

Temporal Genesis VIII. Gauge Holonomy from Inner-Time Orientation

Compact group phases, protected spectral bundles, auxiliary inner-time Yang-Mills blocks, and gap inputs

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Expanded self-contained LaTeX skeleton – June 14, 2026

Abstract

This paper develops the gauge-theoretic branch of the program. It first classifies symmetry-compatible complex structures for compact group representations using the Real commutant and Frobenius-Schur types. It then describes gauge fields as orientation, holonomy, and protected inner-time eigenspace transport. Finally, it organizes the auxiliary inner-time Yang-Mills gap program into local block rigidity, finite-depth detectability, relative cohomology, and nonlinear stability inputs. Strong global mass-gap conclusions are treated as theorem targets, not as established results.

Inputs. Nonabelian spectral orientation paper and auxiliary inner-time Yang-Mills block-gap papers.

Outputs. A careful gauge-sector framework that separates established compact-group phase results from conditional Yang-Mills theorem targets.

Status. Expanded skeleton. Main source keys: [[nonabelian-orienta](#), [block-rigidity-202](#), [nonlinear-block-ga](#), [phase-balanced-202](#)]. Every theorem target, numerical claim, and model realization must keep its status label until fully proved or audited.

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1 Position in the background-generative temporal-genesis program

Status 1.1 (Series placement). **Program level.** Level L_8 .

Role. This paper locates gauge theory after phase and spectral structure. Gauge connections are not primitive fields on a background; they are holonomies of protected inner-time spectral orientations and, in the Yang-Mills subprogram, finite-regulator block structures with local rigidity.

Allowed inputs. It may use spectral triples, selected phase, compact group representations, and completed spatial readout. It must not assume a gauge bundle, connection, or Yang-Mills mass gap as foundational input.

Required outputs. It outputs Real-commutant orientation data for compact groups, protected holonomy bundles, local block gap inputs, rigidity assumptions, and clear theorem targets for the auxiliary inner-time Yang-Mills program.

Background item	Status in this paper
Spatial dimension	Must be either reconstructed from paired inner-time channels, inherited from an earlier paper, or marked as a comparison convention.
Euclidean metric	Must arise from stable norm-preserving readout or be declared as an external calibration.
Lorentzian metric	Must arise from outer-time completion and cone preservation, or be postponed to the Lorentzian papers.
Quantum phase i	Must arise from Real-commutant positive-frequency selection or be inherited from that theorem.
Gauge connection	Must arise from spectral/holonomy data or be marked as a model realization.
String/worldsheet data	Must be late coherent record/excitation structure or a comparison model, never a primitive input.
Physical vacuum	Must be the monadic ground sector $\Omega_{\mathfrak{M}}$, not empty spacetime.
Particle/field data	Must be localized or collective vacuum-excitation sectors, or explicitly marked as effective comparison notation.
Extra dimensions	Must be reinterpreted as inner-time spectral/holonomy/excitation sectors unless marked as external string-theory comparison.

Table 1: Background-entry audit for this paper in the temporal-genesis series.

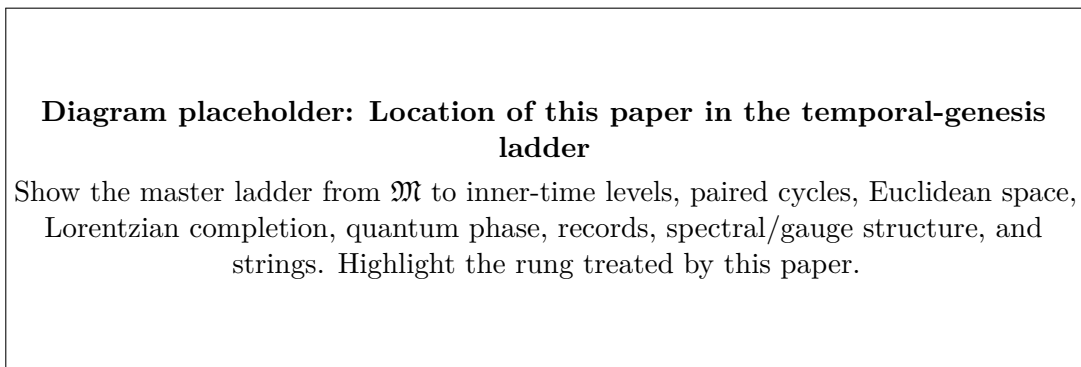


Figure 1: Location of this paper in the temporal-genesis ladder

2 Vacuum-excitation upgrade for this paper

Status 2.1 (Gauge sectors as holonomy excitations). **Vacuum role.** This paper now treats the monadic physical vacuum $\Omega_{\mathfrak{M}}$ as the stable completed ground sector available after the relevant earlier reconstruction steps. It must not use an empty spacetime vacuum as a primitive.

Excitation role. Treat gauge bosons and nonabelian sectors as protected holonomy excitations of inner-time spectral bundles.

No-extra-spatial-dimensions discipline. Any hidden degree of freedom used in this paper must be classified as an inner-time cycle, spectral multiplicity, holonomy sector, regulator, or comparison convention. It must not be silently interpreted as an extra observable spatial dimension.

Item	Content to finalize
Purpose	Vacuum-excitation audit for this paper
Required rows	Rows for vacuum input, excitation class, particle/field/string interpretation, hidden temporal sector, no-extra-spatial-dimensions status, and failure mode.
Status	Mark every row as ESTABLISHED, CONDITIONAL THEOREM TARGET, MODEL REALIZATION, PHENOMENOLOGICAL ANSATZ, or SPECULATIVE EXTENSION.
Cross references	Link rows to equations, definitions, theorem targets, figures, and appendices.

Table 2: Vacuum-excitation audit for this paper

3 Reader guide, scope, and status discipline

This paper is written so that it can be read without the rest of the series. It repeats the minimal SMM/DTT vocabulary, states its local assumptions, and marks each claim by proof status. The result is a detailed skeleton: prose, definitions, equations, proof plans, and placeholders are present; final publication requires replacing all TODO-style instructions with polished arguments and exact citations.

Source integration. This paper should be edited against the following source families: dual-time axiom drafts [[dot-axioms-revised](#), [dot-axioms-2025](#), [smm-dtt-axioms-202](#)]; Real-commutant and phase-selection drafts [[canonical-complexi](#), [phase-balanced-202](#), [complex-origin-202](#)]; spectral and noncommutative geometry drafts [[spectral-triples-v](#), [spectral-space-202](#), [ncg-axioms-2025](#)]; Lorentzian completion and projection-stability drafts [[completion-lorentz](#), [projection-stabili](#), [lorentzian-complet](#)]; gauge and Yang-Mills drafts [[nonabelian-orienta](#), [block-rigidity-202](#), [nonlinear-block-ga](#)]; string-realization drafts [[boundary-string-20](#), [temporal-strings-2](#), [string-tension-v1](#), [string-tension-v2](#)]; and phenomenology/nonlocality drafts [[projection-nonloca](#)].

4 Self-contained core language

This section fixes the common vocabulary used throughout this paper. It is intentionally repeated in abbreviated form across the series so that every paper can be read on its own. The program is written as a conditional reconstruction: it asks what structures follow from explicitly stated assumptions, not what follows from slogans alone.

Definition 4.1 (Single Monad layer). The *Single Monad layer* is the primitive ontological layer of the reconstruction. It is denoted by $\mathfrak{M}$. The Monad is not an event inside spacetime and

Label	Use in this paper
ESTABLISHED	Already proved in a mature source draft or standard literature, modulo editorial polishing and citation verification.
CONDITIONAL THEOREM TARGET	To be proved from explicit hypotheses stated in this paper; failure modes must be listed.
MODEL REALIZATION	A concrete example or embedding showing consistency, not uniqueness.
PHENOMENOLOGICAL ANSATZ	A calibration, parameter bridge, scaling law, or observational proposal requiring independent empirical work.
SPECULATIVE EXTENSION	A forward-looking interpretation that should not be used as a premise in the theorem chain.

Table 3: Claim-status labels used to keep the reconstruction program disciplined.

is not initially modelled as a particle, field, or string. It is represented formally by a source of admissible generative histories

$$\mathbf{H}_{\mathfrak{M}} \subseteq \{\gamma : I \rightarrow \mathcal{X}_{\text{gen}}\},$$

where I is an inner generative parameter domain and $\mathcal{X}_{\text{gen}}$ is a pre-observational configuration carrier. The aim of the paper series is to specify which extra structures on $\mathbf{H}_{\mathfrak{M}}$ are sufficient to reconstruct observer-level quantum, geometric, and field-theoretic structures.

Definition 4.2 (Dual-time convention). The Duality of Time convention used in this series is the following. Inner time t_{in} denotes continuous generative flow, but its stable observable content may be compact, cyclic, or indexed by discrete modes. Outer time t_{out} denotes completed-record order; microscopically it may arise from completed frames or ticks, while macroscopically it is represented by a smooth parameter. This convention resolves the apparent conflict between drafts that call inner time continuous and drafts that call inner time discrete: the flow is continuous, the recorded cycle labels can be discrete.

Definition 4.3 (Para-Hermitian dual time). A minimal dual-time kinematic structure is a triple

$$(\mathcal{T}, J_{\mathcal{T}}, \eta_{\mathcal{T}}),$$

where $\mathcal{T}$ is a smooth two-dimensional carrier, $J_{\mathcal{T}} : T\mathcal{T} \rightarrow T\mathcal{T}$ satisfies $J_{\mathcal{T}}^2 = \text{Id}$, and $\eta_{\mathcal{T}}$ is a neutral metric for which the $+1$ and -1 eigendistributions L_{in} and L_{out} are null line fields. In local split-complex notation one may write

$$z = t_{\text{in}} + jt_{\text{out}}, \quad j^2 = 1,$$

with quadratic form $q(z) = t_{\text{in}}^2 - t_{\text{out}}^2$, subject to the warning that t_{in} and t_{out} are not two macroscopic Lorentzian time coordinates.

Definition 4.4 (Completion and observation). A completion map is a partial or total operation

$$\mathbf{C} : \mathbf{H}_{\mathfrak{M}} \dashrightarrow \mathbf{R},$$

selecting those generative histories or history segments that become stable records. An observation map is a quotient or representation

$$\mathbf{O} : \mathbf{R} \rightarrow \text{Conf}(\Sigma)$$

from completed records to observer-level configurations. The observer does not access all generative distinctions; it accesses equivalence classes of completed records.

Definition 4.5 (Quantum phase layer). Given a real Hilbert representation $U : G \rightarrow O(\mathcal{H}_{\mathbb{R}})$, its complexification V on $\mathcal{H}_{\mathbb{C}} = \mathcal{H}_{\mathbb{R}} \otimes_{\mathbb{R}} \mathbb{C}$, and canonical conjugation C , the Real commutant is

$$\mathcal{A}_{\mathbb{R}}(U) = \{T \in B(\mathcal{H}_{\mathbb{C}}) : TV(g) = V(g)T \ \forall g \in G, \ TC = CT\}.$$

Compatible quantum phases are orthogonal complex structures J_q satisfying $J_q^* = -J_q$, $J_q^2 = -\text{Id}$, and $J_q \in \mathcal{A}_{\mathbb{R}}(U)$. A positive time flow with real generator A selects J_q on the nonzero dynamic sector by

$$A = J_q B = B J_q, \quad B \geq 0.$$

Status 4.6 (Claim-status discipline). Every major claim should be assigned one of five labels: ESTABLISHED, CONDITIONAL THEOREM TARGET, MODEL REALIZATION, PHENOMENOLOGICAL ANSATZ, or SPECULATIVE EXTENSION. This prevents the program from mixing proved operator-algebraic results, conditional reconstruction targets, model examples, empirical bridges, and speculative interpretations.

5 Nonabelian spectral orientation

This section develops nonabelian spectral orientation for the present paper. It states the precise role of the section in the reconstruction program, identifies which assumptions are structural and which are technical, and records the outputs needed by later sections.

Definition 5.1 (Nonabelian spectral orientation: local object). Define the local object of this section as the tuple of data, maps, equivalence relations, and admissibility conditions used below. Replace this boxed definition with the final polished version after importing exact statements from the source drafts.

Assumption 5.2 (Nonabelian spectral orientation: hypotheses). List the minimal hypotheses. Separate structural assumptions, technical regularity assumptions, physical calibration assumptions, and optional strengthening assumptions.

5.1 Compact group representation data

Let G be a second-countable compact group and $U : G \rightarrow O(\mathcal{H}_{\mathbb{R}})$ a continuous orthogonal representation. The complexified representation decomposes by Peter-Weyl data

$$\mathcal{H}_{\mathbb{C}} \cong \bigoplus_{\pi \in \widehat{G}} H_{\pi} \otimes M_{\pi}.$$

Canonical conjugation transports conjugate representation classes and constrains the Real commutant.

Proposition 5.3 (Compact group representation data: reconstruction target). *Under the hypotheses stated in this subsection, formulate the exact reconstruction claim. Mark it as established, conditional, model-realization, phenomenological, or speculative before using it elsewhere.*

Proof plan. Identify the earlier definitions used here, reduce the claim to lemmas, specify external theorems if any, and list failure modes. $\square$

5.2 Frobenius-Schur trichotomy

The compatible phases factor over complex-type conjugate pairs, real-type self-conjugate blocks, and quaternionic-type self-conjugate blocks. Complex-type multiplicity one reduces to orientation signs; real and quaternionic blocks require compatible multiplicity-space complex structures.

Proposition 5.4 (Frobenius-Schur trichotomy: reconstruction target). *Under the hypotheses stated in this subsection, formulate the exact reconstruction claim. Mark it as established, conditional, model-realization, phenomenological, or speculative before using it elsewhere.*

Proof plan. Identify the earlier definitions used here, reduce the claim to lemmas, specify external theorems if any, and list failure modes. $\square$

5.3 Symmetry obstruction

If an additional symmetry identifies each relevant complex-type block with its conjugate in multiplicity one, no invariant orthogonal complex structure may exist. This is a powerful obstruction against arbitrary phase insertion.

Proposition 5.5 (Symmetry obstruction: reconstruction target). *Under the hypotheses stated in this subsection, formulate the exact reconstruction claim. Mark it as established, conditional, model-realization, phenomenological, or speculative before using it elsewhere.*

Proof plan. Identify the earlier definitions used here, reduce the claim to lemmas, specify external theorems if any, and list failure modes. $\square$

Item	Content to finalize
Purpose	Frobenius-Schur phase classification
Required rows	Rows: complex type, real type, quaternionic type, multiplicity data, phase space, obstruction.
Status	Mark every row as ESTABLISHED, CONDITIONAL THEOREM TARGET, MODEL REALIZATION, PHENOMENOLOGICAL ANSATZ, or SPECULATIVE EXTENSION.
Cross references	Link rows to equations, definitions, theorem targets, figures, and appendices.

Table 4: Frobenius-Schur phase classification

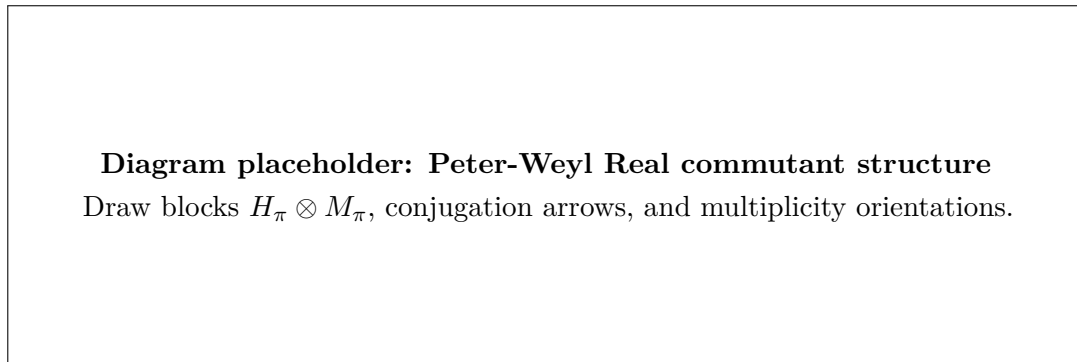


Figure 2: Peter-Weyl Real commutant structure

Audit checklist.

1. Verify that all symbols introduced in this section are in the notation table.
2. Check that every theorem target has explicit hypotheses and a status label.
3. Add at least one example or counterexample showing the role of the assumptions.
4. Confirm that no downstream structure is used circularly.

6 Gauge from temporal spectral structure

This section develops gauge from temporal spectral structure for the present paper. It states the precise role of the section in the reconstruction program, identifies which assumptions are structural and which are technical, and records the outputs needed by later sections.

Definition 6.1 (Gauge from temporal spectral structure: local object). Define the local object of this section as the tuple of data, maps, equivalence relations, and admissibility conditions used below. Replace this boxed definition with the final polished version after importing exact statements from the source drafts.

Assumption 6.2 (Gauge from temporal spectral structure: hypotheses). List the minimal hypotheses. Separate structural assumptions, technical regularity assumptions, physical calibration assumptions, and optional strengthening assumptions.

6.1 Holonomy as gauge connection

Protected inner-time eigenspace bundles over outer parameter space can carry Berry/Wilson holonomies. If a rank r band is gapped and transported adiabatically, the connection has structure group $U(r)$, with possible reductions by real, quaternionic, determinant, or orientation constraints.

Proposition 6.3 (Holonomy as gauge connection: reconstruction target). *Under the hypotheses stated in this subsection, formulate the exact reconstruction claim. Mark it as established, conditional, model-realization, phenomenological, or speculative before using it elsewhere.*

Proof plan. Identify the earlier definitions used here, reduce the claim to lemmas, specify external theorems if any, and list failure modes. $\square$

6.2 Rank patterns and caution

Rank patterns 1, 2, 3 are suggestive for $U(1)$, $U(2)$, and $U(3)$, and reductions may suggest familiar Standard Model factors. However, actual Standard Model gauge group, chirality, anomaly cancellation, coupling constants, and fermion content require separate construction.

Proposition 6.4 (Rank patterns and caution: reconstruction target). *Under the hypotheses stated in this subsection, formulate the exact reconstruction claim. Mark it as established, conditional, model-realization, phenomenological, or speculative before using it elsewhere.*

Proof plan. Identify the earlier definitions used here, reduce the claim to lemmas, specify external theorems if any, and list failure modes. $\square$

6.3 Relation to NCG inner fluctuations

The holonomy route should be compared with standard NCG inner fluctuations. The paper should state when they agree, when they are complementary, and when one is merely an interpretation of the other.

Proposition 6.5 (Relation to NCG inner fluctuations: reconstruction target). *Under the hypotheses stated in this subsection, formulate the exact reconstruction claim. Mark it as established, conditional, model-realization, phenomenological, or speculative before using it elsewhere.*

Proof plan. Identify the earlier definitions used here, reduce the claim to lemmas, specify external theorems if any, and list failure modes. $\square$

Figure placeholder: Protected eigenspace bundle holonomy
 Show a parameter loop, gapped eigenspace band, and resulting Wilson holonomy.

Figure 3: Protected eigenspace bundle holonomy

Item	Content to finalize
Purpose	Gauge-claim status table
Required rows	Rows: $U(1)$, $SU(2)$, $SU(3)$, chirality, anomalies, couplings, status, required proof.
Status	Mark every row as ESTABLISHED, CONDITIONAL THEOREM TARGET, MODEL REALIZATION, PHENOMENOLOGICAL ANSATZ, or SPECULATIVE EXTENSION.
Cross references	Link rows to equations, definitions, theorem targets, figures, and appendices.

Table 5: Gauge-claim status table

Audit checklist.

1. Verify that all symbols introduced in this section are in the notation table.
2. Check that every theorem target has explicit hypotheses and a status label.
3. Add at least one example or counterexample showing the role of the assumptions.
4. Confirm that no downstream structure is used circularly.

7 Auxiliary inner-time Yang-Mills gap program

This section develops auxiliary inner-time yang-mills gap program for the present paper. It states the precise role of the section in the reconstruction program, identifies which assumptions are structural and which are technical, and records the outputs needed by later sections.

Definition 7.1 (Auxiliary inner-time Yang-Mills gap program: local object). Define the local object of this section as the tuple of data, maps, equivalence relations, and admissibility conditions used below. Replace this boxed definition with the final polished version after importing exact statements from the source drafts.

Assumption 7.2 (Auxiliary inner-time Yang-Mills gap program: hypotheses). List the minimal hypotheses. Separate structural assumptions, technical regularity assumptions, physical calibration assumptions, and optional strengthening assumptions.

7.1 Program reduction

The auxiliary inner-time Yang-Mills program should be presented as a conditional sequence: define a finite gauge block with compact simple group and admissible plaquette weights; prove boundary-uniform local block gaps; use finite-depth detectability to assemble global low-window

coercivity; control boundary strata; verify relative cohomology; prove nonlinear stability under refinement.

Proposition 7.3 (Program reduction: reconstruction target). *Under the hypotheses stated in this subsection, formulate the exact reconstruction claim. Mark it as established, conditional, model-realization, phenomenological, or speculative before using it elsewhere.*

Proof plan. Identify the earlier definitions used here, reduce the claim to lemmas, specify external theorems if any, and list failure modes. $\square$

7.2 Local block rigidity

For fixed block discretization and boundary holonomy data, positivity improving transfer operators can give a simple local vacuum separated by a uniform gap over compact boundary data. This is a local input, not the full continuum Yang-Mills mass gap.

Proposition 7.4 (Local block rigidity: reconstruction target). *Under the hypotheses stated in this subsection, formulate the exact reconstruction claim. Mark it as established, conditional, model-realization, phenomenological, or speculative before using it elsewhere.*

Proof plan. Identify the earlier definitions used here, reduce the claim to lemmas, specify external theorems if any, and list failure modes. $\square$

7.3 Nonlinear stability

The nonlinear stability layer requires uniform slice theorems, discrete Sobolev and multiplication bounds, cubic remainder estimates, and a barrier alternative outside small-field charts. Each constant must be tracked under refinement.

Proposition 7.5 (Nonlinear stability: reconstruction target). *Under the hypotheses stated in this subsection, formulate the exact reconstruction claim. Mark it as established, conditional, model-realization, phenomenological, or speculative before using it elsewhere.*

Proof plan. Identify the earlier definitions used here, reduce the claim to lemmas, specify external theorems if any, and list failure modes. $\square$

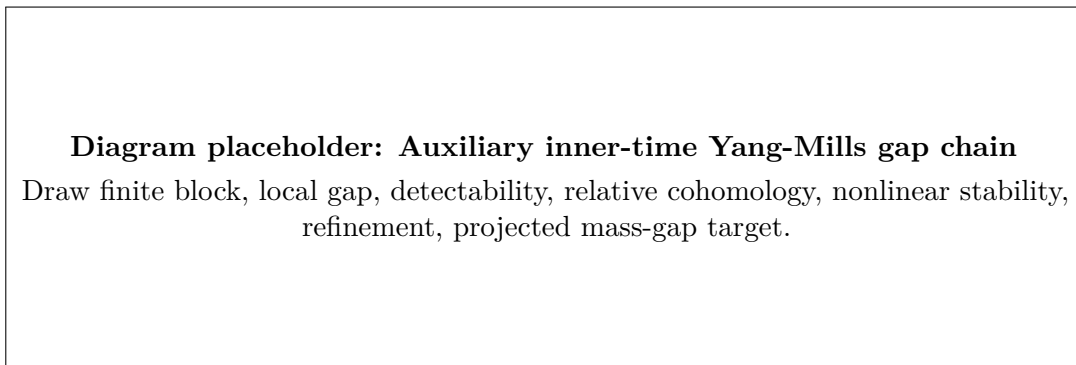


Figure 4: Auxiliary inner-time Yang-Mills gap chain

Audit checklist.

1. Verify that all symbols introduced in this section are in the notation table.
2. Check that every theorem target has explicit hypotheses and a status label.

Item	Content to finalize
Purpose	Block-gap hypotheses
Required rows	Rows: compact group, plaquette weight, boundary data, transfer positivity, cohomology gap, Sobolev bound, barrier alternative.
Status	Mark every row as ESTABLISHED, CONDITIONAL THEOREM TARGET, MODEL REALIZATION, PHENOMENOLOGICAL ANSATZ, or SPECULATIVE EXTENSION.
Cross references	Link rows to equations, definitions, theorem targets, figures, and appendices.

Table 6: Block-gap hypotheses

3. Add at least one example or counterexample showing the role of the assumptions.
4. Confirm that no downstream structure is used circularly.

8 Interfaces with quantum and relativity sectors

This section develops interfaces with quantum and relativity sectors for the present paper. It states the precise role of the section in the reconstruction program, identifies which assumptions are structural and which are technical, and records the outputs needed by later sections.

Definition 8.1 (Interfaces with quantum and relativity sectors: local object). Define the local object of this section as the tuple of data, maps, equivalence relations, and admissibility conditions used below. Replace this boxed definition with the final polished version after importing exact statements from the source drafts.

Assumption 8.2 (Interfaces with quantum and relativity sectors: hypotheses). List the minimal hypotheses. Separate structural assumptions, technical regularity assumptions, physical calibration assumptions, and optional strengthening assumptions.

8.1 Phase compatibility

Gauge orientation requires phase compatibility. The complex structures used in representation blocks must agree with the selected J_q or with a controlled multiplicity of phases balanced by Paper 04.

Proposition 8.3 (Phase compatibility: reconstruction target). *Under the hypotheses stated in this subsection, formulate the exact reconstruction claim. Mark it as established, conditional, model-realization, phenomenological, or speculative before using it elsewhere.*

Proof plan. Identify the earlier definitions used here, reduce the claim to lemmas, specify external theorems if any, and list failure modes. □

8.2 Locality and completion

Gauge block dynamics feeds the completion geometry only after local update and completion hypotheses are stated. Gauge interactions should not be used to postulate the limiting speed; the completion cone is supposed to arise before electromagnetic fields.

Proposition 8.4 (Locality and completion: reconstruction target). *Under the hypotheses stated in this subsection, formulate the exact reconstruction claim. Mark it as established, conditional, model-realization, phenomenological, or speculative before using it elsewhere.*

Proof plan. Identify the earlier definitions used here, reduce the claim to lemmas, specify external theorems if any, and list failure modes. $\square$

8.3 Phenomenological bridge

Possible outputs include holonomy spectra, confinement-like gaps in regulated models, and scale-dependent gauge sectors. These should be transferred to Paper 10 as testable or simulable targets.

Proposition 8.5 (Phenomenological bridge: reconstruction target). *Under the hypotheses stated in this subsection, formulate the exact reconstruction claim. Mark it as established, conditional, model-realization, phenomenological, or speculative before using it elsewhere.*

Proof plan. Identify the earlier definitions used here, reduce the claim to lemmas, specify external theorems if any, and list failure modes. $\square$

Item	Content to finalize
Purpose	Gauge interfaces
Required rows	Rows: phase interface, record interface, completion interface, spectral interface, phenomenology interface.
Status	Mark every row as ESTABLISHED, CONDITIONAL THEOREM TARGET, MODEL REALIZATION, PHENOMENOLOGICAL ANSATZ, or SPECULATIVE EXTENSION.
Cross references	Link rows to equations, definitions, theorem targets, figures, and appendices.

Table 7: Gauge interfaces

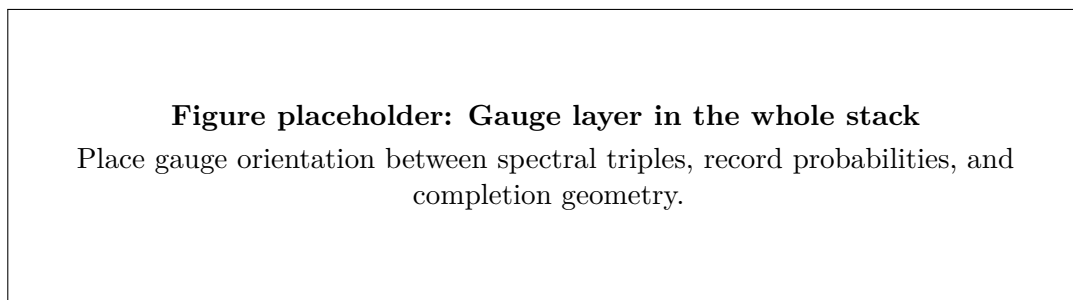


Figure 5: Gauge layer in the whole stack

Audit checklist.

1. Verify that all symbols introduced in this section are in the notation table.
2. Check that every theorem target has explicit hypotheses and a status label.
3. Add at least one example or counterexample showing the role of the assumptions.
4. Confirm that no downstream structure is used circularly.

9 Paper-specific source integration checklist

Table 8: Source integration checklist for this paper.

Source family	Material to import	Status decision	Cleanup required
Axioms/ontology	Definitions of dual time, windows, Monad, completion primitives	Established or conditional	Standardize inner/outer terminology
Real commutants	Phase classification and positive-frequency selection	Established if proof imported	Check zero modes and domains
Records/Born	Stable record effects and trace probability	Conditional	State finite-dimensional hypotheses
Completion/Lorentz	Finite supply, tick, cone, Lorentz group	Conditional theorem target	Avoid circular Lorentz assumptions
Spectral/NCG	Temporal triple, dimension, action, gauge	Model realization or conditional	Separate bounded/unbounded operators
Gauge/YM	Nonabelian orientation, block gaps	Established local / conditional global	Track refinement constants
String	Boundary RG, Wilson holonomy, compactification	Model realization	Audit units and worldsheet consistency
Phenomenology	Constants, delays, tests	Phenomenological	Add error bars and falsification criteria

10 Finalization checklist

Audit checklist.

1. Replace all theorem-target statements with exact theorem statements or downgrade their status.
2. Populate every placeholder table, figure, and diagram.
3. Verify units, domains, spectra, quotient definitions, and circular dependencies.
4. Add precise bibliography entries and page/section references to the source drafts.
5. Compile cleanly and remove all TODO commands before submission.

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