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Motion of Photons in a Gravitational Field of Massive Body

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ABSTRACT
A photon in a gravitational field defined by the accelerates g is found to have a gravitational mass given by a force that is equivalent to the curvature force introduced by Einstein's general relativity. These photons are considered as the radiation emitted by a massive body such as a black hole. A massive body emitting such a radiation develops an entropy that is found to increase linearly with the mass of the massive body, and inversely with the photon mass. Based on this, we investigate detection of motion of photons in gravitational field of massive body using the General Relativity theory and Dynamical Theory of Gravitation. Thus, using supporting theoretical evidence from the photon gravitational effects, light bending near the Sun, radar echo from planets and gravitational lensing in addition to gravitational redshift of light, we calculate the acceleration of point mass and photon by gravity. The result indicate that the propagation of gravitational mass of a photon is not zero as oppose to the previous experiments. Instead, it is equal to its quantum mass, which account for the time delay time experienced by radar signals passing near a massive object. Our finding revealed that the created photons could be seen as resulting from quantum fluctuation and our calculations are were found to be analogous to Larmor power of an accelerating charge. We discuss the motion of photon accelerated by gravity and suggest a systematic theoretical framework for future quantum sensing of the motion of photons in gravitational weak field due to, for example, dark matter and gravitational effects of light.

Keywords:
Photons,
Gravitational Field,
Motion,
Redshift,
General Relativity.

INTRODUCTION

Gravity is one of the fundamental forces in study of modern astrophysics, its discovery has shown that light does not travel in a straight line in a gravitational field. This finding is often cited as convincing evidence for supporting the validity of the theory of General Relativity, which proposed that space-time can be curved by the presence of mass (Hartle, 2003). Previous experiments aimed in testing the validity of general relativity were based on determining the gravitational effects of light, including the observation of light bending near a star (Counselman, 1974), gravitational lensing effect of a galaxy (Refregier, 2016), gravitational redshift of electromagnetic wave (M¨ullerm 2010) and discovery of black holes (Wong et al, 2016) All of these experiments involved measuring the behavior of light in a gravitational field. So far, the results of these experiments all claimed to be supportive of the General Relativity. However, there is still a question on whether such interpretation is unequivocal. Are there possible alternative interpretations? Can these observed gravitational effects of photon also be explained based on other physical principles? On the other hand, gravitational phenomena such as the gravitational spectral shift, deflection of light ray in a gravitational field and the time delay experienced by radar signal in the vicinity of the gravitational field could not be completely explained by Newton's dynamical theory of gravitation.

This paper, theoretically investigate the reported gravitational effects of photon in gravitational field based on General Relativity and the Dynamical Theory of Gravitation and further ascertain the motion of such photon in a gravitational field of massive body. We found that, although the rest mass of a photon is zero, its gravitational mass is equal to its quantum mass which is not zero. Thus, it is not surprising that the photon should interact with a gravitational field regardless of the validity of General Relativity. This new understanding can easily explain the results of most of the earlier experiments.

General Relativity Theory: Photons Motion in Gravitation Field

Red Shift

Red shift otherwise known as Einstein shift is the phenomenon in which electromagnetic waves photons travelling out of a gravitational field seem to lose energy. This loss of energy corresponds to decrease in the wave frequency and increase in the wavelength. The opposite effect whereby photons (seem to) gain energy when travelling in to the gravitational well, is known as a gravitational blue shift. The effect was first described by Einstein in 1907 eight years before his publication of the full theory of relativity.

Consider a photon with frequency V in a gravitational field of the Sun A massive body). According to general theory of relativity, The Schwarzschild metric is given by (Ryder, 2009 and Howusu, 1991)

$$ds^2 = \left(1-\frac{2M}{r}\right)dt^2 - \left(1-\frac{2M}{r}\right)^{-1}dr^2 - r^2(d\theta^2 + \sin^2\theta d\varphi^2). \quad (1)$$

It follows that the metric tensors $g_{\mu\nu}$ which are measure of curvature of space-time due to gravity are:

$$g_{00}=\left(1-\frac{2m}{r}\right) \quad (2)$$

$$g_{11}=\left(1-\frac{2m}{r}\right)^{-1} \quad (3)$$

$$g_{22}=r^2 \quad (4)$$

$$g_{33}=r^2\sin^2\theta \quad (5)$$

$$g_{\mu\nu}=0 \quad \text{if } \mu=v \quad (6)$$

Recall the relation between frequency V and proper time τ (Howusu, 2010, and Ryder, 2009)

$$V=\frac{1}{\tau} \quad (7)$$

Let V_1 and V_2 be the frequency of photon at observers point and emitters point respectively (Howusu, 2010and Ryder, 2009)

$$\tau_1=\frac{1}{V_1} \quad (8)$$

$$\tau_2=\frac{1}{V_2} \quad (9)$$

Equations; (2), (8) and (9) yield

$$\frac{1}{V_1}=\sqrt{\left(1-\frac{2GM}{C^2r_1}\right)}t \quad (10)$$

$$\frac{1}{V_2}=\sqrt{\left(1-\frac{2GM}{C^2r_2}\right)}t \quad (11)$$

Dividing (10) by (11) to yield the require formulae

$$Z_{GR,RR}=\frac{V_1}{V_2}=\left(\frac{1-\frac{2GM}{C^2r_2}}{1-\frac{2GM}{C^2r_1}}\right)^{1/2} \quad (12)$$

Equation (12) can be written as

$$Z_{GR,RR}=\left(1-\frac{2GM}{C^2r_2}\right)^{1/2}\left(1-\frac{2GM}{C^2r_1}\right)^{-1/2} \quad (13)$$

Using binomial expansion (Mahajerani, 2020)

$$Z_{GR,RR}=\left(1-\frac{GM}{C^2r_2}\right)\left(1+\frac{GM}{C^2r_1}\right) \quad (14)$$

But according to (Ryder, 2009), the result of terrestrial experiment performed by Pound and Rebka in 1960 were a gamma ray from a 14.4eV atomic transition in ${}^{57}_{26}Fe$ falls vertically in the Earth's gravitational field through a distance of 22.6 metres. Light travel from r_2 to r_1: V_2 is the frequency measured in a laboratory at r_1, and V_1 is the frequency of the radiation emitted at r_2 and received at r_1(Ryder, 2009). Then, with

$$V_1=V_2+\Delta V \quad (15)$$

Then from (12) we have

$$1+\frac{\Delta V}{V}=1+\frac{GM}{C^2}\left(\frac{1}{r_1}-\frac{1}{r_2}\right)$$

Thus,

$$\frac{\Delta V}{V}=\frac{GM}{C^2}\left(\frac{1}{r_1}-\frac{1}{r_2}\right) \quad (16)$$

Since the experiment was conducted on Earth

M⟶ M_e = Mass of Earth

So that

$$r_1=r_E \quad (17)$$

$$r_2=r_E+Z \quad (18)$$

Using equation; (16), (17) and (18) we obtained

$$Z_{GR,RR}=\frac{\Delta V}{V}=\frac{GM_E}{C^2}\left(\frac{1}{r_E}-\frac{1}{r_E+Z}\right)$$

Which simplifies further and gives

$$Z_{GR,RR}=\frac{GM_E}{C^2}\left(\frac{r_E+Z-r_E}{r_E(r_E+Z)}\right) \quad (19)$$

Eliminating Z in the denominator of parenthesis for been too small when compare to r_E, this yield

$$Z_{GR,RR}=\frac{GM_E}{C^2}\left(\frac{Z}{r_E^2}\right) \quad (20)$$

Equation (20) is red shift formulae as predicted by Einstein

Where; $Z_{GR,RR}$= Red Shift in General Relativity by Ryder, r_E = Radius of the Earth

M_E= Mass of the Earth, G= Gravitational constant

Bending of Light in Gravitational Field

According to General Relativity, a light ray arriving from the left would bend inwards such that its apparent direction of origin, when viewed from the right, would differ by an angle α. The deflected angle whose size is inversely proportional to the distance of the closest approach of the ray path to the centre of mass.

The differential equation which describe the propagation of light in a gravitational field of the Sun is given by (Howusu, 1991, Ryder, 2009 and Obaje, 2024)

$$\frac{d^2U}{d\emptyset^2}+U=\frac{3GMU^2}{C^2} \quad (21)$$

According to (Ryder, 2009)

$$U=\frac{1}{r} \quad (22)$$

In order to solve (3.24) we use the fact that $\frac{3GMU^2}{C^2}$ is very small. For simplicity we take $\emptyset_0=0$. Hence, according to (Ryder, 2009); $U=U_0cos\theta$

Substituting $U=U_0cos\theta$ into right hand side of (21), this yield

$$\frac{d^2U}{d\phi^2} + U = \frac{3GMU_0^2\cos^2\theta}{C^2} \quad (23)$$

Now, complimentary function U_c (Ryder, 2009) yield, $U_c = U_0 \cos\phi$. Thus,

$$\alpha = \frac{3GMU_0^2}{2C^2} \quad (24)$$

Then (23) becomes

$$\frac{d^2U}{d\phi^2} + U = \alpha(2\cos^2\theta) \quad (25)$$

Thus, using all the parameters, we obtained

$$\delta_{GR,A} = \frac{4GM}{c^2 r_0} \quad (26)$$

Equation (26) is the bending angle as predicted in General Relativity

Where; $\delta_{GR,A}$ isdeflected angle in General Relativity, G is the Gravitational constant. M is the mass of the sun, r_0 is the radius of the Sun and C is speed of light

Radar Echo from Planets

According to Harana (2004) Radar echo is the electromagnetic energy received after reflected from an object (planet). Thus, we consider the radar ranging time delay as used in Harana, 2004

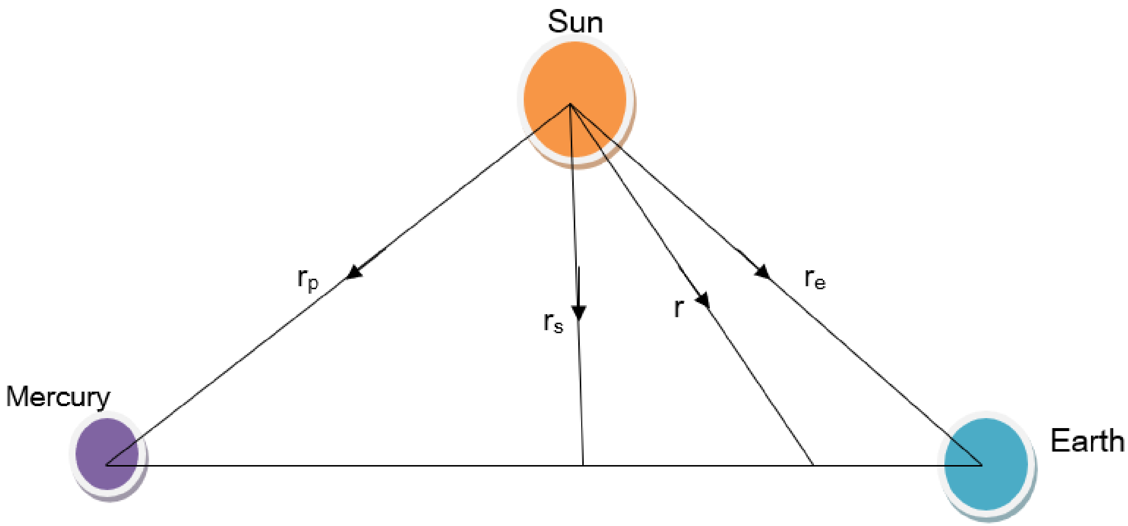

Figure 1: Schematic of the radar ranging time delay experiment (Harana, 2004)

Where; r_p is orbital radius of the planet, r_e is Earth's orbital radius, r_s is the distance of the closest approach taken to be radius of the Sun. Thus, the time delay in the vicinity of the sun is given as (Harana, 2004)

$$t_{GR,H(tot)} = 2\left[\int_0^{\sqrt{r_e^2-r_s^2}} \frac{d\xi}{c'} + \int_0^{\sqrt{r_p^2-r_s^2}} \frac{d\xi}{c'}\right] \quad (27)$$

Also from figure 1 (Harana's, 2004)

$$\xi = \sqrt{r^2 - r_s^2} \quad (28)$$

So that

$$d\xi = \frac{rdr}{\sqrt{r^2-r_s^2}} \quad (29)$$

According to the line element of Dynamic Theory of Gravitation, when light travel in a null geodesic $ds^2 = 0$ and ϕ and θ components are also zero (Harana's, 2004). Thus, the line element becomes

$$0 = c^2\left(1 - \frac{2GM}{c^2 r} e^{-\lambda/r}\right)dt^2 - \left(1 - \frac{2GM}{c^2 r} e^{-\lambda/r}\right)^{-1} dr^2 - 0 \quad (30)$$

Using elimination method (see supplementary Materials) we obtained

$$t_{GR,H(tot)} = \frac{2}{c}\left\{r_e + r_p + \frac{2GM}{c^2} ln\left(\frac{4\, r_e r_p}{r_s^2}\right) + \frac{2GM}{c^2}\right\} \quad (31)$$

Where; $t_{GR,H(tot)}$ = Total time in General Relativity for signal to returned Earth after reflected from planet (Mercury), r_e is the Sun- Earth distance and r_p is the Sun–planet (Mercury) distance

Dynamical Theory of Gravitation: Photons motion in Gravitation field

Red-shift

According to Berry (1989), the recession speed of galaxy is proportional to distance.

Where the recession speed is given by (Berry, 1989)

$$V = \left(\frac{dR}{dt}\right) \quad (32)$$

Here r_1 is a radial coordinate and the distance at cosmological time is given by (Berry, 1989)

$$r = R(t)r_1 \quad (33)$$

Where R(t) is the expansion factor

Now from Hubble's law (32) gives

$$V = HR(t)r_1 \quad (34)$$

Since recession speed is proportional to distance r_1 will cancel

Hence

$$H = \left(\frac{dR}{dt}\right)/R \quad (35)$$

Considering an initial wavelength λ at t = t_0; by the time photon reaches the second speckle, it has been stretched by the factor

$$\frac{R(t)}{R(t_0)} \quad (36)$$

But according to (Berry, 1989) red shift is

$$Z = \frac{\Delta\lambda}{\lambda} = \frac{R(t)}{R(t_0)} - 1 = \frac{R(t)-R(t_0)}{R(t_0)} \quad (37)$$

But by the usual calculus limit, $R(t) - R(t_0)$ =(d$R(t_0)$/dt)(t_1-t_0). Our estimates of the travel time t_1-t_0 is

$$t_1 - t_0 = \frac{R(t_0)}{C} = \frac{r}{C} \quad (38)$$

Then dividing distance by speed. So that

$$Z_H = \frac{(dR(t_0)/dt)(t_1-t_0).}{R(t_0)} = \frac{Hr}{C} \quad (39)$$

Or

$$Z_H = \frac{Hr}{c} \quad (40)$$

It should be noted that this formulae is not valid for large red shifts, where H may change significantly during the duration of the trip whereZ_H is the Hubble red shift and r = D_{min} is the minimum distance between Earth and galaxies

According to (Harana's, 2004), (3.16) can be written as

$$Z_{GR,RR} = \frac{-G}{c^2}\left[\frac{M_{ob}}{R_{ob}} - \frac{M_{em}}{R_{em}}\right] \quad (41)$$

Where; $Z_{GR,RR}$ is the General Relativity Red Shift by Ryder. Thus, the total red shift according to Harana (2004)

$$Z_{DT,H} = Z_H + Z_{GR,RR} \quad (42)$$

$$Z_{DTG,H} = \frac{-G}{c^2}\left[\frac{M_{ob}}{R_{ob}} - \frac{M_{em}}{R_{em}}\right] + \frac{HD_{min}}{c} \quad (43)$$

Where

$Z_{DTG,H}$ is the Red Shift in Dynamic Theory of Gravitation by Harana, $M_{ob}$is the Mass of observer, $M_{em}$is the Mass of emitter, R_{ob} is Radius of observer and $R_{em}$is Radius of emitters

Bending Of Light

Harana (2004) states that:

$$ds^2 = c^2\left(1 - \frac{2GM}{c^2 r}e^{-\frac{\lambda}{r}}\right)dt^2 - \left(1 - \frac{2GM}{c^2 r}e^{-\frac{\lambda}{r}}\right)^{-1} dr^2 - r^2(d\theta^2 + sin^2\theta d\emptyset^2) \quad (44)$$

Thus, from the figure 1 and taking into account the transformations between rectangular and polar coordinates namely (Harana, 2004)

$$r = (\times^2 + y^2)^{1/2} \quad (45)$$

$$cos\theta = \frac{y}{(\times^2+y^2)^{1/2}} \quad (46)$$

$$cos\theta = \frac{y}{r} \quad (47)$$

At grazing point (Harana's 2004, Ryder, 2009)

$y = r_0 = radiusofSun$

So that

$$cos\theta = \frac{r_0}{r} \quad (48)$$

Thus,

$$r = \frac{r_0}{cos\theta} \quad (49)$$

Using the values for dr^2, ×, d × and note that $\emptyset = 0$(see supplementary material) to get

$$ds^2 = c^2\left(1 - \frac{2GM}{c^2 r}e^{-\frac{\lambda}{r}}\right)dt^2 - \left(1 - \frac{2GM}{c^2 r}e^{-\frac{\lambda}{r}}\right)^{-1}\left(\frac{dr}{d\times}\right)^2 d\times^2 - r^2(d\theta^2) \quad (50)$$

Using binomial expansion (Mahajerani, 2020) we have that:

$$c' = c\left[(1 - \frac{2\lambda}{r})\left(1 + \frac{\times^2}{r^2}\right)\right] \quad (51)$$

Expanding and re-arrange (3.139) to get

$$c' = 1 - \frac{2\lambda}{r} + \frac{\times^2}{r^2} - \frac{2\lambda\times^2}{r^3} \quad (52)$$

Substituting the various terms and with additional correction terms, the simplification gives.

$$GM\left(\frac{1}{c^2} - \frac{\pi}{2GM}\right) \quad (53)$$

The terms in bracket of (53) are too small which can be eliminated, hence

$$\frac{1}{c^2} \to 0 \quad (54)$$

$$\frac{\pi}{2GM} \to 0 \quad (55)$$

Hence, using equation (53) and substituting the value, we have that

$$\theta_{DTG,H} = \frac{4GM}{c^2 r_0} \quad (56)$$

Thus, equation (56) is the bending formulae in dynamic theory of gravitation

Where $\theta_{DT,H}$= Bending angle in Dynamic Theory of Gravitation by Harana, M is the mass of the Sun, G is the Gravitational constant, C is the speed of light and $r_0$is Radius of Sun

Radar Echo from Planet

Consider figure 2 for the time for round trip of photon in the vicinity of gravitational field of the Sun.

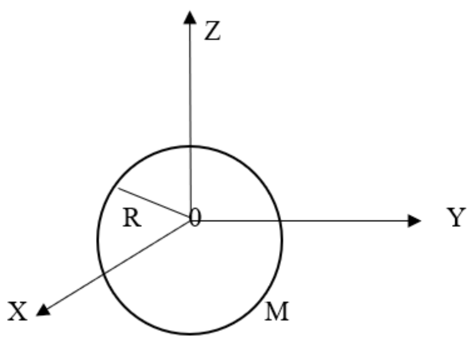

Figure 2: Homogeneous Spherical Massive Body

According to Harana (2024)

$$t_{dyn(tot)} = 2\left[\int_0^{\sqrt{r_e^2-r_s^2}} \frac{d\xi}{c'} + \int_0^{\sqrt{r_p^2-r_s^2}} \frac{d\xi}{c'}\right] \quad (57)$$

On integrating equation (57), we obtained

$$t_{dyn(tot)} = \frac{2}{c}\left[\left(r + 2\lambda lnr + \frac{2\lambda^2}{r}\right)_0^{\sqrt{r_e^2-r_s^2}} + \left(r + 2\lambda lnr + \frac{2\lambda^2}{r}\right)_0^{\sqrt{r_p^2-r_s^2}}\right] \quad (58)$$

Therefore, by substitution of terms (see supplementary material) we obtained

$$t_{dyn(tot)} = \frac{2}{c}\left[r_e + r_p + 2\lambda ln\left(\frac{4\, r_p r_e}{r_s}\right) + \frac{4\lambda^2}{r_s} - \frac{2\lambda^2}{r_p} - \frac{2\lambda^2}{r_p} + 2\lambda\right] \quad (59)$$

Hence, Total Time in Dynamic Theory of Gravitation is given by ((Harana's, 2004). and (Howusu, 1991, 2010).)

$$\Delta T_{DTG,H} = t_{dyn(tot)} - t_{clas(tot)} \quad (60)$$

But

$$t_{clas(tot)} = \frac{2}{c}\left[r_e + r_p + ln\left(\frac{r_e+r_p}{r_p}\right) + \lambda\right] \quad (61)$$

Using (59), (60) and (61) to get

$$\Delta T_{DTG,H} = \frac{2}{c}\left[\frac{4G^2M^2}{c^4 r_s} - \frac{2G^2M^2}{c^4 r_e} - \frac{2G^2M^2}{c^4 r_p} + 2\lambda ln\left(\frac{4\, r_p r_e}{r_s}\right) + 2\lambda\right]. \quad (62)$$

where

$\frac{4G^2M^2}{c^4 r_s}$ (a)

$\frac{2G^2M^2}{c^4 r_e}$ (b)

$\frac{2G^2M^2}{c^4 r_p}$ (c)

(a), (b) and (c) are the correction terms (Harana, 2004) and $\Delta T_{DTGR,H}$ is the total time in Dynamic Theory of Gravitation for signal to return to the Earth after reflecting from planet (Mercury)

RESULTS AND DISCUSSION

Gravitational red shift of electromagnetic wave according to GR

In the literature, the most strong evidence cited for supporting the PE of GR was based on the measurements of the gravitational redshift of electromagnetic waves. According to GR, time can be affected by gravity; and thus, it predicts that there should be a gravitational redshift of light. Here we make use

$$Z_{GR,RR} = \frac{GM_e}{C^2}\left(\frac{Z}{r_e^2}\right) \quad (63)$$

And substituting the values at Z = 22.6m gives

$$Z_{GR,RR} = \frac{GM_e}{C^2}\left(\frac{Z}{r_e^2}\right) = \frac{6.67\times10^{-11} X 5.9736\times10^{24} X 22.6}{(3\times10^8)^2(6.378\times10^6)^2}$$

$$Z_{GR,RR} = 2.5\times10^{-15} \quad (64)$$

Bending of Light in a Gravitational Field of the Sun According to GR

Similarly, Using equation (53)

$\delta_{GR,A} = \frac{4GM}{c^2 r_0}$ (65)

Substituting the values of the parameters into equation (65) we obtained

$\delta_{GR,A} = \frac{4 \times 6.67 \times 10^{-11} m^3 kg^{-1} s^{-2} \times 1.99 \times 10^{30} kg}{(3\times 10^8 ms^{-1})^2 \times 6.96 \times 10^8 m}$

$\frac{53.0932 \times 10^{19}}{60.21 \times 10^{24}} = 8.818 \times 10^{-6}$ (66)

According to (Ryder, 2009)

$\frac{180^0 degre}{\pi rad} \times \frac{60\ minutes}{1\ degree} \times \frac{60\ second}{1\ minute} = 2.06 \times 10^5 sec$ (67)

Hence multiply (66) and (67) to convert to seconds

$8.818 \times 10^{-6} \times 2.06 \times 10^5 = 18.16 \times 10^{-1} = 1.816''$

$\delta_{GR,A} = \frac{4GM}{c^2 r_0}$=$1.816''$ (68)

Radar Echo from Planets According to GR

From equation (58)

$t_{GR,H(tot)} = \frac{2}{c}\left\{r_p + r_e + \frac{2GM}{c^2} ln\left(\frac{4\, r_e r_p}{r_s^2}\right) + \frac{2GM}{c^2}\right\}$ (69)

But

$\frac{2}{c}(r_p + r_e)$=$\frac{2}{3\times 10^8 ms^{-1}}(2.28 \times 10^{11} m + 1.5 \times 10^{11} m)$= 2.52 x 10^{13}sec (70)

This is the Euclidean time. The excess time, or delay is clearly greatest when r_s takes its smallest value, which is the radius of the Sun r_s. In this case

$\frac{4 r_p r_e}{r_s^2} = \frac{4\times 1.5\times 10^{11} m \times 2.28\times 10^{11} m}{(6.96\times 10^8 m)^2} = \frac{13.68\times 10^{22}}{48.4416\times 10^{16}} = 2.82 \times 10^6$ (71)

$ln(2.82 \times 10^5) = 12.55$ (72)

$\frac{4GM}{c^3} = \frac{4\times 6.67\times 10^{-11} m^3 kg^{-1} s^{-2} \times 1.99 \times 10^{30} kg}{27 \times 10^{24} m^3 s^{-3}}$

$\frac{53.0932 \times 10^{19}}{27 \times 10^{24} m^3 s^{-3}} = 1.97 \times 10^{-5} sec$ (73)

Multiplying (72) and (73)

$\frac{4GM}{c^3} ln\left(\frac{4\, r_p r_e}{r_s}\right) = 1.97 \times 10^{-5} m \times 12.55 = 24.7235 \times 10^{-5} sec$ (74)

Finally add (73) and (74) to obtain

$t_{GR,H(tot)}$=$24.7235 \times 10^{-5} sec$ +$1.97 \times 10^{-5} sec$

$t_{GR,H(tot)}$=$2.69235 \times 10^{-5} sec$ (75)

$t_{GR,H(tot)} \cong 2.5 \times 10^{-5} sec$ (76)

Gravitational Red Shift According to the Dynamic Theory of Gravitation

Using equation (41) and substituting the various parameter values, we see that

$Z_{DTG,H} = \frac{-G}{c^2}\left[\frac{M_{ob}}{R_{ob}} - \frac{M_{em}}{R_{em}}\right] + \frac{HD_{min}}{c}$ (77)

$Z_{DTG,H} = \frac{-6.67 \times 10^{-11}}{9 \times 10^{-11}}\left[\frac{5.97 \text{ x } 10^{24}\text{Kg}}{6.37 \text{ x } 10^6} - \frac{3.04 \text{ x } 10^{38}}{25 \times 10^{17}}\right]$

$\frac{(5.6808 \times 10^{17})^{-1} \times 1.89 \text{ x} 10^{22}}{3\times 10^8 ms^{-1}}$=1.11 x 10^{-4}

$Z_{DTG,H}$ = -0.74 x10^{-27}(-120.664 x 10^{18}) + 1.11 x 10^{-4}

$Z_{DTG,H}$= 89.29 x 10^{-9} + 1.11 x 10^{-4}

$Z_{DTG,H}$= 1.1108929 x 10^{-4} (78)

Bending of Light in a Gravitational Field of the Sun According to the Dynamic Theory of Gravitation

Using (56)

$\theta_{DTG,H} = \frac{4GM}{c^2 r_0}$ (79)

Substituting the values into equations (79)

$\theta_{DTG,H} = \frac{4\times 6.67 \times 10^{-11} m^3 kg^{-1} s^{-2} \times 1.99 \times 10^{30} kg}{(3\times 10^8 ms^{-1})^2 \times 6.96\times 10^8 m} = 8.818 \times 10^{-6}$ (80)

Using the value in (80) and converting to seconds

$8.818 \times 10^{-6} \times 2.06 \times 10^5 = 18.16 \times 10^{-1} = 1.816''$

$\theta_{DTG,H} = \frac{4GM}{c^2 r_0} \quad = \quad 1.816''$ (81)

Radar Echo According to the Dynamic Theory of Gravitation

Using (62) by substituting the parameter values, we obtained;

$\Delta T_{DT,H} = \frac{2}{c}\left[\frac{4G^2M^2}{c^4 r_s} - \frac{2G^2M^2}{c^4 r_e} - \frac{2G^2M^2}{c^4 r_p} + 2\lambda ln\left(\frac{4\, r_p r_e}{r_s^2}\right) + 2\lambda\right]$ (82)

$\frac{4r_p r_e}{r_s^2} = \frac{4\times1.5\times10^{11}m\times2.28\times10^{11}m}{(6.96\times10^8 m)^2} = \frac{13.68\times10^{22}}{48.4416\times10^{16}} = 2.82\times10^6$

$\frac{4r_p r_e}{r_s^2} = 2.82\times10^5$

$ln(2.82\times10^5) = 12.55$ (83)

$\frac{4GM}{c^3} = \frac{4\times6.67\times10^{-11}m^3kg^{-1}s^{-2}\times1.99\times10^{30}kg}{27\times10^{24}m^3s^{-3}} = \frac{53.0932\times10^{19}}{27\times10^{24}m^3s^{-3}} = 1.97\ \times10^{-5}sec$ (84)

Multiplying (83) and (84)

$\frac{4GM}{c^3} ln\left(\frac{4\, r_p r_e}{r_s}\right) = 1.97\ \times10^{-5}m\times12.55 = 24.7235\ \times10^{-5}se$ (85)

$\frac{4G^2M^2}{c^5 r_p} = \frac{704.72\times10^{38}}{554.04\ \times10^{51}} = 1.27\ \times10^{-13}sec$ (86)

Substituting (85) and (86) into (83) to obtain time for Mercury

And neglecting other terms for a negligible small values, we get

$\Delta T_{DT,H}$=$2.69235\ \times10^{-5}sec$

$\Delta T_{DT,H} \cong 2.5\ \times10^{-5}sec$ (87)

Equation (64) and (78) are the values of red-shift in General Theory of Relativity and Dynamic Theory of Gravitation, (68) is in agreement with experimental values as observed by Vessot & Levine in 1976 who conducted a gravity probe test confirming the equivalence principle with an accuracy of 0.02% and further gave a value that is not analogous to experimental value but gave a value that is greater than zero. (78) and (68) are the values of Bending Angle in General Theory of Relativity and Dynamic Theory of Gravitation Which are average of experimental values by Combell and Robert, Eddington and Canadian England/Austrlian team (76) and (87) are the values of the time delay in the vicinity of gravitational field of the Sun and agree with the experimental values observed by Shapiro in (1970).

Propagation Effects of Photon in Gravitation Field

The coupling equations (20,31,43, 56 and 86) play the role of the system of interest and this suggests a possibility of the dynamical effect of the motion of photon in gravitational field of massive body.

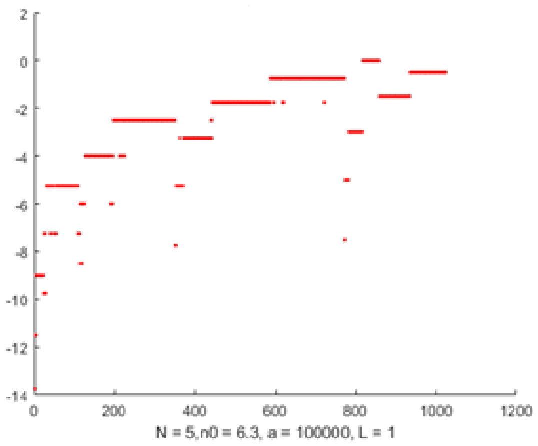

Figure 3: Dispersive Emission of Photon in Gravitational Field

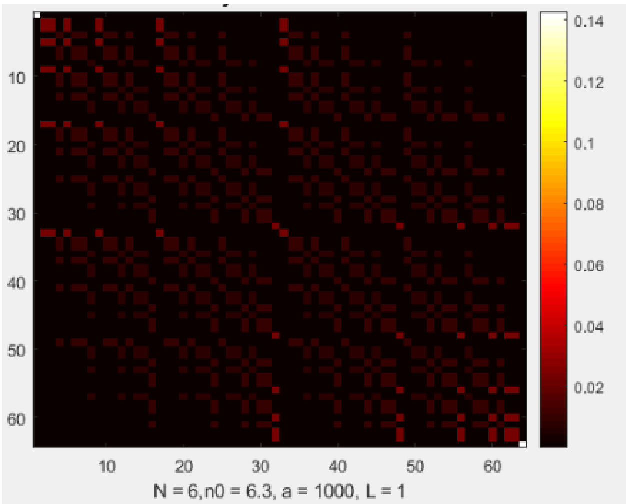

Figure 4: Density of dispersive Emission of Photon in Gravitational Field

Figure 3and 4 correspond to the emission of a photon in Gravitational field of massive body, where *L* is the latice length, *n0* is the wave number and *N* is the photon number. Therefore, the condition that expresses the fact that the propagating photons follows a direction from left to right in the sample. It is worth noticing that these propagation effects directly comes from the real and the imaginary dispersive term which are likely to be the contribution of the quasi-resonant processes obeying the conditions that are essential in the propagation effects of the photon (Oniga and Wang, 2016).

Gravitational Radiation and Dissipative Emission Power

Figure 5 and 6 shows the dynamics of photon in gravitational field showing it radiation power and the dissipative emission power, which are the results of photon interaction with self and the environment (Adamu & Wang, (2020)

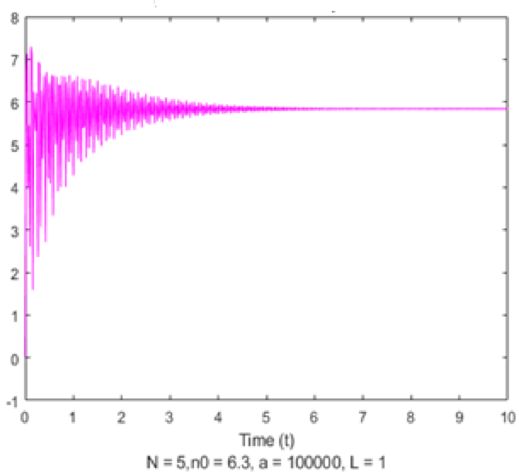

Figure 5: Dispersive motion of photon emission in gravitational field

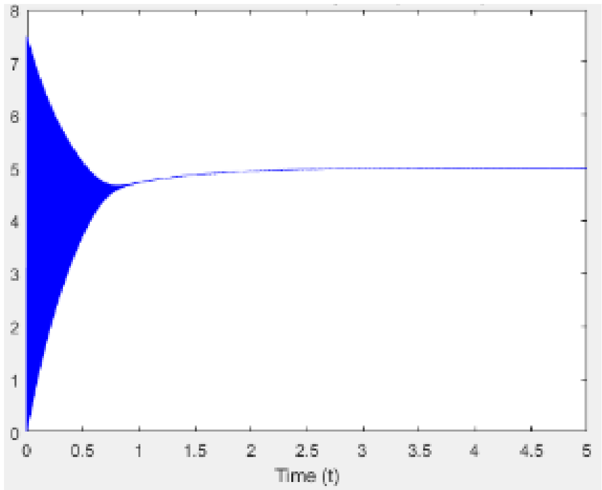

Figure 6: Dispersive Emission power of light bending in gravitational field

The observed dissipative signal is the effect of photon fluctuations that is driven by different decoherence channels and the internal dynamics of the trapped photon in gravitational field. The effects of these dynamics amount to reducing the spontaneous emission rate. Here, only the photons emitted in the diffraction angle are useful to start the super radiant emission process.

CONCLUSION

The results obtained in this study, demonstrated the motion of a photon in a gravitational field of massive body, the dynamics was based on Schwarzschild metric. The derived equations which describe the propagation of light in a gravitational field of the Sun, line element of dynamic gravity, Einstein Red-shift and Hubble shift incorporates gravitational fluctuations and in principle are applied in relativistic domain. The gravitational fields considered in this study are gauge fixed and account only for graviton effects. Thus, versatility of these equations allows us to probe a range of photon motion in gravitational fluctuation scenarios including those due deflection angle and radar echo from planet. All these contain additional correction terms which were not found in well-known General Relativity of bending Angle and Radar Echo from planet. From the numerical calculations the value of Red-Shift, Bending Angle and total travelling times, it appears that there is not much of a significant difference, between Dynamical Theory of Gravitation and General Relativity, However, the exact solutions provide useful insight on the nature of motion in gravitational field of massive body and the dynamics of the photon emission as it interact with gravitational environment.

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