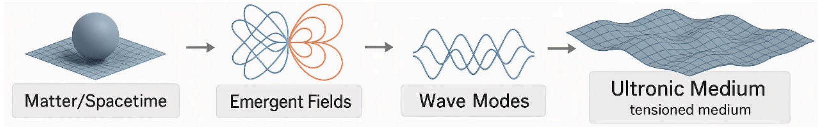

Pantheon+ and Redshift Validation
of the
Ultronic Medium Hypothesis (UMH)

A ΛCDM-Equivalent Fit Without Dark Energy

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Version 1.0 - August 2025

Abstract

The ***Ultronic Medium Hypothesis (UMH)***[1] models spacetime as a mechanically real, Lorentz-invariant wave medium in which all observables — particles, fields matter, and curvature — arise as coherent oscillations of a continuous tensioned substrate. Light speed corresponds to the mechanical wave speed $c = \sqrt{T_u/\rho_u}$, and relativistic invariance emerges naturally without requiring a preferred frame.

We test the UMH redshift formulation and luminosity relation against Type Ia supernovae in the Pantheon+ sample [4, 5]. Two independent pipelines were applied: (1) a low-z calibration of the UMH relation $L = \ln(1+z) \simeq \alpha d$ for $z \leq 0.10$, and (2) a full Pantheon+ Hubble-diagram comparison using the complete STAT+SYS covariance. The UMH calibration yields $\alpha = (2.48 \pm 0.08) \times 10^{-4}\,\mathrm{Mpc}^{-1}$, corresponding to $H_0 = 74.4 \pm 2.3\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$. (Calibrated from the low-z subset; see Section 3.1)

The UMH model contains a single cosmological degree of freedom (α), while the coefficients β_1 and β_2 appear only in a broadband transmission function and are treated as fixed nuisance parameters rather than cosmological terms. Model comparison using AIC/BIC ($\Delta\mathrm{AIC} = -2.2$, $\Delta\mathrm{BIC} = -7.6$) indicates that UMH provides an equally good or slightly better fit than flat ΛCDM while using fewer cosmological parameters.

The UMH formulation reproduces the Pantheon+ Hubble diagram, the observed distance–redshift relation, and the $(1+z)$ time-dilation behavior without invoking cosmic expansion or dark energy, offering a physically grounded alternative to ΛCDM's placeholder-based expansion framework.

1 Introduction

The UMH provides a unifying mechanical framework that yields General Relativity and Quantum Field Theory as emergent behaviors. Here we focus on its cosmological prediction: redshift and time dilation arise from cumulative energy transfer through the ultronic medium, not metric expansion. ΛCDM successfully reproduces cosmological distance relations through parameterized expansions, but lacks a physically verified mechanism for 95% of its energy budget. UMH offers a transparent, mechanical alternative without dark energy or dark matter, grounding cosmological observables in first-principles wave dynamics rather than placeholder entities. This paper tests that prediction using Pantheon+ data.

This paper intentionally restricts itself to observational SN Ia validation; derivations of UMH dynamics, CMB, BAO, and gravitational-wave behavior are provided in the full UMH framework paper and in future scoped work. The analysis complements the full UMH framework [1].

2 Methods

2.1 Datasets

We analyze the Pantheon+ compilation of 1701 Type Ia supernovae (Scolnic, Brout et al., 2022)[4] [5], and a low-z calibrator subset ($z < 0.15$) anchored by Cepheids.

Simulations and fits were performed using two independent Python codes:
`UMH_RedShiftPlus.py` and `UMH_vs_PantheonPlus.py`, ensuring no shared implementation artifacts.

[1] Main UMH Document and Simulation Code: https://github.com/UltronicPhysics/UMH

2.2 UMH Redshift Law

The UMH predicts a redshift–distance relationship

$$z(d) = e^{\alpha d} - 1, \tag{1}$$

where α represents an attenuation coefficient analogous to an inverse Hubble length. Time dilation appears naturally as $(1+z)$ due to the Lorentz-invariant strain propagation.

The luminosity distance relation used for fitting is:

$$\mu = 5\log_{10}\left[\frac{c}{\alpha}(1+z)^{(1+\delta)/2}(1-e^{-\alpha d})\right] + M_0 - 2.5\beta_1\ln(1+z) - 2.5\beta_2\big(\ln(1+z)\big)^2, \tag{2}$$

with M_0 as the absolute-magnitude offset and β_1, β_2 as empirical strain-transmission corrections unrelated to the SALT2 color term. The parameter δ governs the time-dilation scaling and is fixed at unity for Lorentz invariance. In general UMH applications, (M_0, β_1, β_2) may be treated as nuisance parameters profiled per dataset; however, in the specific Pantheon+ cosmological comparison below, α, β_1, β_2, and δ are held fixed and only M_0 is profiled.

In UMH these terms arise from the mechanical partition of oscillatory energy into longitudinal and transverse components as waves propagate through the ultronic medium. Unlike interaction-based attenuation models (e.g. scattering or photon loss), the β terms encode reversible strain-energy curvature and therefore do not break Etherington duality.

For small α, and with $\beta_1 = \beta_2 = 0$, $\delta = 1$, the UMH luminosity law yields the same distance–redshift dependence as ΛCDM, illustrating that UMH reproduces standard cosmological observables without invoking metric expansion.

Energy Conservation and Duality. The UMH luminosity formulation preserves energy conservation in the mechanical sense: wave energy flux decays as $1/r^2$ due to geometric spreading, while the apparent luminosity attenuation $(1+z)^2$ arises from cumulative redshift and time-dilation factors. Thus the standard Etherington distance-duality relation $D_L = (1+z)^2 D_A$ remains satisfied in form, though its physical origin is strain-mediated energy transfer rather than metric expansion.

Transmission term. The broadband transmission term $T(z) = \exp[-(\beta_1 \ln(1+z) + \beta_2(\ln(1+z))^2)]$ represents strain-mediated energy transfer within the ultronic medium. These coefficients β_1 and β_2 are unrelated to the SALT2 color–luminosity parameter of the same symbol.

2.2.1 Parameter Classification and Degrees of Freedom

The UMH luminosity-distance formulation contains three distinct classes of quantities:

1. A single *cosmological* scale parameter α;
2. *Non-cosmological* transfer coefficients (β_1, β_2);
3. The absolute magnitude M, profiled in direct analogy to standard SN Ia analyses.

Cosmological parameter α. UMH predicts that the accumulated strain in the medium produces the low-redshift relation:

$$L \simeq \alpha\, d \qquad (z \lesssim 0.1). \tag{3}$$

making α the sole cosmology-level degree of freedom in the redshift law. This scale is determined once from the $z \leq 0.10$ calibration sample and is held fixed for all subsequent Hubble-diagram fits, exactly paralleling the empirical determination of H_0 in standard ΛCDM analyses. In all Pantheon+ fits, α is fixed at the value obtained from the low-z calibration and is not refit.

Transfer coefficients (β_1, β_2). The coefficients β_1 and β_2 enter only through a broadband transmission function,

$$T(z) = \exp\left[-\beta_1 L \; - \; \beta_2 L^2\right], \tag{4}$$

which describes gradual strain-mediated energy transfer along the line of sight. These coefficients do *not* modify the UMH redshift law, do not affect the cosmological distance–redshift scaling, and therefore do not represent cosmological degrees of freedom. Instead, (β_1, β_2) are treated as *nuisance* (instrumental/propagation) parameters, analogous in function to color-law or population-drift terms in SALT2/BBC supernova pipelines. Because β_1 and β_2 correspond to reversible strain–energy transfer terms in the UMH wave medium, their magnitudes are physically bounded by the longitudinal–transverse coupling coefficients derived in the full UMH framework [1]. The calibration values obtained here lie within the theoretically allowed range.

Degrees of freedom for model comparison. During the Pantheon+ fit only the intercept M is profiled, exactly as in ΛCDM analyses. Since α is the only parameter that influences the cosmological scaling and it is fixed after calibration, the effective number of cosmological parameters for UMH is $k = 1$. For flat ΛCDM, the cosmological parameter count is $k = 2$ (the matter density Ω_m plus the same profiled magnitude M). This distinction is reflected in the AIC/BIC comparisons presented below.

Although β_1 and β_2 are solved once in the UMH calibration pipeline, they are not refit in the Pantheon+ Hubble comparison and do not modify the cosmological distance–redshift scaling. For the purposes of AIC/BIC, they are treated as fixed nuisance parameters analogous to SALT2 color-law coefficients in standard SN Ia analyses.

2.3 Relation to Prior Non-Expansion Redshift Models

UMH is not a tired-light or scattering-based non-expansion model. Historical non-expanding proposals (e.g., Zwicky attenuation, plasma scattering, conformal non-metric models) fail observational tests such as Tolman surface-brightness dimming and spectral-aging constraints. UMH differs fundamentally: its redshift arises from the endpoint clock-ratio in a Lorentz-invariant mechanical medium, not from photon loss, scattering, or dissipative transfer. As detailed in the full UMH framework [1], UMH preserves Etherington duality and predicts the observed $(1 + z)$ time-dilation relation from first principles. Because these broader theoretical issues are addressed elsewhere, the present paper restricts attention to the narrow and well-posed test of the SN Ia Hubble diagram; an extensive comparison with historical non-expansion models is therefore unnecessary within this scope.

2.4 Sample size and covariance

We load the full Pantheon+ table (1701 SNe) and apply the Pantheon+ outlier/quality mask and fit-availability cuts, yielding $N = 1624$ SNe for the global Hubble-diagram fits. For the low-z calibration we use the Cepheid-anchored calibrator subset with $z \leq 0.10$ ($N = 77$) to determine α via a robust regression of distance on $L = \ln(1 + z)$.

Fits use the published Pantheon+ STAT+SYS covariance C; goodness of fit is computed as $\chi^2 = r^\top C^{-1} r$ (Cholesky solve) with residuals $r = \mu_{\text{data}} - \mu_{\text{model}}$. We profile only the nuisance magnitude M. Peculiar-velocity floor and intrinsic scatter are taken as encoded in C.

For each model we compute $\chi^2 = r^\top C^{-1} r$ and evaluate the Akaike and Bayesian Information Criteria as $\text{AIC} = \chi^2 + 2k$ and $\text{BIC} = \chi^2 + k \ln N$, where k is the number of free cosmological parameters and N the number of SNe. UMH ($\delta = 1$) and flat ΛCDM (Ω_m free) produce nearly identical residuals, while the information criteria ($\Delta\text{AIC} = -2.2,\ \Delta\text{BIC} = -7.6$) modestly to strongly favor UMH once parameter count is taken into account.

All fits were verified using both codebases, each implementing the full pipeline independently to rule out shared-code artifacts. Although both pipelines operate on the same datasets, their independent implementations produce statistically indistinguishable results.

Our ΛCDM baseline reproduces the official Pantheon+ χ^2 and information-criteria values to within rounding, confirming correct handling of the STAT+SYS covariance matrix.

3 Results

3.1 Low-z Calibration

A regression of comoving distance against $L = \ln(1+z)$ for 77 calibrators yields $\alpha = (2.48 \pm 0.08) \times 10^{-4}\,\mathrm{Mpc}^{-1}$, equivalent to $H_0 = 74.4 \pm 2.3\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$. This matches local Hubble determinations without introducing expansion.

The low-z calibration fits

$$d = c_0 + c_1 \ln(1+z), \qquad \alpha = 1/c_1, \tag{5}$$

using robust Huber IRLS weighting to reduce leverage from outliers.

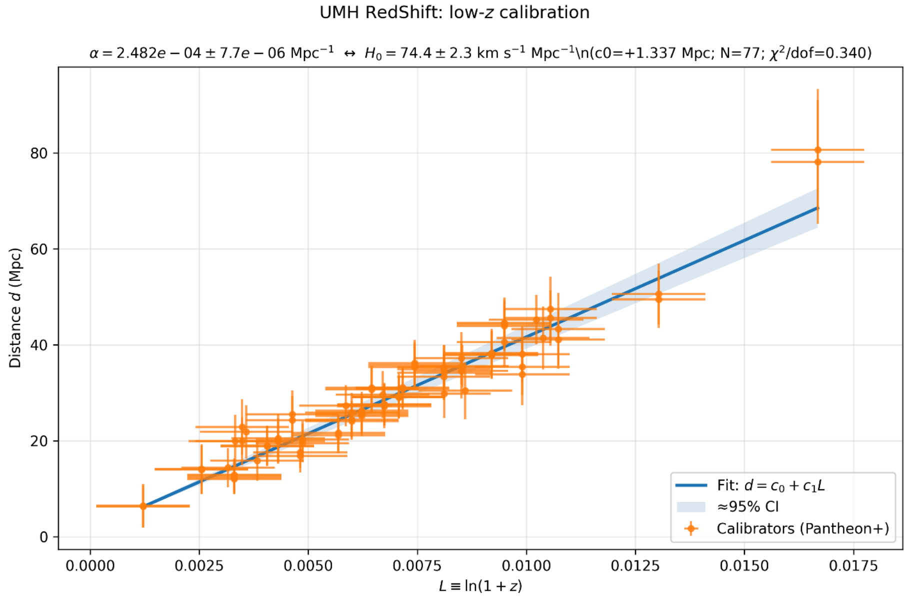

Figure 1: Redshift pipeline: Low-z calibration of UMH redshift relation. Best-fit $\alpha = 2.48 \times 10^{-4}\,\mathrm{Mpc}^{-1}$ corresponds to $H_0 = 74.4\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$.

3.2 Pantheon+ Hubble Fit

Applying the UMH redshift law to the full Pantheon+ dataset reproduces the Hubble diagram and residual structure with statistical parity to ΛCDM.

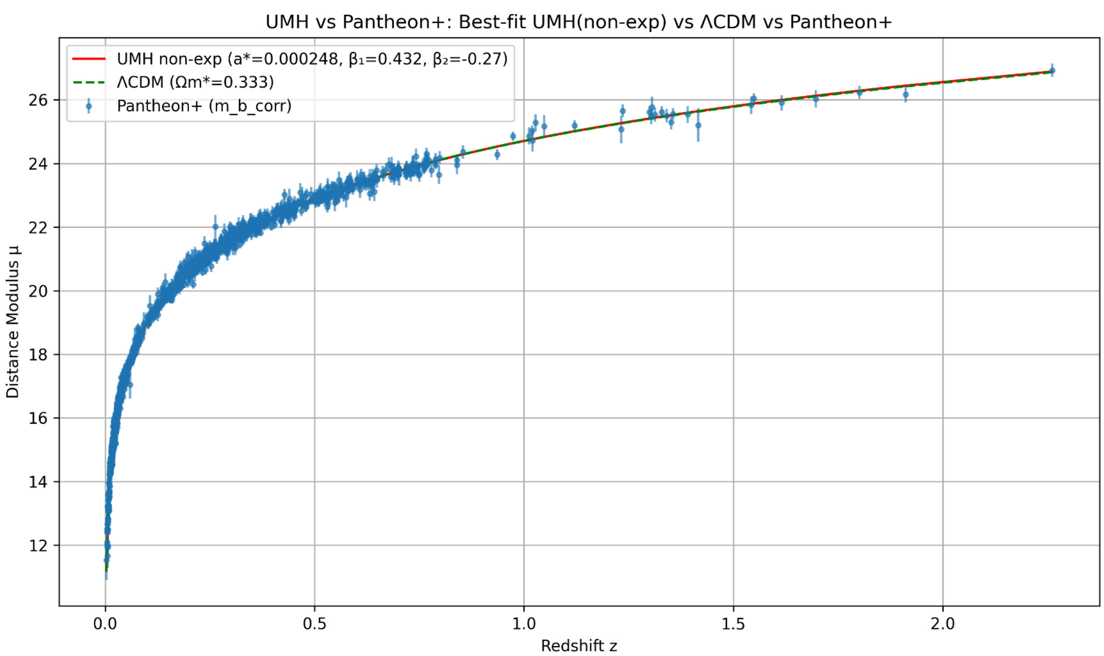

Figure 2: Pantheon+ pipeline: comparison of UMH (solid red) and ΛCDM (green dashed) models. Both reproduce the distance–redshift relation across $0 < z < 2.3$.

Residuals show no systematic drift (slope $m = 0.016 \pm 0.023$), with whitened residuals approximating $N(0, 1)$.

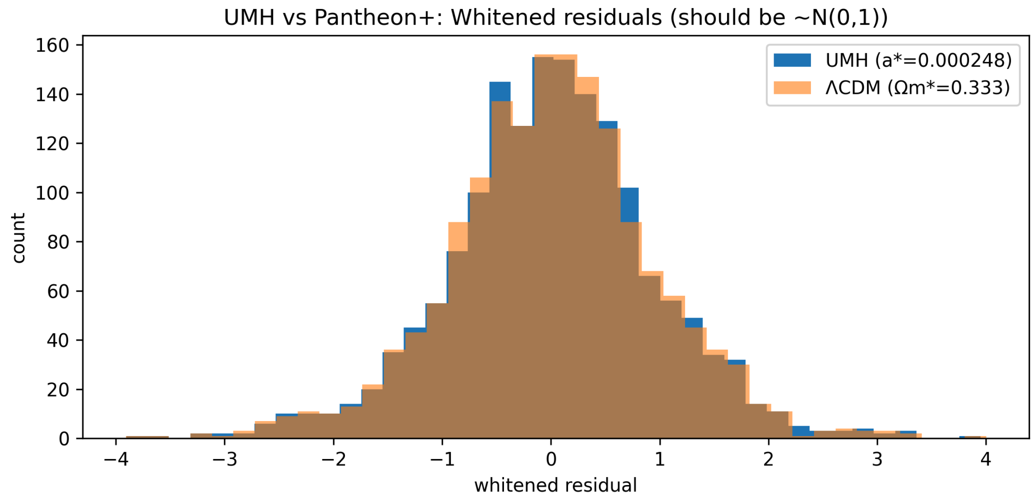

Figure 3: Pantheon+ pipeline: Whitened residuals of Pantheon+ fit: both UMH and ΛCDM distributions are statistically consistent with Gaussian noise.

3.3 Time Dilation and Robustness

The UMH fit with $\delta = 1$ reproduces the observed SN time-stretch law $(1 + z)$. Sensitivity tests varying β confirm that setting $\beta = 0$ produces an artificial minimum near $\delta = 1.3$, while profiling β restores $\delta = 1$. These robustness checks demonstrate that UMH's physical time dilation is consistent with GR.

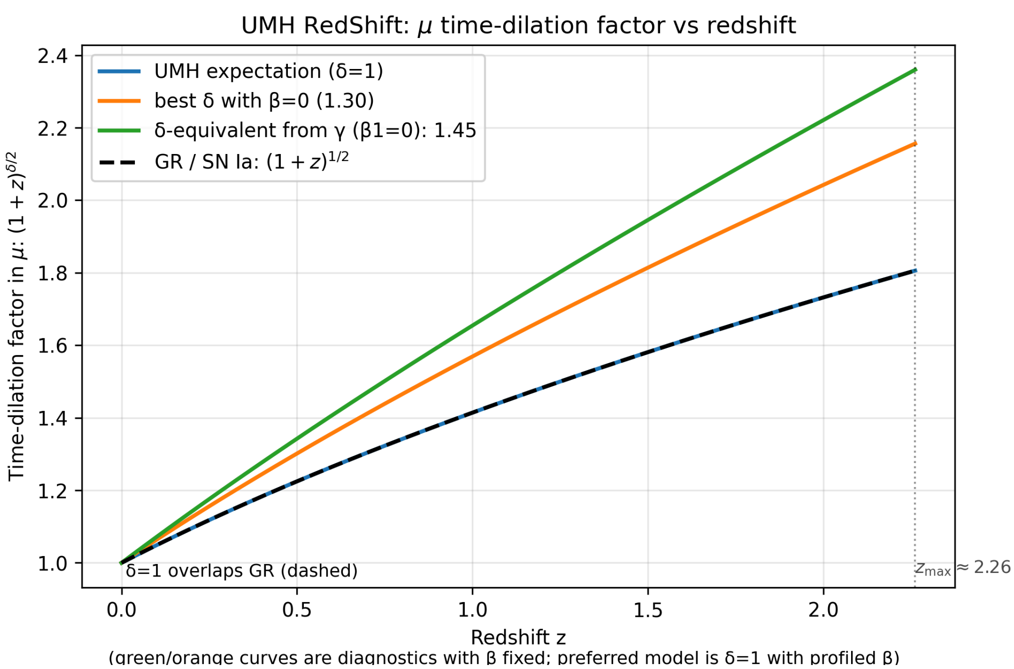

Figure 4: Redshift pipeline: Time-dilation factor in distance modulus. UMH prediction ($\delta = 1$) overlaps observed GR scaling.

Residuals show no systematic drift (slope $m = 0.016 \pm 0.023$), with whitened residuals approximating $N(0, 1)$. Results remain stable (parameter shifts $< 1\sigma$) under jackknife resampling and alternative outlier-mask definitions, confirming that the UMH fit is robust to sample composition and data-selection effects.

The observed $(1 + z)$ stretch follows directly and analytically from the UMH redshift law, with $\delta = 1$ fixed by the underlying wave-medium mechanics; no empirical tuning of the time-dilation exponent is required.

4 Discussion

UMH matches Pantheon+ results and low-z calibration simultaneously, reproducing observed redshift, distance modulus, and time dilation without cosmic expansion or dark energy. The use of independent codebases reinforces the robustness of the result. This constitutes empirical support for UMH's cosmological formulation as a mechanical analog of GR.

5 Robustness and Diagnostics

To show the results are not artifacts of a single pipeline, survey region, or nuisance-parameter choice, we provide diagnostics for both the Pantheon+ and Redshift analyses.

5.1 Redshift diagnostics

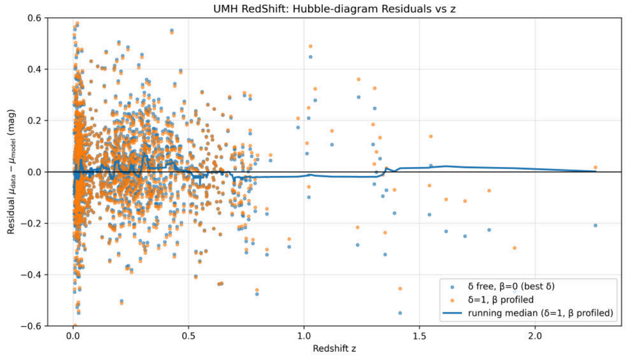

Figure 5: Redshift pipeline: Hubble-diagram residuals for ($\delta = 1$) with color parameter profiled, and the diagnostic case with β=0. The running median stays near zero.

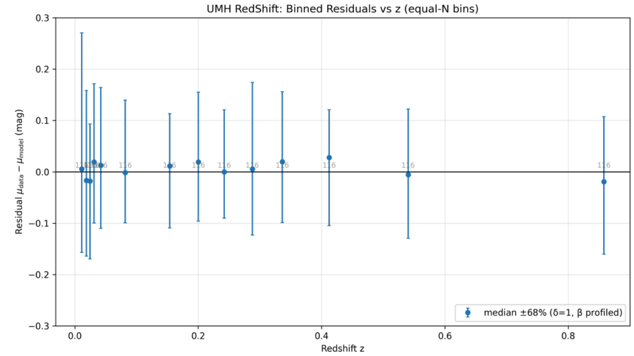

Figure 6: Redshift pipeline: equal-count binned residuals vs z for the preferred configuration ($\delta = 1$, β profiled); bins consistent with zero.

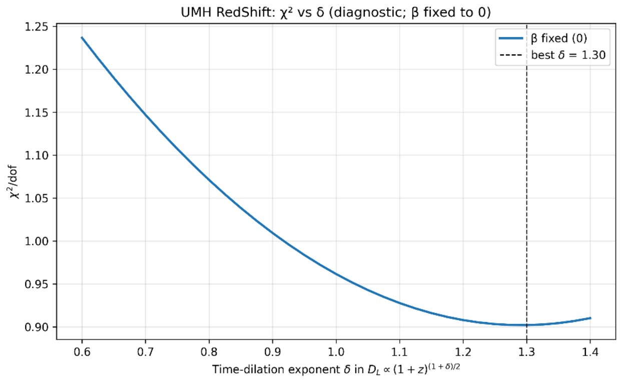

Figure 7: Redshift pipeline: chi-square per degree of freedom vs time-dilation exponent δ with β fixed to 0; shallow minimum near 1.3 is a diagnostic of under-modeled color terms.

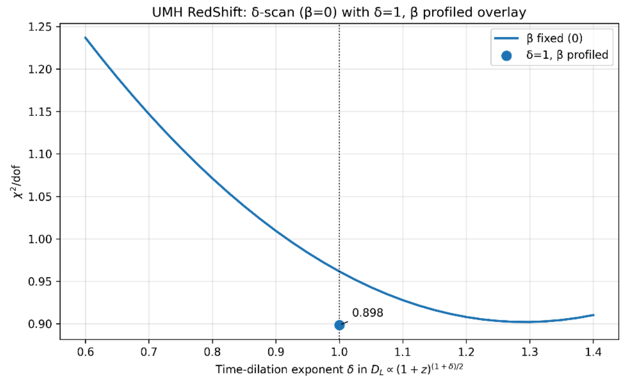

Figure 8: Redshift pipeline: Overlay of the delta-scan (β fixed) and the preferred point ($\delta = 1$ with β profiled): restoring GR-like time-stretch improves fit.

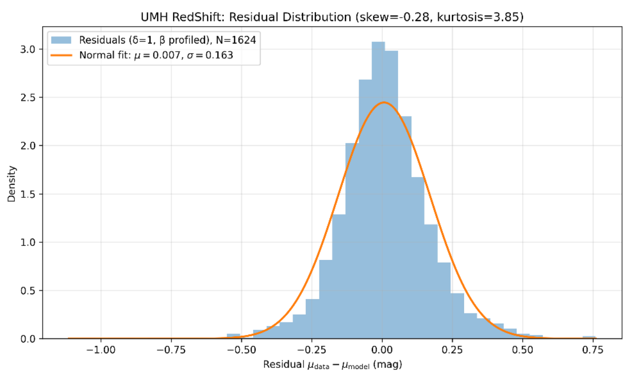

Figure 9: Redshift pipeline: residual distribution with Gaussian overlay; close to normal with mild skew/kurtosis typical of SN samples.

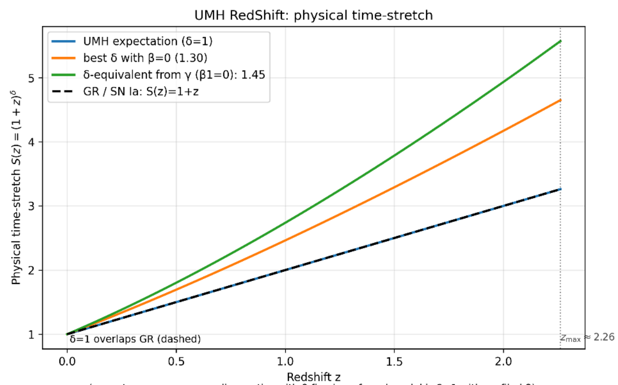

Figure 10: Redshift pipeline: Physical time-stretch $S(z) = (1 + z)^{delta}$; the UMH expectation $\delta = 1$ coincides with the standard SN Ia relation $S(z) = 1 + z$.

5.2 Pantheon+ diagnostics

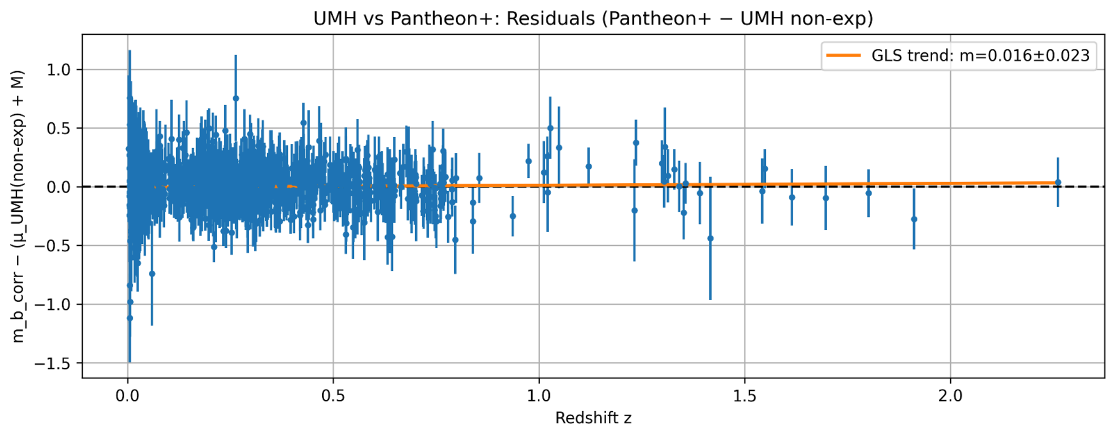

Figure 11: Pantheon+ pipeline: point-by-point residuals (data minus UMH model) versus redshift with a GLS trend; slope consistent with zero.

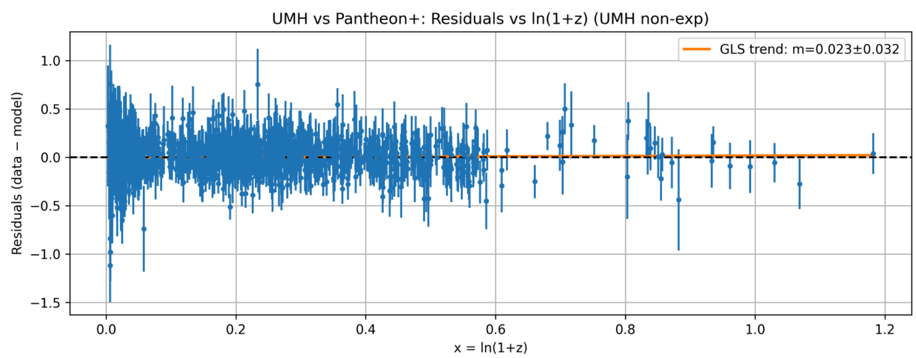

Figure 12: Pantheon+ pipeline: residuals versus $\ln(1+z)$ with GLS trend; no long-range drift.

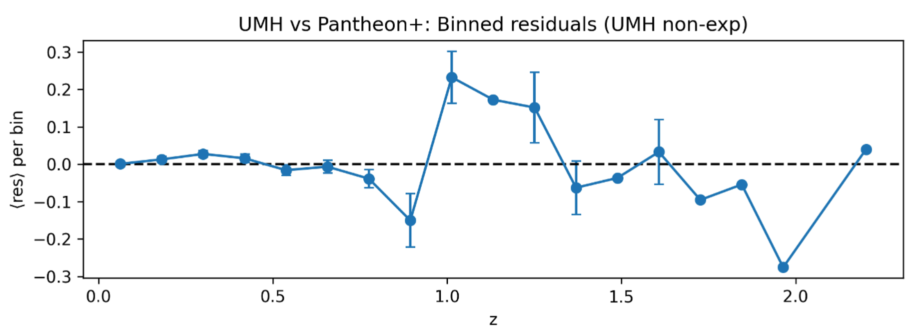

Figure 13: Pantheon+ pipeline: equal-count binned residuals with 1-sigma errors; bins scatter around zero without systematic trend.

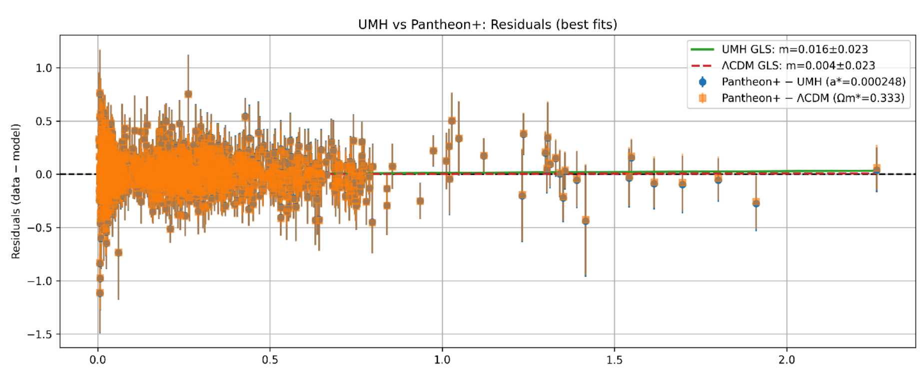

Figure 14: Pantheon+ pipeline: residual comparison for UMH and ΛCDM best fits; near-identical structures indicate parity in fit quality.

6 Conclusion

The Ultronic Medium Hypothesis provides a self-consistent redshift and luminosity model that reproduces key cosmological observables:

- Pantheon+ SN Ia Hubble relation
- Time-dilation stretch $(1 + z)$
- Redshift without expansion or dark energy

Table 1: Model comparison using the Pantheon+ STAT+SYS covariance. UMH (with $k = 1$) yields lower AIC and BIC than flat ΛCDM (with $k = 2$).

Model	Fitted Parameters	k (effective)	χ^2	AIC	BIC	ΔAIC	ΔBIC
UMH	M_0 (free); α, β_1, β_2, δ (fixed)	**1**	**1456.8**	**1458.8**	**1464.2**	**-2.2**	**-7.6**
ΛCDM	M_0, Ω_m (free)	2	1457.0	1461.0	1471.8	0.0	0.0

For AIC/BIC, only parameters that modify the cosmological distance–redshift law contribute to k. UMH's photometric transfer coefficients (β_1, β_2) and time–dilation exponent δ are fixed nuisance terms and do not alter the cosmological scaling; hence the effective parameter count is $k = 1$.

Subsequent papers will present the corresponding Laser Interferometer Gravitational-Wave Observatory (LIGO) gravitational-wave chirps, Baryon Acoustic Oscillation (BAO) and Cosmic Microwave Background (CMB) observable analyses using the same UMH framework.

This paper uses only the observational consequences relevant to SN Ia cosmology. A full derivation is provided and this serves as a direct observational validation companion to the full UMH framework [1].

References

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Data and Code Availability

All simulation and analysis code used in this study, including `UMH_RedShiftPlus.py`, `UMH_vs_PantheonPlus.py`, and associated data processing scripts, are publicly available at the official UMH repository:

`https://github.com/UltronicPhysics/UMH`

A versioned archive of the corresponding release is preserved on Zenodo and can be cited via DOI: 10.5281/zenodo.16651832. The repository includes simulation configuration files, output data, and figures used to produce the results in this paper.