# *"Dark Matter", the Pioneer 10/11 "Anomalous Acceleration", and "Dark Energy" -- A Common Solution to these three Disparate Problems*

*Roger Ellman*

Abstract

Suppose that there existed the same, one, simple explanation that comprehensively resolves the three apparently disparate problems:

[1] The galactic rotation curves' indications of "dark matter", and

[2] The Pioneer 10 and 11 spacecraft' "anomalous acceleration",

[3] The Type Ia Supernovae distance measurements' indications of acceleration of cosmic expansion with its implication of "dark energy" or quintessence.

Suppose further that this single explanation is merely another manifestation of one of the most common and ubiquitous of physical processes -- that of the second order linear differential equation with constant coefficients -- rather than being based on the inventing of disparate new and unknown effects, effects that are not directly detectable, let alone directly measurable: "dark matter" and "dark energy", with no viable explanation at all for the Pioneer "anomalous acceleration".

Suppose still further that this explanation can readily be tested by direct astrophysical observations and measurements whereas both "dark matter" and "dark energy" are not directly observable, let alone directly measurable, and can only be indirectly inferred.

And, suppose even further that this explanation is regularly validated, albeit unknowingly to the researchers, in everyday astronomical and astrophysical research.

That explanation is presented and developed in the following paper.

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*"Dark Matter", the Pioneer 10/11 "Anomalous Acceleration", and "Dark Energy" -- A Common Solution to these three Disparate Problems*

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## *Summary*

**Part 1**. The "anomalous acceleration" of the Pioneer 10 and 11 spacecraft is a real effect, an accidental or serendipitous direct measurement of a universe-wide physical phenomenon new to physicists -- "new physics" as the researchers, the authors of the "anomalous acceleration" data and study, would refer to it.

The principal issues in that regard are as follows.

[1] The anomalous acceleration is "new physics".

[2] The anomalous acceleration is a gravitation - related phenomenon caused by the general overall exponential decay of the universe, a natural behavior just as that same exponential decay form appears throughout the various natural processes of physics.

[3] That decay [developed in full in Part 3, below] 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 $G$, $[\mathbf{L}^3/M \cdot T^2]$.

[4] The Pioneer 10 and 11 researchers' objections that such an effect would conflict with the known planetary system performance per the highly accurate planetary ephemeris, as presented in their subject report, are a mistaken interpretation of the actual situation, and are therefore unfounded.

**Part 2.** It would be expected that valid such new physics would be found in other appearances, which is the case with the present issue. One such appearance is the unaccounted-for part of the centripetal acceleration in galaxies' rotation, as indicated by their rotation curves, which part has heretofore been hypothesized as due to the gravitation of "dark matter", that is matter that we have not directly observed and cannot detect.

The principal issues here are:

[1] That the anomalous acceleration can account for the unaccounted-for part of galaxy's centripetal acceleration and does so in a manner compatible with the rest of known cosmology, and

[2] That the anomalous acceleration is a superior and preferable explanation relative to the several alternatives that have been proposed.

**Part 3.** The explanation and development of the general overall exponential decay of the universe and its relation to gravitation is presented.

To be developed here are:

[1] The nature and behavior of the universal decay, and its relation to gravitation,

[2] The determination of the decay time constant, and

[3] The quantified correlation: the Pioneer "anomalous acceleration" is an aspect of the universal decay.

**Part 4.** Phenomena related to the universal decay account for the Type Ia Supernovae distance measurements results deviating from expectation.

To be developed here are:

[1] How the universal decay is the cause of the results obtained in the Type Ia Supernovae distance measurements, and

[2] That the universal decay is a superior and preferable explanation relative to the generally accepted interpretation, acceleration of cosmic expansion and the implication of unknown / undetected "dark energy" or "quintessence".

**Part 5.** The universal decay can readily be experimentally verified and those experiments can lead to measurement of the decay time constant.

Presented here are:

[1] Two proposed sets of experimental observations which would validate the hypothesized universal decay, and

[2] That the decay has been and is, in fact, regularly observed although in circumstances such that it is not recognized.

## **Part 1**. *The Pioneer 10 and 11 Anomalous Acceleration*

### *1.1 Background of the Anomalous Acceleration Issue*

The "anomalous acceleration" of the Pioneer 10 and 11 spacecraft was first reported in 1998 in *Indication, from Pioneer 10 / 11, Galileo, and Ulysses Data, of an Apparent Anomalous, Weak, Long-Range Acceleration.*[2] and was further analyzed in 1999 in *The Apparent Anomalous, Weak, Long-Range Acceleration of Pioneer 10 and 11.*[3] Those papers reported that a weak, long-range acceleration toward the Sun had been observed in the Pioneer 10 and 11 spacecraft and that no satisfactory explanation had been obtained in spite of diligent efforts by a number of parties, for which reason it has been described as "anomalous".

(The research authors point out that, "The scientific data collected by Pioneer 10 / 11 has yielded unique information about the outer region of the solar system … [because of, in part,] … the spin-stabilization of the Pioneer spacecraft" [page 4, 2nd ¶ ]. They were spin stabilized at launch with the spin axes running through the center of the dish antennae. That and their great distances from the Earth minimized the number of Earth-attitude reorientation maneuvers required, which enabled the reported precision of the acceleration data.)

(Other spacecraft, *Galileo* and *Ulysses*, have provided data that tend to support the existence of the anomalous acceleration, but those data are of less quality than those from the *Pioneer* spacecraft. The *Pioneer 10 and 11* were launched in 1972 and 1973 respectively and provided data into July 1998 and July 2000 respectively.)

The current subject report, *Study of the Anomalous Acceleration of Pioneer 10 and 11* [1] is a comprehensive and in-depth analysis and summarization of the entire issue. The conclusions reported with regard to the anomalous acceleration, notated as $a_p$ by the research authors, are as follows.

1. The $a_p$ is a real acceleration not a pseudo acceleration [page 79, last ¶ ].

2. The researchers can "… find no mechanism or theory that explains …" $a_p$ [page 80, middle ¶ ].

3. The $a_p$ "… is a line of sight constant acceleration of the spacecraft toward the Sun …" [page 80, middle ¶ ], i.e. while always directed toward the Sun the magnitude of the acceleration, unlike solar Newtonian gravitation, does not vary with distance from the Sun.

4. That "… if no convincing explanation is to be obtained, the possibility remains that the effect is real. It could even be related to cosmological quantities …" [page 81, last ¶ ].

5. After a thorough analysis of potential sources of error, that

$$(1) \quad a_p = (8.74 \pm 0.94) \times 10^{-8}\ cm/_{s}2 \quad \text{[report equation \#52, page 72].}$$

### *1.2 Analysis of the Pioneer Study Conclusions*

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] are all thoroughly addressed in the report and are reflected in the error allowed in equation *(1)*, above. All of these 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 these analyses has been not only from the research team of authors but from a number of other sources interested in the problem. While the research authors appear to favor some "… unknown systematic …whether 'gas leaks' or 'heat'…" [page 80, 5th ¶ ] the source area of systematics has been essentially exhausted. This bias would appear to be due to their inability to overcome or deal with the "hard wall" [to "new physics" as they see it] discussed below.

The alternative to systematic error is "… a new force …", "… new physics …", a highly sensitive subject area. The principal argument proposed against these by the research authors is "… a hard experimental wall …" [page 75, after equation #55] as follows. The report contends that such a "new force" would perturb, for example, the orbits of Earth and Mars by a $\Delta r \cong -21\ km$ and $-76\ km$, respectively [equation #56 and following] whereas the Viking mission data determine the difference between those orbits to about a $100\ m$ accuracy.

Using the same reasoning the report points out that the perturbation in the orbital angular velocity would likewise be out of the known range and would involve "… inconsistencies with the [known level of accuracy] of the overall planetary ephemeris …" [equation #57 and bottom, page 75].

That "hard wall" would be valid were an $a_p$ to act, locally, on Earth and / or Mars with no compensating actions; however, for $a_p$ to be "a new force" and "new physics" it must consistently act throughout the Solar System and the universe, not merely locally and in special cases. Einstein's principle of invariance requires that the laws of physics and the fundamental constants in them must be the same everywhere in the universe. When $a_p$ is analyzed as a new force, as cosmologically invariant new physics, the results are quite different and the "hard wall" disappears.

Consider a planet in circular orbit around a sun as in Figure 1, below.

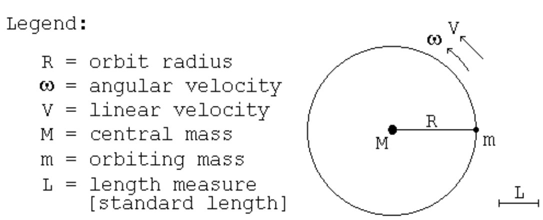



*Figure 1*

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

$$(2) \quad \frac{\text{Centripetal Acceleration Required}}{} = \text{Gravitational Attraction Acceleration}$$

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

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 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 $\tau$ 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 =* ***L****]*

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

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

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

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

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

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 =* $L/T^2$*]*
[and where the G dimensions = $L^3/M\cdot T^2$]

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

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

Furthermore, we observers, using our measuring standard ruler, length *L* of the above Figure 1, 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, then, of this obvious mathematics / physics exercise is that a universal decay of the length aspect of all material reality would not run into the research authors' "… hard experimental wall …", would not conflict with the planetary ephemeris, and would not even be detectable at all except in unusual circumstances. The "anomalous acceleration" of the Pioneer 10 and 11 spacecraft is just such an unusual circumstance.

As will be presented shortly below, the missing gravitational acceleration indicated by galactic rotation curves and the indicated acceleration of the universe' expansion deemed indicated by the recent Type Ia Supernovae distance measurements are other such unusual circumstances; and there are more when the record is examined correctly.

Part of the subject report's error in that regard is the [implicit] deeming of $a_p$ and the related force $m \cdot a_p$ as being "new". If the effect is "new physics" the newness is only to ourselves, not to the universe and not, in particular to the orbital mechanics of the galaxy and the solar system. Similarly, the subject report implicitly limits consideration of $a_p$ to the solar system, not addressing the galaxy nor the overall universe.

The acceleration $a_p$ is always directed toward the Sun in the only instance we know of, the Pioneer data. That is equivalent to its being always directed in the same direction as the otherwise net acceleration acting on the object, because all objects in the solar system experience a net acceleration toward the Sun, an acceleration that maintains their orbits and without which they would pass off into outer space (excepting the Pioneers which are moving in excess of escape velocity, and are not in orbit). Such a direction is what one would expect of an effect due to the exponential decay of the length aspect of all gravitational accelerations $[L/T^2]$ [as well as of all other material reality].

At the planetary system level and all higher levels [galaxy, galactic group, etc.] the net acceleration acting on bodies is gravitational. Thus the anomalous acceleration, $a_p$, is gravitation - related; that is it acts in the same direction as Newtonian gravitation as an additional acceleration.

### *1.3 How the Universal Decay Causes the Anomalous Acceleration, $a_p$*

Returning to the orbiting body of Figure 1, reproduced as Figure 2 below, the figure's annotations slightly modified, the development of the anomalous acceleration is very direct.

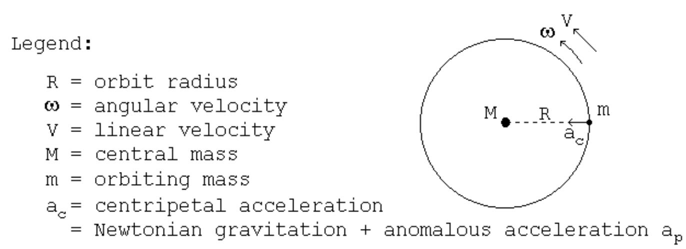



*Figure 2*

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 $a_p$, the anomalous acceleration. It is an unavoidable concomitant effect of the universal exponential decay of the length dimension $[L]$ of $R$ and of all material reality.

The "hard experimental wall" impediment is thus removed, and $a_p$ is a universal effect which we have only now knowingly observed. It yet remains to discover its cause and mechanism as well as how it has the actual value exhibited by the Pioneer spacecraft. These will be addressed further on in this analysis. [It should be noted that $a_p$ itself also decays, the observed Pioneer value being the current value in a decay so very slow and long-term that it appears constant to us within the limitations of our measurement precision.]

## **Part 2**. *Galactic Rotation Curves and the Implied "Dark Matter"*

Addressing $a_p$ as a universal cosmological effect rather than the now quite unlikely case of it being some from of special peculiarity common to two different spacecraft on different paths, as the research authors state their preference, the next issue is to identify other detectable appearances of the $a_p$ effect. Galactic rotation curves are a significant, major such instance.

### *2.1 Background of the Galactic Rotation Curves Issue*

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 vs. path radius 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 [$V = (G \cdot M / R)^{½}$], as for example in our solar system and as illustrated in Figure 3, below. Such rotational dynamics and rotation curves are referred to as Keplerian.

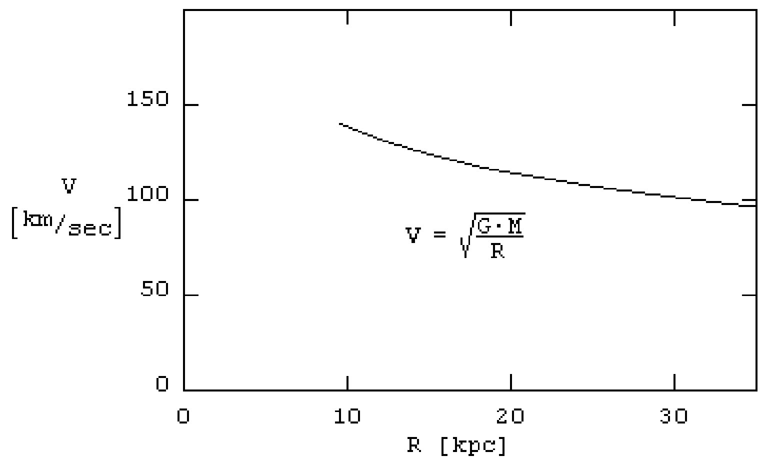



*Figure 3 - A Keplerian Rotation Curve*

In the case of a solid sphere of uniform density throughout, all parts must move at rotational velocities directly proportional to radius as illustrated in Figure 4, below.

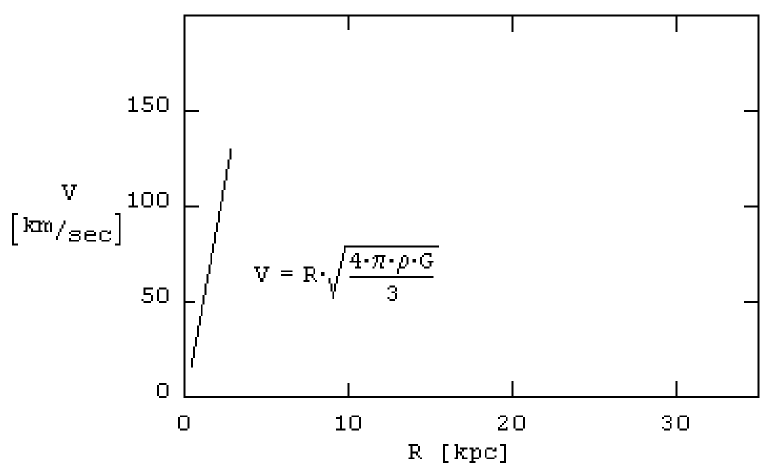



*Figure 4 - The Rotation Curve of a Solid Sphere of Uniform Density*

The form of galaxies as we are able to directly observe them is that of a fairly spherical dense central core and a transition from that to the much more extensive flat disk which has 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 4, 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 3, above. The expected form of galactic rotation curves would be that of the two combined with a smooth transition between as Figure 5, below.

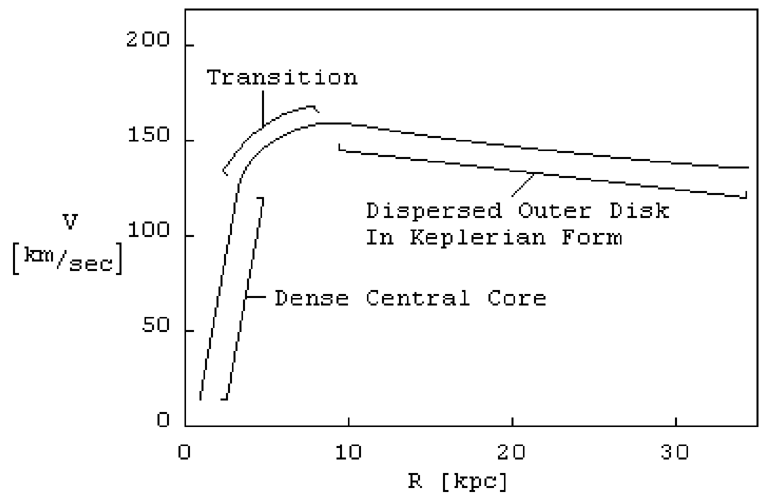



*Figure 5 - The Expected Form of Galactic Rotation Curves*

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 6, below.

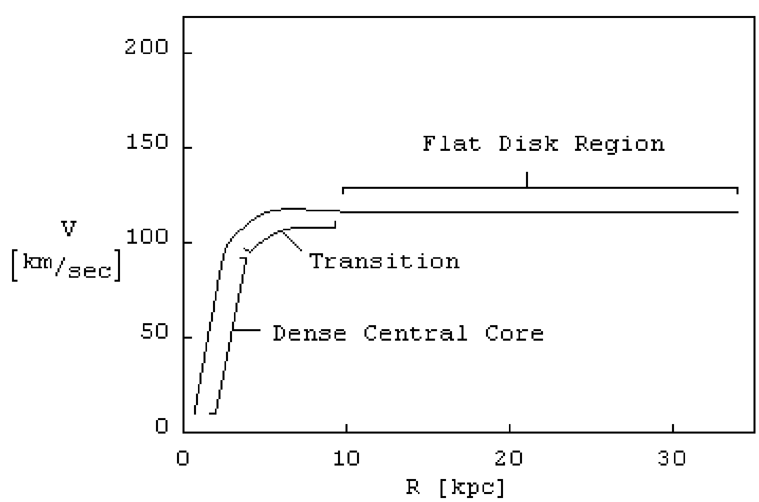



*Figure 6 - A Typical Galactic Rotation Curve as Observed*

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 3], and the case of a uniformly dense mass, with its direct proportion to radius form [Figure 4], 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.[4]

### 2.2 The Relationship of the Anomalous Acceleration to the Galactic Rotation Curves Issue

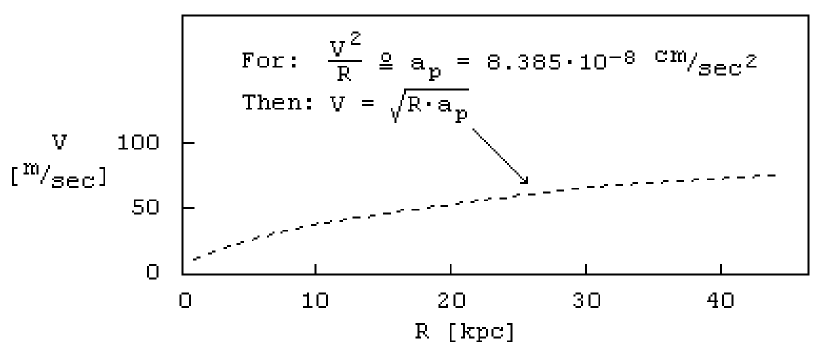
McGaugh[5] points out that "It is often stated that the evidence for dark matter is overwhelming. This is not quite correct in that: the evidence for *mass discrepancies* is overwhelming. These might be attributed to *either* dark matter *or* a modification of gravity."

This mass discrepancy phenomenon is too insignificant to appear where the acceleration is $V^2/R \gg 10^{-8}$ $cm/sec^2$. The phenomenon fully appears where $V^2/R \ll 10^{-8}$ $cm/sec^2$. Milgrom's[6] modeling related to that gives an alternative hypothesis, a Modification of Newtonian Dynamics or MOND, that gravity and inertia behave in a modified manner when the acceleration is small, specifically that where the acceleration is $a \ll a_0$ then $a = [a_{Newtonian} \cdot a_0]^{1/2}$.

No justification or cause for that behavior has been developed other than that, by using [$a_0$ *on the order of* $10^{-8}$ $cm/sec^2$], as a hypothesis the MOND gives results that tend to correlate with the mass discrepancies. That is, using the MOND formulation causes the expected Keplerian region of rotation curves to change to being asymptotic to the flatness found in actual observed data. Subsequent analyses develop constraints which severely impair the MOND concept.[7]

McGaugh's statement more correctly put would be that the evidence for discrepancies in accounting for the observed accelerations is overwhelming, but that that does not necessarily signify a mass discrepancy : there could simply be an acceleration discrepancy, e.g. $a_P$.

The constant acceleration, $a_P$, acting alone as a gravitational acceleration maintaining a




mass in orbit, would produce a rotation curve as in Figure 7, below.

*Figure 7 - The Rotation Curve of $a_p$ Acting Alone*

That rotation curve is of the correct form to convert a galactic rotation curve exhibiting a Keplerian form [as in Figure 3] to a flat one [as in Figure 6]. That is, the rotation curve of $a_P$, 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 Newtonian gravitation modified by the addition of $\Delta a_g = a_P$, the rotation curve becomes flat, as illustrated in Figure 8, below, by superimposing the curves.

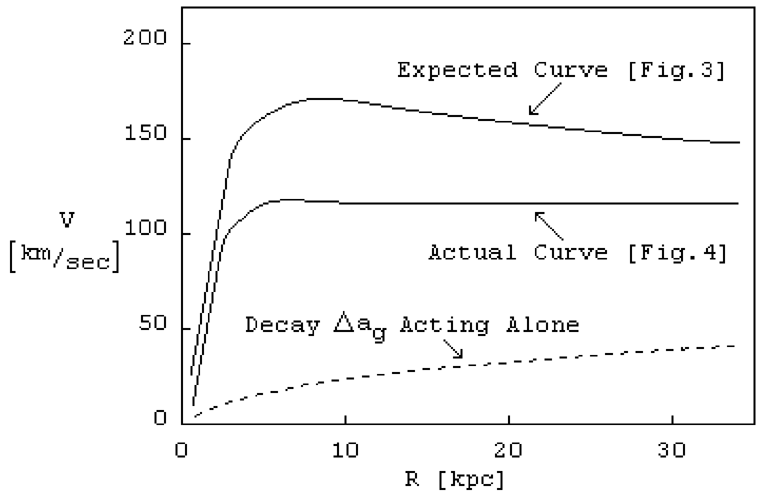



*Figure 8 - The Decay-Produced Increment of Gravitational Acceleration Acting Alone Superimposed on the Expected and Actual Rotation Curves [Figures 5 & 6]*

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" + $\Delta a_G$ [$\Delta a_G = a_p$]

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

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

which produces the observed actual flat portion of the rotation curve in the region corresponding to where the "expected" form is Keplerian and the Newtonian "natural" accelerations are $[G \cdot M / R^2 \ll \Delta a_G]$ that is $[G \cdot M / R^2 \ll a_p]$.

### *2.3 The Significance of This Resolution of the Galactic Rotation Curves Issue*

Other than the here-proposed "anomalous acceleration", the explanations that are offered for the mass or gravitational discrepancies indicated by galactic rotation curves are two alternatives: "dark matter" and MOND.

- The one requires believing in undetected (and perhaps undetectable, and, therefore, perhaps mostly non-existent) additional mass in galaxies in the form of a halo of mass totaling a number of times greater than the observable mass.
- The other requires a modification of the well established Newton's law of gravitation without any real justification other than that it appears to resolve the discrepancy.

The anomalous acceleration addresses the problem with a verified observable behavior consistent with known physics. Something new need not be invented; rather, an existing phenomenon is observed in its natural ramifications and occurrences -- the Pioneer "anomalous acceleration" and the galactic rotation curves.

## **Part 3.** *The General Overall Exponential Decay of the Universe and Its Relation to Gravitation*

### *3.1 Analysis of Gravitation in Relation to the Mass - Energy Equivalence and the Planck Length*

In gravitation between two bodies the action and effects are mutual. Each acts on the other according to Newton's law of gravitation. If we view one side of that, the affect of the "source" or "acting" mass on the "object" or acted-on mass, then Newton's law of gravitation expressed in terms of $m_{source}$ and $m_{acted\text{-}on}$ and with both sides of the equation divided by $m_{acted\text{-}on}$ is, of course,

(6) $$a_{grav} = G \cdot \frac{m_s}{d^2}$$

which states that gravitation is proportional to the mass of the gravitationally attracting body; it is a property of that body's mass.

However, mass and energy are equivalent, so that mass, $m$, is proportional to a frequency, $f$, that is characteristic of that mass. [Strictly speaking this treatment must be applied to each of the individual particle masses of which the gross source mass is composed, not the gross mass as such. Gross gravitational action is the result of each particle of mass in the source body acting on each particle of mass in the body acted-on.] That is

(7) $$m \cdot c^2 = h \cdot f \qquad \text{so that} \qquad f = \frac{c^2}{h} \cdot m$$

so that the source mass of equation *(6)*, $m_s$, has a corresponding, associated, equivalent frequency, $f_s$.

That being the case, the amount of gravitational acceleration, $a_{grav}$, can be expressed in terms of that frequency as the change, $\Delta v$, in the velocity, $v$, of the attracted mass per time period, $T_s$, of the oscillation at the corresponding frequency, $f_s$, as follows.

(8) $$a_{grav} = {}^{\Delta v}/_{T_s} = \Delta v \cdot f_s$$

It can then be reasoned as follows.

(9) $$a_{grav} = \Delta v \cdot f_s = G \cdot \frac{m_s}{d^2}$$ [Equating $a_{grav}$ of Equation's *(6)* and *(8)*]

(10) $$\Delta v \cdot \left[ \frac{m_s}{m_p} \cdot f_p \right] = G \cdot \frac{m_s}{d^2}$$ [Frequency is proportional to mass per Equation *(7)* and $f_p$ and $m_p$ are the proton frequency and mass: $f_s = ({}^{m_s}/m_p) \cdot f_p$.]

$$\Delta v = G \cdot \frac{m_p}{d^2 \cdot f_p}$$ [Rearrange, canceling $m_s$'s.]

Then:

(11) $$\Delta v = G \cdot \frac{1}{d^2 \cdot f_p} \cdot \frac{h \cdot f_p}{c^2}$$ [Substituting $m_p = {}^{h \cdot f_p}/_{c^2}$, Equation *(7)*]

$$\Delta v = G \cdot \frac{h}{\qquad}$$ [Simplifying]

$$d^2 \cdot c^2$$

Now, the Planck Length, $l_{Pl}$, is defined as

(12) $$l_{Pl} \equiv \left[\frac{h \cdot G}{2\pi \cdot c^3}\right]^{1/2}$$ [the $^h/_{2\pi}$ part being h-bar]

so that

(13) $$G = \frac{2\pi \cdot c^3 \cdot l_{Pl}^2}{h}$$

Substituting $G$ as a function of the Planck Length from equation *(13)* into $G$ as in equation *(11)*, the following is obtained.

(14) $$\Delta v = \frac{2\pi \cdot c^3 \cdot l_{Pl}^2}{h} \cdot \frac{h}{d^2 \cdot c^2}$$

$$\Delta v = c \cdot \frac{2\pi \cdot l_{Pl}^2}{d^2}$$ [Simplifying]

This result states that:

- the velocity change due to gravitation, $\Delta v$,
- per cycle of the attracting mass's equivalent frequency, $f_s$,
  - which quantity, $\Delta v \cdot f_s$, is the gravitational acceleration, $a_{grav}$,
- is a specific fraction of the speed of light, $c$, namely the ratio of:
  - $2\pi$ times the Planck Length squared, $2\pi \cdot l_{Pl}^2$, to
  - the squared separation distance of the masses, $d^2$.

That squared ratio is, of course, the usual inverse square behavior.

This result also means that at distance $d = \sqrt{2\pi} \cdot l_{Pl}$ from the center of the source, attracting, mass the acceleration per cycle of that attracting mass's equivalent frequency, $f_s$, namely $\Delta v$, is equal to the full speed of light, $c$, the most that it is possible for it to be. In other words, at that [quite close] distance from the source mass the maximum possible gravitational acceleration occurs. That is the significance, the physical meaning, of $l_{Pl}$ or, rather, of $[2\pi]^{1/2} \cdot l_{Pl}$.

If the original definition of $l_{Pl}$ had been in terms of $h$, not $h\text{-}bar = {}^h/_{2\pi}$ the distinction with regard to $[2\pi]^{1/2}$ would not now be necessary. The $2\pi$ is a gratuitous addition, coming about from the failure to address the Hydrogen atom's stable orbits as defined by the orbital path length being an exact multiple of the orbital matter wavelength. The statement that the orbital electron's angular momentum is quantized, as in

(15) $$m \cdot v \cdot R = n \cdot \frac{h}{2\pi}$$ [n = 1, 2, …]

is merely a mis-arrangement of

(16) $$2\pi \cdot R = n \cdot \frac{h}{m \cdot v} = n \cdot \lambda_{mw}$$ [n = 1, 2, …]

the statement that the orbital path, $2\pi \cdot R$, must be an integral number of matter wavelengths, $\lambda_{mw}$, long. And, that mis-arrangement may have resulted from a lack of confidence in the fundamental significance of matter waves because of the failure to develop theory that produced acceptable, valid, matter wave frequencies, ones such that $f_{mw} \cdot \lambda_{mw} = particle\ velocity$, which is an obvious necessity.

The physical significance of $l_{Pl}$ is in its setting of a limit on the minimum separation distance in gravitational interactions. That is, equation *(14)* clearly means that it is not possible for a particle having rest mass to approach another such particle closer than that distance. It is as if that distance is the radius of some impenetrable core at the center of particles having rest mass. [It further means that the gravitational inverse square law need not worry about the problem of zero separation distance where an unacceptable infinity would occur because $d = 0$ cannot occur.]

That physical significance of $\sqrt{2\pi} \cdot l_{Pl}$, is so fundamental, fundamental to gravitation and apparently fundamental to particle structure, that it more truly represents a fundamental constant than does $l_{Pl}$. For those reasons that distance should replace $l_{Pl}$ as a fundamental constant of nature as follows.

*(17)* <u>The</u> <u>fundamental</u> <u>distance</u> <u>constant</u> δ.

$$\delta^2 \equiv 2\pi \cdot l_{Pl}^2$$

$$\delta = 4.05084 \times 10^{-35} \text{ meters} \qquad \text{[1986 CODATA Bulletin}^{8}\text{]}$$

Equation *(14)*, above, then becomes equation *(18)*, below,

$$(18) \qquad \Delta v = c \cdot \frac{\delta^2}{d^2}$$

a quite pure, precise and direct statement of the operation of gravitation. It states that gravitation is a pure function of the speed of light, $c$, and the inverse square law. Equation *(18)* is exact without involving a constant of proportionality such as the $G$ required in the statement of Newton's law of gravitation.

This development began with the observation that the amount of gravitational acceleration, $a_{grav}$, can be expressed as the change, $\Delta v$, in the velocity, $v$, of the attract<u>ed</u> mass per time period, $T_s$, of the oscillation at the corresponding frequency, $f_s$ of the attract<u>ing</u> mass, equation *(8)*.

In all of this there is more than an implication, there is the requirement that gravitation and the gravitational field involve something oscillatory in nature, traveling or propagating at $c$ while oscillating at $f_s$. Essentially the same description can be made of light and of all electro-magnetic radiation. It would seem somewhat absurd for material reality to involve two different, overlapping or coincidental such propagations, one for gravitational field and another for electro-magnetic field. Rather, there must be one common form of such propagation underlying both effects, gravitational and electro-magnetic.

Equation *(18)* states that gravitation is directly connected to, is caused by, a local change in the natural, non-gravitational value of $c$ by the factor $\delta^2/d^2$. Since the natural value of c is an upper limit, that local change must be a slowing. Gravitation being mutual between two masses, if the attract<u>ing</u> mass is propagating something toward the attract<u>ed</u> mass then that latter mass is doing the same toward the former. The local slowing would then be the arriving propagation slowing the encountered mass's own propagation outward.

And, such an effect could, and should, require some adjustment by the target so as to maintain the flow of its propagation at the un-slowed value of $c$. Such an adjustment would be a compensating increase in the target's velocity toward the source, namely the already obtained $\Delta v$ per time period, $T_s$, of the propagating oscillation.

Such slowing correlates with gravitational lensing's light path bending. Posited in the third preceding paragraph as necessary to avoid the absurd, propagating light waves share the same "underlying form" as gravitational propagation, which slows an encountered similar flow to produce gravitation. Then, light propagation passing a gravitating mass would experience greater slowing of its wave front on the portion nearer to the gravitating mass and lesser slowing farther away [because of the inverse square behavior] -- effects bending the direction of the wave front toward the attracting mass as observed in gravitational lensing.

### *3.2 The Cause of the Universal Decay*

In order to develop the concept, consider the following "thought experiments".

1. Electric Field

- Nothing can travel faster than the speed of light, $c$. Given two static electric charges separated and with the usual Coulomb force between them, if one of the charges is moved the change can produce no effect on the other charge until a time equal to the distance between them divided by $c$ has elapsed.

- For that time delay to happen there must be something flowing from the one charge to the other at speed $c$ and the charge, itself, must be the source of that flow.

  The Coulomb effect is radially outward from the charge, therefore every charge must be propagating such a flow radially outward in all directions from itself, which flow must be the "electric field".

2.- Motion of Charge and "At Rest"

- Comparing two such charges, one moving at constant velocity relative to the other, at least one of the charges is moving with some velocity, $v$.

- The flow (of "field") outward from that charge must always travel at $c$. Forward it would go at $[c+v]$ if propagated at $c$ from the source charge already moving that way at $v$. Therefore, it must be sent forward from the charge at $[c-v]$ so that it will travel at $c$ when the $v$ of its source charge is added.

- Analogously, rearward it would go at speed $[c-v]$ if propagated at $c$ from the source charge already moving the opposite way at $v$. Therefore, it must be emitted rearward from the charge at $[c+v]$ so that it will travel at speed $c$ when the $v$ of the source charge in the opposite direction is subtracted.

- But, that rearward - forward differential means that the direction and speed of motion can be determined by looking at the propagation pattern of the flow as propagated by the charge.

  And, if the pattern were the same in all directions then the charge would be truly "at rest", which means that there is an absolute "at rest" frame of reference.

3. Magnetic & Gravitational Fields

- Except for the kind of field, all of the preceding applies in the same way and with the same conclusions for magnetic field and gravitational field as for electric field.

- Therefore, either a particle that exhibits all three such fields, as for example a proton or an electron, is a source of three separate and distinct such flows, one for each field, or there is only a single such flow which produces all three effects: electric, magnetic, and gravitational.

  The only reasonable conclusion is that electric, magnetic, and gravitational field are different effects of the same sole flow from the source particles.

4. Sources & Their Decay

- The flow is not inconsequential. Rather, it is substantial in that it produces the forces, actions and energies of our universe.

- For a particle to emit such a flow the particle must be a source of whatever it is that is emitted and then flows outward. The particle must have a supply of it.
- The process of emitting the flow from a particle must deplete the supply resource for the particle's emitting further flow, must use up part of its supply, else we would have something-from-nothing and a violation of conservation.

  We must conclude that an original supply [of whatever the flow is, which for convenience we now call "medium"] came into existence at the beginning of the universe and has since been gradually being depleted at each particle by its on-going outward flow.

5. The Beginning

- Before the universe began there was no universe. Immediately afterward there was the initial supply of medium to be propagated by particles. How can one get from the former to the latter while avoiding an infinite rate of change ?

  The only form that can accommodate the change from nothing to something in a smooth transition without an infinite rate of change is the oscillatory form of equation *(19)*, below.

$$A\cdot[1-\mathrm{Cosine}(2\pi\cdot f\cdot t)] \quad (19)$$

  [The only way that such an oscillation can have come into existence without violating conservation is for there simultaneously to have come into existence another oscillation, the negative of equation *(19)* -- that is one identical to the first oscillation in every sense except that in combination with the first oscillation it would yield a net nothing.]

6. The Decay

- The initial medium supply of each particle must be oscillatory in form per equation *(19)*. The outward flow from each particle is, then, likewise an oscillatory medium flow of the form of equation *(19)*.
- The oscillations' amplitude magnitude, $|A|$, corresponds to the amplitude of the flow emitted from the source particles and decays exponentially. That is, the amount available to supply further flow is the depleted value after the immediately prior flow. Such behavior always produces an exponential decay of the form of equation *(20)*, below. That is, both the magnitude of the remaining supply and the amplitude of the propagated oscillation decay exponentially per equation *(20)*.

$$A\cdot\varepsilon^{-t/\tau} \quad (20)$$

[A number of further results with regard to magnetic field, electromagnetic field, the photon, quantization, quantum mechanics, atomic and nuclear structure, gravitation, and so forth develop from the foregoing investigation. However, those all are a diversion from this paper's specific topic, which is the universal decay. It can be observed here, however, that:

  [The amplitude, $A$, of the *[1-Cosine]* form oscillation corresponds to the amplitude of the flow emitted from the source particle, which flow corresponds to the electric field. Thus the oscillation amplitude corresponds to the charge magnitude -- the fundamental electric charge, $q$, in the case of the corresponding fundamental particles.

  [The frequency, $f$, of the *[1-Cosine]* form oscillation corresponds to the energy and mass of the source particle, that is the energy of the oscillation is $W = h\cdot f$ and the mass is $m = W/c^2 = h\cdot f/c^2$.

[The amplitude $+A$ versus $-A$ distinction that maintains conservation corresponds to our positive and negative charge distinction.]

The significant result of the foregoing is the fact of a universal decay. That was obtained starting from an established fact, the speed limitation of $c$, then developing in simple, successive logical steps, the unavoidable consequence -- the universal decay.

### *3.3 The Nature of the Universal Decay*

This decay is intimately involved with the fundamental physical constants because it is involved with charge, the speed of light, gravitation, mass, energy and so forth. Those various physical constants are intimately interrelated through the laws of physics. The universal decay can only take place in a fashion that is consistent with those laws and those interrelationships.

Those physical laws, expressed in equations, are also laws of dimensional relationships. That is, one can substitute merely the dimensions of each of the quantities in any of those equations and the equality must yet stand valid. The problem of the nature of the decay is, then, the problem of the dimensions of the fundamental constants and of the various physical laws in which they interact.

For that purpose, the dimensions of the quantities being dealt with need to be clarified here. A full discussion of dimension systems will be found in *Section 3*, *"Physical Units and Standards*" of *Handbook of Engineering Fundamentals*, First Edition, Ovid W. Eshbach, New York, John Riley & Sons, 1947, as well as other works. Per Eshbach, one could use a different dimension for each physical quantity but it is more economical (as well as more succinctly clear) to use a small set of "fundamental" dimensions with the remainder of the quantities having their dimensions expressed as a combination of the "fundamental" dimensions according to the physical laws (expressed in mathematical relationships) that pertain.

In principal any sufficiently complete set of quantities might be chosen to be the "fundamental" ones; however, practice has been to essentially always make length $[L]$ and time $[T]$ fundamental. Usually to those is then added mass $[M]$, those three being the common dimensions of mechanics. (It can be observed that these three dimensions seem rather natural and fundamental to we humans, perhaps out of habit, perhaps because of the nature of material reality.)

Eshbach states that a minimum of three fundamental dimensions is sufficient for mechanics but a fourth is needed to treat "heat" and / or "electromagnetism". In heat systems the added fundamental dimension is usually temperature $[\theta]$ (because time already uses "$T$"). In treatments of electromagnetism the added fundamental dimension is found to be charge $[Q]$ in some cases and permeability $[\mu]$ in others with several systems not using $[M]$ and having two special fundamental dimensions that include one or more of: electric current $[I]$, voltage $[V]$, and resistance $[R]$.

The present analysis and development treats all phenomena as reduced to mechanics. Only the common three fundamental dimensions $[M]$, $[L]$, and $[T]$ are required. Charge, for example, can readily be related to these three dimensions by means of Coulomb's and Newton's laws. Briefly (using the notation "$\{x\}$" to mean "the dimensions of $x$"), the development is as follows.

$$(21)a.\quad \{Force\} = \{Mass\}\cdot\{Acceleration\} \qquad \text{[Newton's Law]}$$

$$= \frac{M\cdot L}{T^2}$$

$$b.\quad \{Force\} = \left\{\frac{c^2\cdot q^2}{r^2}\right\} \qquad \text{[Coulomb's Law]}$$

$$= \frac{L^2}{T^2} \cdot \{q^2\} \cdot \frac{1}{L^2} = \frac{\{q^2\}}{T^2}$$

c. $\frac{M \cdot L}{T^2} = \frac{\{q^2\}}{T^2}$ [Set a. = b.]

$\{q\} = \sqrt{M \cdot L}$

d. From the speed of light, $\mu_0 \cdot \varepsilon_0 = {}^1/_{c}2$.

$\{\mu_0 \cdot \varepsilon_0\} = \{{}^1/_{c}2\}$

$$= \frac{T^2}{L^2} = \{\mu \cdot \varepsilon\}$$

e. From inductive stored energy, $W = ½ \cdot L \cdot i^2$.

$\{W\} = \{½ \cdot L \cdot i^2\} = \{½ \cdot L \cdot [{}^q/_t]^2\}$

$$= \{L\} \cdot \left[\frac{\sqrt{M \cdot L}}{T}\right]^2 = \{L\} \cdot \frac{M \cdot L}{T^2}$$

but $\{W\} = \{\text{Force} \cdot \text{Distance}\}$

$= \{\text{Mass} \cdot \text{Acceleration} \cdot \text{Distance}\}$

$= M \cdot \frac{L}{T^2} \cdot L = \frac{M \cdot L^2}{T^2}$ so that ...

$\{L\} = L$

f. From the differential equation of the L-R-C circuit, in which the dimensions of each term must be the same, and aside from the L, R, and C the components are "q" and "t"

$$L \cdot \frac{d^2q}{dt^2} + R \cdot \frac{dq}{dt} + \frac{1}{C} \cdot q = 0$$

$$\left\{L \cdot \frac{d^2q}{dt^2}\right\} = \left\{R \cdot \frac{dq}{dt}\right\} = \left\{\frac{1}{C} \cdot q\right\}$$

$$\{L\} \cdot \frac{\{q\}}{\{t^2\}} = \{R\} \cdot \frac{\{q\}}{\{t\}} = \frac{1}{\{C\}} \cdot \frac{\{q\}}{1}$$

$$\{R\} = \frac{\{L\}}{\{t\}} = \frac{L}{T}$$

$$\{C\} = \frac{\{t\}^2}{\{L\}} = \frac{T^2}{L}$$

g. From the general formula for capacitance

$$C = \varepsilon \cdot \frac{\text{Surface Area}}{\text{Separation Distance}}$$

$$\{C\} = \left\{\varepsilon \cdot \frac{\text{Surface Area}}{\text{Separation Distance}}\right\}$$

$$\{\varepsilon\} = \left\{C\cdot\frac{\text{Separation Distance}}{\text{Surface Area}}\right\} = \frac{T^2}{L}\cdot\frac{L}{L^2} = \frac{T^2}{L^2} = \{\varepsilon_0\}$$

h. From d. above the dimensions of μ, permeability, are

$\{\mu\} = \{\mu_0\}$ -- (dimensionless)

($\mu_0$ must be dimensionless so that $\alpha = \frac{1}{2}\cdot\mu_0\cdot c\cdot q^2/h$, the fine structure constant, is dimensionless and because $\{c\cdot q^2\} = \{h\} = M\cdot L^2/T$.)

Then, does the decay represent decay of the mass *[M]*, the length *[L]*, or the time *[T]*, or of some combination of those dimensional aspects of material quantities ?

Time cannot decay. It is the independent variable. It is only made measurable by the occurrence of events, changes which occur in realized space, the volume dimensions. Time being the independent variable of material reality, whether it decays, varies, or is rigorously constant is beyond our ability to detect in any case. For us it cannot but appear constant.

Mass might be thought to be able to decay, especially in that we "feel" about mass as that it is substantial. But mass is merely the ratio of applied force to resulting acceleration. Mass is proportional to frequency, $f$, per the familiar relationship $m\cdot c^2 = h\cdot f$. As with time, frequency, time's inverse, cannot decay nor "anti-decay" and, therefore, neither can mass.

Then the decay must be decay of the length *[L]* aspect of reality by default. Applying that conclusion to some fundamental physical quantities the table of Figure 9, below, is obtained. For the table the mechanical dimensions of the quantities were developed in equation *(21)*, above, except for the Gravitation Constant, $G$, for which the dimensions develop as follows.

*(22)*
$$a_g = \frac{G\cdot m_1}{r^2} \quad \text{so that} \quad G = \frac{a_g\cdot r^2}{m_1}$$

$$\{G\} = \frac{[L/T^2]\cdot[L^2]}{M} = \frac{L^3}{T^2\cdot M}$$

| Quantity | Dimensions | Significance | Relative Decay Rate | Decay Constant |
|---|---|---|---|---|
| $c(t)$ | $L/T$ | Speed of Light | 1 | $\tau$ |
| $\mu_0(t)$ | -- | Free Space Permeability | 0 | - |
| $\varepsilon_0(t)$ | $T^2/L^2$ | Free Space Dielectric | -2 | $-\tau/2$ |
| $q(t)$ | $\sqrt{M\cdot L}$ | Fundamental Charge | $1/2$ | $2\cdot\tau$ |
| $h(t)$ | $M\cdot L^2/T$ | Planck's Constant | 2 | $\tau/2$ |
| $G(t)$ | $L^3/T^2\cdot M$ | Gravitation Constant | 3 | $\tau/3$ |

*Relative Decay Rates of Fundamental Physical Constants*

*Figure 9*

All of the decays are exponentials with the same base, $\varepsilon$ (the natural logarithmic base, not the dielectric constant). In applying these decay rates to the laws of physics, which are expressed in equations involving these quantities, the algebra of exponents applies. In equations with multiplication of variables exponents to the same base are added and for division they are subtracted. Consequently, to find the overall relative decay rate for an expression the relative decay rates of Figure 9 should be added or subtracted correspondingly. The decay constant is $\tau$ times the reciprocal of the relative decay rate.

This procedure, taking the general universal decay to be a decay of the dimension length, *[L]*, is further justified by the results when it is applied to various physical laws. For example, consider the results in the table of Figure 10, below, in which the dimensions of the same quantity are obtained via two different physical laws. The result must be the same, that is any quantity can have only one set of fundamental mechanical dimensions.

If one attempts to achieve this type of result, the proper correlation of related quantities, using the assumption that the fundamental decay of medium is a decay of mass *[M]* or is a decay of time *[T]* or of some combination of *[M]*, *[L]*, and *[T]*, the necessary agreements in the table do not obtain. This tends to confirm the conclusion that the decays are decay of length, *[L]*, only.

| Physical Relationship | Relative Decay Rate | |
|---|---|---|
| A. Energy: | | |
| Mass-Energy Equivalence | | |
| energy = $m \cdot c^2$ | (0) + (1)·2 | = (2) |
| Photon Energy, i.e. Oscillation Energy Equivalence | | |
| energy = $h \cdot f$ | (2) + (0) | = (2) |
| B. Force: | | |
| Coulomb's Law | | |
| force = $\dfrac{c^2 \cdot q_1 \cdot q_2}{r^2}$ | (1)·2 + (½) + (½) - (1)·2 | = (1) |
| Newton's Laws of Motion | | |
| force = $m \cdot a$ | (0) + (1) | = (1) |

*Figure 10 - Some Major Cosmic Decays*

The next issue is to address the rate of decay, to evaluate the time constant, $\tau$. That develops as follows.

We begin with the Planck length, $l_P$, per equation *(23)*, below, the value for which is from "The 1986 Adjustment of the Fundamental Physical Constants"[8].

*(23)*
$$l_P \equiv \left[\frac{h \cdot G}{2\pi \cdot c^3}\right]^{½} = 1.61605 \cdot 10^{-35} \text{ m}$$

Solving equation *(23)* for $G$ …

(24) $$G = \frac{2\pi \cdot l_P^{2} \cdot c^3}{h}$$

… then, into Newton's Law of Gravitation,

(25) $$a_g = G \cdot \frac{m}{r^2}$$

… substituting equation *(24)* for $G$ [= intermediate equation *(26)*, omitted] and the $\delta^2$ of equation *(17)* for the $2\pi \cdot l_P^2$ in that equation *(26)* result the following is obtained.

(27) $$a_g = \frac{\delta^2}{r^2} \cdot \frac{c^3 \cdot m}{h}$$

As discussed following equation *(14)*, at distance $d = [2\pi]^{½} \cdot l_{Pl} \equiv \delta$ from the center of the source, attracting, mass the acceleration per cycle of that attracting mass's equivalent frequency, $f_s$, namely $\Delta v$, is equal to the full speed of light, $c$, the most that it is possible for it to be. Thus, the $\delta$ from equation *(17)* and in equation *(27)* is the radius of a spherical core at the center of the particle generating the gravitational attraction, $a_g$. That is, such a spherical core of radius $\delta$ is at the core of every particle.

The "supply" of medium within a particle, discussed in section 3.2, above, [as a necessity of the on-going outward flow from the particle, which itself is a necessity of the speed of light time delay between interacting particles] must be medium at an enormously higher concentration than that at which it flows outward from the particle because the flow has been going on for billions of years and is expected to so continue. Therefore, within whatever distance from the center of the particle that the "supply" region extends is a region of density immensely greater than that of the radial outward flow. Its outer boundary would be a sharp break in the smooth inverse square variation outside of that region, where the outward flow is. Thus, if the "supply" of medium for a particle occupied a region of radius other than $\delta$ at the center of the particle then equation *(27)* would not obtain. The particle's central core of radius $\delta$ must be where the "supply" of medium to be propagated resides and from which it propagates.

The propagation of that medium, the gradual "leaking" of it outward from the core, both (a) produces the effects we experience as electric field, magnetic field and gravitational field, and (b) depletes the supply of medium in the core -- results in the overall universal decay in the supply within each core and in the amplitude of each core's propagated medium flow. The rate of that "leakage", that propagation, develops as follows.

A process which the core decay resembles is the pumping of gas out of a chamber to create a vacuum. In that case the "gas" corresponds to the medium, the chamber to the core, and the pumping to the loss of medium through, the surface boundary of the core, to outward propagation. The process of the pumping, whether of gas out of a vacuum chamber or of medium out of the core is such that:

- The rate of change of the amount of gas (medium) remaining in the chamber (core) and not yet pumped (propagated) is equal to:
    - · The density, amount per volume, of the gas (medium) to be pumped out times
    - · The pumping speed, that is the volume per time at which the pumping (propagation) occurs.

This is based on the conceptualization of the process as

- · The gas (medium) to be pumped is uniformly distributed within the chamber (core);

- a minute increment of volume is then pumped out at the pump during a minute increment of time [a minute increment of gas (medium), equal in amount to its density times the minute volume pumped, is removed];
- the chamber (core) volume remains unchanged but it now contains slightly less gas (medium) and that remaining, unpumped, part of the substance then automatically, naturally, redistributes itself uniformly within the chamber so that its density is reduced; and
- the cycle repeats over and over.

From this:

*(28)*
$$\text{Rate of Change} = -\left[\left[\text{Amount per Volume}\right] \cdot \left[\text{Pumping Speed} = \text{Surface of Core} \cdot \text{Flow Speed}\right]\right]$$

$$\frac{d\nu}{dt} = -\left[\left[\frac{\nu}{{}^4/_3\cdot\pi\cdot\delta^3}\right] \cdot \left[ = \left[4\cdot\pi\cdot\delta^2\right]\cdot[c]\right]\right]$$

$$= -\frac{3\cdot c}{\delta}\cdot\nu \qquad \text{[where } \nu \text{ is the amount of medium in the core]}$$

The pumping takes place over the entire surface of the core and the rate at which the outward flow takes place is the speed of medium travel, the speed of light, $c$. (Both $c$ and $\delta$ are functions of time, also, each decaying. However, their decay rates are identical so that their ratio, as in equation *(28)*, above, is constant.)

Therefore

*(29)*
$$\frac{d\nu}{\nu} = -\frac{3\cdot c}{\delta}\cdot dt \qquad \text{[Rearranging equation (28)]}$$

and, by integration

*(30)*
$$\log_\varepsilon\nu = -\frac{3\cdot c}{\delta}\cdot t + C \qquad \text{[C is the constant of integration.]}$$

$$\nu = \nu_c\cdot\varepsilon^{-3\cdot c\cdot t/\delta} \qquad [\varepsilon^C \text{ evaluated as } \nu_c]$$

However, while this result demonstrates the exponential decay aspect of the process, it makes no specification of what it is that occupies the volume and is decaying. It merely describes the evacuation of the volume as volume. Specifying of $\nu$ is needed.

We can proceed to the correct description of the decay as follows. See Figure 11, below. The area under the curve $\varepsilon^{-t/\tau}$ from $t=0$ to $t=\infty$ is $\tau$. That is, the decay process involves over the total time span the same amount of propagation of medium as if the initial,

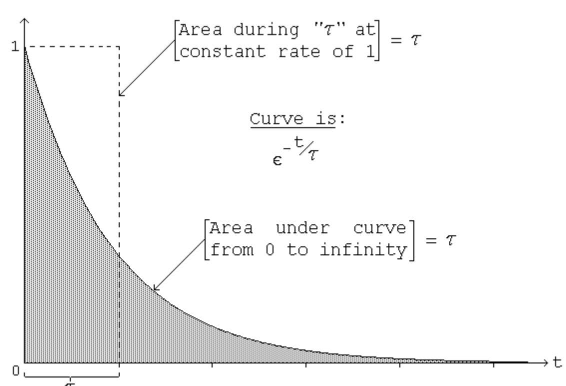


*Figure 11*

un-decayed rate of propagation went on, without decay, for time $\tau$. Therefore, the time constant, $\tau$, can be obtained as the total amount remaining to be propagated divided by the current rate of flow of the propagation.

The volumetric rate of flow out of the core is

*(31)* Rate of Flow = Pumping Speed =

$$[\text{Core Surface}]\cdot[\text{Speed of Flow}] = [4\cdot\pi\cdot\delta^2]\cdot c$$

That which is flowing, the gradual propagation outward of the contents of the core, is "medium" the effect of the flow of which is that which we call electric field, the summation of which over an entire surface that encloses the core corresponds to the enclosed electric charge (Stokes Theorem).

The amount of medium within the core, not yet pumped, at any moment, which amount corresponds to the electric charge [decaying] at that moment is

*(32)* Remaining Core Medium = $^h/_c$

which has the dimensions $[M\cdot L]$ and relative decay rate *1*, [see Figure 9]. This develops as follows.

As developed in the dimensional analysis earlier above at equations *(21)*, the mechanical dimensions of charge are $[M\cdot L]^{½}$. Such dimensions are unacceptable for a material reality in that conceptually the square root of mass or of length has no practical, no material, meaning. Something that actually exists in the universe must have real dimensions as, for example the dimensions of charge-times-charge in Coulomb's Law for which the $[M\cdot L]^{½}$ becomes $[[M\cdot L]^{½}]^2 = M\cdot L$. This problem with the dimensions of charge may be one of the reasons that charge has always been dimensioned in terms of other defined dimensions -- "coulomb" traditionally and "ampere-second" in Standard International (SI) units.

It is now time to adjust our conception of the Coulomb's Law action. Because the law accurately gives the correct Coulomb effect results by multiplying the magnitude of each of the two interacting charges we have naturally come to think that the actual physical action is that way. The reciprocity of the effect of each charge on the other has lead us to assume that they physically interact in that way. However, if the charge is to be real and the electric field is to support its potential energy role neither can have dimensions involving $[M\cdot L]^{½}$. Rather, in terms of the mechanics of the physical action, the charge, the field and the flowing medium must correspond to the charge-squared dimensions $[M\cdot L]$.

The action is not the traveling of the effect of the source charge's $q_s$ (the effect of the source core's flowing *[source medium]*) but rather of its $q_s^2$ (of flowing *[what we have been calling source medium]*$^2$ ) from the source to an encountered charge. At the encountered charge the extent to which the flow arriving from the source charge acts on the encountered charge is moderated by, according to, the magnitude of the encountered charge's own charge squared, $q_e^2$, its own medium-filled core and outward flowing medium propagation.

This discussion is related in our minds to thinking of the medium, both that within the core and that which is being propagated, as the relatively "hard" tangible substance involved with its related energy as an intangible "thing", there because of the medium and only perceived when and because of a tangible energy-involved action taking place. Yet, the medium corresponds only to the effects which we think of as electric field and charge, effects no more tangible than energy, and perhaps less so. It is just as reasonable to think of the core as filled with and propagating some form of energy as to think of it in terms of medium or charge.

Thus the description of the medium supply in the core can also be an energy-related expression that has the same dimensions as $q_s^2$ where $\{q_s^2\} = [M \cdot L]$. The quantity $h/c$ meets those requirements and is the most fundamental quantity to do so, as in $\alpha$, the fine structure constant.

*(33)*
$$\alpha = \tfrac{1}{2} \cdot \mu_0 \cdot c \cdot \frac{q^2}{h}$$

from which

$$h/_c = q^2 \cdot \frac{\mu_0}{2 \cdot \alpha} \qquad [\{\mu_0\} = \{\alpha\} = --]$$

That is, $h/_c$ is equivalent to $q^2$ and vice versa.

The exponential decay time constant as given by equation *(32)* divided by equation *(31)* is as follows.

*(34)*
$$\tau = \frac{\text{Equation } (32)}{\text{Equation } (31)} = \frac{\text{Remaining Core Medium}}{\text{Rate of Flow}}$$

$$= \frac{h/_c}{[4 \cdot \pi \cdot \delta^2] \cdot c}$$

$$= 3.57532 \cdot 10^{17} \text{ s}$$

$$\cong 11.3373 \cdot 10^9 \text{ years}$$

[The precision of $\tau$ is limited by the precision of $\delta$, which is limited by that of $l_P$, which itself is limited by the available measurement precision of $G$.]

however, the dimensions of the numerator of equation *(34)* are $[M \cdot L]$ and those of the denominator are $[L^3/_T]$ so that the quotient dimensions would not be simply $[T]$, as required for $\tau$. The solution to that dilemma is as follows.

The content of the core flows outward at a volumetric flow rate, the denominator of equation *(34)*. Although the decaying exponential process goes on forever, the total amount of such flow is a finite quantity, the area under the decaying exponential curve per Figure 11. That area also corresponds to, then, a finite volume (produced by the medium outflow). The total magnitude of that area under the curve, that finite volume propagated during the decay's process from time $t = 0$ to time $t = \infty$, is the same as the original amount available to so propagate, the numerator of equation *(34)*, the original core medium content. Then the equation *(34)* numerator, $h/c$, is also an ultimate volume of dimensions $[L^3]$, which results in a quotient dimension for $\tau$ of $[T]$.

Therefore, among a number of other quantities, the acceleration due to gravitation and the speed of light are decaying exponentially as in equations *(35)* and *(36)*, below.

*(35)* $$a(t)_{g,decay} = a_{g,newton} \cdot \varepsilon^{-t/\tau}$$

*(36)* $$c(t) = C_0 \cdot \varepsilon^{-t/\tau}$$

where: $a_{g,newton}$ is the gravitational acceleration per Newton's Law of Gravitation,

$C_0$ is the speed of light at $t = 0$, and

$\tau = 3.57532 \cdot 10^{17}$ s [equation *(34)*]

### *3.4 Correlation of the Decay with the Pioneer "Anomalous Acceleration"*

The relationship between the universal decay and the behavior of the Pioneer 10 and 11 satellites is as follows. The Newtonian solar gravitational acceleration, $a_{g,newton}$, of the satellites varies with satellite distance from the Sun, and that has been taken into account in the satellite path calculations. However, the actual solar gravitational acceleration involved is the Newtonian amount exponentially decaying per equation *(35)*.

During the time period from the start of the satellite path observations to the present time $a_{g,newton}$ has decreased less (because its decrease is due solely to radial distance increase) than has $a_{g,decay}$ (the decrease in which is due to decay in addition to radial distance increase). But, NASA has not known about decay and has calculated satellite motion without taking decay into account. Not knowing about the decay, NASA is always calculating and measuring in terms of the at that moment current decayed state, which NASA thinks is a steady, unchanging, undecayed state whereas in fact earlier, less decayed increments of solar gravitational acceleration were larger than current ones.

But, NASA cannot avoid the actual effect of earlier, less decayed, solar gravitation even if it does not know about it. Calculating in terms of the present, measuring in terms of the present, NASA gets results due to (unknown of) earlier less decayed, greater $a_g$ that NASA can only end up interpreting as an anomalous sunward acceleration relative to the only $a_g$ that NASA knows $a_{g,newton}$.

However, NASA does not and cannot measure the location of the satellites to the precision needed to disclose that effect. What NASA has done with sufficient precision is measure the Doppler shift in transmissions received from the satellites. That data is sufficient for the calculation of velocity at a particular time, and a stream of velocity data is sufficient for the calculation of acceleration.

But, the electromagnetic wave propagation that carries the Doppler shift data from the satellites is also subject to the general universe decay. The decay of $c$ produces modification of the Doppler frequency shifts otherwise produced solely by satellite velocity. Satellite velocity away from us produces Doppler reduction of frequency in satellite transmissions received by NASA. But, those transmissions, initiated and traveling at an earlier, less decayed, faster speed, $c$, result in a decay-caused frequency increase that can only appear to NASA observers as a smaller Doppler frequency reduction, a smaller satellite velocity than would have been the case in the (as NASA understands it) absence of universal decay.

(All of the data received by transmission from the satellites must be adjusted for the relative positions of the Earth and the satellite and for the motion of each. The performing of those adjustments by NASA for the non-decay case (as they know of it) also corrects the decay modifications contained in the data (even though NASA does not know it is doing that.)

The decay-produced frequency shift corresponds directly to the speed of light variation due to $c$ decay, which is equal to the satellite velocity change that would be needed to produce the same observed data. Therefore the satellite velocity deviations from NASA's expected values, which deviations yield the anomalous acceleration, and which are due to gravitation decay, are reported to NASA by the satellites as speed of light deviations received by NASA as smaller Doppler shifts than otherwise.

Both $c$ - decay and $a_g$ - decay have the same time constant, $\tau$, because both quantities have dimensions involving length, $[L]$, to the first order. Therefore, while actually measuring $a_p$ from c - decay, the measurements effectively measure $a_p$ as $a_g$ - decay.

The $c$ - decay data unknowingly received by NASA is as follows.

$$(37) \qquad c(t) = c_0 \cdot \varepsilon^{-t/\tau}$$

$$\frac{dc(t)}{dt} = \frac{c_0 \cdot \varepsilon^{-t/\tau}}{\tau}$$

Because $\tau > 10^{17}\ s\ (\cong 10^{10}\ years)$ the rate of change in $c$ appears to us as constant over the span of much less than $100\ years$ that the satellites have been being observed.

The calculation of $a_p$ is then as follows.

$$(38)\quad \frac{dc(t)}{dt} = \frac{c_o}{\tau} = \frac{c}{\tau} \quad \text{[c is our contemporary c with no knowledge of decay]}$$

$$= \frac{2.99792458 \cdot 10^{8}\ {}^{m}/_{s}}{3.57532 \cdot 10^{17}\ s}$$

$$= 8.38505 \cdot 10^{-10}\ {}^{m}/_{s^2}$$

$$= 8.38505 \cdot 10^{-8}\ {}^{cm}/_{s^2}$$

$$= a_p, \text{ the Pioneer anomalous acceleration}$$

This result compares quite well with the value given in the subject report [equation #52, page 72 and equation *(1)* the present paper] of $a_p = (8.74 \pm 0.94) \times 10^{-8}\ {}^{cm}/_{s^2}$.

In the process of seeking explanation of the anomalous acceleration NASA has investigated and reported on a number of candidate effects. In general these have fallen into one or more of the following categories.

a. Effect does not actually occur.

b. Effect is too small to account for the anomalous acceleration.

c. Effect acts in the opposite direction to that of the anomalous acceleration.

For example, "... solar radiation pressure decreases as $r^{-2}$ ... at distances $> 10 - 15\ AU$ it produces an acceleration that is much less than $8 \cdot 10^{-8}\ {}^{cm}/_{s^2}$, directed <u>away</u> from the Sun. (The solar wind is roughly a factor of $100$ smaller than this.)"[2]

Other effects reported on include:

- precessional attitude control maneuvers,
- non-isotropic thermal radiation from the satellites,
- the radiation of the Pioneer radio beam,
- error in the computer programs used to perform the calculations,
- hardware problems,
- unknown internal systemic properties,
- some unknown viscous drag,

and others. All of these effects fall far from explaining the anomalous acceleration. However, such an extensive family of small effects and unknown behaviors might well account for the decay-explained acceleration not exactly matching the observed amounts.

A more clear comparison of data and decay-prediction occurs as follows. From the original (1998) paper reporting the anomalous acceleration:[2]

> "The CHASMP [The Aerospace Corporation's Compact High Accuracy Satellite Motion Program] analysis of Pioneer 10 data showed ... [without using the apparent acceleration] a steady frequency drift of about $-6 \cdot 10^{-9}\ {}^{Hz}/_{s}$. ... This equates to a clock acceleration, $-a_t$, of $-2.8 \cdot 10^{-18}\ {}^{s}/_{s^2}$."

The effective appearance of a clock $[T]$ acceleration (instead of a length $[L]$ decay) was produced by calculations in which the anomalous acceleration was denied forcing a compensating clock acceleration. The clock acceleration that would produce the corresponding effect to the actual effect of a length decay would be a rate of ${}^{1}/_{\tau}$ as follows.

(39) $$a_t = \frac{1}{\tau} = \frac{1}{3.57532\cdot 10^{17}}$$

$$= 2.79695\cdot 10^{-18}\ {}^{s}/_{s^2}$$

calculated from the universal decay,

as compared to

(40) $$= 2.8\cdot 10^{-18}\ {}^{s}/_{s^2}$$

calculated from Pioneer data using "CHASMP"

The identity of clock acceleration with Pioneer acceleration is[2]

(41) $$a_P \equiv a_t\cdot c$$

$$= 8.38505\cdot 10^{-8}\ {}^{cm}/_{s^2}$$

as in equation *(38)*.

The universal decay that was originally analytically developed and predicted in publication in 1996[9] before the original reporting of the "anomalous acceleration"[2], is fact as presented and accounts for the pioneer 10 and 11 "anomalous acceleration".

## **Part 4.** *The Universal Decay Causes the Type Ia Supernovae Distances That Have Been Interpreted as Due to Cosmic Acceleration.*

### *4.1 Background of the Problem*

The, for years generally accepted, Hubble astronomical model of the universe is of a uniformly expanding cosmos in which all galaxies are moving apart so that their speed away from us is proportional to their distance from us, the constant of proportionality being called the Hubble Constant, $H$. Until recently the distance to far distant such bodies has been determined by measuring the redshift, deemed a Doppler effect. From that one obtains the speed of recession, $v$, and then the distance ${}^{v}/_{H}$ .

Recently it has become possible to determine the distance to far distant galaxies by an alternative independent means based on observations of Type Ia Supernovae in those galaxies.[10,11] It has been found that the intrinsic brightness [luminosity] of such supernovae is related to the pattern [light curve] of their flare up and back down, a process taking weeks overall. By comparing the intrinsic brightness, as determined from that pattern, to the observed brightness the distance can be determined from the inverse square law.

Those new distance determinations indicate distances exceeding the Hubble model distance by 10% to 15%[10]. The interpretation of that result proposed by the researchers who developed the data and others is that some "antigravity effect" is accelerating the universe's expansion, which expansion had hitherto been thought to be slowing down because of gravitation. That "antigravity effect", by default, would have to be a property of the empty space, the vacuum, of the universe since it is certainly not a property of the matter.

Those implications are so unsettling to theory and to reasonableness that the data had been initially deemed in error. As a result there have been extensive analyses of sources of error and measurements have been taken on a sufficiently large number of Type Ia Supernovae to be statistically significant, all with the conclusion that the new distance measurements are valid and that theory must be adjusted accordingly.

That line of thought has led to acceptance of the concept that space is filled with "dark [i.e. undetected] energy", also referred to as "quintessence" [the ancients' fifth essence] and to the reinstatement of Einstein's "cosmological constant" a term in his equations that he introduced to account for the universe not promptly collapsing due to gravitation and which he later disavowed as his "greatest error" upon Hubble's discovery of the expansion of the universe.

But, there is an explanation of the data alternative to that of accelerating expansion, one that carries considerably less challenge to theory and negligible challenge to reasonableness -- the general exponential decay of the overall universe. The universal decay accounts for the observed greater distances [and shows that the actual distances are greater than the reported measurements indicate] and provides the necessary cosmic energy without employing an undetected "dark energy", an arbitrary "cosmological constant", a new "quintessential" substance, and "an antigravity effect", which are otherwise unknown, unsupported by theory, and contrary to all other data and experience.

### *4.2 The Universal Decay Applied to the Type Ia Supernovae Observations*

The values of the fundamental constants $c$ and $h$ in the light, emitted long ago, that we now observe locally received from far distant astronomical sources, are much less decayed than our local here, now values of those constants. That is, the light travels at a much greater speed than the $c$ that we know and its photons carry much greater energy for each same frequency than the $E = h \cdot f$ amounts that we know, meaning that they appear more luminous to us. Both of the constants $c$ and $h$ are actually greater than, greater relative to, the values, that we inherently use, directly experience, and in terms of which we interpret that ancient light -- the values to which those constants have currently decayed, "our" local values.

Because that light that we observe from a far distant astronomical source is traveling faster, its source is farther away from us than we deem based on our understood speed of light. For example, the situation for a source the light from which is 5 billion years old when it reaches us [as we conclude from its redshift] is as follows [using equation *(36)* with the time constant of equation *(34)*, $\tau = 3.57532 \cdot 10^{17}\ s$, (which is $\cong$ 11.3 billion years) and the relative decay rates of Figure 9].

```
(42)  As we perceive it:
            distance = [age] × [our value of c]
                     = 5 billion (our) light years
      As it really is:
            distance = [same age] × [155% of our value of c]
                     = [155% of same age] × [our value of c]
                     = 7.75 billion (our) light years
```

That would [in the example of equation *(42)*] tend to make the apparent, the observed, luminosity of the source appear less to us by the factor $[5.00/7.75]^2 = 0.416$ because of the inverse square effect. However, that same light that we observe from its far distant astronomical source also carries a larger value of Planck's constant which makes its intrinsic luminosity greater. For example, the situation for the same source the light from which is 5 billion years old when it reaches us is as follows.

```
(43)  As we perceive it:
            luminosity = per our Planck's constant
      As it really is:
            luminosity = 240% of that per our Planck's constant
                       = 2.40 × [As we expect it]
```

That would tend to make the apparent, the observed, luminosity of the source appear greater to us by the factor $2.40$. The combined effect of the two, the reduction due to greater distance, greater $c$, and the enhancement due to larger Planck's constant, $h$, is for the present example as follows.

```
(44)  Net combined effect on perceived luminosity

            = 0.416 × 2.40 = 1.00
```

That is, there is not net change in the perceived brightness, the inverse square effect of greater distance being exactly cancelled by the effect of greater intrinsic luminosity.

However, in the case of the Type Ia Supernovae experiments, the subject at the moment, the situation is not the same. In those experiments, as reported in the papers[10,11], the relationship between intrinsic luminosity and the light curve [flare up and back down pattern] of Type Ia Supernovae was calibrated by observations on relatively near sources. It is that calibration which is in error, error caused by the [unknown to the experimenters] effects of the general universal decay of the constants $c$ and $h$. That error develops as follows.

The distances were determined by means of data on Cepheid variable type sources. As described in one of the papers reporting the SNe Ia research[11],

> "The relative luminosities of this "training set" of SNe Ia were calibrated with independent distance indicators (Tonry 1991; Pierce 1994). The absolute SN Ia luminosities were measured from Cepheid variables populating the host galaxies (Saha, et al. 1994, 1997)."

[For the benefit of non-specialists in astronomy or astrophysics Cepheid variables are stars that cyclically vary in brightness with regular periods ranging from less than 1 to about 100 days. In 1912 a relationship, since improved, between the period and the brightness of Cepheids was discovered.]

Using Cepheids near enough that their distance could be measured by triangulation, the brightness - period relationship for Cepheids was calibrated. With that calibration, the distance to more distant Cepheids could be determined by comparing the observed brightness with the intrinsic brightness calculated from the Cepheid's period and applying the inverse square law. That calibration of Cepheids by triangulation means that the universal exponential decay had no effect. Therefore, Cepheid determined distances based on such a calibration take no account of the universal decay.

A distant Cepheid has a greater intrinsic brightness as compared to a quite near but otherwise identical Cepheid because the $h$ of the light from the distant Cepheid is larger than the $h$ of the light from the quite near Cepheid. The distant Cepheid's actual distance is also greater than we would conclude on the basis of its redshift because the $c$ of its light is greater. Its light has traveled the time corresponding to the redshift but at a greater speed so that its source's distance must have been greater. As in the hypothetical example of equations *(42) - (44)*, the two effects cancel out. The distant Cepheid's observed brightness is unaffected by the universal decay.

For the calibration of the Type Ia Supernovae light curves by observations on relatively near sources at redshifts in the range $z = 0.01$ to $0.08$ the actual distances to those sources were as follows.

*(45)* The relationship between attributing observed wavelength shift solely to the exponential decay vs. solely to the Doppler effect is as follows. [Such shifts are actually 90-99% decay - caused, the minor balance is Doppler per the analysis at ¶5.2, below].

Exponential Decay

$$\frac{\lambda_{t=T}}{\lambda_{t=0}} = \varepsilon^{-T/\tau}$$

Doppler Effect

$$1 + z = \frac{\lambda_{obs\ v=V}}{\lambda_{v=0\ source}}$$

where:

$\lambda_{t=T}$ corresponds to $\lambda_{v=0\ source}$

$\lambda_{t=0}$ corresponds to $\lambda_{obs\ v=V}$

*(45, cont'd)* Therefore:

$$1 + z = \frac{\lambda_{t=0}}{\lambda_{t=T}} = \varepsilon^{+T/\tau}$$

$$\ln[1 + z] = {}^{T}/_{\tau}$$

$$T = \tau \cdot \ln[1 + z] = \text{Distance in Light-time}$$

The relationship between the initial and final values of a quantity that decays exponentially over a time interval, $T$, with a decay constant, $\tau$, is as follows.

*(46)*
$$c(T) = c(0) \cdot \varepsilon^{-T/\tau} \quad \text{or} \quad c(0) = c(T) \cdot \varepsilon^{+T/\tau}$$

*(47)* For the relatively near sources used for calibrating the Type Ia Supernovae light curve vs luminosity.

| z | Eq 45: T = $\tau \cdot \ln[1+z]$ | $D_1$ @ c(T)≡ Current *c* | $D_2$ @ c(0) ≡ Actual [Less-Decayed] *c* | $D_2/D_1$ |
|---|---|---|---|---|
| 0.01 | 0.11 | 0.11 | 0.11 | 1.01 |
| 0.02 | 0.23 | 0.23 | 0.23 | 1.02 |
| 0.03 | 0.34 | 0.34 | 0.35 | 1.03 |
| 0.04 | 0.45 | 0.45 | 0.47 | 1.04 |
| 0.05 | 0.56 | 0.56 | 0.59 | 1.05 |
| 0.06 | 0.66 | 0.66 | 0.70 | 1.06 |
| 0.07 | 0.77 | 0.77 | 0.82 | 1.07 |
| 0.08 | 0.88 | 0.88 | 0.95 | 1.08 |

where:

$\tau$ = 11.3 billion light years
T is in billions of years
D is in billions of light years

And (from the distribution of the data points):

typical z ≈ 0.04; high z ≈ 0.07
typical T ≈ 0.45; high T ≈ 0.77

The corresponding data and calculations for the distant sources, which are the ultimate subject of the research at issue[10,11] and of the theoretical interpretation being corrected, are as follows.

*(48)* For the distant sources being investigated.

| z | Eq 45: T = $\tau \cdot \ln[1+z]$ | $D_1$ @ c(T)= Current *c* | $D_2$ @ c(0) = Actual [Less-Decayed] *c* | $D_2/D_1$ |
|---|---|---|---|---|
| 0.40 | 3.84 | 3.84 | 5.38 | 1.40 |
| 0.45 | 4.24 | 4.24 | 6.15 | 1.45 |
| 0.50 | 4.62 | 4.62 | 6.93 | 1.50 |
| 0.55 | 5.00 | 5.00 | 7.75 | 1.55 |
| 0.60 | 5.36 | 5.36 | 8.58 | 1.60 |
| 0.65 | 5.71 | 5.71 | 9.42 | 1.65 |
| 0.70 | 6.05 | 6.05 | 10.29 | 1.70 |
| 0.75 | 6.38 | 6.38 | 11.17 | 1.75 |
| 0.80 | 6.70 | 6.70 | 12.06 | 1.80 |

where (from the distribution of the data points):

typical z ≈ 0.55; high z ≈ 0.75
typical T ≈ 5.00; high T ≈ 6.38

To trace the effects of the universal exponential decay as it causes deviations of results in observations of distant Type Ia Supernovae from as they would otherwise be in the absence of the decay, the effects on the cases corresponding to the above cited typical values are analyzed below. The actual investigations presented in the papers[10,11] were of a statistically significant number of such determinations on specific Type Ia Supernovae, the set approximately averaging the typical values above. The analysis process is as follows.

A. The effect of $c$ decay on the "training" Cepheid

A Cepheid variable is identified in the host galaxy of one of the relatively near "training" Type Ia Supernovae and its distance is determined according to the usual Cepheid distance scale. That is, its intrinsic brightness is determined from its variation period and its observed brightness is noted. From those its distance is inferred from the inverse square relationship.

That distance to the Cepheid is then assigned or designated as the known distance to the "training" SN Ia.

> In the light from that Cepheid both its $c$ and its $h$ are greater than our contemporary values. The greater $c$ means a greater distance and greater inverse-square dimming of observed brightness. The greater $h$ means greater photon energy and an enhancement of observed brightness. As in the hypothetical example of equations *(42) - (44)*, the two effects exactly cancel. The resulting observed brightness of the Cepheid is the same as would be the case in the absence of universal decay. The resulting distance determination to the Cepheid is, in that sense, unaffected by the universal decay.
>
> However, from equation *(47)* that distance is moderately incorrect. That is, the calibration of the Cepheid "yardstick" on stars near enough for distance measurement by triangulation takes no account of the universal decay and the related actual progressively greater distances of more distant sources.
>
> The correct distance to the typical Cepheid and the correct deemed distance to its companion "training" SN Ia, for a typical value and a high value, respectively, of those reported in the papers[10,11] and so noted in equation *(47)*, is about 4.2% - 7.5% greater. The intrinsic brightness of the typical "training" SN Ia, inferred from its observed brightness and the Cepheid-determined distance, will be overstated [due to that cause, alone] over its actual intrinsic brightness by about 8.5% - 15.6% because of being inferred using too small a distance. In other words, the affect of the distance on brightness is as the inverse square of the distance so that $[1.00/(1.00-0.04)]^2 = 1.085$ and $[1.00/(1.00-0.07)]^2 = 1.156$.

B - The effect of $c$ decay on the "training" Type Ia Supernova

The observed brightness of the "training" SN Ia is noted. That in conjunction with its distance [from Step A] makes it possible to calculate the intrinsic brightness of the "training" SN Ia using the inverse square relationship. However, the above-described understatement of the Cepheid's distance and, therefore, of the "training" Type Ia Supernova's distance by about 4.2% - 7.5% therefore overstates the "training" SN Ia's intrinsic brightness by about 8.5% - 15.6% due to the effect of $c$ decay, alone.

That intrinsic brightness is correlated with the "training" SN Ia's light pattern, which completes the calibration of the SN Ia. However, there is a further effect on the SN Ia.

C - The effect of $h$ decay on the "training" Type Ia Supernova

> As in the hypothetical example of equations *(42) - (44)*, the combined effects of the $c$ decay and the $h$ decay on the observed brightness of the SN Ia exactly cancel; the observed brightness is independent of the decay. However, while both

distance and intrinsic brightness affect observed brightness, distance has nothing to do with intrinsic brightness; the intrinsic brightness simply is what it is; it is intrinsic to the source. [The determining of intrinsic brightness in some cases by inference from observed brightness and distance is not the same thing.]

The "training" SN Ia's intrinsic brightness is greater [than expected in the absence of knowledge of the universal decay] because its $h$ is greater and greater $h$ means greater photon energy, which enhances brightness. This excess brightness is calculated using the decay time constant for Planck's constant, which is half that for the speed of light; $\tau_h = 0.5 \cdot \tau_c = 5.65$ *billion light years*. Per equation *(46)* and using $T = 0.50$ and $T = 0.77$ [equation *(47)* typical and high values, respectively], the result is as follows.

$$c(0)/c(T) = \varepsilon^{+T/\tau} = \varepsilon^{+0.50/5.65} = 1.093 \quad \text{[typical]} \qquad (49)$$

$$= \varepsilon^{+0.77/5.65} = 1.146 \quad \text{[high]}$$

That is, taking account of $h$ decay the "training" SN Ia's intrinsic brightness is about 9.6% - 14.6% more, due to this effect alone. That means that its observed brightness is likewise that much greater due to taking account of the $h$ decay, which means that the calibration of Step B, above further overstates the calibration that much.

D - The resulting "training" calibration

The calibration of intrinsic brightness versus light curve for Type Ia Supernovae obtained from the "training" set overstates the intrinsic brightness by 8.5% - 15.6% due to distance deviation, Step B, and by 9.3% - 14.6% due to brightness deviation, Step C, which combined is the range from $1.085 \cdot 1.093 = 1.185$ or 18.5% to $1.156 \cdot 1.146 = 1.325$ or 32.5% overstatement of brightness.

E - The distant Type Ia Supernova independent distance determination

Armed with the SN Ia Light Curve vs Intrinsic Brightness relationship, the investigation shifts from the "training" to the far distant SN Ia sources of interest. A distant Type Ia Supernovae is studied and its intrinsic brightness is developed based on its light curve. Its observed brightness is noted. Based on those data its distance is inferred from the inverse square relationship.

In the light from that SN Ia both its $c$ and its $h$ are greater than our contemporary values. The greater $c$ means a greater distance and greater inverse-square dimming of observed brightness. The greater $h$ means greater photon energy and an enhancement of observed brightness. As in the hypothetical example of equations *(42)* - *(44)*, the two effects exactly cancel. The observed brightness is not affected by the decay in that sense. However, the intrinsic brightness, obtained from the light curve, is overstated as at Step D. Per the inverse square relationship, that corresponds to the SN Ia appearing to be at a greater distance by

from: the square root of $1.185$, equals $1.089$, or about 8.9%

to: the square root of $1.325$, equals $1.151$, or about 15.1 %

farther away then expected.

F - The distant Type Ia Supernova "expected" distance determination

The "expected" distance, is determined by identifying a Cepheid variable in the host galaxy of the SN Ia and attributing its distance to the SN Ia, also. In this case no deviation due to the universal decay is applicable because the "expected" distance means that found per the usual methods and with no knowledge of the decay.

G - Overall results

The "expected" distance being unchanged and the light curve derived distance being overstated by 9 - 15% results in a total distance deviation from the "expected" of 9 to 15 %.

> That is what accounts for, what produces, the observation reported in the abstract to astro-ph 9805201[10] that "The distances of the high-redshift SNe Ia are, on average, 10% to 15% farther than expected…."

Because the effects of $c$ and of $h$ decay combined leave observed brightness unchanged it would appear that the decay has no effect on the observation of SN Ia light curves. The analysis of the light curves involves several sophisticated aspects so that the possibility of a decay effect cannot be ruled out.

### 4.3 Actual Distances and Conclusion re SNe Ia

From equation *(48)* at values typical of those reported in the papers[10,11] and so noted in equation *(48)*, the correct distance [due to a somewhat greater value of $c$] is actually about 45% greater than the expected. These actual greater distances [and, of course, the reported 10% to 15% greater distances] do not result from acceleration of expansion, nor an "anti gravity effect", nor a cosmological constant. Rather the Big Bang product particles were not limited to our value of the speed of light. The limit back then was much larger relative to our present, local, much-decayed value. If the present age of the universe is about the 18 billion years [somewhat over 1½ time constants of the speed of light decay] calculated in *The Origin and Its Meaning.*[9] based on the universal decay, then the original value of $c$ was *4.92* times greater than today's value, as follows.

$$(50)\qquad c(0) = c(T)\cdot\varepsilon^{+T/\tau} = c\cdot\varepsilon^{+18/11.3} = 4.92\cdot c(T)$$

$$= 4.92\cdot c \qquad \text{[our value of c]}$$

For ages of 15 and 10 billion light years, which represent some of the extant or recent estimates by astrophysicists, that result is an original $c$ that was *3.77* or *2.42* times greater than today, respectively.

While the universal decay accounts for the Type Ia Supernovae observations in a reasonable way, the concept proposed by others that expansion of the universe is accelerating, rather than decelerating as had been thought, has problems of consistency with the rest of cosmology. Any "antigravity effect" to account for acceleration of expansion of the universe, regardless of its cause, would have the additional effect of counteracting ordinary gravitation. Inasmuch as one of the major current problems in cosmology is to identify more gravitation to account for the cosmos's large scale structure and galaxies' centrifugal force, any "antigravity effect" to act as the cause of acceleration would not appear to fit with the rest of the cosmological estimate.

The greater distances and greater energy disclosed by the SNe Ia studies are the result of greater initial [at the moment of the Big Bang] values of the speed of light, $c$, and of Planck's constant, $h$, which values then very gradually decayed to the present. And, that explanation, which relies on the familiar and ubiquitous natural process of exponential decay, is far preferable to the proposed explanation, which requires accepting the unexplained and undetected: "dark energy", cosmological constant, "antigravity effect" and "quintessence".

## Part 5. *Experimental Verification of the Universal Decay*

### 5.1 Tests Verifying the Universal Decay

The universal decay can be verified and further investigated by conducting two experiments: the measurement of the value of each of the two fundamental constants, $c$ and

$h$, directly as they are in the light from distant astronomical sources. The measurements must be of the actual light emitted long ago from a far distant astronomical source, not local, just emitted, light.

The measurements must directly measure the constant sought; they cannot be a measurement of other quantities with the calculation of $c$ and $h$, using laws of physics relating the quantities. For example, in the usual determinations of the values of the various fundamental constants Planck's constant is not directly measured. Rather its value is inferred from other measurements [e.g. the Rydberg constant] and calculated via other formulations [e.g. the fine structure constant]. Such indirect procedures may not give correct results in the present experiments because they may confuse or intermix contemporary values with ancient ones. It is specific measurement of the ancient values that is called for.

The expected results of the experiments are given in Figure 12, below, which gives the multiples of our contemporary value of the constants c and h that are expected to be found in light that was emitted at various times in the past. The figure is calculated using equation *(36)* with the time constant of equation *(34)*, $\tau = 3.57532 \cdot 10^{17}\ s$, (which is $\cong 11.3$ *billion years*) and the relative decay rates of Figure 9.

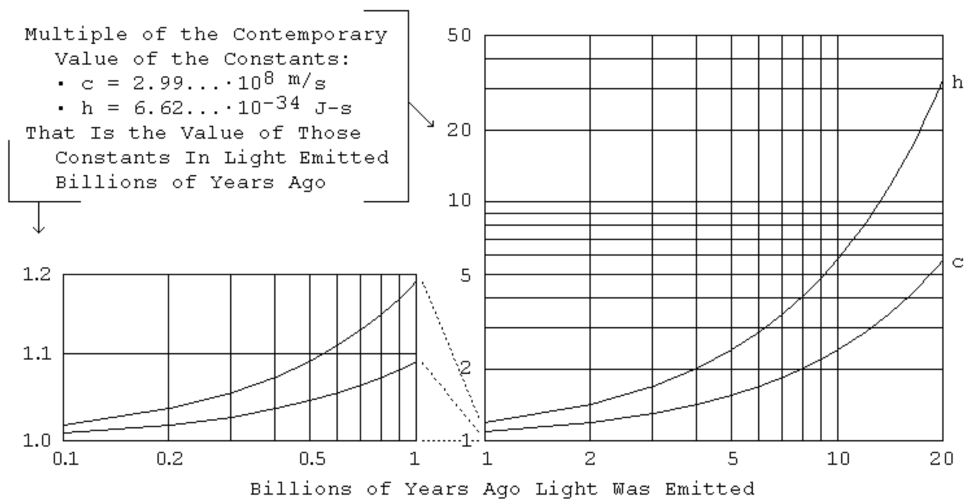



*Figure 12*

### 5.2 The Relationship of Redshifts to the Universal Decay

Every one of the numerous redshift measurements that have been made and are currently regularly being made is a partial observation of the universal decay, that as contrasted to the Hubble attribution of redshifts solely to the Doppler effect.

Universal decay of the speed of light means that astronomical redshifts are dominantly due to that decay rather than the Doppler effect. That is, the attribution of redshifts solely to the Doppler effect requires, in the cases of the larger redshifts, immense recession velocities [and even greater absolute velocities] in immense masses after they have experienced several billion years of gravitational deceleration (star formation is estimated to have begun 2½ to 3 billion years after the Big Bang) at separation distances of the gravitational masses much smaller (gravitational deceleration forces much greater) than those of today. Such immense velocities would seem unreasonable.

On the other hand, the light now arriving from distant stars, emitted billions of years ago at a greater, less decayed speed of light, $c$, would exhibit a longer wavelength, the redshift that is in fact observed [the decay being of the length *[L]* aspect of the dimensions of quantities, not the time *[T]* aspect]. The greater speed means that, and is because, the wavelengths are longer, are redshifted as we perceive them. Furthermore, the more distant the source the earlier its light was emitted and the less decayed is the light's speed. That means that the greater the decay-related redshift the more distant the source is. That relationship is similar to Hubble's except that the universal decay is an exponential function unlike the Hubble model relationship. Thus every redshift measurement is a partial observation of the universal decay, partial because of the following.

However, the universe must nevertheless be expanding because a universe that had a beginning [the Big Bang] must have originated at a point, not over an immense volume all at once. Decay notwithstanding, the sources of redshifted light are, moving away from us so that there is also some Doppler effect component in their redshifts. The redshifts that we observe are a combination of Doppler and decay effects.

The analysis of the universal decay in *The Origin and Its Meaning*[9] addresses the problem of determining what part of the observed redshifts is due to the Doppler effect and what part to decay. The result is that the Doppler-caused parts of the redshifts could not be more than 10% of the total redshift and is more likely on the order of only 1% or less. The remainder of the observed amounts of redshift, 90 - 99% of them, is due to the universal decay of the speed of light. The reasons for this are as follows.

At the Big Bang the material of the universe was thrust rapidly outward in all directions. Since then the mutual gravitational attraction of all of that material has been slowing it all down. The amount of the gravitational slowing is inversely proportional to the square of the distant between the mutually attracting bodies. Starting at a very large speed the distance of separation increased rapidly, meaning that the rate of slowing was rapidly reduced. Therefore, most of the slowing, most of the velocity loss, had to occur early after the "Big Bang".

A very large part of the slowing must have taken place by the time the earliest galaxies formed, about $2^1/_2$ to 3 billion years after the "Big Bang". That the initial speeds, at the moment of the Big Bang, of the material that was to become those earliest galaxies were almost the speed of light, $c$, is quite unlikely. Consider the speeds of particles emitted in radioactive decay, unmoderated nuclear reactors and nuclear explosions. But, even if those initial particle speeds were near that of light, their absolute speeds $2^1/_2$ to 3 billion years later could not have been more than $^1/_{10}$ as much, $^c/_{10}$, and more likely were on the order of $^c/_{100}$, or less.

Further, as compared to their absolute speeds, their speeds of recession from the Earth in each case were only a fraction of those absolute speeds. That means that the Doppler portions of the large $z$, large redshifts that we now observe, which Doppler portions are due to speed of recession relative to the Earth, must be quite modest.

For the cases at the other end of the range of $z$ and of redshifts, the small redshifts related to relatively near sources, their absolute velocities are even much further slowed [their light that we observe is much younger, therefore more decayed] and their recession speeds are an even smaller fraction of their absolute speeds. Therefore, over the whole range of redshifts, the Doppler component is quite small compared to the decay-related component.

As developed in ¶ 3.3, the universal decay is decay of the length $[L]$ dimensional aspect of material reality and does not involve time $[T]$. In spite of the universal decay, the speed of light is a fundamental constant and has the same value everywhere in the universe at any instant of time. It cannot be changed by the Doppler effect. Therefore, while measurement of redshift measures the integrated effect of both decay and Doppler actions, direct measurement of the speed of light $c$ measures the universal decay that that light has experienced and does so independently of the light source's recession velocity.

On the other hand, direct measurement of the frequency of a component of light from a distant source and the comparison of that frequency to the frequency of that same light component in locally generated light measures the recession velocity of the light source independently of its universal decay, measures the related Doppler effect, only.

### 5.3 Measuring The Speed of Light, $c$

Measurements of the speed of light have been based on certain frequencies and wavelengths that are measurable with very great precision, $c$ being the product of a frequency and its related wavelength. To measure the speed of ancient light from far distant sources the product of frequency and wavelength is useless. We already know that the wavelength is significantly different from that in our local light, the difference being the redshift. If that redshift were entirely due to universal decay then the frequency-wavelength product would give the correct speed, but at least some of the redshift is due to the Doppler effect [on the order of 1% - 10%].

The data of interest is a comparison of the $c$ in ancient light with that in contemporary light. One method for comparing light speeds is an interferometer type measurement such as those of Michaelson / Pease and Pearson using the Foucault method. In those revolving mirrors or a toothed wheel were used to break a monochromatic light beam into segments. The beam was then split into two beams which were directed over two different paths of known length and then recombined. If the speed of travel over the two paths were the same then the recombination would produce a perfect overlap of the waves, but if it were different the difference would show in the resulting interference wave pattern.

The modern procedure for measuring the speed of light is to modulate a light beam and then use that modulation to measure the time required for the light to traverse a known distance. Modulating the light beam [e.g. a rotating systematically irregular toothed wheel interrupting the beam] marks the light beam in a manner independent of wavelength. Those markings make it possible to identify when a particular point in the beam left the location at the beginning of a measured distance and when it reached the end of the measured distance. As indicated in Figure 12, the speed difference between local and ancient light, so disclosed, will be large enough to be readily detectable.

### 5.4 Measuring Planck's Constant, $h$.

Planck's Constant, $h$, can be directly measured using the photoelectric effect. Figure 13, below, illustrates the photoelectric effect and its relationship to Planck's constant. While the accuracy using the photoelectric effect is not nearly as good as that provided by other less direct means, the method is quite sufficiently accurate for the accuracies involved for the present purposes. The lines in the figure [which are straight lines] can be plotted from as little as two data points for any one substance [of course accuracy improves with a greater number of data points and interpolation among them].

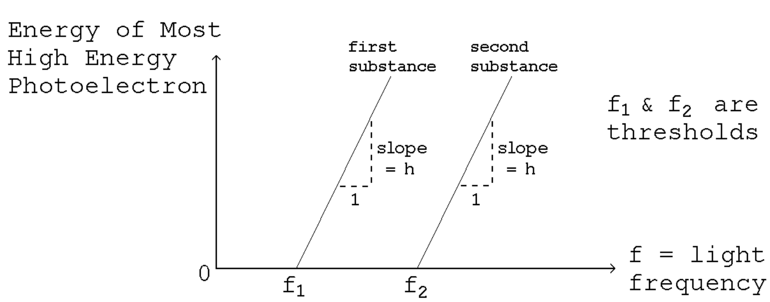



*Figure 13*

Each data point is obtained by shining light [in the present situation the light must be from a far distant astronomical source] of a single frequency [as selected by a spectroscope, one of the lines of the source's line spectrum being selected] on a photosensitive surface that emits photoelectrons [the selected line must be of a frequency greater than the cut-off frequency, e.g. $f_1$ or $f_2$, for the particular photosensitive substance being used].

Normally in the use of the photoelectric effect the objective is to readily collect a current of photoelectrons so that the collection anode is set at a positive electrical potential relative to the photoelectron source, the photosensitive surface on which the light is shined. [Of course, the entire structure must be in a vacuum for the photoelectrons to be free to travel without the interference of a relatively dense gas.]

In the present experiment the collection anode is set negative relative to the photoelectron source, that negative potential being adjustable. Then the negative potential is made progressively less negative until the first, initial photoelectron current is detected. That potential is the energy of the most energetic photoelectron(s) produced by the particular frequency of the light being used on that particular photosensitive material [the photoelectrons emitted at lesser energies having been freed from the photosensitive material with the same high energy but having lost some of that energy within the material before becoming free]. The data point is the energy [negative electric potential] and the frequency.

As indicated in the figure, Planck's constant is the slope of the resulting line(s), which develops as follows. The energy of a photon of light is given by

*(51)* $$E = h \cdot f$$

where:
E is the energy,
h is Planck's constant, and
f is the frequency of the particular photon.

The initial energy datum is the electric retarding potential and must be converted to the units of Planck's constant times frequency as required for the $E$ of equation *(51)*. That done, then the slope of the line in the figure is

*(52)* $$\text{Energy}/_{\text{frequency}} = {}^{h \cdot f}/_{f} = h\text{, Planck's constant.}$$

This measurement performed on light from distant astronomical sources will result in values for Planck's constant quite noticeably larger than our domestic value [per Figure 12], the difference being the universal decay that has taken place since the time the sample light was originally emitted at its distant source.

### 5.5 Measuring The Fundamental Decay Time Constant, $\tau$.

The exponential decays being observed are as follows.

*(53)* $$c(t) = C_0 \cdot \varepsilon^{-t/\tau}$$

*(54)* $$h(t) = H_0 \cdot \varepsilon^{-2 \cdot t/\tau}$$

In those formulations the time constant, $\tau$, is that for the speed of light, $c$. Per the data in Figure 9 and the related analysis, the time constant for Planck's constant, $h$, is half that value, $^{\tau}/_{2}$.

Observed measurement data sets, for example $\{c_1,\ t_1\}$ and $\{c_2,\ t_2\}$ substituted into equation *(53)* result in two equations in two unknowns: $C_0$ and $\tau$. Thus each of those unknowns can be obtained by solving the two equations simultaneously. The same can be done with Planck's constant and equation *(54)*. However, while the $c_1$ and $c_2$ or the $h_1$ and $h_2$ can be readily measured as described above, the associated values for $t_1$ and $t_2$, the ages of the light -- the elapsed times since it was emitted by each of the two different stellar sources, $Source_1$ and $Source_2$ -- are a problem.

The actual data sets are each $\{c_i \text{ or } h_i,\ redshift_i\}$. The Hubble-related procedure of deeming the redshift to be purely Doppler effect, obtaining from that the recession velocity, and obtaining from that the age of the light will only give an approximation to the real age for a number of reasons. Those include: the lack of precision in the value of the Hubble constant, that the method takes the distance - age relationship to be based on our local, much decayed value of $c$, and that the redshift - age relationship is exponential, not per Hubble.

The earlier-described method [in Part 4, re Type Ia Supernovae] using Cepheids near enough for their distance to be determined by triangulation would give accurate distances, but only ones associated with very small ages and decay amounts. Extending those to more distant Cepheids involves the same distance errors discussed in Part 4.

The remaining alternatives would appear to be as follows:

[1] An iterative process of taking many observations and measurements and gradually improving the correctness of the overall end result for $\tau$ by using successively better values obtained from each iteration for the next iteration's distance / age determinations, and / or

[2] Accepting the theoretically calculated value of the fundamental decay time constant, $\tau$, on the basis of its excellent correlation with the Pioneer 10 and 11 data as indicated at equations *(38)* - *(41)*.

## Conclusion

The abstract of this paper offered, and the foregoing in Parts 1, 2, 3, and 4 has fully delivered,

> "… the same, one, simple explanation that comprehensively resolves the three apparently disparate problems:
>
> [1] The Pioneer 10 and 11 spacecraft' 'anomalous acceleration',
>
> [2] The galactic rotation curves' indications of 'dark matter', and
>
> [3] The Type Ia Supernovae distance measurements' indications of acceleration of cosmic expansion with its implication of 'dark energy' or quintessence."

as

> "… merely another manifestation of one of the most common and ubiquitous of physical processes -- that of the second order linear differential equation with constant coefficients [the general overall exponential decay of the universe] -- rather than being based on the inventing of disparate new and unknown effects, effects that are not directly detectable, let alone directly measurable: 'dark matter' and 'dark energy', with no viable explanation at all for the Pioneer 'anomalous acceleration'…."

This has been done with the presentation and development of the general overall exponential decay of the universe, for which it has been shown that the universal decay correlates extremely well quantitatively with the Pioneer 10 and 11 spacecraft' "anomalous acceleration", and with the galactic rotation curves' indications of unaccounted for centripetal acceleration, and with the Type Ia Supernovae distance measurements' deviation from the expected results.

The abstract also offered, and the presentation in Part 5 has fully delivered,

> "… that this explanation can readily be tested by direct astrophysical observations and measurements whereas both "dark matter" and "dark energy" are not directly observable, let alone directly measurable, and can only be indirectly inferred."

and

> "… that this explanation is regularly validated, albeit unknowingly to the researchers, in everyday astronomical and astrophysical research."

The general overall exponential decay of the universe, was first observed in the Pioneer 10 and 11 "anomalous acceleration" [although unknowingly for the Pioneer researchers]. It now offers a much more logical, simple, and unified astrophysical hypothesis than the several independent, partially conflicting, or absent hypotheses extant for the same phenomena that are resolved by the hypothesis of the general overall exponential decay of the universe. For those reasons, alone, the tests proposed in Part 5 should be conducted as soon as reasonably possible.

In addition, however, the costs and difficulty of conducting those tests are much less than the costs and difficulty of the various astrophysical researches presently on-going. And, unlike a considerable portion of contemporary research and testing, the proposed tests call for directly detecting major large numerical differences in results for the cases of confirmation versus failure of the hypothesis. [That as compared to the case of a recently published report, for example, that relies on results such as 1 part per 100,000 and obtained only after a very complicated analysis required in order to infer those tiny changes.] For those reasons, in addition, it is urgent that the tests proposed in Part 5 be conducted as soon as possible.

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