Journal of Scientific Exploration, Vol. 8, No. 2, pp. 251–253, 1994 0892-3310/94

Response to Volkamer *et al.*

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This paper claims to have established the existence of an anomalous variation in mass that results when reacting chemicals, biological entities, or even static physical systems are placed in sealed vessels whose weights are monitored on sensitive analytical balances. Furthermore, the authors then claim that the mass variations reveal the existence of dark matter. The paper presents an interesting dilemma for the reader. Was the work done carefully enough to support the purported anomalous variations in mass? Have all possible sources of bias been adequately investigated? Does the existence of dark matter follow logically from the experimental results? Denis Rousseau at Bell Labs has refined the concept of *pathological science* (scientific error from self-delusion and associated sloppiness) that was developed by the late Nobel Laureate, Irving Langmuir (Rousseau, 1993). Rousseau sees three major characteristics of such science:

(a) The claimed effect is at the limit of detectability or has very low statistical significance.
(b) The effect's discoverers are ready and willing to disregard prevailing theories and ignore criticism from experts.
(c) The discoverers do not conduct the critical experiments needed to determine whether the effect is real.

The characterization of honest but flawed scientific work as *pathological science* is inappropriate, but it should be recognized that Rousseau's three characteristics are pertinent to examining a controversial scientific study. In that respect, the claimed anomalous mass variations reported in this paper occur near the limit of detectability of the analytical balance. While the authors make an attempt to consider prevailing theories, there is considerable doubt in our minds that the critical experiments were performed, or performed adequately.

In the Introduction, the authors survey previous work, primarily by Landolt (1893,1906,1908) and Manley (1913). They state that Landolt rejected apparent violations of the law of conservation of mass in the silver-generating experiment by averaging between such results and subjective assessments. Manley, in his paper on the apparent change in weight during chemical reaction, repeated Landolt's silver experiments, but is quoted totally out-of-context by the authors in the Final Remarks section, when he discusses an "unknown minute disturbing factor" causing an increase in the average measurement variation. They do not report Manley's final statement in his paper, "we are led to conclude that this present research has tended but to confirm the truth of an almost universally accepted belief, that a given total mass is an unchanging and unchangeable quantity." When investigating the effect of reaction-induced changes in vessel internal pressure, Manley built an apparatus in which the change in the flask volume could be measured by liquid displacement. He determined significant weighing anomalies caused by temperature inhomogeneities and pressure variations, and his paper is a model of careful scientific work. The "unknown minute disturbing factor" that Manley describes is on the order of 0.004 mg, several orders of magnitude smaller than the anomalies measured in the Volkamer manuscript. Manley reports that the apparent increase in total mass in his experiments was 0.001 mg, which is 6 times smaller than the average variations of the experiments. Contrast this careful work to that of the current paper, where it is reported in a short paragraph that eight flasks were filled with sulfuric acid and sodium carbonate to create an internal pressure of 3 bar, and that no weight differences from a control were observed after 30 days. This is not to say that they should have seen an effect. Based on Manley's work, they should not have, because the effect is almost an order of magnitude lower than the readability of their balance. But this manner of investigating and reporting possible experimental sources of error is typical of the paper. A more fundamental weakness in their work is the sensitivity of the balance. They are using balances whose sensitivity is one to two orders of magnitude poorer than that used in the experiments almost a century ago. These balances would be unable to resolve most of the effects reported by Manley and Landolt. The effects reported in this paper are much larger than those reported by the previous researchers.

There are several other critical weaknesses in the Volkamer paper. The use of electronic balances, rather than the classical two pan mechanical balances used by Landolt and Manley, make the measurements more sensitive to exotic sources of error such as electromagnetic interference and static charge. The AE163 balance reported by Volkamer to have an "accuracy" of 0.1 mg and a standard deviation of 0.04 mg is reported by the manufacturer to have a readability and a reproducibility (standard deviation) of 0.1 mg. The U.S. Pharmacopoeia requirements for accurate weighing establish a criteria for accuracy that is 3 times the standard deviation of the balance, or 0.3 mg for this balance. Therefore, many of the anomalous results observed by Volkamer are close to the limits of the balance measurement capabilities. The glass flasks should have been coated inside and out with an electrically-conductive material such as tin oxide before beginning the experiment. Large glass flasks are very difficult to weigh because of conductivity effects. In the plant experiment, the moisture content inside the flask will change as the plant grows, changing the conductivity and inducing apparent mass anomalies. Ideally, the inner and outer surfaces of the flasks should have been electrically connected and the flask and balance pan grounded via fine wire. Again, a comparison of experimental technique between the present authors and that of Manley is striking. Perhaps most importantly, a consistency of effect is not seen. Both mass gains and losses are reported, but not for all samples. This has all the trappings of an uncontrolled measurement bias.

Finally, assuming the constancy of kinetic and potential energy equations throughout the universe and the validity of the Doppler effect and Hubble's constant, it is fairly easy to show that the universe may have from 90% to 99% dark matter of some kind, if the universe is closed (less if not). The maximum amount works out to about 10^{-26} kg/m^3, or ~10 amu/m^3. Because the experimenters found discrepancies ~10^{-11} kg/m^3 that they attribute to dark matter, they are claiming to have produced (or attracted?), in their small containers, about 10^{15} times the density needed throughout the universe. That would be 10^{16} particles/m^3 if each had a mass of 1 amu. Now because no one knows what dark matter is (but it clearly includes at least some understood stuff like asteroids and planets that we just can't see), we suppose they can make this claim, but then they should be willing to take their experiment to one of the dark matter detector experiments that have been established to find just one particle unequivocally! It is even less likely, if that's possible, that their process merely attracted dark matter from somewhere else because it is generally conjectured that non-baryonic (non asteroids and such) dark matter is affected only by the gravitational force or else it could be made to radiate and be seen. In any case, they simply do not have sufficient basis to prefer their Conclusion C over Conclusion A.

In conclusion, since the weighing anomalies observed were not consistent within experiments, and since their results did not agree with the more careful work of Manley, insufficient evidence exists to establish the weighing anomalies as anything more than uncontrolled experimental bias, most likely caused by buildup of static charge.

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The authors express their gratitude to R. Schoonover of the Mass Group, and J. Moody and C. Beck of the Atomic and Molecular Spectroscopy Group of the National Institute of Standards and Technology for their comments on the manuscript.