Electromagnetic Gravitation

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Analysis of radiometric data from the Pioneer 10 and 11 probes indicate that they are begin slowed by an anomalous constant acceleration with an average magnitude a_P $\sim 8 \times 10^{-8}\, cm/s^2$ oriented with respect to the sun. We propose that the nature of the acceleration is due to a curvature of the space-time continuum caused by the suns light, which is predicted by G.R. We describe the acceleration as a quantized effect that depends on the frequency of the light and not the intensity, a kind of photo-gravity effect analogous to the photoelectric effect. The acceleration can be described by the equation:

$$a = [h]\nu c$$

The constant used is equal to Planck's constant and is placed in brackets to indicate it is dimensionless:

$$[h] = 6.626068 \times 10^{-34}$$

Although we associate the acceleration with the photons emitted by the Sun, we attribute the actual anomalous acceleration to gravitons associated with these photons. Any change in an emitted photon's energy is accompanied by a change in the energy of its associated graviton. We attribute the observable (acceleration) to the energy of the graviton. A photon's graviton's energy changes independently of its own, so we treat it as a separate variable, in the same manner that charge, spin and mass may be separate characteristics of the same particle.

Separating the magnitude of the acceleration from the energy of its photon effectively shows why the anomalous acceleration is not seen in the planets. The planets, through their gravity fields, attenuate the acceleration associated with the photons by changing their energy through gravitational red-shift. Photons approaching the planets experience an increase in energy, but a decrease in graviton energy, or acceleration. Subsequently, planets alter the degree of perturbation to their trajectories by the acceleration. As the mass of the planets are much larger than the mass of the probes, they are able to effectively mask the anomalous acceleration detected in the Pioneers.

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1. Introduction

In 1980, JPL noted that there was an error in the acceleration residuals that gave a constant bias, a_P, directed *toward* the Sun. Both JPL and The Aerospace Corporation conducted independent analysis of the data up until 1998. They concluded that there is an unmodeled acceleration, $a_{P,}$ towards the Sun of~$8 \times 10^{-8} cm/s^2$, for both Pioneer 10 and 11 space probes.

We attribute the anomalous acceleration noted by JPL to light. Thus is not unusual as GR already predicts that light should produce a curvature of the space-time continuum, or a gravity field. However, we noted that the acceleration was constant with distance; we assumed an analogous relationship to the photoelectric effect noted by Einstein. So this photo-gravity effect was responsible, and was indeed the nature of the effect, explaining why the anomalous force is constant with distance.

Although we treat the acceleration as being associated with the Sun's light, or photons, we specifically treat the acceleration itself as a separate variable caused by gravitons. This approach allows us to explain the presence of the effect noted by NASA in the Pioneer probes, and its absence in affecting the orbits of the planets.

2. Empirical Equation

When noting from the publication submitted by JPL concerning the probes that the acceleration was constant with distance, we decided to model our approach from the perspective that the acceleration was due to the suns light but did not depend on the lights intensity but its frequency, analogous to the photoelectric effect. The range of frequencies emitted by the sun is described by Planck's radiation formula for black bodies:

$$I(\nu,T) = \frac{2h\nu^3}{c^2} \cdot \frac{1}{e^{h\nu/kT} - 1} \quad \textbf{(1)}$$

The next step was deciding which frequency is responsible for the acceleration. We assumed that the highest energy photons were. The acceleration is treated as an expectation value according to Q.M., resulting in:

$$a = [h]\nu c \quad \textbf{(2)}$$

Plugging in the values for *h*, *c*, *a* and re-arranging, we find

$$\frac{8.5 \times 10^{-10} m/s^2}{(6.626068 \times 10^{-34} m^2 kg/s)(2.99792458 \times 10^8 m/s)} = 4.28 \times 10^{15} Hz$$

The next step is to show if photons of this energy lie within the range of the blackbody radiation curve for the sun at a temperature of 6,000*K*. We treat Planck's radiation formula as an inequality:

$$I(\nu,T) \le \frac{2h\nu^3}{c^2} \cdot \frac{1}{e^{h\nu/kT} - 1} \quad \textbf{(3)}$$

Next, we substitute the value for frequency from our empirical equation to obtain a value. Our main focus is to see if the value for intensity at this frequency is reasonably low, and if it is greater than zero. We find a value of

$$2.115 \times 10^{-18}\, J/s \cdot m^2 \cdot sr \cdot Hz \ge 0\,.$$

Considering the constants chosen, the value obtained for intensity is within the range of the upper limit of the sun's black body curve. Of course the units are not correct if viewed in the classical sense, but we took this approach for two reasons. From JPL's publication in 2005, they presented the following:

It is important to realize that out experimental observable is a Doppler frequency shift, i.e., $\Delta\nu(t)$. *[See Figure 8 and Eq. (15).] In actual fact it is a cycle count. We interpret this as an apparent acceleration experienced by the spacecraft. However, it is possible that the Pioneer effect is not due to a real acceleration. (See Section XI.) Therefore, the question arises "In what units should we report our errors?" The best choice is not clear at this point. For reasons of clarity we chose units of acceleration.*

This was the initial reason we ignored the units and instead concentrated on arriving at the right magnitude for the observable. And as the effect was without units, we strove to formulate a relationship that introduced no new constants or theories.

The other reason rests on our choice of relating the acceleration with the energy and intensity of the Sun's light, a concept we borrowed directly from the photo-electric effect. We kept the energy term $h\nu$ and multiplied it by the constant *c*. To be rigorous, we can alternate from the quantum perspective and use a classical relationship:

$$a = [h]\frac{c^2}{\lambda} \quad \textbf{(4)}$$

This is a derivate of our first empirical equation [1] (the element *h* was originally *k*). The constant *h* has the same magnitude as Planck's constant. We placed it in angled brackets to indicate that it is treated as a normalized factor that is dimensionless in order to yield an observable with the correct magnitude and dimensions. Specifically:

$$[h] = 6.626068 \times 10^{-34} \quad \textbf{(5)}$$

3. Possible Dimensions for the Acceleration

Our hypothesis is one of many proposals that have been put forward by theoretical physicists. Here was JPL's comment on the ones published in their 2005 article [3(b)]:

…any universal gravitational explanation for the Pioneer effect comes up against a hard experimental wall. The anomalous acceleration is too large to have gone undetected in planetary orbits, particularly Earth and Mars. NASA's Viking mission provided radio-ranging measurements to an accuracy of about 12 m [137, 138].

They also added:

We conclude that the Viking ranging data limit any unmodeled radial acceleration to no more than $0.1 \times 10^{-8} cm/s^2$*. Consequently, if the anomalous radial acceleration acting on spinning spacecraft is gravitational in origin, it is* <u>*not*</u> *universal. That is, it must affect bodies in the 1000 kg range more than bodies of planetary size by a factor of 100 or more. This would be a strange violation of the principle of equivalence [140].*

After reading these statements, we attempted to show that the effect is indeed gravitational in origin, did not affect the planets, and that the principle of equivalence was preserved.

The Pound-Rebka experiment of 1960 verified the existence of gravitational red-shift in spectral lines at the Lyman Laboratory of Physics at Harvard University. According to the principle of equivalence, gravitational mass is equal to inertial mass, [2] so a photon with a frequency ν should behave gravitationally like a particle of mass $h\nu / c^2$.

A photon falling through a height *H* can show an increase of *mgH* in its energy through an increase in its frequency. It follows that,

Final photon energy = initial photon energy + increase in energy, or

$$h\nu' = h\nu + mgH \, . \qquad \textbf{(6)}$$

It also follows that

$$h\nu' = h\nu + \left(\frac{h\nu}{c^2}\right) gH \qquad \textbf{(7)}$$

The photons final energy after falling through height *H*,

$$h\nu' = h\nu\left(1 + \frac{gH}{c^2}\right). \quad \textbf{(8)}$$

This means that, for the energy of a photon as it leaves the sun, the acceleration JPL noted cannot be exclusively constant with distance, but must be greater near the sun than further away. The classical relationship for the energy of a photon as it leaves a strong gravity field is:

$$E = h\nu - \frac{GMh\nu}{c^2 R} = h\nu\left(1 - \frac{GM}{c^2 R}\right) \quad \textbf{(9)}$$

At the probes distance from the sun, the photons energy is totally electromagnetic, described by the relationship:

$$E = h\nu' \quad \textbf{(10)}$$

So the energy of the photons and thus the acceleration associated with them should be greater nearer the sun, but not due to a $1/r^2$ relationship in the classical sense. Rather it is a result of the change in photon energy due to a decrease in strength of the sun's gravity field. It is as if, once attaining sufficient distance from the sun, the photons attain a 'rest mass', producing a constant acceleration.

In any event, the photons energy increases as they approach the probes or the planets, which would indicate that affect would be even greater for the planets if we exclusively relate the acceleration with increasing photon energy. To account for this, we propose that the acceleration is a separate variable of the photons, like spin. For convenience and simplicity, we describe it as being due to an associated graviton with an energy $h\nu$. The graviton's energy produces the measured observable seen as the anomalous acceleration associated with its photon. As photons approach the planets or probes, they experience an increase in energy, but their gravitons exhibit a decrease in energy.

We drew this conclusion from the data collected regarding the behavior of the Lageos satellites in [6] and [7]. In [6], we read that:

However, the upper limit for any gravitational shielding is now set by Lageos satellites, which suffer an anomalous acceleration of only about $3 \times 10^{-10}\, cm/s^2$ *during "seasons" where the satellites experience eclipses of the Sun by the Earth [5].*

Although the behavior of these satellites appear unrelated to the Pioneer anomaly, but we believe that they correlate with the data obtained by NASA in [3], where they reported an upper limit of $0.1 \times 10^{-8}\, cm/s^2$ for the force as determined by the Viking range data. First, the satellites only suffer this anomaly during eclipses. It is not unusual to consider then that it is a direct result of the gravitational effect due to energy as predicted by G.R., but only due to the *absence* of light. It is also possible that the satellites can be viewed as test particles, mapping the strength of the acceleration due to light at their altitude. In any event, the possible correspondence to the Pioneer effect, and its behavior as alluded to by G.R. should not be overlooked.

The planets then effectively reduce the energy of the gravitons so that the measured acceleration is below $0.1\times10^{-8} cm/s^2$. It can be described as a gravitational attenuation of the photons energy that subsequently changes the acceleration that they (the planets) ultimately 'see'. This contrasts with the common Newtonian concept where for all intents and purposes, the masses of two bodies that interact gravitationally are treated as being invariant.

Lastly, so long as the energy of the photons is not red-shifted to zero, the acceleration still exists. In the probes, their mass is too small to attenuate the energy of either the photons or their gravitons significantly. We can treat them as test point particles, as we do test charges in electric fields in electromagnetism.

4. Quantum Electrodynamic Implications

Our introduction of gravitons tacitly follows the idea presented by Ivanov [4]. His hypothesis was referred to in JPL's paper:

Inavov (sic) [140] suggests that the Pioneer anomaly is the manifestation of a superstrong interaction of photons with single gravitons that form a dynamical background in the solar system.

We shall address what kind of quantized picture the observable may indicate momentarily. One significant aspect that draws immediate consideration is: *where* does the acceleration become constant? JPL reported the following [3(b)]:

Beginning in 1980, when at a distance of 20 astronomical units(AU) from the Sun the solar-radiation-pressure acceleration on Pioneer 10 <u>away</u> from the Sun had decreased to $< 5\times10^{-8} cm/s^2$, *we found that the largest systematic error in the acceleration residuals was a constant bias,* a_P, *directed <u>toward</u> the Sun. Such anomalous data have been continuously received ever since. Jet Propulsion Laboratory (JPL) and The Aerospace Corporation produced independent orbit determination analysis of the Pioneer data extending up to July 1998. We ultimately concluded [12, 13], that there is an unmodeled acceleration,* a_P, *of* $\sim 8\times10^{-8} cm/s^2$ *for both Pioneer 10 and Pioneer 11.*

The distance of 20 A.U. is just beyond the orbit of Uranus. This does not mean that the acceleration becomes constant at Uranus' orbital distance; rather, it implies that there is some value of the observable (acceleration) where the energy of the graviton background no longer 'excites' the photons energies above that of their 'rest masses'.

From this we draw an intriguing picture. Let us consider one system, that of the Sun, probes and electromagnetic radiation emanating from the Sun. We ignore the gravitational red-shift of the electromagnetic waves as they enter the gravity field of the probes, and treat them as 'test particles' in our analysis of the photon/graviton interaction.

We treat the gravity field of the Sun as a graviton background, as stated by Ivanov [5]. A photon of energy $h\nu$ has a property analogous to that of the energy of a level occupied by an electron in an atom. In order for the electron to transition to the next energy level, it must absorb a photon of a minimum energy equal to the energy difference in energy of its own level and that just 'above' it. Comparatively, the photon absorbs a graviton and makes a transition to its next highest level. We can suggest this relationship by the following:

$$\gamma + h \rightarrow \gamma^* \qquad \textbf{(11)}$$

Here γ is a photon and h is a graviton, with γ^* representing the excited state of the photon. Another way of viewing γ^* is as though it is an isomer of γ.

In separating the graviton associated with its photon from the photon's energy, we can draw another analogous relationship:

$$h_B + h_P \rightarrow h_P^* \qquad \textbf{(12)}$$

In this equation h_B is the graviton background, h_P represents the graviton associated with the photon and h_P^* is an 'isomer' of h_P.

At certain distances from the sun, the gravitons are not energetic enough to change the energy of the photon, and its energy remains constant. Concordantly, the energy of its associated graviton becomes constant as well. The difference occurs when the photons interact with the gravity field of a massive body such as a planet. A photon will absorb gravitons and experience an increase in energy, while a graviton will radiate energy by emitting gravitons and experience a decrease in energy.

5. Starlight

For the probes, the gravitational frame of reference is the Sun, since it is the nearest large mass in their vicinity. However, if our interpretation that light produces an acceleration that depends not on its intensity but its frequency is correct, then the light from other stars, though light years distant, none the less should impart some influence on the probes trajectories.

A simple effect of gravitation provides an explanation. In Newtonian mechanics, the net force on an object in a closed shell is zero [5]. One can see this from the following.

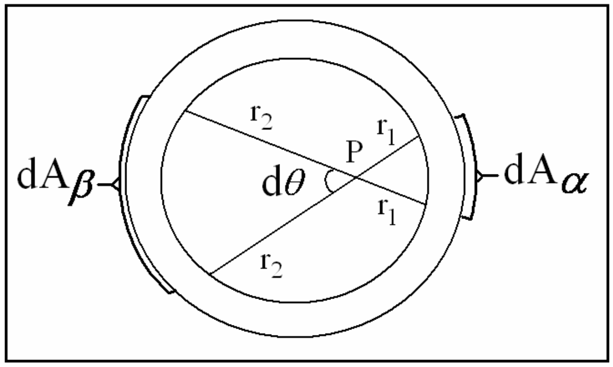

Figure 1
Hollow Spherical Shell

The sphere has a real mass $\rho(kg/m^2)$. The net differential attraction dF of dA_α and dA_β at P directed toward α is just:

$$dF = \rho(dA_{\alpha}/r_1^{\,2} - dA_\beta / r_2^{\,2}). \quad \textbf{(13)}$$

However,

$$dA_\alpha = r_1^{\,2} d\phi \text{, and } dA_\beta = r_2^{\,2} d\phi \quad \textbf{(14)}$$

by definition of the solid angle. It follows that:

$$dF = \rho((r_1^{\,2} d\phi)/r_1^{\,2} - (r_2^{\,2} d\phi)/r_2^{\,2}) = 0\text{,} \quad \textbf{(15)}$$

which is true for all choices of dA_α and dA_β.

Similarly, any additional acceleration acting on the probes due to the light of distant stars would effectively cancel, since they form a general sphere surrounding the solar system.

6. Conclusion

We believe the Pioneer effect represents another perhaps unanticipated but not unusual manifestation of a dimensional relationship between electromagnetism and gravity, or perhaps general relativity and quantum mechanics. The bulk of the effort that created this possibility was born of the efforts of the scientists at JPL [3]. Our hypothesis relies on the fact that the only reason there is a discussion at all about whether the effect may be something new is that (i) JPL has eliminated so many other possible explanations and (ii) the precision with which any possible cause can be measured. Our hypothesis rests on assumptions made in light of their efforts, and those of The Aerospace Corporation.

Our efforts were focused toward developing a quantum mechanical hypothesis for an effect already predicted by G.R., namely, how space-time is curved by electromagnetic radiation. Scientists have long pondered the relationship between electromagnetism and gravity, and have also sought to unify Q.M. and G.R.; optimistically, our hypothesis is correct, and the anomalous acceleration represents this possible new relationship, at least in terms of E.M. waves and gravity.

Though we introduce the concept of gravitons in part 4 as being separate entities associated with photons, we do not imply that the probes behavior confirm their existence according to our hypothesis. Gravitons have not been confirmed, which means they are exactly that-hypothetical particles. Nor did we attempt any special derivation of what structure or behavior they may take dimensionally or mathematically. For us, its introduction was warranted to provide a separable element associated with a photon, thus providing an appropriate framework to explain the absence of the anomalous acceleration in the planets.

However, as the effect with the probes appears quantized, we decided to characterize it quantum mechanically, solely as a comparative exercise. The idea of isomers in Eqs. (10) and (11) represent the closest approach we have taken in describing a possible quantum relationship between hypothetical gravitons and photons.

References

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