Information Recovery, Support Structures, and Stress-Energy:
A Conditional Surtea-Austin Correspondence Note

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Abstract

This note gives a conditional correspondence framework from information recovery to stress-energy. It does not claim that abstract information directly gravitates. The central claim is more structured: generated information can have no fixed upper bound under non-terminating recursion, recovered information is bounded by a finite recovery channel, and physically recoverable information must be encoded on a support whose carrier can possess energy-momentum. Surtea's partition topology supplies one admissible language of support, interior, closure, boundary, and interaction. Austin's Recursive Survival Geometry supplies recursive states, generated histories, survival weights, and represented measure. Stress-energy enters only at the measure and action level. A strong information-stress-energy sector is stated only as a conjectural action-level extension, with explicit failure conditions. The manuscript is therefore a formal and conceptual correspondence note, not an established physical derivation or empirical result.

Keywords: Information Recovery; Stress-Energy; Recursive Survival Geometry; Surtea Topology; Support Structures; Recovered Information; Action Principle.

1 Notation

K_0	finite recursive seed,
$\mathcal{R}_{\mathrm{gen}}$	branching recursive update relation,
K_n	state generated after n recursive steps,
$\mathcal{H}_n$	set of distinguishable histories up to depth n,
$I_{\mathrm{gen}}(n)$	generated information at depth n,
$I_{\mathrm{rec}}(O \mid V_{\mathrm{rec}})$	information recovered from O through recovery vector V_{rec},
V_{rec}	recovery vector, including medium, resolution, coupling, ordering, and decoder,
m_{med}	recovery medium map or carrier medium component,
r_{res}	recovery resolution,
ν_{samp}	sampling or playback rate,
τ_{ord}	temporal ordering used by the recovery map,
C_R	recovery-channel capacity for V_{rec},
t_{obs}	finite observation or recovery time,
$U = (M, \mathcal{D})$	Surtea universe, with underlying set M and partition $\mathcal{D}$,
$X \subset M$	support of an object, carrier, or state,
$\mathrm{int}_{\mathcal{D}}(X)$	Surtea interior of X,
$\mathrm{cl}_{\mathcal{D}}(X)$	Surtea closure of X,
$\mathrm{bd}_{\mathcal{D}}(X)$	Surtea boundary of X,
σ_n	structured recursive state,
φ_n	phase or transport component of σ_n,
μ_n	physical measure package of σ_n,
S_n	survival weight,
A_i	accumulated loss of history i,
Λ_i	effective survival-loss rate of history i,
p_i	normalised represented weight of history i,
$\iota_R(x)$	placeholder recovered-information density,
$\mathcal{L}_I$	conjectural information-sector Lagrangian density,
$T^{\mu\nu}$	stress-energy tensor,
$T_I^{\mu\nu}$	conjectural information-sector stress-energy tensor,
O_{EM}	electromagnetic field state,
P_{beam}	optical beam power,
A_{beam}	optical beam area,
B_{mod}	modulation bandwidth for the worked optical example,
I_{beam}	optical beam intensity,
$\mathbf{P}_{\mathrm{tot}}$	total carrier momentum,
$\mathbf{V}_{\mathrm{IE}}$	effective energy-information transport vector,
v_g	group velocity of a recoverable signal packet,
n_g	group index of a material channel,
Δf	usable recovery bandwidth,
SNR	received signal-to-noise ratio,
$P_{\mathrm{tx}}, P_{\mathrm{rx}}$	transmitted and received channel power,
P_{noise}	noise power used in a channel-capacity estimate,
$L, \alpha_{\mathrm{mat}}, a_{\mathrm{dB}}$	material length, exponential attenuation, and decibel attenuation,
N	noise model attached to a material recovery vector,
B_{real}	engineered recoverable bit-rate,
W	analogue audio bandwidth,
s	invariant momentum-squared variable used in pair-production threshold.

2 Claim Status

The note separates three claims and two levels of physical commitment.

1. **Formal recursion claim.** A finite seed plus a non-terminating recursive rule can generate a history space with no fixed finite upper bound.

2. **Recovery claim.** A finite observer with a finite recovery vector recovers only finite information in finite time.

3. **Stress-energy claim.** Information becomes gravitationally relevant only when it is physically encoded on a carrier whose measure package includes energy-momentum, or when a separately defined information action is supplied.

The first claim is a formal counting result. The second is an operational channel-capacity statement. The third is not an established identity of standard physics. It is a conditional correspondence and, in its strongest version, a conjectural bridge.

Level A, carrier route. Recoverable information inherits gravitational relevance from the physical carrier on which it is encoded.

Level B, independent sector. A separate information stress-energy tensor may be introduced only if an independently specified information density, action, and conservation law are supplied.

Only Level A is conservative. Level B is a strong conjectural extension.

Claim	Status	Required assumptions	Demotion or failure condition
Generated information grows without fixed bound	Conditional combinatorial lemma	Branching relation with $b > 1$ admissible continuations	Single-valued deterministic recursion without labels
Finite recovery is bounded	Operational channel assumption	Finite C_R, finite t_{obs}, specified recovery vector	Undefined channel capacity or recovery protocol
Support and coupling are required	Admissibility condition	Supported object and non-zero coupling	Empty support or vanishing coupling
Carrier route to gravity	Standard carrier physics	Information encoded in a carrier with $T^{\mu\nu}_{\mathrm{car}}$	No carrier stress-energy or no recovery coupling
Independent information sector	Conjectural action-template	Fixed ι_R, $\mathcal{L}_I$, coefficients, and conservation law	No measurable ι_R, no conservation law, or no deviation from carrier-only stress-energy

$$\text{abstract information} \not\Rightarrow T^{\mu\nu}. \tag{1}$$

The proposed route is instead

$$\begin{aligned}\text{generated information} &\to \text{support} \to \text{boundary and closure coupling} \\ &\to \text{recovery} \to \text{physical measure} \to \text{stress-energy}.\end{aligned} \tag{2}$$

Interpretation. The paper does not begin by saying that information is a substance. It begins by asking what must be true before information can be physically recovered. The answer is that some structure must be supported somewhere, coupled to a recovery process, and carried by a state with physical measures. Only at that last stage can stress-energy enter.

3 Generated, Recovered, and Instantiated Information

Definition 1 (Generated information)**.** *Let K_0 be a finite seed and let $\mathcal{R}_{\text{gen}}$ be a branching recursive update relation,*

$$K_{n+1} \in \mathcal{R}_{\text{gen}}(K_n). \tag{3}$$

Let $\mathcal{H}_n$ be the set of distinguishable histories generated up to recursive depth n. Equivalently, one may write a labelled update $K_{n+1} = R_{\text{gen}}(K_n, a_n)$, where a_n is an admissible continuation label. The generated information at depth n is

$$I_{\text{gen}}(n) = \log_2 |\mathcal{H}_n|. \tag{4}$$

Lemma 1 (Conditional branching continuation)**.** *If the recursion preserves at least $b > 1$ distinguishable continuations per step, so that*

$$|\mathcal{H}_n| \geq b^n, \tag{5}$$

then $I_{\text{gen}}(n)$ has no fixed finite upper bound as $n \to \infty$.

Proof. By definition,

$$I_{\text{gen}}(n) = \log_2 |\mathcal{H}_n|. \tag{6}$$

Since $|\mathcal{H}_n| \geq b^n$,

$$I_{\text{gen}}(n) \geq \log_2(b^n) = n \log_2 b. \tag{7}$$

Let $L < \infty$ be any proposed finite upper bound. Choose

$$n > \frac{L}{\log_2 b}. \tag{8}$$

Then

$$I_{\text{gen}}(n) \geq n \log_2 b > L. \tag{9}$$

Hence

$$\forall L < \infty, \quad \exists n \quad \text{such that} \quad I_{\text{gen}}(n) > L, \tag{10}$$

and therefore

$$\lim_{n \to \infty} I_{\text{gen}}(n) = \infty. \tag{11}$$

□

This is a formal combinatorial continuation result. It is not, by itself, a physical infinity result, a storage theorem, or evidence for physical information accumulation. A single-valued deterministic recursion has $|\mathcal{H}_n| = 1$ unless histories are distinguished by additional admissible labels.

> **Interpretation.** The lemma says only that a branching recursive rule can generate more and more possible histories. It does not say that a finite object stores all those histories explicitly, and it does not say that an observer can recover them all. It separates possible continuation from actual recovery.

Definition 2 (Recovered information)**.** *Recovered information is information made accessible through a specified recovery vector. Write*

$$I_{\text{rec}}(O \mid V_{\text{rec}}) \tag{12}$$

for the information recovered from an object or field state O under recovery vector V_{rec}.

For a finite recovery channel with capacity C_R, finite recovery at finite observation time t_{obs} is bounded by the ordinary channel-capacity logic of information theory [1]:

$$I_{\text{rec}}(t_{\text{obs}} \mid V_{\text{rec}}) \leq C_R t_{\text{obs}}. \tag{13}$$

Thus

$$\text{finite seed} + \text{recursive rule} \rightarrow \text{unbounded generated continuation}, \tag{14}$$

whereas

$$\text{finite time} + \text{finite recovery channel} \rightarrow \text{finite recovered information}. \tag{15}$$

> **Interpretation.** The recovery inequality is the operational brake on the infinity language. A rule can keep generating possible continuations, but a detector or observer has a finite channel, finite time, and finite coupling. Recovery is therefore bounded even when continuation is not.

Remark 1. *This distinction prevents two errors. A bounded system need not contain infinite explicit information at a finite time. Conversely, information need not be ontologically destroyed merely because it leaves the current represented measure.*

4 Surtea-Austin Support Layer

The information-to-stress-energy bridge cannot begin with abstract information alone. It requires a support structure.

Following Surtea's partition-topological support language [2], let

$$U = (M, \mathcal{D}), \tag{16}$$

where M is an underlying set and $\mathcal{D}$ is a partition of M. The elements of $\mathcal{D}$ are called D-photons in Surtea's terminology, but they are not assumed to be standard quantum-electrodynamic photons. They are partition elements: the cells through which support, interior, closure, boundary, and interaction are defined.

For a support $X \subset M$, define $\text{int}_{\mathcal{D}}(X)$ as the largest union of $\mathcal{D}$-cells contained in X, and define $\text{cl}_{\mathcal{D}}(X)$ as the smallest union of $\mathcal{D}$-cells containing X. The boundary is

$$\text{bd}_{\mathcal{D}}(X) = \text{cl}_{\mathcal{D}}(X) - \text{int}_{\mathcal{D}}(X). \tag{17}$$

A finite example makes the support structure explicit. Let

$$M = \{a, b, c, d, e, f\}, \qquad \mathcal{D} = \{D_1, D_2, D_3\}, \tag{18}$$

with

$$D_1 = \{a, b\}, \qquad D_2 = \{c, d\}, \qquad D_3 = \{e, f\}. \tag{19}$$

If

$$X = \{a, c, d\}, \tag{20}$$

then the largest union of partition cells contained in X is

$$\text{int}_{\mathcal{D}}(X) = D_2 = \{c, d\}, \tag{21}$$

the smallest union of partition cells containing X is

$$\text{cl}_{\mathcal{D}}(X) = D_1 \cup D_2 = \{a, b, c, d\}, \tag{22}$$

and hence

$$\text{bd}_{\mathcal{D}}(X) = D_1 = \{a, b\}. \tag{23}$$

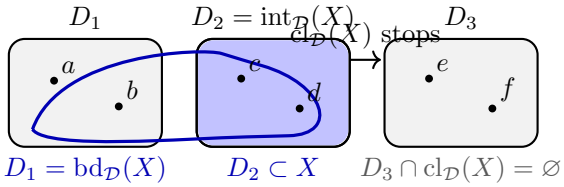

Figure 1: A partition support example. The set $X = \{a, c, d\}$ contains all of D_2, so D_2 is interior. Because X touches D_1 without containing all of it, D_1 enters the closure and becomes boundary.

In this reading, the boundary is not merely an edge. It is the interaction capacity of the support relative to the partition. A recovery process cannot couple to abstract meaning alone. It couples to supported structure through some boundary, closure, or channel relation.

Austin's RSG layer attaches recursive dynamics to this support [3]. A structured recursive state is written

$$\sigma_n = (X_n, \varphi_n, \mu_n, S_n), \tag{24}$$

where

$$X_n \subset M \tag{25}$$

is the Surtea-topological support, φ_n is phase or transport data, μ_n is the physical measure package, and S_n is the survival weight.

This separation is essential:

$$\text{support} \neq \text{whole physical state.} \tag{26}$$

The support X_n tells us where and how the state is topologically available. The phase component φ_n tells us how it propagates. The measure package μ_n is where energy, momentum, frequency, mass-equivalent measures, or stress-energy bookkeeping may be attached. The survival weight S_n tells us which histories remain represented after recursive filtering.

The recovery bridge therefore becomes

$$\text{encoded information} \to X_n \to \mathrm{bd}_{\mathcal{D}}(X_n), \mathrm{cl}_{\mathcal{D}}(X_n) \to \kappa \to I_{\mathrm{rec}} \to \mu_n \to T^{\mu\nu}. \tag{27}$$

In words,

information becomes physically recoverable only through support, boundary, coupling, and measure. (28)

> **Interpretation.** Surtea supplies the language of where a thing is available: support, interior, closure, and boundary. Austin supplies the language of how that supported state moves through recursive histories and survives filtering. Together they prevent a direct jump from abstract information to gravity.

Admissibility condition 1 (Support and coupling requirement for physical recovery)**.** *If* $I_{\mathrm{rec}}(O \mid V_{\mathrm{rec}}) \neq 0$*, then there exists a support* $X \subset M$ *on which* O *is physically or formally encoded, and there is a non-zero recovery coupling*

$$\kappa(O, V_{\mathrm{rec}}) \neq 0. \tag{29}$$

This is a structural requirement of the recovery framework, not an independent empirical theorem.

Proof. Recovered information is defined as information made accessible through a recovery vector. Accessibility requires a domain of application for the recovery map. In the Surtea-Austin structure, the domain of a physical state includes a support X, its boundary and closure relations, and its attached phase and measure data. If no support exists, there is no object or carrier to which the recovery vector can couple. If the coupling vanishes, the recovery map returns no accessible structure. Hence non-zero recovery requires both support and non-zero coupling. □

5 Recovery Vector

Let the recovery vector be

$$V_{\mathrm{rec}} = (m_{\mathrm{med}}, r_{\mathrm{res}}, \nu_{\mathrm{samp}}, \kappa, \delta, \tau_{\mathrm{ord}}, D_{\mathrm{dec}}), \tag{30}$$

where m_{med} is the recovery medium, r_{res} is resolution, ν_{samp} is sampling or playback rate, κ is the coupling channel, δ is scale projection, τ_{ord} is temporal ordering, and D_{dec} is the decoder.

A compressed recovery map is

$$I_{\mathrm{rec}}(O \mid V_{\mathrm{rec}}) = D_{\mathrm{dec}} \circ \kappa \circ \Pi_\delta \circ S_{(r_{\mathrm{res}}, \nu_{\mathrm{samp}}, \tau_{\mathrm{ord}})} \circ m_{\mathrm{med}}(O). \tag{31}$$

This composition is schematic but type-safe when read as a chain of maps:

$$m_{\mathrm{med}} : O \to M_{\mathrm{sig}}, \qquad S : M_{\mathrm{sig}} \to S_{\mathrm{rec}}, \tag{32}$$

$$\Pi_\delta : S_{\mathrm{rec}} \to P_\delta, \qquad \kappa : P_\delta \to C_{\mathrm{rec}}, \qquad D_{\mathrm{dec}} : C_{\mathrm{rec}} \to \mathcal{I}_{\mathrm{rec}}. \tag{33}$$

> **Interpretation.** This equation says that recovery is layered. The object must be present in a medium, sampled at some resolution and ordering, projected at the right scale, coupled through a channel, and decoded. A wrong reader can fail even when encoded structure is still present.

If the recovery vector is incompatible with the object,

$$V_{\mathrm{rec}} \perp O, \tag{34}$$

then

$$I_{\mathrm{rec}}(O \mid V_{\mathrm{rec}}) \approx 0, \tag{35}$$

but this does not imply

$$I_{\mathrm{enc}}(O) = 0. \tag{36}$$

The encoded structure remains, but the recovery path fails.

6 Survival Weighting and Represented Measure

RSG separates generation from representation. A family of histories may be generated, but only some histories remain strongly represented after survival filtering.

Let a history γ_i acquire effective survival-loss rate $\Lambda_i(t)$. The accumulated loss is

$$A_i(t) = \int_0^t \Lambda_i(\tau)\, d\tau. \tag{37}$$

The survival weight is

$$S_i(t) = e^{-A_i(t)}. \tag{38}$$

The represented measure is defined only when the normalisation is finite:

$$Z(t) = \sum_j e^{-A_j(t)}, \qquad 0 < Z(t) < \infty. \tag{39}$$

The represented measure is then the normalised survival measure

$$p_i(t) = \frac{S_i(t)}{Z(t)} = \frac{e^{-A_i(t)}}{Z(t)}. \tag{40}$$

For two histories i and j,

$$\frac{p_i}{p_j} = \frac{S_i}{S_j} = \exp[-A_i + A_j]. \tag{41}$$

Thus if $A_i < A_j$, then $p_i > p_j$. Lower accumulated loss gives stronger represented weight.

The survival entropy is

$$H_{\text{surv}} = -\sum_i p_i \log p_i, \tag{42}$$

and the effective number of represented histories is

$$N_{\text{eff}} = e^{H_{\text{surv}}}. \tag{43}$$

High survival entropy means many survival-compatible histories remain live. Low survival entropy means representation has concentrated into a narrower basin.

> **Interpretation.** The survival equations do not choose one history at generation. They assign weights after loss has accumulated. Histories that lose less weight become more represented. Entropy then measures how many histories remain live in the represented measure.

Remark 2. *In this note S_i and p_i are treated as effective representation weights. They need not be ontic probabilities unless an additional physical interpretation and measurement map are supplied.*

7 Carrier Stress-Energy

Stress-energy does not arise from abstract meaning. In standard field theory it arises from the metric variation of an action.

Unless otherwise stated, the metric signature is $(-+++)$, variations are taken with respect to $g^{\mu\nu}$, and physical constants are kept explicit. The carrier stress-energy below is the standard variational definition [4].

Let a carrier field ψ have action

$$S_{\text{car}}[g, \psi] = \int_{\mathcal{M}} \sqrt{-g}\, \mathcal{L}_{\text{car}}(g, \psi, \nabla\psi)\, d^4x. \tag{44}$$

The stress-energy tensor is

$$T^{\text{car}}_{\mu\nu} = -\frac{2}{\sqrt{-g}} \frac{\delta S_{\text{car}}}{\delta g^{\mu\nu}}. \tag{45}$$

If $\mathcal{L}_{\text{car}}$ contains no derivatives of the metric, this gives

$$T^{\text{car}}_{\mu\nu} = -2\frac{\partial \mathcal{L}_{\text{car}}}{\partial g^{\mu\nu}} + g_{\mu\nu}\mathcal{L}_{\text{car}}. \tag{46}$$

Lemma 2 (Carrier route to gravitational relevance)**.** *If O is encoded on a carrier whose measure package contains energy-momentum data, then a stress-energy tensor may be assigned to the carrier. The recovered information is gravitationally relevant through the carrier stress-energy, not as abstract meaning, and no independent information stress-energy is implied by carrier encoding alone.*

Proof. By the Surtea-Austin decomposition, the structured state has measure package μ_n. If μ_n contains an energy-momentum carrier described by an action S_{car}, then metric variation of that action defines $T^{\text{car}}_{\mu\nu}$. Since $I_{\text{rec}}(O \mid V_{\text{rec}}) \neq 0$ requires non-zero coupling to the carrier, the recovered information is physically instantiated in a stress-energy-bearing state. The stress-energy belongs to the carrier action. The recovered information specifies readable structure within that carrier. A separate information stress-energy tensor requires the independent action construction introduced later. □

The cautious chain is therefore

$$I_{\mathrm{rec}}(O \mid V_{\mathrm{rec}}) \neq 0 \Rightarrow \kappa(O, V_{\mathrm{rec}}) \neq 0 \Rightarrow \text{physical carrier coupling.} \tag{47}$$

If the carrier has energy-momentum,

$$\mu_n \supset S_{\mathrm{car}}[g, \psi], \qquad T^{\mu\nu}_{\mathrm{car}} \neq 0 \Rightarrow \text{encoded information is gravitationally relevant through } T^{\mu\nu}_{\mathrm{car}}. \tag{48}$$

Interpretation. This is the conservative route. The information is gravitationally relevant because it is recovered from a carrier that already has energy-momentum. The stress-energy belongs to the carrier action. The information is the readable organisation of that carrier, not a second substance added on top of it.

8 Conjectural Information Stress-Energy Sector

The carrier route is conservative. The stronger conjecture is that recoverable information may itself define an effective sector once an information functional is placed into an action.

Definition 3 (Recovered information density)**.** *Let $\iota_R(x)$ denote a local recovered-information density associated with a support X, recovery vector V_{rec}, coupling κ, and represented history measure p_i. Its detailed construction is model-dependent, but it must satisfy:*

$$\iota_R(x) = 0 \quad \textit{if} \quad x \notin \mathrm{cl}_{\mathcal{D}}(X) \tag{49}$$

and

$$\iota_R(x) = 0 \quad \textit{if} \quad \kappa(O, V_{\mathrm{rec}}) = 0. \tag{50}$$

8.1 Status of ι_R

The field ι_R is not yet a uniquely defined physical observable. In the present note it is an admissibility placeholder for a future operational construction. The current manuscript supplies only the conditions under which such a density would be allowed to enter a support-coupled action.

At minimum, a completed model must specify:

1. whether ι_R is measured in bits, nats, bits per volume, nats per volume, or as an already converted energy density;
2. the detector, coarse-graining, and recovery procedure used to measure it;
3. the transformation law of ι_R under changes of coordinates and recovery frame;
4. the conservation or exchange law associated with it;
5. the coefficients that convert recovered information into an action density.

If ι_R is an information density in bits per unit volume, then an energy density requires an independently fixed conversion coefficient χ_I:

$$\varepsilon_I = \chi_I \iota_R. \tag{51}$$

For a Landauer-style specialisation [5], one possible coefficient is

$$\chi_I = k_B T_L \ln 2, \tag{52}$$

but T_L must be independently calibrated. It cannot be chosen after the fact to fit a gravitational target.

Conjecture 1 (Information stress-energy sector)**.** *If recovered information has an independent action contribution*

$$S_I[g, \iota_R, X, \kappa, V_{\rm rec}] = \int_{\mathcal{M}} \sqrt{-g}\, \mathcal{L}_I(\iota_R, \nabla\iota_R, X, \mathrm{bd}_{\mathcal{D}}(X), \kappa, V_{\rm rec}; g)\, d^4x, \tag{53}$$

then, as a conditional variational construction, it would define an information-sector stress-energy tensor

$$T^I_{\mu\nu} = -\frac{2}{\sqrt{-g}} \frac{\delta S_I}{\delta g^{\mu\nu}}. \tag{54}$$

This is the strongest version of the bridge. It is not a definition of ordinary information. It is a conjecture that a physically recoverable information density, once coupled to the metric through an action, contributes to stress-energy in the same variational sense as any other field sector. Until ι_R, $\mathcal{L}_I$, and the coefficients in $\mathcal{L}_I$ are independently fixed, this is a conditional embedding template rather than a physical theory. The map $S_I \mapsto T^{\mu\nu}_I$ is not a prediction until ι_R, $\mathcal{L}_I$, all coefficients, and the conservation or exchange law are fixed independently of the target gravitational effect.

> **Interpretation.** The independent sector is more speculative than the carrier route. It becomes mathematical only after an information density is placed inside an action. Without that action and its coefficients, $T^{\mu\nu}_I$ is a slot for a future theory, not a derived physical object.

If $\mathcal{L}_I$ contains no metric derivatives,

$$T^I_{\mu\nu} = -2\frac{\partial \mathcal{L}_I}{\partial g^{\mu\nu}} + g_{\mu\nu}\mathcal{L}_I. \tag{55}$$

8.2 Potential-like information density

If

$$\mathcal{L}_I = -\varepsilon_I(\iota_R), \tag{56}$$

then

$$T^I_{\mu\nu} = -\varepsilon_I g_{\mu\nu}. \tag{57}$$

This has vacuum-like form only if ε_I is homogeneous, conserved, and has the appropriate equation of state.

8.3 Gradient information field

If

$$\mathcal{L}_I = -\frac{1}{2}\alpha\, g^{\mu\nu}\nabla_\mu\iota_R\nabla_\nu\iota_R - V(\iota_R), \tag{58}$$

then

$$T^I_{\mu\nu} = \alpha\nabla_\mu\iota_R\nabla_\nu\iota_R - g_{\mu\nu}\left(\frac{1}{2}\alpha\, g^{\rho\sigma}\nabla_\rho\iota_R\nabla_\sigma\iota_R + V(\iota_R)\right). \tag{59}$$

8.4 Radiation-like information flow

For a null information-bearing radiation channel with null vector k^μ,

$$k^\mu k_\mu = 0, \tag{60}$$

a radiation-like effective stress-energy may be written

$$T^{\mu\nu}_I = \Phi_I k^\mu k^\nu, \tag{61}$$

where Φ_I is an independently specified flux density. This form is appropriate only when the information-bearing carrier is radiation-like.

8.5 Matter-like information concentration

For a recurrent, localised, matter-like sector with four-velocity u^μ, one may write the perfect-fluid form

$$T_I^{\mu\nu} = (\rho_I + p_I)u^\mu u^\nu + p_I g^{\mu\nu}, \tag{62}$$

in units where $c = 1$. This is legitimate only after a recurrent support, equation of state, and conservation law have been supplied.

8.6 Phenomenological coefficients

The parameters α, Φ_I, ρ_I, and p_I are phenomenological placeholders in this correspondence note. They do not have empirical status unless they are fixed before comparison with data by an independent construction, calibration, or conservation law.

> **Interpretation.** The template forms show what kinds of stress-energy an information sector could imitate: vacuum-like, gradient-field-like, radiation-like, or matter-like. They are not predictions until the free coefficients are fixed independently.

9 Conservation and Failure Conditions

If an information sector is added to an Einstein-type equation, one obtains schematically

$$G^{\mu\nu} = \frac{8\pi G}{c^4}\left(T_{\text{car}}^{\mu\nu} + T_I^{\mu\nu}\right). \tag{63}$$

The Bianchi identity requires

$$\nabla_\mu\left(T_{\text{car}}^{\mu\nu} + T_I^{\mu\nu}\right) = 0. \tag{64}$$

If energy-momentum is exchanged between the carrier sector and the information sector, introduce an exchange current Q^ν:

$$\nabla_\mu T_{\text{car}}^{\mu\nu} = -Q^\nu, \qquad \nabla_\mu T_I^{\mu\nu} = Q^\nu. \tag{65}$$

The bridge fails if any of the following are absent:

1. a well-defined support X;
2. a boundary, closure, or channel relation permitting recovery;
3. an independently specified recovered-information density ι_R;
4. an action S_I or carrier action S_{car};
5. a conservation or exchange law;
6. an equation of state if a vacuum-like or matter-like sector is claimed;
7. coefficients fixed before comparison with observation.

10 Required Limits and Falsifiers

The independent information-sector conjecture must reduce correctly in simple limits.

10.1 Weak-coupling limit

If recovery coupling vanishes,

$$\kappa \to 0, \tag{66}$$

then recovered information must vanish,

$$I_{\mathrm{rec}}(O \mid V_{\mathrm{rec}}) \to 0, \tag{67}$$

and the independent information-sector contribution must vanish or become unobservable:

$$T_I^{\mu\nu} \to 0. \tag{68}$$

This limit does not imply that carrier stress-energy vanishes. It implies only that recovery and any independent information-sector contribution vanish.

10.2 Trivial-support limit

If the relevant support is empty or inaccessible,

$$X = \varnothing \quad \text{or} \quad \mathrm{cl}_{\mathcal{D}}(X) \cap \mathrm{supp}(V_{\mathrm{rec}}) = \varnothing, \tag{69}$$

then

$$\iota_R(x) = 0 \tag{70}$$

on the recovery domain.

10.3 Carrier-only limit

If no independent information action is supplied,

$$S_I = 0, \tag{71}$$

then

$$T_I^{\mu\nu} = 0, \tag{72}$$

and all gravitational relevance belongs to the carrier stress-energy:

$$T^{\mu\nu} = T_{\mathrm{car}}^{\mu\nu}. \tag{73}$$

10.4 Flat-spacetime and homogeneous-background checks

In a flat background,

$$g_{\mu\nu} \to \eta_{\mu\nu}, \tag{74}$$

the proposed information-sector dynamics must reduce to a well-defined special-relativistic field or effective-medium model. In a homogeneous background, any vacuum-like information sector must satisfy

$$T_I^{\mu\nu} \propto -g^{\mu\nu} \tag{75}$$

only if the associated energy density is homogeneous, conserved, and has equation of state

$$w = -1. \tag{76}$$

10.5 Falsification conditions

A completed strong-sector model is falsified, or the present framework is demoted to carrier-only status, if:

1. no operationally measurable ι_R can be defined;
2. ι_R is gauge-dependent in a way that changes claimed stress-energy;
3. the proposed $T_I^{\mu\nu}$ violates conservation without a measured exchange current Q^ν;
4. the claimed contribution is indistinguishable from carrier-only $T_{\text{car}}^{\mu\nu}$ in every admissible experiment;
5. equivalence-principle, Lorentz-invariance, or gauge constraints are violated;
6. coefficients must be fitted after observing the target effect.

Carrier-level claims remain standard: if a carrier has stress-energy, it gravitates. The independent information-sector claim requires additional operational evidence.

> **Interpretation.** This section states how the strong conjecture can fail. If there is no measurable information density, no conservation law, or no deviation from carrier-only stress-energy, the paper falls back to the conservative carrier claim.

11 Light as the Clean Carrier Example

Let O_{EM} be an electromagnetic field state. A spectral recovery vector may be written

$$V_{\text{recEM}} = (m_{\text{med}}, r_{\text{res}}, f, \lambda, \kappa, \tau_{\text{ord}}, D_{\text{dec}}), \tag{77}$$

where f is frequency and λ is wavelength. The recovered electromagnetic information is

$$I_{\text{rec}}(O_{\text{EM}} \mid V_{\text{recEM}}) = D_{\text{dec}} \circ \kappa \circ \Pi_{(f,\lambda)} \circ S_{(r_{\text{res}},\tau_{\text{ord}})} \circ m_{\text{med,EM}}(O_{\text{EM}}). \tag{78}$$

The same electromagnetic carrier has energy and momentum:

$$E = hf, \qquad p = \frac{E}{c}, \qquad \mathbf{p} = \frac{E}{c}\hat{\mathbf{n}}. \tag{79}$$

For many photons or modes,

$$E_{\text{total}} = \sum_i N_i h f_i, \tag{80}$$

and

$$\mathbf{P}_{\text{tot}} = \sum_i N_i \frac{h f_i}{c}\hat{\mathbf{n}}_i. \tag{81}$$

The effective energy-transport vector is

$$\mathbf{V}_{\text{IE}} = \frac{c^2 \mathbf{P}_{\text{tot}}}{E_{\text{total}}}. \tag{82}$$

For ideal coherent vacuum light,

$$\mathbf{V}_{\text{IE}} = c\hat{\mathbf{n}}. \tag{83}$$

For a medium,

$$\mathbf{V}_{\text{IE}} \approx v_g \hat{\mathbf{n}}, \tag{84}$$

where v_g is group velocity.

The Maxwell action gives the standard electromagnetic stress-energy tensor [6]

$$T^{\mathrm{EM}}_{\mu\nu} = \frac{1}{\mu_0}\left(F_{\mu\alpha}F_{\nu}{}^{\alpha} + \frac{1}{4}g_{\mu\nu}F_{\alpha\beta}F^{\alpha\beta}\right). \tag{85}$$

Thus light carries information because its field state has recoverable structure. It gravitates because the same field state carries stress-energy. The information does not add energy by abstract meaning. It is the recoverable structure of an energy-bearing carrier.

> **Interpretation.** Light is the clean example because the carrier is already familiar. A modulated electromagnetic field can carry a recoverable message, but its gravitational relevance comes from the electromagnetic stress-energy tensor. The message changes the readable structure of the field, not the basic rule by which the field gravitates.

12 Propagation Speed and Recovery Rate

There is no single universal bit-rate for light-speed information. The light cone fixes the propagation speed,

$$v = c \approx 2.998 \times 10^{8}\,\mathrm{m\,s^{-1}}, \tag{86}$$

but the bit-rate is a recovery and channel-capacity question:

$$\frac{dI_{\mathrm{rec}}}{dt} \leq C_R. \tag{87}$$

The capacity C_R depends on bandwidth, modulation, power, photon flux, detector resolution, coupling, decoder, and noise. It is not fixed by c alone.

If a light beam has resolvable bit spacing Δx, then

$$\tau_{\mathrm{bit}} = \frac{\Delta x}{c}, \qquad B = \frac{1}{\tau_{\mathrm{bit}}} = \frac{c}{\Delta x}. \tag{88}$$

Thus $B = c/\Delta x$ becomes meaningful only after a recovery rule has chosen what spatial length of the beam counts as one resolvable bit.

For the green laser example,

$$\lambda = 532\,\mathrm{nm}, \qquad f = \frac{c}{\lambda} = 5.64 \times 10^{14}\,\mathrm{s^{-1}}. \tag{89}$$

A one-bit-per-optical-cycle scale would therefore be

$$B_{\mathrm{cycle}} \approx 5.64 \times 10^{14}\,\mathrm{bits\,s^{-1}}, \tag{90}$$

but this is a carrier-cycle scale, not an automatic communication capacity. The same example has photon flux

$$\dot{N} = 2.68 \times 10^{15}\,\mathrm{s^{-1}}, \tag{91}$$

so a one-bit-per-photon scale would be

$$B_{\gamma} \approx 2.68 \times 10^{15}\,\mathrm{bits\,s^{-1}}, \tag{92}$$

but one photon is not automatically one reliably recoverable bit.

The worked modulation example instead chooses

$$B_{\mathrm{mod}} = 1.0 \times 10^{6}\,\mathrm{bits\,s^{-1}}, \tag{93}$$

so each bit slot occupies

$$\ell_{\mathrm{bit}} = \frac{c}{B_{\mathrm{mod}}} = 3.00 \times 10^{2}\,\mathrm{m} \tag{94}$$

of the beam and contains 2.68×10^{9} photons per bit slot.

Chosen bit-rate	Beam length per bit	Status
$1\,\mathrm{bit\,s^{-1}}$	$3.00 \times 10^{8}\,\mathrm{m}$	recovery choice
$1.0 \times 10^{6}\,\mathrm{bits\,s^{-1}}$	$3.00 \times 10^{2}\,\mathrm{m}$	worked modulation example
c/λ for 532 nm	$5.32 \times 10^{-7}\,\mathrm{m}$	carrier-cycle scale

The safe distinction is

$$\text{light speed sets transport velocity,} \qquad \text{channel capacity sets bit-rate.} \tag{95}$$

Equivalently,

$$B \neq c, \qquad B = \frac{c}{\Delta x} \quad \text{only after a resolvable bit spacing is chosen.} \tag{96}$$

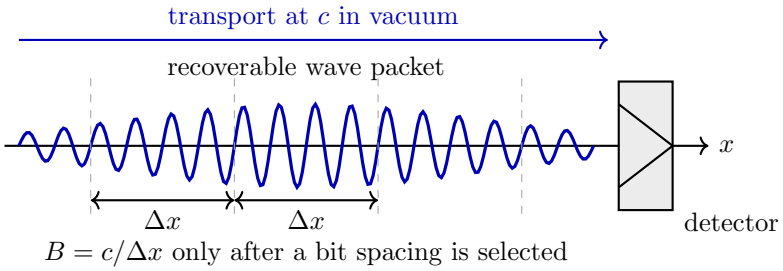

Figure 2: Propagation speed and recoverable bit-rate are distinct. The wave packet moves at the carrier transport speed, while the bit-rate appears only after the recovery process resolves a spatial slot Δx.

> **Interpretation.** There is no universal light-speed bit-rate because speed and capacity are different objects. The carrier may propagate at c in vacuum, but recoverable bits per second require a recovery rule, a detector, a bandwidth, a noise floor, and a decoder.

13 Material Recovery Channels

In a material channel, the recoverable disturbance propagates with group velocity

$$v_g = \frac{c}{n_g}, \tag{97}$$

or, for an electrical transmission line,

$$v_g = \frac{1}{\sqrt{L'C'}}, \tag{98}$$

where L' and C' are inductance and capacitance per unit length. The material changes the transport velocity, attenuation, dispersion, and coupling. It does not by itself determine the bit-rate.

A material recovery vector may be written

$$V_{\mathrm{recmat}} = (m_{\mathrm{med}}, r_{\mathrm{res}}, \nu_{\mathrm{samp}}, \kappa_{\mathrm{mat}}, \delta, \tau_{\mathrm{ord}}, D_{\mathrm{dec}}, L, \alpha_{\mathrm{mat}}, N), \tag{99}$$

where L is channel length, α_{mat} is material attenuation, and N is the noise model. For exponential attenuation,

$$P_{\mathrm{rx}} = P_{\mathrm{tx}} e^{-\alpha_{\mathrm{mat}} L}. \tag{100}$$

For attenuation a_{dB} in decibels per unit length,

$$P_{\mathrm{rx}} = P_{\mathrm{tx}} 10^{-a_{\mathrm{dB}} L/10}. \tag{101}$$

A standard recovery-capacity estimate is

$$C_{R,\mathrm{mat}} = \Delta f \log_2(1 + \mathrm{SNR}), \qquad \mathrm{SNR} = \frac{P_{\mathrm{rx}}}{P_{\mathrm{noise}}}. \tag{102}$$

An engineered bit-rate must therefore satisfy

$$B_{\mathrm{real}} \leq C_{R,\mathrm{mat}}. \tag{103}$$

The spatial length of each recoverable bit in the material is

$$\ell_{\mathrm{bit}} = \frac{v_g}{B_{\mathrm{real}}}. \tag{104}$$

13.1 Vinyl groove as an audio recovery channel

A vinyl record is an analogue material recovery channel. The object is not intrinsically digital. Its effective audio-information rate is bounded by the recoverable bandwidth and signal-to-noise ratio of the groove, stylus, cartridge, phono preamplifier, equalisation, and decoder:

$$I_{\mathrm{rec}}(t_{\mathrm{obs}} \mid V_{\mathrm{recvinyl}}) \leq C_{\mathrm{vinyl}} t_{\mathrm{obs}}. \tag{105}$$

For a mono analogue audio channel,

$$C_{\mathrm{mono}} = W \log_2(1 + \mathrm{SNR}), \tag{106}$$

and for a two-channel stereo estimate,

$$C_{\mathrm{stereo}} \approx 2W \log_2(1 + \mathrm{SNR}). \tag{107}$$

Using a clean illustrative bandwidth and noise assumption,

$$W = 2.0 \times 10^4\,\mathrm{Hz}, \qquad \mathrm{SNR} = 10^{60/10} = 10^6, \tag{108}$$

one obtains

$$C_{\mathrm{mono}} = 2.0 \times 10^4 \log_2(1 + 10^6) = 3.99 \times 10^5\,\mathrm{bits\,s^{-1}}, \tag{109}$$

and therefore

$$C_{\mathrm{stereo}} \approx 7.97 \times 10^5\,\mathrm{bits\,s^{-1}}. \tag{110}$$

The equivalent PCM-style check uses

$$N_{\mathrm{eff}} \approx \frac{\mathrm{SNR_{dB}} - 1.76}{6.02} = 9.67 \tag{111}$$

effective bits per sample. With Nyquist sampling $f_s \approx 2W = 4.0 \times 10^4\,\mathrm{s^{-1}}$,

$$B_{\mathrm{PCM}} \approx 2 f_s N_{\mathrm{eff}} = 7.74 \times 10^5\,\mathrm{bits\,s^{-1}}, \tag{112}$$

consistent with the Shannon estimate.

> **Interpretation.** Vinyl has no intrinsic digital bit-rate. The recoverable audio rate is a property of the full recovery vector: groove geometry, stylus contact, cartridge coupling, speed stability, bandwidth, equalisation, decoder, and noise. Under clean audio assumptions, the stereo audio-equivalent channel capacity is of order 0.5 to 1.0 $\mathrm{Mbit\,s^{-1}}$.

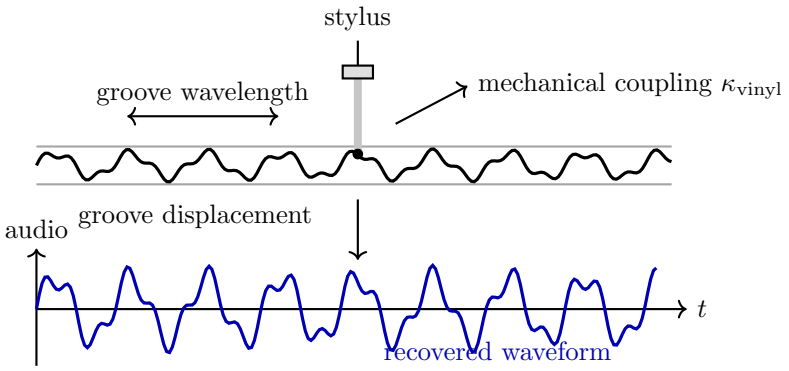

Figure 3: Vinyl recovery is a material contact problem. Groove displacement is not automatically audio until stylus contact, cartridge coupling, equalisation, and decoding recover a waveform.

13.2 Copper wire as a guided electromagnetic channel

Information over copper is not carried by slow electron drift. The recoverable disturbance is a guided electromagnetic field whose group velocity is set by conductor geometry and dielectric environment:

$$v_g = \frac{1}{\sqrt{L'C'}} \approx \frac{c}{\sqrt{\varepsilon_{\text{eff}}}}. \tag{113}$$

For many practical copper channels,

$$0.6c \lesssim v_g \lesssim 0.99c, \tag{114}$$

depending on geometry and dielectric.

Take a representative copper transmission line with

$$v_g = 0.66c = 1.98 \times 10^8\,\text{m}\,\text{s}^{-1}, \qquad L = 100\,\text{m}. \tag{115}$$

The propagation delay is

$$t_{\text{delay}} = \frac{L}{v_g} = 5.05 \times 10^{-7}\,\text{s} = 505\,\text{ns}. \tag{116}$$

For a recoverable bandwidth and noise condition

$$\Delta f = 1.0 \times 10^8\,\text{Hz}, \qquad \text{SNR} = 10^{30/10} = 10^3, \tag{117}$$

the capacity estimate is

$$C_{\text{copper}} = 10^8 \log_2(1 + 10^3) = 9.97 \times 10^8\,\text{bits}\,\text{s}^{-1}. \tag{118}$$

A real engineered rate

$$B_{\text{real}} = 1.0 \times 10^9\,\text{bits}\,\text{s}^{-1} \tag{119}$$

is therefore at the edge of this illustrative capacity estimate. The spatial length of each bit in the guided channel is

$$\ell_{\text{bit}} = \frac{v_g}{B_{\text{real}}} = 0.198\,\text{m}. \tag{120}$$

Interpretation. The material fixes the propagation delay and the receiver-facing degradation of the energy-bearing signal. The maximum recoverable bit-rate is still a recovery-channel quantity: bandwidth, attenuation, impedance matching, coupling, decoder, and noise determine C_{copper}. In the language of this note, copper gives a guided electromagnetic support and a material recovery vector, not a universal informational speed limit.

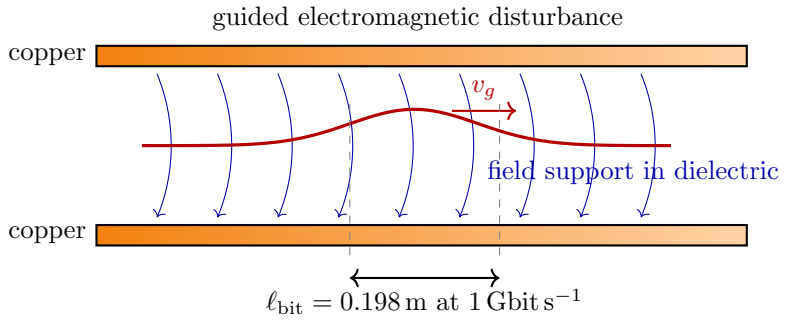

Figure 4: Copper signalling is guided electromagnetic propagation. The conductor geometry and dielectric set v_g; bandwidth and noise set the recoverable bit-rate.

14 Numerical Example: A Green Laser Pointer

Consider a real optical carrier: a green laser pointer with beam power P_{beam}, wavelength λ, beam area A_{beam}, and modulation bandwidth B_{mod}. The carrier quantities are obtained from

$$E_\gamma = \frac{hc}{\lambda}, \qquad \dot{N} = \frac{P_{\mathrm{beam}}}{E_\gamma}, \qquad I_{\mathrm{beam}} = \frac{P_{\mathrm{beam}}}{A_{\mathrm{beam}}}, \tag{121}$$

and, in a travelling plane-wave approximation,

$$u = \frac{I_{\mathrm{beam}}}{c}, \qquad p_{\mathrm{rad}} = \frac{I_{\mathrm{beam}}}{c}, \qquad m_{1\,\mathrm{m}} = \frac{uA_{\mathrm{beam}}L}{c^2}, \quad L = 1\,\mathrm{m}. \tag{122}$$

Quantity	Expression	Value
Beam power	P_{beam}	$1.0 \times 10^{-3}\,\mathrm{W}$
Wavelength	λ	$532\,\mathrm{nm}$
Beam area	A_{beam}	$1.0 \times 10^{-6}\,\mathrm{m^2}$
Modulation bandwidth	B_{mod}	$1.0 \times 10^{6}\,\mathrm{bits\,s^{-1}}$
Photon energy	hc/λ	$3.73 \times 10^{-19}\,\mathrm{J}$
Photon rate	$P_{\mathrm{beam}}/E_\gamma$	$2.68 \times 10^{15}\,\mathrm{s^{-1}}$
Energy per bit slot	$P_{\mathrm{beam}}/B_{\mathrm{mod}}$	$1.0 \times 10^{-9}\,\mathrm{J}$
Photons per bit slot	$P_{\mathrm{beam}}/(B_{\mathrm{mod}}E_\gamma)$	2.68×10^{9}
Intensity	$P_{\mathrm{beam}}/A_{\mathrm{beam}}$	$1.0 \times 10^{3}\,\mathrm{W\,m^{-2}}$
Energy density	I_{beam}/c	$3.34 \times 10^{-6}\,\mathrm{J\,m^{-3}}$
Absorbing-surface pressure	I_{beam}/c	$3.34 \times 10^{-6}\,\mathrm{Pa}$
One metre mass-equivalent	uA_{beam}/c^2	$3.71 \times 10^{-29}\,\mathrm{kg}$

The recoverable message rate is a property of the recovery arrangement:

$$I_{\mathrm{rec}}(t_{\mathrm{obs}} \mid V_{\mathrm{reclaser}}) \leq B_{\mathrm{mod}} t_{\mathrm{obs}}. \tag{123}$$

The optical stress-energy is determined by the carrier power, area, and field state.

This example shows the intended distinction. The recovered information depends on modulation, detector bandwidth, coupling, decoder, and noise. The stress-energy belongs to the electromagnetic carrier. If a detector recovers a message from the beam, that message is not an additional substance floating above the field. It is recoverable structure in an already energy-bearing carrier.

Thus, for the laser pointer,

$$\text{recoverable optical information} \to \text{EM carrier} \to T^{\mathrm{EM}}_{\mu\nu}. \tag{124}$$

The gravitational contribution is tiny, but it is non-zero in principle because the carrier has stress-energy.

Interpretation. The laser example shows the correspondence with real numbers. The bit rate belongs to the recovery arrangement, while the pressure, energy density, and mass-equivalent belong to the optical carrier. They meet because the recovered message is encoded in the same beam that carries energy and momentum.

15 Gamma Conversion Analogy

Gamma light does not become matter merely because it is light. It becomes matter only when sufficient energy, correct interaction channel, conservation of energy-momentum, and boundary or recoil support are present.

Two-photon pair production, the Breit-Wheeler process, may be written [7]

$$\gamma + \gamma \to e^- + e^+, \tag{125}$$

with four-momentum conservation

$$p^\mu_{\gamma 1} + p^\mu_{\gamma 2} = p^\mu_- + p^\mu_+. \tag{126}$$

With the $(-+++)$ signature and a momentum-squared convention,

$$s = -(p_{\gamma 1} + p_{\gamma 2})_\mu (p_{\gamma 1} + p_{\gamma 2})^\mu. \tag{127}$$

The invariant threshold is

$$s \geq 4m_e^2 c^2. \tag{128}$$

Equivalently, for photons with energies E_1, E_2, and collision angle θ,

$$s = \frac{2E_1 E_2}{c^2}(1 - \cos\theta), \tag{129}$$

so a head-on collision has the lowest energy threshold.

Near a nucleus, recoil can supply the missing momentum channel:

$$\gamma + \text{nucleus} \to e^- + e^+ + \text{nucleus}. \tag{130}$$

The photon energy-momentum is not destroyed. It is re-expressed as matter-sector energy-momentum when the interaction closes.

The information analogy is:

$$\text{physical encoding+recovery coupling+energy-momentum support} \to \text{stress-energy contribution}. \tag{131}$$

In both cases, the transition is not automatic. It depends on carrier, support, coupling, conservation, and boundary conditions.

Interpretation. The gamma analogy is conditional. Gamma photons can produce matter only when the interaction closes and conservation laws are satisfied. Likewise, information becomes stress-energy-relevant only when encoding, support, coupling, and energy-momentum support are all present.

16 Observable Limits and Wave History

The observable limit is not the limit of existence:

$$\text{observable universe} \neq \text{whole universe}. \tag{132}$$

The observable limit is better written as

$$\text{observable limit} = \text{horizon} + \text{finite propagation} + \text{finite recovery channel}. \tag{133}$$

The universe should not be described as updating at one global hertz rate. Hertz assumes a periodic cycle counted by a local clock. Light-like propagation is not necessarily a closed cycle. In the RSG language, light-like propagation is closer to

$$\text{non-closing} + \text{norm-preserving} + \text{lossless or near-lossless propagation}. \tag{134}$$

A wave can have local frequency components,

$$E = hf, \tag{135}$$

but the full field history is not one frequency. It is a spectrum, a propagation history, and a boundary-interaction record.

Thus

$$\text{finite recovery} \neq \text{finite generated history}. \tag{136}$$

Hard numerical ceilings should therefore be treated as recovery limits unless an operational existence limit is supplied.

> **Interpretation.** The warning about hertz is not a rejection of frequency. Local waves have frequencies. The point is that a global update rate is the wrong object if the full field history is spectral, propagating, and boundary-dependent. The limit being discussed here is a recovery limit.

17 Conclusion

The statement is:

$$\text{recoverable information is not an extra substance added to energy}. \tag{137}$$

It is the recoverable structure of an energy-bearing carrier.

The rigorous chain is

$$\begin{aligned}\text{generated information} &\to \text{support} \to \text{boundary and closure coupling} \\ &\to \text{recovery} \to \text{physical measure} \to \text{stress-energy}.\end{aligned} \tag{138}$$

The conservative claim is that recoverable information has gravitational relevance through its carrier. The strong conjecture is that a recovered-information density can define its own stress-energy tensor if and only if it is placed inside an action with independently fixed support, coupling, conservation, and failure conditions. This note therefore supplies a conditional correspondence framework, not a completed gravitational theory.

The absence of a universal informational speed limit in this note means that there is no universal bit-rate fixed by c alone. It does not remove the causal propagation bound for physical signals. Propagation velocity belongs to the carrier and medium; recoverable bit-rate belongs to the recovery channel.

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