On universal nature of periods spectrum in time series of planaria chemiluminescence

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A local fractal analysis by all permutations method (APM) was developed. APM-analysis of noise-like time series of alpha decay rate fluctuations made it possible to reveal the spectrum of periods in the range of 1-120 min. The connection of this spectrum with the spectrum of the Earth natural oscillations was shown, and an assumption was made about its universal character, which means that it is present in fluctuations of processes of various nature. In this work, the APM method was used to study the noise-like time series of planarium chemiluminescence fluctuations. A spectrum of periods ranging from minutes to two hours has been obtained. A detailed coincidence of the found spectrum with the spectrum that we found earlier is shown. The results of present study confirm this earlier assumption about the universal nature of the detected spectrum of periods. For the mentioned range of periods, there were shown not only the close relationship of the found spectrum with the spectrum of the Earth's natural oscillations, but also its universal character: the spectra of the periods found for fluctuation in the systems of various nature (physical, chemical, biological) always coincided with the corresponding part of the found spectrum.

***Key words**: planaria; planarium chemiluminescence; universal spectrum; alpha decay; fluctuations; local fractal analysis; all permutations method.*

1. Introduction

The report considers the result of applying the local fractal analysis by all permutations method (APM) [1-2] to the study of noise-like time series of planaria chemoluminescence. The APM-method synthesized in itself the basic ideas of the method of minimal cover (MMC) [3] with the requirement of the invariance of fractal dimension with respect to linear transformations (shifts, dilatation, mirror reflections), as well as with respect to permutations of elements of a time series segment on the basis of which the fractal dimension is calculated. The latter property is a distinctive feature of the APM-method, which gives it a number of unique properties. The most important of them is locality - the ability to calculate the fractal dimension for short (tens of points) segments of the analyzed time series. This means that, in contrast to the MMC-method for $N = 2^n$ points segment, the APM-method allows us to analyze $N - 1$ scales, rather than n, as in the MMC-method. As a result, the value of N can be significantly reduced, but at the same time, the accuracy of the calculation of the fractal dimension increases significantly.

One of the first results of the use of the APM for the analysis of noise-like time series is the study of a 329-day array of alpha-decay rate fluctuations. As a result of this analysis, a stable set of periods was found in the range of 1-115 min [4-5]. It was shown that the periods found in [4-5] were in good agreement with the periods of the Earth's natural oscillations. This coincidence was manifested for both classical (with periods up to 52-56 min) and for Earth's long-wave oscillations (with periods that exceed 52-56 min).

In the course of further studies, application of the APM-analysis, allowed to reveal stable ultradian periods in the range of 2-24 hours [6-7], which also coincided with the corresponding periods of the Earth's natural oscillations.

A review of the studies investigating the periodicities of fluctuations in various nature processes, performed in [4-5], revealed only three periods that were not found in the analyzed 329-day array of the alpha-decay rate fluctuations (36.2 min, 43 min, and 64 min). These periods were discovered in further research. For example, an analysis of a large (about 5 years) array of time series in the alpha-decay rate fluctuations measured in Antarctica revealed that the periods of 80 min and 160 min were more expressed than for the mid-latitude data [4-5]. A period of around 50 minutes not belonging to the spectrum of the Earth's natural oscillations was also discovered. It is interesting to note that the same period was found in [9] in the course of analysis of the spectra of astrophysical masers. It was shown [10-12] that all 16 periods found in the spectra of astrophysical masers and described in [9] coincide with the periods described in the papers published several years earlier [4-5].

2. Raw experimental material

The experiment used an asexual race of the freshwater worms planaria ***Girardia tigrina***. The planarians were maintained in the aquarium water: hardness ~ 3-5 mg-eq/l, pH 6.5, temperature 26°C, and fed weakly with the diptera larvae. The experiment used the 10-11cm-long animals after a seven-day starvation. The regeneration was triggered by the amputation of a planarian forehead at the "eye" level [8]. For each set of experiments, the intact planarians or their parts were placed into 10 mL of water inside the special polypropylene scintillation cuvettes (Beckman, USA) or glass cups.

The luminescence was measured with a chemiluminometer Biotox-7A 2M (ANCO «Inzhenerniy tsentr - ecologia», Russia) equipped with a photomultiplier 9750QB/1 (9750QB/1, EMI Electronics LTD, Middlesex, UK), with spectral sensitivity in the range of 380-710 nm.

The measurements were performed at 26,0±0,2°C, in the photon counting mode with the data record interval of 1 s.

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Fig. 1 a) illustrates one of the time series obtained in the course of the planarian chemiluminescence measurements, and Fig. 1 b) shows experimental distribution of the fluctuations based on this time series. Fig. 1 b) includes also the Gaussian distribution (shown by a solid line) that approximates the experimental distribution. Proximity of the experimental and Gaussian distributions tells that the measurements presented at Fig. 1 a) can be considered as random.

A distinctive feature of the APM-analysis of the time-series [1-2] is that it provides a possibility to reveal the periodicities in the time series, completely random from point of view of the available statistical tests. The following section presents the results of the APM-analysis of the planarian chemiluminescence time series presented at Fig. 1.

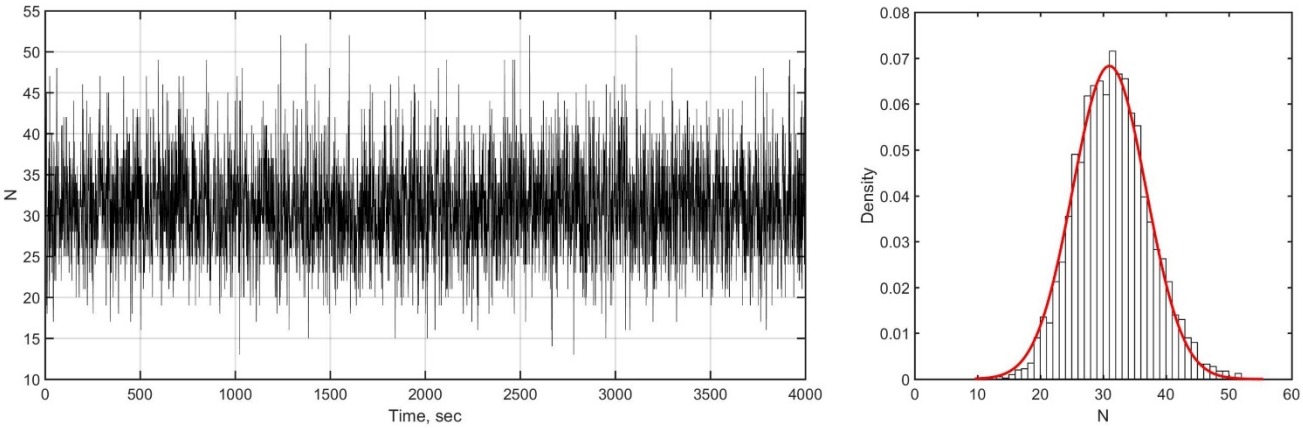

Fig 1. One of the time-series of the planarian chemiluminescence (*a*)), and its distribution function (*b*))

3. Results of the APM-analysis of the planarian chemiluminescence time-series

Using the APM-analysis [1-2], we obtain the spectra of the periods in the time-series of the planarian chemiluminescence fluctuations. After the initial spectrum averaging, one set of periods was obtained. The values of these periods are given in Table 1 (row I). The table also presents (row II), for comparison, the averaged periods obtained at the APM-analysis of an array consisting of 329 one-day time-series of the α-decay rate fluctuations measured in Pushchino [4-5].

In both cases, a fractal dimension was calculated at the basis of the 60-point sections of one-second measurements. Therefore, accuracy of period determination is ±1 min. From this, we may point to the virtually exact coincidence of the two spectra. Only the values presented in the 1st, 17th and 21st columns of Table 1 show the discrepancy somewhat exceeding this value; in all cases a discrepancy is not greater than 0.5 min.

It is significant that Table 1 includes all the periods that present in the spectra of the planarian chemiluminescence and fluctuations of the α-decay rate. That is, in this case the point is the coincidence of just two spectra but not the certain frequencies. Consequently, we may tell about the same spectrum manifested in the fluctuations of the both systems under consideration.

Table 1. Average values of the periods in the time-series of the fluctuations of the planarian chemiluminescnce (I) and average values of the periods presented in [4-5] (II)

№	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*	*21*	*22*
I	5	-	12.5	20.5	25.5	30.5	34.5	-	43.3	47.5	55.8	60.5	65.5	-	74	-	82.5	86	94.5	97.5	108.5	112.5
II	3.3	9	13.8	21.3	27.5	32	36.2	40	43	46	55.8	60.7	64	68.3	73	75.5	80	85.5	95	99.8	106.3	112.3

4. Conclusion

The fact that the spectrum of the periods contained in Table 1 is found in the spectra of the astrophysical masers too [9-12] and the presence of a spectrum frequency of 51 min not belonging to the Earth natural oscillations in it, allows us to make a conservative assumption on its cosmophysical origin. It is possible indeed that this is a case of a global synchronization, which, according to A.M. Molchanov's hypothesis [13], must be reached by any dynamically mature system. From the other hand, a spectrum resulting the analysis of the time-series of the planarian chemiluminescence fluctuations that coincides in all details with the spectrum found in the series of the fluctuations of the α-decay rate, can be considered as a universal one that manifests itself in the fluctuations of the various nature systems. The results of this work can have various practical applications [14-16].

References:

[1] V.A. Panchelyuga, M.S. Panchelyuga Fractal Dimension and Histogram Method: Algorithm and Some Preliminary Results of Noise-Like Time Series Analysis // Biophysics, 2013, Vol.58, No.2, pp.283-289.

[2] V.A. Panchelyuga, M.S. Panchelyuga Local fractal analysis of non-stationary time series by all permutations method // Hypercomplex numbers in

geometry and physics, 2014, Vol.11, No.1(21), pp.107-133.
[3] M.M. Dubovikov, N.V. Starchenko, M.S. Dubovikov Dimension of minimal cover and fractal analysis of time series // Physica A, 339, 2004, pp. 591-608.
[4] Panchelyuga V.A., Panchelyuga M.S. Local Fractal Analysis of Noise-Like Time Series by the All-Permutations Method for 1-115 min Periods // Biophysics, 2015, Vol. 60, No. 2, pp. 317-330.
[5] V.A. Panchelyuga, M.S. Panchelyuga Some preliminary results of local fractal analysis of noise-like time series by all permutations method for periods 1-120 min // Hypercomplex numbers in geometry and physics, 2014, Vol.11, No.1(21), pp. 134-156.
[6] V.A.Panchelyuga, M.S.Panchelyuga, O.Yu.Seraya Preliminary results of the study of the relationship between ultradian periods (2-24 hours) in the time series of alpha decay rate fluctuations with the Earth's natural oscillations // Planet Earth System, Moscow, LENAND, 2017, pp.227-232.
[7] V.A. Panchelyuga, M.S. Panchelyuga, O.Yu. Seraya Preliminary periods investigation in time series of alpha-decay rate fluctuations // Hypercomplex Numbers in Geometry and Physics, 2016, Vol. 13, No. 2(25), pp. 211-216.
[8] Panchelyuga V.A., Vladimirsky B.M., Panchelyuga M.S., Seraya O.Yu., Panikhin V.A. Periods of 50, 80 and 160 min in time series of alpha-decay rate fluctuations // Proceedings of the XXI Russian Conference “Solar and Solar-Earth Physics - 2017”, St. Petersburg, Pulkovo, October 10-14, 2017, p. 261-264.
[9] S. Siparov, V. Samodurov, G. Laptev Origin of observed periodic components in astrophysical maser’s spectra // Monthly Notices of the Royal Astronomical Society, 2017, 467, 2813-2819.
[10] V.A. Panchelyuga, M.S. Panchelyuga On the relationship between the spectrum of periods in the time series of alpha decay rate fluctuations and periodic components in the spectra of astrophysical masers // Proceedings of the XIII International Conference "Finsler Extension of Relativity Theory" (FERT-2017) / Eds.: Pavlov D.G., Panchelyuga V.A. - Moscow, 11th format, 2017 - p. 69-70.
[11] Panchelyuga V.A., Vladimirsky B.M., Panchelyuga M.S. On some possible mechanisms of the relationship between the spectrum of periods in the time series of alpha decay rate fluctuations and periodic components in the spectra of astrophysical masers // Proceedings of the XIV International Conference “Finsler Extension of Relativity Theory” (FERT-2017) / Eds.: Pavlov D.G., Panchelyuga V.A. - Moscow, 11th format, 2018 - pp.89-91.
[12] Panchelyuga V.A., Vladimirsky B.M., Panchelyuga M.S. On the coincidence of the spectrum of periods in the time series of alpha decay rate fluctuations with periodic components in the astrophysical masers spectra // Planet Earth System, Moscow, LENAND, 2019, pp.115-118.
[13] Molchanov A.M. The resonant structure of the Solar system. The law of planetary distances // Icarus, 1968, Vol.8, No.1/3, pp.203-215.
[14] Syngaevskaya A.A., Berberova M.A., Derevyankin A.A. Studying the effect of stress on the probability of errors by NPP personnel as part of personnel reliability analysis // CPT-2018: proceedings of the International Scientific Conference. - Protvino-Moscow: Publishing House. IFTI, p. 282-288.
[15] M.A.Berberova, K.I.Chernyavskii, «Comparative assessment of the NPP risk (on the example of Rostov and Kalinin NPP). Development of risk indicators atlas for Russian NPPs», GraphiCon 2019 Computer Graphics and Vision. The 29th International Conference on Computer Graphics and Vision. Conference Proceedings (2019), Bryansk, Russia, September 23-26, 2019, Vol-2485, urn:nbn:de:0074-2485-1, ISSN 1613-0073, DOI: 10.30987/graphicon-2019-2-290-294, http://ceur-ws.org/Vol-2485/paper67.pdf, p. 290-294.
[16] Nebaba S.G., Pak A.Y., Zakharova A.A. Automated Algorithm for Determining the Interplanar Distances of the Crystal Structure of a Substance from Transmission Electron Microscopy Images // CEUR Workshop Proceedings. 2019. Vol. 2485. pp. 248-251. DOI: 10.30987/graphicon-2019-2-248-251.

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