An Astrophysical Origin to Anomalous Spacecraft Accelerations

Independent Scholar
[submitted to Frontier Perspectives, **Rev. 8 May 26th 2004**]
rgouin@mindspring.com http://rgouin.home.mindspring.com/

Abstract

The anomalous and constant accelerations observed acting on spacecrafts are compared to a value obtained from a well-known astrophysical effect. The frequency shift method applied to the frequency ranges of spacecraft communications confirms the compatibility of the data with the known astrophysical data, to the point that, when combined, they give a much higher precision for the parameter known as the Hubble constant. Through this method the constant is narrowed down to (75.0 + 0.4, - 0.3) km/s-Mpc. Earth-bound experiments are suggested to confirm the validity of this approach. The fact the Hubble effect is not observed in our neighborhood is explained from spatial energetic considerations.

Keywords: anomalous acceleration, microwave communications, spacecraft mechanics, hubble constant, Pioneer effect

Introduction – Purpose

Historically, the Hubble *redshift* has been defined in Astrophysics as

$$z = \frac{\lambda_{obs} - \lambda_{em}}{\lambda_{em}}$$

i.e. the ratio of the change in wavelengths between the time an electromagnetic radiation (mainly light) is emitted (em) and the time it is observed (obs) over the wavelength when emitted. (See [**1**], pp. 104 and 126, and [**2**], p. 165, with [**3**] as a historical reference.) Within the **universal space expansion** view of Astrophysics, the recession velocity V at a distance d from Earth

$$V = \mathrm{H}\, d = \mathrm{c}\, z$$

(with H = Hubble constant, c = speed of light) has to remain the same regardless of the wavelength observed.

Within the universal expansion view above, our galaxy, the Milky Way, has been seen as decoupled from the expansion due to its own gravity ([**4**], pp. 719, 739-740). So it was thought until recently that it made no sense to apply the Hubble law for phenomena inside the Galaxy, and a fortiori inside the Solar system. [**5**] pointed out that a discontinuity in the spacetime metric would exist if a local expansion of space were not to exist; but, due to the very small redshift obtained in the range of the Solar system, he concluded that the resulting effect would never be applicable to planetary systems.

However, it has been known that modeling of space probes motion, such as NASA Pioneer 10 and 11, requires the introduction of an empirical, anomalous acceleration directed toward the Sun or Earth, which can be equated to a *blueshift* of their communication signals ([**6**], [**7**]). Through a quantum analysis using the Berry phase formalism, [**8**] concluded on the face of this fact that photons can feel space expansion even within the Solar system in the way it is felt at astrophysical scales, and this due to the non-local nature of a light quantum. He did not connect the phenomenon to the Hubble effect because the result had a reverse sign, i.e. it is a *blueshift*, although it was in the same order of magnitude in absolute value.

The purpose of this study is then (1) to show that this observed blueshift is another theoretical method to measure the Hubble constant, even though a redshift is involved in the astrophysical effect, thereby leading to a better accuracy of data for future applications to spacecraft mechanics, (2) to identify additional experiments to confirm the origin of the effect, (3) to identify the theoretical reason for the absence of a Hubble effect in our neighborhood. The first goal is experimentally based on the finding that a small negative z in terms of astrophysics numerically matches the observed accelerations from the Pioneer data.

Other studies have been performed to interpret the anomalous accelerations in various ways, but they do not lead to data for mechanical applications, which is the prime concern here. Instead of considering them, we are identifying Earth-bound experiments to confirm the meaning given to the data.

The Pioneer "blueshift" and Hubble effects have the same constant

The blueshift effect comes from a space expansion sensed by a ray of electromagnetic radiation effecting a ***round trip*** between two points A and B while space expands. The one-dimensional ray received back at A is the same ray "mirrored" at B from point A when space was less extent. The ***intrinsic energy*** contained in one ***unit length*** of the ray must remain constant (λ = wavelength):

$$(\lambda_{\text{after trip}}) \text{ X (unit length after trip)} = (\lambda_{\text{before trip}}) \text{ X (unit length before trip).}$$

Since the unit length expands during the trip, the ***locally*** measured wavelength at the return of the ray must be shorter:

$$\lambda_{\text{after trip}} < \lambda_{\text{before trip}} ,$$

and thus an observed ***higher*** frequency, or ***blueshift***. A unit length of ray from the earlier less expanded space must then increase its ***observed* energy** since the unit length containing the energy expands during the trip.

In the case of an astrophysical reading, such as a spectral line of a star located at point B, a pencil of rays is observed (instead of the "mirror" point above). The product of the energy per unit length (linear energy density) by the unit area, i.e. the ***intrinsic energy per unit volume***, must be constant during the one-way trip. This is equivalent to say that the ***scaled wavelength*** at point A must be ***equal to*** the scaled wavelength at point B after the one-way trip:

$$(\lambda_{\text{after trip}}) \text{ / (present unit length)} = (\lambda_{\text{before trip}}) \text{ / (unit length before trip)}$$

But space has expanded since the characteristic emission at point B, so

$$\lambda_{\text{after trip}} > \lambda_{\text{before trip}} ,$$

and thus an observed ***lower*** frequency, or ***redshift***, which is the Hubble effect as identified earlier. A beam of e-m radiation from the less expanded space at point B must then decrease its ***observed energy*** at point A since space (and thus scale) has expanded during the trip. Here the energy of the beam is "diluted" by the change of scale from point B to point A, while in the mirror case earlier, the energy was "accumulated" in the expanding unit length during the round-trip of the one-dimensional ray in an expanding 3D space.

The radius of the hypersphere representing space increases in the same way in both round-trip and one-way cases (see Rosales, 2004, for a metric equation of the hypersphere). ***The Hubble constant characterizes the radius of the hyper-***

sphere, and thus the expansion of space, in both theoretical cases, with only a sign change in the frequency shift. The difference resides in how the ***local*** measuring rod is used: In one case (the one-way trip) it enters in the frequency measurement by dividing it, and in the other (the round-trip) it multiplies it.

Because (1) measurements are made in the Solar system on an e-m ray going between two ***material points*** located there and nowhere else, (2) ***local*** material measuring rods are involved through the reading of e-m frequencies, and (3) the classical physics analysis above does not involve the quantum – only classical rays of e-m radiation, **space expansion must occur *locally* between these points**. This conclusion is to be compared with the quantum Berry phase approach by [**8**], which identifies the blueshift effect as a non-local quantum effect sensing overall space expansion, and, as such, ***may or may*** **not** measure a local expansion.

Why is the Hubble effect not observed in our galaxy?

The one-way trip effect (the Hubble effect) above is not observed in our galaxy because the gravitational energy of the source-observer system ***contained in space*** must be maintained during the propagation of the radiation (as the e-m energy considered earlier was): Indeed, the gravity well of the galaxy in the expanding space is also expanding while this propagation occurs, but if ***space is taken as an e-m entity itself***, it must conserve its energy throughout its evolution. Here is another way to see this: The distance between source and final observer must be measured by ***an observer traveling along the e-m wave path*** using the original rod since the original gravitational energy is quantifies by that rod, so the gravitational energy increase that would otherwise be experienced by the traveling observer through an increase in the length of his rod must be transferred to the e-m wave along the travel, forcing an ***increase*** of its frequency, thereby canceling its energy dilution, thereby ***reducing the apparent distance traveled as seen by the final observer***. This cancellation corresponds to the gravitationally-bound system effect discussed by [**4**], but here ***space is found expanding even within such systems, while the distances between material entities*** **APPEAR not to** ***expand when observed from within the system via e-m means***. The difference in interpretation comes from the accepted approach considering space as a mathematical form with no substance, thereby discarding the energetic consequence of spatial expansion in a gravity well for space itself.

Gravity-bound systems (galaxies) ought to be then seen as expanding when observed from the outside, since in that case only the e-m wave energy needs to be considered in the travel of the wave, the gravity well not reaching the observer. We will come back to this key point in the conclusion.

"Subtle is the Lord, but malicious He is not." –A. Einstein

The Pioneer data

Through a **reduction** in Doppler shift measured in communications (at 2.11 GHz in uplink and 2.292 GHz in downlink per the referenced papers) from spacecrafts such as Pioneer 10 leaving the outer Solar System, [**6**] found an **acceleration decrease** of

$$a = (8.74 \pm 1.33 \times 10^{-8}) \ \text{cm/s}^2.$$

This was closely confirmed via an independent analysis by [**7**] giving

$$a = (8.60 \pm 1.34 \times 10^{-8}) \ \text{cm/s}^2.$$

(A validity analysis of the data obtained by these references will not repeated here, as the above references are two *independent* works providing such an analysis, with the needed error margins identified.)

Using the average of frequencies (2.11 + 2.292)/2 = 2.20 GHz in the up-link and downlink communications per their data, with the low end of the measurement range above, 7.26×10^{-8} cm/s^2, a corresponding "clock acceleration" in the measurement is, with c = speed of light:

$$d(\Delta\nu)/dt = - (a/c) \ \nu$$

$$= - 7.26 \times 10^{-8} \times 1/3 \times 10^{-5} \times 10^{-5} \times 2.2 \times 10^{9} = - 5.3 \times 10^{-9} \ \text{Hz/s}.$$

With a 6-hour trip for the e-m wave from the spacecraft, the **total shift observed in the frequency** is then

$$\Delta\nu_1 = -5.3 \times 10^{-9} \times 3{,}600 \times 6 = \mathbf{-1.15 \times 10^{-4}} \ \text{Hz}.$$

What would be the shift from an object emitting light in the outer parts of the Solar System at that same distance? Since

$$z = H \ d/c$$

with H = 70 km/s-Mpc (± 8 %) (per [**9**]), $c = 3 \times 10^5$ km/s, and 1 Mpc = 3.262×10^6 light-years = 2.858×10^{10} light-hours, (per [**1**], p. 180), we get:

$$z = 70 \times 6/2.858 \times 10^{-10} \times 1/3 \times 10^{-5} = \mathbf{4.9 \times 10^{-14}} \ \textbf{“redshift.”}$$

Since $z = \Delta\lambda/\lambda = \Delta\nu/\nu$, for a 2.2 GHz e-m wave, the above redshift corresponds to a total frequency shift

$$\Delta\nu_2 = 4.9 \times 10^{-14} \times 2.2 \times 10^{9} = \mathbf{1.08 \times 10^{-4}} \ \text{Hz}.$$

In order to match (in absolute value) the lower value obtained from the spacecraft measurement $\Delta\nu_1$, the minimum multiplication factor *x for* $\Delta\nu_2$ will have to be:

$$x = \Delta\nu_1/\Delta\nu_2 = 7.26 \times 3.6 \times 2.8571 \ / \ 70 = 1.06675$$

(using the ***lowest Mpc value*** that can be obtained from [**1**], from the numerical accuracy given - all other parameters disappear in the ratio.)

The Hubble constant needs to be then **at least** 6.68 % greater than the number used, which was 70 km/s-Mpc, or **74.7 km/s-Mpc**.

The upper value from the NASA data is too imprecise to advance the upper value of the Hubble constant. More recent data from astrophysics gives the constant as (71 + 4, - 3) km/s-Mpc. [**10**] The maximum upper value obtained from that source is then 75.4 km/s-Mpc.

The overall error margin on the Hubble constant from the two widely different sets of experimental data (one blueshifted and the other redshifted) is thus drastically reduced, giving now for its known value:

(75.0 +0.4, -0.3) km/s-Mpc

Conclusion

The observed anomalous spacecraft acceleration is found indeed compatible with the astrophysical Hubble law constant, with a change of sign in the effect due to considering a round trip of the same electromagnetic signal instead of one-way diffuse emission as in the Hubble effect. Furthermore, the round trip effect gives a more accurate number for the minimum value of the constant than earlier known from astrophysical data:

$$\mathbf{H_{min} = 74.7\ km/s\text{-}Mpc}$$

Space expansion is thus experimentally verifiable in our spatial neighborhood (Solar system). The expansion of space is then not only a cosmological phenomenon but also a local phenomenon.

To further confirm this drastic assertion, an Earth-bound experiment needs to be run using directed microwave transmissions between microwave mirrors (such as via satellites), or through a microwave loop lasting on the order of 6 to 10 hours. A similar "blueshift" would give a final confirmation that the phenomenon does correspond to local space expansion. In the meantime, the calculation above provides preliminary data for correcting observations of spacecraft motions that otherwise follow classical mechanics, since such observations are mostly done via electromagnetic means.

Finally, a local space expansion leads to a key question when the behavior of matter is considered. With space expanding locally, our material measuring rods expand also since embedded in that space; therefore we are not able to observe a physical effect on local matter. As we have seen earlier, there is no Hubble effect across gravity-bound systems even though such systems expand. However, this is not so when observing other galaxies, as they are seen from outside their gravity well, so ***why are they not seen as expanding, or why are they observed as if they had their present size, and not their past size***?

The prevailing astrophysical approach on this, called the "Swiss Cheese" model, presented for example in [**4**] as mentioned earlier, advances that "galaxies are not expanding, like pennies glued on a balloon," because inside a gravitationally bound system, such as the Milky Way, ***space would be somehow decoupled from cosmic expansion via gravitation of the matter it contains***. However, if local space does not expand, (1) there is a resulting discontinuity in the space-time metric at the edge of the galaxy as [**5**] discussed, which is quite unphysical, and (2) the energetic aspect of space expansion is ignored by taking space as a mathematical form with no substance. Experiments as described earlier using the Pioneer "blueshift effect" will be decisive in distinguishing the two approaches since this effect is independent of the distance between different material objects in a gravitational well, unlike the Hubble effect.

A radically different analysis answering the key question above resulting from a local space expansion conclusion will be addressed in a future article by considering the physical (quantum) character and origin of space instead of the mathematical (geometric) form assumed in the Swiss Cheese model.

Acknowledgement: I thank Ben Connell of Liverpool, England for informing me in 2004 about the discrepancies in NASA spacecrafts measurements that were identified since 1998.

References

[**1**] Longair, M. S., 1996, *Our Evolving Universe*, Cambridge

[**2**] Elmore, W. C. and M. A. Heald, 1969, *Physics of Waves*, Dover

[**3**] Hubble, E., 1929, *A Relation Between Distance And Radial Velocity Among Extra-Galactic Nebulae*, Proc. Natl. Acad. Sci. USA Vol. **15**, No. 3, p. 168-173

[**4**] Misner, C. W., Thorne, K. S. and Wheeler, J. A., 1973, *Gravitation*, W. H. Freeman, pp. 719, 739-740

[**5**] Baker, G. A., 2000, *Bound Systems in an Expanding Universe*, arXiv: astro-ph/0003152

[**6**] Anderson, J. D., *et al.* , 2002, *Study of the anomalous acceleration of Pioneer 10 and 11*, Phys. Rev. D **65**, 082004 (arXiv:gr-qc/0104064)

[**7**] Markwardt, C. B., 2002, *Independent Confirmation of the Pioneer 10 Anomalous Acceleration*, arXiv:gr-qc/0208046 (submitted to Phys Rev D)

[**8**] Rosales, J. L., 2004, *The Pioneer's Anomalous Doppler Drift as a Berry Phase*, arXiv: gr-qc/0401014

[**9**] Finkbeiner, A., 1999, *Hubble Telescope Settles Cosmic Distance Debate - or Does it?* Science **284**, 1438 (28 may) News

[**10**] Spergel, D. N., *et al.*, 2003, *First-Year Wilkinson Microwave Anisotropy Probe (WMAP) Observations*, Astrophysical J. Suppl., **148**(1), pp. 175-194 (sep)