Unified Substrate Closure under Admissible Regime Determination

This work completes a constructive determination of physical mechanics under an explicit admissibility hypothesis: a regime qualifies as physical only if it admits a governing equation, a numerical calibration, and a directly testable observable. Regimes that fail this equation–number–observable criterion do not define predictive physics within the present framework. Under this hypothesis, the admissible expressions of a single physical substrate are sharply constrained. Exactly five regimes satisfy the criterion: Propagation (light), Ordering (time and causality), Localization (matter), Coupling (gravity), and Global Drift (cosmology). Each regime is derived independently, calibrated arithmetically, and associated with an observable channel. No regime introduces additional primitive structures or unfixed constants; all numerical content is fixed internally by calibration. The central result is that, under the same admissibility hypothesis, these five regimes are not independent constructions. They arise as controlled limits of a single mechanical law. The unifying object is the principal phase of a substrate excitation, evolved with respect to an induced ordering parameter rather than a primitive time. From this phase, canonical energy–momentum are defined, and admissible dynamics reduce to a single ordering-covariant Hamilton–Jacobi master constraint involving three induced scalars only: an ordering-distortion potential, a localization gap, and a global ordering drift. Within this admissible class, the master constraint constitutes the minimal closure compatible with all five calibrated regimes. In the gapless limit it enforces null propagation with a single invariant speed. With nonzero gap it yields gapped dispersion and the inertial mass relation. With ordering distortion it reproduces gravitational time dilation and weak-field coupling. With drift of the ordering background it yields redshift as an ordering ratio and enforces the observed one-mode cosmological structure. Any extension of the constraint by additional terms or degrees of freedom violates at least one regime calibration and is therefore excluded under the stated hypothesis. The resulting framework is a closed mechanics conditional on the admissibility criterion: one substrate, one ordering observable, one invariant propagation speed, one localization gap–mass identity, one infrared coupling closure, and one global drift law, unified by a single master constraint whose form and coefficients are fixed by calibration rather than postulated. Under these conditions, the five regimes exhaust the admissible ways in which the substrate can manifest in physical observables.

Jurisdiction, Aim, and Risk Posture

The aim of this work is not to introduce an additional interpretive layer atop existing theories, but to determine—by elimination—the invariant mechanical content common to all admissible predictive descriptions. The framework is deliberately austere and deliberately fragile: where the structural conditions stated herein cannot be satisfied, the framework is not patched or extended. It becomes undefined. This absence of rescue mechanisms is not an aesthetic preference; it is the only way necessity arguments retain scientific authority under hostile inspection.

The manuscript imposes a non-negotiable constructive discipline, later applied regime-by-regime and used again to certify the master closure:

equation → number → observable

Any structure that cannot be commissioned in this way is excluded as non-physical within the present method.

The pre-regime portion of the paper has a single task: to demonstrate that the methodological ledger—admissible re-description, invariant elimination, finite diagnostic closure, logarithmic ordering, scalar collapse to phase, and first-order phase closure—is *forced*, not chosen. Only after this demonstration may regime constructions be admitted as legitimate expressions of a single substrate mechanics.

Prediction, Admissibility, and Invariants

*Prediction as a Minimal Formal Obje*ct

Let $\boldsymbol{\mathcal{C}}$ denote the space of admissible experimental conditions (preparations, boundary settings, interventions), and let $\boldsymbol{\mathcal{M}}$ denote the space of admissible measurement outcomes. A predictive description is a mapping

$$\mathrm{D} : \boldsymbol{\mathcal{C}} \to \boldsymbol{\mathcal{P}}(\boldsymbol{\mathcal{M}}),$$

where $\boldsymbol{\mathcal{P}}(\boldsymbol{\mathcal{M}})$ denotes probability measures on outcomes. Deterministic descriptions appear as delta measures.

At this stage, no assumption is made regarding spacetime, fields, probability interpretation, or dynamics. This is intentional: the admissible structure is derived from the weakest possible starting point.

Admissible Re-description

Prediction is meaningful only if it is comparable across descriptions. If two descriptions yield different conditional predictions for the same physical situation while remaining observationally indistinguishable, then prediction collapses into bookkeeping.

Define an equivalence relation:

$$D_1 \sim D_2 \Leftrightarrow \forall c \in \mathcal{C},\ D_1(c) = D_2(c).$$

A transformation R is *admissible* if it preserves predictive content:

$$D \sim R(D).$$

This condition is not philosophical; it is the minimal requirement for the phrase "same physical situation" to retain meaning across representational encodings.

Invariants and Elimination

An invariant is any functional I on descriptions such that

$I(D) = I(R(D))$ for all admissible R.

Invariants are fixed by elimination. Any relation removable without altering conditional predictions is representational; any relation whose modification changes predictions is invariant. The objective is not to decorate descriptions with symmetry but to isolate what cannot be removed without destroying predictivity.

The Invariant Core and Operational Substrate

Define the invariant algebra of a description D as the set of all invariants preserved under admissible re-description. The operational "substrate" is nothing beyond the equivalence class of D under predictive equivalence together with its invariant algebra.

This designation carries no ontic commitment. It is a bookkeeping label for the invariant core forced by predictivity and admissibility. A reader who dislikes the word "substrate" may delete it and retain only the equivalence class and invariant content. The results that follow are unchanged.

Why Constructivity Is Forced: Derivation of the CRC

The equation–number–observable criterion is binding only if it is necessary. This section establishes that necessity.

No Equation ⇒ No Transport

If a proposed regime supplies no governing relation linking predictions across conditions, the description reduces to a lookup table. No structural transport exists between distinct experimental conditions, and the description does not constitute mechanics.

Equation Without Numbers ⇒ Underdetermined Continuations

If a regime supplies an equation involving parameters that are not numerically commissioned, then it admits a family of inequivalent predictive continuations. Under admissible re-description, parameterizations may be reshuffled without changing formal structure while predictions vary. Such a regime is not physically fixed.

No Observable ⇒ Unfalsifiability

If equations and numerical values are declared but no observable channel is specified, then no tribunal exists by which predictions may be compared. The regime is scientifically empty.

Constructive Regime Criterion (CRC).

A regime qualifies as physical only if it supplies a governing equation, a numerical commissioning, and an observable diagnostic channel.
This criterion is not stylistic. It is the minimal closure required for prediction to remain stable under admissible re-description.

Ordering Enters Only Through Ratios: Logarithmic Inevitability

Ordering information enters physics only through comparisons of intervals. No experiment measures “duration” or “scale” in isolation. All measurement is comparative.

Let $r > 0$ denote an ordering interval. The only physically meaningful comparison between r_1 and r_2 is the ratio r_2 / r_1. Composition of comparisons is multiplicative.

Define a logarithmic coordinate:

$$x = \ln(r / r_0),$$

where r_0 is an arbitrary reference scale. In this coordinate, ratio composition becomes additive translation. No alternative coordinate achieves additive closure under multiplicative composition while remaining invariant under admissible rescaling.

Logarithmic structure is therefore forced by composition, by metrological invariance, and by finite diagnostic closure under translation covariance.

Finite Diagnostic Closure and the Admissible Operator Class

Once ordering lives on a translation-invariant logarithmic scale, admissible substrate dynamics must satisfy locality, translation covariance, finite diagnostic closure, and saturation. These constraints uniquely select a band-selecting, saturating normal form.

Linear analysis reveals a unique dominant logarithmic mode. Finite closure prohibits persistent plurality of independent stable modes, since such plurality would generate independent diagnostics under regeneration. A single logarithmic frequency is therefore forced.

Scalar Collapse: Phase as the Unique Admissible Scalar

Any scalar intended to encode ordering must be invariant under admissible re-description, comparable across carriers, and monotonic under composition. Amplitude fails due to normalization dependence. Correlation length fails due to window dependence. Power-law scalars fail under scale changes. Phase alone is dimensionless, additive under composition, and stable under regeneration.

Scalar Collapse Theorem.

Under admissibility, finite diagnostic closure, and logarithmic ordering, phase is the unique scalar ordering diagnostic that survives regeneration.

This result is substrate-level and licenses the use of phase throughout all subsequent regimes.

Induced Ordering Observable

From logarithmic samples x_i, define a complex order parameter as the mean of $\exp(i\beta_0 x_i)$. The argument of this quantity defines an induced ordering observable τ_ord, up to a conventional reference scale.

At this stage, τ_ord is an ordering observable only. It is not yet identified with primitive time. All subsequent rates will be defined with respect to it once the regimes commission it numerically.

Transport, Principal Phase, and Closure Class

Predictive transport requires stable propagation of distinctions. Distinguishability boundaries define characteristic surfaces, which are level sets of a scalar. By scalar collapse, that scalar must be a phase. Denote the principal phase by S.

Second-order evolution introduces surplus diagnostics and violates finite closure. Nonlocal kernels introduce memory and scale dependence. Higher-derivative closures proliferate independent diagnostic scales. All are inadmissible.

The only admissible closure class is therefore a first-order constraint on phase gradients, of Hamilton–Jacobi type.

Predictivity Exhaustion and Dependency Order

Predictive mechanics must answer exactly five invariant questions: propagation, ordering, localization, coupling, and global drift. Omission of any one destroys prediction. No sixth independent invariant question survives admissibility.

The dependency order is fixed by definability:

Propagation → Ordering → Localization → Coupling → Global Drift.

Minimality and Redundancy

Each independent invariant parameter corresponds to diagnostic freedom. Surplus parameters undermine closure. Once an invariant is commissioned in one regime, it may not re-enter later as an independent constant. Later appearances must be redundancy constraints.

Unification therefore reduces to numerical identity tests, not narrative coherence.

Substrate Invariants vs. Effective Parameters

A substrate invariant is fixed under admissible re-description and regeneration and is commissioned once. An effective parameter is a channel-dependent projection of substrate invariants and may vary without introducing new degrees of freedom.

This distinction prevents parameter inflation and preserves minimality.

Structural Falsifier Ledger

The framework is falsified if any of the following occur:

1. No admissible invariant core exists.
2. Diagnostic degrees of freedom proliferate under regeneration.

3. Multiple independent stable logarithmic modes persist.
4. A scalar ordering diagnostic exists that is not phase-based.
5. Predictive stability requires a second independent evolution parameter.
6. Later regimes require new independent invariants.

Any one falsifies the program before regime-level debate.

Commissioning Ledger (Pre-Regime)

Before regime construction, the paper commits to a binding commissioning ledger specifying where each invariant is introduced, how it is numerically fixed, and through which observable it is tested. The regime sections must fill this ledger explicitly.

Transition

At this point, admissibility, constructivity, logarithmic ordering, scalar collapse, phase closure, minimality, and falsifiability have been established. The remainder of the paper proceeds by constructing the five regimes in the unique dependency order and then deriving the master closure that unifies them.

Regime I: Propagation (Light)

Regime declaration

This regime concerns long-range transmissivity: the existence of a stable relation allowing predictive distinctions present at one ordered situation to be recoverable at another, arbitrarily far removed under admissible refinement.

No primitive notions of spacetime, geometry, metric distance, fields, radiation, or dynamical evolution are assumed. The analysis proceeds exclusively from admissibility constraints on predictive descriptions and their behavior under regeneration.

The objective of this regime is to determine whether long-range transmissivity forces the existence of an invariant propagation scale, and whether such a scale may be commissioned constructively without circular appeal to spacetime primitives.

Primitive structure: ordered distinguishability pairs

Assume the regime admits ordered distinguishability pairs (E_1, E_2), where $E_1 \prec E_2$ denotes minimal precedence in an ordering relation. No metric, temporal, or geometric meaning is ascribed to this ordering; it is a bare pre-order sufficient only to define succession of distinguishability.

Let $D(E_1, E_2)$ denote a distinguishability relation: whether a predictive distinction present at E_1 remains recoverable at E_2 under admissible regeneration. Long-range transmissivity is the condition that $D(E_1, E_2)$ remains non-trivial for arbitrarily extended ordered pairs under refinement.

Remark

The ordering relation employed here is a provisional pre-order, sufficient only to define succession of distinguishability. Its operational realization, calibration, and observable status are derived in Regime II and retroactively license its use in the present regime.

Admissibility constraints

The regime is required to satisfy:

1. **Finite diagnostic closure**
   The set of regeneration-stable predictive distinctions is finite.
2. **Regeneration invariance**
   Admissible re-descriptions do not split predictive equivalence classes.
3. **Non-trivial transmissivity**
   Recoverability of distinctions persists across arbitrarily extended ordered pairs.

These constraints restrict the admissible invariant summaries of $D(E_1, E_2)$.

Theorem: uniqueness of a propagation invariant

Theorem 1 (Propagation invariant).

If a regime admits non-trivial long-range transmissivity and finite diagnostic closure, then there exists at most one non-trivial invariant parameter characterizing how recoverability degrades with ordered separation.

Proof sketch.

If no invariant exists, transmissivity is either trivial or undefined. If more than one independent invariant survives regeneration, admissible refinement cannot collapse them into a single equivalence class; multiple independent long-range diagnostics persist, violating finite closure. Hence at most one invariant propagation parameter is admissible.

Denote this invariant by v_*.

At this stage, v_* is only an invariant scale governing transmissivity; no interpretation as speed, distance-per-time, or geometric quantity is implied.

Induced continuum summary (pre-geometric)

Any finitely parametrized invariant relation on ordered distinguishability pairs admits a smooth coarse-grained summary under regeneration; otherwise arbitrarily small perturbations would generate new diagnostics.

Let $\Delta\alpha$ denote the ordered separation label between E_1 and E_2, defined purely by ordering depth. Let $\Delta\beta$ denote an induced separation label associated with recoverability degradation, defined operationally through the transmissivity tribunal, without geometric interpretation.

The invariant relation may therefore be written as

$$\Phi(\Delta\alpha, \Delta\beta) = 0,$$

with Φ depending only on a single invariant combination of its arguments. Uniqueness of the invariant implies that admissible regeneration can collapse this relation to dependence on one dimensionless ratio:

$$\Phi\left(\frac{\Delta\beta}{\Delta\alpha}\right) = 0.$$

At this level, no functional form is assumed.

Admissible representative form of the propagation relation

Under admissible smooth coarse-graining, regeneration stability, and locality of refinement, any single-parameter characteristic relation admits representations that preserve invariant scale content while suppressing non-essential structure.

Accordingly, without loss of invariant information regarding the existence of a unique propagation scale, the transmissivity relation may be represented by a quadratic characteristic condition of the form

$$\boxed{\Delta\beta^2 - v_*^2\,\Delta\alpha^2 = 0.}$$

This form is not asserted as unique or ontologically fundamental. It is one convenient representative within the admissible class of single-parameter characteristic relations and will later be re-derived as a consistency condition of the unified closure.

Optional representational encoding (non-constitutive)

If a differentiable continuum representation is chosen purely for illustrative purposes, the invariant characteristic relation above may be encoded as the characteristic condition of a second-order hyperbolic operator acting on a carrier ψ.

This representation is not used elsewhere in the analysis, introduces no additional invariants, and plays no role in subsequent regime construction or in the unified closure.

One convenient illustrative encoding is

$$\rho\ \partial_\alpha^2\psi - \kappa\ \partial_\beta^2\psi = 0, v_* = \sqrt{\kappa/\rho},$$

where $\rho > 0$ and $\kappa > 0$ are response coefficients.

Observable consequences

For any monochromatic realization of the transmissive class, the invariant relation implies the identity

$$\boxed{v_* = \nu\,\lambda,}$$

where $\nu$is a realized ordering frequency and λan induced periodic separation label.

This identity is representation-independent and follows solely from the characteristic structure.

Metrological closure without time-of-flight

The invariant v_*may be numerically commissioned without any direct measurement of propagation time or geometric distance.

Frequency standard.

The frequency $\nu$is measured against the atomic time standard via frequency synthesis. In the methane-stabilized laser experiment of Evenson et al. (1972),

$$\nu = 88.376\,181\,627(50)\ \text{THz}.$$

Length standard.

The wavelength λ is measured interferometrically against the krypton-86 length standard (1960–1983 definition of the metre), yielding

$$\lambda = 3.392\,231\,376(12)\ \mu\text{m}.$$

Substitution gives

$$\boxed{v_* = 299\,792\,456.2\ \text{m s}^{-1}.}$$

Uncertainty propagation

For independent uncertainties σ_ν and σ_λ,

$$\left(\frac{\sigma_{\nu_*}}{\nu_*}\right)^2 = \left(\frac{\sigma_\nu}{\nu}\right)^2 + \left(\frac{\sigma_\lambda}{\lambda}\right)^2,$$

Yielding

$$\sigma_{\nu_*} \simeq 1.1 \text{ m s}^{-1}.$$

External identification and regime closure

The regime therefore admits exactly one invariant long-range transmissivity scale, induces a characteristic propagation structure, and permits non-circular numerical commissioning.

The empirical phenomenon historically designated light is identified externally as the physical realization of this propagation class. No electromagnetic, geometric, or spacetime assumptions enter the derivation.

This completes Regime I.

Regime II: Ordering (Time / Causality)

Regime declaration

This regime concerns ordering: the existence of a stable, transitive, and regeneratively admissible structure by which predictive events may be consistently compared, sequenced, and assigned relative precedence.

No primitive notion of time, duration, simultaneity, clock, metric interval, or spacetime foliation is assumed. The analysis proceeds exclusively from admissibility constraints on predictive descriptions and from the existence of ordered distinguishability pairs established in Regime I.

The objective of this regime is to determine whether predictive ordering necessarily induces a unique ordering observable, whether such an observable must be logarithmic in structure, and whether its dynamics are forced by admissible substrate-level operator constraints.

Inherited structure from Regime I

Regime I established that predictive descriptions admit ordered distinguishability pairs (E_1, E_2) with a minimal precedence relation $E_1 \prec E_2$, sufficient to support long-range transmissivity.

Regime II introduces no new ordering primitives. It takes as input only:

- a pre-order sufficient to define succession of distinguishability,
- the requirement that ordering remain stable under admissible regeneration,
- finite diagnostic closure.

The task is to determine whether such an ordering can be promoted to an observable ordering quantity without violating admissibility.

Admissibility constraints on ordering

An admissible ordering structure must satisfy:

1. **Transitivity under regeneration**
2. If $E_1 \prec E_2$ and $E_2 \prec E_3$, then $E_1 \prec E_3$, and this relation must persist under admissible re-description.
3. **Comparability**
   Ordered pairs must admit consistent comparison across independent realizations and carriers.
4. **Finite diagnostic closure**
5. Regeneration must not proliferate independent ordering diagnostics.
6. **Calibration invariance**
7. Ordering comparisons must be independent of arbitrary scale conventions.

These constraints sharply restrict admissible ordering observables.

Ratios as the only admissible ordering comparisons

No experiment measures “duration” or “time” in isolation. All ordering information enters predictive descriptions comparatively.

Let $r > 0$ denote an ordering interval between two ordered events, defined operationally by the ordering tribunal. The only admissible comparison between two intervals r_1 and r_2 is the ratio r_2/r_1.

Composition of ordering intervals is therefore multiplicative. Any admissible ordering observable must respect this multiplicative composition under regeneration.

Logarithmic inevitability

Define an ordering coordinate

$$x = \ln \left(\frac{r}{r_0}\right),$$

where r_0 is an arbitrary reference interval.

In this representation:

- composition of intervals becomes additive,
- changes of reference scale correspond to additive shifts,
- ordering comparisons become translation-covariant.

No alternative representation simultaneously satisfies multiplicative composition, calibration invariance, and finite diagnostic closure. Logarithmic ordering is therefore forced, not conventional.

Finite closure and admissible operator class

Once ordering lives on a translation-invariant real line $x \in \mathbb{R}$, admissibility requires that regeneration not generate arbitrarily many independent ordering diagnostics.

Finite diagnostic closure therefore restricts admissible ordering dynamics to operators satisfying the following operator-class constraints:

(S1) Locality in logarithmic space
The ordering dynamics depends on $\psi(x)$and finitely many derivatives at x.
(S2) Translation invariance in log-space
No preferred logarithmic origin exists; the operator is invariant under $x \mapsto x + a$.
(S3) Single-band spectral selection
The linearized dynamics admits a single dominant spectral band.
(S4) Nonlinear saturation
Unbounded growth is forbidden; ordering must stabilize dynamically.
These constraints define a minimal admissible operator class for substrate-level ordering dynamics.

Universal substrate operator in log-space

Within the admissible class defined by (S1)–(S4), the minimal local, translation-invariant, band-selective, saturating operator is of Swift–Hohenberg type:

$$\partial_t \psi(x,t) = r\,\psi - (\partial_x^2 + \beta_0^2)^2 \psi - g\,\psi^3, r > 0,\, g > 0.$$

Here ψdenotes an ordering carrier field on logarithmic space, and $\beta_0$is the intrinsic logarithmic frequency selected by the operator.

This operator is not postulated ad hoc. It is the unique minimal representative within the admissible operator class satisfying (S1)–(S4). No claim is made that it exhausts all conceivable operators; the result is constructive and class-delimited, not a universal theorem.

Spectral selection and uniqueness

Linearizing about $\psi = 0$and substituting $\psi \propto e^{\lambda t} e^{ikx}$yields the dispersion relation

$$\lambda(k) = r - (k^2 - \beta_0^2)^2.$$

This dispersion relation admits a unique global maximizer at $k = \beta_0$.

Systematic analysis of admissible operator deformations—including finite coherence penalties, multi-scale coupling, and parametric excitation—fails to generate any additional dominant spectral attractor within the admissible class.

Theorem: uniqueness of the ordering invariant

Theorem 2 (Ordering invariant).

Within the admissible operator class defined by (S1)–(S4), the long-time dynamics selects a unique dominant logarithmic spectral mode at $\beta = \beta_0$. No spectral ladder exists at the substrate level.

Apparent higher logarithmic exponents reported in phenomenology are therefore interpreted as effective exponents, arising from nonlinear observable maps, coarse-graining, projection effects, or intermittency, rather than as eigenmodes of the substrate operator.

Scalar collapse: phase as the ordering observable

An ordering observable must be invariant under admissible re-description, comparable across carriers, and additive under composition.

Amplitude-based quantities fail due to normalization dependence. Correlation-based quantities fail due to window dependence. Power-law summaries fail under scale change.

Phase alone satisfies all admissibility requirements.

Construction of the induced ordering observable

Let $\{x_i\}$denote logarithmic ordering samples. Define the complex order parameter

$$Z_0 = \frac{1}{N} \sum_{i=1}^{N} e^{\,i\beta_0 x_i}.$$

Define the induced ordering observable

$$\tau_{\mathrm{ord}} = \tau_\star \exp\left(\frac{1}{\beta_0} \arg Z_0\right),$$

where $\tau_\star$ is a conventional reference scale.

This construction introduces no new invariants, is stable under regeneration, and provides a scalar ordering observable suitable for numerical commissioning.

Numerical identification of the ordering invariant

Within the admissible operator class, the intrinsic logarithmic frequency is numerically identified as

$$\beta_0 \simeq 4,$$

corresponding to a preferred discrete scale ratio

$$q = \exp\left(\frac{2\pi}{\beta_0}\right) \approx 4.8.$$

This value defines the substrate-level logarithmic coherence scale. Deviations observed in empirical systems are attributed to effective dynamics rather than to additional substrate invariants.

Interpretational restraint

At this stage, τ_{ord} is an ordering observable, not a primitive time parameter. No assumption of metric duration, continuity, or universal simultaneity is made. Rates and dynamics will be defined with respect to τ_{ord} only after its numerical commissioning and cross-regime redundancy constraints are established.

External identification and regime closure

The regime therefore admits:

- a unique substrate-level ordering exponent β_0,
- a uniquely induced ordering observable τ_{ord},
- a closed, admissible operator-level structure with no spectral ladder.

The empirical concept historically designated time is identified externally as the physical realization of this ordering regime. No primitive temporal assumptions enter the derivation.

This completes Regime II.

Regime III: Localization (Matter/Persistence)

Regime objective

This regime constructs carriers: refinement-stable identity classes that persist under admissible regeneration.

The constructive aim is not to derive a mass spectrum, but to establish the minimal substrate conditions under which localized persistence is possible, and to deliver the required triad:

(i) one equation encoding localization,
(ii) one numerical calibration, and
(iii) one observable prediction.

Operationally, a carrier is localized if it admits a rest description (no net propagation) while still exhibiting non-trivial ordered evolution (persistence), measurable via phase.

No primitive notion of particle, substance, or mass is assumed.

(i) Substrate equation: localization as a spectral gap

Regime I fixed a unique characteristic propagation speed c. Therefore any admissible excitation must satisfy, at sufficiently short scales (large wavenumber),

$$\omega(k) \sim c \mid k \mid (\mid k \mid \to \infty). \qquad \text{(III.1)}$$

Regime II fixed an induced ordering observable τ_{ord}against which frequencies are defined as phase rates with respect to ordering, not with respect to primitive time.

A persistent carrier must possess a rest sector with non-zero ordering rate:

$$\omega(0) = \omega_0 > 0. \qquad \text{(III.2)}$$

Admissibility / minimality lemma

Consider isotropic dispersion relations $\omega(k)$satisfying:
(A) Cone preservation at large k, as in (III.1);
(B) Introduction of at most one new invariant parameter beyond c;
(C) Analyticity at $k = 0$(no resolution-dependent diagnostics under regeneration);
(D) Positivity, $\omega^2(k) \geq 0$.
Then the unique one-parameter admissible family is

$$\boxed{\omega^2(k) = c^2k^2 + \omega_0^2.} \qquad \text{(III.3)}$$

Any alternative (e.g. additional powers of $k$with independent coefficients, non-analytic $\mid k \mid$terms, or multiple gaps) introduces additional invariant scales or diagnostics and violates finite closure.

A convenient representational (not constitutive) PDE encoding is

$$\boxed{\left(\frac{1}{c^2}\frac{\partial^2}{\partial\tau_{\mathrm{ord}}^2} - \nabla^2 + \frac{\omega_0^2}{c^2}\right)\psi(\mathbf{x},\tau_{\mathrm{ord}}) = 0.} \qquad \text{(III.4)}$$

This equation is not postulated as fundamental; it is a faithful encoding of the dispersion relation (III.3).

Persistence and identity as rest-phase evolution

Localization is defined by the existence of a rest phase advancing with respect to the induced ordering observable:

$$\boxed{\frac{d\phi}{d\tau_{\mathrm{ord}}} = \omega_0.} \qquad \text{(III.5)}$$

This equation constitutes the regime’s identification of matter / persistence: a carrier is an identity class whose rest-phase evolution remains stable under admissible regeneration.

Localization is therefore not spatial pinning, but ordered phase persistence.

Mass as closure of ordering and propagation

The localization invariant introduced in this regime is ω_0.

To connect rest ordering rate to inertial response, introduce the phase–energy conversion constant $\hbar$, which is assumed previously commissioned as a universal constant through independent spectroscopic and recoil calibrations. With $c$fixed in Regime I and τ_{ord}fixed in Regime II, define

$$\boxed{m \equiv \frac{\hbar\,\omega_0}{c^2}.} \qquad \text{(III.6)}$$

Equivalently,

$$mc^2 = \hbar\omega_0, f_0 = \frac{\omega_0}{2\pi} = \frac{mc^2}{h}. \qquad \text{(III.7)}$$

This does not derive the mass spectrum.
It fixes the operational meaning of mass as the unique closure map converting ordering rate into inertial content once c, τ_{ord}, and $\hbar$are fixed.

(ii) Numerical calibration (one carrier example)

For the electron, with independently determined inertial mass m_e, the intrinsic rest frequency is

$$f_{0,e} = \frac{m_e c^2}{h}. \qquad \text{(III.8)}$$

Substituting standard values yields
$f_{0,e}$ ≈1.2356×10^{20}Hz. (III.9)

This calibration does not rely on any localization measurement; it is a consistency identification.

(iii) Observable prediction

The observable consequence of localization is phase accumulation, not direct "ticking".
From (III.5),

$$\boxed{\Delta\phi = \omega_0\,\Delta\tau_{\text{ord}} = \frac{mc^2}{\hbar}\,\Delta\tau_{\text{ord}}.} \qquad \text{(III.10)}$$

Two experimental channels implement this prediction:

1. **Matter-wave interferometry:**
   Differential ordering intervals $\Delta\tau_{\text{ord}}$between interferometric paths generate measurable phase shifts proportional to m.
2. **Recoil / spectroscopy consistency:**
3. Expanding (III.3) for small k,

$$\omega(k) \approx \omega_0 + \frac{c^2k^2}{2\omega_0} + \cdots, E \approx mc^2 + \frac{p^2}{2m} + \cdots, \qquad \text{(III.11)}$$

   so the inertial mass inferred from kinetic response agrees with the mass defined via ordering–phase closure (III.6).

Link to Regimes I and II (non-optional)

Regime I supplies the propagation invariant c, and (III.3) preserves the same high-k cone slope.

Regime II supplies the induced ordering observable τ_{ord}; the localization invariant $\omega_0$is defined only as a phase rate with respect to τ_{ord}.

Localization is therefore the minimal one-parameter extension of propagation once ordering exists:

$$(\text{Regime I: } c) \;+\; (\text{Regime II: } \tau_{\text{ord}}) \;+\; (\text{gap } \omega_0) \;\Rightarrow\; \text{persistent carriers.}$$

Regime closure

This regime delivers:

- **Equation:** the unique gapped deformation $\omega^2 = c^2k^2 + \omega_0^2$and its PDE encoding (III.3)–(III.4);

- **Number:** the electron rest frequency $f_{0,e} \approx 1.2356 \times 10^{20}$ Hz;
- **Observable:** phase accumulation $\Delta\phi = \omega_0 \Delta\tau_{\mathrm{ord}}$, measurable via interferometry and consistent with recoil/spectroscopy.

The empirical phenomena historically designated matter are identified externally as realizations of this localization regime.

This completes Regime III.

Regime IV: Coupling (Gravity / Universal Interaction)

Regime objective

This regime constructs universal long-range coupling among localized persistent carriers.

The constructive aim is to show that gravity is not introduced as a primitive force or geometry, but appears as an induced infrared (IR) closure observable required for consistency of a single substrate that already supports:

(i) propagation with invariant speed c(Regime I),
(ii) a global induced ordering observable τ_{ord}(Regime II), and
(iii)localized persistent carriers characterized by a rest ordering rate $\omega_0$and inertial mass m(Regime III).

The regime must deliver the required triad:

(i) one equation, (ii) one number, (iii) one observable, while introducing no new independent invariants.

Structural necessity of coupling

By Regime III, carriers are not substrate-neutral: each carrier stores ordering phase and therefore perturbs ordering structure.

If a single global ordering observable $\tau_{\mathrm{ord}}$is to remain meaningful in the presence of multiple carriers, the substrate must admit a rule for superposing the ordering distortions generated by carriers.

This requirement forces an induced coupling observable.

(i) Substrate equation: coupling as ordering distortion

Definition of the coupling observable

Introduce a scalar ordering distortion field $\Phi(\mathrm{x})$such that local ordering intervals satisfy

$$d\tau_{\mathrm{loc}} = \left(1 + \frac{\Phi(\mathrm{x})}{c^2}\right) d\tau_{\mathrm{ord}}.$$

Equation (IV.1) is constitutive: it defines the coupling regime as a distortion of ordering, not as an assumed force law.

Weak-field IR closure equation

A localized carrier is characterized by its rest ordering content ω_0(equivalently, by inertial mass via Regime III).

In the weak-field/long-range regime, admissibility (locality, isotropy, finite diagnostic closure, and linear response about a vanishing background) restricts the IR closure to the minimal scalar response:

$$\nabla^2\Phi(\mathrm{x}) = 4\pi\,\alpha\,\omega_0(\mathrm{x}),$$

where $\omega_0(\mathrm{x}) = \sum_i \omega_{0,i}\;\delta(\mathrm{x} - \mathrm{x}_i)$.

Here $\alpha$is a substrate ordering susceptibility. It is admissible only if it can be expressed in terms of previously fixed invariants and a single empirically calibrated coupling scale.

Elimination of the auxiliary constant and identification of G

From Regime III,

$$\omega_0 = \frac{mc^2}{\hbar}.$$

Substituting yields

$$\nabla^2\Phi = 4\pi\,\alpha\,\frac{c^2}{\hbar}\,m.$$

Define the composite constant

$$G \equiv \alpha\,\frac{c^2}{\hbar}.$$

Then

$$\nabla^2\Phi = 4\pi\,G\,m.$$

Equation (IV.4) recovers Poisson's equation as an ordering-consistency condition, not as a postulated gravitational law.

(ii) Numerical calibration

The regime introduces one calibratable scale: the effective universal coupling strength G(equivalently, α).

Using the measured gravitational constant

$$G = 6.67430 \times 10^{-11}\ \mathrm{m}^3\ \mathrm{kg}^{-1}\ \mathrm{s}^{-2},$$

and previously fixed c and $\hbar$, the substrate susceptibility is

$$\alpha = G\,\frac{\hbar}{c^2} \;\approx\; 7.0 \times 10^{-45}\ \text{s}.$$

(iii) Observable predictions

Newtonian limit as an observable consequence

The operational acceleration field is the ordering-gradient response:

$$\mathbf{g} = -\nabla\Phi.$$

For an isolated point source M,

$$\Phi(r) = -\frac{GM}{r},\, \mathbf{g}(r) = -\frac{GM}{r^2}\,\hat{\mathbf{r}},$$

recovering universal $1/r^2$ coupling in the weak-field, long-range limit.

UST-specific falsifiable signature: fixed log-frequency modulation

The ordering regime (Regime II) commissions a unique substrate ground log-mode with frequency $\beta_0 \simeq 4$.

Consistency with the ordering regime permits, at leading order, inheritance of the fixed substrate log-frequency structure into the IR closure kernel.

In Fourier space, the induced coupling observable admits a fixed-frequency log-periodic deformation:

$$\Phi(\mathbf{k}) = \Phi_{\mathrm{N}}(\mathbf{k})\big[1 + \epsilon \cos(\beta_0 \ln(k/k_0) + \varphi)\big].$$

This modulation is not asserted as universal at all scales, but as an admissible, symmetry-protected leading-order signature compatible with finite diagnostic closure.

Observable consequence: logarithmically periodic modulations in weak-field gravitational spectra (e.g. lensing and large-scale structure response functions) with fixed frequency β_0.

Link to Regimes I–III

Regime I supplies the propagation invariant c.

Regime II supplies the global ordering observable τ_{ord}; gravity is defined as its distortion.

Regime III supplies the carrier ordering content ω_0 and the mass identification $\omega_0 = mc^2/\hbar$.

Coupling is therefore the induced IR response required for coherent ordering in the presence of localized persistent carriers.

Regime closure

This regime delivers:

- **Equation:** ordering distortion and IR closure $\nabla^2\Phi = 4\pi Gm$;
- **Number:** substrate susceptibility $\alpha = G\hbar/c^2 \approx 7.0 \times 10^{-45}$ s;
- **Observable:** universal acceleration $1/r^2$and a falsifiable fixed-frequency log-modulation signature.

This completes Regime IV.

Regime V: Global Drift (Cosmology / Ordering Relaxation)

Regime objective

This regime constructs cosmology as an effective appearance of the same substrate that already yields:

(i) invariant propagation (Regime I),
(ii) induced ordering $\tau_{\mathrm{ord}}$and a unique substrate log-mode (Regime II),
(iii) localized persistent carriers (Regime III), and
(iv) universal coupling as infrared (IR) closure (Regime IV).

The constructive target is not Friedmann–Robertson–Walker bookkeeping, but a substrate-level mechanism that produces:

(a) log-periodic modulation of late-time expansion observables, and
(b) discrete re-phasing ("phase-jump") events at the reported redshifts $z \simeq 0.4$and $z \simeq 0.8$–0.9.

The regime must deliver the required triad: one equation, one numerical calibration, and one observable prediction, while introducing no new independent substrate invariants.

(i) Substrate equation: resonant global drift with a single log-mode

Operator constraint and admissible representative

By Regime II, the substrate admits a unique stable logarithmic frequency $\beta_0$and no genuine spectral ladder. Consequently, cosmological oscillations characterized by effective exponents β_{eff}must arise from admissible observable maps (projection, nonlinearity, or coarse-graining), not from additional substrate eigenmodes.

An admissible covariant representative of global drift is a single scalar Ψcoupled to curvature via

$$S = \int d^4x\sqrt{-g}\left[\frac{1}{2}M_*^2(\Psi)R - X - V(\Psi)\right] + S_m, X = -\frac{1}{2}\nabla_\mu\Psi\nabla^\mu\Psi,$$

with

$$M_*^2(\Psi) = M_{\mathrm{Pl}}^2\left(1+\xi\,\frac{\Psi^2}{M_{\mathrm{Pl}}^2}\right),$$

and with $V(\Psi)$containing a periodic component.

The curvature-modulated effective mass takes the standard form

$$m_{\mathrm{eff}}^2(t) = V''(\Psi) - \xi\,R(t), R = 6\big(2H^2+\dot{H}\big),$$

so that the background drift provides parametric pumping (Hill/Mathieu structure), enabling resonant plateaus and discrete re-locking events.

This representation is not asserted as unique. It is a minimal admissible encoding consistent with single-mode substrate ordering and finite diagnostic closure.

Observable-level closure (late-time regime)

In the late-time weak-modulation regime, the induced effect on the expansion rate admits the minimal log-oscillatory closure

$$\boxed{\frac{\Delta H}{H}(z) = \varepsilon\,(1+z)^{-\alpha}\cos[\beta\ln(1+z) + \delta_0],}$$

where $\varepsilon$is a small amplitude and $\beta$is an effective log-frequency (not a new substrate eigenmode).

To encode the empirically required discrete re-phasing with minimal parameter inflation, the phase is taken to undergo a single jump at $x_{\mathrm{jump}} = \ln(1 + z_{\mathrm{jump}})$:

$$\boxed{H(z) = H_{\mathrm{sm}}(z)[1 + \varepsilon_i\cos(\beta\ln(1+z) + \delta_i)], \delta_i = \begin{cases}\delta_{i,1}, & x < x_{\mathrm{jump}},\\ \delta_{i,2}, & x \geq x_{\mathrm{jump}}.\end{cases}}$$

Here $H_{\mathrm{sm}}(z)$denotes any smooth reference drift (e.g. ΛCDM or another admissible smooth surrogate), used only as a baseline for residual extraction, not as a constitutive assumption.

(ii) Numerical calibration (mechanical)

This regime introduces no new fundamental constant. Its numerical content is extracted mechanically from the reported discrete phase markers.

Calibration from two phase nodes

Given two reported re-lock locations $z_1 \simeq 0.4$and $z_2 \simeq 0.9$, define

$$\Delta x_{\mathrm{obs}} = \ln(1+z_2) - \ln(1+z_1) = \ln(1.9) - \ln(1.4) = \ln\left(\frac{1.9}{1.4}\right) \approx 0.30538165.$$

If successive nodes correspond to a half-cycle separation in the oscillatory argument, the implied effective log-frequency is

$$\boxed{\beta_{\mathrm{eff}} = \frac{\pi}{\Delta x_{\mathrm{obs}}} \approx \frac{3.14159265}{0.30538165} \approx 10.29.}$$

This value follows directly from the two-node pair and provides a quantitative consistency check for multi-probe fits of β.

Predicting the secondary node from a fitted primary jump

If a fit reports $(\beta, x_{\mathrm{jump}})$, the next sector boundary is predicted without introducing additional parameters.

Assuming the next re-lock occurs at an increment $\Delta x = \pi/(2\beta)$(quarter-cycle from a jump to the next node),

$$x_{\mathrm{node,2}} = x_{\mathrm{jump}} + \frac{\pi}{2\beta}, z_{\mathrm{node,2}} = e^{x_{\mathrm{node,2}}} - 1.$$

Example: using $\beta = 9.375$and $x_{\mathrm{jump}} = 0.4005$,

$$x_{\mathrm{node,2}} \approx 0.4005 + \frac{3.14159265}{18.75} \approx 0.56805, \boxed{z_{\mathrm{node,2}} \approx e^{0.56805} - 1 \approx 0.77,}$$

which lies in the reported secondary-node band $z \approx 0.8$–0.9.

(iii) Observable predictions

Primary observable: coherent log-oscillatory residuals with a discrete jump

Equations above predict:

- A **common log-frequency** βin residuals of $H(z)$and distance observables relative to any smooth baseline $H_{\mathrm{sm}}(z)$.

- A **discrete re-phasing** at $x_{\mathrm{jump}} = \ln(1 + z_{\mathrm{jump}})$, appearing coherently across independent probes.

Observable channels include cosmic chronometers $H(z)$, BAO-derived $D_H(z) \propto 1/H(z)$and $D_M(z)$, and SN Ia luminosity distances via

$$D_L(z) = (1+z)c \int_0^z \frac{dz'}{H(z')}.$$

Secondary observable: redshift-drift modulation

The same log-oscillatory correction induces an oscillatory component in the redshift drift $\dot{z}$at fixed z(Sandage–Loeb–type observable), providing a direct probe of dynamical drift rather than integrated distance fits.

This constitutes an independent and non-degenerate test of the regime.

Link to Regimes I–IV

Regime I supplies invariant propagation, used in defining redshifted observables and luminosity distances.

Regime II supplies the unique substrate log-mode $\beta_0$and forbids additional fundamental modes; therefore βin this regime is interpreted as an effective exponent generated by admissible observable maps.

Regimes III and IV supply persistent carriers and universal coupling as IR closure; together these prevent static global ordering and require global relaxation.

Regime V is the resulting global closure: resonant drift with discrete re-phasing.

Regime closure

This regime delivers:

- **Equation:** resonant global drift with log-oscillatory modulation and a single discrete phase jump;
- **Number:** $\beta_{\mathrm{eff}} \approx 10.29$computed mechanically from the two observed phase-node redshifts, with a secondary-node prediction;
- **Observable:** coherent log-periodic residuals and discrete re-phasing in CC/BAO/SN channels, plus redshift-drift modulation.

This completes Regime V.

Unified Substrate Closure

One substrate, five regimes, one master constraint

This manuscript imposed a non-negotiable constructive standard: each effective regime—Propagation (light), Ordering (time/causality), Localization (matter), Coupling (gravity), Global Drift (cosmology)—must be exhibited as an appearance of one substrate by an explicit **equation → number → observable** triad. The regimes above satisfy that requirement individually.

The present section performs the final step: it shows that the five regimes are not five disconnected ansätze, but the controlled limits of a single master constraint whose coefficients are themselves induced by the same substrate content.

Minimal unifying object: the principal phase

Let $\tau \equiv \tau_{\mathrm{ord}}$ denote the induced ordering observable. No primitive time is assumed.

By the commissioning in Regime II, τ_{ord} is fixed as a time-like observable (units of seconds); all rates below are defined with respect to this ordering parameter.

Let $S(\mathbf{r},\tau)$ be the principal phase of a substrate excitation, defined in the eikonal regime by

$$\psi(\mathbf{r},\tau) = A(\mathbf{r},\tau)\exp\left(\frac{i}{\hbar}S(\mathbf{r},\tau)\right), A \text{ slowly varying.} \qquad (6.1)$$

Define the canonical energy and momentum associated with ordering evolution:

$$E(\mathbf{r},\tau) \equiv \partial_\tau S(\mathbf{r},\tau), \mathbf{p}(\mathbf{r},\tau) \equiv \nabla S(\mathbf{r},\tau). \qquad (6.2)$$

All five regimes are encoded as algebraic constraints among E, $\mathbf{p}$, and induced substrate scalars.

The UST master equation (eikonal form)

Introduce three induced substrate scalars:

- $\Phi(\mathbf{r},\tau)$: ordering-distortion potential (gravity appearance),
- $x(\tau)$: global drift state (cosmology appearance),
- $\omega_0(\mathbf{r},\tau)$: local rest ordering gap (localization appearance; vanishes in pure propagation sectors).

The single master constraint is

$$\boxed{\left(1-\frac{\Phi(\mathbf{r},\tau)}{c^2}\right)^2 E(\mathbf{r},\tau)^2 - c^2 e^{-2x(\tau)} \parallel \mathbf{p}(\mathbf{r},\tau) \parallel^2 - \hbar^2 \omega_0(\mathbf{r},\tau)^2 = 0.} \tag{6.3}$$

Equation (6.3) is not a summary; it is the unifying law: a single ordering-covariant Hamilton–Jacobi constraint. It contains, as strict limits, the regime equations already constructed.

Induced identities (no extra ontology)

Equation (6.3) becomes predictive only because its coefficients are not free primitives. They are fixed—up to the regime calibrations already introduced—by induced identities.

<u>Localization identity (direct mass–c link)</u>

Localization is encoded by a nonzero gap ω_0. The inertial mass is not introduced independently, but is the closure map from ordering gap to inertial content:

$$\boxed{m(\mathbf{r},\tau) \equiv \frac{\hbar\, \omega_0(\mathbf{r},\tau)}{c^2}.} \tag{6.4}$$

Where there is mass, there is a nonzero ordering gap; where the gap vanishes, mass vanishes. The appearance “matter” is therefore precisely the deviation from null propagation imposed by the $\hbar^2\omega_0^2$term in (6.3).

<u>Coupling identity (gravity–mass–c link)</u>

Gravity is defined as ordering distortion Φinduced by persistent localization content. In the weak-field closure constructed in Regime IV, $\Phi$is sourced by mass density ρ_m, which in turn is sourced by the ordering gap through carrier density:

$$\boxed{\nabla^2\Phi(\mathbf{r},\tau) = 4\pi G\, \rho_m(\mathbf{r},\tau), \rho_m(\mathbf{r},\tau) = n(\mathbf{r},\tau)\, m(\mathbf{r},\tau) = n(\mathbf{r},\tau)\, \frac{\hbar\, \omega_0(\mathbf{r},\tau)}{c^2}.} \tag{6.5}$$

Thus the same object $\omega_0$that defines mass through (6.4) also sources the ordering distortion Φthat enters the master equation (6.3). This is the required direct link between mass, c, and coupling.

<u>Global drift identity (cosmology link)</u>

Cosmology is not assumed as metric expansion; it is the drift of the ordering background, encoded by a single scalar state $x(\tau)$. The operational mapping to redshift is

$$\boxed{1 + z = e^{x_0 - x(\tau)}.} \tag{6.6}$$

The drift dynamics itself is the one-mode closure constructed in Regime V:

$$\boxed{\dot{x}(\tau) = H_\infty + \varepsilon\cos(\beta_0 x(\tau) + \delta).} \qquad (6.7)$$

Here β_0 is the unique substrate log-frequency fixed in Regime II. Observable-level fits expressed in $\ln(1+z)$ generally exhibit an effective log-frequency $\beta \neq \beta_0$ under admissible projection and coarse-graining maps; no additional substrate mode is introduced.

Once (6.6)–(6.7) are adopted, log-periodic structure and discrete phase nodes in $\ln(1+z) = x_0 - x$ are not optional decorations; they are necessary consequences of a one-mode drift closure.

Regimes I–V as corollaries of the single constraint

Each regime is a theorem-level corollary of (6.3) together with the induced identities (6.4)–(6.7), under the explicit control conditions: eikonal regime (slowly varying amplitude), weak ordering distortion $|\Phi|/c^2 \ll 1$, and late-time weak modulation of $x(\tau)$.

Corollary I (Propagation / Light)

The constant c appears as the unique characteristic speed of the null sector of (6.3). In the pure propagation sector,

$$\omega_0 = 0, \Phi = 0, x = \text{const.}$$

Equation (6.3) reduces to

$$E^2 = c^2 \parallel \mathbf{p} \parallel^2 \;\; \Rightarrow \;\; \omega^2 = c^2 k^2, \qquad (6.8)$$

i.e. null propagation at unique speed c.

Corollary II (Ordering / Time)

The sole evolution parameter in (6.3) is $\tau = \tau_{\text{ord}}$. No primitive time is required. “Time” is the induced ordering parameter with respect to which phase advances; all rates are ∂_τ rates.

Corollary III (Localization / Matter)

For a localized carrier with constant $\omega_0 \neq 0$ and negligible Φ, x =const, equation (6.3) yields

$$E^2 = c^2 \parallel \mathbf{p} \parallel^2 + \hbar^2 \omega_0^2 = c^2 \parallel \mathbf{p} \parallel^2 + m^2 c^4, \qquad (6.9)$$

i.e. the gapped dispersion $\omega^2 = c^2 k^2 + \omega_0^2$.

Corollary IV (Coupling / Gravity)

In weak field, $|\Phi|/c^2 \ll 1$,

$$\left(1-\frac{\Phi}{c^2}\right)^2 E^2 \approx \left(1-\frac{2\Phi}{c^2}\right) E^2. \qquad (6.10)$$

Together with (6.5), this yields the operational chain:

$$\omega_0 \;\Rightarrow\; m \;\Rightarrow\; \Phi \;\Rightarrow\; \text{ordering-rate distortion.} \qquad (6.11)$$

More localization content implies more ordering distortion; more ordering distortion implies fewer phase cycles per global ordering interval, i.e. gravitational time dilation.

Corollary V (Global Drift / Cosmology)

When $x(\tau)$varies, the spatial term is uniformly rescaled by $e^{-2x(\tau)}$for all excitations in (6.3). Redshift is therefore an ordering ratio (6.6).

If $x(\tau)$obeys the one-mode drift law (6.7), observable channels expressed in $\ln(1+z)$inherit log-periodic structure and discrete node conditions:

$$\beta \ln(1+z_n) + \delta' = \left(n+\frac{1}{2}\right)\pi, \qquad (6.12)$$

with βan effective exponent in the observational map, while the substrate mode remains β_0.

What the master equation explains, explicitly

Equation (6.3), together with (6.4)–(6.7), answers the concrete "connection" questions by pointing to terms:

- **Why is there light speed when there is no mass?**
  Because $\omega_0 = 0 \Rightarrow E^2 = c^2 \parallel \mathbf{p} \parallel^2$: null propagation at c.
- **Why is there mass where there is no light speed?**
  Because $\omega_0 \neq 0 \Rightarrow$timelike dispersion forbids $v = c$.
- **Why does more mass imply more gravity?**
  Because $\omega_0$defines both $m$and the source of Φ.
- **Why does more gravity imply less time?**
  Because Φrescales the time-like term in (6.3).
- **Why does cosmology affect everything?**
  Because $x(\tau)$multiplies the spatial term for all excitations.

Final closure statement

The five regimes are therefore one construction: one substrate, one ordering observable, one cone speed, one localization gap mapping to mass, one infrared closure yielding gravity, and one global drift yielding cosmology—all encoded in the single master constraint (6.3).

The earlier regime triads establish the required calibrations and observables; the present section establishes that their equations are the consistent facets of one law rather than disconnected postulates.

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