A Thermodynamic Explanation of the Cosmic Background Radiation in a Stationary State Universe

by R.F. Vaughan

Abstract The observed temperature of the cosmic microwave background (CMB) radiation is commonly interpreted as relic emitted from an early phase of the universe, redshifted now by cosmic expansion. This paper offers an alternative, thermodynamically grounded explanation that requires neither an expanding spacetime nor a surface of last scattering. It is a stationary-state model of the universe as it is, composed primarily of hydrogenous plasma and organized into gravitationally bound galaxy cluster cells. We demonstrate how redshift, optical depth, and the lack of uniformity in the hydrostatic clustering of intergalactic plasma all interact to yield the observed CMB temperature of 2.728 K—this despite what would otherwise be a much lower average kinetic energy density of a uniform plasma gas. The model provides a consistent explanation for the disparity between expected kinetic and observed radiant energy densities and offers a reinterpretation of the Hubble constant as an essential property of radiative propagation.

1. Introduction. A conventional "big bang" explanation of the CMB posits an early hot phase followed by adiabatic cooling and decoupling at a redshift of ~1200. The observed radiant energy density of the CMB greatly exceeds the kinetic energy density of baryonic matter one would expect, if one used the product of the averages of plasma temperature and density of the current universe. This disparity of six orders of magnitude contradicts usual thermodynamic principles, but it is explained by the difference in the average of a product and a product of averages with temperature and density varying synchronously through extreme ranges. Figure 1 depicts the dilemmas of competing the conjectures.

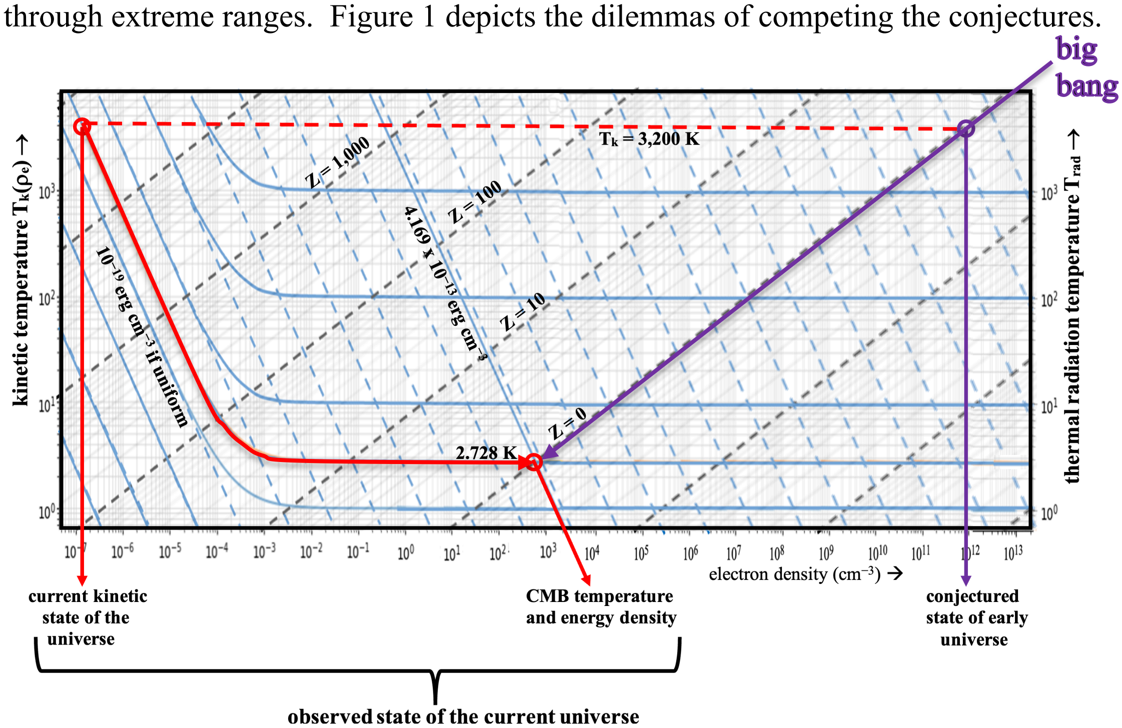


Figure 1: Competing conjectures to account for the observed CMB

In this paper, we advocate for a stationary-state thermodynamic model that avoids the cosmological expansion of the standard model and instead treats the current universe as a globally uniform but locally inhomogeneous plasma gas. In this model, observed CMB arises, not from a primordial surface, but from the cumulative redshifting of photons as they are forward scattered through extensive distances of hot, inhomogeneous plasma.

2. The Plasma Structure of the Universe. We assume a universe of baryonic matter that is predominantly hydrogenous plasma organized into galaxy cluster cells, each roughly a Jeans length in radii (~20 Mpc). The plasma within each cell is non-uniform, with hot, dense cores and cooler, sparse peripheries. The cells are packed in a voronoi tessellation; inter-cluster boundary surfaces are characterized by gravity and thermodynamic pressure minima.

While the average baryon density $\langle \rho_e \rangle$ and kinetic temperature $\langle T^k \rangle$ may be relatively modest, the average of their product $\langle \rho_e T^k \rangle$ out to the boundary of each structure is significantly elevated due to the nonlinear weighting of density and temperature toward cluster cell centers. This is illustrated in figure 2 for a representative cluster cell.

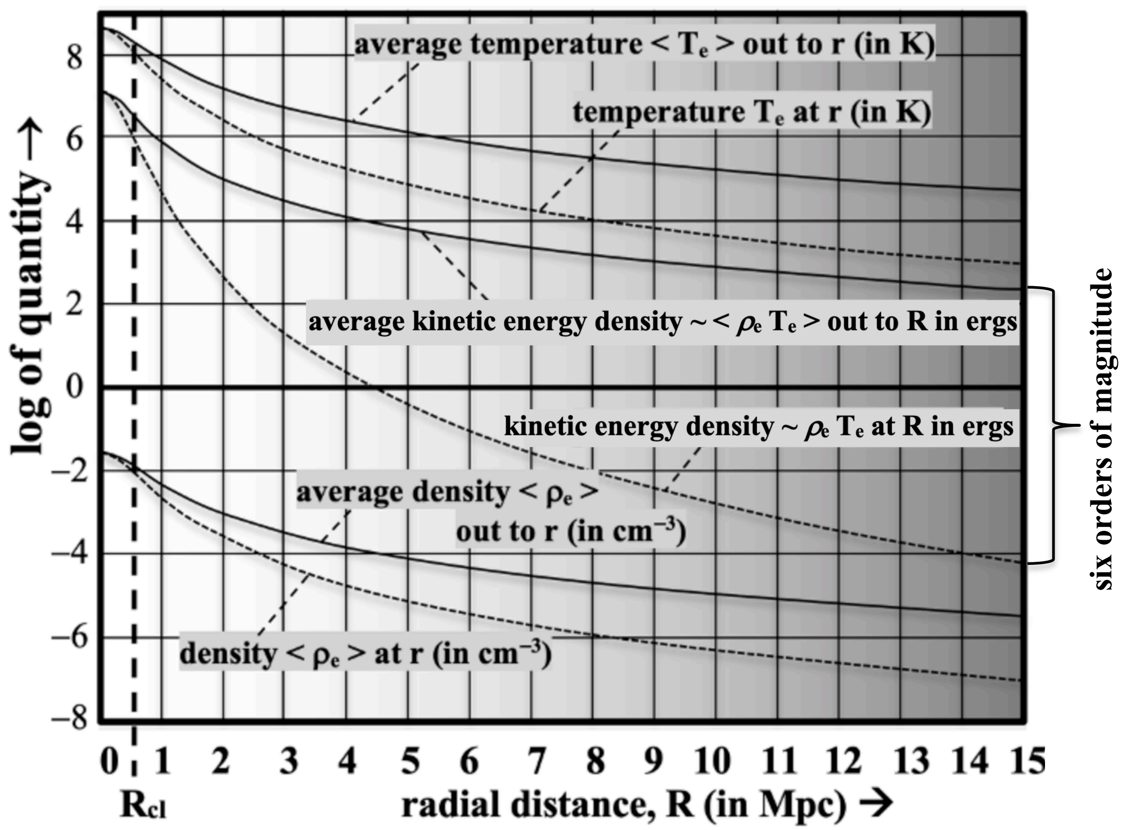


Figure 1: Representative functionality of plasma gas properties in galaxy cluster cells

Based on intergalactic observations and thermal modeling of plasma within galaxy clusters [Yan-Jie Xue , Xiang-Ping Wu (2000), and Motokazu Takizawa (1998)], we adopt an average free electron density of $\langle \rho_e \rangle \approx 2 \times 10^{-7}$ cm^{-3} and a kinetic temperature of $\langle T^k \rangle \approx 3.4 \times 10^3$ K across the observable universe. These represent of plasma gases averaged over galaxy cluster cells and are consistent with known cluster hydrostatic profiles. The average of the product of coincident values of kinetic electron temperature and density, $\langle \rho_e T^k \rangle$, is used throughout this analysis to quantify kinetic energy density and (ultimately) redshift potential.

3. Kinetic vs. Radiant Energy Densities. In a uniform plasma, the average kinetic energy density would be:

$E_{k,uniform} = (3/2)\, k\, \langle T_k \rangle \langle \rho_e \rangle \approx 2 \times 10^{-19}$ erg/cm³

In a uniform or otherwise isolated environment, the equipartition of energy requires:

$$\underbrace{\text{kinetic energy}}_{(3/2)\, k\, \rho_e T_k} = \underbrace{\text{radiant energy}}_{7.56 \times 10^{-15}\, T_k^4}$$

However, as shown in figure 2, concentrations within cluster cells increases the energy density, such that, $\langle \rho_e T^k \rangle >> \langle \rho_e \rangle \langle T^k \rangle$, with the actual kinetic energy density being:

$E_{k,nonuniform} = (3/2)\, k\, \langle \rho_e T_k \rangle \approx 4 \times 10^{-13}$ erg/cm³

This disparity (a factor $\sim 10^6$) is a direct result of structure in the universe; it reconciles the observed radiation energy density with observed kinetic energy density. However, (let us pretend it is mysteriously) the temperature of the observed radiation is three orders of magnitude less than the average kinetic temperature.

$E_{rad} \approx 4.2 \times$ 10^-13 erg/cm³ for T = 2.728 K

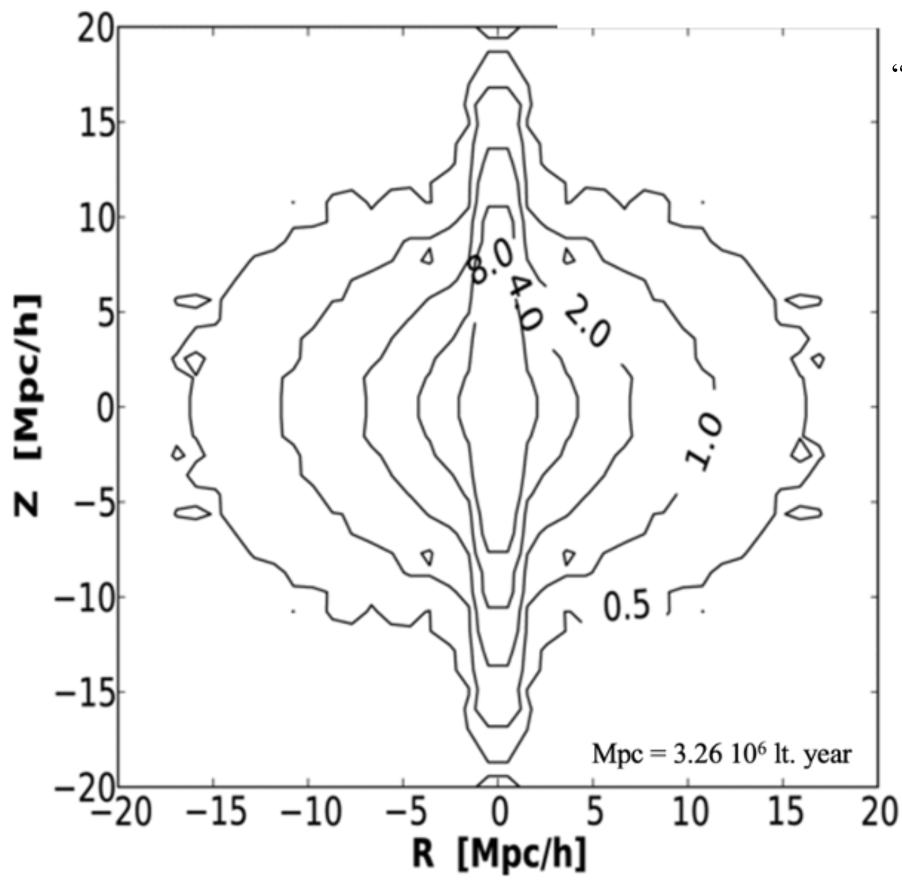
Having solved the energy disparity, we are left to resolve the temperature disparity.

4. Redshift in a Structured Plasma Medium. In this stationary-state model, redshift arises not from cosmic expansion, but from the cumulative effect of forward scattering by electrons in a hot, ionized plasma. This mechanism is described in a companion paper. Unlike in static dielectric media, plasma electrons have appreciable thermal velocities. Although any redshift or blueshift of secondary scattered radiation, due to radial components of the motion, cancels over the long propagation paths, transverse components of these thermal motions of electrons exhibit relativistic Doppler effects that introduce a unilateral redshift after propagation through many extinction intervals.

An incident photon induces numerous forward-scattering interactions whose secondary radiations ultimately replace the incident photon with a cloned copy after passing through a distance (extinction interval) determined by the electron density. Frame independence of relativity theory informs us that the angularly converging secondary wavefront will retain coherence. This angular convergence at each interval accommodates a momentum transfer without producing image blurring that had famously concerned Yakov Zeldovich with regard to any possible ‘tired light’ theory. The length of the extinction interval is determined by the electron density, and the photon wavelength. There are incremental wavelength increases in the secondary photon emerging from each interval. The increment is proportional to the convergence angle resulting from the local plasma temperature; it is miniscule over a single interval but unilaterally positive. And since extinction intervals become shorter with longer wavelength (due to λ^{-2} dependence in scattering), the cumulative effect of the increments is a distance-dependent redshift. Over many such intervals, the integrated redshift grows exponentially with propagation distance, d as:

$Z \sim \exp(H_{eff}\ d)$,

where H_{eff} is an effective Hubble-like constant proportional to $\langle \rho_e\ T^k \rangle$, averaged along lines of sight. This dependence produces the 'redshift-correlation contours' surrounding galaxy cluster cores evident in the BOSS data [White et al. 2011]. Refer to figure 3 taken from White with their description.



"Contours of the redshift-space correlation function, ξ(*R*, *Z*), for our 0.4 < *z* < 0.7 galaxy sample (see the text). Note the characteristic elongation in the *Z* direction at small *R* (fingers-of-god) and squashing at large *R* (super-cluster infall). [This] panel shows the results from the BOSS data."

Figure 3: Redshift-space correlation function in cluster cells (aka 'dark matter halos')

When averaged over all space this mechanism reproduces the familiar exponential redshift-distance relation without invoking spacetime expansion. This redshift naturally connects the radiation background temperature with thermodynamic conditions of the intergalactic plasma, similar to how that is described for the standard model. But this, however accurately observed temperature, is still somehow disassociated with the observed baryonic matter density of the universe. That is the remaining challenge.

5. Sky Cover and Optical Depth in Baryonic Plasma. In any medium without a rigid surface, such as the intergalactic plasma, radiative closure depends on the cumulative cross-sectional area of particles along lines of sight. This 'sky cover' determines whether the thermodynamic condition of radiative equilibrium can be attained. In dense solids, complete closure occurs rapidly. In tenuous plasma, closure occurs only after light has traveled a sufficient distance through the medium for the cumulative cross-section of emitters and absorbers to statistically encompass the observer's view.

We define the fractional closure a(r) at distance r by the probability that a line of sight intersects the cross-sectional area of an electron within that radius. For a homogeneous distribution of scattering centers with density ρ_e and cross-sectional area σ, define:

$$\eta = \sigma \langle\rho_e\rangle \cong 10^{-31}\ \text{cm}^{-1}$$

Then the fractional closure is:

$$a(r) = 1 - \exp(-\eta\, r)$$

The optical depth, τ, is defined by $\tau = \eta^{-1} \cong 10^{31}$. Radiation intensity is reduced to 1/e of its initial value after propagating to this distance. Given $H_o \cong 7.3 \times 10^{-29}$ cm^{-1}, this makes the optical depth roughly a thousand times larger than the radius of the universe accepted by the standard model.

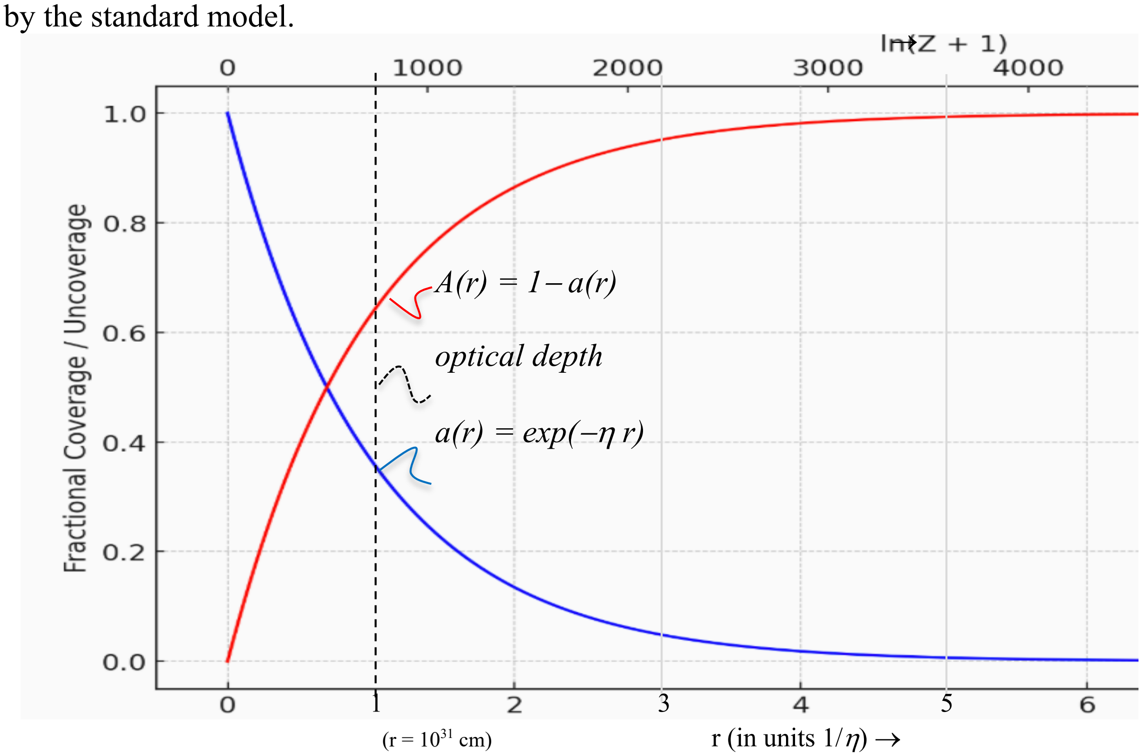


Figure 4: Sky cover and optical depth

This formulation provides criteria for whether a plasma medium will yield blackbody-like radiation spectra. With the kinetic temperature profiles the same for cluster cells throughout the universe, sky cover closure will not in itself alter the observed radiation temperature:

$$T_{rad\_obs} = T_{rad\_emit} \int_o^{\infty} \eta\, e^{-\eta r}\, dr = T_{rad\_emit}$$

However, when we include redshift as a function of distance, $Z(r)+1= \exp(H_o r)$, the integration of Wien's law must be altered by this weighting factor:

$$T_{rad\_obs} = T_{rad\_emit} \int_o^{\infty} (1/Z(r)+1)\ \eta\, e^{-\eta r}\, dr = T_{rad\_emit}\ \eta \int_o^{\infty} e^{-(H_o + \eta) r}\, dr = T_{rad\_emit} / (1 + H_o/\eta)$$

So redshift in conjunction with sky cover does have a major effect when η is significantly less than H_o, Hubble's constant. And this occurs when,

$$\rho_e \le H_o / \sigma \cong 2 \times 10^{-4}\ cm^{-3}$$

This becomes a constraint on cosmological thermodynamic analyses. This was illustrated in the log-log grid used in figure 1 where the relationship between kinetic and radiant temperature is not one-to-one. It is why (as in 'how') the CMB temperature differs so appreciably from the kinetic temperature of baryonic material aspects of a stationary state universe without implying the unrealistic electron density of 744 cm^{-3}.

6. Conclusion

This paper offers a thermodynamic explanation of the cosmic microwave background radiation based on a stationary-state universe filled with non-uniform baryonic plasma. We focus on the combined effects of kinetic energy density, redshift through forward-scattering by free electrons with relativistic velocities, and cumulative optical depth. We derive an internally consistent model that replicates observed CMB properties compatible with current intergalactic realities without invoking a primordial hot phase or spacetime expansion.

The disparity between kinetic and observed radiant energy is resolved by nonlinear averaging of density and temperature across cluster cell structures. We show that the incremental wavelength increases in secondary radiation through wavelength dependent extinction intervals, produce an exponential redshift–distance relation akin to the Hubble law but rooted in local thermodynamic interactions. Weighting the temperature reduction effects of redshift by an exponentially increasing sky cover reduces background temperature compatible with the current electron density.

While this model accounts for the observed CMB temperature and redshift-distance relation, it remains to fully investigate compatible nucleosynthesis predictions and large-scale structure formation. Nevertheless, the thermodynamic consistency and observational congruence of the model invite further exploration of stationary-state plasma cosmology as a viable alternative to expanding-universe paradigms.

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