A Quantum Field Theory Conjecture for the Origin of Gravitation

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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 of 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 Field 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, then there must be a mechanism for inducing a change in c 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 [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 could make to the velocity changes to the index of refraction.

Some say that the sum-over-histories picture is just a mathematical equivalence of QFT that predicts the proper path, and not really a probability of the particle being elsewhere. The action at distance of phenomena of the bell inequality, and the Aharonov-Bohm Effect [3], suggest a reality to the many path view, and for our purpose it will be proposed that the photons are real near point particles that have a probability density located off the classical trajectory.

Speed of light in gravity

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 with a flat metric is: [4], [5]

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

The confined lightspeed sub-particles in a massive particle functions inertially equivalent to a mass particle and experiences the same acceleration in a variable index of refraction as a mass particle in a gravitational field. And it has been argued that the internal constituents of all mass propagate at c and are thus are accelerated in a gradient just as confined photons. Thus the effect of gravitation on massive particles would be equivalent to a gradient in c. [6]

Simplest Rest Mass Model

The photon carries an energy that, though in general tiny, must exert a gravitational pull on the particle whose position we wish to measure [7]. 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 interference 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 be the causation.

Feynman Photons

From the Path integral formulation of QFT by Feynman, for a photons moving from point a, to point b there is a probability of existence outside the classical path [2], and as such there should be a probability of interaction with passing photons. With a few assumptions it will be shown that the change in c induced in the passing photons can be equivalent to the change in c induced by gravitation. Note that the photons discussed here are not an "off shelf" or virtual photon, but the real probable presence of the fully energetic photon existing throughout space. For the purpose of this paper, these photons will be referred to as "Feynman photons"

As an illustration Fig.1, shows a single photon oscillating as a standing wave between two points with the approach of an interloping external photon. On each cycle there is a new set of paths going both ways, and thus there is a multi trip averaging of trajectories for a single photon. Lorentz principles allow only free photons having velocity components in opposite directions to interact [8].

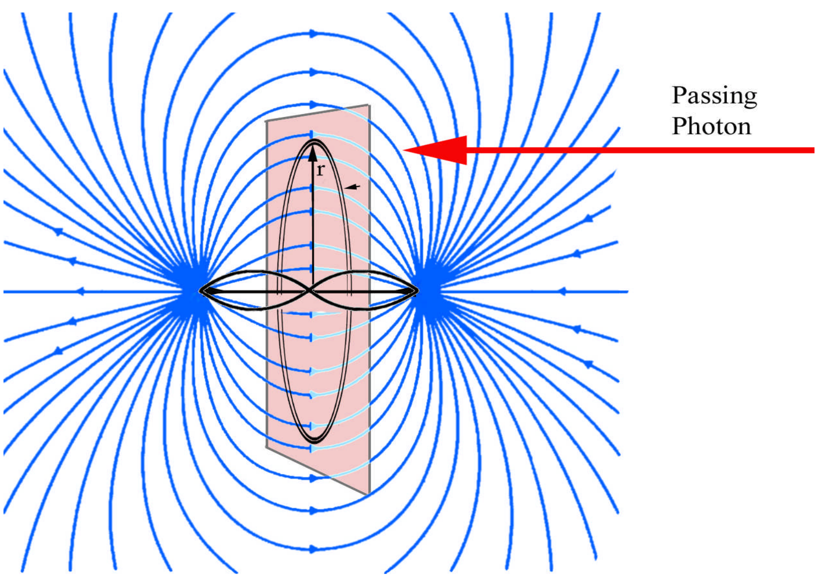

Fig 1 some of the possible Feynman paths for a photon oscilating between two points.

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]. This is a central problem to the issue and accurate results await further developments in QFT

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. A presentation of this was by K, Bliokh, et.al [12], showing a radial probability density proportional to 1/r

$$\psi^{*}\psi = \mathbf{P}\left(r_{\perp}\right) = \frac{k}{r} \tag{2}$$

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 it is apparent that the instantaneous transfer of energy requires the physical carrier of the energy of the photon to be very small.

Propositions

1

The change in the speed of light on passing through a volume of space containing photons is proportional to the probability of a collision with a photon in that volume of space.

From Eq.(1), this is:

$$\frac{\Delta c}{c_0} = \Delta P \rightarrow \int n\sigma \, dx \tag{3}$$

In the integral, n is the number density and σ is the photon-photon cross section.

2

The electromagnetic wave associated with the photon is only the probability amplitude of the location of the photon and the radius is the Compton radius $\lambda\!\!\!^{-}_{PH}$, *and has no energy density.*

The Energy and momentum of a photon is contained within the Planck radius, $\lambda\!\!\!^{-}_{PL}$. *The transfer of energy and momentum by a photon is by the probability of interaction with its Planck cross section* $\lambda\!\!\!^{-2}_{PL} = \sigma_{PL}$

Specifics

Photon location probability radius:

$$\lambda\!\!\!^{-}_{PH} \tag{4}$$

Photon radius = Planck length:

$$\lambda\!\!\!^{-}_{Ph} = \lambda\!\!\!^{-}_{PL} = \sqrt{\frac{G\hbar}{c^3}} \tag{5}$$

The cross section of the photon:

$$\sigma_{PH} = \lambda\!\!\!^{-2}_{PL} = \frac{G\hbar}{c^3} \tag{6}$$

The energy density for the photon within the Planck volume:

$$\rho_{PH} = \frac{\hbar\omega}{\lambda\!\!\!^{-3}_{PL}} = \frac{\hbar c}{\lambda\!\!\!^{-3}_{PL}\lambda\!\!\!^{-}_{PH}} \tag{7}$$

If a photon is passing within the Compton radius of a second photon, the probability of scattering for the passing particle is proportional to the ratio of the cross section of the Planck particle to the Compton area.

$$P_{\gamma\gamma} = \frac{\lambda_{PL}^2}{\lambda_{PH}^2} = \left(\frac{\sigma_{PL}}{\sigma_{PH}}\right) \quad (8)$$

Rational

A photon as proposed, (Proposition 2) the size of the Planck particle, can transfer its total energy to an electron of atom instantaneously is consistent with observation. Such a transfer of energy is consistent with a quantum measurement, in that it destroys the future probability of the photon location everywhere, (i.e. the electromagnetic wave) without a violation of relativity. The frequency and wavelength of a photon is only an indicator of the energy.

If a photon intersects a second photon within its location probability distribution $r < \lambda_{PH}$, then the probability of scattering with the Planck sized particle λ_{PL}^2, inside that distribution is the ratio of the cross section of the Planck particle to the area of the distribution λ_{PH}^2.

$$P_{\gamma\gamma} = \frac{\lambda_{PL}^2}{\lambda_{PH}^2} \quad (9)$$

The photon-photon definitions and interaction proposed here could be more formerly cast, in the quantum mechanical S scattering matrix incorporating the Wigner-Smith time delay of the expectation value of the wave packet, but the approach presented here is intuitive, and the same assumptions will yield the same results.[15-20]

Feynman Photon Probabilities and Interaction

Vacuum Polarization

The first interaction between the Feynman photons and an interloping photon that comes to mind is the vacuum Polarization, which is at least twenty orders of magnitude greater than the effect of the proposed scattering and the effects odgravitation [21]. The interaction of the photon electromagnetic field, with static fields and other photons with strength enough to produce Electron-Positron pairs known as Vacuum Polarization is the most widely studied and developed Photon-Photon interaction.

Vacuum Polarization however is a vector effect, related to the probability density of the electromagnetic fields [22]. In the aggregate of a large number of random photon sources, the vector directions and phases cancel yielding an absence of any effect, and thus this effect is not likely to play a role in gravitation. (See appendix I for a more extended discussion of this)

Probability of Feynman photon location

There is current no direct way of calculation the probability density of the Feynman particle path or particle density. By the use of methods developed by Aharonov, Albert, and Vaidman related to "Weak Values" and "weak measurements", there is however some theoretical as well as experimental indication of the photon probability density associated with the actions paths. Although there are many that have worked on this particular issue a definitive theoretical result awaits further development. This paper will take note of the theoretical and experimental work of K. Bliokh *et al.* [12] in arrival at a radial probability density.

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. Bliokh subsequently showed that the local momentum density of a photon can be represented by the Poynting vector normalized by the energy density and thus can represent the probability density of the photon perpendicular to the trajectory. This normalized probability density of the field is shown to be proportional to 1/r. This is not an unreasonable relation and fits the value developed by others, using other methods.

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:

$$\mathbf{P}(r_{\perp}) = \psi^{*}\psi \rightarrow k/r \qquad (10)$$

The value of k in Eq.(10), 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, and the relation can only be valid for values of $r >> ƛ_{PH}$. The value near the classical tract is not linear in r, it has a higher probability near $ƛ_{PH}$ and the integral over all space cannot exceed one.

For the change in c induced by the Path Integrals from the trapped photon to match the change in c induced by gravitation, the value of k must be set to $k = 2ƛ_{PH}$, thus the probability density of the Feynman photons would have to be:

$$P_F = \frac{2ƛ_{PH}}{r} \qquad (11)$$

This is not an unreasonable nor unexpected value, but only new methods in QFT will be able to accurately evaluate this constant.

The Interaction between an Interloping Photon and a Feynman Photon

From Eq.(3), Eq.(8), and Eq(11), The change in the velocity of light for a photon passing a confined photon with mass of $m = E/c^2$ can be found by multiplying the change in c as the result of being inside the probability distribution of the photon, times the probability of the photon being there, Eq.(11), giving the total probability of the change in c at a distance r from the reciprocating photon.

$$\frac{\Delta c}{c_0} = \Delta P = P_{\gamma\gamma} P_F = \frac{ƛ_{PL}^2}{ƛ_{PH}^2}\frac{2ƛ_{PH}}{r} = \frac{2\mu}{r} \qquad (12)$$

This is the same change in c as determined for gravitation in Eq.(1).

Not to be overlooked however, is the fact that k from Eq.(10), was set to get this result.

Ambient Value of c in the Universe

If Eq.(12), is correct then it should be applicable to all gravitation, and therefore it should not produce contrary results if applied to the universe as a whole. Using estimates of the size and mass of the universe the ambient value of c can be calculated, and shown to be consistent with the value of c[24] (See Appendix II), the results is:

$$\frac{\Delta c}{c_0} = \sum_n \frac{\lambdabar_{PL}}{\left(\lambdabar_{PH}^2\right)_n} \frac{\left(2\lambdabar_{PH}\right)_n}{r_n} = \frac{G}{c_0^2} \frac{M}{R/2} \approx 1 \quad , \qquad (13)$$

Thus showing that the change in c induced by the mass distribution of the universe is equal the ambient value. This is not proof of concept but a contrary value would not give confidence in the proposed relations.

Conclusion

General Relativity is curved multi-space construct without energy localization, and has not yet been proven to be compatible with QFT. This development has shown a path to connect gravitation, and QFT through principles totally consistent with Quantum Mechanics, and with methodology much less onerous than a unified field concept.

The assumptions regarding the nature the photon and its interaction with other photons are not out of bounds with experimental evidence, and the interaction of photons with probability amplitudes fits what is known of quantum interactions.

The postulation of the energy carrying kernel of the photon being the size of the Planck particle is a little unusual, but it fits better than the electromagnetic wave being the energy carrier. This is true both from the perspective of general relativity and quantum mechanics.

The absence of accurate QFT calculations of the Feynman particle probability amplitudes creates an obstacle to finalization, but few would doubt that there is some Feynman particle density, and that it would have some effect on passing photons. Finding the value to be consistent with the value necessary to induce a change in c equivalent to the effect of gravitation would settle the issue.

This theory allows the photon not only to serve as the gauge boson and force carrier for electromagnetism but also to be the force carrier of gravitation.

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Appendix I

Vacuum Polarization Photon-Photon Interaction

As a photon passes an oscillating photon path as defined above it is expected that there will be a probability of interaction between the passing photon and the Feynman photons. The most significant interaction for two interaction photons is the vacuum polarization defined by the Schwinger limit:

$$\frac{\Delta c}{c_0} = \frac{\bar{E}^2}{E_S^2} = \frac{\left(E^2 + B^2 + 2|S|\right)}{E_S^2} \qquad (2,1)$$

The last term is the electromagnetic field density in terms of the electric magnetic, and Poynting vectors for a collision of two photons. E_S^2 is the Schwinger density and the fields are the sum of the electromagnetic vectors of the two photons[25].

From Y. Lang, et. al. [26] and R. Battesti, et. al. [27] the Vacuum Polarization photon cross section for photon-photon collision in the low energy approximation for unpolarized light, the total cross section can be written as:

$$\sigma_{\gamma\gamma\to\gamma\gamma} = \frac{973\alpha^2}{10125\pi}\frac{\bar{\lambda}_e^6}{\bar{\lambda}_{PH}^8} \qquad (2,2)$$

This cross section is dependent of the mutual energy of the interaction photons thus any global effect of the speed of passing photons would be dispersive and inconsistent with a gravitational induced change in c. For a 1 ev photon this is about 1.34e-61 cm^2 for a electron mass equivalent photon this would be about 9.0e-40 cm^2

The source being considered, however are the Feynman photons of atoms, for which a mass source is a large number of randomly oriented positions and phases, and as the number of randomly oriented sources goes large, (6.0 $\times$ 10^{23} Avogadro's number), the sum of the vacuum polarization inducing electromagnetic vectors vanish.

$$\begin{aligned} E &= \sum_n E_n \sin\theta_n \to 0 \\ B &= \sum_n E_n \cos\theta_n \to 0 \end{aligned} \qquad (2,3)$$

And the effects of vacuum polarization vanishes also vanish.

Vacuum polarization is a vector phenomenon, and just like an electric field can effectively cancel everywhere. The existence in space of the Feynman particles is a probability density that is conserved. Unlike Vacuum Polarization the accumulation of the probability density for massive particles is conserved regardless of the relative phases or size.

Appendix II

Cosmological c

From Eq.(13), the relation for the change in c in propinquity with a mass particle can be summed over all the particles in the observable universe to give the ambient value of c in the universe. From D. Valev [24], the value of this can be estimated to be:

$$M \approx \frac{c^3}{GH} \approx \frac{c^2 R}{G} \qquad (3,1)$$

R is the radius of the universe, H is the Hubble constant and G is the Newton gravitation constant. This can be written as:

$$\sum \frac{mG}{c^2 R} = 1 \qquad (3,2)$$

By presuming the average distance is about half the radius of the universe the value of c for the universe Eq.(12), can be found by summing over all the particles as:

$$\frac{\Delta c}{c_0} = \sum_n \frac{\bar{\lambda}_{PL}}{\left(\bar{\lambda}_{PH}^2\right)_n} \frac{\left(2\bar{\lambda}_{PH}\right)_n}{r_n} = \frac{G}{c_0^2} \frac{M}{R/2} \approx 1 \qquad (3,3)$$

M is the mass of the universe R is the radius and R/2 is on the order of the average distances r_n to each of the particles. Eq.(3,3), matches Eq.(3,2) if $\Delta c \approx c_0$, indicating relation Eq.(12), which applies to the change in c induced by a single particle, also applies to the total of the mass particles in the universe and sets the ambient level of c.