SCRIPTA MEDICA (BRNO) – 75 (6): 303–308, *December 2002*

ABOUT-10-YEARLY (CIRCADECENNIAN) COSMO-HELIO-GEOMAGNETIC SIGNATURES IN *ACETABULARIA*

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A b s t r a c t

Infradian aspects of *Acetabularia* are explored in a composite time series consisting of about 200 individual series collected during 1980–1991. The total duration of each study on a given cell and the duration of the initial span of light and darkness alternating at 12-hour intervals were taken as admittedly complex gauges of the alga. These two indices obtained from each cell were assigned to the midpoint of the corresponding study span. The series thus formed were analysed chronobiologically. In addition to a circannual variation, an about 10-year component was found and compared to the time structure of the planetary geomagnetic activity.

K e y w o r d s

Alga, *Acetabularia,* About-ten-year-rhythm, Cosmo-helio-geomagnetism

INTRODUCTION

Photic and non-photic solar or, more broadly, cosmic (including galactic) signatures have been documented in both bacteria (*1*) and multicellular organisms, including humans (*2–5*). We searched for spectral components that were possibly shared by a eukaryotic alga, *Acetabularia*, with cosmo-helio-geomagnetic disturbances. It seemed reasonable to look for infradians with a period of about a decade (corresponding to cycles in solar activity) in populations of organisms that have a much shorter lifespan than any periodicity explored here, notably since colonies of relatively short-lived bacteria have been shown to exhibit circadecennian features (*1*).

MATERIALS AND METHODS

During the span of 1980–1991, 341 experiments were performed on the giant unicellular alga *Acetabularia.* Oxygen production, electrical potential and/or chloroplast migration were recorded at 30-minute intervals for spans ranging from 19 to 109 days. In most experiments, the cells were first maintained for up to 7 days in the initial span of light and darkness alternating at 12-hour intervals (LD12:12). When the circadian rhythm was well expressed *ad oculos,* the cells were exposed to continuous light (LL). In many experiments, after 7 to 18 days, different pulses were applied to the

Table 1

Estimates and 95% confidence limits of spectral components characterising the rhythms of two planetary indices of geomagnetic activity and the alga *Acetabularia*

Trial period		Geomagnetic indices		*Acetabularia*	
(years)		Kp	Dst	Study span	LD12:12 spans
		(arbitrary units)		(duration, in days)	
10.5	Period	8.013 (7.523; 8.535)	7.780 (7.192; 8.494)	10.017 (8.003; 12.031)	10.469 (7.680; 13.258)
	Amplitude	0.43 (0.36; 0.50)	6.07 (4.50; 7.66)	5.75 (1.71; 9.79)	2.13 (0.73; 3.54)
5.25	Period	3.282 (3.148; 3.431)	3.374 (3.257; 3.502)	4.563 (3.549; 5.904)	4.265 (3.758; 4.918)
	Amplitude	0.20 (0.12; 0.27)	5.72 (4.16; 7.28)	3.56	2.10 (0.56; 3.65)
1.75	Period	1.750 (1.713; 1.789)	1.739 (1.711; 1.769)	1.585 (1.481; 1.711)	1.848 (1.698; 2.058)
	Amplitude	0.22 (0.14; 0.29)	5.79 (4.24; 7.35)	4.51 (0.93; 8.08)	1.30
1.0	Period	1.316 (1.294; 1.340)	1.019 (0.999; 1.038)	0.902 (0.864; 0.941)	1.032 (0.996; 1.091)
	Amplitude	0.19 (0.11; 0.27)	3.81 (2.22; 5.40)	5.10 (0.68; 9.53)	2.10 (0.54; 3.65)
0.5	Period	0.499 (0.494; 0.503)	0.502 (0.500; 0.505)	0.485 (0.475; 0.498)	0.498 (0.402; 0.504)
	Amplitude	0.21 (0.13; 0.28)	6.22 (4.66; 7.79)	5.07 (1.27; 8.88)	2.81 (1.28; 4.34)

K_p and Dst, geomagnetic activity indices; LD 12:12, light and darkness alternating at 12-hour intervals cells, such as dark pulses (for 8–24 h), or a drug was added to the medium (3-aminobenzamide, caffeine, geneticin, oligomycin, ouabain, pentanol, ethanol, etc.), for spans of up to 97 days (*6–10*).

Each stage of each experiment was examined for validity of protocol by the actual times originally recorded by computer in 341 experiments. Experiments ended as soon as the alga started to form gametangia (sign of maturation), or their cap diameter reached a size filling the diameter of the cuvette (sign of fast growth), or (less frequently) because of sudden cell death.

Two endpoints were examined herein, the total duration of each study on a given cell, and the duration of the initial span during which the cell was kept in LD12:12 conditions. The duration of LD12:12 standardisation spans was used as a primary check on algal behaviour, since a subjectively satisfactory behaviour (rhythm) in LD12:12 was the condition for release into LL. For comparison, data on two planetary indices of geomagnetic activity, K_p and Dst, were considered over matching spans. In order to check against influences of artifacts, 100 noise series were generated.

For each cell, the total study duration and the length of the LD12:12 span were assigned to the calendar date of the mid-time of the corresponding span. These data were analysed by least-squares spectra (*11, 12*) with periods ranging from 10.5 years to 2.5 months, followed by a nonlinear least-squares scrutiny (*13, 15*) of the periods found linearly with ordering statistical significance (without correction for multiple testing). The same procedures were also applied to a planetary (K_p) and an equatorial (Dst) index of geomagnetic disturbance and to the 100 control series of noise (which corresponded to the length, density and calendar dates of the biological data, i.e., to the actual times of the midpoints of LD12:12 and total spans).

RESULTS

Components resolved by linear-nonlinear rhythmometry are summarized in *Table 1*. Both K_p and Dst were characterised by components with periods of about 8.0 and 3.4 years rather than 10.5 and 5.25 years. An about 4.4-year component characterised both the total study span and the duration of LD12:12 spans of *Acetabularia.* Two endpoints related to the alga thus provided similar results.

The effect of geomagnetic activity on the schedule of the investigators was similar to that on *Acetabularia's* growth features. An about 1.75-year component was documented for the total experimental span in *Acetabularia,* but not for the duration of LD12:12 spans. Both the yearly and the half-yearly components characterised the duration of LD12:12 spans, yet only the geomagnetics-associated, half-yearly component was validated for the study span of *Acetabularia,* with the circannual component being significantly shorter than 1 year.

No statistically significant results were obtained from similar analyses applied to the series of noise. The periods found in geomagnetic disturbance also had overlapping 95% confidence intervals, as those found in *Acetabularia.*

DISCUSSION

The long years of checking, cataloguing and rechecking by senior scientists in Minnesota as well as the extensive earlier data collection and editing by Sigrid Berger and Lübbo von Lindern made this study possible. The consideration herein of the results of 341 studies yielded the expected circadecennian and half-yearly periodicities. These heliogeomagnetic signatures have been reported for the giant eukaryotic unicellular algae that have presumably been on earth for 500 million years. There was a general agreement between the periods found in geomagnetic disturbance and those found in *Acetabularia,* although some differences between biological and environmental periods existed. These may be scrutinised in further studies with the use of circadian characteristics of the actual measurements in each experimental series. The series of noise used as controls did not provide similar results. The circadecadal and circasemiannual components complement the circaseptan rhythms that were of special interest to Hans-Georg Schweiger, the former director of medicine at the Max-Planck Society (*16*). These findings have by far extended the "bitemporal hemianopsia" of those who focus only upon circadian systems, ignoring the fact that other components of the spectral element of chronomes can make the difference between an acceleration and an inhibition of malignant growth (*17, 18*).

Acknowledgements

This study was supported by the U.S. Public Health Service (GM-13981; FH), Dr. h.c. Dr. h.c. Earl Bakken Fund (FH, GC) and the University of Minnesota Supercomputing Institute (FH, GC).

This report is dedicated to Dr. Sigrid BERGER, Dr. Lübbo von LINDERN and Dr. Peter TRAUB, who made these analyses possible by providing the original edited data and by giving helpful advice. This is also to commemorate the late Hans-Georg SCHWEIGER, whom we enjoyed hosting in our Centre as an associate in research and a visiting professor.

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Souhrn

Infradiánní rytmy v jednobuněčných organismech rodu *Acetabularia* byly zkoumány v časových seriích z 200 individuálních serií sbíraných v létech 1980–1991. Celková doba trvání každé studie na dané buňce a trvání původních fází světla a tmy alterujích v 12-hodinových intervalech (LD12:12). Údaje získané z každé buňky byly analyzovány ve studovaných časových úsecích. Série dat byly chronobiologicky hodnoceny. Kromě cirkaannuálního kolísání byla nalezena asi-desetiletá komponenta, která odpovídala časové struktuře planetární geomagnetické activity.

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