An Attempt to Explain the Flyby Anomaly and to Account for the Anomalous Torque of the Gravity Probe-b Gyroscopes Using LITG

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Abstract

The first attempt to construct a gravitational theory similar to Maxwell,s electromagnetic theory was done by the English physicist Oliver Heaviside, then it was improved by the German physicist Hermann Minkowski , and given the name Lorentz Invariant Theory of Gravity or LITG for short, so from the name it's Lorentz transformation's invariant in conformity with the special theory of relativity, again it was further improved and generalized by the Russian mathematician Sergey Fedosin to be known as the co-variant theory of gravitation, the co-variant theory will reduce to LITG at low velocities and week gravitational fields, therefore for our work we need only use the LITG theory as a special case of the co-variant theory, and we will use the similarity between electromagnetism and gravitomagnetism to drive laws.

To explain flyby effect we argue that the individual photons of the telemetry signal emitted from the free-falling spacecraft being themselves a source of gravitomagnetic field, interact with the field generated by the relatively moving Earth, because the spacecraft is in free-fall state an observer on-board it can claim to be at absolute rest according to the equivalence principle, therefore an observer and in this case the telemetry photons can assume being emitted from the spacecraft which is at rest towards the Earth which is now moving towards them with the same velocity of the spacecraft, the gravitomagnetic force in this case will be attractive, and due to the highly symmetric trajectory of the spacecraft an equivalent force of repulsion will be experienced by telemetry photons during the departure of the spacecraft, because in this case the photons and the Earth will be moving in the same direction, the force of attraction will manifest in the form of a blue-shift and that of the repulsion will manifest as a red-shift, so if we measure the effect equally during the inbound and the outbound, the two effects will add to zero, the effect is highly dependent on the way we observe it, that is why the effect is minimum when the trajectory is symmetrical about the equator, because the DSN antennae are distributed near the equator, hence the blue-shift and the red-shift cancel out.

As for the gravity probe-b case, we argue that, one of the most important results of the theory of relativity, is that there is no absolute frame of reference, we have to ask a particular observer about the results of his observations within his frame, we are not allowed to dictate or force our own conceptions on him, this condition wasn't fulfilled in the case of gravity probe-b theoretical framework, the researchers assumed that the spacecraft is revolving around Earth along with the four perfectly manufactured gyroscopes, from our point of view as observers on Earth this is true but for an observer on-board the spacecraft the situation is totally different, in this case the spinning gyroscopes are in free fall state which is according to the equivalence principle is a privileged inertial frame of reference, where Newton's first law of motion is perfectly operational, therefore anyone of the four gyroscopes have the full right to claim the state of absolute rest while the Earth is revolving around them with the same period by which the spacecraft is revolving around Earth as judged by us on Earth, also the gyroscopes as observers they claim that the Earth is spinning around an axis perpendicular to its own axis of rotation, with the same period of about 97.5 minutes of the spacecraft, using this reasoning and applying the approximate version of the co-variant theory of gravitation namely LITG, we obtained a gravitomagnetic effect nearly 100 times as large as that expected by the researchers, as we will show.

1 Introduction

Newton's theory of gravitation was originally designed to describe only the field produced by any mass, no field of any kind was assumed by Newton to be generated by a moving mass, hence according to Newton's theory, the gravitational field produced by a certain mass will have the same value and form if the mass is at rest or in motion, but a new addition was made by the physicist Oliver Heaviside where he introduced a new field similar to the magnetic field in classical electrodynamics, this field is produced when a mass is in motion relative to another observer, this theory proposed by Heaviside was further generalized by the mathematician Hermann Minkowski to be invariant under Lorentz transformations, therefore given the name Lorentz Invariant Theory of Gravitation or LITG for short, now finally the mathematician Sergey Fedosin generalized the LITG to be valid even in cases of strong gravitational field, this new theory proposed by Fedosin is known as co-variant theory of gravity, the co-variant theory will reduce to LITG at low velocities and week gravitational fields.

While trying to solve the flyby anomaly problem I first realized that this anomalous acceleration can't be accounted for using Newton's theory of gravity, so I thought this anomalous acceleration must be due a gravitomagnetic interaction between the Earth and the telemetry signal photons if we insist on the particle nature of photons, therefore photons will generate their respective gravitomagnetic fields due to their perpetual movement, so while trying to do this it became very clear to me that it's possible to account for this anomaly if we use the LITG or simply the Heaviside equations, and if we fully apply the equivalence principle to claim that an observer in a free falling frame of

reference can have the right to claim the state of absolute rest while the rest of the Universe is moving with his same velocity in the opposite direction, then we can explain the flyby anomaly and calculate the acceleration.

As for the gravity probe-b designed to calculate two effects, the geodetic effect, and the Lense-Thirring effect, what concerns us here is the second effect, this effect is produced by a mass in motion and it's analogous to the effect produced by a moving charge, while a moving charge generates an electric current, a moving mass generates what is known as matter current, and as the electric current generates an additional field known as the magnetic field, so according to Heaviside's theory a matter current generates an additional gravitational field known as the gravitomagnetic field, this field is similar to the magnetic field, and also as a rotating spherical charge produce a dipole magnetic field so a rotating spherical mass generates a dipole gravitomagnetic field.

The gravity probe-b experiment was constructed to measure the two mentioned effects and one of them is the frame-dragging or the the Lense-Thirring effect which is concerning us here, everything in this experiment was nearly perfect, the devices were checked and tested many times, the spherical gyroscopes were a wonder, no anomaly was observed during all these extensive tests, everything was in a very good condition, and this is what anyone will expect from an experienced and highly professional scientists and engineers of the greatest space agency, no one will expect the expensive spacecraft to be launched unless every item in it was checked and many times of that, but we believe that one vital thing was neglected by the researchers, the four gyroscopes were designed to be unaffected by the spacecraft movement and they were designed to not touch the housing, the spacecraft was in free fall state and so were the four gyroscopes, and according to the equivalence principle a free falling observer can claim the state of absolute rest while the rest of the Universe is performing his motion in the opposite direction, for the gyroscopes the Earth was revolving around them completing one revolution in 97.5 minutes, for the gyroscopes this revolution of Earth around them wasn't apparent as we used to say, it was a real revolution which is generating a gravitomagnetic field according to LITG as we will show, because according to the theory of relativity every observer has the right to conduct his own experiments within his frame and we have to accept the results obtained by him even if they contradicted the results obtained by us, this gravitomagnetic field produced by the relatively moving Earth can interact only with the spin of the gyroscope, because the gyroscope will claim to be at rest and the gravitomagnetic field acts only on moving matter.

2 Flyby anomaly as a manifestation of LITG gravitomagnetism

As defined in Wikipedia, the flyby anomaly is an unexpected energy increase during Earth-flybys of spacecrafts, this anomalous change of velocity was discovered by J.D. Anderson and other engineers at JPL, here we will use the Lorentz

invariant theory of gravitation or LITG for short, and the similarity between the gravitomagnetic field and the magnetic field, to explain the anomaly, note that the co-variant theory developed by the Russian physicist Sergey Fedosin reduces to LITG at low velocities and low fields and in this case it is valid for inertial frames of reference.

The spacecraft during the flyby is surely in a free fall state and according to equivalence principle an observer inside it can claim the state of rest, so in this case he can insists that while approaching Earth, that the Earth is moving towards him by the same velocity of his craft, this movement according to special relativity theory have to be taken seriously, and the Earth due to this movement generates a gravitomagnetic field according to LITG theory given as:

$$\Omega = \frac{Gm_e v}{c^2 R_e^2} \tag{1}$$

where m_e is the Earth's mass and R_e is it's radius and v is velocity by which the Earth is approaching the spacecraft as judged by an observer inside it, now consider an electromagnetic signal sent as a ranging telemetry, in principle electromagnetic waves composed of photons, and photons are particles of light with no rest mass, but according to special relativity they possess a mass while moving with the speed of light which is given as $m_{ph} = \frac{E}{c^2}$, so in principle the photon generates a gravitomagnetic field while moving with the speed of light, and therefore the photon can be affected by the field produced by Earth, the signal's photon is coming from a free falling spacecraft, or a rest frame as judged by the photon as an observer, instead the Earth will be viewed by the photon to be moving with the same velocity towards the spacecraft, because the photon and Earth are moving in opposite directions the gravitomagnetic force will be an attractive force, and the acceleration given to the photon can be calculated using equation (1) one can write

$$a_{ph} = \Omega c = \frac{Gm_e v}{cR_e^2} \tag{2}$$

hence substituting the values of constants and the velocity of NEAR spacecraft at perigee during (1998) Earth fly-by or v =12.7 km/sec we get:

$$a_{ph} = 4.149 \times 10^{-4}\, m/s^2 \tag{3}$$

which is exactly the same as the value obtained by modeling the effect.

Now since the speed of light is constant the only way for this acceleration to manifest is in a blue-shift, thus we will register a blue-shift in the telemetry signal, note that the effect is highly dependent on observation, because during the departure of the spacecraft the effect will be a red-shift of exact magnitude, so the two effects will cancel each other if both are observed, this explains clearly why the effect is minimum if the trajectory of the spacecraft is symmetrical around the equator simply because the antennae of the NASA Deep Space Network or DSN are situated near the equator, so both the blue-shift during

the approach and the red shift during departure will be equally registered, and they will cancel each other, therefore if a large number of DSN antennae are distributed evenly all over Earth's surface the flyby effect will not be observed.

Note that the above treatment is just to explain the effect, but in practice a component of the velocity of light vector parallel to the relative Earth's velocity have to be taken, the other component perpendicular to Earth's relative movement will not be affected by the gravitomagnetic field of the Earth, also note that this gravitomagnetic field produced by the relative movement of the Earth will not interact with the spacecraft, because the spacecraft is in free fall state therefore an observer in it can claim the state of rest and the gravitomagnetic field won't act on matter at rest.

3 Gravity probe-b gyroscopes measured the true torque

One of the basic tenets of the theory of relativity is the equivalence of different frames of reference, in special theory of relativity this is valid for inertial frames of reference, and it means simply that an observer in a particular inertial frame conducting experiments within his frame can have the right to obtain results differing than those obtained by another observer in a different inertial frame, and according to special theory of relativity both observers results are correct within their frames, now for frames in a gravitational field we can use the equivalence principle and consider free fall to be as a most privileged inertial frame of reference where gravitational field is switched off and Newton's first law of motion is operating fully, a free falling observer can assume the state of rest while the whole observable Universe is moving with the same velocity of the observer in free fall in the opposite direction, as far as the free falling observer is concerned this is not an apparent movement it's real and can produce measurable effects.

Using the above reasoning we can reinterpret the results obtained by the gravity probe-b researchers and show that the first results obtained weren't anomalous and there was no need for thinking about different sources of noise to correct the obtained results, the experiment was wonderful, the technical details were ingenious, the four spherical gyroscopes were nearly perfect, in fact so perfect they calculated exactly the effects experienced by them, not the effects expected by the respected researchers as we will show.

For an observer on Earth it is so evident that the spacecraft is revolving around Earth with a period of about 97.5 minutes in a circular polar orbit, so we expect the four gyroscopes to measure the two effects predicted by general relativity, namely the geodetic effect and the Lense-Thirring effect, what concerns us here is the second effect which is analogous to the magnetic field in electromagnetism, but actually this wasn't the case from the point of view of the four gyroscopes, the four spinning gyroscopes were in free falling frame of reference, the gyroscopes as observers in free fall state will claim the state of absolute rest while the Earth will be revolving relatively around them with

exactly the same period by which we observe the spacecraft to be taking to complete one revolution around Earth, the four gyroscopes were designed to spin unaffected by the orientation of the spacecraft and therefore the fixation of the spacecraft to a certain star will not make any difference to the gyroscopes, they were in free fall, due to this relative rotation of the Earth around the spinning gyroscopes, Earth will become a source of a gravitomagnetic field according to LITG, so the revolving Earth's mass here will be equivalent to an electric charge moving in a circle of radius $d = R_e + r$ where d is the distance between the center of Earth and the spacecraft, R_e is Earth's radius and r is the distance between Earth's surface and the spacecraft, using the analogy between magnetism and gravitomagnetism we can use the same laws obtained for moving electric charges for moving masses, so in this case we can use the law obtained to calculate the magnetic field at the center of a circle of radius d where a charge Q is revolving, we need only replace Q by m_e where m_e is the Earth's mass, and the magnetic constant $\frac{\mu_o}{4\pi}$ by the gravitomagnetic constant $\frac{G}{c^2}$ where G is the universal gravitational constant and c is the speed of light, the magnetic field using Biot-Savart law is given as:

$$B = \frac{\mu_o I}{2d} \tag{4}$$

where I is the electric current and in our case $I = \frac{Q}{T}$ where T is the time period, for the analogous matter current we can write $I = \frac{m_e}{T}$ where I in this case is the matter current, equation (4) can be rewritten as:

$$B = \frac{2\pi\mu_o Q}{4\pi T d} \tag{5}$$

in this form we can replace the constants by those of the relatively revolving Earth and equation (5) can be written as:

$$\Omega = \frac{2\pi G m_e}{c^2 T d} \tag{6}$$

where Ω is the torsion field analogous to the magnetic field B , the dimension of it is same as that of the angular velocity as explained in length by Sergey Fedosin, for the free falling gyroscopes not only the Earth is revolving around them but it will be claimed by them to be spinning around an axis perpendicular to its original rotation axis with a period of 97.5 minutes, therefore the Earth now become a source of a dipole gravitomagnetic field and at the equatorial plane using LITG equations can be given as:

$$\Omega_s = \frac{2\pi G m_e}{5c^2 T d} \tag{7}$$

where Ω_s is the dipole field due spin observed by the gyroscopes, now this field will be added to the previous field to give the total field acting on the gyroscopes as:

$$\Omega_t = \Omega + \Omega_s = \frac{12\pi G m_e}{5c^2 T d} \tag{8}$$

substituting the values of constants, we take the radius of Earth to be $R_e = 6.378 \times 10^6\ m$ and the distance between the spacecraft and Earth's surface $r = 650\,km$ and the values of c , G , and m_e taken from wikipedia, the value of Ω_t will be:

$$\Omega_t = 8.13 \times 10^{-13}\ s^{-1} \tag{9}$$

now if we consider the value obtained for the dipole field due to Earth's daily rotation around its own axis to be:

$$\Omega_E = 8.5 \times 10^{-15}\ s^{-1} \tag{10}$$

then by dividing equation (9) by equation (10) we can compare between the true field sensed by the gyroscopes and the field expected by the gravity probe-b team or:

$$\frac{\Omega_t}{\Omega_E} = 95.649 \tag{11}$$

this is nearly about 100 times larger than the expected effect, and this is exactly the value measured by the gyroscopes without any intervention or correction.

Hence we conclude that the value of the torque measured by the gyroscopes needs no correction, the gyroscopes revealed faithfully the true effect experienced by them, also we conclude that, the true field calculated using the equivalence principle and the LITG is so large than the expected one due to Earth's spin to the extent that measuring this tiny effect is impossible using this type of experiment.