Exploration

A Prediction of Quantized Gravitational Deflection of Starlight

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Abstract

In an earlier reading, it is argued that the pivotal, all-important, critical, crucial and supposedly watershed factor "2" emerging from Einstein's General Theory of Relativity (GTR) and used in Solar eclipse measurements by Sir Arthur S. Eddington as the clearest indicator yet that Einstein's GTR is indeed a superior theory to Newton's theory of gravitation may not be adequate as an arbiter to decide the fate of Newtonian gravitational theory. In the present reading, using ideas from research that we have carried out over the years – research whose endeavour is to obtain a *General Spin Dirac Equation in Curved Spacetime* (GS-Dirac Equation); we present yet another "surprising" result, namely that – if the ideas leading to the GS-Dirac Equation and as-well those presented in the reading rendering the factor "2" as being inadequate as an arbiter to decide the fate of Newtonian gravitational theory, then, the gravitational deflection of a photon may very well depend on its spin in such a manner that if photons of different spins where to be observed undergoing gravitational deflection by a massive object such as the Sun, the resulting deflection may very well be seen exhibiting distinct deflection quantization as a result of the quantized spins.

Keywords: mass: inertial mass, gravitational – light: gravitational bending – principle of equivalence.

1 Introduction

In the readings Nyambuya & Simango (2014) and Nyambuya (2015), we argued that the pivotal, all-important, critical, crucial and supposedly watershed factor "2" used by Sir Arthur S. Eddington (1882 – 1944) as the clearest indicator yet that Einstein (1915a,b, 1916a,b)'s General Theory *of* Relativity (GTR) is a superior theory to Sir Isaac Newton (1642 – 1727)'s theory of gravitation, this may not be adequate as an arbiter to decide the fate of Newtonian gravitational theory. Herein, we make further investigations on the frontiers of the gravitational deflection of starlight, by in-cooperating the spin of the photon undergoing gravitational deflection. These investigations lead us to predict the quantised gravitational deflection of photons of different spins.

This endeavour we conduct by making use of some of the research that we have carried out over the years; research whose effort is to obtain a *General Spin Dirac Equation in Curved Spacetime* (Nyambuya 2008, 2009, 2013). The present effort leads us to present a rather "surprising" or "unexpected" result, namely that – if the ideas presented in the readings Nyambuya (2008, 2009, 2013) and as-well those presented readings Nyambuya (2014a,c) are correct or anything to go by, then, the gravitational deflection of radiation may very well depend on its spin in such a manner that if radiation of different spins where to be observed undergoing gravitational deflection by a massive object such as the Sun, the resulting deflection may very well be seen exhibiting distinct deflection quantization as a result of the quantized spins.

For photons of spin-$s/2$ (where $s = 1, 2, 3, \ldots$ *etc*) grazing the Solar limb, we find that the gravitational deflection angle will be $\delta_{\odot} = 0.87''s$. Effectively, this means that spin-1/2 photons will undergo a Newtonian deflection of $0.87''$, while spin-1 photons will undergo an Einsteinian deflection of $1.75''$ and spin-2 photons will undergo a deflection of $2.61''$ *etc*. The deflection is quantised in units of $0.87''$.

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As far as physicists understand, know and can tell, photons are spin-1 particles, the meaning of which is that – according to the above stated; they will undergo an Einsteinian deflection of $1.75''$. At present, our understanding of the Solar gravitational deflection of starlight is that a $1.75''$-deflection is purely an Einsteinian result and nothing more. Here we find that it (the $1.75''$-deflection) can be obtained in the Newtonian framework on the basis of spin thereby taking away the privilege that Einstein's GTR has enjoyed ever-since, the privilege of being the only theory that has legitimately been accepted as capable of explaining this result which Newtonian gravitational theory had failed to explain.

Further on the shores of the gravitational deflection starlight measurements; we have the June 19, 1936, Solar gravitational bending of starlight measurement of Mikhailov (1940) which were made in the then United Soviet Socialist Republic (USSR) and gave the result $2.73 \pm 0.31''$, a result which is $0.98 \pm 0.31''$ in excess of the expected Einsteinian $1.75''$-deflection – that is, a 56% deviation. If we are to trust this measurement as accurate, then, we must admit to ourself – unless off-case we are prepared to do the unscientific and sweep this result under the carpet; that Einstein's GTR fails to explain this result adequately. Yes, the result is significantly above that predicted by Newtonian gravitation (it is $\sim 213\%$ larger); true also is that this very same result is significantly above that predicted by Einsteinian gravitation (it is $\sim 56\%$ larger). In all probity, open-mindedness and fairness, there clearly is a very strong call for an explanation as to why this is so. A good scientist must favour the truth and not a particular theory.

To this rather contentious "*June 19, 1936, USSR Measurement*", the ideas propagated herein can explain this on the basis that this measurement most certainly is a measurement of Fermionic spin-3/2 photons. We know it is at present difficult to think this, *i.e.*, of Fermionic photons, but we have to consider this if an acceptable thesis leads us to that point. If we scientists are to hold true to the creed to which is assumed of us, the creed of open-mindedness, fairness and probity, we must therefore provisionally accept this pending verification from *Nature* herself. Fermionic spin-3/2 photons would – according to the ideas propagated herein, undergo a gravitational deflection of $2.61''$, thus making the USSR measurement only a mere $0.12 \pm 0.31''$ deviation from this result; this is $\sim 5\%$ deviation from the theoretically predicted result.

The synopsis of this reading is as follows: in §(2) we are going to give a succinct summary of the work presented in Nyambuya (2008, 2009, 2013). In §(3), we apply the results of General Spin Dirac Equation where we deduce the spin relation to the gravitational to inertial mass ratio of photon. In §(4), we apply the results of §(3) to the gravitational deflection of starlight where upon is it seen that the General Spin Dirac Theory leads us to quantised gravitational deflection of starlight. In §(5), we give a general discussion, conclusion drawn thereof and thereafter make recommendations for future work.

2 General Spin Dirac Equation in Curved Spacetime

In the readings Nyambuya (2008, 2009, 2013, 2016) a general spin and general curved spacetime Dirac equation (Nyambuya 2008) has been presented. In the said works, the usual Einstein energy-momentum equation for a particle of energy E, momentum p and rest-mass m_0, namely:

$$E^2 = p^2c^2 + \mathrm{m}_0^2c^4, \tag{2.1}$$

this equation is modified to become:

$$E^2 = s^2p^2c^2 + \mathrm{m}_0^2c^4, \tag{2.2}$$

where ($s = \pm1, \pm2, \pm3, \cdots$) is the spin quantum number for a particle of spin $s/2$. A spin-1/2 particle will have ($s = 1$), a spin-1 particle will have ($s = 2$) *etc.*

In the reading, Nyambuya (2014*a*), it is suggested that the mass energy equivalence of E *i.e.*, E/c^2, this must be identified with the gravitational mass of the particle *i.e.* ($\mathrm{m_g} = E/c^2$), while the rest-mass

m_0 is identified with the particle's inertial mass m_i *i.e.* ($\mathrm{m}_0 = \mathrm{m}_i$). What this means is that equation (2.2) can now be written as:

$$E_{\mathrm{g}}^2 = s^2 p^2 c^2 + \mathrm{m}_i^2 c^4. \tag{2.3}$$

We shall use this equation (2.3) to deduce a gravitational to inertia ratio of photons and as-well that of ordinary mass.

3 Spin-Gravity Coupling for Photons

Despite our strong feelings (as expressed in the readings, Nyambuya 2014*a*,*b*,*c*) against a vanishing rest-mass for a photon, we shall, in the present assume a vanishing rest-mass – for the photon. This assumption on the rest-mass of the photon made in the readings Nyambuya (2014*a*,*b*,*c*) is that ($\mathrm{m}_0 \neq 0$) such that ($\mathrm{m}_0^2 c^4 \lll p^2 c^2$). Therefore, from equation (2.3), this assumption of a vanishing photon rest-mass implies that: ($E^2 = s^2 p^2 c^2 \Rightarrow E = |s| pc > 0$). From this – taking the momentum of the photon to be such that ($p = \mathrm{m}_i c$) where m_i is the inertial mass of the photon, it follows from this that ($\mathrm{m}_{\mathrm{g}} c^2 = |s| \mathrm{m}_i c^2$), hence:

$$\frac{\mathrm{m}_{\mathrm{g}}}{\mathrm{m}_i} = 2\gamma_{\mathrm{g}} = |s| \qquad \Rightarrow \qquad \gamma_{\mathrm{g}} = \frac{1}{2}|s|. \tag{3.1}$$

From the above equation (3.1), the suggestion is clear that the gravitational to inertial mass ratio γ_{g}, is – here; determined by the spin of the photon – there is strong coupling between the gravitational mass, inertia mass and spin. *Prima facie*, one may erroneously extend this result to include ordinary matter leading to the conclusion that if this result (3.1) is correct, experiments must be able to detect a strong correlation between γ_{g} and spin. Experiments (Duan et al. 2016, Tarallo et al. 2014, Fray et al. 2004) appear to disagree with this.

In a measurement of which it is the first of its kind, Tarallo et al. (2014) have tested the Einstein's equivalence principle by comparing the gravitational interaction for a bosonic particle (a strontium-88 isotope which spin-0 particle) to that of a fermionic particle (a strontium-87 isotope, which is a spin-1/2 particle). These researchers find no evidence for any spin-gravity coupling thus somewhat ruling out theoretical models predicting that spin and gravity should couple. They further find no evidence of free-fall dependence on spin-orientation. This result (of non-dependence of free-fall on spin-orientation) is also confirmed by Duan et al. (2016) and Fray et al. (2004) who report a test of the universality of free fall by comparing the gravity acceleration of the Rb^{87} atoms in for different spin orientations and they find no dependence of the free-fall in spin-orientation.

In the case of massive particles (*i.e.*, $\mathrm{m}_0 \neq 0$), assuming as suggested in the reading Nyambuya (2014*a*) that the gravitational mass is such that ($\mathrm{m}_{\mathrm{g}} = E/c^2$) and that the inertia mass is such that ($\mathrm{m}_i = \mathrm{m}_0$) and as-well that ($\mathrm{m}_0^2 c^4 \ggg p^2 c^2$), then – taking equation (2.2) to first order approximation in terms of v^2/c^2, it follows that:

$$\frac{\mathrm{m}_{\mathrm{g}}}{\mathrm{m}_i} = \left(1 + \frac{s}{2}\frac{v^2}{c^2}\right) = 2\gamma_{\mathrm{g}}, \tag{3.2}$$

for ($s = \pm 1, \pm 2, \pm 3, \dots$ *etc*). IF one where to compare the accelerations (a) of different particles of different spins, then, the results (3.2) implies that:

$$\frac{\Delta a}{a} = \frac{1}{2}\left(\frac{v^2}{c^2}\right)\Delta s, \tag{3.3}$$

If this result (3.3) is correct or has any significant correspondence with physical and natural reality, then one can or might explain the results of Duan et al. (2016), Tarallo et al. (2014), Fray et al. (2004) by positing that the failure to detect a strong coupling between gravity and spin is as a result of the factor v^2/c^2 which renders the factor-s undetectable within the margins of experimental error because of the obtain non-relativistically small values of v^2/c^2.

4 Quantized Gravitational Deflection

In the reading Nyambuya & Simango (2014), it is demonstrated or argued that the gravitational deflection of electromagnetic waves barely passing the limb of a massive object with mass $\mathcal{M}_{\rm star}$ and radius $\mathcal{R}_{\rm star}$ is given by:

$$\delta_\gamma = \frac{4\gamma_{\rm g} G\mathcal{M}_{\rm star}}{c^2\mathcal{R}_{\rm star}}. \tag{4.1}$$

Now, given that $\gamma_{\rm g}$ for photons of spin-$s/2$ is given by (3.1), it follows that substituting this into (4.2), we will have:

$$\delta_s = \frac{2|s| G\mathcal{M}_{\rm star}}{c^2\mathcal{R}_{\rm star}}. \tag{4.2}$$

Since, ($s = \pm1, \pm2, \pm3, \dots$ *etc*), it follows that the deflection is quantised as a result of the spin of the photon and in the case of light passing the Solar limb, the deflection is quantised in the units of $0.87''$.

Now, since photons are spin-1 particles, it follows that ($s = 2$). With ($s = 2$), we obtain Einstein's GTR formula for gravitational deflection. If the ideas propagated herein are correct or prove themself to have a direct correspondence with physical and natural reality, then, this brings us to ask an important question, namely: 'Is the Einsteinian $1.75''$ Solar gravitational deflection of starlight a result of the curvature of spacetime as Einstein claimed or is it a result of the spin of the photon?' We leave this question as something to be pondered upon.

5 General Discussion

As is well known, Einstein's GTR predicted that starlight grazing the Solar limb must – as a result of the Sun's gravitational field, suffer a $1.75''$ deviation from its otherwise straight path. However, the thirteen available measurements (Dyson et al. 1920, Dodwell & Davidson 1924, Chant & Young 1924, Campbell 1923, Freundlich et al. 1929, 1931, 1933, Mikhailov 1940, 1949, Matukuma 1941, *van* Biesbroeck 1949, 1953, Schmeidler 1963, Jones 1976) exhibit a significant 19% root-mean-square scatter about Einstein's $1.75''$ prediction (Nyambuya & Simango 2014). This scatter is and has largely been attributed to the level difficulty in the measurements themselves (see *e.g.*, Will 2006, 2009, 2014*a*,*b*,*c*), and hence the results are plagued with systematic errors. Amongst these thirteen measurements, we have the June 19, 1936, Solar measurement of Mikhailov (1940) which were made in the then United Soviet Socialist Republic (USSR) and gave the result $2.73 \pm 0.31''$, a result which is $0.98 \pm 0.31''$ in excess of the expected Einsteinian $1.75''$-deflection – that is, a 56% deviation.

If – for whatever reason – we are to trust this measurement as accurate, then, we must admit to ourself – unless off-case we are prepared to do the unscientific and sweep this result under the carpet; that Einstein's GTR fails to explain this result adequately. In all probity, open-mindedness and fairness, there clearly is a very strong call for an explanation as to why this is so. However, the present attitude is that – because of the excellent agreement with Einstein's $1.75''$ prediction obtaining in VLBA measurements, it is no longer an issue of experimental importance as to why starlight measurements exhibit this significant scatter. We herein have argued that, there may be need to revisit this issue of the scatter obtaining in starlight measurements.

VLBA measurements (Anderson et al. 2004, Bertotti et al. 2003, Lebach et al. 1995, Robertson et al. 1991, Fomalont & Sramek 1976, Counselman et al. 1974, Muhleman et al. 1970, Shapiro 1964, Shapiro et al. 2004) from quasar radio waves have not only given an improved result in the scatter; they have given an unprecedented 99.9998% agreement with Einstein's $1.75''$, hence, the issue of agreement between the GTR with experience is considered a matter of forgone conclusion that has sine been resolved by VBLA measurements.

In-closing, allow us to say that: according to the ideas propagated herein – the Soviet result of $2.73 \pm 0.31''$, this result may mean fermionic higher spin photons *i.e.*, photons of spin-3/2. Currently – if any at all, no physicist will accept this (spin-3/2 photons) as an explanation to this Soviet result. Reacting on first instinct, I too feel opposed to this, but given that this explanation flows from the logic of our work and that nature may have surprises, the feeling is to leave Nature to be the final judge on the correctness of this result.

6 Conclusion

Assuming the acceptability of the works presented in Nyambuya (2008, 2009), Nyambuya *&* Simango (2014), Nyambuya (2014*a*,*c*, 2013) and the thesis here presented, we hereby make the following conclusion: that, the factor "2" that was used by Sir Arthur Eddington to rule that Einstein's GTR is superior to Newtonian gravitational theory, this may not be the case if the spin of a photon affects gravitational deflection as given in (4.2).

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