Does Radioactivity Correlate with the Annual Orbit of Earth around Sun?

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In a previous issue of this journal [1] E.D. Falkenberg reported on a long-term experiment concerning the radioactive ß-decay of tritium. He tried to prove a correlation of the radioactive decay with the annual path of our earth around the sun by means of a sophisticated analysis of his experimental data given in [1], Fig. 2. We shall approach Falkenberg's ideas in three steps. In Section 1 we shall analyse the experimental database independently, showing that the data can be described in good approximation by two different decreasing exponential functions that are pasted together near t = 223. If this effect were—according to Falkenberg's conjecture—caused by the earth's passing its aphelion on its orbit around the sun, then analogous effects should appear near the perihelia, but no irregularities can be seen there. Hence the irregularity near t = 223 could be caused by other reasons, namely, by a sudden change of the relevant physical conditions. In the following Sections we shall analyse Falkenberg's method of detecting a background effect in his database. In Section 2 we shall see that Falkenberg's method yields effects that are strongly depending on the measurements interval selected from his database. Hence the detected

background effects cannot have causes in physical reality. Finally in Section 3 we shall analyse Falkenberg's method from a mathematical point of view. The result is that Falkenberg's idea of detecting background effects by applying a least squares method is erroneous: He takes the "optimal" solution given by his method to be the *true* solution, but this is—as will be shown—a flawed reasoning.

Keywords: Radioactivity, Neutrinos, Solar activity, Determinism, Quantum mechanics, Causality

1 Analysing the data

Since Figure 2 in [1] is not sufficient for a mathematical analysis of the data, I asked E.D. Falkenberg for the data in form of a numerical list. Falkenberg was so kind as to send me his data of 73 measurements $[t, M(t)]$ (attached in the Appendix) adding the comment that he wondered what an analysis of the data by a mathematician could bring out in addition.

Now, here is the result:

First of all I plotted the graph of the measurements $[t, M(t)]$ (see Fig. 1). A careful examination of the graph of $M(t)$ seems to show a slight corner at $t_1 = 223.4$. In order to consider the graph in more detail we make use of a kind of "microscope."

We know from experience that radioactive decay is (at least roughly) governed by exponential decrease. Hence we remove the exponential function by taking the logarithms of Falkenberg's original data $M(t)$. Then we add an appropriate linear function which brings the values of $\log M(t)$ at the ends of the observation interval $[t_0,t_2] = [-38.3, 515.2]$ to the same level $\log M(t_0)$. Altogether this means that we apply the "discriminator" function

$$d(t) = \log M(t) - (t-t_0)\,(t_2-t_0)^{-1} \log\,[M(t_2)/M(t_0)]$$

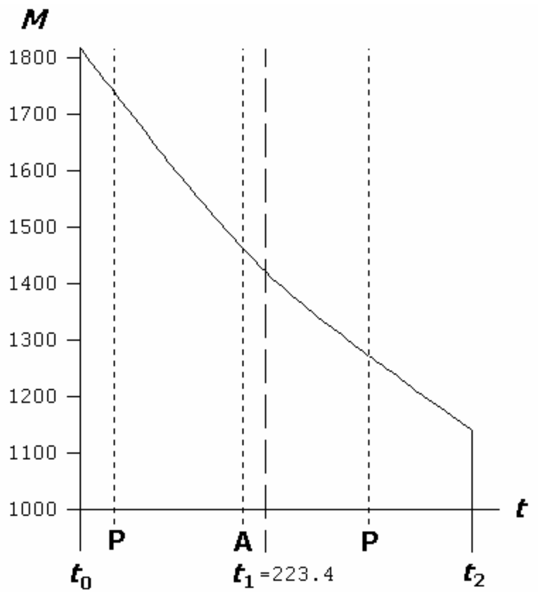

Figure 1. Plot of Falkenberg's original experimental data. The Perihelia and the Aphelion are marked by P and A.

to Falkenberg's data. This allows us to view the *M*-graph and especially the corner in much more detail and what we see is rather surprising:

The shape of the discriminator plot can—in very good approximation—be described as a combination of two straight lines pasted together at $t_1 = 223.4$. There we see the corner again quite distinctly, the indication of which we had already detected in Fig. 1.

Retransformed to Falkenberg's original data this means that the plot of the original measurements $[t, M(t)]$ in Fig.1 can be understood as a combination of two different exponentially decreasing functions pasted together at the corner point at $t_1 = 223.4$. $M(t)$ can be approximated by

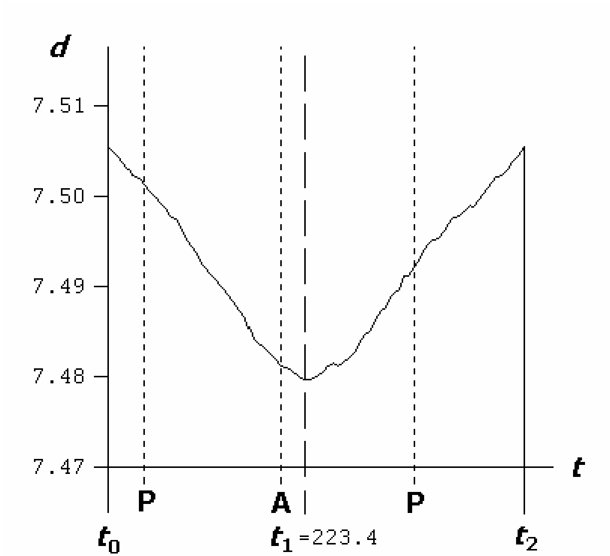

Figure 2: Plot of the discriminator applied to Falkenberg's original data. The **P**erihelia and **A**phelion positions are marked by **P** and **A**.

(1) $$M_1(t) = 1817 \cdot e^{-0.000938\,(t-t0)} \text{ for } t_0 \le t \le t_1$$

and

(2) $$M_2(t) = 1420 \cdot e^{-0.000748\,(t-t1)} \text{ for } t_1 \le t \le t_2$$

respectively. The relative approximation error is in both cases less than 0.2 %.

Discussion

The corner of the M-graph near $t_1 = 223.4$ undoubtedly has physical causes, since it is contained in Falkenberg's original data. The point $t_1 = 223.4$ is close to the aphelion position A (*cf*. Fig. 1). Hence following E.D. Falkenberg one should guess a connection between both events. But if this were true, then similar irregularities should appear near the two perihelia P (*cf.* Fig. 1) in the measurement interval, but nothing of the kind is visible: There are no corner points near the two perihelia P; the *M*-graph is accurately smooth there (*cf.* Fig. 2 too). Hence the surmised reasons are very unlikely; other physical reasons should be taken into account.

2. Changing the interval of observation

E.D. Falkenberg states a deviation between the experimental data and his theoretical approximation (see Fig. 3 in [1]) that has a period of about one year and is quite similar to a cosine graph. His conclusion is that this periodic deviation is caused by the annual orbit of the earth around the sun passing its aphelion in January and the perihelion in July each year.

But we already know the exception time $t_1 = 223.4$ approximately in the middle of the total measurements interval $[t_0, t_2] = [-38.3, 515.2]$ separating the interval into two subintervals $[t_0, t_1] = [-38.3, 223.4]$ and $[t_1, t_2] = [223.4, 515.2]$, each of which shows a relatively smooth shape of the measurements plot such that the exponential approximations (1) and (2) yield relative deviations < 0.2 %.

The subintervals contain 34 and 39 measurements respectively, sufficient to apply Falkenberg's analysis to each of the subintervals separately. If Falkenberg's periodic deviation would be of any physical reality, then the repetition of Falkenberg's analysis for each of the subintervals should reproduce the former result. Hence we expect a result as is shown in the upper part of our Fig. 3.

But the resulting deviations are much more similar to that ones obtained by our rough approximations (1) and (2) (compare Fig. 3 and Fig. 4).

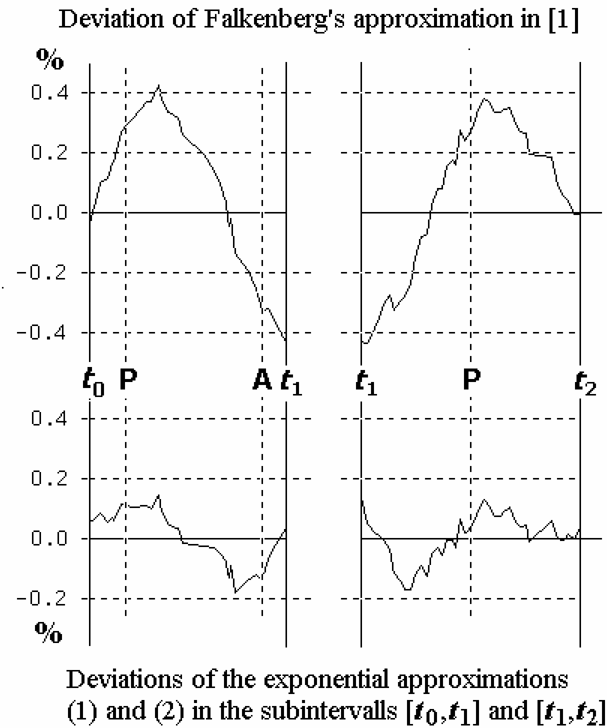

Figure 3. Comparison of percentile relative approximation errors.

We remark that the shape of the deviations has completely changed. And especially near the perihelia **P** the deviations are reduced from about 0.4 % to about 0.1 %. Additionally the deviation near the aphelion **A** of about –0.4 % has changed to a value near 0.

Falkenberg's data admit another numerical experiment too. We evaluate the approximation procedure for the 42 measurement data of the reduced interval [86.5,387.6]. Again, due to Falkenberg, the

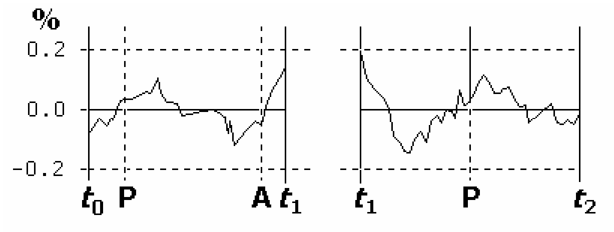

Figure 4. Deviations obtained by Falkenberg's approximation applied for the subintervals separately.

result should be the part of the deviation graph in [1], Fig.3, over the reduced interval. At first glance Fig. 5 presents a shape quite similar to the one presented by Falkenberg in [1].

But then we observe that neither the periods nor the amplitudes of the deviations coincide. The period is now only about half a year and the maximal deviation is a fourth of the deviation in [1].

I believe Falkenberg would never have come to his conjecture if he had restricted himself to evaluating measurements of the reduced interval [86.5, 387.6].

And if Falkenberg had compared the evaluations for the complete interval and the two subintervals, then he would have doubted his method of detecting hidden background information.

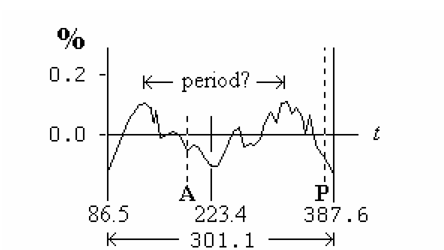

Fig. 5. Deviations calculated from 42 consecutive pairs of Falkenberg's measurement data.

Summary

The resulting deviation graphs depend significantly on the choice of measurement interval. Thus it seems very unlikely that Falkenberg's deviation in Fig. 3 of [1] should be of any physical reality; at least his results are not sufficient for deducing a correlation between the tritium decay rate and the orbital motion of our earth.

3. Viewing the mathematical background

Let us have a look now at the mathematics behind this to explain the discovered inconsistencies.

We assume with E.D. Falkenberg that there exists a *true* (formula) solution, which describes the course of the measurements *without* the hypothetical disturbances by the earth's orbit. The problem with the formula is that it depends on 3 unknown parameters. If we knew the *true* parameter values, then we could predict the course of the measurements (and separate unknown background effects), but regrettably we don't. Now applying the Gaussian least squares method to our formula with respect to the measurement data we obtain "optimal" values of the parameters. It is worth noting that these *optimal* values will in general differ from the *true* values, since the *optimal* values are influenced by numerous unavoidable measurement errors contained in the measurement data. Thus the *optimal* formula solution will also differ from the *true* formula solution in general. But the difference between both solutions will be small; hence we can take the *optimal* solution instead of the unknown *true* solution for all purposes where the solution *itself* is of interest.

E.D. Falkenberg seeks the *deviation* between his measurements and the *true* solution (abbreviated by *true* deviation) to prove his conjecture. But nobody knows the *true* solution. Hence Falkenberg takes the computed *optimal* solution instead of the *true* solution. But now the situation is quite different from the situation before: The true deviation differs from the deviation w.r.t. the *optimal* solution (abbreviated by *optimal* deviation) just by the difference between the true and the optimal solution, which is small. Hence, if one takes the small *optimal* deviation instead of the *true* deviation, then a small quantity is to be corrected by another small quantity. This will cause *large relative errors* in general.

The illegal use of the *optimal* deviation instead of the *true* deviation is Falkenberg's mathematical flaw. While he should be able to deduce his conjecture (if correct) from the *true* deviation, it is not permitted to take the *optimal* deviation as a substitute. By mixing up both deviations he provokes a "mathematical ghost" that appears promptly.

Falkenberg uses an approximating function $A_0(t) = b\, F(a,c;t)$ that contains the parameter b as an amplitude factor (*cf.* [1], p.38). For least squares problems of this class the normal equation corresponding to the parameter b is nothing but

$$(3) \qquad \Sigma_{\, i=1,\ldots,n}\, [M(t_i) - A_0(t_i)] / M(t_i) = 0.$$

This means that the sum of the relative deviations is balanced for the *optimal* solution. We can confirm this by the graphs in our Figures 4-5, where the displayed functions fulfil the balance condition (3). And beyond this: the upper part of our Fig. 3 shows the predicted subinterval-courses of Falkenberg's deviation function in Fig.3 of [1] (on the assumption that the Falkenberg conjecture were correct). Evidently these functions violate the balance condition (3) for the respective subintervals, and hence never can be the result of a least squares evaluation, *i.e.*, if these graphs were physical reality, then Falkenberg could not detect them by his method.

But the graphs in the lower part of Fig. 2, of course, that are produced by the least squares method, fulfil (3) again. These graphs are "optimal."

Conclusion

By taking the deviation of the measurement data with respect to the *optimal* solution instead of the *true* solution E.D. Falkenberg cannot separate any (hypothetical) additional background effects in his data from the *true* solution. Hence Falkenberg's least squares method must fail.

4. Virtual discussion with the referees

One of the referees remarks that E.D. Falkenberg's conjecture may be true while his proof in [1] is weak. He points out that the Falkenberg *result* correlates with the articles [2], [3] and [4a]. (The reader will find an English recapitulation of the article in [4b].) I agree with this position: As I have stated above, my criticism is directed against nothing but Falkenberg's *evaluation method*.

The other referee admits:

> *The applied processing of the author … is correct from the mathematical point of view, but it is incorrect to see it as a treatment of the results of a physical experiment.*

And then:

> *The author… has erroneously divided the considered time interval into two parts and has applied a mathematical analysis to each one of these two parts. Dividing the interval into two parts is permissible only if during the first part and the second part of the interval we have action of different physical phenomena and/or*

measurements are made by means of equipment with different characteristics. In the case of the experiment presented by Dr. Falkenberg there is no change in the conditions of the experiment.

I cannot follow this argument: If there is a physical phenomenon hidden in a list of 73 measurement data, then why should the phenomenon *completely* change its character, If the list is divided into two sublists of 37 and 39 consecutive pairs of data, Falkenberg's choice of the first and the last measurement was completely determined *by chance* with the only restriction that the *Gauss requirement of a sufficiently large number* of measurements should be fulfilled. Now, in our modifications of the measurement interval the number of data is about half of the original number. This could slightly reduce the accuracy of evaluation. But the number of data in each subinterval is still sufficiently large to guarantee a meaningful Gauss evaluation. Hence, if there were a physical phenomenon hidden in the data, the result should show its parts in the subintervals again (with slight modifications), *i.e.*, the result should be alike the upper part of our Fig. 3 with only slight deviations. But Fig. 4 shows two completely changed curves. The same holds when we reduce the interval of measurements as shown in Fig. 5. Hence the conclusion should be justified that Falkenberg's evaluation does not yield any physical phenomenon.

If we accepted the method of the author … as correct, we would have to go further: each of the two parts of the interval is divided in two, it is again divided in two, etc. We can thus select the ends of the intervals, which in each made step obtain better and better coincidence between the experimental data and analytical formulas. As an extreme case we could apply a linear interpolation

> *between each pair of neighbouring points, and this way reduce the error of analytical description to zero. But as a result of this procedure the oscillations predicted by Dr Falkenberg become "invisible."*

This method of *repeated* interval division is not permissible, since after few division steps the *Gauss requirement of a sufficiently large number* of data would be violated, *i.e.*, the Gauss approximation process would become more and more meaningless.

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Appendix

Falkenberg's data in Maple-V format:

[[–38.3,1818], [–32.3,1808], [–23.2,1793], [–14.3,1777.5], [–8.7,1768.5], [–5.5,1763], [3.6,1749], [9.7,1739], [17.6,1726], [37.6,1694], [43.8,1684], [53.8,1669], [57.7,1662], [66.3,1648], [72.7,1638], [79.8,1627], [86.5,1616], [113.8,1575], [128.4,1553.5], [135.8,1542.5], [141.8,1533.5], [143.5,1531], [145.8,1527], [148.5,1523], [150.3,1521], [155.7,1512], [171.4,1490.5], [177.6,1482], [184.2,1473], [191.3,1463], [199.3,1453], [206.3,1444], [216.7,1430.5], [223.4,1422], [232.6,1411], [241.7,1401], [247.3,1395], [254.8,1387], [262.6,1378.5], [268.2,1371.5], [275.3,1364], [282.3,1356.5], [289.7,1349], [296.3,1343], [303.7,1336], [312.3,1327], [317.8,1322.5], [325.7,1315], [331.5,1309], [338.8,1302.5], [345.5,1296], [350.3,1291], [356.8,1286], [361.4,1281], [366.7,1276], [373.4,1270], [380.8,1263.5], [387.6,1257.5], [394.3,1251], [401.3,1244],[409.4,1236.5],[414.5,1232], [422.8,1224.5], [430.4,1217], [436.8,1211], [443.5,1205], [448.3,1200], [477.4,1175], [485.7,1167], [493.7,1160], [500.3,1154.5], [507.7,1148], [515.2,1142]]