T≡M Theory — Time Is Motion: Cosmological Expansion as the Root Tick

Time as Hierarchical Motion Nested within Cosmological Expansion (Root Tick Θ)

Author: Mateo Moreira
Country: Uruguay
Email: mateomoreira@gmail.com
Version: T≡M Theory v2.1 — Preprint (Zenodo)
Date: June 2026

Dedicated to: my son and my wife, my guides in the Tempo.

Successor document to:

Moreira, M. *T≡M Theory — Time Is Motion: Cosmological Expansion as the Root Tick* (v2.0). Zenodo. DOI: https://doi.org/10.5281/zenodo.18856653

Moreira, M. *T≡M Theory — Time Is Motion* (v1.0). Zenodo. DOI: https://doi.org/10.5281/zenodo.17514234

Tempo symbol DOI: https://doi.org/10.5281/zenodo.17545235

Author's note

I do not come from the scientific or academic world. This theory comes from a long-held intuition: **time is motion**. In my v1.0 I tried to express it with words. In v2.0 I tried to express it with a more technical structure without losing my way of speaking.

This v2.1 exists because v2.0 did what it was supposed to do: it invited review, and the review found something real. The minimal ansatz of v2.0, in its simplest form, turned out to have **no observable content** — the residual parameter cancels in the only quantity metrology actually measures. This version corrects that, adopts the minimal form that *does* have observable content, and translates existing experimental constraints into the **first numerical bound** on the T≡M residual parameter.

As in previous versions, the order, notation, and formalization were produced with AI assistance, because my expertise in physics is limited. The idea, the conviction, and the decisions about what to keep are mine; the tool helps me say them with more rigor. I do not present this as a closed result, but as the next step of an open process: corrections, counterexamples, and proposals remain welcome.

What changed in v2.1 (changelog)

1. **The observability problem (new).** It is shown that the v2.0 minimal ansatz with a constant residual ($G(\Theta) = 1$) is unobservable: a universal ε_R cancels exactly in frequency ratios, and a clock-dependent constant ε_R is absorbed into the calibration of κ_R. Equation (8) is therefore revised.
2. **Drift ansatz promoted (revised eq. 8).** The minimal choice with observable content is $G(\Theta) = \Theta$: a residual *drift* of clock rates with accumulated expansion. What v2.0 left as "future work" becomes

the main ansatz, for a principled reason: minimality is now defined by observability, not by simplicity of form.

3. **First numerical bound (new, eqs. 9–11).** Existing long-term optical frequency-ratio comparisons translate into an order-of-magnitude bound on the differential residual: $|\Delta\varepsilon_R| \lesssim 10^{-8}$.
4. **Honest limit made explicit (new).** Frequency ratios can only constrain the *differential* (species-dependent) part of ε_R. A *universal* residual cancels in all ratio measurements and would require non-ratio tests. This sharpens what the weak version of T≡M can and cannot claim today.
5. **Notation (new).** The residual parameter is renamed ε_R (denoted α_R in v2.0) to avoid collision with the fine-structure constant α, which appears in the very literature on constants variation that this manuscript cites.

Everything else — postulates, the definition of Θ, the nested structure, the minimal event, the strong conjecture — is unchanged from v2.0.

Abstract

I propose a framework where **Time (Tempo)** is not an independent entity, but is **identical to universal motion**. The **root tick** of Tempo is cosmological expansion, represented as accumulated expansion Θ. All local motions exist as **nested motions** inside that root tick: different clocks measure different "elapsed time" because they do not measure an external container, but **internal motion counts**.

In this v2.1 the weak (testable) branch is corrected and sharpened. The v2.0 constant-residual ansatz is shown to be unobservable in frequency-ratio measurements; the minimal observable extension is a residual **drift** of clock rates with accumulated expansion, parametrized by ε_R per unit Θ. Translating existing long-term optical-clock ratio constraints (fractional drifts $\lesssim 10^{-18}\ \mathrm{yr}^{-1}$) through today's expansion rate ($H_0 \approx 7 \times 10^{-11}\ \mathrm{yr}^{-1}$) yields the first numerical bound on the differential residual:

$$|\Delta\varepsilon_R| \lesssim 10^{-8}$$

A universal residual remains unobservable in ratios and is explicitly flagged as such. T≡M thus stands as an ontological/synthesis framework whose weak experimental branch is now quantitatively bounded — which is itself a result.

What is conviction and what is experiment

This manuscript mixes three layers, and I separate them so we don't confuse them:

- **Conviction / Ontology:** how I interpret what time is (my base idea: Tempo ≡ motion).
- **Synthesis:** a conceptual re-organization using language compatible with known physics (using Θ as the root tick, clocks as counts).
- **Experiment (weak hypothesis):** a minimal extension that, if it exists, can be bounded by data — now in its corrected, observable form (eq. 8, v2.1), with a first bound (eq. 11).

Central idea (no detours)

Tempo ≡ universal motion.

And the **root motion** (the most fundamental tick) is **cosmological expansion**.

Everything else is **nested motion** inside that root: subfolders inside a parent folder.

T≡M postulates (the minimum I claim)

T≡M-0 — Identity

Time (Tempo) is identical to the motion/change of the universe; it does not exist as a separate entity.

T≡M-1 — Root tick

The **root tick** of Tempo is identified with cosmic becoming: the **expansion of the universe**.

T≡M-2 — Nested motion

Local motions are **nested motions**: they occur inside the advance of the root tick, across levels (cosmological, astrophysical, planetary, biological, microscopic, etc.).

T≡M-3 — Minimal event and no-pause

There exists a form of **minimal activity** required for local change to exist. If that minimal activity is null, local change is null (**total pause**).

The root tick Θ: how I write it without inventing "a clock"

Cosmological expansion can be expressed as an accumulated quantity. I take it as the root tick of Tempo.

$$\Theta = \ln(a/a_0) \tag{1}$$

$$\Theta = -\ln(1+z) \tag{2}$$

- a: scale factor
- a_0: reference
- z: redshift

In this framework, it is not that Θ "measures" time: **Θ is the tick of Time**.

Cosmological scope: when I say "expansion" in T≡M, I mean the universe at large scales under the standard cosmological approximation of homogeneity/isotropy (FLRW-type). My "root tick" Θ is meant to describe the global average becoming of the universe, not local details.

Coordinates vs foundation: in cosmology one often writes $a(t)$, but in T≡M I do not take t as fundamental; I take it as a useful coordinate. The point of T≡M is interpretive: Θ represents the root tick of becoming, and usual time parametrizations are used as descriptive convenience, not as the primary ontological entity.

Nested motion

Let X be a representation of the physical state of the universe. I consider the elemental change dX without introducing "per unit time".

To express the idea without committing to a strict mathematical sum, I use "+" as **conceptual composition** (not as literal numerical addition). If the reader prefers, it can be read as "combination" or "level-decomposition".

$$dX = dX_{\text{root}} + dX_{\text{local}} \tag{3}$$

$$dX_{\text{local}} = \sum_{k \geq 1} dX_k \tag{4}$$

- dX_{root} is associated with the advance of Θ.
- dX_k represents motions at internal levels: from cosmological down to microscopic.

About the decomposition: the form (3)–(4) is not presented as a mathematical theorem nor as a strict sum of magnitudes. It is a conceptual map: root → levels → counts. My goal is to capture the hierarchy of motions as an interpretive structure of Tempo.

Minimal event $E_{\min}$

Functional definition

In this version I do not define $E_{\min}$ by saying "it is decoherence" or "it is some specific interaction." That would commit to a microphysics I do not yet have.

Instead, I define it by its role:

> **Definition:** $E_{\min}$ is the elemental event that increments a counter $N_{\min}$ and represents the minimal unit of physical activity required for locally observable change to exist within the root tick.

Minimal counter

I introduce $N_{\min}$ as an accumulated counter of minimal events.

Conjectures (what I want to be challenged on)

Strong conjecture — "Total pause"

Status of the strong conjecture: "total pause" is presented as a conceptual/ontological limit of T≡M. I do not offer it today as a direct laboratory prediction. The empirically discussable core is the weak conjecture below.

$$dN_{\min} = 0 \;\Rightarrow\; dX_k = 0 \;\; (\text{for all } k) \tag{5}$$

Interpretation: if minimal activity is null, local motion is null at any level. There is no "empty time" left: there is **total pause**.

And the root conditioning:

$$d\Theta > 0 \;\Rightarrow\; dN_{\min} > 0 \tag{6}$$

Weak conjecture — Relation between clocks and the root tick

The testable path is to study the relation between local counts N_R and Θ.

Let R be a clock-process with counter N_R. Central object:

$$\frac{dN_R}{d\Theta} = F_R(\text{local conditions}) \tag{7}$$

Why the constant residual is unobservable (the v2.1 correction)

The v2.0 minimal ansatz read $dN_R/d\Theta = \kappa_R(1+\varepsilon_R) + \delta_R$, with constant ε_R (the choice $G(\Theta) = 1$). Review showed that this form, while simplest, **cannot leave a trace in any real measurement**. The argument has two arms, and both close the door:

Arm 1 — universal residual. Metrology does not measure $dN_R/d\Theta$ directly; it measures **frequency ratios** ν_1/ν_2 between two clocks. Note that the lab-time ratio equals the Θ-ratio, because the conversion factor $d\Theta/dt$ cancels:

$$\frac{\nu_1}{\nu_2} = \frac{dN_1/dt}{dN_2/dt} = \frac{dN_1/d\Theta}{dN_2/d\Theta}$$

If ε_R is the same for all clocks (universal), the factor $(1+\varepsilon_R)$ appears in numerator and denominator and **cancels exactly**. No ratio measurement, at any precision, can ever see it.

Arm 2 — clock-dependent residual. If ε_R differs per clock species but is constant, then $\kappa_R(1+\varepsilon_R)$ is indistinguishable from a redefined intrinsic scale $\kappa'_R = \kappa_R(1+\varepsilon_R)$. Since κ_R is not predicted from first principles but **calibrated**, the residual is silently absorbed into the calibration. Invisible again.

Conclusion: the $G(\Theta) = 1$ ansatz of v2.0 has no observable content. The honest move is not to defend it but to replace it. The minimal form that survives both arms is a residual that **changes with the advance of the root tick** — a drift.

Minimal ansatz, corrected (revised eq. 8)

$$\frac{dN_R}{d\Theta} = \kappa_R \left[\, 1 + \varepsilon_R\, G(\Theta) \,\right] + \delta_R(\text{conditions}), \qquad G(\Theta) = \Theta - \Theta_{\text{ref}} \tag{8}$$

- κ_R: intrinsic scale of clock R (calibrated).
- δ_R: corrections from local conditions (gravity, velocity, environment) — the known physics.
- ε_R: residual drift parameter (if it exists), per unit Θ.

Minimal choice, restated: in v2.0 I adopted $G(\Theta) = 1$ "to avoid arbitrariness." v2.1 redefines what minimal means: the minimal ansatz is the simplest one **with observable content**, and that is a drift. A constant cannot be seen; a drift can.

Reference epoch: I take $\Theta_{\text{ref}} = 0$ at the present epoch ($a = a_0$), which $\Theta = \ln(a/a_0)$ already satisfies by construction. Writing $G(\Theta) = \Theta - \Theta_{\text{ref}}$ explicitly makes the ansatz manifestly invariant under shifts of the Θ origin: a shifted origin would otherwise reintroduce a constant term — exactly the absorbable case the correction removes. Only the drift is physical; the reference point is convention.

Clear reading:

- If $\varepsilon_R = 0$ for all clocks, T≡M remains an ontological/synthesis framework.
- If a consistent drift $\varepsilon_R \neq 0$ appeared across configurations and epochs, T≡M would gain physical content (and would demand formalization far beyond this manuscript).

The observable, and the first numerical bound (new)

With the drift ansatz, take two clock species and form the measurable ratio.

Assumptions behind eq. (9), stated explicitly:

- **Small residuals:** the expression is leading-order in ε_R; higher-order terms are negligible at current precision.
- **Known effects subtracted:** $\delta_R(\text{conditions})$ — gravity, velocity, environment, systematics — is modeled and removed, which is standard metrology practice.
- **Effective sensitivity absorbed:** different transitions respond with different sensitivity to any underlying drift; here those factors are absorbed into effective coefficients. A rigorous treatment propagates per-pair sensitivity coefficients, as Sherrill et al. (2023) do for constants variation.

Under these assumptions:

$$\frac{d}{d\Theta}\,\ln\frac{\nu_1}{\nu_2} \;\approx\; \varepsilon_{R,1} - \varepsilon_{R,2} \;\equiv\; \Delta\varepsilon_R \tag{9}$$

Only the **difference** between species survives — this is the honest limit of ratio metrology, stated below. Converting to laboratory time with $d\Theta/dt = H(t) \approx H_0$ today:

$$\frac{d}{dt}\,\ln\frac{\nu_1}{\nu_2} \;\approx\; \Delta\varepsilon_R \cdot H_0 \tag{10}$$

Now the numbers. Long-term comparisons of optical frequency ratios constrain fractional drifts at the level of $\sim 10^{-18}\,\mathrm{yr}^{-1}$ (optical lattice clocks and clock networks; see Bloom et al. 2014, Beloy et al. / BACON Collaboration 2021, and the constants-variation analyses of Sherrill et al. 2023). Today's expansion rate is $H_0 \approx 70\ \mathrm{km\,s^{-1}\,Mpc^{-1}} \approx 7 \times 10^{-11}\,\mathrm{yr}^{-1}$ (the exact value, within the current ~ 67–73 range of the Hubble tension, does not affect an order-of-magnitude bound). Then:

$$|\Delta\varepsilon_R| \;\lesssim\; \frac{10^{-18}\,\mathrm{yr}^{-1}}{7 \times 10^{-11}\,\mathrm{yr}^{-1}} \;\approx\; 10^{-8} \tag{11}$$

This is the first numerical bound on the T≡M residual: if the weak version of T≡M exists as a species-dependent drift, it is smaller than about one part in a hundred million per unit of accumulated expansion. Using the strongest published constraints (drifts bounded near $10^{-19}\,\mathrm{yr}^{-1}$) tightens this proportionally, toward 10^{-9}.

Caveats, stated plainly:

- This is an **order-of-magnitude translation**, not a dedicated re-analysis. A rigorous bound requires propagating the sensitivity coefficients of each clock pair (different transitions respond differently to any underlying drift), exactly as Sherrill et al. (2023) do for variations of fundamental constants. That re-analysis is the natural next step and is explicitly invited.
- Operationally, a $\Delta\varepsilon_R$ drift is **the same class of signal** as a temporal variation of fundamental constants. Existing bounds therefore transfer directly — and, symmetrically, a future detection could not be attributed to T≡M rather than varying constants without additional structure. I state this overlap rather than hide it.
- For T≡M to acquire a **signature of its own** someday, it would need a rule for how ε_R depends on the type of transition (electromagnetic vs. nuclear, different sensitivity classes). v2.1 does not have that rule and does not invent one. It is marked as the concrete direction in which the framework would stop being a reparametrization and start being physics.

The honest limit: what ratios can never see (new)

Equation (9) makes something explicit that v2.0 did not say: **frequency ratios are blind to the universal part of ε_R.** If every clock in the universe drifted identically with Θ, every ratio would stay perfectly constant and no laboratory comparison would ever notice.

Constraining a universal residual would require comparing local counts against a **non-clock reference** — cosmological observables tied to Θ itself (redshift drift programs, for example). That is far beyond this manuscript, and I flag it as the hard, long-term branch of the weak program.

A further caution is required here, and I state it rather than hide it: a strictly universal drift could be physically equivalent to a **pure reparametrization**. If every process drifts identically, no dimensionless relation between observables changes — and only dimensionless relations are unambiguously physical. The universal branch may therefore be not merely unobservable in ratios, but potentially empty of physical content. Whether it is a real degree of freedom or a relabeling of units is itself an open question of the program.

So the weak version of T≡M now splits cleanly:

- **Species-dependent drift:** observable in ratios; bounded today at $|\Delta\varepsilon_R| \lesssim 10^{-8}$ (eq. 11).
- **Universal drift:** unobservable in ratios by construction; open in principle, untested today.

A theory that says out loud where it cannot be seen is worth more than one that hides it.

Figure 1 (conceptual toy model, updated)

Toy model (conceptual):

- **Clock A:** $N_A(\Theta) = \kappa_A\,(\Theta + \frac{1}{2}\varepsilon_A\Theta^2)$
- **Clock B:** $N_B(\Theta) = \kappa_B\,(\Theta + \frac{1}{2}\varepsilon_B\Theta^2) + \epsilon\, g(\mathrm{environment})$
- **Clock C:** $N_C(\Theta) = \kappa_C\,\Theta$ (reference clock; its residual is set to zero *by convention*, since only differences between clocks are observable — see eq. 9)

More concrete version (still schematic):

- R can be an atomic clock (Cs, Sr, Yb), a pulsar, or a stable nuclear process.
- The relevant comparison is not "seconds," but how the **ratios of counts** evolve with respect to Θ.

How it could be tested (minimal program, updated)

If someone with expertise wanted to test the weak version of T≡M, the program is now sharper than in v2.0:

1. **Choose concrete clock pairs R_1, R_2:** different species (e.g., Sr vs Yb, Cs vs optical), because only differential residuals are visible.
2. **Practical observable:** the frequency ratio ν_1/ν_2 and its **long-term drift** (not just its stability).
3. **Base model:** compute/fit all known effects (gravity, velocity, environment, systematics). This corresponds to $\delta_R(\mathrm{conditions})$.
4. **Minimal T≡M fit:** fit a residual linear drift in Θ — equivalently, a drift rate $\Delta\varepsilon_R \cdot H_0$ in laboratory time (eq. 10).

5. **Outcome A:** $\Delta\varepsilon_R$ is bounded ever more tightly (T≡M as ontology + quantitative empirical bounds — the current state, eq. 11).
6. **Outcome B:** a consistent residual drift appears across pairs and epochs, with a pattern not attributable to known constants-variation channels (which would be extraordinary and would demand real formalization).

Note: "no signal" + tighter bounds is also a result. It is, in fact, the result this v2.1 already delivers at order-of-magnitude level.

Compatibility with standard relativity/cosmology (interpretation)

I do not intend to replace standard cosmology or general relativity. I propose an ontological reading:

- Θ as the root tick.
- Clocks as nested sub-counts.
- A weak program (8) as a possible residual extension — now in drift form, now bounded.

Methodological transparency and call for review

The correction at the heart of this v2.1 — the unobservability of the constant residual, and the translation of existing bounds into a first number — came out of a careful review of v2.0. I adopted it because the argument stands on its own, not because of where it came from.

I present this as an open preprint and welcome corrections, counterexamples, and review, especially regarding:

- The cancellation argument (eqs. arm 1 / arm 2): is there a ratio-accessible effect of a constant residual that I missed?
- The translation (9)–(11): proper treatment of sensitivity coefficients per clock pair.
- How to design a non-ratio test for the universal branch.

Closing (my way of saying it)

In T≡M, the universe "Tempo-ed" from its beginning: by expanding, it initiated the root tick. Local motions do not occur "in" time; they constitute time as motions nested within cosmic becoming.

v2.0 planted a parameter. v2.1 learned where that parameter can and cannot hide, and put the first number on it. If the residual exists as a difference between clocks, it is smaller than one part in a hundred million per unit of expansion. If it is universal, it hides where ratios cannot reach — and now that hiding place is named.

The seed is planted. The Tempo will tell.

Minimal references

- Page, D. N., & Wootters, W. K. (1983). *Evolution without evolution: Dynamics described by stationary observables.* Physical Review D, 27, 2885.
- Connes, A., & Rovelli, C. (1994). *Von Neumann algebra automorphisms and time-thermodynamics relation in generally covariant quantum theories.* Classical and Quantum Gravity, 11(12), 2899–2917.

- Bloom, B. J., et al. (2014). *An optical lattice clock with accuracy and stability at the* 10^{-18} *level.* Nature, 506(7486), 71–75.
- Beloy, K., et al. (BACON Collaboration) (2021). *Frequency ratio measurements at 18-digit accuracy using an optical clock network.* Nature, 591, 564–569.
- Sherrill, N., et al. (2023). *Analysis of atomic-clock data to constrain variations of fundamental constants.* New Journal of Physics, 25, 093012.

Appendix — Minimal notation

Symbol	Meaning
$\Theta = \ln(a/a_0) = -\ln(1+z)$	Root tick (cosmological Tempo)
a	Cosmological scale factor
z	Redshift
$X,\ dX$	Universe state; elemental change
$E_{\min},\ N_{\min}$	Minimal event; minimal counter
$R,\ N_R$	Local clock-process; process count
ε_R	Residual drift parameter, per unit Θ (if it exists); denoted α_R in v2.0
$\Delta\varepsilon_R$	Differential residual between two clock species
$G(\Theta)$	Residual structure function; v2.1 adopts $G(\Theta) = \Theta - \Theta_{\text{ref}}$, with $\Theta_{\text{ref}} = 0$ today
κ_R	Intrinsic scale of clock R (calibrated)
δ_R	Corrections from local conditions
$H_0 \approx 7 \times 10^{-11}\ \text{yr}^{-1}$	Present expansion rate (conversion $d\Theta/dt$)

Numbered equations

- (1)–(2) definition of Θ (root tick)
- (3)–(4) nested-motion structure
- (5)–(6) strong conjecture (total pause and root conditioning)
- (7) general clock–root relation
- (8) minimal ansatz with observable content (drift form, $G(\Theta) = \Theta - \Theta_{\text{ref}}$)
- (9) ratio observable: differential drift $\Delta\varepsilon_R$
- (10) laboratory-time translation via H_0
- (11) first numerical bound: $|\Delta\varepsilon_R| \lesssim 10^{-8}$

Suggested citation: Moreira, M. (2026). *T≡M Theory — Time Is Motion: Cosmological Expansion as the Root Tick* (v2.1) [Preprint]. Zenodo.