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Anomalies in Radioactive Half Period: New Look

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Last years there is a broad discussion about the possibility that a radioactive decay constant slightly changes with the one-year period.

In this work, we try to show that this issue is only a part of a more general question about the instability (nonrandomness) of the radioactive decay process. However, such effects may not be revealed in half-life estimations.

Keywords: radioactive decay, instability, periodicities

Recently, there has been an active discussion in the literature about the possibility that the rate of radioactive decay is not a constant (for given a nucleus). The last two works of supporters [1] and opponents [2] of the idea of the possibility of the instability of radioactive decay, clearly demonstrate the positions of the opposite parties. At first glance, it seems, given the credibility of research conducted in specialized metrology laboratories [3-5], that the main idea of the opponents, the incorrectness of measurements, which showed the effects of decay instability, is quite sound. However, we want to show that this is not the case, and the positions of the parties can be brought closer.

First of all, it should be noted that there are experiments with the observation of the radioactive decay half-life variability, where results cannot be attributed to the influence of the surrounding environment.

Thus, in [6], it is stated that the half-life of the ^{213}Po nucleus has diurnal, monthly and seasonal periods. Since the decay period of ^{213}Po is microseconds (half-life $T_{1/2} = 4.2 \mu\text{s}$), no weather conditions during this time can affect the equipment. In [7], decay rate measurements were performed simultaneously on two adjacent identical detectors that were differently oriented in space.

The differences in the statistics of the measurement series, obtained in these experiments, also cannot be attributed to changes in meteorological conditions, because the detectors were in the same conditions. Therefore, the statements that all the results of the observation of changes in the decay rate are erroneous remains not proved.

However, another aspect of such research allows us to look at this problem in a new way. In the discussions [1-5], they are talking about the half-life. Because the decay process is considered random, the half-life is defined as the result of some statistical processing of the measurement results. The axiom is that the Poisson function describes the data distribution. But note that this is only an approximation. Therefore, the half-life is a value derived from the rate of pulse counting observed in the experiment (i.e., acts of particles detecting that are created as a result of acts of decay of the nucleus).

It follows from the above that it would be logical to investigate the decay statistics in the issue of finding the variability of the decay rate. Therefore, the subject of our attention is that there are many studies of the decay rate, which did not put the half-life determination task but studied the decay statistics. Such studies can be performed only on a sufficiently good statistical material, which practically means: they must be based on the analysis of the long series of measurements obtained on computerized installations.

In such studies, a somewhat paradoxical result was obtained. The decay continues to be like Poissonian, but in sets of data some regularities are observed, meaning that the series are no longer random. This paradox is easy to explain "on your fingers". Let us take a series of generated on a computer Poissonian random numbers, and organize it in ascending and descending order. All three sets of numbers (random and ordered) in terms of standard statistics will have a Poisson distribution.

The research in this field fulfilled under the direction of S.E. Shnoll [8-10] can be considered as fundamental. In these works, using a very specific statistical analysis (analysis of histograms of short subsamples from a full range of measurements), they found regular repetitions with periods from minutes to years. Note that the critique of the methods of analysis used by S.E. Shnoll, in our opinion, from the beginning was prejudiced and incorrect. But after creating computer methods of analysis [11,12], there are no doubts about the existence of periodic components in a regular decay series. It is emphasized [19] that according to the standard criteria, the series remains to be Poissonian.

In Baurov's works [13], statistical analysis shows the difference in the rate of radioactive decay in January and July, and this is related to the existence of a selected direction in space.

In [14,15], the statistics of radioactive decay after action on a radioactive sample by a pulsed electromagnetic field was investigated. The sample was influenced by an electromagnetic field, and then for several months the count rate was measured. In these experiments, we found that periodicities and other regularities were appeared in a series of measurements and disappeared after some time.

In [16-18], the results of regular measurements of the gamma background of the radioactively contaminated area around the Chernobyl NPP were analyzed. These measurements should be treated with extreme caution because the detectors are outdoors and the question immediately raises about the influence of weather conditions. However, the authors have analyzed the possible causes of signal variability and concluded that the signals from this control system contain periodic components, which cannot be explained by hardware effects. In this paper, we will consider the example of analysis of gamma background measurements in the contaminated area around the destroyed Chernobyl NPP to demonstrate that in the series of measurements of radioactive decay various patterns are reliably recorded, which also, and not only the change in half-life, will indicate decay is not a random process.

First, we use the standard approach: consider the Fourier spectrum of the sample being

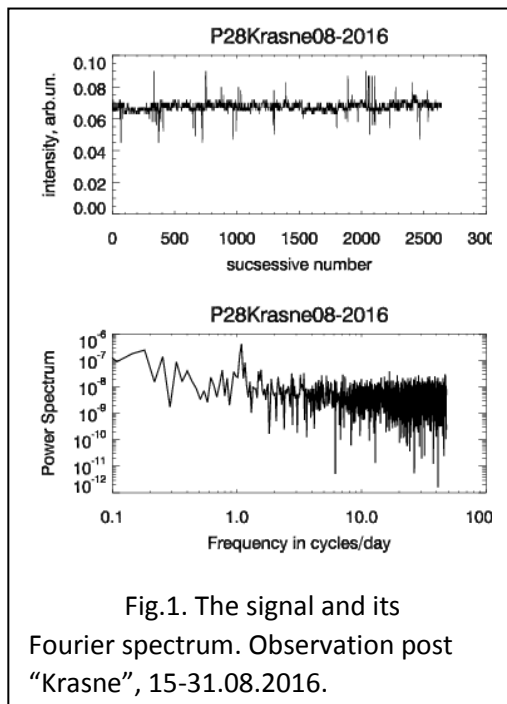


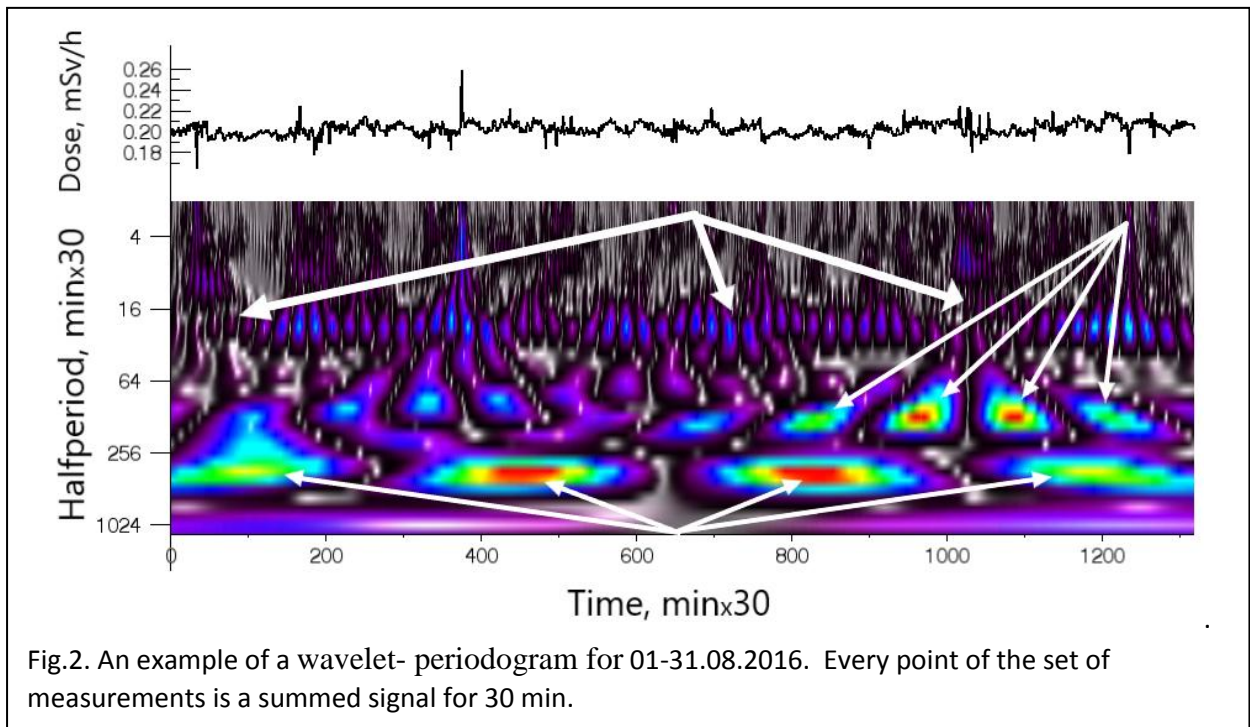
Fig.1. The signal and its Fourier spectrum. Observation post "Krasne", 15-31.08.2016.

analyzed (Fig. 1). The upper graph shows an example of the signal received for the period 01-31.08.2016 at the observation post "Krasne", at the bottom - its Fourier spectrum. The Fourier spectrum shows only one broad peak in the region of about one cycle per day. Of course, the conclusion about the diurnal period's existence is not enough for the conclusions about the instability of decay. Therefore, for further analysis, we will use the wavelet transform.

In fig. 2 graphical results of wavelet analysis are presented (for details, see Appendix). The upper graph is the signal collected every 15 minutes. The color picture below is a graphical representation of the matrix of coefficients of its wavelet transformation. On the given wavelet-periodogram, we see three distinct rows of spots located horizontally (shown by arrows). In our case, the wavelet analysis is qualitative: we will consider only those rows of spots, which stand

out without special analysis. We emphasize that such regular patterns are not formed in wavelet-periodograms of random series.

The upper row of spots, which is observed throughout the observation period, corresponds to diurnal changes (see Appendix). But this series of spots does not look geometrically strict, as it would be for a model sine wave. And we note on it two features (white arrows show them), which are typical and are often observed in signals of ASRC. The color and size of the spots depend on the signal intensity to some extent, i.e. on the amplitude of the sine wave. This is most clearly seen in the area shown by the far-right white arrow. There, the spots are slightly below the average daily level. In fact, these spots are located with an interval of 13.5-15 hours (not exactly 12 hours). Differences from the mean go beyond the error (extended uncertainty) of estimating the intervals



between spots, which is ± 0.5 hours. And in this area, a series of short-period spots appear above them. Also, we note that the average value for the half-period at all intervals between spots is 11.4 hours. This result can also be obtained by dividing the entire interval of observations by the number of spots (while the accuracy of estimating the position of the center of the spots will no longer matter at all). Therefore, the diurnal period, despite the fact that it is obviously the time between spots, was less than 12 hours, assuming the existence of some external source such as a group of sunspots, the direction to which will change due to the Sun's rotation (analogous to sidereal shift).

A series of spots with a half-period of about 2.5 days (four arrows in the right of a pattern) appears in the middle of the month at 700 steps, the number of spots is five.

Table. Comparing a lower spots set of the wavelet-periodogram in Fig. 2 with the Moon phases in August 2016.

Spot position on a horizontal axis	Date, Time	Tabular time for the Moon's phases
Minimum at 107	8/3/2016 05:15:00	New Moon 02.08 23:45
maximum at 451	8/10/2016 11:00:00	10 August 9:22:00 PM, first quarter
Minimum at 819	8/18/2016 03:00:00	Full Moon 18 August 12:27
maximum at 1183	8/25/2016 18:00:00	Fourth quarter 25 August 06:41
Minimum at 1389	8/30/2016 00:15:00	New Moon 01.09 12:04

The last series (lower arrow) has a half-period of 7-8 days. That is, their average period is 15 days. Dates for the position of the centers of the spots in this series are summarized in Table 1. We compared them with astronomical tabular data of the Moon phases. The rows that correspond to the new and full Moon are highlighted. As one can see, the coincidence of tabular and experimental values is almost complete.

Conclusions

The question of the stability of radioactive decay is not limited to estimating the half-life. Statistics of long regular series of measurements should also be investigated. When studying the statistical properties of the data of measurements of the radioactive decay rate by various authors, it was found that radioactive decay is not a random process. The count rate series can contain various patterns, among which the most obvious are the periodic components. The existence of periodic components may not appear when estimating the half-life but looks like a usual data scatter.

The experiments revealed regular changes in the signal of decay velocity, with periods of approximately one, five, and 15 days. The discovered correlation with the Moon phases cannot be considered as an accidental coincidence, especially as caused by meteorological conditions.

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Appendix A

In the Appendix, the method of analysis using the wavelet transform is presented, and additional examples of the existence of periodicities in the data series of ASRC are given. The signal is the results of regular measurements of the decay rate, i.e. the time series. The result of the wavelet transformation – wavelet-periodogram – for some set of data is shown in Fig. 2. Schematically, the wavelet transform consists in the calculation the sliding correlation between some time-limited function (wavelet) and the corresponding signal section. Then the wavelet's period is changed, and for each new period, a sliding series of decomposition coefficients is calculated.

The result is a two-dimensional matrix of decomposition coefficients, the horizontal axis of which is a time of measurements, and the vertical value is proportional to the period. Gaussian wavelet of the 10th order was used in the analysis. Its feature is that in the presence of a periodic component in the signal, the wavelet decomposition's coefficients will have increased values at the points of maxima and minima of the sinusoid (there is an increased correlation between the studied function and wavelet). Then on the corresponding period (vertical axis) a number of spots regularly located horizontally will be observed. Therefore, in the future, for convenience, we will call this picture a wavelet-periodogram. This regularity can be distorted by the irregularity of the sinusoidal component and its distortion by noise disturbances.

From fig. 2 (by the program), you can get the time of appearance of spots on the horizontal axis. From these data you can calculate the interval between the spots and the time of occurrence of the minima and maxima of the diurnal "sinusoid". The data on the half-periods given in the table (shaded column of distances between daily spots for the period 01-31.08.2016) are shown in fig. A1. The horizontal axis is a consecutive number of the spot, and the vertical one is the distance in hours from the previous spot. The graph shows the variability of the intervals between adjacent spots during the measurement time. Although the changes are small relative to the accuracy of measurements, we can conclude that there are regular changes with a period of 8-10 half-day intervals, i.e. with a period of about five days.

To compare and demonstrate the repeatability of the effect, a graph for similar measurements for 05-06 months of 2014 is given.

Table A1. Analysis of diurnal spot positions on horizontal axis (in a time) for Fig. 2.

No – consecutive spot number from the beginning of measurements

Spot position - position of the center of the spot (Gaussian 10 wavelet);

Morlet 6 - position of the spot center for the Morlet 6 wavelet;

Interval - the interval between spots in units of the horizontal axis.

More 6		Gaussian10					More 6		Gaussian10				
		+- 3points											
spot	No	spot	Interval,	Half-	Half-	spot	No	spot	Interval,	Half-	Half-		
position		position	min×30	period,	period,	position		position	min×30	period,	period,		
				min	hours					min	hours		
	1	8											
32	2	34	26	780	13	742	34	743	25	750	12.5		
	3	56	22	660	11		35	766	23	690	11.5		
78	4	76	20	600	10	786	36	788	22	660	11		
	5	100	24	720	12		37	805	17	510	8.5		
117	6	120	20	600	10	825	38	827	22	660	11		
	7	143	23	690	11.5		39	849	22	660	11		
165	8	163	20	600	10	870	40	870	21	630	10.5		
	9	184	21	630	10.5		41	892	22	660	11		
204	10	207	23	690	11.5	915	42	914	22	660	11		
	11	230	23	690	11.5		43	936	22	660	11		
250	12	250	20	600	10	958	44	958	22	660	11		
	13	274	24	720	12		45	984	26	780	13		
297	14	296	22	660	11	1007	46	1011	27	810	13.5		
	15	320	24	720	12		47	1042	31	930	15.5		
337	16	340	20	600	10	1070	48	1071	29	870	14.5		
	17	359	19	570	9.5		49	1099	28	840	14		

381	18	381	22	660	11	1123	50	1124	25	750	12.5
	19	405	24	720	12		51	1145	21	630	10.5
427	20	429	24	720	12	1167	52	1167	22	660	11
	21	454	25	750	12.5		53	1189	22	660	11
471	22	473	19	570	9.5	1213	54	1211	22	660	11
	23	494	21	630	10.5		55	1234	23	690	11.5
512	24	514	20	600	10	1257	56	1257	23	690	11.5
	25	539	25	750	12.5		57	1282	25	750	12.5
560	26	563	24	720	12		58	1308	26	780	13
	27	585	22	660	11						
609	28	609	24	720	12			Mean =	22.2	665.6	11.1
	29	634	25	750	12.5						
656	30	655	21	630	10.5						
	31	675	20	600	10						
694	32	696	21	630	10.5						
	33	718	22	660	11						

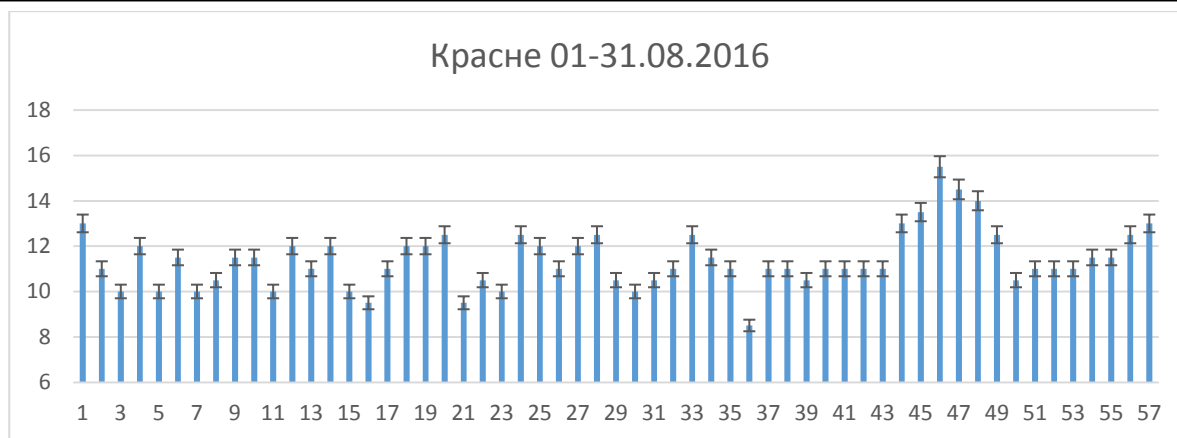


Fig. A1. Time intervals in hours between consecutive spots of a half-day course (the shaded column in the tab. A1). As we can see, this value is somewhat variable, and the changes go beyond the uncertainty of its estimate. Although the result is at the noise level and not regular enough, we can expect that the variability is 7-10 half-periods, i.e. about five days.

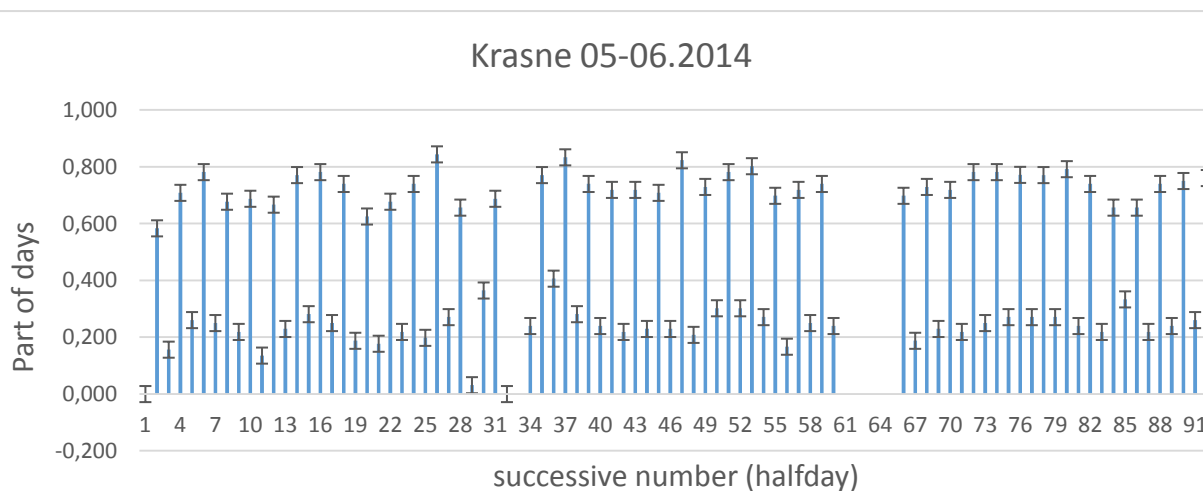


Fig. A2. The time of appearance of spots of the half-day course for the period 05-06.2014 in units of the parts of a day. Because each subsequent spot corresponds to half a day and appears at about 5 a.m. and 5 p.m., two series of minimum and maximum values are formed. As one can see, these values are kept within certain limits throughout the observation time and are not being at noon and midnight. The changes are beyond uncertainty. Although this variability is at the estimation accuracy level, it is clear that this is not statistical variability. We can expect that the variability is 7-10 half-periods, i.e. about five days.