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# The Physical Implications of Multidimensional Geometries and Measurement

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**Abstract.** Non-Abelian gauge groups for real and complex amended Maxwell's equations in a complex 8-Dimensional Minkowski space are developed to describe nonlocality in quantum theory and Relativity which has quantum gravitational implications. Mapping between the twistor algebra of the complex 8-space and the spinor calculus of 5D Kaluza-Klein geometry attempts to unify Gravitational and EM theory. Solving the Schrödinger equation in complex 8D geometry yields coherent collective state phenomena with soliton wave solutions. The model shows that standard quantum theory is a linear approximation to a higher Dimensional complex space allowing nonlinear systems to be defined with in conventional quantum theory expressed in a hyper-geometric space.

**Keywords**: Bell's Theorem, Complex Geometry, Gauge Theory, Maxwell's Equations.

## 1. Introduction

We have analyzed, calculated and extended the modification of Maxwell's equations in a complex Minkowski metric, $M_4$ in a $C_2$ space using the $SU_2$ gauge, SL(2,c) and other gauge groups, such as $SU_n$ for $n > 2$ expanding the $U_1$ gauge theories of Weyl. We utilize our complex dimensional geometry to formulate nonlocal correlated phenomena, including the quantum description of the 1955 EPR paradox formulated with Bell's theorem. Tests by Clauser, Aspect, and Gisin have demonstrated that particles emitted with approximate simultaneity at velocity of light *c* remain correlated nonlocally over meter and kilometer distances. As Stapp has said, Bell's theorem and its experimental verification is one of the most profound discoveries of the $20^{th}$ century. We will demonstrate the application of our formalism for complex systems and review the history of our model from 1974, including fundamental properties of nonlocality on the spacetime manifold. This work yields additional predictions beyond the electroweak unification scheme.

Some of these are:

1) Modified gauge invariant conditions,
2) Short range non-Abelian force terms and Abelian long range force terms in Maxwell's equations,
3) Finite but small rest mass of the photon, and
4) A magnetic monopole like term
5) Longitudinal as well as transverse magnetic and electromagnetic field components in a complex Minkowski metric $M_4$ in a $C_2$ space and
6) Formalism of nonlocality in the 8D spacetime metric.

This is an 8D complex Minkowski space $M_4$ (1) composed of four real and four imaginary dimensions consistent with Lorentz invariance and analytic continuation in the complex plane [1-4]. The unique feature of this geometry is that it admits nonlocality consistent with Bell's theorem, (EPR paradox), possibly Young's double slit experiment, the Aharonov – Bohm effect and multi mirrored interferometric experiment.

Additionally, expressing Maxwell's electromagnetic equations in complex eight space, leads to some new and interesting predictions in physics, including possible detailed explanation of some of the previously mentioned nonlocality experiments [5-8]. Complexification of Maxwell's equations require a non-Abelian gauge group which amend the usual theory, which utilizes the usual unimodular Weyl $U_1$ group. We have examined the modification of gauge conditions using higher symmetry groups such as $SU_2$, $SU_n$ and other groups such as the SL(2,c) double cover group of the rotational group SO(3,1) related to Shipov's Ricci curvature tensor [3] and a possible neo-aether picture. Thus we are led to new and interesting physics involving extended metrical space constraints, the usual transverse and also longitudinal, non Hertzian electric and magnetic field solutions to Maxwell's equations, possibly leading to new communication systems and antennae theory, non zero solutions to $\nabla \cdot \underline{B}$ [9], and a possible finite but small rest mass of the photon [10-12].

Comparison of our theoretical approach is made to the work of J. P. Vigier, [13-15] T.W. Barrett [16] and H.F. Harmuth [17] on amended Maxwell's theory. We compare our predictions such as our longitudinal field to the $B^{(3)}$ term of Vigier, and our Non-Abelian gauge groups to that of Barrett and Harmuth [16,17]. This author interprets this work as leading to new and interesting physics, including a possible reinterpretation of a neo-aether with nonlocal information transmission properties.

## 2. Complexified *EM* Fields in $M_4$ Minkowski Space and Nonlocality

We expand the usual line element metric $ds^2 = g_{nm} dx^n dx^m$ in the following manner. We consider a complex eight dimensional space, $M_4$ constructed so that $Z^u = x^u_{\text{Re}} + i\, x^u_{\text{Im}}$ and likewise for $Z^n$ where the indices $n$ and $m$ run 1 to 4 yielding (1, 1, 1, -1). Hence, we now have a new complex eight space metric as $ds^2 = h_{nm} dZ^v dZ^m$. We have developed this space and other extended complex spaces [1,48] and examined their relationship with the twistor algebras and asymptotic twistor space and the spinor calculus and other implications of the theory [18,19]. The Penrose twistor SU(2,2) or $U_4$ is constructed from four spacetime, $U_2 \otimes \tilde{U}_2$ where $U_2$ is the real part of the space and $\tilde{U}_2$ is the imaginary part of the space, this metric appears to be a fruitful area to explore [20].

The twistor $Z$ can be a pair of spinors $U^A$ and $p_A$ which are said to represent the twistor. The condition for these representations are:

1) The null infinity condition for a zero spin field is $Z^m \overline{Z}_m = 0$,
2) Conformal invariance and
3) Independence of the origin.

The twistor is derived from the imaginary part of the spinor field. The underlying concept of twistor theory is that of conformally invariance fields occupy a fundamental role in physics and may yield some new physics. Since the twistor algebra falls naturally out complex space [21].

Other researchers have examined complex dimensional Minkowski spaces. In reference [10], Newman demonstrates that $M_4$ space do not generate any major “weird physics” or anomalous physics predictions and is consistent with an expanded or amended special and general relativity. In fact the Kerr metric falls naturally out of this formalism as demonstrated by Newman [2].

As we know twistors and spinors are related by the general Lorentz conditions in such a manner that all signals are luminal in the usual four N Minkowski space but this does not preclude super or trans luminal signals in spaces where N > 4. Stapp, for example, has interpreted the Bell’s theorem experimental results in terms of trans luminal signals to address the nonlocality issue of the Clauser, et. al and Aspect experiments. C.N. Kozameh and E.T. Newman demonstrate the role of non local fields in complex 8 - space [21].

We believe that there are some very interesting properties of the $M_4$ space which include the nonlocality properties of th e metric applicable in the non-Abelian algebras related to the quantum theory and the conformal invariance in relativity as well as new properties of Maxwell’s equations. In addition, complexification of Maxwell’s equations in $M_4$ space yields some interesting predictions, yet we find the usual conditions on the manifold hold [10,11]. Some of these new predictions come out of the complexification of four space 2 and appear to relate to the work of Vigier, Barrett, Harmuth and others [12,16,17]. Also we find that the twistor algebra of the complex eight dimensional, $M_4$ space is mapable 1 to 1 with the twistor algebra, $C_2$ space of the Kaluza-Klein five dimensional electromagnetic - gravitational metric [17, 18].

Some of the predictions of the complexified form of Maxwell’s equations are 1) a finite but small rest mass of the photon, 2) a possible magnetic monopole, $\nabla \cdot \underline{b \neq 0}$, 3) transverse as well as longitudinal B(3) like components of $\underline{\mathrm{E}}$ and $\underline{\mathrm{B}}$, 4) new extended gauge invariance conditions to include non-Abelian algebras and 5) an inherent fundamental nonlocality property on the manifold. Vigier also explores longitudinal $\underline{\mathrm{E}}$ and $\underline{\mathrm{B}}$ components in detail and finite rest mass of the photon [13].

We consider both electric and magnetic fields to be complexified as $\underline{E} = \underline{E}_{\mathrm{Re}} + i\underline{E}_{\mathrm{Im}}$ and $\underline{B} = \underline{B}_{\mathrm{Re}} + i\underline{B}_{im}$ for $E_{\mathrm{Re}}, E_{\mathrm{Im}}, B_{\mathrm{Re}}$ and $B_{\mathrm{Im}}$ are real quantities. (Sometimes the imaginary part is written in italics, but we utilize the subscript for this paper.) Then substitution of these two equations into the complex form of Maxwell’s equations above yields, upon separation of real and imaginary parts, two sets of Maxwell-like equations. The first set is

$$\nabla \cdot \underline{E}_{\mathrm{Re}} = 4p r_e ,\ \nabla \times \underline{E}_{\mathrm{Re}} = -\frac{1}{c}\frac{¶\,\underline{B}_{\mathrm{Re}}}{¶t};\ \nabla \cdot \underline{B}_{\mathrm{Re}} = 0 ,\ \nabla \times \underline{B}_{\mathrm{Re}} - \frac{1}{c}\frac{¶\,\underline{E}_{\mathrm{Re}}}{¶t} = \underline{J}_e \tag{1}$$

the second set is

$$\nabla \cdot \left(i\underline{B}_{\mathrm{Im}}\right) = 4pir_m ,\ \nabla \times \left(i\underline{B}_{\mathrm{Im}}\right) = \frac{1}{c}\frac{¶\left(i\underline{E}_{\mathrm{Im}}\right)}{¶t};\nabla \cdot \left(i\underline{E}_{\mathrm{Im}}\right) = 0 , \nabla \times \left(i\underline{E}_{\mathrm{Im}}\right) - \frac{1}{c}\frac{¶\left(i\underline{B}_{\mathrm{Im}}\right)}{¶t} = i\underline{J}_m \tag{2}$$

The real part of the electric and magnetic fields yield the usual Maxwell’s equations and complex parts generate “mirror” equations; for example, the divergence of the real component of the magnetic field is zero, but the divergence of the imaginary part of the electric field is zero, and so forth. The structure of the real and imaginary parts of the fields is parallel with the electric real components being substituted by the imaginary part of the magnetic fields and the real part of the magnetic field being substituted by the imaginary part of the electric field.

In the second set of equations, (2), the $i$'s, "go out" so that quantities in the equations are real and not zero, hence $\nabla \cdot \underline{B}_{\text{Im}} = 4pr_m$, yielding a term that may be associated with some classes of monopole theories. See references in [10] and references therein.

We express the charge density and current density as complex quantities based on the separation of Maxwell's equations above. Then, in generalized form $r = r_e + ir_m$ and $J=J_e+iJ_m$ where it may be possible to associate the imaginary complex charge with the magnetic monopole and conversely the electric current has an associated imaginary magnetic current.

The alternate of defining and using, which Evans does $\underline{E} = \underline{E}_{\text{Re}} + i\underline{B}_{\text{Im}}$ and $\underline{B} = \underline{B}_{\text{Re}} + i\underline{E}_{\text{Im}}$ would not yield a description of the magnetic monopole in terms of complex quantities but would yield, for example $\nabla \cdot \left(i\underline{B}_{\text{Im}}\right) = 0$ in the second set of equations.

Using the invariance of the line element $s^2 = x^2 - c^2t^2$ for $r = ct = \sqrt{x}^{\,2}$ and for $s^2 = x^2 + y^2 + z^2$ for the distance from an electron charge, we can write the relation,

$$\frac{1}{c}\frac{\partial\left(iB_{im}\right)}{\partial t} = iJm \text{ or } \frac{1}{c}\frac{\partial B_{im}}{\partial t} = J_m \text{ ; } \nabla \times \left(iE_{\text{Im}}\right) = 0 \text{ for } \underline{E}_{\text{Im}} = 0 \text{ or } \frac{1}{c}\frac{¶\left(iB_{\text{Im}}\right)}{¶t} = iJm \qquad (3)$$

## 3. New Gauge Conditions, Complex Minkowski $M_4$ Space & Implications For Physics

In a series of papers, Barrett [16], Harmuth [17] and Rauscher have examined the modification of gauge conditions in modified or amended Maxwell theory. The Rauscher approach, as briefly explained in the preceding section is to write complexified Maxwell's equation in consistent form to complex Minkowski space [10,11].

The T.W. Barrett amended Maxwell theory utilizes non-Abelian algebras and leads to some very interesting predictions which have interested me for some years. He utilizes the non commutive $SU_2$ gauge symmetry rather than the $U_1$ symmetry. Although the Glashow electroweak theory utilizes $U_1$ and $SU_2$, but in a different manner, but his theory does not lead to the interesting and unique predictions of the Barrett theory.

T.W. Barrett, in his amended Maxwell theory, predicts that the velocity of the propagation of signals is not the velocity of light. He presents the magnetic monopole concept resulting from the amended Maxwell picture. His motive goes beyond standard Maxwell formalism and generate new physics utilizing a non-Abelian gauge theory.[5]

The $SU_2$ group gives us symmetry breaking to the $U_1$ group which can act to create a mass splitting symmetry that yield a photon of finite (but necessarily small) rest mass which may be created as self energy produced by the existence of the vacuum [9,11]. This finite rest mass photon can constitute a propagation signal carrier less than the velocity of light.

We can construct the generators of the SU2 algebra in terms of the fields $\underline{E}$, $\underline{B}$, and $\underline{A}$. The usual potentials, $A_m$ is the important four vector quality $A_m = \left(\underline{A}, f\right)$ where the index runs 1 to 4; where $\overline{A}$ is the three vector potential and $j$ is the scalar term. One of the major purposes of introducing the vector and scalar potentials and also to subscribe to their physicality is the desire by physicists to avoid action at a distance. In fact in gauge theories

$A_m$ is all there is! Yet, it appears that, in fact, these potentials yield a basis for a fundamental nonlocality!

Let us address the specific case of the $SU_2$ group and consider the elements of a non-Abelian algebra such as the fields with $SU_2$ (or even $SU_n$) symmetry then we have the commutation relations where $XY-YX \neq 0$ or $[X,Y] \neq 0$ which is reminiscent of the Heisenberg uncertainty principle non-Abelian gauge. Barrett does explain that $SU_2$ fields can be transformed into $U_1$ fields by symmetry breaking. For the $SU_2$ gauge amended Maxwell theory additional terms appear in term of operations such $A \cdot E, A \cdot B$ and $A \times B$ and their non Abelian converses. For example $\nabla \cdot B$ no longer equals zero but is given as $\nabla \cdot B = -jg(A \cdot B - B \cdot A) \neq 0$ where $[A,B] \neq 0$ for the dot product of A and B and hence we have a magnetic monopole term and j is the current and g is a constant. Also Barrett gives references to the Dirac, Schwinger and G. t Hooft monopole work. Further commentary on the $SU_2$ gauge conjecture of H.F. Harmuth [17] that under symmetry breaking, electric charge is considered but magnetic charges are not. Barrett further states that the symmetry breaking conditions chosen are to be determined by the physics of the problem [16]. These non Abelian algebras have consistence to quantum theory.

In our analysis, using the $SU_2$ group there is the automatic introduction of short range forces in addition to the long range force of the $U_1$ group. $U_1$ is one dimensional and Abelian and $SU_2$ is three dimensional and is non-Abelian. $U_1$ is also a subgroup of $SU_2$. The $U_1$ group is associated with the long range $1/r^2$ force and $SU_2$, such as for its application to the weak force yields short range associated fields. Also $SU_2$ is a subgroup of the useful SL(2,c) group of non compact operations on the manifold. SL(2,c) is a semi simple four dimensional Lie group and is a spinor group relevant to the relativistic formalism and is isomorphic to the connected Lorentz group associated with the Lorentz transformations. It is a conjugate group to the $SU_2$ group and contains an inverse. The double cover group of $SU_2$ is SL(2,c) where SL(2,c) is a complexification of $SU_2$. Also SL(2,c) is the double cover group of $SU_3$ related to the set of rotatio ns in three dimensional space [20]. Topologically, $SU_2$ is associated with isomorphic to the three dimensional spherical, $O_3^+$ (or three dimensional rotations) and $U_1$ is associated with the $O_2$ group of rotations in two dimensions. The ratio of Abelian to non Abelian components, moving from $U_1$ to $SU_2$, gauge is 1 to 2 so that the short range components are twice as many as the long range components.

Instead of using the $SU_2$ gauge condition we use SL (2,c) we have a non-Abelian gauge and hence quantum theory and since this group is a spinor and is the double cover group of the Lorentz group (for spin ½) we have the conditions for a relativistic formalism. The Barrett formalism is non-relativistic. SL (2,c) is the double cover group of $SU_2$ but utilizing a similar approach using twistor algebras yields relativistic physics.

It appears that complex geometry can yield a new complementary unification of quantum theory, relativity and allow a domain of action for nonlocality phenomena, such as displayed in the results of the Bell's theorem tests of the EPR paradox [24], and in which the principles of the quantum theory hold to be universally. The properties of the nonlocal connections in complex 4-space may be mediated by non - or low dispersive loss solutions. We solved Schrödinger equation in complex Minkowski space [25,26].

In progress is research involving other extended gauge theory models, with particular interest in the nonlocality properties on the spacetime manifold, quantum properties such as expressed in the EPR paradox and coherent states in matter [25-27].

Utilizing Coxeter graphs or Dynkin diagrams, Sirag lays out a comprehensive program in terms of the $A_n$, $D_n$ and $E_6$, $E_7$ and $E_8$ Lie algebras constructing a hyper dimensional geometry for as a classification scheme for elementary particles. Inherently, this theory utilizes complexified spaces involving twistors and Kaluza-Klein geometries. This space incorporates the string theory and GUT models [20,28].

## 4. The Complex Vector Potential, Advanced Potentials and Bell's Inequality

The issue of whether Bell's theorem and other remote connectedness phenomena, such as Young's double slit experiment, demands superluminal or space-like signals or prior luminal signals is an area of hot debate [1,30]. Also, the issue of advanced vs. retarded potentials is of interest in this regard.

Using the complex model of $A^m$ we will examine the issue of the non-locality of Bell's theorem as quantum mechanical "transactions" providing a microscopic communication path between detectors across space-like intervals, which do not violate the EPR locality postulate [6,24,25]. This picture appears to be consistent with the remote connectedness properties of complex Minkowski space. Also there are implications for macroscopic communications channels; another area of hot debate. Detailed discussions of Bell's theorem are given in [7,8,29-34].

We will formulate fields in terms of $A$ or $\underset{\sim}{A} = (A^j, f)$ where $A^j$ is $\underline{A}$ rather than the tensor $F_{mn}$ or $\underline{E}$ or $\underline{B}$. We can proceed from the continuity equation $\nabla \cdot J + \partial r / \partial t = 0$ and the expression $F_{mn} = \partial A_n / \partial X_m - \partial A_m / \partial X_n$. For the usual restored potentials then, we have the Lorentz condition

$$\nabla \cdot A + me \frac{\partial f}{\partial t} = 0 \quad \text{and also} \quad \nabla^2 A - me \frac{\partial^2 A}{\partial t^2} = -mJ \tag{4}$$

We can also derive
$$\nabla^2 f - me \frac{\partial^2 f}{\partial t^2} = -\frac{1}{e} r \tag{5}$$

These equations possess a restored potential solution. The radiation field in quantum electrodynamics is usually quantized in terms of $(A, f)$.

(We can also convert back to the notation $\underline{E}$ and $\underline{B}$ fields using $E = -\nabla f - \partial A / \partial t$ and $B = \nabla \times A$.)

Quantization of the field consists of regarding the coordinates (x, k) or (q, p) as quantum mechanical coordinates of a set of equivalent harmonic oscillators [34]. We denote the wave number $k = 1/l$, q is the space coordinate and p is the momentum coordinate in the usual phase space notation. In the second quantized method treating $k_r, q_r$ and $A_r$ as quantum numbers then we have quantized allowable energy levels such as $W = \sum_r (n_r + h_2)\hbar w_r$. Solutions are given in the form

$$\Psi \propto \sum_{n_r} n_r e \exp\left[-\frac{iW(n_r)}{\hbar}\right] \tag{6}$$

and we have a Hamiltonian equation of motion

$$\dot{p}_{ab} + (ck)^2 q_{ab} = 0 \text{ or } \dot{q}_{ab} = p_{ab} \quad \text{and} \quad H = \tfrac{1}{2} \sum [p_{ab}^2 + (ck)^2 q^2 q_{ab}^2]. \tag{7}$$

The electromagnetic field energy of the volume integral $(E^2 + B^2)/8p$ is just equal to the Hamiltonian.

We can examine such things as absorption and polarization in terms of the complexification of $\underline{E}$ and $\underline{B}$ or $\underline{A}$ and $f$. We define the usual $D = eE$ (or displacement field) and $B = mH$ for a homogeneous isotopic media. If we introduce $p_0$ and $m_0$ as independent of $\underline{E}$ and $\underline{H}$ where the induced polarizations of the media are absorbed into the parameters $e$ and $m$, we have

$$D = eE + p_0 \quad \text{and} \quad H = \tfrac{1}{m} B - m_0 \tag{8}$$

Then we define a complex field as $\underline{Q} \equiv \underline{B} + i\sqrt{em}\,\underline{E}$ (9)

so that we have Maxwell's equations now written as

$$\nabla \times Q + i\sqrt{em}\, \partial Q \big/ \partial t = mJ \quad \text{and} \quad \nabla \cdot Q = i\sqrt{m/e}\quad r\ . \tag{10}$$

Using vector identities [35,36] with $c \equiv 1$ units, and resolving into real and imaginary parts, we have

$$\nabla^2 H - em\frac{\partial^2 H}{\partial t^2} = -\nabla \times J \quad \text{and} \quad \nabla^2 E - em\frac{\partial E}{\partial t^2} = m\frac{\partial J}{\partial t} + \frac{1}{e}\nabla r \tag{11}$$

Defining $Q$ in terms of the complex vector potential $A_{\mathrm{Re}} \to L_{complex}$ and $f_{\mathrm{Re}} \to f_{complex}$ [11]. Then

$$Q = \nabla \times L - i\sqrt{em}\,\frac{\partial L}{\partial t} - i\sqrt{em}\nabla f \tag{12}$$

subject to the condition similar to before, $\nabla \cdot \underline{L} + em\, \partial f \big/ \partial t = 0$. Then we have

$$\nabla^2 L - em\, \partial^2 L \big/ \partial t^2 = -mJ \quad \text{and} \quad \nabla^2 f - em\, \partial^2 f \big/ \partial t^2 = -1\big/ e \quad r \tag{13}$$

Separation into real and imaginary parts of these potentials, $L$ and $f$ can be written as

$$L = A_{\mathrm{Re}} - i\sqrt{m/e}\ A_{\mathrm{Im}} \quad \text{and} \quad f = f_{\mathrm{Re}} - i\sqrt{m/e}\ f_{\mathrm{Im}} \tag{14}$$

Upon substitution into the equation for Q and separation into real and imaginary parts we have

$$\underline{B}_{\mathrm{Re}} = \nabla \times \underline{A}_{\mathrm{Re}} - \frac{m\partial \underline{A}_{\mathrm{Im}}}{\partial t} - m\nabla f_{\mathrm{Im}}\ ;\ \underline{E}_{\mathrm{Re}} = -\nabla f_{\mathrm{Re}} - \frac{\partial \underline{A}_{\mathrm{Re}}}{\partial t} - \frac{1}{c}\nabla \times \underline{A}_{\mathrm{Im}} \tag{15}$$

The usual equations are allowed when $A_{\mathrm{Im}}$ and $f_{\mathrm{Im}}$ are taken as zero.

If free currents and charges are everywhere zero in the region under consideration, then we have

$$\nabla \times Q + i\sqrt{em}\, \partial Q \big/ \partial t = 0\ ; \qquad \nabla Q = 0 \tag{16}$$

and we can express the field in terms of a single complex Hertzian vector $\underline{\Gamma}$ as the solution of

$$\nabla^2 \underline{\Gamma} - em\ \ \partial^2 \underline{\Gamma} \big/ \partial t^2 = 0 \tag{17}$$

We can define $\Gamma$ by $\Gamma \equiv p_{\text{Re}} - i\sqrt{m/e}\ \ p_{\text{Im}}$ (18)

where $f_{\text{Re}} = -\nabla \cdot \underline{p}$ and we can write such expressions as

$$A_{\text{Im}} = me \,\partial p_{\text{Im}} / \partial t \qquad \text{and} \qquad f_{\text{Im}} = \nabla \cdot \underline{p}_{\text{Im}} \tag{19}$$

This formalism works for a dielectric media but if the media is conducting the field equations is no longer symmetric then the method fails. Symmetry can be maintained by introducing a complex induced capacity $e' = e_{\text{Re}} \pm i\ \ s_{\text{Im}}/w$. The vector $B$ is in a solenoid charge-free region; this method works. Calculation of states of polarization by the complex method demonstrates its usefulness and validity. Also, absorption can be considered in terms of complex fields. We will apply this method to solutions that can be described as restored and advanced and may explain Bell's theorem of non-locality. Linear and circular polarization can be expressed in terms of complex vectors $A = A_{\text{Re}} + iA_{\text{Im}}$. The light quanta undergoing this polarization is given as $\hbar w\hat{n} = \hbar s = \hbar k$. Complex unit vectors are introduced so that real and imaginary components are considered orthogonal. We have a form such as $A = (A \cdot \hat{\ell}_{\text{Im}})\hat{\ell}_{\text{Re}} + (A \cdot \hat{j}_{\text{Im}})\hat{j}_{\text{Re}}$. The linearly polarized wave at angle $q$ is

$$A = \frac{A}{\sqrt{2}}(\ell_{\text{Re}}\ \ e^{-iq} - ij_{\text{Re}}\ \ e^{iq})\,. \tag{20}$$

Now let us consider use of this polarization formalism to describe the polarization-detection process in the calcium source photon experiment of J. Clauser, et al [7,32], Aspect, et al [33-35] and Gisin, et al [31,37].

Let us first look at solutions to the field equations for time-like and space-like events. The non-locality of Bell's theorem appears to be related to the remote connected-ness of the complex geometry and the stability of the soliton over space and time.

We will consider periodically varying fields which move along the x-axis. For source-free space, we can write

$$c^2\nabla^2 \underline{F} = f^2 \underline{F} / f t^2 \tag{21}$$

where $\underline{F}$ represents either $\underline{E}$ or $\underline{B}$. The two independent solutions for this equation are [36]

$$\underline{E}_{\pm}(x,t) = E_0 \sin(2pkx \pm nt) \ \text{ and } \ \underline{B}_{\pm}(x,t) = B_0 \sin 2p(kx \pm nt) \tag{22}$$

and $k$ is the wave number and $n$ the frequency of the wave. The $\forall$ sign refers to the two independent solutions to the above second order equation in space and time. The wave corresponding to $E_+$ and $B_+$ will exist only when t < 0 (past lightcone) and the wave corresponding to $\underline{E}$ and $\underline{B}$ will exist for $t > 0$ (future lightcone). Then the $E\_$ wave arrives at a point $x$ in a time $t$ after emission, while $E_+$ wave arrive at $x$ in time, $t$ before emission (like a tachyon).

Using Maxwell's equations for one spatial dimension, $x$, and the Poynting vector which indicates the direction of energy and momentum flow of the electromagnetic wave, we find that $E_+$ and $B_+$ correspond to a wave emitted in the $+x$ direction but with energy flowing in the $-x$ direction. For example, $E_+(x, t)$ is a negatives-energy and negative-frequency solution. The wave signal will arrive $t = x/c$ before it is emitted, and is termed an advanced wave. The solution $\underline{E}\,(x,t)$ is the normal positive-energy solution and arrives at $x$ in time, $t = x/c$, after the instant of emission and is called the retarded potential, which is the usual potential.

The negative energy solutions can be interpreted in the quantum picture in quantum electrodynamics as virtual quantum states such as vacuum states in the Fermi-sea model [10,11,33]. 'These virtual states are not fully realizable as a single real state but can definitely effect real physical processes to a significant testable extent [33]. The causality conditions in S-matrix theory, as expressed by analytic continuation in the complex plane, relate real and virtual states [10,11]. Virtual states can operate as a polarizable media leading to modification of real physical states. In fact, coherent collective excitations of a real media can be explained through the operations in a underlying virtual media [33].

Four solutions emerge: Two <u>retarded</u> ($F_1$ and $F_2$) connecting processes in the forward light cone and two <u>advanced</u>, ($F_3$ and $F_4$) connecting processes in the backward slight cone.

These four solutions are

$$F_1 = F_0 e^{-i(-kx-wt)}, \quad F_2 = F_0 e^{i(kx-wt)}; \quad F_3 = F_0 e^{i(-kx+wt)}, \quad F_4 = e^{i(kx+wt)} \tag{23}$$

where $F_1$ is for a wave moving in the (-x, + t) direction, $F_2$ is for a (+x, +t) moving wave, $F_3$ is for a (-x, -t) moving wave, and $F_4$ is a (+x, -t) moving wave. $F_1$ and $F_4$ are complex conjugates of each other and $F_2$ and $F_3$, are complex conjugates of each other, so that $F_1^+ = F_4$ and $F_2^+ = F_3$. Then the usual solutions to Maxwell's equations are retarded plane wave solutions.

The proper formulation of non-local correlations, which appear to come out of complex geometries may provide a conceptual framework for a number of quantum mechanical paradoxes and appear to be explained by Bell's nonlocality, Young's double slit experiment, the Schrödinger cat paradox [38], superconductivity, superfluidity, and plasma "instabilities" including J.A. Wheeler's "delayed choice experiment" [39]. Interpretation of these phenomena is made in terms of their implications about the lack of locality and the decomposition of the wave function which arises from the action of advanced waves which "verify" the quantum-mechanical transactions or communications.

J.G.Cramer [40] has demonstrated that the communication path between detectors in the Bell inequality experiments can be represented by space-like intervals and produce the quantum mechanical result. By the addition of two time-like four vectors having time components of opposite signs which demonstrate the locality violations of Bell's theorem and is consistent with the Clauser, Fry and Aspect experimental results [31-34]. This model essentially is an "action-at-a-distance" formalism.

One can think of the emitter (in Bell's or Young's quantum condition) as sending out a pilot or probe "wave" in various allowed directions to seek a "transaction" or collapse of the wave function. A receiver or absorber detects or senses one of these probe waves, "sets its state" and sends a "verifying wave" back to the emitter confirming the transaction and arranging for the transfer of actual energy and momentum. This process comprises the non-local collapse of the wave function [32-34]. The question now becomes: does such a principle have macroscopic effects? Bell's non-locality theorem cancan be effective over a matter of distance.

An attempt to examine such a possible macroscopic effect over large distances has been made by R.B. Partridge [41]. Using 9.7 GHz microwave transmitted by a conical horn antenna so that waves were beamed in various directions. Partridge found that there was little evidence for decreased emission intensities in any direction for an accuracy of a few parts per $10^{9th}$. Interpretation of such a process is made in terms of advanced potentials. Previously mentioned complex dimensional geometries give rise to solutions of equations that form subluminal and superluminal signal propagations or solitons [41].

The possibility of a remote transmitter-absorber communicator now appears to be a possibility. The key to this end is an experiment by R.L. Pflelgov and L. Mandel [42]. Interference effects have been demonstrated, according to the authors, in the superposition of two light beams from two independent lasers. Intensity is kept so low that, to high probability, one photon is absorbed before the next one is emitted. The analogy to Young's double slit experiment is enormous [29].

In J.A. Wheeler's recent paper, he presents a detailed discussion of the physics of delayed choice proton interference and the double slit experiment (from the Solvay conference, Bohr-Einstein dialogue). Wheeler discusses the so-called D. Bohm "hidden variables" as a possible determinant that nonlocality collapses the wave function [43].

It is clear that further theoretical and experimental investigation is indicated but there appears to be a vast potential for remote non-local communication and perhaps even energy transfer.

In the next section we detail the forms of transformations of the vector and scalar potentials at rest and in moving frames, continuing our formulation in terms of $(\underline{A}, f)$. The issues of sub and superluminal transformations of $\underline{A}$ and $f$ are given in a complex Minkowski space. Both damped and oscillatory solutions are found and conditions for advanced and restored potentials are given.

## 5. Transformation Laws for Vector and Scalar Potential Under a Superluminal Boost (SLB)

For simplicity we will consider Superluminal Boost (SLB) $v_x = \infty$ along the positive $x$ direction. The space and time vectors in the real four dimensional Minkowski space transform as follows [1]:

$$x' = +t, \quad y' = -iy, \quad z' = iz, \quad t' = x \tag{24}$$

for real and imaginary parts separately, where $x, y, z, t$ are real quantities in the laboratory (S) frame, and $x', y', z', t'$ are the real quantities in the moving (S') frame. Now in the six dimensional ($M^6$) complex Minkowski space, the above transformation laws for a superluminal boost $(v_x = +\infty)$ in the positive $x$ direction become [44]

$$\begin{gathered} x'_{\text{Re}} + ix'_{\text{Im}} = t_{x,\text{Re}} + it_{x,\text{Im}}, \quad y'_{\text{Re}} + iy'_{\text{Im}} = y_{\text{Im}} - iy_{\text{Re}}, \quad z'_{\text{Re}} + iz'_{\text{Im}} = z_{\text{Im}} - iz_{\text{Re}}; \\ t'_{x,\text{Re}} + it'_{x,\text{Im}} = x_{\text{Re}} + ix_{\text{Im}}, \quad t'_{y,\text{Re}} + it'_{y,\text{Im}} = t_{y,\text{Im}} - it_{y,\text{Re}}, \quad t'_{z,\text{Re}} + it'_{z,\text{Im}} = t_{z,\text{Im}} - it_{z,\text{Re}} \end{gathered} \tag{25}$$

The transformation laws given by (25) preserve the magnitude of the line element but not the sign as in:

$$-x'^{m} x'^{n} = x^{m} x^{n} \tag{26}$$

where index $m$ and $n$ run over 1,2,3,4 representing 1 as time vector and 2,3,4 as spatial vectors. Therefore we have the signature (+++-). Similar to the transformation laws for space and time vectors as given by (25) we can write the transformation laws for the vector and scalar potential. For a superluminal boost in positive $x$ direction, the transformation laws for $(\underline{A, f})$ are:

$$A_x^{'} = b\left(A_x - \frac{v_x^2}{c^2} f\right), \quad A_y^{'} = A_y, \quad A_z^{'} = A_z, \quad f^{'} = b(f - v_x A_x) \tag{27}$$

where $f$ is the scalar potential and $b$ is defined as the usual Lorentz term

$$b \equiv 1 \Big/ \left(\frac{v_x^2}{c^2} - 1\right)^{\frac{1}{2}} \tag{28}$$

We consider $A_x^{'}$, etc., transforming as a gauge. In eq. (27), the vector potential $A$ is considered to be a four-vector real quantity, $A_m$ or $\underset{\sim}{A} = (A_x, A_y, A_z, \frac{if}{c})$, which preserves the length of the line element but not the sign, i.e. we have

$$A_m A_m = -A_m^{'} A_m^{'} \tag{29}$$

Equation (27) then simplifies to the following relationships for the velocities approaching infinity, $v_x = \infty$.

We can write the transformation laws for scalar and vector potentials under the superluminal boost in the positive $x$ direction for $v_x = +\infty$. From the rest frame, S, to the moving frame, S', for unaccelerated vector and scalar potentials, we have

$$A_x = -f^{'}, \quad A_y = A_y^{'}, \quad A_z = A_z^{'}, \quad f = -A_x^{'} \tag{30}$$

From the moving frame, S', to the rest frame, S, for the unaccelerated vector and scalar potentials we obtain

$$A_x^{'} = -f, \quad A_y^{'} = A_y, \quad A_z^{'} = A_z, \quad f^{'} = -A_x \tag{31}$$

Equation (31) is valid for real or complex vector and scalar potentials. Real and imaginary parts are easily separable in a complex quantity and they will transform according to eq. (31) under the influence of a superluminal boost in the positive x direction. Now if these are the retarded (or accelerated or advanced) vector and scalar potentials then the transformation laws under the superluminal boosts will be different from the ones given by equation (31).These will be given by the combination of equation (31) and the transformation laws of the complex space and time vectors as given by equation (25).

The propagation constant is considered to be isotropic in vacuum and defined as $k_x = w / v_f$, where $v_f$, is the phase velocity and $w$ is the radian frequency of the propagating signal. Usually in most cases the phase velocity of propagation in vacuum is a constant $v_f = c$, where $c$ is the velocity of light in vacuum. For the purpose of this paper, we will consider a tachyon traveling faster than light emitting an electromagnetic signal at frequency $w$ which propagates at the velocity of light. This assumption will simplify the subject matter of this paper. Later on, in a separate paper, we will examine the faster than light electromagnetic signals emitted by a traveling tachyon [16] which might lead into a Doppler effect [17] at velocities faster than light. See [1,10,11,44] and references therein.

Let us consider the advanced potential solution only from equation (24). Equation (24) can now be rewritten as two separate terms, so that in the $S$ frame $A_x$ goes to

$$A_x = (A_{0x,\mathrm{Re}} + iA_{0x,\mathrm{Im}})\{\exp i[wt_{x,\mathrm{Re}} - kx_{\mathrm{Re}}] \times \exp - [wt_{x,\mathrm{Im}} - kx_{\mathrm{Im}}]\} \tag{32}$$

where the first exponent represents the usual type of oscillatory terms and the second exponent represents a decaying component which is not present in the usual four dimensional spacetime model. Note also that we have used the isotropy of the vector $k$ in equation (32) as examined in the previous section.

Now let us examine the complex exponential of equation (32) using the transformations of equation (24) as follows so that we have for the exponents

$$\exp i[wx'_{\mathrm{Re}} - kt'_{x,\mathrm{Re}}] \times \exp - [wx'_{\mathrm{Im}} - kt'_{x,\mathrm{Im}}] \tag{33}$$

We regroup terms in $w$ and $k$ so that we have

$$\exp i[w(x'_{\mathrm{Re}} + ix'_{\mathrm{Im}}) - k(t'_{x,\mathrm{Re}} - it'_{x,\mathrm{Im}})] \tag{34}$$

Now using equations from [11,45,46] for $\underline{x}' = x'_{\mathrm{Re}} + ix'_{\mathrm{Im}}$ we have

$$\exp i[wx' - k(t'_{z,\mathrm{Re}} - it'_{x,\mathrm{Im}})] \tag{35}$$

Note that the second part of the exponent for the $k$ term does not reduce to $t$' since there is a minus before $it'_{x,\mathrm{Im}}$. Thus for the boost $v_x \to \infty$ or $v > c$, we obtain for $e \exp i[wt + kx]$ from equation (24) under this transformation going to

$$\exp i[wx'] \times \exp - k[t'_{x,\mathrm{Re}} - it'_{x,\mathrm{Im}}] \tag{36}$$

Let us look at the example of the transformation from $A'_x$ (in the moving frame $S'$) to its form in the restframe, $S$. We find a mixing vector and scalar potential.

In the SLT from the restframe $S$ to the moving $S'$ frames we have a change of length of the time component vector in equation (36). The vector potential term $A_{0x}$ transforms as

$$A'_x = b\left(A_x - \frac{v_x^2}{c^2} f\right) \tag{37}$$

which is the same as equation (28), so that for the superluminal boost $v_x \to \infty$ , implies that

$$b \equiv \frac{1}{\sqrt{\frac{v_x^2}{c^2} - 1}} = \frac{1}{\frac{v_x}{c}\sqrt{1 - \frac{c^2}{v_x^2}}} \cong \frac{c}{v_x} \tag{38}$$

where the $\sqrt{1 - c^2 / v_x^2}$ term approaches unity as $v_x \to \infty$. Then we rewrite the transformed vector potential as

$$A'_x = \frac{1}{\sqrt{\frac{v_x^2}{c^2} - 1}} \quad and \quad A_x - \frac{\frac{v_x}{c}}{\sqrt{\frac{v_x^2}{c^2} - 1}} f \tag{39}$$

Then for $v_x \to \infty$ and from equations (38) and (39),

$$A'_x = \frac{cA_x}{v_x} - \frac{v_x}{c^2}\frac{c}{v_x} f = 0 - \frac{r}{cf} \equiv -f \tag{40}$$

for units in which $c = 1$. Therefore $A_x' = -f$ for a superluminal boost, $v_x \to \infty$.

For the transformation of the scalar potential, in analogy to equation (28), we have

$$f' = b(f - v_x A_x) \tag{41}$$

and for $v_x \to \infty$, we have $g \cong c / v_x$ so that in the limit of the SLT,

$$f' \lim_{v\to\infty} \frac{c}{v_x} f - cA_x = -cA_x \tag{42}$$

and for the units of $c = 1$, then $f' = -A_x$. Compare this equation to equation (40). Also for $A_y' = A_y$ and $A_z' = A_z$ we can now write

$$A_x = [A_{0x,\mathrm{Re}} + iA_{0x,\mathrm{Im}}]\exp i[wt + kx] = [-f_{\mathrm{Re}}' - if_{\mathrm{Im}}']\exp iwx' \ \times \ \exp \pm k_x[t_{x,\mathrm{Re}} - it_{x,\mathrm{Im}}'] \tag{43}$$

where $x' = x_{\mathrm{Re}}' + ix_{\mathrm{Im}}'$ and using the result of equation (40)and (42) for the non-exponent part and the exponential term which is given in equation (35), equation (43) gives us the vector and scalar form in the moving $S'$ frame.

If we consider only the accelerated potential, then we consider only the plus sign in equation (43). By use of the definition of complex quantities, equation (43) can be rewritten in a compact, simplified form:

$$A_x = -f_{0x}' \exp(iwx') \cdot \exp(ik_x t_x') \, . \tag{44}$$

Then by use of equation (44) we can describe the $x$ component of the complex vector potential in moving frame $S'$ after a superluminal boost in the positive $x$ direction. The same vector potential in the rest frame is defined by $|t| = (t_x^2 + _{ty}^2 + t_z^2)^{1/2}$ or $A_x = A_{0x} \exp[i(wt \pm k_x \cdot x)$ [10,29].

The transformation of the $A_y$ and $A_z$ components of the complex vector potential under a superluminal boost in the positive $x$ direction can similarly be written as

$$\begin{aligned} A_y &= A_{0y}' \exp[-w(t_{y,\mathrm{Re}}' + it_{y,\mathrm{Im}}')] \cdot \exp[-ky(z_{\mathrm{Re}}' + iy_{\mathrm{Im}}')] \\ A_z &= A_{0z}' \exp[-w(t_{z,\mathrm{Re}}' + it_{z,\mathrm{Im}}')] \cdot \exp[-ky(z_{\mathrm{Re}}' + iz_{\mathrm{Im}}')] \end{aligned} \tag{45}$$

We will now consider the scalar potential as defined by a complex quantity, so that

$$f' = f_{\mathrm{Re}}' + if_{\mathrm{Im}}' \tag{46}$$

which we use for the non-exponential term of equation (44)which then becomes

$$A_x = -f' e \exp iwx' \ \times \ \exp k[t_{x,\mathrm{Re}} - it_{x',\mathrm{Im}}] \tag{47}$$

Let us now compare the vector potential forms of $A_x$ in equation (42) in the $S$ or laboratory frame, and $A_x$ of equation (47) in the $S'$ frame or moving frame. (Table 1.)

TABLE 1. Comparison of the Exponential Part of the Vector Potential $A_x$ in the $S$ and $S'$ Frames of Reference

| | **OSCILLATORY** | **DAMPED** |
|---|---|---|
| S Frame: | $A_{0x} \propto \exp i[wt_{x,\mathrm{Re}} - kx_{\mathrm{Re}}]$ | $\exp -[wt_{x,\mathrm{Im}} - kx_{\mathrm{Im}}]$ |
| S\` Frame: | $f' \propto \exp i[wx']$ | $\exp k[t_{x,\mathrm{Re}}' - it_{x,\mathrm{Im}}']$ |

In the oscillatory solution of the $S'$ frame for $f'$, we find no dependence on the wave number factor $k$ and hence we have apparent media independence, recalling $x' = x_{\mathrm{Re}} + ix_{\mathrm{Im}}$, whereas in the $S$ frame for $A_{ox}$, we have dependence on $w$ and $k$.

For the damped solution, we have $w$ and $k$ dependence in the $S$ frame for $A_{ox}$, which is a pure real exponential and hence not oscillatory. In the $S'$ frame then, $f'$ sometimes has a damped solution dependent on $k$ which has a real and imaginary component. The exponential factor can be written as

$$t'_{x,\mathrm{Re}} - it'_{x,\mathrm{Im}} = x_{\mathrm{Re}} - ix_{\mathrm{Im}} \tag{48}$$

Time dilation and vector length are modified in the complex twelve dimensional space [44]. We find that a superluminal, unidimensional ($x$-dimensional) boost in complex Minkowski space not only modifies space and time (as well as mass [47,48]) by the $b$ factor, it also modifies $\underset{\sim}{A} = (\underline{A}, f)$ and we find a mixing of $\underline{A}$ and $f$ for $\underline{A} = A_j$ where $j$ runs 1 to 3 (or spacelike quantities) and $f$ transforms as a temporal quantity for subluminal transformations. The notation $\underset{\sim}{A}$ refers to 4-vector potential

Work is in progress to continue the examination of the forms of transformations of the vector and scalar potentials in sub and superluminal transformations [45,46,49].

## 6. Conclusions

It appears that utilizing the complexification of Maxwell's equations with the extension of the gauge condition to non-Abelian algebras, yields a possible metrical unification of Relativity, electromagnetism and quantum theory. This unique new approach yields a universal nonlocality. No radical spurious predictions result from the theory; but some new predictions are made which can be experimentally examined, such as the effects of advanced potentials, non Hertzian receivers such as in biological materials, nonlocal solitary wave phenomena and interpretations of string theory. Also, this unique approach in terms of the twistor algebras may lead to a broader understanding of macro and micro nonlocality and possible transverse electromagnetic fields observed as nonlocality in collective plasma state and other non plasma media.

Although we did not make specific mention of anticipatory parameters in this work; it should be noted that our model of complex geometries aligns well with anticipation as a fundamental physical principle, a scenario that is more evident in the self-organized symmetry conditions of our model when cast in 12D, which we intend to develop more fully for CASYS07.

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