# The Temporal Void Hypothesis
## Gravitation as a Boundary-Condition Resultant

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## Abstract

The Temporal Void Hypothesis (TVH) is a thermodynamic model in which the Present, a radiant three-sphere Boundary Manifold of energy potential, advances into an absolute Temporal Void. Gravitation is defined as a boundary-condition resultant of a discrete, Planck-scale state transition, offering a bottom-up thermodynamic alternative to the geometric formalism of relativity. A Generative Operator, driven by a Thermodynamic Differential, governs the local state-transition rate and establishes a universal baseline of simultaneity. The Differential is the energy density of the Boundary Manifold measured against the null-state of the Void. Entropy and temperature are assigned to the Present's horizon, making the Differential inversely proportional to the entropy. From a single unit of entropy at the Origin, the Present's entropy grows as the Differential falls toward an irreducible minimum, at which the metric ordering parameter reverses.

Localized mass produces a scalar impedance that lowers the state-transition rate; because both the transition rate and the spatial extent of bound systems scale exponentially with this impedance, the TVH recovers Newtonian gravitation, solar light deflection, the Shapiro time delay, Mercury's perihelion advance, gravitational redshift, and the clock-rate offsets of GPS satellites and the lunar surface. Relativistic singularities and event horizons do not form; gravitational collapse yields asymptotic metric stasis, and compact-object shadows and innermost stable orbits are predicted to be about 4.6% and 5.6% larger than in standard relativity. Thermodynamic accounts of the dark sector and the Hubble tension are proposed, and the extensions required for gravitational-wave polarization and rotation are identified.

Keywords: presentism; thermodynamic gravity; emergent gravity; variable speed of light; exponential metric; horizon thermodynamics; black hole shadows; modified inertia; arrow of time; temporal void

# Introduction

Albert Einstein held that the experience of the present is distinct for human beings, but that this difference "does not and cannot occur within physics" [2]. Inverting this premise, the TVH asserts that the Present is all that is, and therefore all of physics must occur within it. The Present is thus defined: a radiant three-sphere Boundary Manifold advancing into an absolute Temporal Void. The measure of "time", the duration of metric intervals, is distinguished from this Temporal Void: an absolute *absence*. The radiant energy of the Present and the absolute absence of the Void constitute a universal Thermodynamic Differential, which the Present resolves by maximizing entropy—it expands.

The Temporal Void must be distinguished from a physical vacuum. It is not an empty "space" or a pre-existing dimension to be occupied; it is strictly thermodynamic, the null-state against which the Present's energy density forms the Differential. The advance of the Present is the emergence of the Boundary Manifold, generating metric structure, dimension, and duration where there is none.

# Section I: The Present Entropic Horizon

To quantify the instant the expanding Present actualizes its local metric, the boundary condition at which this advance occurs must be defined. As established, this boundary—an entropic horizon—is not a spatial edge expanding into a pre-existing space. It is the leading front of state transition. Its metric scale acts strictly as the ordering parameter for the expansion. The Temporal Void is a topological null-state functioning as a universal entropic sink into which the Present boundary advances at the baseline velocity of light ($c$). This velocity is the rate at which the Present advances, not the growth rate of its radius (Section I.6).

## 1. The Thermodynamic Differential

The Present expansion is driven by the Thermodynamic Differential ($\Delta\Theta$): the potential difference between the global energy density of the radiant boundary ($\rho_E$) and the absolute null-state of the Temporal Void. The differential therefore reduces strictly to the density of the boundary itself:

$$\Delta\Theta = \rho_E$$

The Present resolves this differential through hyperspheric expansion, a thermodynamic necessity distributing $\rho_E$ across the scaling Boundary Manifold until it is uniformly distributed.

## 2. The Generative Operator

The Generative Operator ($\Upsilon$) governs the Planck-scale boundary transition as the expanding Present resolves the Temporal Void. General Relativity requires ten coupled non-linear differential equations to account for the complex curvature of spacetime; in the TVH, gravitational effects emerge directly from localized gradients generated by this single boundary operator. Standard geometric models rely on a structural fourth dimension; here the Temporal dimension is absolutely absent, rendering such models inapplicable. The Generative Operator is therefore not a geometric function; rather, it establishes the global metric that governs the localized rate of state transition across the Boundary Manifold.

Acting upon the radiant three-sphere, the macroscopic action of the operator can be expressed to a first-order scalar approximation as an integral over the local state-transition volume ($V$):

$$\Upsilon(\mathrm{x}) = \int_V \phi_\mathrm{T}(\mathrm{x},\mathrm{x}')\rho_\mathrm{L}(\mathrm{x}')\mathrm{d}^3\,\mathrm{x}' \qquad (1)$$

where $\phi_\mathrm{T}(\mathrm{x},\mathrm{x}') = G/|\mathrm{x}-\mathrm{x}'|$ is the temporal transition potential ($G$ is the gravitational constant), $\rho_\mathrm{L}$ is the local mass density, and $\mathrm{d}^3\mathrm{x}'$ is the differential volume element, yielding the scalar impedance $\Upsilon(\mathrm{x})$, an energy per unit mass (J/kg) that measures the load localized mass places on the Generative Operator at each point. Divided by $c^2$, it becomes the dimensionless attenuation that sets the local state-transition rate (Eq. 2); its gradient governs gravitational acceleration (Section I.3); and, with the contraction of bound systems, it sets the transit velocity of light (Eq. 6).

## 3. The Metric Impedance Gradient

The Boundary Manifold is a contiguous thermodynamic front upon which localized mass density acts as a load against the resolution of the Thermodynamic Differential, imposing a drag on the Generative Operator. Because the manifold operates as a coupled medium, this localized drag extends outward, attenuating the state-transition rate of the expanding three-sphere. The exponential form of this attenuation follows from a single premise: each increment of scalar impedance $\mathrm{d}\Upsilon$ attenuates the local state-transition rate ($\Theta$) in proportion to the rate already present, $\mathrm{d}\Theta/\Theta = -\mathrm{d}\Upsilon/c^2$. Integrating from the unimpeded baseline gives a rate that decays exponentially and remains strictly positive regardless of local mass density:

$$\Theta(\mathrm{x}) = \Theta_0 \exp(-\Upsilon(\mathrm{x})/c^2) \qquad (2)$$

where $\Theta_0$ is the baseline global transition rate, $c$ denotes the baseline velocity of light $c_0$, and $\Upsilon(\mathrm{x})$ is the scalar impedance of Eq. (1); for a point mass m at distance r, $\Upsilon = Gm/r$. The motion of a free body follows from the same rates. A body moving through the Boundary Manifold follows

the path along which its accumulated state transitions are maximal, its own rate $\Theta_S = \Theta(x)/\gamma$, where $\gamma = 1/\sqrt{(1 - v^2/c^2)}$ is the Lorentz factor for speed $v$, combining gravitational impedance (Eq. 2) with kinematic attenuation (Section III.2), its speed measured with local, contracted rulers (Section IV.7). For slow motion this principle yields $a = -c^2 \nabla \ln \Theta = \nabla \Upsilon$, recovering Newtonian gravitation. At the next order, the same principle yields the anomalous perihelion advance of Mercury (Section IV.9).

## 4. The Emergence of Gravitation and Inertia

As the radiant Present advances into the Temporal Void, mass constitutes a localized load against the global expansion, delaying resolution of the Thermodynamic Differential. The Generative Operator maintains the coherence of the Boundary Manifold; consequently, the load mass imposes on the operator extends across the emerging metric as a graded impedance. Gravitation is thus defined: a localized reduction in the generative rate of the expanding Present. This impedance does not change the dynamics of a pre-existing space; it is a drag on the very emergence of the metric itself. Rather than an intrinsic property of spacetime, gravitation emerges as a macroscopic boundary-condition resultant.

Inertia emerges as the global counterpart to gravitation: the thermodynamic drive of the expanding Boundary Manifold, countering any local deviation from the baseline state-transition rate. The two are asymmetric in scope. Gravitational impedance is local, sourced by each concentration of mass, while the inertial drive is global, sourced by the Manifold as a whole. Because both are concurrent resultants of a *single* generative operation, their effects scale identically with mass, so that gravitational and inertial mass are equivalent. This equivalence establishes the causal basis for Newton's first and third laws, Einstein's Equivalence Principle, and the inertial effects of rotating systems, including centrifugal pseudo-forces and the moment of inertia.

## 5. The Variable Velocity of Light

Localized mass impedes the Generative Operator in proportion to that mass, resulting in a local reduction of the state-transition rate. Because every interaction, electromagnetic propagation included, is intrinsically bound to this transition baseline, $c$ cannot be an absolute, independent constant—it must be variable. Combined with the contraction of bound systems (Section IV.7), the transit velocity of light scales with the square of the transition rate, $c(x) = c_0 \exp(-2\Upsilon/c^2)$. This variable transition rate establishes the causal basis for phenomena such as time dilation and metric lensing, while the resulting variable $c$ carries cosmological implications (Section IV).

As emergent products of the Present state transition, measuring instruments transition at the local rate and contract with the local scale. Local observations will therefore always measure the velocity of light as a constant, rendering any variability directly unobservable. This variation, however, remains detectable differentially between regions of differing scalar impedance (Sections IV.4 – IV.8).

## 6. Entropy and Temperature of the Present

The entropic horizon of the Present is the apparent horizon of the expanding three-sphere, of radius

$$r_a = c / \sqrt{(H^2 + c^2/R^2)}$$

where $R$ is the radius of the Boundary Manifold, $H$ its fractional expansion rate, and c the baseline velocity of light $c_0$. The radius grows at $HR$, not at $c$. Within standard analyses, the observed near-flatness of the Universe requires $R$ to exceed about fifteen Hubble radii ($c/H_0$), a bound the TVH's variable $c$ may modify; the horizon radius is then $r_a \approx c/H$. Following horizon thermodynamics [3,4], the TVH assigns this horizon one quarter unit of entropy per Planck area and a temperature set by its radius:

$$S = k\,\pi\, r_a^2 / l_p^2 \qquad T = \hbar c / (2\pi k\, r_a) \qquad (3)$$

where $l_p = \sqrt{(\hbar G/c^3)}$ is the Planck length and $k$ is Boltzmann's constant. Applying the first law, $dE = T dS$, to energy crossing the horizon reproduces the cosmological expansion equation [5] and fixes the Thermodynamic Differential:

$$\Delta\Theta = 3c^4 / (8\pi G\, r_a^2) = (3/8)\, \rho_p\, (k/S) \qquad (4)$$

where $\rho_p = c^7/(\hbar G^2)$ is the Planck energy density. The Differential is inversely proportional to the entropy of the Present: resolving the one and maximizing the other are a single process. At the Origin, the Present holds a single unit of entropy at the Planck density and a temperature of order the Planck temperature. For the observed expansion rate ($H_0 \approx 70$ km/s/Mpc), $S \approx 2.1 \times 10^{122}\ k$, $T \approx 2.8 \times 10^{-30}$ K, and $\Delta\Theta \approx 8.3 \times 10^{-10}$ J/m$^3$, equal to the critical energy density of the Universe.

# Section II: Thermodynamic Reconciliation of the Dark Sector

The current standard cosmological model (ΛCDM) relies on phenomenological placeholders such as "dark energy" and "dark matter" to account for the anomalous acceleration and rotational dynamics observed at cosmological and galactic scales. The TVH maintains that the associated search for discrete particles or independent cosmic fields is fundamentally misdirected.

## 1. Dark Energy as Cosmological Entropic Sink

In contemporary cosmology, dark energy is a hypothetical negative pressure, represented by the cosmological constant ($\Lambda$), causing an accelerated expansion of the Universe. In the TVH, $\Lambda$ is not a separate constant but a consequence of metric scaling: as the Boundary Manifold expands, the dilution of localized mass density ($\rho_L$) lowers the global scalar impedance, raising the transit velocity of light at which the Present boundary advances, yielding a net acceleration in metric emergence. Because Eq. (4) is the standard expansion equation, matter and radiation alone would decelerate the expansion; in the TVH the acceleration enters through the variation of $c$, which appears in the horizon entropy as $c^5$ ($S = k\pi c^5/(\hbar G H^2)$, from Eq. 3 with $r_a \approx c/H$). Reproducing the observed transition from early deceleration to late acceleration requires a quantitative treatment of this scaling. Applied to the closed three-sphere as a whole, Eq. (1) requires a kernel adapted to its closed topology; that evaluation is not developed here.

## 2. Dark Matter as Global Inertial Offset

The TVH defines dark matter as a Global Inertial Offset. Gravitation is the local metric impedance delaying the expansion of the Present, while inertia is the nonlocal thermodynamic drive sustaining the advance. Every localized mass causes a metric impedance, to which the global inertial drive responds. The "missing mass" implicated in galactic dynamics is not unseen matter: at galactic scales, the response of the global inertial baseline to the aggregated local impedance adds to the inward acceleration produced by the visible mass. A physical basis for this response follows from the temperature of the Present (Eq. 3). A body accelerating at $a$ within the Present's horizon registers a temperature that rises as $\sqrt{(a^2 + a_H^2)}$, where $a_H = c^2/r_a \approx cH_0$. If inertia is set by the excess of this temperature over the horizon's own, it takes its standard value for $a \gg a_H$ and is reduced for $a \lesssim a_H$, so that a given force produces a larger acceleration [6]. The observed onset of the excess, $\sim 1.20 \times 10^{-10}$ m/s$^2 \approx cH_0/2\pi$, matches this scale to within an underived factor of $2\pi$.

# Section III: Time's Apparent Arrow and Kinematic Attenuation

## 1. The Thermodynamic Arrow

In the TVH, the unidirectional "arrow of time" is the entropic advance of the radiant Present into the Temporal Void, driven by the Thermodynamic Differential. Because the Temporal Void acts as an inexhaustible entropic sink, the scaling of the Boundary Manifold maximizes entropy, and the Present expansion is one-way within each expansion phase (Section VI).

## 2. Kinematic State-Transition Attenuation

Gravitational impedance is a property of a region of the Boundary Manifold; kinematic attenuation is a property of a system moving through it, and operates independently. When a localized mass accelerates relative to the Boundary Manifold, its total energy rises to $E = \gamma m_0 c^2$, while its rest energy $m_0 c^2$ is unchanged. The TVH holds that a system's internal state-transition rate is set by the share of its total energy held as rest energy:

$$\Theta_S = \Theta(x)\,(m_0 c^2 / E) = \Theta(x)/\gamma \qquad (5)$$

Kinematic attenuation therefore depends on velocity alone, not on rest mass. The accompanying contraction of moving systems and the reciprocity of attenuation between observers follow from the propagation premise of Section I.5 and are not developed here [7]. Together they render motion relative to the Manifold undetectable by local experiment.

# Section IV: Empirical Alignments

## 1. Inertial Coupling and Mach's Principle

Whereas standard relativity relegates the definition of inertia to Mach's Principle—linking local inertia to global mass without a physical mechanism—the TVH provides the direct linkage. Inertia is the global thermodynamic drive of the expanding Boundary Manifold countering the local impedance that mass imposes on the Generative Operator. The equivalence of gravitational and inertial mass is therefore dynamically accounted for rather than accepted as a theoretical postulate. Equation (1) depends only on mass density, so a rotating mass produces the same impedance as a static one; the frame dragging measured by Gravity Probe B and by laser-ranged satellites therefore also requires the rotational extension, which is not developed here.

## 2. The Hubble Tension

Discrepancies in $H_0$ measurements are an expected consequence of how the scaling Boundary Manifold determines the variable generative baseline. The extreme mass density of the early universe generated a commensurate metric impedance, notably lowering the baseline of $c$. As the manifold expanded and this mass diluted, the reduced metric impedance accelerated the rate of state transition. The Hubble tension is the failure to reconcile the highly impeded state-transition rates of the early universe with the largely unimpeded $H_0$ measurements of the late universe.

## 3. The JWST Early Galaxy Anomaly

Observations with the James Webb Space Telescope have revealed massive, evolved galaxies at redshifts at which the standard cosmological model affords insufficient cosmic time for their assembly. That model attributes the entire redshift of their light to spatial expansion. In the TVH, part of that redshift arises instead from the elevated scalar impedance of the dense early universe: atoms there transitioned at a reduced rate and emitted at lower frequencies. Attributing this impedance redshift to expansion overstates the expansion since emission and understates the generative age of these galaxies. The division of observed redshift between impedance and expansion is not quantified.

## 4. Satellite Clock Rates

Combining Eqs. (2) and (5), a clock in GPS orbit ($r \approx 26{,}560$ km, $v \approx 3.87$ km/s) gains $\approx 45.7$ μs/day relative to a ground clock from its lower scalar impedance ($\Delta\Upsilon \approx 4.76 \times 10^7$ J/kg) and loses $\approx 7.2$ μs/day to kinematic attenuation. The net gain of $\approx 38.5$ μs/day matches the fractional frequency offset ($\approx 4.465 \times 10^{-10}$) built into GPS satellite clocks.

## 5. Invariance of the Fine-Structure Constant and Gravitational Redshift

The fine-structure constant $\alpha = e^2/(4\pi\varepsilon\hbar c)$ is a dimensionless ratio and is invariant across the Boundary Manifold. Because $c$ scales with the square of the local state-transition rate, this invariance requires the permittivity $\varepsilon$ of the Boundary Manifold to scale inversely with the square of that rate ($\varepsilon \propto 1/\Theta^2$), while $e$ and $\hbar$ remain invariant; the product $\varepsilon c$, and with it $\alpha$, is then unchanged, and local metric impedance remains unobservable (Section I.5). Atomic clock comparisons tracking the annual variation of the solar potential bound any coupling of $\alpha$ to the scalar potential to below $\sim 10^{-6}$ of $\Delta\Upsilon/c^2$ [8].

Spectra originating in regions of differing scalar impedance are nonetheless shifted. An atom in a high-impedance region transitions at the reduced local rate $\Theta(\mathrm{x})$, so its emission frequency, relative to the baseline $\Theta_0$, is lower by the factor $\Theta(\mathrm{x})/\Theta_0 \approx 1 - \Upsilon/c^2$. The frequency is unchanged in propagation, and an observer in a lower-impedance region detects the line redshifted by $\Delta\nu/\nu \approx \Delta\Upsilon/c^2$. The entire spectrum shifts uniformly; line ratios, including fine-structure splittings, are unchanged. This reproduces the measured gravitational redshift, from the Pound–Rebka experiment to Gravity Probe A.

## 6. The Equivalence Principle and Earth–Moon Clock Rates

A clock in a region of lower scalar impedance transitions faster (Eq. 2). In a uniform external field, however, two freely falling clocks share the same acceleration, and a signal exchanged between them acquires a Doppler shift equal and opposite to the rate difference produced by the field's linear potential gradient. The linear component of the solar impedance ($\pm 2.3 \times 10^6$ J/kg across the Earth–Moon separation) therefore produces no observable rate difference or range signal within the freely falling Earth–Moon system; only the much smaller tidal component remains. This accords with the Equivalence Principle (Section I.4) and with the null results of lunar laser ranging.

The impedance of the Earth and Moon themselves is not cancelled. A clock on the lunar surface sits at lower scalar impedance than one on Earth, by $\Delta\Upsilon \approx 5.87 \times 10^7$ J/kg including each body's impedance at the other's location, and by Eq. (2) gains $\approx 56.4$ μs/day. Kinematic attenuation (Eq. 5) at the Moon's orbital speed ($\approx 1.02$ km/s) removes $\approx 0.5$ μs/day, and Earth's rotation slows the ground clock by $\approx 0.1$ μs/day, a net lunar gain of $\approx 56.0$ μs/day. This agrees with the $\approx 56$ μs/day computed for the proposed lunar time standard [9]. The derivation is given in the Appendix.

## 7. Gravitational Lensing as Metric Refraction

Gravitational lensing is the refraction of radiation by a variable refractive index of the Present. Attenuation of the state-transition rate alone would reduce the transit velocity of light by $\exp(-\Upsilon/c^2)$, yielding a solar-limb deflection of $0.88''$, half the observed value. The TVH holds that, in a region of scalar impedance, the spatial extent of bound systems contracts by the same factor as their transition rate, $\exp(-\Upsilon/c^2)$. Measured against the baseline rate $\Theta_0$ and the baseline scale of the unimpeded Manifold, the transit velocity of light then carries both factors:

$$c(\mathrm{x}) = c_0 \exp(-2\,\Upsilon/c^2) \approx c_0\,(1 - 2\,\Upsilon/c^2) \qquad (6)$$

Local measurements, made with attenuated clocks and contracted rulers, still return $c_0$ (Section I.5). The Boundary Manifold therefore has an effective refractive index $n = \exp(2\Upsilon/c^2) \approx 1 + 2\Upsilon/c^2$. Radiation passing a concentration of mass propagates more slowly on the side nearer the mass, and its path bends toward the source of the impedance. A ray passing a mass $m$ at closest approach $b$ is deflected by $4Gm/(bc^2)$: $1.75''$ at the solar limb, in agreement with observation. The index $n = \exp(2\Upsilon/c^2)$ coincides with the exponential metric of Yilmaz [10] and with the polarizable-vacuum treatments of Dicke [11] and Puthoff [12]. The TVH shares their weak-field predictions; it differs in deriving the index from transition-rate attenuation and the contraction of bound systems, and in its thermodynamic interpretation.

## 8. The Shapiro Time Delay as Metric Refraction

The same refractive index governs the transit of radar signals. Integrating $n$ along the path gives an excess round-trip transit of $(4Gm/c^3)\ \ln(4r_1 r_2/b^2)$ for a signal exchanged between points at distances $r_1$ and $r_2$ from the mass. This is twice the delay produced by rate attenuation alone, and matches the delay measured by planetary radar and spacecraft ranging.

## 9. Perihelion Advance of Mercury

Because both the transition rate and the spatial extent of bound systems scale as $\exp(-\Upsilon/c^2)$ (Sections I.3 and IV.7), the free-path principle of Section I.3 yields, beyond Newtonian order, an additional perihelion advance of $6\pi Gm/(A(1-e^2)c^2)$ per orbit, where $A$ is the semi-major axis and $e$ the eccentricity. For Mercury this gives 43″ per century, in agreement with observation.

## 10. Gravitational Waves

In the TVH, gravitational waves are propagating fluctuations in the local metric impedance rather than distortions of a pre-existing spacetime. Because every interaction propagates at the local transit velocity of light (Section I.5), these fluctuations propagate at $c(\mathrm{x}) = c_0 \exp(-2\Upsilon/c^2)$ and undergo the same refraction and Shapiro delay as electromagnetic radiation. Gravitational and electromagnetic signals from a common source therefore arrive together regardless of the impedance gradients crossed, consistent with GW170817 and GRB 170817A, whose arrival times constrain the speed of gravity to between $-3\times10^{-15}$ and $+7\times10^{-16}$ of the speed of light [13].

Interferometric detectors register a transverse, direction-dependent strain: one axis stretches as the perpendicular axis contracts, in two independent patterns. An isotropic fluctuation in $\Upsilon$, which contracts bound systems equally in every direction, produces no such differential signal. Reproducing the observed waveforms therefore requires extending the contraction of Section IV.7 to direction-dependent contraction in propagating disturbances, consistent also with the orbital decay observed in binary pulsars. That extension is not developed here.

## 11. Quantum Nonlocality as Boundary Coherence

Experiments on quantum entanglement demonstrate state correlations that operate independently of intervening distance. Standard relativity permits these correlations because they cannot transmit signals; the TVH offers a physical basis for them. Because the expanding Present boundary constitutes a universal phase-coherent threshold, all points resident on it couple to a single state-

transition baseline. Nonlocal quantum coherence is thus consistent with absolute simultaneity across the Boundary Manifold, although, like motion relative to the Manifold (Section III.2), that simultaneity cannot be identified by local experiment.

## 12. Gravitational Centers and Horizonless Collapse

Because the local state-transition rate is $\Theta(x) = \Theta_0 \exp(-\Upsilon/c^2)$, it remains positive at every finite impedance and reaches zero only in the limit of a point mass. At a baseline radius of $2Gm/c^2$, where standard relativity places an event horizon, the rate is still $e^{-1/2} \approx 0.61\,\Theta_0$. No event horizon forms. Newton's point centers of mass and the singularities of standard relativity are replaced by regions of metric stasis approached only asymptotically, and gravitational collapse produces ultra-compact objects without horizons. Radiation from infalling matter is redshifted by $\exp(-\Upsilon/c^2)$, severely but finitely; whether such objects appear as dark as observed black-hole candidates is not addressed here. The primordial Origin is likewise not a mathematical singularity but a finite Planck-scale state: a single unit of entropy at the Planck density (Section I.6).

# Section V: Testable Predictions

## 1. Compact-Object Shadow Size

Light circling a compact mass $m$ travels on a circular path where $n \cdot r$ is stationary, with $n = \exp(2Gm/(rc^2))$; this occurs at a baseline radius of $2Gm/c^2$. The critical impact parameter, which sets the apparent radius of the shadow, is $b = n \cdot r = 2e \cdot Gm/c^2 \approx 5.44\ Gm/c^2$, about 4.6% larger than the $3\sqrt{3}\ Gm/c^2 \approx 5.20\ Gm/c^2$ of standard relativity for a non-rotating mass. Current EHT measurements of Sgr A*, whose mass is fixed independently by stellar orbits, give $\delta = -0.08 \pm 0.09$ (VLTI) and $-0.04$ (+0.09/−0.10) (Keck) for the fractional deviation from the non-rotating standard shadow, placing the TVH value ($\delta \approx +0.046$) about $1\text{–}1.4\,\sigma$ above them [14]. These values are inferred from ring images using calibrations derived for standard black holes, and rotation, not treated here, alters shadow size by a few percent. Measurements at the few-percent level will confirm or exclude the prediction.

## 2. Baryonic Impedance Mapping

The TVH attributes dark-matter effects to a Global Inertial Offset responding to local gravitational impedance, determined entirely by a galaxy's baryonic mass distribution. Rotation-curve discrepancies should therefore follow from the baryonic distribution alone, as the observed radial

acceleration relation indicates; the TVH must reproduce that relation's form and its characteristic acceleration ($\sim 1.2 \times 10^{-10}$ m/s$^2$), plausibly of order $cH_0$. Under the mechanism of Section II.2, the offset modifies inertia rather than scalar impedance, so lensing would trace the baryonic mass alone unless the inertial response also couples to the scalar impedance. Current weak-lensing and cluster observations, which indicate that lensing and dynamical masses agree, therefore require such a coupling; whether the TVH supplies it remains an open constraint on the mechanism.

## 3. Innermost Stable Orbits

The free-path principle of Section I.3 fixes the orbits of matter close to a compact mass. For a non-rotating mass $m$, the innermost stable circular orbit lies at a baseline radius of $(3+\sqrt{5})\,Gm/c^2$, corresponding to a circumference, measured with local rulers, of $2\pi \times 6.34\ Gm/c^2$, compared with $2\pi \times 6.00\ Gm/c^2$ in standard relativity. Its orbital frequency, measured by a distant observer, is $0.0633\,c^3/(Gm)$, about 7% below the standard $0.0680\,c^3/(Gm)$, and matter reaching it releases 5.48% of its rest energy rather than 5.72%. These values bear on X-ray timing and spectroscopy of accreting black-hole candidates and on flares observed close to Sgr A*; as with the shadow, rotation must be accounted for in any comparison.

# Section VI: The Closed Cycle and Universal Origin

The evolution of the radiant Universe is the resolution of its Thermodynamic Differential with the Temporal Void. As the Present advances, its energy is distributed across the scaling Manifold and its entropy grows, the Differential falling in inverse proportion (Eq. 4). Energy crossing the entropic horizon obeys the first law, $\mathrm{d}E = T\mathrm{d}S$ (Section I.6). As the expansion rate approaches a constant, the entropy of the Present approaches its maximum and the Differential its irreducible minimum; in this limit the resolution is complete and the metric ordering parameter reverses.

Because the thermodynamic arrow points from lower to higher entropy (Section III.1), the arrow in the reversed phase also points away from the Origin: within that phase, the Present again advances from a single Planck unit of entropy toward its maximum. The return to the primordial Origin is distinguishable only from a standpoint outside both phases, which, in a Universe where the Present is all that is, does not exist [15]. The cycle is thus closed in the ordering parameter, while entropy increases within each phase, in accordance with the second law.

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# Appendix: Earth–Moon Clock-Rate Derivation

Within the TVH framework, local mass acts as a thermodynamic drag across the expanding Boundary Manifold, attenuating the state-transition rate of its emerging metric. The scalar impedance at a point is given by the Generative Operator (Eq. 1):

$$\Upsilon(x) = \int_V \phi_T(x,x')\rho_L(x')d^3x'$$

and the local state-transition rate by Eq. (2), $\Theta(x) = \Theta_0 \exp(-\Upsilon/c^2)$. Because the Earth–Moon system lies deep within the weak-field regime ($\Upsilon/c^2 \sim 10^{-9}$), the rate difference between two locations reduces to first order to $\delta\Theta/\Theta = \Delta\Upsilon/c^2$. For a spherical body of mass $m$ and radius $r$, the kernel $\phi_T = G/|x-x'|$ integrates to $\Upsilon = Gm/r$ at its surface and to $Gm/d$ at an external distance $d$.

Earth's surface impedance: Using Earth's mass ($5.972\times10^{24}$ kg) and radius (6,371 km), $\Upsilon = 6.256\times10^{7}$ J/kg. The Moon contributes a further $1.27\times10^{4}$ J/kg at Earth's distance ($3.844\times10^{8}$ m), for a total of $6.257\times10^{7}$ J/kg.

Moon's surface impedance: Using the Moon's mass ($7.342\times10^{22}$ kg) and radius (1,737 km), $\Upsilon = 2.821\times10^{6}$ J/kg. Earth contributes a further $1.037\times10^{6}$ J/kg at the lunar orbital radius, for a total of $3.858\times10^{6}$ J/kg.

Gravitational rate difference: The impedance difference is $\Delta\Upsilon = 5.872\times10^{7}$ J/kg, giving $\delta\Theta/\Theta = \Delta\Upsilon/c^2 = 6.533\times10^{-10}$. Per day (86,400 s), a clock on the lunar surface gains 56.44 μs relative to one on Earth.

Kinematic attenuation: By Eq. (5), a clock moving at speed $v$ is attenuated, to first order, by $v^2/2c^2$. The Moon's orbital speed (≈ 1.02 km/s) attenuates the lunar clock by $5.79\times10^{-12}$, or 0.50 μs/day. Earth's equatorial rotation speed (465 m/s) attenuates the ground clock by $1.20\times10^{-12}$, or 0.10 μs/day.

Net rate: 56.44 − 0.50 + 0.10 ≈ 56.04 μs/day. A clock on the lunar surface gains ≈ 56.0 μs per day relative to a clock on Earth's equator, in agreement with the ≈ 56 μs/day computed for the proposed lunar time standard [9].

The linear component of the solar impedance across the Earth–Moon separation ($\pm2.3\times10^{6}$ J/kg) does not enter. For the freely falling Earth–Moon system it is cancelled by the Doppler shift accompanying common free fall (Section IV.6). The residual tidal term, and corrections for Earth's oblateness and the eccentricity of the lunar orbit, are of order 0.1 μs/day or less and lie beyond this first-order estimate.