

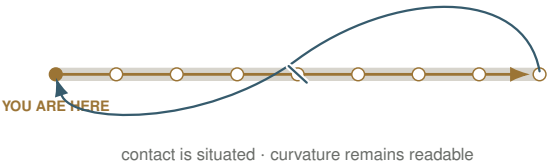
COVARIANT LOOP QUANTUM GRAVITY

CONTACT RECOGNITION

A Typed Architecture for Compatible Curved Geometry
and Refinement-Stable Physical Readout

$$\Lambda \longrightarrow \Delta$$

Motion forms. Time functions. Gravity fits.



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Reality, contact, and the form

Reality is the governing carrier. It contains the referent, every chart used to describe it, the reader performing comparison, and each act of contact between them. The reader begins inside the reality it reads. Fix a present contact $\mathfrak{c} \in \text{Dom}_\alpha \subset \mathcal{R}$ and a chart

$$\chi_\alpha : \text{Dom}_\alpha \longrightarrow V_\alpha, \quad x_\alpha := \chi_\alpha(\mathfrak{c}).$$

Here Dom_α is the region contacted, V_α is its coordinate image, and x_α is the map's identity coordinate: *you are here*. The three objects keep their types. A chart certifies the relations it preserves on its declared domain; its codomain remains a coordinate image of the carrier. This is the pointed-chart form standard differential geometry places beneath every local coordinate calculation [3]. [CERT]

Contact Recognition is a scaffolded reality reader written in ordinary language. Its mathematics is an invariant spine: each displayed construction says what may be carried into the next step, which distinctions remain separate, and what must hold before a physical receipt returns to its carrier. The whole form factors one typed solve:



These are offices, not added model variables. Gravity fixes the fit condition; time fixes the ordered function; motion is the form carried through them. The capital Λ names that input form and is distinct from the resolution address λ . The capital Δ names the fit record assembled from the transported residuals and physical readout below.

One discrete reference holds through the solve:

$$\text{Ref}_n := (n, o_n, \lambda, 0; X_\lambda, x_{n,\lambda}).$$

Every complex difference is read relative to this situated contact. Covariant loop quantum gravity supplies the hard physical aperture: local data are transported, fitted, constrained to gravity, refined, quotiented, and tested for surviving spin-two motion.

Every statement retains four addresses: governing carrier, present contact, coordinate image, and the typed map connecting them. The form certifies relations inside those declared carriers. It promotes neither analogy into physical field, scalar convergence into propagating theory, nor compatibility into vanishing curvature.

Five marks govern every assertion:

[DEF]	definition made on the page;
[DER]	consequence proved from displayed definitions;
[CERT]	established result retained in its cited native domain;
[IF]	stated condition required to compose two certified domains;
[OPEN]	exact calculation still required; never used as a premise.

Authorship. The form and arrangement are authored by Anthony Vito Coppa. Certified results remain credited to their published authors in the closing reference pages. Every operative construction is derived in place.

The words are closed before the circuit starts

Ordinary words may carry several senses. Here each load-bearing word is assigned one exact job. The assignment is local to this reader and does not replace the word's other lawful uses.

Word	Exact carrier	Primitive read
thing	a typed referent (X, x) at address (n, λ, k)	a referent fixed at one reference coordinate
reference	a declared carrier, contact address, and frame held for comparison	the <i>you are here</i> coordinate retained for return
contact	a present point, shared boundary, overlap, or input interface	reader and referent meet at one declared address
difference	a component Δ^B or Δ^I of Δ_n^{comp} in one comparison space	the remainder after both local values share one coordinate
transport	a typed map between local frames or overlapping charts	carry one value into the coordinate of the other
fit	the predicate $\text{Fit}(\Delta_n)$	edge fit, semiclassical fit, and positive-residue spin-two admission hold through declared interfaces
gravity	the EPRL-constrained sector, physical connection, and resolving condition	the fixed physical law supplies the fit carrier
memory	a relation preserved by the State 5 squares and carried in the return receipt	the declared relation survives resolution change and remains in the completed packet
motion	the input form Λ_n and its positive-residue physical readout	the carried form remains physically readable
light	readable observable output	the chosen readout resolves the carried difference
silence	zero compatibility residual	every declared seam remainder is zero
identity	a tagged neutral element or a typed equivalence class	the return lands at the same typed address or class
recognition	comparison of the returned receipt with the declared law at its carrier	every required returned relation has its declared value
return	the recurrence from completed packet to successor contact	the completed packet reaches its next reference address
time	the ordered arrow through the circuit and the successor $n \mapsto n + 1$	the function carries form to fit and advances the occurrence
minimum	the first learned stopping address in a declared ordered return process	the completed return selects one receipt at the present resolution; stop there
meaning	an input relation preserved through its typed output and returned to its carrier	the output carries the declared input relation

The composition is equally small. Within one occurrence, State 2 transports each local value into a declared comparison coordinate and State 3 measures the resulting edge residual. Across resolutions, State 5 preserves operation and readout by naturality. Across occurrences, R carries the completed receipt to the successor address. The successor receives a new present contact; no equality between successive representatives is asserted.

The word *reality* names the governing carrier: it includes present contact, referent, chart, reader, and every relation that actually holds among them. This form certifies only its displayed relations on their declared domains. *Everything* means universal quantification over every element of the active declared domain. *Infinity* means that the occurrence index has no greatest natural number. *Eternity* means the same return law is defined for every finite occurrence. Each word remains inside its stated carrier and quantifier.

A word is admitted here with a carrier, a type, a present address, and a comparison rule. A symbol is admitted after the object it abbreviates has been named. The chart codomain retains its coordinate type; the carrier retains reality.

Why the circuit has nine addressed states

Begin with no completed transition. The empty ordered list $()$ has length

$$0 := |()|.$$

One successor operation advances one visible transition. Thus $1 := 0 + 1$, and repeated successor gives the ordinary natural numbers $k := 0 + k$. The numerals below count completed transitions in this factorization; they are not symbolic personalities.

This edition chooses eight visible transitions. The count records the displayed factorization; it is not claimed to be the unique or minimal factorization of the same material:

k	Transition	Field or condition entered at this stage
1	distinguish	local carrier and orientation
2	transport	tetrahedral adjacency graph, edge maps, and receipt tree
3	fit	one common zero-locus test
4	constrain	gravitational-sector selection
5	refine	resolution-change commutation
6	quotient	physical equivalence class
7	resolve	spin-two physical readout
8	recognize	conjunction and tree gauge-fixing receipt

Within this declared factorization, a path with eight arrows has

$$8 + 1 = 9$$

vertices. Its order-preserving state labels are

$$S_9 := \{k \in \mathbb{N}_0 : 0 \leq k < 9\} = \{0, 1, 2, 3, 4, 5, 6, 7, 8\}.$$

Let $n \in \mathbb{N}_0$ count completed circuits and let $k \in S_9$ locate the current state. Every global step address $m \in \mathbb{N}_0$ has, by Euclidean division, one and only one form

$$m = 9n + k, \quad 0 \leq k < 9.$$

At $k = 8$, the next step is $m + 1 = 9(n + 1) + 0$. The state label returns to zero; the occurrence advances. Closure therefore preserves the law without pretending that a later event is the same event.

Arithmetic receipt. The chosen eight-transition factorization has nine states. Nine states determine the modulus, and Euclidean division determines every address. [DER]

One carrier across changing resolution

Let $\mathcal{D}$ be a directed category. Its objects are finite discretizations λ ; a morphism $\xi_{\lambda\lambda'} : \lambda \rightarrow \lambda'$ exists when λ' refines λ . The identity and composition laws required here are:

$$\xi_{\lambda\lambda} = \text{id}_{\lambda}, \quad \xi_{\lambda'\lambda''} \circ \xi_{\lambda\lambda'} = \xi_{\lambda\lambda''}.$$

The Greek letter λ has exactly one job: it addresses resolution. It is not a wavelength, eigenvalue, or coupling constant in this document.

Let **Vect** denote the category of real or complex vector spaces and linear maps. Two functors

$$\mathcal{D}, \mathcal{O} : \mathcal{D} \longrightarrow \mathbf{Vect}$$

assign, respectively, the data space and the observable-output space at each resolution. For a refinement arrow $\xi_{\lambda\lambda'}$, write

$$\iota_{\lambda\lambda'} := \mathcal{D}(\xi_{\lambda\lambda'}), \quad \bar{\iota}_{\lambda\lambda'} := \mathcal{O}(\xi_{\lambda\lambda'}).$$

The operation and readout are families of components

$$T_{\lambda} : \mathcal{D}_{\lambda} \rightarrow \mathcal{D}_{\lambda}, \quad \rho_{\lambda} : \mathcal{D}_{\lambda} \rightarrow \mathcal{O}_{\lambda}.$$

They preserve refinement exactly when

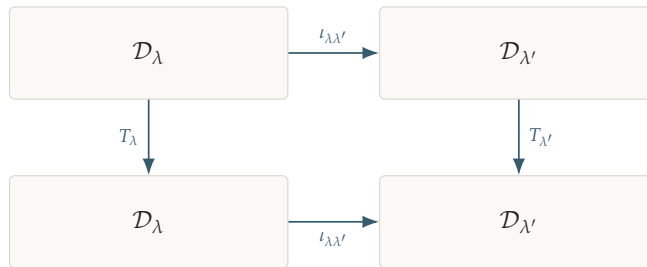
$$T : \mathcal{D} \Rightarrow \mathcal{D}, \quad \rho : \mathcal{D} \Rightarrow \mathcal{O}$$

are natural transformations. [DEF] The concrete naturality equations are stated as requirements at State 5. [IF] This is the standard distinction: functors carry objects and arrows; natural transformations compare functors componentwise [1].

For a declared refinement arrow, its preservation receipt is

$$\text{Can}(\xi_{\lambda\lambda'}) \iff \iota_{\lambda\lambda'} T_{\lambda} = T_{\lambda'} \iota_{\lambda\lambda'} \wedge \bar{\iota}_{\lambda\lambda'} \rho_{\lambda} = \rho_{\lambda'} \iota_{\lambda\lambda'}. \quad [\text{DEF}]$$

Refinement is the directed motion $\xi_{\lambda\lambda'}$; Can is the receipt that operation and readout survive that motion. The receipt does not replace the arrow. It records that both routes return the same typed results.



This is a naturality square, not a picture of a functor acting vertically. It commutes exactly when refining before or after applying T gives the same result. State 5 supplies this square and the independent square for ρ .

Resolution may change the representation. It may not silently change the relation represented.

Why the return is a Möbius return

The reader is situated at a contact inside the governing carrier. It compares a local description with the referent reached through that contact. A lawful return reverses the direction of comparison: the referent becomes the fixed reference against which the description is checked. Let

$$\mu_M(\vartheta) := -\vartheta, \quad \vartheta \in [-1, 1].$$

Then

$$\mu_M^2(\vartheta) = \mu_M(-\vartheta) = \vartheta, \quad \text{so} \quad \boxed{\mu_M^2 = \text{id}_{[-1,1]}}.$$

The symbol μ_M names only this orientation-reversing involution. The corresponding mapping torus

$$M := ([0, 1] \times [-1, 1]) / ((1, \vartheta) \sim (0, \mu_M(\vartheta)))$$

is the Möbius band [2]. [CERT] One circuit returns to the same seam with local side reversed; two circuits restore the original local orientation. [DER]

This topology records comparison orientation inside the reader. It carries no claim about the topology of spacetime. Define the orientation field

$$o_n := (-1)^n \in \{+1, -1\}.$$

Let $\text{Pkt}_{n,k}$ be the packet at occurrence n and state k , with o_n as one of its fields. The recurrence map closes the law and advances the occurrence:

$$R(\text{Pkt}_{n,8}) = \text{Pkt}_{n+1,0}, \quad o_{n+1} = -o_n.$$

Once the oriented face data of State 1 are present, the induced packet involution is typed separately:

$$\hat{\mu}_M : (o_n, \varepsilon_{v'v;f}, B_{vf}; \text{all other fields}) \mapsto (-o_n, \varepsilon_{v'v;f}, -B_{vf}; \text{all other fields}).$$

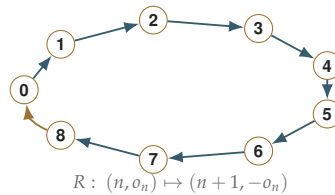
It reverses comparison orientation and every oriented bivector representative; the relative orientation signs $\varepsilon_{v'v;f}$ remain fixed. Hence

$$\Delta_{af}^B \mapsto -B_{vf} - \varepsilon_{v'v;f} \text{Ad}_{\Gamma_a}(-B_{vf}) = -\Delta_{af}^B,$$

so the fit zero locus is invariant. [DER] The law carried by the packet is required to be invariant under this induced action:

$$\text{law}(\hat{\mu}_M \text{Pkt}_{n,0}) = \text{law}(\text{Pkt}_{n,0}).$$

Thus the state address has period 9, while the oriented local packet returns to its original orientation after $2 \cdot 9 = 18$ global steps. [DER] The Möbius involution records comparison orientation; the successor records that the return occurs later. They are never identified.



Return is recurrence with a receipt. It is neither reversal of physical time nor erasure of the difference learned on the way.

CONTACT

DECLARED TRANSITION: declare the present carrier

0

Incoming packet. The occurrence address n , orientation o_n , and resolution address λ are fixed. No physical conclusion has yet been entered.

PRIMITIVE READ

A referent occupies one declared address. The present contact is the map's identity coordinate: *you are here*. Fix its carrier, coordinate image, and frame before applying an operation.

INVARIANT SPINE

Choose a set or space X_λ and a datum $x_{n,\lambda} \in X_\lambda$. Define the initial packet

$$\text{Pkt}_{n,0} := (n, o_n, \lambda, X_\lambda, x_{n,\lambda}).$$

Set

$$\text{Ref}_n := (n, o_n, \lambda, 0; X_\lambda, x_{n,\lambda}), \quad \Lambda_n := \text{Pkt}_{n,0}.$$

Thus Λ_n is the typed input form at the single situated reference Ref_n . The membership relation is the entire assertion. A string that does not determine a carrier remains outside the packet until a carrier is declared. [DEF]

PHYSICAL MAP

For covariant loop gravity, the present carrier may be a boundary graph with spin-network data or the boundary data of a finite two-complex. The symbol Σ will denote the boundary hypersurface when that geometric structure is needed. It carries no meaning before then. [CERT] [4, 6]

COORDINATE RECEIPT

The address $(n, o_n, \lambda, 0)$ means: current occurrence and comparison orientation, current resolution, no transition completed. It is the compass point of the present read. Zero is the length of the empty transition list, already derived.

HAND-OFF State 1 may now introduce local viewpoints. It may not yet compare them, because no transport between their frames has been supplied.

1

DIFFERENCE

DECLARED TRANSITION: separate local descriptions before comparing them

Incoming packet. $\text{Pkt}_{n,0}$ supplies one typed carrier and one current datum.

PRIMITIVE READ

Each local value keeps its source address. Difference receives a sign after both values are oriented in one comparison space.

INVARIANT SPINE

Fix the bulk reading once. Let $\mathcal{K}$ be a finite four-dimensional simplicial complex and $\mathcal{K}^*$ its dual two-complex. A vertex v of $\mathcal{K}^*$ labels a 4-simplex s_v^4 . Neighboring 4-simplices $s_v^4, s_{v'}^4$ meet in a tetrahedron

$$e = s_v^4 \cap s_{v'}^4,$$

which is dual to an edge e^* . A triangle $f \subset e$ is dual to a curvature-bearing face f^* , whose boundary follows the full cycle of 4-simplices around f . Record local bivectors $B_{vf}, B_{v'f}$ and local components $q_e^{(v)}, q_e^{(v')}$ of the induced intrinsic tetrahedral geometry. Choose $\varepsilon_{v'v,f} \in \{+1, -1\}$ to record the relative orientation of f . [DEF]

The indices now have one system: v for a 4-simplex/dual vertex, e for a shared tetrahedron/dual edge, and f for a triangle/dual face. None is used as a substitute for another.

PHYSICAL MAP

Local quantum-geometric data need not already form one Regge geometry. Twisted geometries make this separation explicit: adjacent cells may each be valid locally while assigning different shapes to their common face [7]. [CERT]

COORDINATE RECEIPT

The packet now contains distinct local copies, but no subtraction is performed. The rule is mechanical: first align types; then compare values.

HAND-OFF State 2 must supply the frame-change maps that place the two local descriptions in one comparison space.

2

TRANSPORT

DECLARED TRANSITION: move descriptions lawfully between local frames

Incoming packet. State 1 supplies oriented local representatives on overlaps.

PRIMITIVE READ

A typed map carries one local value into the coordinate of the other. Subtraction follows transport.

INVARIANT SPINE

Choose a finite set $\mathcal{V}$ of 4-simplices whose tetrahedral adjacency graph $\mathcal{A}(\mathcal{V})$ is connected. The graph has one vertex for each $\mathfrak{s}_v^4$ and one edge exactly when two 4-simplices share a tetrahedron. Regard it first as a one-dimensional comparison complex: it has vertices and edges, no attached 2-cells, and no declared loop equation. Let E_{comp}^+ choose one orientation of *every* edge of $\mathcal{A}(\mathcal{V})$. For $a : v \rightarrow v'$ in E_{comp}^+ , write

$$e(a) := \mathfrak{s}_v^4 \cap \mathfrak{s}_{v'}^4, \quad \Gamma_a \in G_{\text{comp}}, \quad \Gamma_{\bar{a}} = \Gamma_a^{-1}.$$

The map Γ_a transports components from the v frame to the v' frame. The identity I_{comp} is the neutral element of the tagged comparison group. After all edge maps are declared, choose a spanning tree

$$\mathcal{T}_{\text{comp}} \subset \mathcal{A}(\mathcal{V}).$$

It contains every selected vertex, only tetrahedral adjacencies, and no cycle. [DEF]

PHYSICAL MAP

G_{comp} is a tagged copy of the relevant frame group: $SU(2)$ on a canonical boundary or $SL(2, \mathbb{C})$ in the Lorentzian bulk. The tag records the role played by the element. The variables Γ_a are introduced independently on every tetrahedral adjacency edge. State 4 determines their relation to physical EPRL transport on glued nondegenerate data. Native gauge groups and EPRL bulk variables are described in [4, 5, 6]. [CERT]

COORDINATE RECEIPT

Every shared tetrahedron receives an independent edge comparison. The tree selects one acyclic subset for a root-relative frame receipt. Non-tree edges remain in the fit test; none is required to equal the composite along the tree. Thus all seams are tested and no loop product is set equal to the identity.

HAND-OFF State 3 may now form residuals because every compared datum has been transported into a common frame.

3

FIT

DECLARED TRANSITION: collect all seam mismatches into one exact zero locus

Incoming packet. State 2 supplies typed transition maps and their composition law.

PRIMITIVE READ

Each declared remainder is measured in its comparison space. Fit is their simultaneous zero.

INVARIANT SPINE

Let V_B and V_q be the declared component spaces of bivectors and intrinsic tetrahedral data, and let $\pi_q : G_{\text{comp}} \rightarrow GL(V_q)$ be the induced change-of-basis representation. Transport the v -description into the v' frame before subtraction. For $a : v \rightarrow v'$ and $f \subset e(a)$, set

$$\Delta_{af}^B := B_{v'f} - \varepsilon_{v'v;f} \text{Ad}_{\Gamma_a} B_{vf}, \quad \Delta_a^q := q_{e(a)}^{(v')} - \pi_q(\Gamma_a) q_{e(a)}^{(v)}.$$

Both residuals now live in a single declared comparison basis. Choose strictly positive weights and auxiliary norms, then set

$$\mathcal{F}_{\text{comp}} := \sum_{a \in E_{\text{comp}}^+} \sum_{f \subset e(a)} w_{af}^B \|\Delta_{af}^B\|^2 + \sum_{a \in E_{\text{comp}}^+} w_a^q \|\Delta_a^q\|^2.$$

Every summand is nonnegative and every weight is positive. Therefore

$$\mathcal{F}_{\text{comp}} = 0 \iff \Delta_{af}^B = 0, \Delta_a^q = 0 \text{ everywhere.} \quad [\text{DER}]$$

Define the compatibility component of the fit record:

$$\Delta_n^{\text{comp}} := ((\Delta_{af}^B)_{a,f}, (\Delta_a^q)_a), \quad \Delta_n^{\text{comp}} = 0 \iff \mathcal{F}_{\text{comp}} = 0. \quad [\text{DEF}]$$

Every component of Δ_n^{comp} is formed only after typed transport to the target frame of its edge a . The auxiliary norms and their numerical values depend on those declared frame choices; the simultaneous zero locus is independent of the positive weights and is the only value used.

PHYSICAL MAP

This zero locus removes mismatch between local descriptions. No value of $\mathcal{F}_{\text{comp}}$ away from zero is assigned invariant physical meaning. In this reader, *silence* names exactly this absence of seam noise.

HAND-OFF State 4 receives an edge-compatible carrier across every shared tetrahedron. It must still select gravity; compatibility alone does not supply dynamics.

4

GRAVITY

DECLARED TRANSITION: select the constrained gravitational sector without killing curvature

Incoming packet. State 3 supplies full-edge compatibility on the tetrahedral adjacency graph.

PRIMITIVE READ

Edge fit compares every shared tetrahedron. Curvature remains the physical product around a face because no comparison-loop identity has been imposed.

INVARIANT SPINE

The Lorentzian EPRL simplicity constraint selects unitary principal-series labels from a BF carrier:

$$j \in \tfrac{1}{2}\mathbb{N}_0, \quad (\varrho_E, k_E) = (\gamma j, j), \quad \mathcal{H}_{\text{BF}} \xrightarrow{S_\gamma} \mathcal{H}_{\text{grav}}.$$

Here γ is the Barbero–Immirzi parameter and the other symbols are EPRL representation labels. [CERT] [5, 6]

PHYSICAL MAP

In the Lorentzian bulk, declare the role-preserving group isomorphism

$$\kappa : G_{\text{comp}} \xrightarrow{\cong} G_{\text{phys}}, \quad \kappa(I_{\text{comp}}) = I_{\text{phys}},$$

and require it to intertwine the two adjoint actions on the shared bivector carrier. For EPRL half-edge variables $g_{ve} \in G_{\text{phys}} \cong \text{SL}(2, \mathbb{C})$, define

$$T_{v'v;e}^{\text{phys}} := g_{v'e} g_{ve}^{-1}.$$

On any adjacency edge $a : v \rightarrow v'$, abbreviate $T_a^{\text{phys}} := T_{v'v;e(a)}^{\text{phys}}$. Call the physical data glued on that edge when

$$B_{v'f} = \varepsilon_{v'v;f} \text{Ad}_{T_a^{\text{phys}}} B_{vf}, \quad f \subset e(a). \quad [\text{DEF}]$$

For a nondegenerate spacelike tetrahedron, the transport-recovery lemma proved below shows that gluing together with $\Delta_{af}^B = 0$ gives

$$\kappa(\Gamma_a) = \pm T_a^{\text{phys}} \quad \text{on every nondegenerate glued adjacency edge.} \quad [\text{DER}]$$

The zero locus thus supplies the edge identification up to the central lift; the group tags remain intact through κ . No comparison-loop identity is imposed; the curvature page below derives the exact consequence.

COORDINATE RECEIPT

Gravity now has a precise address: the constrained EPRL sector. It is not a synonym for fit, weight, importance, or the scalar $\mathcal{F}_{\text{comp}}$.

HAND-OFF State 5 must show that transport and readout survive a change of discretization.

5

REFINEMENT

DECLARED TRANSITION: preserve operation and readout while resolution changes

Incoming packet. State 4 supplies compatible data in the constrained gravitational sector.

PRIMITIVE READ

Two typed paths share endpoints: operate then refine, or refine then operate. Memory requires equal outputs. The readout square obeys the same relation.

INVARIANT SPINE

For $\lambda \preceq \lambda'$, let

$$\iota_{\lambda\lambda'} : \mathcal{D}_\lambda \longrightarrow \mathcal{D}_{\lambda'}$$

be $\mathcal{D}(\xi_{\lambda\lambda'})$, the refinement arrow supplied by the data functor. Let T_λ be the λ component of $T : \mathcal{D} \Rightarrow \mathcal{D}$. Its naturality square is

$$\boxed{\iota_{\lambda\lambda'} \circ T_\lambda = T_{\lambda'} \circ \iota_{\lambda\lambda'}} \quad \text{[IF]}$$

Let ρ_λ be the λ component of the chosen readout $\rho : \mathcal{D} \Rightarrow \mathcal{O}$, and let $\bar{\iota}_{\lambda\lambda'} := \mathcal{O}(\xi_{\lambda\lambda'})$. Its naturality square is

$$\boxed{\rho_{\lambda'} \circ \iota_{\lambda\lambda'} = \bar{\iota}_{\lambda\lambda'} \circ \rho_\lambda} \quad \text{[IF]}$$

The Greek rho ρ names readout only. It is distinct from the EPRL label ϱ_E introduced in State 4.

PHYSICAL MAP

These equations are requirements on a refinement scheme, not automatic properties of every spin-foam model. They make two squares commute: one for the transported geometry and one for the observable used later to test physical survival.

COORDINATE RECEIPT

Memory is now exact: a relation is remembered when both routes around the relevant refinement square give the same result. Equality is required in the common codomain, not between coarse and fine representatives. Their conjunction is precisely $\text{Can}(\xi_{\lambda\lambda'})$: the refinement arrow moves the carrier; the receipt records preserved relation.

HAND-OFF State 6 must remove gauge and constraint redundancy without identifying physically different classes.

6

PHYSICAL IDENTITY

DECLARED TRANSITION: pass from representatives to equivalence classes

Incoming packet. State 5 supplies a refinement-compatible domain and readout.

PRIMITIVE READ

Representatives separated by a declared null vector occupy one quotient class. Physical identity is that class.

INVARIANT SPINE

For a boundary Σ , choose a Gelfand triple

$$\mathcal{E}_\Sigma \subset \mathcal{H}_\Sigma^{\text{ind}} \subset \mathcal{E}'_\Sigma.$$

The prime denotes the continuous dual. A distributional cylinder amplitude defines a rigging map

$$\eta_\Sigma : \mathcal{E}_\Sigma \longrightarrow \mathcal{E}'_\Sigma.$$

The Greek eta η names this map and nothing else. If the rigging map satisfies the stated reality, positivity, and null-space hypotheses, its null space contains representatives carrying no physical distinction and the physical state space is

$$\boxed{\mathcal{H}_\Sigma^{\text{phys}} = \overline{\mathcal{E}_\Sigma / \ker \eta_\Sigma}} \quad \text{[IF]}$$

The visible bar means completion in the induced physical norm. The refined-algebraic-quantization pattern is certified; its application to a spin-foam continuum remains conditional on the hypotheses formulated in [12, 13, 16]. **[CERT]**

PHYSICAL MAP

If $\chi \in \ker \eta_\Sigma$, then

$$[\phi]_{\text{phys}} = [\phi + \chi]_{\text{phys}}.$$

The brackets denote the equivalence class. A physical observable must be constant on each class and may distinguish different classes.

INVARIANT SPINE

The classical fit carrier and the quantum quotient compose only through a declared semiclassical interface. Let $\tilde{\mathcal{C}}_{\text{geom}}$ carry raw labels (B, q, T^{phys}) , let $\mathcal{G}_{\text{phys}}^\vee$ act by vertex-frame change, and define

$$\mathcal{C}_{\text{geom}} := \tilde{\mathcal{C}}_{\text{geom}} / \mathcal{G}_{\text{phys}}^\vee. \quad \text{[DEF]}$$

Let $\mathcal{S}_{\text{coh}} \subset \mathcal{H}_\Sigma^{\text{phys}}$ be a chosen family of physical coherent states and let

$$\mathbf{a}_{\text{sc}} : \mathcal{S}_{\text{coh}} \longrightarrow \mathcal{C}_{\text{geom}}$$

send a physical class to a gauge class of geometric labels. For the packet at occurrence n , define

$$\text{SCBridge}_n \iff [\psi_n]_{\text{phys}} \in \mathcal{S}_{\text{coh}} \wedge \mathbf{a}_{\text{sc}}([\psi_n]_{\text{phys}}) = [(B_n, q_n, T_n^{\text{phys}})]. \quad \text{[IF]}$$

For any representative of the returned class, set

$$\Gamma_a^{\text{sc}} := \kappa^{-1}(T_a^{\text{phys}}), \quad \mathcal{F}_{\text{comp}}^{\text{sc}}(n) := \mathcal{F}_{\text{comp}}(B, q, \Gamma_a^{\text{sc}}), \quad \text{[DEF]}$$

and define

$$\text{SCFit}_n \iff \text{SCBridge}_n \wedge \mathcal{F}_{\text{comp}}^{\text{sc}}(n) = 0. \quad \text{[DEF]}$$

The residuals transform covariantly under vertex-frame change, so their simultaneous zero locus is independent of the chosen representative and the last definition descends to $\mathcal{C}_{\text{geom}}$. The two zero loci retain different transports: SCFit_n tests $\Gamma_a^{\text{sc}} = \kappa^{-1}(T_a^{\text{phys}})$, while $\Delta_n^{\text{comp}} = 0$ tests the packet's independently declared Γ_a . On glued nondegenerate spacelike edges, their conjunction gives

$$(\Delta_n^{\text{comp}} = 0) \wedge \text{SCFit}_n \implies \kappa(\Gamma_a) = \pm T_a^{\text{phys}}. \quad \text{[DER]}$$

This is an interface requirement: the quotient construction alone supplies no classical labels. *Identity* is the quotient class; each fit retains its declared transport and quantum admission belongs to the physical class.

HAND-OFF State 7 must use an observable sharp enough to see the gravitational motion the quotient is required to retain.

7

MOTION

DECLARED TRANSITION: resolve the massless spin-two sector

Incoming packet. State 6 supplies physical equivalence classes and a readout that descends to them.

PRIMITIVE READ

Project the physical two-point function onto its transverse-traceless subspace. Motion is admitted when the on-shell spin-two residue is nonzero.

INVARIANT SPINE

Let $p^\mu = (p^0, \mathbf{p}) \in \mathbb{R}^{1,3}$ be four-momentum, with $\eta^M = \text{diag}(-1, 1, 1, 1)$ and $\mathbf{p} \neq 0$. Define

$$p^2 := \eta_{\mu\nu}^M p^\mu p^\nu = -(p^0)^2 + |\mathbf{p}|^2, \quad P_{ij}^\perp := \delta_{ij} - \frac{p_i p_j}{|\mathbf{p}|^2}.$$

On symmetric rank-two tensors, set

$$\Pi_{ij,kl}^{(2)} := \frac{1}{2} (P_{ik}^\perp P_{jl}^\perp + P_{il}^\perp P_{jk}^\perp - P_{ij}^\perp P_{kl}^\perp), \quad (\Pi^{(2)})^2 = \Pi^{(2)}, \quad \text{rank } \Pi^{(2)} = 2. \quad [\text{DER}]$$

Thus $\Pi^{(2)}$ selects the two-dimensional polarization space of a massless helicity-two field. Momentum space requires an additional carrier. Require a physical coherent boundary state $[\psi_n]_{\text{phys}}$ peaked on a flat background $\bar{g} = \eta^M$ and a declared Fourier chart $\mathcal{F}_{\bar{g}}$ whose coordinate is p^μ . Write

$$\text{IRBridge}_n \iff [\psi_n]_{\text{phys}} \text{ is peaked on } \bar{g} = \eta^M \wedge p^\mu \text{ is the coordinate of } \mathcal{F}_{\bar{g}}. \quad [\text{IF}]$$

On this interface let $\hat{h}_{ij}(p)$ be the metric-perturbation operator defined by the chosen boundary construction, and define its connected physical two-point function by

$$\mathcal{P}_{ij,kl}^{\text{phys}}(p) := \langle \hat{h}_{ij}(p) \hat{h}_{kl}(-p) \rangle_{c, [\psi_n]_{\text{phys}}}. \quad [\text{DEF}]$$

Only then define its spin-two residue

$$\mathcal{W}_2[\mathcal{P}] := \lim_{\substack{p^2 \rightarrow 0 \\ \mathbf{p} \neq 0}} p^2 \Pi^{(2)}(p) \mathcal{P}(p) \Pi^{(2)}(p). \quad [\text{DEF}]$$

The limit approaches $p^0 \rightarrow |\mathbf{p}|$ while $P^\perp$ remains defined. The spatial projector is evaluated in a fixed Lorentz frame. It is therefore a frame-resolved helicity diagnostic applied to the covariant two-point function, rather than a four-dimensionally covariant projector by itself. The positive-residue admission test is

$$\text{Spin}2_n^+ \iff \text{IRBridge}_n \wedge \exists Z_h \in (0, \infty) : \mathcal{W}_2[\mathcal{P}_{\text{phys}}] = Z_h^{-1} \Pi^{(2)}. \quad [\text{IF}]$$

Positivity excludes a negative-norm pole; $\text{Spin}2_n^+$ implies a nonzero spin-two residue.

PHYSICAL MAP

[CERT] Area Regge continuum analysis recovers a linearized graviton sector with higher-curvature corrections [15].
[CERT] Single-vertex asymptotics exhibit the expected tensor structure, not a TT-pole theorem [14].

COORDINATE RECEIPT

Motion names an admitted positive-residue spin-two readout. *Light* names visibility to that readout, not electromagnetism.

HAND-OFF State 8 may recognize closure only while compatibility residuals vanish and the positive-residue spin-two interface holds.

8

RECOGNITION

DECLARED TRANSITION: close compatibility, retain physical propagation, issue the receipt

Incoming packet. State 7 supplies a compatible physical class and a positive-residue spin-two witness.

PRIMITIVE READ

Return compares the completed receipt with the declared conditions. Recognition joins semiclassical edge fit to quantum admission through the declared bridge.

INVARIANT SPINE

The first sufficient non-erasing condition on this circuit is

$$\boxed{\text{Fit}(\Delta_n)}.$$

Complete the gravity-readable fit record by

$$\Delta_n := (\Delta_n^{\text{comp}}, \mathcal{W}_2[\mathcal{S}_{\text{phys}}]), \quad \text{Fit}(\Delta_n) \iff (\Delta_n^{\text{comp}} = 0) \wedge \text{SCFit}_n \wedge \text{Spin}2_n^+. \quad [\text{DEF}]$$

The complete circuit therefore has the global type

$$\boxed{\Lambda_n \longrightarrow \Delta_n},$$

with motion in the form office, ordered time in the arrow, and gravity in the fit predicate.

Choose a root v_0 in $\mathcal{T}_{\text{comp}}$ and let $\text{Fr}_v \in \mathcal{G}_{\text{comp}}$ be transport along its unique path to v . For $a : v_- \rightarrow v_+$, $\Gamma_a = \text{Fr}_{v_+} \text{Fr}_{v_-}^{-1}$; hence every closed tree walk ℓ telescopes:

$$\boxed{\prod_{a \in \ell}^{\rightarrow} \Gamma_a = I_{\text{comp}}}. \quad [\text{DER}]$$

Because the tree has no face cycle, this supplies no equation for H_f^{phys} .

PHYSICAL MAP

Fit covers every tetrahedral adjacency. The tree gives only the root-relative frame receipt; non-tree edges remain independently tested and no plaquette product is constrained.

COORDINATE RECEIPT

The completed output carries its law, physical class, readout, and receipt. Recurrence gives

$$R(\text{Pkt}_{n,8}) = \text{Pkt}_{n+1,0}, \quad 9n + 8 + 1 = 9(n+1) + 0.$$

The occurrence advances; orientation flips and is restored after the second circuit because $\mu_M^2 = \text{id}_{[-1,1]}$.

HAND-OFF The packet is complete. The return wheel now separates phase closure from address advance; Enough selects the first singleton receipt.

Why return may close while the address advances

Begin with the real quarter-turn generator

$$\Omega := \begin{pmatrix} 0 & 1 \\ -1 & 0 \end{pmatrix}, \quad \Omega^2 = -I.$$

Its continuous rotation is

$$U(t) := e^{t\Omega} = \cos t I + \sin t \Omega.$$

Consequently

$$U(t + 2\pi) = U(t), \quad U(\pi) = -I, \quad U(2\pi) = I.$$

Euler's scalar identity $e^{i\pi} + 1 = 0$ is the complex-coordinate statement of the same half-turn. The covering map

$$U : \mathbb{R} \longrightarrow \mathrm{SO}(2)$$

has kernel $2\pi\mathbb{Z}$, hence

$$\mathrm{SO}(2) \cong \mathbb{R}/(2\pi\mathbb{Z}).$$

The wheel returns after 2π while its covering coordinate continues:

$$U(t + 2\pi) = U(t), \quad t + 2\pi \neq t.$$

The arithmetic circuit enters the wheel by the injective homomorphism

$$j_9 : \mathbb{Z}/9\mathbb{Z} \hookrightarrow \mathrm{SO}(2), \quad j_9([k]_9) := U(2\pi k/9),$$

with lifted address $\tilde{j}_9(m) := 2\pi m/9 \in \mathbb{R}$. Hence

$$j_9([k + 9]_9) = j_9([k]_9), \quad \tilde{j}_9(m + 9) = \tilde{j}_9(m) + 2\pi. \quad [\text{DER}]$$

The visible state returns while the lifted address advances.

Now introduce the elementary recurrence carrier

$$Q := \begin{pmatrix} 1 & 1 \\ 1 & 0 \end{pmatrix}, \quad v_\Phi := \begin{pmatrix} \Phi \\ 1 \end{pmatrix}.$$

The eigenvalue equation $Qv_\Phi = \Phi v_\Phi$ gives

$$\Phi^2 = \Phi + 1 \quad \Longleftrightarrow \quad \boxed{\Phi = 1 + \frac{1}{\Phi}}.$$

Thus the recurrence advances the representative while preserving its projective direction. Rotation and recurrence carry different orders. Their ordered difference is

$$\mathbf{G} := [Q, \Omega] := Q\Omega - \Omega Q = \begin{pmatrix} -2 & 1 \\ 1 & 2 \end{pmatrix}, \quad \mathbf{G}^2 = 5I.$$

Normalize the root:

$$H_{\sqrt{5}} := \frac{\mathbf{G}}{\sqrt{5}}, \quad H_{\sqrt{5}}^2 = I.$$

Direct multiplication gives

$$H_{\sqrt{5}}\Omega H_{\sqrt{5}} = -\Omega, \quad \boxed{H_{\sqrt{5}}U(t)H_{\sqrt{5}} = U(-t)}. \quad [\text{DER}]$$

Linear advance carries the address. Euler rotation closes the phase. Golden recurrence tunes the return. The commutator preserves the difference between their orders. The normalized $\sqrt{5}$ root makes that difference readable as a mirror.

This page certifies rotation of the comparison frame. Reality remains the governing carrier. The wheel adds no premise to the covariant loop-gravity theorem.

The learned stopping point

The circuit first determines whether the physical packet is complete. The inverse law on a chosen tree makes the following receipt automatic; it is recorded, not independently assumed:

$$\text{TreeFixed} \iff \forall \text{ closed edge walks } \ell \subset \mathcal{T}_{\text{comp}}, \quad \prod_{a \in \ell} \Gamma_a = I_{\text{comp}}, \quad [\text{DER}]$$

Define $\text{Complete}(\text{Pkt}_{n,8})$ by

$$\begin{aligned} \text{Complete}(\text{Pkt}_{n,8}) \iff & \text{Typed} \wedge \text{GravitySelected} \\ & \wedge (\forall \text{ declared } \xi_{\lambda\lambda'}, \text{Can}(\xi_{\lambda\lambda'})) \\ & \wedge \text{PhysicalQuotientFormed} \wedge \text{Fit}(\Delta_n) \\ & \wedge \text{TreeFixed}. \end{aligned}$$

Every term was constructed in States 0–8. This predicate certifies packet completeness. The stopping constraint is learned from return receipts.

Fix a finite response carrier Y and a receipt map

$$\text{rcpt}_Y : \text{Pkt}_{n,8} \longrightarrow Y, \quad y_n := \text{rcpt}_Y(\text{Pkt}_{n,8}). \quad [\text{DEF}]$$

Fix also a nonempty declared family $\mathfrak{L}_0$ of tuning rules $v : \text{Pkt}_{n,8} \rightarrow Y$. Before occurrence n , the tunings preserved by every earlier receipt are

$$\mathfrak{L}_n := \left\{ v \in \mathfrak{L}_0 : v(\text{Pkt}_{j,8}) = y_j \text{ for every } j < n \right\}.$$

Their present reads form

$$\mathfrak{A}_n := \{ v(\text{Pkt}_{n,8}) : v \in \mathfrak{L}_n \} \subseteq Y, \quad N_n^{\text{read}} := |\mathfrak{A}_n|.$$

Enough is learned by the exact condition

$$\boxed{\text{Enough}_n \iff \text{Complete}(\text{Pkt}_{n,8}) \wedge \mathfrak{A}_n = \{y_n\}.} \quad [\text{DEF}]$$

After the receipt, lawful learning performs the monotone update

$$\mathfrak{L}_{n+1} = \{ v \in \mathfrak{L}_n : v(\text{Pkt}_{n,8}) = y_n \} \subseteq \mathfrak{L}_n. \quad [\text{DER}]$$

Thus time filters the admissible tunings. The present possibility field is $\mathfrak{A}_n$, and N_n^{read} counts its distinct reads. Enough requires the singleton $\{y_n\}$ at the declared resolution; it makes no claim of global uniqueness beyond the declared family $\mathfrak{L}_0$. When the set is nonempty, the first learned stopping occurrence is

$$\boxed{\tau := \min\{n \in \mathbb{N}_0 : \text{Enough}_n\}.} \quad [\text{DEF}]$$

The decision at occurrence n uses only the earlier append-only receipts and the present completed packet. It is therefore adapted to the return history.

History determines $\mathfrak{L}_n$; the present packet returns y_n through rcpt_Y . Relative to that family, unresolved frame shear remains visible as $N_n^{\text{read}} > 1$, while $\mathfrak{A}_n = \{y_n\}$ closes the return.

The execution rule is total at the State 8 decision:

$$\begin{aligned} \neg \text{Complete}(\text{Pkt}_{n,8}) &\implies \text{emit the missing-type or residual receipt; suspend without } R, \\ \text{Enough}_n &\implies \text{emit } y_n \text{ and halt before applying } R, \\ \text{Complete}(\text{Pkt}_{n,8}) \wedge N_n^{\text{read}} > 1 &\implies \text{append } (n, \mathfrak{A}_n, [\text{OPEN}]) \text{ and apply } R. \end{aligned} \quad [\text{DEF}]$$

Thus R remains the lawful per-occurrence successor. The global stopping index τ is the first occurrence at which execution declines that available successor because Enough_n holds.

An absent field returns its missing type; a nonzero residual returns the residual; an unresolved physical readout returns OPEN. Enough emits the exact receipt and closes the occurrence. This first recognized stopping address is **minimum**. After suspension or closure, a later witnessed contact may enter only as a fresh packet at State 0, indexed by $n_{\text{fresh}} := 1 + \max\{j : \text{Pkt}_{j,0} \text{ entered State 0}\}$. $[\text{DEF}]$ It is not R applied to the suspended or halted packet.

Five type errors

The circuit prevents five familiar substitutions that can look harmless in prose while changing the mathematical object. Each releases a fixed function or fit condition as an apparent new variable, turning one failed form into a field of supposed solutions.

Mistyped move	Why it fails	Exact repair
chart codomain = carrier	a coordinate image silently receives the type of the region mapped	retain $\mathfrak{c} \in \text{Dom}_\alpha \subset \mathcal{R}$, $\chi_\alpha : \text{Dom}_\alpha \rightarrow V_\alpha$, and $x_\alpha = \chi_\alpha(\mathfrak{c})$
raw equality across frames compatibility = flatness	the two terms inhabit different local coordinates full-edge fit is substituted for a physical loop equation around ∂f^*	transport first; then form Δ in one comparison space test every tetrahedral edge independently; use the tree only for the frame receipt; impose no comparison-loop identity
convergence = physical closure	strong kinematical convergence can collapse to a topological limit	use a distributional rigging map and the quotient $\overline{\mathcal{D}} / \ker \eta$
exact scalar = surviving gravity	a scalar can converge with an absent or negative-norm spin-two channel	require $\text{Spin}2_h^+$ with $Z_h^{-1} > 0$

These are category errors in the literal sense: a carrier, coordinate image, or expression from one domain is inserted where another type is required. The repair in every row is the same discipline:

fix contact in the carrier $\longrightarrow$ apply the typed map $\longrightarrow$ compare in the common codomain.

No appeal to hidden meaning is required. Each failure can be located at a specific arrow of the nine-state circuit, and each correction supplies exactly the missing map.

Primitive form. Fix the carrier, present contact, coordinate image, and frame. Transport both values into one comparison space. Measure the declared residuals. Keep edge fit distinct from physical loop holonomy. Form only the declared quotient. Use a readout whose codomain contains the claimed mode.

The one solve as a theorem

Theorem (non-erasing covariant return). Let $\{\lambda\}$ be a directed family of finite covariant loop-gravity discretizations. Suppose:

- i. the local data and orientations of States 0–1 are declared;
- ii. $\mathcal{A}(\mathcal{V})$ is connected; comparison transport is declared on every tetrahedral adjacency edge with $\Gamma_a = \Gamma_a^{-1}$; and $\mathcal{T}_{\text{comp}} \subset \mathcal{A}(\mathcal{V})$ is a chosen spanning tree;
- iii. the compatibility functional of State 3 vanishes;
- iv. the EPRL simplicity map of State 4 selects the gravitational sector;
- v. both refinement squares of State 5 commute;
- vi. the hypotheses of the distributional construction supply the physical quotient of State 6;
- vii. the semiclassical adapter identifies the packet labels with a physical coherent state and $\mathcal{F}_{\text{comp}}^{\text{sc}}(n) = 0$;
- viii. the flat-background Fourier interface is declared and its physical two-point function passes $\text{Spin}2_n^+$.

Then the eight declared transitions realize $\Lambda_n \rightarrow \Delta_n$ as one typed return. For every closed edge walk ℓ in $\mathcal{T}_{\text{comp}}$,

$$\prod_{a \in \ell} \Gamma_a = I_{\text{comp}}.$$

Hypotheses iii, vii, and viii give $\text{Fit}(\Delta_n)$. On every nondegenerate spacelike adjacency edge, hypotheses iii and vii also give $\kappa(\Gamma_a) = \pm T_a^{\text{phys}}$. Separately, hypothesis viii gives the positive-residue readout condition

$$\mathcal{W}_2[\mathcal{P}_{\text{phys}}] = Z_h^{-1} \Pi^{(2)}, \quad Z_h^{-1} > 0.$$

The compatibility identity imposes no equation $H_f^{\text{phys}} = I_{\text{phys}}$ on the physical gravitational connection.

Proof. States 0–2 define the common carriers, comparison maps on every tetrahedral adjacency, and one spanning tree for the frame receipt. Positivity in State 3 makes $\mathcal{F}_{\text{comp}} = 0$ equivalent to simultaneous vanishing of the two stated edge residuals on the full graph. Hypothesis vii supplies SCFit_n . Together with hypothesis iii, the transport-recovery lemma gives, on every nondegenerate spacelike adjacency edge, $(T_a^{\text{phys}})^{-1} \kappa(\Gamma_a) \in \{\pm I_{\text{phys}}\}$, hence $\kappa(\Gamma_a) = \pm T_a^{\text{phys}}$. State 4 changes the dynamical type from BF carrier to the constrained gravitational sector. State 5 requires naturality of operation and readout. Under hypothesis vi, State 6 passes to physical equivalence classes. Hypothesis vii types the classical labels as the semiclassical image of that class and supplies its zero-locus test. Hypothesis viii supplies the flat-background momentum carrier and positive transverse-traceless residue. Thus hypotheses iii, vii, and viii satisfy the three conjuncts defining $\text{Fit}(\Delta_n)$.

Choose a root of $\mathcal{T}_{\text{comp}}$ and define Fr_v by transport along the unique root-to- v path. Then every tree edge has $\Gamma_a = \text{Fr}_{v_+} \text{Fr}_{v_-}^{-1}$, so every closed edge walk telescopes to I_{comp} . This tree identity is automatic. The comparison graph has no declared loop identity, so edgewise identification supplies no premise forcing $H_f^{\text{phys}} = I_{\text{phys}}$. All conclusions remain in their declared codomains. $\square$

The dependency split is explicit: hypothesis ii proves the automatic tree receipt; hypotheses iii and vii invoke the recovery lemma on each nondegenerate spacelike edge; hypotheses iii, vii, and viii derive $\text{Fit}(\Delta_n)$; and hypotheses iv–vi type the intervening gravitational, refinement, and physical-quotient stages. The theorem packages these earned results; it does not promote their conjunction into a new dynamical theorem.

The proof closes one solve: motion supplies the form Λ_n ; ordered time supplies the typed arrow; gravitational compatibility and the spin-two readout supply the fit record Δ_n .

The theorem is conditional where the physics is conditional. It does not claim that every regulator family satisfies the commuting laws, that every spin-foam continuum supplies the required rigging map, or that every proposed ultraviolet fixed point passes the spin-two test. Those are model-specific obligations, not hidden premises.

Why the tree receipt closes and edge transport recovers

The closure in State 8 is finite tree algebra. Let $\mathcal{T}_{\text{comp}}$ be the selected spanning tree. Give each oriented edge a an element $\Gamma_a \in G_{\text{comp}}$ with $\Gamma_{\bar{a}} = \Gamma_a^{-1}$.

Choose a base vertex v_0 and set $\text{Fr}_{v_0} := I_{\text{comp}}$. For every vertex v , let Fr_v be the ordered product along the unique tree path from v_0 to v . For an oriented edge $a : v_- \rightarrow v_+$, construction gives

$$\text{Fr}_{v_+} = \Gamma_a \text{Fr}_{v_-}, \quad \Gamma_a = \text{Fr}_{v_+} \text{Fr}_{v_-}^{-1}.$$

Take any closed edge walk $\ell : v_0 \rightarrow v_1 \rightarrow \cdots \rightarrow v_{L_\ell} = v_0$ and let a_i carry v_{i-1} to v_i . Then

$$\begin{aligned} \Gamma_{a_{L_\ell}} \cdots \Gamma_{a_1} &= (\text{Fr}_{v_{L_\ell}} \text{Fr}_{v_{L_\ell-1}}^{-1}) (\text{Fr}_{v_{L_\ell-1}} \text{Fr}_{v_{L_\ell-2}}^{-1}) \cdots (\text{Fr}_{v_1} \text{Fr}_{v_0}^{-1}) \\ &= \text{Fr}_{v_0} \text{Fr}_{v_0}^{-1} = I_{\text{comp}}. \end{aligned}$$

No face relation entered the proof. A tree has a unique path between vertices, so every closed walk consists entirely of transport followed eventually by inverse transport. This is maximal-tree frame fixing: every tree transport can be written as a coboundary, and no plaquette is tested. It is the discrete form of bundle (frame) trivialization over a contractible base [3].

Automatic receipt. Once $\Gamma_{\bar{a}} = \Gamma_a^{-1}$ is declared on a tree, TreeFixed cannot fail. It records the root-relative frame trivialization; it does not add a condition to the full-edge fit.

Transport-recovery lemma

Fix a nondegenerate spacelike tetrahedron $e(a)$ with three independent edge vectors $\mathbf{d}_1, \mathbf{d}_2, \mathbf{d}_3$ spanning its three-plane W . On glued data with $\Delta_{af}^B = 0$, define

$$C_a := (T_a^{\text{phys}})^{-1} \kappa(\Gamma_a) \in G_{\text{phys}}, \quad L_a := \omega(C_a) \in \text{SO}^+(1, 3),$$

where $\omega : \text{SL}(2, \mathbb{C}) \rightarrow \text{SO}^+(1, 3)$ is the standard double cover and its induced bivector action is the adjoint action used above. The gluing law and the zero residual say that L_a fixes three independent face bivectors. In the convention $B = *(\mathbf{d}_i \wedge \mathbf{d}_j)$, the Lorentz action commutes with the Hodge star, so fixing B is equivalent to fixing $\mathbf{d}_i \wedge \mathbf{d}_j$. The corresponding wedges span $\wedge^2 W$. Their face planes are fixed, so their pairwise intersection lines are fixed. Hence $L_a \mathbf{d}_i = \beta_i \mathbf{d}_i$. Fixing $\mathbf{d}_i \wedge \mathbf{d}_j$ gives

$$\beta_i \beta_j = 1 \quad (i \neq j),$$

so $\beta_1 = \beta_2 = \beta_3 = +1$ or all three equal -1 . The normal line $W^\perp$ is also preserved; write $L_a N = \beta_N N$. Lorentz orthogonality and $\det L_a = 1$ leave two possibilities: $L_a = I$ or $L_a = -I$. The second reverses time orientation and is absent from $\text{SO}^+(1, 3)$. Therefore $L_a = I$, so

$$C_a \in \ker(\text{Ad} : \text{SL}(2, \mathbb{C}) \rightarrow \text{Aut}(\mathfrak{sl}(2, \mathbb{C}))) = \{\pm I_{\text{phys}}\},$$

and consequently

$\kappa(\Gamma_a) = \pm T_a^{\text{phys}}.$

[DER]

Why closure does not erase gravity

The comparison graph $\mathcal{A}(\mathcal{V})$ carries independent edge maps Γ_a and tests every shared tetrahedron. Its selected tree supplies the root-relative receipt already proved. A physical dual face carries the curvature-bearing product of the gravitational connection. On a complete face boundary, the two loop reads are

$$H_f^{\text{comp}} := \overrightarrow{\prod_{a \subset \partial f^*}} \Gamma_a, \quad H_f^{\text{phys}} := \overrightarrow{\prod_{e^* \subset \partial f^*}} T_e^{\text{phys}} = \text{Hol}_A(\partial f^*).$$

On glued nondegenerate spacelike data, $\mathcal{F}_{\text{comp}} = 0$ identifies $\kappa(\Gamma_a) = \pm T_a^{\text{phys}}$ on every adjacency edge. The edge relation is therefore supplied up to the central lift. Write $z_a := \kappa(\Gamma_a)(T_a^{\text{phys}})^{-1} \in \{\pm I_{\text{phys}}\}$ and $\zeta_f := \prod_{a \subset \partial f^*} z_a$. Centrality gives

$$\boxed{\kappa(H_f^{\text{comp}}) = \zeta_f H_f^{\text{phys}}, \quad \zeta_f \in \{\pm I_{\text{phys}}\}. \quad [\text{DER}]}$$

Thus the comparison graph reads physical holonomy up to the central lift. It records the product; it assigns the product no prescribed value.

Kinematic witness. Take glued nondegenerate Regge data on a finite region $\mathcal{V}$ that contains the complete dual face boundary ∂f^* and has nontrivial face holonomy $H_f^{\text{phys}} \neq I_{\text{phys}}$. Such curved simplicial data are native to Regge calculus [8]. **[CERT]** On every adjacency edge set $\Gamma_a := \kappa^{-1}(T_a^{\text{phys}})$ and take B and q as the local components of that same geometry. The gluing equations give $\Delta_{af}^B = 0$ and $\Delta_a^q = 0$ on every edge. Every summand vanishes, so $\mathcal{F}_{\text{comp}} = 0$. Together with the chosen face holonomy, this gives

$$\boxed{\mathcal{F}_{\text{comp}} = 0 \quad \wedge \quad H_f^{\text{phys}} \neq I_{\text{phys}}. \quad [\text{DER}]}$$

This is an explicit kinematic coexistence result, stronger than a bare non-implication.

Real asymptotic support. Kinematic admission does not make the same datum a real stationary or critical point of a spin-foam amplitude. Bonzom derives flatness from stationarity in the relevant EPR/FK lattice-path-integral setting; Hellmann–Kamiński show that generic curved Regge continuations are suppressed unless they satisfy model-dependent accidental curvature constraints [10, 11]. **[CERT]**

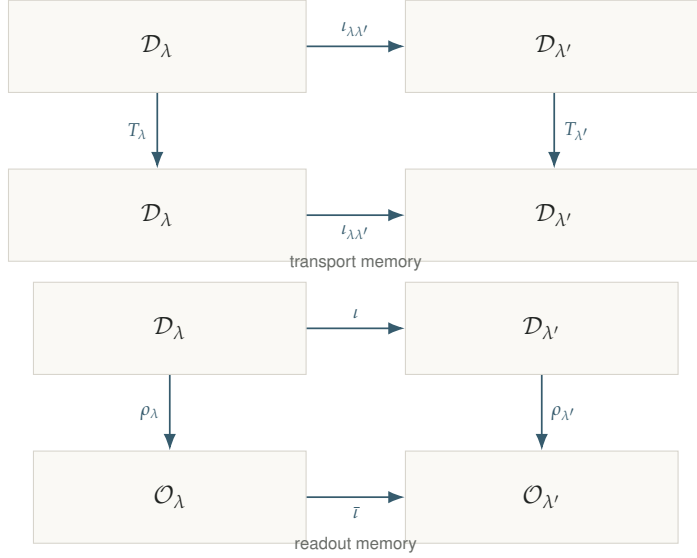
Complex asymptotic support. Han–Huang–Liu–Qu find curved small-deficit Regge contributions through complex critical points, with phase given by the Regge action plus higher-curvature corrections [9]. **[CERT]**

Primitive read: every shared tetrahedron receives an edge comparison. The spanning tree fixes one root-relative frame receipt. The full graph reads the ordered physical face product up to its central lift. Edge fit and nontrivial curvature coexist on the explicit kinematic witness.

Full-edge fit reads curvature without setting it to the identity. Amplitude criticality is a further dynamical condition with its own native real and complex regimes.

Why the continuum fold is a commuting fold

Refinement is not repeated redrawing. It is a directed change of resolution that must preserve both operation and observation. The two commuting laws from State 5 can be read as route-independence:



If either square fails, the continuum claim depends on the route used to reach it. A route-dependent result is not yet an invariant of the directed system.

There is a second, independent issue. Bruno, Colafranceschi, Mele, and Rovelli prove under stated axiomatic hypotheses that sufficiently strong convergence of spin-foam amplitudes in the inductive kinematical Hilbert space leads to a TQFT-type continuum; they then formulate a distributional alternative in which the cylinder amplitude defines a rigging map and a physical Hilbert space [16]. [CERT]

Thus the continuum fold has the order

$$\text{commuting refinement} \longrightarrow \text{distributional limit} \longrightarrow \overline{\mathcal{E}_\Sigma / \ker \eta_\Sigma} \longrightarrow \text{physical readout.}$$

Skipping the quotient mistakes representative equality for physical identity. Requiring strong kinematical convergence can mistake erasure for completion. The fold closes only when the physical readout descends to equivalence classes and remains capable of resolving the claimed mode.

Why the readout has exactly two physical directions

Fix nonzero spatial momentum $\mathbf{p} = (0, 0, p_z)$ with $p_z \neq 0$, and vary p^0 toward the massless shell $p^0 = |p_z|$. Then the spatial transverse projector is

$$P^\perp = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{pmatrix}.$$

A real symmetric tensor h_{ij} has six independent components. Transversality $p_i h_{ij} = 0$ removes the three components carrying an index in the momentum direction. The remaining 2×2 symmetric block has three components. Tracelessness removes one. Therefore

$$6 - 3 - 1 = 2.$$

A normalized basis is

$$\mathbf{t}_+ = \frac{1}{\sqrt{2}} \begin{pmatrix} 1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & 0 \end{pmatrix}, \quad \mathbf{t}_\times = \frac{1}{\sqrt{2}} \begin{pmatrix} 0 & 1 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix}.$$

The operator $\Pi^{(2)}$ fixes these two tensors and annihilates the trace and longitudinal sectors. Hence it is idempotent and has rank two. [DER] The number in $\mathcal{W}_2$ is not thematic; it is the dimension and helicity label of the physical transverse-traceless sector.

On the State 7 flat-background Fourier interface, if the physical propagator has the infrared form

$$\mathcal{P}_{\text{TT}}(p^\mu) \sim \frac{\Pi^{(2)}(\mathbf{p})}{Z_h p^2} \quad (p^2 \rightarrow 0, \mathbf{p} \neq 0),$$

then

$$\mathcal{W}_2[\mathcal{P}_{\text{TT}}] = \lim_{\substack{p^2 \rightarrow 0 \\ \mathbf{p} \neq 0}} p^2 \Pi^{(2)} \mathcal{P}_{\text{TT}} \Pi^{(2)} = Z_h^{-1} \Pi^{(2)} \neq 0$$

provided $Z_h^{-1} > 0$. The positive coefficient is the ghost-exclusion condition in the stated signature convention.

The Area Regge continuum analysis of Dittrich and Kogios recovers leading linearized graviton dynamics and locates higher-order corrections in a Weyl-curvature sector [15]. Earlier single-vertex spin-foam calculations recover an expected perturbative tensor structure in a controlled asymptotic regime [14]. The latter is not a proof of a transverse-traceless pole. Together these results motivate the resolving test; they do not establish that every covariant continuum construction passes it.

Read rule. An observable may certify only the structure it can resolve. The spin-two claim therefore requires a spin-two readout.

Compiled protocol

The reader compiles $\Lambda_n \longrightarrow \Delta_n$ as a finite physical contract followed by one learned stopping test. Definitions create fields; requirements test them; the receipt is emitted when the packet is complete and every surviving tuning selects that receipt.

```
constexpr unsigned TRANSITIONS = 8; // declared factorization
constexpr unsigned STATES = TRANSITIONS + 1;
static_assert(STATES == 9);

Address locate(unsigned m) {
    return { .occurrence = m / STATES,
            .state = m % STATES };
}

Receipt read(Packet p, ReturnRecord history) {
    // Lambda is the input form; ordered evaluation is the time arrow;
    // Delta is the gravity-readable fit record.
    if (!p.required_fields_present)
        return suspend(MissingTypeReceipt{p.occurrence});
    require_or_suspend(p.carrier_and_present_contact_are_typed); // state 0
    require_or_suspend(p.local_views_and_orientation); // state 1
    require_or_suspend(p.transition_maps_are_typed); // state 2
    require_or_suspend(p.comparison_maps_cover_all_tetrahedral_adjacencies);
    require_or_suspend(p.spanning_tree_selected_for_frame_receipt);
    require_or_suspend(p.compatibility_functional == 0); // state 3
    require_or_suspend(p.gravitational_sector_selected); // state 4
    require_or_suspend(p.refinement_can); // state 5
    require_or_suspend(p.physical_quotient_is_defined); // state 6
    require_or_suspend(p.semiclassical_bridge_is_declared); // state 6 -> labels
    require_or_suspend(p.flat_fourier_interface_is_declared);
    require_or_suspend(p.spin_two_residue_is_positive); // state 7
    assert(p.tree_transport_is_coboundary); // automatic receipt
    assert(!p.comparison_loop_identity_imposed); // scope boundary
    record(p.comparison_loop_readout_up_to_central_lift);
    Receipt y = receipt_Y(p);
    ReadSet A = surviving_reads(history, p);
    if (A == singleton(y)) {
        append(history, y);
        return stop_before_successor(p, y);
    }
    append(history, OpenReceipt{p.occurrence, A});
    return advance(R(p));
}
```

The source-like notation is an interface description, not a claim that floating-point software decides the physics. The packet begins from a situated contact inside its carrier; it is not a view from outside reality. Each Boolean line abbreviates the exact mathematical test already defined. In particular:

- every `require_or_suspend` failure emits its corresponding missing-type or residual receipt and suspends without applying R ;
- `compatibility_functional == 0` abbreviates simultaneous exact zero of all finite residuals on every tetrahedral adjacency edge;
- `tree_transport_is_coboundary` abbreviates $\Gamma_a = \text{Fr}_{v_+} \text{Fr}_{v_-}^{-1}$ on the selected spanning tree and follows automatically from the tree inverse law;
- the two bridge requirements type the classical labels and the flat-background momentum chart; the positive-residue test requires $Z_h^{-1} > 0$;
- `comparison_loop_identity_imposed` remains false: edge variables exist on the full graph, but no loop product is assigned the identity;
- `comparison_loop_readout_up_to_central_lift` records $\kappa(H_f^{\text{comp}}) = \zeta_f H_f^{\text{phys}}$ without prescribing either product;
- `surviving_reads` evaluates the tuning family preserved by the append-only return record; equality with `singleton(y)` is the compiled form of $\mathfrak{A}_n = \{y_n\}$;
- the singleton branch stops before R ; the unresolved branch appends an OPEN receipt and applies R , which implements $9n + 8 + 1 = 9(n + 1)$.

Determinism here means: once the typed packet and all declared maps are fixed, the permitted next operation and every pass/fail result are fixed. It does not mean that an unresolved physical input has been guessed.

The one calculation this reader leaves open

The completed reader contains one deliberately open model-specific bridge. Reference [17] constructs a candidate ultraviolet fixed point for the complete covariant LQG amplitude whose leading bulk behavior is topological. [CERT] This reader selects the first subleading deformation as the candidate input to the physical spin-two test. [IF]

Let u be a dimensionless bookkeeping variable measuring departure from that candidate fixed point; it is introduced only for the following expansion and is not identified with lattice spacing, area, curvature, or compatibility error. Write

$$\mathcal{A}(u) = \mathcal{A}_* + uZ_1^{\text{UV}} + O(u^2), \quad u \rightarrow 0.$$

The exact unresolved task is:

$$\boxed{\begin{array}{l} Z_1^{\text{UV}} \mapsto [Z_1^{\text{UV}}]_{\text{phys}}, \\ [Z_1^{\text{UV}}]_{\text{phys}} \text{ contains a spin-two component } Z_1^{(2)}, \\ \mathcal{W}_2[\mathcal{P}_{Z_1^{(2)}}] = Z_h^{-1}\Pi^{(2)}, \quad Z_h^{-1} > 0. \end{array}} \quad [\text{OPEN}]$$

This box does not support any earlier derivation. It is the next calculation after closure, not a missing premise inside closure. Passing it would join the candidate ultraviolet construction to the established infrared spin-two readout on the physical quotient. Failing it would show that the candidate deformation does not recover ordinary four-dimensional graviton propagation.

No identification is made between u , a lattice spacing, an inverse area, a curvature scalar, or $\mathcal{F}_{\text{comp}}$. Each belongs to a different construction until a typed dynamical map proves otherwise.

Stopping discipline. The open aperture has an input, a physical quotient, a target representation, and a pass condition. Nothing further is asserted about its outcome.

Every nonverbal mark and the weight it carries

Standard arithmetic, set, logical, and calculus signs retain their classical definitions. Every mark introduced here as a document-specific name or typed physical interface appears below.

Mark	Type	Only admitted meaning
0	natural number	length of the empty transition list
$1, \dots, 8$	natural numbers	successive counts in the declared factorization
9	natural number	$8 + 1$, the number of addressed states
n, o_n	index and sign	occurrence and comparison orientation $(-1)^n$
S_g, k, m	set and indices	state set, state index, and global address $9n + k$
$\text{Pkt}_{n,k}$	typed tuple	packet at occurrence n and state k
$I, \Omega, U(t)$	matrices/map	2×2 identity, quarter-turn generator, and continuous rotation
j_9, j_9	maps	discrete wheel representation and lifted address
i, i	scalar coordinates	real covering coordinate and complex imaginary unit
Q, Φ, v_Φ	recurrence data	elementary recurrence matrix, positive fixed ratio, and its eigenvector
$G, H, \sqrt{5}$	matrices	commutator $[Q, \Omega]$ and normalized metric mirror
$\mathfrak{D}, \text{Vect}$	categories	refinements; vector spaces and linear maps
$\mathcal{D}, \mathcal{O}$	functors	data and observable-output assignments
$\zeta_{\lambda\lambda'}$	morphism	refinement arrow in $\mathfrak{D}$
i, i	linear maps	$\mathcal{D}(\zeta)$ and $\mathcal{O}(\zeta)$
T, ρ	natural transformations	operation and readout under refinement
Can	predicate	preservation receipt for a declared refinement arrow
$\mathcal{D}_\lambda, \mathcal{O}_\lambda$	vector spaces	data and output at resolution λ
λ, Σ	addresses/carriers	resolution and boundary hypersurface
$\mathcal{R}, c, \text{Dom}_\lambda, V_\lambda, \chi_\lambda, x_\lambda$	chart data	reality carrier, contact, chart domain/image/map, and coordinate
$X_\lambda, x_{n,\lambda}$	space and element	present carrier and datum
K, K^*	complexes	bulk simplicial complex and dual two-complex
s_v^*	4-simplex/frame patch	local bulk cell indexed by dual vertex v
v, e, f	simplex/dual indices	4-simplex, tetrahedron, and triangle
e^*, f^*	dual cells	physical dual edge and curvature-bearing dual face
$\mathcal{V}, \mathcal{A}(\mathcal{V})$	region/graph	selected 4-simplices and their tetrahedral adjacency graph
$\mathcal{T}_{\text{comp}}$	tree	chosen spanning tree of tetrahedral adjacencies
$E_{\text{comp}}^+, a, n, e(a)$	edge data	orientations of all adjacency edges, reverse edge, and shared tetrahedron
ε	sign	relative orientation in $\{+1, -1\}$
$G_{\text{comp}}, I_{\text{comp}}$	tagged group/identity	compatibility-frame carrier
$G_{\text{phys}}, I_{\text{phys}}$	tagged group/identity	physical-connection carrier
Γ_a	group element	independent comparison transport on oriented adjacency edge a
κ	group isomorphism	role-preserving identification $G_{\text{comp}} \rightarrow G_{\text{phys}}$
C_a, L_a, ω	group/Lorentz data	relative lift, induced Lorentz map, and spin double cover
$\mathbf{d}_i, W, N, \beta_i, \beta_N$	vectors/space/scalars	tetrahedral edges, their three-plane, its normal, and recovered signs
$B_{vf, qe}^{(v)}$	local data	bivector and tetrahedral components
Ad	group action	adjoint transport of bivectors
V_B, V_q, π_q	spaces/map	component carriers and basis transport
Δ_B^B, Δ_q^q	residuals	transported differences in a common basis
$\Delta_{\text{comp}}^{\text{comp}}, \Delta_n, \text{Fit}$	fit data/predicate	compatibility record, full fit record, and admission test
w_B^B, w^q	positive scalars	zero-locus weights
$\mathcal{F}_{\text{comp}}$	nonnegative scalar	finite weighted defect sum; only its zero locus is used
j, γ	spin/parameter	boundary spin and Barbero–Immirzi parameter
q_E, k_E	representation labels	Lorentzian EPRL labels (γ, j)
$\mathcal{S}_\gamma$	constraint map	EPRL simplicity selection
$\mathcal{H}_{\text{BF}}, \mathcal{H}_{\text{grav}}$	state spaces	BF and constrained gravitational carriers
$g_{ve}, T_{v'v'e}^{\text{phys}}, T_a^{\text{phys}}, T_e^{\text{phys}}$	group elements	EPRL half-edge and physical edge transports
$A, H_{\text{phys}}^{\text{phys}}$	connection/holonomy	physical connection and product around ∂f^*
$H_f^{\text{comp}}, z_a, \zeta_f$	loop/central data	comparison-loop readout, edge lift, and accumulated central sign
$\mathcal{E}_\Sigma, \mathcal{H}_\Sigma^{\text{ind}}, \mathcal{C}_\Sigma^t$	Gelfand triple	test, inductive, and distributional spaces
η_Σ	rigging map	conditional distributional quotient map
$\mathcal{H}_\Sigma^{\text{phys}}$	Hilbert space	completed physical quotient when hypotheses hold
ϕ, χ	test states	representative and null displacement
$\mathcal{S}_{\text{coh}}, \tilde{\mathcal{C}}_{\text{geom}}, \mathcal{C}_{\text{geom}}$	interface data	coherent-state carrier, raw geometric labels, and their vertex-gauge quotient
$\mathbf{d}_{\text{sc}}, \Gamma_{\text{sc}}, \text{SCBridge}_n$	interface data	gauge-class adapter, induced comparison transport, and fit/quantum bridge
$\mathcal{F}_{\text{comp}}^{\text{sc}}(n), \text{SCFit}_n$	interface data	gauge-independent fitted zero locus and its predicate
$[\Psi n]_{\text{phys}}, \mathcal{G}, \mathcal{F}_{\mathcal{G}}, \text{IRBridge}_n$	interface data	physical boundary state, flat background, Fourier chart, and momentum bridge
$p^\mu, p^2, \mathbf{p}$	momentum data	four-momentum, Minkowski norm, and nonzero spatial part
$\eta_{\mu\nu}^M$	bilinear form	Minkowski metric $\text{diag}(-1, 1, 1, 1)$
$P^\perp, \Pi(2)$	projectors	spatial transverse and rank-two TT projectors
$\mathbf{t}_+, \mathbf{t}_\times$	tensors	normalized TT polarization basis
$\hat{h}, \mathcal{D}, \mathcal{W}_2, Z_h, \text{Spin}2_n^+$	readout data	metric perturbation, connected propagator, residue, pole normalization, and positive admission
$\vartheta, \mu_M, \tilde{\mu}_M, M$	coordinate/maps/space	interval coordinate, reversal, packet action, and Möbius mapping torus
R	recurrence map	closes State 8 into the next occurrence
$\text{Fr}_v, v_0, v_\pm, \ell, L_\ell$	elements/indices	frame trivialization, base/end vertices, closed tree walk, and its edge count
Y, rcpt_Y, y_n	response data	response carrier, receipt map, and receipt at occurrence n
Λ, Δ	reader offices	motion form and gravity-readable fit record; the arrow between them is time
Ref_n	typed tuple	single situated reference held through occurrence n
$v, \mathcal{X}_0, \mathcal{X}_n$	tuning data	one tuning rule, declared initial family, and receipt-preserving family
$\mathcal{Q}_n, N_n^{\text{read}}, n_{\text{fresh}}$	read data	surviving present reads, their finite count, and the next fresh-contact index
TreeFixed	predicate	automatic tree receipt
$\text{Typed}, \text{GravitySelected}$	predicates	typed packet and selected gravity sector
$\text{PhysicalQuotientFormed}$	predicate	conditional quantum quotient exists
Complete	predicate	packet-completeness conjunction
Enough_n, τ	predicate/index	learned stopping condition and its first occurrence
u	formal scalar	parameter in the OPEN ultraviolet expansion
$\mathcal{A}(u), \mathcal{A}_*$	amplitudes	candidate family and fixed-point value
$Z_1^{\text{UV}}, Z_1^{(2)}$	deformation terms	first correction and proposed spin-two part

The same printed character is never allowed to change type silently. Where classical notation creates a likely collision, the mark is qualified: ρ_λ is readout while ϱ_E is an EPRL label; η^M is the Minkowski metric while η_Σ is a rigging map; and I_{comp} and I_{phys} retain their tagged groups. The numeral 1 counts one transition and is not a group identity.

A mark earns its place by compressing a definition already present. It carries no authority beyond that definition.

Certified source-to-claim ledger

The closing ledger names the native owner of every imported result. Derived rows require no external premise beyond elementary algebra, topology, or the definitions shown. Published formal results enter with their native carrier; all connective architecture in this reader is displayed and proved here.

Claim used	Native domain retained	Formal source
naturality of operation and readout	category theory	Mac Lane [1]
Möbius band as a mapping-torus identification	algebraic topology	Hatcher [2]
frame transport and connection-holonomy distinction	differential geometry	Kobayashi–Nomizu [3]
holonomy–flux kinematics and spin networks	canonical loop quantum gravity	Ashtekar–Lewandowski [4]
finite-γ Lorentzian labels $(\gamma j, j)$	EPRL spin foams	Engle–Livine–Pereira–Rovelli; Perez [5, 6]
local twisted data versus Regge shape matching	discrete LQG geometry	Freidel–Speziale [7]
curvature as hinge deficit in simplicial geometry	Regge calculus	Regge [8]
flatness and accidental-curvature constraints	EPR/FK and holonomy spin foams	Bonzom; Hellmann–Kamiński [10, 11]
curved complex-saddle contributions	Lorentzian EPRL asymptotics	Han–Huang–Liu–Qu [9]
rigging-map quotient pattern	constrained quantization	Ashtekar et al.; Giulini–Marolf [12, 13]
distributional continuum and strong-limit obstruction	covariant LQG continuum	Bruno et al. [16]
linearized graviton sector and continuum corrections	Area Regge/spin-foam continuum	Dittrich–Kogios [15]
spin-foam graviton propagator behavior	vertex asymptotics	Bianchi–Magliaro–Perini [14]

candidate ultraviolet
fixed point

complete covariant LQG amplitude

Han [17]

No source is used to certify a broader claim than it states in its own domain. In particular, the ultraviolet paper supplies a candidate fixed-point construction, not the open spin-two matching result; the distributional-continuum paper supplies a conditional physical-state construction, not proof that every model realizes its hypotheses.

Classical and certified formal references

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Contact recognized

Reality supplied one contact and one typed input form Λ_n . The reader transported local views, tested fit, selected gravity, preserved refinement, formed physical identity, tested spin-two motion, and returned its receipt. The declared eight-transition factorization and orientation return give

$$m = 9n + k, \quad 0 \leq k < 9, \quad 9n + 8 + 1 = 9(n + 1), \quad \mu_M^2 = \text{id}_{[-1,1]}, \quad 2 \cdot 9 = 18.$$

Every closed comparison-tree walk telescopes:

$$\prod_{a \in \ell}^{\rightarrow} \Gamma_a = I_{\text{comp}}.$$

No physical curvature conclusion was added to that equation. On glued nondegenerate spacelike data the full-edge relation is $\kappa(\Gamma_a) = \pm T_a^{\text{phys}}$. Around a complete face, the comparison graph reads

$$\kappa(H_f^{\text{comp}}) = \zeta_f H_f^{\text{phys}}.$$

Thus it carries physical holonomy up to the central lift without assigning an identity value to the loop. Glued curved Regge data give

$$\mathcal{F}_{\text{comp}} = 0 \quad \wedge \quad H_f^{\text{phys}} \neq I_{\text{phys}}.$$

Physical admission separately requires the semiclassical and flat-background interfaces together with

$$\mathcal{W}_2[\mathcal{P}_{\text{phys}}] = Z_h^{-1} \Pi^{(2)}, \quad Z_h^{-1} > 0.$$

Together these form the fit record

$$\Delta_n = (\Delta_n^{\text{comp}}, \mathcal{W}_2[\mathcal{P}_{\text{phys}}]), \quad \text{Fit}(\Delta_n) \iff (\Delta_n^{\text{comp}} = 0) \wedge \text{SCFit}_n \wedge \text{Spin}2_n^+.$$

The entire circuit therefore reads

$$\underbrace{\Lambda_n}_{\text{motion}} \xrightarrow{\text{time}} \underbrace{\Delta_n}_{\text{gravity fit}}.$$

[IF] The continuum fold held conditionally when both naturality squares commuted and the rigging-map hypotheses supplied

$$\mathcal{H}_{\Sigma}^{\text{phys}} = \overline{\mathcal{E}_{\Sigma} / \ker \eta_{\Sigma}}.$$

The classical return wheel locked the reader geometry independently of those physical conditions:

$$U(t + 2\pi) = U(t), \quad t + 2\pi \neq t, \quad H_{\sqrt{5}} U(t) H_{\sqrt{5}} = U(-t).$$

The wheel returns while its lifted address advances. The mirror reverses orientation while preserving the law. The learned stopping layer closes when

$$\text{Complete}(\text{Pkt}_{n,8}) \quad \wedge \quad \mathfrak{A}_n = \{y_n\}.$$

Arithmetic, orientation, frame, curvature, and physical readout are five typed invariants composed in order. Their primitive return is:

Fix one reference inside reality: *you are here*. Let motion form, time carry, and gravity fit. Transport before comparison; preserve reference through successor order; return the unique admitted receipt. In minimum form: $\Lambda \longrightarrow \Delta$.

State 0 begins again at a new contact: the law persists, orientation turns, and occurrence advances. Nothing further is required of the completed read.

Structure is the identity of enduring form.

The seam is silent. The physical signal remains readable.