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PHOTON – GRAVITON INTERACTIONS

[1*]Emea, Ajike Eziyi, [2]Nnanna, Lebe, [3]Nwasuka, Stanley C., [1]Orji, Obinwa and Okere Chukwuemeka.

[1]Department of Physics, Clifford University, Owerrinta, Abia State, Nigeria.

[2]Department of Physics, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria

[3]Department of Mathematics, Clifford University, Owerrinta, Abia State, Nigeria.

[*]**Corresponding Author. Email:** emeeajike@gmail.com

ABSTRACT

In theories of quantum gravity, the graviton is a hypothetical quantum of gravity, an elementary particle that mediates the force of gravity. There is no complete quantum field theory of gravitons due to an outstanding mathematical problem with renormalization in general relativity. This research work is aimed at finding the possible mathematical relationship between photon particle and graviton. Analytical method was used to find a model that may possibly relate Photon to graviton. After some analyses, the mathematical relation, $Eg = \frac{-Gm_o h\nu_g \hbar^2 k^2}{rE_\gamma^2}$ was obtained. Where G is the gravitational constant, m_o is the mass source, h = Planck's constant, ν_g is the graviton frequency, E_y is the photon energy, K is the wave factor, $\hbar$ is the modified Planck's constant, z is the Redshift and t is the time. This shows that gravity and photon are related according to $E_g \sim E_y^{-2}$. The mathematical relation obtained could possibly explain the scattering of photons from a massive body which converts the energy into gravity force, which in redshift (photon moving away from massive bodies), there is a decay of virtual photons into positive and negative sun quantum energies, further decay leads to the formation of color charges and magnetic colors, upon the loss of these colors, the photon becomes the graviton. So the equation showed the scattering of virtual photons to give graviton. The significance of the negative sign indicates the decaying of the negative photon; this suggestively indicates an inverse relationship between the two quantities.

Keywords: photon, graviton, energy, interaction, frequency, gravity

1.0 Introduction:

The graviton is a hypothetical quantum of gravitational energy that is viewed as an elementary particle that mediates the gravitational force in theories of quantum gravity. Due to persistent mathematical issue with renormalization in general relativity, there is no comprehensive quantum field theory of gravitons. The graviton is a massless state of a fundamental string according to the string theory, which is thought to be a consistent theory of quantum gravity. Because the gravitational force has an extremely vast range and seems to move at the speed of light, the graviton is predicted to have no mass. Since the stress-energy tensor, a second-order tensor, is the source of gravitation, the graviton must be a spin-2 boson (as opposed to the spin-1 photon of electromagnetism, whose source is the four-current, a first-order tensor) (Misner*et al,* 1973). A massless spin-2 field would couple to the stress-energy tensor in the same way that gravitational interactions do, which further demonstrates that any massless spin-2 field

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would produce a force identical to gravity. (Misner *et al*, 1973). It is well known that gravitational contact unites all matter in the universe, regardless of its form, whether it is solid, liquid, gaseous, or plasma particles with or without electrical charge, or photons. Mass and gravitation interact in some way.

Gravitational interactions are produced by mass interactions. It is an established fact supported by observations (Gibbon and Hawking, 1993; Froning, 2004). This suggests that the matter's underlying structure has a "common cause." This "common cause" is a general factor that can also be a type of matter that is present in all the scenarios mentioned and is located inside the structure of matter.

On the other hand, gravitational force appears to exist anywhere there is matter, and it acts in a manner that is proportionate to the density of that matter, according to observations of its appearance and method of operation. We can conclude that each particle of matter corresponds to a gravitational force proportional to its mass by drawing an analogy between matter and gravitational force.

Gravitational Wavelength and Energy

Despite the fact that gravitons are thought to have no mass, they would nevertheless possess energy, just like any other quantum particle. Furthermore, massless particles also carry gluon and photon energy. The factors that might determine the energy carried by a single graviton and its graviton energy are unknown. Alternately, the study of gravitational waves produced a new upper bound on the mass of gravitons, if they are substantial at all. A graviton with a Compton wavelength of at least 1.6×10^{16} m, or roughly 1.6 light years, would have a mass of no more than $7.7 \times 10^{-23} eV/c^2$ (Abbot 2017). The Planck-Einstein connection, which links electromagnetic wavelength to photons, is used to compute the relationship between wavelength and mass-energy.

$$E = \frac{hc}{\lambda} \quad (1)$$

Where E is the energy of the photon, c is the speed of light, h is Planck's constant (6.62×10^{-34}) and λ is the electromagnetic wavelength.

Since the graviton's Compton wavelength is not the same as the gravitational-wave wavelength, if gravitons are the quanta of gravitational waves, then the relationship between wavelength and corresponding particle energy for gravitons differs fundamentally from that for photons. Instead, the gravitational wavelength for the GW170104 event, which is approximately 1,700 km, times smaller than the lower-bound graviton Compton wavelength. In their report, (Abbott *et al*., 2017) didn't go into further detail about where this ratio came from.

The Photon and gravitational field

Think about a redshift, which is the stretching of photons released by galaxies as a result of the recession of the emitting object. The separation between these galaxies widens due to cosmic expansion. Any frequency shift that can be demonstrated to result from an acceleration of a radiating source may also be created by the proper gravitational field, according to the principle of equivalence from general relativity (Eziyi *et al.*, 2020). Suppose that a photon with energy given in equation 2

$$E = hV \quad (2)$$

is emitted as a result of receding of objects such as galaxies, assuming that the photon has relativistic mass $m = \frac{hV}{c^2}$, since it's under the influence of gravity, the weight of the photon is given as $\frac{hV}{c^2} g$ where g is the acceleration due to gravity. In gravitational field, when a photon falls through a distance x towards the earth, according to the law of conservation of energy as highlighted by (Javadi*et al.*,2016)

$$E = hV + mgX \quad (3)$$

From equation (3),

$$E = hV(1 + \frac{gX}{c^2}) \quad (4)$$

Quantum Mechanics of Photons

Without a doubt, photons are quantum particles, and the principles of quantum physics apply to

how they behave. This implies, among other things, that wave functions can adequately characterize their (pure) states. The sum of two wave functions explains a permitted state of the photon in quantum mechanics, which abides by the superposition principle. The right-handed and left-handed photons are described by two different representations of the Poincare group, hence one cannot combine the wave functions of two distinct photons. Similar to this, it is commonly known that one cannot directly add two distinct vector components, such as the x and y components. Then, how can one create states with linear polarization or, more generally, with an elliptical polarization, by superimposing photon wave functions?

Dark Photon

The dark photon is a spin-1 boson connected to a potential massless U (1) gauge field that exhibits electromagnetism-like properties (Carrol, 2008). However, it might be huge and unstable, rapidly decompose into electron-positron pairs, and interact with electrons. Sean M. Carroll and colleagues made the initial suggestion for the dark photon in 2008, explaining the "g-2 anomaly" in experiment E821 at Brookhaven National Laboratory (Bennet*et al.*, 2006). However, certain experiments, like the PHENIX detector at the Relativistic Heavy Ion Collider at Brookhaven, rejected it (Walsh and Karen, 2015). A new light spin-1 boson 34 times heavier than the electron was proposed in 2015 by the Institute for Nuclear Research of the Hungarian Academy of Sciences in Debrecen, Hungary (Cartlidge, 2016). This boson decays into an electron and positron pair with a combined energy of 17 MeV. It was proposed that the m-2 muon anomaly may be explained by an X-boson with a mass of 16.7 MeV. (Feng*et al.*, 2016; Cartlidge, 2016).

Dual Photons

The dual photon is a theoretical elementary particle in theoretical physics that is predicted by several theoretical models (Bakas, 2010; Bilokh et al., 2013) and some findings of M-theory in eleven dimensions. It is a dual of the photon under electric-magnetic duality (Tong and Lambert, 2008). It's been established that adding a magnetic monopole to Maxwell's equations causes a singularity to appear. The inclusion of a second four-vector potential, known as dual photon, in addition to the standard four-vector potential, photon, is the only way to prevent the singularity (Singleton, 1996). It was also discovered that the electromagnetic standard Lagrangian is not dual symmetric, leading to dual-asymmetric issues with the energy-momentum, spin, and orbital angular-momentum tensors. A dual-symmetric electromagnetic Lagrangian with a self-consistent separation of the spin and orbital degrees of freedom has been developed (Bliokh*et al.*, 2013) to address this problem. The dual electromagnetism naturally generates self-consistent conservation rules, according to the Poincaré symmetries (Bliokh*et al.*, 2013).

Gravitons, Photons and their Interactions

Numerous academic studies on gravitons, photons, and their interactions have been published. According to (Shlomo 2017) who wrote a paper titled "The Graviton," the gravitational space wave that was observed and predicted by general relativity does not have any theoretical or empirical support for the existence of quanta, but some researchers believe that these quanta are the "force-carrying" intermediaries between masses, which he called gravitons. He put up a case for the existence of gravitons by proposing a model of the hypothetical graviton and relating it to quantized gravitation.

In 2016, Javadi and Forouzbakh looked at the graviton exchange process between objects/particles. They believed that the standard model's previous characterization of the graviton—an elementary particle that mediates the gravitational force within the framework of quantum field theory—was inadequate to capture the essence of the quantum gravity's mechanism and theory. The definition states that the graviton, if it exists, must be a spin-2 boson and is predicted to be massless (because the gravitational force appears to have an infinite range). The fact that the stress-energy tensor, a second-rank tensor, is the source of gravitation causes the spin to result.

There is a need for a new definition of graviton because the gravity problem in the standard model cannot be resolved by the current graviton theory.

Returning to the behavior of a photon in a gravitational field, consider a photon that is falling in a gravitational field. Gravitons behave like charged particles and change color when they interact with photons due to gravity. The electromagnetic energy is made up of these color charges and magnetic colors. Graviton density increases when it moves from a lower layer to a higher layer. They presumptively believed that the graviton was not a solid sphere with any appreciable influence. Because the graviton conveys the force of gravity, additional gravitons can absorb it (in general graviton absorb each other and combine). They used the photon (electromagnetic energy) relation to define graviton and the graviton relation to define virtual photons. These relationships explained the interdependence and unification of electromagnetism and gravity (Barry, 2006). Barry asserted in 2006 that graviton interactions with matter are computed concurrently with a well-known photon scenario. He examined how graviton scattering amplitudes can be factored into a mixture of well-known electromagnetic forms in his study. The Helicity approach was used to directly assess the cross sections for various relations (Barry, 2006).

How particles like the photon absorb gravitons was studied by Hossein*et al*. In their research, they employed the color charge notion from photon characteristics to explain how photons absorb gravitons. The electromagnetic energy was the basis for their hypothesis, which they called "creating particles of Higgs" or CPH theory (Hossein*et al.*, 2008). Alves et al. examined the graviton's mass and the conservation of energy-momentum in 2007. They paid particular attention to Visser's 1998 bi-metric theory of gravitation with heavy gravitons. They conducted their research using the Minkowski metric as a foundation and proposed an interpretation of the energy-momentum conservation in Visser's theory that is consistent with the equivalence principle and recovers special relativity naturally in the absence of gravitational sources. Despite the fact that they did not provide a general demonstration for their theory, they were able to demonstrate its viability in the straightforward scenario of a universe dominated by planes and dust. (Alves*et al.*, 2007).

Steven examined exclusively S-matrix theoretical evidence for the equivalence of gravitational and internal mass as well as the conservation of charge (defined by the strength of soft photon interactions). His presumptions included Lorentz invariance, the S-pole matrix's structure, the zero mass, numbers 1 and 2, and graviton and photon zero masses. Additionally, he demonstrated that Lorentz invariance alone necessitates the S-matrix for the emission of a massless particle with any integer spin in order to satisfy the "mass-shell gauge invariance" condition. He then went on to explain why there are no macroscopic fields corresponding to particles with spins of three or higher (Steven, 1964).

A universal approach for characterizing the polarization effect of an incident photon (γ) or graviton (g) beam and for figuring out the polarization of an outgoing photon (γ) or graviton (g) beam in any reaction was described by (Hee and Seong2015). By investigating the four processes, $(\gamma, g) + S \rightarrow (\gamma, g) + S$ with a heavy and charged spinless particle S in the context of linearized gravity with electromagnetic and gravitational gauge invariance, their methodology was explicitly demonstrated. The isospin for the particle is connected to other quantum numbers by:

$$\frac{q}{e} = I_3 + \frac{s+B}{2} \qquad (5)$$

Where, I_3 is the projection of isotopic spin, S is the strangeness, B is the baryon number and q is the charge ($\frac{q}{e}$ used to make it dimensionless).

The photon,γ, can also be calculated by

$$\gamma = S + B = 2(Q - I)$$

(6).

The photon has a negative intrinsic parity of -1, spin of 1 and isospin of zero.

Alternative theories of gravity were examined by (Jose *et al.*, 2018) in relation to graviton-photon oscillation in the presence of an external magnetic field. They took into account the impact of an electromagnetic radiation effective refractive index. They developed the first method to account for the alteration of gravitational wave predictions in different theories of gravity in the graviton-photon mixing phenomenon.

Secure communication, quantum computation, quantum simulation, and quantum metrology are just a few of the applications of quantum information technology that have recently gained a lot of interest. Due to its de-coherence tolerance, photons are one of the most significant physical quantities in these applications. Reviewing developments in single-photon/entangled-photon emitters and their applications, heralded single-photon sources using parametric down conversion and their use in quantum key distribution, highly indistinguishable heralded single-photon sources, fiber-coupled solid-state single-photon sources, and ultra-broad band-frequency entanglement generation, (Shigeki and Takeuchi, 2004) demonstrates the interactions of the photon, its generation, and various applications.

A straightforward new method that offers information on the processing time, energy density, and length of optical pulses involved in electron-photon interactions. He came up with a connection between processing time and energy. It has been determined that the processing time is inversely related to the amount of energy used in the particular procedure. That is a quality of material that is intrinsic. (Tibor, 2009).It is within the purview of this research work to derive the mathematical relationship between the photon particle and the graviton and to also show how these particles can undergo scattering or absorption of each other.

MATERIALS AND METHOD

3.1 The Energy of a Photon in a Vacuum

The analytical method was used to obtain the result. When photon travels in the medium, the energy of photon can be divided into kinetic energy and potential energy of that photon. This, comply with the principles of conservation of energy which states that "the total energy of an isolated system remains constant". This means that energy can neither be created nor destroyed but can only be transformed or transferred from one form to another. When photon travels at a speed of light where the magnetic and electric vectors of the photon are perpendicular to each other, the photon possess full kinetic energy and when it is brought to rest the total energy of the photon is transformed into potential energy (E_p).

This is also called the rest energy mass (Loudon, 2005).

The total energy of the photon is given by the Lagrangian equation (4) (Loudon, 2005).

$$E_t = E_k + E_p \qquad (7)$$

whereE_t is the total energy of the photon, E_k is the kinetic energy of the photon and E_p is the potential energy of the photon. Assuming that the photon is travelling at the speed of light where the magnetic and electric vectors are perpendicular to each other then the total energy of the photons becomes:

$$E_t = E_k \qquad (8)$$

Equation (8) appears so because the energy will solely become kinetic energy since the potential energy, E_p is zero.

Let the kinetic energy of the photon be given as:

$$E_K = mc^2 \qquad (9)$$

where m is the relativistic mass of the photon, and c is the speed of light.

It implies that equation (8) becomes:

$$E_t = mc^2 \qquad (10)$$

We recall that the amount of energy assigned to each photon or the quantized energy of photon

(Planck's-Einstein equation) is given as (Tibor, 2009).

$$E_\gamma = hV_\gamma \qquad (11)$$

If we introduce n number of photon particles, we then have:

$$E_\gamma = nhV_\gamma (12)$$

where, E_γ is the energy of the photon particle, h, is the Planck's constant given as 6.62 $\times 10^{-34} js$ and V is the frequency of photon particle in (Hz). Equating equations (10) and (12) we have:

$mc^2 = nhV_\gamma$ and V_γ is given by:

$$V_\gamma = \frac{mc^2}{nh} \qquad (13)$$

Substituting equation (11) into (13) we obtain:

$$E_\gamma = \frac{mc^2}{n} \qquad (14)$$

Equation (3.8) is the energy of a photon with rest mass in vacuum.

Moreover, the frequency, V_γ, of a photon is determined from the measurement of the wave-length, λ, of radiation using the equation:

$$V_\gamma = \frac{c}{\lambda} \qquad (15)$$

where c is the velocity of the photon and λ is the wavelength.

The frequency or wavelength is a concept relevant to a wave and quantum having the isolated energy hV_γ is the concept of a particle hence photon exihibits dual character.

Supposing a photon with velocity, c, is travelling in the positive x-direction with an angular frequency, ω, then the propagation constant is obtained as:

$$\omega = 2\pi V_\gamma \qquad (16)$$

$V_\gamma = \frac{\omega}{2\pi}$, also recall that $V_\gamma = \frac{c}{\lambda}$. We then have that, $\frac{c}{\lambda} = \frac{\omega}{2\pi}$. Therefore, $\omega = \frac{2\pi c}{\lambda}$ but $\frac{2\pi}{\lambda} = k$ where, k, is the propagation constant of the photon, this implies that

$$k = \frac{\omega}{c} = \frac{2\pi f_\gamma}{c} \qquad (17)$$

Substituting equation (13) into (17) we obtained

$$k = \frac{2\pi mc}{nh} \qquad (18)$$

But $\frac{h}{2\pi} = \hbar$ which implies that, $\frac{2\pi}{h} = \frac{1}{\hbar}$. Therefore;

$$k = \frac{mc}{n\hbar} \qquad (19)$$

where $\hbar$ is the modified Planck's constant which is the measure of the change undergone by the amplitude and phase of the photon as it propagates in a given direction (Wang, 2016).

Equating equations (14) and (19) we obtained

$$E_\gamma = \hbar kc \qquad (20)$$

Equation (20) means that the energy of photon is the product of the modified Planck's constant, propagation constant and the speed of light.

The photon has both kinetic and potential energy when it moves through a medium at a speed slower than the speed of light. Only kinetic energy determines the photon's momentum, which is determined by (Garrison, 2014).

$$P_\gamma = \frac{E_k}{c} \qquad (21)$$

where P_γ is the momentum of the photon, E_k is the kinetic energy of the photon and c is the velocity of the photon. But recall from equation (11) that $E_\gamma = hV_\gamma$. Equation (21) will then be:

$$P_\gamma = \frac{hV_\gamma}{c} \qquad (22)$$

Equation (22) means that the momentum of photon is directly proportional to its frequency and inversely proportional to the speed of light of the photon in the medium.

3.2 Gravitational Energy and Momentum

Despite the fact that gravitons are thought to have no mass, they would nevertheless have energy just like any other quantum particle. Particles with no mass are photons. Uncertainty surrounds the variables that could be used to calculate the energy or volume of a single graviton (Abbott *et al.*, 2017).

Alternatively, if gravitons are massless at all, the analysis of gravitational wave yields a new

upper bound on the mass of graviton (Abbott *et al*, 2017). Assuming a massive graviton in a gravitational field, the gravitational force acting on the graviton is given by

$$F = \frac{Gm_o m_g}{r^2}$$

where G is the gravitational constant, assuming that m_o is the source mass and m_g is the mass of the graviton and r is distance between the two masses. Integrating the equation above (i.e 23) we obtained:

$$E = Gm_o m_g \int_{\infty}^{r} r^{-2}\, dr \qquad (24)$$

Therefore, the energy of the graviton is obtained to be:

$$E_g = -\frac{Gm_o m_g}{r} \qquad (25)$$

From equation (21), the momentum of graviton P_g is dependent on the kinetic energy given

$$P_g = \frac{E_k}{v} \text{ but } E_g = -\frac{Gm_o m_g}{r} \text{ therefore;}$$

$$P_g = -\frac{Gm_o m_g}{rv} \qquad (26)$$

Where E_g is the energy of the graviton and v is the velocity of the particle.

If the concept of "redshift" is introduced which is a phenomenon where electromagnetic radiation from an object undergoes an increase in wavelength, then for a large value of redshift, Z, (when the speed of the particle is comparable with the speed of light) we have

$$Z = \frac{v}{c} \qquad (27)$$

where Z is the redshift, c is the speed of light and v is the speed of graviton.

From equation (27), we obtained:

$$v = Zc \qquad (28)$$

Substituting (28) into (26) we then have:

$$P_g = -\frac{Gm_o m_g}{rzc} \qquad (29)$$

where, r is the distance between the graviton particle and the source.

Therefore the energy of graviton becomes

$$P_g = -\frac{Gm_o m_g}{zct} \qquad (30)$$

From equation (30) t, represent the time in (seconds)

3.3 Mass of Graviton

From Einstein-planck equation of a massless particle, the energy of a graviton is given as:

$$E_g = hV_g \qquad (23)$$

Also from Einstein's equation and assuming gravitons' speed to be c, the energy of a graviton can also be given as:

$$E_g = m_g c^2 \qquad (32)$$

where m_g is the mass of graviton. Equating (31) and (32):

$$hV_g = m_g c^2$$

$$m_g = \frac{hV_g}{c^2} \qquad (33)$$

Equation (33) is the mass of a graviton with frequency, V_g, planck constant, h, and thespeed of light, c. Substituting equation (22) into (30) we have

$$P_g = -\frac{Gm_o m_g p_y}{zth} \qquad (34)$$

Equation (34) is the momentum of graviton.

3.4 Photon-Graviton Interaction

From equation (20), we can deduce that

$$c = \frac{E_\gamma}{kh}$$

Substituting equation (33) for c in equation (25) we obtain

$$E_g = \frac{-Gm_o hV_g \hbar^2 k^2}{rE_\gamma^2}$$

Equation (36) is the interaction between photon and graviton. It means that the potential energy of graviton is inversely proportional to photon energy if other parameters are assumed constant.

4.0 Discussion of Results

Although photon energy is quantized, under certain conditions, the quantized energy of photon can be sub-divided into the kinetic and the potential energy just as can be seen in equation (7) which gave the total energy of photon as the sum of kinetic and potential energy of that photon. This photon travels with the speed of light, c. When the magnetic and electric components are perpendicular to each

other the photon possesses full kinetic energy of mc^2 since the potential energy is zero as seen in equation (10), where the various parameters used have their different meanings as earlier mentioned. The energy of a quantized photon was given from Plancks' –Einstein equation to be $E_y = h\nu_\gamma$ and the number of photon particles as $nh\nu_\gamma$ as can be seen in equations (11) and (12) respectively. The frequency of the photon was obtained by equating equations (10) and (12) and the energy is dependent on the frequency of the photon quantized.

Equation (36) can be written as

$$E_g \sim E_y^{-2} \quad (37)$$

if other parameters are assumed constant.

This suggestively indicates an inverse relationship between photon and graviton. In equation (37), the energy of the graviton is inversely proportional to the square of the photon's enegy. This supports (Javadi and Forouzbaksh2016) whose findings described the dependency and unity between gravity and electromagnetism which is an inherent property of the photon. Also, the result obtainedis in line with result obtained by(Hossein*et al.*,2008), which is of the fact that in the interaction between gravity and photons, gravitons convert to negative and positive charges and also magnetic color and that these color charges and magnetic color form the electromagnetic energy. However, the result obtained is not in consonance with (Barry 2006) which is of the view that the interactions of gravitons with matter are calculated in parallel with the familiar photon case and that graviton scattering amplitudes can be factorized into a product of familiar electromagnetic forms.The mathematical relation obtained in equation (36) maypossibly explain the scattering of photons from a massive body which converts the energy into gravity force, which in redshift (photon moving away from massive bodies as the objects recedes from each other), there is a decay of virtual photons into positive and negative sun quantum energies. Further decay leads to the formation of color charges and magnetic colors, upon the loss of these colors, the photon becomes the graviton hence the equation showed the scattering of virtual photons to give graviton. The significance of the negative sign indicates the decaying of the negative photon; this suggestively indicates an inverse relationship between the two quantities.

Equation (34) correlates the momentum of graviton and that of photon revealed that in a gravitational field, the momentum of a virtual photon (negative photon) is directly proportional to the momentum of the graviton. The momentum of the massive graviton absorbed during scattering is proportional to the momentum of the photon.

5.0 CONCLUSION

In summary, from the mathematical analysis of the result obtained, it can be understood that graviton energy has an inverse proportionality with the square of the photon energy which balances the creation of graviton from photon scattering. After some plausible assumptions, Analytical method was used to obtain $E_g = \frac{-Gm_o hV_g \hbar^2 k^2}{rE_\gamma^2}$ where E_g is the energy of the graviton, G is the gravitational constant, m_o is the mass of the observer, h is the plank's constant, $\hbar$ is the modified plank's constant k is the wave number, r is the distance apart, V_g is the frequency of the graviton and E_γ is the energy of the photon.This shows that gravity and photon are related according to $E_g \sim {E_\gamma}^{-2}$ and this suggestively indicates an inverse relationship between the two quantities. Equation (36) obtained explained the absorption of graviton from the scattering of photon particles through redshift and the negative sign indicates the decaying of the negative photon to form the graviton.

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