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Indications of an unexpected signal associated with the GW170817 binary neutron star inspiral

E. Fischbach[a,*], V.E. Barnes[a], N. Cinko[b,a], J. Heim[a], H.B. Kaplan[c,a], D.E. Krause[d,a], J.R. Leeman[a], S.A. Mathews[e], M.J. Mueterthies[a], D. Neff[f,a], M. Pattermann[a]

[a] Department of Physics and Astronomy, Purdue University, West Lafayette, IN 47907, USA
[b] Department of Physics, University of California, Berkeley, CA 94720, USA
[c] Department of Physics, University of Maryland, College Park, MD 20742, USA
[d] Physics Department, Wabash College, Crawfordsville, IN 47933, USA
[e] US Naval Research Laboratory, Material Science Division, Washington, DC 20375, USA
[f] Department of Physics and Astronomy, University of California, Los Angeles, CA 90024, USA

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ABSTRACT

We report experimental evidence at the 2.5σ level for an unexpected signal associated with the GW170817 binary neutron star inspiral. This evidence derives from a laboratory experiment simultaneously measuring the β-decay rates of Si-32 and Cl-36 in a common detector. Whereas the Si-32 and Cl-36 decay rates show no statistical correlation before or after the inspiral, they are highly correlated (~95%) in the 5-h time interval immediately following the inspiral. If we interpret this correlation as arising from the influence of particles emitted during the inspiral, then we can estimate the mass m_x of these particles from the time delay between the gravity-wave signal and a peak in the β-decay data. We find for particles of energy 10 MeV, $m_x \lesssim 16$ eV which includes the neutrino mass region $m_\nu \lesssim 2$ eV. The latter is based on existing limits for the masses m_i of the three known neutrino flavors. Additionally, we find that the correlation is even stronger if we include data in the 80 minute period before the arrival of the gravity wave signal. Given the large number of radionuclides whose decays are being monitored at any given time, we conjecture that other groups may also be in a position to search for statistically suggestive fluctuations of radionuclide decay rates associated with the GW170817 inspiral, and possibly with other future inspirals.

1. Introduction

The recent detection by the Advanced LIGO and Advanced Virgo detectors of a gravitational wave signal from a binary neutron (NS-NS) star inspiral [1,2], GW170817 was quickly followed by an optical detection of the remnants of the inspiral as well. The gravitational wave signal was received at 12:41:04 UTC on 17 August 2017, and the source of the inspiral was localized to a luminosity distance of 1.30×10^8 ly $= 1.23 \times 10^{26}$ cm from Earth. A subsequent search for high-energy neutrinos associated with the inspiral by the ANTARES, IceCube, and Pierre Auger observatories did not detect any neutrinos [3].

Here we report a possible indication of an additional signal associated with the NS-NS inspiral obtained from an experiment at Purdue University that was underway at the time of the inspiral. The experiment was aimed at obtaining an improved half-life for Si-32 ($T_{1/2} \sim 172$ yr), using an upgraded apparatus originally designed and built by a group at Brookhaven National Laboratory [4,5], and subsequently donated to our group. The special feature of this apparatus, shown in Fig. 1, is that it allowed the decay rate of Si-32 to be continually compared to that of Cl-36 ($T_{1/2} \sim 301,000$ yr) which acted as an internal calibration standard. As noted in [4], Si-32 decays via β^- emission 100% of the time to the ground state (g.s.) of P-32 emitting an electron with energy $Q(\beta^-) = 225$ keV. P-32 ($T_{1/2} = 14.28$ d) decays in turn 100% of the time via β^- emission to the g.s. of S-32 with $Q(\beta^-) = 1709$ keV. Cl-36 ($T_{1/2} \sim 301,000$ yr) decays via β^- emission to the g.s. of Ar-36 98.1% of the time with $Q(\beta^-) = 709$ keV, and via electron capture (e.c.) to the g.s. of S-36 1.9% with $Q(\text{e.c.}) = 1144$ keV. Since the 225 keV $Q(\beta^-)$ for Si-32 decay is too low an energy to be detected reliably, the Si-32 decay rate is determined from the subsequent decay of P-32 which is presumed to be in equilibrium with Si-32.

* Corresponding author.
E-mail addresses: ephraim@purdue.edu, ephraim@physics.purdue.edu (E. Fischbach).

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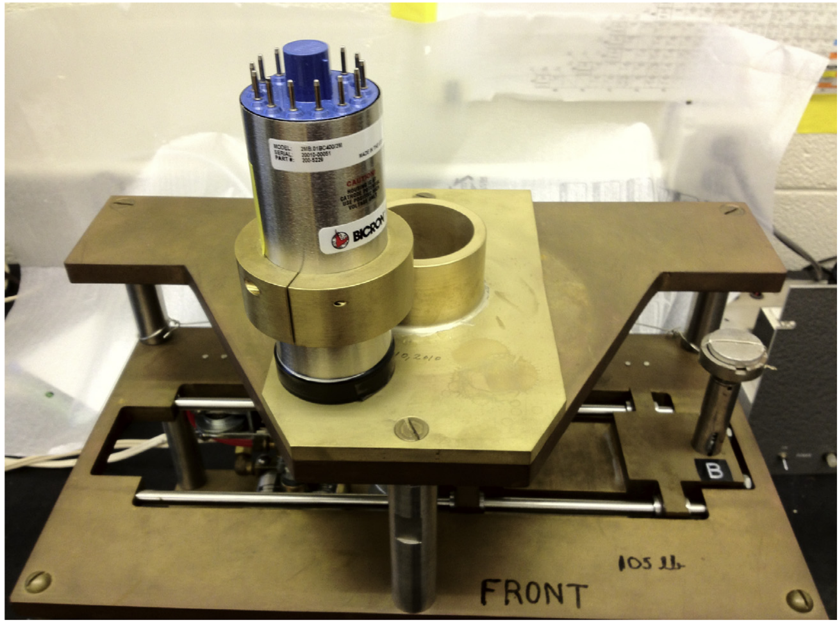

Fig. 1. The BNL apparatus for measuring the decay rates of Si-32 and Cl-36. Shown is pedestal B on which the Si-32 sample is placed, the Bicron plastic scintillation detector, and the collar to keep the detector rigidly in place. In the configuration shown, the Cl-36 sample (hidden) would be directly under the detector. The samples are driven along the track rails in the foreground by a pneumatic system which places each in turn under the detector. See text for further details.

Any short-term perturbations of the "Si-32" decay rate would actually be perturbations of the P-32 decay rate.

The Si-32 and Cl-36 samples were separately positioned on top of two pedestals affixed to two precision micrometers, one of which (B) is shown in Fig. 1. The micrometers were rigidly fixed to a carriage which moved back and forth to position each sample under the detector(shown) in 30 minute intervals. Given the long half-life of Cl-36, its measured rate should have been effectively constant over the 4-year duration of the original experiment $(4/301,000 \simeq 1.3 \times 10^{-5})$ [4]. Hence any short-term or long-term deviations from a constant Cl-36 count rate could be attributed to drifts in the apparatus, which would then apply to the Si-32 count rate as well. By comparing the Si-32 and Cl-36 count rates over time, specifically by computing their ratio Si-32/Cl-36, the correct Si-32 half-life could be determined.

The BNL experiment was the first to report an unexpected annual oscillation in the decay rates of their samples, superimposed on their respective exponential decay curves [4]. Data acquired during approximately the same period at the Physikalische Technische Bundesanstalt (PTB) in Germany exhibited a similar annual variation in their decay data for Ra-226 [6]. Subsequently a number of other decay experiments and analyses have reported similar results [7–19]. Of particular significance in the present context is evidence of changes in nuclear decay rates associated with solar storms [10,20]. Although there is at present no known mechanism to account for these correlations, various considerations suggest that they may be attributed to solar or relic neutrinos, or to similar dark matter candidates. If we assume this to be the case, then it is natural to ask whether a signal from the GW170817 inspiral might also show up in our system.

2. Experimental details

As we now demonstrate, we have applied a variant of the BNL technique to compare the short-term behaviors of the Si-32 and Cl-36 count rates before, during, and after the inspiral event. We then show that in the 5-h period immediately following the arrival of the inspiral signal, the Si-32 and Cl-36 signals become highly correlated, which we interpret as evidence for an external influence affecting the respective decays. Our modified BNL detection system is shown in Fig. 1. We upgraded the original BNL apparatus by introducing a collar (shown) designed to secure our detector to the sample changer. The data acquisition system (DAQ) consisted of a 2-inch Bicron plastic scintillation detector (shown) coupled to an Ortec 276 base and preamplifier. The remainder of the system consisted of a spectroscopy amplifier, and a multi-channel analyzer (MCA) connected to a PC running Maestro 32 and custom LabView software. The upgraded sample changer was placed in a modified 55 gallon steel drum which acted as Faraday shield, and was kept at a controlled pressure with dry nitrogen. This arrangement also allowed us to minimize variations in relative humidity. The temperature in the room was controlled by a water-cooled air conditioner set to 21 °C. The entire system was then completely encased in a styrofoam box with 2-inch thick walls to suppress temperature variations. The temperature inside the box itself was further controlled by a Technology, Inc. model AC-073 heating/cooling unit set to 22.0 °C. Electrical power to the system was supplied by a constant voltage transformer to mitigate any effects from fluctuating line voltage. This system allowed the voltage output to be held constant at 117 V for an input voltage in the range 109–125 V. Further details can be found in [21]. Since the Si-32 and Cl-36 counts are acquired by the BNL system in successive 30 min runs, the data acquired from one sample should be statistically uncorrelated to the data acquired from the other. Hence, in the absence of evidence for a malfunction in the detection system, any indication of a correlation can be attributed to either a statistical fluctuation (see below), or to evidence of an external influence common to both the Si-32 and Cl-36 samples. In what follows we verify that the fluctuations in the decays of the Si-32 and Cl-36 are in fact statistically uncorrelated, as expected, with three significant exceptions, one of which happens during the period immediately preceding and following the inspiral. To facilitate the various statistical tests that we have carried out, the Si-32 data have been correlated with the Cl-36 data points which are 30 min later in time. As we have noted above, we expect that the Si-32 and Cl-36 decay fluctuations should be uncorrelated, precisely because they