On the Preponderance of Matter Over Antimatter

Symmetry Properties of the Curved Spacetime Dirac Equations

G. G. Nyambuya[1]

[1]*National University of Science and Technology, Faculty of Applied Sciences, Department of Applied Physics, Bulawayo, Republic of Zimbabwe**

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Quantum Electrodynamics (QED) is built on the original Dirac equation [1, 2], an equation that exhibits perfect symmetry in that it is symmetric under charge conjugation ($\mathcal{C}$), space ($\mathcal{P}$) and time ($\mathcal{T}$) reversal and any combination of these discrete symmetries. We demonstrate herein that the proposed Lorentz invariant *Curved Spacetime Dirac Equations* (*CSTD-Equations*) [3], while they obey $\mathcal{CPT}$ and $\mathcal{PT}$*-Symmetries*, these equations readily violate $\mathcal{C}$, $\mathcal{P}$, $\mathcal{T}$, $\mathcal{CP}$ and $\mathcal{CT}$*-Symmetries*. Realising this violation, namely the $\mathcal{C}$*-Violation*, we take this golden opportunity to suggest that the *Curved Spacetime Dirac Equations* may help in solving the long standing riddle and mystery of the preponderance of matter over antimatter. We come to the tentative conclusion that if these *CSTD-Equations* are to explain the preponderance of matter over antimatter, then, photons are to be thought of as described by the flat version of this set of equations, while ordinary matter is to be explained by the positive and negatively curved spacetime versions of this same set of equations.

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"I think that the discovery of antimatter was perhaps the biggest jump of all the big jumps in physics in our century [20]."

– **Werner Karl Heisenberg** (1901 – 1976)

INTRODUCTION

THE Dirac equation is a relativistic quantum mechanical wave equation serendipitously discovered by the eminent British physicist, Professor Paul Adrien Maurice Dirac in 1928 [1, 2]. This equation possess perfect symmetry in that it is invariant under charge conjugation ($\mathcal{C}$), space ($\mathcal{P}$), time ($\mathcal{T}$) reversal and any combination of these discrete symmetries. The fact that it is symmetric under $\mathcal{C}$*-Symmetry* implies that the Universe must constitute matter and antimatter in equal proportion, the resultant meaning of which is that the Universe must be a radiation bath since matter and antimatter annihilate to form photons. The fact that this prediction of the successful Dirac equation is at odds with physical and natural reality has worried scientists eversince this dearth came to notice. This reading works-out the symmetries of the proposed curved spacetime Dirac equation [3] and uses them to make a suggestion on this riddle of why the Dirac equation's prediction on matter-antimatter proportions are at odds with physical and natural reality.

The Dirac equation was discovered as part of an effort (by Professor Dirac) to overcome the criticism levelled against the Klein-Gordon equation [4]. The Klein-Gordon equation [4] gave negative probabilities and this is considered to be physically meaningless. Despite this fact, this equation [the Klein-Gordon equation] accounts very well for spin-zero Bosons. Though this criticism levelled against the Klein-Gordon equation can be overcome without the need for the Dirac equation [5], this criticism motivated Professor Dirac to successfully seek an equation devoid of negative probabilities, whereupon he discovered the Dirac equation. By giving the correct gyromagnetic ratio of the Electron which at the time was a mystery, the Dirac equation gave an accurate description of the Electron and is thus largely believed to be an equation for the Electron.

The Dirac equation applies to a flat Minkowski spacetime. Thus, it was born without the corresponding curved spacetime version. Realising this gap to be filled, several researchers proposed their own versions of the curved spacetime versions of the Dirac equation [*cf.* 6–14]. In our modest view; save for the introduction of a seemingly mysterious four vector potential A_μ, what makes the curved spacetime version of the Dirac equations presented in the reading [3] stands-out over other attempts in that the method used in arriving at these curved spacetime Dirac equations [3] is exactly the same as that used by Professor [1, 2]. As will be demonstrated shortly, this method used in [3] appears to us as the most straight forward and logical manner in which to arrive a curved spacetime version of the Dirac equation. All that has been done in [3] is to decompose the general metric $g_{\mu\nu}$ in a manner that allows us to apply Professor Dirac [1, 2]'s prescription at arriving at our proposed curved spacetime Dirac equation.

Professor Dirac [1, 2]'s original equation is arrived at from the Einstein momentum-energy equation $\eta_{\mu\nu}p^{\mu}p^{\nu} = \mathrm{m_0}^2c^4$ where $\eta_{\mu\nu}$ is the usual Minkowski metric, (p^{μ}, m_0c) are the four momentum and rest mass of the particle in question respectively and c is the usual speed of light in a vacuum. In curved spacetime, we know very well that the equation $\eta_{\mu\nu}p^{\mu}p^{\nu} = \mathrm{m_0}^2c^4$ is given by $g_{\mu\nu}p^{\mu}p^{\nu} = \mathrm{m_0}^2c^4$ where $g_{\mu\nu}$ is the general metric of a curved spacetime manifold. If a curved spacetime version of the Dirac equation is to be derived, it must be derived from the fundamental equation $g_{\mu\nu}p^{\mu}p^{\nu} = \mathrm{m_0}^2c^4$ in the same way the flat spacetime Dirac equation is derived from the fundamental equation $\eta_{\mu\nu}p^{\mu}p^{\nu} = \mathrm{m_0}^2c^4$. Professor Dirac derived his equation by taking the '*square-root*' of the equation $\eta_{\mu\nu}p^{\mu}p^{\nu} = \mathrm{m_0}^2c^4$. It is a fundamental mathematical fact that a two rank tensor (such as the metric tensor $g_{\mu\nu}$) can be written as a sum of the product of a vector A_μ, *i.e.*:

$$\begin{aligned} g^{(a)}_{\mu\nu} &= \tfrac{1}{2}\left\{A_\mu\gamma^{(a)}_\mu, A_\nu\gamma^{(a)}_\nu\right\} \\ &= \tfrac{1}{2}\left\{\gamma^{(a)}_\mu, \gamma^{(a)}_\nu\right\}A_\mu A_\nu \\ &= \sigma^{(a)}_{\mu\nu}A_\mu A_\nu, \end{aligned} \tag{1}$$

where $\sigma^{(a)}_{\mu\nu}$ are 4×4 matrices such that $\sigma^{(a)}_{\mu\nu} = \frac{1}{2}\left\{\gamma^{(a)}_\mu, \gamma^{(a)}_\nu\right\}$ and $\gamma^{(a)}$-matrices [21] are defines such that:

$$\begin{aligned} \gamma^{(a)}_0 &= \begin{pmatrix} I_2 & 0 \\ 0 & -I_2 \end{pmatrix}, \\ \gamma^{(a)}_k &= \frac{1}{2}\begin{pmatrix} 2\lambda I_2 & i^{\lambda}\sqrt{1+\lambda^2}\sigma^k \\ -i^{\lambda}\sqrt{1+\lambda^2}\sigma^k & -2\lambda I_2 \end{pmatrix}, \end{aligned} \tag{2}$$

where I_2 is the 2×2 identity matrix, σ^k is the usual 2×2 Pauli matrices and the 0's are 2×2 null matrices and $a = (1,2,3)$ such that for:

$$a = \begin{cases} 1, \text{ then } (\lambda = 0): & \text{Flat Spacetime.} \\ 2, \text{ then } (\lambda = +1): & \text{Positively Curved Spacetime.} \\ 3, \text{ then } (\lambda = -1): & \text{Negatively Curved Spacetime.} \end{cases} \tag{3}$$

The index "a" is not an active index as are the Greek indices – its an index which labels a particular representation of the metric – it labels a particular curvature of spacetime *i.e.* whether spacetime is flat [22], positive or negatively curved. Written in full, the three metric tensors $g^{(1)}_{\mu\nu}$, $g^{(2)}_{\mu\nu}$ and $g^{(3)}_{\mu\nu}$ are given by:

$$\left[g^{(a)}_{\mu\nu}\right] = \begin{pmatrix} A_0A_0 & \lambda A_0A_1 & \lambda A_0A_2 & \lambda A_0A_3 \\ \lambda A_1A_0 & -A_1A_1 & \lambda A_1A_2 & \lambda A_1A_3 \\ \lambda A_2A_0 & \lambda A_2A_1 & -\lambda A_2A_2 & \lambda A_2A_3 \\ \lambda A_3A_0 & \lambda A_3A_1 & \lambda A_3A_2 & -A_3A_3 \end{pmatrix}, \tag{4}$$

Especially for a scientist and/or mathematician, there is little if anything they can do but accept facts as they stand and present them-self thus the writing of $g_{\mu\nu}$ as $g_{\mu\nu} = \frac{1}{2}\left\{A_\mu\gamma^{(a)}_\mu, A_\nu\gamma^{(a)}_\nu\right\}$ is to be accepted as a legitimate mathematical fact for as long as $g_{\mu\nu}$ is a tensor. Since A_μ is a vector and the $\gamma^{(a)}$-matrices are all constant matrices, $g_{\mu\nu}$ is a tensor. Therefore, it follows that the equation $g_{\mu\nu}p^{\mu}p^{\nu} = \mathrm{m_0}^2c^4$ can now be written as $\frac{1}{2}\left\{A_\mu\gamma^{(a)}_\mu, A_\nu\gamma^{(a)}_\nu\right\}p^{\mu}p^{\nu} = \mathrm{m_0}^2c^4$. As clearly demonstrated in [3], if we are to have the equation $g_{\mu\nu}p^{\mu}p^{\nu} = \mathrm{m_0}^2c^4$ written in the decomposed form $\frac{1}{2}\left\{A_\mu\gamma^{(a)}_\mu, A_\nu\gamma^{(a)}_\nu\right\}p^{\mu}p^{\nu} = \mathrm{m_0}^2c^4$, and one where to follow Professor [1, 2]'s original derivation method, they will arrive at the three curved spacetime Dirac equations, namely:

$$\left[i\hbar A^{\mu}\gamma^{\mu}_{(a)}\partial_\mu - \mathrm{m}_0c\right]\psi = 0. \tag{5}$$

It is not a difficult exercise to show that multiplication of (5) from the left hand-side by the conjugate operator $\left[i\hbar A^{\mu}\gamma^{\mu\dagger}_{(a)}\partial_\mu - \mathrm{m}_0c\right]^{\dagger}$ leads us to the Klein-Gordon equation $g_{\mu\nu}\partial^{\mu}\partial^{\nu}\psi = (\mathrm{m}_0c^2/\hbar)^2\psi$ provided $\partial_\mu A^{\mu} = \partial^{\mu}A_\mu = \kappa$ where κ is a constant. The condition $\partial_\mu A^{\mu} = \partial^{\mu}A_\mu = \kappa$, should be taken as a gauge condition restricting this four vector. For the case $(a = 1)$, if $A_\mu = 1$, we have the original Dirac equation.

As it stands, equation (5) would be a horrible equation insofar as its solutions are concerned because the vector A_μ is expected to be a function of space and time *i.e.* $A_\mu = A_\mu(\boldsymbol{r}, t)$. Other than a numerical solution, there is no foreseeable way to obtain an exact solution is if that is the case. However, we found a way round the problem; we fortunately realised that this vector can actually be used to arrive at a general spin Dirac equation thereby drastically simplifying the equation so that it now is given by:

$$\left[i\hbar\gamma^{(a)}_{\mu}\partial^{\mu}_{(s)} - \mathrm{m}_0c\right]\psi = 0, \tag{6}$$

where now $\partial^0_{(s)} = \partial^0$ and $\partial^k_{(s)} = s\partial^k$: where $k = (1,2,3)$ and $s = 0, \pm 1, \pm 2, \pm 3, \dots$ *etc* [15, 16]. In equation (6), the vector A_μ has completely disappeared from our midst thus drastically simplifying the resultant equation in the process. For the purposes of the present reading, we will consider (5) and not (6). The vector A_μ appearing in (5) will be taken as presenting this electromagnetic of the particle. This idea finds support from out on-going work on an all-encompassing *Unified Field Theory* of all the Forces *of* Nature [See Ref. 17].

SYMMETRIES

Now, on the main business of the day: we shall workout the symmetries of the curved spacetime Dirac equations for the case $(a = 2, 3)$. We shall assume as is the case with the Dirac equation that the electromagnetic four potential A_μ is a real function and that the components of this vector are zero-rank objects.

$\mathcal{C}$-Symmetry Violation

To demonstrate the symmetric of the *CSTD-Equations* under charge conjugation, we proceed as usual, that is, we bring the Dirac particle under the influence of an ambient electromagnetic magnetic field A^{ex}_μ (which is a real function). Having done this, the normal procedure of incorporating this ambient electromagnetic magnetic field into the Dirac equation is by making the transformation $\partial_\mu \longmapsto D_\mu = \partial_\mu + iA^{ex}_\mu$, hence equation (5) will now be given by:

$$\left[i\hbar A^\mu \gamma^\mu_{(a)} \left(\partial_\mu + iA^{ex}_\mu\right) - \mathrm{m}_0 c\right]\psi = 0. \tag{7}$$

Equation (7) represents the curved spacetime Dirac particle ψ which is immersed in an ambient electromagnetic magnetic field. If we are to reverse the particle's electromagnetic field and that of the ambient electromagnetic magnetic field *i.e.* $(A^\mu, A^{ex}_\mu) \longmapsto (-A^\mu, -A^{ex}_\mu)$, then, (7) becomes:

$$\left[-i\hbar A^\mu \gamma^\mu_{(a)} \left(\partial_\mu - iA^{ex}_\mu\right) - \mathrm{m}_0 c\right]\psi = 0. \tag{8}$$

If the *CSTD-Equation* is symmetric under charge conjugation, then, there must exist some mathematical transformation, which if applied to (8) would lead us back to an equation that is equivalent to (7).

Starting from (8), in-order to revert back to (7), the first mathematical operation to be applied to (8) the complex conjugate operation on the entire equation. So doing, we will have:

$$\left[i\hbar A^\mu \gamma^{\mu *}_{(a)} \left(\partial_\mu + iA^{ex}_\mu\right) - \mathrm{m}_0 c\right]\psi^* = 0. \tag{9}$$

If (7) is invariant under charge conjugation, then, there must exist a matrix Ω_1, such that:

$$\Omega_1 \gamma^{\mu *}_{(a)} = \gamma^\mu_{(a)} \Omega_1. \tag{10}$$

If such a matrix Ω_1 where to exist, then, multiplying (9) from the left by Ω_1, will lead us to the equation:

$$\left[i\hbar A^\mu \gamma^\mu_{(a)} \left(\partial_\mu + iA^{ex}_\mu\right) - \mathrm{m}_0 c\right]\psi' = 0, \tag{11}$$

where $\psi'(p^\mu, x^\mu, m_0, q) = \Omega_1 \psi^*(p^\mu, x^\mu, m_0, -q)$. However, there does not exist such a matrix Ω_1 that fullfils the conditions (10). Therefore, the *CSTD-Equations* for which $(a = 2, 3)$ are not symmetric under charge conjugation.

$\mathcal{P}$-Symmetry Violation

A parity transformation requires that we reverse the space coordinates *i.e.* $(x^k \longmapsto -x^k) \Longrightarrow (\partial_k \longmapsto -\partial_k)$. So doing, we will have (5) now being given by:

$$i\hbar A^0 \gamma^0_{(a)} \partial_0 \psi - i\hbar A^k \gamma^k_{(a)} \partial_k \psi = \mathrm{m}_0 c \psi. \tag{12}$$

If (5) is invariant under a parity transformation, then, there must exist a matrix Ω_2, such that:

$$\begin{array}{rcl} \Omega_2 \gamma^0_{(a)} & = & \mp \gamma^0_{(a)} \Omega_2 \\ \Omega_2 \gamma^k_{(a)} & = & \pm \gamma^k_{(a)} \Omega_2 \end{array}. \tag{13}$$

There does not exist such a matrix Ω_2 that fullfils the conditions (13). Therefore, the *CSTD-Equations* for the case $(a = 2, 3)$ are not symmetric under space reversal.

$\mathcal{T}$-Symmetry Violation

A time reversal transformation requires that we reverse the time coordinate *i.e.* $(t \longmapsto -t) \Longrightarrow (\partial_0 \longmapsto -\partial_0)$. So doing, we will have (5) now being given by:

$$-i\hbar A^0 \gamma^0_{(a)} \partial_0 \psi + i\hbar A^k \gamma^k_{(a)} \partial_k \psi - \mathrm{m}_0 c \psi' = 0, \tag{14}$$

If (5) is invariant under a time reversal transformation, then, there must exist a matrix Ω_3, such that:

$$\begin{array}{rcl} \Omega_3 \gamma^0_{(a)} & = & \pm \gamma^0_{(a)} \Omega_3 \\ \Omega_3 \gamma^k_{(a)} & = & \mp \gamma^k_{(a)} \Omega_3 \end{array}. \tag{15}$$

There does not exist such a matrix Ω_3 that fullfils the conditions (15). Therefore, the *CSTD-Equations* for the case $(a = 2, 3)$ are not symmetric under time reversal.

$\mathcal{CP}$-Symmetry Violation

A simultaneous charge conjugation and parity transformation requires that we reverse the particle's electromagnetic field and that of the ambient electromagnetic magnetic field *i.e.* $(A^{\mu}, A_{\mu}^{ex}) \longmapsto (-A^{\mu}, -A_{\mu}^{ex})$ and aswell the space coordinates *i.e.* $(x^k \longmapsto -x^k) \Longrightarrow (\partial_k \longmapsto -\partial_k)$. So doing, (7) becomes:

$$i\hbar A^0\gamma^0_{(a)}\left(\partial_0 - iA_0\right)\psi - i\hbar A^k\gamma^k_{(a)}\left(\partial_k - iA_k\right)\psi = \mathrm{m}_0 c\psi. \tag{16}$$

If (7) is invariant under a simultaneous charge conjugation and parity transformation, then, there must exist a matrix Ω_4, such that:

$$\begin{aligned} \Omega_4\gamma^{0*}_{(a)} &= \mp\gamma^0_{(a)}\Omega_4 \\ \Omega_4\gamma^{k*}_{(a)} &= \pm\gamma^k_{(a)}\Omega_4 \end{aligned}. \tag{17}$$

There does not exist such a matrix Ω_4 that fullfils the conditions (17). Therefore, the *CSTD-Equations* $(a = 2, 3)$ is not symmetric under a simultaneous reversal of charge and space.

$\mathcal{CT}$-Symmetry Violation

A simultaneous charge conjugation and time transformation requires that we reverse the particle's electromagnetic field and that of the ambient electromagnetic magnetic field *i.e.* $(A^{\mu}, A_{\mu}^{ex}) \longmapsto (-A^{\mu}, -A_{\mu}^{ex})$ and aswell the time coordinates *i.e.* $(t \longmapsto -t) \Longrightarrow (\partial_0 \longmapsto -\partial_0)$. So doing, (7) becomes:

$$-i\hbar A^0\gamma^0_{(a)}\left(\partial_0 - iA_0\right)\psi + i\hbar A^k\gamma^k_{(a)}\left(\partial_k - iA_k\right)\psi = \mathrm{m}_0 c\psi', \tag{18}$$

If (7) is invariant under a simultaneous charge conjugation and time transformation, then, there must exist a matrix Ω_6, such that:

$$\begin{aligned} \Omega_6\gamma^{0*}_{(a)} &= \pm\gamma^0_{(a)}\Omega_6 \\ \Omega_6\gamma^{k*}_{(a)} &= \mp\gamma^k_{(a)}\Omega_6 \end{aligned}. \tag{19}$$

There does not exist such a matrix Ω_6 that fullfils the conditions (19). Therefore, the *CSTD-Equations* for the case $(a = 2, 3)$ are not symmetric under a simultaneous reversal of charge and time.

$\mathcal{PT}$-Symmetry Observance

If we are to reverse the spacetime coordinates, that is $(x^{\mu} \longmapsto -x^{\mu}) \Longrightarrow (\partial^{\mu} \longmapsto -\partial^{\mu})$, and thereafter multiply the resulting equation by γ^5 from the left and then make use of the fact that $\gamma^5\gamma^{\mu}_{(a)} = -\gamma^{\mu}_{(a)}\gamma^5$, it is seen that the resulting equation is equivalent to the original. The wavefunction of the orginal particle ψ is related to the wavefunction of the equivalent particle ψ' by the relation $\psi' = \gamma^5\psi$. Thus, the *CSTD-Equations* for the case $(a = 2, 3)$ are symmetric under $\mathcal{PT}$-*Transformations*. The original wavefunction ψ is related to the resulting particle ψ' by the relation $\psi'(p^{\mu}, x^{\mu}, m_0, q) = \gamma^5\psi(-p^{\mu}, -x^{\mu}, m_0, q)$.

$\mathcal{CPT}$-Symmetry Observance

If we are to reverse the particle's electromagnetic field and that of the ambient electromagnetic magnetic field *i.e.* $(A^{\mu}, A_{\mu}^{ex}) \longmapsto (-A^{\mu}, -A_{\mu}^{ex})$ together with the spacetime coordinates $(x^{\mu} \longmapsto -x^{\mu}) \Longrightarrow (\partial^{\mu} \longmapsto -\partial^{\mu})$, then, inserting these transformations into (7), it is seen that the resulting equation is exactly the same as the original. Thus, the *CSTD-Equations* for the case $(a = 2, 3)$ are not only symmetric under $\mathcal{CPT}$-*Transformations*, but completely, wholly and totally invariant as no extra mathematical operations are required in-order to revert to the original equation. The original wavefunction ψ is related to the resulting particle ψ' by the relation $\psi'(p^{\mu}, x^{\mu}, m_0, q) = \psi(-p^{\mu}, -x^{\mu}, m_0, -q)$.

Summary

In the table below, we give a summary of the symmetries of all the three *CSTD-Equations*.

TABLE I: **Symmetries of the CSTD-Equations**

Symmetry	Case $(a = 1)$ $(\lambda = 0)$	$(a = 2)$ $(\lambda = +1)$	$(a = 3)$ $(\lambda = -1)$
$\mathcal{C}$	*Yes*	*No*	*No*
$\mathcal{P}$	*Yes*	*No*	*No*
$\mathcal{T}$	*Yes*	*No*	*No*
$\mathcal{CP}$	*Yes*	*No*	*No*
$\mathcal{CT}$	*Yes*	*No*	*No*
$\mathcal{PT}$	*Yes*	*Yes*	*Yes*
$\mathcal{CPT}$	*Yes*	*Yes*	*Yes*
Lorentz	*Yes*	*Yes*	*Yes*

The flat *CSTD-Equation* (in which the Dirac equation emerges on the condition $A_{\mu} = 1$) is in complete observance of all the symmetries while the positive $(a = 2)$ and negatively $(a = 3)$ curved spacetime components of this set of equations only observe $\mathcal{CPT}$ and $\mathcal{PT}$-*Symmetries* and violate $\mathcal{C}$, $\mathcal{P}$, $\mathcal{T}$, $\mathcal{CP}$ and $\mathcal{CT}$-*Symmetries*.

DISCUSSION AND CONCLUSION

The symmetries of the Lorentz invariant *CSTD-Equations* have here been worked out and we have shown that the positive ($a = 2$) and negatively ($a = 3$) curved spacetime components of this set of equations, while they are in complete and total observance of $\mathcal{CPT}$ and $\mathcal{PT}$-*Symmetries*, these same equations readily violate $\mathcal{C}$, $\mathcal{P}$, $\mathcal{T}$, $\mathcal{CP}$ and $\mathcal{CT}$-*Symmetries*. Of particular interest to us here is the $\mathcal{C}$-*Violation*. In the present discussion, we would like to point out that these three equations combined, may help in unlocking and solving the long standing riddle and mystery of the preponderance of matter over antimatter.

Insofar as the preponderance of matter over antimatter is concerned, one of the problems with the original Dirac equation is that it was born solo, as an equation explaining a Minkowski flat spacetime particle with no curved spacetime version of it. Realising the clear evident gap, over the years, researches proposed curved spacetime versions of the Dirac equation [*cf.* Refs.: 6–14]. The problem with most of these proposed curved spacetime Dirac equations [6–14], is that they preserve the symmetries of the original Dirac equation. This means that insofar as the preponderance of matter over antimatter is concerned, these equations [6–14] do no better job than the original Dirac equation.

If the predictions of the original Dirac equations together with its descendants [6–14] are to hold, then, it would mean that the Laws *of* Nature explaining the existence and production of matter point to the fact that there must exist at the instant of creation of matter, equal positions of matter and antimatter. This obviously throws us into a conundrum because as far as experimental and observational evidence is concerned, we live in a matter dominated Universe. Our manned and unmanned exploration of the Solar system and the most distant portions of the heavens (using radio astronomy and cosmic ray detection), tell us that the Universe is made up of the same stuff as the Earth. The currently accepted and most favoured explanation as to how our Universe comes to be dominated by matter is that handed down to us by Professor Andrei Dimitriev Sakharov ($1921 - 1989$) in 1967.

In 1967, Professor Andrei Dimitriev Sakharov described three minimum properties of *Nature* which are required for any baryogenesis to occur, regardless of the exact mechanism leading to the excess of baryonic matter. In his seminal paper, Professor Sakharov [18] did not list the conditions explicitly. Instead, he described the evolution of a Universe which goes from a Baryon-excess ($\mathcal{B}$-excess) while contracting in a *Big Crunch* to an anti-$\mathcal{B}$-excess after the resultant *Big Bang*. In summary, his three key assumptions are now known as they *Sakharov Conditions*, and these are:

(1). At least one $\mathcal{B}$-*number violating* process.
(2). $\mathcal{C}$ and $\mathcal{CP}$-*violating* processes.
(3). Interactions outside of thermal equilibrium.

These conditions must be met by any explanation in which ($\mathcal{B} = 0$) during the *Big Bang* but is very high in the present day. They are necessary but not sufficient – thus scientists seeking an explanation of the currently obtaining matter asymmetry on this basis (Sakhorov conditions) must describe the specific mechanism through which baryogenesis happens. Much theoretical work in cosmology and high-energy physics revolves around finding physical processes and mechanism which fit the three Sakhorov pre-conditions and correctly predicting the observed baryon density.

Therefore, the current thrust in research especially at *CERN* [23] is to search for physical processes in *Nature* that violate $\mathcal{CP}$-*Symmetry*. In 2011 during high-energy Proton collisions in the LHCb experiment [19], scientists working at *CERN* created B_s^0 mesons – *i.e.* hadronic subatomic particles comprised of one quark and one antiquark – inside the LHCb experiment [19] and this experiment seems to have yeilded some very interesting results insofar as the Sakhorov conditions are concerned. By observing the rapid decay of the B_s^0, physicists of the *LHCb-Collaboration* [19] were able to identify the neutral particle's decay products - *i.e.* the particles that it decayed into. After a significantly large number of Proton collisions and B_s^0 decay events, the *LHCb-Collaboration* [19] concluded that more matter particles where generated than antimatter during neutral B_s^0 decays.

The first violations of $\mathcal{CP}$-*Symmetry* was first documented in Brookhaven Laboratory in the US in the 1960*s* in the decay of neutral Kaon particles. Since then, Japanese and US labs forty years later found similar behaviour in B^0-mesons systems where they detected similar $\mathcal{CP}$-*Symmetry Violations*. *LHCb-Collaboration* [19] results indicating that antimatter decays at a faster rate than antimatter only come in as further supporting evidence and from a Sakhorov [18] standpoint, these observations certainly provide key insights into the problem of the preponderance of matter over antimatter.

This is not the case with the *CSTD-Equations* which clearly predict $\mathcal{C}$-*Violation* as a permissible Law *of* Nature. That is to say, in as much as the Dirac equation is taken as a Law *of* Nature, here we have (if we accept these equations) these *CSTD-Equations* standing as candidate Laws *of* Nature in which case they predict $\mathcal{C}$-*Violation*. If we accept them as legitimate equations of physics as is the case with the Dirac equation, then, we can use them to explain the apparent preponderance of matter without the need for the Sakhorov conditions.

The Sakhorov conditions assume that the Laws *of* Nature are symmetric with respect to matter and antimatter. According to these pre-conditions, the preponderance of matter will arise in a Universe whose laws are perfectly symmetric with respect to matter and antimatter if there exists physical mechanisms and processes satisfying these conditions. If however the Laws *of* Nature are asymmetric with respect to matter and antimatter, there is no need for the Sakhorov conditions to explain the preponderance of matter over antimatter.

If all the three *CSTD-Equations* are to operate simultaneously in the same Universe (there is nothing stopping this occurrence), then, the flat spacetime version of the *CSTD-Equations*, *i.e.*, the case ($a = 1$) should lead to the production of equal portions of matter and antimatter. This matter-antimatter concoction should annihilate to form radiation *i.e.*, to form a photon bath. The positive and negatively curved spacetime version of the *CSTD-Equations*, *i.e.*, the case ($a = 2, 3$) will lead to the exclusive production of matter with no production of antimatter as the Laws *of* Nature leading to the production of this matter are asymmetric with respect to matter and antimatter. Clearly, there here is no need for the Sakhorov conditions in-order for there to be a preponderance of matter over antimatter. We do not say nor make the claim that this is "*The Solution*" to the long-standing problem of the preponderance of matter over antimatter, but that, it is (perhaps) a viable solution worthy of consideration.

Conclusion

The present work is to be taken as work in progress toward a *Unified Field Theory* [See Ref. 17] that would encompass all the Forces *of* Nature, thus the conclusions we here make are only tentative. Be that it may, our strong feeling is that when the entire work is finally brought to its logical and final conclusion, the present conclusion regarding the *CSTD-Equations* will still hold, thus, assuming the correctness or acceptability of the ideas presented herein, we hereby make the following conclusion (tentative):

(1). The positive ($a = 2$) and negatively ($a = 3$) curved spacetime components of Lorentz invariant *CSTD-Equations* [3] uphold $\mathcal{CPT}$ and $\mathcal{PT}$*-Symmetries*, and these same equations readily violate $\mathcal{C}$, $\mathcal{P}$, $\mathcal{T}$, $\mathcal{CP}$ and $\mathcal{CT}$*-Symmetries*.

(2). If the Lorentz invariant *CSTD-Equations* are to explain the prepondarance of matter over antimatter, then, photons are to be thought of as obeying the flat *CSTD-Equations i.e.*, the *CSTD-Equations* for which ($a = 1$), while ordinary matter is to be explained by the positive ($a = 2$) and negatively ($a = 3$) curved spacetime versions of this set of equations.

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* Electronic address: `golden.nyambuya@nust.ac.zw`, `physicist.ggn@gmail.com`

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[20] From "Development of Concepts in the History of Quantum Theory", in Jagdish Mehra (Ed.) The Physicist's Concept of Nature (1973), *Vol.* 1972, 271
[21] In equation (5) above, the term $A^{\mu}\gamma^{\mu}_{(a)}$ must be treated as a single object with one index μ. This is what this object is. One can set $\Gamma^{\mu}_{(a)} = A^{\mu}\gamma^{\mu}_{(a)}$. The problem with this setting is that we need to have the objects, A^{μ} and $\gamma^{\mu}_{(a)}$, clearly visible in the equation.
[22] By *flat*, it here is not meant that the spacetime is Minkowski *flat*, but that the metric has no off diagonal terms. On the same footing, by *positively curved spacetime*, it meant that metric has positive off diagonal terms and likewise, a *negatively curved spacetime*, it meant that metric has negative off diagonal terms.
[23] European Organization for Nuclear Research (CERN) is located at the France-Swiss border near Geneva Swirtherland.