Test of claims that radioactive half-lives depend on the earth-to-sun distance

J. R. Goodwin, V. V. Golovko, V. E. Iacob, and J. C. Hardy

Several recent publications by J.H. Jenkins and E. Fischbach [1-4] have claimed evidence that radioactive half-lives vary as a function of the earth-to-sun distance at the time of measurement. When the first of these claims appeared as an arXiv preprint, we had already made three sequential measurements of the half life of the β-decay of ^{198}Au for another purpose [5, 6], so we decided to make four more measurements of that half-life at times chosen so that the dates of all seven measurements would span the complete range of earth-sun distances.

The main claims by Jenkins and Fischbach [2] are based on their interpretation of published data taken by others, one set of measurements done at Brookhaven National Laboratory [7] and another at the Physikalisch Technische Bundesanstalt in Germany [8]. The BNL measurements compared the decay rate of ^{32}Si ($t_{1/2}$ = 172 yr) to that of ^{36}Cl ($t_{1/2}$ = 300,000 yr) on a regular basis over four years; they used an end-window gas-flow proportional counter to detect decay β particles. The PTB measurements, which were made for calibration purposes, periodically obtained the decay rate of ^{226}Ra ($t_{1/2}$ = 1600 yr) over 11 years using a high-pressure 4πγ ionization chamber. The data from both groups show a weak but statistically significant oscillatory behavior of decay rate with a one-year period. Both groups acknowledged the oscillations in their data, with BNL noting that it corresponded with seasonal variations in temperature and humidity, which could have affected the relative absorption of the β particles from ^{32}Si and ^{36}Cl, while PTB attributed it to background radioactivity such as radon and daughter products, which are known to show seasonal concentration changes.

In their reanalysis of the data, Jenkins and Fischbach superimposed a plot of the earth-sun distance over the sequence of half-life values measured by each group. A copy of their plot [2] for the BNL ^{32}Si data appears in Fig. 1. The solid (cyclic) line is a plot of $1/R^2$, where R is the earth-sun distance in a.u. units; each individual data point represents the average of 4 runs, each lasting 10 hr. They conclude [2] that there is a strong correlation between the data and the earth-sun distance, and they speculate that this could arise from a terrestrial modulation in the fine-structure constant caused by a scalar field from the sun, or because the terrestrial radioactive nuclei are interacting in some way with the neutrino flux from the sun. They even present an argument for how the latter might cause the "phase shift" between the $1/R^2$ curve and the BNL (and PTB) data.

Since both the BNL and PTB measurements were of total un-discriminated decay rates for long-lived radioactivities, any observed cyclic variations cannot definitively be attributed to variations in the half-lives involved. A variety of other factors, such as the seasonal effects already mentioned, could plausibly be involved, and their elimination requires elaborate argumentation [4] – and is certainly open to debate [9].

We seek to avoid these ambiguities by measuring the half-life of the much shorter-lived ^{198}Au ($t_{1/2}$ = 2.695 d), which we uniquely identify by observing the decay of its prominent 411-keV β-delayed γ ray (in ^{198}Hg) in a HPGe detector. We also follow the decay for 10 half lives and determine the half-life from a fit to the decay curve over three decades. Contaminant activities are completely eliminated by

this process, as are the atmospheric effects previously indicated as possible sources of seasonal variations.
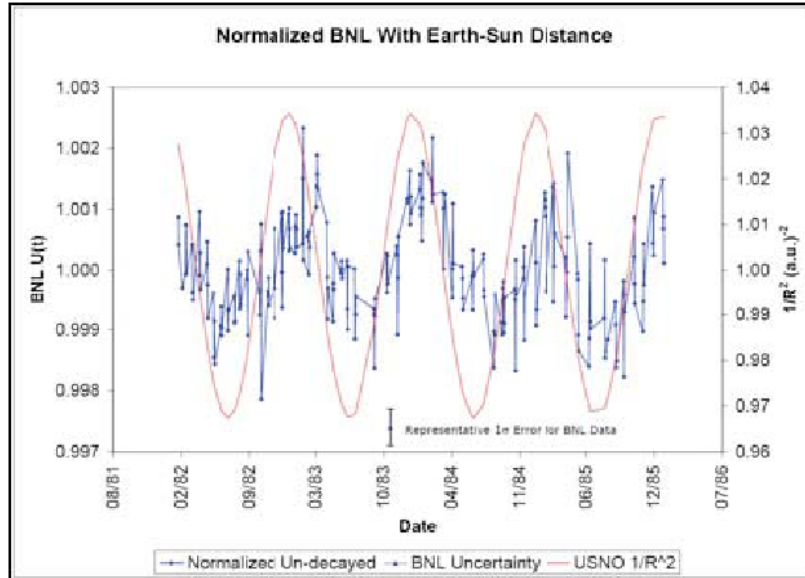
FIG. 1. Plot of $U(t)$ for the raw BNL ^{32}Si/^{36}Cl ratio (points) together with $1/R^2$, where R is the earth-sun distance. The values of $U(t)$ are obtained by multiplying each data point by $\exp(+\lambda t)$, where $\lambda = \ln(2)/t_{1/2}$ with $t_{1/2} = 172$ yr for ^{32}Si. The left axis gives the scale for the normalized $U(t)$, and the right axis denotes the values of $1/R^2$ in $1/(\text{a.u.})^2$.

We used the procedures we have described previously [5]. For each measurement, a circular disc of 99.99+ % pure gold, 10 mm in diameter and 0.1 mm thick, was activated by being placed in a flux of $\sim 10^{10}$ neutrons/cm^2·s for 10 s, at the Texas A&M Triga reactor. It was then placed in a fixed geometry with respect to a 70% HPGe detector, and not moved for the one-month duration of the measurement. Over 100 consecutive γ-ray spectra were acquired for a pre-set live time and saved in computer memory. We extracted the number of counts in the 411-keV γ-ray peak in each spectrum using the least-square peak-fitting program GF3 (in the RADware series) [10], and corrected the results for small residual, rate-dependent effects, which we had determined from an independent measurement [5,6]. We then fitted the decay curve obtained from this analysis using the method of maximum-likelihood with a single-exponential in a code based on ROOT [11].

The seventh measurement is only just completed and our analysis of some of the earlier measurements is still not finalized. However, the plot shown in Fig. 2 compares our preliminary results with BNL data and the 1/R^2 oscillations (both taken from Fig. 1). So far, we see no indication of any dependence of the half-life of ^{198}Au on the earth-sun distance.
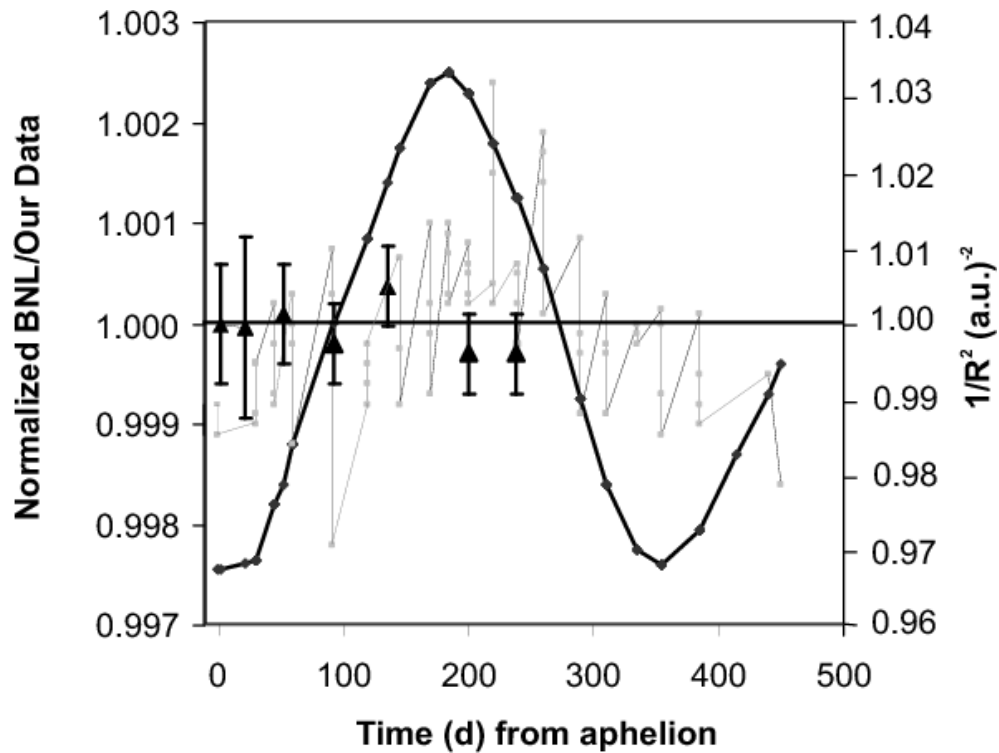
FIG. 2. Plot of a portion of the material shown in Fig. 1, starting at approximately 07/82 and ending at 09/83, about 450 days later. Superimposed on the BNL data (grey) and $1/R^2$ curve are our preliminary results for seven half-life measurements of ^{198}Au (solid triangles with error bars) placed at their appropriate time of measurement relative to the aphelion.

[1] J.H. Jenkins and E. Fischbach, Astropart. Phys. **31**, 407 (2009).

[2] J.H. Jenkins, E. Fischbach, J.B. Buncher, J.T. Gruenwald, D.E. Krause, and J.J. Mattes, Astropart. Phys. **32**, 42 (2010).

[3] E. Fischbach, J.B. Buncher, J.T. Gruenwald, J.H. Jenkins, D.E. Krause, J.J. Mattes, and J.R. Newport, Space Sci. Rev. **145**, 285 (2009).

[4] J.H. Jenkins, D.W. Mundy, and E Fischbach, arXiv:0912.5385v1.

[5] J. R. Goodwin, V.V. Golovko, V.E. Iacob, and J.C. Hardy, Eur. Phys. J. A **34**, 271 (2007).

[6] J.R. Goodwin, V.E. Iacob, N. Nica, A. Dibidad, and J.C. Hardy, *Progress in Research*, Cyclotron Institute, Texas A&M University (2009-2010) p. I-18.

[7] D. Alburger, G. Harbottle, and E.F. Norton, Earth and Planet. Sci. Lett. **78**, 168 (1986).

[8] H. Siegert, H. Schrader, and U. Schötzig, Appl. Radiat. Isot. **49**, 1397 (1998).

[9] H. Schrader, Appl. Radiat. And Isot., in press.

[10] D. Radford, http://radware.phy.ornl.gov/main.html (private communication).

[11] R. Brun and F. Rademakers, Nucl. Instrum. Methods Phys. Res. **A389**, 81 (1997).