The asymmetry of the solar cycle: Analysis of the cycle #24 forecast.

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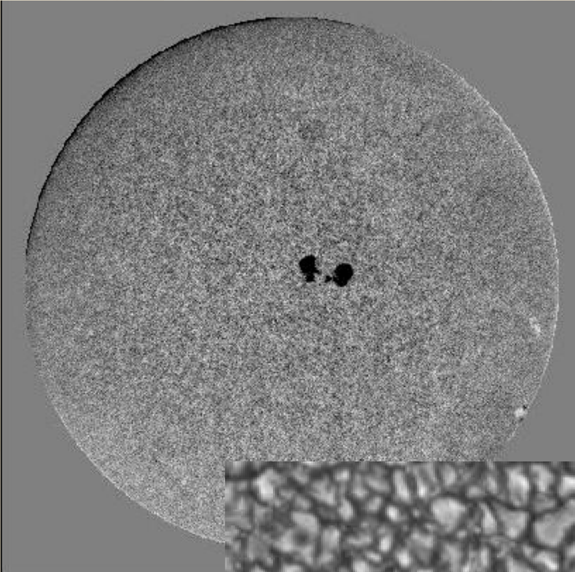
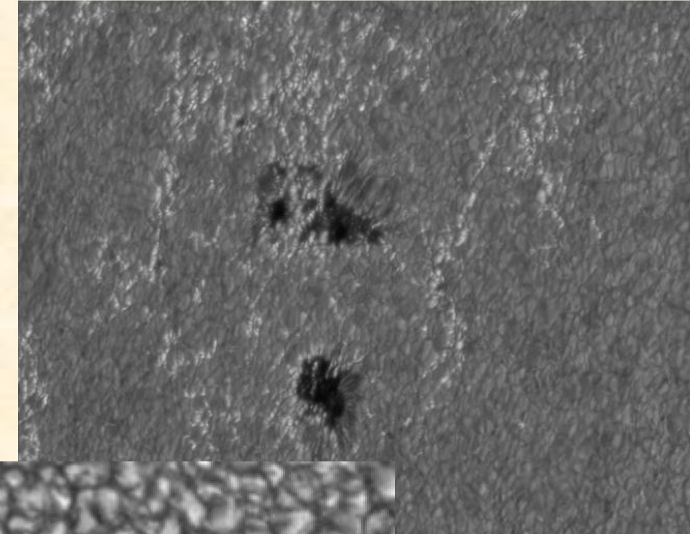
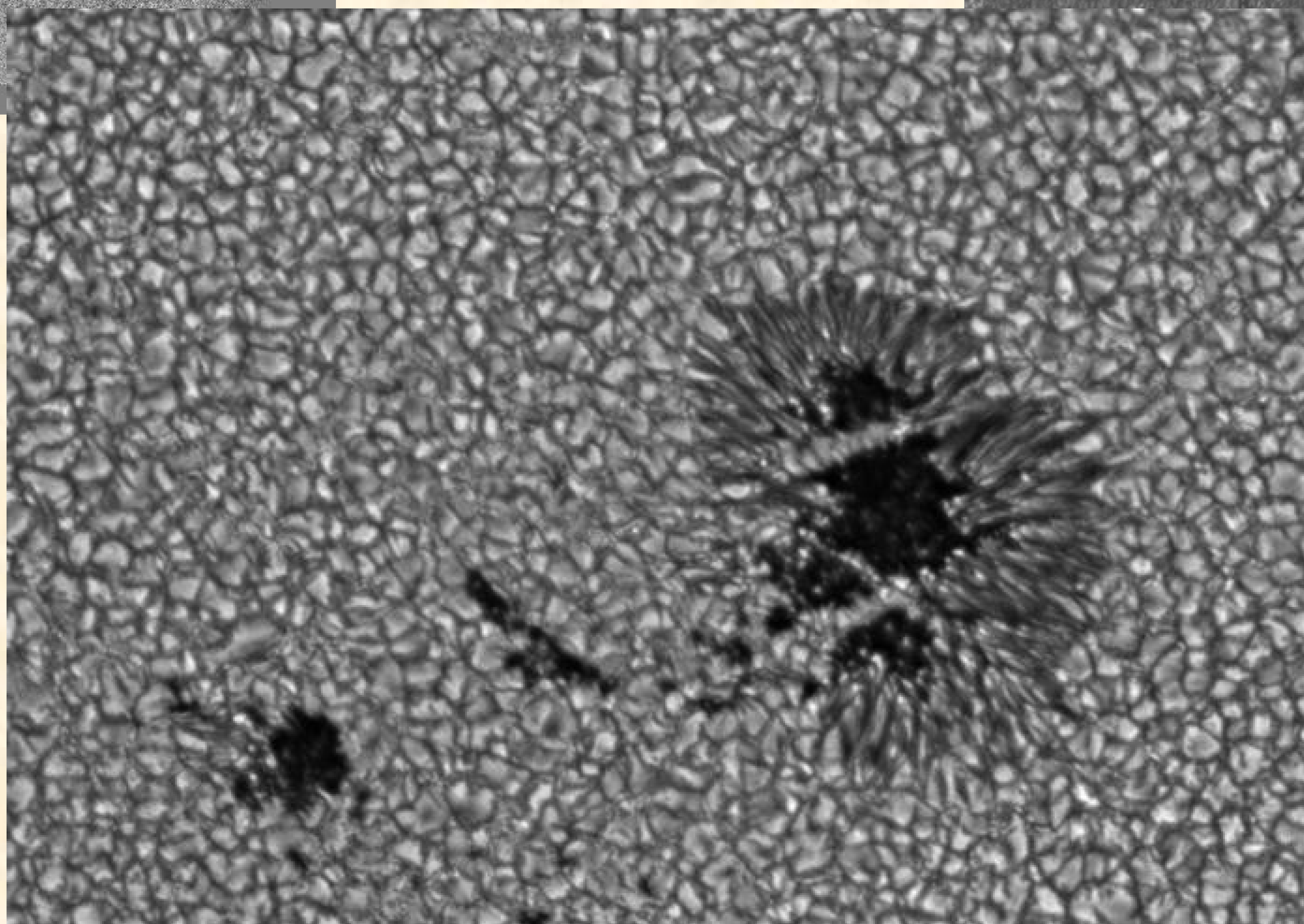
Introduction

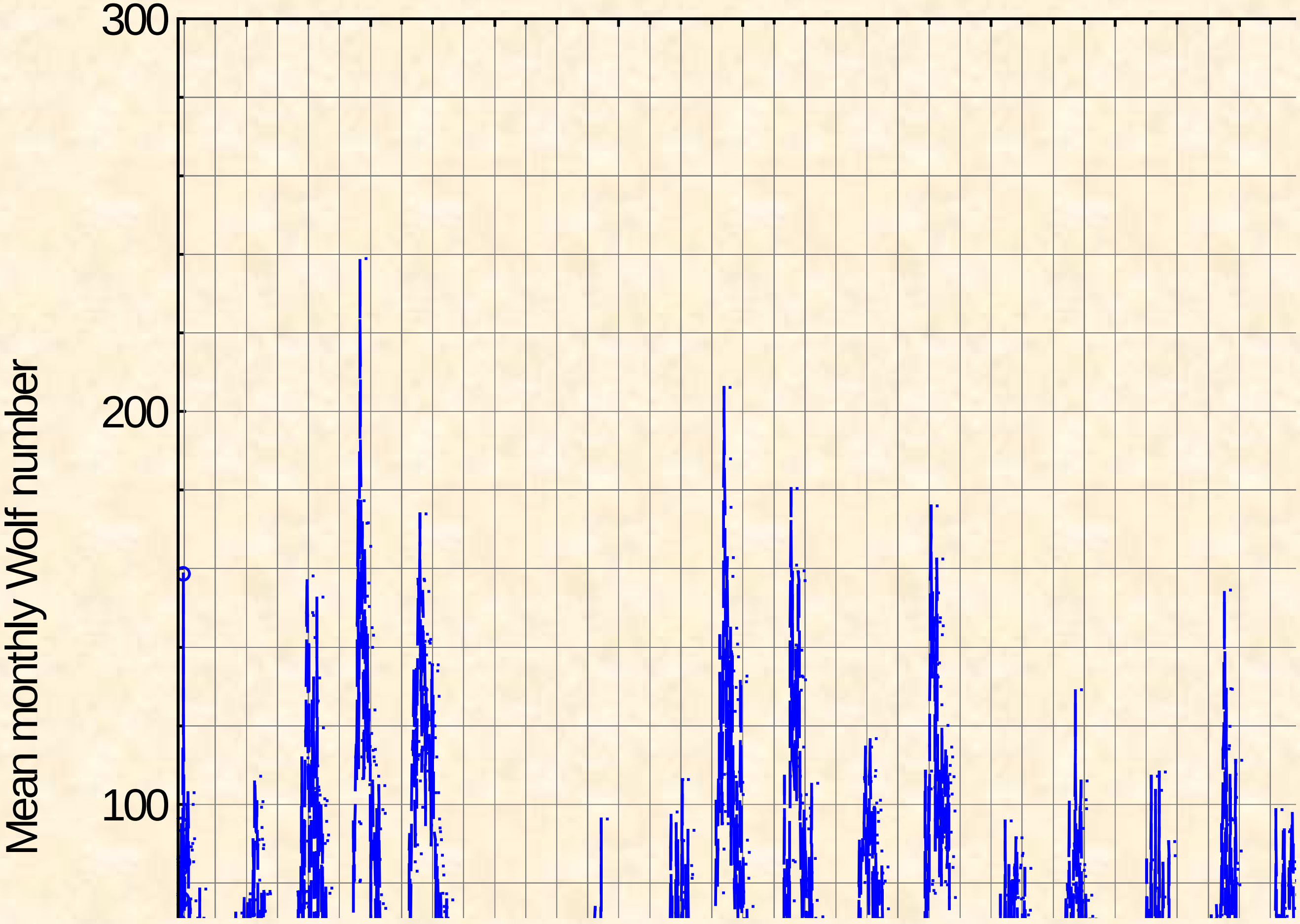
- Different numerical analysis models for fitting the shape of Wolf number evolution – not satisfactory

- Few attempts to base the forecast on a physical basis

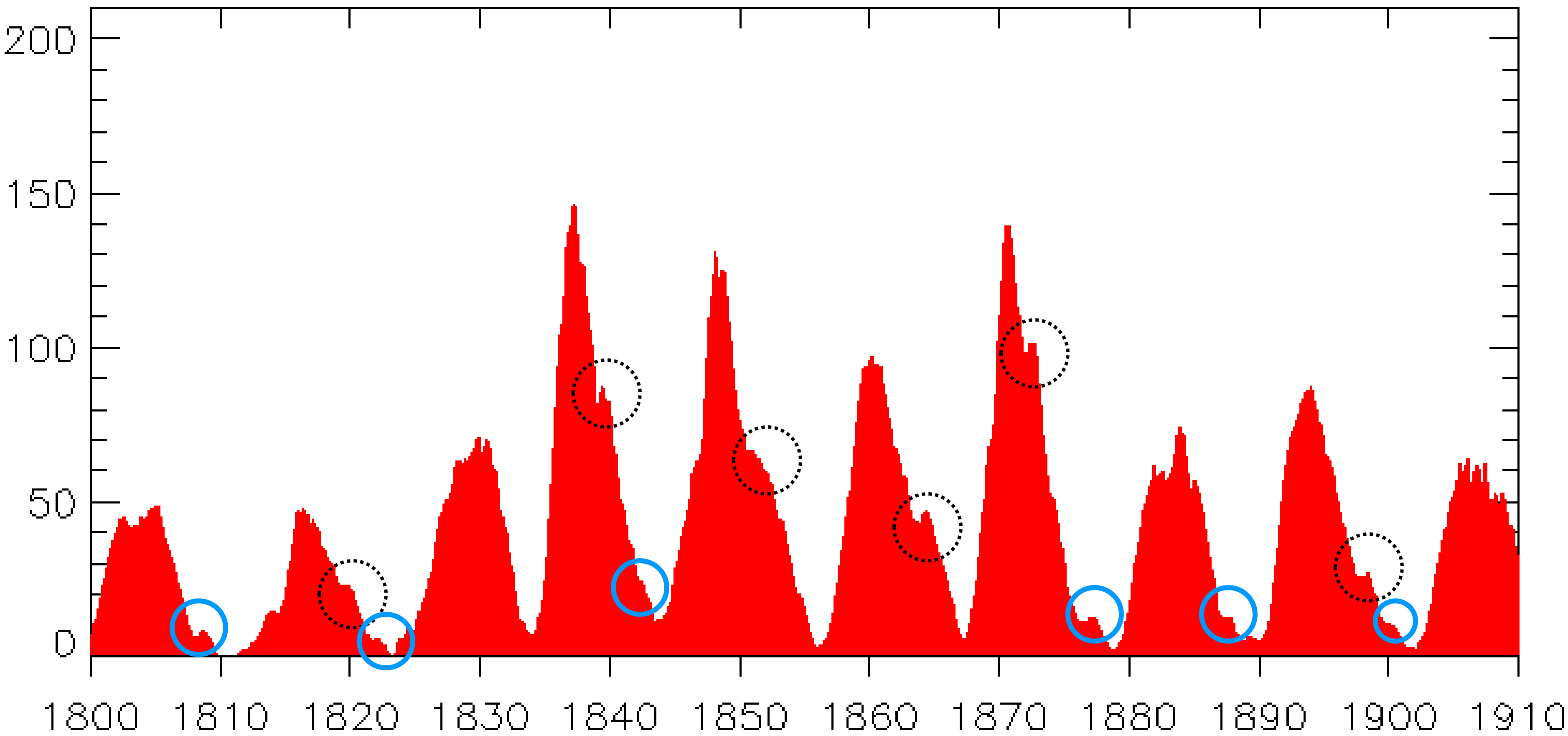
- The paper presents the progress we made in analysis of the Wolf sunspot numbers with a special attention on the asymmetry exhibited for each cycle based on our previous findings:
  - Periodicity of approximately 11 years of maxima
  - Variability of the “amplitude” of these maxima
  - Asymmetry of the variation: a quick increase and a much slower decrease of the sunspot numbers (maxima present asymmetry)
  - Many of them the presence of two maxima

The pattern of the time series of wolf numbers for a log period

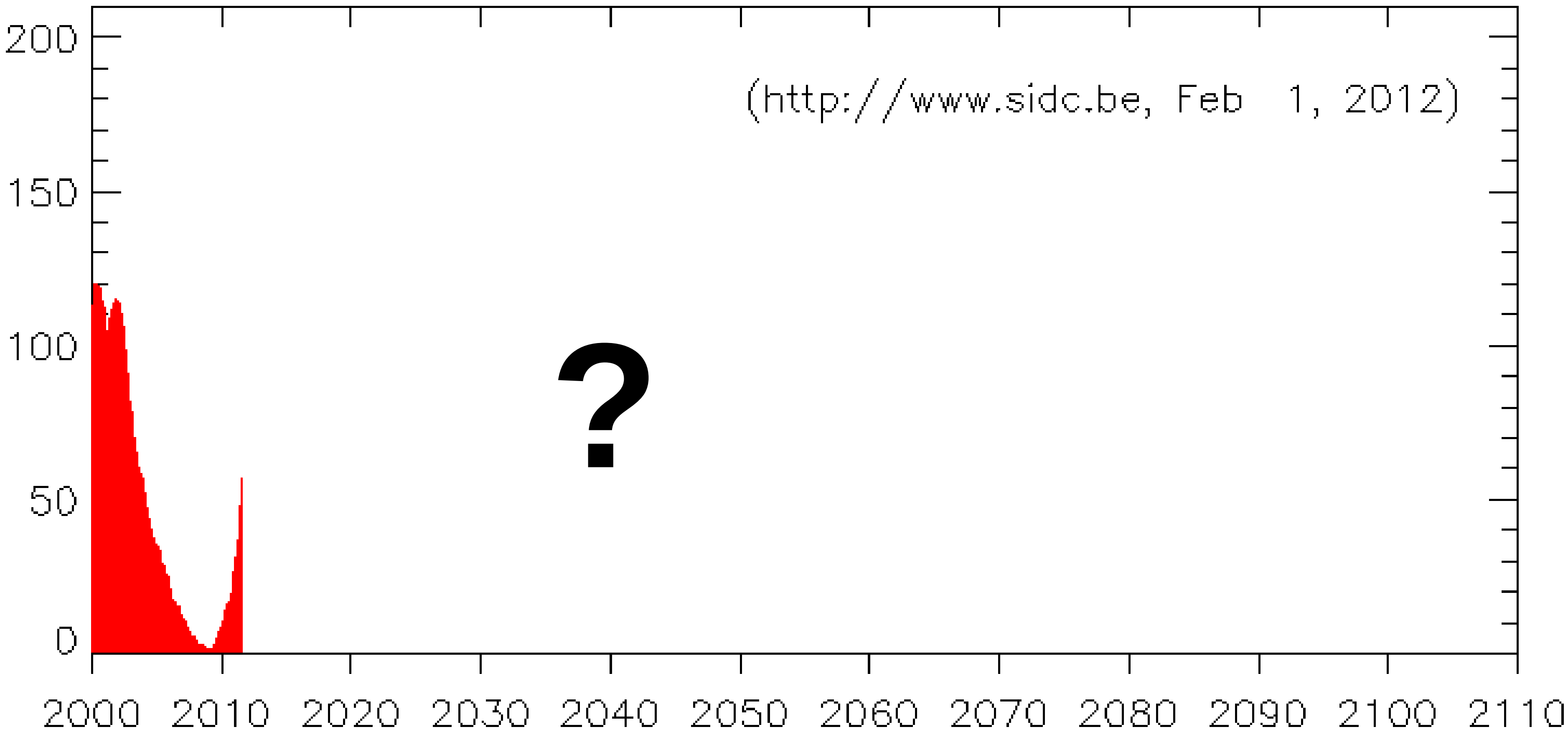


The pattern of the time series of wolf numbers for a log period

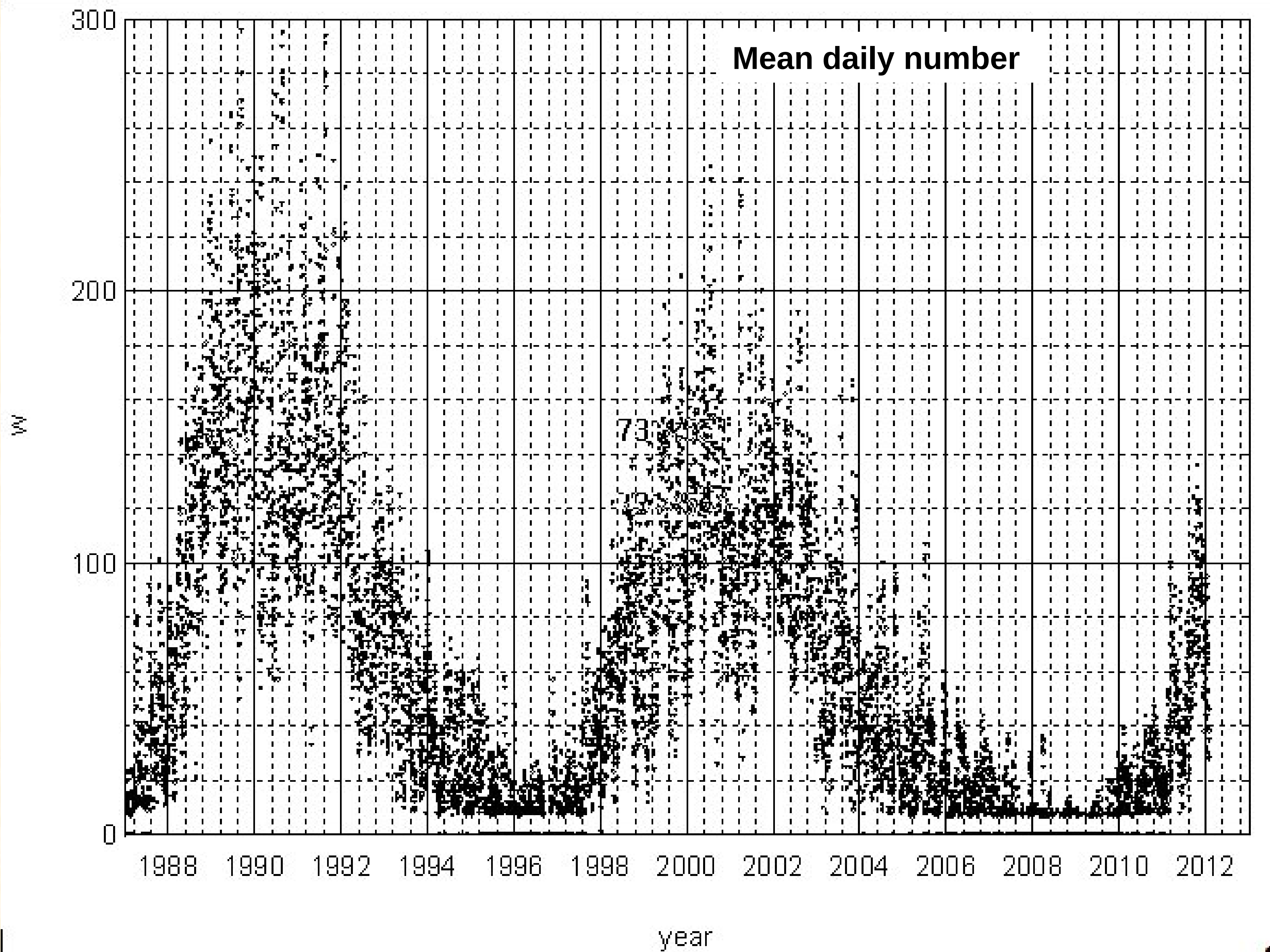


Mean monthly number

The pattern of the time series of wolf numbers for a log period

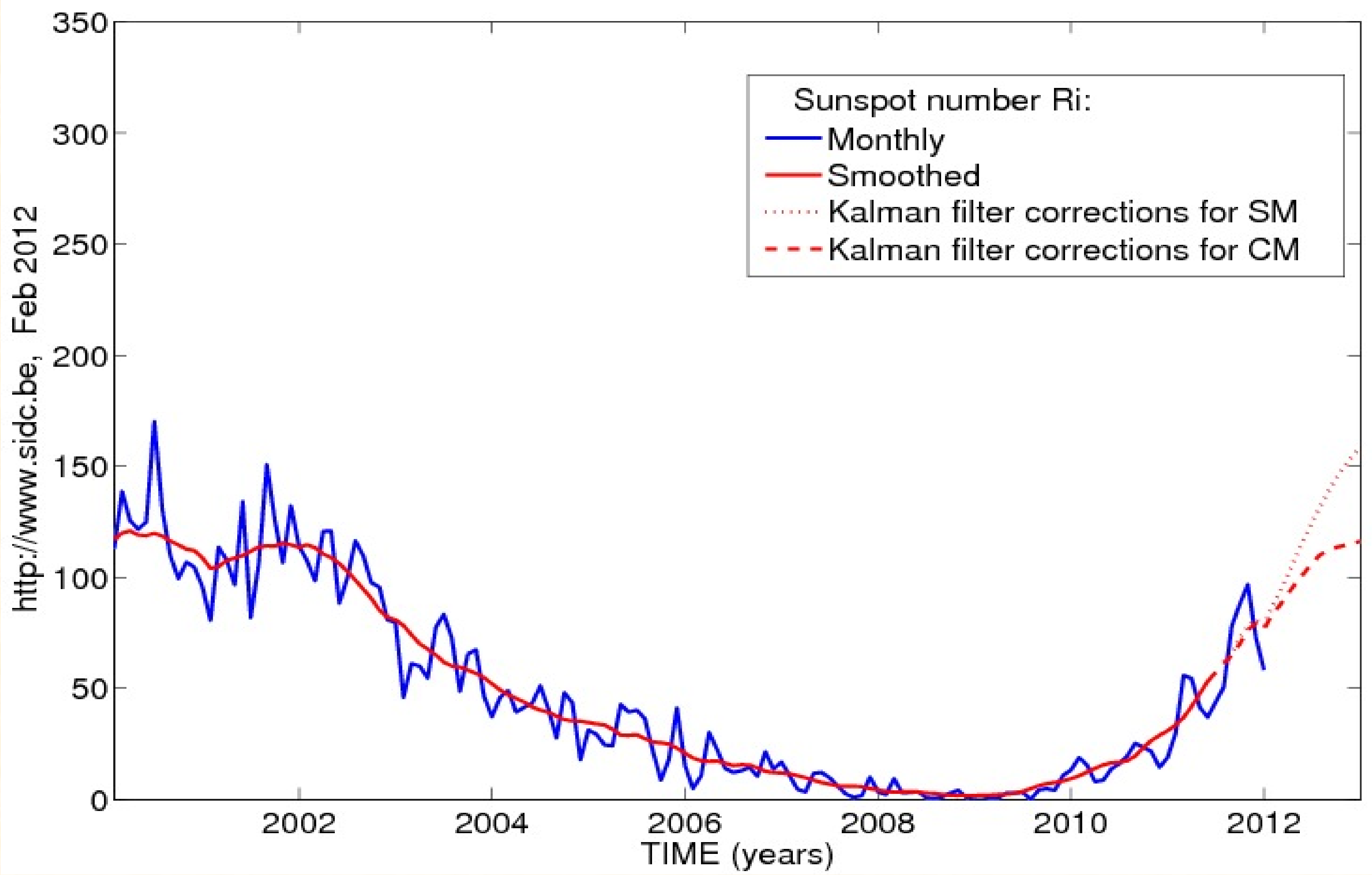


Mean monthly number

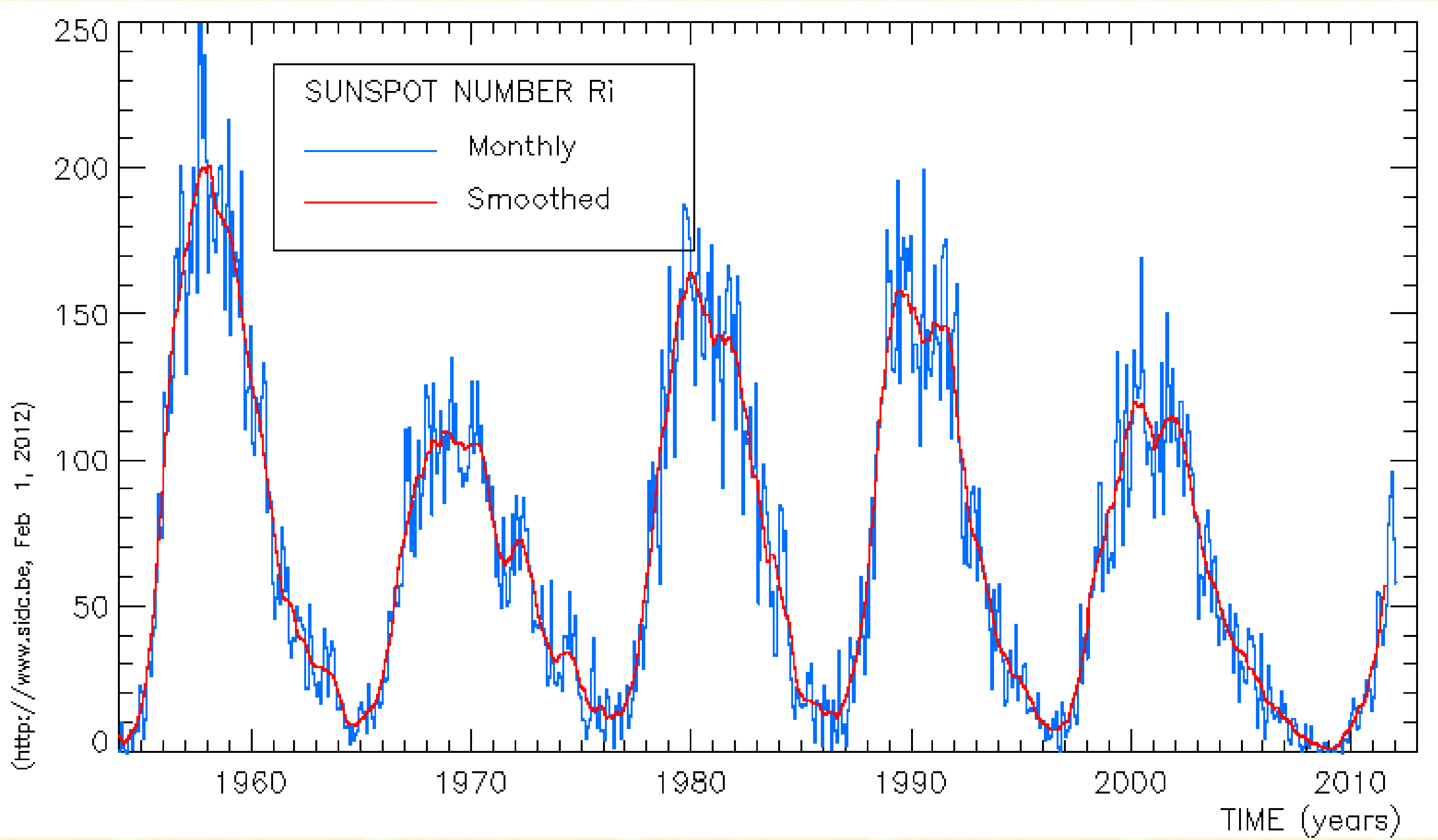


Mean daily number
W
year
0
100
200
300
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012

General models – smoothed

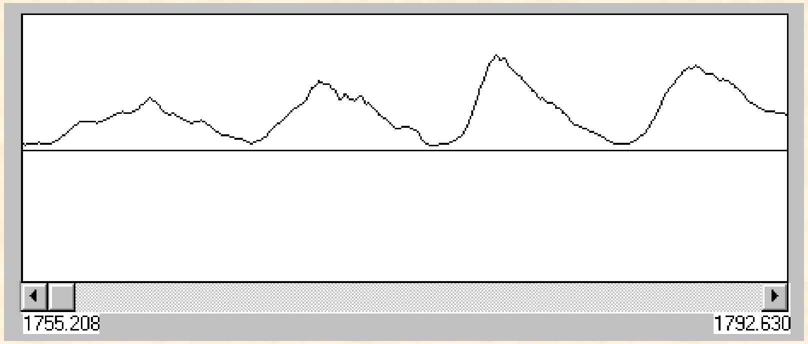


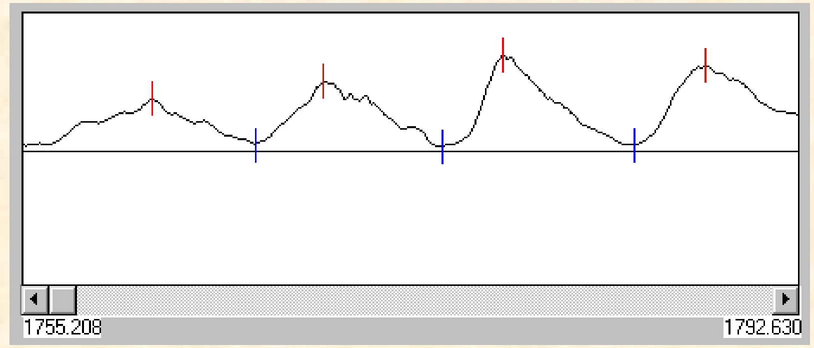
Pattern for the mean values – sliding mean

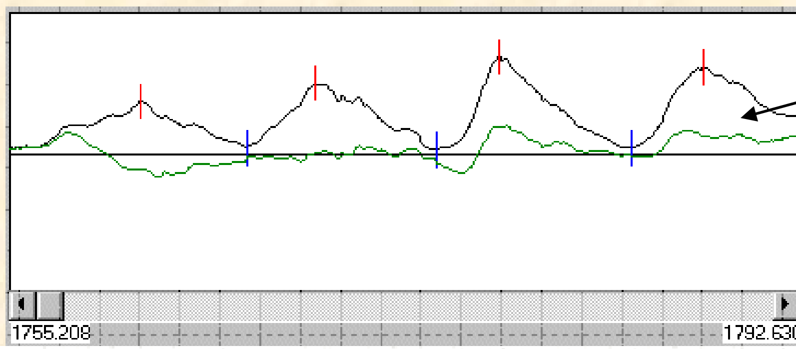


Our procedure for finding the minima & maxima of the wolf number series

(O. Tesileanu, Z. Mouradian, M. Rusu – 2002)

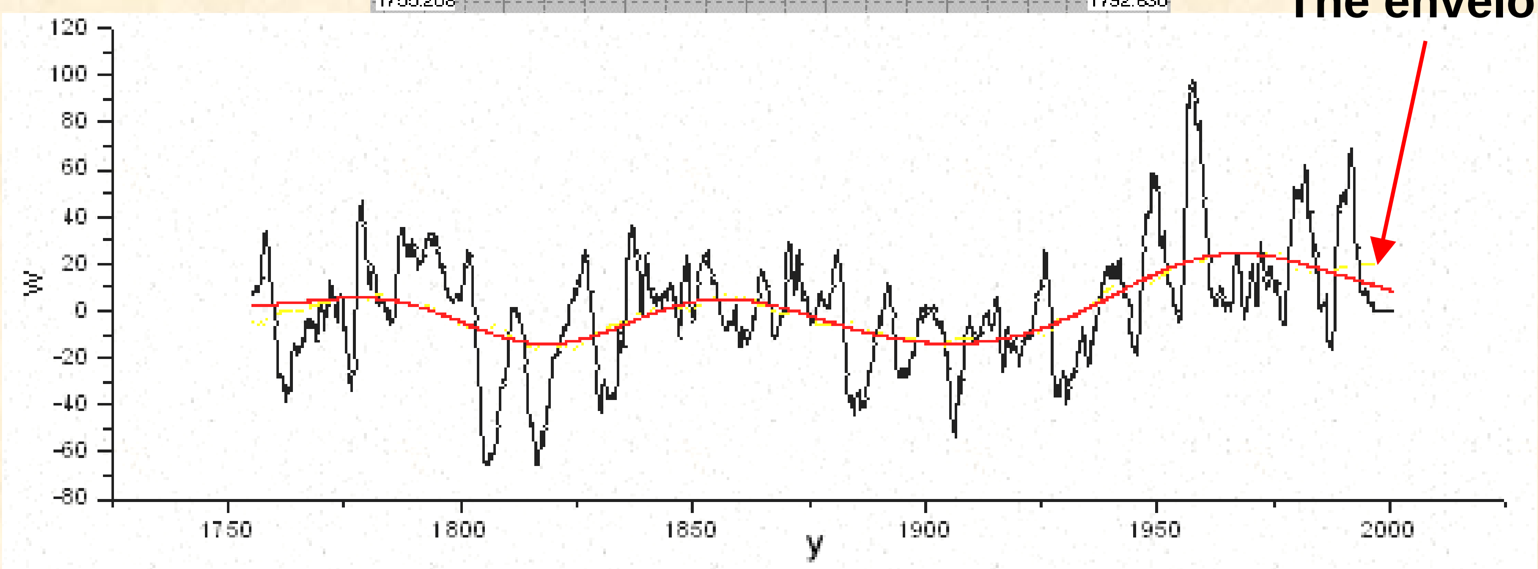


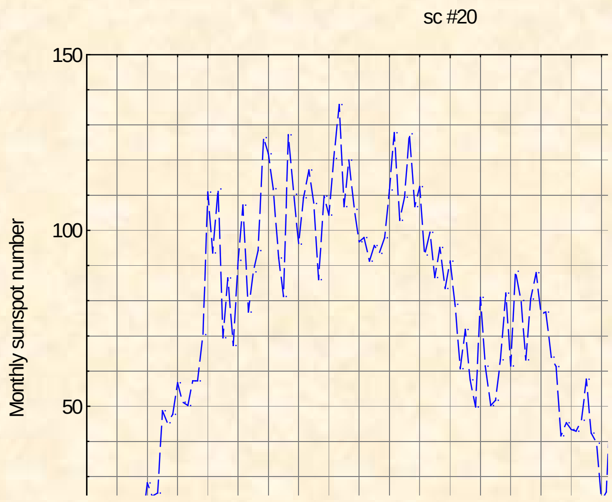




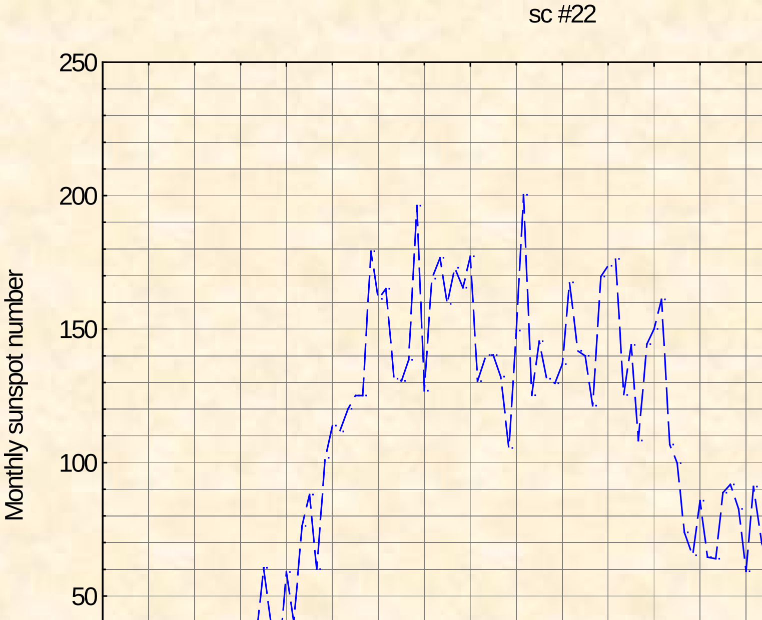
The difference

The envelope



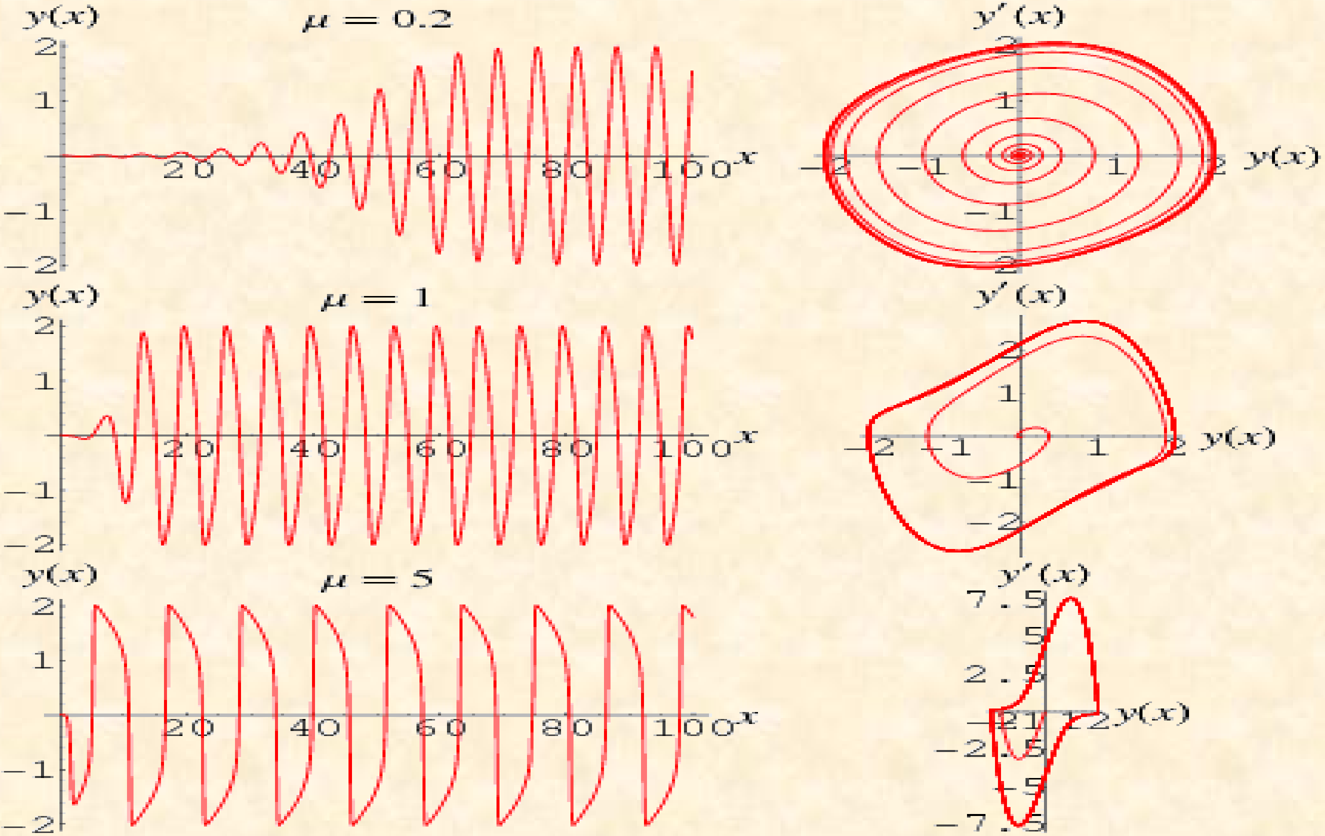


The asymmetry



Nonlinear van der Pol model

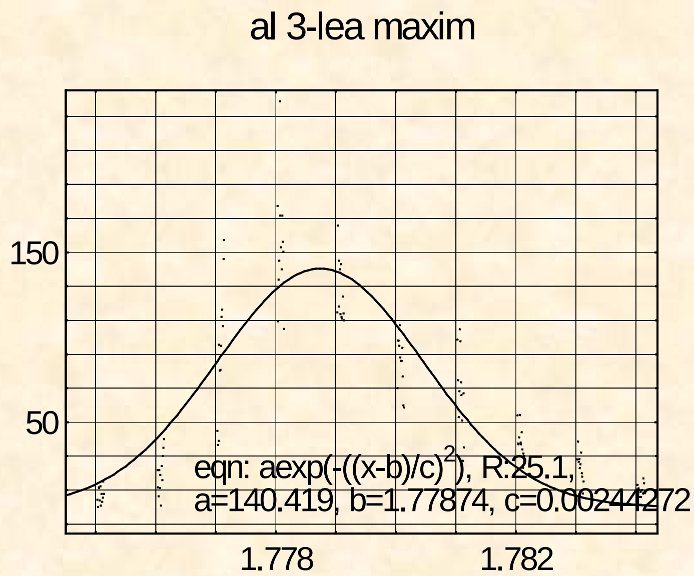
(J.M. Polyagiannakis, X. Moussas, C.P. Sonett - 1996)

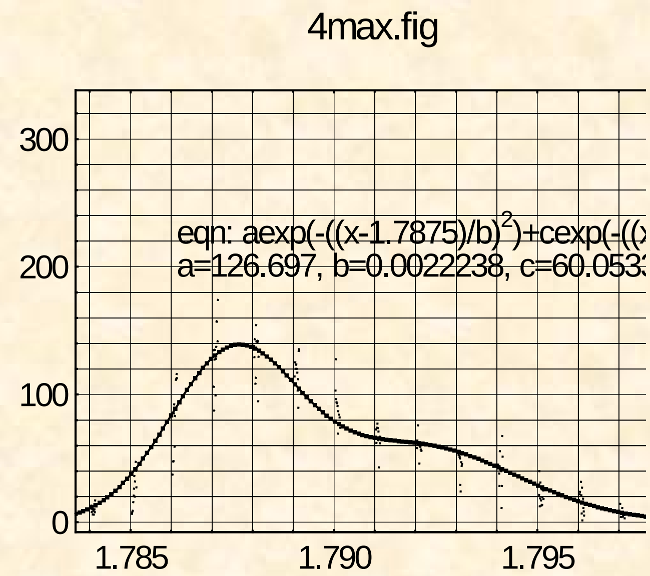


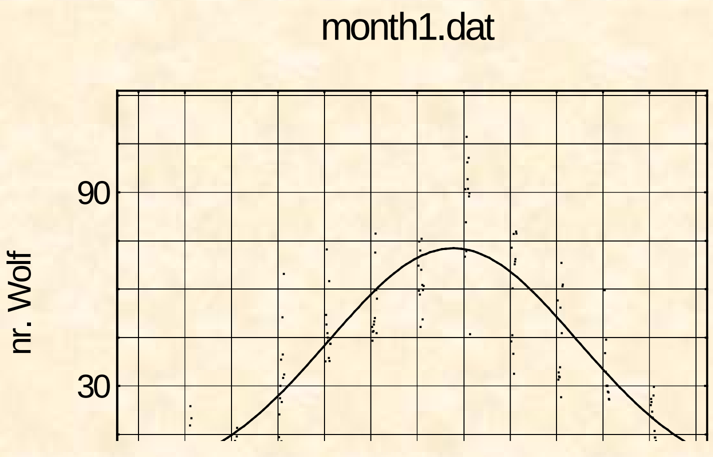
Time series and space faze plot for van der Pol oscillator

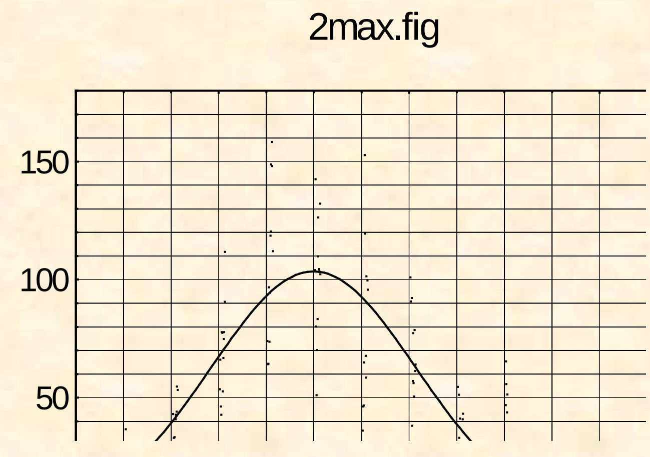
A detailed analysis of each cycle – samples

(M.V.Rusu – 2004 - 2006)

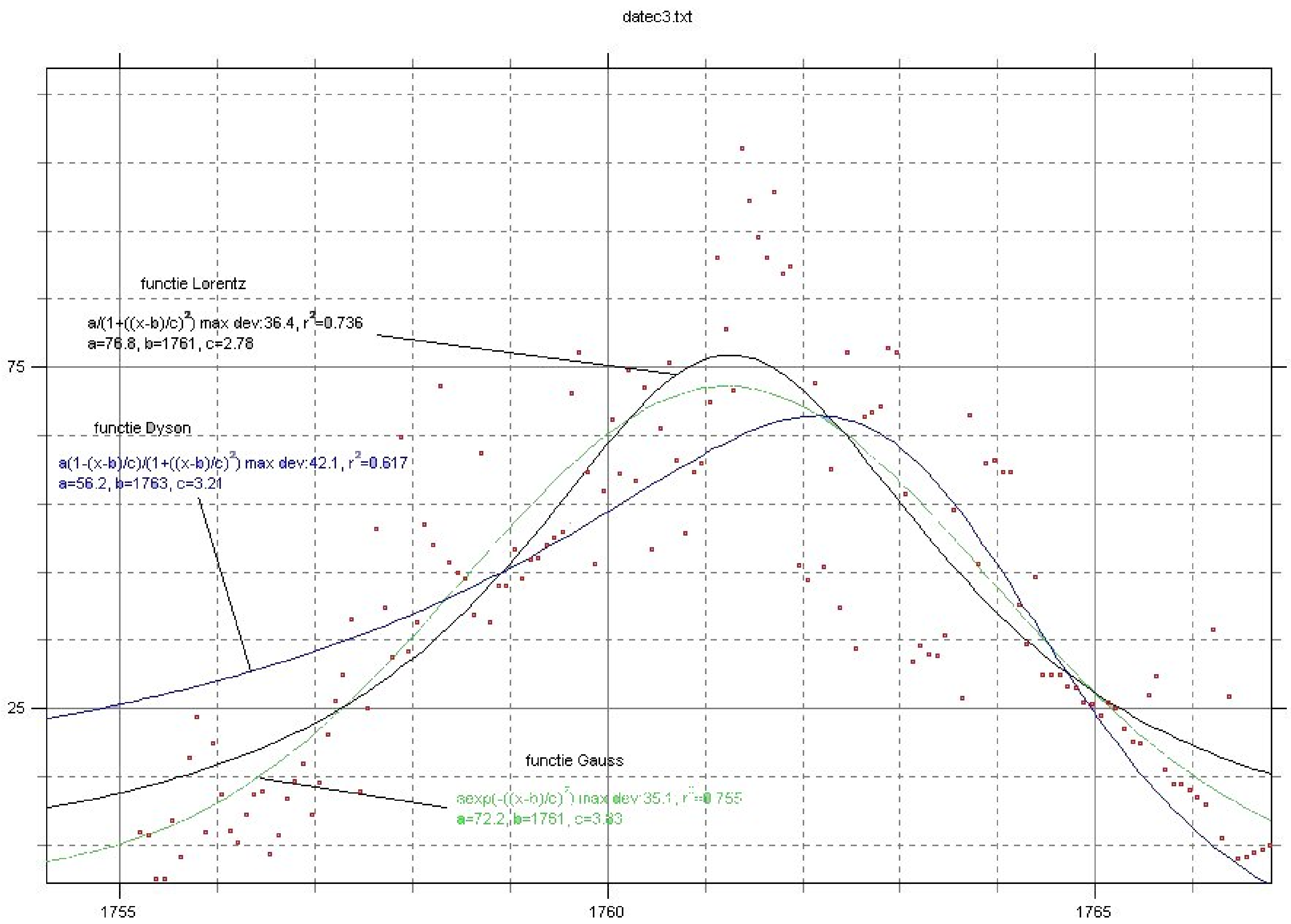






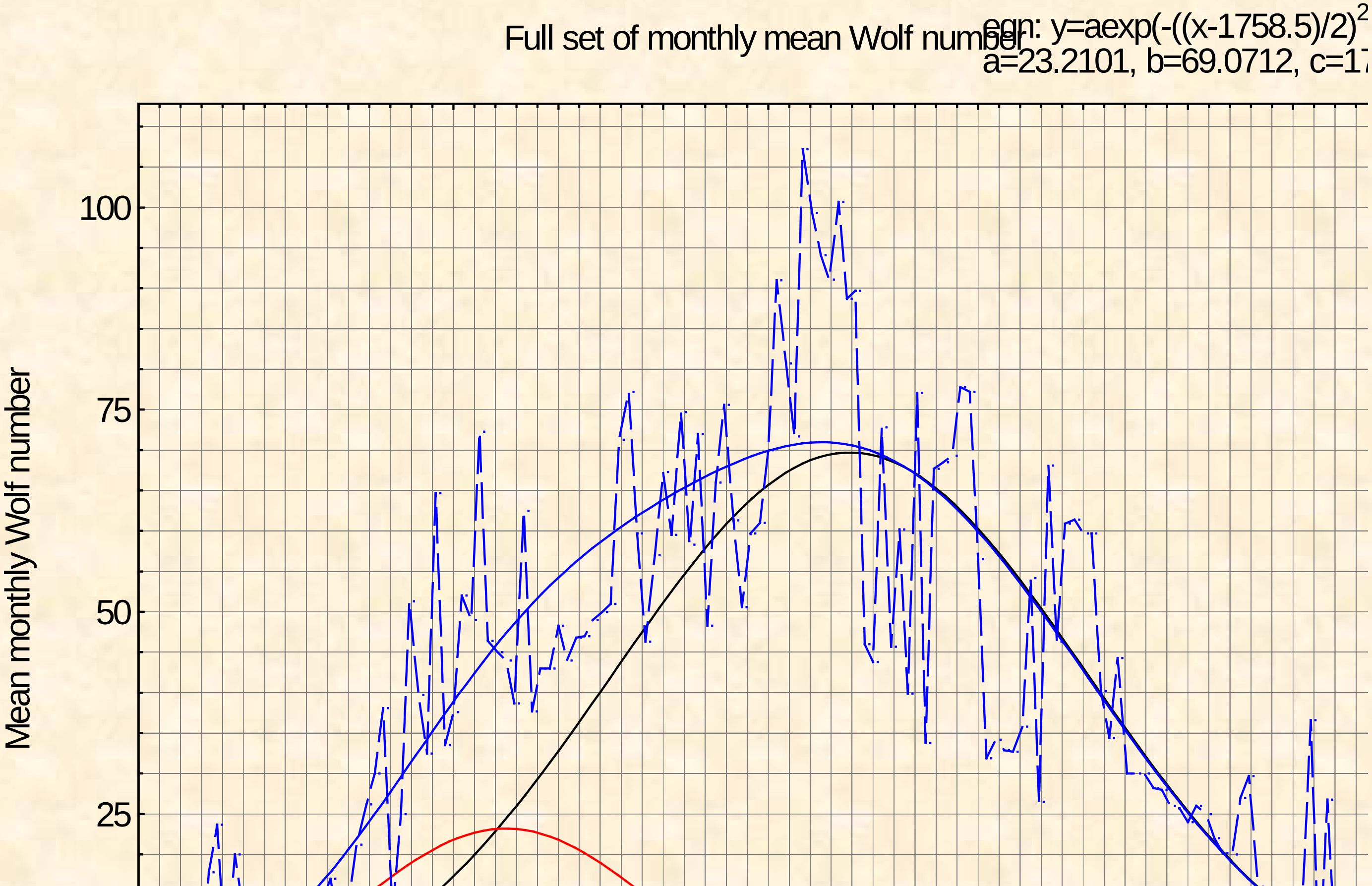


Search for the best fit symmetrical curve: Gauss, Lorenz, Dyson

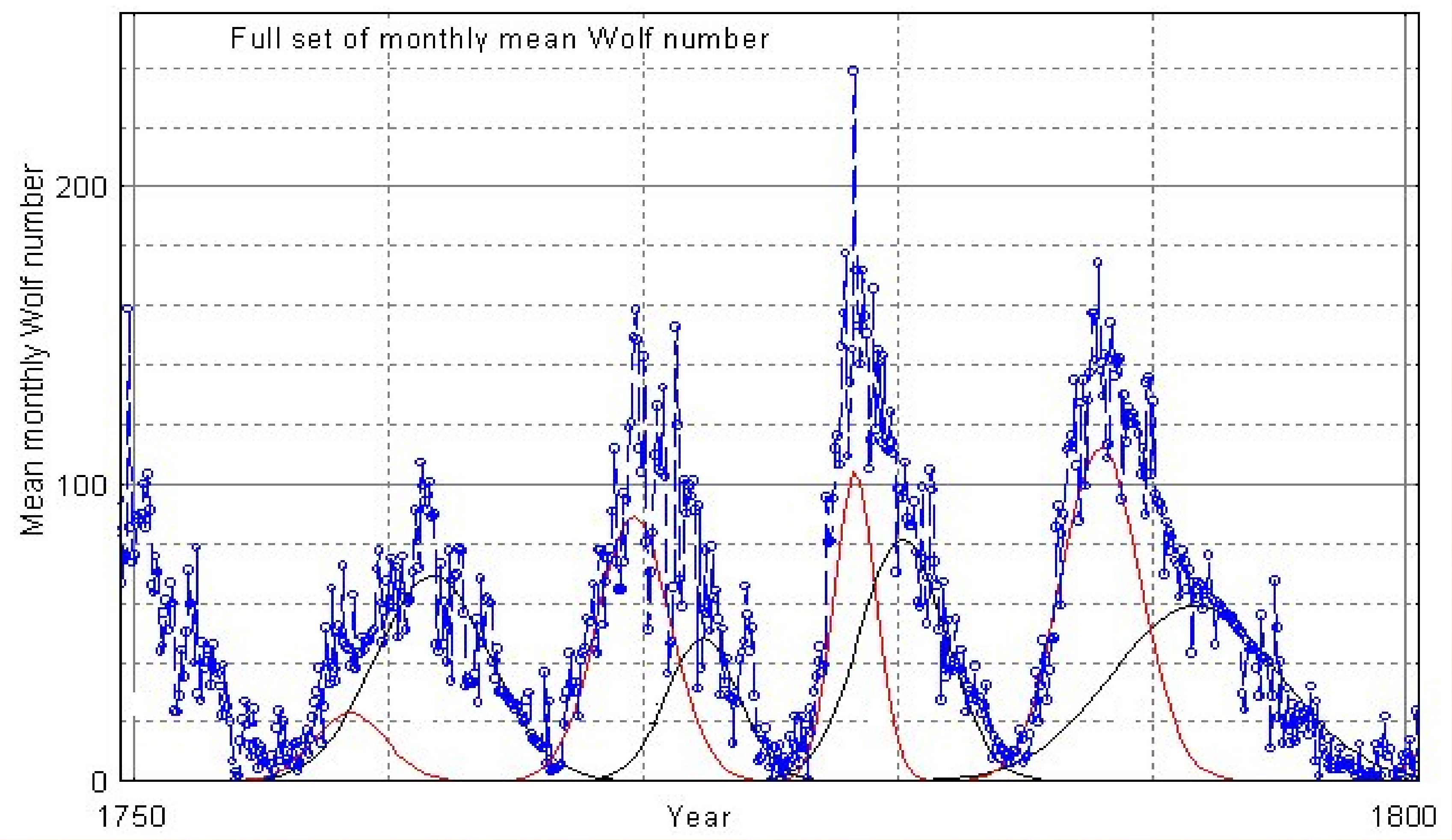


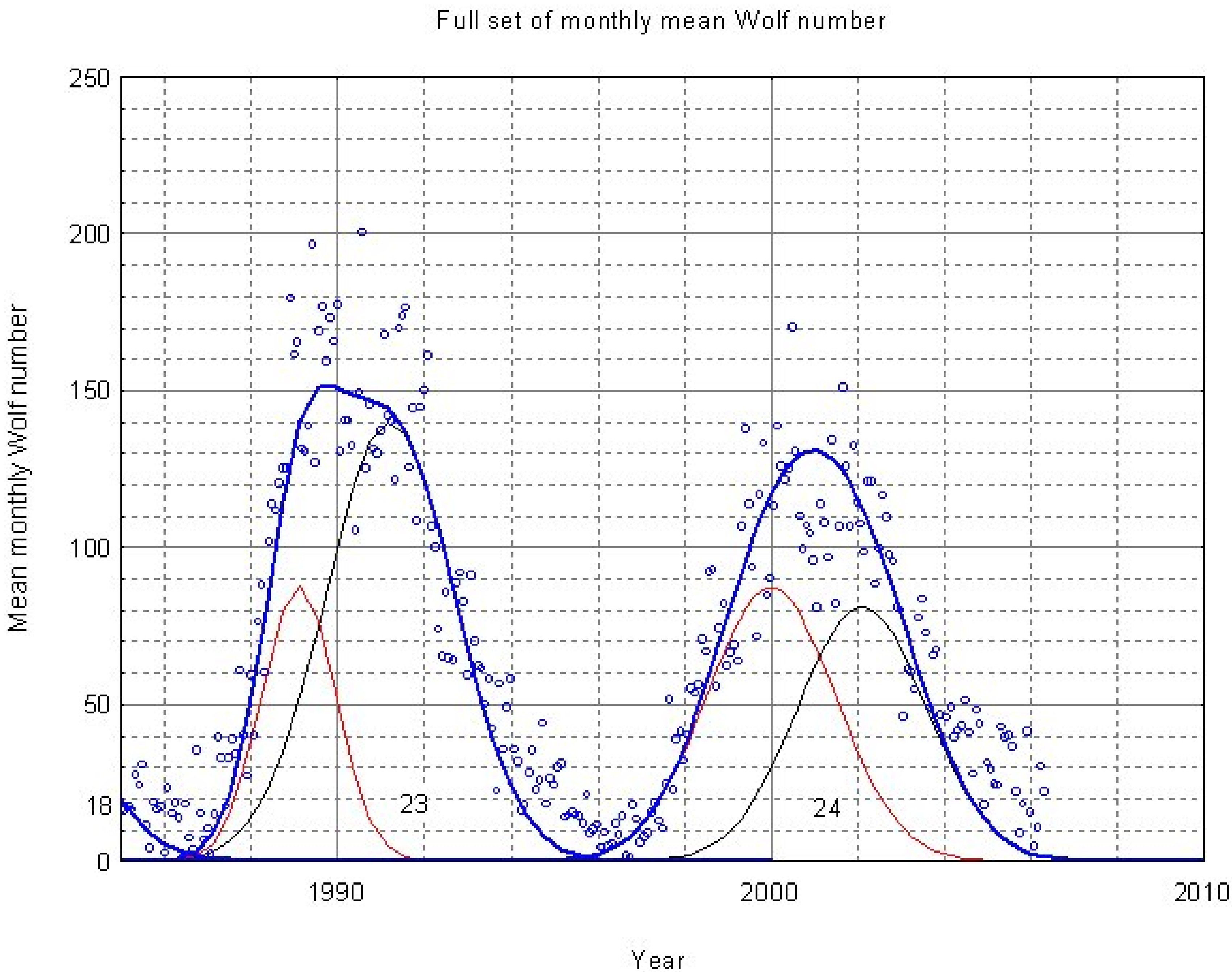
De-convolution

The idea: **the asymmetry is due to presence of superposition of two peaks**



De-convolution





Full set of monthly mean Wolf number
Mean monthly Wolf number
250
200
150
100
50
18
0
23
24
1990
2000
2010
Year

$$f(x) = a \cdot e^{-\left(\frac{x-b}{c}\right)^2} + d \cdot e^{-\left(\frac{x-f}{g}\right)^2}$$

Gaussian functions - describe the normal distributions (statistics)

- solve heat equations and diffusion equations (math);

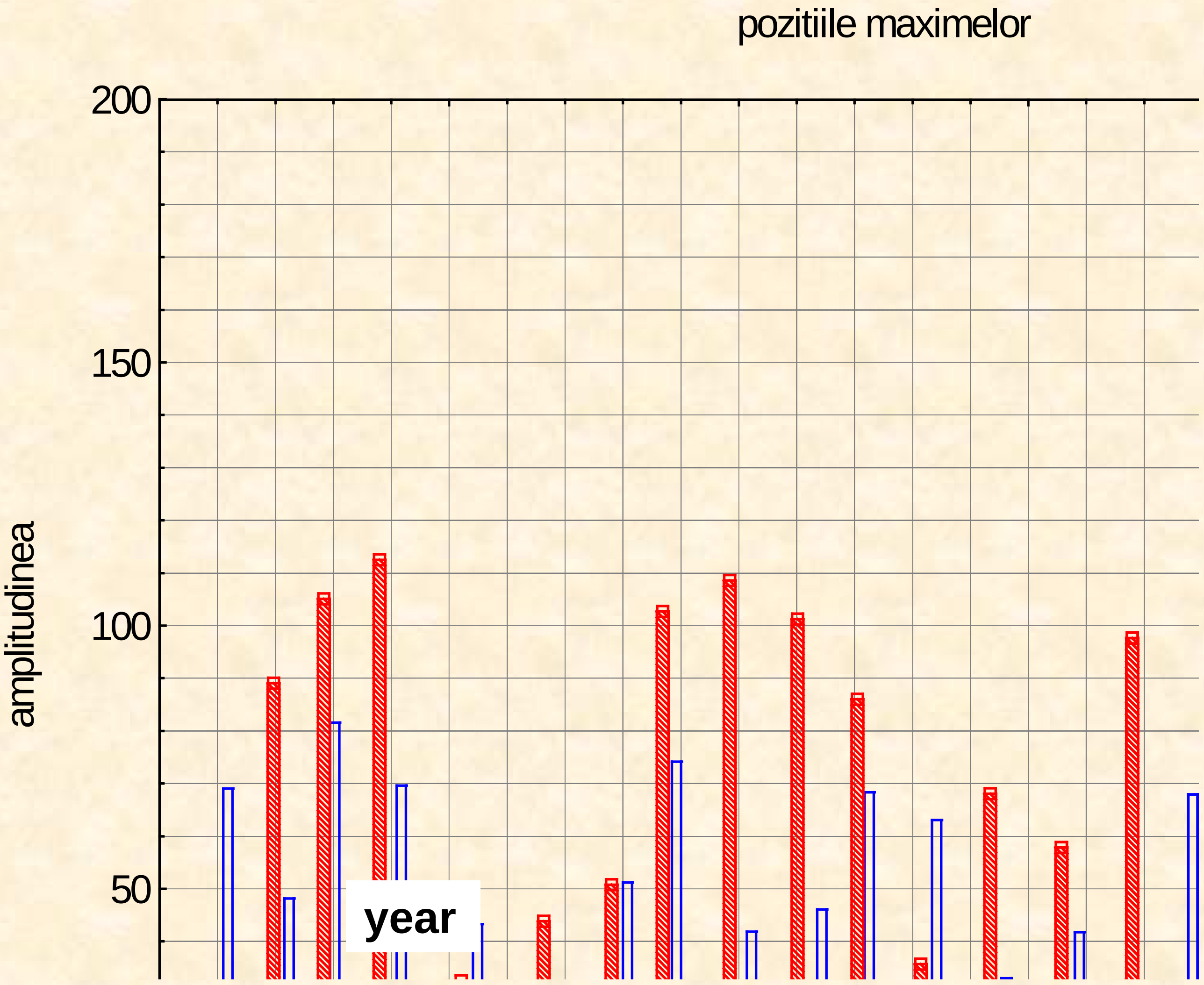
Mean $\mu = b$, Variance $\sigma^2 = c^2$: Area $a \cdot c \cdot \sqrt{2\pi}$

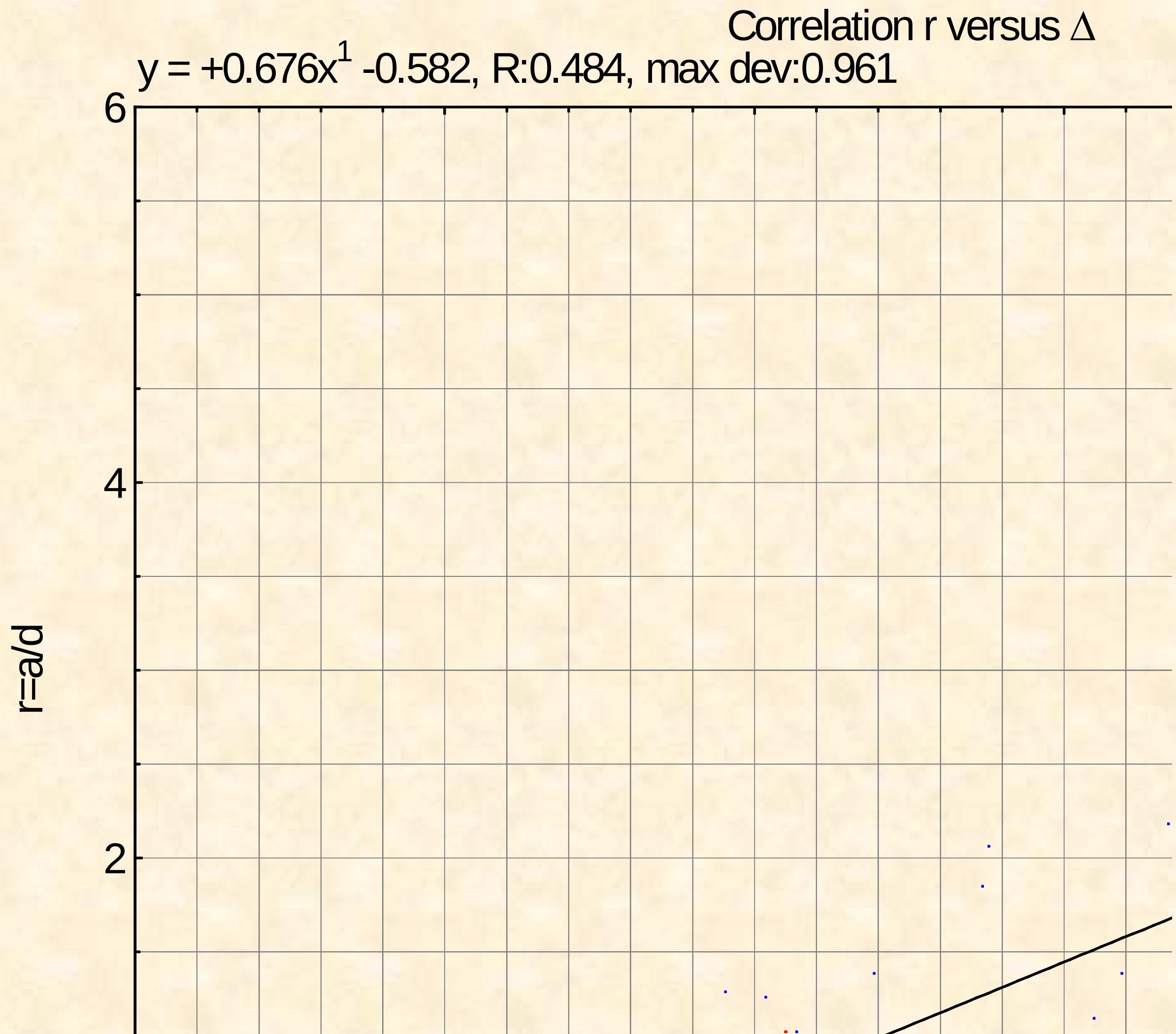
The product of two Gaussian functions is a Gaussian,

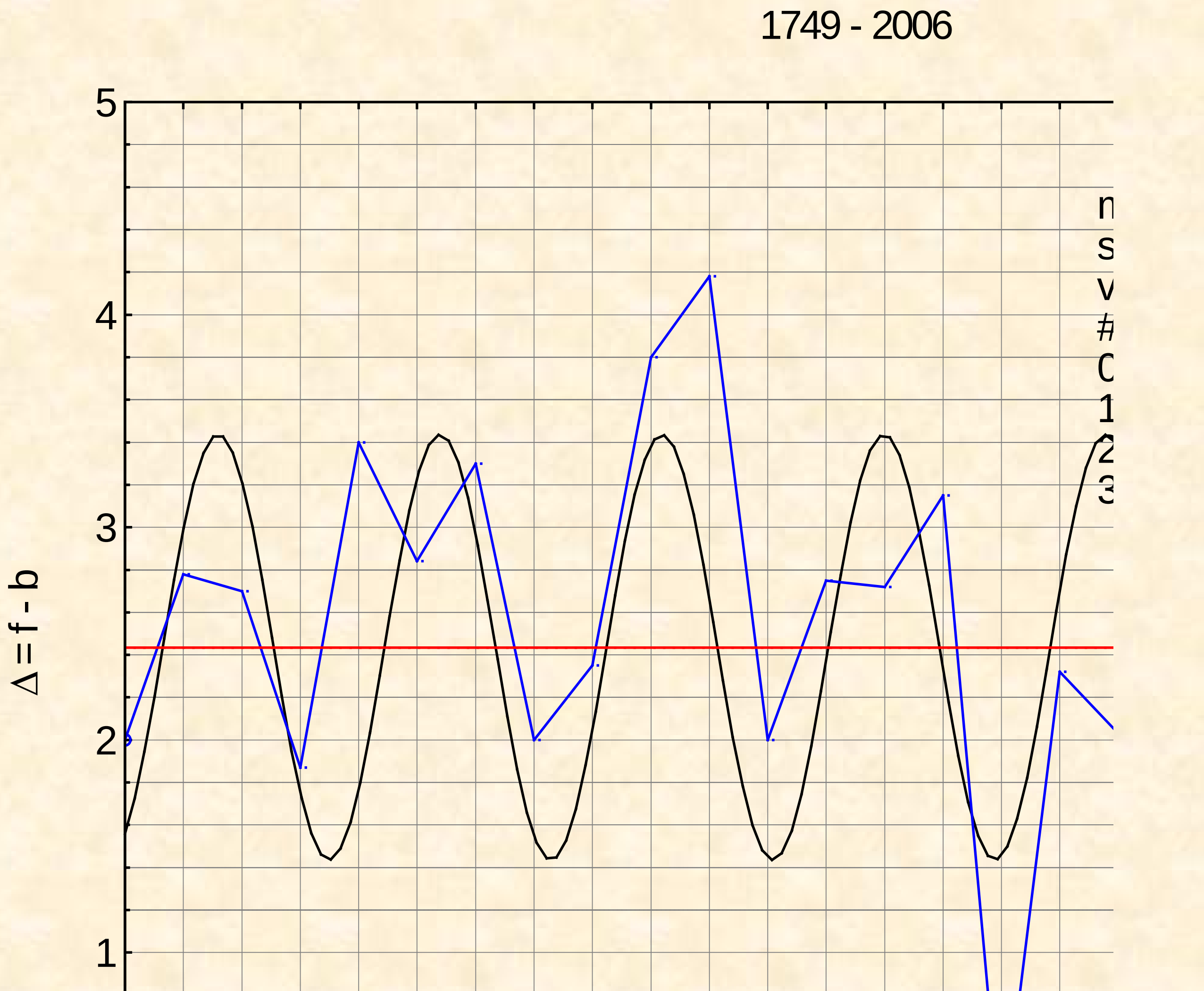
The convolution of two Gaussian functions is a Gaussian, with $\Delta = \sqrt{c^2 + g^2}$

No.	A					B					Δ	R
Cycle.	b poz 1	a ampl 1	c width 1	a/c	a*c area A	f poz 2	d ampl 2	g width 2	d/g	d*g area B	f - b	a/d
1	1759.03	23.21	1.05	22.10	24.3705	1761.78	69.07	3.23	21.38	223.0961	2.75	0.336
2	1769.67	89.10	2.04	43.67	181.764	1772.37	48.19	2.20	21.90	106.018	2.70	1.849
3	1778.35	105.07	1.16	90.58	121.8812	1780.22	81.59	2.40	34.00	195.816	1.87	1.288
4	1788.03	112.51	2.20	51.14	247.522	1791.40	64.09	4.40	14.56	281.996	3.37	1.755
5	1802.05	36.54	1.44	25.37	52.6176	1804.89	45.34	2.03	22.33	92.0402	2.84	0.806
6	1816.20	48.00	2.09	22.97	100.32	1819.50	22.03	1.50	14.69	33.045	3.30	2.179
7	1828.04	50.79	2.22	22.88	112.7538	1830.00	51.23	2.30	22.27	117.829	1.96	0.991
8	1836.88	102.71	1.43	71.82	146.8753	1839.23	74.16	2.60	28.52	192.816	2.35	1.385
9	1848.42	108.58	2.14	50.74	232.3612	1852.22	45.05	2.11	21.35	95.0555	3.80	2.410
10	1860.25	101.24	2.33	43.45	235.8892	1864.22	46.06	1.80	25.59	82.908	4.18	2.198
11	1870.50	86.03	1.64	52.46	141.0892	1872.50	68.36	2.44	28.02	166.7984	2.00	1.258
12	1881.40	35.70	1.21	29.50	43.197	1884.15	63.07	2.24	28.16	141.2768	2.75	0.566
13	1893.41	68.09	2.06	33.05	140.2654	1896.13	33.01	3.15	10.48	103.9815	2.72	1.629
14	1905.69	57.87	2.17	26.67	125.5779	1908.84	41.79	1.91	21.88	79.8189	3.15	1.385
15	1916.89	70.05	1.66	42.20	116.283	1919.26	65.50	2.33	28.11	152.615	2.38	1.069
16	1926.10	40.00	1.07	37.38	42.8	1928.42	81.04	2.49	32.55	201.7896	2.32	0.493
17	1937.33	59.09	1.65	35.81	97.4985	1939.36	81.68	2.60	31.41	212.368	2.03	0.723
18	1947.25	48.56	1.00	48.56	48.56	1948.94	128.76	2.81	52.77	361.8156	1.69	0.377
19	1957.75	66.46	1.50	44.31	99.69	1959.02	170.94	2.44	70.06	417.0936	1.27	0.389
20	1968.42	79.05	2.50	31.62	197.625	1971.48	68.94	3.20	21.54	220.608	3.06	1.146
21	1979.37	76.54	1.36	56.28	104.0944	1981.49	135.15	2.51	53.84	339.2265	2.12	0.566
22	1989.13	87.60	1.20	73	105.12	1991.21	140.05	2.11	66.37	295.5055	2.08	0.625
23	1999.77	107.40	1.55	69.29	166.47	2002.41	96.05	1.80	53.36	172.89	2.71	1.118
24	2010.98	74.98	1.68	44.63	125.9664	2014.05	50.83	2.44	20.83	124.0252	3.07	1.475

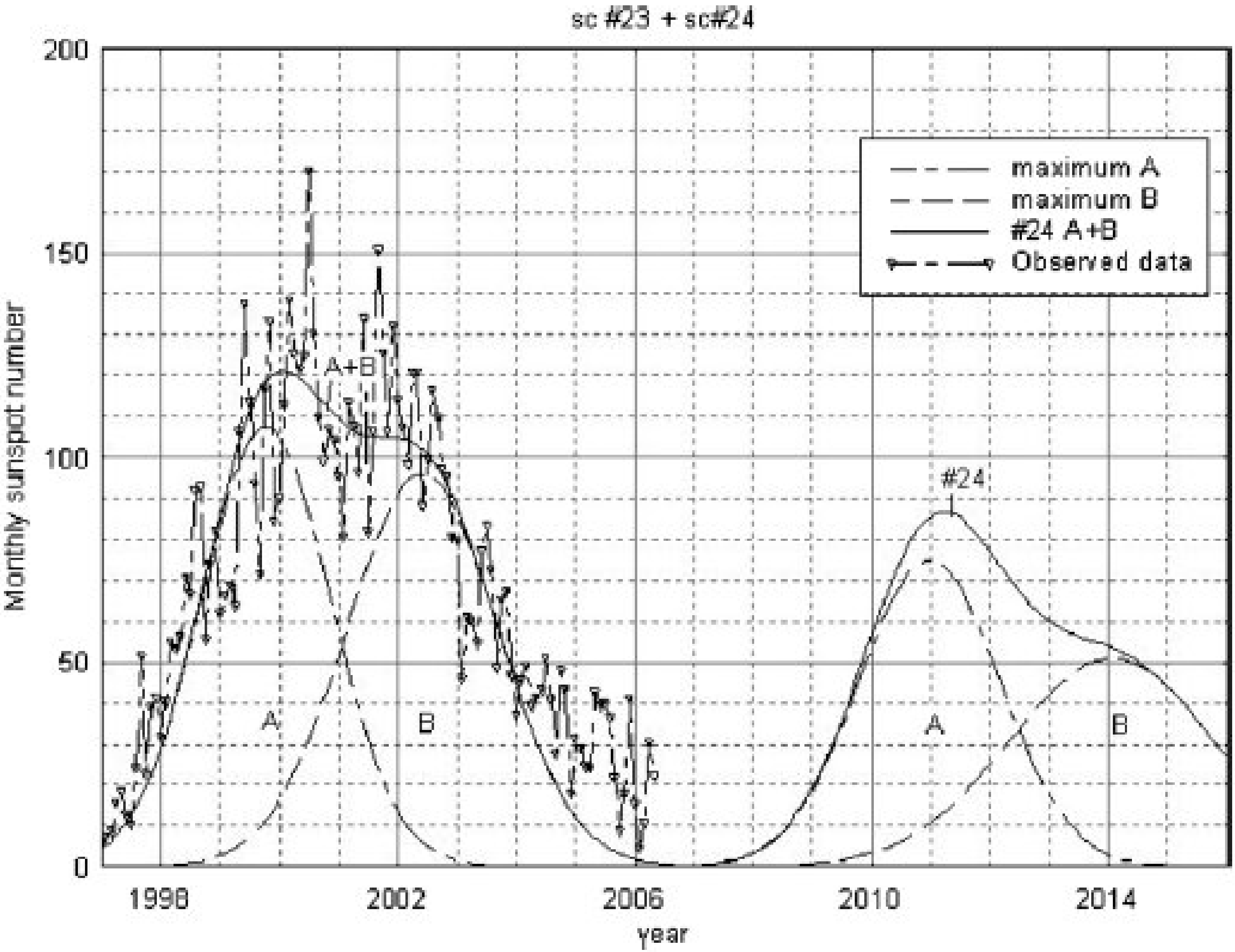
Peaks position and their amplitude




Correlation r versus Δ
y = +0.676x1 -0.582, R:0.484, max dev:0.961
6
4
2
r=a/d

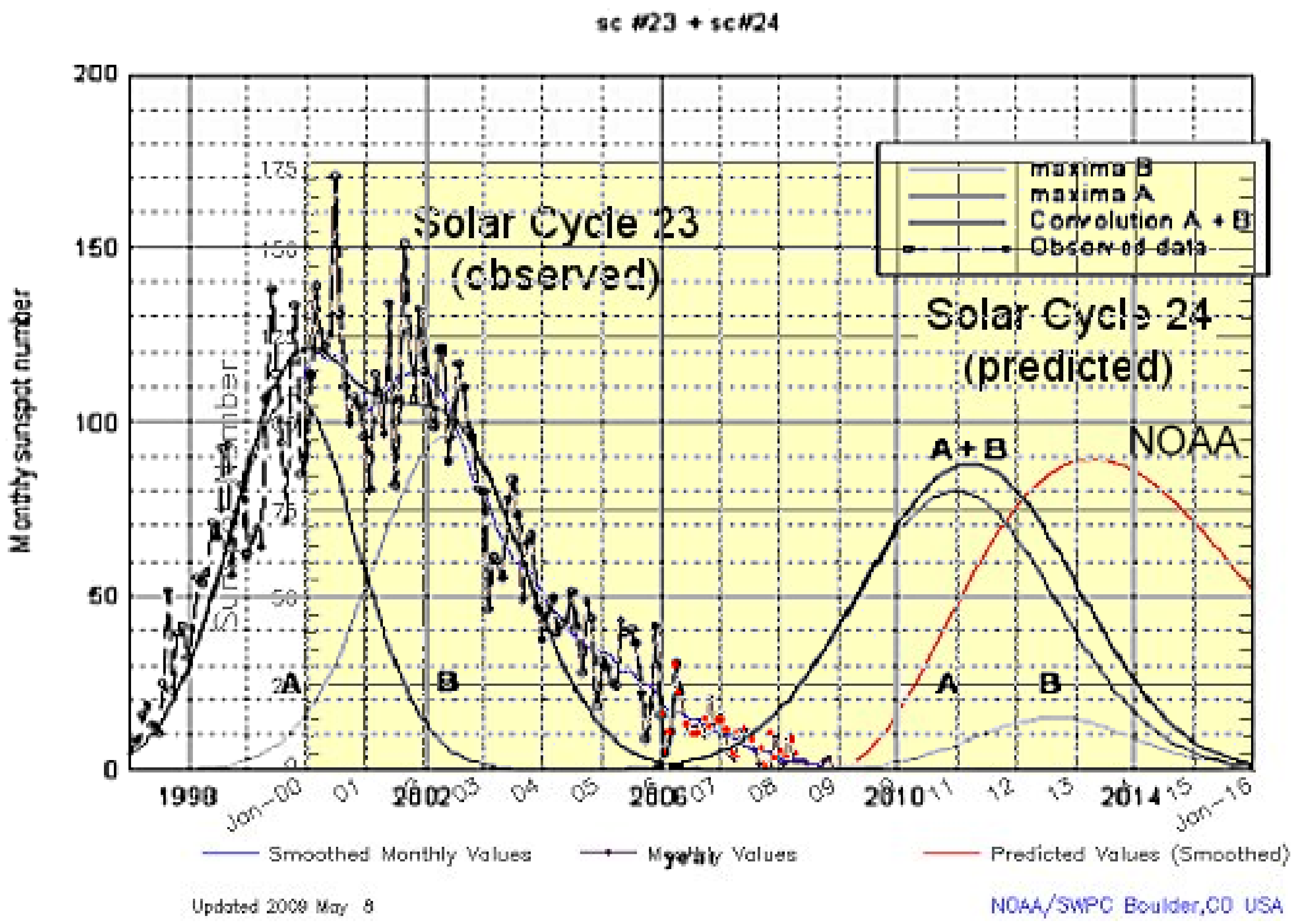


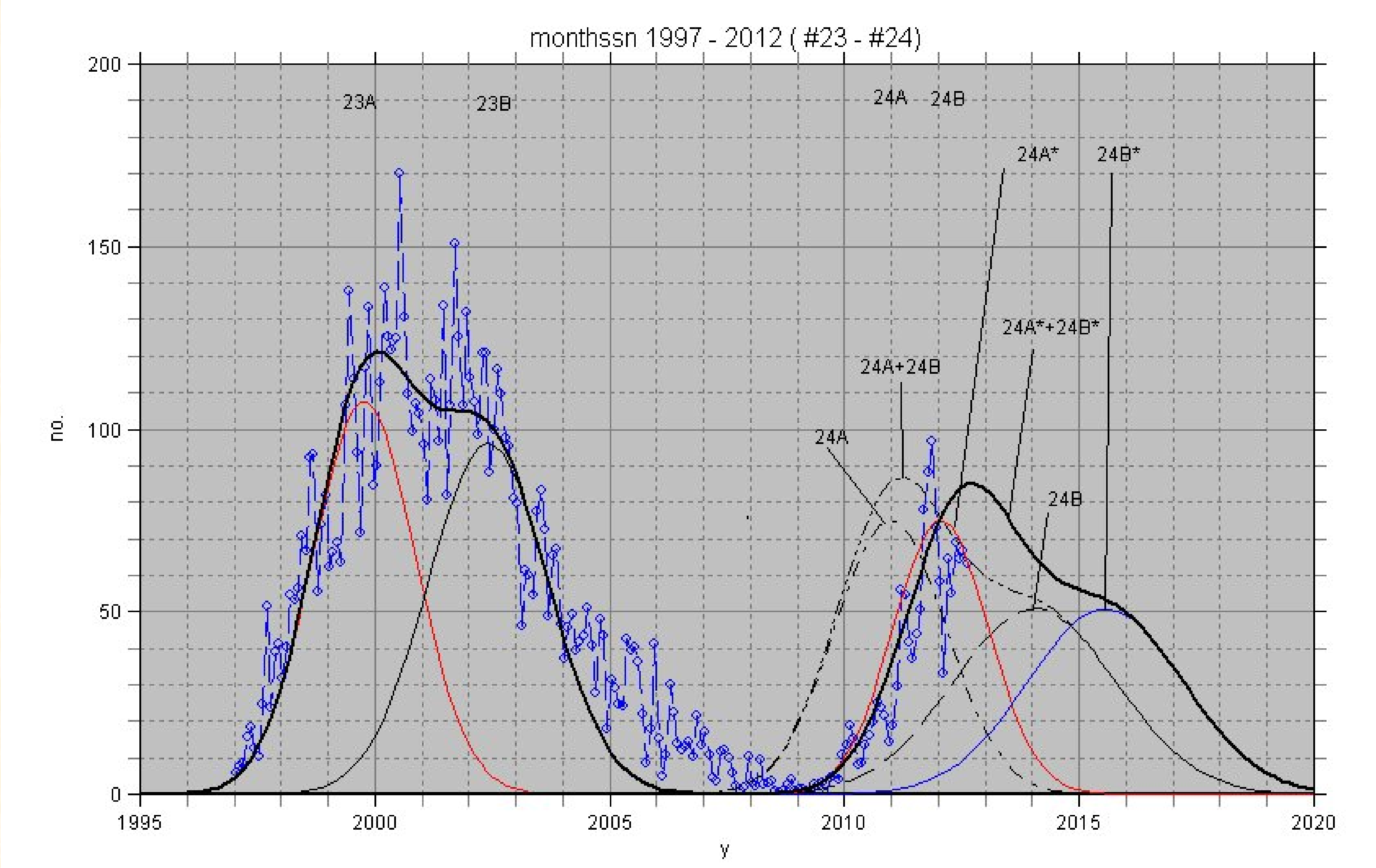
1749 - 2006
5
4
3
2
1
Δ = f - b



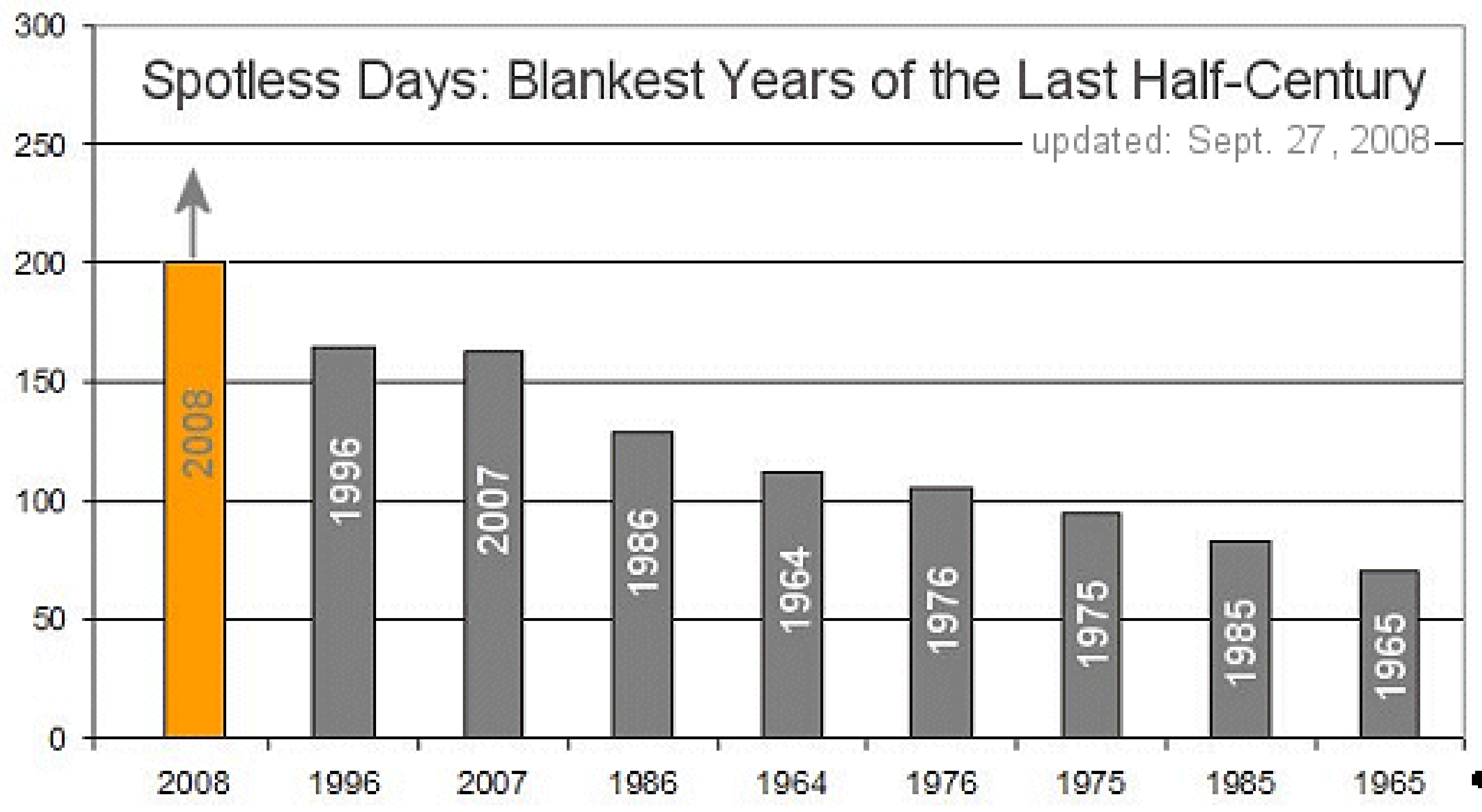
(M.V.Rusu, *Advances in Space Research* **40**, 2007)

Forecast of NOAA and ours



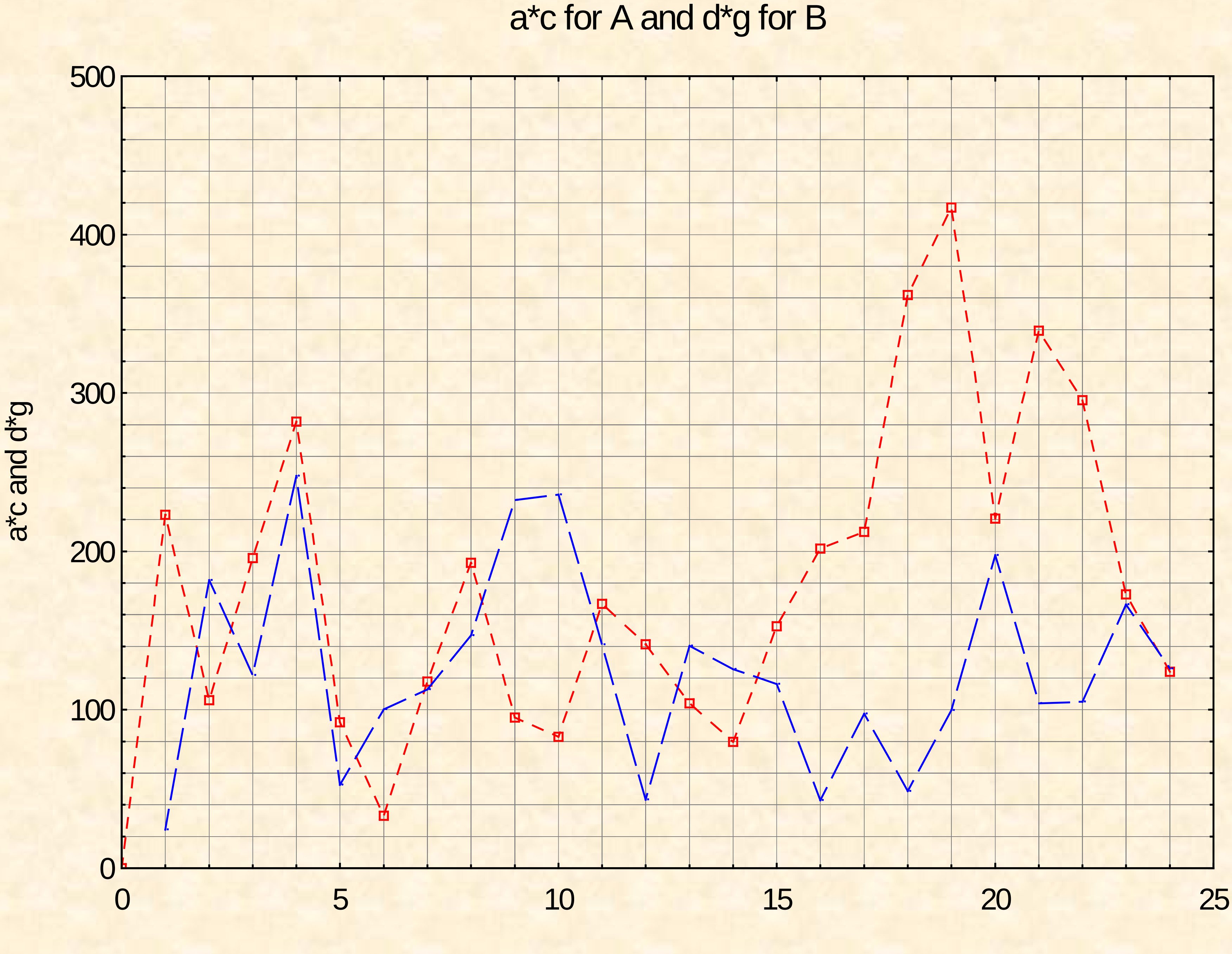


Prediction and correction for cycle #24

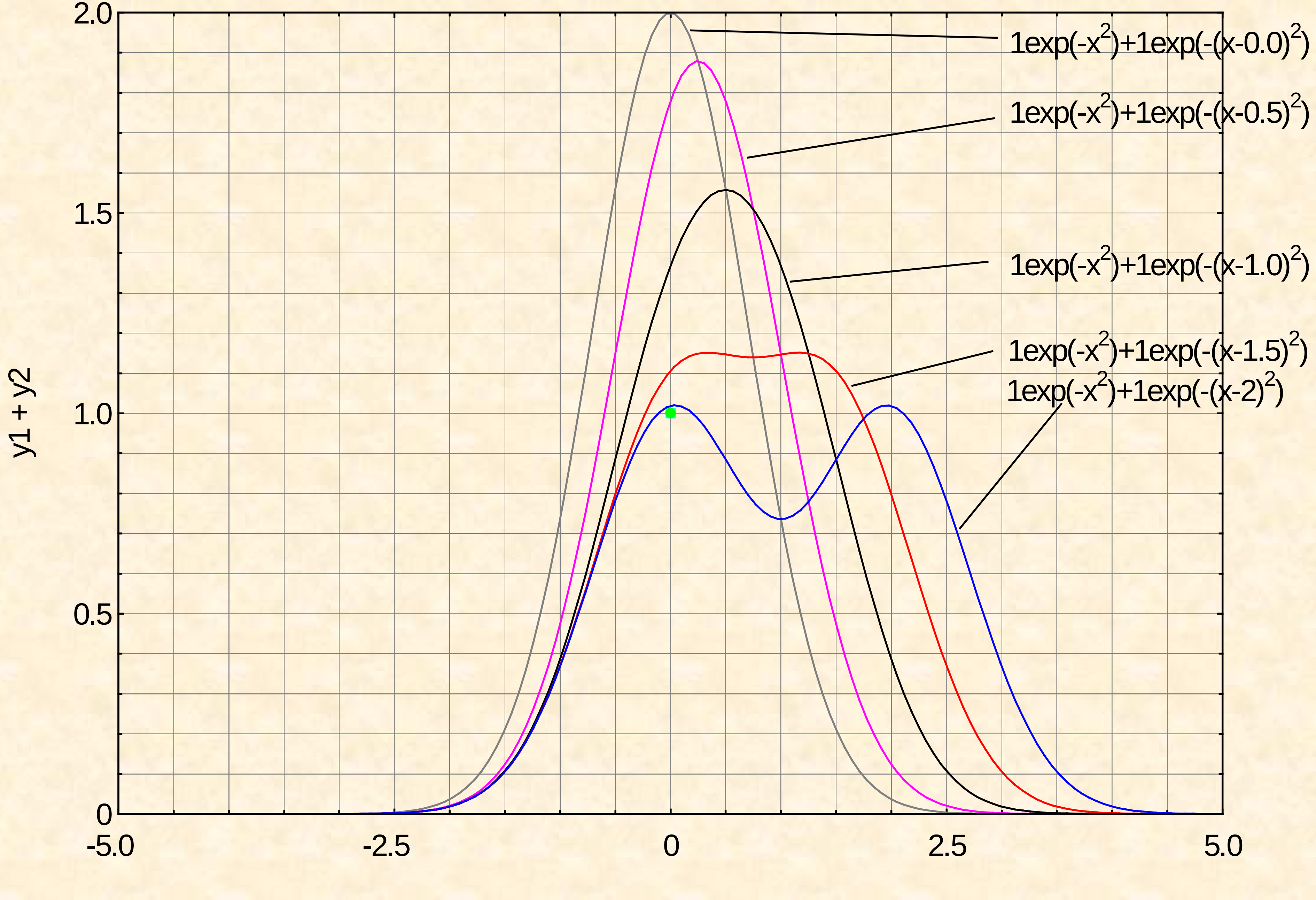


New Solar Cycle Prediction   05.29.2009

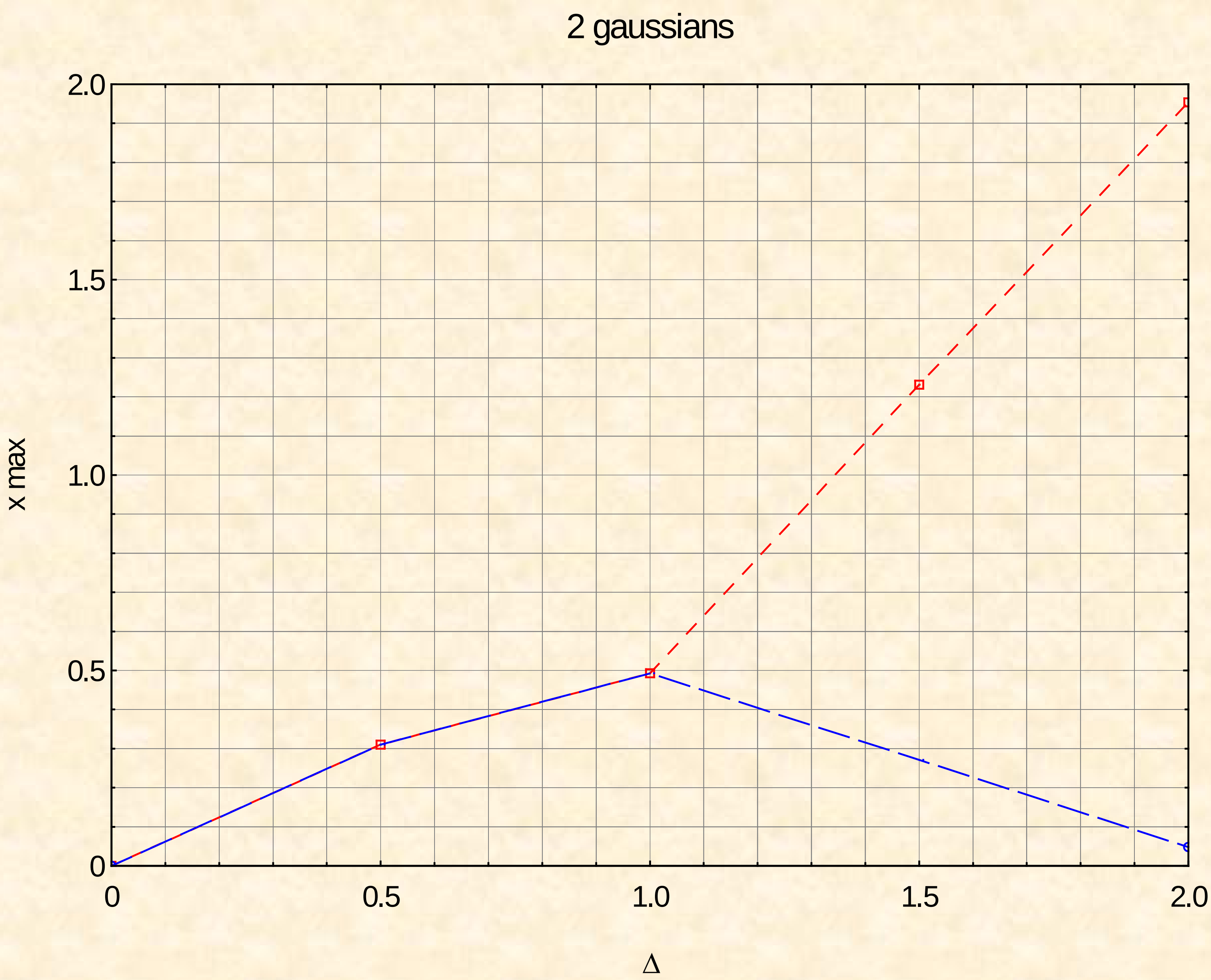
An international panel of experts led by NOAA and sponsored by NASA has released a new prediction for the next solar cycle. Solar Cycle 24 will peak, they say, in May 2013 with a below-average number of sunspots.



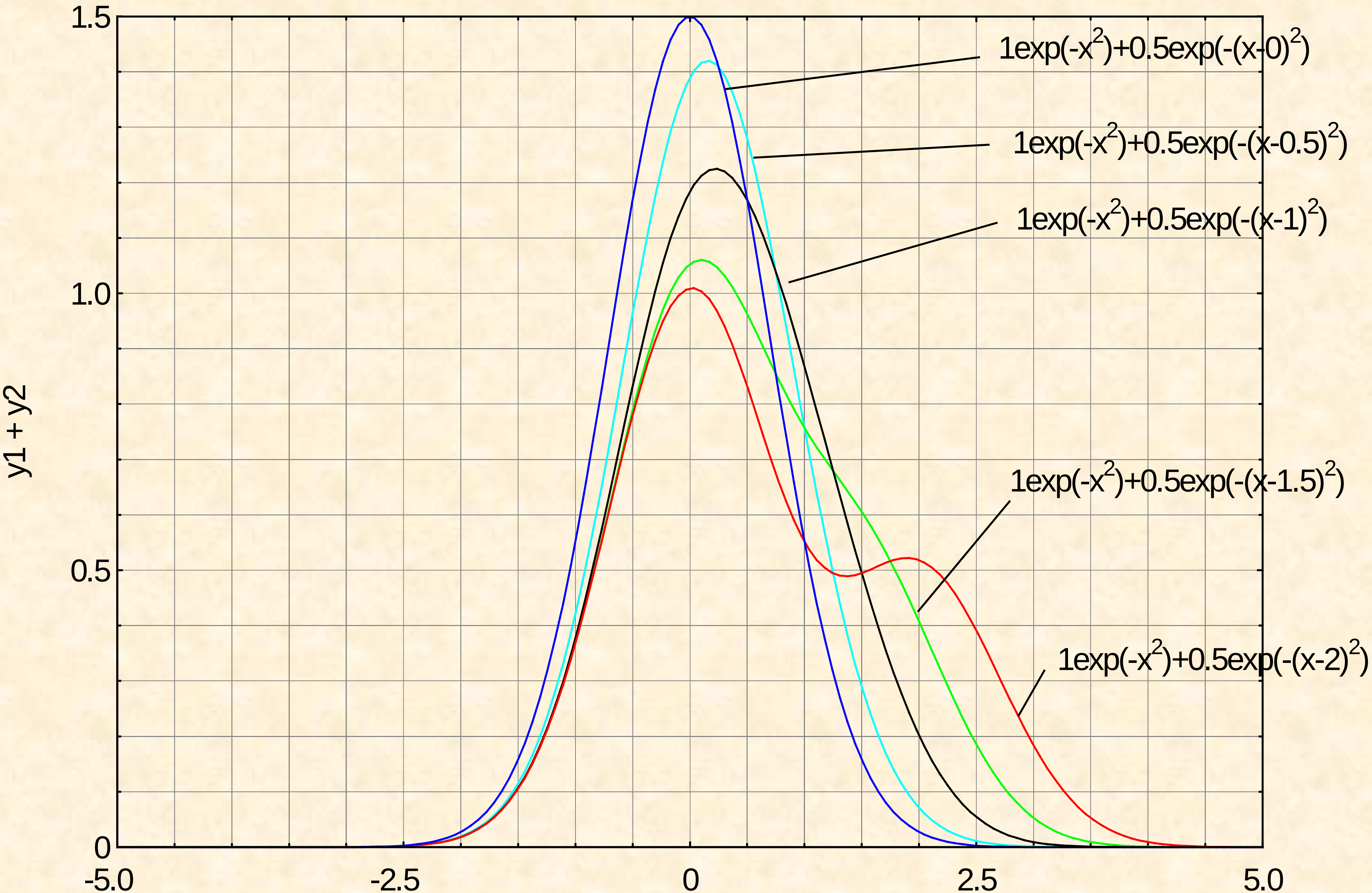
The area under the picks - constant



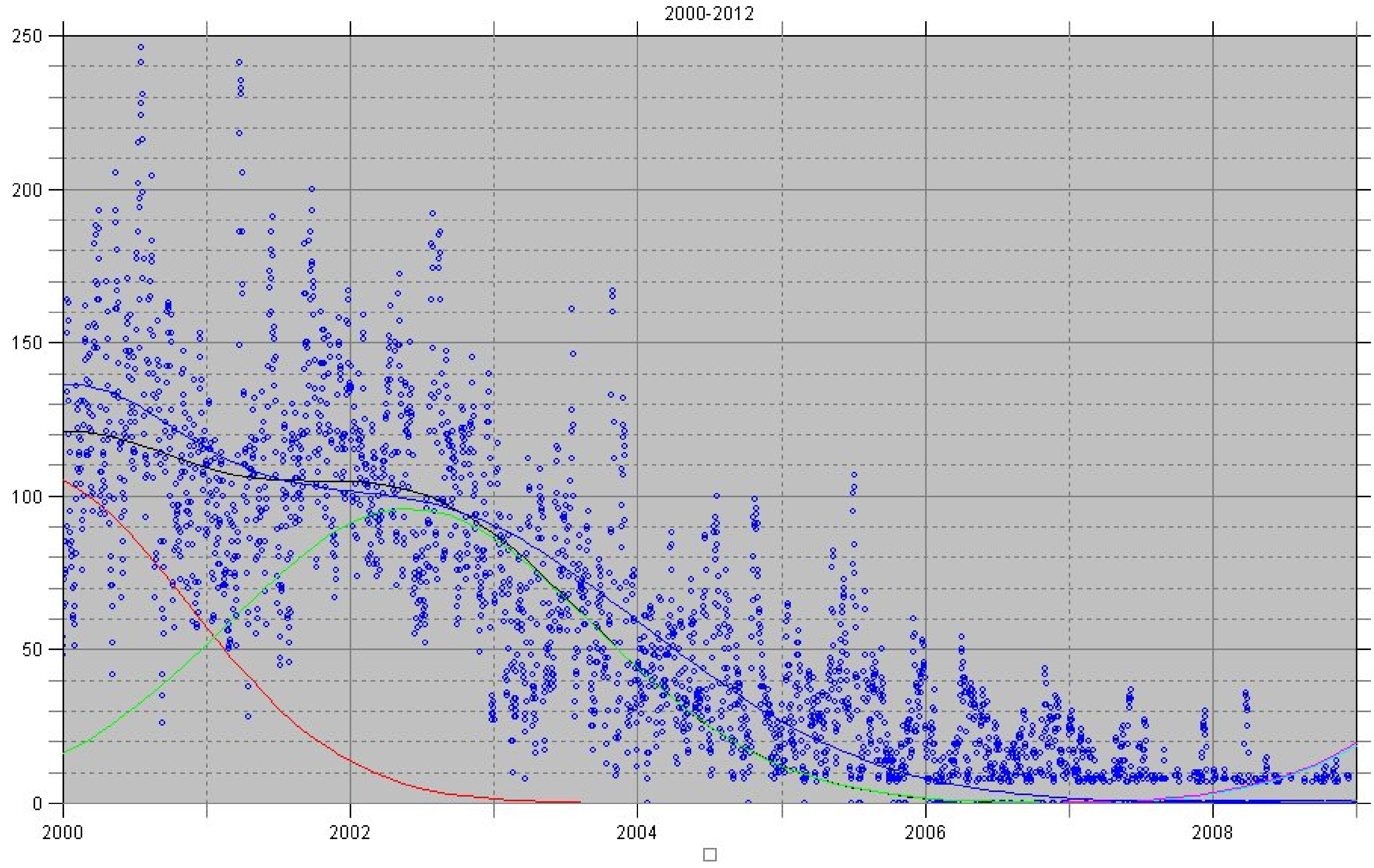
The position of the superposed picks **equal heights**



The position of the superposed picks – the shift

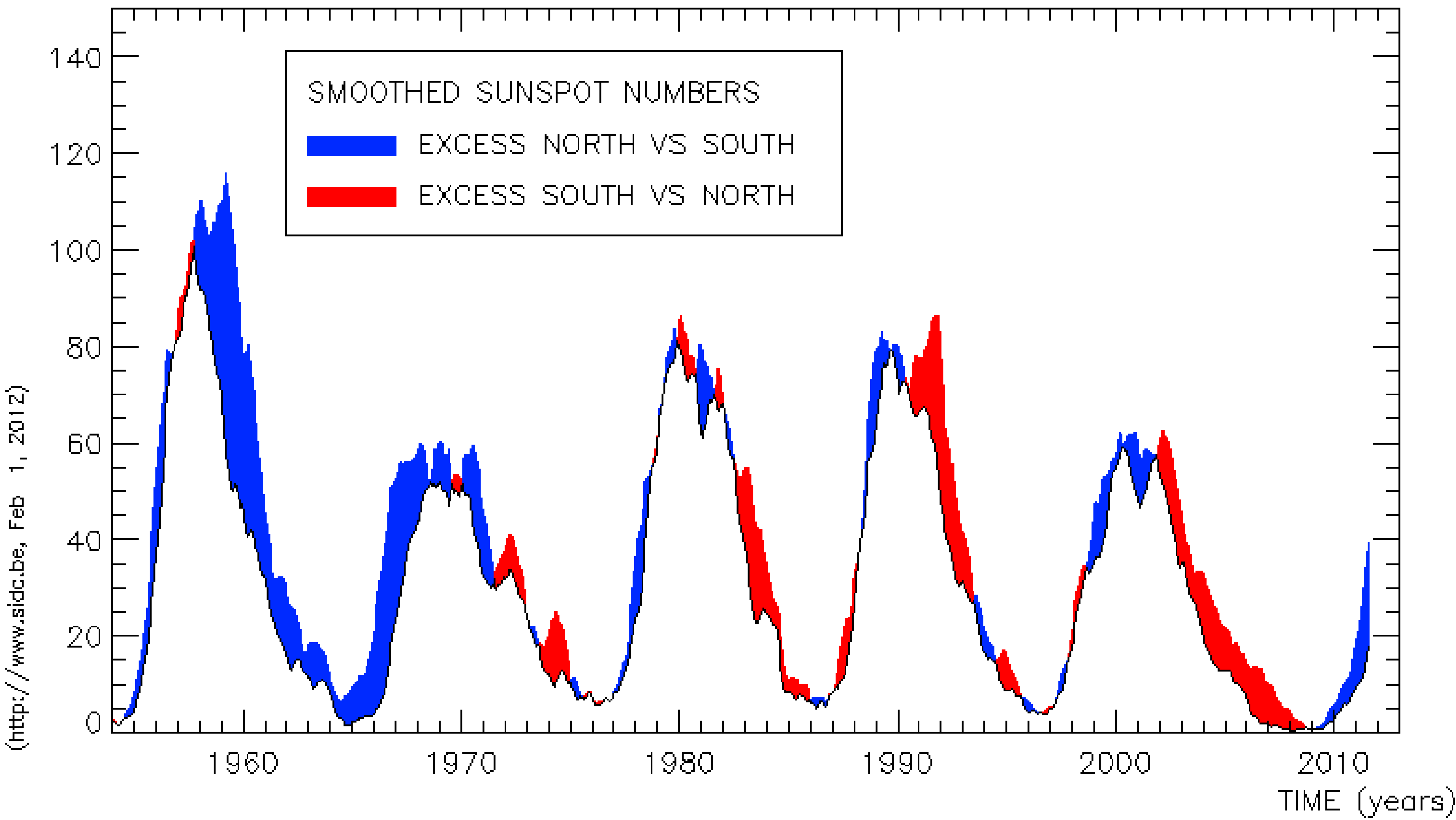


The position of the superposed picks Δ unequal heights



eqn: 107.4exp(-((x-1999.77)/a)^2)+96.05exp(-((x-2002.41)/b)^2), R:26.6,
a=1.40629, b=2.28715

The position of the third possible pick


SMOOTHED SUNSPOT NUMBERS
EXCESS NORTH VS SOUTH
EXCESS SOUTH VS NORTH
140
120
100
80
60
40
20
0
1960
1970
1980
1990
2000
2010
TIME (years)
(http://www.sidc.be, Feb 1, 2012)

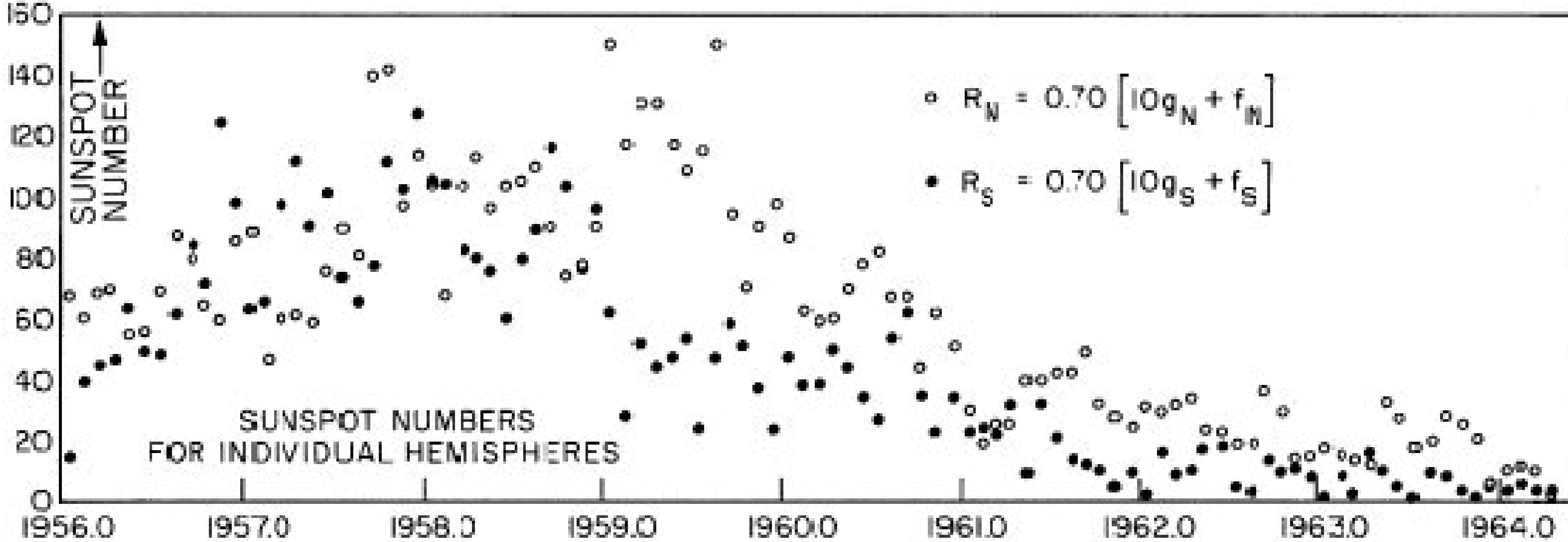


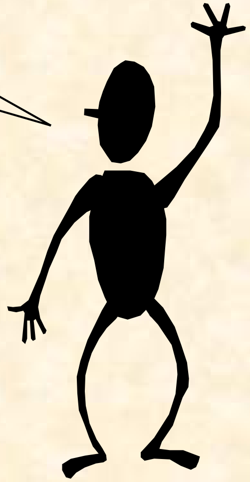
Figure 17

Monthly averages of the sunspot numbers, for the northern and southern hemispheres, derived from Fraunhofer Institut daily maps of the sun during the period 1956-1964. R_N and R_S refer to the sunspot numbers for the northern and southern hemispheres respectively. The g's refer to the number of groups and the f's refer to the number of spots.

Conclusions

- New model for sunspot cycle variation having also a physically interpretation besides the statistical one
- Nonlinearly coupled oscillators could be assimilated to a parametric self sustained oscillator
- The periodicity of 11 year becomes more conventional, being difficult to assume the “distance’ between two peak activities
- The “elementary” Gaussian peaks
  - correspond physically to a combination of normal errors distribution
  - are bound to the Green function solution of the nonlinear partial differential equation of the diffusion phenomena that govern surface phenomena of the Sun
- Statistically it is shown that the two peaks are not related to the North- South asymmetry
- The model of two peaks give us analytical function, inferred form the statistically and physically correlated characteristics, that permit forecast of the next cycle, we did for the cycle #24
- Equal area means constant energy in the sunspot systems

Thanks for your attention!



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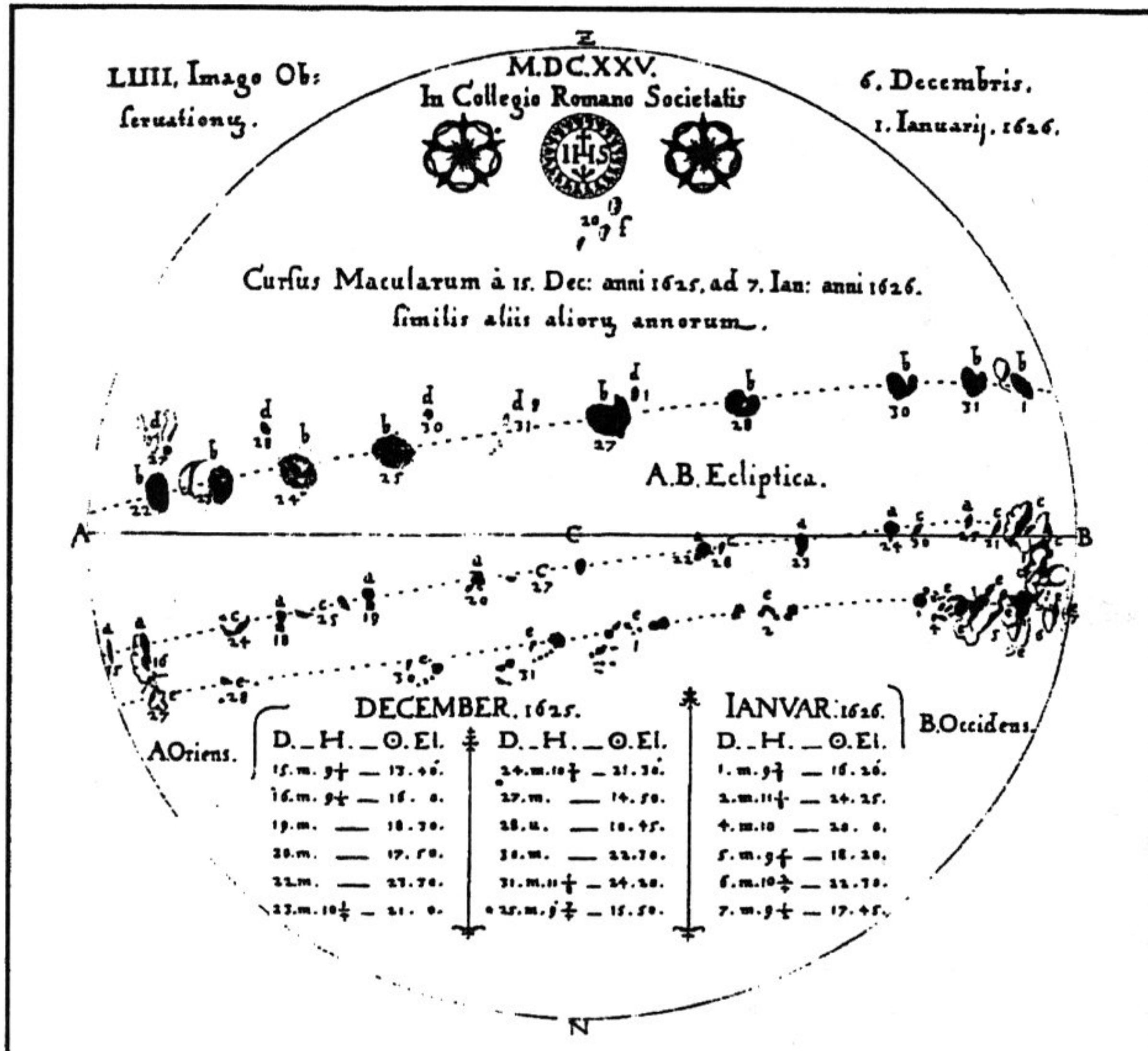
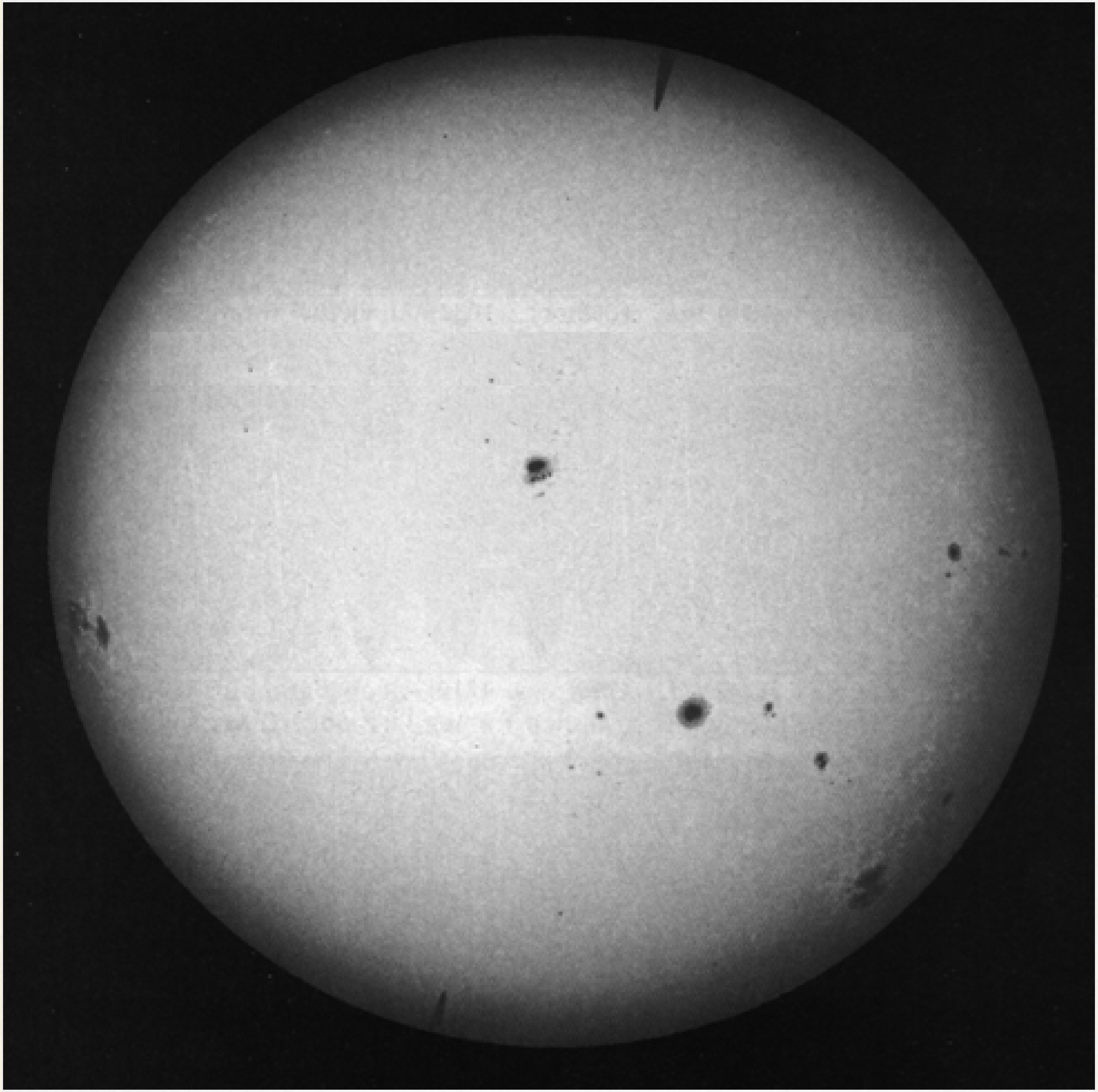
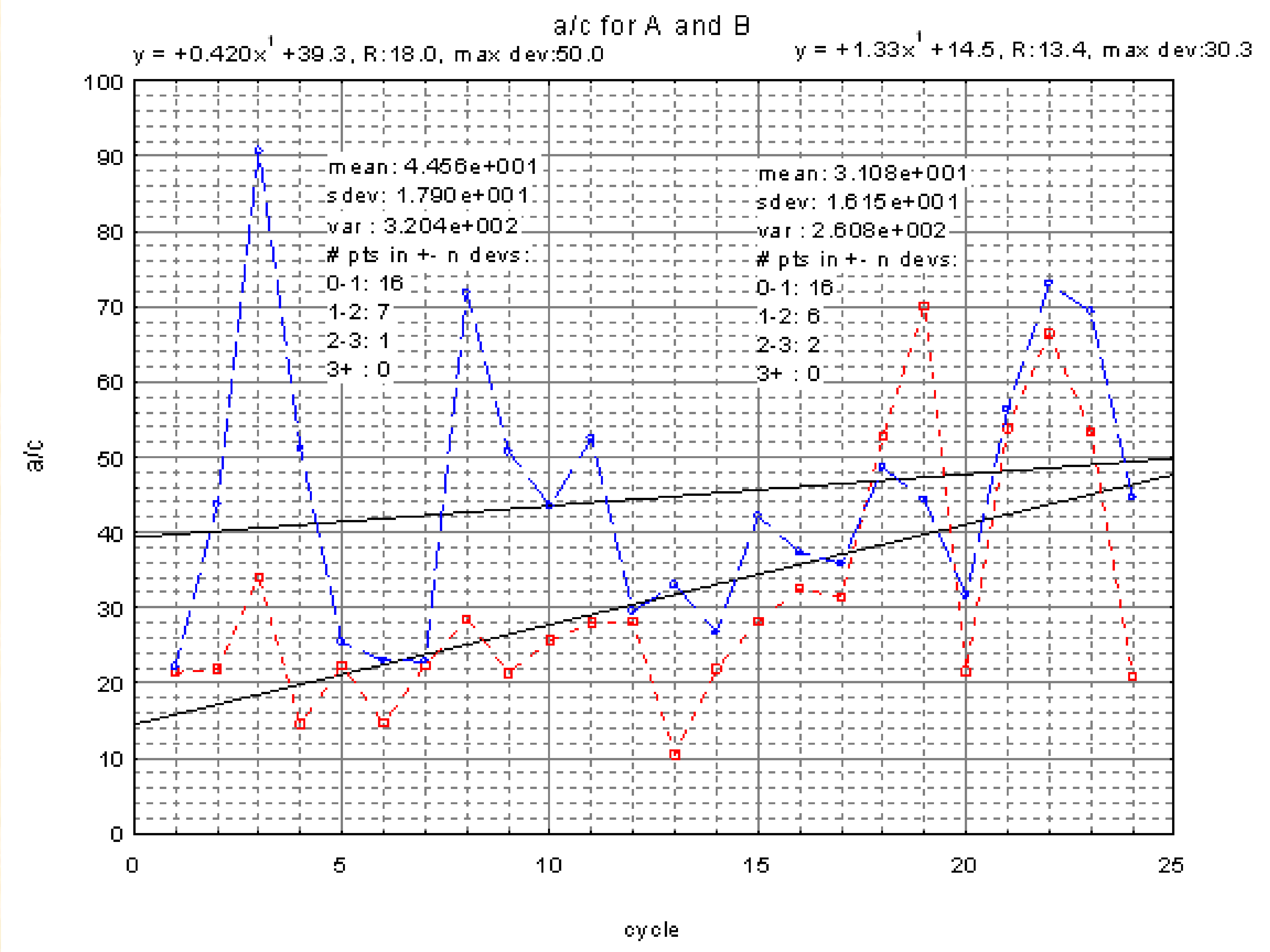


Early sunspot observations. This figure, from Scheiner's *Rosa Ursina*, completed in 1630, shows several sunspots on successive days, as they are carried round by the Sun's rotation. The distinction between the umbra and penumbra of a sunspot had already been recognized. (Courtesy of the RAS.)



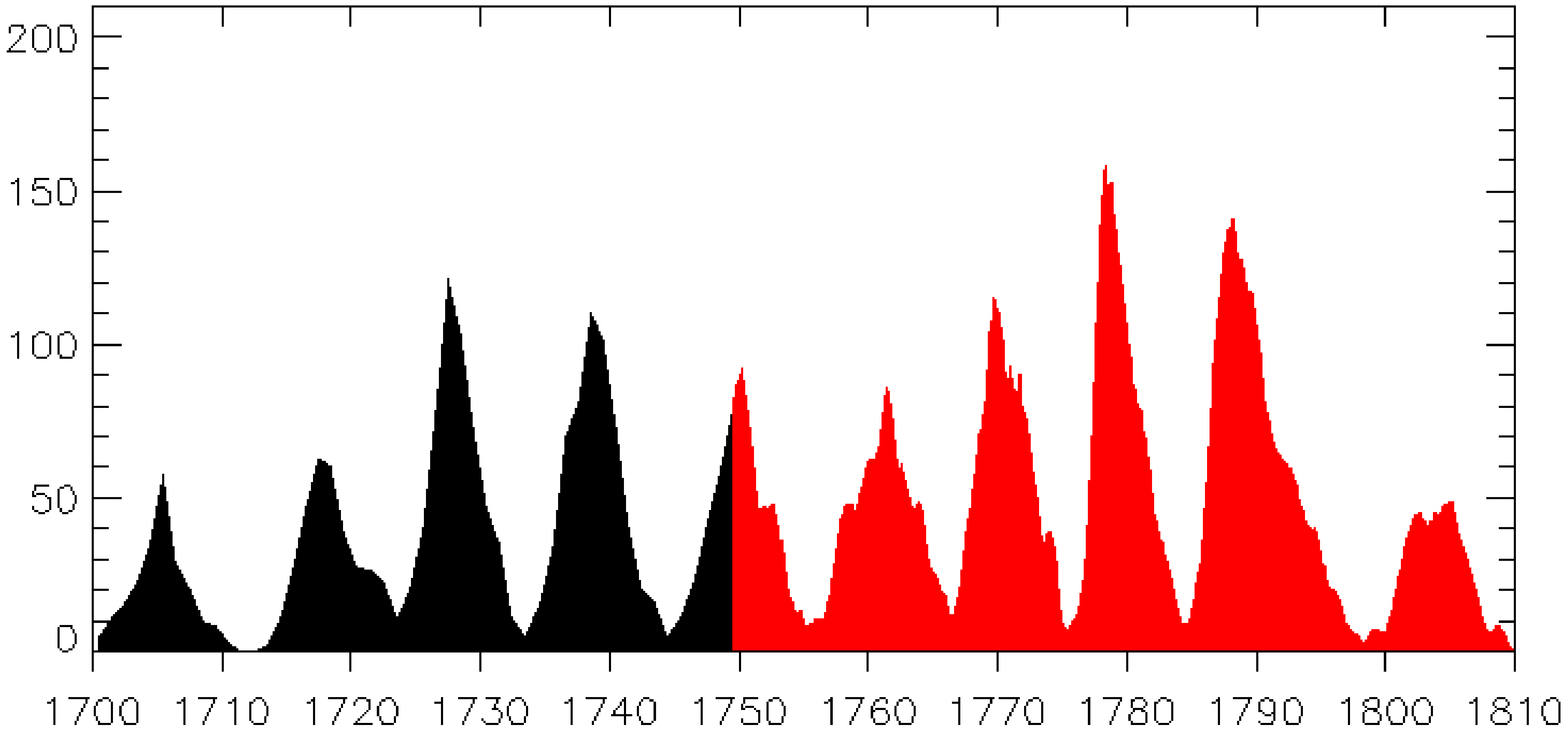

a/c for A and B
y = +0.420x^1 +39.3, R:18.0, max dev:50.0
y = +1.33x^1 +14.5, R:13.4, max dev:30.3
mean: 4.456e+001
sdev: 1.790e+001
var : 3.204e+002
pts in +- n devs:
0-1: 16
1-2: 7
2-3: 1
3+ : 0
mean: 3.108e+001
sdev: 1.615e+001
var : 2.608e+002
pts in +- n devs:
0-1: 16
1-2: 6
2-3: 2
3+ : 0
a/c
cycle
0
10
20
30
40
50
60
70
80
90
100
0
5
10
15
20
25

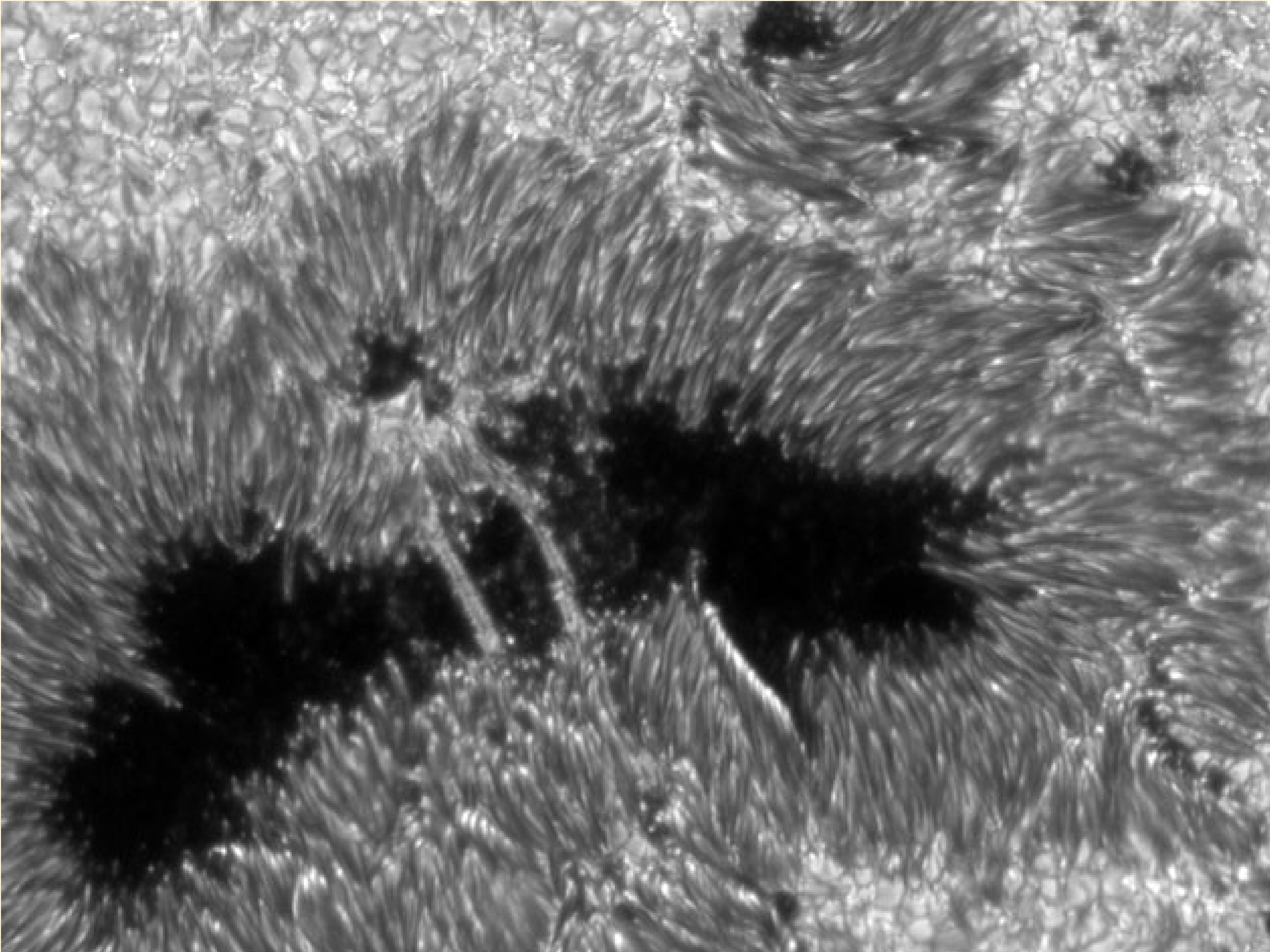
No.	A				B				Δ	R
cycle	b poz 1	a ampl 1	c width 1	a/c	f poz 2	d ampl 2	g width 2	d/g	f - b	a/d
1	1759.03	23.21	1.05	22.10	1761.78	69.07	3.23	21.38	2.75	0.336
2	1769.67	89.10	2.04	43.67	1772.37	48.19	2.20	21.90	2.70	1.849
3	1778.35	105.07	1.16	90.58	1780.22	81.59	2.40	34.00	1.87	1.288
4	1788.03	112.51	2.20	51.14	1791.40	64.09	4.40	14.56	3.37	1.755
5	1802.05	36.54	1.44	25.37	1804.89	45.34	2.03	22.33	2.84	0.806
6	1816.20	48.00	2.09	22.97	1819.50	22.03	1.50	14.69	3.30	2.179
7	1828.04	50.79	2.22	22.88	1830.00	51.23	2.30	22.27	1.96	0.991
8	1836.88	102.71	1.43	71.82	1839.23	74.16	2.60	28.52	2.35	1.385
9	1848.42	108.58	2.14	50.74	1852.22	45.05	2.11	21.35	3.80	2.410
10	1860.25	101.24	2.33	43.45	1864.22	46.06	1.80	25.59	4.18	2.198
11	1870.50	86.03	1.64	52.46	1872.50	68.36	2.44	28.02	2.00	1.258
12	1881.40	35.70	1.21	29.50	1884.15	63.07	2.24	28.16	2.75	0.566
13	1893.41	68.09	2.06	33.05	1896.13	33.01	3.15	10.48	2.72	1.629
14	1905.69	57.87	2.17	26.67	1908.84	41.79	1.91	21.88	3.15	1.385
15	1916.89	70.05	1.66	42.20	1919.26	65.50	2.33	28.11	2.38	1.069
16	1926.10	40.00	1.07	37.38	1928.42	81.04	2.49	32.55	2.32	0.493
17	1937.33	59.09	1.65	35.81	1939.36	81.68	2.60	31.41	2.03	0.723
18	1947.25	48.56	1.00	48.56	1948.94	128.76	2.81	52.77	1.69	0.377
19	1957.75	66.46	1.50	44.31	1959.02	170.94	2.44	70.06	1.27	0.389
20	1968.42	79.05	2.50	31.62	1971.48	68.94	3.20	21.54	3.06	1.146
21	1979.37	76.54	1.36	56.28	1981.49	135.15	2.51	53.84	2.12	0.566
22	1989.13	87.60	1.20	73	1991.21	140.05	2.11	66.37	2.08	0.625
23	1999.77	107.40	1.55	69.29	2002.41	96.05	1.80	53.36	2.71	1.118
24	2010.98	74.98	1.68	44.63	2014.05	50.83	2.44	20.83	3.07	1.475

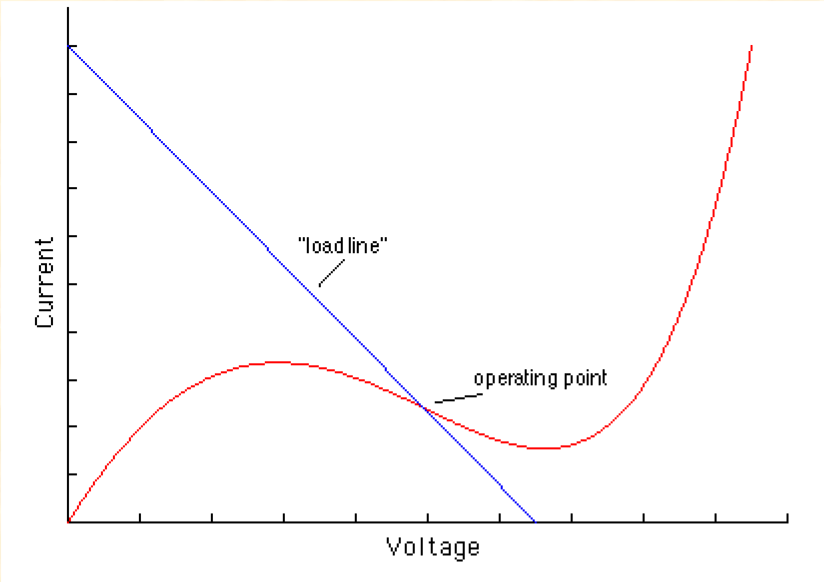
Abstract

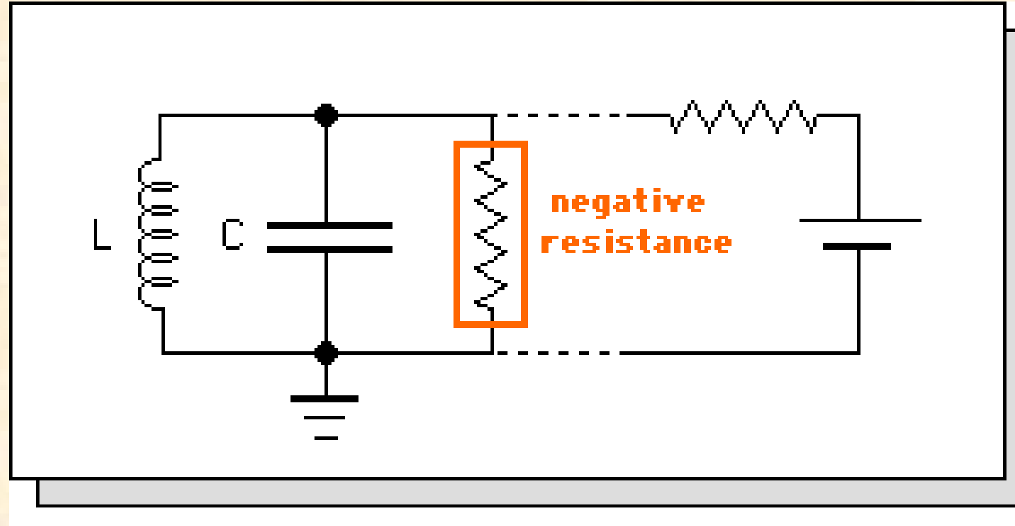
- In an early paper we analyzed the asymmetry of the sunspot cycles from the point of view of its non-linearity. There are many attempts to predict the features of the future evolution of the solar activity which are based on different models for fitting the shape of Wolf number evolution. None of them are fully satisfying and the recent delay of the solar cycle #24 is one example. Unfortunately the majority of the predictions are based on the numerical analysis, and just a few attempts to base the forecast on a physical basis. We try to go closer to a solution of the prediction problem, using some physical evidences we found presented in the early article and now we made a critical analysis of our prediction based on the accumulated data that from 2007.

The pattern of the time series of wolf numbers for a log period









$$\frac{d^2}{dt^2}v(t) - \frac{d}{dt}\left[\alpha\, v(t) - \overline{\beta}\, v^3(t)\right] + \omega_0^2\, v(t) = 0$$

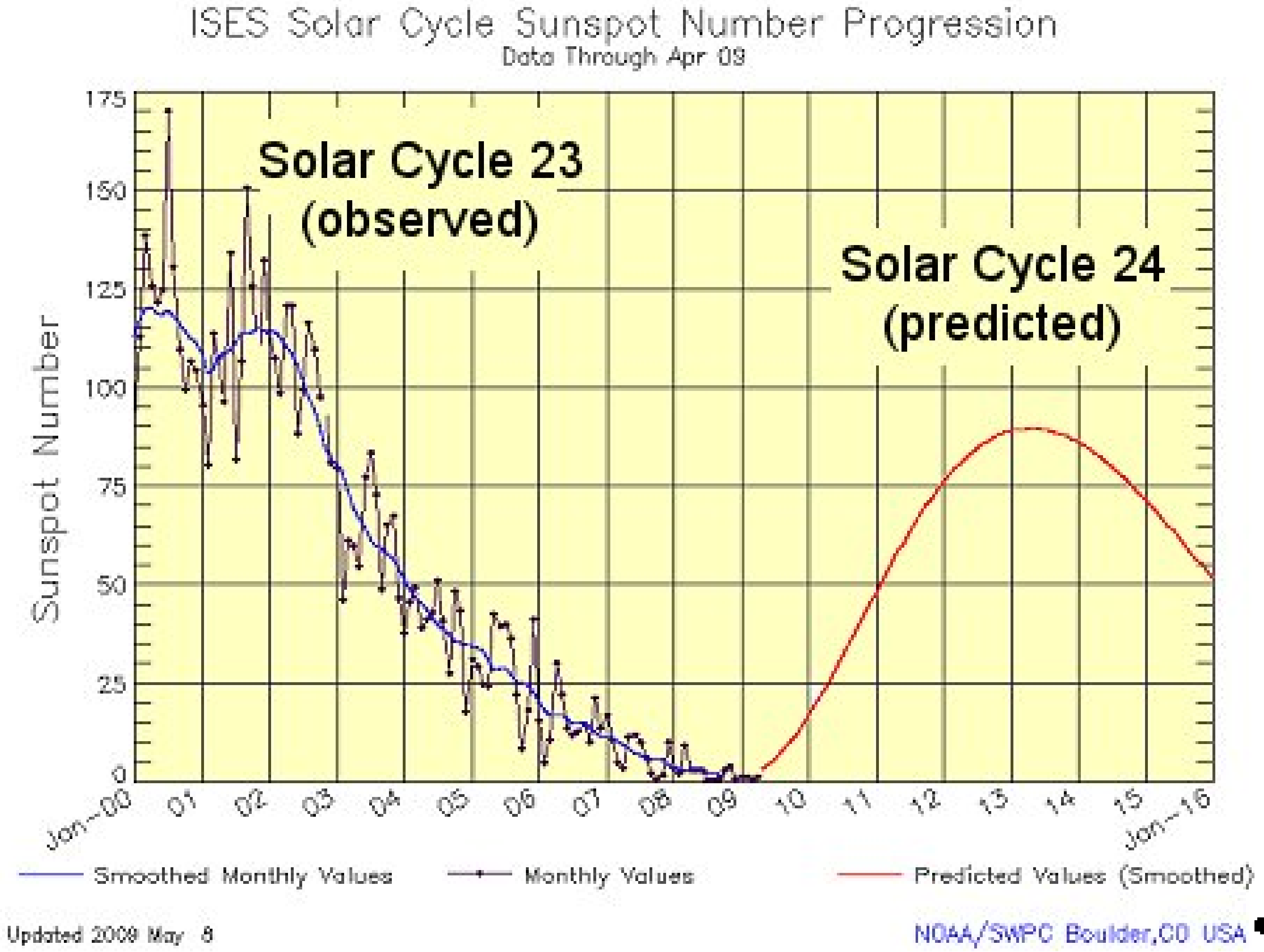
$$\frac{1}{2}\left(\omega_0^2 - \omega^2\right)V(t) - i\omega\dot{V}(t) + i\omega\frac{1}{2}\left[\alpha - \beta\left|V(t)\right|^2\right]V(t) = i\frac{\omega^2 V_0}{2}$$

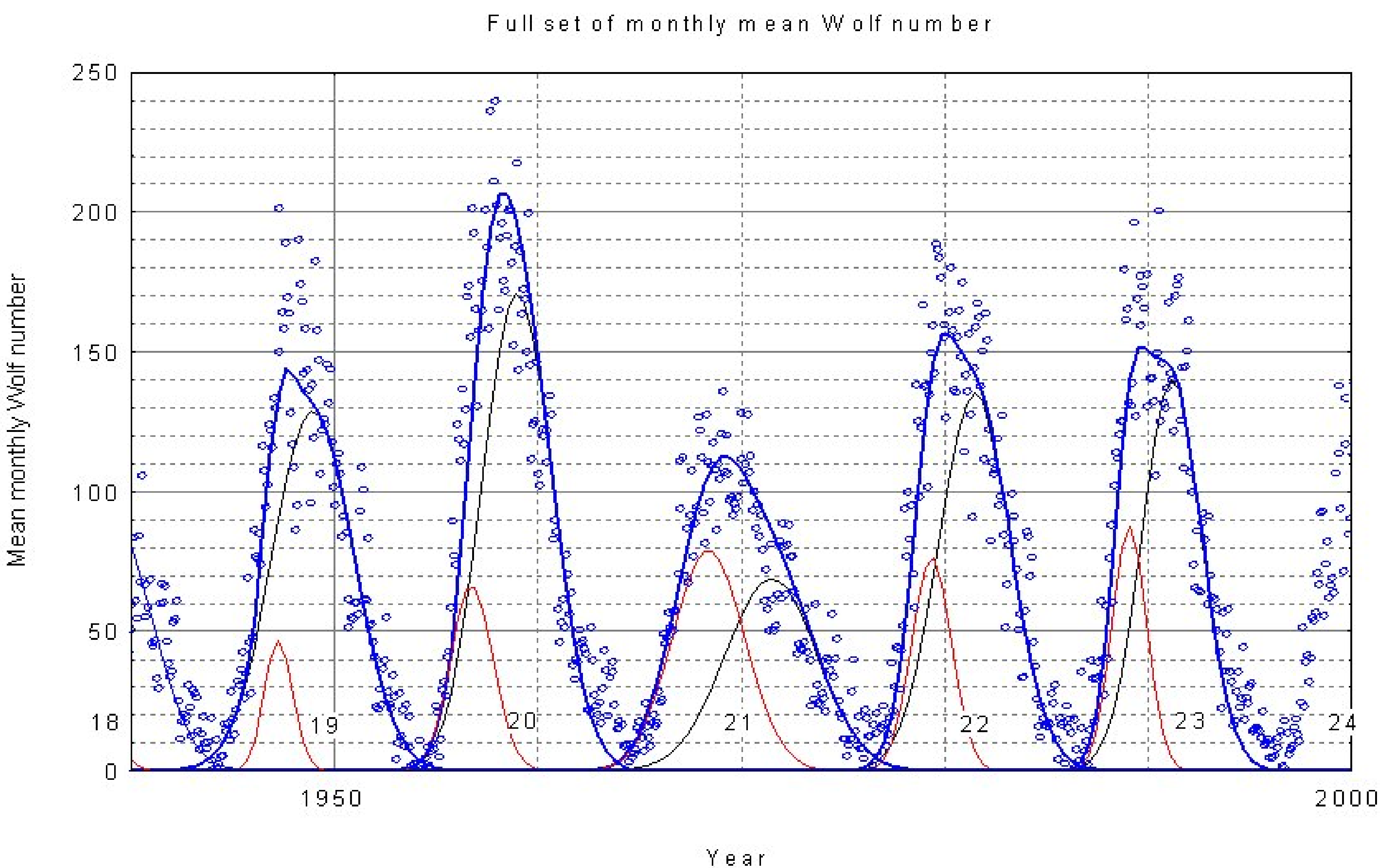
B. van der Pol, *Radio Rev.* 1, 704-754, 1920 and B. van der Pol, *Phil. Mag.* 3, 65, 1927

$$y'' - \mu\left(1 - y^2\right)y' + y = 0.$$

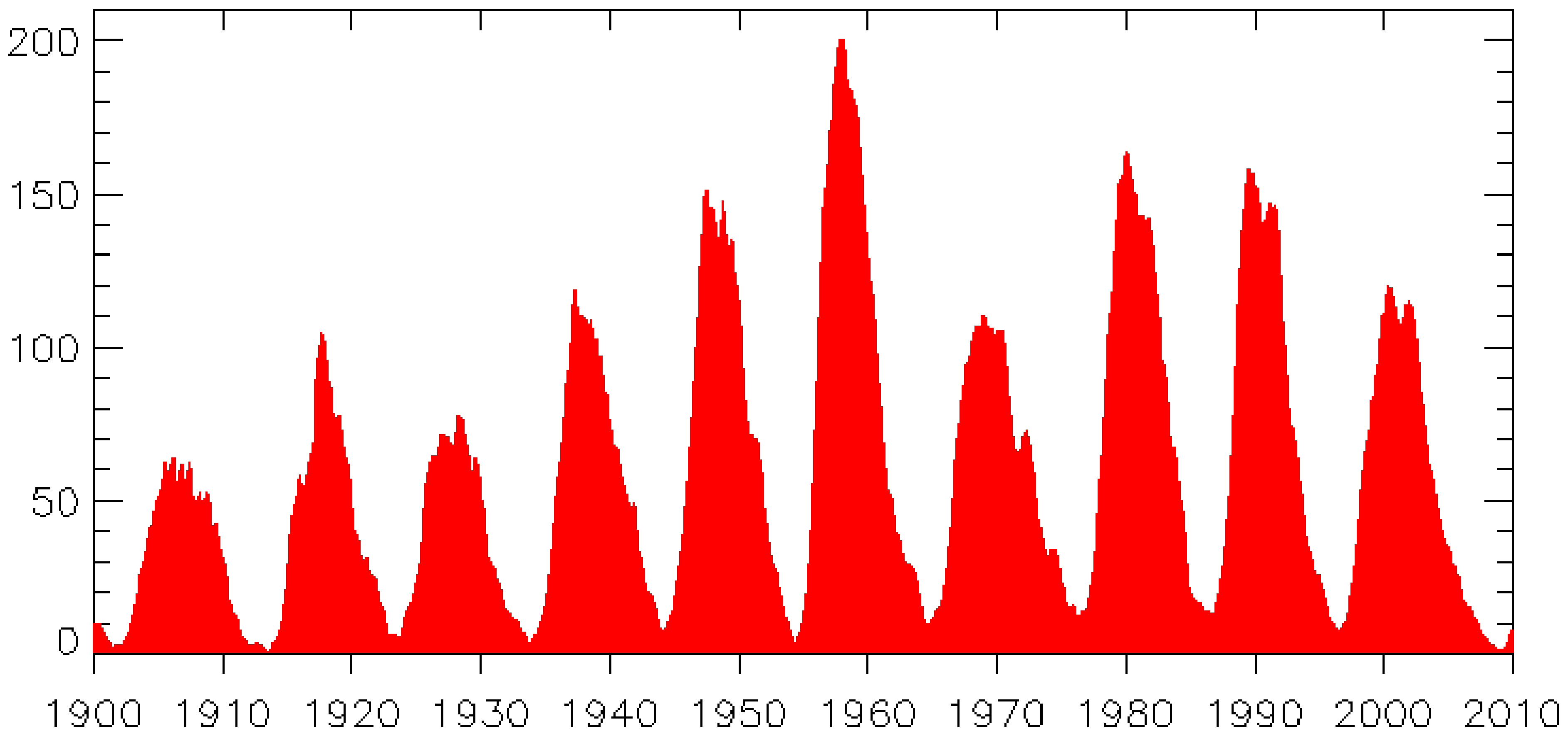
Parametric oscillator

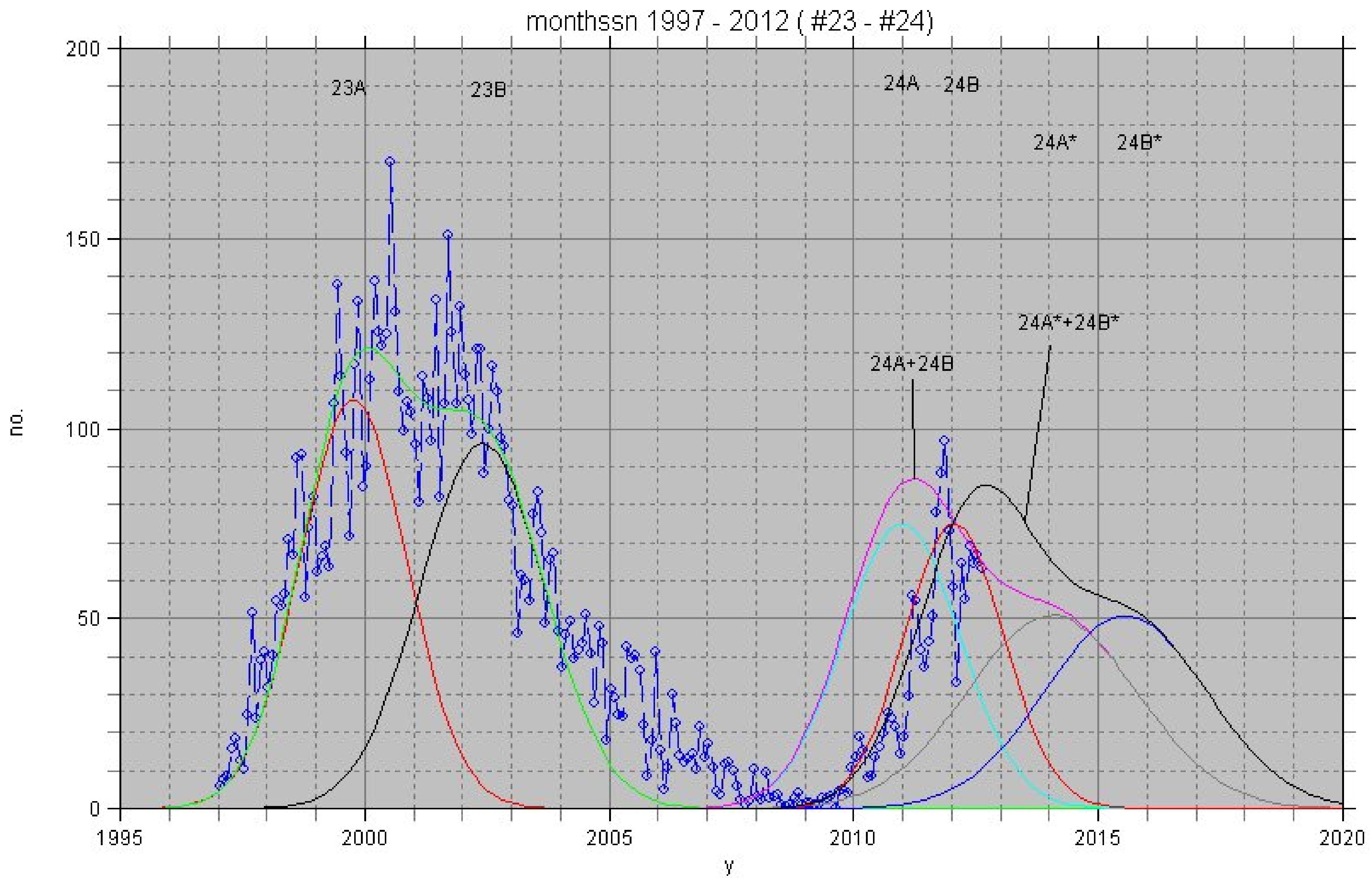
$$\frac{d^2x}{dt^2} + \beta(t)\frac{dx}{dt} + \omega^2(t)x = 0$$

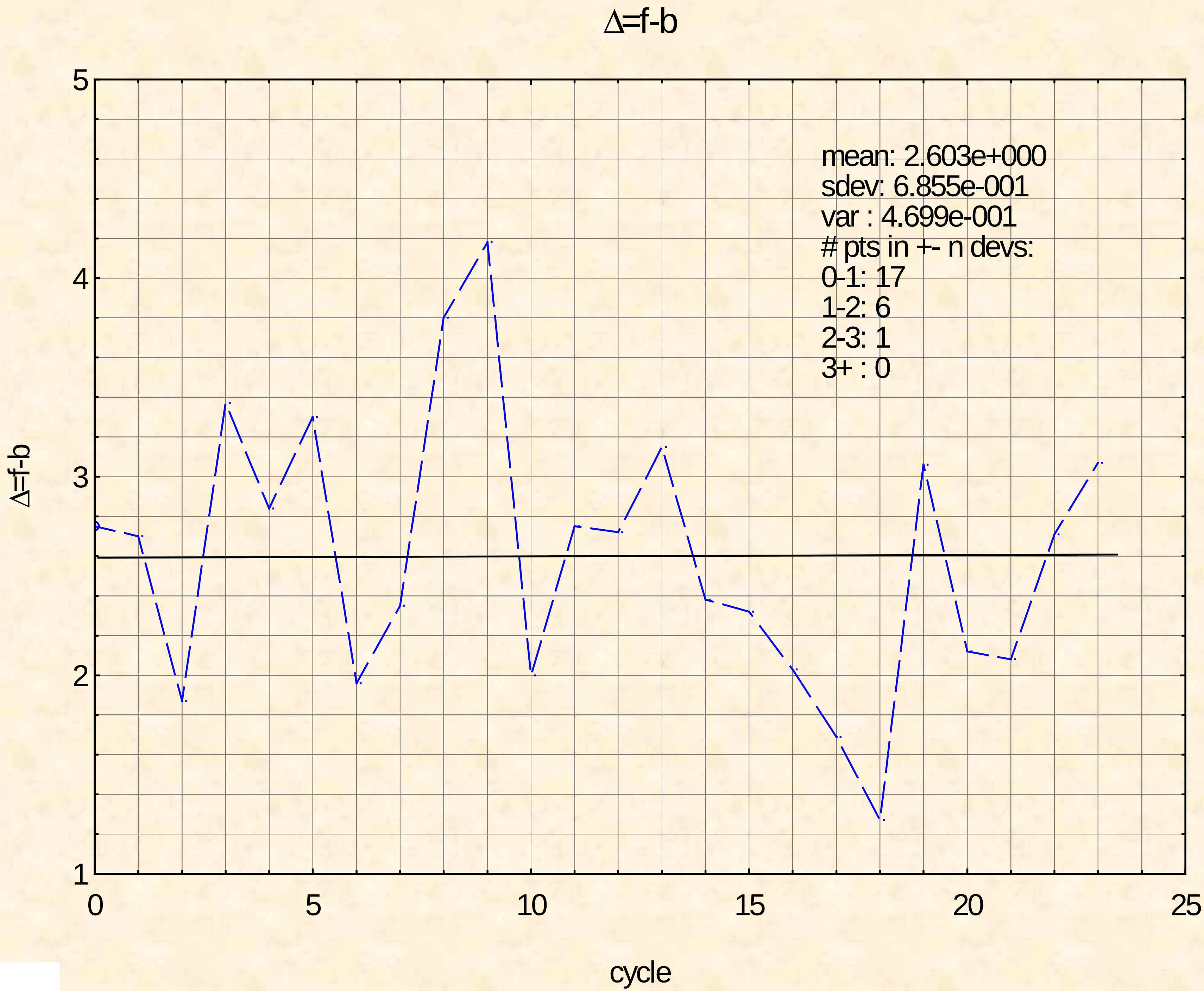

ISES Solar Cycle Sunspot Number Progression
Data Through Apr 09
Solar Cycle 23
(observed)
Solar Cycle 24
(predicted)
Sunspot Number
175
150
125
100
75
50
25
0
Jan-00
01
02
03
04
05
06
07
08
09
10
11
12
13
14
15
Jan-16
Smoothed Monthly Values
Monthly Values
Predicted Values (Smoothed)
Updated 2009 May 6
NOAA/SWPC Boulder,CO USA
¶


Full set of monthly mean Wolf number
Mean monthly Wolf number
250
200
150
100
50
18
0
19
20
21
22
23
24
1950
2000
Year

The pattern of the time series of wolf numbers for a log period




monthssn 1997 - 2012 (#23 - #24)
23A
23B
24A
24B
24A*
24B*
24A*+24B*
24A+24B
no.
y
0
50
100
150
200
1995
2000
2005
2010
2015
2020


Δ=f-b
5
4
3
2
1
0
5
10
15
20
25
mean: 2.603e+000
sdev: 6.855e-001
var : 4.699e-001
pts in +- n devs:
0-1: 17
1-2: 6
2-3: 1
3+ : 0
Δ=f-b
cycle