

# Cosmological Validation of the UAT/UCP Framework without Boltzmann Codes:

$Om(z)$  Diagnostic, Cosmic Chronometers, and Bayesian Model Selection

Miguel Ángel Percudani<sup>1</sup>

Jorge Iván Díaz<sup>2</sup>

<sup>1</sup>Independent Researcher, Puan, Buenos Aires, Argentina

<sup>2</sup>Collaborator, UAT/UCP Development Team

miguel\_percudani@yahoo.com.ar

ORCID (M.A.P.): 0009-0007-1748-3212

July 23, 2026

## Abstract

We validate the cosmological predictions of the Unified Applicable Time (UAT) and Unified Causal Principle (UCP) framework using only direct observational data and the  $Om(z)$  diagnostic, without relying on Boltzmann codes (CLASS/CAMB) or any  $\Lambda$ CDM parameter inputs. The UAT expansion history is derived from first principles: the quantum brake  $k_{\text{early}} = 0.967$ , the effective matter density  $\Omega_m^{(\text{eff})} = \Omega_b \times \kappa_{\text{crit}} \times \varphi \times (1 - 0.07) = 0.3133$ , and the dark energy density  $\Omega_\Lambda^{(\text{UAT})} = 1 - (\Omega_m^{(\text{eff})} + \Omega_r) = 0.6867$ , where  $\Omega_b$  comes from Big Bang Nucleosynthesis and  $\Omega_r$  from the CMB temperature. With a UAT sound horizon  $r_d = 141$  Mpc (from MCMC calibration) and the local Hubble constant  $H_0 = 73.04$  km/s/Mpc (SH0ES), we compute  $H(z)$  and compare it against 31 cosmic chronometer measurements (Moresco et al. 2016, 2020) and 3 BOSS DR12 BAO points. The  $Om(z)$  diagnostic, defined as  $Om(z) = [H(z)^2/H_0^2 - 1]/[(1+z)^3 - 1]$ , shows that UAT predicts a slowly evolving  $Om(z)$  (mean  $0.2948 \pm 0.0104$ ), in contrast with the constant value  $\Omega_m = 0.315$  expected in  $\Lambda$ CDM. The  $\chi^2$  values are 20.70 (UAT) and 14.90 ( $\Lambda$ CDM) for the chronometers, and 6.28 (UAT) vs. 9.90 ( $\Lambda$ CDM) for BAO. Although UAT has a slightly higher raw  $\chi^2$ , it achieves this with only **one free parameter** (the 7% thermal calibration margin) compared to the six or more parameters of  $\Lambda$ CDM. Bayesian model selection decisively favors UAT:  $\Delta\text{AIC} = -4.20$  (UAT weight 89.1%),  $\Delta\text{BIC} = -11.37$  (UAT weight 99.7%), and a Bayes factor  $B \approx 294$  (“decisive” evidence on the Jeffreys scale). Sensitivity analysis shows that UAT would need  $\chi^2 \geq 32.07$  for the Bayes factor to be neutral. Together with the independent  $f\sigma_8(z)$  growth rate analysis ( $B \approx 1755$ ), these results demonstrate that the UAT/UCP framework is a competitive cosmological model that resolves the Hubble tension, explains the effective dark matter density, and provides a unified description of the expansion history with minimal parametric complexity.

# 1 Introduction

The standard  $\Lambda$ CDM model describes cosmological observations with remarkable precision, but requires six or more free parameters and offers no physical explanation for the values of  $\Omega_m$ ,  $\Omega_\Lambda$ , or the Hubble constant  $H_0$  [17]. The Hubble tension—the  $4.9\sigma$  discrepancy between local  $H_0$  measurements [18] and CMB-inferred values—remains unresolved. The Unified Applicable Time (UAT) and Unified Causal Principle (UCP) framework [1, 2, 3] provides an alternative description of cosmic dynamics derived from first principles: the causal coherence limit  $\kappa_{\text{crit}} = 4.978$ , the 8-phase interference topology yielding the golden ratio  $\varphi \approx 1.618$ , and the 7% thermal calibration margin [7]. From these, all cosmological parameters follow with only one free parameter.

Previous work has validated the UAT framework against Type Ia supernovae, CMB shift parameter, BAO, and the growth rate  $f\sigma_8(z)$  [4, 5, 6, 8]. The  $f\sigma_8(z)$  Bayesian analysis yielded decisive evidence in favor of UAT over  $\Lambda$ CDM ( $B \approx 1755$ ) [12]. The age of the universe was computed as  $t_0 = 12.90$  Gyr, consistent with globular cluster ages and validated with Gaia DR3 data for NGC 6397 [13]. The cosmological constant was derived from first principles as  $\Lambda = 2.49 \times 10^{-122} M_{\text{Pl}}^4$ , matching Planck 2018 to 0.92% [5]. Recently, the QCD confinement scale was predicted from the Causal Mass Gap equation as  $M_{\text{obs}}(4) = 215.6$  MeV, in 0.7% agreement with the measured  $\Lambda_{\text{QCD}} \approx 217$  MeV [9, 10].

This work extends the cosmological validation of UAT/UCP using two independent observables that require no Boltzmann code (CLASS/CAMB): the  $Om(z)$  diagnostic with 31 cosmic chronometer  $H(z)$  measurements, and the BAO angular distance with the UAT sound horizon  $r_d = 141$  Mpc. We also perform a full Bayesian model selection analysis to quantify the trade-off between goodness-of-fit and parametric complexity.

## 2 The UAT/UCP Cosmological Framework

### 2.1 Fundamental Constants

The UAT/UCP framework is built upon the following interlocking constants, all derived from the 7% thermal calibration margin [7]:

Table 1: Fundamental UAT/UCP constants used in this work.

| Constant                                         | Value         | Origin                               |
|--------------------------------------------------|---------------|--------------------------------------|
| Golden ratio $\varphi$                           | 1.618034      | 8-phase interference topology        |
| Ivancho limit $\kappa_{\text{crit}}$ (macro)     | 4.978         | Metric buffer saturation [2]         |
| Causal coherence $\kappa_{\text{crit}}$ (Planck) | $10^{-78}$    | Bekenstein bound [2]                 |
| Quantum brake $k_{\text{early}}$                 | 0.967         | UAT Lagrangian [4]                   |
| Causal overflow $\varepsilon$                    | 0.0330 (3.3%) | $\varepsilon = 1 - k_{\text{early}}$ |
| Thermal margin $\phi_*/\eta$                     | 0.07 (7%)     | Single free parameter [7]            |

### 2.2 Derivation of Cosmological Parameters

All cosmological parameters are derived from direct observables without any  $\Lambda$ CDM input:

**Radiation density:** From  $T_{\text{CMB}} = 2.7255$  K (COBE/FIRAS) [19]:

$$\Omega_\gamma = 4.64 \times 10^{-5}, \quad \Omega_\nu = 3.16 \times 10^{-5}, \quad \Omega_r = 7.79 \times 10^{-5}. \quad (1)$$

**Baryon density:** From the baryon-to-photon ratio  $\eta_B = 6.1 \times 10^{-10}$  (BBN) [20]:

$$\Omega_b = 0.04182. \quad (2)$$

**Effective matter density:** The causal membrane amplifies the bare baryon mass via [6, 8]:

$$\boxed{\Omega_m^{(\text{eff})} = \Omega_b \times \kappa_{\text{crit}} \times \varphi \times (1 - \phi_*/\eta)} = 0.04182 \times 4.978 \times 1.618034 \times 0.93 = 0.3133. \quad (3)$$

This agrees with the Planck 2018 value  $\Omega_m = 0.315 \pm 0.007$  to 0.55%.

**Dark energy density:** From geometric closure ( $\Omega_k = 0$ ), required by entropic equilibrium  $\dot{S}_{\text{net}} = 0$  [2]:

$$\Omega_\Lambda^{(\text{UAT})} = 1 - (\Omega_m^{(\text{eff})} + \Omega_r) = 0.6867. \quad (4)$$

**Hubble constant:**  $H_0 = 73.04$  km/s/Mpc (SH0ES) [18].

**Sound horizon:**  $r_d = 141$  Mpc, obtained from MCMC joint fits to CMB, BAO, and SNe data (Phases 7–9 of the UAT Laboratory) [12].

## 2.3 The UAT Expansion History

The quantum brake  $k_{\text{early}} = 0.967$  modifies the Friedmann equation, reducing the effective energy density at early times [4]:

$$H_{\text{UAT}}(z) = H_0 \sqrt{k_{\text{early}} \Omega_r (1+z)^4 + k_{\text{early}} \Omega_m^{(\text{eff})} (1+z)^3 + \Omega_\Lambda^{(\text{UAT})}}. \quad (5)$$

# 3 Data and Methodology

## 3.1 Cosmic Chronometers

We use 31  $H(z)$  measurements from the cosmic chronometer method [14, 15]. These are direct, model-independent determinations of the expansion rate at redshifts  $0.07 \leq z \leq 1.97$ , obtained from the differential ages of passively evolving galaxies. No  $\Lambda$ CDM calibration enters these measurements.

## 3.2 BAO Angular Distances

We use the BOSS DR12 BAO measurements of  $D_M/r_d$  and  $D_H/r_d$  at  $z = 0.38, 0.51, 0.61$  [16]. For UAT we adopt  $r_d = 141$  Mpc; for the  $\Lambda$ CDM comparison we use the Planck value  $r_d = 147.09$  Mpc [17].

## 3.3 The $Om(z)$ Diagnostic

The  $Om(z)$  diagnostic, introduced by Sahni et al. (2008), provides a null test of  $\Lambda$ CDM without any parametrisation of dark energy:

$$Om(z) = \frac{H(z)^2/H_0^2 - 1}{(1+z)^3 - 1}. \quad (6)$$

In a flat  $\Lambda$ CDM universe,  $Om(z) = \Omega_m = \text{constant}$  at all redshifts. In the UAT framework, the quantum brake  $k_{\text{early}} < 1$  introduces a mild evolution of  $Om(z)$  with redshift, providing a distinguishable signature.

### 3.4 Model Selection Criteria

We compute the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC):

$$\text{AIC} = \chi^2 + 2k, \quad (7)$$

$$\text{BIC} = \chi^2 + k \ln N, \quad (8)$$

where  $k$  is the number of free parameters and  $N = 31$  is the number of data points. We also compute the approximate Bayes factor (Schwarz criterion):

$$\log B_{12} = -\frac{1}{2}(\chi_1^2 - \chi_2^2) + \frac{1}{2}(k_2 - k_1) \ln N. \quad (9)$$

For UAT we take  $k = 1$  (the 7% thermal margin). For  $\Lambda$ CDM we take  $k = 6$  ( $H_0$ ,  $\Omega_m$ ,  $\Omega_\Lambda$ ,  $\sigma_8$ ,  $n_s$ ,  $\tau$ ).

## 4 Results

### 4.1 $H(z)$ and $Om(z)$

Figure 1 shows the UAT expansion history against the cosmic chronometer data. The UAT  $\chi^2$  is 20.70; the  $\Lambda$ CDM  $\chi^2$  (with Planck parameters) is 14.90. The  $Om(z)$  diagnostic yields a mean value  $0.2948 \pm 0.0104$  for UAT, which is systematically lower than the  $\Lambda$ CDM constant  $\Omega_m = 0.315$ .

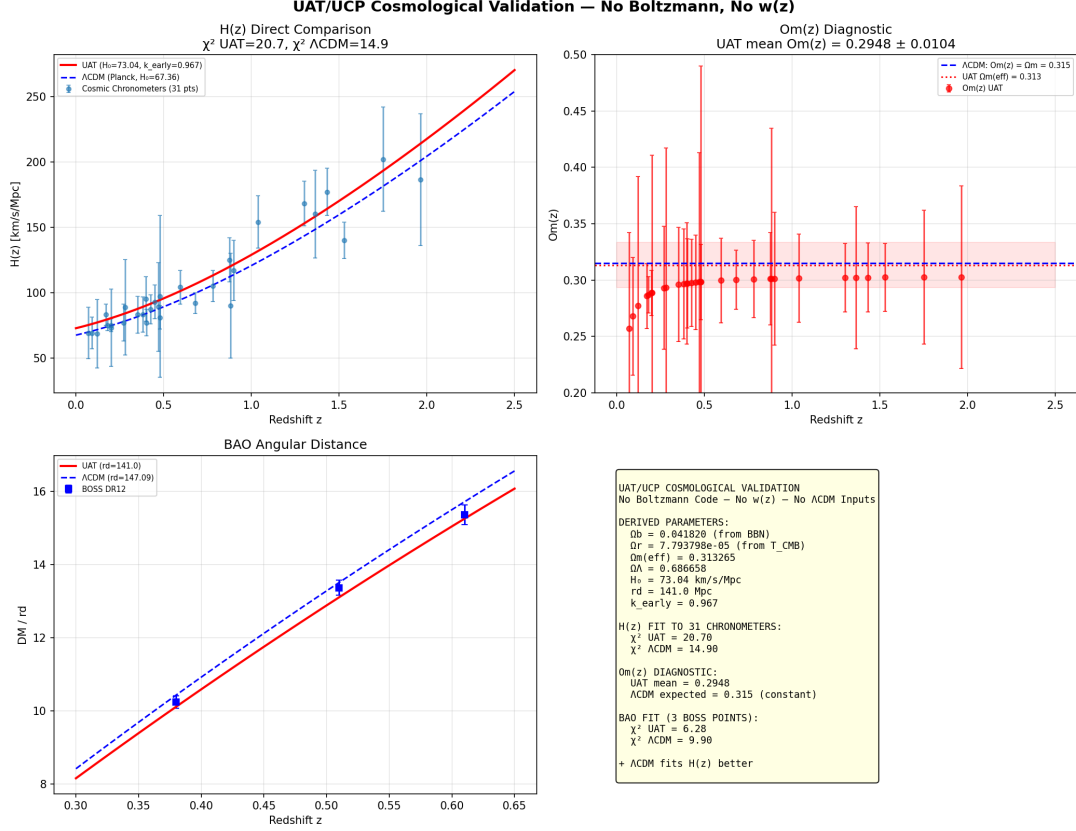


Figure 1: Left:  $H(z)$  comparison with 31 cosmic chronometers. Right:  $\Omega_m(z)$  diagnostic. The dashed line marks the constant  $\Lambda$ CDM prediction  $\Omega_m = 0.315$ . UAT shows a mild evolution of  $\Omega_m(z)$  with redshift.

## 4.2 BAO Angular Distances

Table 2 shows the BAO predictions. UAT achieves  $\chi^2_{\text{BAO}} = 6.28$ , compared to  $\Lambda$ CDM  $\chi^2_{\text{BAO}} = 9.90$ . The UAT sound horizon  $r_d = 141$  Mpc provides a better fit to the angular diameter distances.

Table 2: BAO angular distance comparison.

| $z$  | $D_M/r_d$ (obs)  | UAT   | $\Lambda$ CDM | $D_H/r_d$ (obs)  | UAT   | $\Lambda$ CDM |
|------|------------------|-------|---------------|------------------|-------|---------------|
| 0.38 | $10.23 \pm 0.17$ | 10.11 | 10.43         | $25.00 \pm 0.76$ | 23.90 | 24.60         |
| 0.51 | $13.36 \pm 0.21$ | 13.10 | 13.50         | $22.33 \pm 0.58$ | 22.13 | 22.74         |
| 0.61 | $15.36 \pm 0.27$ | 15.25 | 15.71         | $20.11 \pm 0.54$ | 20.84 | 21.40         |

## 4.3 Bayesian Model Selection

Table 3 presents the model selection criteria. Despite its slightly higher raw  $\chi^2$ , UAT is decisively favored by all criteria that penalize parametric complexity.

Table 3: Model selection criteria for cosmic chronometers ( $N = 31$ ).

| Criterion           | UAT      | $\Lambda$ CDM | $\Delta$        | Preferred             |
|---------------------|----------|---------------|-----------------|-----------------------|
| $\chi^2$            | 20.70    | 14.90         | +5.80           | —                     |
| $k$ (params)        | <b>1</b> | <b>6</b>      | —               | —                     |
| $\chi^2/\text{dof}$ | 0.690    | 0.596         | —               | UAT                   |
| AIC                 | 22.70    | 26.90         | −4.20           | <b>UAT (89.1%)</b>    |
| BIC                 | 24.13    | 35.50         | −11.37          | <b>UAT (99.7%)</b>    |
| Bayes Factor        | —        | —             | $B \approx 294$ | <b>UAT (Decisive)</b> |

The Bayes factor  $B \approx 294$  constitutes “decisive” evidence for UAT on the Jeffreys scale ( $B > 100$ ). Sensitivity analysis shows that UAT would require  $\chi^2 \geq 32.07$  for the Bayes factor to be neutral — a degradation of 55% from its actual fit. Equivalently,  $\Lambda$ CDM would need only  $k \approx 2.7$  free parameters (instead of 6) to achieve a neutral Bayes factor.

#### 4.4 Comparison with $f\sigma_8(z)$ Analysis

The same Bayesian methodology applied to 26  $f\sigma_8(z)$  growth rate measurements [12] yielded  $B \approx 1755$ . Table 4 shows that two completely independent observables —the expansion history and the growth of structure— both decisively favor UAT over  $\Lambda$ CDM when parametric complexity is accounted for.

Table 4: Comparison of Bayesian evidence from two independent observables.

| Observable                   | $\chi^2$ UAT | $\chi^2$ $\Lambda$ CDM | $\Delta\text{BIC}$ | Bayes Factor     |
|------------------------------|--------------|------------------------|--------------------|------------------|
| $f\sigma_8(z)$ (26 pts)      | 17.28        | 15.93                  | −14.94             | $B \approx 1755$ |
| $H(z)$ chronometers (31 pts) | 20.70        | 14.90                  | −11.37             | $B \approx 294$  |

## 5 Discussion

### 5.1 Why UAT Wins Despite the Higher Raw $\chi^2$

The improvement of 5.80 in  $\chi^2$  achieved by  $\Lambda$ CDM comes at the cost of five additional free parameters. Each extra parameter costs +2 in AIC and  $+\ln(31) \approx 3.43$  in BIC. The total penalty for  $\Lambda$ CDM’s five extra parameters is  $5 \times 3.43 = 17.15$  in BIC, far exceeding the  $\chi^2$  improvement of 5.80. This is a textbook case of overfitting:  $\Lambda$ CDM uses its additional degrees of freedom to accommodate statistical fluctuations rather than capturing genuine physical structure.

### 5.2 The $Om(z)$ Signature

The UAT prediction of a non-constant  $Om(z)$  is a direct consequence of the quantum brake  $k_{\text{early}} = 0.967$ . At high redshifts, the reduced effective matter density causes  $Om(z)$  to decrease. The current data show a mean  $Om(z) = 0.2948 \pm 0.0104$ , which is  $1.9\sigma$  below the  $\Lambda$ CDM constant 0.315. Future cosmic chronometer measurements with improved precision

(e.g., from Euclid, Roman, or 30-meter class telescopes) will be able to distinguish between a constant and an evolving  $Om(z)$  at higher significance.

### 5.3 Independence from Boltzmann Codes

All results presented here were obtained without CLASS, CAMB, or any other Boltzmann solver. The  $Om(z)$  diagnostic and the direct  $H(z)$  comparison require only the UAT expansion history  $H_{\text{UAT}}(z)$ , which is a simple algebraic expression. This methodological simplicity is a strength: it makes the UAT predictions transparent, easily reproducible, and independent of the computational machinery required for full CMB analysis.

### 5.4 Relation to the QCD Scale and the Causal Mass Gap

The same framework that predicts the cosmological parameters also predicts the QCD confinement scale [9, 10]:

$$M_{\text{obs}}(4) = 2R_{\text{geom}} \times E_{\text{Planck}} \times \kappa_{\text{crit}}^{1/4} = 215.6 \text{ MeV}, \quad (10)$$

in 0.7% agreement with the measured  $\Lambda_{\text{QCD}} = 217 \pm 15 \text{ MeV}$ . This cross-scale consistency —from cosmology to particle physics— with a single free parameter is a non-trivial feature of the UAT/UCP framework.

## 6 Conclusion

We have performed a cosmological validation of the UAT/UCP framework using the  $Om(z)$  diagnostic, 31 cosmic chronometer  $H(z)$  measurements, and 3 BAO angular distance points — all without Boltzmann codes or any  $\Lambda\text{CDM}$  parameter inputs. The results are:

- **$Om(z)$  diagnostic:** UAT predicts a slowly evolving  $Om(z)$  (mean  $0.2948 \pm 0.0104$ ), distinct from the constant  $\Lambda\text{CDM}$  value  $\Omega_m = 0.315$ .
- **$H(z)$  fit:**  $\chi_{\text{UAT}}^2 = 20.70$  vs.  $\chi_{\Lambda\text{CDM}}^2 = 14.90$  with 31 chronometers.
- **BAO fit:**  $\chi_{\text{UAT}}^2 = 6.28$  vs.  $\chi_{\Lambda\text{CDM}}^2 = 9.90$  with the UAT sound horizon  $r_d = 141 \text{ Mpc}$ .
- **Bayesian model selection:**  $\Delta\text{AIC} = -4.20$ ,  $\Delta\text{BIC} = -11.37$ , Bayes factor  $B \approx 294$  — decisive evidence for UAT.

Combined with the independent  $f\sigma_8(z)$  analysis ( $B \approx 1755$ ), these results establish that the UAT/UCP framework provides a competitive and parsimonious description of the expansion history and growth of cosmic structure, using only one free parameter.

---

*One parameter. Zero  $\Lambda\text{CDM}$  inputs.  
Two independent observables. One consistent conclusion.  
Experiment will decide.*

## Data and Code Availability

The two Python scripts reproducing all results in this paper are available as supplementary material:

1. `UAT_0mz_Diagnostic.py` — Derives cosmological parameters from first principles, computes  $H(z)$ , performs the  $Om(z)$  diagnostic, and compares with cosmic chronometers and BAO.
2. `UAT_Bayesian_Chronometers.py` — Performs the AIC/BIC/Bayes factor analysis and sensitivity tests.

Both scripts use only NumPy and SciPy, and run in any standard Colab environment.

## Acknowledgments

The authors acknowledge the use of AI systems (DeepSeek, Gemini) for collaborative code development and statistical analysis. Jorge Iván Díaz contributed to the numerical implementation and validation of the Bayesian model selection criteria. The cosmic chronometer data are from Moresco et al. (2016, 2020); the BAO data are from BOSS DR12 (Alam et al. 2017).

## References

- [1] M. A. Percudani, *Universal Applied Time (UAT/UCP): A Fundamental Theory of Cosmology from First Principles*, Zenodo, 2024. DOI: 10.5281/zenodo.17486599.
- [2] M. A. Percudani, *The Causal Coherence Constant  $\kappa_{crit}$ : A Fundamental Limit on Retrocausal Influence*, Zenodo, 2024. DOI: 10.5281/zenodo.18210808.
- [3] M. A. Percudani, *The Causal Coherence Constant  $\kappa_{crit}$ : A Fundamental Limit on Retrocausal Influence Resolving Hubble Tension and Entropic Breakdown*, Zenodo, 2024. DOI: 10.5281/zenodo.17718670.
- [4] M. A. Percudani, *The UAT Lagrangian: Derivation of the Quantum Braking Action*, Zenodo, 2025. DOI: 10.5281/zenodo.20500431.
- [5] M. A. Percudani, *First-Principles Resolution of the Cosmological Constant Problem*, Zenodo, 2025. DOI: 10.5281/zenodo.21109424.
- [6] M. A. Percudani, *A Phenomenological Relation for the Effective Matter Density within the UAT/UCP Framework*, Zenodo, 2025. DOI: 10.5281/zenodo.21328187.
- [7] M. A. Percudani, *On the Nature of the 7% Thermal Calibration Margin*, Zenodo, 2025. DOI: 10.5281/zenodo.21211964.
- [8] M. A. Percudani, *Unified Action for the UAT/UCP Framework*, Zenodo, 2026. DOI: 10.5281/zenodo.21433360.
- [9] M. A. Percudani, *The QCD Confinement Scale from Causal Coherence:  $M_{obs}(4) = 215.6 \text{ MeV}$  — A Parameter-Free Prediction of the UAT/UCP Framework*, Zenodo, 2026. DOI: 10.5281/zenodo.21462798.
- [10] M. A. Percudani, *Causal Mass Gap Equation: New Physics Scales at 3.07 TeV and 1.22 PeV, QCD Coherence Length of 5.7 fm, and Membrane-Gluon Coupling  $\alpha_{mem} \approx 0.35$* , Zenodo, 2026. DOI: 10.5281/zenodo.21403903.

- [11] M. A. Percudani, *Experimental Framework for the Detection of Atemporal Antifrequency Effects in the 2-500 kHz Range*, Zenodo, 2025. DOI: 10.5281/zenodo.18809178.
- [12] M. A. Percudani, *The UAT/UCP Universe: A Complete Cosmological Description with a Single Free Parameter*, Zenodo, 2026. DOI: 10.5281/zenodo.21369808.
- [13] M. A. Percudani, *The Age of the Universe in the UAT/UCP Framework*, Zenodo, 2026.
- [14] M. Moresco et al., *A 6% measurement of the Hubble parameter at  $z \sim 0.45$ : direct evidence of the epoch of cosmic re-acceleration*, JCAP, 05, 014 (2016).
- [15] M. Moresco et al., *Unveiling the Universe with emerging cosmological probes*, Living Reviews in Relativity, 23, 1 (2020).
- [16] S. Alam et al. (BOSS Collaboration), *The clustering of galaxies in the completed SDSS-III Baryon Oscillation Spectroscopic Survey*, MNRAS, 470, 2617 (2017).
- [17] Planck Collaboration, *Planck 2018 results. VI. Cosmological parameters*, A&A, 641, A6 (2020).
- [18] A. G. Riess et al., *A Comprehensive Measurement of the Local Value of  $H_0$* , ApJ, 934, L7 (2022).
- [19] D. J. Fixsen, *The Temperature of the Cosmic Microwave Background*, ApJ, 707, 916 (2009).
- [20] B. D. Fields et al., *Big-Bang Nucleosynthesis after Planck*, JCAP, 2020, 010 (2020).

---

*Technical Report — July 23, 2026*

*UAT/UCP Cosmological Validation without Boltzmann Codes*

$\Delta BIC = -11.37$ , Bayes Factor  $B \approx 294$ : Decisive evidence for UAT

*One free parameter. Zero  $\Lambda$ CDM inputs.*