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Analysis of beta-decay data acquired at the Physikalisch-Technische Bundesanstalt: Evidence of a solar influence

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ABSTRACT

According to an article entitled *Disproof of solar influence on the decay rates of 90Sr/90Y* by Kossert and Nähle of the Physikalisch-Technische Bundesanstalt (PTB) [1], the PTB measurements show no evidence of variability. We show that, on the contrary, those measurements reveal strong evidence of variability, including an oscillation at 11 year^{-1} that is suggestive of an influence of internal solar rotation. An analysis of radon beta-decay data acquired at the Geological Survey of Israel (GSI) Laboratory for the same time interval yields strong confirmation of this oscillation.

1. Introduction

In recent years, a number of articles have been published presenting evidence that some beta-decay rates are variable. Falkenberg, writing in 2001, reported evidence of an annual variation in the decay rate of tritium and suggested an association with the varying Earth-Sun distance [2]. This article was criticized by Bruhn [3], to which Falkenberg responded in a further article [4]. Such interchanges have recurred not infrequently. Jenkins and Fischbach [5,6] reviewed the experimental results of Alburger *et al.* of the Brookhaven National Laboratory [7] concerning the decay rates of ^{32}Si and ^{36}Cl, and of data acquired at the Physikalisch-Technische Bundesanstalt (PTB) in Braunschweig, Germany, concerning the decay rate of ^{226}Ra [8]. Like Falkenberg, Jenkins and Fischbach proposed a relationship to the varying Earth-Sun distance. The Jenkins-Fischbach articles led to critical articles by Cooper [9], Norman [10] and Semkow [11], which led to responses by Krause et al. [12], O'Keefe et al. [13], and Jenkins et al. [14].

The variability of beta-decay rates has more recently been called into question by Kossert and Nahle (KN) of PTB [1]. KN base their concerns on their power-spectrum analysis of measurements of the decay of ^{90}Sr/^{90}Y using the TDCR (Triple-to-Double Coincidence Ratio) experimental method [15–17]. Their results appear to contradict the positive results of earlier experiments by one of us (AP) [18].

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KN have kindly made their measurements available to us for independent analysis. In Section 2, we carry out a power-spectrum analysis of the PTB measurements and assess the statistical significance of the principal peaks in the resulting power spectra. In Section 3, we discuss the difference between the KN significance estimates and our estimates. In Section 4, we carry out a power-spectrum analysis of beta-decay data, for the same time interval, extracted from data compiled at the Geological Survey of Israel Laboratory [19–21]. We carry out spectrogram analyses in Section 5, we discuss our results in Section 6, and we summarize our conclusions in Section 7. We present some of the basic information about the PTB experiment in the Appendix.

2. Power spectrum analysis

KN have investigated possible variations in the decay of ^{90}Sr/^{90}Y sources by using the TDCR method that has been developed by standards laboratories as a way to arrive at accurate estimates of absolute decay rates [15–17]. This experiment therefore differs significantly from all other experiments designed to study the possible variability of beta decays. All other experiments simply measure the count rates of nuclides. The PTB experiment measured the *triple coincidences* of decay events as registered by three photo-multiplier tubes (PMTs). We show the layout of the PMTs and some of the characteristics of the measurement procedure in the Appendix.

KN made sequential measurements of three samples (S2, S3 and S4) and also of a blank sample (S1) to monitor environmental

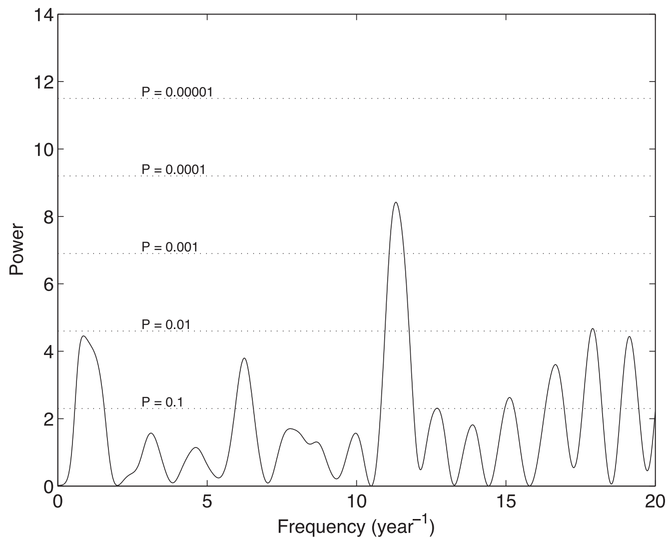

Fig. 1. Power spectrum for PTB sample 2. (c.f. KN Fig. 6.) Counting only peaks with powers of 5 or more, we find one peak with power 8.4.

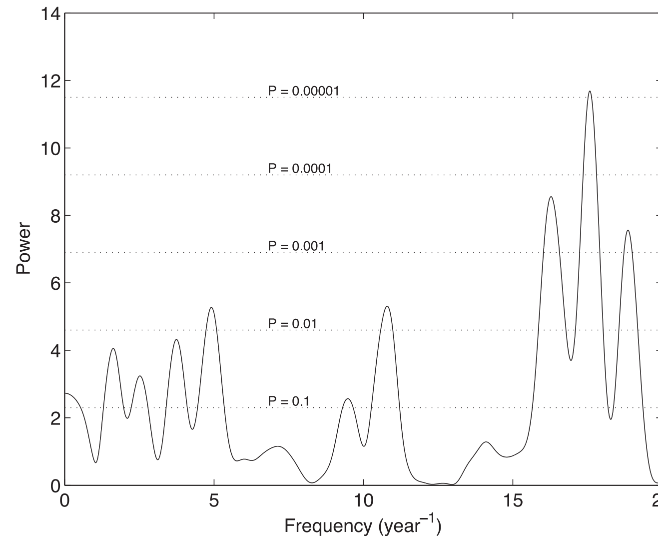

Fig. 2. Power spectrum for PTB sample 3. (c.f. KN Fig. 7.) Counting only peaks with powers of 5 or more, we find 5 peaks with powers 11.7, 8.6, 7.6, and two at 5.3.

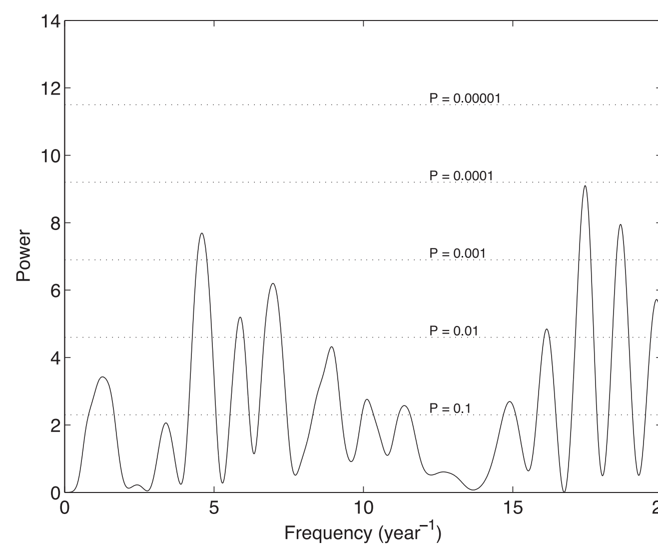

Fig. 3. Power spectrum for PTB sample 4. (c.f. KN Fig. 8.) Counting only peaks with powers of 5 or more, we find 6 peaks with powers 9.1, 8.0, 7.7, 6.2, 5.7 and 5.2.

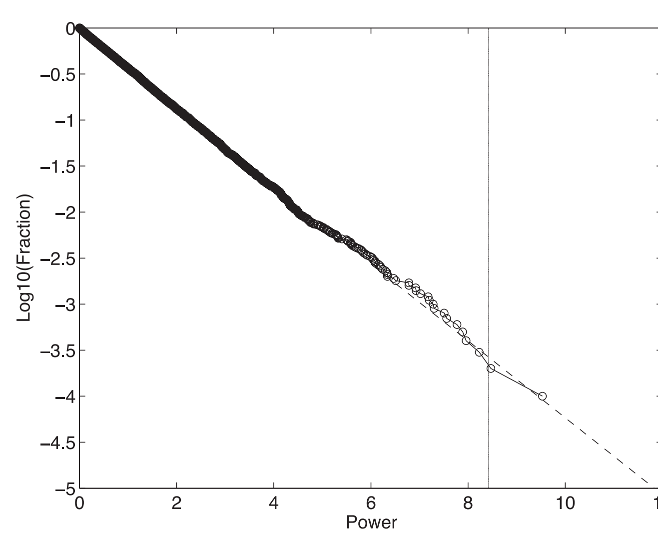

Fig. 4. Shuffle test of the principal peak in the power spectrum for PTB sample 2.

effects. KN derived "activity" estimates, shown in KN Figs. 4–6, from their triple-coincidence measurements and theoretically calculated counting efficiencies.

We show in Figs. 1–3 power spectra formed from the activity measures by a likelihood procedure [22] which, for present purposes, is equivalent to the Lomb-Scargle procedure [23,24].

We see that the curves in these figures are very close to those shown in KN Figs. 6–8. However, the significance estimates are completely different. For example, the biggest peak in Fig. 1 is found at frequency 11.32 year^{-1} and has power $S = 8.42$. According to Scargle theory [24], the probability of finding that power or more at a specified frequency is given by

$$P = \exp\left(-S\right). \tag{1}$$

This probability is found to be 2×10^{-4}.

By contrast, KN indicate significance levels by a quantity α which is not defined but appears to be related to the power by

$$\alpha = \exp\left(-S^{1/2}\right). \tag{2}$$

According to KN Fig. 6, the biggest peak (at about 11.2 year^{-1}, with S close to 8.4) is near to the $\alpha = 0.5$ level, leading KN to conclude that the modulation at that frequency is not significant. The power spectra for samples 3 and 4, shown in Figs. 2 and 3 (virtually identical to KN Figs. 7 and 8), show even stronger peaks with powers up to 11.7, which corresponds to a statistical significance level of 8×10^{-6}. However, based on their estimates of the quantity α, KN regard all of these peaks as insignificant.

3. Comparison of significance estimates

To further check this discrepancy, we have carried out a Monte Carlo calculation, using the shuffle test [25]. Fig. 4 shows the reverse-cumulative distribution of the maximum power at a specified frequency (taken to be that of the principal peak in Fig. 4, although the choice is not significant) computed from 10,000 shuffles of the data. We find that a fraction 2×10^{-4} of the shuffles give powers larger than the actual power (8.42), which is what one would expect from Eq. (1), confirming that Eq. (1) is indeed the appropriate formula for statistical significance estimation.

We now make an approximate estimate of the probability of obtaining the power spectra shown in Figs. 1–3. Counting only peaks with power 5 or more, we find that, for sample 2,