Test of claims that radioactive half-lives depend on the Earth-Sun distance

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Several recent publications by J.H. Jenkins and E. Fischbach [1-4] have claimed to find 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 experiments involving other claims of changes in radioactive half-lives [5, 6]; we then decided to append four additional measurements of the ^{198}Au half-life, with the measurements to be conducted at times such that the seven measurements as a whole would cover, fairly evenly, a typical perihelion-aphelion interval

The major claims by Jenkins and Fischbach [2] are based upon their interpretation of published data taken by others – one set of measurements having been performed at the Brookhaven National Laboratory (BNL) [7] and the other at the Physikalisch Technische Bundesanstalt (PTB) in Germany [8]. The BNL measurements compared the decay rate of ^{32}Si ($t_{½}$ = 172 yr) to that of ^{36}Cl ($t_{½}$ = 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 ($t_{½}$ = 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 the decay rate, with a period of one year. Both the groups acknowledged the oscillations in their data, the group from BNL noting that the oscillations 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; the PTB group attributed them to background radioactivity, such as radon and daughter products, which 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 astronomical 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 oscillations in the data and the Earth-Sun distance, and they speculate that this correlation could arise from a terrestrial modulation in the fine-structure constant, caused by a scalar field from the sun, or could arise because the terrestrial radioactive nuclei are interacting in some way with the neutrino flux from the sun. They even present an argument for how this 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 totally non-discriminated decay rates for long-lived radioactivities, any observed cyclic variations cannot definitely 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].

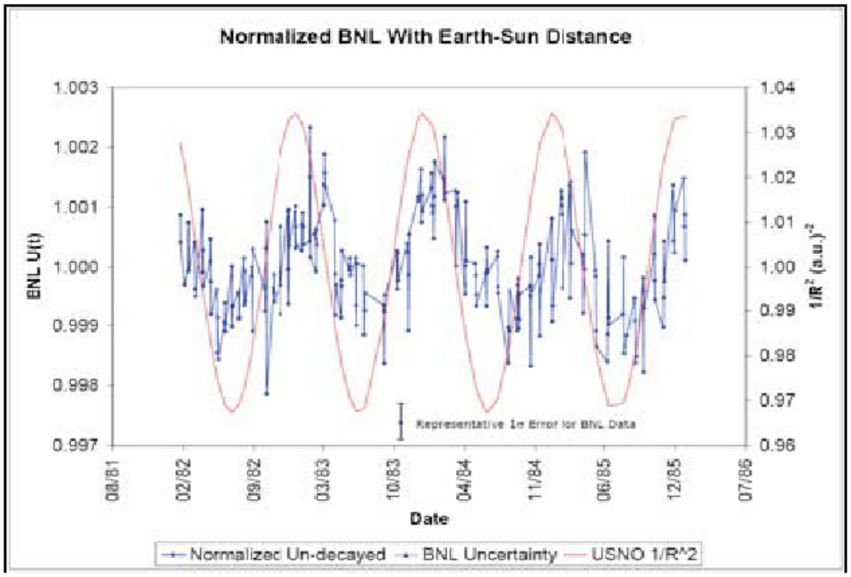

FIG. 1. Plot of *U(t)* for the raw BNL ^{32}Si/^{36}Cl ratio (points) together with 1/R^2, where R is the Earth-Sun distance. The values of *U(t)* are obtained by multiplying each data point by exp(+λt), where λ =(ln2)/$t_{½}$ with $t_{½}$ = 172 yr for ^{32}Si. The left axis gives the scale for the normalized *U(t),* and the right axis denotes the values of 1/R^2 in 1/(a.u.)^2.

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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 ~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 approximately one-month duration of the measurement. Over 100 consecutive γ-ray spectra were acquired for a pre-set live time, and then saved. 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].

How does our result compare with the BNL-observed activity oscillations, upon which Jenkins, Fischbach *et al.* base their claims? In Figure 2 we present the BNL activity results plotted against the dates of their measurement over a period of four years from early 1982 to early 1986. The dotted curve shows the 1/R^2 behavior of the Earth-Sun distance over the same period, which is very nearly a pure sine wave. We have therefore fitted the BNL data with a sine wave, which has a fixed one-year period but variable amplitude and phase shift. A least squares fit to the data, shown as the dashed curve in the figure, yielded an amplitude of 7.9(3) × 10^{-4} and a phase shift of 35(2) d relative to the $1/R^2$ plot. This phase shift was also noted by Jenkins [2].

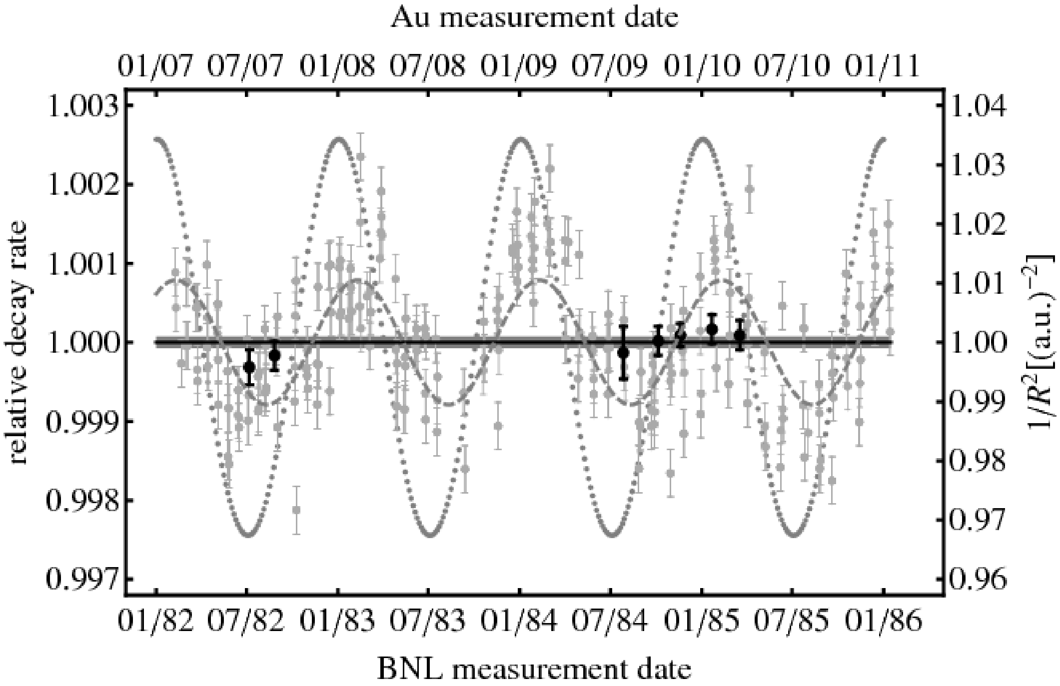

FIG. 2. The BNL data for the activity ratio, $^{32}Si/^{36}Cl$ [7], as published in [2], are plotted as grey circles with error bars (referred to the vertical axis at the left) against the dates of their measurement between 1982 and 1985 (horizontal axis at the bottom). The dotted curve shows the $1/R^2$ behavior of the Earth-Sun distance, where R is measured in astronomical units, a.u. (vertical scale at the right), over the same period; and the dashed curve gives our fit to the BNL data (see text). Our seven results for the decay rate of ^{198}Au normalized to their average value (with the same vertical scale as the BNL data) are plotted as black circles with error bars against their dates (shown on the horizontal axis at the top, which is shifted exactly 25 years compared to the bottom scale).

Since the BNL measurements were of activity not half-life we plot our results in Fig. 2 as decay rates, λ (= ln2 / $t_{1/2}$), normalized to their average; they appear as black circles with error bars. The time scale for our measurements has been displaced by exactly 25 years from the BNL scale, so our data appear with the same perihelion synchronization. The horizontal shaded band shows the one-standard-deviation uncertainty limits on the average value from our results. Our data are statistically consistent with a constant half-life value to within a relative precision of ±7 × 10^{-5}, an order of magnitude smaller than the amplitude of the oscillations attributed to the BNL data.

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