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The Flyby Anomalies - A Possible Explanation

Abstract

Using a recently developed model of gravity that differs from both the Newton and Einstein models, agreement may be achieved between the anomalous velocities of the flyby mission vehicles and the predictions of the model. This conjecture supports the notion of a ***temporal-inertial (TI)*** field that is the principle mediator of the gravitational and inertial interactions. The TI field is subject to gravity and, in response to the acceleration of gravity, transmits its own acceleration to massive particles and objects comprising massive particles. No assertion is made relating properties of the TI field to those of the Higgs field. The ***flux model*** posits that in a gravitational field, the velocity of the TI field combines with that of gravitons emitted by the gravitational body to increase the flux of gravitons relative to the TI field. Thus the response of the TI field to gravity adds to the force of gravity. Thus, again, the flux model may explain the unexpected changes in velocity seen by the so-called flyby spacecraft in their gravity assist maneuvers past Earth.

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List of Tables and Figures

^ The Temporal-Inertial (TI) Field

The relation of the Higgs field or the Higgs mechanism [1] and what I designate as the TI field is undefined. I may attribute properties to the TI field (such as the particles of the field being subject to gravity) that are not attributed to the Higgs field.

The characteristics of the TI field as they affect gravity are developed in reference [2]. Some of the conclusions of the referenced paper are summarized below.

1. When a matter particle or an object composed of matter particles is accelerated by an external force, its motion is resisted by its acceleration relative to the TI field. This reactive force of the TI field of space is the familiar inertial force.
2. Particles of the TI field are accelerated by gravity directly toward the center of each gravitational body just as a test particle would be and reaches the escape velocity of such a particle at the distance of that particle from the barycenter of the gravitational body.
3. The ***flux model*** of gravity [3] posits that in a gravitational field, the velocity of the TI field combines with that of the gravitons emitted by the gravitational body to increase the flux of gravitons relative to the TI field. Thus the response of the TI field to gravity adds to the force of gravity.
4. The gravitational acceleration of the TI field relative to a matter particle or an object composed of matter particles applies a force to that matter particle or object. This force is the familiar gravitational force applied indirectly through the intermediary of the acceleration of the TI field of space.
5. The TI field accelerates massive particles at the same rate as its own acceleration.
6. Acceleration of the TI field in its own response to gravity is the sole accelerator of massive particles in response to gravity. Accordingly, massive particles are not directly subject to the gravitational force.
7. Acceleration of the TI field is moderated by a second field termed the static field.

^ The Flux Model of Gravity

The behavior of the TI field described in the previous section is described more fully in reference [3]. The flux model posits that in the gravitational field of a massive body, the velocity of the TI field falling toward the gravitational body combines with the velocity of the gravitons emitted by the body to increase the flux of gravitons relative to the TI field. Velocities are not combined in violation of Special Relativity, but graviton fluxes are combined. Thus the response of the TI field to gravity adds to the force of gravity.

An iterative process is used to construct the acceleration and velocity profiles about a gravitational body as outlined in Appendix B. The profiles are represented by two mathematical series as shown in Table B-1. The series converge so rapidly for the modest gravitational field of the Earth that only two terms are needed to express the acceleration and velocity profiles for Earth. The acceleration profile for Earth is given in Eq (1).

From Eq (B-5) in reference [3] :

$$a_{Total} = (GM / r^2) * (1 + (2GM / r\ c^2)^{1/2}) \qquad (1)$$

The Newtonian value of acceleration is familiar and is given by the first term in Eq (1). The incremental acceleration posited by the flux model is given by the second term in Eq (1).

$$a_{incremental} = (GM / r^2) * (2GM / r\ c^2)^{1/2} \qquad (2)$$

Rewrite Eq (2) more compactly as

$$a_{incremental} = 2^{1/2} * (GM)^{3/2} / (r^{5/2}\ c) \qquad (3)$$

List Eq (2) and Eq (3) in Table 1.

^ Table 1. Acceleration Equations of the Flux Model of Gravity

Total Acceleration	Incremental Acceleration
$(GM / r^2) * (1 + (2GM / r\ c^2)^{1/2})$	$(GM / r^2) * (2\ GM / r\ c^2)^{1/2}$
$(GM / r^2) * (1 + (2GM / r\ c^2)^{1/2})$	$21/2 * (GM)^{3/2} / (\ r^{5/2}\ c)$

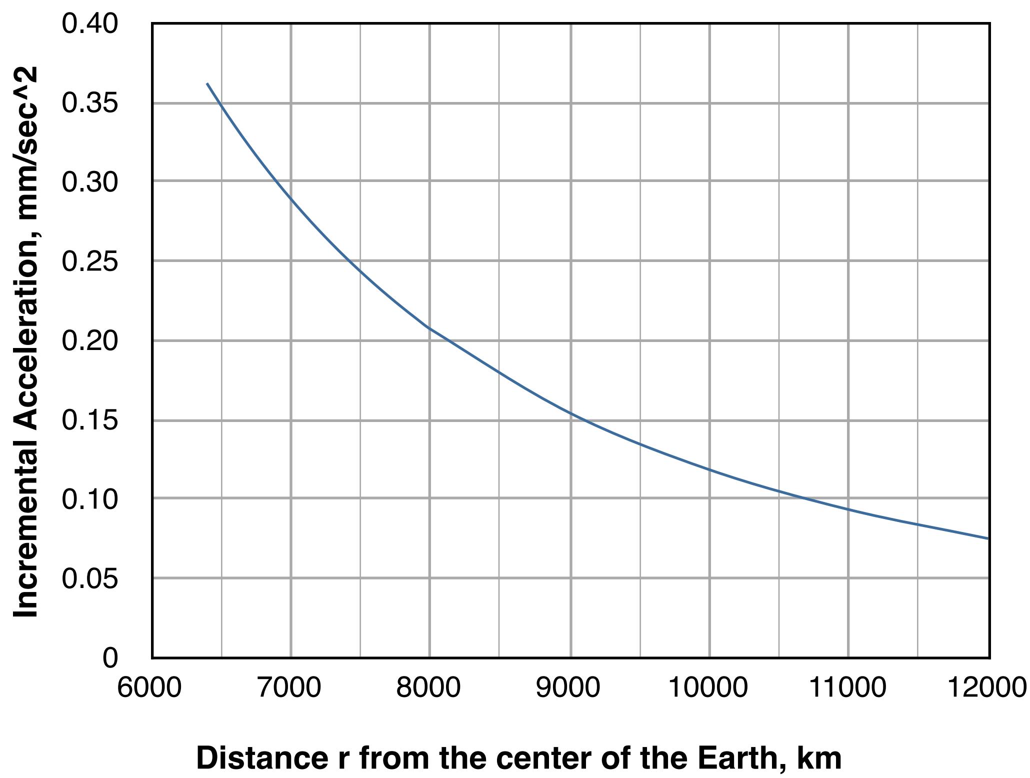
^ The Flyby Missions

Exploration of the outer solar system is enabled by the so-called flyby missions in which the energy to reach the outer solar system is enhanced by gravity assist maneuvers past Earth and other planets [4]. The increase in energy of the spacecraft is provided by the planet as the spacecraft moves by the planet in the orbital direction of the planet. Thus the spacecraft gains velocity and changes direction without the expenditure of fuel. The trajectory and velocity of the spacecraft is closely monitored in these maneuvers and discrepancies have been observed in their velocities relative to those expected from Newtonian mechanics.[5] [6] [7].

^ The Flyby Anomalies

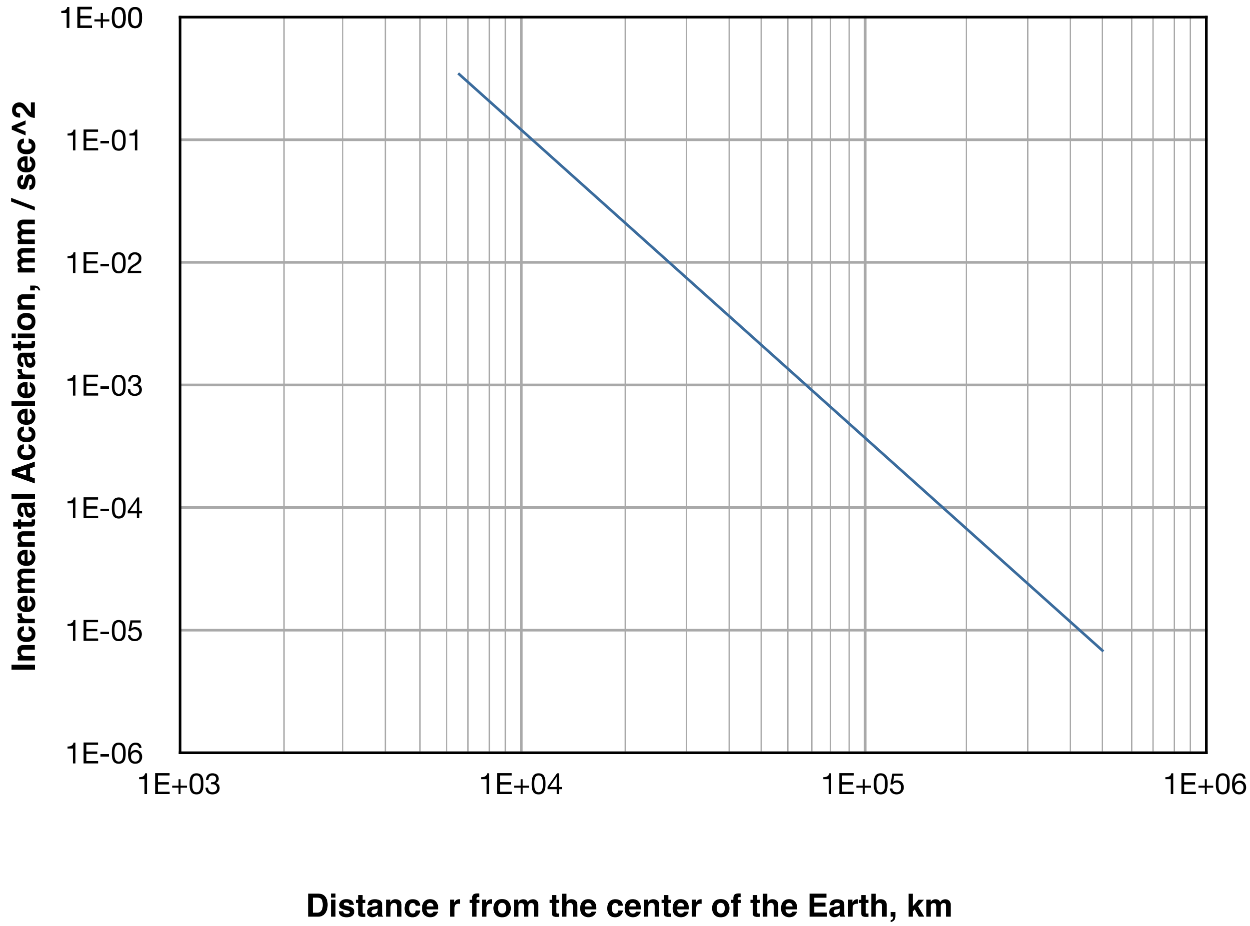
A number of spacecraft, using Earth for gravity assist maneuvers, have experienced increases in energy unaccounted for by conventional physics. These increases in energy are measured by increases in velocity of the spacecraft of a few mm/sec [7]. The flux model may explain these unexpected changes in velocity.

The incremental acceleration profile about the Earth is graphed in Figure 1 and Figure 2. To determine whether the flux model can account for a particular flyby anomaly, the acceleration at the radius from the Earth of the spacecraft would have to be integrated over the path of the spacecraft. According to the flux model of gravity, the gravitational force in the vicinity of a gravitational body is larger than modeled by Newtonian physics. The incremental value of acceleration is described by Eq (2) and (3) and listed in Table 1. Applying the total acceleration of Eq (1) of the flux model to the calculation of the trajectories of the flyby mission spacecraft may account for the differences in velocity measured during the missions.



^ Figure 1. Incremental Acceleration Toward the Earth Predicted by the Flux Model, mm / sec^2 (linear scales)

Governing equation: $a_{Incremental} = 2^{1/2} * (GM)^{3/2} / (r^{5/2}\ c)$



^ Figure 2. Incremental Acceleration Toward the Earth Predicted by the Flux Model, mm/sec^2 (log-log scales)

Governing equation: $a_{Incremental} = 2^{1/2}\ (GM)^{3/2} / (\ r^{5/2}\ c)$

^ Conclusions

1. According to the flux model of gravity, the gravitational force in the vicinity of a gravitational body is larger than modeled by Newtonian physics.
2. The trajectories of spacecraft using the Earth in gravity assist maneuvers approach closely enough to Earth to experience the incremental acceleration predicted by the flux model of gravity.
3. The magnitude of the incremental acceleration profile about the Earth is in the 'right ballpark' to account for the anomalous increase in velocity observed for the flyby mission spacecraft.
4. Applying the total acceleration of the flux model to the calculation of the trajectories of the flyby mission spacecraft may account for the differences in velocity measured during the missions.

^ Appendix A
Basic Parameters Used to Generate the Tables and Figures

^ Table A-1. Basic Parameters [8] [9]

Reference	Parameter	Value	Units
Earth	GM	398,600.4418	km^3 / sec^2
Earth	Radius r	6,371	km

^ Appendix B

Iterative Development of the Acceleration Profile About a Weak Gravitational Body

The flux model of gravity posits the following:

1. The infall velocity of particles of the TI field falling toward a gravitational body is the same magnitude (but opposite in sign) as the escape velocity at any given distance from the body.
2. The velocity of the particles of the TI field toward a gravitational body increases the flux of gravitons 'seen' by these particles and thus increases the gravitational force acting on the particles. The magnitude of the infall velocity of the TI field is increased beyond the value expressed in the classic formula:

   $v_{Infall} = v_{Escape} = (2GM / r)^{1/2}$.
3. We must evaluate the effect of this change. In other words, the increase of the infall velocity increases the gravitational force which then increases the infall velocity and so on.
4. The process to determine the outcome of this feedback problem is to step through the following:
   a. Calculate the acceleration at a given distance from a gravitational body for the current value of the infall velocity.
   b. Integrate the acceleration to yield a new expression for the infall velocity.
   c. Continue back to step a until the contribution of the last iteration is negligible.

The process and results are summarized in Table B-1.

^ Table B-1. Summary of the Iterative Evaluation of the Acceleration and Infall Velocity Profiles About a Weak Gravitational Body

Step	Expression **
Determine escape velocity v	$v = (2 GM / r)^{1/2}$
Determine acceleration $a = (GM / r^2) (1 + v/c)$	$a = (GM / r^2) * (1 + (r_S / r)^{1/2})$
Integrate acceleration to get next iteration of escape velocity v.	$v = (2 GM / r)^{1/2} * [1 + (1/3) (r_S / r)^{1/2}]$
Determine acceleration $a = (GM / r^2) (1 + v/c)$	$a = (GM / r^2) * [1 + (r_S / r)^{1/2} + (1/3) (r_S / r)]$
Integrate acceleration to get next iteration of escape velocity v.	$v = (2 GM / r)^{1/2} * [1 + (1/3) (r_S / r)^{1/2} + (1/12) (r_S / r)]$
Determine acceleration $a = (GM / r^2) (1 + v/c)$	$a = (GM / r^2) * [1 + (r_S / r)^{1/2} + (1/3) (r_S / r) + (1/12) (r_S / r)^{3/2}]$
Integrate acceleration to get next iteration of escape velocity v.	$v = (2 GM / r)^{1/2} * [1 + (1/3) (r_S / r)^{1/2} + (1/12) (r_S / r) + (1/60) (r_S / r)^{3/2}]$
Determine acceleration $a = (GM / r^2) (1 + v/c)$	$a = (GM / r^2) * [1 + (r_S / r)^{1/2} + (1/3) (r_S / r) + (1/12) (r_S / r)^{3/2} + (1/60) (r_S / r)^2]$
The general form of the series for the infall velocity can now be written	$v = (2 GM / r)^{1/2} * [1 + \sum$ (from n= 1 to ∞) $[(2 / (n+2)! * (r_S / r)^{n/2}]$
The general form of the series for the infall acceleration can now be written	$a = (GM / r^2) * [1 + \sum$ (from n= 1 to ∞) $[(2 / (n+1)! * (r_S / r)^{n/2}]$

** I use the abbreviation $r_S = (2 GM / c^2)$ even though the development here is not valid for black holes. The term r_S is the Schwarzschild radius [10].

^ References

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