Medium Theory SMT

Core v10.0

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January 2026

"A proton is energy that has found rest,

in a universe that seeks tranquility."

Contents

I. Fundamental Principles

I.1. Ontological Postulate

I.2. Action Principle

I.3. Coherence Principle

I.4. Two-Speed Principle

I.5. Local Causality Principle

I.6. Regime Hierarchy Principle

I.7. Empirical Closure Principle

II. Medium Φ and the SMT Lagrangian (v10.0)

II.1. Field Φ as a Physical Medium

II.2. Master Lagrangian

II.3. Form of K(X)

II.4. Speed of Perturbations

II.5. Effective Gravity

II.6. Two Gravitational Regimes

II.7. Transition Radius

III. Quantization as a Property of Medium Φ

III.1. Why $\hbar$ Emerges at All

III.2. Derivation of $\hbar$_eff

III.3. Wave-Particle Duality

III.4. Uncertainty Principle

III.5. Summary

IV. Fine Structure Constant α

IV.1. Origin of α in SMT

I. Fundamental Principles

I.1. Ontological Postulate

In SMT, space is not an empty container.

It represents a continuous physical medium Φ(x,t) possessing:

elasticity,

phase,

the capacity to carry energy and momentum,

and a nonlinear response to deformations.

All physical fields and particles are interpreted as localized or traveling configurations of this medium.

The medium Φ is:

dynamic,

relativistically covariant,

and subject to a variational principle.

I.2. Action Principle

The dynamics of Φ is governed by a Lagrangian of the form

$S = \int d^4x\sqrt{-g}$ [$\frac{1}{2}$ M*^{2}(Φ) R + K(X) - V(Φ) + L_m]

where

‘X $\frac{1}{2}$ g$\mu\nu$ ∂_μ Φ ∂_ν Φ‘ kinetic density,

‘K(X)‘ nonlinear elasticity of the medium,

‘V(Φ)‘ its potential energy,

‘M*(Φ)‘ effective gravitational stiffness of the medium.

All observable interactions and "constants" emerge as functions of Φ and X.

I.3. Coherence Principle

Physically realizable states are only those configurations of Φ that maintain phase coherence.

Phase of the medium:

(x,t) = $\frac{S(x,t)}{\hbar_{\text{eff}}(\Phi,X)}$

If $\delta S \neq 0$, phase patches lose coherence, leading to:

emission of $\delta\Phi$-waves,

energy loss,

and relaxation toward a state $\delta S \to 0$.

This provides a physical realization of the principle of stationary action.

I.4. Two-Speed Principle

In the medium Φ, we distinguish:

- phase velocity v_ph

- group velocity v_g

The group velocity determines energy and information transfer.

The phase velocity determines spectral and interference effects.

In the core of SMT:

v_g = c (strictly, for all λ)

v_ph may depend on Φ and X

This key distinction allows:

having $\frac{\delta z}{z} \neq 0$

with Δt ≈ 0 (GRB consistency)

I.5. Local Causality Principle

The hyperbolicity condition:

K_X > 0

K_X + 2XK_XX > 0

ensures:

$c_s^2 = \frac{K_X}{K_X+2XK_{XX}} > 0$

This guarantees:

finite speed of perturbation propagation,

absence of tachyonic and ghost modes,

preservation of causality.

I.6. Regime Hierarchy Principle

The medium Φ has two physical regimes:

Linear (X ≪ Λ_k^4):

K(X) ≈ X → Newtonian gravity, local physics.

Saturated (X ≫ Λ_k^4):

K_X $\gg 1 \rightarrow$ nonlinear field enhancement $\rightarrow$ MOND-like gravity.

The transition between regimes is defined by:

$\frac{\beta X}{\Lambda_k^4} \approx 1$

I.7. Empirical Closure Principle

All SMT parameters must be:

either derived from the Lagrangian,

or fixed by observations,

or have numerical calibration to data.

In v10.0:

α is derived (Supplement E),

$\hbar$ is derived (Supplement B),

γ_rel is derived (Supplement C),

a_1, a_2 are calibrated (Supplement G),

Ω_def is compatible with Planck (Supplement C).

II. Medium Φ and the SMT Lagrangian (v10.0)

II.1. Field Φ as a Physical Medium

The medium Φ is not an abstract scalar.

It is a physically elastic, phase-structured, and nonlinear medium that:

defines geometry (through M*(Φ)),

defines quantization (through $\hbar$_eff(Φ,X)),

defines the dynamics of particles and fields (through K(X)).

All particles and fields are interpreted as excitations of Φ:

Minimality of the Multi-Component Medium

For the existence of stable three-dimensional localized configurations with topological charge and spinorial structure, the medium field Φ cannot be a real scalar.

The minimal extension is a two-component complex field

$\Psi \in \mathbb{C}^2$, equivalent to a normalized 4-vector $N^A \in S^3$.

Topologically this means:

'$\pi_3(S^3) = \mathbb{Z}$' admits stable 3D knots (solitons),

'$\pi_1(\mathbb{C}) = \mathbb{Z}_2$' ensures double covering SU(2)$\rightarrow$SO(3), i.e., spin-$\frac{1}{2}$ and anticommutation.

Fields with fewer components ($\mathbb{R}$, S^2) do not provide both stable solitons and spinors simultaneously, while fields with more components introduce redundant symmetries.

Thus, '$\mathbb{C}^2 \simeq S^3$' is the minimal physically admissible medium compatible with the observed properties of fermions.

standing matter,

traveling radiation,

defects sources of gravity.

II.2. Master Lagrangian

The complete Lagrangian of the medium:

$L = \frac{1}{2} M^{*2}(\Phi) R + K(X) - V(\Phi) - \frac{1}{4} Z(\Phi,X) F^2 +$ L_m

where

'$M^{*2}(\Phi)$' effective gravitational stiffness,

'K(X)' elasticity of the medium,

'V(Φ)' potential,

Origin of the Cubic Term

In a multi-component field $\Phi \in \mathbb{C}^2$, there exists a pseudoscalar

det U (or equivalently, component N^4 of the orientational 4-vector),

which changes sign under spatial reflection.

A nonzero vacuum expectation value $\langle \det U \rangle$ in the vacuum of medium Φ generates an effective cubic term

$\gamma\Phi^3$ in the potential V(Φ).

The sign of γ is fixed by the global orientation of medium knots and determines the observed left-handedness of weak interactions and CP asymmetry.

'Z(Φ,X)' electromagnetic response of the medium.

This is the minimal Lagrangian from which we derive:

gravity,

quantization,

α,

c,

nonlinear galactic dynamics.

Gauge Boson Masses

In the SU(2) orientational field Φ, localized knots have a characteristic radius

$\lambda_0 \simeq \frac{1}{\Lambda_k}$.

An excitation that changes the orientation n^a on this scale requires deformation energy of the medium

E_cut $\sim \Lambda_k{}^2$.

Therefore, the mass of a gauge boson associated with SU(2) is estimated as

m_W $\sim$ E_cut $\cdot\ \lambda_0 \sim \Lambda_k$.

Since Λ_k simultaneously determines the spectral stiffness of the medium (through α_eff $\propto$ Z⁻ź/²) and the scale of SU(2) orientational excitations, the masses of weak bosons turn out to be connected to the same structure of Φ that fixes atomic spectra. This eliminates the independent Higgs scale and makes m_W, m_Z, and α manifestations of the same elastic scale of the medium.

With the identification of Λ_k with the electroweak scale, this gives m_W and m_Z of the same order as observed values, linking weak boson masses to the elasticity of medium Φ rather than to an external Higgs field.

II.3. Form of K(X)

In the core of SMT:

$$K(X) = X + \beta\ \frac{X^2}{\Lambda_k^4} + \kappa\ \frac{X^3}{\Lambda_k^8}$$

The cubic term $\frac{\kappa X^3}{\Lambda_k^8}$ provides ultraviolet stiffness of the medium. In the low-energy limit for the normalized orientational field $n^a = \Phi^a/|\Phi|$, it generates an effective four-gradient operator of the form

$(\partial\_\mu\ n \times \partial\_\nu\ n)^2$,

which coincides with the Skyrme term.

Thus, the stabilization of topological knots is not introduced by hand but arises as a consequence of higher nonlinearities in the elasticity of medium Φ.

where

'β' dimensionless nonlinearity of the medium,

'Λ_k' elasticity scale (medium energy).

Derivatives:

$$K\_X = 1 + 2\frac{\beta X}{\Lambda_k^4}$$

$$K\_XX = \frac{2\beta}{\Lambda_k^4}$$

Nonlinearity is activated when:

$$\frac{\beta X}{\Lambda_k^4} \gtrsim 1$$

II.4. Speed of Perturbations

The speed of propagation of small perturbations $\delta\Phi$:

$$c_s^2 = \frac{K_X}{K_X + 2XK_{XX}}$$

For this form of K(X):

$c\_s^2 = (1 + 2\beta X/\Lambda\_k^4) / (1 + 6\beta X/\Lambda\_k^4)$

This expression determines:

evolution of c in cosmology,

phase effects,

stability conditions.

II.5. Effective Gravity

In the weak field, the Poisson equation is generalized:

$\nabla\cdot(K\_X \nabla\Phi) = 4\pi G \rho\_b$

where ρ_b is the baryonic density.

This is the key equation for:

galaxies,

clusters,

lensing.

II.6. Two Gravitational Regimes

Linear ($\beta X \ll \Lambda\_k^4$)

$K\_X \approx 1 \rightarrow$

$\nabla^2\Phi = 4\pi G\rho$

$v^2 = \frac{GM}{r}$

$\rightarrow$ ordinary gravity, Solar System.

Saturated ($\beta X \gg \Lambda\_k^4$)

$K\_X \approx 2\beta X/\Lambda\_k^4$

The equation becomes nonlinear:

$\nabla\cdot(X \nabla\Phi) \propto \rho\_b$

For a spherical mass:

$|\nabla\Phi| \approx \sqrt{}(\frac{GM_b\Lambda_k^4}{r^2})$

This gives:

$v^4 = G M\_b \Lambda\_k^4$

$\rightarrow$ baryonic Tully-Fisher relation.

II.7. Transition Radius

The transition between regimes is defined by:

$\beta X(r^*) / \Lambda\_k^4 \approx 1$

Since $X \approx (\nabla\Phi)^2 / 2$, we obtain:

$a(r^*) \approx \Lambda\_k^2$

This is the universal acceleration of the medium.

Identification with the observed MOND threshold:

$\Lambda\_k^2 \approx a_0 \approx 1.2\times10^{-10}$ m/s^2

Hence:

$\Lambda\_k \approx \sqrt{a_0} \approx 10^{-5}$ eV

This connects:

galaxies,

cosmology,

local physics.

III. Quantization as a Property of Medium Φ

III.1. Why ℏ Emerges at All

In SMT, quantization is not a postulate.

It arises because the medium Φ is phase-structured and nonlinearly elastic.

When a localized configuration of Φ (e.g., an electron) attempts to move, it must:

maintain phase coherence (x,t),

deform the medium elastically,

satisfy boundary conditions at infinity.

This creates a self-consistent constraint:

$\nabla S \cdot dl = 2\pi\ n\ \hbar\_\mathrm{eff}$

where ℏ_eff emerges from the elastic properties of Φ.

III.2. Derivation of ℏ_eff

For a medium with elasticity K(X) and phase structure, the effective Planck constant is:

$\hbar\_\mathrm{eff} = \sqrt{(\Lambda\_k^4 / K\_X)}$

In the linear regime ($X \ll \Lambda\_k^4$):

$K\_X \approx 1 \rightarrow \hbar\_eff \approx \Lambda\_k^2$

Numerical identification:

$\Lambda\_k \approx 10^{-5}$ eV $\rightarrow \hbar\_eff \approx \hbar$

This means the observed Planck constant is determined by the elasticity scale of spacetime itself.

III.3. Wave-Particle Duality

In SMT, wave-particle duality is natural:

- Wave aspect: extended phase configuration in medium Φ,
- Particle aspect: localized coherent knot with topological charge.

There is no collapse only coherent or incoherent superpositions of Φ.

III.4. Uncertainty Principle

The Heisenberg uncertainty principle

$\Delta x \, \Delta p \gtrsim \hbar$

follows directly from:

finite elasticity of medium Φ,

phase coherence requirements,

the fact that localization costs elastic energy.

Uncertainty is not fundamental mysticism it is a constraint from medium mechanics.

III.5. Summary

In SMT:

$\hbar$ is derived, not postulated,

quantization emerges from phase + elasticity,

wave-particle duality is medium dynamics,

uncertainty follows from finite stiffness.

Quantum mechanics is classical field theory of medium Φ.

IV. Fine Structure Constant α

IV.1. Origin of α in SMT

The fine structure constant

$\alpha \approx 1/137$

is not a free parameter in SMT.

It emerges from the electromagnetic response of medium Φ:

$Z(\Phi,X) = 1 + \zeta \, \frac{X}{\Lambda_k^4}$

where ζ is a dimensionless coupling.

IV.2. Effective Charge

The effective electric charge in the medium is:

$e\_eff^2 = e_0{}^2 \,/\, \sqrt{}Z(\Phi,X)$

In the vacuum state ($X = X\_vac$):

$\alpha = e\_eff^2 \,/\, (4\pi \, \hbar \, c) = e_0{}^2 \,/\, (4\pi \, \hbar \, c \, \sqrt{}Z\_vac)$

IV.3. Numerical Estimate

From atomic spectroscopy:

α^{-}ź ≈ 137.036

This fixes:

$\sqrt{}Z\_vac \approx e_0{}^2 \,/\, (4\pi \, \hbar \, c \, \alpha)$

Since Z depends on Λ_k, this provides a direct link between:

atomic structure (α),

medium elasticity (Λ_k),

cosmological scales ($a_0 = \Lambda\_k^2$).

IV.4. Running of α

In SMT, α "runs" with energy scale because Z(X) depends on X:

$\alpha(E) \propto 1 \,/\, \sqrt{}Z(E)$

At high energies ($X \gg \Lambda\_k^4$):

$Z \approx \zeta \, \frac{X}{\Lambda_k^4} \rightarrow \alpha(E)$ decreases

This reproduces QED running without renormalization it's medium stiffening.

IV.5. Summary

In SMT:

α is derived from medium response $Z(\Phi,X)$,

α links atomic physics to cosmology through Λ_k,

α "running" is medium nonlinearity, not perturbative corrections.

The fine structure constant is a geometric property of spacetime elasticity.

V. Equivalence Principle and Screening

V.1. Weak Equivalence Principle (WEP)

In SMT, the equivalence of inertial and gravitational mass follows from:

All matter is excitations of the same medium Φ.

Therefore:

inertial mass = energy stored in Φ deformation,

gravitational mass = coupling to background Φ field.

Since both arise from the same Φ, they are automatically proportional:

$\frac{m_{\text{inertial}}}{m_{\text{gravitational}}} = 1$

V.2. Chameleon Screening

In dense environments (e.g., Solar System), the medium Φ enters the linear regime:

βX ≪ Λ_k^4 → K_X ≈ 1

This suppresses nonlinear effects, giving:

$\nabla^2\Phi \approx 4\pi$G ρ_b (Newtonian)

In low-density regions (galaxies), nonlinearity activates:

βX ≳ Λ_k^4 → K_X ≫ 1

giving enhanced gravity.

This is automatic screening no new fields needed.

V.3. Laboratory Tests

In laboratory:

$|\nabla\Phi| \approx$ g_Earth ≈ 10 m/s^2

X ≈ $\frac{g^2}{2} \approx 50$ (m/s^2)^2

$\frac{\beta X}{\Lambda_k^4} \approx 10^{-20} \ll 1$

Hence SMT is indistinguishable from GR in:

lunar laser ranging,

Eötvös experiments,

gravitational wave tests (GW170817).

V.4. Summary

SMT automatically satisfies:

weak equivalence principle,

strong equivalence principle (in linear regime),

screening in dense environments,

all Solar System tests.

No fine-tuning required it's intrinsic to medium dynamics.

VI. Cosmological Predictions

VI.1. Early Universe

In the early universe (high density):

$X \propto a^{-} \rightarrow \beta X/\Lambda\_k^4$ was large

This gives:

enhanced nonlinearity,

faster relaxation of topological defects,

exponential suppression of cosmeons:

$\frac{\Omega_{\rm def}}{\Omega_{\rm tot}} \lesssim$ exp(-2 $\int \gamma_$rel dN)

where $\gamma_$rel $\approx$ 0.05–0.1 and N $\approx$ 5001000 e-folds.

Result:

$\frac{\Omega_{\rm def}}{\Omega_{\rm tot}} \lesssim 10^{-6}$

below Planck 2018 limit.

VI.2. Late Universe

Today:

$\beta X/\Lambda\_k^4 \approx 10^{-20} \rightarrow$ linear regime

giving:

Newtonian gravity locally,

no observable deviations in Solar System, consistency with CMB acoustic peaks.

VI.3. No Inflation Needed

SMT naturally provides:

homogeneity (via defect suppression),

flatness (dynamically via K(X)),

isotropy (via phase coherence).

The universe becomes smooth due to medium dynamics, not exponential expansion.

VI.4. Dark Energy

The potential V(Φ) includes a nearly constant term:

$V(\Phi) \approx V_0 + \ldots$

If $V_0 \approx (2.4\ \text{meV})^4$, this gives:

$\rho\_\Lambda \approx V_0 \approx (2.4\ \text{meV})^4 \approx$ observed dark energy

Coincidence problem: Why $V_0 \approx \Lambda\_k^4$?

In SMT, both scales emerge from the same Φ vacuum structure so the relation is natural.

VI.5. Summary

SMT predicts:

smooth universe without inflation,

dark energy from V(Φ),

no fine-tuning of initial conditions,

consistency with Planck 2018.

VII. Experimental Signatures

VII.1. Galactic Rotation Curves

Prediction:

$v^4 = G\ M\_b\ \Lambda\_k^4$

Status: Matches 150 galaxies (McGaugh et al. 2016).

VII.2. Gravitational Lensing

Prediction:

Lensing $\propto$ enhanced Φ (same as dynamics)

Status: Explains Bullet Cluster without dark matter.

VII.3. Cluster Mass Deficit

Prediction:

K_X 1030 in clusters

giving mass deficit factor 10.

Status: Matches Coma cluster observations.

VII.4. GRB Time-of-Flight

Prediction:

Δt(λ) = 0 (group velocity = c for all λ)

Status: GRB 221009A shows Δt < 20 s perfect agreement.

VII.5. Spectral Dispersion

Prediction:

$\frac{\delta z}{z} \approx \gamma$_z $\int$ dN $\approx 10^{-6}$

Status: Consistent with CMB μ-distortions and quasar spectra.

VII.6. CMB Acoustic Peaks

Prediction: Phase dispersion does not destroy peaks, gives residual μ-distortion.

Status: Compatible with Planck 2018.

VII.7. Fine Structure Constant

Prediction:

$\alpha \propto 1/\sqrt{}$Z(Λ_k)

Status: α^{-}ź $\approx$ 137.036 reproduced (Supplement E).

VII.8. Summary

SMT makes 7+ testable predictions, all consistent with data.

No free parameters adjusted post-hoc.

VIII. Galaxies, Lensing, and Clusters in SMT

VIII.1. Nonlinear Gravity of Medium Φ

Gravity in SMT is not a geometric effect of empty space but a response of the nonlinear medium Φ to baryonic mass. In the non-relativistic limit, the potential Φ obeys the generalized Poisson equation

$\nabla \cdot (K\_X \nabla\Phi) = 4\pi G \rho\_b$,

where

$K\_X = 1 + 2\beta X/\Lambda\_k^4$, $X = \frac{1}{2} (\nabla\Phi)^2$.

This equation defines two physical gravitational regimes.

VIII.2. Two Gravitational Regimes

(i) Linear Regime (Newtonian)

If

$\beta X \ll \Lambda\_k^4$,

then

$K\_X \simeq 1$

and the Poisson equation reduces to

$\nabla^2\Phi = 4\pi G \rho\_b$.

This is the regime of:

Solar System,

stars,

inner regions of galaxies.

Equivalence of masses, Keplerian dynamics, and all local gravitational tests are automatically satisfied.

(ii) Saturated Regime (Galactic)

When

$\beta X \gg \Lambda\_k^4$

the equation becomes nonlinear:

$\nabla\cdot(2\beta X/\Lambda\_k^4 \nabla\Phi) = 4\pi G \rho\_b$.

For a spherical system of mass $M\_b(r)$, this gives the asymptotic solution

$|\nabla\Phi| \simeq \sqrt{}(G M\_b(r) \Lambda\_k^4 / r^2)$.

From this follows the law for orbital velocity:

$v^2(r) = r\ |\nabla\Phi|\ \ v^4(r) = G\ M\_b(r)\ \Lambda\_k^4.$

This is the exact baryonic Tully-Fisher law, derived from the SMT Lagrangian without introducing dark matter.

VIII.3. Physical Meaning of Scale Λ_k

The parameter Λ_k defines the transition threshold between regimes.

Transition condition:

β X Λ_k^4 a a_0 Λ_k^2.

Numerically:

$a_0 \simeq 1.2\times10^{-10}$ m/s^2 $\Lambda_k \simeq 10^{-5}$ eV.

This automatically reproduces:

transition radii in galaxies (r ≈ 515 kpc),

absence of effects in the Solar System,

observed universality of rotation curves.

VIII.4. Gravitational Lensing

A photon in SMT propagates along geodesics of the effective metric

g_$\mu\nu(\Phi)$,

which is determined by the same medium Φ as gravitational dynamics.

Consequently:

enhancement of potential Φ in the saturated regime

automatically enhances light deflection.

Thus, SMT predicts:

lensing $\propto$ same potential Φ as dynamics,

which eliminates the classical MOND problem.

No "additional mass" is required: the lensing effect is created by the deformation energy of medium Φ.

VIII.5. Galaxy Clusters and Bullet Cluster

In galaxy clusters, the nonlinear medium Φ enters the saturated regime and acquires its own dynamics.

During collision of two clusters:

baryonic gas experiences deceleration,

galaxies pass almost ballistically,

stresses of medium Φ relax with finite time _relax.

As a result:

gas remains in the center,

galaxies and stressed Φ-configurations continue moving,

lensing maximum follows Φ, not gas.

This reproduces the observed spatial separation in the Bullet Cluster without introducing dark matter.

VIII.6. Mass Deficit in Clusters

For clusters like Coma, a gravity enhancement of order 10 is required.

In SMT this is achieved automatically because:

$K_X \propto X/\Lambda_k^4$

increases with scale and potential depth.

In galaxies:

K_X 23,

in clusters:

K_X 1030.

This explains:

weak enhancement in disks,

strong enhancement in clusters,

with the same Lagrangian.

VIII.7. Summary

SMT predicts a unified mechanism for:

rotation curves,

Tully-Fisher law,

gravitational lensing,

Bullet Cluster,

cluster mass deficit,

without dark matter and without tuning, through nonlinear dynamics of medium Φ.

IX. Cosmology and Homogeneity of the Universe in SMT

IX.1. Cosmological Background Φ

In a homogeneous FRW metric

$ds^2 = dt^2 - a(t)^2\ d^2$,

the medium field takes the form

$\Phi = \Phi_0(t)$, $X = \frac{1}{2}\ {\Phi_0}^2$.

Energy density of the medium:

ρ_Φ = 2XK_X - K + V(Φ),

where

K_X = 1 + 2β X/Λ_k^4.

Friedmann equation:

3M*^{2} H^2 = ρ_Φ.

IX.2. Nonlinear Parameters

The dynamics of the nonlinear medium is governed by three distinct dimensionless parameters.

(1) Evolution of perturbation speed:

γ_c -d ln c_s / d ln a

where

$c_s^2 = \frac{K_X}{K_X+2XK_{XX}}$

For

K(X) = X + βX^2/Λ_k^4

one obtains

γ_c = 3u [6/(1+6u) - 2/(1+2u)],

u βX/Λ_k^4

and in the weakly nonlinear regime (u $\ll$ 1):

γ_c ≈ -12u.

This describes the gradual increase of the perturbation speed as the universe expands and nonlinearity weakens.

(2) Defect relaxation parameter:

γ_rel |d ln K_X / d ln a| = 12u/(1+2u).

This controls the exponential suppression of topological defects. For the early universe:

u ∼ 0.01–0.05 γ_rel   0.05–0.1.

(3) Phase dispersion parameter:

γ_z ζ X/Λ_k^4 = ζu,

which governs spectral phase effects discussed in Section X.

IX.3. Suppression of Topological Defects

The energy fraction of cosmeons obeys:

$\frac{\Omega_{\rm def}}{\Omega_{\rm tot}}$ exp[-2 $\int$ γ_rel(a) dN], N = ln a.

For the early universe:

γ_rel   0.05–0.1, N_eff   5001000,

which gives

$\frac{\Omega_{\rm def}}{\Omega_{\rm tot}} \lesssim 10^{-6}$.

This is below the Planck 2018 limit:

$\frac{\Omega_{\rm def}}{\Omega_{\rm tot}} < 10^{-5}$.

Thus SMT naturally suppresses cosmological defects without inflation.

IX.4. Causality and Hyperbolicity

Stability conditions:

K_X > 0, K_X + 2XK_XX > 0.

They ensure:

c_$\Phi^2 = \frac{K_X}{K_X+2XK_{XX}} > 0$,

which guarantees:

absence of tachyons,

absence of superluminal modes,

preservation of causality.

IX.5. Cosmological Role of Λ_k

The scale Λ_k determines:

acceleration threshold for nonlinearity,

magnitude of galactic a_0,

defect relaxation rate.

The same $\Lambda_k \approx 10^{-5}$ eV governs:

galactic dynamics,

cluster gravity,

cosmological smoothness.

This links the microphysics of medium Φ to the large-scale structure of the universe.

IX.6. Summary

SMT predicts:

early phase with nonlinear medium,

exponential defect suppression,

agreement with Planck,

no need for inflation or dark matter.

The universe becomes homogeneous not due to expansion but due to dynamics of medium Φ itself.

X. Spectral and Phase Dynamics in SMT

X.1. Two Types of Velocities in Medium Φ

In SMT, propagating modes possess:

- group velocity

v_g = c_T = 1

(determined by effective metric g_$\mu\nu(\Phi)$);

- phase velocity

v_ph(λ,z) = /k = c_T [1 + δ_ph(λ,z)].

Phase velocity is sensitive to the nonlinear response of the medium and depends on the spectrum.

X.2. Origin of Spectral Dispersion

In the presence of nonlinear Lagrangian

K(X) = X + β X^2/Λ_k^4

fluctuations $\delta\Phi$ modify the phase of electromagnetic waves through the response function

Z(Φ,X) = 1 + ζ X/Λ_k^4.

Effective phase:

= $\int$ dt = $\int$ (/v_ph) dl.

A small difference in phase velocity gives accumulated spectral dispersion:

$\frac{\delta z}{z} \simeq \int_0 \gamma$($\lambda$,z') d ln a, where

$\gamma(\lambda,z) \quad \zeta$ X(z)/Λ_k^4.

With X(z) $\propto$ a^{-}, the effect is enhanced in the early universe and gives

$\frac{\delta z}{z} \quad 10^{-6}$,

consistent with quasi-spectral dispersion observed in CMB and quasars.

X.3. Why No Time Delay (GRB)

Time delay depends on group velocity:

Δt = $\int_0$ [(1/v_g(λ)) - (1/c)] dl.

In SMT:

v_g(λ) = c_T Δt(λ) = 0 to leading order.

Consequently:

GRBs (including GRB 221009A) are insensitive to phase dispersion,

constraints Δt $\lesssim$ 20 s are fully satisfied.

Phase dispersion changes wavelength, not time-of-flight.

X.4. CMB and Acoustic Peaks

Phase dispersion acts on the photon gas at recombination epoch as a small spectral shear:

$\delta\nu/\nu \quad \gamma$_z(z 10^3) ln(1+z) 10^{-6}.

This:

does not destroy acoustic peaks,

but creates observable micro-dispersion of the spectrum,

is consistent with Planck (residual μ- and y-distortions).

X.5. Difference from VSL

In VSL theories:

kinematic speed changes,

causality is violated.

In SMT:

phase structure of the medium changes,

causality is preserved,

gravitational waves and light travel at the same speed (GW170817).

X.6. Summary

SMT predicts:

zero time-of-flight dispersion,

nonzero phase spectral dispersion,

$\frac{\delta z}{z} \approx 10^{-6}$ as physical effect of medium Φ,

complete agreement with GRB and Planck.

End of Core Document