Analysis of The Anomalous Orbital-Energy Changes Observed in Spacecraft Flybys of Earth

by

Roger Ellman

Abstract

In March 2008 anomalous behavior in spacecraft flybys of Earth was reported in Physical Review Letters, Volume 100, Issue 9, March 7, 2008, in an article entitled "Anomalous Orbital-Energy Changes Observed during Spacecraft Flybys of Earth"[1].

The data indicate unaccounted for changes in spacecraft speed, both increases and decreases, for six different spacecraft involved in Earth flybys from December 8, 1990 to August 2, 2005. The article states that, "All … potential sources of systematic error …. [have been] modeled. None can account for the observed anomalies…. Like the Pioneer anomaly … the Earth flybys anomaly is a real effect …. Its source is unknown."

In this article it is shown that the Earth flybys anomaly is caused by a very small centrally directed acceleration, [in addition to that of natural gravitation], the same effect as that which produces the Pioneer anomaly. How that effect operates to produce the observed results is analyzed. A common cause of the centrally directed accelerations is presented.

Roger Ellman, The-Origin Foundation, Inc.
320 Gemma Circle, Santa Rosa, CA 95404, USA
RogerEllman@The-Origin.org
http://www.The-Origin.org

Analysis of The Anomalous Orbital-Energy Changes Observed in Spacecraft Flybys of Earth

by
Roger Ellman

The Problem

In March 2008 anomalous behavior in spacecraft flybys of Earth was reported in Physical Review Letters, Volume 100, Issue 9, March 7, 2008, in an article entitled "Anomalous Orbital-Energy Changes Observed during Spacecraft Flybys of Earth"[1].

The data indicate unaccounted for changes in spacecraft speed, both increases and decreases, for six different spacecraft involved in Earth flybys from December 8, 1990 to August 2, 2005. The article states that, "All … potential sources of systematic error …. [have been] modeled. None can account for the observed anomalies…. "Like the Pioneer anomaly … the Earth flybys anomaly is a real effect …. Its source is unknown."

Analysis of the Flyby Anomaly

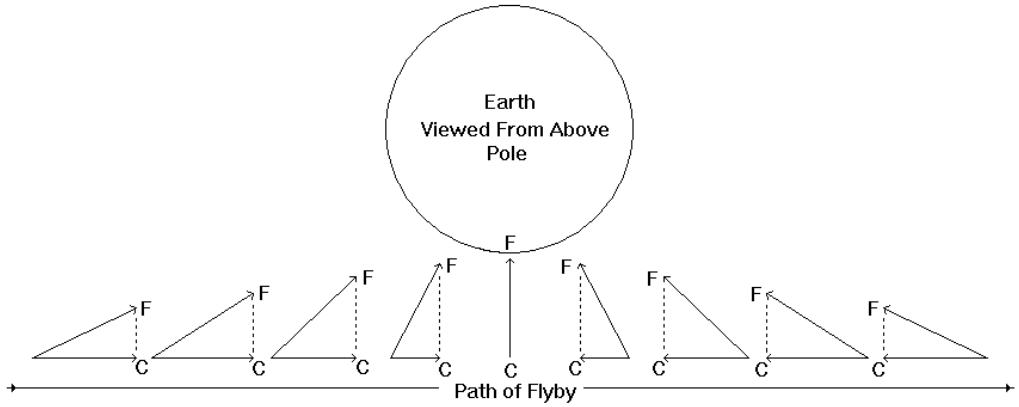
The phenomenon that would account for the highly varied occurrences of the flyby anomaly is a centrally directed acceleration [in addition to that of natural gravitation], that is a modest and otherwise unknown acceleration directed toward the core center of the Earth, the principle body involved in the mechanics of the flyby.

Such an acceleration shares characteristics with the Pioneer anomaly, which appears as a centrally directed acceleration, that is a modest and otherwise unknown acceleration directed toward the Sun, the principle body involved in the mechanics of the Pioneer spacecrafts' flight paths. The Pioneer anomaly is thoroughly analyzed and explained in *A Comprehensive Resolution of the Pioneer 10 and 11 "Anomalous Acceleration" Problem Presented in the Comprehensive Report "Study of the Anomalous Acceleration of Pioneer 10 and 11" and the Relationship of that Issue to "Dark Matter", "Dark Energy", and the Cosmological Model*[2].

In that article the centrally directed Pioneer acceleration is shown to be an effect that concomitantly involves centrally directed acceleration in all cosmic structures. Thus its occurrence in the Earth flyby cases is to be expected.

To observe the effects of an extra centrally directed acceleration the first step is to consider a simple spacecraft pass of Earth where the pass is all at zero latitude as shown in Figure 1, below. When the spacecraft is at a great distance out from Earth the spacecraft's motion is close to being directed toward the center of the Earth but not exactly so. A centrally directed acceleration there analyzed into components parallel and perpendicular to the spacecraft's motion would show most of the centrally directed acceleration acting to increase the spacecraft's speed.

As the spacecraft travels nearer to Earth that component parallel to its motion decreases, becoming zero at the closet approach to Earth. From that point on the parallel component acts in the opposite direction on the spacecraft, that is its effect is to decelerate the spacecraft not accelerate it. Ultimately the anomalous acceleration and anomalous deceleration experienced by the spacecraft become equal and cancel each other out leaving as the only flyby effect the gravitational boost that is the overall purpose of the flyby.



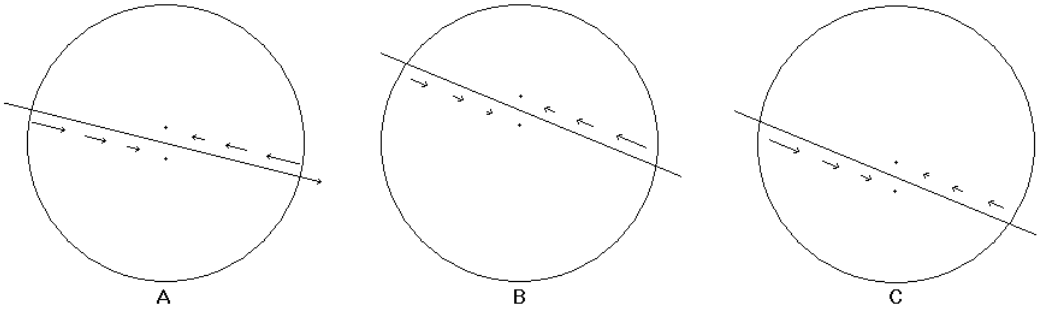
F = Centrally directed anomalous force [same effect as Pioneer Anomaly]

C = Component of F that is parallel to Path of Flyby:
- accelerates flyby throughout approach to mid-point of pass;
- decelerates flyby throughout disengagement from mid-point of the pass on outward.

At a completely zero latitude flyby path the component of the overall centrally directed anomalous force is greatest at greatest distance from Earth, declines to zero at the mid-point of the pass and there reverses and increases as distance from the Earth increases.

Figure 1
Centrally Directed Anomalous Acceleration Effect on Zero Latitude Flyby Path

The latitude of the flyby pass has a significant effect on the magnitude of the component of the overall centrally directed acceleration that is parallel to the spacecraft flight path. As latitude increases the magnitude of the parallel component decreases as shown in Figure 2, below.



The Effect of Latitude -

At zero latitude the component of the total anomalous force that is parallel to the path of the flyby is greatest at great distance from the Earth and null at the closest approach [the centrally directed force being there perpendicular to the flyby path].

As latitude increases the component parallel to the flyby path is further reduced because the overall anomalous force is directed toward the core center of the Earth.

- In pass A the acceleration phase and the deceleration phase are equal, a balance of equal latitude effects. The result is no net anomalous - effect - caused change in the spacecraft velocity.
- In pass B the acceleration phase is weaker than the deceleration phase because of the higher approach latitude. The result is a net anomalous - effect - caused decrease in the spacecraft velocity.
- In pass C the acceleration phase is stronger than the deceleration phase because of the latter's higher latitude. The result is a net anomalous - effect - caused increase in the spacecraft velocity.

Figure 2
Centrally Directed Anomalous Acceleration Effect of Latitude of Flyby Path

For a zero latitude path the center of the Earth, toward which the centrally directed anomalous acceleration is directed, lies in the plane of the pass. Consequently there is only one angle determining the magnitude of the components of the centrally directed acceleration. But at latitudes other than zero the angle of that latitude above the zero is a second angle introducing further modification of the portion of the overall centrally directed acceleration that is parallel to the flight path of the spacecraft and therefore affects its speed.

Consequently the magnitude of the effect of the centrally directed anomalous acceleration is less at higher latitudes than at lower. Therefore, depending on the specific flight path of the spacecraft's pass of Earth the spacecraft may experience an overall net anomalous acceleration or a net anomalous deceleration, those in various amounts depending on the specific encounter, and zero net modification if the path is perfectly symmetric.

It only remains, then, to determine the cause of centrally directed anomalous accelerations appearing as a near Earth effect, a Solar effect and in general as a cosmic effect.

The Cosmic Anomalous Acceleration

Beside the relatively recent Pioneer and Flyby anomalies there is another instance of an anomalous centrally directed acceleration [in addition to that of natural gravitation] that has been observed for the better part of a century. That is the indication by galactic rotation curves that galaxies are held together by what has been referred to as dark matter, matter intended to supply centrally directed acceleration that appears to otherwise be unaccounted for in the rotating galaxy structure and equilibrium.

That dark matter has never been detected in spite of substantial efforts. It is only hypothesized as the expected solution to the problem of indicated galactic centrally directed acceleration without apparent cause or source. That anomalous centrally directed acceleration is of the same magnitude as that involved in the Pioneer and Flyby anomalies. That anomalous centrally directed acceleration appears not merely in one or a few cases; rather, it appears in every rotating galactic structure observed.

What could produce such a phenomenon ? What would cause there to be a universe-wide occurrence of small centrally directed same accelerations ? A systematic contraction, a gradual reduction in the length component of every physical quantity in the universe would produce such a phenomenon as follows.

[1] The anomalous acceleration is a gravitation - related phenomenon caused by the general overall exponential decay of the universe with a time constant of $11.3373 \cdot 10^9$ years, a natural behavior just as that same form of exponential decay appears throughout the various natural processes of physics.

[2] That decay involves the fundamental constants (c, q, G, h, etc.) and decay of any of those must be dimensionally consistent with the decay of the others. The dimension that is decaying is length, the $[L]$ dimension in the dimensions of, for example: h, $[M \cdot \mathbf{L}^2/_T]$; c, $[\mathbf{L}/_T]$; and G, $[\mathbf{L}^3/_{M \cdot T^2}]$.

[3] Objections that such an effect would conflict with the known planetary system performance per the highly accurate planetary ephemeris are a mistaken interpretation of the situation.

Consider a planet in circular orbit around a sun as in Figure 3, below.

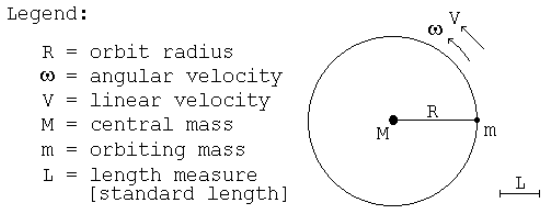


Figure 3

The relationship governing the motion is, of course, equation *(2)*, below

(2)	*Centripetal Acceleration Required*	=	*Gravitational Attraction Acceleration*
	$V^2/_R$ (or) $R \cdot \omega^2$	=	$G \cdot M/_{R^2}$

Now, let the length dimensional aspect [with the dimensions of all quantities expressed in the fundamental dimensions of mechanics, *[L], [M],* and *[T]*] of all quantities decay, becoming gradually smaller exponentially with time. That is, let all lengths, *[L]*, decrease by being multiplied by the decay function, *D(t)*, per equation *(3)*, below.

(3) $D(t) \equiv \varepsilon^{-[t/\tau]}$, where τ is the time constant of the decay

Then the quantities involved in equation *(2)* all change to as follows.

(4) *The Orbital Radius, R, [dimension =* $\boldsymbol{L}$*]*

R becomes $R(t) = R(t=0) \cdot \varepsilon^{-[t/\tau]}$

The Gravitational Constant [dimensions = $\boldsymbol{L}^3/_{M \cdot T^2}$*]*

G becomes $G(t) = G(t=0) \cdot \left\{ \varepsilon^{-[t/\tau]} \right\}^3$

Centripetal Acceleration Required [dimensions = $\boldsymbol{L}/_{T^2}$*]*

$$R \cdot \omega^2 \text{ becomes } R(t) \cdot \omega^2 = \left[R(t=0) \cdot \varepsilon^{-[t/\tau]} \right] \cdot \omega^2 = \left[R(t=0) \cdot \omega^2 \right] \cdot \varepsilon^{-[t/\tau]}$$

or

$$\frac{V^2}{R} \text{ becomes } \frac{[V(t)]^2}{R(t)} = \frac{\left[V(t=0) \cdot \varepsilon^{-[t/\tau]} \right]^2}{\left[R(t=0) \cdot \varepsilon^{-[t/\tau]} \right]} = \frac{[V(t=0)]^2}{R(t=0)} \cdot \varepsilon^{-[t/\tau]}$$

Gravitational Attraction Acceleration [dimensions = $\boldsymbol{L}/_{T^2}$*]*
[and where the G dimensions = $\boldsymbol{L}^3/_{M \cdot T^2}$*]*

$$\frac{G \cdot M}{R^2} \text{ becomes } \frac{G(t) \cdot M}{[R(t)]^2} = \frac{\left[G(t=0) \cdot \left\{ \varepsilon^{-[t/\tau]} \right\}^3 \right] \cdot M}{\left[R(t=0) \cdot \varepsilon^{-[t/\tau]} \right]^2} = \frac{G(t=0) \cdot M}{[R(t=0)]^2} \cdot \varepsilon^{-[t/\tau]}$$

The overall net effect is: *R* decreases, the required centripetal acceleration decreases in proportion, the gravitational attraction likewise decreases in proportion, and ω is unchanged.

Furthermore, we observers, using our measuring standard ruler, length *L* of the above Figure 3, would never detect any of the decay because our standard length would also be decaying at exactly the same rate, in the same proportion.

The point of this obvious mathematics / physics exercise is that a universal decay of the length aspect of all material reality would not conflict with the planetary ephemeris and would

not even be detectable at all except in unusual circumstances such as the Pioneer and Flyby anomalies and the evidence of galactic rotation curves.

Returning to the orbiting body of Figure 3, reproduced as Figure 4 below, the figure's annotations slightly modified, the development of the anomalous acceleration is very direct.

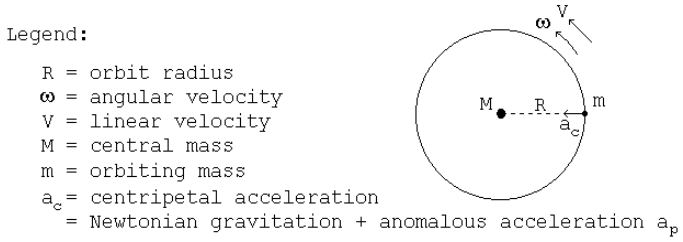


Figure 4

The Newtonian component of the centripetal acceleration is only sufficient to maintain the orbit, to keep R constant, to prevent its increasing. For the orbiting body, m, to gradually approach the central mass, M, that is for R to decrease, additional acceleration is required. That acceleration is the anomalous acceleration. It is an unavoidable concomitant effect of the universal exponential decay of the length dimension $[L]$ of R in the above example and of all material reality.

Details on the universal decay -- its cause, origin and characteristics are too lengthy for this report and are provided in full in references **2** and **3**.

Experiments to test the universal decay and measure its parameters are proposed in detail in reference **2** and briefly in reference **3**.

References

[1] John D. Anderson, James K. Campbell, John E. Ekelund, Jordan Ellis, and James F.Jordan, *Anomalous Orbital-Energy Changes Observed during Spacecraft Flybys of Earth*, Physical Review Letters, PRL **100**, 091102 (2008).

[2] R. Ellman, *A Comprehensive Resolution of the Pioneer 10 and 11 "Anomalous Acceleration" Problem Presented in the Comprehensive Report "Study of the Anomalous Acceleration of Pioneer 10 and 11" and the Relationship of that Issue to "Dark Matter", "Dark Energy", and the Cosmological Model*, Los Alamos National Laboratory Eprint Archive at http://arxiv.org, physics/9906031. [The value of the error range of a_P, the Pioneer "anomalous acceleration", was adjusted by the researchers in a later paper, at http://arxiv.org, gr-qc/0409117 , from $\pm\ 0.94$ to $\pm\ 1.33$.]

[3] R. Ellman, *The Origin and Its Meaning*, The-Origin Foundation, Inc., http://www.The-Origin.org, 1997. [The book may be downloaded in .pdf files from http://www.The-Origin.org/download.htm].