On Four Independent Phenomena Sharing a Common Cause

by

Roger Ellman

Abstract

Four independent unrelated phenomena, none of which has an established explanation, have now been extensively observed and a large amount of data substantiating the phenomena have been developed. The phenomena are as follows.

- In 1933 F. Zwicky reported [1] that the rotational balance of gravitational central attraction and rotational centripetal force in galaxies appeared to be out of balance, that a small additional centrally directed acceleration of unknown source appeared to be needed and to be acting. Numerous galactic rotation curves confirm that there is such an anomalous acceleration present and necessary in all rotating galaxies.
- In 1998 the Pioneer Anomaly was first reported [2]. The anomaly is a small acceleration, centrally directed [toward the Sun], constant, distance independent, and of unknown cause, observed in the tracking of the Pioneer 10 and 11 spacecraft from launch until their near departure from the Solar System.
- In 2008 the Flybys Anomaly was first reported [3]. The anomaly is 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.
- Also in 2008 a previously unknown large scale flow of galaxy clusters all in the same direction toward “the edge” of the observable universe was reported [4].

Analysis discloses that the first three have in common the same locally centrally directed, small acceleration, one that is non-gravitational, distance independent, apparently constant, and unaccounted for.

A cause and explanation of that common acceleration is presented. It is shown that the fourth phenomenon is fully consistent with that same cause and explanation.

Roger Ellman, The-Origin Foundation, Inc.
320 Gemma Circle, Santa Rosa, CA 95404, USA
RogerEllman@The-Origin.org
707-537-0257
http://www.The-Origin.org

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The Problem

Four independent unrelated phenomena, none of which has an established explanation, have now been extensively observed and a large amount of data substantiating the phenomena have been developed. The phenomena are as follows.

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- Also in 2008 a previously unknown large scale flow of galaxy clusters all in the same direction toward "the edge" of the observable universe was reported [4].

Analysis discloses that the first three have in common the same locally centrally directed, small acceleration, $a_{Anomalous}$, one that is non-gravitational, distance independent, apparently constant, and unaccounted for. The fourth phenomenon is shown to be fully consistent with that same cause and explanation.

The Centrally Directed Anomalous Acceleration in all Rotating Galaxies

In general, galaxies are rotating systems, a balance of gravitational attraction $[G \cdot M \cdot m / R^2]$ and centripetal force $[m \cdot V^2 / R]$ maintaining the structure. A curve or plot of such rotational velocity, V, versus path radius, R, is termed a Rotation Curve.

When the central mass is far greater than the orbiting masses the dynamics are such that the orbital velocities are inversely proportional to the square root of the radial distance from the center mass $[V = (G \cdot M / R)^{1/2}]$, as for example in our solar system and as illustrated in Figure 1, below. Such rotational dynamics and rotation curves are referred to as Keplerian.

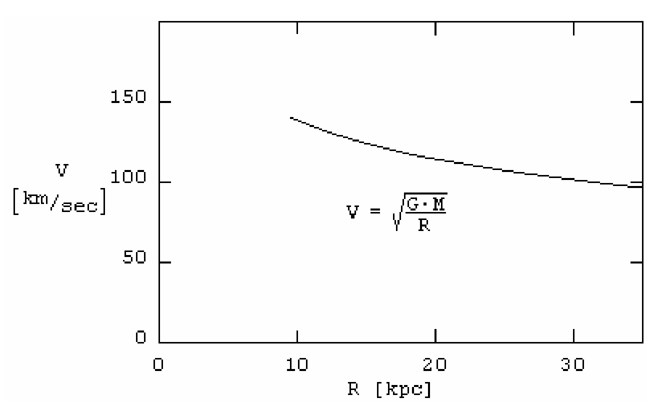


Figure 1 - A Keplerian Rotation Curve

In the case of a solid sphere of uniform density, ρ, throughout, all parts must move at rotational velocities directly proportional to radius as illustrated in Figure 2, below.

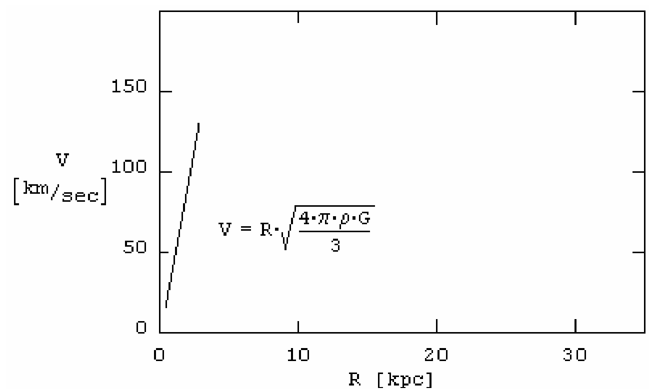


Figure 2 - The Rotation Curve of a Solid Sphere of Uniform Density

The form of galaxies as we are able to directly observe them is that of a fairly spherical star-dense central core and a transition from that to the much more extensive flat disk of a far smaller density of more widely dispersed stars. The portion of galactic rotation curves that pertains to the dense central core of the galaxy would be expected to exhibit approximately the same velocity-proportional-to-radius form as illustrated for a solid sphere in Figure 2, above. Likewise, the more dispersed flat disk, minor in mass compared to the dense central core, would be expected to exhibit the Keplerian form of Figure 1, above. The expected form of galactic rotation curves would be the two combined with a smooth transition between as Figure 3, below.

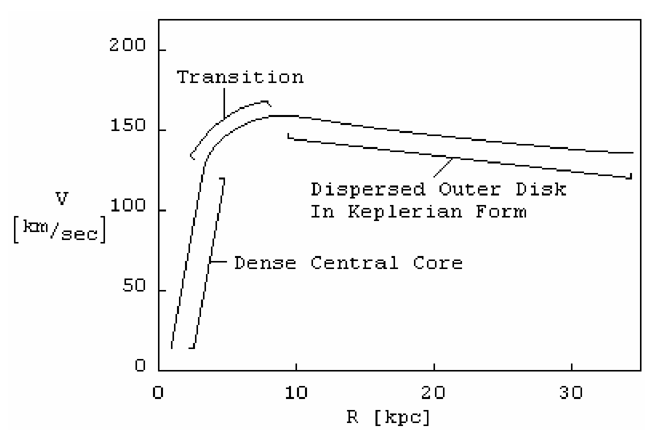


Figure 3 - The Expected Form of Galactic Rotation Curves

For galaxies that present themselves in an edge view of the thin disk not as their spiral or globular spread in space, it is possible to measure the rotational velocities and obtain a rotation curve. We see one end of the presented flat disk moving toward us relative to the center and the other end moving away. The rotational velocities are measured along the galactic diameter represented by our view of the disk by observing the variations in redshift, those variations being a Doppler effect. Galactic rotation curves so obtained do not exhibit the expected Keplerian form, an inverse square root of radius. Rather, they exhibit a flat form, that is, they exhibit rotational velocity independent of radius. The overall curve, after the portion pertaining to the dense central core of the galaxy, is a transition to a flat curve in the region corresponding to the spread-out galactic disk as in Figure 4, below.

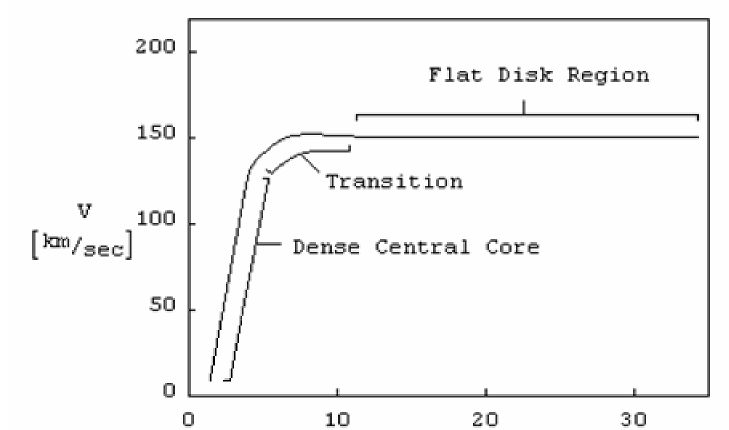


Figure 4 - A Typical Galactic Rotation Curve as Observed

Because the form of the flat portion of galactic rotation curves lies between the case of a dominant central mass, as in the Keplerian inverse square root of radius form [Figure 1], and the case of a uniformly dense mass, with its direct proportion to radius form [Figure 2], it has been inferred that matter that we have not observed must be present similarly distributed within the galaxy. That is, it is inferred that unobservable matter must be distributed in the galaxy in a manner that lies between the matter distribution of a dominant central mass [the Keplerian case] and that of a uniformly dense mass [the direct proportion to radius case] as a halo of "dark matter" which causes the rotation to take the form that the rotation curve exhibits. Thus arose the "dark matter" hypothesis.

No explanation has been offered for why the “dark matter”, while performing a gravitational function in the galaxy nevertheless fails to be distributed in the same manner as the “visible matter” in a fairly spherical dense central core with a transition from that to a much more extensive flat disk which has a far smaller density of more widely dispersed stars

However, what the rotation curves demonstrate is not the existence of a hypothesized cause [dark matter]; they only demonstrate the existence of an acceleration that is not accounted for. That acceleration is identified as follows. A constant acceleration, $\Delta a_{Anomalous} = 8.7 \cdot 10^{-8}\ cm/_{sec^2} = a_A$, acting alone as a gravitational acceleration maintaining a mass in orbit, would produce a rotation curve as in Figure 5, below.

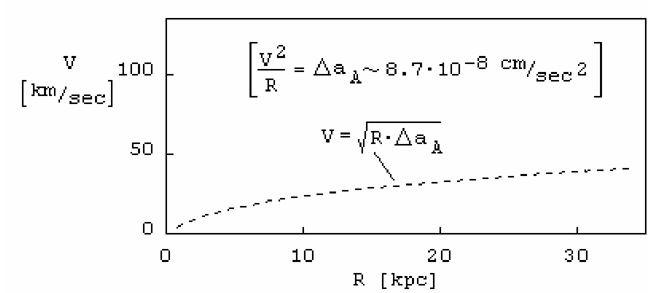


Figure 5 - The Rotation Curve of $a_{Anomalous}$ Acting Alone

That rotation curve is of the correct form to convert a galactic rotation curve exhibiting a Keplerian form [as in Figure 1] to a flat one [as in Figure 4]. That is, the rotation curve of $a_{Anomalous}$ exhibits V directly proportional to the square root of R and the Keplerian rotation curve exhibits V inversely proportional to the square root of R. The two effects tend to cancel and leave a flat rotation curve. With the naturally occurring typical rotation curve modified by the addition of $a_{Anomalous}$ the rotation curve becomes flat, as illustrated in Figure 6, below, by superimposing the curves.

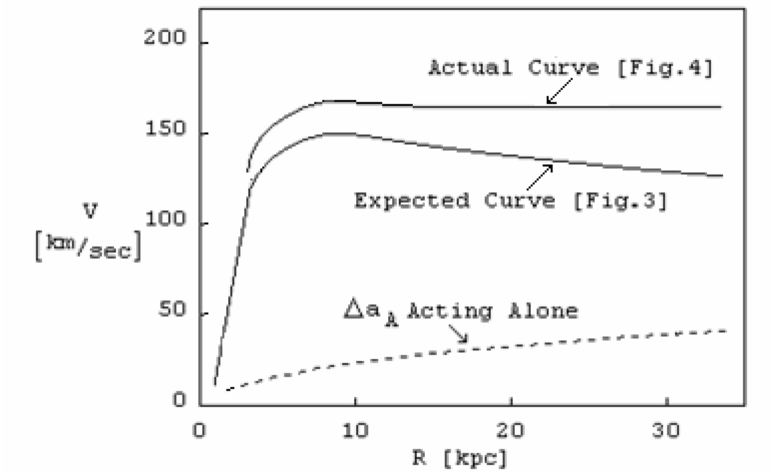


Figure 6 - The Anomalous Acceleration, $a_{Anomalous}$, Acting Alone Superimposed on the Expected and Actual Rotation Curves [Figures 3 & 4]

Of course, the rotational velocities corresponding to the components of the total acceleration cannot properly be added. Rather, the accelerations must be summed and the resulting rotational velocities then obtained as follows,

(5) Total Acceleration = "natural acceleration" + $\Delta a_A = a_{Anomalous}$]

$$\frac{V^2}{R} = \frac{G \cdot M}{R^2} + \Delta a_A$$

$$V = \left[\frac{G \cdot M}{R} + R \cdot \Delta a_A\right]^{1/2}$$

which produces the observed actual flat portion of the rotation curve in the region corresponding to where the "expected" form is Keplerian.

The Pioneer Anomaly

The just preceding galactic rotation curve anomalous acceleration $\Delta a_{Anomalous} = 8.7 \cdot 10^{-8}\ cm/_{sec^2}$ is identical in magnitude to the Pioneer Anomaly anomalous acceleration. The Pioneer Anomaly is a small acceleration of $8.7 \cdot 10^{-8}\ cm/_{sec^2}$, centrally directed [toward the Sun], constant, distance independent, and of unknown cause. The evidence for it is abundant tracking data that have been reviewed and re-reviewed in search of error with the result that the effect is highly validated.

Since the original reporting of the Pioneer Anomaly in 1998 sources of systematic error external to the spacecraft [e.g. solar wind / radiation], internal to the spacecraft [e.g. gas leakage], and in the computational system [e.g. model accuracy / consistency] have all been thoroughly examined. All of those sources of error are either too small, not applicable, and / or act in the wrong direction to account for the phenomenon. The input of suggested sources of systematic error to those analyses has been not only from the research team of authors but from a number of other sources interested in the problem. The source area of systematics has been essentially exhausted.

The only difference between the Pioneer Anomaly acceleration and the galactic rotation curve anomalous acceleration is that in the Pioneer case the acceleration is directed toward the Sun, the dominant factor in the mechanics of the Pioneer spacecrafts' motion whereas the galactic rotation curve anomalous acceleration is directed toward the rotational center of the galaxy, the dominant factor in the mechanics of galaxy rotation.

The Flybys Anomaly

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. These anomalous energy changes are a function of the incoming and outgoing geocentric latitudes of the asymptotic spacecraft velocity vectors and further indicate that a latitude symmetric flyby does not exhibit the anomalous speed change. 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."

A phenomenon like that involved in galactic rotation curves and in the Pioneer Anomaly would account for the highly varied occurrences of the flyby anomaly: a small acceleration [in addition to that of natural gravitation], centrally directed and independent of distance; that is a modest and otherwise unknown acceleration directed toward the core center of the Earth, the principle body involved, the dominant factor in the mechanics of the flyby.

To observe the relation to the Flybys Anomaly of an otherwise unknown or un-detected anomalous, centrally directed, distance independent 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 7, on the following page. In the vectors analysis part of the figures A is the full anomalous acceleration, C is its component parallel to the direction of motion of the satellite, and θ is the angle between the direction of action of those two.

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.

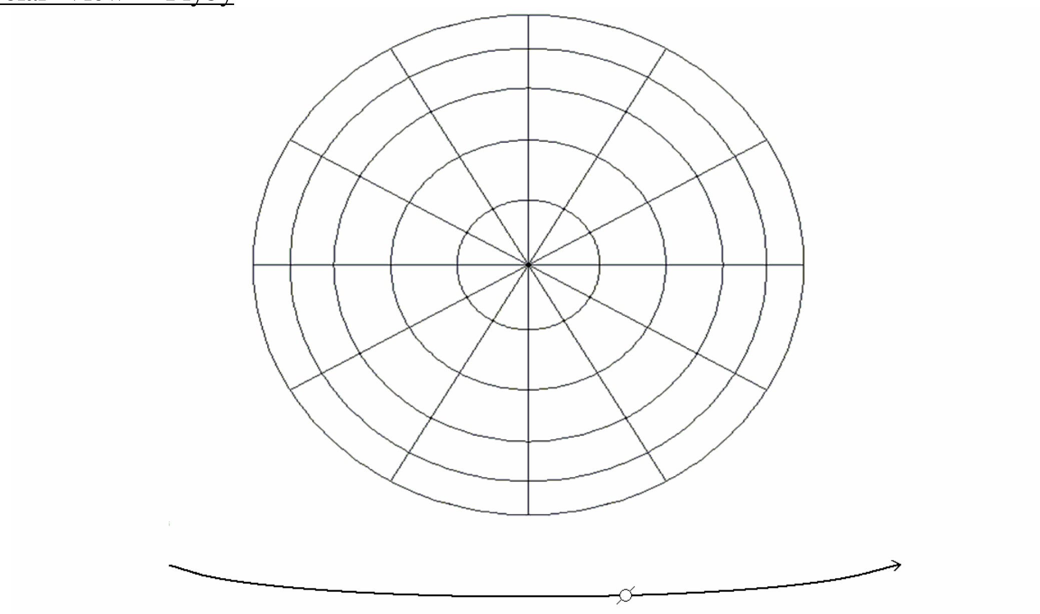
As the spacecraft travels nearer to Earth that component parallel to its motion decreases, becoming zero at the closest approach to Earth. From that point on the parallel component acts in the opposite direction on the spacecraft, that is its effect is to decelerate the spacecraft not accelerate it. 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, due to another effect, that is the overall purpose of the flyby.

Of the full centrally directed acceleration, A, the component, C, parallel to the path of the flyby in this case is

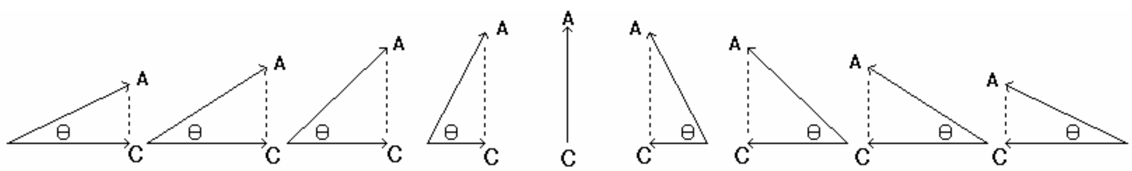
$$(1) \quad C = A \cdot \mathrm{Cos}[\theta]$$

which is apparent if the flyby path is a straight line. However, the actual flyby path is somewhat curved by the Earth's gravitation. But, the anomalous acceleration is always centrally directed toward the core of the Earth so that C is nevertheless as stated.]

a. Polar View - Flyby



b. Polar View - Anomalous Acceleration Vectors



Here the acceleration phase and the deceleration phase are equal and offset each other.

b. Equatorial View

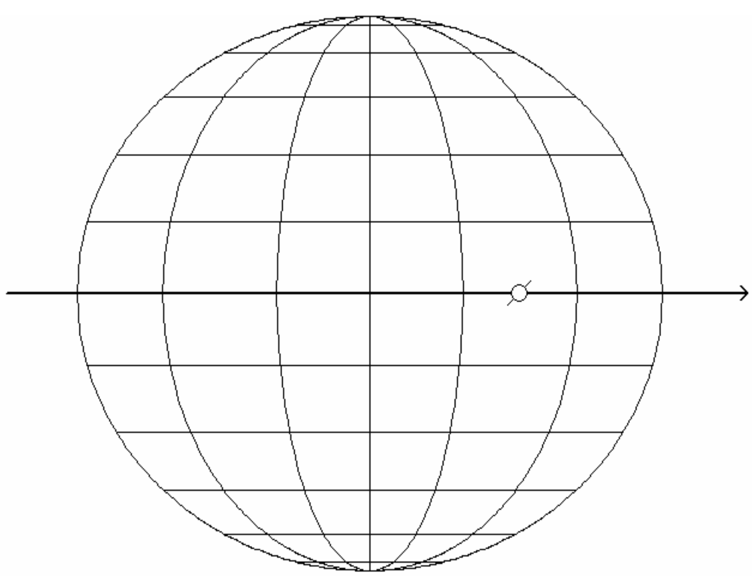


Figure 7
A Zero Latitude Pass

Equation (1) is valid when the flyby pass is solely at zero latitude. However, if other than zero the latitude of the flyby pass has a significant effect on the magnitude of C, the component of the overall centrally directed acceleration parallel to the spacecraft flight path. As latitude increases the magnitude of C, decreases. That is most easily visualized by imagining the flyby over the geographic north pole at $90°$ north latitude. There the centrally directed acceleration toward the center of the Earth has no component parallel to the flight path.

Therefore, for flyby paths at other than zero latitude the effective value of A is $A(\lambda)$ a function of latitude, λ, as equation (2)

$$(2) \quad A = A(\lambda) = A \cdot \text{Cos}[\lambda]$$

so that equation (1) then becomes equation (3) the full expression for the extent to which the centrally directed anomalous acceleration actually accelerates or decelerates the spacecraft.

$$(3) \quad C = A \cdot \text{Cos}[\lambda] \cdot \text{Cos}[\theta]$$

The gross effect of latitude can be evaluated by examining three cases:

A - The flyby path is symmetrical relative to the equator so that the latitude effect in the first half of the flyby, $\theta = 0°$ to $90°$, is exactly offset or balanced by the second half of the flyby, $\theta = 90°$ to $180°$. This case is essentially the same as presented in Figure 7, above.

B - The flyby path starts at low latitude and finishes at high latitude, Figure 8 on the following page.

C - The flyby path starts at high latitude and finishes at low latitude, Figure 9 on the second following page.

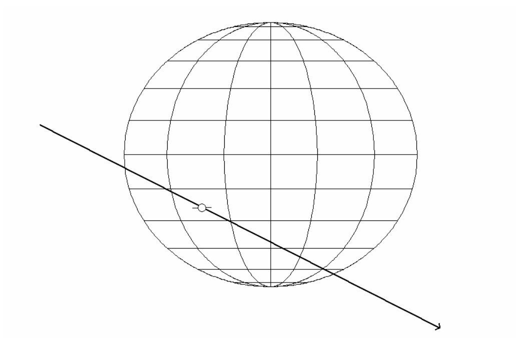
Per the equations and Figure 7 in the first half of the flight path the effect of the anomalous, centrally directed acceleration is to increase the speed of the spacecraft whereas the effect in the second half of the flight path is to decrease the spacecraft's speed. By its definition Case A produces no net anomalous acceleration or deceleration of the spacecraft because the first and second halves of the flight path balance and offset each other.

In Case B, the first half, i.e. the acceleration half, of the flight path is at low latitude where the latitude effect only modestly reduces the anomalous acceleration magnitude. But for that case and path the second half, i.e. the deceleration half, of the flight path is at a high latitude where the latitude effect greatly reduces the anomalous acceleration magnitude. The net effect is a relatively large acceleration followed by a lesser deceleration for a net increase in the spacecraft's speed.

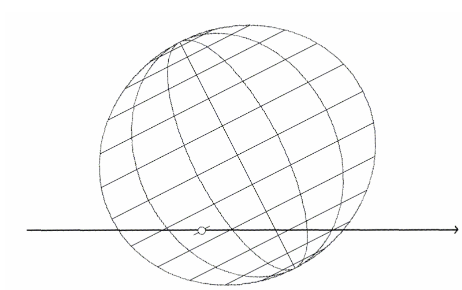
In Case C, the effect is just the reverse of that in Case B; the first, i.e. the acceleration, half of the flight path is at high latitude where the effect of the latitude greatly reduces the anomalous acceleration magnitude. But for that case and path the second, i.e. the deceleration, half of the flight path is at a low latitude where the effect of the latitude only modestly reduces the anomalous acceleration magnitude. The net effect is a relatively small acceleration followed by a greater deceleration for a net decrease in the spacecraft's speed.

Therefore, depending on the specific flight path of the spacecraft's flyby 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 the latitudes involved, and zero net modification if the path is perfectly latitude symmetrical.

a. Equatorial View - Flyby



b. Equatorial View - Flyby, Rotated



c. Anomalous Acceleration Vectors

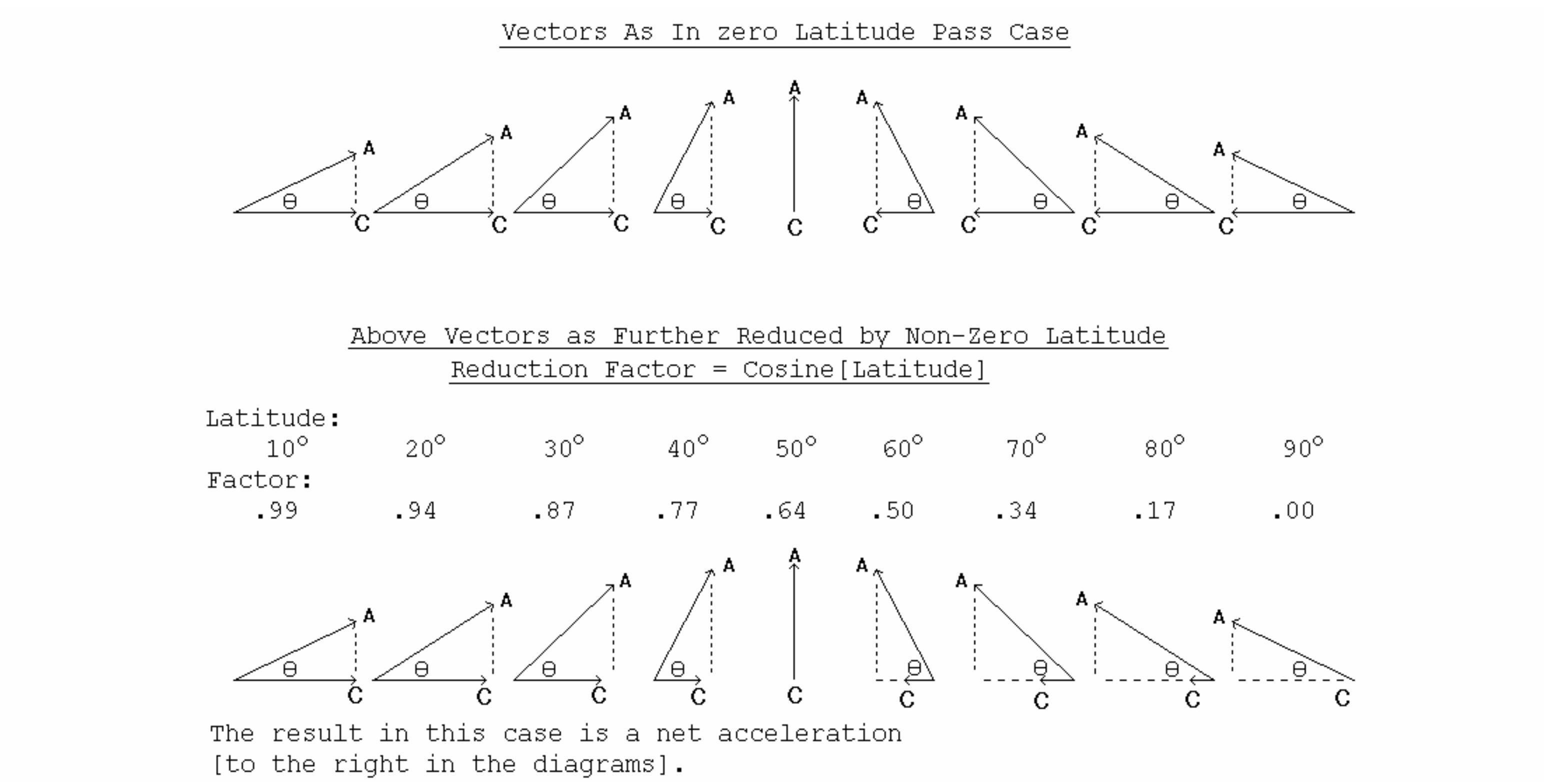
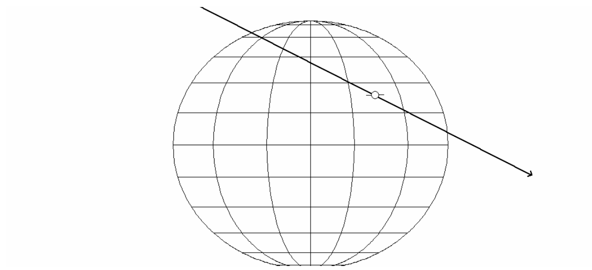
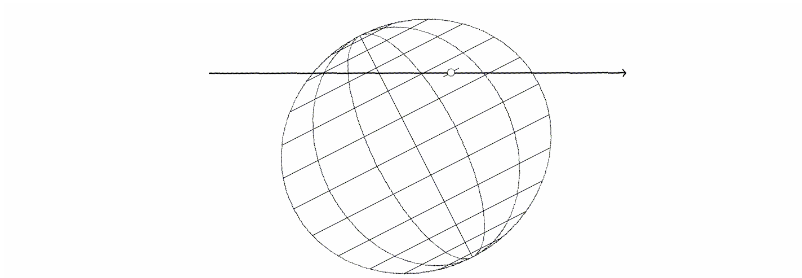


Figure 8
A Pass at Increasing Latitude

a. Equatorial View - Flyby



b. Equatorial View - Flyby, Rotated



c. Anomalous Acceleration Vectors

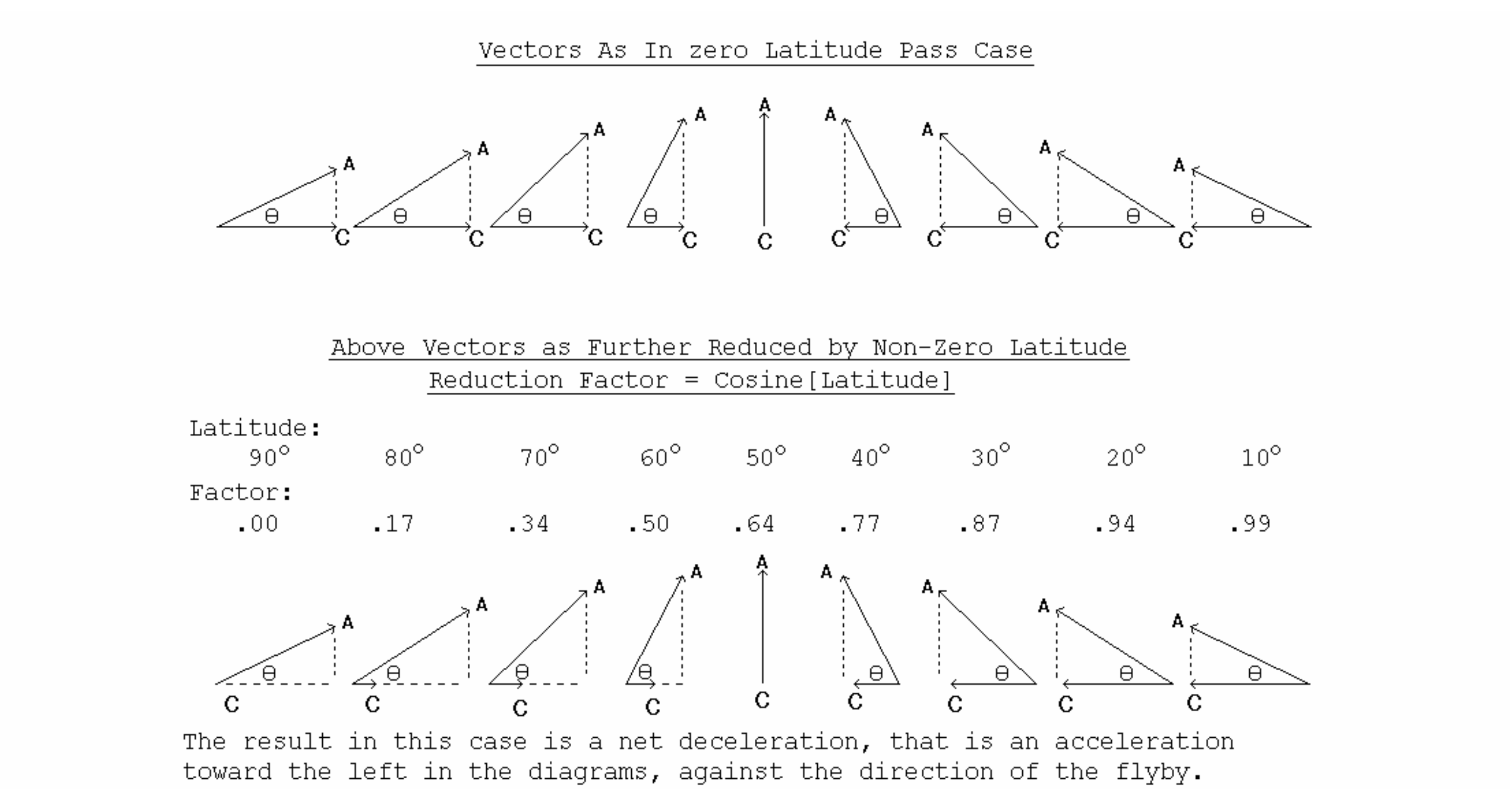


Figure 9
A Pass at Decreasing Latitude

A General Anomalous Acceleration Throughout the Universe

Thus there are small, centrally directed, distance independent, non-gravitational, same anomalous accelerations appearing as a near Earth effect [the Flybys Anomaly], a Solar effect [the Pioneer Anomaly], and a galactic effect [galactic rotation curves]. It can only be concluded that the same effect must appear relative to every planet [and every planet's moons], every sun [star], every galaxy and group of galaxies, and the universe overall. In other words as a general cosmic effect.

What could produce such a phenomenon ? What would cause there to be a universe-wide occurrence of such same accelerations ?

Taken together, planet relative, star relative, galaxy relative, they collectively are a systematic contraction, a gradual reduction in the length component of every physical quantity in the universe.

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 4, below.

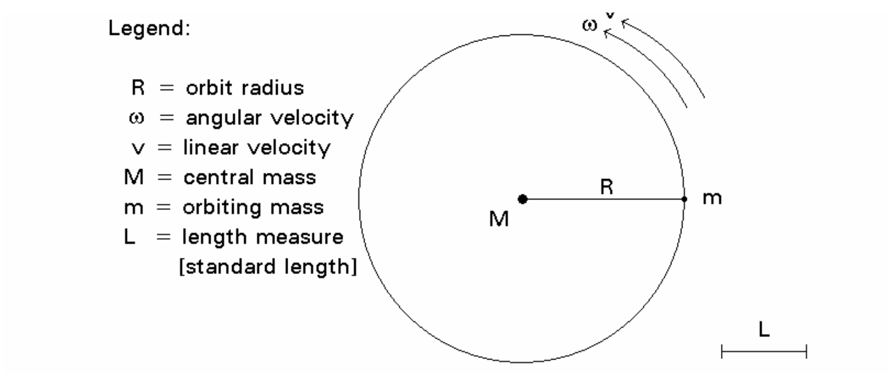


Figure 10

The relationship governing the motion is, of course, equation *(4)*, below

(4) *Centripetal Acceleration Required* = *Gravitational Attraction Acceleration*

$$v^2/R \text{ (or) } R\cdot\omega^2 = G\cdot M/R^2$$

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 with time. That is, let all lengths, *[L]*, decrease by being multiplied by the decay function, *D(t)*, per equation *(3)*, below. [For the present purpose the form of the decay function is irrelevant except that it must be a function of time. The decaying exponential is used because it is common in nature and is a complicated case.]

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

Then the quantities involved in equation *(4)* all change to as follows.

(6) *<u>The Orbital Radius</u>, R, [dimension =* ***L****]*

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

(6, continued)

The Gravitational Constant [dimensions = $L^3/M \cdot T^2$]

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

The Centripetal Acceleration Required [dimensions = L/T^2]

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

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

or

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

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

The Gravitational Attraction Acceleration [dimensions = L/T^2]
[and where the G dimensions = $L^3/M \cdot T^2$]

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

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

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 10, 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; nor would it interfere with the relative values of the fundamental constants and their interactions in physical laws.

Returning to the orbiting body of Figure 10, reproduced as Figure 11 below, the figure's annotations slightly modified, the development of the anomalous acceleration is very direct.

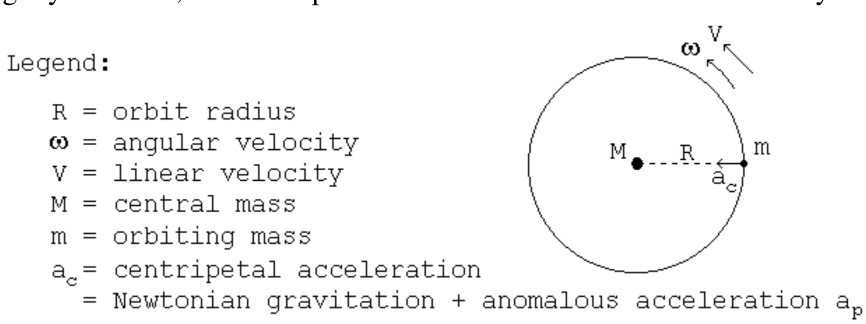


Figure 11

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 inward acceleration is required.

That inward acceleration is the anomalous acceleration appearing as a near Earth effect [the Flybys Anomaly], a Solar effect [the Pioneer Anomaly], and a galactic effect [galactic rotation curves]. It is an unavoidable concomitant effect of the contraction of the length dimension $[L]$ of R in the above example and of the systematic contraction, the gradual reduction in the length component, of every physical quantity in the universe, of all material reality.

The Large Scale Flow of Galaxy Clusters Reported in 2008

In September 2008 a previously unknown large scale flow of galaxy clusters all in the same direction, all directed toward "the edge" of the observable universe, was reported in Astrophysical Journal Letters in a paper titled *A Measurement of Large-Scale Peculiar Velocities of Clusters of Galaxies: Results and Cosmological Implications*.[4]

The article reports on a newly discovered "dark flow" that appears to carry clusters of galaxies toward a point in the southern sky. Researchers detected what they have dubbed dark flow while surveying 700 galaxy clusters — each containing hundreds to thousands of galaxies — within a radius of approximately 1 billion light-years. On average, the clusters appeared to move in a uniform direction at about 1,000 kilometers per second. A coauthor of the studies, says that he and his team checked and rechecked their results for more than a year before publishing them.

The universe began with the "Big Bang", an immense explosion radially outward in all directions, largely spherically symmetrically, from an original source "singularity".

We, residing on planet Earth, of star Sol, in one of several branches of spiral galaxy Milky Way, are located off some significant distance in "our general direction" from and relative to the location of the original singularity.

We can "see" or detect a large number of neighbor galaxies, distant and near, whose components similarly proceeded outward from that "Big Bang" in directions slightly or significantly other than our particular direction.

But, there is a further mass of stellar bodies that proceeded outward from the "Big Bang" in directions away from us. What we can detect is only well less than half the total product of the "Big Bang".

Of those that traveled relatively away from us, those that traveled outward relatively slowly may nevertheless be detectable by us because their light traverses distance more rapidly than their distance from us increases. But those that traveled away from us at higher speeds remain undetected and probably undetectable.

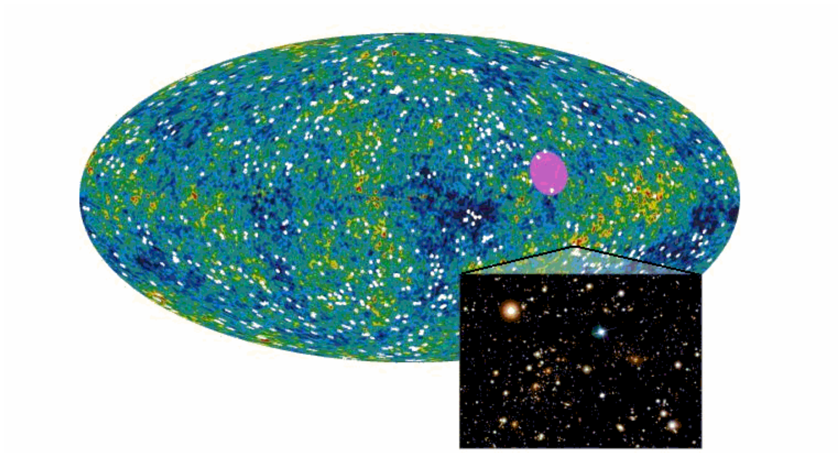
Now, the original location of the singularity, the origin, lies essentially at the center of the largely spherical volume of the source's product, the expanding universe. And the universe that we "see" lies largely to one side of that origin's location, but includes that origin's location and a small part of the universe on the other side of it. [See Figure 12, further below.]

The overall systematic contraction of the universe as identified in the above study of galactic rotation, the Pioneer Anomaly and the Flybys Anomaly is an action that naturally accelerates all the matter of the universe gradually back toward the location of its origin even while that matter also is affected by its role in the expansion of the universe because of that matter's original outward velocity and the gradual slowing of that velocity due to gravitation.

Thus the reported "Dark Flow" of clusters of galaxies toward a point in the southern sky is another indication of the small, centrally directed, distance independent, non-gravitational, same anomalous accelerations that appear as a near Earth effect [the Flybys Anomaly], a Solar effect [the Pioneer Anomaly], and a galactic effect [galactic rotation curves]. The "Dark Flow" joins that family of effects further confirming the overall systematic contraction of the universe.

[See, at http://www.arXiv.org, arXiv:physics/0004053 [pdf] Title: *Analysis of the "Big Bang" and the Resulting Outward Cosmic Expansion: Hubble - Einstein Cosmology vs. The Universal Exponential Decay* [6]].

A "map" of the universe that we "see" would look somewhat as Figure 12, below, where the shaded-in circular region near the right edge in the map [purple if in color] corresponds to the location and region of the original source singularity, toward which the contraction caused by the systematic contraction of the universe is directed.



Galaxy clusters across the sky (white spots, shown here on an all-sky survey of the cosmic microwave background) appear to move, on average, in one direction toward the southern sky (purple or shaded patch on the right).

Figure 12
A Map of That Part of the Universe Observable to Us
(Credit: NASA/WMAP/A. Kashlinsky et al.)

Summary Conclusions

1 – All three effects: the Galactic Rotation Curves Anomaly, the Pioneer Anomaly, and the Flybys Anomaly involve the same common action, a small, centrally directed, non-gravitational, distance independent acceleration, apparently the same common acceleration $\Delta a_{Anomalous} = 8.7 \cdot 10^{-8}\ cm/_{sec^2}$.

2 – The occurrence of such an acceleration apparently universe-wide is indicative of an on-going general contraction of the length aspect of all material reality including the length dimensional aspect of all fundamental constants.

3 – The recently discovered large scale flow of galaxy clusters tends to further support the conclusion of an on-going general contraction of the universe.

Details on the universal contraction, or decay -- its cause, origin and characteristics are too lengthy for this report and are provided in full in reference [5].

Experiments to test the universal decay and measure its parameters are proposed in reference [5].

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