Tired Light – Proximate Cause of Cosmological Redshift

by R. F. Vaughan

The tired light conjecture contended that the increases in observed redshift of galaxy spectra with distance was due to light having lost energy in propagating through billions of light years of an intergalactic medium. The simple fact is that redshifted light has traveled billions of light years *has* lost energy, hence the phrase, 'tired light' does makes sense. Photon energy is $E = h\, c/\lambda$, where $h = 6.626 \times 10^{-27}$ erg sec is Planck's constant, $c = 2.9979 \times 10^{10}$ cm/sec is the speed of light in a vacuum, and λ is the wavelength of the propagating radiation. Lengthening its wavelength from λ_1 to λ_2 is tantamount to an associated photon losing energy as follows:

$\Delta E = hc/\lambda_1 - hc/\lambda_2 = (hc/\lambda_2)\, Z$ → *that redshift is tantamount to 'tired light'*

Since $Z = (\lambda_2 - \lambda_1) / \lambda_1$ is redshift, one way or another redshift is in fact associated with, and proportional to the energy that has been removed from each photon during its travels from its source to its ultimate observation through intergalactic plasma. However one sugarcoats it, what one observes from the cosmos *is*, in fact, tired light that is intimately associated with redshift.

So why are 'tired light' theories of cosmological redshift lampooned so viciously when as a mere matter of fact what we observe from cosmological distances is tired light? That somehow light could lose energy as a mere consequence of traveling many millions of light years through space is insufficient reason to accept a theory without advancing an explanation of a mechanism that produces that result. Zwicky and others attempted to discover such a mechanism without success. Eventually Yakov Zeldovich lowered the hammer by impugning as follows: The only possible mechanism would involve scattering phenomena whereby energy is transferred from photons to scattering electrons, but the conservation laws would necessitate a deflection which would alter the direction of the light. Such a deflection would blur images to oblivion.

Zeldovich was correct about any such mechanism requiring scattering of photons (but without absorption) which leaves forward scattering as the possible mechanism. So ignoring for the moment the deflection objection, let us consider what is involved in forward scattering through any medium whose electrons resonate with the radiation and ultimately replace a photon with one comprised of secondary radiation from the scattering electrons.

The increment of distance δ over which replication takes place and any changes (including the effective speed of light) occur when light propagates through a dispersive medium is called the *extinction interval*. This incremental distance is dependent on electron density, absorption properties of the medium, and the wavelength of the propagating light, all as determined by the Lorentz-Lorenz equation describing behavior in a dispersive medium. The resulting distance is:

$\delta = \lambda / 2\pi\, |\, Re(\mathbf{n}-1)\, |$ → *dependence of extinction interval on index of refraction*

Here $|\, Re(\mathbf{n}-1)\, |$ is the absolute value of the *real* part of the *dielectric susceptibility* (the *complex index of refraction* minus one) of the medium. With the properties of the intergalactic plasma this distance is inversely proportional to both electron density and the wavelength of light propagated through the interval, so in intergalactic hydrogenous plasma medium the length of this interval is:

$\delta(\lambda,\rho) \approx m_e c^2/(\rho\, e^2\, \lambda) \cong 3.55 \times 10^{12}/\lambda\, \rho$ cm → *dependence on wavelength and electron density*

Here λ is wavelength entering the interval, $m_e = 9.109 \times 10^{-28}$ gm is the mass of an electron, e = 4.8×10^{-10} stat-coulombs is the electronic charge, and ρ is the density of free electrons. In propagating through regions of appreciable electron density rather than a vacuum, photons of radiation are replaced by *similar* photons previously accepted as being *identical*. This process repeats as light passes through each successive extinction interval distance in the medium. These intervals are not of equal length along a propagation path because either or both the density and wavelength change. In usual media the wavelength has been shown to remain unchanged but that is not the case in a hot (relativistic) plasma.[1] The distance r that light has traveled from its source to its observation is the sum of the lengths of all N intervening extinction intervals as follows:

$$r(N) = 3.55 \times 10^{12} \sum_{n=0}^{N} 1 / \lambda_n \rho_n \qquad \rightarrow \textit{dependence of distance on number of extinction intervals}$$

If wavelength were to increase in passing through a medium, incremental increases would occur at each extinction interval along the way. The first step in refuting Zeldovich's assertion that there can be no such redshift mechanism is to demonstrate the required functionality. A mechanism that results in that functionality must then be theorized. To refute the accepted notion one must then demonstrate implications that theoretical approach and distinguish it from the accepted approach.

The transverse Doppler effect of thermal velocities of scattering electrons in each interval does in fact produce incremental increases in wavelength $\Delta\lambda$. It is a tiny second order effect in v/c that produces unilateral increases in wavelength. By applying thermodynamic statistics to Compton's conservation analyses of transverse velocity components of astronomical numbers of free plasma electrons involved in scattering radiation within an extinction interval, one obtains the expected amount of wavelength shift that occurs through an extinction interval as follows:

$$\Delta\lambda_\delta \approx 3h\, k \langle T\rangle / 4m_e^2c^2 \approx 2.225 \times 10^{-4}\, k \langle T\rangle \text{ cm} \rightarrow \textit{increased wavelength per extinction interval}$$

$\langle T\rangle$ is average temperature measured in Kelvin; $k = 1.38 \times 10^{-16}$ erg/K is Boltzmann's constant. (This result is derived in the paper Effects of Transverse Doppler on this site.) Thus, wavelength of a photon is increased by a fixed amount that is independent of wavelength in propagating through a single extinction interval. That does *not* in itself constitute a redshift, but one can use this result to determine the amount of increase in wavelength per unit distance:

$$\Delta\lambda_{\delta cm} = \Delta\lambda_\delta / \delta(\lambda_n,\rho) \approx 6.27 \times 10^{-17}\, k \langle \rho T \rangle\ \lambda_n \text{ cm} \qquad \rightarrow \textit{wavelength increase per centimeter}$$

Therefore, by dividing total increase in wavelength by the number of centimeters of propagation through a single extinction interval, one obtains the amount of redshift per centimeter through the interval:

$$\Delta z_{\delta cm} = \Delta\lambda_{\delta cm} / \lambda_n \approx 6.27 \times 10^{-17}\, k \langle \rho T\rangle = 6.27 \times 10^{-17} \langle P\rangle \qquad \rightarrow \textit{redshift per centimeter}$$

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[1] This phenomenon was previously undiscovered because the extreme temperatures in galaxy clusters and propagation distances are not realized in laboratories. The effect is summarized briefly in this section; a full description of the mechanism addressing Zeldovich's concerns is included in the paper 'Cosmological Redshift Mechanism' on this site.

For this redshift to match Hubble's constant of proportionality $H_o = 7.4 \times 10^{-29}$ cm^{-1}, we must have the average pressure $\langle P \rangle \equiv k \langle \rho T \rangle$ of the hydrogenous plasma along lines of sight through the universe of:

$\langle P \rangle = H_o / 6.27 \times 10^{-17} \approx 1.18 \times 10^{-12}$ $\rightarrow$ *constraint on average intergalactic plasma pressure*

Since the total change in wavelength is $\Delta\lambda_n = n\, \Delta\lambda_\delta$ and $\lambda_n = \lambda_e + n\, \Delta\lambda_\delta$ we obtain:

Ƶ $= N\, \Delta\lambda_\delta/\lambda_e \approx N \times 3.11 \times 10^{-20} \langle T \rangle / \lambda_e$ $\rightarrow$ *wavelength-dependent 'redshift' through interval*

Here λ_e is the wavelength of the light that was originally emitted from the distant source. The problem with this formulation is that this 'redshift' is not directly associated with distance. It is a linear function of N (not distance) and depends on the source wavelength as shown in the left panel of figure 1.

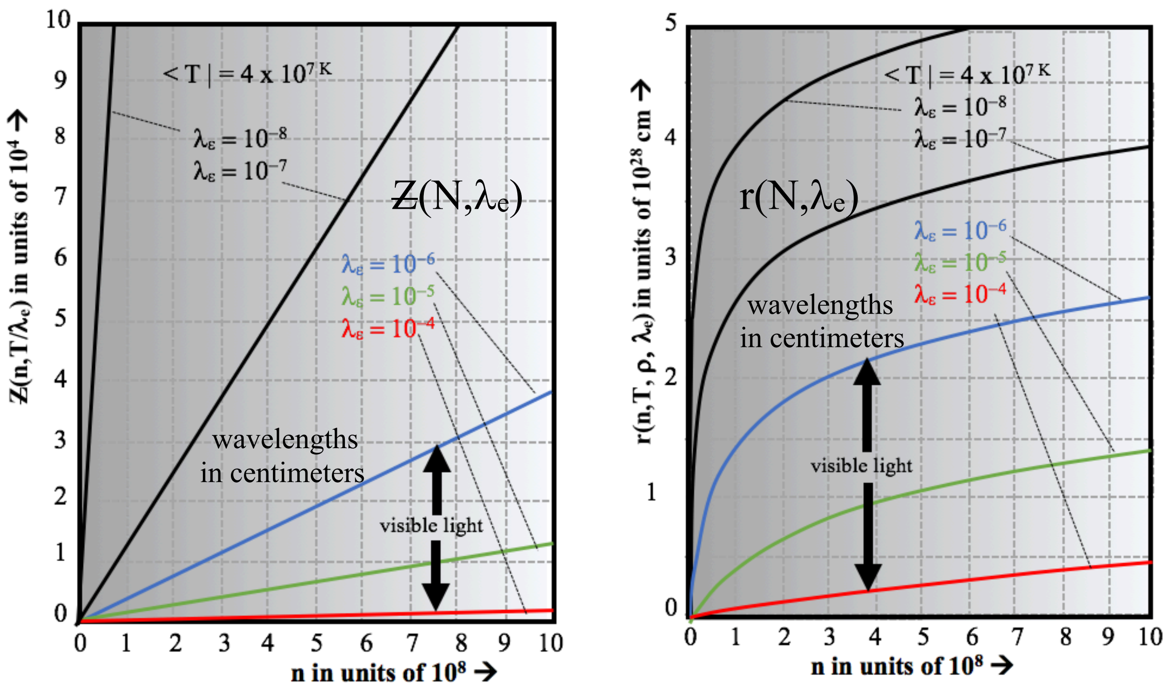

Figure 1: Redshift and distance versus number of extinction intervals in plasma medium

To obtain a redshift-distance relation like that demonstrated by Hubble (with the subsequent improvements) requires incorporation of distance as a function of N. This requires an assessment of the incremental increases in wavelength from the source wavelength onward. The total increase in wavelength is additive for photons propagating through N identical segments along the light path in a uniform plasma medium as we showed above. The increments will vary for each segment only as, and if, the electron temperature varies. Assuming the average is unchanged throughout, the observed wavelength will increase relative to the emitted wavelength as follows:

$$\lambda(N, \lambda_e) \approx \lambda_e + \sum_{n=0}^{N} \Delta\lambda_n = \lambda_e \left(1 + N \times 3.11 \times 10^{-20} \langle T \rangle / \lambda_e \right) \quad \rightarrow \textit{ wavelength progression}$$

The distance after which a given redshift is realized is dependent on the initially emitted wavelength as well as the average of the product of electron density and temperature (which is tantamount to pressure). This functionality is shown in the right panel of figure 19.

$$r(N, \lambda_e) \cong (3.55 \times 10^{12}/\langle\rho\rangle\lambda_e) \sum_{n=0}^{N} 1/(1 + n\, 3.11 \times 10^{-20} \langle T\rangle /\lambda_e) \quad \rightarrow \quad \textit{distance progression}$$

For large N, which will certainly always be the case for measurable redshift, the series in the preceding equation can be replaced by integration which obtains a log functionality. In the limit as number of extinction intervals becomes very large, the following mathematical formula applies:

$$\operatorname*{Limit}_{N\rightarrow\infty} \sum_{n=0}^{N} 1 / (1 + A\, n) = A^{-1} \ln (1 + A\, N) \quad \rightarrow \quad \textit{mathematical identity}$$

Therefore:

$$r(N, \lambda_e) \cong 1.16 \times 10^{32} \times \ln(1 + N \times 3.11 \times 10^{-20} \langle T\rangle /\lambda_e) / \langle\rho\, T\rangle \quad \rightarrow \quad \textit{distance progression}$$

We plot distance against the log of N for the various source wavelengths in figure 2. For longer emitted wavelengths, more extinction intervals are required to obtain linearity on the log scale. Of course redshift plotted in figure 1 would become exponential if plotted against log of N. Refer to table below.

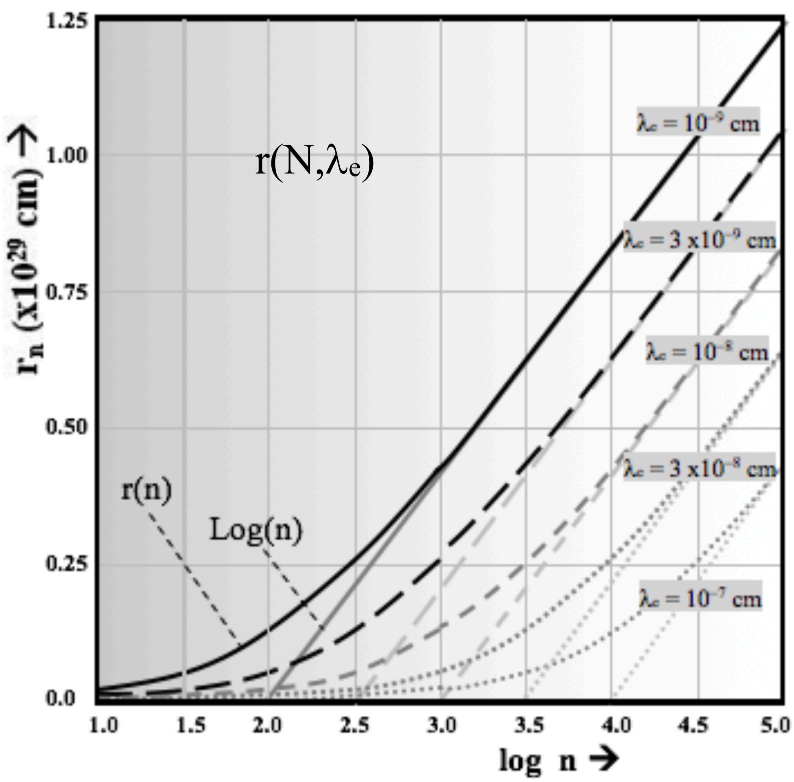

Figure 2: logarithmic form of distance progression with number of extinction intervals

To obtain a viable distance-redshift relationship to apply to galaxy spectra, we must convert the redshift determined above from a function of number of intervals to a function of distance. Having now determined distance as a function of n with redshift already expressed as a function of n, we have the basis for a redshift-distance relationship which we illustrate in figure 3.

By assuming an average intergalactic plasma pressure $\langle P\rangle = k \langle \rho\, T\rangle$ throughout the distance from the source of the radiation to its ultimate observation, we obtain the relation:

$r(Z) \;\cong\; (1.608 \times 10^{16} / \langle P\rangle) \ln (Z+1) = (1/H_o) \ln (Z+1)$ → *distance as a function of redshift*

number of extinction intervals, n	initial wave-length, λ_e (cm)	redshift Z_n (unitless)	distance r_n $\times 10^{28}$ (cm)	ratio Z_n / r_n $\times 10^{-29}$ (cm)
1	10^{-11}	1.268	2.560	4.592
3	3×10^{-11}	1.268	1.591	7.970
10	10^{-10}	1.268	1.277	9.927
100	10^{-9}	1.268	1.160	10.926
1,000	10^{-8}	1.268	1.149	11.035
10,000	10^{-7}	1.268	1.148	11.047
100,000	10^{-6}	1.268	1.147	11.048
1,000,000	10^{-5}	1.268	1.147	11.048
10,000,000	10^{-4}	1.268	1.147	11.048

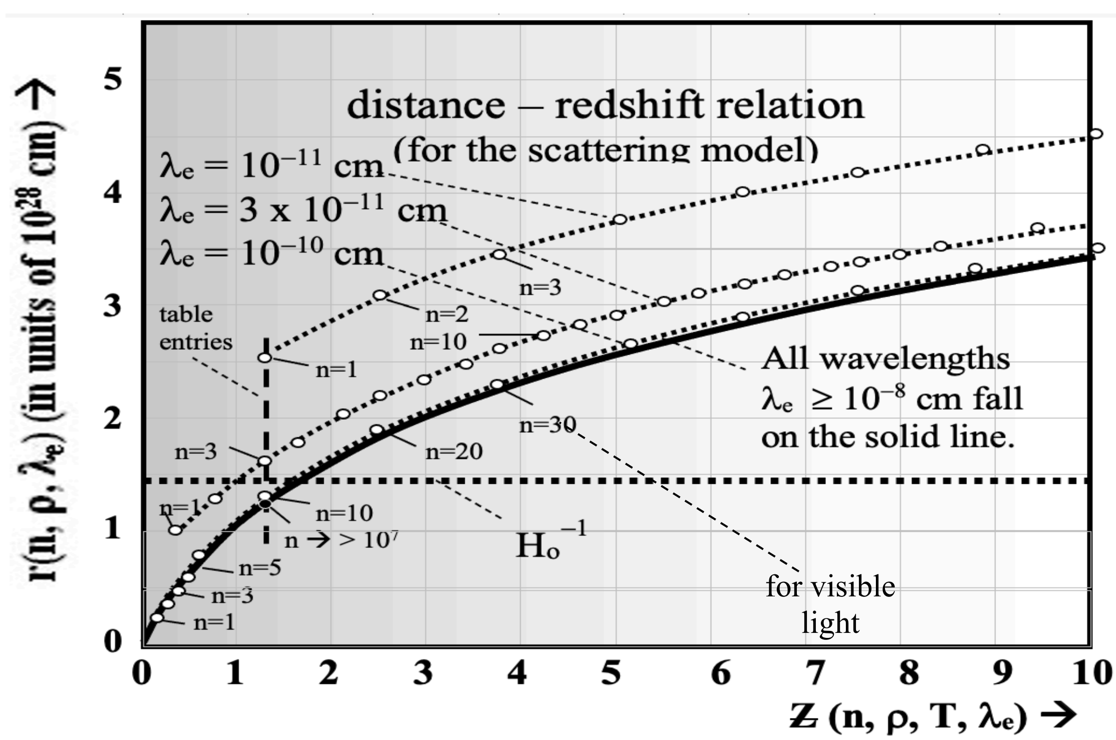

***Figure 3:** The emergence of a distance versus redshift relation for wavelengths less that 10^{-8} cm showing number of extinction intervals n associated with redshifts and distances*

The representative curve associated with wavelengths greater than 10^{-8} cm is associated with the observed cosmological redshift-distance relation. Since $1/H_o = 1.35 \times 10^{28}$, $\langle P \rangle \approx 1.19 \times 10^{-12}$ dyne/cm^2 is required for this curve to match observation. However, for shorter wavelengths in the Xray and gamma ray region of the electromagnetic spectrum, there are unique curves which serve as distinguishing characteristics of the plasma pressure redshift model.

The previous analyses apply to the extent that the average thermodynamic pressure throughout the universe is $\langle P \rangle = k \langle \rho T \rangle \approx 1.19 \times 10^{-12}$. There is every reason to believe that this average is realized for an average taken over large enough volumes of space, so that the extremely high pressures within galaxy cluster cores averages out in looking through them to further and further distances. Variations due to extremely high pressures near the centers of cluster cells as shown in figures 1 require detailed analyses of what observations made through a representative cluster cell imply as far as the observed redshift effects of the spectra of the orbiting galaxies near the center of the intense plasma density region.

In the paper (on this site) 'Cosmological Redshift Mechanism' we derive and explain the plasma scattering mechanism responsible for 'tired light' being the valid explanation of cosmological redshift in the end. That paper also illustrates the profiles of the thermodynamic parameters in and around galaxy clusters producing these effects.