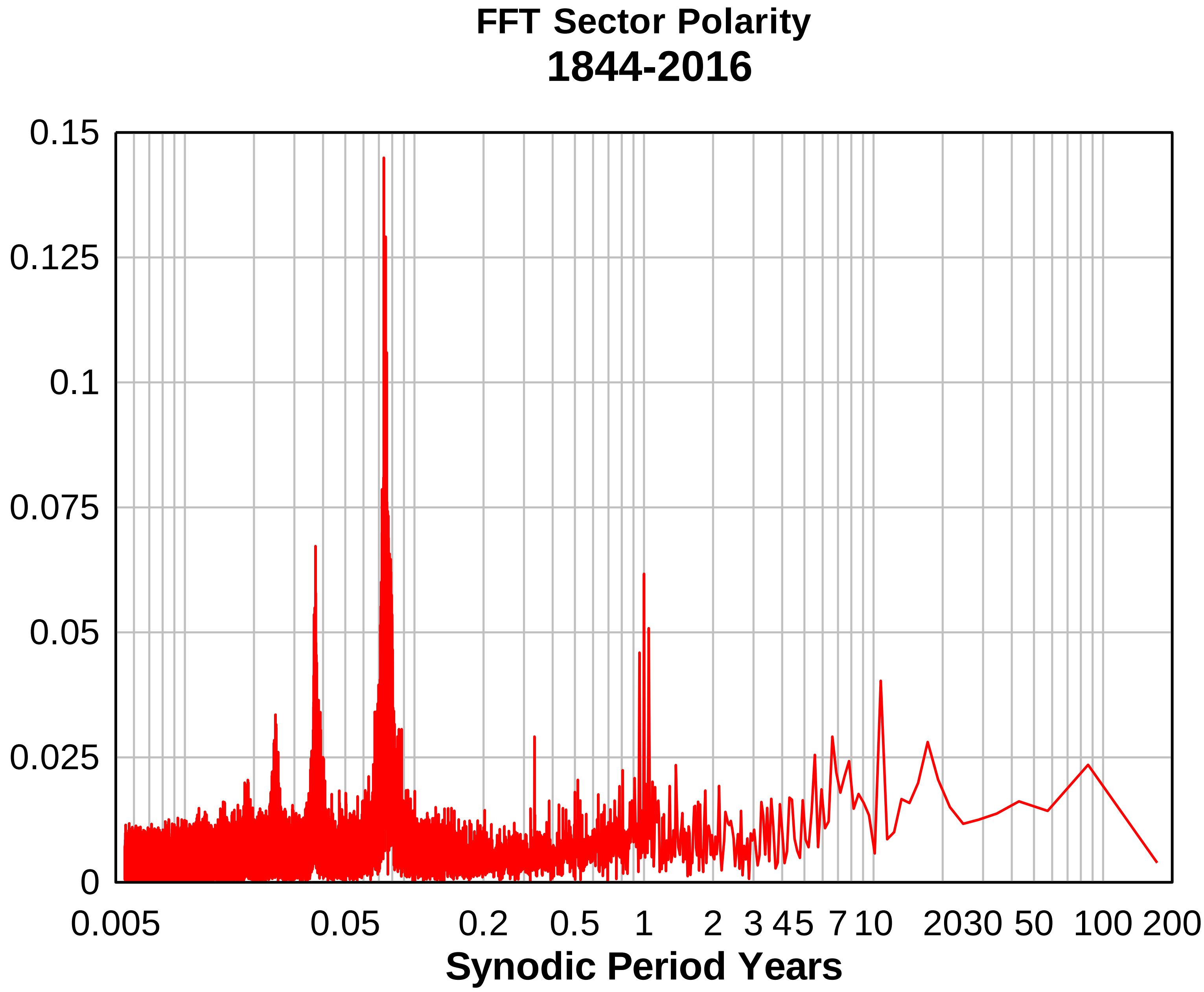
Hunting… Don’t know what it means…

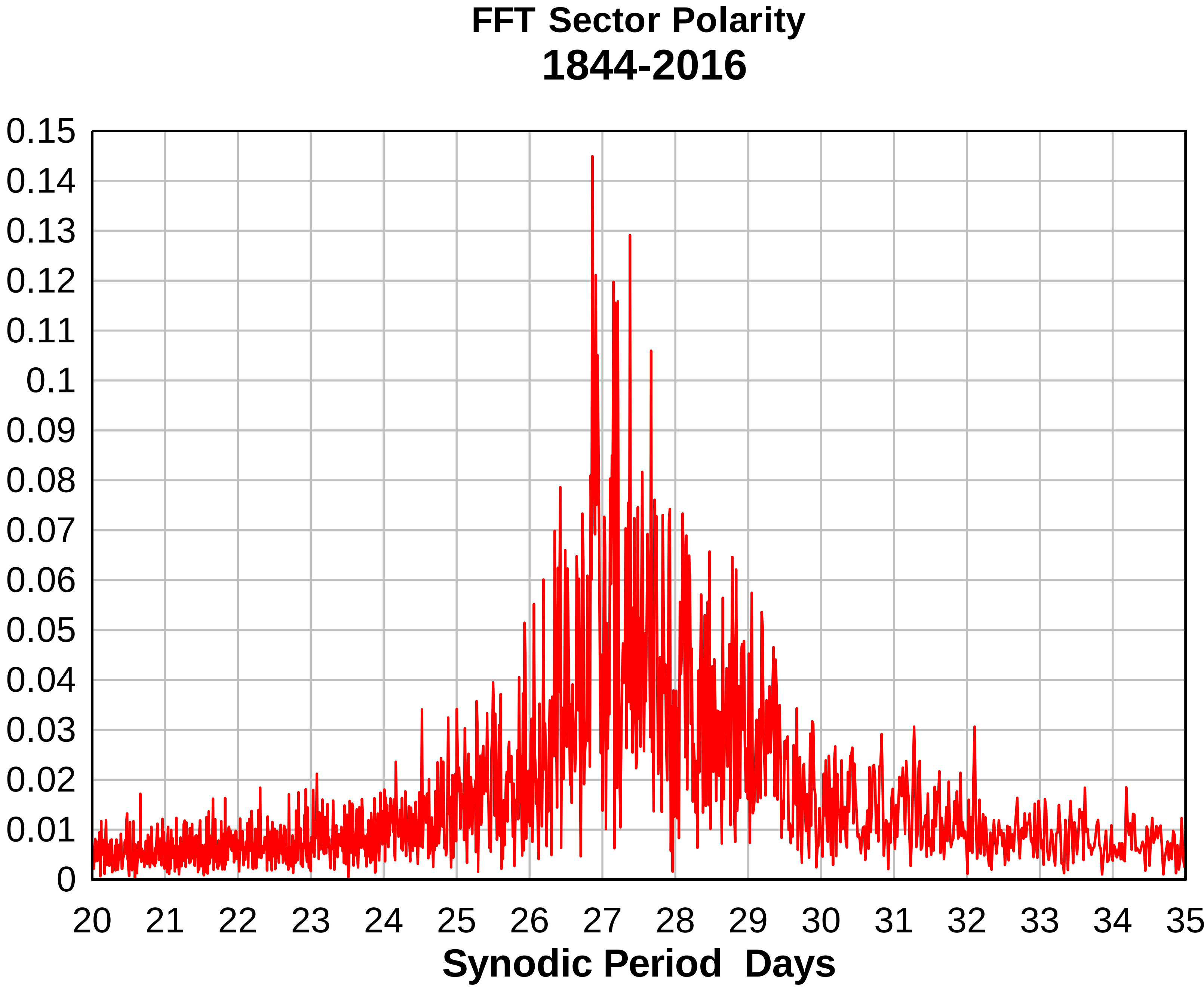


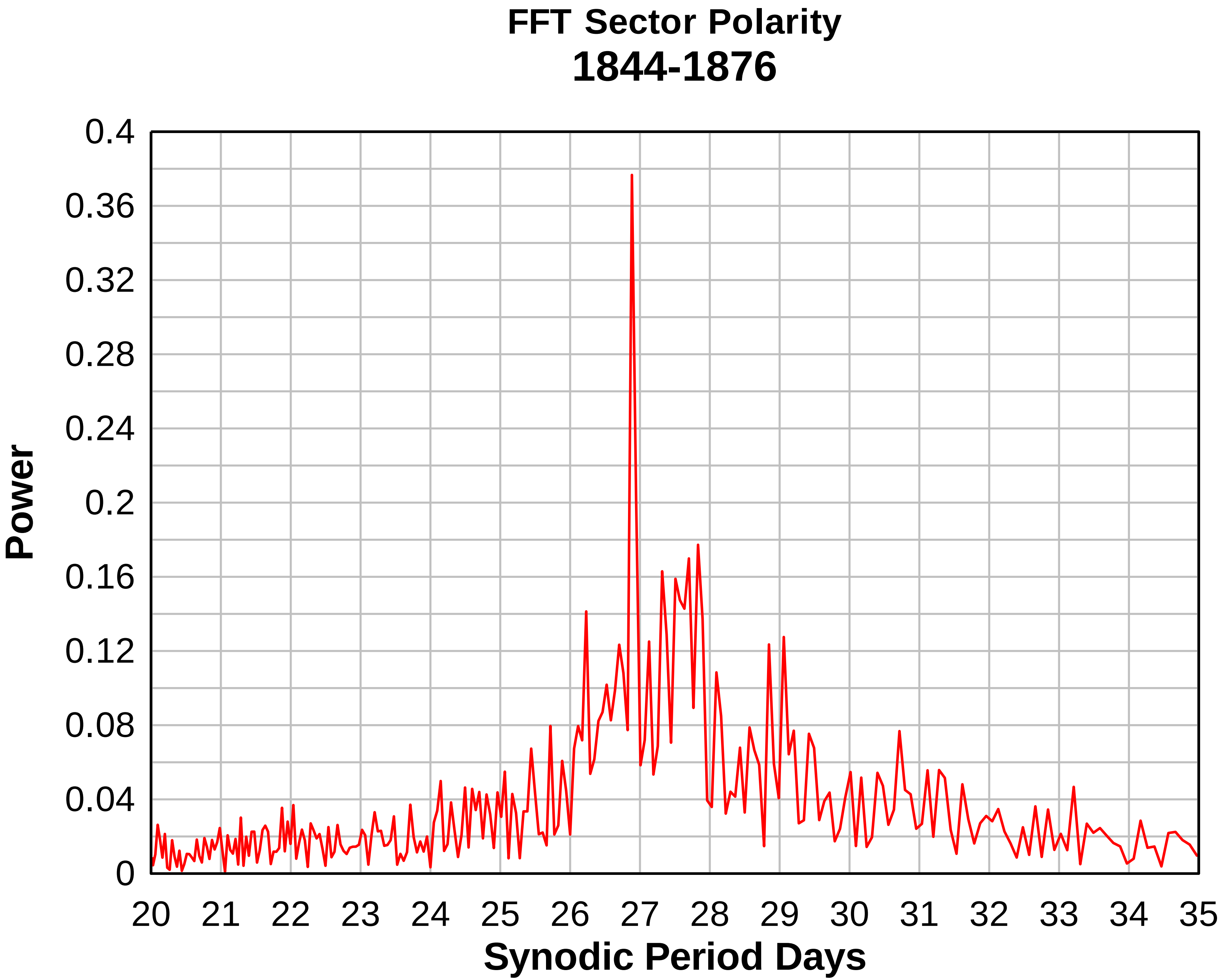
(+,-) Boundary


Sector Polarity Randomizaiton
1963-2016
Month
Window Size Days

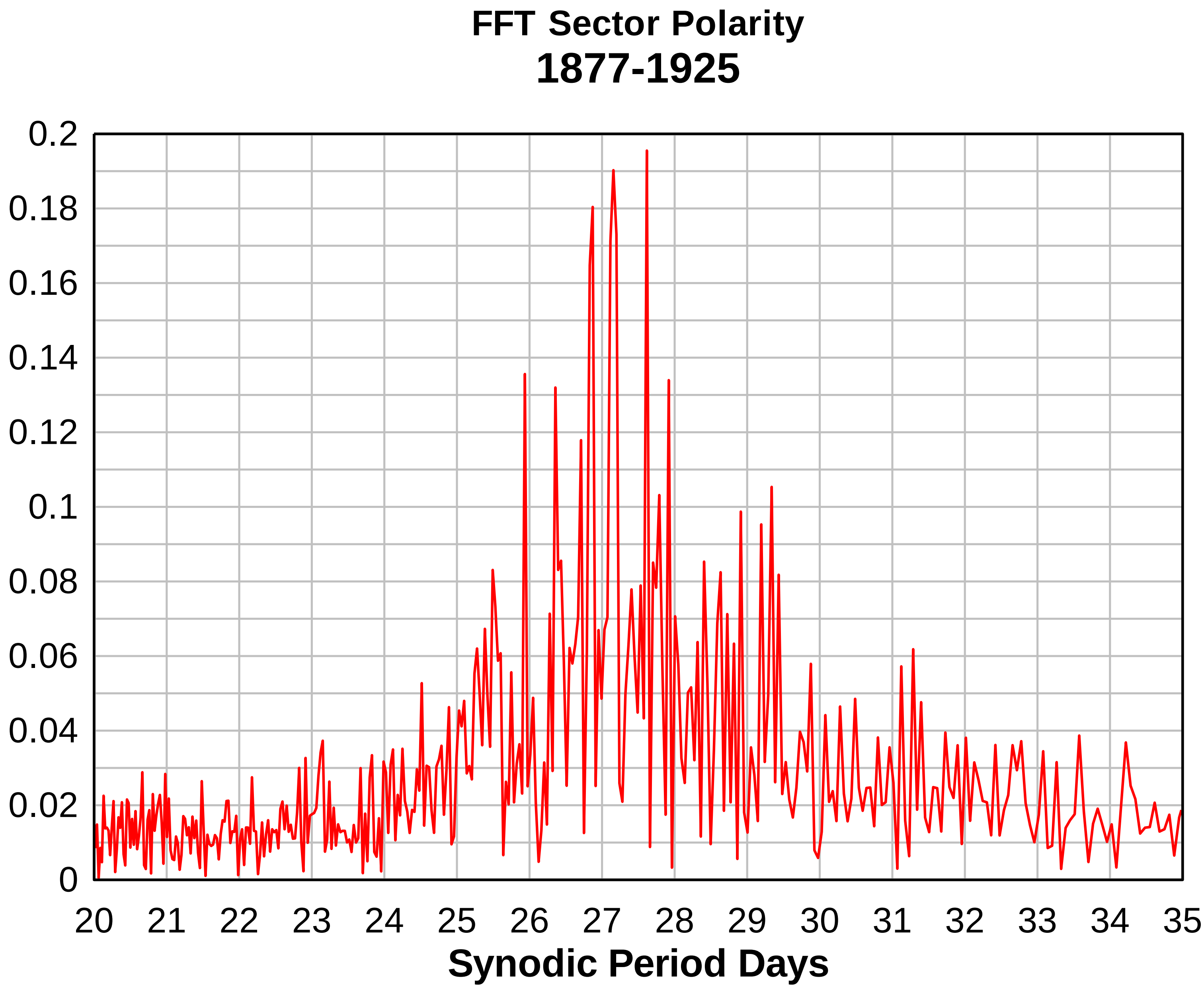

Sector Polarity Randomizaiton
1844-1876
Month
Window Size Days

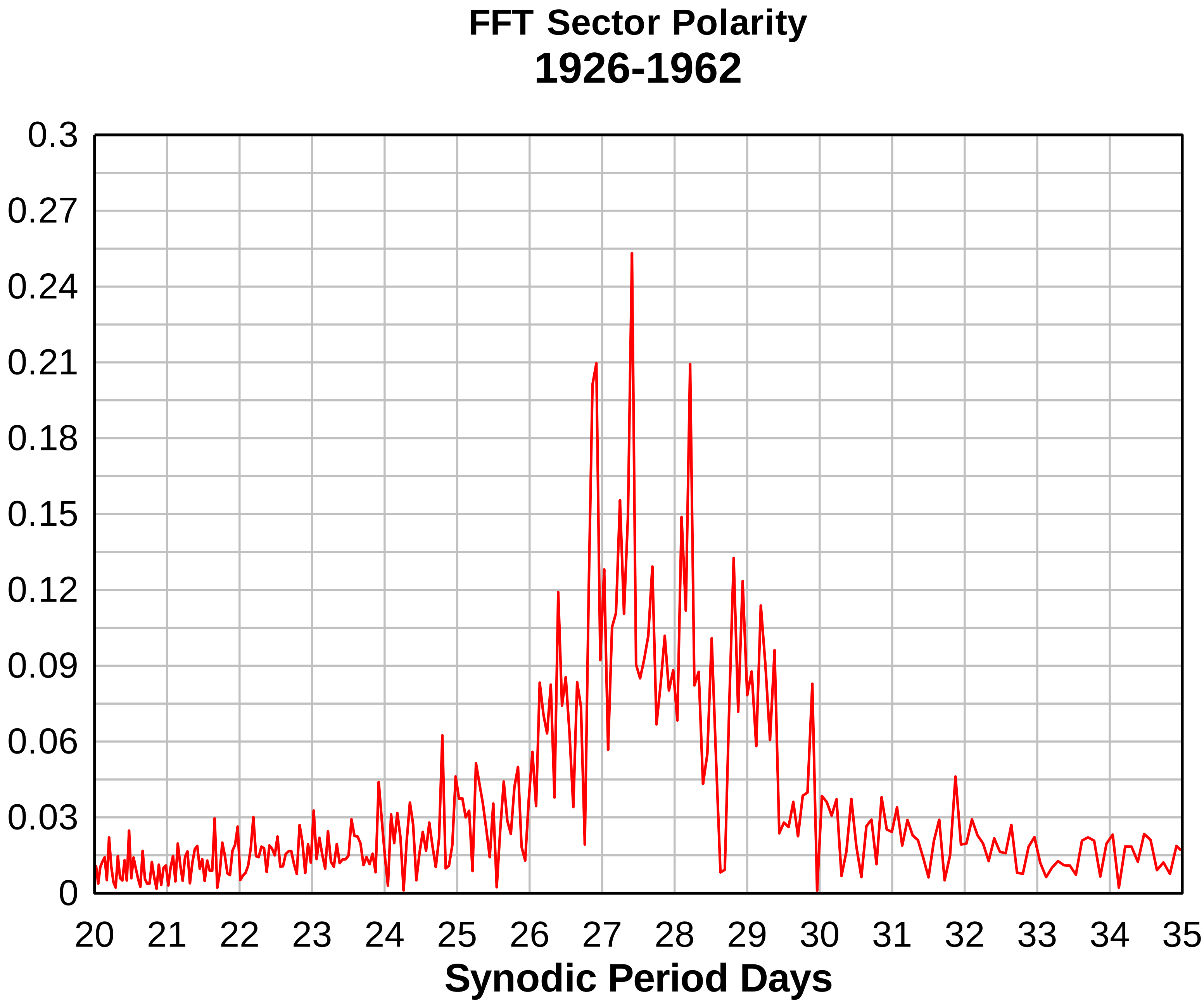

FFT Sector Polarity
1844-2016
0.15
0.125
0.1
0.075
0.05
0.025
0
0.005
0.05
0.2
0.5
1
2
3
4
5
7
10
20
30
50
100
200
Synodic Period Years

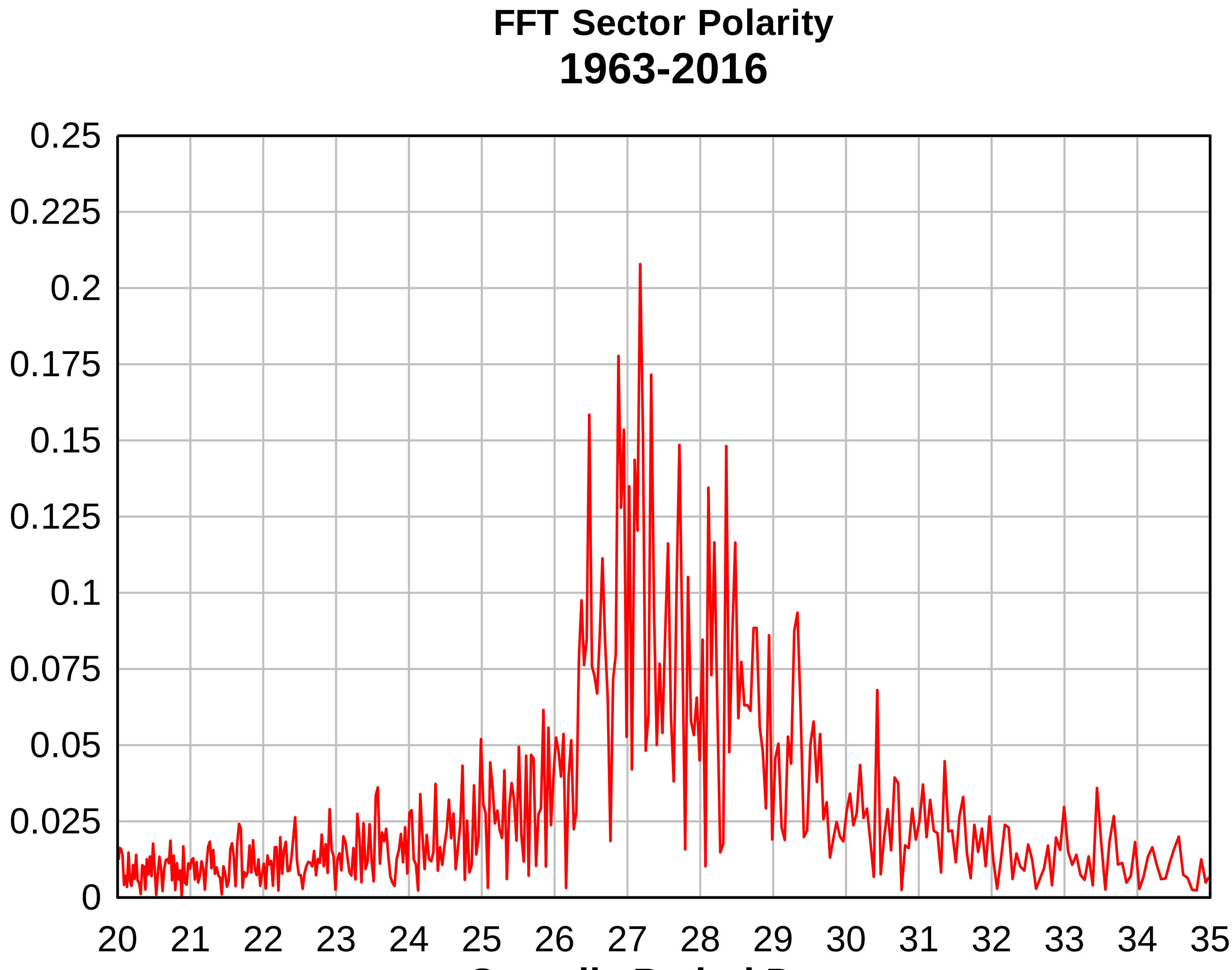

FFT Sector Polarity
1844-2016
0.15
0.14
0.13
0.12
0.11
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
Synodic Period Days



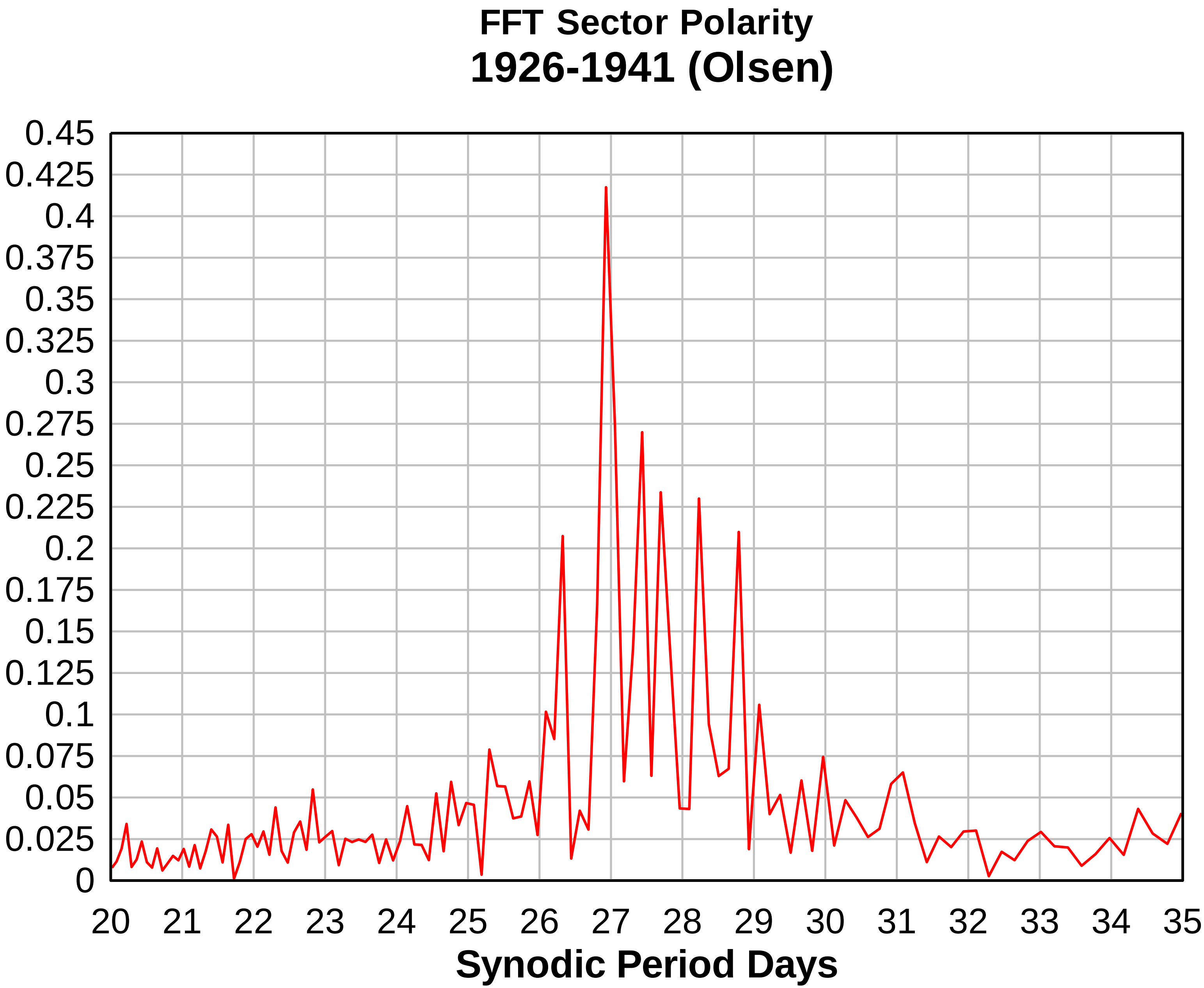
FFT Sector Polarity
1844-1876
Power
0.4
0.36
0.32
0.28
0.24
0.2
0.16
0.12
0.08
0.04
0
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
Synodic Period Days


FFT Sector Polarity
1877-1925
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
Synodic Period Days


FFT Sector Polarity
1926-1962
0.3
0.27
0.24
0.21
0.18
0.15
0.12
0.09
0.06
0.03
0
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
Synodic Period Days



FFT Sector Polarity
1963-2016
0.25
0.225
0.2
0.175
0.15
0.125
0.1
0.075
0.05
0.025
0
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
Synodic Period Days


FFT Sector Polarity
1926-1941 (Olsen)
0.45
0.425
0.4
0.375
0.35
0.325
0.3
0.275
0.25
0.225
0.2
0.175
0.15
0.125
0.1
0.075
0.05
0.025
0
20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35
Synodic Period Days

Abstract