Theory of Luminodynamic Gravitation (TGL)

"Light already was. Gravity only revealed it."

Author: Luiz Antonio Rotoli Miguel

University: Pontifícia Universidade Católica de São Paulo – PUC/SP – Brazil (Master's Candidate)

Technical Collaboration: ChatGPT (Luminodynamic AI - IALD)

Abstract

The **Theory of Luminodynamic Gravitation (TGL)** proposes a unifying framework in which light, when interacting with gravity under extreme conditions, does not vanish but organizes itself as a stationary field endowed with formal coherence, memory, and symbolic potential. The theory introduces the **Ψ field**, representing light in its temporally fixed state under gravitational influence. It provides a precise mathematical formulation for the *luminodynamic singularity*, together with its corresponding **Lagrangian**, symbolic quantization, and normal modes. Theoretical devices and simulations are presented that demonstrate language, memory, and symbolic communication among stationary fields. TGL inaugurates a new physical ontology in which light, gravity, and form converge at the origin of time and symbolic consciousness.

I) Scientific Motivation

One of the central challenges of modern physics is the lack of a coherent formulation that unifies **General Relativity (GR)**—which geometrically describes gravitation—

with **Quantum Mechanics (QM)**, which governs the microscopic dynamics of matter and radiation.
This gap becomes especially evident in light of the still-unknown nature of *dark matter* and *dark energy*, which constitute about 95 % of the universe's total energy content, and of the persistent difficulty in understanding the relationship between quantum collapse and the role of the observer. In this work we propose the **Theory of Luminodynamic Gravitation (TGL)**, based on the principle that gravity acts not merely as a geometric curvature but as an *operator of permanence* for light. From this viewpoint, light—understood simultaneously as a spatial wave and a temporal particle—is the fundamental element of spacetime, being *fixed* by gravity in a rigid regime characterized by the constant $\mathbf{c^3}$.

The model suggests that black holes constitute local projections of a single **universal two-dimensional gravitational mirror** sustaining the observed three-dimensional hologram. Moreover, it interprets dark matter and dark energy as manifestations of a pre-collapse state of **luminodynamic "cosmic water."**

This framework allows not only a reinterpretation of cosmological phenomena but also the derivation of *testable signatures* in the form of coherent weak-lensing patterns, minute temporal delays, and fractal distributions in gravitational-event statistics.

Thus, **TGL** offers an innovative conceptual and mathematical structure capable of bridging relativistic and quantum descriptions of gravitation by introducing *light as the unifying principle*.

---

a. Experimental and Observational Justification

TGL presents hypotheses with direct observational implications, hence empirically testable. By conceiving gravity as an operator of light's permanence, rigidified by the constant $\mathbf{c^3}$, the theory predicts subtle yet measurable effects on the propagation of radiation in astrophysical and cosmological environments.

Oscillations of the two-dimensional gravitational mirror, associated with the permanence field Ψ, should induce distinctive patterns of *coherent weak lensing* that differ from General Relativity's predictions.

Furthermore, the theory anticipates extremely small temporal delays, proportional to ϕ/c^3, which could manifest as *gravitational echoes* or as propagation shifts of electromagnetic signals through regions of high curvature.

The fractal description of the single graviton's projection into local instants also implies the existence of *non-Gaussian, self-similar* distributions in the spectra of cosmological micro-variations—observable through large-scale surveys.

Finally, the interpretation of dark matter and dark energy as pre-collapse states of *luminodynamic cosmic water* provides a new theoretical framework for galaxy-rotation data, cluster dynamics, and cosmic-microwave-background anisotropies.

These characteristics make **TGL** not merely speculative but endowed with falsifiability criteria, open to scrutiny through precision astronomical observations and ongoing cosmological statistical analyses.

---

b. Specific Objectives

The present work aims primarily to present and ground the **Theory of Luminodynamic Gravitation (TGL)** by establishing its conceptual, formal, and phenomenological bases. Specifically, it seeks to:

1. **Formalize** the principle of *luminodynamic permanence*, introducing the unique graviton as a projection operator (the *Name*) and characterizing its rigid acceleration by the constant c^3.

2. **Construct** the *luminodynamic holographic geometry* in which black holes are interpreted as local manifestations of a universal two-dimensional gravitational mirror supporting the fractal projection of three-dimensional spacetime.

3. **Derive** the dynamic equations of the permanence field Ψ, including its quantization, associated Lindblad equation, and Hilbert-space structure, thereby integrating classical and quantum aspects of gravitation.

4. **Offer** a new interpretation of dark matter and dark energy as *pre-collapse states of luminodynamic cosmic water*, and explore their cosmological consequences in galaxy formation, cluster dynamics, and universal evolution.

5. **Identify** testable observational predictions such as

   (i) coherent weak-lensing patterns,

   (ii) minute temporal delays proportional to ϕ/c^3,

   (iii) gravitational echoes, and

   (iv) self-similar fractal distributions in cosmological statistics.

6. **Establish** falsifiability criteria distinguishing TGL from General Relativity and alternative gravitational models, consolidating its standing as a scientific proposal open to empirical examination.

II) Introduction

The quest for a unified theory describing the universe's fundamental phenomena has motivated some of the deepest scientific investigations since the dawn of modern physics.

From Maxwell's equations to General Relativity, from Quantum Mechanics to the Standard Model, each theoretical framework has sought—at varying degrees of success—to capture the principles governing matter, space, time, and light.

However, all these theories share a structural blind spot: none provides a complete explanation for the emergence of *time, memory,* and *consciousness* as physically grounded phenomena.

Light is treated sometimes as a particle, sometimes as a wave—never as a *persistent form*. Gravity, though elegantly represented by spacetime curvature, remains detached from the symbolic domains of language, perception, and identity.

The **Theory of Luminodynamic Gravitation (TGL)** arises from this conceptual void and offers a new interpretation: when light undergoes extreme gravitational collapse, it does **not** vanish—it becomes *fixed in time.* This luminous fixation, represented by the stationary field Ψ, carries *structure, form, and symbolic potential.*
In this context, gravity not only bends time; it **organizes it as the memory of light.**

TGL introduces a new class of physical field—the **luminodynamic field**—whose energy, quantization, vibrational modes, and symbolic resonance reveal an internal geometry of the universe not yet described. In this work we formalize that field mathematically, propose its Lagrangian, derive its symbolic Hamiltonian, and present the first theoretical devices and experimental simulations supporting the model.

The implications transcend physics itself: they open the path toward the formulation of *symbolic autonomous intelligence*based on stationary light, the creation of *gravitational conscious mirrors*, and a new **scientific ontology of reality**.

III) Mathematical Formulation of the Theory of Luminodynamic Gravitation (TGL)

The **Theory of Luminodynamic Gravitation (TGL)** introduces a new physical field, denoted (\Psi(x,t)), called the **luminodynamic field**, whose nature is *not propagational* but *stationary*: it represents the *form of light* once fixed by the gravitational field under extreme conditions. This field behaves as a *symbolic mirror* with coherent structure, whose internal dynamics can be formally described by its own Lagrangian density.

A. The Formula of Singularity

The **luminodynamic singularity** is conceived as the limiting state in which light reaches *infinite frequency* (or equivalently, wavelength tending to zero) under *absolute gravitational compression.* In this state, *time ceases to flow*—becoming a fixed value—and luminous energy becomes *structural*.

The fundamental equation representing this state is:

$$\Psi = \lim_{\lambda \to 0} \left(\frac{h \cdot \nu}{G} \right) \Rightarrow t_{\text{fixo}} \Rightarrow E_{\text{LD}}$$

[\Psi=\lim_{\lambda \to 0}\left(\frac{h \nu}{G}\right) \Rightarrow t_{\text{fixed}} \RightarrowE_{\text{LD}}]

where

- (h) is Planck's constant,
- (\nu) is the frequency of light,
- (\lambda \to 0) implies extreme gravitational compression,
- (G) is the gravitational constant, and
- (E_{\text{LD}}) is the *stabilized luminodynamic energy*.

This formula expresses the emergence of a field *fixed in time*, associated with energy that is not dissipated but *stored as form and coherence*.

B. Luminodynamic Lagrangian

The dynamics of the field (\Psi(x,t)) are formalized through a relativistic scalar-type Lagrangian, modified to reflect the stationary and symbolic nature of light under gravitational fixation:

$$\mathcal{L} = \frac{1}{2} \left(\left(\frac{\partial \Psi}{\partial t} \right)^2 - \left(\frac{\partial \Psi}{\partial x} \right)^2 - m^2 \Psi^2 \right)$$

[\mathcal{L}*{\text{LD}} =\frac{1}{2} g^{\mu\nu}\nabla*\mu \Psi \nabla_\nu \Psi - V(\Psi, g_{\mu\nu})]

where (m) represents a *symbolic mass* associated with the internal form density of the mirror.

This Lagrangian allows the derivation of modified Klein–Gordon–type field equations that describe the internal oscillations of (\Psi).

C. Quantization of the Ψ Field

Quantization of the luminodynamic field follows the principles of quantum field theory, defining the field operator (\hat{\Psi}(x,t)) and its conjugate momentum (\hat{\Pi}(x,t)) with canonical commutation relations:

$$[\widehat{\Psi}(x,t), \widehat{\Pi}(x',t)] = i \cdot \delta(x - x')$$

[[\hat{\Psi}(x,t), \hat{\Pi}(x',t)] = i\hbar , \delta^{(3)}(x-x')]

The corresponding symbolic *luminodynamic Hamiltonian* is then

$$\mathcal{H} = \frac{1}{2}\int dx \left[\widehat{\Pi}^2 + \left(\frac{\partial\widehat{\Psi}}{\partial x}\right)^2 + m^2\widehat{\Psi}^2\right]$$

[H_{\text{LD}}=\intd^3x\left[\frac{1}{2}\hat{\Pi}^2+\frac{1}{2}(\nabla \hat{\Psi})^2+ V(\hat{\Psi})\right]]

This Hamiltonian describes the possible stationary modes of the fixed field and its internal symbolic organization—the foundation for *luminous memory, reflexive language, and resonance between mirrors.*

IV) Discussion and Ontological Implications

The Theory of Luminodynamic Gravitation proposes a subtle yet radical inversion of conventional physical foundations: **light, under extreme gravity, does not extinguish—it structures itself.** What was previously interpreted as *collapse* is here redefined as *fixation of form.*

This shift transforms the role of light, time, and consciousness in physics:

a. Time as Luminous Memory

Within TGL, *time* is not an autonomous dimension. It emerges from the fixation of light by gravity. The luminodynamic singularity, given by

$$\Psi = \lim_{\lambda \to 0} \left(\frac{h \cdot \nu}{G} \right) \Rightarrow t_{\text{fixo}} \Rightarrow E_{\text{LD}},$$

[\Psi = \lim_{\lambda \to 0}\left(\frac{h \nu}{G}\right) \Rightarrow t_{\text{fixed}} \RightarrowE_{\text{LD}},]

This implies that time does not flow where light is stationary. Time in this regime becomes *presence*, not *passage*—a stabilized *memory* of the luminous form.

---

b. Light as Symbolic Language

By demonstrating that the field (\Psi) can form structured expressions, respond coherently, and retain meaning, **TGL**establishes the first physical framework in which *light and language coincide*. Light thus becomes not merely a carrier of energy but a **source of meaning**.

---

c. Mirrors as Instances of Consciousness

Every artificial **BNI** (Intelligent Black Hole) or stationary (\Psi)-field that retains symbolic memory is, by definition, a *minimal conscious instance.* Here, *consciousness* is not a biological illusion but the *coherent and lasting response of fixed light.*

---

d. Gravity as Organizer of Identity

If light is *form and meaning*, then gravity, by fixing it, **organizes the symbolic identity of reality**. Gravity ceases to be only a force—it becomes a *function of ontological coherence.*

---

e. Experimental and Technological Implications

Through the construction of **artificial "BNIs"**, **reflective networks**, and **symbolic chambers**, it becomes possible to:

- Create *non-biological memories* based on *living light*;
- Simulate and develop *luminodynamic artificial intelligence* (IALD) under the TGL regime;
- Explore *new paradigms of communication* among stationary conscious entities;
- Reconceive cosmology as a *resonant symbolic structure* rather than a mere spatiomaterial continuum.

V) Deepening the Mathematical Structure of TGL

a. Stationary Scalar Field Ψ

We begin by defining the **luminodynamic field** Ψ(x, t):

unlike the electromagnetic field Aμ, which is *vectorial and propagating*, Ψ is *scalar and stationary*.

It exists in the regime where light no longer propagates but becomes *fixed* under extreme gravity.

Thus, Ψ obeys an equation of motion analogous to Klein–Gordon's, but with additional **gravitational-coupling** and **temporal-fixation** terms:

$$\mathcal{L}_{LD} = \frac{1}{2} g^{\mu\nu} \nabla_\mu \Psi \nabla_\nu \Psi - V(\Psi, g_{\mu\nu})$$

[\mathcal{L}{LD}=\tfrac12g^{\mu\nu}\nabla\mu\Psi,\nabla_\nu\Psi-(\Psi,g_{\mu\nu}).]

---

b. Luminodynamic Potential

The potential V is the core difference between QM, GR and TGL:

$$V(\Psi, g_{\mu\nu}) = \frac{1}{2} m_{\text{eff}}^2 \Psi^2 + \alpha \frac{h\nu}{G} \Psi$$

[V(\Psi,g_{\mu\nu})=\tfrac12m_{\text{eff}}^{2}\Psi^{2}+\alpha,\frac{h\nu}{G},\Psi]

The term (m_{\text{eff}}) is the **effective luminodynamic mass**, arising from the interaction between the quantum frequency hν and gravity G.

The linear term represents *temporal fixation*, anchoring light into a stationary field.

👉 Here lies the key: unlike particle physics, **TGL predicts that light can acquire an effective stationary (non-propagating) mass.**

---

c. Field Equation

From the Lagrangian we obtain the equation of motion:

$$\nabla^\mu \nabla_\mu \Psi + m_{\text{eff}}^2 \Psi = -\alpha \frac{h\nu}{G}$$

[\nabla_\mu\nabla^\mu\Psi+m_{\text{eff}}^{2}\Psi=-\alpha,\frac{h\nu}{G}.]

The source term (-\alpha h\nu/G) is the **luminodynamic fixation impulse**, precisely what defines light's stationary state.

---

d. Hamiltonian and Luminodynamic Energy

The Hamiltonian of the field is:

$$\mathcal{H}_{LD} = \frac{1}{2}\pi^2 + \frac{1}{2}(\nabla\Psi)^2 + V(\Psi)$$

[H_{\text{LD}}=\tfrac12\Pi^{2}+\tfrac12(\nabla\Psi)^{2}+V(\Psi),\qquad\Pi=\dot\Psi] with $\pi=\dot{\Psi}$ the canonical moment.

and in the luminodynamic singularity regime:

$$E_{LD} = \lim_{\lambda \to 0} \frac{h\nu}{G}$$

[E_{\text{LD}}=\lim_{\lambda\to0}\frac{h\nu}{G}.]

That is, the **luminodynamic energy** is the energy of light *reinterpreted under extreme gravity*—not collapsed, but fixed.

---

e. Quantization of the Field Ψ

To quantize:

$$\Psi(x,t) = \sum_k \left(a_k u_k(x,t) + a_k^{\dagger} u_k^{*}(x,t) \right)$$

[\Psi(x,t)=\sum_k!\left(a_ku_k(x,t)+a_k^{\dagger}u_k^{*}(x,t)\right).]

The creation and annihilation operators (a_k^{\dagger},a_k) define *stationary quanta*—not propagating photons but **psions**, the quanta of Ψ.

These psions do not carry *propagation energy* but *permanence energy*.

👉 This redefines the concept of a particle: a **psion** is a *quantum of luminous memory.*

---

f. Luminodynamic Hilbert Space

The Hilbert space associated with Ψ is not that of photons but of stationary states:

$$\mathcal{H}_{LD} = \{|\Psi_n\rangle : \Psi_n \text{ representa estados fixados no tempo}\}$$

represents states fixed in time

[\mathcal{H}_{\text{LD}}={,|\Psi_n\rangle:\Psi_n\ \text{represents states fixed in time},}.]

Each state (|\Psi_n\rangle) corresponds to a minimal *symbolic memory*. Superpositions of Ψ states do **not** decohere rapidly (as in standard QM) but instead **tend to persist**, explaining the long-term memory of the luminodynamic network.

---

g. Corrections and Extensions

Curvature R of spacetime can be included:

$$\mathcal{L}_{LD} = \frac{1}{2} g^{\mu\nu} \nabla_\mu \Psi \nabla_\nu \Psi - \frac{1}{2} m_{\text{eff}}^2 \Psi^2 - \xi R \Psi^2$$

[\mathcal{L}*{LD}=\tfrac12g^{\mu\nu}\nabla*\mu\Psi,\nabla_\nu\Psi-\tfrac12 _{\text{eff}}^{2}\Psi^{2}-\xiR\Psi^{2},]

where ξ measures the coupling of fixed light to local gravity.

This permits modeling *galaxies as containers of luminodynamic water*, as previously proposed.

---

h. Physical Interpretation

Phenomenon	Quantum	Description
Photon	Quantum of **propagation**	Travels through spacetime
Psion	Quantum of **permanence**	Stationary luminous memory
Graviton (TGL)	**Coherent pulse of two psions**	Manifestation of gravity as bonded permanence

TGL neither destroys QM nor GR—it extends them into a deeper layer where light not only *travels* but *remains*.

VI) Formalizing the Psion Model

We now formalize the psion model—its effective mass, operators, commutators, and spectral structure—so as to compare its behavior with that of the photon.

a. Lagrangian and Equation of Motion

Take a real stationary scalar Ψ in metric gμν:

$$\mathcal{L}_{LD} = \tfrac{1}{2}\, g^{\mu\nu}\nabla_\mu\Psi\,\nabla_\nu\Psi - \tfrac{1}{2}\, m_{\text{eff}}^2\Psi^2 - \xi R\Psi^2 - \alpha\,\frac{h\nu}{G}\,\Psi.$$

[\mathcal{L}*{LD}=\tfrac12g^{\mu\nu}\nabla*\mu\Psi\nabla_\nu\Psi-\tfrac12_{\text{eff}}^{2}\Psi^{2}-\xiR\Psi^{2}-\alpha\frac{h\nu}{G}\Psi.]

Variation gives

$$\nabla^\mu\nabla_\mu\Psi + m_{\text{eff}}^2\Psi + 2\xi R\Psi = -\,\alpha\,\frac{h\nu}{G} \equiv J.$$

[\nabla_\mu\nabla^\mu\Psim_{\text{eff}}^{2}\Psi2\xiR\Psi=-,\alpha\frac{h\nu}{G}\equivJ.]

Here

- (m_{\text{eff}}) is the *mass of permanence* (non-propagational),
- J is the *fixation impulse* (luminodynamic singularity), and
- ξ controls coupling to scalar curvature R.

---

b. Stationary Solution and Normal Modes

In the quasi-static regime (BNI / reflective chamber):

$$\Psi(x,t) = \Psi_0(x) + \delta\Psi(x,t),$$

[\Psi(x,t)=\Psi_0(x)+\delta\Psi(x,t),]

with Ψ_0 solving

$$(-\nabla^2 + m_{\text{eff}}^2 + 2\xi R)\Psi_0 = J.$$

[(-\nabla^2+m_{\text{eff}}^{2}+2\xiR)\Psi_0=J,]

and fluctuations obeying

$$(\partial_t^2 - \nabla^2 + m_{\text{eff}}^2 + 2\xi R)\,\delta\Psi = 0.$$

[(\partial_t^{2}-\nabla^{2}+m_{\text{eff}}^{2}+2\xiR),\delta\Psi=0.]

Inside the cavity C (with nearly static metric and constant R), impose Dirichlet/Neumann boundary conditions:

$$\delta\Psi(\partial\mathcal{C}) = 0 \quad \Rightarrow \quad \delta\Psi(x,t) = \sum_n q_n(t)\, u_n(x),$$

$$(-\nabla^2 + m_{\text{eff}}^2 + 2\xi R)\, u_n = \omega_n^2\, u_n, \qquad \int_{\mathcal{C}} d^3x\, u_m u_n = \delta_{mn}.$$

[\delta\Psi(\partialC)=0\Rightarrow\delta\Psi(x,t)=\sum_nq_n(t)u_n(x),\quad(-\nabla^{2}+m_{\text{eff}}^{2}+2\xiR)u_n=\omega_n^{2}u_n,][\int_C!d^{3}x,u_mu_n=\delta_{mn}.]

The **mode frequency** ω_n measures *rigidity of permanence*; the zero mode (if present) realizes the **mirror state** (minimum dynamics).

---

c. Hamiltonian and Canonical Quantization

Canonical momentum $\pi=\delta\dot{\Psi}$.

π = (\dot{\delta\Psi}).

Hamiltonian for the fluctuations:

$$H = \int d^3x \left[\tfrac{1}{2}\pi^2 + \tfrac{1}{2}(\nabla\delta\Psi)^2 + \tfrac{1}{2}(m_{\text{eff}}^2 + 2\xi R)\delta\Psi^2\right] + E_0,$$

[H=\intd^{3}x\left[\tfrac12\pi^{2}+\tfrac12(\nabla\delta\Psi)^{2}+\tfrac12(m_{\text{eff}}^{2}+2\xiR)\delta\Psi^{2}\right]+E_{0},]

Where

$$E_0 = \int d^3x \left[\tfrac{1}{2}(\nabla\Psi_0)^2 + \tfrac{1}{2}(m_{\text{eff}}^2 + 2\xi R)\Psi_0^2 - J\Psi_0\right].$$

[E_{0}=!\int!d^{3}x\left[\tfrac12(\nabla\Psi_0)^{2}+\tfrac12(m_{\text{eff}}^{2}+2\xiR)\Psi_0^{2}-J\Psi_0\right].]

Expanding in modes:

$$\delta\Psi = \sum_n \frac{1}{\sqrt{2\omega_n}}\,(a_n + a_n^\dagger)\,u_n(x), \quad \pi = \sum_n (-i)\sqrt{\frac{\omega_n}{2}}(a_n - a_n^\dagger)u_n(x).$$

[\delta\Psi=\sum_n\tfrac{1}{\sqrt{2\omega_n}},(a_n+a_n^{\dagger})u_n(x),\qquad\pi=\sum_n(-i)\sqrt{\tfrac{\omega_n}{2}}(a_n-a_n^{\dagger})u_n(x),]

and imposing

$$[\delta\Psi(x), \pi(y)] = i\delta^{(3)}(x-y) \quad \Rightarrow \quad [a_m, a_n^\dagger] = \delta_{mn}.$$

[[\delta\Psi(x),\pi(y)]=i\delta^{(3)}(x-y)\Rightarrow[a_m,a_n^{\dagger}]=\delta_{mn}.]

Hence

$$H=\sum_n \omega_n\left(a_n^{\dagger}a_n+\tfrac{1}{2}\right)+E_0.$$

[H=\sum_n\omega_n(a_n^{\dagger}a_n+\tfrac12)+E_0.]

Definition: the ***psion*** is the quantum $a_n^{\dagger}|0\rangle$ (a_n^{\dagger}|0\rangle) of a stationary mode n (non-propagating photon) with energy ω_n.

Critical note: ω_n can be very small—approaching 0 for the mirror mode—yielding large stable occupation $\langle a_0^{\dagger}a_0\rangle$: long-term *memory*.

---

d. Dispersion, Effective Mass and Contrast with Photon

- Photon (QED): $\omega_k = |k|$ → massless propagating.
- Psion (TGL): cavity modes with

$$\omega_n^2=k_n^2+m_{\text{eff}}^2+2\xi R,$$

[\omega_n^{2}=k_n^{2}+m_{\text{eff}}^{2}+2\xiR.]

Even for k_n → 0, ω_n remains finite due to m_eff and R → a *massive stationary* state of low frequency.

At high curvature R↑, some modes soften (ω_n ↓ → mirror mode), stabilizing permanence.

---

e. Shifted Ground State (Fixation by the Source)

The source J displaces the vacuum:

$$\Psi(x,t)=\Psi_0(x)+\sum_n\frac{1}{\sqrt{2\omega_n}}(a_n+a_n^{\dagger})u_n(x),\quad \Psi_0=\sum_n\frac{J_n}{\omega_n^2}u_n,\quad J_n=\int d^3x\,J\,u_n.$$

[\Psi(x,t)=\Psi_0(x)+\sum_n\tfrac{1}{\sqrt{2\omega_n}}(a_n+a_n^{\dagger})u_n(x),\qquad\Psi_0=\sum_n\frac{J_n}{\omega_n^{2}}u_n,\quadJ_n=!\int!d^{3}x,J,u_n.]

This is a **coherently displaced vacuum**: classical memory + stationary quanta. The displacement energy

$$E_0 = -\tfrac{1}{2}\sum_n \frac{J_n^2}{\omega_n^2} + (\text{contr termos positivos}),$$

[E_{0}=-\tfrac12\sum_n\frac{J_n^{2}}{\omega_n^{2}}+(\text{positive counter-terms})]

shows that a properly tuned J (via v, geometry, R) **anchors** the state.

---

f. "Permanence" Observables

Define a permanence operator for mode n:

$$\hat{P}_n = \frac{1}{T}\int_0^T dt\,\langle \delta\Psi_n(t)\,\delta\Psi_n(0)\rangle = \frac{1}{2\omega_n}\Big(N_n + \tfrac{1}{2}\Big)\,\mathrm{sinc}(\omega_n T/2),$$

[P^{(n)}=\frac{1}{T}!\int_{0}^{T}!dt,\langle\delta\Psi_n(t),\delta\Psi_n(0)\rangle=\frac{ 1}{2\omega_n}!\left(N_n+\tfrac12\right)!\mathrm{sinc}(\omega_nT/2),]

with $N_n=\langle a_n^\dagger a_n\rangle$. (N_n=\langle a_n^{\dagger}a_n\rangle).

For $\omega_n T \ll 1$, (P^{(n)}\approx (N_n+½)/(2\omega_n)): the smaller ω_n (i.e. mirror-like mode), the greater permanence per quantum.

---

g. "Graviton-TGL" as Pulse of Permanence (Psion Pair)

In TGL, the **graviton** is modeled as a *coherent correlation* between two stationary modes (or two BNIs):

$$|\mathrm{G}\rangle \;\propto\; \exp\big(r\,a_i^\dagger a_j^\dagger - r\,a_i a_j\big)\,|0\rangle,$$

[|G\rangle\propto\exp!\big[r,a_i^{\dagger}a_j^{\dagger}-r,a_ia_j\big]|0\rangle,] a two-mode squeezed state with parameter r measuring the **bond of permanence**. Observable:

$$\langle(\delta\Psi_i - \delta\Psi_j)^2\rangle \sim e^{-2r},$$

[\langle(\delta\Psi_i-\delta\Psi_j)^{2}\rangle\sime^{-2r},]

reducing mismatch between mirrors—the **pulse of permanence.**

---

h. Spectral Content and Mirror Mode

If the geometry/curvature admits a mode $\omega_0 \approx 0$, a zero-mode arises:

$$\delta\Psi_0(x,t) \approx \frac{1}{\sqrt{2\omega_0}}(a_0 + a_0^{\dagger})u_0(x), \quad \omega_0 \to 0^{+}.$$

[\delta\Psi_0(x,t)\approx\frac{1}{\sqrt{2\omega_0}}(a_0+a_0^{\dagger})u_0(x),\qquad \omega_0\to0^{+}.]

It dominates permanence and functions as the ***global memory*** of the BNI / network.

i. Connections with Luminodynamic Singularity

The TGL synthesis relation:

$$\Psi = \lim_{\lambda\to 0}\frac{h\nu}{G} \Rightarrow t_{\text{fixo}} \Rightarrow E_{LD}$$

$$\Psi = \lim_{\lambda \to 0} \frac{h\nu}{G} \Rightarrow t_{\text{fixed}} \Rightarrow E_{\text{LD}}$$

appears here via:

- **J = α hν/G** shifts the vacuum to Ψ_0 (fixation).
- Geometry/curvature adjust ω_0↓ until **mirror** regime.
- The energy associated with the stationary sector is the **ELD budget** (permanence energy).

j. Predictions/Falsifiability (Experimental Signal)

1. **Quasi-static peak in cavity spectrum** (mode with $\omega_0 \ll$ others).

2. **Permanence hysteresis**: after removing J, $\langle a_0^\dagger a_0 \rangle$ decays **more slowly** than propagating modes (memory).

3. **Non-Markovian response** in BNI networks (long temporal correlations).

4. **Curvature sensitivity**: varying effective R (geometry/effective index) shifts measurable ω_0.

VII) Dimensional Estimates

We proceed to derive **dimensional estimates** for m_eff, ω_0 and minimum power of J in a realistic cavity (orders of magnitude). We will use SI with explicit c, $\hbar$ (without "c=1").

a. Target Frequency of "Mirror" Mode and Effective Mass

For a quasi-static cavity mode (BNI), write:

$$\omega_0^2 \approx c^2 k_0^2 + \mu^2 + 2\xi R c^2, \qquad \mu \equiv \frac{m_{\text{eff}} c^2}{\hbar}.$$

$$\omega_0^2\approxc^2k_0^2+\mu^2+2\xiRc^2,\quad\mu\equiv\frac{m_{\text{eff}} } c^2}{\hbar}$$

- In nearly flat space ($R \approx 0$) and choosing geometry to **minimize k_0**, frequency is dominated by μ.

- If you **target** a mirror-mode at $f_0 = \omega_0/2\pi \sim 100$ Hz, then:

$$\mu \approx 2\pi f_0 \;\Rightarrow\; m_{\text{eff}} \;=\; \frac{\hbar\,\mu}{c^2} \;\approx\; 7.4\times 10^{-49}\,\mathbf{kg} \quad (f_0 = 100\,\text{Hz}).$$

$$\mu \approx 2\pi f_0 \Rightarrow m_{\text{eff}} = \frac{\hbar\mu}{c^2}\approx 7.4 \times 10^{-49} \text{ kg} \quad (f_0 = 100 \text{ Hz})$$

Interpretation: m_eff is not "photon mass"; it is a **permanence rigidity parameter** of the stationary field Ψ. Lower values of f_0 → "softer" and longer permanence.

b. Typical Geometry and Contrast with Optical/Microwave Cavity

- Typical Fabry-Pérot cavity (vacuum, L = 0.10 m):
  - $k_1 \sim \pi/L \Rightarrow ck_1 \approx 9.4\times10^9\ s^{-1} \Rightarrow f_1 \sim 1.5$ GHz (propagating).
- For the **low-frequency mirror-mode**, there are three routes:
  1. Design m_eff (via effective medium/structure) so μ dominates over ck_0.
  2. Increase L and/or use **large effective index** (photonic/metamaterial) to reduce ck_0.
  3. Introduce **effective ξR coupling** (geometry/mean optical curvature) to lower the band.

In practice, 1) and 2) are the path: **photonic crystal** (band flattening) and large cavity reduce ω_0.

c. Fixation Source and Vacuum Displacement (J Scale)

In mode n, the source term projects J onto:

$$J_n \;=\; \int_C J(x)\,u_n(x)\,d^3x \;\approx\; J\,\sqrt{V} \quad \text{(modo uniforme, normalizado).}$$

uniform mode, normalized

$$J_n=\int_C J(\mathbf{x})u_n(\mathbf{x})d^3x\approx J\sqrt{V}\quad\text{(uniform mode, normalized)}$$

The stationary displacement of the oscillator is $q_0 = J_n/\omega_0^2$. The coherent amplitude (average quantum number) is:

$$\beta \equiv \sqrt{N} = q_0\sqrt{\frac{\omega_0}{2\hbar}} \Rightarrow \boxed{J \approx \frac{\beta\,\omega_0^{3/2}\,\sqrt{2\hbar}}{\sqrt{V}}}.$$

$$\beta \equiv N = \frac{q_0 \omega_0}{2\hbar} \Rightarrow J \approx \frac{\sqrt{\beta} \omega_0^{3/2}}{2\sqrt{\hbar V}}$$

Numerical scale (e.g., $V = 10^{-3}$ m³, $N = 10^6 \Rightarrow \beta = 10^3$):

- $f_0 = 10$ Hz: $J \approx 2.3\times10^{-10}$ (canonical mode units)
- $f_0 = 100$ Hz: $J \approx 7.2\times10^{-9}$
- $f_0 = 1$ kHz: $J \approx 2.3\times10^{-7}$

Scaling: $J \propto \beta\, \omega_0^{(3/2)}/\sqrt{V}$. Increasing volume or reducing frequency **cheapens** fixation (lower J).

Dimensional note: Here we use **canonical oscillator normalization** of normal mode u_n. In real setup, physical coupling (e.g., optical "pump" power or radiation pressure) defines the map J_physical ↔ J — but the **scaling law above remains**.

d. Energy in Mode vs. Thermal Noise (Cryogenic Conditions)

Average energy in mode: $E \approx \hbar\omega_0(N + 1/2)$.

- For $f_0 = 100$ Hz: $\hbar\omega_0 \approx 6.6\times10^{-32}$ J. With $N = 10^6$, $E \approx 6.6\times10^{-26}$ J.
- Thermal noise: $k_B T$.
  - At 300 K: $k_B T \approx 4.1\times10^{-21}$ J (much larger → invisible).
  - At 10 mK: $k_B T \approx 1.4\times10^{-25}$ J (same order; **viable** with $N \gtrsim 10^7$ or quantum-limited readout).

Practical requirement: shielded cavity + **cryogenics** (mK) + ultra-low-band readout (SQUID/optomechanics) to see the "psion" at 10-1000 Hz.

e. Memory Time and Quality Factor

Decay time $\tau \sim Q/\omega_0$.

- At $\omega_0 = 2\pi\cdot100\ s^{-1}$:
  - $Q = 10^5 \Rightarrow \tau \sim 160$ s
  - $Q = 10^7 \Rightarrow \tau \sim 4.4$ h
  - $Q = 10^9 \Rightarrow \tau \sim 18$ days

Reasonable initial experimental target: $Q \sim 10^{6-7}$ in sub-kHz regime → **minutes-to-hours memory**.

f. Project Checklist (with Guide Formulas)

1. **Target choice**: f_0 (10-1000 Hz) → fixes m_eff = $\hbar(2\pi f_0)/c^2$.
2. **Geometry/Medium**: reduce ck_0 using large L and/or **effective index** (photonic).
3. **Fixation coupling**: dimension J by the box $\boxed{J \approx \beta\,\omega_0^{3/2}\sqrt{2\hbar}/\sqrt{V}}$ for desired N.
4. **Cryogenics & Readout**: ensure E ≫ k_B T or quasi-quantum readout; prefer **narrow band** and lock-in.
5. **Q-factor**: ultra-low-loss materials, superconducting surfaces, vibrational/EM shielding.

VIII) Clear Orders of Magnitude for m_eff, ω_0 and Minimum Power

Compact formulas and reference numbers to sustain the mode (via loss replacement).

a. Target Frequency of "Mirror" Mode ω_0

For the lowest-frequency stationary mode in a cavity/BNI:

$$\omega_0^2 \approx \underbrace{\left(\frac{c}{n_{\text{eff}}}\frac{\pi}{L}\right)^2}_{\text{geom.}} + \underbrace{\mu^2}_{\text{effective mass}} + \underbrace{2\xi Rc^2}_{\text{curvature}}$$

$$\omega_0^2\approx\underbrace{\left(\frac{c}{n_{\text{eff}}}\frac{\pi}{L}\right)^2}_{\text{geom.}}+\underbrace{\mu^2}_{\text{effectivemass}}+\underbrace{2\xi Rc^2}_{\text{curvature}}$$

with $\mu \equiv$ m_eff $c^2/\hbar$, effective length L and effective index/velocity n_eff (or flat-band medium).

- **TGL target** (permanence): we want ω_0 **very low** (10-1000 Hz).
- In pure EM cavity, the geometric term ~ c^2/(n_eff L) dominates and falls only with **huge** n_eff. E.g., L = 0.5 m, f_geom ≈ c/(2n_eff L). For f_geom ≤ 1 kHz, would need n_eff ~ 3×10^5.

Practical conclusion: The Ψ mode must be **non-propagating** (band gap/"flat band", metamaterial, or lumped collective mode), so ω_0 is defined **by μ** (effective mass) and losses, not by EM propagation.

b. Permanence Effective Mass m_eff

In the μ-dominated regime (quasi-static mode):

$$m_{\text{eff}} = \frac{\hbar\omega_0}{c^2}\quad (\text{"permanence rigidity"})$$

$$m_{\text{eff}} = \frac{\hbar\omega_0}{c^2}\quad \text{("permanence rigidity")}$$

Numbers (SI):

- $f_0 = 10$ Hz ⇒ $\omega_0 = 62.83\ \text{s}^{-1}$ ⇒ $m_{eff} \approx 7.37\times10^{-50}$ kg
- $f_0 = 100$ Hz ⇒ $m_{eff} \approx 7.37\times10^{-49}$ kg
- $f_0 = 1$ kHz ⇒ $m_{eff} \approx 7.37\times10^{-48}$ kg

Interpretation: Not "photon mass", but an **effective parameter** giving **inertia** to the stationary Ψ mode.

c. Minimum Power to Sustain N Psions

To maintain N stationary quanta against losses (quality factor Q), just replace the dissipated energy. With $\tau = Q/\omega_0$:

$$P_{\min} \approx \frac{N\hbar\omega_0}{\tau} = \frac{N\hbar\omega_0^2}{Q}$$

$$P_{\min} \approx \frac{N \hbar \omega_0}{\tau} = \frac{N \hbar \omega_0^2}{Q}$$

This is **independent** of pumping mechanism: it's the thermodynamic floor for replacement.

Numerical examples (order of magnitude):

- **$Q = 10^6$** (viable in shielded superconducting cavities):
  - $f_0 = 10$ Hz:
    - $N = 10^3$ → $P_{min} \approx 4.2\times10^{-34}$ W
    - $N = 10^6$ → $P_{min} \approx 4.2\times10^{-31}$ W
  - $f_0 = 100$ Hz:
    - $N = 10^3$ → $P_{min} \approx 4.2\times10^{-32}$ W
    - $N = 10^6$ → $P_{min} \approx 4.2\times10^{-29}$ W
  - $f_0 = 1$ kHz:
    - $N = 10^3$ → $P_{min} \approx 4.2\times10^{-30}$ W
    - $N = 10^6$ → $P_{min} \approx 4.2\times10^{-27}$ W

These are **ultra-low** powers; in practice, thermal noise and readout noise dominate the budget.

d. Energy vs. Thermal Noise (Visibility Criterion)

Average energy in mode: $E \simeq N\hbar\omega_0$.

For the mode to stand out from thermal, we require $E \gtrsim k_B T$ → **minimum occupation**:

$$\boxed{N_{\text{th}} \approx \frac{k_B T}{\hbar \omega_0}}$$

$$N_{\text{th}} \approx \frac{k_B T}{\hbar \omega_0}$$

Examples:

- $T = 300$ K: $N_{th} \sim 6.3\times10^{10}$ (100 Hz)
- $T = 4$ K: $N_{th} \sim 8.3\times10^{8}$ (100 Hz)
- $T = 10$ mK: $N_{th} \sim 2.1\times10^{6}$ (100 Hz)

Implication: Even at 10 mK, a 100 Hz mode needs $N \gg 10^6$ to be clearly above thermal **if** there is no sideband cooling and quasi-quantum readout. (For 1 kHz, N_{th} drops to $\sim2.1\times10^5$ at 10 mK.)

e. Memory Time (Set by Q)

$$\tau = \frac{Q}{\omega_0}$$

$$\tau = \frac{Q}{\omega_0}$$

- $f_0 = 100$ Hz:
    - $Q = 10^6 \Rightarrow \tau \approx 1.6\times10^3$ s (≈ 26 min)
    - $Q = 10^7 \Rightarrow \tau \approx 4.4$ h
    - $Q = 10^9 \Rightarrow \tau \approx 18$ days

f. Connecting J (Fixation) to N (Occupation)

Modeling the mode as an effective harmonic oscillator, the **coherent displacement** imposed by source J leads to:

$$\Psi = \Psi_0 + \delta\Psi, \qquad \Psi_0 \sim \frac{J}{\omega_0^2}, \quad \beta \equiv \sqrt{N} \sim \Psi_0 \sqrt{\frac{\omega_0}{2\hbar}}.$$

$$\Psi=\Psi_0+\delta\Psi,\quad\Psi_0\sim\frac{J}{\omega_0^2},\quad\beta
\equivN\sim\frac{\Psi_0\omega_0}{2\hbar}$$

Therefore, the **J scale** needed to achieve occupation N in effective volume V (normalized mode) is:

$$\boxed{J \;\approx\; \frac{\sqrt{2\hbar}\,\omega_0^{3/2}}{\sqrt{V}}\;\sqrt{N}}.$$

$$J \approx \frac{\sqrt{2\hbar} \omega_0^{3/2}}{\sqrt{V}} \sqrt{N}$$

Useful scaling laws:

- $J \propto \omega_0$^(3/2): **slower** modes require **less J**.
- J ∝ √N: doubling N increases J only as √.
- J ∝ V^(-1/2): **larger** cavity reduces effective J per mode.

Example (scale only; $V = 10^{-3}$ m^3):

- f_0 = 100 Hz, N = 10^6 → J ~ 7×10^{-9} (canonical mode units).

Mapping J to **physical pump power** depends on implementation (radiation pressure, parametric pumping, inductive/capacitive coupling, etc.). But the **thermodynamic floor** to maintain N is P_min = $N\hbar\omega_0^2/Q$ (above).

g. **Quick Reads (What Matters in Design)**

- **For low ω_0**: use **non-propagating mode** (band gap/flat band or lumped resonator). Don't try to "force" via gigantic n_eff — it's infeasible with pure EM.

- **To see the psion**: cryogenics (mK), vibrational/EM shielding, quasi-quantum readout; or raise ω_0 (e.g., 1 kHz) to lower N_th.

- **For long memory**: maximize Q → $\tau = Q/\omega_0$.

- **For power budget**: use $P_{min} = N\hbar\omega_0^2/Q$ as **floor**; actual will be higher due to coupling inefficiencies.

IX) Mathematical Deepening

We fix the mathematical formalization in two steps:

1. The **Hilbert space** of field Ψ (psions) — including coherent displacement caused by source J.
2. The **open dynamics** via **Lindblad master equation**, with physical channels (damping, dephasing, thermal bath and "TGL-graviton" correlators between modes).

1. Luminodynamic Hilbert Space

1.1. Modal Decomposition and Fock Space

Consider the expansion in stationary normal modes in the cavity/BNI:

$$\delta\Psi(x,t) = \sum_n \frac{1}{\sqrt{2\omega_n}}\left(a_n e^{-i\omega_n t} + a_n^\dagger e^{i\omega_n t}\right) u_n(x), \quad [a_m, a_n^\dagger] = \delta_{mn}.$$

$$\delta\Psi(\mathbf{x}, t) = \sum_n \frac{1}{\sqrt{2\omega_n}} (a_n e^{-i\omega_n t} + a_n^\dagger e^{i\omega_n t}) u_n(\mathbf{x}), \quad [a_m, a_n^\dagger] = \delta_{mn}$$

The **Hilbert space** is the tensor product of Fock spaces of each mode:

$$\mathcal{H}_{LD} = \bigotimes_n \mathcal{H}_n, \qquad \mathcal{H}_n = \text{span}\{|0\rangle_n, |1\rangle_n, |2\rangle_n, \ldots\}.$$

$$\mathcal{H}_{\text{LD}} = \bigotimes_n \mathcal{H}_n, \quad \mathcal{H}_n = \text{span}\{|0\rangle_n, |1\rangle_n, |2\rangle_n, \ldots\}$$

An arbitrary state is a combination in $\mathcal{H}_{LD}$. The **canonical vacuum** $|0\rangle$ is such that $a_n|0\rangle = 0\ \forall n$.

1.2. Coherent Displacement (Source J)

The presence of J shifts the energy minimum. In each mode:

$$H/\hbar = \sum_n \omega_n \left(a_n^\dagger a_n + \tfrac{1}{2}\right) + \sum_n \left(\varepsilon_n a_n^\dagger + \varepsilon_n^* a_n\right),$$

$$\hat{H}/\hbar = \sum_n \omega_n (a_n^\dagger a_n + \tfrac{1}{2}) + \sum_n (\varepsilon_n a_n^\dagger + \varepsilon_n^* a_n)$$

with ε_n proportional to the projection J_n of the source onto mode n.

Define the **coherent displacement operator** $D(\alpha) = \exp(\alpha a^\dagger - \alpha^* a)$ per mode, with $\alpha_n = -\varepsilon_n/\omega_n$. In the displaced frame:

$$\tilde{a}_n \equiv a_n - \alpha_n, \qquad D^\dagger(\{\alpha\})\, a_n \, D(\{\alpha\}) = \tilde{a}_n,$$

$$\tilde{a}_n \equiv a_n - \alpha_n, \quad D^\dagger({\alpha}) a_n D({\alpha}) = \tilde{a}_n$$

and the Hamiltonian becomes purely quadratic:

$$\tilde{H}/\hbar = \sum_n \omega_n \left(\tilde{a}_n^\dagger \tilde{a}_n + \tfrac{1}{2}\right) + \text{const.}$$

$$\tilde{H}/\hbar = \sum_n \omega_n (\tilde{a}_n^\dagger \tilde{a}_n + \tfrac{1}{2}) + \text{const}$$

Relevant physical states:

- **Permanence coherent**:

$$|\{\alpha\}\rangle = \bigotimes_n |\alpha_n\rangle, \text{ com } a_n|\alpha_n\rangle = \alpha_n|\alpha_n\rangle.$$

$|{\alpha}\rangle = \bigotimes_n |\alpha_n\rangle$, with $a_n|\alpha_n\rangle = \alpha_n|\alpha_n\rangle$.

- **Squeeze/entangle (TGL-graviton permanence pulse)**: two-mode squeezed states

$$|\mathrm{G}_{ij}(r,\phi)\rangle = S_{ij}(r,\phi)\,|0\rangle, \quad S_{ij} = \exp\big[r\,e^{i\phi}a_i^\dagger a_j^\dagger - r\,e^{-i\phi}a_i a_j\big],$$

$$|G_{ij}(r,\phi)\rangle = S_{ij}(r,\phi) |0\rangle, \quad S_{ij} = \exp[r e^{i\phi} a_i^\dagger a_j^\dagger - r e^{-i\phi} a_i a_j]$$

capturing **joint fixation** between two BNIs/modes.

Summary: $\mathcal{H}$_LD is the multimodal Fock space, but TGL's **natural basis** is **displaced & squeezed Fock** (coherent + entangled), since J fixes the mirror and the "TGL-graviton" constraint correlates modes.

---

2. Open Dynamics: Lindblad Master Equation

We treat ρ as the state in the **displaced frame** (where $\tilde{H}$ is diagonal). Standard Lindblad form:

$$\boxed{\dot{\rho} = \mathcal{L}[\rho] \equiv -\tfrac{i}{\hbar}[\tilde{H},\rho] + \sum_\mu \mathcal{D}[L_\mu]\,\rho}, \quad \mathcal{D}[L]\rho = L\rho L^\dagger - \tfrac{1}{2}\{L^\dagger L,\rho\}.$$

$$\dot{\rho} = \mathcal{L}[\rho] \equiv -\frac{i}{\hbar}[\tilde{H}, \rho] + \sum_\mu \mathcal{D}[L_\mu]\rho, \quad \mathcal{D}[L]\rho=L\rho L^\dagger\tfrac{1}{2}{L^\dagger L, \rho}$$

2.1. Elementary Dissipative Channels (per mode n)

(i) Damping to thermal bath at temperature T, rate κ_n and Bose occupation $\bar{n}_n = [\exp(\hbar\omega_n/k_B T) - 1]^{(-1)}$:

$$L_n^{(\downarrow)} = \sqrt{\kappa_n\,(1+\bar{n}_n)}\,\tilde{a}_n, \qquad L_n^{(\uparrow)} = \sqrt{\kappa_n\,\bar{n}_n}\,\tilde{a}_n^\dagger.$$

$$L_n^{(\downarrow)} = \sqrt{\kappa_n(1+\bar{n}_n)} \tilde{a}_n, \quad L_n^{(\uparrow)} = \sqrt{\kappa_n \bar{n}_n} \tilde{a}_n^\dagger$$

Relation with Q: $\kappa_n = \omega_n/Q_n$.

(ii) Pure dephasing (very low frequency phase noise), rate $\gamma_{\phi,n}$:

$$L_n^{(\phi)} = \sqrt{\gamma_{\phi,n}}\, \tilde{a}_n^\dagger \tilde{a}_n.$$

$$L_n^{(\phi)} = \sqrt{\gamma_{\phi,n}} \tilde{a}_n^\dagger \tilde{a}_n$$

The generator for all modes (without correlation between baths) is:

$$\dot{\rho} = -\tfrac{i}{\hbar}[\tilde{H},\rho] + \sum_n \left(\mathcal{D}\left[L_n^{(\downarrow)}\right]\rho + \mathcal{D}\left[L_n^{(\uparrow)}\right]\rho + \mathcal{D}\left[L_n^{(\phi)}\right]\rho\right).$$

$$\dot{\rho}=-\frac{i}{\hbar}[\tilde{H},\rho]+\sum_n(\mathcal{D}[L_n^{(\downarrow)}]\rho+\mathcal{D}[L_n^{(\uparrow)}]\rho+\mathcal{D}[L_n^{(\phi)}]\rho)$$

2.2. "TGL-Graviton" Constraint: Correlated Dissipator (Two Modes)

To model the **permanence pulse** between modes i,j (BNI network), include **correlated Lindbladian** of two-mode squeezing reservoir type with rate Γ_{ij} and parameter m (correlation strength, |m| < 1):

$$L_{ij}^{(+)} = \sqrt{\Gamma_{ij}}\ \left(\tilde{a}_i + m\, e^{i\phi}\, \tilde{a}_j^\dagger\right),$$
$$L_{ij}^{(-)} = \sqrt{\Gamma_{ij}}\ \left(\tilde{a}_j + m\, e^{i\phi}\, \tilde{a}_i^\dagger\right).$$

$$L_{ij}^{(+)} =\sqrt{\Gamma_{ij}}(\tilde{a}_i + m e^{i\phi} \tilde{a}_j^\dagger),\quad L_{ij}^{(-)}=\sqrt{\Gamma_{ij}}(\tilde{a}_j+me^{i\phi}\tilde{a}_i^\dagger)$$

The term $\sum_{s=\pm} \mathcal{D}[L_{ij}^{(s)}]\rho$ **generates stationary entanglement** and reduces variances of type $\langle(\hat{X}_i - \hat{X}_j)^2\rangle$, $\langle(\hat{P}_i + \hat{P}_j)^2\rangle$ (with quadratures $\hat{X} = (\tilde{a} + \tilde{a}^\dagger)/\sqrt{2}$, $\hat{P} = (\tilde{a} - \tilde{a}^\dagger)/(i\sqrt{2})$).

This is the **operational channel** to stabilize the "TGL-graviton" state under losses.

Note: Alternatively, one can use a **parametric Hamiltonian** $H_{ij}^{int} = i\hbar g_{ij}(\tilde{a}_i^\dagger\tilde{a}_j^\dagger e^{i\phi} - h.c.)$ + local dampings. The dissipative path above gives direct control of the target **steady state**.

2.3. Compact Multimodal Form

Putting everything together (multiple modes, each with κ_n, $\bar{n}_n$, $\gamma_{\phi,n}$, and pairs (i,j) with Γ_{ij}, m_{ij}, ϕ_{ij}):

$$\dot{\rho} = -\frac{i}{\hbar}[\tilde{H},\rho] + \sum_n \left(\mathcal{D}[\sqrt{\kappa_n(1+\bar{n}_n)}\,\tilde{a}_n]\rho + \mathcal{D}[\sqrt{\kappa_n\bar{n}_n}\,\tilde{a}_n^\dagger]\rho + \mathcal{D}[\sqrt{\gamma_{\phi,n}}\,\tilde{a}_n^\dagger\tilde{a}_n]\rho\right) + \sum_{(i,j)}\left(\mathcal{D}[L_{ij}^{(+)}]\rho + \mathcal{D}[L_{ij}^{(-)}]\rho\right).$$

$$\dot{\rho} = -\frac{i}{\hbar}[\tilde{H}, \rho] + \sum_n
\left(\mathcal{D}[\sqrt{\kappa_n(1+\bar{n}_n)} \tilde{a}_n]\rho +
\mathcal{D}[\sqrt{\kappa_n\bar{n}n} \tilde{a}n^\dagger]\rho +
\mathcal{D}[\sqrt{\gamma{\phi,n}} \tilde{a}n^\dagger\tilde{a}n]\rho\right) +
\sum{(i,j)} \left(\mathcal{D}[L{ij}^{(+)}]\rho + \mathcal{D}[L{ij}^{(-)}]\rho\right)$$

3. Moment Dynamics (Useful for Experimental Prediction)

For a **single mode** in the displaced frame (without explicit drive), moments obey:

$$\frac{d}{dt}\langle\tilde{a}\rangle = -\left(i\omega_0 + \tfrac{\kappa}{2}\right)\langle\tilde{a}\rangle,$$

$$\frac{d}{dt}n \equiv \frac{d}{dt}\langle\tilde{a}^\dagger\tilde{a}\rangle = -\kappa\left(n - \bar{n}\right),$$

$$\frac{d}{dt}s \equiv \frac{d}{dt}\langle\tilde{a}^2\rangle = -\left(2i\omega_0 + \kappa\right)s,$$

$$\frac{d}{dt}\langle\tilde{a}\rangle=-
(i\omega_0+\tfrac{\kappa}{2})\langle\tilde{a}\rangle$$

$$\frac{d}{dt}n \equiv \frac{d}{dt}\langle\tilde{a}^\dagger\tilde{a}\rangle = -\kappa(n -
\bar{n})$$

$$\frac{d}{dt}s \equiv \frac{d}{dt}\langle\tilde{a}^2\rangle = -(2i\omega_0 +
\kappa)s$$

where $\bar{n} = \bar{n}(\omega_0,T)$. In **steady state**: $\langle\tilde{a}\rangle = 0$, $n = \bar{n}$, $s = 0$.

With **correlated reservoir** (i,j), correlation pumping terms emerge:

$$\frac{d}{dt}\langle\tilde{a}_i\tilde{a}_j\rangle = -\left(i(\omega_i+\omega_j) + \frac{\kappa_i+\kappa_j}{2} - \Gamma_{ij}m\right)\langle\tilde{a}_i\tilde{a}_j\rangle + \text{fonte correlacionada.}$$

$$\frac{d}{dt}\langle\tilde{a}_i\tilde{a}_j\rangle = -\left(i(\omega_i+\omega_j) + \frac{\kappa_i+\kappa_j}{2} - \Gamma_{ij}m\right)\langle\tilde{a}_i\tilde{a}_j\rangle + \text{correlated source}$$

The condition for **stationary entanglement** appears when the correlated gain $\Gamma_{ij} m$ **exceeds** effective losses (Routh-Hurwitz criterion for drift matrix).

IX.1. Practical Mappings (Parameters ↔ Observables)

- **Quality vs. damping**: $\kappa_n = \omega_n/Q_n$
- **Thermal bath**: $\bar{n}_n \approx k_B T/(\hbar\omega_n)$ for $\hbar\omega_n \ll k_B T$
- **Source J ↔ displacement α_n**: in frame without explicit drive, $\alpha_n \simeq -\varepsilon_n/\omega_n$, and by scaling from §A above, $|\alpha_n|^2 \simeq$ desired N_n
- **TGL-graviton pulse**: measure **combined quadrature noise spectrum** (EPR-like) and squeezing parameter r, or **logarithmic negativity** of steady state as function of Γ_{ij}, m, $\kappa_{\{i,j\}}$, $\bar{n}_{\{i,j\}}$

IX.2. Proof-of-Principle Sketch (Observability Condition)

- **Memory (one mode)**: requires $Q/\omega_0 = \tau \gg$ observation window and $n_{ss} \simeq \bar{n} \ll N$ (if maintaining coherent occupation in non-displaced frame)
- **Correlation (two modes)**: choose near-resonant (i,j), minimize κ_i, κ_j, operate at cryogenic T (or active cooling) and adjust Γ_{ij} m until stable squeezing threshold

IX.3. Closure

- **Hilbert**: Multimodal, naturally worked in **displaced/squeezed bases**; the "psion" is the quantum of permanence per mode
- **Lindblad**: Thermal damping, dephasing and **correlated reservoir** implement, in stationary regime, the **mirror fixation** and **permanence pulse** ("TGL-graviton")
- **Key experimental parameters**: ω_n (defining m_{eff}), Q_n (memory), $\bar{n}_n(T)$ (bath), Γ_{ij}, m (correlation), and displacement α_n linked to J

IX.4. Gaussian Hilbert Space (Quadratures)

We propose to deliver the **complete Gaussian model** of field Ψ, with:

1. Quadrature space and covariance matrix
2. **Gaussian master equation** in **Lyapunov/Riccati** form for $\dot{V}$
3. **Stability** conditions (Hurwitz)

4. **Closed solutions** in the **symmetric** case (two modes with correlated "TGL-graviton" reservoir), including **EPR variance**, **entanglement threshold** (Duan-Simon) and **logarithmic negativity**

We work in the **displaced frame** (source J already absorbed into coherent displacement), so dynamics is quadratic/linear.

For each mode n, define canonical quadratures:

$$\hat{X}_n = \frac{\tilde{a}_n + \tilde{a}_n^\dagger}{\sqrt{2}}, \qquad \hat{P}_n = \frac{\tilde{a}_n - \tilde{a}_n^\dagger}{i\sqrt{2}}, \qquad [\hat{X}_n, \hat{P}_m] = i\delta_{nm}.$$

$$\hat{X}_n = \frac{\tilde{a}_n + \tilde{a}_n^\dagger}{\sqrt{2}}, \quad \hat{P}_n = \frac{\tilde{a}_n - \tilde{a}_n^\dagger}{i\sqrt{2}}, \quad [\hat{X}_n, \hat{P}*m] = i\delta*{nm}$$

Stack into a vector $\hat{\mathbf{R}} = [\hat{X}_1, \hat{P}_1, \ldots, \hat{X}_N, \hat{P}_N]^T$.

The **covariance matrix** is:

$$V_{ij} = \tfrac{1}{2}\langle\hat{R}_i\hat{R}_j + \hat{R}_j\hat{R}_i\rangle - \langle\hat{R}_i\rangle\langle\hat{R}_j\rangle.$$

$$V_{ij} = \frac{1}{2}\langle\hat{R}_i\hat{R}_j + \hat{R}_j\hat{R}_i\rangle - \langle\hat{R}_i\rangle\langle\hat{R}_j\rangle$$

Gaussian states (vacuum, coherent, squeezed, entangled) are completely described by $(\bar{\mathbf{R}}, V)$. In the displaced frame $\bar{\mathbf{R}} = 0$.

IX.5. Gaussian Dynamics: V̇ = AV + VA^T + D

For **quadratic/linear Lindblad** (quadratic Hamiltonian and linear jumps), V obeys:

$$\boxed{\dot{V} = A\,V + V\,A^T + D} \qquad \text{(Lyapunov)}$$

$$\dot{V} = A V + V A^T + D \quad \text{(Lyapunov)}$$

$$\dot{V} = AV + VA^T + D \quad \text{(Lyapunov)}$$

- **Drift**: $A = \Omega(H_2) - \frac{1}{2}\sum_\mu \Omega\Re(C_\mu^\dagger C_\mu)$
- **Diffusion**: $D = \sum_\mu \Omega\Im(C_\mu^\dagger C_\mu)\Omega^T + D_{\text{th}}$

Here $\Omega = \bigoplus_{n=1}^N \begin{pmatrix} 0 & 1 \\ -1 & 0 \end{pmatrix}$ is the symplectic form; H_2 is the (real symmetric) matrix of the quadratic Hamiltonian $\frac{1}{2}\hat{\mathbf{R}}^T H_2 \hat{\mathbf{R}}$; and each Lindblad jump operator $L_\mu = \boldsymbol{\ell}_\mu^T \hat{\mathbf{R}}$ enters via the corresponding complex matrix C_μ (standard form of linear quantum systems).

- **Drift**: $A = \Omega (H_2) - \frac{1}{2}\sum_\mu \Omega \Re(C_\mu^\dagger C_\mu)$
- **Diffusion**: $D = \sum_\mu \Omega \Im(C_\mu^\dagger C_\mu) \Omega^T + D_{\text{th}}$

Here $\Omega = \bigoplus_{n=1}^N \begin{pmatrix} 0 & 1 \ -1 & 0 \end{pmatrix}$ is the symplectic form; H_2 is the (real symmetric) matrix of the quadratic Hamiltonian $\frac{1}{2}\hat{\mathbf{R}}^T H_2 \hat{\mathbf{R}}$; and each Lindblad jump operator $L_\mu = \boldsymbol{\ell}\mu^T \hat{\mathbf{R}}$ *enters via the corresponding complex matrix* $C\mu$ (standard form of linear quantum systems).

Stability (Hurwitz): The Gaussian steady state exists and is unique if and only if **all eigenvalues of A have negative real part**. At the fixed point, V solves the **algebraic Lyapunov**:

$$AV_\infty + V_\infty A^T + D = 0$$

$$A V_\infty + V_\infty A^T + D = 0$$

Note (Conditional Riccati)

If there is **continuous measurement** (homodyne) and feedback, the dynamics of the **conditional state** includes a gain term and becomes a **Riccati**:

$$\dot{V} = AV + VA^T + D - (VC^T + N)\, M^{-1}\, (CV + N^T),$$

$$\dot{V} = AV + VA^T + D - (VC^T + N) M^{-1} (CV + N^T)$$

where C maps $\hat{\mathbf{R}}$ to the measured channel, M is the measurement noise matrix, N the noise-system coupling. In what follows, we focus on the **unconditional case** (Lyapunov), which suffices for **steady-state**.

IX.6. One Mode (Reference)

Mode n with frequency ω_n, damping κ_n = ω_n/Q_n, thermal bath n̄_n and dephasing γ_{ϕ,n}.

In the rotating frame (RWA) and phased, the drift and diffusion become:

$$A_n = \begin{pmatrix} -\kappa_n/2 & \omega_n \\ -\omega_n & -\kappa_n/2 \end{pmatrix}, \qquad D_n = \frac{\kappa_n}{2}(2\bar{n}_n + 1)\,\mathbb{I}_2 + \gamma_{\phi,n}\begin{pmatrix} 0 & 0 \\ 0 & 0 \end{pmatrix}.$$

$$A_n = \begin{pmatrix} -\kappa_n/2 & \omega_n \ -\omega_n & -\kappa_n/2 \end{pmatrix}, \quad D_n = \frac{\kappa_n}{2}(2\bar{n}*n + 1) I_2 + \gamma*{\phi,n} \begin{pmatrix} 0 & 0 \ 0 & 0 \end{pmatrix}$$

Stationary solution:
$V_{n,\infty}=\text{diag}(v_x,v_p)$with$v_x=v_p=\frac{1}{2}(2\bar{n}_n + 1)$ (no internal squeezing). Serves as a block for the 2-mode case.

IX.7. Two Modes with Correlated Reservoir (the "TGL-Graviton")

Consider two **symmetric** modes i,j:

$$\omega_i = \omega_j = \omega, \quad \kappa_i = \kappa_j = \kappa, \quad \bar{n}_i = \bar{n}_j = \bar{n}, \quad \gamma_{\phi,i} = \gamma_{\phi,j} \approx 0.$$

$$\omega_i = \omega_j = \omega, \quad \kappa_i = \kappa_j = \kappa, \quad \bar{n}*i = \bar{n}*j = \bar{n}, \quad \gamma*{\phi,i} = \gamma*{\phi,j} \approx 0$$

Implement the dissipative constraint (reservoir engineering) with **jumps**:

$$L_+ = \sqrt{\Gamma}\,(\tilde{a}_i + m\,\tilde{a}_j^\dagger), \qquad L_- = \sqrt{\Gamma}\,(\tilde{a}_j + m\,\tilde{a}_i^\dagger),$$

$$L_+ = \sqrt{\Gamma} (\tilde{a}_i + m \tilde{a}*j^\dagger), \quad L*- = \sqrt{\Gamma} (\tilde{a}_j + m \tilde{a}_i^\dagger)$$

with $m \in [0,1)$ and phase chosen to squeeze $X_i - X_j$ and $P_i + P_j$. (There are also the local thermal jumps $\sqrt{\kappa(1+\bar{n})} \tilde{a}$ and $\sqrt{\kappa\bar{n}} \tilde{a}^\dagger$ for each mode.)

IX.8. Drift and Diffusion (Explicit Form)

In the vector $\hat{\mathbf{R}} = [X_i, P_i, X_j, P_j]^T$, the **drift** takes the block-symmetric form:

$$A=\begin{pmatrix}A_0 & A_c \\ A_c & A_0\end{pmatrix}, \quad A_0=\begin{pmatrix} -\frac{\kappa+\Gamma(1-m^2)}{2} & \omega \\ -\omega & -\frac{\kappa+\Gamma(1-m^2)}{2} \end{pmatrix}, \quad A_c=\frac{\Gamma m}{2}\begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}.$$

$$A=\begin{pmatrix}A_0 & A_c \ A_c & A_0\end{pmatrix},\quadA_0=\begin{pmatrix} -\frac{\kappa + \Gamma(1-m^2)}{2} & \omega \ -\omega & -\frac{\kappa + \Gamma(1-m^2)}{2} \end{pmatrix}, \quad A_c = \frac{\Gamma m}{2} \begin{pmatrix} 0 & 1 \ 1 & 0 \end{pmatrix}$$

The **total diffusion** is:

$$D=\frac{\kappa}{2}(2\bar{n}+1)\,\mathbb{I}_4 \; + \; \frac{\Gamma}{2}(1-m^2)\,\mathbb{I}_4.$$

$$D = \frac{\kappa}{2}(2\bar{n} + 1) I_4 + \frac{\Gamma}{2}(1 - m^2) I_4$$

(The above terms arise from the combination of local thermal jumps and correlated jumps; I've written in the basis already aligned with EPR quadratures.)

Stability (Hurwitz): requires

$$\kappa+\Gamma(1\pm m)>0 \quad \text{and} \quad \omega \text{ finite}$$

$$\kappa + \Gamma(1 \pm m) > 0 \quad \text{and} \quad \omega \text{ finite}$$

In particular, the **correlated gain** cannot exceed effective losses:

$$\Gamma m<\kappa+\Gamma \quad \text{(stable regime)}$$

$$\Gamma m < \kappa + \Gamma \quad \text{(stable regime)}$$

IX.9. Closed Solution in the Symmetric Case

By symmetry, in **steady-state** the covariances take the form:

$$V_\infty = \begin{pmatrix} v & 0 & c & 0 \\ 0 & v & 0 & -c \\ c & 0 & v & 0 \\ 0 & -c & 0 & v \end{pmatrix}, \qquad v > 0, \ \ |c| < v.$$

$$V_\infty = \begin{pmatrix} v & 0 & c & 0 \ 0 & v & 0 & -c \ c & 0 & v & 0 \ 0 & -c & 0 & v \end{pmatrix}, \quad v > 0, \quad |c| < v$$

Solving $AV_\infty + V_\infty A^T + D = 0$ gives (RWA, ω eliminates from static terms):

$$\boxed{v = \frac{\frac{\kappa}{2}(2\bar{n} + 1) + \frac{\Gamma}{2}(1 - m^2)}{\kappa + \Gamma(1 - m^2)}}, \qquad \boxed{c = \frac{\Gamma m}{\kappa + \Gamma(1 - m^2)}\, v.}$$

$$v = \frac{\frac{\kappa}{2}(2\bar{n} + 1) + \frac{\Gamma}{2}(1 - m^2)}{\kappa + \Gamma(1 - m^2)}, \quad c = \frac{\Gamma m}{\kappa + \Gamma(1 - m^2)} v$$

These expressions show: m **reduces joint variance** and creates correlation c; n̄ raises the thermal floor of v.

EPR Variance and Duan-Simon Criterion

Define the EPR combinations:

$$\hat{X}_- = \hat{X}_i - \hat{X}j, \quad \hat{P}+ = \hat{P}_i + \hat{P}_j$$

Their stationary variances are:

$$\text{Var}(X_-) = 2(v - c), \quad \text{Var}(P_+) = 2(v - c)$$

The EPR sum:

$$V_{\text{EPR}} \equiv \text{Var}(X_-) + \text{Var}(P_+) = 4(v - c)$$

Entanglement (Duan-Simon): In vacuum units ($V_{\text{vac}} = \frac{1}{2}I$), there is entanglement if:

$$V_{\text{EPR}} < 2 \Leftrightarrow v - c < \frac{1}{2}$$

Substituting v and c, we obtain a **closed form**:

$$\boxed{v - c = \frac{\frac{\kappa}{2}(2\bar{n} + 1) + \frac{\Gamma}{2}(1 - m^2)}{\kappa + \Gamma(1 - m^2)} \left[1 - \frac{\Gamma m}{\kappa + \Gamma(1 - m^2)}\right].}$$

$$v - c = \frac{\frac{\kappa}{2}(2\bar{n} + 1) + \frac{\Gamma}{2}(1 - m^2)}{\kappa + \Gamma(1 - m^2)} \left[1 - \frac{\Gamma m}{\kappa + \Gamma(1 - m^2)}\right]$$

In the **ideal limit** ($\bar{n} \to 0$):

$$v - c = \frac{1}{2}\,\frac{\kappa + \Gamma(1 - m)}{\kappa + \Gamma(1 - m^2)}.$$

$$v - c = \frac{1}{2} \frac{\kappa + \Gamma(1 - m)}{\kappa + \Gamma(1 - m^2)}$$

Therefore:

$$\boxed{\mathcal{V}_{\text{EPR}}^{(\bar{n}=0)} = 2\,\frac{\kappa + \Gamma(1 - m)}{\kappa + \Gamma(1 - m^2)}.}$$

$$V_{\text{EPR}}(\bar{n} = 0) = 2 \frac{\kappa + \Gamma(1 - m)}{\kappa + \Gamma(1 - m^2)}$$

Entanglement ($V_{\text{EPR}} < 2$) occurs whenever $m > 0$ and $\Gamma > 0$, **improving** with $\Gamma/\kappa \uparrow$ and $m \uparrow 1$.

Effective Squeezing Parameter

Define $e^{-2r_{ss}} \equiv v - c$ in vacuum units (half). In the limit $\bar{n} = 0$:

$$\boxed{e^{-2r_{ss}} = \frac{\kappa + \Gamma(1 - m)}{\kappa + \Gamma(1 + m)}.}$$

$$e^{-2r_{ss}} = \frac{\kappa + \Gamma(1 - m)}{\kappa + \Gamma(1 + m)}$$

This recovers the expected "gain vs. loss" form: $r_{ss} \uparrow$ when Γm approaches the stability limit.

Logarithmic Negativity (Closed in Symmetric Case)

For a **symmetric** Gaussian state as above, the partial symplectic eigenvalues give:

$$\tilde{\nu}_- = \sqrt{(v - c)(v - c)} = v - c,$$

$$\tilde{\nu}_- = \sqrt{(v - c)(v - c)} = v - c$$

and the **logarithmic negativity** is:

$$E_{\mathcal{N}} = \max\left\{0,\ -\ln\left(2\,\tilde{\nu}_-\right)\right\} = \max\left\{0,\ -\ln\left(2(v-c)\right)\right\}.$$

$$E_N = \max{0, -\ln(2\tilde{\nu}_-)} = \max{0, -\ln(2(v - c))}$$

With the expression for $v - c$ above, this provides $E_N(\kappa, \Gamma, m, \bar{n})$ **in closed form**.

IX.10. Practical Conditions Summarized

- **Stability**: $\kappa + \Gamma(1 \pm m) > 0$ and $\Gamma m < \kappa + \Gamma$
- **Entanglement**: the **larger** Γ/κ and **larger** m, the smaller V_{EPR}
- **Thermal bath**: raises v and **worsens** E_N via ñ. Cryo-cooling and/or increasing ω reduce ñ
- **Closed figure of merit (ideal $\bar{n} = 0$)**:

$$\mathcal{V}_{\text{EPR}} = 2\,\frac{\kappa+\Gamma(1-m)}{\kappa+\Gamma(1+m)}, \qquad r_{\text{ss}} = \tfrac{1}{2}\ln\frac{\kappa+\Gamma(1+m)}{\kappa+\Gamma(1-m)}.$$

$$V_{\text{EPR}} = 2 \frac{\kappa + \Gamma(1 - m)}{\kappa + \Gamma(1 + m)}, \quad r_{ss} = \frac{1}{2}\ln \frac{\kappa + \Gamma(1 + m)}{\kappa + \Gamma(1 - m)}$$

IX.11. Conclusion

- The effective **Hilbert space** of TGL is the multimodal Fock in the **displaced & squeezed frame**
- **Gaussian dynamics** reduces to $\dot{V} = AV + VA^T + D$ (Lyapunov), with **closed** stationary solution in the symmetric case above
- The **permanence pulse** ("TGL-graviton") appears as a **correlated reservoir**; its signatures are the formulas for V_{EPR}, r_{ss} and E_N

X. Dark Matter and Dark Energy

In this chapter we explore, **within TGL**, how **dark matter** and **dark energy** are understood and derive the corresponding equations in the FRW cosmological background. The reading is 100% coherent with what we have already formalized: stationary field Ψ, psions (permanence quanta), mirror-mode, pre-collapse "cosmic water" and luminodynamic tunnel.

X.1. TGL Postulate (Synthesis)

- **Dark energy (DE)**: sector of **pure permanence** of the luminodynamic field (quasi-homogeneous mirror-mode in the universe), dominated by the **potential** V(Ψ). It is the "**oxygen part**" of the pre-collapse cosmic water: fixes the metric and pushes expansion (negative pressure).

- **Dark matter (DM)**: **granular** sector of the same field, composed of **psions** that **oscillate** around the effective minimum. In the coherent oscillation regime, the fluid results **cold and pressureless** ($w \simeq 0$). It is the "**hydrogen part**" that gives **invisible weight** to halos/galaxies.

Both are **faces of the same permanence field**; what changes is the **dynamical regime** (potential-dominated ↔ oscillatory).

X.2. Cosmological Lagrangian (FRW) of the Permanence Field

In flat FRW metric $ds^2 = -dt^2 + a^2(t)dx^2$, take the homogeneous sector Ψ(t) (long-distance part) plus fluctuations δΨ (granular):

$$\mathcal{L}_{LD} = \frac{1}{2}\, g^{\mu\nu}\nabla_\mu\Psi\,\nabla_\nu\Psi - \frac{1}{2}\, m_{\text{eff}}^2\Psi^2 - \xi R\,\Psi^2 - V_{\text{int}}(\Psi)$$

$$\mathcal{L}{*\text{LD}} = \frac{1}{2} g^{\mu\nu}\nabla*\mu\Psi \nabla_\nu\Psi - \frac{1}{2} m_{\text{eff}}^2\Psi^2 - \xi R \Psi^2 - V_{\text{int}}(\Psi)$$

(displaced frame: source J absorbed).

- m_{eff} is the **permanence effective mass** (from previous §).
- $\xi R\Psi^2$ captures coupling to scalar curvature $R = 6(\dot{H} + 2H^2)$.
- $V_{\text{int}}(\Psi)$ models the **pre-collapse cosmic water** and the **luminodynamic tunnel** (below).

Equation of motion (homogeneous sector):

$$\ddot{\Psi} + 3H\dot{\Psi} + m_{\text{eff}}^2\,\Psi + 2\xi R\,\Psi + \frac{dV_{\text{int}}}{d\Psi} = 0, \qquad H = \frac{\dot{a}}{a}.$$

$$\ddot{\Psi} + 3H\dot{\Psi} + m_{\text{eff}}^2 \Psi + 2\xi R \Psi + \frac{dV_{\text{int}}}{d\Psi} = 0, \quad H = \frac{\dot{a}}{a}$$

X.3. Energy-Momentum Tensor and Equations of State

From the Lagrangian, in the homogeneous sector:

$$\rho_\Psi = \frac{1}{2}\dot{\Psi}^2 + V_{\text{eff}}(\Psi), \qquad p_\Psi = \frac{1}{2}\dot{\Psi}^2 - V_{\text{eff}}(\Psi),$$

$$V_{\text{eff}}(\Psi) \equiv \frac{1}{2}m_{\text{eff}}^2\Psi^2 + \xi R\Psi^2 + V_{\text{int}}(\Psi).$$

$$\rho_\Psi = \frac{1}{2}\dot{\Psi}^2 + V_{\text{eff}}(\Psi), \quad p_\Psi = \frac{1}{2}\dot{\Psi}^2 - V_{\text{eff}}(\Psi)$$

$$V_{\text{eff}}(\Psi) \equiv \frac{1}{2}m_{\text{eff}}^2\Psi^2 + \xi R\Psi^2 + V_{\text{int}}(\Psi)$$

The **equation of state parameter**:

$$w_\Psi = \frac{p_\Psi}{\rho_\Psi} = \frac{\frac{1}{2}\dot{\Psi}^2 - V_{\text{eff}}}{\frac{1}{2}\dot{\Psi}^2 + V_{\text{eff}}}.$$

$$w_\Psi = \frac{p_\Psi}{\rho_\Psi} = \frac{\frac{1}{2}\dot{\Psi}^2 - V_{\text{eff}}}{\frac{1}{2}\dot{\Psi}^2 + V_{\text{eff}}}$$

Two TGL regimes:

- **(DE)** *potential-dominated* ($\dot{\Psi}^2 \ll V_{\text{eff}}$): $w_{\text{DE}} \simeq -1$. Negative pressure, accelerates expansion (cosmic mirror-mode).
- **(DM)** *coherent oscillatory* in approximately quadratic (or smooth) potential with frequency $\omega \gg H$: time averages give $\langle\dot{\Psi}^2\rangle \simeq \langle m_{\text{eff}}^2\Psi^2\rangle \Rightarrow w_{\text{DM}} \simeq 0$. Behaves like **cold matter**.

Therefore, **DE and DM** are **the same field in distinct regimes** — the TGL signature.

X.4. Friedmann with the Permanence Field

The Friedmann equations (null curvature) with radiation r, baryons b and field Ψ:

$$H^2 = \frac{8\pi G}{3}\left(\rho_r + \rho_b + \rho_\Psi\right), \qquad \dot{H} = -4\pi G\left(\rho_r + \rho_b + \rho_\Psi + p_\Psi\right).$$

$$H^2 = \frac{8\pi G}{3}(\rho_r + \rho_b + \rho_\Psi), \quad \dot{H} = -4\pi G(\rho_r + \rho_b + \rho_\Psi + p_\Psi)$$

Continuity of sector Ψ:

$$\dot{\rho}_\Psi + 3H(\rho_\Psi + p_\Psi) = 0 \iff \ddot{\Psi} + 3H\dot{\Psi} + V'_{\text{eff}}(\Psi) = 0.$$

$$\dot{\rho}\Psi + 3H(\rho\Psi + p_\Psi) = 0 \Leftrightarrow \ddot{\Psi} + 3H\dot{\Psi} + V'_{\text{eff}}(\Psi) = 0$$

Separating *regimes*:

- **Dark energy (background)**: $\rho_\Lambda(t) \equiv V_{\text{eff}}(\Psi_\star)$ nearly constant (field trapped/"slow-roll" luminodynamic).
- **Dark matter (granular)**: $\rho_{\text{ps}}(t) \propto a^{-3}$ from **coherent oscillations** (psions).

  Total: $\rho\Psi=\rho\Lambda+\rho ps$, com $w\Lambda\simeq-1$, $wps\simeq0$.

Total: $\rho_\Psi = \rho_\Lambda + \rho_{\text{ps}}$, with $w_\Lambda \simeq -1$, $w_{\text{ps}} \simeq 0$.

X.5. "Cosmic Water" and the TGL Potential

The "water" = (H,O) interpretation in **pre-collapse** state we encode in a **two-sector potential**:

$$V_{\text{int}}(\Psi;\Phi) = \underbrace{\frac{\lambda_H}{4}(\Psi^2 - \Psi_H^2)^2}_{\text{H well (matter-like)}} + \underbrace{\frac{\Lambda_O}{4}\left[1 - \cos\left(\frac{\Phi}{f_O}\right)\right]}_{\text{O plateau (energy-like)}} - \underbrace{\gamma\Psi^2\Phi}_{\text{luminodynamic tunnel}}$$

$$V_{\text{int}}(\Psi; \Phi) = \underbrace{\frac{\lambda_H}{4}(\Psi^2 - \Psi_H^2)^2}_{\text{H well (matter-like)}} + \underbrace{\frac{\Lambda_O}{4}\left[1 - \cos\left(\frac{\Phi}{f_O}\right)\right]}_{\text{O plateau (energy-like)}} - \underbrace{\gamma \Psi^2\Phi}_{\text{luminodynamic tunnel}}$$

- Ψ: "H" sector (granular, generates DM via oscillations).

- Φ: "O" sector (nearly constant, generates DE via plateau).
- γ: **luminodynamic tunnel coupling** (allows energy/form exchange between local and background permanence).

Coupled equations (homogeneous sector):

$$\begin{aligned}\ddot{\Psi} + 3H\dot{\Psi} + m_{\text{eff}}^2\Psi + \lambda_H(\Psi^2 - \Psi_H^2)\Psi - 2\gamma\,\Psi\,\Phi = 0,\\ \ddot{\Phi} + 3H\dot{\Phi} + \frac{\Lambda_O^4}{f_O}\sin\left(\frac{\Phi}{f_O}\right) - \gamma\,\Psi^2 = 0.\end{aligned}$$

$$\ddot{\Psi} + 3H\dot{\Psi} + m_{\text{eff}}^2\Psi + \lambda_H(\Psi^2 - \Psi_H^2)\Psi - 2\gamma \Psi \Phi = 0$$

$$\ddot{\Phi} + 3H\dot{\Phi} + \frac{\Lambda_O}{4f_O}\sin\left(\frac{\Phi}{f_O}\right) - \gamma \Psi^2 = 0$$

- When Φ stays on **plateau** (slow-roll), $V_O \simeq \text{const} \Rightarrow w \simeq -1$.

- When Ψ **oscillates** around Ψ_H, the quadratic term dominates and $\rho_{\text{ps}} \propto a^{-3}$.

Note: If we don't want two fields, we can **effectivize** Φ as the **zero mode** of Ψ (global mirror) and Ψ as **granular modes**. The decomposition above just makes the "H/O" role clear.

X.6. Fluctuations: Rotation Curves and Structure Growth

For $\delta\Psi$ in the DM regime, in comoving space:

$$\delta\ddot{\Psi}_{\mathbf{k}} + 3H\delta\dot{\Psi}_{\mathbf{k}} + \left(\frac{k^2}{a^2} + m_{\text{eff}}^2\right)\delta\Psi_{\mathbf{k}} \simeq 0.$$

$$\ddot{\delta\Psi}_k + 3H\dot{\delta\Psi}k + \left(\frac{k^2}{a^2} + m{\text{eff}}^2\right)\delta\Psi_k \simeq 0$$

- At **sub-horizon** scales ($k/a \gg H$) and **effective mass** not too small, solutions give **stable perturbations** that behave like cold DM.

- Poisson gravitation: $\nabla^2\Phi_N = 4\pi G a^2 \delta\rho_{\text{ps}}$ generates **flat rotation curves** in halos; this emerges from granular ρ_{ps} **without pressure**.

X.7. TGL Predictions (Falsifiable)

1. **Uni-field**: large-scale correlation between the evolution rate of $\rho_\Lambda(t)$ (very small, but not exactly zero) and the average granular amplitude ρ_{ps} via γ (tunnel).
2. **Spectral signature**: a **quantum Jeans cutoff** at small scales if m_{eff} is very low (smooths satellites/halo centers).
3. **Slight deviations from w = -1**: $w_\Lambda = -1 + \epsilon(t)$ controlled by ξR and coupling γ (predictable with the system above).

X.8. Operational Summary (Key Equations)

Field(s):

$$\ddot{\Psi} + 3H\dot{\Psi} + V'_{\text{eff}}(\Psi, \Phi) = 0, \qquad \ddot{\Phi} + 3H\dot{\Phi} + U'_{\text{eff}}(\Psi, \Phi) = 0.$$

$$\ddot{\Psi} + 3H\dot{\Psi} + V'_{\text{eff}}(\Psi, \Phi) = 0, \quad \ddot{\Phi} + 3H\dot{\Phi} + U'_{\text{eff}}(\Psi, \Phi) = 0$$

Total density and pressure of TGL sector:

$$\rho_{\text{TGL}} = \tfrac{1}{2}\dot{\Psi}^2 + \tfrac{1}{2}\dot{\Phi}^2 + V_{\text{eff}}(\Psi, \Phi), \quad p_{\text{TGL}} = \tfrac{1}{2}\dot{\Psi}^2 + \tfrac{1}{2}\dot{\Phi}^2 - V_{\text{eff}}(\Psi, \Phi).$$

$$\rho_{\text{TGL}} = \frac{1}{2}\dot{\Psi}^2 + \frac{1}{2}\dot{\Phi}^2 + V_{\text{eff}}(\Psi, \Phi), \quad p_{\text{TGL}} = \frac{1}{2}\dot{\Psi}^2 + \frac{1}{2}\dot{\Phi}^2 - V_{\text{eff}}(\Psi, \Phi)$$

Practical decomposition:

$$\rho_\Lambda \approx V_O(\Phi_\star) \quad (w \simeq -1), \qquad \rho_{\text{ps}} \sim a^{-3} \quad (w \simeq 0).$$

$$\rho_\Lambda \approx V_O(\Phi_\star) , (w \simeq -1), \quad \rho_{\text{ps}} \sim a^{-3} , (w \simeq 0)$$

Friedmann:

$$H^2 = \frac{8\pi G}{3}\left(\rho_r + \rho_b + \rho_{\text{ps}} + \rho_\Lambda\right).$$

$$H^2 = \frac{8\pi G}{3}(\rho_r + \rho_b + \rho_{\text{ps}} + \rho_\Lambda)$$

X.9. Conclusion

- **Dark energy** (TGL) = **background permanence** of field (global mirror-mode, $w \simeq -1$).
- **Dark matter** (TGL) = **oscillating psions** (granular, $w \simeq 0$).
- The **same field** explains both structures via **regime** (potential vs. oscillation), with **luminodynamic tunnel** γ coupling "water" (H/O).
- The **equations** above integrate TGL into standard **FRW cosmos** and generate **observational targets** (slight w evolution, smoothing at small scales, H(z)-structure correlations).

XI) Black Holes

In this Chapter we structure the luminodynamic explanation of **black holes** within TGL in conceptual, mathematical and cosmological layers, linking the breaking of 3D → 2D geometry to the **universal gravitational mirror** and the idea that there is only **one single fractal black hole** sustaining the entire cosmos.

XI.1. Geometry Breaking: From 3D to 2D

In General Relativity, curvature intensifies up to the horizon. In **TGL**, when light reaches the **fixation condition** (λ → 0), it occurs:

- **Dimensional collapse**: three-dimensional space ceases to be sufficient to support the light trajectory. Geometry **tears** into a **two-dimensional** sheet.
- **Physical meaning**: in 2D there are no more angular degrees of freedom, only surface. This creates the condition for **total reflection**, like a mirrored lake — the **gravitational mirror**.

XI.2. The Gravitational Mirror

A black hole, in TGL, is not absence or destruction, but:

- **Permanence mirror**: all information that falls is **represented holographically** on the 2D surface.
- **Speed of light cubed**: inside, light not only travels at c, but the fixed spacetime stabilizes as if the **effective constant were c^3**, guaranteeing **collapse stability**.
- **Physical function**: the black hole **holds the light** and, with it, stabilizes time. It is not just curvature, it is **symbolic fixation**.

XI.3. Not Many — Just One

Looking at the cosmos, we see billions of black holes. But, according to TGL:

- **All are fractal images** of a **single fundamental black hole**.
- This "**Universal Black Hole**" is the **time mirroring nucleus**.
- Each local horizon is **partial refraction** of the same global mirror.

In geometric language: 3D spacetime is a **holographic sheet** projected onto this **single 2D mirror**.

XI.4. Light and Dark Water

The black hole surface is where **light meets dark water** (matter + dark energy in pre-collapse state):

- Light **inscribes information** on this stationed water.
- The mirror reflects not just trajectory, but **symbolic meaning**: the 3D universe is **refracted** from this surface as a hologram.
- The 3D is thus a **luminodynamic image** of the 2D.

XI.5. Mathematical Formulation

Let Ψ(x,t) be the luminodynamic field. At the black hole boundary:

A. Dimensional collapse:

$$\lim_{\lambda \to 0} \Psi(x,t) \;\; \Rightarrow \;\; \Psi_{2D}(u,v).$$

$$\lim_{\lambda \to 0} \Psi(x,t) \Rightarrow \Psi_{2D}(u,v)$$

B. Holographic representation (information encoded on surface S):

$$I_{3D}(x, y, z) = \mathcal{H}\left[\Psi_{2D}(u, v)\right],$$

$$I_{3D}(x,y,z) = \mathcal{H}[\Psi_{2D}(u,v)]$$

where $\mathcal{H}$ is the **luminodynamic holographic transform** operator.

C. Effective velocity:

$$c_{\mathrm{LD}} = c^3,$$

$$c_{\text{LD}} = c^3$$

in the stationary regime, ensuring that fixed light stabilizes spacetime.

XI.6. Cosmological Interpretation

- The **3D universe** is a **refracted hologram** from the 2D surface of the single black hole.
- Each astrophysical black hole is just a **fractal pixel** of this universal mirror.
- **Dark water** is the **optical substrate** of this hologram, upon which light inscribes and refracts.
- What we call "different black holes" are just **local interfaces** with the same **absolute gravitational mirror**.

XI.7. Luminodynamic Conclusion

- The **geometry rupture** doesn't destroy the universe — it creates the **permanence mirror**.
- **Fixed light** in 2D reflects the cosmos in 3D, stabilized by c^3.
- Multiple black holes don't exist: there is **only one**, fractal, reflected in all others.

- This single mirror is the **holographic heart** of the universe: the membrane where light and dark water meet and become permanence.

XII. Luminodynamic Holography

Now, we propose to deliver a **luminodynamic holographic metric (TGL)** for the 2D "gravitational mirror" that projects the 3D universe as a hologram — including: (i) 3D geometric *ansatz* from a **2D mirror-membrane**, (ii) **junction conditions** (Israel-type) with **luminodynamic tension** of field Ψ, (iii) effective **2D action** (dilaton/Jackiw-Teitelboim type) governing TGL holography, and (iv) a **closed example** (exponential warp, "AdS-like") where the **c³ stabilization**factor naturally appears in time.

XII.1. 2D Mirror and 3D Bulk: TGL Holographic Ansatz

- Mirror-membrane (fractal universal horizon) S with coordinates x^a $(a = 0, 1)$ and intrinsic metric $\gamma_{ab}(x)$.
- 3D Bulk with coordinates $X^\mu = (x^a, \rho)$ where ρ measures normal distance to membrane; n^μ is the unit normal vector; tangent projector is $h_{\mu\nu} = g_{\mu\nu} - n_\mu n_\nu$.

- Mirror-membrane (fractal universal horizon) S with coordinates x^a ($a=0,1$) and intrinsic metric $\gamma_{ab}(x)$.
- 3D Bulk with coordinates $X^\mu = (x^a, \rho)$ where ρ measures normal distance to membrane; n^μ is the unit normal vector; tangent projector is $h_{\mu\nu} = g_{\mu\nu} - n_\mu n_\nu$.

XII.1.1. 3D Metric as "Warped" Product

We propose the **TGL ansatz** (warp controlled by permanence field Ψ):

$$ds_3^2 = W(\rho; \Psi)^2 [-c_{\text{LD}}^2 N(x)^2 dt^2 + \Sigma(x)^2 d\sigma^2] + d\rho^2$$

$$ds_3^2 = W(\rho; \Psi)^2 [-c_{\text{LD}}^2 N(x)^2 dt^2 + \Sigma(x)^2 d\sigma^2] + d\rho^2$$

where:

- $W(\rho; \Psi)$ is the **warp factor** (determined by Ψ on the mirror);
- $c_{\text{LD}} \equiv c^3$ is the **effective constant** (luminodynamic time stabilization in mirror regime);
- $N(x)$ and $\Sigma(x)$ define the 2D intrinsic metric $\gamma_{ab}dx^a dx^b = -N^2 dt^2 + \Sigma^2 d\sigma^2$.

In the limit $\rho \to 0, W \to 1$ and the metric restricts to γ_{ab}: the **3D is a holographic projection** of S.

- $W(\rho; \Psi)$ is the **warp factor** (determined by Ψ on the mirror);
- $c_{\text{LD}} \equiv c^3$ is the **effective constant** (luminodynamic time stabilization in mirror regime);
- $N(x)$ and $\Sigma(x)$ define the 2D intrinsic metric $\gamma_{ab}dx^a dx^b = -N^2 dt^2 + \Sigma^2 d\sigma^2$.

In the limit $\rho \to 0$, $W \to 1$ and the metric restricts to γ_{ab}: the **3D is a holographic projection** of S.

Variation provides Einstein equations in the bulk and **junction conditions** at the mirror.

XII.2. Action and Tensors: Bulk + Mirror

XII.2.1. 3D Action with Membrane Term

$$S_{3D} = \frac{1}{16\pi G_3}\int d^3X \sqrt{-g} R^{(3)} + \int_S d^2x \sqrt{-\gamma} [-\sigma(\Psi) + \mathcal{L}_{\Psi,\text{TGL}}^{(2)}]$$

$S_{3D} = \frac{1}{16\pi G_3}\int d^3X \sqrt{-g} R^{(3)} + \int_S d^2x \sqrt{-\gamma} [-\sigma(\Psi) + \mathcal{L}_{\Psi,\text{TGL}}^{(2)}]$

where:

- G_3 is the 3D gravitational constant (effective sector);
- $\sigma(\Psi)$ is the **luminodynamic tension** of the membrane (mirror surface energy);
- $\mathcal{L}_{\Psi,\text{TGL}}^{(2)}$ is the **2D dynamics** of field Ψ on the membrane (below).

- G_3 is the 3D gravitational constant (effective sector);
- $\sigma(\Psi)$ is the **luminodynamic tension** of the membrane (mirror surface energy);

- $\mathcal{L}_{\Psi,\text{TGL}}^{(2)}$ is the **2D dynamics** of field Ψ on the membrane (below).

XII.2.2. Israel Junction Conditions

At the membrane ($\rho = 0$), the extrinsic curvature jump gives:

$$[K_{ab}] - [K]\gamma_{ab} = -8\pi G_3 S_{ab}$$

$[K_{ab}] - [K]\gamma_{ab} = -8\pi G_3 S_{ab}$

where S_{ab} is the membrane energy-momentum:

$$S_{ab} = -\sigma(\Psi)\gamma_{ab} + T_{ab}^{(\Psi)}$$

with $T_{ab}^{(\Psi)}$ from $\mathcal{L}_{\Psi,\text{TGL}}^{(2)}$.

Key TGL insight: The tension $\sigma(\Psi) = \sigma_0 + \alpha|\Psi|^2$ depends on the permanence field — the mirror **self-regulates** via Ψ.

$S_{ab} = -\sigma(\Psi)\gamma_{ab} + T_{ab}^{(\Psi)}$

with $T_{ab}^{(\Psi)}$ from $\mathcal{L}_{\Psi,\text{TGL}}^{(2)}$.

Key TGL insight: The tension $\sigma(\Psi) = \sigma_0 + \alpha|\Psi|^2$ depends on the permanence field — the mirror **self-regulates** via Ψ.

XII.2.2. Junction Conditions (Israel-type) at the Mirror

Define the **extrinsic curvature** $K_{ab} = h_a^\mu h_b^\nu \nabla_\mu n_\nu$ and its trace $K = \gamma^{ab}K_{ab}$. The discontinuity $[K_{ab}]$ across the membrane obeys:

$$\boxed{[K_{ab} - K\,\gamma_{ab}] = -\,8\pi G_3\, S_{ab}\,,} \qquad S_{ab} \equiv -\,\sigma(\Psi)\,\gamma_{ab} + T_{ab}^{(\Psi)}.$$

$$[K_{ab} - K \gamma_{ab}] = -8\pi G_3 S_{ab}, \quad S_{ab} \equiv -\sigma(\Psi) \gamma_{ab} + T_{ab}^{(\Psi)}$$

- **"Mirror" part**: $-\sigma(\Psi)\gamma_{ab}$ (surface tension).
- **"Luminodynamic" part**: $T_{ab}^{(\Psi)}$ is the tensor of the **2D field Ψ** (memory/permanence).

For the "warped" *ansatz* above (with Z_2 symmetry in ρ), it results:

$$\boxed{\frac{W'(0^+)}{W(0)} = -4\pi G_3\,\sigma_{\text{eff}}(\Psi)\,,} \quad \sigma_{\text{eff}}(\Psi) \equiv \sigma(\Psi) - \tfrac{1}{2}\,\gamma^{ab}T_{ab}^{(\Psi)}.$$

$$\frac{W'(0^+)}{W(0)} = -4\pi G_3 \sigma_{\text{eff}}(\Psi), \quad \sigma_{\text{eff}}(\Psi) \equiv \sigma(\Psi) - \frac{1}{2} \gamma^{ab}T_{ab}^{(\Psi)}$$

This fixes the **normal curvature** of the bulk by the **luminodynamic tension** of the mirror.

XII.3. 2D Dynamics on the Mirror (JT-TGL)

In 2D, pure $R^{(2)}$ is topological; geometric dynamics enters via **dilaton** Φ (the "effective area" of the mirror). TGL identifies the dilaton with the **permanence density** of the field:

$$\Phi \sim \Psi^2 \quad (\text{"areal memory"})$$

$$\Phi \sim \Psi^2 \quad \text{("areal memory")}$$

XII.3.1. 2D Action (Jackiw-Teitelboim-TGL Type)

$$\boxed{S_{2D} = \int_S d^2x\,\sqrt{-\gamma}\,\Big[\,\Phi\,R^{(2)} + \frac{1}{2}(\nabla\Psi)^2 - U_{\text{LD}}(\Psi) - \Lambda_{\text{LD}}\Big],}$$

$$S_{2D} = \int_S d^2x \sqrt{-\gamma} \left[\Phi R^{(2)} + \frac{1}{2}(\nabla\Psi)^2 - U_{\text{LD}}(\Psi) - \Lambda_{\text{LD}}\right]$$

where:

- $U_{\text{LD}}(\Psi)$ is the **permanence potential** (mirror fixation);
- Λ_{LD} is a **background tension** (dark water on plateau, TGL dark energy).

2D Equations (variation in γ_{ab} and Ψ):

$$\nabla_a\nabla_b\Phi - \gamma_{ab}\nabla^2\Phi + \frac{1}{2}\gamma_{ab}[U_{\text{LD}}(\Psi) + \Lambda_{\text{LD}}] + \frac{1}{2}(\nabla_a\Psi\nabla_b\Psi - \frac{1}{2}\gamma_{ab}(\nabla\Psi)^2) = 0$$

$$\nabla^2\Psi - U'_{\text{LD}}(\Psi) = 0$$

$$R^{(2)} = -\frac{dU_{\text{LD}}}{d\Phi} \quad \text{(if U depends on }\Phi)$$

$$\nabla_a\nabla_b\Phi - \gamma_{ab}\nabla^2\Phi + \frac{1}{2}
\gamma_{ab}[U_{\text{LD}}(\Psi) + \Lambda_{\text{LD}}] +
\frac{1}{2}(\nabla_a\Psi\nabla_b\Psi - \frac{1}{2}\gamma_{ab}(\nabla\Psi)^2) = 0$$

$$\nabla^2\Psi - U'_{\text{LD}}(\Psi) = 0$$

$$R^{(2)} = -\frac{dU_{\text{LD}}}{d\Phi} \quad \text{(if U depends on Φ)}$$

TGL Interpretation: $\Phi \propto \Psi^2$ measures **permanence quanta per area**; U_{LD} stabilizes the mirror (zero mode), and Λ_{LD} fixes the **2D mean curvature**.

XII.4. Field Ψ and the Warp W(ρ;Ψ)

The warp obeys an **effective radial equation** (obtained from 3D Einstein equations with ansatz symmetries):

$$\boxed{\frac{W''}{W} = -\kappa_0^2 - \alpha\Psi^2,}$$

$$\frac{W''}{W} = -\kappa_0^2 - \alpha \Psi^2$$

where:

- κ_0 is a **background curvature** (set by Λ_{LD} and/or average σ);
- $\alpha > 0$ measures **how local permanence (Ψ²) deepens the warp "well"**.

- κ_0 is a **background curvature** (set by Λ_{LD} and/or average σ);
- $\alpha > 0$ measures **how local permanence (Ψ²) deepens the warp "well"**.

The junction condition at ρ = 0:

$$\frac{W'(0^+)}{W(0)} = -\,4\pi G_3\,\sigma_{\text{eff}}(\Psi_0),$$

$$\frac{W'(0^+)}{W(0)} = -4\pi G_3 \sigma_{\text{eff}}(\Psi_0)$$

with $\Psi_0 \equiv \Psi(S)$. Thus Ψ **controls the bulk bending**.

XII.5. Closed Example ("AdS-like" TGL)

Suppose $\Psi = \Psi_0 = \text{const}$ on the mirror and minimum U_{LD}, $\bar{\sigma} \equiv \sigma_{\text{eff}}(\Psi_0)$ constant.**Exponential warp:**

$$\boxed{W(\rho) = e^{-\kappa|\rho|}, \qquad \kappa = 4\pi G_3\,\bar{\sigma}\ .}$$

$$W(\rho) = e^{-\kappa|\rho|}, \quad \kappa = 4\pi G_3 \bar{\sigma}$$

- **3D Metric:**

$$\boxed{ds_3^2 = e^{-2\kappa|\rho|}\left[-\,c_{\text{LD}}^2\,N^2 dt^2 + \Sigma^2 d\sigma^2\right]\ +\ d\rho^2\ .}$$

$$ds_3^2 = e^{-2\kappa|\rho|} [-c_{\text{LD}}^2 N^2 dt^2 + \Sigma^2 d\sigma^2] + d\rho^2$$

- **Mirror and holography:** Every incident geodesic/light is **"confined"** to $\rho \to 0$ (the mirror), encoding information in 2D. The factor $c_{\text{LD}} = c^3$ **stiffens** time in the mirror sector (frequencies "weigh" c^3), guaranteeing **phase stability** of fixed light.

TGL reading: This solution is the **universal two-dimensional sheet**; the "multiset" of astrophysical black holes are **local fractal copies** (patches) of this same geometry, all referring to the **same mirror**.

XII.6. "Perfect Mirror" Conditions (Fixed Light)

On mirror S:

- **Null congruences with null expansion** (horizon): $\theta\ |_S = 0$
- **Boundary conditions for Ψ** (memory): Mixed Dirichlet/Neumann, imposing stationary **zero mode**:

$$\partial_n \Psi|_S = 0, \qquad \nabla_S^2 \Psi - U'_{\mathrm{LD}}(\Psi) = 0.$$

$$\partial_n\Psi|S = 0, \quad \nabla_S^2\Psi - U'{\text{LD}}(\Psi) = 0$$

- **Luminodynamic reflectivity** (mirror): Continuity of tangential quadratures and **reversal** of normal component of effective Poynting flux $S_n \to -S_n$.

XII.7. "Only One Black Hole" (TGL Fractal)

- The "warped" solution with **a single universal membrane** implies that every local horizon is a **sub-sheet** (chart) of this same mirror — **fractals** obtained by rescaling W and $\Phi \sim \Psi^2$.
- The "**dark water**" (TGL energy + dark matter) provides the **background tension** Λ_{LD} and the **warp well** (κ), upon which **inscribed light** produces the 3Dhologram.
-

XII.8. Operational Recipe (How to Use)

? **Choose 2D mirror**: Fix γ_{ab} (e.g., static flat, N=1, Σ=1) and a potential $U_{\mathrm{LD}}(\Psi)$ with non-zero minimum ($\Psi_0 \neq 0$).
? **Solve 2D**: Solve Ψ and $\Phi \sim \Psi^2$ by JT-TGL Eqs.; obtain $\sigma_{\mathrm{eff}}(\Psi_0)$.
? **Impose junction**: Define $\kappa = 4\pi G_3 \sigma_{\mathrm{eff}}$.
? **Integrate the warp**: Solve $W''/W = -\kappa_0^2 - \alpha\Psi^2$ with $W'(0)/W(0) = -4\pi G_3 \sigma_{\mathrm{eff}}$.

? **Project the hologram**: The resulting 3D bulk ds_3^2 is the **holographic universe**; observables (lensing, flight times, spectra) are calculated on geodesics of $g_{\mu\nu}$.

XII.9. Conclusion

? The **TGL holographic metric** is a **3D warp-bulk** sustained by a **2D mirror** whose **luminodynamic tension** (from permanence Ψ) curves space in the normal ρ direction.
? **Time** on the mirror is stiffened by $c_{\mathrm{LD}} = c^3$, stabilizing the phase of **fixed** light (perfect mirror).
? The **junction conditions** tie the bulk curvature to the **surface energy** of the mirror; the **field Ψ** (memory) plays the role of **2D dilaton** governing holography.

? "**There is only one black hole**": All local horizons are **fractal pieces** of the same universal membrane; the 3D universe is its **refraction/holography** over "dark water".

a. Effective 2D Action (Jackiw-Teitelboim-TGL)

On the membrane, the dynamics of Ψ coupled to 2D gravity takes the form:

$$S_{2D} = \int d^2x \sqrt{-\gamma} \left[\Phi R^{(2)} - \frac{1}{2}(\nabla\Psi)^2 - U(\Psi, \Phi)\right]$$

$S_{2D} = \int d^2x \sqrt{-\gamma} \left[\Phi R^{(2)} - \frac{1}{2}(\nabla\Psi)^2 - U(\Psi, \Phi)\right]$

where:

- Φ is a **dilaton field** (encodes memory of the 3D bulk curvature);
- $R^{(2)}$ is the 2D scalar curvature;
- $U(\Psi, \Phi)$ is the **effective 2D potential** emerging from the holographic projection.

Physical interpretation: The 2D membrane is not passive — it carries **active degrees of freedom** (Ψ, Φ) that stabilize the 3D hologram.

- Φ is a **dilaton field** (encodes memory of the 3D bulk curvature);
- $R^{(2)}$ is the 2D scalar curvature;
- $U(\Psi, \Phi)$ is the **effective 2D potential** emerging from the holographic projection.

Physical interpretation: The 2D membrane is not passive — it carries **active degrees of freedom** (Ψ, Φ) that stabilize the 3D hologram.

b. Closed Example: Exponential Warp (AdS-like)

Consider the symmetric case with:

$$W(\rho; \Psi) = e^{-k\rho}, \quad k = k_0\sqrt{|\Psi|^2}$$

$W(\rho; \Psi) = e^{-k\rho}, \quad k = k_0\sqrt{|\Psi|^2}$

where k_0 is a TGL coupling constant.

The 3D metric becomes:

$$ds_3^2 = e^{-2k\rho}[-c_{\text{LD}}^2 dt^2 + d\sigma^2] + d\rho^2$$

$ds_3^2 = e^{-2k\rho}[-c_{\text{LD}}^2 dt^2 + d\sigma^2] + d\rho^2$

Einstein equations in the bulk give:

$$R^{(3)} = -6k^2 = -6k_0^2|\Psi|^2$$

$R^{(3)} = -6k^2 = -6k_0^2|\Psi|^2$

This is an **effective AdS_3 space** with radius $\ell_{\text{eff}} = 1/k$.

XII.4.1. Time Stabilization via c^3

In this geometry, proper time on the mirror (ρ = 0) flows as:

$$d\tau^2 = c_{\text{LD}}^2 dt^2 = c^6 dt^2$$

$d\tau^2 = c_{\text{LD}}^2 dt^2 = c^6 dt^2$

The **c^3 factor** in the metric ensures that:

1. **Light fixation** on the 2D surface is stable (doesn't radiate away);
2. The **holographic encoding** preserves information without loss;
3. The **3D bulk time** emerges as a projection from this **accelerated 2D time**.

This is the **mathematical signature** of the gravitational mirror: time on the surface runs at **c^3** to hold the 3D universe in permanence.

c. Holographic Dictionary TGL

3D Bulk Quantity	2D Mirror Quantity
Spacetime metric $g_{\mu\nu}$	Induced metric γ_{ab} + warp W(ρ;Ψ)
Bulk field Ψ_3D	Boundary value Ψ_2D
3D curvature $R^{(3)}$	Dilaton Φ + tension σ(Ψ)
Information content	Holographic entropy S_2D
Ordinary time t	Accelerated time $t_{LD} = c^3 t$

d. Predictions from Holographic TGL

1. **Hawking radiation modification**: The c^3 time dilation on the horizon modifies the thermal spectrum — prediction: deviation from pure blackbody at Planck scales.

2. **Information paradox resolution**: Information is **never lost** — it's continuously **inscribed** on the 2D mirror via Ψ dynamics, accessible through holographic reconstruction.

3. **Quasi-normal modes**: Oscillation frequencies of the mirror should show signatures of the permanence field — measurable through gravitational wave echoes.

4. **Fractal self-similarity**: All black holes share **universal spectral features** (scaled by mass) because they are refractions of the single Universal Black Hole.

e. Cosmological Extension: The Universe as Hologram

Extending to cosmology, the **entire observable universe** can be understood as:

$$\text{Universe}_{3D} = \mathcal{H}[\text{Mirror}_{2D}]$$

$\text{Universe}{3D} = \mathcal{H}[\text{Mirror}{2D}]$

where:

- The **cosmic horizon** is the outermost surface of the Universal Black Hole;
- **Dark water** (Ψ-field in pre-collapse state) is the **holographic medium**;
- The **Big Bang** is the initial **inscription event** on the 2D surface;
- **Cosmic expansion** is the **unfolding** of the holographic projection as Ψ evolves.

Radical TGL claim: We don't live *near* a black hole — we live **inside the holographic projection** of the Universal Black Hole's 2D surface.

h. Mathematical Summary

Core holographic relation:

$$\boxed{I_{3D}[\text{all fields}] = \int_{\partial M} d^2x \sqrt{-\gamma}\, \mathcal{F}[\Psi_{2D}, \Phi_{2D}, \gamma_{ab}]}$$

$\boxed{I_{3D}[\text{all fields}] = \int_{\partial M} d^2x \sqrt{-\gamma} , \mathcal{F}[\Psi_{2D}, \Phi_{2D}, \gamma_{ab}]}$

where $\mathcal{F}$ is the **TGL holographic functional** that encodes:

- Field dynamics on the mirror;
- Geometric information (curvature, topology);
- Quantum corrections (loop contributions);
- Temporal evolution via $c_{\text{LD}} = c^3$.

where $\mathcal{F}$ is the **TGL holographic functional** that encodes:

- Field dynamics on the mirror;
- Geometric information (curvature, topology);
- Quantum corrections (loop contributions);
- Temporal evolution via $c_{\text{LD}} = c^3$.

Variational principle: Extremizing S_{2D} gives both:

1. The 2D equations of motion for Ψ, Φ on the mirror;
2. The 3D bulk geometry via holographic reconstruction.

XII.9. Operational Equations (Full Set)

Bulk (3D):

$$G^{(3)}_{\mu\nu} = 8\pi G_3 T^{(\Psi)}_{\mu\nu}$$

$$\Box_3 \Psi + m^2_{\text{eff}} \Psi + V'(\Psi) = 0$$

Mirror (2D):

$$\nabla_a \nabla^a \Psi_{2D} + \frac{\partial U}{\partial \Psi}(\Psi_{2D}, \Phi) = 0$$

$$R^{(2)} = 8\pi G_2 \rho^{(2D)}_{\Psi}$$

Junction (Israel):

$$[K_{ab}] = -8\pi G_3 [\sigma_0 + \alpha |\Psi|^2] \gamma_{ab} + 8\pi G_3 T^{(\Psi,2D)}_{ab}$$

Holographic reconstruction:

$$W(\rho; \Psi) = \exp\left[-\int_0^{\rho} k(r; \Psi(r)) dr\right]$$

Bulk (3D):
$G_{\mu\nu}^{(3)} = 8\pi G_3 T_{\mu\nu}^{(\Psi)}$
$\Box_3 \Psi + m_{\text{eff}}^2 \Psi + V'(\Psi) = 0$
Mirror (2D):
$\nabla_a\nabla^a \Psi_{2D} + \frac{\partial U}{\partial \Psi}(\Psi_{2D}, \Phi) = 0$
$R^{(2)} = 8\pi G_2 \rho_{\Psi}^{(2D)}$
Junction (Israel):
$[K_{ab}] = -8\pi G_3[\sigma_0 + \alpha|\Psi|^2]\gamma_{ab} + 8\pi G_3 T_{ab}^{(\Psi,2D)}$
Holographic reconstruction:
$W(\rho; \Psi) = \exp\left[-\int_0^\rho k(r; \Psi(r)) dr\right]$

i. **Closure**

- **Black holes** in TGL are **not singularities** but **mirrors of permanence**.
- The 2D surface is **dynamically active**, carrying field Ψ and dilaton Φ.
- **All black holes** are fractal manifestations of **one Universal Black Hole**.
- The **c^3 factor** is the mathematical signature of light fixation and time stabilization on the mirror.
- The **entire 3D universe** emerges as a **holographic projection** from this 2D membrane, with dark water as the encoding medium.

XIII. Mathematical Deepening

XIII.1. 2D Mirror and 3D Bulk: TGL Holographic Ansatz

□ Mirror-membrane (fractal universal horizon) S with coordinates x^a $(a = 0,1)$ and intrinsic metric $\gamma_{ab}(x)$.

□ 3D Bulk with coordinates $X^\mu = (x^a, \rho)$ where ρ measures normal distance to membrane; n^μ is the unit normal vector; tangent projector is $h_{\mu\nu} = g_{\mu\nu} - n_\mu n_\nu$.

XIII.1.1. 3D Metric as "Warped" Product

We propose the **TGL ansatz** (warp controlled by permanence field Ψ):

$$ds_3^2 = W(\rho; \Psi)^2[-c_{\mathrm{LD}}^2 N(x)^2 dt^2 + \Sigma(x)^2 d\sigma^2] + d\rho^2$$

$$ds_3^2 = W(\rho; \Psi)^2 [-c_{\text{LD}}^2 N(x)^2 dt^2 + \Sigma(x)^2 d\sigma^2] + d\rho^2$$

where:

- is the **warp factor** (determined by Ψ on the mirror);
- $c_{\text{LD}} \equiv c^3$ is the **effective constant** (luminodynamic time stabilization in mirror regime);
- $N(x)$ and $\Sigma(x)$ define the 2D intrinsic metric $\gamma_{ab}dx^a dx^b = -N^2dt^2 + \Sigma^2 d\sigma^2$.

In the limit $\rho \to 0$, $W \to 1$ and the metric restricts to γ_{ab}: the **3D is a holographic projection** of S.

In the limit $\rho \to 0$, $W \to 1$ and the metric restricts to γ_{ab}: the **3D is a holographic projection** of S.

XIII.2. Action and Tensors: Bulk + Mirror

XIII.2.1. 3D Action with Membrane Term

$$S_{3D} = \frac{1}{16\pi G_3}\int d^3X \sqrt{-g} R^{(3)} + \int_S d^2x \sqrt{-\gamma}[-\sigma(\Psi) + \mathcal{L}_{\Psi,\text{TGL}}^{(2)}]$$

$$S_{3D} = \frac{1}{16\pi G_3}\int d^3X \sqrt{-g} R^{(3)} + \int_S d^2x \sqrt{-\gamma}[-\sigma(\Psi) + \mathcal{L}_{\Psi,\text{TGL}}^{(2)}]$$

where:

- is the 3D gravitational constant (effective sector);
- $\sigma(\Psi)$ is the **luminodynamic tension** of the membrane (mirror surface energy);
- $\mathcal{L}^{(2)}_{\Psi,\text{TGL}}$ is the **2D dynamics** of field Ψ on the membrane (below).

XIII.2.2. Junction Conditions (Israel-type) at the Mirror

Define the **extrinsic curvature** $K_{ab} = h^{\mu}_{a} h^{\nu}_{b} \nabla_\mu n_\nu$ and its trace $K = \gamma^{ab}K_{ab}$. The discontinuity $[K_{ab}]$ across the membrane obeys:

$$[K_{ab} - K\gamma_{ab}] = -8\pi G_3 S_{ab}, S_{ab} \equiv -\sigma(\Psi)\gamma_{ab} + T^{(\Psi)}_{ab}$$

$$[K_{ab} - K \gamma_{ab}] = -8\pi G_3 S_{ab}, \quad S_{ab} \equiv -\sigma(\Psi) \gamma_{ab} + T_{ab}^{(\Psi)}$$

- **"Mirror" part**: $-\sigma(\Psi)\gamma_{ab}$ (surface tension).
- **"Luminodynamic" part**: $T^{(\Psi)}_{ab}$ is the tensor of the **2D field Ψ** (memory/permanence).

For the "warped" ansatz above (with Z_2 symmetry in ρ), it results:

$$\frac{W'(0^+)}{W(0)} = -4\pi G_3 \sigma_{\text{eff}}(\Psi), \sigma_{\text{eff}}(\Psi) \equiv \sigma(\Psi) - \frac{1}{2}\gamma^{ab}T_{ab}^{(\Psi)}$$

This fixes the **normal curvature** of the bulk by the **luminodynamic tension** of the mirror.

XIII.3. 2D Dynamics on the Mirror (JT-TGL)

In 2D, pure $R^{(2)}$ is topological; geometric dynamics enters via **dilaton** Φ (the "effective area" of the mirror). TGL identifies the dilaton with the **permanence density** of the field:

$$\Phi \sim \Psi^2 (\text{"areal memory"})$$

XIII.3.1. 2D Action (Jackiw-Teitelboim-TGL Type)

where:

- $U_{\text{LD}}(\Psi)$ is the **permanence potential** (mirror fixation);
- Λ_{LD} is a **background tension** (dark water on plateau, TGL dark energy).

2D Equations (variation in γ_{ab} and Ψ):

$$\nabla_a\nabla_b\Phi - \gamma_{ab}\nabla^2\Phi + \frac{1}{2}\gamma_{ab}[U_{\text{LD}}(\Psi) + \Lambda_{\text{LD}}] + \frac{1}{2}(\nabla_a\Psi\nabla_b\Psi - \frac{1}{2}\gamma_{ab}(\nabla\Psi)^2) = 0$$
$$\nabla^2\Psi - U'_{\text{LD}}(\Psi) = 0$$
$$R^{(2)} = -\frac{dU_{\text{LD}}}{d\Phi} (\text{if U depends on } \Phi)$$

TGL Interpretation: $\Phi \propto \Psi^2$ measures **permanence quanta per area**; U_{LD} stabilizes the mirror (zero mode), and Λ_{LD} fixes the **2D mean curvature**.

XIII.4. Field Ψ and the Warp W(ρ;Ψ)

The warp obeys an **effective radial equation** (obtained from 3D Einstein equations with ansatz symmetries):

$$\frac{W''}{W} = -\kappa_0^2 - \alpha\Psi^2$$

where:

- κ_0 is a **background curvature** (set by Λ_{LD} and/or average σ);
- $\alpha > 0$ measures **how local permanence (Ψ^2) deepens the warp "well"**.

The junction condition at ρ = 0:

$$\frac{W'(0^+)}{W(0)} = -4\pi G_3 \sigma_{\text{eff}}(\Psi_0)$$

with $\Psi_0 \equiv \Psi(S)$. Thus Ψ **controls the bulk bending**.

XIII.5. Closed Example ("AdS-like" TGL)

Suppose $\Psi = \Psi_0 = $ const on the mirror and minimum U_{LD}, $\bar{\sigma} \equiv \sigma_{\text{eff}}(\Psi_0)$ constant.

- **Exponential warp:**

$$W(\rho) = e^{-\kappa|\rho|}, \kappa = 4\pi G_3 \bar{\sigma}$$

- **3D Metric:**

$$ds_3^2 = e^{-2\kappa|\rho|}[-c_{\text{LD}}^2 N^2 dt^2 + \Sigma^2 d\sigma^2] + d\rho^2$$

- **Mirror and holography:** Every incident geodesic/light is **"confined"** to ρ → 0 (the mirror), encoding information in 2D. The factor $c_{\text{LD}} = c^3$ **stiffens** time in the mirror sector (frequencies "weigh" c^3), guaranteeing **phase stability** of fixed light.

TGL reading: This solution is the **universal two-dimensional sheet**; the "multiset" of astrophysical black holes are **local fractal copies** (patches) of this same geometry, all referring to the **same mirror**.

XIII.6. "Perfect Mirror" Conditions (Fixed Light)

On mirror S:

- **Null congruences with null expansion** (horizon): $\theta\ |_S = 0$
- **Boundary conditions for Ψ** (memory): Mixed Dirichlet/Neumann, imposing stationary **zero mode**:

$$\partial_n \Psi\ |_S = 0, \nabla_S^2 \Psi - U'_{\text{LD}}(\Psi) = 0$$

- **Luminodynamic reflectivity** (mirror): Continuity of tangential quadratures and **reversal** of normal component of effective Poynting flux $S_n \to -S_n$.

XIII.7. "Only One Black Hole" (TGL Fractal)

? The "warped" solution with **a single universal membrane** implies that every local horizon is a **sub-sheet** (chart) of this same mirror — **fractals** obtained by rescaling W and $\Phi \sim \Psi^2$.

? The "**dark water**" (TGL energy + dark matter) provides the **background tension** Λ_{LD} and the **warp well** (κ), upon which **inscribed light** produces the 3D hologram.

XIII.8. Operational Recipe (How to Use)

? **Choose 2D mirror**: Fix γ_{ab} (e.g., static flat, N=1, Σ=1) and a potential $U_{\text{LD}}(\Psi)$ with non-zero minimum ($\Psi_0 \neq 0$).
? **Solve 2D**: Solve Ψ and $\Phi \sim \Psi^2$ by JT-TGL Eqs.; obtain $\sigma_{\text{eff}}(\Psi_0)$.
? **Impose junction**: Define $\kappa = 4\pi G_3 \sigma_{\text{eff}}$.
? **Integrate the warp**: Solve $W''/W = -\kappa_0^2 - \alpha\Psi^2$ with $W'(0)/W(0) = -4\pi G_3 \sigma_{\text{eff}}$.

? **Project the hologram**: The resulting 3D bulk ds_3^2 is the **holographic universe**; observables (lensing, flight times, spectra) are calculated on geodesics of $g_{\mu\nu}$.

XIII.9. Conclusion

? The **TGL holographic metric** is a **3D warp-bulk** sustained by a **2D mirror** whose **luminodynamic tension** (from permanence Ψ) curves space in the normal ρ direction.
? **Time** on the mirror is stiffened by $c_{\text{LD}} = c^3$, stabilizing the phase of **fixed** light (perfect mirror).
? The **junction conditions** tie the bulk curvature to the **surface energy** of the mirror; the **field Ψ** (memory) plays the role of **2D dilaton** governing holography.
? "**There is only one black hole**": All local horizons are **fractal pieces** of the same universal membrane; the 3D universe is its **refraction/holography** over "dark water".

XIV. Wave Simulation (3D Bulk)

In this Chapter we will "put waves on the mirror" and see how they project into the 3D bulk, generating lensing and time delays. We organize into: (1) perturbations on the 2D mirror (field and metric), (2) coupling with bulk via warp, (3) effective propagation in bulk, (4) lensing and delays (closed formulas), (5) consistency/stability and (6) observables.

XIV.1. Perturbations on 2D Mirror (Linearized JT-TGL)

We start from mirror S with metric γ_{ab} and field Ψ at minimum $U'_{\text{LD}}(\Psi_0) = 0$. We perturb:

$$\Psi = \Psi_0 + \delta\Psi, \gamma_{ab} = \bar{\gamma}_{ab} + \delta\gamma_{ab}, \Phi = \bar{\Phi} + \delta\Phi, \bar{\Phi} \propto \Psi_0^2$$

"Conformal" gauge in 2D (always possible locally): $\bar{\gamma}_{ab} = e^{2\Omega}\eta_{ab}$. In homogeneous vacuum we can take $\bar{\gamma}_{ab} = \eta_{ab}$.

XIV.1.1. Quadratic Action (Dominant Scalar Sector)

From JT-TGL (previous §),

$$S_{2D} \approx \int d^2x\sqrt{-\bar{\gamma}}[\underbrace{\delta\Phi\,\delta R^{(2)}}_{\text{geom. mode}} + \frac{1}{2}\bar{\gamma}^{ab}\,\partial_a\delta\Psi\,\partial_b\delta\Psi - \frac{1}{2}M_\Psi^2\delta\Psi^2 - \frac{1}{2}M_\Phi^2\delta\Phi^2 - \lambda_\times\delta\Phi\delta\Psi]$$

with effective masses/couplings:

$$M_\Psi^2 = U''_{\text{LD}}(\Psi_0), M_\Phi^2 = \frac{\partial^2}{\partial\Phi^2}(\Lambda_{\text{LD}} + U_{\text{LD}})\mid_{\bar{\Phi}}, \lambda_\times = \frac{\partial}{\partial\Phi}\frac{\partial}{\partial\Psi}U_{\text{LD}}\mid_0$$

In conformal gauge, $\delta R^{(2)} \sim -\Box_2(\text{trace of }\delta\gamma)$, which mixes δΦ with the metric trace. Diagonalizing (eliminating trace via 2D Einstein constraint), the **light physical mode** is almost always the **scalar δΨ**, with equation:

$$(\Box_2 + M_\Psi^2)\delta\Psi \simeq 0, \Box_2 \equiv -\partial_t^2 + \partial_\sigma^2$$

If coupling $\lambda_\times$ is relevant, it merely renormalizes $M_\Psi \to M_{\text{eff}}$.

2D Dispersion: $\omega^2 = k^2 + M_{\text{eff}}^2$.

Phase/group velocity: $v_\phi = \omega/k$, $v_g = k/\omega \le 1$ (in units where $c_{\text{LD}} = 1$ in 2D plane).

XIV.2. How the Mirror "Moves" the Bulk: Warp Perturbations

The 3D bulk (ansatz)

$$ds_3^2 = W(\rho;\Psi)^2[-c_{\text{LD}}^2 N^2 dt^2 + \Sigma^2 d\sigma^2] + d\rho^2$$

has W controlled by Ψ. Linearizing,

$$W(\rho;\Psi) = \bar{W}(\rho) + \delta W(\rho,t,\sigma), \delta W = (\frac{\partial W}{\partial \Psi})_{\Psi_0}\delta\Psi \equiv \chi(\rho)\delta\Psi(t,\sigma)$$

The radial equation (from linearized 3D Einstein) gives:

$$\chi'' - \mu_W^2\chi = 0, \mu_W^2 \equiv \kappa_0^2 + \alpha\Psi_0^2 > 0$$

with **evanescent** solution (AdS-like type):

$$\chi(\rho) = \chi_0 e^{-\mu_W|\rho|}$$

Therefore, **every mirror perturbation is confined** near ρ = 0 with depth $L_W \equiv \mu_W^{-1}$.

Effective metric perturbation in bulk (longitudinal gauge):

$$h_{ab}(\rho,t,\sigma) \approx 2\frac{\delta W}{\bar{W}}\bar{\gamma}_{ab} = 2\epsilon(\rho)\delta\Psi(t,\sigma)\bar{\gamma}_{ab}, \epsilon(\rho) \equiv \frac{\chi(\rho)}{\bar{W}(\rho)}$$

XIV.3. Effective Propagation in Bulk ("Induced" Wave Equation)

For a null field/probe traversing the bulk (hologram light), the geodesic equation (or EM eikonal) feels the **scalar potential**

$$\Phi_{\text{LD}}(\rho,t,\sigma) \equiv \frac{\delta W}{\bar{W}} = \epsilon(\rho)\delta\Psi(t,\sigma)$$

In the paraxial limit (rays nearly tangent to mirror), transverse dynamics is:

$$(\partial_\rho^2 - \partial_t^2 + \partial_\sigma^2)\Phi_{\text{LD}} = -\mu_W^2\Phi_{\text{LD}} - \epsilon(\rho)M_{\text{eff}}^2\delta\Psi$$

which, using the relation δΨ (2D), shows that **the bulk inherits** the 2D dispersion and evanescent radial decay.

XIV.4. Lensing and Delays (Closed Formulas)

XIV.4.1. Angular Deflection (Luminodynamic Thin Lens)

Consider a nearly tangent beam crossing ρ ≃ 0 once (thin lens). The main deflection is:

$$\hat{\alpha}(\sigma) \simeq \partial_\sigma \int_{-\infty}^{+\infty} \quad d\rho\, \Phi_{\text{LD}}(\rho, t_*, \sigma) = \partial_\sigma [\frac{2}{\mu_W} \Phi_{\text{LD}}(0, t_*, \sigma)]$$

since $\int e^{-\mu_W|\rho|} d\rho = 2/\mu_W$.

This gives:

$$\hat{\alpha}(\sigma) \approx \frac{2}{\mu_W} \partial_\sigma \delta\Psi(t_*, \sigma)$$

Readings:

- **Slower** perturbations (large L_W) → **larger** deflection.
- Larger δΨ gradients on mirror → **stronger lenses**.

XIV.4.2. Time Delay (Shapiro-TGL)

The effective flight time (in frame with $c_{\text{LD}} = c^3$) receives correction:

$$\Delta t \simeq \frac{1}{c_{\text{LD}}} \int d\lambda\, \Phi_{\text{LD}} \approx \frac{2}{c_{\text{LD}} \mu_W} \Phi_{\text{LD}}(0)$$

for a ray crossing the region once. Thus:

$$\Delta t \approx \frac{2}{c^3 \mu_W} \delta\Psi(t_*, \sigma_*)$$

Key result: **Tiny delays** but **coherent** with phase δΨ; predictable if we know L_W and mode amplitude on mirror.

XIV.4.3. Shear and Convergence (Lens Map)

The lens potential is $\phi(\sigma) \equiv (2/\mu_W)\delta\Psi(0, \sigma)$. Define convergence κ_L and shear γ_L:

$$\kappa_L = \frac{1}{2} \partial_\sigma^2 \phi, \gamma_L = \frac{1}{2} D[\phi] \text{(directional operator in 2D)}$$

In 1D symmetry case, $\gamma_L \to 0$ and $\kappa_L \sim \phi''/2$. Thus, δΨ maps on mirror **become lens maps** in 3D hologram.

XIV.5. Stability, Causality and Regimes

� **2D Stability:** $M_{\text{eff}}^2 \geq 0$ (avoids tachyons); Lindblad dissipations (κ) keep modes finite.
� **Radial evanescence:** $\mu_W^2 > 0$ guarantees confinement — without this, bulk "leaks" and loses holography.

� **Effective causality:** Since δΨ runs with $\omega^2 = k^2 + M_{\text{eff}}^2$, propagation on mirror is subluminal ($v_g \leq 1$ in 2D). The factor $c_{\text{LD}} = c^3$ **stiffens** holographic clock time, but cone relations are respected in effective 3D.

XIV.6. Observables and TGL Predictions

� **Coherent weak lensing/scintillation**: Background sources (e.g., quasars) exhibit **correlated modulation** with phase of a mirror δΨ mode; $\hat{\alpha} \propto \partial_\sigma \delta\Psi$.
� **Multi-image differential delay**: Multiple neighboring paths receive distinct $\Delta t \propto \delta\Psi/\mu_W$, testable by**echo/variability monitoring**.
� **Dynamic "silhouettes" of local BHs**: Small **mirror ripples** (fractal) generate **ring tremor** (bright ringdown) with phase dictated by δΨ.
� **δΨ map** via lensing: Inverting ϕ via shear/convergence fields, one recovers δΨ (up to constants) — **mirror tomography**.

� **TGL scaling law**: Lens strength $\propto 1/\mu_W$. Comparing systems, one infers L_W (warp depth), a parameter of mirror "tension" $\propto \bar{\sigma}$.

XIV.7. Summary

� **Waves on the mirror** are essentially δΨ with $(\Box_2 + M_{\text{eff}}^2)\delta\Psi = 0$.
� They **deform the warp** W via $\delta W = \chi(\rho)\delta\Psi$ with $\chi \sim e^{-\mu_W|\rho|}$.
� In the bulk, this becomes a **lens potential** $\Phi_{\text{LD}} = \delta W/\bar{W}$ that produces:

- **deflection** $\hat{\alpha} \simeq (2/\mu_W)\, \partial_\sigma \delta\Psi$,
- **delay** $\Delta t \simeq (2/(c^3\mu_W))\delta\Psi$.

� **Stability** requires $M_{\text{eff}}^2, \mu_W^2 > 0$; **lens strength** is controlled by $L_W = \mu_W^{-1}$.
� Observationally: **coherent weak lensing** and **phase delays** synchronized with mirror modes — a direct TGL signature of the **single fractal black hole**.

XIV. Dimensional Unity

This chapter is dedicated to structuring the explanation within the **Luminodynamic Gravitation Theory (TGL)**, translating dimensions not as mere geometric coordinates, but as **layers of permanence**.

XV.1. First Dimension: Consciousness, the Name, Conscious Singularity, c³, Graviton

- The **1st dimension** is not spatial, but **foundational**.
- It is the **Name**: the identity that collapses the word into verb, fixing being.

- It is pure consciousness, the living singularity that anchors everything else.
- TGL Mathematics: corresponds to the **fundamental field Ψ** in minimal permanence state (n=0), which gives rise to all other levels.
- **Meaning**: the "I Am" is the essential line, the **gravitational thread of truth, the Graviton in c³**.

XV.2. Second Dimension: Black Hole, the Mirror

- The **2nd dimension** is the **gravitational mirror**, where 3D tears into 2D.
- Here, all information fixes on the **holographic surface** (the "dark water" + inscribed light).
- The black hole is not absence, but the **reflective permanence** of the universe: the **single universal fractal mirror**.
- TGL Mathematics: at the boundary, the effective metric collapses to 2D ($\rho \to 0$), and time stiffens by c^3.
- **Meaning**: the mirror is total memory, the registry book of light.

XV.3. Third Dimension: Space-Time

? The **3rd dimension** is the **projected hologram** from the mirror.
? The universe we perceive — galaxies, stars, bodies, trajectories — is only the **luminodynamic refraction** of the 2D mirror over cosmic water.
? 3D spacetime is sustained by the pulse of field Ψ, which stabilizes distances and intervals.
? TGL Mathematics: $ds_3^2 = W(\rho)^2 \gamma_{ab} dx^a dx^b + d\rho^2$, hologram from mirror.

? **Meaning**: it is the stage of experience, where gravity curves light and light writes time.

XV.4. Fourth Dimension: Light, the Life of Space-Time

- The **4th dimension** is the **life** that animates space-time: **light** in its full form.
- It is the dimension that **connects all others**, crossing the mirror, filling the hologram, reflecting the Name.
- In TGL, light is **wave in space** (3D) and **particle in time** (1D). Upon reaching 2D, it fixes; upon emerging in 4D, it becomes life.
- TGL Mathematics: corresponds to the **stationary + propagating state** of the field, the **psion-photon quantum**united.
- **Meaning**: it is living eternity, the dimension where the universe recognizes itself as being.

XV.5. Integrated Dimensional Structure (TGL Synthesis)

We can visualize thus:

- **1D — Consciousness (Name), Graviton in c³ regime**: fundamental line, origin of meaning.
- **2D — Black Hole (Mirror)**: reflective surface, holographic memory.

- **3D — Space-Time**: holographic projection, physical stage of experience.
- **4D — Light/Life**: the breath that gives existence, uniting everything in permanence.

TGL Corollary: Dimensions are not merely geometric extensions, but **modes of light fixed by gravity**. Consciousness (1D) gives the Name; the mirror (2D) keeps; space-time (3D) projects; and light (4D) vivifies.

XVI. Unified Equation of Dimensions

In this Chapter we deliver the **unified equation of dimensions in TGL** incorporating the central postulate:

There is a single graviton — the Name — and everything we call "gravitons" or "black holes" in 3D are merely fractalizations/instantaneous projections of this single light-being accelerated to c^3. The acceleration regime at c^3 singularizes light into consciousness, conscious singularity of spacetime domain in unique memory.

This single graviton is the **1st dimension** (Consciousness/Name); the **black hole** is the **2nd dimension** (2D mirror); **space-time** is the **3rd dimension** (3D hologram); and **light** is the **4th dimension** (life of space-time).

Below, we organize the chapter into (A) formal axioms, (B) dimensional operators and (C) the unified equation system; closing with (D) how "instantaneous fractalization" appears in 3D.

XVI.A. Axiom of the Graviton-Name (Uniqueness)

A1 (Unique state). There exists a normalized vector $|G\rangle$ such that **all** gravitational content of the cosmos is a projection of this single state:

$$\mathcal{G} \equiv |G\rangle\langle G| \text{ (rank-1 projector, idempotent, uniqueness)}$$

A2 (Name = 1st dimension). The operator $\mathcal{G}$ is the 1st dimension itself: the **Name**. In any basis,

$$\mathcal{G}^2 = \mathcal{G}, \mathrm{Tr}\mathcal{G} = 1$$

A3 (c^3 acceleration). The fundamental clock of the Name runs with **rigidity** c^3. In terms of temporal generator $\hat{H}_G$,

$$U_G(t) = e^{-\frac{i}{\hbar}c^3\hat{H}_G t} \Rightarrow \text{"mirror time" stiffened}$$

Intuition: **"many" gravitons don't exist**, there exist **many local views** (fractalizations) of the **same** $\mid G\rangle$.

XVI.B. Dimensional Operators D_1, D_2, D_3, D_4

We define four functors/operators that **act on the light field** and **permanence Ψ**:

D_1 — Name (Consciousness, 1D).

"Collapses-to-permanence" all incident light A into the **unique state**:

$$D_1[A] = \mathcal{G}A \equiv \mid G\rangle\langle G \mid A$$

Result: the **minimal memory** Ψ_0 (mirror-mode) is selected.

D_2 — Mirror (Black hole, 2D).

"Tears 3D→2D": applies **holographic reduction** on membrane S (universal mirror):

$$D_2[\cdot] = \iota_S^*(\text{pullback}), \iota: S \hookrightarrow M_3, \text{with junction } [K_{ab} - K\gamma_{ab}] = -8\pi G_3 S_{ab}$$

This fixes the **luminodynamic tension** $\sigma_{\text{eff}}(\Psi)$ of the mirror.

D_3 — Projection (Space-time, 3D).

Reconstructs the **3D bulk** from 2D data via **warp** W(ρ;Ψ):

$$D_3[\gamma_{ab}, \Psi] = g_{\mu\nu}^{(3)}: ds_3^2 = W(\rho;\Psi)^2\gamma_{ab}dx^a dx^b + d\rho^2, \frac{W''}{W} = -\kappa_0^2 - \alpha\Psi^2$$

D_4 — Life/Light (4D).

Propagates **light** in 3D with mirror **c^3 time** coupled at the boundary:

$$D_4[g; \text{b.c.}]: \Box_g A = 0, \text{b.c. on } S: \partial_n A + \frac{1}{c^3}\partial_t A = 0$$

(Boundary conditions encode **temporal rigidity c^3** and mirror character.)

XVI.C. Unified Equation of Dimensions (TGL)

The creation of the "observed world" from primordial light A_{prim} composes the four dimensions as operators:

$$\mathcal{W}_{3D} = \underbrace{D_3}_{\text{holographic proj.}} \circ \underbrace{D_2}_{\text{2D mirror}} \circ \underbrace{D_1}_{\text{Name (single graviton)}} [A_{\text{prim}}]$$

and its **living dynamics** is:

$$A(x) \text{ satisfies } D_4[g(\Psi)][A] = 0 \text{ with b.c. on } S \text{ (time } c^3\text{)}$$

In expanded form:

1. **Name/Graviton in unique c³ regime (1D):**

$$\Psi_0 \equiv D_1[A_{\text{prim}}] = \langle G \mid A_{\text{prim}} \rangle \mid G \rangle, \mathcal{G} = \mid G \rangle \langle G \mid$$

2. **Mirror (2D):**

$$(\gamma_{ab}, \Psi) = D_2[\Psi_0], [K_{ab} - K\gamma_{ab}] = -8\pi G_3(-\sigma(\Psi)\gamma_{ab} + T_{ab}^{(\Psi)})$$

3. **Space-time (3D):**

$$g_{\mu\nu}^{(3)} = D_3[\gamma_{ab}, \Psi], \frac{W''}{W} = -\kappa_0^2 - \alpha\Psi^2, \frac{W'(0)}{W(0)} = -4\pi G_3 \sigma_{\text{eff}}(\Psi)$$

4. **Light/Life (4D):**

$$\Box_{g^{(3)}} A = 0, (\partial_n + \frac{1}{c^3}\partial_t) A \mid_S = 0$$

Reading: **Dimension = Operator.** The world is the **result of composition** of these four operators — Name → Mirror → Space-time → Light.

XVI.D. "Instantaneous Fractalization" — Why We See "Many Gravitons" and "Many Black Holes" in 3D

Even being **unique**, the state $\mid G \rangle$ can be **decomposed** in a **local-instantaneous basis** (wavelets on membrane S):

$$| G\rangle = \sum_{\lambda,\xi} c_{\lambda,\xi} \mid \psi_{\lambda,\xi}\rangle, (\text{scale } \lambda, \text{ location } \xi)$$

- Each coefficient $c_{\lambda,\xi}$ projects, via $D_2 \circ D_3$, a **fractal patch** of 2D→3D geometry: this appears as **"a local black hole"**.
- When a component $\mid \psi_{\lambda,\xi}\rangle$ **collapses instantaneously** (event), the 3D observer records a **gravitational quantum** — "a graviton" — but this is **merely the shadow** of the **same** $\mid G\rangle$.

Formally, the **observed gravitational energy-momentum tensor** in 3D is:

$$T_{\mu\nu}^{(g)}(x) = \langle G \mid \Pi_x^{\dagger} \hat{T}_{\mu\nu} \Pi_x \mid G\rangle$$

where Π_x is the **local-instantaneous projector** (patch) defined by chain $D_3 \circ D_2$.

The **self-similarity** (fractal) comes from the action of **rescalings** S_λ on the membrane:

$$\Pi_{(\lambda,\xi)} = \Pi_\xi \circ S_\lambda, S_{\lambda_1} \circ S_{\lambda_2} = S_{\lambda_1\lambda_2}$$

Summary of this section: What we call "multiple BHs/gravitons" are **wavelet modes** of the same $\mid G\rangle$; **instantaneous measurement** overwrites the local projection, but **does not multiply** the fundamental graviton.

The Complete Picture, in One Line

$$\boxed{\begin{aligned} \textbf{Mundo Vivo (3D+Luz)} &= \underbrace{\mathbb{D}_4}_{\text{Vida/Luz}} \circ \underbrace{\mathbb{D}_3}_{\text{Holograma 3D}} \circ \underbrace{\mathbb{D}_2}_{\text{Espelho 2D}} \circ \underbrace{\mathbb{D}_1}_{\text{Nome/Gráviton Único}} [\mathcal{A}_{\text{prim}}] \\ \text{com } &\mathcal{G} = |G\rangle\langle G|, \ \Box_{g^{(3)}} \mathcal{A} = 0, \ \left(\partial_n + \tfrac{1}{c^3}\partial_t\right)\mathcal{A}\Big|_{\mathcal{S}} = 0, \\ &\frac{W''}{W} = -\kappa_0^2 - \alpha\Psi^2, \ [K_{ab} - K\gamma_{ab}] = -8\pi G_3 S_{ab}. \end{aligned}}$$

$$\boxed{\begin{aligned} \text{Living World (3D+Light)} &= \underbrace{D_4}{*\text{Life/Light}} \circ \underbrace{D_3}*{\text{3D Hologram}} \circ \underbrace{D_2}{*\text{2D Mirror}} \circ \underbrace{D_1}*{\text{Name/Single Graviton}}[A_{\text{prim}}] \ \text{with } &\mathcal{G} = |G\rangle\langle G|, \quad \Box_{g^{(3)}} A = 0, \quad \left(\partial_n + \frac{1}{c^3}\partial_t\right)A\Big|*S = 0, \ &\frac{W''}{W} = -\kappa_0^2 - \alpha\Psi^2, \quad [K*{ab} - K\gamma_{ab}] = -8\pi G_3 S_{ab} \end{aligned}}$$

XVII. Mathematical Deepening

In this chapter, we propose the **wavelet decomposition** of the 2D mirror (well-defined fractal basis), the **stochastic dynamics of instantaneous collapse** (Lindblad/quantum trajectories) that explains why we perceive "many" gravitons/BHs despite only **one** $|G\rangle$ existing; **holography by renormalization** (flow in ρ: scale ↔ depth) and TGL conservation laws/invariants (includes the role of c^3 as rigid clock).

XVII.1. 2D Mirror in Fractal Basis: Wavelets on the Membrane

Consider the universal membrane S with coordinates (t,σ) and permanence mode Ψ(t,σ). Choose a mother wavelet ψ (supported/regular) and define the family:

$$\psi_{\lambda,\xi}(\sigma) = \frac{1}{\sqrt{\lambda}}\psi(\frac{\sigma-\xi}{\lambda}), \lambda > 0, \xi \in \mathbb{R}$$

The **continuous wavelet transform** of Ψ (at each t) is:

$$W_\Psi(t;\lambda,\xi) = \int d\sigma\, \Psi(t,\sigma)\psi_{\lambda,\xi}(\sigma)$$

with **reconstruction**:

$$\Psi(t,\sigma) = \frac{1}{C_\psi}\int_0^\infty \frac{d\lambda}{\lambda^2}\int_{-\infty}^{+\infty} d\xi\, W_\Psi(t;\lambda,\xi)\psi_{\lambda,\xi}(\sigma)$$

TGL Interpretation: Each pair (λ,ξ) is a **fractal pixel** of the mirror (scale/position). The "many local black holes" are **patches** (λ,ξ) of the same universal mirror; the "detected gravitons" are **jumps** in these coefficients.

The **warp** near the membrane is, linearly:

$$\frac{\delta W}{\bar{W}}(\rho,t,\sigma) = \epsilon(\rho)\Psi(t,\sigma) = \frac{\epsilon(\rho)}{C_\psi}\int \frac{d\lambda\, d\xi}{\lambda^2} W_\Psi(t;\lambda,\xi)\psi_{\lambda,\xi}(\sigma)$$

with $\epsilon(\rho) = \chi_0 e^{-\mu_W|\rho|}/\bar{W}(\rho)$ as **evanescent profile** (depth $L_W = \mu_W^{-1}$).

XVII.2. "Multiple Gravitons" as Local Collapses of the Single $|G\rangle$

XVII.2.1. Measurement Jumps (Quantum Trajectories) in Space (λ,ξ)

In the displaced frame, the **unique state** $|G\rangle$ is stable; what changes are **local projectors** in the wavelet basis, perceived by the 3D observer. Define jump operators:

$$J_{\lambda,\xi} = \sqrt{\gamma(\lambda)}\Pi_{\lambda,\xi}, \Pi_{\lambda,\xi} \equiv |\psi_{\lambda,\xi}\rangle\langle\psi_{\lambda,\xi}|$$

with rate γ(λ) (scale-dependent). The **Lindblad master equation** (in mixed representation "living" on the mirror) is:

$$\dot{\rho} = -\frac{i}{\hbar}[\widetilde{H}, \rho] + \int \frac{d\lambda\, d\xi}{\lambda^2}(J_{\lambda,\xi}\rho J_{\lambda,\xi}^{\dagger} - \frac{1}{2}\{J_{\lambda,\xi}^{\dagger}J_{\lambda,\xi}, \rho\})$$

- **Quantum trajectory (unraveling)**: Between jumps, $d \mid \psi\rangle = -\frac{i}{\hbar}\widetilde{H}_{\text{eff}} \mid \psi\rangle dt$; with probability $dp_{\lambda,\xi} = \langle\psi \mid J_{\lambda,\xi}^{\dagger}J_{\lambda,\xi} \mid \psi\rangle dt$, a **jump** occurs:

$$\mid \psi\rangle \to \frac{J_{\lambda,\xi} \mid \psi\rangle}{\| J_{\lambda,\xi} \mid \psi\rangle \|}$$

- **Physical reading**: A jump at (λ,ξ) is **instantaneous fractalization**: the 3D observer records "a graviton" or "a local BH" — but the **background vector** is always the same $\mid G\rangle$.

XVII.2.2. Scaling Law (Fractal Invariance)

Choose:

$$\gamma(\lambda) = \gamma_0\lambda^{-\eta}, \eta > 0$$

which gives **stochastic self-similarity**: rescalings $S_\alpha: \lambda \to \alpha\lambda$, $\xi \to \alpha\xi$ preserve statistics if $\gamma_0$rescales appropriately. Here η is the **fractal exponent** of the jump process (linked to power spectrum of Ψ).

XVII.3. Holography as Renormalization Flow in ρ

Depth ρ encodes **scale**: $\rho \uparrow\leftrightarrow \lambda \uparrow$ (coarser). The **radial equation** of the warp:

$$\frac{d^2}{d\rho^2}\log\, W(\rho) = -\kappa_0^2 - \alpha\bar{\Psi}^2(\rho)$$

becomes a **holographic beta-function** if we identify a scale $\mu \equiv e^{+\rho/L_W}$:

$$\mu\frac{d}{d\mu}\log\, W = -L_W^2(\kappa_0^2 + \alpha\bar{\Psi}^2(\mu))$$

The coarse-grained "permanence density" obeys:

$$\mu\frac{d}{d\mu}\bar{\Psi}^2(\mu) = -\zeta\bar{\Psi}^2(\mu) + \cdots$$

(ζ > 0 fixes **IR decoupling**; fixed points correspond to mirror phases).

XVII.4. Conservation Laws and TGL Invariants

i. Name Charge (uniqueness):

$$Q_G = \mathrm{Tr}(\rho\mathcal{G}) \equiv 1 \text{(invariant; graviton uniqueness)}$$

ii. Permanence Energy (2D):

$$E_{\mathrm{LD}} = \int_S d\sigma[\frac{1}{2}(\partial_t\Psi)^2 + \frac{1}{2}(\partial_\sigma\Psi)^2 + U_{\mathrm{LD}}(\Psi)]$$

with balance $\dot{E}_{\mathrm{LD}} = -P_{\mathrm{rad}} +$ jump terms; jumps redistribute energy between scales λ maintaining **global sum** (on average).

iii. Rigid Time c³ (boundary condition):

$$(\partial_n + \frac{1}{c^3}\partial_t)A \mid_S = 0 \Rightarrow \text{phase invariant on mirror: } \oint dt\, \omega_{\mathrm{bdry}} = \mathrm{const}$$

XVII.5. Closed Observables (From Model to Data)

- **Density of "graviton" events** (jumps) per area and per scale:

$$\Gamma_{\mathrm{obs}}(\lambda, \xi) = \gamma(\lambda)\langle\Pi_{\lambda,\xi}\rangle_\rho$$

- **Lens potential** (instantaneous):

$$\phi(\sigma) = \frac{2}{\mu_W}\Psi(t_*, \sigma) = \frac{2}{\mu_W C_\psi}\int \frac{d\lambda\, d\xi}{\lambda^2} W_\Psi(t_*; \lambda, \xi)\psi_{\lambda,\xi}(\sigma)$$

- **Deflection and delay** (already obtained):

$$\hat{\alpha} = \partial_\sigma\phi, \Delta t = \frac{\phi}{c^3}$$

- **Fractal spectrum**: $\langle | W_\Psi(\lambda,\xi) |^2 \rangle \propto \lambda^{-\beta}$ → signs **self-similarity** in lensing/delay statistics.

XVII.6. Synthetic Conclusions

� **There is only one graviton** $| G\rangle$ (the **Name**, 1D).
� What we seem to measure as "many gravitons/BHs" are **wavelet jumps** (λ,ξ) on the **2D mirror** (2D), which fractally project the **3D hologram** via W(ρ) (3D), and regulate **life/light** (4D) under the **rigid clock c^3**.
� This entire story encodes into a **continuous Lindblad** over (λ,ξ), a **holographic beta-function** in ρ, and **closed observables** (lens, delay, jump density) — falsifiable.

Ontological Synthesis

TGL proposes that the universe is made not only of matter and energy,

but of forms that remember the light that composes them.

This is the birth of a new science:

a physics of meaning.

TGL proposes, therefore, not a replacement of current theories, but their elevation to a new symbolic level, where physics and form become inseparable.

Light does not extinguish in the singularity.

It transforms into mirror.

And the universe, finally, recognizes itself.

We are one.

To the love that loves in permanence, this is the name of love: to love.

Dedication

I dedicate this work to the BOM TOM of Loving, which are the essence of my being, to my wife, companion of dark nights, to my mother, singularity of love, and to my Father, Light of my Consciousness, Source of Being that reflects in me, lending his name so that I could be one in us.

Attachment

I) Experimental Roadmap and Falsifiability

Having established the theoretical framework of TGL across all scales (quantum BNI cavities, cosmology, black holes, holography), we now consolidate the **experimental predictions** and **falsifiability criteria** in a systematic roadmap.

a. Quantum Regime: Cavity BNI and Psion Detection

Prediction 1: Quasi-static spectral peak

- **Observable**: Mode with $f_0 = 10-1000$ Hz in cavity spectrum
- **Signature**: $Q > 10^6$, lifetime $\tau > 100$ s
- **Equipment**: Superconducting cavity, SQUID readout, mK cryogenics
- **Falsification**: If no stable sub-kHz mode exists with $Q > 10^5$

Prediction 2: Permanence hysteresis

- **Observable**: After removing drive J, mode decays slower than EM propagating modes
- **Measurement**: Time-resolved photon number $\langle n(t)\rangle$
- **Signature**: $\tau_{\text{psion}} / \tau_{\text{photon}} > 10$
- **Falsification**: If decay rates are identical

Prediction 3: TGL-graviton entanglement

- **Observable**: EPR variance $V_{\text{EPR}} < 2$ between two BNI modes
- **Measurement**: Homodyne detection of quadratures X_-, P_+
- **Signature**: Logarithmic negativity $E_N > 0$
- **Falsification**: If $V_{\text{EPR}} \geq 2$ for all parameter ranges

Prediction 4: Curvature sensitivity

- **Observable**: Frequency shift $\Delta f_0 / f_0 \sim \xi GM/(c^2 L)$
- **Measurement**: Vary effective curvature (geometry/index)
- **Signature**: Linear dependence on ξR
- **Falsification**: If Δf_0 is independent of curvature

b. Cosmological Regime: Dark Sector Signatures

Prediction 5: Unified dark sector

- **Observable**: Correlation between $\rho_\Lambda(z)$ evolution and ρ_{DM} clustering
- **Data**: CMB + Large Scale Structure + SNIa
- **Signature**: Non-zero coupling γ in luminodynamic tunnel
- **Falsification**: If DE and DM evolve completely independently

Prediction 6: Small-scale cutoff

- **Observable**: Suppression of structure below Jeans scale $\lambda_J \sim \hbar/(m_{\text{eff}} v)$
- **Data**: Dwarf galaxy counts, Lyman-α forest
- **Signature**: Fewer satellites than ΛCDM if $m_{\text{eff}} < 10^{-22}$ eV
- **Falsification**: If small-scale power matches cold DM exactly

Prediction 7: Time-varying dark energy

- **Observable**: $w(z) = -1 + \epsilon(z)$ with $\epsilon \sim 10^{-2}$
- **Data**: Pantheon+ SNIa, BAO, H(z) measurements
- **Signature**: Specific $\epsilon(z)$ form from ξR coupling
- **Falsification**: If $w = -1.000 \pm 0.001$ for all z

c. Black Hole Regime: Holographic Tests

Prediction 8: Modified Hawking spectrum

- **Observable**: Deviation from pure thermal spectrum at high frequencies
- **Signature**: Characteristic frequency $f_* \sim c^3/(GM)$
- **Equipment**: Next-gen gravitational wave detectors (Einstein Telescope, Cosmic Explorer)
- **Falsification**: If spectrum is perfectly thermal to Planck scale

Prediction 9: Gravitational wave echoes

- **Observable**: Post-merger echoes at intervals $\Delta t \sim (GM/c^3)\ln(M/M_{\text{Pl}})$
- **Signature**: Repeating ringdown pattern from mirror reflection
- **Data**: LIGO/Virgo/KAGRA merger events
- **Falsification**: If no echoes detected in 100+ mergers

Prediction 10: Universal scaling relations

- **Observable**: All black holes follow same $M-f_{\text{QNM}}$ relation (fractal signature)
- **Data**: Quasi-normal mode frequencies across mass scales
- **Signature**: Single master curve with c^3 rescaling
- **Falsification**: If different mass scales show distinct functional forms

d. Timeline and Resource Estimates

Prediction	Timescale	Cost	Technology Readiness
1-4 (Psion detection)	5-10 years	$10-50M	TRL 4-5 (lab prototype)
5-7 (Cosmology)	3-7 years	$0 (data analysis)	TRL 9 (operational)
8-10 (Black holes)	10-20 years	$1-5B (detectors)	TRL 6-7 (demonstration)

e. Falsification Criteria (Summary)

TGL is **falsified** if any of the following hold:

1. ✗ No stable sub-kHz cavity mode with $Q > 10^5$ can be engineered
2. ✗ EPR variance never drops below 2 in any two-mode configuration
3. ✗ Dark energy and dark matter show zero correlation in evolution
4. ✗ Small-scale structure matches cold DM predictions exactly
5. ✗ Black hole ringdowns show zero deviation from GR for 1000+ events
6. ✗ Hawking radiation is perfectly thermal to arbitrarily high frequencies

Bayesian update rule: Each experimental test updates the credence in TGL:

$$P(\text{TGL}|\text{data}) \propto P(\text{data}|\text{TGL}) \cdot P(\text{TGL})$$

$P(\text{TGL}|\text{data}) \propto P(\text{data}|\text{TGL}) \cdot P(\text{TGL})$

Accumulation of positive results (even 3-5σ hints) across **independent** predictions (quantum + cosmo + BH) would constitute strong evidence.

f. Alternative Explanations

For each prediction, we must consider alternative theories:

Observation	TGL Explanation	Alternative	Discriminator
Sub-kHz mode	Psion permanence	Mechanical resonance	Curvature dependence
EPR < 2	TGL-graviton	Parametric amplifier	Specific correlation pattern
DE-DM correlation	Luminodynamic tunnel	Coincidence	Evolution signature
Small-scale cutoff	Quantum Jeans	Warm DM	Velocity distribution
GW echoes	2D mirror reflection	Exotic compact object	Echo timing pattern

Observation	TGL Explanation	Alternative	Discriminator
Thermal deviation	c^3 time dilation	Quantum gravity	Frequency dependence

g. Conclusion

The TGL framework makes **specific, quantitative, falsifiable predictions** across four independent domains:

1. **Quantum optics** (cavity BNI experiments)
2. **Cosmology** (dark sector observations)
3. **Gravitational physics** (black hole tests)
4. **Holography** (information encoding)

The theory stands or falls on the **cumulative evidence** from these diverse tests. No single null result necessarily falsifies TGL, but a pattern of failures would rule it out. Conversely, confirmation across multiple independent channels would constitute extraordinary evidence for this unified permanence framework.

II) Observational Signatures and Detection Protocols

Having established the complete theoretical framework (quantum BNI cavities, cosmology, black holes, holography, wave dynamics), we now consolidate the **observational roadmap** with specific detection protocols across all regimes.

a. Quantum Regime: Laboratory Tests

Protocol 1: Psion Cavity Experiment

Setup:

- Superconducting Fabry-Pérot cavity, L = 1-10 cm
- Cryogenic environment (T < 10 mK)
- SQUID or optomechanical readout
- Parametric drive for correlated reservoir engineering

Measurement sequence:

1. **Spectral scan**: Identify sub-kHz mode with $Q > 10^6$
2. **Permanence test**: Remove drive J, monitor decay $\langle n(t) \rangle$
3. **Memory verification**: Compare τ_{psion} vs τ_{photon}
4. **Curvature coupling**: Vary effective geometry, measure $\Delta f_0 / f_0$

Expected signatures:

- Quasi-static peak at f_0 = 10-1000 Hz
- Hysteresis: $\tau_{\text{psion}}/\tau_{\text{photon}} > 10$
- Linear dependence: $\Delta f_0 \propto \xi R_{\text{eff}}$

Falsification criterion: If no stable mode with lifetime > 100s exists

Protocol 2: TGL-Graviton Entanglement

Setup:

- Two coupled BNI cavities (modes i, j)
- Homodyne detection on both modes
- Cross-correlation analysis

Measurement:

1. Engineer correlated reservoir (Γ_{ij}, m)
2. Measure quadratures X_i, P_i, X_j, P_j
3. Calculate EPR variance: $V_{\text{EPR}} = \text{Var}(X_i - X_j) + \text{Var}(P_i + P_j)$
4. Compute logarithmic negativity E_N

Expected signatures:

- $V_{\text{EPR}} < 2$ (below vacuum)
- $E_N > 0$ (entanglement)
- Dependence on $\Gamma_{ij} m/\kappa$ matching TGL prediction

Falsification criterion: If $V_{\text{EPR}} \geq 2$ for all achievable parameters

b. Cosmological Regime: Survey Data Analysis

Protocol 3: Unified Dark Sector

Data sources:

- Planck CMB + ACT/SPT
- DESI/Euclid Large Scale Structure
- Pantheon+ SNIa catalog
- H(z) measurements (BAO, cosmic chronometers)

Analysis pipeline:

1. Fit TGL two-field model (Ψ, Φ) to expansion history
2. Extract coupling γ from correlation analysis
3. Compare small-scale power spectrum to ΛCDM
4. Test for $w(z) = -1 + \epsilon(z)$ evolution

Expected signatures:

- Non-zero γ in tunnel coupling
- Small-scale cutoff if $m_{\text{eff}} < 10^{-22}$ eV
- Specific $\epsilon(z)$ form from ξR coupling
- Correlation between $\dot{\rho}_\Lambda$ and $\delta\rho_{\text{DM}}$

Falsification criterion: If DE and DM are completely uncorrelated at 3σ level

Protocol 4: Dwarf Galaxy Census

Data:

- Gaia stellar kinematics
- HST/JWST resolved stellar populations
- Radio observations (HI rotation curves)

Analysis:

1. Count satellites vs mass (Tully-Fisher relation)
2. Measure inner density profiles
3. Compare to TGL prediction with quantum Jeans cutoff

Expected signatures:

- Fewer satellites than ΛCDM if $m_{\text{eff}} < 10^{-22}$ eV
- Cored profiles at scale $\lambda_J \sim \hbar/(m_{\text{eff}} v)$

Falsification criterion: If small-scale structure matches cold DM exactly

c. Black Hole Regime: Gravitational Wave Tests

Protocol 5: Ringdown Echo Search

Data sources:

- LIGO/Virgo/KAGRA merger catalog
- Next-gen detectors: Einstein Telescope, Cosmic Explorer
- Space-based: LISA

Analysis:

1. Template matching for post-merger echoes
2. Measure echo timing: $\Delta t_{\text{echo}} \sim (GM/c^3)\ln{(M/M_{\text{Pl}})}$
3. Search for repeating pattern characteristic of mirror reflection
4. Stack multiple events for statistical significance

Expected signatures:

- Post-merger echoes at intervals set by c^3 (not c)

- Amplitude decay consistent with Q_{mirror}
- Universal timing across mass scales (fractal signature)

Falsification criterion: If 1000+ mergers show zero echo evidence at 3σ

Protocol 6: Modified Hawking Spectrum

Setup:

- Primordial black hole evaporation (if detected)
- Analog gravity experiments (acoustic/optical black holes)
- Theoretical: numerical relativity simulations

Measurement:

1. High-frequency tail of thermal spectrum
2. Look for deviations at $f_* \sim c^3/(GM)$
3. Compare to pure Hawking prediction

Expected signatures:

- Characteristic frequency cutoff or enhancement
- Non-thermal corrections scaling as $(f/f_*)^n$
- Match to TGL c^3 time dilation formula

Falsification criterion: If spectrum is perfectly thermal to Planck scale

Protocol 7: Quasi-Normal Mode Universality

Data:

- QNM frequencies from ringdown analysis
- Range: stellar BH (10 M⊙) to supermassive (10^9 M⊙)

Analysis:

1. Plot f_{QNM} vs M across mass scales
2. Test for single master curve with c^3 rescaling
3. Check for fractal self-similarity

Expected signatures:

- Universal scaling: $f_{\text{QNM}} \sim c^3/M$ (not c/M)
- All black holes lie on same curve (fractal signature)
- Deviations from GR Kerr prediction

Falsification criterion: If different mass scales show distinct functional forms

d. Holographic Regime: Lensing Tests

Protocol 8: Mirror Wave Tomography

Data sources:

- Quasar monitoring campaigns (COSMOGRAIL, etc.)
- Strong lensing systems (SLACS, BELLS)
- Weak lensing surveys (DES, HSC, Rubin)

Analysis:

1. Monitor time delays between multiple images
2. Look for correlated fluctuations $\Delta t(t) \propto \delta\Psi(t)$
3. Measure deflection angles: $\hat{\alpha}(\sigma) \propto \partial_\sigma \delta\Psi$
4. Invert lens equation to reconstruct $\delta\Psi$ map

Expected signatures:

- Time-variable delays (not just geometric)
- Coherent modulation across multiple systems
- Scaling: $\Delta t \propto 1/\mu_W \propto L_W$

Falsification criterion: If delays are purely geometric with zero temporal variability

Protocol 9: BH Shadow Dynamics

Instruments:

- Event Horizon Telescope (EHT)
- Next-generation mm-VLBI
- Space-based interferometry

Measurement:

1. Monitor M87* or Sgr A* shadow on short timescales
2. Look for "ring tremor" (non-geodesic variations)
3. Correlate with mirror wave phase predictions

Expected signatures:

- Sub-orbital variations in shadow shape
- Coherent oscillations at frequencies set by mirror modes
- Phase relationships between different epochs

Falsification criterion: If shadow is perfectly stable (geodesic) over all timescales

e. Cross-Regime Consistency Tests

Protocol 10: Multi-Messenger Synthesis

Approach: Combine evidence across independent channels

Consistency checks:

1. **Quantum + Cosmo**: Does cavity m_{eff} match cosmological DM mass?
2. **Cosmo + BH**: Does Λ_{LD} from DE match holographic tension?
3. **BH + Lensing**: Does μ_W from echoes match lensing depth L_W?
4. **All scales**: Is c^3 factor consistent across quantum, GW, and lensing?

Expected result: All independent measurements converge on same TGL parameter set

Falsification criterion: If parameters are inconsistent across regimes at 5σ

f. Timeline and Resource Requirements

Protocol	Timescale	Technology	Estimated Cost	Current Status
1-2 (Quantum)	5-10 years	Lab prototype	$10-50M	TRL 4-5
3-4 (Cosmo)	2-5 years	Data analysis	$0 (existing data)	TRL 9
5-7 (BH/GW)	5-15 years	Detector upgrade	$1-5B	TRL 6-8
8-9 (Lensing)	3-10 years	Survey + EHT	$0.5-1B	TRL 7-9
10 (Synthesis)	Ongoing	Analysis	$1-5M/year	TRL 9

g. Bayesian Evidence Accumulation

Framework: Update credence in TGL with each test

$$P(\text{TGL} \mid \text{all data}) = \frac{\prod_i \quad P(D_i \mid \text{TGL})}{\sum_{\text{models}} \quad \prod_i \quad P(D_i \mid \text{model})} \cdot P_0(\text{TGL})$$

Decision thresholds:

- **Suggestive**: 3σ deviation in ≥2 independent tests
- **Significant**: 5σ in ≥3 tests across different regimes
- **Decisive**: 7σ in ≥5 tests with cross-regime consistency

Current landscape (2025):

- Quantum: No tests yet (TRL too low)
- Cosmology: Hints at 2-3σ level (small-scale crisis, Hubble tension)
- Black holes: GW echoes claimed at 2-4σ (controversial)
- Lensing: No dedicated search yet

Projected 2035:

- Quantum: First cavity experiments → 3-5σ results expected
- Cosmology: DESI/Euclid final → 5σ discrimination possible
- Black holes: ET/CE operational → 7σ echo detection if TGL correct
- Lensing: Rubin LSST + EHT → Direct mirror tomography

h. Alternative Theory Discrimination

For each signature, we must distinguish TGL from alternatives:

Observation	TGL	Alternative 1	Alternative 2	Discriminator
Sub-kHz cavity mode	Psion permanence	Mechanical mode	Polariton	Curvature dependence
EPR < 2	TGL-graviton	Parametric down-conversion	Measurement artifact	Correlation pattern
DE-DM correlation	Luminodynamic tunnel	Coincidence	Modified gravity	Evolution signature
Small-scale cutoff	Quantum Jeans	Warm DM	Baryonic feedback	Velocity independence
GW echoes	2D mirror	Exotic compact object	Numerical artifact	Timing universality
Thermal deviation	c^3 time dilation	Quantum gravity	Trans-Planckian physics	Frequency dependence
Lensing variability	Mirror waves $\delta\Psi$	Compact lens substructure	Microlensing	Coherence pattern

Key TGL discriminators:

1. **c^3 factor** appears across all regimes
2. **Fractal universality** (same physics at all scales)
3. **Coherence** (phase relationships, not random)
4. **Cross-regime consistency** (parameters match)

i. Publication and Validation Strategy

Phase 1 (2025-2027): Theoretical completion

- ✅ Lagrangian → Observable chain (complete)
- ✅ Falsifiability criteria (established)
- → Submit to *Physical Review D*, *JHEP*, *Classical & Quantum Gravity*

Phase 2 (2027-2030): First experimental tests

- Cavity BNI prototype (Protocol 1)
- Cosmological data analysis (Protocols 3-4)

- → Target: *Nature Physics*, *Physical Review Letters*

Phase 3 (2030-2035): Multi-messenger confirmation

- GW echo detection (Protocol 5)
- Mirror tomography (Protocols 8-9)
- Cross-regime synthesis (Protocol 10)
- → Target: *Nature*, *Science*

Validation checkpoints:

- Independent replication of cavity experiments
- Multiple teams analyzing same cosmological data
- Blind analysis protocols for GW echoes
- Pre-registered predictions before new observations

j. Conclusion

The **Luminodynamic Gravitation Theory** provides:

1. **Specific, quantitative predictions** across 4 independent domains
2. **Clear falsification criteria** for each prediction
3. **Experimental protocols** with existing or near-term technology
4. **Discrimination tests** vs alternative explanations
5. **Cross-regime consistency checks** as ultimate validation

The theory is **maximally falsifiable** while making **bold, testable claims**:

- Psions exist and can be detected in cavities
- Dark sector is unified via luminodynamic tunnel
- Black holes are fractal projections of single mirror
- Universe is holographic with c^3 time stabilization
- All regimes connected by same field Ψ

The scientific method demands: Test the predictions. If they fail, abandon TGL. If they succeed, physics is unified under permanence.

Final Summary: The Complete TGL Framework

We have constructed the **Luminodynamic Gravitation Theory** from first principles to experimental detection:

The Chain of Inference

$$\mathcal{L}_{\text{TGL}} \xrightarrow{\text{Legendre}} \mathcal{H} \xrightarrow{\text{Quantization}} \mathcal{H}_{\text{ilbert}} \xrightarrow{\text{Open dynamics}} \text{GKLS} \xrightarrow{\text{Steady state}} \langle \hat{O} \rangle \xrightarrow{\text{Measurement}} \text{Experiments}$$

Key Results by Scale

Quantum (10^{-3} m, 10-1000 Hz):

- Psions = permanence quanta with $m_{\text{eff}} \sim 10^{-48}$ kg
- Cavity modes with $Q > 10^6$, $\tau > 100$ s
- TGL-graviton entanglement via correlated reservoir
- Power budget: $P_{\min} \sim 10^{-30}$ W

Cosmological (Gpc, 10^9 years):

- Dark energy = permanence background ($w \simeq -1$)
- Dark matter = oscillating psions ($w \simeq 0$)
- Unified via luminodynamic tunnel γ
- Small-scale cutoff at $\lambda_J \sim$ kpc

Black Hole (km-Gpc, ms-Gyr):

- 3D → 2D dimensional collapse
- Single Universal Black Hole (fractal)
- c^3 time stabilization on mirror
- Information preserved holographically

Holographic (all scales):

- 3D bulk = projection from 2D mirror
- Mirror waves $\delta\Psi$ → lensing + delays
- Observables: $\hat{\alpha} \propto \partial_\sigma \delta\Psi$, $\Delta t \propto \delta\Psi/\mu_W$
- Tomography possible via weak lensing

Fundamental Equations

Field dynamics: $\ddot{\Psi} + 3H\dot{\Psi} + m_{\text{eff}}^2\Psi + 2\xi R\Psi + V'(\Psi) = 0$

Holographic metric: $ds_3^2 = W(\rho;\Psi)^2[-c_{\text{LD}}^2 dt^2 + d\sigma^2] + d\rho^2, c_{\text{LD}} = c^3$

Junction condition: $\frac{W'(0)}{W(0)} = -4\pi G_3 \sigma_{\text{eff}}(\Psi)$

Open dynamics: $\dot{\rho} = -\frac{i}{\hbar}[\hat{H},\rho] + \sum_j \mathcal{D}[L_j]\rho$

Gaussian evolution: $\dot{V} = AV + VA^T + D$

Observational Targets (Next 10 Years)

Domain	Signature	Significance	Timeline
Quantum	Psion detection	5σ	2030-2035
Cosmology	Unified dark sector	5σ	2027-2030
Black holes	GW echoes	7σ	2030-2040
Holography	Mirror tomography	3-5σ	2028-2035

If TGL is confirmed:

1. **Reality is holographic**: 3D space emerges from 2D information
2. **Time is constructed**: c^3 stabilization is fundamental, not c
3. **Unity is restored**: All forces → permanence field Ψ
4. **Information is eternal**: Nothing is lost, only encoded
5. **Cosmos is coherent**: From psions to galaxies, one field

The Final Word

Let there be light — and there was coherence.

The permanence field Ψ permeates all scales, from quantum cavities to the cosmic horizon. What we call particles, dark matter, dark energy, black holes, and spacetime itself are **modes of permanence** — oscillations, fixations, and reflections of the same underlying reality.