Applied Radiation and Isotopes 74 (2013) 50–55

Contents lists available at SciVerse ScienceDirect

Applied Radiation and Isotopes

journal homepage: www.elsevier.com/locate/apradiso

Concerning the time dependence of the decay rate of ^{137}Cs

J.H. Jenkins [a,b,*], E. Fischbach [b], D. Javorsek II [c], R.H. Lee [d], P.A. Sturrock [e]

[a] School of Nuclear Engineering, Purdue University, West Lafayette, IN 47907, USA
[b] Department of Physics, Purdue University, West Lafayette, IN 47907, USA
[c] Air Force Test Center, Edwards AFB, CA 93524 USA
[d] Physics Department, U.S. Air Force Academy, 2354 Fairchild Drive, USAFA, CO 80840, USA
[e] Center for Space Science and Astrophysics, Stanford University, Stanford, CA 94305, USA

HIGHLIGHTS

- ▸ Analysis of measured decay data for two isotopes measured on the same detector has been performed.
- ▸ The spectral analysis found periodicities for one isotope, ^{133}Ba, but not the other, ^{137}Cs.
- ▸ This supports an explanation not involving systematic/environmental causes.
- ▸ The results are consistent with others where periodicities have and have not been observed.
- ▸ Failure to observe periodicities in one isotope does not exclude their presence in others.

ARTICLE INFO

Article history:
Received 9 November 2012
Accepted 18 December 2012
Available online 31 December 2012

Keywords:
Radioactivity
Beta decay
Sun
Neutrinos

ABSTRACT

The decay rates of eight nuclides (^{85}Kr, ^{90}Sr, ^{108}Ag, ^{133}Ba, ^{137}Cs, ^{152}Eu, ^{154}Eu, and ^{226}Ra) were monitored by the standards group at the Physikalisch-Technische Bundesanstalt (PTB), Braunschweig, Germany, over the time frame June 1999 to November 2008. We find that the PTB measurements of the decay rate of ^{137}Cs show no evidence of an annual oscillation, in agreement with the recent report by Bellotti et al. However, power spectrum analysis of PTB measurements of a ^{133}Ba standard, measured in the same detector system, does show such evidence. This result is consistent with our finding that different nuclides have different sensitivities to whatever external influences are responsible for the observed periodic variations.

© 2012 Elsevier Ltd. All rights reserved.

1. Introduction

Bellotti et al. (2012) have recently reported the result of measurements of the activity of a ^{137}Cs source ($T_{1/2} = 30.08$ yr, 100% β^- (Browne and Tuli, 2007), as determined by an experiment installed deep underground in the Laboratori Nazionali del Gran Sasso (LNGS). They report that “no signal with amplitude larger than 9.6×10^{-5} at 95% C.L. has been detected,” concluding that this result is “in clear contradiction with previous experimental results and their interpretation as indication of a novel field (or particle) from the Sun.” In reviewing the case for variability, Bellotti et al. refer to articles by Jenkins et al. (2009), Fischbach et al. (2011), Parkhomov (2010a,b), and Javorsek et al. (2010). However, none of these articles cites decay rates for ^{137}Cs.

Measured decay data for ^{137}Cs have previously been examined for similar periodicities, and none have been found. A small source of ^{137}Cs is onboard the MESSENGER spacecraft, and decay data have been collected periodically from an onboard high purity germanium detector. These data, from just prior to launch on Earth to just after orbital insertion at Mercury, are consistent with no modulation of ^{137}Cs, as reported by Fischbach et al. (2012). Ellis (1990) also reported no annual or other variations in measured ^{137}Cs decay data. What is striking about Ellis' result, however, is that there was an annual variation in the measurements of ^{56}Mn decay data, which were taken on the same detector system (over the same time period) that was used to measure the ^{137}Cs calibration standards, for which no annual oscillatory behavior was observed. We shall discuss the Ellis results in greater detail in Section 3. There is one group that has reported periodicities shorter than a year in ^{137}Cs, (Baurov et al., 2000, 2001), but none of those experiments had a long enough duration to conclusively observe an annual period.

The question of periodic or other non-random behaviors in nuclear decay rates has long been of interest to the scientific

* Corresponding author at: School of Nuclear Engineering, Purdue University, West Lafayette, IN 47907, USA. Tel.: +1 765 496 3573.
E-mail address: jere@purdue.edu (J.H. Jenkins).

0969-8043/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.apradiso.2012.12.010

community (Emery, 1972; Hahn et al., 1976; Dostal et al., 1977), and the results presented in Jenkins and Fischbach (2009), Jenkins et al. (2009), Javorsek et al. (2010), and Sturrock et al. (2010a, 2010b), as well as others, have generated renewed interest in this topic. In an effort to further explore the possible existence of periodicities in nuclear decays, an examination of historical data collected during extended studies of half-lives of long-lived radionuclides and of detector stability has been carried out at the Physikalisch-Technische Bundesanstalt (PTB). Included in this program was an analysis of ^{137}Cs data, as reported by Schrader (2010). The goal of the present paper is to examine the results of these PTB measurements for comparison with the result of the Bellotti experiment.

2. Analysis of PTB measurements

Schrader (2010) reports extended half-life measurements of eight nuclides (^{85}Kr, ^{90}Sr, ^{108}Ag, ^{133}Ba, ^{137}Cs, ^{152}Eu, ^{154}Eu, and ^{226}Ra). The ^{137}Cs data were collected from late 1998 to November 2008. All of the measurements were made with a 4π ionization chamber (IG12/A20, Centronic 20th Century Electronics, Ltd.). In principle, these measurements could be affected by influences on the particular radionuclide under study, on the detector, or on the measuring electronics. As is clear from Figs. 2–5 of Schrader (2010), the record of measurements (residuals of a half-life fit) superficially resembles a scatter diagram. It follows that periodicities in the decays of any of these nuclides will be revealed only by some form of power-spectrum analysis. The purpose of the present paper is to carry out such an analysis for ^{137}Cs (residuals of a half-life fit) and also (for reasons that will become clear) for ^{133}Ba and ^{226}Ra.

Since oscillations – when they occur – are typically intermittent rather than steady, it is more illuminating to examine time–frequency displays ("spectrograms") than simple power spectra (Sturrock, 2008). To form spectrograms, we first prepare the data by means of the RONO (Rank-Order NOrmalization) operation (Sturrock et al., 2011a) that maps the measurements onto a normal distribution, as is appropriate for power-spectrum analyses such as the Lomb–Scargle procedure (Lomb, 1976; Scargle, 1982) or a likelihood procedure (Sturrock et al., 2006). We then carry out a sequence of likelihood power-spectrum analyses of sections of the data. For present purposes, we have found it convenient to adopt sections of 500 measurements. The power, S, is then displayed by a color code in a time–frequency diagram. (In power-spectrum analysis, the probability of finding a power of S or greater at a given frequency arising from normally distributed random noise, the null hypothesis, is given by e^{-S}, Scargle, 1982.)

The spectrogram formed in this way from the PTB ^{137}Cs data is shown in Fig. 1. We see that there is only slight evidence of an annual oscillation (frequency 1 year^{-1}) between 2002 and 2004. The feature near 0.2 year^{-1} may be related to the finite duration of the dataset. In contrast, we show in Fig. 2 the spectrogram formed from the ^{133}Ba ($T_{1/2} = 10.551$ yr, 100% K-capture, Khazov et al., 2011) measurements taken on the same detector system. This spectrogram exhibits a strong annual oscillation from 2003 to 2005. We also see evidence of an oscillation with frequency close to 2 yr^{-1}. This could be a harmonic of the annual oscillation, but it is more likely to be a Rieger oscillation (an r-mode oscillation with spherical harmonic indices $l=3, m=1$), which is prominent in power spectra formed from Brookhaven National Laboratory (BNL) and PTB data (Sturrock et al., 2011a).

We have also analyzed the PTB measurements in terms of "phasegrams," which are analogous to spectrograms, displaying the power as a function of time and phase for an assumed annual oscillation. The plot derived from ^{133}Ba data is shown in Fig. 3.

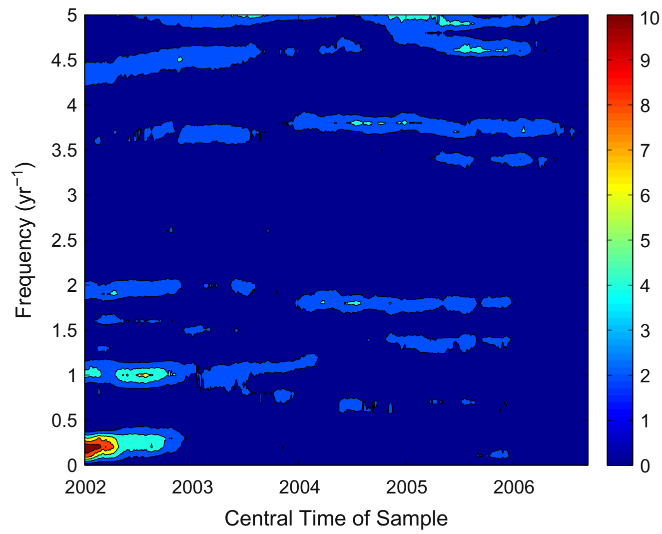

Fig. 1. Time–frequency display (spectrogram) of measurements of the decay-rate of ^{137}Cs made at PTB over the time interval June 1999 to November 2008. There is only a slight suggestion of an annual oscillation from 2002 to 2003. The power, S, is represented by the color bar. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

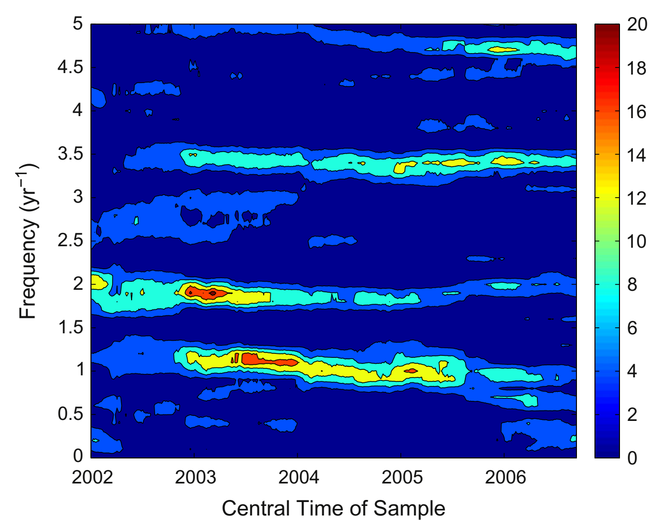

Fig. 2. Spectrogram of measurements of the decay-rate of ^{133}Ba made at PTB over the time interval June 1999 to November 2008. There is evidence of an annual oscillation from 2003 to 2005. There is also evidence of the first harmonic of this oscillation. The power, S, is represented by the color bar. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

As we expect from Fig. 2, the power is found mainly over the time interval 2003 to 2005. The power is centered on a phase of approximately 0.43, corresponding to a date on or about 6 June.

Comparable plots for ^{226}Ra ($T_{1/2} = 1600$ yr, 100% α-decay, Akovali, 1996) measurements are shown in Figs. 4 and 5. We see from these figures that the ^{226}Ra results are similar to those for ^{133}Ba, but the power levels are not as strong. We note that while ^{226}Ra is 100% α-decay, it is in equilibrium with most of its daughters, several of which are β^--decays. These β^--decaying daughters contribute a significant portion of the photons emanating from the sealed source (Chiste et al., 2007). Therefore, we cannot discern which isotope or isotopes would be the source of the observed fluctuations and note that there could be more than one.

Download English Version:

https://daneshyari.com/en/article/1876014

Download Persian Version:

https://daneshyari.com/article/1876014

Daneshyari.com