# A Quantum Theory Conjecture on the Origin of Gravitational and Electric Particle Interaction

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*Abstract*

Gravitation defined in curved space has never been found to be compatible with electromagnetic theory or quantum mechanics. This paper presents a theory of gravitation and electric interaction constructed within the locally conserved concepts of QFT.

It is proposed that a photon moving through probability density amplitude of approaching Feynman photons experiences an alteration in the index of refraction. This alteration of photon dynamics can be shown to be the causation of gravitation, electric charge, the structure of the electron, and the velocity of light.

In the 1950's Feynman developed what is referred to as the path integral, or sum over all histories approach to QFT this asserts that the action path taken by a particle or photon is a composition of an infinite number of action paths, the classical path being the most probable. In essence these paths represent the amplitude probability distribution of the particle as it moves through space, and as such represent a probability of the particle being on those paths.

## Order of Presentation

## Introduction

Paul Davies in his introduction to *Six Easy Pieces* by Richard P. Feynman said:

> ”You could not imagine the sum-over-histories picture being true for a part of nature and untrue for another part. You could not imagine it being true for electrons and untrue for gravity”[2]

If gravitation is a gradient in c as discussed by the author in other papers [3], then there must be a mechanism for inducing a change induced by a locally confined energy. This paper discusses how this is possible.

Feynman proposed that for a photon, or any particle, going from one point to another, there is a probability on arrival that the particle has traveled every possible path [2], and by very accurate measurements of quantum effects there is every reason to believe that this is true. It is not unreasonable to presume that the interaction of these photons with passing photons.

The probability of a photon is asserted to be a density amplitude and devoid of energy, but the interaction of the flow density amplitudes, of oncoming photons exchange creates the effect of particle interaction. By Lorentz consideration, photons having a negative velocity vector dot product do not interact.

Although the Dirac and Schrodinger QM waves associated with a particle are have long been accepted to be a Born probability distribution, the waves associated with a photon have generally been asserted to be electromagnetic. This is not necessary and in fact is counterproductive to understanding quantum dynamics and particle-particle interactions. The ascribing the discrete energy of a photon to be a continuous electromagnetic field is an artifact that leads to violations of special relativity, and in the case of the electron structure leads to unacceptable infinities.

## Postulates

The following are the basic postulates that define the interaction of particles in the universe, and how they interact. The proposed postulates collectively yield known physically results, but are not mathematically rigorous.

The photon is presumed to be a Planck size particle with radius $\lambda_{PL}^2 = G\hbar / c^3 = \mu\lambda$. The wavefunction is defined as the future probability of the location with a cross section equal to the square of the Compton radius $\lambda_C$. The wave, generally thought of as electromagnetic, is asserted to be the flow of the amplitude probability of the Planck particle's future location and is devoid of energy content. On measurement or absorption by the Planck particle in an atom, the future probable location instantly vanishes everywhere, there being no energy content, there is no violation of Special relativity. In Quantum language, this is the collapse of the wavefunction. It is presumed to collapse each time there is a particle-particle interaction.

*Wave Function Considerations*

The change in the structure of QM By the proposed structure of the photon can be shown as it relates to the normalization condition of the wavefunction.

$$\int_0^\infty \psi^* \psi = 1$$

For the photon this presumes that the expectation value of the energy of the photon would be:

$$E = \frac{\langle p \rangle}{c} = \int_0^\infty e^{-ikx+i\omega t}\left(\frac{\hbar}{i}\frac{\partial}{\partial x}\right)e^{ikx-i\omega t}\,d\tau$$

$$\langle E \rangle = \hbar\omega$$

The postulate presented here on the nature of the photon is that the wavefunction is only an amplitude of the of the probability flow.

$$\psi_1 = e^{-ikx+i\omega t}$$

The square of this is still imaginary and does not represent an energy density or energy flow. Our presumption is that the conjugate is an actual opposite going photon carrying a probability amplitude coincident, and such that it is a conjugate of the first.

$$\psi_1 = e^{-ikx+i\omega t} \qquad \psi_1 = e^{+ikx-i\omega t}$$

The presumption of QM has been that the product of the wavefunctions times its own conjugate is the probability density of that wavefunction. The presumption here is that it is only the product of wavefunctions of separate photons that have a probability density. That is a probability density and transfer of momentum or energy only takes place when a second photon is going in the opposite direction with an opposite phase

$$\int_0^\infty \psi_1\psi_2 \, d\tau = 1$$

Under normal conditions this is not unity for two random photons, their phases are not conjugate, and they are not in the same location. The square of a photon's wavefunction is not energy.

The normalization condition can occur when an in phase stream of photons is incident on a higher index of refraction target. The reflection reverses the phase of the first photon, and when they are coincident.

$$\psi_1 = \psi_2{}^*$$

At this point the normalization condition is satisfied and there exists an energy density that the reflecting target can absorb.

This is the condition for defining the location of two photons arriving at a target screen for the double slit, and the coincident probability at the detector, for Bell's inequality.

**1**

*The change in the speed of light, or index of refraction, on passing through the Compton volume of another photon per unit length is proportional to the probability of a collision with the Planck core of that photon in that volume of space.*

$$\frac{\Delta c}{c_0} = \frac{\lambda\!\!\!^{-}{}^2_{PL}}{\lambda\!\!\!^{-}{}^2} \tag{1.1}$$

*This is the same as the probability of hit or miss of the Planck particle in the flow number density equivalent to the photon.*

$$P_{\gamma\gamma} = \frac{\Delta c}{c} = \frac{\lambda\!\!\!^{-}{}^2_{PL}}{\lambda\!\!\!^{-}{}^2_{P}} = \frac{\sigma_{PL}}{\sigma_c} \tag{1.2}$$

$$\sigma_{PL} = \lambda\!\!\!^{-}{}^2_{PL} = \mu\lambda\!\!\!^{-} = \frac{G\hbar}{c^3} \tag{1.3}$$

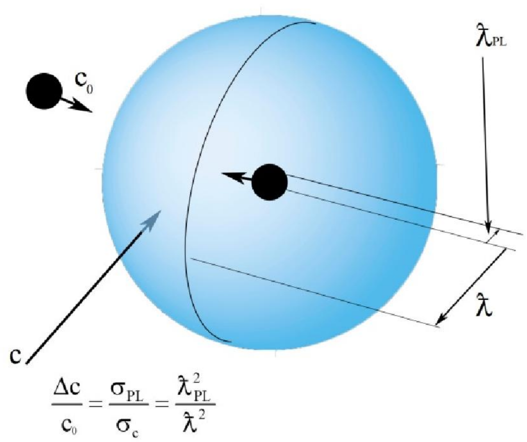


Fig.1 photon delay passing through flow amplitude density of another photon.

2

*The time average probability density ratio of Feynman Photon at a point at a distance r to the probability of being at the center of mass particle is:*

$$P = \frac{2\bar{\lambda}_C}{r} \tag{1.4}$$

(See Appendix I for discussion)

3

*Multiplying Postulate #1 times postulate #2 gives the change in the speed of light as a function of the distance from the particle as the result of the density of Feynman photons at that position.*

$$\frac{\Delta c}{c_0} = \frac{\bar{\lambda}_{PL}^2}{\bar{\lambda}_P^2}\frac{2\bar{\lambda}}{r} \tag{1.5}$$

*This postulate is the fundamental relationship that provides the mechanisms for both Gravitational and Electric interactions and the structure of the electron. For gravitation the expression reduces to the well-known value.*

$$\frac{\Delta c}{c_0} = \frac{2\mu}{r} \tag{1.6}$$

*5*

*A particle may have many internal constituents, but the average probability of location will be the same that defined in* Eq.(1.4)*. All massive hadron particles are considered as the ½ spin quantum number entangled confinement of a number of light speed particles that can be summed into a single rotating action path of two photons with density equivalent to the combined mass energy of the particle.*

6

*The photon is a Planck particle with a probability of location within the Compton radius. The wavefunction associated with the electromagnetic field is the amplitude flow probability of the particle, and is devoid of energy content. There is no continuous energy field associated with the photon.*

7

*Variable Speed of Light: Constants and Dependences*

*In a volume of space with a locally altered velocity of light such as induced by gravitation, the energy and frequency of a photon is considered to be a Lorentz universal constant and equal to* $\hbar\omega$*. The other fundamental relations for particles and photons must be therefore functions of c:*

$$\varepsilon = \hbar\omega = \hbar\frac{c}{\lambda\!\!\!^{-}} = mc^2 = pc \qquad p = \frac{\varepsilon}{c} \qquad m = \frac{\varepsilon}{c^2} \qquad \lambda\!\!\!^{-}_c = \frac{\hbar}{mc} = \frac{\hbar c}{\varepsilon}$$
$$\mu_m = \frac{Gmc^2}{c^4} = \frac{\lambda\!\!\!^{-\,2}_{PL}\omega_m}{c} \qquad \lambda\!\!\!^{-\,2}_{PL} = \mu\lambda \qquad \hbar = mc\lambda\!\!\!^{-}_c \tag{1.7}$$

*The energy & angular momentum are invariants with respect to c, but the rest shown here are dependent. The mass of the photon is a variable of c and defined as* $m = \varepsilon / c^2$ *, is inversely proportional to the square of the velocity of light and the momentum* p *is inversely proportional to c. The particle Compton wavelength is directly proportional to c, and gravitational constant,* $\mu$*, is inversely proportional to c thus the product square of the Planck radius,* $\lambda\!\!\!^{-\,2}_{PL} = \mu\lambda$*, is independent of c.*

*The Compton wavelength* $\lambda\!\!\!^{-}_c$ *is proportional to the value of c, and thus the Compton size of an electron* $\lambda\!\!\!^{-}_e = \hbar c / mc^2 = c / \omega_e$ *is determined by the local speed of light.*

8

*The electron is a composite of two photons bound in circular motion by the gradient in c produced by the first postulate. The circular orbit is the result of the gradient in generated by the probable interaction. The composite angular momentum of the two photons is ½* $\hbar$

*(See Appendix III for summary)*

*The photons in the core of the electron are radially polarized such that their transverse flow probability amplitude is polarized along the radial direction keeping the photon on a most probable circular path. The Feynman photons generated by an electron or positron also have a radial polarization of the transverse flow component.*

**Feynman Photons**

From Feynman's Path Integral formulation or, sum over all histories, of QFT, the action path of a particle from one spacetime point to another is the sum of the action paths over all possibilities, [2]. For a repetitive action path that is from one point to another and back, there is continuously regenerated set of paths resulting in the particle having a time average probability of being at a distance from the most probable path.

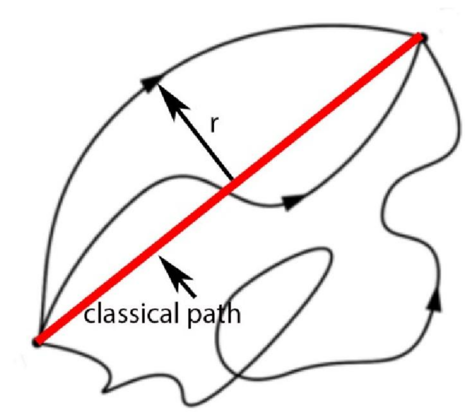


Fig.2 As a photon moves from one point to another there is the probability of being at a distance r from the classical path.

Since the developed of the path integral approach, it has been apparent that particles traveling on action paths have some probability of existence exterior to the classical path [4], [5], [6], [7], [8], [9] . When photons are confined such as between two reflectors or are in an orbit of mutually generated gradient in the index of refraction such as in an electron, [10],[11]. Feynman's argument requires there are multiple action paths repeating at the frequency of the cycling of the action paths throughout the surrounding space, and inducing the probability of existence of "Feynman" photons in the space surrounding the "classical" paths.

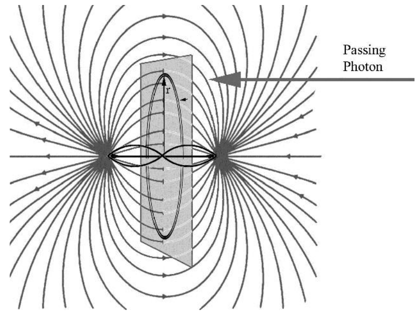


Fig.3 Some of the possible Feynman paths for a photon oscilating between two points.

For an entangled pair of photons, such as exist in a particle, the exchange of momentum by external Feynman photons alters the velocity of the center of momentum, and thus exchanges both energy and momentum for the entangled pair. The probability density of the Feynman photons does have physical consequences.

The knowledge of the probabilities of discrete photons existing off the classical paths has existed more than half a century yet the exploitation of the interaction of particles has defaulted to a continuous field theory, (QFT) [11],[11a]. The continuous field is replete with infinities and is not exactly equivalent to the discrete "path integral", or "sum over all histories" approach.

As developed from work of others in and discussed in [12][13}, and in Appendix I, the time average ratio of the probability density of a Feynman photon being at the distance r from the particle, to the probability of within the Compton radius of the classical path is postulated to be:

$$P = \frac{2\lambda\!\!\!^{-}_C}{r} \tag{1.8}$$

This is the time average relative probability density of the particle being at a point in space to the center of the action path, or the particle probable density at that point.

In the authors paper "Photon-Photon Vacuum Polarization Composite Electron Model" a model was presented showing the electron as two photons bound by an index of refraction generated by the nonlinear vacuum polarization [13]. (Summary in Appendix III)

As the photons revolve the Feynman action paths exist throughout space and repeat at each cycle of the photon circuit around the center of momentum. There is then generated a time average probability density of the photon existing at a point in space as stated in Eq.(1.8), and shown in fig. 4.

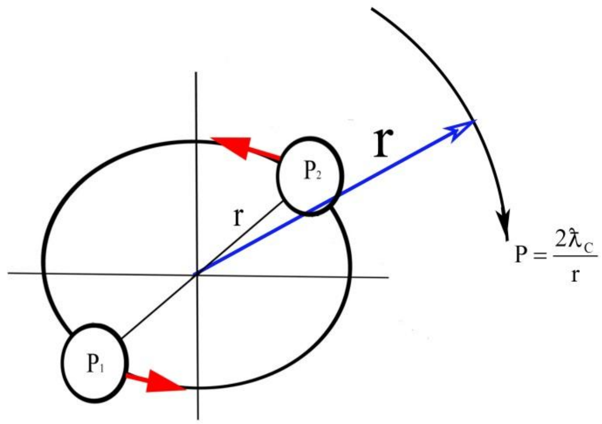


Fig. 4 Shows the time average probability density for a Feynman photon on an action path

From Eq.(1.5), and Eq.(1.6), the presumption is made that this probability density is a general property of matter and applies to all mass particles.

Photons orbiting inside mass particles are not necessarily axially aligned with other particles and do not have a common rotation axis thus this expression is the time average density of all random directed photons and constitutes the probability density of photons generated by a mass.

Although a composite particle can consists of a number of discrete internal constituents, the time average probability of the particle being at a point is the same as that from the action path of two orbiting particles with the sum of the mass. From a single particle or a collection of particles the direction of these photons in space would entirely random.

$$ƛ_c = \frac{\hbar}{m_1c + m_2c + m_3c +} \qquad (1.9)$$

## Gravitation and the Speed of Light

*Vacuum Induced Index of Refraction*

A number of researchers using the Schwinger electric density limit have investigated the index of refraction as it relates to pair production and, birefringence primarily at the lower limits of the energy density. It is certain that the velocity of light in the universe is related to vacuum polarization and thus it is important to understand the relation between mass and the velocity of light.

The vacuum polarization effect between two interaction photons is a well-researched process both from theoretical and experimental aspects. The first development by Sauter, Serber, Euler and others, [15][16][17], and later by more sophisticated methods of QFT by Schwinger and others[18][19].
The study of the vacuum polarization on the index of refraction is quite extensive in the lower levels of E when birefringence on photons in static fields effects are predominant, [20][21][22][23][24][25][26][27][28].

Urban [29] has proposed an index of refraction of space based on the vacuum polarization creating and annihilating electron pairs Within the uncertainty limit, In another publication Urban, [30], proposed an index of refraction depending on the time delay of a photon passing through the volume of intersecting particles Others have proposed field time delay operators that assert a delay photon delays [31][32][33][34]. This paper will propose that density of Feynman photons from the internal paths of massive particles sets the velocity of light and is the result of the probability of intersecting Feynman photons from the mass particles that inhabit the universe.

It is well known that a photon moving in a gravitational field has a trajectory that can be defined by Fermat's principle in Minkowski flat space with a variable speed of light with no other gravitational influence. The relation for the index of refraction developed from GR by Blandford, & Thorne, and others, with a flat metric is: [4], [35]

$$\eta^{-1} = \frac{c}{c_0} = \left(1 - \frac{2\mu}{r}\right) \rightarrow \quad \frac{\Delta c}{c_0} = \frac{2\mu}{r} \tag{1.10}$$

(this paper will refer to $\Delta c / c_0$ as an in Eq.(1.10), as an index of refraction.)

In previous papers [2], the author has illustrated that for photons, and confined light speed particles; a gradient in c produces the exact effect of gravitation on a massive particle with the same energy content. The illustration of a gradient in c generated by QFT equivalent to gravitation therefore creates a mechanism for gravitation within a Lorenz, local conservation of energy four-space.

The value $\Delta c$ is the difference between the value of c a fixed point in space and the value induced by an intervening mechanism, generally induced by Feynman photons.

*Logical Points*

1: A photon trapped between two reflectors whether mirrors or in a black box cavity, represents rest mass. From the outside the photon is part of the total energy and cannot be ignored as part of the proper mass.

2: If a trapped photon is mass then a photon oscillating between two points must generate gravitation the same as a mass particle of the same energy.

Gravitation

Multiplying the change in c as a result of being in the probable location of a photon times the probability of a Feynman photon being at that point distant form its center, gives the change in c. (Postulate #3).

$$\Delta c = c_0 \frac{\lambda_{PL}^2}{\lambda_C^2} \frac{2\lambda_C}{r} \tag{1.11}$$

This simplifies to the change in c induced by gravitation

$$\frac{\Delta c}{2c} = \frac{\mu}{r} \tag{1.12}$$

Comparing the results of Eq.(1.12), with the well-established velocity of light induced by gravitation in flat Minkowski space Eq.(1.10), The proposed probability of the Feynman photons, and the proposed change in the index of refraction induced by interaction with those photons establishes physical agreement with the gravitationally induced change in c.

**The Ambient Speed of Light and Vacuum Density of the Universe**

As can be seen from Postulate #1, the velocity of light is slowed by the probable presence of Feynman Photons. Every particle in the universe generates Feynman photons and the protons-neutrons mass are the largest constituents, and thus have by far the greatest effect of the ambient speed of light. Estimates of the mass and number of protons in the universe have been made, and can be used to approximation of the number density of Feynman photons. The speed of light in an empty universe would infinite, thus, the sum of the change and the current value is due to the probability density of Feynman photons, and the change predicted in postulate #1

From an estimate of the mass in the universe by D. Valev [39], which is the same as setting the radius of the visible universe as the Schwarzschild radius, the relation between the mass and the radius in a flat universe is:

$$R = \frac{2Gm}{c^2} \quad \rightarrow \quad \frac{Gm}{c^2 \left(R/2\right)} = 1 \tag{1.13}$$

Most of the mass in the universe consists of proton mass particles then the sum of the number of those particles is:

$$n_P = \frac{R}{2\mu_P} \quad = \quad 5.2176112E+79 \quad \text{Proton equivalent masses} \tag{1.14}$$

This mass estimate in Eq.(1.13), can be written in the form of a sum of the particles in the postulates, Eq.(1.5), relating the velocity of light to the sum of the Feynman photons.

$$\frac{Gm}{c_0^2}\frac{\lambda}{\lambda^2}\frac{2\lambda}{R} \quad = \quad \sum_n \frac{\lambda_{PL}^2}{\lambda_p^2}\frac{\left(2\lambda_P\right)_n}{r_n} \quad = \quad 1 \quad , \tag{1.15}$$

or:

$$c_0 \sum_n \frac{\lambda_{PL}^2}{\lambda_p^2}\frac{\left(2\lambda_P\right)_n}{r_n} \quad = \quad c_0 \tag{1.16}$$

This is a sum over all the particles in the universe and a single mass particle or group of particles can be separated such that:

$$c_0\left(\frac{\mu_1}{\lambda_1}\frac{(2\lambda_P)_1}{r_n}\right)+c_0\sum_n\frac{\mu mc}{\hbar}\frac{(2\lambda_P)_n}{r_n}=c_0 \tag{1.17}$$

The second term is the speed of light in the universe; less the contribution of the first term, thus this term becomes c

$$c= c_0\sum_n\frac{\lambda_{PL}^2}{\lambda_p^2}\frac{(2\lambda_P)_n}{r_n} \tag{1.18}$$

The value of c is the value of $c_0$ without the contribution from the particle or group of particles separated thus Eq.(1.17), becomes:

$$c_0-c==c_0\left(\frac{\mu}{\lambda}\frac{(2\lambda_P)_n}{r_n}\right)\qquad\rightarrow\quad\frac{\Delta c}{c_0}=\left(\frac{\mu}{\lambda}\frac{(2\lambda_P)_n}{r_n}\right) \tag{1.19}$$

Thus postulate #3, which is the change in the local index of refraction as a result of the Feynman photons, is the same as its change in the ambient index of refraction in the universe.

## Feynman Photon Density in the Universe

The sum in Eq.(1.16), of the probability density ratio is just the density of Feynman photons in the universe, and can be found noting that the most of the contributions to the sum is due to the protons and thus can be factored out of Eq.(1.15). The ratio of the proton gravitational radius and the Compton radius is then gives the value of the sum, which is the number density of Feynman photons inhabiting the universe.

$$\frac{\lambda_P}{\mu_P}=\sum_n\frac{(2\lambda_P)_n}{r_n}=n_F \tag{1.20}$$

The sum is the total time average probability density of Feynman photons $n_F$ at any given point in the universe, and the value is just the ratio of the Compton wavelength to the gravitational radius of the proton or, $\lambda\!\!\!^{-}_P / \mu_P$

$$n_F = \frac{\lambda\!\!\!^{-}_P}{\mu_P} = 1.69321E+38 \quad \text{Photons per cm}^3 \tag{1.21}$$

The ratio in Eq.(1.20), would be exact if the free particle protons-neutron mass constituted all the mass, but there are chemical, nuclear, and gravitational mass defects for particles in the universe that induce some difference.

Eq.(1.20), is the total probability number density of Feynman photons in the universe, but only half are responsible for any photon-photon interaction. The one-half reduction is the result of the Lorentz transform that prohibits the interaction of photons in the same direction [40], thus generally the interacting photons experience a flux density of just $n_F / 2$.

$$\frac{n_F}{2} = 8.4660E+37 \tag{1.22}$$

The Feynman photon density Eq.(1.22), is thus the oncoming flux that a moving photon experiences inducing the index of refraction. (See endnote on the de Broglie-Bohm Pilot Wave Connection)

The Feynman photons thus set the index of refraction for the universe:

$$\frac{\Delta c}{c_0} = \frac{\bar{\mu}}{\bar{\lambda\!\!\!^{-}}} n_F = \frac{2\bar{\mu}}{\bar{\lambda\!\!\!^{-}}}\left(\frac{n_F}{2}\right) \tag{1.23}$$

The bars indicate the average mass and wavelength of the individual mass particles in the universe. This density in Eq.(1.22), compares nearly exactly with the number density of photons in an electron in its classical volume which is:

$$\frac{2}{(\alpha \lambda\!\!\!^{-}_e)^3} = 8.9374E+37 \tag{1.24}$$

Combining Eq.(1.21), and Eq.(1.24), the mass of the electron can then be approximated from the ratio of the gravitation radius and the Compton radius of the proton.

$$\lambda\!\!\!^{-}_e = \frac{1}{\alpha}\left(\frac{4\mu_P}{\lambda\!\!\!^{-}_P}\right)^{1/3} = 3.93216\text{E}-11 \text{ cm} \qquad (1.25)$$

The Feynman photon density $n_F$ of the universe provides the index of refractions responsible for the effects attributed to the vacuum polarization defined by the Schwinger limit of electromagnetic energy density [41], and discussed in the section on electric scaling.

## The Photon

The following is a proposed model that gives a physical interpretation of the result of the equations that induce the electrical particle-particle interaction. The graphical representation may not be the only possibility.

In earlier papers [13], there has been proposed a model of the electron consisting of Photons locked by vacuum polarization generated changes in the index of refraction. The purpose here is to present a plausible model of a photon that fits the known properties and allows calculations of physical values.

Presented here is the photon being a Planck size particle rotating at the Compton frequency inside the Compton volume. The Planck particle contains the spin of the photon. The Planck core has an inherent angular momentum of $\hbar$ that has a defined axis and is present even when the particle is not rotating. The rotation of the Planck particle defines the direction of a probability amplitude flow of where the Planck particle may be, but gives no contribution to the fixed $\hbar$ angular momentum.

The wave of the photon is regarded as the probability amplitude of its future location having no energy or energy density. When the particle transfers energy to another particle by Planck particle-particle interaction, the past probability amplitude of where it could be, vanishes everywhere instantly, and the future probability of where it may be is instantly created. The wavefunction, which is a probability of where it could be, collapses instantaneously on any interaction without a violation of special relativity.

Previously energy assigned to the photon has been thought of as an electromagnetic energy envelope, but as in the case of particle solution of the Schrodinger and Dirac Equation it has been demonstrated that the probability localization of the electron defined by the Photon Wave Equation is proportional to the electromagnetic energy density [37], [38]. The identification and replacement of the energy density of the electromagnetic field with the Planck particle probability flow amplitude is thus a scaling issue.

*Model*

As the Planck core rotates around its spin axis, there is radiated away in opposite directions probability flow amplitude of the future location of where the particle could be. This probability flow moves with c, and terminates at the Compton radius.

Figures 1, and illustrates the revolving of the photon around the spin axis and the probability flow amplitude emanating from core.

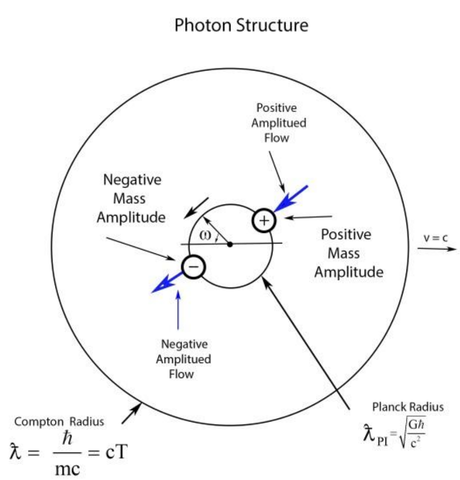


Fig. 1

The flow amplitudes continuously radiate from the core at the velocity of light making the amplitude flow probability an Archimedes spiral. The maximum distance of this flow is the Compton radius since at that distance the source rotates back to its initial position and the flow at the Compton radius, which can't radiate must vanish.

The probability amplitude flows from the positive to the negative starting at the Compton radius and vanishing at the Compton radius as it flows out.

The spin vector of the Planck particle can have three orientations: forward, backward, and perpendicular to the path, thus the amplitude flow probability is polarized as; helictical, anti-helictical, and planar. If the rotation is transverse to the motion then the forward motion is a plane polarized wave, with a two state configuration of up and or down.

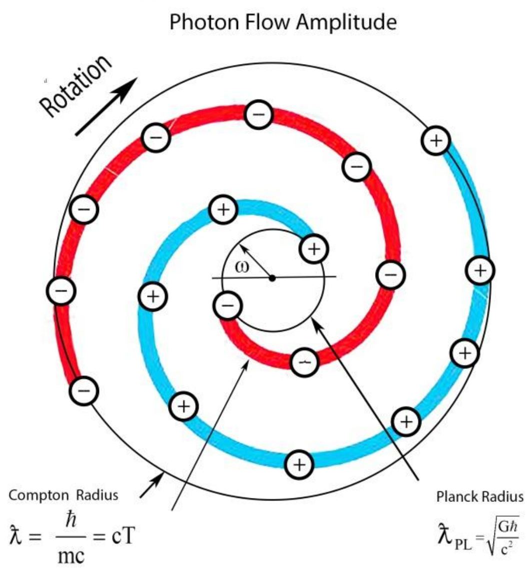


Fig. 2

Figure 2, shows the positive and negative flow amplitude originating at the rotating Planck particle, moving outward and terminating at the Compton radius when the angle returns to the original position. Probability flow from a Planck particle can't radiate beyond the Compton radius. The flow amplitude probability is the location the particle could intersect the probability flow amplitude of another photon and the product of the amplitudes determines the flow density and the direction of the oncoming photon.

*Bound Radially polarized Photons*

If the photons in Fig. 2 are moving around a circle, at the same frequency as the rotation of the photon, then the flow would be in a line constantly along the radial axis.

Inside the electron this product of the flow amplitude induces a flow density between the two orbiting photons and thus a radial index of refraction in the direction of the opposite photon.

On the exterior of the electron the Feynman photons probability flow amplitude are likewise polarized along the radius vector Fig. 3.

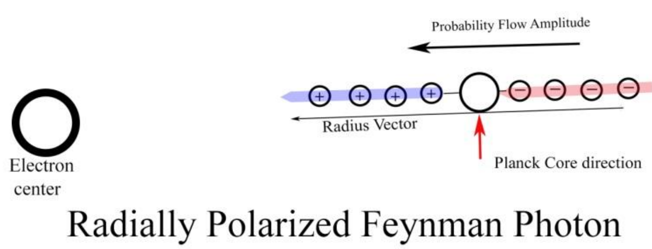


Fig. 3 Illustration of the flow probability amplitudes and direction of the Feynman photons resulting from the rotation of the photon around a center of momentum with the same frequency that it revolves around its core.

The Feynman photons existing exterior to the core action path, maintain the radial polarization, on encountering photons from other particles.

On encountering a polarized photon from another electron or positron, the photon will see the photon flow density either positive or negative along the radial vector, causing the photon to be either attracted or repelled to the other particle.

The illustration of this interaction is shown in Fig. 4

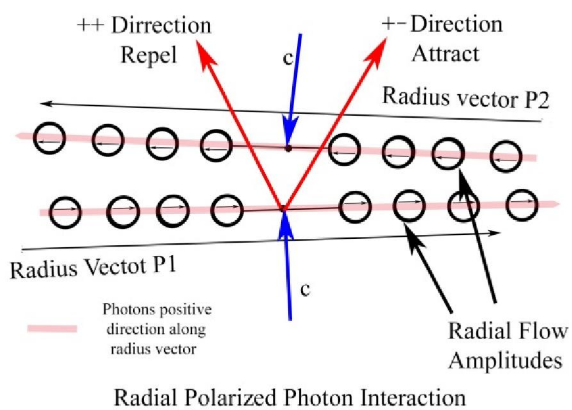


Fig.4. Photon-Photon interaction

When the Feynman photons from opposite particles meet at a point in space the probability flow amplitudes multiply to form a flow density. The relative signs determine the flow density for each oncoming photon.

In the electron the transverse probability amplitudes are opposite thus the flow is negative along the radius vector and the photons are bound together Fig. 5.

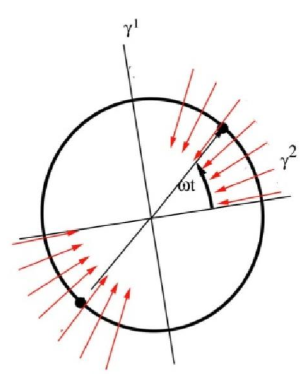


Fig a. Probability flow direction as the photons revolve areound the center of momentum.

As probability amplitude of the exterior Feynman photons encounter similar photons from other charged particles there's a deflection either positively or negatively along its own radius vector. The product of the probability amplitudes which gives the flow density to the oncoming photon is the source of the charge effect of the particles.

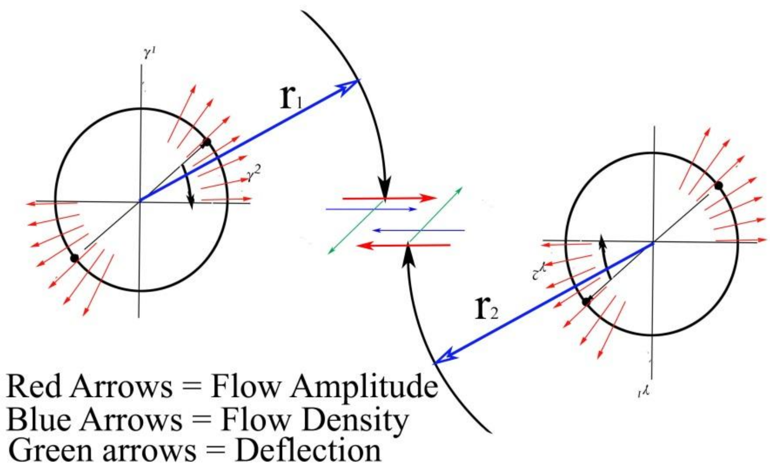


Fig 6. As polarized photons from different electrons arrive at the same point in space, the product of the amplitudes determines the flow density direction. The effect is symmetric for both photons being attracted or repelled along their respective radius vectors

## Charged Particle Interaction and the Value of the Fine Structure Constant

From the third postulate Eq.(1.5), the probability of a Feynman photon from an electron being at a point is:

$$\frac{\Delta c}{c} = \frac{\lambda\!\!\!^{-}{}_{PL}^{2}}{\lambda\!\!\!^{-}{}_{e}^{2}} \frac{2\lambda\!\!\!^{-}{}_{e}}{r} \tag{1.26}$$

The photons both in the electron orbit axially around the spin vector maintaining a ½ angular momentum, thus at any point in space the Feynman radially polarized photon repeats in the same direction and orientation as the action path of the orbit repeats. The repetition of this is then at the Compton frequency which increases the flow density at that point, Eq.(1.26), by $\nu$, the Compton frequency $\nu_e = \omega_e / 2\pi$.

Eq.(1.26), then becomes:

$$\frac{\Delta c}{c} = \frac{\bar{\lambda}_{PL}^2}{\bar{\lambda}_e^2}\frac{2\bar{\lambda}_e}{r}\nu_e \tag{1.27}$$

or:

$$\Delta c = c_0\left(\frac{\mu_e}{\bar{\lambda}_e}\frac{2\bar{\lambda}_e\nu_e}{r_1}\right) \tag{1.28}$$

This $c_0$ is the value of $\Delta c$ at a distance $r_1$ from the origin of the particle.

If there is a second particle at a distance $\Delta r_{21}$ from form the observation point then:

$$c = c_0\left(1 - \frac{\mu_e}{\bar{\lambda}_e}\frac{2\bar{\lambda}_e\nu_e}{\Delta r_2}\right) \tag{1.29}$$

The c of the second particle at the observation point becomes $c_0$ at the observation point thus:

$$c = c_0\left(1 - \frac{\mu_e}{\bar{\lambda}_e}\frac{2\bar{\lambda}_e\nu_e}{\Delta r_2}\right)\left(\frac{\mu_e}{\bar{\lambda}_e}\frac{2\bar{\lambda}_e\nu_e}{r_1}\right) \quad , \tag{1.30}$$

or:

$$\frac{\Delta c}{c_0} = \frac{\Delta c_1}{c_0} - \left(\frac{\mu_e}{\bar{\lambda}_e}\frac{2\bar{\lambda}_e\nu_e}{\Delta r_2}\right)\left(\frac{\mu_e}{\bar{\lambda}_e}\frac{2\bar{\lambda}_e\nu_e}{r_1}\right) \tag{1.31}$$

The first term is the change in $\Delta c$ due to the first particle. The second term is the interaction term between the particles dependent on the distance between the particles. This could be written:

$$\frac{\Delta c}{c_0} = \frac{\Delta c_1}{c_0} - \frac{\Delta c_I}{c_0} \tag{1.32}$$

Where $\Delta c_I / c_0$ is now the change in the index of refraction due to the interaction of the particles thus:

$$\frac{\Delta c_I}{c_0} = \left(\frac{\mu_e}{\bar{\lambda}_e}\frac{2\bar{\lambda}_e\nu_e}{\Delta r_2}\right)\left(\frac{\mu_e}{\bar{\lambda}_e}\frac{2\bar{\lambda}_e\nu_e}{r_1}\right) \tag{1.33}$$

Regrouping, and noting from the previous discussion on the interaction of radial polarized photons the product of this interaction has a $\pm$ sign:

$$\frac{\Delta c_1}{2c_0} = \pm\left(\frac{2\mu_e}{\lambda\!\!\!^{-}_e}\nu_e\right)^2 \frac{\lambda\!\!\!^{-}_e}{r_1}\frac{\lambda\!\!\!^{-}_e}{\Delta r_{12}} \tag{1.34}$$

The quantity in brackets must be and is the Fine Structure Constant squared, ( $\alpha^2$), value of which is discussed and calculated in Appendix II. The merit of this theory hinges considerably on this fact, and since most of the terms in this expression are known to at least 10 significant digits there is very little room for error. The uncertainty in the value of the gravitational constant may be the most significant issue.

Eq.(1.34), can thus be written as:

$$\frac{\Delta c_I}{2c} = \frac{\alpha\lambda\!\!\!^{-}_{e1}}{r_1}\frac{\alpha\lambda\!\!\!^{-}_{e2}}{\Delta r_{12}} \tag{1.35}$$

The value of the index of refraction in this expression is at the position $r_1$ from the first particle thus valuating the index of refraction at the classical radius $r_1 = \alpha\lambda\!\!\!^{-}_e$ of the first particle gives, the value function of the distance to the second particle. This is then the ratio of the potential energy to the total to the total energy of the particle, or the energy ratio ot the potential to the total energy of the electron.

$$\frac{\Delta c_I}{2c} = \frac{1}{m_e c^2}\frac{Q^2}{\Delta r_{12}} \tag{1.36}$$

I appears that $r_1 = \alpha\lambda\!\!\!^{-}_e$ is the time average orbital radius of the two orbiting photons, and the time average density of the two particles is expressed in Eq.(1.24).

## The interaction of two mass particles by gravitation

The gravitational interaction of two masses can be found using the same procedure for gravitation as charge, and Eq.(1.12).

The combined effect of the two particles at a point at a distance r from the fist point and that point being $\Delta r_{12}$ from that point is:

$$\frac{\Delta c}{c_0}=\frac{\Delta c_1}{c_0}\frac{\Delta c_2}{c_0}, \qquad (1.37)$$

The total index of refraction at r is then:

$$\frac{\Delta c_T}{c_0}=\frac{2\mu_1}{r_1}\frac{2\mu_2}{\Delta r_{21}} \qquad (1.38)$$

Since the value of the index of refraction is valid at any point it is convenient to pick a point a constant relative point independent of the relative motion

For the same reason as for the electric evaluation the evaluation point is set at the sum of the Schwarzschild radius.

$$|\vec{r}|=(2\mu_1+2\mu_2) \qquad (1.39)$$

then

$$\frac{\Delta c}{c_0}=\frac{2\mu_1}{2(\mu_1+\mu_2)}\frac{2\mu_2}{\Delta r_{12}} \qquad (1.40)$$

Writing this out explicitly gives the index of refraction in terms of the particle separation thus:

$$\frac{\Delta c}{2c_0}=\frac{1}{(m_1+m_2)c^2}\frac{Gm_1m_2}{\Delta r_{12}} \qquad (1.41)$$

This is the proper value of the ratio of the potential energy to total energy of two gravitating particles or the energy extractable by a change in relative position.

## Energy and the Index of Refraction

The first point is to note that the gravitation and electric potentials for an electron in Eq.(1.12), and Eq.(1.27), are identical accept for the factor of the Compton frequency $\nu$

$$\text{Gravity}\quad \frac{\Delta c_e}{c} = \frac{\mu_e}{\lambda\!\!\!^{-}_e}\frac{2\lambda\!\!\!^{-}_e}{r_1} \tag{1.42}$$

$$\text{Electric}\quad \frac{\Delta c_e}{c} = \frac{\mu_e}{\lambda\!\!\!^{-}_e}\frac{2\lambda\!\!\!^{-}_e}{r_1}\nu_e \tag{1.43}$$

The difference is in the fact that $\Delta c$ for gravitation is the result of the probability amplitude of a direct hit of a Planck particle, whereas the electric change is the selective change in c along the radius

interaction is the probability amplitude of a Feynman photon having a direct hit with the tangential flow which is repetitive at a point in space at the Compton frequency.

For each of the potential relations, half the change in the index of refraction relative to the ambient value is equal to the ratio of the extractable or potential energy, to the total energy. The value of this can be understood in terms of the relation between potential and kinetic energy.

$$\frac{\Delta c}{2c_0} = \frac{1}{mc^2}\frac{Q^2}{\Delta r_{12}} \qquad \frac{\Delta c}{2c_0} = \frac{1}{(m_1+m_2)c^2}\frac{Gm_1m_2}{\Delta r_{12}} \qquad \frac{\Delta c}{2c_0} = \frac{\mu}{r} = \frac{Gmm}{mc^2 r} \tag{1.44}$$

The left side of these expressions is the ratio of the extractable potential energy for two particles to the total energy of the mass.

$$\frac{\Delta c}{2c_0} = \frac{\varepsilon_P}{\varepsilon} \tag{1.45}$$

Identifying the index of refraction relation, Eq.(1.45), with the dynamics of mass and particle interaction is facilitated using the relativistic mass energy relation which can be expressed in the form:

$$\frac{(m-m_0)c^2}{mc^2} = \frac{1}{2}\frac{v^2}{c^2} \qquad (1.46)$$

The energy difference in Eq.(1.45), can be written as a change in the mass as a result of the change in c , That is:

$$\varepsilon_P = \frac{(m_0-m)c^2}{mc^2} \qquad (1.47)$$

From the Relativistic energy relation, the mass energy difference is the result of the kinetic energy, and in a conservative system these are just opposites, thus:

$$\frac{\Delta c}{2c_0} = \frac{\varepsilon_P}{\varepsilon} = \frac{(m_0-m)c^2}{m^2c^2} = -\frac{1}{2}\frac{v^2}{c^2} \qquad (1.48)$$

For a particle moving is space the change in the index of refraction of space is thus connected to the change in the kinetic energy.

**Electric Field Scaling and the Schwinger Limit**

Has been asserted here that the electric field is actually the future flow amplitude of photons, and as such it has no energy content. If this is true, then there must currently be an artificial energy scaling between the electric and probability densities. The assignment of a continuous energy field distribution to a probability distribution works well for engineering purposes and conforms to Maxwell’s equations, but fails in theoretical applications. Historically this extractable energy been assumed to be the result of an energy in a field, that can be extracted by relative position of the charges

In order to have a consistent energy relation the energy density of the electric field is assigning to a point in space surrounding a charge has nominally been set to be:

$$E^2 = \frac{1}{8\pi}\frac{Q^2}{r^4}, \qquad (1.49)$$

This has been arrived at by integrating this density over all space, down to the classical radius of the electron and set it equal to the total energy.

$$\varepsilon_T = \int_{r_0}^{\infty} E^2\, 4\pi r^2 dr = \int_{r_0}^{\infty} \frac{1}{8\pi}\frac{Q^2}{r^4}\, 4\pi r^2 dr = \int_{r_0}^{\infty} \frac{Q^2}{r^2}\, dr = -\frac{Q^2}{r}\Big|_{\alpha\bar{\lambda}}^{\infty} = m_e c^2 \qquad (1.50)$$

Although this mechanically works it is arbitrary and obscures the actual mechanics of charge-charge interaction.

*Charge Electric Field*

We can look at this in terms of the ratio between the energy density and the Feynman photon density.

From the energy density perspective the potential from a charge is:

$$\frac{Q^2}{r} = \frac{\alpha c\hbar}{r} \qquad (1.51)$$

At the Bohr distance from the charge the potential energy is:

$$\varepsilon_P = \frac{\alpha c\hbar}{\bar{\lambda} / \alpha} = \alpha^2 mc^2 = 2\Re \qquad (1.52)$$

Dividing this by the Rydberg energy gives:

$$P = \frac{2\bar{\lambda}_e}{r} \rightarrow \frac{2\bar{\lambda}}{\bar{\lambda}} = 2 \qquad (1.53)$$

From the density perspective this is the number density for the electron, or the number density of our postulate for the number of Feynman photons at the Compton radius. This leads to the presumption that the energy density defined for the electric field per Feynman photon is the Rydberg energy

*Schwinger Energy Density Limit*

Eq.(1.52), is the probability density at its lowest level of particle interaction. The Schwinger limit represents the other end or the highest level of particle interaction, and both can be shown to have the same scale factor between the electric and particle density.

From definitions the Schwinger electrical energy density limit and the Rydberg energy are:

$$E_S{}^2 = \frac{c\hbar}{\alpha ƛ_e{}^4} \qquad \Re = \frac{\alpha^2 mc^2}{2} \tag{1.54}$$

The ratio of the Schwinger energy density divided by the Rydberg gives exactly the classical volume of the electron,

$$\frac{E_S{}^2}{\Re} = \frac{2}{(\alpha ƛ_e)^3} = 8.9374E+37\ \text{cm}^{-3} \tag{1.55}$$

If as we have postulated the electron has two photons, then the Schwinger electric energy density is the Feynman photon density times one Rydberg of energy per photon

From Eq.(1.22), the number density of Feynman photons in the universe is

$$\frac{n_F}{2} = 8.466E+37\ \text{cm}^{-3} = \frac{2}{(\alpha ƛ_e)^3} \tag{1.56}$$

Multiplying it by the Rydberg constant gives the Schwinger limit.

$$E_{SW}^2 = \frac{n_F}{2}\Re = 1.94824E+27\ \text{erg cm}^{-3} \tag{1.57}$$

This is about 5% from the calculated value of the Schwinger Limit derived by Schwinger of 1.8454874E+27 $\text{ergs cm}^{-3}$

Both Eq.(1.53), and Eq.(1.57), lead to the presumption that the energy density, $\varepsilon_D$ of the electric field has been defined arbitrarily equivalent to be the Feynman photon probability density times the Rydberg constant.

$$\varepsilon_D = n_F \Re \tag{1.58}$$

It is concluded that this represents the scaling relation between the Feynman photon probability amplitude and the electric field density.

*Only half of the Feynman photons in space can interact with another photon because Lorentz considerations prevent photons not having velocity components in the same direction from interacting

**Conclusion**

Presented has been a of a plausible causation of gravitation and electrical charge interaction within the confines Quantum Theory in Minkowski four-space, as well as a causation of the ambient velocity of light in the universe.

It has to be regarded as a new approach to physics, and as such a degree of speculation has been incorporated, many parts lack mathematical rigor, but fit well with known physical parameters. How the postulates and speculation impact or elucidate the understanding of QM will be left to future clarification.

Hopefully it will lead to a better understand between quantum mechanics and the internal dynamics of particles

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## Appendix I

*Probability Density of Off Path Feynman Photons*

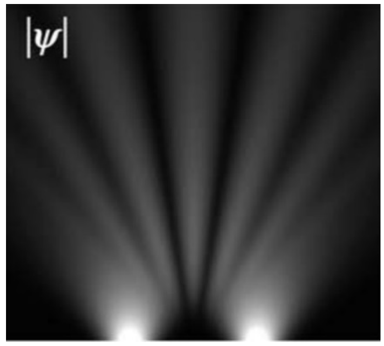
Though Feynman's proposal that a particle has a an equal probability of all paths, it is not true that the particle has an equal probability of being an any position at any distance from the path, in fact, there is no way at this time to directly calculate the probability amplitude as a function of the distance from the classical trajectory

For approximations one can turn to the work introduced by Aharonov, Albert, and Vaidman on "Weak measurements" [6], [12], [38], [45], ]46], [47], that pre-selects an initial state, a measuring device, and a post-selected final state. The results that can be measured as well as calculated can yield approximations regarding the probability density as a function of distance from the classical trajectory

K. Bliokh *et al.* [12], extending the work of Kocsis *et al,* [6], using the quantum weak-measurements method introduced by Aharonov *et al*. [45], made measurements of the "average trajectories of single photons" in a two-slit interference experiment.

The "Weak Values", method implies averaging over many events, i.e., the same as a multi-photon limit of classical linear optics, and applicable to the multiple path of a reciprocating photon. Bliokh was able to give a classical-optics interpretation to the experiment, and asserted that weak measurements of the local momentum of photons made by Kocsis *et al*. [6], represent measurements represented an average over many events and thus the measurements of the Poynting vector in an optical field.

Bliokh found that the transverse location probability density for a Feynman photon as a function of radius form a Feynman path to be proportional to 1/r thus [12]:




Bliokh

The value of k in Eq.(3.2), is not found by the properties of the path integrals near the classical tack, and are not well understood even with the weak theory & weak measurements, but Sakoda and Omote [11] did calculated the differential cross section from the scattering amplitudes finding the asymptotic probability distribution $r >> ƛ$ to be proportional to:

$$\mathbf{P}(r_\perp) = \psi^* \psi \rightarrow ƛ / r \tag{1.59}$$

For the consideration of a trapped photon oscillating between two points or in circular motion Fig. 1a, bound by vacuum polarization induced gradient in the index of refraction, the path goes from one point to another and then back, thus doubling the probability density. The relative time average probability density of the Feynman photons being at a position at a distance r from the classical tract is postulated to be:

$$P_F = \frac{2ƛ}{r} \tag{1.60}$$

# Appendix II

*Calculated Value of the Fine Structure Constant*

DT Froedge 06-02-19

In the Charged Particle Interaction Section of this paper, Eq.(1.34), there is a value of $\alpha^2$ found in fundamental constants that can be useful in testing the theory.

$$\alpha^2 = \frac{2\lambda_{PL}^2}{\lambda_e^{\;2}} \nu^2 \qquad (2.1)$$

This is the value of the fine structure constant, Alpha$(\alpha)$, in terms of fundamental constants that are known to a high degree of precision by calculations from QFT considerations. The $\lambda_e$ is the Compton radius of the electron, and $\nu$ is the Compton frequency $\nu = c/(2\pi\lambda_c)$. The Planck length is:

$$\lambda_{PL}^2 = \frac{G\hbar}{c^3}, \qquad (2.2)$$

The value of $\alpha^2$ is nominally:

$$\alpha^2 \quad = \quad (1/137)^2, \qquad (2.3)$$

or more accurately from the work of Gabrielse et.al.[42],

$$\alpha = 0.00729735253594 \qquad (2.4)$$

Whether this theory has merit or not, hinges to a degree on the accuracy of the prediction of this relation. This value of $\alpha$ (Eq.(2.1)), is expressed in fundamental constants known to a high accuracy (~12 significant digits) and there are no "fudge" factors, The major uncertainty in the calculated value is the value of the gravitational constant G, which is experimentally determined to only about 5 significant digits, is the major uncertainty. the gravitational constant..

A more explicit for Eq.(2.1), is:

$$\alpha^2 = \frac{G\hbar}{c^3}\frac{2}{\lambda\!\!\!^{-}_e{}^2}\frac{c^2}{2^2\pi^2\lambda\!\!\!^{-}_e{}^2} == \frac{G\hbar}{2\pi^2 c\lambda\!\!\!^{-}_e{}^4} \tag{2.5}$$

The model for the electron that generates the relation for $\alpha$ is of two photons revolving round the center of momentum, and just as an in the case of an electron revolving around the proton, the quantum loops of the Feynman paths of the orbiting photons must be taken into account. The mass calculated Compton wavelength is the first loop, and the effect on the wavelength of all the other loops must be taken into account, this is done by multiplying the Compton radius $\lambda\!\!\!^{-}_e$, by the anomalous gyromagnetic ratio $g_e / 2$

$$g_e / 2 = 1.0011596522 \tag{2.6}$$

To assess the predicted theoretical value, the expression Eq.(2.5), can be solved for the gravitational constant, and compared with current experimental values.

Solving for the electron mass in terms of fundamental constants gives:

$$m_e = \frac{\hbar g_e}{c}\left(\frac{2\pi^2 c\alpha^2}{G\hbar}\right)^{1/4} \tag{2.7}$$

Solving, for the gravitational constant gives:

$$G = \frac{\alpha^2 2\pi^2 c\left(\lambda\!\!\!^{-}_e g_e\right)^4}{\hbar}, \tag{2.8}$$

Calculating G from Eq.(2.8), to 12 significant digits gives:

G = <u>6.67586</u>727955 x 10-08 $cm^3 gm^{-1} s^{-2}$

This is slightly higher (0.02%) than the current Codata consensus recommended value of 6.67430(15) $x10-11\ m^3kg^{-1}s^{-2}$, , but it is not outside the scatter of current measurements, and is exactly on the Cavendish balance measured International Bureau of Weights and Measures, BIPM value by T. Quinn et.al,[43], published in 2015.

$$G = \underline{6.67586}(36) \text{ x } 10\text{-}11\ m^3kg^{-1}s^{-2}$$

The calculated value is in agreement with this value to the limits of its experimental accuracy of this measurement.

Accept for some numerology associations, the above relation Eq.(2.1), is the only known physical relation between the fine structure constant, the Gravitational constant, and the mass of the electron.

Reference values:

Constants used in calculation in CGS units.

| | | | |
|---|---|---|---|
| $c =$ | 2.9979245800E+10 | $g_F = g_e / 2 =$ | 1.00115965218 |
| $\hbar =$ | 1.0545918473E-27 | $\lambda\!\!\!^{-}_e = \hbar / (m_e c) =$ | 3.8616633678E-11 |
| $\alpha =$ | 1/137.03599971 | $m_e =$ | 9.109389966E-28 |

Summary:

| | |
|---|---|
| Calculated value of G | G = 6.67586727955 x 10-11 $m^3kg^{-1}s^{-2}$ |
| BIPM Cavendish balance value of | G = 6.67586(36) x 10-11 $m^3kg^{-1}s^{-2}$ |
| Codata Consensus Value | G= 6.67430(15) x 10-11 $m^3kg^{-1}s^{-2}$ |

Excerpt from BPIM report: *https://royalsocietypublishing.org/doi/pdf/10.1098/rsta.2014.0032*



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# The BIPM measurements of the Newtonian constant of gravitation, *G*

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## 12. A value for Newton's constant of gravitation

The peak-to-peak servo torque, $\tau_s$, obtained as an unweighted mean of 10 data runs was $3.148869(94) \times 10^{-8}$ N m and using equations (9.2*a*) and (11.3) we can write

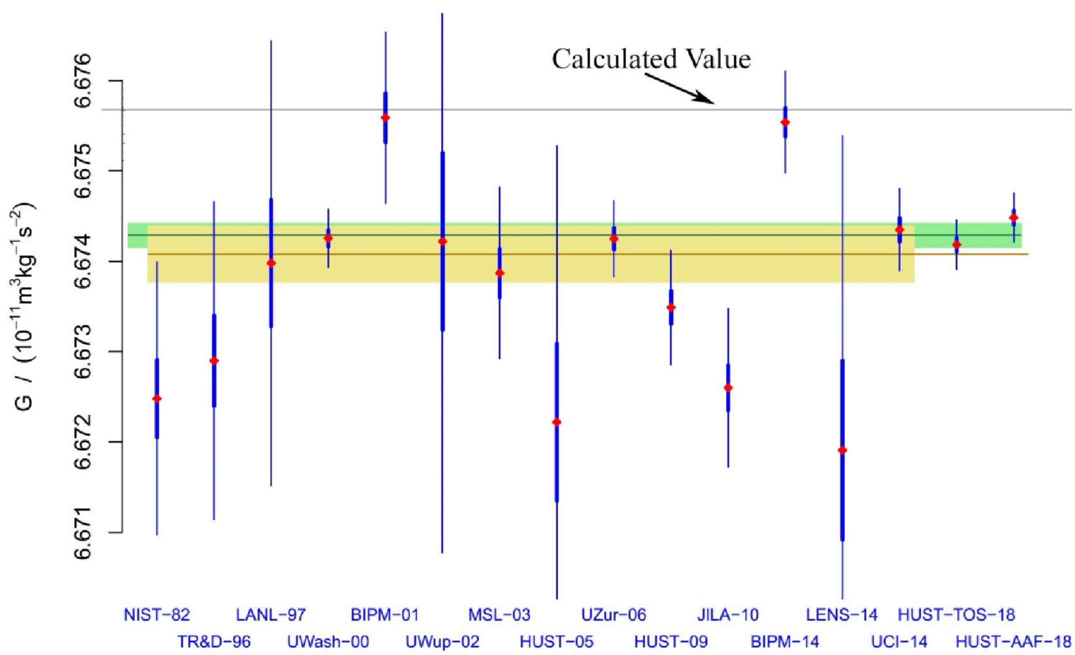
$$G_s = \frac{\tau_s}{\Gamma_s} = 6.67515(41) \times 10^{-11}\ \mathrm{m^3\,kg^{-1}\,s^{-2}}\ (61\ \mathrm{ppm}). \qquad (12.1a)$$

The unweighted mean of the 10 data runs giving a value of the peak-to-peak deflection angle of 0.1529322(29) mrad using equations (9.2*b*), (8.2) and (11.8) we can write

$$G_c = \frac{\tau_c}{\Gamma_c} = 6.67586(36) \times 10^{-11}\ \mathrm{m^3\,kg^{-1}\,s^{-2}}\ (54\ \mathrm{ppm}). \qquad (12.1b)$$

We have used the values for the uncertainties in the experimental measurements given in §11.

Experimental Data




Experimental values used for statistical calculation of Codata consensus value of G [53]

# Appendix III

*Summary of Electron Model*

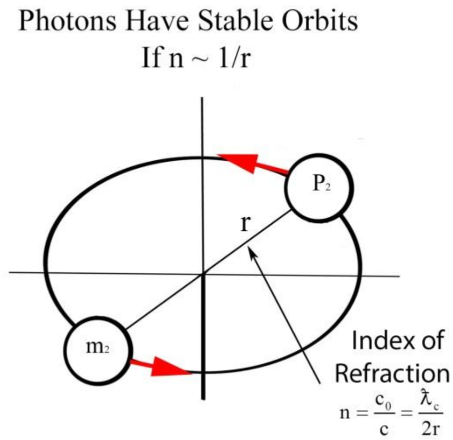



Fig. 1a. Orbiting Photons .

In an earlier paper "The Electron as a Composition of Two Vacuum Polarization Confined Photons" [13] the author developed the model of an electron as two bound photons in radially polarized along the orbital radius. Work done by a number of researchers on the index of refraction at electromagnetic energies near the Schwinger limit, [41], have shown that the index of refraction as the result of the nonlinearity of the vacuum polarization is substantial . There is no doubt that the index of refraction at the Schwinger limit, [48],[49],[50],[51], is be sufficient to induce stable circular motion, and there is no doubt that single photons can have that density.

The general form of the index of refraction developed from that work is:

$$\frac{c}{c_0} = \left(1 - k\frac{\alpha^2 E^2}{E_{SW}^2}\right) \quad \rightarrow \quad \frac{\Delta c}{c_0} = k\frac{\alpha^2 E^2}{E_{SW}^2} \qquad (3.1)$$

By the Lorentz transformation, manifest in the Thomas precession, an inertial frame rotating around a central point rotates about its path. If there is a helictical polarized photon moving in a circular orbit in a circular index of refraction, the helictical rotation rate decreases proportional to the radius of the rotation. As the radius decreases to the Compton radius, the helictical rotation is stopped leaving the polarization continuously along the radial axis at one cycle per two revolution, in agreement with spinor considerations [52].

That is from an electrical perspective the electric field is radial about a point, and from the electrical perspective this would be a charged particle. From the perspective presented here this would be a probability of flow along the radial axis.

From classical mechanics it is known that a stable orbit for a photon requires an index of refraction proportional to 1/r, [53]. Thus:

$$\frac{c_0}{c} = \frac{k}{r} \quad \rightarrow \quad r = \frac{kc}{c_0} \tag{3.2}$$

The angular momentum, the sum of the angular momentum of the two photons in the electron must be 1/2 thus:

$$L = rm_e c = \frac{kc}{c_0} mc = \frac{\hbar}{2} \tag{3.3}$$

From the postulates energy is an invariant of c thus:

$$m_e c^2 = \hbar\omega_e \tag{3.4}$$

Then Eq.(3.3), five the value of k to be:

$$\frac{k}{c_0}\hbar\omega_e = \frac{\hbar}{2} \quad , \tag{3.5}$$

and:

$$k = \frac{c_0}{2\omega_e} = \frac{\lambdabar_e}{2} \tag{3.6}$$

Putting this into Eq.(3.2), gives:

$$\frac{c}{2r} = \frac{c_0}{\lambdabar_e} = \omega_e \tag{3.7}$$

Since $\omega_e$ is a constant the electron orbits are stable and the angular momentum is, $1/2\hbar$.