Experimental Design for Time Variations in Decay Rate for Thallium-204

Alexander Eggleston

Introduction

- The half-life of a radioactive isotope can be defined as the amount of time that it takes for said isotope to decay to half of its original value (Hallare, Gerriets, 2020)
- Radioactive isotopes have a set half-life, this helps scientists create more precise measurements and predictions during experiments because of the set timeline for each specific isotope
- The current known value for the half-life of 204Th is given as 4.0 +/- 0.1 years (Harbottle, 1953).
- The half-life of Thallium-204 is recorded in the experiments to create a random number generator based off the small spread of decay amounts that the detector records during different time segments. During the experiments, a Geiger–Müller detector was used to record the half-life of Thallium-204. While doing such experiments, Dr. Ephraim Fischbach found that during the summer, when the Earth is further from the Sun, the half-life of Thallium-204 is slower than during the winter. After observing the results, Dr. Ephraim Fischbach concluded that because the Earth is closer to the Sun during the winter that the Earth is receiving more neutrinos from the Sun and entering the Earth's atmosphere. Dr. Ephraim Fischbach then concluded that because there are extra neutrinos entering the atmosphere in the winter, that the neutrinos were interacting with the radioactive material and causing particles to deflect and cause fluctuations in the data recordings made by the Geiger– Müller detector.
- After reviewing and replicating Dr. Ephraim Fischbach's experiments, we found that there might be a different variable that could explain the possible discrepancies in Dr. Fischbach's results. During our experiments, a temperature variable was found to slightly change the results collected from the Geiger–Müller detector. After applying an exponential curve to account for the temperature changes, the results seem to follow the natural laws of beta-decay half-life and does not seem to indicate any new findings in fundamental physics.

Methods & Materials

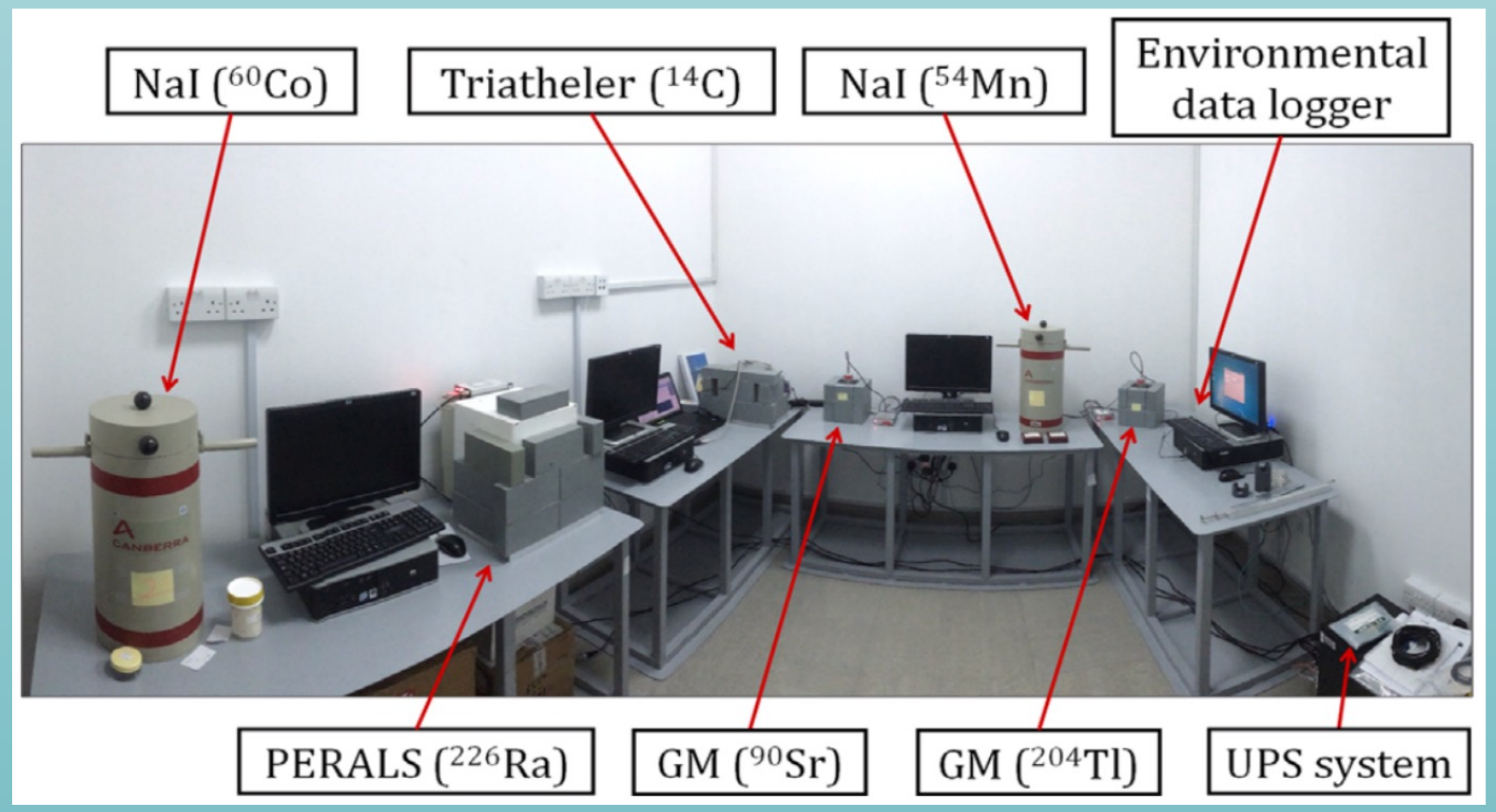

Figure 3: Laboratory setup highlighting important experimental equipment

Results

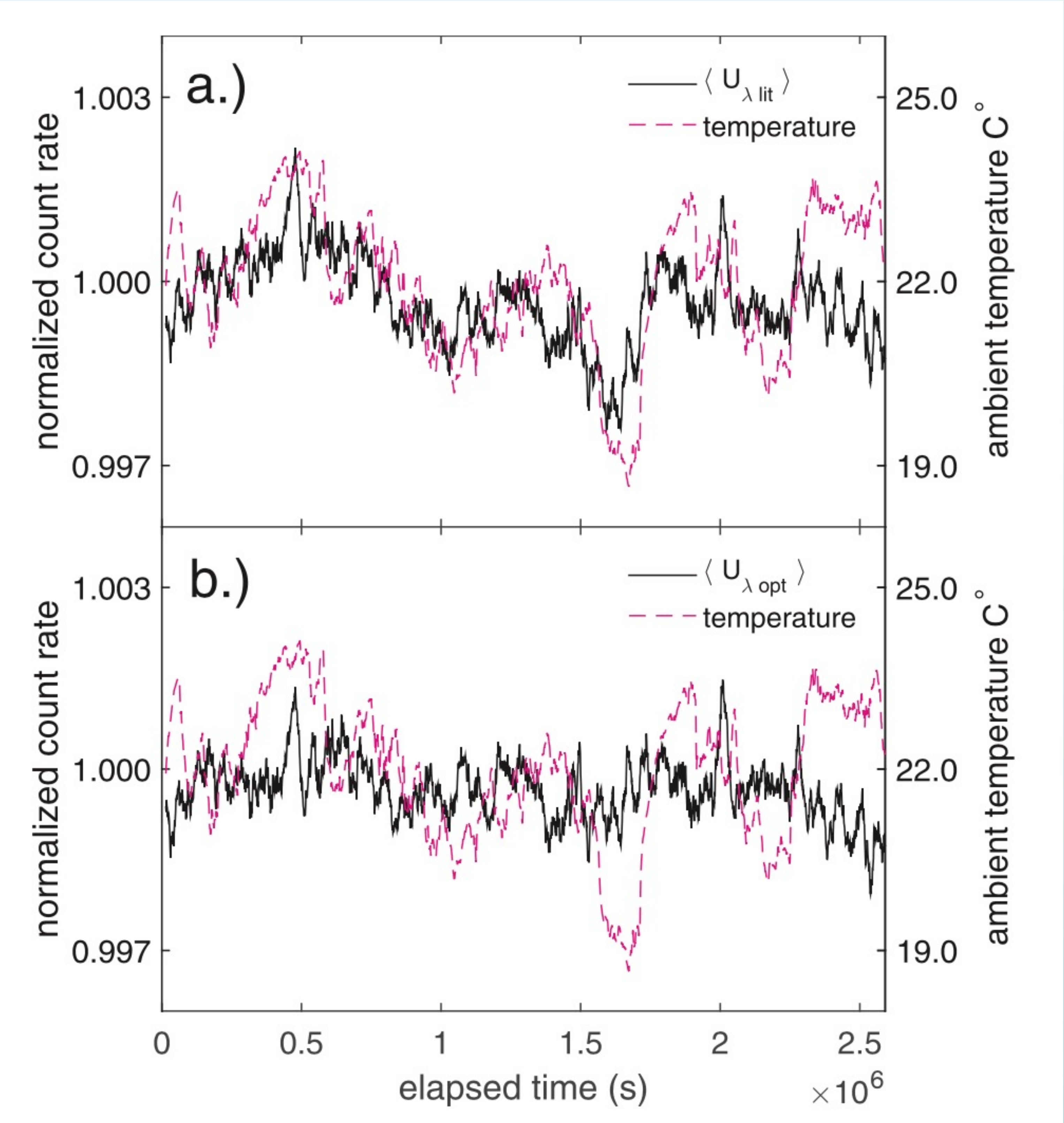

Figure 1: Moving average of a normalized count rate from a 30-day span of ^{204}Th decay data (black line) and the temperature measured in the room (purple dash), (a.) pre-correction and (b.) post-correction

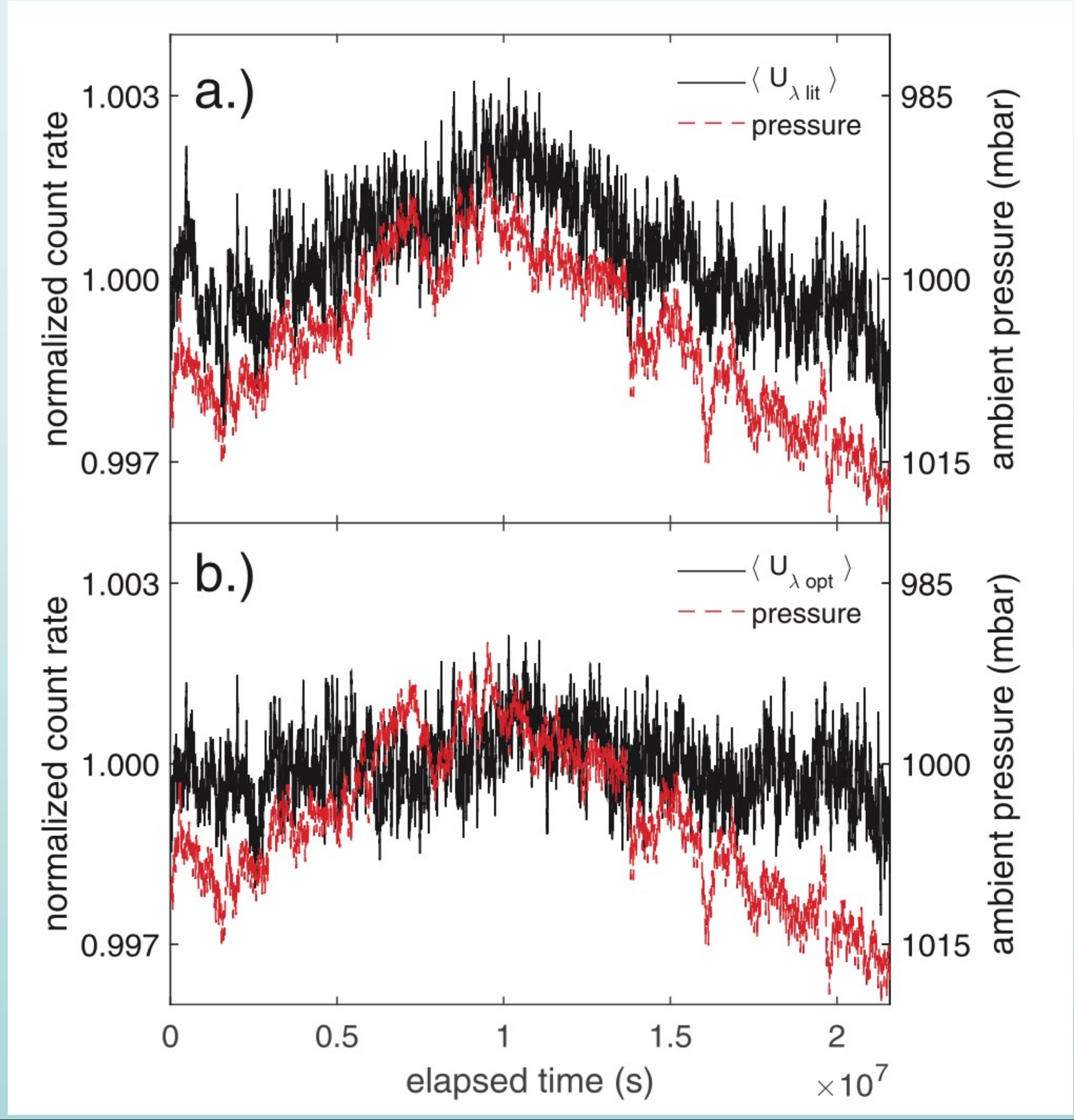

Figure 2: Moving average of a normalized count rate from a 30-day span of ^{204}Th decay data (black line) and the pressure that is measured in the room (purple dash), (a.) pre-correction and (b.) post-correction

Conclusions

- From Figure 1b, the dash lines equate to the temperature variable being applied and as seen in the top image of Figure 1a, the temperature curve more closely correlates to the beta-decay rate of 204Th
- From Figure 2b, the dash lines equate to the pressure variable being applied
- After applying a temperature curve and pressure curve to the normalized count rates, the data shows the external factors like pressure and temperature have similar effects on data recorded from the Geiger–Müller detector
- If other experiments and research prove to find that neutrinos interacting with a radioactive source can alter the rate of decay, then this could be used in the nuclear defense field of study. These findings could lead to more research into whether the same detectors could be used to locate large amounts nuclear radiation.

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Advisor, Dr. George Hitt, ghitt@coastal.edu
Professor, Dr. Monica Gray, mgray2@coastal.edu

References

- Harbottle, Garman. "The Half-Life of Thallium-204." *Physical Review*, vol. 91, no. 5, 1953, doi:10.1103/physrev.91.1234.
- "Access NCBI through the World Wide Web (WWW)." *Molecular Biotechnology*, vol. 3, no. 1, 1995, pp. 75–75., doi:10.1007/bf02821338.
- Jenkins, Jere H., et al. "Evidence of Correlations between Nuclear Decay Rates and Earth–Sun Distance." *Astroparticle Physics*, North-Holland, 30 May 2009, www.sciencedirect.com/science/article/pii/S092765050900084X?via%3Dihub.
- Goddard, Braden, et al. "Experimental Setup and Commissioning Baseline Study in Search of Time-Variations in Beta-Decay Half-Lives." *Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment*, North-Holland, 18 Dec. 2015, www.sciencedirect.com/science/article/pii/S0168900215015971?casa_token=xX5ht6aFdsQAAAAA%3AgPJR4ZlIt8yqiQff7NSloqMDOro0wBrxixlJKl7k-6N5LVYPLdHEYv6il6sviUhBcY737_Xptg.
- Goddard, Braden, et al. "Data from Multi Year and Multi Radiation Detector Measurements of Different Radiation Sources with Environmental Data." *Data in Brief*, Elsevier, 7 June 2020, www.sciencedirect.com/science/article/pii/S2352340920307228.