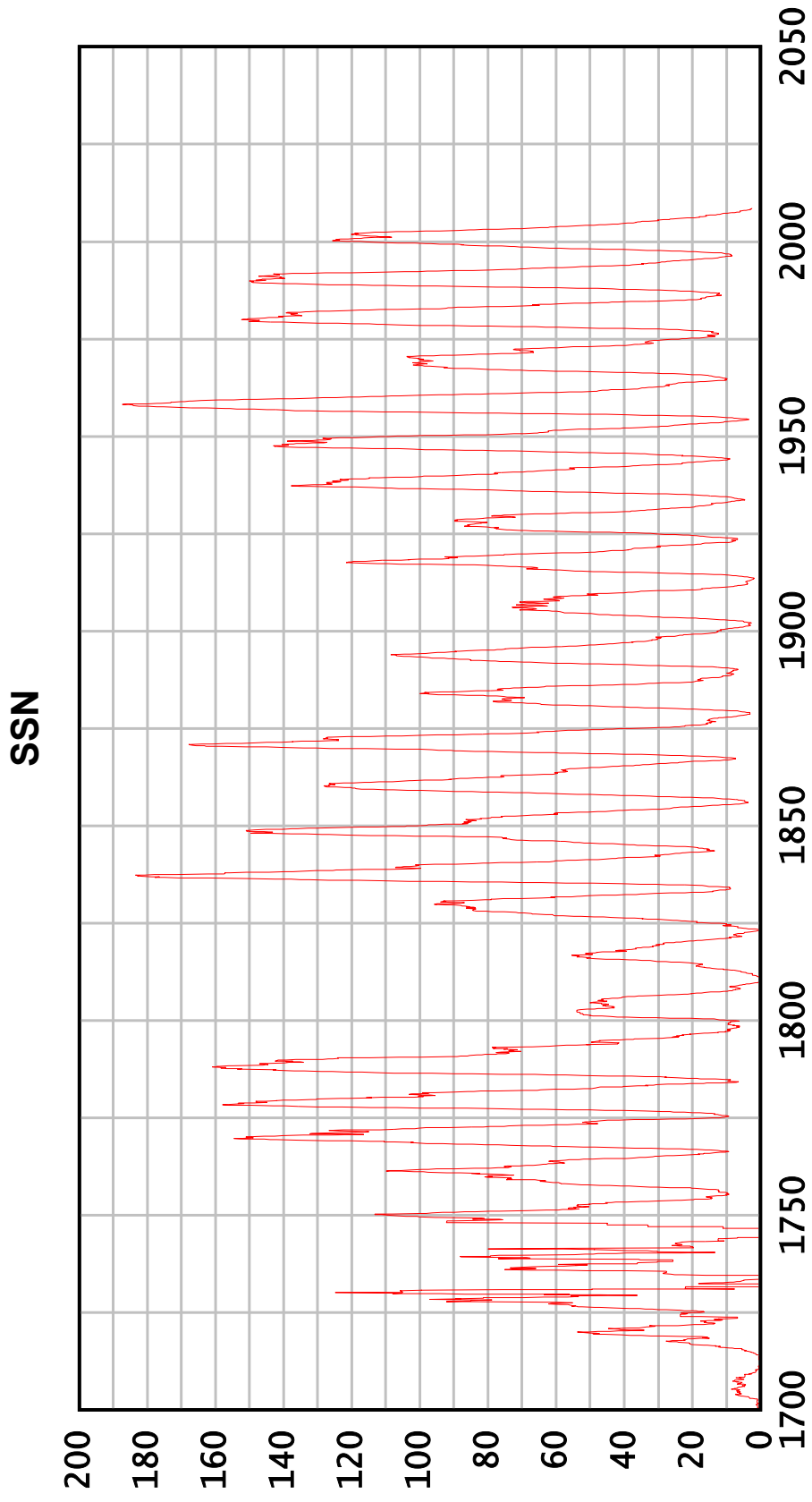
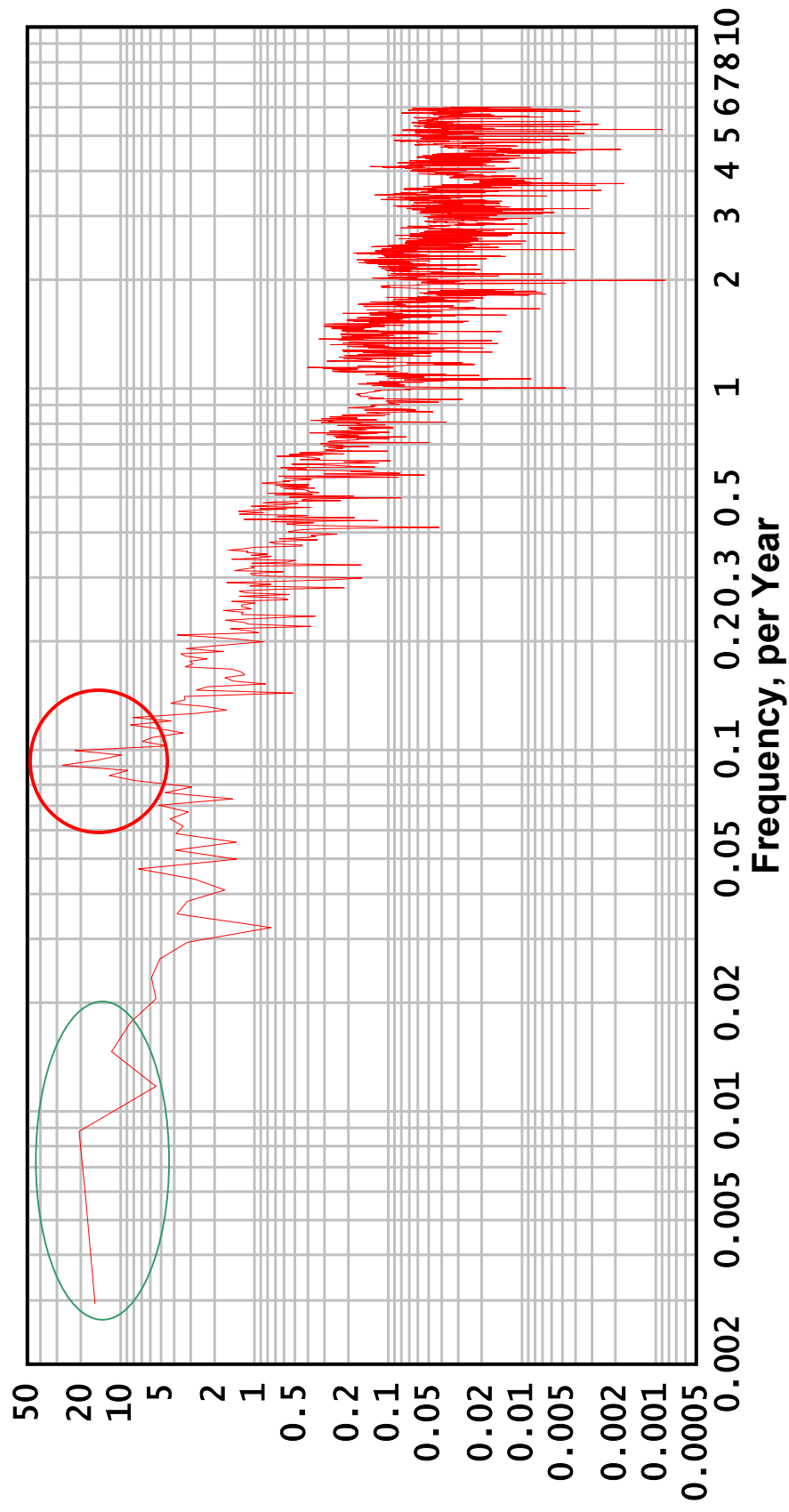


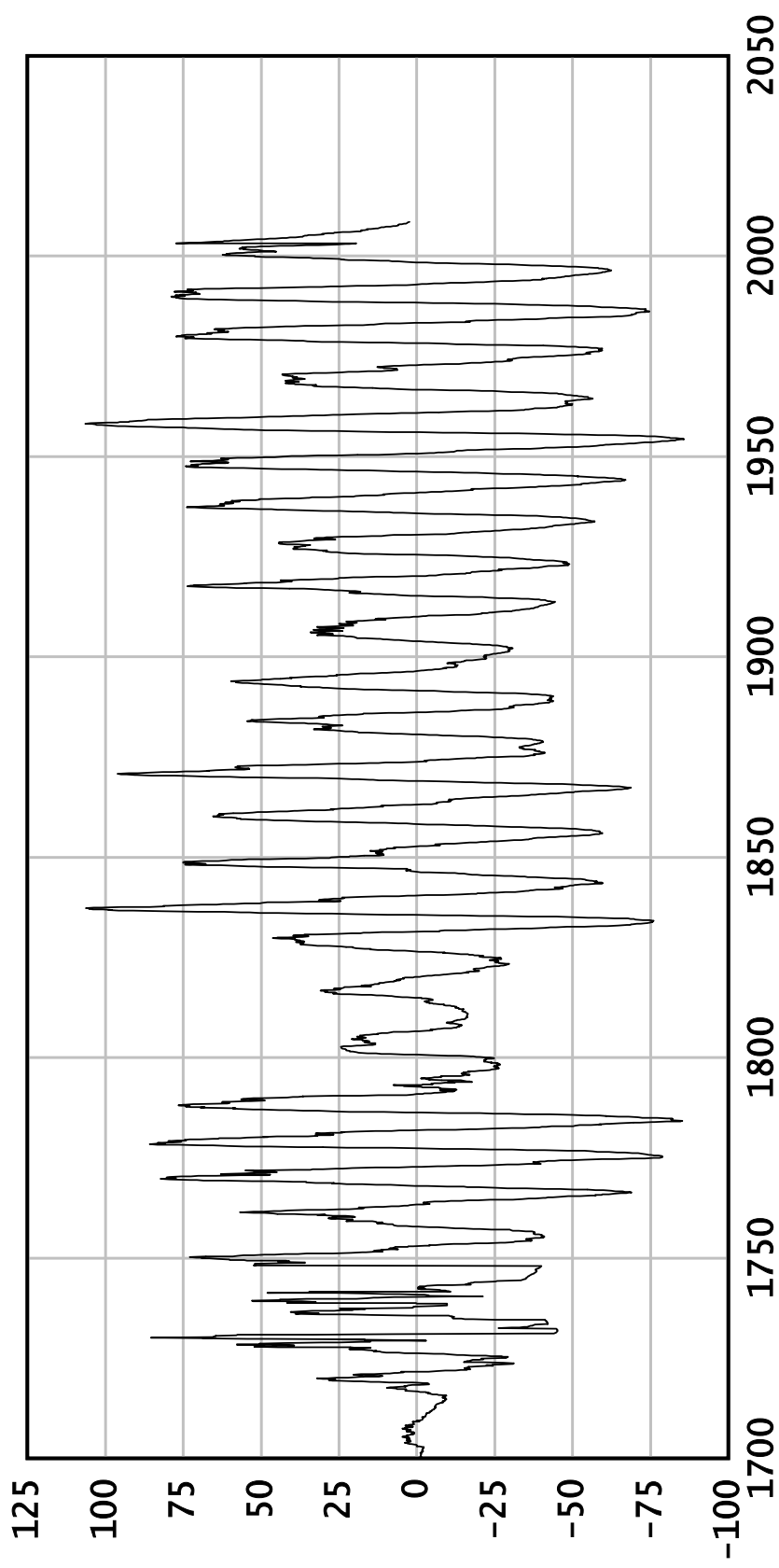
We have good sunspot number data since 1700:



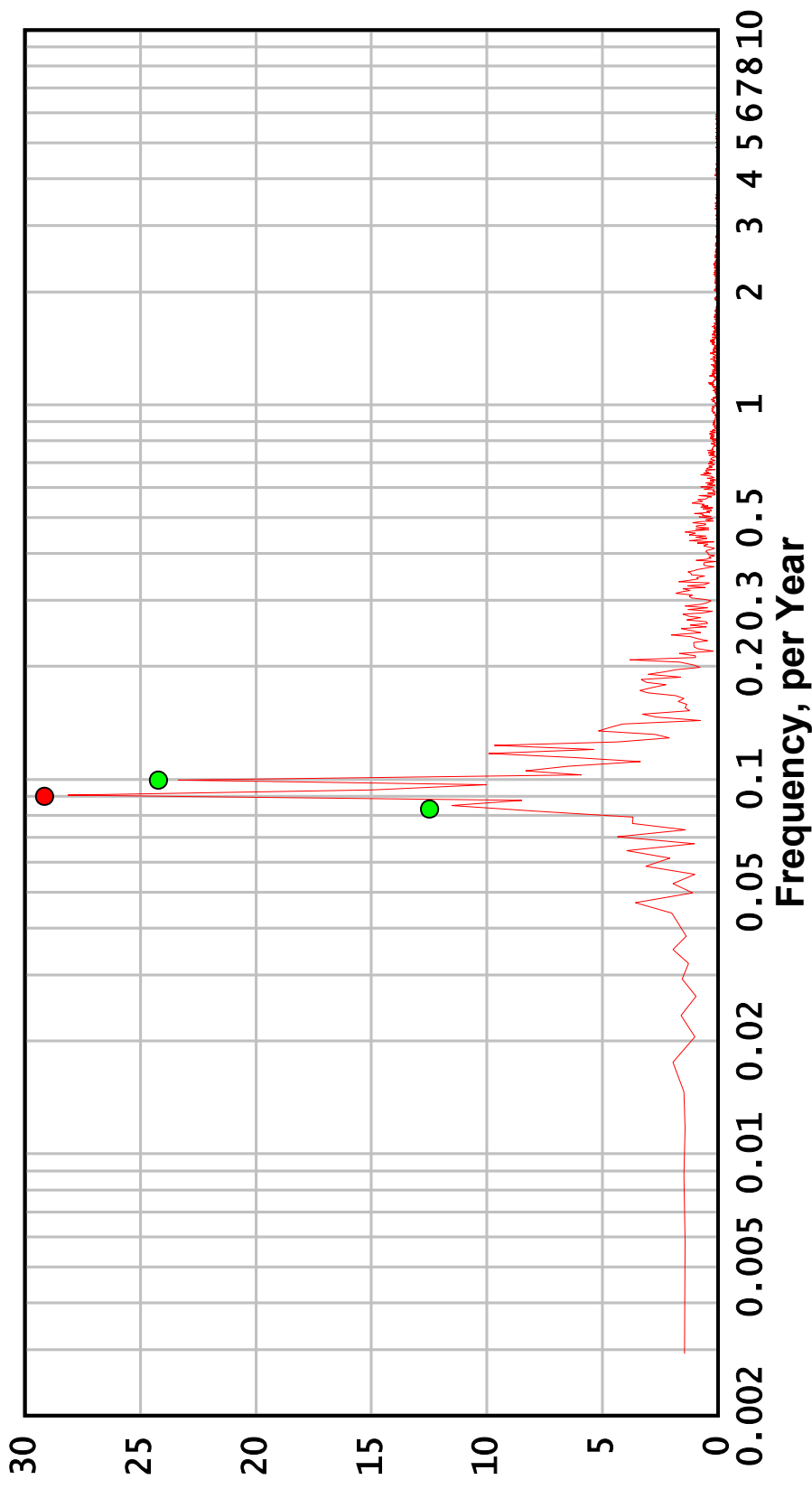
The FFT power spectrum shows a broad peak at 11.01 y with fine structure and power above 50 y:



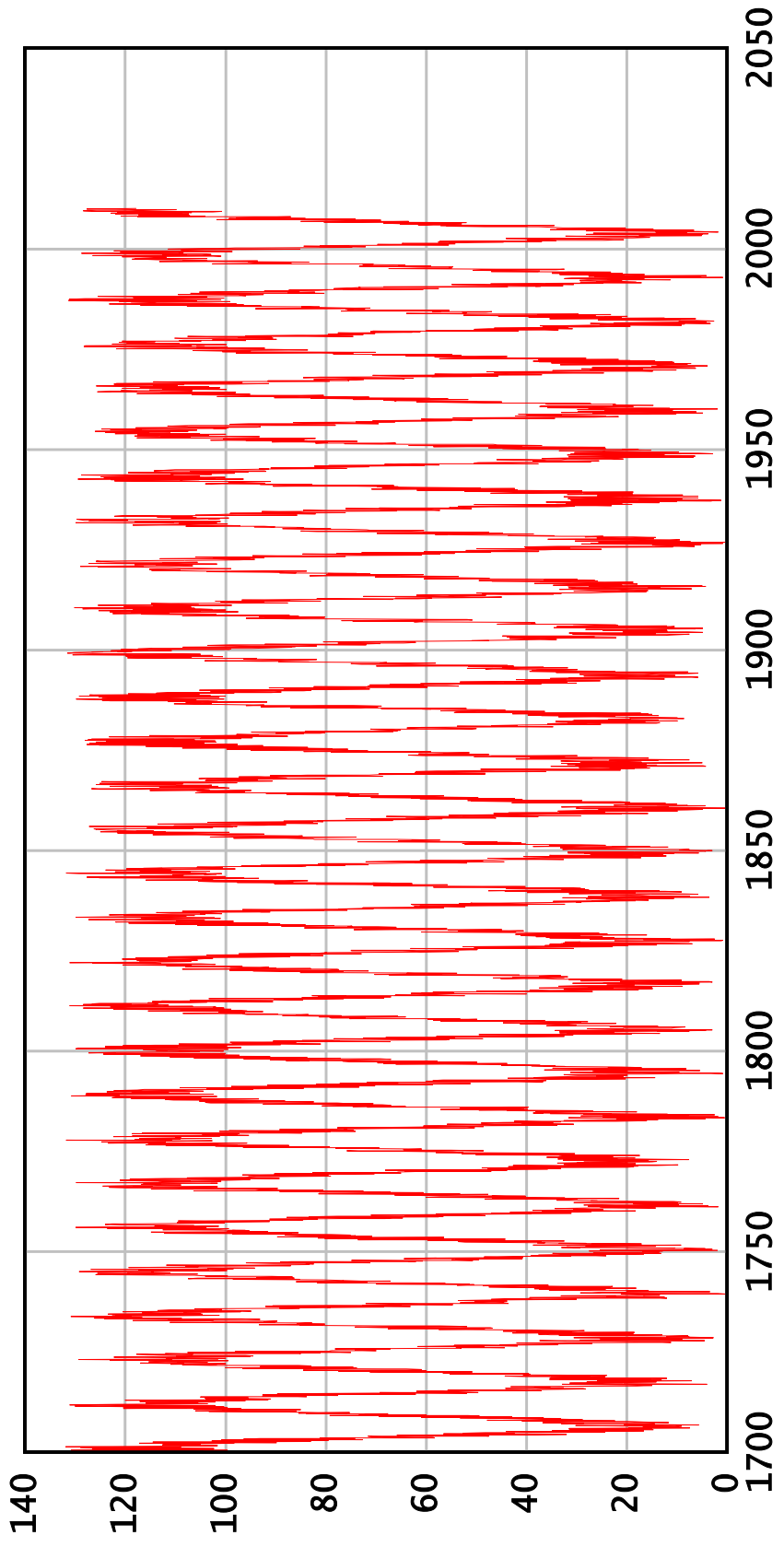
A standard technique is to remove the long-period power by filtering. A simple filter is just the 11-year running mean. Removing that we get:



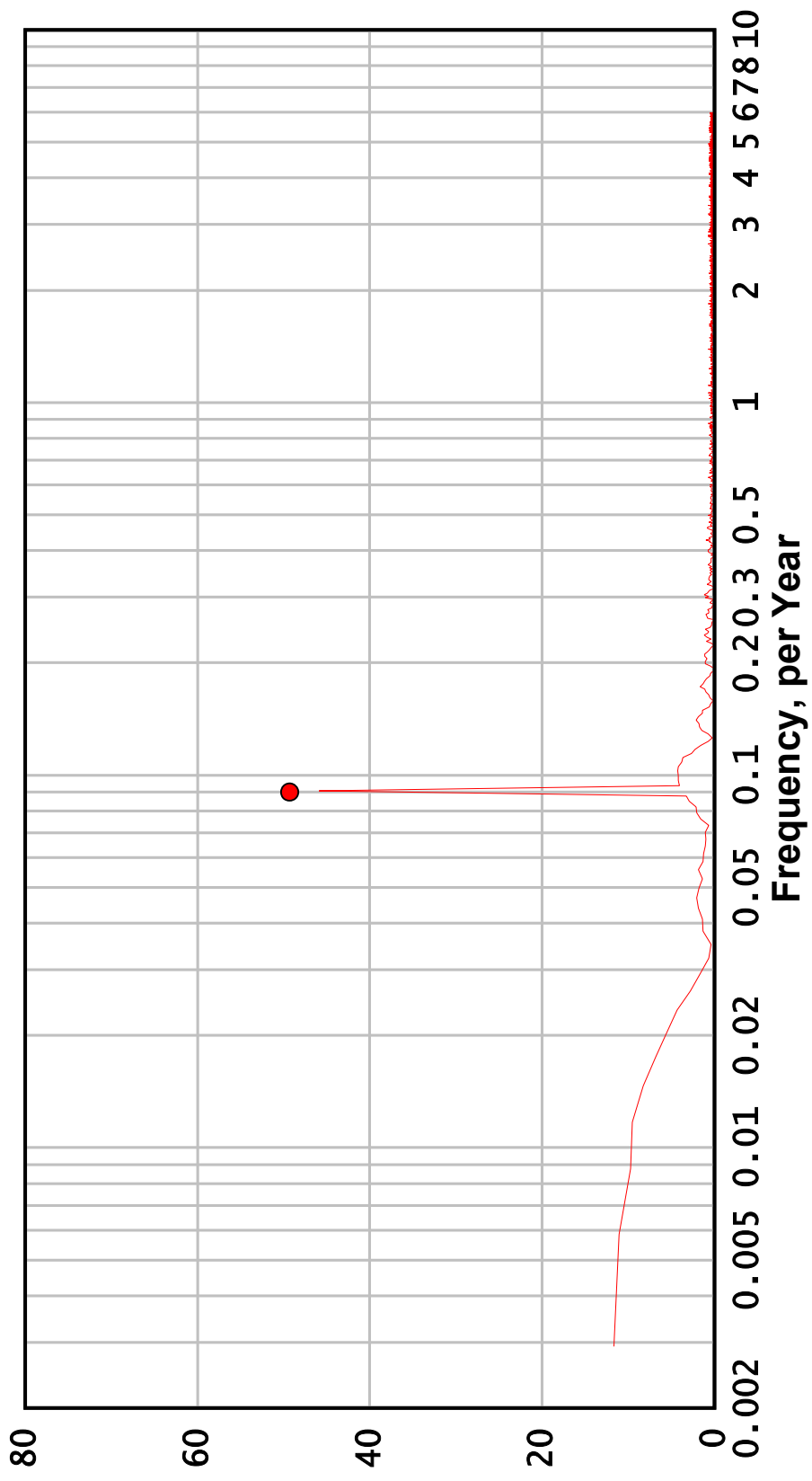
This brings out the fine structure clearly. There is a strong main peak [red dot] at 11.01 y and two weaker side peaks [green dots] at 10.04 y and 11.77 y. In addition there are other lower peaks on both sides, reflecting the variability of the solar cycle:



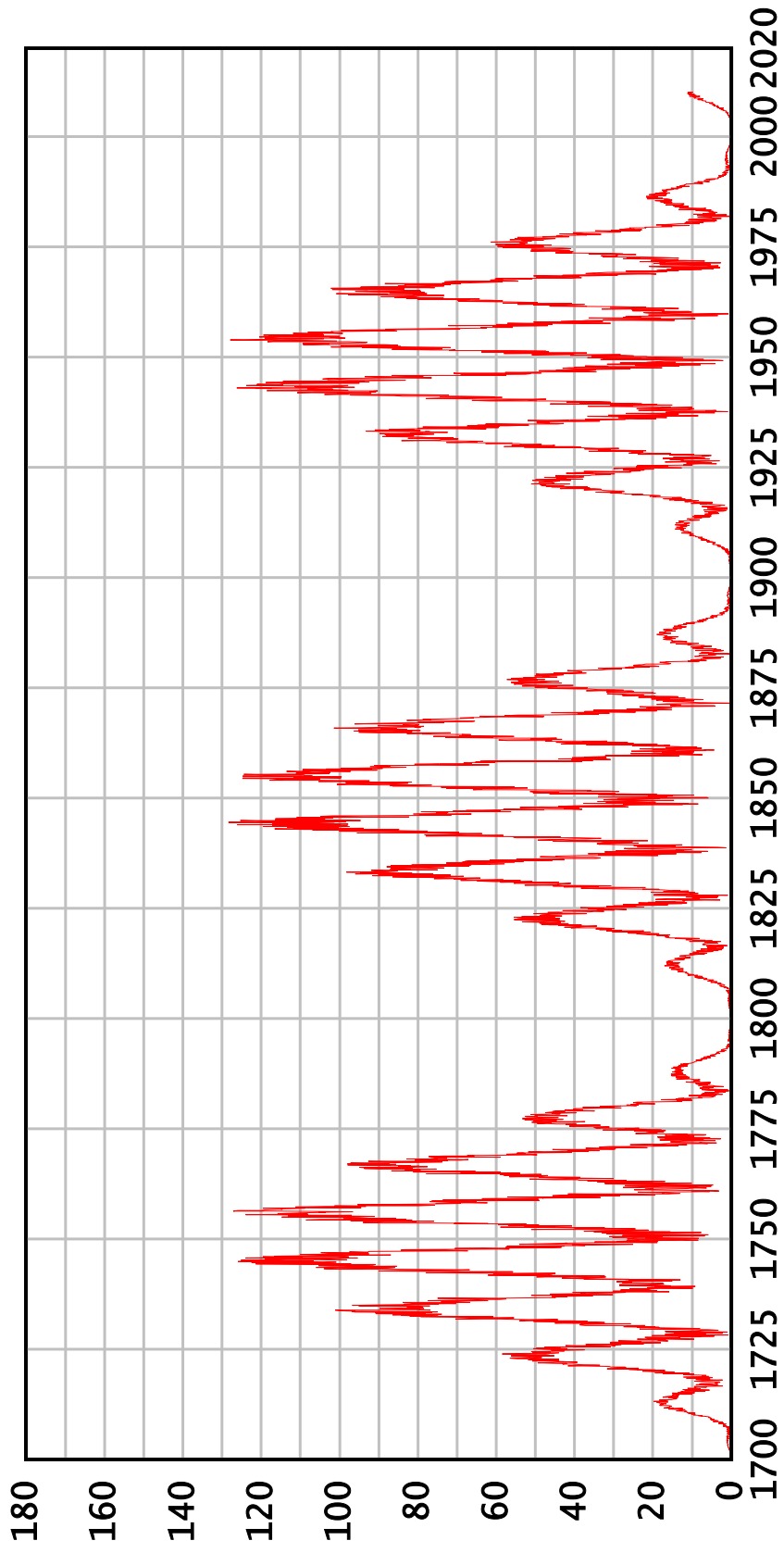
To see what the side peaks [the green dots] mean, we construct an artificial solar cycle with period 11.01 years and with random noise added:



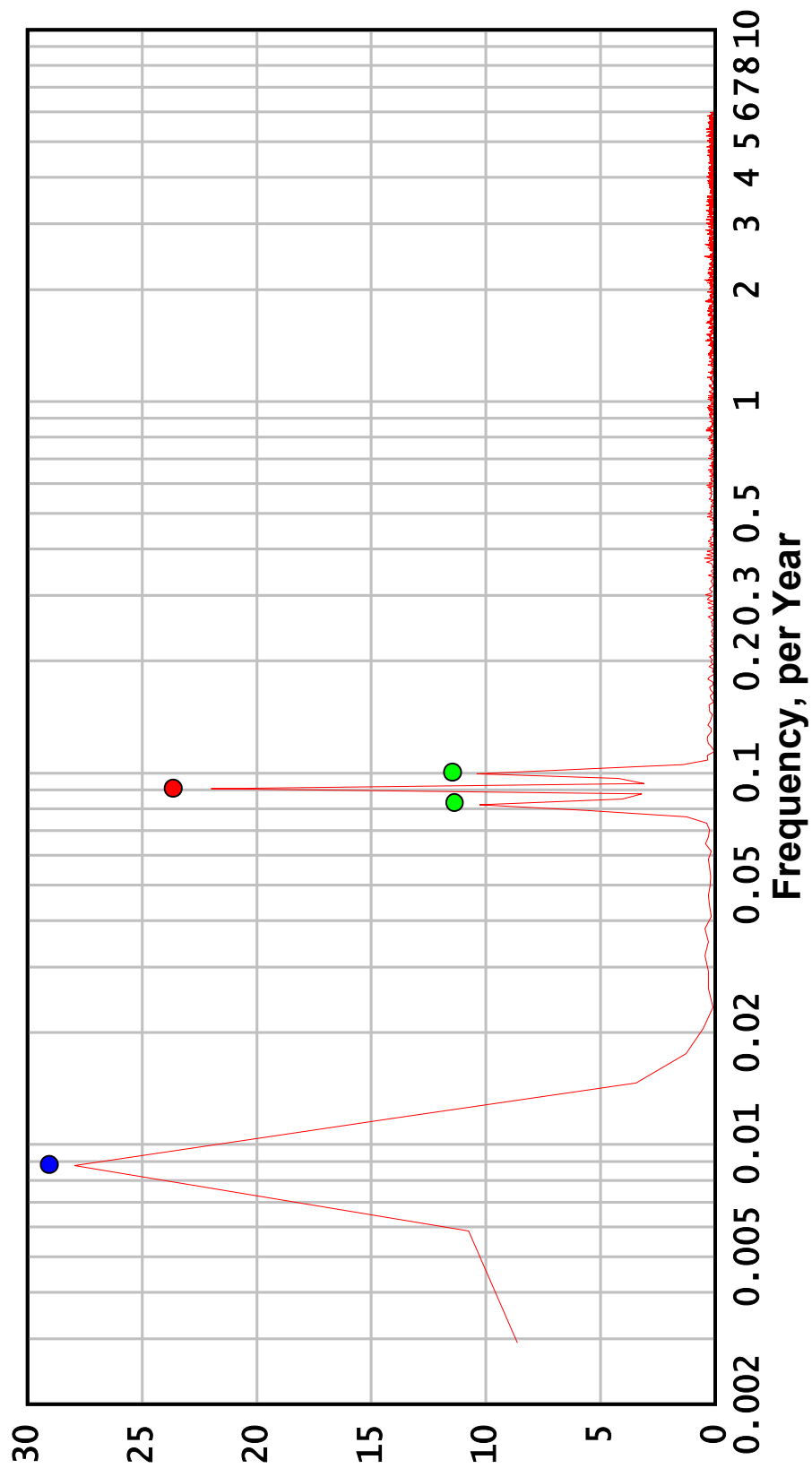
As expected, the FFT power spectrum shows a very sharp peak right at 11.01 y and no side peaks:



We now *modulate* the artificial cycle with a period of 100 years [even having a Grand Minimum – no cycle – every 100 years]:



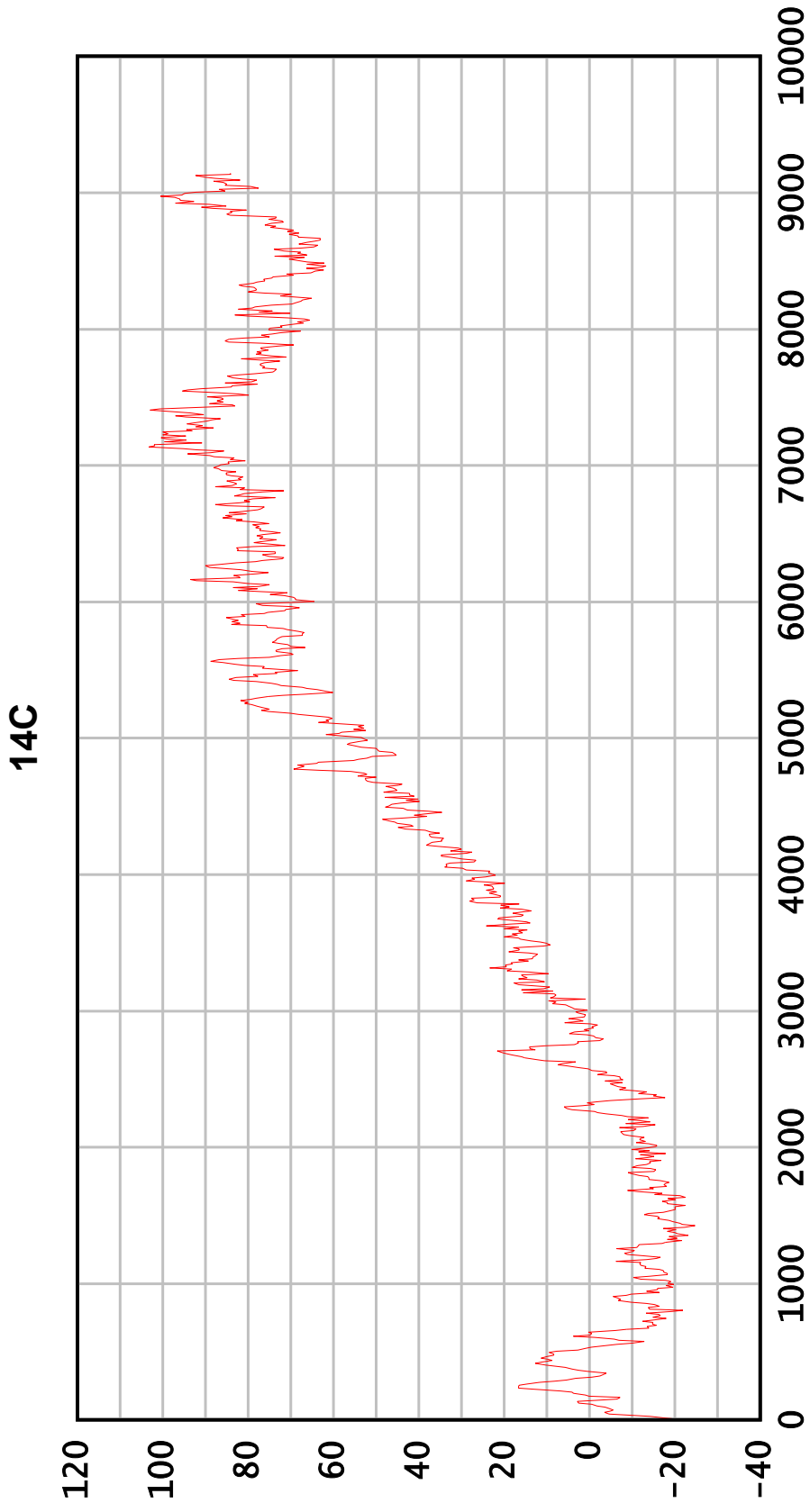
The FFT power spectrum now shows a main peak [red dot] at 11.01, side peaks [green dots] at 10.04 y and 12.19 y, and the long-cycle [blue dot] at ~114 years [the noise and the short length of the series makes it difficult to determine the precise period which we know is 100 y, but close enough]:



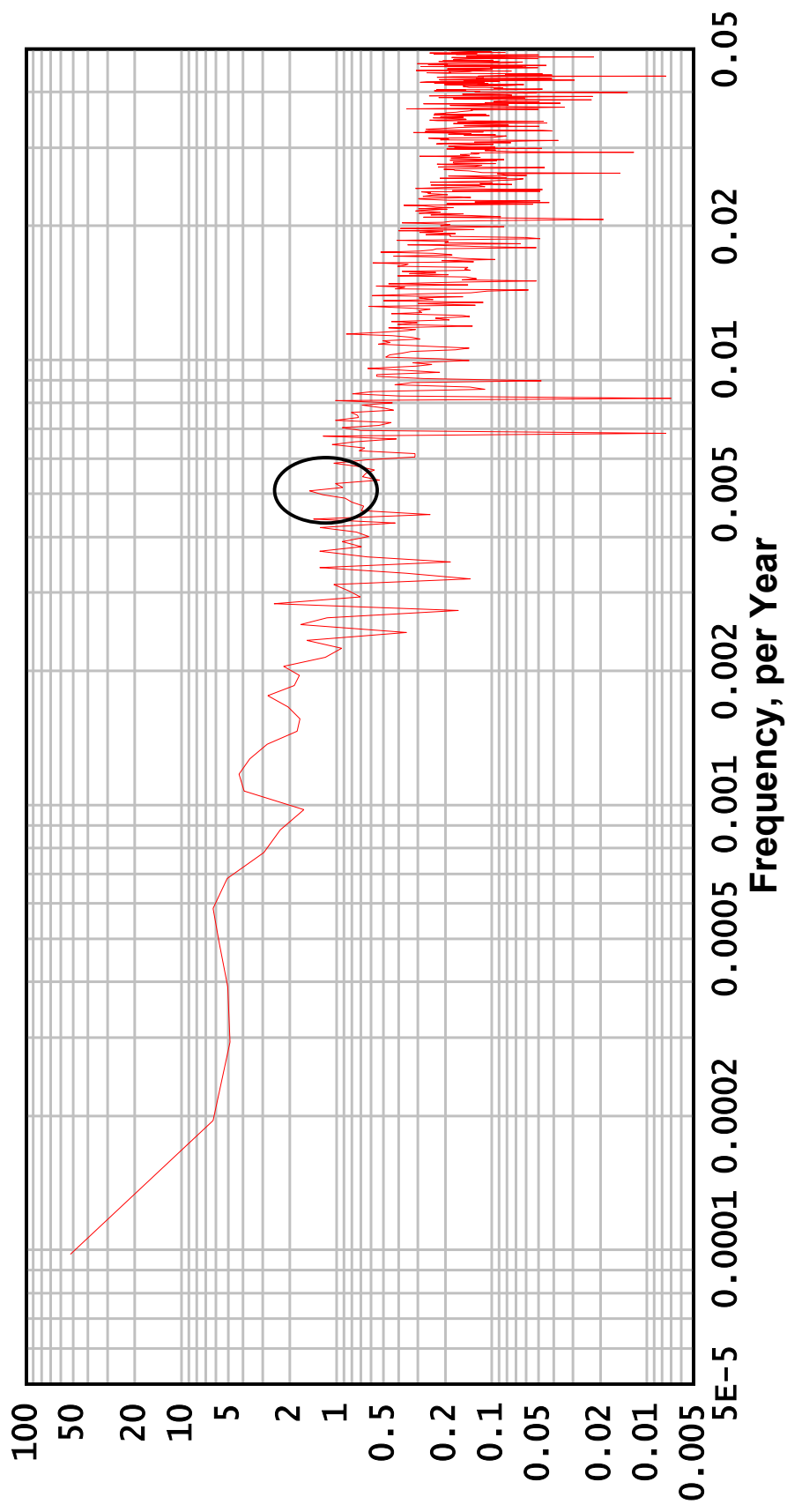
This is the meaning of the side peaks: modulation by a longer cycle.



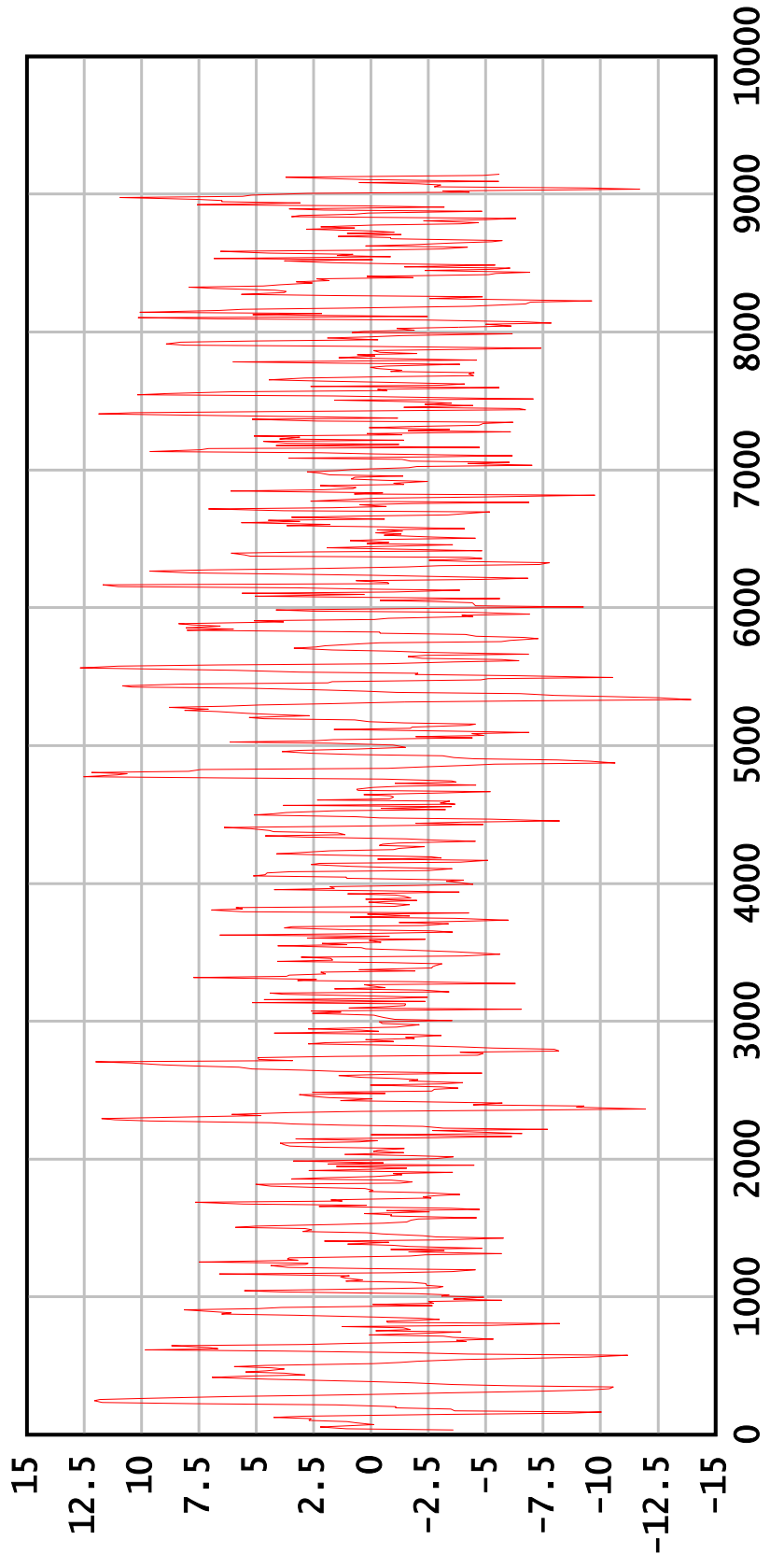
The 14C record is strongly influenced by the change [with period of thousands of years] of the Earth's magnetic field:



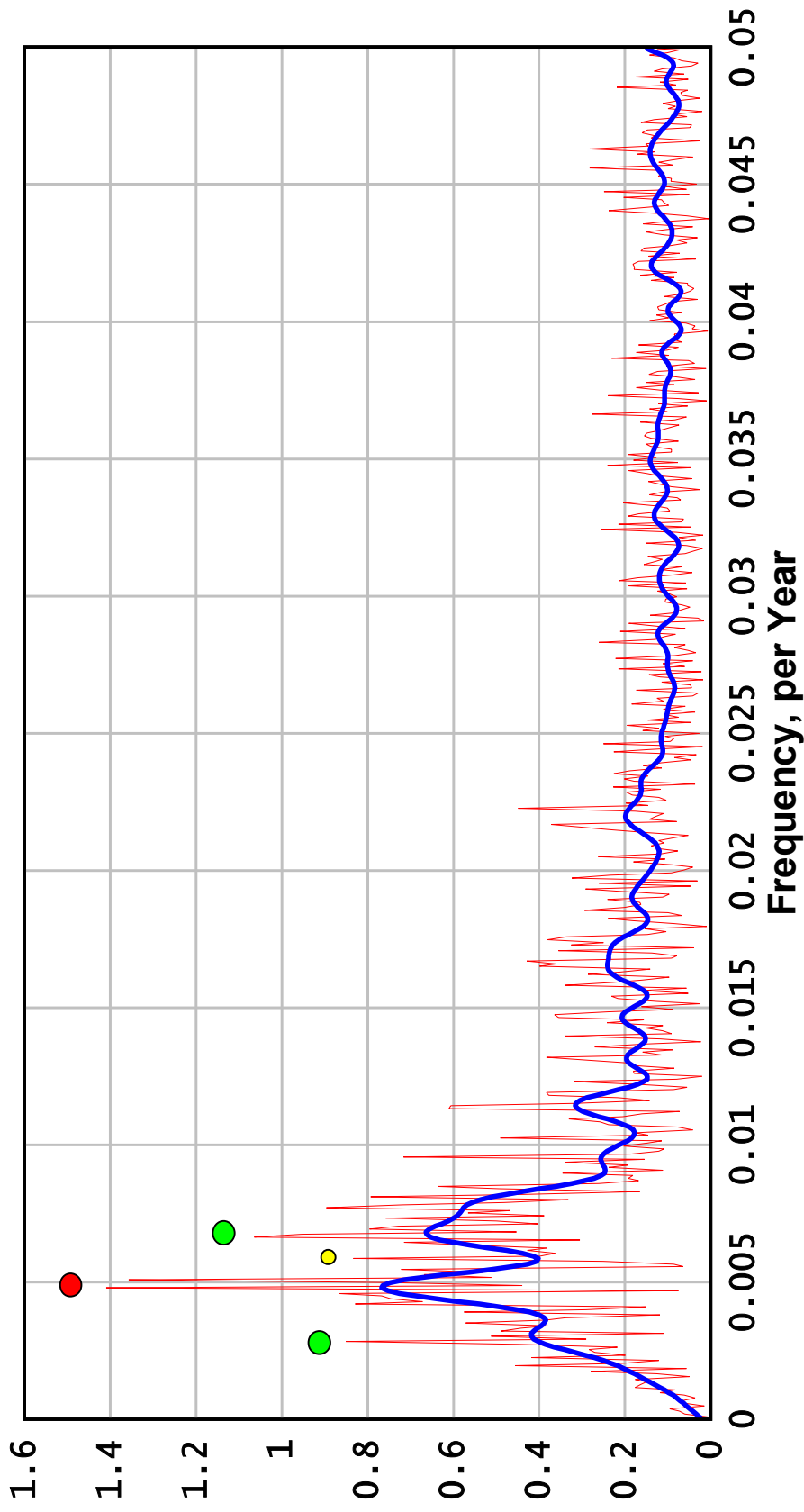
The power spectrum does not show any strong peaks as we would expect from the strict periodicity of planetary influences, but there is a well-known small peak near 200 years [the Suess or de Vries cycle]:



As before, we can remove the long-term variation, by subtracting a running mean with a period near the peak [the exact length does not make any difference, 195, 200, 205 all give very similar results]:



Since we have removed the dominant part of the variation [the background – part of which may actually be solar] the FFT power spectrum now shows the power around ~200 years more clearly. We see the Suess/de Vries peak [red dot]. There are even two side peaks [green dots] corresponding to a modulation of 525 y. In addition there are numerous smaller peaks reflecting the fact that the series may not be stationary [and there are also systematic errors in the timing], but the 200 y peak is clear:



There is even a weak 170.7 y peak! [yellow dot]. The blue curve is a running 33-point average of the spectrum.

The Suess/de Vries peak is split. If this is due to modulation the period would be 6827 y, which the record cannot really support, so the splitting is probably just due to noise or timing errors:

