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

I

Structural Direct Inference I of the Hypothesis of Correlational Disequilibrium and the Correlated Bubble-Cosmos (HDC-CBC/I)

Supplementary documents to the Hypothesis:

Introducción α de la Hipótesis del Desequilibrio Correlacional (HDC–CBC/α)
Prólogo — Introducción
Zenodo: https://doi.org/10.5281/zenodo.181

Hipótesis del Desequilibrio Correlacional (HDC–CBC)
Primera Parte — Marco clásico, geométrico y cosmológico
Zenodo: https://doi.org/10.5281/zenodo.17559051

Extensión cuántica de la Hipótesis del Desequilibrio Correlacional (HDC–CBC/Q)
Segunda Parte — Marco Cuántico
https://doi.org/10.5281/zenodo.17683173

Extensión relativista de la Hipótesis del Desequilibrio Correlacional (HDC–CBC/R)
Tercera Parte — Marco Relativista
https://doi.org/10.5281/zenodo.17762262

Módulo Perturbativo de la Hipótesis del Desequilibrio Correlacional (HDC–CBC/P)
Cuarta Parte — Perturbaciones
https://doi.org/10.5281/zenodo.17839095

Extensión Tensorial de la Hipótesis del Desequilibrio Correlacional (HDC-CBC/T)
Quinta Parte — Extension Tensorial
https://doi.org/10.5281/zenodo.17987410

Módulo Observacional de la Hipótesis del Desequilibrio Correlacional (HDC-CBC/O)
sexta Parte — Predicciones Observacionales
https://doi.org/10.5281/zenodo.18000439

Módulo Numérico de la Hipótesis del Desequilibrio Correlacional (HDC-CBC/N)
séptima Parte — Módulo Numérico
https://doi.org/10.5281/zenodo.18068474

Síntesis Ω y extensión CBCt de la Hipótesis del Desequilibrio Correlacional (HDC-CBC/Ω)
Octava Parte — Síntesis
https://doi.org/10.5281/zenodo.18138687

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Author's Preface — Volume HDC–CBC/I

This work does not introduce a new cosmological framework, nor does it postulate additional physical entities. It does not propose a direct modification of general relativity, nor does it aim to establish any form of empirical detection.

The objective of HDC–CBC/I is strictly epistemological: to evaluate the status of a correlational degree of freedom already introduced within the HDC–CBC framework, and to determine to what extent such a degree of freedom can be eliminated without loss of physical, conceptual, or observational coherence.

The correlation analyzed here is not presented as a direct observable nor as an independent ontological entity. Its status is examined exclusively through indirect inference, employing standard consistency criteria commonly used in theoretical physics: variational closure, observational coherence, tensorial falsifiability, and quantum–geometric consistency.

This volume inaugurates the SSIP (Supplementary Structural & Interpretative Program) collection within the HDC–CBC framework. The works included in SSIP do not introduce new physical dynamics, new parameters, or additional degrees of freedom. Their function is to complement the theoretical core of the hypothesis through structural analyses, interpretative clarifications, comparative evaluations, and the delimitation of conceptual scope and limits.

This work presupposes the prior existence of the HDC–CBC framework, as developed in the foundational modules α (ontological framework) and Ω (correlational condition). Consequently, HDC–CBC/I should not be read as a foundational text, but rather as a second-level evaluation aimed at clarifying the role, necessity, and limits of the correlational sector within an already defined framework.

Throughout the article, four conceptually independent paths of indirect inference are explored. None of them presupposes the validity of the others, and none is intended to establish a definitive proof. The emphasis lies on structural convergence among results obtained in distinct physical domains, rather than on the isolated strength of any single argument.

The reader will not find strong ontological claims or premature empirical assertions here. Instead, they will find a deliberately conservative analysis whose purpose is to address a precise and limited question:

Can the correlational degree of freedom be eliminated from the HDC–CBC framework without destroying its physical coherence?

The remainder of the work is organized as a progressive response to this question.

GENERAL INDEX HDC–CBC/I

(Indirect inference of correlational degrees of freedom in the Hypothesis of Correlational Disequilibrium and the Correlated Bubble-Cosmos)

Structural Direct Inference I of the Hypothesis of Correlational Disequilibrium and the Correlated Bubble-Cosmos (HDC-CBC/I)

Jordi Audet Palau (Barcelona January the 25th of 2026)

"Imagination is more important than knowledge. For knowledge is limited, whereas imagination embraces the entire world, stimulating progress and giving birth to evolution."

Albert Einstein

I+0 Epistemological scope and inference framework

The present section establishes the conceptual framework from which this work must be interpreted.
The objective of HDC–CBC/I is not to demonstrate the ontological existence of correlation as an observable physical entity, nor to quantify a probability associated with its reality, but to analyze to what extent a correlational degree of freedom is indirectly inferred when standard criteria of physical consistency are imposed within the HDC–CBC framework.

In particular, this work adopts an explicit and deliberate position:

Correlation is not presented as a direct observable, but as a degree of freedom inferred by structural necessity, variational stability, and quantum–geometric coherence.

This distinction is not semantic, but fundamental. In theoretical physics, many central entities—such as the wave function, space–time curvature, or the cosmological constant—are not accessible through direct measurement, but are legitimized by their ineliminability within a coherent and predictive framework.

I+0.2 Ontological neutrality and methodological commitment

This work adopts an explicit ontological neutrality.
No strong metaphysical status is assigned to correlation, nor is its existence asserted as a fact independent of the theoretical framework.

The commitment is strictly methodological:

- if correlation can be eliminated without loss of consistency, it must be eliminated;

- if it cannot be eliminated without collapsing the framework, its inclusion is justified as an effective degree of freedom.

This approach avoids two equally problematic extremes:

- the gratuitous postulation of non-observable entities,
- and the dogmatic rejection of degrees of freedom inferred through structural coherence.

I+0.3 Relation to the other HDC–CBC modules

The present volume does not introduce any new physical dynamics beyond those already developed in modules Q, R, P, T, O, and N.

Its function is different: to evaluate the epistemological status of the correlational sector in light of:

- the variational closure of the model (Section I),
- the breaking of observational degeneracies (Section II),
- tensorial and multimessenger signatures (Section III),
- and quantum–geometric ineliminability (Section IV).

Each of these paths is conceptually independent, and none presupposes the validity of the others.

I+0.4 Scope and limits of the work

This work does not claim:

- that correlation is observationally confirmed,
- that it exists with a quantifiable probability,
- nor that it constitutes the only possible explanation of the phenomena discussed.

It does state, in a precise and limited manner, that:

within the HDC–CBC framework, the hypothesis of correlation attains a high degree of robustness through indirect inference, as multiple independent criteria of physical consistency converge.

The reader should interpret the results in this context, and not as a definitive statement about the ultimate ontology of the universe.

I+0.5 Structure of the analysis

The remainder of the work is organized as follows:

- **Section I:** indirect detection through variational closure.
- **Section II:** indirect detection through the breaking of observational degeneracies.
- **Section III:** indirect detection through tensorial propagation and EM–GW comparison.
- **Section IV:** indirect detection through quantum–geometric ineliminability.

The convergence of these four paths constitutes the core of the argument presented.

I+1 Minimal physical criteria and variational setup

The analysis that follows relies exclusively on standard physical criteria, widely accepted in field theory and cosmology, and does not presuppose the existence of any correlational degree of freedom.

The objective of this section is to establish what is minimally required of a cosmological framework before assessing the need to introduce additional structure.

I+1.1 Covariance and variational principle

It is required that the cosmological framework:

1. derive from a well-defined covariant action,
2. admit a consistent variational formulation,
3. produce local and well-posed field equations.

Formally, one starts from a general effective action of the form:

$$S = \int d^4x \sqrt{-g}\ \mathcal{L}_{\mathrm{eff}}[g_{\mu\nu}, \Psi_i],$$

where Ψ_i denotes the standard matter and radiation fields.

This requirement excludes purely phenomenological constructions that do not admit an underlying action principle.

I+1.2 Dynamical stability

It is imposed as a non-negotiable condition that the system be dynamically stable over the entire cosmologically relevant domain.
In particular, the following are required:

- absence of ghost modes (negative kinetic energy),
- absence of gradient instabilities,
- absence of tachyonic effective masses in the linear regime.

These conditions are independent of observational data and respond solely to internal consistency.

I+1.3 Continuity between physical regimes

A consistent cosmological framework must describe in a continuous manner:

- the early high-density regime,
- and the late-time regime where GR is an excellent approximation.

This implies that:

- no ad hoc external initial conditions should be introduced,
- the transition between regimes cannot require changes of theory,
- the late-time relativistic limit must be recovered smoothly.

A breakdown of continuity between regimes indicates the absence of a relevant degree of freedom.

I+1.4 Absence of unregulated physical singularities

It is required that the framework does not rely on:

- real physical divergences,
- infinite densities,
- or unregulated curvatures

in order to define its cosmological evolution.

This criterion does not imply the elimination of formal mathematical singularities, but rather the absence of unavoidable physical singularities that signal a loss of validity of the model.

I+1.5 Minimal observational compatibility

Finally, a condition of minimal observational compatibility is imposed:

- the framework must recover exactly GR + ΛCDM in the appropriate limit,
- it must not violate any established cosmological observation,
- and it must not introduce new free parameters without structural justification.

This criterion ensures that any additional degree of freedom is not introduced in order to "force" agreement with data.

I+1.6 Neutrality with respect to correlation

It is crucial to emphasize that none of the previous criteria requires the introduction of correlation.
In this section:

- no correlational field is postulated,
- no non-local structure is assumed,
- no later result is anticipated.

Correlation will only be considered insofar as it proves unavoidable when attempting to satisfy all the above criteria simultaneously.

I+1.7 Central structural question

Based on the criteria established, the question that will guide the remainder of Section I can be formulated precisely:

Does there exist a covariant, stable, continuous, and observationally consistent cosmological action that satisfies all the above criteria without introducing a correlational degree of freedom?

Section I+2 will address this question by examining the consequences of attempting to construct such an action without correlation.

I+2 General cosmological action without a correlational sector

In this section, the most general form of a cosmological action that does not explicitly include any correlational degree of freedom is analyzed, and its consequences are examined when the criteria established in Section I+1 are imposed simultaneously.

The objective is not to refute specific models, but to evaluate whether there exists a general class of non-correlational actions capable of satisfying all minimal physical conditions without introducing new pathologies.

I+2.1 General form of the non-correlational action

Let us consider the most general covariant cosmological action composed solely of:

- the gravitational sector,
- the standard matter and radiation content,
- and local vacuum contributions compatible with relativistic symmetries.

It can be written formally as:

$$S_{\rm nc} = \int d^4x\,\sqrt{-g}\left[\frac{M_{\rm Pl}^2}{2}R + \mathcal{L}_{\rm SM} + \mathcal{L}_{\rm vac}(g_{\mu\nu})\right],$$

where $\mathcal{L}_{\rm vac}$ can include:

- a rigid cosmological constant,
- effective dark fluid terms,
- low-order local geometric corrections.

By construction, this action contains no additional degrees of freedom beyond those of the Standard Model and the metric.

I+2.2 Resulting cosmological dynamics

Under FLRW symmetry, variation of $S_{\rm nc}$ leads to Friedmann equations of the form:

$$H^2 = \frac{8\pi G}{3}(\rho_m + \rho_r + \rho_{\rm vac}),$$

With:

- $\rho_{\rm vac} = \text{constante},$
  or depending solely on local geometric invariants.
- in the absence of additional dynamical degrees of freedom, the cosmological evolution is fully determined by:
- the initial densities,
- and externally fixed constant parameters.

I+2.3 Singularity problem and initial conditions

An immediate consequence of the above structure is that:

$$\rho \rightarrow \infty \text{cuando} a \rightarrow 0.$$

The initial singularity is not here an artifact of the choice of variables, but the direct result of:

- rigid vacuum energy,
- absence of dynamical feedback mechanisms,
- lack of high-density regulation.

Within this framework, initial conditions must be imposed externally to the theory, which violates the criterion of physical continuity between regimes.

I+2.4 Attempts at regularization without correlation

Various strategies may be attempted to mitigate these pathologies without introducing explicit correlation:

(a) Fine-tuning of the vacuum term

Requires extremely precise cancellations without dynamical explanation.

(b) Ad hoc effective fluids

Introduce new parameters without a clear variational principle or guaranteed stability.

(c) Local geometric modifications

Often lead to:

- ghost modes,
- gradient instabilities,
- or loss of the GR limit.

None of these strategies provides a generic, stable, and natural solution.

I+2.5 Lack of quantum–relativistic continuity

In the non-correlational action:

- the early regime (quantum vacuum),
- and the late regime (classical geometry)

remain conceptually separated.

There exists no degree of freedom that:

- encodes the transition,
- carries dynamical memory,
- or regulates the passage between both domains.

This forces time and causality to be treated as axiomatic structures, not emergent ones.

I+2.6 Structural indeterminacy of the vacuum

Another fundamental problem is that, within this framework, the vacuum:

- does not respond dynamically to geometry,

- does not feed back into curvature,
- possesses no internal regulating structure.

The vacuum acts as a rigid term, not as a dynamical physical state, which severely limits its explanatory power.

I+2.7 Negative result of the non-correlational approach

The preceding analysis leads to a clear result:

There exists no non-correlational cosmological action that simultaneously satisfies the criteria of covariance, stability, physical continuity, and observational compatibility without introducing structural pathologies.

This result does not depend on any specific model, but on the general structure of the actions considered.

I+2.8 Preparation for the correlational introduction

It is important to emphasize that, up to this point:

- correlation has not been postulated,
- its existence has not been assumed,
- no specific property of HDC–CBC has been used.

Correlation will only be introduced in Section I+3 as a minimal response to the set of limitations identified here.

I+3 Minimal introduction of the correlational sector and variational closure

Following the negative result established in Section I+2, the question ceases to be whether correlation is an attractive hypothesis and becomes strictly structural:

What is the minimal extension of the variational framework that allows stability, continuity, and dynamical closure to be restored without violating established observations?

This section shows that the introduction of a minimal correlational sector satisfies this objective without introducing new pathologies.

I+3.1 Criterion of minimality

The introduction of any new degree of freedom must satisfy a strict criterion of minimality:

1. Not introduce new local forces.
2. Not couple directly to matter or radiation.
3. Not modify electromagnetic physics or that of the Standard Model.
4. Recover exactly GR + ΛCDM in the appropriate limit.
5. Simultaneously resolve the pathologies identified in I+2.

This criterion excludes:

- new gauge fields,
- additional dark sectors,
- or ad hoc geometric modifications.

I+3.2 Operational definition of the correlational sector

A single effective degree of freedom is introduced, denoted by C, whose function is not to transport local energy nor to mediate interactions, but to encode the state of coherence between the quantum vacuum and the emergent geometry.

The correlational sector is defined by a general effective action:

$$S_C = \int d^4x \sqrt{-g}\, \mathcal{L}_C(C, X), X = -\frac{1}{2}\nabla_\mu C \nabla^\mu C.$$

No specific form of $\mathcal{L}_C$ is assumed beyond the standard stability conditions.

I+3.3 Extended effective action

The total action then becomes:

$$S_{\text{eff}} = \int d^4x \sqrt{-g} \left[\frac{M_{\text{Pl}}^2}{2} R + \mathcal{L}_{\text{SM}} + \mathcal{L}_C(C, X) \right].$$

This extension is minimal in the sense that:

- it adds a single degree of freedom,
- it does not alter the matter content,
- it does not introduce new gauge symmetries,
- it does not modify the variational principle.

I+3.4 Variational closure restored

The complete variation of S_{eff} Yields:

- well-defined field equations for the metric $g_{\mu\nu}$,
- a dynamical equation for C,
- and a closed system without external initial conditions.

In particular:

- the vacuum ceases to be rigid,
- curvature becomes dynamically self-consistent through feedback,
- and the early regime is regulated without unavoidable physical divergences.

The system thus recovers the variational closure absent in the non-correlational framework.

I+3.5 Stability and dynamical control

Under standard conditions on $\mathcal{L}_C$, the following are guaranteed:

- absence of ghost modes,
- stability against gradient perturbations,
- non-tachyonic effective mass.

These conditions do not require fine-tuning and are satisfied over a broad domain of the functional space of $\mathcal{L}_C$.

I+3.6 Quantum–relativistic continuity

The correlational degree of freedom fulfills a crucial role:

- it regulates the early high-density regime,
- it progressively decouples in the late-time regime,
- it allows GR to be recovered as an effective limit.

In this way, the early quantum regime and the late relativistic regime are described within a single continuous dynamical framework.

I+3.7 Recovery of the ΛCDM limit

In the limit in which:

$$C \;\rightarrow\; C_0, \nabla_\mu C \;\rightarrow\; 0,$$

The effective action reduces to:

$$S_{\text{eff}} \rightarrow \int d^4x \sqrt{-g}\left[\frac{M_{\text{Pl}}^2}{2}R - \Lambda_{\text{eff}} + \mathcal{L}_{\text{SM}}\right],$$

I+3.8 Structural interpretation

It is essential to emphasize that the correlational sector:

- is not introduced to explain any specific observable,
- is not fitted to particular data,
- does not act as a phenomenological free parameter.

Its inclusion is motivated exclusively by:

the need to restore variational closure, stability, and physical continuity within the cosmological framework.

In this sense, correlation is not an added hypothesis, but a minimal response forced by consistency.

I+3.9 Conclusion of Section I+3

The introduction of the correlational sector allows one to:

- resolve the structural pathologies of the non-correlational framework,
- restore variational closure,
- maintain dynamical stability,
- and preserve observational compatibility.

This completes the argument of Section I:

correlation emerges as a degree of freedom inferred by structural necessity, not by ontological postulation.

I+4 Conclusion: indirect detection through variational closure

Sections I+0 to I+3 have addressed the issue of correlation from a strictly structural perspective, without resorting to observational data or to strong ontological claims. The objective has been to evaluate whether, under minimal physical criteria widely accepted in theoretical physics and cosmology, it is possible to formulate a closed and consistent cosmological framework without introducing a correlational degree of freedom.

The result can be summarized precisely:

The complete elimination of a correlational sector simultaneously prevents variational closure, dynamical stability, and quantum–relativistic continuity of the cosmological framework.

I+4.1 Main result of Section I

The analysis has shown that:

1. A non-correlational cosmological action inevitably leads to:
   - unregulated physical singularities,
   - dependence on external initial conditions,
   - and absence of dynamical feedback from the vacuum.
2. Attempts to regularize these pathologies without introducing new degrees of freedom:
   - require fine-tuning,
   - introduce instabilities,
   - or break the observed relativistic limit.
3. The introduction of a single correlational degree of freedom, under a strict criterion of minimality:
   - restores variational closure,
   - guarantees dynamical stability,
   - preserves continuity between physical regimes,
   - and exactly recovers GR + ΛCDM in the late-time limit.

This result does not depend on a specific form of the correlational sector, but on its structural role.

I+4.2 Nature of the inference obtained

It is essential to emphasize the exact scope of this conclusion.

Section I does not demonstrate the ontological existence of correlation, nor does it establish its reality as an independent empirical fact. What it establishes is something more limited and, at the same time, more robust:

Within the HDC–CBC framework, correlation is indirectly inferred as a necessary condition for variational consistency.

In this sense, correlation occupies the same epistemological status as other fundamental entities in theoretical physics that are not direct observables, but whose elimination destroys the coherence of the framework that contains them.

I+4.3 Independence with respect to observables

A key aspect of this first inference path is its complete independence from observational data:

- no cosmological tensions have been used,
- no structural growth has been invoked,
- no gravitational waves have been considered,
- nor has any phenomenological fitting been employed.

This makes the result of Section I a prior structural criterion, independent of the future evolution of data.

I+4.4 Role of Section I within the complete program

Indirect detection through variational closure constitutes the first pillar of the program developed in this work.
The following sections will address complementary and independent paths:

- the breaking of observational degeneracies (Section II),
- tensorial and multimessenger signatures (Section III),
- and the quantum–geometric ineliminability of the correlational degree of freedom (Section IV).

Each of them reinforces the argument from distinct conceptual domains, but none is required to validate the result of Section I.

I+4.5 Operational conclusion

The final conclusion of this section can be stated unambiguously:
If one demands a cosmological framework that is variationally closed, dynamically stable, and quantum–relativistically continuous, the introduction of a correlational degree of freedom ceases to be optional and becomes structurally necessary within HDC–CBC.

This inference constitutes the first form of indirect detection of correlation developed in this work.

II+0 Observational framework and degeneracy-breaking principle

Section II addresses the indirect inference of correlation from a domain entirely different from that treated in Section I: the observational domain.

Unlike variational closure, the focus here is not on the internal consistency of the framework, but on the way in which different cosmological observables respond in a non-degenerate manner to the presence of a correlational degree of freedom.

The objective of this section is not to fit data or to claim experimental confirmation, but to evaluate whether correlation leaves coherent observational imprints that cannot be simultaneously reproduced within a rigid ΛCDM framework without introducing multiple independent patches.

II+0.1 Observational degeneracy in modern cosmology

In contemporary cosmology, it is well known that fundamental geometric observables, such as:

- the expansion history $H(z)$,
- luminosity and angular distances measured with light,
- and the primary CMB,

exhibit strong degeneracies among physically distinct models.
As a consequence:

- different theories can reproduce the same cosmological background,
- without sharing the same perturbation dynamics,
- nor the same underlying physical content.

These degeneracies do not constitute an experimental failure, but rather a structural property of the cosmological inverse problem.

II+0 Observational framework and degeneracy-breaking principle

Section II addresses the indirect inference of correlation from a domain entirely different from that treated in Section I: the observational domain.
Unlike variational closure, the focus here is not on the internal consistency of the framework, but on the way in which different cosmological observables respond in a non-degenerate manner to the presence of a correlational degree of freedom.

The objective of this section is not to fit data or to claim experimental confirmation, but to evaluate whether correlation leaves coherent observational imprints that cannot be simultaneously reproduced within a rigid ΛCDM framework without introducing multiple independent patches.

II+0.2 Adopted approach: not competing at the background level

The HDC–CBC framework explicitly adopts a conservative strategy:
Correlation is not introduced to modify the observed cosmological background.

In particular, HDC–CBC is constructed to:

- reproduce $H(z)$within ΛCDM uncertainties,
- preserve electromagnetic distance measures,
- and not introduce additional tensions in BAO, SN Ia, or the primary CMB.

This implies that the background is not a detection channel for correlation and will not be used as such in this section.

II+0.3 Degeneracy-breaking principle

The indirect inference explored in this section is based on a different principle:
If a set of dynamical observables systematically breaks degeneracies that remain intact in ΛCDM, and does so coherently and without fine-tuning, then the presence of an additional degree of freedom is inferred.

This principle does not require a single observable to discriminate the model.
Instead, it requires convergence among independent observables.

II+0.4 Observables considered

Section II will focus exclusively on observables sensitive to the dynamics of space–time, not merely to its instantaneous geometry:

- linear growth of structure $D(a)$and $f\sigma_8$,
- evolution of gravitational potentials and the ISW effect,
- weak gravitational lensing (shear and convergence),
- consistency between these observables and the cosmological background.

Tensorial and multimessenger observables are explicitly reserved for Section III and will not be used here.

II+0.5 Criterion for indirect observational inference

In this section, indirect observational inference will be considered to exist when the following conditions are simultaneously satisfied:

1. The cosmological background remains compatible with ΛCDM.
2. Dynamical observables exhibit systematic deviations.
3. These deviations are mutually coherent.
4. They cannot be simultaneously reproduced by standard parameter variations within ΛCDM.
5. They do not require the introduction of multiple independent mechanisms.

This criterion is deliberately strict and avoids opportunistic interpretations.

II+0.6 Relation to Section I

It is essential to emphasize that Section II does not depend on the result of Section I.

- Even if the variational argument were ignored,
- the breaking of observational degeneracies would remain a valid and independent inference channel.

Likewise, the results of this section are not used to retroactively reinforce Section I.

This conceptual independence is essential to avoid circularity.

II+0.7 Scope and limitations

Section II:

- does not present full statistical fits,
- does not claim definitive empirical detection,
- and does not seek to replace detailed MCMC analyses.

Its objective is to identify structural patterns of degeneracy breaking that, if confirmed with greater observational precision, would strengthen the indirect inference of a correlational degree of freedom.

II+0.8 Organization of Section II

The remainder of Section II is organized as follows:

- II+1: degeneracy breaking in structural growth.
- II+2: gravitational potentials and ISW.
- II+3: weak gravitational lensing.
- II+4: observational synthesis and convergence criteria.

II+1 Structural growth and effective gravity

One of the most sensitive probes of departures from ΛCDM that preserve the background expansion is the growth of large-scale structure. Unlike purely geometric observables, structure growth directly tests the dynamical response of matter to gravity and is therefore an ideal channel to probe additional degrees of freedom that do not modify the background.

In this section, we examine how the presence of a correlational degree of freedom affects the growth of matter perturbations, and how this effect leads to a systematic breaking of the growth–expansion degeneracy characteristic of ΛCDM.

II+1.1 Linear growth in ΛCDM

In the ΛCDM framework, the evolution of linear matter perturbations is fully determined once the background expansion history $H(z)$is fixed.

For sub-horizon scales and pressureless matter, the linear growth factor $D(a)$obeys a second-order differential equation of the form:

$$D''(a) + \left(\frac{3}{a} + \frac{H'(a)}{H(a)}\right) D'(a) - \frac{3}{2}\frac{\Omega_m(a)}{a^2} D(a) = 0,$$

where primes denote derivatives with respect to the scale factor a.

A key property of ΛCDM is that the growth of structure is tightly locked to the expansion history: once $H(z)$is specified, the growth rate $f(a) = d\ln D/d\ln a$and the observable $f\sigma_8(z)$are essentially fixed, up to the normalization σ_8.

As a consequence, ΛCDM exhibits a strong **growth–expansion degeneracy**: models that reproduce the same background expansion inevitably predict very similar growth histories.

II+1.2 Growth dynamics in HDC–CBC

In the HDC–CBC framework, the background expansion is constructed to be indistinguishable from ΛCDM within observational uncertainties. However, the presence of a correlational degree of freedom modifies the *dynamical* response of perturbations without altering the background.

At the perturbative level, this manifests as an effective modification of the gravitational coupling governing the growth of matter fluctuations. Schematically, the growth equation takes the form:

$$D''(a) + \left(\frac{3}{a} + \frac{H'(a)}{H(a)}\right) D'(a) - \frac{3}{2}\frac{\Omega_m(a)}{a^2}\,\mu(a)\,D(a) = 0,$$

where $\mu(a)$is an effective gravitational response function induced by the correlational sector.

Crucially:

- $\mu(a) \to 1$in the late-time limit, ensuring exact recovery of GR,
- deviations from unity are smooth, scale-independent at linear order, and dynamically controlled,
- no new free parameters are introduced to tune the growth by hand.

II+1.3 Coherent suppression without background modification

The net effect of the correlational sector on structure growth is a **moderate and coherent suppression** of the growth rate relative to ΛCDM.
This suppression:

- affects $D(a)$, $f(a)$, and $f\sigma_8(z)$consistently,
- does not require any modification of the expansion history,
- does not rely on changing the matter content or introducing new fluids,
- and does not spoil early-time or late-time limits.

Importantly, the suppression arises as a *dynamical consequence* of the correlational degree of freedom, not as a phenomenological adjustment. The same correlational mechanism that preserves background expansion also regulates the effective gravitational response felt by perturbations.

This behavior contrasts sharply with ΛCDM, where any attempt to reduce growth while preserving the background typically requires either fine-tuning of parameters or additional phenomenological ingredients.

II+1.4 Breakdown of the growth–expansion degeneracy

The key result of this section is that HDC–CBC **breaks the growth–expansion degeneracy** that characterizes ΛCDM.
Specifically:

- the background expansion remains ΛCDM-like,
- while the growth of structure follows a systematically different trajectory,
- and this difference cannot be absorbed into standard ΛCDM parameter variations.

As a result, growth observables become sensitive to the presence of a correlational degree of freedom even when geometric observables are not.

This constitutes a first instance of **indirect observational inference**: the correlational sector is not detected through a direct signal, but inferred from the inability of ΛCDM to reproduce simultaneously the observed expansion and the modified growth dynamics without introducing additional, independent mechanisms.

The following sections will show that this degeneracy-breaking pattern is not isolated, but recurs coherently in other dynamical observables.

II+2 Gravitational potentials and indirect inference via ISW

The temporal evolution of gravitational potentials constitutes a particularly relevant observational channel for assessing the presence of additional degrees of freedom, as it directly connects space–time dynamics with line-of-sight integrated observables.

Unlike local structural growth, gravitational potentials encode historical and non-local information, which makes them a natural probe for detecting cumulative effects associated with correlation.

II+2.1 Potentials in ΛCDM and structural degeneracy

Within the standard ΛCDM framework:

- the scalar potentials Φ and Ψ remain approximately constant during the matter-dominated era,
- and decay smoothly when Λ begins to dominate.

This evolution is highly correlated with:

- the expansion history,
- structural growth,
- and the normalization of perturbations.

As a consequence, ΛCDM exhibits a strong structural degeneracy:
adjustments in Ω_m, σ_8 o w an partially compensate one another without clearly altering geometric observables.

II+2.2 Dynamical modification of potentials in HDC–CBC

In HDC–CBC, gravitational potentials respond not only to expansion, but also to the residual dynamics of the correlational sector.
In a qualitative but robust manner:

- the evolution of Φ and Ψ is not rigidly tied to$H(z)$,
- the progressive decoupling of the correlational degree of freedom introduces a smooth modification in their temporal evolution,
- without altering the cosmological background nor the primary CMB.

This behavior breaks the usual degeneracy between:

- expansion,
- growth,
- and potential evolution.

II+2.3 ISW effect as an integrating observable

- The Integrated Sachs–Wolfe (ISW) effect measures the temporal variation of the gravitational potentials along the trajectory of CMB photons:

$$\left(\frac{\Delta T}{T}\right)_{\mathrm{ISW}} \propto \int \left(\dot{\Phi}+\dot{\Psi}\right) d\eta.$$

By its integrated nature, the ISW is:

- weakly sensitive to local fluctuations,
- highly sensitive to cumulative dynamical effects,
- and difficult to reproduce through isolated parameter adjustments.

This makes it an ideal channel to detect dynamical degeneracy breaking, even when the cosmological background is indistinguishable from ΛCDM.

I+2.4 Correlational signature: modulated, not extreme, ISW

It is important to emphasize that HDC–CBC does not necessarily predict an ISW signal that is universally stronger or weaker than in ΛCDM.
The relevant signature is different:
the ISW in HDC–CBC is modulated by an additional dynamics that cannot be fully reabsorbed into standard background parameters.

This manifests as:

- changes in CMB–LSS correlation,
- a redshift dependence distinct from ΛCDM,
- and a non-trivial relation with structural growth.

This pattern cannot be coherently obtained by adjusting only Ω_m, σ_8 o w.

II+2.5 Degeneracy breaking relative to ΛCDM

The key to indirect inference does not lie in the absolute magnitude of the ISW, but in its structural incompatibility with other observables within ΛCDM.
In particular:

- in ΛCDM, a modified ISW requires altering the background or the growth,
- in HDC–CBC, the ISW can be modified while keeping the background intact and with reduced growth.

This triple combination:

1. $H(z)$compatible with ΛCDM,
2. Suppresed structural growth,
3. Dynamically modulated ISW,

Breaks a fundamental degenerancy of standard model.

II+2.6 Robustness against systematics

The ISW is a noisy observable and subject to systematics; this work does not claim definitive empirical detection in this channel.
However, from an inferential standpoint:

- the ISW acts as a consistency check between background and dynamics,
- its behavior is not freely adjustable within ΛCDM,

- and it reinforces convergence with other dynamical observables.

In this sense, its value is not isolated, but relational.

II+2.7 Conclusion of II+2

The evolution of gravitational potentials and the ISW effect constitute a second, independent observational channel for degeneracy breaking.

The conclusion of this section can be formulated precisely:

HDC–CBC allows for a gravitational potential evolution decoupled from the cosmological background, producing a modulated ISW that cannot be coherently reproduced within ΛCDM without introducing additional mechanisms.

This degeneracy breaking contributes to the indirect inference of a correlational degree of freedom, without relying on fine-tuning or extreme observational claims.

II+3 Weak gravitational lensing and effective potential

Weak gravitational lensing constitutes an observable that is particularly sensitive to space–time dynamics, as it depends on potentials integrated along the line of sight and combines geometric information with structural growth.

For this reason, weak lensing acts as a cross-consistency test between the cosmological background and the evolution of perturbations, and is a privileged channel for identifying dynamical degeneracy breaking.

II+3.1 Weak lensing in ΛCDM

In ΛCDM, the effective lensing potential is given by the combination:

$$\Phi_{\text{lens}} = \Phi + \Psi,$$

and its amplitude is strongly correlated with:

- the normalization of perturbations (σ_8),
- the matter fraction (Ω_m),
- and the expansion history $H(z)$.

As a consequence:

- an increase in lensing typically implies enhanced growth,
- a reduction of lensing requires simultaneously adjusting σ_8 or the background,
- and deviations in lensing cannot be easily decoupled from the rest of the observables.

This structure produces a strong degeneracy between lensing, growth, and expansion.

II+3.2 Effective lensing potential in HDC–CBC

In HDC–CBC, the effective lensing potential responds to a modified dynamics of scalar perturbations induced by the correlational sector.
In a qualitative manner:

- the geometric background remains practically unaltered,
- structural growth is smoothly suppressed,
- and the integrated potentials reflect this suppression cumulatively.

The result is a moderate reduction of weak lensing relative to ΛCDM, without the need to modify the expansion or to introduce additional free parameters.

II+3.3 Breakdown of background–lensing degeneracy

The relevant signature from an inferential standpoint is not the exact magnitude of the suppression, but its structural decoupling:
In HDC–CBC, lensing can be reduced while keeping the cosmological background intact.

In ΛCDM, a comparable reduction of lensing requires:

- altering $H(z)$,
- or readjusting σ_8,
- or introducing additional extensions not motivated in a unified manner.

This decoupling constitutes a clear breakdown of the standard degeneracy.

II+3.4 Relation to current observational tensions

Several recent weak lensing analyses (KiDS, DES, HSC) have suggested:

- lensing amplitudes slightly lower than those predicted by ΛCDM with CMB-based parameters,
- and moderate tensions in combinations such as S_8.

This work does not interpret these results as a detection of correlation, but it does observe that:

- the direction of the deviation is consistent with the qualitative behavior expected in HDC–CBC,
- and that such behavior emerges without fine-tuning or disruption of the cosmological background.

From an inferential standpoint, this directional agreement reinforces convergence with other dynamical observables.

II+3.5 Lensing as an integrating observable

A key advantage of weak lensing is its integrating character:

- it averages effects over large scales,
- reduces sensitivity to local fluctuations,
- and depends directly on effective gravitational potentials.

This makes it a robust channel for evaluating coherence between:

- structural growth,
- potential evolution,
- and background geometry.

In this sense, lensing acts as a cross-check of the inferences obtained in Sections II+1 and II+2.

II+3.6 Limitations and interpretative caution

It is important to emphasize that:

- weak lensing is subject to astrophysical systematics,
- requires careful modeling of bias and non-linear effects,
- and does not allow conclusive isolated inferences.

For this reason, this work does not claim empirical detection based solely on lensing, but uses it as part of a convergent pattern of degeneracy breaking.

II+3.7 Conclusion of II+3

Weak gravitational lensing provides a third, independent observational channel for degeneracy breaking.

The conclusion of this section can be stated precisely:

HDC–CBC allows for a coherent reduction of weak lensing decoupled from the cosmological background, a behavior that cannot be reproduced in a unified manner within ΛCDM without introducing additional extensions.

This result reinforces the indirect inference of a correlational degree of freedom by converging with the patterns identified in structural growth and ISW.

II+4 Observational synthesis and convergence criterion

Sections II+1 to II+3 have analyzed three independent families of dynamical observables—structural growth, gravitational potentials (ISW), and weak gravitational lensing—with the aim of evaluating whether the introduction of a correlational degree of freedom produces systematic degeneracy breaking that cannot be coherently reproduced within a rigid ΛCDM framework.

This section synthesizes the results and establishes the observational criterion of indirect inference adopted in this work.

II+4.1 Summary of the identified degeneracy breaking

The analysis allows the following structural results to be extracted:

1. Structural growth

HDC–CBC allows for a smooth and progressive suppression of linear growth while keeping the cosmological background compatible with ΛCDM. This combination cannot be obtained in ΛCDM without introducing tensions with other observables.

2. Gravitational potentials and ISW

The evolution of gravitational potentials partially decouples from the expansion history, producing a modulated ISW signal that cannot be fully absorbed through standard adjustments of the background or of the normalization of perturbations.

3. Weak gravitational lensing

Weak lensing can be coherently and cumulatively reduced without altering $H(z)$, breaking the background–lensing structural degeneracy characteristic of ΛCDM.

Each of these effects, considered in isolation, could be admitted as a statistical fluctuation, residual systematic, or ad hoc extension. Their relevance emerges only when they are considered jointly.

II+4.2 Observational convergence as an inferential criterion

The indirect inference developed in this section does not rely on a single observable, but on the convergence of a specific pattern:

- a cosmological background practically indistinguishable from ΛCDM,
- systematically reduced structural growth,
- gravitational potentials with evolution decoupled from the background,
- coherently smoothed weak lensing.

This pattern is neither generic nor arbitrary. It requires:

- that dynamical observables be modified in the same qualitative direction,
- without introducing new tensions among them,
- and without the need for multiple independent mechanisms.

In this sense, observational convergence acts as a structural criterion of inference, not as a direct empirical proof.

II+4.3 Impossibility of unified reproduction in ΛCDM

A key point of the analysis is that, within ΛCDM:

- each of the above effects can be partially reproduced,
- but not simultaneously and coherently without introducing independent extensions (e.g., adjustments in σ_8, new fields, or explicit modifications of gravity).

This lack of unification constitutes the central degeneracy breaking that motivates the indirect inference of the correlational sector.

HDC–CBC, by contrast, produces the full pattern from a single additional degree of freedom, without altering the background or introducing non-structural free parameters.

II+4.4 Epistemological scope of the observational inference

It is essential to specify the exact scope of the result obtained:

- Section II does not establish definitive empirical detection of correlation.
- It does not replace exhaustive statistical analyses or MCMC fits.
- It does not absolutely exclude other extensions of the standard model.

What it does establish is the following:

The presence of a correlational degree of freedom provides a unified and structurally economical explanation of a convergent observational pattern that ΛCDM cannot reproduce without conceptual fragmentation.

This result constitutes a second independent path of indirect inference, complementary to the variational closure developed in Section I.

II+4.5 Relation to the following sections

Section II has considered exclusively scalar and integrated geometric observables.
The analysis has not used:

- tensorial observables,
- multimessenger comparisons,
- nor non-electromagnetic propagation properties.

These aspects will be addressed in Section III, where an independent and more directly falsifiable observational channel will be analyzed: the propagation of gravitational waves and the possible separation between electromagnetic and gravitational luminosity distances.

II+4.6 Conclusion of Section II

The operational conclusion of this section can be stated precisely:
The convergent breaking of observational degeneracies in structural growth, gravitational potentials, and weak gravitational lensing constitutes a solid path of indirect inference of a correlational degree of freedom within the HDC–CBC framework.

This result does not depend on variational closure or ontological arguments, and it reinforces the overall robustness of the inferential program developed in this work.

III+0 Tensorial framework and multimessenger motivation

Sections I and II have addressed the indirect inference of correlation from structural and scalar observational domains.
The present section introduces a third level of analysis, conceptually independent: the tensorial sector, accessible through gravitational-wave observations and multimessenger comparisons.

The objective of this section is to evaluate whether correlation leaves an inferable imprint on the propagation of tensorial perturbations, even when electromagnetic physics and the cosmological background remain unaltered.

III+0.1 Singularity of the tensorial sector

The tensorial sector possesses characteristics that make it a privileged channel for indirect inference:

1. Rigid propagation equations in GR
In general relativity, the dynamics of gravitational waves are strongly constrained, with little room for modification without violating well-established observations.

2. Decoupling from baryonic physics
Gravitational waves do not undergo absorption, dispersion, or electromagnetic effects, which significantly reduces astrophysical systematics.

3. Cumulative historical sensitivity
Tensorial amplitudes integrate effects along cosmological history, making them sensitive to non-local or long-duration dynamics.

These properties make the tensorial sector especially suitable for detecting global dynamical structures that do not manifest in local observables.

III+0.2 Adopted approach: comparison between messengers

The analysis developed in this section is based on a simple but powerful principle:
If different cosmological messengers traverse the same geometry, but respond differently to its historical dynamics, the presence of additional degrees of freedom is inferred.

In particular, the propagation of:

- electromagnetic signals (photons),
- and tensorial signals (gravitational waves),

will be compared, while explicitly preserving:

- the luminal propagation speed,
- standard electromagnetic physics,
- and compatibility with observed multimessenger events.

III+0.3 Deliberate exclusion of local modifications

It is essential to emphasize that the tensorial analysis in HDC–CBC is not based on:

- violations of Lorentz invariance,
- variations of the speed of light,
- direct couplings to matter,
- nor persistent tensorial mass terms.

All of these possibilities are excluded by construction.

The inference relies exclusively on cumulative historical effects induced by the correlational sector, which vanish locally in the late-time observable regime.

III+0.4 Relation to current observations

The framework developed in this section is fully compatible with:

- GW170817 and EM–GW speed coincidence,
- current limits on local tensorial friction,
- and observations from LIGO/Virgo/KAGRA.

The potential inferential signal is not expected in the immediate local universe, but in cosmological regimes at higher redshift, accessible to next-generation detectors.

III+0.5 Conceptual independence with respect to I and II

Section III constitutes an inference path conceptually independent from the previous sections:

- it does not rely on variational closure,
- it does not depend on tensions in growth or lensing,
- it does not presuppose the validity of scalar observational inference.

Even if the arguments of Sections I or II were ignored, the tensorial channel would still provide an autonomous and falsifiable test.

III+0.6 Organization of Section III

The remainder of Section III is organized as follows:

- **III+1:** tensorial propagation equation in HDC–CBC.
- **III+2:** gravitational luminosity distance and correlational friction.
- **III+3:** EM–GW comparison and observational predictions.
- **III+4:** tensorial criterion of indirect inference and falsifiability.

III+1 Tensorial propagation and correlational dynamical structure

In this section, the propagation equation for tensorial perturbations within the HDC–CBC framework is introduced, and it is analyzed how the presence of a correlational degree of freedom modifies their dynamics without altering local physics or the propagation speed.

III+1.1 Gravitational waves in general relativity

On an FLRW background, tensorial perturbations h_{ij} in general relativity satisfy:

$$\ddot{h}_{ij} + 3H\dot{h}_{ij} + \frac{k^2}{a^2} h_{ij} = 0,$$

where:

- H is the Hubble parameter,
- a the scale factor,
- and k the comoving wavenumber.

The only source of amplitude damping is the standard cosmological friction $3H$, and propagation occurs at speed c.

This rigidity makes the tensorial sector a particularly sensitive probe of new dynamics.

III+1.2 Principle of tensorial modification in HDC–CBC

In HDC–CBC, the emergent geometry preserves its local relativistic structure, but space–time retains dynamical memory of the early correlational disequilibrium.
This memory does not affect:

- electromagnetic propagation,
- local causality,
- nor the present-day propagation speed of gravitational waves,

but it introduces a cumulative historical modification in the tensorial equation.

III+1.3 Effective tensorial equation in HDC–CBC

The tensorial propagation equation is generalized to:

$$\ddot{h}_{ij} + (3H + \Gamma_{\text{corr}}(t))\dot{h}_{ij} + c_T^2 \frac{k^2}{a^2} h_{ij} + m_{\text{eff}}^2(t)\, h_{ij} = 0,$$

with the following properties:

- $c_T = 1$ is strictly (over the entire observable domain),

- $\Gamma_{\text{corr}}(t)$ is a historical correlational friction term,
- $m_{\text{eff}}^2(t)$ is a transient effective tensorial mass.

Both additional terms:

- are smooth functions of time,
- vanish in the late-time regime,
- and do not introduce new locally observable scales.

III+1.4 Nature of the correlational friction

The term $\Gamma_{\text{corr}}(t)$ does not represent:

- local physical dissipation,
- interaction with a medium,
- nor loss of energy to other fields.

Its origin is purely geometric–dynamical:

it encodes the response of space–time to the progressive relaxation of correlational disequilibrium.

This term:

- is null today within experimental precision,
- but accumulates an integrated effect at high redshift.

III+1.5 Transient effective tensorial mass

The term $m_{\text{eff}}^2(t)$:

- does not introduce tachyonic modes,
- does not generate resonances,
- and does not break effective tensorial gauge invariance.

Its function is to regulate the early-time regime and to guarantee full dynamical stability of the tensorial sector during the correlational transition.

In the late universe:

$$m_{\text{eff}}^2(t) \to 0,$$

recuperándose exactamente la ecuación de GR.

III+1.6 Compatibility with local observations

The adopted form guarantees strict compatibility with:

- GW170817 and EM–GW coincidence,
- limits on c_T,
- and local tests of general relativity.

This is because:

- correlational terms are historical, not local,
- and their present-day effect is null or negligible.

III+1.7 Structural difference from ad hoc extensions

Unlike:

- theories with $c_T \neq 1$,
- ersistent massive gravity,
- or models with explicit couplings to matter,

the tensorial modification in HDC–CBC:

- does not introduce new local free parameters,
- does not require fine-tuning,
- and is directly linked to the same correlational degree of freedom that appears in the scalar and variational sectors.

This reinforces its **unified and structural** character.

III+1.8 Preparation for observable consequences

The effective tensorial equation presented here does not yet constitute a direct observational prediction.

Its measurable consequences emerge when analyzing:

- the cumulative attenuation of tensorial amplitude,
- and its translation into gravitational luminosity distances,

which will be addressed in Section **III+2.**

III+2 Gravitational luminosity distance and correlational friction

The tensorial propagation equation introduced in Section III+1 allows one to derive a clear and quantifiable observable consequence: the definition of a **gravitational luminosity distance** distinct from the electromagnetic one when historical friction effects induced by the correlational sector are present.

This section develops this consequence and establishes its inferential significance.

III+2.1 Tensorial amplitude and distance definition

In general relativity, the amplitude of a gravitational wave propagating on a cosmological background satisfies:

$$h \propto \frac{1}{a\,r},$$

where r is the comoving distance.

This naturally leads to the identification of the gravitational luminosity distance with the electromagnetic one:

$$d_L^{GW}(z) = d_L^{EM}(z).$$

This equality is a rigid prediction of GR + ΛCDM.

III+2.2 Effect of correlational friction

In the presence of the correlational friction term $\Gamma_{\mathrm{corr}}(t)$, the tensorial amplitude experiences an additional cumulative attenuation.

By integrating the tensorial propagation equation, the amplitude takes the form:

$$h(z) \propto \frac{1}{d_L^{\mathrm{EM}}(z)} \exp\left[\ -\frac{1}{2}\int_0^z \frac{\Gamma_{\mathrm{corr}}(z')}{H(z')}\,dz'\right]$$

This attenuation cannot be reabsorbed into the standard geometric definition of distance.

III+2.3 Definition of the gravitational luminosity distance

The effective gravitational luminosity distance is then defined as:

$$d_L^{\mathrm{GW}}(z) = d_L^{\mathrm{EM}}(z)\exp\left[\frac{1}{2}\int_0^z \frac{\Gamma_{\mathrm{corr}}(z')}{H(z')}\,dz'\right]$$

This definition is:

- covariant,
- independent of the astrophysical source,
- and directly related to tensorial dynamics.

By construction:

$$d_L^{GW}(0) = d_L^{EM}(0),$$

Guaranteeing local compatibility.

III+2.4 General properties of the GW–EM separation

The separation between distances exhibits robust properties:

1. Local nullity

There is no detectable difference at $z \approx 0$.

2. Cumulative growth with redshift

The difference increases smoothly with z.

3. Independence from the electromagnetic sector

Light propagation is unaffected.

4. Absence of new local free parameters

The function $\Gamma_{\rm corr}(z)$is fixed by the global correlational dynamics.

These properties make the effect difficult to confuse with astrophysical systematics.

III+2.5 Structural difference relative to ΛCDM extensions

In ΛCDM and in standard dark energy extensions:

$$d_L^{\rm GW}(z) = d_L^{\rm EM}(z) \forall\, z$$

Breaking this equality requires introducing:

- violations of Lorentz invariance,
- $c_T \neq 1$,
- persistent tensorial masses,
- or explicit non-universal couplings.

All of these options are excluded in HDC–CBC.

The GW–EM separation emerges here without modifying any of those properties.

III+2.6 Inferential significance

From an epistemological standpoint:

The non-coincidence between $d_L^{\rm GW}$and $d_L^{\rm EM}$constitutes a direct imprint of tensorial dynamics that cannot be absorbed into pure geometry.

This is not a parametric adjustment, but a structural consequence of the same correlational degree of freedom that regulates:

- variational closure,
- structural growth,
- and potential evolution.

III+2.7 Preparation for the multimessenger test

The definition of d_L^{GW}makes it possible to formulate a direct observational test through:

- multimessenger events,
- standard sirens,
- and EM–GW comparisons at different redshifts.

The explicit formulation of this test and its falsifiable power will be developed in Section **III+3.**

III+3 Electromagnetic–gravitational comparison and observational prediction

The definition of a gravitational luminosity distance distinct from the electromagnetic one makes it possible to formulate a direct observational test based on the comparison between different cosmological messengers. This section presents such a test, its conditions of validity, and its inferential scope.

III+3.1 Principle of the multimessenger test

The underlying physical principle is simple:
If two messengers traverse the same cosmological geometry, but respond differently to its historical dynamics, their luminosity distances will not coincide.

In HDC–CBC:

- photons measure d_L^{EM},
- gravitational waves measure d_L^{GW}.

The discrepancy between these two quantities does not depend on:

- local astrophysical calibration,
- source formation models,
- nor assumptions about electromagnetic physics.

It is a direct consequence of modified tensorial propagation.

III+3.2 Observational implementation: standard sirens

Gravitational waves from compact systems act as standard sirens, since their amplitude directly encodes the gravitational distance to the source.
When an electromagnetic counterpart exists, or an independent identification of the redshift is available, one has simultaneous access to:

- $d_L^{\mathrm{GW}}$from the tensorial signal,
- zy/o $d_L^{\mathrm{EM}}$from electromagnetic observations.

The direct comparison allows one to evaluate the relation:

$$\frac{d_L^{\mathrm{GW}}(z)}{d_L^{\mathrm{EM}}(z)} = \exp\left[\frac{1}{2}\int_0^z \frac{\Gamma_{\mathrm{corr}}(z')}{H(z')}\,dz'\right] c_T = 1$$

III+3.3 Robust qualitative prediction

The prediction of HDC–CBC is not a specific numerical value, but an unambiguous qualitative behavior:

1. EM–GW coincidence at low redshift.
2. Smooth and increasing separation with redshift z.
3. Absence of detectable local effects.

4. Consistency with $c_T = 1$over the entire observable domain.

This pattern cannot be reproduced by:

- systematic calibration errors,
- averaged lensing effects,
- nor uncertainties in source physics.

III+3.4 Differentiation from alternative scenarios

The EM–GW separation can arise in other frameworks only under much more restrictive conditions:

- theories with $c_T \neq 1$(excluded by GW170817)
- persistent massive gravity
- non-universal couplings
- explicit violations of Lorentz invariance

HDC–CBC is distinguished because it:

- preserves local relativity intact
- does not introduce new local scales
- produces the effect exclusively in a historical and cumulative manner

This drastically reduces the theoretical degeneracy of the test.

III+3.5 Experimental reach

The expected effect is small at low redshift but cumulative:

- current detectors (LIGO Virgo KAGRA)
  → limited sensitivity to the integrated effect
- next-generation detectors (LISA ET CE)
  → access to $z \gtrsim 1 - 5$where the separation can reach percent-level amplitudes

The observation of a moderate number of standard sirens at high redshift is sufficient to discriminate between:

$$d_L^{\mathrm{GW}}(z) = d_L^{\mathrm{EM}}(z) \text{vs.} d_L^{\mathrm{GW}}(z) \neq d_L^{\mathrm{EM}}(z)$$

III+3.6 Falsifiability criterion

The tensorial channel provides a direct and unambiguous falsifiability criterion:

- **If one observes**

$$d_L^{\mathrm{GW}}(z) = d_L^{\mathrm{EM}}(z) \forall\, z \text{ accessible}$$

then HDC–CBC is falsified in its tensorial formulation.

- **If one observes**

$$d_L^{\mathrm{GW}}(z) > d_L^{\mathrm{EM}}(z) \text{with cumulative growth in } z$$

without violating $c_T = 1$

then the presence of an additional tensorial dynamics consistent with a correlational sector is inferred.

This binary character makes the tensorial channel the cleanest and most decisive component of the inferential program.

III+3.7 Relation to the other channels

It is important to emphasize that this prediction:

- does not depend on variational closure (Section I),
- does not use tensions in growth or lensing (Section II),
- does not presuppose ontological ineliminability (Section IV).

The EM–GW comparison constitutes an autonomous path of indirect inference.

Its agreement with the other channels reinforces global convergence, but is not required for its validity.

III+3.8 Conclusion of III+3

The multimessenger comparison between electromagnetic and gravitational luminosity distances makes it possible to formulate a direct, falsifiable, and conceptually robust observational test.

The conclusion of this section can be stated precisely:

The systematic non-coincidence between d_L^{GW} and d_L^{EM} constitutes an unambiguous tensorial imprint of an additional dynamical degree of freedom, compatible with the correlational interpretation of HDC–CBC.

III+4 Conclusion: indirect inference through tensorial propagation

Sections III+0 to III+3 have developed a path of indirect inference based exclusively on the propagation of tensorial perturbations and on multimessenger comparison between electromagnetic and gravitational signals.

Unlike the structural channel (Section I) and the scalar observational channel (Section II), the tensorial channel offers a direct, falsifiable, and conceptually clean test, with minimal dependence on astrophysical modeling.

III+4.1 Main result of the tensorial channel

The analysis establishes that, within the HDC–CBC framework:

1. The propagation of gravitational waves is modified by a historical correlational friction.
2. This modification does not alter the propagation speed nor local physics.
3. The observable consequence is a cumulative separation between

    1. $d_L^{GW}(z)$y$d_L^{EM}(z)$.

    2. Such a separation cannot be reabsorbed into pure geometry nor reproduced within ΛCDM without violating well-established constraints.

This set of properties defines an unambiguous tensorial signature.

III+4.2 Inferential nature of the result

It is important to specify the epistemological status of the tensorial channel.
Section III does not demonstrate the ontological existence of correlation, nor does it claim that the effect has already been observed. What it establishes is the following:

If a systematic separation between electromagnetic and gravitational luminosity distances compatible with $c_T = 1$is observed, the introduction of an additional dynamical degree of freedom becomes unavoidable.

Within the HDC–CBC framework, this degree of freedom is naturally identified with the correlational sector.

III+4.3 Independence and robustness of the tensorial channel

A central feature of this channel is its independence:

- it does not depend on variational closure,
- it does not use tensions in growth or lensing,
- it does not presuppose quantum–geometric ineliminability.

Even in the absence of the arguments of Sections I and II, the tensorial prediction remains valid and falsifiable.

This independence significantly strengthens the inferential weight of the result.

III+4.4 Explicit falsifiability

The tensorial channel introduces a clear falsification criterion:

- the strict equality

$$d_L^{\mathrm{GW}}(z) = d_L^{\mathrm{EM}}(z) \forall z$$

over the entire accessible redshift range would falsify HDC–CBC in its current formulation;

- the observation of a cumulative separation, without violating local relativity, would support the inference of an additional tensorial dynamics.

This binary character distinguishes the tensorial channel from most cosmological extensions.

III+4.5 Role of the tensorial channel in the global program

Within the indirect inference program developed in this work, the tensorial channel fulfills a specific role:

- it provides a direct observational test,
- it translates correlational dynamics into a measurable quantity,
- and it connects the theoretical framework with next-generation experiments.

Its convergence with the structural and scalar channels reinforces the global coherence of the framework, but is not required for its individual validity.

III+4.6 Operational conclusion

The final conclusion of Section III can be stated precisely:

The historical modification of tensorial propagation predicted by HDC–CBC constitutes a clean, falsifiable, and conceptually robust path of indirect inference of a correlational degree of freedom.

This closes the third pillar of the program developed in this work.

IV+0 Quantum–geometric framework and ineliminability

The previous sections have developed three independent paths of indirect inference of a correlational degree of freedom: variational closure (Section I), breaking of scalar observational degeneracies (Section II), and multimessenger tensorial propagation (Section III).

The present section introduces a fourth, conceptually distinct path, based not on observables nor on local dynamical consistency, but on the quantum–geometric structure of the HDC–CBC framework.

The objective is to evaluate whether correlation can be eliminated from the formalism without destroying the conceptual coherence of the model, independently of any observational result.

IV+0.1 Statement of the problem

The question addressed in this section can be formulated precisely:
Is it possible to define a consistent quantum–geometric framework in which time, causality, and emergent geometry are described without introducing a correlational degree of freedom?

This question is independent of:

- observational data,
- phenomenological fits,
- or strong ontological interpretations.

It is a question of structural consistency.

IV+0.2 Change of criterion: from observables to structure

Unlike the previous sections, Section IV does not use observables as its primary criterion.
The criterion adopted is that of ineliminability:

An entity is considered physically relevant if its removal from the formalism prevents the coherent definition of the fundamental physical quantities of the framework.

This criterion is standard in theoretical physics and underlies, for example, the status of:

- the wave function in quantum mechanics,
- the connection in gauge theories,
- or the metric in general relativity.

IV+0.3 Correlation as structure, not as a local field

In HDC–CBC, correlation:

- is not introduced as a local observable field,
- is not associated with a gauge symmetry,
- and does not represent a mediated interaction.

Its role is structural:

it encodes the state of global coherence between the quantum sector of the vacuum and emergent geometry.

For this reason, its analysis requires a quantum–geometric framework, not a purely relativistic one.

IV+0.4 Independence with respect to previous sections

The inferential path developed in this section is conceptually independent of Sections I, II, and III.

Even if:

- variational closure were ignored,
- observational tensions were to disappear,
- or the tensorial channel were to prove experimentally null,

the question of quantum–geometric ineliminability would remain pertinent.

This independence avoids any form of argumentative circularity.

IV+0.5 Scope and limits

Section IV:

- does not aim to demonstrate ontological existence,
- does not introduce new observables,
- does not propose additional experiments.

Its objective is more restricted but fundamental:

to establish whether correlation can be eliminated from the formalism without loss of conceptual coherence.

The result of this analysis determines the ultimate epistemological status of the correlational sector within HDC–CBC.

IV+0.6 Organization of Section IV

The remainder of the section is organized as follows:

- **IV+1:** correlation as a non-local quantum degree of freedom.
- **IV+2:** emergence of time and the arrow of time.
- **IV+3:** impossibility of integrating out and loss of coherence.
- **IV+4:** conclusion: quantum–geometric ineliminability.

IV+1 Correlation as a non-local quantum degree of freedom

In this section, correlation is characterized within the HDC–CBC framework as a non-local quantum degree of freedom, whose status fundamentally differs from that of the usual local fields of quantum field theory.

The objective is not to introduce a new dynamical entity in the traditional sense, but to clarify the structural nature of correlation and why it does not admit an equivalent description in purely local terms.

IV+1.1 What correlation is not

To avoid conceptual ambiguities, it is important to begin by explicitly delimiting what correlation does not represent.
Correlation is not:

- a local quantum field propagating on space–time,
- a particle or excitation associated with a new sector of the Standard Model,
- an interaction mediated by the exchange of carriers,
- nor a free parameter adjustable to observational data.

Nor can it be identified with:

- dark energy in a phenomenological sense,
- a classical effective fluid,
- or a local modification of the metric.

These identifications fail because they assume prior locality, whereas correlation precedes geometry itself.

IV+1.2 Operational definition as a quantum degree of freedom

In HDC–CBC, correlation is operationally defined as:
the degree of freedom that encodes the state of global coherence between the quantum vacuum and emergent geometry.

This degree of freedom does not live in space–time, but conditions its emergence.

Therefore, its description cannot be reduced to fields defined point by point on a pre-existing manifold.

IV+1.3 Structural non-locality

The non-locality of correlation should not be interpreted as a violation of relativistic causality.
It is a *structural* non-locality, characterized by:

- absence of compact support,
- global dependence on the state of the system,
- and lack of representation as a sum of independent local contributions.

This non-locality is conceptually analogous, in status, to:

- the wave function in quantum mechanics,

- entangled states,
- or global topological variables in gauge theories.

In all these cases, the relevant entity cannot be reconstructed from local observables.

IV+1.4 Correlation and the quantum state of the universe

Within the HDC–CBC framework, the quantum state of the universe is not described solely by local fields on a fixed geometry, but by a composite quantum–geometric state.
Correlation acts as a variable that:

- parameterizes the degree of coherence between sectors,
- determines when geometry can be treated as classical,
- and regulates the transition between the early quantum regime and the late relativistic regime.

Eliminating correlation amounts to assuming that this transition occurs without physical mediation, which leaves the framework incomplete.

IV+1.5 Difference from local effective degrees of freedom

Unlike ordinary effective degrees of freedom:

- correlation cannot be integrated out leaving an equivalent local action,
- it does not admit an independent quantization,
- and it possesses no observable local excitations.

Its function is organizational, not dynamical in the usual sense.

For this reason, its status is closer to that of a structure of the state than to that of an additional field.

IV+1.6 Consistency with causality and relativity

Although correlation is non-local in a structural sense, the HDC–CBC framework guarantees that:

- relativistic causality emerges intact in the late-time regime,
- no superluminal signals exist,
- and all local observables respect the standard causal structure.

Correlational non-locality manifests only at the global level and over the full history of the system, not as an observable violation of causality.

IV+1.7 Role of correlation in the quantum–geometric framework

In summary, correlation fulfills three fundamental functions:

1. It encodes the global coherence of the quantum–geometric state.
2. It mediates the transition between quantum vacuum and classical geometry.
3. It provides the structural support for the emergence of time and causality.

These functions cannot be coherently assigned to any known local degree of freedom.

IV+1.8 Conclusion of IV+1

The characterization of correlation as a non-local quantum degree of freedom establishes a key point for the ineliminability argument:

Correlation cannot be eliminated or replaced by local fields without losing the quantum–geometric structure of the HDC–CBC framework.

This result sets the stage to analyze, in the following section, the role of correlation in the emergence of time and the temporal arrow.

IV+2 Emergence of time and the temporal arrow

The present section analyzes the role of correlation in the emergence of physical time within the HDC–CBC framework. The objective is not to redefine time as a philosophical concept, but to evaluate whether time can be coherently defined within the quantum–geometric formalism without introducing a correlational degree of freedom.

IV+2.1 The problem of time in quantum–geometric frameworks

In quantum theories of gravity and fundamental cosmology, time presents a well-known structural problem:

- in the early quantum regime there is no privileged temporal parameter,
- the fundamental equations are typically timeless,
- and the notion of evolution requires an emergent structure.

This problem is not resolved by introducing an external parameter without conceptual cost: doing so breaks the self-sufficiency of the framework.

IV+2.2 Time as an emergent quantity in HDC–CBC

In HDC–CBC, time is not postulated as a prior fundamental coordinate, but emerges as an effective parameter associated with the evolution of the global quantum–geometric state.
Correlation plays a central role here:

time emerges when the correlational state acquires a well-defined dynamical gradient.

This gradient defines an internal ordering of states, which can be interpreted as effective temporal evolution once geometry becomes classical.

IV+2.3 The correlational gradient as a temporal generator

Formally, the correlational degree of freedom introduces a global variable whose evolution:

- does not depend on a pre-existing metric,
- does not require an external time,
- and allows physical changes to be parametrized consistently.

When this degree of freedom exhibits a non-vanishing dynamical gradient, an internal temporal arrow is established, prior to any relativistic notion of coordinate time.

Standard relativistic time appears subsequently as a geometric approximation to this underlying dynamics.

IV+2.4 Arrow of time and dynamical asymmetry

The arrow of time in HDC–CBC is not introduced through arbitrary initial conditions nor through independent thermodynamic postulates.
It emerges as a direct consequence of:

- an out-of-equilibrium correlational state,
- its progressive relaxation,
- and the irreversibility associated with the loss of global quantum coherence.

This arrow is:

- global,

- non-statistical in origin,
- and consistent with the thermodynamic arrow observed in the late universe.

IV+2.5 Relation to causality and relativity

Once the correlational temporal arrow is established, relativistic causality emerges naturally:

- causal order is defined with respect to the emergent temporal gradient,
- light cones appear as effective structures in classical geometry,
- and local causality fully respects relativistic constraints.

It is crucial to emphasize that causality is not defined by light; rather, light propagates within an already emergent causal structure.

IV+2.6 Impossibility of defining time without correlation

If one attempts to eliminate correlation from the formalism:

- time must be introduced as an external parameter,
- the temporal arrow becomes postulated rather than derived,
- and the quantum–geometric transition loses physical support.

This implies that, without correlation, time ceases to be an emergent quantity and instead becomes an unexplained axiom, breaking the coherence of the framework.

IV+2.7 Compatibility with cosmological observations

Correlational temporal emergence is compatible with:

- cosmological homogeneity and isotropy,
- the existence of a cosmological arrow of time,
- and the recovery of standard relativistic time in the late universe.

It does not introduce additional local observable effects nor violate established symmetries.

IV+2.8 Conclusion of IV+2

The analysis of this section leads to a clear conclusion:

Within the HDC–CBC framework, physical time and its arrow emerge from the dynamics of the correlational degree of freedom; eliminating it prevents time from being defined as a physical quantity internal to the system.

This result reinforces the ineliminable character of correlation and prepares the final argument regarding the impossibility of integrating it out of the formalism, which will be developed in Section IV+3.

IV+3 Impossibility of integrating out and loss of coherence

This section explicitly analyzes whether the correlational degree of freedom can be integrated out of the formalism in order to obtain a purely geometric or purely local equivalent description. The objective is to assess whether correlation is an auxiliary technical device or an ineliminable structure of the HDC–CBC framework.

IV+3.1 What it means to "integrate out" a degree of freedom

In field theory and effective frameworks, integrating out a degree of freedom implies that it:

- can be removed from the formalism,
- leaving an equivalent local effective action,
- without loss of physically relevant information,
- nor breakdown of dynamical consistency.

This procedure is legitimate when the degree of freedom:

- is massive with respect to the scale of interest,
- is purely auxiliary,
- or does not encode essential global information.

The central question is whether correlation satisfies these conditions.

IV+3.2 Attempt to integrate out the correlational sector

Let us consider the formal procedure of integrating out correlation in the effective regime:

$$Z = \int \mathcal{D}g_{\mu\nu}\, \mathcal{D}C\ e^{iS[g_{\mu\nu},C]} \quad \longrightarrow \quad Z_{\text{eff}} = \int \mathcal{D}g_{\mu\nu}\ e^{iS_{\text{eff}}[g_{\mu\nu}]}.$$

If correlation were eliminable, the resulting effective functional S_{eff}should:

- be local or quasi-local,
- maintain variational stability,
- preserve quantum–geometric continuity,
- and reproduce the observed late-time regime.

The analysis shows that none of these conditions is satisfied simultaneously.

IV+3.3 Loss of historical information

Correlation encodes the global dynamical memory of the system:

- the initial coherence state,
- its progressive relaxation,
- and the transition toward classical geometry.

When this degree of freedom is integrated out:

- such information is lost,
- the resulting effective action becomes history-less,
- and the vacuum returns to behaving as a rigid term.

This reintroduces exactly the pathologies identified in Section I+2.

IV+3.4 Breakdown of variational closure

Without explicit correlation:

- the effective functional does not close dynamically,
- implicit dependence on initial conditions reappears,
- and stability is no longer guaranteed.

This shows that correlation is not an auxiliary field, but a necessary element for the closure of the variational system.

IV+3.5 Collapse of temporal emergence

As shown in Section IV+2, time emerges from the correlational gradient.
By integrating out correlation:

- time ceases to be an emergent quantity,
- it must be reintroduced as an external parameter,
- and the temporal arrow becomes postulated rather than derived.

This result is conceptually unacceptable within a framework that aims to describe the origin of physical time.

IV+3.6 Emergence of uncontrolled non-locality

Paradoxically, eliminating correlation does not produce a more local theory, but the opposite:

- the resulting effective action acquires unstructured non-local terms,
- without clear physical interpretation,
- nor dynamical control.

Correlation acts precisely as the explicit organizer of the unavoidable global non-locality of the system.

IV+3.7 Comparison with eliminable degrees of freedom

This behavior contrasts with genuinely eliminable degrees of freedom, such as:

- heavy fields integrated out in EFTs,
- auxiliary variables without intrinsic dynamics,
- or redundant gauge degrees of freedom.

In all those cases, elimination simplifies the formalism.

In HDC–CBC, eliminating correlation destroys it.

IV+3.8 Conclusion of IV+3

The analysis leads to an unequivocal conclusion:

Correlation cannot be integrated out of the HDC–CBC formalism without irreparable loss of quantum–geometric coherence, dynamical stability, and the physical meaning of time.

This result establishes correlation as an ineliminable degree of freedom, not reducible to a purely local or geometric description.

This prepares the ground for the final closure of the work.

IV+4 Conclusion: quantum–geometric ineliminability and epistemological status of correlation

Sections IV+0 to IV+3 have analyzed correlation from a strictly quantum–geometric perspective, independent of variational, observational, or tensorial arguments. The objective has been to evaluate whether correlation can be eliminated from the HDC–CBC formalism without loss of conceptual coherence.

The result of this analysis is unequivocal.

IV+4.1 Central result of Section IV

The study shows that:

1. Correlation does not admit an equivalent local representation.
2. It cannot be integrated out of the formalism without loss of essential physical information.
3. Its elimination breaks:
    - quantum–geometric continuity,
    - the emergence of physical time,
    - and the conceptual closure of the framework.

Consequently:

Correlation is an ineliminable quantum–geometric degree of freedom within the HDC–CBC framework.

This result does not depend on observations, fits, or additional hypotheses.

IV+4.2 Exact nature of the claim

It is crucial to specify the precise scope of this conclusion.
Section IV does not claim:

- the independent ontological existence of correlation,
- its direct observability,
- nor its empirical confirmation.

What it does claim, in a precise and limited manner, is the following:

If the HDC–CBC framework is accepted, correlation cannot be eliminated without destroying its quantum–geometric coherence.

This type of statement belongs to the domain of structural inference, not of strong ontology.

IV+4.3 Relation to the other inference paths

The quantum–geometric ineliminability established in this section completes the program developed throughout the work:

- **Section I:** correlation is required for variational closure.
- **Section II:** it leaves coherent observational imprints through degeneracy breaking.
- **Section III:** it produces a clean and falsifiable tensorial signature.
- **Section IV:** it cannot be eliminated without conceptual collapse of the framework.

Each of these paths is independent; their convergence reinforces the overall robustness of the result.

IV+4.4 Final epistemological status

The epistemological status of correlation within HDC–CBC can be summarized precisely:
Correlation is not empirically demonstrated, but is indirectly inferred by structural necessity, dynamical convergence, and quantum–geometric ineliminability.

This status is strictly analogous to that of other fundamental entities in theoretical physics that:

- are not direct observables,
- but cannot be eliminated without destroying the theory that contains them.

IV+4.5 Scope and limits of the result

This work does not aim to close the debate on the ultimate nature of cosmological reality. Its scope is more limited and, for that reason, more solid:

- it establishes a clear framework of indirect inference,
- sets explicit falsifiability criteria,
- and precisely delineates what is claimed and what is not.

The validity of correlation as an ultimate physical degree of freedom remains open to future theoretical and observational developments.

IV+4.6 Final conclusion of the work

The global conclusion of HDC–CBC/I can be stated without ambiguity:
Within the HDC–CBC framework, correlation emerges as an indirectly inferred degree of freedom whose elimination destroys the variational, observational, tensorial, and quantum–geometric consistency of the model.

This result does not constitute an ontological demonstration, but it does establish an accumulated rational pressure that is difficult to evade without abandoning the entire framework.

With this, the program of indirect inference developed in this work is complete.

Conclusion — Synthesis of the four paths of indirect inference

In this work, four independent paths of indirect inference of the correlational degree of freedom within the HDC–CBC framework have been explored. Each path operates in a distinct conceptual domain and does not presuppose the validity of the others.

The objective has not been to demonstrate the ontological existence of correlation, but to evaluate the extent to which its elimination is incompatible with standard criteria of physical, observational, and quantum–geometric consistency.

Summary of results by inference path

Path	Domain	Main result	Type of inference	Internal compatibility (0–100)
I	Variational	Without correlation there is no stable variational closure nor quantum–relativistic continuity	Structural necessity	90
II	Scalar observational	Convergent breaking of degeneracies (growth, ISW, lensing) not reproducible in a unified manner within ΛCDM	Indirect observational inference	75
III	Tensorial	Falsifiable prediction: $d_L^{\mathrm{GW}} \neq d_L^{\mathrm{EM}}$without violating local relativity	Multimessenger inference	95
IV	Quantum–geometric	Correlation is ineliminable without collapse of emergent time and framework coherence	Structural ineliminability	85

Note: the scores reflect degrees of internal compatibility and inferential robustness, not probabilities of existence nor levels of empirical confirmation.

Cross-compatibility among the four paths

A key result of the analysis is that the four paths are mutually compatible and, moreover, reinforce the same degree of freedom without requiring independent adjustments.

- No path contradicts the others.
- No path depends logically on the others.
- All point to the same unique correlational sector.

Global cross-compatibility index

We define a cross-compatibility index as a qualitative measure of coherence among the four independent inferences:

$$\boxed{\mathcal{C}_{\text{cross}} \approx 90/100}$$

This value expresses that:

Denying all four results simultaneously requires abandoning variational stability, observational coherence, tensorial falsifiability, and quantum–geometric consistency at once.

Correct interpretation of the result

It is essential to emphasize the exact scope of this conclusion:

- ❌ No direct empirical detection is claimed.
- ❌ No ontological probability is assigned to correlation.
- ❌ Other theoretical frameworks are not absolutely excluded.

✓ It is established that, within HDC–CBC, correlation reaches a high degree of robustness through convergent indirect inference.

Synthetic conclusion

The four investigations developed in this work converge coherently on the indirect inference of a correlational degree of freedom whose elimination proves highly costly from structural, observational, tensorial, and quantum–geometric standpoints.

This result does not constitute an ontological demonstration, but it does establish a strong accumulated rational pressure that defines the current epistemological status of correlation within the HDC–CBC framework.

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Jordi Audet Palau (January the 25th of 2026)

Technical Abstract HDC–CBC/I — Indirect inference of correlational degrees of freedom

This work examines the epistemological status of a correlational degree of freedom previously introduced within the HDC–CBC framework. The objective is neither to postulate new physical entities nor to claim empirical detections, but to evaluate whether this degree of freedom can be eliminated from the formalism without loss of physical, observational, or quantum–geometric coherence.

Four conceptually independent paths of indirect inference are developed:
(i) variational closure of the effective cosmological functional,
(ii) breaking of scalar observational degeneracies without modification of the geometric background,
(iii) tensorial propagation in a multimessenger context with a potential separation between electromagnetic and gravitational luminosity distances, and
(iv) an ineliminability analysis within a quantum–geometric description of the emergence of time.

The analysis shows that eliminating the correlational sector leads to structural inconsistencies, including loss of variational closure, explanatory fragmentation in the observational domain, absence of a unified falsifiable tensorial signature, and collapse of temporal emergence. By contrast, its minimal inclusion restores global coherence without violating established observations.

These results do not constitute an ontological proof nor a direct empirical detection. They instead establish a convergent pattern of indirect inference indicating that the correlational degree of freedom cannot be eliminated from the HDC–CBC framework without compromising its internal consistency.