Panel Discussion:
Are Electrons Oscillating Photons, Oscillating "Vacuum," or Something Different?

Moderators:
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Platform: What physical attributes separate EM waves, of the enormous band of radio to visible to x-ray, from the high energy narrow band of gamma-ray? From radio to visible to x-ray, telescopes are designed based upon the optical imaging theory; which is an extension of the Huygens-Fresnel diffraction integral. Do we understand the physical properties of gamma rays that defy us to manipulate them similarly? One demonstrated unique property of gamma rays is that they can be converted to elementary particles (electron and positron pair); or a particle-antiparticle pair can be converted into gamma rays. Thus, EM waves and elementary particles, being inter-convertible; we cannot expect to understand the deeper nature of light without succeeding to find structural inter-relationship between photons and particles. This topic is directly relevant to develop a deeper understanding of the nature of light; which will, in turn, help our engineers to invent better optical instruments.

Participants and Sub-Titles

1. Chip Akins, *"Understanding the puzzle of space and energy"*
2. Richard Gauthier, *"The electron is a helically-circulating spin-1/2 charged photon generating the de Broglie wavelength"*
3. A. F. Kracklauer, *"Theory and reality"*
4. John A. Macken, *"The Single Component Universe"*
5. Andrew Meulenberg, *"Photon trapping and the transition to electrons"*
6. Chary Rangacharyulu, *"Elementary Quanta- Are you There?"*
7. Chandrasekhar Roychoudhuri, *"The next level of unification: Waves and particles as emergent oscillations of the same Complex Tension Field (CTF)"*
8. Martin B. van der Mark, *"Topological electromagnetism is the stuff that matters!"*
9. John G. Williamson, *"An unprecedented engineering opportunity: a dynamical theory of energy as light and matter"*

Understanding the puzzle of space and energy

(Chip) Charles Akins – AE Research

1. It seems that Euclidian 3 dimensional space is fundamental, and time is created by the "speed of light" propagation of energy in space. For me, it seems that assuming space to be "spacetime", as a 4 dimensional frame, causes an error in our basis, our foundation, which leads to misunderstandings, and a set of irreconcilable conclusions.

2. A new set of field equations is required which recognizes that space is 3 dimensional and the speed of energy propagation (light) is "fixed" in homogenous space. This yields both left and right solutions for the field equations, explains the perceived "spin" of "photons", and polarization properties for light. As well as "Poincare" and other confinement forces.

3. Space is the media which manages all energy in the universe. Space contains all energy. It is therefore perfectly sound to assume that space can act as the absorber of energy, and that particle-particle interaction is not required for the conservation of energy in the universe. So that an emission-absorption event can be between a particle, or atom, and space. Space is the container for energy. Space is not just the region between particles, but is the volume of the universe, permeating and sustaining all energy, and therefore matter. Matter cannot exist without the fabric of space to sustain it.

4. Given the non-point-like nature of particles, and the "spin" from new field equations, it seems that entanglement is an illusion. And deterministic local variables explain the Bell and CSHS inequalities.

5. Fermionic particles, are confined, circulating, configurations of energy in space. Fields and forces are the result of the properties, displacement, topology, and resultant "polarizations" of space. But perhaps it is more enlightening to state that forces are the result of the topology of particles, and the properties of space. In other words, the complexity of the properties of space are sufficient to be able to sustain electric, magnetic, weak, confinement, and strong forces, and as an aside, gravity.

6. Gravity is a change in the mass-equivalence (density p) of space, caused by energy in the fields of particles. This increase in the energy density of space in the vicinity of particles, causes space to display a slightly increased density term, slightly slowing the speed of light, resulting in gravitational force.

7. Any energy in space displays mass-like properties in the fabric of space.

The electron is a helically-circulating spin-1/2 charged photon generating the De Broglie wavelength

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My approach [1] is to model the relativistic electron as a helically-circulating double-looping charged photon. The photon carries the electron's charge and has spin $S_z = \pm \hbar/2$, the same as that of an electron, rather than spin $S_z = \pm 1\hbar$ of an uncharged photon. By equating the moving electron's relativistic energy $E = \gamma mc^2$ with the photon's energy $E = h\nu$, the charged photon is found to have a relativistic frequency $\nu = \gamma mc^2/h$ and a relativistic wavelength $\lambda = h/\gamma mc$. While this relativistic frequency $\nu = \gamma mc^2/h$ was used by de Broglie to derive the electron's de Broglie wavelength, the relativistic wavelength $\lambda = h/\gamma mc$ of a hypothesized photon that models a relativistic electron has never to my knowledge previously been utilized in describing the electron, neither by de Broglie nor by others (including other electron modelers.)

The spin ½ charged photon in this electron model has these three photon characteristics: 1) the photon's energy $E = h\nu$, 2) the photon's momentum $p = h/\lambda$, and 3) the photon's speed of light $c = \nu\lambda$. In addition the charged photon has 4) the electron's charge e^-, 5) a light-speed helical motion and 6) a spin $S_z = \pm\hbar/2$. The radius of the helix for a resting electron (where the helix becomes a circle) is $R_o = \hbar/2mc$. When these first three characteristics and the resting electron's radius $R_o = \hbar/2mc$ are combined with a double-looping light-speed helical motion, a unique helical trajectory (except for right or left turning) is found for the spin ½ charged photon model of the electron. See Figure 1 below. Some of the characteristics of the charged photon on its helical trajectory are:

1) The trajectory's radius for a resting electron is $R_o = \hbar/2mc$.
2) The helical trajectory's radius decreases with increasing electron speed as $R = R_o/\gamma^2$.
3) The pitch of the helical trajectory is maximum for electron speed $v = c/\sqrt{2}$, $\gamma = \sqrt{2}$ and $\theta = 45°$. The maximum helical pitch here is πR_o, and decreases towards zero as $v \to 0$ and as $v \to c$.
4) The longitudinal component of the charged photon's helical speed c is the speed v of the electron being modeled. The forward angle θ of the circulating helical trajectory is given by $\cos\theta = v/c$.
5) The relativistic energy-momentum equation of the electron $E_{electron}{}^2 = p_{electron}{}^2 c^2 + m^2 c^4$ becomes in the charged photon model $p_{photon}{}^2 = p_{electron}{}^2 + (mc)^2$, where the electron's momentum $p_{electron} = \gamma mv$ is the longitudinal component of the circulating charged photon's momentum $p_{photon} = \gamma mc$. The rotating transverse component of the circulating charged photon's momentum is $p_{trans} = mc$.
6) For a slowly moving electron, this rotating transverse momentum $p_{trans} = mc$ when multiplied by the circulating photon's helical radius $R_o = \hbar/2mc$ gives the electron's spin $S_z = \pm\hbar/2$.
7) The helically circulating charged photon's wave vector $\bar{k} = 2\pi/\lambda$, corresponding to the circulating charged photon's relativistic wavelength $\lambda = h/\gamma mc$, has a longitudinal component which generates the relativistic de Broglie wavelength of the electron $\lambda_{dB} = h/\gamma mv$ in the direction the electron is moving with velocity v. The generated de Broglie waves move at the de Broglie wave's superluminal phase velocity $v_{phase} = c^2/v$. So de

Broglie's "matter wave" of a freely moving electron is generated by waves from the helically circulating spin ½ charged photon that is modeling the electron.

This spin ½ charged photon model of the electron is a generic model of the photon because it does not present a more detailed model of a photon that may compose an electron. This generic model of the charged photon could be used with a variety of more detailed photon models that also have the basic photon characteristics of light speed, frequency, wavelength, energy and momentum listed above.

In a more detailed charged photon model, the charged photon's spin $S_z = \pm \hbar / 2$ must remain constant at all velocities to give the electron model a spin of $\hbar / 2$ at all velocities.

An objection to the spin ½ charged photon model of the electron is that an electron has spin $S_z = \pm \hbar / 2$ and is a fermion while a photon has spin $S_z = \pm 1 \hbar$ and is a boson, so an electron cannot be a charged photon. But if a circulating photon carries the electron's charge and has spin $S_z = \pm \hbar / 2$, it is not a boson but a fermion. In other words, I am proposing that photons may be of two varieties: 1) uncharged and moving linearly with spin 1 (a boson) with no rest mass, and 2) charged and moving helically with spin ½ (a fermion) and having a rest mass.
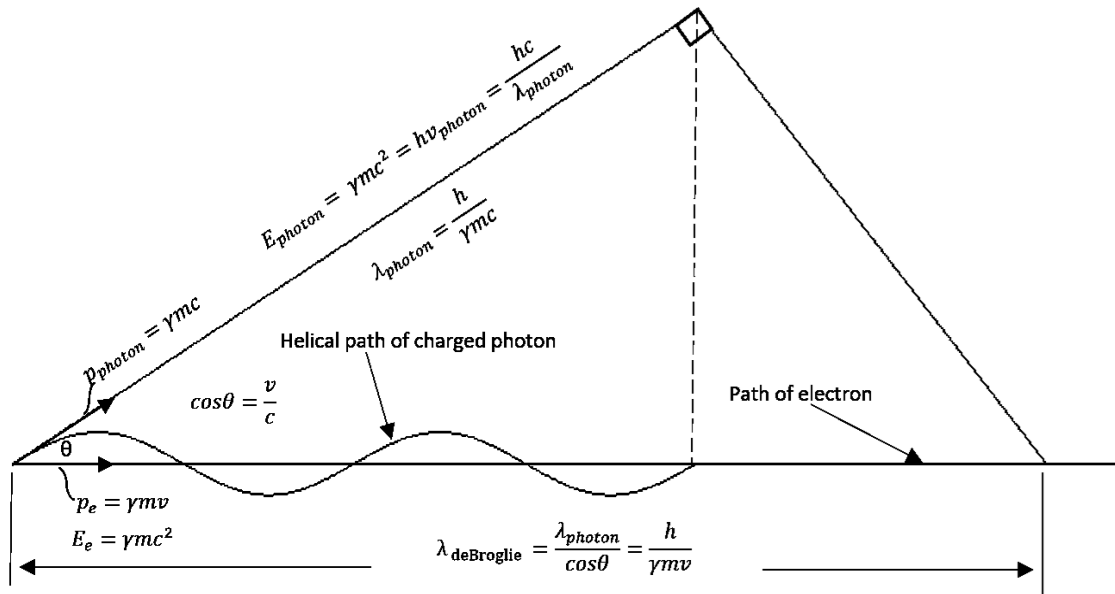

Figure 1. The electron's de Broglie wavelength is generated from the spin ½ charged photon model of electron. The electron is moving to the right with speed v. The charged photon modeling the electron is moving helically to the right with speed c along its helical trajectory. The helical trajectory for one wavelength of the double-looping charged photon is mathematically unrolled to show the geometrical relations more clearly. Each wavelength of the double-looping charged photon along its helical trajectory generates the electron's de Broglie wavelength along the helical axis of the charged photon. As the electron moves to the right with speed v, the de Broglie waves move to the right with speed $v_{phase} = c^2 / v$.

REFERENCE

[1]   Gauthier, R., "Electrons are spin ½ charged photons generating the de Broglie wavelength", paper [9570-13], SPIE Optics + Photonics, San Diego, (9-13 August 2015).

Theory and reality

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In the course of the panel discussion at the 2015 SPIE Conference it was my intention to make and support two main points: one, only the positions as a function of time are related to the ontological essence of material particles, all other assigned characteristics, e.g., "energy, momentum" and so on are theoretical "bookkeeping" concepts. Two, "space" is the empty capacity to contain material stuff, by itself it has no physical properties.

Point 1: Experiments in the end determine the position of particle as a function of time and then this information is used to calculate various quantities that have turned out to be useful for mathematical analysis of the motion of these particles. Energy is a prime example of this fact.

There is no such thing as an "energy meter." Kinetic energy cannot be handled, or put in a container, etc. Rather, it is a bookkeeping notion which tells an observer how much work must be done on the particle to which it is attributed to bring that particle to a rest in the observer/calculator's rest frame. Potential energy likewise tells an observer how much work, for example, has to be done against some constraint to deplete the particle of tendency to respond to the interaction with the constraining agent.

Both of these energy types are frame dependent, in one sense or another, and thus cannot be identified with intrinsic, immutable characteristics of the particle. Momentum is also frame dependent and another sort of bookkeeping concept. In the end, it seems all such concepts except position as a function of time have this character. I consider it important to keep this in mind when analyzing the physical of natural events to prevent illogical, circular, unproductive reasoning.

Charge and mass of a material particle are also derived from the analysis of the motion of the particle, but are also somehow attached to the particle in a manner independent of reference frames. In this regard their existence poses "philosophical" problems, especially regarding their origin. To my best information, efforts to explain or motivate the nature of these two properties have sunk into a morass of circular, infinite regress.

Point 2: First a lexicographical issue. The word "space" originally pertained to the 3-dimensional void in which we find material entities located. Its properties, mostly its metric relationship between the dimensions, give it a certain structure that is very useful, for, among many things, geometry. In the course of time, for lack of a better term, the word "space" has been commandeered for use with abstract entities having dimensions other than three. This has led to endless empty rumination. Abstract thought-complexes cannot be considered some kind of new "thing" analogous to the 3-space in which we sentient being experience existence.

From Algebraic topology we know that as the dimension of abstract entities labeled "space" (in math technically terminology: manifolds, varieties, etc.) increases, some structure is gained and other is lost. In fact, it turns out that, the dimension "3" is located at a certain optimum point; higher dimension spaces are such that life might not even be possible in them. In fact, physical solids or multi connected contiguous bodies (such as living creatures with an alimentary canal, i.e., a torus) may be impossible within them! On the other hand, mathematical "spaces," defined precisely (and virtually always with much less structure than our home 3-space) are really spaces only in the sense that they share a few specific algebraic properties with 3-space (typically, vector space structure).

To be kept in mind always is the fact that the term space is used also to describe the totality of solutions for, among other types, differential equations. These solution spaces can have all kinds of exotic properties. The solutions of Einstein's gravitational equation, for example, constitute a 4-dimensional bundle of curved orbits for infinitesimal "test particles" surrounding a relatively large mass that meld smoothly with flat Minkowski space at infinity. Their existence, however, does not negate the existence of 3-space as the void in which the large mass exists. Equations for two interacting particles have a solution space of dimension 6 (or 8, depending on how time can be treated, i.e., how it appears in the equations); again this use of the term "space" leads to a tendency to ascribe 3-space features to these technical spaces and to consider them as somehow ontologically existing.

Additionally, the perception of space seems to be realizable for humans only in connection with entities that fill it. Einstein and Poincare, for example, claimed that without physical objects, it is impossible to even perceive of space at all. This does not mean that the notion of vacant interstices is invalid or imperceptible. Once the notion of occupation of a portion of space is consciously grasped, the generalization to voids or unoccupied portions follows easily. In short, I see no argument that precludes utterly empty space.

Point 3: The above two points combined lead to an objection to the claim that 3-space itself is filled with background energy. If energy is a bookkeeping concept pertaining to particles, then ineluctably there can be no energy where there is no particle. This is, of course, in full accord with empirical evidence in the sense that if one wishes to measure the energy at a point in space, it is logically necessary to insert a measurement device at that point, at which time there are then many particles are at that point. In this view, the total energy measured or sensed at that point would be the total work to be done to bring the inserted particles at that point to rest with respect to all other particles in the universe with which they are in beginning-less and endless interaction as described by Gauss's Law. Naturally, such particles cannot be brought to rest in all these exterior rest frames simultaneously, so that harvesting or exploiting the sum of all potential total energy is impossible. In this view, space is just an ethereal stage for the humanly unknowable interaction between knowable particles.

Remark: Many of my comments made while participating in the panel discussion were motivated by the thoughts presented herein, but not expressed in complete and cogent form in the hurly-burly of competing viewpoints struggling for attention. In addition, on occasion, my motivation was to warn of the complexities in formal thought that too often lead theoretical thinking on the fundamentals of Physics into circularity, infinite regress, inconsistency and the like. The evidence seems to be that it would take an infinitely long discussion to resolve almost any issue. While panel organizers are thus challenged, they may also be encouraged in that they will never be faced with an empty docket.

The single component universe

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Photons and electrons are related because they are both proposed to be oscillations of energetic spacetime. In fact, the author's previous publications have made the case that everything in the universe (all particles, fields and forces) are derived from the single building block of 4 dimensional spacetime. This will seem impossible if spacetime is visualized as an empty void which has an average energy density of about 10^{-9} J/m^3 resulting from of the known fermions, bosons and dark matter in the universe. However, there are numerous indications that the vacuum itself has another form of distributed energy which gives the vacuum its properties represented by the constants c, G, ' and μ_o. Many parts of quantum mechanics require the vacuum to have energy density. For example, the vacuum has zero point energy usually modeled as "quantum oscillators", each with energy of $E = \frac{1}{2}$ ' $É$. All frequencies are present up to Planck frequency. Quantum electrodynamics assumes that the vacuum has a vast energy density and this assumption is validated because QED calculations use this energy density to achieve results which are correct to 12 significant figures. Even the standard model is really a field theory where multiple fields are assumed to be present in the vacuum. The proposed model of the universe characterizes the vacuum energy in a way that can be reduced to equations. The particles, fields and forces generated from this spacetime field can be analyzed and computer modeled.

The model of the vacuum required by quantum mechanics and QED is about 10^{120} larger than the "critical" energy density of the universe obtained from general relativity. It is usually assumed that the energy density required by quantum mechanics must somehow be canceled without also eliminating all the effects which require this energy density. However, there is a proposed model of the vacuum that not only explains the undetectable energy density but also explains how it can be the basic building block of all particles, fields and forces. The uncertainty principle allows waves in spacetime which modulate the distance between points by $\pm L_p$ (Planck length) and allows the rate of time to be modulated such that perfect clocks in flat spacetime can differ by $\pm T_p$ (Planck time). These waves can last indefinitely and create an undetectable form of energy density which fills the universe. This sea of small waves in spacetime gives the vacuum its properties and is the building block of all particles. In fact, these waves in spacetime *cause* the uncertainty principle and the probabilistic characteristic of quantum mechanics.

This short description can only introduce topics without giving complete descriptions and equations. However, the concepts are covered in detail in 3 technical papers and a 400 page book (all available at: http://onlyspacetime.com/). The best of the papers for an introduction to the subject is titled *Spacetime Based Foundation of Quantum Mechanics and General Relativity* (Springer, 2015). This paper and its references should be considered to be incorporated here.

So far we have only set the stage by mentioning the structure of the vacuum. Now a brief description will be given of how electrons and photons can be formed from this energetic spacetime. When angular momentum is introduced into this sea of small amplitude waves, the angular momentum is quarantined into quantized units of $\frac{1}{2}$' or '. Electrons are just a wave that possesses $\frac{1}{2}$ ' angular momentum. This results in a rotation disturbance of the spacetime field at the electron's Compton frequency. A model of an electron is depicted in the figure designated 5-1. This is a rotating dipole wave in spacetime. The figure designates "Lobe A (slow time)" and "Lobe B (fast time)". The circumference of this rotating disturbance is equal to the electron's Compton wavelength which means that the radius is equal to $ɯ_c = $ ' $/mc = c/É_c$ H 3.86×10^{-13} m. This distance is shown to be the natural unit of length for forces incorporation an electron.
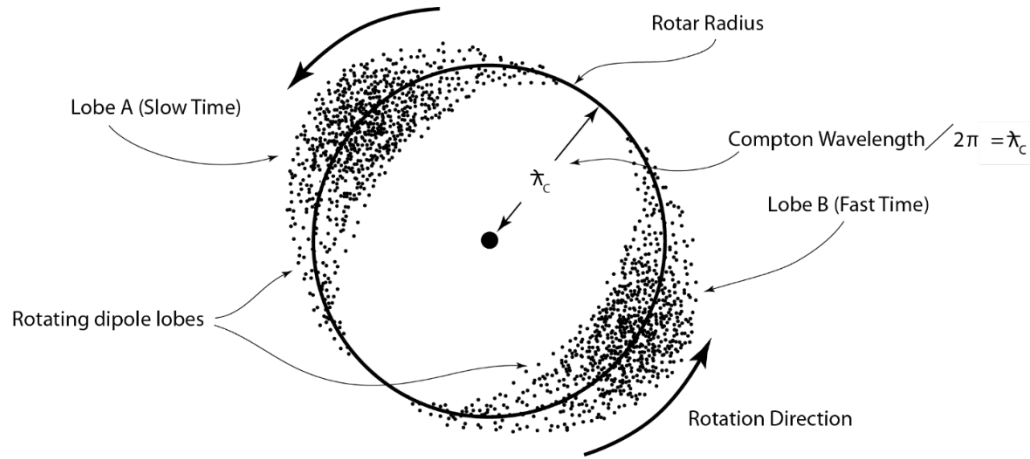
FIGURE 5-1 Depiction of the Rotar Model Emphasizing the Rotating Lobes
This is a rotating spacetime dipole that is one wavelength in circumference.

The referenced paper and book show that the electron model can be quantified and analyzed. For example, since the electron's wave amplitude, frequency, impedance, and size is characterized, the model can be analyzed and shown to possess the correct energy and energy density. This model is also shown to reduce its size in collision experiments and appear to be a point particle. Most important, the electron model creates standing waves in the surrounding spacetime which can be analyzed. These standing waves have been computer modeled and shown to create the electron's de Broglie waves when the electron is viewed in a moving frame of reference. Also the standing waves create a non-oscillating disturbance in the surrounding spacetime with the characteristics of the electron's electric field. There is also a much weaker nonlinear effect which scales with wave amplitude squared. This nonlinear effect is the electron's gravitational field. The paper and book show that this produces the correct curvature of spacetime in the surrounding volume. The force between two electrons created by this nonlinear effect exactly corresponds to the electron's gravitational force. The non-oscillating effect corresponding to the electric field is equivalent to Planck charge rather than elementary charge e. Therefore, a correction equal to the square root of the fine structure constant ($\pm$) must be manually inserted to create the electron's electric field. Planck charge is actually the more fundamental unit of charge since it has a coupling constant equal to 1 while charge e has a coupling constant equal to the fine structure constant $\pm$ H $^1/_{137}$.

This model makes numerous predictions. For example, generating forces from waves gives previously unrecognized insights into the relationship between the forces. About 8 equations have been generated relating the electrostatic and gravitational forces. For example, if we extrapolate the gravitational and electrostatic forces to a separation distance equal to the electron's radius $\lambdabar_c$ H 3.86×10^{-13} m, then the following force relationship would exist between the gravitational force F_g, the electrostatic force F_e and Planck force $F_p = c^4/G$.

$$\frac{F_g}{F_e \alpha^{-1}} = \frac{F_e \alpha^{-1}}{F_p}$$

(1)

Photons are also made from a quantized disturbance of the spacetime field. The technical paper titled: *Energetic Spacetime: The New Aether* is available in another part of this proceedings volume.

Photon trapping and the transition to electrons

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Photon

The photon is a self-generated soliton (https://en.wikipedia.org/wiki/Soliton_%28optics%29#Spatial_solitons). It is a resonance in space-time that forms a periodic light pipe that is equivalent to a graded index optical fiber (Fig. 1). The periodicity is based on the high energy density associated with electric and magnetic field concentrations **E** and **B**. These are the gradients of potentials that are distortions of space which provide an increase in index of refraction (a region of reduced speed of light).
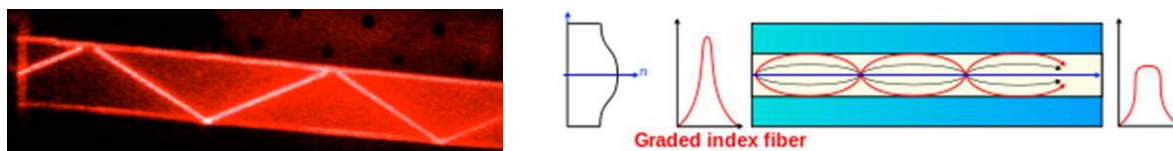

Fig. 1. Laser beams confined by multiple total internal reflections in a rectangular rod and in a GRIN fiber. The latter displays the change in beam profile as it proceeds.

Both internal-magnetic and -electric potentials are required to give the photon its unique properties that are normally models as sinusoidally varying transverse fields. These AC fields are potentials that oscillate in time, not space. To have closed field lines (a necessity of the definition), they can be crudely represented as the result of an alternating-orientation, linear, array of electrets and magnets (Fig. 2).
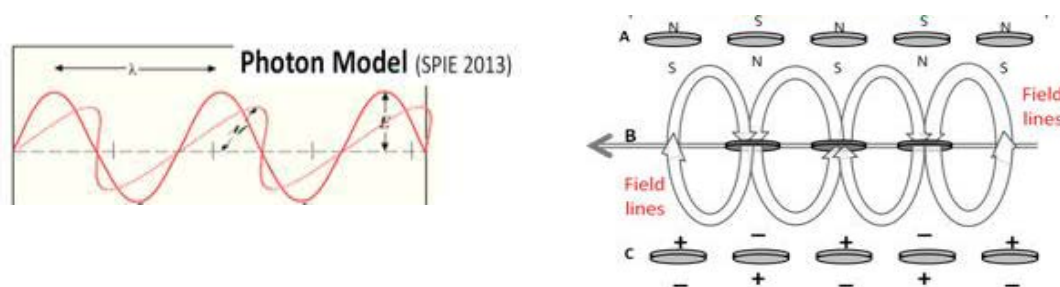

Fig. 2. Standard model of EM field amplitudes in light (a plane wave) and a physical representation of fields and sources (distributed electrets and magnets) in a photon.

Light properties needed to form an electron

Total internal reflection (TIR, https://en.wikipedia.org/wiki/Whispering-gallery_wave#Whispering-gallery_waves_for_light) is the physical means of confining a photon within a medium. In the concentrated field-energy density of light, trapped in a 'whispering-gallery' mode (Fig. 3, https://en.wikipedia.org/wiki/Whispering-gallery_wave#Whispering-gallery_waves_for_light), a spherical region of increased 4-space distortion turns the linear confinement of the photon into a spherical containment 'vessel'. The photon is 'wrapped' along the surface of a self-generated picosphere. Evanescent waves (https://en.wikipedia.org/wiki/Evanescent_wave) of the trapped photon provide the charge of the electron.

Electron charge

Instead of invoking QM 'magic' to explain a physically observable effect, I seek mechanisms based on accepted models of the photon and of charged particles. Strong (non-linear) electric-field gradients, Δ**E,** are required (e.g., those near a nucleus). Using the analogy of rectification of an AC electrical current, I propose that the AC fields of a photon are 'rectified' by the nuclear Coulomb potential into a pair of oscillating field sets that are, on average, DC offset from each other. These are short-lived states ('charged' photons) that reform into the original photon (or possible break up into

unobservable non-photonic EM fields) unless they can coalesce into resonant DC-charge states (an electron/positron pair).
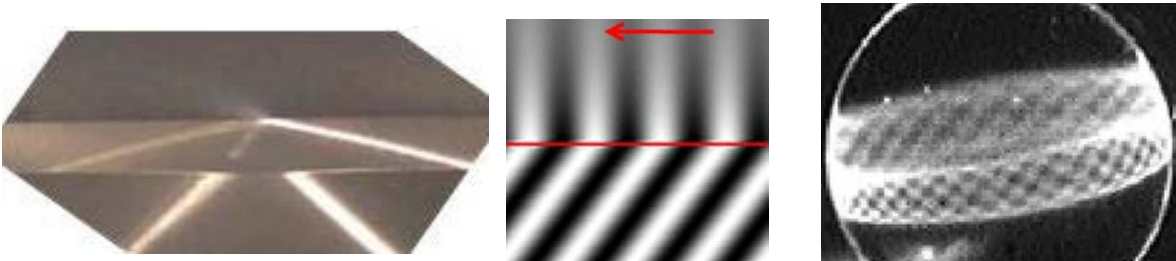

Fig. 3. Total internal reflection from a surface (left) showing the evanescent waves along that surface (center) and bound to the surface of a microsphere (right).

Rectification of photonic charge fields (Fig. 4) both separates the photon net-neutral potentials (charge) and divides its spin (angular momentum of one photon becomes two spin-1/2 particles). Rectified net-negative fields curl toward the nuclear central potential. The net-positive fields are bent away. A moving charge sees a magnetic field about a stationary charge so the charged photons are bent in opposite directions from that effect also. Furthermore, as highly relativistic charged 'structures', they will produce their own magnetic fields (as strong as the electric fields at $v = c$) that will also repel each other, if on near-parallel paths. Individually, the net-charged photons of many cycles length will produce magnetic fields that will be highly self attractive (sufficient to counter their self repulsion?). I propose (not yet supported by the mathematics) that the energy density and 'torsion' of space in this interaction can result in stable vortex pairs that are connected in the manner of Falaco solitons (Fig. 5). However, being vortices of a 3-D surface in 4-space, the connection is in time, not in space. It is a wormhole.
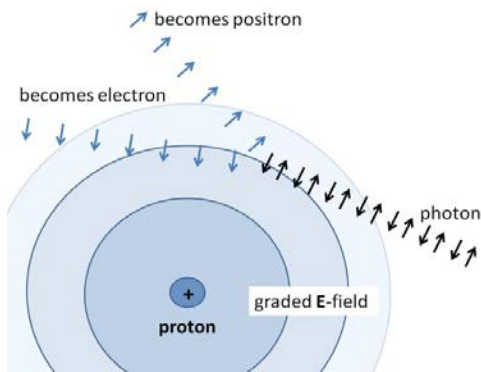

Fig. 4. Rectification of a photon in the potential gradient of a nucleus.

Some members of this discussion group hold that the electron is a photon with a twist or two per wavelength in field orientation of a photon and this gives a net 'charge' that is isotropic. While several variants are proposed (and I have my own), I now question if this is an essential construct.

In summary, starting with the known "an energetic photon with AC fields become two DC charges with the mass of a lepton pair," I propose a model with time-oscillating potentials in a photon that become central potentials of a lepton pair which are permanent distortions of 4-space. These may be vortices (about the time axis) that require resonance conditions in a unique set (quantized?), which involve the interaction of a 'charged' photon with itself.
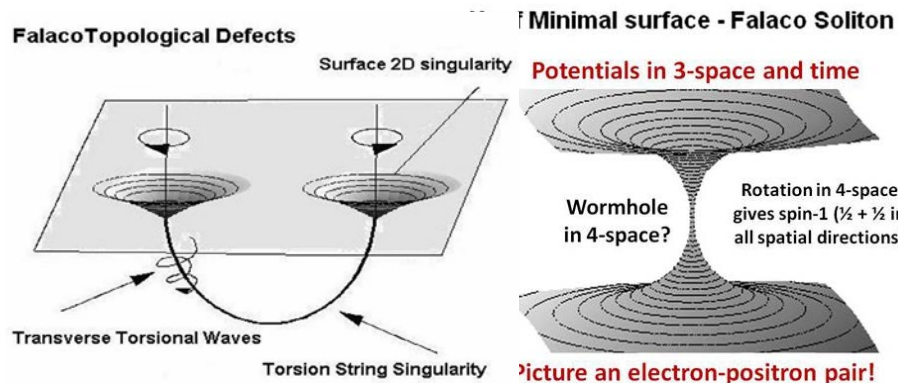
Fig. 5. The Falaco solitons: a 2-dimensional representation of a 4-D structure proposed for the electron-positron pair at the time of formation.

Elementary Quanta - Are You There?

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In 1931, Kurt Gödel published two articles on the incompleteness of mathematical theorems. His premise was that any formal theory will have statements of the language which can neither be proved nor disproved in its own framework. He contends that formal theories are not internally fully consistent nor complete. It is my guess that the publication of Einstein, Podolsky and Rosen (EPR) with title "Can Quantum-Mechanical Description of Physical Reality Be Considered Complete?" (Physical Review, vol. 47, page 777, 1935) was inspired by Gödel's work.

It is important to note that for EPR the issue is not so much whether quantum mechanics is a correct description of nature but they question if it can be considered as means to achieve complete description of physical reality. In this context, it is enough if there is one fundamental assumption which cannot be verified within the scope of physical theories to deem them incomplete. All physical theories assume that the dynamics of physical universe can be modeled on one hand as things that exist, the entities, and on the other the interactions among the entities which drive the processes. The interactions themselves are defined to have their own characteristics. In present-day theories we have strong force, electro-weak force and gravitational force to do this. The entities have their individual identities and interactions mediate the processes. It is well established that experiments or observations yield results which cannot fully disentangle the measurement process from the entities they act on. Thus, from the very beginning, the quest to arrive at the holy grail of ultimate building blocks of matter was doomed to failure.

In simple quantum mechanical language, we can write the operation or interaction as a function of $\langle \Phi_f | O | \Phi_i \rangle$. Here, the Φs are wave functions describing the entities or states and 'O' is the interaction or measurement operator or a combination of both interaction and measurement. An experiment or observation cannot disentangle any further. Perturbative approaches rely on keeping the interaction as weak as possible with the hope to determine the entities. Heisenberg's uncertainty principle suggests an ultimate precision one can attain but 'O' is not zero or perturbation maybe small but finite, rendering the precision non-zero. If we take a quantum field theoretical approach, the wave functions are considered as projection of an operator in the Hilbert space. Thus, a particle is defined only in relation to the space it inhabits.

Soon after the hypothesis of pion as mediator of strong force, a vigorous activity was pursued to measure the interactions at shorter and shorter distances in the hope to determine the interaction mechanisms among nuclei and particles to higher precisions. These efforts were met with grand failure as higher energies resulted in the production of multi- meson final states and particle-antiparticle pair creations. The result of many body final states meant more parametrizations and more ambiguities. In many ways, the 1964 quark hypothesis of particle physicists is an ultimate concession to the nature that the reductionist approach failed. For all practical purposes, quarks are quasi-particles (i.e. mathematical constructs), analogs of fractional charges known to condensed matter physicists working on fractional quantum Hall effect phenomena. The description of physical phenomena by quasi particles and effective interactions was widely known to physicists. Bardeen- Cooper- Schrieffer theory of super conductivity is a well celebrated example.

It is important to recognize that quantum theories allow a great deal of freedom of parametrization to describe physical phenomena as they pertain to scientific and industrial applications. After all, Schrödinger equation is a Hamiltonian, simply the energy content of a system. What we put in as potential energies are fully arbitrary and we expand those terms to fit our physics images or data points. We begin with a few symmetries or equivalently conservation principles that we cherish and see the data in such framework. When we hit the brick wall, we re-parametrize the potential energy terms to fit the data. This is clearly an empiricist method, but that is what we have been resigned to in the last century. For physics applications, this approach proved to be a very fertile ground. Heisenberg is credited to have asserted that we should not insist our theories to provide better precisions or deeper knowledge than what we can measure or observe in our laboratory. In the laboratory, we measure the energies and momenta of electrons, protons, pions, photons etc. and their composite structures as deduced from invariance principles and kinematical relations. Can we go deeper without making unverifiable assumptions?

With regard to the topic of this conference, "the photon" has been a mysterious object for centuries. While Newton, Gassendi and their contemporaries were observing only propagation phenomena such as interference, diffraction and imaging, they were quite adamant about the corpuscular nature of light. Their corpuscules were not indivisible. Today, I am tempted to call them photon-waves. At very low energies below about 1 MeV, photons are electromagnetic waves for propagation. When they interact with other matter by exchanging energies and momenta, particle-like kinematics do the job as long as the intensities are not too high. We describe photo electric effect and the scattering phenomena by employing particle-like kinematics for energy/momentum exchanges and assuming monochromatic waves for intensity distributions. At much higher energies, photons can interact with matter and yield particle-antiparticle pairs or mesons. Now, can we describe a photon to be made up of electron-positron pairs for one to a few MeV and then as of mesons at higher energies? Are the particle-antiparticle pairs inner constituents of photons waiting to be released when the energy and momentum conservations can be satisfied in interactions with external materials? Or, as we say, are photons off mass-shell particle-antiparticle pairs? How far off mass-shell can an entity be and still own its identity? Are the high energy photons simple cousins of their low energy counterparts or are they different entities altogether? It is useful to remember that effective models of hadronization of photons in the fields of material media worked very well, which does not insist that photons are hadrons but that they are materialized due to an interaction.

It is remarked that this approach works for intensities less than about 10^{13} W/cm^2. Present-day lasers achieve much higher power densities and we see non-linear effects, which cannot be described as particle-like behaviors. A nice example is the acceleration of electrons to 4.2 GeV energy by Ti:Sapphire laser photons of 1.5 eV energies with a peak power of 300 Tera Watts (WR Leemans et al, Physical Review Letters, vol. 113, December 2014, p.245002). It requires a collective interaction of about 10^{20} photons with the electron medium to achieve this acceleration. Physical description of this phenomenon does not require a photon at all. A wakefield created by a laser pulse offers an effective description. It is another good example where reductionism serves no purpose.

In conclusion, the basic premise of existence of tangible ultimate structures of elementary quanta must be questioned. Several decades of experimental research has shown that efforts to answer this question led us to effective interactions and quasi particles, which are mathematical constructs devoid of physical reality.

The next level of unification: Waves and particles as emergent oscillations of the same Complex Tension Field (CTF)

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1. Preamble: Over the last few centuries, our knowledge, about the micro universe of elementary particles and that of the macro universe of innumerable galaxies, has advanced enormously. The successes have been dominantly achieved through consistent steps of *"unification"* of explanatory concepts; while consistently applying Measurable Data Modeling Epistemology (MDM-E). It started with *Galileo*'s recognition that we have difficulty differentiating between *uniform linear velocity and zero velocity*; but acceleration is easily discernable. Then, *Newton unified* the *"gravity" forces* under which the apple falls towards the center of the earth and the earth "falls" towards the common center of mass of our solar system. *Faraday unified* the concepts behind the *emergence of magnetic field generated by a coil carrying current and the coil generating a current when a magnet moves through it*. Electromagnetism was born; *which was mathematically formalized by Maxwell* through his set of equations along with the equation for the electromagnetic waves, from Radio to Gamma rays. Then *Planck paved the way for unifying the light-matter interaction processes* through his *equation for Blackbody cavity radiation* that is quantized in energy at birth, but radiates out as non-interacting wave packet. Later, mathematical formalism of Quantum Mechanics evolved over several decades to get deeper understanding of the light-matter interactions in the micro- and the macro-universe. *Starting from the successes of Maxwell, the physics culture steadily fell in love with the "unusual effectiveness" of mathematics*, capped by Planck's success. The flare for mathematical approach to solve natural phenomena took over physics culture; even though Planck in his writings and teachings kept on underscoring the *importance of understanding the interaction processes* that give rise to the data and the ability to identify parameters in a theory that are directly connected with the physical transformation processes that give rise to measurable data. The *next unification attempts were made through the mathematics* that came to be known as "Special Relativity" by a large number of people, Lorentz, Einstein, Minkowski, etc.; which the author believes, has been a major mis-adventure and mis-direction in physics; since these efforts constituted efforts to *eliminate the physical reality of space* as ether in some form or other; while succeeding to raise a secondary parameter (not directly measurable), the running time, as a Homo Sapiens' new reality, the imaginary fourth dimension of the universe. Much later, this success of convincing ourselves of the 4D-reality inspired almost two generations of physicists to devote their lives developing 5 to 13 dimensional String Theories without succeeding in leading us any better to ontological reality of nature than we learnt by 1950's, or probably, earlier. It is historically important to recognize that while Minkowsky's mathematical genius helped us believe nature to be 4D, *Einstein was engaged in another higher level of unification* between acceleration and gravity by invoking the "curvature of space", implicating space, as some form of "ether", possessing real physical properties; which was fairly explicit from the writings of Newton, Huygens, Faraday, Maxwell, to name only a few!

2. Non-Interaction of Waves, a unifying behavior of nature: Here I will articulate and generalize another unifying behavior in nature, Non-Interaction of Waves (NIW); valid for all propagating waves in any medium holding some tension field. We have been rather reluctant to recognize this NIW-property explicitly for several centuries while hiding behind "wave-particle duality" (elevating our ignorance as a new knowledge)! NIW can be appreciated simply by re-training our observing and thinking process to conceptually reverse engineer the ongoing natural processes, albeit being invisible. I have suggested [Ch.12 in ref. 1] that we add in our repertoire the iterative application of Interaction Process Mapping Epistemology (IPM-E), over and above the immensely successful and prevailing MDM-E, mentioned earlier. Propagating waves are generated due to "external" perturbations of a parent quiescent tension filed within its linear restoration capability. If we postulate, validated by general observations, that these parent tension fields are

inherently *incapable* of assimilating the external perturbation energies; then these perturbations must be pushed away indefinitely to restore the local steady-state (quiescence). That is precisely the assumption behind deriving wave equations for material based waves. Unfortunately, Maxwell's wave equation was derived through genius mathematical manipulation of previously observed experimental rules. But it can also be derived exactly as the wave equation for a stretched mechanical string under tension [Ch.4&11 in 1], once we identify ε_0^{-1} as the "electric tension" and μ_0 as the "magnetic restoring tension", then the velocity of light appears as $c^2 = (\varepsilon_0^{-1} / \mu_0)$, as it is in Maxwell's equation. Then, the space must possess these physical properties. So, we are bringing back old ether with a new descriptive phrase, Complex Tension Field (CTF). What do we gain by accepting NIW as another unifying property of nature? Does it clarify existing physics any better? Does it predict anything new of significance? Affirmative answers can be found below!

3. *Validating NIW for light waves:* We can never observe (register) Superposition Effects due to multiple beams crossing through a volume in space without inserting resonant detector arrays within this volume of superposition. The measurable signal, say, released photo electrons, due to multiple waves, as per QM recipe, is the ensemble average of the square modulus of all the simultaneous (joint) amplitude stimulation experienced by the detecting dipole, $\langle D \rangle = \left\langle \left| \sum_n \psi_n \right|^2 \right\rangle = \left\langle \left| \sum_n \chi E_n \right|^2 \right\rangle = \chi^2 \left\langle \left| \sum_n E_n \right|^2 \right\rangle$, where χ is the *linear* polarizability of the detecting dipoles, assumed constant for narrow band of optical frequencies. Our prevailing mathematical rule allows us to take χ out of all the three mathematical steps. We, thus, confuse ourselves by thinking that the filed amplitudes E_n sum themselves (Superposition Principle of amplitude summation); rather than the photo detector summing the simultaneous amplitude stimulations (Superposition Effect as experienced by a detector). We continue to assume wave amplitudes sum themselves in spite of Glauber famously saying "I see a photon when I detect one"! The book [1] describes all the key optical phenomena based on the NIW-property where superposition effect plays key role. It is now easy to appreciate that the quantumness that we observe in the photoelectric effect is due to the quantized binding energy of electrons in material, built into χ of the material experiencing wave induced stimulation χE.

4. *NIW-property guides us to accept space (old ether) as a Complex Tension Field (CTF):* The perpetual velocity of light in the vast cosmic space forces us to accept the space as a physical medium, CTF, as already mentioned. The validity of CTF is systematically corroborated by optical science and engineering; which has been progressing steadily uninterrupted using Huygens-Fresnel "secondary wavelet" based Diffraction integral as the key analytical tool, formulated during 1816. The HF integral is also accommodated by Maxwell's wave equation. Note that the experimental validations of most of the predictions of Quantum Mechanics and Astrophysics models are via optical tools (microscope, telescope, spectroscope, etc.) and popagational phenomena (Doppler Effect, Emission and Absorption Spectroscopy, Refraction or bending of light wave fronts due to *velocity variation*; etc.). While we are struggling with particle theories, gravity theories, etc., optical science and technologies are being led by HF integral with steady even keel, weathering all other storms in physics since 1678, when Huygens "wavelet" concept was enunciated.

5. *NIW-property + finite envelope causal signal = new spectrometric formula -> Natural Line width does not represent existence of a band of new optical frequencies.* The detailed derivations can be found in [Ch.5 in 1]; the natural line width is discussed in [2]. The super precision atomic clocks work by eliminating Doppler Effect by putting the light emitting atoms at close to 0^0K, while automatically eliminating the "Natural Linewidth"; because it never existed! We assume that spontaneous signals, after the emissions of quantized packets (pre-photons), emerge as time-finite classical wave packets with a unique carrier frequency given by QM transition and propagate out spreading diffractively as per HF integral. The physics of temporal envelopes of these wave packets are not described by QM. However, we assume that these "classical" temporal envelopes are actually related to the spontaneous emission life times with semi-exponential envelope. Propagation of such time finite signals through a spectrometer give rise to a time-integrated fringe structure close to Lorentzian (Fourier transform of the temporal envelope function). This fringe

broadening is the time integrated instrumental response function. It does not contain any optical frequencies. It is an artifact of the measuring spectrometers.

6. NIW requires CTF; CTF as the cosmic inertial frame of reference. Linearity of Maxwell's wave equation accommodates NIW by allowing co-propagation and cross propagation of different light waves through the same volume; which requires a tension field, proposed here as universal CTF. Then what happens to the negative result of Michelson Morley and related experiments? The CTF is the universal stationary reference frame in which light is always moving with the velocity $c^2 = (\varepsilon_0^{-1} / \mu_0)$. Then, CTF being the light wave sustaining medium, the optical Doppler Effect, as for sound waves in air pressure tension field, consists of separate frequency shifts due to source movement (real frequency shift) and detector movement (apparent frequency shift) [Ch.11 in 1]. Then, the "redshift" of dark (absence-of-signal absorption) line spectra from distant stars and galaxies can acquire frequency "position" shifts through white light only during propagation through vast distances; they are not due to "receding" velocities of the galaxies. Thus, the NIW-property effectively helps us challenge the prevailing foundational postulate, Doppler Shift, behind the "Expanding Universe".

7. Particles as emergent non-linear oscillations of the same CTF, facilitating the future development of a true unified field theory. Einstein's final dream can come true! The most vexing problem behind the ether concept has been due to our assumption that the material universe is built out of "particles" which are separate from the ether. To inspire the next generation to accept the reality of the CTF postulate (modified ether), we are postulating that all particles are closed looped (doughnut- and /or more complex) 3D harmonic undulations of the same CTF triggered by nonlinear perturbations; unlike linear dipolar perturbations giving rise to perpetually propagating EM waves [Ch.11 in 1]. When the closed loop is perfectly in phase, they are stable (like protons and electrons). This is the origin of quantumness in particle energies and their associations with other particles. As in the case for linear EM waves that are propagating excited states of otherwise stationary CTF; "particle" oscillations are also excited states of the CTF; bulk CTF remains stationary. It is the excitation gradients that are oscillating in time and/or moving in the 3D space. 100% energy is still held by the CTF; the postulate of Dark Energy and dark Matter are not needed. Waves and particles are different excited states of CTF. The phases of the harmonically oscillating "particles" are built into Schrodinger's ψ function. They are physically real and are not abstract mathematical probability amplitudes; neither are they "hidden variables". Particles are neither "plane waves', nor are guided by Pilot Waves'. De Broglie wavelength, that becomes infinite at zero velocity, can be eliminated by recognizing that particles acquires kinetic harmonic oscillation as it acquires kinetic motion; and hence projects phase properties when they interact with other particles while exchanging energies. Thus, QM is a more realistic theory, albeit being incomplete, than has been assumed by the Copenhagen Interpretation. Further, the universal CTF is 3D. The necessity of 4D arose to negate the existence of ether; which we have re-presented as CTF. CTF also accommodates further unification of all the four forces as various kinds of secondary and tertiary potential gradients generated around the oscillating "particles" into which they "fall" or get "repelled by". We do not need separate "particles" to create forces. Einstein's experimentally validated relation $m = E / c^2 = E\varepsilon_0\mu_0$ represents inertial properties to movement imposed by stationary CTF. Thus, "mass" is a perceived emergent property, not an immutable primary physical parameter by itself.

We believe that the addition of conceptual reverse engineering thinking to understand nature by imposing IPM-E, over and above the prevailing MDM-E, will help us re-direct physics along a path that is congruent with learning physical evolution processes that guide nature's evolution, bio-spherical and cosmo-spherical. Physics is now matured enough that the stage and the need have arrived to re-visit the foundational hypotheses behind all of our "working" theories. We cannot finalize the foundation of the cosmic edifice since we are still a long way from understanding the complete structure of the edifice. Reverse engineering thinking will keep us grounded to reality and help us refrain from telling nature how she ought to behave! We must keep on iterating our theories.

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Topological Electromagnetism is the Stuff that Matters!

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First of all, experimental results should be guiding, models are only a (very important) intermediate step to help us think. Theory should be made that matches the experiment and describes no less, but also not any more than is observed eventually. Of any theory that is supposed to be fundamental, one must take the full consequences, not just the nice bits!

Special and general relativity as well as their common interpretation are correct (until proven differently).

Light is heavy[2]: the total energy in a confined radiation field is equivalent to (and the reason for) both the inertial and the gravitational mass of an otherwise massless confining box: $m = E/c^2$. Energy is *strictly equivalent* to mass. While matter can be converted to radiation, we find that mass is energy and neither can be created or destructed.

The photon is the transfer of a single quantized amount of energy and/or angular momentum between an electromagnetic emitter and absorber. No more, no less. It is not a particle, nor a wave. It is merely the process of energy flow between a transmitter and a receiver intermediated by the electromagnetic field. The field is not quantized by itself, but the transfer of energy is quantized by the nature of the emitter and absorber. Why this is true for all emitters and absorbers, from radio antennas to gamma ray sources remains to be explained in detail, but should result from the notion that all matter is, in fact, built of "light".

The electron is a particle that shows no structure in scattering experiments. It is therefore a very fundamental *single* object. It may be constructed of a circulating wave of electromagnetic energy in a non-trivial topology[1]. Indeed, all other elementary particles may be constructed of a knotted flow of some (extended) form of electromagnetic energy[3,4].

The charge of the elementary particles, given the previous, should then be emergent from the interplay of topology and non-linearity on the one hand and the confined electromagnetic wave on the other hand. Only a proper theory may explain how this can, or cannot be. It is of the highest priority to find a theory[4] that can explain this, and deal with the associated binding forces, the topology as well as quantum behavior.

Given the previous statement, electromagnetism and relativistic quantum mechanics must come from the same starting point[4].

Vacuum fluctuations occur only near material objects. This is certainly what the Casimir forces (the retarded Van der Waals forces) already suggest. The vacuum is not completely filled with fluctuations down to the Planck scale, but only with near-field fluctuations near to a "probe", perhaps induced also by the rest of the universe (a Machian view). The energy of the fluctuations cannot exceed the energies intrinsic to the probe. The total energy of all fluctuations in the universe is rather low, not exceeding the total mass or energy $E = mc^2$ of material particles.

Granularity of material "stuff" is absent below the length scales of elementary particles[3]. This appears to be the consequence of the internal energy balance of matter. The internal energy balance implies that quarks and gluons cannot exist as such, by themselves (an experimental fact). The symmetries that come with the quark model, explaining the hadron spectrum, are however perfect and any future theory should keep those!

It is not always appreciated that the De Broglie wavelength for quantum particles is a direct consequence of the reciprocal relativistic transformation of mass $m = E/c^2$ and frequency $f = E/h$ while representing the same energy. Note that while the particle velocity is always below light speed, the De Broglie wave is simultaneously associated with a phase velocity $v_{phase} = c^2/v$ that is always higher than light speed.

Although perhaps counter intuitive to most, non-locality is *also* a consequence of special relativity. Non-locality (faster than light phenomena) occur in quantum mechanics as a consequence of entanglement (EPR experiments) or "wave function collapse", and also (seemingly) in the Coulomb field for electromagnetism. It can be explained in terms of the coherence between particles as well as the detector and their faster-than-light phase velocity: $v_{phase} = c^2/v$. It is the phase of the wave function that is the common factor in a coherent state! A "polarized" particle of spin ½ has two *independent*

components that are correlated over the entire wave function, so communicating, by phase difference, the spin state at super-luminal phase velocity.

For the "photon", the previous statement is just as true, but the phase and group velocity are equal to the speed of light. Here, an extra insight, obtained from Tetrode, Einstein and Wheeler and Feynman can be applied: The interval of time and space are both zero as seen from an observer traveling at the speed of light watching the emission and absorption of a co-moving light ray or "photon". In this frame, the emission can be interpreted as the *causal transfer* of energy to the absorber, by invitation of the absorber. The emitter, electromagnetic wave and absorber are part of the same, indivisible single event.

A more detailed explanation of my position can be found in the papers listed in the references.

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An unprecedented engineering opportunity: a dynamical linear theory of energy as light and matter

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Firstly: nature (as measured in experiment) is primary. Theories are merely speculations one makes up to try to describe her underlying processes. Mathematics is a powerful, but formal and strictly limited language, which may be used to try to describe certain aspects of whatever nature does in reality. Mere mathematics, however, must not be allowed to cloud any of the fundamental features of nature observed in experiment. Any (practically useful) mathematics should follow nature, not the other way round. If one cannot measure it, it is, (for all practical purposes) not there. Any theories predicting things which are (observed to be) just not there should be modified or discarded. This is the proper process of the scientific method. It may be that the logical conclusion of this process, the solution of Hilbert's sixth problem such that a complete mathematical system describing all of nature just and no more is found, is not possible at all. Though that remains to be seen, it is worth striving for.

Having said this, the body of theory as it stands in the early twenty-first century, is a marvelous intellectual achievement garnered through generations of the thinking of many excellent folk. Human theory encapsulates a great deal of truth about the nature of reality. Any new theories should either encompass, improve on, or underpin that thinking - or they are likely to fail. The creation of new theories may be a deeply creative process - but it is also strongly constrained.

My current favored position is that there are only the three dimensions of space, time and a square-root-energy density. These five degrees of freedom, for me, are sufficient to encompass most, if not all, of that which has been so far observed in human experiment. In particular they are sufficient to derive models of the photon, electron and other particles. It proves possible to derive why, how and to what extent light is quantised, what the underlying nature of the elementary charge and the quantum spin is and what the underlying nature of some of the fundamental forces of nature are. They are also, in my view, sufficient to either encompass, underpin or improve the existing practical theories of current physics. The development of a new, continuous linear theory to describe this has been the subject of the papers presented last year at FFP14 and submitted this year to this conference. If this approach should prove of any merit, it will remain the work of many man-years to develop the solutions to the level of those of Maxwell, Dirac or Schrödinger theories. Even if the new theory is worth anything, there remains much work to be done.

The new theoretical view holds that space and time are primary. They exist everywhere (and for all time!), whether or not any energy is present within them or not. The underlying four dimensions of space and time may also manifest in products and quotients of the base four "directions". This allows root-energy to manifest not only in vectors, but also such things as physical areas - as the product of space with perpendicular space. Multiplying any space (or time) with a parallel space gives a conceptually different kind of object to an area. The sequence area-line-point would identify this with a "point". This object, however, is not a point in the way the word is usually understood. Just as a line may be extended to one of any length (magnitude), this kind of point may also have any magnitude. If one attributes the experimentally measured (relativistic) properties of space and time to lines in space and time, then the lines must vary as a four-vector, the plane product as a field, and the point product as a Lorentz invariant. Introducing root-energy into these forms then gives stuff with the physical properties of a 4-current density, an electromagnetic field and a rest-mass, respectively. Further, the volume forms act as a root angular momentum - a spin. It is simple to show that the equations

describing this for the field are identical to the four, coupled differential equations known as the Maxwell equations. A new, general, equation over the sixteen terms (1 scalar, 4-vector, 6-field, 4-spin, 1 pseudo-scalar) encompassing the free-space Maxwell equations is then:

$$\mathcal{D}_4\mathcal{G}_{16} = \alpha_0(\vec{\nabla}.\vec{E} + \partial_0 P) + \alpha_{123}(\vec{\nabla}.\vec{B} + \partial_0 Q) + \alpha_i(\vec{\nabla} \times \vec{B} - \partial_0\vec{E} - \vec{\nabla}.P)$$
$$- \alpha_{0ij}(\vec{\nabla} \times \vec{E} + \partial_0\vec{B} + \vec{\nabla}.Q) + \alpha_P(\vec{\nabla}.\vec{A} + \partial_0\vec{A}) + \alpha_{0123}(\vec{\nabla}.\vec{T} + \partial_0 T_0)$$
$$+ \alpha_{i0}(\vec{\nabla} \times \vec{T} + \partial_0\vec{A} + \vec{\nabla}A_0) + \alpha_{jk}(-\vec{\nabla} \times \vec{A} + \partial_0\vec{T} + \vec{\nabla}T_0) = 0$$

Here the basis vectors, denoted by the α's have one numerical index for the vectors, two for the planes, three for the volumes and four for the 4-volume. $\mathcal{D}_4$ is a 4-vector differential. $\vec{E}$ and $\vec{B}$ denote the electric and magnetic fields and $\vec{A}$ and $\vec{T}$ the vector and tri-vector potential respectively. P and Q are rest-mass like components invariant under a Lorentz transformation. The special root-energy density scalar is denoted α_P. For the field only part, the first four equations without the P and Q terms, this reduces to Maxwell's equations. The new approach, however, allows new kinds of holomorphic, covariant solutions to the pure field (light-speed) Maxwell equations describing a covariant wave. Viz, for a single photon travelling in the "z" direction[1]:

$$F_L = H_0\, U_F R \mathcal{E}(\alpha_{10} + \alpha_{31})e^{\frac{\mathcal{E}}{\hbar}R\,(\alpha_3\frac{z}{c} - \alpha_0 t)\alpha_{012}} = F_0\, R(\alpha_{10} + \alpha_{31})e^{R(k\alpha_3 z - \omega\alpha_0 t)\alpha_{012}}$$

Except for U_F, which is a new universal constant converting to field units and related to $\hbar$ the pre-factor terms are normalisation terms in phase (H_0) and energy $(R$ and $\mathcal{E})$. The crucial features of this new wave function are that the photon energy $(\mathcal{E})$, appears in both pre-factor and exponent, that the argument of the exponential is not a simple number but contains explicitly the proper nature of space and time in the form of α_3 a proper spatial unit vector in the direction of z, α_0, a proper unit vector in the direction of time and that a proper unit angular momentum (α_{012}) is required for this to be a travelling wave solution. Lorentz transformations are described in the wave-function by the single parameter R - scaling both field and frequency (and hence integral energy) linearly. This allows the same photon to be described in different frames - particularly those of the emitter and absorber. The function describes photons of any energy from gamma to radio and beyond - right to the limit of as close as you like to zero energy.

Extending the theory to include some of the new terms, especially the square-root invariant rest-mass term P, allows qualitatively new kinds of solutions[2]. These contain, as well as the rest-mass component, re-circulating field components. Such solutions are necessarily charged, have half-integral spin and have the proper 720 degree symmetry of fermions. These solutions are identified with the electron and positron. The new theory then describes both light-speed field only solutions corresponding to the photon and re-circulating solutions corresponding to the electron within the same framework. It allows, for the first time, the description of the whole process of particle-antiparticle pair creation or annihilation within a single linear theory.

Within the theory, the elementary charge q may be estimated in terms of the elementary spin, $\hbar$, (or vice-versa) and is found to be close to the value observed in experiment[3]. The new solutions describe both light and material particles and arise from the constraints imposed by the deeper principles of the nature of space and time and the linearity of field and energy. Quantisation arises from the rigorous development of relativity.

In the new theory space and time - the defining components of the physical vacuum, are primary and are always present. Space and time condition any root-energy into different forms, manifesting as mass (scalar), charge and current (vector), fields (areas), spin (volumes) and a spin root (a 4-dimensional volume). The theory allows, however, for the possibility that the root-energy at certain places may go to zero - an empty vacuum. For all practical purposes, of course, "free"

space is always full of the photons that paint our world - even if they are only those of the 3K background radiation. The answer then, for me, to the question posed in the title is "all three". With the "something different", here being the proper underlying nature of space, time and energy - the underlying form of the "vacuum" present at all localities.

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