Radioactive Decay Caused by Neutrinos?

Eckhard Dieter Falkenberg
Uhldingen, Germany
e.falkenberg@efsystems.fn.shuttle.de

The result of a long-term experiment is presented and discussed. The experiment aimed at testing the hypothesis that radioactive ***b***-decay might be caused by the omnipresent neutrino flux coming from the sun and other sources, by trying to find a positive correlation between the decay rate of tritium and the annually varying solar neutrino flux, due to the annually changing distance from sun to earth.

Keywords: Radioactivity, Radioactive decay, Neutrinos, Solar activity, Determinism, Quantum mechanics, Causality, Tesla

1 Introduction and Approach

The idea that our world might function in a principally deterministic way, whereby seemingly probabilistic phenomena such as radioactive decay would be in fact merely pseudo-probabilistic, has been dismissed after the development of quantum mechanics. In contemporary physics, it is well-known and widely accepted that radioactive decay is governed by quantum-mechanical tunnel effects, and thus occurring in a purely and genuinely random way.

Dependencies of radioactive decay rates on various parameters such as temperature, pressure, electric and magnetic fields, and molecular structures were measured [*e.g.*, 1, 2]. Those measurements reveal most often only very small dependencies, and it is doubtful whether they really challenge the supposed principle of genuinely probabilistic phenomena, since they possibly can be explained in terms of more or less small variations of the quantum-mechanic tunnelling parameters.

Especially in the early days after detecting the phenomenon of radioactivity, there have been speculations that radioactive decay might be caused by hitherto unknown, external causes, and thus might not occur in a genuinely random way. Most famous is Albert Einstein's metaphor "God is not a gambler." Not quite so well known is Nicola Tesla's speculation that radioactivity might be caused by small particles which are omnipresent and capable of passing any (non-radioactive) matter almost without leaving any traces [3].

Neutrinos fit that description very well. A part of the omnipresent neutrinos come from the sun. The distance from sun to earth varies periodically with a period of 365 days, with the minimum distance around mid January and the maximum distance around mid July. Consequently, the solar neutrino flux on earth should change approx. sinusoidally throughout the year, with the maximum around mid January and the minimum around mid July, under the assumption that the number of neutrinos produced by the sun and radiated towards the earth remains fairly stable. The relative peak amplitude of the annual neutrino flux variation on earth should in this case be approx. ± 3.3%. If Nicola Tesla were right, there should be some periodic, approx. sinusoidal variation of the decay rate of radioactive substances, with a period of 365 days and its positive peak around mid January.

In the early 1980s, I performed an experiment which took one and a half years, in order to test a part of that hypothesis. The approach was to monitor the β-decay rate of tritium and to analyze the resulting decay curve, whether there would be any periodic deviation from the aperiodic decay.

Note that whenever the term ‘periodic’ is used in this paper, it means ‘periodic with a period of 365 days’, unless stated otherwise.

2 Apparatus

A strip of phosphorescent material containing tritium was placed in front of an array of photo diodes. The sum of the photo currents was amplified, low-pass-filtered and displayed on a 3½-digit display. A block diagram of the apparatus is shown in Figure 1.

Special care was taken to avoid any effects from summer/winter temperature differences, humidity changes and other unwanted seasonal effects and long-term drifts. The phosphorescent material and the adjacent array of photo diodes were placed in a small light- and air-proof, sealed container. A precisely stabilized power supply was used. For amplification, a low-offset, low-drift operational amplifier was applied. The limiting frequency of the low pass was approx. 1/min. The overall temperature drift of the monitoring system was +0.35%/°C. The critical parts of the system were thoroughly shielded against light and electromagnetic radiation, and put into a temperature-stabilized container. A precision PID temperature controller kept the temperature in the container at 23.0°C, with ± 0.01°C short-term stability and ±0.08°C long-term stability. The apparatus was placed and operated in a basement where the temperature was almost independent from seasonal changes, 17 ± 2°C.

By these measures, noise as well as long-term drifts of the monitoring system were kept to a minimum, better than ± 0.1%, including the rounding error of the 3½-digit display.

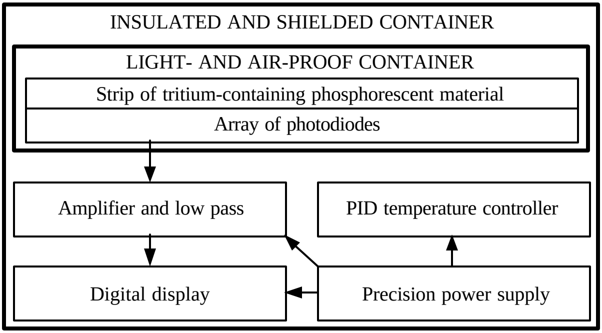

Figure 1: Block diagram of the apparatus

3 Experimental Results and Data Analysis

The experiment was performed from fall 1980 to spring 1982, for 553 days. The stability of the apparatus was tested in an initial phase of the experiment. It was verified that there was no short- or long-term noise larger than the expected experimental error (± 0.1%). In particular, there were no detectable differences between measurements taken during the day compared to those taken at night. After that initial phase altogether $n = 73$ measurements were recorded, approx. one per week. The raw experimental data $M(t)$ are graphically represented in Figure 2.

The data in Figure 2 are the combined result of the decay of tritium, the degradation of the phosphorescent material, and other degradation effects. This overall decay and degradation is significantly faster than the decay of tritium alone.

Due to the long-term stability of the apparatus and the suppression of seasonal changes of the external conditions, it is a reasonable assumption that degradation took place in an aperiodic way.

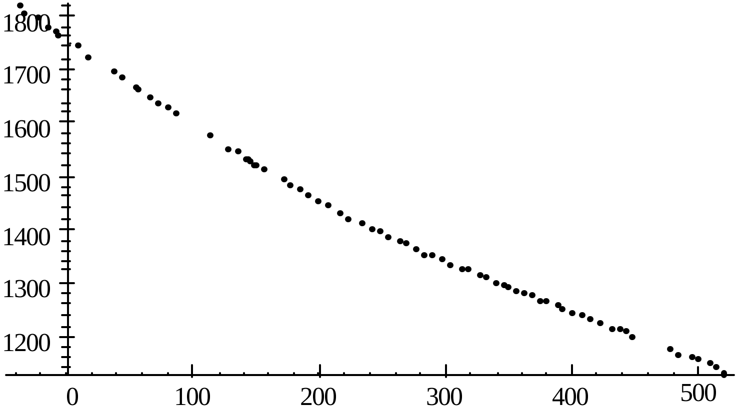

Figure 2: Graphical representation of the raw experimental data
Legend: Abscissa: Time t in days; t = 0 is 1 January 1981, 0.00 MET
Ordinate: Measured values M(t); n = 73 measurements

The degradation is partially dependent on the decay rate of tritium. The experimental data are therefore, in any case, not matched by a plain exponential function. However, if one makes the usual assumption that tritium, like any other radioactive matter, decays exponentially, the data will be matched by an aperiodic function, regardless of the dependency of the degradation on the decay rate of tritium.

The degradation is practically not calculable, but nevertheless empirically derivable from the experimental data, by finding an aperiodic function matching them reasonably well.

If the decay rate of tritium varies periodically, the experimental data will show some periodic deviation from that aperiodic function, and vice versa, if there is any periodic deviation from an aperiodic function, it will be due to a periodic variation of the decay rate of tritium, provided the apparatus was indeed suppressing seasonal changes of the external conditions reliably.

In order to determine whether there are any significant periodic deviations from an aperiodic function, the experimental data were subjected to the following analysis procedure. It aims at a clear separation of the inevitable aperiodic decay and degradation effects from potential periodic effects:

I Specification of an aperiodic function $A(t)$, such that the standard deviation S_a of the n experimental data $M(t)$ from $A(t)$ becomes a minimum. S_a is calculated on the basis of the relative differences $R(t)$ in the following way:

$$R(t_i) = \frac{M(t_i) - A(t_i)}{A(t_i)} \quad \text{for } i = 1..n$$

$$S_a = \sqrt{\frac{\sum_{i=1..n}\left[(R(t_i))^2\right]}{n-1}}$$

$$\Rightarrow \quad \text{minimum } S_{am} \quad \Rightarrow \quad \text{best fitting } A_o(t)$$

II Specification of a cosine function $P(t)$ with a period of 365 days, such that the standard deviation S_p of the n relative differences $R(t)$ from $P(t)$ becomes a minimum:

$$S_p = \sqrt{\frac{\sum_{i=1..n}\left[(R(t_i) - P(t_i))^2\right]}{n-1}}$$

$$\Rightarrow \quad \text{minimum } S_{pm} \quad \Rightarrow \quad \text{best fitting } P_o(t)$$

The result of this procedure, $R(t)$ and the cosine functions presenting the upper and lower bounds for 95% of $R(t)$, is shown in Figure 3.

One of the best fitting aperiodic functions $A_o(t)$ has turned out to be a plain exponential function reflecting the decay of tritium (where the factor d is the decay rate of tritium, equivalent to its half-life of

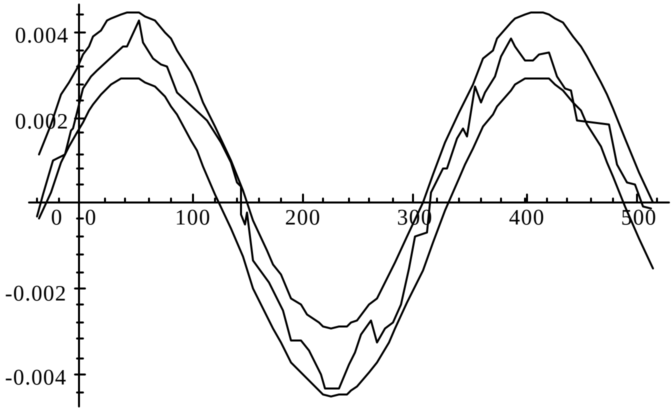

Figure 3: Result of the analysis procedure
Legend: Abscissa: Time t in days; t = 0 is 1 January 1981, 0.00 MET
Ordinate: R(t), upper and lower bounds ($P_o(t) \pm T_{pm}$) for 95% of R(t)

12.35 years [4]), multiplied by an exponential function with a non-linear exponent containing itself an exponential function, reflecting the degradation effects (factor *c*).

$$A_o(t) = b \times e^{-d \times t} \times e^{-(1 - e^{-c \times t})}, \text{ with}$$

- $b = 1750.5$
- $d = 0.1538 \times 10^{-3}$ / day
- $c = 0.82965 \times 10^{-3}$ / day

For that aperiodic function, the minimum standard deviation is:

$$S_{am} = \pm 0.257\%$$

The best fitting cosine function $P_o(t)$ has its positive peak around mid February and a peak amplitude $a = 0.37\%$:

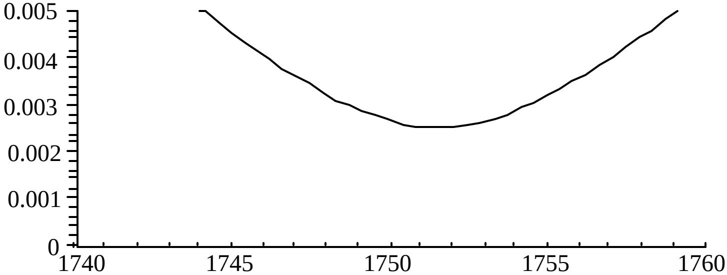

Figure 4: S_{am} dependent on b, whereby $c = 0.82965 \cdot 10^{-3}$/day

$$P_o(t) = a \cdot \cos(2\pi \cdot t / 365\text{days} - p), \text{ with}$$

- $a = 0.0037$
- $p = 0.81$ (47 days phase shift from $t = 0$)

The corresponding minimum standard deviation is:

$$S_{pm} = \pm 0.040\%$$

This implies for the given number of measurements $n = 73$, that for 95% of the experimental data $M(t)$, the deviation of $R(t)$ from $P_o(t)$ is within:

$$T_{pm} = 2 \cdot S_{pm} = \pm 0.080\%$$

There is only one measurement value outside this range (–0.1%). For the statistical certainty of 95%, the overall confidence range is:

$$C_{pm} = \frac{T_{pm}}{\sqrt{n}} = \pm 94 ppm$$

The minimum standard deviation for the periodic case, S_{pm}, is very well compatible with the expected experimental error of the monitoring system. It is only about double the calculated "rock-bottom" standard deviation S_r for this experimental set-up, which is due to the rounding error of the digital display:

$$S_r = \pm 0.018\%$$

For judging whether there is indeed a clear separation of the aperiodic decay and degradation effects from periodic effects, it is useful to calculate the ratio between the standard deviations for the aperiodic and for the periodic case:

$$Q_{ap} = \frac{S_{am}}{S_{pm}} = 6.4$$

This is a fairly clear indication that there is indeed a significant periodic, sinusoidal deviation from the aperiodic effects.

The result of the above procedure turned out to be fairly insensitive with respect to the choice of the kind of aperiodic function $A(t)$. Several kinds of aperiodic functions were applied to find an optimum $A_o(t)$. All of them gave almost the same relative differences $R(t)$, with almost the same values a and p for $P_o(t)$, with almost the same standard deviations S_{am} as well as S_{pm}, and with confidence ranges C_{pm} within ± 100 ppm. The above specified function $A_o(t)$ is not better than some others from a statistical analysis point of view, it only has the additional feature to clearly separate the pure tritium decay rate from the degradation effects. The procedural result is necessarily very sensitive with respect to the choice of the aperiodic parameters b and c, and is also quite sensitive with respect to the choice of the periodic parameters a and p. Figures 4–7 show the dependencies of the standard deviations S_{am} and S_{pm} on these parameters.

4 Discussion of Experimental Results

There are three major questions to be discussed:

a) Due to the relatively fast and hardly calculable degradation, can one derive from the experimental data with sufficient confidence,

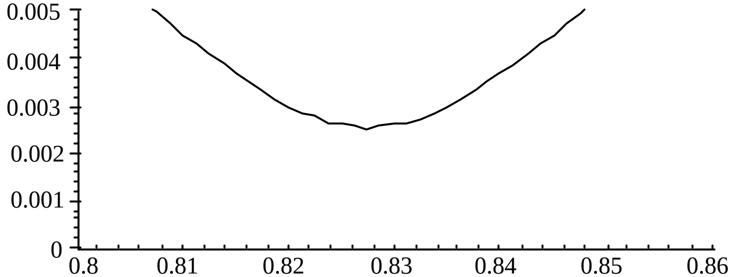

Figure 5: S_{am} dependent on c ($\cdot 10^{-3}$), whereby b = 1750.5

that there is indeed a periodic deviation from the aperiodic degradation and decay?

b) If there is indeed a periodic deviation, is it due to

- a systematic periodic error caused by an inadequately constructed apparatus, or to
- a periodic variation of the decay rate of tritium?

c) If there is indeed a periodic variation of the decay rate of tritium, what is its cause?

Question (a) has already been answered. It is true that there are much better methods to measure decay rates than the one applied, where a significant degradation of a part of the monitoring system took place. However, the applied data analysis has filtered out that effect quite reliably. The ratio between the standard deviations for the aperiodic and the periodic case, $Q_{ap} = 6.4$, is fairly significant. Thus, according to the applied data analysis, there is little doubt that there is indeed an approx. sinusoidal relative deviation from the aperiodic degradation and decay, with approx. ±0.37% peak amplitude and a period of 365 days, in spite of the relatively short observation time of approx. 1.5 periods.

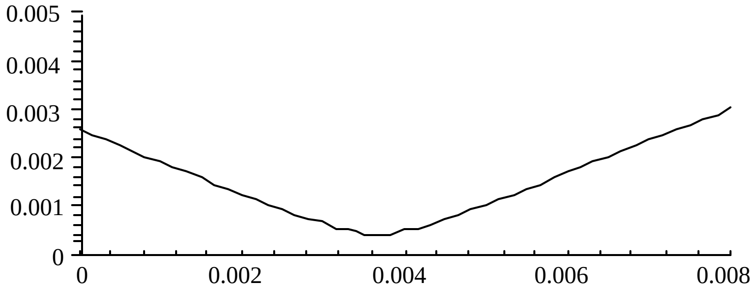

Figure 6: S_{pm} dependent on *a*, whereby *b* = 1750.5, *c* = $0.82965 \cdot 10^{-3}$/day, *p* = 0.81

Question (b) is more crucial and difficult. It is obvious that long-term experiments aiming at detecting small periodic variations where the period is very long, are inherently tricky. However, I am confident that seasonal changes of the external conditions (temperature, *etc.*) were ruled out by the construction of the apparatus or at least smaller than the periodic variation measured. Nevertheless, it is just an educated guess that the periodic variation measured is indeed a variation of the decay rate of tritium.

If this were true indeed, then I would answer question (c) as follows: The phase of $P_o(t)$ is such that the positive peak is around mid February, quite close to the expected positive peak if one assumes that b-decay is caused partially by the periodically varying solar neutrino flux and partially by a supposedly more constant neutrino flux from other sources. In my view, this phase match, as well as the fact that the periodic variation is approx. sinusoidal, are fairly strong arguments in favour of that hypothesis.

The following considerations are made under the assumption that the hypothesis is true indeed:

If there were no other neutrino sources than the sun, then the expected peak amplitude of $P_o(t)$ would be approx. $\pm 3.3\%$. That is

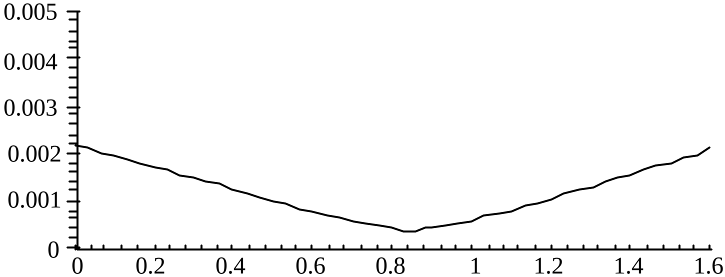

Figure 7: S_{pm} dependent on p, whereby b = 1750.5, $c = 0.82965 \cdot 10^{-3}$/day, a = 0.0037

approx. 9 times more than the measured amplitude of ± 0.37%. This implies that the neutrino flux from other sources has an approx. 8 times stronger effect on *b*-decay than that from the sun.

As stated above, the deviation of $R(t)$ from $P_o(t)$ is statistically within T_{pm} = ± 0.080% for 95% of the experimental data, and *de facto* within ± 0.1% for all data. Since these ranges are very well compatible with the expected experimental error (better than ± 0.1%), it would hardly make sense to look for harmonics (*i.e.*, to perform a complete Fourier analysis), or for any further potential correlation between the experimental data and other parameters modifying the solar neutrino flux on earth non-annually, such as long-term fluctuations of solar activities. In spite of the little chance, I tried to find a correlation between the deviation of $R(t)$ from $P_o(t)$ and the daily sunspot numbers on the relevant days in the years 1980 to 1982 [5]. I did not find such a correlation.

The hypothesis does not say in which way neutrinos would cause radioactive decay. Results of contemporary particle physics indicate that it would be very unlikely that neutrinos are used up by the decay in some way and transformed into some end-products of the decay. It would be more likely that neutrinos only trigger the decay, without being transformed themselves into other particles, similar to catalysts in chemistry.

Note that exact calculation will reveal some slight phase shift and amplitude change of the periodic function $P_o(t)$ representing the periodically varying decay rate of tritium, due to the influence of the decay rate on the number of remaining tritium atoms. However, these influences are too small to change the result significantly.

5 Conclusions

It is clear to me that most contemporary physicists will dismiss this experiment and its results out of hand, since according to quantum mechanics, radioactive decay occurs in a genuinely random way, and is, at least to a large extent, independent from any external causes. They will simply assume a systematic experimental error due to seasonal or other influences.

My own position about this experiment is as follows: Taking all arguments into account, I consider the hypothesis that *b*-decay is caused by neutrinos, although not really proven beyond doubt, a realistic possibility, realistic enough to justify further research about it. It is my educated guess that on earth, there is a positive correlation between the periodically changing solar neutrino flux and the β-decay of tritium.

Further research does not necessarily only mean new and better experiments. The best option would of course be to perform an experiment of this sort on board of a space ship travelling further away from or closer to the sun than the earth does. However, earth-bound investigations may be useful as well. For example, there have been numerous measurements of decay rates performed world-wide over the years. A statistical analysis of all those measurements would be already very helpful to further test the hypothesis, provided the calendar dates of the measurements were recorded and the relative experimental errors were smaller than, say, ± 0.37% or so.

If the hypothesis is true indeed, numerous questions will have to be raised, such as:

- Does the same principle apply to *a*- and *g*-decay, and to other quantum-mechanical tunnelling effects as well?
- Which influence has neutrino velocity or energy on radioactive decay?
- Do the various kinds of neutrinos have different effects on radioactive decay?
- In which way will quantum theory be affected?
- Do the contemporary positions about randomness on the quantum level need to be revised?

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