

THE EPISTEMIC FIELD

A Four-Dimensional Research Program for a Candidate Relational Scalar

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DIFFERENTIATE → RELATE → MEASURE

A0 IS THE PREMISE. THE FIELD IS A HYPOTHESIS. THE EQUATIONS ARE THE TEST.

This edition formulates the candidate I-field directly in observed 3+1-dimensional spacetime. It removes compact dimensions and carries forward only the mathematical results that can be stated and tested without them.

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Abstract

This manuscript consolidates two earlier investigations of the candidate epistemic field into a single four-dimensional research program. The previous higher-dimensional arena is removed: the field is defined directly on observed 3+1-dimensional spacetime, with no compact manifold, compactification radius, higher-dimensional Planck scale, or Kaluza–Klein tower assumed. The central hypothesis is that a real scalar field, $\mathcal{I}(x)$, could provide a covariant dynamical representation of some physically instantiated relational or distinguishability structure. This is a research hypothesis motivated by A0—“ALL IS EPISTEMIC”—not a consequence uniquely entailed by A0 and not an established discovery.

The strongest calculable bridge is a conventional quantum-field model in which $\mathcal{I}$ couples to a probe scalar χ through $-g\mathcal{I}\chi^2$. In four dimensions, the canonical field dimensions are $[\mathcal{I}]=[\chi]=1$ and $[g]=1$. The renormalized χ fluctuations contribute a local first-order term, while integrating out a Gaussian χ field produces a generally bilocal second-order kernel built from connected χ^2 correlations. This is genuine model-level quantum response, but it is not a derivation of mutual information as a fundamental local source.

The integrated paper preserves two tests from the earlier manuscript: an analytic two-mode Gaussian comparison and a finite harmonic-chain calculation. The latter finds a roughly stable mutual-information/correlation-proxy ratio over one restricted separation sweep, but a change from about 0.798 to 298 across the tested mass sweep. The simplest universal conversion rule therefore fails. The result narrows the hypothesis rather than eliminating every possible state-dependent mapping. A four-dimensional cosmological branch and the five-state graviton-qdit hypothesis are discussed as research directions, with the necessary distinctions between established spin-2 kinematics and TOE-specific interpretation kept explicit.

The conclusion is constructive but conditional: the I-field is mathematically modelable and has a plausible route to a testable effective description. Its physical identity, source map, potential, radiative stability, and distinctive observable consequence remain unestablished. The argument for the field is strongest when it is treated as a minimal covariant candidate whose added predictive value must be demonstrated against a scalar-free baseline.

Status at a glance

Status	What this manuscript can responsibly claim
Established framework	Four-dimensional scalar-field variation, canonical mass-dimension bookkeeping, Gaussian-state entropy methods, Wick contractions, and one-loop functional determinants are standard tools.
Derived in specified models	The χ – $\mathcal{I}$ toy interaction gives a renormalized local fluctuation term; its Gaussian effective action yields a connected-correlation kernel at second order.
Numerically tested	In the stated one-dimensional oscillator chain, mutual information and the chosen correlation proxy both decline with separation, while their ratio changes strongly as the mass parameter varies.
Conjectural	The ontological identification of $\mathcal{I}$ with physical relational structure, a fundamental coupling between $\mathcal{I}$ and quantum-state structure, and any unified dark-sector role.
Not established	That A0 uniquely implies a scalar field; that mutual information is a universal local source; that $\mathcal{I}$ exists as a new field in nature; or that it explains dark energy.

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1. The question and the evidential contract

A new field is not established by writing its Lagrangian. A source term is not established by attaching the word “information” to it. A finite numerical result is not proof that the quantity being summed represents a physical state. This manuscript starts by separating a compelling research idea from the claims that have actually been derived.

The central question is deliberately narrow: can a covariant scalar field $\mathcal{J}$ be defined so that it represents a specified aspect of physical relational structure, responds consistently to changes in a quantum state, and produces a quantitative prediction not already captured by conventional scalar-field effective theory? That question can be attacked mathematically. A universal slogan that “information sources the field” cannot.

1.1 The contract

- A0 remains the foundational premise of the broader project; the field model does not prove A0 or derive all of physics from it.
- No additional spatial dimensions are assumed. Every field, integral, and mass dimension in this edition is four-dimensional.
- Quantum correlation functions, entanglement entropy, mutual information, thermodynamic entropy, and energy are distinct quantities. A relation between them must be derived.
- Every proposed interaction requires an action or other precise dynamical rule, consistent units, a renormalization prescription, and a domain of validity.
- A negative result is a result. The model must be allowed to fail without changing the definition after seeing the output.

The status labels used below mean: ESTABLISHED FRAMEWORK for standard mathematical physics; DERIVED HERE for consequences of the displayed model; CONJECTURE for a TOE-specific identification or interaction not forced by the equations; OPEN OBLIGATION for calculations required before a physical claim is warranted.

2. A0 and the strongest case for a relational scalar

A0—ALL IS EPISTEMIC—is used here in a physical, non-anthropocentric sense. “Epistemic” refers to distinguishability, relations among physical states, constraints on possible transitions, and the measurements by which distinctions could in principle be resolved. It does not mean that human beliefs create the universe, that consciousness is required for matter to exist, or that information is a magical substance.

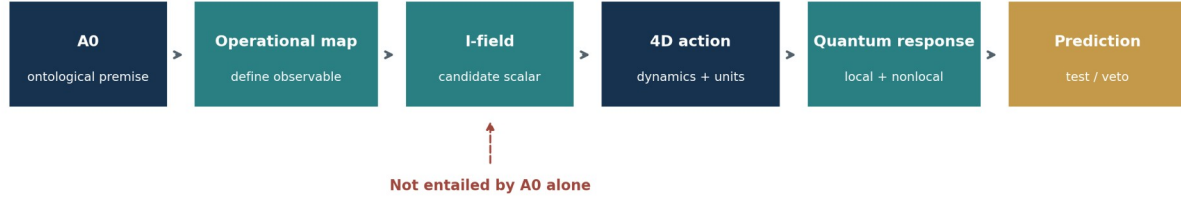
s_1 and s_2 are operationally distinguishable if some allowed measurement M gives different outcome statistics on them. (1)

The strongest rationale for $\mathcal{J}$ is an economy argument. If some aspect of relational structure has a continuous, local, covariant dynamical influence, a scalar is the least elaborate field representation one can test first. It can assign one real degree of freedom to each spacetime point without inserting a preferred direction. Its action, stress-energy, couplings, and perturbations can be written in the language of ordinary effective field theory. That makes the idea calculable and falsifiable.

But this is a selection of a useful ansatz, not a deduction from A0. A0 alone does not imply that relational structure is scalar rather than tensorial, discrete, nonlocal, emergent, or fully encoded in existing fields. The physical meaning of $\mathcal{J}$ must be defined by a map to observables. Otherwise, “epistemic field” is only a new name for an ordinary scalar.

A disciplined candidate chain is therefore: A0 motivates the question; an operational quantity defines what relational structure means; $\mathcal{J}$ is proposed as its covariant dynamical representation; an action generates equations; the equations generate predictions; measurements decide whether the extra field is needed.

THE EPISTEMIC-FIELD ARGUMENT: EACH ARROW IS A DERIVATION OBLIGATION



Correlations may diagnose the response; they are not automatically the source.

A0 remains fixed as the premise. The field, coupling, and prediction remain testable hypotheses.

Figure 1. The proposed inference chain. Each arrow is a separate derivation obligation; A0 does not automatically supply the later steps.

3. Four-dimensional baseline and candidate action

Work in observed 3+1-dimensional spacetime with metric $g_{\mu\nu}$, signature $(-,+,+,+)$, and natural units $\hbar=c=1$. The candidate field is a real scalar $\mathcal{J}(x)$. The minimal action is

$$S\mathcal{J} = \int d^4x \sqrt{(-g)} \left[-\frac{1}{2} g_{\mu\nu} \nabla_\mu \mathcal{J} \nabla_\nu \mathcal{J} - V(\mathcal{J}) + \mathcal{J}_I \mathcal{J} \right] \quad (2)$$

Here $V(\mathcal{J})$ is the potential and $\mathcal{J}_I$ is an externally specified or microscopically derived source. The source is written explicitly to distinguish a source assumption from a consequence of the field's name. The minimal model sets any nonminimal curvature coupling to zero until it is independently motivated.

A possible extension is a nonminimal term $-\frac{1}{2} \xi \mathcal{J}^2 R$. In four dimensions ξ is dimensionless, but adding this term changes the metric equations and the effective gravitational coupling. In the convention used here, the coefficient of R becomes $(M_{\text{Pl}}^2 - \xi \mathcal{J}^2)/2$, so a viable regime must preserve the correct sign of the gravitational kinetic term. This extension is not needed to formulate the baseline scalar and should not be used as a rescue term without an independent reason.

3.1 What would give $\mathcal{J}$ operational meaning?

The required definition should specify a family of physical subsystems or local algebras, a state, a finite spatial or energy resolution, and an invariant rule for calculating distinguishability. In relativistic quantum field theory, the entropy of a sharply defined region is often ultraviolet-sensitive; a coarse-grained or relative-information construction may be better behaved, but the region and regulator are part of the definition. There is no unique universal local “information density” that follows simply from using information-theoretic vocabulary.

One possible research direction is to define a coarse-grained functional $D\ell(x; \rho, \mathcal{A})$ from a state ρ , a specified local algebra $\mathcal{A}$, and resolution scale ℓ , then test whether $\mathcal{J}$ is related to $D\ell$ by a covariant, renormalized map. No such map is asserted here. Its uniqueness, locality, observer dependence, and dynamics are open questions.

4. Field equations, stress-energy, and dimensional audit

4.1 Field equation

Varying the minimal action with respect to $\mathcal{J}$ gives

$$\square \mathcal{J} - V'(\mathcal{J}) + \mathcal{J}_I = 0 \quad (3)$$

This is the equation of motion for the chosen action, not an independently established law of nature. If a source is derived by adding a consistent interaction to the action or by integrating out other fields, its contribution must appear with the same convention in the effective field equation.

4.2 Stress-energy and conservation

For the minimally coupled scalar, metric variation gives

$$T(\mathcal{J})_{\mu\nu} = \nabla_{\mu} \nabla_{\nu} \mathcal{J} - g_{\mu\nu} [\frac{1}{2}(\nabla \mathcal{J})^2 + V(\mathcal{J})] \quad (4)$$

On the equations of motion, the divergence of the scalar stress-energy is balanced by the source and by energy exchange with the sectors that generate that source. Once interactions are included, the conserved quantity is the total stress-energy of the coupled system. An effective loop correction cannot be counted once as an explicit χ contribution and again as an independent reservoir without a consistent accounting scheme.

4.3 Four-dimensional mass dimensions

The action is dimensionless in natural units, so $[d^4x]=-4$ and $[\mathcal{L}]=4$. The kinetic term fixes the canonical scalar dimension:

$$2 + 2[\mathcal{J}] = 4 \Rightarrow [\mathcal{J}] = [\chi] = 1 \quad (5)$$

For the interaction $-g\mathcal{J}\chi^2$, the operator $\mathcal{J}\chi^2$ has dimension three, and therefore $[g]=1$. This replaces—not merely relabels—the earlier higher-dimensional bookkeeping. No exponent involving an internal radius survives into this model.

Quantity	Mass dimension	Reason
Spacetime coordinate x_{μ}	-1	$[\partial_{\mu}]=+1$
$\mathcal{L}$ and $V(\mathcal{J})$	4	Action density in 4D
$\mathcal{J}, \chi$	1	Canonical scalar kinetic term
m_{χ}, μ_I	1	Mass parameters
J_I in $J_I \mathcal{J}$	3	$[J_I]+[\mathcal{J}]=4$
g in $g\mathcal{J}\chi^2$	1	$4 - [\mathcal{J}] - 2[\chi] = 1$
ξ in $\xi \mathcal{J}^2 R$	0	$[\mathcal{J}^2 R]=2+2=4$
λ_4 in $\lambda_4 \mathcal{J}^4/4!$	0	Renormalizable quartic coefficient

A polynomial potential may be organized as $V(\mathcal{J})=V_0+\frac{1}{2}\mu_I^2 \mathcal{J}^2+\lambda_3 \mathcal{J}^3/3!+\lambda_4 \mathcal{J}^4/4!+\dots$. Here $[V_0]=4$, $[\mu_I]=1$, $[\lambda_3]=1$, and $[\lambda_4]=0$. Coefficients of higher operators carry the compensating negative dimensions and signal an effective-field-theory expansion. Dimensional consistency is necessary; it does not establish the field's existence or naturalness.

5. Microscopic quantum response: local tadpole and bilocal kernel

The simplest calculable bridge introduces a real probe field χ . It is a generic quantum degree of freedom, not an identified Standard Model particle. Take

$$\mathcal{L}_{\chi} = -\frac{1}{2}(\nabla \chi)^2 - \frac{1}{2}m_{\chi}^2 \chi^2 - g\mathcal{J}\chi^2 \quad (6)$$

This interaction shifts the probe's quadratic operator. In a simple flat background, a necessary local stability condition is that the effective quadratic mass squared remain positive, $m_{\chi, \text{eff}}^2 = m_{\chi}^2 + 2g\mathcal{J}$, for this normalization. In curved spacetime the full operator, boundaries, state, and interactions determine stability; a local mass inequality alone is not sufficient.

5.1 Semiclassical response equation

Taking the quantum expectation value of χ^2 and using the same interaction convention yields

$$\square \mathcal{J} - V'(\mathcal{J}) + \int \mathcal{I} - g \langle \chi^2 \rangle_{\text{ren}} = 0 \quad (7)$$

The renormalization label is essential. Coincident composite operators such as χ^2 are generally ultraviolet-sensitive. Their finite definition requires a regulator, counterterms, renormalization conditions, a background, and a specified quantum state. The equation provides a legitimate source mechanism inside the toy model. It does not identify that source with mutual information.

5.2 Integrating out a Gaussian χ field

In Euclidean signature, write $A_0 = -\nabla^2 E + m\chi^2$ and $G_0 = A_0^{-1}$. Since the interaction changes the quadratic operator to $A_0 + 2g\mathcal{J}$, the one-loop contribution is formally

$$\Gamma_{E,1}[\mathcal{J}] = \frac{1}{2} \text{Tr} \ln(A_0 + 2g\mathcal{J}) \quad (8)$$

Expanding the logarithm to second order in $g\mathcal{J}$ gives

$$\Gamma_{E,1} = \text{constant} + g \text{Tr}(G_0 \mathcal{J}) - g^2 \text{Tr}(G_0 \mathcal{J} G_0 \mathcal{J}) + O(g^3) \quad (9)$$

In coordinate space, the first nonconstant term is local in $\mathcal{J}$, up to its renormalization:

$$\Delta \Gamma_E(1) = g \int d^4x \mathcal{J}(x) G_0(x,x) \quad (10)$$

The second-order term contains a bilocal response:

$$\Delta \Gamma_E(2) = -g^2 \int d^4x d^4y \mathcal{J}(x) G_0(x,y)^2 \mathcal{J}(y) \quad (11)$$

For a free Gaussian field, Wick's theorem gives $\langle \chi^2(x) \chi^2(y) \rangle_c = 2G_0(x,y)^2$, so equivalently

$$\Delta \Gamma_E(2) = -(g^2/2) \int d^4x d^4y \mathcal{J}(x) \langle \chi^2(x) \chi^2(y) \rangle_c \mathcal{J}(y) \quad (12)$$

This is the strongest model-level argument for a correlation-sensitive I-field response in the present manuscript. It is not just a verbal analogy: a stated interaction produces a definite connected-correlation kernel in the effective action. It remains conditional on the toy action, Gaussian integration, and a proper renormalization prescription. At long wavelengths, if a mass gap exists, a derivative expansion may approximate the kernel by local operators. That approximation must be checked against the masses, momenta, curvature scales, and cutoff.

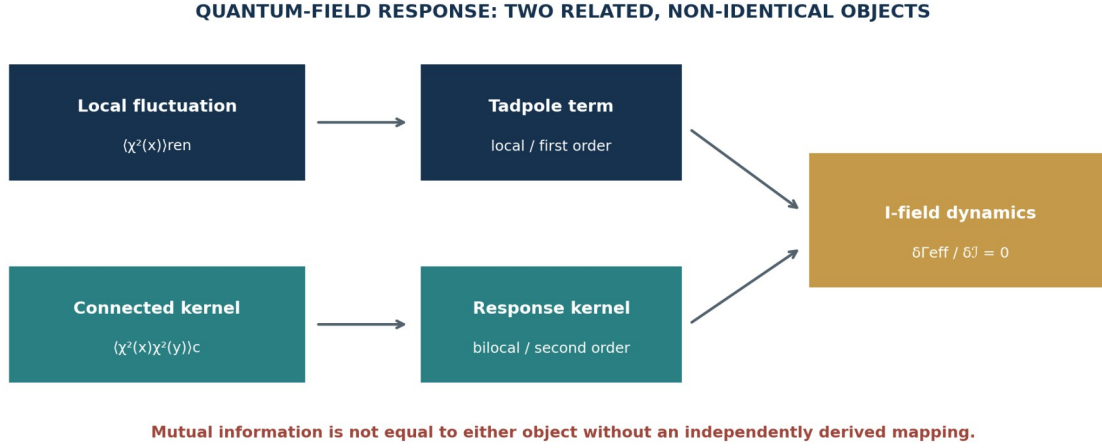


Figure 2. The first-order local fluctuation and second-order bilocal connected kernel are distinct objects. Mutual information is not automatically equal to either.

5.3 State-dependent static response

For an illustrative homogeneous, static mean-field limit, let $V(J) = \frac{1}{2}\mu_- I^2 J^2$ and treat $G = \langle \chi^2 \rangle_{\text{ren}}$ as a prescribed constant. Minimizing the effective potential $\frac{1}{2}\mu_- I^2 J^2 + gJG$ gives

$$J^* = -gG / \mu_- I^2 \quad (13)$$

For two matched states on the same background, and the same renormalization prescription, the shift is

$$\Delta J^* = -g \Delta G / \mu_- I^2 \quad (14)$$

The dimensions close: $[g] + [\Delta G] - [\mu_- I^2] = 1 + 2 - 2 = 1$. If the reference source is zero, the induced potential-density shift at the minimum is $-g^2(\Delta G)^2 / (2\mu_- I^2)$. For a nonzero reference source G_0 , however, the difference is proportional to $G_1^2 - G_0^2$, not just $(G_1 - G_0)^2$. These are conditional stationary relations, not universal identities for arbitrary states or spacetime-dependent field profiles.

6. Correlation is not information: the locality problem

Quantum mutual information for subsystems A and B is

$$I(A:B) = S(\rho_A) + S(\rho_B) - S(\rho_{AB}), \quad S(\rho) = -\text{Tr}(\rho \ln \rho) \quad (15)$$

It quantifies total correlations between the chosen subsystems. It is not exclusively a measure of quantum entanglement, and it is not automatically a local density. Its value depends on the subsystem definition, the joint state, and the measurement algebra. In continuum field theory, regional entropies can be ultraviolet-divergent; regulators or suitably separated-region constructions can help, but do not eliminate the need to specify geometry and state. [1–3]

The first-order χ contribution is proportional to the renormalized local fluctuation $\langle \chi^2(x) \rangle_{\text{ren}}$. Local fluctuations can be present even when two independently prepared regions have zero mutual information. Therefore, in general,

$$\langle \chi^2(x) \rangle_{\text{ren}} \neq I(A:B) \quad (16)$$

At second order the effective action contains a connected two-point kernel, which is more directly related to correlations than the local tadpole is. Even then, the kernel is not identical to mutual information: it is a specific correlation function with its own dimensions, spectral properties, and renormalization behavior. The strongest defensible claim is that mutual information can diagnose aspects of a state while the effective action determines the response. A local or nonlocal mapping from one to the other must be independently derived.

Information–energy guardrail: Landauer’s bound, $E \geq k_B T \ln 2$ per bit of ideal irreversible erasure, concerns the minimum thermodynamic cost of that operation at temperature T ; it does not say that a stored bit contains $k_B T \ln 2$ of extractable energy. Likewise, an entropy-equivalent bit count is not a count of addressable qubits. Any claim that $\mathcal{I}$ contributes physical energy must come from its normalized action and stress-energy—not from multiplying an information count by Landauer’s bound. [7]

6.1 What a legitimate mapping must specify

- Which physical regions or local algebras are being compared, and at what resolution?
- Which quantum state and background geometry define the density matrices and correlation functions?
- How does the proposed functional transform under coordinate changes and changes in the observer’s slicing?
- How are overlapping regions, vacuum terms, regulator dependence, and counterterms handled?
- What quantitative law maps the information diagnostic to a source in $\delta\Gamma_{\text{eff}}/\delta\mathcal{I}$, and what result would falsify it?

7. Analytic test: two Gaussian modes

A controlled finite example asks whether mutual information and a connected correlation proxy can be related. Consider two Gaussian oscillator modes with covariance matrix

$$V = [[a, 0, c, 0], [0, a, 0, -c], [c, 0, a, 0], [0, -c, 0, a]], \quad a > \frac{1}{2}, \quad a^2 - c^2 \geq \frac{1}{4} \quad (17)$$

The two local symplectic eigenvalues equal a ; the joint symplectic eigenvalues are both $v = \sqrt{a^2 - c^2}$. Define, in nats,

$$h(v) = (v + \frac{1}{2}) \ln(v + \frac{1}{2}) - (v - \frac{1}{2}) \ln(v - \frac{1}{2}) \quad (18)$$

The exact mutual information is

$$I(A:B) = 2[h(a) - h(\sqrt{a^2 - c^2})] \quad (19)$$

For weak correlations $|c| \ll a$, expand $\sqrt{a^2 - c^2} \approx a - c^2/(2a)$. To leading order,

$$I(A:B) \approx (c^2/a) \ln[(a + \frac{1}{2})/(a - \frac{1}{2})] \quad (20)$$

For the same Gaussian state, Wick’s theorem gives the connected squared-quadrature correlation $\langle qA^2 qB^2 \rangle_c = 2c^2$. Therefore

$$\langle qA^2 qB^2 \rangle_c \approx 2a I(A:B) / \ln[(a + \frac{1}{2})/(a - \frac{1}{2})] \quad (21)$$

This is a valid weak-correlation relation for the selected Gaussian family. The conversion factor depends on the local variance a . The result supports a controlled, state-specific relationship, not a universal identification of information with correlation. A continuum field introduces additional region, regulator, locality, and covariance questions.

8. Numerical test: a finite harmonic chain

The second test replaces the two chosen modes with a coupled free Gaussian field model discretized as a one-dimensional chain of N harmonic oscillators. The Hamiltonian is

$$H = \frac{1}{2} \sum_j [p_j^2 + m^2 q_j^2] + \frac{1}{2} \sum_j (q_{j+1} - q_j)^2 \quad (22)$$

The sites use open boundaries and $[q_i, p_j] = i\delta_{ij}$. The potential matrix K has diagonal entries $m^2 + \deg(j)$, where $\deg(j)=1$ at an endpoint and 2 in the interior, and nearest-neighbor entries -1 . If $K=U \text{diag}(\omega_k^2)U^T$, the ground-state covariance matrices are

$$X = \frac{1}{2} K^{-1/2}, \quad P = \frac{1}{2} K^{1/2} \quad (23)$$

For any region R , the positive square roots of the eigenvalues of $X_{RP}R$ give its symplectic eigenvalues v_k , and its entropy is $S(R) = \sum_k h(v_k)$. The mutual information between A and B is $S(A) + S(B) - S(A \cup B)$. The correlation proxy was defined as

$$K_{\text{corr}}(A, B) = 2 \sum_{i \in A} \sum_{j \in B} X_{ij}^2 \quad (24)$$

By Wick's theorem this proxy sums the connected equal-time correlations $\langle q_i^2 q_j^2 \rangle_c$ for this zero-mean Gaussian ground state. It is a deliberately limited diagnostic—not the full spacetime kernel in the effective action, and not a dimensionless fundamental constant.

8.1 Separation sweep

With $N=48$, $m=0.5$, $A=\{8,9\}$, and B moved from $\{12,13\}$ to $\{22,23\}$, both quantities fell sharply with separation. The ratio $I(A:B)/K_{\text{corr}}$ drifted slowly from 3.4590 to 3.6406. Over this selected window, the ratio looks nearly constant. That appearance alone could tempt one to infer a proportionality law.

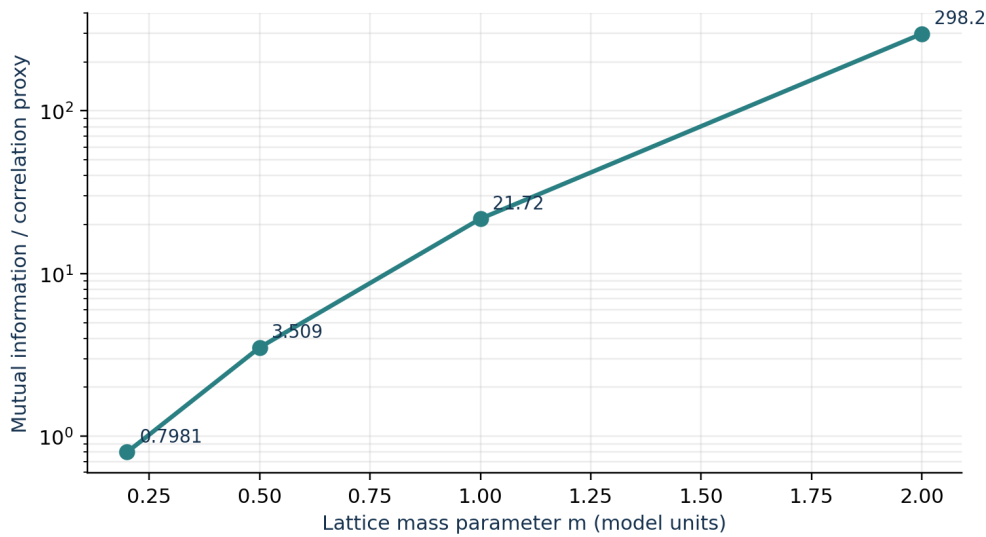
Empty sites between regions	Region B	$I(A:B)$, nats	K_{corr}	I/K_{corr}
2	12–13	0.0130882	0.00378383	3.4590
4	14–15	0.00120744	0.000344092	3.5091
6	16–17	0.000126742	3.55143×10^{-5}	3.5688
8	18–19	1.41252×10^{-5}	3.9189×10^{-6}	3.6044
10	20–21	1.63475×10^{-6}	4.50818×10^{-7}	3.6262
12	22–23	1.94261×10^{-7}	5.33597×10^{-8}	3.6406

8.2 Mass sweep: the decisive adversarial test

Hold $N=32$, $A=\{8,9\}$, and $B=\{14,15\}$; vary the lattice mass parameter. The ratio changes by more than two orders of magnitude, from approximately 0.798 at $m=0.2$ to 298 at $m=2.0$. The simplest constant-factor law $I(A:B)=C K_{\text{corr}}$ cannot survive this sweep.

Mass m	$I(A:B)$, nats	K_{corr}	I/K_{corr}
0.2	0.01818489	0.02278594	0.7981
0.5	0.001207441	0.0003440919	3.509
1.0	2.41816×10^{-5}	1.113417×10^{-6}	21.72
2.0	3.695835×10^{-8}	1.239444×10^{-10}	298.2

The proposed universal conversion factor fails the mass sweep



Zero-temperature Gaussian chain; $N = 32$; regions $A = \{8,9\}$, $B = \{14,15\}$. Values are dimensionless/model-unit outputs.

Figure 3. Ratio of mutual information to the chosen correlation proxy across the mass sweep. The changing ratio defeats a universal conversion constant for this family of states and regions.

8.3 Finite-size check and boundaries

At $m=0.5$ with $A=\{8,9\}$ and $B=\{14,15\}$, $N=16$ shows a noticeable boundary effect. The values at $N=24, 32$, and 48 converge to the displayed precision for this selected setup. This is a finite-box convergence check, not a continuum limit: the lattice spacing was not varied while physical distances and masses were held fixed.

Sites N	$I(A:B)$, nats	K_{corr}	I/K_{corr}
16	0.0016468853	0.00056946956	2.89196
24	0.0012074935	0.0003441321	3.50881
32	0.0012074412	0.00034409185	3.50907
48	0.0012074412	0.00034409184	3.50907

The negative result is useful and narrow. It rules out the simplest universal conversion between mutual information and this squared-correlation proxy in the tested model; it does not rule out all state-dependent functionals, all local algebras, or all microscopic couplings. Nor does a one-dimensional free chain demonstrate dynamics in a full 3+1D interacting theory.

9. The five-state graviton qdit and the I-field

The new 3+1D baseline keeps the graviton-qdit hypothesis available without using compactification. This does not make the qdit established physics; it clarifies what a consistent interface would require.

9.1 The five states are not five spatial dimensions

In four-dimensional spacetime, a conventional massless spin-2 field has two radiative helicities, $+2$ and -2 . A massive spin-2 representation has five physical polarization states, conventionally labeled $m \in \{-2, -1, 0, +1, +2\}$. This supplies a natural five-element basis for a candidate qdit, but it does not show that every graviton is massive or that the qdit is a measured property of nature.

For a five-level complex Hilbert space, the full linear operator space has complex dimension 25. Hermitian operators form a 25-dimensional real vector space: one identity operator plus 24 independent traceless Hermitian

generators. This algebraic “24” is a property of a five-level register; it is not evidence for 24 additional spatial coordinates and does not automatically imply 24 new propagating fields or an SU(5) grand-unified gauge theory.

$$\rho g = I_5/5 + \Sigma A_{=1}^{24} r_A T_A, \quad \text{Tr}(T_A T_B) = \frac{1}{2} \delta_{AB} \quad (25)$$

The expansion is a state representation; positivity constrains the coefficients r_A . To make it dynamical, the theory must specify which operators are observable, how they transform under spacetime and gauge symmetries, and what Hamiltonian or covariant action governs them.

9.2 What this means for $\mathcal{J}$

A 3+1D epistemic field could in principle respond to scalar invariants of a gravitational or quantum state sector. But “the qdit is entangled” is not yet a source term. A valid coupling would require an explicitly defined covariant scalar operator $\mathcal{O}g$, a term such as $-g\mathcal{O}\mathcal{J}\mathcal{O}g$ with dimensions and symmetry properties fixed, and a derivation showing how that operator is generated or measured. For example, if $[\mathcal{O}g]=d$, then the coefficient multiplying $\mathcal{J}\mathcal{O}g$ must have mass dimension $3-d$ in four dimensions. The operator’s renormalization and its backreaction must then be calculated.

Today’s massive-spin-2 investigation is adjacent rather than a proof of the I-field. A massive spin-2 model requires a consistent helicity-zero sector, acceptable nonlinear completion, and appropriate screening or constraints where needed. dRGT massive gravity and Vainshtein screening provide established benchmarks, but a five-state qdit interpretation is new only if it yields a clear derived result beyond that benchmark. The same standard applies to $\mathcal{J}$.

The massless/massive distinction is a hard boundary condition: any model claiming the observed long-range graviton as its infrared limit must recover the two-helicity behavior and known gravitational tests. A proposed five-state internal register may contain additional abstract states, but the physical map from those states to propagating modes must be shown. The I-field cannot be used to paper over a failure of the gravitational sector.

10. A cosmological branch: a possible role, not a solution

A four-dimensional scalar with a suitable potential can behave like a dark-energy component. This makes the I-field cosmologically interesting, but not automatically cosmologically successful. For a minimally coupled homogeneous field in a spatially flat FLRW background,

$$\rho_{\mathcal{J}} = \frac{1}{2}\dot{\mathcal{J}}^2 + V(\mathcal{J}), \quad p_{\mathcal{J}} = \frac{1}{2}\dot{\mathcal{J}}^2 - V(\mathcal{J}) \quad (26)$$

$$w_{\mathcal{J}} = p_{\mathcal{J}}/\rho_{\mathcal{J}} = (\frac{1}{2}\dot{\mathcal{J}}^2 - V)/(\frac{1}{2}\dot{\mathcal{J}}^2 + V) \quad (27)$$

If potential energy dominates kinetic energy for a sufficiently long interval, $w_{\mathcal{J}}$ can approach -1 . The homogeneous field equation, in the convention with source J_{I} , is

$$\mathcal{J} + 3H\mathcal{J} + V'(\mathcal{J}) = J_{\text{I}} \quad (28)$$

This is a plausible branch to test, not a solution to the cosmological-constant problem. The model still owes the small observed vacuum-energy scale, radiative stability, initial conditions, a sufficiently long-lived near-stationary regime, and compatibility with structure formation and expansion data. If the χ sector exchanges energy with $\mathcal{J}$, the source and the matter-sector collision term must be derived from the same covariant interaction; the total energy exchange must cancel in the full conservation law.

Do not double count $V(\mathcal{J})$ as both the field’s potential energy and a separate cosmological constant. A model should choose its convention, solve the coupled equations, and fit one shared parameter set to independent data. If the scalar-free model explains the observations equally well with fewer unconstrained assumptions, the I-field has not yet earned a new physical role.

11. What the old higher-dimensional scaffolding contributed—and what is removed

The earlier research note was useful as a formal exercise: it forced explicit actions, mass-dimension checks, source terms, fluctuation operators, and a list of ways the hypothesis could fail. Those methodological lessons remain. Its higher-dimensional equations, however, depended on a stipulated 28D arena, a 24D compact internal manifold, a particular flux, a radion, and a compact-mode spectrum. Those assumptions are not derived from A0 and are not needed for the four-dimensional model developed here.

Earlier construct	Disposition in this edition
28D scalar normalization $[J]=13$	Removed. The canonical 4D scalar has $[J]=1$.
Coupling dimension $[q]=-11$ for $qJ\chi^2$	Removed. In 4D, the coefficient of $-gJ\chi^2$ has $[g]=+1$.
Compact manifold K_{24} , radius, flux and radion	Removed from the model; no radius or flux prediction is retained.
Kaluza–Klein tower from compactification	Removed as an assumed source of massive gravitational modes. Any 4D massive state must be derived independently.
Gaussian-state comparison and χ effective action	Retained and re-audited with 4D dimensions and explicitly stated model assumptions.
Finite oscillator-chain tests	Retained as narrow toy-model diagnostics, not as evidence of a fundamental I-field.
“Information” as a direct universal source	Rejected as un-derived. Mutual information remains a diagnostic until a covariant mapping is established.

This is a substantive change of model, not a cosmetic edit. The former compactification calculations may remain mathematically conditional statements about their original ansatz, but they are not evidence for this 4D model. No extra spatial dimension is introduced to rescue a failed result. If a later consistency calculation genuinely requires new structure, it must identify the exact obstruction and demonstrate why the proposed extension resolves it.

12. Falsification program and next calculations

The strongest next step is not to enlarge the ontology. It is to force the present model to make a precise claim that can fail. The following sequence is the proposed decision program.

Stage	Calculation required	Failure signal
1. Operational definition	Define a covariant, finite-resolution relational/distinguishability functional and the subsystems or local algebras it uses.	No observer-independent or reproducible definition; output depends on arbitrary region choices.
2. Quantum response	Compute $\delta\Gamma_{\text{eff}}/\delta J$, including the renormalized local term and nonlocal kernel for the same state.	The claimed source cannot be recovered from the underlying action, or changes under allowed scheme changes without compensation.
3. Correlation mapping	Compare the kernel with information measures over independent states, masses, temperatures, geometries and separations.	Only arbitrary retuning produces the desired mapping; simple universality is already disfavored by the mass sweep.
4. Renormalization and EFT	State counterterms, cutoff, operator dimensions, mass hierarchy and validity regime; check higher-order corrections.	Uncontrolled UV sensitivity or no regime where the truncation is valid.
5. Stability	Calculate the quadratic fluctuation operator around candidate backgrounds; check kinetic signs, tachyons and gradient stability.	Ghostlike kinetic term, runaway instability, or no stable background in the claimed regime.
6. Gravitational consistency	Vary the full coupled action; verify total stress-energy conservation and recover the GR limit.	Energy double counting, broken conservation, or disagreement with established gravitational behavior.
7. Cosmology	Solve the background and perturbation equations with initial conditions and one shared parameter set.	Wrong expansion history, clustering, lensing, or excessive fifth-force effects.
8. Distinct prediction	Calculate at least one observable deviation before fitting data; compare with the scalar-free baseline.	No independent observable difference, or the prediction is excluded.
9. Numerical robustness	Refine the lattice spacing at fixed physical lengths and masses, enlarge the volume, vary temperature, and extend to a suitable 3D	No continuum/volume convergence or a relation that collapses outside the original toy setup.

Stage	Calculation required	Failure signal
	spatial lattice.	

12.1 The decisive comparison

The fair test is not “can the I-field model fit some data?” Flexible scalar theories can fit a wide range of behavior. The test is whether the model, with its parameters fixed or constrained independently, predicts something the standard model without $\mathcal{I}$ does not, and does so without adding a matching collection of new arbitrary functions. Compare predictions, uncertainties, parameter counts, and null results. A zero deviation within experimental error is evidence against the proposed extra effect in that parameter regime.

13. Conclusion: the strongest defensible case

The strongest argument for the I-field is methodological and physical, not rhetorical. A0 motivates the search for a description in which physical distinctions and relations are fundamental. A scalar field is a minimal covariant candidate for representing one continuous local degree of relational structure. Standard field theory gives it a consistent starting action. A specified coupling to a quantum probe produces a renormalized local response and, at second order, a nonlocal kernel built from connected correlations. These are calculable structures that can be tested in controlled models.

The two Gaussian tests sharpen the program. The analytic two-mode example shows that mutual information and a particular connected correlation are related in a state-dependent way. The finite-chain calculation finds a near-constant ratio over a narrow distance sweep but a dramatic change across mass, defeating the simplest universal proportionality. That is not a defeat of every possible information-related mechanism; it is a precise constraint on what the next model may claim.

The limitations are equally clear. A0 does not uniquely imply a scalar field; the physical observable represented by $\mathcal{I}$ is not yet defined; the χ interaction is a toy coupling rather than a discovered interaction; the kernel is not mutual information; the cosmological branch has not solved the vacuum-energy problem; and the graviton-qdit connection remains a separate conjecture that must recover established spin-2 physics. There is no verified new force, energy reservoir, dark-energy explanation, or observational signature in this manuscript.

The verdict is therefore positive about the research direction and restrained about the physical claim: the I-field is a mathematically modelable candidate with a legitimate route to quantum response, but its existence and necessity have not been established. Its case becomes strong only when a covariant operational definition, a renormalized coupling, a stable solution, and a distinctive quantitative prediction all emerge from the same theory.

A0 IS THE PREMISE. THE MODEL IS THE TEST. REALITY HAS VETO POWER.

Appendix A. Derivations and dimensional checks

A.1 Canonical dimension

In natural units the action S is dimensionless. Because $[d^4x]=-4$, the Lagrangian density has $[\mathcal{L}]=4$. The canonical kinetic term gives $[\partial\mathcal{I}\partial\mathcal{I}]=2+2[\mathcal{I}]=4$, hence $[\mathcal{I}]=1$. The probe χ has the same canonical dimension. The operator $\mathcal{I}\chi^2$ therefore has dimension 3, requiring $[g]=1$ in $-g\mathcal{I}\chi^2$.

A.2 Variation of the scalar action

For the coupled Lagrangian

$$\mathcal{L} = -\frac{1}{2}(\partial\mathcal{I})^2 - V(\mathcal{I}) + \int \mathcal{I} \mathcal{J} - g\mathcal{I}\chi^2$$

the Euler-Lagrange equation is

$$\square J - V'(J) + J I - g\chi^2 = 0$$

Replacing χ^2 by its renormalized expectation value produces the semiclassical equation in Section 5. If a nonminimal term $-\frac{1}{2}\xi J^2 R$ is included, the field equation gains $-\xi R J$; the matching metric-variation terms must also be retained.

A.3 Expansion of the Euclidean determinant

Let the unperturbed quadratic operator and its Green function be

$$A_0 = -\nabla^2 E + m\chi^2, \quad G_0 = A_0^{-1}$$

The Euclidean one-loop action is

$$\Gamma E = \frac{1}{2} \text{Tr} \ln(A_0 + 2gJ) = \text{constant} + \frac{1}{2} \text{Tr} \ln(1 + 2gG_0J)$$

Using the standard trace-log expansion

$$\text{Tr} \ln(1+Z) = \text{Tr} Z - \frac{1}{2} \text{Tr} Z^2 + \frac{1}{3} \text{Tr} Z^3 - \dots$$

the first two nonconstant terms become

$$\Delta \Gamma E(1) = g \text{Tr}(G_0 J), \quad \Delta \Gamma E(2) = -g^2 \text{Tr}(G_0 J G_0 J)$$

In coordinate space, the quadratic contribution is

$$\Delta \Gamma E(2) = -g^2 \int d^4x d^4y J(x) G_0(x,y) G_0(y,x) J(y)$$

For a free Gaussian field, Wick's theorem gives $\langle \chi^2(x) \chi^2(y) \rangle_c = 2G_0(x,y)G_0(y,x)$, which yields the connected-kernel form in Equation (12). This expansion is formal until a regulator, counterterms, and EFT domain are specified.

A.4 Weak-correlation Gaussian expansion

For $c^2 \ll a^2$, expand the joint symplectic eigenvalue:

$$\sqrt{(a^2 - c^2)} = a - c^2/(2a) + O(c^4)$$

Substituting into the exact mutual information gives

$$I(A:B) \approx (c^2/a) h'(a), \quad h'(a) = \ln[(a + \frac{1}{2})/(a - \frac{1}{2})]$$

Wick's theorem gives $\langle qA^2 qB^2 \rangle_c = 2c^2$. The conversion coefficient therefore depends on a . The approximation fails when the weak-correlation or state-physicality assumptions fail.

A.5 Mean-field shift and energy

For $V(J) = \frac{1}{2} \mu_I^2 J^2$ and prescribed $G = \langle \chi^2 \rangle_{\text{ren}}$, the stationary potential is

$$V_{\text{eff}}(J) = \frac{1}{2} \mu_I^2 J^2 + gJG$$

Its minimum and the corresponding potential-density value are

$$\mathcal{I}^* = -gG/\mu_I^2, \quad V_{\text{eff}}(\mathcal{I}^*) = -g^2 G^2 / (2\mu_I^2)$$

For two states with sources G_1 and G_0 , the energy-density difference is $-g^2(G_1^2 - G_0^2)/(2\mu_I^2)$, before additional renormalized vacuum terms and spatial gradients are included. Only when $G_0=0$ does this simplify to $-g^2(\Delta G)^2/(2\mu_I^2)$.

Appendix B. Reproducibility protocol for the lattice test

The reported lattice outputs are intended to be reproducible from a symmetric eigendecomposition. Sites are zero-indexed and boundaries are open. Build K with $K_{jj}=m^2+\text{deg}(j)$, where $\text{deg}(j)$ equals one at the endpoints and two in the interior; set $K_{j,j+1}=K_{j+1,j}=-1$. Diagonalize $K=U \text{diag}(\lambda)U^T$, form $X=U \text{diag}[1/(2\sqrt{\lambda})]U^T$ and $P=U \text{diag}[\sqrt{\lambda}/2]U^T$, restrict the covariance matrices to each region, and compute the Gaussian entropies from the symplectic eigenvalues. The following pseudocode expresses the calculation protocol; implementation details should be checked against the stated conventions before reusing it.

```
# Minimal protocol (NumPy/SciPy)
import numpy as np
from scipy.linalg import eigh

def covariances(N, m):
    K = np.zeros((N, N), dtype=float)
    for j in range(N):
        degree = int(j > 0) + int(j < N - 1)
        K[j, j] = m*m + degree
        if j > 0:
            K[j, j-1] = K[j-1, j] = -1.0
    lam, U = eigh(K)
    X = (U * (0.5 / np.sqrt(lam))) @ U.T
    P = (U * (0.5 * np.sqrt(lam))) @ U.T
    return X, P

def entropy(X, P, region):
    ids = np.asarray(region, dtype=int)
    XR = X[np.ix_(ids, ids)]
    PR = P[np.ix_(ids, ids)]
    nu = np.sqrt(np.maximum(np.linalg.eigvals(XR @ PR).real, 0.0))
    total = 0.0
    for v in nu:
        n = max(float(v) - 0.5, 0.0)
        if n > 1e-14:
            total += (n+1)*np.log(n+1) - n*np.log(n)
    return total

def metrics(N, m, A, B):
    X, P = covariances(N, m)
    AB = sorted(list(A) + list(B))
    MI = entropy(X, P, A) + entropy(X, P, B) - entropy(X, P, AB)
    Kcorr = 2*sum(X[i, j]**2 for i in A for j in B)
    return MI, Kcorr, MI/Kcorr
```

Example: metrics(32, 0.5, [8, 9], [14, 15])

Limits of this calculation: zero-temperature ground state; free Gaussian chain; one spatial lattice direction; equal-time position-covariance proxy; no interactions, curvature, finite temperature, backreaction, continuum extrapolation, or experimental input. The data test the selected relation, not the existence of $\mathcal{I}$.

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Research-status note

This is a speculative research manuscript. Standard quantum-field, Gaussian-state, and effective-field-theory machinery is used as mathematical scaffolding. The ontology of the I-field, the correlation-sensitive source, any qdit-to-field coupling, and any cosmological interpretation remain conjectural until the operational definitions, dynamics, renormalization, stability, and quantitative predictions are completed and confronted with observation. The revised model contains no additional physical spatial dimensions.