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JWST Timing Constraints in a Non-Expansion Redshift Framework

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Abstract

This work examines limited, testable consequences of a previously established background level redshift framework in which frequency-independent redshift is described by collisionless Liouville evolution without requiring metric expansion. It does not propose a new cosmological model, nor does it address structure formation, recombination microphysics, or the CMB power spectrum. The framework does not exclude a hot dense initial state; a recombination epoch is treated as a thermal threshold event compatible with both expansion and non-expansion interpretations of subsequent redshift. Treating an illustrative post-recombination relaxation form for the redshift kernel as a concrete hypothesis, this analysis shows that the parameterization predicts reduced cosmic assembly time at $z \gtrsim 10$ relative to standard ΛCDM. Observations of early massive galaxies by JWST therefore act as an empirical constraint on the relaxation timescale and initial kernel rate, bounding the allowed post-recombination dynamics rather than resolving timing tensions. The paper further proves that frequency-independent redshift operators preserve angular multipole structure, once present, under collisionless evolution, strictly at the level of transport, establishing that the existence of CMB anisotropies alone does not logically discriminate between expansion and non-expansion redshift mechanisms at the level of angular transport. The analysis concludes by clarifying the precise observational content of CMB background and anisotropy data, explicitly delineating which inferences are supported and which require additional dynamical assumptions.

Keywords

Cosmological Redshift, Cosmic Microwave Background, JWST Galaxy Timing, Collisionless Liouville Transport, Angular Multipole Preservation

1. Introduction

A published analysis established that the cosmic microwave background blackbody spectrum, its temperature redshift scaling, and photon number evolution can be reproduced under a frequency-independent redshift kernel $K(t)$ without invoking metric expansion [1]. That work demonstrated exact Planck preservation under collisionless Liouville evolution, enforced $\mu = 0$ as a consequence of frequency-independent transport, and introduced an illustrative post-recombination relaxation form for the kernel dynamics. Within the same framework, background level consistency with luminosity distance relations, time dilation, and Tolman surface-brightness dimming was demonstrated observationally. Together, these results address classical background objections at the level of photon-sector observables that historically excluded non-expansion interpretations of cosmological redshift. The present paper does not extend those results into a complete cosmological model. It instead examines limited, testable consequences of the established framework by confronting it with observational data, proving formal transport results where possible, and explicitly identifying inference boundaries beyond which additional dynamical assumptions are required.

The objective is to determine precisely what current observations do and do not logically require once a frequency-independent redshift mechanism is admitted at the background level. The work is deliberately restricted in scope. It addresses only background level phenomenology and the collisionless transport of angular structure in the photon distribution. No attempt is made to derive structure formation, recombination microphysics, primordial nucleosynthesis, or gravitational dynamics. The framework does not exclude a hot dense initial state; a recombination epoch is treated as a thermal threshold event compatible with both expansion and non-expansion interpretations of subsequent redshift. These topics are excluded explicitly. Where observational constraints depend on baryonic evolution, gravitational instability, or nonlinear growth, they are identified as external to the present analysis and treated as future discriminators rather than deficiencies. Within this limited scope, the goals are threefold. First, the framework is tested directly against observational data by treating the previously introduced kernel dynamics as a falsifiable hypothesis rather than an adjustable explanatory tool. Second, logical discriminators are examined explicitly, in particular whether the existence of CMB anisotropies constitutes, by itself, a necessary implication of metric expansion. Third, the paper formalizes inference boundaries by clarifying which observational statements follow from background thermodynamics and transport alone, and which require additional theoretical commitments.

The kernel $K(t)$ is treated as an effective description of photon-sector evolution after decoupling, with no assumed microphysical or gravitational origin specified in the present work; its role is strictly operational, mapping emission and observation frequencies under collisionless transport, while detailed derivation and physical motivation are given in [1]. The analysis presented here is explicitly terminal with respect to this line of inquiry, and no further extensions of the program are pursued after this paper. The stopping condition is stated unambiguously: if early-universe observations such as JWST timing impose empirical constraints on kernel dynamics, and if angular anisotropy transport is shown to be non-discriminatory at the level of collisionless evolution, then the analysis is complete. Any remaining questions necessarily concern dynamical structure formation, gravity, or matter evolution, and therefore lie outside the logical domain of the present framework.

2. Kernel-Based Redshift Framework

The present analysis relies on a background level redshift framework previously established and published, and only the minimal machinery required for the arguments that follow is restated here [1]. Natural units ($k_B = 1$) are adopted throughout; the companion analysis [1] retains explicit k_B, but the resulting relations are identical. The framework is treated strictly as an effective description of photon-sector kinematics after decoupling, with collisionless propagation and photon number conservation assumed throughout. Cosmological redshift is defined operationally through a time-dependent kernel $K(t)$ relating emission and observation epochs, where t denotes the time parameter governing photon-sector evolution after decoupling. For a photon emitted at time t_e and observed at time t_0, the redshift is given by

$$1+z = \frac{K(t_0)}{K(t_e)}. \tag{1}$$

This definition does not assume metric expansion as the physical origin of redshift, and functions instead as a kinematic mapping between observed frequency ratios and an underlying time parameterization in the photon sector, with all observable redshift relations used in this paper derived from this operational definition alone. The instantaneous rate associated with the kernel is defined by

$$H_{\text{eff}}(t) = \frac{\dot{K}(t)}{K(t)}, \tag{2}$$

which enters the redshift evolution algebraically in the same manner as a Hubble rate enters standard treatments, but is defined here purely as a property of the kernel rather than of a spacetime scale factor. In the present work, $H_{\text{eff}}(t)$ is used only as an operational rate governing frequency evolution and time–redshift mapping, without any assumption that it describes gravitational expansion [2] [3]. Photon propagation after decoupling is treated as collisionless. Let $f(t,p)$ denote the photon distribution function, where p is the magnitude of the comoving momentum. Under a uniform, frequency-independent redshift action, the collisionless Boltzmann equation reduces to

$$\frac{\partial f}{\partial t} - H_{\text{eff}}(t)\, p \frac{\partial f}{\partial p} = 0, \tag{3}$$

which is standard in cosmological radiative transfer when collisions are negligible and the redshift action is homogeneous in frequency space, and constitutes the only kinetic statement required in what follows [2] [3]. Solving this equation by the method of characteristics yields

$$f(t,p) = f_0\left(pK(t)\right), \tag{4}$$

where f_0 is the distribution function evaluated at a reference time. If the initial photon distribution is Planckian,

$$f_0(p) = \frac{1}{\exp(p/T_0) - 1}, \tag{5}$$

then the solution remains exactly Planckian at all later times, with an effective temperature

$$T(t) = \frac{T_0}{K(t)}. \tag{6}$$

Expressed in terms of redshift, this implies

$$T(z) = T_0(1+z), \tag{7}$$

which is identical in form to the temperature–redshift relation used in standard cosmology, but arises here from frequency-independent Liouville transport rather than adiabatic expansion. The evolution of photon number and energy densities follows directly from this temperature scaling. The standard Stefan-Boltzmann integrals give

$$n_\gamma = aT^3, \quad \rho_\gamma = bT^4, \tag{8}$$

where a and b are constants determined by the Planck integral, and their explicit forms are not required for the scaling argument. From $T(t) = T_0/K(t)$, differentiation yields

$$\frac{\dot{T}}{T} = -\frac{\dot{K}}{K} = -H_{\text{eff}}, \tag{9}$$

and applying the chain rule to $n_\gamma = aT^3$ gives

$$\dot{n}_\gamma = 3aT^2\dot{T} = 3aT^3 \cdot \frac{\dot{T}}{T} = -3H_{\text{eff}} n_\gamma, \tag{10}$$

with an analogous result for $\rho_\gamma = bT^4$:

$$\dot{\rho}_\gamma = 4bT^3\dot{T} = 4bT^4 \cdot \frac{\dot{T}}{T} = -4H_{\text{eff}} \rho_\gamma. \tag{11}$$

These scaling laws are algebraically identical to those arising from adiabatic expansion in standard cosmology, where $n_\gamma \propto a^{-3}$ and $\rho_\gamma \propto a^{-4}$, while in the present framework the same coefficients emerge from the temperature dependence of the integrals combined with frequency-independent Liouville transport, without invoking metric expansion. No assumption regarding spacetime expansion, metric dynamics, or gravitational degrees of freedom enters this derivation; only collisionless Liouville evolution and frequency-independent redshift are used. Observational determinations of the present CMB temperature and limits on spectral distortions are taken from COBE/FIRAS measurements and subsequent analyses

[4]-[6]. Because the redshift action is uniform in frequency, no chemical potential distortion is generated by the evolution described above, and the chemical potential μ, defined as the dimensionless parameter characterizing deviations from a Planck spectrum, therefore remains identically zero under collisionless propagation governed by the kernel, consistent with the absence of observed μ-type distortions in the CMB spectrum. This statement aligns with the standard theory of spectral distortions when energy injection or frequency-dependent processes are absent [7] [8].

At the background level, the kernel framework reproduces the same observable photon-sector scalings commonly attributed to expansion, including temperature evolution, photon number dilution, and the relations entering luminosity distance, time dilation, and surface-brightness tests, and in this paper that background level degeneracy is taken as an established premise rather than a claim of full cosmological equivalence. No attempt is made here to describe the generation of anisotropies, the growth of structure, or the microphysics of recombination, and the only statements used in later sections concern collisionless photon transport and background kinematics. Predictions for anisotropy generation and acoustic structure require perturbation theory and coupling to matter and gravity, as in standard Boltzmann treatments, and are explicitly outside the scope of the present analysis [9]-[11].

3. JWST Timing

A recurring criticism of non-expansion redshift frameworks is that they are underconstrained by observation and therefore lack empirical falsifiability. This section addresses that criticism directly by using early galaxy timing inferred from James Webb Space Telescope observations as an empirical constraint on post-recombination kernel dynamics. The analysis is not framed as a resolution of the early-galaxy timing tension. Instead, it treats a specific, previously introduced kernel evolution as a concrete hypothesis and evaluates whether it is compatible with the minimum cosmic time implied by JWST observations. The kernel dynamics considered here are imported unchanged from the illustrative post-recombination relaxation model introduced in the CMB analysis [1]. No new functional freedom is introduced at this stage. The effective rate governing redshift evolution is taken to be

$$H_{\mathrm{eff}}(t) = H_0 + \left(H_{\mathrm{init}} - H_0\right)\exp\left[-\frac{t - t_{\mathrm{rec}}}{\tau}\right], \tag{12}$$

where H_0 is the present effective rate, H_{init} is the effective rate immediately after recombination, t_{rec} denotes the recombination epoch, and τ is the relaxation timescale. The exponential form is an ansatz, introduced previously as an illustrative post-recombination kernel dynamics rather than as a unique or derived solution. No claim is made that this form is unique or physically preferred; it is adopted solely to demonstrate how post-recombination kernel dynamics may be empirically constrained. In the companion CMB analysis, this relaxation form arises as the closed-form solution of a damped scalar field equation with $H_{\mathrm{eff}} = g\dot{\Phi}$

[1]; it is treated here as a testable post-recombination hypothesis. The parameter values are fixed by two independent background level conditions imposed by the CMB. First, the present-day effective rate is required to satisfy $H_{\text{eff}}(t_0) = H_0$. Second, the observed CMB temperature ratio requires

$$\frac{K(t_0)}{K(t_{\text{rec}})} = 1 + z_{\text{rec}} \approx 1100, \tag{13}$$

which fixes the integral of H_{eff} between recombination and the present. For the illustrative choice $H_{\text{init}}/H_0 \approx 281$, enforcement of this boundary condition uniquely determines the relaxation timescale to be $\tau \approx 0.314$ Gyr. The relaxation timescale is therefore not an independently adjustable parameter once H_{init} and the CMB boundary conditions are specified. The time-redshift mapping follows directly from the operational definition of redshift. For photons observed at t_0 and emitted at time t, one has

$$\ln(1+z) = \int_t^{t_0} H_{\text{eff}}(t')\,\mathrm{d}t'. \tag{14}$$

This relation is exact within the kernel framework and does not rely on any approximation beyond collisionless propagation. Given $H_{\text{eff}}(t)$, it uniquely determines the cosmic time $t(z)$ associated with an observed redshift. The mapping is evaluated numerically for the parameter set specified above.

For comparison, a reference flat ΛCDM model is used to compute the corresponding cosmic times. The standard relation

$$t(z) = \int_z^{\infty} \frac{\mathrm{d}z'}{(1+z')H(z')} \tag{15}$$

is evaluated with

$$H(z) = H_0\sqrt{\Omega_m(1+z)^3 + \Omega_\Lambda}, \tag{16}$$

using $H_0 = 67.4\ \text{km}\cdot\text{s}^{-1}\cdot\text{Mpc}^{-1}$, $\Omega_m = 0.315$, and $\Omega_\Lambda = 0.685$, consistent with recent Planck determinations [12]. Radiation is neglected in this comparison, as the focus is restricted to relative timing differences at $z \sim 10$ - 20. The cosmic times corresponding to redshifts $z = 20, 15, 12$ and 10 are computed under both the illustrative kernel dynamics and the reference ΛCDM model. The resulting values are summarized in **Figure 1**.

The numerical values in **Figure 1** and Eqs. (17)-(18) were obtained by direct numerical quadrature of the defining integrals for the parameter set specified above. From these values, the available assembly interval between $z = 20$ and $z = 10$ is

$$\Delta t_{\text{eff}}(20 \to 10) \approx 0.113\ \text{Gyr}, \tag{17}$$

under the illustrative kernel dynamics, compared to

$$\Delta t_{\Lambda\text{CDM}}(20 \to 10) \approx 0.293\ \text{Gyr}, \tag{18}$$

This distinction reflects differences in the time–redshift mapping rather than a contradiction in absolute cosmic age. For the parameter set fixed by the CMB

z	t_{eff} (Gyr)	$t_{\Lambda\text{CDM}}$ (Gyr)
20	0.330	0.179
15	0.373	0.269
12	0.409	0.368
10	0.443	0.472

Figure 1. Cosmic time $t(z)$ at selected redshifts under the illustrative kernel dynamics and reference ΛCDM cosmology. While absolute cosmic time since the initial epoch may be larger under the kernel framework, the relevant quantity for early galaxy assembly is the interval $\Delta t(20 \to 10)$, which is shorter than in ΛCDM for the parameters shown in this illustrative realization. The kernel parameters are fixed by CMB boundary conditions with $H_{\text{init}}/H_0 \approx 281$ and $\tau \approx 0.314\ \text{Gyr}$ [1].

boundary conditions, the kernel framework therefore predicts a significantly shorter assembly interval over this redshift range. Observations with JWST have reported the presence of galaxies with inferred stellar masses of order $10^9 M_\odot$ or greater at redshifts $z \gtrsim 10$, based on photometric and spectroscopic analyses of early deep-field data. While the interpretation of these masses and formation histories remains under active debate, multiple independent studies report assembly timescales of order a few hundred Myr or less [13]-[17]. These results are cited here only as timing indicators and not as settled determinations of stellar mass or star-formation history. Compatibility is taken to require that the available assembly interval Δt exceed the minimum timescales inferred from observed stellar masses, estimated at order ~100 - 300 Myr in the cited studies. The comparison above shows that, if the illustrative exponential kernel dynamics are taken as physically realized, the framework predicts less cosmic time for early galaxy assembly than ΛCDM. JWST observations therefore act as an empirical constraint on the allowed kernel dynamics. Compatibility with the inferred timing requires either a sufficiently long relaxation timescale, a reduced initial effective rate, or alternative post-recombination kernel evolution. In this sense, JWST supplies an independent third constraint on the kernel ansatz, beyond the two background level conditions imposed by the CMB. This provides an additional observational constraint on the framework. The kernel-based description admits empirical exclusion at the background level, and specific kernel dynamics can be ruled out by early-universe timing data independently of CMB thermodynamics or angular transport. No claim is made that JWST observations favor the kernel framework over ΛCDM, nor that uncertainties in stellar mass estimates or baryonic physics have been resolved. The sole conclusion of this section is that early-galaxy timing provides a direct observational bound on post-recombination kernel dynamics. The same relaxation dynamics that fix $H_{\text{eff}}(z \approx 1100) \approx 281 H_0$ also determine the timing behavior at $z \sim 10\text{ - }20$, providing an internal consistency check across cosmic epochs. Any viable extension of the framework must satisfy this bound in addition to reproducing the observed CMB blackbody spectrum and background redshift relations. It is important to emphasize that the CMB constraint derived in this work fixes only the time-integrated redshift kernel,

$$\int_{t_{\mathrm{rec}}}^{t_0} H_{\mathrm{eff}}(t)\,\mathrm{d}t = \ln(1+z_{\mathrm{rec}}), \tag{19}$$

and does not uniquely determine the functional form of $H_{\mathrm{eff}}(t)$. The exponential relaxation profile adopted here arises naturally from the scalar-field dynamics developed in the companion CMB analysis [1] and serves as a concrete realization of the framework. Other admissible kernel shapes satisfying the same integral constraint may yield substantially different cosmic time-redshift mappings at $z \gtrsim 10$. Consequently, JWST observations should be interpreted as constraining the detailed kernel dynamics rather than falsifying the kinematic redshift mechanism itself.

4. Formation Timescales

Early JWST observations of massive galaxies at $z \gtrsim 10$ were initially interpreted as indicating a timing crisis. Under standard assumptions, the inferred stellar masses appeared to require more cosmic time than available within reference ΛCDM timelines [15] [18]. This interpretation implicitly assumed that pre-JWST prescriptions for star formation efficiency, feedback regulation, and halo assembly were approximately correct, and that discrepancies therefore reflected tension in the cosmological clock rather than in formation physics. Subsequent analyses have revised this view substantially. Multiple studies now conclude that JWST observations are compatible with standard ΛCDM cosmology when formation physics is adjusted rather than cosmic time extended. Yung *et al.* [19] demonstrated that star formation efficiencies of order 20% - 65% are sufficient to reproduce observed luminosity functions without modifying cosmological parameters, while McCaffrey *et al.* [20] found no tension between JWST galaxy counts and Renaissance simulations. Dekel *et al.* [21] further identified feedback-free starburst regimes in which star formation efficiencies can approach unity when gas free-fall times fall below ~1 Myr, a condition naturally satisfied in dense, low-metallicity environments at cosmic dawn.

The kernel-based timing analysis presented here reaches a closely related conclusion through a fundamentally different logical route. The compressed high-redshift timeline does not arise from fitting JWST data, revising formation prescriptions, or accommodating observed galaxy masses. Instead, it follows directly from cosmic microwave background boundary conditions alone. The kernel parameters governing post-recombination redshift evolution are fixed entirely by CMB temperature-redshift constraints at $z \approx 1100$, independent of any galaxy formation considerations. Once these constraints are enforced, the resulting time-redshift mapping yields an effective assembly window of approximately 113 Myr between $z = 20$ and $z = 10$, compared to ~293 Myr under reference ΛCDM parameters. This compressed timeline is therefore a prediction of the framework rather than a post-hoc accommodation. JWST observations enter only as an external consistency check. Galaxies are observed to exist at $z \gtrsim 10$ despite the reduced available time implied by the kernel dynamics. Compatibility, in the sense defined in the preceding section, requires that this available assembly interval exceed the minimum timescales inferred from observed stellar masses, estimated at order ~100 - 300 Myr in the cited JWST studies. The logical implication is not that the kernel framework fails, but that galaxy formation must proceed even more rapidly than required by current "fast formation" revisions within standard cosmology. This reframes the original JWST timing discussion. The question posed by early observations was never strictly whether cosmology provides sufficient time, but whether formation models accurately captured the efficiency of early star formation. The present result sharpens this conclusion further. If observed structures are compatible with an effective assembly window of order ~100 Myr derived independently from CMB constraints, then the ~300 Myr available under ΛCDM was never the binding constraint. Formation physics at cosmic dawn must therefore operate at efficiencies exceeding even those invoked in recent revisions.

The logical structure is unambiguous. The CMB fixes the kernel dynamics. The kernel dynamics predict a compressed high-redshift timeline. JWST observes galaxies within that interval. Therefore, if the illustrative kernel dynamics are physically realized, formation timescales must be shorter than either those assumed in pre-JWST models or those implied by standard ΛCDM timelines. This inference does not depend on the detailed microphysics of star formation, nor on the specific functional form of the kernel beyond the CMB-imposed boundary conditions. It follows generically from any framework in which high-redshift timing is compressed relative to ΛCDM while remaining consistent with background observables. Rather than constituting a failure of the kernel framework, JWST observations provide an independent empirical constraint on its timing implications. This provides a consistency check between CMB-imposed background evolution and early-universe structure formation timescales. The convergence between a CMB-driven prediction and an astrophysical reassessment of formation efficiency demonstrates that the perceived timing crisis may have been mischaracterized from the outset. The bottleneck at cosmic dawn lies not in the cosmological clock, but in the physics of rapid structure assembly.

5. Angular Anisotropy Transport

A common assertion in cosmology is that the existence of angular anisotropies in the cosmic microwave background constitutes a logical requirement for metric expansion. This section examines that claim directly by analyzing the transport of angular structure in the photon distribution under a frequency-independent redshift operator. The purpose is not to explain the origin of anisotropies, but to determine whether their mere existence discriminates between expansion and non-expansion redshift mechanisms at the level of collisionless transport. The analysis begins with the phase-space photon distribution retaining full angular dependence,

$$f = f(t, p, \hat{n}), \tag{20}$$

where p is the photon momentum magnitude and $\hat{n}$ is the propagation direction. In the absence of collisions, gravitational lensing, or scattering, the evolution of f is governed by the collisionless Liouville equation. For a frequency-independent redshift kernel, the evolution equation takes the form

$$\frac{\partial f}{\partial t} - H_{\text{eff}}(t)\, p \frac{\partial f}{\partial p} = 0, \tag{21}$$

where $H_{\text{eff}}(t) = \dot{K}/K$ is the effective redshift rate. The derivation does not depend on whether the redshift arises from metric expansion or from an alternative isotropic mechanism, only on the absence of angular dependence in the operator. Crucially, no angular derivatives appear in this equation. The redshift operator acts only on the momentum magnitude and is isotropic by construction. To track angular structure explicitly, the distribution is expanded in spherical harmonics,

$$f(t, p, \hat{n}) = \sum_{\ell m} f_{\ell m}(t, p) Y_{\ell m}(\hat{n}), \tag{22}$$

which is standard in treatments of radiative transfer and CMB anisotropies [2] [3]. Substitution of this expansion into the Liouville equation yields, for each multipole coefficient,

$$\frac{\partial f_{\ell m}}{\partial t} - H_{\text{eff}}(t)\, p \frac{\partial f_{\ell m}}{\partial p} = 0. \tag{23}$$

The evolution equation is identical for all (ℓ, m) and contains no coupling between different angular modes. In particular, there is no ℓ- or m-mixing introduced by the redshift operator. The equation is solved by the method of characteristics. Along characteristic curves defined by

$$\frac{\mathrm{d}p}{\mathrm{d}t} = -H_{\text{eff}}(t)\, p, \tag{24}$$

the solution is

$$p(t) = \frac{p_0}{K(t)}, \tag{25}$$

where p_0 is the momentum at a reference time. Along these curves, the distribution function is conserved,

$$f(t, p, \hat{n}) = f_0(pK(t), \hat{n}). \tag{26}$$

Projecting onto spherical harmonics gives

$$f_{\ell m}(t, p) = f_{\ell m}^{(0)}(pK(t)), \tag{27}$$

where $f_{\ell m}^{(0)}$ denotes the multipole coefficients at the reference time. Each multipole is transported independently, with its momentum dependence rescaled by the kernel $K(t)$ and its angular structure unchanged. This result establishes that angular anisotropies are transported, not generated, by a frequency-independent redshift operator. The preservation of multipole structure follows directly from the isotropy of the operator and the absence of angular derivatives in the Liouville equation. No assumption about metric expansion enters the derivation. It is worth emphasizing that the same transport structure arises in standard expanding cosmologies once collisions, metric perturbations, and source terms are neglected; the present result isolates the redshift operator itself rather than the full Boltzmann hierarchy [9] [10].

It follows that the existence of angular anisotropies in the CMB does not, by itself, constitute a logical test of expansion versus non-expansion redshift mechanisms. Anisotropies present at some initial time are preserved under collisionless propagation regardless of whether redshift is attributed to metric expansion or to a frequency-independent kernel. Any discrimination between models must therefore arise from the generation and statistical structure of anisotropies, or from their coupling to matter perturbations, not from their mere persistence. The limits of this result are explicit. No claim is made regarding the origin of anisotropies, acoustic oscillations, or the angular power spectrum. The analysis does not address gravitational instability, baryon–photon coupling, recombination microphysics, or the dynamics responsible for setting initial conditions. These effects enter through collision terms, metric perturbations, and source functions in the Boltzmann hierarchy, which lie outside the scope of collisionless Liouville transport [22] [23]. Accordingly, the result should be interpreted strictly as a statement about angular transport under the stated assumptions, and not as a claim regarding the origin or detailed statistical properties of CMB anisotropies. Within its stated domain, the result is definitive. Under collisionless evolution with a frequency-independent redshift operator, angular multipoles are preserved exactly. There is no angular scrambling, no mode mixing, and no generation of structure. The presence of CMB anisotropies alone therefore does not uniquely discriminate between expansion and non-expansion redshift mechanisms at the level of angular transport.

6. Conclusions

This work sets out to determine what cosmological observations logically require once a frequency-independent redshift mechanism is admitted at the background level, and to identify the precise boundaries beyond which additional theoretical assumptions become necessary. That objective has been met. At the background level, cosmological redshift observables are shown to be degenerate under a broad class of redshift implementations that preserve collisionless Liouville evolution. The cosmic microwave background constrains phase-space preservation, Planck spectrum stability, temperature-redshift scaling, and photon number evolution, but does not uniquely determine the spacetime origin of redshift. These results address and resolve the classical objections historically raised against non-expansion redshift interpretations at the level of background thermodynamics and transport. When specific post-recombination kernel dynamics are treated as concrete hypotheses rather than explanatory devices, independent observational data provide meaningful constraints. In particular, early-galaxy timing inferred from JWST observations bounds the allowed parameter space of illustrative relaxation models, demonstrating that kernel dynamics are empirically testable and, in some cases, subject to observational exclusion. This establishes falsifiability at the background level rather than explanatory freedom. The angular structure of the CMB has been addressed separately and rigorously. Under collisionless evolution, a frequency-independent redshift operator transports existing angular anisotropies without generating, suppressing, or mixing multipole structure. The existence of CMB anisotropies therefore does not, by itself, constitute a logical discriminator between expansion-based and non-expansion redshift mechanisms. Anisotropy generation, acoustic features, and power-spectrum morphology depend on additional physics not invoked here.

Taken together, these results show that metric expansion is sufficient to account for observed cosmological redshift phenomena, but it is not uniquely required at the level of background observables and angular transport. Interpretations that treat expansion as the sole admissible explanation rely on additional dynamical assumptions beyond the redshift phenomenology itself. Further progress beyond this point requires either a concrete model of structure formation and gravitational dynamics within a non-expansion framework, or independent, physically motivated proposals for kernel dynamics capable of satisfying all observational constraints simultaneously. Such developments lie outside the scope of the present analysis. This work completes the background level analysis of the $K(t)$ framework with respect to CMB thermodynamics, photon transport, and post-recombination timing constraints.

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No original datasets were generated for this study.

Ethical Approval

Not applicable.

Author's Contribution

This article is the sole work of the author.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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