# A Quantum Field Theory Conjecture for the Origin of Gravitation

**APS Apr. 14, 2019 Denver, Co.**

D.T. Froedge

*Formerly Auburn University*
*dtfroedge@glasgow-ky.com*

V041419
@ http://www.arxdtf.org

*Abstract*

Gravitation defined in curved space has never been found to be compatible with quantum mechanics or quantum field theory. This is likely due to the fact that one theory is based in local conservation of energy and the other defines energy globally, and not locally conserved [1]. Equations mixed with variables from the two conservation laws, could neither be invariant nor covariant under coordinate transformations. This paper presents a theory of gravitation constructed within the locally conserved concepts of QFT. In previous papers the author has illustrated that for photons, and confined light speed particles, a gradient in c demonstrates the effect of gravitation. The illustration of a gradient in c generated by Quantum Field Theory equivalent to gravitation therefore could create a theory a mechanism for gravitation within a Lorenz, local conservation of energy four-space.

With a few assumptions regarding the nature of photons and the reality of path integrals, gravitation can be illustrated as a feature of Quantum Theory.

## 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”

If gravitation is a gradient in c as discussed by the author in other papers [2],, 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 of the particle has traveled every possible path [3], 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 could make velocity changes to the index of refraction for these photons Nature of the Photon

The photon, the first of the discovered particles is still not well understood. It contains a quanta of energy and although the wavelength can be thousands of miles long, it can deliver that energy to a single atom or electron instantly.

A photon moving through a probability density amplitude of approaching Feynman photons should experiences an alteration in the index of refraction, velocity and direction. This alteration of photon dynamics, with minimal assumptions, can be shown to be the causation of gravitation, electric charge, pair production and the structure of the electron, within a four dimensional Lorentz space.

When Einstein was searching for the cause of gravitation, the classical mechanism offered nothing to effect the phenomena. The electric charge and fields worked fine for electric interactions, but nothing except action at a distance could effect gravitation. His proposal to effect gravitation was to assert a curvature of space as defined by the Ricci tensor.

In the 1950's Feynman developed what is referred to as the path integral approach to QFT, this asserts that any action path taken by a particle of particle of photon is a composition of an infinite number of paths, what we refer to as the classical path being the most probable. One could look at this is the amplitude probability distribution of the particle as it moves through space. If the particle is in a reciprocating path then there is a probability of the particle being at a distance from that path.

It is the probable existence, and effect of the Feynman photons, generated by the repeating action of confined photons in massive particles that can be shown to be the vacuum energy, sets the speed of light, and provides the effect of gravitation.

This probability density amplitude is devoid of energy, but reacts with the density amplitude, and changes the momentum and velocity of oncoming photons having an opposite velocity vector. By Lorentz consideration, photons having a negative velocity dot product cannot 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 of the energy of a photon to be a continuous electromagnetic field is an approximation that leads to violations of special relativity, and in the case of the electron structure leads to unacceptable infinities.

## Order of Presentation

Defining Photon and Series of postulates
Feynman Photons
Gravitation
Vacuum probability and speed of light in universe

## Postulates

The basic postulates in this paper will define: The velocity of light in the probability amplitude of another photon; the physical structure of a photon; the interaction of two photons; and the probability of finding a Feynman photon existing off the classical path.

## The Photon

**1**

The photon is presumed to be a Planck size particle with radius $\lambdabar_{PL}$. The wavefunction is the future probability of the location with a cross section equal to the square of the Compton radius $\lambdabar_{C}$. The wave, generally thought of as electromagnetic, is asserted to be only the amplitude probability of the photons future location and is devoid of energy content. The entire energy and angular momentum of the photon is asserted to lie within the Planck volume. (See discussion **Appendix I**)

**2**

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

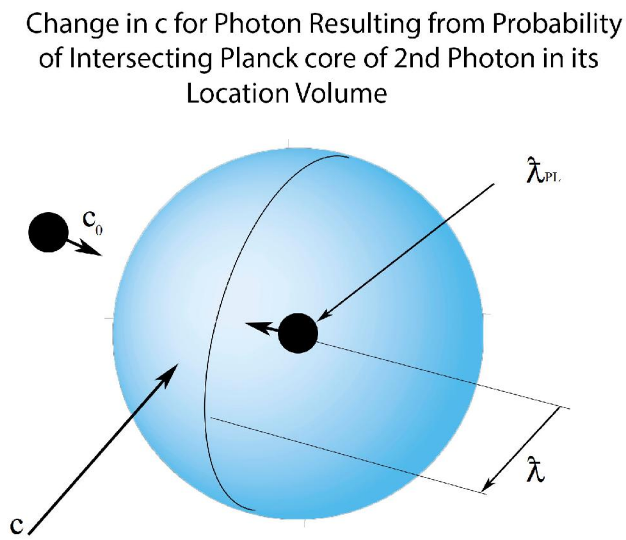



Fig.1 photon delay passing through location distribution of another photon

$$P_{\gamma\gamma} = \frac{\Delta c}{c} = \frac{\bar{\lambda}_{PL}^2}{\bar{\lambda}_{PH}^2} = \left(\frac{\sigma_{PL}}{\sigma_c}\right) \tag{1}$$

3

Association a continuous electromagnetic wave with the photon can be done [4], but it is unnecessary and counterproductive. The presumption of a continuous field associated with the photon creates singularities and integration issues that distort actual particle interactions. The discrete values associated with probability amplitudes and density does not have that problem. The probability of the location of the photon lies within the Compton radius $\bar{\lambda}_C$, and does not represent an energy density.

4

The photon physical cross section is The Planck area:

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

5

The probability of a Feynman Photons being at a point at a distance r from the classical path of a photon reciprocating in a confined space is

$$P = \frac{2\lambda\!\!\!^{-}{}_{C}}{r} \tag{3}$$

(See discussion **Appendix II**)

6

All massive Fermion 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 with a mass equivalent to the combined mass. (See **Note1)**

## Variable Speed of Light: Constants and Dependences

In a volume of space with an altered velocity of light such as a gravitational potential, the energy of a photon is considered to be a Lorentz universal constant and equal to $\hbar\omega$. The other fundamental constants must be therefore functions of c:

$$\varepsilon = \hbar\omega = \hbar\frac{c}{\lambda\!\!\!^{-}} = mcc = pc \qquad p = \frac{\varepsilon}{c} \qquad m = \frac{\varepsilon}{c^{2}} \qquad \lambda\!\!\!^{-} = \frac{\hbar}{mc} = \frac{\hbar c}{\varepsilon} \tag{4}$$

$$\hbar = mc\lambda\!\!\!^{-}$$

Note that the energy and angular momentum are constant, but the rest are dependent on c. The mass of the photon is defined as $m = \varepsilon / c^{2}$.

**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 paths over all possible paths [3]. For a repetitive action path, that is from one point to another and back, there is generated and continuously regenerated set of paths resulting in the particle having a probability of being at a distance from the most probable path.

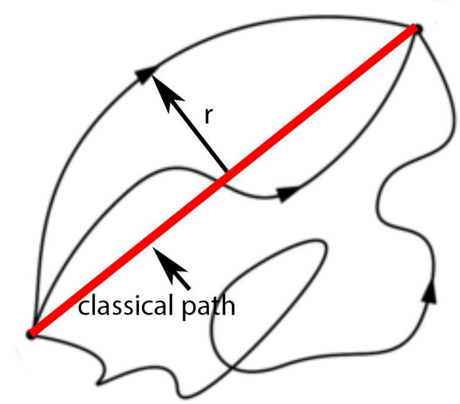



Fig.2 As a photon moves from one point to another there is the probability of being at a distance r from the classical path.

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 (discussed in authors papers on photon structure [10],[11]). Feynman's argument requires there are continuously generated action paths throughout the surrounding space, and the probability of existence of these polarized photons in the space surrounding the "classical" paths.

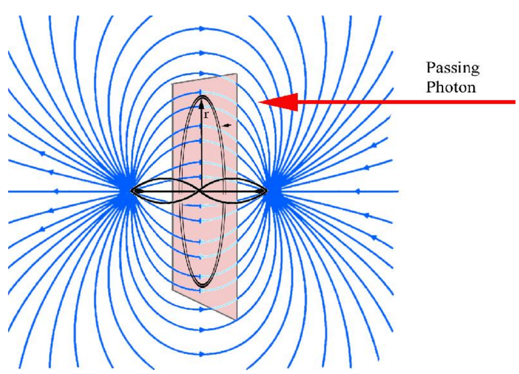



Fig.3 Some of the possible Feynman paths for a photon oscilating between two points.

**For an entangled pair of photons, such as exist in a particle, the exchange of momentum by 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.**

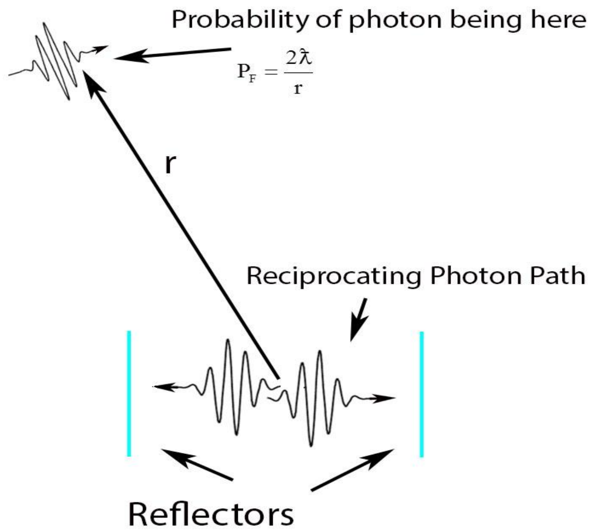



Fig.2 Feynman photon being located at a distance r from classical path

The knowledge of the probabilities of discrete photons existing off the classical paths has existed for half a century yet the exploitation of the interaction particles has defaulted to a continuous field theory, (QFT) [3]. 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 [11][11a], the probability of a Feynman photon being located at a distance r from a confined photon moving in a repetitive action (or classical) path is determined to be:

$$P = \frac{2ƛ_C}{r} \tag{5}$$

(See discussion **Appendix II**)

### *Photon Induced Change in Speed of Light*

Urban [13] has proposed an index of refraction of space based on the vacuum polarization creating and annihilating electron pairs, and in another publication [14] proposed an index of refraction depending on the time delay of a photon passing through the volume of intersecting particles There are also field time delay operators that assert a delay photon delays [15], [16], [17], [18], [19], [20]. This paper will propose that the vacuum photon delay is the result of intersecting Feynman photons that inhabit the universe and the change in velocity is proportional to the ratio of the Planck cross section to the Compton cross section in intersecting those particles. Feynman photons being the same as any other photon predominantly scatter exchanging.

### Gravitation and the Speed of Light

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: [21], [22]

$$\eta^{-1} = \frac{c}{c_0} = \left(1 - \frac{2\mu}{r}\right) \quad \rightarrow \quad \frac{\Delta c}{c_0} = \frac{2\mu}{r} \qquad (6)$$

In a 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 could create a theory of a mechanism for gravitation within a Lorenz, local conservation of energy four-space.

**If it can be shown that the effect of Feynman path action of oscillating photons on interloping photons produces the same change in the speed of light as gravitation, and it can be shown that the effect of a gradient in c produces the**

**equivalent effect of gravitation on confined energy: then the cause of gravitation is established.**

Multiplying the change in c as a result of being in the probable location of a photon (Postulate 1 Eq.(1),), times the probability of a Feynman photon being at that point (Postulate 2 Eq.(3), ), gives a change in c as.

$$\Delta c = c_0 \frac{\lambda_{PL}^2}{\lambda_C^2} \frac{2\lambda_C}{r} = \frac{\mu \lambda_C}{\lambda_C^2} \frac{2\lambda_C}{r} \tag{7}$$

or:

$$\frac{\Delta c}{c} = \frac{2\mu}{r} \tag{8}$$

Comparing the results of Eq. (8) , with the well-established velocity of light induced by gravitation in flat Minkowski space Eq. (6), the connection is established between the Feynman photon induced change in c and the gravitationally induced change in c..

## Ambient Speed of Light in the Universe

As can be seen from Eq.(1), the velocity of light is slowed down by the presence of Feynman Photons. We have postulated that every particle in the universe generates Feynman photons and the protons and neutrons make up the bulk of the mass and have by far the greatest effect. For the purpose of counting it will approximated that all mass in the universe are protons.

From an estimate of the mass in the universe by D. Valev [24], the relation between the mass and the radius from the value of the mass in a flat universe is from the relation:

$$\frac{Gm}{c^2 (R/2)} = 1 \tag{9}$$

R is the visible radius of the universe.

This can be rewritten in the format of Eq.(7), as:

$$\frac{G}{c_0^2}\frac{M}{R/2} = \sum_n \frac{\lambda_{PL}}{\left(\lambda_{PH}^2\right)_n}\frac{\left(2\lambda_{PH}\right)_n}{r_n} = 1 = \frac{\sum \Delta c_n}{c_0} \tag{10}$$

Note that the sum of the effect of the Feynman photons on passing photons in the universe sets the velocity of light

$$\Delta c \ \text{Per Photon} = c_0 \frac{\lambda^2{}_{PL}}{\left(\lambda_C^2\right)} \tag{11}$$

and the probability of the Feynman photon being there is.

$$\frac{\left(2\lambda_C\right)}{r} \tag{12}$$

The sum of the change in c as the result of all the photons in the universe must equal to the ambient velocity.

$$\Delta c_n = c_0 \frac{\lambda^2{}_{PL}}{\lambda_n^2}\frac{2\lambda_n}{r_n} \tag{13}$$

The velocity in an empty universe is not slowed down by the probability of interaction with Planck particles and thus is infinite.

Knowing that most of the particle mass is primarily protons or neutron equivalents, then Eq.(9), can be written as a sum of these particles. The implication of Eq.(10), is that the average distance to the individual particles in the universe is $\overline{r} = R/2$, or half the radius of the universe, and the change in c is the ambient $\Delta c = c_0$

This is more apparent if rewritten as:

$$c_0 \frac{\lambda_{PL}^2}{\lambda_{P1}^2}\frac{2\lambda_{P1}}{r_1} + c_0 \frac{\lambda_{PL}^2}{\lambda_{P2}^2}\frac{2\lambda_{P2}}{r_2} + c_0 \frac{\lambda_{PL}^2}{\lambda_{P3}^2}\frac{2\lambda_{P3}}{r_3} + .. = \Delta c_1 + \Delta c_2 + \Delta c_3 + .. = \Delta c \tag{14}$$

Since the protons masses (P), are the most prevalent terms, this sum can be written as:

$$\frac{\mu_P}{\lambda_P}\sum_n \frac{2\lambda_P}{r_n} = 1 \tag{15}$$

This is the sum of the Feynman probability of photons being at a point in the universe times their individual delay. The probable number of proton equivalent Feynman photons at any point in the universe is then just the ratio of the Compton wavelength to the gravitational radius of the proton:

$$n_F = \frac{\lambda_P}{\mu_P} = 1.69321E + 38 \tag{16}$$

The probable number of Feynman photons at any point in the universe.

## Electric Field Scaling

If the speed of light is set by the Feynman photons in the universe then, and it has been asserted here that there is no electric field only a probability of photons that sets the speed of light then the scaling of the electric field should be proportional to the density of the Feynman photons.

The assignment of the probability density of one to the lowest energy potential of electrical particle interactions, the Rydberg energy, then there is a scaling between the probability density of the Feynman photons and the electric energy density of the electric field.

$$\frac{2\lambda_P}{r_P} = \frac{2\lambda_p}{\lambda_P} = m_e c\alpha^2 / 2 \tag{17}$$

Since only photons moving in opposite directions interact, multiplying half the number of Feynman Photons $n_F$ in the universe times the Rydberg energy gives the maximum electrical energy density:

$$n_F R / 2 = 1.948e + 27 \text{ erg/cm}^3 \tag{18}$$

This is within about 6% of the Schwinger electrical limit (1.948E+27 $\text{erg/cm}^3$), [25], which is the energy density inducing pair production [26].

## Conclusion

This has been a presentation of a plausible mechanism inducing gravitation within the confines Quantum Theory in Minkowski four-space and illustrating the ambient causation of the velocity of light in the universe.

References:


1. E. Noether's Discovery of the Deep Connection between Symmetries and Conservation Laws
Nina Byers, arXiv:physics/9807044v2 [physics.hist-ph] 23 Sep 1998

2. DT Froedge, “Gravitation is a Gradient in the Velocity of Light”
http://www.arxdtf.org/css/Gravitation.pdf, http://vixra.org/abs/1501.0052

3. Feynman, Hibbs, 1965, Quantum Mechanics and Path Integrals McGraw-Hill

4 A. Kregar Aharonov-Bohm effect, http://mafija.fmf.uni-lj.si/seminar/files/2010_2011/seminar_aharonov.pdf

5. B. Smith, Photon wave functions, wave-packet quantization of light, and coherence theory,
http://iopscience.iop.org/article/10.1088/1367-2630/9/11/414

6. S. Kocsis *et al*. Observing the average trajectories of single photons in a two-slit interferometer,
Science. 2011 Jun 3;332(6034):1170-3. doi: 10.1126/science.1202218

7. Time-delay of classical and quantum scattering processes: a conceptual overview and a general definition Review Article Massimiliano Sassoli de Bianchi1∗

8. Yi Liang and Andrzej Czarnecki Alberta Thy 12-11
Photon-photon scattering: a tutorial arXiv:1111.6126v2 [hep-ph] 8 Dec 2011

9. I, Bialynicki-Birulaphoton Photon Wave Function, Progress In Optics XXXVI, pp. 245-294 arXiv:quant-ph/0508202v1 26 Aug 2005

10. DT Froedge, A Physical Electron-Positron Model in Geometric Algebra, V041917
http://www.arxdtf.org/css/electron.pdf, http://vixra.org/pdf/1703.0274v2.pdf

11 . DT Froedge, Photon-Photon Vacuum Polarization Composite Electron Model

11. S Sakoda , M Omote, Difference in the Aharonov-Bohm Effect on Scattering States and Bound States
Difference in the Aharonov-Bohm Effect on Scattering, Advances in Imaging and Electron Physics, v 110, 1999, Pages 101-171, Academic Press, 1999

12a. K, Bliokh, et.al, Photon trajectories, anomalous velocities,
and weak measurements: A classical interpretation, New J. Phys. 15, 073022 (2013) ,
https://arxiv.org/abs/1304.1276

13. M. Urban A particle mechanism for the index of refraction, LAL 07-79, 2007,
Dmitri Kharzeeva and Kirill Tuchinb,Vacuum self–focussing of very intense laser beams, BNL-NT-06/43, RBRC-657,arXiv:hep-ph/0611133v2 21 Feb 2007 https://arxiv.org/abs/0709.1550

14. M. Urban, F. Couchot, X. Sarazin, A. Djannati-Atai, The quantum vacuum as the origin of the speed of light, EPJ manuscript, arXiv:1302.6165v1 [physics.gen-ph] 2013

15. Eisenbud-Wigner-Smith time (delay) operator Eisenbud (1948), Wigner (1955), Smith (1960)

16 . E.P. Wigner, Phys. Rev. 98, 145 (1955). [39.26] F.T. Smith, Phys. Rev. 118, 349 (1960).

17. E.P. Wigner, Phys. Rev. 98, 145 (1955). [39.26] F.T. Smith, Phys. Rev. 118, 349 (1960).

18. P. Brouwer, K. Frahm and C. Beenakker, Quantum mechanical time-delay matrix in chaotic scattering, arXiv:chao-dyn/9705015v1 20 May 1997

19. M. deBianchi, Time-delay of classical and quantum scattering processes: a conceptual overview and a general definition Review Article, Central European Journal of Physics, Volume 10, Number 2 (2012), 282-319 arXiv:1010.5329v3 [quant-ph] 2 Nov 2011

20. Yi Liang and Andrzej Czarnecki Alberta Thy 12-11
Photon-photon scattering: a tutorial arXiv:1111.6126v2 [hep-ph] 8 Dec 2011
Department of Physics, University of Alberta, Edmonton, Alberta, Canada T6G 2E1

21. Roger Blandford, Kip S. Thorne, Applications of Classical Physics, (in preparation, 2004), Chapter http://pmaweb.caltech.edu/Courses/ph136/yr2012/1227.1.K.pdf

22. F. Karimi, S. Khorasani, Ray-tracing and Interferometry in Schwarzschild Geometry, arXiv:1001.2177 [gr-qc] arXiv:1206.1947v1 [gr-qc] 9 Jun 2012

24. D. Valev, Estimations of total mass and energy of the universe, arXiv:1004.1035v1 [physics.gen-ph] 7 Apr 2010

25. J Schwinger, On Gauge Invariance and vacuum polarization , Physical Review volume e82, 1951

26. R. Battesti, C. Rizzo. Magnetic and electric properties of quantum vacuum.
Reports on Progress in Physics, IOP Publishing, 2013, in press. https://hal.archives-ouvertes.fr/hal-00748532

27. P. Avery, Relativistic Kinematics II PHZ4390, Aug. 26, 2015,
http://www.phys.ufl.edu/~avery/course/4390/f2015/lectures/relativistic_kinematics_2.pdf

28. S. Hossenfelder, Research Fellow Frankfurt Institute for Advanced Studies, discussion: The Planck length as a minimal length, http://backreaction.blogspot.com/2012/01/planck-length-as-minimal-length.html

29. Y. Aharonov, L. Vaidman, Measurement of the Schrödinger wave of a single particle, Phys. Lett. A 178, 38 (1993).

30. Y. Aharonov, D. Albert, and L. Vaidman How the result of a measurement of a component of the spin of a spin-1/2 particle can turn out to be 10**,** https://doi.org/10.1103/PhysRevLett.60.1351,

# Appendix I

*Nature of the Photon*

The photon, the first of the discovered particles is still not well understood. It contains a quanta of energy and although the wavelength can be thousands of miles long, it can deliver that energy to a single atom or electron instantly.

Because of the energy assigned to the electromagnetic wave  the photon is mostly thought of as being the electromagnetic 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 interchangeable with the electromagnetic energy density [13], [14]. Thus the identification and replacement of the energy density of the electromagnetic field with the photon location probability density is well justified. The energy of the photon is demonstrably not distributed over the entire wave but is localized well enough to be transferred instantaneously to a point particle. The distribution of the energy over distances of kilometers would make the instantaneous transfer of the energy a violation of special relativity.

If the electromagnetic envelope is just the probability envelope of location it is apparent that the instantaneous transfer of energy requires the physical energy carrier of the photon to be very small.

## Appendix II

### Probability Density of Off Path Feynman Photons

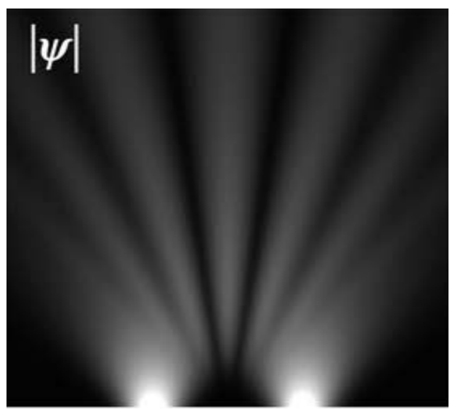
Though Feynman's proposal that a particle has a an equal probability of all paths, it is not true that the particle has an equal probability of being an any position at any distance from the path, in fact, there is no way at this time to directly calculate the probability amplitude as a function of the distance from the classical trajectory [9].

For approximations one can turn to the work introduced by Aharonov, Albert, and Vaidman on "Weak measurements" [10-11] 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.* extending the work of Kocsis *et al,* [23], using the quantum weak-measurements method introduced by Aharonov *et al*. [11], 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*. [23], 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:




Bliokh[]

$$\mathbf{P}(r_\perp) = \psi^*\psi \rightarrow k / r \tag{19}$$

The value of k in Eq.(19), 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 $r >> \lambda$ to be proportional to:

$$\mathbf{P}(r_\perp) = \psi^*\psi \rightarrow \lambda / r \tag{20}$$

For the consideration of a trapped photon oscillating Fig. 2, between two points or in circular motion 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 probability of the Feynman photons being at a position at a distance r from the classical tract is then presumed to be:

$$P_F = \frac{2\lambda}{r} \tag{21}$$

This density fits well with the effects of gravitation

## Note 1

On the location probability of Feynman photons.

It is presumed that the probability of a Feynman photon existing at a distance r form the classical track of two entangled photons is:

$$P = \frac{2\lambda}{r} \tag{22}$$

If a particle is a composition of several entangled pairs of internal photons, each pair having an energy equivalent energy mass of m the probability of being at a distance r form the classical track, and entangled by the ½ spin quantum number. is:

$$P = \frac{2\lambda}{r} = \frac{2\hbar}{\left(\sum_n m_1 + m_2 + m_3 + \right) cr}, \tag{23}$$

and not:

$$P \neq \sum_n \frac{2\hbar}{m_1 cr} + \frac{2\hbar}{m_2 cr} + \frac{2\hbar}{m_3 cr} + \tag{24}$$

That is: the probability of a photon being at a position r from its classical track with mass energy equivalent to the mass of the particle is inversely proportional to the sum of its energy, not the sum of its wavelengths. This fits what is known of particle force ranges and is the result of the anti-commutation of the internal momentum constituents of a particle, and the conservation of energy. The probability of a particle of that energy being at that distance would be equal to the sum of the probability of the particles constituents.

## Note 2

### *Simplest Rest Mass Model Must Generate Gravitation*

The photon carries an energy that, though in general tiny, must exert a gravitational pull on the particle whose position we wish to measure [28]. In order to define a simple thought experiment, the start will be by setting forth the simplest form of rest mass possible: a standing wave photon oscillation between two reflectors. This photon is functionally equivalent to a rest mass and must generate gravitation proportional to its confined energy $m = E / c^2$ . The mechanism that induces gravitation must be present in this simple system, but there is very little in classical physics that would suggest a causal connection between the oscillating photon and the passing photon. The interaction induced by the conjecture of Feynman, of the photon paths taken by a particle going from one point to another existing outside the classical path could offer the causal connection.