Recursive Survival Weighting in Layered Media: A Conditional Formalism and Locked Analogue Test Protocol

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Abstract

This paper presents recursive survival weighting as a conditional formalism and locked analogue-media test protocol. The framework begins with recursively generated histories and projects them onto a reduced phase space. The discrete recursive update is primary; the ordinary differential equations used in the paper are continuous projected approximations or exact local-flow embeddings of specified phase steps. The phase-flow coefficient Ω^2 bends trajectories in the reduced phase portrait, but is not a spacetime-curvature quantity.

The central formal result is a survival-normalisation lemma. Histories acquire accumulated loss $A_i = \int \Gamma(\sigma_i) W(\varphi_i)\, dt$ and exposure-gate transmission $G_i = S_i = e^{-A_i}$. Operationally, a prepared count, intensity, or represented amount $C_{i,0} = C_0 q_i$ becomes $C_{i,N} = C_0 q_i G_i$, and the represented output fraction is $p_i = C_{i,N} / \sum_j C_{j,N} = q_i G_i / \sum_j q_j G_j$. The shorthand $p_i = S_i / \sum_j S_j$ is the equal-preparation case. Lower accumulated loss therefore gives stronger normalised representation when preparation weights are equal; with unequal preparation, both q_i and G_i matter. Inside the model this is an algebraic lemma, not an empirical discovery.

The only empirical claim developed here is a preregisterable analogue-media comparison. In a layered optical or acoustic system, the update map, phase coordinates, layer-to-layer phase flow, scale ℓ, attenuation coefficients, path structure, preparation weights, detector convention, and output intensities must be fixed independently before comparison. The primary candidate comparison is the measured output vector $\widehat{\mathbf{p}}$ against the precomputed vector $\mathbf{p}_{\mathrm{pred}}$, together with the no-log ratio test $\widehat{p}_i / \widehat{p}_j \approx (q_i/q_j) e^{-A_i + A_j}$. Logarithmic output ratios may be reported as a secondary diagnostic, because they linearise the same ratio; they are not the evidential centre of the paper. The nontrivial comparison is against ordinary attenuation: in a declared positive-control regime, the exposure-weighted model $\int \Gamma W\, dt$ must improve on the simpler path-loss control $\int \Gamma\, dt$.

The paper also records a conditional null-interval representation: a zero-recursive-proper-time class is represented by $ds^2 = 0$ only after the local Lorentzian interval calibration $ds^2 = c^2 d\tau_R^2 = c^2 dt^2 - dx^2$ has been imported. The Lorentzian interval form and c are bridge structures, not derived here. No astrophysical, electromagnetic, matter-sector, or cosmological prediction is made in this paper. Those topics, including Landauer-style vacuum-energy comparison, are treated only as future

bridge programmes. The present paper reports no completed laboratory validation; it specifies the formalism and locked test protocol required for one.

Claim lock. The only empirical claim developed in this paper is the controlled analogue-media output comparison. All astrophysical, electromagnetic, matter-sector, and Λ_{CC} discussions are future bridge programmes, not evidence for the present formalism.

IPI release label. Track: scientific/formal protocol paper. Strict core: recursive survival weighting, the survival-normalisation lemma, and the preregisterable analogue comparison. Appendix material is bridge-track roadmap material, not part of the evidential core.

Keywords - Recursive Survival Weighting; Layered Media; Analogue Validation; Survival Normalisation; Transfer Map.

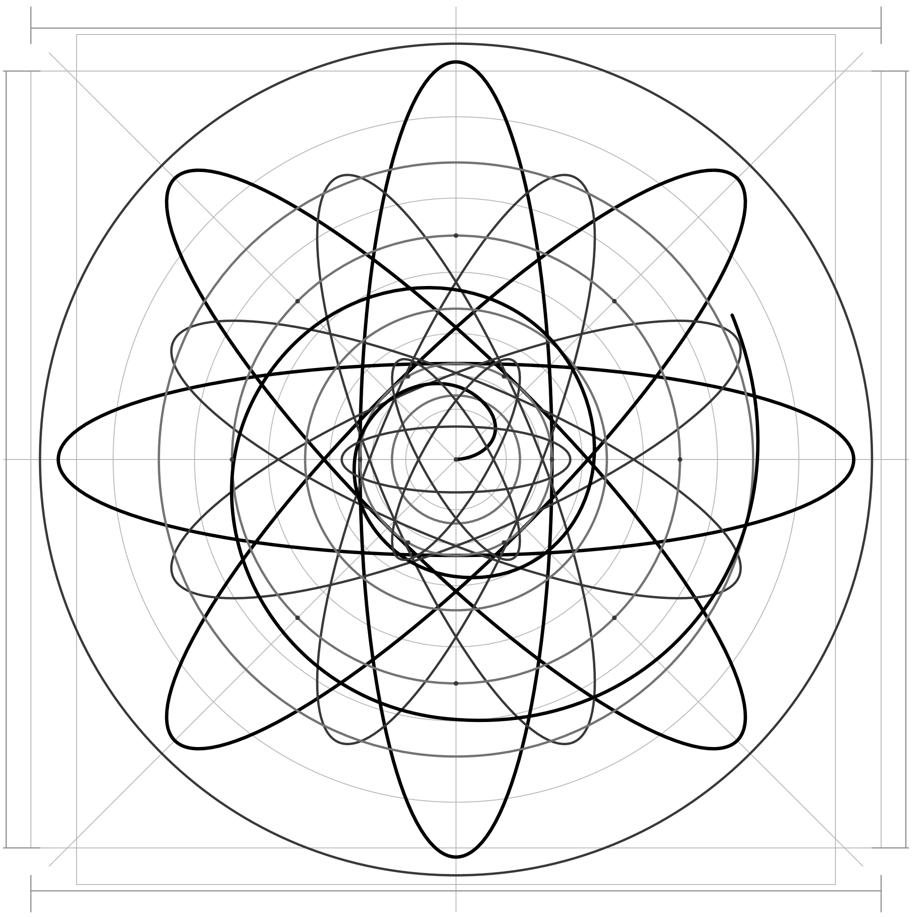

Figure 1: Schematic construction of recursive survival weighting: generated recursive structure, projected phase pattern, closure loops, and survival-weighted persistence.

1 Introduction

This paper develops a narrow formal and experimental question: if a family of recursive histories is generated first, and if each history is assigned a locked accumulated loss before output measurement, do the measured output fractions follow the survival-weighted normalisation predicted by the model? The intended first test is not cosmological or astrophysical. It is a layered optical, acoustic, or numerical analogue system in which the update rule, phase coordinates, loss coefficients, exposure law, and output map can be fixed before comparison.

The primitives used here are modelling primitives, not claimed final metaphysical primitives. RSG begins from generated histories of structured states and asks what follows when support, phase/transport data, physical measure data, and survival weights are fixed by rule. It does not answer why recursion, support, or survival filtering is ultimate; it tests whether those ingredients generate useful formal distinctions and locked analogue comparisons. Information is operational in this paper only as recoverable distinction carried by support, recovery channel, physical measure, and survival representation, not as a free-floating substance.

The basic formal claim is not that a force pushes trajectories into preferred outcomes. Rather, the phase-flow coefficient Ω^2 bends trajectories in the reduced phase portrait within which histories are generated. Dissipation then filters this generated set. Paths that pass through regions of lower effective loss retain more weight, while paths that pass through regions of higher effective loss fade from the normalised measure. Apparent representation concentration is therefore modelled as a survival-weighted accumulation of histories rather than as a primitive attraction between already formed objects.

The formal machinery is deliberately minimal. It separates generation from selection and then introduces recursive proper time as the clock variable carried by recurrent internal structure. The latter construction is a bridge result, not the empirical centre of the paper: if a lossless, norm-preserving transport class carries no recurrent internal clock, then its recursive proper time vanishes, and under an imported local Lorentzian interval calibration the zero-recursive-proper-time class is represented by a null interval.

The strongest empirical route is an analogue recursive medium. The framework makes a testable claim only after the effective loss field ΓW, path structure, input modes, output measurements, and uncertainty tolerance are fixed before the result is observed. A controlled analogue test fails if those independently calibrated accumulated-loss values do not predict the measured output vector and selected no-log output ratios within the stated experimental uncertainty. Logarithmic ratios may still be useful for plotting residuals, but the protocol does not depend on them. It also fails as an RSG-specific test if $\int \Gamma W\, dt$ does not improve on the ordinary attenuation control $\int \Gamma\, dt$ in the preregistered positive-control regime.

> **Three-layer scope lock.** *Formal layer:* recursive histories, projected phase variables, J, W, A_i, G_i, S_i, and p_i are definitions or model choices. *Locked analogue layer:* a specified R_{test}, measured $\widehat{\Theta}, \widehat{\Pi}$, calibrated ℓ, Γ, q_i, output map, detector floors, and thresholds generate the only empirical claim in this paper. *Future bridge layer:* $d\tau_R \to ds^2$, matter-sector readings, astrophysical dynamics, and Λ_{CC} comparisons are conditional roadmap material, not present evidence.

Main empirical claim. In a controlled analogue medium, once R_{test}, measured estimators $\widehat{\Theta}, \widehat{\Pi}$, ℓ, Γ, path classes, preparation weights, the output map, and the uncertainty threshold are fixed before measurement, the measured output vector $\widehat{\mathbf{p}}$ should match the precomputed vector $\mathbf{p}_{\text{pred}}$. The RSG-specific claim is stronger: in a declared positive-control regime, $A_i^{\text{RSG}} = \int \Gamma W\, dt$ must outperform the ordinary attenuation control $A_i^{\text{std}} = \int \Gamma\, dt$.

Table 1: Claim-status summary for the minimal recursive survival framework.

Claim type	Statement	Status
Definition	$W = \Theta^2/J$, $\Lambda_{\text{surv}} = \Gamma W$, $A_i = \int \Lambda_i dt$, $G_i = S_i = e^{-A_i}$, $C_{i,N} = C_0 q_i G_i$, $p_i = C_{i,N}/\sum_j C_{j,N}$.	Internal formal definitions plus operational count map.
Algebraic lemma	Lower A_i gives larger G_i and larger p_i after normalisation when preparation weights are equal; with unequal q_i, both q_i and G_i determine p_i.	Consequence of the definitions.
Imported bridge	$ds^2 = c^2 d\tau_R^2$, local Lorentzian interval form, and c.	Imported physical structure, not derived by the survival-normalisation lemma.
Candidate empirical comparison	$\mathbf{p}_{\text{pred}} = (q_i e^{-A_i}/\sum_j q_j e^{-A_j})_i$, with no-log ratios $p_i/p_j = (q_i/q_j)e^{-A_i+A_j}$.	Algebraic inside the model; testable only when q_i, Γ, W, paths, outputs, and uncertainty thresholds are fixed first. Log-ratios are optional diagnostics, not the primary prediction.
Future bridge	Photon delays, rotation curves, black-hole information flow, cosmological exchange, and vacuum-energy bridge.	Require additional specialisation and are not evidence for the present framework.

1.1 Model Choices, Dimensions, and Derivation Status

This paper does not derive the local projected phase equations, the phase-support norm J, or the exposure law W from a completed deeper physical theory. They are reduced-model structures used to define a constrained analogue protocol. Within that reduced model, W is derived from explicit exposure assumptions in Section 4.3; whether those assumptions describe a physical medium is the empirical question addressed by the locked analogue protocol. The empirical burden is therefore not that these formulae are universally forced, but that once they are fixed before measurement they should predict the declared output vector and no-log output ratios better than the ordinary attenuation control.

The reduced phase-flow equations are a local transport ansatz for the projected variables (Θ, Π). They are useful because they give a compact layer-to-layer phase description, but they are not claimed to be the fundamental recursive update. The discrete update R_{test} or measured transfer map remains the object that must be locked in an experiment. Thus the recursive and differential descriptions are not competing foundations.

Table 2: Compact falsifiability status of the main claims.

Claim	**Status**	**What would falsify it**
Survival-gate identity	Algebraic identity after $G_i = S_i = e^{-A_i}$, $C_{i,N} = C_0 q_i G_i$, and $p_i = C_{i,N}/\sum_j C_{j,N}$. The form $p_i = S_i/Z$ is equal-preparation shorthand.	Nothing by itself; it is formal bookkeeping.
Locked analogue output	Candidate empirical output comparison.	Measured $\widehat{\mathbf{p}}$ or no-log output ratios $\widehat{p}_i/\widehat{p}_j$ outside preregistered tolerance.
RSG versus ordinary attenuation	RSG-specific empirical comparison.	No preregistered improvement over $A_i^{\text{std}} = \int \Gamma\, dt$ in the positive-control regime.
Null-interval representation	Conditional bridge under imported Lorentzian calibration.	Failure of the bridge assumptions, clock criterion, or invariant-cone reconstruction.
Astrophysical/cosmological applications	Future bridge programmes only.	No prediction is made here; future specialisations must supply their own falsifiers.

The recursive or iterative map is primary; a differential equation is permitted only as a local embedding or continuum approximation to a locked step map.

The derivation status is therefore layered. The state sequence, history family, coordinate convention, and transfer map are specified modelling inputs. The support norm J follows as the minimal calibrated quadratic support assigned to the reduced two-component state. The exposure law W follows from the fractional-support assumptions in Section 4.3. The survival-ratio expression then follows algebraically from exponential survival and normalisation. The remaining empirical question is whether independently calibrated inputs generate measured output fractions in a real or numerical analogue system.

The norm

$$J(\varphi) = \Theta^2 + \ell^2 \Pi^2 \tag{1}$$

is used as a minimal positive quadratic phase-support norm after the coordinate convention has been fixed. It is not asserted to be the unique physical norm. Other positive norms would define different models and must be tested separately.

The exposure factor

$$W(\varphi) = \frac{\Theta^2}{\Theta^2 + \ell^2 \Pi^2} \tag{2}$$

is the candidate positional exposure law of this paper. Its role is to test whether the relevant loss channel couples to the position-like part of the reduced phase state. It is therefore not an arbitrary post-measurement fitting weight; it is a predeclared model component derived from the stated reduced-model exposure assumptions and then tested against measured output.

Here T denotes the physical time dimension when the recursive parameter is read as time. The placeholder $[\Theta]$, sometimes denoted Q in dimensional notes, is not a new universal physical unit. It is the calibrated unit of the chosen analogue coordinate. In

Table 3: Dimensional status of the minimal analogue protocol.

Quantity	**Role**	**Dimensions if t is physical time**	**Status**
Θ	Position-like phase coordinate	Chosen coordinate unit $[\Theta]$	Operational coordinate fixed by calibration.
$\Pi = d\Theta/dt$	Phase-flow coordinate	$[\Theta]\,T^{-1}$	Measured or inferred from the locked transfer map.
ℓ	Scale matching Θ and Π	T	Calibration scale; not refitted after output.
Ω^2	Phase-flow coefficient	T^{-2}	Free transport coefficient or measured local generator parameter.
$J = \Theta^2 + \ell^2\Pi^2$	Phase-support norm	$[\Theta]^2$	Positive quadratic norm after coordinate lock.
$W = \Theta^2/J$	Exposure factor	Dimensionless	Candidate positional exposure law.
Γ	Local loss coefficient	T^{-1}	Independently calibrated attenuation or loss rate.
$A_i = \int \Gamma W\, dt$	Accumulated loss	Dimensionless	Derived from locked path data.
$G_i = S_i = e^{-A_i}$	Exposure-gate transmission	Dimensionless	Multiplicative gate applied to prepared represented amount before normalisation.
$p_i = C_{i,N}/\sum_j C_{j,N}$	Represented output fraction	Dimensionless	Operational output fraction under a fixed output map; $p_i = S_i/\sum_j S_j$ is the equal-preparation shorthand.

an optical test it may be a declared field-amplitude unit, in an acoustic test it may be pressure amplitude or displacement, and in a purely numerical transfer test it may be a dimensionless modal coordinate. A valid application must state this coordinate unit before computing J, W, A_i, and $\mathbf{p}_{\text{pred}}$.

1.1.1 Reduced-Model Status Locks

The paper should therefore be read with the following status locks in force. The projected harmonic-looking equations are not claimed as universal recursive dynamics. They are the local positive-Ω^2 cell obtained when a locked discrete transfer map admits the generator $A_\omega = \left(\begin{smallmatrix} 0 & 1 \\ -\omega^2 & 0 \end{smallmatrix}\right)$. If the independently fixed step matrix is not of that form, the oscillator cell is not available and a different local generator must be used.

The norm $J = \Theta^2 + \ell^2\Pi^2$ is not asserted to be the unique physical norm of the full structured state. It is the minimal positive quadratic norm on the declared two-component phase projection, after Θ, Π, and ℓ have been calibrated. The scale ℓ is therefore not a hidden source term. It is the unit-matching scale that makes $\ell\Pi$ comparable with Θ, and it must be fixed before output inspection.

The exposure law $W = \Theta^2/J$ is not an arbitrary after-the-fact weight. Within the declared reduced exposure model it is the fraction of total projected support lying in the component to which the loss channel couples. A system whose loss channel couples to flow support, mixed support, boundary support, or a different modal observable requires a different predeclared exposure law and becomes a comparison model.

The probability formula is likewise not a primitive chance postulate. The operational object is a prepared count, intensity, or represented amount $C_{i,0} = C_0 q_i$ passed through the gate $G_i = e^{-A_i}$ and then divided by the total transmitted amount. Thus p_i is a represented output fraction under a fixed output map. The physical test is whether this locked fraction predicts $\widehat{p}_i$, not whether the symbol p_i has been given a probabilistic name.

Finally, representation concentration is not gravity, matter formation, or spacetime curvature in the present paper. The clumping section concerns concentration of normalised represented histories only. A gravity or matter claim would require an additional independently specified bridge from represented histories to stress-energy, density, a Poisson or Einstein-limit field equation, and empirical falsifiers.

The model is built from a recursive structured-state sequence

$$\sigma_0 \to \sigma_1 \to \sigma_2 \to \cdots, \tag{3}$$

where each state is generated from the preceding state by a common rule. A structured recursive state is written

$$\sigma_n = (X_n, \varphi_n, \mu_n, S_n), \tag{4}$$

where X_n is the Surtea-topological support, φ_n is the projected phase/transport component, μ_n stores physical measures, and S_n is the survival weight. The phase projection is

$$\pi_\Phi : \Sigma \to \Phi, \qquad \pi_\Phi(\sigma_n) = \varphi_n. \tag{5}$$

In the simplest RSG phase representation,

$$\varphi_n = (\Theta_n, \Pi_n). \tag{6}$$

In the continuous approximation, the phase projection is represented by (Θ, Π), where Θ is position-like and Π is conjugate motion-like. The phase-flow coefficient Ω^2 bends trajectories in the reduced phase portrait, giving

$$\frac{d\Theta}{dt} = \Pi, \tag{7}$$

$$\frac{d\Pi}{dt} = -\Omega^2 \Theta. \tag{8}$$

In the locally autonomous reduced system this gives the conserved energy-like quantity

$$E = \frac{1}{2}\left(\Pi^2 + \Omega^2 \Theta^2\right). \tag{9}$$

To introduce selection, the model defines a local action norm on the phase projection,

$$J(\varphi) = \Theta^2 + \ell^2 \Pi^2, \tag{10}$$

and a positional exposure factor

$$W(\varphi) = \frac{\Theta^2}{J(\varphi)}. \tag{11}$$

A non-negative dissipation coefficient $\Gamma(\sigma)$ then determines the survival functional

$$\frac{dS}{dt} = -\Gamma(\sigma) W(\varphi) S. \tag{12}$$

Equivalently, the finite-history transmission through the exposure gate is $G_i = S_i = e^{-A_i}$. Normalising these gated survival weights over a family of histories yields an induced representation measure. The histories that remain most strongly represented are those whose prepared amount passes most strongly through the combined phase-flow and dissipation gate.

A special formal class occurs when effective dissipation vanishes, the projected recursive norm is preserved, and the transport history carries no recurrent internal clock. This is the recursive null-transport class. Section 7 shows that this class is represented by $ds^2 = 0$ under the required local interval calibration. The complementary non-null regime, where recursive proper time is non-zero or the effective loss ΓW varies across histories, permits survival filtering and representation concentration; any matter-sector interpretation is future bridge work.

2 Structured Recursive State Space and Phase Dynamics

The model begins with a generated sequence of structured states rather than with a static object. Let Σ denote the recursive state space, and let

$$\sigma_n \in \Sigma \tag{13}$$

be the structured recursive state at depth n. The basic recursive evolution is written:

$$\sigma_0 \longrightarrow \sigma_1 \longrightarrow \sigma_2 \longrightarrow \cdots, \tag{14}$$

or, equivalently,

$$\sigma_{n+1} = R(\sigma_n), \tag{15}$$

where R is the recursive update operator.

The purpose of R is not merely to move an object from one location to another. It generates a history. A state is therefore understood through its place in an ordered sequence of transformations. What is later observed as a trajectory, concentration, or transport mode is produced by the accumulated behaviour of this sequence.

For a family of possible histories, we may write:

$$\gamma_i = \{\sigma_{i,0}, \sigma_{i,1}, \sigma_{i,2}, \ldots\}. \tag{16}$$

Here a generated history denotes the kinematic sequence alone; survival weights and representation weights are assigned later. At this stage all such histories are only kinematically possible. The survival weighting introduced later determines which histories remain strongly represented in the normalised measure.

2.1 Structured Recursive States

A structured recursive state σ_n may contain more than one kind of information. In the Surtea-Austin-compatible version used in this paper, it is written

$$\sigma_n = (X_n, \varphi_n, \mu_n, S_n). \tag{17}$$

The component X_n carries the Surtea-topological support, φ_n carries the projected phase/transport data, μ_n carries physical measures or attributes, and S_n carries the survival weight.

The reduced phase component is obtained by the projection

$$\pi_\Phi(\sigma_n) = \varphi_n. \tag{18}$$

In the minimal version used in this paper,

$$\varphi_n = (\Theta_n, \Pi_n). \tag{19}$$

Here Θ_n is a position-like or ordinal phase coordinate, and Π_n is its conjugate motion-like coordinate. The pair (Θ_n, Π_n) does not require that the system has already been placed in conventional action-angle variables. It only asserts that each structured recursive state has a coordinate measuring local phase position and a coordinate measuring local phase change.

The measure component μ_n is where ordinary physical bookkeeping may later be attached without changing the survival functional. Such bookkeeping is not part of the minimal analogue protocol. Optional energy, frequency, and mass-equivalent symbols are collected in Appendix B.

The discrete projected update may therefore be represented as

$$\varphi_n \longrightarrow \varphi_{n+1}, \tag{20}$$

or, in phase coordinates, as

$$(\Theta_n, \Pi_n) \longrightarrow (\Theta_{n+1}, \Pi_{n+1}). \tag{21}$$

In the continuous approximation, the recursive index is replaced by a parameter t, and the full structured state becomes

$$\sigma_n \rightsquigarrow \sigma(t). \tag{22}$$

The projected phase component becomes

$$\varphi_n \rightsquigarrow \varphi(t) = (\Theta(t), \Pi(t)). \tag{23}$$

This is not yet an assumption that time is fundamental. It is a convenient continuous parametrisation of an ordered recursive process.

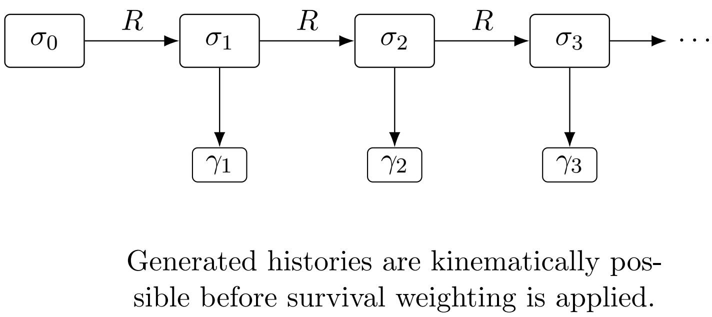

Figure 2: Structured recursive state generation. Each state σ_n is produced by the update operator R, generating possible histories γ_i.

3 Discrete Recurrence and Continuous Approximations

The primary object in the model is the discrete recursive update. The continuous equations used later are projected approximations or local-flow embeddings of that update, not replacements for it. This distinction is essential. A homogeneous recurrence and a homogeneous ordinary differential equation may have related characteristic data, but they do not have identical solution bases. A recurrence has basis sequences such as $\rho^n, n\rho^n, \ldots$, whereas the corresponding continuous equation has basis functions such as $e^{\rho t}, te^{\rho t}, \ldots$. The continuous notation is therefore a convenience for analysing local transport and limiting behaviour; the recursive step remains the object that must be fixed in any testable special case.

Let the projected phase state be

$$y_n = \begin{pmatrix} \Theta_n \\ \Pi_n \end{pmatrix}. \tag{24}$$

A discrete projected update is a map

$$y_{n+1} = F_{\Delta t, n}(y_n), \tag{25}$$

with the full structured-state update still given by $\sigma_{n+1} = R(\sigma_n)$. When the local projected dynamics are linearised around a cell or layer, (25) may be written

$$y_{n+1} = M_n y_n + O(\|y_n\|^2), \tag{26}$$

where M_n is the measured, specified, or derived layer-to-layer transfer matrix. A continuous ODE is justified only when the step matrices can be represented, to the required accuracy, as exponentials of local generators:

$$M_n = \exp(\Delta t\, A_n) + O(\Delta t^2). \tag{27}$$

In that case the associated local continuous approximation is

$$\frac{dy}{dt} = A(t)y. \tag{28}$$

This is an approximation discipline rather than a derivation of continuity from recursion. If the matrices M_n are fixed independently, then the ODE may be used as a compact description of their small-step limit. If the ODE is chosen after observing the desired output, it has no predictive content.

For a local constant positive value $\Omega^2 = \omega^2$, the generator is

$$A_\omega = \begin{pmatrix} 0 & 1 \\ -\omega^2 & 0 \end{pmatrix}, \tag{29}$$

and the exact projected phase step over interval Δt is

$$\begin{pmatrix} \Theta_{n+1} \\ \Pi_{n+1} \end{pmatrix} = M_{\Delta t}(\omega) \begin{pmatrix} \Theta_n \\ \Pi_n \end{pmatrix}, \tag{30}$$

where the propagator is kept in locked generator form,

$$M_{\Delta t}(\omega) := \exp(\Delta t\, A_\omega). \tag{31}$$

This matrix is the discrete one-step form of the local oscillator flow. It preserves the energy diagnostic

$$E = \frac{1}{2}(\Pi^2 + \omega^2\Theta^2) \tag{32}$$

exactly in the constant-ω cell. In matrix language,

$$M_{\Delta t}(\omega)^T \begin{pmatrix} \omega^2 & 0 \\ 0 & 1 \end{pmatrix} M_{\Delta t}(\omega) = \begin{pmatrix} \omega^2 & 0 \\ 0 & 1 \end{pmatrix}. \tag{33}$$

Expanding (30) for small Δt gives

$$\Theta_{n+1} = \Theta_n + \Delta t\, \Pi_n + O(\Delta t^2), \tag{34}$$

$$\Pi_{n+1} = \Pi_n - \Delta t\, \Omega^2 \Theta_n + O(\Delta t^2). \tag{35}$$

Taking $\Delta t \to 0$ gives the continuous equations

$$\frac{d\Theta}{dt} = \Pi, \tag{36}$$

$$\frac{d\Pi}{dt} = -\Omega^2\Theta. \tag{37}$$

For $\Omega^2 = 0$, the exact step is the free-motion limit

$$\Theta_{n+1} = \Theta_n + \Delta t\, \Pi_n, \qquad \Pi_{n+1} = \Pi_n. \tag{38}$$

For $\Omega^2 < 0$, write $\Omega^2 = -\kappa^2$. The corresponding step is generated by a hyperbolic rather than rotational local map:

$$A_\kappa^{\text{hyp}} = \begin{pmatrix} 0 & 1 \\ \kappa^2 & 0 \end{pmatrix}, \qquad M_{\Delta t}^{\text{hyp}}(\kappa) := \exp(\Delta t\, A_\kappa^{\text{hyp}}). \tag{39}$$

Such a cell does not represent bounded oscillator-like phase flow. Any physical interpretation of a hyperbolic cell must therefore be supplied separately.

When Ω^2 varies from step to step, the finite update is not a single exponential of one constant generator. Instead one obtains the ordered product

$$y_N = M_{N-1} \cdots M_1 M_0\, y_0. \tag{40}$$

In the continuous limit this corresponds to a time-ordered exponential. Consequently, the simple energy diagnostic is generally local rather than globally conserved. The manuscript uses E as a strict invariant only in constant-Ω^2, lossless cells; elsewhere it is a diagnostic of the instantaneous projected phase state.

The same discrete-first rule applies to survival weighting. The accumulated loss after n transitions is

$$A_{i,n} = \sum_{k=0}^{n-1} \Gamma(\sigma_{i,k}) W(\varphi_{i,k}) \Delta t_k, \tag{41}$$

and the survival weight is

$$S_{i,n} = S_{i,0} \exp(-A_{i,n}). \tag{42}$$

The integral expression $A_i(t) = \int_0^t \Gamma W \, d\tau$ is recovered only as the mesh or layer spacing becomes sufficiently fine and the independently fixed loss values converge. Thus both the phase ODE and the survival integral are continuous approximations to locked discrete data, not licences to choose smooth functions after the output is known.

3.1 Phase Variables and Phase-Flow Coefficient

The minimal continuous phase dynamics are defined on the projection $\varphi(t) = (\Theta(t), \Pi(t))$ by

$$\frac{d\Theta}{dt} = \Pi, \tag{43}$$

and

$$\frac{d\Pi}{dt} = -\Omega^2 \Theta. \tag{44}$$

The coefficient Ω^2 is a phase-flow coefficient that bends trajectories in the reduced phase portrait. It is not introduced as a force acting between objects. It determines how the local phase trajectory bends within the generated state space. A physical model must separately state how Ω^2 is determined and whether it corresponds to any spacetime curvature quantity.

Equations (43) and (44) can be written in matrix form as

$$\frac{d}{dt} \begin{pmatrix} \Theta \\ \Pi \end{pmatrix} = \begin{pmatrix} 0 & 1 \\ -\Omega^2 & 0 \end{pmatrix} \begin{pmatrix} \Theta \\ \Pi \end{pmatrix}. \tag{45}$$

Thus Ω^2 determines the local character of the projected flow. Positive Ω^2 gives oscillator-like phase rotation. The limit $\Omega^2 = 0$ gives free linear phase motion. Negative Ω^2 gives hyperbolic rather than rotational behaviour and must not be interpreted as the same transport class without additional assumptions.

In this sense, gravitational language can only be used at this stage as a reduced embedding interpretation. More precisely, Ω^2 shapes the projected phase update

$$\varphi_n \mapsto \varphi_{n+1}, \tag{46}$$

while the full recursive update remains

$$\sigma_{n+1} = R(\sigma_n). \tag{47}$$

The coefficient Ω^2 is therefore not itself the complete structured-state update operator.

3.2 Lossless Energy

In the locally autonomous case, where Ω^2 is constant over the phase step being considered, the projected system has the energy-like invariant

$$E = \frac{1}{2}\left(\Pi^2 + \Omega^2\Theta^2\right). \tag{48}$$

Differentiating gives

$$\frac{dE}{dt} = \Pi\frac{d\Pi}{dt} + \Omega^2\Theta\frac{d\Theta}{dt}. \tag{49}$$

Using (43) and (44),

$$\frac{dE}{dt} = \Pi(-\Omega^2\Theta) + \Omega^2\Theta\Pi = 0. \tag{50}$$

So, in the lossless locally constant-Ω^2 limit,

$$\frac{dE}{dt} = 0. \tag{51}$$

This conservation law separates phase propagation from survival selection. Equations (43) and (44) generate the possible projected flow. They do not decide which histories dominate. Selection only enters when the survival functional is introduced.

If $\Omega^2 = \Omega^2(x,t)$ varies across the state space, then E is a local diagnostic rather than a global invariant. In that case, strict conservation requires either local constancy, an adiabatic approximation, or an explicitly extended invariant.

4 Action Norm, Exposure, and Survival

The phase equations in Section 2 generate possible projected recursive trajectories. They do not, by themselves, decide which trajectories are most strongly represented in an observed state. To introduce selection, the model assigns each trajectory a projected local magnitude, an exposure factor, and a survival weight.

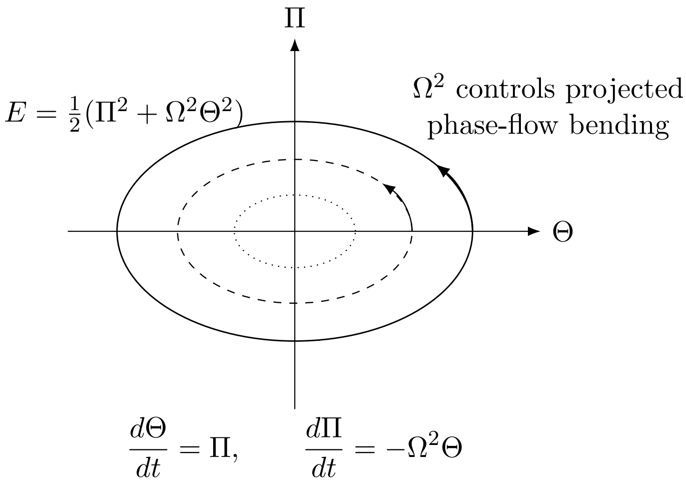

Figure 3: Reduced phase-space flow. The phase-flow coefficient Ω^2 bends the local trajectory in the projected (Θ, Π) plane.

4.1 The Action Norm

For a phase projection $\varphi = (\Theta, \Pi)$, define the local action norm

$$J(\varphi) = \Theta^2 + \ell^2\Pi^2. \tag{52}$$

Here ℓ is a scale factor that places the position-like and motion-like terms on comparable footing. In this reduced model, J is the chosen positive quadratic phase-support norm after the coordinate convention is fixed. It is not asserted to be the unique physical norm.

For a structured recursive state σ_n, define its projected phase norm by

$$\|\sigma_n\|_\Phi := J(\varphi_n), \tag{53}$$

where

$$J(\varphi_n) = \Theta_n^2 + \ell^2\Pi_n^2. \tag{54}$$

This projected norm is not automatically conserved by the phase equations. In the continuous reduced dynamics,

$$\frac{dJ}{dt} = 2\Theta\Pi + 2\ell^2\Pi\frac{d\Pi}{dt} = 2\Theta\Pi(1 - \ell^2\Omega^2). \tag{55}$$

Thus $dJ/dt = 0$ requires a special relation such as $\ell^2\Omega^2 = 1$, a vanishing product $\Theta\Pi = 0$ at an instant, or a separate norm-preservation condition on the recursive update. The null-transport class below therefore imposes projected norm preservation as a condition; it is not a generic consequence of (43)–(44).

4.2 The Exposure Weight

The action norm J measures total local phase support, but it does not say how that support is distributed between the position-like and motion-like components. For this, define the exposure weight

$$W(\varphi) = \frac{\Theta^2}{J(\varphi)} = \frac{\Theta^2}{\Theta^2 + \ell^2\Pi^2}. \tag{56}$$

For $J(\varphi) > 0$,

$$0 \leq W(\varphi) \leq 1. \tag{57}$$

The case $J = 0$ is singular in this definition and must be excluded or regularised in any application.

The interpretation is straightforward. When Θ^2 dominates, W is close to one. The trajectory is then positionally exposed. When $\ell^2\Pi^2$ dominates, W is close to zero. The trajectory is then motion-dominated and less positionally exposed.

A minimal use calculation shows what J contributes operationally. Consider two histories passing through the same lossy layer with $\Gamma\Delta t = 1$, the same position-like coordinate $\Theta = 1$, and the same calibration $\ell = 1$, but different flow coordinates:

$$\varphi_1 = (1, 0), \qquad \varphi_2 = (1, 2). \tag{58}$$

For the first history,

$$J_1 = 1^2 + 1^2(0)^2 = 1, \qquad W_1 = \frac{1}{1} = 1, \qquad A_1 = \Gamma W_1 \Delta t = 1, \qquad G_1 = e^{-1} \approx 0.368. \tag{59}$$

For the second history,

$$J_2 = 1^2 + 1^2(2)^2 = 5, \qquad W_2 = \frac{1}{5}, \qquad A_2 = \Gamma W_2 \Delta t = \frac{1}{5}, \qquad G_2 = e^{-1/5} \approx 0.819. \tag{60}$$

Both histories have the same Θ, but the second carries more projected support in the flow component. In the positional exposure model, J therefore prevents exposure from being identified with Θ^2 alone. It converts exposed support into a fraction of total projected support before the survival gate $G = e^{-A}$ is applied. This calculation illustrates the bookkeeping role of J; it is not a physical derivation of the norm.

This exposure law is a model choice, not a theorem. It is intended to represent a loss channel that couples to the position-like part of the reduced phase state. The high-$|\Pi|$ limit is therefore not a general claim that fast or motion-dominated physical systems are loss-free; it says only that this particular positional exposure channel becomes weak. Applications that require dissipation in motion-dominated states must add and independently calibrate an additional loss term, declared as a different model before comparison.

4.3 Conditional Derivation of the Exposure Factor

The exposure law used in this paper is derived inside a declared reduced exposure model. It is not claimed as a universal law of nature. The derivation rests on four explicit assumptions:

1. **State split.** The reduced phase state separates a loss-exposed coordinate Θ from a transport or flow coordinate Π.

2. **Calibrated support.** After the coordinate convention is fixed, local phase support is represented by the minimal positive quadratic form in those calibrated coordinates.

3. **Scale matching.** The product $\ell\Pi$ converts the flow coordinate into the same units as Θ.

4. **Fractional exposure.** Exposure is the fraction of total phase support lying in the component to which the loss channel couples.

This is the first-principles derivation claimed here: a derivation relative to the stated reduced-model assumptions, not a proof that those assumptions are universal. Because the coordinates have been chosen as exposed and transported axes, the minimal model contains no mixed cross term; adding one would introduce an additional calibrated coupling and define a different exposure model. Under these assumptions the total reduced phase support is the sum of exposed and transported support,

$$J_{\mathrm{tot}}(\varphi) = J_{\Theta}(\varphi) + J_{\Pi}(\varphi), \tag{61}$$

with component supports

$$J_{\Theta}(\varphi) = \Theta^2, \qquad J_{\Pi}(\varphi) = \ell^2\Pi^2. \tag{62}$$

Therefore

$$J_{\mathrm{tot}}(\varphi) = \Theta^2 + \ell^2\Pi^2. \tag{63}$$

If the loss channel couples only to the position-like support, the exposed support is

$$J_{\mathrm{exp}}(\varphi) = J_{\Theta}(\varphi) = \Theta^2. \tag{64}$$

The exposure factor is then the exposed fraction of total support:

$$W(\varphi) = \frac{J_{\mathrm{exp}}(\varphi)}{J_{\mathrm{tot}}(\varphi)} = \frac{\Theta^2}{\Theta^2 + \ell^2\Pi^2}. \tag{65}$$

In this sense, $WJ = \Theta^2$ is not an independent physical axiom. It is the definition of fractional exposure once the reduced state split, quadratic support convention, scale ℓ, and positional loss coupling have been declared. A medium whose loss channel couples to flow support, to mixed support, or to a different calibrated modal observable would require a different exposure function and would constitute a comparison model rather than the present RSG specialisation.

4.4 Operational Status of the Exposure Factor

The exposure factor is not invariant under arbitrary redefinitions of the phase coordinates. It becomes meaningful only after an operational convention fixes Θ, Π, and ℓ. In an analogue test, Θ and Π must be measured from specified modal observables, while ℓ must be calibrated before output intensities are observed. Once that convention is fixed, W is a testable exposure law rather than an adjustable weight.

The proposed law

$$W = \frac{\Theta^2}{\Theta^2 + \ell^2\Pi^2} \tag{66}$$

tests the hypothesis that the relevant loss channel couples to the position-like part of the reduced phase state. Other exposure laws are possible, but they define different models. A comparison model may therefore replace W by 1, by a constant, or by another predeclared function of the modal state. The RSG-specific claim is not merely exponential attenuation; it is that the exposure-modulated accumulated loss $\int \Gamma W\, dt$ predicts the represented output better than an ordinary path-loss law using $\int \Gamma\, dt$ alone.

4.5 The Survival Functional

Let $\Gamma(\sigma)$ be a non-negative dissipation coefficient on the full structured state:

$$\Gamma(\sigma) \geq 0. \tag{67}$$

The product

$$\Lambda_{\text{surv}}(\sigma, \varphi) = \Lambda(\sigma, \varphi) = \Gamma(\sigma)W(\varphi) \tag{68}$$

defines the effective local survival-loss rate. Survival decay is controlled by Λ_{surv}, not by Γ alone. The subscript is useful because this Λ_{surv} is not the cosmological constant Λ_{CC}. A history with $\Gamma > 0$ but $W = 0$ has no local survival decay in this reduced law.

The dimensions must make A_i dimensionless. If t is a physical time, then Γ and Λ_{surv} have units of inverse time, while W is dimensionless. If t is a layer index or recursive step count, then Δt is the chosen step unit and $\Gamma\Delta t$ is dimensionless. Since $\Pi = d\Theta/dt$ in the continuous approximation, ℓ has the units needed to make $\ell\Pi$ comparable with Θ; for physical time this means $[\ell] = [\text{time}]$ and $[\Omega^2] = [\text{time}]^{-2}$. These unit choices must be fixed before any analogue test.

The discrete-first form is most transparent in terms of accumulated loss. Define

$$A_{i,n+1} = A_{i,n} + \Lambda_{i,n}\Delta t, \qquad \Lambda_{i,n} = \Gamma(\sigma_{i,n})W(\varphi_{i,n}). \tag{69}$$

Then

$$S_{i,n} = e^{-A_{i,n}}, \qquad S_{i,n+1} = S_{i,n}\exp(-\Lambda_{i,n}\Delta t). \tag{70}$$

For small Δt,

$$\frac{S_{i,n+1} - S_{i,n}}{\Delta t} = -\Lambda_{i,n}S_{i,n} + O(\Delta t), \tag{71}$$

which gives the continuous survival equation in the limit.

For a discrete recursive history

$$\gamma_i = \{\sigma_{i,0}, \sigma_{i,1}, \ldots, \sigma_{i,n}\}, \tag{72}$$

define the survival weight after n transitions, with $A_{i,0} = 0$ and $S_{i,0} = 1$, by

$$S_i(n) = \exp\left(-\sum_{k=0}^{n-1}\Gamma(\sigma_{i,k})W(\varphi_{i,k})\Delta t\right). \tag{73}$$

Because $\Gamma \geq 0$ and $W \geq 0$, the exponent is non-positive. Hence, for finite accumulated loss,

$$0 < S_i(n) \leq 1. \tag{74}$$

For operational readout, the same multiplier is named the exposure-gate transmission:

$$G_i(n) := S_i(n) = e^{-A_i(n)}. \tag{75}$$

The word gate does not add a new force or a new random choice. It names the multiplicative transmission factor through which prepared representation must pass before normalisation. The term stochastic gate is appropriate only for an extension in which the gate variables themselves are random; in the strict analogue protocol, G_i is computed from the locked Γ, W, and path data.

Additional structural, topological, boundary, class, or interaction losses are not part of the minimal analogue protocol. They may be introduced only as a declared extension

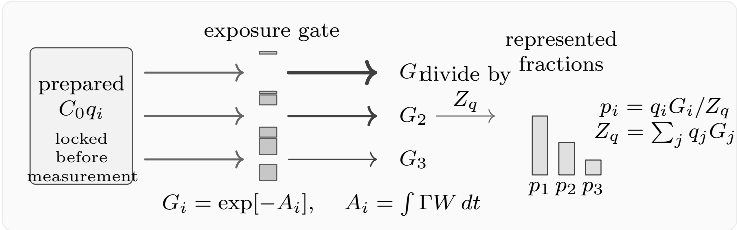

Figure 4: Exposure-gate schematic for the operational count map. The gate multiplies the prepared amount by $G_i = e^{-A_i}$ before any probability-like output fraction is formed.

with independently fixed coefficients. In the present paper, the empirical test is restricted to the exposure-weighted loss channel $\Lambda_{\text{surv}} = \Gamma W$.

In the continuous approximation, with $S_i(0) = 1$, the same rule becomes

$$S_i(t) = \exp\left(- \int_0^t \Gamma(\sigma_i(\tau)) W(\varphi_i(\tau)) \, d\tau \right). \tag{76}$$

More generally, a non-unit initial weight gives $S_i(t) = S_i(0) \exp[-\int_0^t \Gamma W \, d\tau]$. Such initial weights are part of the history measure or preparation protocol and must be fixed before normalisation. The corresponding continuous gate transmission is

$$G_i(t) := S_i(t) = \exp[-A_i(t)]. \tag{77}$$

Differentiating gives the local survival equation

$$\frac{dS_i}{dt} = -\Gamma(\sigma_i(t)) W(\varphi_i(t)) S_i. \tag{78}$$

Equation (78) is the central filtering equation. It does not describe a force. It describes the decay of representation. The trajectory remains part of the generated history space, but its contribution to the normalised measure is reduced.

4.6 Normalisation Over Histories

Given a family of generated histories $\{\gamma_i\}$, each with survival weight $S_i(t)$, the equal-preparation shorthand for the normalised representation weight is

$$p_i(t) = \frac{S_i(t)}{\sum_j S_j(t)}. \tag{79}$$

This gives

$$\sum_i p_i(t) = 1, \qquad p_i(t) \geq 0. \tag{80}$$

The representation measure is therefore induced by survival within the chosen history family. In the analogue protocol, p_i is interpreted operationally as a represented output fraction under the fixed detector/output map, not as an independently derived physical probability law. The count-derived form in Section 4.7 is the general operational map; (79) is the equal-preparation shorthand. Histories that lose less weight under the $\Gamma(\sigma)W(\varphi)$ filter become more strongly represented after normalisation when preparation weights are equal. With unequal preparation, both q_i and accumulated loss determine the represented output fraction.

Consequently, (79) should not be read as a new physical postulate saying that survival weight simply is observable probability. It is the equal-preparation abbreviation of the count map derived below, where prepared amounts are multiplied by $G_i = e^{-A_i}$ and then divided by the total transmitted amount.

This gives the model its basic selection mechanism:

$$\text{generated histories} \quad \longrightarrow \quad \text{exposure gates} \quad \longrightarrow \quad \text{normalised representation.} \tag{81}$$

The projected phase flow determines which histories are available. The survival functional determines the gate transmission G_i. The observed distribution is then the normalised result of prepared amounts after this phase-flow and dissipation gate.

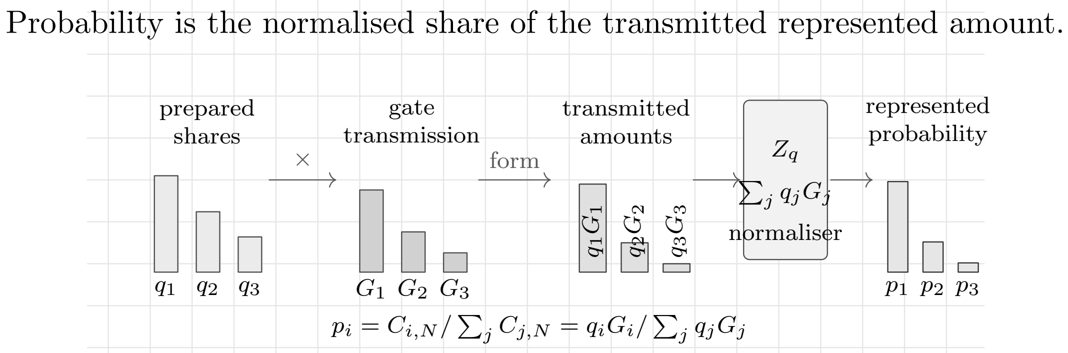

Figure 5: Probability-section schematic. Preparation weights and exposure-gate transmissions are kept separate until the transmitted amounts are divided by the shared normaliser Z_q.

4.7 Operational Probability Map from Counts

The symbol p_i is not introduced merely by grammatical convention. It is the large-count or represented-measure fraction associated with a fixed output map. This is the same minimal finite-state discipline used in information theory: one must first declare the states, counts, or probabilities over which information is evaluated [8, 7]. Information-physics proposals such as Vopson's mass-energy-information equivalence and infodynamics programme also rely on explicitly defined information-bearing states or state probabilities before physical claims are made [9, 10]. The present paper adopts the weaker operational claim: in an analogue protocol, p_i is the predicted fraction of represented output in channel i, not a universal probability law.

Let $C_{i,0}$ be the number, intensity unit, or represented preparation count initially assigned to history class i. If the preparation weights are q_i and the total prepared count is C_0, then

$$C_{i,0} = C_0 q_i. \tag{82}$$

For a discrete locked survival process, each step multiplies the represented count by the corresponding survival factor:

$$C_{i,k+1} = C_{i,k} \exp[-\Gamma_{i,k} W_{i,k} \Delta t_k]. \tag{83}$$

Iterating the locked update gives

$$G_i = \exp\left[-\sum_{k=0}^{N-1} \Gamma_{i,k} W_{i,k} \Delta t_k\right] = e^{-A_i}, \tag{84}$$

and therefore

$$C_{i,N} = C_0 q_i G_i = C_0 q_i e^{-A_i}. \tag{85}$$

The represented output fraction is therefore

$$p_i = \frac{C_{i,N}}{\sum_j C_{j,N}} = \frac{q_i G_i}{\sum_j q_j G_j} = \frac{q_i e^{-A_i}}{\sum_j q_j e^{-A_j}}. \tag{86}$$

Thus the probability-like quantity is a normalised count, intensity, or represented-measure fraction after a declared gate process. In a finite repeated experiment, the measured fraction

$$\widehat{p}_i = \frac{\widehat{C}_i}{\sum_j \widehat{C}_j} \tag{87}$$

is the empirical object compared with p_i.

A toy drawing example makes the counting logic explicit without invoking a continuous curve formula. Suppose a plotting algorithm draws a circular-looking closed loop on a square pixel grid using only local integer updates. At each boundary step it may choose among a finite set of candidate pixels that keep the loop close to its intended path. Candidate class i is prepared $C_{i,0}$ times across repeated drawings. If paper drag, ink spread, or clipping removes visible marks with locked step loss $\Gamma_{i,k} W_{i,k} \Delta t_k$, then the expected visible count after N steps is the prepared count multiplied by the gate transmission G_i. The normalised visible fraction is then (86). The example does not prove a physical law; it shows how survival gating becomes a countable output fraction once the candidate classes, loss rule, and detector convention are fixed.

This count map also matches the information-recovery discipline used in the companion recovery note [15]. In that note, information does not become physically meaningful merely by being generated. It must pass through support, boundary or closure coupling, a recovery channel, and a physical measure package before any stress-energy claim can be made. The present probability map uses the same caution at the level of represented outputs: a generated history receives a probability-like weight only after its support class, preparation count, survival rule, recovery or detector map, and normalisation convention have been specified.

4.8 Minimal Model and Finite-History Lemma

Minimal model in one box.

$$
\begin{array}{ll}
\text{Input:} & \{\gamma_i\}_{i=1}^{N} \text{ generated histories,} \\
\text{Dynamics:} & \sigma_{n+1} = R(\sigma_n) \text{ or fixed phase-step map,} \\
\text{Loss:} & \Lambda_{\mathrm{surv},i} = \Gamma_i W_i, \\
\text{Gate:} & G_i = S_i = \exp\Big(-\int_{\gamma_i} \Lambda_{\mathrm{surv},i}\, dt\Big), \\
\text{Preparation:} & C_{i,0} = C_0 q_i, \\
\text{Surviving output:} & C_{i,N} = C_0 q_i G_i = C_0 q_i e^{-A_i}, \\
\text{Representation:} & p_i = C_{i,N} / \sum_j C_{j,N}, \\
\text{External test target:} & \widehat{\mathbf{p}} \text{ matches } \mathbf{p}_{\mathrm{pred}}, \\
 & \widehat{p}_i/\widehat{p}_j \text{ matches } (q_i/q_j)e^{-A_i+A_j}.
\end{array}
\tag{88}
$$

The minimal model can be stated without physical interpretation. Start with a finite family of generated histories $\{\gamma_i\}_{i=1}^{N}$. Choose a recursive update or measured step map, a phase projection, and an effective survival-loss rate

$$
\Lambda_{\mathrm{surv},i}(t) = \Gamma(\sigma_i(t))W(\varphi_i(t)). \tag{89}
$$

For the uniform finite-history measure, or equal-preparation count case $q_i = 1$, define

$$
A_i = \int \Lambda_{\mathrm{surv},i}(t)\, dt, \qquad G_i = S_i = e^{-A_i}, \qquad p_i = \frac{G_i}{\sum_{j=1}^{N} G_j}. \tag{90}
$$

If the generated histories have independently fixed preparation weights $q_i > 0$, the finite-history rule becomes

$$
p_i = \frac{q_i G_i}{Z_q} = \frac{q_i e^{-A_i}}{Z_q}, \qquad Z_q = \sum_{j=1}^{N} q_j e^{-A_j}. \tag{91}
$$

The unweighted case in (90) is the special case $q_i = 1$ for all represented histories. For finite real A_i, the normaliser

$$
Z = \sum_{j=1}^{N} e^{-A_j} \tag{92}
$$

is finite and strictly positive in the unweighted case. Therefore p_i is well defined and

$$
\frac{p_i}{p_j} = e^{-A_i+A_j} \tag{93}
$$

for equal preparation. With non-uniform preparation weights, the no-log ratio is

$$
\frac{p_i}{p_j} = \frac{q_i}{q_j} e^{-A_i+A_j}. \tag{94}
$$

The primary empirical comparison may therefore be made without logarithms by comparing the measured output vector with

$$
\mathbf{p}_{\mathrm{pred}} = \left(\frac{q_i e^{-A_i}}{\sum_j q_j e^{-A_j}} \right)_i, \tag{95}
$$

and by checking selected ratios

$$\frac{\widehat{p}_i}{\widehat{p}_j} \approx \frac{q_i}{q_j} e^{-A_i + A_j}. \tag{96}$$

A preregistered whole-vector discrepancy can be stated, for example, as

$$D_1 = \sum_i \left| \widehat{p}_i - p_i^{\text{pred}} \right|, \qquad D_{\text{RMS}} = \sqrt{\frac{1}{N} \sum_i \left(\widehat{p}_i - p_i^{\text{pred}} \right)^2}. \tag{97}$$

These scores are not evidence by themselves. They become empirical only when the input quantities and acceptance thresholds are fixed before the output is inspected.

The same ratio may also be written in logarithmic form,

$$\ln \left(\frac{p_i}{p_j} \right) = -A_i + A_j. \tag{98}$$

Within the formalism, (93) and (98) are algebraic identities once $G_i = S_i = e^{-A_i}$ and the equal-preparation normalisation $p_i = G_i/Z$ have been defined. In the operational count map, this is the special case of $C_{i,N} = C_0 q_i G_i$ with equal q_i. The logarithmic version is useful because it converts a ratio into a difference, but it is not required by the formalism and should not be mistaken for a separate physical law. The comparison becomes empirically risky only when A_i, G_i, q_i, and the output map are fixed from independently calibrated path data before the measured outputs are observed. With non-uniform preparation weights, the corresponding identity is

$$\ln \left(\frac{p_i}{p_j} \right) = \ln \left(\frac{q_i}{q_j} \right) - A_i + A_j. \tag{99}$$

Equivalently,

$$A_i < A_j \quad \Longleftrightarrow \quad p_i > p_j. \tag{100}$$

The ordering equivalence in (100) assumes equal preparation weights. With unequal q_i, the ordering depends on both preparation weight and accumulated loss. This is a formal survival-normalisation lemma. It becomes empirically meaningful only when the histories, preparation weights, loss field, scale choices, and output map are fixed before the measured output is known.

Non-circularity rule. No empirical claim follows if R, Ω^2, ℓ, Γ, W, path class, history family, path weights, or output normalisation are adjusted after observing the output. If any of these are chosen after the output is known, the test is invalid as a prediction. A valid test fixes these structures before comparison.

4.9 History Measure and Normalisability

For a finite family of histories, the representation weights in (90) are enough. For a continuous, branching, or otherwise infinite family of histories, the formalism also needs a base measure. Let $d\mu(\gamma)$ be the chosen history measure and let $A[\gamma]$ be the accumulated survival loss along history γ. Then the represented history measure is

$$dP(\gamma) = \frac{e^{-A[\gamma]}}{Z}\, d\mu(\gamma), \qquad Z = \int e^{-A[\gamma]}\, d\mu(\gamma). \tag{101}$$

Equivalently, if the generated histories already carry a prior or generation weight $q(\gamma)$, one may write

$$dP(\gamma) = \frac{q(\gamma)e^{-A[\gamma]}}{Z_q}\, d\mu(\gamma), \qquad Z_q = \int q(\gamma)e^{-A[\gamma]}\, d\mu(\gamma). \tag{102}$$

The representation measure is defined only on domains where the relevant normaliser satisfies

$$0 < Z < \infty. \tag{103}$$

Equivalently, in the weighted case, $0 < Z_q < \infty$. This condition is part of the formal model. If the normaliser vanishes, diverges, or depends on an after-the-fact choice of history measure, the representation weights are not operationally meaningful.

4.10 Survival Entropy

The normalised survival measure also defines an entropy over represented histories. For equal preparation weights, write

$$Z(t) = \sum_j e^{-A_j(t)}, \qquad p_i(t) = \frac{e^{-A_i(t)}}{Z(t)}, \tag{104}$$

define

$$H_{\text{surv}}(t) = -\sum_i p_i(t) \ln p_i(t). \tag{105}$$

Substituting $p_i = (e^{-A_i})/Z$ gives

$$H_{\text{surv}}(t) = \sum_i p_i(t)A_i(t) + \ln Z(t) = \langle A \rangle_p + \ln Z. \tag{106}$$

The associated effective number of represented histories is

$$N_{\text{eff}}(t) = e^{H_{\text{surv}}(t)}. \tag{107}$$

High H_{surv} means many distinguishable histories remain represented. Low H_{surv} means survival filtering has concentrated representation into a narrower basin. This entropy is derived from the normalised survival measure; it is not an additional primitive probability law, thermodynamic entropy, or particle count unless an explicit measurement bridge is supplied.

With prepared counts or unequal preparation weights, the same entropy is computed from the operationally normalised fractions

$$p_i(t) = \frac{q_i e^{-A_i(t)}}{\sum_j q_j e^{-A_j(t)}}. \tag{108}$$

5 Analogue Prediction and Validation Protocol

The preceding sections define recursive states, projected phase steps, and survival weighting. Before introducing the later null-transport and representation-concentration interpretations, the paper fixes the empirical target: a locked analogue validation protocol. To be useful as physics, the formalism must state which quantities are internally defined, which are free structures, which are pre-measurement model outputs, and which measured observations would falsify the constrained analogue special case.

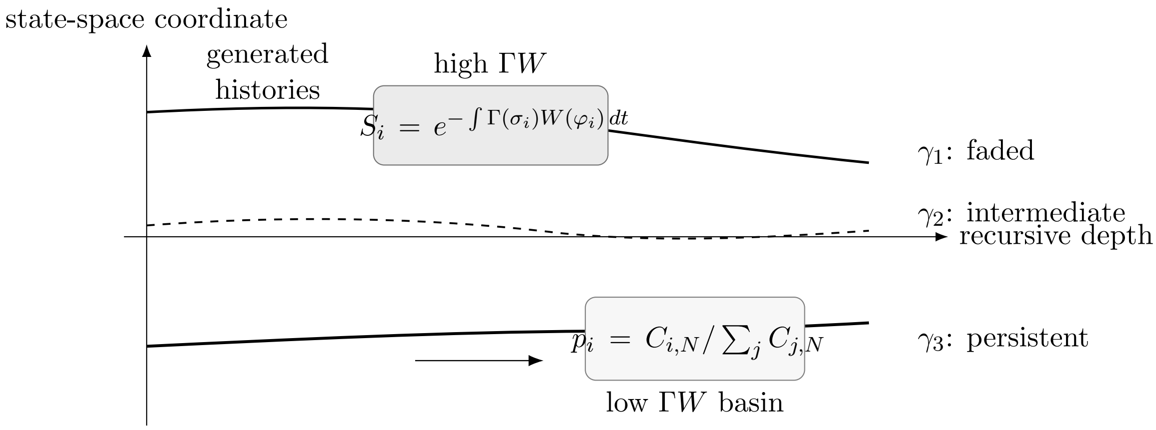

Figure 6: Survival filtering over generated histories. Histories passing through lower effective loss retain more survival weight and dominate the normalised representation.

5.1 What Is Free and What Is Fixed

The minimal formalism separates internally defined quantities from free structures and imported bridge assumptions. This distinction is necessary because otherwise the model could be made to fit data after the fact.

5.2 Coordinate Convention Lock

The exposure factor

$$W(\varphi) = \frac{\Theta^2}{\Theta^2 + \ell^2 \Pi^2} \tag{109}$$

is an operational exposure law, not a coordinate-invariant scalar on arbitrary phase-space parametrisations. The analogue test therefore requires a locked coordinate convention. The measured quantities Θ, Π, and ℓ must be defined by calibration before the output intensities are inspected, and the same convention must be used in computing every A_i.

The same locked test is preserved by sign changes and fixed unit rescalings that leave W unchanged. For example, if

$$\Theta' = a\Theta, \qquad \Pi' = b\Pi, \qquad \ell' = \frac{a}{b}\ell, \qquad a, b > 0, \tag{110}$$

then

$$\frac{(\Theta')^2}{(\Theta')^2 + (\ell')^2 (\Pi')^2} = \frac{\Theta^2}{\Theta^2 + \ell^2 \Pi^2}. \tag{111}$$

Such a transformation is only a change of units if it is declared before calibration. By contrast, translations of the zero of Θ, nonlinear reparametrisations, rotations mixing Θ and Π, post-measurement changes of ℓ, or changes in the phase-unwrapping convention generally change W. They therefore define a different model or a different test. They cannot be introduced after the output vector is known.

Coordinate-convention lock. A valid analogue test must declare the observable meaning of Θ, the estimator for Π, the scale ℓ, the zero of the phase coordinate, the phase-wrapping convention, and the allowed unit transformations before the output measurement. If a transformation changes the computed exposure history $W_i(t)$, the transformed calculation is a new model and must be preregistered as such.

Table 4: Status of quantities used in the minimal formalism and its optional extensions.

Status	**Quantities**	**Role**
Internal definitions	$\sigma_n, \varphi_n, J, W, \Lambda$ A_i, S_i, p_i, Z $H_{\text{surv}}, N_{\text{eff}}$	Defined by the formalism. They are not independent empirical inputs.
Free structures	$R, \Omega^2, \Gamma, \ell$ $\sim, \Delta t$	Must be fixed by a rule, calibration, or operational definition before comparison with data.
Optional extensions	$L_D, Q_H, \lambda_{\text{bd}}, \lambda_{\text{class}}$ $\lambda_{\text{int}}, \lambda_H, M_{R,n}$ ρ_R, C, Ω_R, Ξ $I_{\text{hist}}, E_{\text{L}}$ $\varepsilon_{\text{R,vac}}$	May be used in topological, measure, cosmological, or Landauer-style specialisations, but are not part of the minimal transport proof.
Imported bridge structures	ds^2, c Lorentzian signature interval calibration	Standard physical structures used when embedding the recursive model into spacetime or measure bookkeeping.
Operational observables	Θ, Π, Γ path structure output intensity	Must be measurable or controllable in the analogue test. They are inputs to the locked prediction.
Derived test outputs	W, A_i $\mathbf{p}_{\text{pred}}$ p_i/p_j optional $\ln(p_i/p_j)$	Computed from locked observables, conventions, and path data before measurement. They are not calibration knobs.

The same convention must also declare a singular-state rule. In a real validation run the denominator

$$J = \Theta^2 + \ell^2 \Pi^2 \tag{112}$$

must satisfy a predeclared lower bound $J \geq J_{\min} > 0$, or else the state must be excluded, regularised, or assigned a separately declared convention before output data are inspected.

5.3 Algebraic Reduction and Identity Status

The central survival-ratio equation is not a derived physical law inside the formalism. It is the algebraic consequence of the definitions. In the equal-preparation shorthand, once

$$S_i = e^{-A_i}, \qquad Z = \sum_j e^{-A_j}, \qquad p_i = \frac{S_i}{Z}, \tag{113}$$

one obtains

$$\frac{p_i}{p_j} = \frac{e^{-A_i}/Z}{e^{-A_j}/Z} = e^{-A_i + A_j}, \tag{114}$$

and therefore

$$\ln\left(\frac{p_i}{p_j}\right) = -A_i + A_j. \tag{115}$$

No empirical content follows from the no-log or logarithmic ratio identity by itself. Empirical content begins only when A_i, A_j, and the preparation convention are computed from an independently locked accumulation map before the measured output ratio is known.

With non-uniform preparation weights q_i, the same reduction gives

$$p_i = \frac{q_i e^{-A_i}}{\sum_j q_j e^{-A_j}}, \qquad \ln\left(\frac{p_i}{p_j}\right) = \ln\left(\frac{q_i}{q_j}\right) - A_i + A_j. \tag{116}$$

The logarithmic expression is the diagnostic form of the same no-log ratio $p_i/p_j = (q_i/q_j)e^{-A_i+A_j}$. Thus q_i must also be fixed before measurement. If A_i, q_i, the output map, or the history family are chosen after $\widehat{p_i}$ is known, the relation is post-hoc fitting rather than prediction.

5.4 Real Prediction Structure

The central empirical object is the accumulated survival-loss functional

$$A_i(t) = \int_0^t \Gamma(\sigma_i(\tau)) W(\varphi_i(\tau)) \, d\tau, \tag{117}$$

with survival weight

$$S_i(t) = e^{-A_i(t)} \tag{118}$$

and count-normalised representation

$$p_i(t) = \frac{q_i e^{-A_i(t)}}{\sum_j q_j e^{-A_j(t)}}. \tag{119}$$

Table 5: Input-output status for the locked analogue protocol.

Class	Quantities	Status in a valid test
Independent measured observables	$\Theta, \Pi, \Gamma, I_i, I_{i,\mathrm{bg}}$, path structure	Measured or calibrated before output comparison.
Calibration constants and conventions	$\ell, \Delta t, q_i, J_{\min}, I_{\mathrm{floor}}, p_{\mathrm{floor}}$, detector map	Declared before the validation run.
Free structures	$R_{\mathrm{test}}, \Omega^2, \sim$, boundary/interface conditions	Locked by rule, measured transfer map, or preregistered convention.
Derived quantities	$W, A_i, S_i, C_{i,N}, \mathbf{p}_{\mathrm{pred}}, p_i/p_j$, optional $\ln(p_i/p_j)$	Computed from locked inputs; not fitted to output.
Conjectural bridges	$ds^2, c, \Lambda_{\mathrm{CC}}$, matter-sector or cosmological variables	Not part of the empirical analogue claim.

A genuine test must identify a system in which different paths, modes, histories, or layers acquire independently specified effective values of

$$\Lambda_i(t) = \Gamma(\sigma_i(t))W(\varphi_i(t)). \tag{120}$$

Here Γ, measured estimators $\widehat{\Theta}$, $\widehat{\Pi}$, ℓ, path structure, and the output map are independently fixed inputs. The formal coordinates Θ, Π are instantiated by $\widehat{\Theta}, \widehat{\Pi}$ only after the coordinate-convention lock has been declared. The quantities W, A_i, and $\mathbf{p}_{\mathrm{pred}}$ are derived from those locked inputs before the output is measured; they are not fitted calibrands.

The pre-measurement model output is the relative survival identity

$$\ln\left(\frac{p_i}{p_j}\right) = \ln\left(\frac{q_i}{q_j}\right) - A_i(t) + A_j(t). \tag{121}$$

The empirical comparison is that independently measured output ratios match this precomputed relation within the declared uncertainty. For equal preparation weights, the first term vanishes and the relation reduces to $-A_i + A_j$. For a multi-channel test, the stronger pre-measurement output is the full represented vector

$$\mathbf{p}_{\mathrm{pred}} = \left(\frac{q_1 e^{-A_1}}{Z_q}, \ldots, \frac{q_N e^{-A_N}}{Z_q}\right), \qquad Z_q = \sum_{j=1}^{N} q_j e^{-A_j}. \tag{122}$$

This becomes an empirical output claim only when all A_i, q_i, and output-map conventions are computed from independently fixed quantities before the output distribution is measured.

5.5 Analogue Recursive Media

The most direct test is not cosmological. It is an analogue system in which propagation through layered or recursive media can be controlled. Such a system should allow repeated transitions

$$\sigma_n \to \sigma_{n+1} \tag{123}$$

with measurable phase-like and motion-like coordinates. The aim would be to engineer a known effective loss field

$$\Lambda = \Gamma(\sigma)W(\varphi) \tag{124}$$

and measure whether mode persistence follows

$$S = e^{-\int \Lambda\, dt}. \tag{125}$$

A simple analogue experiment would require three elements:

1. a discrete or layered propagation medium;
2. a measurable phase coordinate and conjugate flow coordinate;
3. a tunable loss mechanism that couples more strongly to one part of the phase state than another.

One possible implementation is a layered optical or acoustic medium. The primary candidate output signature is that the measured output vector and selected no-log intensity ratios between modes follow accumulated effective loss, rather than depending only on geometric path length. Logarithmic ratios are useful secondary diagnostics when the channels remain safely above the detector floor.

The output map must also be fixed. Unless otherwise stated, the protocol uses an intensity- or power-weighted convention, so p_i is estimated from background-subtracted and detector-calibrated output powers or intensities:

$$\widehat{p}_i = \frac{I_i - I_{i,\mathrm{bg}}}{\sum_j (I_j - I_{j,\mathrm{bg}})}. \tag{126}$$

Here I_i is the measured output intensity or acoustic power in channel i, and $I_{i,\mathrm{bg}}$ is the independently measured background. This convention treats S_i as an intensity or power transmission weight. If an experiment instead applies survival weighting to field amplitudes, the predicted intensity law changes by the corresponding square; that alternative convention must be declared before the test and is a different output map.

A minimal two-path example makes the pre-measurement model output explicit. Suppose the independently calibrated accumulated losses are

$$A_1 = 0.2, \qquad A_2 = 1.2. \tag{127}$$

Then

$$S_1 = e^{-0.2} \approx 0.819, \qquad S_2 = e^{-1.2} \approx 0.301, \tag{128}$$

and

$$p_1 = \frac{S_1}{S_1 + S_2} \approx 0.731, \qquad p_2 = \frac{S_2}{S_1 + S_2} \approx 0.269. \tag{129}$$

Equivalently,

$$\frac{p_1}{p_2} = e^{-A_1 + A_2} = e^1. \tag{130}$$

In logarithmic diagnostic form this is

$$\ln\left(\frac{p_1}{p_2}\right) = -A_1 + A_2 = 1. \tag{131}$$

Within the formalism this equality is an identity. The controlled analogue experiment tests whether the independently measured output ratio follows the precomputed accumulated loss difference, not a loss field chosen after the measured output is known.

5.6 Example Protocol for an Analogue Test

In an optical or acoustic implementation, Θ may be taken as a calibrated phase or position-like modal coordinate, while Π is the measured layer-to-layer phase-flow coordinate. The coefficient Γ is the independently calibrated attenuation or loss coefficient for each layer, channel, or mode, and $W = \Theta^2/J$ is computed from the measured phase state rather than fitted to the output.

A serious analogue validation cannot rest on a three-channel toy fit. Small examples in this paper illustrate the algebra and the locking discipline only. As evidence, a valid test must either use many independently measured output channels, or make a sharply constrained small-channel prediction whose input quantities have been calibrated without access to the target output. Merely declaring many adjustable quantities before a three-bin comparison is not enough if those quantities were chosen to match the known target. The protocol therefore requires independent calibration, held-out output inspection, and an ordinary-attenuation control.

Table 6: Concrete measurement and calibration map for a layered optical or acoustic analogue test.

Symbol	**Physical observable**	**Calibration procedure**	**Uncertainty or failure mode**
R_{test}	Layer-to-layer transfer map for the selected mode family.	Measure transfer through calibration layers before the validation run; lock boundary and interface conventions.	Invalid if updated after output data or if unmodelled coupling dominates.
Θ	Phase, modal displacement, or position-like coordinate read from the calibrated mode state.	Extract from interferometric phase, acoustic phase, or modal-position measurement before output comparison.	Phase wrapping, sensor noise, or coordinate drift outside calibration range.
Π	Layer-to-layer phase-flow coordinate, such as $(\Theta_{n+1} - \Theta_n)/\Delta t$.	Estimate from adjacent calibrated layer states using the locked transfer map and declared step interval.	Finite-difference noise, layer jitter, or unresolved mode mixing.
ℓ	Scale converting Π into units comparable with Θ.	Fix from calibration data or dimensional convention before prediction; do not refit after output.	Parameter trade-off with Γ or boundary coupling.
Γ	Independent attenuation or loss coefficient for a layer, channel, or mode.	Measure from control transmissions or ring-down/decay calibration with W not fitted to the validation output.	Drift in material loss, detector response, or source power.
W	Exposure $W = \Theta^2/(\Theta^2 + \ell^2\Pi^2)$.	Compute from calibrated Θ, Π, ℓ before output measurement.	Invalid if tuned to match $\widehat{\mathbf{p}}$.

continued on next page

Symbol	Physical observable	Calibration procedure	Uncertainty or failure mode
A_i	Accumulated exposure-weighted loss along path i.	Integrate or sum ΓW along the locked path family before output measurement.	Path misidentification, timing error, or calibration covariance.
$\widehat{p}_i$	Background-subtracted output intensity or power fraction.	Use the fixed output map (126) after prediction is locked.	Background error, saturation, detector nonlinearity, or amplitude/intensity convention mismatch.

A minimal protocol is:

1. choose the layered medium and lock the test update rule R_{test}, or its measured layer-to-layer map, before collecting output data;
2. choose initial input modes, preparation weights q_i when they are not equal, and path classes before propagation;
3. declare the boundary and interface conditions, including reflection, transmission, mode coupling, detector aperture, and any absorbing or periodic boundary conventions;
4. calibrate Θ, Π, ℓ, and Γ independently for each layer or channel;
5. compute $W = \Theta^2/(\Theta^2 + \ell^2\Pi^2)$, then integrate $A_i = \int \Gamma W \, dt$ along each specified path;
6. propagate calibration errors in Θ, Π, ℓ, Γ, q_i, path length, background subtraction, and detector response into uncertainty bounds for $\mathbf{p}_{\text{pred}}$, selected no-log ratios $(q_i/q_j)e^{-A_i+A_j}$, and any optional logarithmic diagnostics;
7. preregister D_1, D_{RMS}, k, χ^2, $\Delta\chi^2$, calibration ranges, and refinement tolerance before output data are inspected;
8. compute the pre-measurement vector $\mathbf{p}_{\text{pred}}$, together with selected no-log ratios $p_i/p_j = (q_i/q_j)e^{-A_i+A_j}$, using that uncertainty bound;
9. measure the output intensity distribution only after the prediction has been fixed.

The output-vector and no-log ratio formulae are internal identities once the accumulated losses and normalisation are defined. The analogue test fails if independently calibrated accumulated-loss values do not predict the measured output vector and preregistered no-log output ratios within stated experimental uncertainty. Log-ratios may be retained as optional secondary diagnostics because they linearise the same ratio. Figure 7 summarises the required order of operations.

Preregistration checklist. Before output inspection, a valid analogue run must record: the release track and claim status; the update map R_{test}; the coordinate convention for Θ, Π, ℓ; the independent loss calibration for Γ; the path family and preparation weights q_i; the output convention and detector/background model; the detector floors and censoring rules; the ordinary-attenuation control; the selected vector statistic, no-log ratios, and any optional log-ratios; and the D_1, D_{RMS}, k, χ^2, $\Delta\chi^2$, and refinement thresholds. If any item is chosen after output inspection, the run is not a prediction.

Model fails if. The constrained analogue model fails if the locked output vector or preregistered no-log ratios disagree with measured $\widehat{\mathbf{p}}$ outside the declared uncertainty. It also fails as an RSG-specific test if the exposure-weighted prediction does not beat the ordinary attenuation control in the preregistered positive-control regime. The test is invalid, rather than merely unsuccessful, if R_{test}, Θ, Π, ℓ, Γ, W, path classes, preparation weights, output map, or acceptance threshold are changed after the output data are inspected.

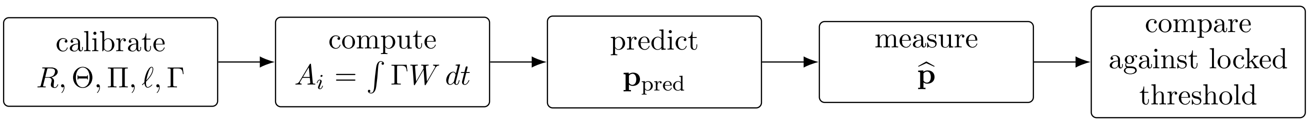

Figure 7: Analogue validation flow. Calibration and prediction must be locked before output intensities are measured; the comparison is made only against the preregistered uncertainty or goodness-of-fit threshold.

Table 7: Locked quantities, uncertainty sources, and failure thresholds for the analogue protocol.

Quantity	**How fixed before measurement**	**Uncertainty contribution**	**Output comparison**	**Failure threshold**
R_{test}	Locked layer-to-layer map	Refinement/model uncertainty	Same map used in A_i	Invalid if changed after output.
Boundary/ interface	Declared reflection, transmission, coupling, aperture, and boundary conventions	Coupling and aperture uncertainty	Included in R_{test}	Invalid if undeclared effects dominate.
Θ, Π	Measured from the mode state	Phase-coordinate calibration	Used to compute W	Invalid outside calibration range.
ℓ	Calibration scale between Θ and Π	Scale uncertainty	Enters W and A_i	Not refitted after output.

continued on next page

Quantity	How fixed before measurement	Uncertainty contribution	Output comparison	Failure threshold
Γ	Calibrated loss coefficient	Attenuation uncertainty	Enters A_i	Not fitted after output.
A_i	Integrated along specified path	Propagated from Γ, W, path, and timing	Predicts $\mathbf{p}_{\text{pred}}$, no-log ratios, and optional log-ratios	Failure outside stated tolerance.
Output map	Background and detector calibration	Detector and background uncertainty	Defines $\widehat{p}_i$ from intensity or power	Locked before comparison.
Failure threshold	Preregistered k, χ^2, or $\Delta\chi^2$ rule	Acceptance-region choice	Compares measured and predicted vectors	Failure outside acceptance region.

Table 8: Identity-risk status of the main analogue-test claims.

Claim	Algebraic?	Independent input needed	Measurement that can fail
$p_i = q_i e^{-A_i}/Z_q$	Yes	q_i, A_i fixed from preparation and path data	None by itself; measured output fractions can fail.
$p_i/p_j = (q_i/q_j)e^{-A_i+A_j}$	Yes	q_i, q_j, A_i, A_j fixed before measurement	Measured output ratio; log-ratio only as optional diagnostic.
$d\tau_R = 0 \Rightarrow ds^2 = 0$	Bridge identity	Lorentzian interval calibration	Failure of bridge assumptions, not algebra.
RSG beats ordinary attenuation	No	Locked $\Gamma, W, \ell, R_{\text{test}}$ and output map	No improvement over the $\int \Gamma\, dt$ control.

5.7 Known-Output Demonstrations of the Exposure Idea

Before a new analogue experiment is attempted, the exposure law can be sanity-checked against systems where component-selective weighting already has a known interpretation. These demonstrations do not validate the full RSG framework. Their role is narrower: to show that W can be instantiated as a measured exposed-support fraction, and that exposure-weighted loss can be compared against a simpler unweighted control.

A companion numerical note collects the beam-mask exposure demonstration, the Surtea boundary-valuation gate, and the probability-gate examples used in this section [11]. The note is not used as empirical validation here. Its role is reproducibility: it shows how W, $G = \exp(-A)$, and $p_i = q_i G_i / \sum_j q_j G_j$ are computed from locked inputs before comparison with controls or held-out readouts. The associated Colab notebook is deliberately trig-free: it uses no sine, cosine, tangent, or inverse-trigonometric functions [12].

The numerical examples below are deliberately small and should be read as worked demonstrations of the calculator, not as evidence that the model has survived an external test. A three-bin or five-bin output can often be matched by many simple rival models if enough freedom is allowed. The evidential requirement is therefore not a low error in a small toy table. It is independent calibration of q_i, Γ, W, the path family, and the output map, followed by a held-out comparison in which the exposure-weighted prediction beats the ordinary-attenuation control under preregistered criteria.

Polarisation-selective attenuation. A linearly polarised optical field entering a component-selective absorbing layer provides the cleanest physical example. Standard polarisation optics treats a polarising element as transmitting or absorbing field components according to their projection onto a selected axis [13]. Let the field support aligned with the lossy axis be $E_{\rm loss}$, and let the orthogonal transported support be $E_{\rm trans}$. Identify

$$\Theta = E_{\rm loss}, \qquad \ell\Pi = E_{\rm trans}. \tag{132}$$

Then the total measured field support and exposed support are

$$J_{\rm tot} = E_{\rm loss}^2 + E_{\rm trans}^2, \qquad\qquad J_{\rm exp} = E_{\rm loss}^2, \tag{133}$$

so the RSG exposure factor becomes

$$W = \frac{E_{\rm loss}^2}{E_{\rm loss}^2 + E_{\rm trans}^2}. \tag{134}$$

For a thin weakly absorbing layer whose loss acts only on $E_{\rm loss}$, the measured total intensity satisfies, to first order in the calibrated layer loss η,

$$\frac{I_{\rm out}}{I_{\rm in}} = 1 - \eta W + O(\eta^2). \tag{135}$$

Across many weak layers this becomes the discrete survival product

$$\frac{I_{\rm out}}{I_{\rm in}} \approx \exp\left[-\sum_k \eta_k W_k\right]. \tag{136}$$

The ordinary attenuation control would use the same η_k but replace W_k by one. Thus this known optical case makes the role of W concrete: it is the measured fraction of support coupled to the loss channel.

The probability map in the laser example is again a normalised surviving-output map. If channel m begins with input intensity or count $C_{m,0} = C_0 q_m$, then a selective layer gives

$$G_m^{\rm laser} = \exp[-\eta_m W_m], \tag{137}$$

and hence

$$C_{m,1} = C_0 q_m G_m^{\rm laser}, \tag{138}$$

and the represented output fraction is

$$p_m^{\rm laser} = \frac{C_{m,1}}{\sum_j C_{j,1}} = \frac{q_m G_m^{\rm laser}}{\sum_j q_j G_j^{\rm laser}} = \frac{q_m \exp[-\eta_m W_m]}{\sum_j q_j \exp[-\eta_j W_j]}. \tag{139}$$

Thus $p_m^{\rm laser}$ means the fraction of total detected output in channel m, after the selective exposure gate has acted.

For a numerical laser-layer check, take a weak dichroic layer with calibrated loss $\eta = 0.20$. Let the input laser intensity be normalised to $I_{\text{in}} = 1$, and prepare five field states with measured exposed-support fractions $W = 1.00, 0.75, 0.50, 0.25, 0.00$. The component-selective model and the RSG exposure-weighted gate both give

$$G_{\text{laser}}(W) = I_{\text{RSG}}(W) = \exp(-0.20W), \tag{140}$$

while ordinary attenuation predicts the same output for every state,

$$I_{\text{std}} = \exp(-0.20) = 0.819. \tag{141}$$

The intermediate calculation is explicit. The exposure-weighted loss exponents are

$$0.20\,\mathbf{W} = (0.200,\ 0.150,\ 0.100,\ 0.050,\ 0.000), \tag{142}$$

so the gate transmissions, and therefore the surviving channel amounts for unit prepared amount in each channel, are

$$\mathbf{C}_1^{\text{RSG}} = \exp[-0.20\,\mathbf{W}] \approx (0.819,\ 0.861,\ 0.905,\ 0.951,\ 1.000). \tag{143}$$

The laser normaliser is

$$Z_{\text{laser}} = \sum_m C_{m,1}^{\text{RSG}} \approx 4.536, \tag{144}$$

and therefore the represented output fractions are

$$\mathbf{p}_{\text{laser}}^{\text{RSG}} = \frac{\mathbf{C}_1^{\text{RSG}}}{Z_{\text{laser}}} \approx (0.181,\ 0.190,\ 0.199,\ 0.210,\ 0.221). \tag{145}$$

By contrast, ordinary attenuation gives $\mathbf{C}_1^{\text{std}} = (0.819, 0.819, 0.819, 0.819, 0.819)$, so equal-preparation normalisation gives

$$\mathbf{p}_{\text{laser}}^{\text{std}} = (0.200,\ 0.200,\ 0.200,\ 0.200,\ 0.200). \tag{146}$$

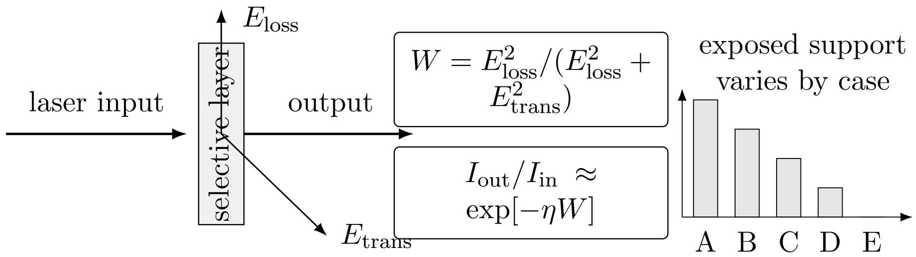

Figure 8: Laser-layer exposure demonstration. A component-selective absorbing layer couples only to the exposed field support E_{loss}, so W is the measured support fraction seen by the loss channel.

The point of Table 9 is not that RSG has discovered polarisation optics. It is that W has a direct experimental interpretation in a known system: a measured fraction of support coupled to a selective loss channel. In this known-output case, the exposure-weighted model reproduces the component-selective result, while ordinary path attenuation is too coarse whenever $W \neq 1$. This shows ordinary attenuation is too coarse whenever only part of the field support couples to the lossy channel.

Table 9: Numerical laser-layer check for component-selective attenuation.

Case	**Exposed support W**	**RSG output**	**Ordinary output**	**Interpretation**
A	1.00	0.819	0.819	Fully exposed; both models agree.
B	0.75	0.861	0.819	Partial exposure reduces effective loss.
C	0.50	0.905	0.819	Half of the support is exposed.
D	0.25	0.951	0.819	Weak exposure gives weak attenuation.
E	0.00	1.000	0.819	No support in the lossy component.

FFT/windowing comparison. A second sanity check comes from signal analysis. The National Instruments FFT tutorial describes how finite sampled records are transformed into frequency-domain bins, and how windowing is used because finite-record boundaries can introduce leakage into neighbouring bins [14]. The discrete transform baseline is

$$X_m = \sum_{n=0}^{N-1} x_n \exp\left(-2\pi i\, mn/N\right). \tag{147}$$

An RSG-style survival layer should not replace this transform. Instead, the transform supplies independently measured candidate components. A declared post-transform test may treat each bin or component class m as a generated candidate with preparation weight

$$q_m = \frac{|X_m|^2}{\sum_j |X_j|^2}, \tag{148}$$

then apply a predeclared persistence or leakage exposure W_m and loss Γ_m. Here the probability-like quantity is again a normalised output fraction, not a name attached to the bins. The gate for bin m is

$$G_m^{\mathrm{FFT}} = \exp[-\Gamma_m W_m]. \tag{149}$$

If the raw bin mass is $C_{m,0} = C_0 q_m$, the gate-filtered bin mass is

$$C_{m,1} = C_0 q_m G_m^{\mathrm{FFT}}, \tag{150}$$

and the normalised represented bin fraction is

$$p_m^{\mathrm{surv}} = \frac{C_{m,1}}{\sum_j C_{j,1}} = \frac{q_m G_m^{\mathrm{FFT}}}{\sum_j q_j G_j^{\mathrm{FFT}}} = \frac{q_m \exp[-\Gamma_m W_m]}{\sum_j q_j \exp[-\Gamma_j W_j]}. \tag{151}$$

Thus the FFT example follows the same count chain as the general probability map:

$$\text{raw bin mass} \quad \longrightarrow \quad \text{gate-filtered bin mass} \quad \longrightarrow \quad \text{normalised represented bin fraction.} \tag{152}$$

The useful comparison is therefore not “RSG versus FFT”. It is raw transform magnitude versus a locked survival-ranked transform output for a declared task such as identifying persistent components under boundary leakage, noise, or repeated-window perturbation. The RSG-style weighting is useful only if the survival-ranked output improves the pre-registered task metric without changing W_m after seeing the answer.

As a numerical transform toy, take three FFT bins with raw preparation weights

$$\mathbf{q} = (0.60,\ 0.25,\ 0.15), \tag{153}$$

predeclared leakage exposures

$$\mathbf{W} = (0.05,\ 0.70,\ 0.95), \tag{154}$$

and common $\Gamma = 1.20$. The exposure-weighted losses are

$$\mathbf{A} = \Gamma \mathbf{W} = (0.060,\ 0.840,\ 1.140), \tag{155}$$

with gate transmissions

$$\mathbf{G}_{\mathrm{FFT}} = \exp[-\mathbf{A}] \approx (0.942,\ 0.432,\ 0.320). \tag{156}$$

The gate-filtered bin masses are therefore

$$\mathbf{C}_1 = \mathbf{q} \odot \mathbf{G}_{\mathrm{FFT}} \approx (0.565,\ 0.108,\ 0.048), \tag{157}$$

where $\odot$ denotes componentwise multiplication. The normaliser is

$$Z_{\mathrm{FFT}} = \sum_m C_{m,1} \approx 0.721. \tag{158}$$

Equation (151) then gives

$$\mathbf{p}^{\mathrm{surv}} \approx (0.784,\ 0.150,\ 0.067). \tag{159}$$

If a held-out repeated-window reveal gives

$$\widehat{\mathbf{p}} = (0.781,\ 0.142,\ 0.077), \tag{160}$$

then the absolute-error totals are

$$\sum_m |\widehat{p}_m - q_m| = 0.362, \qquad \sum_m |\widehat{p}_m - p_m^{\mathrm{surv}}| = 0.021. \tag{161}$$

Explicitly,

$$\begin{aligned} E_{\mathrm{raw}} &= |0.781 - 0.600| + |0.142 - 0.250| + |0.077 - 0.150| \\ &= 0.362, \\ E_{\mathrm{surv}} &= |0.781 - 0.784| + |0.142 - 0.150| + |0.077 - 0.067| \\ &\approx 0.021. \end{aligned} \tag{162}$$

The error score in (161) is zero for a perfect match to the held-out vector. The survival-ranked output is therefore closer to zero-error than the raw transform weights in this toy comparison. The same ordering is obtained from a scale-normalised error:

$$\mathrm{RMSE}(\widehat{\mathbf{p}}, \mathbf{q}) \approx 0.129, \qquad \mathrm{RMSE}(\widehat{\mathbf{p}}, \mathbf{p}^{\mathrm{surv}}) \approx 0.0076. \tag{163}$$

The log-ratio residuals also favour the gate-filtered vector. Summing absolute residuals over the three bin pairs gives

$$\sum_{i<j} \left| \ln \frac{\widehat{p}_i}{\widehat{p}_j} - \ln \frac{q_i}{q_j} \right| \approx 1.861, \qquad \sum_{i<j} \left| \ln \frac{\widehat{p}_i}{\widehat{p}_j} - \ln \frac{p_i^{\mathrm{surv}}}{p_j^{\mathrm{surv}}} \right| \approx 0.388. \tag{164}$$

These additional scores do not promote the toy into a laboratory validation. They show only that the predeclared gate layer is not the same as using the raw preparation weights.

This is a toy held-out calculation, not a laboratory result. It shows the kind of verification the paper requires: the raw transform supplies the candidate components, while the survival layer is judged only by a locked external comparison.

Recursive prediction algorithms. The same count-normalisation structure appears in recursive computational selection. In a beam-search or generative-prediction setting, the update rule generates candidate continuations, each step supplies a locked score or

Table 10: FFT-style numerical check: locked gate filtering versus raw transform weights.

Bin	**Raw** q_m	**Exposure** W_m	**Gate-filtered** p_m	**Held-out** $\widehat{p}_m$
1	0.600	0.05	0.784	0.781
2	0.250	0.70	0.150	0.142
3	0.150	0.95	0.067	0.077

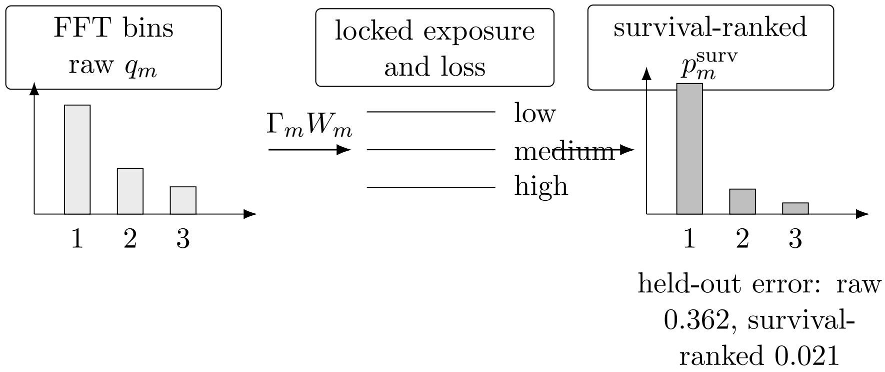

Figure 9: FFT-style survival-ranking demonstration. The FFT supplies raw candidate bins; a locked exposure-loss layer reweights them and is judged against a held-out output comparison.

survival multiplier, and low-survival candidates are pruned or weakly represented. If $r_{i,k}$ is a predeclared survival multiplier for candidate i at step k, then

$$A_i = -\sum_k \ln r_{i,k}, \qquad S_i = e^{-A_i} = \prod_k r_{i,k}. \tag{165}$$

With equal prepared candidates, the represented output fraction is the shorthand $p_i = S_i / \sum_j S_j$; with unequal prepared candidates it is $p_i = q_i S_i / \sum_j q_j S_j$. For a three-candidate recursive prediction toy, take locked step multipliers

$$\mathbf{r}_1 = (0.90,\ 0.85,\ 0.80), \quad \mathbf{r}_2 = (0.70,\ 0.82,\ 0.78), \quad \mathbf{r}_3 = (0.95,\ 0.60,\ 0.55). \tag{166}$$

The resulting survival weights are

$$S_1 = 0.90 \cdot 0.85 \cdot 0.80 = 0.612, \quad S_2 = 0.70 \cdot 0.82 \cdot 0.78 \approx 0.448, \quad S_3 = 0.95 \cdot 0.60 \cdot 0.55 \approx 0.314. \tag{167}$$

Thus

$$\mathbf{S} = (0.612,\ 0.448,\ 0.314), \tag{168}$$

with normaliser

$$Z_{\text{rec}} = 0.612 + 0.448 + 0.314 \approx 1.373. \tag{169}$$

The normalised prediction is

$$\mathbf{p}^{\text{surv}} \approx (0.446,\ 0.326,\ 0.228). \tag{170}$$

Against a held-out generated count fraction

$$\widehat{\mathbf{p}} = (0.444,\ 0.326,\ 0.230), \tag{171}$$

the uniform baseline has absolute-error total 0.221, while the locked survival prediction has absolute-error total 0.003. The error calculation is

$$\begin{aligned} E_{\text{unif}} &= |0.444 - 0.333| + |0.326 - 0.333| + |0.230 - 0.333| \\ &\approx 0.221, \\ E_{\text{surv}} &= |0.444 - 0.446| + |0.326 - 0.326| + |0.230 - 0.228| \\ &\approx 0.003. \end{aligned} \tag{172}$$

Since zero is the ideal error value, the locked survival prediction is much closer to zero-error than the uniform baseline. An exploratory implementation of related recursive generation and survival-weighting ideas is available at `https://recursivedynamics.net`; that public interface is heuristic only and is not used here as validation data.

Table 11: Recursive prediction toy: locked survival multipliers versus uniform baseline.

Candidate	**Step multipliers**	**Survival** S_i	**Predicted** p_i	**Held-out** $\widehat{p}_i$
1	0.90, 0.85, 0.80	0.612	0.446	0.444
2	0.70, 0.82, 0.78	0.448	0.326	0.326
3	0.95, 0.60, 0.55	0.314	0.228	0.230

This computational example is not physical evidence for RSG, but it shows that recursive generation followed by survival weighting is a standard and useful algorithmic pattern when the score rule is fixed before selection.

5.8 Worked Three-Path Benchmark

A minimal validation benchmark can be specified without claiming empirical support. This benchmark demonstrates protocol discipline, not physical validation.

Mini-proposition: locked finite benchmark. Consider N paths with preparation weights $q_i > 0$, independently calibrated layer losses $\Gamma_{i,k}$, independently measured exposures $W_{i,k}$, and fixed layer intervals Δt_k. Define

$$A_i^{\text{RSG}} = \sum_k \Gamma_{i,k} W_{i,k} \Delta t_k. \tag{173}$$

Then the pre-measurement RSG output vector is

$$p_i^{\text{pred}} = \frac{q_i e^{-A_i^{\text{RSG}}}}{\sum_j q_j e^{-A_j^{\text{RSG}}}}, \tag{174}$$

and for two paths

$$\frac{p_i^{\text{pred}}}{p_j^{\text{pred}}} = \frac{q_i}{q_j} e^{-A_i^{\text{RSG}} + A_j^{\text{RSG}}}. \tag{175}$$

The same relation can be written as an optional logarithmic diagnostic,

$$\ln\left(\frac{p_i^{\text{pred}}}{p_j^{\text{pred}}}\right) = \ln\left(\frac{q_i}{q_j}\right) - A_i^{\text{RSG}} + A_j^{\text{RSG}}. \tag{176}$$

For equal preparation weights this reduces to the survival-ratio identity $p_i/p_j = e^{-A_i+A_j}$. Within the locked benchmark this is still an algebraic identity; it becomes an empirical test only after q_i, $\Gamma_{i,k}$, $W_{i,k}$, Δt_k, the path family, and the output map are fixed before measurement and then compared with measured outputs.

Let the test state be

$$\sigma_{i,k} = (k, i, \Theta_{i,k}, \Pi_{i,k}, I_{i,k}), \qquad \pi_\Phi(\sigma_{i,k}) = (\Theta_{i,k}, \Pi_{i,k}), \tag{177}$$

where i labels the input path or mode and k labels the layer. The locked test map is

$$R_{\text{test}} : \sigma_{i,k} \mapsto \sigma_{i,k+1}, \tag{178}$$

with $(\Theta_{i,k+1}, \Pi_{i,k+1})$ obtained from the measured layer-to-layer phase map and $\Gamma_{i,k}$ obtained from independent attenuation calibration. Boundary and interface behaviour, including reflection, transmission, and mode coupling, is treated as part of R_{test} and must be locked before the output intensities are measured. With $\Delta t = 1$, the predicted accumulated loss is

$$A_i^{\text{RSG}} = \sum_k \Gamma_{i,k} W_{i,k}, \qquad W_{i,k} = \frac{\Theta_{i,k}^2}{\Theta_{i,k}^2 + \ell^2 \Pi_{i,k}^2}. \tag{179}$$

The benchmark below uses the equal-preparation case $q_1 = q_2 = q_3$, so preparation weights cancel. Under unequal preparation, the no-log ratio includes the additional factor q_i/q_j, as in (94).

For an illustrative three-path benchmark, suppose the independently calibrated loss coefficient is the same for all paths, $\Gamma = 0.20$ per layer, the path duration is $T = 10$ layers, and the measured mean exposures are $\bar{W}_1 = 0.50$, $\bar{W}_2 = 0.80$, and $\bar{W}_3 = 0.20$. Then

$$A_i^{\text{RSG}} = \Gamma \bar{W}_i T. \tag{180}$$

The predicted vector is: Using unrounded exponentials, $Z = e^{-1.00} + e^{-1.60} + e^{-0.40} =$

Table 12: Illustrative three-path benchmark with equal preparation weights.

Path	Γ	$\bar{W}_i$	A_i^{RSG}	$S_i = e^{-A_i}$	$\mathbf{p}_{\text{pred}}$
1	0.20	0.50	1.00	0.368	0.297
2	0.20	0.80	1.60	0.202	0.163
3	0.20	0.20	0.40	0.670	0.541

1.240096, giving

$$\mathbf{p}_{\text{pred}} \approx (0.296654,\ 0.162807,\ 0.540539). \tag{181}$$

The standard attenuation model gives $A_i^{\text{std}} = \Gamma T = 2.00$ for all three paths and therefore predicts equal normalised outputs. The RSG benchmark instead predicts the ordering $p_3 > p_1 > p_2$, with

$$\frac{p_3}{p_2} = e^{-A_3+A_2} = e^{1.20}. \tag{182}$$

In optional logarithmic form,

$$\ln\left(\frac{p_3}{p_2}\right) = -A_3 + A_2 = 1.20. \tag{183}$$

This table is a locked synthetic protocol demonstration, not empirical validation. Its purpose is to show what a nontrivial test must lock before measurement. The displayed no-log ratio is an identity for the predicted weights; the external test is whether the independently measured intensity ratio agrees with it.

5.9 Synthetic Blind Validation Package

A paper-standalone numerical validation should be separable from the public exploratory interface. One minimal synthetic package is:

$$R_{\text{test}}: \quad (\Theta_{i,k}, \Pi_{i,k}, I_{i,k}) \mapsto (\Theta_{i,k+1}, \Pi_{i,k+1}, I_{i,k+1}), \tag{184}$$

$$I_{i,k+1} = I_{i,k} \exp[-\Gamma_{i,k} W_{i,k} \Delta t], \tag{185}$$

with

$$W_{i,k} = \frac{\Theta_{i,k}^2}{\Theta_{i,k}^2 + \ell^2 \Pi_{i,k}^2}. \tag{186}$$

The validation file must record the frozen values of $\Theta_{i,k}$, $\Pi_{i,k}$, ℓ, $\Gamma_{i,k}$, Δt, q_i, boundary conditions, and detector noise model before any synthetic output vector is generated. A blind synthetic test then proceeds by committing the precomputed $\mathbf{p}_{\text{pred}}$, generating or revealing $\widehat{\mathbf{p}}$ from a separately seeded output routine, and applying the locked failure rule without parameter adjustment.

For example, the positive-control vector in (215) may be treated as the frozen prediction. A synthetic pass case could draw $\widehat{\mathbf{p}}$ from a declared multinomial, Gaussian, or detector-specific noise model centred on that vector; a synthetic fail case could instead draw from the ordinary-attenuation vector $(1/3, 1/3, 1/3)$. The paper does not claim either draw as empirical evidence. The purpose is only to demonstrate that the protocol can distinguish a locked RSG prediction from a locked ordinary-attenuation control without moving the parameters after the output is seen.

5.10 Fully Locked Toy Numerical Demonstration

The following toy instantiation is included to remove ambiguity about what "locked" means. It is not empirical validation. It is a complete synthetic protocol rule that could be implemented without changing any parameter after output is revealed.

Take three equal-preparation channels, $q_1 = q_2 = q_3 = 1$, ten layers, $\Delta t = 1$, initial intensities $I_{i,0} = 1$, and a fixed loss coefficient

$$\Gamma_{i,k} = 0.20 \qquad \text{for all } i, k. \tag{187}$$

Let $\ell = 1$, $\Pi_{i,k} = 1$, and choose constant phase coordinates

$$\Theta_{1,k} = \sqrt{\frac{1}{3}}, \qquad \Theta_{2,k} = 1, \qquad \Theta_{3,k} = \sqrt{3}. \tag{188}$$

Using the reduced exposure law in (65), these locked phase coordinates determine the exposures:

$$\begin{aligned} W_1 &= \frac{1/3}{1/3 + 1} = 0.25, \\ W_2 &= \frac{1}{1 + 1} = 0.50, \\ W_3 &= \frac{3}{3 + 1} = 0.75. \end{aligned} \tag{189}$$

Thus W is not supplied as a separate fit parameter in the demonstration. It is computed from the declared Θ, Π, ℓ convention before any output vector is considered.

The frozen update rule is

$$\Theta_{i,k+1} = \Theta_{i,k}, \qquad \Pi_{i,k+1} = \Pi_{i,k}, \qquad I_{i,k+1} = I_{i,k} \exp[-0.20\, W_i]. \tag{190}$$

The accumulated losses after ten layers are therefore

$$(A_1, A_2, A_3) = (0.50, 1.00, 1.50), \tag{191}$$

and the locked RSG output vector is

$$\mathbf{p}_{\text{pred}} = \frac{(e^{-0.50}, e^{-1.00}, e^{-1.50})}{e^{-0.50} + e^{-1.00} + e^{-1.50}} \approx (0.506,\ 0.307,\ 0.186). \tag{192}$$

The ordinary attenuation control has the same Γ and the same ten-layer duration in all channels, so it predicts

$$\mathbf{p}_{\text{std}} = \left(\frac{1}{3}, \frac{1}{3}, \frac{1}{3}\right). \tag{193}$$

The conclusion of this numerical demonstration is limited but useful: the conditional exposure law produces a distinguishable locked output vector from the same ordinary attenuation background. It demonstrates operational distinguishability and non-ad hoc computation of W; it does not demonstrate that the exposure assumptions have already been realised in a laboratory medium.

The preregistered comparison is:

1. output convention: background-subtracted intensity fractions;
2. detector floor: $I_{\text{floor}} = 10^{-4}$, $p_{\text{floor}} = 0.05$;
3. required no-log ratios: $(1, 2)$ and $(2, 3)$;
4. optional log-ratio diagnostic uncertainty: $\sigma_{12} = \sigma_{23} = 0.10$;
5. failure threshold: the output vector and required no-log ratios must pass the preregistered tolerance; if log diagnostics are used, any log-ratio error greater than 0.20 fails;
6. RSG-specific success condition: the measured vector must pass the RSG ratio thresholds and fail or underperform the ordinary-attenuation tie by the preregistered $\Delta\chi^2$ comparison.

Canonical locked benchmark record. Update rule: (190). Initial conditions: $I_{i,0} = 1$, $q_i = 1$, ten layers, $\Delta t = 1$. Fixed parameters: $\Gamma = 0.20$, $\ell = 1$, $\Pi_i = 1$, $\Theta_i = (\sqrt{1/3}, 1, \sqrt{3})$. Derived exposure: $W = (0.25, 0.50, 0.75)$. Precomputed output: $\mathbf{p}_{\text{pred}} = (0.506, 0.307, 0.186)$. Control: $\mathbf{p}_{\text{std}} = (1/3, 1/3, 1/3)$. Failure rule: required ratios $(1, 2), (2, 3)$ fail if the measured no-log ratios leave the preregistered tolerance, if optional diagnostics satisfy $|\widehat{L}_{ij} - L_{ij}^{\text{pred}}| > 0.20$, or if the detector-floor rule is violated. This box is the one-page reproducibility core for the toy example.

For illustration, if the blinded synthetic output is revealed as

$$\widehat{\mathbf{p}} = (0.500,\ 0.315,\ 0.185), \tag{194}$$

then

$$\widehat{R}_{12} = 0.500/0.315 \approx 1.587, \qquad \widehat{R}_{23} = 0.315/0.185 \approx 1.703. \tag{195}$$

The locked RSG no-log prediction gives $R_{12}^{\text{pred}} = R_{23}^{\text{pred}} = e^{0.50} \approx 1.649$. In optional logarithmic diagnostic form,

$$\widehat{L}_{12} = \ln(0.500/0.315) \approx 0.462, \qquad \widehat{L}_{23} = \ln(0.315/0.185) \approx 0.533. \tag{196}$$

The locked RSG log diagnostic gives $L_{12}^{\text{pred}} = L_{23}^{\text{pred}} = 0.50$, so both optional diagnostic errors are below 0.20. The ordinary attenuation control predicts $R_{12} = R_{23} = 1$, equivalently $L_{12} = L_{23} = 0$, so it fails the same declared ratio test for this synthetic output. This is a protocol demonstration only: in a real experiment the output vector must be measured after all values above have been frozen.

5.11 Uncertainty and Failure Threshold

For each pair of paths, define the primary predicted no-log ratio

$$R_{ij}^{\text{pred}} = \frac{q_i}{q_j} e^{-A_i + A_j} \tag{197}$$

and the measured no-log ratio from the output map

$$\widehat{R}_{ij} = \frac{\widehat{p}_i}{\widehat{p}_j}. \tag{198}$$

A simple preregistered ratio-failure rule is

$$\left| \frac{\widehat{R}_{ij}}{R_{ij}^{\text{pred}}} - 1 \right| > \epsilon_{R,ij} \quad \Longrightarrow \quad \text{failure for that ratio}, \tag{199}$$

where $\epsilon_{R,ij}$ is fixed before measurement. If logarithmic diagnostics are also declared, define

$$L_{ij}^{\text{pred}} = -A_i + A_j \tag{200}$$

and the measured log-ratio from the output map

$$\widehat{L}_{ij} = \ln \left(\frac{\widehat{p}_i}{\widehat{p}_j} \right). \tag{201}$$

Calibration uncertainty in Γ, W, ℓ, path duration, background subtraction, and detector response must be propagated into an uncertainty for the log-ratio. A simple first-order form is

$$\sigma_{ij}^2 = \sigma_{A_i}^2 + \sigma_{A_j}^2 - 2\,\mathrm{Cov}(A_i, A_j) + \sigma_{\text{out},ij}^2, \tag{202}$$

where $\sigma_{\text{out},ij}$ is the measurement uncertainty in the background-subtracted logarithmic output ratio. A preregistered k-sigma failure rule is then

$$\left| \widehat{L}_{ij} - L_{ij}^{\text{pred}} \right| > k\sigma_{ij} \quad \Longrightarrow \quad \text{failure for that ratio}. \tag{203}$$

For the full output vector, one may instead use a preregistered goodness-of-fit statistic, for example

$$\chi^2_{\mathrm{RSG}} = \sum_i \frac{(\widehat{p}_i - p_i^{\mathrm{pred}})^2}{\sigma^2_{p_i}}. \tag{204}$$

Because the components of $\widehat{\mathbf{p}}$ sum to one, their errors are generally correlated. A stricter implementation should therefore use the covariance matrix on $N-1$ independent components:

$$\chi^2_{\mathrm{RSG}} = (\widehat{\mathbf{p}} - \mathbf{p}_{\mathrm{pred}})^T C_p^{-1} (\widehat{\mathbf{p}} - \mathbf{p}_{\mathrm{pred}}), \tag{205}$$

where the vectors are restricted to a preregistered set of $N-1$ independent components, or else C_p^{-1} is a preregistered generalised inverse on the constrained subspace. The covariance matrix C_p is fixed by the detector, background, and calibration uncertainty model before comparison. Equation (204) is only the diagonal-uncertainty special case. The constrained analogue model fails if the preregistered statistic lies outside the stated acceptance region, or if it does not improve on the ordinary attenuation control by the preregistered comparison threshold.

For the locked benchmark, the failure conditions are therefore fixed before measurement:

1. the benchmark fails if any of R_{test}, q_i, Γ, W, ℓ, path duration, path family, background subtraction, detector response, or output map is changed after the output intensities are inspected;
2. the benchmark fails if one or more preregistered no-log ratios violate (199), or if optional log-ratios violate (203);
3. the benchmark fails if the full output vector violates the preregistered covariance or goodness-of-fit acceptance region;
4. the benchmark fails as an RSG-specific test if it does not outperform the ordinary attenuation control in the declared positive-control regime;
5. a numerical implementation fails verification if the predicted vector is not stable under the preregistered refinement test.

5.12 Detector-Floor and Ratio-Stability Rules

Logarithmic ratios are fragile when a measured channel is close to the detector floor. A real analogue protocol must therefore lock a floor rule before output data are inspected. Let I_{floor} be the minimum background-subtracted intensity or power for which the detector calibration is valid. A channel is admissible for ordinary log-ratio comparison only if

$$I_i - I_{i,\mathrm{bg}} > I_{\mathrm{floor}} \qquad \text{and} \qquad \widehat{p}_i > p_{\mathrm{floor}}, \tag{206}$$

where p_{floor} is computed from the same locked output map as $\widehat{p}_i$.

If a channel falls below this floor, the experiment must not choose a convenient ratio after the fact. The preregistered options are:

1. exclude the affected channel from all declared log-ratio tests and use only the remaining preregistered components;

2. treat the channel as a censored or one-sided measurement with a declared inequality test;

3. declare the run invalid if any channel in the required comparison set is below floor.

The choice among these rules is part of the output map. It must be fixed before measurement. Background subtraction that produces $I_i - I_{i,\mathrm{bg}} \le 0$, detector saturation, or operation outside the calibrated dynamic range invalidates the corresponding log-ratio unless a one-sided rule has already been declared.

5.13 Verification and Validation Discipline

If the analogue test is implemented numerically, or if a layered experiment is interpreted through a transfer model, the comparison must include a verification and validation check. The discretisation or layer resolution should be refined, for example by replacing Δt with $\Delta t/2$ or by subdividing layers, and the predicted vector $\mathbf{p}_{\mathrm{pred}}$ should remain stable within a predeclared refinement tolerance. A useful convergence condition is

$$\left\| \mathbf{p}_{\mathrm{pred}}^{(\Delta t/2)} - \mathbf{p}_{\mathrm{pred}}^{(\Delta t)} \right\| < \epsilon_{\mathrm{ref}}, \tag{207}$$

where the norm and tolerance are fixed before the output comparison.

The validation report should also include sensitivity to the independently calibrated quantities, especially Γ, ℓ, and the measured exposure W. Parameter identifiability must be checked: the test is weak if changes in Γ, ℓ, boundary coupling, or detector response can compensate one another while leaving the same predicted output. As a formal validation requirement, no unreported parameter trade-off may reproduce the same output vector within tolerance unless that degeneracy and its acceptance rule were declared before measurement. A strong validation therefore locks R_{test}, boundary/interface conditions, input modes, calibration data, background subtraction, detector response, k-sigma rule, and $\Delta\chi^2$ threshold before the final output intensities are inspected. In that case the comparison is blind with respect to the measured output vector, rather than a fit performed after the fact.

5.14 Nontriviality Against Ordinary Attenuation

The analogue test should not merely rediscover ordinary exponential attenuation. A useful control compares the RSG exposure-weighted model

$$A_i^{\mathrm{RSG}} = \int_{\gamma_i} \Gamma W \, dt \tag{208}$$

with a standard attenuation model

$$A_i^{\mathrm{std}} = \int_{\gamma_i} \Gamma \, dt. \tag{209}$$

The RSG-specific test is nontrivial only in regimes where two paths have similar ordinary attenuation but different measured exposure histories $W_i(t)$, or where ordinary attenuation predicts the wrong output ordering while ΓW predicts the measured ordering. A strong test should therefore preselect a family of modes or paths for which W varies independently of total path length and calibrated Γ.

A useful null control is a configuration in which $W_i(t)$ is constant or equal across the compared channels. In that case the RSG output collapses to ordinary calibrated attenuation up to the common exposure factor. For example, if

$$W_i(t) = W_0 \qquad \text{for all compared paths } i, \tag{210}$$

then

$$A_i^{\mathrm{RSG}} = \int_{\gamma_i} \Gamma W_0 \, dt = W_0 A_i^{\mathrm{std}}. \tag{211}$$

If $W_0 = 1$, the two models are identical. If W_0 is a common constant different from one, the distinction is only a common rescaling of the calibrated loss. This null control should not be counted as RSG-specific support. A useful positive control is instead a configuration with matched $\int \Gamma \, dt$ but deliberately separated $\int \Gamma W \, dt$. The exposure law is supported only if the latter separation improves the predeclared output-vector prediction without being fitted after measurement.

The positive-control design should be visually and statistically blunt. Choose channels with the same ordinary path loss,

$$\int_{\gamma_1} \Gamma \, dt = \int_{\gamma_2} \Gamma \, dt = \int_{\gamma_3} \Gamma \, dt, \tag{212}$$

but with independently measured exposure histories satisfying

$$\int_{\gamma_1} \Gamma W \, dt < \int_{\gamma_2} \Gamma W \, dt < \int_{\gamma_3} \Gamma W \, dt. \tag{213}$$

Ordinary attenuation then predicts a tie, while RSG predicts a strict output ordering.

Table 13: Positive-control contrast: ordinary attenuation predicts a tie, while the exposure-weighted model predicts an ordered output vector.

Path	$A_i^{\mathrm{std}} = \int \Gamma dt$	$\bar{W}_i$	A_i^{RSG}	**Predicted result**
1	2.00	0.25	0.50	Highest output.
2	2.00	0.50	1.00	Intermediate output.
3	2.00	0.75	1.50	Lowest output.

With equal preparation weights, the ordinary attenuation control gives

$$\mathbf{p}_{\mathrm{std}} = \left(\frac{1}{3}, \frac{1}{3}, \frac{1}{3} \right), \tag{214}$$

whereas the exposure-weighted model gives

$$\mathbf{p}_{\mathrm{RSG}} = \frac{(e^{-0.50}, e^{-1.00}, e^{-1.50})}{e^{-0.50} + e^{-1.00} + e^{-1.50}} \approx (0.506,\ 0.307,\ 0.186). \tag{215}$$

The locked test is therefore not whether attenuation exists. It is whether measured output breaks the ordinary-attenuation tie in the precomputed RSG order, within the preregistered uncertainty.

Table 14: Compact comparison of the analogue-test models.

Model	**Accumulated loss**	**When W is common**	**Positive-control role**
Ordinary attenuation	$A_i^{\text{std}} = \int_{\gamma_i} \Gamma\, dt.$	Predicts equal outputs when ordinary path loss is matched.	Baseline control; support for RSG requires improvement over this model.
Constant-W exposure	$A_i = W_0 \int_{\gamma_i} \Gamma\, dt.$	Collapses to a common rescaling of ordinary attenuation.	Null control; not RSG-specific support.
Exposure-weighted RSG	$A_i^{\text{RSG}} = \int_{\gamma_i} \Gamma W_i\, dt.$	Reduces to the constant-W case if $W_i(t) = W_0$.	Positive-control target; should predict the locked output ordering when W_i differs independently of ordinary path loss.

One simple comparison statistic is

$$\Delta\chi^2 = \chi^2_{\text{std}} - \chi^2_{\text{RSG}}, \tag{216}$$

where χ^2_{std} is computed from the ordinary attenuation prediction and χ^2_{RSG} from (204). A successful analogue test should predeclare the required sign and size of $\Delta\chi^2$, rather than choosing the criterion after the output is known.

5.15 What Would Count as Success?

A successful analogue run would not validate the whole framework. It would show that, in one locked positive-control regime, independently calibrated exposure-weighted losses predict the measured output vector and selected no-log output ratios within the preregistered uncertainty while outperforming the ordinary attenuation control under the same output map. Optional log-ratios may be reported as diagnostics. The result would support the constrained exposure law for that analogue system only; broader physical bridges would still require separate maps, constants, and falsifiers.

The route toward a stronger proof is therefore staged rather than asserted. First, the reduced-model assumptions must generate J, W, and p_i without post-measurement adjustment. Second, known-output demonstrations such as component-selective optical attenuation and transform-based signal classification must show that the operational maps behave as claimed. Third, a locked analogue experiment must outperform ordinary attenuation. Only after those stages would broader physical bridges become candidates for independent testing.

6 Closure and Transport Classes

The previous sections define how recursive histories are generated and how they acquire survival weights. We now classify transport behaviour according to recurrence, projected norm preservation, effective survival loss, and recursive proper time. The aim is not merely to name a null-like class, but to identify the conditions under which the class has zero intrinsic clock time and therefore is represented by a null interval under a Lorentzian embedding.

6.1 Recurrence and Closure

Closure requires a chosen equivalence relation. Let $\sim$ denote the rule under which two structured recursive states count as equivalent for the purpose of recurrence. A history is closed if

$$\sigma_{n+m} \sim \sigma_n \quad \text{for some } m > 0. \tag{217}$$

It is non-closing if

$$\sigma_{n+m} \not\sim \sigma_n \quad \text{for all finite } m > 0. \tag{218}$$

This is the general closure criterion used in the present paper.

The scalar ratio

$$r_n = \frac{\Theta_{n+1}}{\Theta_n}, \qquad \Theta_n \neq 0, \tag{219}$$

may be a useful diagnostic in special reductions, but it is not by itself a general closure criterion. The primary criterion is state-level recurrence under the chosen equivalence relation in (217). No empirical prediction or null-transport bridge in this paper depends on the scalar ratio alone. For example, a multiplicative sequence $\Theta_{n+1} = 2\Theta_n$ has rational ratio 2, but it does not recur. Closure depends on the transformation, the state space, and the equivalence relation, not on rationality of this coordinate ratio alone.

A rational/irrational criterion becomes legitimate when the reduced dynamics admits an angular rotation form. If

$$\theta_{n+1} = \theta_n + \alpha \pmod{2\pi}, \tag{220}$$

define the rotation number

$$r = \frac{\alpha}{2\pi}. \tag{221}$$

Then

$$r \in \mathbb{Q} \quad \Longrightarrow \quad \text{periodic phase closure,} \tag{222}$$

while

$$r \notin \mathbb{Q} \quad \Longrightarrow \quad \text{non-closing angular phase orbit.} \tag{223}$$

In the rest of the paper, occurrences of $r \in \mathbb{Q}$ or $r \notin \mathbb{Q}$ refer to this rotation-number reduction, not to the bare coordinate ratio Θ_{n+1}/Θ_n.

6.2 Recursive Clocks and Proper Time

A rest frame is operationally tied to a clock carried by the system. In a recursive setting, a clock is a locally recurrent subsystem. Let $C_n \subset \sigma_n$ denote the recurrent clock component of a structured state when such a component exists. A clock cycle is present when

$$C_{n+m} \sim C_n \quad \text{for some } m > 0. \tag{224}$$

If a history carries such a recurrent component, the number of completed local cycles defines a recursive clock count N_R. After calibration by a local period T_R, the recursive proper time is

$$d\tau_R = T_R \, dN_R. \tag{225}$$

Thus a rest-frame-admitting recursive history is one that carries a local recurrent clock and therefore admits $d\tau_R > 0$ along the history.

A transport history with no recurrent internal clock has

$$dN_R = 0, \qquad d\tau_R = 0. \tag{226}$$

This is the step that connects recursive closure to proper time. It does not say that every non-repeating spatial path is light-like. It says that a transport class with no recurrent internal clock cannot accumulate its own recursive proper time. Massive inertial transport may be spatially non-repeating while still carrying an internal recurrent clock; such a history is not in the zero-$d\tau_R$ class.

In a test case, the equivalence relation $\sim$ must be operational. The experimenter must state which clock observables define C_n, what tolerances count as return to an equivalent clock state, and how many measured returns constitute one calibrated cycle. Without those tolerances, neither $d\tau_R > 0$ nor $d\tau_R = 0$ is an empirical claim.

6.3 Projected Norm Preservation

Closure alone does not determine the full transport class. A trajectory may close while losing survival weight, or it may fail to close while preserving its projected norm. Using the reduced identification

$$\|\sigma_n\|_\Phi = J(\varphi_n), \tag{227}$$

a recursive history is projected-norm-preserving when

$$\|\sigma_{n+1}\|_\Phi = \|\sigma_n\|_\Phi \tag{228}$$

for each step, or in the continuous approximation when

$$\frac{d}{dt}\|\sigma(t)\|_\Phi = 0. \tag{229}$$

As shown in (55), this is an imposed condition or special case of the reduced dynamics, not a generic consequence of the phase equations.

6.4 Recursive Null-Transport Class

A recursive history belongs to the null-transport class when four conditions hold:

$$\Gamma W \to 0, \tag{230}$$
$$\|\sigma_{n+1}\|_\Phi = \|\sigma_n\|_\Phi, \tag{231}$$
$$\sigma_{n+m} \not\sim \sigma_n \quad \text{for all finite } m > 0. \tag{232}$$
$$d\tau_R = 0. \tag{233}$$

The last condition is not independent when the non-closure condition is understood as absence of a recurrent internal clock. It is written explicitly because it is the bridge quantity used in the null-interval derivation.

In an angular reduction, the non-closure condition may be represented by

$$r \notin \mathbb{Q}. \tag{234}$$

Equivalently, this class is effectively lossless, projected-norm-preserving, non-closing, and zero-proper-time. The first condition is written as $\Gamma W \to 0$, because survival decay depends on the effective loss rate $\Lambda = \Gamma W$. The stronger condition $\Gamma \to 0$ is a sufficient special case.

In compressed angular form:

$$\boxed{\Gamma W \to 0, \quad \|\sigma_{n+1}\|_\Phi = \|\sigma_n\|_\Phi, \quad r \notin \mathbb{Q}, \quad d\tau_R = 0} \quad \Longrightarrow \quad \text{recursive null transport.} \tag{235}$$

The null interval representation is obtained from this class in Section 7, once the local spacetime embedding is stated.

6.5 Non-Null Transport

A recursive history belongs to the non-null transport class when at least one of the null-transport conditions fails. The most important cases for the present model are non-zero recursive proper time and differential effective loss:

$$d\tau_R > 0 \quad \text{or} \quad \Lambda_i(t) = \Gamma(\sigma_i(t))W(\varphi_i(t)) \text{ varies across histories.} \tag{236}$$

When effective loss varies,

$$\Lambda_i(t) = \Gamma(\sigma_i(t))W(\varphi_i(t)) \tag{237}$$

Then the survival functional gives

$$\frac{dS_i}{dt} = -\Lambda_i(t)S_i. \tag{238}$$

Histories lose survival weight relative to alternatives with smaller accumulated loss.

A non-null history may be spatially non-repeating while still carrying an internal recurrent clock. This matters: non-repetition of the path is not enough to make a history null. What matters for the null derivation is zero recursive proper time.

7 Conditional Null-Interval Representation

Section 6 defined recursive null transport by effective losslessness, projected norm preservation, non-closure in the transport clock, and zero recursive proper time. This section shows how that zero-recursive-proper-time class is represented as a null interval under an explicit Lorentzian interval calibration.

7.1 Bridge Postulates for the Embedding

The survival functional alone does not contain a spacetime metric. To obtain a metric null interval, the recursive model must be embedded into a local spacetime representation. The following bridge postulates state exactly what is imported.

Postulate 1: recursive clock calibration. A local rest-frame clock is a recurrent internal recursive subsystem. Its calibrated cycle count defines recursive proper time:

$$d\tau_R = T_R\, dN_R. \tag{239}$$

If no such recurrent internal clock exists along the transport class, then $dN_R = 0$ and hence $d\tau_R = 0$.

Postulate 2: local interval calibration. In a local inertial embedding, recursive proper time calibrates the spacetime interval by

$$ds^2 = c^2 d\tau_R^2. \tag{240}$$

In local flat coordinates this interval has the form

$$ds^2 = c^2 dt^2 - dx^2. \tag{241}$$

This postulate imports the operational Lorentzian interval. It does not insert the null condition $ds^2 = 0$.

Postulate 3: non-trivial propagation. The history is a transport history, so it has $dt > 0$ and non-zero spatial displacement in the local embedding. The constant c is the invariant conversion speed of the local metric representation.

7.2 Lossless Survival

The strongest lossless condition is

$$\Gamma \to 0. \tag{242}$$

Substituting this into the survival functional

$$\frac{dS}{dt} = -\Gamma(\sigma)W(\varphi)S \tag{243}$$

gives

$$\frac{dS}{dt} = 0. \tag{244}$$

More generally, $dS/dt = 0$ follows whenever $\Gamma W = 0$. This distinction matters in boundary cases such as $W = 0$ with $\Gamma > 0$.

7.3 Zero Recursive Proper Time

For recursive null transport, the transport class has no recurrent internal clock:

$$\sigma_{n+m} \not\sim \sigma_n \quad \text{for all finite } m > 0. \tag{245}$$

In an angular rotation-number reduction this may be expressed as $r \notin \mathbb{Q}$, provided r is the rotation number defined in (221). By the recursive clock calibration postulate, absence of a recurrent internal clock gives

$$d\tau_R = 0. \tag{246}$$

7.4 Conditional Null-Interval Representation Under Imported Calibration

Conditional embedding proposition. In a local Lorentzian embedding satisfying (240) and (241), every zero-recursive-proper-time transport history is represented by a null interval and by speed c in the local flat metric representation.

Proof. Recursive null transport has zero recursive proper time:

$$d\tau_R = 0. \tag{247}$$

By interval calibration,

$$ds^2 = 0 \tag{248}$$

because $ds^2 = c^2 d\tau_R^2$. In local flat coordinates,

$$0 = c^2 dt^2 - dx^2. \tag{249}$$

Therefore

$$dx^2 = c^2 dt^2, \tag{250}$$

and for non-trivial propagation with $dt > 0$,

$$\left| \frac{dx}{dt} \right| = c. \tag{251}$$

This proves the result. □

The derivation can be summarised as

$$\boxed{\Gamma W \to 0, \quad \|\sigma_{n+1}\|_\Phi = \|\sigma_n\|_\Phi, \quad \text{no recurrent internal clock}} \Longrightarrow d\tau_R = 0 \Longrightarrow ds^2 = 0 \Longrightarrow v = c. \tag{252}$$

7.5 What Is Shown and What Is Assumed

Under the stated embedding, the zero-recursive-proper-time class is represented by $ds^2 = 0$. The speed relation $v = c$ is then the standard consequence of the flat local metric form. The value of c, the Lorentzian signature itself, electromagnetic polarisation, gauge-field structure, and the full massless field equations are not derived here. They remain additional physical structures that a complete theory must recover.

8 Survival-Measure Concentration

The non-null regime is different from the recursive null class. Once the effective loss ΓW varies across histories, histories are no longer equally represented after propagation. They acquire different survival weights, and normalisation turns those differences into concentration.

This section develops concentration in the represented survival measure only. It is not a derivation of Newtonian gravity, Einstein curvature, or matter formation. Any matter-sector reading is deferred to future bridge work. No primitive pairwise attraction is required at this formal level: a generated family of trajectories passes through a phase-flow and dissipation landscape, and the histories that lose the least survival weight dominate the normalised measure.

8.1 Dissipative Transport

Let a generated history γ_i have survival weight

$$S_i(t) = \exp\left(-\int_0^t \Gamma(\sigma_i(\tau)) W(\varphi_i(\tau))\, d\tau \right). \tag{253}$$

If $\Gamma(\sigma_i) W(\varphi_i) > 0$ on any interval of non-zero measure, then $S_i(t)$ decreases. The local survival equation is

$$\frac{dS_i}{dt} = -\Gamma(\sigma_i) W(\varphi_i) S_i. \tag{254}$$

Thus survival decay is controlled by the product ΓW, not by Γ alone.

The relevant quantity is therefore

$$\Lambda_i(t) = \Gamma(\sigma_i(t))W(\varphi_i(t)), \tag{255}$$

where Λ_i is the effective survival-loss rate.

The accumulated loss along the history is

$$A_i(t) = \int_0^t \Lambda_i(\tau)\,d\tau = \int_0^t \Gamma(\sigma_i(\tau))W(\varphi_i(\tau))\,d\tau. \tag{256}$$

Then

$$S_i(t) = e^{-A_i(t)}. \tag{257}$$

Histories with smaller accumulated loss retain larger survival weight.

8.2 Normalised Concentration

The observed or represented weight of a history is not S_i alone, but the normalised output fraction. In the equal-preparation case this is

$$p_i(t) = \frac{S_i(t)}{\sum_j S_j(t)}. \tag{258}$$

Substituting $S_i = e^{-A_i}$ gives

$$p_i(t) = \frac{e^{-A_i(t)}}{\sum_j e^{-A_j(t)}}. \tag{259}$$

With prepared counts or unequal preparation weights, the operational form is

$$p_i(t) = \frac{q_i e^{-A_i(t)}}{\sum_j q_j e^{-A_j(t)}}. \tag{260}$$

For two histories i and j, the relative weight is

$$\frac{p_i}{p_j} = \frac{S_i}{S_j} = \exp\left[-A_i(t) + A_j(t)\right]. \tag{261}$$

in the equal-preparation case. In the weighted case the relative represented output is multiplied by q_i/q_j. Thus if

$$A_i(t) < A_j(t), \tag{262}$$

then

$$\frac{p_i}{p_j} > 1. \tag{263}$$

The lower-loss history dominates after normalisation when preparation weights are equal. With unequal preparation weights, dominance depends on both q_i and A_i.

This is the mathematical core of concentration in the present model. It becomes an empirical output claim only when $\Lambda = \Gamma W$ is fixed independently and measured or controlled before comparison with the represented distribution.

8.3 Local Minima of Survival Loss

Let x denote a coarse state-space coordinate, and let the effective loss field be

$$\Lambda(x,t) = \Gamma(\sigma(x,t))W(\varphi(x,t)). \tag{264}$$

Regions where Λ is locally small act as persistence basins. A simple condition for such a region is

$$\nabla\Lambda(x,t) = 0, \qquad \nabla_x^2\Lambda(x,t) \text{ positive definite}, \tag{265}$$

where the second condition means that the local Hessian of the effective loss field is positive definite in the relevant coarse coordinates.

A trajectory passing near such a region accumulates less loss than a comparable trajectory passing through a higher-Λ region. Over many recursive steps, this difference compounds exponentially through

$$S = e^{-\int \Lambda\, dt}. \tag{266}$$

Small differences in Λ can therefore become large differences in normalised representation.

8.4 Survival-Measure Concentration; Matter-Sector Bridge Deferred

Representation concentration is modelled as the concentration of normalised history weight around low-loss recursive structures. The present section does not derive physical matter-sector dynamics. If a set of histories $\mathcal{C}$ has lower accumulated loss than its complement, then

$$A_i < A_j \quad \text{for } i \in \mathcal{C},\ j \notin \mathcal{C}, \tag{267}$$

and therefore

$$\sum_{i\in\mathcal{C}} p_i > \sum_{j\notin\mathcal{C}} p_j \tag{268}$$

when the survival contrast is sufficiently large.

The cluster $\mathcal{C}$ is then observed as a concentration of represented histories. In the present formalism, what has gathered is survival-weighted representation, not physical matter unless an additional physical identification has been supplied. This is a formal concentration mechanism within the model. To become an empirical theory of matter formation, the effective loss law ΓW must be specified independently.

8.5 Phase-Flow Coefficient and Survival Basins

The phase-flow coefficient Ω^2 shapes the available projected phase-space flow. It determines how (Θ, Π) trajectories bend through recursive state space:

$$\frac{d\Theta}{dt} = \Pi, \tag{269}$$

$$\frac{d\Pi}{dt} = -\Omega^2\Theta. \tag{270}$$

The survival field $\Gamma(\sigma)W(\varphi)$ then filters these phase-flow-shaped trajectories.

Thus the model separates two roles:

$$\Omega^2 \quad \text{shapes the generated projected flow,} \tag{271}$$

while

$$\Gamma(\sigma)W(\varphi) \quad \text{filters the generated histories.} \tag{272}$$

Representation concentration occurs when the phase-flow coefficient Ω^2 makes certain low-loss regions dynamically accessible and survival normalisation amplifies their representation. In this sense, Ω^2 does not describe a force pulling objects together. It describes bending in the reduced phase portrait, while dissipation selects which parts of that flow persist.

8.6 Non-Null Contrast with Recursive Null Transport

The contrast with recursive null transport is now clear. In the null-transport class,

$$\Gamma W \to 0, \qquad \|\sigma_{n+1}\|_\Phi = \|\sigma_n\|_\Phi, \qquad r \notin \mathbb{Q}, \tag{273}$$

so there is no survival filtering, no accumulation, and no phase closure in the angular reduction.

In the non-null concentration regime,

$$\Gamma(\sigma)W(\varphi) \text{ varies across histories.} \tag{274}$$

After normalisation, those differences become representation contrast.

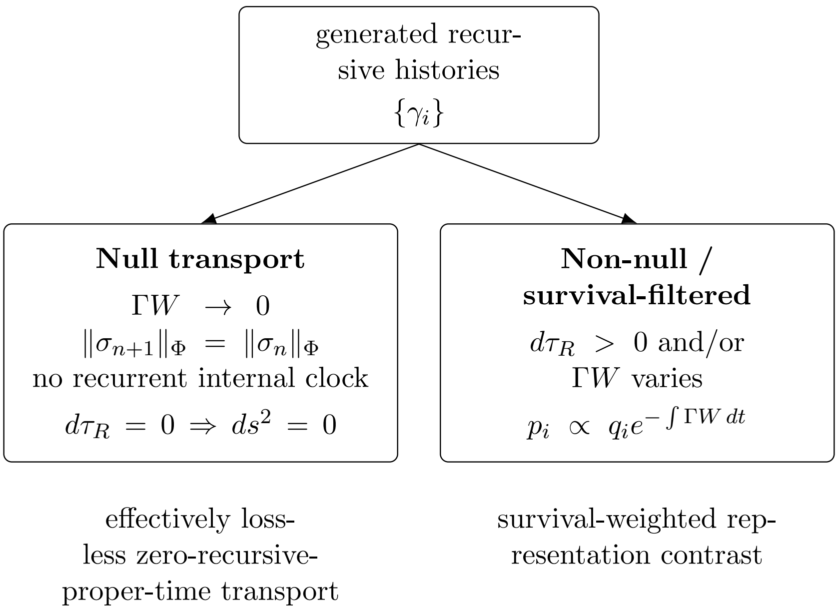

Figure 10: Transport classification. Null transport is effectively lossless, projected-norm-preserving, and carries no recurrent internal clock. Non-null or survival-filtered transport has non-zero recursive proper time and/or varying effective loss ΓW.

In Figure 10, $\Gamma W \to 0$ is the effective lossless condition. The stronger condition $\Gamma \to 0$ is only a sufficient special case. Non-closure may still be represented by the angular rotation-number shorthand $r \notin \mathbb{Q}$ when the reduction of Section 6 applies, but the operative null condition is absence of a recurrent internal clock and hence no recursive proper-time accumulation.

9 Relation to Existing Frameworks

Recursive survival weighting sits closest to laboratory and numerical traditions in which propagation through a specified medium is represented by a locked transfer map. Optical waves in layered media are commonly analysed by transfer-matrix methods [1]. Acoustic and mechanical layered systems use closely related transfer descriptions for transmission, absorption, and loss through coupled layers [2]. These literatures support the use of a layer-to-layer R_{test}; they do not imply the exposure law $W = \Theta^2/J$.

Non-Hermitian optics is also a close neighbour because it studies how gain, loss, and complex refractive-index landscapes shape wave propagation [3]. This supports the idea that loss structure can be experimentally engineered and tested. It does not by itself justify the RSG survival normalisation or the specific exposure factor W. Analogue-gravity work provides a methodological warning: laboratory analogues become persuasive only when the mapping from formal variables to measured observables is explicit and operational [4]. That is why the present paper treats the analogue protocol, not the cosmological bridge material, as the empirical centre.

The survival-normalisation lemma also sits near standard exponential-weighting machinery. Gibbs and Boltzmann weights, softmax normalisation, survival analysis and hazard functions, transfer-matrix attenuation, large-deviation weighting, Markov killing or absorption, non-Hermitian attenuation, and Bayesian evidence normalisation all use related exponential selection structures [5, 6, 7]. The present formalism does not claim novelty merely from e^{-A_i}. Its proposed novelty lies in the recursive-state generation picture, the explicit separation between generated histories and survival selection, the exposure-modulated loss $\Lambda_{\text{surv}} = \Gamma W$, and the locked analogue calibration in which W must outperform a standard attenuation model.

More distant theoretical comparisons are included only as boundary markers. KAM-style persistence shows that organised structures may be studied through geometric properties of a flow without beginning from canonical action-angle variables [16]; it does not imply weighted recursive histories. Sakharov's induced-gravity proposal and Jacobson's entanglement-equilibrium argument connect gravity with vacuum response or entropy balance [17, 18]; they do not derive ΓW or the analogue output law. String background-field and sigma-model methods constrain propagation through conformal consistency [19, 20, 21, 22]; the present model is not a string sigma model and does not identify ΓW with a beta function.

The closure language has a natural relation to topological partition approaches, where a universe may be specified by a set M and a partition D, with the partition generating a clopen topology $[D]$ [23]. The present paper uses the simpler operational recurrence criterion $\sigma_{n+m} \sim \sigma_n$ for closure and $\sigma_{n+m} \not\sim \sigma_n$ for non-closure. Informational dark-energy work in IPI Letters is relevant only to the optional appendix bridge: Denis discusses dark matter, dark energy, vacuum energy, and the cosmological constant using Landauer-style bit-counting arguments [24], while Landauer's principle concerns thermodynamic cost associated with logical irreversibility [25]. Recursive survival weighting does not adopt those numerical claims and does not assume ontological information destruction. In the present notation, any later bridge must keep $\Lambda_{\text{surv}} = \Gamma W$ separate from Λ_{CC}.

The role of these comparisons is to locate the formalism, not to claim completion. The core model remains

$$\sigma_{n+1} = R(\sigma_n), \qquad \frac{d\Theta}{dt} = \Pi, \qquad \frac{d\Pi}{dt} = -\Omega^2\Theta, \tag{275}$$

together with

$$J(\varphi) = \Theta^2 + \ell^2\Pi^2, \qquad W(\varphi) = \frac{\Theta^2}{J(\varphi)}, \qquad \frac{dS}{dt} = -\Gamma(\sigma)W(\varphi)S. \tag{276}$$

10 Limits, Future Applications, and Falsifiability

10.1 Future Constrained Applications

The null interval is obtained in Section 7 from zero recursive proper time plus local interval calibration. The survival-weighted representation lemma follows from exponential survival and normalisation. Broader physical bridge programmes are not part of the present derivation.

Photon time-of-flight delays, black-hole information flow, rotation-curve modelling, cosmological exchange, and vacuum-energy comparisons all require additional bridge laws. In particular, $\Lambda_{\text{surv}} = \Gamma W$ is not the cosmological constant, and representation concentration is not a matter-sector theory. Appendix C records the future bridge requirements; Appendix D records optional vacuum-energy/Λ_{CC} bridge conditions. These appendices are roadmap material only, not evidence for the analogue protocol.

10.2 Limit Tests

The formalism has several important boundary cases. They are listed in Table 15 because each limit carries a different interpretive risk.

Table 15: Limit tests and boundary cases for the minimal formalism.

Limit or condition	**Mathematical effect**	**Interpretive consequence**
$\Gamma \to 0$	$dS/dt \to 0$.	Survival weights become constant and the survival filter disappears.
$W = 0$ with $\Gamma > 0$	$\Lambda_{\text{surv}} = \Gamma W = 0$.	There is no local survival decay despite a non-zero dissipation coefficient; the loss channel is exposure-limited.
$J = 0$ or $J < J_{\min}$	$W = \Theta^2/J$ is undefined or outside the calibrated domain.	The state must be excluded, regularised, or assigned an independent preregistered convention before output comparison.
$\Theta = 0$	$r_n = \Theta_{n+1}/\Theta_n$ is undefined.	The scalar ratio r_n cannot be the general closure criterion; recurrence must be stated at the state or equivalence-class level.
$\Omega^2 = 0$	$\Theta_{n+1} = \Theta_n + \Delta t\, \Pi_n$, $\Pi_{n+1} = \Pi_n$.	Projected motion is free linear motion rather than oscillator-like phase flow.
$\Omega^2 < 0$	The projected step is hyperbolic.	The cell is not a bounded rotational phase-flow cell; any physical interpretation must be supplied separately.

continued on next page

Limit or condition	Mathematical effect	Interpretive consequence
High $\|\Pi\|$	$W \to 0$.	Motion-dominated histories become nearly immune to this positional exposure channel. This is acceptable only when that is the intended coupling; otherwise an additional calibrated loss term is required.
Variable Ω^2	The simple E diagnostic is not generally conserved.	Energy-like conservation is local or approximate unless an extended invariant is supplied.
Massless or light-like limit	$d\tau_R = 0$ is represented by $ds^2 = 0$ only under the Lorentzian embedding.	Non-closure alone is insufficient; the class must also lack a recurrent internal clock and satisfy the stated bridge postulates.

10.3 Falsifiability Conditions

The broad framework is too flexible to be falsified unless its free structures and bridge postulates are constrained. A serious special case must satisfy the following conditions:

1. R must be specified by a rule, not freely chosen per observation.
2. Ω^2 must be specified by a rule, not freely fitted for each observation.
3. ℓ must be fixed before comparison with data.
4. Γ must have a physical or mathematical interpretation independent of the desired outcome.
5. W must remain tied to $W(\varphi) = \Theta^2/J(\varphi)$, unless a new model is explicitly declared.
6. $G_i = e^{-A_i}$ must be computed from locked A_i, not chosen as an independent fitting weight.
7. Predictions must be made before comparison with data.
8. The clock criterion defining $d\tau_R = 0$ must be operationally stated for the system under study.

A clean falsifier is a controlled analogue recursive medium with known Γ, W, and path structure that fails to show the predicted exponential survival ratios within the stated measurement precision. More sharply, the analogue test fails if independently calibrated accumulated-loss values do not predict the measured output vector and selected no-log output ratios within stated experimental uncertainty. Optional logarithmic diagnostics may be reported, but they are not required for the falsifier. A broader falsifier would be a fully specified astrophysical ΓW law that produces time delays, concentration profiles, or survival distributions incompatible with independent observation.

11 Limitations

The present manuscript does not derive Lorentzian signature, the numerical value of c, Maxwell equations, gauge structure, photon polarisation, a massless wave equation, or physical matter-sector dynamics. It does not supply a fixed astrophysical ΓW law for photon delays, rotation curves, black-hole information flow, cosmological exchange, or vacuum energy. It also does not prove coordinate invariance of the exposure factor W; instead, W is an operational exposure law that must be fixed by the chosen phase-coordinate convention in any test.

The survival-normalisation result is a formal lemma until the free structures are fixed. Predictive content begins only when R, Ω^2, ℓ, Γ, W, the induced gate transmissions $G_i = e^{-A_i}$, the history measure, path family, clock criterion, output map, and uncertainty threshold are specified before data comparison. The analogue-media test is therefore the present falsifiable target of the paper. The present paper is therefore a protocol-formalism paper; it does not report a completed laboratory validation.

12 Conclusion

Recursive survival weighting, as developed here, is a survival-weighted formalism for recursive transport. The central construction begins with the discrete update

$$\sigma_{n+1} = R(\sigma_n), \qquad \varphi_{n+1} = M_{\Delta t}\varphi_n \tag{277}$$

in any locally specified linear phase cell. In the continuous approximation this becomes

$$\boxed{\frac{d\Theta}{dt} = \Pi, \quad \frac{d\Pi}{dt} = -\Omega^2\Theta, \quad \frac{dS}{dt} = -\Gamma(\sigma)W(\varphi)S} \tag{278}$$

with

$$J(\varphi) = \Theta^2 + \ell^2\Pi^2, \qquad W(\varphi) = \frac{\Theta^2}{J(\varphi)}. \tag{279}$$

Normalising surviving represented counts gives

$$G_i = e^{-A_i}, \qquad p_i = \frac{C_{i,N}}{\sum_j C_{j,N}} = \frac{q_i G_i}{\sum_j q_j G_j} = \frac{q_i e^{-A_i}}{\sum_j q_j e^{-A_j}}, \tag{280}$$

so histories with lower accumulated loss have more open exposure gates and receive higher normalised representation weight within the specified history family when preparation weights are equal. The shorthand $p_i = S_i / \sum_j S_j$ is recovered for equal q_i, with $S_i = G_i$.

The recursive null-transport class is the effectively lossless, projected-norm-preserving class with no recurrent internal clock. Its recursive proper time is therefore

$$d\tau_R = 0. \tag{281}$$

Under the local interval calibration

$$ds^2 = c^2 d\tau_R^2 = c^2 dt^2 - dx^2, \tag{282}$$

this gives

$$ds^2 = 0, \qquad \left|\frac{dx}{dt}\right| = c. \tag{283}$$

Thus, under the stated embedding, the zero-recursive-proper-time class is represented by a null interval. The value of c, the metric signature, and electromagnetic field structure remain external constraints for a complete physical theory.

When the effective loss field and output map are independently fixed, the survival-weighted representation mechanism gives the controlled analogue-media comparison target:

$$\frac{p_i}{p_j} = e^{-A_i+A_j} \qquad \text{for equal preparation.} \tag{284}$$

Within the model this equation is the equal-preparation identity following from $G_i = S_i = e^{-A_i}$ and $p_i = G_i/Z$. The operational count form is $p_i = q_i G_i/Z_q = q_i e^{-A_i}/Z_q$, which gives $p_i/p_j = (q_i/q_j)e^{-A_i+A_j}$. The logarithmic version is only a diagnostic rewriting of this ratio. Empirical content lies only in the external comparison: independently calibrated accumulated losses, gate transmissions, and preparation weights must predict independently measured output vectors and output ratios. No symbol in the present paper is permitted to be fitted to target output after measurement; any post-hoc adjustment of R_{test}, Θ, Π, ℓ, Γ, W, G_i, q_i, path class, output map, or acceptance threshold invalidates the empirical claim. Broader bridge programmes require separate object maps, locked laws, constants, and falsifiers. They are not part of the present analogue claim.

The immediate empirical claim is narrower. In a controlled analogue medium, independently calibrated accumulated-loss values must predict the measured output vector and selected no-log output ratios within the stated uncertainty. If they do not, the constrained special case fails.

A Notation and Symbol Status

The following symbols are used throughout the paper. The full RSG recursive state is written σ_n, while the reduced phase/transport projection is written φ_n. The table also marks whether a quantity is an internally defined object of the formalism, a free structure requiring independent specification, or an imported physical quantity.

Symbol	Name	Status	Meaning
Σ	Structured recursive state space	Internal definition	Space of RSG structured recursive states.
σ_n	Structured recursive state	Internal definition	Full state at recursive depth n, usually $\sigma_n = (X_n, \varphi_n, \mu_n, S_n)$.
X_n	Topological support	Internal definition	Surtea-topological support carried by σ_n.
φ_n	Phase projection	Internal definition	Projected phase/transport component of σ_n.
π_Φ	Phase projection map	Internal definition	Map $\pi_\Phi : \Sigma \to \Phi$, with $\pi_\Phi(\sigma_n) = \varphi_n$.
μ_n	Measure data	Model-dependent	Physical measures or attributes attached to the structured state.
R	Update operator	Free structure	Rule $\sigma_{n+1} = R(\sigma_n)$. A predictive model must specify R before comparison with data.
γ_i	History	Internal definition	Generated sequence $\{\sigma_{i,0}, \sigma_{i,1}, \ldots\}$.
Θ_n	Phase coordinate	Model coordinate	Position-like or ordinal coordinate of φ_n. It requires operational definition in applications.
Π_n	Phase-flow coordinate	Model coordinate	Motion-like coordinate conjugate to Θ_n.
Ω^2	Phase-flow coefficient	Free structure	Bends trajectories in the reduced phase portrait. It is not, by itself, spacetime curvature.
ω	Local phase frequency	Derived quantity	In a positive constant-Ω^2 cell, $\omega = \sqrt{\Omega^2}$.
$M_{\Delta t}$	Discrete phase-step matrix	Derived/local model	Exact projected step matrix for constant $\Omega^2 > 0$, or a specified local approximation in a discrete model.
E	Energy diagnostic	Internal definition	$E = \frac{1}{2}(\Pi^2 + \Omega^2\Theta^2)$, conserved only in the locally constant-Ω^2 reduced system.

Symbol	Name	Status	Meaning
J_n	Action norm	Internal definition	$J_n = J(\varphi_n) = \Theta_n^2 + \ell^2\Pi_n^2$.
ℓ	Scale factor	Free scale	Converts Θ and Π into comparable units. Must be fixed in any test.
W_n	Exposure weight	Internal definition	$W_n = \Theta_n^2/J_n$, with $0 \leq W_n \leq 1$ when $J_n > 0$.
Γ_n	Dissipation	Free structure	Non-negative local survival-loss coefficient, usually $\Gamma_n = \Gamma(\sigma_n)$. Requires independent meaning.
$\Lambda, \Lambda_{\text{surv}}$	Effective survival-loss rate	Internal definition	$\Lambda_{\text{surv}} = \Lambda = \Gamma(\sigma)W(\varphi)$. Survival depends on Λ_{surv}, not on Γ alone. This is not the cosmological constant.
A_i	Accumulated loss	Internal definition	$A_i(t) = \int_0^t \Gamma(\sigma_i)W(\varphi_i)\,dt$.
$S_n, S(t)$	Survival weight	Internal definition	Discrete or continuous survival weight, with $dS/dt = -\Gamma W S$.
G_i	Exposure-gate transmission	Internal definition	$G_i = S_i = e^{-A_i}$. Multiplicative gate applied to prepared represented amount before normalisation.
q_i	Preparation weight	Operational input	Pre-measurement preparation weight or prior represented amount for history or channel i.
$C_{i,0}$	Prepared represented amount	Operational input	Initial count, intensity, bin mass, or represented amount, usually $C_{i,0} = C_0 q_i$.
$C_{i,N}$	Surviving represented amount	Derived output	Surviving count or intensity after the locked survival process, $C_{i,N} = C_0 q_i e^{-A_i}$.
$\widehat{C}_i$	Measured output amount	Operational output	Measured count, intensity, bin mass, or represented output amount in channel i.
p_i	Represented output fraction	Derived output	Normalised represented output fraction $p_i = C_{i,N}/\sum_j C_{j,N} = q_i e^{-A_i}/Z_q$. The form $p_i = S_i/\sum_j S_j$ assumes equal preparation.
Z, Z_q	Survival normalisers	Internal definitions	$Z = \sum_j e^{-A_j}$ for equal preparation; $Z_q = \sum_j q_j e^{-A_j}$ for prepared counts.
H_{surv}	Survival entropy	Internal definition	$H_{\text{surv}} = -\sum_i p_i \ln p_i = \langle A \rangle_p + \ln Z$.
N_{eff}	Effective represented histories	Internal definition	$N_{\text{eff}} = e^{H_{\text{surv}}}$.
$\sim$	Equivalence relation	Model choice	Defines when two recursive states count as the same state for recurrence.

Symbol	Name	Status	Meaning
C_n	Recursive clock component	Model choice	Recurrent internal subsystem of σ_n, when present, used to define recursive clock cycles.
θ_n	Phase angle	Optional reduction	Angular coordinate when the projected dynamics admits a rotation-number description.
r	Rotation number	Optional diagnostic	If $\theta_{n+1} = \theta_n + \alpha \pmod{2\pi}$, then $r = \alpha/(2\pi)$. Rational r gives phase closure; irrational r gives non-closure in this angular reduction.
r_n	Scalar ratio diagnostic	Limited diagnostic	$r_n = \Theta_{n+1}/\Theta_n$ when $\Theta_n \neq 0$. This ratio alone is not a general closure criterion.
x, ∇, ∇^2	Coarse coordinate and derivatives	Standard mathematical notation	Coarse state-space coordinate, gradient, and Hessian/Laplacian notation used in loss-basin expressions.
$\widehat{\Theta}, \widehat{\Pi}$	Measured phase estimators	Operational observables	Calibrated measurements or estimators used in an analogue test to instantiate the formal coordinates Θ, Π.
$\widehat{p}_i, \widehat{R}_{ij}, \widehat{L}_{ij}$	Measured output fraction, no-log ratio, and optional log-ratio	Operational outputs	Background-subtracted output fraction, measured ratio $\widehat{R}_{ij} = \widehat{p}_i/\widehat{p}_j$, and optional diagnostic $\widehat{L}_{ij} = \ln(\widehat{p}_i/\widehat{p}_j)$. The primary comparison uses $\widehat{\mathbf{p}}$ and $\widehat{R}_{ij}$.
$\|\sigma_n\|_\Phi$	Projected recursive norm	Internal definition	Norm assigned to the phase projection, here $\|\sigma_n\|_\Phi = J(\varphi_n)$.
Δt	Step size	Model choice	Discrete interval in the survival functional.
ds^2	Metric interval	Imported structure	Used only after an effective spacetime embedding is assumed.
c	Light speed	Empirical constant	Standard light speed in the metric representation.

Optional cosmological, Landauer-style, and future-bridge symbols are collected in Appendix B. They are not part of the minimal analogue-test formalism.

B Bridge-Track Supplement: Optional Bridge Notation

The following symbols are used only in optional bridge discussions. They are not part of the minimal analogue-media protocol and should not be treated as empirical inputs to the present paper.

Table 16: Optional bridge notation for structural, matter-sector, and cosmological roadmap variables.

Symbol	Name	Status	Meaning
$\mathcal{E}_n, f_n, M_{R,n}, h$	Optional measure data	Optional bridge notation	Energy, frequency, Planck constant, and Einstein–Planck mass-equivalent measures carried in μ_n for future matter-sector bookkeeping.
$Q_H, L_D, \lambda_{\text{bd}}, \lambda_{\text{class}}, \lambda_{\text{int}}, \lambda_H$	Optional structural-loss notation	Optional extension	Hopf-like charge, discrete structural loss, and boundary/class/interaction/topological coefficients. Not part of the minimal analogue protocol.
$N, \mathcal{E}_N$	E-fold and exposure variables	Optional cosmological projection	$N = \ln a$ and $\mathcal{E}_N = dA/dN = \Gamma W/H$, used only in speculative cosmological reductions.
ρ_R, C, Ω_R, Ξ	Recursive cosmological variables	Optional cosmological projection	Recursive density, coherence memory, density fraction, and homogeneous exchange scalar.
$\alpha_R, \alpha_0, \gamma_C, \eta$	Exchange/coherence parameters	Optional cosmological projection	Coupling and memory parameters; must be fixed before any future cosmological model is tested.
$T^{\mu\nu}, T_R^{\mu\nu}, Q^\nu$	Stress-energy and exchange current	Optional cosmological projection	Ordinary stress-energy, recursive-sector stress-energy, and exchange current for future conservation models.
Λ_{CC}	Cosmological constant	Imported target	Standard cosmological-constant notation. Not identical with Λ_{surv} without a dimensional map, conservation law, and equation-of-state condition.
$a, H, \rho, z, E_\gamma, \mathcal{F}$	Application variables	Optional application notation	Scale factor, Hubble rate, density, redshift, photon energy, and photon-delay kernel.

Table 17: Optional bridge notation for historical-record and vacuum-energy roadmap variables.

Symbol	Name	Status	Meaning
I_{hist}	Historical-record information measure	Optional information bridge	Coarse-grained information displaced from the current represented measure into the historical energetic record; not information destruction.

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Table 17: Optional bridge notation for historical-record and vacuum-energy roadmap variables, continued.

Symbol	Name	Status	Meaning
$E_{\mathrm{L}}, k_B, T_{\mathrm{L}}, V$	Landauer-style quantities	Optional information bridge	Energy scale, Boltzmann constant, effective temperature, and coarse-graining volume, used only if an accessibility-cost bridge is supplied.
$\varepsilon_{\mathrm{R,vac}}$	Recursive vacuum-sector energy density	Optional vacuum bridge	Candidate energy density from E_{L}/V, only if a conserved vacuum-like sector is defined.

C Bridge-Track Supplement: Exploratory Interface and Future Bridge Programme

Exploratory Interface

An exploratory public simulation interface associated with this project is available at `https://recursivedynamics.net`. It is not evidence for the claims in this paper. Its role is heuristic: to inspect candidate path families, projection artefacts, numerical instabilities, and possible analogue-test configurations before a locked validation protocol is run. Because the interface is exploratory and may change, numerical outputs from it are not cited here as validation data. Such outputs become evidential only after the update rule, path family, calibration data, output map, and failure thresholds have been fixed in advance.

Future Bridge Programme

This appendix records bridge conditions for later work. It is separated from the main argument because the analogue-media test is the only empirical target developed here.

Table 18: Future bridge conditions required before broader physical derivations can be claimed.

Target	**What RSG currently supplies**	**Bridge or derivation still needed**	**Failure or success condition**
Lorentzian signature	Recursive clocks, recursive proper time $d\tau_R$, and a null class with $d\tau_R = 0$.	A causal-order reconstruction showing that admissible recursive updates preserve a finite invariant cone with one clock-like sign and spatial transverse directions.	Fails if the recursive update admits no invariant causal cone, requires Euclidean signature, or produces more than one independent time-like direction.
c	A clock-step/spatial-step calibration can define an effective recursive signal speed c_R.	A universality theorem showing that c_R is independent of state, path, and observer convention, followed by empirical calibration $c_R = c$.	Fails if different calibrated recursive clocks or media require incompatible limiting speeds.
Electro -magnetism	Phase variables and non-closing, lossless transport classes.	A local phase-symmetry postulate, a gauge connection, Lorentz-covariant field strength, and a recovery of Maxwell or massless $U(1)$ dynamics including polarisation.	Fails if the required connection cannot be defined from recursive phase transport or gives non-Maxwell propagation in the calibrated limit.
Matter sectors	Recurrent histories, non-zero recursive proper time, projected norm, and survival concentration.	Stable localised recurrent sectors with conserved energy/frequency measure, inertia, stress-energy coupling, and compatible quantum statistics.	Fails if recurrent sectors cannot remain localised, lack inertial response, or violate the required conservation laws.
Astrophysical dynamics	A formal representation density can be built from weighted histories, and ΓW can in principle define concentration profiles.	A universal or restricted astrophysical ΓW law, an effective density map, and a Poisson/Einstein-limit field equation fixed before fitting galaxies or lensing data.	Fails if one must choose a separate loss law per galaxy, or if the fixed law contradicts rotation, lensing, or structure data.

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Target	**What RSG currently supplies**	**Bridge or derivation still needed**	**Failure or success condition**
ΛCDM limit	Survival sectors can be assigned representation densities in future models.	A dust-like sector with $\rho_{\mathrm{R,m}} \propto a^{-3}$, a conserved vacuum-like sector with $w = -1$, and no observationally relevant exchange current Q^{ν}.	Fails if a new ΓW law is needed per dataset, or if the matter/vacuum sectors do not reproduce the standard limiting behaviours.
Vacuum-energy bridge	H_{surv}, I_{hist}, and a possible Landauer-style energy map.	A historical-record accessibility criterion, effective temperature T_{L}, coarse-graining volume, conservation law, and vacuum equation of state.	Fails if the historical-record sector is not conserved, is not homogeneous on the claimed scale, or does not behave as $T^{\mu\nu} \propto -g^{\mu\nu}$.

A bridge is not established merely by naming an RSG quantity after a physical one. It must constrain both sides: the recursive construction must specify the physical observable before comparison, and the physical data must be capable of ruling out the proposed bridge. Until such a bridge is supplied, the correct label is candidate correspondence or future constrained specialisation.

D Bridge-Track Supplement: Vacuum-Energy Bridge and the Cosmological Constant

This appendix is a containment note for future work. It is not part of the strict analogue-protocol core and may be omitted from a strict-core submission without changing any result in the main paper. Recursive survival weighting does not identify its survival-loss rate with the cosmological constant, and it does not assume that information is destroyed. Any future vacuum-sector claim would require an independently defined historical-record measure, an operational energy scale, a conserved homogeneous sector, and an equation of state before comparison with Λ_{CC}.

The symbol Λ_{surv} used in the main text is not the cosmological constant. It is an effective survival-loss rate,

$$\Lambda_{\mathrm{surv}}(\sigma, \varphi) = \Gamma(\sigma) W(\varphi), \tag{285}$$

with units of inverse time when the recursive parameter is physical time. By contrast, the cosmological constant Λ_{CC} is a spacetime curvature source with units of inverse length squared. The two symbols can be related only through an additional information-energy bridge and a vacuum-sector stress-energy model.

Table 19: Status of the proposed vacuum-energy bridge.

Object	**Status in this paper**	**Required before a Λ_{CC} claim**
$\Lambda_{surv} = \Gamma W$	Internal survival-loss rate.	Must not be identified directly with Λ_{CC}.
I_{hist}	Optional historical-record information measure.	Must count recoverable historical information in bits, not destroyed information and not merely a change of notation.
T_L	Imported/operational temperature.	Must be independently calibrated, not chosen to fit Λ_{CC}.
$\varepsilon_{R,vac}$	Candidate recursive vacuum-sector energy density.	Must be homogeneous, conserved, and associated with $w = -1$.
Λ_{CC}	Imported cosmological target.	Follows only if $\varepsilon_{R,vac}$ behaves as a vacuum stress-energy source.

The present paper supplies only the survival-weighting side of this possible bridge. The bridge fails if the historical-record measure is not well defined, if the information is not recoverably encoded in the physical history, if any energy scale or coarse-graining volume is fitted after the fact, if the resulting energy density is not conserved and homogeneous, or if the stress-energy does not have the required vacuum form. This is why the appendix is framed as a bridge note rather than as a claim about the observed cosmological constant.

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