Chronon Field and the End of Timeless Physics

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Résumé

This article reformulates the concept of time through the Chronon Field $\Phi(x)$ introduced in the treatise *Time May Not Exist!*. It explores the hypothesis of a rhythmic physics in which reality is structured by pulses rather than by continuous flow. Bridging quantum gravity, relativistic dynamics, and the philosophy of temporality, it proposes that the coherence of the real emerges from local synchronization phenomena. We give a minimal mathematical scaffold for $\Phi(x)$, clarify its covariance and dimensions, and state falsifiable signatures spanning relativistic geodesy and quantum coherence. Time thus appears not as an external parameter but as an intrinsic rhythm of being, offering a new path toward reconciling structure and becoming within the foundations of modern physics.

Keywords : Chronon Field, intrinsic time, local synchronization, rhythm, quantum gravity, philosophy of time

CHRONON FIELD AND THE END OF TIMELESS PHYSICS

I — The problem of a frozen universe

Modern physics has achieved astonishing precision, yet it seems to have mislaid something essential : time itself. At the heart of canonical quantum gravity lies an enigma — the Wheeler–DeWitt equation for the quantum state of the universe,

$$\hat{H}\,\Psi[g,\varphi]=0,$$

with $\hat{H}$ the Hamiltonian constraint acting on geometric and matter degrees of freedom (g,φ). Majestic symmetry — and an unbearable silence : in this formalism the universal state is stationary, and change appears as a perspectival bookkeeping rather than an intrinsic feature of reality.

This "problem of time" is not rhetorical ; it follows from the very structure of general relativity (no preferred temporal parameter) and from applying quantum theory to the whole. In a closed system there is no external clock. Meanwhile, experiments in relativistic timing and quantum information reveal how fragile simultaneity is in practice : at relativistic velocities or within gravitational wells, sub-nanosecond mismatches (down to $\sim 10^{-12}\,$s on operational links) already threaten phase coherence in state-of-the-art optical clocks and interferometers. If our equations describe a world that does not move while our experience is of continuous becoming, a bridge is missing — between timeless constraints and the effective rhythm that underwrites observation.

II — The return of intrinsic time

The Chronon Field, $\Phi(x)$, is not a new force ; it is a new mode of description. It proposes that the universe is not merely geometrical but *rhythmical*. Each spacetime event carries a local frequency $\Phi(x)$ that sets the rate at which reality reconstructs itself — a pulsation of coherence rather than a flow of substance. This frequency does not "flow *in* time" ; it *creates* time, as an internal beat that yields persistence through fluctuation.

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Operationally, Φ is a scalar with inverse-time dimension,

$$[\Phi] = \mathrm{s}^{-1},$$

covariantly defined so that in any local rest frame Φ coincides with the proper-time beat of reconstruction. In precision atomic physics, long-lived coherence (ion traps, optical transitions) depends on sustained phase alignment, not on spatial endurance. Likewise, $\Phi(x)$ assigns each region of the cosmos an intrinsic phase — a clock without appeal to an external one. It introduces no preferred frame and violates no covariance : Φ is relational and locally defined by invariant procedures tied to proper time and phase.

Operational conventions & anchors (non-metric).

$$\boxed{d\tau = \Phi^{-1}(x)\,dt}, \qquad \boxed{J^\mu = \Phi\,u^\mu}, \qquad \boxed{\nabla_\mu J^\mu = \Gamma(x)}.$$

Weak-field dictionary (phenomenological, $\mathcal{O}(c^{-2})$) :

$$\nabla \ln \Phi \;\simeq\; \frac{\nabla\psi}{c^2} \quad\Rightarrow\quad \frac{\Delta\Phi}{\Phi} \;\simeq\; \frac{\Delta\psi}{c^2} \;\approx\; 1.1\times 10^{-16}\,\mathrm{m}^{-1}\times \Delta h,$$

with ψ the Newtonian potential. *Caveat :* Φ carries no stress–energy, does not alter null cones, and leaves GR geometry intact. Cosmology (homogeneous background) :

$$\boxed{a(t) \propto \Phi^{-1}(t)}, \qquad \boxed{H(t) = -\dot{\Phi}/\Phi}, \qquad H_0 \simeq 2.3\times 10^{-18}\,\mathrm{s}^{-1}.$$

III — The rhythm beneath the geometry

Einstein taught us that space and time form a single fabric — the metric field. Quantum theory teaches us that this fabric fluctuates. Yet in both frameworks, time mostly functions as a coordinate, an index for ordering events rather than a generator of persistence.

The Chronon Field $\Phi(x)$ suggests otherwise : beneath geometry lies *rhythm*. The metric $g_{\mu\nu}$ encodes curvature ; $\Phi(x)$ encodes *temporal density* — the local tempo of reality's endurance. In regions of strong gravity, where proper time dilates, the local beat slows : clocks tick more slowly not only by geometric redshift but as a modulation of temporal density itself. At quantum scales, where fluctuations dominate, $\Phi(x)$ becomes more irregular ; the beat jitters and phase stability is harder to maintain.

A minimal kinematic identity captures this reading. Let $\theta(x)$ be a local phase whose gradient orders events :

$$\Phi_\mu(x) \equiv \partial_\mu\theta(x), \qquad \Phi(x) \equiv \sqrt{\Phi_\mu\Phi^\mu}\,,$$

so that the scalar Φ sets the local rate at which phase — hence coherence — is renewed along a worldline. The field is not energetic in the Maxwellian sense ; it is rhythmic, specifying the density of re-instantiation events that constitute duration. As with temperature (not a coordinate but an emergent scalar of microscopic motion), time here is read as an emergent *beat* sustained by local coherence.

IV — Quantum gravity and the rhythm of existence

The challenge of quantum gravity is to reconcile two apparent contraries : deterministic geometry and probabilistic discontinuity. In the timeless Wheeler–DeWitt picture the universal wave function is stationary. Empirically, however, composite systems display revivals and recurrences whose timing is internally generated.

The Chronon Field offers a reconciliation : the universal state need not evolve in an external parameter t ; it *oscillates* with respect to an internal phase θ whose local rate is set by Φ. Relational-time constructions can be recast by promoting θ to a material phase variable ; the Hamiltonian constraint then selects stationary states, while predictions are expressed as *conditional* changes with respect to θ :

$$\frac{d\mathcal{O}}{d\theta} = \frac{1}{\hbar}\,[\mathcal{O},\hat{H}], \qquad \frac{d\theta}{d\tau} \propto \Phi,$$

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so that observable change is indexed to the *local beat* rather than to an external time coordinate. On bounded spectra, quantum revivals (e.g., Rydberg packets or trapped-ion cat states) illustrate how phase architectures reconstruct order without an outside clock ; $\Phi(x)$ extends the same logic to curved and interacting domains by supplying a covariant scalar rate for the phase variable.

Crucially, this does not introduce a preferred frame nor an energetic back-reaction : Φ is read operationally through phase-coherence protocols while the spacetime geometry remains governed by GR. Where $\nabla \ln \Phi \neq 0$, interferometric transport and network loops (Appendix A) provide null-tests and signed holonomies for *rhythmic* non-integrability ; where the system is effectively closed, conservation of phase current reduces to a continuity law (Appendix B), yielding falsifiable constraints on the allowed dynamics of Φ without adding any $T_{\mu\nu}$.

V — The measure of becoming

Understanding time as rhythm unifies disparate laws under a single operational reading : energy, momentum, and entropy become measures of *temporal coherence* and of its exchange. By Noether's theorem, energy is associated with time translation ; within the Chronon framework this conservation reflects phase continuity sustained across events — energy as the *amplitude* of temporal resonance maintained by Φ.

Gravity as rhythmic modulation. To first order in the Newtonian potential U (weak field, slow motion), the fractional modulation of the local beat obeys

$$\frac{\delta\Phi}{\Phi} \simeq \frac{\delta f}{f} \simeq \frac{\Delta U}{c^2},$$

which mirrors the gravitational redshift while *interpreting* it as a change in *temporal density* (higher $U \Rightarrow$ faster beat). Useful anchors : near sea level,

$$\frac{\Delta f}{f} \approx 1.1 \times 10^{-16}\,\mathrm{m}^{-1} \times \Delta h,$$

and at cosmological scale the softness of the mean beat corresponds to $\hbar H_0 \sim 10^{-33}\,\mathrm{eV}$.

Empirical program (beat-density metrology). Treat Φ as a *beat density* accessible through precision phase protocols :

— *Relativistic geodesy as Φ-cartography.* Compare optical lattice clocks separated by height Δh to resolve $\delta\Phi/\Phi \sim g\,\Delta h/c^2$; read the result as a controlled modulation of temporal density.

— *Coherence windows (quantum platforms).* From superconducting qubits (mK) to trapped ions/cold atoms, measure coherence while varying gravitational potential and controlled noise. A systematic correlation between dephasing rates and $\Delta\Phi$ tests

$$\Gamma = \Gamma_{\mathrm{env}} + \xi\,\Phi + b\,|\nabla\Phi|\,,$$

and yields bounds on (ξ, b) (Appendix B for the non-energetic status of these effective laws).

— *Interferometric phase transport.* Ramsey and Mach–Zehnder sequences across gravitational gradients test whether phase accumulation tracks $\int \Phi\,d\tau$ beyond the standard redshift ; any signed residual, bounded or null, is diagnostic (Appendix A for loop null-tests).

VI — Beyond timeless physics

The dream of a timeless universe arose from a noble aspiration to symmetry. Yet an equation that erases time also erases observation — and thus physics. Without succession there is no measurement, no memory, no experiment.

The Chronon Field does not *break* symmetry ; it *animates* it. It grants the universe not a direction but a pulse — a principle of recurrence that turns static form into living structure. At cosmological scale, one

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may model $\Phi(x)$ as a scalar coupled only through geometry and information flow, with its spatial mean setting the global tempo of expansion (already encoded in the operational identities of Sec. II). In this reading, the Hubble parameter H_0 is a macroscopic beat rate, a very slow echo of Φ integrated over cosmic order.

Minimal kinematics (closed vs. open). Conservation of temporal order admits a continuity law for a phase current :

$$J^\mu_\Phi \;\equiv\; \partial^\mu \ln\Phi \qquad \Longrightarrow \qquad \nabla_\mu J^\mu_\Phi = 0 \quad \text{(closed systems)},$$

i.e. redistribution (but not annihilation) of local beat in the absence of sources. In *open* settings one allows source terms that encode entropy exchange and decoherence, aligning the rhythmic view with thermodynamic arrows without postulating micro-level asymmetry :

$$\nabla_\mu J^\mu_\Phi = \Gamma(x), \qquad \Gamma \sim T_2^{-1} \;\; \text{(platform-dependent, operationally measured)}.$$

In media endowed with a preferred congruence u^μ, the transport current

$$\boxed{J^\mu = \Phi\, u^\mu}$$

recovers the operational picture used across this series (phase advection, diffusion projected with $h^{\mu\nu}$, and relaxation via Γ). Throughout, spacetime geometry remains entirely governed by GR : no modification of light cones and *no* additional stress–energy $T_{\mu\nu}$ is introduced. Detectability is therefore *metrological* (Appendix A : loop null-tests) and *informational* (Appendix B : effective, non-energetic dynamics), not gravitational in the Einstein equations.

VII — Conclusion : the reconciliation

The Chronon Field reconciles what modern physics had set apart : structure and becoming, geometry and duration, law and life. It does not import time from outside the theory ; it reveals an *intrinsic* rhythm by which reality maintains coherence locally. Spacetime geometry remains entirely governed by General Relativity — no alteration of light cones, no additional stress–energy — while $\Phi(x)$ reparametrizes operational standards (frequencies, durations) and renders the *measure of becoming* experimentally accessible. The framework is falsifiable by construction : closed-loop null tests in clock networks, residuals after GR subtraction on long baselines, and platform-dependent coherence protocols (qubits, ions, cold atoms) jointly bound or reveal gradients of $\ln\Phi$ and effective rates $(S, \mathcal{D}, \Gamma)$.

Beyond the rhetoric of a frozen universe, the program is to let rhythm animate symmetry : a covariant scalar beat that turns static constraints into living structure. If successful, this reading integrates metrology and information flow into the foundations, offering a minimalist but testable path to relate quantum coherence, relativistic time dilation, and cosmological expansion through the single operational variable Φ.

Outlook. The next article, *La Renaissance du Substrat — pourquoi le vide n'est pas vide*, extends the program by reading the “vacuum” as a rhythmic substrate : not an energy reservoir, but a phase-keeping background in which $\Phi(x)$ sustains appearance and stabilizes coherence.

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Appendix A. ANTI-GAUGE THEOREM : CLOSED-LOOP OBSERVABLE IS STRICTLY UNITY IN PURE GR, NON-UNITY IF $\nabla \ln \Phi \neq 0$

Setup and observable. Consider four events A, B, C, D forming a closed loop C (timelike segments along a congruence u^μ joined by lightlike links that transport phase). For each light link i, denote by $\left(\nu^{\rm GR}_{\rm rec,\,i}/\nu^{\rm GR}_{\rm em,\,i}\right)$ the frequency ratio predicted by *pure* General Relativity (GR)—i.e., the standard combination of gravitational and kinematic redshift—expressed via the scalars $u\cdot k$ at emission and reception. Define the *closed-loop observable* as the multiplicative residual

$$\boxed{\mathcal{L}[C] \;\equiv\; \prod_{i\in C} \frac{\nu_{\rm rec,\,i}}{\nu_{\rm em,\,i}} \Big/ \prod_{i\in C} \frac{\nu^{\rm GR}_{\rm rec,\,i}}{\nu^{\rm GR}_{\rm em,\,i}}} \tag{1}$$

where $\nu_{\rm em/rec}$ are the *measured* frequencies of local standards. Within the non-energetic Chronon framework, local standards are reparametrized by a scalar modulation

$$\nu_{\rm loc}(x) \;=\; \Phi(x)\,\nu^{\rm GR}_{\rm loc}(x), \qquad [\Phi] = {\rm s}^{-1}, \qquad d\tau = \Phi^{-1}(x)\,dt, \tag{2}$$

with no change to spacetime geometry (light cones intact, no extra $T_{\mu\nu}$).

Statement (anti-gauge theorem). *(i) In pure GR (no nontrivial Φ), the loop observable* (1) *is identically unity : $\mathcal{L}[C] = 1$ for any loop C built from ideal light links and coherent local transports. (ii) If $\nabla \ln \Phi \neq 0$, then for a generic (nondegenerate) loop the leading correction is nonzero and given by a covariant surface integral*

$$\boxed{\ln \mathcal{L}[C] \;=\; \iint_{\Sigma(C)} \Omega_{\mu\nu}[\Phi, u]\, d\Sigma^{\mu\nu} \;+\; \mathcal{O}(\Sigma^{3/2})}\,, \tag{3}$$

where $d\Sigma^{\mu\nu}$ is the oriented area bivector of a surface $\Sigma(C)$ bounded by C, and

$$\boxed{\Omega_{\mu\nu}[\Phi, u] \;\equiv\; a_{[\mu}\,\nabla_{\nu]}\ln\Phi \;+\; 2\,\omega_{\mu\nu}\,u^\rho\nabla_\rho \ln\Phi}\,, \qquad a_\mu \equiv u^\rho\nabla_\rho u_\mu, \quad \omega_{\mu\nu} \equiv h_\mu{}^\alpha h_\nu{}^\beta \nabla_{[\alpha} u_{\beta]}, \tag{4}$$

with $h_{\mu\nu} = g_{\mu\nu} + u_\mu u_\nu$ the orthogonal projector. In particular, if $a_\mu = \omega_{\mu\nu} = 0$ ***or*** *if $u^\rho\nabla_\rho \ln\Phi = 0$ and $\nabla_\perp \ln\Phi = 0$ on $\Sigma(C)$, then $\ln \mathcal{L}[C] = 0$.*

Proof (covariant sketch). *(i) Pure GR.* For a light link $p \to q$, the frequency ratio is $(u\cdot k)_q/(u\cdot k)_p$ (geodesic transport of k^μ and metric compatibility). Along a closed loop these factors telescope by concatenation of events, giving $\prod (u\cdot k)_q/(u\cdot k)_p = 1$, hence $\mathcal{L}[C] = 1$.

(ii) Scalar modulation. With (2), each local readout acquires a factor Φ evaluated at emission or reception. To first order in slowly varying Φ and for a small loop, one may write (discrete Stokes form)

$$\ln \mathcal{L}[C] = \sum_{i\in C} \big(\ln \Phi|_{\rm rec} - \ln \Phi|_{\rm em}\big)_i = \oint_C \alpha, \qquad \alpha \equiv \Pi \cdot d(\ln \Phi),$$

where Π is the operational projector induced by the segment kinematics (choice of u^μ on timelike edges and simultaneity hypersurfaces for links). By Stokes, $\oint_C \alpha = \iint_\Sigma d\alpha$. A standard covariant decomposition of $\nabla_\mu u_\nu$ (shear/expansion/vorticity/acceleration) together with Cartan's identity $d(\iota_u \beta) = \mathcal{L}_u \beta - \iota_u d\beta$ applied to $\beta = d \ln \Phi$ yields (4), hence (3). If Φ is constant, $d(\ln \Phi) = 0$ and the surface term vanishes ; if $\nabla \ln \Phi \neq 0$, coupling to a_μ or $\omega_{\mu\nu}$ makes the operational holonomy nontrivial.

Corollaries and protocols.

— **(C1) Null test in pure GR.** In a clock-and-link network, the closed product of ratios, after GR subtraction, must satisfy $\mathcal{L}[C] = 1$ (up to noise). Any stable deviation falsifies *pure* GR at the level of standards, without touching geometry.

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— **(C2) Rhythmic non-integrability criterion.** A nonzero loop requires both (i) $\nabla \ln \Phi \neq 0$ and (ii) at least one nonzero kinematic invariant over $\Sigma(C)$: a_μ (congruence acceleration) or $\omega_{\mu\nu}$ (vorticity).
— **(C3) Experimental design.** Maximize $\iint_\Sigma \Omega_{\mu\nu} d\Sigma^{\mu\nu}$ using mixed loops (fiber $\leftrightarrow$ satellite, long baselines, co-/counter-rotating segments) and time windows where $u^\rho \nabla_\rho \ln \Phi$ is most readable (slow modulation). No cone modification nor extra $T_{\mu\nu}$ is implied : only the *standard* is reparametrized by Φ.
— **(C4) Bounds and falsifiability.** If a family of loops $\{C\}$ with varied kinematics yields $\ln \mathcal{L}[C] = 0$ at sensitivity σ, one obtains direct bounds on $\nabla \ln \Phi$ and $u \cdot \nabla \ln \Phi$ via (3)–(4).

Editorial note (integrity of the framework). The “anti-gauge theorem” introduces no additional gauge field : a *scalar* Φ that reparametrizes standards makes the composition of transfers *operationally* non-integrable when kinematics $(a_\mu, \omega_{\mu\nu})$ is nontrivial. GR geometry remains intact ; the effect is entirely a matter of *standards' metrology.*

Appendix B. ZERO-ENERGY LEMMA : EFFECTIVE DYNAMICS OF Φ WITHOUT MEASURABLE $T_{\mu\nu}$ & DOMAINS OF VALIDITY

Operational hypotheses (non-energetic baseline).

(H1) **Unchanged geometry.** The pair $(g_{\mu\nu}, T^{\mathrm{mat}}_{\mu\nu})$ obeys Einstein's equations $G_{\mu\nu} = 8\pi G\, T^{\mathrm{mat}}_{\mu\nu}$. No additional contribution $T^{\Phi}_{\mu\nu}$ is allowed.

(H2) **Role of Φ.** Φ *reparametrizes standards* (frequencies/durations) operationally via

$$\boxed{d\tau = \Phi^{-1}(x)\, dt}, \qquad \boxed{J^\mu = \Phi\, u^\mu}, \qquad \boxed{\nabla_\mu J^\mu = \Gamma(x)},$$

with u^μ a unit timelike congruence ($u^\mu u_\mu = -1$), J^μ a phase current, and Γ a source/loss rate of coherence (dimension s^{-1}).

(H3) **Variational decoupling.** Φ does not enter any metric/matter Lagrangian density that contributes to $\delta S/\delta g^{\mu\nu}$. If constraints are used, they appear only as *pure divergences* (see below) and/or algebraic relations among auxiliary fields.

Statement — Zero-energy lemma. *Under (H1)–(H3), one can posit covariant and falsifiable effective dynamics for Φ (transport, projected diffusion, relaxation) while satisfying identically*

$$\boxed{T^{\Phi}_{\mu\nu} \equiv -\frac{2}{\sqrt{-g}} \frac{\delta S_\Phi}{\delta g^{\mu\nu}} = 0},$$

so Einstein's equations remain unchanged and every signature of Φ is operational *(metrological/informational) rather than gravitational.*

Proof — two equivalent constructions. *(A) Kinematic law without action.* Take as *operational postulates*

$$u^\mu \nabla_\mu \ln \Phi = S(x), \qquad \nabla_\mu(\Phi\, u^\mu) = \Gamma(x), \qquad h^{\mu\nu} \nabla_\mu \nabla_\nu \ln \Phi = \mathcal{D}(x),$$

where $h^{\mu\nu} \equiv g^{\mu\nu} + u^\mu u^\nu$ projects orthogonally to u^μ, and $S, \Gamma, \mathcal{D}$ are *measured* scalars (clock protocols, decoherence, common-mode noise) that are *not varied* in the gravity/matter action. No action S_Φ is introduced, hence trivially $T^{\Phi}_{\mu\nu} = 0$ while Φ remains testable through dimensioned residuals (cf. Appendix A).

(B) Constrained action with pure divergence. Introduce Lagrange multipliers to *impose* the laws while keeping metric dependence as a pure divergence :

$$S_\Phi = \int d^4x \sqrt{-g} \Big[\Lambda(\nabla_\mu J^\mu - \Gamma) + \lambda(J^\mu - \Phi u^\mu) u_\mu + \sigma(u^\mu u_\mu + 1)\Big].$$

After integration by parts, $\sqrt{-g}\, \Lambda\, \nabla_\mu J^\mu = \nabla_\mu(\sqrt{-g}\, \Lambda J^\mu) - J^\mu \nabla_\mu \Lambda \sqrt{-g}$; the metric variation of S_Φ is proportional to the imposed constraints and vanishes *on shell.* Thus $T^{\Phi}_{\mu\nu} = 0$ while yielding covariant Euler–Lagrange equations for J^μ, u^μ, Φ (transport/relaxation with transverse diffusion).

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Corollaries (explicit exclusions).

— **No metric "kinetic" term.** Any piece $\alpha\, g^{\mu\nu}\partial_\mu \ln\Phi\,\partial_\nu \ln\Phi$ produces $T^{\Phi}_{\mu\nu} \neq 0$ and is *excluded* in the baseline framework.

— **No potential $V(\Phi)$.** A $V(\Phi)$ would appear as an effective pressure/energy $(\propto V g_{\mu\nu})$: not allowed here. Earlier *energetic* ansätze are archived for historical traceability but no longer define the default reading.

Admissible effective forms (testable examples).

$$\begin{aligned}
&\text{(E1) Transport along } u^\mu: && u^\mu\nabla_\mu \ln\Phi = S(x), && (S \text{ measured; e.g. } S \simeq -H + \delta S)\\
&\text{(E2) Transverse diffusion}: && h^{\mu\nu}\nabla_\mu\nabla_\nu \ln\Phi = \mathcal{D}(x), && (\mathcal{D} \text{ readable by clock networks})\\
&\text{(E3) Continuity with source}: && \nabla_\mu(\Phi\, u^\mu) = \Gamma(x), && (\Gamma \simeq T_2^{-1} \text{ on qubits/ions}).
\end{aligned}$$

These laws are *dimensionally* homogeneous ($[\Phi]=\mathrm{s}^{-1}$, $[S]=[\mathcal{D}]=[\Gamma]=\mathrm{s}^{-1}$) and *covariant* (scalar/projected tensors only).

Domains of validity & fail-fast rules.

— **Local adiabatic regime.** Slow gradients : $|\nabla \ln\Phi| \ll |\nabla\psi|/c^2$ and $|u^\mu\nabla_\mu \ln\Phi| \ll 10^{-15}\,\mathrm{s}^{-1}$ on precision sites (optical clocks resolve 10^{-18}).

— **Geometry/standard decorrelation.** Signatures of Φ must *vanish* under link permutations and loop null-tests unless a robust $\nabla\ln\Phi$ structure is present (Appendix A).

— **Closed energy budget.** No gravitational reinterpretation of residuals : if a metric adjustment is required to fit data, the non-energetic baseline is falsified.

— **Experimental bounds.** If $\mathcal{L}[C] \to 1$ (Appendix A) at sensitivity σ, one sets direct bounds on $S, \mathcal{D}, \Gamma$ and on $\nabla\ln\Phi$.

Practical consequence. The lemma licenses a *rich effective dynamics* (advection/diffusion/relaxation) accessible to metrology and quantum information while guaranteeing *no* $T_{\mu\nu}$ footprint in Einstein's equations. Falsifiability is immediate : any need for $T^{\Phi}_{\mu\nu} \neq 0$ to explain data *rejects* the baseline or triggers a separate *energetic* variant (archived, outside the present article).

Appendix C. NOTATION, DIMENSIONS & COVARIANCE AUDIT + EDITORIAL NOTE

General conventions. Fully covariant (GR intact). Unless stated otherwise we set $c = 1$ for tensor identities; factors of c are reinstated in the weak-field dictionary and in order-of-magnitude anchors. "Operational" quantities (frequencies, durations, ratios) are defined by measurement protocols and do not imply any additional $T_{\mu\nu}$.

Weak-field reminders & useful anchors.

— $\nabla \ln\Phi \simeq \nabla\psi/c^2 \;\Rightarrow\; \Delta\Phi/\Phi \simeq \Delta\psi/c^2 \approx 1.1\times 10^{-16}\,\mathrm{m}^{-1}\times\Delta h$ (near sea level).

— Network target (optical clocks) : $(\Delta\nu/\nu)_{\mathrm{res}} \lesssim 10^{-18}$ with long independent baselines, link permutations, and loop null-tests.

— Rhythmic cosmology : $H_0 \simeq 2.3\times 10^{-18}\,\mathrm{s}^{-1}$; interpretation $H = -\dot\Phi/\Phi$ (testable via $H(z)$, strong-lens time delays, $f\sigma_8$).

Covariance checklist (controls).

1. **Geometry unchanged** (no cone alteration, no $T^{\Phi}_{\mu\nu}$) : any signature is *operational.*
2. **Local gauge invariance** of protocols (frequency ratios, closed products) : scalar observables ($\mathcal{L}[C]$, residuals).
3. **Falsifiability** : loop null-tests ($\mathcal{L}[C]\to 1$), link permutations, channel independence.

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Symbol	Type & covariance	Dimension	Definition / Operational role	Status
$\Phi(x)$	Covariant scalar	s^{-1}	*Local cadence of coherence.* Reparametrizes standards : $\boxed{d\tau = \Phi^{-1}dt}$.	Non-energetic
J^μ	Vector (free $\perp$)	s^{-1}	Phase current : $\boxed{J^\mu = \Phi\, u^\mu}$; conservation/relaxation $\boxed{\nabla_\mu J^\mu = \Gamma}$.	Operational
$\Gamma(x)$	Scalar	s^{-1}	Source/loss rate of coherence (e.g., T_2^{-1}) in $\dot{C} = (i\Phi - \Gamma)C$.	Measurable
u^μ	4-velocity, $u^2 = -1$	—	Congruence of observers/standards; transports J^μ.	Kinematic
$h_{\mu\nu}$	Projector $g_{\mu\nu} + u_\mu u_\nu$	—	Transverse projection (projected diffusion, null tests).	Geometric
a_μ	4-acceleration	s^{-1}	$a_\mu = u^\rho \nabla_\rho u_\mu$; enters loop holonomy.	Kinematic
$\omega_{\mu\nu}$	Vorticity	s^{-1}	$\omega_{\mu\nu} = h_\mu{}^\alpha h_\nu{}^\beta \nabla_{[\alpha} u_{\beta]}$.	Kinematic
ψ	Newtonian potential	$\mathrm{m}^2\mathrm{s}^{-2}$	Weak-field dictionary : $\nabla \ln \Phi \simeq \nabla\psi/c^2$.	Approx.
$a(t)$	Scale factor	—	*Rhythmic reading :* $\boxed{a(t) \propto \Phi^{-1}(t)}$.	Cosmology
H	Scalar	s^{-1}	*Rhythmic reading :* $\boxed{H = -\dot{\Phi}/\Phi}$ (with $H_0 \sim 2.3 \times 10^{-18}$).	Cosmology
$\mathcal{L}[C]$	Scalar (ratio)	—	**Closed-loop observable** (App. A) : $\mathcal{L}[C] = 1$ in pure GR; $\ln \mathcal{L}[C] = \iint \Omega_{\mu\nu} d\Sigma^{\mu\nu}$ if $\nabla \ln \Phi \neq 0$.	Null test
$\Omega_{\mu\nu}$	2-form	—	$a_{[\mu}\nabla_{\nu]} \ln \Phi + 2\omega_{\mu\nu}\, u^\rho \nabla_\rho \ln \Phi$ (App. A).	Detection
$S, \mathcal{D}$	Scalars	s^{-1}	Effective laws (App. B) : $u \cdot \nabla \ln \Phi = S$, $h^{\mu\nu} \nabla_\mu \nabla_\nu \ln \Phi = \mathcal{D}$.	Effective
$(\Delta\nu/\nu)_{\mathrm{res}}$	Scalar (ratio)	—	**Dimensioned residual** after GR subtraction; 10^{-18} target; maps $\delta\Phi/\Phi$.	Metrology

Table 1 Audit of notation, dimensions, and covariance. Boxed identities form the operational core of the non-energetic baseline.

Editorial note — Non-energetic baseline (present) *vs* energetic ansätze (archived). The **current baseline** is strictly **non-energetic** : *(i)* no $T^{\Phi}_{\mu\nu}$, *(ii)* no metric "kinetic" terms $\propto \partial \ln \Phi\, \partial \ln \Phi$, *(iii)* no potential $V(\Phi)$. Signatures of Φ are *operational only* (metrology, information, network correlations) and are tested via dimensioned residuals and closed-loop observables. **Earlier energetic ansätze** (Lagrangian forms with $T^{\Phi}_{\mu\nu} \neq 0$, conformal couplings, $V(\Phi)$, etc.) are **kept as historical archive** for traceability but no longer define the default reading of this article. If compelled by data, an *energetic* variant must be presented in a separate document with explicit discrimination protocols and associated bounds.

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