Application of the Theory of Hyperrandom Phenomena in the Search for Signs of the External Influence on Radioactive Decay and the Possibility of Quantitative Estimates

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We have developed the relevant setup and studied a possibility of the influence on the radioactive decay by an external impulsive electromagnetic field. It is shown that such action can result not only in a change in the rate of decay (rate of counting of gamma-quanta), but also in a clear variation of the statistical properties of the series of successive measurements of the counting rate such as the appearance of periodicities and hyperrandom properties. It is found that the excitation of a system of radioactive nuclei induced by the external influence disappears approximately in 4–6 days.

1 Introduction

We will describe our attempt to find a possibility to affect parameters of the radioactive decay with the help of an impulsive electromagnetic field. As is known, at the radioactive decay, the number of decays per unit time is a random variable which is described by the Poisson distribution [1]. Hence, from the viewpoint of the statistical analysis, the problem of search for the signs of changes after some treatment of a radioactive specimen can be reformulated as a problem of changes in the statistical properties of samples which are the records of the results of measurements before and after the treatment.

It should be emphasized that we intend to seek the weak changes which can be only precursors of the changes seen by naked eye (hence, of those possessing a practical significance). From the viewpoint of the dominant theory, the rate of radioactive decay cannot be affected at all (see [2]). While experimentally determining the influence of some factor, the researchers try to find, as a rule, the changes in the counting rate at least on the level of the statistical effects. We pose the problem in a more general form: to seek the differences between samples which can or cannot be reduced to a change in the mean counting rate.

The sought signs can be the periodic variations in a counting rate or the appearance of irregular "splashes" of the intensity or other irregularities leading to that the series of measurements of the counting rate cease to be random in the sense of mathematical statistics. In this case, a change in the form of a distribution function (loss of the Poisson property) can be only one of the possible sought signs.

The radioactive decay can be considered as an example of the process (if the radioactive half-life is much more than the time of measurements), for which the long series of measurements of its parameters is considered to be stationary in the sense of mathematical statistics, i.e. its statistical parameters do not vary with time. For comparison, we can indicate examples of other natural processes without the property of stationarity such as the noise of the ocean, where ships move from time to time near a detector of noises. The problem of the analysis of such data was considered, for example, in [3, 4].

In the present work, we will analyze changes in the decay statistics for signals of the rate of counting of gamma-quanta from radioactive specimens after the action of an impulsive electromagnetic field onto them.

2 Data and methods of their analysis

We will examine a possibility to influence the process of radioactive decay by external impulsive electromagnetic field. The setup generating the electromagnetic impulses that act on a radioactive specimen will be called a driver for simplicity. In order to use the statistical methods of analysis, we need the long series of regular measurements of the rate of decay. Such series were recorded with the use of a dosimeter-radiometer "Pul's" aimed at the remote radiation control. The device was produced at the small joint-stock enterprise "Opyt", includes a detector on the basis of NaI(Tl), and allowed us to execute every-second measurements with the record of results into a memory unit.

We analyzed the results of measurements of a specimen treated with a driver during February–May in 2018 in the city of Chornobyl'. As a specimen, we took monazite sand, i.e. we measured and analyzed the summary signal (gamma-radiation) from decay products of ^{232}Th. First, before the treatment of the specimen with a driver, we carried out the measurements of the counting rate for several days. Later on, we compared those data with the results obtained after the action of a driver onto the specimen.

In the analysis of the statistical properties of the measured signals, we used the statistical theory of hyperrandom phenomena [5]. This theory is based on the hypothesis that the results of measurements of natural processes are not independent and identically distributed. Hence, they do not obey the basic preconditions for the application of well-known methods of mathematical statistics. In other words, the basic assertion of the theory of hyperrandomness consists in that the process under study can undergo the action of external influences, which induces, respectively, changes in the statistics of a signal. This is manifested in the loss of the statistical stability by data, i.e. the results of measurements become dependent on the time. However, it can turn out that very long series of measurements should be made for such changes to be revealed.

The main distinction of the hyperrandom data from the standard random numbers which are independent and identically distributed consists in that the variance of the former does not decrease, as the number of measurements increases (increase in the size of a sample). On the contrary, starting from some number of measurements, the variance of hyperrandom data increases [3, 4]. Such effect can be a consequence of the tendency to a change in the mean, the autocorrelated function, *etc* during the measurement. (We emphasize once more that the similar changes in a sample can have the statistical character and can be invisible for naked eye.)

The formulas for the analysis of hyperrandom data can be found in [5, 6]. We now indicate only the principle of such analysis. Let us have the sample of the results of measurements X with size N: $X = (x_1, x_2, \dots x_N)$ is a regular temporal series of the results of measurements. We accentuate that the series is ordered in the meaning that the elements of the series should not be permuted. We are interested in the dependence of its parameters on the size of a sample, i.e. on the time. For this purpose, we calculate the accumulated means, i.e. the means for the first two, three, *etc* elements of the input series. As a result, we get a new first-order series of data in the form of accumulated means $Y^{(1)} = (Y_1, Y_2, \dots Y_N)$, where $Y_n = \frac{1}{n}\sum_{i=1}^{n} x_i (n = \overline{1, N})$, with its mean $\overline{m}_{Y_N} = \frac{1}{N}\sum_{n=1}^{N} Y_n$. Then we can repeat the procedure and form the series of higher orders $Y^{(2)}$, $Y^{(3)}$, *etc*.

The object of our analysis is the function, being the unbiased variance of fluctuations from the accumulated mean, $\overline{D}_{Y_N} = \frac{1}{N-1}\sum_{n=1}^{N}(Y_n - \overline{m}_{Y_N})^2$.

As the quantitative measure of one of the hyperrandom properties, specifically, the statistical instability of a series of data, we take the coefficient γ_N characterizing the absolute level of statistical instability: $\gamma_N = \frac{M[\overline{D}_{Y_N}]}{N D_{Y_N}}$, where $M[*]$ is the operator of mathematical expectation.

To have a possibility to compare different samples with one another, the units of statistical instability are introduced in the theory. For the coefficient γ_N, the role of a unit of statistical instability of measurements is played by the quantity γ_{0N} which corresponds to the noncorrelated series of readings with constant variance $D_{x_n} = D_x$ and zero mathematical expectation at a fixed value of N. The coefficient γ_{0N} is given by the formula

$$\gamma_{0N} = \frac{N+1}{(N-1)\,N}\,C_N - \frac{2}{N-1}, \text{ where } C_N = \sum_{n=1}^{N}\frac{1}{n}\,.$$

Using the unit of measurements γ_{0N}, we introduce the ratio $h_N = \frac{\gamma_N}{\gamma_{0N}}$, i.e. the coefficient characterizing the absolute level of statistical instability in units of γ_{0N}. These coefficients are dimensionless. The degree of hyperrandomness h_N of the analyzed data will be considered in what follows.

We note that though the hyperrandom properties of our data are manifested undoubtedly (see below), the derivation of the quantitative estimates of the degree of hyperrandomness is not a simple matter. We clarify this point by the example. Let us deal with a really random stationary process, so that its signal has no signs of the hyperrandomness. At some time moment, let a quite short external influence arise (the duration of the external action is assumed to be much less than the time of observations). It causes an increase in the mean and, respectively, to the appearance of the hyperrandomness. After some time period, the signal again becomes random and stationary.

Hence, the sample as a temporal signal can be partitioned into three parts. The midsection is hyperrandom, and the beginning and the end are normal stationary signals. In this situation, the sample has, on the whole, hyperrandom properties. But the results of calculations for each of the three parts separately will give different results.

In real situations, the information about the very fact of the external influence (treatment by a driver) can be unknown. Hence, we should consider the problem of determination of changes in the statistics of a series, the problem of analysis of the dynamics of those changes in time, and the problem of searching for the time, when the driver acts. If, for example, the aftereffect is present and varies in time, we can say nothing about the time moment of the transition of the sample into the third part, even if we are based on the analysis of the whole series. Moreover, the very fact of such transitions should be studied. We reformulate this problem as follows: Are there some regularities of changes in the hyperrandomness indicating the action of a driver and can we determine, for example, the characteristic time of relaxation of the "hyperrandomness state" arisen due to the action of a driver?

In view of the above discussion, we need to analyze the separate parts of samples with the purpose to find the distinctions between them and to establish the optimum size of such subsamples. To make it, we chose a "window" of a definite size, i.e. we set the size of a subsample. With such window, we scan the whole series of measurements. For each "window", we calculated the necessary parameters.

3 Results and discussion

As was indicated, the hyperrandomness by its nature arises at a change in time of some parameters of the process such

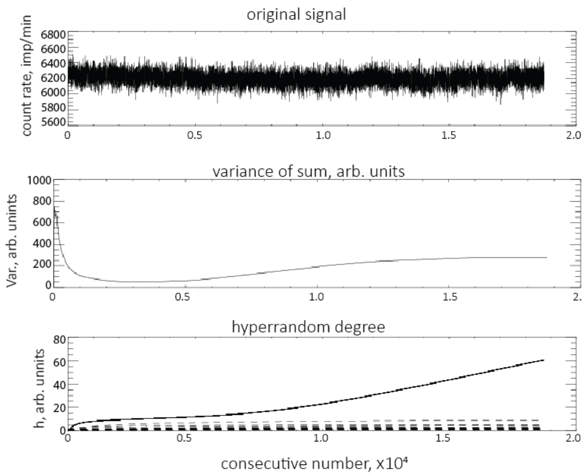

Fig. 1: Analysis for hyperrandomness of a series of measurements during 13 days from 14.02.2018 to 26.02.2018 (prior to the treatment). There is the sign of the hyperrandomness, which is revealed as an increase in h_N after approximately 5000–8000 min of measurements.

as, in particular, the solitary short-time splashes. The statistical characteristics of a series calculated before the splash can be changed after it. If the duration of the action of a driver is from several minutes up to several hours, it can be considered a short-time influence against the background of measurements during several days.

One of the tasks of the present work is the search for the time of relaxation of a signal after the action of a driver, which is reduced to the analysis of short segments of the entire series. In Fig. 1, we present the results of a test for the hyperrandomness. We took a sufficiently long-time (13 days) series of measurements before the action of a driver in order to estimate the order of long-time changes.

In each of the figures below, the upper plot is the input series of data; the middle plot presents a variation in time of the accumulated variance; and the lower plot shows the parameter h_N which characterizes the degree of hyperrandomness. The results of calculation of the hyperrandomness parameter are accompanied by the analysis of whether such result can be formed accidentally. It is a reasonable question, because we analyze the series of random numbers. For this purpose, we generated a computer-created sample of random numbers with the same parameters (mean and variance), as those of the experimental series. For such model sample with the same programs, we made analysis for hyperrandomness. This procedure was repeated several times for the sake of reliability, and the results were drawn on one figure. In the presence of a noticeable hyperrandomness, the experimental curve must be outside the zone, where the curves for model samples are placed. This zone for the model series of random numbers is shown in the lower plot by dotted lines.

As is seen in Fig. 1, the series manifests some hyperrandomness during 13 days before the treatment. It starts to reveal itself after approximately 5–6 days of measurements.

Then, on 27.02.2018, we executed the treatment of the specimen with a driver (impulsive electromagnetic field).

In Fig. 2, we present the results of analysis for the hyperrandomness of a series of measurements before and after the action of a driver. We recall that our purposes are to register the time of a manifestation of the action of a driver and to determine the temporal changes of the signs of such action. We analyzed the subsamples 4 days in duration. In other words, we analyzed a part of the series 4 days in duration, then the "window" was shifted by one day, and so on. Hence, the subsamples were overlapped during 3 days in order to more or less reliably notice the times of changes in the degree of hyperrandomness.

In view of Fig. 2, we can formulate the following main results:

1. After the action of a driver, the rate of counting of gamma-quanta somewhat increased.
2. In the analyzed series, the hyperrandomness was not observed practically for 4 days (accepted size of a scanning "window") before the treatment: the variance decreased, as the size of a sample increased.
3. After the action of a driver on 27.02.2018, we observe a sharp increase in the hyperrandomness. The variance starts to grow already approximately in 1200 min (20 h).
4. This effect of hyperrandomness practically disappeared on 04.03.2018 (in 4–5 days) to the level of noises.

4 Conclusions

1. We have revealed that, under the action of electromagnetic impulses, the statistics of the radioactive decay is changed.
2. It is found that, after the action of a driver, the process of decay became hyperrandom. This means that its characteristic such as the accumulated variance increases in time, rather than decreases. In turn, this means that the process of decay stops to be stationary.
3. This forced nonstationarity was observed during approximately 5 days. Then the process of decay returns to the stationary mode (experimental curve in Fig. 2f is located in the zone of random values).
4. Such time of existence of the aftereffect (tens of hours), which is much more than the characteristic time of the evolution of a separate nucleus, is, most probably, the experimental confirmation of the theories (see [7–10]) that assert that the radioactive decay is a collective process in the system of correlated nuclei. From this position, we may assert that the quantitative estimates of the process of relaxation of a system of nuclei are made

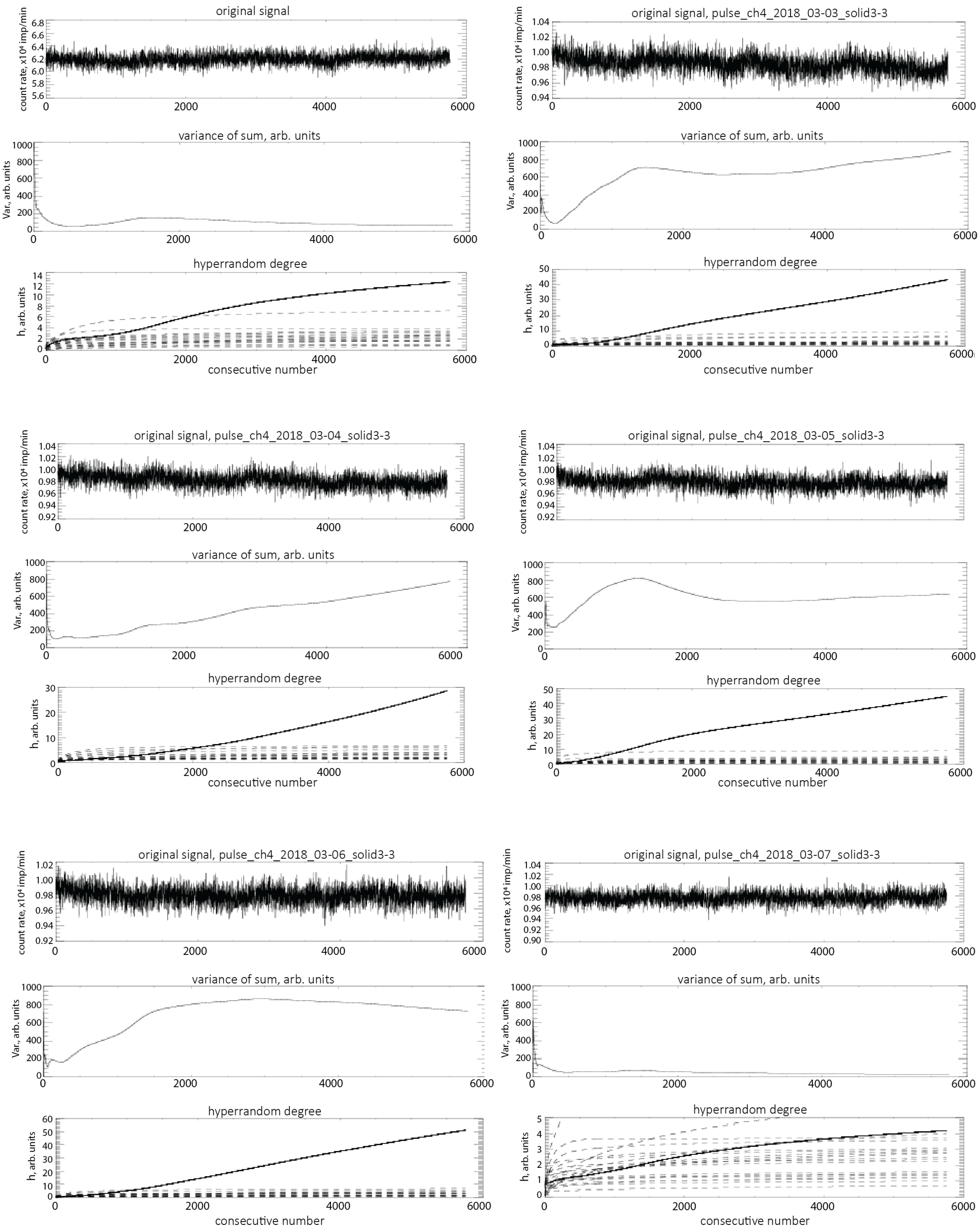

Fig. 2: Analysis for hyperrandomness: the series of successive overlapping subsamples from 28.02.2018 to 03.03.2018. The measurement at once after the treatment which occurred 27.02.2018. After the action of a driver, the hyperrandomness appeared: an increase in the variance and in h is clearly seen. On the fifth day, the hyperrandomness drops to the level of random noises.

for the first time. The determined time of the relaxation has the order of hours.

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