



A reply to the rebuttal by Sturrock et al.

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ARTICLE INFO

Article history:

Received 25 July 2018

Accepted 28 November 2018

Available online 28 November 2018

Keywords:

Solar rotation

Solar neutrino

Cosmic neutrino

Decay constant

Radioactivity

ABSTRACT

Sturrock et al. have published a “rebuttal” to a paper by Pommé et al. who refuted their claim that variations in a radon decay experiment at the Geological Survey of Israel (GSI) can be associated with solar rotation. Sturrock et al. misinterpret the variability of the decay rates in the gamma counter to assert influences by solar and cosmic neutrinos on beta decay and draw unsubstantiated conclusions about solar dynamics. Evidence suggests that the radon measurements were susceptible to solar irradiance and rainfall, whereas there is no indication that radioactive decay is influenced by the solar neutrino flux. In this reply to the rebuttal, the arguments raised by Sturrock et al. are scrutinised.

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1. Introduction

In recent work, a consortium of national metrology institutes has analysed a vast collection of precise activity measurements looking for possible violations of the exponential decay law [1–10]. Contrary to the claims raised by Fischbach, Sturrock, and co-workers on ‘neutrino-induced decay’ (see e.g. [11–15]), it was demonstrated that radioactive decay rates shown no relationship with variations in the solar neutrino flux due to seasonal changes in the Earth-Sun distance [4] or solar dynamics [9].

The most recent investigation [10] concerned the claim by Sturrock et al. [13–15] that measurements of gamma radiation associated with the emanation and decay of radon in a sealed container at the Geological Survey of Israel (GSI) laboratory [16] performed over a decade show cyclic modulations indicative of the dynamics of the solar interior. We received a subset of the data, covering a one-year period from April 2013 to June 2014, and could establish a direct relationship between daily peaks around noon with solar irradiance on the experimental set-up as well as a baseline shift of nocturnal signals due to exposure to rainfall driven by southern wind [10]. Consequently, we concluded that the radon measurements performed at the GSI [16] are insufficiently stable to investigate the variability of decay constants. Moreover, on physical grounds, the short half-lives of the beta emitters in the radon decay chain rule out neutrino-induced beta decay as the governing process behind the hypothetical monthly fluctuations [10].

Sturrock et al. [17] wrote a “rebuttal” to the conclusions of our work, in which their argumentation mostly consisted of ignoring the counterevidence. They reluctantly admit that neutrinos do not necessarily induce decay, but repeat the gratuitous assertion that solar influences affect the “directionality” of the subsequent gamma emissions. Shortly after, Sturrock et al. [18] and Steinitz et al. [19] published papers in which they reiterate their assertions, haphazardly associating count rate instabilities at a monthly time scale with solar rotation. In this short reply to their rebuttal, we scrutinise the arguments raised in their recent papers [17–19] and provide a non-exhaustive list of flaws in their analysis.

2. Rebuttal

2.1. Environmental conditions

Sturrock et al. emphasise in their rebuttal paper [17] that there is no clear correlation between the count rates in the gamma counter and the environmental conditions that were recorded in the hut. They show spectrograms of atmospheric pressure and temperature (as well as the battery voltage) and point out that their daily and monthly frequencies do not coincide with those in the radon decay measurements. Moreover, they say that the cycles in the environmental parameters have a lower power than the radon data, therefore ‘it is impossible to attribute oscillations in the gamma measurements to environmental influences’ (sic).

There are flaws in their reasoning: (1) we argued that their experiment is susceptible to solar irradiance and rainfall [10], which are parameters not monitored by GSI and only loosely related to ambient temperature and pressure, (2) we demonstrated a direct correlation between solar irradiance and the daily peaks in the

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gamma count rates and also correlations between unusual peak heights with extreme weather conditions [10], yet they did not address this evidence, and (3) they disregard radon transport inside the tank, such that small temperature gradients can have large effects on the local radon density and perceived decay rate [20].

2.2. Day and night

Sturrock et al. present power spectra of count rates in the gamma detector recorded around noon and around midnight. In the frequency band 6–16 a^{-1} – say at a monthly rate – they find comparably stronger oscillations in the night time than in the daytime, which they interpret as ‘*indicating a directional response to a solar influence*’. In our interpretation, the measurements at noon are dominated by large solar-irradiance peaks, which are seasonally dependent (with a frequency of 1 a^{-1}) but otherwise free of recurring patterns at a monthly scale. The nocturnal measurements, on the other hand, peak after rainfall and gradually decrease in the following days and weeks. It is not surprising that occasional showers leave a small trace in the power spectra at this time scale. Associating these effects with solar rotation is arbitrary and far-fetched in the light of all counterevidence against the concept of neutrino-induced beta decay [1–10].

2.3. Incomplete data set

Sturrock et al. point out that the full data set covers a decade of continuous measurements, whereas we analysed only a period of 405 days in Ref. [10]. Unfortunately, at the time of publication they had not granted us the permission to obtain the full data set. In the meantime, a larger data set has been analysed and the susceptibility of the experiment to direct sunlight and humidity is more firmly established.

They state that ‘*this small section does not reveal the fact that the annual (and other) oscillations are steady over a complete decade*’. Obviously, we agree that the annual oscillations are recurrent over the entire decade, in so far as the (lack of) protection of the set-up against sunlight has not essentially changed. However, no evidence has been provided that the “*other*” oscillations (e.g. at a monthly rate) have been consistent over the entire experiment. On the contrary, our periodograms suggest that there are no steady oscillations in the 6–16 a^{-1} frequency range and the nocturnal data show no regular cyclic pattern.

2.4. Power statistic

Sturrock et al. mention that ‘*it did not help that Pomme et al. used an unconventional statistic in place of the conventional power, and this statistic was neither defined nor explained*’. This statement is incorrect, since we used a conventional normalised statistic in our weighted power density graphs and we referred to our paper [9] in which the exact equations and a summary of the commonly used normalisation conventions were provided.

The normalisation issue should not dissimulate the following facts that falsify their claims: (1) Lomb-Scargle periodograms of the 2013–2014 [10] and 2007–2011 data sets [19] do not show the slightest sign of the cyclic pairs which Sturrock et al. announced as the ultimate proof of the association of radon decay with oblique solar rotation, (2) sinusoidal functions in the solar rotational frequency band fitted to the radon decay rates have a statistically insignificant amplitude [10], and (3) the same applies to other nuclides [9].

Sturrock et al. [17,18] provide evidence through spectrograms reflecting the power of transient oscillations through a rainbow colour map [21] as a function of frequency and time. Irrespective

of the statistical significance of the oscillations, they use highly saturated colours – from bright red to cool blue – to distinguish between the highest and lowest power values, respectively. In the 6–16 a^{-1} frequency range, this pseudocolour scale is misleading, since the red areas suggest strong cyclic events in the nocturnal Gamma-C measurements whereas in reality the periodicity of the anomalies is weak. Moreover, they are largely induced by occasional rainfall and these environmental influences have not been filtered out.

2.5. Directional dependency

Sturrock et al. [17] refer to the experimental work of Bellotti et al. [20], who measured radon diffused into olive oil as well as radon in air inside a glass sphere. Whereas the former configuration produced stable half-life values within 8·10⁻⁵ precision, there were significant daily variations in the latter. Bellotti et al. could prove experimentally that this was due to displacement of the radon inside the globe caused by temperature gradients. They demonstrated a correlation between the count rate in a NaI detector and the local temperature at the surface of the sphere facing the detector and could reproduce the displacement of the radon in the sphere by means of an external heater. They could drastically improve the measurement stability by filling the sphere with polystyrene particles to confine the radon into the interstitial space.

Sturrock et al. [17] express doubts about this physical explanation and call it a ‘*conjecture, not a demonstrated fact*’. They undermine their own hypothesis of ‘*neutrino-induced beta decay*’ saying that ‘*this is a hypothesis for which there is at this time no theoretical support*’ and their ‘*current inference is that an unknown process can and sometimes does influence beta decays*’. Moreover, they get ‘*the impression that neutrinos (or some other form of radiation) do not initiate beta decays, but rather influence the direction of travel of the decay products if and when decay occurs*’. Apparently, the hypothesis of neutrino-induced decay may finally be buried and ‘*a new generation of experiments*’ should be devised to investigate ‘*a directional aspect to beta-decay variability*’ which is ‘*suppressed when the source is immersed in an opaque liquid such as olive oil*’ (sic).

Sturrock et al. seem to be oblivious of the fact that practically every radioactivity measurement performed in the world successfully relies on the directional isotropy of radiation emitted by a source. Moreover, they ignored direct evidence [10] that there are no daily variations in the count rates of alpha particles and gamma rays measured in a detector covering a small solid angle to a radon source (fed by its radium parent). They wrongly claim that Triple-to-Double Coincidence Ratio (TDCR) [22] measurements have an intrinsically anisotropic response and that ³⁶Cl decay rate measurements by TDCR show cyclic events [18], even though explicit evidence was published of the contrary [8]. If their assertion would be true that the gamma emissions are emitted in the same direction as the stimulating neutrino, the gamma count rates in Gamma-C should show a negative peak at noon instead of a positive one. In their latest paper [18], they point to cosmic neutrinos as the instigating particles, without providing an explanation for the seasonality in the data.

In addition, the external detectors in the east and west corner of the hut should observe anti-correlated count rates, with extreme values in the morning and evening (when the Sun aligns with the tank and sensors) and “neutral” values at noon and at night (perpendicular to the solar neutrino flux). The observed positive correlation between the Gamma-E and Gamma-W count rates [19] disprove the role attributed to solar neutrinos as well as cosmic neutrinos, since they cannot be held responsible for creating a count rate pattern which is inversely correlated with ambient temperature and sensitive to rainfall.

3. Unaddressed issues

3.1. Where is the rebuttal?

Sturrock et al. have called their paper [17] “a rebuttal” of our work, but which conclusions do they contest and what are their arguments? They repeat their old mantra that the radon measurements are susceptible to solar influences, but do not provide new arguments, nor do they disprove any of the findings made in our work. They do not present a rebuttal against our conclusions that:

- The GSI radon measurements are susceptible to solar irradiance and humidity.
- The half-lives of the beta emitters ^{214}Pb (27 min) and ^{214}Bi (20 min) are too short to induce monthly oscillations of 0.35 % amplitude in the gamma emissions of the radon decay chain.
- The progeny activity is generally in equilibrium with the radon parent. The consistency of the most accurate half-life measurements of ^{222}Rn within 0.027 % are at variance with claims that the radon chain decay rates vary in monthly cycles.
- Measurements in stable conditions confirm the validity of the exponential decay law and refute the presence of modulations of any frequency in the decay rates of ^{226}Ra , ^{222}Rn , and any other radionuclide tested, independent of its type of decay (α , β^- , β^+ or EC).
- The consistency of half-life measurements and equivalence of primary activity standards, independent of the time and place of measurement, does not favour the assertion of cyclic variations in the decay constants.
- The invariability of measurements of alpha particle and gamma-ray emission rates in a small solid angle as a function of time disprove the assertion that the radiations are emitted in the same direction as the impinging neutrinos, i.e. away from the Sun.

As a result, even after the “rebuttal” paper there is no evidence for variability of decay constants, and a fortiori for the association of radioactive decay with solar processes. The exponential-decay law remains a solid foundation of nuclear physics and the measurement system for radioactivity [9,23,24].

3.2. Mimic environmental conditions

Sturrock et al. content themselves with reiterating their old claims that environmental parameters do not come into play in the radon decay rate measurements, whereas the evidence strongly suggests the opposite. Steinitz et al. could have performed a few simple tests to rule out the sensitivity of the apparatus to sunlight and rainfall. They could have (1) protected the set-up with an opaque cover or moved it into temperature-controlled laboratory conditions, (2) sprayed water on the set-up to verify its (in)sensitivity to humidity, (3) recorded pulse height spectra of the detectors to verify if spectral changes occur due to changes in amplification and electronic noise. The scientific relevance of a decade of measurements is at stake, not only in the context of solar-induced decay but also for its primary aim in radon research [19]. Scrutiny of the integrity of the experiment should primarily take place at the GSI, rather than recommending other laboratories to perform ‘an independent but precise reproduction of the GSI experiment’ [17].

3.3. The other sensors

In their study of the solar effects on radon decay, Sturrock et al. [13,15,17,18] use the count rate data from the Gamma-C detector only, whereas they deliberately ignore the two alpha detectors

(Alpha-H and Alpha-L) and the external gamma counters (Gamma-W and Gamma-E) in the same set-up. Since a power analysis of the Alpha-H and Alpha-L count rates show no significant cycles, it appears that these data do not serve the message that Sturrock et al. want to bring. After all, if the radon decay is really influenced by solar rotation, this should not only be visible as an increase of the activity in the Gamma-C detector alone. One would expect similar cyclic events in the alpha detectors, at the least coherent in timing and ideally also in amplitude.

Whereas Steinitz et al. [19] mention the anti-correlation between the count rates in the external and internal gamma sensors, they cannot provide a coherent explanation based on directionality of gamma emissions by radon progeny (^{214}Pb and ^{214}Bi). Why are there no enhanced count rates in the morning in Gamma-W and in the evening in Gamma-E, respectively? Why is there a large diurnal dip in the Alpha-H count rates and not in Alpha-L? Why is there no consensus on the relevant solar frequencies through the periodograms of different data sets? By not addressing such inconsistencies, Sturrock et al. implicitly recognise that the measurements by the alpha and external gamma detectors do not reinforce their assertions.

4. Conclusions

The “rebuttal” paper by Sturrock et al. contains no scientific arguments which could invalidate the refutation of their claims of daily, monthly and annual cycles in the decay of radon as well as their assertion that beta decay is induced by solar and cosmic neutrinos and that activity measurements can be used for neutrino flux monitoring. Throughout the “neutrino-induced decay” saga, the focus was on dubious measurement results obtained with sensitive instruments in varying environmental conditions, whereas precise decay rate measurements with robust techniques in well-controlled conditions were ignored as being “not fit for purpose” and “insensitive to the directional relationship between neutrinos and emitted radiations”. This immunisation strategy against empirical evidence and rational criticism is on its last legs.

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