

LETTERS TO THE EDITORS

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Regular variation of the fine structure of statistical distributions as a consequence of cosmophysical agents

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Abstract. **Considered is the statistical ground of the certainty of cosmophysical effects on the fine structure of distributions governing the results of measurements in various physical processes. We show that the previously discussed effects of synchronous variations of histogram shapes in independent processes, and the periodical occurrence of histograms of a particular shape, do not depend on the form of the integral distribution. The adequacy of visual (expert) estimation when comparing the shapes of histograms as an alternative to the standard statistical methods is justified.**

1. Introduction. Subject matter

As often happens in polemics, the controversy is only indirectly concerned with the point at issue. So, before embarking on a detailed analysis of the critical comments, let us recapitulate the main topic of our work [1].

Our findings are as follows:

1. The fine structure of the distributions governing the results of simultaneous measurements of *any* processes in each time interval is similar with a fairly high probability. This similarity is observed even when the labs are hundreds or thousands of miles away from one another. The similarity of histogram shapes cannot be attributed to any artifacts, because the experimental setups are totally independent, and sometimes there occurs principal difference even in the method of measurements.

2. The shape of histograms is reproduced with a high probability in adjacent time intervals (the effect of 'close neighbors'), and is repeated with a periodicity of 24 hours, 27 days, and 1 year.

3. From statements 1 and 2 it follows that the phenomenon under discussion is caused by cosmophysical factors.

The authors realize the eccentricity of these conclusions. This is why the reliability of results have been subjected to a long and comprehensive process of verification.

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2. The compliance of radioactive decay rates with the Poisson distribution is not questioned

Our critics pay special attention to the fact that the distributions in Figs 1 and 2 in Ref. [1] diverge from a Poisson distribution. This deviation may by attributed to a number of causes (including those suggested by our correspondents), and could be the subject of a separate study, but this is not what we are concerned with. The effect in question does not depend on the general form of the distribution that describes a given process.

We would like to emphasize once again that we do not question the fact that the process of radioactive decay on the whole obeys the law of small numbers, as other processes comply with their respective distributions. We only draw attention to the fact that the phenomenon described in our paper cannot be exposed by the standard statistical methods — for them it is simply 'invisible'. The conventional statistical criteria of comparison of samples, or the procedures based on comparing distances in some space, are insensitive to the fine structure of the distributions, being developed for entirely different purposes.

It seems that we have made a tactical mistake in our paper [1] by presenting Figs 1 and 2 without duly emphasizing this circumstance. Irrespective of the causes of certain deviations of the distributions given in these diagrams from the Poisson distribution, the fine structure of the respective diagrams derives from other factors. It is clear that methodological faults can only blur the fine structure of the distributions. In any case, all the main features show themselves when the results obtained are in strict compliance with the Poisson distribution. This point is illustrated below.

So, this critique does not concern the essence of our presentation.

3. Methodological details

The above-formulated conclusions are based on the comparison of histograms constructed on evidence of repeated measurements on time-domain processes of different natures. The cornerstone of our study, however, is the continuous measurement, taken for many years without interruption, of alpha activity of ^{239}Pu radioactive sources fixed on solid-state detectors. Such a selection springs from the fact that radioactive decay is certainly independent of trivial factors, and on the practical absence of beta and gamma background. The measurement proceeds from counting the decay events on a 0, 1 basis, which facilitates elimination of possible methodological artifacts.

Now let us describe in greater detail our method for plotting the histograms and comparing their shapes.

Construction of histograms. Expert estimation of the similarity of their shapes. Figure 1a shows a record of alpha activity of ^{239}Pu. The distribution of readings in this series complies with the Poisson distribution by the χ^2 criterion. Figure 1 illustrates the individual steps in processing and analyzing the form of the histograms.

The time-stretched record is split into nonoverlapping segments of equal length, usually from 60 to 100 consecutive readings each (Fig. 1a).

A histogram is constructed for each such segment — a selected distribution of values; in the upshot, a sequence of histograms is coming into play (Fig. 1b).

To facilitate subsequent comparison, the resultant histograms are smoothed a few times by the standard method of moving average (Fig. 1c).

The series of histograms obtained in this way was presented to the expert for selecting similar pairs (Fig. 1d). From the series, the expert displays two diagrams on the screen, superimpose one on the other after appropriate stretching or compressing along the x-axis (horizontal scaling), or rotation around a vertical axis ('mirror reflection'), and decides whether they are similar or not. If he decides that they are 'similar', this pair of histograms is recorded in a special journal file. For an unbiased estimate, the serial numbers of histograms are encrypted with the aid of a random number generator, so that the expert does not know how far the histograms are from one another in the series.

Figure 1e displays examples of pairs of similar-in-shape histograms. We see that histogram *2* is mirror-similar to histograms *3* and *4*; histogram *3* is mirror-similar to *7*, *12*, *19*; histogram *9* to *10* and *17*, etc.

For each pair of similar histograms selected by the expert, the computer calculates the time interval between the histograms and plots the distribution of the number of similar histograms as a function of their time displacement (Fig. 1f). From this example we see that the similarity is more likely for adjacent histograms: *2* and *3*, *3* and *4*, *9* and *10*, *14* and *15*, *19* and *20*. This is an indication of the effect of close neighbors, which becomes statistically reliable for a wealth of histogram array.

It should be emphasized that since the task of the expert is to make a decision concerning the similarity of shapes of histograms, the operations of linear stretching, shift and rotation around the vertical axis are completely lawful. This is true both for histograms of different processes and for histograms of one and the same process. In the former case this is due to the need for combining different scales, while in the latter case this is associated with the stochastic nature of processes, owing to which the time intervals of readings may have different mean amplitudes of fluctuations.

The biggest concern of the critics is the expert (visual) estimation of similarity of histograms. This method, however, gives much clearer results than computerized techniques based on calculating the Euclidean distance (sum of differences squared), coefficient of correlation, χ^2 criterion, Kolmogorov — Smirnov criterion, and other measures of similarity. This apparent paradox is explained by the fact

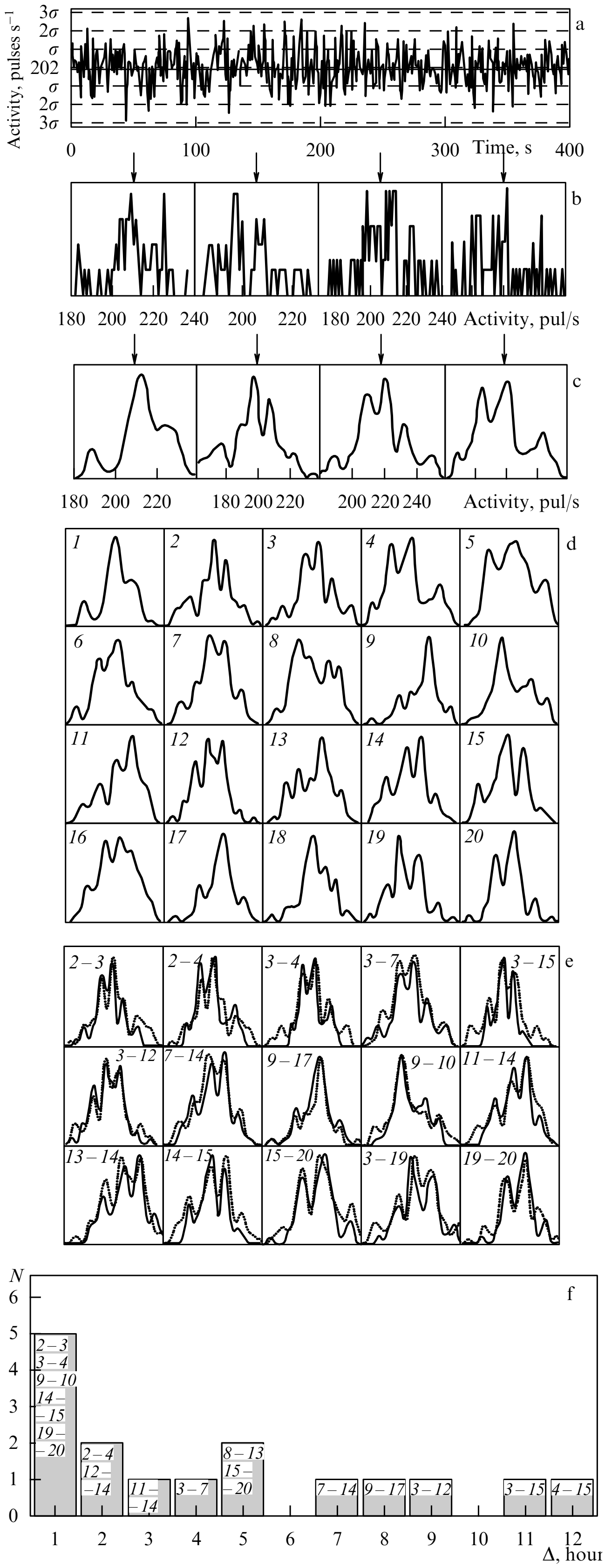

Figure 1. Sequence of operations in processing the time series of data, construction of histograms and comparison of their shapes.

that in visual estimation the expert disregards the minor quantitative distinctions of the curves under comparison as being irrelevant for the 'idea of shape'. This situation is illustrated in Fig. 2, which depicts pairs of histograms that are similar (a) and nonsimilar (b) for the eye of the expert. For each such pair we also give the values of two statistical criteria of similarity, namely

'cosine of the angle':

$$\max q = \frac{\sum_{i=1}^{n} X_i \cdot Y_i}{\sqrt{\sum_{i=1}^{n} x_i^2 \cdot \sum_{i=1}^{n} Y_i^2}}\,,$$

and normalized difference area:

$$\min \Delta S = \frac{2\sum_{i=1}^{n} |X_i - Y_i|}{\sum_{i=1}^{n} |X_i| + \sum_{i=1}^{n} |Y_i|}\,.$$

The pairs were optimized beforehand with respect to translation and stretching according to the former criterion.

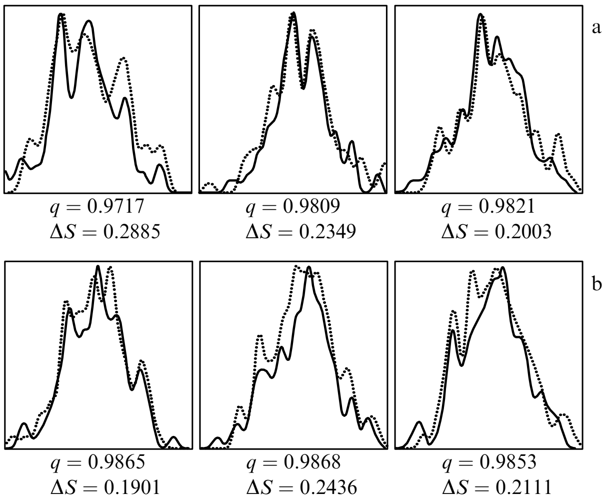

Figure 2. Examples of histogram pairs selected as similar (a) and nonsimilar (b) by an expert. For each pair optimized through translation and stretching we indicate at the bottom the values of the 'cosine' q and normalized difference area ΔS. The values of ΔS and q obviously do not correlate with the decision of the expert. Examples of histograms are taken from the measurements of alpha activity of ^{239}Pu.

We see that the values of q and ΔS are practically the same for histograms classified by the expert as similar and obviously nonsimilar. This means that such criteria cannot replace expert estimation. The development of an adequate criterion and the appropriate algorithm for automatic comparison of histograms (owing primarily to the complexity of such comparison) seems to be the most urgent and the most difficult of the tasks that face us. As a matter of fact, the selection of similar shapes is akin to recognition of characters written by different hands. Such pattern recognition is readily accomplished in observable form, but any automatic character recognition algorithm will fail without being first taught to recognize samples of characters in a particular handwriting.

The adequacy of expert estimation is proved by the fact that in physical experiments we observe narrow distributions of the probability of histogram shape similarity over time intervals between their recording, and that they are totally absent in the control experiments where the Poisson process was simulated by the random number generator. At the same time (as demonstrated above), it is not possible to obtain narrow distributions when standard statistical methods are used for estimating the shape similarity of histograms.

Estimating the certainty of the distributions of intervals between similar histograms. When pairs of histograms are sorted out for comparing their similarity, the number of possible combinations depends on the distance between the histograms. For example, if the length of the histogram series is N, then at a distance of 1 there are $N-1$ pairs (each histogram with its neighbor), while there is only one pair (the first and the last histograms) at a distance of $N-1$. This means that the number of possible combinations decreases linearly with increasing distance between the histograms. After looking through all the combinations and construction of the sample distribution of distances corresponding to similar histograms, one can estimate the certainty of deviation of this distribution from the uniform distribution, i.e. estimate the significance of the 'peaks' at hand. Assume that for each pair of histograms occurring at a distance r from one another, the probability q of being similar is the same irrespective of the value of r — in other words, the 'null' hypothesis consists in the assumption of the uniform distribution of the distances. Then for each distance r we get one's own binomial scheme: with probability q, a pair of histograms falls into the number of combinations selected from the total number $N_0(r) = N - r$ of pairs possible for this distance, with the mean $qN_0(r)$ and the variance $q(1-q)N_0(r)$. For a given significance level P, the confidence interval for the number of like pairs $m(r)$ at distance r is now given by

$$m(r) = qN_0(r) \mp \lambda(P)\sqrt{q(1-q)N_0(r)}\,.$$

The solution of the inverse problem is similar. If some occurrence rate is suspected of being 'exceptional', we substitute it into the function of binomial distribution with the parameters $N_0(r)$ and q, and find the probability of this being a random event, namely evaluating the significance level of our suspicion being true.

This approach was used both in calculating the confidence interval for the distribution of distances and for evaluating the probability of stochastic occurrence of the observed 'prominent' frequencies (Figs 3, 4).

4. Illustrations of the main effects

It will be worthwhile giving here some recent results that confirm the conclusion about the very high probability of occurrence of similar histograms constructed from simultaneous measurements of the rates of various processes studied at remote laboratories.

These results are presented in Figs 3 and 4.

Figure 3 depicts the distribution of time intervals between similar histograms constructed from (a) measurements of the beta-decay rate from ^{137}Cs source with a scintillation counter starting at 2:00 p.m. on 3 January 1999 (Joint Institute for Nuclear Research, Dubna), through the courtesy of the authors of Ref. [3], and (b) synchronous measurements of the alpha-decay rate from ^{239}Pu source in Pushchino by our standard techniques [5–8]. The measurements in Ref. [3] were performed with all the necessary precautions for the stabilization of voltage, temperature, and the pulse discrimination regime. Each measurement continued for 1 minute; the

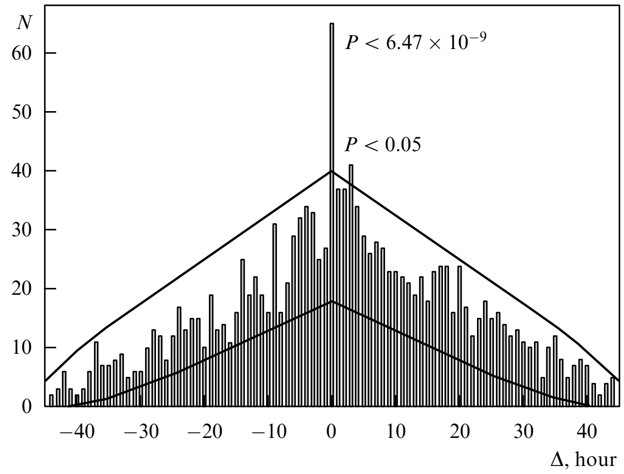

Figure 3. Illustration of the effect of synchronism for the example of shape variation of the histograms plotted from simultaneous measurements of alpha activity of ^{239}Pu in Pushchino and β activity of ^{137}Cs in Dubna. We give the number N of pairs of similar histograms as a function of time interval between the histograms in the pair. The solid lines mark the confidence interval under assumption of a random distribution of similar shapes. The number near the maximal peak (corresponding to synchronous appearance of histograms in the pair) gives the probability of its occurrence by chance.

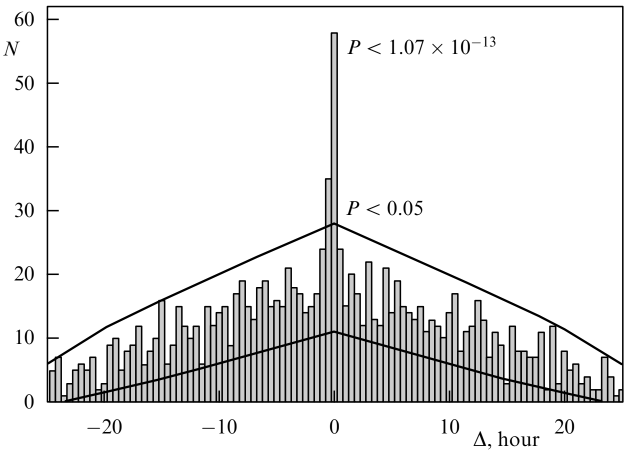

Figure 4. Another example of synchronous change of the shape of histograms for different processes occurring at faraway locations. Under comparison are the shapes of histograms plotted from synchronous measurements of alpha activity of ^{239}Pu in Pushchino and the intensity of the neutron flux from the earth's crust in Moscow.

histograms were constructed from 60 points (throughout 1 hour).

As usual, pairs of similar-in-shape histograms were selected by comparing 'all with all' (with the encrypted histogram numbers) and the distribution of occurrence of such pairs was plotted as a function of time displacement between the histograms. Nine simultaneous arrays were analyzed with 48 one-hour histograms in each — that is, $48^2 \times 9 = 20736$ comparisons were made. 1454 like pairs were selected from these, or 7% of the total number of comparisons. Out of 432 (48×9) synchronous pairs there were 64 similar pairs, or 14.8%. The probability of random occurrence of such a number of similar synchronous histograms is less than 10^{-8}.

Figure 4 presents the analogous results obtained from comparison of histograms constructed from (a) measurements of the flux intensity of neutrons produced by alpha particles from the natural radioactive elements in the earth's crust (Scientific Research Institute of Nuclear Physics of Moscow State University, Moscow), through the courtesy of the authors of Ref. [4], and (b) synchronous measurements of the alpha-decay rate from ^{239}Pu source in Pushchino by our standard techniques [5–8]. The measuring system of the neutron monitor consisted of an array of detectors arranged in one horizontal layer without shields, which registered neutron fluxes coming from any directions [4].

In this case the histograms were constructed from 30 measurements (over 30 minutes). Four synchronous data arrays of 60 histograms each were analyzed, which amounted to $60^2 \times 4 = 14400$ comparisons. Of these, 1192 pairs were found similar, or 8.3%. The number of synchronous pairs was 240, of which 58 were similar, or 24%. The probability of random occurrence of such an event is less than 10^{-12}.

This experiment also gives convincing proof of synchronous variation of the fine structure of distributions governing the measurement results for processes of different nature using various methods, and with large distances between the measuring stations.

From Figs 3 and 4 we see that the fine structure of distributions of the measurement results for processes of different nature, produced with various methods, varies synchronously in *Dubna, Moscow and Pushchino, in laboratories 100 to 200 kilometers away from one another*.

These results offer a good illustration of the adequacy of the visual methods employed for comparison of histograms and prove the existence of the phenomenon under discussion.

5. "Cosmophysical periods"

The most important evidence of the cosmophysical origin of the phenomenon under consideration is the existence of characteristic periods in the distribution of the time intervals between histograms of similar shapes. The absence of effects stemming from synchronism, close neighbors and 24-hour histogram period (as follows from arguments developed above) only points to the inadequacy of the standard methods used in Ref. [2] for selecting the like histograms.

The absence of a peak at 48 hours in Fig. 6 of Ref. [1], as noted in Ref. [2], can be attributed to the 'nontransitive' similarity of the histogram shapes. This means that the fact that histogram A is similar to histogram B, and histogram B is similar to histogram C (where serial histograms A, B and C are separated by 24 hours) does not imply that histogram A is similar to histogram C. So the period of 48 hours may be absent. It may be present though — see Fig. 5, which shows the distribution plotted from the results of measurements of alpha activity from ^{239}Pu source in Pushchino in January 1998. Here histograms of similar shape are likely to reappear not only after 48 hours, but also after 72 hours. We published analogous results a few years ago [7].

6. Discussion. Hypotheses

In Ref. [1], like in some earlier papers, we only tasked ourselves with the proof of the 'theorem of existence'. Now we suppose that this theorem has been proved. The analysis of critical feedback has strengthened our assurance. Everything points to the existence of a very exotic phenomenon, whose interpretation may require making quite extravagant assumptions. Some of them can be found in Refs [1, 5–9].

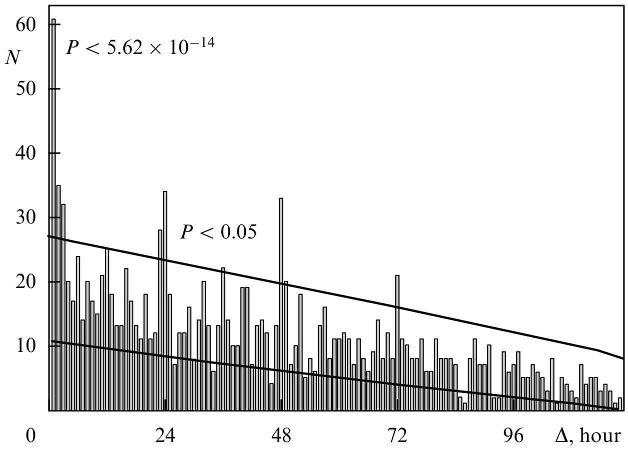

Figure 5. Illustration of the effects of 'close neighbors' and the 24-hour period with histograms plotted from measurements of alpha activity from ^{239}Pu source in Pushchino. An increased likelihood of similarity is observed both for nearest neighbor histograms and for histograms separated by 24, 48, and even 72 hours.

We would like to make a reference to the work of L A Blumenfeld [10], who proposed an explanation of independence of the observed effects from the range of energy variation in different processes (for example, in alpha decay and in chemical reactions). According to L A Blumenfeld, we may be dealing with the influence of low-frequency electromagnetic fields on transient complexes whose states do not depend on the depth of the 'potential well'.

In this article we just point out once again that the synchronous changes of the fine structure of histograms for independent processes, including those separated by hundreds and thousands of kilometers, and the reoccurrence of histograms of a given shape with periods of 24 hours, 27 days, and 1 year, are indications of the global scale of the phenomenon being discussed.

These regularities may be a consequence of the inhomogeneity of the surrounding world. The Earth rotating around its axis exposes the objects located on its surface to different points in the nonhomogeneous Universe, and first of all to the Sun. This causes reoccurrence of similar-in-shape histograms with the period of 24 hours. Rotation of the Sun around its axis may be the cause of histogram periods equal to 25–29 days. Orbital motion of the Earth around the Sun may naturally lead to the period of one year.

From this hypothesis we evolve our plans for future investigations, and we invite other researchers to join us. We consider it worthwhile to create a global network for monitoring the macroscopic fluctuations, which will include the ever-operating radioactivity counters placed at different geographical locations, and sending the results to a single computerized data bank (archive). No less promising would be such monitoring aboard satellites orbiting the Earth (then one could expect reoccurrence of similar histograms with the orbital period). Of course, owing to the greatly increased volume of measurement data, the success of such a project will depend on the development of computer-assisted methods for comparing the shapes of histograms. We do not give up hope of succeeding in this challenging undertaking.

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Notes added in prof

Having read all comments and remarks, we feel that our opponents in a sense are 'running in circles', asking questions which have already been answered. In paragraph 3 of their 'Notes added in prof', for example, A V Derbin with colleagues tell us that the number distribution of similar histograms in our paper differs from binomial distribution, although, as follows from our arguments, it is not expected to be binomial because the binomial scheme is applied to each distance separately. Further in paragraph 4 our opponents disclose that the maxima may or may not be repeated every 24 hours and 48 hours, but this has been indicated in our text earlier, etc. Incidentally, the drawing of A V Derbin with colleagues clearly show the fine structure of discrete distributions.

We believe that this naturally winds up the discussion. We are deeply grateful to all who expressed their interest and concern, and appreciate the opportunity to discuss once again the phenomenon of macroscopic fluctuations.

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