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Gauged Unparticles Contribution to the Neutrino Anomalous Dipole Moment

E Redouane Salah[1] and N Mebarki
Laboratoire de Physique Mathematique et Subatomique
Mentouri University, Constantine, Algeria

E-mail: assma12001@yahoo.fr

Abstract. A one loop gauged unparticles contribution to the anomalous neutrino magnetic and electric dipole moments is presented and a prescription is proposed.

1.Introduction

A Dirac neutrino of type "i" with standard model interactions within the standard model has a magnetic dipole moment given by [1]-[2]:

$$\mu_{\nu_i} \approx 3.10^{-19}(\frac{m_{\nu_i}}{eV})\mu_B \tag{1}$$

Where $\mu_B = e/2m_e$ is the Bohr magneton.The observation of a magnetic moment larger than that of eq.(1), would be an indication of new physics beyond the standard model. From the practical point of view, the Borexino experiment, gives upper bounds at *90%* CL,$\mu_{\nu_e} < 5.8\,10^{-11}\mu_B$, $\mu_{\nu_\mu} < 1.5\,10^{-10}\mu_B$ and $\mu_{\nu_\tau} < 1.9\,10^{-10}\mu_B$ [3]-[5]. Recently the authors of ref.[6] have derived an upper bound on the Dirac neutrinomagnetic moment within a low energy effective theory $\mu_\nu \leq 10^{-14}\mu_B$. In all the above cases experimental or theoretical and others which are not mentioned here, the derived upper limit is several order of magnitude larger than the one of eq.(1). Moreover, all particles exist in states that may be characterized by a certain energy, momentum and mass. In the standard model, particles cannot exist in another state with all these properties scaled up or down by a common factor.Electrons, for example, always have the same mass regardless of their energy or momentum. But this is not always the case: massless particles, such as photons can exist with their properties scaled equally. This immunity to scaling is called "scale invariance".The idea of unparticles comes from Georgi [7]-[8] by conjecturing that there may exist "stuff" that does not necessarily have zero mass but is still scale-invariant, with the same physics regardless of a change of energy. This stuff is unlike particles, and called unparticle.These unparticleshave not been observedso far. This means that if it exists, it must couple with normal matter weakly at observable energies. One of the great hopes for the LHC is to try to give signatures to these unparticles through their contribution to the observable physical quantities like the neutrino magnetic moment or others. Moreover, unparticles are like neutrinos interact weakly with the particles of the standard modeland we can infer their presence only by calculating the "missing" energy and momentum after an interaction that would not be detected by

[1] To whom any correspondence should be addressed.

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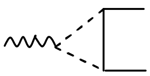
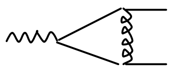
the experimental apparatus. If such signatures are not observed, bounds on the model can be set and refined. Moreover, according to scale invariance, a distribution containing unparticles would become apparent because it would resemble a distribution for a fractional number of massless particles. Recently, many interestshave been devoted to the so-called gauged unparticles which carry the standard model quantum numbers[9]-[11].In this work, we present a contribution of gauged unparticles to the neutrino electric and magnetic dipole moments (EDM respect. MDM).

2. General Mathematical Formalism

In what follows, we assume that the gauged unparticles carry the standard model quantum numbers and they come into pairs in intermediate states (via loops, vertices etc..) and the interactions $U_l U_W \nu_l$, $U_{\nu_l} U_Z \nu_l$and $U_s U_l \nu_l$(U and l stand for unparticles and charged leptons respectively) are the same as those of the standard model. However, those with the photon (wavy line) that is $\gamma U_W U_W$. Here s and ν_l denote charged scalar and neutrino of type l respectively. The new contributions of the gauged unparticles to the anomalous electric and magnetic dipole moments come from the diagrams of types (a),(b),(c) and (d).

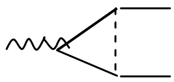


(a)



(b)

(c)



(d)

If we denote by $D = 4 - 2\varepsilon$ (using dimensional regularization prescription),q = $p_3 + p_4$,p_3,s_3 , s_4, p_4,μ_{U_s}, μ_{U_l}, μ_{U_W} , $\varepsilon^\mu(q)$ are the 4-momenta of the incoming photon, the momenta and spin of the outgoing neutrino and antineutrino and the masses of unparticles charged scalar, leptonic and W boson and the photon polarization respectively than:

i)Contribution of diagram type (a):

In this case, we have in the intermediate state two charged scalar unparticles U_s (dashed line) and one charged lepton unparticle U_l (solid line). The corresponding transition amplitude denoted by $M_{(a)}$ is:

$$M^{\mu}_{(a)} = -\frac{g^2\mu^2_{U_l}}{8M^2_W}\int \frac{d^D k}{(2\pi)^D}\bar{u}(p_3,s_3)(1-\gamma^5)\Delta_{U_l}(p_3+k)(1-\gamma^5)\Gamma^{\mu}_s(k,q)\Delta_{U_s}(k)\Delta_{U_s}(q+k)u(p_4,s_4)\varepsilon^{\mu}(q) \quad (2)$$

ii)Contribution of diagram type (b):

In this case, we have in the intermediate state two charged leptons unparticles U_l (solid line) and one charged vector unparticle U_W(spring line). The corresponding transition amplitude denoted by $M_{(b)}$ is:

$$M^{\mu}_{(b)} = -\frac{g^2}{8}\int \frac{d^D k}{(2\pi)^D}\bar{u}(p_3,s_3)\gamma^{\rho}(1-\gamma^5)\Delta_{U_l}(k)\Gamma^{\mu}_l(k,q)\Delta_{U_l}(p_3+k)\gamma^{\sigma}(1-\gamma^5)\Delta^{\rho\sigma}_{U_W}(q+k)u(p_4,s_4)\varepsilon^{\mu}(q) \quad (3)$$

iii)Contribution of diagram type (c):
In this case, we have in the intermediate state one charged leptons unparticles U_l (solid line) and two charged vector unparticle U_W (spring line). The corresponding transition amplitude denoted by $M_{(c)}$ is:

$$M^{\mu}_{(c)} = -\frac{g^2}{8}\int\frac{d^Dk}{(2\pi)^D}\bar{u}(p_3,s_3)\gamma^{\rho}(1-\gamma^5)\Delta_{U_l}(p_3+k)\gamma^{\sigma}(1-\gamma^5)u(p_4,s_4)\Gamma_v^{\mu,\alpha,\beta}(k,q)\Delta^{\beta\sigma}_{U_W}(q+k)\Delta^{\rho\alpha}_{U_W}(k)\varepsilon^{\mu}(q) \quad (4)$$

iv)Contribution of diagram type (d):
In this case, we have in the intermediate state two charged leptons unparticles U_l (solid line) and one charged scalar unparticle U_s (spring line). The corresponding transition amplitude denoted by $M_{(d)}$ is:

$$M^{\mu}_{(d)} = -\frac{g^2\mu^2_{U_l}}{8M_W^2}\int\frac{d^Dk}{(2\pi)^D}\bar{u}(p_3,s_3)(1-\gamma^5)\Delta_{U_l}(k)\Gamma_l^{\mu}(k,q)\Delta_{U_l}(p_3+k)(1-\gamma^5)\Delta_{U_s}(q+k)u(p_4,s_4)\varepsilon^{\mu}(q) \quad (5)$$

where

$$\Delta_{u_f}=\frac{A_{(d_{u_f}-1/2)}}{2\cos(\pi d_{u_f})}\frac{i}{(k-\mu_f)\Sigma_0^f(k,\mu_f)} \quad (6)$$

$$\Delta_{u_s}=\frac{A_{(d_{u_s})}}{2\sin(\pi d_{u_s})}\frac{i}{\Sigma_0^s(k,\mu_s)} \quad (7)$$

$$\Delta^{\mu\nu}_{u_v}=\frac{iA_{(d_{u_v})}}{2\sin(\pi d_{u_v})}\left(\frac{-g_{\mu\nu}+\frac{k_\mu k_\nu}{k^2}}{\Sigma_0^s(k,\mu_v)}\right) \quad (8)$$

$$\Gamma_f^{\mu}(k,q) = \frac{1}{2}[\gamma^{\mu}\left(\Sigma_0^f(k+q)+\Sigma_0^f(k)\right)+(2k+q-2\mu_f)(2k+q)^{\mu}\Sigma_1^f(k,q) \quad (9)$$

$$\Gamma_s^{\mu}(k,q) = (2k+q)^{\mu}\Sigma_1^s(k,q) \quad (10)$$

$$\Gamma_v^{\mu,\rho,\sigma}(k,q) = [(2k+q)^{\mu}g^{\rho\nu}\Sigma_1^s(k,q)+(q-k)^{\rho}g^{\mu\nu}\Sigma_1^s(q,q+k)+[(-2q-k)^{\nu}g^{\rho\mu}\Sigma_1^s(q+k,k) \quad (11)$$

with

$$\Sigma_1^s(k,q) = \frac{2\sin(\pi d_{u_s})}{A_{(d_{u_s})}}\frac{\Sigma_0^s(k+q)-\Sigma_0^s(k)}{(k+q)^2-k^2} \quad (12)$$

$$\Sigma_1^f(k,q) = \frac{2\cos(\pi d_{u_s})}{A_{(d_{u_s}-1/2)}}\frac{\Sigma_0^f(k+q)-\Sigma_0^f(k)}{(k+q)^2-k^2} \quad (13)$$

$$\Sigma_0^f(k,\mu_f) = \left({\mu_f}^2-k^2\right)^{\frac{3}{2}-d_{u_f}} \quad (14)$$

$$\Sigma_0^s(k,\mu_f) = \left({\mu_s}^2-k^2\right)^{2-d_{u_f}} \quad (15)$$

Now, using the following asymptotic forms of the scalar $\Gamma_s^{\mu}(k,q)$fermionic $\Gamma_f^{\mu}(k,q)$ and vector $\Gamma_v^{\mu,\rho,\sigma}(k,q)$vertices:

$$\Gamma_s^{\mu}(k,q) = \frac{2\sin(\pi d_{u_s})}{A_{(d_{u_s})}}\frac{(-1)^{2-d_{u_s}}(2-d_{u_s})(2k+q)^{\mu}}{((k+q)^2-{\mu_s}^2)^{d_{u_s}-1}} \quad (16)$$

$$\Gamma_f^{\mu}(k,q) = \frac{2cos\left(\pi d_{u_f}\right)}{A_{\left(d_{u_f}-1/2\right)}} \frac{(-1)^{3/2-d_{u_f}} 2(2-d_{u_f})}{((k+q)^2-\mu_f{}^2)^{d_{u_f}-3/2}} \tag{17}$$

and

$$\Gamma_v^{\mu,\rho,\sigma}(k,q) = \frac{2sin(\pi d_{u_s})}{A_{(d_{u_s})}}(-1)^{2-d_{u_s}}(2-d_{u_s})\Big[\frac{(2k+q)^{\mu} g^{\rho\nu}}{((k+q)^2-\mu_s{}^2)^{d_{u_s}-1}} + \frac{(q-k)^{\rho} g^{\mu\nu}}{((k+2q)^2-\mu_s{}^2)^{d_{u_s}-1}} + \frac{(-2q-k)^{\nu} g^{\rho\mu}}{((2k+q)^2-\mu_s{}^2)^{d_{u_s}-1}}\Big] \tag{18}$$

Now, using the integrals results:

$$I(D,\alpha,\beta,a) = \int \frac{d^D k}{(2\pi)^D} \frac{(k^2)^{\alpha}}{(k^2-a^2)^{\beta}} = \frac{i}{(2\pi)^{D/2}} (a^2)^{D/2} (-a^2)^{\alpha-\beta} \frac{\Gamma\left(\beta-\alpha-\frac{D}{2}\right)\Gamma(\beta)}{\Gamma\left(\alpha+\frac{D}{2}\right)\Gamma\left(\frac{D}{2}\right)} \tag{19}$$

and

$$\int \frac{d^D k}{(2\pi)^D} \frac{(k^2)^{\alpha} k^{\mu} k^{\nu}}{(k^2-a^2)^{\beta}} = \frac{g^{\mu\nu}}{D} I(D,\alpha+1,\beta,a) \tag{20}$$

and the identity

$$\left(1-\frac{4}{D}\right)\Gamma\left(3-\alpha-\frac{D}{2}\right) = \frac{(-1)^{\alpha-1}}{(\alpha-1)!}\left(\frac{1}{2}+\frac{\varepsilon}{2}(\psi(\alpha)+1)\right) \tag{21}$$

where $\psi(z)$ is the Digamma Euler function, one can easily determine the sum of the above amplitudes. Summing over the neutrino spin in the final state and averaging over the photon polarizations, one can obtain the new contribution to the neutrino electric and magnetic dipole moments and make a phenomenological study for this new physics (Work in progress).

3. Conclusions

Through this paper, we have shown the possible loop contributions of the gauged unparticles to the neutrino dipole moment. The observation of a significantly larger magnetic moment will provide a clear signal of new physics beyond the standard model. The current experimental limits on the neutrino magnetic moments are orders of magnitude larger than the prediction with the standard model interactions. Comparison with these data, may give some constraints on the masses and couplings of the unparticles (More theoretical and phenomenological studies are under investigation).

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