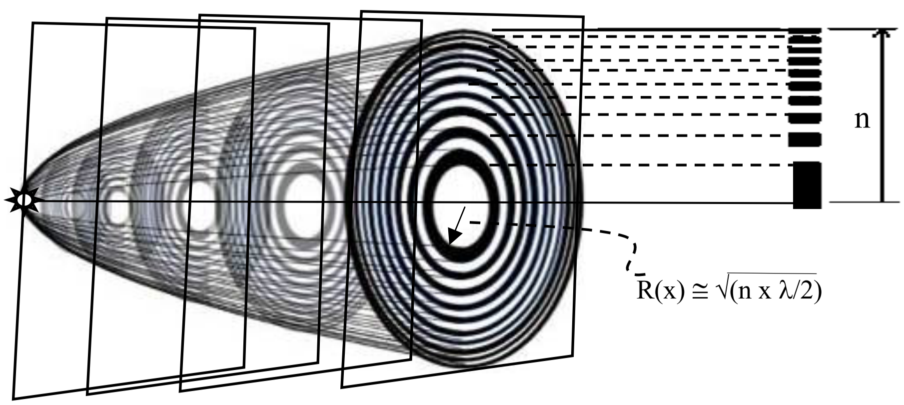
Excerpt from Cosmological Considerations p 39 to 55

(Summary discussion of concepts covered in the Cosmological Effects of Scattering in the Intergalactic medium.)

#4 Ray's Cosmological Obsession

The work that Lesa had begun looking into with him when he had first reestablished contact with her in the late spring and early summer after Helen had died had involved several major problems. These needed to be solved before a viable alternative to the standard model of the Big Bang and an evolving universe could be established. It had enticed and frustrated Lesa just as it had Ray over a much longer span of years. There had been areas of research that he would work on enthusiastically for several months until he finally accepted one of the challenges as an impasse, and then he would shelve his work and not bring it out again for a year or so. This had gone on for well over twenty years by then. Gradually, however minor accomplishments had accumulated, and a glimmer of hope had shown through his body of work.

Spherical wavefronts (surfaces of constant phase) emanating from a point source of light can be assumed for all practical purposes to be plane surfaces over appreciable areas $\pi R^2(x)$ of the tangential plane if the detection of the light takes place at a great enough distance. This parabolic shape (similar to reflection telescopes) guarantees that secondary radiation (detected and emission by electrons within this first Fresnel zone) will have the same phase. This size of this area depends upon the distance from the source x and the wavelength of the radiation λ.



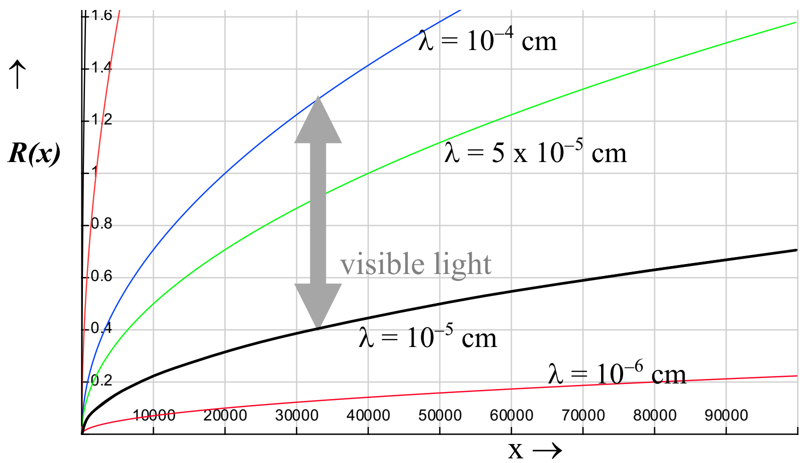
Fresnel interference zones of constant phase on planar surfaces

Coherent interference of secondary radiation had intrigued Ray in courses on opics even while at the university. Constructive as well as destructiive interference occurs when two wave functions with the same wavelength pass a point in space within the 'coherence length' of each wave function; this involves photons with on the order of ten million wavelengths (λ) of the radiation. All electrons that happen to be located within a Fresnel zone will oscilate in phase with the same wavelength as the original radiation.

The radius of the area of the central zone on the plane of constant phase is very dependent on the value of the wavelength. At a large distance $x \gg \lambda$, the radius of the inner Fresnel zone is $R(x) = x \tan\theta \cong x\theta$, for small values of θ, where θ is the angle to the perpendicular of the plane from the source.

$$x / \cos\theta - x \cong x\,(1 - \cos\theta) / \cos\theta \cong \tfrac{1}{2}\, x \sin^2\theta \cong (x\,\theta)^2 \le x\,\lambda / 2$$

$$R(x) = \sqrt{x\,\lambda / 2}$$



$R(x) = R(x\lambda/2)$

Radius of the central Fresnel zone as a function of distance in centimeters

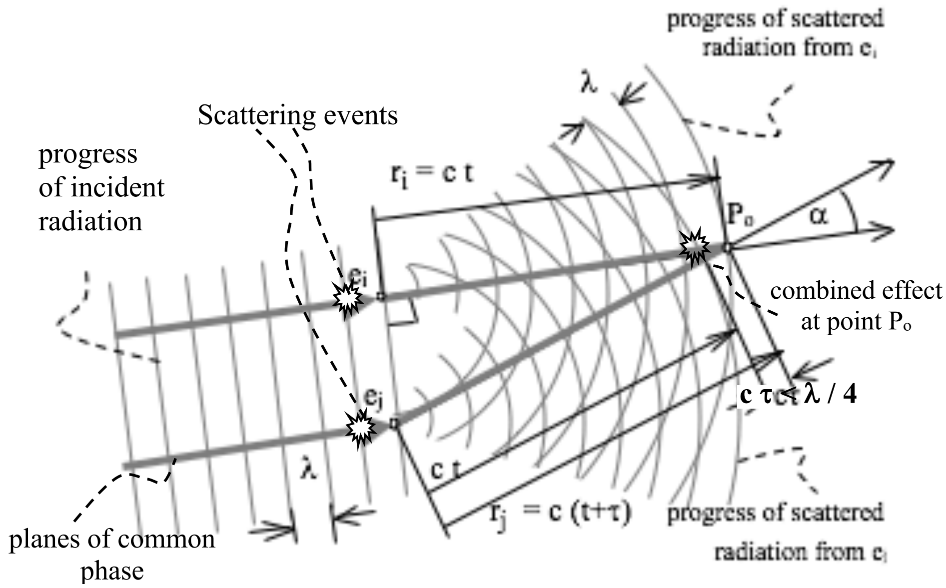
Ray's initial breakthrough had been realizing that however sparse electron density in intergalactic plasma, forward scattering of photons does occur. Tremendous distances to redshifted galaxies accommodate an extremely large number of scattering events in the propagation of a photon from such distant regions of the cosmos to observation here on earth, notwithstanding the fact that individual photon replacement intervals involve astronomical distances.

What is involved in the forward scattering process is that photons are 'cloned' by a replication process – a process formerly thought to be reversible. (Lesa hated his use of the word cloned in this context, but that is what it is.) Any net change in the dynamic state of an ensemble of electrons involved in replication would involve a transfer of energy and momentum from the photon to the electrons. The most famous advocate for this *not* happening was Yakov Zel'dovich who averred that the electrons whose motions are altered in the process must return immediately to their former state after the replication has taken place. In short, that there can be no net transfer of energy or momentum from the photon to the electrons; thus, no red shifting of radiation associated with the scattering process. This opinion became a final nail in the coffin of all so-called 'tired light' theories of cosmological redshift even though initially favored by Edwin Hubble. As proof, Zel'dovich claimed that if he was wrong, the direction of photons would be altered, ultimately blurring and totally obscuring images of distant galaxies after the innumerable replications.

Discrediting Zel'dovich's proclamation would constitute a cosmological breakthrough. Ray had found that mechanism whereby energy and momentum are transferred to scattering electrons that does not alter the direction of the photon despite the decrease in its momentum and energy. The mechanism involves coherent constructive interference of scattered radiation.

Ray's initial intuition was as simple as accepting 'there is no free lunch', that all physical processes must involve energy exchanges. Having written a book on irreversibility with Lesa made that a no brainer in retrospect. He rejected the notion that forward scattering cannot alter the wavelength of the cloned photon. Earlier work by Born and Wolf had been thorough but their analyses leading to that conclusion had not considered relativistic effects.

Kirckoff rigorously refined Huygen's wave propagation process. Electrons along the general direction of a photon's path contribute to the cloning process. Constraints of in-phase coherent reinforcement define a domain throughout which electron scattering contributes to the process. This coherency domain defined by Fresnel zones is the same shape as a domain originating at a point source, a region where plane waves can be assumed rather than spherical wavefronts. Outside of the central Fresnel zone, reinforcement alternates between destructive and constructive so that the net effect is small from outside this region; A line to/from any point in the central Fresnel zone is no more than a quarter wavelength greater in length than along the centerline to the point P_o.

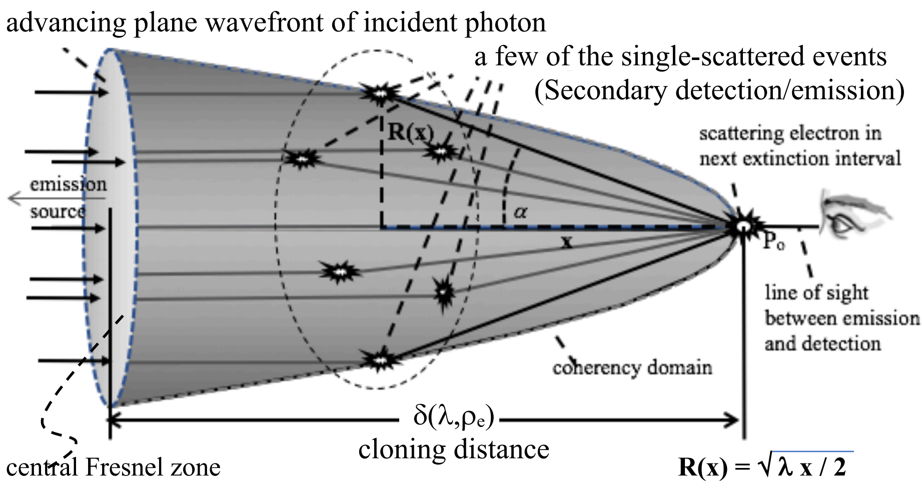


Conditions for in-phase coherent forward scattering

The length of this domain as applied to forward scattering is inversely proportional to electron density and wavelength. This cloning distance is how far light travels in a medium before the speed of light becomes that determined by the density of scattering electrons in the new medium rather than that of the medium it just left. In verifying Einstein's Second Postualte using light from pulsars in globular clusters, this distance was determined to be:

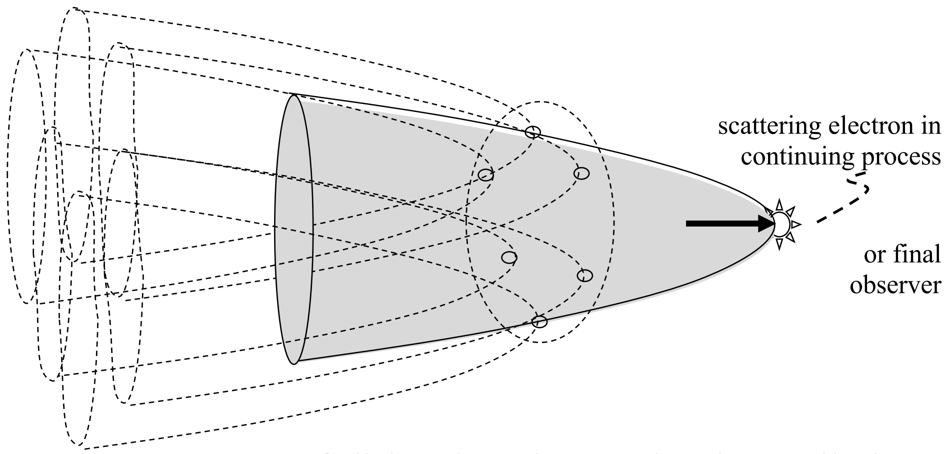
$\delta(\lambda,\rho_e) \approx m_e c^2 / (\rho_e e^2 \lambda) \cong 3.55 \times 10^{12} / \lambda \rho_e$ cm.

Here m_e is the mass of an electron, c the speed of light in a vacuum, ρ_e is the electron density, and λ is the wavelength of the radiation.



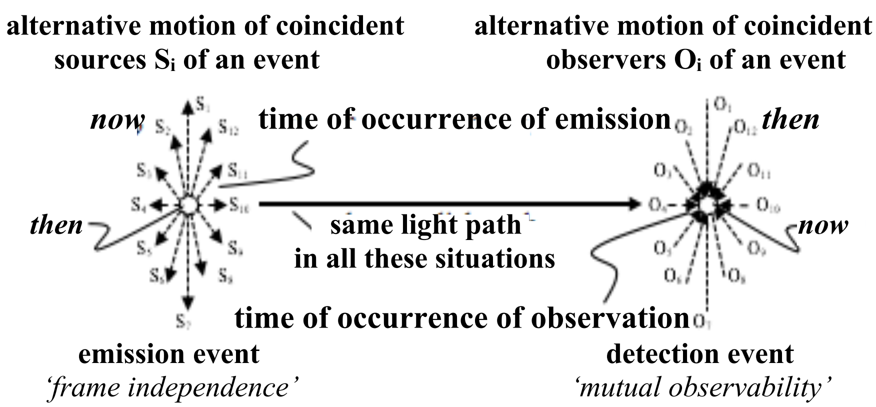
Parabolic coherency domain in a scattering medium

For visible light, the number of electrons involved in a single cloning process in intergalactic plasma is on the order of 10^{36}. It is a continuous process, not discrete, involving all electron in the path of the incident radiation.



Collaborative coherency domain contributions

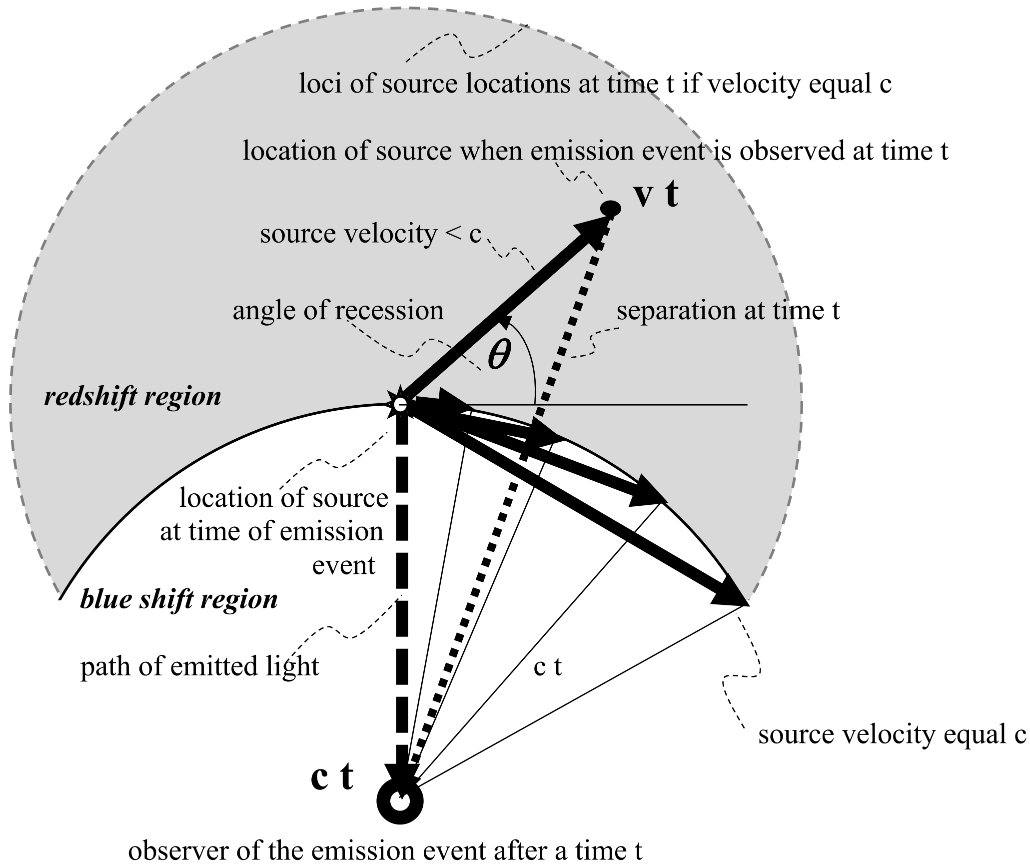
High velocity electrons in a plasma such as the intergalactic medium require a revised conclusion. Interpreting Hubble's discovery of increasing redshift with distance as a Doppler effect of recessional velocities of observed objects had been accepted by default since there had seemed to be no other viable mechanism that produced redshift. However, electromagnetic wave functions induced from high-speed scattering electrons can be shown to have altered wavelengths using Einstein's special relativity that addresses a transverse component. Thus, even without a recessional velocity, induced secondary emissions from electrons (contributors to the cloned photon) are unilaterally redshifted with the cumulative effect indistinguishable from a recessional Doppler redshift of photons emitted directly from the object. His recognition of the mechanism had required Ray's familiarity with relativity. Implicit in the Lorentz equations is the concept of 'frame independence'; it involves the fixing of an emission (of electromagnetic radiation) event relative to the observer's frame of reference independent of the velocity of the source of the radiation that is emitted. Radiation from sources that are in coincidence at the time of the emission event *will appear in the same direction* for an observer – any observer.



'Frame independence' and 'mutual observability' in relativity

The scattering from electrons at or near the plane of common phase of the incident radiation involves a transition of electrons entering, to those leaving, an area of approximate coincidence where secondary emission takes place. The direction from which light is detected will depend upon the velocity of the detecting electron, but the secondary emissions from all. Electrons will be from the same direction at the next step in the propagation process.

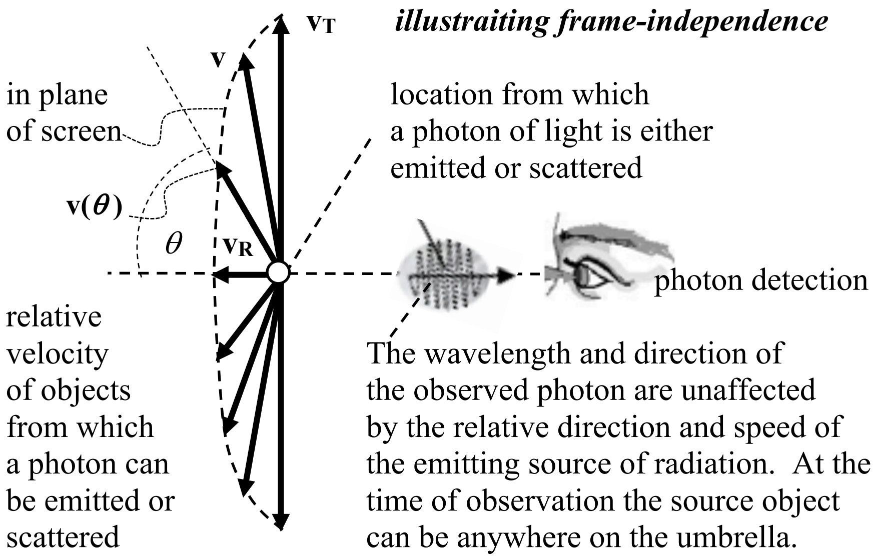
However, the observed wavelength of that radiation will differ depending on the net change in the separation of the emission location and detection location *by the time the observation takes place*. If that distance increases following the emission event in the frame of reference of the detecting electron, then the radiation will be redshifted in proportion to the ratio of the distances. If that distance decreases, then the light will be blue shifted. Lesa had illustrated that effect for him years ago now.



Lesa's diagram showing preponderance of redshifted light

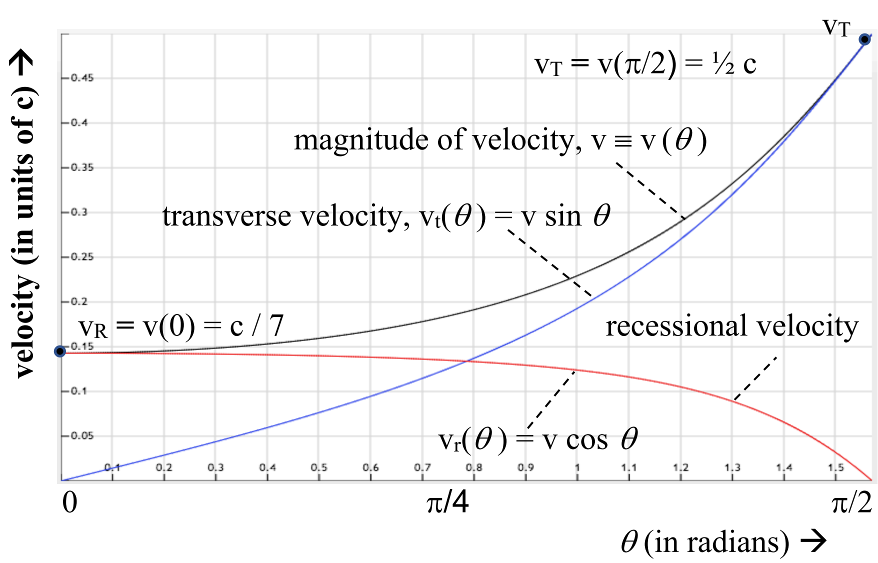
Later she had provided a more specific diagram illustrating the effect of the transverse velocity on scattering electrons and then plotted the equivalence between recessional and transverse Doppler effects. Thus, relativistic phenomena significantly alter the coherency domains for cloning processes. The very concept of relative motion assures us that whether the velocity is considered that of an emitting or of a detecting electron is immaterial; they are one and the same. But the coherency domain is in the frame of the detecting electron so an electron moving parallel to a constant phase plane will detect scattered as well as incident light from the direction of the primary source. This is *not* the aberration effect; it is in the opposite direction and applies to uniquely separate rather than the same locations of coincident emission events.

To convince herself Lesa had produced the diagram aplot that illustrated this phenomenon. The relativistic process is spread out into a penumbra of coordinated coherency domains, whose width is proportional to the velocities of the scattering electrons. There is a convergence of scattered wave functions associated with the photon such that Zel'dovich is both correct and incorrect as far as his assessment of scattering in an intergalactic plasma medium. There is a momentum exchange and there is a bending of each light path, but because it is convergent rather than divergent, there is no net change in direction.



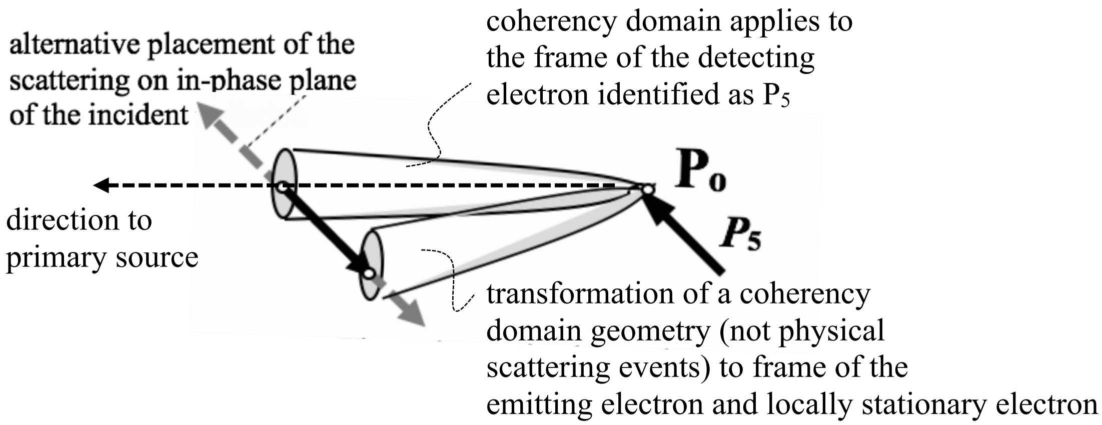
Indistinguishability of Doppler redshift of an emitted photon caused by variously directed velocities of a source (whether primary or secondary)

Redshift: $Z(v(\theta)) + 1 = (1 + (v(\theta)/c)\cos\theta) / (1 - v(\theta)^2/c^2)^{½}$

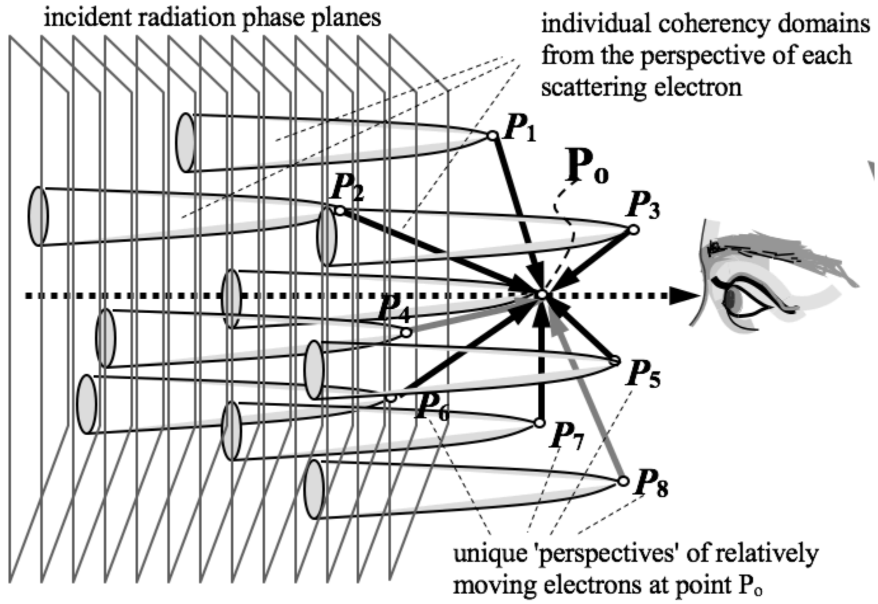


***Range of electron velocities with a redshift that is indistinguishable from a strictly recessional (θ = 0.0) velocity* v_R**

The 'bending' is relative to the perpendicular to the 'locally stationary' planes of constant phase of the incident radiation. These planes are fixed relative to the frame of the primary source of the radiation. This is equally true in the frame of the ultimate observer if the primary source is stationary with respect to the ultimate observer. The conservation laws to which Zel'dovich deferred are essentially those that pertain to the Compton scattering effect of energy and momentum being transferred to electrons.



Different perspectives of a coherency domain for scattering electrons



Composite of coherency domains for scattering electrons with various relative velocities to the line of sight to primary source

The rationale for the extreme electron velocities involves thermodynamic issues. The Maxwell/Boltzmann distribution of energies in a thermal plasma specifies the average root-mean-squared transverse velocity component $< v_e^2 >$ of electrons. The classical formula is:

$$\sqrt{< v_e^2 >} \approx \sqrt{3/2\, k\, T / m_e} = 4.77 \times 10^5 \sqrt{T} \quad \text{cm/sec}$$

The constant k is Boltzmann's constant and m_e is the mass of an electron. This solution is valid for temperatures T to about 10^8 K which is a nominal value encountered in intra-cluster plasma, this non-relativistic formula provides a fairly accurate approximation up to two or three percent of the speed of light.

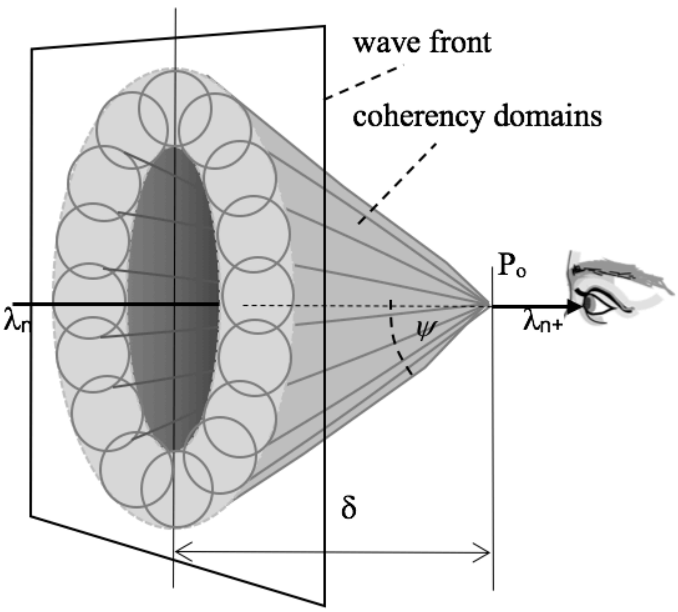
It is the bending of the light path that transfers energy and momentum to the medium as Zel'dovich averred. So the length of the coherency domains δ affects a change in wavelength along a light transmission path. Applying the results of Compton's conservation analysis to coherency domains of forward scattering, one obtains the following net change in wavelength per cloning interval:

$$\Delta\lambda_\delta \approx 3\,h\,k\,T / 4\,m_e^2\,c^3 \approx 3.07 \times 10^{-20}\ T\ \text{cm}$$

The constant h is Planck's constant. Thus, wavelength is increased at every cloning interval independent of wavelength, but that is not in itself a redshift. The accumulated change in wavelength divided by the wavelength from the primary source emission can be determined by regression as follows:

$$\lambda(n) = \lambda_s + n\,\Delta\lambda_\delta > \cong \lambda_s\,(\,1 + n\,3.07 \times 10^{-20}\ T / \lambda_s\,)$$

$$Ƶ(n, \lambda_s) = (\,\lambda_n - \lambda_s\,) / \lambda_s \cong n\,3.07 \times 10^{-20}\ T / \lambda_s$$



Convergence of secondary radiation at cloning event that constitutes Zel'dovich's 'bending' of the light path without changing direction

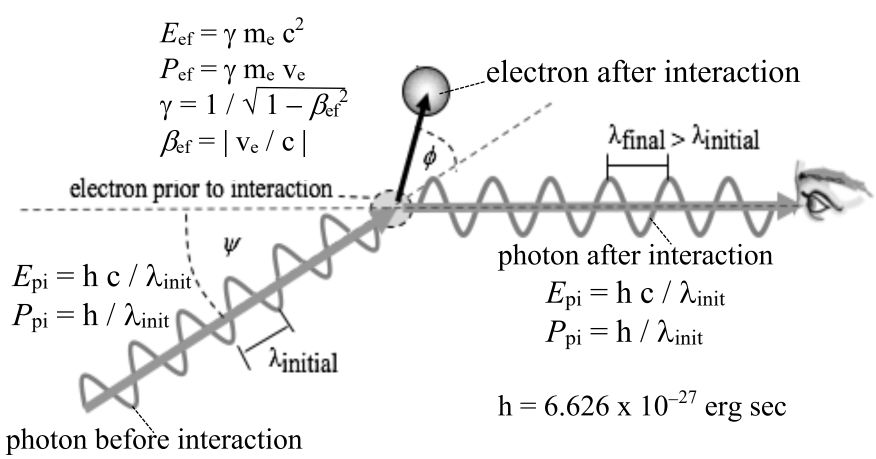
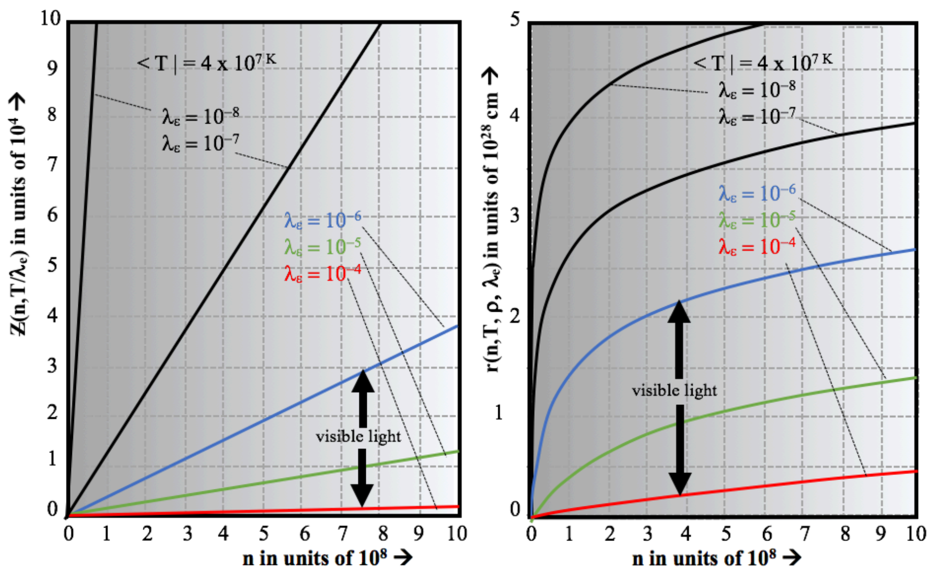


Illustration of similarity to Compton scattering conservation relations

As seen in the plots, this does not provide a redshift-distance relationship per se. To demonstrate the relationship of distance to the change in wavelength the distance r(n) as a function of the number of cloning intervals n must be established. But because the length of ethese intervals depends upon the wavelength entering the interval, r(n) becomes a summation of the lengths $\delta(\lambda)$ that are continuously changing rather than just the total number of intervals N times a uniform length. The length of a coherency domain is also dependent on the free electron density as defined earlier. Because of the inverse relationship to wavelength, the net result is dependence on wavelength that does in fact constitute a redshift. Using formulas derived in the previous chapter for the length of the extinction interval, we obtain:

$$r(N) = \sum_{n=0}^{N} \delta(n,\lambda(n)) \cong (3.55 \times 10^{12} / \rho_e(n)) \sum_{n=0}^{N} 1/\lambda(n)$$



'Redshift and distance versus number of cloning intervals

In the limit as the number of extinction intervals becomes very large, the following mathematical formula applies:

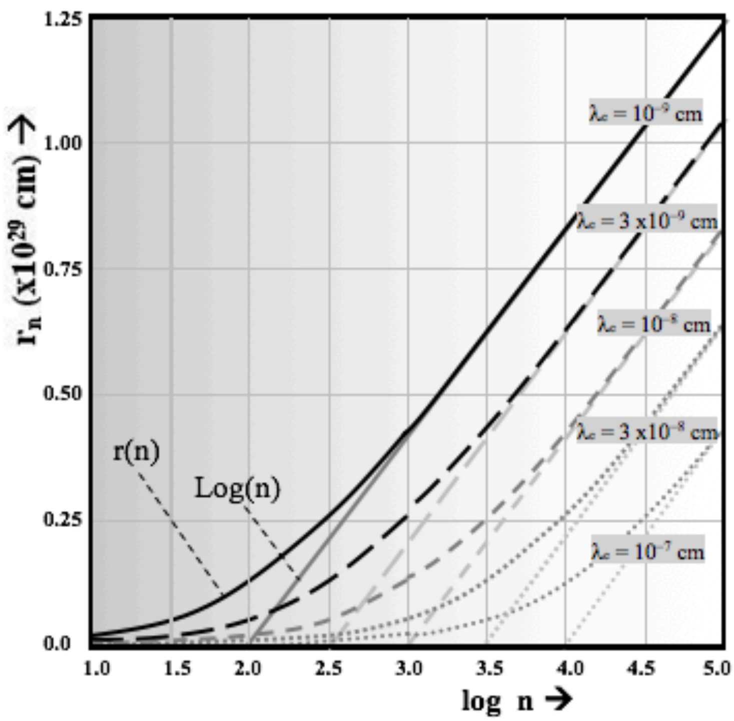
$$\lim_{N \to \infty} \sum_{n=0}^{N} 1 / (1 + A\,n) = A^{-1} \ln(1 + A\,N)$$

And thus, one obtains:

$$r(N) = [1.156 \times 10^{32} / T_e\, \rho_e] \log(1 + N\, 3.07 \times 10^{-20}\, T_e / \lambda_e)$$

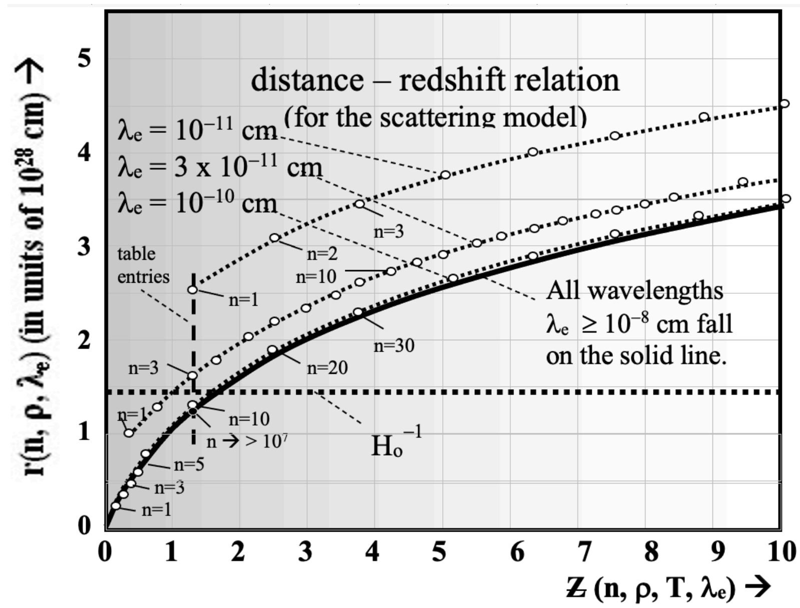
The curves of r(n) vs. n are plotted for the averaged dynamic pressure of free electrons $\langle T_e | \rho_e \rangle$ determined by averaging the product of T_e and ρ_e at each point along the transmission path. If we plot r(n) vs. log n we obtain the plots below with an asymptotic approach to linearity on a log graph.

In situations for which merging the functionalities of r(n) and Ƶ (n) is warranted, one obtains a distance-redshift relationship by plotting one versus the other. When one does that, the dependence on number of cloning intervals n is eliminated. Since distance is a linear function of the log of n for large n but inversely dependent on emission wavelength, the distance versus redshift plot is *extremely* similar for all values of wavelength. It is a virtually identical relationship that holds from hard X-rays ($\lambda_e \approx 10^{-9}$ cm) through extremely long wavelength radio signals ($\lambda_e > 10^7$ cm). In this way, at shorter distances we obtain a linear recessional-Doppler-like distance-redshift relation directly applicable to this broad range of wavelengths. It can easily be seen that the wavelength dependence is virtually eliminated for wavelengths greater than 10^{-10} cm. It is also clear that for wavelengths less than 10^{-9} cm, there is a unique relationship that pertains at every wavelength.



The logarithmic form of the relationship between distance and number of cloning interval

number of extinction intervals, n	initial wave-length, λ_e (cm)	redshift, Z_n (unitless)	distance, r_n x 10^{28} (cm)	ratio, Z_n / r_n x 10^{-29} (cm)
1	10^{-11}	1.268	2.560	4.592
3	3 x 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

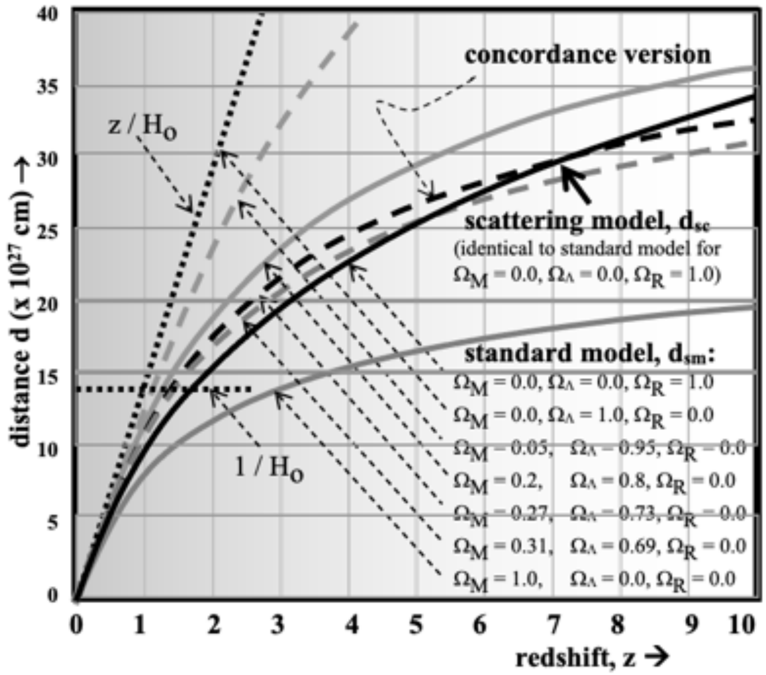


The emergence of a distance versus redshift relation for the scattering model independent of wavelength over a broad range

Ray guessed that this refresher course in the cosmology of Raymond F. Bonn was just his personal version of stations of the cross although he acknowledged that his had more stations than the Catholic observance, his uncapitalized 'all-embracing variety of things' – the universe. Having just strolled down the hallway of his own personal Vatican noting the statues, murals, and hangings on the way, Ray was now in his own little Sistine Chapple. He saw himself as on the ceiling reaching for significance. Beside him Lesa was on his arm sleeping soundly; he longed for her as a more constant companion, taking a more active part in their search for scientific truth. Before all his other digressions into the status of his opus he had first been awakened thinking about an alternative to dark matter, evidenced by the 'fingers of God' phenomena. He guessed it was because he was thinking about this on his own and had not yet broached the subject of what he was trying to work out with Lesa. He might do that in the morning. He had been withholding information, he guessed, but she was too damned fast. Sometimes she dismissed his ideas without first convincing him that they were not viable.

As so often happened ideas would come to him in the night. It was still just as it had been with Helen, he would pursue his lonely thoughts on the nature of reality until implications got too entwined to maintain in a sleepy brain without having written them down. So he got up gently now without waking Lesa. He'd work for an hour or two before coming back to bed. It was how he kept his place in the long list of complex thoughts so that he wouldn't have to work his way up that same slippery slope over and over again on other sleepless nights. Metaphors be damned.

Ray had followed developments of cosmology throughout most of his life including the emergence of a 'concordance' model employing the parameter values that accommodated a closest fit to the actual observations of redshift of the increasingly distant galaxies. Of primary importance to the standard model in this regard is the overall density of the universe which Einstein related to its rate of expansion in accord with his general theory of relativity. Observations were roughly compatible with a value determined by Hubble's constant of expansion rate. There had been what Einstein had admitted as his 'most egregious error' that Hubble's expansion explanation exposed for what it was, and then a 'missing mass problem' for a time, which then was 'corrected' by the supposition of 'dark matter' that resurrected Einstein's erroneous constant without evoking embarrassment or shame for some odd reason. Ultimately the density of the universe denoted by the symbol Ω became characterized by three density parameters: Ω_m the density of 'ordinary' luminous baryonic matter that we've known about since Mendeleev, Ω_Λ, the density of dark matter accommodating the symbol of Einstein's greatest error, and Ω_R a density of an even more totally mysterious dark energy.



Predicted line-of-sight distance r_{sm}[Ƶ] versus redshift for various density parameter values in the standard model are plotted. Also included is the plot for r[Ƶ] in the scattering model.

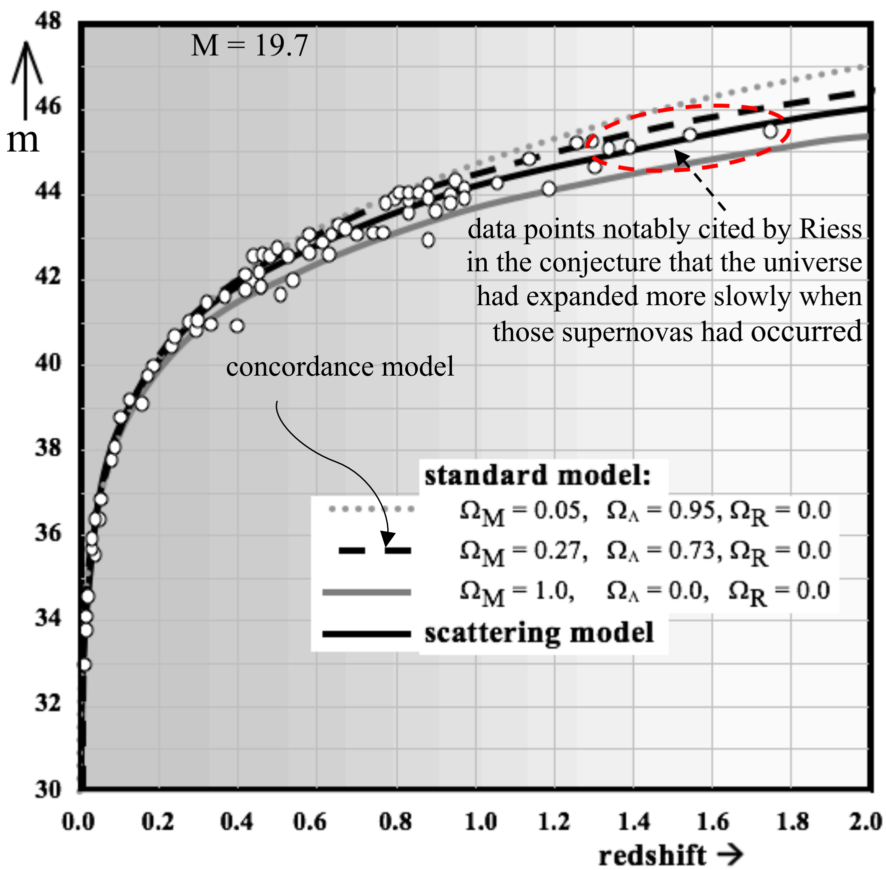
The results of the scattering model were extremely similar to that of the 'concordance' model out to appreciable redshifts. One can plot predictions out to large redshifts, but the data does not support comparison even out to a redshift of unity because the luminosities of galaxies (as great as they are) are insufficiently bright to get more accurate data. There are multiple metrics used in cosmological investigations, most of them designed to assess which density parameter values provide the best fit to actual data. Ray's model based on his scattering mechanism required only the free electron density and temperature profiles of intergalactic plasma. The product of those two parameters accommodates a best fit to observations. Primarily *only* the average of the product of the two parameters (proportional to the hydrostatic pressure) over all space, affect the performance of the model. He had plotted comparisons with different values of this product, determining ultimately a value of about 4 x 10^3 K/cm^3 that produced a redshift very close to the concordance version of the standard model out to a redshift $Z \cong 0.6$ or more.

But variations of temperature and density result in local variations in the redshifting of light passing through these regions. In particular, the tremendously increased hydrostatic pressure in galaxy clusters which results in greatly increased redshifting through the central regions of clusters where galaxies 'cluster'. This phenomenon produces the intensified redshifting denominated 'fingers of God' in redshift surveys. The effect was first attributed to 'dark matter' by Fritz Zwicky using the virial theorem to determine how much additional unobserved mass would be required to produce such extreme Doppler redshifting. Ray's scattering model did a better job with no such deus ex machina required.

Then along had come Riess et al. with their audacious conjecture for which Riess received the Nobel prize. Their claim was that the universe had somehow suddenly accelerated its expansion with no clear reason given. This had supposedly occurred at some point in the distance/past before a redshift of Z = 1.0. This determination seems to have been based solely on the fact that observations of type 1-A supernovas no longer supported *any* of the versions of the standard model without introducing the additional fudge factor of expansion having suddenly accelerated. This deus ex machina appalled Ray as had so many previous kludges that had been integrated into the standard model just to salvage the presumption of an expanding universe; each was staged as a part of what is considered by the cosmologist's community to be an evolving universe. Ray saw it more as an evolving rationalization.

Reiss's explanation involved the quality of the fit between the concordance model and SN1A supernova luminosity data. When the data and versions of the standard model and Ray's scattering model were plotted, it was clear that no version of the unmodified standard model matched the data – the data points beyond the redshift of Z = 1.2 clearly did not fit the concordance or any other of the standard model variations, but they fell precisely on the plot for the scattering model.

The cosmic microwave background radiation was another difficulty Ray encountered as what was considered to be an 'irrefutable' argument that there had to have been a Big Bang, which would have to have emitted high energy radiation associated with annihilation of whatever superfluous antimatter was created by whatever presumed quantum 'fluctuation' had brought about an origin of the universe. Expansion would have reduced the temperature of the radiation, presumably down to the current microwave background radiation temperature of 2.728 Kelvin. But when analyzed, that explanation evaporated.



SN1A supernova luminosity magnitude data with model predictions

Ray refreshed his memory of the finding of Wagoner, Fowler, and Hoyle from their seminal paper in 1967 which had solidified the understanding of the creation of the light elements. He scrolled though his file to where he had quoted from pages. 23 and 24 of that paper. He read it again:

> "… we do think it worthwhile pointing out the following remarkable coincidence. The average spatial density of galactic material is ~ $3 - 7 \times 10^{-31}$ gm cm^{-3} (Oort 1958). Of this, about one third is probably helium, giving an average helium density of ~10^{-31} gm cm^{-3}. Since the conversion of 1 gm of hydrogen to helium yields ~ 6×10^{18} ergs, the average energy production – if helium has come from

hydrogen – has been ~ 6 x 10^{-13} ergs cm^{-3}. This energy density, *if thermalized*, would yield a temperature of just 3° K. Because in a cosmological expansion baryon density decreases as R^{-3} while the radiation density decreases as R^{-4}, the coincidence is an accident if the 3° K is a relic of a cosmological fireball. On this view the expansion factor R has increased since the fireball by a factor of 10^9 so that no such coincidence could have obtained over most of the expansion. It would be an accident of the present epoch. This is not the case if the observed radiation results from the thermalization of energy from the recent hydrogen to helium conversion in stars."

More recent, and much more accurate, data on the temperature of the radiation (2.728 K) and percentage of helium throughout the universe (23% by mass) alters the numbers in their conclusion slightly. But the degree of the precision of the coincidence is even more compelling. It reduces the Wagoner et al. estimate of the density of energy in the microwave background to 4.08 x 10^{-13} ergs per cm^3. Accurately measured energy in the background radiation is precisely 4.169×10^{-13} ergs per cm^3. Coincidences like these do not happen in nature without a clear logical explanation.

The standard model had adopted a supposed intermediate staging when matter and radiation became 'decoupled' after which radiation (as if from a surface) became cooled by recessional Doppler (of that 'surface') associated with expansion. About 300 years after the supposed Big Bang thermodynamic temperature was assumed to have been reduced to 3,400 K at a redshift of about 1,200. Why those numbers? An artificial coincidence established to accommodate the narrow and inaccurate explanation of photons never being scattered again until they are observed here on earth – or by orbiting instruments. But photons are, in fact, scattered continually throughout their propagation in any medium – in this case supported by the hydrostatic pressure of the intergalactic plasma medium pervading all galaxy clusters and their neighborhoods throughout all epics.

These thoughts were comfort zones for Ray. But increasingly he was just reviewing concepts with evident pleasure rather than extending them. He had become increasingly aware that his creative abilities were waning. He could still recognize good ideas, but he seemed to be unable to come up with them on his own. Lesa had thus become ever more important to any scientific achievement he could be a party to. It was usually at about that point in his nocturnal thought processes that he would become aware of the time and that he had been up for too long. He would head back to the bedroom defeated, slip under the covers as gently as he could, to sleep a few more hours before his day began in earnest.