Preprint Article

Are Tachyons Governed by an Upper Bound Uncertainty Principle?

$[\delta x \delta p < \hbar \ \ldots \ \delta t \delta E < \hbar]$

G. G. Nyambuya[1]
National University of Science & Technology,
Faculty of Applied Sciences – School of Applied Physics,
P. O. Box 939, Ascot, Bulawayo, Republic of Zimbabwe.

Abstract

In an earlier reading, we argued from a physical and number theoretic standpoint that an upper bound speed limit such as the speed of light implies the existence of a lower limit to the duration of events in the Universe. Consequently, this leads to a minimum characteristic length separation for events in the Universe. Herein, we argue that matter and energy that is in compliance with and in observance of the upper bound light speed limit is governed by the lower limiting uncertainty principle of Professor Werner Heisenberg. If there is a lower limiting uncertainty principle, we ask the natural and logical question '*What would an upper bound uncertainty principle mean?*' We come to the interesting conclusion that an upper bound uncertainty principle must apply to particles that travel at speeds, equal to, or greater than the speed of light. Further, we argue that consequently, a tachyon must exist in a permanent state of confinement and must be intrinsically and inherently unstable in which event it oscillates between different states. These two requirements place quarks in a position to be good candidates for tachyons.

Keywords: Doubly Special Relativity, Special Theory of Relativity, Tachyons, Uncertainty Principle.

1 Introduction

In an earlier reading (Nyambuya 2010*b*) published four years ago in the present journal, we argued from a physical and number theoretic standpoint that an upper bound speed limit such as the speed of light $c = 2.99792458 \times 10^{8}\ \mathrm{ms}^{-1}$ implies the existence of a lower limit to the duration (t_{min}) of events in the Universe. Consequently, this leads to a minimum characteristic length (ℓ_{min}) separation for events in the Universe. Herein, we argue that matter and energy that is in compliance with and in complete observance of the upper bound light speed limit is governed by the lower limiting quantum mechanical uncertainty principle $(\delta x \delta p \geq \hbar$ and $\delta t \delta E \geq \hbar)$ of Professor Werner Heisenberg (1927). Further, we argue that – if tachyons exist; they must be governed by an upper bound and not a lower bound uncertainty principle. Such particles must exist in confined regions of space as 'permanent prisoners'. This leads us to ask the natural and logical question '*Given their nature as seemingly eternally confined particles, are quarks not tachyons?*'

At present, tachyons exist in the figment of the physicist's imagination only as *hypothetical particles*. They are presumed to always travel faster than the speed of light. The word '*tachyon*' is a

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[1] Correspondence: E-mail: physicist.ggn@gmail.com

word derived from the Greek word '*tachys*', meaning '*swift*', '*quick*', '*fast*' or '*rapid*'. This term was first coined by Professor Gerald Feinberg (1967). While we hardly hear of tachyons today, in the 1960's through to the mid-and-late-70s (*cf.* Robinett 1978, Everett 1976, Recami *&* Mignani 1976, Sigal *&* Shamaly 1974, Ben-Abraham 1970, Aharonov et al. 1969, Parker 1969, Bilaniuk et al. 1962, Bilaniuk *&* Sudarshan 1969), they attracted a great deal of attention. Little has been written about them in the recent scientific literature apart from some fevered speculations in September of 2011 when CERN[2] researchers erroneously thought they had observed Neutrinos (OPERA-Collaboration 2011) moving faster than the speed of light, the results of which where refuted (*e.g.*, ICARUS-Collaboration 2012) and later found to be in serious error[3]. What really happened to tachyons? Who killed them? Did they 'die'? Can they be resurrected from their 'tomb' where they seem to 'lay in-state' for an eternal 'body viewing'? This is what this reading hopes to accomplish – *i.e.*, bring tachyons back to the mind and imagination of the living physicist.

The two complementary particle types to the tachyon are called (1) *luxon* – these particles always travel at the speed of light, and; (2) *bradyon* – these are particles which always travel slower than light (Bilaniuk *&* Sudarshan 1969). The possibility of particles travelling *faster-than-light* was first proposed by Bilaniuk et al. (1962), Bilaniuk *&* Sudarshan (1969) and the term they used for referring to them was '*meta-particle*'. Current wisdom and thought holds that for a particle to travel at the speed of light, its mass must be identically equal to zero, it must vanish. This wisdom and thinking has been questioned in the reading Nyambuya (2014*b*), where it has been argued that photons may very well be *massive* with this mass being so small that it would require much more sensitive measurements than presently obtaining if we are to detect it. If photons are massive, this would cause some problems with the Standard Model *of* Particle Physics (SMPP) as this would lead to a violation of the seemingly sacrosanct gauge invariance; this problem has been well attended to in the readings Nyambuya (2014*c*,*d*). A particle is said to be *massive* if it has a real non-zero rest mass m_0; such particles, are according to Professor Albert Einstein (1905)'s Special Theory *of* Relativity (STR), going to always have their speed being lower than the speed of light (*cf.* Folman *&* Recami 1995).

In principle, the STR has no problem whatsoever with the existence of tachyons (Bilaniuk et al. 1962, Bilaniuk *&* Sudarshan 1969). All the STR tells us is that, if they really did exist, they would be bizarre objects. For example, they would always be found travelling faster than the speed of light such that dropping their speed to less than c would be as impossible for them as is the case with bradyons to exceeding c. Worse still, their mass m_0 would be imaginary *i.e.* $(\mathrm{m}_0^2 < 0)$. Not only that, adding kinetic energy to a tachyon would make it slow down, but it would take an infinite amount of energy to drop its velocity down to the speed of light! Conversely, a tachyon shedding energy would continuously accelerate. These seemingly strange and bizzare properties leads to subtle arguments against their existence.

The nature of particles *i.e.*, whether there are braydons or tachyons, this can be linked to the uncertainty principle of quantum mechanics. The uncertainty principle of quantum mechanics is a lower limiting uncertainty principle ($i.e.$, $\delta x \delta p \geq \hbar$). If there is a lower limiting uncertainty principle, we ask the rather natural and logical question '*What would an upper bound uncertainty principle* ($\delta x \delta p < \hbar$) *mean?*' We come to the interesting conclusion that an upper bound uncertainty principle must apply to particles that travel at speeds greater than the speed of light c. To see this, we know that if $(\Delta x = x_2 - x_1)$ and $(\Delta t = t_2 - t_1)$ are the space and time intervals for a particle starting at time $(t = t_1)$ and position

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[2] CERN is the *European Organization for Nuclear Research*.

[3] See http://profmattstrassler.com/articles-and-posts/particle-physics-basics/neutrinos/neutrinos-faster-than-light/opera-what-went-wrong/

$(x = x_1)$ to move to position $(x = x_2)$ at time $(t = t_2)$, then the speed v of such a particle is:

$$v = \frac{\Delta x}{\Delta t}. \tag{1}$$

Quite trivial and straight forward result – isn't it? In Nyambuya (2010*b*), we argued that if there is an upper speed limit such as the speed of light c, that is $v \leq c$, then, from a number theoretic standpoint and as-well from a physical standpoint of the uncertainty principle, there must exist a finite minimum time internal t_{min}. If such a time interval exists, it follows from this that there must exist as as-well a finite minimum distance l_{min} for which any two events can be separated. The values l_{min} and t_{min} must be fixed and must be such that every observer in the Universe must measure them and obtain the same value just as is the case with the speed of light c. Because of this fact that the values l_{min} and t_{min} must have the same numerical value for all observers, this means the very existence of an upper speed limit implies a fundamental universal limiting space and time interval.

Therein Nyambuya (2010*b*), we took this implied existence of a fundamental and universal limiting space and time interval as directly pointing to the invariable fact that there was no need for a Doubly Special Relativity (DSR) theory in the sense that it was first championed by Amelino-Camelia (2002*a*,*b*). DSR theories assume that the STR does not have within its fabric a fundamental and universal limiting space and time interval – so, on the basis of credible arguments to do with quantum gravity, they [DSR advocates] urge into existence a fundamental and universal limiting space and time interval. Once a fundamental and universal limiting space and time interval is justified, DSR theories are there-from built – *albeit*, usually not in position space [*i.e.* on spacetime with the usual coordinates (x, y, z, t)] but predominately in momentum space [*i.e.* on the momentum coordinate space $(p_x, p_y, p_z, p_0 = E/c)$]. Despite the existence of other position space DSR theories, we made our own endeavour to develop our own DSR in position space (Nyambuya 2012) and not in momentum space as is usually the case. To a larger extent, DSR theories are built so as to cross the light speed barrier that is predicted by the STR. With this reading, we are begining to have a change of heart – namely that, perhaps the light speed barrier predicted by the STR must be left as is. We present our thinking on this matter in the sections below.

2 Tachyons

As already said, the STR does not in any way exclude nor forbid the existence of *faster-than-light particles* (Bilaniuk et al. 1962, Bilaniuk & Sudarshan 1969). All it does is to predict that in-order for a bradyon to become a luxon, there is need to accelerate it with an infinite force for this to be so. On the same footing, in-order for a tachyon to become a luxon, one would have to accelerate it with an infinite force. As to how one can turn a luxon into a brayon or a tachyon, the STR is silent on this. The luxon state is an asymptote state, the meaning of which is that it is a state which the tachyon and bradyon approach asymptomatically from opposite ends of the divide of the asymptote.

Taken at face value, the massive $(\mathrm{m}_0^2 \neq 0)$ luxon will have an infinite momentum and energy, that is to say, the energy E and momentum p are in the STR given by:

$$E = \pm \frac{\mathrm{m}_0 c^2}{\sqrt{1 - v^2/c^2}} \text{ and } p = \frac{\mathrm{m}_0 v}{\sqrt{1 - v^2/c^2}}. \tag{1}$$

Clearly, from the above formulae $(E = \pm\infty)$ and $(p = \pm\infty)$ for $(v = \pm c)$. In its raw form, the STR is consistent with a zero-mass particle travelling at the speed of light and nothing else. Under such a setting, the difficulties with the infinities somehow vanish when one applies quantum theory to try and understand luxons.

In their quest to understand, infinity has been such a pain for the human-mind to comprehend, so painful that whenever infinities appear in our theories, we take this as the clearest signal yet – that our theory has just met its *Waterloo* – it has just collapsed, its entire edifice has just come down crushing. If in its past application the theory has faired well in explaining a diverse of physical phenomenon before meeting this Waterloo, in most cases, it is said that the theory needs to be repaired in-order to cross this bridge and efforts are made to repair it. This is often done so as to preserve that which the theory has already explained so well. If the theory only explained a handful of physical phenomenon before meeting its Waterloo, humans have more often been quick to throw such theories out the window without much wasting time and effort.

Our present feeling about the seemingly insurmountable double-edged light speed barrier is that, maybe, we should let that which the *Good Lord has put together no man put asunder*. That is, perhaps we must accept this barrier as real and not as reflective of the STR's Waterloo. Our reason for this are as follows.

In Nyambuya (2014*b*), we argued that a photon's mass may be non-zero and in Nyambuya (2014*c*), we solved the technical problems that come along with a non-zero photon mass such as the range and the lifetime of a photon. Additionally, we demonstrated in Nyambuya *&* Simango (2013), that Newtonian gravitation – under the assumption of massive photon; is very much compatible with the $1.75''$ gravitational bending of light result first measured by Sir Eddington's expedition (Dyson et al. 1920) for light passing the Solar limb. This $1.75''$ bending is usually taken as vindicating Professor Albert Einstein (1916)'s General Theory *of* Relativity (GTR), placing it on a sure pedal on which it now clearly becomes superior to Newtonian gravitation. Beside explaining very well the $1.75''$ gravitational bending of light result, the GTR explains with unprecedented accuracy the $43.1''$ per century anomalous precession of the orbit of the planet Mercury and as-well of other Solar planets and planetary bodies. More than anything else, this feat lone, that is, the successfully prediction of the $43.1''$ per century anomalous precession of the orbit of Mercury, this rather rare feat convinced many that the GTR was the new superior theory of gravitation, and ever-since then, the GTR has enjoyed this status of being the most accurate theory of gravitational at our disposal.

Be that it may, in Nyambuya (2010a), we did demonstrate that one can account for the $43.1''$ per century anomalous precession of the orbit of the planet Mercury and as-well of other Solar planets and planetary bodies from within the context of Newtonian gravitation by consideration of the azimuthal gravitational potential as derived from the Poisson-Laplace equation of gravitation where the Newtonian gravitational theory finds its foundational basis for existence. Given these interesting developments, that is to say, the demonstration that Newtonian gravitational theory can explain the $1.75''$ gravitational bending of light result on the assumption of a massive photon and that the $43.1''$ per century anomalous precession of the orbit of Mercury can be explained with within the context of Newtonian gravitation, this naturally led us to begin to think that a photon may have a non-zero mass (Nyambuya 2014b,c).

A novelty introduced (in Nyambuya 2014*b*) to solve the issue that only a particle of zero mass can travel at the speed of light, it that, the photon's mass m_0 has been assumed to be dependent on its frequency. Under this assumption, it is seen that a massive photon's speed c_{g} can only lay in the range $(\frac{1}{2}c \leq c_{\mathrm{g}} \leq c)$. For ordinary matter, its mass has been assumed to be a fixed constant and under this assumption it is seen that the speed of matter must lay in the range $(v_{\min} \leq v < c)$ where $v_{\min}$ is a fixed non-zero minimum possible speed which is determined by the uncertainty principle. The resulting theory from Nyambuya (2014*b*) is that the speed of light becomes dependent on the energy of the photon such that only photons of zero momentum are the ones that can travel at the speed c and the rest of the photons have speed within the range $(\frac{1}{2}c \leq c_{\rm g} < c)$.

How do we achieve a photon of zero momentum? This can be achieved from the modified Einstein mass-energy-momentum dispersion relation $(E^2 - p^2c^2 = {\rm m}_0^2c^4)$ so that it now reads (Nyambuya 2013, 2009):

$$E^2 - s^2p^2c^2 = {\rm m}_0^2c^4, \tag{2}$$

where E, p, s are the energy, momentum and spin quantum number of the photon in question respectively and s is such that $(s = 0, \pm1, \pm2, \pm3, \ldots\ etc)$; s is such that a particle with spin quantum number s will have a spin $\boldsymbol{S} = \frac{1}{2}s\hbar\boldsymbol{\sigma}$. The mass ${\rm m}_0$ is such that ${\rm m}_0 = {\rm m}_0(\lambda)$, *i.e.*, the mass is a function of the the wavelength λ of the photon; alternatively, ${\rm m}_0 = {\rm m}_0(f)$ where f is the frequency of the photon. The equivalent Dirac equation that emerges from this dispersion relation is:

$$\left[i\hbar\gamma^{\mu}_{(s)}\partial_{\mu} - {\rm m}_0c\right]\psi = 0, \tag{3}$$

where $\gamma^0_{(s)} = \gamma^0$ and $\gamma^k_{(s)} = s\gamma^k : (k = 1, 2, 3)$ and γ^0 and γ^k are the usual 4×4 Dirac γ-matrices. The resulting speed of the photon $c_{\rm g}$ from all this is:

$$c_{\rm g} = \frac{1}{2}\left[1 + \exp\left(-\frac{1}{s}\frac{p_*}{p}\right)\right]c = \frac{1}{2}\left[1 + \exp\left(-\frac{1}{s}\frac{\lambda}{\lambda_*}\right)\right]c, \tag{4}$$

where p_* and λ_* are fundamental physical constants. From this formula, it is clear that when $(s = 0)$ we will have $c_{\rm g} = c$, therefore, a photon with spin-zero (if it exists) is the only photon can can move at the speed c while all other photons will have a speed $(\frac{1}{2}c \leq c_{\rm g} < c)$. Despite the fact that the ideas expressed in the readings Nyambuya (2014*a*,*b*,*c*,*d*, 2009), Nyambuya & Simango (2013), Nyambuya (2013, 2010*a*) are relatively new, these ideas seem to flow from the logic presented therein. It is our genuine feeling that these ideas must be given a chance to prove themselves.

3 Tachyons and the Uncertainty Principle

Now, if for tachyons, we are going to have both an upper and lower limit to the duration between any two events, what uncertainty relation will they obey? If they obey the usual time-energy Heisenberg (1927) uncertainty relation $(\delta t\delta E \geq \hbar)$, then, it would not be possible for tachyonic events to have an upper limit in the time duration because they could have quantum fluctuations that exceed the permitted duration between events. The only way would be if they obeyed the following time-energy quantum mechanical uncertainty relation:

$$\delta t\delta E < \hbar. \tag{1}$$

To see why this must be so, we will provide the following thesis. We have argued that the very fact that tachyons must travel at greater than light speed implies that $(0 \leq \Delta t < t_{\rm min})$. This very fact that $(0 \leq \Delta t < t_{\rm min})$ logically implies that even for quantum mechanical time fluctuations δt must lay in this same range, *i.e.* $(0 \leq \delta t < t_{\rm min})$. If as usual δt has δE as its complementary uncertainty variable, then, if Δt is to have an upper bound, the product $\delta t\delta E$ must have an upper bound as well, hence (1).

For the position-momentum uncertainty relation: we know that the very fact that $(v > c)$ and that $(\Delta t < t_{\text{min}})$, from this it follows that the spacing Δx of events in the tachyonic world must have an upper bound, that is to say $(\Delta x < ct_{\text{min}} = l_{\text{mim}})$, or written more completely $(0 \leq \Delta x < l_{\text{mim}})$. If $(\delta x \delta p \geq \hbar)$, it would be impossible to have an upper bound in the spacing of events. The only way to have $(\Delta x < l_{\text{mim}})$ is if:

$$\delta x \delta p < \hbar. \tag{2}$$

Therefore, tachyons must be governed not by the usual lower bound uncertainty relations of Professor Werner Heisenberg (1927), but by the upper bound uncertainty relations (1) and 2. If we accept the above thesis that tachyons must be governed by the upper bound uncertainty relations (1) and 2, then naturally and logically, we must ask the question '*What physics – if any; is implied by these upper bound uncertainty relations?*'.

3.0.1 Interpretation of the Uncertainty Principle

We are going to interpret the uncertainty principle as follows. The time uncertainty δt is the time lapse for a system to change from one state to the next. That is to say, a system that is intrinsically uncertain in its energy by an amount δE, this system is going to be forced to change its state in a time duration lasting not more than δt from the time it entered its present state. Thus, such a system is not going to be unstable on a time-scale of δt.

On the same footing, the position uncertainty δx is the position which a system can not travel before it changes from one state to the other. That is to say, a system that is intrinsically uncertain in its momentum by an amount δp, this system is going to be forced to change its present state before travelling not more than a distance δx from the position (in space) where it entered its present state. Thus, such a system is not only going to be unstable but short ranged. This interpretation is more or less the way the uncertainty principle is traditionally interpreted when in comes to the lifetime and range of particles. But there is a subtlety in the above interpretation.

For example, as far we are concerned, the Electron, is a stable particle. Its lifetime is expected to be infinity. We know of no decay of the photon; it very much appears to stay in its seemingly permanent state of being the Electron we have always known. According to the above interpretation of the uncertainty principle, it would mean that, the Electron should be able to move from whatever position that it finds itself in and be able to travel to infinity without changing its state. Its uncertainty in energy must be exactly zero, leading to it to having an infinity lifetime. What would happen if $\delta E \neq 0$? We will answer this question below.

3.1 Confined Tachyons

Clearly, the fact that $(\Delta x < l_{\text{min}})$ and $(\delta x < \hbar/\delta p)$, points to the invariable fact that particles obeying these relations must be spatially bound. No two tachyons can be separated by a distance which is greater than l_{min} and no tachyonic quantum fluctuations can exceed a time duration greater than $\delta t = \hbar/\delta p$; it follows therefore that, for tachyons – if they exist; they must exist in a 'tiny little world' that is not more than l_{min} in diameter. We say 'tiny little world' because we expect l_{min} to be very small; it must be of the order of the size of the Proton for example.

3.2 Oscillating Tachyons

Clearly, the fact that $(\Delta t < t_{\min})$ and $(\delta t < \hbar/\delta E)$, points to the clearly undeniable fact that particles obeying these relations must be unstable. The can not live for a time exceeding $t_{\min}$. They must decay into other types of tachyons of smaller masses. There is going to be a problem with this kind of state of affair, because this means that the resulting tachyons must decay into particles of even smaller mass, thus, this decay process can not go on forever as it could lead to infinitely many particles being generated as the generated tachyon decays into a smaller mass tachyon.

An intelligent way out would be if a tachyon has two or more states $(S_1, S_2, \dots, S_j, \dots)$ in which it can exist. At any given time, the tachyon can only exist in one of its possible states. If this where the case, it would mean that on a time-scale of $\sim t_{\min}$, it would change from one state to the other in which case, no two subsequent states would the same. This means that a tachyon must oscillate between different states, in this way, it would preserve the sanctity of the conservation laws of mass-energy and momentum, in which proceed, it save us from the creation of an infinitely many tachyons of smaller mass begin generated.

The idea of a particle oscillating between different states brings to mind neutrinos (ν) and quarks (q). Let us look at neutrinos first. At present, experimental philosophy has revealed upto us only three types (or flavours) of neutrinos, namely the Electron-neutrino ν_e, the Muon-neutrino ν_μ, the Tau-neutrino ν_τ and their anti-matter counterparts *i.e.* the anti-Electron-neutrino ν_e, the anti-Muon-neutrino ν_μ and the anti-Tau-neutrino ν_τ respectively. Further, experimental philosophy has it on good record that a neutrino – once produced; oscillates in seemingly random fashion between these three flavours types, it does not stay in one flavour-state which it was created but changes from one flavour to the other.

According to the foregoing, this oscillatory nature of neutrinos may lead one to think or entertain the idea that neutrinos may very well be tachyons since – as expected of tachyons, they oscillate. However, a closer look will tell us that this can not be so because they (neutrinos) do not satisfy another important property of tachyons that we have discussed above namely that tachyons must exist in confinement. It is interesting to note that Neutrinos have long been considered as candidate tachyons (*cf.* Ehrlich 2013, Konoplya 2012, Jentschura 2012, Chodos *&* Kostelecký 1994, Chodos et al. 1992, 1985). In the foregoing thesis, we can not classify them as tachyons simple because they do not exist in a state of permanent confinement as is here required for tachyons.

The best candidates that we have for tachyons are quarks because they not only exist in seemingly permenant state of confinement but they oscillate between three states (*cf.* Veltman 2003, Feynman 1985). According to our present knowledge, there exists only six quarks and they come in three generations and three flavours *i.e.*:

1. **First Generation:** We have the *up* and the *down*-quark represented by the symbols $\mathfrak{u}$ and $\mathfrak{d}$ and these have electric charges $+\frac{2}{3}$ and $-\frac{1}{3}$ respectively.
2. **Second Generation:** We have the *charm* and the *strange*-quark represented by the symbols $\mathfrak{c}$ and $\mathfrak{s}$ and these have electric charges $+\frac{2}{3}$ and $-\frac{1}{3}$ respectively.
3. **Third Generation:** We have the *top* and the *bottom*-quark represented by the symbols $\mathfrak{t}$ and $\mathfrak{b}$ and these have electric charges $+\frac{2}{3}$ and $-\frac{1}{3}$ respectively.

Each of the six quarks come in three flavours known as Red (R), Green (G) and Blue (B) and they oscillate in a seemingly random fashion between these three flavours. Given that quarks appear to be prisoners for life – *i.e.*, they seem to exist in a permanent state of confinement; it is therefore seductively tempting to think of them as tachyons for they possess all the requisites for tachyons.

4 General Discussion

Tachyons may not be dead after all! Herein, we have advanced the idea that tachyons – if they exist; they must obey not the lower bound uncertainty principle of Professor Werner Heisenberg (1927) as one would naturally presume, but these must obey the upper bound uncertainty relations (1) and 2. If we accept this, then as discussed in the present reading, tachyons must be confined eternally in small regions of space and they must oscillate between different states as happens with neutrinos and quarks which oscillate between different neutrino and quark states respectively.

This fact that neutrinos and quarks oscillate between different neutrino and quark states makes then candidate tachyons but we did argue that neutrinos can not be tachyons for the shear reason that they exist not in a permanent state of confinement, only quarks do. Therefore, quarks posses these two requisite properties necessary for a particle to be a tachyon – thus making them *good candidate tachyons*. We would like to post here as a *hypothesis* that quarks may very be tachyons.

This means that experiments must try to verify this by measuring their speeds. To the best of our searches and knowledge, it is not known with exactness whether or not quarks are *time-like* or *space-like*. If they are space-like, then, they are tachyonic and if they are time-like, they must be bradyons. We however feel that if surely quarks are tachyons, measuring their speed would be an experimental impossibility and this is so because of the uncertainty principle. We human observers living outside the confinement zone of quarks, we are limited by the lower bound uncertainty principle in measuring the speed of quarks. Because they obey the upper bound uncertainty principle, quarks will move from place to their next position in a region of space that is smaller than we are permitted to measure by *Nature*, thus all such efforts of measuring their speed will never work. We have to find another way to verify their tachyonic nature.

5 Conclusion

Assuming the correct-and-soundness of the ideas propagated herein, we here make the following conclusion:

1. An upper limiting speed such as the speed of light implies a lower limiting uncertainty principle while a non-zero lower limiting speed implies an upper bounding uncertainty principle.

2. The fact that tachyons must travel at speeds greater than the speed of light implies that they [tachyons] must – *independent of whether or not they exist* – be governed by the upper bound uncertainty principle ($\Delta x \Delta p < \hbar$).

3. Because of their observance of the upper bound uncertainty principle ($\Delta x \Delta p < \hbar$), tachyons must exist in eternally bound spacial regimes.

4. If quarks are tachyons as we have hypothesised herein, then, what is responsible for their confinement is not the mutual forces acting between them, but the upper bound uncertainty principle. Further, if quarks are tachyons, any attempt to separate them beyond their demarcated region of confinement will never succeed – it is an impossible feat. Simple stated – no matter how powerful a machine we build, quarks will never be isolated if they are tachyonic in nature.

5. Because we exist in a world governed by the lower bound uncertainty principle of Professor Werner Heisenberg (1927), it is impossible for us to measure the speed of tachyons. Insofar as finding tachyons is concerned,

our only hope is to find confined particles (such as quarks) that oscillate between different states. Therefore, if quarks are tachyons, we are forbidden by *Nature's* sacrosanct laws from knowing how fast there travel because this could require us to measure distances that exist beyond what the lower bound uncertainty principle of Professor Werner Heisenberg (1927) permits.

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