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

Mutasim A. Ahmed

June 24, 2017

Abstract

To explain the flyby anomaly we fully applied the equivalence principle, and we allowed the observer on-board the free-falling craft to claim the state of rest. The telemetry photons considered as particles possessing their mass due to their movement with the light speed. The telemetry photons assumed to generate their respective gravitomagnetic fields according to LITG. The telemetry photons were emitted from the craft and can only be judged by an observer on-board the craft. The observer on-board the spacecraft will claim that the Earth is moving relatively with his same velocity in the opposite direction. The effect will be detected by an observer on-board the craft, that is the frame of reference attached to the craft. The Earth will generate its respective gravitomagnetic field due to its relative motion as claimed by the observer on-board the craft. The flyby effect is highly dependent on the way we observe it, as we will show.

As for the gravity probe-b case, we insisted that the equivalence principle must be fully applied. Therefore an observer in a free falling frame, have the right to claim being at rest, while the rest of the Universe will be moving with his same velocity, in the opposite direction. So from the point of view of the spinning gyroscope, Earth will be orbiting the gyroscope. We usually call this an apparent revolution. But for the gyroscope this apparent revolution of the Earth can produce measurable effects. Using this reasoning and applying the LITG we obtained a field which is nearly 100 times greater than the expected one.

1 Introduction

Newton's theory of gravitation was originally designed to describe only the static gravitational field produced by any mass. No additional 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 particular mass will have the same value and form, no matter 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. This field is similar to the magnetic field in classical electrodynamics, and is produced when a mass is in motion relative to another observer. And according to this theory the mass of a body is analogous to the electrostatic charge of a body, but when a body moves it produces an additional field analogous to the magnetic field in classical electrodynamics. 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 Russian mathematician Sergey G. Fedosin generalized the LITG to be valid even in cases of strong gravitational field. This new theory proposed by Fedosin is known as covariant theory of gravity. The covariant theory will reduce to LITG at low velocities and week gravitational fields.

As for the flyby anomaly, and because all known fields and forces were tested by different investigators, and proved insufficient to account for the anomalous acceleration, so I thought this anomalous acceleration, might be due to a gravitomagnetic interaction between Earth and the telemetry signal photons, but with respect to the frame of reference attached to the free-falling spacecraft, provided we insisted on the particle nature of photons. Therefore photons will generate their respective gravitomagnetic fields due to their perpetual movement with speed of light. So while trying to do this it became very clear to me, that it is possible to account for this anomaly if we use the LITG , and if we fully applied 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 relatively with his 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, namely the geodetic effect, and the Lense-Thirring effect. What concerns us here is the second effect. The Lense-Thirring effect is produced by rotating objects and it's analogous to the effect produced by a rotating spherical 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 LIGT 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 spinning 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 Lense-Thirring effect which is concerning us here. 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 as in Fig.3. We usually call this an apparent revolution, but for the gyroscopes this revolution of the

Earth around them is quite real and have a measurable effects. This relative revolution will generate 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. In addition to this Earth will appear to spin for the gyroscopes as explained in Fig.2 with a period $T = 97.5\,minutes$. Hence Earth will act as a source of gravitomagnetic dipole field as judged by the gyroscopes. This time it's a new spin with a new axis of rotation. From Fig.2 and Fig.3 the orientations of these two fields are same, and can be added to each other.

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 we will use the similarity between the gravitomagnetic field and the magnetic field to explain the anomaly. Note that for the same movement or rotation, the magnetic field differ than the torsion field in sign. Note also that the co-variant theory 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 the Earth that he is at rest, and that the Earth is moving towards him by the same velocity of his craft. This relative movement according to the special theory relativity have to be taken seriously. And due to this movement of the Earth a gravitomagnetic field will be generated according to LITG theory. This field which is denoted by Ω, and given the name gravitational torsion field for the first time by the Russian mathematician Sergey G. Fedosin (1999) . So we can write:

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

The minus sign because the gravitational force is an attractive one, hence the field is negative.

For an observer on-board the craft, R_e have to be replaced by $d = R_e + r$, where d is the distance between the craft and Earth's center, and r is the distance between the craft and Earth's surface, also we have to use a component of the the velocity of the photons c in the direction parallel to that of the Earth's relative velocity v. But as in Fig.1 r is changing continuously as the craft approaches Earth during inbound. So we will use Eq.1 as an approximation.

In Eq.1 m_e is Earth's mass and R_e is its radius and $-v$ is velocity by which Earth is approaching the spacecraft as judged by an observer inside it. Now consider an electromagnetic signal sent as a ranging telemetry from the craft. 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 $m_{ph} = \dfrac{h\nu}{c^2}$ where h is the Planck's constant and ν is the frequency of the photon. 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 the relatively moving Earth. Now the signal's photon is coming from a free falling spacecraft, or a rest frame as judged by an observer on-board the spacecraft. Since the the photons were emitted from the craft's frame of reference, we have to judge the situation relying on the observations performed by an observer on-board the craft. Now for this observer the Earth will be viewed to be moving with the same velocity of the craft, towards it, while the craft itself claimed by him to be at rest. Now this observer will detect a gravitomagnetic interaction between the photons and the Earth. And because the photons and the Earth are moving in opposite directions the gravitomagnetic force will be an attractive force. Now if the spacecraft's velocity as judged by us is v then Earth's relative velocity as judged by an observer on board the spacecraft will be $-v$. Therefore the acceleration given to the photon can be calculated using Eq.1 and one can write:

$$a_{ph} = \Omega c = \frac{G m_e v}{c R_e^2} \tag{2}$$

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

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

Which is exactly of the same order of the value obtained by modeling the effect. See Andereas Aste.pdf {Spacecraft Anomalies: An Update (2008)}.

Now since the speed of light is constant the only way for this acceleration to manifest is as a blue-shift. Thus we will register a blue-shift in the telemetry signal. Note that the effect is highly dependent on observation. As in Fig.1 the effect depends on the angle θ and the maximum effect will be measured for the minimum value of θ . Provided one of the NASA's Deep Space Network antennae is there to register it, otherwise it will go unnoticed, because at infinity the effect will disappear. Also note that during the departure of the spacecraft the effect will be a red-shift of the exact magnitude of the blue-shift produced during the inbound. So if the flyby is equally monitored during both the inbound and the outbound, the two effects will cancel each other. This explains clearly why the effect is minimum if the trajectory of the spacecraft is symmetrical around the equator. Simply because the DSN antennae were 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. Therefore to observe the maximum value for this effect we have to observe only one of the two symmetrical paths around Earth during the flyby event and ignore the other one. The one which is during the inbound will be manifested as a blue-shift, and that during the outbound as a red-shift as discussed before. Therefore we conclude that the flyby effect can only be detected due to an asymmetrical tracking during the flyby, the effect will disappear if we track the spacecraft evenly and faithfully during this short process.

Note that the above treatment is just to explain the effect. But in practice as explained in Fig.1 a component of the velocity of light vector parallel to the relative Earth's velocity or $c\cos\theta$ have to be taken. And R_e must be replaced by R_e+r, where r is the distance between the craft and the surface of the Earth . Hence we can write:

$$a_{ph} = \Omega c\cos\theta = \frac{Gm_e v}{c(R_e+r)^2}\cos\theta \tag{4}$$

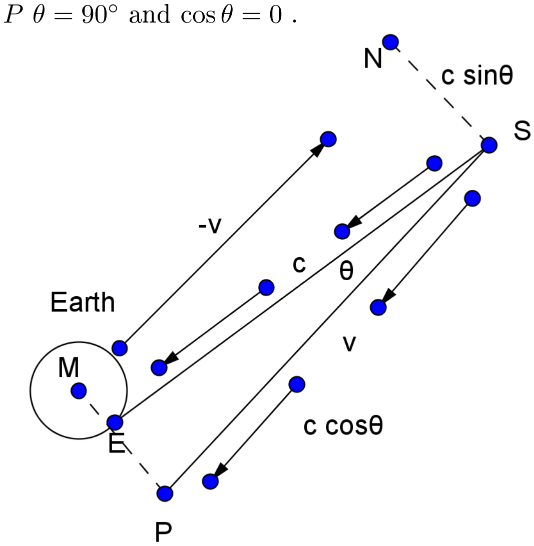
The other component $c\sin\theta$ perpendicular to Earth's relative movement will not be affected by the gravitomagnetic field of Earth. Also from Fig.1 there will be three cases. The first is when the spacecraft is at the infinity, and there will be no interaction between the photons and Earth in this case. The second when the craft is relatively near Earth and the angle θ is relatively small, and this is the case of a maximum effect. The third case is when the craft approaches point P and the angle θ approaches $90°$ at this point the effect ceases to manifest. And this last case will explain why the effect wasn't observed for spacecrafts in orbit around Earth at great distance from it. But a careful examination may reveal a tiny frequency shift for the low orbit spacecrafts near rising and setting. Also note that this gravitomagnetic field produced by the relative movement of Earth will not interact with the spacecraft, because the spacecraft is in a free fall state therefore an observer inside it can claim the state of rest and the gravitomagnetic field won't act on matter at rest, because motion is essential for producing the gravitomagnetic field.

3 Gravity probe-b gyroscopes measured the true torque

One of the basic assumptions 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. Hence we consider free fall to be as a most privileged inertial frame of reference. Where the gravitational field is switched off and Newton's first law of motion is operating fully for a free falling observer. A free falling observer can assume the state of rest while the whole observable Universe is moving with his same velocity in the opposite direction. And 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 guided by Francis Everitt. And show that the first results obtained weren't anomalous and there was no need for thinking about

Figure 1: The figure is not drawn to scale. An observer is on Earth's surface at point E . At point S is the spacecraft approaching Earth with velocity v . The path of the spacecraft is SP . A telemetry signal's path is SE . The angle PSE is θ which is the angle between the path of spacecraft and the signal's path. Earth's apparent velocity towards the craft is $-v$. The component of the velocity of the signal c parallel to Earth's apparent velocity is $c\cos\theta$. And the component perpendicular to this is $c\sin\theta$. This last component is along the line SN which is parallel to the line PM . This component will have no effect on the the anomaly. Note that the angle θ increases as the spacecraft approaches point P . At point P $\theta = 90^\circ$ and $\cos\theta = 0$.



different sources of noise to correct the obtained results. The experiment was wonderful and the technical details were ingenious. The four spherical gyroscopes as described were nearly perfect. Therefore the gyroscopes were assumed by this paper to calculate exactly the effects experienced by them, not the effects expected by us 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. The geodetic effect was proved with high accuracy. What concerns us here is the second effect which is analogous to the magnetic field in electromagnetism. Where the daily rotation of Earth affects space-time in the vicinity of Earth. 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 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, as explained in Fig.3. Earth due to this relative movement 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 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. We remind that if the magnetic field is positive the gravitomanetic one will be negative for the same movement. The magnetic field using Biot-Savart law is given as:

$$B = \frac{\mu_o I}{2d} \tag{5}$$

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 (5) can be rewritten as:

$$B = \frac{2\pi\mu_o Q}{4\pi T d} \tag{6}$$

In this form we can replace the constants by those of the relatively revolving Earth and equation (6) can be written as:

$$\Omega_1 = -\frac{2\pi G m_e}{c^2 T d} \tag{7}$$

Where Ω_1 is the torsion field analogous to the magnetic field B . The dimension of this field is same as that of the angular velocity as explained in length by Sergey Fedosin. for the free falling gyroscopes not only 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 as explained in Fig.2. Therefore Earth now become a source of a dipole gravitomagnetic field and at the equatorial plane using LITG equations this dipole field can be given as:

$$\Omega_2 = -\frac{2\pi G m_e}{5c^2 T d} \tag{8}$$

See Fig.2 for more clarification. Here Ω_2 is the dipole due to the apparent spin observed by the gyroscopes, and $T = 97.5\, minutes$.

From Fig.2 and Fig.3 we can see clearly that Ω_1 and Ω_2 are in the same directions. Therefore we can add them. Now the total field Ω_t acting on the gyroscopes will be:

$$\Omega_t = \Omega_1 + \Omega_2 = -\frac{12\pi G m_e}{5c^2 T d} \tag{9}$$

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 neglecting the minus sign will be:

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

Now if we consider the value obtained for the dipole field due to Earth's daily rotation around its own axis, for an observer on Earth's surface along the equator to be: $\Omega = 8.5 \times 10^{-15}\ s^{-1}$. This value of Ω taken from wikiversity was calculated by Sergey Fedosin. Now for the value at distance $d = R_e + r$ we can write: $\Omega = \dfrac{8.5 \times 10^{-15} \times R_e}{R_e + r}\mathrm{s}^{-1}$. Now substituting the values of constants we get:

$$\Omega = 7.71 \times 10^{-15}\ s^{-1} \tag{11}$$

Then by dividing equation (10) by equation (11) we can compare between the true field sensed by the gyroscopes and the field expected by us or:

$$\frac{\Omega_t}{\Omega} = 105.39 \tag{12}$$

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 the Earth's daily rotation, to the extent that measuring this tiny effect is impossible using this type of experiment.

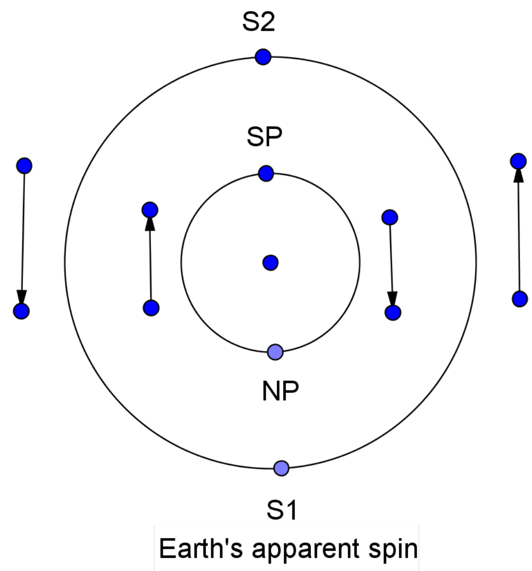


Figure 2: Here we explain how an observer orbiting a large object. And due to his free fall state. Could claim that the larger object is spinning, with spin periodic time exactly matching his period of revolution. The spacecraft is in a polar orbit around Earth. Starting at point $S1$ above the north pole NP counterclockwise. Now after time $t = \frac{T}{2}$ the spacecraft will be above the south pole SP . Again after time $t = \frac{T}{2}$ the craft will come back to point NP . But being in free fall an observer on-board craft will claim the state of rest at point $S1$. Therefore the only way to explain the changing views of Earth's surface observed by him, is to claim that Earth is spinning. For this observer Earth is spinning in a clockwise manner.

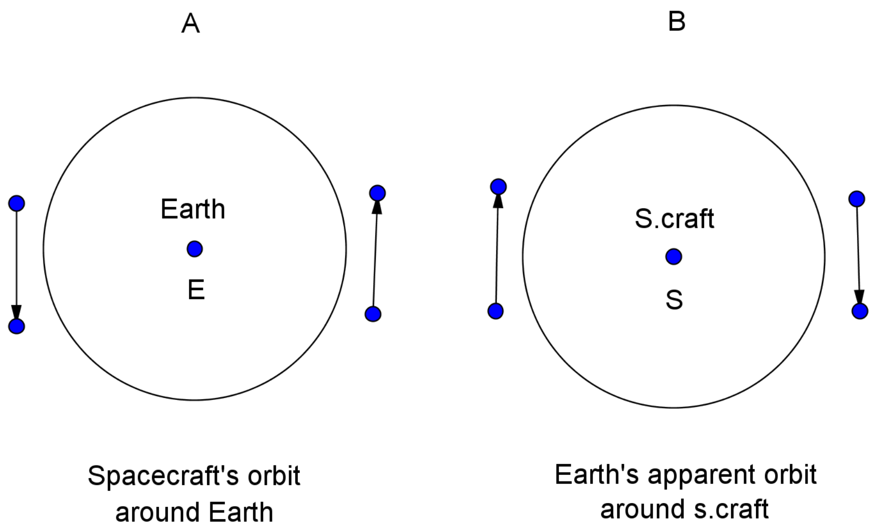


Figure 3: In figure A represents an ordinary circular orbit of any spacecraft around Earth. This what we judge here on Earth. The spacecraft is orbiting counterclockwise. But B represents the situation from the point of view of the observer on-board the spacecraft. Being in a free fall he will claim the state of rest. He will claim that Earth is revolving around him in a clockwise manner. For him this revolution is true and not apparent.