Journal of High Energy Physics, Gravitation and Cosmology, 2023, 9, 524-529
https://www.scirp.org/journal/jhepgc
ISSN Online: 2380-4335
ISSN Print: 2380-4327

Part I: Explaining the “Muon g – 2” Results with Probabilistic Spacetime

Dennis M. Doren*, **James Harasymiw**

Independent Researcher, Wisconsin, USA
Email: *dmdoren@yahoo.com

How to cite this paper: Doren, D.M. and Harasymiw, J. (2023) Part I: Explaining the “Muon g – 2” Results with Probabilistic Spacetime. *Journal of High Energy Physics, Gravitation and Cosmology*, **9**, 524-529.
https://doi.org/10.4236/jhepgc.2023.92043

Received: February 20, 2023
Accepted: April 15, 2023
Published: April 18, 2023

Abstract

A recent experimental finding replicated an earlier research result, both of which demonstrated conflict with a specific Standard Model prediction. The “Muon g – 2” studies have indicated that the degree of muon precession predicted by the Model is not the same as observed. The researchers offer many posteriori atheoretical hypotheses as possible explanations of their findings, but no fundamental theoretical understanding of the near discovery is among them. This article describes both an explication for the unexpected result and describes its underlying mechanism based on an existing cosmological theory, the Probabilistic Spacetime Theory. The paper also discusses the potential value of this theory.

Keywords

Muon g – 2, Probabilistic Spacetime, Muon Anomaly, Muon Precession, Standard Model

1. Introduction

This is the first of three articles demonstrating the utility of the Probabilistic Spacetime Theory (PST) towards explaining experimental and observational findings contrary to the expected outcomes stemming from accepted paradigms. Each of the three articles addresses one unexpected finding and shows how the previously published PST offers both an explanation of the finding and the underlying mechanism. The purposes of these articles are: 1) to offer explanations of the unexplained and 2) to promote an expansion of observational and experimental research concerning the PST’s facets and predictions.

In this article, the concentration is on a very well-designed and implemented set of experiments that measured the muon precession in a magnetic field. As is detailed below, the observed degree of muon “wobble” (precession) was greater than that predicted by the Standard Model (SM). The experiments demonstrating this outcome are described in Section 2 of this paper. In Section 3, there is a brief delineation of the relevant portions of the PST. Section 4 describes how the PST explains the "extra" precession and the underlying mechanism causing it.

2. The "Muon g – 2" Experiments and Findings

When entered in a stable magnetic field, charged particles with natural angular momentum (spin) demonstrate precession, a wobble around their central axis. The causes for this precession are thought to include the particle's 1) interaction with the magnetic field, 2) magnetic interaction with itself (which is a characteristic of all charged particles), and 3) interactions with the virtual particles both it creates (through its interaction with itself) and that exist along its path. (Virtual particles are thought to be everywhere, collectively being referred to as the quantum foam. In theory, they are very brief representations in the quantum realm that the "very geometry of spacetime fluctuates" [1]). The SM specifies the amount of precession to be expected using these measurable factors, though precision in measurement is always a significant challenge.

To test the SM's prediction (*i.e.*, to test the SM itself), experiments were conducted by placing muons in a uniform external magnetic field. Because of the particles' angular momentum, their spin direction rotates around the direction of the magnetic field. Being tested was whether the SM accurately predicted the observed precession of the charged particles.

The first tests of muon precession were conducted between 45 - 60 years ago at CERN [2] [3] [4]. Those results were suggestive that the SM did not exactly predict the observed muon precession. However, given the measurements were only as precise as the technology of the time (which left much room for measurement error), any conclusion contrary to the SM was held in abeyance. More trustworthy support for such a conclusion needed to await improvements in technology.

About 20 years ago, a far more intriguing finding was found at Brookhaven National Laboratory (BNL) [5]. Essentially repeating the same experiment but with far greater measurement and analysis precision, the BNL study (entitled "Muon g – 2") again showed the unexpectedly extra degree of muon precession compared to what the SM predicted. Statistically, the difference compared to chance was computed to be almost 3σ. On the one hand, the difference of 5σ is the standardized threshold for a finding to be proclaimed a discovery, meaning the BNL's failure to support the SM did not rise to the level considered analogous to statistical certainty. On the other hand, the fact the BNL results replicated the CERN findings, and did so while conducting the study with far greater precision (involving 100 s to 1000 s of times improvements in precision) strongly suggested there was reason for further exploration.

Most recently, the same experiment was run again, using current technological abilities. Researchers at Fermi National Accelerator Laboratory (Fermilab) repeated the experiment using more precise instrumentation and ability to be comprehensive in analyzing their data [6] [7] [8] [9]. Despite increased scrutiny concerning possible sources of error, BNL's unexpected finding was replicated at Fermilab. The conclusion drawn from the Fermilab study was that the tension between the SM and the BNL finding was confirmed [6] [7] [8] [9]. Together, the BNL and Fermilab studies represent a "world average" difference from the SM at 4.2σ. Additionally, Fermilab is still conducting multiple analyses of data from other runs of their experiment, so further updates are expected [6] [7] [8] [9]. Those updates could bring the world average result to discovery level. In the meanwhile, however, the evidence of new physics already seems quite strong, with the current likelihood of the results being due to chance of about 1 in 40,000.

Something "extra" seems required to explain the unanticipated degree of muon precession. The Fermilab researchers offer a large set of hypothetical causes for their finding (e.g., dark photon, dark Z, two-Higgs doublet model, scalar leptoquarks, vector-like leptons, scalar singlet plus fermion, some three-field extensions of the SM, various supersymmetry scenarios, etc.) [10] [11]. Importantly, all of these are posteriori and atheoretical in their connection to the phenomenon uncovered. Put another way, none of these would have been used to predict the research findings and only currently serve as possible explanations after the fact. As such, they may fit the data but as a group they do not offer us any theoretical basis for choosing among them in deciding which to evaluate for verification.

3. Relevant Portions of the PST

The purpose for theory is to help guide research. By summarizing what is known into a coherent whole, theory helps us develop further hypotheses for testing; with that testing leading to an increase in our knowledge no matter what is found. That is true for the SM, and any other internally consistent and externally supported theory. Without a theoretical basis for selecting what to study, accounting for intervening variables and even making sense of results from our research is far more difficult. The Muon g − 2 researchers conducted incredibly meaningful research because they knew what factors to address, what variables to control, and what outcome to expect based on a well-defined theory (the SM).

To explain the additional experimentally observed muon precession energy beyond what the SM predicted, starting with existing theory would seem best, rather than working from a list of posteriori atheoretical hypotheses. Relative to the Muon g − 2 results, such a theory exists; a cosmological theory that describes an explanatory factor and mechanism.

The Probabilistic Spacetime Theory (PST) was developed in response to the many years of failure in determining the essence of dark matter. The original impetus for the theory was to see if the phenomena thought to require "dark matter" for explanation (e.g., why stars at the outside of galaxies do not fly off, why there is more gravitational lensing than known sources of gravity can explain) could be understood without presuming anything "dark". The theory was formally first applied to resolving the Hubble tension [12], and in its full description [13] was used to explain not only the nature of dark matter, but also how supermassive primordial black holes came to exist, why magnetism is everywhere, and why filaments have angular momentum. Since then, the PST has provided a resolution to the black hole information paradox (without any conjectures changing the structure of black holes) [14]. The PST was designed to address cosmological phenomena and did so by starting with the smallest entities in the universe. It is the PST's view of the most fundamental entities in the universe that directly explains the Muon g − 2 results.

Briefly, the PST posits spacetime is not simply a void or empty container of energy fields but is itself composed of wave functions of probabilistic energy. These energy fragments are the most fundamental entities in the universe. Nothing else is more fundamental. Everything in the universe has its roots in the probabilistic energy we call spacetime.

The probabilistic nature of these energy fragments means they are constantly sharing and exchanging energy among themselves. This is the same as how we view interacting quantum wave functions in general except the energy described in the PST is probabilistic in its essence, not of a macro nature. Even so, the constant swirling of probabilistic energy does what swirling energy does in the macro world—it creates magnetism. The PST posits that through that mechanism, magnetism exists everywhere there is spacetime. In any given small volume of spacetime, the spacetime-generated magnetic force is tiny, but it is always there.

There are other foundational principles to the PST (five in total) [13], but the facets necessary to explain the Muon g − 2 results have already been specified. The Muon g − 2 researchers worked extremely hard to ensure the crucial magnetic field in their experiment was measurable and stable. At the same time, given the BNL and Fermilab experiments' purpose was to test the SM, it is fully understandable that the researchers did not consider that magnetism created by spacetime itself might be a relevant factor.

4. Explaining the Results with the PST

The primary principle of the PST states that spacetime is the fundamental entity of the universe, composed of probabilistic energy. That energy constantly is shared and exchanged among spacetime wave functions, a process that causes magnetism everywhere there is spacetime.

The muons in the Muon g − 2 study obviously existed within the context of spacetime. They therefore necessarily interacted with the spacetime in which the muons traversed. That spacetime necessarily brought a small degree of magnetism to the muons' environment beyond what the researchers intended to control or planned on measuring.

The PST therefore indicates that the muon precession found beyond the SM prediction was due to the interaction between the muons and the spacetime-generated magnetic field they traversed. The effect of this interaction on the muons would be extremely small, but these experiments were incredibly precise in their measurements. To exemplify how precise, the research was able to control for the effect on the muons of the quantum foam (*i.e.*, virtual particles) [9]. Likewise, the extra muon precession result needing explanation was measured in terms involving 10^{-11}, and as having the precision of 0.46 ppm [6]. It is the very precision of these experiments that points to how the PST's interpretation can be correct.

The PST tells us that the interaction between muons and spacetime's magnetic field may have become measurable due to the experiments' extreme sensitivity. From the perspective of the PST, the Muon g − 2 experiments were the first to detect the magnetic strength of spacetime itself!

5. Discussions

There are many possible reasons the Muon g − 2 experiments show an excess amount of muon precession. Only the PST offers a ready explanation without hypothesizing new particles, new forces, new interactions, etc., beyond existing theory. In fact, the application of the PST to interpreting the Muon g − 2 results is straightforward, including in describing the underlying mechanism causing the excess precession. The excess precession reflected the magnetism in the test chamber that the researchers did not know to anticipate. If the PST had been available to be considered prior to the Muon g − 2 tests, the theory would have predicted there would be an effect of the muon − spacetime interaction on the experimental outcomes.

The PST has previously shown similar explanatory and predictive power. The Hubble tension was predicted (based on a theorized mechanism causing differences in local expansion rates) [12] [13]. The possible existence of glueballs (self-adhering clusters of gluons that exist absent the presence of fermions) was theorized at about the same time their reality was demonstrated. Described prior to the phenomenon being observed was that black holes would grow along with the expansion of the universe even without ingesting new mass [13] (Also see the Part II article in this three-part series). Additionally, the PST was shown to offer a straightforward resolution to the 50-year-old black hole information paradox [14].

The extra muon precession can be explained by the PST using its existing tenets. Given the theory's other demonstrated explanatory and predictive utility, the authors hope that the PST's other facets and predictions will be investigated further.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Wheeler, J.A. and Ford, K.W. (2010) Geons, Black Holes, and Quantum Foam: A

Life in Physics. W. W. Norton & Company, New York.

[2] Charpak, G., Farley, F.J.M., Garwin, R.L., Muller, T., Sens, J.C., Telegdi, V.L. and Zichichi, A. (1962) Measurement of the Anomalous Magnetic Moment of the Muon. *Physical Review Letters,* **6**, 128. https://doi.org/10.1103/PhysRevLett.6.128

[3] Aldins, J., Brodsky, S.J., Dufner, A.J. and Kinoshita, T. (1970) Photon-Photon Scattering Contribution to the Sixth-Order Magnetic Moments of the Muon and Electron. *Physical Review D*, **1**, 2378. https://doi.org/10.1103/PhysRevD.1.2378

[4] Bailey, J., Bartl, W., von Bochmann, G., Brown, R.C.A., Farley, F.J.M., Giesch, M., Jöstlein, H., van der Meer, S., Picasso, E. and Williams, R.W. (1972) Precise Measurement of the Anomalous Magnetic Moment of the Muon. *Nuovo Cimento A,* **9**, 369-432. https://doi.org/10.1007/BF02785248

[5] Bennett, G.W., *et al.* (Muon g − 2 Collaboration) (2006) Final Report of the E821 Muon Anomalous Magnetic Moment Measurement at BNL. *Physical Review D*, **73**, Article ID: 072003. https://doi.org/10.1103/PhysRevD.73.072003

[6] Abi, B., *et al.* (Muon g − 2 Collaboration) (2021) Measurement of the Positive Muon Anomalous Magnetic Moment to 0.46 ppm. *Physical Review Letters,* **126**, Article ID: 141801. https://doi.org/10.1103/PhysRevLett.126.141801

[7] Girotti, P., *et al.* (Muon g − 2 Collaboration) (23 Feb. 2022) Status of the Fermilab Muon g − 2 Experiment. https://doi.org/10.1051/epjconf/202226201003

[8] Labe, K.R., *et al.* (Muon g − 2 Collaboration) (12 May 2022) The Muon g − 2 Experiment at Fermilab. ArXiv: 2205.06336v1.

[9] Keshavarzia, A., Khawb, K.S. and Yoshiokac, T. (26 January 2022) Muon g − 2: A Review. ArXiv: 2106.06723v3.

[10] Crivellin, A. and Hoefrichter, M. (9 May 2020) Combined Explanations of $(g-2)_\mu$, $(g-2)_e$ and Implications for a Large Muon EDM. https://doi.org/10.22323/1.360.0009

[11] Athron, P., Balázs, C., Jacob, D.H.J., Kotlarski, W., Stöckinger, D. and Stöckinger-Kim, H. (8 Oct. 2021) New Physics Explanations of a_μ in Light of the FNAL Muon g − 2 Measurement. *Journal of High Energy Physics*, **2021**, Article Number: 80. https://doi.org/10.1007/JHEP09(2021)080

[12] Doren, D.M. and Harasymiw, J. (2020) Resolving the Hubble Constant Discrepancy: Revisiting the Effect of Local Environments. *International Journal of Cosmology, Astronomy and Astrophysics*, **2**, 94-96. https://doi.org/10.18689/ijcaa-1000121

[13] Doren, D.M. and Harasymiw, J. (2021) Everything Is Probabilistic Spacetime: An Integrative Theory. *International Journal of Cosmology, Astronomy and Astrophysics*, **3**, 130-144. https://doi.org/10.18689/ijcaa-1000127

[14] Doren, D.M. and Harasymiw, J. (2023) Resolving the Information Paradox with Probabilistic Spacetime. *Journal of High Energy Physics, Gravitation and Cosmology*, **9**, 83-99. https://doi.org/10.4236/jhepgc.2023.91008