Periodic Changes in Beta Decay Rates

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Some of the results obtained with multichannel installation created for investigation of various processes, including α and β decays, with simultaneous recording of environment parameters, are presented. The experimental setup has been in operation for more than 13 years practically continuously. While measuring the decay rates of the ^{60}Co and ^{90}Sr-^{90}Y β sources, rhythmic changes of 0.3 % in average magnitude with a period of 1 year, and up to 0.02 % with a period of about one month were detected. Periodic patterns in the decay rate of α sources ^{239}Pu have not been detected. Our findings are compared to similar results of other researchers. The arguments of opponents are analyzed.

Until recently it was believed, that the nuclear decays are caused exclusively by *intranuclear* processes, which cannot be noticeably modified by common external influences (electromagnetic, thermal, acoustic, etc.). Therefore, measurements of radioactive decay rates should reveal exponential time dependence with chaotic fluctuations obeying the Poisson distribution. All the experiments performed so far seem to be consistent with this prediction. But recently, with the advent of computers, it has become possible to organize long-term precise measurements, and some of the results obtained in this way could be interpreted as evidence of the presence of rhythmic and sporadic deviations from an exponential decrease. The hints at a possibility of deviations from the exponential decay law emerged, for example, during long-running experiments with the aim of determining half-lives of long-lived radionuclides [1]. Results, obtained with our purpose-built installation for long-term recording of radioactive decay rates, offer further evidence in favor of existence of such effects.

Experimental setup.

In itself, detection of *variations in radioactivity measurements* does not represent a proof of the presence of *variations in the rate of radioactive decay*. The observed deviations are very small and vary on large time scales. Therefore, it is necessary to extend the recording period to months or even years. Collecting large data samples and reducing the instability of registering equipment are essential during such precision measurements.

In order to obtain results of measurements which could with some confidence be interpreted as variations in radioactive decay rates, an experimental installation capable of long-term measurements of count rates from several α and β sources was built. The external factors which could introduce errors in the data (temperature, atmospheric pressure, humidity, radiation background, voltage level of power supply unit) are being constantly monitored and controlled. The detectors, rather stabiles and possessing practically unlimited resource - halogen G-M counters were applied to registering a β and γ radiation, the silicon detectors were employed to detect α particles. The detectors, along with radioactive sources and power supplies, are enclosed in a thermostat. The installation works practically continuously on stretch 13 years. More detailed description of experimental installation and techniques of signals registration can be found in [2, 3, 4].

Basic results

Figure 1 shows, as varies the count rates from ^{60}Co and ^{90}Sr-^{90}Y β sources, measured by various detectors on stretch more than 10 years. Rhythmic variations with amplitudes of 0.3 % from the average value with the period of a 1 year are obvious. The comparison of average courses of a count rate and temperature near the installation (Fig.2) reveals different dynamics of year cycles. Other basic parameters of an exterior medium such as radiation background, atmospheric pressure and air humidity, power voltage levels, also exhibit no apparent correlations with the dynamics of decay rates. It allows to state, that detected variability in count rates is not a result of some influences by the environment.

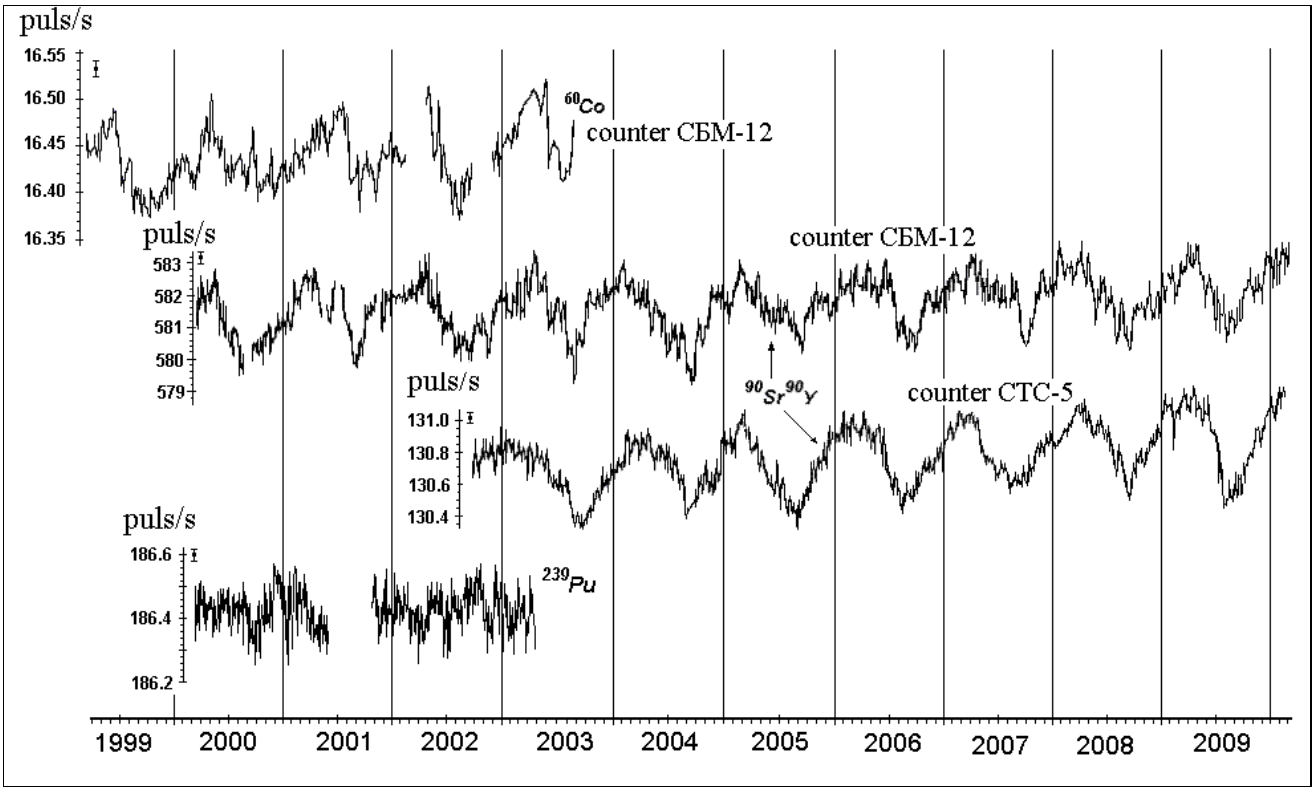

Fig. 1. Count rates for ^{60}Co and ^{90}Sr-^{90}Y β sources measured by G-M counters, adjusted for a decrease in source activity with half-lives of 5,27 and 28,6 years, and count rate for ^{239}Pu α source measured by the silicon detector [3, 5].

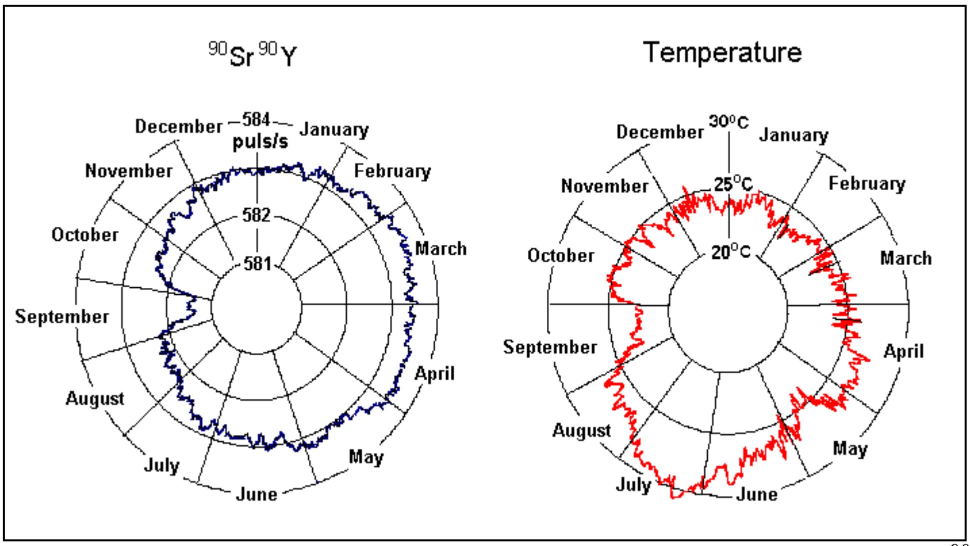

Fig. 2. Comparison of an average count rate for ^{90}Sr-^{90}Y β source with temperature variations near the installation. The results obtained since April 2000 till March 2007 are treated.

Large duration of measurements and sufficiently high number of data samples enabled us to apply the frequency analysis and to construct periodograms. On the periodogram of the count rate of the device with ^{90}Sr-^{90}Y source (Fig.3), the 1-year period and its harmonics (182, 91.5, 61 days) are the most prominent. The period of the lunar month (29.27 days) is shown also. This rhythm can be seen especially clearly by averaging the results on cycles of synodical lunar month. Near the new moons the count rates are on average 0.02 % higher than those for full moons (Fig. 4).

In the area of the periodogram around 1 day period, peak of the solar day, along with a fine structure reflecting interaction of this rhythm with the annual period and its harmonics, can be seen readily. The peak corresponding to the lunar day (1.0375) is also present. The amplitude of these diurnal changes does not exceed 0.003% and, in contrast to the annual and monthly variations, it is impossible to state with confidence that they are not caused by temperature changes.

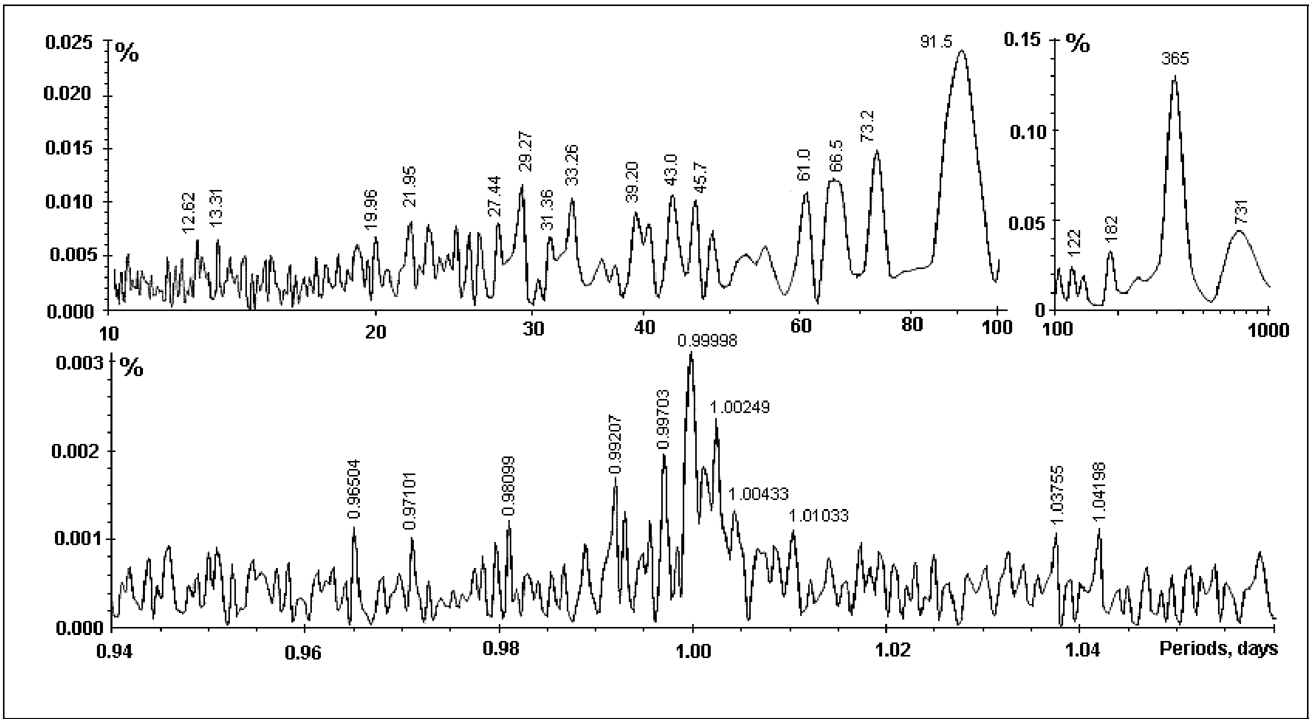

Fig. 3. Periodograms of count rate variations for the ^{90}Sr-^{90}Y β source with the G-M counter СБМ-12. The corresponding data were recorded between April 2000 and March 2007. Amplitude deviations are shown as percentage of the average count rate [3, 5]. The numbers near the peaks represent values of the corresponding periods in days.

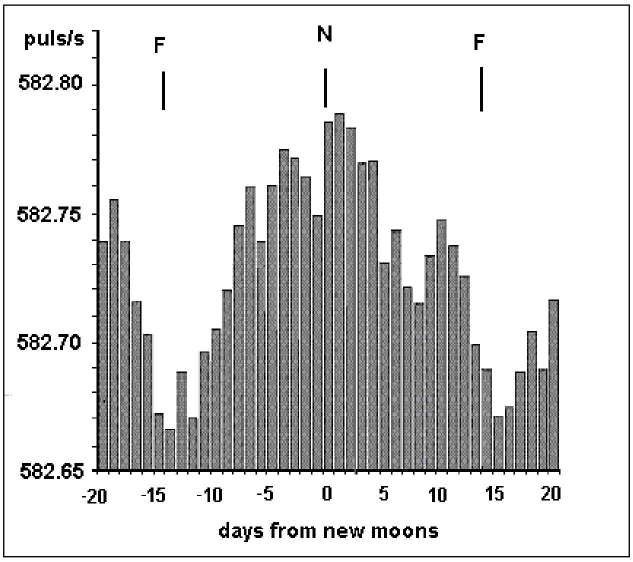

Fig. 4. 87 cycles of synodical lunar month average for the ^{90}Sr-^{90}Y β source count rate with the G-M counter СБМ-12 (April 2000 - March 2007). N – new moon, F – full moon.

It is important to note, that the experiments detected rhythmic variations in count rates only for measurements of β radioactivity. Similar tests of α decays from ^{239}Pu source using a silicon detector, which is practically insensitive to β and γ radiation, have not revealed any periodic patterns in the count rate. The observed chaotic fluctuations with a magnitude of the order 0.1% from the average count rate (see Fig. 1) are likely to be caused by noise processes in the silicon detector and recording electronics setup. This conclusion is confirmed by results of long-term registrations of α particle emissions from one ^{239}Pu source by two silicon detectors (Fig.5).

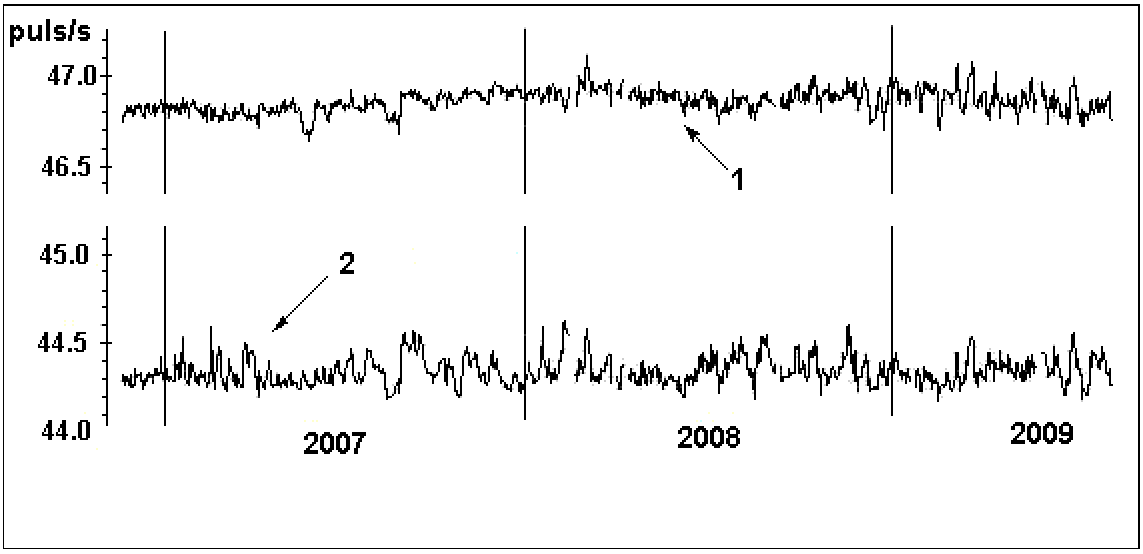

Fig. 5. Count rates for one ^{239}Pu α source, registered by two silicon detectors.

Experiments of other researchers

The annual rhythm has been found in Troitsk during a series of spectrometric measurements of tritium β decay with the aim of determining mass of the electron antineutrino [6] (Fig. 6). Monthly and diurnal rhythms have been observed in experiments registering gamma radiation from ^{60}Co and ^{137}Cs sources by a NaJ(Tl) detector (Dubna) [7]. In paper [8] (Dubna and Troitsk), presence of diurnal variations in data samples from ^{60}Co and ^{137}Cs γ radiation measurements by Ge(Li) detector is revealed. However, it is necessary to concern with caution to these dates, as their magnitude (up to 0.7 %), is improbably great. In our experiments, the value of diurnal fluctuations in count rates does not exceed 0.003 % for ^{90}Sr - ^{90}Y source and 0.01% for ^{60}Co source.

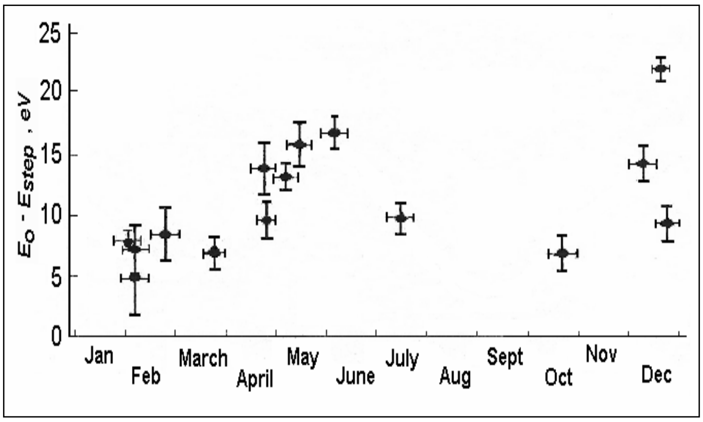

Fig. 6. Results of the Troitsk experiment [6]. Annual dynamics of the difference between theoretical and experimental segments of a spectrum of tritium β decay near the maximum electron energy (1994-2001).

Annual rhythm in radioactive decays can manifest itself in measurements of half-lives of long-lived radionuclides. This effect was clearly visible during attempts to determine half-life of ^{32}Si [1] (Brookhaven National Laboratory). For measurements of β activity, a gas-flow proportional counter was used. The results of measurements covering a time span of more than four years are shown in Fig. 7. Simultaneously the same counter was also used to register the activity of a slowly decaying ^{36}Cl sample (with half-life $3 \cdot 10^5$ years) with the purpose of compensating for instabilities of the equipment. It is visible, that the count rates for both radionuclides vary synchronously with amplitude of 0.2 – 0.3 % and a period of 1 year.

Rhythmic deviations from average value with approximately the same magnitude and period of 1 year have been detected in 15-year's ^{226}Ra radioactivity measurements involving ionization chamber (Fig. 8) [11] (Physikalisch-Technische-Bundesandstalt in Germany).

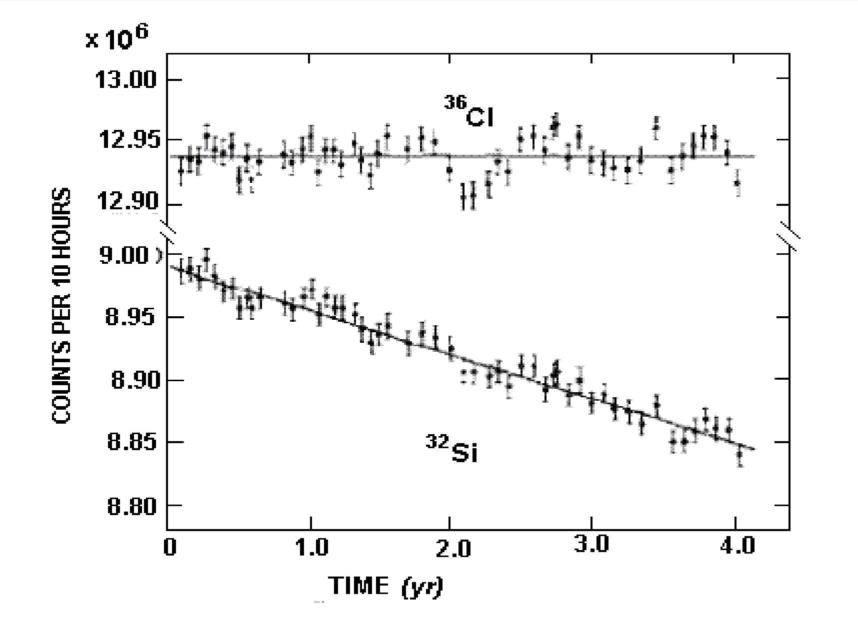

Fig. 7. Periodic changes in count rates for ^{32}Si and ^{36}Cl [1]

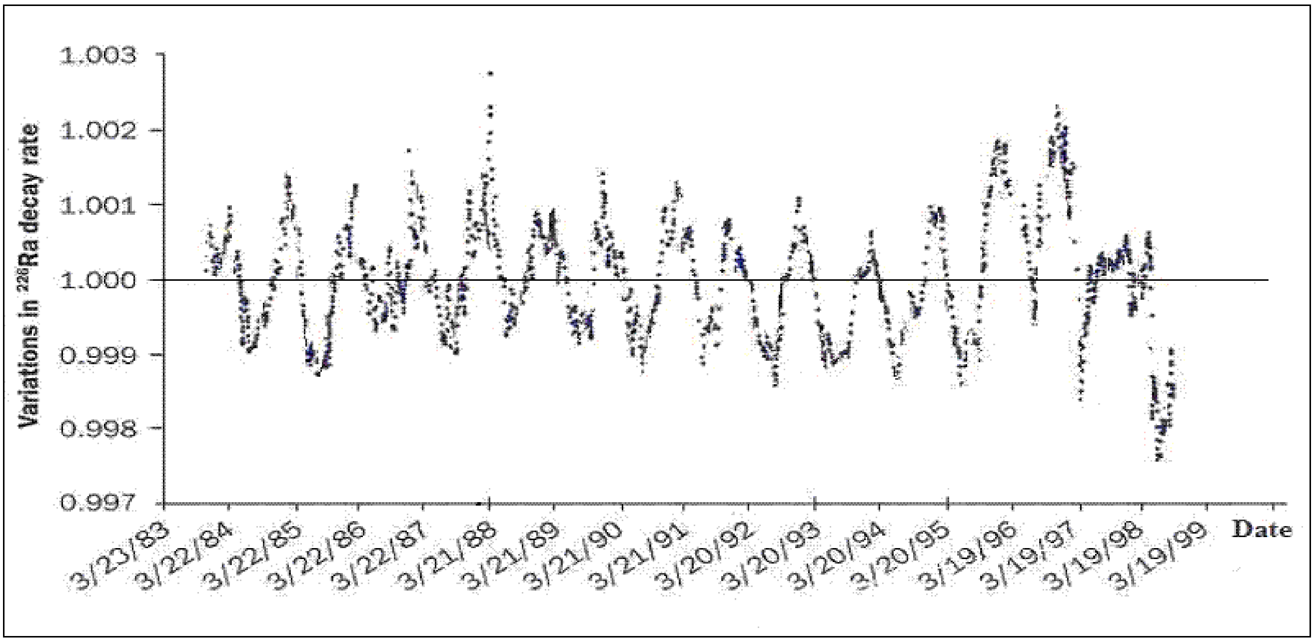

Fig.8. Deviations of ^{226}Ra count rates from average value [11].

Discussion

Quite naturally, the results described above are highly controversial from the traditional point of view on radioactivity. Let's consider the arguments of the opponents, exemplified by [12, 13].

1. γ radiation measurements with germanium detector of count rate ratios for $^{22}Na\,/\,^{44}Ti$, $^{241}Am\,/\,^{121}Sn$ и $^{133}Ba\,/\,^{108}Ag$ did not reveal any authentic modifications with a 1-year period. This fact is used to conclude that the effect of rhythmic variations of radioactive decay rates does not exist [12].

But the constancy of a ratio does not mean an invariance of the numerator and denominator. It can be connected to uniformity modifications in the registered count rates. And the reason uniformly influencing to results of measurements, is not necessary connected to instability of the measuring equipment. Therefore, lack of variations in the ratio of radioactivities does not mean a lack of variations in radioactivities of separate radionuclides. Instability of equipments and action of varying temperature, pressure, humidity etc. are very various in different laboratories. Nevertheless, periods, phase and magnitude of the effects found in measurements of decay rates of various radionuclides in several laboratories with differing equipment are very close. It indicates existence of the nontrivial reason uniformly influencing to activity of various radionuclides at different times and in different places.

2. In [13], data from ^{238}Pu radioisotope thermoelectric generators aboard the Cassini spacecraft are analyzed. For distances from the Sun in the range from 0.7 to 1.6 a.u., the deviation from an exponential decay curve was found to be less than 0.01%. Based on this, the ideas about correlations of decay rates with the distance between the Earth and the Sun [9, 10] were rejected.

But since the power output ^{238}Pu is almost completely provided by α decays, the results of analysis of the Cassini spacecraft power source hold true for ***α decays only,*** and represent an independent confirmation for a conclusion about a lack of noticeable anomalies in the rate of α decays, which emerged from the analysis of our experiments [3, 5].

All the currently known results, which seem to suggest the existence of anomalies in radioactive decay rates, pertain to ***β*** radioactivity. At first sight, this statement is in contradiction with an annual rhythm found in measurements of ^{226}Ra activity [11] (Fig 8). But ^{226}Ra is ***not only an α*** source, as it generates a long decay cascade including not only *α*, but also β decays. For radioactivity measurements of ^{226}Ra, the ionization chamber was used. This kind of detector is sensitive to β and γ radiations. Usually ^{226}Ra sources are placed in hermetic ampoules which are not passing α particles. In this case registered effect is connected to a β and γ radiation completely. Therefore, the presence in radioactivity measurements ^{226}Ra of variations with 1-year periodicity can be connected with a β radioactivity. The experiment [11] cannot be used to draw any conclusions about presence of such variations in α decay rates.

So, the results of the analysis of the Cassini spacecraft power output seem unlikely to refute the idea about possible correlation of β radioactivity decay rates with the distance between the Sun and Earth, because this effect is not present in α decays. Other matter, that idea about connection of changes of radioactivity with 1-year period with Sun neutrino fluence oscillations [9, 10] looks extremely doubtful because of exclusive weakness of interaction such neutrino with substance. On the other hand, presence of this effect for β decays and its lack for α radioactivity hints at a possible involvement of neutrino in this phenomenon (neutrino are an essential ingredient in β processes, but do not take part in α decays). It is conceivable that these periodic variations are related to streams of "relic" neutrino [14, 15]. A hypothesis about a probable role of relic neutrino offered also for explanation of the vague effects which have been observed at a measurement of neutrino mass [6]. The substantiation of these ideas requires the special consideration.

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