Anomalous Magnetic Moment of the Tau Lepton

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Abstract: Here, within the Scale-Symmetric Theory (SST), we calculated the anomalous magnetic moment of the tauon: 0.0011771783. Our value is consistent with the Standard-Model (SM) prediction. We show that the anomalous magnetic moments of the charged leptons strongly depend on how they are created. Our model is very simple because we do not neglect internal structure of the bare particles.

1. Introduction

In SST [1], magnetic moment of a charged lepton, L_{mm}, is defined as follows

$$L_{mm} = (m_{bare} + m_{rad}) / m_{bare} = 1 + m_{rad} / m_{bare} = 1 + a \,, \quad (1)$$

where m_{bare} is the bare mass of charged lepton (the spin-1/2 torus/electric-charge plus the spin-0 central spacetime condensate responsible for the <u>weak</u> interactions), and m_{rad} is the radiation mass that leads to the anomalous magnetic moment a.

The virtual field around the bare electron consists of only one virtual bare electron-positron pair – it disappears in one place and appears in another one, and so on. The same concerns the electron as a whole so it interacts also with the SST dark matter [1]. The electroweak interactions of such a system lead to the anomalous magnetic moment of the electron a_e. The two different SST descriptions lead to

$$a_{e1} = 0.00115965217932 \text{ (see (2.3.13) in [1][) ,} \quad (2)$$

$$a_{e2} \approx 0.001159652175 \text{ (see (2.6.5) in [1]) .} \quad (3)$$

In the muon and tauon, due to their creations that differ from the creation of the electron (see Sections **2.10** and **2.11** in [1]), there appears an additional radiation mass, $\Delta m_{i,rad}$, that changes the definition of the anomalous magnetic moment

$$a_i = a_{e1} (1 + \Delta m_{i,rad} / m_{i,bare}) \,, \quad (4)$$

where $i = e, \mu, \tau$, the a_{e1} represents the electron-like anomalous magnetic moment, i.e. the number of created the virtual bare electron-positron pairs is equal to $N_i = 2m_{i,bare}/(2m_{e,bare})$, where $m_{i,bare}$ is the bare mass of a lepton while $m_{e,bare}$ is the bare mass of the electron. Notice that for the electron is $N_e = 1$ and $\Delta m_{e,rad} = 0$.

In paper [1] in Section **2.10**, we already calculated the muon anomalous magnetic moment and our result is perfect. The muons are created in the collisions of baryons because of the weak interactions of the spacetime condensates $Y^* = 2\pi m_{FGL} \approx 424.39406$ **MeV** that exchange the bare electron-positron pair $2m_{e,bare} \approx 1.020814$ **MeV**. It suggests that the bare mass of the muon is directly proportional to $m_{\mu,bare} \sim 2Y^* + 2m_{e,bare}$. The muons are created also due to the decays of the charged pions so we can assume that the additional radiation mass is directly proportional to the mass distance between the charged pion and neutral pion $\Delta m_{\mu,rad} \sim \Delta\pi^* = \pi^{\pm} - \pi^{o}$. The above remarks and the assumption that one $\pi^{+}\pi^{-}$ pair is created per four colliding Y^* (see the four-particle symmetry described in SST) cause that formula (4) for the muon looks as follows

$$a_{\mu} = a_{e1} [1 + \Delta\pi^* / (2Y^* + 2m_{e,bare})] = 0.0011659204067 . \quad (5)$$

Our model of the tauon is an analogy to the muon model presented in [1].

The conclusion is as follows: the SST shows that the anomalous magnetic moments depend on how the particles are created.

2. Anomalous magnetic moment of the tauon

The anomalous magnetic moments of electron and tauon are different because they are created in different ways.

Our formula for the mass of tauon is (see formula (2.11.2) in [1])

$$m_{tauon} = 8 \pi^2 m_{FGL} / 3 - 2 m_{e,bare} = 1776.67688470713 \textbf{ MeV} . \quad (6)$$

Formula (6) suggests that the additional radiation mass of the tauon, $\Delta m_{\tau,rad}$, is directly proportional to the mass of the bare electron-positron pair ($\Delta m_{\tau,rad} \sim 2m_{e,bare}$) **because such energy is emitted (it is some analogy to emission of $\Delta\pi^*$ by charged pion) while the mass of the bare tauon, $m_{\tau,bare}$, is directly proportional to the mass of the fundamental gluon loop** $m_{\tau,bare} \sim m_{FGL}$. The above remarks and the assumption that one bare $e^{+}e^{-}$ pair is created per one fundamental gluon loop cause that formula (4) for the tauon looks as follows

$$a_{\tau} = a_{e1} (1 + 2 m_{e,bare} / m_{FGL}) = 0.0011771783 . \quad (7)$$

Due to the very short lifetime of the tauon, the precision of the current experimental measurement is very low [2]

$$a_{\tau}(\textbf{Exp}) = - 0.018(17) . \quad (8)$$

The theoretical Standard-Model (SM) result is [3]

$$a_{SM,\tau} = 0.001177171(39) , \quad (9)$$

so it is very close to our result.

We see that the Standard-Model (SM) and SST theoretical results are very close to each other. It should be noted, however, that the SST method used here sums the contributions from the SM diagrams via the characteristic masses appearing during the creation of electrically charged leptons, which greatly simplifies the calculation of the radiation masses that lead to the anomalous magnetic moments.

The SST values, SM values, and experimental values of the anomalous magnetic moments of the electron, muon and tauon are collected in Table 1.

Table 1 *Anomalous magnetic moments of charged leptons*

Charged lepton	Anomalous mag. mom. Experiment	Anomalous mag. mom. SST	Anomalous mag. mom. SM
Electron	0.00115965218076(28) [4]	0.00115965217932 [1]	0.00115965218161(23) [5]
Muon	0.0011659206(4) [4]	0.0011659204067	0.00116591810(43) [6]
Tauon	– 0.018(17) [2]	0.0011771783	0.001177171(39) [3]

3. Summary

Based on this section, we can conclude that the Standard-Model description of the magnetic moments of charged leptons is complicated and very extensive compared to SST because the SM neglects both the internal structure of the bare leptons and their interactions with the SST dark matter via the weak interactions of the virtual bare electron-positron pairs – we must take them into account because the wavefunction of a single electron fills the whole spacetime.

However, we did not answer yet the basic question: why do processes expressed by the Feynman diagrams with loops and the SM diagrams lead to correct values for anomalous magnetic moments of charged leptons? Are the two essentially different descriptions, i.e. the SM description and SST description, equivalent? Does the sum of contributions from all the diagrams for a charged lepton coincide with the value obtained in SST? The fact that we are not yet able to measure the anomalous magnetic moment of the tauon with great accuracy and the fact that the values obtained in SM and SST for the tauon are practically the same suggest that both descriptions are equivalent. The proper solution to this problem is suggested by the description of the electron creation in the framework of the Scale-Symmetric Theory. The electron is created as a loop/electric-charge in the SST absolute spacetime with shifted the zero-point of the local zero-energy field (due to the $E = mc^2$, the excess energy is equal to $m_{e,bare}/2$), so we can ignore the weak interactions of such an object and use the SM diagrams (they describe the excitations of the thickened zero-energy field) to calculate the radiation mass. SST shows that such an electron loop, with thickened the local zero-energy field, transforms into the torus/electric-charge and central spacetime condensate, so we can apply the much simpler SST model. This is the source of the equivalence of the two very different descriptions – just the involved energy and electric charge in both descriptions are the same.

I mention here the weak interactions of the virtual bare electron-positron pairs to emphasize the particle-cosmology coherence in the Scale-Symmetric Theory. Just the SST via the weak interactions (global or local) explains both the rotation of spiral galaxies modified by the local weak interactions of the dark-matter loops with baryon matter (see Section **H1** in [1]) and, via the global weak interactions, the anomalous magnetic moment of the electron (see Section **2.6** in [1]), and the main part of the anomalous magnetic moment of the muon (see Section **2.10** in [1]) and tauon (see this paper).

References

[1] Sylwester Kornowski (7 October 2022). "Particles, Cosmology and Applications: Scale-Symmetric Theory (SST)"
http://vixra.org/abs/2110.0171v2
[2] J. Abdallah, *et al.* (DELPHI Collaboration).
Eur. Phys. J. C **35** (2004) 159
[3] A. Keshavarzi, *et al.* (2020). "The g – 2 of charged leptons, $\alpha(M_Z^2)$ and the hyperfine splitting of muonium"
Phys. Rev. D **101**, 014029 (2020)
arXiv:1911.00367v2 [hep-ph]
[4] R. L. Workman, *et al.* (Particle Data Group)
Prog. Theor. Exp. Phys. **2022**, 083C01 (2022)
[5] T. Aoyama, *et al.* (22 February 2019). "Theory of the Anomalous Magnetic Moment of the Electron"
Atoms **2019**, 7, 28
[6] T. Aoyama, *et al.* (3 December 2020). "The anomalous magnetic moment of the muon in the Standard Model"
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