Unified Cycle Theory: Statistical Validation

Stephen J. Puetz
Progressive Science Institute, 2233 Ala Wai 3-C, Honolulu, Hawaii 96815
e-mail: puetz.steve@gmail.com

Since publication of *The Unified Cycle Theory* in 2009, only one major criticism has surfaced. Some reviewers claim that random processes occur in nature often enough to give an appearance of periodicity, thus producing the oscillations described by the theory. In response, this paper statistically tests the null hypothesis that random fluctuations caused the Extra-Universal Wave Series (EUWS) cycles. To test the null hypothesis of randomness, several statistical methods were used to objectively assess EUWS oscillations. The tests include the following methods: Lomb-Scargle periodograms to determine the power of frequencies detected in each time-series; smoothed periodograms to estimate wavelengths when multiple frequencies cluster together in the spectrum; smoothed periodograms to determine confidence levels associated with frequencies; and Monte Carlo simulations to show how often random numbers produce correlations equivalent to those between the time-series data and the EUWS models. These tests were performed on 31 different time-series. The data included histories of star formation rates, asteroid impacts, volcanic activity, evolution (appearance of new gene families), global climate oscillations, spot activity on stars and the Sun, geomagnetic activity, the rise and fall of major civilizations, commodity prices, and stock market prices. This paper also discusses issues related to the testing process. The major issues include the reliability of signal measurements, the reliability of age estimates, and various forms of sampling bias. The magnitude of age-errors is especially critical – because small age-errors greatly impact spectral analysis. In sum, a significant percentage of the tests rejected the null hypothesis of randomness. For these cycles, the theory of random fluctuations is no longer credible. An alternative theory must be sought. Now, the EUWS cycles, as described in *The Unified Cycle Theory*, become the leading candidates for explaining many naturally occurring oscillations.

1. Introduction

Since publishing *The Unified Cycle Theory*, [1] reviewers have expressed only one major criticism. Some claim that the harmonic EUWS cycles described in the theory resulted from subjective judgments, determined by a biased observer, coming from misconstrued random fluctuations. To assess the validity of the criticism, this paper objectively tests the null hypothesis of EUWS cycles resulting from random fluctuations.

The general equation below serves as a model for each cycle in the EUWS sequence:

$$y_i = d_n * \sin\left(\frac{2\pi\left(t_i + t_{scale}\right)}{\lambda_n} + \theta_n\right) \quad [2]$$

Plugging in individual values for λ_n (wavelengths) and θ_n (phases) creates sinusoidal models for the null hypothesis tests. These tests involved 31 datasets, with cycles ranging from 9.57 days to 822-myr.

Wavelengths, along with their statistical significance, were estimated by using both a Lomb-Scargle periodogram and a smoothed periodogram. The wavelengths from the periodograms were then compared to theoretical periods from the model. The timing of cyclical peaks and troughs, along with their statistical significance, were determined from lagged correlation analyses. This paper further describes the details of the null hypothesis tests, and it summarizes the test results.

2. Definitions, Acronyms, Methods

Lomb-Scargle Periodogram [3] – Serving as a special form of spectral analysis, a Lomb-Scargle periodogram combines least-squares with the standard periodogram method. A Lomb-Scargle periodogram accurately estimates frequencies with as few as 2 cycles in a time-series. Additionally, a Lomb-Scargle periodogram does not require evenly spaced observations.

Smoothed Periodogram [4] – This method of spectral analysis smoothes the spectrum derived from a raw periodogram. Smoothing produces a rough estimate of where the true spectral peak lies. Smoothing is useful when uncertainty exists because of either large age-errors in the time-series or a concentration of peaks in one area of the spectrum from a raw periodogram.

Pearson Correlation Coefficient [5] – A number ranging from +1 to -1 that measures the degree of conformity between two time-series – or a time-series and a model. +1 indicates perfect positive correlation, 0 indicates no correlation, and -1 indicates perfect negative correlation.

Lagged Correlation Analysis [6] – This refers to an analysis that measures correlation at every phase of a time-series by leaving the time-series fixed while shifting the model one point at a time. By analyzing a time-series in this manner, lead/lag relationships are easily identified.

Extra-Universal – An oxymoron used to clearly differentiate the portion of the universe that resides outside of the observable portion of our universe.

EUWS cycles – Extra-Universal Wave Series cycles can be traced back to the timing of the event horizon of our observable universe. The largest detectable cycle (a ½ cycle) in the EUWS sequence equals 22.2-gyr. Because of the length of the 22.2-gyr cycle and its timing with the 13.73 Ga event-horizon, the EUWS cycles are assumed to possess an extra-universal origin. The wavelengths for EUWS cycles occur in multiples of 3.

Timescales:

Ga – billion years ago
Ma – million years ago
Ka – thousand years ago
tyr – trillion year
gyr – billion year
myr- million year
kyr – thousand year
yr – year

3. Testing Methods and Issues

Four types of tests were performed to determine the statistical significance of the EUWS cycles. The tests are listed below:

1. A Lomb-Scargle periodogram [3] estimates wavelengths for a time-series with age-errors less than 2%.
2. A smoothed periodogram [4] estimates wavelengths for a time-series with less certainty in the ages or the spectrum. Confidence bands surrounding the spectrum of a smoothed periodogram are used to determine the significance of estimated wavelengths.
3. A Pearson correlation coefficient [5] is calculated from a detrended time-series and a relevant EUWS model. The correlation is established at the point where the maximum lagged correlation occurs. [6] Then, the maximum lagged correlation is compared to equivalent lagged correlations derived from Monte Carlo simulations. [7] This Monte Carlo comparison provides a direct test of how often random fluctuations are able to produce an equivalent correlation.
4. The probability mass function also serves as a good method for testing periodicity when only one phase of a cycle is known with certainty. This paper uses the Exact Binomial Test (binom.test) from the R Statistical Package. [8] The Exact Binomial Test (a) automatically calculates the probability mass function, and it (b) performs hypothesis testing at the 99% confidence level.

The preceding methods were used to test the null hypothesis of random fluctuations creating the episodes associated with EUWS cycles. Depending on the nature of each time-series, these methods are used in combination with one of two criteria.

Criteria A – For a time-series with minimal data gaps, the tests involved spectral analysis and lagged correlation analysis. A cycle achieved confirmation status by meeting the following criteria:

a. The cycle being investigated must be among the top three peaks in the spectrum. Preferably, the spectral peak comes from the Lomb-Scargle periodogram. However, when age-errors are relatively large or multiple peaks occur, the spectrum from the smoothed periodogram becomes more useful.
b. The periodogram's wavelength must fall within 3% of a theoretical EUWS period.
c. At the frequency associated with the EUWS cycle being tested, confidence bands from the smoothed periodogram must exceed the null continuum at the 95% level.
d. The lagged correlation analysis must produce a correlation coefficient with significance above the 90% confidence level.
e. For myr and gyr cycles, the maximum correlation from the lagged correlation analysis must not deviate more than 20% from the model's phases. For some sub-myr cycles (this is especially true for climate cycles), lags often occur because of a sequence of chain reactions with delays occurring at all points in the chain. In these cases, the lagged correlation analysis becomes meaningless for validating turning points.

Criteria B – For a time-series where one phase of a cycle is better known than other phases, the Exact Binomial test becomes the preferred testing method. To confirm an EUWS cycle with this method, the time-series must pass the Exact Binomial test at the 99% confidence level.

Now, another aspect of spectral analysis must be noted. With the binning and filtering methods used in these tests, if two cycles have approximately the same wavelength, the stronger cycle tends to block the weaker cycle. A simple experiment demonstrates how this happens. The experiment begins by producing a single time-series from two perfect sine-waves. The first cycle equaled a period of 41.762-kyr and the second equaled 41.0-kyr. Each time-series covered 23 cycles.

In the first experiment, both cycles were given the same amplitude before merging them into one time-series. Additionally, age-errors and signal-errors were set to zero. In this case, the Lomb-Scargle periodogram only detected one cycle – essentially equaling the average of the two wavelengths at 41.381-kyr.

In the second experiment, the amplitude of the 41.762-kyr cycle was set at 3 times the amplitude of the 41.0-kyr cycle. Again, the errors were set to zero. This time, the Lomb-Scargle periodogram estimated the wavelength at 41.679-kyr – which came close to homing-in on the 41.762-kyr cycle while mostly ignoring the less powerful 41.0-kyr cycle. This demonstrates that the periodogram only reveals the stronger of the two cycles when their wavelengths are nearly identical.

Next, the experiments shifted to investigate the impact from age-errors and signal-errors. Sequences of random numbers were generated to simulate measurement errors. Seven tests were conducted (Table 1).

Age Err.	Signal Err.	Lomb-Scargle	Smooth P'gram	C. Level
0	10%	41.651-kyr	41.681-kyr	99.99%
0	33%	41.639-kyr	41.668-kyr	99.99%
0	100%	41.669-kyr	41.706-kyr	99.99%
1%	0	41.631-kyr	41.665-kyr	99.99%
2%	0	41.613-kyr	41.604-kyr	99.99%
5%	0	43.643-kyr	42.517-kyr	99.99%
10%	0	37.198-kyr	39.006-kyr	99%

Table 1. Experiment with Age & Signal Errors

For the initial three tests, signal-variance was set to levels equaling 10%, 33%, and 100% of the time-series variance. In all three cases, adding the signal-noise to the time-series barely altered the periodogram results. Even a signal-error as large as 100% barely affected the estimated period. This demonstrates that signal errors are relatively unimportant when it comes to detecting cycles. Signal estimates must be terribly butchered before they begin affecting periodogram results.

For the final four tests, age-variance was set to levels equaling 1%, 2%, 5%, and 10% of the time-series variance. As the results in Table 1 show, the 41.613-kyr estimate associated with the 2% age-error was distorted more than the 41.669-kyr estimated from the 100% signal-error! Without distortion, the estimate should have been in the range of 41.64-kyr to 41.66-kyr.

By the time the age-errors increased to 5%, the Lomb-Scargle periodogram results were still somewhat meaningful and significant, but greatly altered. With a 10% age-error, the Lomb-Scargle periodogram estimated the wavelength at 37.198-kyr (11% below the correct value) while the smoothed periodogram estimated the wavelength at 39.006-kyr (6.3% below the correct value).

Actually, when age-errors rise above 3%, the smoothed periodogram tends to estimate wavelengths better than the Lomb-Scargle periodogram. When age-errors rise above a 10% threshold, testing with a periodogram should cease. Periodicity cannot be determined reliably beyond that threshold. Furthermore, periodograms from a time-series with age-errors in the 5% to 10% range should be viewed with some caution.

4. Test Results

To determine the areas where EUWS cycles exert their greatest influence, 140 tests were performed on 31 different time-series. Of those tests, 47 resulted in EUWS confirmations, thus rejecting the null hypothesis of random fluctuations; another 40 tests showed moderate evidence of EUWS cycles, but not strong enough for statistical confirmation; while 53 tests failed to reveal EUWS influences.

Table 2 provides details about the 47 confirmed EUWS cycles. The columns in Table 2 describe (1) the theoretical EUWS period being tested, (2) reference for the researchers responsible for producing the data, (3) estimated wavelength from the Lomb-Scargle or smoothed periodogram, (4) percentage deviation between the estimated wavelength and the theoretical EUWS period, (5) the confidence level indicated from the smoothed periodogram, (6) the number of cycles in the time-series, and (7) the confidence level indicated from the lagged correlation/Monte Carlo analysis.

In addition to the confirmed cycles, another 40 tests came close to confirming EUWS cycles by producing confidence levels above 95% in the smoothed periodogram test. These failures primary resulted from wavelength estimates falling outside of the 3% tolerance range.

The datasets for the tests included a wide variety of events, coming from the following areas of study:

Sun & Stars -- Star formation rates [12], reconstructed sunspots derived from tree-ring data [37], [38], daily sunspot numbers [39], and starspots on CoRoT-Exo-2a. [40]

Geomagnetic Activity – From ocean sediments. [10], [17]

Volcanic Activity – Derived from Earth's crustal formation [11], histogram of zircon occurrence [14], volcanic aerosol [20], [21], and volcanic dust from the Vostok ice-core. [43], [44]

Global Climate – Determined from fossils and minerals [13], ocean sediments [16], Dome Fuji in Antarctica [18], [19], Sofular Cave in Turkey [22], [23], Greenland ice-core [24], [25], and Soreq and Peqiin Caves in Israel. [26], [27]

Biological Evolution -- Appearance of new genes. [15]

Human Behavior – Index of the rise and fall of civilizations [1], commodity prices in ancient Babylonia [28], stock market indices [29], [30], [31], [32], [33], [34], [35], [36], [45], consumer confidence [41], and rice prices in China. [42]

EUWS Period	**Data Source**	**L.S. P'gram**	**P'grm Dev.**	**P'grm C. Lvl**	**# of Cyc.**	**Lg.Cor C. Lvl**
822-myr	[11]	830.0-myr	+1.0%	95%	6	95%
822-myr	[15]	812.8-myr	-1.1%	99.9%	7	99.9%
274-myr	[13]	273.3-myr	-0.3%	95%	10	95%
274-myr	[14]	268.5-myr	-2.0%	99%	6.7	90%
274-myr	[14]	268.9-myr	-1.9%	99.9%	14	95%
91.3-myr	[14]	93.02-myr	+1.9%	95%	11	90%
91.3-myr	[15]	92.18-myr	+1.0%	99%	30	99%
30.4-myr	[13]	30.98-myr	+1.9%	99%	17	95%
30.4-myr	[14]	30.33-myr	-0.2%	99%	13	90%
30.4-myr	[16]		Exact	Binom	2	99.9%
10.1-myr	[16]		Exact	Binom	6	99.9%
3.38-myr	[16]	3.36-myr	-0.6%	99.9%	19	95%
1.13-myr	[16]	1.11-myr	-1.8%	99.99%	19	90%
1.13-myr	[16]	1.12-myr	-0.9%	99.99%	19	99%
376-kyr	(not	confirm'd)				
125-kyr	[16]	124.8-kyr	-0.4%	99%	58	95%
41.8-kyr	[17]	41.45-kyr	-0.7%	99%	53	99.9%
13.9-kyr	[22,23]	13.70-kyr	-1.4%	95%	3	99.9%
13.9-kyr	[26,27]	13.84-kyr	-0.5%	95%	14	99%
13.9-kyr	[26,27]	14.15-kyr	+1.6%	95%	12	99%
13.9-kyr	[43,44]	13.75-kyr	-1.2%	99.9%	12	99.9%
4.64-kyr	[18,19]	4.649-kyr	+0.2%	99.99%	37	99%
4.64-kyr	[20,21]	4.522-kyr	-2.5%	95%	8	95%
4.64-kyr	[22,23]	4.674-kyr	+0.7%	95%	10	99%
4.64-kyr	[24,25]	4.687-kyr	+1.0%	99%	14	99%
4.64-kyr	[26,27]	4.655-kyr	+0.3%s	99.99%	35	99%
1.55-kyr	[22,23]	1.525-kyr	-1.4% s	99%	32	99%
1.55-kyr	[22,23]	1.511-kyr	-2.3%	99.9%	16	99%
1.55-kyr	[24,25]	1.509-kyr	-2.4% s	99.99%	33	90%
516-yr	[37]	521.5-yr	+1.1%	99%	21	99%
516-yr	[1]	505.1-yr	-2.0%	99.99%	9	99.9%
516-yr	[1]		Exact	Binom	9	99.99%
172-yr	[24,25]	174.47-yr	+1.5%	99.9%	23	99%
172-yr	[42]		Exact	Binom	5	99%
57.3-yr	[37]	57.23-yr	-0.1%	99.9%	67	99.9%
19.1-yr	[28]	18.81-yr	-1.5%	99.99%	16	99.9%
19.1-yr	[30,33]	18.88-yr	-1.1%	95%	11	99%
19.1-yr	[30,33]		Exact	Binom	11	99.99%
6.37-yr	(not	confirm'd)				
2.12-yr	[39]	2.122-yr	0.005%	99%	66	99.9%
2.12-yr	[29,30]	2.097-yr	-1.2% s	99.9%	27	99%
258-day	[29,30]	266.0-day	+3.0%	99.9%	84	95%
86.1-day	[39]	86.16-day	+0.1%	99.9%	97	99%
86.1-day	[29,30]	83.70-day	-2.8%	99.9%	127	99%
86.1-day	[41]	84.04-day	-2.4%	99%	16	99%
28.7-day	[45]	28.54-day	-0.6% s	99.9%	7	99%
28.7-day	[39]	28.79-day	+0.3%	99.9%	292	99%
28.7-day	[40]	28.696-day	-0.02%	99%	4	99.9%
9.57-day	[45]	9.518-day	-0.2%	99.9%	43	99.9%

Table 2. Confirmed EUWS Cycles

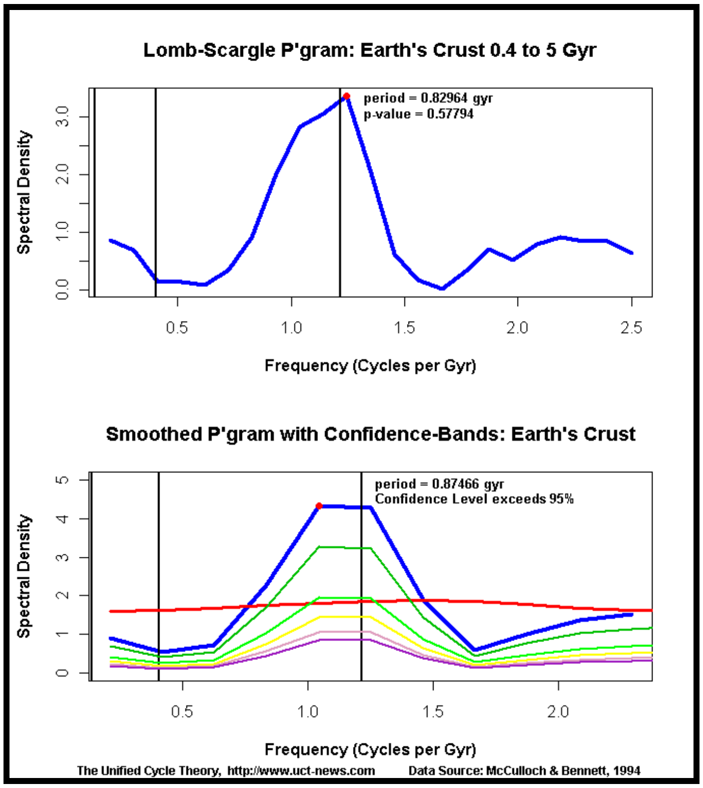
In the range from 9.57-day to 822-myr, only two theoretical EUWS cycles failed to achieve confirmation – the 6.37-yr cycle and the 376-kyr cycle (Table 2).

In addition to confirming EUWS cycles 47 times, these tests also verified previously identified Milankovitch cycles 14 times, solar cycles 19 times, and geomagnetic cycles 7 times.

5. Discussion

This discussion focuses on the periodograms produced during the testing process for 8 of the 47 confirmed cycles.

Figure 1 shows an 830-myr estimate for volcanism – well within the 3% tolerance for the 822-myr EUWS cycle. This time-series [11] contained 6 cycles, and the maximum correlation with the model occurred with a lead-time of only 9.1-myr. The smoothed periodogram test and the lagged correlation test both indicated a confidence level of 95% for the 822-myr cycle.

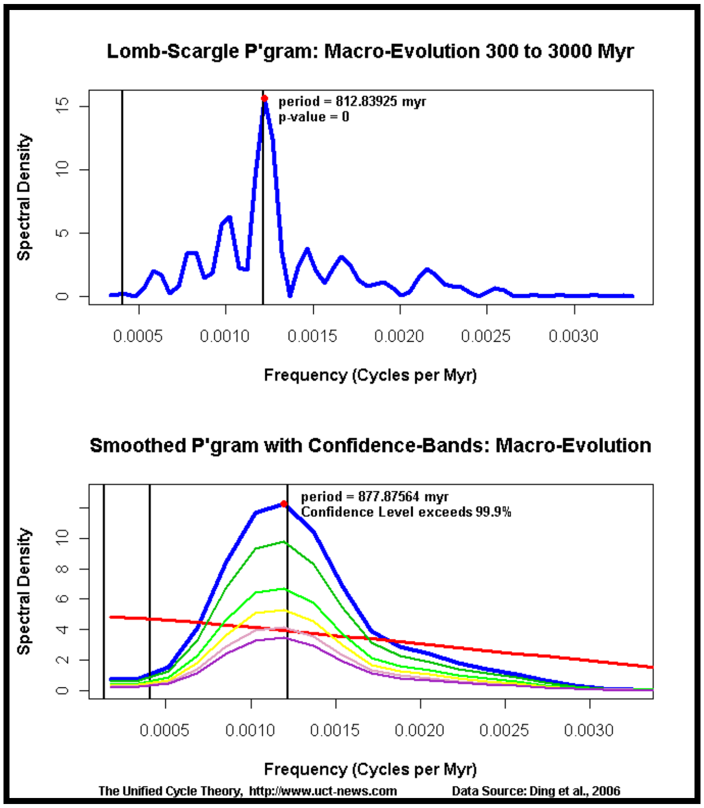


The Unified Cycle Theory, http://www.uct-news.com Data Source: McCulloch & Bennett, 1994

Fig. 1. Periodograms from 822-Myr Volcanic Cycle Test.

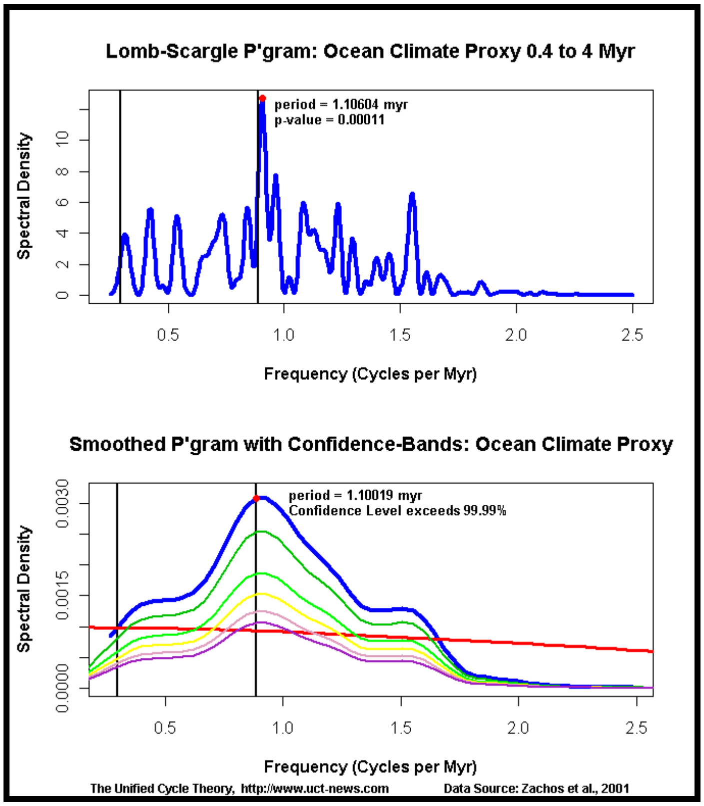
The periodogram for Figure 2 estimated an 813-myr evolutionary cycle – within the 3% tolerance of the 822-myr EUWS cycle. This time-series, measuring the appearance of new gene families, [15] contained 7 cycles. Both the smoothed periodogram test and the lagged correlation test showed the 822-myr evolutionary cycle was significant at the 99.9% confidence level. However, undetermined age-errors prevent this test from being completely reliable. In all likelihood, this evolutionary cycle results from environmental changes caused by the 822-myr cycle in volcanic activity.

The periodograms in Figures 5.3 and 5.4 were used to test a 1.13-myr climate cycle. Both spectral estimates came within the 3% tolerance of the 1.13-myr EUWS cycle. This lengthy climate time-series [16] contained enough cycles that the analysis was split into two parts – from 44-to-22 Ma and from 22-to-0 Ma. Each test contained 19 cycles. This was done to test for the **stability** of the cycle. If these cycles resulted from pure chance, it's highly unlikely that the Lomb-Scargle periodograms would produce identical spectral peaks for both tests.



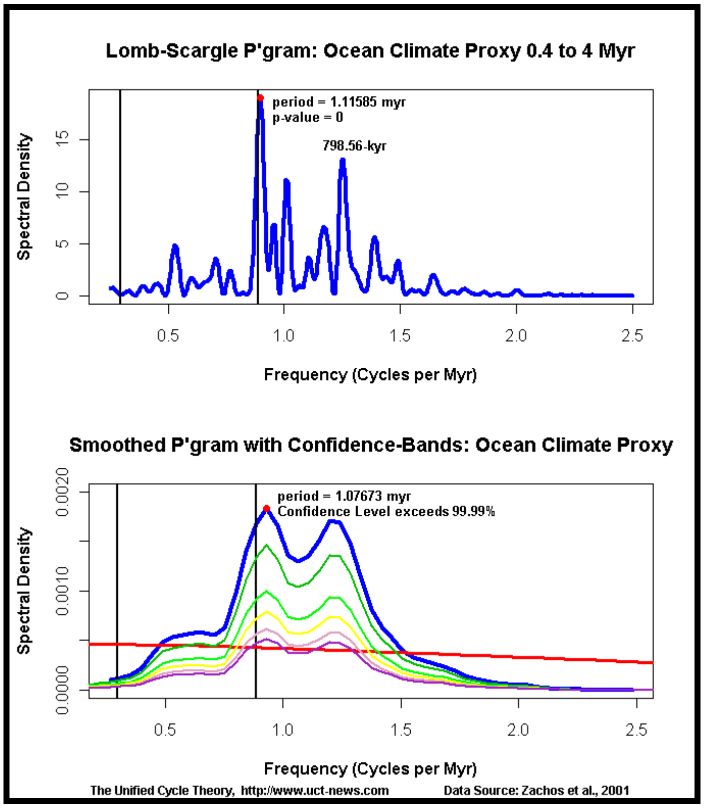
The Unified Cycle Theory, http://www.uct-news.com Data Source: Ding et al., 2006

Fig. 2. Periodograms from 822-Myr Evolutionary Cycle Test



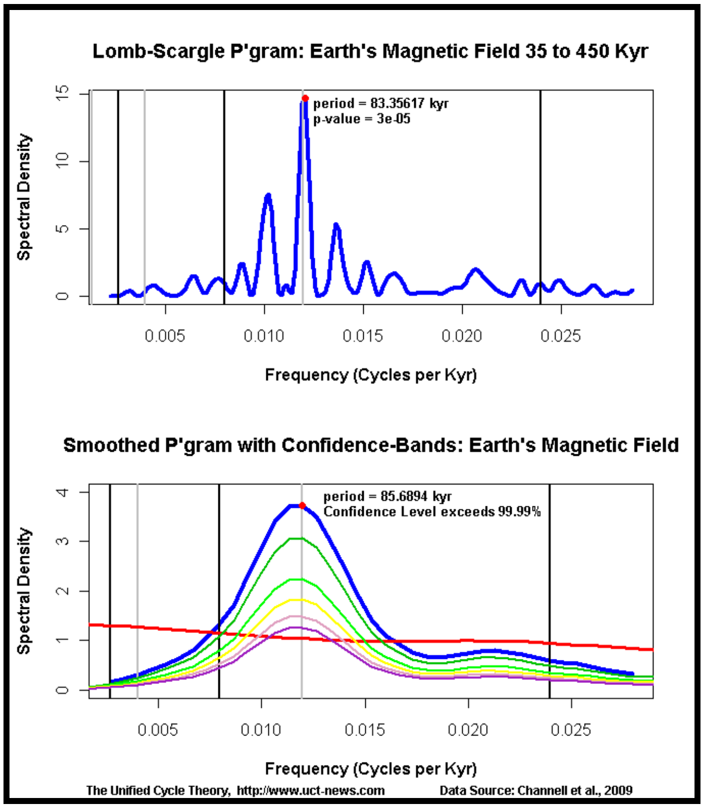
The Unified Cycle Theory, http://www.uct-news.com Data Source: Zachos et al., 2001

Fig. 3. Periodograms for Climate Data from 44 Ma to 22 Ma



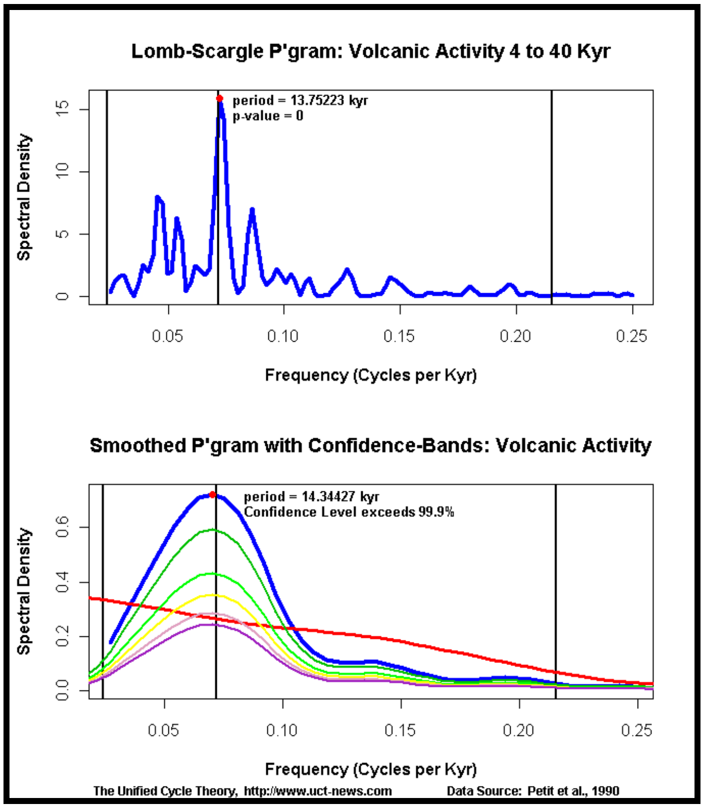
The Unified Cycle Theory, http://www.uct-news.com Data Source: Zachos et al., 2001

Fig. 4. Periodograms for Climate Data from 22 Ma to Present.



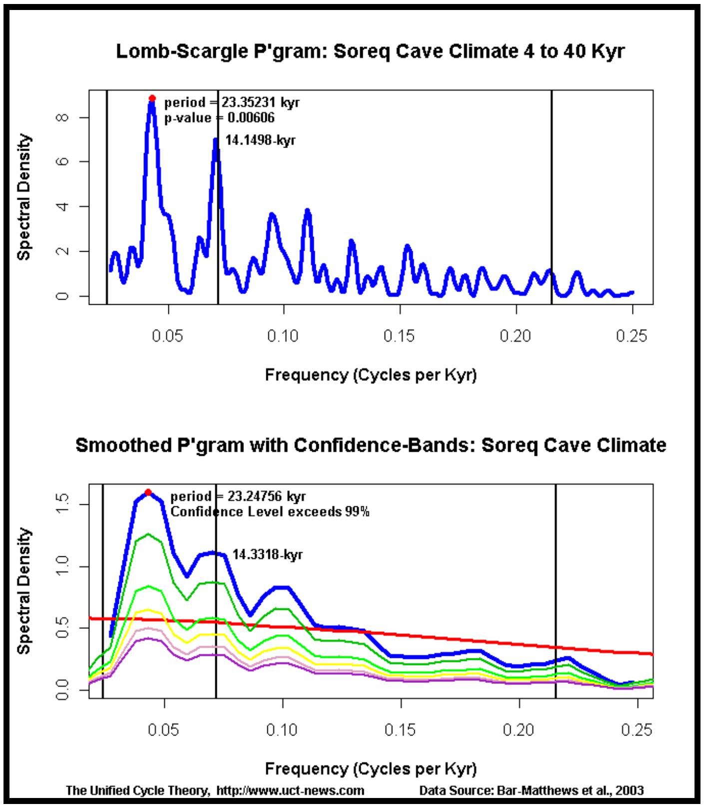
The Unified Cycle Theory, http://www.uct-news.com Data Source: Channell et al., 2009

Fig. 5. Periodograms from 125-Kyr Geomagnetic Cycle Test



The Unified Cycle Theory, http://www.uct-news.com Data Source: Petit et al., 1990

Fig. 6. Periodograms from 13.9-Kyr Volcanic Cycle Test



The Unified Cycle Theory, http://www.uct-news.com Data Source: Bar-Matthews et al., 2003

Fig. 7. Periodograms from 13.9-Kyr Climate Cycle Test.

The periodogram in Figure 5 tested for a 125-kyr cycle in geomagnetism. However, it produced a surprise. Instead of a 125-kyr period, the periodogram showed a dominant 83.356-kyr cycle – within 0.2% of double the size of 41.7616-kyr cycle. This geomagnetic time-series [10] contained 17 cycles, and it suggests that EUWS oscillations possess polarity – similar to the 22-yr polarity cycle associated with the 11-yr Schwabe sunspot cycle.

The periodogram in Figure 6 used a volcanic-dust time-series extracted from the Vostok ice-core. [43], [44] The analysis showed a 13.75-kyr volcanic cycle – within the 3% tolerance of the 13.9-kyr EUWS cycle. This cycle was significant at the 99.9% level for both the smoothed periodogram and lagged correlation tests. This test also showed that the 23.7-kyr Precession cycle has minimal, if any, effect on volcanic activity. In other words, Milankovitch cycles do not cause volcanic cycles. Instead, EUWS cycles are the leading candidates for oscillations in volcanism.

The periodogram in Figure 7 tested for a 13.9-kyr climate cycle. This Israeli climate time-series [26], [27] from Soreq Cave contained 12 cycles. The 13.9-kyr climate cycle was significant at the 95% level from the smoothed periodogram and at the 99% level from the lagged correlation test. Even though the 13.9-kyr cycle was significant, the 23.7-kyr Precession cycle still dominated the climatic impact from volcanic activity. Other tests also show that Milankovitch cycles are the main contributors to climate variation for periods between 20-kyr and 400-kyr. Outside of that range, EUWS cycles (via volcanism) are the primary drivers of global climate change.

A time-series of volcanic aerosol [20] confirmed another volcanic oscillation – the 4.64-kyr cycle. The periodogram in Figure 8 also tested for a 4.64-kyr cycle in Antarctic climate. This time-series [18], [19] contained 37 cycles, and the smoothed periodogram indicated a 99.99% confidence level, while the lagged correlation analysis showed a 99% level of confidence in the estimate. Once again, this strong correlation indicates that volcanic activity drives sub-Milankovitch cycles in global climate.

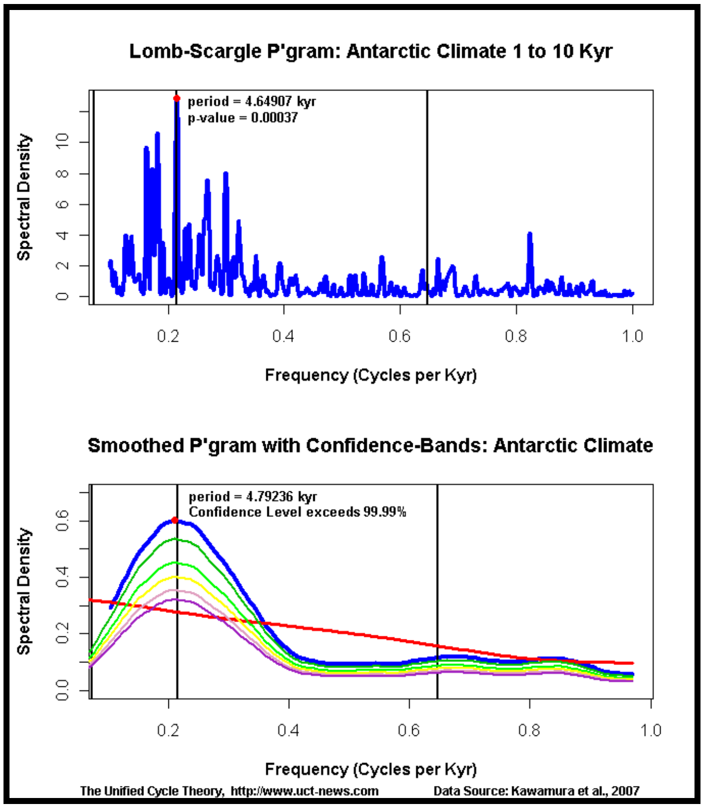


Fig. 8. Periodograms from 4.64-Kyr Climate Cycle Test.

Figure 9 shows the cross-correlations among volcanic activity, climate change, and macroevolution. The red line, showing macroevolution, was adjusted on the graph to reflect a 43-myr lag. The relationship between volcanic activity and evolution showed an exceptionally strong positive correlation from 3.5 Ga until about 1.0 Ga. Then the relationship turned into a strong negative correlation. In all likelihood, the reversal occurred because oxygen-dependant life first appeared on Earth around 1.0 Ga. Before then, photosynthesis-dependant organisms prevailed.

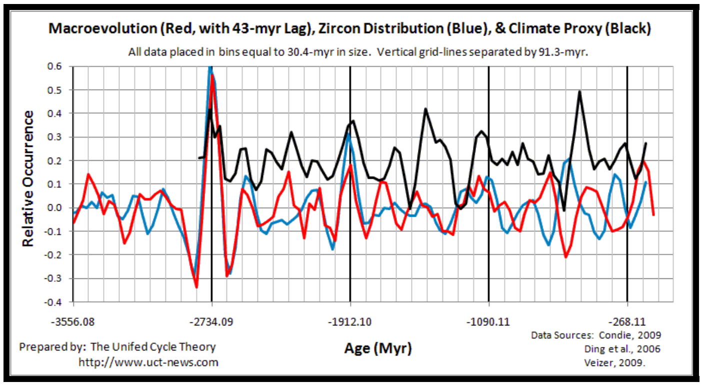


Fig. 9. Correlation: Evolution, Volcanism, & Climate.

How accurate are the current EUWS estimates presented in "Unified Cycle Theory: Introduction & Data?" [2] Based on the average deviation from the 42 confirmed cycles using Criteria A, the EUWS wavelengths are currently over-estimated by 0.46%. Because this difference is relatively small, and because most of the time-series contained age-errors, the theoretical EUWS wavelengths will remain as originally stated.

However, as an example of one timing adjustment resulting from a -0.46% revision, it would reduce the wavelength of the 22.2-gyr cycle to 22.1-gyr. And the trough of the new 22.1-gyr cycle would be placed at 13.768 Ga. That age falls just 0.3% from the 13.73±0.12 Ga WMAP estimate [9] of the event horizon detected in the microwave background.

6. Conclusion

By consistently rejecting the null hypothesis that random fluctuations cause EUWS cycles, the burden of proof now lies with the critics. Any hypothesis modeled on chaos, stochastic processes, or random oscillations must now explain why a subjective model of randomness should be favored over the objective assessment of non-random fluctuations in EUWS cycles.

This analysis provides strong statistical evidence that random fluctuations must be rejected as the cause for oscillations found in astronomical, geological, climatic, biological, and human activity histories. Based on the evidence, episodes of volcanic activity show the strongest link to theoretical EUWS cycles. Thus, volcanism holds the primary key for solving the mysteries behind EUWS cycles. That's the area where future research must focus.

7. Acknowledgements

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