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THE REDSHIFT AND THE ZERO POINT ENERGY

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Abstract
The history of the redshift is traced and a variety of problems listed in addition to two major anomalies. One of these anomalies is the quantized redshift, which was first noted by Tifft in 1976 and has been confirmed a number of times, most recently by Bell in 2003. The second anomaly is the breakdown in the redshift/distance relationship, evidenced by the observations of distant Type Ia supernovae, that has revived interest in the existence of the cosmological constant. These problems and anomalies admit a resolution if the energy density of the electromagnetic fields making up the vacuum Zero Point Energy (ZPE) is increasing with time. This approach predicts that light emitted from distant galaxies should have a basic redshift quantization of 2.671 km/s, which is in good agreement with Tifft's basic quantum of 2.667 km/s. In addition, the standard redshift/distance relationship is shown to derive from known physical processes that produced the ZPE rather than the expansion of space-time or the motion of galaxies. The equations governing these processes readily allow an alternate explanation for the deviation from the standard formula at high redshifts without recourse to the action of a cosmological constant or so-called 'dark energy'.

Introduction

One of the key pieces of evidence that cosmologists use to indicate universal expansion is the redshift of light from distant galaxies. The redshift is an astronomical term that describes the shifting of the spectral lines of elements towards the red end of the spectrum when compared with a laboratory standard here on earth. The redshift, *z*, is then defined as the measured change in wavelength, when compared with the standard, divided by that laboratory standard wavelength. If the change in wavelength is given by $\Delta\lambda$ and the laboratory standard wavelength is λ, then the redshift is defined as [1 - 2]

$$z = \Delta\lambda/\lambda \qquad (1)$$

This is the quantity that is actually measured. Notice that *z* is a dimensionless number as the units of wavelength cancel out. One might reasonably ask how this dimensionless number came to represent the expansion of the universe.

Historical Background

The historical development of the idea began with the work of Vesto Slipher and Francis Pease between 1912 and 1922 at the Lowell Observatory in Flagstaff, Arizona. They measured the redshift of forty-two galaxies.[3] In 1919, Harlow Shapley noted that the vast majority of those redshifts were positive, with the only exceptions being those in our own galactic neighborhood. Then during the period 1923-24, Edwin Hubble discovered Cepheid variables in neighboring galaxies.[4] These stars vary in light output in such a way that their intrinsic luminosity and the period of variability are linked. Measuring the period of variability can thereby in principle establish their intrinsic luminosity and hence their distance. Hubble used these stars to measure the distances to all forty-two galaxies that Slipher and Pease had examined. In so doing, he discovered that the observed redshifts were proportional to distance. In 1929 he published the law of spectral displacements, which is now called Hubble's Law.[5] If astronomical distance is *r* and redshift is *z*, then in mathematical terms Hubble's Law can be written as:

$$r = z/h \qquad (2)$$

where *h* is a constant of proportionality.

Essentially Hubble's Law is a redshift/distance relationship, and as such simply notes that the redshift of galaxies is proportional to their distance. That is the hard core of data that astronomers and cosmologists have to deal with. Although cautious about the procedure until more data came in, Hubble suggested that *z* could be multiplied by the speed of light, *c*, thereby transforming the dimensionless number into a velocity. Hubble pointed out that this procedure then allowed the redshift to be interpreted as a Doppler effect of galactic recessional velocities, *v*.[6] This was done by analogy with the effect heard when a police car passes you with its siren going. As it pulls away from you, the pitch of the siren drops. In a similar way, Hubble suggested that the redshift, which lengthened the wavelengths of light from distant galaxies, might indicate they are moving away from us also. On this approach to the redshift data, equation (1) was thereby interpreted to read

$$zc = v \quad \text{or re-arranging} \quad z = v/c \quad \text{which suggested} \quad v/c = \Delta\lambda/\lambda \qquad (3)$$

This then allowed equation (2) to be re-written as[7]

$$r = cz/H_o = v/H_o \qquad (4)$$

where H_o is the new constant of proportionality called the Hubble constant. This was the situation up until the 1960's. By 1960, the highest value of *z* obtained was around 0.4. From the interpretation of equation (3) this meant these galaxies were receding at two-fifths of the velocity of light, and an essentially linear relationship was being maintained on the Hubble graph of redshift/distance from (2) or (4).[8-9]

However, around a redshift of about 0.4, and post-1960, a departure from linearity began to be noted as galaxy 'velocities' became more relativistic. Consequently, by the mid-1960's, the relativistic Doppler formula was applied and, even with the advent of the

Hubble Space Telescope, it was found to be a reasonably accurate approximation for objects even at the frontiers of the universe. Thus equation (3) came to be re-written as [10]

$$z = \{[1+(v/c)]/ \sqrt{[1-(v^2/c^2)]}\} - 1 \quad (5)$$

In many astronomical applications, however, it has proven more convenient to use the formulation of *(1 + z)* for the description of reality rather than just *z*, so that (5) becomes

$$(1 + z) = \{[1+(v/c)]/ \sqrt{[1-(v^2/c^2)]}\} \quad (6)$$

Noting Some Problems

Let us pause right there for a moment. Because of Hubble's multiplication of *z* by *c*, a Doppler shift interpretation has been given to the redshift data. This interpretation has led to the impression that galaxies are racing away from each other at speeds which increase with distance. Indeed, near the frontiers of the cosmos, those speeds are thought to be close to the current speed of light. But was Hubble justified in multiplying *z* by *c* in the first place? Some professional comment seems desirable. In 1995, Malcolm Longair wrote: [11] *"Thus, redshift does not really have anything to do with velocities at all in cosmology. The redshift is a … dimensionless number which … tells us the relative distance between galaxies when the light was emitted compared with that distance now. It is a great pity that Hubble multiplied z by c. I hope we will eventually get rid of the c."*

Using quasars of high redshifts with *z > 1* as examples, Misner, Thorne and Wheeler use an argument similar to Schmidt[12] to reject Doppler shifts on different grounds. They state: *"Nor are the quasar redshifts likely to be Doppler; how could so massive an object be accelerated to v ~ 1 [the speed of light] without complete disruption?"* [13] In thus rejecting the redshifts as Doppler effects, they also point out the problem that exists with one alternative explanation, namely gravitational redshifts. They state: *"Observed quasar redshifts of z ~ 1 to 3 cannot be gravitational in origin; objects with gravitational redshifts larger than z ~ 0.5 are unstable against collapse."* [13] So in knocking out Doppler shifts and gravitation as the origin of the observed redshifts they come to what they see as the only other solution, namely a *"cosmological redshift."* [13]

This cosmological redshift introduces the other interpretation commonly used to explain the observed lengthening of wavelengths. About the time that the initial redshift and distance measurements were being made in the mid 1920's, the mathematician Alexander Friedmann was examining Einstein's field equations describing a static universe. Friedmann found that these equations were capable of an infinite number of solutions if Einstein's model of a static universe was abandoned. [14] Then in 1927, the Abbe, Georges Lemaitre produced equations describing a universe which exploded out of an infinitely dense state and continued to expand ever since.[15] In Einstein's case, the equations required the very 'fabric' of space-time to be static with the galaxies moving through it. This meant that the redshift really was due to galaxy motion. By contrast, Friedmann and Lemaitre's universe had this 'fabric' of space-time expanding so that the universe's spatial co-ordinates are time dependent. Importantly, Lemaitre pointed out that if the fabric of space was itself expanding, then photons of light in transit should have their wavelengths stretched in a manner proportional to the expansion. These hypothesized space-time expansion redshifts can then be described by the relationship

$$z = \{R_2/R_1\} - 1 \quad \text{or} \quad (1 + z) = \{R_2/R_1\} \tag{7}$$

where R_1 and R_2 are the values of the space-time expansion factor at emission and reception respectively.[16] It is on this basis that the balloon analogy is often used to describe the redshift. As it is being inflated, the fabric of the balloon expands in the same way that the fabric of space-time is proposed to be expanding. Wavelengths of light in transit through space will be stretched proportionally resulting in a redshift when that light is compared with the laboratory standard.

Two Further Problems

But there are two further problems if this approach is adopted. First, if the expansion of space-time does cause light waves in transit to be lengthened, then atoms might also be expected to undergo such expansion. However, the customary explanation states that this expansion would be unobservable since everything would be expanding, including our measuring sticks. In order to overcome this difficulty, it is then concluded that the expansion does not occur within the galaxies themselves, but rather is external to them. However, doubts can be raised whether this expansion really would be unobservable since W. Q. Sumner thoroughly examined this matter in 1994. He established that, due to the effects of cosmological expansion on the atom, the results would certainly be observable and would lead to a blue-shift of light received from such atoms [*Astrophysical Journal*, 429:491]. If the Friedmann equations are logically followed through, then the observed redshift implies that the very fabric of space must be contracting rather than expanding. Sumner's analysis thus re-emphasizes the fact that, if cosmological expansion is really occurring, a redshift can only be obtained if galaxies, stars, atoms and matter do not expand also. This proviso therefore becomes a vital necessity to maintain the accord between theory and observation.

But another problem also exists. Following an examination of the Lemaitre model, Robert Gentry made a pertinent comment on the space-time expansion factor *R* in equation (7). He states: *"Despite its crucial role in big-bang cosmology, the foregoing expression [essentially equation (7)] is unique in that the physical presence of R has never been verified by experiment; the reason is that no method has yet been proposed to measure R, either past or present."* [17] As a possible explanation for redshifts, (7) should also be compared with (5) or (6). There it can be seen that the quantities within the curly brackets may be equated so that

$$\{[1+(v/c)]/ \sqrt{[1-(v^2/c^2)]}\} = \{R_2/R_1\} \tag{8}$$

In other words, the space-time expansion factor $\{R_2/R_1\}$ must be behaving in a way that mimics the relativistic Doppler formula. Therefore, no matter which interpretation of the redshift is used, the relativistic Doppler formula may be considered to be a good approximation to the actual behaviour of the redshift.

On that basis, a graph of redshift *z* on the y-axis against distance, *x*, on the x-axis is usually drawn.[2, 18] Until recently, the precise distance scale was in doubt since the Hubble constant, H_o, which determines the distance scale, had not been accurately delineated. To overcome this problem on the horizontal axis, the values there are often arranged to go from $x = 0$ near our own locality in space, to $x = 1$, the furthest distance in space, essentially at the origin of the cosmos. In this case, *x* becomes a dimensionless number since it is then the ratio of the distance of any given object to the furthest distance in space. On this approach, the redshift/distance relationship is then be expressed as [19]

$$(1 + z) = [(1 + x) / \sqrt{(1 - x^2)}] \qquad (9)$$

The total distance in LY at $x = 1$ is then dependent upon the value of the Hubble constant. However, two observational anomalies question the whole basis of these equations. The first of these anomalies came into focus with the work of William Tifft at Steward Observatory in Tucson, Arizona starting in 1976. The second became apparent in 1998 with distance measurements based on the light output of Type Ia supernovae at the frontiers of the cosmos. Let us take a moment to examine these anomalies.

The Quantized Redshift

From 1976 onward, Tifft published several papers indicating that redshift differences between galaxies were not smooth but went in jumps, or were quantized.[20] The Coma cluster exhibited this effect in such a way that bands of redshift ran through the whole cluster.[21] Shortly after, Tifft was presented with a list of accurate redshifts using radio measurements of hydrogen. Astronomer Halton Arp reports on the outcome of Tifft's analysis of this data set by stating: *"Not only did the quantization appear in this independent set of very accurate double galaxy measurements, but it was the most clear cut, obviously significant demonstration of the effect yet seen. …The results were later reconfirmed by optical measures in the Southern Hemisphere…"* [22]

These results have important consequences. If the redshift was indeed due to galaxies racing away from each other as the Doppler shift interpretation requires, then these speeds of recession should be distributed like those of cars smoothly accelerating on a highway. That is to say, the overall redshift function should be a smooth curve. The results that Tifft had obtained indicated that the redshift went in jumps from one plateau to another like a set of steps. It was as if every car on the highway traveled only at speeds that were multiples of, say, 5 miles per hour. Even more puzzling was the fact that some jumps actually occurred within galaxies. On either the Lemaitre or the Doppler model, it was difficult to see how any cosmological expansion of space-time or, alternatively, the recession of galaxies, could go in jumps. These results did not fit either concept at all.

In 1981, the results of an extensive redshift survey by astronomers Fisher and Tully were published, but without any apparent quantization.[23] In 1984, Tifft and Cocke published their analysis of this catalogue. They noted that the motion of the Solar System through space imparted a genuine Doppler shift of its own to all measurements of redshift. When this Doppler shift was subtracted from the survey results, redshift quantization appeared globally across the whole sky.[24] In 1985, there was an unexpected and independent confirmation of this quantization. Sulentic and Arp used radio-telescopes to accurately measure the redshifts of over 260 galaxies from more than 80 different groups for an entirely different purpose. As they did their analysis, the same quantizations that Tifft and Cocke had discovered surprisingly appeared in their data, and the measurement error was only 1/9th of the size of the quantization.[25-26]

Attempting To Settle The Issue

These were disturbing developments. In order to prove Tifft was wrong, Guthrie and Napier of Royal Observatory, Edinburgh, used the most accurate hydrogen line redshift data. By the end of 1991 they had studied 106 spiral galaxies and detected a quantization of about 37.5 km/s, close to Tifft's quantum multiple of 36.2 km/s.[27] By November 1992, a further 89 spiral galaxies had been examined and a quantization of 37.2 km/s emerged. [28-29] In 1995 they submitted a paper to Astronomy and Astrophysics with the results from a further 97 spiral galaxies showing a 37.5 km/s quantization.[30] The prevailing wisdom said the quantization only appeared because of small number statistics, so the referees asked them to repeat their analysis with another set of galaxies. This Guthrie and Napier did with 117 other galaxies. The same 37.5 km/s quantization was plainly in evidence in this 1996 data set, and the referees accepted the paper.[31] A Fourier analysis of all 399 data points showed a huge spike at 37.5 km/s with a significance of one in a million. The measurement error was about 1/10th the size of the quantization. One comment on the redshift quantization graph stated: [32] *"One can see at a glance how accurately the troughs and peaks of redshift march metronomically outward from 0 to over 2000 km/s."*

The Latest Evidence

The outcome of the most accurate studies by Tifft indicates a possible basic redshift quantization of about 8/3 km/s [33] with a claim by Brian Murray Lewis that the redshift measurements used had an accuracy of 0.1 km/s at a very high signal to noise ratio.[34] Tifft demonstrated that higher redshift quantum values were simply multiples of this basic figure. More recently, on 5th and 7th May 2003, two Abstracts appeared in *Astrophysics* authored by Morley Bell. The second Abstract read in part: *"Evidence was presented recently suggesting that [galaxy] clusters studied by the Hubble Key Project may contain quantized intrinsic redshift components that are related to those reported by Tifft. Here we report the results of a similar analysis using 55 spiral … and 36 Type Ia supernovae galaxies. We find that even when more objects are included in the sample there is still clear evidence that the same quantized intrinsic redshifts are present…"*

These results are important. On the Lemaitre model, if the fabric of space is expanding, it must be expanding in jumps. This is virtually impossible. On the Doppler model, the galaxies are themselves moving away through static space-time, but in such a way that their velocities vary in fixed steps. This is unlikely. However, when it is considered that the quantum jumps in redshift values have been observed to even go through individual galaxies,[20-21, 35] it becomes apparent that the redshift can have little to do with either space-time expansion or galactic velocities through space.

One final piece of observational evidence may help settle the matter. Tifft, Arp and others have pointed out that the quantized redshift means that the actual velocities of galaxies in clusters are very low.[21, 36] It is only at the very centers of clusters that high velocities would be expected. This was borne out by evidence mentioned at the Tucson conference on quantization in April 1996. Observations of the Virgo cluster have shown that in the innermost parts of the cluster *"deeper in the potential well, [galaxies] were moving fast enough to wash out the periodicity."* [32] Here, "periodicity" is the quantization by another name. In other words, if galaxies have a significant velocity, it actually smears out the quantization. As a consequence, these quantization results reveal that redshifts are not basically due to galaxy motion at all, but must have some other primary cause, with Doppler effects from motion being secondary.

The Second Anomaly

Along with this evidence from the quantized redshift comes the evidence from a second anomaly. This evidence comprises data relating to Type Ia supernovae and the resulting redshift/distance measurements. A supernova essentially is an exploding star, and Type Ia supernovae all explode with a standard brightness, rather like light bulbs with a known wattage. Thus, when these Type Ia supernovae occur in very distant galaxies, their set brightness allows an accurate distance measurement to be made. In 1998, Saul Perlmutter examined data that measured the brightness of these stellar explosions at redshifts from about $z = 0.83$ to about $z = 1.2$.[37-42] These explosions were about 20% fainter than expected. Their observed change in brightness by 0.2 magnitudes corresponds to a reduction in intensity by a factor of 1.2. This meant that they were further away than their redshift indicated by a factor of ($\sqrt{1.2} = 1.1$). [43]

This disconcerting result spawned a number of explanations, but there were two predominant explanations. The first attributed the dimming of the light from these supernovae to the action of interstellar dust. The more distant they are, the fainter they should be compared with predictions from the redshift/distance relation. This (minority) approach was subsequently shown to be incorrect. In the meantime, the other (majority) interpretation was that these results could be accounted for if the Big Bang expansion rate was speeding up with time. Up until then, the majority of astronomers had accepted that the Big Bang expansion rate was gradually slowing under the action of gravity.

However, if the integrity of Big Bang modelling was to be maintained, this new result could only be accounted for if cosmological expansion was speeding up. This postulate required the existence of the cosmological constant, Λ, which acted like gravity in reverse. While Einstein had postulated the existence of this mathematical term, most had regarded the existence of this quantity with some skepticism. This reaction came from the fact that its calculated size when compared with observational data results in a large discrepancy. Barrow and Magueijo pointed out in 2000 "*If $\Lambda > 0$, then cosmology faces a very serious fine-tuning problem…There is no theoretical motivation for a value of Λ of currently observable magnitude*". [44] Greene also noted that *"…the cosmological constant can be interpreted as a kind of overall energy stored in the vacuum of space, and hence its value should be theoretically calculable and experimentally measurable. But, to date, such calculations and measurements lead to a colossal mismatch: Observations show* *that the cosmological constant is either zero (as Einstein ultimately suggested) or quite small; calculations indicate that quantum-mechanical fluctuations in the vacuum of empty space tend to generate a nonzero cosmological constant whose value is some 120 orders of magnitude larger than experiment allows!"* [45] This is still the situation, despite these recent developments. This approach to the problem must therefore be questioned.

But astronomers had hardly recovered from their surprise when a further shock came in 2001. Adam Riess had just examined the most distant Type Ia supernova yet discovered. It was at a redshift of $z = 1.7$ and was not fainter, but brighter than expected.[46] This meant that it was closer to us than the redshift distance relationship indicated. This result was confirmed on 10th October 2003 when Riess announced that ten more distant supernovae were all brighter than expected.[47-48] Since dust can only make things dimmer, but never brighter, some other factor had to be the cause. At the same time, the Big Bang model also needed to be revised to account for the new data. The explanation offered was that in the early universe with $z > 1.5$, expansion was slowing under gravity. However, at about $z = 1.5$ the action of the cosmological constant became greater than the pull of gravity, and the expansion of the universe started to accelerate as a result of Λ which is often called "dark energy." But, as Science News Vol. 164:15 points out, science is not sure of the source of this energy. Furthermore, X-ray data from the European XMM satellite *"leaves little room for dark energy"* according to Alain Blanchard in a European Space Agency News Release 12 Dec. 2003 [see paper at arxiv.org/abs/astro-ph/0311381 and news release at: http://spaceflightnow.com/news/n0312/12darkenergy/].

A Static Universe?

These explanations assume one thing, namely that the relationship between redshift and distance is essentially given by the relativistic Doppler formula. However, what the observations are actually showing is that this formula is breaking down at large distances. In a word, it means that this formula is not exact, but only an approximation to reality. This in turn means that the redshift may not be due to cosmological expansion at all, a point which is reinforced by the quantization of the redshift. The possible cause of the redshift will be discussed in a moment. However, there is a matter requiring immediate attention. The fact that the Doppler formula is only an approximation to reality plus the fact that the redshift is quantized may mean that the universe is in fact static, neither expanding nor contracting. Narliker and Arp demonstrated in 1993 that a static, matter-filled universe was stable against gravitational collapse without the action of a cosmological constant, provided that mass increases with time.[49] They point out that *"stability is guaranteed by the mass-dependent terms… Small perturbations of the flat Minkowski spacetime would lead to small oscillations about the line element rather than to a collapse."* [49] The increase in atomic masses with time has been documented [50] and receives support from the increase in officially declared values of electron rest-masses graphed at http://www.setterfield.org/Charts.htm#graphs . Thus the possibility that we live in a static universe is certainly feasible.

But this is not the only possible model. In 1987, V. S. Troitskii from the Radiophysical Research Institute in Gorky, presented a concept in which the radius of curvature of space remained constant. Stability in this static cosmos occurred because "*agreement with the* *fundamental physics laws is achieved by introducing the evolution of a number of other fundamental constants synchronously with the variation of the speed of light."* [51] Three years earlier, Van Flandern from the US Naval Observatory in Washington, made a similar observation. He said *"For example, if the universe had constant linear dimensions in both dynamical and atomic units, the increase in redshift with distance (or equivalently, with lookback time) would imply an increase in c at past epochs, or that c was decreasing as time moves forward."* [52] In these scenarios, stability was maintained by variation in some atomic quantities. In other words, these three examples reveal that a static cosmos can be stable against collapse even without the action of Λ.

If the cosmos is indeed static, the outstanding issue then becomes the origin of the redshift itself. With galactic motion and space expansion ruled out, there seems to be only one option left, one first mentioned by John Gribbin.[53] He suggested that the quantized redshift is inherent to the atomic emitters of light within the galaxies themselves. If this is the case, there would be no need to change the wavelength of the light in transit as the wavelength would be fixed at the moment of emission. This avoids a difficulty Hubble perceived in 1936, namely that *"… redshifts, by increasing wavelengths, must reduce the energy in the quanta. Any plausible interpretation of redshifts must account for the loss of energy."* [6] The conservation of energy of light photons (quanta) in transit has been a problem for cosmologists ever since. In fact some openly claim that this is one case where energy is not conserved.[54] But any model that implicates the atomic emitters themselves changes the problem and energy conservation in transit is no longer an issue since the wavelengths themselves remain constant in transit.

If the redshift of light from distant galaxies is due to the behaviour of atomic emitters within those galaxies as a universal phenomenon, it can only be in response to the changing properties of the vacuum. The key property of the vacuum that is universal and implicated here is the Zero Point Energy (ZPE). The outcome of this line of investigation is that the behaviour of the ZPE allows a formula for the redshift to be derived that is the same as the relativistic Doppler formula, but without it having anything to do with space-time expansion or the motion of galaxies. Furthermore, the observed size of Tifft's basic quantization can be reproduced. An exploration of this possibility now follows.

Properties Of The Vacuum

The Zero-Point Energy (ZPE) derives its name from the fact that it is present even when there is no temperature radiation at zero degrees Kelvin.[55] This energy exists as a universal "sea" of electromagnetic radiation, a bath in which every atom in the cosmos is immersed. The energy density of the ZPE that permeates every cubic centimetre of the universe was recently estimated by Davies as around 10^{110} Joules per cubic centimetre, a fairly typical figure.[56] We are unaware of the presence of the ZPE for the same reason that we are unaware of atmospheric pressure on our bodies – its presence is balanced both inside and outside our bodies, and it permeates our instruments as well. Nevertheless experimental evidence confirms the presence of the ZPE in a number of ways. These include the Casimir effect, where two metal plates brought close together in a vacuum experience a measurable force pushing them together.[55, 57-59] The same effect at the atomic and molecular level is the origin of the feebly attractive Van der Waals forces.

The ZPE is also the cause of random "noise" in electronic circuits that puts a limit on the levels to which signals can be amplified.[60] This same vacuum energy also explains why cooling alone will never freeze liquid helium. Unless pressure is applied, the vacuum energy fluctuations prevent the atoms from getting close enough to trigger solidification.[60]

Zero-Point Energy And Atomic Stability

This all-pervasive ZPE 'sea' also appears to maintain atomic structures throughout the cosmos. In 1987 an important paper was written on this matter.[61] It explained that, according to classical physics, an electron in orbit around a proton should be radiating energy and so spiral into the nucleus. Obviously this does not happen, and physicists invoke quantum laws as an explanation. Nevertheless, an actual physical explanation is still desirable, and this was addressed by the paper in question. It assumed that classical physics was correct. The energy that electrons radiated as they orbited around their protons was calculated along with the energy that such electrons received from the all-pervasive ZPE. It turns out that the two were identical. In the Abstract, Hal Puthoff summarizes the results as follows: *"the ground state of the hydrogen atom can be precisely defined as resulting from a dynamic equilibrium between radiation emitted due to acceleration of the electron in its ground state orbit and radiation absorbed from the zero-point fluctuations of the background vacuum electromagnetic field…"* [61]

In the same way that a child on a swing receives resonantly times pushes from an adult to keep the swing going, so also the electron received resonantly timed "pushes" from the ZPE. Puthoff elaborated on this explanation as follows: *"The circular motion [of an electron in its orbit] can be thought of as two harmonic oscillator motions at right angles and 90 degrees out of phase, superimposed. These two oscillators are driven by the resonant components of the ZPE just as you would keep a kid swinging on a swing by resonantly-timed pushes. The oscillator motion acts as a filter to select out the energy at the right frequency (around 450 angstroms wavelength for the hydrogen atom Bohr orbit ground state)."* [62] Energy is therefore transferred from the Zero Point Fields (ZPF) to maintain electrons in their atomic orbits by this resonance mechanism.

It has also been explained another way. If an electron is orbiting too far out from the nucleus, it radiates more energy than it receives from the ZPE and spirals inwards to the position of stability. However, if the electron is orbiting too far in, it receives more energy from the ZPE than it is radiating, and so moves outwards to its stable position.[63] The concluding comment in Puthoff's paper carries unusual significance. It reads: *"Finally, it is seen that a well-defined, precise quantitative argument can be made that the ground state of the hydrogen atom is defined by a dynamic equilibrium in which the collapse of the state is prevented by the presence of the zero-point fluctuations of the electromagnetic field. This carries with it the attendant implication that the stability of matter itself is largely mediated by ZPF phenomena in the manner described here, a concept that transcends the usual interpretation of the role and significance of zero-point fluctuations of the vacuum electromagnetic field"* [61] Therefore, the very existence of atoms and atomic structures depends on this underlying sea of the electromagnetic ZPE.

As this analysis seems to be correct, then without the ZPE all matter in the universe would undergo instantaneous collapse.

ZPE And The Redshift

On this basis, then, it seems that atomic orbit energies are sustained by the ZPE. It is therefore possible that, if the energy density of the ZPE were to vary significantly, then all atomic structures throughout the cosmos might be expected to adjust their orbit energies in accord with the sustaining power available from the vacuum. Now orbit energies go in quantum jumps, and it appears that orbit radii have remained constant throughout time, otherwise the change in the sizes of atoms would result in defects in crystals called dislocations, which are not generally observed. It might thus be anticipated that any changes in the energy density of the ZPE might have to cross a quantum threshold before atoms took up their new energy state. For example, if the strength of the ZPE was lower in the past, then, as a series of quantum thresholds was reached, atomic orbit energies might also be expected to decrease in a set of jumps. The light emitted by atomic processes would therefore be redder in a series jumps as we look back in time, since the red end of the spectrum is the low energy end.

A brief analysis therefore suggests that the quantised redshift of light from distant galaxies may be evidence for the increase in the strength of the ZPE with time. First of all, allow the energy density of the ZPE to decrease as we look back in time. As it does so, the time arises when the energy of the first Bohr orbit takes a quantum change to an energy E_1. At that stage, the energy density of the ZPE has a value of U_1. As the energy density of the ZPE continues to change to a value U_2, the energy of atomic orbits undergoes a proportional change from E_1 before the jump to E_2 after the jump. But the energy of a given orbit is equal to the energy of a photon of light emitted from that orbit when an electron makes a transition to that orbit from outside the atom. The wavelength of light emitted from that orbit before the jump will thus be λ_1 which is related to E_1 by the expression $E_1 = hc/\lambda_1$. Similarly the wavelength of light emitted after the jump is then λ_2 in the expression $E_2 = hc/\lambda_2$. But it has been shown that the product hc is invariant on an astronomical time-scale.[64-65] Therefore, for all variations in the ZPE, we have

$$U_2/ U_1 = E_2/ E_1 = \lambda_1/\lambda_2 \qquad (10)$$

Now these wavelengths change such that

$$\lambda_2 = \lambda_1 + \Delta\lambda_1$$

Therefore

$$\lambda_2/\lambda_1 = 1 + \Delta\lambda_1/\lambda_1 = (1 + z) \qquad (11)$$

where the last step follows from (1). But in equation (10) we need λ_1/λ_2. Therefore, taking the inverse of (11), we have

$$U_2/ U_1 = E_2/E_1 = \lambda_1/\lambda_2 = 1/(1 + z) \qquad (12)$$

As a result of (12), it follows that the redshift factor *(1 + z)* is inversely proportional to the strength of the ZPE. The key conclusion from this is that the mathematical equation describing the behaviour of *(1 + z)* must be the inverse of the behaviour of the ZPE.

Determining The Basic Redshift Quantum

However, we can go further and determine the size of the basic redshift quantum. As noted above, the most accurate studies by Tifft indicate a possible basic redshift quantization of about 8/3 km/s with a measurement error which is 1/25th the size of the quantization.[33] Our assessment using the ZPE tends to support this contention. We begin with the equation describing the transfer of energy from the vacuum ZPE to electron orbits as derived by Puthoff.[61] His analysis revealed that P_a (the power available for absorption from the random background zero-point field by a charged harmonic oscillator) is given by the expression

$$P_a = e^2 h\omega^3/(24\pi^2 \varepsilon\, m_0 c^3) \quad (13)$$

However, in this equation the power available from all possible directions of propagation of the ZPF has been included, whereas on average only one third of the total energy of the field will be absorbed by such an oscillator.[66] The utilizable power P_u is thus

$$P_u = e^2 h\omega^3/(72\pi^2 \varepsilon\, m_0 c^3) \quad (14)$$

Here, *e* is the electronic charge, *h* is Planck's constant, *c* is the speed of light, ε is the permittivity of the vacuum, m_0 is the "bare" mass of the point particle oscillator, and the oscillator resonance frequency is ω. All the changes at the jump that are being considered here are due to the change in the utilizable energy or power available from the ZPE. If E_u is the utilizable energy available for absorption from the ZPE, then E_u is proportional to P_u. Therefore, as we look further out in space, if the power maintaining the electron in its orbit before the jump is P_1 and the power utilized after the jump is P_2 , then (12) gives us

$$U_2/U_1 = E_2/E_1 = 1/(1 + z) = P_2/P_1 \quad (15)$$

As a consequence, (15) can be written as:

$$P_1 = P_2 + zP_2 \quad (16)$$

Equation (16) therefore indicates that the increase in P_2 at the quantum jump is given by the dimensionless fraction z. This requires z to be a dimensionless component of (14), that is $1/(72\pi^2)$.

But that does not exhaust the dimensionless components of *P*, since the electronic charge *e* is expressed in units of Coulombs, where one Coulomb is an Ampere-second. This helps us since, by definition, the Ampere is a force per unit length, which has the same dimensions as energy per unit area. If the electron's surface area is represented by *a*, then

$$e = \text{Coulombs} = (\text{energy/area}) \times \text{time} = (\text{power/area}) \times \text{time}^2 = d/a \quad (17)$$

where d contains proportionality factors. In this equation, the electron surface area *a* can be replaced by $a = 4\pi r_0{}^2$, where r_0 is the "bare" electron radius. The dimensionless component of *e* that emerges from this can be seen in the expression

$$e = d/a = D/(4\pi\ ) \quad (18)$$

where *D* also contains proportionality factors. If the results of (18) are substituted in (14), then the utilizable power becomes

$$P_u = [D/(4\pi\ )]^2 h\omega^3/(72\pi^2\, \varepsilon\, m_0\, c^3) \quad (19)$$

From (19), the full dimensionless component making up the value of the redshift quantum $n\Delta z$ when $n = 1$ can finally be written as:

$$[(1/4\pi\ )^2]\ [1/(72\pi\ ^2)] = 1/(1152\pi\ ^4) = 1/112215 = 8.91144 \times 10^{-6} = \Delta z \quad (20)$$

If we multiply Δz by *c* as in equation (3) the result in km/s can be compared with Tifft's.

$$c\Delta z = (299792) \times (8.91144 \times 10^{-6}) = 2.671 \text{ km/s} \quad (21)$$

This compares favourably with Tifft's 8/3 = 2.667 km/s. Therefore, a consideration of an increasing ZPE not only accounts for the redshift, but it also accounts for the observed basic redshift quantum jump. The evidence supporting an increase in the ZPE now needs to be summarized, following which we conclude with the relationship describing the origin of the ZPE that mimics the relativistic Doppler formula.

Statistical Trends In Atomic Constants

In 1911 Planck predicted the existence of the ZPE and indicated that what is now Planck's constant *h* was a measure of its strength.[67-68] Importantly, both experimentally obtained and officially declared values of Planck's constant have increased with time. This trend in the declared values of *h* is graphed in the second graph linked here (http://www.setterfield.org/graphs). In 1965, Sanders noted that the increasing value of *h* can only partly be accounted for by improvements in instrumental resolution and changes in listed values of other constants.[69] It is quantitatively inadequate to blame the increase in *h* on these factors. This suggests that the strength of the ZPE has increased with time, since *h* is a measure of this quantity.

But this is not the only evidence. It has been shown that the speed of light is inversely related to the strength of the ZPE.[65, 70] Consequently, it is important to note that the measured values of lightspeed, *c*, have shown a systematic decrease with time. This confirmatory evidence was a topic of discussion by important physicists in key journals that ranged from Newcomb's article[71] in 1886 to that of Birge in 1941.[72] With the inverse link between the strength of the ZPE and *c*, the measured decline in the values of *c* also indicates an increase in the strength of the ZPE. An increasing ZPE is also supported by officially declared values of electron rest mass, *m*, which have increased with time. (Graphs of all three quantities are online at http://www.setterfield.org/graphs).

These statistical trends in the atomic constants and the 638 measurements by 41 methods upon which they are based were documented in August of 1987 in a Report (online at http://www.setterfield.org/report/report.html) for Stanford Research Institute International by Norman and Setterfield.[50] The data trends were confirmed in 1993 with an independent statistical examination (online at http://www.ldolphin.org/cdkgal.html) by Montgomery and Dolphin[73]. This present paper suggests that these data all point to the conclusion that the strength of the ZPE has been increasing with time cosmologically. The reason for this increase now needs to be elucidated.

Discerning The Origin Of The ZPE

Quantum electrodynamics (QED) and General Relativity (GR) consider the ZPE to be a manifestation of the cosmological constant Λ. However this approach runs into problems outlined in reference [65]. There, it was pointed out that stochastic electrodynamics (SED) offers an approach that overcomes these problems and suggests an origin for the ZPE independent of Λ. This line of investigation is followed here. We begin by noting that there were two current explanations for the origin of the ZPE.[74] They were assessed as follows: "*The first explanation … is that the zero-point energy was fixed arbitrarily at the birth of the Universe, as part of its so-called boundary conditions.*" [75] A second school of thought proposes that *"the sum of all particle motions throughout the Universe generates the zero-point fields"* and that in turn *"the zero-point fields drive the motion of all particles of matter in the Universe … as a self-regenerating cosmological feedback cycle."* [75] On this second explanation the ZPE plus atomic and virtual particles require the existence of each other. Several papers on the topic have capably demonstrated that this mechanism can maintain the presence of the ZPE once it had formed, but avoid the question of its origin. Since Puthoff has shown that the ZPE is required to maintain atomic structures across the cosmos as noted above, [76] it becomes difficult to envisage how atomic structures emerged in the first place by the feedback mechanism. A closer look at conditions at the inception of the universe may be pertinent. An initial outline of a probable process was given in "Exploring the Vacuum", which can be found online here: http://www.journaloftheoretics.com/Links/Papers/Setterfield.pdf) , but this paper updates that work.

The model accepted here is that the cosmos underwent rapid expansion or inflation at its origin, following which it became stable and static at its present size. This expansion process fed energy into the vacuum. This energy manifested as the smallest particles the cosmos is capable of producing, namely Planck particle pairs (PPP). PPP have a unique property; their dimensions are also those of their own Compton wavelengths.[77] Each pair is positively and negatively charged so that the net result is that the vacuum is electrically neutral. Because quantum uncertainty only exists as a result of the ZPE according to SED physics, then there was no time limit initially for these particles to remain in existence as a physical reality. Furthermore, since the Planck length is the cutoff wavelength for the ZPE, these particles were thereby unaffected by the ZPE as it built up during the expansion process. As the cosmos continued to expand, the separation between particles increased, and the turbulence among the PPP resulted in spin. The separation between these charges gave rise to electric fields, while their spin created magnetic fields. This may be considered to be the origin of the primordial electromagnetic fields of the ZPE. By this means, the energy of the expansion was converted into the Zero Point Energy.

Why The ZPE Strength Is Increasing

But we can go further. Changes in the three physical quantities mentioned earlier indicate that the strength of the ZPE has increased with time. The reasons why now need to be summarized. Gibson has pointed out that the expansion of the fabric of space will generate separation, spin and intense vorticity/turbulence between the PPP.[78] He demonstrated that this vorticity feeds energy into the system, which allows the production of more PPP. Therefore, additional PPP are spawned by this vorticity and turbulence and PPP numbers will increase. Thus, part of the reason for the increase in the strength of the ZPE may be found from the initial expansion of space and the effect of this on the PPP.

However, the formation stage of vortex production is only the first of three phases, the other two being the persistence and decay stages. Gibson has pointed out that the PPP system is characteristically inelastic,[78] while Bizon has established that such inelastic systems have stronger vortices and longer persistence times.[79] In these persistence and decay stages, the vorticity in the fabric of space would have continued, and hence more PPP would form via this ongoing process. This would result in an increase in the ZPE strength until the vorticity died away completely. Since the cosmos is a very large system with immense energies, the persistence and decay stages for these vortices may be expected to be relatively long. As the strength of the ZPE builds up by this process, it would be maintained by the feedback mechanism mentioned earlier.[74-75]

The next point is of even greater importance. Under the conditions being considered here, PPP will have a tendency to re-combine due to electrostatic attraction. Once recombination occurs, a pulse of electromagnetic radiation is emitted with the same energy that the Planck particle pair had originally.[80] The resulting energy further augments the primordial electromagnetic ZPE fields. This recombination process will eventually eliminate the majority of the PPP, although the initial production of PPP from turbulence partly offset that. The strength of the ZPE will thereby increase until these processes cease. Once that happens, the ZPE strength would be maintained by the feedback mechanism noted above.

The fact that the recombination of the PPP has occurred is evidenced by recent photographs from the Hubble space telescope and the ensuing discussion. If the "*fabric of space*" is made up of Planck particle pairs as Greene indicated, [81] so that "*space assumes a granular structure*" as Pipkin and Ritter suggested,[82] then the ultimate result is that photographs of astronomical objects should be more "fuzzy" as distance increases. Such "fuzziness" is not in evidence despite several searches, and there has been some discussion about this in the scientific literature.[83 - 88] These observations suggest that the PPP which had originally formed as a result of the rapid expansion process have now nearly all recombined, leaving the ZPE as the only evidence of their original existence.

Thus the ZPE is an intrinsic feature of the physical vacuum due to the conversion of energy from the initial expansion of the cosmos into PPP which then recombined, emitting the electromagnetic radiation of the ZPE. The ZPE was then maintained by the feedback mechanism. When the origin of the ZPE is considered in this fashion, its existence apart from the cosmological constant becomes a viable option. Furthermore, the anomalous behaviour of the physical constants is readily accounted for in contrast to other approaches. The modeling here also has the advantage that the mathematical form of the behaviour of the ZPE, and the anomalous quantities mentioned above, can be reproduced. In other words, the cosmological behaviour of the ZPE and hence the redshift can be derived from the physics involved.

Examining The Redshift/Distance Equation

In order to begin this derivation, we note that the standard form of the recombination equation is $dN/dt = q - r N^2$, where N is the number of ion pairs per unit volume available for recombination, r is the recombination coefficient, and q is the number of ion pairs created per unit volume per unit time by any given process, such as ionization.[89] It is possible to reproduce this equation by working backwards from the Doppler equation. It then follows that the Doppler equation can be reproduced by rationalizing the recombination equation in the reverse order. We start in equation (9) where the distance scale given by the quantity x is a dimensionless number since it is the ratio of the distance of the object in question to the total distance to the frontiers of the cosmos. But we look back in time when we see these distant objects. Thus equation (9) of the redshift versus the distance ratio, x, is the same equation as the redshift versus a dynamical (orbital) time ratio T. As in the case with the distance ratio, x, the dynamical time ratio $T = 1$ at the origin of the cosmos, with $T = 0$ at the present. Equation (9) then becomes

$$(1 + z) = \{[1+ T]/ \sqrt{[1- T^2]}\} \tag{22}$$

Note that $T = (1 - t)$ where t is dynamical time increasing from the origin of the universe. This means that at the origin time $T = 1$ and $t = 0$, while $T = 0$ at the present epoch when the quantity $t = 1$. We also designate the original number of PPP = N_1 and make the number of PPP present at time $T = N$. Now the strength of the Zero Point Energy per unit volume is proportional to the number of PPP that have combined which is given by the quantity $(N_1 - N)$. Furthermore, from the discussion around (12), the quantity $(1 + z)$ is inversely proportional to the strength of the ZPE per unit volume. Therefore, if we ignore constants of proportionality for the moment, we can write

$$(1 + z) = \{[1+ T]/ \sqrt{[1- T^2]}\} = 1/(N_1 - N) \tag{23}$$

If we now make the substitution

$$N_1 - N = M = \sqrt{[1- T^2]}/(1 + T)$$

we then have:

$$d(N_1 - N)/dT = dM/dT \qquad \text{which means that} \qquad - dN/dT = dM/dT$$

Now

$$M = \sqrt{[1- T^2]}/(1 + T) = (1 - T^2)^{½} /(1 + T) \tag{24}$$

Therefore the following mathematical operations can be performed on equation (24).

$$dM/dT = [- 2T(1 - T^2)^{- ½} (1 + T) - 1(1 - T^2)^{½}] / (1 + T)^{2}$$

$$dM/dT = [(1 - T^2)^{½} / (1 + T)] \{[-2T(1 - T^2)^{-1} (1 + T) - 1]/(1 + T)\}$$

$$= M\{[- 2T/(1 - T^2)] - [1/(1 + T)]\}$$

$$= M\{[-2T -(1 - T)]/(1 - T^2)]\}$$

$$= M \{(-2T - 1 + T)/[(1 + T)(1 - T)]\}$$

$$= - M\{ (1 + T)/[(1 + T)(1 - T)]\}$$

$$= - M/(1 - T)$$

Therefore we can write

$$- dN/dT = dM/dT = - M/(1 - T) \tag{25}$$

We now need to find an expression for *T* in terms of *M*. In order to do this we start with equation (24) which reads

$$M = \sqrt{[1- T^2]}/(1 + T)$$

If we now square both sides of this equation we find that

$$M^2(1 + T)^2 = (1 - T^2)$$

Expanding this out allows us to manipulate the equation as follows:

$$M^2(1 + T)(1 + T) = (1 - T)(1 + T)$$

$$M^2(1 + T) = (1 - T)$$

$$M^2 + T M^2 = 1 - T$$

$$T(M^2 + 1) = 1 - M^2$$

$$T = (1 - M^2)/(1 + M^2) \tag{26}$$

Substituting this expression for T from equation (26) back into (25) then gives us

$$dM/dT = - M / \{1 – [(1 - M^2)/(1 + M^2)]\}$$

$$= -M(1 + M^2) / [(1 + M^2) – (1 - M^2)]$$

$$= - M(1 + M^2)/(2 M^2)$$

$$= - \{[1/(2M)] + [M/2]\}$$

Therefore, if we now insert a constant of proportionality, k, which is required to be negative, we have the result that

$$dM/dT = -dN/dT = dN/dt = k\{[1/(2M)] + M/2\} \quad (27)$$

Substituting $(N_1 - N)$ for M in (27) we obtain the result that

$$dN/dt = k\{1/[2(N_1 - N)] + (N_1 - N)/2\} \quad (28)$$

Now N_1 is a constant, which, to avoid confusion with N, we shall call A. Therefore,

$$dN/dt = k\{1/[2(A - N)] + (A – N)/2\} \quad (29)$$

$$dN/dt = k\{1/[2(A - N)] + A/2 – N/2\} \quad (30)$$

We now multiply the last term in (30) by N/N to give us the form

$$dN/dt = k\{1/[2(A - N)] + A/2 - N^2/(2N)\}$$

Now $A/2$ is also a constant which we shall call B. We then proceed as follows:

$$dN/dt = k\{1/[2(A - N)] + B - N^2/(2N)\}$$

$$dN/dt = k\{[1/(2\{A – N\}) + B] – [1/(2N)][N^2/1]\}$$

$$dN/dt = k\{[1/(2M) + B] – [1/(2N)][N^2/1]\} \quad (31)$$

It can therefore be seen that equation (31) has the form

$$dN/dt = k\{q – r N^2\} \quad (32)$$

which is the standard equation for recombination phenomena where N is the number of ion-pairs per unit volume available for recombination, r is the recombination coefficient, and q is the number of ion pairs created per unit volume per unit time by any given process, such as ionization. In the interpretation being given here, N is the number of Planck Particle Pairs (PPP) available for recombination per unit volume at any given time. The recombination coefficient, $r = 1/(Nt)$, where t is the recombination time.[90] As such, the recombination coefficient bears the units of $cm^3/(ion\text{-}seconds)$ as pointed out by Zwaska et al.[91] Since the quantity N is the number of PPP available for recombination per unit volume at any given unit of time, the identification that $r = 1/(2N)$ intrinsically has units of $cm^3/(PPP\text{-}seconds)$ is to be expected.

It is usual for q to represent the ionization rate. In the case under consideration here, q is given by the term $[1/(2M) + B]$ in equation (31). This is equivalent to the number of PPP created per unit volume in a given time by the decaying turbulence after the original expansion. This quantity, q, also is the basis of the first term in (29) above. There, it can be seen when PPP numbers are high, near the origin of the cosmos, the quantity $(A – N)$ which is equal to M, is small, so the term $1/[2(A – N)] = 1/(2M)$ will dominate in equation (29). This means that q is the dominant process determining the behaviour of the ZPE, and hence the shape of the graph, near the origin of the universe. Therefore the term $1/(2M)$ attracts our attention since it is the major component of q when equation (31) is compared with (32).

Now for the PPP system being considered here, the term q is directly related to the decay in turbulence, L. It is generally conceded that the decay in turbulence follows a power law such that for time, t,[92]

$$L = t^{-n} \qquad (33)$$

As such, it might be anticipated that, since the number of PPP forming is dependent upon the turbulence, then this means that q is also proportional to $1/t^n$. Therefore, the relationship between $1/(2M)$ and $1/t^n$ needs to be established. Since we have already made the identification

$$dN/dt = k[1/(2M) + M/2]$$

we can therefore proceed as follows:

$$t = 2M^2/(1 + M^2)$$

$$t(1 + M^2) = 2M^2$$

$$t + tM^2 = 2M^2$$

$$M^2(2 – t) = t$$

$$M^2 = t/(2 – t) \quad \text{so that} \quad M = t^{1/2}(2 – t)^{-1/2} \qquad (34)$$

Focusing for the moment on the term $(2 – t)^{-1/2}$ and using the binomial expansion, we get:

$$(2 – t)^{-1/2} = [2(1 – t/2)]^{-1/2}$$

$= (1/\sqrt{2})[1 - t/2]^{-½}$

$= (1/\sqrt{2})\ \{1 + (-½)(-t/2) + [(-½)(-3/2)(-t/2)^2] / 2! + [(-½)(-3/2)(-5/2)(-t/2)^3] / 3! + \ldots\}$

$$= (1/\sqrt{2})\ \{1 + t/4 + (3t^2/8)/2 + (15t^3/16)/6 + \ldots\} \qquad (35)$$

Substituting this result from (35) back into (34) we find that the quantity *M* is given by

$$M = t^{1/2}/(\sqrt{2}) + t^{3/2}/(4\sqrt{2}) + [3t^{5/2}/(8\sqrt{2})] / 2 + [15t^{7/2}/(16\sqrt{2})] / 6 + \ldots$$

Therefore, near the origin of the universe, when *t* is small, higher order terms can be ignored and we obtain:

$$M = t^{1/2}/(\sqrt{2}) \qquad (36)$$

It thus follows that the quantity

$$1/(2M) = 1/(\sqrt{2}t^{1/2})$$

so that the expression for *q* becomes

$$q = \{1/(2M) + B\} = 1/(\sqrt{2}t^{1/2}) + B \qquad (37)$$

Since this has the form of $1/t^n$, this means that the quantity $\{1/(2M) + B\}$is consistent with turbulence. In this case, the value of n in equation (33) is equal to one half. Now the value of *n* is different for various systems, and it is known that in incompressible systems the value of *n* can be much lower than unity. It is further known that for spatially free turbulence the value of *n* is lower in any given system than for turbulence in a confined system. In confined systems, the value of *n* in incompressible turbulence can reach as low as $n = 0.66$. [92] In the case of spatially free turbulence it may therefore not be unreasonable to expect n to drop to a value of $n = 0.5$.

From this it may be seen that the relativistic Doppler formula may be reproduced by the behaviour of a universal PPP system in a way which has nothing to do with either the expansion of space-time or the motion of galaxies. Rather, it has everything to do with turbulence in the early universe and the production and recombination of Planck particle pairs. Furthermore, the term designated *q* in (32) and (37) allows for a range of values for *n* in (24). Consequently, it should now be possible, at least in principle, to obtain a better fit to the data for redshifts from about $z = 0.8$ or greater. This would then allow a resolution of the redshift/distance discrepancies at the frontiers of the universe without recourse to the action of a cosmological constant or dark energy.

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