INTERGALACTIC REDSHIFT

Terence R. Witt

Abstract: The uniform redshift of light from astronomically distant sources is currently interpreted as a dynamic universal expansion. In this paper the author argues for a static interpretation of this phenomenon.

I. BACKGROUND

Intergalactic redshift is caused by the gradual loss of light energy over great distances, similar to the tired light concept Fritz Zwicky originally postulated. This is why the effect is linear with distance. The farther the source, the more energy is lost, and the greater the redshift. This is also why the structure of the universe looks so uniform; the only real motions in the heavens are the peculiar motions generated by differences in mass distributions. These tend to be no more than a few hundred km/s, not the significant fractions of c required by universal expansion.

The concept of tired light has never had much success in modern cosmology because it fails (at least in its original form) to explain why distant signals are *stretched* as well as redshifted. Supernovae provide the prima facie case for this. Their intensity/duration curves tend to broaden proportionately with distance. An event at a distance corresponding to (z = 1) has, on average, twice the duration of a local explosion. If photons are just losing energy by crossing space, why are they also being dispersed along their path? Efforts to resolve tired light's dispersion problem have proven ineffectual and it has been thoroughly trumped by the drama of the Big Bang, pushing cosmology away from the elegant truth Zwicky recognized.

Although Zwicky had the intuition to realize light was losing energy, he lacked the Null Axiom, thereby relegating tired light to just another untestable premise. Our approach suffers no such limitations. It expands the concept significantly beyond Zwicky's original idea, resolves the signal dispersion issues, and is buoyed by the fact that it is the *only possible explanation* for the effect. No changes can occur to the universe as a whole. It doesn't expand, it doesn't contract, and it won't grow old and die. If light acquires a spectral change after crossing billions of light years of deep space, this is the full extent of the phenomenon. It is not a commentary on the dynamics of reality.

Intergalactic redshift has some surprising ramifications that provide the basis for other global phenomena, including the material density of the universe, the CMB field, and dark matter. Even Zwicky would probably have been surprised to learn just how important this process is. So why does light lose energy when traveling across broad gulfs of space? Why indeed. This phenomenon has some truly curious properties.

II. ANCIENT LIGHT

Intergalactic redshift is caused by photons' gradual loss of energy over immense distances. Cosmic equilibrium leaves no other alternative. It is a given and is just as certain as the conservation of energy it obeys. But what causes it? Its characteristics are:

a) Proportional to distance for cosmically short distances. If light travels twice as far, it loses twice the energy.

b) Proportional to photon energy. Visible light and radio waves from the same source lose the same fraction of their energy.

c) No associated scattering. Light reaching us from distant spiral galaxies preserves exquisite details of their disks' structure.

d) Long-range and weak, requiring ~10 Gly to cause a 50% energy loss.

e) Uniform broadening. The duration of a transient signal grows in direct proportion to the increased wavelength of the individual redshifted photons within it.

f) No refractive frequency dispersion, as is typical of an interaction between light and matter. An ancient pulse's red component arrives at the same time as its blue component, although the pulse itself is broadened in accordance with e) above.

One of intergalactic redshift's more intriguing aspects is that light loses energy *without any observable scattering*. If it were caused by a photon-photon or photon-particle interaction, every incremental energy loss would have a corresponding change in direction. Scattering related to a 5% loss is enough to make celestial images unrecognizable, yet our instruments show galaxies in pristine detail even at energy reductions greater than 10%. Also, scattering is generally not linear with incident energy. It is rarely a situation where *energy loss is proportional to the incident energy*. Furthermore, scattering *requires* a change of direction in order to conserve momentum. Preservation of directional integrity with an energy loss proportional to energy has no precedent in known physical interactions.

Intergalactic redshift's other (even more enigmatic) property is its signal dispersion in the absence of refractive dispersion. Not only do photons attain longer wavelengths, the spatial separation between them increases with distance traveled *irrespective of their individual frequency*. The greater an object's range, the greater the duration of its transient signals, *and all frequencies from some remote source experience a comparable amount of broadening*. This means there is far more to this effect than just the energy loss of individual photons. Moreover, the lack of refractive dispersion indicates that *intergalactic redshift is not caused by an interaction between photons and matter*.

Our premise is that intergalactic redshift arises from a *known* entity, because the Cosmological Principle tells us intergalactic space is similar to, albeit more sparse than, local space. The only things found in deep space are:

- Space.
- A weak gravitational field.
- Trace amounts of matter, the equivalent of ~3 hydrogen atoms/meter^3.
- The CMB field.
- Photons of various energies in addition to the CMB.
- Neutrinos.

The dispersion (broadening) found in deep-space signals is the pivotal consideration for evaluating this list. Ancient photons do not lose energy as a result of collisions with particles, other photons, or other entities in deep space. *Collisions would only cause the loss of energy in individual photons; they wouldn't increase the distance between them*. This effectively eliminates the matter, neutrinos, and radiation in intergalactic space, leaving only space and a weak universal gravitational field as possible redshift agents. Space is dimensionally distinct from energy and cannot interact with it, *so a gravitational interaction is the only possible source of intergalactic redshift*.

The universal gravitational background is the one entity in deep space capable of inducing a loss of energy in ancient photons. The only other explanation is photons are intrinsically unstable and spontaneously decay at a certain rate, but this is not viable because it fails to address signal dispersion. Further, all interactions are causal; there is no such thing as "spontaneous" decay. Any transformation photons experience must be facilitated by an external agent and *the only weak mechanism able to act over billions of light years of neutral space is gravity*. This process will be referred to as *lumetic decay*.

§ LUMETIC DECAY

INTERGALACTIC REDSHIFT IS CAUSED BY THE UNIVERSAL GRAVITATIONAL FIELD

There is no viable alternative, but this phenomenon's underlying dynamic is far from obvious.

III. LUMETIC DECAY

Gravitational fields produce a number of different effects on light and matter's interaction with light, all of which have been well documented. Photons appear to lose energy when they move out of a gravitational well; they appear to gain energy upon falling into such a well. They are deflected as they pass near massive objects. What is intriguing is no *known* gravitational effect could possibly be responsible for lumetic decay. The photons traversing deep space move out of as many gravitational wells as they fall in. There should be no net frequency shift. While it is true they are also deflected around superclusters and galaxies, this is an elastic interaction. Even if it were not, gravitational deflection *doesn't cause signal dispersion*. In short, lumetic decay is a new type of photon-gravitational interaction. It occurs between deep space photons and the universal gravitational field through which they pass.

According to the General Theory of Relativity, the universe's energy content, composed of elementary particles, photons, and neutrinos, gives space an average radius of curvature of the form:[1]

$$R_G = \frac{c^2}{\sqrt{4\pi G\rho_U}} \tag{1}$$

where ρ_U is universally average energy density in units of (energy/volume), and R_G will be called the *gravitational radius* of space.

General Relativity relies heavily on the mathematical equivalence between free space acceleration and the acceleration induced by a gravitational field. Space has no physical reality in this theory. As such, Equation (1) represents the *effect* of internal spatial distortion, not the spatial distortion itself. Since space's *net* internal distortion necessarily sums to zero as a consequence of its overview, R_G is the result of its *average* spatial distortion. Think of space as a sheet of rubber that has been unevenly stretched across a perfectly flat floor. Its gravitational radius is the averaged effect of its internal nonlinearity.

Even though General Relativity does not address space's physical geometry (please see Whitepaper #1, nullphysics.com), it is a brilliant and accurate generalization of the measurement of space and time, and can be used to calculate the magnitude of lumetic decay.

The easiest way to understand the curvature of Equation (1) is to take the case of two photons moving down the same axis in curved as compared to Euclidean (rectilinear) space, departing two seconds apart:

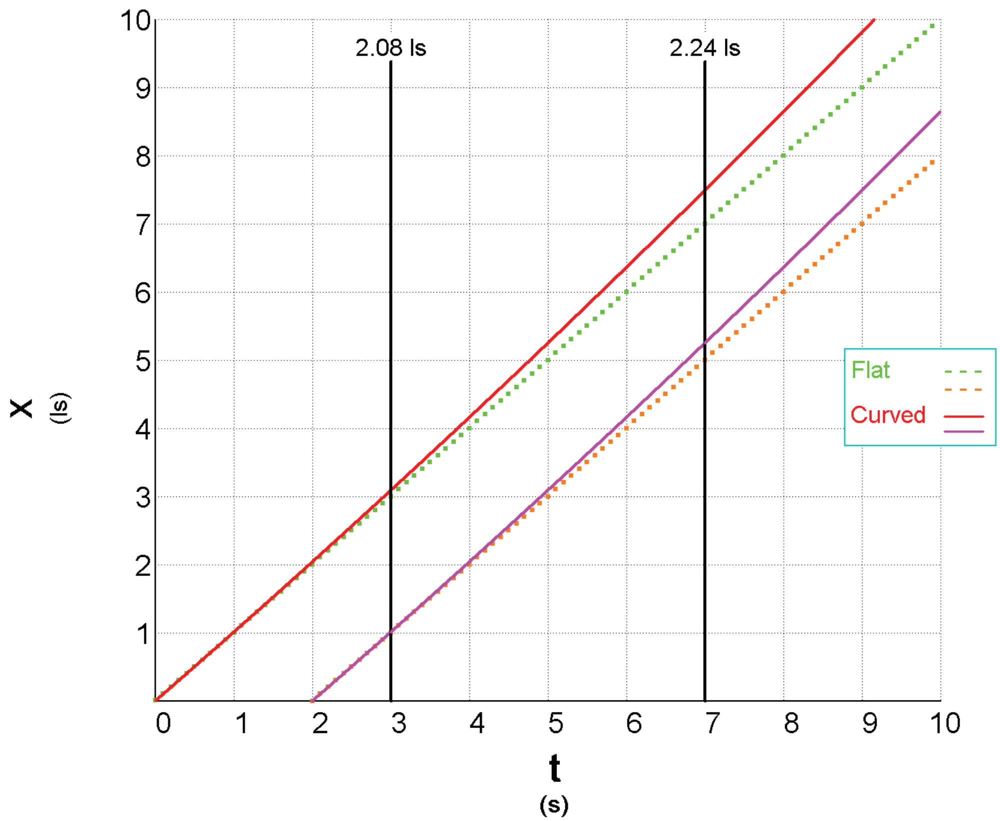

Figure (1) Photons moving along an axis through rectilinear versus curved space, initially two seconds apart

Time is the horizontal axis, in seconds, and distance is the vertical axis, in light-seconds (ls). This graph is a physically accurate representation of motion through space because time, in relation to motion, is the internal, fourth-dimensional difference of space. It is an additional dimension that does not increase space's universal extent: *space-time*.

If space were perfectly rectilinear, the two photons shown in Figure (1) would follow the dotted traces, always separated by a distance of two light-seconds. However, due to its energy content, space exhibits, on average, a slight fourth-dimensional curvature. This has been markedly exaggerated (by a factor of $\sim 10^{16}$) in Figure (1) to make its effect visible. The photons' paths through this artificially curved space-time corresponds to the solid traces. Three seconds after the first (red) photon departs, the two photons are separated by a distance of 2.08 ls. Four seconds later, they are separated by 2.24 ls. The space of our universe exhibits such a small average curvature that this same deviation would require ~1.2 billion years. *Curved space simulates spatial expansion*. Ironically, whereas Special Relativity shows us that it is not possible to directly measure a reference frame's movement, the only way to measure spatial curvature is to move through it.

Gravity's universal curvature creates a differential velocity difference per unit distance. *This is what the Hubble constant represents*:

$$\frac{d\mathrm{v}}{dx} = \frac{c}{R_G} = H_0 \tag{2}$$

A value of 60 Hz-km/Mpc exposes light to a tiny differential velocity gradient of $1.95(10)^{-18}$ meters per second per meter. Although H_0 is usually evaluated in terms of megaparsecs of distance, *space is continuous, so it is equally applicable to the space within a photon's topology*.

Energy *acquires* the differential velocity of Equation (2) through propagation. Since this occurs along straight line trajectories through the third dimension, the Hubble constant represents a tiny positive acceleration, and the energy distributed throughout a photon's substructure accrues differential velocity at a steady pace. A photon's leading edge has traveled farther than its trailing edge by its wavelength λ, inducing an internal velocity gradient of the form:

$$d\mathrm{v} = \frac{d\lambda}{dt} = \frac{c}{R_G}\lambda = H_0\lambda \tag{3}$$

Differential velocity generated by interaction with universal curvature stretches photons, causing a continuous expansion throughout their energy distributions. *The universe isn't expanding; intergalactic photons are*. Moreover, just as it acts within a single photon's structure, spatial curvature also creates differential velocity between photons, causing a general broadening of ancient signals in direct proportion to their redshift. From a local perspective, photons, regardless of their age, appear to be moving at *c*, but on a larger scale their effective speed along the path they have taken depends on their departure time relative to other photons.

Although the universe is ultrastatic, it does have a relationship between time as change and time as dimension. R_G manifests as spatial expansion because it induces a *nonlinear* relationship between distance and time. Even though space's size is invariant, its phenomenological curvature represents a differential velocity field - the same field that would exist if it were actually expanding. The difference between a billion light years now and a billion light years a billion years ago *is not linear*, and gives the false impression of universal expansion. Scientists have grossly misinterpreted the physical reality of gravitation in both of its most extreme environments - black holes and deep space.

All photons move at *c*, so it certainly seems like it should take the same amount of time to cross the same amount of space. But this is only true if a photon's motion had a purely linear relationship to time, and this is not possible when they move through space infused with fourth-dimensional curvature.

In summary, universal curvature causes photons to expand on their epic journey across deep space. This results in an isotropic redshift of all signals from distant sources, the magnitude of which is roughly proportional to their distance from Earth. *The intergalactic redshift of photons is nothing more than a direct measurement of the average universal curvature predicted by the General Theory of Relativity*.

§ LUMETIC DECAY EXPANSION

RADIANT ENERGY DECAYS AS A RESULT OF THE INTERNAL ISOTROPIC EXPANSION OF ITS STRUCTURE CAUSED BY THE DIFFERENTIAL VELOCITY FIELD OF UNIVERSAL CURVATURE

Universal expansion is not only wrong - it is unnecessary and redundant. The universe's average spatial curvature is already known to exist. It ought to have *some* effect, and the fact that it emulates universal expansion is certainly no coincidence. Nor is the fact that the magnitude of its effect (redshift) is consistent with the universe's average energy density. Michelson and Morley demonstrated, in 1887, that space *is not a material thing*. Any distortion it experiences is by definition fourth-dimensional. Cosmologists have chosen to ignore this fact when they claim that space is somehow expanding upon itself.

Lumetic decay is not limited to a photon's wavelength. The universe's differential velocity field is isotropic, and so therefore is the expansion it causes, increasing the size of a photon's spatial footprint along all three of its extents. Let's quantify the energy loss that this expansion causes.

IV. LUMETIC DECAY'S ENERGY LOSS

Simplify Equation (3):

$$\frac{d\lambda}{dt} = H_0\lambda \tag{4}$$

Solve for wavelength:

$$\lambda = \lambda_0 e^{H_0 t} \tag{5}$$

As a photon expands, the differential velocity at its boundaries slowly increases, producing an exponential decay.

Convert Equation (5) to energy and simplify:

$$\frac{1}{E} = \frac{1}{E_0} e^{H_0 t} \rightarrow E = \frac{E_0}{e^{H_0 t}} \rightarrow E = E_0 e^{-H_0 t} \tag{6}$$

When a photon expands over time, it has to release energy in order to satisfy both the unit hypervolume relationship and conservation, so it is forced to slowly decay:

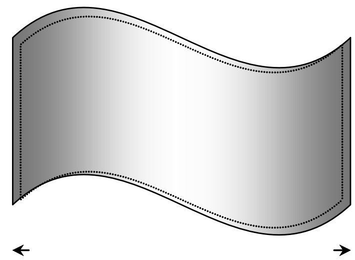

Figure (2) Universal curvature stretches photon wavelength, inducing a gradual energy loss

From Equation (6), a photon's energy loss rate is given by the Hubble constant as:

$$E = E_0 e^{-H_0 t} \rightarrow \frac{dE}{dt} = H_0 E_0 e^{-H_0 t} \tag{7}$$

Energy loss rate *per unit energy* is the Hubble constant:

$$\left(\frac{1}{E}\right)\left(\frac{dE}{dt}\right) = \frac{H_0 E_0 e^{-H_0 t}}{E_0 e^{-H_0 t}} = H_0 \tag{8}$$

Decay rate is not a function of gravitational potential, but rather the average spatial *distortion* caused by energy's presence. Thus it is relatively uniform even though the density of matter and other forms of energy varies throughout the universe.

All photons lose the same fraction of energy per unit time, so the decay rate of any frequency band is simply the product of its total energy density and the Hubble constant:

$$\frac{d\rho_E}{dt} = H_0 \rho_E \qquad \left\{ \rho_E = \int \frac{\rho_E(\lambda)}{\lambda} d\lambda \right\} \tag{9}$$

Distant objects appear to lose surface brightness far more rapidly than an exponential decay would suggest, but this is only because the optical band is relatively narrow and has virtually no energy density above it. Please see Appendix M for a detailed analysis of the relationship between surface brightness loss and redshift.

The relationship between photon energy, distance traveled, and redshift follows from Equation (6):

$$x = \left(\frac{c}{H_0}\right) \ln\left(\frac{E_0}{E}\right) = \left(\frac{c}{H_0}\right) \ln(z+1) \tag{10}$$

On object with a redshift of (z = 6), for instance, is ~30 billion light years from Earth.

V. DECAY VERSUS RECESSION

Before delving more deeply into lumetic decay's numerous and profound ramifications, let's briefly compare its energy loss profile with the expanding universe concept in accelerating and non-accelerating formulations. Simplified versions of both are presented below. They do not contain many of the Big Bang's ad hoc revisions, such as inflation, but are sufficiently representative for the purposes of this section.

The relationship between a deep-space photon's energy loss and the Hubble constant for a universe with uniform expansion has the form:

$$E = E_0 \sqrt{\frac{c - xH_0}{c + xH_0}} \tag{11}$$

This restricts the observable universe's size, since a photon's energy goes to zero at any distance x greater than (c/H_0). Cosmologists have recently (at least as compared to the introduction of the original expanding universe concept) embraced the idea of a universal expansion whose rate changes with time.

In the most straightforward rendition of the *accelerating* expanding universe, the Hubble constant is a linear function of distance (and therefore time) of the form:

$$H_0^*(x) = (1 - a_U x)H_0 \tag{12}$$

where a_U is the acceleration of the universe's expansion in units of distance^{-1}. a_U is positive for an accelerating universe because the Hubble constant needs to be smaller in the past if the rate of universal expansion were actually increasing. The energy loss associated with this acceleration is somewhat more complex than for the uniform expansion of Equation (11):

$$E = E_0 \sqrt{\frac{c - (x - a_U x^2)H_0}{c + (x - a_U x^2)H_0}} \tag{13}$$

Compare lumetic decay to the two simplified expanding universe models:

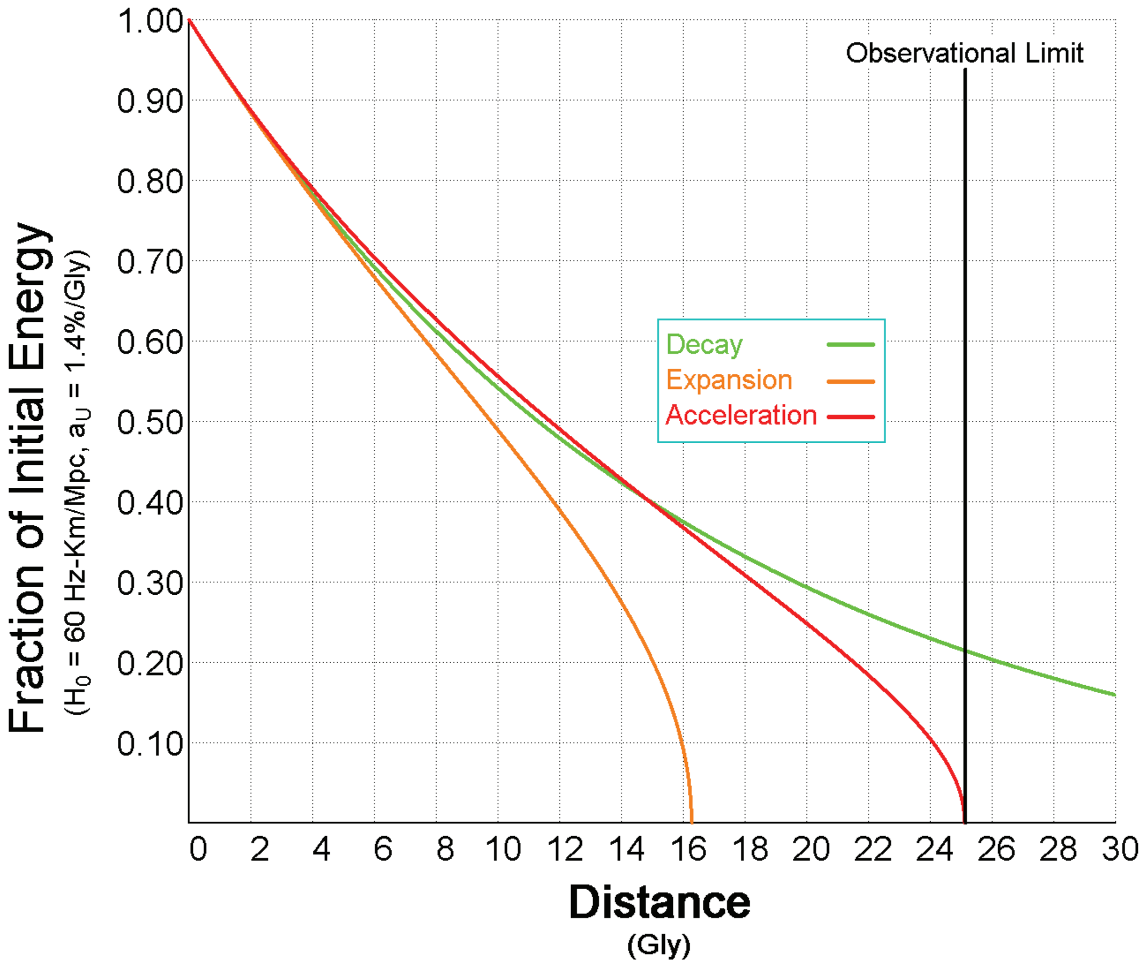

Figure (3) Lumetic decay versus two simplified versions of the expanding universe

The orange trace ending at ~16 Gly is of the constant expansion model. The red trace ending at 25 Gly is the accelerating expansion model of Equation (15.13) with an a_U of 1.4% per Gly. The green trace extending past 30 Gly is lumetic decay. As shown in the graph, it became necessary for the universe's expansion to accelerate in the Big Bang model because long-distance measurements of supernovae (>4 Gly) are clearly more consistent with lumetic decay than with a fixed rate of expansion.[37] As long as the Big Bang is the dominant cosmology, its expansion/acceleration profile will have to be repeatedly adjusted as new technology allows astronomers to penetrate more deeply into space. Indeed, timing is everything in science. If Einstein would have predicted intergalactic redshift based on the universal curvature required by his own theory of gravitation, modern cosmology would have a very different conceptual landscape.

According to the plot of lumetic decay, an energy loss of 50% occurs over a distance of about 11 Gly. Photon age is given by solving Equation (6) for time:

$$t = -\left(\frac{1}{H_0}\right)\ln\left(\frac{E}{E_0}\right) \tag{14}$$

Lumetic half-life is the special case where the energy ratio in Equation (14) is 0.5:

$$\tau_\gamma = \frac{-\ln(0.5)}{H_0} \tag{15}$$

This is not the average time it takes for a decay to occur. The smoothness of the redshift distribution indicates at least a hundred decays occur prior to reaching a 50% energy loss. Equation (15)'s half-life is the time required for a photon to lose half its energy.

A Hubble constant of 60 Hz-km/Mpc corresponds to a photon half-life of 11.3 Gyr. The Hubble constant is thought to lie somewhere between 50 and 85 Hz-km/Mpc.[1.2] This puts lumetic half-life in the range $\{8 \text{ Gyr} < \tau_\gamma < 13.6 \text{ Gyr}\}$.

VI. UNIVERSAL DENSITY

The Hubble constant measures the net effect of the strained geometry of space-time, as presented earlier by Equation (2):

$$H_0 = \frac{c}{R_G}$$

Substituting Equation (1) for R_G yields the Hubble constant as a function of the universe's average energy density:

$$H_0 = \frac{\sqrt{4\pi G \rho_U}}{c} \tag{16}$$

Solve for energy density:

$$\rho_U = \frac{H_0^2 c^2}{4\pi G} \tag{17}$$

or $4.0(10)^{-10}$ J/m^3 at a Hubble constant of 60 Hz-km/Mpc.

The universe's average energy density is related to the Hubble constant as follows:

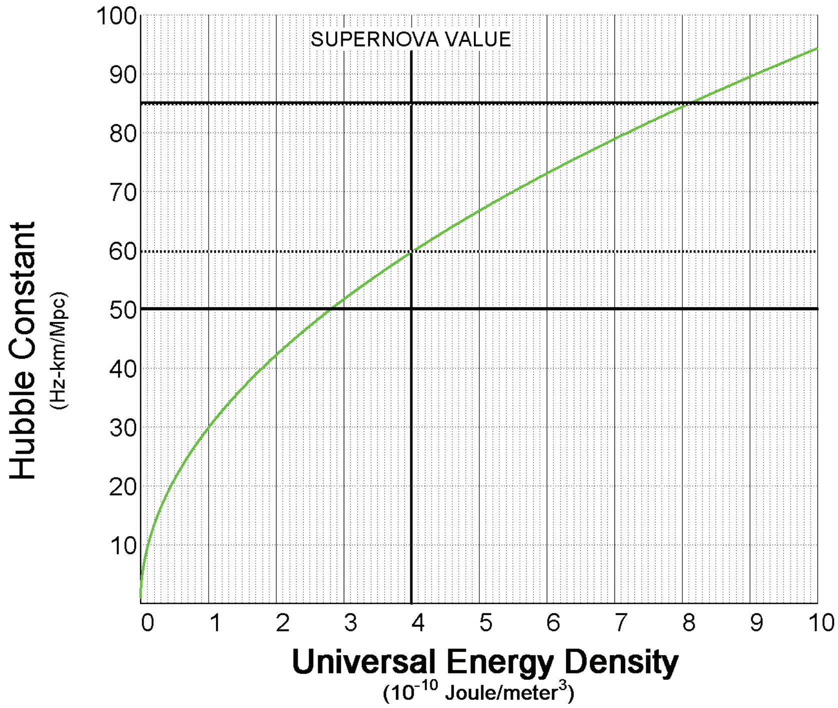

Figure (4) Relationship between Hubble constant and average universal energy density

The vertical line indicates the best current estimate of the Hubble constant using supernovae as standard candles. It puts the universe's average energy density at about 2.7 hydrogen atoms per cubic meter. This is consistent with the estimates of the total amount of matter in space and supports the idea that the majority of it is nonluminous. The horizontal lines reflect the amount of error thought to currently exist in the Hubble constant, from 50 to 85 Hz-km/Mpc. This corresponds to a fairly wide (~3x) range of universal energy density, $\{2.8(10)^{-10}\ \mathrm{J/m^3} < \rho_U < 8.1(10)^{-10}\ \mathrm{J/m^3}\}$. Luminous matter, whose energy density is estimated to be on the order of $\sim 10^{-11}\ \mathrm{J/m^3}$,[3.1] constitutes only a small fraction ~(1%–3%) of the universe's average energy density.

VII. UNIVERSAL COMPOSITION

In accordance with nature's causal singularity, radiant energy ultimately originates from matter. This means every photon or neutrino throughout space at this very moment has a direct relationship to binding energy at either an atomic or nuclear level. Our universe's chemical binding energy is negligible in comparison to its nuclear, so *the universe's radiant energy density is the difference between the mass density of free protons and the mass density of compound nuclei*. Although annihilation is also a source of radiant energy, the gamma flux in space is so small that its mass density equivalent is insignificant.

The cosmic balance between compound nuclear matter and electromagnetic energy density will be referred to as *correspondence*:

§ MATTER-ENERGY CORRESPONDENCE

THERE IS A ONE-TO-ONE CORRESPONDENCE BETWEEN MATTER FIELD POTENTIAL AND PHOTON/NEUTRINO/KINETIC ENERGY

This occurs exclusively in terms of energy's *quantity* and has no relationship to quantal number. The binding energy between two nucleons, for instance, might eventually take the form of millions of CMB photons, but the primary consideration is underlying magnitude, not quantal configuration.

Matter-energy correspondence can be expressed mathematically as:

$$\rho_U = \rho_\wedge m_\wedge c^2 = \rho_M c^2 \tag{18}$$

where ρ_M is the product of the numerical density of the universe's elementary particles, $\rho_\wedge$, and their free-space rest masses, $m_\wedge$. In other words, if all of the universe's particles were unbound and at no potential, gravitational or otherwise, the sum of their rest energies would be precisely equal to the universe's total energy density.

In essence, the temporal closure (Ψ4.9) between matter and (photons/neutrinos) requires the sum total of the universe's kinetic, luminous, and neutrino energy to be balanced by and equal to the negative potential of all of its particles, primarily protons. Thus:

$$\rho_R + \rho_{KE} \cong \varepsilon_U \rho_{bp} c^2 + \rho_{\Phi_g} \tag{19}$$

where ρ_{bp} is the universally average concentration of bound protons, ρ_R is the average density of all radiant energy, and ρ_{Φ_g} is matter's average gravitational potential. Equation (19) is shown as a close approximation because the universe's electron content, whose negative potential contribution is negligible, has been excluded. Solve for the concentration of bound protons:

$$\rho_{bp} \cong \left(\frac{\rho_R + \rho_{KE} - \rho_{\Phi_g}}{\varepsilon_U c^2} \right) \tag{20}$$

Most of the universe's mass is dark, so it has low average kinetic energy content. Also, compact objects tend to emit radio and high-energy radiation. Since the cosmic density of such sources is small, most of the universe's dark mass exists at a relatively weak average gravitational potential.

Applying these provisions to Equation (20) yields:

$$\rho_{bp} \cong \frac{\rho_R}{\varepsilon_U c^2} \tag{21}$$

NEUTRINO DENSITY

Given neutrinos' remarkably small absorption cross-sections,[2.4] one might think that their equilibrium number density in an eternal universe is extraordinarily high. This is not the case. Neutrinos move at the speed of light, so they decay just like electromagnetic radiation, and the only neutrino sources with significant luminosity are transient - supernovae or compact objects experiencing a change of state. Thus their universal density is fairly small. Matter-energy correspondence is consistent with this, as it also requires a low universal neutrino density. Neutrinos are only released by the binding of free particles. Even if all of the universe's matter were confined into compact objects, the *complementary* cosmic neutrino energy density would be orders of magnitude less than the electromagnetic radiation released from the mass fraction of all of these bound particles. For additional information about neutrinos, please refer to Appendix N.

When neutrino and other low-density radiant bands, such as gamma and radio wave, are omitted from Equation (21), the result is the universe's average bound proton concentration as a function of the most prominent luminous backgrounds in space:

$$\rho_{bp} \cong \frac{\rho_R}{\varepsilon_U c^2} \cong \frac{\rho_{B\gamma} + \rho_{I\gamma} + \rho_{CMR}}{\varepsilon_U c^2} \tag{22}$$

or $9(10)^{-29}$ kg/m^3 using the values listed in Appendix C.

VIII. DARK HYDROGEN

Measurement of *luminous* matter density doesn't reveal much about cosmic composition since it originates from a mixture of free (hydrogen) and bound protons. Equation (22) does, however, in concert with Figure (4), indicate that the universe is composed of a large fraction of nonluminous material. Although modern cosmology is full of speculation about a host of exotic dark matter candidates, such as gravitons and HIGGS and Z bosons, there is really only one viable contender for the missing energy density - *hydrogen*.

Electrons constitute only ~0.05% of the universe's mass, so its average material density is close to the sum of its free and bound proton concentrations:

$$\rho_M \cong \rho_{fp} + \rho_{bp} \tag{23}$$

where ρ_{fp} is the density of free protons (hydrogen).

The universally average *fraction* of bound protons is given by the ratio of Equations (22) and (17):

$$f_{bp} \cong \frac{4\pi G\left(\rho_{B\gamma} + \rho_{I\gamma} + \rho_{CMB}\right)}{H_0^2 \varepsilon_U c^2} \tag{24}$$

or 2% at a Hubble constant of 60 Hz-km/Mpc. The universe is about 98% hydrogen (and antihydrogen). This fraction is inversely proportional to the square of the Hubble constant so is fairly sensitive to its value. If the Hubble constant is 50 Hz-km/Mpc, the universe is 97.3% hydrogen; at 85 Hz-km/Mpc, it is 99%. Astronomers have estimated the composition of luminous matter to be about ~70% hydrogen, ~25% helium, and perhaps ~5% other elements.[1.1] Equation (24) indicates that dark matter is overwhelmingly hydrogen.