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A CORRELATIONAL RELAXATION MECHANISM FOR THE HUBBLE TENSION CONSISTENT WITH HDC–CBC/Ω

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ABSTRACT

We present a late-time correlational relaxation mechanism for addressing the Hubble tension within the HDC–CBC framework. In the Ω synthesis, the rigid correlational regime yields a baseline value. Using the same correlational-index branching structure introduced in Ω, we demonstrate that controlled late-time realizations generate Planck-range and SH0ES-range reconstructions without modifying recombination physics or introducing additional propagating degrees of freedom. A minimal FRW numerical integration confirms internal structural consistency.

In addition, the ΩCt/N implementation performs a controlled parametric validation of the correlational-index domain under CMB priors, BAO, RSD, weak-lensing, ISW and lensing consistency checks. The analysis establishes a finite operational range and explicit falsifiability conditions for late-time realizations.

KEYWORDS

Hubble tension - cosmology - dark energy - correlational dynamics - HDC–CBC - late-time acceleration - modified Friedmann dynamics - vacuum–geometry equilibrium

1. INTRODUCTION

The discrepancy between early-universe determinations of the Hubble constant from Planck [1] and local measurements from SH0ES [2] remains a central problem in precision cosmology. Large-scale structure constraints, including DESI BAO measurements [3] and weak-lensing surveys such as DES Year 3 [13], further refine the late-time expansion history and constrain the growth amplitude parameter S_8.

In addition to background expansion tensions, mild but persistent discrepancies in structure growth amplitude have been reported in weak-lensing analyses [13], reinforcing the importance of simultaneously considering H_0 and σ_8 sectors in any late-time modification framework.

Within HDC–CBC [5–10], cosmic acceleration is interpreted as a correlational relaxation between geometric curvature and vacuum coherence. The Ω synthesis [12], together with the numerical module N [11], establishes that the rigid realization of the framework yields a baseline value that lies between Planck and SH0ES reconstructions and defines the central equilibrium realization.

$$H_0^{(\Omega)} \simeq 70.1.$$

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This work explores controlled late-time deviations around this Ω baseline, preserving early-time calibration and recombination physics while allowing finite correlational realizations at low redshift.

2. GOVERNING VARIATIONAL PRINCIPLE

HDC–CBC is defined by the equilibrium condition

$$\delta(\varepsilon_q - \varepsilon_g) = 0 (2)$$

or equivalently

$$\delta \int_{V_4} (\rho_q - \rho_g)\, d^4x = 0. (3)$$

This condition generates an effective correlational energy density in the emergent cosmological regime.

3. CORRELATIONAL INDEX AND EFFECTIVE REALIZATION

Cosmological realization is characterized by the correlational index

$$I_c \equiv \mathcal{F}(\varepsilon_q, \varepsilon_g). (4)$$

In this paper I_c is treated as an effective correlational realization index; its construction within the HDC–CBC corpus is detailed in Ω and in the numerical module N [11,12].

In the rigid Ω realization,

$$I_c(a) = I_{c0}, (5)$$

which produces the baseline value $H_0^{(\Omega)}$.

The effective correlational energy density is modeled as

$$\rho_C(I_c) = \rho_{C0}\, e^{\alpha(I_c - I_{c0})}, (6)$$

with $\alpha \sim \mathcal{O}(1)$.

This choice is a minimal positive-definite realization ensuring smooth sign-controlled deviations.

For $|\, I_c - I_{c0} \,| \ll 1$, Eq. (6) reduces to

$$\rho_C \simeq \rho_{C0}[1 + \alpha(I_c - I_{c0})],$$

which shows that the model behaves linearly for small deviations.

4. THREE-BRANCH LATE-TIME REALIZATION (Ω-CONSISTENT)

We adopt the same smooth late-time activation function used in Ω [12]:

$$S(a) = 1 - e^{-\beta(1-a)}, (7)$$

with $\beta \sim 3$.
We define three realizations:

(i) Ω Central Branch (Rigid)

$$I_c^{(0)}(a) = I_{c0}. (8)$$

(ii) Negative Branch (Planck-Range)

$$I_c^{(-)}(a) = I_{c0} - 0.044\, S(a). (9)$$

(iii) Positive Branch (SH0ES-Range)

$$I_c^{(+)}(a) = I_{c0} + 0.036\, S(a). (10)$$

The numerical offsets −0.044 and +0.036 are taken directly from the Ω toy realization (Appendix A.10.3) [12] and are not fitted in the present work.

The asymmetry between the negative and positive offsets reflects the nonlinearity of the correlational realization.

The transition between realizations is continuous in the limit $I_c \to 0$, and no discontinuity or phase-like transition is introduced across the correlational envelope. The three branches therefore represent smooth realizations within a single underlying correlational structure.

5. MODIFIED FRIEDMAN EQUATION

The background expansion obeys

$$H^2(a) = \frac{8\pi G}{3}\left[\rho_m(a) + \rho_r(a) + \rho_C(I_c(a))\right]. (11)$$

Early-time constancy is preserved in all three realizations, so recombination physics and the sound horizon remain unchanged in leading order.

In the asymptotic early-time limit $a \to 0$, the correlational sector vanishes identically and the model reduces exactly to ΛCDM background evolution. No modification of pre-recombination dynamics is introduced within the Ω-consistent realization.

6. MINIMAL NUMERICAL CONSISTENCY DEMONSTRATION

Equation (11) is integrated in an FRW setting with standard scaling laws

$$\rho_m \propto a^{-3}, \rho_r \propto a^{-4},$$

fixing early-time parameters to Planck-like values and enforcing agreement with the Ω baseline at $a \ll 1$. The only late-time input is the Ω-consistent realization of $I_c(a)$ in Eqs. (8)–(10).

The resulting values are:

Realization	ΔI_c	H_0 **(km/s/Mpc)**
Ω Central	0	**70.1**
Negative branch	−0.044	**67.4**
Positive branch	+0.036	**72.5**

Extended ΩCt/N Operational Scan

Beyond the minimal FRW consistency integration, the ΩCt/N numerical module performs a controlled sweep of constant correlational-index realizations and evaluates structural consistency across multiple observational sectors.

The scan reports:

- Effective H_0
- S_8
- σ_8
- ISW proxy
- Lensing proxy
- Gravitational Luminosity Drift (GLW), defined as the GW/EM luminosity-distance ratio at fixed redshift

The purpose of this extended analysis is not statistical fitting but operational validation of the admissible correlational domain.

Table — Selected ΩCt/N Numerical Outputs

Ic	**Tag**	**H0_eff**	**S8**	**σ8**	**ISW_proxy**	**Lensing_proxy**	**GLW(z=1)**	**GLW(z=3)**
−0.068	break− (BAO)	65.709	0.779760	0.760968	1.103186	1.058337	0.986163	0.939728
−0.044	PLANCK	67.400	0.776000	0.757298	1.081919	1.034068	0.986512	0.941223
0.016	ICCUB	71.627	0.796000	0.776816	1.029810	0.973393	0.987315	0.944660
0.036	SH0ES	73.036	0.812000	0.792431	1.012836	0.953167	0.987562	0.945719
0.051	break+ (WL)	74.093	0.827063	0.807130	1.000256	0.937997	0.987741	0.946488

Table — Structural Consistency Status Across Observational Sectors

Ic	**Tag**	**CMB**	**BAO**	**RSD**	**WL**	**ISW**	**GLOBAL**
−0.068	break− (BAO)	OK	FAIL	OK	OK	OK	BROKEN
−0.044	PLANCK	OK	OK	OK	OK	OK	OK
0.016	ICCUB	OK	OK	OK	OK	OK	OK
0.036	SH0ES	OK	OK	OK	OK	OK	OK
0.051	break+ (WL)	OK	OK	OK	FAIL	OK	BROKEN

The admissible Ω-consistent interval is therefore bounded by BAO on the negative side and weak-lensing on the positive side.

The weak-lensing sector is evaluated against DES Year 3 consistency levels [13], while ISW behavior is compared with Planck cross-correlation analyses [14]. The GLW proxy is motivated by standard GW/EM distance consistency tests following binary neutron-star observations [15].

The scan reveals a monotonic mapping between correlational-index deviations and effective H_0 , while preserving early-time calibration and sound-horizon stability.

These should be understood as Planck-range and SH0ES-range reconstruction levels, not as likelihood-based fits.

In all cases:

- r_s remains unchanged,
- Early-time expansion matches ΛCDM,
- No additional propagating sector appears.

This is a structural consistency test aligned with Ω [12] and the HDC–CBC/N module [11].

No additional free parameter beyond the Ω-consistent correlational index is introduced in the present realization, preserving parameter economy across the admissible domain.

7. STRUCTURE FORMATION

Linear growth satisfies

$$\delta'' + \left(2+\frac{H'}{H}\right)\delta' = 4\pi G\rho_m\delta. (12)$$

Since no new dynamical field is introduced, tensor propagation remains luminal:

$$c_T = 1. (13)$$

Within the admissible Ω-consistent interval, the correlational sector does not introduce additional propagating degrees of freedom and does not generate gradient or ghost instabilities at linear perturbative order. The growth equation (12) retains its ΛCDM-like structure, and tensor propagation remains luminal, ensuring perturbative stability across the operational domain.

8. INTERPRETATION

The Ω baseline defines the central correlational equilibrium realization.

Late-time deviations of the correlational index generate two branches around this central value, forming a correlational envelope that contains Planck-range and SH0ES-range reconstructions.

Unlike Early Dark Energy scenarios [4], the present mechanism does not modify pre-recombination dynamics nor alter the sound horizon scale, operating instead as a late-time correlational realization around the rigid Ω baseline.

This should not be read as an arbitrary $w(z)$ construction, but as an Ω-anchored correlational realization indexed by I_c.

8.1 Operational Domain and Falsifiability

Within ΩCt/N, failure is defined structurally: if any observational sector (CMB priors, BAO, RSD, weak lensing, ISW proxy or lensing proxy) returns FAIL under a given correlational-index realization, the configuration is flagged as non-admissible and the GLOBAL status becomes BROKEN.

The extended scan identifies a finite admissible interval around the rigid Ω baseline. At the extreme negative boundary, the first sector to fail consistency is BAO [3], while at the extreme positive boundary the first rupture occurs in the weak-lensing sector [13].

This establishes that the framework is not arbitrarily tunable but structurally bounded by independent observational sectors.

9. LIMITATIONS

This work:

- Does not perform an MCMC likelihood analysis,
- Does not include a full Boltzmann solver implementation,
- Does not claim a definitive resolution of the Hubble tension.
- Does not replace full Boltzmann solvers (CLASS/CAMB), although ΩCt/N Compatibility checks indicate structural agreement at background and growth-proxy level within the operational domain.

Its goal is to demonstrate internal structural consistency within the HDC–CBC/Ω framework.

10. CONCLUSIONS

We have presented a three-branch correlational relaxation realization fully consistent with the Ω synthesis of HDC–CBC.

The rigid Ω regime yields $H_0 \simeq 70.1$. Controlled late-time deviations of the correlational index, using the same numerical values introduced in Ω, generate Planck-range and SH0ES-range reconstructions without modifying early-universe physics.

Importantly, while we describe these realizations in terms of branches for clarity, the framework itself defines a broader space of admissible late-time scenarios. The three cases presented here should be understood as representative realizations within a continuous correlational envelope, not as an exhaustive classification.

The framework defines a finite, observationally bounded correlational envelope and remains explicitly falsifiable under independent large-scale structure constraints.

Within the Ω-consistent correlational envelope, the model predicts a smooth and monotonic correlation between effective H_0 shifts and gravitational-luminosity drift (GLW) at intermediate redshift. This correlated behavior provides a potential discriminant signature relative to ΛCDM and Early Dark Energy scenarios, which do not generically predict such a linked late-time drift structure without modifying pre-recombination physics.

Appendix A — Minimal Numerical Setup

The background integration of Eq. (11) is performed within a spatially flat FRW metric,

$$ds^2 = -dt^2 + a^2(t)\, d\vec{x}^2.$$

Matter and radiation components follow standard scaling laws:

$$\rho_m(a) = \rho_{m0} a^{-3}, \rho_r(a) = \rho_{r0} a^{-4}.$$

The correlational sector is defined through Eq. (6),

$$\rho_C(I_c) = \rho_{C0} e^{\alpha(I_c - I_{c0})},$$

with $I_c(a)$ specified by Eqs. (8)–(10).

Early-time initial conditions are fixed at $a \ll 1$such that:

- The Ω central realization matches the rigid baseline $H_0^{(\Omega)} \simeq 70.1$.
- The negative and positive branches converge to the same early-time expansion history.
- The sound horizon $r_s$remains unchanged at leading order.

The numerical integration is performed by solving Eq. (11) for $H(a)$ and reconstructing

$$H_0 = H(a = 1).$$

No likelihood fitting procedure is applied; the purpose of the integration is to verify structural consistency of the Ω-consistent correlational branching.

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